ESSAS Report Series **Number 2**

Report of the 2007 ESSAS Annual Science Meeting

with Workshops on

The Role of Seasonal Sea Ice Cover in Marine Ecosystems

Evaluation of Future ESSAS Climate Scenarios

and

Modeling Ecosystem Responses

Hakodate, Japan

4-9 June 2007

George L. Hunt, Jr., Compiler

5 May 2008

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1. Background

The 2007 annual ESSAS science meeting was held in Hakodate, Japan from 4 to 6 June and was followed by the annual meeting of the ESSAS Science Steering Committee (SSC) on 7 and 8 June. The annual meeting was opened June 4, 2007 with a welcome address by the Vice Mayor of Hakodate, His Honor Toshiki Kudoh, followed by welcoming remarks by our host, Professor Yasunori Sakurai and ESSAS Co-Chair, Professor George Hunt. The annual meeting consisted of three workshops, one on the role of sea ice cover, one on the evaluation of future ESSAS climate scenarios, and one on modeling ecosystem responses (Appendix 1, Schedule of Activities). The meeting was attended by 71 registered participants from seven countries (Canada, 3; France, 1; Japan, 49; Korea, 1; Norway, 4; Russia, 2; USA, 11) (See Appendix 2, List of Participants).

The May 2007 ESSAS Hakodate meetings were built on decisions taken in the June 2006 ESSAS Workshop held in St. Petersburg, Russia (Hunt and Drinkwater, 2007). The St. Petersburg workshop explored the development of fruitful approaches for comparative studies of sub-arctic marine ecosystems. There, participants decided that ESSAS should systematically investigate the major mechanisms by which climate change might be expected to affect the sub-arctic seas. To this end, it was proposed to hold a series of annual workshops, each of which would be focused on a different aspect or mechanism by which climate would be expected to influence the sub-arctic seas. Initial topics for these proposed workshops included the role of sea ice, the importance of advection and its sources, and determinants of stratification, among others. Emphasis would be on developing papers that compared all or as many of the ESSAS areas as possible. It was also decided that ESSAS should investigate which of the IPCC (Intergovernmental Panel on Climate Change) Climate models best predicted regional climate patterns and thus could be expected to provide the most useful future climate scenarios. It was further realized that ESSAS would have to use modeling approaches, both to compare present-day sub-arctic marine ecosystems, and to predict how climate change might be expected to affect these ecosystems and their ability to sustain fisheries and other human activities.

To these ends, the 2006 Workshop participants recommended to the ESSAS SSC that, at the outset, three ESSAS Working Groups be formed: WG-1, Working Group on Regional Climate Prediction (WGRCP); WG-2, Bio-Physical Coupling (WGBPC); and WG-3, Modeling Ecosystem Response (WGMER) (see Appendices 3-5 for terms of reference). The participants requested that the ESSAS SSC organize an annual meeting and that, in 2007 it should consist of a 1.5 day workshop on the role of sea ice in Sub-Arctic marine ecosystems under the guidance of the WGBPC; and a 1-day workshop on Future Climate under the guidance of the WGRCP (see Appendix 1, Schedule of Activities) (see appendices 6 and 7 for Terms of Reference for these workshops). Additionally, Working Group 3, on Modeling Ecosystem Responses was requested to hold an organizational workshop to seek advice from the ESSAS community as to how they might proceed with developing a modeling program within ESSAS.

2. Workshop Reports

2.1. Workshop 1.The role of seasonal sea ice cover in marine ecosystems

Co-conveners: Professor Egil Sakshaug (Norwegian University of Science and Technology, Trondheim), **Professor Sei-ichi Saitoh** (Faculty of Fisheries, Hokkaido University) and **Dr. John Bengtson** (National Marine Mammal Laboratory, Seattle).
Sponsored by: ESSAS Working Group 2: Bio-Physical Coupling (WGBPC).

The first day of the workshop on the role of sea ice cover was dedicated to 15 invited talks, by scientists from France, Japan, Korea, Norway, and USA on ice, physical oceanography and ice-biota in sub-arctic seas, as a preparation for the discussions to follow in the late afternoon and the following day. There was one overview talk (by Dr. L. Legendre), three talks on “monitoring and methodological progress”, five talks on “Physical characteristics”, four talks on “phytoplankton, zooplankton” one talk on “fish”, and three talks on “marine mammals and seabirds”. A total of about 70 people attended the workshop, which offered many recent results from Japanese research in the Bering Sea and in the Sea of Okhotsk.

A common denominator for the workshop was to clarify the underlying mechanisms that regulate fluctuations in productivity and biomass at different trophic levels, especially changes brought about by climate fluctuations. Furthermore, the workshop discussed the possibility of writing review papers for refereed journals, with the expressed goal to distill new knowledge from synthesizing existing knowledge from different seas. Accordingly, during the second day, the workshop split into two groups to discuss the possibility of writing two review papers, focusing on “Hotspots” and “Thresholds for Change”, respectively. Both groups emphasized identification of mechanisms that are crucial for improving models and relevant for modeling the biological impact of climate change in the Arctic.

The Hotspot group suggested a paper, *Mechanisms of hotspot generation in sub-arctic seas – relationship with sea ice.* Hotspots are here defined as areas of high productivity and/or biomass. The rationale is that hotspots are spatially and numerically limited and therefore tractable to scientific study and to model and hypothesis testing. Moreover, hotspots are important to food webs in sub-arctic marine ecosystems overall, including the resilience of fisheries and the success of species at higher trophic levels. Among the hotspots under debate were the Hudson Strait, the Kurile Islands, Unimak Pass, Shiretoko, and the NOW Polynya, which offer examples of more or less different underlying mechanisms for high productivity and biomass. Also “hotbands” (greenbelts) were under consideration, such as those along the western shelf break of the Barents Sea north to Fram Strait, the region along the shelf break of the Bering Sea, areas of the Sea of Okhotsk and the Greenland slope/shelf, and moving fronts and the retreating ice edge, with its associated ice-edge bloom that follows the retreating ice.

