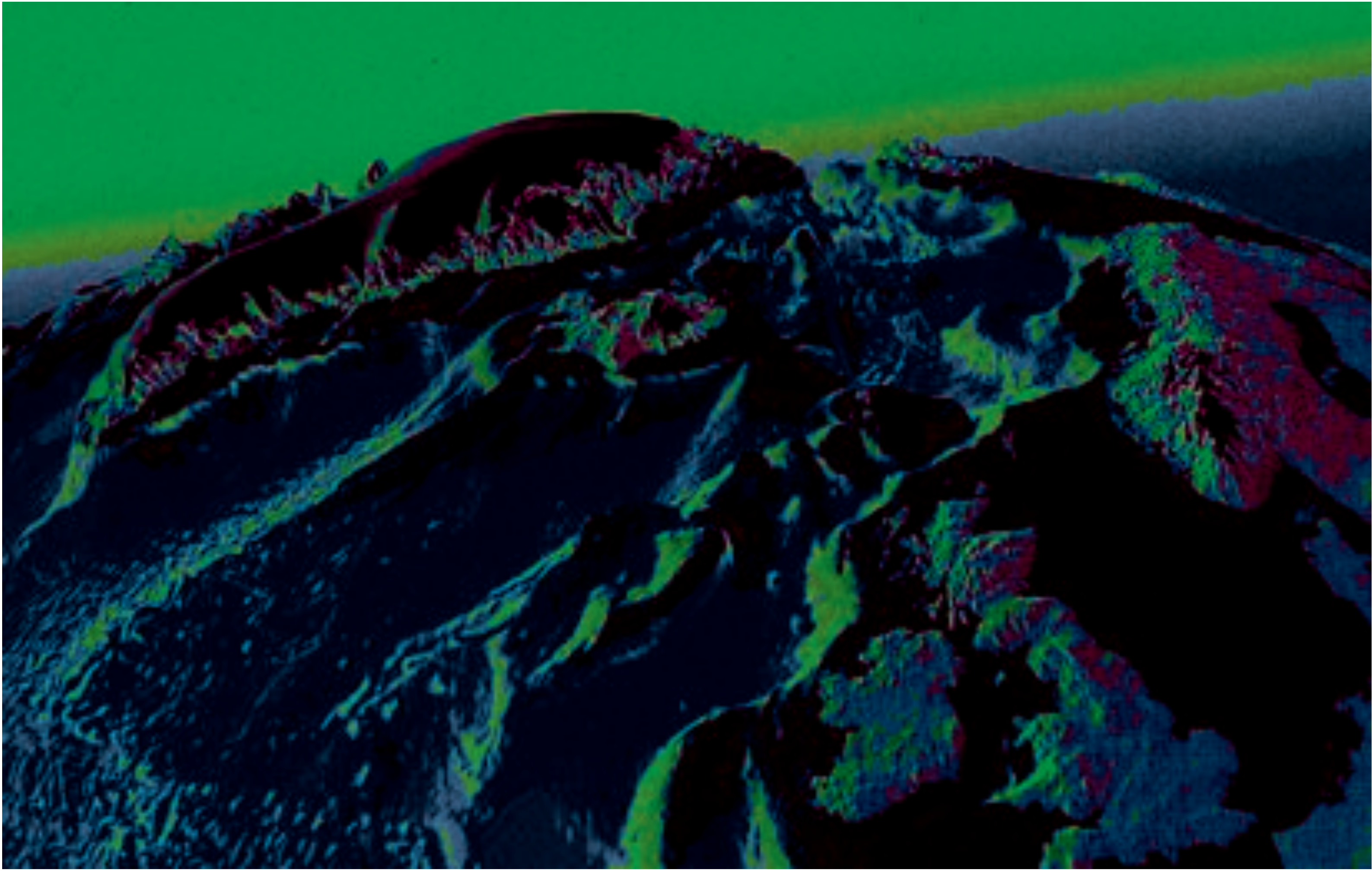

The Earth Systems Science Institute *of* Iceland

Science and business plan

November 2006

Cover illustration: The submarine topography of the Iceland region has been shaped by the volcanic activity of the Iceland mantle plume during the opening of this part of the North Atlantic sea floor in the last fifty million years. The volcanic activity has built up the submarine ridges that connect Greenland and Iceland and Iceland and Scotland and the British Isles. This topography has an important control on both warm surface currents from the south and deep and cold ocean currents from the north, having a major impact on the region's climate.
This is one of the many factors that make scientific studies in the Iceland region crucial for understanding global climate change.

The Earth Systems Science Institute *of* Iceland

Science and business plan

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and Björgólfur Thorsteinsson.

The authors of this report are Björn Erlingsson (physical oceanographer) and Haraldur Sigurðsson (oceanographer, marine geologist) and Björgólfur Thorsteinsson (management economist). We wish to acknowledge the following persons for providing comments on various aspects of the report: Gunnar Pálsson, Halldór Björnsson, Halldór Þorgeirsson, Héðinn Valdimarsson, Kristján Kristjánsson, James Overland, Robert Dickson, Steingrímur Jónsson, Tómas Jóhannesson, Trausti Jónsson and Þorsteinn I. Sigfússon.

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Executive Summary

Scientific evidence indicates that global climate change is one of the most important issues facing the human race today. Its effects are likely to be felt most at high northern latitudes, and it is also in this region where some of the important processes involved in global climate change occur. The Iceland region and adjacent seas is ideally situated for the study of processes closely related to global climate change, including oceanographic processes that drive the global ocean conveyor belt, and sea-ice formation in the northern seas that acts as a regional amplifier on climate. Gaining a better understanding of the processes taking place in the region is vital in order to fill knowledge gaps in existing international research programs on global change. This calls for scientific monitoring, information on climate change in the north, data dissemination and forecasting of trends in the oceanographic, climatic and other environmental fields, that can have profound impact on decision-making and improve the economic security and resilience of our modern society.

The establishment of a new international research institute (ESSI) in Iceland is proposed to address this important need. Adopting an earth systems science approach, the scientific concept of ESSI relies on interdisciplinary work between scientists, bridging the fields of oceanography, cryosphere studies, geology and climatology/meteorology, in order to gain a unified view of the climate system and the problem of climate change. ESSI is envisaged as a center of excellence in global change research. This will be achieved by the recruitment of world-class scientists to the institution and the implementation of a novel research program, taking advantage of the geographic location of ESSI in a critical region with respect to oceanographic and cryospheric (glaciers and sea-ice) processes. This will place ESSI among the preeminent research institutes in global change research around the globe, where tools of modern science and software technology are arranged in a way that facilitates analysis and diagnostics on the state of the atmosphere-ocean environment in the sub-Arctic region.

The underlying objective with the establishment of ESSI is to enable advancement of global change science, trans-disciplinary studies, and to contribute to improved adaptation to changing environmental conditions, all within the auspices of a single entity. In particular, ESSI will address six lines of activities related to regional climate change in the North Atlantic region and its impact on global climate change:

Monitoring: ***Measurements of Denmark Strait Ocean Fluxes.*** It is proposed that ESSI take responsibility for monitoring one oceanographic parameter that is of fundamental significance, both in the regional context as well as in global climate research.

Science: ***Climate and the cryosphere, ice-caps, snow and sea-ice.*** Appearance and disappearance of sea-ice is one of the most important amplifiers of climate change. ESSI would track sea-ice conditions and develop input to Global Circulation Models that replicate adequately the conditions in the Central Arctic during the winter when the freezing and sea-ice formation takes place.

Research: ***Regional coupled atmosphere ocean model climatology data.*** ESSI would carry out advanced studies of high-resolution regional climatology and other hindcast data on the state of the atmosphere and the ocean to allow for a new set of studies that take in the impact from short-term and long-term trends and temporal and spatial variability.

Outreach: ***Informatics - data access, analysis and publishing.*** ESSI would support end-to-end delivery of new information and findings to facilitate Climate Change research and associated impact analysis studies through Informatics, i.e. structured computer-aided data access, analysis and publishing

Benefits: ***Econometrics and Regional Climate Diagnostics.*** ESSI would deliver valuable knowledge through deriving parameters on regional and global climate conditions that have direct and indirect impact on many macro-economic variables, like the supply and demand for energy, consumer items, travel, transport and service requirements. Through engaging in econometric studies, the applied research and derived knowledge can be turned into tangible benefits, contributing to economic resilience and competitive edge.

Revenue: ***Climate Expert Service System.*** Establish and market an advanced climate expert service system with high potential revenue spin, directed towards fisheries, offshore transports and trade with natural resources.

ESSI is not conceived as a traditional research institute, but as an activity with a broad scope that cuts across the entire field, from basic science to applied science, with monitoring, data distribution and dissemination of information that creates economic value for the institute and eventually sustains it financially

The following key steps would constitute a plan of action for the establishment of ESSI:

- Finalize enabling agreements with the Government of Iceland and other potential funders.
- Develop the key infrastructure for ESSI.
- Identify and implement scientific appointments for the areas of activity.
- Establish the research areas and relevant programs.
- Generate sufficient outside revenue to establish financial self-sufficiency after seven years.
- Leverage research investment and scientific talent through outreach activities.

ESSI would be established as a limited company, run by a director who is appointed by the shareholders. An advisory committee would work with the director in setting the research and administrative policy. It is proposed that ESSI would be initially staffed by a minimum of eight scientists.

Financial projections show that cumulative expenses during the first five years of operation amount to approximately €15 million (average of approx. €3million per year). However, taking projected income into account, the projections show that ESSI could evolve into a self-sustained and profitable organization in 5 to 7 years, with €4-5 million cumulative funding requirement or venture loan guarantee for this start-up period. ESSI offers an interesting partnership structure for private and governmental organizations that would be interested in joining on different terms of reference. Such partnerships could take the form of venture capital investment, governmental district infrastructure investment or to strengthen competitive advantage of financial businesses. ESSI can thus strengthen the resilience of the Icelandic economy and provide competitive edge for organizations with wide investment interests.

Samantekt

Vísindarannsóknir benda til að loftslagsbreytingar og áhrif þeirra verði eitt stærsta viðfangsefnið sem mannkynið mun glíma við í framtíðinni. Áhrifa loftslagsbreytinga mun að líkindum gæta hvað mest á norðurslóðum, en þar eiga sér stað ýmis ferli, bæði í hafi og í ís, sem miklu máli skipta varðandi loftslagsbreytingar. Ísland og hafið umhverfis landið er mjög vel staðsett hvað rannsóknir á þessu sviði snertir, til dæmis rannsóknir á straumakerfum sem knýja "færiband hafsins" og einnig á myndun hafíss í norðurhöfum sem magnar upp svæðisbundin loftslagsáhrif á norðurhveli. Til þess að bæta þekkingargrunn í alþjóðlegum rannsóknaráætlunum á sviði loftslagsbreytinga er nauðsynlegt að auka skilning á þeim ferlum sem eiga sér stað á þessu svæði. Þetta kallar á auknar rannsóknir, að fylgst sé vel með breytingum á loftslagi í norðrinu, að upplýsingar séu gerðar aðgengilegar og að gerðar séu spár sem sýna líklega þróun í hafinu, ís og jöklum og skyldum umhverfisþáttum. Slíkar rannsóknir gætu komið að miklu gagni í tengslum við margvíslega ákvarðanatöku stjórnvalda og stuðlað að efnahagslegu öryggi og hagsælli framþróun nútímaþjóðfélags.

Lagt er til að stofnuð verði alþjóðleg rannsóknarstofnun á sviði jarðkerfisfræða á Íslandi (Earth Systems Science Institute - ESSI) til þess að mæta brýnni þörf á rannsóknum.

Hvað er Jarðkerfisfræði? Jarðríkið er flókið og samtvinnað kerfi, þar sem hinir ýmsu þættir jarðar, hafsins, andrúmsloftsins og lífríkisins hafa áhrif hvern á annan. Þannig hafa hafstraumar bein áhrif á lífríkið og einnig á loftslag. Einnig valda skorpuhreyfingar landsflekanna eldvirkni, og síðan valda eldgos loftslagsbreytingum. Maðurinn hefur með aðgerðum sínum breytt efnasamsetningu andrúmsloftsins og er að valda breytingum í lofti og á landi. Svona mætti lengi telja upp varðandi tengslin milli hinna ýmsu þátta jarðríkisins. Hefðbundnar vísindagreinar í háskólum og rannsóknastofnunum, eins og jarðfræði, haffræði, loftslagsfræði og líffræði, hafa þróast að nokkru leyti í einangrun hvor frá annarri og þar af leiðandi hefur heildarmynd jarðríkisins ekki komið fram fyrr en nýlega. Í lok tuttugustu aldarinnar var vísindamönnum úti í heimi orðið það ljóst að við verðum að líta á jarðríkið sem eitt kerfi, og af þeim sökum þróaðist ný vísindagrein sem nefna má Jarðkerfisfræði (Earth Systems Science). Þessi þróun hefur vægast sagt leitt til byltingar á skilningi okkar á tengslum milli hinna ýmsu þátta jarðríkissins. Þessum fræðum hefur enn ekki verið sinnt á skipulegan hátt á Íslandi. Jarðkerfisfræði er þverfagleg, og kannar tengingar og samspil milli meginþátta í jarðríkinu, eins og samspilið milli hafstrauma og loftslags. Eitt höfuð keppikefli þeirra sem leggja stund á Jarðkerfisfræðina er að kanna breytingar: þær breytingar í jarðríkinu sem eru nú að eiga sér stað, þær breytingar sem hafa áður átt sér stað, eins og fram kemur í jarðsögunni og þær breytingar sem munu eiga sér stað í framtíðinni.

ESSI er hugsuð sem stofnun þar sem vísindamenn úr ólíkum en skyldum greinum vinna saman til að brúa bilið milli haffræði, ís- og jöklarannsókna, loftslags- og veðurfræði og nútímajarðfræði til að nálgast heildarmynd af loftslagskerfinu, loftslagsbreytingum, orsökum þeirra og afleiðingum. ESSI er ekki ætlað að vera hefðbundin rannsóknastofnun, heldur stofnun sem er þverfagleg og spannar allt sviðið frá frumrannsóknum til hagnýtra rannsókna, mælinga, úrvinnslu gagna, og dreifingu niðurstaðna. Starfseminni er ætlað að skapa tekjur fyrir stofnunina sem standa að hluta til undir rekstri hennar. ESSI yrði öndvegisstofnun, þar sem beitt yrði nútíma vísindum og hugbúnaði til að gera greiningu og spár á ástandi kerfisins sem samanstendur af hafi og lofthjúpi á norðurslóðum. Markmiðið er að auka þekkingu á lofslagsbreytingum, en einnig að setja fram, kynna og dreifa þessarri þekkingu, til að auka hagvöxt og jákvæða þróun á svæðinu.

Innan ESSI yrði starfað á sex sviðum í tengslum við rannsóknir á loftslagsbreytingum, orsökum og afleiðingum þeirra:

Vöktun: ***Straumamælingar í Grænlandssundi.*** Lagt er til að ESSI helgi sig (taki að sér) könnun og endurteknar mælingar á einum mikilvægasta þætti hafstraumakerfisins í Norður Atlantshafi, á sundinu milli Grænlands og Íslands.

Vísindi: ***Tengslin milli loftslags og frosthvelfisins (jöklar, hafís, snjór).*** Hafís gjörbreytir endurskini frá hafinu og virkar sem einn sterkasti magnarinn í loftslagsbreytingum. ESSI myndi vakta hafísbreytingar í norðri og þróa endurbætur á reiknilíkönum fyrir spár á loftslagsbreytingum.

Rannsóknir: ***Svæðisbundin loftslagsreiknilíkön sem tengja hafið og lofthjúpinn.*** ESSI myndi beita sér í háþróuðum rannsóknum á ástandi loftslags og hafsins til að gera kleift að búa til spár um áhrif þeirra á loftslag til skemmri og lengri tíma.

Miðlun: ***Upplýsingastreumi, aðgangur að gögnum, túlkun og birting.*** ESSI myndi auðvelda aðgang að og sjá um birtingu á gögnum um rannsóknir á sviði loftslagsbreytinga og áhrif þeirra.

Ábati: ***Hagrænar mælingar og svæðisbundin loftslagseinkenni.*** ESSI myndi hafa fram að bjóða mikilvægar upplýsingar um bæði svæðisbundnar og víðtækari loftslagsbreytingar, sem geta haft bein áhrif á ýmsa þætti hagkerfisins, til dæmis ferðir og flutninga, framboð og eftirspurn eftir orku, neysluvörum, og fleiru.

Tekjur: ***Loftslagsgreiningarkerfi.*** Þróa og markaðssetja fullkomið loftslagsgreiningarkerfi, sem gefur möguleika á tekjum frá fiskveiðigeiranum, skipaflutningageiranum og fjármálastarssemi sem tengist náttúruauðlindum.

Eftirfarandi atriði eru hluti af framkvæmdaáætlun til að stofnsetja ESSI:

» Vekja frekari áhuga íslenska ríkisins og hvetja til stofnunar á ESSI.
» Vinna að meginþáttum í stofnun ESSI: skipun ráðgjafanefndar og forstöðumanns.
» Ákvarða vísindasvið ESSI og verkefni.
» Afmarka stöður vísindamanna við stofnunina.
» Fjármagna stofnunina á þann hátt að hún yrði fjárhagslega sjálfstæð innan sjö ára.
» Efla þekkingu og uppskera fjárfestingu í rannsóknum og afrakstri þeirra með þekkingarmiðlun.

Til að ESSI verði öndvegisstofnun, þá þarf hún að vera mönnuð af vísindafólki á heimsmælikvarða. Lögð er áhersla á að staðsetning ESSI á Íslandi gefur kost á að hafa greiðan aðgang að umhverfi þar sem mikilvægar breytingar eru að eiga sér stað, bæði í hafinu og á landi á norðurslóðum. Þessi staðsetning getur gefið ESSI lykilaðstöðu til rannsókna. Lagt er til að ESSI verði stofnað sem almennt hlutafélag, sem stýrt yrði af forstöðumanni. Hann yrði útnefndur af íslenska ríkinu, sem yrði stærsti hluthafinn í ESSI. Ráðgjafanefnd mun starfa með forstöðumanni við að þróa rannsóknasvið og skipulag stofnunarinnar. Gert er ráð fyrir að ekki færri en átta vísindamenn starfi við stofnunina frá upphafi.

Fjárhagsáætlanir sýna að heildarkostnaður við ESSI yrði u.þ.b. 15 milljónir evra fyrstu fimm árin (u.þ.b. €3 milljónir á ári að meðaltali) en jafnframt að stofnunin geti orðið að fjárhagslega sjálfbærri einingu eftir fimm til sjö ár, með 4-5 milljón evra heildarfjárfestingu eða með lánsábyrgðum á þessu stofnsetningartímabili. ESSI býður einka- og opinberum fyrirtækjum álitlegan kost til samstarfs. Slíkt samstarf gæti verið í formi nýsköpunarfjárfestingar, fjárfestingar í byggðaþróun og fjárfestingar til að styrkja samkeppnishæfni fjármálastofnana. ESSI getur með þessu styrkt stöðugleika íslenska hagkerfisins og aukið samkeppnisforskot aðila með fjölbreytta fjárfestingahagsmuni.

1. Introduction

Global warming is a fact today. Our Earth's climate has changed, both visibly, tangibly and measurably. An additional increase in average global temperatures is not only possible, but highly probable, where the human intervention in the natural climatic system plays an important, if not decisive role. Everyone is affected by climate changes. The change can have both positive and negative effects in individual cases, but it can never be without consequences. The weather influences all areas of life, and climate change will affect each and every on of us. Climate change affects marine life, fisheries, agriculture, commerce and all aspects of our activities as people and nations. If climate change accelerates and we fail to adapt in time, we will suffer losses in terms of safety and prosperity. If we learn to manage our natural resources responsibly and adapt readily and intelligently to the constant change in the decisive factors, we can maintain and even enhance safety and prosperity. This is the inherent opportunity in climate change (Porro 2002).

Lately, almost every year brings with it new records in terms of climate change. In the year 2005 the global combined sea surface temperature (SST) and land surface air temperature anomaly (with respect to the 1961-1990 average) was +0.48°C. Thus 2005 is the second warmest year on record and one of the warmest 4 years since 1861. The last 10 years (1996-2005) are the warmest years on record in terms of land surface temperature. The anomaly so far for the Northern Hemisphere is 0.65°C and for the Southern Hemisphere 0.32°C. The current 2005 values for the Northern Hemisphere make it the warmest on record and the current value for the Southern Hemisphere make it the fourth warmest.

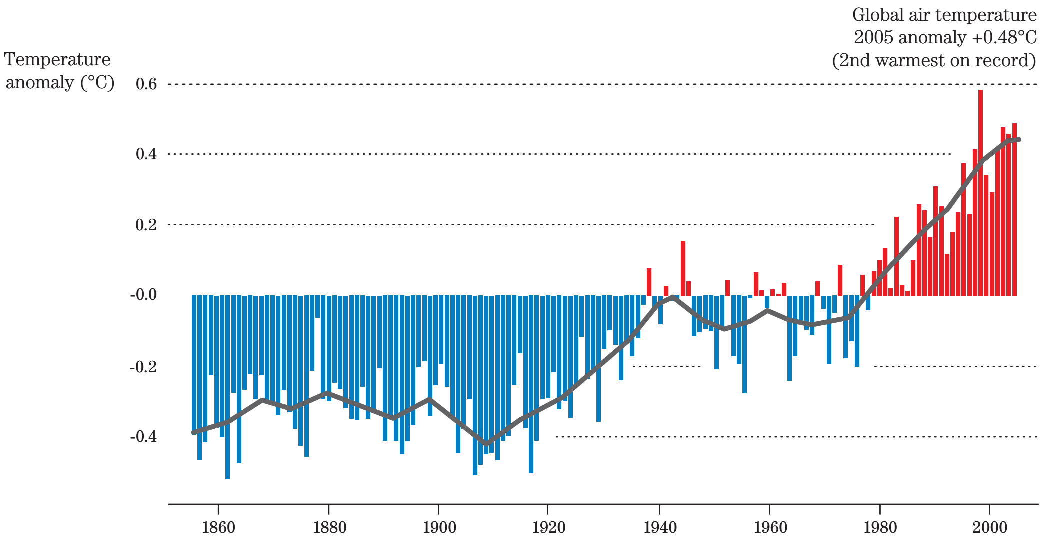

Fig. 1: The figure is a time series that shows the combined global land and marine surface temperature record from 1856 to 2005. The year 2005 was the second warmest on record, exceeded only by 1998 (Climatic Research Unit of East Anglia and the UK Met. Office Hadley Centre). http://www.cru.uea.ac.uk/

Climate change is one aspect of global change. The evidence for and monitoring of global change has primarily been gathered through scientific research in the fields of oceanography, meteorology, glaciology and Quaternary geology. Now that global change is accepted, the logical next step is to develop and refine methods of prediction for future climate change and its impact. In meteorology, relatively short–range forecasting is made possible by monitoring and numerical modeling. Similarly, the integration of information gathered in the environmental sciences into earth systems science is being used to construct models and predictions of global climate change in the future. The current change is largely driven by increased levels of anthropogenic greenhouse gases in the Earth's atmosphere, but an important opportunity for prediction of climate change effects exists because of the lag time between greenhouse gas input and the response of ocean currents and temperature. The ocean is by far the largest reservoir of heat in the ocean-atmosphere-climate system at high latitudes such as the Iceland region, and its planet-wide circulation, termed the global ocean conveyor belt, is greatly and perhaps dominantly influenced or controlled by oceanographic processes occurring in the region around Iceland.

In September 2005 a working group delivered to the Government of Iceland a first report on the establishment of an Earth Systems Science Institute in Iceland (ESSI), designed for research on global climate change and its effects: "ESSI - Alþjóðleg rannsóknarstofnun á sviði jarðkerfisfræða - Könnun á forsendum". The proposal was favorably received and the Icelandic Government requested a second report for further consideration of implementation of the proposal. Additional funding from Althing, the Parliament of Iceland, was also granted for preparation of this report.

