WORLD CLIMATE RESEARCH PROGRAMME
ARCTIC CLIMATE SYSTEM STUDY (ACSYS)

REPORT ON THE
HYDROLOGY MODELS INTERCOMPARISON PLANNING
MEETING
(Koblenz, Germany, 27-29 March 1999)

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EXECUTIVE SUMMARY

The ACSYS/GHP Hydrological Modelling Workshop held in Quebec City, Canada from 25-27 August 1998 recommended that an intercomparison of hydrological models be planned with the objective of identifying the capabilities of models to simulate high latitude water and energy cycles. It was suggested that a small working group be formed jointly by ACSYS and GEWEX to develop a science plan for the intercomparison. The suggested meeting took place in Koblenz, Germany from 27-29 March 1999. Appendix A contains a list of the meeting participants. The meeting examined:

(1) The feasibility and desirability of study areas for the proposed intercomparison, and

(2) The structure of the intercomparison and participating models.

This report summarizes the strategy developed by the participants at the Koblenz 1999 meeting, and constitutes an Experiment Plan for the proposed intercomparison. The project will take place in a phased approach, and will be modeled after the WCRP/GEWEX Project for Intercomparison of Land-surface Parameterizations (PILPS) 2c experiment. Dr. Dennis Lettenmaier at the University of Washington has agreed to coordinate Phase 1, which will utilize data from the Torne River basin in Sweden. Phases 2 and 3, planning for which will depend on the outcome of Phase 1, would tentatively utilize data from GEWEX Continental Scale Experiments in the Mackenzie River basin (MAGS) and the Lena River basin (GAME-Siberia).
1.0 INTRODUCTION

1.1 Background

Climate modeling studies indicate that global warming may be larger at high latitudes than elsewhere primarily due to lowered albedo associated with a reduction in sea ice and seasonal snow cover extent. The strength of the coupling between the ocean, land, and atmosphere in the Arctic is particularly important because of its influence on the net transfer of heat northward, and fresh water southward, which in turn affects global climate and weather. A long-term increase in high latitude temperatures could be accompanied by migration of the northern boundary of the boreal forest, implying changes in the runoff response of the major Arctic rivers, and in turn other elements in the coupled climate system.

Furthermore, recent work by Betts et al. (1996) has shown substantial systematic biases in spring temperature forecasts produced by the European Center for Medium Range Weather Forecasting model in the continental interior of the northern hemisphere due to the model’s improper representation of two important high latitude processes: snow albedo, and soil freezing. Use of unrealistically high albedo has had the effect of biasing the model’s net radiation downward, which in turn incorrectly extends the length of the model’s snow cover season. Errors in the same direction result from improper representation of soil freezing, the effect of which is to elevate Bowen ratios artificially, which in turn biases predictions of boundary layer depth.

All of these considerations motivate the improvement of high latitude land surface representations within coupled land-atmosphere models used for numerical weather and climate prediction. There is a need for off-line testing of land surface models in high latitudes, in a context that allows evaluation of their ability to capture key processes. These include snow accumulation and ablation, soil freeze/thaw and permafrost, and existence of large seasonally frozen lakes and wetlands. Also of importance are the spatial manifestations of these processes (e.g., interseasonal and interannual variations in extent of snow cover, and associated changes in albedo). Experiments like the Project for Intercomparison of Land Surface Parameterization Schemes (PILPS) Phase 2d (http://cic.mq.edu.au/pilps-rice/phase2/phase2d.html) and proposed future PILPS experiments are critical for evaluation of the ability of land surface schemes to represent cold season processes. However, it is especially important that models be evaluated in the spatial context in which they are applied. For this purpose, study designs must go beyond one-dimensional tests to evaluate model performance in the context of moderate to large sized river basins. The design of the experiments is expected to follow roughly the PILPS 2c (Wood et al. 1998) design, modified as necessary to account for specific physical and observational characteristics of the Arctic.

1.2 Science Questions

Among the science questions that could be addressed by an intercomparison of land surface schemes in Arctic regions are:
1. What is the ability of the inter-comparison models to estimate runoff in gauged and ungauged catchments? An important problem for the ACSYS is the estimation of riverine freshwater inputs to the Arctic from ungauged areas, which make up about 30% of the land area draining to the Arctic. Application of hydrologic models offers one option for estimation of the discharge of these areas, but the errors inherent in such an approach are not currently well known.

