INTERNATIONAL COUNCIL FOR SCIENCE

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

WORLD METEOROLOGICAL ORGANIZATION

WORLD CLIMATE RESEARCH PROGRAMME

ARCTIC CLIMATE SYSTEM STUDY (ACSYS)

PROCEEDINGS OF A WORKSHOP ON ARCTIC REGIONAL CLIMATE MODELS

(Bracknell, UK, 4-6 November 1996)

sponsored by the

International Arctic Science Committee,
the European Marine and Polar Science Board,
and the
World Climate Research Programme

Edited by H. Cattle

December 1999

WMO/TD No. 981

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The World Climate Applications and Services Programme
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NOTE

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FOREWORD

This Workshop grew out of a previous one-day Workshop on a future Arctic programme called by the European Marine and Polar Science Board (EMaPS) in Copenhagen on 14 June 1996 and which brought together a number of players in Arctic research, including the World Climate Research Programme Arctic Climate System Study (WCRP ACSYS) and the International Arctic Science Committee (IASC). At the 14 June workshop, the need to bring together those involved in regional modelling of Arctic climate and in Arctic climate impacts studies was identified. Hence the idea grew for a 'Workshop on Arctic Regional Climate Models'. The objective of this Workshop was agreed to be as follows:

- to bring together the regional climate modelling community and the potential users of regional climate model outputs in the impacts community.

The Workshop goals being to:

- review the current state of high resolution limited area modelling of the Arctic in terms of the simulation of present day climate and climate change;

- review the role and requirements of ACSYS for high resolution limited area modelling of the Arctic;

- establish the requirements of the IASC Barents Sea Region Impact Study (BASIS) and the Bering Sea Region Impact Study (BESIS) for scenario data;

- establish the extent to which limited area models can be used to meet the data requirements of BASIS and BESIS and a mechanism by which these can be met;

- explore the statistical predictors of regional climate change in the Barents and Bering Sea regions, e.g. regression analysis models and model output statistics.

In its deliberations, the Workshop addressed aspects of the first four of these goals, but had little basis for discussion of the fifth. However, at the time (and the lateness of these Proceedings is regretted) the Workshop was judged to be a success with a particular direct result of the Workshop having been the establishment of a European Science Foundation Scientific network entitled 'Regional Climate Modelling and integrated global change: impact studies in the European Arctic' or CLIMPACT which, under the chairmanship of Professor Manfred Lange, is still ongoing.

Howard Cattle
Workshop Convenor and Chair, WCRP ACSYS Scientific Steering Group

MEETING SUMMARY

The Workshop was attended by some 27 participants from Canada, Denmark, Germany, Finland, France, Japan, Norway, Switzerland, Russia, the USA and the UK. The first 1.5 days were spent in presentations by participants and the remaining time in plenary and Working Group discussions. The final goals of the Workshop were agreed to be to:

- review the current state of high resolution limited area modelling of the Arctic in terms of the simulation of present day climate and climate change;
- review the role and requirements of ACSYS for high resolution limited area modelling of the Arctic;
- establish the requirements of the International Arctic Science Committee (IASC) Barents Sea Impact Study (BASIS) and Bering Sea Impact Study (BESIS) for scenario data;
- establish the extent to which limited area models can be used to meet the data requirements of IASC BASIS and BESIS and a mechanism by which these can be met.

The general feeling of participants was that the Workshop had been a considerable success. More involvement of members of the impacts community would have been advantageous but overall it was felt that the Workshop had made good progress with development of the interaction between modellers and those seeking data for impacts studies.

In plenary (see Appendix D), the modelling data needs of for impact studies were scoped. These guided the discussions of the two Working Groups. Principal conclusions, given in more detail in the Working Group Reports in Appendix D, were as follows:

(i) General approach: Impact studies require information on different spatio-temporal scales, which implies a need for a hierarchical modelling approach. IASC BASIS/BESIS data needs for current and future climate were reviewed.

(ii) Timing issues: There was consensus that the modelling community is not ready to deliver credible climate change scenarios of the detail required by the IASC BASIS and BESIS programmes by the end of summer 1997 (the approximate timescale for BASIS/BESIS initial needs). However, a way forward would be to:

- carry out verification of regional climate models for todays climate over the BASIS/BESIS areas;
- carry out 'time slice' simulations driven by large-scale models for present and future climate (e.g. present day and doubled greenhouse gas concentrations) and assess.

