US EPA ARCHIVE DOCUMENT

Continental-Scale Water Cycle Modeling:

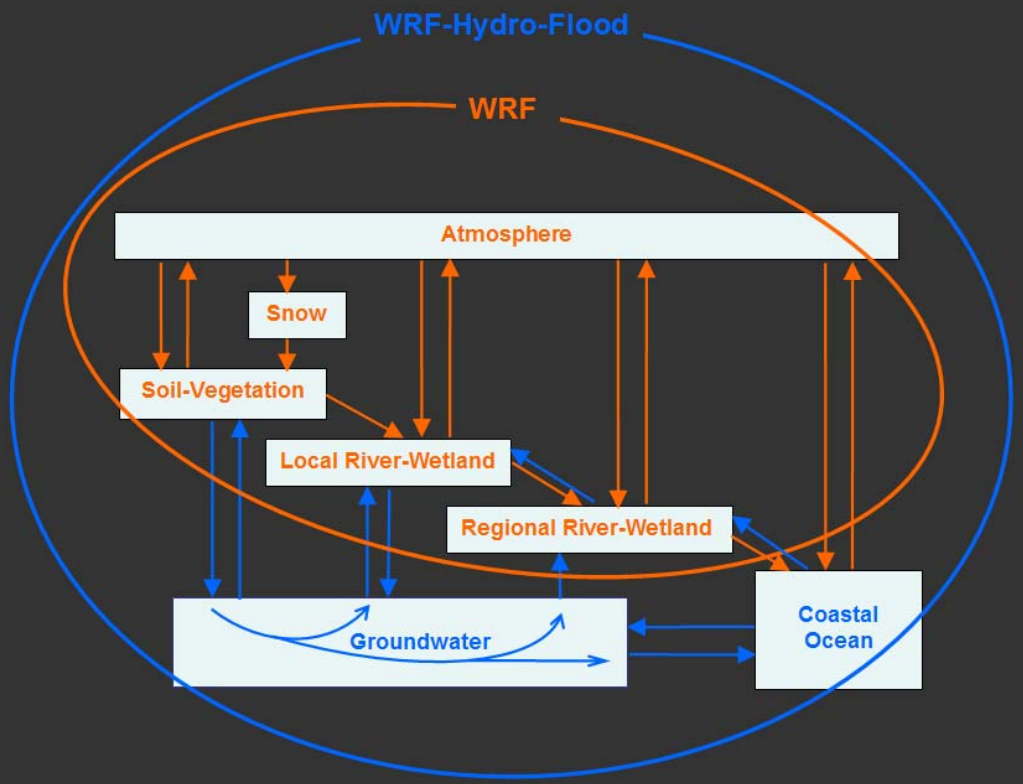
Integrating Climate, Surface Water, Groundwater, Sea-Level, and Human Use

Project Goal:

- Assess US freshwater resource
  - climate variability & change
  - increasing human demands

Scale:

- 5km - Continental

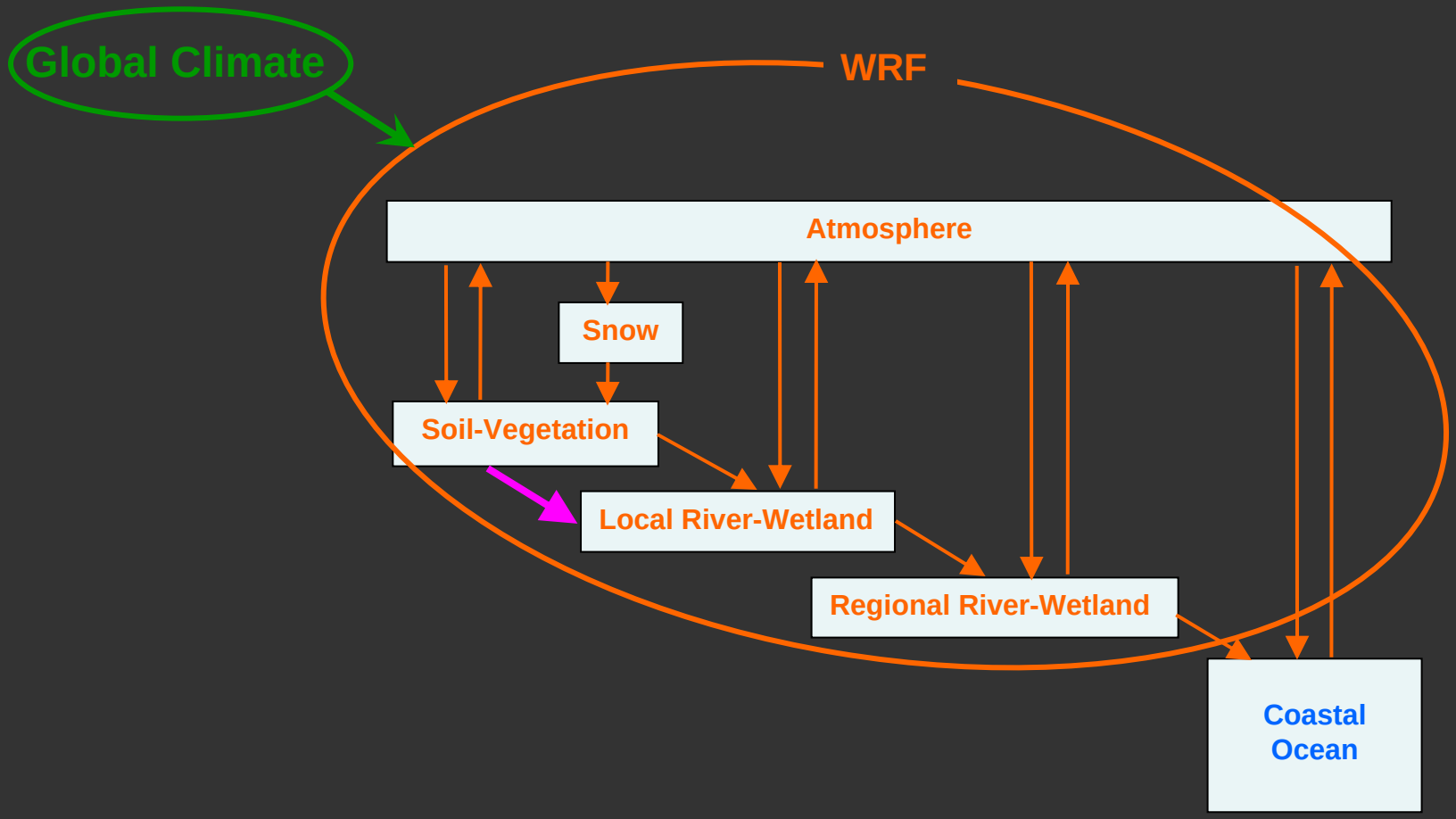


Tool:

- Integrated Water Cycle Model, ***WRF-Hydro-Flood***
  - groundwater and interfaces

Typical Approach:

- Regional Climate Model Downscaling



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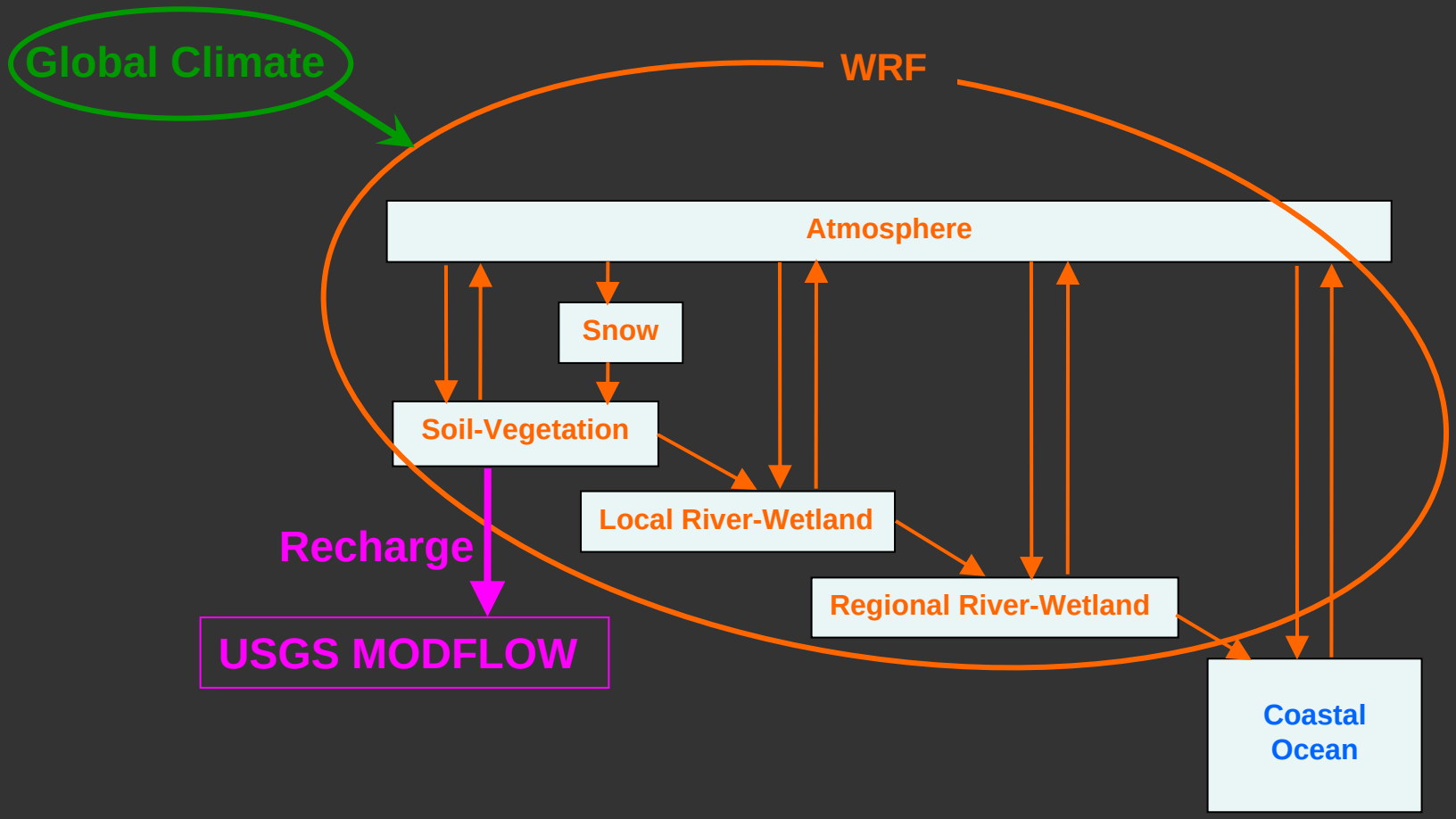

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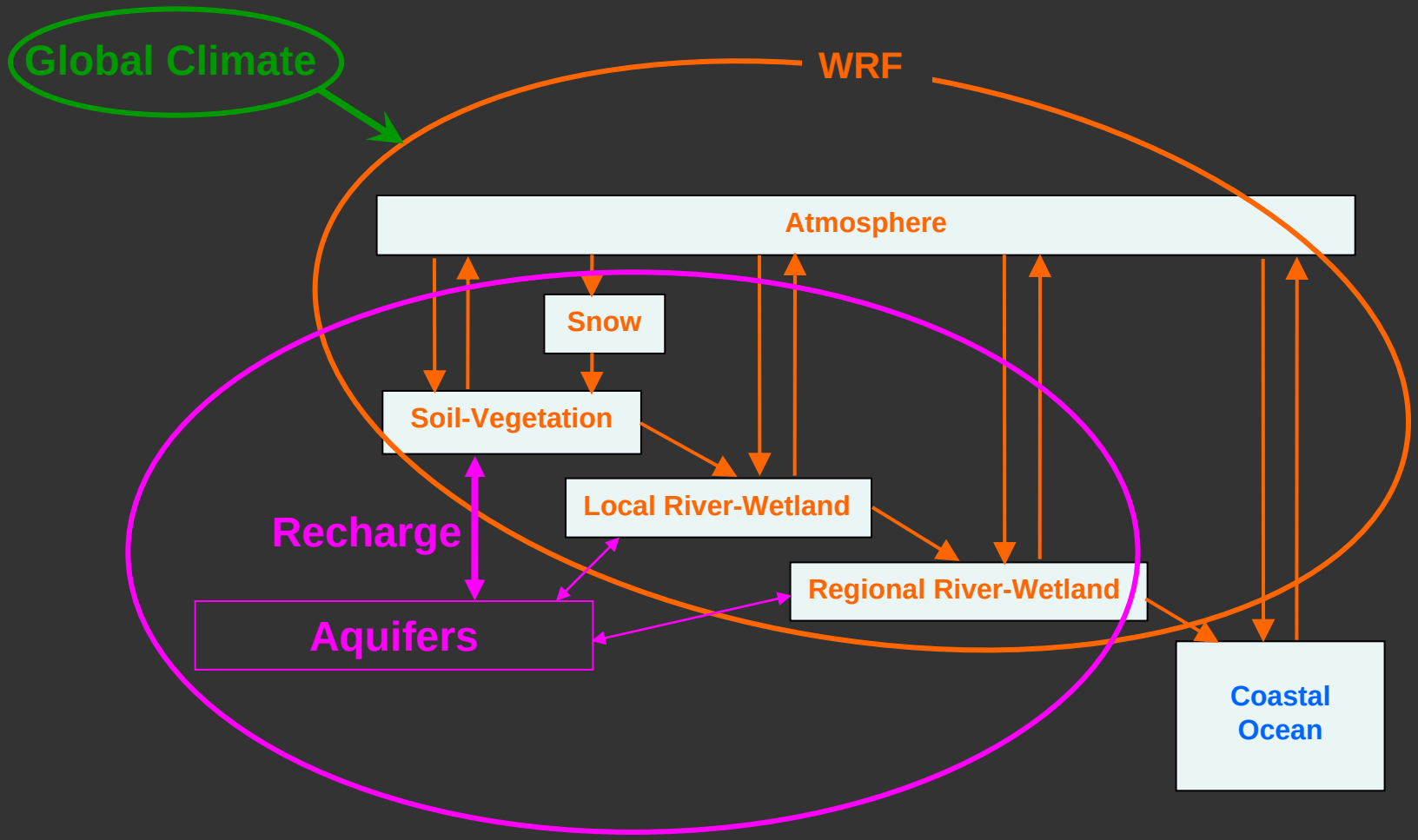

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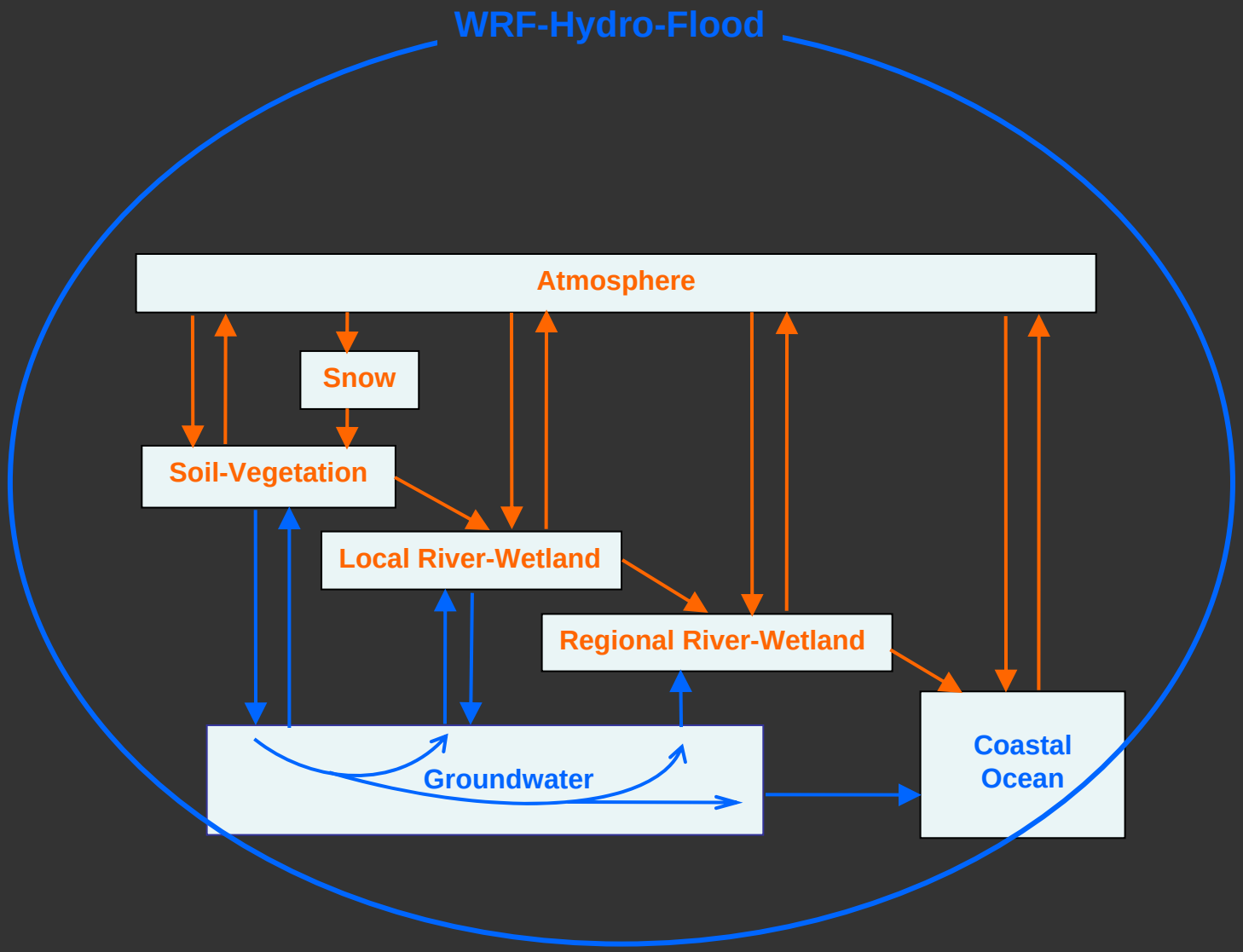

