Advancing Representation of Terrestrial Physics to Support Water-Carbon Coupling in GFDL's Earth-System Models

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Water and Carbon Coupling at Regional Scales: Key Issues and a New Approach
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U.S. Department of the Interior
U.S. Geological Survey

Once upon a time, anthropogenic climate change was very simple. CO_2 emissions raised atmospheric CO_2 concentrations, which affected radiative transfer, which warmed and moistened the lower atmosphere, affecting precipitation, soil moisture, and runoff. Some details remained to be worked out.

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Questions:

- How does land (soil, vegetation, topography) contribute to the determination of global climate and water cycle?
- How does climate change affect the water cycle and water availability?

- How does (did, will…) vegetation disturbance (natural and anthropogenic) and recovery affect the global carbon cycle? What is the role of water?
- How does vegetation disturbance and recovery directly affect climate and global water and energy cycles?
- How do ecosystems respond to changes in the global carbon cycle? What is the role of water?
- How does climate change affect the carbon cycle through terrestrial and aquatic ecosystems?
- How does climate respond to development of water resources?
- How does sea level respond to development of water resources?
- What role does land play in generating long-term persistence in the climate system?
- How can new observational technologies be exploited to improve land models?

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canopy interception,
throughfall, etc.

photosynthesis
respiration
carbon fluxes
dynamic vegetation

multi-layer
snow pack

multi-layer soil
sat/unsat
frozen/unfrozen

plant phenology

fire

land clearance,
wood harvesting

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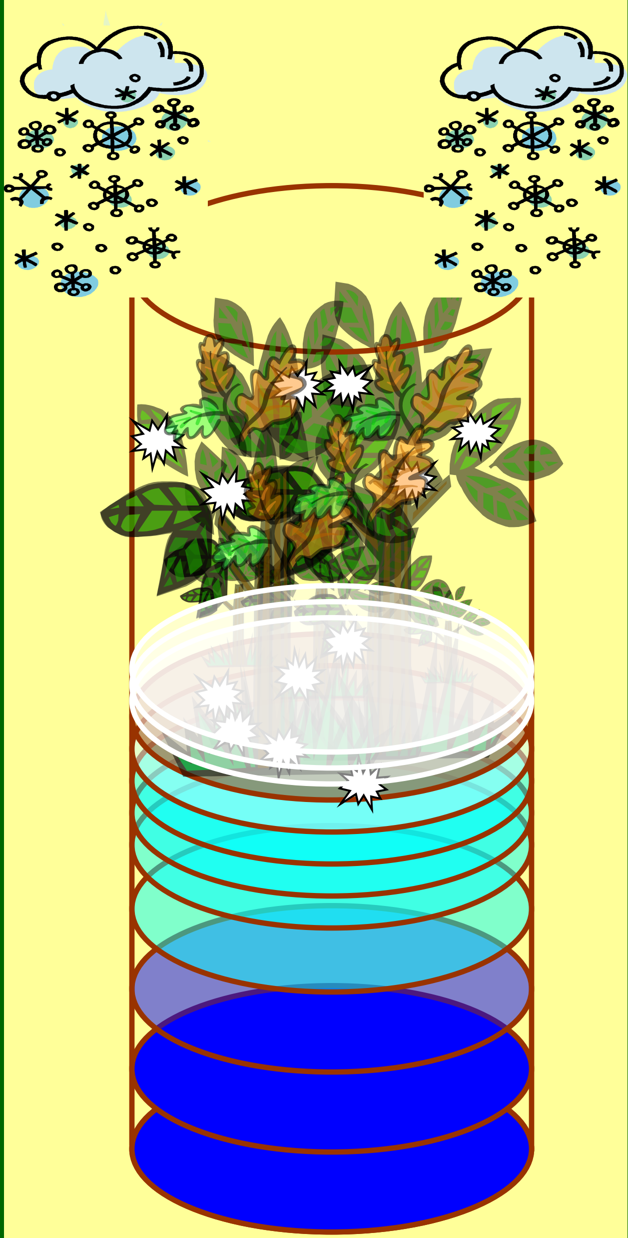
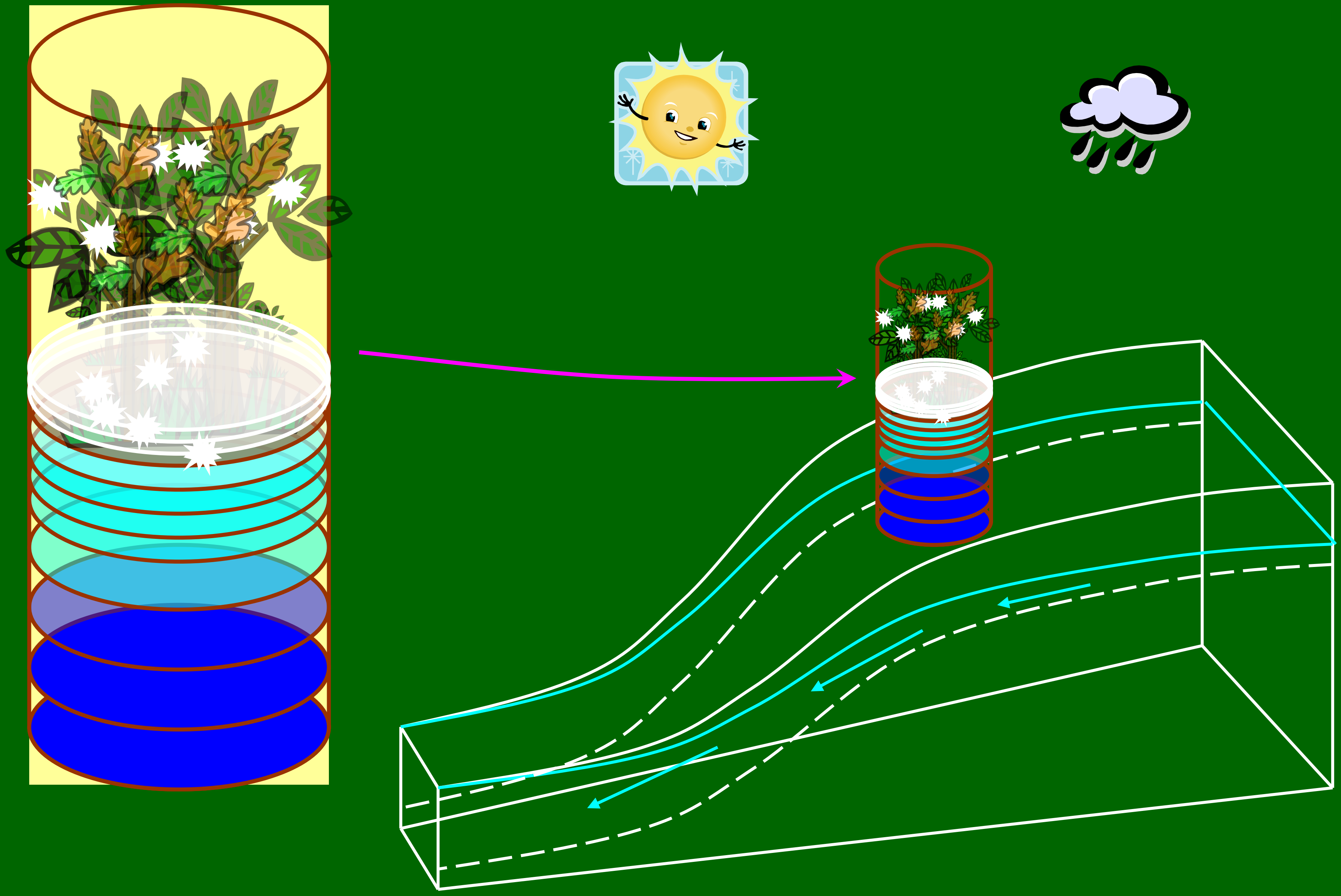


