Report from the 3rd HEPEX Workshop Stresa, Italy 27th-29th June 2007

(R. Hartman and J. Schaake, 25th November 2007)

The 3rd HEPEX workshop was held in Stresa, Italy, from 27th-29th June 2007. A total of 65 participants from 19 different countries and several International and European organizations presented a good platform for international exchange on hydrological ensemble prediction research. The workshop brought together 47 researchers from the field of hydrology (35) and meteorology (12), operational hydrological and meteorological forecasters (13) as well as 5 end users from reservoir operations, keeping a good balance between science and operational applications. The full list of participants is provided in Appendix A.

The workshop was co-organized by *John Schaake* (NOAA), *Jutta Thielen* (JRC), *Robert Hartman* (NOAA), and *Roberto Buizza* (ECMWF). The JRC took care of all local organizational details and arrangements.

Notes taken by Roberto Buizza during the workshop highlight some of the interesting aspects of the workshop. These are attached in Appendix B.

The Hydrological Ensemble Prediction Experiment (HEPEX) was founded in the spring of 2004 during the first workshop held in Reading, England. The participants formulated scientific questions that, once addressed, should help produce valuable hydrological ensemble prediction to serve users' needs. The aim of HEPEX was postulated as "To bring the international hydrological and meteorological communities together to

demonstrate how to produce reliable hydrological ensemble forecasts to make decisions for the benefit of public health and safety, the economy and the environment."

During the second workshop, held in Boulder, Colorado in July of 2005, a series of coordinated test-bed demonstration projects (8) were set up as a method for answering these questions. The test-beds are collections of data and models for specific hydrological basins or sub-basins, where relevant meteorological and hydrological data has been archived. The test-beds will facilitate the inter-comparison of various hydrological prediction methods and linkages to users.

The test-beds were also a focus during the 3rd HEPEX workshop where progress from the test-bed projects started in July 2005 was reported and new test-beds proposed. Six of the eight test-beds proposed in July 2005 provided updates, progress, and status reports. Progress in the development of shared datasets and new forecast tools were discussed. Furthermore, new research on weather and climate forecast applications, hydrologic ensemble processing and uncertainty in hydro-meteorological forecasting were presented. Presentations and discussions indicated that meteorological services (including forecasters) and scientific institutions are convinced of the value of a probabilistic approach to flood prediction. Skepticism, however, can still be detected in the end users. The user perspective of making decisions based on uncertain forecasts was a major discussion point during the workshop.

A portion of the workshop was dedicated to discussion among participants relative to specific topics of interest to HEPEX. Three work groups were formed for this purpose and each developed and shared their ideas with the larger group. The topics for the work groups were: (1) user oriented topics, (2) hydro-meteorological forcings, and (3) sources of uncertainty. The discussion points from each of the three work groups are provided in Appendix C.

Presentations and materials from the 3rd HEPEX Workshop are available on-line at http://hydis8.eng.uci.edu/hepex/thrdwksp/thrdwksp.html. It was proposed that some of the presentations as well as the workshop report be published in a new on-line Research Letters publication of the Royal Meteorological Society. This is being pursued.

During the workshop, *J Thielen* was appointed co-chair of the HEPEX project, following *R Buizza's* resignation. *J Schaake* was re-confirmed as a co-chair. The next HEPEX workshops will most likely be sub-workshops focused on downscaling, post-processing, and users of probabilistic hydrologic forecasts. The next full HEPEX workshop will likely be in three years, possibly at NOAA's new NCEP facility in Camp Springs, Maryland, USA.

HEPEX Test-beds

Nine new test-beds were proposed making the total seventeen. There are two types of test-bed projects. Ten of them focus on scientific issues to make end-to-end ensemble forecasts for a particular river basin. Six of them focus on specific science issues that potentially cut across all of the basin-oriented projects. Over time we expect the projects to work together to form a tightly knitted matrix (see figure below) of techniques and

HEPEX Test-bed Projects

Science \ Applications	Bangladesh	Brazil	Po River	MAP D-Phase	France	Rhine	E. US	W. US/Ca	Great Lakes	Hydrocomp
Atmospheric downscaling										
Ensemble QPE										
Parameter estimation										
Hydrologic uncertainty										
Post processing										
Product generation										

HEPEX
Hydrologic Ensemble Prediction EXperiment

experimental applications. The elements of this matrix represent potential opportunities for collaboration among the test-bed projects on specific scientific issues.