2. How would Arctic river runoff respond to spatial and temporal variations in climate forcings? These changes could, for instance, be related to changes in precipitation, temperature, net radiation, or combinations of the three. It is important that the proper physical mechanisms be represented in land surface models, as they exert important controls on runoff formation.

3. What are the effects of permafrost on the surface water and energy cycles, and their related impacts on carbon sequestration at high latitudes? One important result of the Boreal Ecosystem-Atmosphere Study (BOREAS; Sellers et al. 1995) was identification of mechanisms by which global warming could affect high latitude sequestration of carbon. The most important among these appeared to be increase of growing season length. However, at latitudes where permafrost is presently widespread, changes in the length of seasonal thawing, and increased active layer depth, could also be important mechanisms affecting fluxes of soil carbon to the atmosphere. Therefore, it is especially important that soil freeze-thaw processes be properly represented in land surface models.

4. What is the feasibility of using the intercomparison models for assessment of hydrologic impacts in Arctic drainage basins via long-term climate simulations. Snow and other cold season and cold region processes are especially sensitive to global warming. It is not presently known, however, how well current generation land surface models capture these processes, which calls into question the ability of models to predict the both the direct and indirect effects of global warming. These include, direct effects such as changes in the timing of peak runoff, and the onset of the growing season, and indirect effects such as an increase in net radiation associated with reduced albedo.

1.3 ACSYS SSG-VII Charge and the Planning Meeting:

At the ACSYS SSG-VII meeting (Tokyo, Japan, 2-6 November 1998) there was a discussion of the recommendation from the August 1998 Quebec City Workshop for a hydrology model intercomparison project for Arctic regions. The text of the recommendations (taken from the draft report on the Quebec City workshop) is attached as Appendix B. The SSG decided to take action to initiate such an intercomparison, with the following provisions:

1. The objective of the intercomparison project would be to evaluate performance of land surface parameterizations capable of simulating water and energy cycles over ACSYS hydrological region, and suitable for ultimate inclusion in coupled land-atmosphere models;
2. The intercomparison would/should be patterned after PILPS (Project for Intercomparison of Land-surface Parameterization Schemes – a GEWEX project) activities, and perhaps cosponsored by PILPS (WCRP Informal Report No. 10/1999);

3. Interaction with the GEWEX/GHP Coordinated Enhanced Observing Period (CEOPS), and planned CEOPS model intercomparison activities, is essential;

4. Formation of a small planning group is needed, possibly to meet mid or late winter 1998;

5. The format would include application of models to a small, well-instrumented catchment (possibly the Torne River basin, in northern Sweden), then progressively larger, and less well instrumented watersheds (e.g., possibly the Mackenzie and Lena, (in that order)); and

6. Involvement of GPCC/ARDB is highly advisable.

Directive 4) was addressed by the Hydrology Models Intercomparison planning meeting held at the offices of the Global Runoff Data Center (Koblenz, Germany) from 27-29 March 1999. The meeting drafted the experiment plan reported here.

In comparing the recommendation from the Quebec City meeting with the SSG-VII directives summarized above, one significant difference is that the SSG was in favor of an activity that would focus on land surface schemes suitable for inclusion in coupled land-atmosphere models (item 1 above). The emphasis would be on the models’ ability to simulate both the water and energy cycles (and not just the water cycle, to which many hydrology models are limited).

1.4 PILPS Strategy Forum

At the PILPS Post-2000 Strategy Forum (Honolulu, Hawaii, 23-26 February 1999) a conceptual proposal was brought forward for a high latitude model intercomparison project along the lines of that suggested at the Quebec City meeting. The forum endorsed the proposal, which was assigned PILPS Project number 2e (see http://cic.mq.edu.au/pilps-rice for workshop report).

2.0 BACKGROUND

2.1 Relationship to WCRP programs and sponsorship:

ACSYS and the GEWEX Hydrometeorological Panel (GHP) would carry out the proposed model intercomparison under the direction of PILPS, with co-sponsorship. PILPS is a GEWEX activity, which has undertaken evaluation of land surface schemes suitable for inclusion in coupled models. It has sponsored both off-line and on-line intercomparisons. Descriptions of PILPS are included in (Henderson-Sellers et al. 1993; 1995). Most previous PILPS projects have focused on temperate latitude processes, with the exception of PILPS 2d, which evaluated performance of snow accumulation and ablation models using data from the Valdai station, Russia. Brief summaries of PILPS, ACSYS, and GEWEX are included below.
2.1.1 PILPS

PILPS is a World Climate Research Programme (WCRP) project operating under the auspices of GEWEX. It has been designed to be an on-going project. Since its establishment in 1992, PILPS has been responsible for a series of complementary experiments, with focuses on identifying land surface parameterization strengths and inadequacies. About 30 land surface process modelling groups have participated in PILPS to date.