$$\frac{\partial(\theta_l+\theta_s)}{\partial t}=\frac{\partial}{\partial z}\left[K\left(\frac{\partial\psi}{\partial z}-1\right)\right]-r-g$$

$$\frac{\partial\left[C(\theta_l,\theta_s)T\right]}{\partial t}-L_f\frac{\partial\theta_s}{\partial t}=\frac{\partial}{\partial z}\left[\lambda\frac{\partial T}{\partial z}-q_l c_l T\right]-h_r-h_g$$

$$K=\left[\alpha(z)\right]^2K_{ref}(\theta_l)\qquad\psi=\psi_{ref}(\theta_l,\theta_s)/\alpha(z)$$

$$\alpha(z)=\alpha_\infty+(\alpha_0-\alpha_\infty)\exp(-z/z_s)$$



landscape-based groundwater divergence and saturated areas

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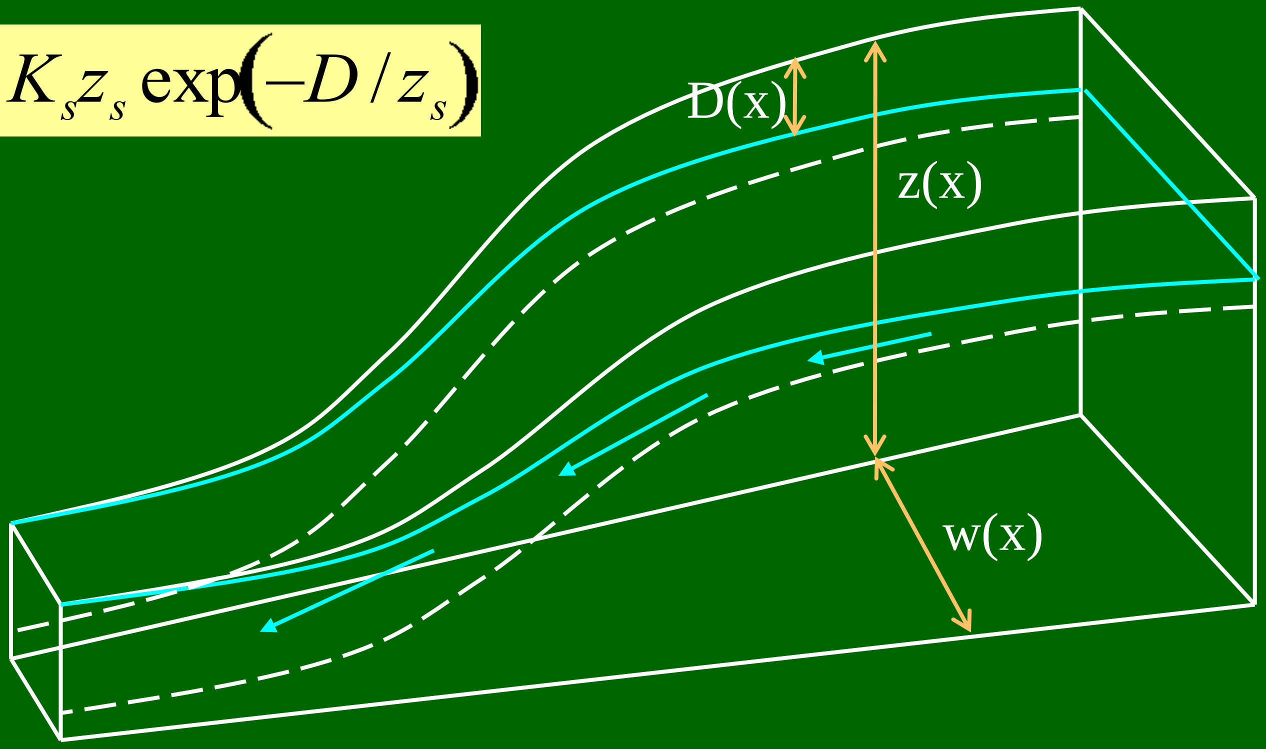
$$w(x)T(D)\frac{d}{dx}\left[z(x)-D\right]=q\int_x^l w(x')dx' \quad D>0$$

