"Next Generation" Hydrologic Modeling: A superficial model show-and-tell, followed by a tired rant about hooking models together

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Part 1:
Superficial Model Show-and-Tell

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Some Science Issues

- Non-greenhouse forcing of hydroclimatic change
  - Water management
  - Land management
- Internal variability (long-term persistence, Hurst)
- Impacts and Feedbacks
  - Vegetation and carbon cycle
  - Groundwater
  - Subsurface cryosphere
  - Dust, aerosols
- Spatial/temporal scaling (e.g., floods)
- Application of new observational technologies

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GFDL Land-Model Development

Model	Manabe (1969)	LaD/LM2 (2002)	LM3 (2011)
Host	MCM	CM2	CM3/ESM2.1.ESM3/CM2.5/HiRAM
IPCC	AR1/2/3	AR4	AR5
New Physics	•Mass & energy balance •Water store •River basins from model topography	•Static global vegetation & soil fields •Diurnal cycle •Realistic river basins •Lumped GW/SW stores	•Advanced biophysics/canopy •C dynamics •Vegetation dynamics •Stream storage •Soil-water phase change •Soil-water diffusion •Vertically resolved snowpack •Tiled heterogeneity •Landscape-based GW
New Applications	•Global climate •Global water cycle •Global warming	•“Great floods” •Gross LC change •Sea level •Gravity •Geodynamics	•Biospheric feedbacks •Carbon cycle •Land-use impacts •Thaw feedbacks •Streamflow variability •Water-use impacts

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canopy interception,
throughfall, etc.

photosynthesis
carbon fluxes
dynamic vegetation

plant phenology

fire

land clearance,
wood harvesting

~5-layer
snow pack

~20-layer soil
sat/unsat
frozen/unfrozen

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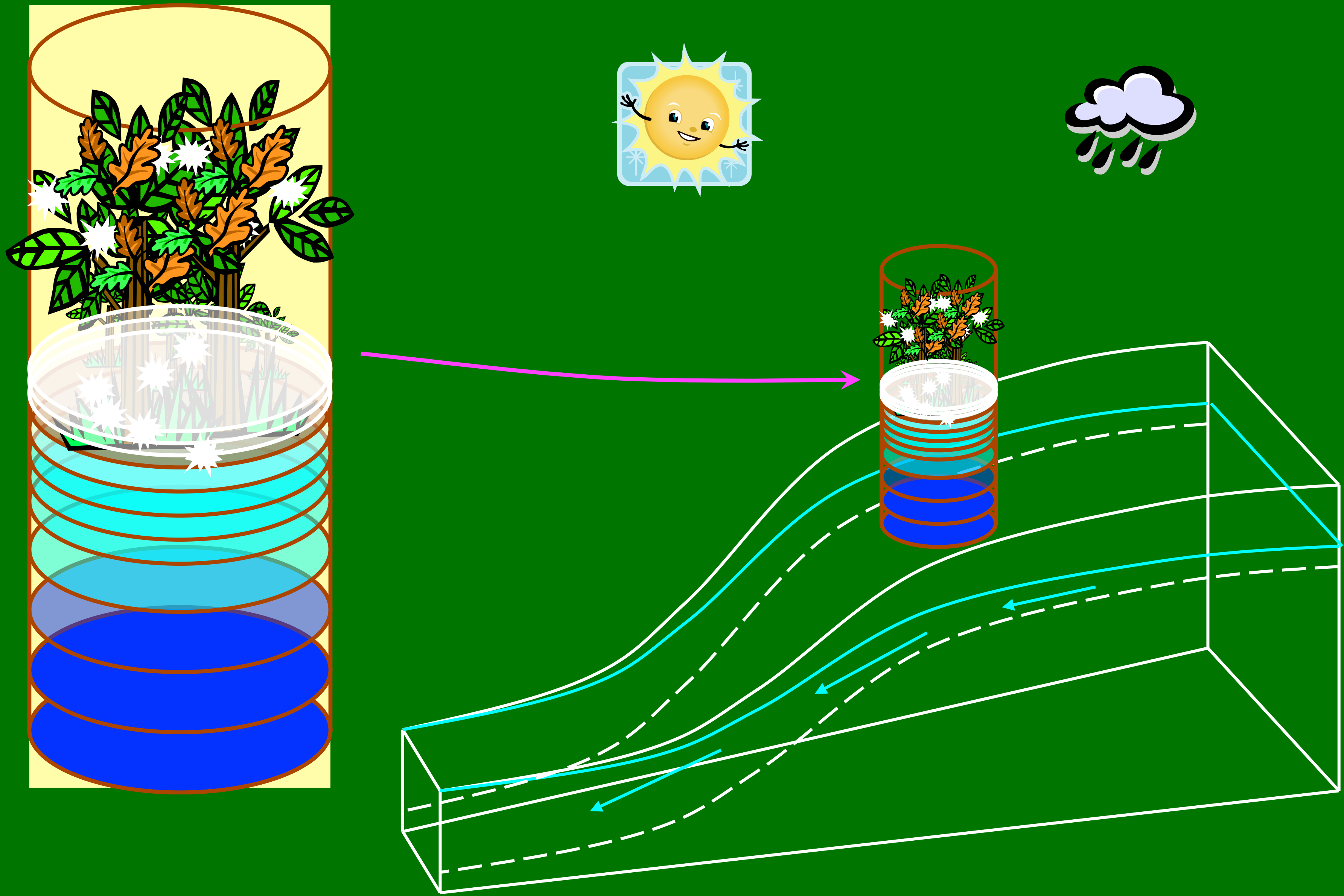

