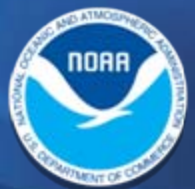


Geophysical Fluid Dynamics Laboratory Review

June 30 - July 2, 2009



Response of the Tropical Climate System to Warming

Presented by
Gabriel Vecchi

Geophysical Fluid Dynamics Laboratory Review

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Response of the Tropical Climate System to Warming

GOALS:

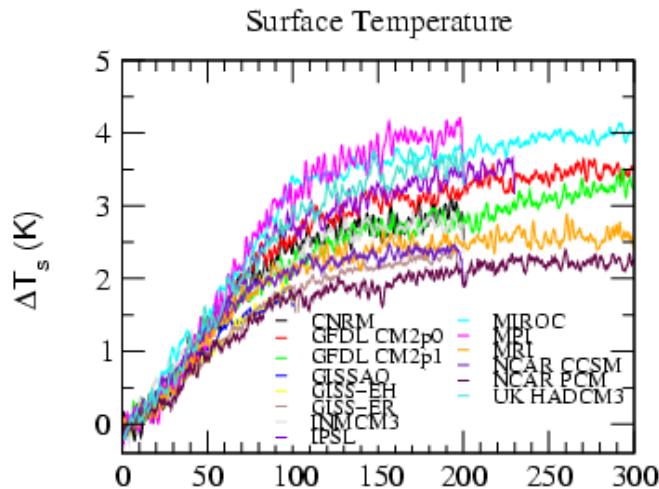
- Use numerical modeling, theory and observations to understand the controls on tropical climate change.
- Build predictive understanding of the global and regional impacts of tropical climate change.

EXAMPLES

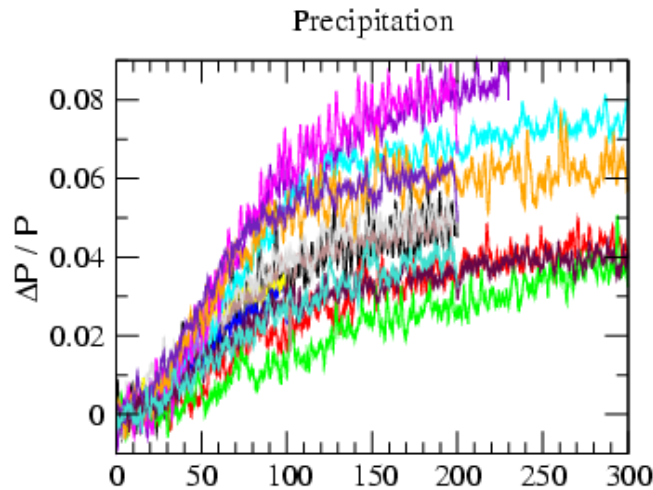
- Weakening of tropical circulation from increased CO₂.
- Controls to subtropical precipitation changes.

IPCC-AR4 model projections: warm, moist and more rainfall, but reduced atmospheric circulation

