Proposed THORPEX/HEPEX Hydrologic Applications Project (THEPS)

Input for discussion at the 1st TIGGE WS, ECMWF, 1-3 March 2005

Goal

The basic goal of the THEPS project is to meet the HEPEX meteorological forecast data requirements from the TIGGE datasets, to provide feedback to the THORPEX community on the hydrologically useful information content of the TIGGE data sets and to help the international hydrological community to understand how to meteorological forecast data.

HEPEX Background

- **Goal**
  HEPEX aims to bring the international hydrological and meteorological communities together to demonstrate how to produce reliable hydrological ensemble forecasts that can be used with confidence by the emergency management and water resources sectors to make decisions that have important consequences for the economy, for public health and safety.

- **HEPEX Elements**
  The main elements of a hydrological ensemble prediction system are illustrated below in Figure 1. There are many science issues for each of these that need to be addressed to meet the HEPEX goal.

- **Science Issues**
  The main HEPEX science issues that are important for this proposed project involve the hydrologic application of meteorological forecasts. These include:
  - What are the requirements of ensemble weather forecasts to support hydrologic prediction?
  - Do the existing meteorological forecasts account for important meteorological and climate uncertainties?
  - What is the role of operational forecasters?
  - What are the scientific questions and issues that need to be addressed to meet requirements?

- **HEPEX Implementation**
  HEPEX is organizing a set of cooperative activities that include test-beds, inter-comparison experiments as well as scientific workshops and meetings. This THORPEX/HEPEX Applications Project would be an integral part of these activities.

THORPEX Background

- **Goal**
  One of the THORPEX activities will be a THORPEX Interactive Grand Global Ensemble (TIGGE). The 1st Workshop of TIGGE will be held at ECMWF March 1-3, 2005. The workshop planning documents note that "a major research challenge of 21 century is to reduce and mitigate natural disasters and to realize the societal and economic benefits of improved weather forecasts. THORPEX will address this research challenge, thereby contributing to the development of a future truly integrated Global Interactive Forecast System (GIFS), which would generate numerical probabilistic products, available to all nations including developing countries".

  One of the first tasks of the TIGGE working group will be to define the scientific requirements for TIGGE and then to plan and develop the infrastructure accordingly. This proposed project a basis for some of these TIGGE requirements.

THEPS Project Rationale:

- **Focus on one of HEPEX elements**
  The project would focus on 1-2 week time frame of the atmospheric preprocessor in Figure 1.

- **Provide feedback to THORPEX science community**
  The project would develop hydrological applications of TIGGE forecasts. This would help the TIGGE community to get a better understanding of the strengths and limitations of their forecasts – as viewed from a hydrological perspective. This could include diagnostic information that might be used to improve TIGGE forecasts.

- **Enable P-I driven research projects**
  A key requirement for P-I driven research is to have convenient and inexpensive access to data. For hydrological ensemble research this includes meteorological forecasts as well as hydrological basin data. This project will be designed to support these requirements.

Data Sets

- **Data set requirements**
  Both meteorological as well as hydrological data are required. This applies to both near real-time data as well as historical or retrospective data. Hydrological basin characteristics are also needed. It is likely there will be scale mis-matches between the spatial scales at which some of the meteorological data are available

and the scales at which hydrological models typically operate. Therefore, techniques will be needed to deal with this issue.

Historical hydrometeorological data are needed to: (i) calibrate hydrological models and to calibrate the processors that are needed to translate the meteorological forecasts into hydrological model forcing data at hydrological time and space scales, (ii) remove biases from meteorological forecasts and (iii) assure reliable probabilistic hydrological forcing.

Meteorological forecast data are needed for hydrological prediction at specific locations where hydrological data are available. These forecasts need to be extracted from the larger TIGGE data sets to produce manageable data sets for hydrological applications.

A plan needs to be developed to provide TIGGE data sets for the various hydrological applications selected to be part of the project.