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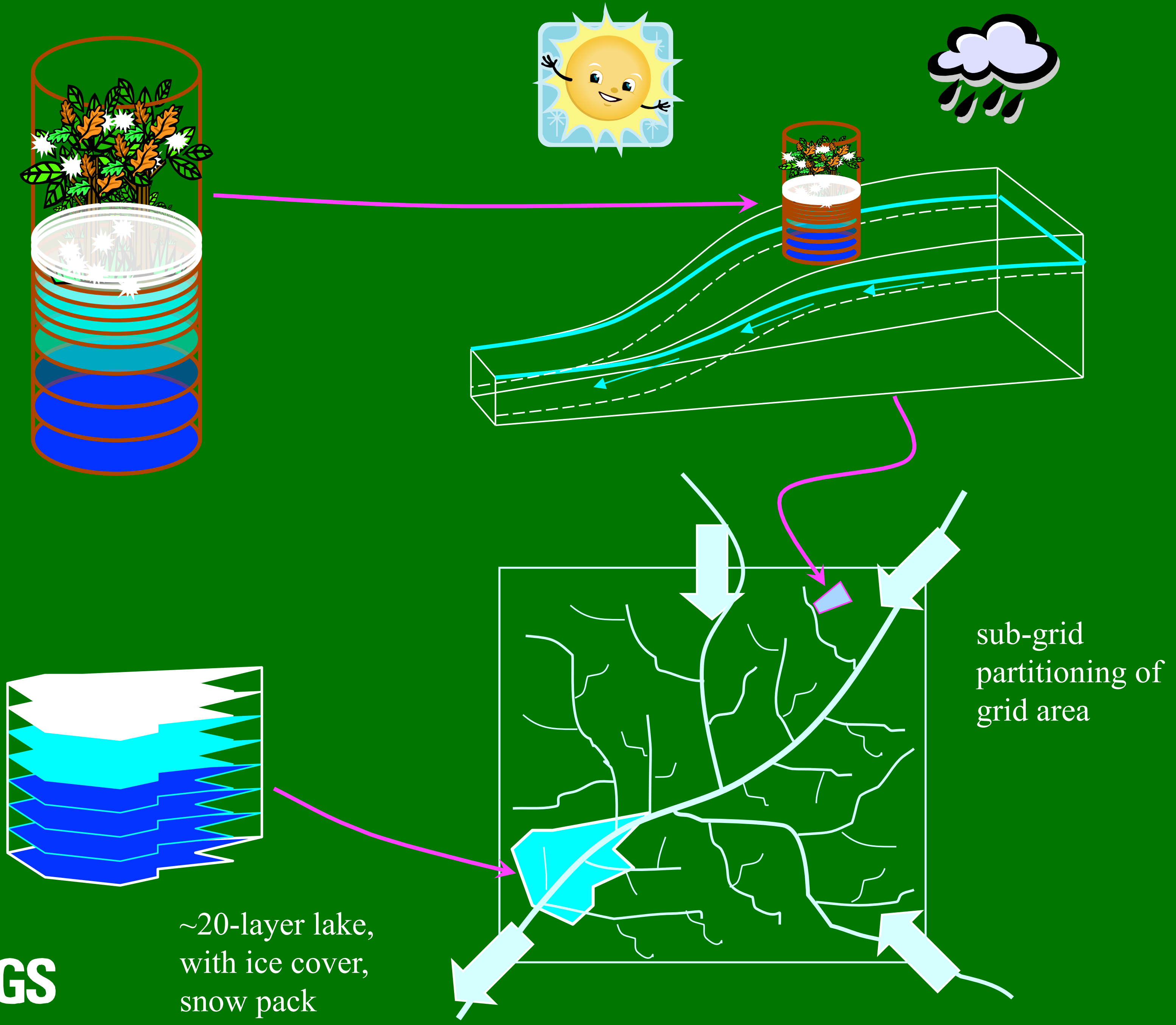
landscape-based groundwater divergence and saturated areas


