Introduction of CIESS and Potential for Seasonal Hydrological Forecast in Texas

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THE UNIVERSITY OF TEXAS AT AUSTIN CIESS CENTER FOR INTEGRATED EARTH SYSTEM SCIENCE

THE UNIVERSITY OF TEXAS AT AUSTIN JACKSON SCHOOL OF GEOSCIENCES

1st Water Forum, Austin, Texas, 13 February, 2012

Center for Integrated Earth System Science

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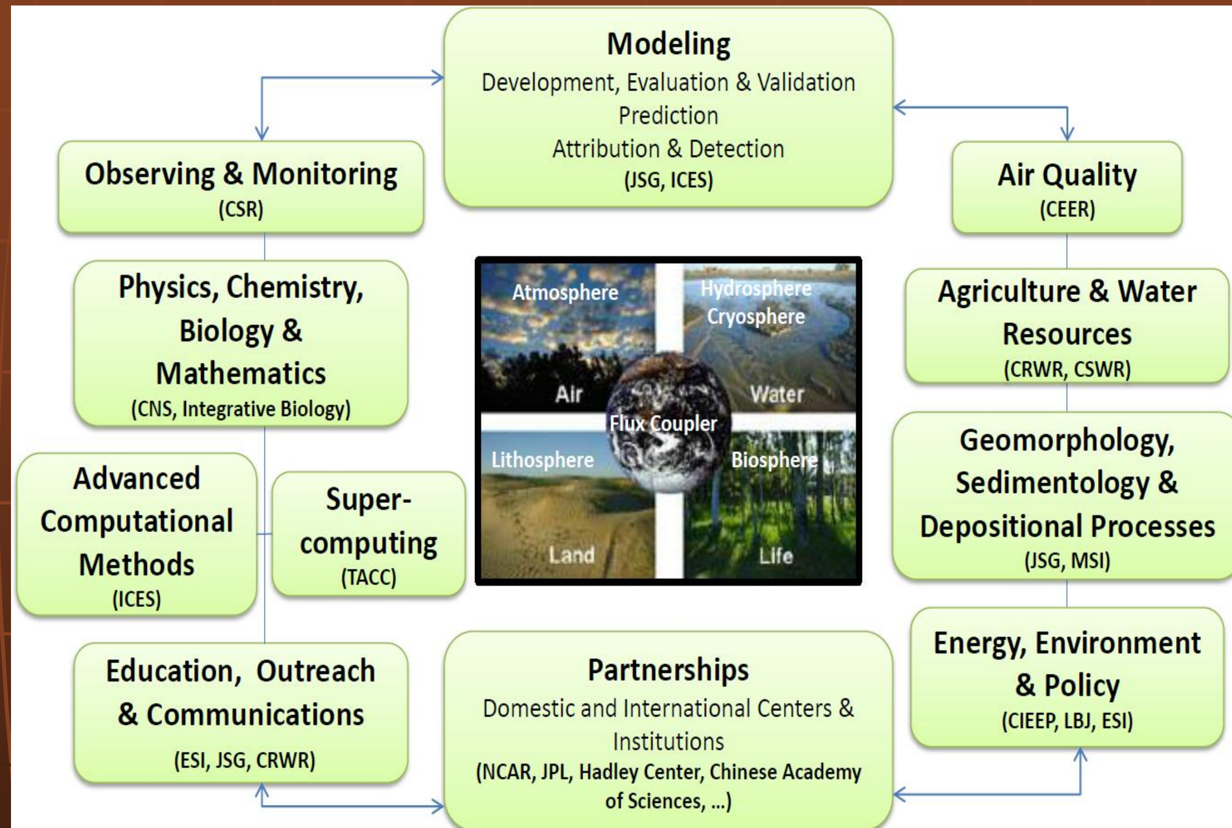
CIESS
CENTER FOR INTEGRATED EARTH SYSTEM SCIENCE

- Formed in August 2011
- Director: Liang Yang
- Associate Director: David Maidment
- A cooperative effort between



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Cockrell School of Engineering

http://www.jsg.utexas.edu/ciess

Center for Integrated Earth System Science

Integrate UT's expertise in geosciences, engineering, technology, observations, and modeling;

Promote wide ranging national and international collaborations;

Seek a deeper understanding of the physical, chemical, biological, and human interactions that determine the past, present, and future states of the Earth;

Place a strong emphasis on the societal impacts of research in earth system science; and

Provide a fundamental basis for understanding the world in which we live and seek sustainability.

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http://www.geo.utexas.edu/ciess

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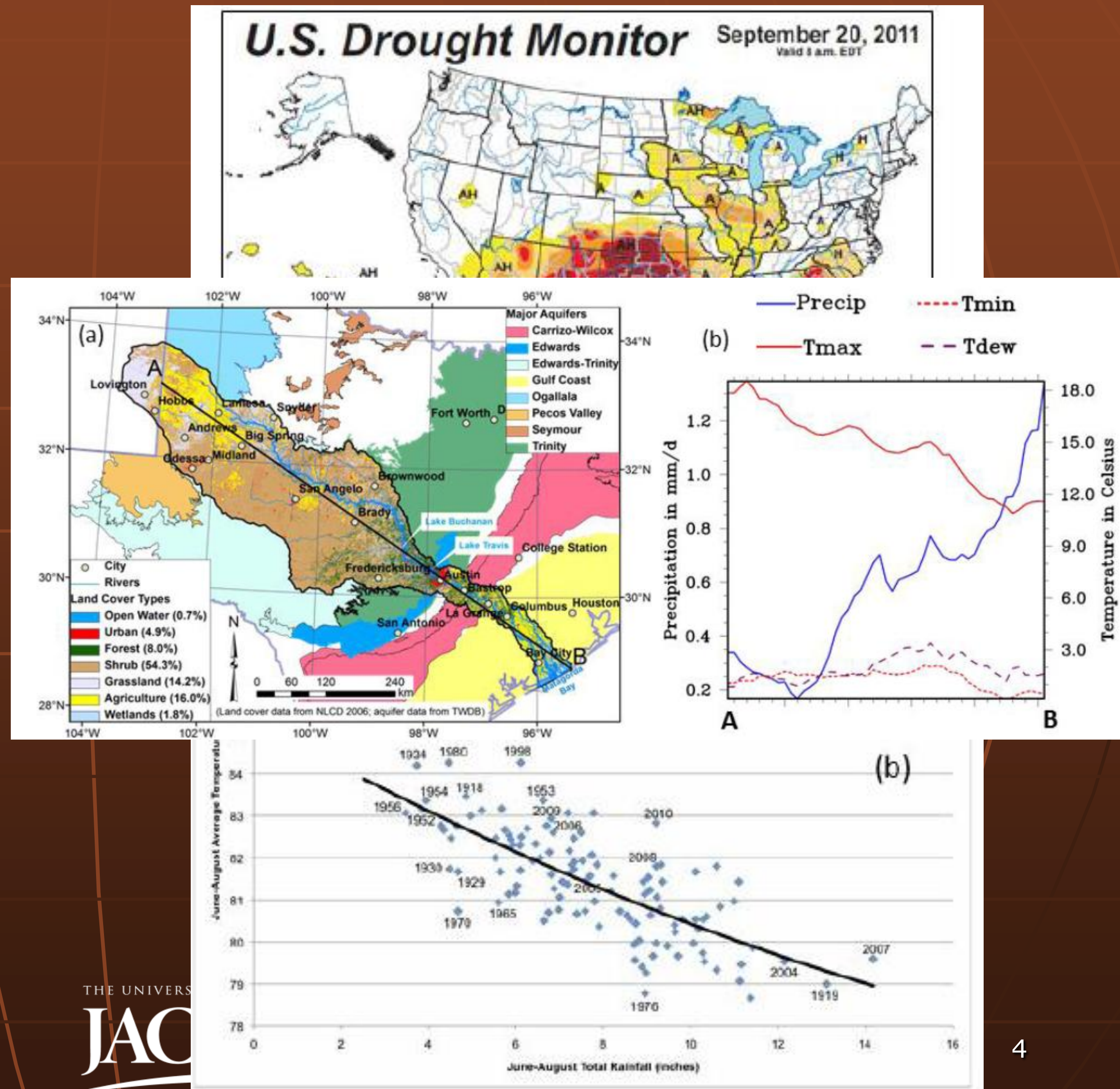
Water Sustainability and Climate

- CIESS submitted an NSF WSC proposal in October 2011.
- Proposal Title: **Water ARTS** (**A**daptability, **R**esilience, **T**ransformability, and **S**ustainability) in Texas’ Water Systems in the Face of Changing Climate, Land Use, and Human Demands.
- PI: Yang
- Co-PIs: Maidment, Eaton, Hendrickson, Kahlor
- Senior personnel: 12



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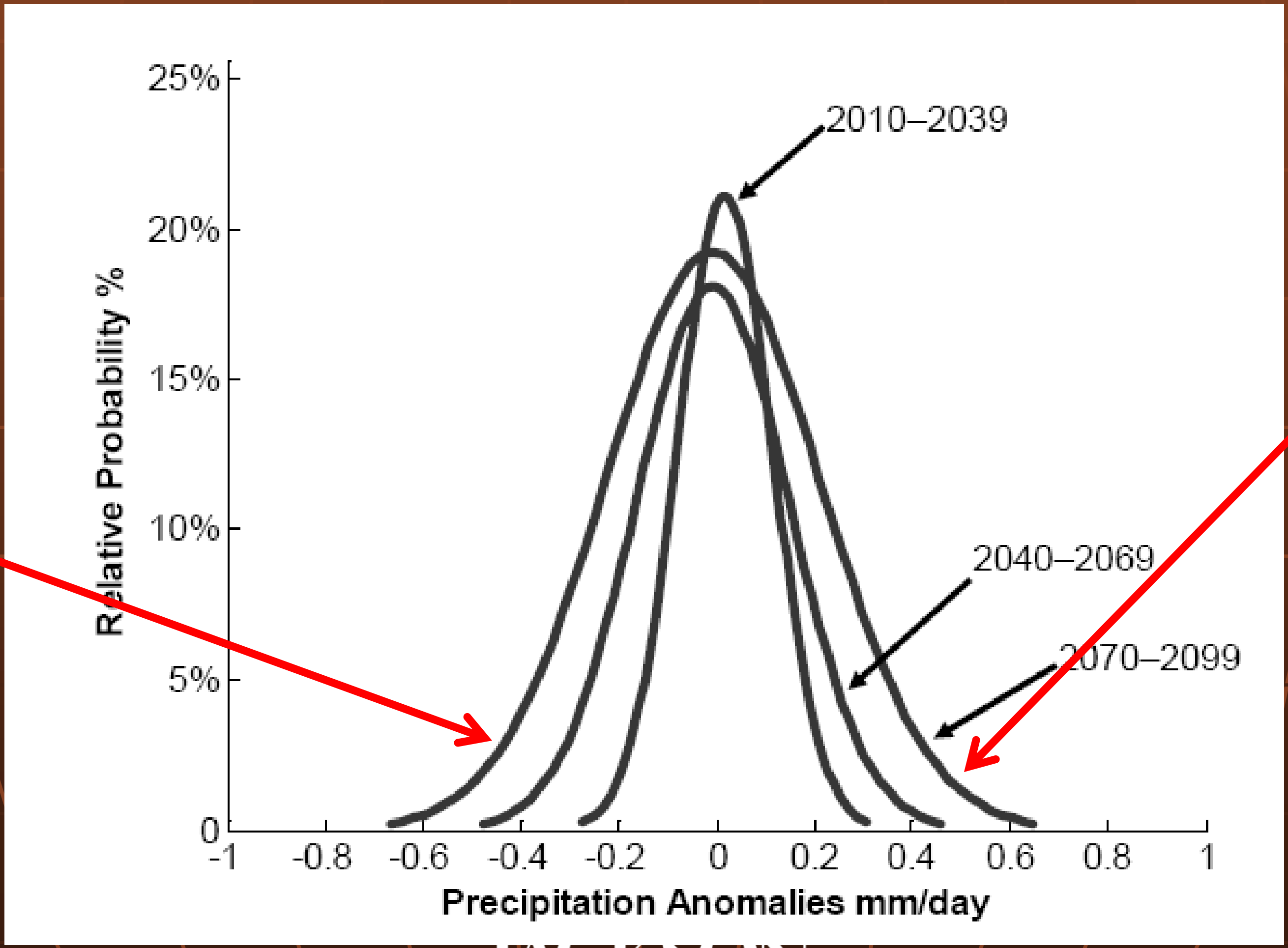
Future Precipitation Projections in Texas
from WCRP CMIP3

More dry periods and intense droughts



More heavy rainfalls and more floods

Jiang and Yang (2012)

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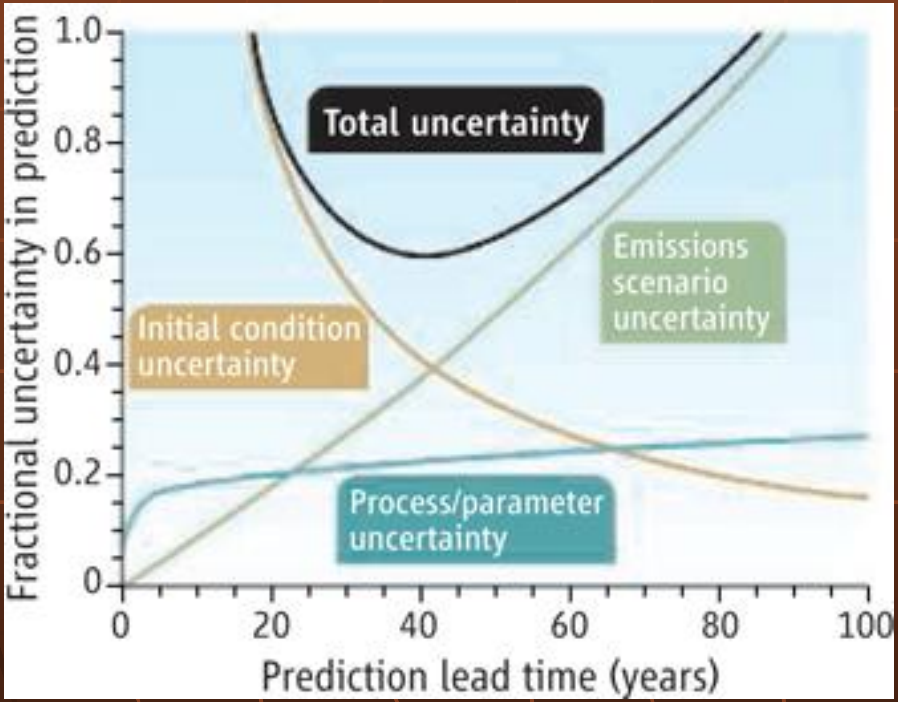
Unified Weather and Climate Modeling and Seamless Prediction



Peter Cox and David Stephenson, *Science,* 2007

1. **Climate Mode? Weather Forecast Mode?**
2. **Uncertainty Quantification**
   - **Different initial conditions (global + regional)**
   - **Different emission scenarios**
   - **Different parameterizations (physical + chemical) and parameters**
   - **Different land use and land cover conditions**
3. **Integrated Modeling and Analysis**

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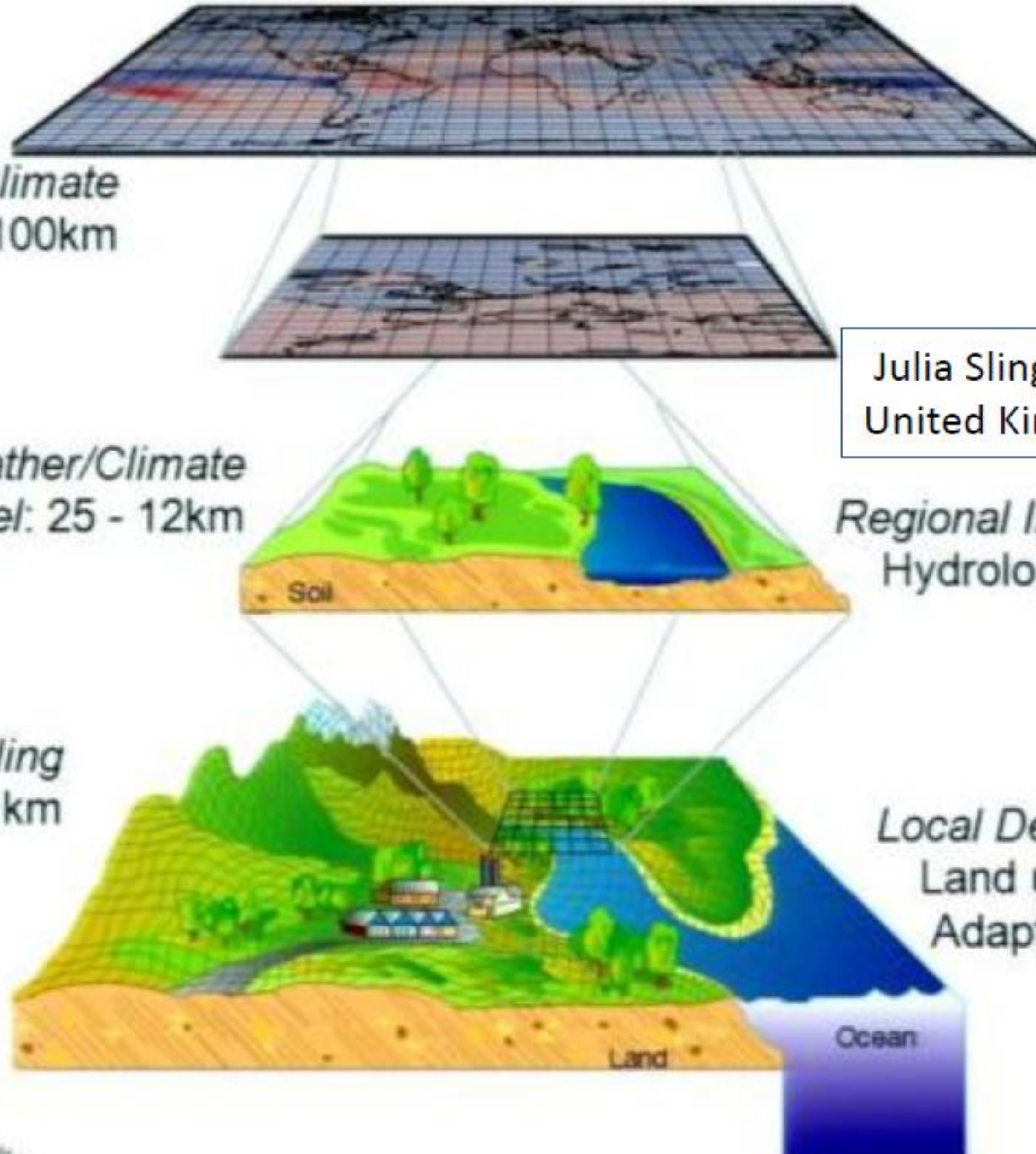
Bridging the Gaps and Bridging the Scales

Met Office

Julia Slingo, Chief Scientist
United Kingdom Met Office

Global Weather/Climate Model: 25 -100km



Regional Weather/Climate model: 25 - 12km

Regional Impacts Model: Hydrology, Vegetation, Topography

Local downscaling model: 4 - 1km

Local Decision-Making: Land use, Water use, Adaptive Responses

Dynamic Seasonal Hydrologic Forecasts

Step 1: Seasonal climate forecasts: precipitation, temperature, radiation, winds, humidity; coarse spatial resolution, O(100 km)

Step 2: Seasonal climate downscaling: precipitation, temperature, radiation, winds, humidity; fine spatial resolution, O(10–1 km)

Step 3: Seasonal land surface forecasts; soil moisture, evapotranspiration, runoff, water table

Step 4: Seasonal river flow forecasts; river flow

Step 5: Seasonal reservoir forecasts; lake storage

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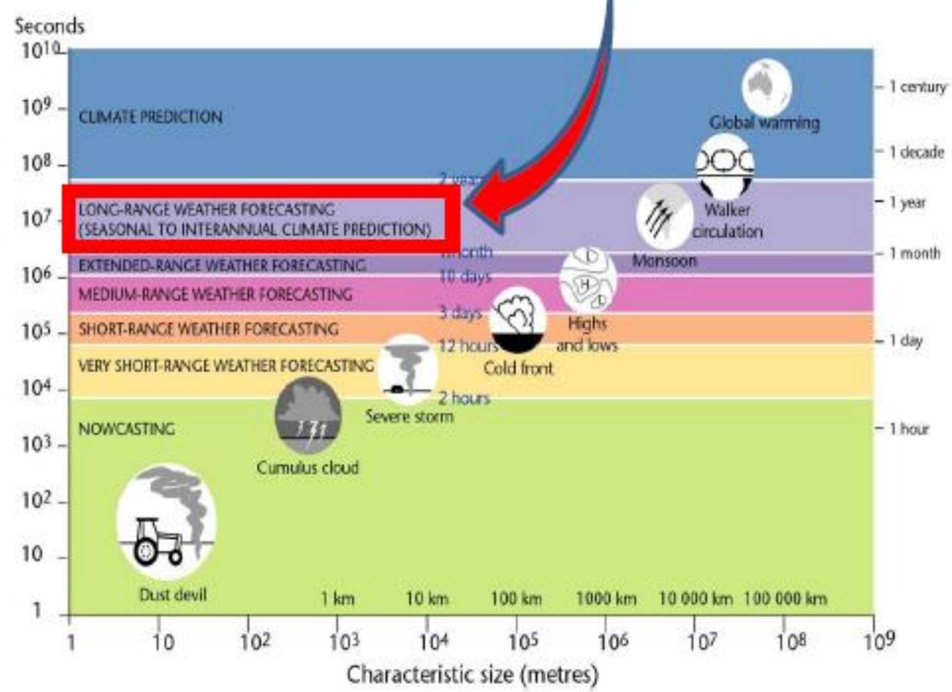
Step1: Seasonal Climate Forecasts

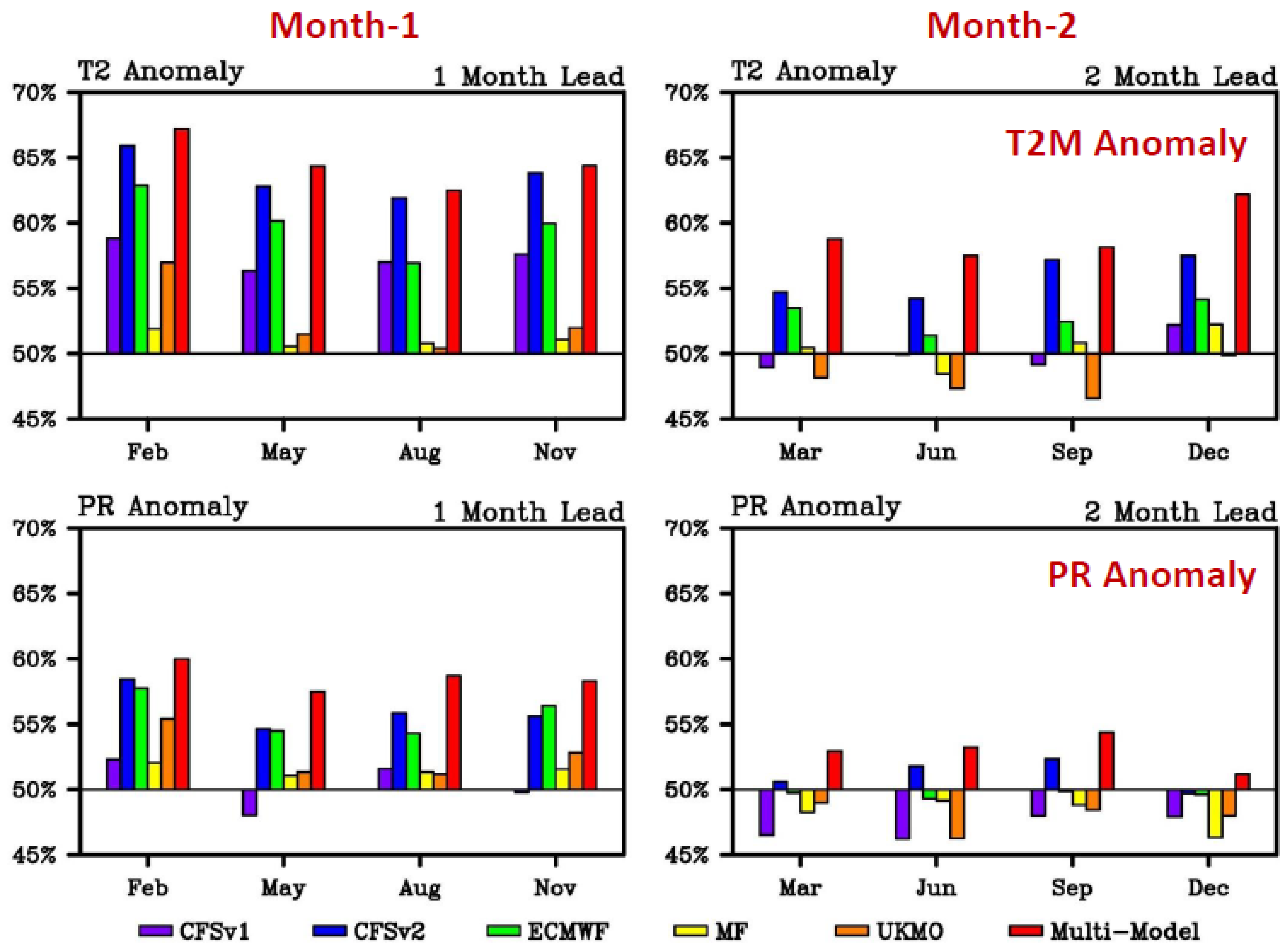
Seasonal forecast: linking climate to weather for a seamless prediction (WWRP+WCRP)

- ➢Seasonal climate anomalies are predictable if there are strong anomalies in the **slowly varying boundary conditions** of SST and land surface conditions.
- ➢**CGCM-based seasonal climate forecast** since 1990s (numerical models, data assimilation, and computing resources).
- ➢Operational seasonal forecast with CGCMs (NCEP, ECMWF, UKMO).



Yuan (2011); Shukla (2009)

Skill of the state-of-art seasonal climate forecast models



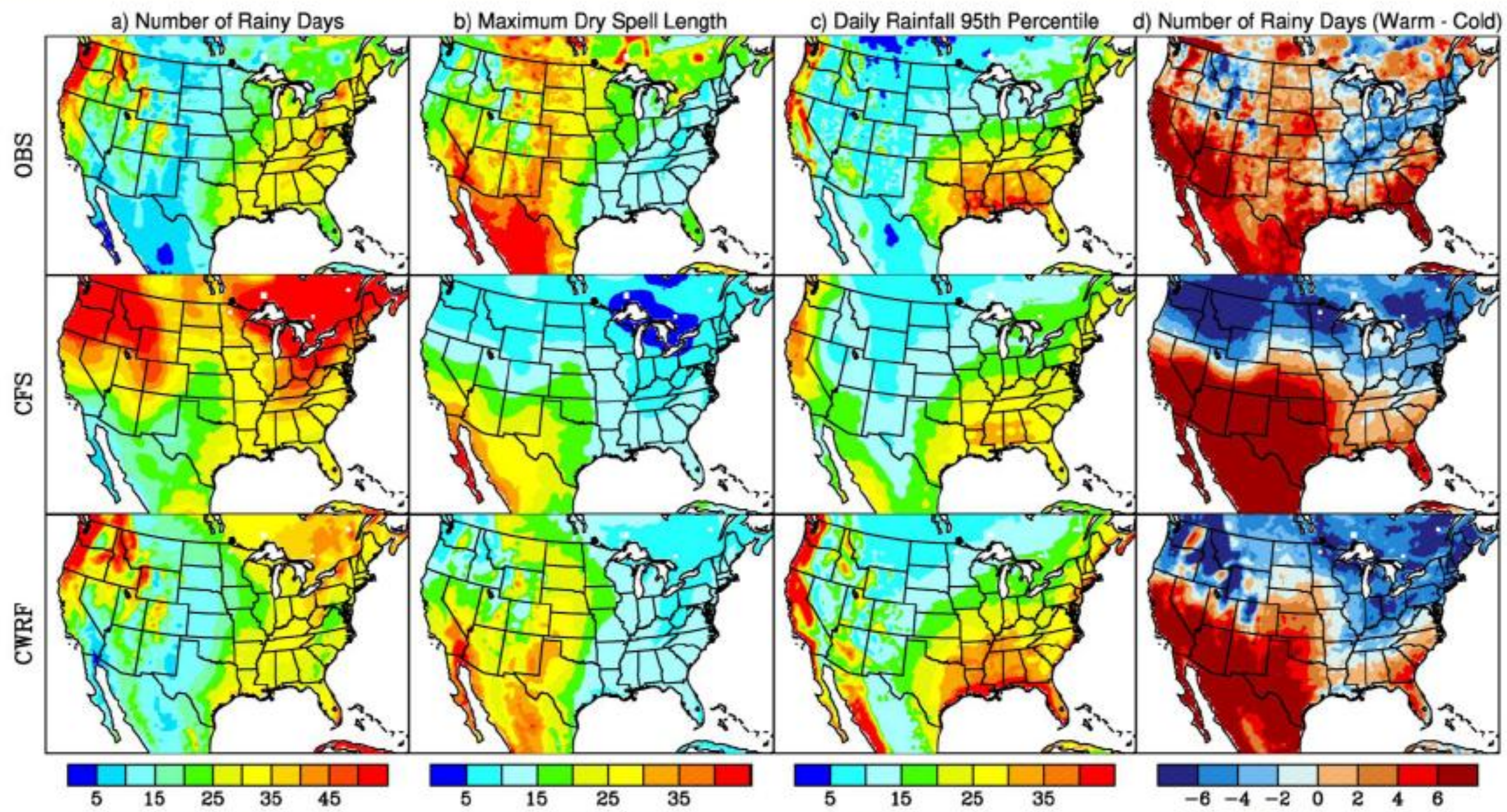
Percentage of positive Ranked Probability Skill Score (RPSS) for global monthly surface air temperature and precipitation anomaly

Yuan et al., *GRL*, 2011

Step 2: Seasonal Climate Dynamic Downscaling

Daily mean precipitation characteristics (JFM)

Yuan and Liang (2011) GRL



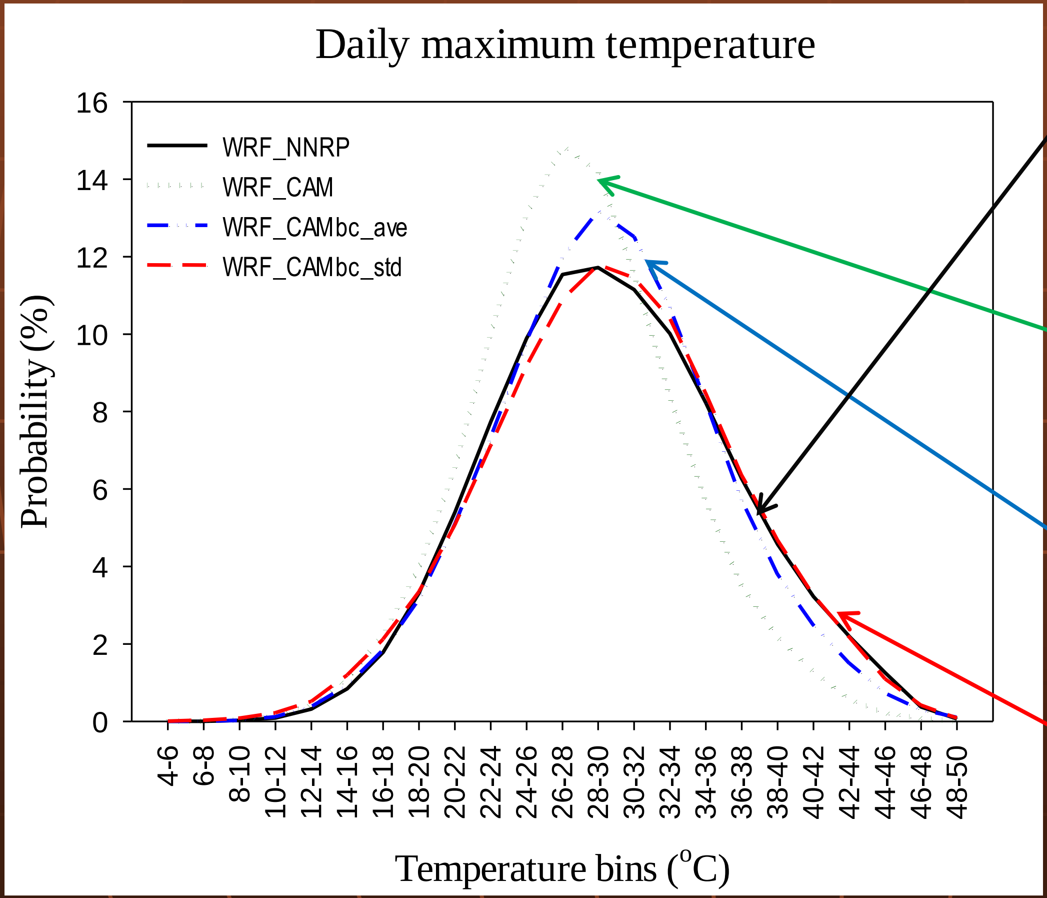
OBS

CFS

CWRF

No. of rainy days | Max. dry length | 95% percentile | Rainy day (El Niño- La Niña)

Dynamic Downscaling with Bias Correction Improves the PDF of Daily Maximum Temperature in Summer



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Black:
WRF simulation driven by NNRP

Green:
WRF simulation driven by GCM output without bias correction

Blue:
With mean value bias correction

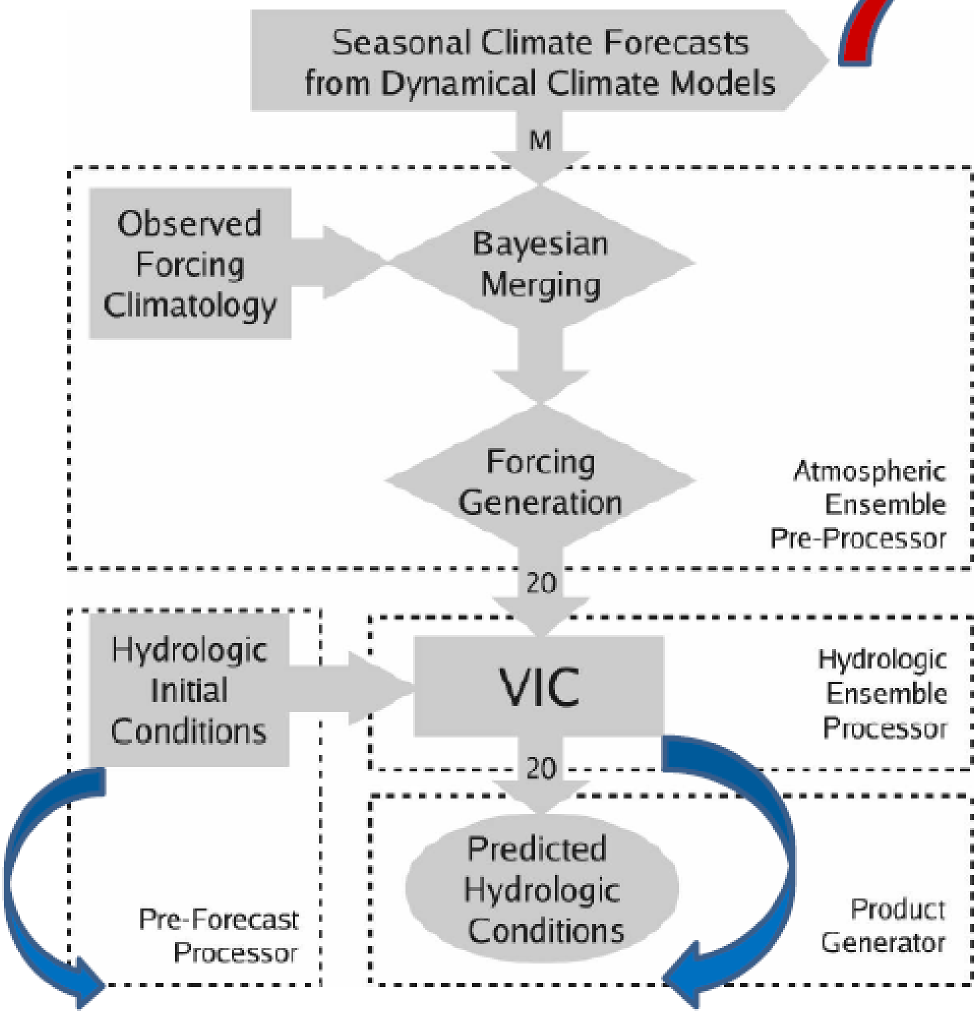
Red:
With mean value and variance bias corrections

The PDF is computed over the central US region (40°–50°N, 100°–85°W) at **60-km** resolution

Xu and Yang (2012)

Seasonal hydrologic forecast system and its uncertainty

Xing Yuan & Eric Wood, Princeton University



Major uncertainty is from climate forecast models: downscaling, ensemble?

CFSv1
- NCEP GFS (T62)
- GFDL MOM3 (1/3-1°)
- OSU LSM

CFSv2
- NCEP GFS (T126)
- GFDL MOM4 (0.25-0.5°)+Sea ice
- NOAH LSM

Upgrading hydrologic forecast system

Uncertainty from IC: offline simulation, data assimilation

Uncertainty from LSM: parameter calibration and regionalization

UT has world-class expertise in

- Understanding and modeling terrestrial hydrological processes & global water cycle
  - Land Model for Climate Prediction
  - Land Model for Weather Forecasts
- Mapping geospatial datasets
- Observing the global water cycle
- High Performance Computing
  - Lonestar
  - Ranger
  - Stampede

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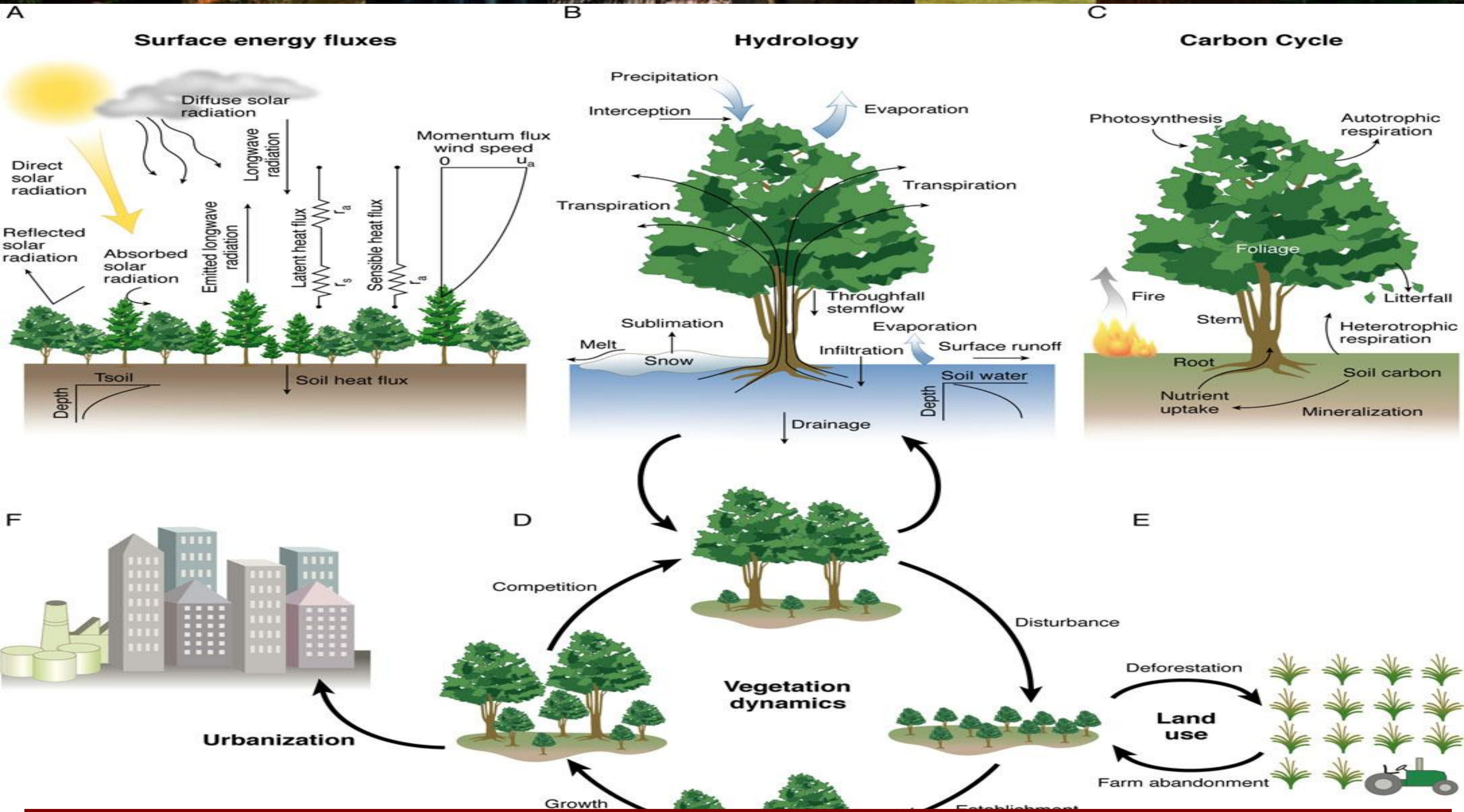
NCAR Community Land Model (CLM4) for Climate Models in 2010



Co-Chairs: David Lawrence (NCAR), Zong-Liang Yang (Univ of Texas at Austin)

Noah-MP Land Model for Weather Forecasts

- **A new paradigm** in land-surface hydrological modeling
- In a broad sense,
  - o Multi-parameterization ≡ Multi-physics ≡ Multi-hypothesis
- **A modular & powerful framework for**
  - o Diagnosing differences
  - o Identifying structural errors
  - o Improving understanding
  - o Enhancing data/model fusion and data assimilation
  - o Facilitating ensemble forecasts and **uncertainty quantification**

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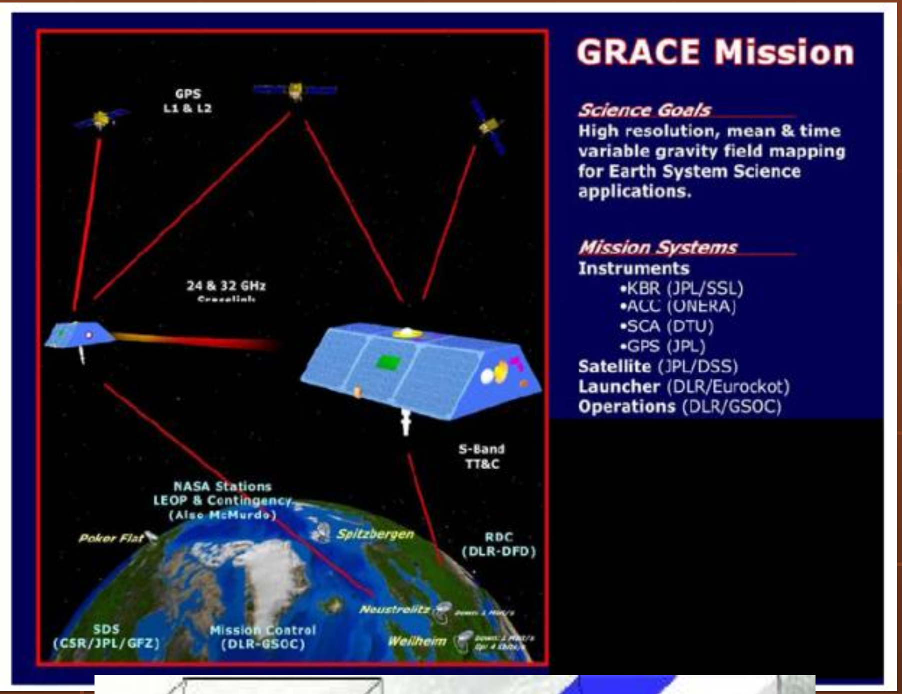
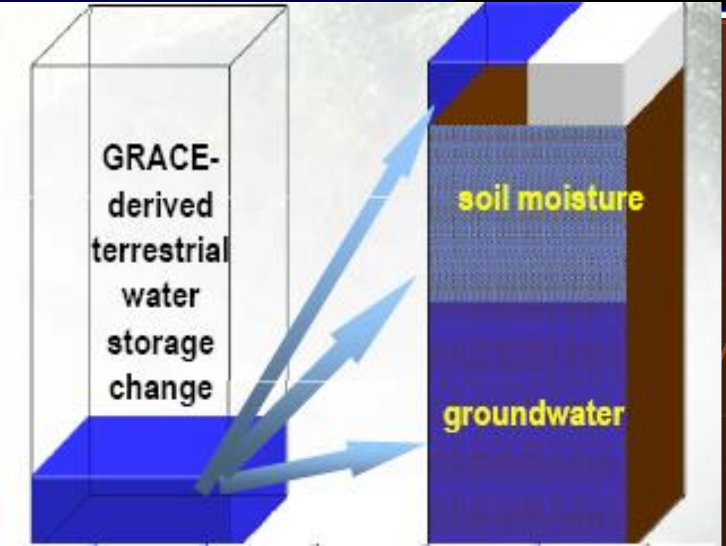
Niu et al. (2011); Yang et al. (2011)

Collaborators: Yang, Niu (UT), Chen (NCAR), Ek & Mitchell (NCEP/NOAA), and others

Gravity Recovery and Climate Experiment (GRACE)

- 8+ years of mission operation (Tapley et al., 2004)
- First-time global data of gravity (~100 km, monthly to 10-day)
- Unprecedented accuracy of mass variations
- Allowing a better understanding of the global water cycle





High Performance Computing

- Petascale [$O(10^{15})$] Computing Architectures
  - Massively parallel supercomputers (10^4–10^5 multi-core processors)

World's "Fastest" Supercomputer in 2013
10 peta math operations per second (**PFlops**)
500,000 processors
Texas Advanced Computing Center, UT-Austin
Stampede
January 2013

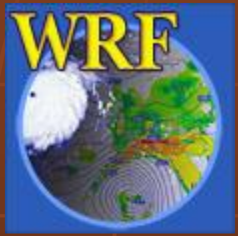
World's "Fastest" Supercomputer in 2011
579.4 trillion math operations per second (**TFlops**)
3936 nodes, 62976 core processors
Texas Advanced Computing Center, UT-Austin
Ranger
5/19/2011

Revolution in Modeling

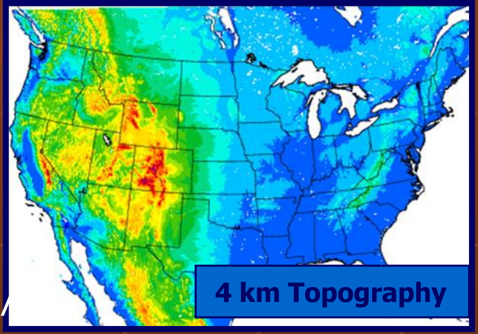
Shuttleworth (2011)

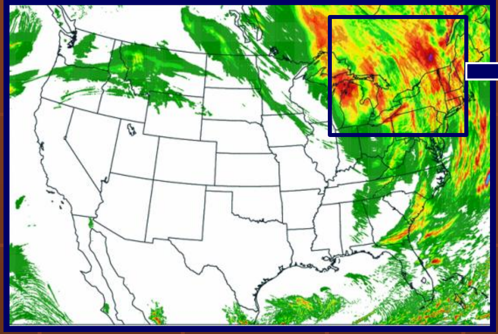
The grid resolution of regional and global models has reduced hugely, and will continue to do so

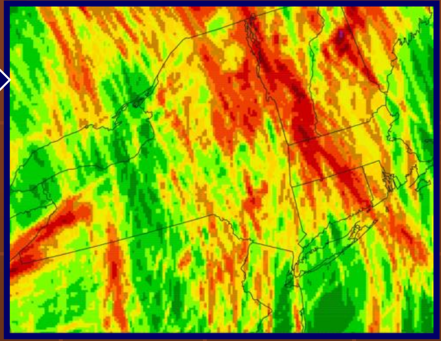
e.g. 4 km resolution Weather Research and Forecasting (WRF) Model



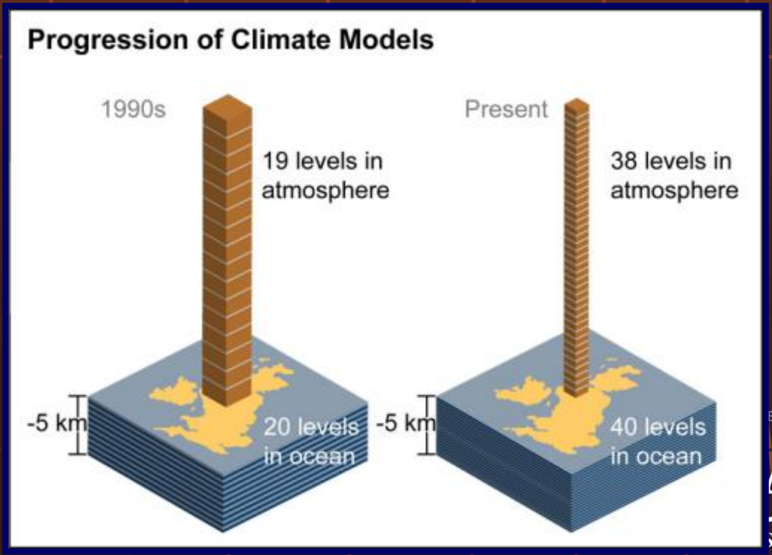
www.nssl.noaa.gov/wrf/



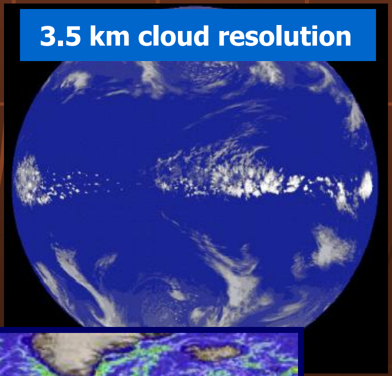


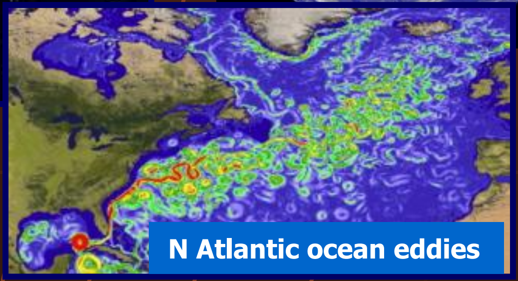


e.g. increasing spatial resolution in Global Models



www.nec.co.jp





Summary

- CIESS was formed to integrate UT's expertise in earth system science for the betterment of society.
- As high-resolution seasonal to decadal climate and hydrologic forecasts are emerging as a new paradigm for modeling and prediction research, CIESS is positioned to develop an integrated atmosphere–land-surface–river network modeling system, applicable to Texas for water resource applications; see Cedric David's talk.

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