The *Thresholds for Change* group suggested a paper titled *Non-linear biological responses to sea ice [climate] change in Sub-Arctic Seas,* to focus on how non-linear biological responses in sea ice ecosystems may be triggered by climate change when

certain thresholds are exceeded. The group, moreover, suggested initiation of a threshold information data base for the sub-arctic seas. The topic of thresholds is important because there is a high probability of exceeding critically important biological thresholds in marine ecosystems the sub-arctic seas during the next fifty years.

The paper will define what the thresholds are and will also discuss how statistical and dynamical climate models can be applied to estimate the probabilities of future changes in the thresholds. Thresholds can be evident by a failure or switch in annual production, or in altered population status through several years. Non-linear thresholds are, among many, the relationship between sea ice and black guillemot nesting, certain species of fish and *Calanus* species, let alone seals and polar bears. A crucial question is how statistical and dynamic climate models can be applied to estimate the probabilities of future changes in thresholds.

2.2. Workshop 2. Evaluation of Future ESSAS Climate Scenarios

Convenor: Dr. James Overland (NOAA Pacific Marine Environmental Laboratory).
Sponsored by: ESSAS Working Group 1: Regional Climate Prediction (WGRCP).

A Goal of the Working Group on Regional Climate Prediction (WGRCP) is to provide quantitative estimates of the magnitude and uncertainty of future climate change, and the frequency distribution of the large natural variability, known to influence the ESSAS marginal seas. A major resource for the development of future climate scenarios is the recently available results from 22 state-of-the art coupled atmosphere-ocean climate models which are part of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4).

A one day workshop was held on 6 June 2007, which provided background material on the IPCC AR4 process and results, investigated the state of the art in high resolution physical models of the ESSAS Seas, and charted a path forward for the WG during the next two years.

V. Kattsov, J Walsh, T Furevik, and J Overland reported on the AR4. The process had 450 lead authors, 130 countries, and represented six years of work. The physical science basis was published in February 2007, while the direct results from the 22 climate models have been available for review over the last two years. A major AR4 conclusion is that most of the observed increase in global average temperatures since the mid-20th century is very likely due to observed increase in anthropogenic green house gas concentrations contributed by humans. Observed changes in high latitude regions over the last 45 years are shown in Figure 1.

The AR4 forecast models appear to be much improved from the Third Assessment Report of six years ago, in terms of spatial resolution, better ice parameterization and ocean physics. Because of a lag effect, climate projections out to 2050 depend more on known CO_2 concentration increases than differences in economic

or conservation scenarios. Thus the largest uncertainties in future climate projections are from model to model differences. Models that are run several times with slightly different starting conditions (termed ensembles) seem to capture some of the natural variability in climate when the models are compared to 20th century data. Figure 2 shows that the models vary in terms of how much ice they produce relative to recent observations.