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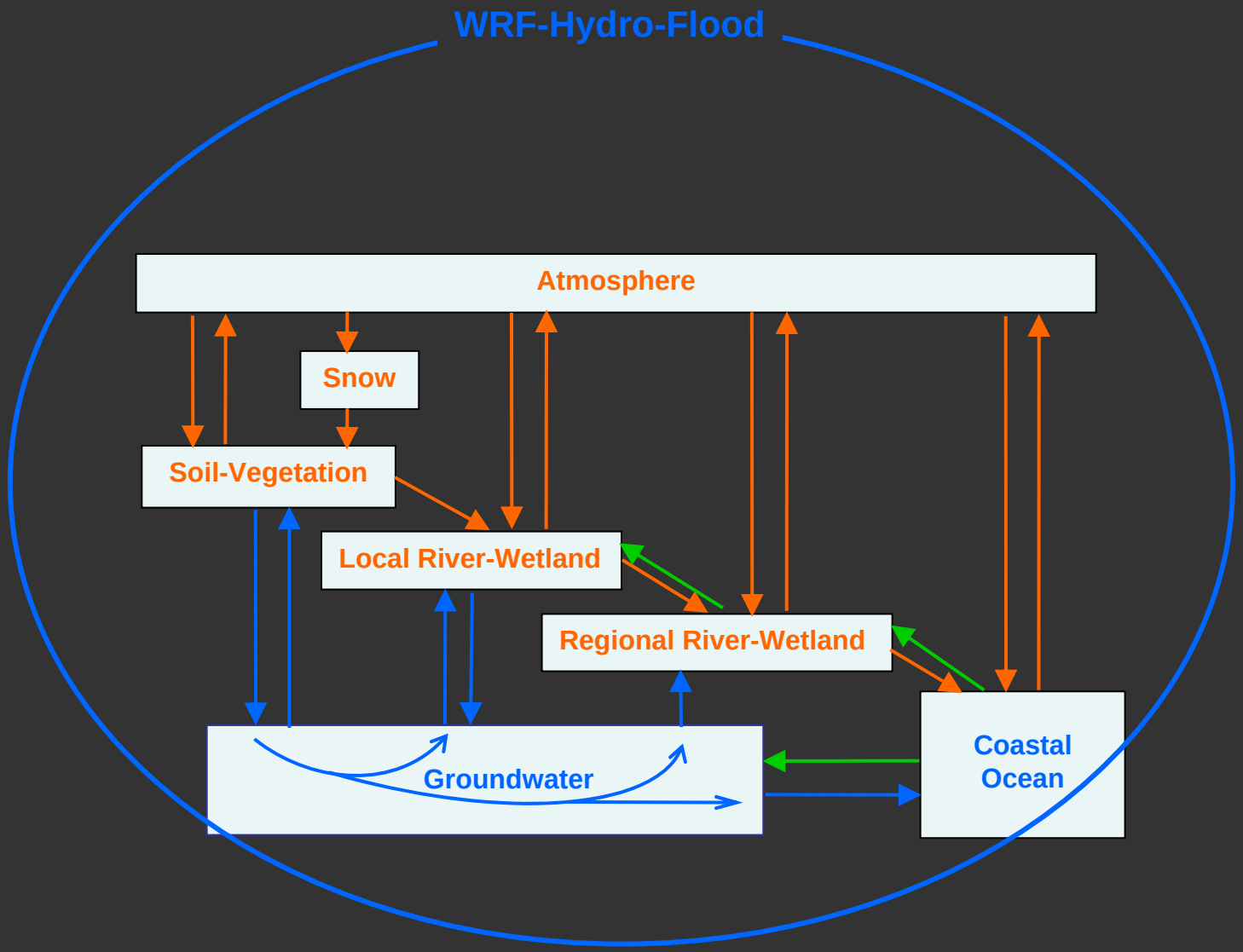

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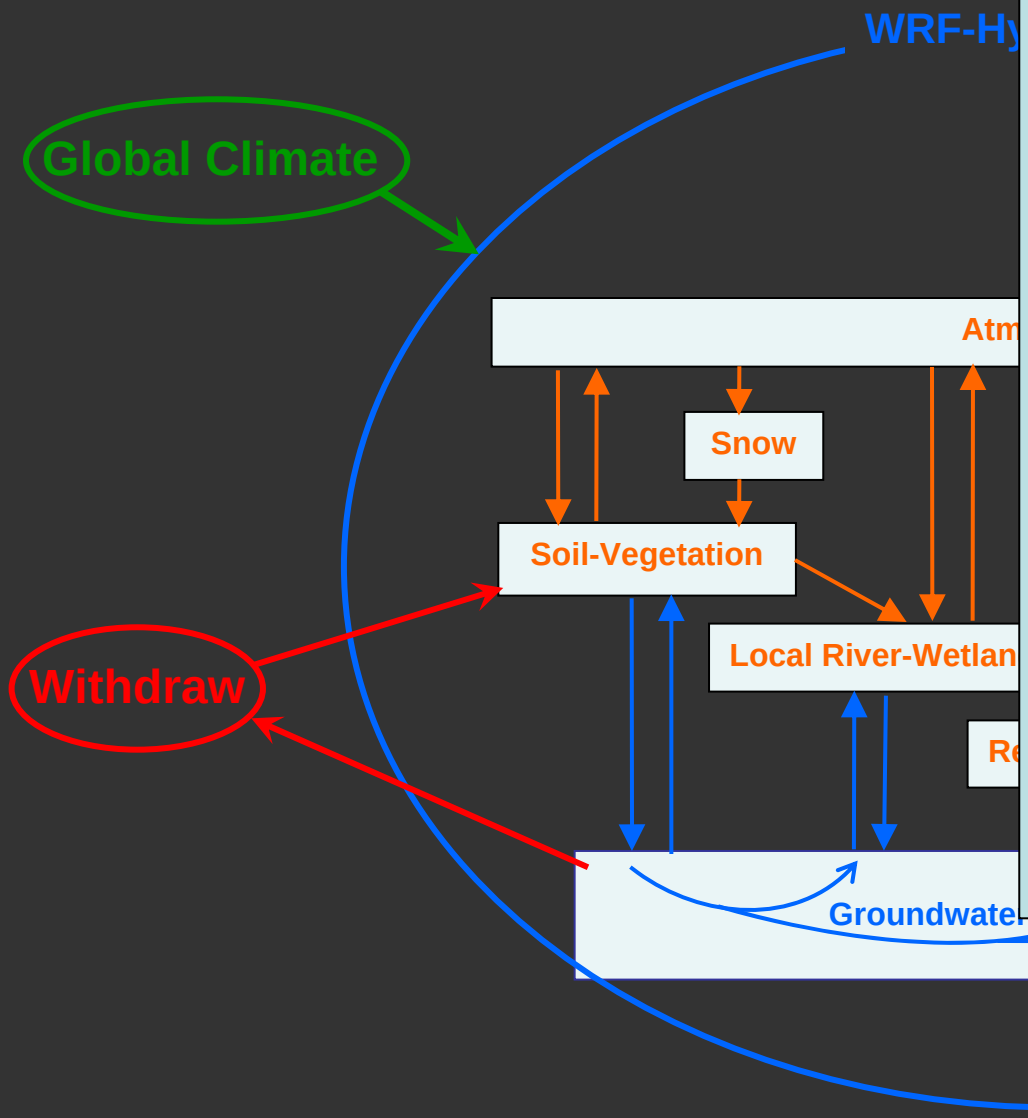

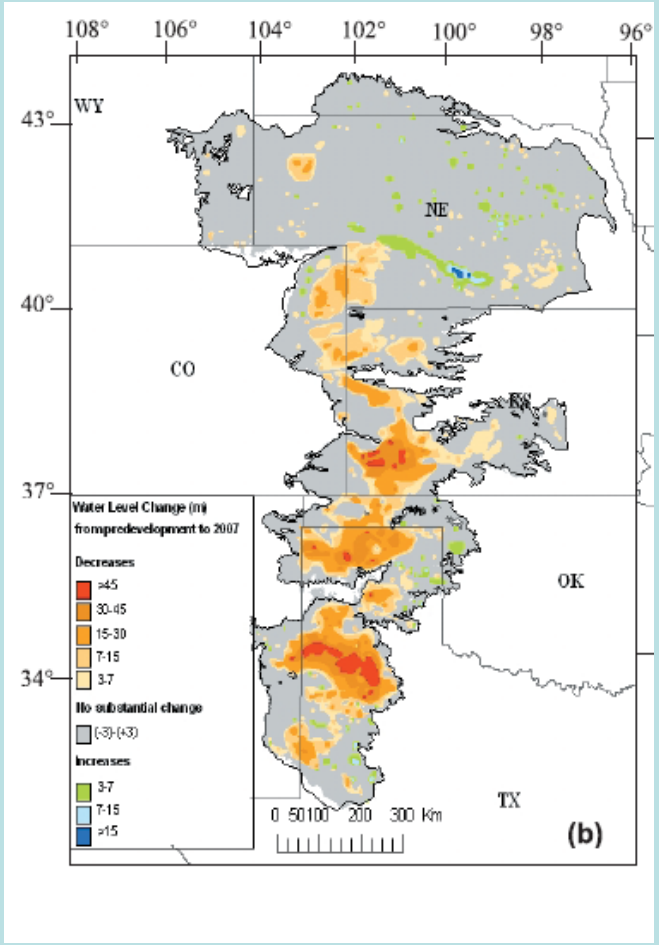

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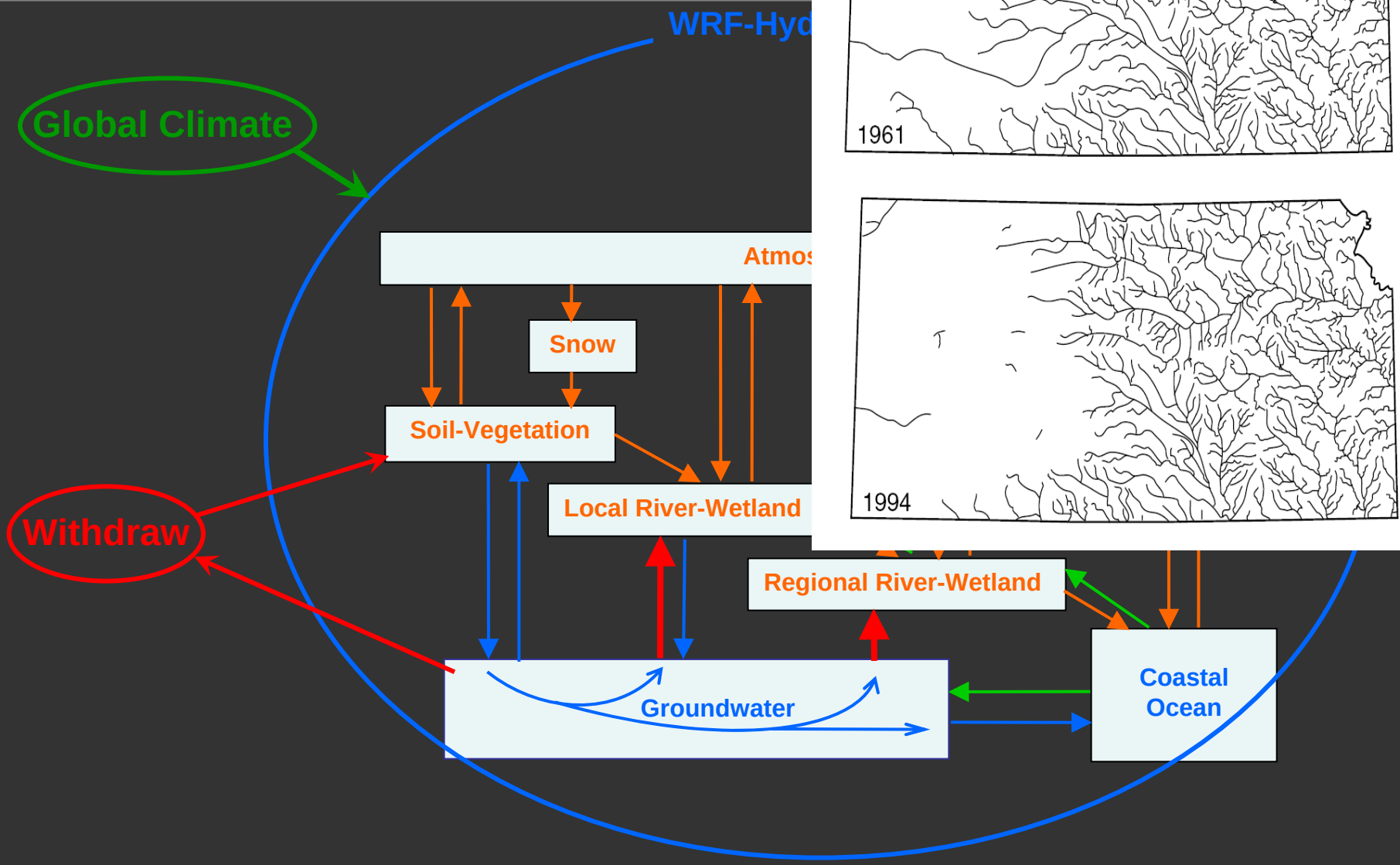