PILPS is intended to improve the parameterization of land surfaces, especially hydrological, energy, momentum and carbon exchanges, in coupled land-atmosphere models. The PILPS science plan incorporates enhanced documentation, comparison, and validation of continental surface parameterization schemes by community participation. PILPS model intercomparisons to date demonstrate that there are significant differences in the formulation of individual processes in the available land surface schemes. These differences are comparable to other recognized differences among current global climate models such as cloud and convection parameterizations. It is also clear that too few sensitivity studies have been undertaken with the result that there is not yet enough information to indicate which simplifications or omissions are important for the near-surface continental climate, hydrology and biogeochemistry. PILPS emphasizes sensitivity studies with and intercomparisons of existing land surface codes and the development of areally extensive data sets for their testing and validation.

2.1.2 ACSYS

The scientific goal of ACSYS, a regional climate research component of the WCRP, is to ascertain the role of the Arctic in global climate. To attain this goal, ACSYS seeks to develop and coordinate national and international Arctic science activities and to assemble complete and accurate enough data to determine the variability of the Arctic hydrological cycle as well as regional differences; to assess the role and contributions of the various atmospheric, oceanic and land surface processes that influence the fresh water budget, and to provide a basis for further diagnostic studies of long-term climate change.

The specific objectives of the ACSYS hydrological programme are to:

1. Determine the elements of the fresh water cycle in the Arctic region and their time and space variability;

2. Quantify the role of atmospheric, hydrological and land surface processes in the exchanges between different elements of the hydrological cycle;

3. Develop mathematical models of the hydrological cycle under specific Arctic climate conditions, suitable for inclusion in coupled climate models; and

4. Provide an observational basis for the assessment of possible long-term trends of the components of the fresh water balance in the Arctic region under changing climate.

2.1.3 GEWEX

The Global Energy and Water Cycle Experiment (GEWEX) is a major sub-program of WCRP. GEWEX has established the GEWEX Hydrometeorology Panel (GHP) to help
develop a quantitative understanding of the global hydrologic cycle and energy flux based on observations and comprehensive climate models. An essential step toward this objective is comparing model formulations of hydrological and energy processes with corresponding observed properties. This task will be accomplished within the framework of five GEWEX Continental Scale Experiments (CSEs): GEWEX Continental-scale International Project (GCIP), BalTic sea Experiment (BALTEX), Mackenzie GEWEX Study (MAGS), the Large-scale Biosphere-atmosphere experiment in Amazon (LBA) and the GEWEX Asian Monsoon Experiment (GAME). These 5 CSEs are being conducted around the world. More details about GHP and the CSEs can be found at http://www1.tor.ec.gc.ca/GEWEX/GHP/ghp.html.

2.2 Experimental Synopsis

The proposed experiment will be carried out in three stages, with each stage focused on a different region. The first stage study site will be the Torne River in Sweden, followed by the Mackenzie River in Canada and the Lena River in Russia. The intercomparison experiments at each stage will be conducted in a manner similar to PILPS 2c. In particular, the evaluation will focus on simulations conducted over multiple grid cells on decadal time scales, with some point process evaluation at smaller intensive study areas. Different data sets will be available for model forcing, calibration and evaluation in each stage and as such, the specific focus of each stage will be adapted in accordance with the basin hydrology and available data sets. Brief descriptions of the three catchments are included in Section 3.1, while a schedule for stage 1 is given in Section 3.2.

2.3 Organization

The proposed organization of the model experiment will include designation of a lead PI for each stage of the experiment. The PI will organize the experimental procedure, as well as the comparison and ultimate dissemination of model results through an intercomparison workshop and journal publications. In addition, the lead PI will investigate the possibility of financial support for each stage intercomparison workshop, with the understanding that funds will be limited and all participants will be expected to provide their own support for time devoted to the project. The lead PI for stage 1 will be Dennis P. Lettenmaier from the University of Washington, USA.