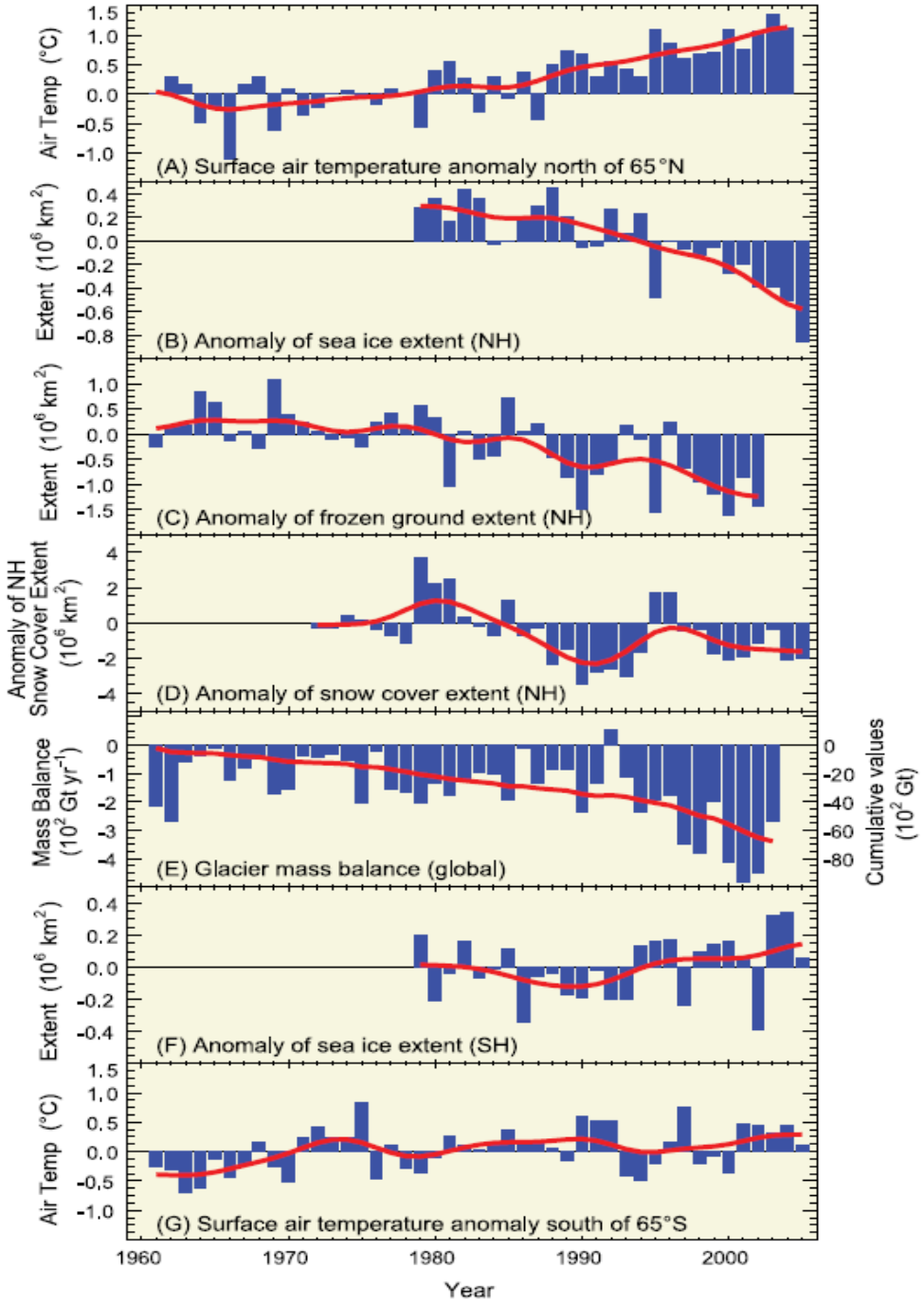

Figure 1. IPCC summary of recent variations in polar temperatures and cryospheric variables. Note change of more than 1 ºC temperature and 20 % ice loss in the north. Similar systematic changes were not found in the Southern Hemisphere.

A first conclusion from the workshop is that, while there are still problems with the details of some of the variables, there is utility for ESSAS in the temperature, sea ice, and perhaps ocean stratification projections from a subset of the IPCC AR4 models. This conclusion is based on model improvements compared to previous Reports, comparison with data, the large community involvement in AR4, and the modeling of key processes such as greenhouse warming and ice-albedo feedback. A second conclusion is that there are an number of outliers among the group of models compared to 20th century data and that selection rules would be helpful to constrain the uncertainty in future projections. There were several possibilities for selection approaches suggested to address this issue: single indicator versus multivariate indicators, regionally specific versus inter-regional consistency. Exploration of these rules and their statistical rigor is a challenge for the Working Group for the next year.

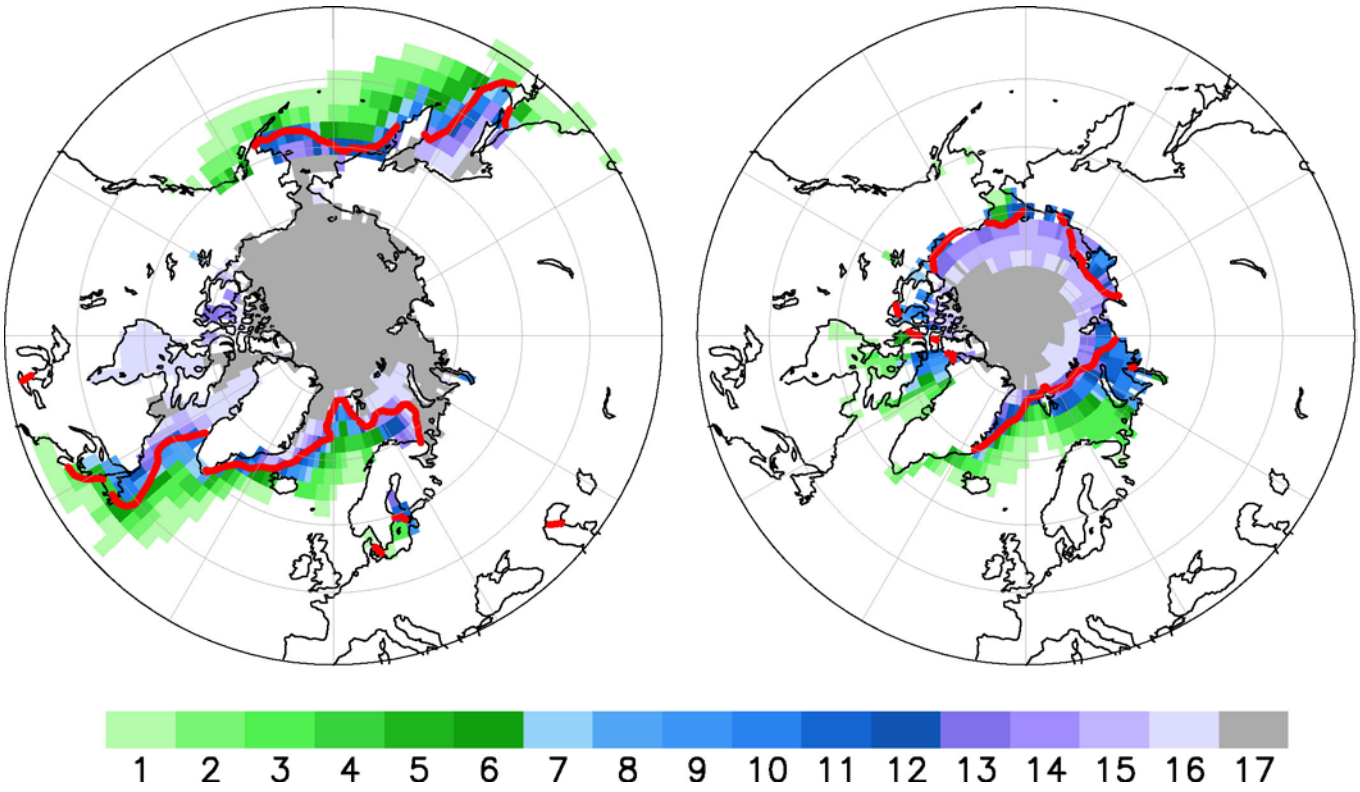

Figure 2. Sea ice in 17 IPCC AR4 models compared to recent data (red line) for March (Left) and September (Right). The colors indicate how many models have ice this far south. Note that about 5 of the models have too much ice in the Pacific and western Atlantic in winter. The Barents Sea has a large percentage of models that have too much ice in both winter and summer.