As emphasized in this report, ESSI is conceived as an international research institution with the mission to study climate change and its consequences in the Nordic region, whose future funding would come primarily from international corporate entities and science foundations. It is the goal of this activity that the research findings of ESSI would be marketable products that would sustain its operation in the long run.

2. Scientific Background

2.a Climate Changes in the North

The global increase in surface temperatures that has been documented in the past decades is most pronounced in the Arctic. Nevertheless, the surface temperature increase in Iceland is so far relatively modest by comparison. Iceland is located in a climatically critical part of the North Atlantic, and its environment is a key region of ocean–atmosphere interaction and atmospheric dynamics (Wang and Rogers, 2001). The region is highly influenced by the Iceland low, a low pressure system that is a persistent feature to the west or south-west of Iceland.

Fig. 2: A low-pressure system in the Iceland region, as seen in a NASA satellite image. In the Northern Hemisphere, the circulation around low pressure systems is counterclockwise and inward, a result of the Coriolis Force. Air flowing inward in low pressure systems has no where to go but up. The rising air cools, and if it rises far enough, clouds and precipitation can form. The image was taken by the Aqua MODIS instrument on September 4, 2003.

The longest continuous instrumental temperature record that is available in Iceland is for Stykkishólmur, since 1845. A net surface warming over Iceland of between 0.7–1.6 °C has occurred during 1871–2002, consistent with 20th century global warming trends. Superimposed on this was a marked cooling between the 1940s and early 1980s. Warming in Iceland resumed around 1985 and this trend has continued unbroken. The mid–late 20th century cooling is in agreement with observed cooling in southern Greenland, suggesting that large-scale changes in atmospheric circulation were probably responsible. The 1930s was the warmest decade of the 20th century in Iceland, in contrast to the Northern Hemisphere land average (Hanna et al. 2004).

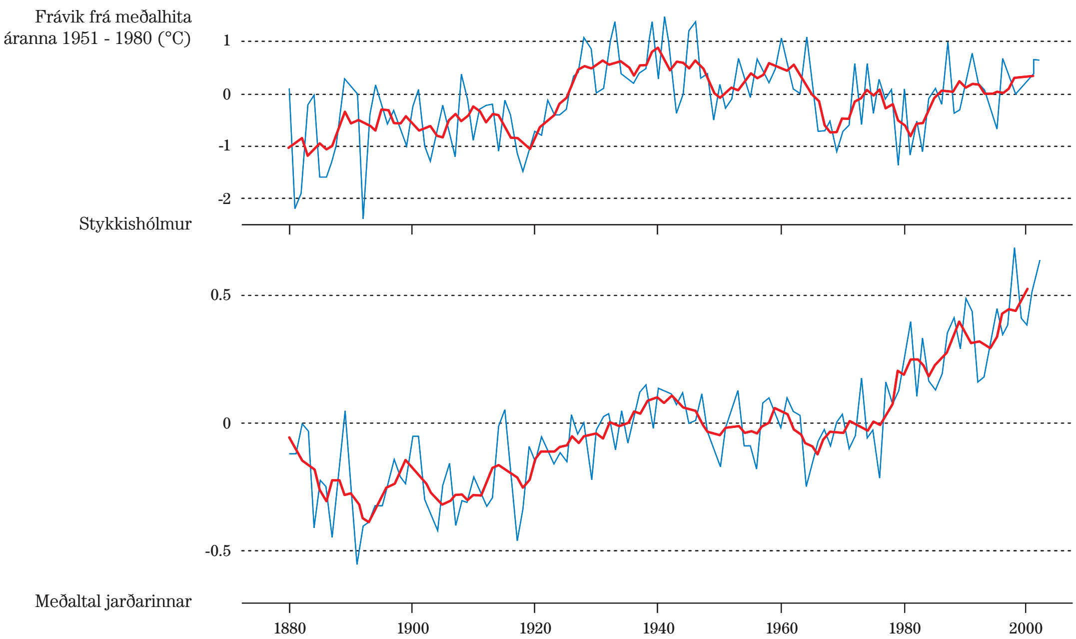

Fig. 3: The surface temperature trend in Stykkisholmur, west Iceland, compared with the global mean. The graphs are the deviations from the mean for 1951-1980, in °C. Note the different temperature scales, which may be misleading. The mean surface temperature in Stykkishólmur has increased about 1°C in the last 20 to 25 years, whereas the global mean has increased about 0.5°C in this period.

Perhaps the most astonishing results of global climate change come from the long-term studies of global sea surface temperature (Delworth and Knutson, 2000). The global sea surface temperatures have steadily increased in the last one hundred years, as shown for the zonal mean anomalies in figure 4. It is also notable that the warming is most marked at high latitudes. Sea surface temperatures have also increased considerably in the Nordic region, and ocean temperatures have also increased world-wide and so has the heat content of the oceans. Levitus et al. (2000) quantified the variability of the heat content (mean temperature) of the world ocean from the surface to 3000-meter depth for the period 1948 to 1998. Their results show that the heat content of the world ocean increased by 2×10^{23} joules between the mid-1950s and mid-1990s (Fig. 5). This corresponds to a warming rate of 0.3 watt per square meter per unit area of Earth's surface. Substantial changes in heat content occurred in the 300- to 1000-meter layers of each ocean and in depths greater than 1000 meters of the North Atlantic. The global volume mean temperature increase for the 0- to 300-meter layer was 0.31°C, corresponding to an increase in heat content for this layer of $\sim10^{23}$ joules between the mid-1950s and mid-1990s. The Atlantic and Pacific Oceans have undergone a net warming since the 1950s and the Indian Ocean has warmed since the mid-1960s (Levitus et al. 2000).

Other important indicators of global warming, in addition to the sea and land surface temperature trends, are a decrease in Arctic ice volume and shrinking of glaciers in Iceland, Greenland and Svalbard. NASA satellites show that Arctic sea ice cover is decreasing at a rate of about 35,000 km^2/year. In late 2005 the area covered by ice fell to 5.32 million km^2, the lowest ever recorded since 1978, when satellite records became available; it is now 20% less than the 1978-2000 average. The current rate of shrinkage is 8% per decade and at this rate there may be no ice left at all in the Arctic during the summer of 2060.

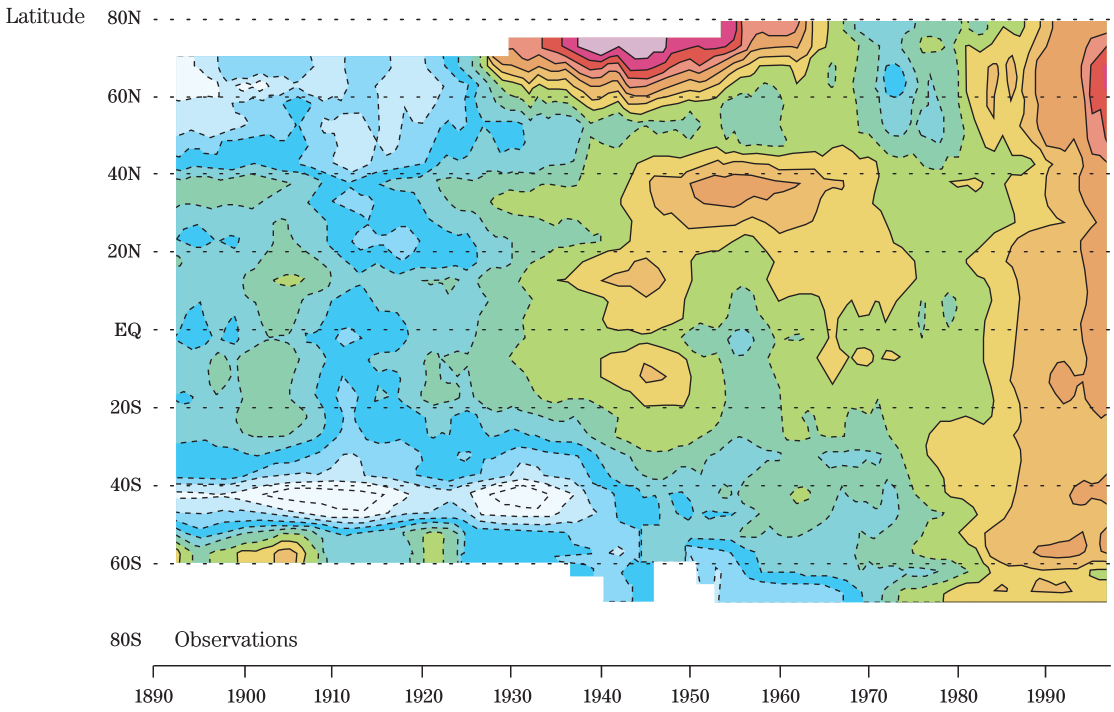

Fig. 4: Zonal mean anomalies of surface temperature (the temperature scale below is in degrees Kelvin, cooling –ve or warming +ve). Note that the heating is most marked at high latitudes in the Northern Hemisphere. Anomalies are relative to the 1961-1990 climatology (Delworth & Knutson 2000).

The decrease in sea ice cover has a number of implications. Its melting contributes fresh water to the Arctic seas and results in their freshening or decrease in salinity and density. The freezing or formation of Arctic sea ice, on the other hand, leads to removal of fresh water from the seas, bringing about increased density of the sea and thus may contribute to dense waters that play a crucial role in deep circulation of the ocean. One major consequence of sea ice melting are feed-back phenomena, mainly related to the albedo, i.e. the reflectivity of the surface of the sea or the ice. Sea ice has high albedo; it reflects a great deal of incoming sunlight. The ice-free ocean is dark (low albedo) and absorbs more in-coming solar heat than the former ice-cover, contributing to retention of heat and further melting in a feed-back loop until all sea-ice is melted. Locally, the residence time and extent of sea ice has had major impact on Icelandic climate (Hanna et al. 2004). When sea ice is present along the northern coast, Iceland temporarily assumes a more continental-type climate; whereas southern coastal temperature anomalies are quite small, due to the proximity to the open ocean. But temperature anomalies on the northern coast during ice years are much greater than normal, giving a large south–north temperature difference (Wallevik and Sigurjónsson, 1998). Such frigid periods occurred in the late 19th century and late 1960s (Ogilvie and Jónsson, 2001).

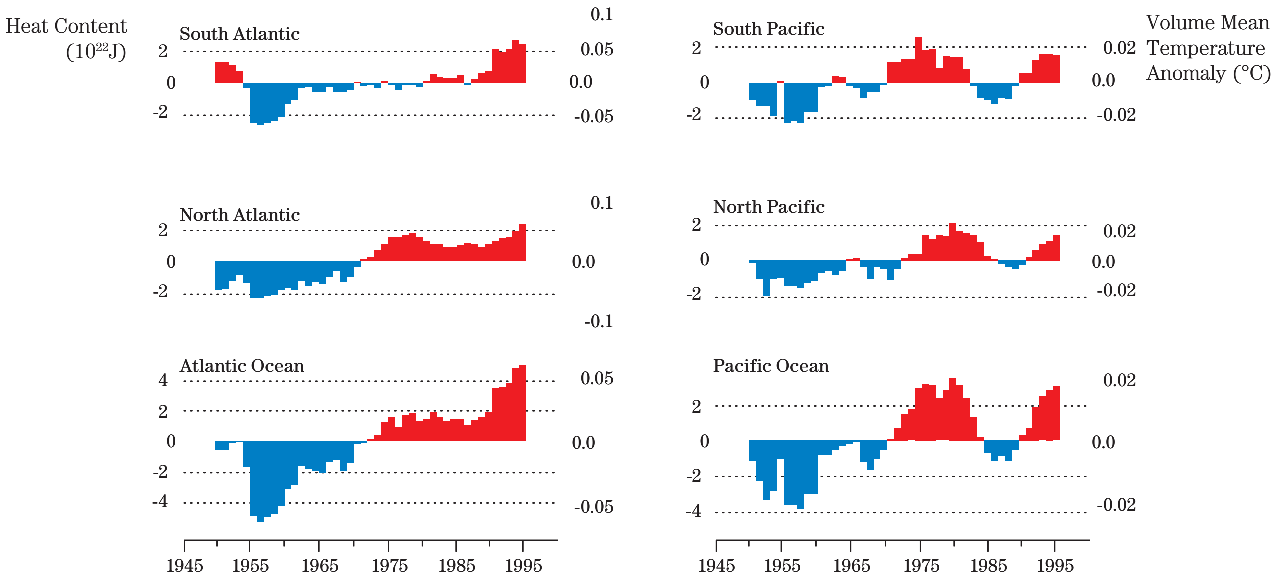

Fig. 5: Historical data shows the ocean heat content (to depths of 3000 meters) to be slowly increasing, related to climate variability. The sequestering of heat deep into the ocean mitigates global warming of the atmosphere for some time (Levitus et al. 1999).

Another important indicator of global warming is the rapid change of glaciers in Antarctica and Greenland. Thus, for example, the Kangerdlugssuaq glacier in Greenland has now accelerated and is moving a rate of 15 km per year, the fastest glacier known on Earth. Similarly, the Helheim glacier is moving at a rate of 11 km per year. These high rates are attributed to melt water that trickles to the base of the glaciers and lubricates their movement towards the sea. Similarly, Icelandic glaciers are showing major changes due to the warming trend. The Sólheimajökull in southern Iceland retreated 6 m in 1996, 10 m in 1997, 33 m in 1998, 98 m in 2003 and 95 m in 2004 (Oddur Sigurðsson, 1998). On the whole, the Icelandic glaciers are retreating rapidly and at an accelerating rate, and the total Icelandic ice cover is decreasing at a rate of about 0.3% every year, or exposing a new ice-free land area of about 30 km²/year. With this trend, it is estimated that Iceland will be ice-free within 100 to 200 years.

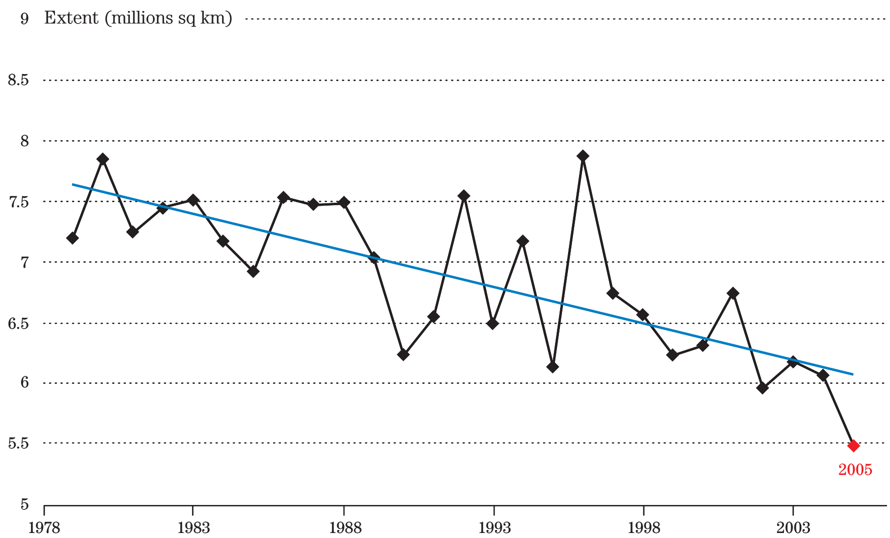

Fig. 6: The shrinking extent of Arctic sea ice cover from 1978 to 2005. Sea ice in the Arctic shrinks at a rate of about 8% per year and will most likely be all gone by about 2060 (source: National Snow and Ice Data Center, Boulder, Colorado; www.greencarcongress.com/ images/arctic_ice_2.gif).

2.b Oceanographic Trends

Ocean currents have an important impact on climate, and any changes in ocean circulation can have far-reaching effects. The dominant thermo-haline (i.e. temperature and salinity-controlled) circulation in the world's oceans is known informally as the Global Conveyor Belt and it is driven in many respects by oceanographic processes that occur in the region north of Iceland (Broecker 1999). On the global scale, the Atlantic meridional ocean circulation (MOC) carries warm upper waters into far-northern latitudes and returns cold waters southwards across the Equator. Its heat transport makes a major contribution to the moderate climate of northern Europe, and any slow-down in the overturning would have profound implications for climate change in Iceland, northern Europe and elsewhere (Bryden et al. 2005). One may simplify by stating that there are two important ocean currents in the Iceland region that have a crucial effect on the region's climate. One of these is the northward inflow of warm (ca. 8.5°C) and saline (35.25 pro mil) near-surface water. About ten per cent of this warm and so-called Atlantic Water flows north through the Denmark Strait between Iceland and Greenland, another 45% flows over the Iceland –Faroes ridge and an equal amount over the Faroes-Shetlands channel (Osterhus et al. 2005). The total inflow of Atlantic Water is about 8.5 Sverdrup Units (1 Sv = million cubic meters per second) and it plays a major role in keeping the region ice-free, as well as carrying salt northwards, which is an important component of the thermo-haline circulation of the ocean. The Atlantic Water is generally restricted to flow shallower than about 200 m depth.

The shallow-level northerly inflow of 8.5°C Atlantic Water through these passages is balanced by deep outflow of colder and denser currents, such as the Denmark Strait overflow water (DSOW) at a temperature of about 0°C. This large temperature difference of about 8°C between inflow and outflow water in the seas of the Iceland region is a measure of the large transfer of thermal energy from south to north via the ocean currents. It is therefore important to monitor the natural variability in the Atlantic inflow, in order to provide early warning, if global change were to induce a weakening of this integral part of the Atlantic thermo-haline circulation, as some climate models predict (Osterhus et al. 2005).

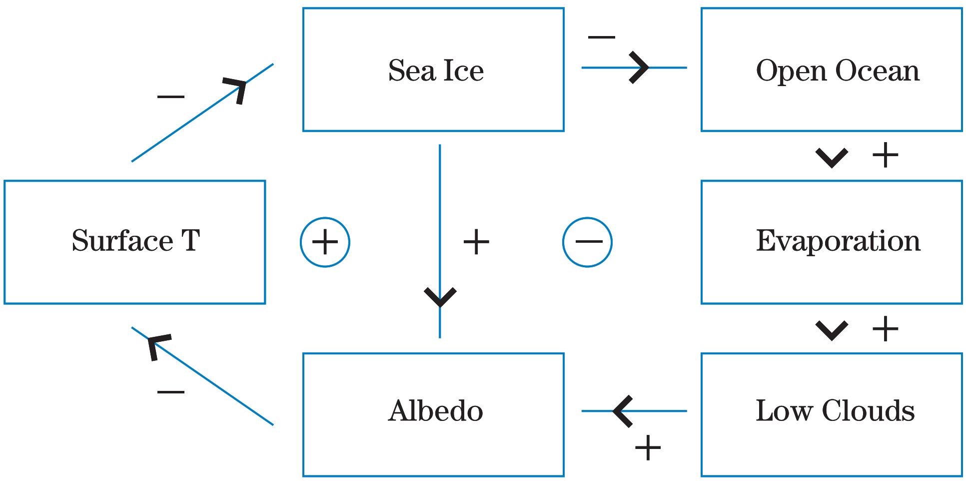

Fig. 7: An idealised feed-back loop involving sea ice and albedo. The signs next to the arrows indicate the correlation between changes in the quantity of the outgoing box with that of the ingoing box, e.g., more sea ice leads to larger albedo. Resulting correlations of a loop are circled and they indicate whether a process is self-reinforced (positive sign) or damped (negative sign). The classical ice-albedo effect is shown in the left loop, a feedback involving the overlying atmosphere is on the right (Intergovernmental Panel on Climate Change).

The Denmark Strait overflow of dense water to the south has long been considered to be about 2.9 Sv (1 Sv = million cubic meters per second), but the overflow is through a channel on the Greenland-Iceland Ridge that is only about 100 km wide. Most of the flow in the channel is a thin sheet of about 50 to 350 m in thickness and 10 to 20 km wide, that follows the slope of the East Greenland continental shelf. Deployment of sensors in the Denmark Strait for the period 1999 to 2003 has revealed major changes in the transport rate (Macrander et al. 2005). The results show that during this period the overflow was much larger than previously estimated, as high as 3.8 Sv, and highly variable. Similarly, temperature was variable, ranging from -0.2 to 0.6 °C. There is a trend of overall decrease in the Denmark Strait overflow during the period of observation by about 20%.

These changes highlight the need to establish long-term observation system for the transport of dense overflow water in the Denmark Strait between Greenland and Iceland, as well as between Iceland, the Faroes and Scotland. Such changes in the downstream transport of dense water are of major interest to the overall southward transport of the global overturning circulation which therefore needs to be observed in concert. Thus the narrow passages between Iceland and Greenland and Iceland and Scotland are key regions and to some extent control points for the global conveyor belt, and southward flow through these regions of dense water moves further south as a concentrated flow between 2000 and 4000 m depth along the western rim of the Atlantic Ocean, and flows into the Pacific and Indian Oceans (Dengg and Kase 2004).

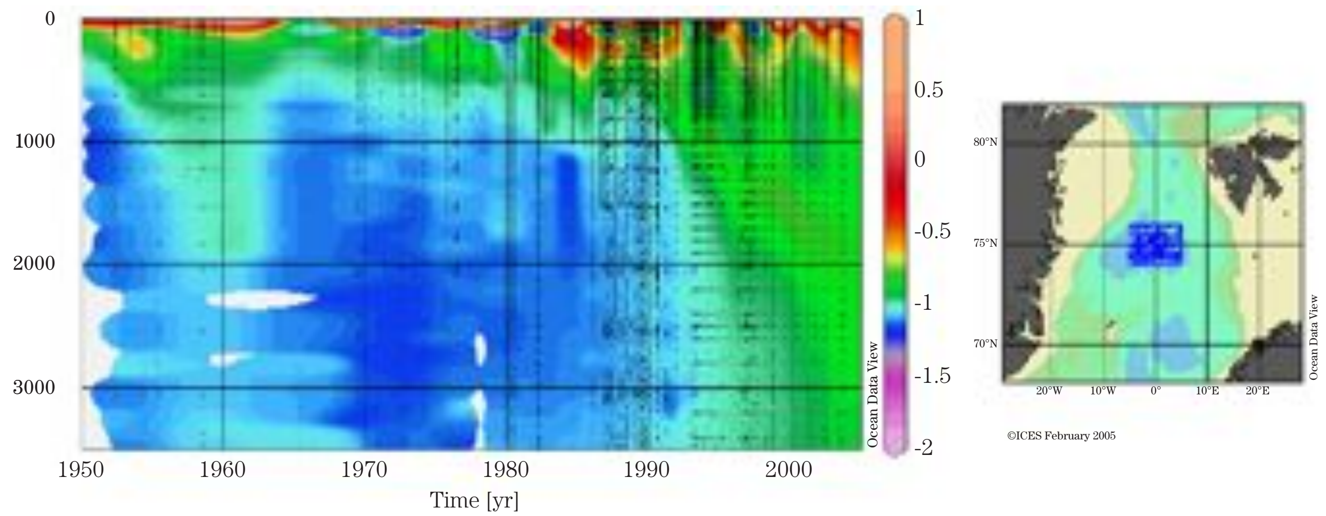

Fig. 8: Half a century of temperature change in the central Greenland Sea, based on 1824 stations. While the surface temperature change is not notable, the gradual increase in the temperature of the deep water masses is striking. The temperature scale on the right is in degrees Centigrade. The insert on the right shows the distribution of stations. Figure from ICES, the International Council for the Exploration of the Sea. http://www.ices.dk/ocean/welcome.htm

Where is the important cold and dense overflow water formed and what drives the current? Wind forcing and buoyancy fluxes (thermo-haline) are both potentially important in flow over the Greenland-Iceland-Scotland ridge (Biastoch et al. 2003). Some models suggest that the dense overflow water is formed during winter cooling in the subarctic North Atlantic Ocean. The Greenland sea is a large reservoir of dense water, and it drains dense water through the Denmark Strait at a rate of several million cubic meters per second. Gradual warming of the deep water mass in the Greenland Sea has been observed during recent decades and the effect of this warming on the overflow may become significant.

The Denmark Strait overflow has recently been traced up-stream, back into the Iceland Sea, by Steingrímur Jónsson and Héðinn Valdimarsson (2004). They show that the overflow is carried to the Greenland-Iceland sill by a hitherto unknown current that flows along the slope north of Iceland, in a narrow (15 to 20 km) and high-velocity (~40 m/sec) jet. Thus the Iceland Sea is an important region for the study of the formation of this water mass, that has a critical influence on the global conveyor belt.