(iii) Model validation and verification: Three methods of regional model validation were discussed - comparisons with site specific data, with analyses and via intercomparison of models. A major need identified was for an Arctic Regional Climate Model Intercomparison similar to the current global Atmospheric Model Intercomparison Project. The meeting agreed to explore ways of carrying this out in the coming months. Strategies for verification of models were reviewed.

(iv) Infrastructure and communication: The above requires a coordinated modelling framework to be set up and in addition much closer collaboration and communication between the impacts and modelling communities. This should occur on a specific project basis as well as more generally. Identified mechanisms were:

- to explore problems jointly via informal contacts;
- to hold a workshop with wider participation from the impact community in about one year to help facilitate the discussions further;
- to explore the possibility of a network approach and in particular to explore the possibility to make a bid for an ESF network in this area of work;
- to explore other joint funding opportunities.

APPENDICES

APPENDIX A

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APPENDIX B

AGENDA

Monday, 4 November

0905	Howard Cattle	Welcome, background to the Workshop, logistic arrangements, introductions
0925	Carol Williams	EMaPS and ESF opportunities
0935	Roger Colony	The WCRP ACSYS Programme
0955	P. Kuhry	The IASC Global Change Programme
1015	***Tea/coffee***	
1045	Manfred Lange	Climate modelling and climate impact research: Two worlds?
1115	Gunter Weller	IASC BESIS/BASIS modelling needs
1145	Howard Cattle	Global climate model simulations of Arctic climate and climate change
1215	***Lunch***	
1345	Manda Lynch	Regional climate system modelling in the Western Arctic: Issues and Applications
1415	Egil Sakshaug	Impact of weather on marine ecosystems of the North
1445	Peter Olsson	Cloud/radiation/cryosphere interactions on timescales of days to weeks
1515	***Tea/coffee***	
1545	Jens Hesselbjerg Christensen	Simulations of the hydrological cycle over Scandinavia using a very high resolution regional climate model
1615	Daniela Jacob	Runs with the MPI REMO model
1645	Discussion	
1715	***Adjourn***	

Tuesday, 5 November

0915	David McGinnis	Data resources for regional model verification
0945	Richard Harding	Surface data for verification of Arctic regional climate models

1015	***Tea/coffee***	
1045	Murray MacKay	Validating the Canadian Regional Climate Model over the Mackenzie Basin: the hydrological cycle
1115	Vladimir Kattsov	AMIP simulations of precipitation and evaporation over the Arctic Ocean and its land watershed basins
11.45	Klaus Dethloff	Influence of physical parametrisations on high resolution regional climate simulations over the Arctic
1215	***Lunch***	
1345	Jeff Tilley	Surface packages for land applications of ARCSyM
1415	Aleksandr Makshtas	The parameterisations of air-sea interaction processes in polar regions
1445	David Holland	Ice-ocean coupling
1515	***Tea/coffee***	
1545	Discussion and identification of issues and Working/Writing Groups discussions	
1715	***Adjourn***	

<u>Wednesday, 6 November</u>

0900	Working/Writing Groups continue
1015-1045	***Tea/coffee***
1045	Working/Writing Groups continue
	Lunch
1330	Working Group Reports
1500	***Close***

PLEASE NOTE: Extended abstracts are not available digitally. Please contact ACSYS (acsys@npolar.no) or WCRP for hardcopies.

APPENDIX C

EXTENDED ABSTRACTS OF PRESENTATIONS

APPENDIX D

REPORTS OF INITIAL PLENARY DISCUSSION AND AD-HOC WORKING GROUPS ESTABLISHED AT THE MEETING

Report on initial plenary discussion

Submitted by H. Cattle (Chair) and P. Kuhry (Rapporteur)

This note records the plenary discussion, which took place prior to the participants splitting into Working Groups. As a general framework for discussion, a number of key questions were raised from the chair, including:

1) Do we need RCMs, or are the GCMs and their statistical downscaling sufficient?

2) What kind of data and temporal and spatial scales are needed for regional impact studies (BASIS/BESIS)

3) What are the specific advantages of RCMs?

4) How should RCMs be validated?

5) What is the model sensitivity to domain size, etc.?

6) What regional climate data are available/needed?