The following new test-beds were identified:

- Bonneville Power Administration (BPA) use of weather forecasts (*C. Howard* will contact BPA for interest).
- Parameter uncertainty in conjunction with MOPEX, including DMIP2 (*T. Hogue*).
- Observational uncertainty (*T. Bellerby*).
- Rhine Catchment. Seasonal forecasts with climate change. An end-to-end process with end-users (*T.Maurer*).
- Value and application of probabilistic forecasts for end-users in the Tuolumne and Cedar River watersheds (*N. Crawford*).

- MAP D-PHASE (*M.Rotach*).

- Hydrologic post-processor (*P.Regianni*). Also, this is likely to be the focus of a HEPEX sub-workshop.

- Ensemble and probabilistic product generation for customers and partners (*M. Mullusky and K. Werner*).

- France, end-to-end ensemble prediction system (M. Ramos).

Leaders of the new test-beds are encouraged to develop a written plan describing the objectives and envisioned approach of the test-bed for posting on the HEPEX website as soon as reasonably possible.

Actions Items

- V. Fortyn invites HEPEX participants to test their forecast models, downscaling and verification techniques in a sub-basin of the North American Lakes test-bed. In this way, in 3 years time, an inter-comparison study between the different forecasts could be achieved. The data are available on ftp-site.

- Establish working group on skill scores (lead**:** *V. Fortyn*)

- The HEPEX webpage has a wiki-facility which should allow visitors of the web-page the uploading of information. *K. Franz* will investigate how this could be used to allow the building of a dynamic webpage.

- On HEPEX webpage: Literature collection relevant to HEPEX, ordered by topics. (***volunteer needed***)

- Develop draft position paper on the needs of the hydrological community for meteorological model reforecasts (lead *E.. Wood*)

- Develop draft position paper on where the hydro-met community is with regard to uncertainty assessment (***volunteer needed***)

- Contact Meteo France regarding the availability of hindcasts (***volunteer needed***)

- Initiate organization of HEPEX Downscaling Workshop to be held in 2009. (J. Schaake will coordinate leadership)

- Initiate organization of HEPEX User Workshop to be held in 2009 (Lead : *C. Howard*)

- Develop and conduct Hydrologic Ensemble and Forecast Uncertainity Users Survey: (Lead: *F. Weber and R. Hartman*).

- Broaden the hydrological community by including scientific groups with related studies, like PUB and MOPEX community. (Lead: *J. Schaake*).

- Initiate organization of HEPEX Post-processing Workshop to be held in 2009. (Lead: *P.Regianni*)

- Call for 2005 test-beds to produce written summary of design, work accomplished, key developments, and issues identified for posting on the HEPEX website by the spring of 2008. (*J Thielen and J. Schaake*).

Vision for the Future of HEPEX

The most important objective for HEPEX is to demonstrate that its work is meeting real user needs. This means that users must participate in HEPEX activities and the HEPEX User Council needs to provide strong leadership.

In particular, the attention will be focused on the progress being made by the many testbed projects and to encourage meaningful and productive collaboration among them. This includes calling attention to testbed accomplishments and success stories, especially through our HEPEX web site. Anyone who can make a valuable contribution to the core activities described in the strategic Implementation Plan will be welcome to participate in HEPEX. Particular efforts will be made to engage participants from, Asia, Africa and Oceana. The core activities are:

- Testbed projects
- Supporting data sets
- Components of a Community Hydrologic Prediction System (CHPS)
- Convening special sessions at professional meetings
- Publications

HEPEX must develop and maintain strong collaborative ties to other important organizations such as:

- The International Association of Hydrological Sciences (IAHS) - The IAHS formed a new Working Group on Hydrometeorological Projects at its last meeting in Perugia, Italy in July, 2007 to facilitation collaboration with projects such as HEPEX. The IAHS project Prediction for Ungaged Basins (PUB) is a major potential source to meet some of HEPEX science requirements
- WCRP/GEWEX/HAP -
- GEO/GEOSS -
- UNESCO -
- WMO/HWRP -
- WWRP/THORPEX/TIGGE -
- Operational Forecast Organizations -
- Water management professional organizations -

Annual reports will be produced to some of these organizations. It is anticipated that steering comities of some of them will review these reports and suggest new opportunities for HEPEX to contribute to their work.

The progress of HEPEX will be reviewed again 4th International HEPEX workshop scheduled in 2009/2010.