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

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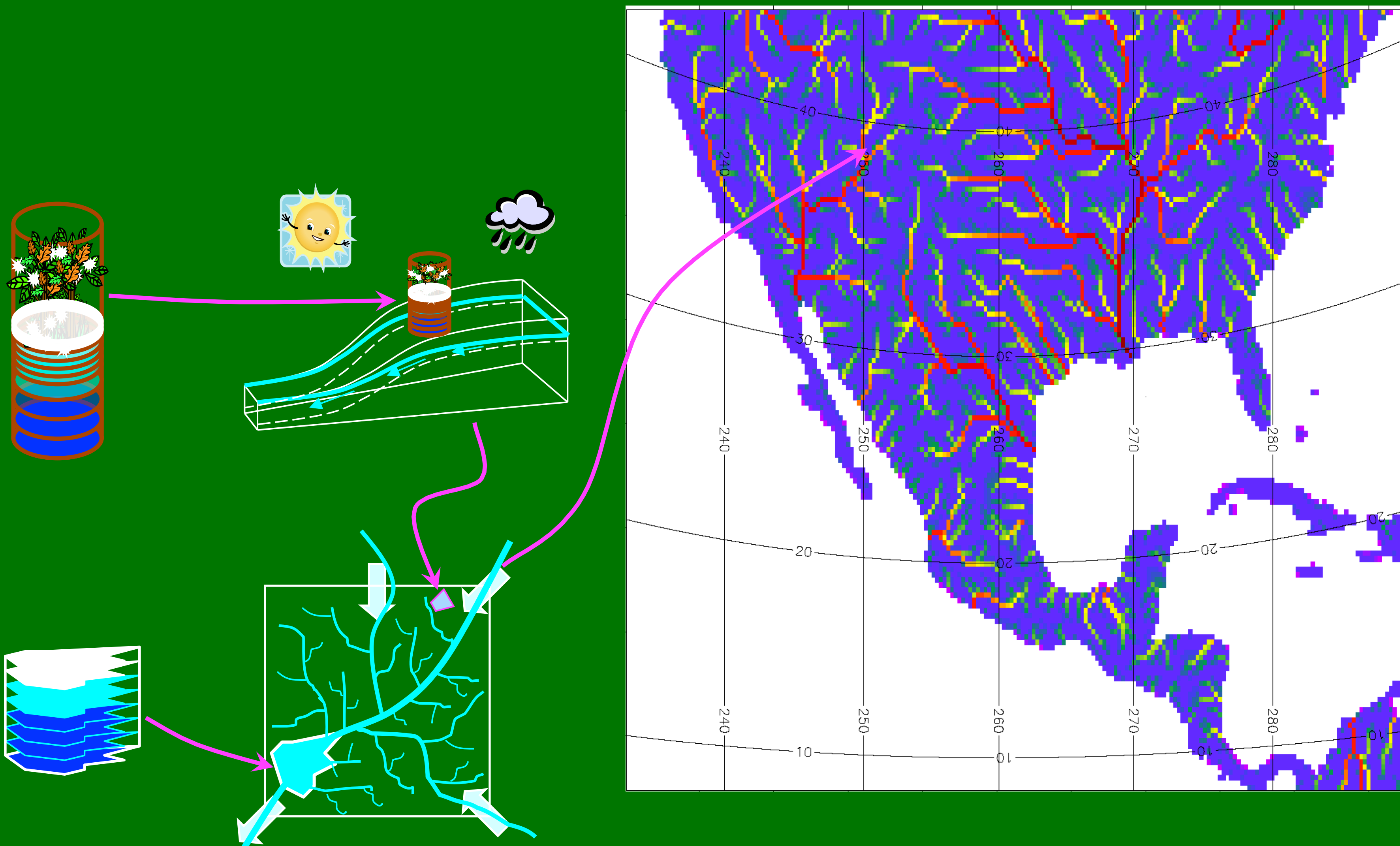