In discussion, the participants raised the following main points:

- the importance of reliable climate scenarios for regional impact studies;

- the need to better establish the reliability of RCMs though modelling of present regional climates and model intercomparison;

- the need to scope the prospects for better regional climate and regional climate change models, keeping in mind that the reliability of model output may be dependent on the variable (e.g. temperature versus precipitation);

- the need for clarification of the kind of climate data needed for impact studies, in particular the need to define the important variables and the time and spatial scales they were required on, together with associated acceptable error bars;

- the iterative character of regional impact studies, in which consultation with stakeholders dictate to a certain extent the kind of impact studies that need to be carried out;

- that often weather data expressing variability and extremes was of greater use than climate mean data for regional impact studies; this could perhaps be better provided by RCMs than GCMs, though the importance of results from GCMs for large-scale policy decisions such as those associated with the greenhouse gas issues was recognised;

- the advantage of RCMs in terms of spatial resolution, in terms of their representation of the effects of orography, though in terms of BASIS/BESIS, mountains are of less importance in the Barents region (up to 2000m), than in the Bering region (up to 6000m);

- the importance of sea ice in the BASIS and BESIS regions, acknowledging that the high spatial and temporal resolution needed for e.g. sea ice concentration and extent in relation to industrial and subsistence fisheries would certainly not be available from GCMs;

- that since there are obvious practical limits for temporal and spatial scales in regional climate models, application (intermediate) models such as SVAT (Soil, Vegetation-Atmosphere) models. Patch dynamics models and hydrological models were recommended to further downscale the impacts of climate and climatic change to sub-regional and landscape levels.

Report of the Working Group on Impact Studies (WG-1)

Working Group 1 membership:

M. Lange, D. McGinnis, R. Harding, A. Lynch,
A. Makshtas, B. Maxwell, M. Mackay, V, Savtchenko, G. Weller,

Submitted by M. Lange (Chair) and D. McGinnis (Rapporteur)

Brief: *Impact studies, what are the needs and how do we meet them? Can regional models help and if so how?*

Working Group 1 focused primarily on Impact Studies (ISs) and how both general circulation models (GCMs) and regional climate models (RCMs) can provide input to impact assessment studies. In general, ISs need finely detailed information as input which are best supplied by RCMs. The group identified the following problem statement:

Impact studies may be greatly aided by the fine detail information provided by RCMs and other downscaling methods; the provision of this information requires a close collaboration between the IS and the RCM scientific communities.

General Approach and Background:

Current climate:

Impact studies utilise information on many different spatial and temporal scales. While some studies may need GCM scale output, other research needs high resolution data not possible with GCMs. Development of hierarchical modelling approaches may be the best methodology to link climate modelling to impact studies. In addition, we suggest that impact studies focus upon climate variability and extreme events.

Data availability and quality often limit current climate and impact studies. There are several data archives where climate-related data can be obtained including the National Snow and Ice Data Center located at the University of Colorado, Boulder, Colorado, USA, the Global Precipitation Climatology Centre of the Deutscher Wetterdienst at Offenbach/Main, Germany and the Global Runoff Data Centre in the Federal Institute of Hydrology at Koblenz, Germany. Data availability for RCM validation is critical in order to provide the best information to impact studies.

Future projections:

Projections of future climate involve many variables and details and we focus here on RCMs. However, future climate scenarios produced by GCMs is an important issue because these will provide the boundary conditions for RCMs. RCMs are more likely to aid impact studies due to the higher resolution and the ability to provide greater detail (e.g., orography). Impact assessments consist of various sub-models addressing, among others, regional hydrology, ecosystems and economic sectors specific to the region. Regional climate modelling efforts should be aware of the

needs of these various models and should provide appropriate model output to the impact study community.

Infrastructure and Communication:

A major result of this workshop is identifying the need for close collaboration and communication between the impact studies and the regional climate modelling communities. We suggest that such collaboration should occur on specific projects and on Arctic-wide issues. To accomplish this, it is desirable to involve regional climate modellers with impact study investigators. Specifically discussed were collaborations between the BASIS and BESIS programmes where communication between GCM, RCM and impacts modellers should be fostered.