$$T(D)=K_b b+K_s z_s \exp\left(-D/z_s\right)$$



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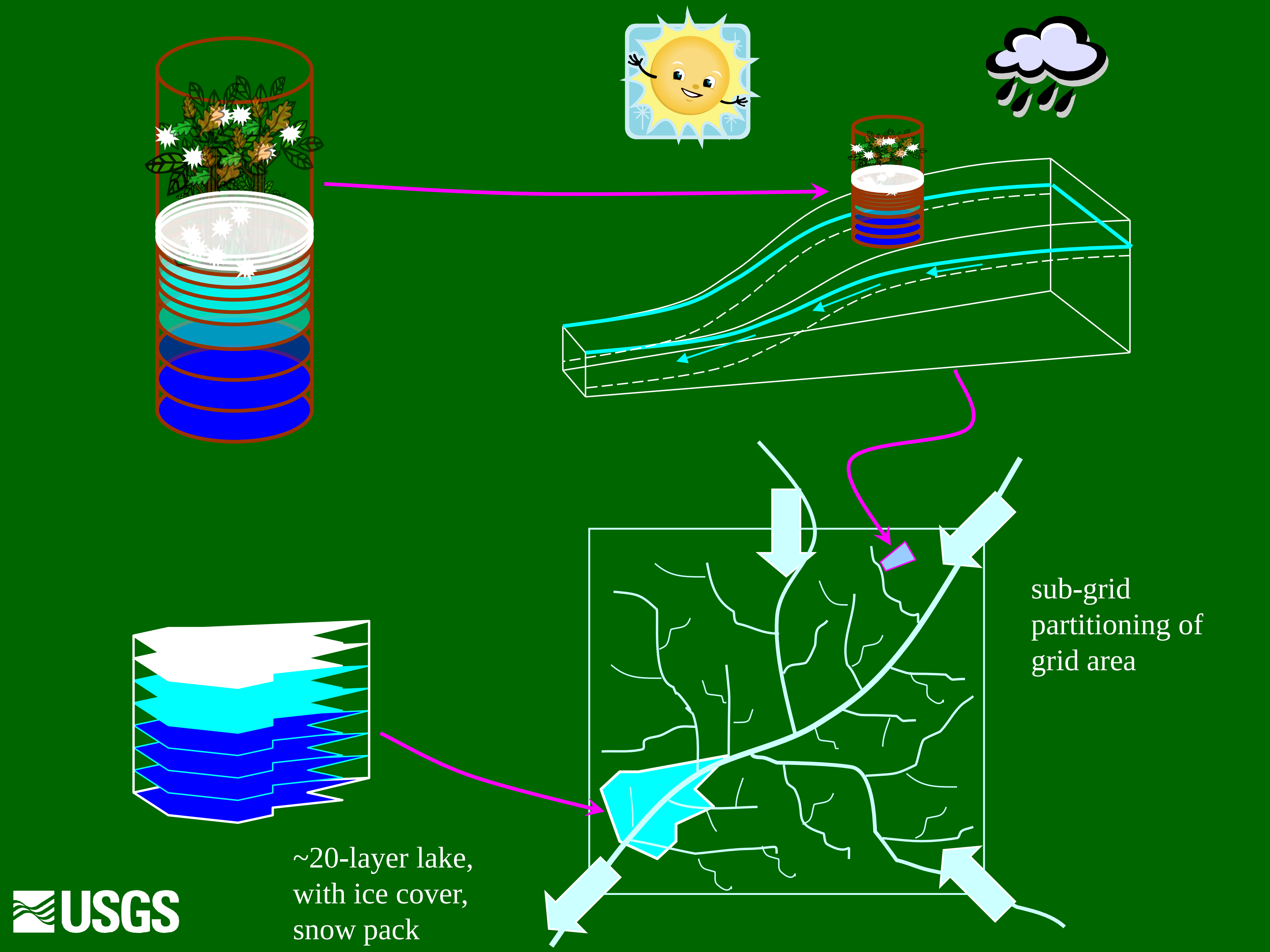
landscape-based groundwater divergence and saturated areas


sub-grid partitioning of grid area
~20-layer lake, with ice cover, snow pack
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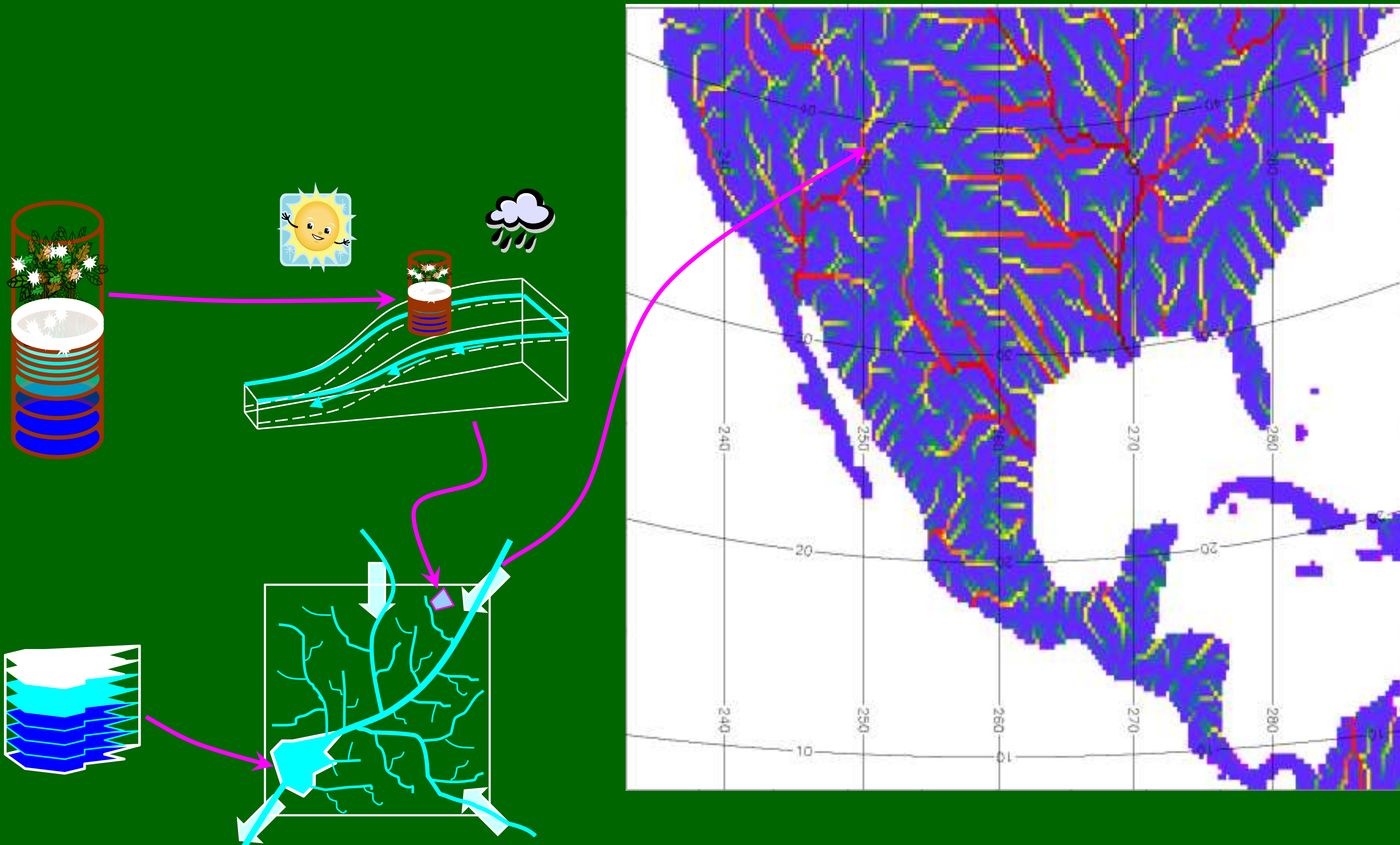