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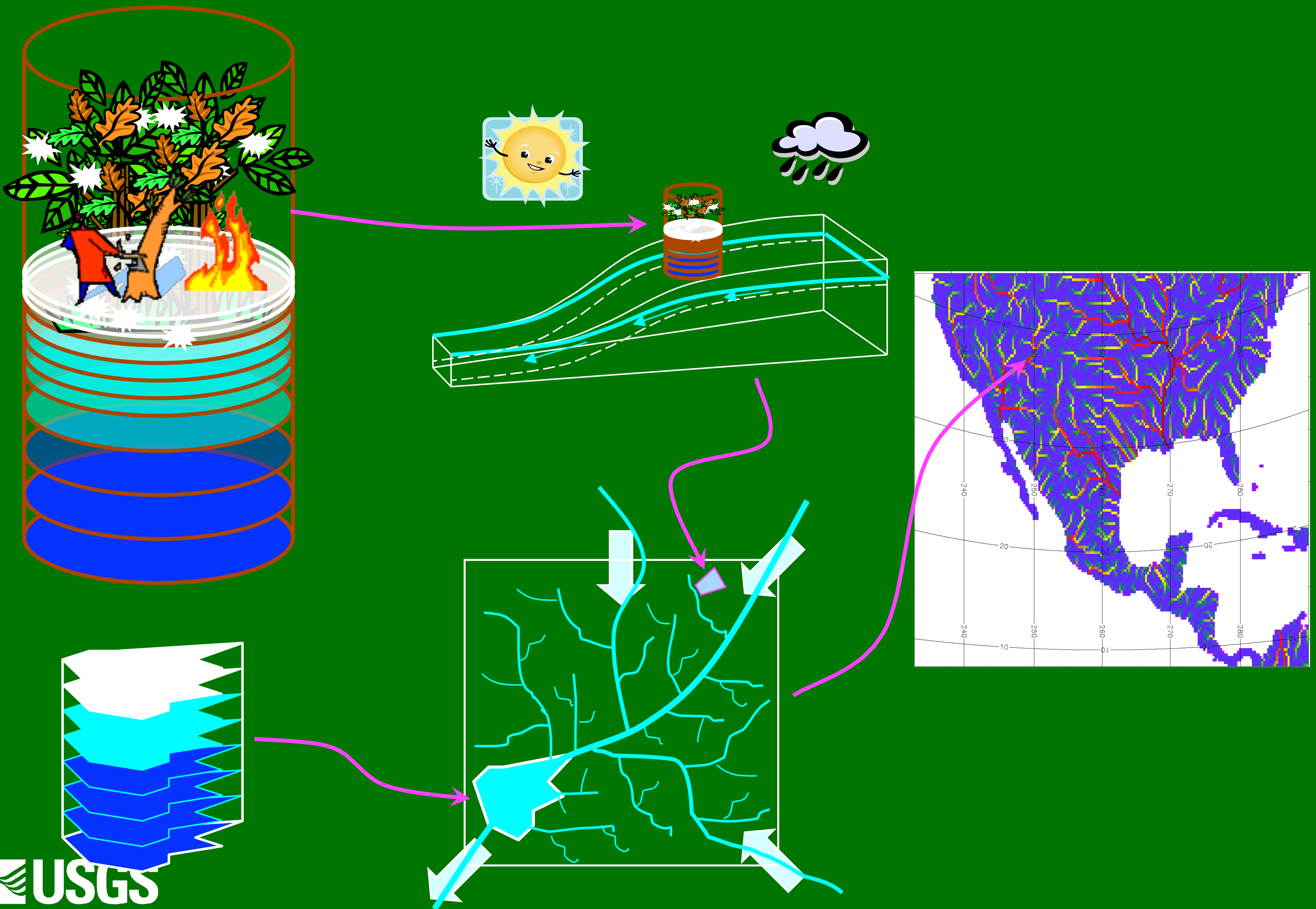
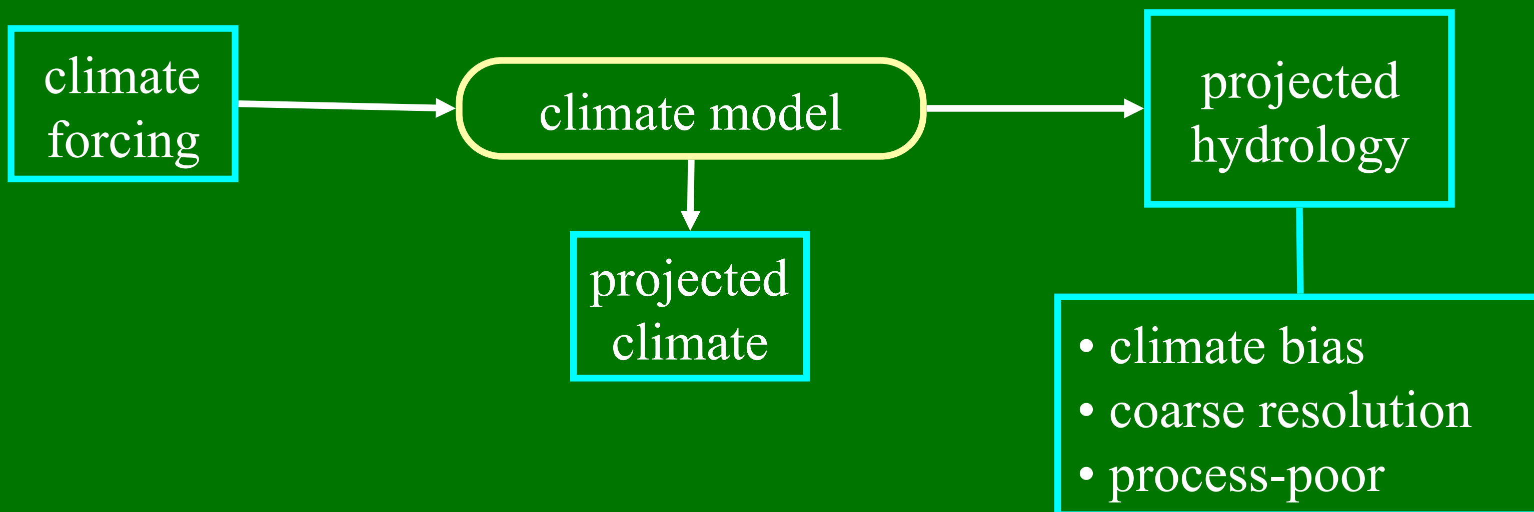