Drs. P. Budgell, H. Nakamura, and J. Zhang discussed high resolution modeling for the Barents Sea/North Atlantic, waters near Japan, and the Bering Sea. The Barents Sea model is a nested ROMS model at 4 km resolution. Hindcasts of ice

variability are well handled by the model given good meteorological forcing. The difficulty for downscaling IPCC to this model relates to the selection rules mentioned above, as most IPCC models over-predict the extent of cold temperatures. The models for Japanese waters predict an intensification of the Kuroshio with global warming; realistic simulations require an eddy resolving model (0.1 x 0.1 deg). The Bering Sea model has a multi-category sea ice thickness, tides, and a POP ocean model. It is able to describe some of the basic features of sea ice advance and retreat, ocean circulation, and SST. These regional models are an active area of research, and a third conclusion of the workshop is that these models should be encouraged and that further planning of coupling (downscaling) of these models to the range of variability shown by the IPCC models, should be explored.

Drs. M Wang, G. Hunt and K. Drinkwater, discussed the climatology of the ESSAS regions and how the physics may be coupled to the biology. In the example of cod in the Atlantic, climate shifts at the extreme southern and northern ranges show the most biological sensitivity. Thus, stating particular climate thresholds for different species may be more relevant approach than requiring an overall high accuracy from the models. In the Pacific, it was pointed out that it is important for the modeling group to know from the biologists where, what months, what variable(s) and why (species and impact) potential ecosystem stress points may occur.

The priorities for the Working Group are to: 1) pursue and evaluate a range of IPCC AR4 model selection rules for ESSAS regions, 2) work with other Working Groups on matching potential biological impacts from climate change to the limits of credible projections from IPCC, 3) explore the general area of downscaling, particularly in the context of high resolution ocean models.

2.3. Workshop 3: Modeling Ecosystem Responses.

Convened by: **Dr. Bernard A. Megrey** (NOAA Alaska Fisheries Science Center), **Professor Kenneth Rose** (Louisiana State University), and **Dr Sei-ichi Ito** (Tohoku National Fisheries Research Institute)
Sponsored by: ESSAS Working Group 3: Modeling Ecosystem Response

The goal of the ESSAS Working Group on Modeling Ecosystem Response is to devise approaches for understanding and predicting ecosystem responses to climate change through the use of modeling. To this end, a workshop was convened to develop strategies within the ESSAS framework. The Workshop participants met briefly in an impromptu caucus on Monday June 5th, and again in plenary session on the morning of June 7th to discuss approaches to the use of models within ESSAS with all participants in the ESSAS meeting.

During the plenary, four presentations were made. One, by Dr. Bern Megrey, concerned the status of the MENU program, one, by Professor Ken Rose, covered possible collaborative opportunities with working groups 1 and 2, one, by Dr. M. Fujii, discussed a JGOFS model comparison experiment, and the final presentation, by Dr. S-I. Ito, discussed some NEMURO applications, comparison of models from the NEMURO

family of models, and the EUR-OCEAN model shopping tool web page (http://www.eur-oceans.eu/WP3.1/shopping_tool/index.php?mode=fromEuroceans).

The remainder of the plenary covered topics such as the draft terms of reference (see Appendix 5), the possibility of preparing a proposal to create an IOC/SCORE working group on high latitude ecosystems, membership suggestions, and the preparation of an action plan.

3. References:

Hunt, G.L., Jr. and Drinkwater, K. (Compilers) 2007. Report of the ESSAS Workshop: Development of Methods for Comparisons of the Sub-Arctic Seas, St. Petersburg, Russia, 12-14 June 2006. ESSAS Report Series 1, 47pp.

4. Acknowledgments

We thank the attendees at the ESSAS Hakodate Workshops for their active participation in discussions and for their comments on earlier drafts of this report. Special thanks go to Professor Yasunori Sakurai for his support and efforts in arranging the venue and logistics for the meeting. We thank the North Pacific Research Board, PICES, and the GLOBEC International Project Office for their financial support of the workshop. The Research Council of Norway and NESSAS supported several of the Norwegian participants, and the U.S. National Science Foundation, Office of Polar Programs supported participation by scientists from the Bering Ecosystem Study (BEST) program.

Appendix 1: Agenda

Schedule of Activities

ESSAS Hakodate Meeting

4-9 June 2007

June 4 (Monday)

08:30 Registration, Hakodate Community Design Center

009:00 Opening / welcome address by Toshiki Kudoh, Vice Mayor of Hakodate

09:10 Welcoming Remarks- Professor Yasunori Sakurai and George Hun

09:20 **Sea Ice Workshop (Egil Sakshaug, Sei-Ichi Saitoh and John Bengtson, Co-converors)**

09:30-10:00 **L. Legendre**: Importance of the sea ice ecosystem in the larger polar context

Monitoring and methodological progress

10:00-10:15 **K. Tateyama, H. Enomoto, K Shirasawa**. Observations of sea ice concentration and thickness used by ship-borne sensors (including satellite observation in the Okhotsk and Bering Seas)

10:15-10:30 **T. Hirawake, A. Fujiwara and S.-I. Saitoh**: Discrimination of dominant size in natural phytoplankton community in sub-Arctic waters

10:30-10:45 **G. Johnsen**. Fine-scale studies using hyperspectral remote sensing

10:45-11:00 ***Break***

Physical characteristics

11:00-11:20 **K. I. Ohshima**: Impact of sea ice variability on physical and biological processes in the Sea of Okhotsk.

11:20- 11:40 **T. Hiwatari, K. Shirasawa, Y. Fukamachi, R. Nagata, T. Koizumi, H. Koshikawa, and K. Kohata.** Material flux under seasonal sea ice at an offshore site along the Okhotsk coast of Hokkaido, Japan

11:40-12:00 **J. Clement-Kinney, W. Maslowski**. On the processes controlling shelf-basin exchange and outer shelf dynamics in the Bering Sea

12:00- 12:20 **K. Mizobata, J. Wang, S-I. Saitoh, T. Hirawake, and M. Jin.** Chlorophyll and primary production in the Pan-Arctic Oceans and Submarginal Seas

12:20-13:40 ***Lunch***

Phytoplankton, zooplankton

13:40-14:00 **T. Iida**. Comparative study on temporal and spatial variability of chlorophyll-a concentration in the Okhotsk and Bering Seas

14:00-14:20 **D. Slagstad**. Simulated inter-annual variability in primary production in the seasonal ice zone

14:20-14:40 **H. Hattori, M. Sampei, Y. Makabe, H. Sasaki, M. Fukuchi, L. Fortier**: Seasonal vertical migration of *Calanus hyperboreus* (Copepoda) in the Amundsen Gulf, south-eastern Beaufort Sea.