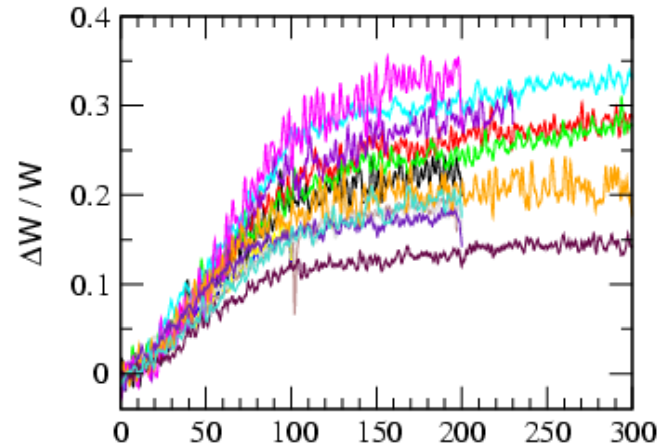
**Temp.
Increases**



**Precip.
Increases**



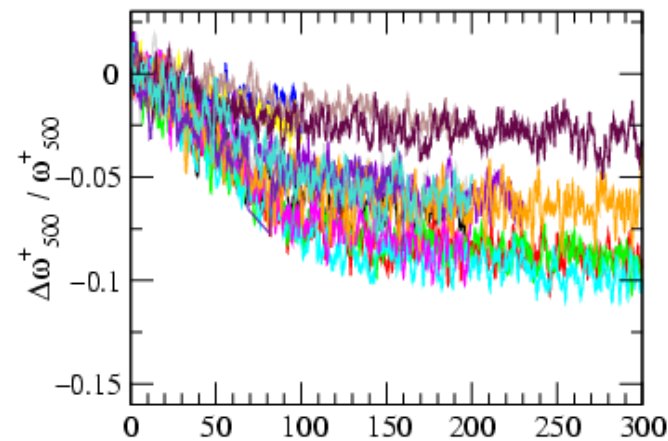
Column Water Vapor



SRESA1B

**Moisture
Increases**

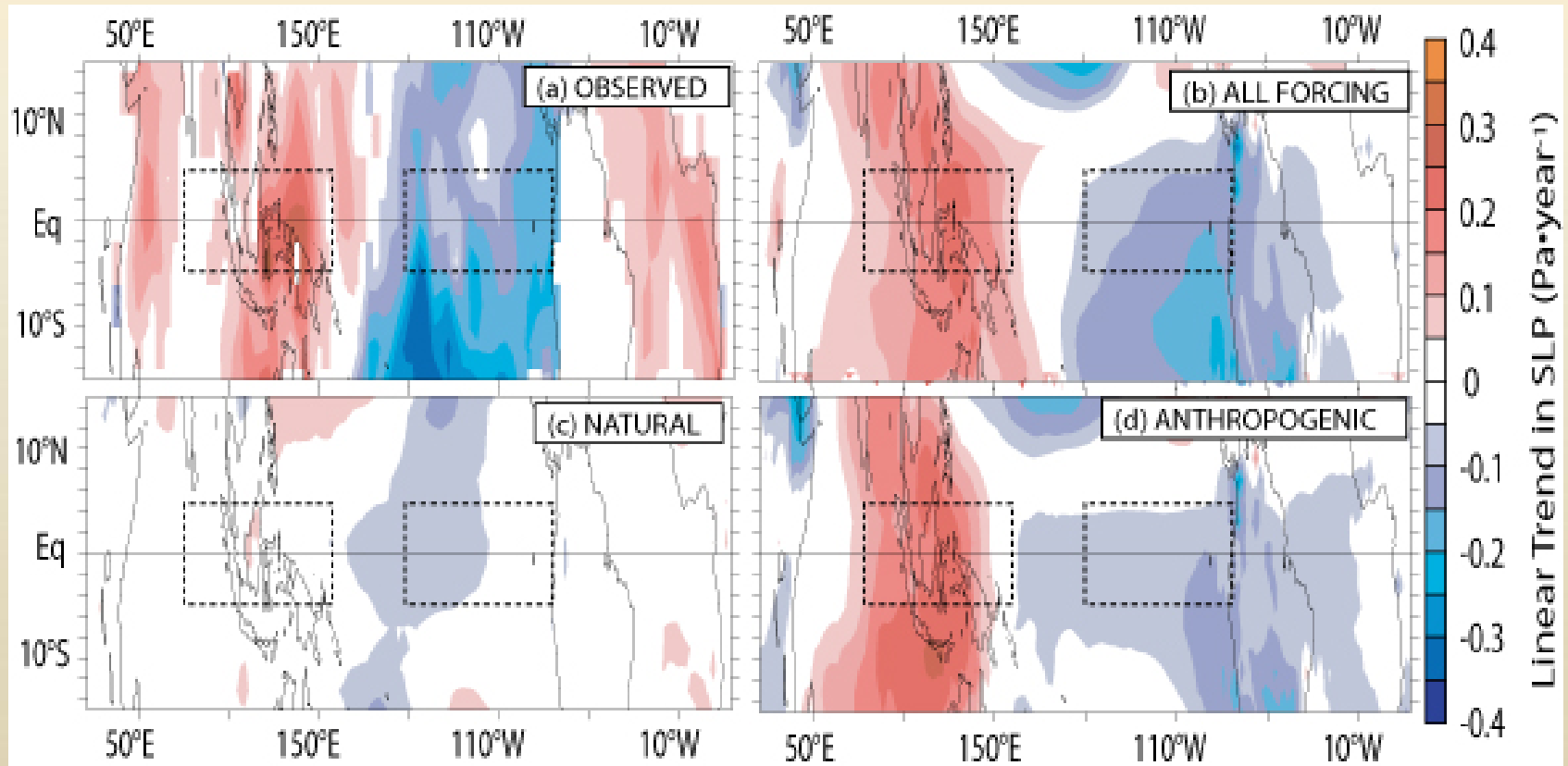
Upward Vertical Velocity



**Circulation
decreases**

Held and Soden (2006, J. Clim.) Vecchi and Soden (2007, J. Clim.)