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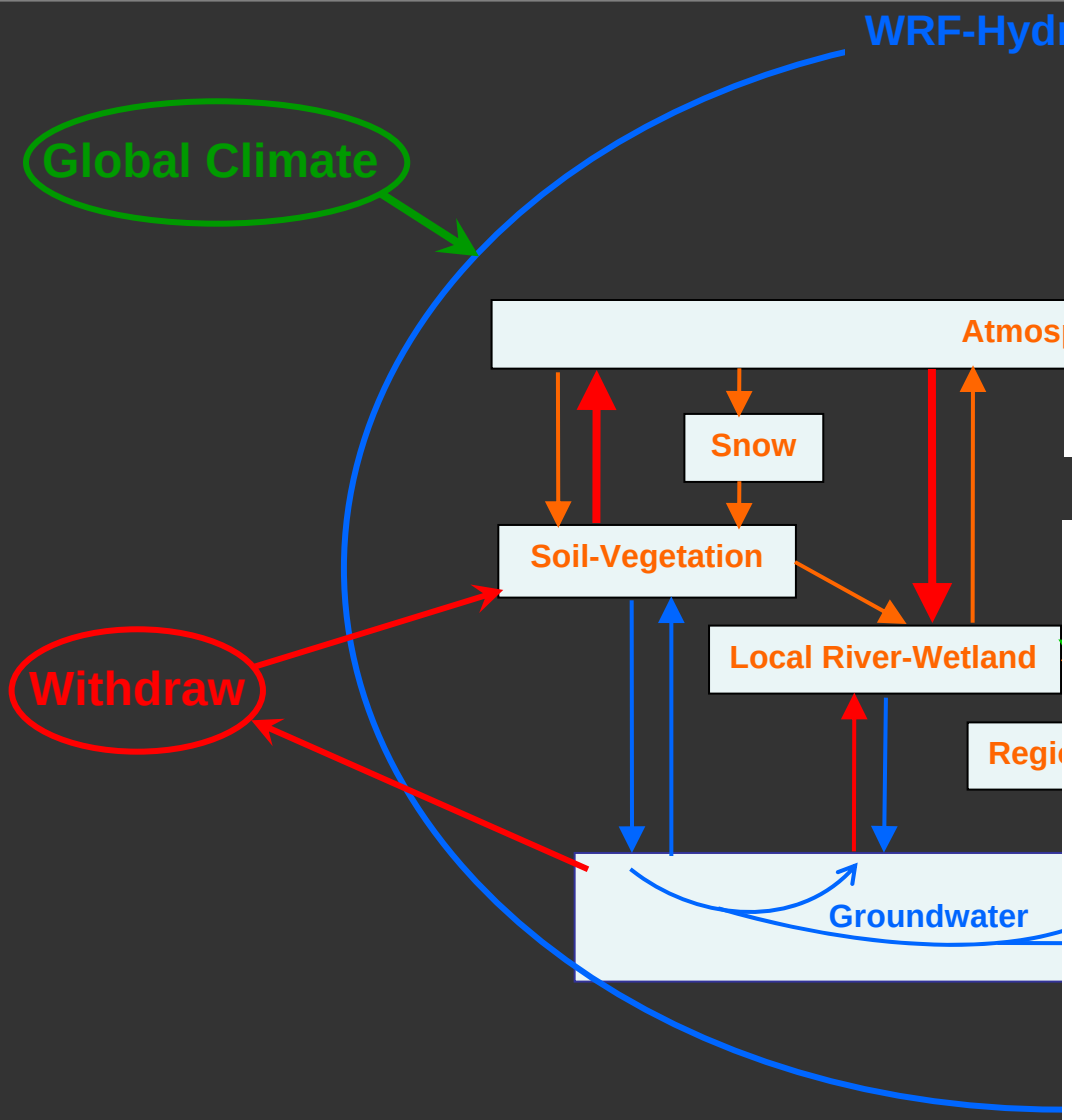
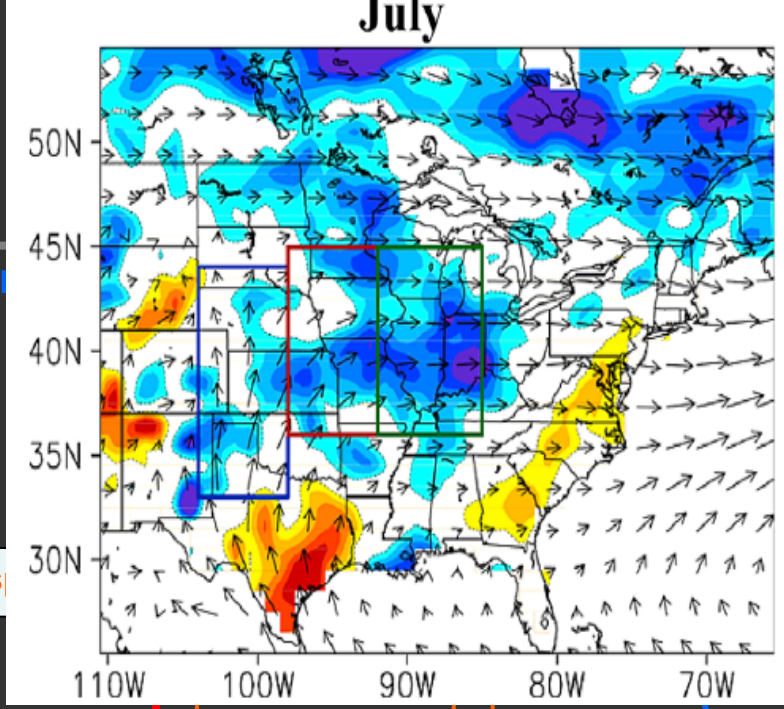
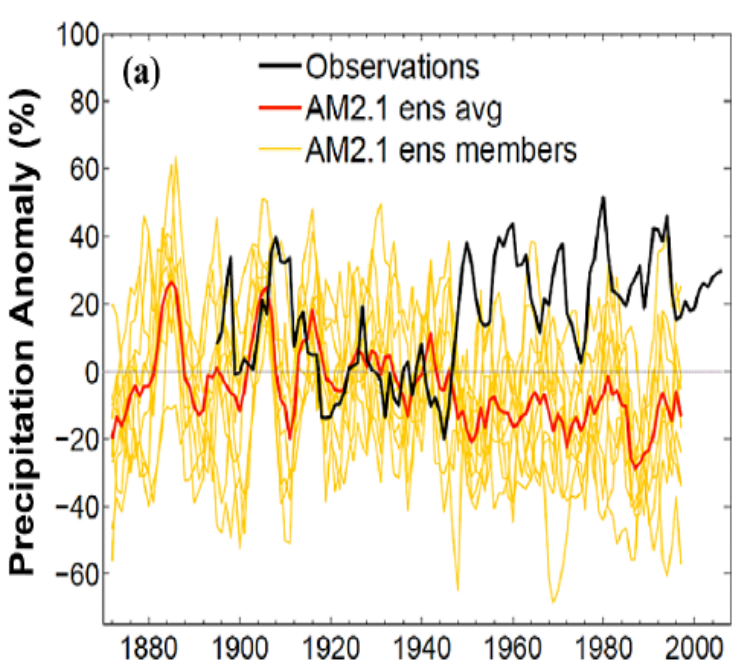
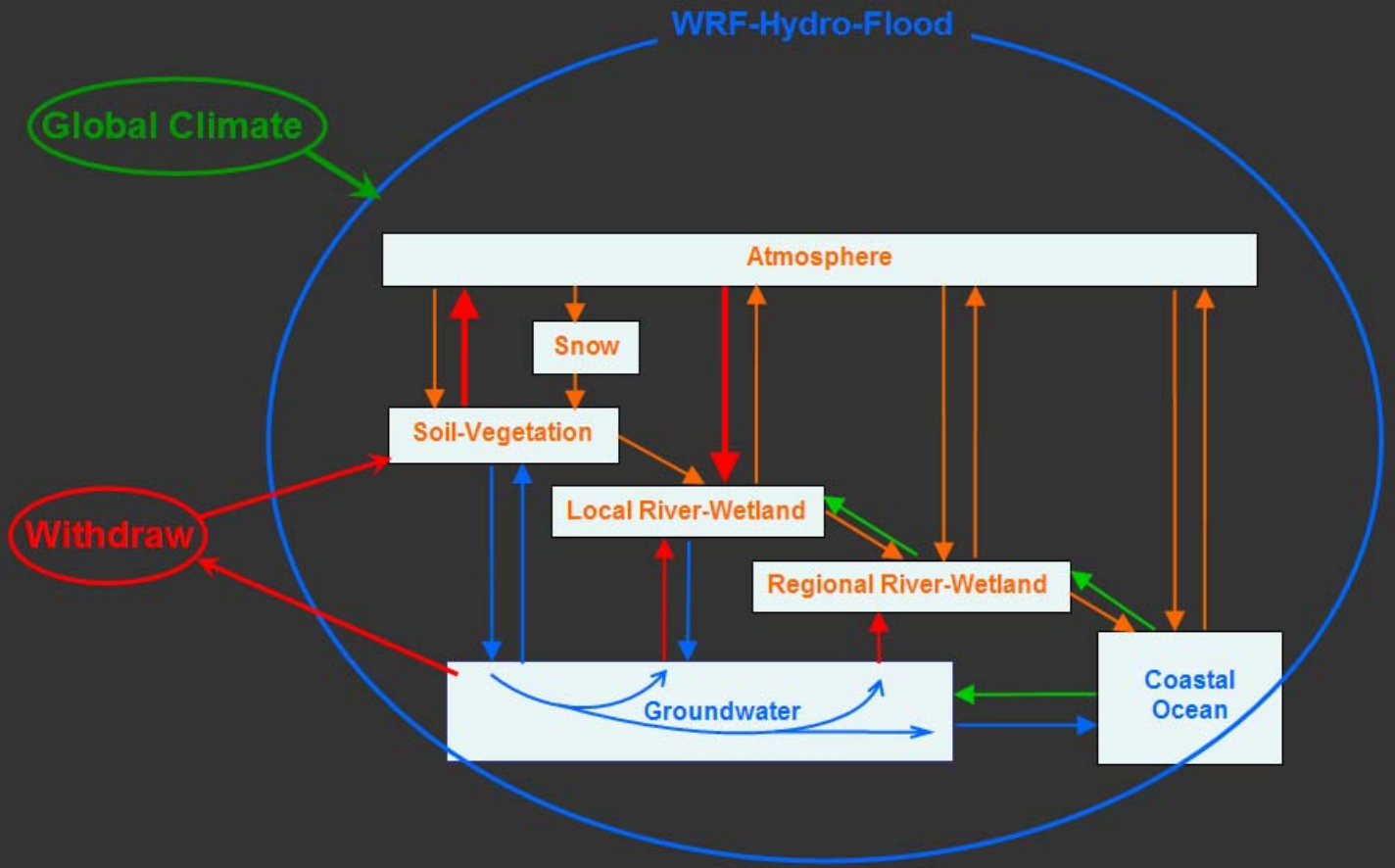


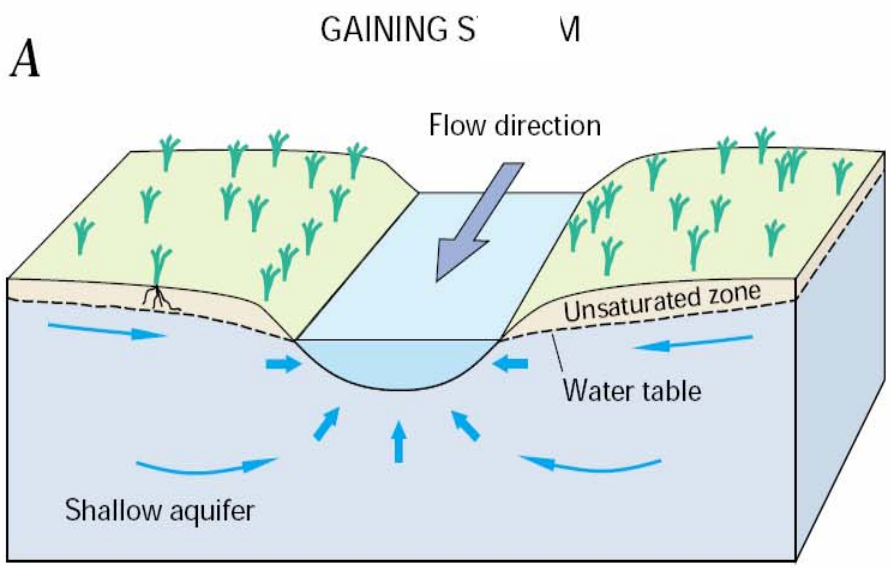


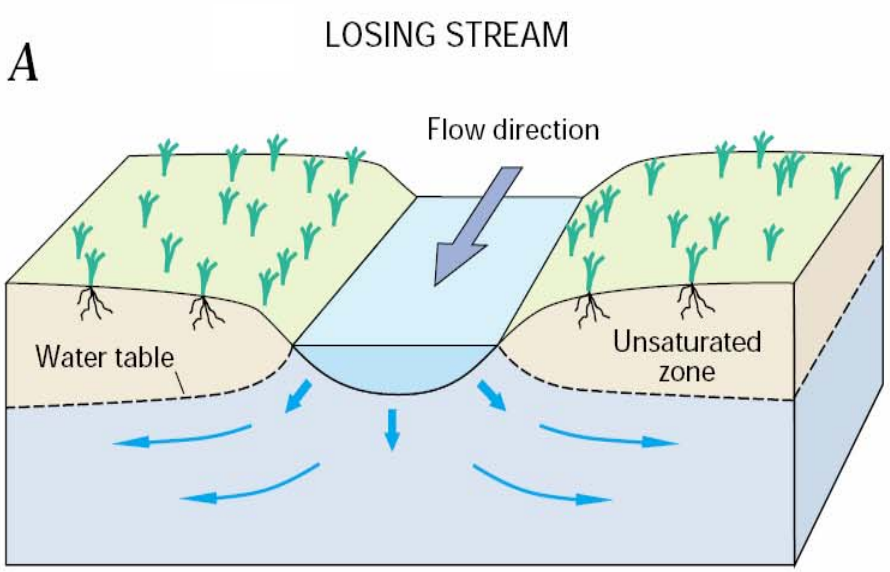


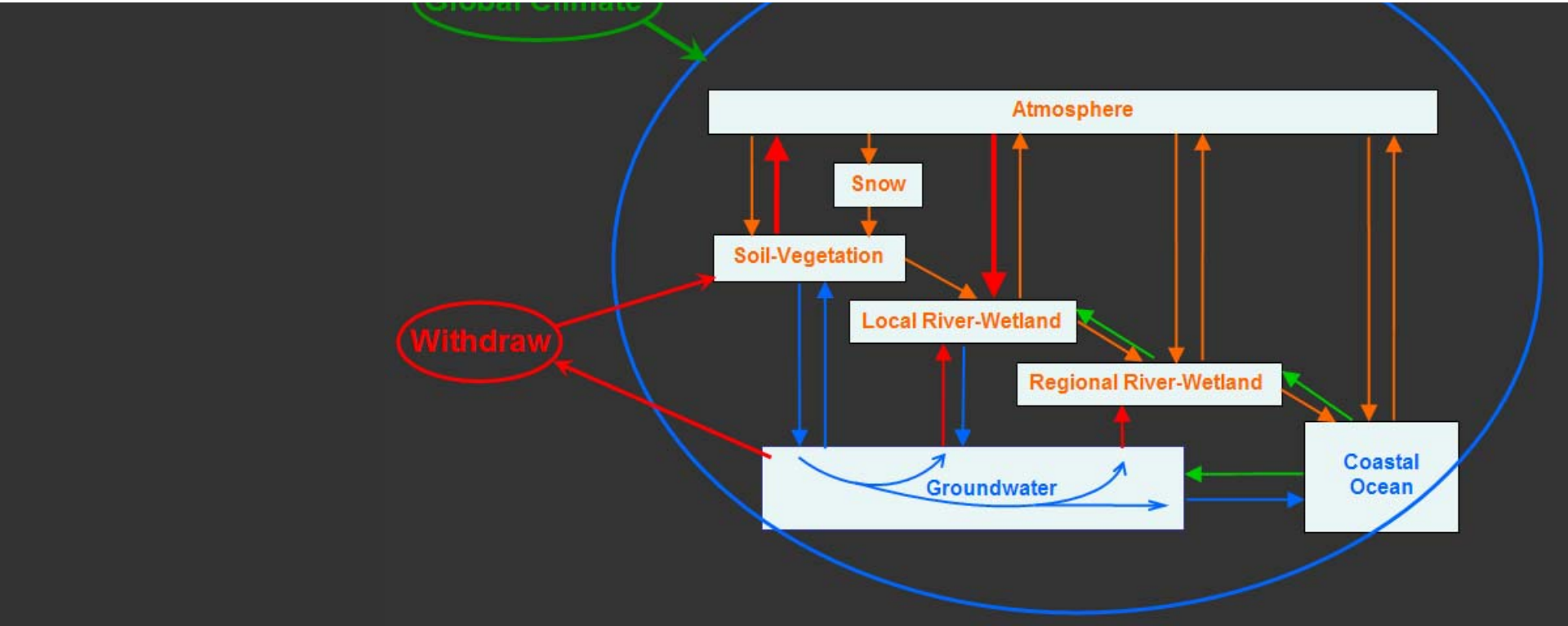
Advantages:

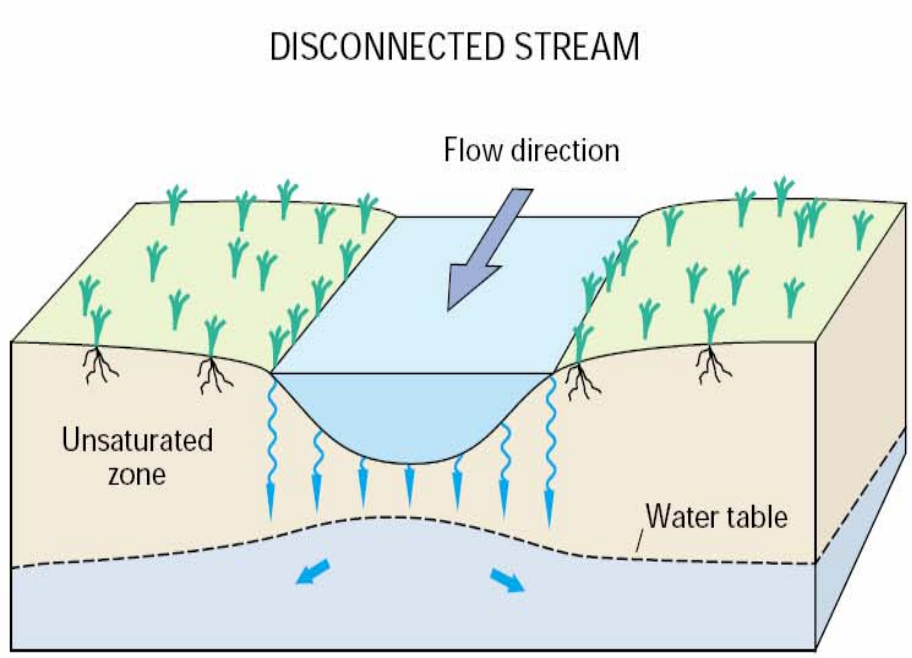
- Fully coupled, internally consistent water cycle
- Enabled several interfaces related to the GW
- Takes into account of GW buffer
- Physical framework for building in biogeochemistry

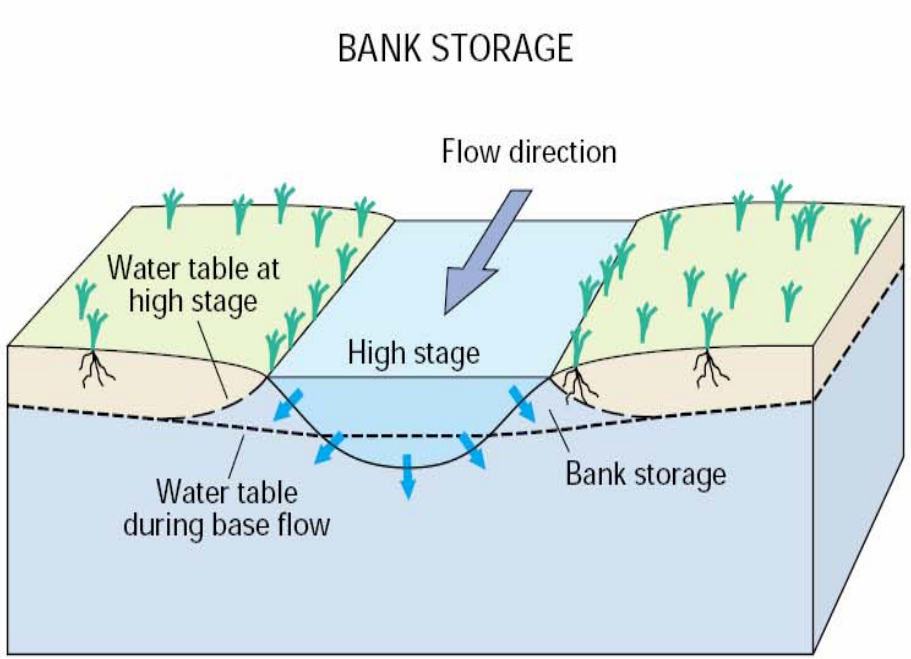


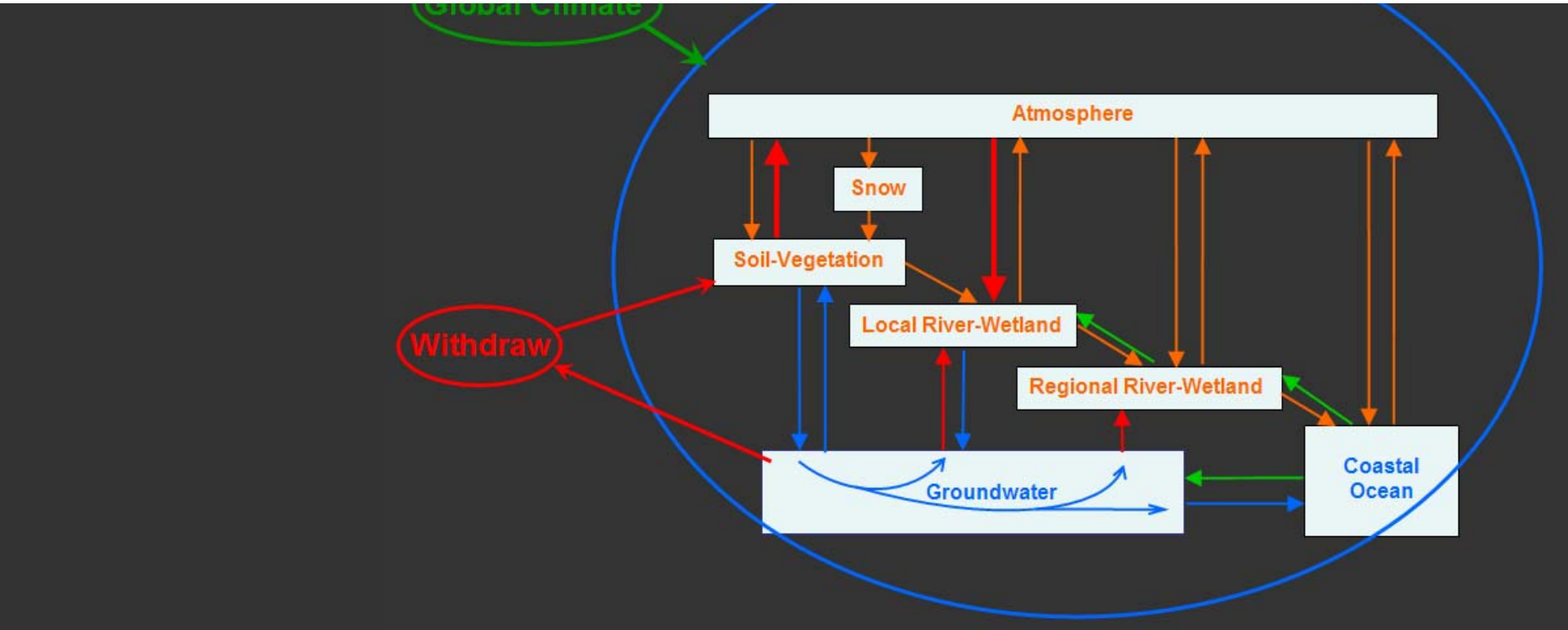

A
GAINING S VI
Flow direction
Unsaturated zone
Water table
Shallow aquifer


A
LOSING STREAM
Flow direction
Water table
Unsaturated zone


Atmosphere
Snow
Soil-Vegetation
Withdraw
Local River-Wetland
Regional River-Wetland
Groundwater
Coastal Ocean


DISCONNECTED STREAM
Flow direction
Unsaturated zone
Water table


BANK STORAGE
Flow direction
Water table at high stage
High stage
Water table during base flow
Bank storage


Global Climate
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Advantages:

- Fully coupled, intern
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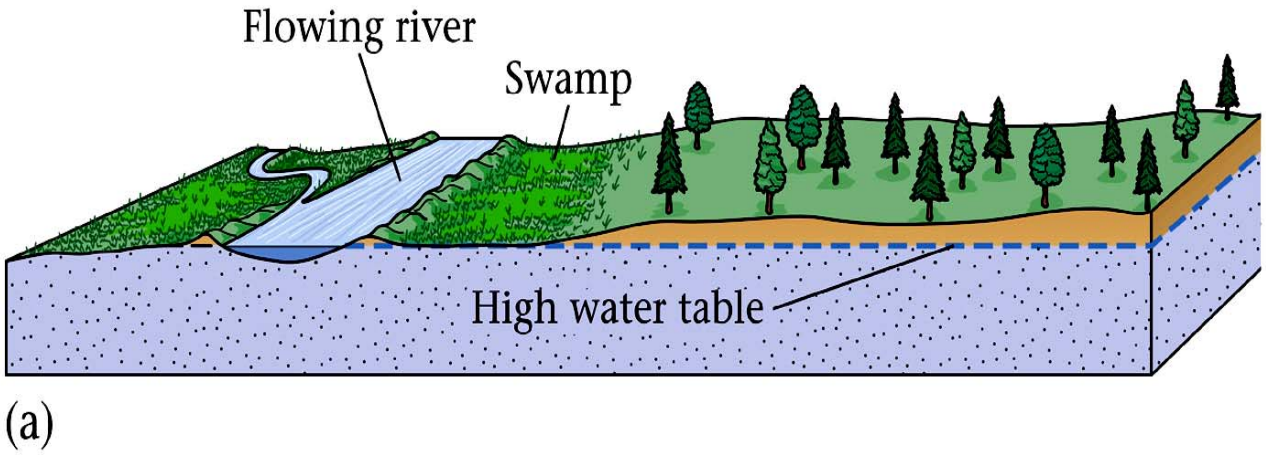
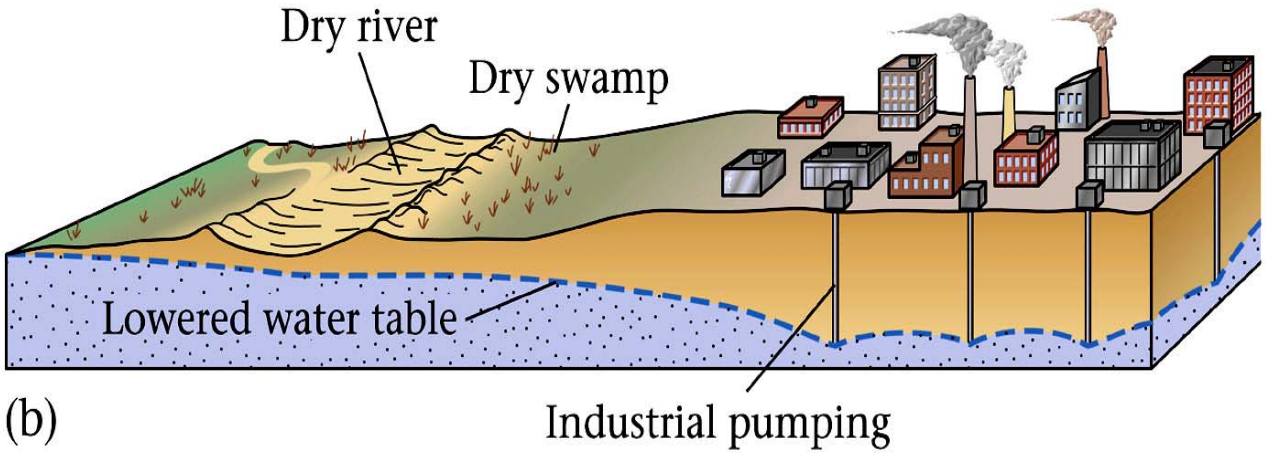
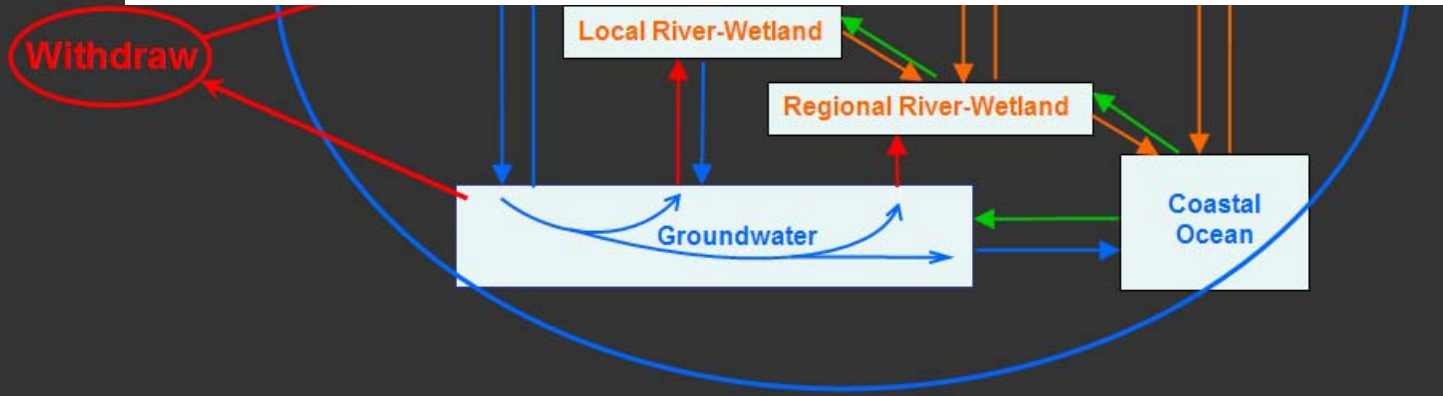
- Takes into account c
- Physical framework







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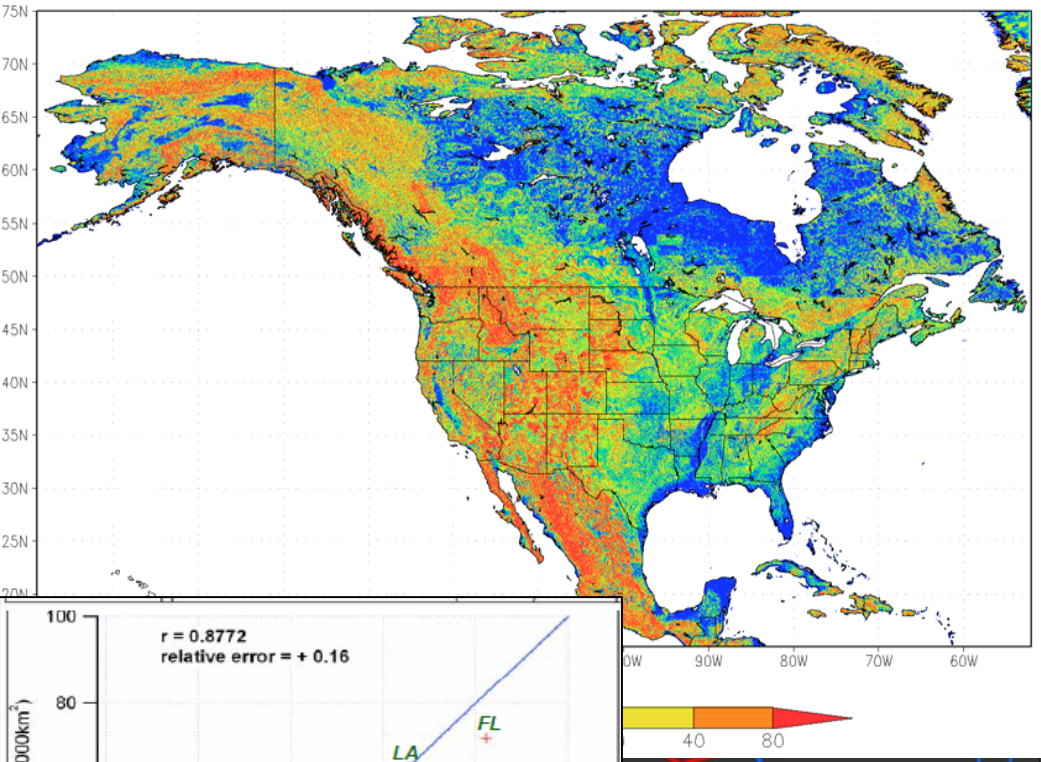

