

**HAP**  
*CEOP*

**Hydrologic  
Application  
Project**

# **Hydrologic Application Project (HAP)**

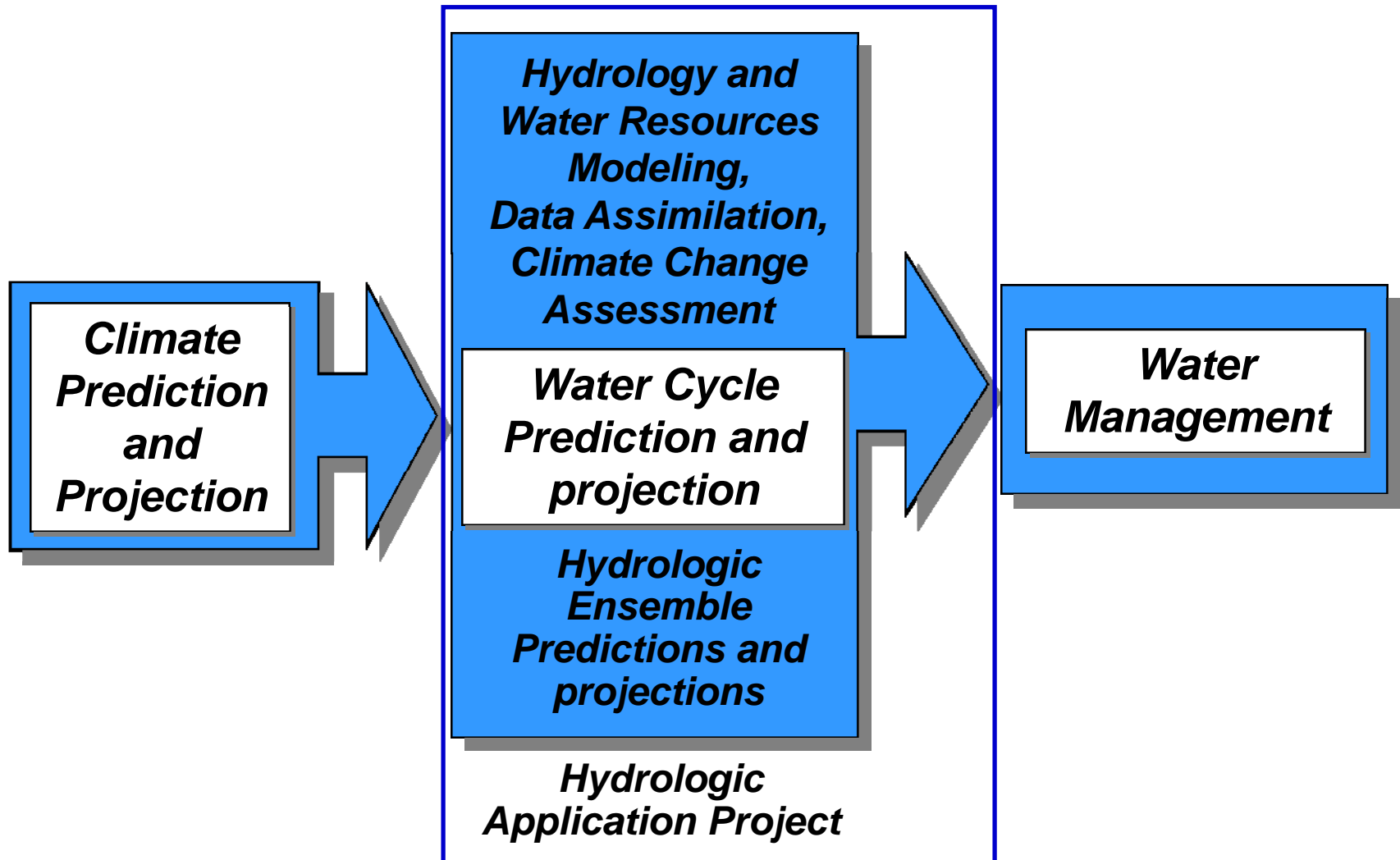
Report on 2009 Activities  
and planned future activities

Eric F Wood, Chair  
(Princeton University)

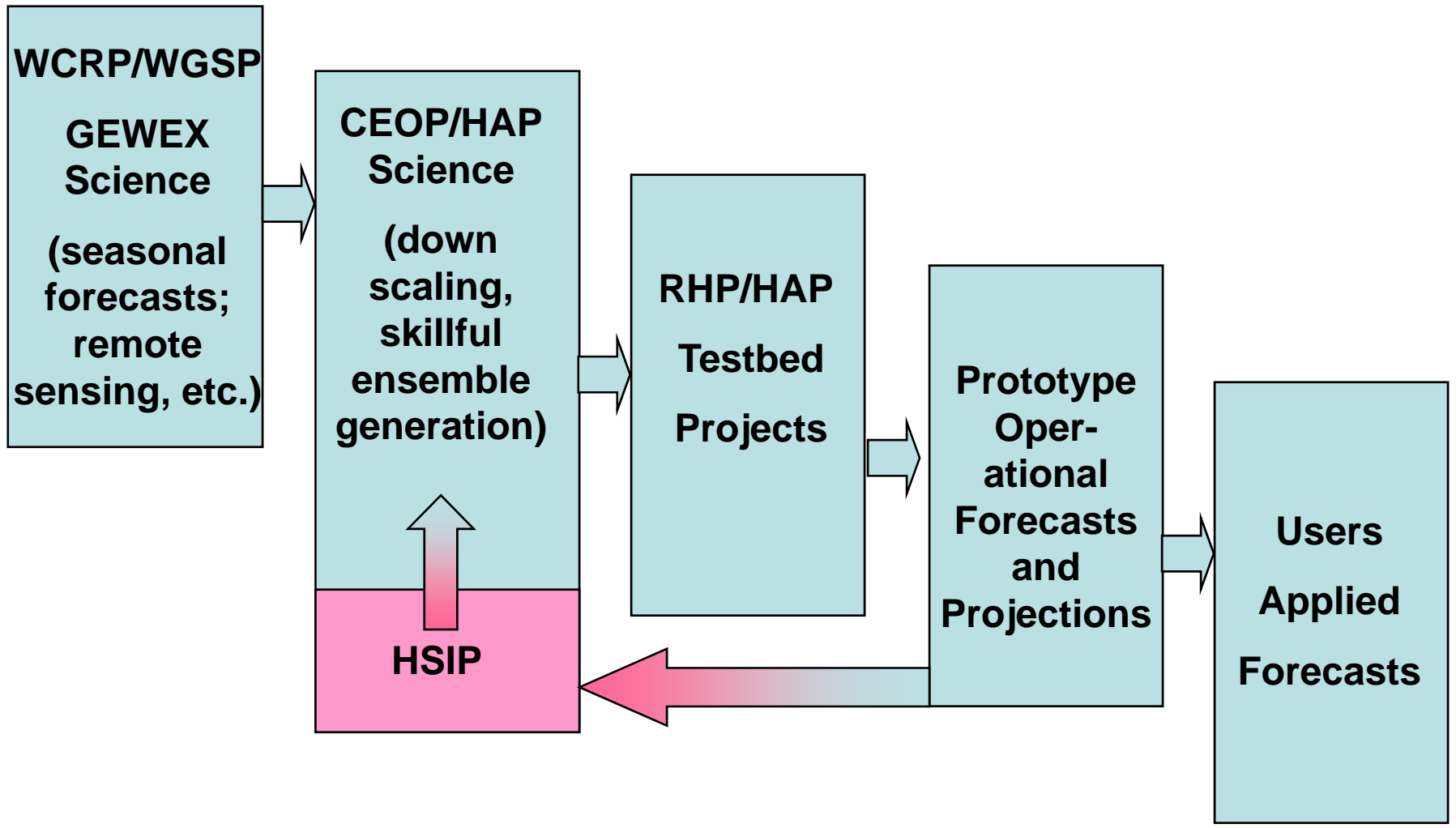
Presented at the CEOP Science Meeting

August 19-21, 2009  
Melbourne, Australia

## From Climate Prediction to Water Management



# HAP Science Infusion Process (HSIP)



***E2E-HSIP*: End-to-End test-beds demonstrating the value of HAP Science Infusion Process in the water cycle and climate applications arenas.**

**“Developing the science behind skillful ensemble hydrologic seasonal forecasts, and demonstrating their usefulness.”**

CEOP Hydrologic Application Project (HAP) current goals:

1. Developing procedures for **assessing current hydrologic conditions** through application of GEWEX supported data products, including remotely sensing;
2. Developing and **testing** of reliable, skillful hydrologic **ensemble forecast procedures** based on seasonal climate model forecasts;
3. Demonstrating that the procedures can be applied at scales **useful for water resources** through test-bed sites and demonstration projects;
4. Working with related projects, (HEPEX, WGSP, GWSP)