End of Part 1:

- If there’s anything new in all of that, it’s the ***integration*** of the pieces, in a physically consistent framework, with appropriate feedbacks.

Part 2:
The Rant

Hydrologic Adjustment ("Downscaling") of Climate Change Projections



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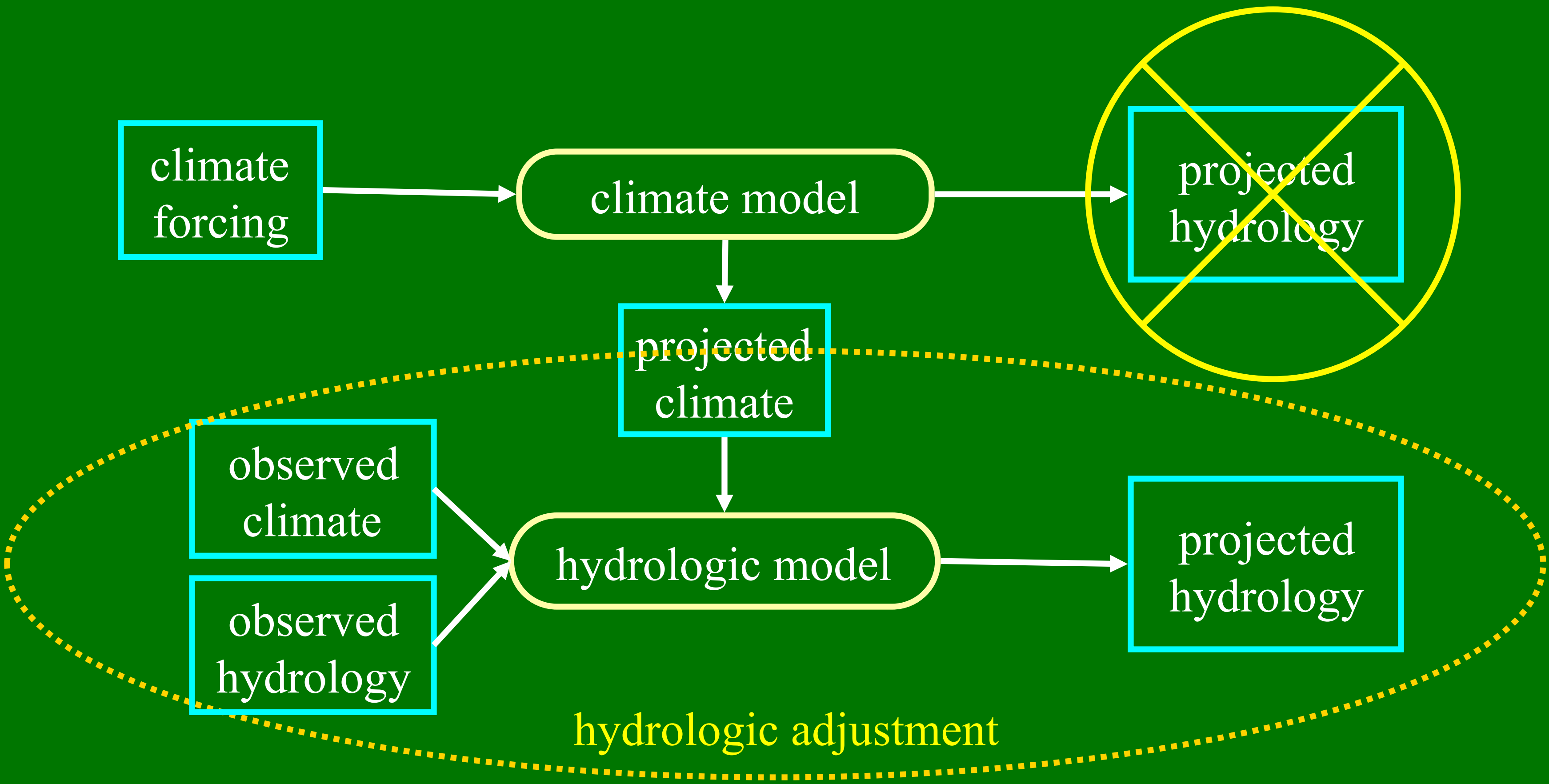
Hydrologic Adjustment of Climate Change Projections



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No Free Lunch

Hydrologic adjustment implicitly assumes…

- local climate change is independent of local climate; and
- local climate change is independent of surface feedback.

These assumptions generally fail, so hydrologic adjustment trades one set of errors for another.

Furthermore, more “moving parts” allows for more errors in implementation. “Devil in the details.”

In particular, energy balance and potential ET is a weak spot for hydrologists.