Appendix A

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Appendix B

Workshop Notes from R. Buizza

Approximately 65 people (from American, Canadian, Brazilian and European Institutions) attended the WS. Groups reported progress on 6 of the 8 test-beds around which the HEPEX project is organized. Presentations and discussions indicated that meteorological services (including forecasters) and scientific institutions are convinced of the value of a probabilistic approach to flood prediction. But skepticism can still be detected in the end users (water authorities, planners of water companies and utilities with hydro-electrical power stations). HEPEX is thinking to organize a training/educational meeting to show end-users which probabilistic hydrological forecasts are available, and how they can be used in operational activities. ECMWF should continue to support HEPEX' effort to promote a probabilistic approach to hydrological prediction, since this may increase the request of ECMWF probabilistic products.

The meeting was co-organized by *John Schaake* (NOAA), *Jutta Thielen* (JRC), *Robert Hartman* (NOAA) and Roberto Buizza (ECMWF), with JRC taking care of local organizational details.

A de Roo (JRC, EU) opened the meeting with a welcome speech, stating that this was a very important activity for JRC, which has been heavily involved in the past decades in the planning, design and development of a European flood prediction capability. He said that JRC has been extending the work from flood prediction to the whole problem of the management of water resources, i.e. also on the prediction of draughts. He mentioned that the European Commission is preparing a paper where the issue of the prediction of both floods and draughts is discussed.

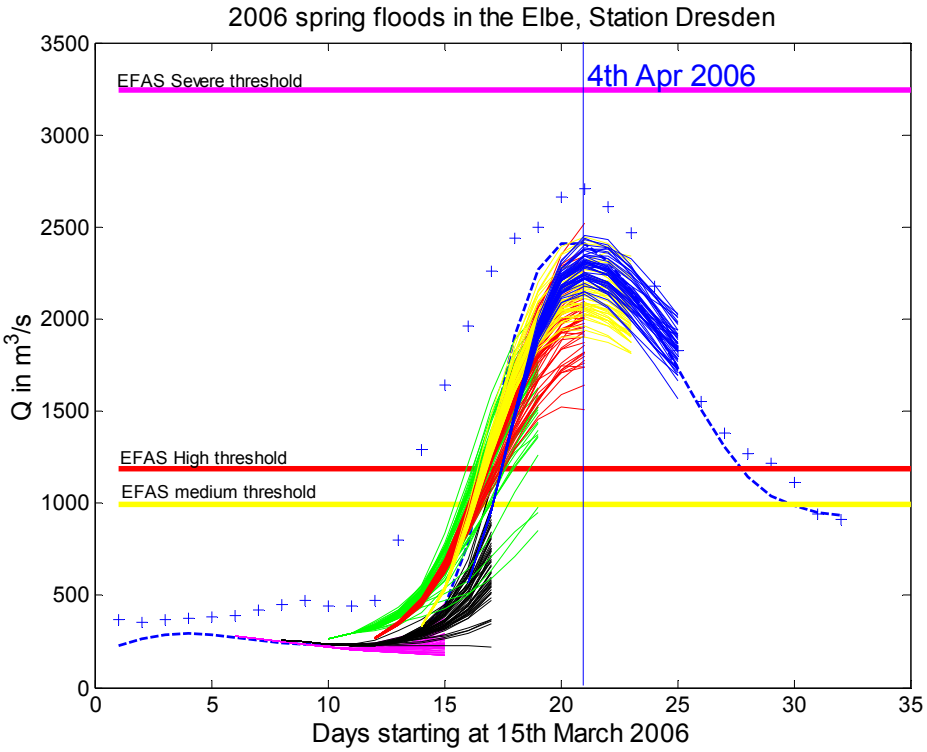
R Buizza (ECMWF, UK) opened the meeting with a general talk on the status of HEPEX, stating that it was essential to decide how to make further progress both on the scientific development of a probabilistic hydrological prediction system and on the exploitation of the probabilistic products already available. He said that from contacts with end users he gathered that one of the key questions that remain unanswered is *'How can decision makers (managers of water resources or of hydro-electric power stations) take decisions using probabilistic forecasts?'* He strongly invited HEPEX to address this question. *R Buizza* then gave a talk on the status of the ECMWF ensemble system, during which he showed some very recent 15-day VAREPS verifications, and discussed ongoing research. Participants expressed appreciations of the ECMWF plan to run operationally a re-forecast suite, and interest in accessing this data-set, and asked questions on the problem of verification of weather variables of interest for hydrologist, and of hydrological variables (e.g. discharge): which is the 'best' skill score to use?