The large-scale circulation in the Atlantic Ocean, with warm surface water flowing north and cold deep water to the south, is referred to as the meridional overturning circulation (MOC). Some have suggested that the anthropogenic increase in atmospheric carbon dioxide will result in or is already slowing down the MOC. Thus, for example, Hakkinen and Rhines (2004) have documented some weakening of subpolar circulation in the North Atlantic, declining from the 1970's to the 1990's. More recently, Bryden et al. (2005) present results of a five-decade long study of the MOC in a transatlantic section at 25°N, from 1957 to 2004, that shows a slowing by about 30% for this period.

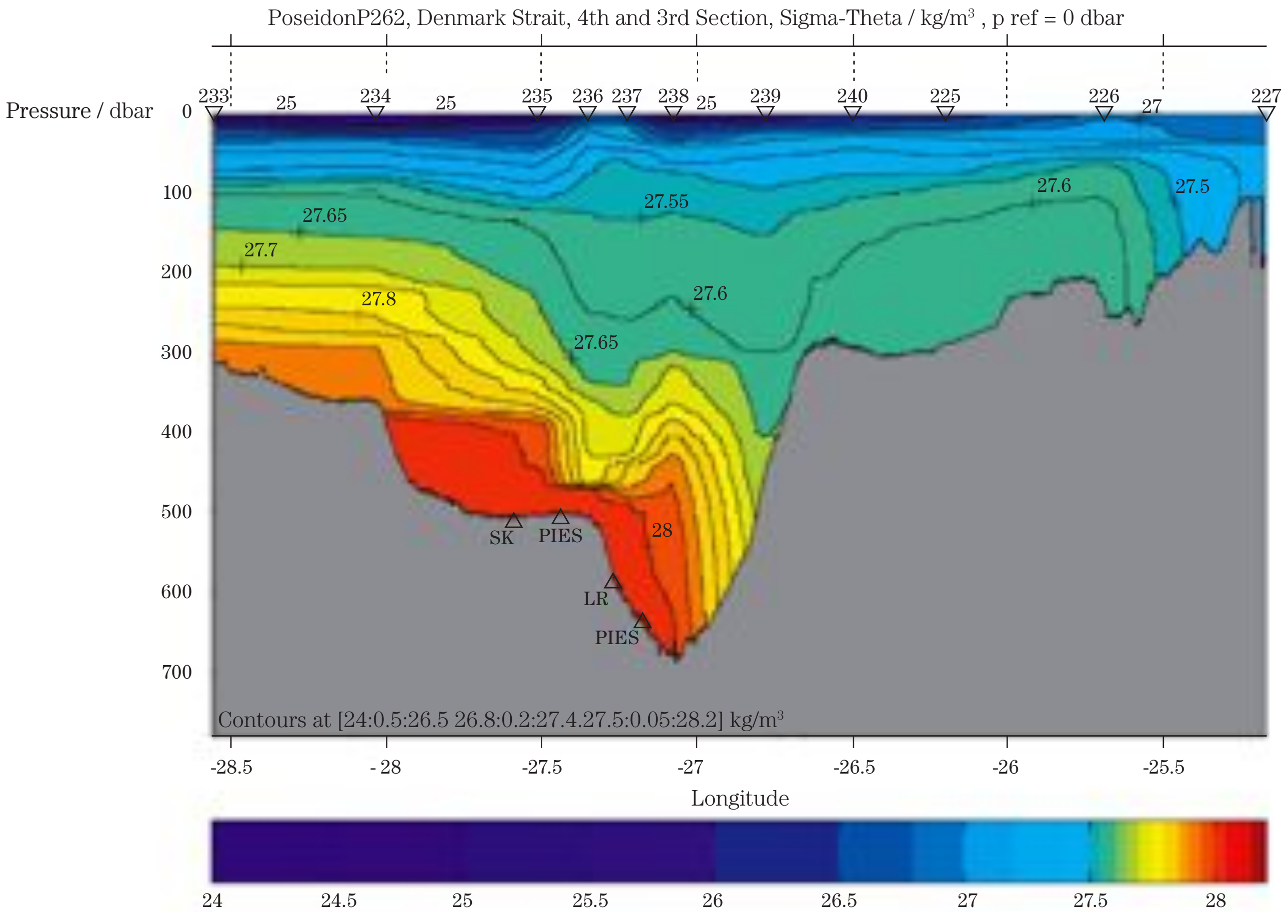

Fig. 9: The dense and cold overflow water in the Denmark Strait, between Greenland and Iceland, is a critical factor in the global thermo-haline ocean circulation. The figure shows density variations in a section ascross the Denmark Strait in July 2000, from west (left) to east (right). The color code shows the density variations, in kg/m³ abbreviated, but 1000 needs to be added to the density numbers for total density. Note southerly flow of very dense water (red) along the bottom. The vertical scale is pressure (dbar). Maximum depth in the Strait is about 630 m (Macrander 2001).

Part of this is a 50% decrease in the southward transport of North Atlantic Deep Water (NADW) between 3000 and 5000 depth. These results also indicate a significant net reduction in the northward heat transport across 25°N in recent years, but a large uncertainty still exists in these results. The Bryden team estimate a decrease in the overturning from 20 Sv in earlier surveys to 14 Sv in 2004. Could it have slowed by 30%? Similarly, southward overflow of dense water through the Faroe Bank Channel (FBC) decresed in strength in the last 50 years (Hansen et al. 2001). Long-term decrease in salinity in the Denmark Strait are consistent with these findings (Dickson et al. 2002).

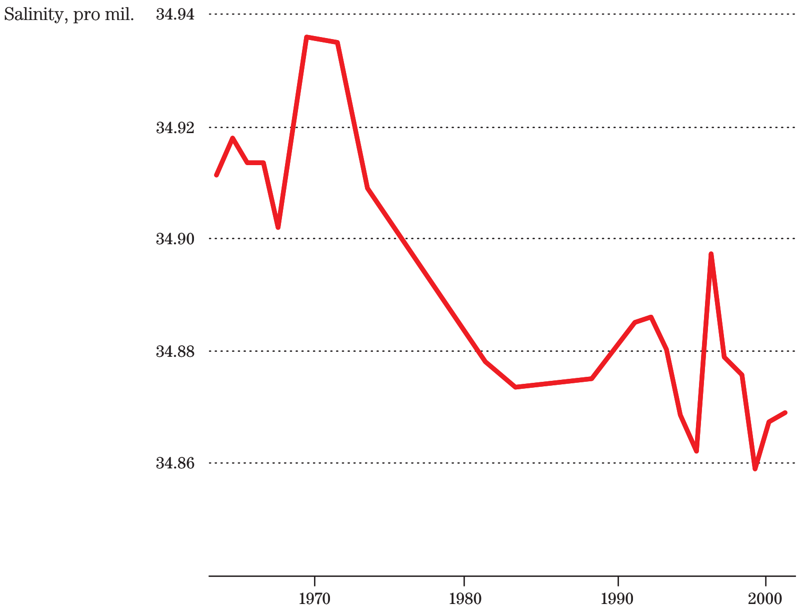

Fig. 10: The salinity of Denmark Strait Overflow Water has changed with time. Four decades of decreasing salinity of the subpolar gyre has resulted in widespread freshening or decreased salinity of the deep abyssal ocean in the north (after Dickson et al. 2002).

All of these results indicate that the North Atlantic is in a state of change, and it raises the possibility that decrease in the overflow of dense water to the south may affect the Gulf Stream and climate in the north.

2.c Sea Level Change

Among the effects of global climate change, the rise in sea level is likely to have one of the most important economic effects. Sea level has fluctuated greatly in the geologic past. The sea level on Earth rose the average by about 120 meters as the glaciers melted and the Ice Age came to an end, from about 20 to 10 thousand years ago. This dramatic sea level rise was followed by relatively stable conditions during post-glacial time (Holocene), as shown in figure 11. However, it appears that this stability of sea level is about to change – and may indeed already have begun to change. The global population is very vulnerable to sea level rise. For example, about 17 million people in Bangladesh live less than one meter above sea level.

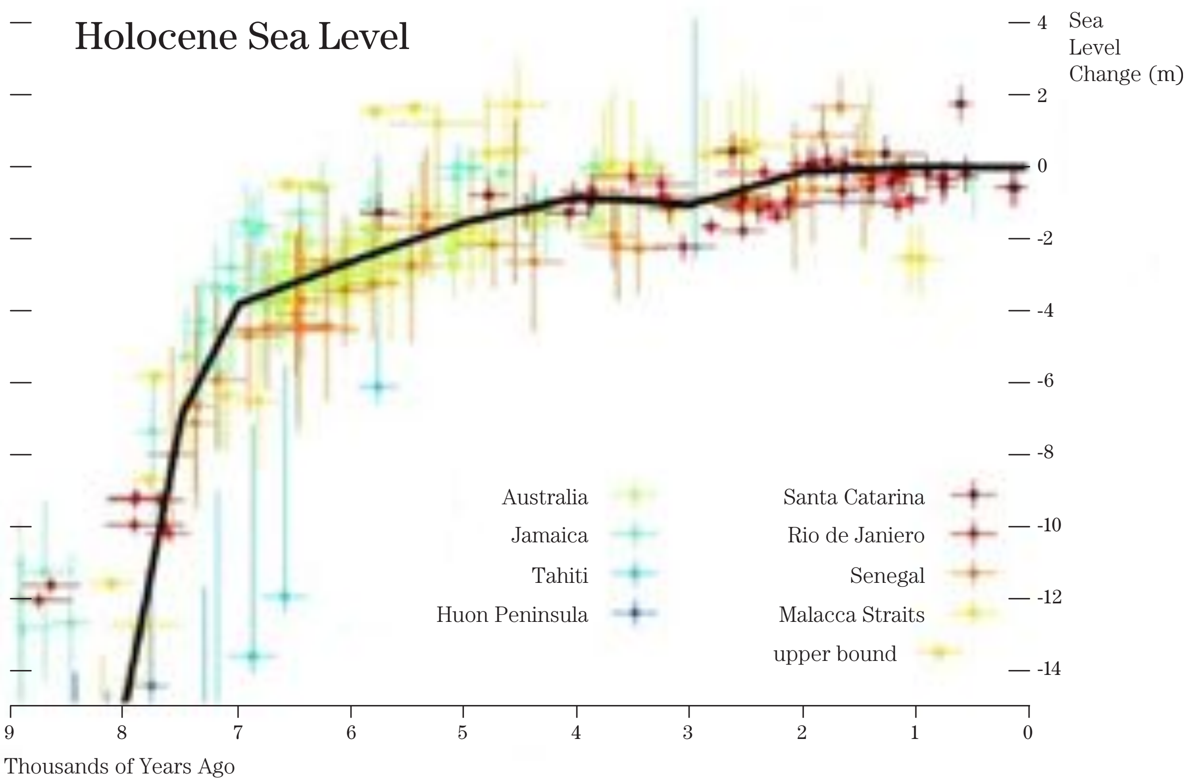

Figure 11: The global rise in sea level at the end of the Ice Age about ten thousand years ago was very rapid, as shown in the diagram above, but has remained relatively stable during the post-glacial or Holocene ti me.

As Earth's climate continues to warm, the volume of water still stored in the ice- sheets of Greenland and Antarctica will decrease. Just the melting of the Greenland ice sheet alone would result in a global sea-level rise of 6.5 meters. Melting of the west Antarctic ice sheet would raise sea level another 8 meters. Thus melting at the poles could easily result in sea level rise of about 10 meters globally. Such a rise would flood about 25 percent of the population of the United States of America, with the major impact being mostly on the people and infrastructures in the Gulf and East Coast States (fig. 12).

Figure 12: Red shows areas along the Gulf Coast and East Coast of the United States that would be flooded by a 10-meter rise in sea level. Population figures indicate that a 10-meter rise in sea level would flood approximately 25 percent of the Nation's population.

The sea level rise is measured globally by satellite altimetry on a continuous basis. The results of such surveys are shown in fig. 13 for the period 1992 to 2005. During this period, the global mean sea level rise has been between 2.64 to 3.29 mm/year, depending on the satellite. The currently observed sea level rise may accelerate greatly, if we make a comparison with the rapid climate change event that took place 130,000 years ago. At that time the Greenland ice sheet melted at a highly accelerated rate, prompting a sea level rise at a rate of 2 to 5 m per century. Is that the trend that we are now heading in the direction of? Only time will tell.

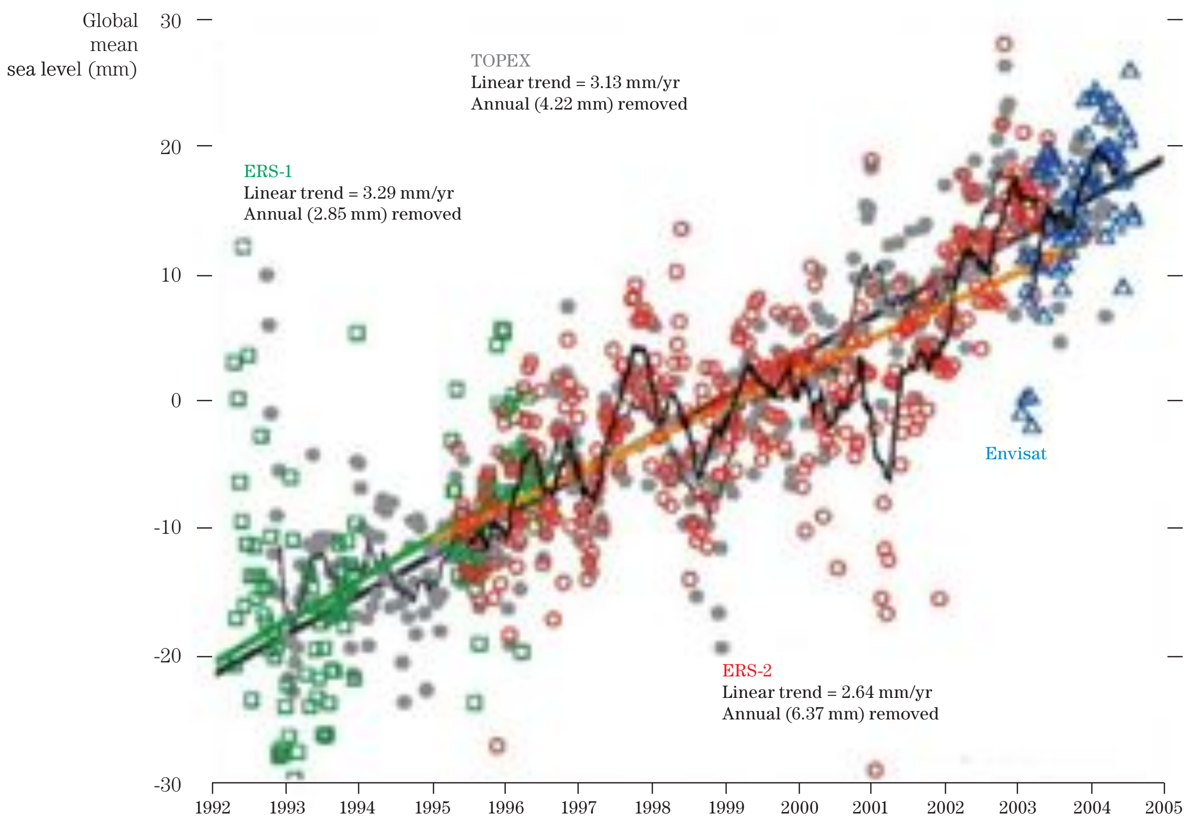

Figure 13: Global sea level rise in the past thirteen years, as measured by satellite altimetry. The mean linear trend is between 2.64 to 3.29 mm/year.

In Iceland the evolution of the sea level is recorded by ancient strandlines. At the end of the glaciation, the crust was greatly depressed by the load of the glaciers. But the ice sheet over Iceland melted extremely rapdily and as a result sea level was established in regions that are far inland at this time. However, the very rapid rebound of the land, when the glacier overburden was removed, resulted in rapid rise, and consequently sea level fell to near present level shortly after the end of glaciation, i.e. about 9000 years ago (fig. 14).

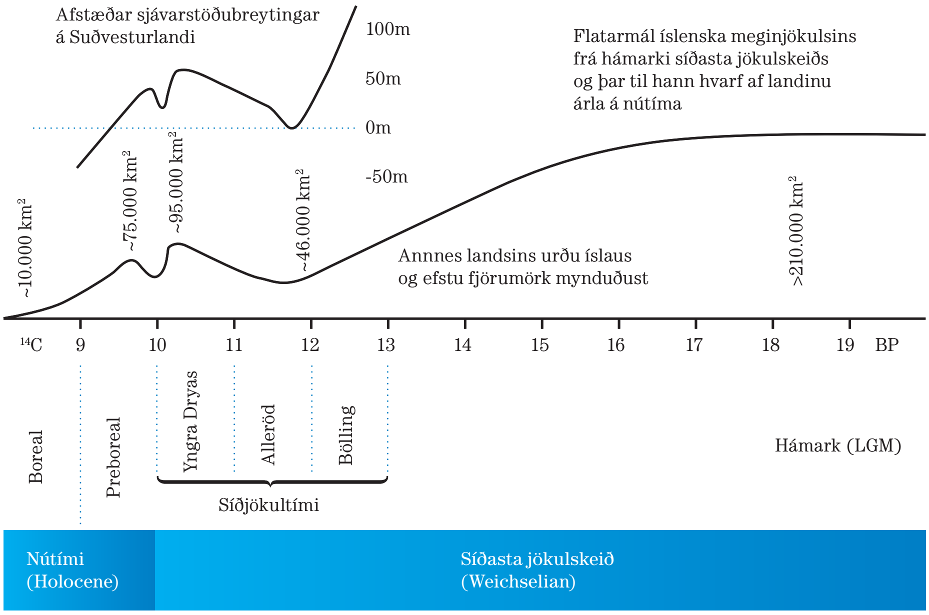

Figure 14: The evolution of sea level change in Iceland during the close of the last glacial period (Weichselian) and the beginning of post-glacial time (Holocene). After Norðdahl et al. (2005).

2.d Icelandic Research on Climate Change

Climate change in the Iceland region has long been a topic of considerable interest to historians and scientists in Iceland and the evidence come from a variety of sources, including proxy information such as the sea ice extent and the record of cod fishing catches, as well as direct measurements. In 1961 the Icelandic meteorologist Jón Eyþórsson remarked on the measurable increase in annual mean temperatures in Iceland during the first half of the twentieth century, along with shrinking glaciers. The instrumental record, which dates back to the earliest temperature measurements in Stykkishólmur in 1823, shows clear trends, but the historical and proxy record is much longer. One of the longest proxy records of climate in the Iceland region is the occurrence of sea ice at the north coast of Iceland, the so-called Koch index of sea ice, extending back to the twelfth century (Wallevik and Sigurjónsson 1998). The utility of this proxy is demonstrated by the close correlation between sea ice at the north coast of Iceland and surface temperature in Iceland (Bergþórsson 1969, 1985).

Eight hundred years of historical data from Iceland, including the sea ice index shown in figure 15, shows that the climate has fluctuated greatly from the settlement in the ninth century A.D. to the present time. The first cold period, with a maximum at about 1300 A.D., is also coincident with a period of severe climate in continental Europe. The second cold period, about 1550-1900 A. D., has a maximum in the nineteenth century, followed by an abrupt warming in the first decades of the twentieth century, and it occurs at the same time as the so-called Little Ice Age. It is possible that the historical record of the all-important cod fishing may be regarded as one proxy of climate change in the Iceland region. Thus Ogilvie and Jónsdóttir (2000) have examined the correlations between sea-ice extent, sea temperatures, ocean currents, and cod fishing. The sources suggest that fishing was generally successful in Iceland during the medieval period and well into the 16th century. However, in the 17th through the 19th centuries, the fisheries failed on numerous occasions, sometimes for several years. The causes of these failures were complex but climate likely played a part, however, socio-economic factors were also involved (Ogilvie and Jónsdóttir 2000).

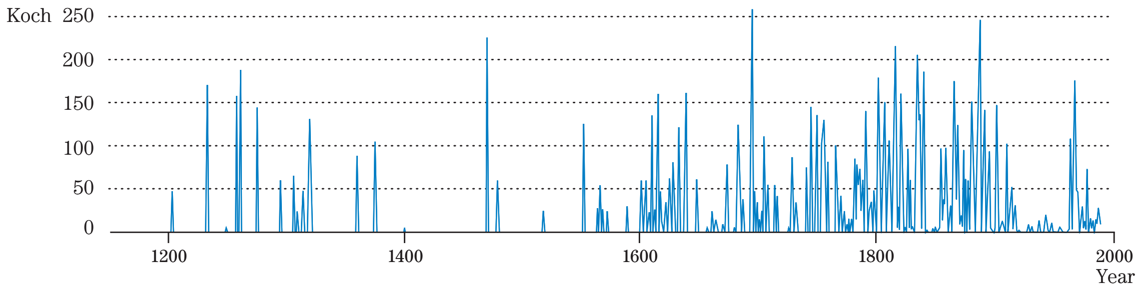

Figure 15: The occurrence of sea ice at the north coast of Iceland (Koch ice index) is a good proxy for climate variations in the region. The Koch ice index is the number of weeks per year that ice affects the coast of Iceland (Wallewik and Sigurjónsson 1998).

Various programs at Icelandic educational and scientific research institutions involve current research related to global change. They include studies in oceanography, climatology, glaciology, hydrology and paleo-climatology. A very brief review of these research programs is given below, as far as they apply to global climate change and related problems that fall within the concept of the Earth Systems Science Institute proposed in this document.

Oceanography

One of the goals of Hafrannsóknastofnun (the Marine Research Institute of Iceland; established 1965) is to accumulate knowledge and a data base on the physical and chemical properties of the oceans around Iceland, with special respect to the biota and particularly the relationship between oceanographic properties and fish stocks. The largest of these projects is "The State of the Sea", where changes in the temperature and salinity of the ocean around Iceland are monitored regularly since 1950 in sixteen profiles across the Iceland shelf.

The profiles are now measured four times a year, providing a very important time series of the state of the sea on the Iceland shelf, largely through the work of Héðinn Valdimarsson, Steingrímur Jónsson and Jón Ólafsson. Chemical oceanographic parameters are also evaluated regularly, including the nutrients, and the concentration of carbon dioxide in the sea water and other chemical parameters, principally conducted by Jón Ólafsson, who has a joint appointment at the University of Iceland and Hafrannsóknastofnun. The resulting data series of surface water pCO_2 measurements around Iceland is providing a look at the regional and interannual differences in carbon and nutrient chemistry in the North Atlantic near Iceland. Iceland's participation in the Nordic Arctic Research Programme (NARP) includes Jón Ólafsson, who is also project coordinator, and it is revealing the linkages between indices of atmospheric circulation variations and hydrographic conditions in Icelandic waters. His studies address the effects of increasing atmospheric CO_2 on lowering ocean pH around Iceland, and effects on calcium carbonate solubility and sensitivity of the marine ecosystems to these changes.