Representatives from each of the data providing organizations are encouraged to participate throughout the process.

3.0 EXPERIMENTAL DESIGN

3.1 Proposed site locations

This section provides a general overview of the physiography and hydroclimatology of each of the proposed basins. A more detailed description of data possibilities for each site is provided in Appendix C.
3.1.1 Torne Basin

The Torne Basin (aka Torneälven) is situated along the Swedish-Finnish border and flows southeast into the Bothnian Bay of the Baltic Sea as shown in Figure 1. The Torne basin is part of the GEWEX BALTEX study area. The basin area is 40,200 km$^2$, of which 57% lies in Sweden, 42% in Finland and 1% in Norway. The western part of the basin consists of mountainous terrain with the river channel itself rising to an elevation of almost 700 m. Predominate vegetation is boreal forest with significant bog areas. The highest mountain terrain rises above tree line. Less than 1% of the basin is used for agriculture. The basin does not contain permafrost, although seasonal freezing occurs at the higher elevations. River flows are for all practical purposes unregulated (i.e. there are no significant dams). A natural bifurcation of the main river channel in the center of the basin results in diversion of some of the runoff to the Kalix Basin in the south.

Mean annual flow for the Torne River is approximately 390 m$^3$/s. Mean annual temperature varies between 2$^\circ$ to -3$^\circ$ C, and is less than 0$^\circ$ C for most of the basin. Annual precipitation is between 400 and 800 mm with maximum precipitation occurring in the summer months.

3.1.2 Mackenzie Basin

The Mackenzie basin is one of the world’s largest Arctic drainage basins with an average annual runoff (1950-1996) of 9100 m$^3$/s. This basin is the focus of the Canadian GEWEX initiative, the Mackenzie GEWEX study (MAGS). This large drainage basin stretches over 15$^\circ$ of latitude and covers about 1.8 million km$^2$ or about 20% of the total Canadian land mass (Figure 2). The basin includes parts of the Yukon and Northwest Territories, British Columbia, Alberta and Saskatchewan and flows northward into the Beaufort Sea. The Williston Reservoir regulates river flows of one major tributary, the Peace River. In addition, there are storage effects of three major natural lakes, the Great Slave Lake, Great Bear Lake and Lake Athabasca.

The hydrological regime of the basins is influenced by 4 major physiographic regions (Western Cordillera, Interior Plain, Precambrian Shield and Arctic Coastal Plain), by permafrost which underlies a significant portion of the basin, and by vegetation which varies from boreal forest in the south to alpine in its mountains and arctic tundra in the north. The basin consists of mountainous terrain in the headwaters along the Rocky Mountains in the south and west. The predominate vegetation in the southern portion of the basin is boreal forest, characterized by extensive bogs and wetlands. North of about 68 degrees latitude, the vegetation changes to moss-lichen tundra.
Seasonal monthly average temperatures are about -25 to -30°C in winter, and 15°C in summer. On particular days, temperatures can be as low as -50°C in winter and well above 30°C in summer. The critical snowmelt period takes place in April-June, and average temperatures again fall below the freezing point during September-October. The mean annual precipitation over the basin is estimated to be about 410 mm but there is
considerable uncertainty due to inadequate sampling and errors with gauge measurement in winter conditions (Goodison 1978). Maximum precipitation rates occur in the summer in association with convective systems, when almost 50% of the total annual precipitation occurs. However, snow dominates 6-8 months of the year, with the largest amounts in the mountains on the west side of the basin.

Figure 2: Routing network and station locations for the Mackenzie River Basin

3.1.3 Lena River Basin

With a drainage area of about 2.4 million km$^2$ the Lena River in Eastern Siberia is one of the largest permafrost watersheds in the world. It covers several climatic and land cover zones (Figure 3). The tundra with scarce vegetation and the taiga with coniferous forest characterize the landscape of the Lena basin. A large area of the basin lies at low elevation (46% under 400 m). The mountain taiga region consists of primarily mixed forest in the southern headwaters in the Stanovoi Mountains and conifer forest in the
other parts of the basin. In the east, the basin includes the "plain taiga" region (primarily conifer forest) before transitioning into the scarcely vegetated tundra near the mouth in the Laptev Sea. Annual precipitation varies between 200 and 700 mm, with the highest precipitation areas lying to the Southeast.