C Howard (Consulting Engineer, Victoria, BC, Canada) said that price and load forecasts based on ensemble forecasts are considered very important by the companies for which he works, but so far forecasts are mainly based on single forecasts. An Ensemble

Optimization Procedure that explicitly considers the ensemble forecasts in recommending the best possible decisions is under development. Products will depend on the time range.

Van Andel (UNESCO-IHE, France) discussed the use of ECMWF precipitation forecasts as input to a water-system model for the Rijnland (in The Netherlands) water system. Results were based on 7.5 years of ECMWF EPS grid-point forecasts for De Bilt). He said that there is useful information in global ECMWF EPS precipitation forecasts for regional water system control. Because the water board wants to know the highest achievable level of safety against flooding, the main product they are using is the maximum water level that can be reached in 3 days. He said that the EPS provides very valuable forecasts for regional water system control.

J Thielen (JRC, EU) described the JRC European Flood Alert System (EFAS), and pointed out that EFAS has been increasingly used as an information exchange platform for many institutes. She showed some very nice 10 day forecasts of the flood of March 2006 (see encl. figures).



EFAS discharge-gram prediction for Dresden, during the 2006 spring flood (from J Thielen, JRC).

R Hartmann (Hydrologist in charge, NOAA, US) said that NOAA's NWS has been using ensemble stream flow techniques for more than 20 years to produce long-range seasonal predictions, and is now developing a way to exploit medium-range ensemble forecasts to drive the Experimental Ensemble Forecasting System (XEFS).

C Tucci (IPH, Porto Alegre, Brazil) discussed how CPTEC seasonal ensemble precipitation forecasts (200km resolution, 9 members, up to 6 months) are used to predict discharge in the Rio Grande (this is one of the most important rivers for Brazil, since the hydro-electric energy produced on Rio Grande is ~10% of the total national production). He concluded that for forecast times up to 12 days, ensemble flow forecasts have been shown to improve operational planning of the hydroelectric reservoirs, but long-term (up to few months) ensemble forecasts had not been found useful yet.

V Fortin (MSC, Canada) said that the regional, raster-based, MESH prediction system has been nested in the MSC ensemble to generate ensemble forecasts of surface variables and basin stream flow. During a discussion after his talk, he said that the resolution of the MSC ensemble system will soon increase (the change was planned for June but it has been slightly postponed): this increase follows earlier results have indicated a good positive impact especially on precipitation forecasts (he mentioned ~1 day improvement compared to the old system, but did not show any result). On the North American Ensemble Forecasting System (NAEFS), he said that combining the MSC and the NCEP ensembles in NAEFS is giving ~1 day improvement in the probabilistic forecasts of T850, mainly because of the increased membership of the combined ensemble (rather than on the fact that NAEFS uses two different models). He mentioned that the plan is to substitute MSC ensemble products for end-users located in the Great Lakes with NAEFS products in the forthcoming years.

M Ramos (JRC, EU) discussed the combined use of single-based and probabilistic discharge forecasts in EFAS, and raised the following issues: how many EPS members above a threshold should be considered to launch a flood pre-alert? Which consistency between single high-resolution forecasts and ensemble forecasts should be expected? Can EPS-based forecasts contribute to an earlier detection of floods (increased preparedness)? Which decision rules should be followed to issue a flood warning?

D Hou (NCEP, US) said that NCEP is planning to run, as part of its ensemble system, a river rooting model (RRM, developed by *Lohmann et al* 1998, 2004) driven by their land surface model (NOAH) to forecast stream flow (m3/s). Results based on 2 months indicate that the correlation coefficient is higher for the largest river basins, and that ensemble-based probabilistic forecasts are better than the ones based on the single control forecast only. NCEP plans to extend the RRM to the global domain, and to run it operationally by end of 2007, beginning of 2008.

Discussions were organized in three working groups: *WG-A* on users' oriented issues, *WG-B* on the connection of meteorological and hydrological systems, and *WG-C* sources of forecast uncertainties:

- *WG-A* suggested that it is important to interact more with the end users, to collect information from/about end-users for better understanding of their needs. It suggested that visibility/credibility of hydrological probabilistic predictions in the end user community must be increased. This could be achieved by organizing

training schools, and by involving more end users in the test bed projects. It also concluded that it was essential to provide some guidance on what will be available in the near future (say in 10 year).