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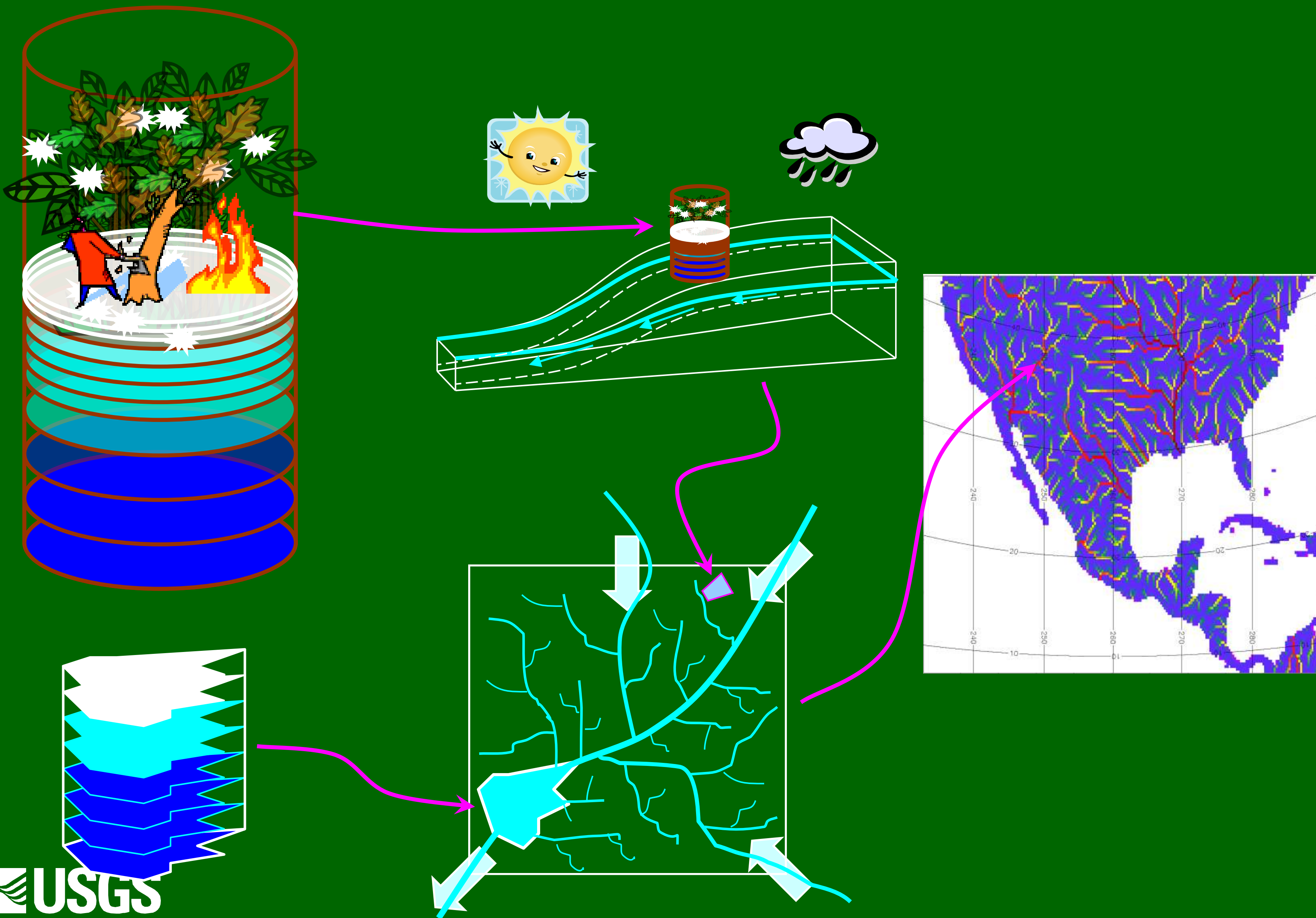