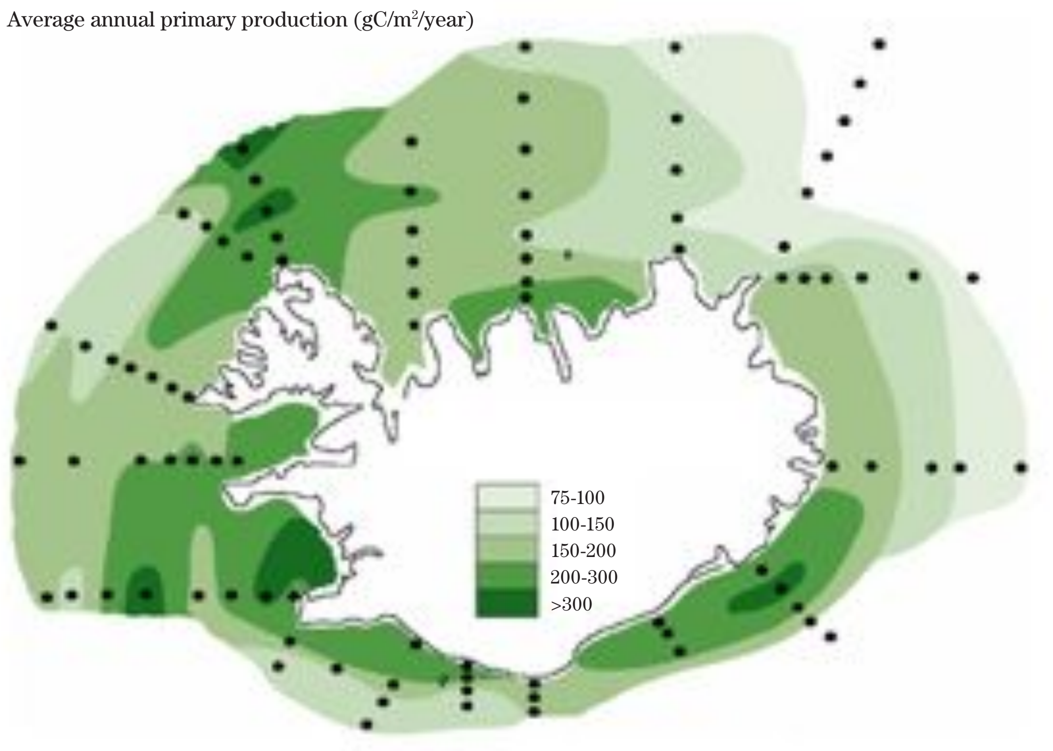

Figure 16: "The State of the Sea" project of Hafrannsoknastofnun (Marine Research Institute of Iceland) measures changes in the temperature, salinity and productivity of the ocean around Iceland, monitored regularly since 1950 in sixteen profiles across the Iceland shelf. The figure shows the average annual productivity, in terms of grams carbon per square meter per year.

Physical oceanographers of Hafrannsóknastofnun, including Steingrímur Jónsson and Héðinn Valdimarsson, participated in the VEINS project. This program includes eight European nations, with the overall objective to measure and model the variability of fluxes between the Arctic Ocean and the Atlantic Ocean. A long-term goal of this program is to gather the critical measurements that are needed to understand the role of the high-latitude oceans in steering decadal climate variability. The aim is to measure and model the oceanic fluxes between the Arctic and the North Atlantic Ocean through the Nordic Seas in order to develop a measurement system for the longer term variability of these fluxes. The means of operation have been time series measurement with moored instrumentation and repeat hydrography in the major passages of the Nordic Seas as well as modelling of flux in the individual passages. Steingrímur Jónsson and Héðinn Valdimarsson are also an active participants in international programs, such as MOEN (Meridional overturning exchange with the Nordic Seas) and ASOF-West (Arctic-Subarctic ocean flux-array for European climate). The recent studies of Steingrímur Jónsson and Héðinn Valdimarsson (2004a; 2004b) on the sources of Denmark Strait overflow water are of critical importance to our understanding of the thermo-haline circulation in the north, as discussed above.

Climatology

Studies in climatology in Iceland have been primarily conducted at Veðurstofan (The Icelandic Meteorological Office), which was established 1920 (Jónsson and Garðarsson 2001). In addition to maintaining the long and detailed meteorological record, its scientists have conducted a number of climate-related studies. Halldór Björnsson conducts a wide range of research, including climate modeling, climate dynamics, and ocean circulation research (eg. Björnsson et al. 1997). His research includes the fundamental question of the basic temperature and salinity structure of the oceans.

An important area of research for Tómas Jóhannesson is the modeling of CO_2 induced warming and studies of glacier variations in Iceland and their response to variations in climate (Jóhannesson 1991; Jóhannesson et al. 1998). The increase in glacier runoff is one of the most important hydrological consequences of future climate changes in Iceland and Greenland. Collaborative studies between the Iceland Meteorological Office, Orkustofnun and the Unviersity of Iceland, as a part of the Nordic CWE and CE research projects, of the relationship between climate change and runoff, indicate that climate changes are likely to have a substantial effect on glaciers and runoff from glaciated areas in the Nordic countries in the future. These models indicate that as a result of climate change, many glaciers and ice caps are projected to essentially disappear over the next 100–200 years. Modeling indicates that runoff from Nordic glaciers will increase by about 30% by 2030. The expected runoff increase is likely to have important future implications for the design and operation of hydroelectric power plants (Jóhannesson et al 2004).

Climate in Iceland is characterized by low-frequency natural variability on decadal time-scales which may be partly driven by changes in the North Atlantic thermo-haline circulation. Future behaviour of the North Atlantic ocean circulation is highly uncertain and model predictions of climate development in this part of the world are perhaps more difficult than for most other regions of the world. In view of these difficulties, models and scenarios must be considered an extremely uncertain, although plausible, description of what might happen in the future rather than a prediction of what most likely will happen. Jóhannesson and colleagues have evaluated a climate change scenario that has been defined for application in hydrological models in the Nordic research project Climate Change and Energy Production. Using global coupled atmosphere and ocean general circulation models and statistical downscaling of the model results, the scenario specifies a warming rate which increases from 0.3 °C per decade for Iceland. Summer warming is relatively uniform over the area, ranging from 0.25 °C per decade in Iceland, whereas winter warming is more variable, of about 0.35 °C per decade in the North Atlantic area. Precipitation is increased by 3-6% per degree of warming (Jóhannesson et al. 1995).

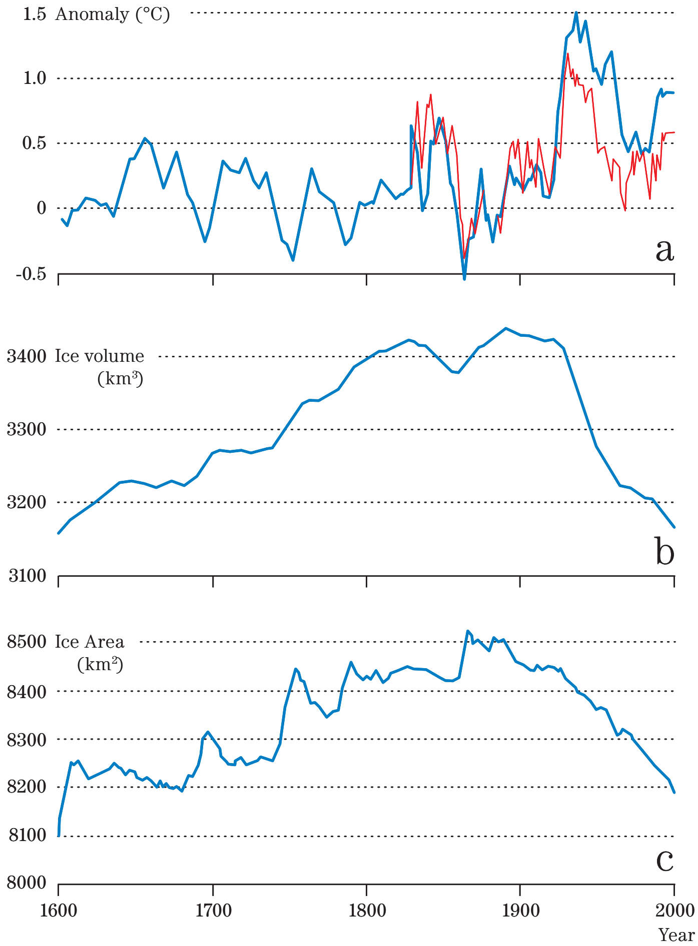

Figure 17: The simulated ice cap evolution of Vatnajokull glacier from 1600 to 2000, based on climatological records (Flowers er al. 2005). The temperature anomaly (a) is from the Stykkisholmur 1823-2000 measurements and from historical records of sea ice cover. The ice cap volume (b) and ice cap area (c) are simulated.

Glaciology

Geoscientists at the University of Iceland conduct a wide range of studies on Icelandic glaciers. Much of this research is on glacier dynamics (Helgi Bjornsson, Guðfinna Aðalgeirsdottir and co-workers) and volcano-glacier interactions (eg. Magnús Tumi Guðmundsson et al. 2004). More recent work in this group is also addressing global change aspects (Magnússon et al. 2005, Marshall et al. 2005) and a good example of this program is the work published by Flowers et al. (2005). Iceland's glaciers are sensitive indicators of climate change, and small changes in air temperature can be expected to have profound effects on glacier geometry (fig. 17). Using recent simulations of the NCAR-CCSM climate model, a roughly 3°C warming of Iceland is suggested by 2140, and this scenario has been used in modeling the hydrology and dynamics of Vatnajökull (Flowers et al. 2005). Glaciological forecasting is fraught with difficulties, mainly because of the uncertainty in the rate of surface warming in the region. On the basis of four warming scenarios (1, 2, 3 and 4°C warming per century), the ice cap extent can be simulated, as shown in figure 18, showing that no ice remains in the Vatnajökull region after 200 years for the 4°C scenario, and little more than a trace for the 3°C scenario.

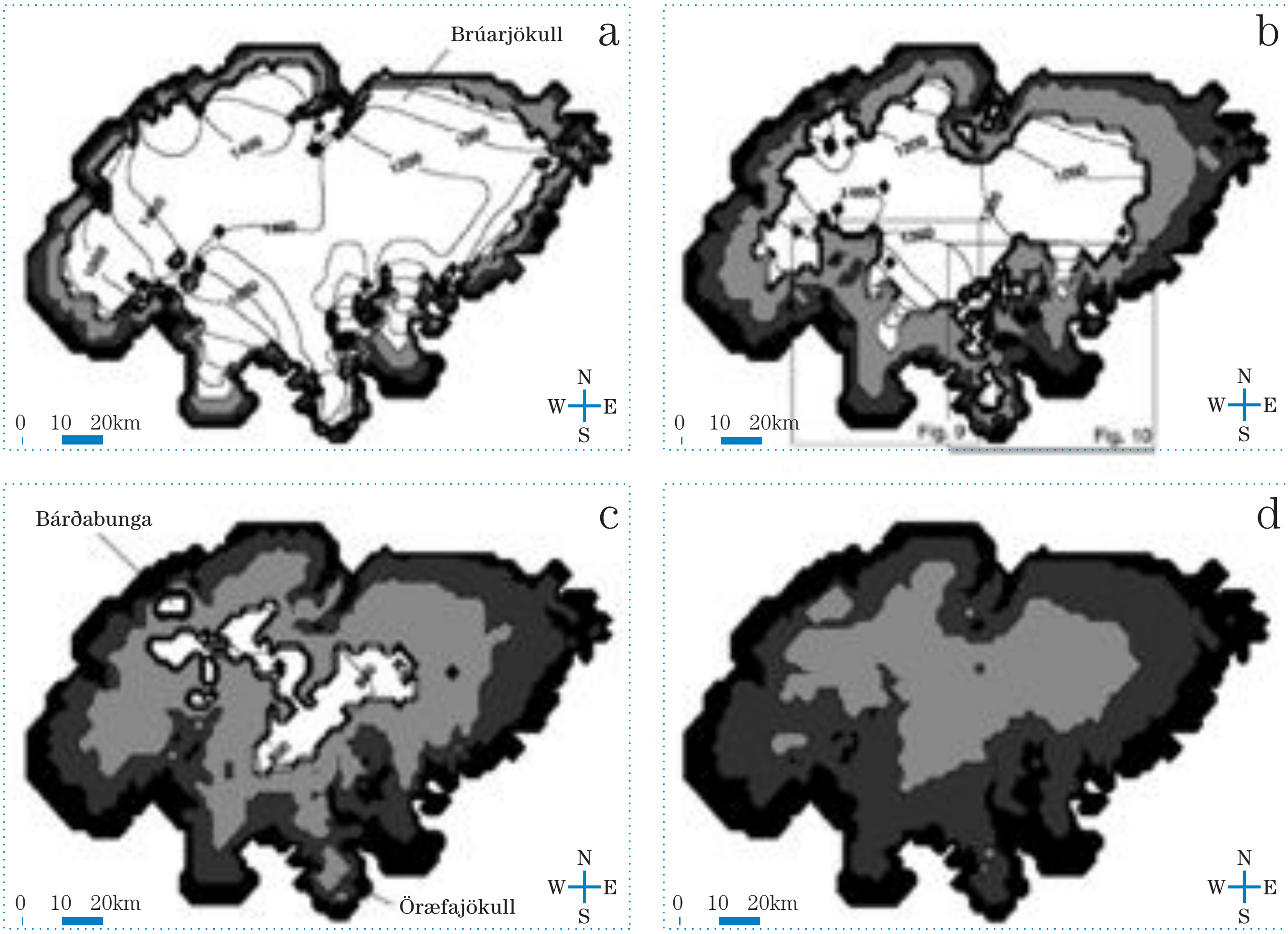

Figure 18: The shrinking and disappearance of the Vatnajokull ice cap, based on a glaciological forecasting scenario (Flowers et al. 2005). Panels (a), (b), (c) and (d) are scenario resluts assuming warming rates of 1, 2, 3 and 4°C, respectively. The dark shaded region is after 100 years, the light shaded after 200 years and the white after 200 years of warming.

According to the Marshall et al (2005) model, a positive mass balance is no longer retained after 2030, and model scenarios show that Vatnajökull is then likely to enter a state of monotonic and accelerating retreat with disappearance of the ice cap by 2300 under the 2°C climate scenario.

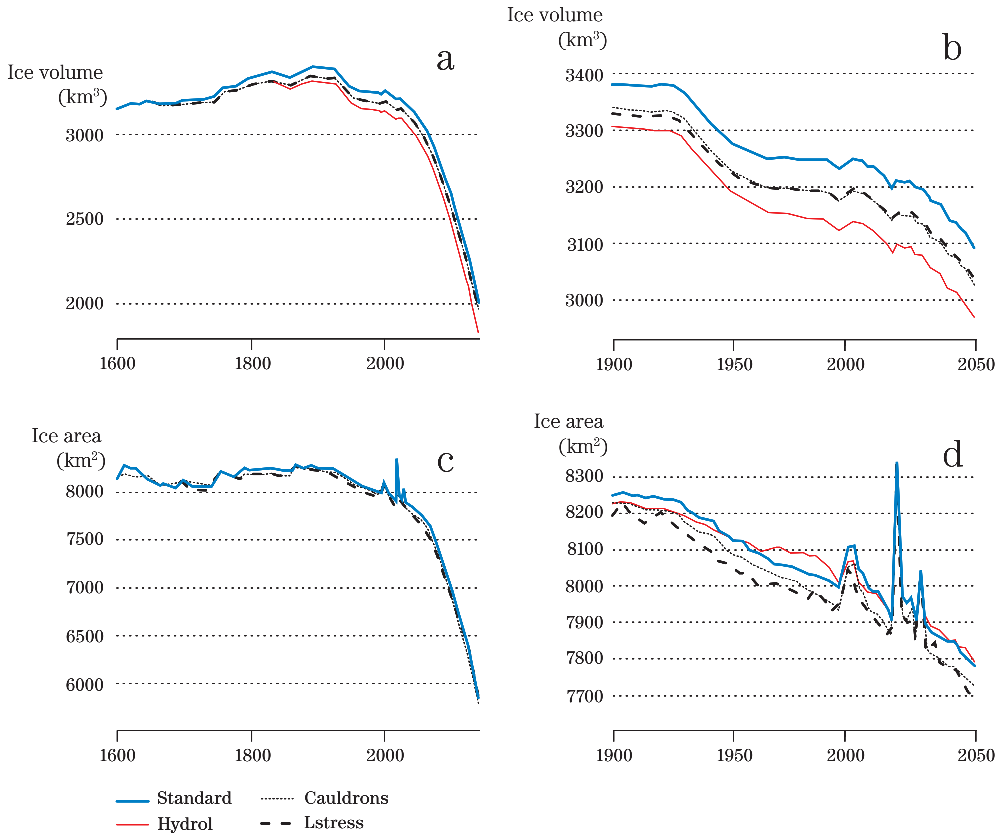

Figure 19: The historical and future evolution of Vatnajokull glacier under different precipitation/ temperature relationships, indicating disappearance of the ice cap by 2300 (Marshall et al. 2005). (a) Average air temperature over the ice field, in °C. (b) Mean ice field mass balance, in m/yr of ice loss. (c) Ice volume, in km³. (d) Ice area, in km².

All climate change scenarios for Vatnajökull indicate a pronounced discharge rate to rivers in the region, with marked peacks in discharge rate several decades to a century after the major onset of warming, followed by large decline in runoff (Flowers et al. 2005). The rivers from the northern and western flanks of Vatnajökull are of curical importance to hydroelectic power projects in Iceland, and the discharge in these rivers will be affected differently depending on the location of their glacial drainage basins their distance from the coast.

Hydrology

It is evident from the discussion above that climate change affects glacier runoff in Iceland, and indeed changes in glacier runoff are one of the most important consequences of future climate changes in Iceland, with important implications for the hydroelectric power industry. The rapid retreat of glaciers also has other implications, for example changes in fluvial erosion from currently glaciated areas, changes in the courses of glacier rivers, which may affect roads and other communication lines, and changes that affect travel in highland areas and the tourist industry. In addition, glacier changes are of international interest due to the contribution of glaciers and small ice caps to rising sealevel (Jóhannesson et al 2004).

Orkustofnun (the National Energy Authority of Iceland) has a primary charge to conduct research on energy resources. Secondly, Orkustofnun collects basic data on hydrological conditions and on the hydrological budget of Iceland's freshwater resources. A range of hydrological studies and monitoring are conducted at Orkustofnun with respect to the water budget of Iceland, and several of these have a bearing on climate change issues. Thus Orkustofnun has accumulated a valuable long-term record of runoff, and this has been utilized in studies by Páll Jónsson and others of trend analysis of Icelandic discharge, precipitation and temperature series. Glaciological studies are conducted by Oddur Sigurdsson and Þorsteinn Þorsteinsson on Icelandic glaciers, in relation to run-off. One of the proposed projects at Orkustofnun is the Nordic program

Arctic-HYDRA - the effect of climate change on the hydrologic budget (proposed for the IPY 2007-08), where Arni Snorrason is principal investigator. The scientific goals of Arctic-HYDRA are to characterize variability in the Arctic hydrological cycle and to examine linkages between atmospheric forcing and continental discharge to the ocean. The program will also assess the historical response of the Arctic Ocean to variations in freshwater input from rivers and net precipitation over the ocean.

Paleoclimatology

An important group of scientists work in the field of paleoclimatology and related disciplines at the Institute of Earth Sciences of the University of Iceland. They conduct a range of studies that have a bearing on climate change in the Nordic region, including paleoclimatic studies of Greenland ice-cores by oxygen and hydrogen isotope measurements (Arný E. Sveinbjörnsdóttir and Sigfús Johnsen). This group is also focusing on the application of sedimentological methods to study the climate record preserved on the shelf surrounding Iceland (Áslaug Gerisdóttir, Jón Eiríksson, Hreggviður Norðdahl; see eg. Eiríksson et al. 2004 and Geirsdóttir and Eiríksson 1994). The scope of research by this group range far outside the Iceland region, however, such as the studies of Ólafur Ingólfsson on Late Quaternary glacial and climatic history and environmental change during the current geological period, that include work on glacial and climatic developments in both southern and northern polar regions (Ingólfsson et al, 1997).

Jon Eiriksson heads the collaborative paleoceanography project ALDA or “Marine Reservoir Age as a North Atlantic Climate Proxy”, which targets palaeoceanographic changes in the North Atlantic by using marine reservoir age variability as a proxy for water mass changes. Using marine sequences and tephrochronological correlation with land sections, the reservoir age at tephra markers can be determined with AMS 14C dating. The present-day reservoir age of the East Greenland Current that carries Arctic Water southwards along Greenland is 550 years whereas the reservoir age of the Irminger Current that flows clockwise around Iceland is 400 years. A southward shift of the Polar Front towards or beyond Iceland would be expected to increase the reservoir age on the North Icelandic Shelf by at least 150 years. The main aim of the project is to reconstruct a continuous record of reservoir age variability for the Holocene, the Lateglacial, and the Last Glacial. A pilot study has already been successfully carried out to test the use of this novel palaeoceanographic proxy (Eiríksson et al. 2000a; 2000b; 2004).

3. Scientific and Economic Plan

3.a The ESSI concept

Iceland is in a uniquely important position with respect to scientific research on global climate change. As reviewed in Section 2, some fundamental oceanographic processes take place in the region around Iceland, that have an impact on ocean currents and climate change, not just in the North Atlantic region, but globally. Icelandic scientists have contributed a great deal to research on these topics, but their research is conducted on an individual basis and no single foundation, institute, department or scientist group is focused on global climate change research in Iceland. We propose the establishment of a new institute devoted to climate change: the Earth Systems Science Institute (ESSI), that would play a leading role in this type of scientific research and monitoring in Iceland, with close collaboration with international agencies. Because of their importance for society and our national economy, studies of climate change are not only of interest for pure scientific research, but are properly regarded as an applied science, and can produce information that is of value for regional and global entities, including re-insurance corporations, foreign governments, and multi-national organizations of any kind. As outlined below, we propose that a component of ESSI will generate marketable products, with the aim of largely sustaining the operating costs of the institute from such income in the long run.

The principal value-added chain of ESSI follows through the following links:

A. Enhancing scientific knowledge through focused contribution on cryospheric feedback components, the terrestrial ice caps and sea-ice in GCM models.

B. Establishing a fully coupled atmosphere-ocean regional model system and use it to generate regional climatology that takes into account the vigorous coupling between the atmosphere and the ocean in the North Atlantic region, with critical impact on the climate in Iceland and the North-West Europe, using existing data and methods.

C. Derive knowledge of actual situations through monitoring, make those available in near-real-time context and facilitate access and usage of the data for various applications and on-line publications independent of the line of study, interest or need.

D. Derive benefits through developing methods and contextual analysis of the information, for users that have on-going needs for the information. The information can enhance the revenue potential of the customer-client activity and benefit ESSI to feed its sustainability in the future.

The value-added and financial footing of ESSI follows from four principal lines:

A. Through national and international research programs that are driven by the need for advancement of science and research in the global change field.

B. Through innovative business development programs that acknowledge the need for the development of value-added business capacity in the global change field, as a contribution to adapting to change and enhancing resilience.

C. Through business partners that see potential economical benefits of investment in the activity, both as regarding investment return and as enhancing the competitive edge of their core activity.

D. Through marketing and sales of service products in a consumer market of businesses that are sensitive to conditions that ESSI has provided tools and methods for insight into.

3.b Iceland Research Policy

How does ESSI fit into the scientific research environment in Iceland? An overall policy statement for scientific research in Iceland is not in place, but Vísinda- og Tækniráð, the Science and Technology Council of the Icelandic Government, has proposed some research policy guidelines for 2006-2009 and we quote here the part of their report that is most relevant to the objectives of ESSI. Paragraph 6.2 of this report is titled "Environmental Monitoring and Development of Natural Resources", and it states:

> "Knowledge of the land we live on and of its nature is the foundation for policy development for the utilization of natural resources, environmental protection and response to natural disasters. There is a need to define more fully the role of the state in gathering base line data, mapping, fundamental research and monitoring of the natural environment on land and in the sea. Monitoring projects are less suited for participation in competitive bidding for funds from scientific research funds. Such projects require coordination of the roles of institutions that are run through several government ministries. A coordinated monitoring system is critical for implementing the government's goals within the framework of international commitments. The data base accumulated by monitoring programs is the essential source for a variety of research projects on the environment, environmental change and human evolution in Iceland and in communities in the north. The Science and Technology Council encourages further and continued research on self-sustained utilization of natural resources on land and at sea, including renewable energy resources, and development of environmentally-friendly technology, which is likely to lead to a more favorable environment in Iceland, promote employment opportunities and export of technology and marketable knowledge. The Science and Technology Council proposes:
>
> » The foundation of databases dedicated to the land surface, the ocean floor and nature of Iceland, and that a plan be developed to improve and coordinate such data bases in the coming years.
>
> » The development and sustainability of such databases be in digital form and that they be made accessible for general use and research.
>
> » The government develop a coordinated plan for monitoring in the fields of development of natural resources, environmental protection and natural disasters, which is linked to policy development in these fields.
>
> » Increased scientific international cooperation be sought in these areas."