14:40-15:00 **H.-C. Shin.** Enhancement and containment of biological productivity and krill abundance in the southwestern Weddell Sea; what are the controls?

Fish

15:00- 15:20 **F. Mueter**. The effects of sea ice dynamics on the distribution of fish

15:20-15:40 ***Break***

Marine mammals and seabirds

15:24-16:00 **T. Ichii**. Interannual changes in distribution and body fat condition of Antarctic minke whales in relation to sea ice extent

16:00-16:20 **J. Bengtson.** Polar seals in sea ice ecosystems

16:20-16:40 **G. Hunt** The importance of seasonal sea ice cover for sub-arctic marine birds

Discussion of presentations

16:40-18:00 Plenary Session: mechanisms and relationships in sea ice ecosystems

18:00 ***End of day one***

18:30 Welcome Reception (Goto-ken), walk from Hakodate Community Design Center (100 m)

June 5 (Tuesday)

Day 2, Sea Ice Workshop, continued

Discussion of possible paper/papers from workshop

09:00 Plenary Session: scoping of possible paper(s) to be developed

10:30-11:00 ***Break***

11:00 Breakout writing groups as necessary

12:00-13:30 ***Lunch***

13:00 Breakout writing groups as necessary

15:00-15:30 ***Break***

15:30 Plenary Session: report of breakout groups, further discussion on paper(s)

17:30 ***End of Sea Ice Workshop***

18:00 Traditional Japanese dinner with hot-spring (Tikuba-Shinyotei, Yunokawa Hot-spring), transfer by bus from Hakodate Community Design Center)

June 6 (Wednesday)

09:00 **Workshop on the Evaluation of Future ESSAS Climate Scenarios (Jim Overland, Convenor)**

09:00 **James Overland**, PMEL, and **Junlin Zhang**, U. Washington
Introduction and Climate Model Primer

09:30 **Vladimir Kattsov,** Main Geophysical Observatory of Roshydromet, Russia: IPCC Process/Results-Atmosphere

10:00 **John Walsh**, U. Alaska, Fairbanks: IPCC Process/Results-Sea Ice/Atmosphere

10:30 ***Break***

11:00 **Tore Furevik**, Via **Paul Budgel**, Geophysical Institute, Bergen: Models/Projections Barents Sea-NE Atlantic

11:30 **Hisashi Nakamura**, University of Tokyo: Models/Projections Japanese waters

12:00 -13:30: ***Lunch break***

13:30 **Ken Drinkwater** Via **Paul Budgell**, Institute of Marine Resources and Bjerkness Center: Cod Predictions for the North Atlantic

14:00 **Muyin Wang**, Pacific Marine Environmental Laboratory/UW-JISAO:
Regional Climatologies

14:30 **George Hunt,** University of Washington. Report on the May 2007 PICES CFAME workshop.

14:45 **James Overland**, Pacific Marine Environmental Laboratory:
Open Discussion of Regional Projections and Scenarios: Bering, Labrador, Barents/N Iceland, NW Pacific. Includes 15 minute Bering talk by **J. Zhang**

16:30 Way Forward

17:30 ***Adjourn***

19:30 visit Hakodate Mountain (Night view) by bus. We pick up at your each hotel.

June 7 (Thursday)

09:000 **Discussion of Modeling approaches to comparison of Sub-arctic seas**

09:00 **Discussion Leaders: Bern Megrey**, Alaska Fisheries Science Center, **Kenny Rose**, Louisiana State University, **Shin-ichi Ito**, Tohoku National Fisheries Research Institute:

09:15 *Approaches for Model comparison (**S-I. Ito**).*

a) Simple ways to use one or more models in as many ESSAS systems as possible. NEMURO/ECOPATH/Others??
b) Presentations
   i) MENU developments (**B. Megrey**)
   ii) EuroOcean Model Shop (**S-I. Ito**)
   iii) Masahiko Fujii's JGOFS model comparison work (**M. Fujii**)

10:15 Break

10:30 *WG Membership suggestions (all)*

a) ideal size and international/disciplinary balance

10:50 *TOR of WG-III (**B. Megrey**)*

a) We have a draft. We need to decide if the TOR strategy should take an active approach or a more passive planning approach. Perhaps this would be done better after we have full membership?

11:05 Approaches for coupling with WG-I & II (**K. Rose**)

11:20: IOC/SCORE Proposal idea (**B. Megrey**)

a) Prepare a proposal to form a WG under IOC/SCORE to look at ecosystem comparisons between northern and southern hemisphere high latitude ecosystems. Upside: The northern hemisphere comparisons would overlap completely with ESSAS and IOC/SCORE monies would help finance the necessary ESSAS meetings. Downside: Time spent at any one meeting would be shared between N and S hemisphere issues and IOC/SCORE report requirements etc would not directly benefit ESSAS..

11:40 *Action plan during 2008-2009 (**B. Megrey**)*

a) We need to have a proposal or a draft outline prepared for the SSC meeting based on what we hear at the earlier workshops.
b) Develop a 3-5 year plan for activities; perhaps do it in 2 phases (phase I - years 1-5, phase II - years 6-10). Depends on how long ESSAS will exist.