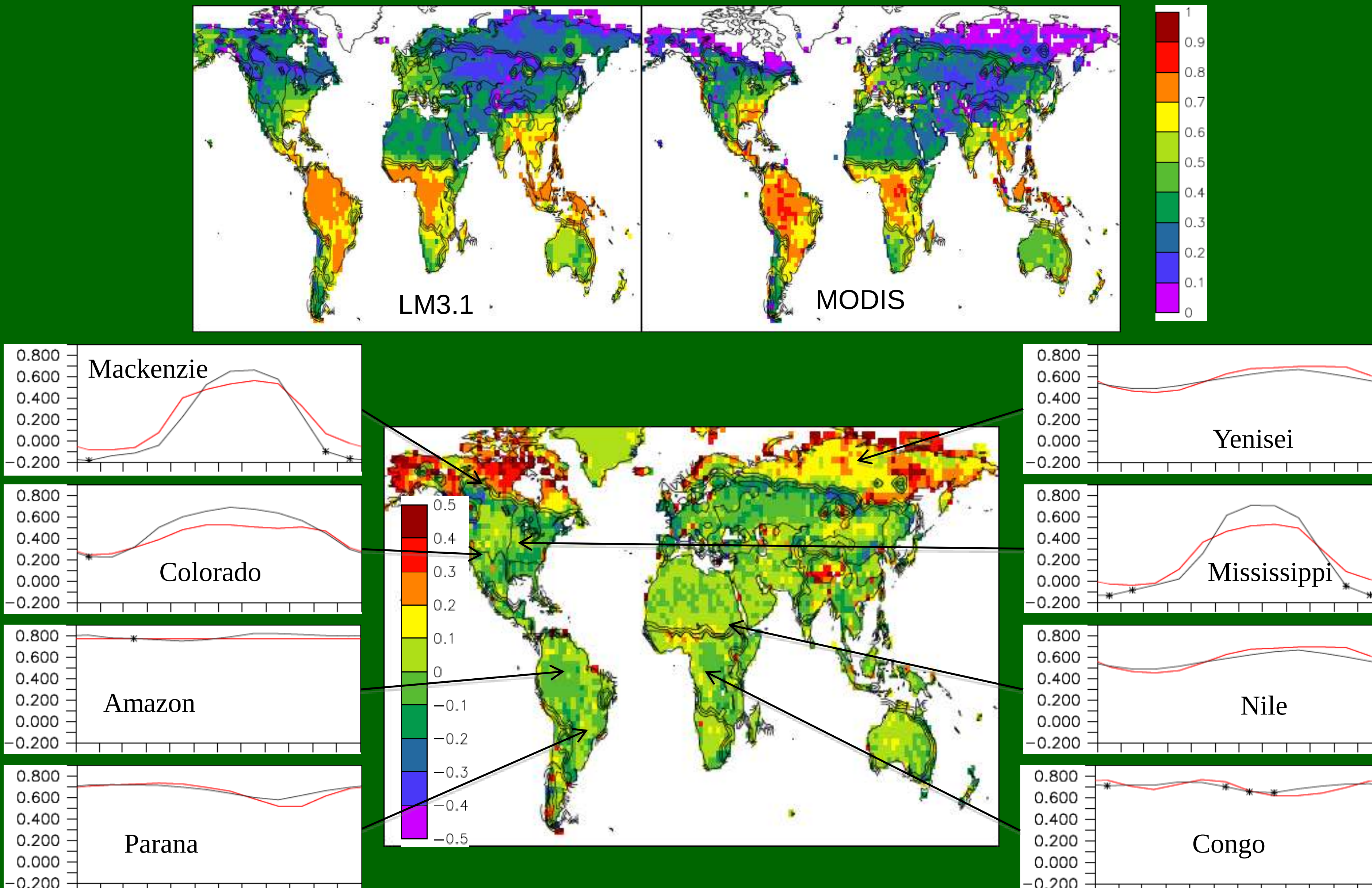
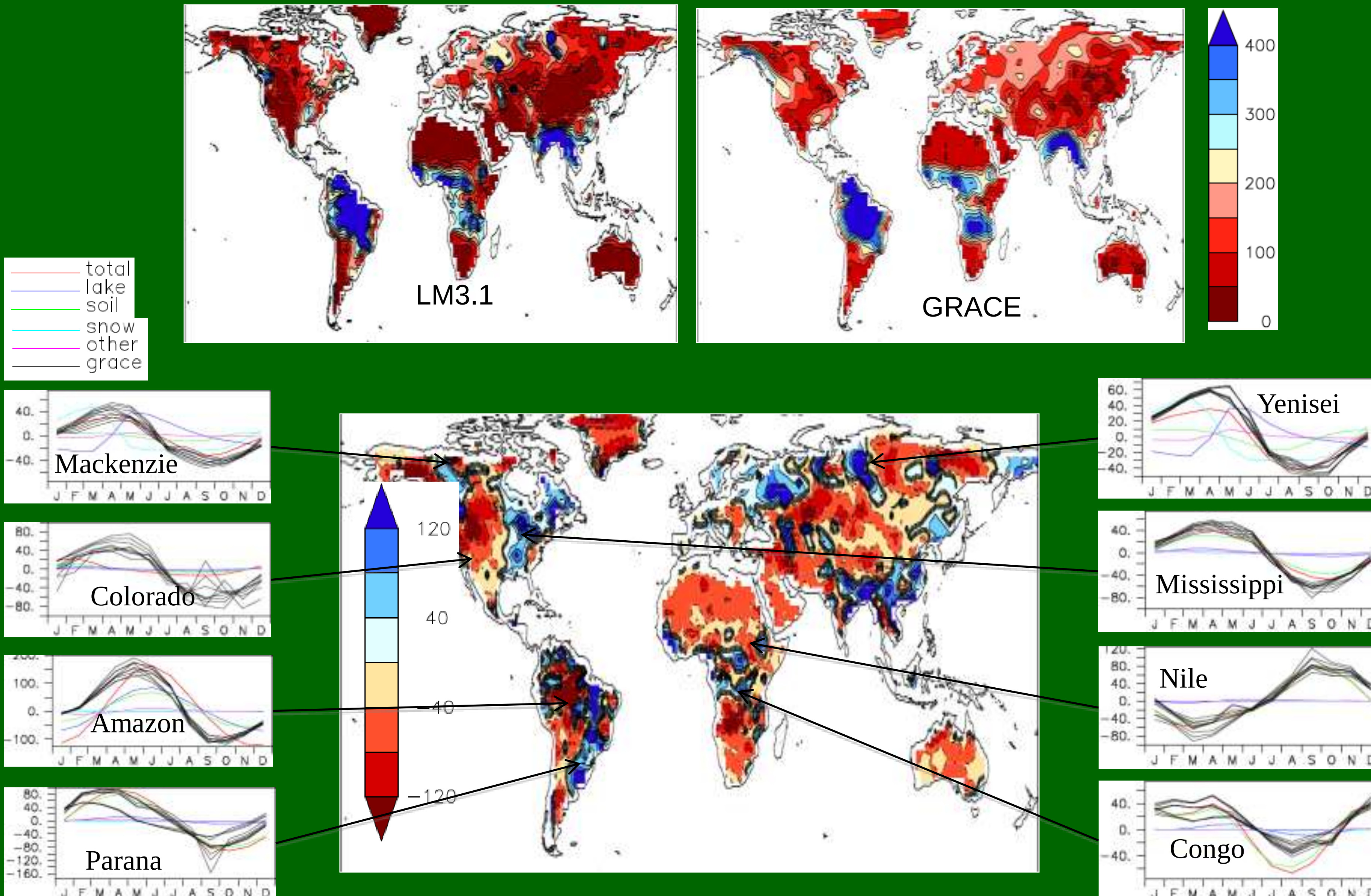