As discussed below, the terms of reference of ESSI fall squarely within these scientific research policy guidelines of the Icelandic Government.

3.c The Scope of ESSI

The principal objectives of ESSI are to address research and assessment of Global Change in the region around Iceland that has direct impact on the Icelandic economy and contributes to increased economic resilience and adaptation to change. ESSI aims at making a significant contribution to Global Change research in the region, and to fill knowledge gaps in Global Change science of particular interest for the region. ESSI would contribute to advanced impact assessment studies through leveraging the regional global change research, as well as providing enabling means that facilitate trans-disciplinary impact studies. ESSI aims at establishing an economically sustainable organization that is eligible for domestic as well as international funding, with the capability of deriving revenue from its own services and findings.

As conceived in this report, ESSI is an eligible and very interesting partner for pursuing funding opportunities in collaboration with other research organizations in this field. There are a number of European and other international funds and foundations that provide funding for and support research related to climate change. These are listed in part in Appendix. ESSI would seek funding from these organizations, alone or in collaboration with other institutes, to support part of the research program on global climate change.

The proposed structure of ESSI addresses the Global Change Research from end-user perspective through five lines of activities:

Monitoring: Measurements of Denmark Strait Ocean Fluxes.

Science: Climate and the Cryosphere, ice-caps, snow and sea-ice.

Research: Regional Coupled Atmosphere Ocean Model Climatology Data.

Outreach: Informatics, Data Access, Analysis and Publishing

Benefits: Econometrics and Regional Climate Diagnostics.

Revenue: Climate Expert Service System.

The Monitoring component meets the objectives of identifying the state of the regional climate system and validation of the model framework used for conducting the research. The Science component aims at advancing the treatment of the most important climate indicator in the region, acknowledging the fact that only 3 out of 5 Global Circulation Models have dealt with the treatment of sea-ice and ice-caps, thus contributing an important modification of the circulation models. The Research component aims at addressing the coupling between the ocean and the atmosphere, with recognition of the influence of the ice-caps and the sea-ice, and generate hindcast and Global Climate scenarios data-sets based on the best possible models and in situ data. In order to make the results and the facilities useful and applicable to trans-disciplinary studies and regional analyzes, we propose a component of Outreach and framework data access, analysis and publishing. The facilities and the climate data would be coupled with econometric variables, to derive new knowledge and findings that can lead to financial Benefits and improved resilience to climate change in the social economical system. These Benefits and Revenue components would be used to sustain the financial footing of ESSI as well as strengthening the competitive advantage of the Icelandic economy.

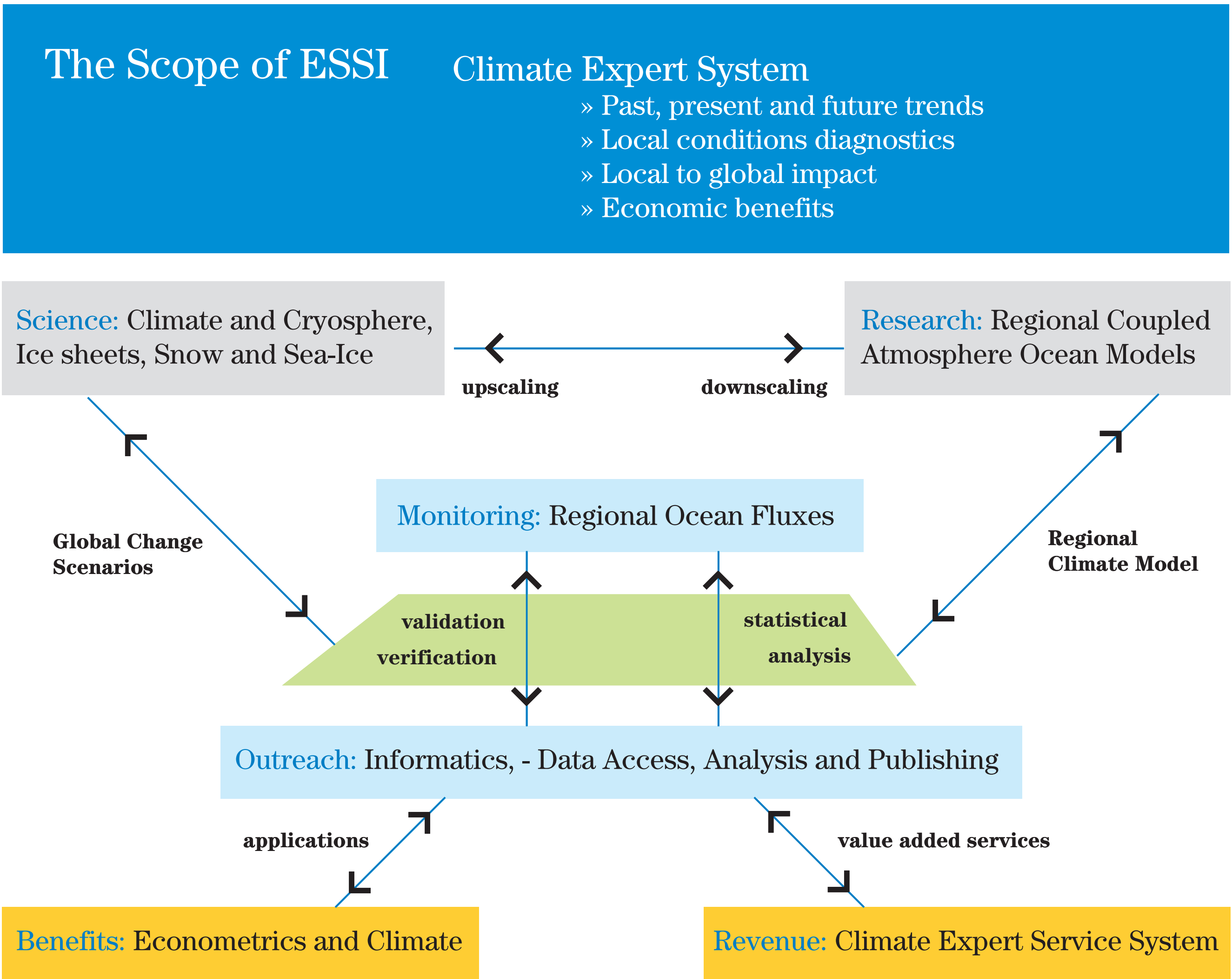

Figure 20: The scope of ESSI ranges across the board, from pure research to outreach, applied research and Econometrics.

3.d ESSI Components

Below is an overview of the principal components of ESSI which together build a coherent structure that addresses the coupling between the spheres (ocean, atmosphere and cryosphere) across scales (time and space) that allows for advanced impact studies as well as adaptation to change in the region through an econometrics approach.

Monitoring: Measurements of Denmark Strait Ocean Fluxes.

As outlined in section 2.b above, monitoring of the North Atlantic ocean region surrounding Iceland is a major scientific challenge, especially in terms of physical oceanographic processes. The northerly inflow of warm and saline surface waters into the region, and outflow of cold and dense bottom waters to the south modulates the climate in Europe and in the north, and may play a crucial role in global circulation and climate change. ESSI would assume a leading role in some aspects of ocean monitoring in this region. Through monitoring the southward flow of deep water through the Denmark Strait between Iceland and Greenland, ESSI would be taking responsibility for monitoring a key parameter in regional as well as global climate change. In situ soundings (temperature, salinity and current) would be collected in near real-time with sensors on trawlers in the fishing banks west of Iceland and the data transmitted on to international data exchange networks in near real-time. This activity addresses data collection and monitoring focused on ocean fluxes, which is directly related to the thermo-haline convection in the region, to support climate diagnostics in the region as well as the near-real-time conditions.

Specific objectives of the Monitoring component:

A. Deployment of two moorings in the Denmark Strait for monitoring of currents, water temperature, salinity and sea-ice draft.

B. Conduct two biannual transects across the Denmark Strait of hydrographic surveys for spatial and short-term temporal variability of ocean fluxes.

C. Deployment sounders on fishing trawlers in the Iceland region, collecting real time in situ data and transmit as TESAC/BATHY(footnote) messages.

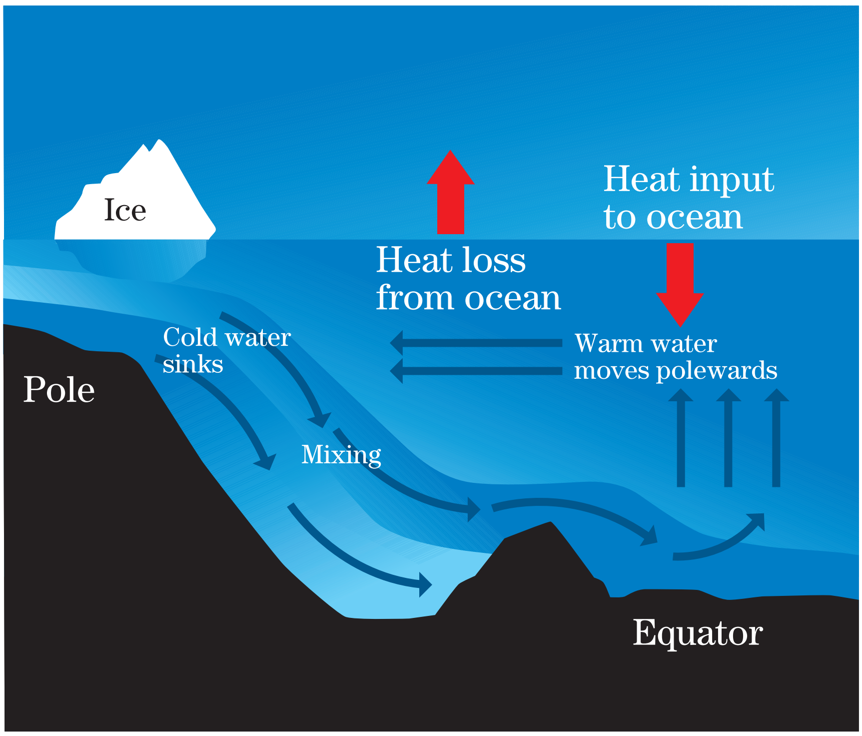

Figure 21: Monitoring of deep and surface ocean flow in the Denmark Strait between Greenland and Iceland is an important facet of ESSI research, and a critical component of global change research.

Resources for the Monitoring component:

The following resources are required for the Monitoring component:

A. One principal scientist position and one technician initially, increasing to four positions year 5.

B. Two weeks of research vessel ship-time and standard vessel equipment. Rental of two moorings with acoustic doppler current profilers (ADCP) and upward looking sonar (ULS).

C. Ten trawl sounders with CTD and acoustic current meter.

Methods and accomplishments of Monitoring:

ESSI would establish liaison with the ASOF (Arctic/Subarctic Ocean Fluxes) program group and coordinate activities for mooring deployment, retrieval and data exchange of physical oceanographic data. The biannual transects follow on from integration with the activities on the Icelandic Marine Research Institute (see fig. 16 page 20). The deployment of sounders on trawlers would be with commercially available and compact instrumentation that is attached to equipment already in use on most merchant vessels and trawlers, but instruments are calibrated, data collected and quality-checked and sent as near-real-time messages. The trawler-based monitoring fills in gaps in the collection of comprehensive data for the region, for the study of spatial and temporal variations, for monitoring trends and studying variability. Making the near-real-time in situ data available on global data exchange networks (e.g. GTS as TESAC/BATHY) would result in these data taken into account in advanced data assimilations of various data resources, such as e.g. SST and SSH collected by satellites. The availability of such data contributes to proper calibration and quality enhancement, thus enhancing the quality and usability of remote sensing data with respect to the surface mixed layer in which coupling between the atmosphere and the ocean takes place. The near-real-time data component would extend the usability of the mooring data as well as the biannual transect snapshots with a linking across spatial and temporal scales.

Customer-client relationship of Monitoring:

The principal customer for this activity is initially the Icelandic Government that makes contribution to environmental monitoring in international programs through this effort of ESSI. Participation in international programs, such as EU FP framework programs, provides avenues for funding in this area and international cooperation like within iAOOS (Integrated Arctic Ocean Observing System (see Appendix 1) and in other programs in the area that are open for concerted action. The near-real-time monitoring opens up opportunities for services on real-time ocean diagnostics. It is known that fish breeding patterns are related to dynamics in sea water type and to tidal motions. Likewise, fishing and cargo vessel fuel consumption is also related to ocean currents. The value of the services in paid-for customer service relationships can be used to fund the near-real-time monitoring efforts, which also paves the way for useful and marketable contribution to the offshore transport and fishing industry.

Science: Climate and the Cryosphere, ice-caps, snow and sea-ice.

ESSI addresses scientific research through focusing on the role of the Cryosphere (sea-ice and ice caps) in Global Circulation models (GCM) as a triggering parameter in Arctic climate. The current Global Circulation models fail to replicate adequately the conditions in the Central Arctic during the winter when freezing takes place. Only three out of five reference Global Circulation Models incorporate some sea-ice rheology. The sea-ice thickness redistribution is coupled to the forces and ice motion parameters. Models that account for both sea-ice and icecaps need to be further enhanced and developed and contributed to the large Global Circulation Modeling Centers to derive new Global Change Scenarios that correspond to the new thermal equilibrium state. The volume (primarily height above sea level) of the ice caps stipulate the regional circulation as well as freshwater transports in the region. The opening and closing of sea ice stipulates the ice formation during winter, thus having triggering impact on the thermohaline circulation and therefore on the climate of the region. Thinning of the ice significantly affects the ice drift in response to atmospheric forcing.

Specific objectives of Science component:

A. Modeling of glacier mass balance with respect to precipitation variations in enhanced regional climate models.
B. Work on a sea-ice model for the GCM's for new sea-ice thickness redistribution data base with ice motion and internal forces accounted for.
C. Studies of special weather events with respect to snow accumulation and avalanches and land slides.

Resources required for the Science component:

The following resources are required for this component:

A. One principal scientist positions, starting at month 1 after founding of ESSI. A second position to be added in year 6.
B. One computer scientist and data analyst for model run and development of computational algorithms starting in year 2. Two further positions to be added in years 4 and 8.
C. Work stations laboratory and storage access to new and experimental GCM data output scenarios.

Methods and accomplishments of Science component:

ESSI could establish a working relationship with two or three GCM centers, for developing joint approach to modeling of ice-cap mass balance and sea-ice rheology. Natural cooperation partners are centers such as CPOM (Center for Polar Observation and Modeling, which would contribute through cooperation to new model runs and model enhancements.

A picture of a new thermal equilibrium for the Arctic ocean would arise in the model data output statistics through these innovations in sea-ice thickness redistribution attributed to internal forces and sea-ice motion parameters. Study of those and the associated changes in coupling to regional and global climate would require further validation and study. The accomplishments are new ice-cap and sea-ice community models that would capture important and yet uncovered coupling mechanism in the GCM studies. This would mean that all studies that are derived from the new scenarios would come closer to the current understanding of the climate system physics in the context of treating the most important climatic variable in the Arctic/Sub-Arctic (sea-ice) more thoroughly.

Customer-client relationship of the Science component:

The principal customers are the major international programs (Appendix) and the associated national and international funding agencies. Likewise the new scenarios would constitute a new basis for various impact studies which call upon extended customer-client relationships that are addressed under the 'Outreach' and 'Benefits' lines of ESSI.

Research:
Regional Coupled Atmosphere Ocean Model Climatology Data.

ESSI would address regional coupled atmosphere ocean model climatology data. The response of ice-caps to climate change and their sensitivity to changes in regional storm tracks and associated precipitation patterns are highly coupled to atmosphere ocean interaction in the region. Combined mass balance modeling and ice cap dynamical modeling require careful treatment of precipitation patterns, their mean fields as well as the temporal and spatial variability. Advanced studies of high resolution regional climatology and other hindcast data on the state of the atmosphere and the ocean allow for a new set of studies as the impact from short term and long term variability can be studied through combining data of different kind. The current evidence is that the quality of studies related to renewable energy resources are highly dependent on the quality and usability of regional climatology. Furthermore, the improved sea-ice models in global circulation models require studies on their impact and ability to enhance regional climatology data in the context of coupled atmosphere ocean regional climatology data. ESSI contributes to research in regional climate through establishing data sets from coupled atmosphere ocean models which forms the basis for research on spatial and temporal variability and are made accessible for advanced impact studies.

Specific objectives of Research component:

A. Coupling of high-resolution ocean and atmosphere models using public domain near real time initial data.

B. Generation of regional coupled atmosphere ocean climatology data from available reanalysis data sets.

C. Rerun regional climatology data corresponding to GCM scenarios, using the ice-cap and sea-ice model of ESSI (see Science component above).

Resources required for the Research component:

The following resources would be required to set up the Research component of ESSI:

A. One principal scientist starting in year 2. A further scientist position to be added in year 5.

B. Two computer scientists for model run operations and system infrastructure, starting at years 1, 3 and 7.

C. Between eight and sixteen processors for a parallel-processing PC cluster for model runs and numerical experiments.

Methods and accomplishments for Research component:

ESSI would build liaisons with operational centers which provide public domain access (see GEOSS Implementation Plan) to analysis of atmospheric and oceanographic data, as well as reanalysis of data of the atmosphere (GODAE and the IOC ARGO project). Several model candidates exist in the atmospheric and ocean model domain, such as the MM5 of Penn State and NOAA-NCEP NMM in the Atmosphere and the Ocean models of the HICOM of University of Miami and the HIM. The models are coupled so that the momentum, radiation and latent heat transfers are treated at each time step. Through fully coupled tide and wave field decompositions, the coupling becomes more adequately represented in the regional climatology, derived from the model data output statistics and proxy time series on various parameters. Through continuous model enhancements, a run environment is established so that the statistics can be updated and arranged with on-line access so that users can update their analysis and publishing through the ESSI Informatics on-line arrangements. The parameters requiring special attention are the surface parameters of radiation, wind, temperature and moisture; the upper air temperatures, wind speeds and moisture and the precipitation at different heights. The ocean parameters are the salinity (density), temperature, current and surface mixed-layer parameters, like wave field, depths stability etc. The model output data would be accompanied with advanced output statistical parameterization on principal atmospheric and oceanic components, that can be accessed on-line through ESSI-Outreach. The model setup is also arranged for initialization on atmospheric and oceanographic real time analysis, which is also kept on-line for allowing near real-time diagnostics on the regional atmosphere ocean system, using the best concurrent available data, both in-situ from ESSI-Monitoring and remote sensing data on SSH's and SST's subject to data assimilation through cooperation with the GODAE and the IOC ARGO-project and operation arrangements. Likewise, the models are forced with the GCM climatology that have enhanced ice-cap and sea-ice model components from ESSI-Science.

Customer-client benefits of the Research component:

The customers that principally benefit here are those who are conducting studies that link to the regional climate in the past, present and future sense. Thus in the final analysis, the clients are the funding agencies that support such research. The proposed enhancements establish a unique setup, that would make special reference in the global change research community. Through comparing the past decades with the present situation, then the reference and relation to changes attributed to global change can be studied with more confidence. The customers of ESSI-Monitoring and ESSI-Science would derive direct benefit from this and the content that is readily prepared for the ESSI-Outreach and to be used in the context of applied climatological analysis and econometrics, ESSI-Benefits are using the data and resources in this component. Important benefits go also to international research programs and partners in terms of sharing roles and tasks for research enhancement and the funding agencies.

Outreach: Informics, Data Access, Analysis and Publishing.

We envision outreach as the dissemination of information and engagement of ideas between ESSI, the scientific community, the clients and the general public. Outreach to the general public will be through web-based presentation of ESSI's findings in connection to climate change, as well as public lectures and other media events. The outreach to the public will be in both English and Icelandic, with a web site that features at least daily updates of climatological and oceanographic parameters of interest.

ESSI addresses outreach to the global science community that is engaged or interested in global change research and associated impact analysis and studies. This community is in need of well structured computer-aided data access, analysis and publishing that we refer to as Informatics. In order to support end-to-end delivery of new information and findings, researchers are in need of a comprehensive system through which data can be accessed and exported in de facto global standard formats with sufficient support in meta data for knowledge on the source. Likewise, to make use of advanced statistical analysis one is in need of access to on-line statistical software packages and display facilities.

During the last decade the development of Open Source software has brought about resources that can be used as plug-ins in web publishing and content management systems that can be used for this purpose. This trend would continue into the future. With such a setup, together with subject-focused study workshops, one can allow new disciplines to combine and focus on particular subsets of climatology data and to combine those with different data sources to generate new information and impact assessments that are normally not a subject of study within the Earth Systems Sciences. The publishing of such results can be in a web-content management framework, which tracks the changes in the source data and allows for live updates of display material, once improved or enhanced data resources come about. The setup of such a facility within ESSI would allow a much wider research community to engage in advanced impact studies, with far better means to generate conclusive quantitative results and derive new and useful knowledge. The outreach would be arranged to open up facility and dialog for and with other disciplines for advancing impact assessment for the science community, also outside the Earth System Sciences.

Specific objectives of the Outreach component:

A. Display highlights of regional climate change and principal impact on the societies and in the west Nordic region.

B. Establish open source software modules and templates for on-line access, analysis and publishing of Arctic data.

C. Set up seminars/workshops for training in use of ESSI on-line publishing for multi-disciplinary studies.

Resources required for the Outreach component:

A. One principal scientist with a background in natural sciences and artificial intelligence/statistics starting at year 1. A further position to be added in year 7.

B. Three computer programming specialists, with background in web publishing and computer graphics, starting in years 2, 3 and 8.

C. A computer-aided visualization laboratory and web service.

Method and accomplishments of Outreach component:

ESSI would prepare computer-based and web-based displays of principal components of the Sub-Arctic atmosphere ocean system and their coupling with the icecaps and sea-ice. The display would be kept current with principal findings and new evidence on global change in the region. Through the use of multimedia and computer graphics, multi-media is applied to aid the layman and students in gaining insight in this complex system, using the real data of ESSI-Monitoring and ESSI-Research. Through preparing web content management systems like e.g. World Press, for simple reporting or more advanced systems like PLONE (roots from the Earth System Science community), DRUPAL (see report on open source in education) etc .with plug-ins that facilitate access to the ESSI-Research data with statistical analysis package (like R-statistical package) as on-line plug-ins and extensions to the web publishing and content management system. Users would be able to establish their own portal on a particular theme and various theme templates would be shared among the users in the context of the Open Source philosophy. ESSI would prepare seminars and short courses that address particular problem settings and impact studies on sub-regional level, particularly addressing local municipality level, renewable energy power plants, transport, fish and spawn migration patterns, tourism etc. with statistical analysis and artificial intelligence in pattern recognition relating social economic parameters. ESSI would arrange the seminars and workshops in a manner that can be credited in graduate studies and employee training programs in biology, geography, social economy and other environmental sciences.

Customer-client benefits of Outreach Component:

ESSI would serve the general public as well as the expert with a facility that opens general insight and allows for multidisciplinary studies and have access to development of impact studies. This facility would serve as a laboratory for students and other research studies. Universities and corporations would have access to facilities that would take time and resources to establish. ESSI would derive income in proportion to the resources made available and the activity could form a backbone for small value added special services addressing particular sectors and would be the backbone for the ESSI-Benefit branch.

Benefits: Econometrics and Regional Climate Diagnostics.

One of the principal motivations behind ESSI is the fact that changes in regional and global climate conditions will have stimulating impact (either positive or negative) on many economic variables, such as supply and demand of energy, consumer articles, travel, transport and service requirements, agriculture, breeding and growth of fish stocks etc. The impact comes through different temporal and spatial scales on the short term, seasonal variations and even decadal variations related to ENSO (El'Nino Southern Ocean Oscillation), NAO (North Atlantic Oscillation) and AOI (Arctic Oscillation Index). These parameters can be derived from the regional climatology. Through combination with econometric variables, valuable knowledge can be derived and used for supplying trade funds in natural resources and other related goods, and information on consumer behavior patterns and short-term natural impacts.

ESSI would engage in quantitative studies of economic model variables and measures (econometrics). ESSI addresses tangible benefits through collaborating with industry players, users of advanced climate diagnostics and with financial institutions for generating revenue through the business lines of ESSI (see the Revenue Component).