## ***Seasonal Hydrologic Predictions.***

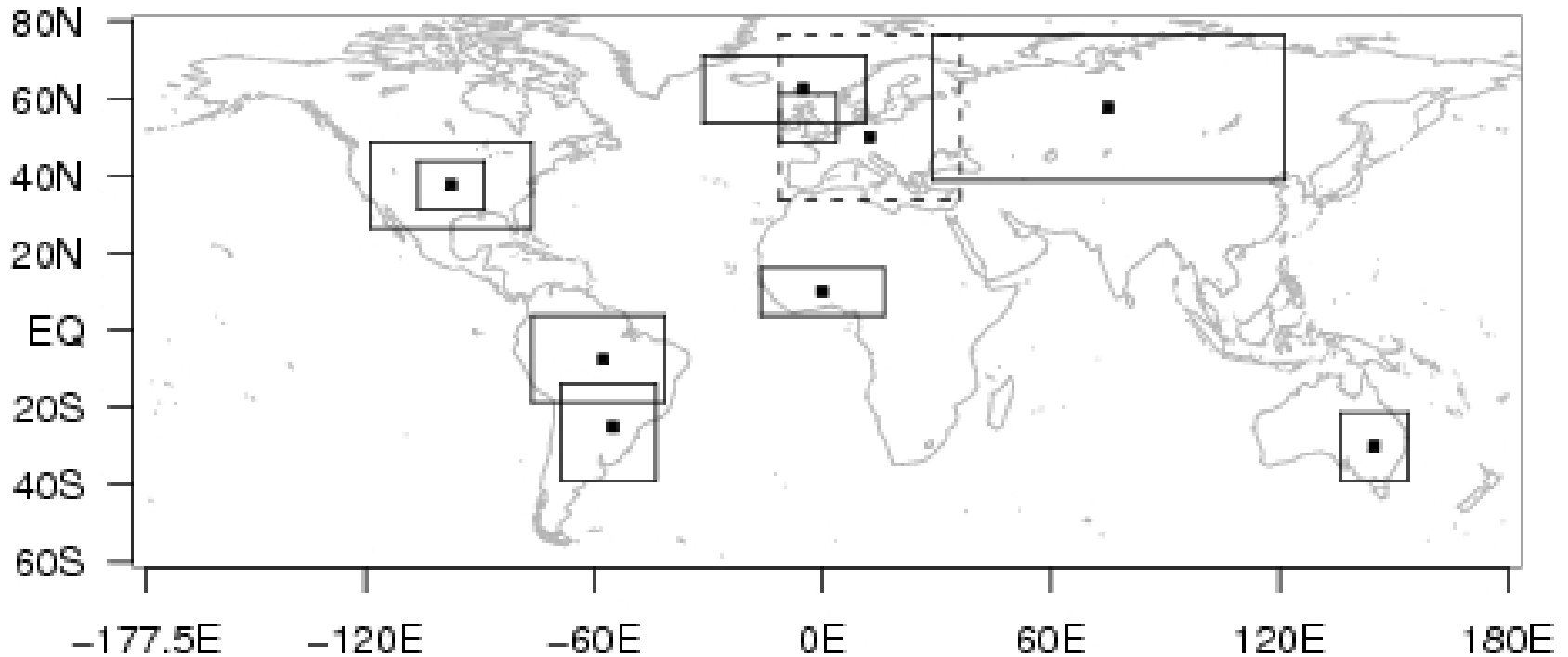
```` HAP has evaluated global (land) seasonal precipitation and 2-m temperature forecasts based on re-forecasts (hindcasts) from NOAA/CFS and DEMETER seasonal models.

These forecasts can be bias corrected and downscaled, and hydrologic seasonal forecasts evaluated on regional testbeds for water management. Current collaboration exists with HEPEX with this activity, and initially will **focus on HAP/HEPEX testbed** basins.

Currently experimental hydrological seasonal forecasts are being produced over the United States in collaboration with NOAA/NCEP under NOAA/CPPA support. An experimental system will be tested over Africa during 2010 (unfunded).

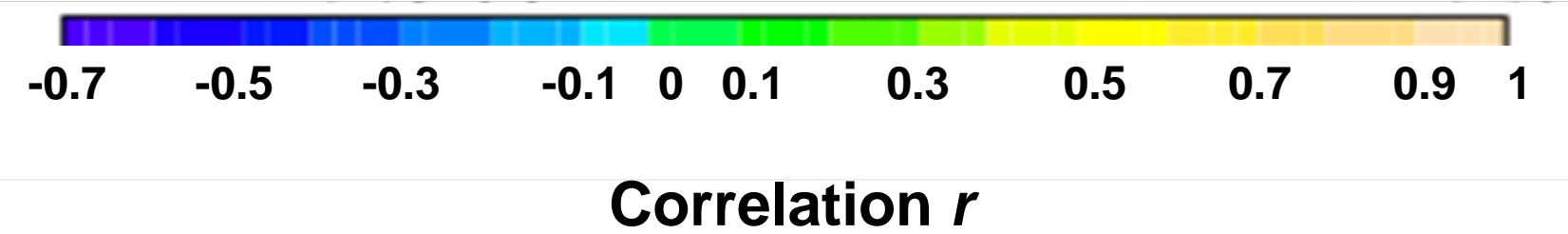
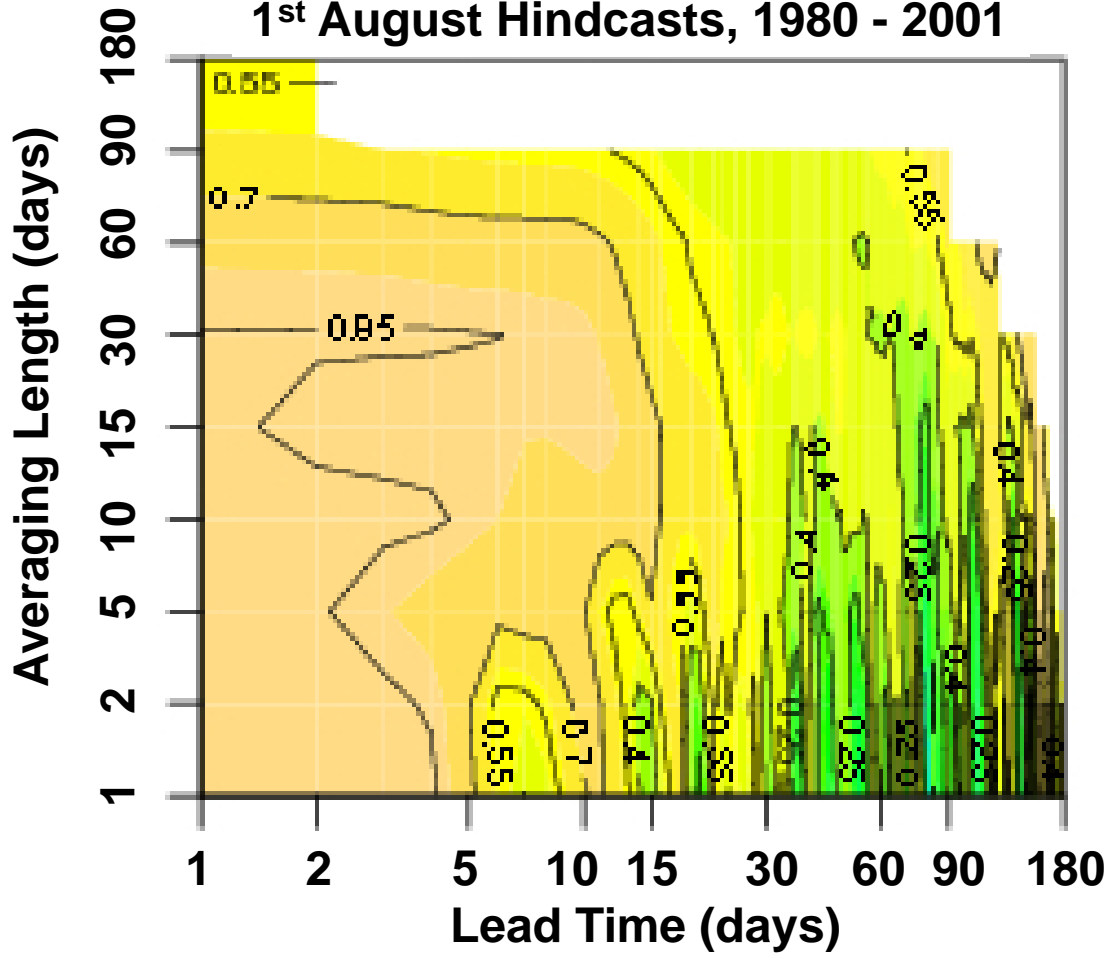
# End-to-End test-bed demonstration of HAP seasonal forecasting contributions

Seasonal predictive skill over the GEWEX RHP Basins  
(Work done by David Lavers, CEH and Princeton)

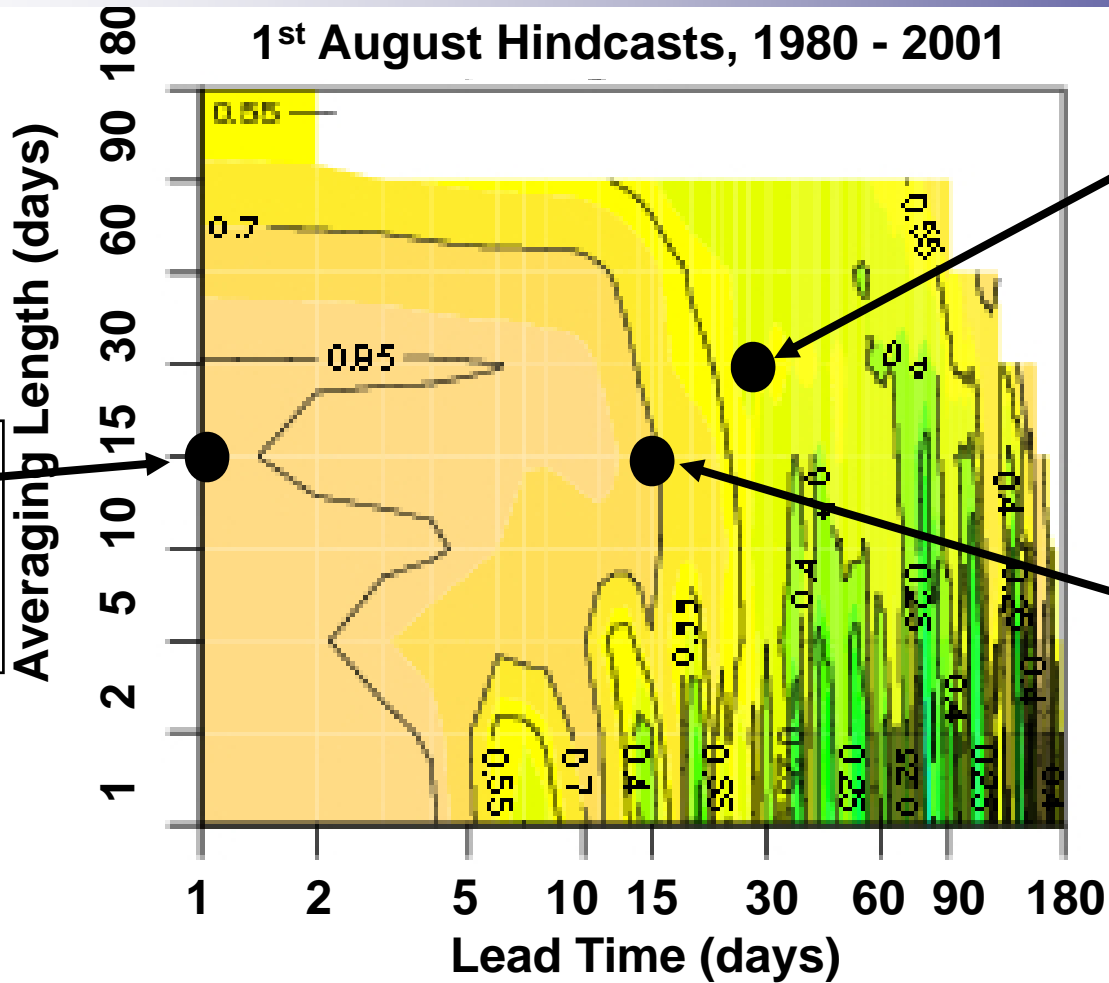


Eight regions chosen. Six are GEWEX regions: Amazon, La Plata and Murray-Darling basins, Europe, Icelandic Low area, Siberia, West Africa and USA

### 1<sup>st</sup> August Hindcasts, 1980 - 2001



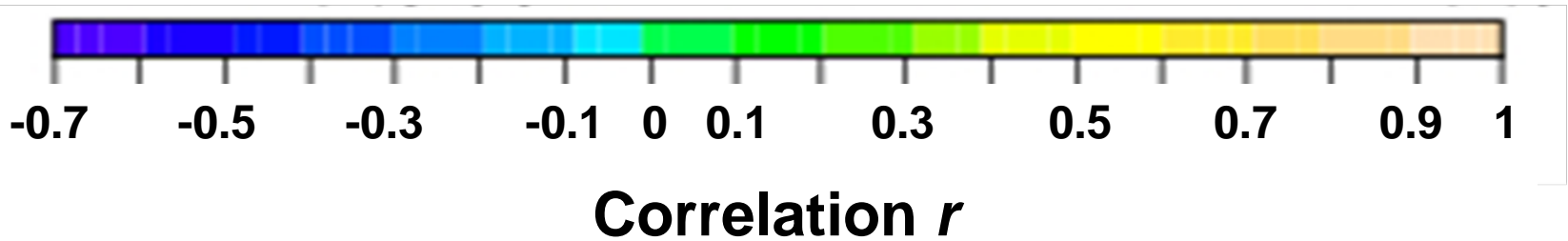
### 1<sup>st</sup> August Hindcasts, 1980 - 2001



15 day  
forecast  
starting on  
day 1

Forecast for  
month 2

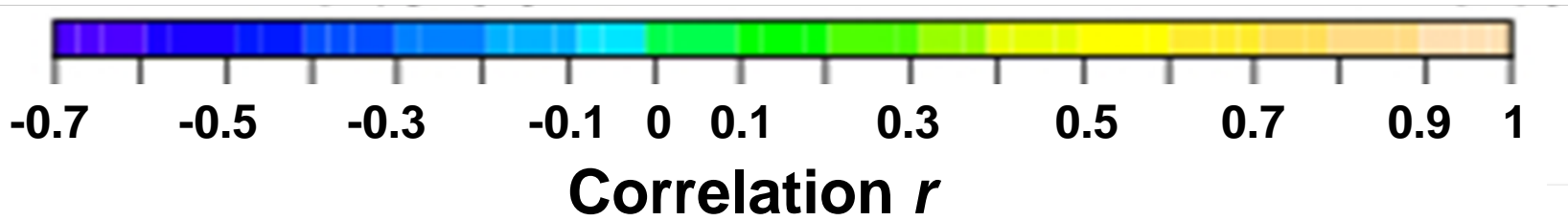
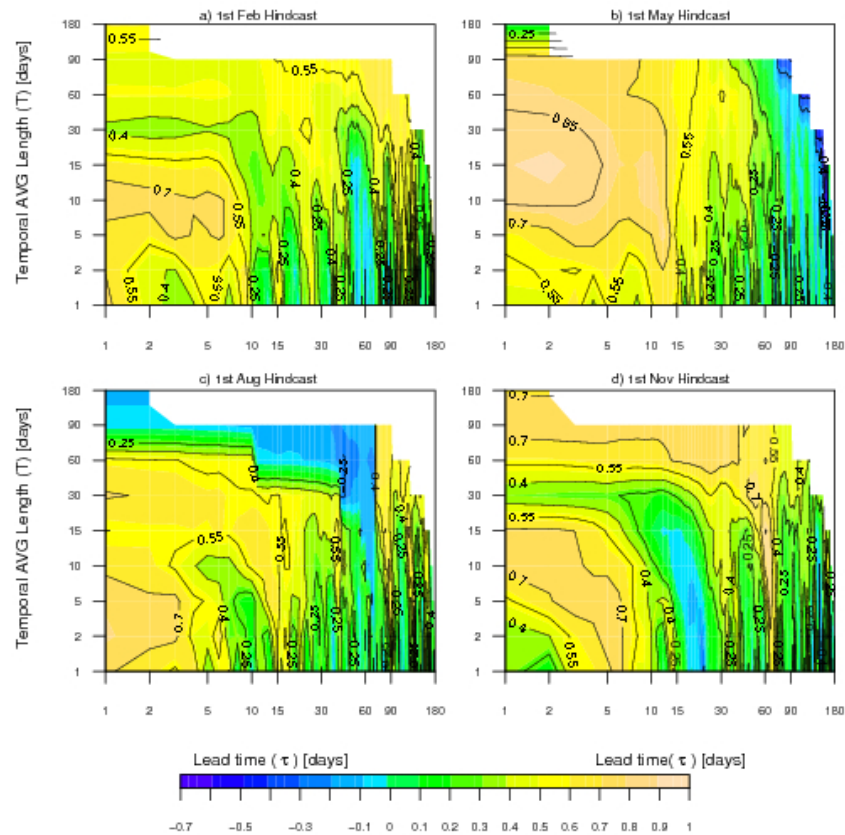
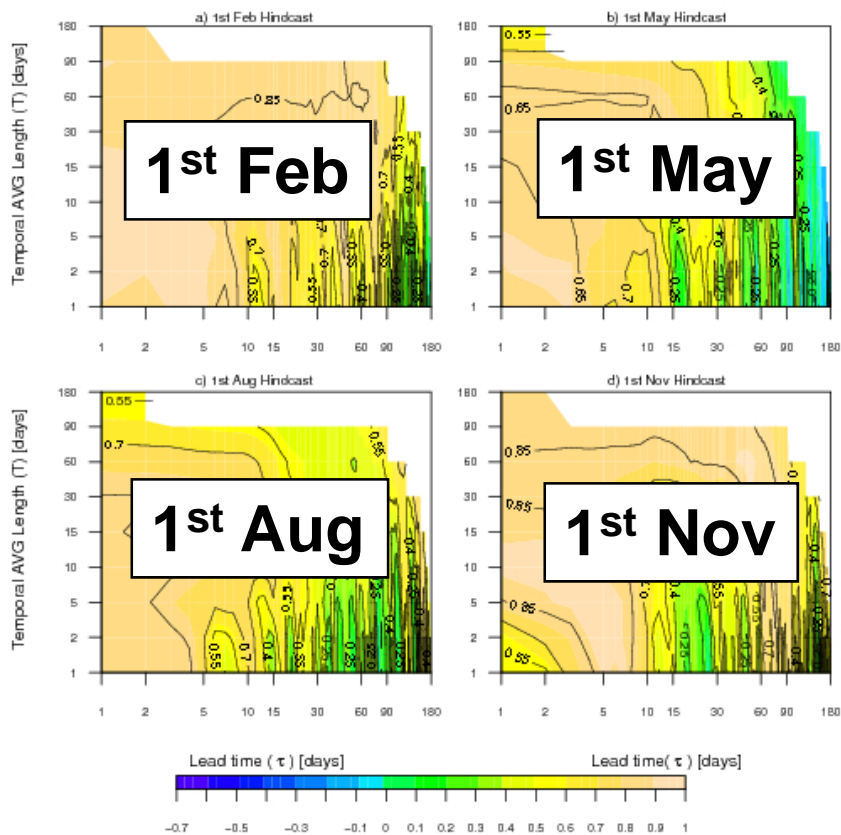
15 day  
forecast  
starting on  
day 15  
(forecast for  
weeks 2 – 4)



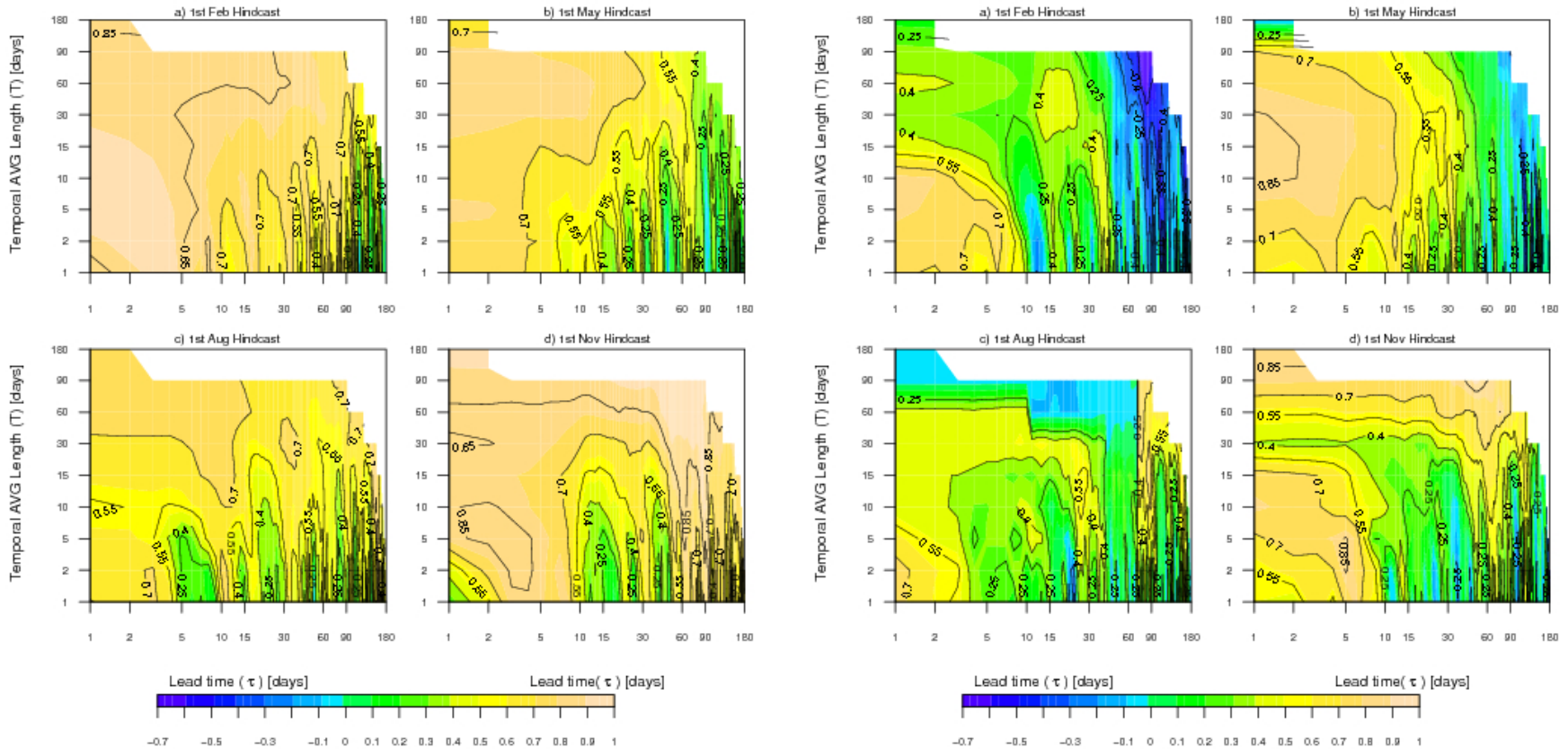


# 2 meter temperature

# Precipitation



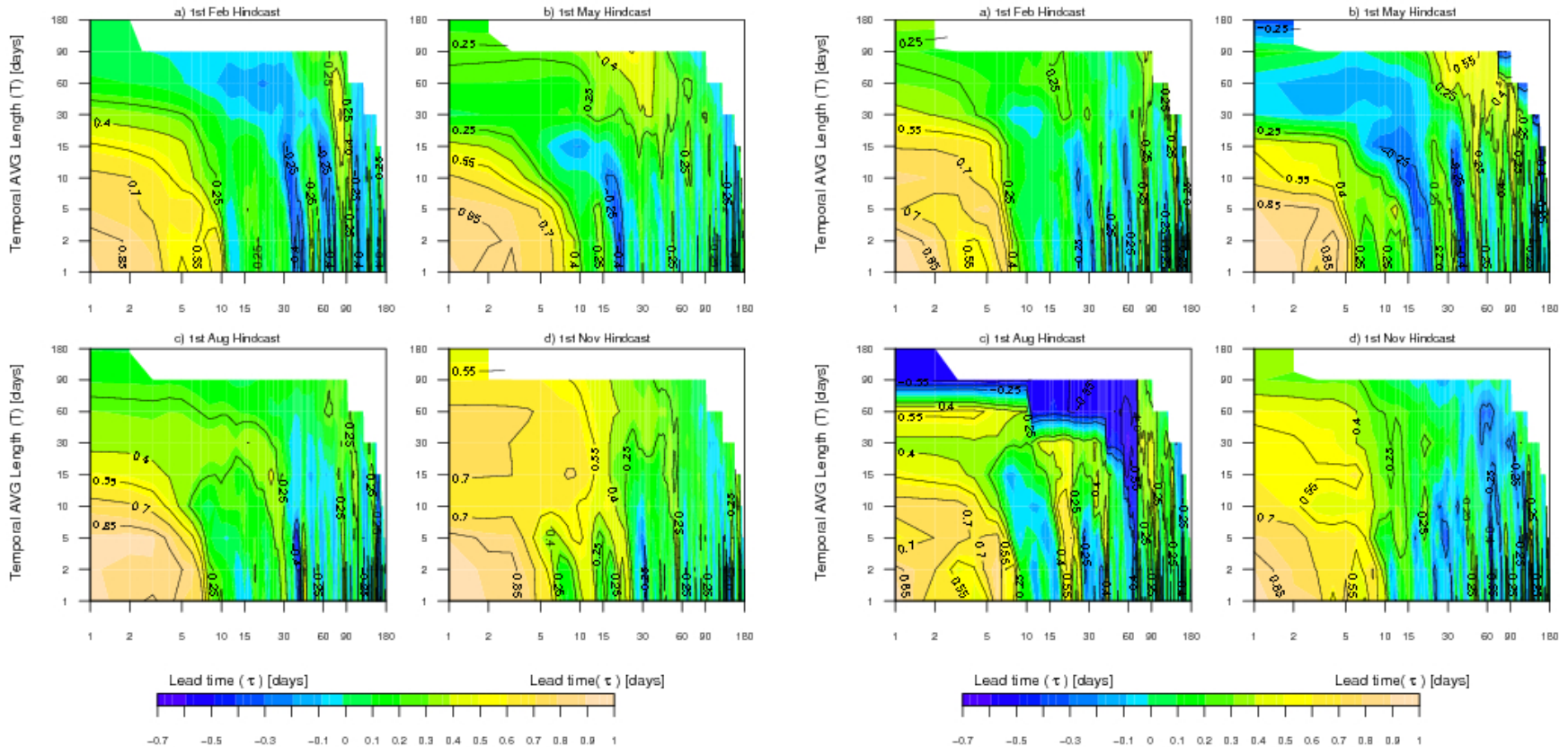
# Amazon 2m air temperature and precipitation from ECMWF, METEO FRANCE and UKMO



ECMWF  
METEO FRANCE  
UKMO

2 meter temperature      Precipitation

# Murray-Darling 2m air temperature and precipitation from ECMWF, METEO FRANCE and UKMO

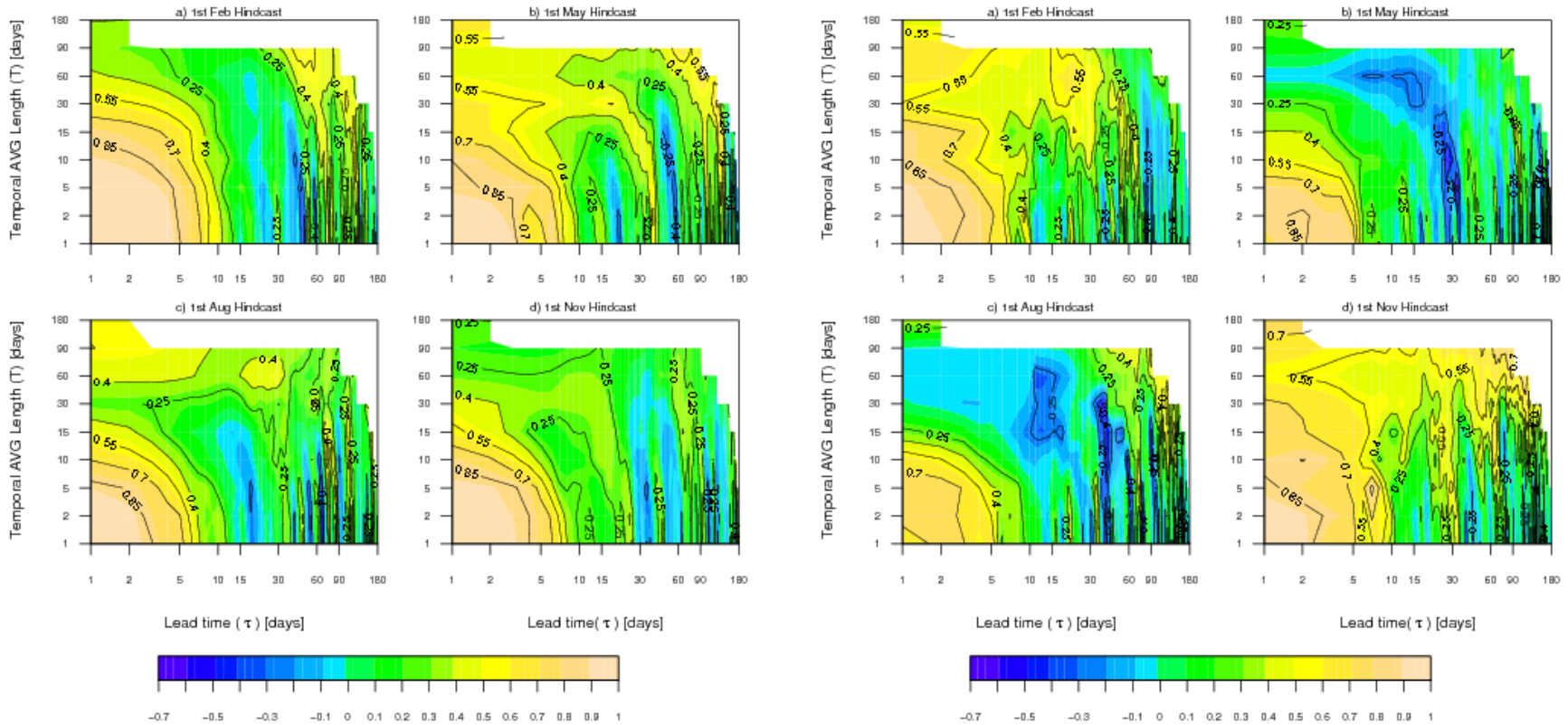


2 meter temperature

ECMWF  
METEO FRANCE  
UKMO

Precipitation

# Contiguous USA 2m air temperature and precipitation from ECMWF, METEO FRANCE and UKMO



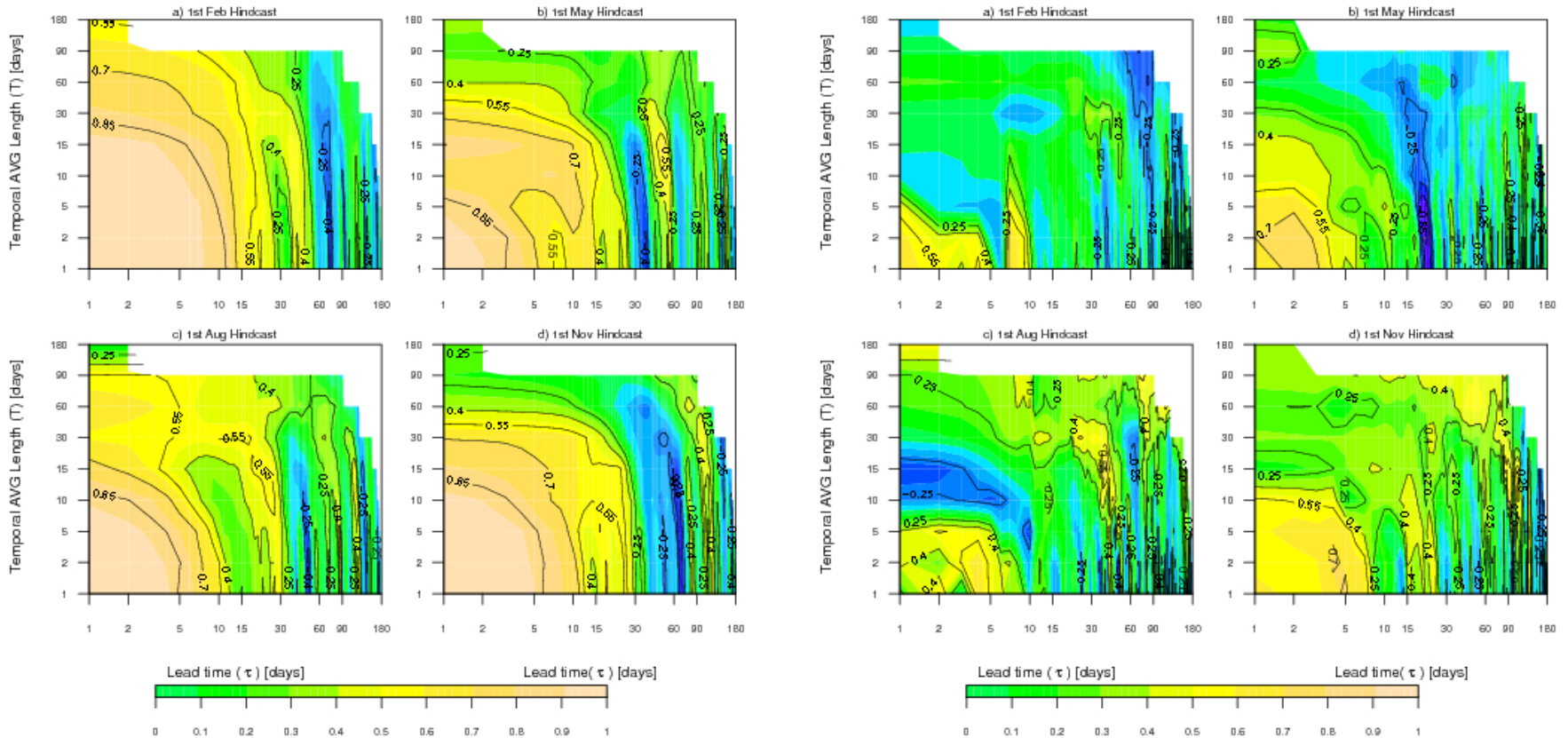
2 meter temperature

ECMWF  
METEO FRANCE  
UKMO

Precipitation



# Siberia (NEESPI) 2m air temperature and precipitation from ECMWF, METEO FRANCE and UKMO

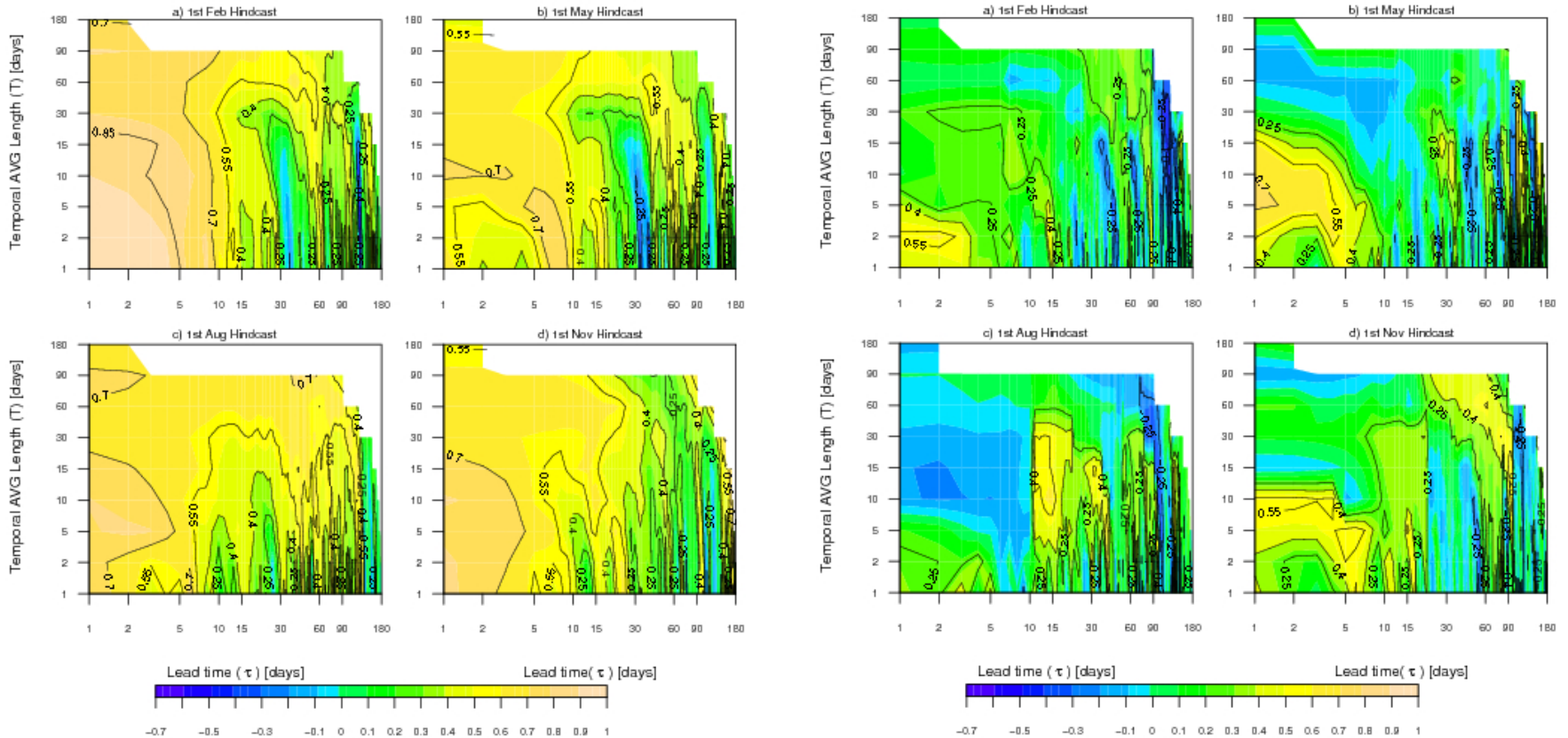


2 meter temperature

ECMWF  
METEO FRANCE  
UKMO

Precipitation

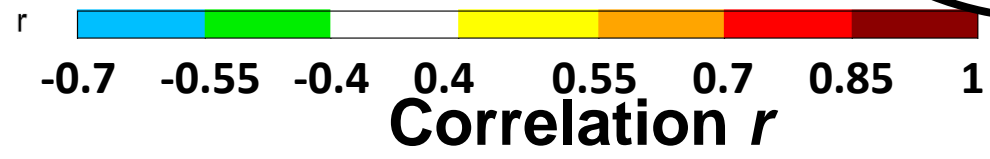
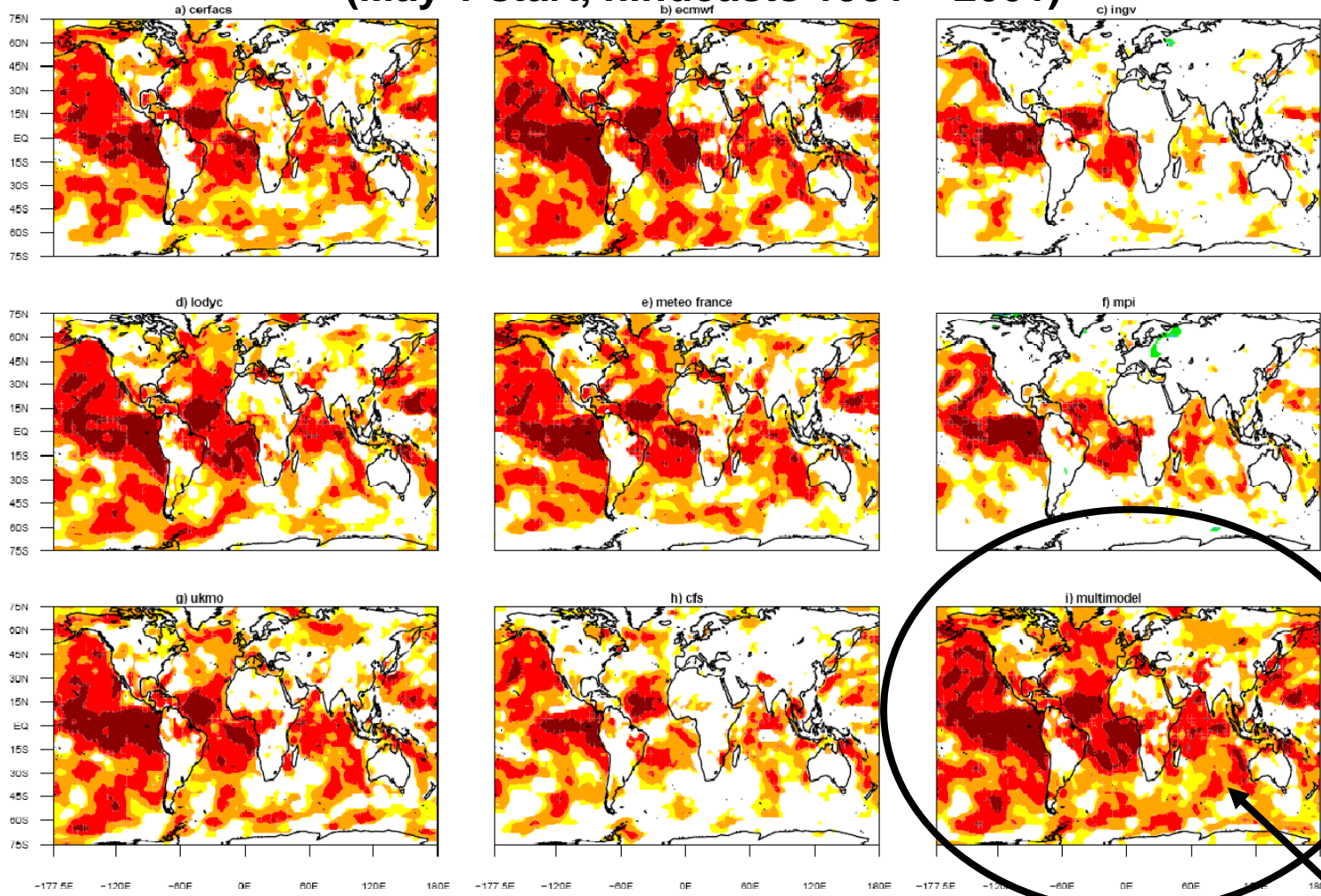
# West Africa 2m air temperature and precipitation from ECMWF, METEO FRANCE and UKMO



ECMWF  
METEO FRANCE  
UKMO

2 meter temperature      Precipitation

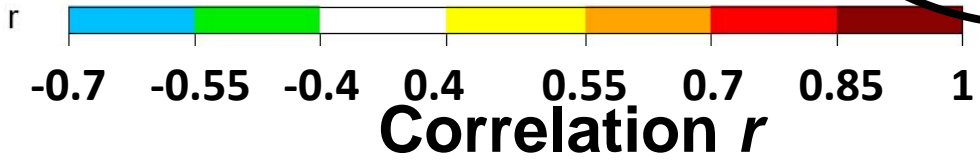
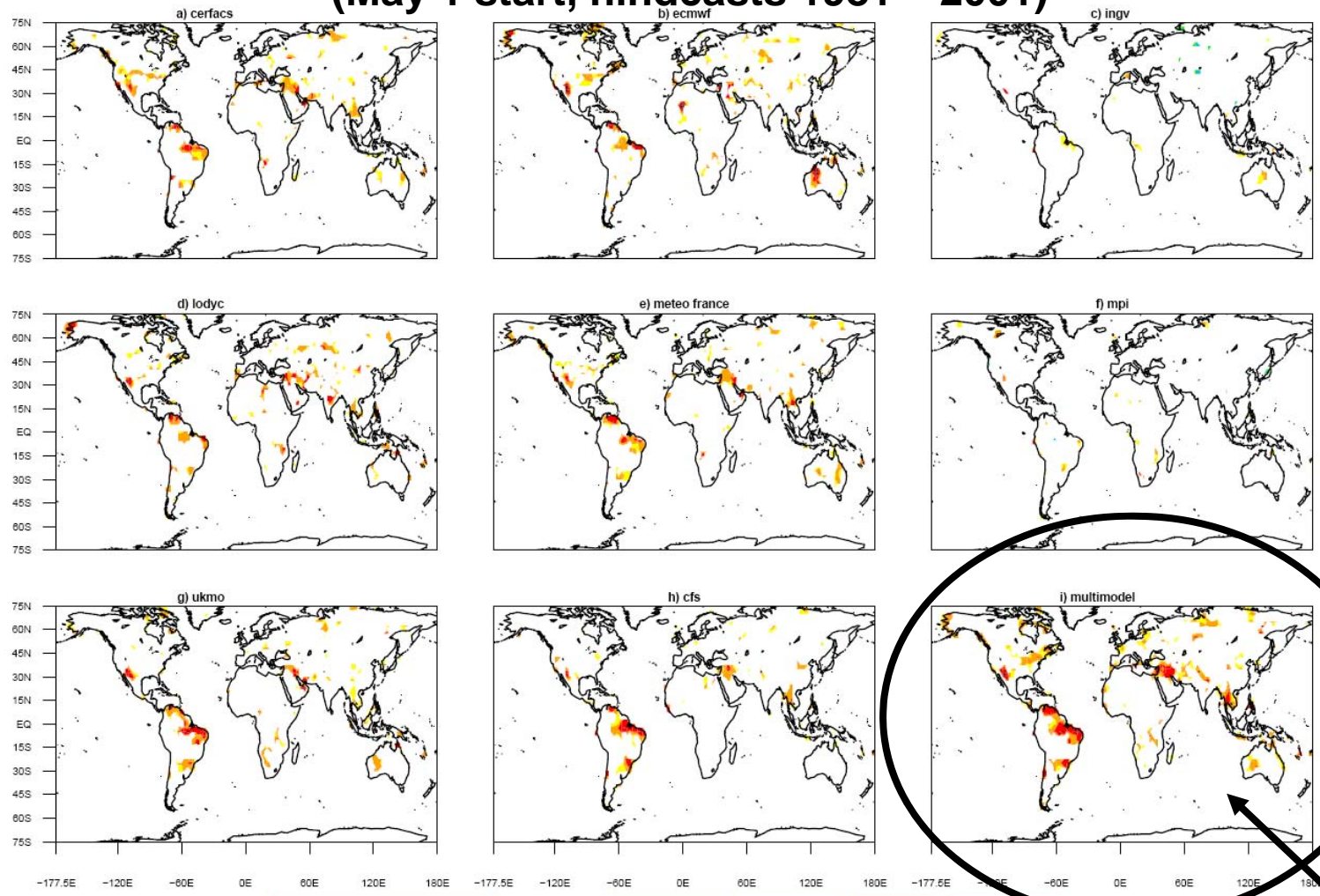
# Global predictability for Month 1 forecasts of 2-m temperature (DEMETER + CFS) (May 1 start, hindcasts 1981 – 2001)



Multi-model



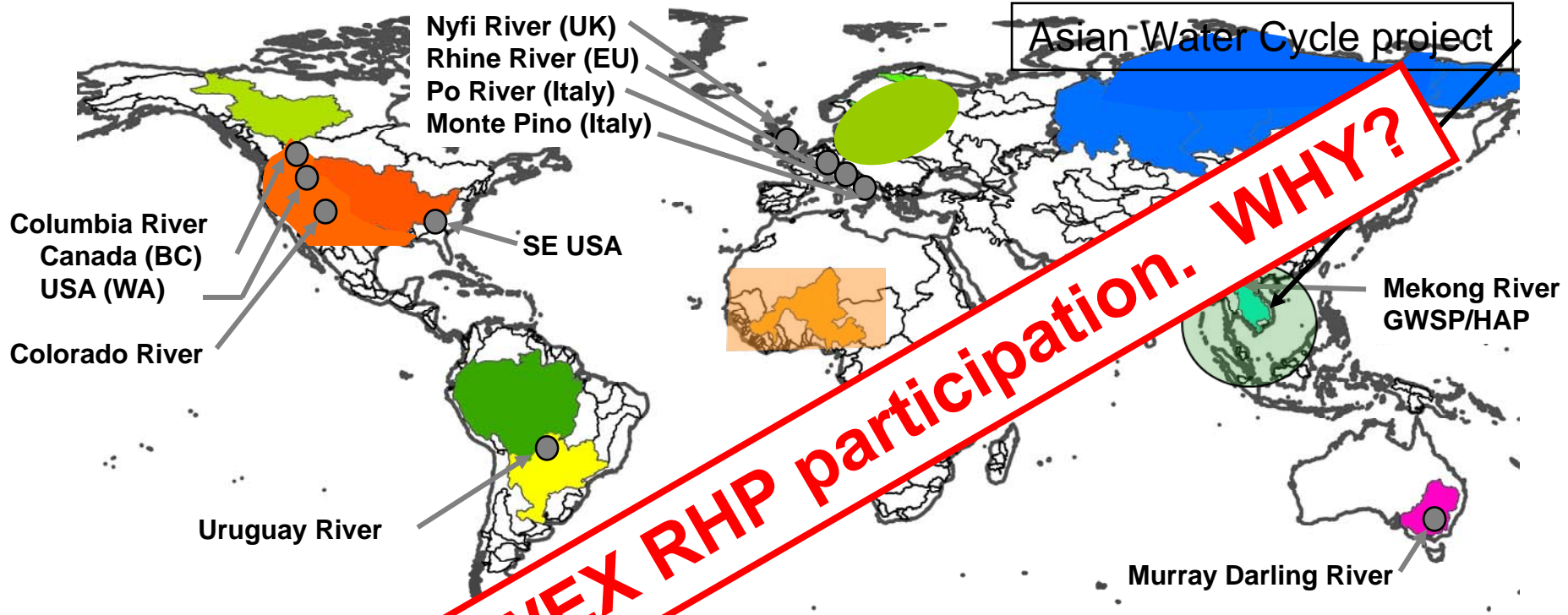
# Global predictability for Month 1 forecasts of precipitation (DEMETER + CFS) (May 1 start, hindcasts 1981 – 2001)



Multi-model



# Current and potential HAP/HAPEX Testbeds.



**No GEWEX RHP participation. WHY?**

- Need more GEWEX RHP Regional Hydrometeorology Project (RHP) participation
- Planning to develop collaborative activities with the Asian Water Cycle project and the African Water Cycle activities.

## ***Collaboration with HEPEX in 2009.***

HEPEX with co-sponsorship from HAP, THORPEX, Meteo-France and other groups organized the **Workshop on post-processing and downscaling of atmospheric ensemble forecasts for hydrologic applications** in Toulouse, France (15-18 June 2009).

The workshop focus was on scientific questions concerning how atmospheric prediction systems can be used for hydrologic streamflow applications and probabilistic quantitative precipitation forecasting. Special attention would be given to how to produce skillful and reliable ensemble forcing for hydrologic applications using both single-value and ensemble atmospheric forecasts.

## ***Collaboration with HEPEX in 2009.***

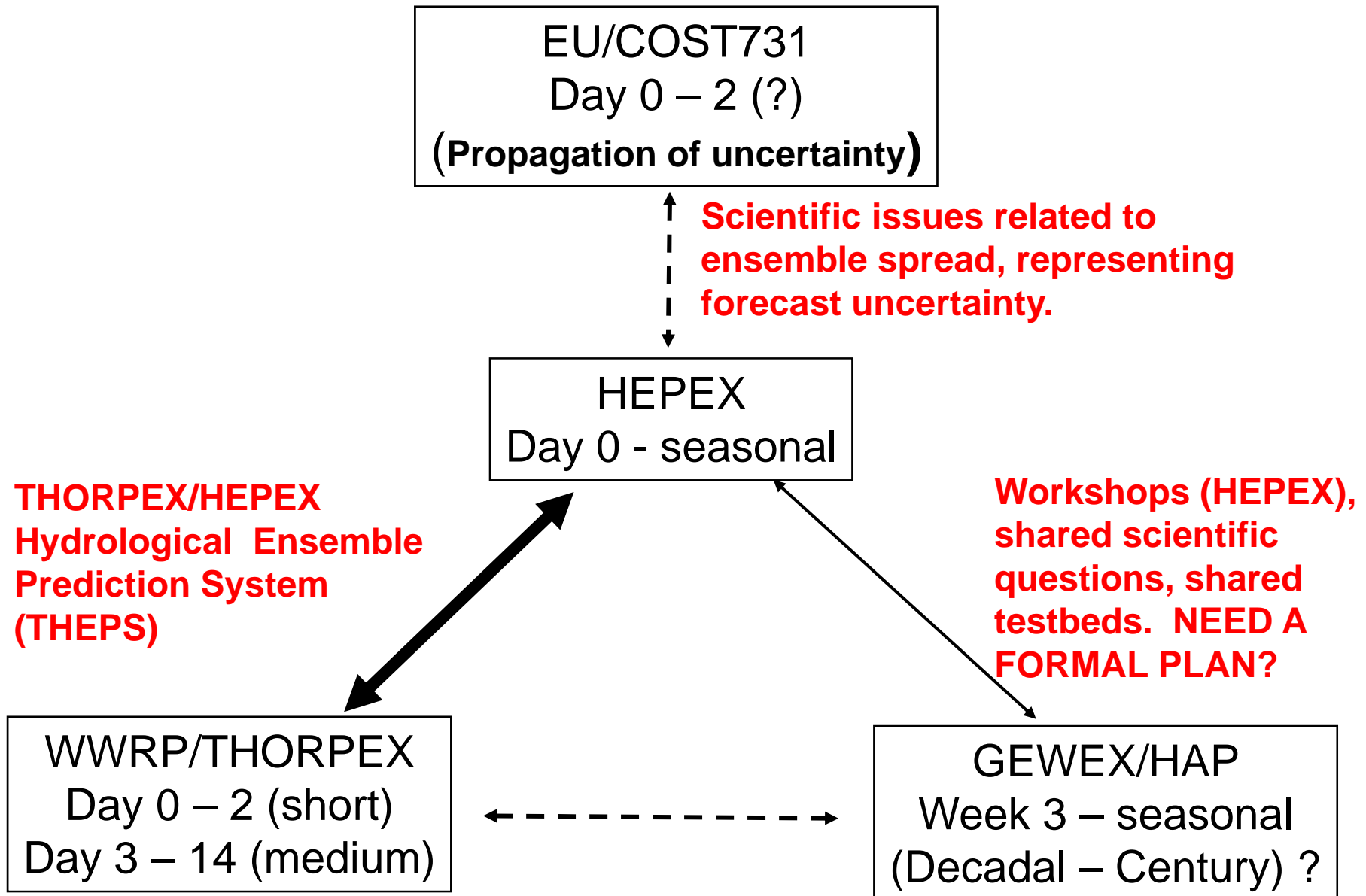
### **Workshop on post-processing and downscaling of atmospheric ensemble forecasts for hydrologic applications**

More than 100 participants from 21 different countries and several International and European organizations were present; held jointly with the 2<sup>nd</sup> COST731 (Propagation of uncertainty in advanced meteo-hydrological forecast systems) workshop.

The workshop included researchers from the fields of hydrology and meteorology, operational hydrological and meteorological forecasters; and, end users from reservoir operations and electric power utilities.

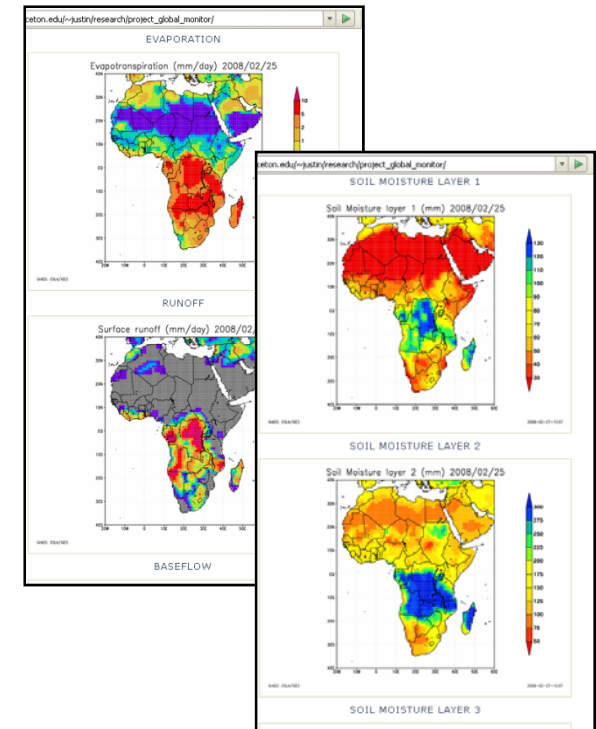
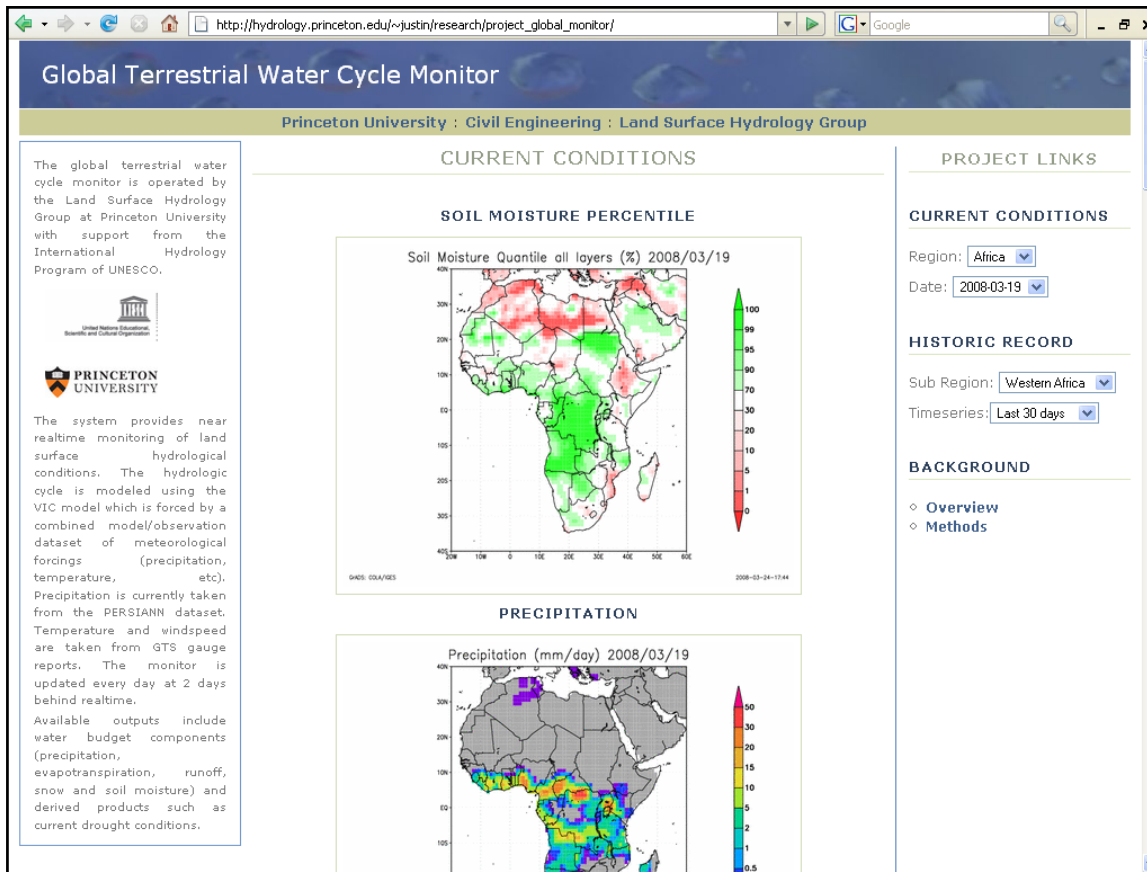
Three WG (short term (0 – 2 days); medium (3 – 14 days); and long term (>week 2 to inter-annual) proposed scientific issues and future activities. HAP's activities are consistent with long range WG.

# Connections among international forecasting activities



# End-to-End test-bed demonstration of HAP **water cycle and drought monitoring** contributions to GEO

<http://hydrology.princeton.edu/monitor>



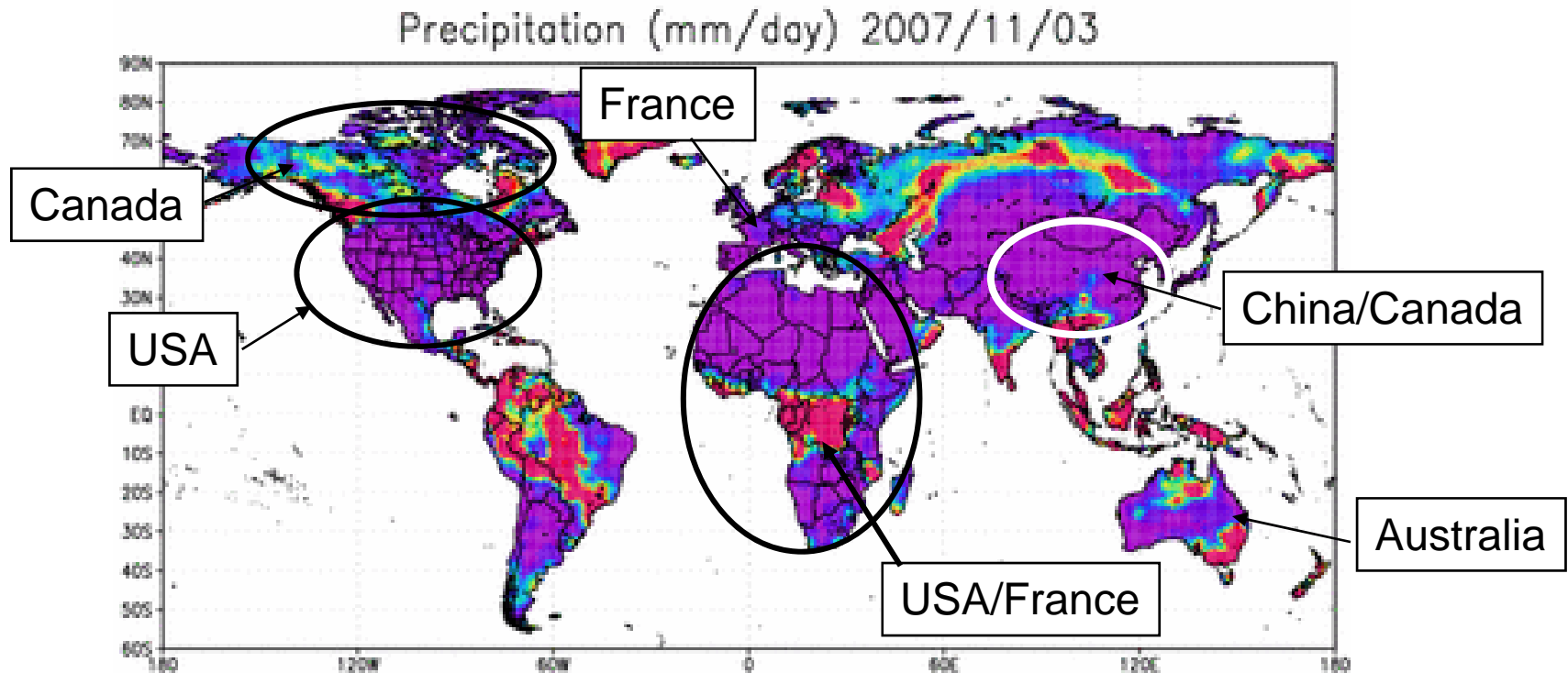
Terrestrial water cycle (evaporation, runoff, soil moisture, snow) simulated using the VIC land surface model, forced by observed and remotely sensed precipitation and temperature

Background forcing data sets:

1. Multiple LSM forcing data sets (with GMPP/GLASS, IGBP)
2. Multiple precipitation data sets. (with GRP)

Multiple LSM that will:


1. Provide LSM and RS based water cycle monitoring (GWSP, GEO)
2. Provide initial conditions for hydrologic forecasts (THEPS, HAP)






# End-to-End test-bed demonstration of hydrological monitoring and seasonal forecasting contribution to GEO and THEPS

**Drought monitoring and seasonal forecast system over Africa based remote sensing data, land surface modeling (monitoring) and on downscaled and bias corrected precipitation and temperature forecasts from NOAA/CFS (see poster next week: Sheffield, Luo and Wood)**



## Development of a Real Time Hydrologic Monitoring and Seasonal Forecast System for Drought Assessment over Africa

Justin Sheffield, Lifeng Luo and Eric F. Wood, Princeton University



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### INTRODUCTION

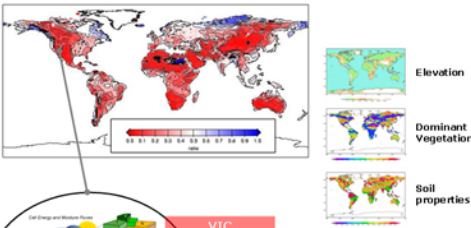
Drought is a pervasive natural hazard that has large economic and humanitarian impacts. It can cover extensive areas and last from months to multiple years and may have major impacts on agriculture, water supply and the environment. While forecasts and real-time assessments of drought offer the potential to mitigate the impacts, our ability to predict the development and recession of drought is generally insufficient. Part of the reason for this is the lack of detailed data about its large scale spatial and temporal variability. In regions without dense in-situ observations, remote sensing and modeling approaches are the only viable alternative. For drought, precipitation is a key variable, and remotely sensed precipitation products offer a potential source of data both at large scales and in real time.

### THE AFRICAN DROUGHT MONITOR AND SEASONAL FORECAST SYSTEM

Here we present results from our experimental real time African drought monitoring and seasonal forecast system (<http://hydrology.princeton.edu/monitor>) which relies heavily on remote sensing products to drive a macroscale hydrologic model. This system tracks the development and dissipation of drought in terms of soil moisture and other water budget variables against a 50-yr (1950-2000) climatology. For real time monitoring, we rely on a combination of available observations, remote sensing (e.g. PERSIANN) and data from atmospheric analyses (e.g. GDAS), to provide precipitation and other forcings. We show results from the historic climatology (1950-2000) of drought, and some real time results in the context of uncertainty in the forcing data. Recently a seasonal forecast component has been implemented based on our existing U.S. system. The system uses seasonal global climate forecasts from the NCEP Climate Forecast System (CFS) and merges them with observed climatology in a Bayesian framework to produce ensemble atmospheric forcings that better capture the uncertainties. At the same time, the system bias corrects and downscales the monthly CFS data to scales more appropriate for hydrologic modeling. We show some initial African seasonal (up to 6-month lead) hydrologic forecast results.

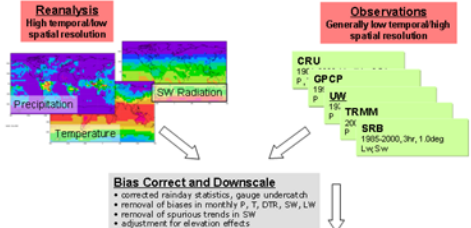