12:30-13:30 ***Lunch break***

13:30 **ESSAS SSC Business Meeting**, Agenda to be provided

17:30 ***Adjourn for the day***

June 8 (Friday)

09:00 **ESSAS SSC Business Meeting**, continued

10:30 ***Break***

10:45 Continue Discussion

12:15-13:30 ***Lunch break***

13:30 Continue Discussions

17:30 ***Adjourn the ESSAS SSC Meeting***

June 9 (Saturday)

Excursion to Oonuma Lake National Park, coastal fisheries area (Fishers Festival in Usujiri, Hakodate), if need, and outdoor hot-spring, details to be provided

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Appendix 2: List of Participants:

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Appendix 3: Terms of Reference ESSAS WG-1

Terms of Reference

ESSAS Working Group 1: Regional Climate Prediction (WGRCP)

28 February 2007

Introduction

A major goal of ESSAS is to predict the potential impacts of climate variability on the sustainable use of the sub-arctic seas. ESSAS has elected to employ a comparative approach, investigating in each of the sub-arctic seas which energy pathways appear particularly vulnerable to decadal and longer-term climate change. The ecosystem response to climate can be non-linear with thresholds, have complex interactions between species, and different species impacts from similar climate fluctuations. Reducing uncertainty about the future states of ESSAS ecosystems depends on knowledge of the response of the ecosystem to changes in climate and a quantitative ability to project future climate states. The first task represents understanding and modeling the complex linkages between climate variables and species distributions and is a primary focus of the other two ESSAS Working Groups (ESSAS Working Group 2: Biophysical Coupling Mechanisms and ESSAS Working Group 3: Modeling Ecosystem Responses).

A Goal of the **Working Group on Regional Climate Prediction (WGRCP)** is to provide quantitative estimates of the magnitude and uncertainty of future climate change for the ESSAS regions, and the frequency distribution of natural variability, such as the well known ecosystem reorganization of the North Pacific in the mid-1970s and historical interdecadal variability in the marginal seas of the North Atlantic. Climate elements known to be crucial to ESSAS ecosystems include sea ice cover, ocean temperature, circulation, and stratification.

A major resource for the development of future climate scenarios is the recently available results from 22 state-of-the art coupled atmosphere-ocean climate models which are part of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). A preliminary investigation has shown that a subset of these models represents the physical forcing in several ESSAS ecosystems reasonably well based on comparison with *in situ* data for the late 20th century. There are several factors that lead to the perceived credibility of future climate scenarios from climate models, including the differences between models, validation exercises for different physical variables, and matching the spatial scales that are important to ecosystem biology.

Tasks

1. Evaluate the credibility of the 22 IPCC models as applied to each of the different ESSAS regions based on comparison of 20th century hindcasts with data, and model to model consistency and physical reliability in their forecasts. Produce a report which provides recommendations on which models perform well for each region.

2. Working within the larger ESSAS framework, establish which seasons, regions and variables are most important to potential ecosystem shifts and provide report on future scenarios and confidence estimates of these conditions for different future time horizons. Assess the contributions from intrinsic climate variability and external anthropogenic forcing.

3. Recommend IPCC models and procedures for downscaling of the model output for use in regional ocean/ecosystem models.

4. Be a community resource on retrospective and future climate change issues.

Implementation

1. The Working Group on Prediction shall exist for a period of three years, ending six months after the 2009 annual meeting of ESSAS.

2. Six to eight members will be chosen from the fields of climate science and numerical modeling. Input from experts on ecosystem processes will be sought through collaboration with ESSAS WG 2 and 3.

3. The development of the proposed products includes conducting workshops held at the annual ESSAS meetings and will require inter-sessional work. The purpose of the workshops is to vett and reach consensus on information made available prior to the workshops from the published IPCC Reports and from direct model evaluations provided by members.

Expected Results

To ensure the perceived credibility of future regional climate scenarios, we will develop a white paper after the ESSAS Workshop in 2007 that examines the differences between IPCC models, identifies the spatial scales and variables that are of relevance to ecosystem-effects of climate change, and delineates further validation exercises for different physical variables that have been performed.

After the ESSAS Workshop in 2008, we plan to have a set of climate predictions for the major ESSAS ecosystems, based on the IPCC climate models. These regional climate scenarios will have sufficient credibility that they can be used by other ESSAS Working Groups as the basis for their ecosystem modeling efforts.

Membership

A list of the initial members of ESSAS WG 1 is as follows:

James Overland,	acting Chair, USA	Lennart Bengtsson	Germany
Paul Budgell	Norway	Vladimir Kattsov	Russia
Ken Drinkwater	Norway	Mike Foreman	Canada
Hisashi Nakamura	Japan	John Walsh	USA

Appendix 4: Terms of Reference ESSAS WG-2

Terms of Reference

ESSAS Working Group 2: Bio-Physical Coupling (WGBPC)

28 February 2007

Introduction

A major goal of ESSAS is to predict the potential impacts of climate variability on the sustainable use of the Sub-Arctic seas. ESSAS has elected to employ a comparative approach, investigating, in each of the sub-arctic seas, which energy pathways appear particularly vulnerable to decadal and longer-term climate change. The ecosystem response to climate can be non-linear with thresholds, have complex interactions between species, and feature different species responses to similar climate fluctuations in different ecosystems. Reducing uncertainty about the future states of ESSAS ecosystems depends on developing the ability to project future climate states as well as predicting the response of the ecosystem to changes in climate. Predicting future climate states is the primary focus of ESSAS Working Group I on Regional Climate Prediction. This requires quantitative estimates of the magnitude and uncertainty of future climate change for the ESSAS regions, and the frequency distribution of natural variability, such as the well-known ecosystem reorganization of the North Pacific in the mid-1970s and historical inter-decadal variability in the marginal seas of the North Atlantic. Predicting ecosystem response requires both understanding and modeling the complex linkages between climate variables and species distributions. This represents the primary focus of two ESSAS Working Groups (ESSAS Working Group 2: Biophysical Coupling Mechanisms and ESSAS Working Group 3: Modeling Ecosystem Responses).

A Goal of the **Working Group on Bio-Physical Coupling (WGBPC)** is to determine how climate-driven variability in physical conditions and processes in the ocean will affect the organisms that make up marine ecosystems and thus the transfer of energy and material through sub-arctic marine ecosystems. Physical aspects of the ocean thought to be crucial to ESSAS ecosystems include sea ice cover, ocean temperature, circulation, and stratification.