Figure 3: Routing network and station locations for the Lena River Basin
3.2 Format and Schedule

Participants will be required to perform the experiments at their home institutions and submit the results to the study area coordinator. For each phase, preliminary results comparing the schemes will be presented at a project workshop. If necessary, model re-runs or correction of data discrepancies will be discussed at the workshop, as well as a plan for the subsequent dissemination of final results.

The design of phase 1 of PILPS 2e will begin in fall 1999 with the solicitation of participating schemes via the ACSYS and GEWEX newsletters and the PILPS community. A detailed experimental design and proposed model parameters will be circulated among the participants in the winter of 2000. Approximately two months will be allowed for discussion and agreement on the parameters and design. The forcing data, final model parameters and validation data will be made available to the participants in spring or summer 2000. Model results will be returned in approximately three months, to be summarized in a workshop in autumn 2000 or winter 2001.

3.3 Data Handling

Due to the spatial nature of the proposed analysis, large data volumes are anticipated. For example, for the stage 1 application to the Torne River basin at ¼ degree resolution, the forcing files in binary format will consume approximately 400 Mb. The output data volume to be returned to the lead institution will be on the order of 800 Mb per participant. The data volumes may double for the phase 2 and 3 applications. Due to the large volume, network transfer (e.g., FTP) is not the first choice for dissemination of the entire data set, although discrete sections of the data will be made available via FTP for institutions in which this is the best option. The remainder of the data will be distributed via writeable CD, 8 mm or DLT tape.

4.0 MODEL EVALUATION

Evaluation of model performance will be performed in close accordance with the procedures established under PILPS 2c. Streamflow is a critical factor for comparison, and will constitute a minimum requirement. Evapotranspiration is of equal importance, but is more difficult to evaluate in comparison with observations. Evapotranspiration fields can, however, be estimated using atmospheric budget computations. For this purpose, it appears that the ECMWF reanalysis (ERA) will be most appropriate.

Additional parameters pertinent to high latitude processes will be evaluated where possible. These include the following:

- snow cover extent;
- snow water equivalent;
- soil freeze/thaw; and
- lake ice cover.
Snow cover extent for the northern hemisphere on a 25 km grid derived from the manual interpretation of AVHRR, GOES and other visible-band satellite data will be obtained from NSIDC for the period 1971-1995. Availability of the other parameters will vary considerably from basin to basin. In addition, snow depths are also available from synoptic stations, but these data are of limited value given that snow density is usually not available.

A preliminary list of output variables that will be collected and evaluated from each participating scheme is included in Appendix D. Models that do not include all of these variables will be permitted to participate. The specific evaluation criteria will be formulated separately for each phase.

REFERENCES


APPENDICES
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Hydrological models are the most plausible means of representing runoff to the Arctic Ocean from ungauged basins (IAPO Information Report No. 1). Hydrological models for cold regions are in an advanced state of development within each GEWEX Continental Scale Experiment (CSE) concerned with the ACSYS study region. An intercomparison of hydrological models for cold regions was envisioned as an important part of future cooperation between ACSYS and GEWEX (WCRP Informal Report No. 4/1998).

The Quebec City workshop recommends that an intercomparison of hydrological models is necessary to identify the capabilities of models to simulate high latitude water and energy cycles. An intercomparison would aid the goals of both ACSYS and GEWEX, since it would define the range of variability of model estimates, provide valuable feedback for model improvement, help assess the transferability of models, and ultimately improve estimates of discharge from ungauged basins.

The workshop recommends the following strategy to initiate the intercomparison process that will culminate in a workshop to be held in 2000. A small working group should be formed jointly by ACSYS and GEWEX to develop a science plan for the intercomparison. The working group should be formed shortly after the ACSYS Scientific Steering Group's seventh meeting in November 1998, and should consist of one member each from BALTEX, GAME and MAGS. The working group should decide upon a principle investigator, and a lead institution (or institutions) to coordinate and take responsibility for the intercomparison. The P.I. will be expected to apply for funds to help finance the intercomparison.

The working group should propose the science plan, and recommend a P.I. and lead institute(s) at the GEWEX Scientific Steering Group meeting in February 1999. The Science Plan will include:

i) a procedure describing how models will be compared,
ii) a time frame to be followed,
iii) the test basin(s),
iv) modeling parameters,
v) data sets,
vi) time and space scales to be used in the intercomparison,
vii) the model output to be compared, and
viii) the models to take part in the intercomparison.