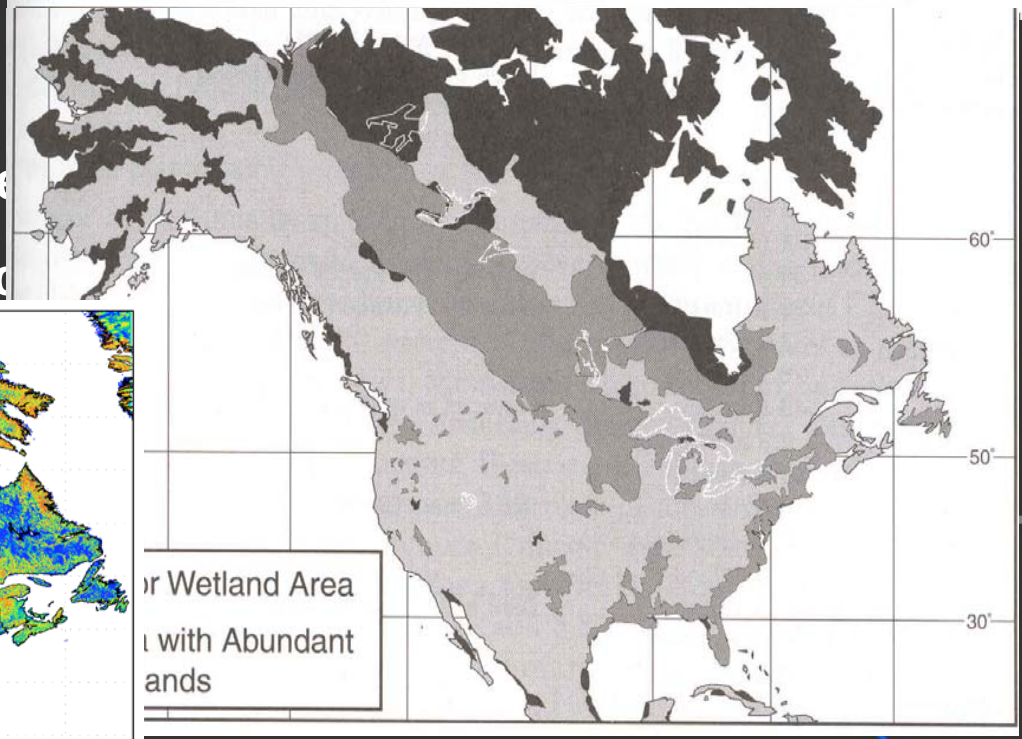

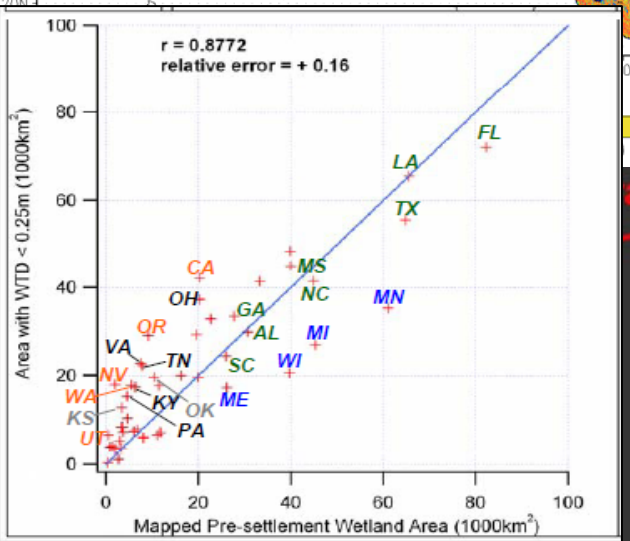

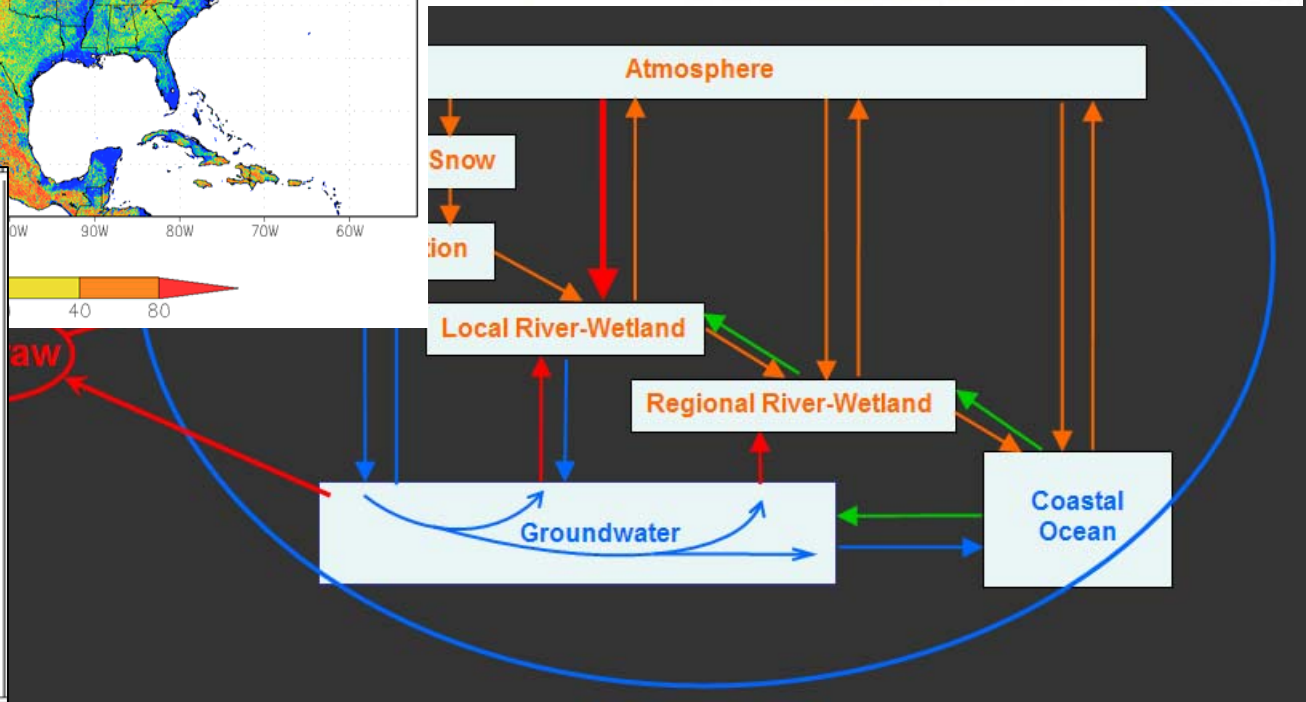

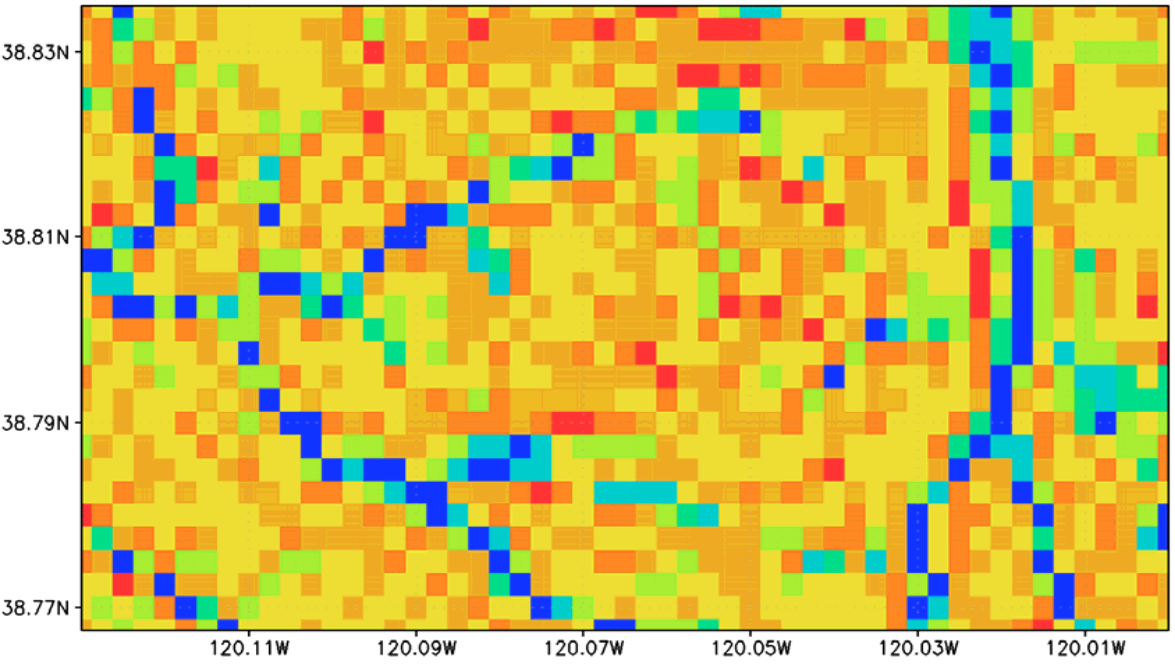
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38.81N
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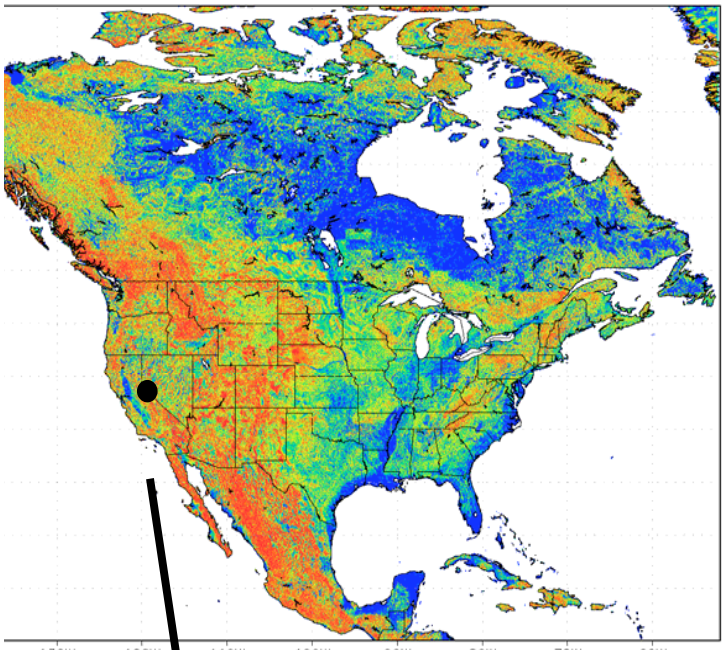
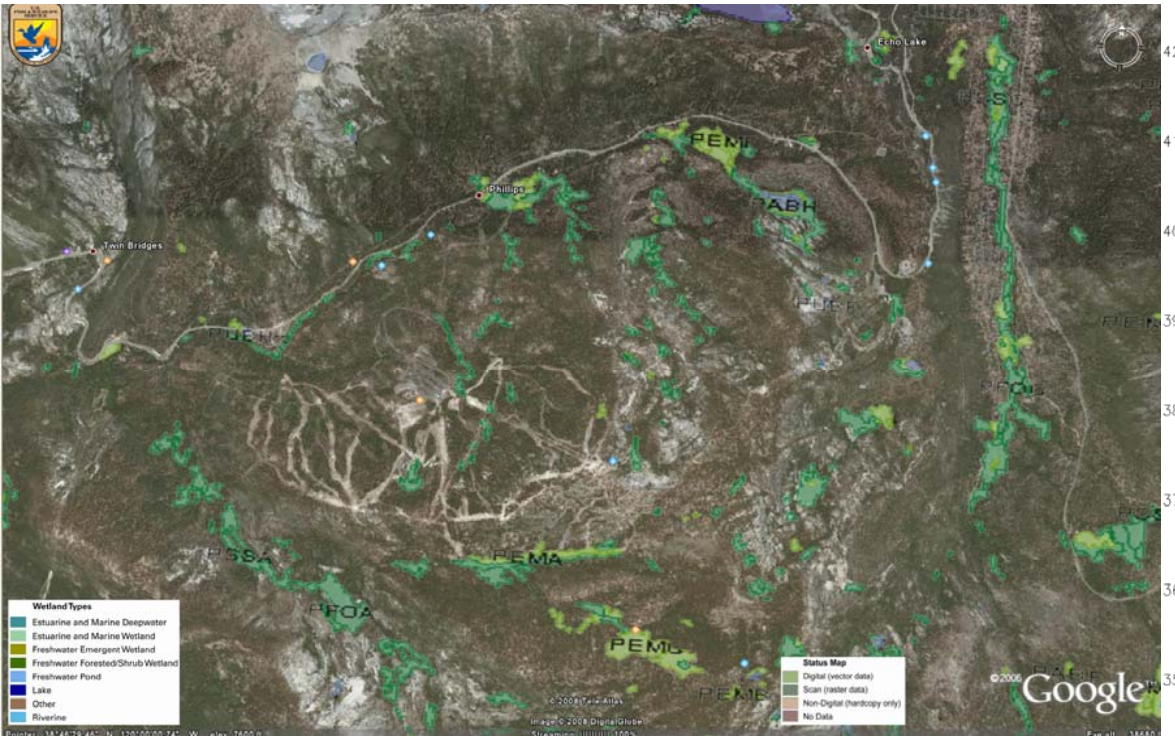
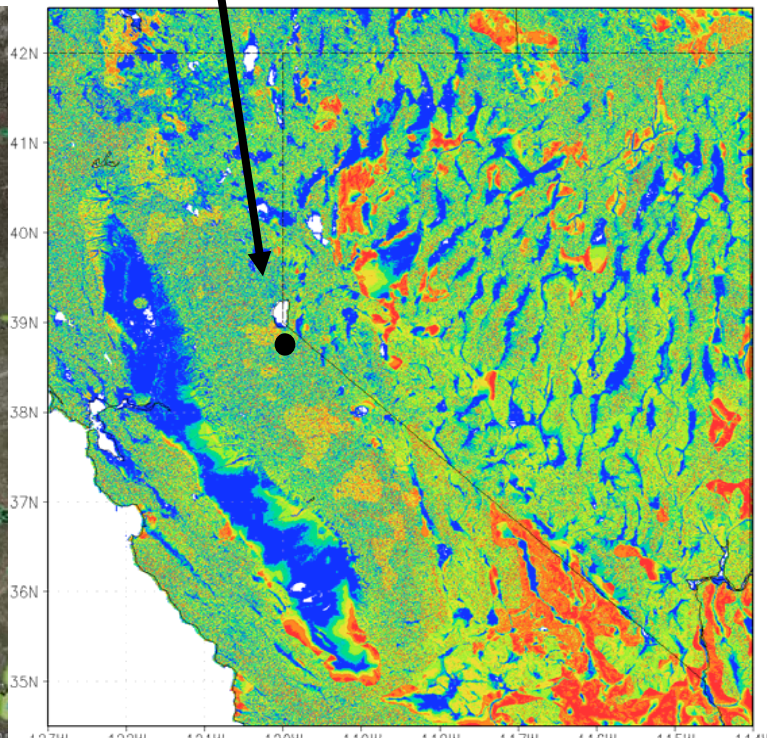

130W
120W
110W
100W
90W
80W
70W
60W


Echo Lake
Phillips
Twin Bridges
PEMF
PABH
PEMA
PEMC
Wetland Types
Estuarine and Marine Deepwater
Estuarine and Marine Wetland
Freshwater Emergent Wetland
Freshwater Forested/Shrub Wetland
Freshwater Pond
Lake
Other
Riverine
Status Map
Digital (vector data)
Scan (raster data)
Non-Digital (hardcopy only)
No Data
©2008 Google


42N
41N
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38N
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36N
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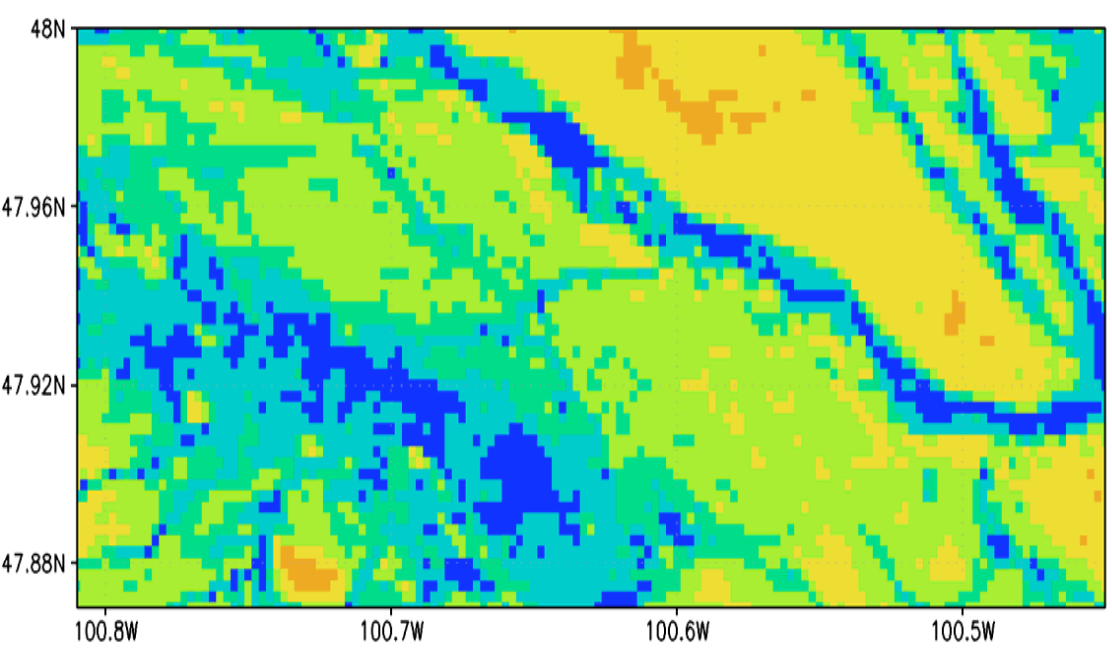
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47.88N
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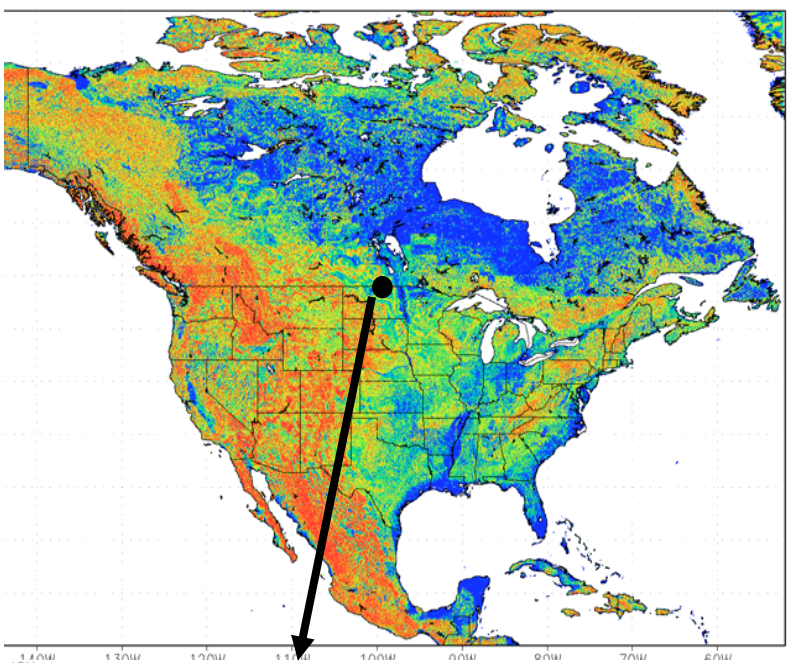
100.7W
100.6W
100.5W




Cottonwood Lake, North Dakota
Wetland Types
Estuarine and Marine Deepwater
Estuarine and Marine Wetland
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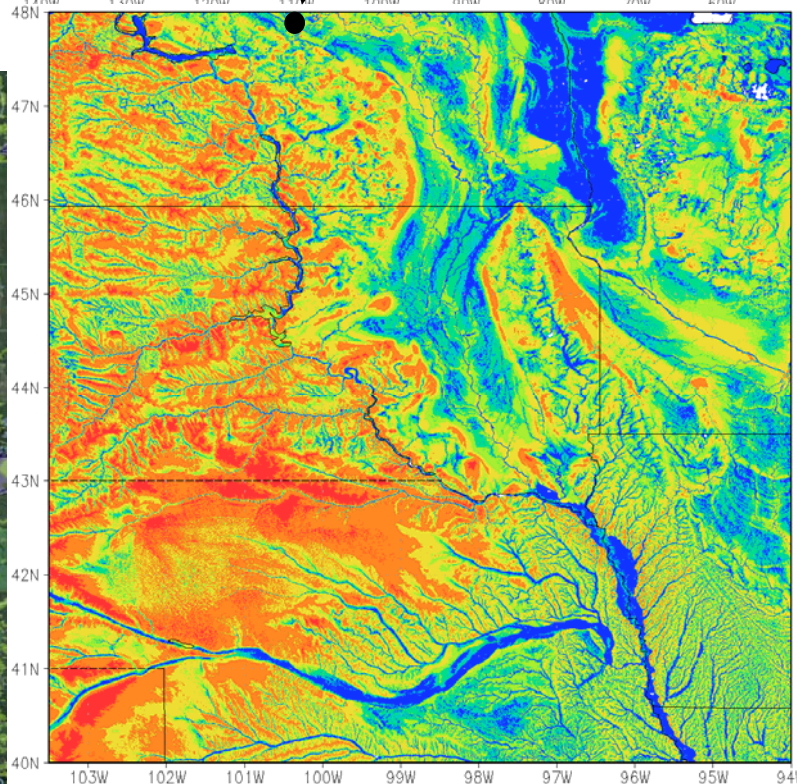
Freshwater Pond
Lake
Other
Riverine
Google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98W
97W
96W
95W