- *WG-B* concluded that skill scores are too generic: it is important to use 'user related' skill scores to be able to convince end users on the usefulness of flood forecasts. It suggested that there is the need for a proper comparison of downscaling methods, with the goal to evaluate and understand how the various approach to work, and to identify the best one(s). It also discussed the possibility that that the HEPEX community writes a position paper on the scientific needs of re-forecasts, to be sent to the main meteorological institutes.
- *WG-C* concluded that there is the need to define what are the characteristics of a 'good' ensemble (e.g. unbiased and reliable, as sharp as possible, with the highest resolution and discrimination as possible, ..). It also suggested that HEPEX should recommend reasonable models and/or forecasts to the user community, that it helps the community to identify the best way of combining them to build ensemble forecasts, and that it produces a bibliography containing documents on the topics of uncertainty and ensemble forecasts.

During the meeting, *J Thielen* has been appointed co-chair of the HEPEX project, following *R Buizza* resignation, while *J Schaake* as been re-confirmed. The next HEPEX meeting will most likely be most likely focusing on downscaling, and could be held in 2008, possibly at Delft Hydraulics.

These notes were part of my mission report to the ECMWF management: they are not supposed to be omni-comprehensive, but they only provide a brief summary of some of the topics discussed during the meeting. Thus, not all the talks and posters are mentioned in this summary.

Roberto Buizza - 10 July 2007

Appendix C

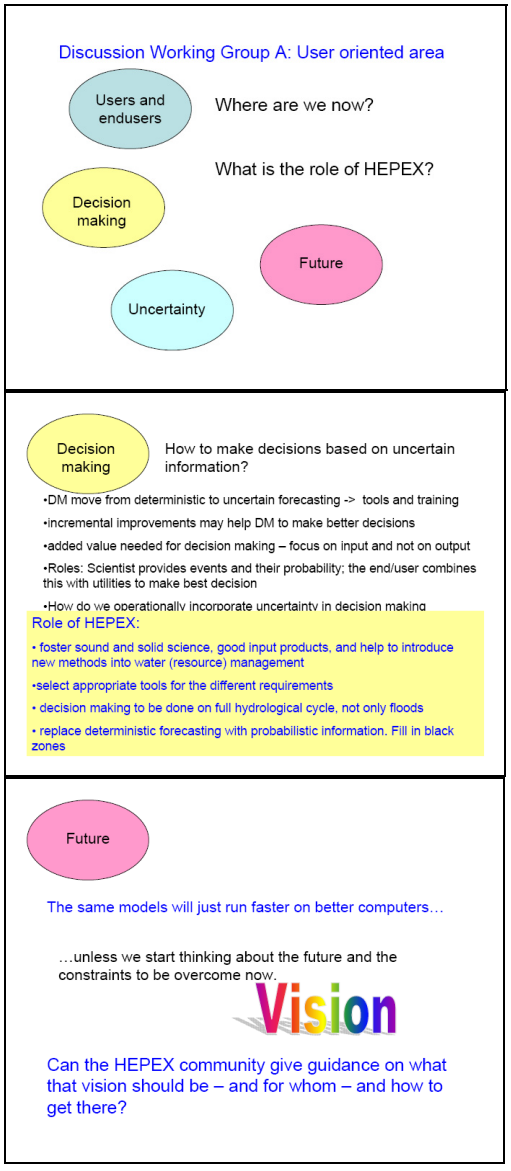
Work Group Discussion Points

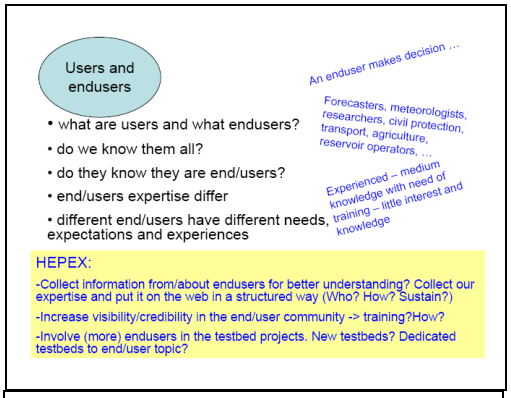
Work Group A – User Oriented Issues

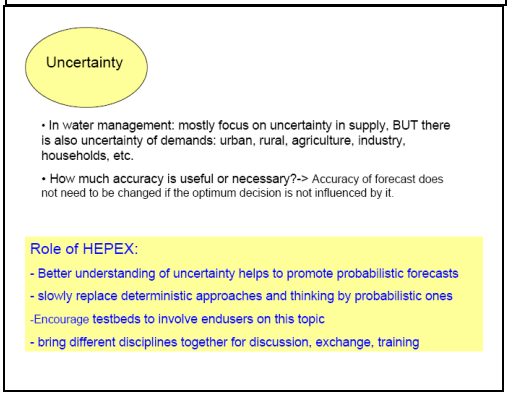
Recommended:

- More involvement of users in HEPEX test-beds
- Bring users into discussions with scientists on the nature of forecast uncertainty and on ways that decisions can be made considering uncertainty
- Collect information from/about end users
- Need to develop credibility with end user community

Materials:





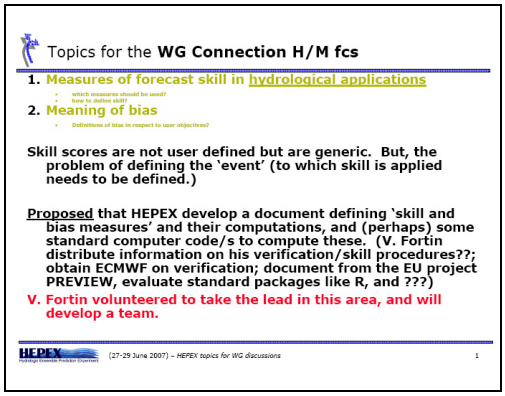


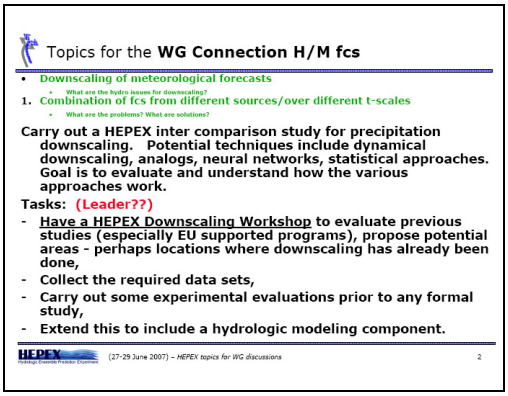
Work Group B – Hydro-meteorological Forcings

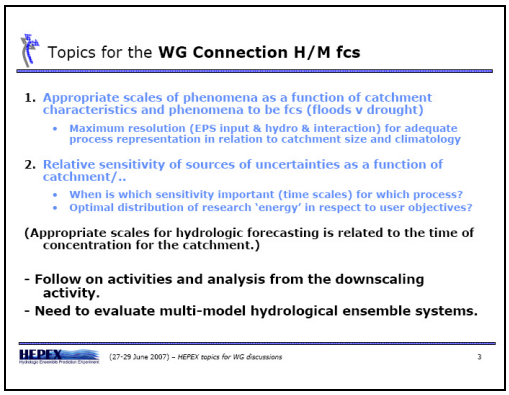
Recommended:

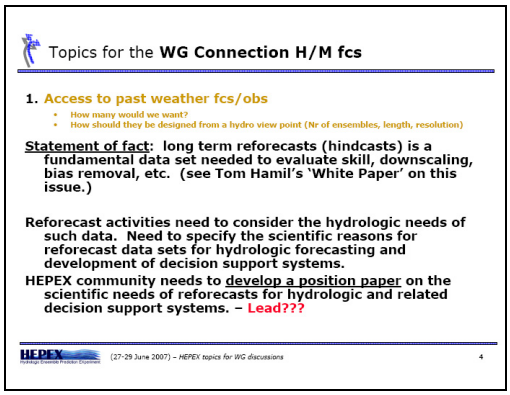
- HEPEX develop a document defining skill and bias and other forecast verification measures together with computational tools for their computation and visualization. Vincent Fortin offered to lead a team to do this.
- Develop a HEPEX intercomparison project on precipitation downscaling techniques. This would begin with a workshop and would involve experimental intercomparisons before a formal study would be undertaken.
- Extend the intercomparison activities to include hydrologic ensemble predictions as well
- Develop a position paper on the scientific requirements for atmospheric ensemble re-forecasts (*E. Wood*)

Materials:









Work Group C – Sources of Uncertainty

Recommended:

- There is a need for a statement about the properties of a "good" probabilistic/ensemble forecast
- Need to identify the components of the hydrologic ensemble forecast process for which the nature of uncertainty is not well defined
- Users need more information about the nature of forecast uncertainty
- More information needs to be made available for them to experiment

Materials: