CWRF Advances for Water Management (Chesapeake Bay)

Xin-Zhong Liang

Department of Atmosphere & Ocean Science

Earth System Science Interdisciplinary Center

University of Maryland, College Park

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Brief CBP

Acknowledgement

Supercomputing Support

NOAA/ESRL, DOE/NERSC,
NCSA/UIUC, NCAR, NASA

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EPA, NOAA/NCAS, NOAA/CPPA,
DOE, USDA/UVB, NSF, NASA

CWRF http://cwrf.umd.edu

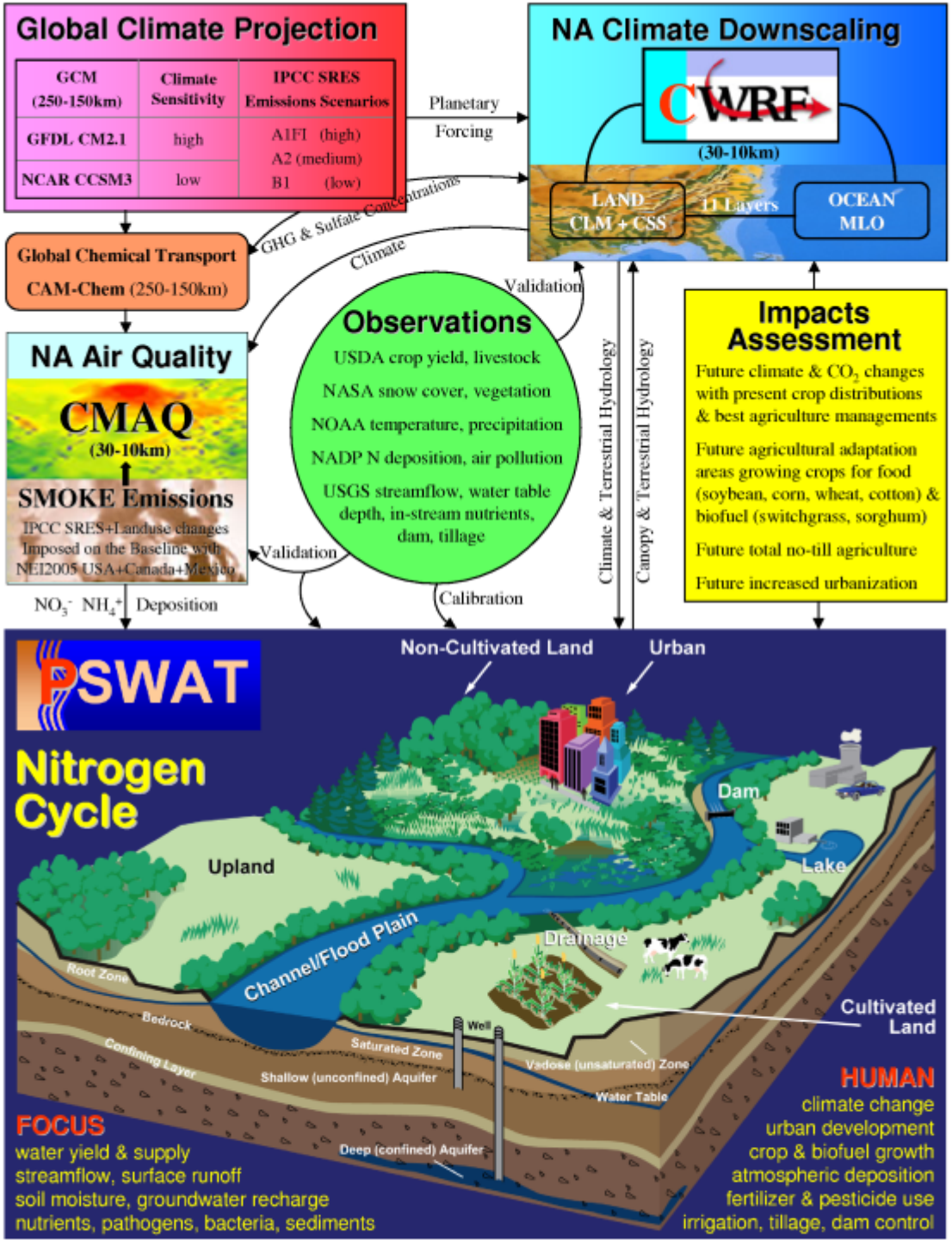
EPA STAR 2003-2011

FOCUS

Consolidate O_3

Elaborate PM

Explore Hg



EPA STAR 2009-2012

FOCUS

Nutrients

Pathogens

Bacteria

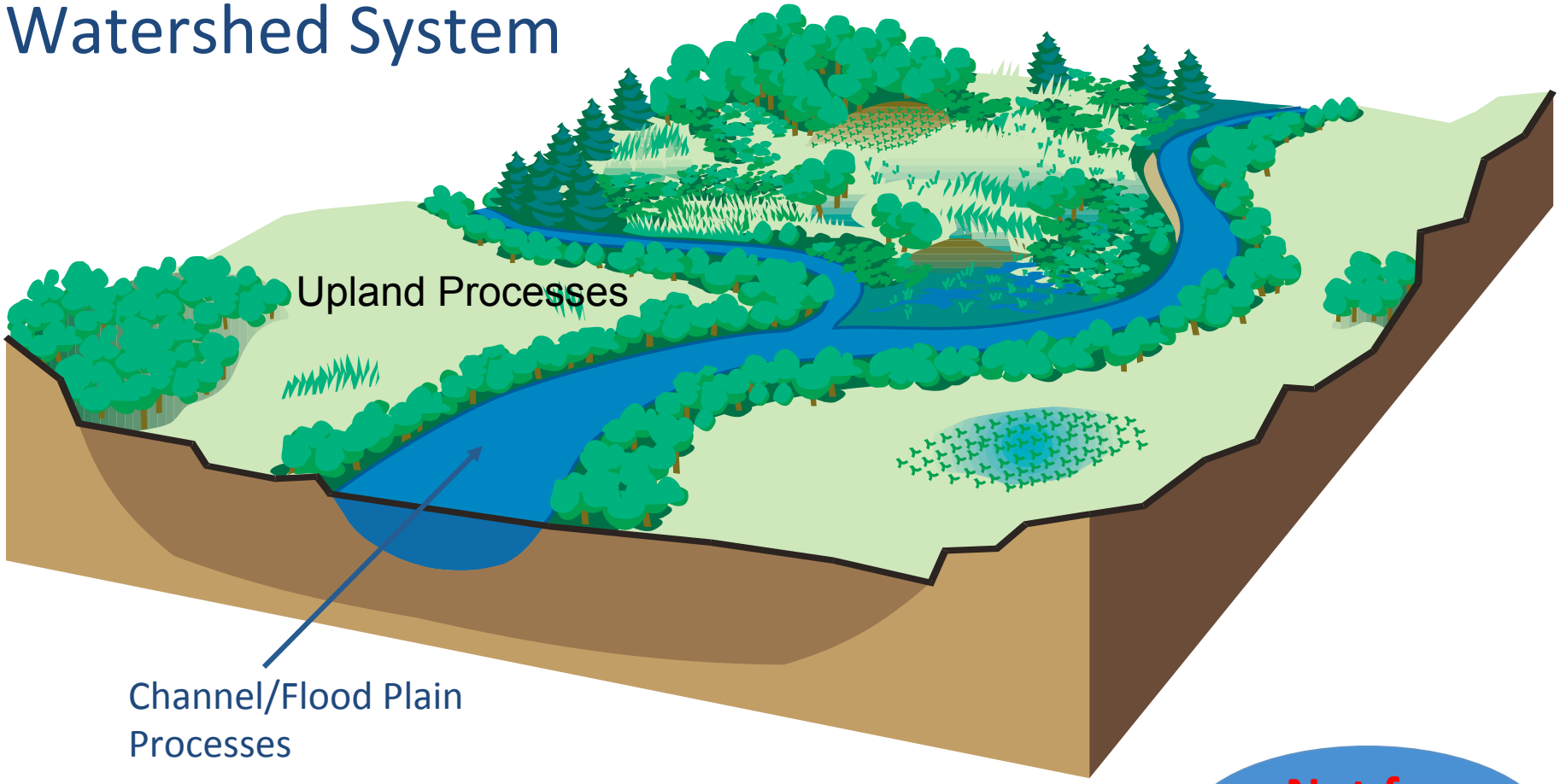
Sediments

Agriculture

Urban

SWAT

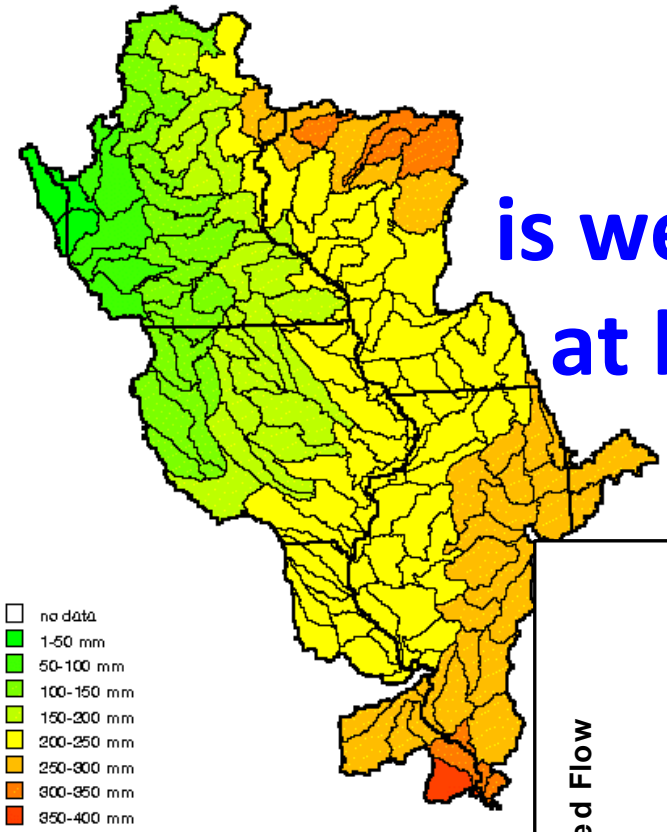
Watershed System



Soil and Water Assessment Tool

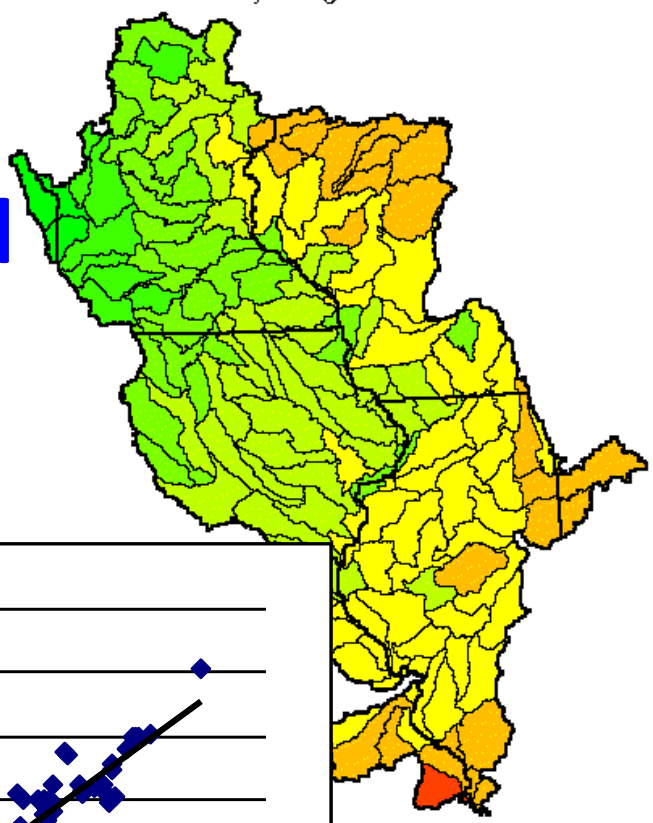
Not for Prediction

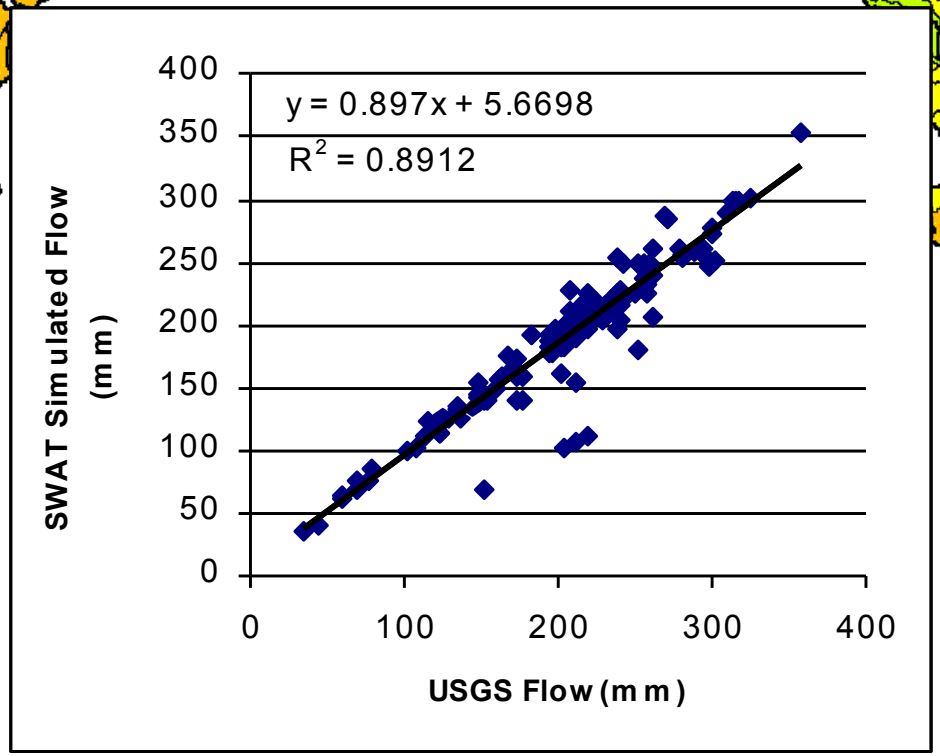
Upper Mississippi Water Resource Region
Average Annual Observed (USGS) Total Flow
By 8-digit HUA



SWAT is well validated at basin scale

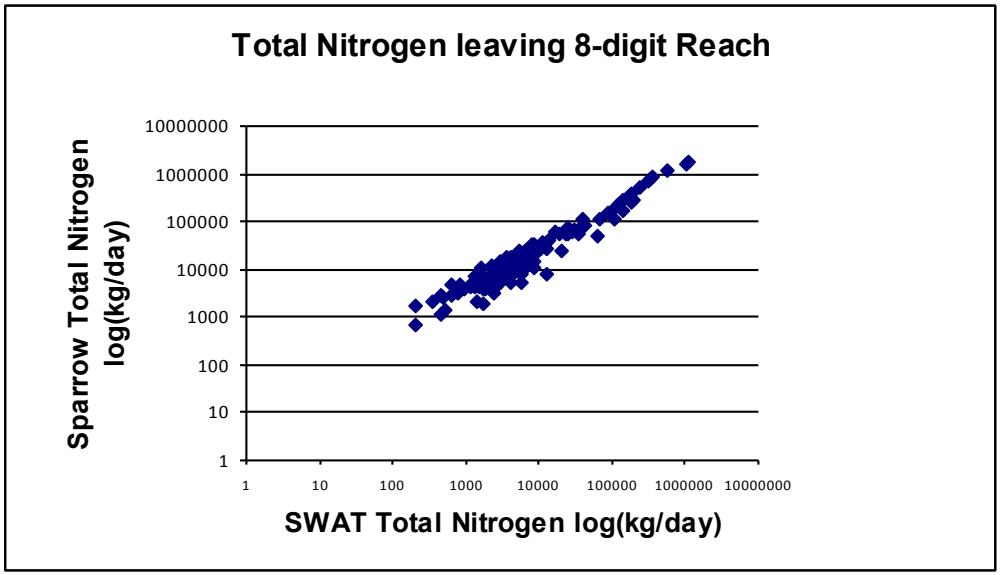
Upper Mississippi Water Resource Region
Average Annual SWAT Simulated Total Flow
By 8-digit HUA



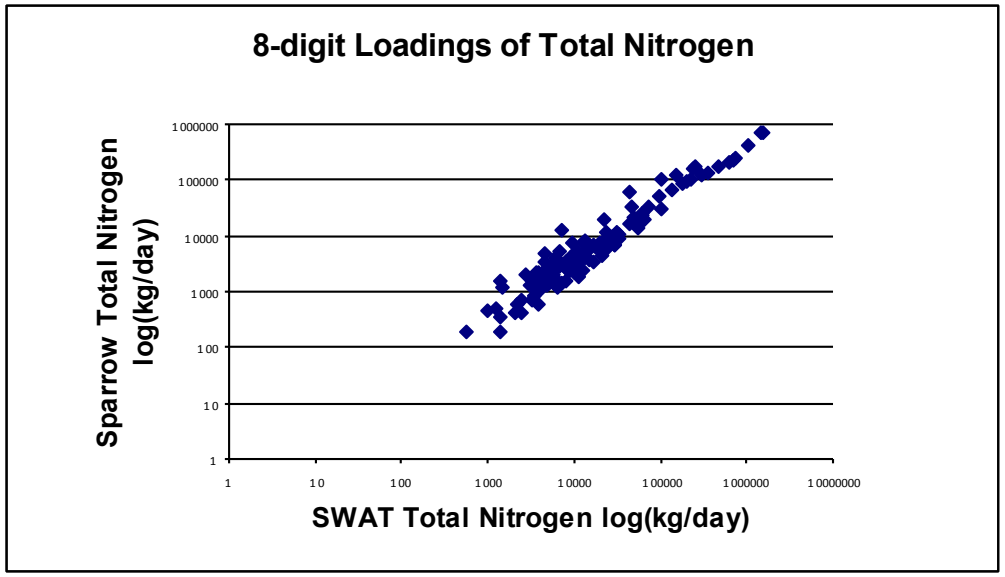


Upper Mississippi (131 8-digits)

8-digit Transport

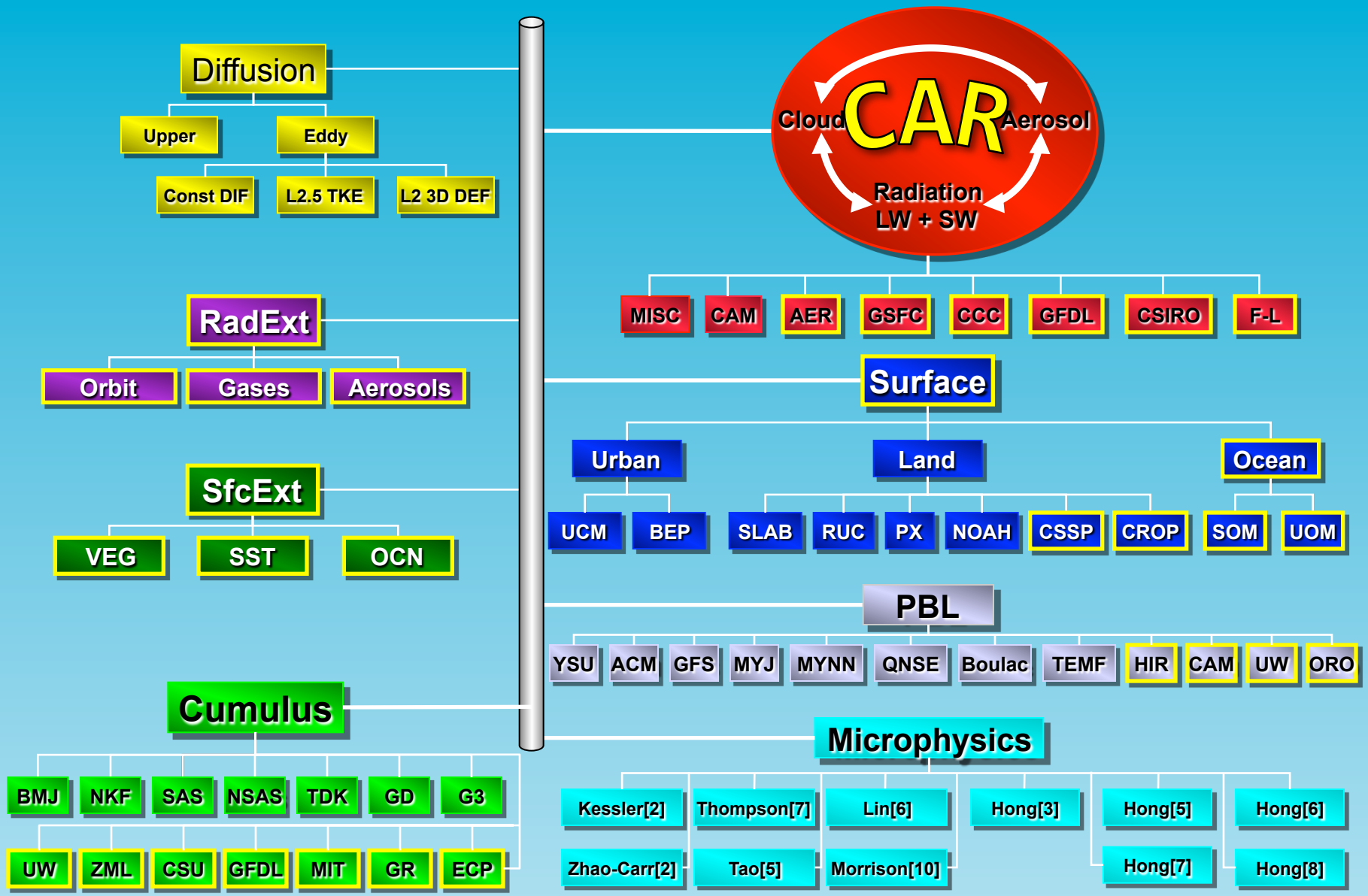


8-digit Loadings

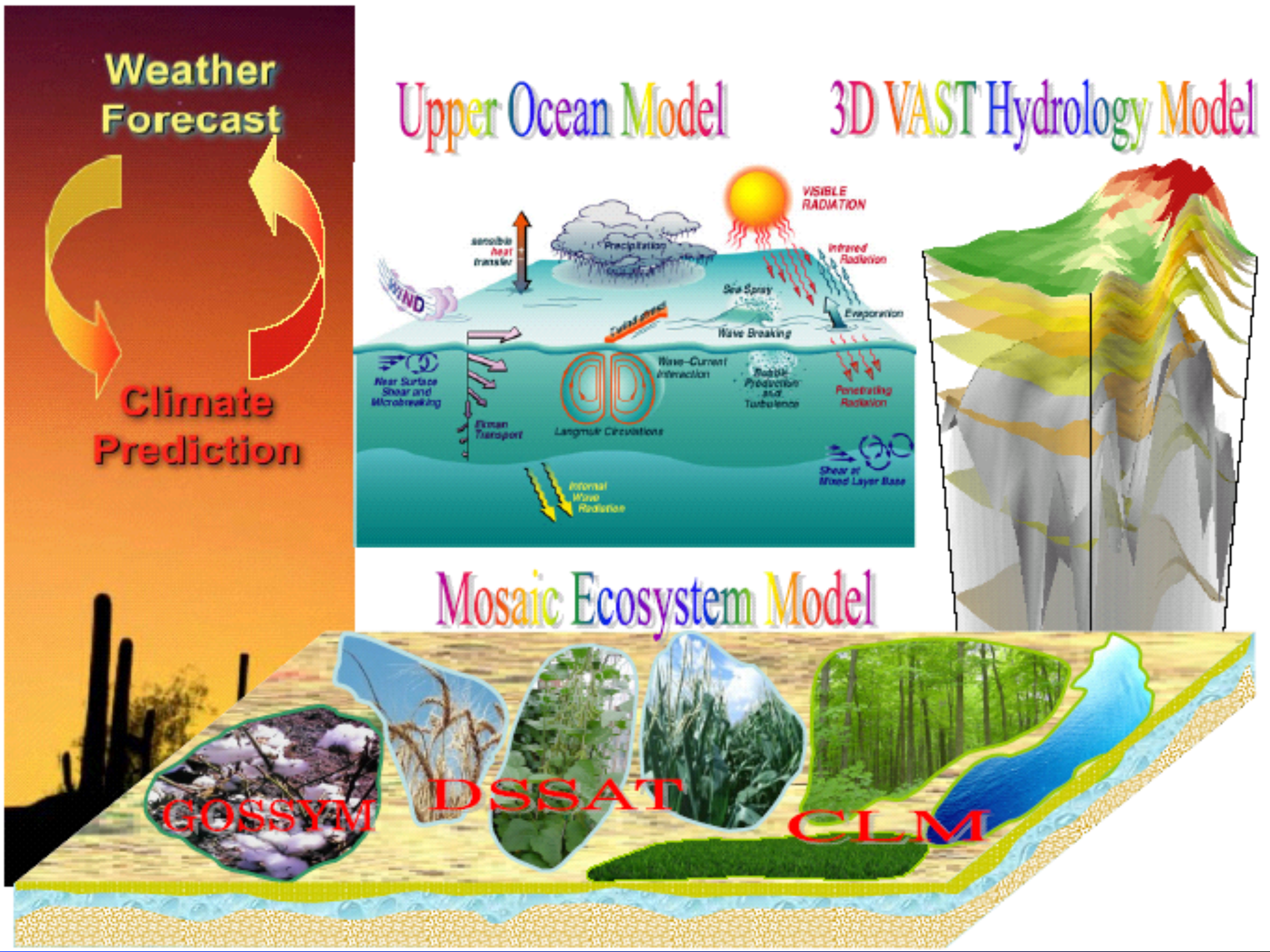


Sparrow Comparison USGS Regression Model

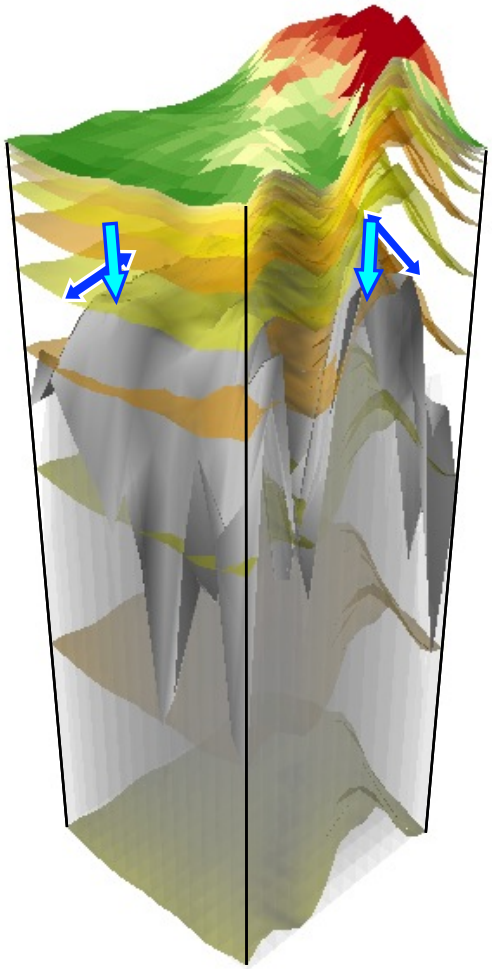
CWRF Physics Options

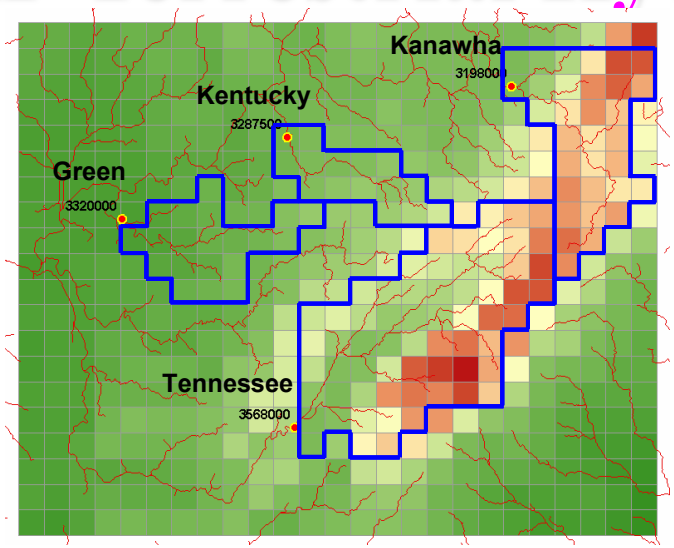


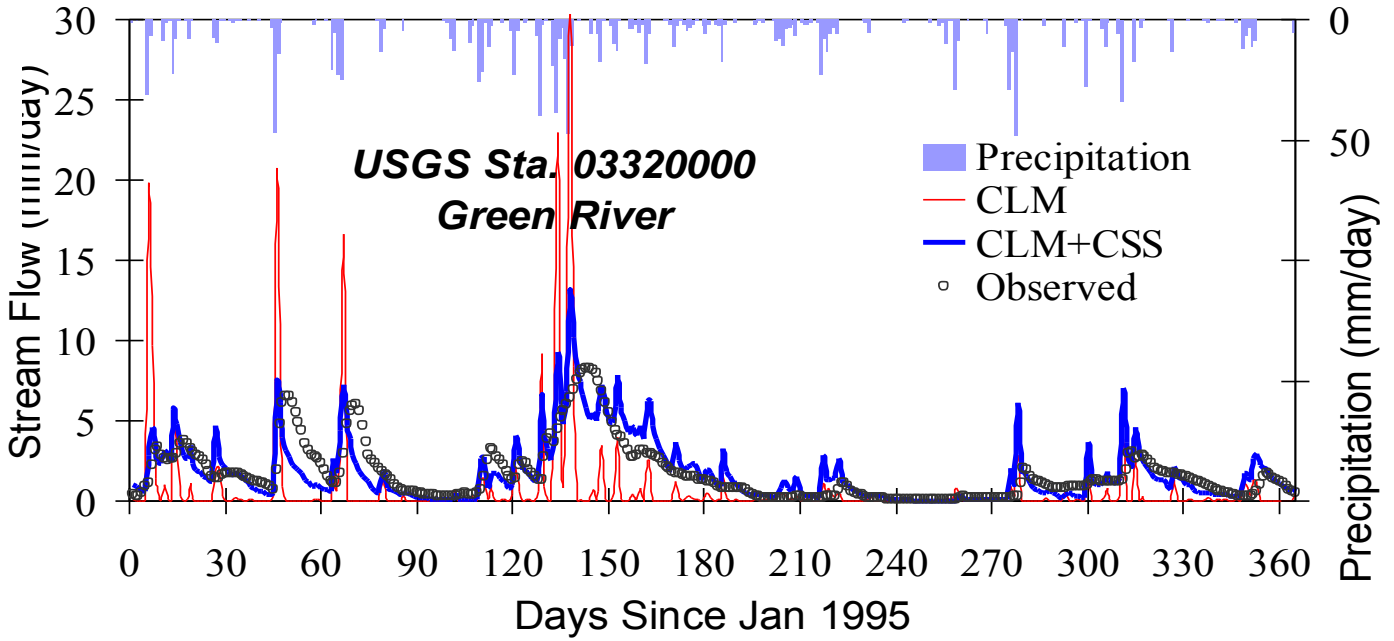
http://cwrf.umd.edu


Weather Forecast
Climate Prediction
Upper Ocean Model
3D VAST Hydrology Model
Mosaic Ecosystem Model
VISIBLE RADIATION
Infrared Radiation
Precipitation
sensible heat transfer
WIND
Sea Spray
Evaporation
Wave Breaking
Near Surface Shear and Microbreaking
Wave-Current Interaction
Bubble Production and Turbulence
Penetrating Radiation
Ekman Transport
Langmuir Circulations
Shear at Mixed Layer Base
Internal Wave Radiation
GOSSYM
DSSAT
CLM

CWRF Terrestrial Hydrology

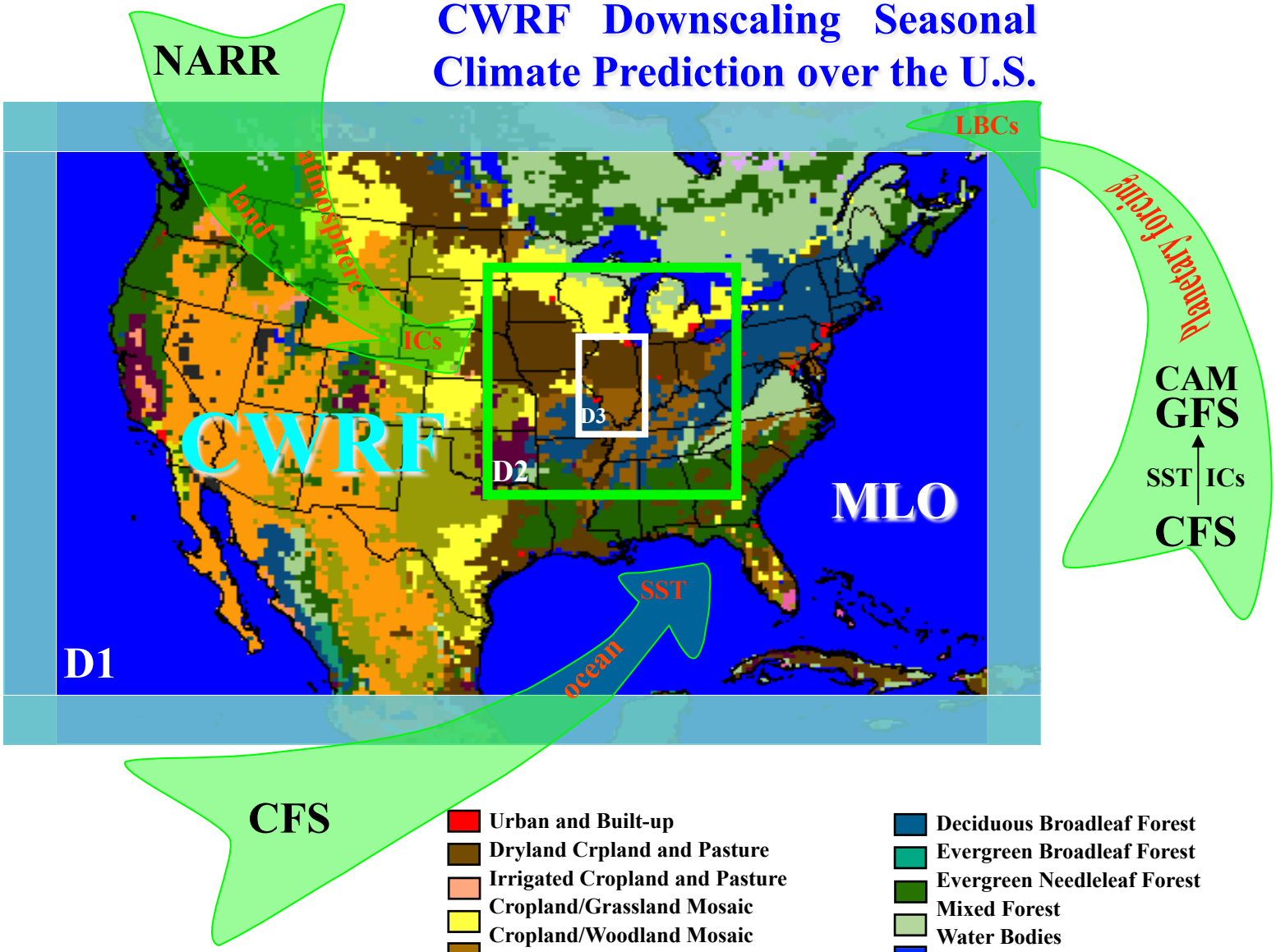






Choi 2006; Choi et al. 2007; Choi and Liang 2010; Yuan and Liang 2010; Liang et al. 2010d

CWRF Downscaling Seasonal Climate Prediction over the U.S.

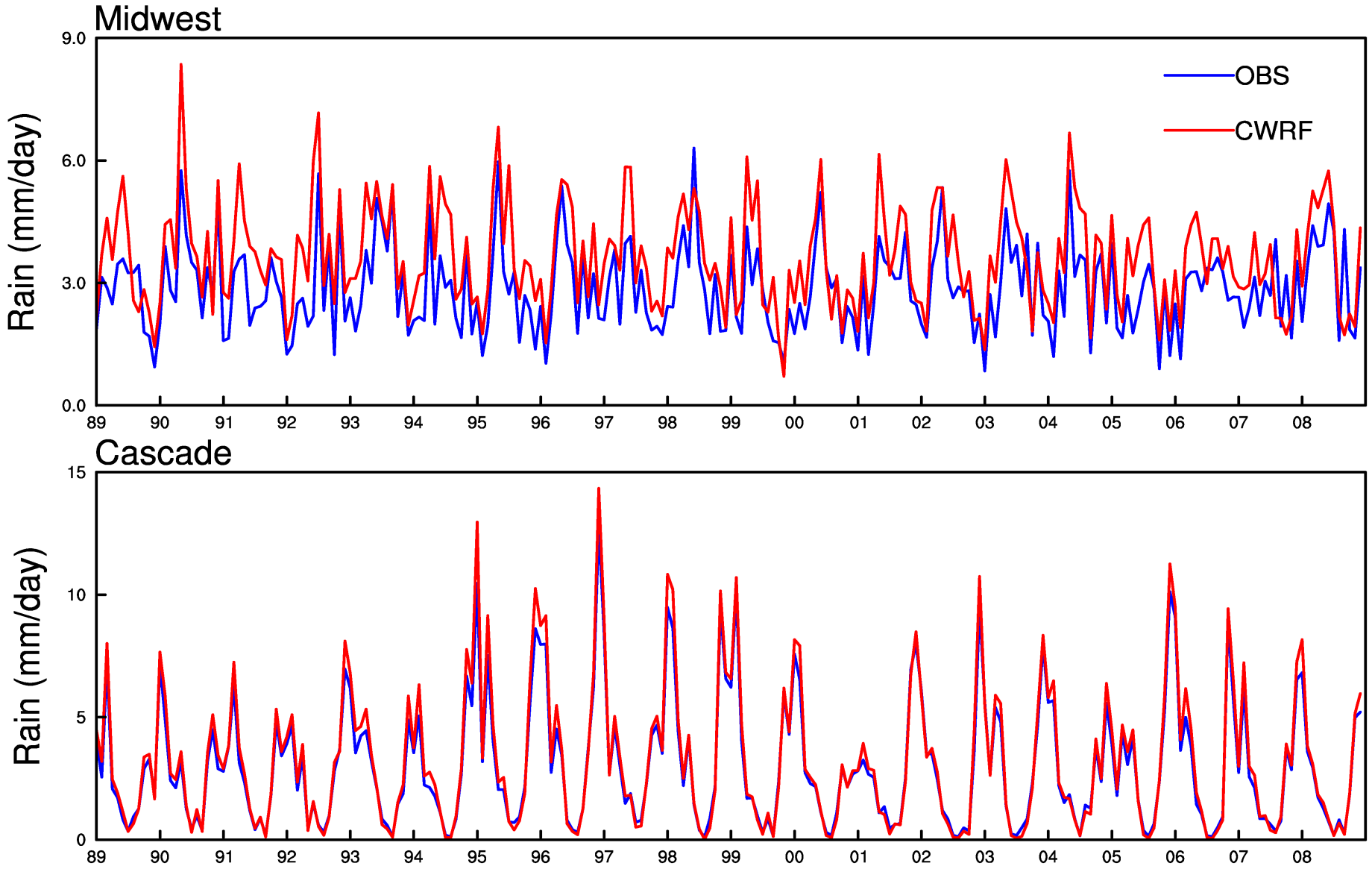


NOAA

2008-2011

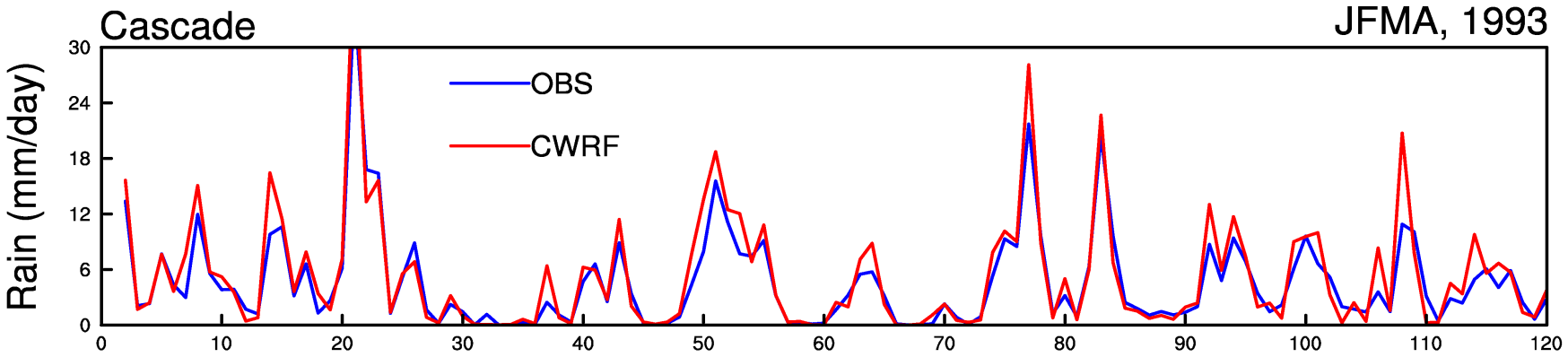
CWRF

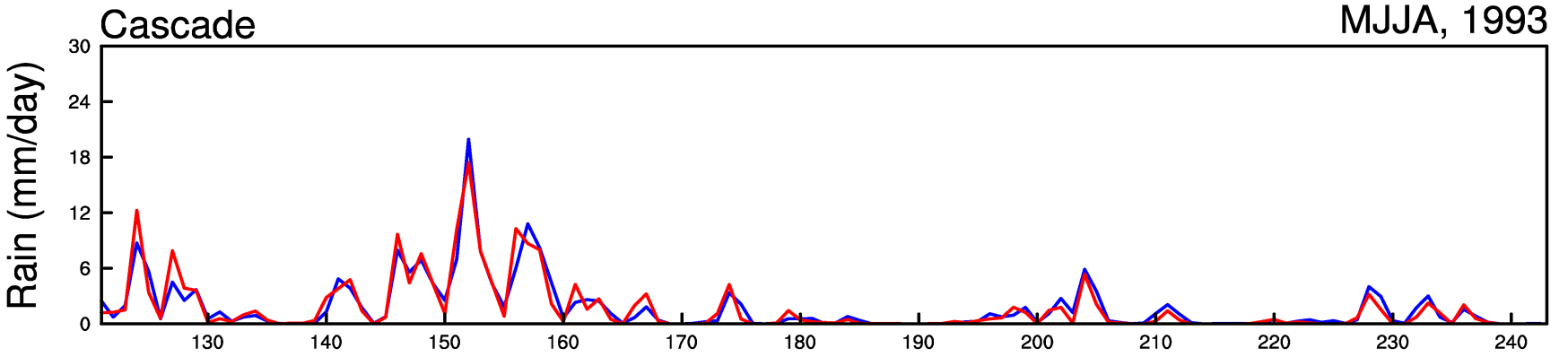
Monthly

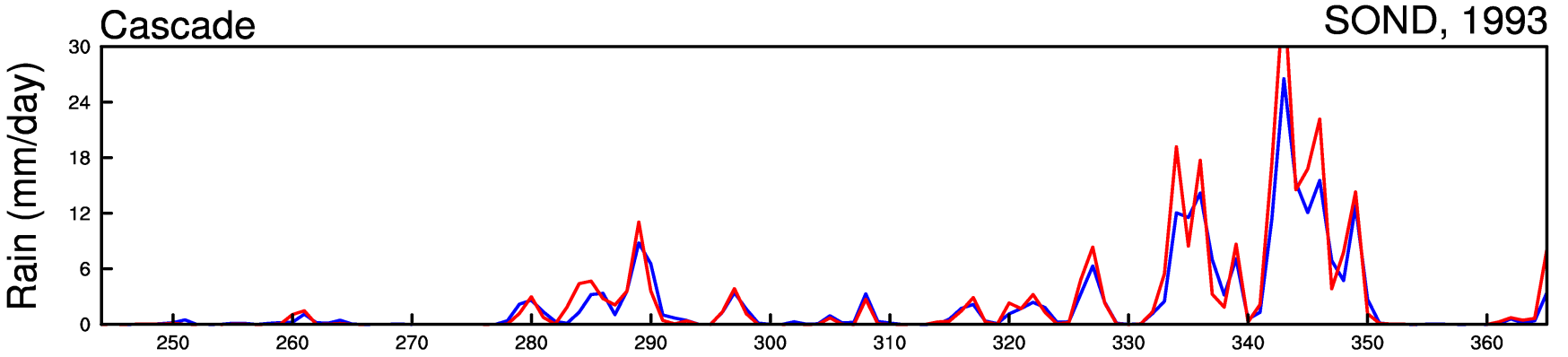


CWRF

Daily

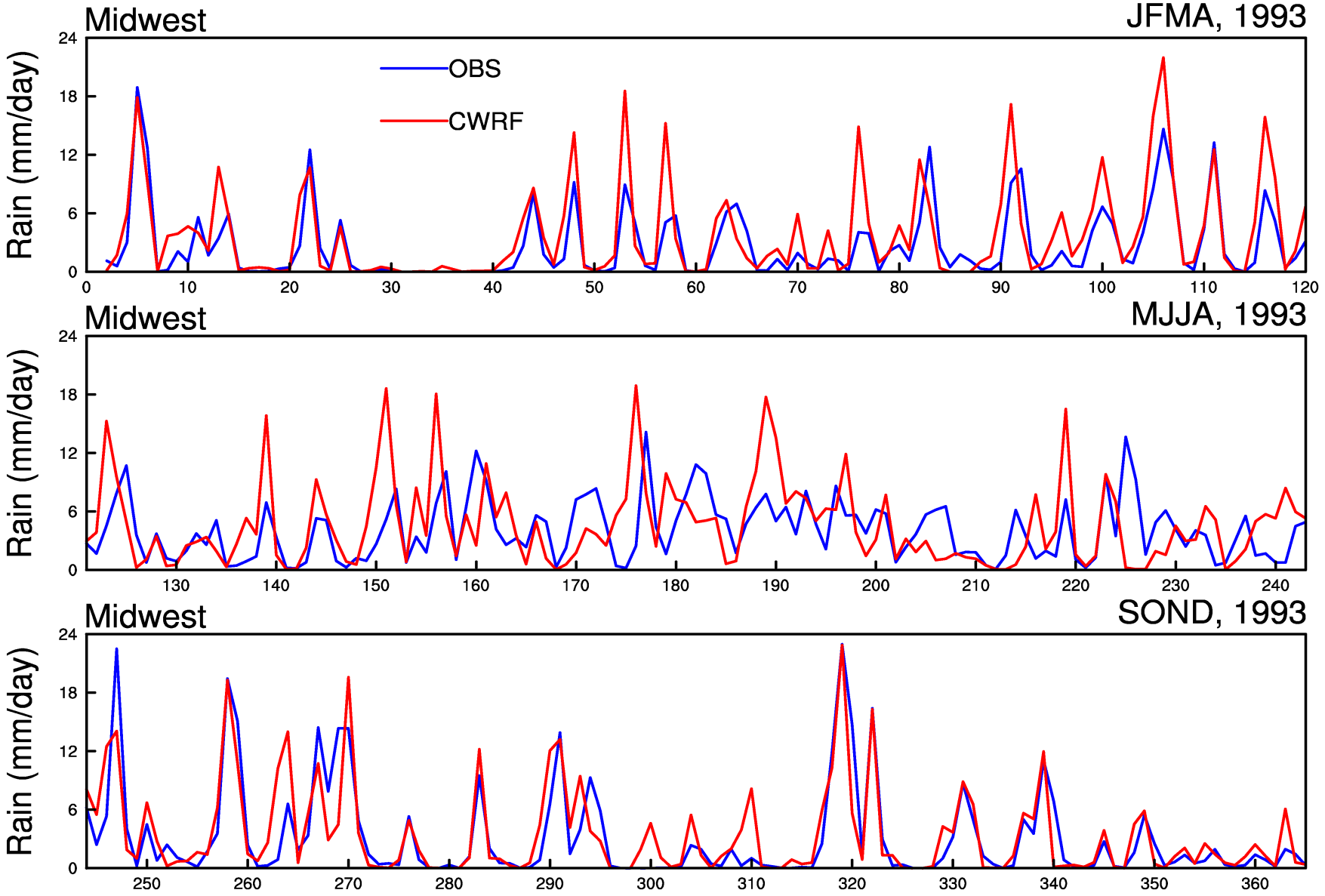

Cascade
JFMA, 1993
OBS
CWRF
Rain (mm/day)
0
6
12
18
24
30
0
10
20
30
40
50
60
70
80
90
100
110
120


Cascade
MJJA, 1993
Rain (mm/day)
0
6
12
18
24
30
130
140
150
160
170
180
190
200
210
220
230
240

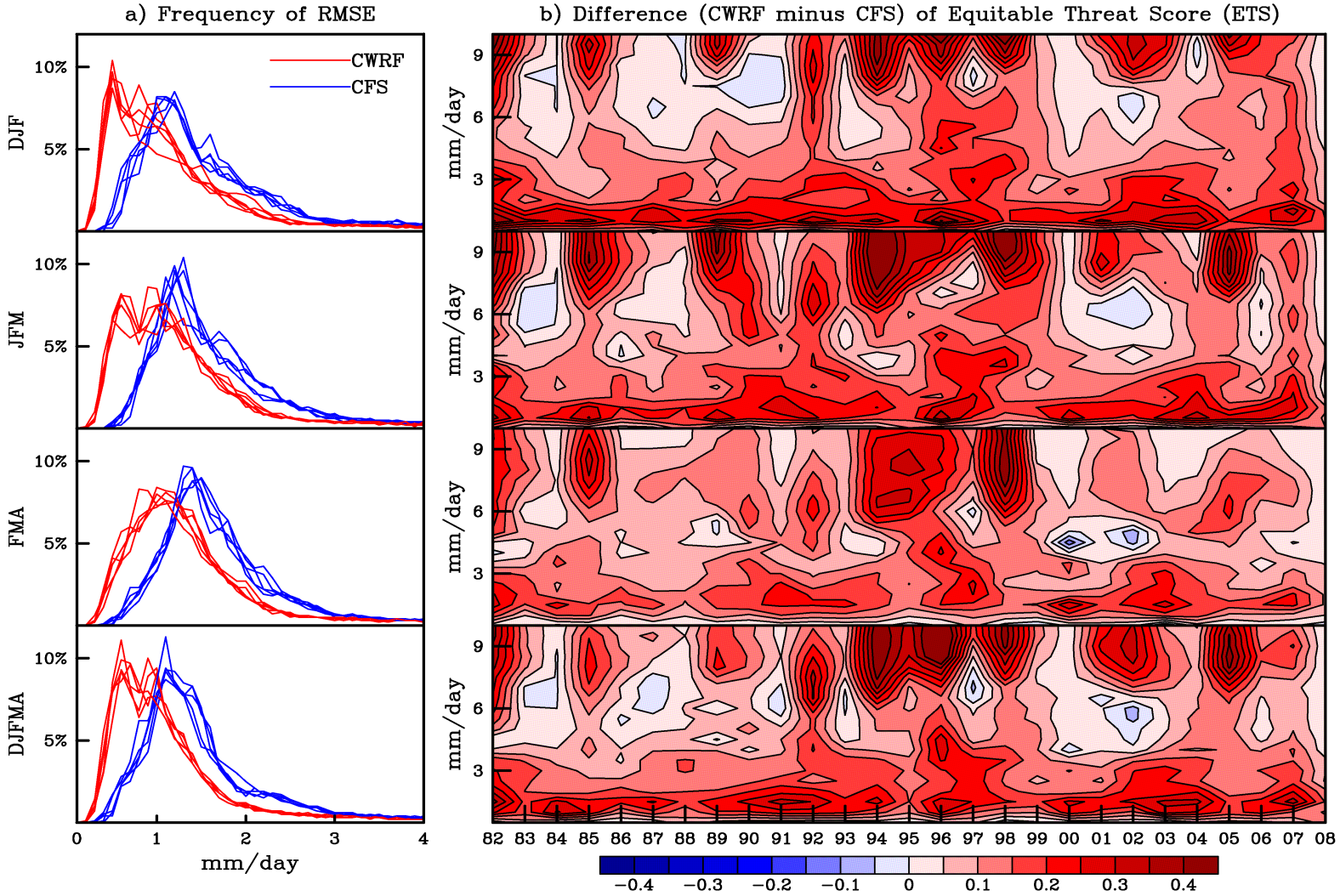

Cascade
SOND, 1993
Rain (mm/day)
0
6
12
18
24
30
250
260
270
280
290
300
310
320
330
340
350
360

CWRF

Daily

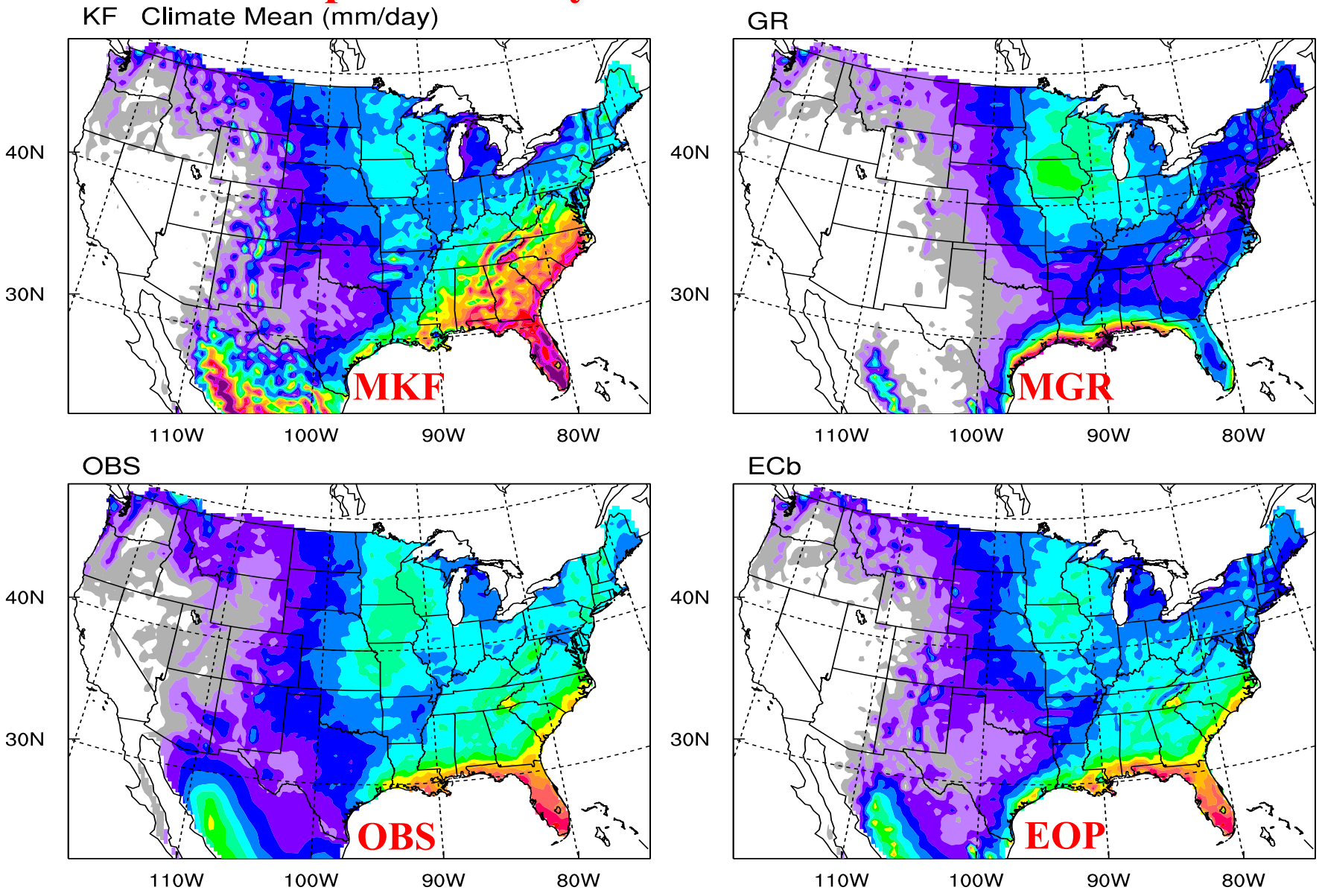

Midwest
JFMA, 1993
OBS
CWRF
Rain (mm/day)
0
6
12
18
24
0
10
20
30
40
50
60
70
80
90
100
110
120
Midwest
MJJA, 1993
Rain (mm/day)
0
6
12
18
24
130
140
150
160
170
180
190
200
210
220
230
240
Midwest
SOND, 1993
Rain (mm/day)
0
6
12
18
24
250
260
270
280
290
300
310
320
330
340
350
360

CWRF Improves Seasonal Climate Prediction

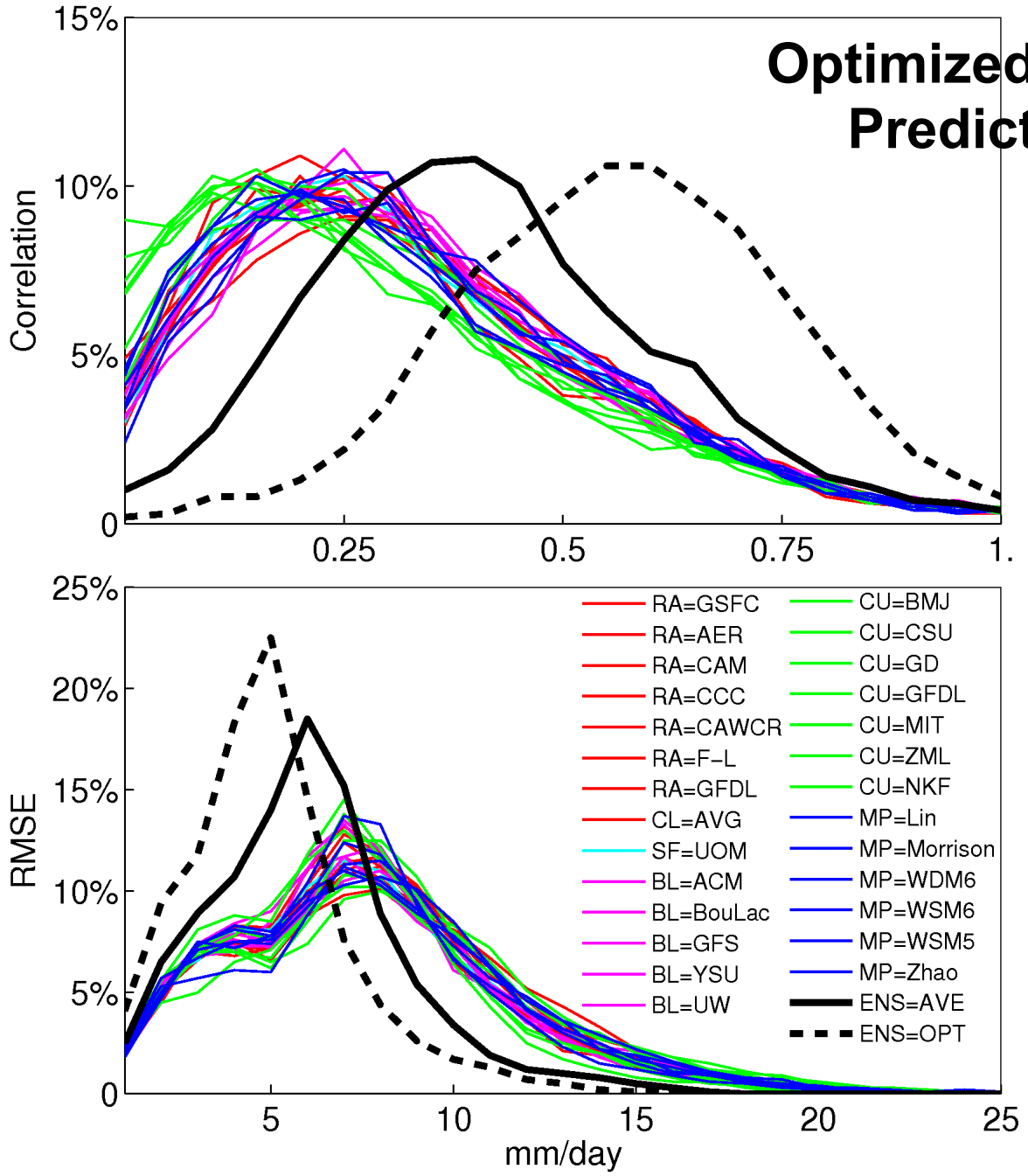


a) Spatial frequency distributions of root mean square errors (*RMSE*, mm/day) predicted by the CFS and downscaled by the CWRF and **b)** CWRF minus CFS differences in the equitable threat score (*ETS*) for seasonal mean precipitation interannual variations. The statistics are based on all land grids over the entire inner domain for DJF, JFM, FMA, and DJFMA from the 5 realizations during 1982-2008. *From* Yuan and Liang 2011 (GRL).

Optimized Physics-Ensemble Prediction



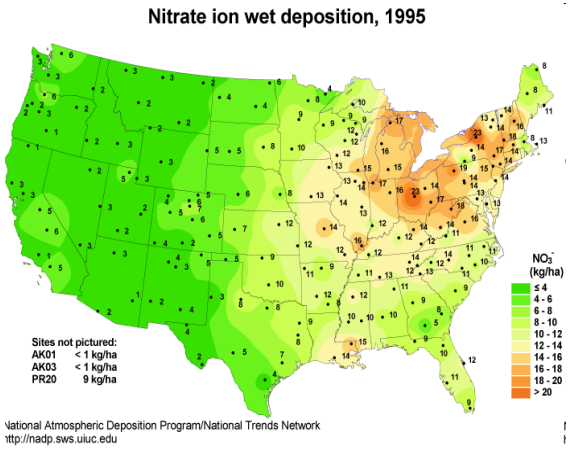
Optimized Physics Ensemble Prediction of Precipitation In summer 1993

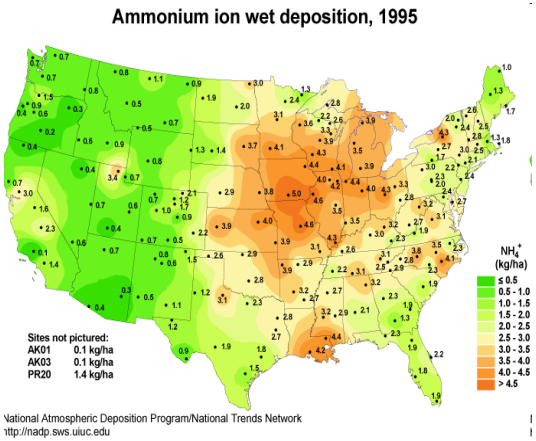


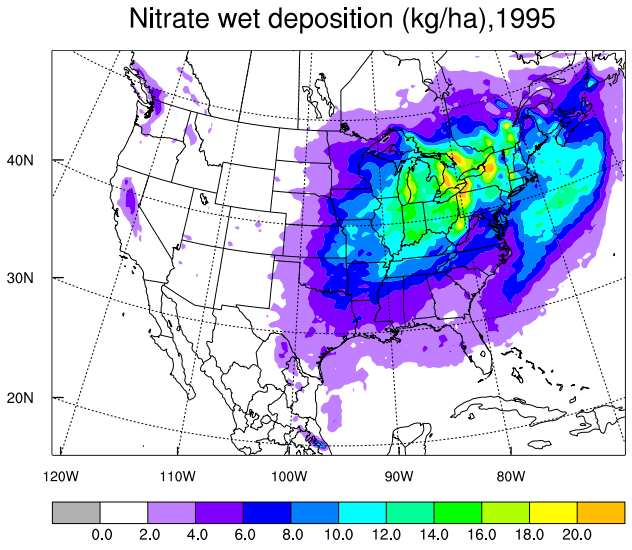
The physics ensemble mean substantially increases the skill score over individual configurations, and there exists a large room to further enhance that skill through intelligent optimization.

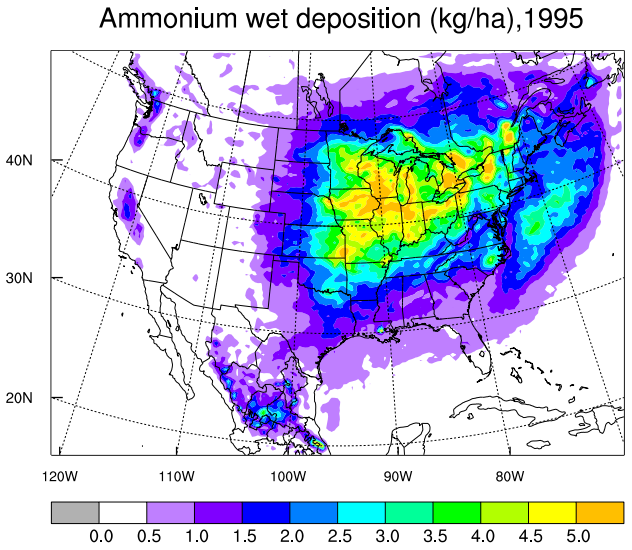
Spatial frequency distributions of correlations (*top*) and rms errors (*bottom*) between CWRF and observed daily mean rainfall variations in summer 1993. Each line depicts a specific configuration in group of the five key physical processes (*color*). The ensemble result (ENS) is the average of all runs with equal (Ave) or optimal (OPT) weights, shown as *black solid* or *dashed* line.

CMAQ Captures Depositions





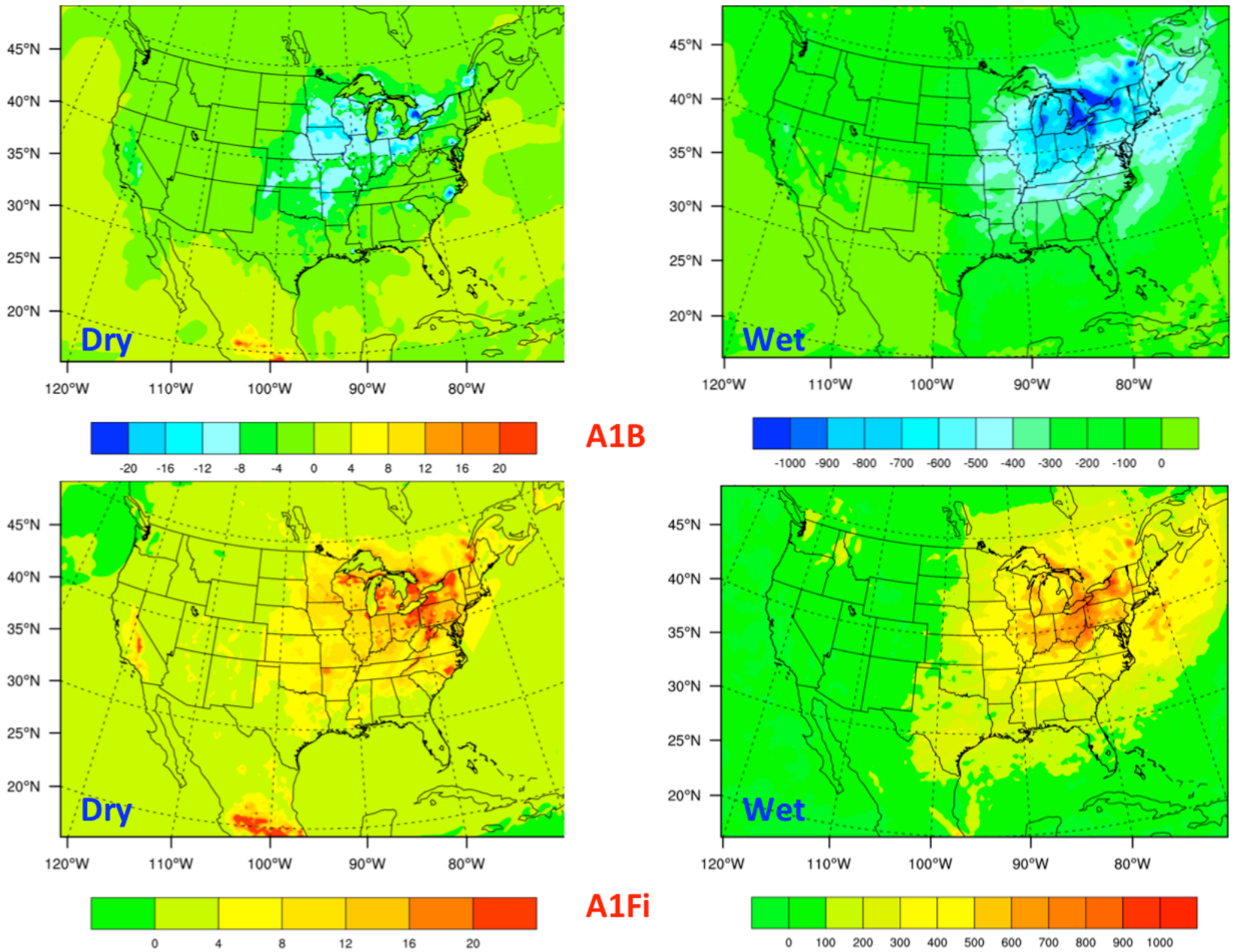




CMAQ Projected N Deposition Change

When changes in both climate and emissions are incorporated, the two scenarios project opposite changes of nitrate wet deposition in the Midwest and Northeast: increases under A1Fi but decreases under A1B with similar magnitudes of 400-1000 mg/m2/year.

The wet deposition changes resemble dry deposition in spatial pattern but with substantially larger magnitudes by a factor of 40-50. Thus the wet deposition is the predominant sink for nitrate aerosols.

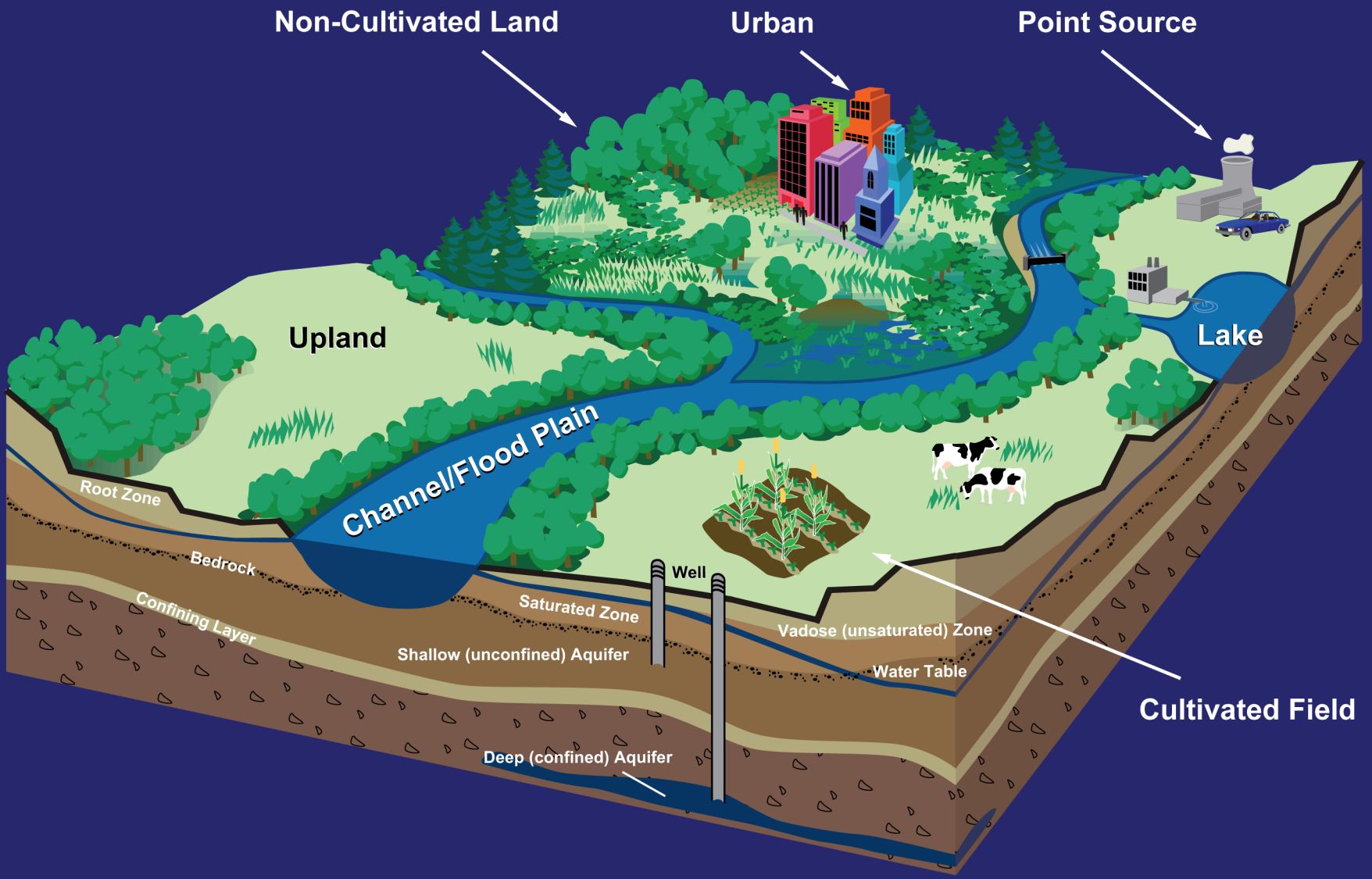


CMAQ projected differences in annual total nitrate deposition (mg/m^2/year) between future (2048-2052) and present (1995-1999)

PSWAT

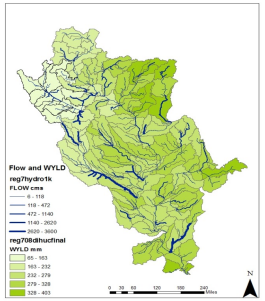
Predictive Water Quality Modeling System

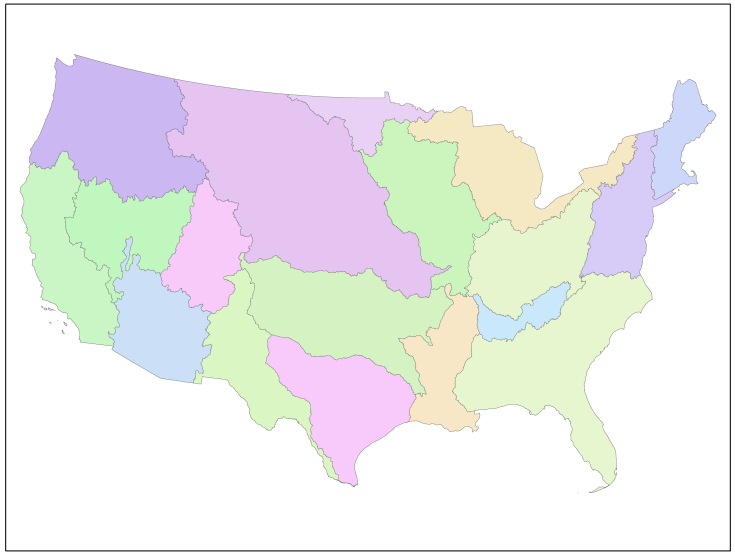
CWRF



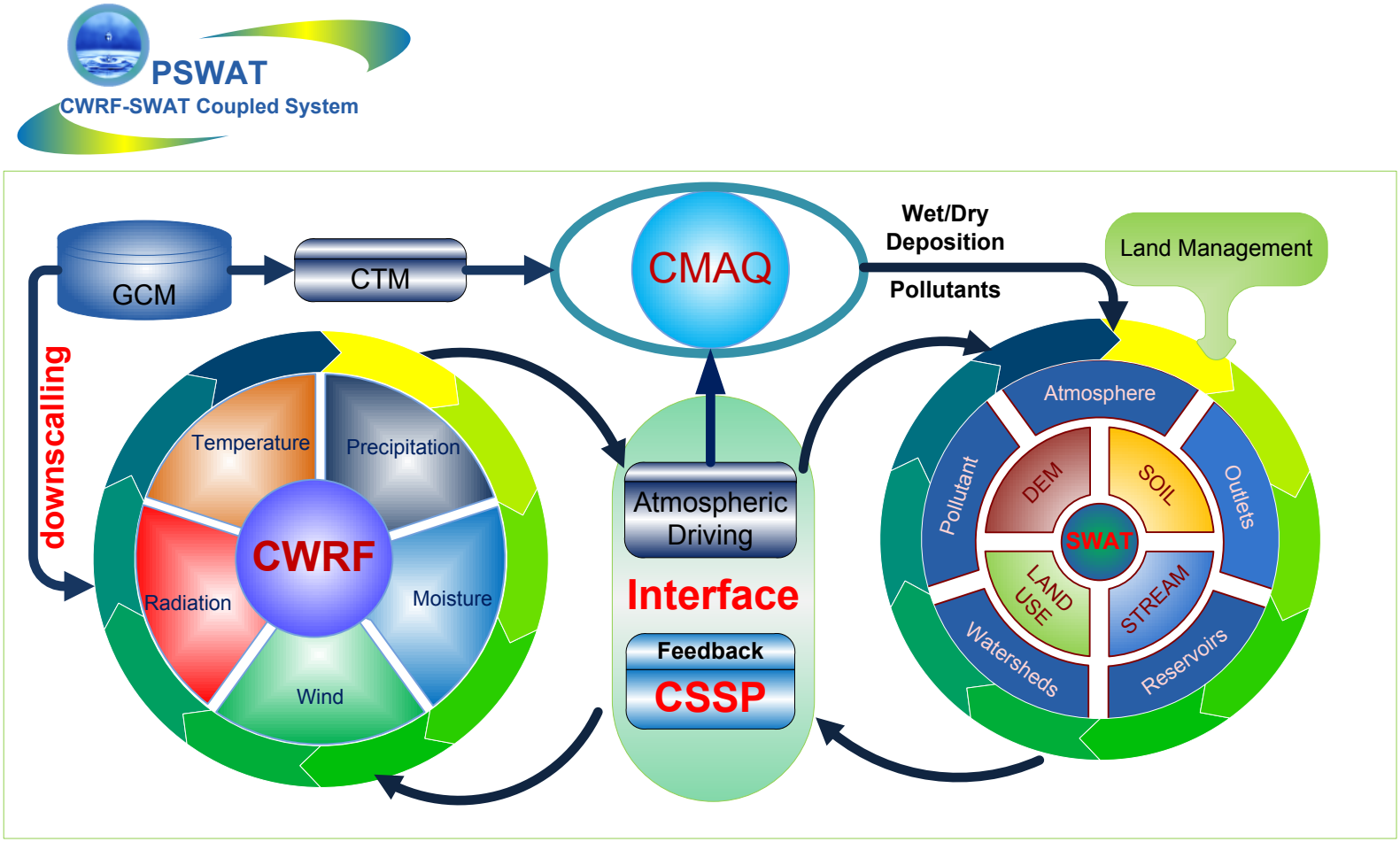
Build National Predictive Capability

SWAT → PSWAT

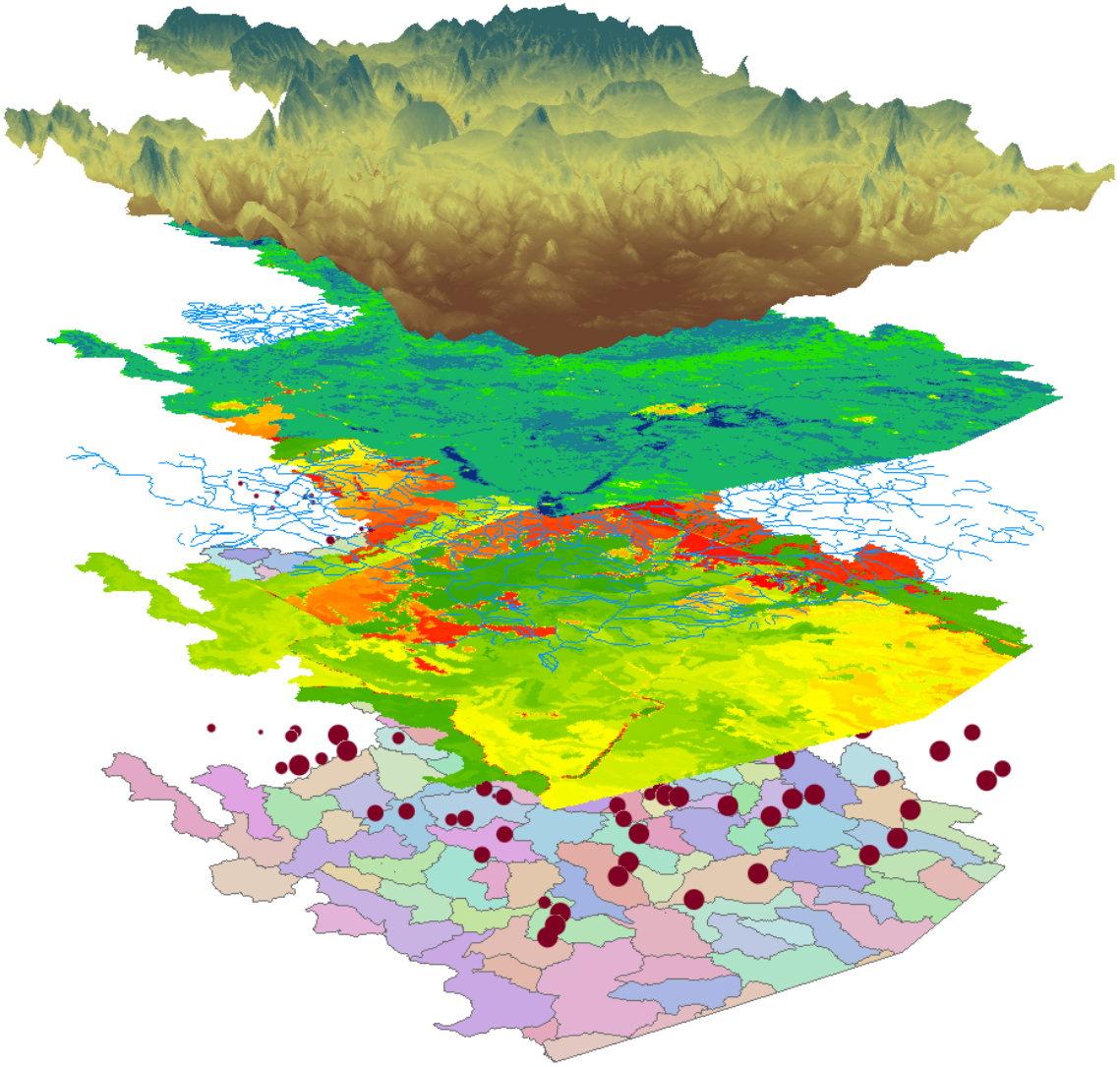




Couple the System Components



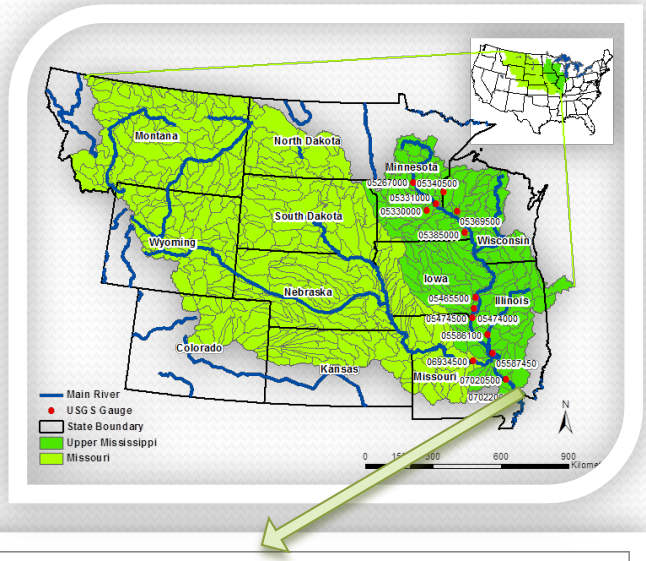
Hydrologic Properties

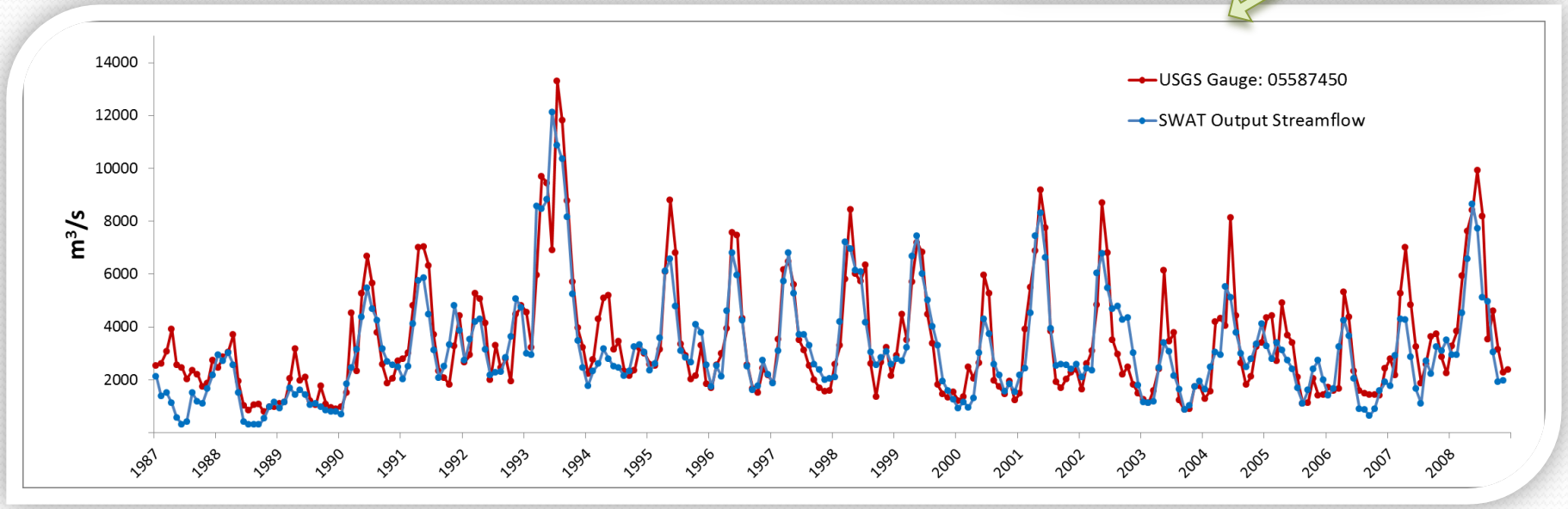


1. DEM
2. Soil properties
3. Land Use/Land Cover
4. Drainage system
5. Point sources
   Outlets
   Reservoirs
6. Watersheds

Streamflow Comparison

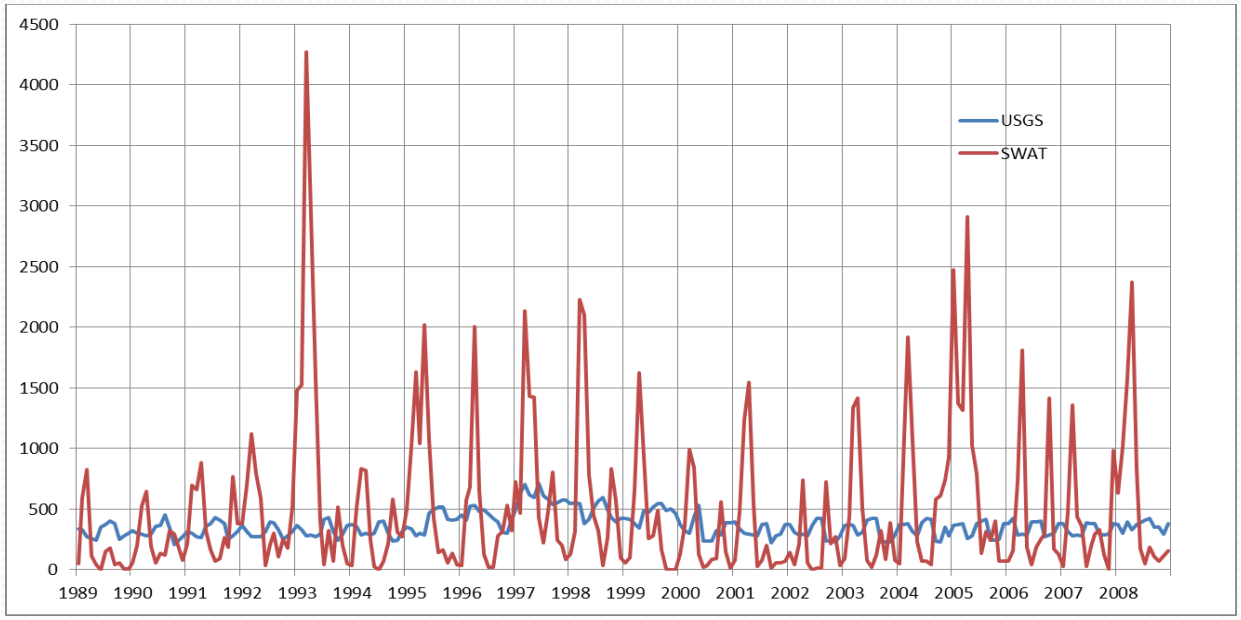
Correlation coefficient of PSWAT streamflow with USGS observations is 0.88





Streamflow at the Colorado River

The original SWAT simulates it very poorly

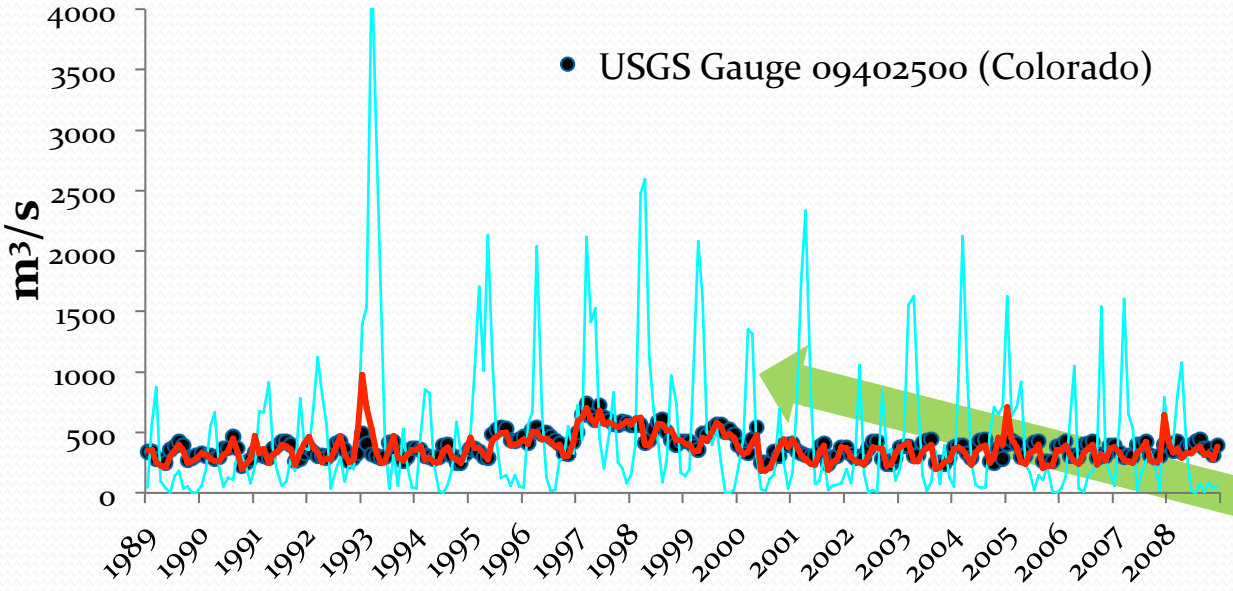


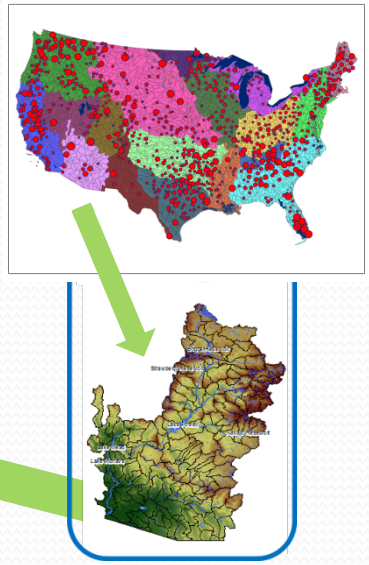
Simulating Human Management

from Historical Records to Future Predictions

- Numerical schemes in macroscale hydrological models for simulating reservoir outflow, irrigation, and other management strategies are very limited, especially lacking operation-based predictive schemes
- We have developed such a predictive scheme for
  - Reservoir management
  - Irrigation
  - Point sources, non point sources

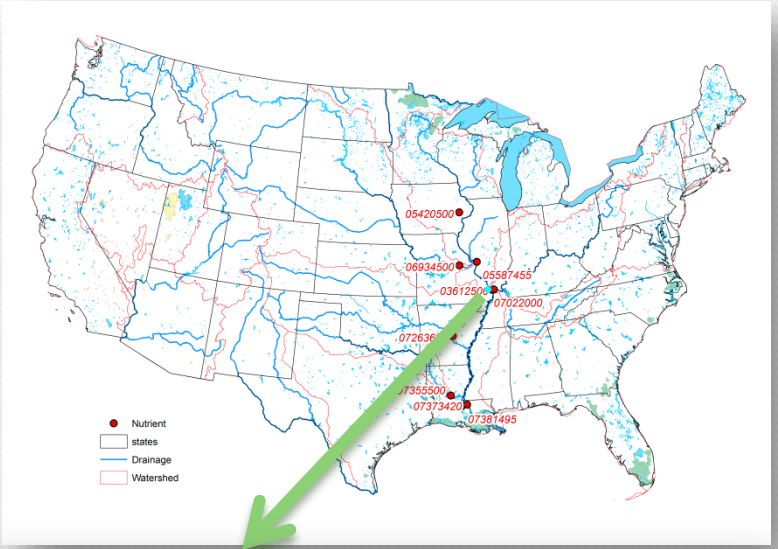


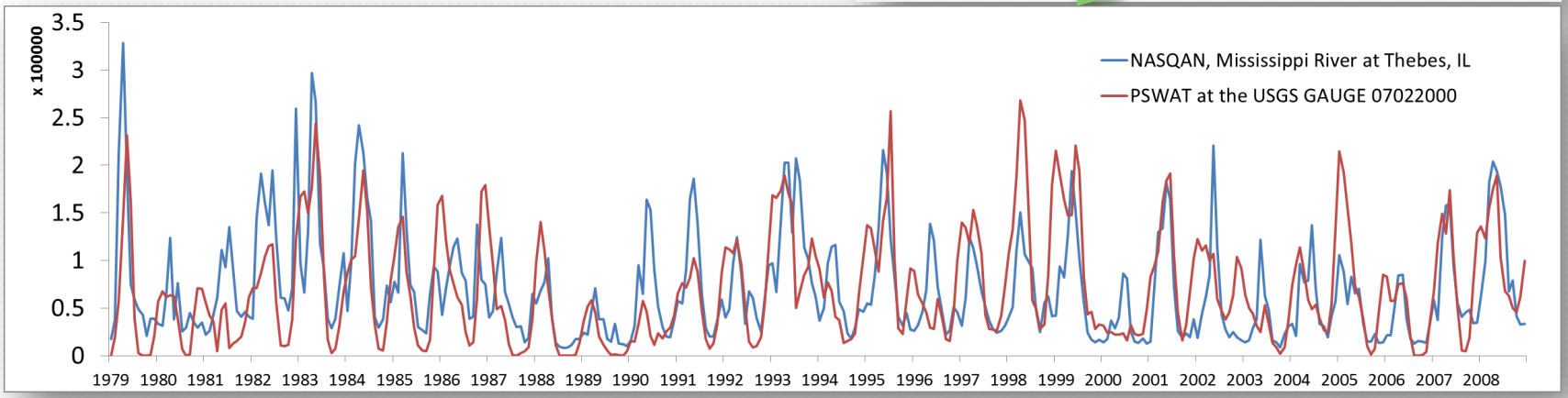




Simulated and Observed Nitrogen

The observed data from monitoring large rivers in the national stream quality accounting network (NASQNA)





PSWAT is Built to Predict Water Change

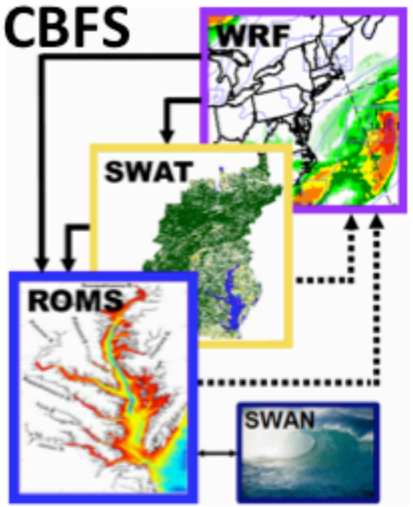
- Predictive SWAT (PSWAT) has been developed, tested, and is ready for online coupling with CWRF, further refinement and system optimization
- It incorporates atmospheric information (precipitation, temperature, radiation, wind, humidity, and nitrogen deposition) and point sources and management strategies
- It captures the streamflow characteristics in most regions of the U.S.
- It provides a unique modeling tool to better understand and predict potential consequences of climate change on hydrologic processes
- Its application next will enable us to identify, at the national scale, relative vulnerabilities of U.S. water resources to global change and provide scientific guidance for developing adaptive strategies

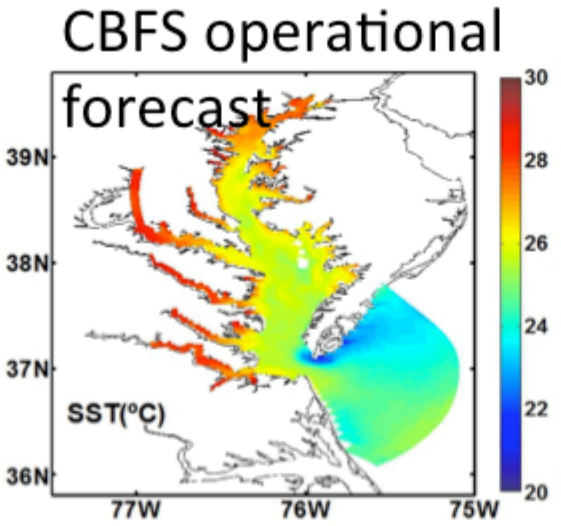
Chesapeake Bay Forecast System (CBFS)

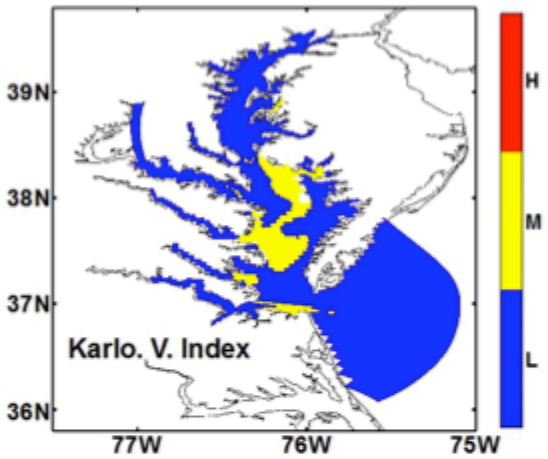
Making Operational Short-range Forecasts and Seasonal Outlooks

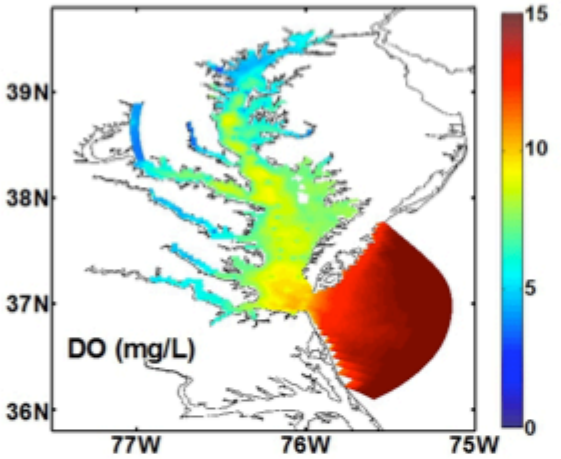
http://cbfs.umd.edu

The prototype *Chesapeake Bay Forecast System* is providing short-range forecasts (since January 2008) and seasonal outlooks (since August 2009) of atmosphere, coastal ocean, watershed, and ecosystem conditions in the CBay. It consists of one-way coupling between WRF for atmosphere plus land surface, ROMS with interactive SWAN for ocean, SWAT for watershed, and empirical habitat models for the ecosystem including sea nettles, HABs, pathogens, and striped bass indices. The CBFS short-range forecasts are made from the NOAA GFS weather prediction and seasonal outlooks from the IRI ECHAM4.5 climate prediction. The CWRF, including all WRF functionalities by design, can easily adopt the one-way coupling with ROMS, SWAN, SWAT and the habitat models. To take the next leap toward a full Earth system predictive capability for the RESM, the two-way coupling will be developed between these component models along with the advanced data assimilation.







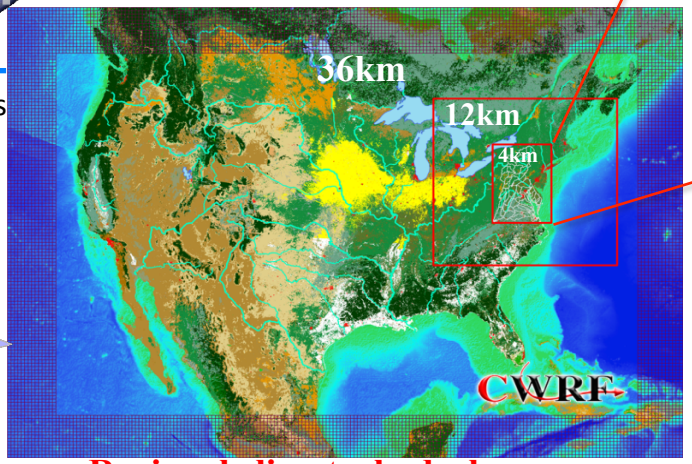


Regional Earth System Model (RESM) Predicting Chesapeake Bay Watershed Sustainability under Climate Change

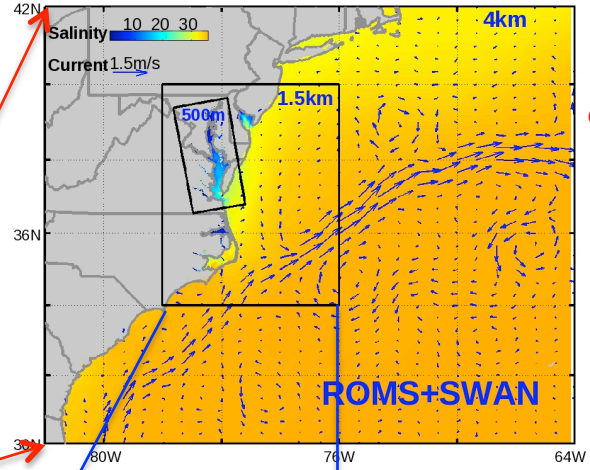
(Multi-scale nested approach)

Global drivers

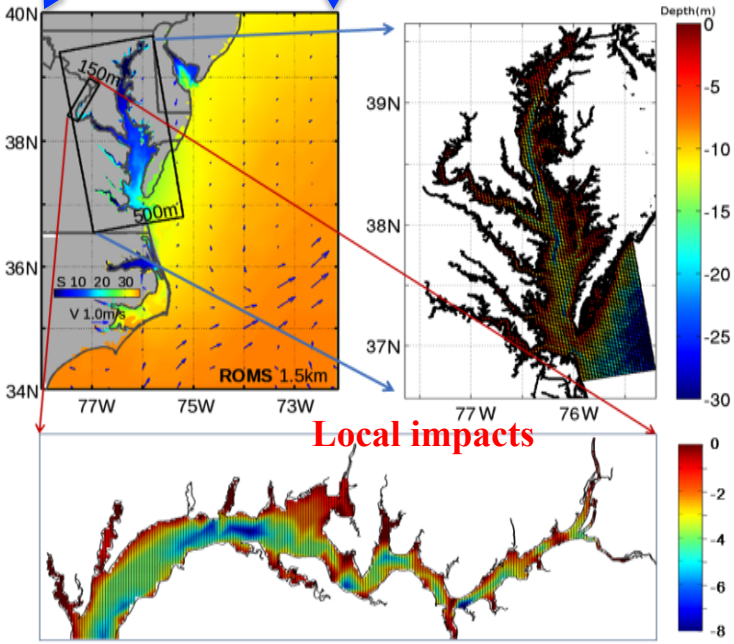
Climate anomalies
Increasing CO_2
Global warming
Sea level rise



Regional climate, hydrology, crop, air quality, water quality



Coastal ocean: currents, surges, tides, waves, sea level, salinity



Local impacts

Schematic of the Regional Earth System Model (RESM) for predicting Chesapeake Bay watershed sustainability under climate change. This includes its components each listed with key functions and grid resolution, the nesting between the components with connecting arrows, as well global drivers to force the regional system under climate anomalies and changes. The CWRF outer domain resolves the continental scale at 36-km while the Chesapeake watershed is represented with a 12-km outer grid and a 4-km inner grid. Detailed land use types are explicitly depicted to generate sector-specific information. The Bay will be modeled at 3/2 to 1/2-km with resolution of a few meters in the tributaries to explicitly represent local impacts.