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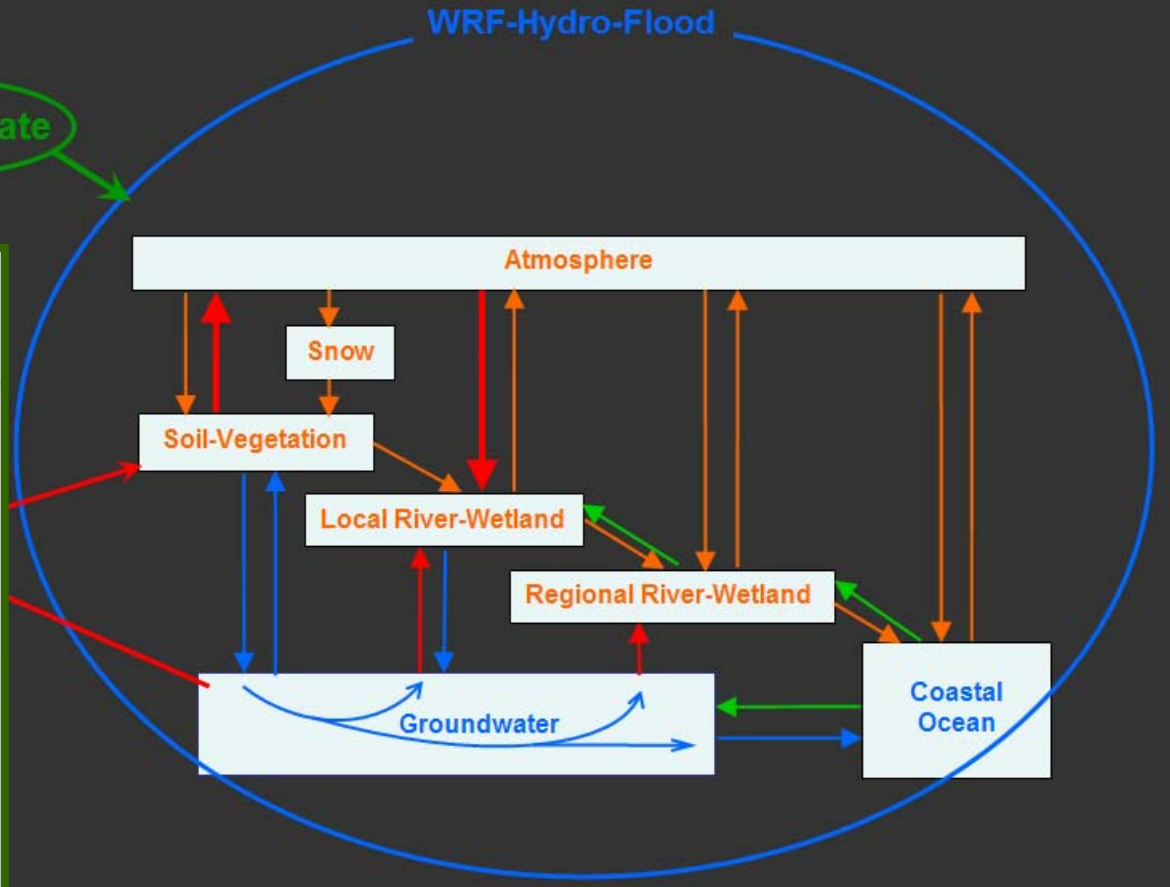
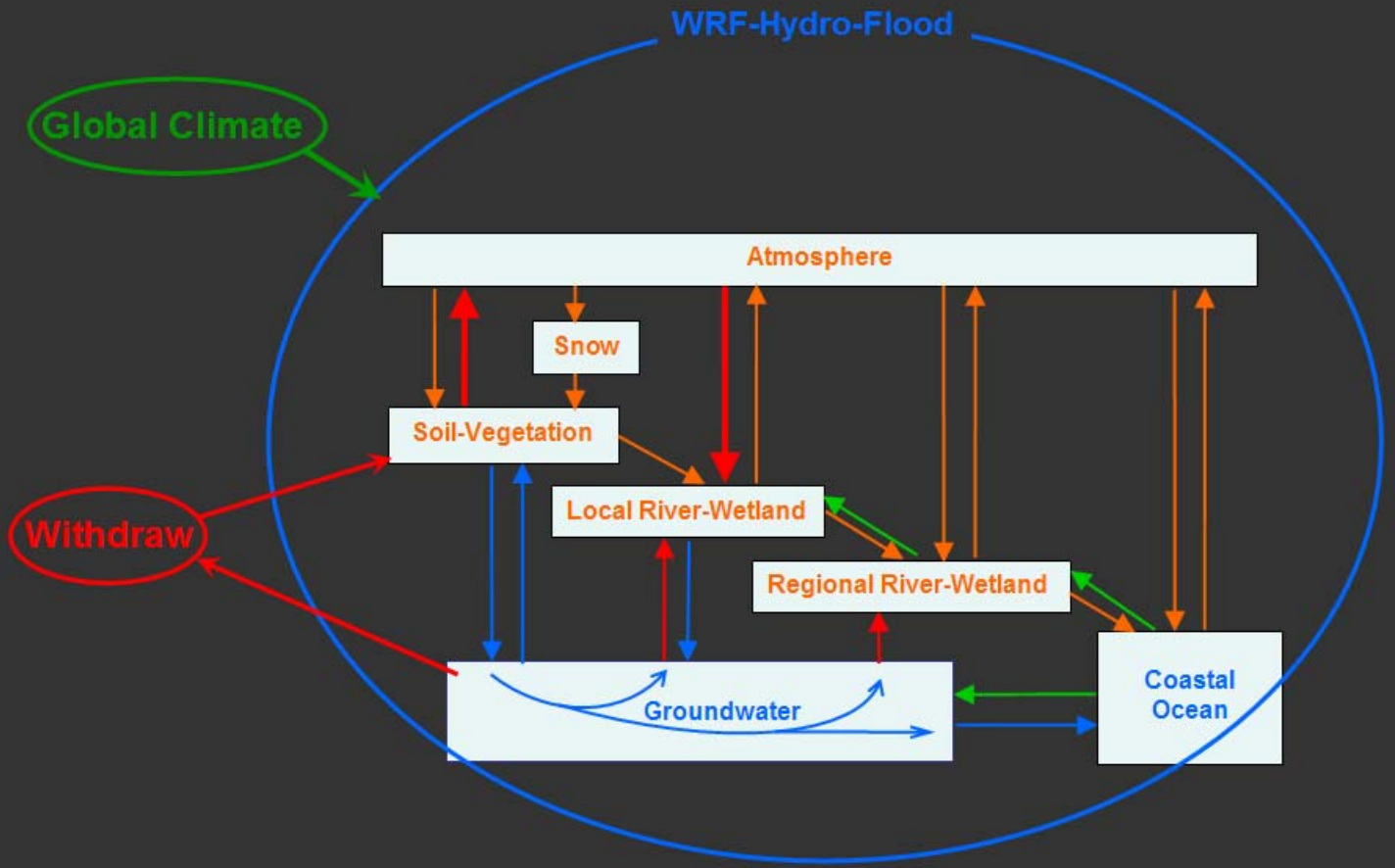


Project Tasks:

1. **Reconstruct the hydrology over the past decades**
2. **Reconstruct the coupled climate-hydrology**
3. **Project the coupled climate-hydrology in mid and end of century**



Project Tasks:

1. **Reconstruct the hydrology over the past decades (1979-2011)**

- Test and improve land hydrology

Space:

Lambert projection
5 km grids with → 1,450x1,510 (2.2)

Time:

2 min canopy, soil, flood routing
30 min water table, 1hr GW flow

Output: Daily

Soil moisture at 4 depths
intercept-evap-transpr fluxes
GW recharge, water table depth
GW-stream exchange
Stream flow, floodplain inundation

Project Tasks:

1. **Reconstruct the hydrology over the past decades (1979-2011)**

- Test and improve land hydrology

1. **Flooding**

   Solving the full momentum equation

2. **Obtaining Computation Resources**

   NCAR-CSL supercomputer (Bluefire)
   Apr 2011 – June 2012
   (2 days per model year)

   NCAR-WSCN Peta-grid
   June 2012-June 2014

3. **Writing the code in parallel**

   Using 256 processors

4. **Completed Model Setup**

   Land parameters

5. **Compiling Validation Data**

   stream flow (78)
   water table depth (813)
   soil moisture (132)

6. **Diagnostic Runs**

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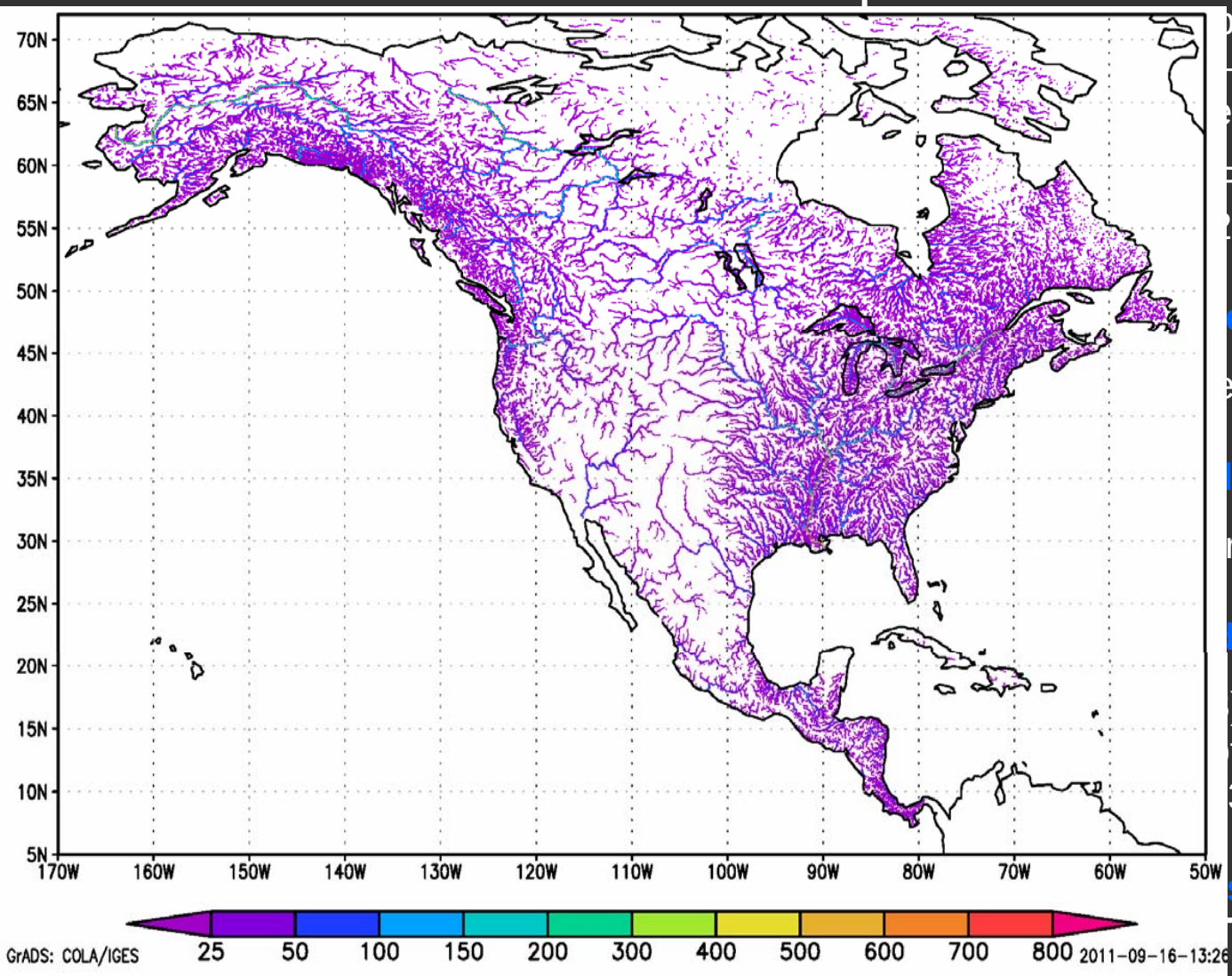

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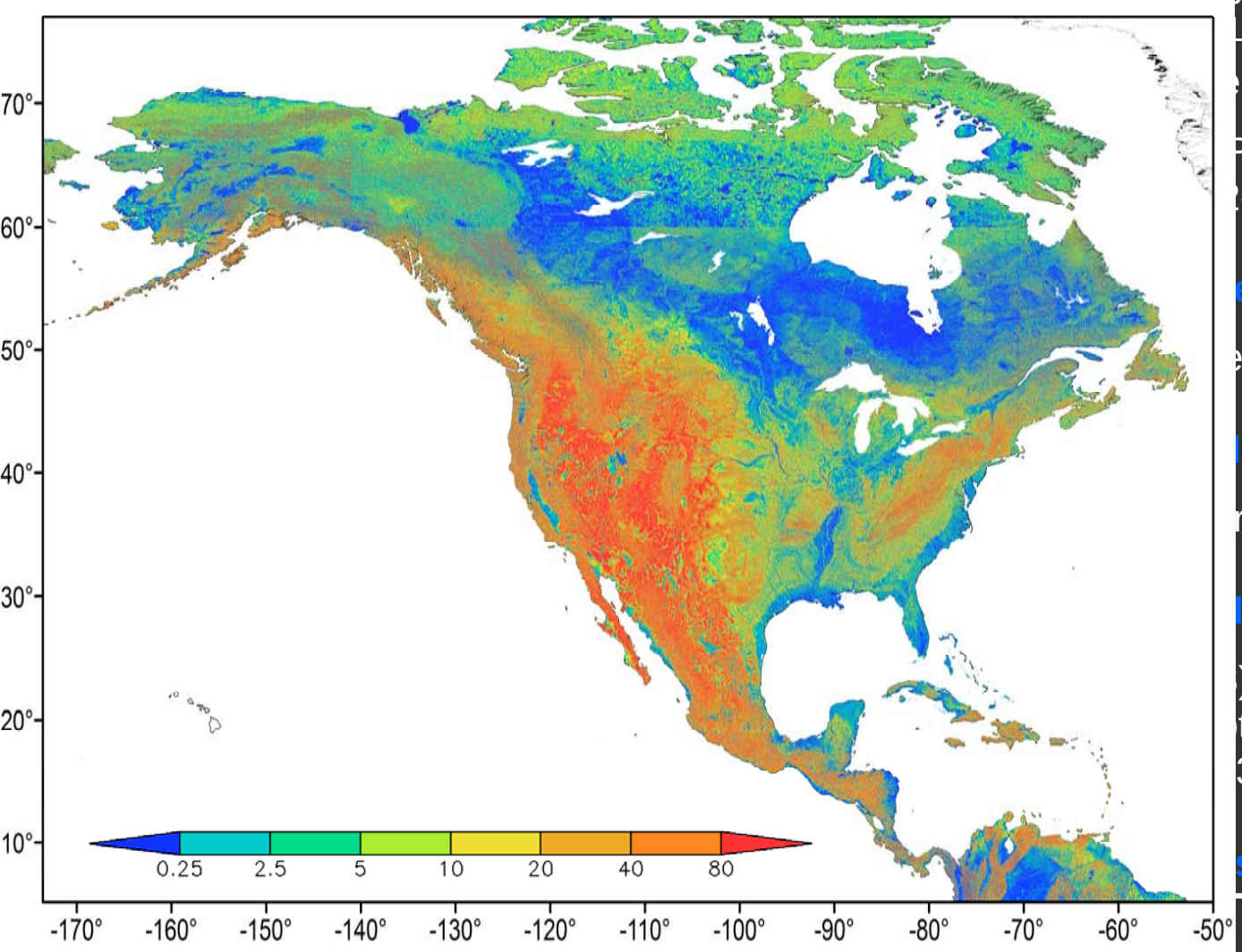

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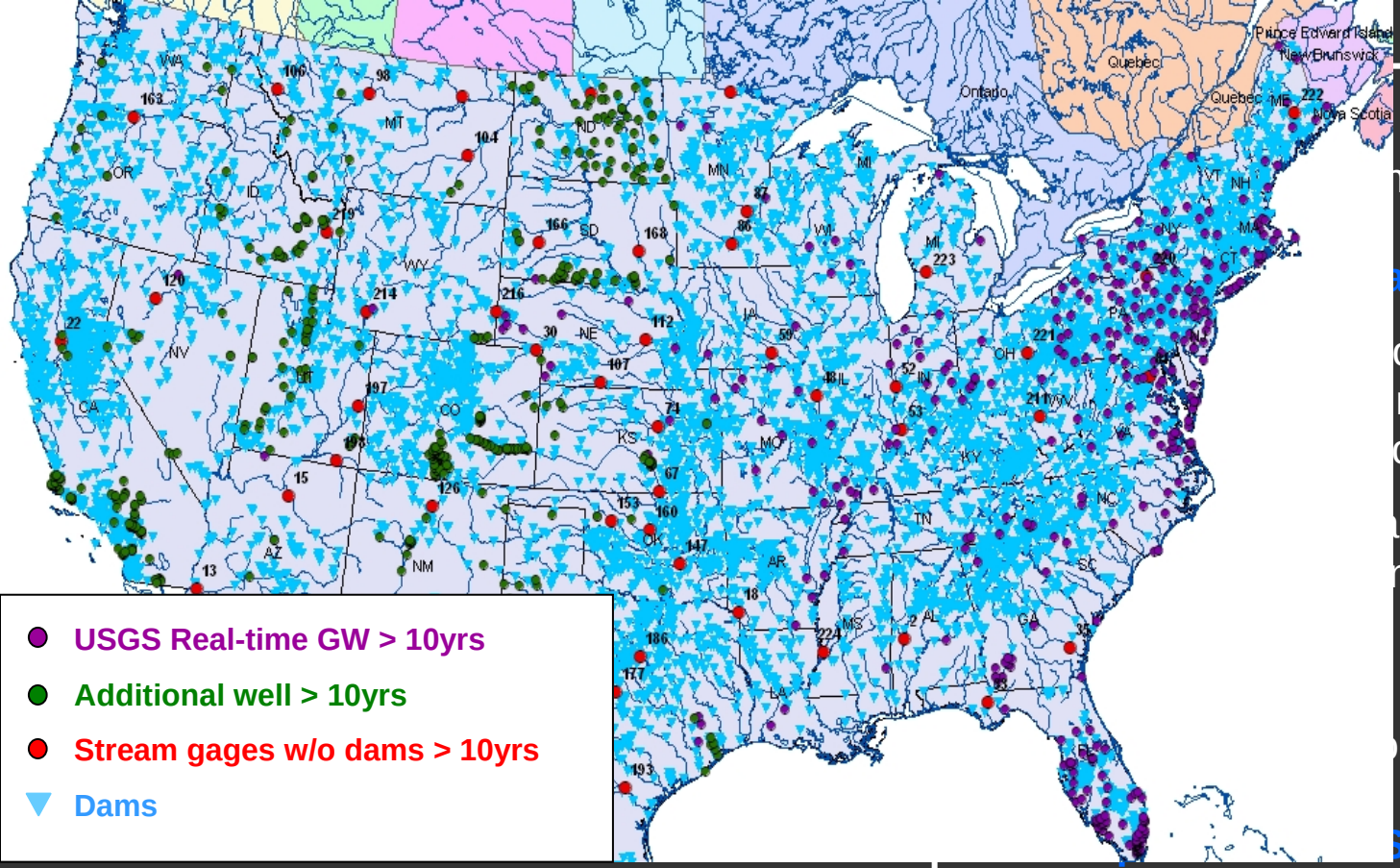

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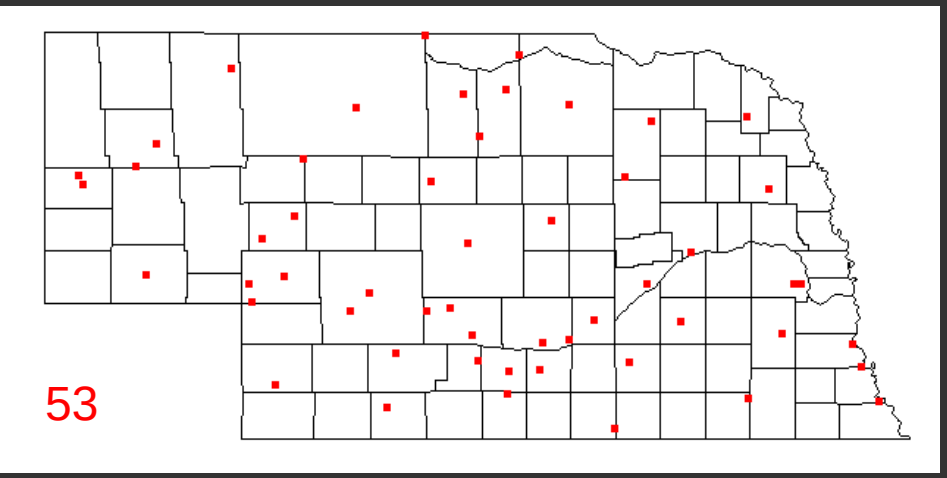