Normalized-Difference Vegetation Index, Annual Mean



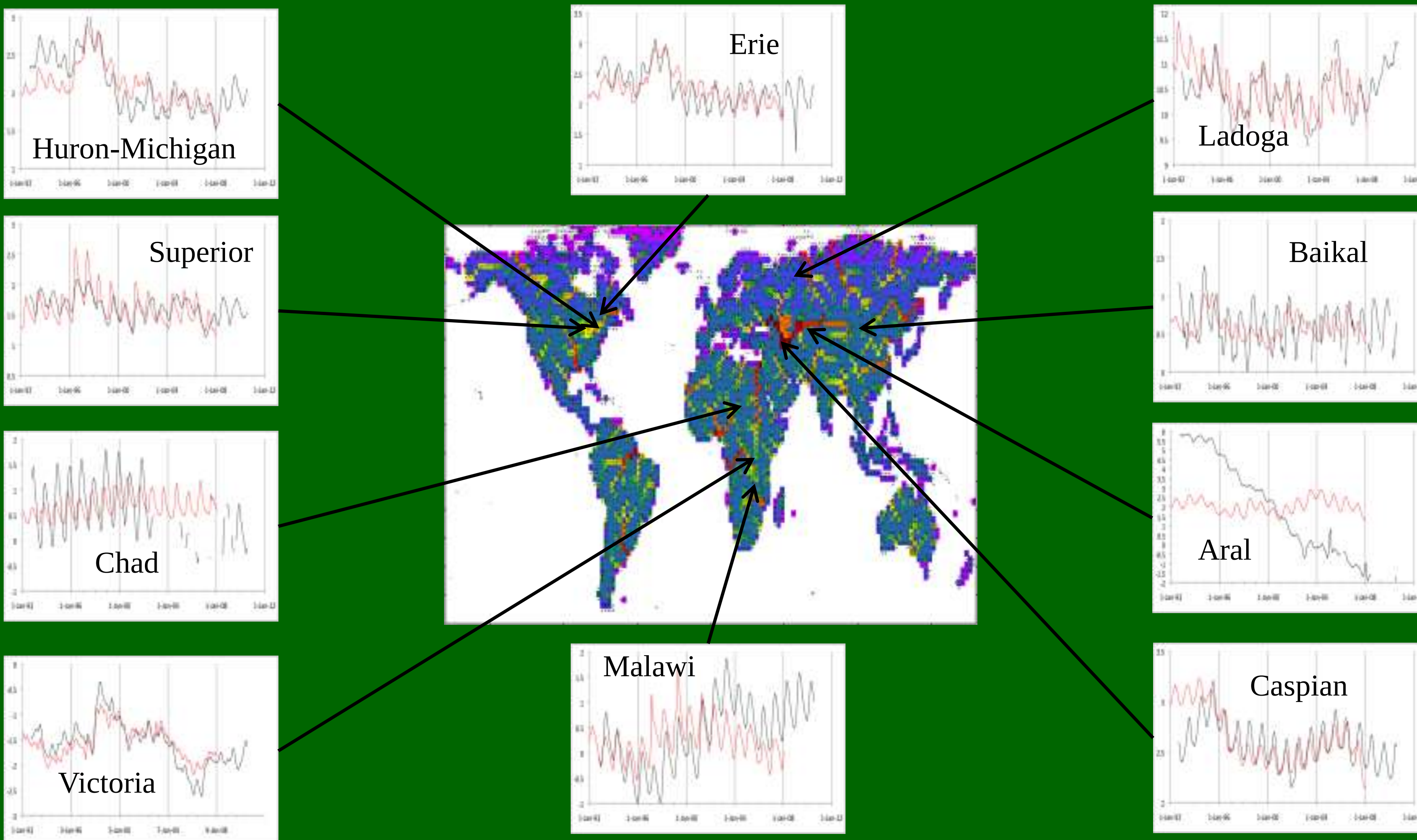
Observed data from MOD43C2 V004 MODIS BRDF/Albedo Parameters 16-day L3 Global 0.05-Degree Climate Modeling Grid (CMG) Binary Data Sets

Annual Range of Vertically Integrated Water-Mass Storage (kg m^{-2})



Observed data from the GRACE mission as processed by the Center for Space Research, Univ. of Texas.

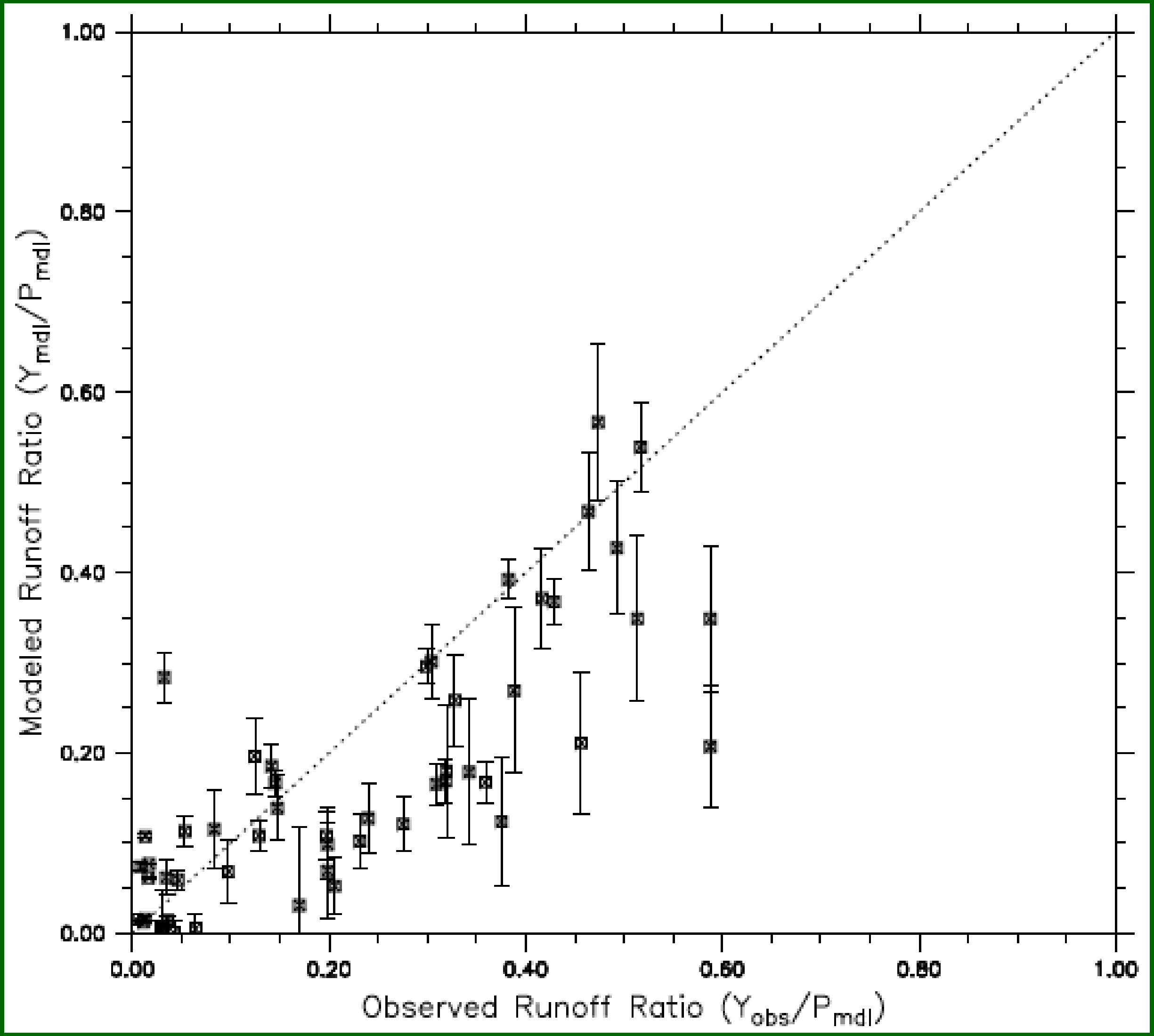
Lake-Level Variations (m)



Observed data from USDA/FAS/OGA and NASA Global Agricultural Monitoring Project. Lake surface height variations from the USDA's Global Reservoir and Lake web site. Altimetric lake-level time-series variations from the Topex/Poseidon and Jason-1 missions.

Basin Runoff Ratios

Good news,
bad news.



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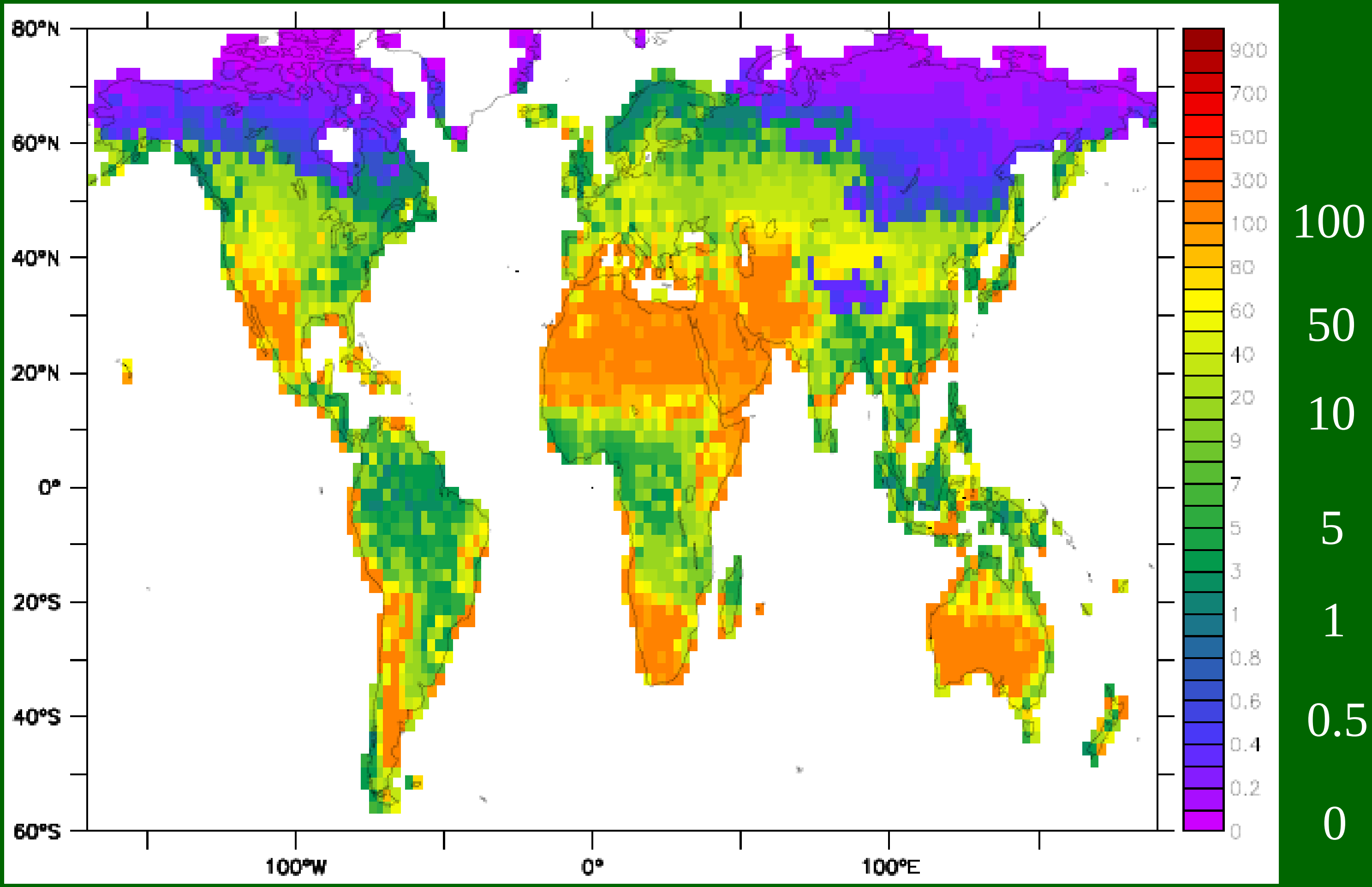
Depth to Water Table or Permafrost (m)