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### Global Hydrological Modeling



**VIC and Surface**

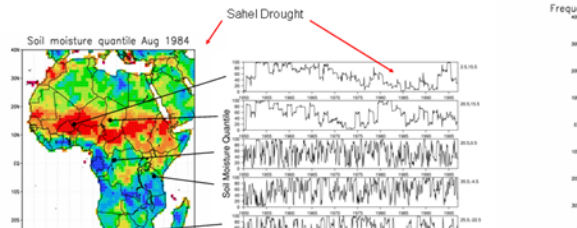
### Global Meteorological Forcing Dataset



**Bias Correct and Downscale**

- corrected rainy statistics, gauge undercatch
- removal of biases in monthly P, T, DTR, SW, LW
- removal of spurious trends in SW
- adjustment for elevation effects
- downscale in time and space

### Historic African Drought 1950-2000



Sahel Drought

Soil Moisture Quantile

## ***Collaboration with HEPEX*** (implementation and execution)

HAP interacts closely with the Hydrological Ensemble Predictions Experiment (HEPEX). HEPEX involves the scientific issues related to hydrologic ensemble forecasts at the time frame of a few hours out to 2 weeks that stands alone as a self-organizing activity, and has links into Thorpex, and through THEPS will formalize activities. HAP focuses on seasonal ensemble hydrological predictions and should develop a similar EPS plan.

The linkage between HAP and HEPEX is important because

- (i) 2-week forecasts control the skill and uncertainty of the hydrologic initial conditions for periods beyond 2 weeks.

- (ii) statistical post processing issues are the same for both weather and climate forecast periods.

- (iii) need HEPEX/HAP to address the transition of forecasts from weather to climate time scales; the "seamless" approach to weather and climate prediction from a users perspective.



## ***Collaboration with HEPEX (2009/2010). (execution)***

HAP and HEPEX co-sponsored (with several other organizations) a workshop on **Post-Processing and Downscaling of Atmospheric Ensemble Forecasts for Hydrologic Applications**. This was hosted by Meteo-France in Toulouse, **June 15-18, 2009**. As a follow-up, HAP and HEPEX will propose seasonal forecasting experiments. Plans will be developed in the 2009-2010 timeframe.

HAP and HEPEX plan to develop a **test-bed project** on Ensemble Representations of Rainfall Observation and Analysis Uncertainty, with a related workshop in the 2010 timeframe.

HAP and HEPEX expect to sponsor a **Hydrologic Ensemble Forecast User's workshop in 2010** where example hydrologic ensemble forecast applications and potential applications can be discussed with the user community

## ***Seasonal Hydrologic Predictions. (execution)***

HAP will continue its activity to generate a global (land) hydrologic re-forecasts (hindcasts) based on NOAA and DEMETER/EuroSIP seasonal forecasts. **2009:** Evaluation of seasonal forecast skill using DEMETER and CFS **(completed)**. **2010:** Hindcasts will be generated for all the current RHP regions. RHPs should identify testbed activities, and groups to evaluate the hydrologic ensemble forecasts. HAP will expand its collaboration with HEPEX and THORPEX.