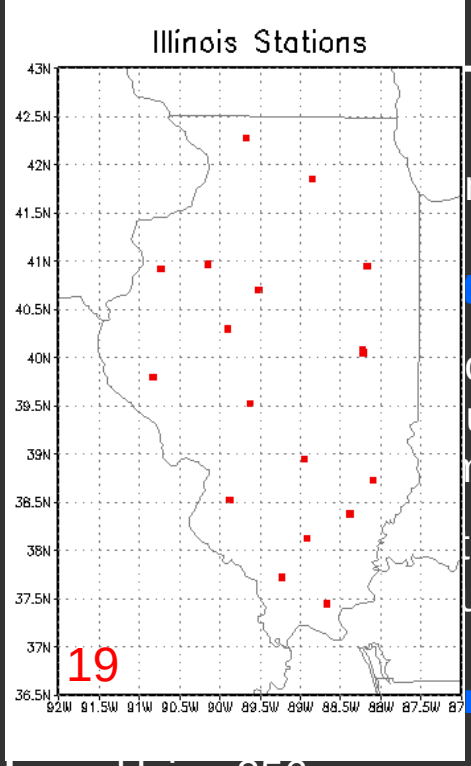

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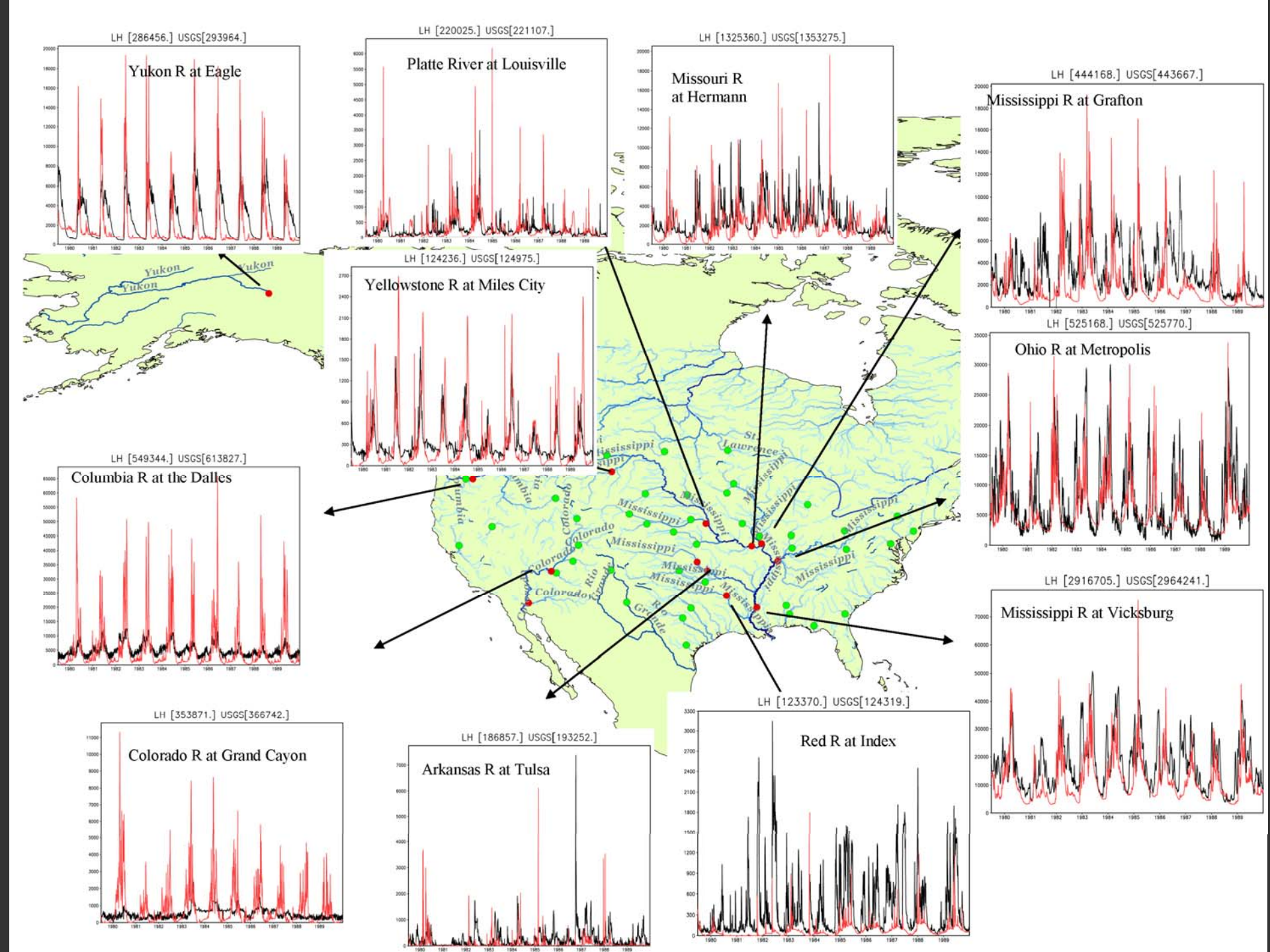
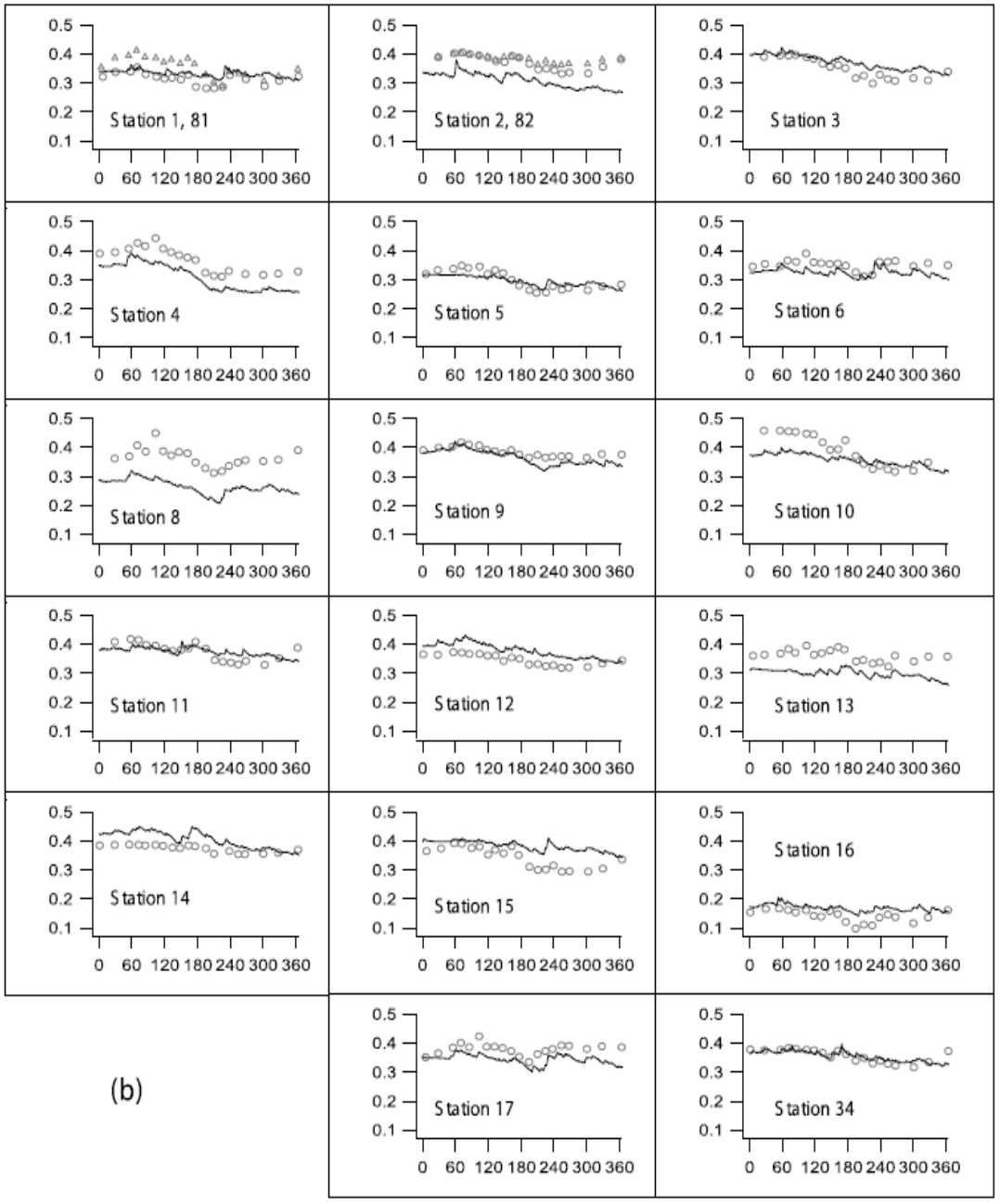
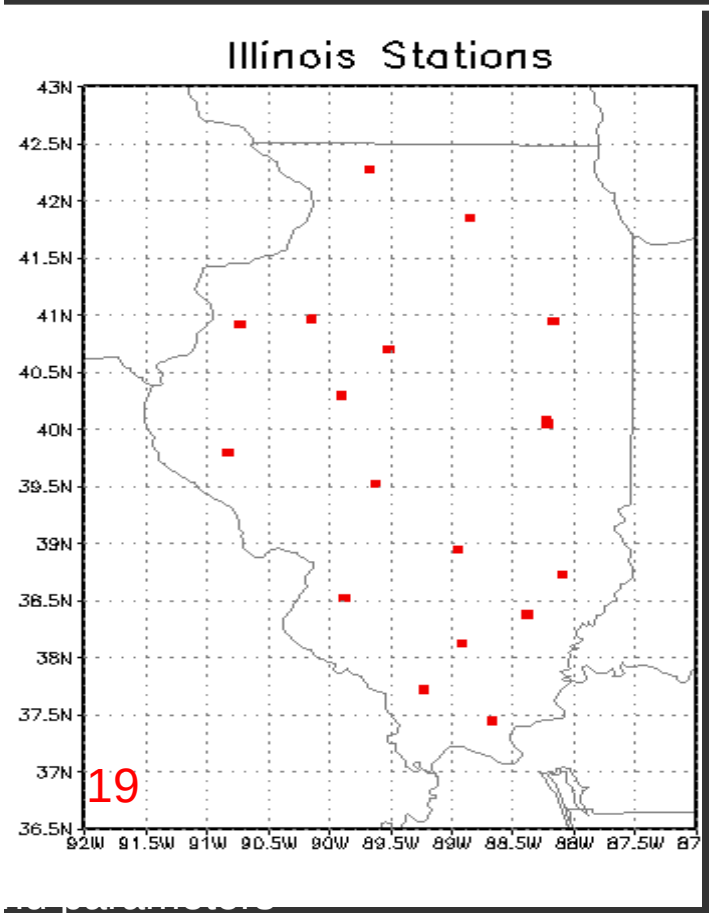

LH [286456.] USGS[293964.]
Yukon R at Eagle
LH [220025.] USGS[221107.]
Platte River at Louisville
LH [1325360.] USGS[1353275.]
Missouri R at Hermann
LH [444168.] USGS[443667.]
Mississippi R at Grafton
LH [124236.] USGS[124975.]
Yellowstone R at Miles City
LH [525168.] USGS[525770.]
Ohio R at Metropolis
LH [549344.] USGS[613827.]
Columbia R at the Dalles
LH [2916705.] USGS[2964241.]
Mississippi R at Vicksburg
LH [353871.] USGS[366742.]
Colorado R at Grand Cayon
LH [186857.] USGS[193252.]
Arkansas R at Tulsa
LH [123370.] USGS[124319.]
Red R at Index
Yukon
Mississippi
Colorado
Rio Grande
St. Lawrence
Columbia





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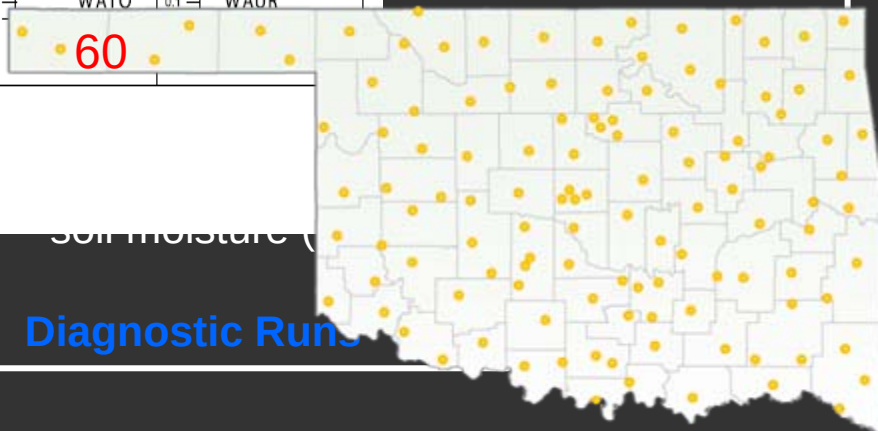

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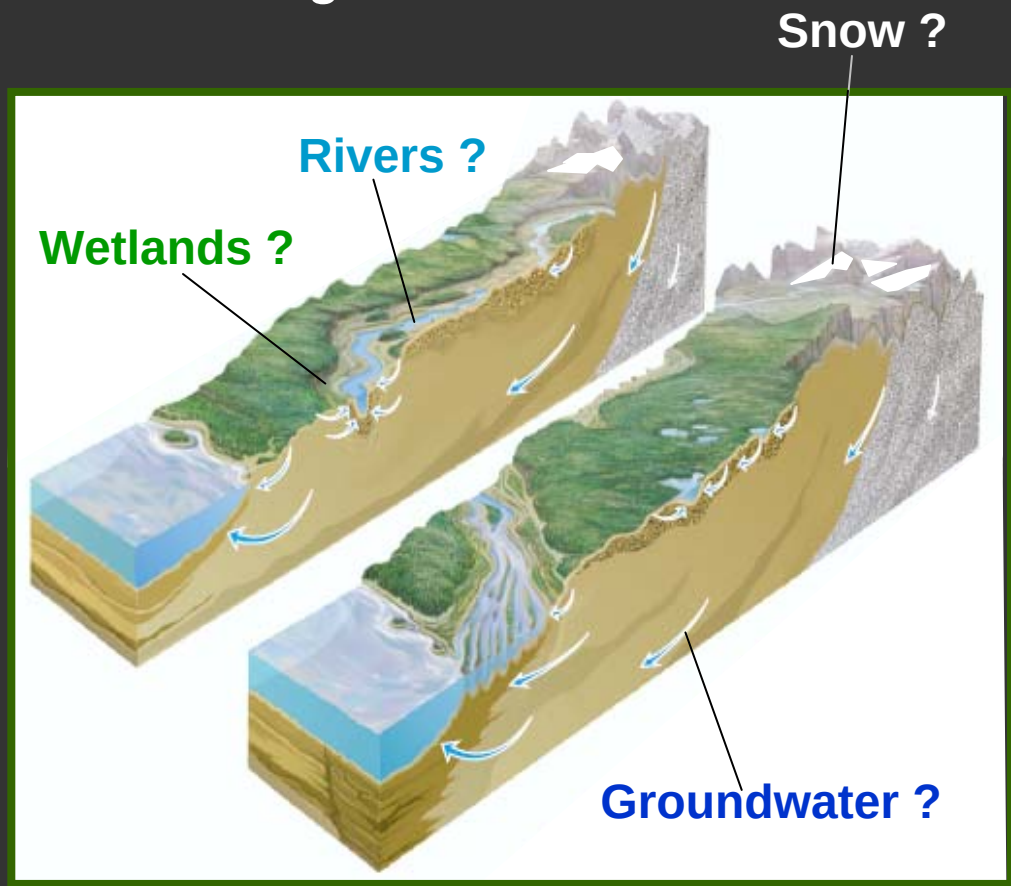
Project Goal:

- Assess US freshwater resources in the coming decades

climate variability & change

increasing human demands

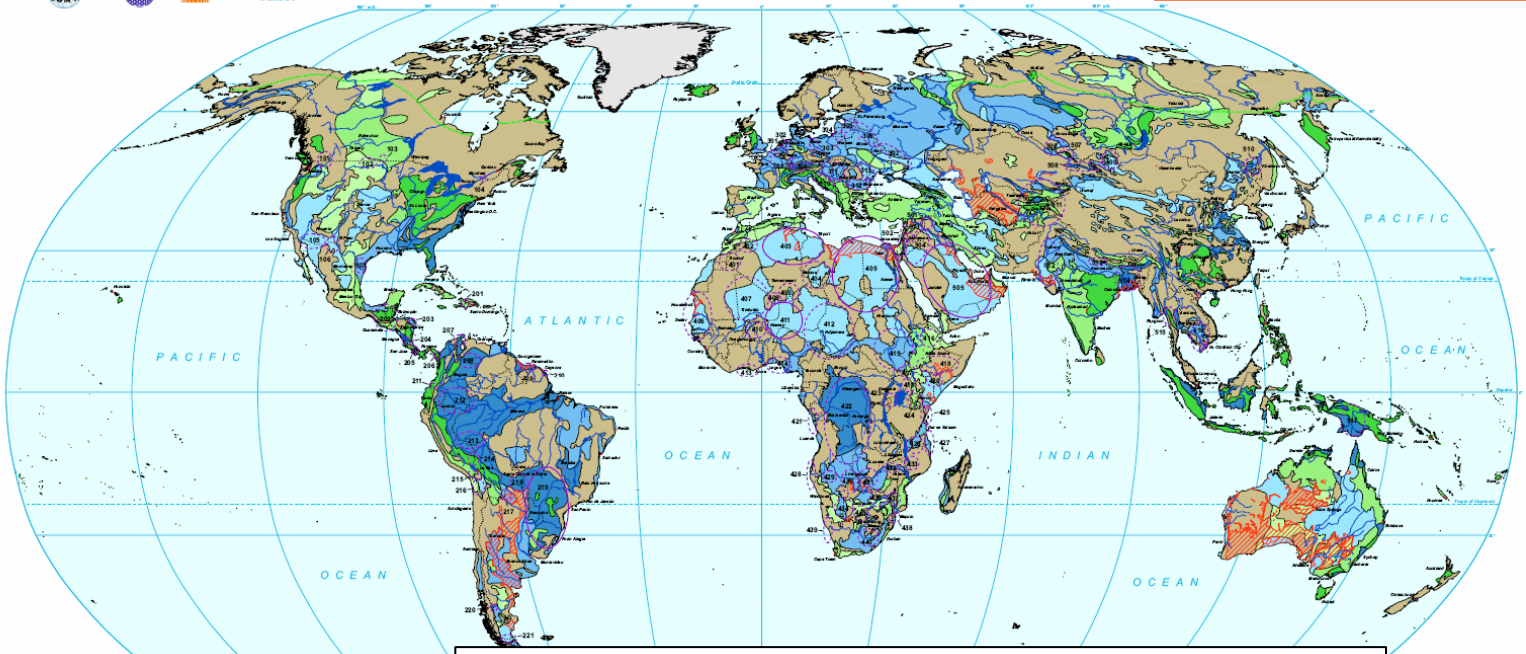


Water Quantity		*Water Quality*
Storage		Stream T
Flow Regime	→	Sediment load
Residence Time		Stream Chem
Pathways		Biota