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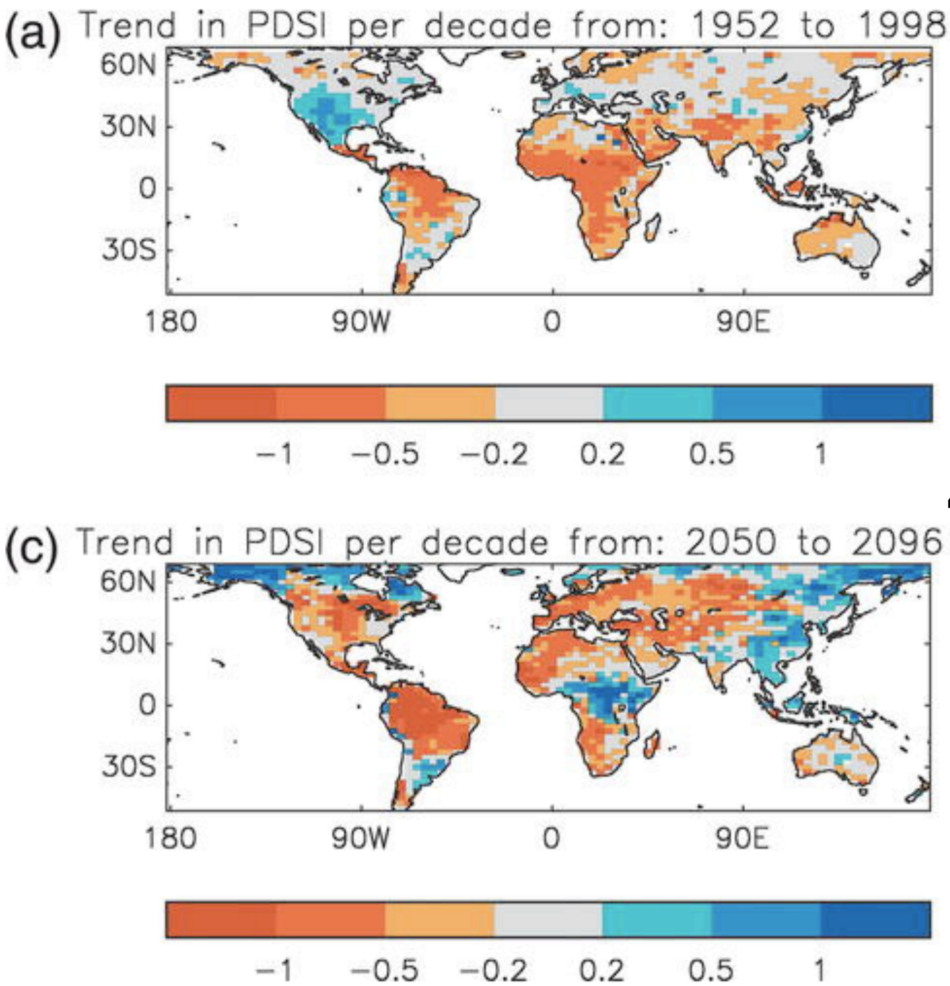
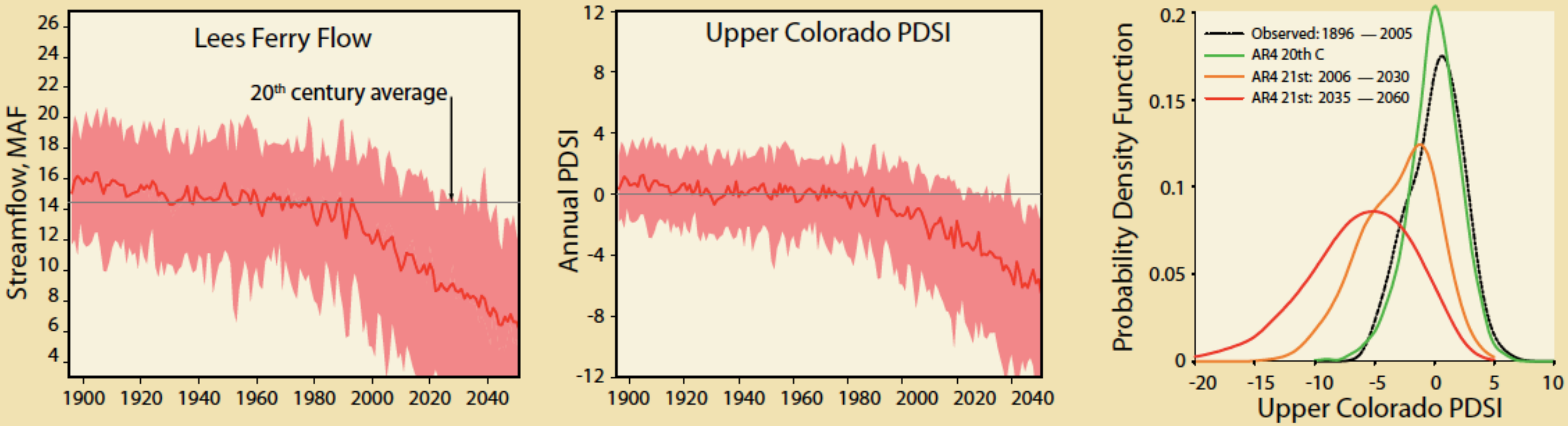


"…the proportion of land surface in extreme drought is predicted to increase from 1% for the present day to 30% by the end of the twenty-first century." (Burke, E.J. et al., J. Hydromet., 2006)