CM2.1 used to attribute historical weakening of Walker Circulation to anthropogenic forcing



1861-1992 Trends

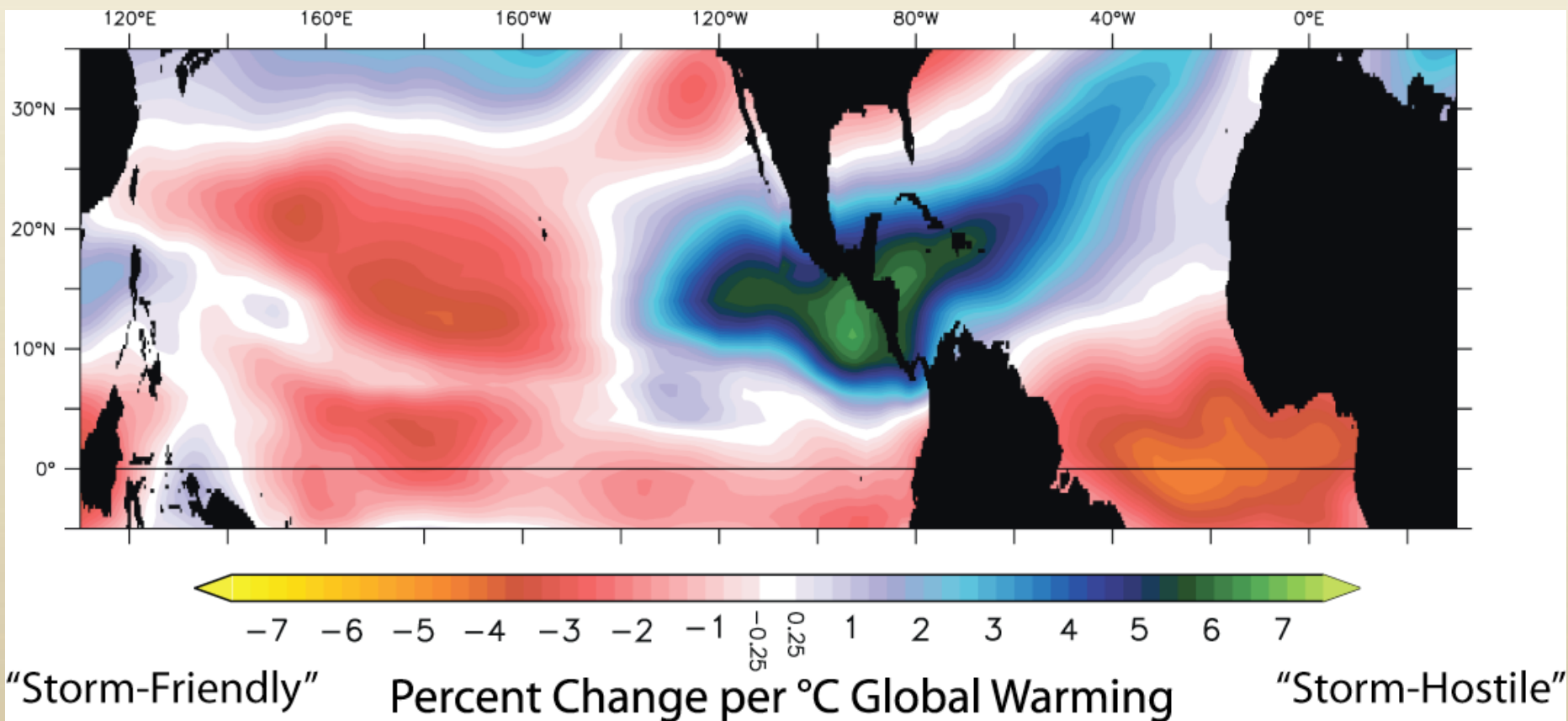
2007 OAR Outstanding Paper

Vecchi, Soden, Wittenberg, Held, Leetmaa and Harrison (2006, *Nature*)

Models project changes in wind shear connected to a weakened Walker Circulation.