Groundwater Resources of the World

- Transboundary Aquifer Systems -

World-wide Hydrogeological Mapping (WHYMAP)



Groundwater
- major groundwater basin
- high groundwater recharge (> 150 mm/a)
- medium groundwater recharge (15 - 150 mm/a)
- low groundwater recharge (< 15 mm/a)
- area with complex hydrogeological structure
- high groundwater recharge (> 150 mm/a)
- medium groundwater recharge (15 - 150 mm/a)
- low groundwater recharge (< 15 mm/a)
- area with local and shallow aquifers
- area of saline groundwater (> 5 g/l TDS)

Surface water
- major river
- large freshwater lake
- large saltwater lake
- continuous ice sheet

Geography
- selected city
- country boundary
- boundary of continuous permafrost

Prepared by

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Under the auspices of

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AEA	Pradeep Aggarwal and Bill Wallin
AH	Stephen Foster and Andrew Skinner

Cartographical editing / GIS

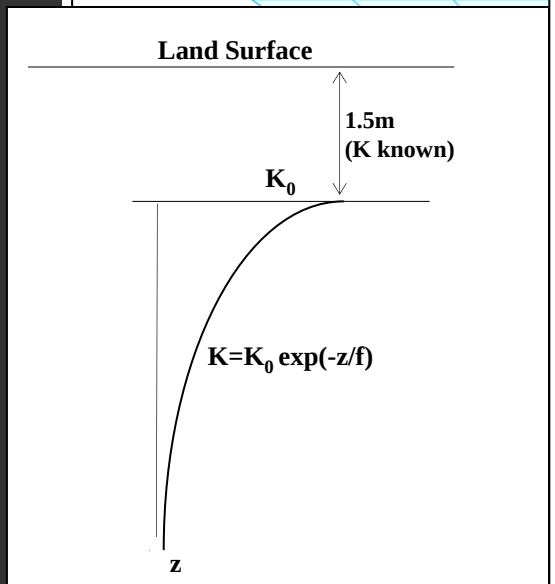
BGR	Ute Philipp, Andrea Richts and Patrick Cox

Topographic base map

CGMW / UNESCO (2000)	Geological Map of the World 1 : 25 000 000, second edition
ESRI (2005)	Data & Maps
USGS (2003)	Global GIS

modified by BGR (2006)

Map projection



USGS RASA

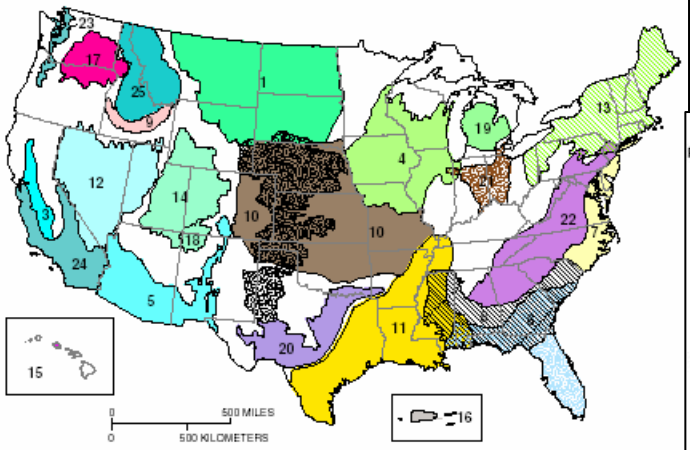


Figure 1. *The Regional Aquifer-System Analysis program of the USGS studied 24 of the most important aquifers and aquifer systems in the United States, and one in the Caribbean Islands.*

Modified from Sun and Johnston, 1994

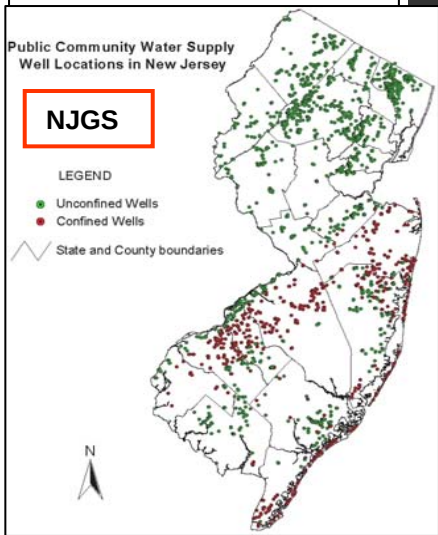
EXPLANATION

Regional aquifer system study areas

1 Northern Great Plains
2 High Plains
3 Central Valley, California
4 Northern Midwest
5 Southwest alluvial basins
6 Floridan
7 Northern Atlantic Coastal Plain
8 Southeastern Coastal Plain
9 Snake River Plain
10 Central Midwest
11 Gulf Costal Plain
12 Great Basin
13 Northeast glacial aquifers
14 Upper Colorado River Basin
15 Oahu, Hawaii
16 Caribbean Islands
17 Columbia Plateau
18 San Juan Basin
19 Michigan Basin
20 Edwards–Trinity
21 Midwestern basins and arches
22 Appalachian valleys and Piedmont
23 Puget–Willamette Lowland
24 Southern California alluvial basins
25 Northern Rocky Mountain Intermontane Basins

Public Community Water Supply Well Locations in New Jersey

NJGS



Lithologic composition of the Earth's continental surfaces derived from a new digital map emphasizing riverine material transfer

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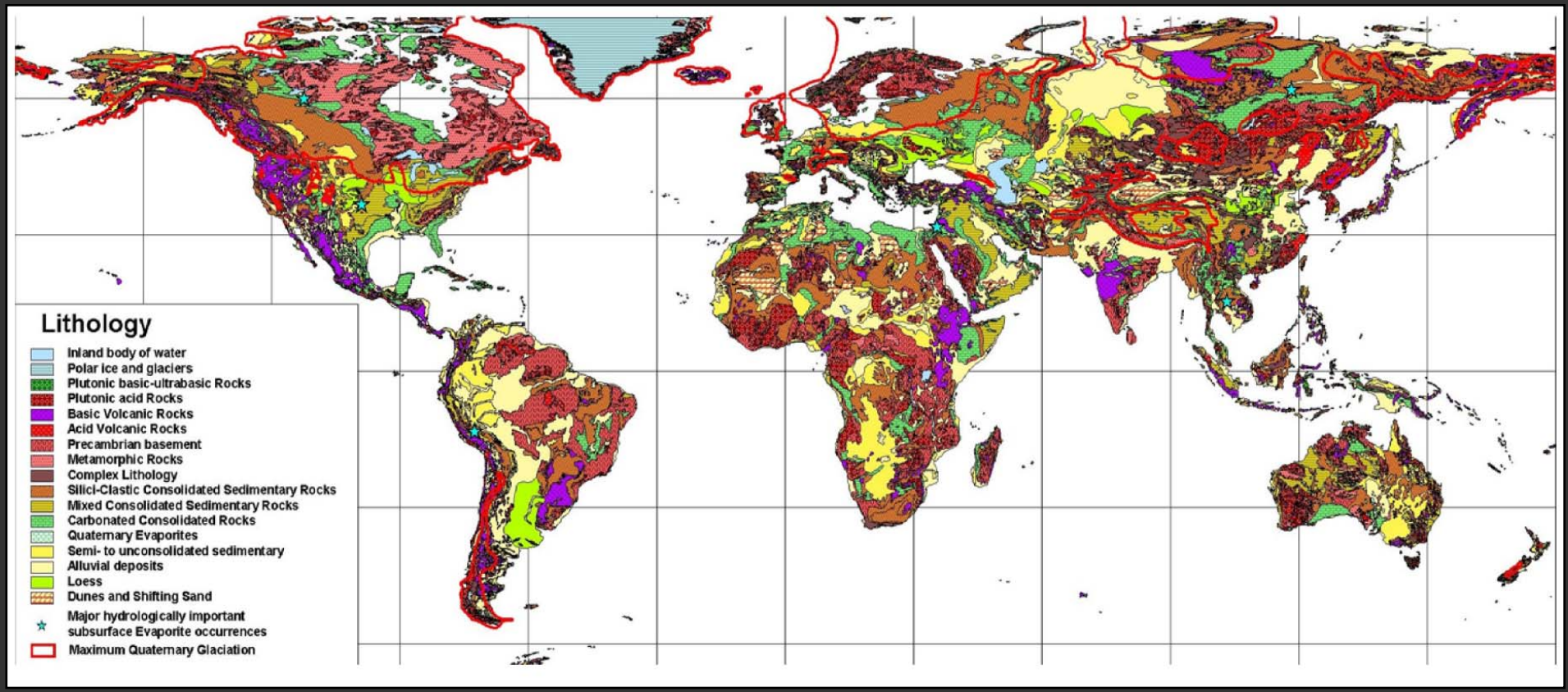
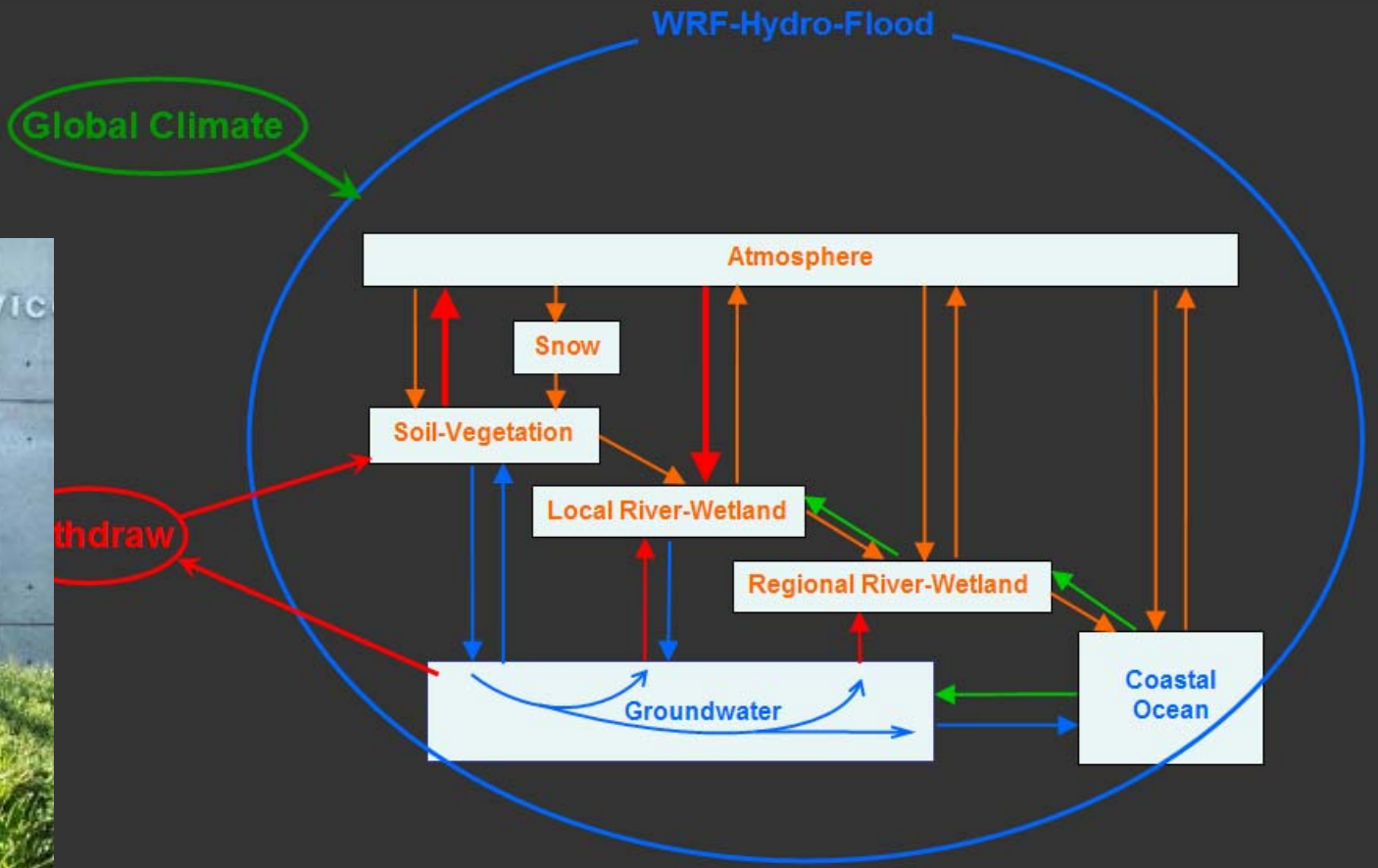


Project Tasks:

1. **Reconstruct the hydrology over the past decades**
2. **Reconstruct the coupled climate-hydrology**
3. **Project the coupled climate-hydrology in mid and end of century**



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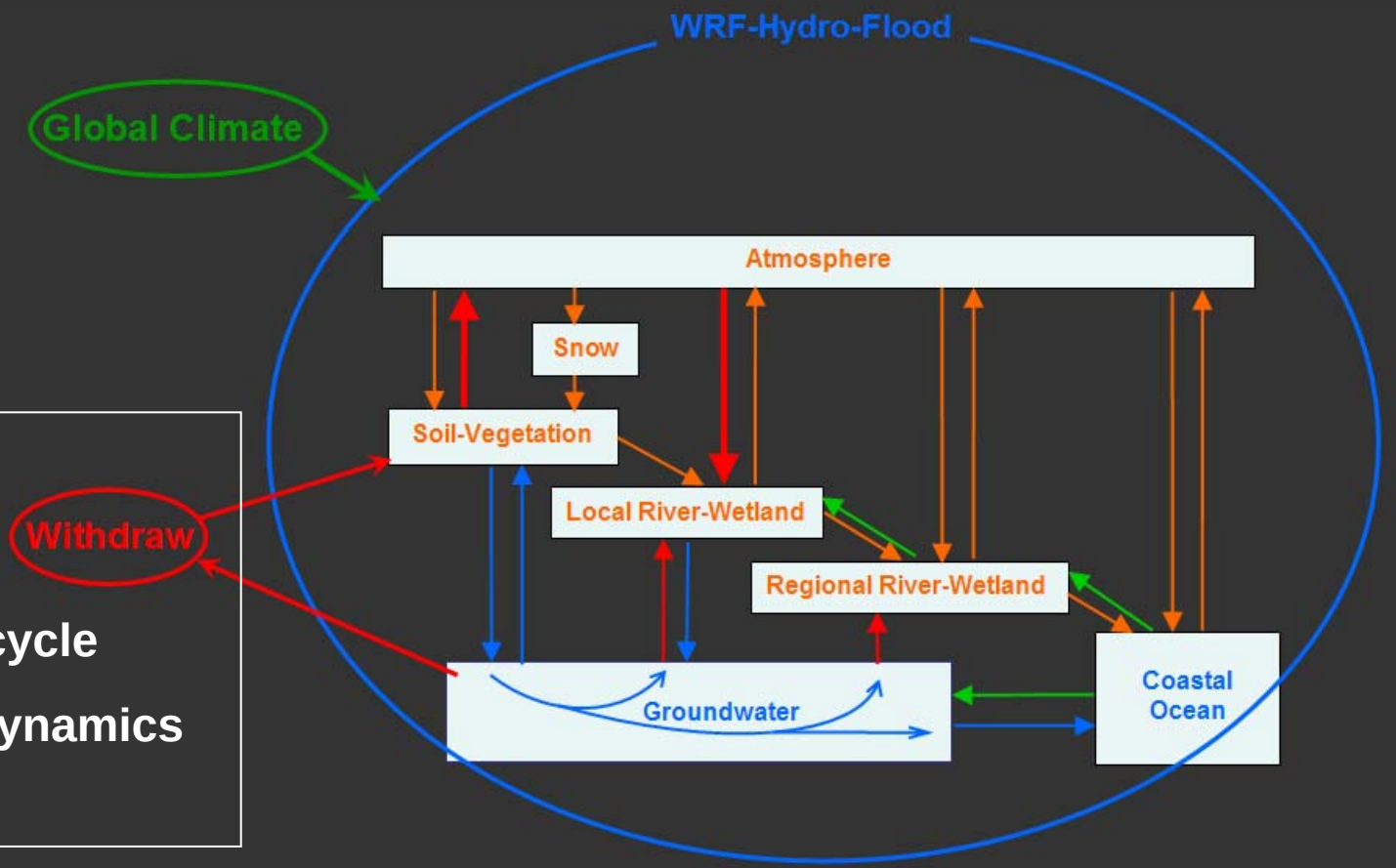

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EPA STAR

NSF water-carbon cycle

NSF climate & LS dynamics

NSF EaSM - NCAR