## ***Contribution to WGSP/WGSP, GWSP***

## ***Establish and archive of seasonal forecast model hindcasts (challenge)***

Archives exists at a few locations but are incomplete with regard to models from major centers, and GEWEX research isn't using them in either CEOP or GMPP. Can the equivalent of TIGGE be developed and better promoted for research? ***Contribution to WGSP/WGSP, GWSP***

## ***Collaboration with GMPP on GLACE-2 (execution; completion 2009)***

HAP seasonal forecasting working group members will continue to participate in the GMPP GLACE-2 experiment whose goal is to assess the role of using soil moisture initial conditions to improve seasonal forecasting.

## ***Global Monitoring of the water cycle (snow, soil wetness) (implementation)***

HAP will try to work with other GEWEX activities and weather centers to obtain real-time data that will allow for such estimation. GEWEX needs to help to facilitate this. Perhaps the TIGGE archive can be used?

***Contribution to WGSP, Thorpex/WWRP, GEO and GWSP***

***“We note the HAP theme leader’s ambitions to develop stronger links with the RHPs. This should be a priority for the years to come.” (Rapporteur’s Comments on CEOP, 20 January 2009)***

## ***Develop new HAP test-beds in the RHP regions (challenge)***

HAP would like to establish test-beds in the RHP regions, but needs the RHP coordinators to help identify collaborators. CEOP management needs to encourage the RHP coordinators to identify these testbeds so the goals of GEWEX can be met. **The SSG identified this as a priority but it needs help from CEOP leadership and IGPO..**

***Contribution to WGSP/COPES, GWSP***

## ***Collaboration with IAHS (WG on Hydrometeorologic Projects) (challenge)***

Complete plans to collaborate with WGHP on applying GEWEX science and data sets to the international Prediction of Ungauged Basins (PUB) and hydrologic model calibration under MOPEX. PUB has just changed leadership (to G Bloeschl).

**“concerns .. that HAP has insufficient membership to carry out its responsibilities...more accessible to the hydrologic community... collaborate with GRP, WMO Hydrology Department, ..(activities in) THORPEX and the UNESCO’s IHP G-WADI activity.”**

## **Entrain collaboration with GEWEX scientists for HAP WGs (challenge)**

HAP needs to further develop and encourage scientists interested in HAP science issues to participate. Funding to participate is an issue, separation of hydrological services and meteorological services in most countries, etc.

A potential strategy may be as follows:

In water and energy cycle monitoring, HAP currently has established ties with UNESCO and G-WADI for African drought monitoring. Discussions have started with WMO and GEO for drought. HAP needs help from IGPO and CEOP leadership to encourage RHP-based hydrological services to become involved. There is potential collaborations with GMPP and GRP that need to be developed and WGs populated.