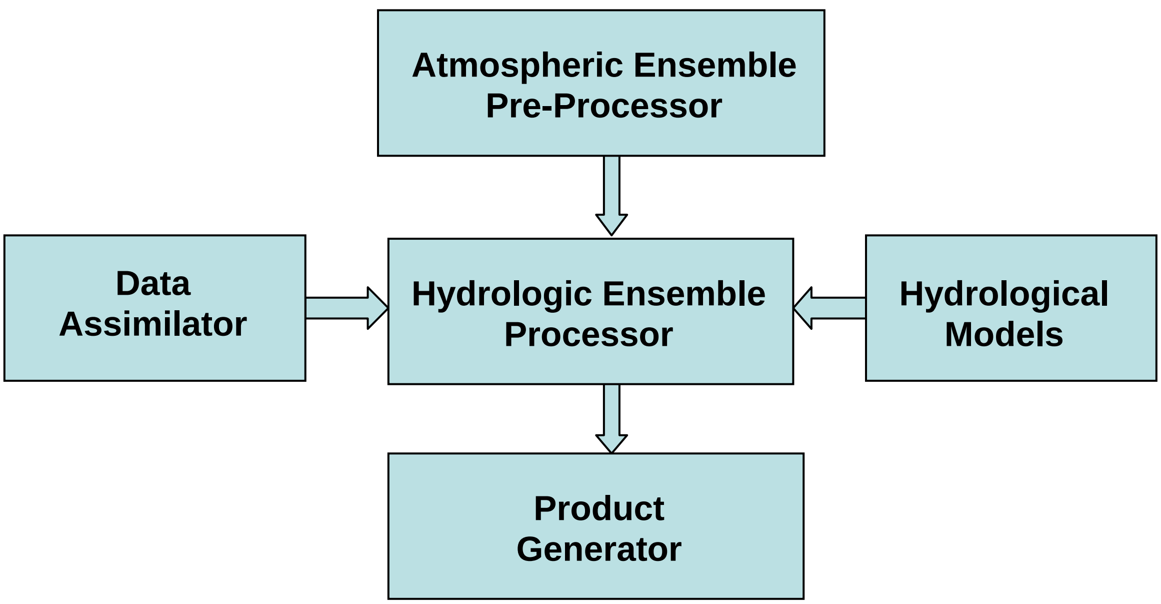

Figure 1 – Elements of a Hydrologic Ensemble Prediction System

Appendix A – Data Requirements

Data Types

Hydrologic applications require the following data types:

- Precipitation
- Air temperature
- Solar insolation
- Atmospheric radiation
- Dew point or relative humidity
- Wind speed
- Surface pressure
- Freezing level (in complex terrain)

Analysis and Forecast Requirements

Analyzed fields for the above data types are needed as well as forecast fields. Also related observations of these are needed as well, especially observations of precipitation and solar insolation and objective analyses of these observations. Ideally, the analyzed fields are needed at the same time step as the forecast fields for day 1.

Spatial Domains

The spatial domain required for a specific hydrologic application can vary from small basins of a few square kilometers to global scale land data assimilation systems. Most hydrologic applications require data for only limited land areas. Most hydrologic investigators are unable to handle the large data volumes associated with continental or global scale data sets. Therefore, a land surface subset of the TIGGE forecast data must be extracted and this subset must be further subsampled into a limited number of selected regions.

The selected THEPS regions would support clearly defined potential hydrological applications. TIGGE would supply land surface data sets for these regions from its full global data sets. Some of these regions may be contiguous or even overlapping to permit continental scale applications (e.g. for all of North America or all of Europe).

To be manageable for TIGGE, the selected regions must be: (i) fixed and (ii) large enough to include many catchments or small river basins. It is not practical to ask TIGGE to produce forecast data for many small basins. Therefore, some mechanism may need to be developed by THEPS to provide convenient access to basin-scale data for hydrological studies, including retrospective data sets.

Real-time vs Retrospective Data

Hydrologic applications of TIGGE forecasts will require a processing step to remove model biases in the forecast climatology and to remove ensemble spread biases to produce reliable conditional probabilistic forecasts. This processing step likely will require a historical archive of TIGGE forecasts and corresponding observations as well as a historical archive of hydrologic model input and output data, including streamflow observations and other special observations such as soil moisture, groundwater levels, surface energy fluxes, etc.

Because hydrologic systems are highly nonlinear, this archive should be as long as possible. Users of hydrological ensemble forecasts typically are interested in forecasts for specific places. The accuracy and reliability of these forecasts can only be assessed through a re-forecast or retrospective forecast process. This means historical forecasts are needed not only to estimate atmospheric model output statistics but to drive the hydrological retrospective forecast verification system as well.

Data Time Scale

The forecast period for TIGGE forecasts is for 0 – 14 days. The temporal frequency of the information content of atmospheric forecasts during this period changes with forecast lead time. High temporal frequencies attenuate. Although it may be a practical requirement to have a constant time step for the entire forecast period, it should be possible to substantially reduce the total size of the data set by using a variable time sampling strategy. Using any fixed sampling interval beyond 1hr for the entire forecast period will loose information from the short term and likely be redundant (relative to climatological diurnal variability) for the long term.

The absolute maximum time step should not be longer than 1 day (which would require at least 14 data values). At the other extreme, a 1hr time step for 14 days would require 366 data values (24 times more). Between these extremes might be a nested data strategy that samples the initial period at the highest frequency (perhaps 1hr). The sampling interval might then be increased up to 24hr after several days. This could be done differently for precipitation.

Average vs instantaneous values are preferred for each sampling interval.

Spatial Scale

Spatial scale needs some discussion. One approach would be to provide data on each model's native grid. Another would be to have a common grid for all models. Interpolating precipitation to a common grid tends to introduce spurious information. Hydrologic models require the highest spatial resolution consistent with the spatial frequency of the information contained in the model output. This is especially important in complex terrain.

The spatial frequency of the information content of model output is higher for the first few days than later. Therefore, it may be useful to consider a nested grid approach to reduce the size of the total data set.

Proposed topics for THEPS

1. Identify candidate regions with potential applications and recommend specific regional domains and priorities.

2. Specify required data types

3. Specify time scales and temporal sampling strategy

4. Specify special scale and spatial sampling strategy

5. Propose strategies for user access

6. Explore potential for a THEPS data system to provide convenient user access to basin-scale data

7. Represent THEPS on TIGGE and HEPEX working groups

8. Inform science community about THEPS and organize appropriate science activities.

9. Foster collaboration with WMO (including HWRP), UNESCO (IHP), IAHS (PUB), GEWEX (WRAP) and other THORPEX and HEPEX activities.

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