Specific objectives of Benefits component:

A. Prepare regional climatology data for use by the renewable energy industry, with associated customer-specific tools.

B. Establish tools for the consumer goods trading industry for deriving consumer pattern forecasts from climatology.

C. Establish tools for use by speculative trading funds that use ESSI regional climatology data and tools.

Resources required for the Benefits component:

A. Two persons in the following fields: market analyst, statistician or computer scientist, starting in year 1.

B. Parallel computing cluster.

Methods and accomplishments in the Benefits component; Customer-client relationship:

ESSI would use the techniques developed in the Outreach component above for setting up studies addressing the renewable energy industry, with the new GCM-scenarios for runoff modeling and wind energy production potential for some offshore regions. ESSI would establish contacts with market operators that are ready to take advantage of combining information on regional climate with data on various sales and consumer behavior figures. ESSI would couple artificial intelligence methods and environmental parameters and indexes to derive forecast skills and associated error statistics out of historical data.

We would prepare special tools for relating ship fuel consumption and wind, wave and current conditions in order to allow for weather routing of offshore vessels, based on forecasts of atmosphere and ocean conditions. Records of location and fuel consumption in conjunction with hindcast data will be used to predict fuel consumption for a given route thus opening for finding the optimal route for a given forecasted weather and ocean situation along a particular route.

ESSI would establish working relationship with financial institutions and insurance companies that are active in speculative trade, and ready to address natural resources whose market parameters (supply and demand) relate to regional climate variations. We would set up arrangements where ESSI can derive income from broker-fee arrangements, where trade is guided by analysis and tools derived by ESSI. The business and conditions for reinsurance companies, for example, rely heavily on regional climate and environmental conditions.

Revenue: Climate Expert Service System.

Applying regional climate information using past experience, insight into present situation and ongoing and predicted trends or regional change bears the potential of generating economical benefits. The fact that information and services can lead to cost savings, better planning and unique decision support can be turned into revenue through establishing the right service and decision support systems. These resources can be established so that services allow for reasonable charges and associated revenue generation. The value of having a one-stop-shop for information on atmospheric and oceanographic parameters is also presented in climatological context (derived from ESSI proxy data resources). This situation is most evident for the North Atlantic fishing industry where trawling in high seas and strong wind wave requires careful consideration and insight into the present and expected situation. Likewise, fish catches are concentrated in frontal zones, where nutrition conditions and mixing is favorable for the primary production in the sea. Furthermore, the fish feeding and migration pattern are unanimously connected to the phase and strength of the tidal current. The speed and oil consumption of modern container ship and oil vessels are very sensitive to weather, wave and ocean current conditions [tide]. Studies on ship fuel consumption suggest that 30% of the variations in fuel consumption is attributed to variable weather and ocean conditions. Loading and unloading cargo ships is inhibited under certain conditions like high winds, precipitation, freezing, visibility etc. These time windows can be better targeted with proper weather routing and the cost and benefits studied in terms of the operation of the vessel. The energy market in Europe is highly dependent on environmental conditions both with respect to supply and demand. Price fluctuations on various segments of that market are subject to changes on decadal as well as seasonal time scales. Abrupt changes in weather have impact on short time scales. These variations can be analyzed through logging changes and variations that relate to regional environmental conditions in general and the associated error statistics derived. Based on this expert system support, decisions in speculative trading can be taken with more certainty on short term as well as long term basis.

Specific objectives of Revenue component:

1. Near real time environmental data access system customized for the fishing industry.
2. Ocean weather routing and expert system applications.
3. Establishing a decision support system for natural resource funds engaging in speculative trading.

Resources required for the Revenue component:

Two computer scientist for application development, starting in year 5 and 8, one international asset managers, starting in year 2, two researchers / analysts, starting in years 3 and 7 respectively.

Methods and accomplishments in the Revenue component:

The near real time data access service establishes one-stop-shop subscription of numerical data resources. The data is updated on regular basis as new real time data emerge through the International public domain data exchange networks. Subsequently (typically twice a day) the data is processed in the ESSI operational model setup for furnishing the ESSI on-line data resources where users can set up their subsample subscription of the data in line with their needs and region of interest. The data subscription setups responds to user requirement for variable resolution requirements associated with need for a) 3-5 days outlook overview area covering major synoptic weather systems, b) 2 day regional focus for detailed operational planning and c) 1 day study area for tactical planning. The hybrid resolution data samples are compressed format and platform independent software (e.g. Java or similar) also for extraction to grib/grib2/netCDF/HDF for data ingestion to other software applications, e.g. Electronic navigation charting software etc. Powerful compression techniques, emerging offshore Internet Protocol network upgrades and powerful data browser software constitute a strong technological background for this service. The conventional service will have weather in terms of wind fields [and stability], temperatures [freezing heights], precipitation [also types], cloud heights [bottom and ceiling], and surface radiation and energy flux parameters [radiative and latent heat]. The surface ocean fields will include mixed layers depth temperatures and currents, period and heights of the wind wave, significant wave, most frequent wave and swell parameters. The subsurface parameters are the currents, temperature and salinity and water mass mixture coloring in line with the salinity and temperature parameters and typical water mass types in the region [Atlantic Water, Arctic Water and GIN Intermediate water etc.]. This information is all useful for the operational users and if presented with climatology, means and associated variances derived from the ESSI-hindcast data it attains usability value that is unique and becomes ESSI´s principal marketing strength.

Typical operational hourly turnover for a deep sea fishing vessel is of the order of €1-5 thousand per hour, only a few hours gain in proper marine weather planning will lead to considerable cost savings. The data service market for the fishing industry is open for products in the range of €1-2 thousand per annum for a high quality service that can lead to cost and operational savings in the range of €1-2 thousand per hour. The number of potential customers in the North Atlantic is in the range of 2-3 thousand and with a market reach of 10-20% for this high level product the annual revenue potential is in the order of €0.2 – 1.0 million. The market paradigm is also open for high volume, high quality and low cost with different income numbers and marketing cost. Records of location speed and fuel consumption can be analyzed with proxy data to train skill for forecasting the fuel consumption for a given [forecasted] weather and ocean condition. Through this the various options of weather routing can be analyzed in terms of forecasted fuel consumption and routing data, either using trained data or estimated engineering parameters. A fair amount of low price electronic navigation systems as well as vehicle tracking services can take routing functions based on ESSI resources and methods with minor modifications. ESSI´s climate expert system allows a user with generic requirements to predict a relationship between a variable subject to study and the climatic situation at the location. This relationship can therefore, with the associated error statistics derived from the training process, be used to furnish a forecast of a variable that is of special interest to a particular user, such as fuel consumption as function of location of time. The value of such decision support is high as for a typical trading ship operating cost is in the range of €1-5 thousand/hour and if operational and routing support systems can lead to savings on the order of 10–20 hours per year with additional safety benefits, such product can be marketed with an annual service price in the range of €2-4 thousand per annum. The world´s trading ships number 46 thousand, with 28 thousand general cargo, bulk and container carriers and 11 thousand tankers, where 10% out of these can be assessed as a potential target group, or 4-5 thousand in the North Atlantic region. With an estimated market reach of 10-25% the revenue potential of this business line is in the range of €0.8–5 million per year.

For speculative trading the method is to establish, in cooperation with financial institution, a trading desk which has operational access to all the tools derived in the Benefits component and can also submit requests for specialized analysis of particular econometric and environmental parameters. One example is to give assessment of evaporation, precipitation and radiation in a particular area prior to yielding seasonal, econometric as well as environmental parameters. Further details of the setup will be outlined in cooperation with a partner that will be chosen for this part of ESSI. ESSI will derive revenue from a split in brokers fees for trading with assets in this fund. A relatively modest fund could generate turnover of €50-500 million per annum and 1% broker´s fee forms the basis for €0.5-5 million income per annum. This revenue would be shared in line with the partnership established for this financial and trading activity and should form the basis for income in the range of €0.2-2 million per annum while the partner would also share the marginal cost for activities that ESSI undertakes directly for this component. ESSI could also develop tools that could be used by other funds that would not be in direct competition with this activity and expand the income potential. Hedging with futures and an insurance consultancy could become a follow up and future activity of this part of ESSI.

The scenarios given above, regarding climatological and oceanographic service of ESSI to the merchant fleet and fishing vessels, are only a couple of examples of the perceived market need of ESSI products. Studies regarding climate change, and its effects on the ocean and on land will lead to a diverse range of products related to agricultural activities, fisheries, the hydrological budget, the power industry and other activities that are sensitive to environmental change.

4. Implementation Plan

4.a Organizational Structure

ESSI is conceived as a public-private partnership and would be established as a limited company with a five person Board of Directors. The Board could also serve as an advisory committee. Approval of general policy and research programs would be made by Board members, at least three of whom would have international standing in scientific research. The members of the Board would be appointed by the shareholders, and could broadly consist of persons from science, government, and with experience in the financial sphere. The directors would be elected at the company´s Annual General Meeting.

Executive Director:

The Executive Director would be appointed by the Board of Directors. He/she should be a prominent senior scientist with an international reputation in research in the field of earth systems science or related fields. The Executive Director should preferably have the following qualifications:

» considerable knowledge of international Arctic research,
» experience in cooperative, international scientific programs,
» relevant science management and administrative experience.

The Executive Director would submit an annual research plan to the Board of Directors for approval and be responsible for ESSI research activities and general management of the Institute, including recruitment decisions, subject to final approval of the Board of Directors. The Executive Director would also be the spokesperson for the Institute and act as Head of Outreach programs, as well as communications and marketing.

Scientific Staff:

ESSI Scientific Staff would be organized along horizontal format and each should report to the Executive Director. Earth systems science is by definition an interdisciplinary activity and recruiting and appointment of the scientific staff should take that fully into account. Individual scientists should be principal investigators on relevant research grants and should be in charge of and responsible for their development, financial management and execution of grants. ESSI would initially be staffed by eight scientists, with excellent qualifications and demonstrated principal expertise in one or more of the following areas:

» Climate and Cryosphere: glaciology and sea ice studies
» Atmospheric Ocean Models
» Monitoring Regional Ocean Fluxes: physical oceanography, ocean circulation dynamics
» Data Processing and Informatics.

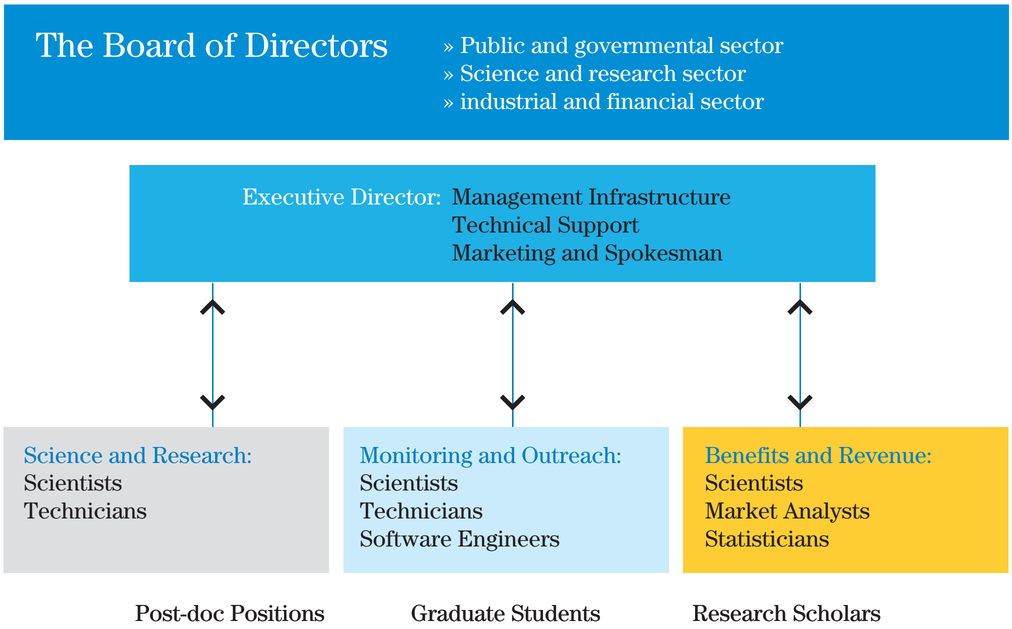

Figure 22: ESSI proposed organizational structure.

Administration:

Administration and Science Support would include a finance function. This individual would have responsibility for the accounts of the institution, book-keeping and payroll functions, as well as procurement (purchasing), billing and communications. He/she would work with the Executive Director in allocating resources to support scientific needs. The Electronics and Computer Science Technician would work with the scientific staff on technical issues. This individual is responsible for developing and maintaining adequate computer infrastructure in the institute.

Post-doctoral positions:

ESSI would offer post-doctoral science positions as well as opportunities for graduate students to work at the institute. It is proposed that post-doctoral science positions be created within the institute shortly after it is established. These positions would be created on a needs basis, in response to developing funded programs. Salaries for the post-doc positions would be generated from international and national grants and ESSI income.

Graduate students:

It is proposed that ESSI develop liaisons with universities world-wide, with interest in research on global change and earth systems science in the North. Such relationships and affiliations should lead to the residence of several graduate students at ESSI for months or years where they conduct field and laboratory research with ESSI staff. Partial funding for graduate student support should come from ESSI income and grants. The reporting relationships and an organizational chart are shown in Figure 22.

4.b Infrastructure Development

Facilities:

It is envisaged that ESSI will require approximately 600 square meters of space. This would proceed in two phases:

Phase I. About 300 square meters of space would be required initially in 2007. This should be general office and laboratory space.

Phase II. A further 300 square meters of space in the same location would be required in 2008. This should include a small auditorium and an exhibition area, as well as storage facilities for equipment and instrumentation.

Capital Equipment:

Investment in monitoring equipment, computers and other instrumentation will proceed gradually during the initial years of ESSI. In situ monitoring instrumentation will include three acoustic Doppler current profilers (ADCP's) with an estimated cost of €50,000. In addition, twenty trawl-mounted sensors will be acquired at a cost of €2,000 each. A number of conductivity-temperature-depth meters (CTD) will be acquired for €2,000 each. These are the principal components, but other instrumentation will be required.

Computational facilities:

A parallel computing set-up and ten computer work stations are required initially. We estimate a total cost of computer facilities of €100,000. Audio-visual equipment, printers and associated electronics will be required for outreach purposes, meetings and displays, at initial cost of €6,000. Additional specialized capital equipment will be necessary to enable specific research programs. Many of the computational facilities would be financed on a lease basis.

ESSI will require a structurally and functionally diverse library, but major costs related to library facilities would be the on-line subscription of scientific journals, estimated at €10,000 per year.

Oceanographic Vessel Use:

The institute should have funds for the lease of an oceanographic research vessel for about 15 days per year, from the Icelandic Marine Research Institute (Hafrannsóknastofnunin). The vessel would be deployed mainly for monitoring studies in the Greenland Strait and in the Iceland Sea. We estimate annual oceanographic vessel lease cost of approximately €300,000 per year.

4.c Scientific Staff Recruitment

Recruitment would be initiated by the ESSI Executive Director and would follow guidelines for recruitment of scientists which include presentations of candidates, visits, letters of recommendation, the names of two referees, and a written summary of their proposed research activities.

Start-up packages for scientists may include research support for three to five years. It would be expected that most scientists would develop sufficient grant-related support after three years to sustain most of their research programs, including up to 50% of their salaries.

Specific hiring projections for Years 1-8 are shown in Table 1.

Year	Year 1				Year 2				Year 3		Year 4		Year 5		Year 6		Year 7		Year 8	
Science																				
Principal scientists	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
Computing scientist	0	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	3	3
Research																				
Principal scientists	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
Computer scientists	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3
Total science and research	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10
Outreach																				
Principal scientists	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2
Computer scientist	0	0	0	0	0	0	1	1	2	2	2	2	2	2	2	2	2	2	3	3
Monitoring																				
Principal scientists	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
Technicians	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2
Total Outreach and Monitoring	1	2	3	3	3	3	4	4	5	5	6	6	7	7	7	7	8	8	9	9
Benefits																				
Market analyst	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Computer scientist	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Revenue																				
Computer scientists	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2
Asset managers/researcher	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3
Total Benefits and Revenue	1	1	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	7	7
Management & tec. Support	1	1	2	2	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	4
Total number of employees	4	5	9	9	11	11	14	14	17	17	19	19	22	22	23	23	27	27	30	30

Pilot | Startup | Running | Expanding

Table 1: Work Matrix

4.d Implementation steps:

The following key steps would constitute a plan of action for the establishment of ESSI:

- Finalize enabling agreements with the Government of Iceland and other potential funders.
- Develop key infrastructure for ESSI.
- Identify and implement scientific appointments for the areas of activity.
- Establish the research areas and relevant programs.
- Leverage research investment and scientific talent through outreach activities.
- Generate sufficient outside revenue to establish financial self-sufficiency after seven years.

5. Business Structure and Financial Projections

5.a Business Structure

The business model of ESSI deals with three principal components, in line with ESSI's aims to create value and income within three spheres of activity:

1. Science and Research ESSI will be eligible for funding and partnership in international earth system science research programs on global and regional climate change, with the principal objective of producing high quality regional climate data that can be used for various regional climate impact studies.
2. Monitoring and Outreach ESSI takes responsibility for monitoring the North Atlantic ocean water transports in the region, and will make the analysis from those observations available to the global community in near real-time context, with extensive support for access, display and publishing on the Internet, with the principal objective of facilitating the use of regional climate data in various contexts for laymen and experts working in a variety of scientific and professional disciplines.
3. Benefit and Revenue ESSI establishes methods for combining quantitative atmosphere-ocean system data (currents, temperature etc.) with variables and measures that can be turned into economical benefits and cost savings for fisheries, ocean transports and traded with renewable energy resources.

The thee different spheres of activitylisted above are different in nature, albeit closely connected, with respect to value-added nature and economical terms of reference. The principal value-added feature of the Science and Research component derives from sharing of roles, responsibility and knowledge and partnership in applying for funding from international research and development programs on shared cost [no more than 50% of full cost] or marginal cost [only the additional cost associated with the funded activity]. See Appendix 1 for some of the international programs. The competitive edge in seeking international funding comes from the fact that ESSI takes measure of contributing with unique scientific skills and knowledge in the field of sea-ice and ice-caps modeling. The full coupling of atmospheric and ocean model systems in generation of regional climatology [hindcast/proxy] data with tidal currents will produce unique high quality data, which deals with the impact of marine climate in the North and Northwest European region. The global change scenarios that emerge from the new community ice models will bring about unique reference data in the global change impact studies.

The second component, Monitoring and Outreach, derives the value added contribution from establishing data access, analysis display and publishing. The costs are associated with instrumentation, which is shared with the global monitoring and research community. Furthermore, costs associated with research vessels and in situ instrument deployment, will be shared by the by the participating governments and international cooperative monitoring programs. Moreover, the special data access, analysis and display support services will be shared through nominal cost and account subscription by the users, where the government subscribes to a certain minimum number for governmental education and research organizations.

The third component, Benefit and Revenue, addresses the value added through developing methods that identify cost savings and economical benefits from combining regional climate data and other parameters, as relates to local migration patterns of fishing stocks, fuel consumption of ships related to ocean wind, wave and current conditions, and derivative trading on renewable energy with respect to coupling of regional climatology on supply and demand. The methods and the associated revenue spins will be focused on sectors in the Icelandic economy where one may expect contribution to adaption to global change and sustaining of economic growth. The revenue is derived from advanced data analysis and processing subscription, ship route optimization and share in trade fund brokers fee charges. The competitive edge is driven by the high quality data resources and advanced method development, in close connection with high level expertise in the relevant fields from the fishing, transport and financial industries.

5.b Financial Projections

Projections of expenses and income of ESSI for the first eight years of operation are shown in Table 2. The key parameters for this Scenario-1 are plotted in Figure 23. In this scenario, the staff increases from 4 persons at the end of the first quarter, to 19 at the end of the fourth year of operation, to 30 at the end of the eighth year.

Table 2: Projected Income and Expenses for ESSI

Year	Year 1				Year 2				Year 3		Year 4		Year 5		Year 6		Year 7		Year 8	
Branch: Quarter [thousands €]	1	2	3	4	1	2	3	4	1 – 2	3 – 4	1 – 2	3 – 4	1 – 4	3 – 4	1 – 4	3 – 4	1 – 4	3 – 4	1 – 4	3 – 4
Expenses																				
1. Science and Research																				
Number of employees	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10
Salaries and related [1]	20	20	40	40	60	60	80	80	200	200	240	240	280	280	320	320	360	360	400	400
Operational expenses [2]	18	18	28	28	38	38	48	48	117	117	137	137	157	157	177	177	197	197	217	217
2. Outreach and Monitoring																				
Number of employees	1	2	3	3	3	3	4	4	5	5	6	6	7	7	7	7	8	8	9	9
Salaries and related [1]	20	40	60	60	60	60	80	80	200	200	240	240	280	280	280	280	320	320	360	360
Operational expenses [2]	18	28	38	38	38	38	48	48	117	117	137	137	157	157	157	157	177	177	197	197
Field activities [3]	1wm	1wm	1wm	1wm	1wm	1wm	1wmp	1wmp	2wm	2wm	2wm	2wmp	2wm	2wm	2wm	2wm	2wm	2wmp	2wm	2wmp
Instruments and ship time	125	125	175	175	125	125	175	175	250	250	250	350	250	250	250	250	250	350	250	350
3. Benefits and Revenue																				
Number of employees	1	1	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	7	7
Salaries and related [1]	20	20	40	40	60	60	60	60	160	160	160	160	200	200	200	200	240	240	280	280
Operational expenses [2]	18	18	28	28	38	38	38	38	97	97	97	97	117	117	117	117	137	137	157	157
External consulting expenses	20	40	40	40	60	60	60	70	140	140	160	160	160	160	140	140	140	120	100	100
Marketing [9]	0	0	0	0	1	4	9	24	71	104	138	167	195	225	255	287	318	368	420	488
Total expenses	260	310	450	450	481	484	599	624	1351	1384	1558	1687	1795	1825	1895	1927	2138	2268	2380	2548
Income																				
1. Science and Research																				
Cost share ratio [4] (%)	0	0	10	10	20	30	40	50	50	60	70	70	80	80	80	80	80	80	80	80
Income	0	0	7	7	20	30	51	64	158	190	264	264	349	349	397	397	445	445	493	493
2. Outreach and Monitoring																				
Hundreds of user accounts [5]	0	0	0	0	0	2	6	12	24	36	48	56	64	72	80	90	100	110	120	130
Income from user accounts	0	0	0	0	0	5	15	30	120	180	240	280	320	360	400	450	500	550	600	650
Ship and instrument cost share (%)	0	0	50	50	60	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Instrument cost sharing partners	0	0	88	88	75	100	140	140	200	200	200	280	200	200	200	200	200	280	200	280
3. Benefits and Revenue																				
Number of fishing vessels	0	0	0	0	10	20	50	100	150	220	300	350	400	450	500	550	600	700	800	900
Fishing vessels revenue [6]	0	0	0	0	5	10	25	50	150	220	300	350	400	450	500	550	600	700	800	900
Number of merchant vessels [7]	0	0	0	0	0	20	40	60	100	140	180	230	280	340	400	460	520	600	700	800
Merchant vessels revenue	0	0	0	0	0	10	20	30	100	140	180	230	280	340	400	460	520	600	700	800
Investment fund turnover [M€]	0	0	0	0	0	0	0	10	20	30	40	50	60	70	80	90	100	120	140	180
Broker fee revenue [8]	0	0	0	0	0	0	0	50	100	150	200	250	300	350	400	450	500	600	700	900
Total income	0	0	94	94	100	155	251	364	828	1080	1384	1654	1849	2049	2297	2507	2765	3175	3493	4023
Net profit/loss	-260	-310	-356	-356	-381	-329	-348	-260	-522	-304	-174	-33	54	224	402	581	627	908	1113	1476
Cumulative profit/loss (funding requirement)	-260	-570	-926	-1281	-1662	-1992	-2339	-2599	-3121	-3425	-3599	-3632	-3578	-3353	-2951	-2370	-1743	-835	278	1754

Variables

[1] Man-months cost per quarter	20	[4] Cost share ratio	Varying
[2] Fixed operational cost pr. Quarter	25	[5] Price per 100 user account per/quarter	2.5
[2] Operational expenses per person	10	[6] Price per fishing vessel per/quarter	0.5
[3] Field activities:		[7] Price per merchant vessel per quarter	0.5
m = mooring; p = current meter; w = ship time week		[8] Brokers fee 0.5%	0.5
Cost pr mooring	25	[9] Marketing share of sales revenue (%)	15
Cost pr ADCP installation	50		
Cost pr week ship time 100			

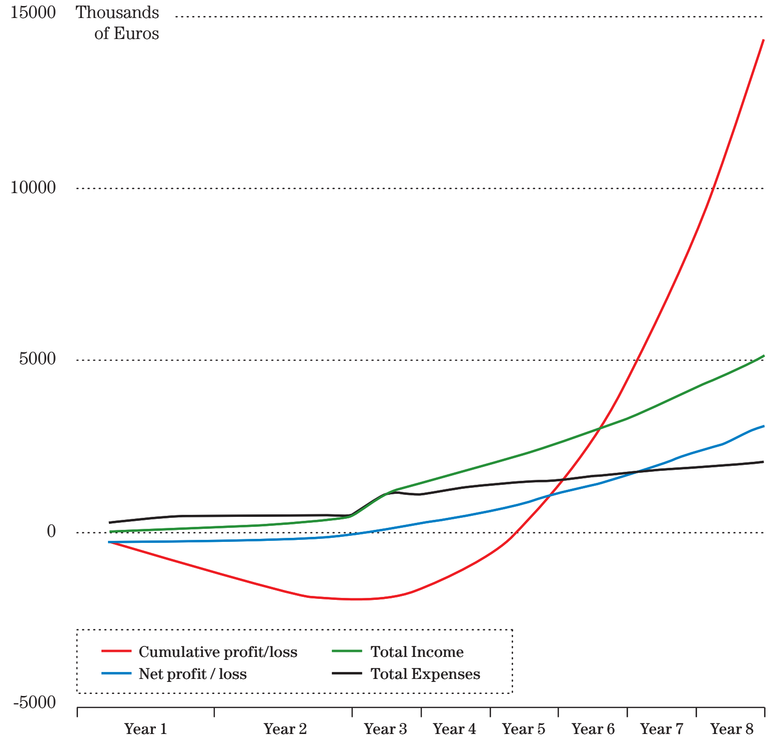

Figure 23: Projected expenses and income of ESSI for the first eight years of operation (Scenario-1; see Table 2 for details of the model). Note that in this projection, ESSI begins to show profit in Year-4 (income and expenses are equal), and further note that the cumulative investment in the organization is fully recovered in Year-7.