POTENTIAL ACTION ITEM: IGPO and CEOP host a workshop on the accomplishments and potential activities of RHPs to GEWEX CEOP goals..

**“concerns .. that HAP has insufficient membership to carry out its responsibilities...more accessible to the hydrologic community... collaborate with GRP, WMO Hydrology Department, ..(activities in) THORPEX and the UNESCO’s IHP G-WADI activity.”**

In seasonal prediction, draw on HEPEX participants to form WGs around specific experiments that test/evaluate seasonal hydrological forecasts, much like GLACE-2. This suggests that HAP develop collaborations with GMPP. Initial discussion with M Best have been initiated.

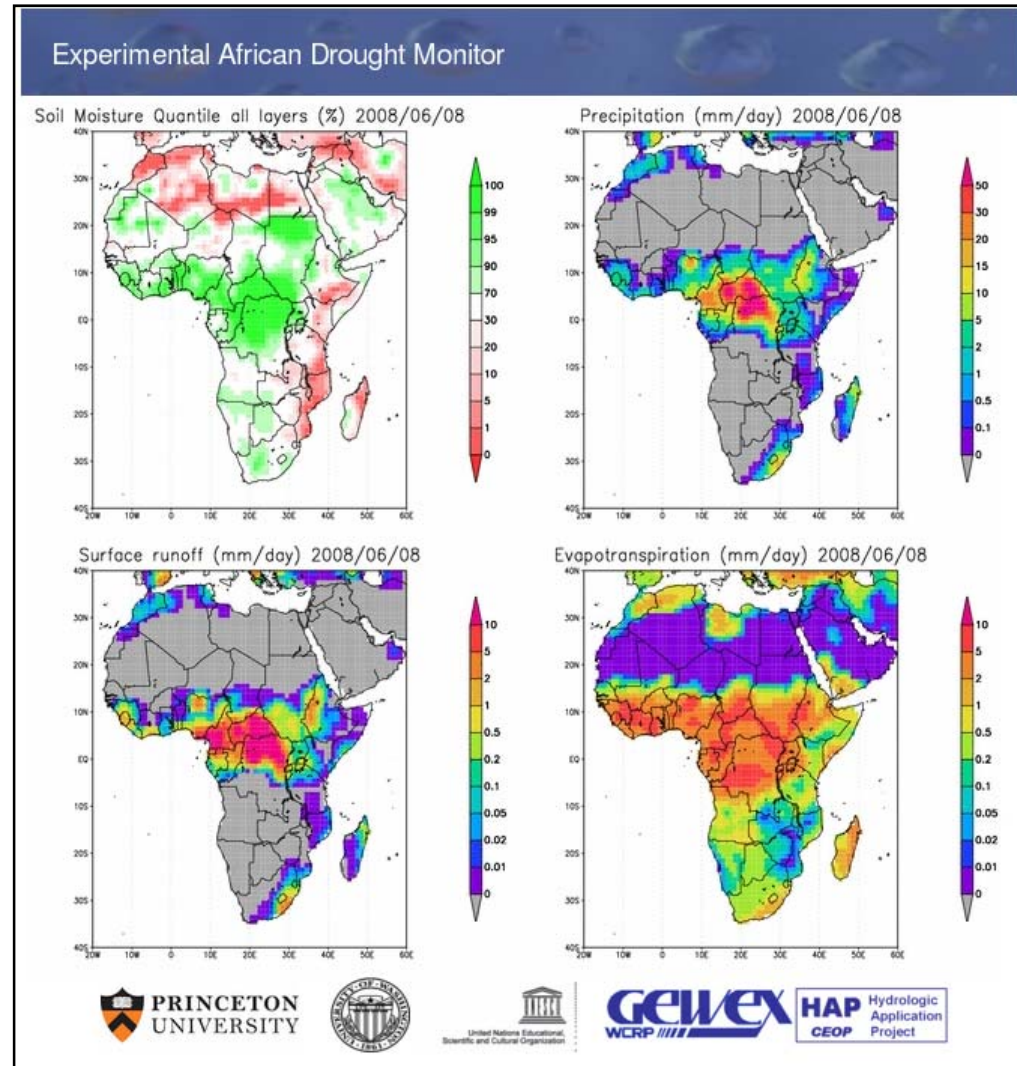
In decadal to century projections (action item from the 21st Session of the GEWEX Scientific Steering Group), form a WG related to bias correcting and downscaling IPCC AR4 climate scenarios. Some action items from the 21<sup>st</sup> SSG have already been started (e.g. HAP has already analyzed 21<sup>st</sup> C drought projections.)

## *Hydrologic nowcasting and drought monitoring.*

**Goal:** To develop an integrated Drought Monitoring and Prediction System (DMAPS) that utilizes NASA-supported science and satellite data products that are central to GEWEX and to HAP's goal of providing GEWEX data and science products to water resources managers and related users.

**Collaborators:** UNESCO's International Hydrology Programme (IHP)

**Data Product:** Developed "Africa Drought Monitoring" (ADM) system, which runs in real-time at Princeton University.





**“User community urgently requires scientific guidance to support the management of hydrological extremes (floods and droughts) under scenarios of climate change”**

## **HAP Activities in 2009:**

- future drought scenarios using AR4 projections
- initiated downscaling of AR4 projections, which should be completed in 2010.

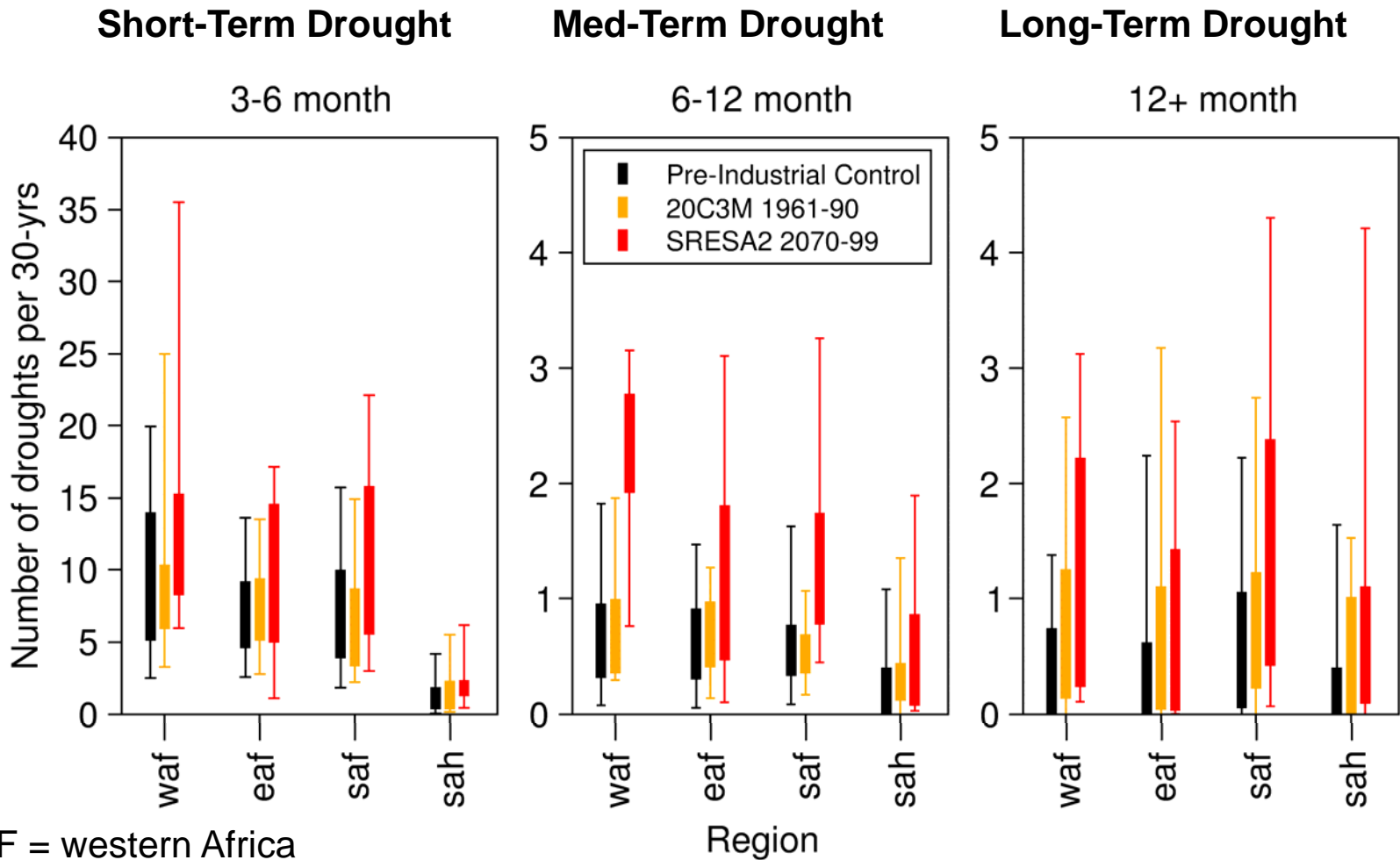
## **Potential future activities** (partnering with GWSP?)

- water resources adaptation study. Propose that HAP organize a workshop on “climate change adaptation in hydrology and water resources”

POTENTIAL ACTION ITEM: CEOP needs to develop requirements for archived IPCC AR5 model runs (time resolution, hydrologic variables). This is critical for any projection analysis of heavy precipitation and flooding, which requires archiving precipitation data at time resolutions of 3-hrly or finer.



## 21<sup>st</sup> C drought projections over Africa



WAF = western Africa  
 EAF = eastern Africa  
 SAF = southern Africa  
 SAH = Saharan region

Soil moisture data taken from IPCC-4AR GCM future projections. Sheffield and Wood, *Climate Dynamics*, 2008

# Downscaling, bias correcting AR4, PCM1 A2 scenario over NEESPI as a contribution to WCRP and IPCC

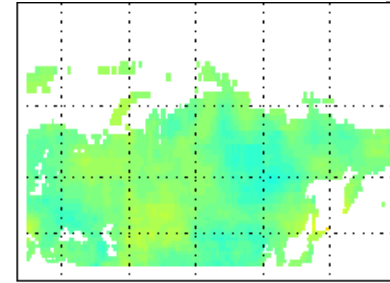