The Lena, Mackenzie and Torne, as well as some of their subbasins, were considered as possible test basins. It is recommended that the working group invite all cold-regions, regional-scale models within GEWEX to participate in the intercomparisons, and then use criteria to decide which of them will take part in the intercomparison, such as the requirement that they contain a land surface scheme (for the calculation of the vertical
water balance) and be coupled with an atmospheric model. Modeling runs will be conducted prior to the 2000 workshop, and the workshop will serve as a forum for the intercomparison. It is recommended that the working group draw upon the experience of other intercomparisons of hydrological models, as well as intercomparisons in related disciplines (e.g. atmospheric models, sea ice flow models, etc.).

REFERENCES

Hydrometeorological Data

The Torne Basin contains 14 precipitation stations and 10 synoptic stations that have complete data coverage for the period 1968 to the present. River gaging stations are strategically located at 18 sites. A factor that plagues flow measurements in this region is the occurrence of ice jams on rivers during spring thaw, which create temporary dams that influence gaging records. This is a problem that likely affects gaging in many cold region areas. SMHI has developed routines to adjust for this type of occurrence, but there is nevertheless added uncertainty to the records during these periods.

Gridded Data

Meteorological synoptic station data have also been optimally interpolated to a (1x1°) grid covering the entire Baltic Sea Drainage Basin. Data from all available synoptic weather stations were used. The parameters were interpolated in space using a two-dimensional univariate optimum interpolation scheme. The degree of spatial filtering for optimum interpolation is determined by an isotropic autocorrelation function, and this function was estimated from the database. A quality control algorithm to reject erroneous observations was built into the objective analysis scheme. The 3-hour data set includes pressure, temperature, cloud cover, u and v geostrophic wind, and relative humidity. Global radiation is available daily and precipitation is available two times daily. The current available time period is 1979 through 1998.

Snow water equivalent measurements in the basin are scarce, but there may be snow course data available from the Finnish side of the Torne. It is also unlikely that there exist soil temperature measurements. These data questions remain to be investigated.

Research Basins

There are no established intensive research basins within the Torne basin.

Land-cover

Gridded soil and vegetation data have not previously been developed for BALTEX. A general map of soil type for the basin is available (mostly morrain and alluvial material). Soils are approximately 3 meters thick. A GIS-based land use map may be available from Stockholm University.

Digital Elevation Model and Streamflow Routing

Specific DEMs have not previously been adopted for BALTEX.
2.0 MAGS DATA AVAILABILITY

The MAGS observations that would be useful for the proposed model intercomparison can be derived from existing numerical model outputs, as well as atmospheric, hydrometric and upper air observations. The collection of additional measurements during the 1998/99 enhanced observation period may provide critical model validation data sets.

Many of the observations that would be useful are currently being processed and reviewed by the MAGS research community. For instance, historical precipitation records have been reviewed, corrected, and used with the hydrometric data base to generate the mean monthly distribution of precipitation and runoff over the basin (Mekis and Hogg 1998).

There are a number of research basins, synoptic station, hydrometric observation sites and enhanced observation sites within and outside the basin. There are also a number of gridded data sets also developed for the region.

Hydrometeorological Data

Synoptic, meteorologic and hydrometric data have been collected within the MAGS region, however, the number of observing sites is relatively small (Figure 2). For the study of basin-scale atmospheric water budget studies, the number of sounding sites over the Mackenzie Basin is small, and the number and location of surface observing sites for parameters such as precipitation and radiation is also far from satisfactory, although there are two operational radars covering portions of the basin. In terms of hydrologic measurements, the current networks are reasonably capable of measuring the river runoff. However, there are possibly large errors associated with measurements at some crucial periods of ice break-up.

Research Basins

In support of MAGS, special research basins have been created by the National Water Research Institute in five areas. These sites provide ongoing information on a variety of atmospheric, surface, hydrological and sub-surface parameters within regions that typify conditions found across the Mackenzie Basin. The research basins are an attempt to understand the runoff regime at a micro or meso scale for the full range of physiographic zones within the larger basin. These research basins could potential provide validation points of near-surface fluxes for the inter-comparison.