The income in this scenario is considered realistic, based on the likely estimate of subscriber accounts to the products of ESSI. Under these conditions, ESSI's income will equal expenses already at the end of the second year of operation (figure 23). The cumulative profit/loss curve or funding requirement (figure 24) for this scenario shows that the total investment in the enterprise will be recovered in the eighth year of operation. The financial projections in Table 2 are an average parameterization, based on number of employees, and sales, with the following assumptions taken into account:

[1] ESSI needs to have competitive advantage for acquiring work force of high skill and the average annual salaries per person are assumed to be €16 thousand/quarter. Part of the salaries could also be given in equity stock options. The quarterly labor expenses per person with social security and administration costs amount to €20 thousand.

[2] The €25 thousand fixed operational cost consists of €10 thousand on floor space and €15 thousand on administration cost per quarter. The €10 thousand quarterly variable operating costs per employee are roughly divided into €2 thousand on floor space, €3 thousand on travel, €2 thousand on external services and €3 thousand on special facilities.

[3] The field activities refer to ship time [w: week in Table 2], moored in situ current meters and oceanographic instruments [m: moorings], and acoustic Doppler current profilers [ADCP] to be deployed on merchant vessels between North America and Iceland, and Western Europe and Iceland [p: current profiler].

[4] This project relies heavily on scientific and technical cooperation for sharing of costs and also on external funding from international or national research and monitoring programs.

[5] The backbone of ESSI outreach is an on-line access, processing, display and publishing facility. Users will be able to access data and processing resources free of charge. Once users require customization in line with their interests and special requirements they will need to sign up for a paid user service. The user services will be arranged in a way that makes it useful for advanced use by laymen, secondary and primary school students and experts for a subscription fee in the range of €5-10/month. Environmental and near-real time conditions have direct impact on 2-3% of the population in coastal regions. At least 10 million people live in the coastal regions of Northwest Europe in communities that make a living in the coastal zone, where the full market potential is of the order of 200-300,000 users. It is assumed that 5-10% out of this full market potential can be reached in 8 years and with strong marketing activity once income revenue emerges.

[6] The revenue from service sales to fishing vessels has a direct bearing on the market potential in the North Atlantic region. There are 3-4000 larger fishing vessel platforms in the region that are potential customers of high level data service that is useful for operational performance. It is assumed that 900 users out of this group can be recruited in the first eight years of operation, or 25-30% potential customer recovery rate, for a price that is €150-200/month on a mixture of subscription and pay-per view arrangement. Once sales take off, 15% of the revenue will be channeled into marketing, which should help sales and establish a presence in the user-service market. See the Revenue section in chapter 3.d ESSI Components above, for further discussion of this factor (p. 40).

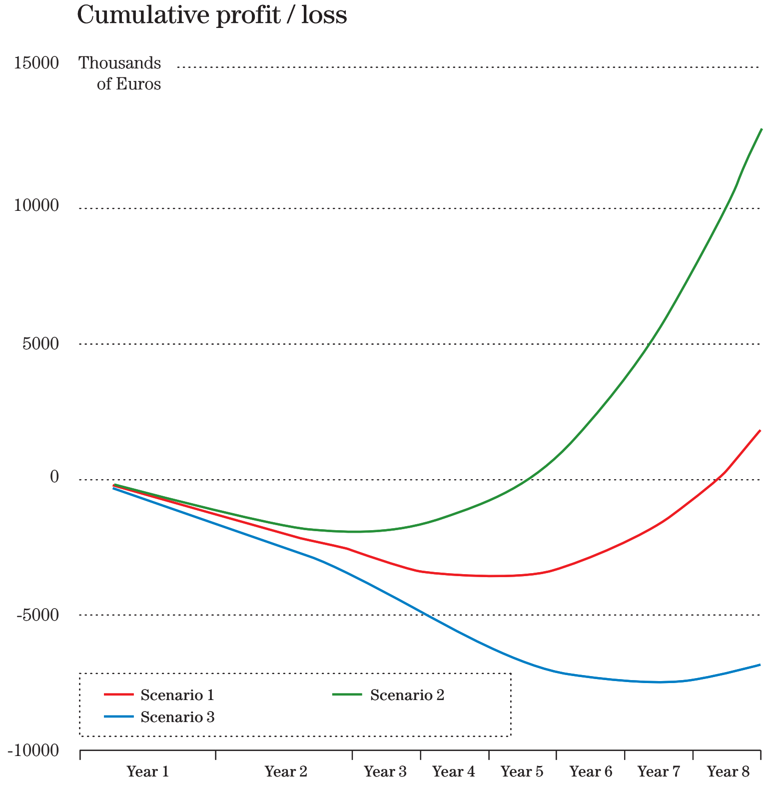

Figure 24: Three scenarios for projected expenses and income of ESSI for the initial eight year period. The curves show the cumulative profit/loss or funding requirement for the most realisitc scenario (Scenario-1; data given in Table 2), a pessimistic view of income (Scenario-3), and the most optimistic projection of income/expenses configuration (Scenario-2).

[7] The revenue from merchant vessels has a bearing on the fact that they number at least 4000 – 5000. It is assumed that 800 of those can be reached in 8 years (100 on average each year) or 15-20% of the full market potential. The value of the service concerns the fuel consumption and the conditions for shipping of sensitive cargo in harbors and has impact on routing and on shore preparations for ship arrival.

[8] The brokers fees are from 1-2% of turnover. Depending on cooperation with partners in the finance industry it is expected that at least a 0.5% fee can be negotiated. (ESSI could develop services out of this for other stakeholders in the renewable energy market such as the wind energy market to increase the turnover).

[9] Once sales take off the marketing of the products requires strong visibility in order to explain to potential users what competitive advantages can be gained by using ESSI services and support. It is therefore in line with the economic interests of ESSI to maintain strong visibility in the market and marketing costs are assumed to be 15% of revenue.

Two other scenarios have been considered (a more optimistic Scenario-2 and pessimistic Scenario-3). In these, the expenses are held similar to Scenario-1, whereas subscription accounts and other income is varied within reasonable bounds. The results of these boundary conditions are shown in figure 24 for cumulative profit/loss trends, and in figure 25 for the net profit/loss trends.

The financial projections follow from the three scenarios that lead to different economical views for the operation of ESSI. In the following table (Table 3) the principal characteristics of the scenarios are shown. The maturing time is defined as the time when concurrent three years net profits can cover the cumulative losses. At that time, refinancing could be conducted by selling less than 50% of the equity stock. It should be noted that the financial projections are very sensitive to the estimated sales figures.

Table 3:
Summary of Financial Scenarios

Annual figures, based on 5- year average:	Man- years	Expenses [thousand €]	Income [thousand €]	Brake-even time	Max loss [thousand €]	Maturing time
Scenario 1	5-19	2600	2000	4.5 years	3600	7 years
Scenario 2	4-18	2300	2500	2.5 years	2000	3 years
Scenario 3	5-15	2500	1100	7.5 years	7500	10+ years

All scenarios conclude with a finance situation that has a long-term investment return. The income is to a large extent derived from the north-west European and Scandinavian markets within the fishing, transports and energy industries. The ESSI business model should therefore interest governmental research organizations within the terms of private-public partnerships, where public or governmental research funds invest in ESSI in order to meet research and monitoring objectives. The development of ESSI as a business entity should consider the possibility of establishing contact with a venture capital fund that could in turn mobilize resources for strengthening the benefit and revenue component of ESSI, marketing of the services and support in particular.

It is estimated that start-up expenses will amount to €720 thousand, including capital equipment, premises, location and administration expenses, promotional expenses, working capital and a reserve for contingencies.

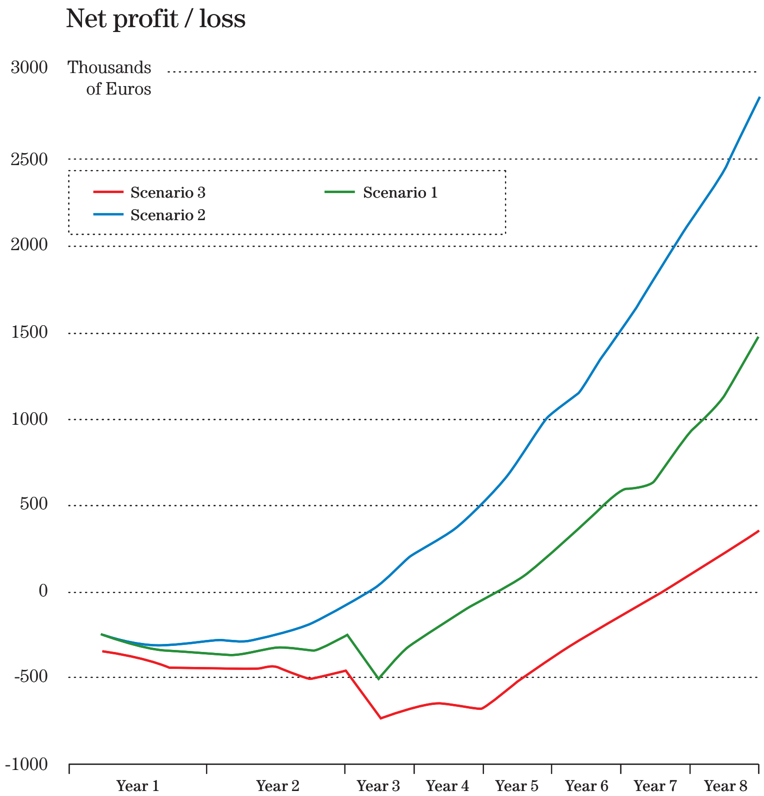

Figure 25: A plot of net profit/loss for three scenarios of ESSI financial projections during the first eight years of operation. The data for the most likely scenario (Scenario-1) is provided in Table 2.

5.c Risks

Access to natural resources and renewable energy is and will be one of the principal driving factors for the sustainable development of the Icelandic, North West European as well as the global economy. Moreover, Iceland is at the edge of the sustainable/habitable world and is therefore particularly vulnerable to climate change. These facts have a major bearing on the principal justification for ESSI, in addition to the fact that global environmental change calls upon response to a threat of economical instability and need for adaptation to the change. This principal setting for the scene for ESSI is envisaged to enhance the need and importance of it's contribution to the outside community.

ESSI's activities require international cooperation at some level. Each cooperative effort has three components, the cooperation in the science, technical implementation and funding. ESSI is built to deal with all of them in a different manner, and this structure makes ESSI both unique, strong and an interesting partner in the field of global change science. The structure of ESSI allows it to adjust its contributions to the different segments, in line with its goals and/or operational requirements, which makes ESSI more robust to external conditions and risks.

The internal risks of failures associated with sustainability of establishment, development and operation of ESSI have a principal bearing on its three components:

» people and personal risk associated with the Science andRresearch component of ESSI, where the principal human resources and innovative methods are developed together with the uniqueness and competitive edge of ESSI in the environmental and global change sciences sector.

» technical or instrument risk associated with failure in software and hardware systems employed by ESSI, associated with the Monitoring and Outreach component, This component generates valuable new facts and new findings through access, analysis and publications, disseminated to the scientific and public community.

» financial and capital investment risk associated with the Benefits and Revenue components of ESSI, where financial benefits are derived from the findings of ESSI, through deriving revenue from analyzing the economical impact of environmental conditions on both macro and social economic scales.

ESSI is will deal with the above principal risk factors in the following manner:

A. The science part builds up on the uniqueness of ESSI. Likewise, the research activities require skill and expertize from the scientific community. ESSI will build up expertise to become an eligible and interesting partner in international research and development programs, where the other remaining components, that is the Monitoring and Outreach and Benefit and Revenue components, are to support the Science and Research component directly to enhance its eligibility infrastructure resources. International cooperation will reduce the people and personal risk through sharing roles and expertise and facilitate scientific advances and research efforts that are beyond the scope of ESSI alone and thus secure and maintain it's competitive edge in the Science and Research part of ESSI. Through continuous recruitment of young scientists, researchers and experts in various fields through the Post-doc, Graduate Student and Research Scholar programs, fresh knowledge and flow of human resources into ESSI and between the components of ESSI is also secured and the internal arrangements will be enhancing flow of human resources between the components. As an outcome of this, ESSI becomes an interesting place to work and through competitive salary arrangements the people and personal risk is minimized.

B. Monitoring and Outreach vs technical or instrument risk . The monitoring will be conducted using standard instruments and methods with continuous flow of innovation and improvements. The software systems will as much as possible be derived from Open Source systems, using Internet synergy to the degree that is possible. This will bring large development, testing and verification efforts into the picture, which will reduce software risk, costs and maintenance requirements. Bringing the monitoring data into public use in near-real time context will mobilize on-the-spot verification and validation that will bring enhanced value, added to both the data acquisition and the model data assimilation systems. Through this, human resources are mobilized to the reduction of technical and instrumental risk, which is essential.

C. Benefits and Revenue vs financial and capital investment risk. Climate conditions, their short and long term variability and trends will have profound impacts on socio-economic conditions. ESSI takes measure of identifying this impact through study of the couping between econometric measures, where these can be identified and quantified. Through employing sophisticated tools, methods and computational resources, these findings can be transformed into economical benefits and/or cost savings. A few examples provided in this report have demonstrated that there is a need and demand for services and capacity of this kind within the fisheries sector, marine transport sector and the financial sector. These sectors will always be sensitive to gains in competitive edge and thus have persisting need and requirements in this area. New areas within the agriculture and consumer behavior studies in relation to very advanced climate conditions studies subject to different time scales are yet to be explored and are expected to have high potential in generating benefits. The resources of ESSI will allow active search and adaptation of new findings in this area as a follow-up from the right partnership in the financial service and trade sector. The backbone of ESSI's capacity will always bring it competitive edge and lay the foundations for it to become an leading stake holder in this area.

6. Discussion and Conclusions

Each line of activity given above deals with the fundamental values of ESSI that would put ESSI into a position to contribute in an important manner by strengthening Icelandic as well as global change research. The atmospheric and ocean circulation in the Arctic and Sub-arctic region is to a large extent forced by freshwater run-offs and sea-ice formation and melting. The study of Earth System processes in the region requires a balance between knowledge on the atmosphere, ocean and cryosphere. Furthermore, enhancing the quality of studies in these fields in terms of more adequate models has limited meaning unless these are made useful and applicable in other socio-economical studies and impact assessment for industry. Through addressing regional-scale processes in the global context, ESSI takes measure of facilitating studies of local regional processes in global context that is useful on a wide range of temporal and spatial scales.

Long Range Vision: ESSI addresses research and studies in the Global Climate system by facilitating extensive studies of the regional conditions through several past decades and studying the current trends in the coupled atmosphere-ocean system through generating useful datasets and providing tools for access, analysis and display. Through nesting of the same model system in Global Change scenarios, ESSI is facilitating studies of recent past-to-present trends to be inferred in Global Change scenarios. ESSI addresses enhanced ice-sheet and sea-ice models in the GCMs, thus contributing with more realistic scenarios for the region and the Earth System in general, thus making a contribution to Global Change research in general.

Multi-Facet Perspective: The outreach through on-line data access, analysis and publishing, together with extensive data access relevant for the atmosphere-ocean system, facilitates studies ranging from atmosphere-ocean studies to social sciences and economics. Through improved modeling of air-ocean interaction, all terrestrial studies, e.g. Hydrology and biology, become more conclusive when they are addressing global change.

Global Context: ESSI puts particular emphasis on improving the sea-ice models which, if successful, would improve one of the most evident weaknesses in the Global Circulation Models. All studies that seek support in the regional hindcast data from the coupled atmosphere-ocean models can be drawn up in context with global change scenarios.

Data Management: ESSI would build plug-ins for Internet content management and web publishing systems (CMS) that allow for access to data queries, statistical processing and analysis in on-line publishing system. ESSI would use de facto standard global formats and software that is subject to Internet synergy, such as Open Source or GPL [GNU Public License]. Open formats like HDF and/or NetCDF are widely accepted and have support for meta-data that makes them applicable to a wide range of studies.

Outreach and Communications: ESSI outreach and communications are three-tiered, one through on-site display to the general public in a museum, second through the Internet using de facto standard Open Source content management systems and thirdly holding seminars and workshops for multidisciplinary studies, using advanced on-line statistical diagnostic tools.

Infrastructure: ESSI's contribution to infrastructure is to enhance the quality of regional climatology and make it accessible to other disciplines. The contribution to infrastructure comes through two components. Firstly, with improved GCM scenarios, the coupled nested ocean and atmosphere models generate more realistic regional climatology, thereby making an important improvement on any study and analysis of regional processes. Secondly, through facilitating access, analysis display and publishing in one comprehensive setup would be a very important contribution to making feasible and possible to different disciplines to make use of ESSI knowledge and findings.

Enabling Institutions: The Science and Research components of ESSI take measure of enhancing the coupling of the most important climatic signal in the region, through addressing the cryosphere. ESSI will open up new avenues for studies of Global Change.through generating regional climatology data of enhanced quality and in a global context and making those available in a facility that supports access, analysis and publishing to use in multidisciplinary studies These studies would make it possible to generate new knowledge on Global Change impact on various components of societies and industries and assist the communities in inevitable adaptation to global change.

Balance across the Spheres of the Arctic: One of the principal aims of ESSI is to seek more balance between the spheres of the Arctic: the atmosphere, ocean and cryosphere. This balance has more importance here than anywhere in the world, from the Northwest Peninsula (Vestfirðir), across the Denmark Strait and across the Greenland ice cap.

Spatial and Temporal Scaling: The temporal scaling follows the lead of using coupled models to capture the tidal and seasonal variability and its contribution to regional scale conditions. The use of several decades of reanalysis data in the coupled models allow one to capture inter-decadal variability and study regional trends in more local contexts within the region, making the analysis more applicable for study social and industrial impacts on inter-decadal time scales. Future studies and modeling of the new equilibrium state of the Climate System is addressed by contributing to improved ice-cap and sea-ice models in coupled models.

Financial and Organizational Aspects: ESSI would be established as a limited company, run by a director who is appointed by the shareholders. An advisory committee would work with the director in setting the research and administrative policy. It is proposed that ESSI would initially be staffed by a minimum of eight scientists. Financial projections show that cumulative expenses during the first five years of operation amount to approximately €15 million (average of approx. €3million per year). However, taking projected income into account, the projections show that ESSI could evolve into a self-sustained and profitable organization in 5 to 7 years, with a €4-5 million cumulative funding requirement or venture loan guarantee for this start-up period. ESSI offers an interesting partnership structure for private and governmental organizations that would be interested in joining on different terms of reference. Such partnerships could take the form of venture capital investment, governmental district infrastructure investment, or to strengthen competitive advantage of financial businesses. ESSI can thus strengthen the resilience of the Icelandic economy and provide competitive edge for organizations with wide investment interests.

Concluding Remarks: The scope of ESSI is quite unique in the context of modern Earth System Sciences, particularly with respect to how it addresses the end-user or the outside society. Firstly, ESSI takes advantage of its own science advancements in the study of the cryosphere and brings it directly into the regional climatology research, which also links to in situ data collection and monitoring and derives data and results from coupled atmosphere-ocean models, which is essential for study of the Sub-Arctic climate system. Secondly, these data and information resources are made available in a framework that is presented in a way that allows for its use in multi-disciplinary studies. ESSI takes direct action in developing a setup that is useful for impact assessment, which involves earth system climatology and conditions in the past, present and also aiming at more realistic future scenarios. Furthermore, ESSI takes the data and analysis of the Earth System and brings it into a context for generating tangible economic benefits and therefore becomes a direct player in contributing to economic resilience and adaptation to change and builds up its financial sustainability at the same time. Being end-user oriented, small and adaptive to environmental conditions, ESSI lines up with fundamental elements in the Icelandic heritage and culture, living in intimate harmony with nature at the edge of the sustainable world.

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Appendix

International Programs in the North

In this section we provide a general review of the international programs that are participating in research on global climate change, the scientific research institutions and the funding agencies that relate to the proposed research environment of ESSI. This is only a sample of the large number of international programs and institutions that conduct research in this area, but further listings can be obtained for example at: http://www.smhi.se/sgn0106/if/rc/int_links.htm

1. International Organizations:

IOC

The Intergovernmental Oceanographic Commission - of UNESCO was founded in 1960 on basis of the recognition that the oceans, covering some seventy percent of the earth's surface, exert a profound influence on mankind and even on all forms of life on Earth. In order to properly interpret the full value of the oceans to mankind, they must be studied from many points of view. While pioneering research and new ideas usually come from individuals and small groups, many aspects of oceanic investigations present far too formidable a task to be undertaken by any one nation or even a few nations. http://ioc.unesco.org/iocweb/about.php
Virtually all of the UN member states participate in IOC, as well as a number of important intergovernmental and non-governmental organizations. IOC participates in the World Climate Research Programme, which has just issued its 25 Anniversary WCRP brochure.
» http://www.wmo.ch/web/wcrp/wcrp-home.html

AOSB

The Arctic Ocean Sciences Board - was established in May, 1984 to fill a recognized need to coordinate the priorities and programs of countries and institutions engaged in research in the Arctic Ocean and adjacent seas. The AOSB is a non-governmental body that includes members from research and governmental institutions in Canada, China, Denmark, Finland, France, Germany, Iceland, Japan, Korea, The Netherlands, Norway, Poland, Russia, Sweden, Switzerland, the United Kingdom and the United States of America.
» http://www.aosb.org/about.html

ISAC

The International Study of Arctic Change - is a science program launched by the International Arctic Science Committee (IASC) and the Arctic Ocean Sciences Board (AOSB). The International Study of Arctic Change, or ISAC, is a long-term, multidisciplinary program to study the effects of environmental changes (including physical/chemical, biological/ecological, and socioeconomic /cultural changes) on the circumpolar Arctic system and the globe. ISAC is planned as a long-term, international, cross-disciplinary, pan-Arctic program aiming at answering the scientific questions that are the basis of scientific impact assessments of Arctic change.
» http://www.aosb.org/isac.html

ICES

International Council for the Exploration of the Sea - Primarily on fisheries - ICES is the organisation that coordinates and promotes marine research in the North Atlantic. We are an intergovernmental organisation and our 19 member countries are as follows: Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Latvia, the Netherlands, Norway, Poland, Portugal, Russia, Spain, Sweden, the United Kingdom, and the United States of America. Produce useful annual climate reports for the northern region.
» http://www.ices.dk/indexfla.asp

GOOS

Global Observing Ocean System - is a permanent global system for observations, modeling and analysis of marine and ocean variables to support operational ocean services worldwide.
» http://ioc.unesco.org/goos/

IPY

International Polar Year. The IPY 2007-2008, an intense, interdisciplinary, and internationally coordinated campaign of research and observations, would deepen understanding of polar processes and their global linkages. IPY knowledge and the observations upon which it is built must be effectively managed to ensure the greatest benefit in the future. IPY-generated data should be carefully and thoughtfully collected, used collaboratively, and adequately preserved.
» http://www.ipy.org/

iAOOS

The integrated Arctic Ocean Observing System - : an AOSB-CliC Observing Plan for the International Polar Year. By the Arctic Ocean Sciences Board (AOSB) and the WCRP Climate and Cryosphere

Programme (CliC).
» http://www.ipy.org/development/eoi/AOSB-CLIC%20short%20plan%20v4.pdf.

IGBP

International Geosphere-Biosphere Programme. The Vision of IGBP is to provide scientific knowledge to improve the sustainability of the living Earth. IGBP studies the interactions between biological, chemical and physical processes and human systems IGBP collaborates with other programs to develop and impart the understanding necessary to respond to global change. As one of four international global environmental change research programs, IGBP works towards its objective in close collaboration with the International Human Dimensions Programme on Global Environmental Change (IHDP), the World Climate Research Programme (WCRP), and DIVERSITAS, an international programme of biodiversity science. The International Council for Science (ICSU) is the common scientific sponsor of the four international global environmental change programmes.
» http://www.igbp.kva.se/cgi-bin/php/frameset.php

2. Research Institutions

BCCR

Bjerknes Center for Climate Research.
The Bjerknes Centre for Climate Research (BCCR) is a joint climate research venture between the University of Bergen (UoB), the Institute of Marine Research (IMR) and the Nansen Environmental and Remote Sensing Center (NERSC). The BCCR integrates observationalists and modellers in a concerted interdisciplinary research effort with the ambition to be a world-class centre on studies of high-latitude climate change. The BCCR is the largest climate research group in Norway. In 2002 it was awarded the status of a national Center of Excellence by the Research Council of Norway .
» http://www.bjerknes.uib.no/

NERSC

Nansen Environmental and Remote Sensing Center is a research institute affiliated with the University of Bergen, Norway. The Nansen Center conducts basic and applied environmental research funded by national and international governmental agencies, research councils and industry. Research includes studies of global and regional climate processes using numerical models together with observations from earth-monitoring satellites and field experiments. Modelling of the global and regional marine ecosystem and carbon cycle combined with use of satellite ocean color observations.
» http://www.nersc.no/index2.php

IFM GEOMAR – The Leibniz Institute of Marine Sciences at the University of Kiel . The goal of the institute is the investigation of all areas relevant for actual research in marine sciences, ranging from Geology of the Ocean Floor to Marine Meteorology. The institute operates world-wide in all ocean basins. The main research topics are grouped in four areas: Ocean Circulation and Climate Dynamics, Marine Biogeochemistry, Marine Ecology, and Dynamics of the Ocean Floor.
» http://www.ifm-geomar.de/

CRU

the Climatic Research Unit, University of East Anglia, United Kingdom. The Climatic Research Unit is one of the world's leading institutions concerned with the study of climate change. The Unit has developed a number of the data sets widely used in climate research, including the global temperature record used to monitor the state of the climate system, as well as statistical software packages and climate models.
The aim of the Climatic Research Unit is to improve scientific understanding in three areas: past climate history and its impact on humanity; the course and causes of climate change during the present century; prospects for the future. The Unit undertakes both pure and applied research, sponsored almost entirely by external contracts and grant from academic funding councils, government departments, intergovernmental agencies, charitable foundations, non-governmental organisations, commerce and industry.
» http://www.cru.uea.ac.uk/

ZICER

The Zuckerman Institute for Connective Environmental Research is the parent body of the Climatic Research Unit in the UK. ZICER brings together five existing research centres based in UEA's School of Environmental Sciences: Tyndall Centre for Climate Change Research, this national centre with partners in eight other locations around the country undertakes integrated research into sustainable solutions to climate change; Centre for Social and Economic Research in the Global Environment (CSERGE) carries out policy-relevant interdisciplinary research on environmental issues; Centre for the Economic and Behavioural Analysis of Risk and Decision (CEBARD), which focuses on the economic basis for making decisions; Centre for Environmental Risk, which is looking at analysis, perception, communication and management of risk, in order to provide practical guidance for policy makers; Climatic Research Unit, which examines the variability of climate and climate change.
» http://www.uea.ac.uk/zicer/

INSTAAR

The Institute of Arctic and Alpine Research strives for excellence in research, education, and societal outreach related to Earth System Science and Global Change in high-latitude, alpine, and other environments. The Institute facilitates and accomplishes interdisciplinary studies offering special expertise in high-altitude and high-latitude regions of the world. INSTAAR also offers excellence in global and environmental research including non-cold-region Quaternary studies and geochronology, earth-system dynamics, landscape and seascape evolution, and climate dynamics. INSTAAR aims to understand how the varied regions of the world are affected by natural and human induced physical and biogeochemical processes on the local, regional, and global scales.
» http://instaar.colorado.edu/

CICERO

Center for International Climate and Environmental Research, Oslo, Norway. As a major exporter of fossil fuels, Norway bears a special responsibility in the international cooperation on climate and the environment. For this reason, the Norwegian government established CICERO (the Center for International Climate and Environmental Research – Oslo) by royal decree in 1990. CICERO is an independent research center associated with the University of Oslo. CICERO conducts research on and provides information and expert advice about national and international issues related to climate change and climate policy.
» http://www.cicero.uio.no/index_e.asp

PAGES

(Past Global Changes) supports research aimed at understanding the Earth's past environment in order to make predictions for the future. We encourage international and interdisciplinary collaborations and seek to involve scientists from developing countries in the worldwide paleo-community. PAGES, founded in 1991, is a core project of the International Geosphere-Biosphere Programme (IGBP) and is funded by the U.S. and Swiss National Science Foundations, and the National Oceanic and Atmospheric Administration (NOAA). It is overseen by a Scientific Steering Committee comprised of members chosen to represent the major techniques and disciplines, while at the same time providing regional geographic representation.
» http://www.pages.unibe.ch/index.html

Rossby Centre - The Rossby Centre in Sweden is the climate modelling research unit at SMHI. The Centre was built up as a central resource within SWECLIM, the Swedish Regional Climate Modelling Programme, 1996-2003. Research activities at the Rossby Centre focus on regional climate modelling covering meteorological, oceanographic and hydrological aspects as well as supercomputing. Work is conducted both on model development and evaluation as well as modelling applications on process studies, climate system studies, climate change research and impact studies.

The regional climate models developed at the Rossby Centre are the atmospheric model RCA, the oceanographic model RCO models as well as their coupled set-up, the RCAO system. Use is made also of the HBV hydrological model of SMHI.

The Rossby Centre is involved in a number of projects, many of which are funded by EU, on climate modelling and other aspects of climate and climate change research. The projects are carried out in co-operation with other research groups on a national as well as on an international level. Running and analysing climate model simulations is one of the main lines of activity at the Rossby Centre.
» http://www.smhi.se/sgn0106/if/rc/main.htm

NOAA

the US National Oceanic and Atmospheric Administration, conducts a wide range of studies on climate. One of these is the NOAA Climate Program Office http://www.climate.noaa.gov/ which incorporates the Office of Global Programs, the Arctic Research Office, the Climate Observations and Services Program, and coordinates climate activities across NOAA. The CPO focuses on developing a broader user community for climate products and services, provides a focal point for climate activities within NOAA, leads NOAA climate education and outreach activities, and coordinates international climate activities.
NCDC - NOAA's Climatic Data Center NCDC is the world's largest active archive of weather data. NCDC produces numerous climate publications and responds to data requests from all over the world. NCDC operates the World Data Center for Meteorology and the World Data Center for Paleoclimatology which is located in Boulder, Colorado. NOAA's climate services would receive funding of $24 million in FY 2007.
» http://www.ncdc.noaa.gov/oa/climate/climateextremes.html

NCAR

The US National Center for Atmospheric Research, is a federally funded research and development center of the National Science Foundation (NSF). It plays a key role in helping to shape the scientific agenda in climate research for the only agency of the U.S. government that has basic research at the core of its mission. NCAR has a focus on the geosciences, it has an important responsibility to both lead and support the nation's researchers in the interdisciplinary study of the atmosphere and related systems. A growing international concern about a variety of global environmental issues including global climate change. NCAR has throughout adopted an earth systems science approach with respect to research.
» http://www.ncar.ucar.edu/

GISS

NASA's Goddard Institute for Space Sciences, emphasizes a broad study of Global Change, which is an interdisciplinary initiative addressing natural and man-made changes in our environment that occur on various time scales (from one-time forcings such as volcanic explosions, to seasonal/annual effects such as El Niño, and on up to the millennia of ice ages) and affect the habitability of our planet. Program areas at GISS may be roughly divided into the categories of climate forcings, climate impacts, model development, Earth observations, planetary atmospheres, paleoclimate, radiation, atmospheric chemistry, and astrophysics and other disciplines. However, due to the interconnections between these topics, most GISS personnel are engaged in research in several of these areas.

A key objective of GISS research is prediction of atmospheric and climate changes in the 21st century. The research combines analysis of comprehensive global datasets, derived mainly from spacecraft observations, with global models of atmospheric, land surface, and oceanic processes. Study of past climate change on Earth and of other planetary atmospheres serves as a useful tool in assessing our general understanding of the atmosphere and its evolution. The perspective provided by space observations is crucial for monitoring global change and for providing data needed to develop an understanding of the Earth system. As the principal NASA center for Earth observations, Goddard Space Flight Center plays a leading role in global change research.

» http://www.giss.nasa.gov/research/

3. Conferences

ICARP II

INTERNATIONAL CONFERENCE ON ARCTIC RESEARCH PLANNING II

The Arctic System in a Changing World, COPENHAGEN, DENMARK, November 10-12, 2005.

Since the first Conference on Arctic Research and Planning held in 1995 in New Hampshire, there has been a paradigm shift to a holistic and multidimensional perspective in the Arctic. This holistic perspective integrally includes the human dimension, Indigenous insights and a more full integration of Arctic processes in the earth system.

» http://www.icarp.dk/

ASSW - The Arctic Science Summit Week

ASSW is an initiative of the International Arctic Science Committee (IASC). The purpose of the summit is to provide for opportunities for co-ordination, collaboration and co-operation in all areas of Arctic science, and to combine science and management meetings to save on travel and time. The ASSW also offers insight into Arctic research undertaken by the host country. Previous ASSW's have been held in Norway, UK and Canada, The Netherlands, Sweden, Iceland and China. The ASSW 2006 is organised in Potsdam, Germany. The Summit is organised by a local host and an International Contact Group, advised by a national group. The local host of this year's ASSW is the Alfred Wegener Institute.

» http://www.assw2006.de/

4. Funding Agencies

ESF

the European Science Foundation – Activities in the field of climate change and related sciences are, in large part, directed by the Standing Committee for the Life, Earth and Environmental Sciences (LESC). This includes a program on Holocene Climate Variability (HOLIVAR) This project seeks to bring together European scientists interested in climate variability of the last 6,000 years. The scientists are palaeoclimatologists, climate historians and climate modellers. The over-arching research questions concern how and why climate has varied naturally on different time-scales (annual to centennial) over this period and how an understanding of past variability can improve the predictability of climate models. Answers to these questions require interactions amongst scientists that as yet have not taken place and that are best promoted by an ESF programme, building on the aims and objectives of two global projects sponsored by both the International Geosphere Biosphere Programme (PAGES) and the World Climate Research Programme (CLIVAR).

Another program within ESF, relevant to ESSI, is Interdisciplinary Tropospheric Research: from the Laboratory to Global Change (INTROP) Climate change and air quality are key societal challenges. In fact it has become clear over the last decade that the development of our societies cannot be uniquely wealth orientated but that a sustainable development requires an "environmentally friendly" approach. However, such an approach is only possible if scientifically sound knowledge is made available to our societies. Therefore, a scientific programme on Atmospheric Chemistry is believed to respond to issues of strategic importance in European science policy. Accordingly, the ESF Scientific Programme on Atmospheric Chemistry would contribute to strengthening collaborative research, enhancing multidisciplinary in the field and promoting mutual awareness, in timely response to the up-coming research needs of the European countries.

ESF also has a program on Climate Variability and the (past, present and future) Carbon Cycle (EuroCLIMATE). EuroCLIMATE is an ESF-EUROCORES programme that calls for basic research addressing climate variability and the carbon cycle (past, present and future), and in particular their

interrelationship, in a European framework. It is supported particularly by research funding agencies from Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, The Netherlands, Spain, and Sweden, and by the European Science Foundation. Multi-proxy reconstructions from all available archives bring the marine, the terrestrial and the ice-core communities together on cross-cutting issues, such as obtaining a common timeframe, and would allow coupled climate models used for global warming scenarios to be validated on European and regional scales. In this session, we invite contributions to those themes.
» http://www.esf.org/esf_article.php?language=0&article=335&domain=3&activity=7

European Union In September 2005 the European Commission approved its proposals for a Council decision concerning the Specific Programmes implementing the Seventh Framework Programme (FP7; 2007-2013) of the European Community for scientific research and technological development. FP7 is the EU's chief instrument for funding scientific research and technological development over the period 2007 to 2013. More than half the total FP7 budget will be devoted to supporting cooperation between universities, industry, research centres and public authorities in order to gain leadership in key scientific and technology areas.

NSF

the U.S. National Science Foundation. Climate has a pervasive effect on the U.S. through its impact on the environment, natural resources, and the economy. To respond to the challenge of understanding climate and climate variability, the Climate Change Science Program (CCSP) was established in 2002 (http://www.climatescience.gov/). It is providing the US nation and the world with the science-based knowledge to predict change, manage risk, and take advantage of opportunities resulting from climate change and climate variability. Research conducted through CCSP builds on the scientific advances of the last few decades and deepens our understanding of how the interplay between natural factors and human activities affect the climate system. The CCSP engages thirteen U.S. agencies in a concerted interagency program of basic research, comprehensive observations, integrative modeling, and development of products for decision-makers. NSF provides support for the broad range of fundamental research activities that form a sound basis for other mission-oriented agencies in the CCSP and the Nation at large. NSF funding for climate change research in 2006 and 2007 is shown in the table below:

NSF Climate Change Science Program Funding
(Dollars in Millions)

	FY 2005 Actual	FY 2006 Current Plan	FY 2007 Request	Change over FY 2006 Amount	Percent
Biological Sciences	15.10	15.10	15.10	-	-
Engineering	1.00	1.00	1.00	-	-
Geosciences	150.35	149.35	157.72	8.37	5.6%
Mathematical and Physical Sciences	5.45	5.45	5.45	-	-
Social, Behavioral and Economic Sciences	15.48	15.48	15.48	-	-
Office of Polar Programs	10.50	10.50	10.50	-	-
Total, Climate Change Science Programs	$197.88	$196.88	$205.25	$8.37	4.3%

In addition, NSF funds a variety of programs closely related to climate change research, in oceanography, paleoclimatology, paleooceanography etc.
As a major focus in FY 2007, NSF programs continue to emphasize climate variability and change across temporal scales. This research element supports observational campaigns and numerous analytical and modeling activities. Ocean science efforts will concentrate on changes in ocean structure, circulation, and interactions with the atmosphere to improve our current understanding of the processes and models that address future changes, particularly those that may happen abruptly. Major support will continue to permit the Community Climate System Model to improve model physics and parameterizations that will lead to more comprehensive models incorporating interactive chemistry and biogeochemical cycles. Studies of paleoclimatology will continue to be supported as a means to provide baseline data on natural climate variability from the past and from key climatic regions. These studies will improve our understanding of the natural variability of the climate system and in particular will enable reconstructions and evaluations of past environmental change as inputs for model validations.
» http://www.nsf.gov/index.jsp
Long-term predictions of SST http://www.cdc.noaa.gov/forecast1/Globalsst.html

5. Icelandic Research Institutes relevant to global climate research in the north:

Jarðvísindastofnun Háskóla Íslands

Institute of Earth Sciences of the University of Iceland

» http://www.jardvis.hi.is/

The institute is dedicated to academic research and graduate studies within the Earth sciences with a main focus on the unique geological features of the Iceland region. The institute takes advantage of Iceland's location in the North Atlantic for studies aimed at reconstructing the dynamics of past environmental and climatic variability in order to understand interactions between components of the global system. Iceland's glaciers are indicators of the response of the cryosphere to climate warming, ideal for the coupling of field studies and numerical modelling of the response of glaciers to climate change. Sedimentary and volcanic rock sequences on land contain a detailed record of Tertiary and Quaternary palaeoenvironments including glaciation and vegetation history. Integration of records from Icelandic glaciers, lake and marine sediments and paleontology can be used to reconstruct past environmental changes and to identify and understand processes that may affect climate on Earth in the coming decades. High resolution, paleoclimate records from lake and marine sediments provide information regarding natural climatic variability during the Quaternary.

Hafrannsóknarstofnunin

Marine Research Institute of Iceland

» http://www.hafro.is/index.php

The Marine Research Institute is a government institute under the auspices of the Ministry of Fisheries. MRI conducts various marine research and provides the Ministry with scientific advice based on its research on marine resources and the environment.

The institute has around 170 employees, 3 research vessels, 5 branches around Iceland and a mariculture laboratory. The three main areas of activities of the MRI are the following: (a) to conduct research on the marine environment around Iceland and its living resources. (b) to provide advice to the government on catch levels and conservation measures. (c) to inform the government, the fishery sector and the public about the sea and its living resources.

Veðurstofan

The Icelandic Meteorological Institute

» http://www.vedur.is/

The Institute is under the Icelandic Ministry of the Environment and its charge is to provide a meteorological service for Iceland and conduct research in meteorology and related fields.

Siglingastofnun

Icelandic Maritime Administration

» http://www.sigling.is/

The institute is under the Icelandic Minstry of Communication.

Umhverfisstofnun

The Environmental Institute of Iceland

» http://www.ust.is/

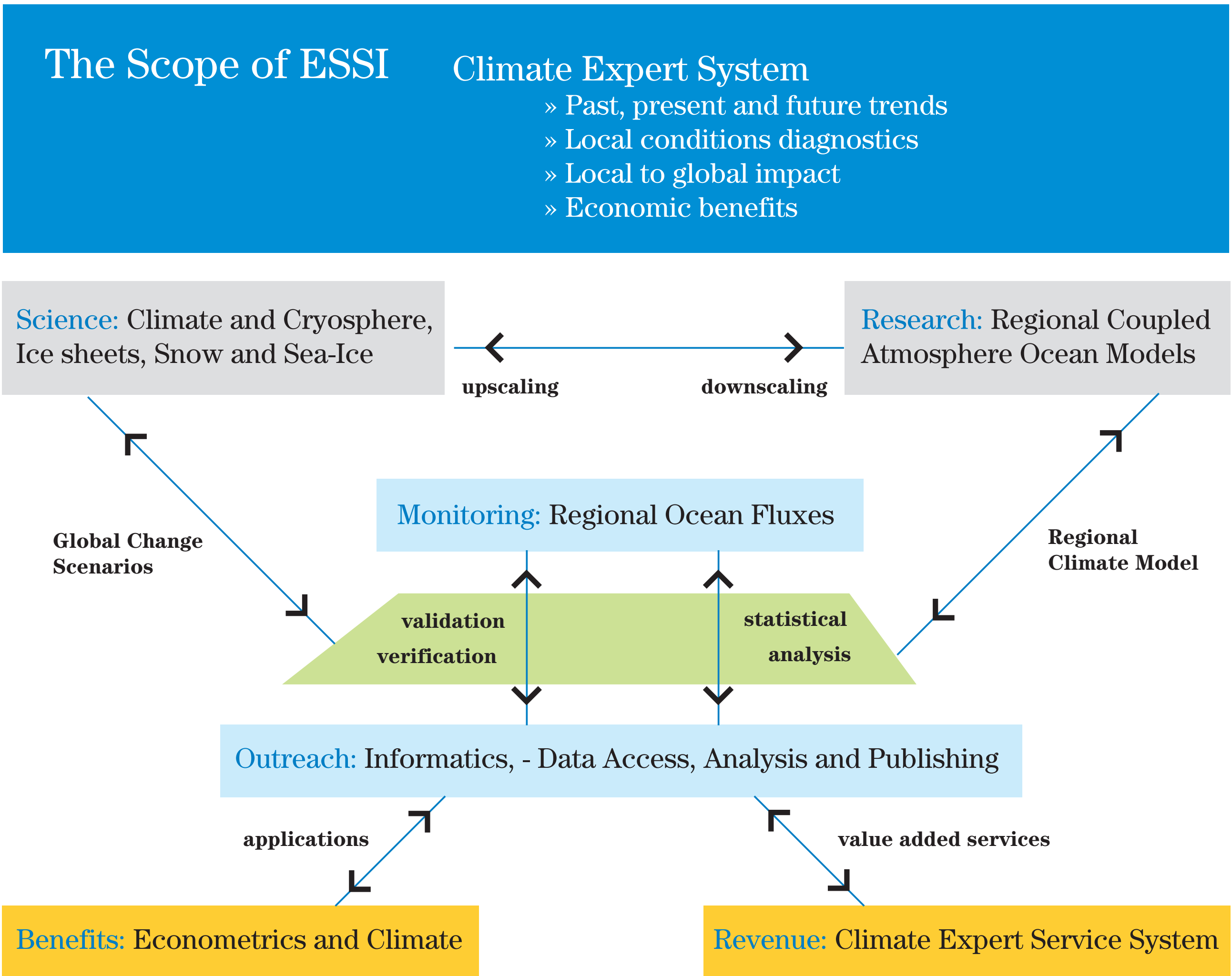
The institute is under the ministry of the Environment. Its role is to work towards a healthy physical environment in Iceland, safety in consumer goods, environmental protection and sustained development of natural resources.

Náttúrufræðistofnun Íslands

Icelandic Insitute of Natural History

» http://www.ni.is/english/about.phtml

The Institute conducts basic and applied research on the nature of Iceland in the fields of botany, geology and zoology with emphasis in biology on taxonomy and ecology; maintains scientific specimen collections; holds data banks on Icelandic nature; assembles literature on the natural history of Iceland; operates the Icelandic Bird-Ringing Scheme, prepares distribution, vegetation and geological maps; assists in environmental impact assessments; advises on sustainable use of natural resources and landuse; and assesses the conservation value of species, habitats and ecosystems.


The Scope of ESSI
Climate Expert System
» Past, present and future trends
» Local conditions diagnostics
» Local to global impact
» Economic benefits
Science: Climate and Cryosphere, Ice sheets, Snow and Sea-Ice
upscaling
downscaling
Research: Regional Coupled Atmosphere Ocean Models
Global Change Scenarios
Monitoring: Regional Ocean Fluxes
Regional Climate Model
validation
verification
statistical
analysis
Outreach: Informatics, - Data Access, Analysis and Publishing
applications
value added services
Benefits: Econometrics and Climate
Revenue: Climate Expert Service System