A great deal is already known about the responses of organisms to physical variability in the ocean, but the literature is scattered and there is need to summarize what is known specifically about the responses of populations and the ecosystem as a whole in the Sub-Arctic seas and how information gathered in one basin may be applied to ocean regions elsewhere in the Sub-Arctic. Thus a major task for the WGBPC will be to provide the modelers in the ESSAS WGMER with realistic values for parameterizing predictive models of ecosystem response to climate variability.

Tasks

1. Summarize and evaluate the available information on the responses of marine organisms of the Sub-Arctic seas from phytoplankton to marine mammals and seabirds to variability in physical attributes of the ocean such as seasonal sea ice cover, ocean temperature, stratification, and circulation.

2. Working within the larger ESSAS framework, provide the WGMER with a realistic set of values with which to model organism responses to climate-driven variability in the physical attributes of the Sub-Arctic seas.

3. Be a community resource on retrospective and future climate change issues.

Implementation

1. The Working Group on Bio-Physical Coupling shall exist for an initial period of three years, ending six months after the 2009 annual meeting of ESSAS. At this time, the ESSAS SSC will evaluate whether the WG should continue, be revised slightly or dissolved.

2. Eight to ten members will be chosen from the fields of biological and fisheries oceanography. Input from experts on future climate variability and the needs of ecosystem modelers will be sought through collaboration with ESSAS WG 1 and 3, respectively.

3. The development of the proposed products includes conducting workshops held at the annual ESSAS meetings and will require inter-sessional work. The purpose of the workshops is to review information on how changes in various physical attributes of the ocean will affect important ecosystem components. Foci of workshops will include the roles of: seasonal sea ice cover, temperature, stratification and circulation.

Expected Results

Workshop products will be one or more review papers based on comparative studies, to be published in the refereed literature, that summarize the important mechanisms whereby the changes in the physical attribute under discussion affect biological constituents of Sub-Arctic ecosystems and their inter-relationships. Where possible, these papers should provide the information necessary for parameterizing the biophysical coupling parameters in ecosystem models of the sub-arctic seas. Where sufficient data are lacking to accomplish this task, there should be a clear statement concerning the lack of specific data that could guide fieldwork during ESSAS.

Membership

A list of the initial members of ESSAS WG-2:

George Hunt	USA, Acting Chair	Earl Dawe	Canada
Elena Dulepova	Russia	Erica Head	Canada
Franz Mueter	USA	Emma Orlova	Russia
Vladimir Ozhigin	Russia	Vladimir Radchenko	Russia

Marit Reigstad	Norway	Sei-ichi Saitoh	Japan
Egil Sakshaug	Norway	Yasunori Sakurai	Japan
Paul Wassermann	Norway	Kai Wieland	Denmark

Appendix 5: Terms of Reference ESSAS WG-3

Terms of Reference

ESSAS Working Group 3: Modeling Ecosystem Response (WGMER)

28 February 2007

Introduction

A major goal of ESSAS is to predict the potential impacts of climate variability on the sustainable use of the sub-arctic seas. ESSAS has elected to employ a comparative approach, investigating in each of the sub-arctic seas which energy pathways appear particularly vulnerable to decadal and longer-term climate change. Ecosystem-level response to climate can vary spatially, geographically, and ontogentically. It can manifest itself locally (i.e., be non-linear with threshold responses), involve complex species-to-species interactions (i.e. ecosystem reorganization in response to climate change, and/or demonstrate different within-species responses between different regional geographic locations within the same ocean basin, all originating from similar climate fluctuations.

Reducing uncertainty about the future states of ESSAS ecosystems depends on knowledge of the response of the ecosystem to changes in climate and a quantitative ability to project future climate states. The first ESSAS goal of prediction requires a fundamental understanding of climate-biological interactions. With understanding comes the ability to model the complex linkages between climate variables and species distributions, which are the primary focus of the other two ESSAS Working Groups (ESSAS Working Group 1: Regional Climate Prediction and ESSAS Working Group 2: Biophysical Coupling Mechanisms).

The goal of the **Working Group on Modeling Ecosystem Response (WGMER)** is to develop conceptual, mechanistic/process, statistical/empirical, and simulation models to facilitate comparison of ESSAS ecosystems and to forecast the impacts of climate change on ecosystem structure and function in multiple ESSAS ecosystems.

Much data has already been collected in ESSAS ecosystems. Thus a major task of WGMER will be to inventory these data and evaluate the suitability of using these data in comparative analysis, modeling and forecasting climate impacts.

Tasks

1. Identify modeling methodologies that will facilitate comparison of the biological, physical, and trophodynamic aspects of the ESSAS ecosystems across regions. Identify and suggest suitable conceptual, mechanistic/process, statistical/empirical, and simulation models to examine for potential application.

2. Assemble existing biophysical datasets and time series from ESSAS ecosystems to facilitate joint comparative studies.

3. Apply the identified candidate models and modeling techniques to ESSAS ecosystems and ecosystem data sets to describe and validate the models.

4. Evaluate ESSAS modeling proposals and offer recommendations to the SSC.

Implementation

1. The Working Group on Modeling Ecosystem response shall exist for a period of three years, ending six months after the 2009 annual meeting of ESSAS.

2. Six to eight members will be chosen from the fields of quantitative ecology and fisheries oceanography. Input from experts on future climate variability and ecosystem process will be sought through collaboration with ESSAS WG 1 and 2, respectively.

3. The development of the proposed products will include conducting workshops held at the annual ESSAS meetings and also inter-sessional workshops as required. The purpose of the workshops will be to review candidate modeling methodology, to facilitate ecosystem comparisons, and the identification of suitable data sets. Inter-sessional work will involve pre-workshop preparation, data analysis, model coding, model application post-workshop report preparation, and the preparation of peer-reviewed manuscripts.

Expected Results

Workshop products will be one or more review papers, to be published in the refereed literature, that summarize the important ecosystem features that facilitate comparison.

Other products will include short position reports on the models evaluated, strategies for implementing the models, recommendations on future data collection and on synthesis of existing data, and methodological recommendations for ensuring appropriate among and between ecosystem comparisons. Joint efforts on these and other specific topics will be done in collaboration with the WG 1 and WG 2.

Membership

The initial members of WG 3 are as follows:

Bernard A. Megrey	USA, Co-Chair	Shin-ichi Ito	Japan, Co-Chair
Kenneth Rose	USA, Co-Chair	Paul Budgell	Norway
Lorenzo Ciannelli	USA	Masahiko Fujii	Japan
Gennady Kantakov	Russia	Franz Mueter	USA

Appendix 6: Terms of Reference for the Sea Ice Workshop

The role of seasonal sea ice cover in marine ecosystems

Hakodate, Japan

4-6 June 2007

Co-conveners: Professor Egil Sakshaug (Norwegian University of Science and Technology, Trondheim)
Professor Sei-ichi Saitoh (Faculty of Fisheries, Hokkaido University)
Dr. John Bengtson (National Marine Mammal Laboratory, Seattle)

Local Host: Professor Yasunori Sakurai, Hokkaido University

Terms of Reference:

The global sea-ice cover forms a highly diverse habitat. The ice and the adjacent waters are likely to differ in terms of both physical and nutrient properties, not only from sea to sea (Barents Sea, Bering Sea, Canadian Archipelago, Sea of Okhotsk, Southern Ocean) but also from month to month and as a function of latitude. Moreover, the ice edge and the adjacent waters are likely to differ whether the ice is withdrawing or advancing, and on wind speed and direction

The Workshop will focus on the mechanisms whereby seasonal sea ice cover affects the amount, timing and fate of primary production and other biota in the ice and the adjacent waters. The workshop will examine how the thickness, timing of retreat, and temporal and spatial extent of the ice cover influences ecosystem processes at a variety of latitudes from the low latitudes found in the Sea of Okhotsk to the high latitudes characteristic of the Barents Sea.. The topics will address questions that will be the focus of new regional programs in both the Atlantic and Pacific regions of interest to ESSAS

Because the focus is on sub-arctic marine ecosystems; it is expected that most of the ice present will be first year ice (less than one-year ice). It is, for the reason of comparison, therefore of value to encourage participation by scientists who have worked in the marginal ice zone in the Southern Ocean.

Products of the Workshop should include one or more review papers to be published in the refereed scientific literature and possibly a “White Paper” to be published in the GLOBEC Report series. The papers and report should be comparative in approach and will take advantage of the opportunity to use information from the different ESSAS regions to assess the role of latitude and timing of ice retreat on the impact of sea ice on ecosystem function.

Participation: About 35 scientists
Invited (outside) speakers: At least 2 experts of international renown
Length: About 1.5 days

APPENDIX 7: Terms of Reference for the Climate Workshop

Evaluation of Future ESSAS Climate Scenarios

Hakodate, Japan

6 June 2007

Convener: Dr. James Overland (NOAA Pacific Marine Environmental Laboratory)

Local Host: Professor Yasunori Sakurai, Hokkaido University

Reducing uncertainty about the future states of ESSAS ecosystems for the coming decades depends on two factors, knowledge of the response of the ecosystem to changes in climate and the quantitative ability to project future climate. The first task represents understanding and modeling the complex linkages between climate and species distributions, energy pathways, and economic impacts, and is a primary focus of other ESSAS Working Groups. The ecosystem response can be non-linear with thresholds, have complex interactions between species, and different species impacts from similar climate fluctuations. Projecting the future ecosystem response also requires information on the magnitude of climate change and the frequency distribution of natural decadal variability, such as the well known ecosystem reorganization of the Bering Sea in the mid-1970s.

ESSAS climate scenarios can be based on making full use of recently available results from 20 state of the art coupled atmosphere-ocean climate models which are part of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). A preliminary investigation has shown that a subset of these models represent the physical forcing in several ecosystems reasonably well based on comparison with *in situ* data for the late 20th century. This provides some confidence for developing ocean climate scenarios and assessing attendant uncertainty.

The Terms of reference for the Workshop are:

(i) Evaluate and rank forecasts of critical physical variables for each of the ESSAS marine ecosystems derived from the IPCC AR4 data sets.

(ii) By the end of the Workshop have a set of climate predictions for the major ESSAS ecosystems which have enough credibility to be provided to the other ESSAS Working Groups for use in developing predictions of the impacts of climate change on the sub-arctic seas.

(iii) Begin production of one or more review papers to be published in the refereed literature. The papers should provide an overview of the IPCC predictions by ESSAS region, and evaluate which models are most appropriately used for predicting critical physical variables in each of the ESSAS marine ecosystems.

To accomplish these tasks, several climate scientists will be invited to provide their expertise for this process, including Vladimir Kattsov from Russia who was an author both on the Arctic Climate Impact Assessment (ACIA) and the IPCC AR4. To be useful to other ESSAS working groups, and to the scientific community in general, the climate scenarios developed for use in individual ESSAS regions must be perceived as credible. There are several factors the lead to the perceived credibility of future climate scenarios from climate models, including the differences between models, validation exercises for different physical variables, and the spatial scales that are important to ecosystem biology. A final set of region-specific climate scenarios, to be developed in a 2008 workshop, will be based on the full IPCC Report, which will be available in spring 2007. These ESASS regional scenarios will provide a rigorous data comparison for the late 20th century for ESSAS physical variables, and will be vetted by climate experts.

Participation: about 35 scientists
Invited (Outside) Speakers: At least 2 experts of international renown
Length: 1 day

This workshop is sponsored by the ESSAS Working Group on Regional Climate Prediction (WGRCP) and will be held as part of the annual ESSAS meeting that will also include a 2-day workshop on “The role of seasonal sea ice cover in marine ecosystems.”