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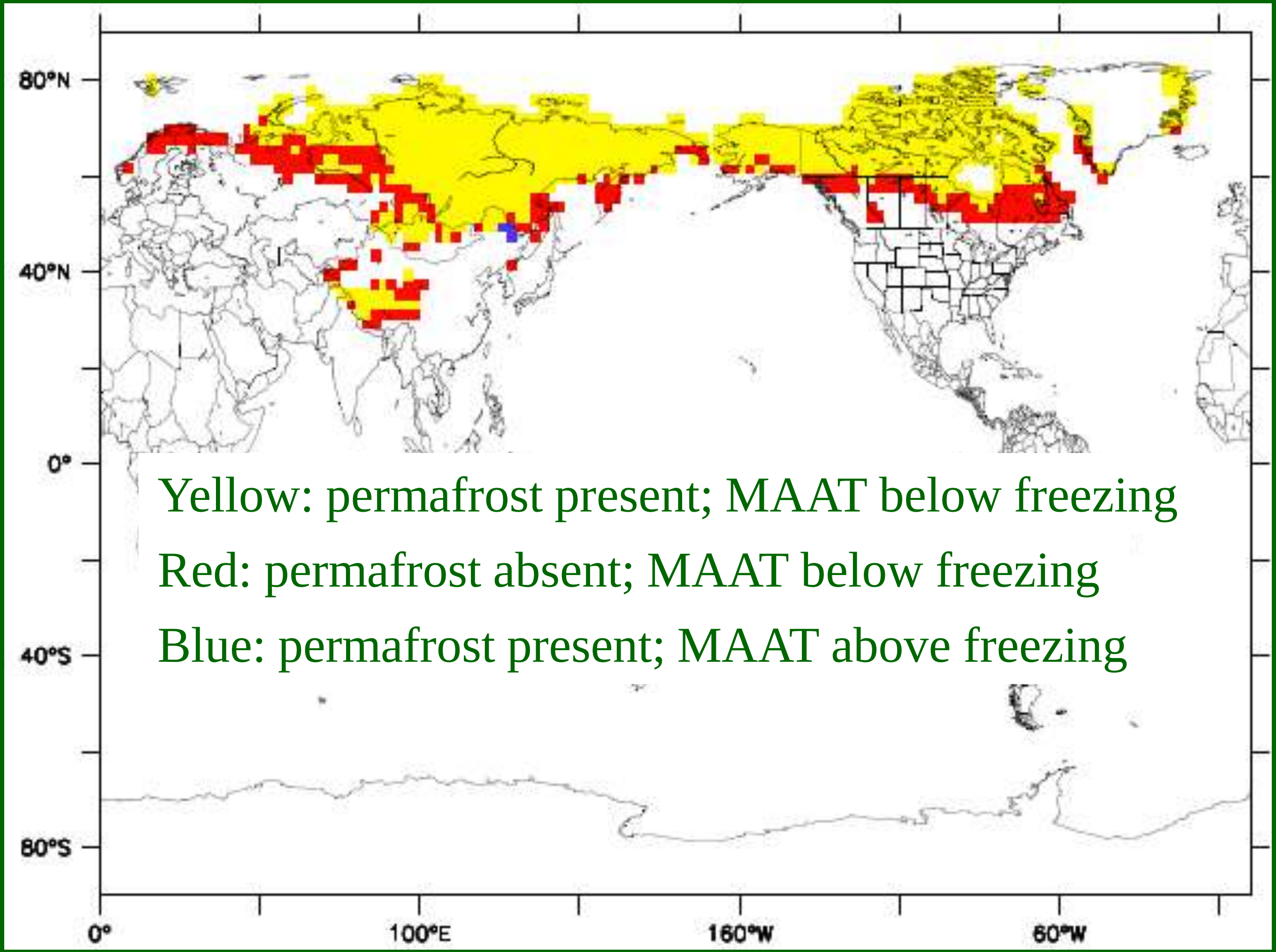
Permafrost Extent



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Summary Comments

- Extended scope/”granularity,” qualitatively realistic
  - Soil water profile (vs. “bucket”)
  - Permafrost and seasonal freezing
  - Landscape-driven heterogeneity
  - Rivers
  - Lakes
  - Groundwater
  - Framework for water use
- Improvement/degradation of water-balance partitioning
- Work in progress
  - Input data sets -> parameters
  - Hillslope tiling
  - Water use and irrigation
- Applications: Return to the questions

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