Several concepts were discussed that lead to uncertainties in impact studies. While the regional climate modellers suggested that their model output will improve in the near future, they should be encouraged to make their current model runs available to the impacts community along with appropriate error bars on the data. Further, we encourage new experiments to be designed that mitigate some of the problems currently found in linking modelling efforts. Also, intermediate steps should be used while RCM development continues, especially statistical downscaling methods. Statistical downscaling methods allow for sub-GCM grid scale information to be simulated from large-scale information (e.g., specific site temperature and precipitation derived from GCM-scale atmospheric circulation). These methods are being constantly refined and are becoming increasingly successful; thus, continued effort in downscaling is valuable as RCMs develop. Both scientific methods are directed at providing information on a scale appropriate for impact studies. Finally, data rescue is a key issue; any appropriate data not currently known or adequately stored and/or accessible to the research community should be rescued and archived in a national or international data centre.

Scientific Issues:

Working Group 1 discussed common issues related to regional climate modelling and impact studies. These include common variables available from climate models, derived variables, and the question of appropriate spatial and temporal scales. The common variables we would like to see available from regional climate model experiments include: temperature, humidity, winds (speed and direction), cloudiness, solar radiation variables, storm tracks, precipitation (in all forms), soil moisture, sea ice extent, sea ice thickness and characteristics, timing of events in the marginal sea-ice zone, sea surface temperatures, and ocean vertical structure. Variables that can be derived from climate models may include frequency of extreme events, growing/heating/freezing-thawing degree days, fire weather index, runoff, permafrost margin, soil fertility, vegetation maps, ocean waves (fetch, speed and direction), net primary productivity, and ocean chemistry (including contaminants). These variables all have different spatial and temporal scales.

Three main areas of concern are detailed below:

Terrestrial Environments:

1. The hydrologic cycle is the most important consideration. We need detailed information as input to impact studies. Therefore, we need to improve the quality of RCM hydrology and land-surface descriptions.

2. Surface patchiness (vegetation, snow, etc.) is another vital issue where we need to define problems carefully and assess the level of spatial detail necessary. Long RCM integrations may be needed, but the high resolution temporal detail may not be necessary. Alternative methodologies include nested runs, where a RCM is integrated into a GCM, and statistical downscaling.

3. Permafrost is a key Arctic parameter where high resolution spatial detail in the discontinuous permafrost regions is needed. The primary model output variables necessary to model permafrost include surface temperature, soil moisture, surface vegetation cover, and changes in snow cover.

Coastal and Estuary Environments:

1. Ice cover (both fast and floating ice) and ice conditions need to be better modelled for impact studies.

2. Storm surges and coastal erosion are key impact variables to be modelled.

3. Salinity changes in estuaries need to be modelled.

4. We anticipate that many problems related to coastal regions may be best investigated with off-line models rather than fully coupled RCMs.

Marine:

1. While current projects may focus on specific regions (e.g., BASIS/BESIS), it is important to understand the entire Arctic Ocean.

2. Better models for sea ice are vital for shipping, fishery management, off-shore oil and natural gas development and subsistence hunting communities.

3. Better resolution of open water and leads is needed. We must resolve small-scale sea level pressure fields. Statistical representations may be an interim methodology.

4. The structure of the mixed layer is important for biological activity, therefore we need to develop fully coupled ocean-atmosphere-ice RCMs.

5. Variability in surface winds and storm events needs to be known as it affects the sea ice edge position and upwelling regions.

6. Sea-surface temperatures and ocean vertical structure are needed for fishery studies.

7. Specific data needs include the characteristics of tides, bathymetry, ocean circulation and freshwater runoff in the study region.

Report of the Working Group on Regional Models (WG-2)

Working Group 2 membership:

D. Jacob, J. Walsh, J. Christenssen, R. Colony,
K. Dethloff, V. Kattsof, P. Kuhry, Y. Muraji, P. Olsson,

Submitted by D. Jacob (Chair) and J. Walsh (Rapporteur)

Brief: *Regional models - current status, future developments and prospects for meeting needs of impact studies. Data requirements for model development and verification - implications for Arctic programmes.*

The Working Group's discussions were guided by the general objectives of (1) a scientific contribution to the production of credible climate change scenarios for the BASIS and BESIS regions, and (2) an improved understanding of the physical mechanisms underpinning the Arctic Climate System. The time frame of the climate change scenarios, guided by the needs of the Impacts Community, was assumed to be the next 50-60 years in increments of approximately 10 years. Given the general objectives, two foci of discussion emerged. The first was a statement of what can now be provided by the regional modelling community. The second was the issue of validation of regional climate model simulations of the Arctic.