Five research basins have been established within or near the Mackenzie Basin, in the following locations:

- Beartrap Creek - Boreal forest, southern plain
- Inuvik – Taiga forest, tundra, permafrost
- Wolf Creek – Brush, tundra, discontinuous permafrost
- Fort Simpson – Wetland dominated, discontinuous permafrost
• Yellowknife River Basin – Canadian shield, discontinuous permafrost

Several new meteorological stations, or improvements of existing ones, are being installed across the basin. Each of the stations is equipped to measure air temperature, humidity, air pressure, wind speed and direction, precipitation, snow depth, and soil temperature. All the sites report in real-time, operate as operational sites and in some cases contain instrumentation for observing soil wetness and/or extra solar radiation information. These stations are located in data-sparse areas of the basin that are representative of the different land cover regimes of the Mackenzie River Basin. The stations are in the vicinity of Fort Simpson near the center of the basin (wetland discontinuous permafrost regime), Fort Liard (mountainous regime); the Great Divide between the Yukon and the North West Territories (barren regime), Yellowknife, between Great Slave and Great Bear Lakes (tundra regime), Fort Good Hope in the northern portion of the basin (forested wetland regime), and Inuvik at the northern edge of the basin (tundra regime).

Land-cover

Consistent land-cover information has been assembled by MAGS for the entire Mackenzie basin, based on a USGS (EROS Data Center) AVHRR-based 1 km product. For local (e.g., research basins) studies, higher resolution products derived from LANDSAT TM are available.

Digital Elevation Model and Streamflow Routing

The DEM adopted for the MAGS project is the current version of GTOPO30 (30-arcsecond global product). It has been used to generate the streamflow routing files used in the MAGS hydrological modeling effort. One option for the proposed model intercomparison project would be to use the MAGS WATROUTE model as the routing mechanism for all participating land-surface schemes, as was done in the PILPS-2c experiment.

Reference


3.0 LENA/GAME DATA AVAILABILITY

Hydrometeorological Data

There currently exist 40 meteorological stations in and around the Lena Basin. As part of GAME, streamflow data are available at six main locations. The precipitation data have not been corrected for gauge catch errors. Precipitation correction is planned for the next 1 to 2 years, and so may be accomplished before initiation of this phase of the model intercomparison project.

Gridded Data

The meteorological synoptic station data has been optimally interpolated to a (1x1°) grid covering the entire Lena Basin. Available variables include precipitation, air temperature, wind speed and cloud cover.
**Research Basins**

As part of the GAME-Siberia GEWEX study, three intensive study areas have been established: a tundra site, near Tiksi, a plain taiga site near Yakutsk and a mountain taiga site in the Stanovoi mountains. Two years of tower observations and soil moisture are available at these sites.

**Land-cover**

A 1° resolution vegetation data set including roughness length is recently available. Gridded soils data have not yet been compiled. However, some Russian soil maps are available.

**Digital Elevation Model and Streamflow Routing**

Specific DEMs have not previously been adopted for GAME.
APPENDIX D

PROPOSED PILPS 2E OUTPUT VARIABLES

1. Pr    Total Precipitation  (mm/time step)
2. Evap  Total evaporation    (mm/time step)
3. Rsurf Surface runoff      (mm/time step)
4. Rb    Subsurface runoff and/or baseflow  (mm/time step)
5. McanopyTotal interception storage (end of time step) (mm)
6. Mroot Root-zone soil moisture (end of time step)  (mm)
7. Msoil1 Soil moisture in top 0.1 m (end of time step) (mm)
8. Mtotal Total soil moisture (end of time step)  (mm)
9. Trad  Effective surface radiative temperature (avg over time step) (K)
10. SolAbs Absorbed solar radiation (avg. over time step)  (Wm$^{-2}$)
11. Rnet  Net radiation (avg. over time step)  (Wm$^{-2}$)
12. LH    Surface latent heat flux (avg. over time step) (Wm$^{-2}$)
13. SH    Surface sensible heat flux (avg. over time step) (Wm$^{-2}$)
14. G     Surface ground heat flux (avg. over time step)  (Wm$^{-2}$)
15. Albedo Surface albedo (avg. over time step)  (Wm$^{-2}$)
16. Swq   Snow water equivalent (end of time step)  (mm)
17. Sfrac Snow fractional coverage (end of time step)  (% of cell)
18. Dthaw Depth to frozen layer (end of time step)  (mm)