The 1895-2050 Lees Ferry annual streamflow (left) was derived from the AR4 simulations of PDSI (middle) using the downscaling formula that relates observed Lees Ferry flow to observed PDSI during the 20th century. The dark red curve denotes the 42-run average, and the cloud describes the 10 to 90 percent range of individual simulations. The right panel summarizes the probability distribution function of PDSI averaged over the Upper Colorado Drainage Basin for individual years of observations 1895-2005 (black), for the 42 models for 1895-2005 (green), and for the 42-model projections of the average PDSI during 2006-2030 (orange) and 2035-2060 (red). Note that the models produce a realistic range of PDSI drought events during the 20th century, and for the future they produce surface moisture conditions that denote progressive aridification and severe drought conditions.

$$\mathrm{FLOW} = A_o + (A_1 \times \mathrm{PDSI})$$

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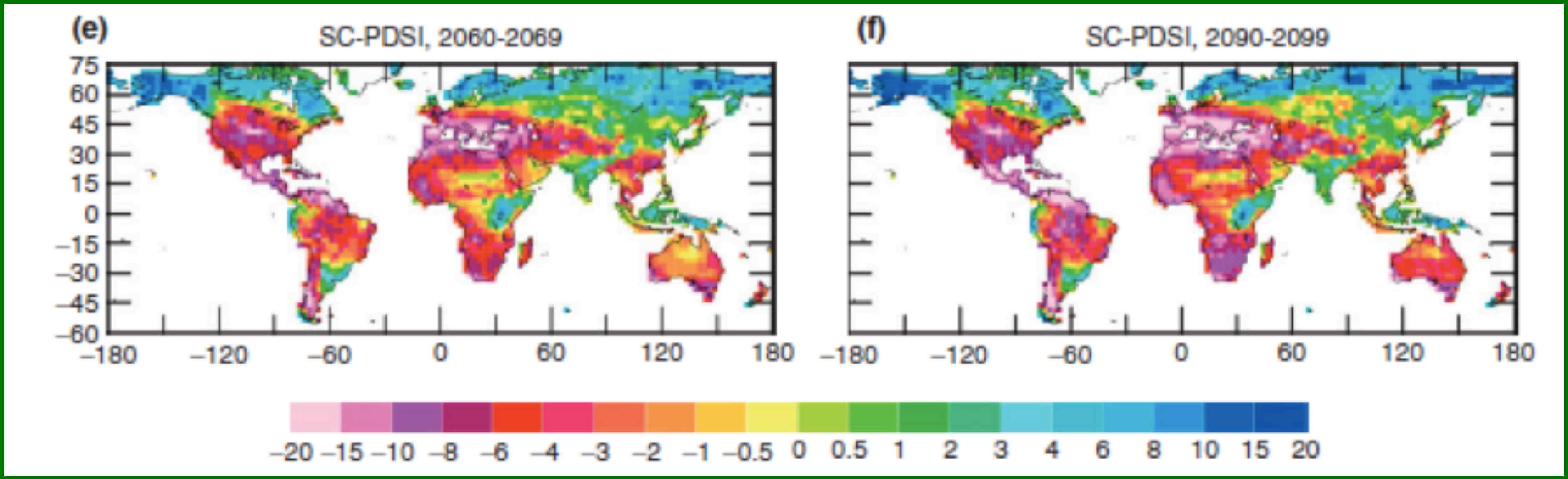
- Hoerling, M., and J. Eischeid, "Past peak water in the Southwest," Southwest Hydrology, 2007.



Dai, A., “Drought under global warming: a review,” John Wiley, WIREs Climate Change, 2011.

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What all the most dire/alarming projections for drying have in common is a dependence of the drying on increased evaporative demand, rather than precipitation deficit.

Climate models, which do the best job of energy balances, do not support the most extreme drying projections.

In at least some cases, the discrepancy can be traced to stealth (i.e., implicit) assumptions of stationarity.

End of Part 2:

- We can get into trouble when we dissect the whole into its pieces.

Primary Technical Topics

- 1. What are the forcings needed for NOAA hydrologic prediction services…
- 2. What methods are best for extreme event…
- 3. How to combine obs, paleo, climate projections…
- 4. NOAA's future hydrologic models… IWRSS
- 5. Define needed inputs for policy makers…
- 6. How better to use weather/climate predictions…

my “water cycle”

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