With regard to the question of what can now be provided, it was noted that the longest regional model simulations to date for the Arctic are 1-2 years. The provision of statistics on ranges and extremes may require even longer simulations than the 30-year runs that have been made for regions other than the Arctic. If Arctic runs are extended to the multidecadal timescales, then most of the variables requested by the Impacts Community can, "in principle," be provided. However, an overriding concern is the reliability of the simulated variables. The Group noted that there are, and will likely continue to be, various "categories" of reliability among the variables. Since the different levels of reliability are not well quantified, the Group saw the validation of Arctic regional models as a top priority.

The validation of Arctic regional models is made difficult by the sparseness of data for much of the region. Accordingly, the discussion of validation took place in a three-part framework:

(1) What do we have today for the validation of Arctic regional models?

Point measurements spanning periods as long as several decades are now available for some variables at specific sites. The measurements are from selected synoptic observing stations, ice stations, drifting buoys, and special field programmes. In some cases, the point measurements have been "binned" into grid-cells for which means have been compiled. Available data on ice extent span periods of approximately 50 years for some regions.

The variety of available measurements and the mix of formats creates a need for an inventory of available data for the BASIS/BESIS regions, especially in the context of a 15-20 year climatology. Attention needs to be given to quantifying the number of stations needed for verification, i.e., how robust is

the verification database? Removing some stations from the database and seeing if the errors "converge" as the data are reinstated can test the adequacy of the point data for verification purposes.

(2) What do we expect from satellite data?

Satellite measurements provide additional supplementary data. In the case of some variables (e.g., sea ice extent), the record is more than adequate for a global climatology spanning approximately 20 years. (Ice concentrations are more problematic because of complications by melt processes.) In the case of other variables (e.g., vertical air temperature profiles), algorithm development for the provision of useful products is ongoing. The air temperature and moisture profiles illustrate the general need for value-added work with regard to satellite data before these data can be used directly for model verification. Additionally, there is a general need for a more efficient mechanism for employing the satellite data, i.e., there is a need for community discussion with regard to uniformity of format.

(3) What types of data do we really need?

Climatological fields and measures of variability (ranges, probability distributions, etc.) were identified as primary needs. In addition, the validation of process formulations will require data from special field campaigns (e.g., SHEBA and its cloud-radiative measurements), in which there is a need to ensure that quantities appropriate to atmospheric model verification are indeed produced.

RECOMMENDED STRATEGY

Given the Working Group's consensus that the Arctic regional modelling community is not ready to deliver credible climate change scenarios by the summer of 1997 (the timeline for BASIS/BESIS initial needs), the Group recommends a regional modelling "preparation phase" consisting of (1) dataset preparation, including the inventorying, assessment, enhancement and formatting of data for the purpose of Arctic regional model validation, and (2) a coordinated intercomparison of Arctic regional models. The model intercomparison should both guide and draw upon the data-based work. The recommended effort has parallels with the Atmospheric Model Intercomparison Project, which is now well into its assessment of (uncoupled) global atmospheric models. While the details of the Arctic regional model intercomparison require further community discussion (i.e., a possible workshop), the Group seemed to be in general agreement on several issues:

- the intercomparison should proceed in two phases: first, with atmosphere-only models; second, with fully coupled models;

- the intercomparison should be made for separate domains centred on the BASIS and BESIS study areas;

- use should be made of atmospheric reanalyses (ECMWF, NCEP) for the forcing of the lateral boundaries and, to the extent that can be justified, in the evaluation of the regional model simulations. (The use of reanalyses for lateral boundary

- forcing eliminates the dependence on the choice of the GCM for the lateral forcing);

- the intercomparison should emphasise the variables and parameters that are important for impact assessments.

A logical sequence for the regional model intercomparison is:

a) verification of the regional model simulations of today's climate for the BASIS/BESIS regions,

b) time-slice simulations driven by GCM output at the lateral boundaries,

c) (possibly) transient-CO_2 simulations using historical databases for evaluation.

With regard to coordination, the joint planning of the regional model intercomparison/ evaluation should continue via the EU Network or by other means. Discussion should ensue immediately as to which of the two regions to focus upon first (or whether the two regions should be approached in a parallel manner). Among the issues to be resolved are the precise domains, the length of the simulations, the lower boundary conditions, output delivery, and the variables for intercomparison. Another meeting or workshop to address implementation issues should be held in approximately one year. There is a critical need for the next meeting to include a greater representation of the user community.

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