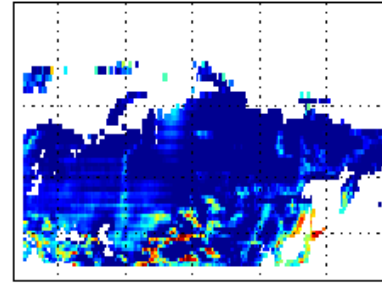
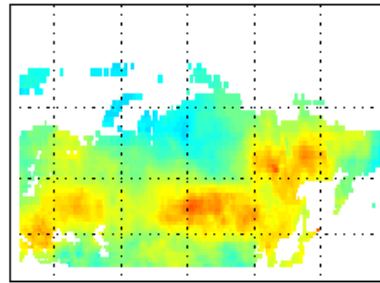
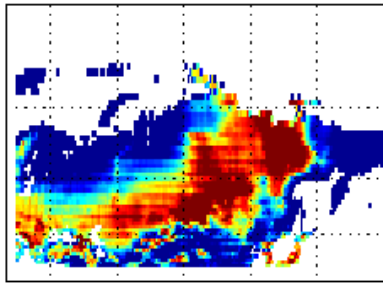
## January Temperature July

Model-Obs

Correction-Obs

Model-Obs

Correction-Obs

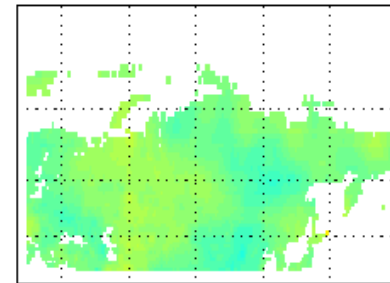
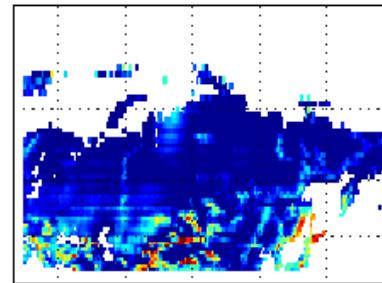
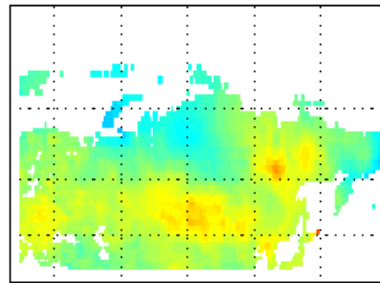
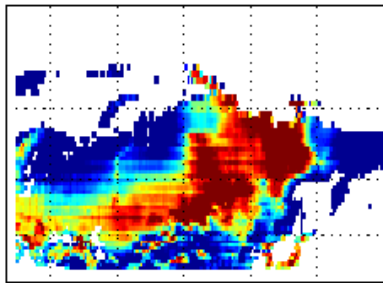
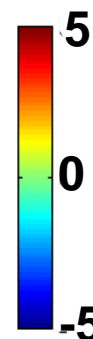


MODEL - OBS (50%)

EDCDFm - OBS

MODEL - OBS (50%)

EDCDFm - OBS

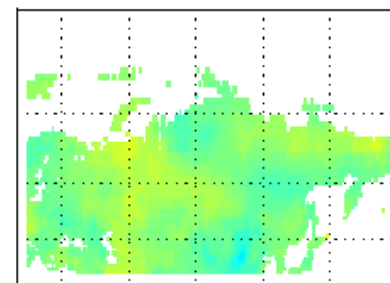
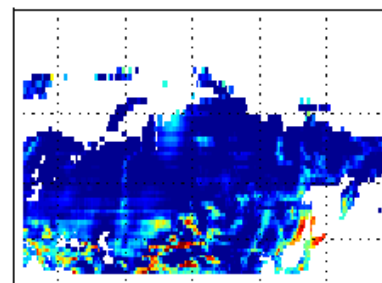
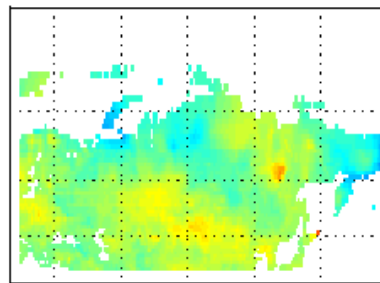
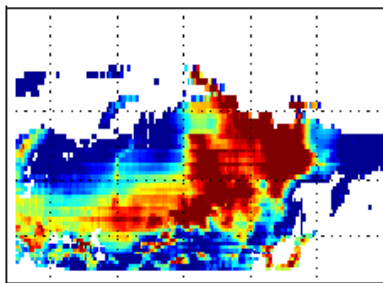


MODEL - OBS (75%)

EDCDFm - OBS

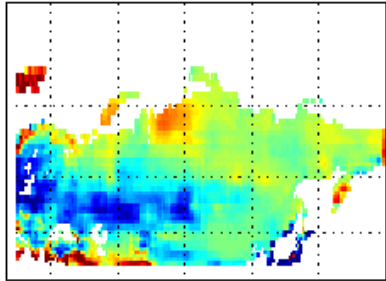
MODEL - OBS (75%)

EDCDFm - OBS



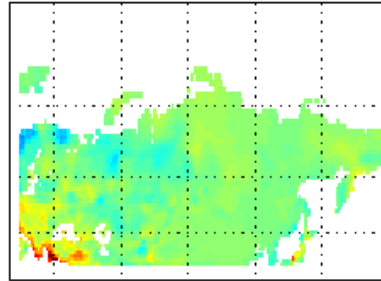
## January Precipitation July

**Model-Obs**



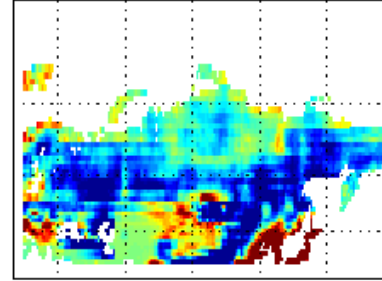
MODEL - OBS (50%)

**Correction-Obs**



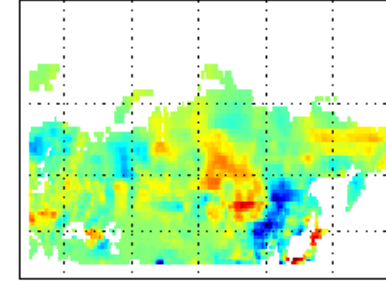
EDCDFm - OBS

**Model-Obs**

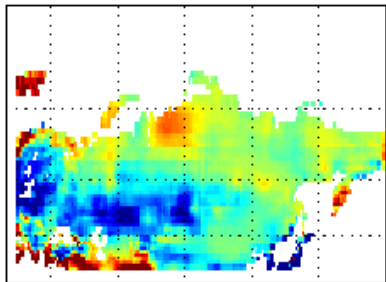


MODEL - OBS (50%)

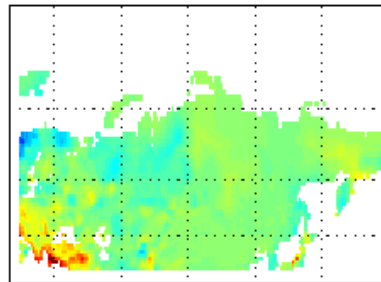
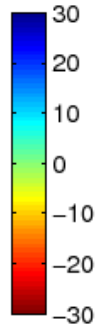
**Correction-Obs**



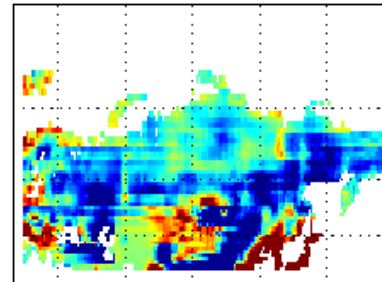
EDCDFm - OBS



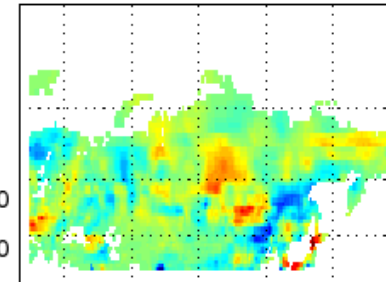
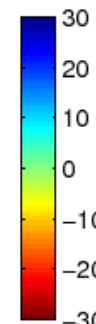
MODEL - OBS (75%)



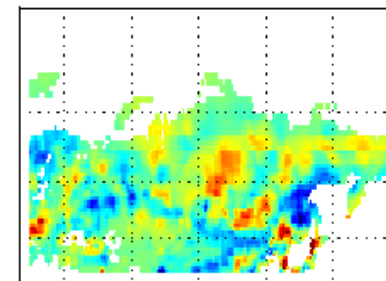
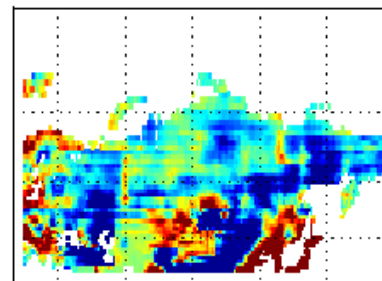
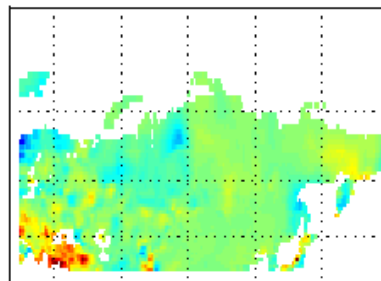
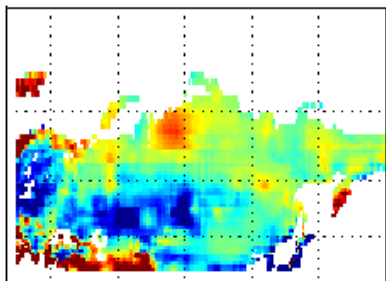
EDCDFm - OBS



MODEL - OBS (75%)



EDCDFm - OBS



**“Organize a workshop under the GEWEX/Global Water System Project (GWSP) umbrella to assess existing GEWEX activities and provide suggestions for future regional GEWEX initiatives specifically targeted on water availability problems”**

GWSP is undergoing a change in focus (Dennis Lettenmaier can provide details) and has a new executive director, and (??) a new focus on water governance.

ACTION ITEM. Contact C Vorosmarty (GWSP SSG) about the potential for such a workshop. (Who would participate from CEOP? What role would RHP play? Could it be part of RHP workshop suggested earlier?)

**“GEWEX/CLIC) will co-sponsor (a) workshop...on high latitude and cold region hydrology and land surface models”**

NEESPI is planning a NEESPI-PILPS activity to begin in 2010. GEWEX/CEOP needs to provide guidance regarding whether the proposed workshop should be part of the NEESPI PILPS activity, a NEESPI PILPS “kick-off” workshop, or a separate workshop.

## ***Contributions to the GEWEX Milestones.***

HAP will contribute to GEWEX objectives through “Improve the predictive capability for key water and energy cycle variables....and determine the geographical and seasonal characteristics over land areas” and “...demonstrating the value of GEWEX research” to operational hydrometeorological services.

***Contribution to WGSP, Thorpex/WWRP, GEO and GWSP***