Atlantic wind shear increases connected to reduced Atlantic hurricane frequency

(e.g., Knutson et al 2008, Nature Geosci.; Garner et al 2009, J. Climate; Zhao et al. 2009, J. Climate).



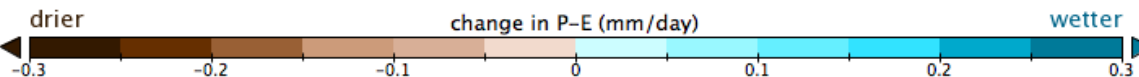
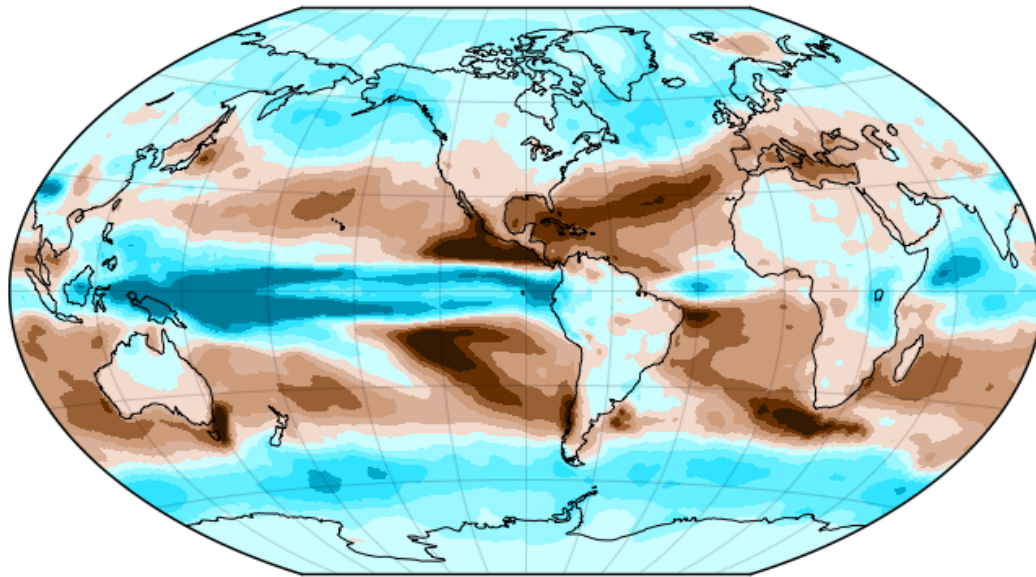
Adapted from Vecchi and Soden (2007, GRL), CCSP 3.3 (2008)

Wet-get-wetter, Dry-get-drier

Thermodynamic Control:

Warming (increase q_{sat}) \rightarrow increase atmospheric moisture. \rightarrow increase moisture flux divergence/convergence.

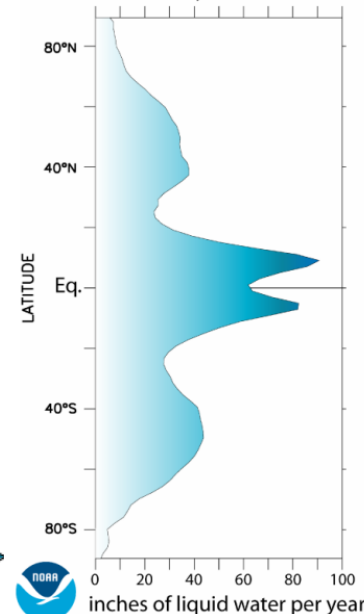
Change in P-E (2021–2040 minus 1950–2000)



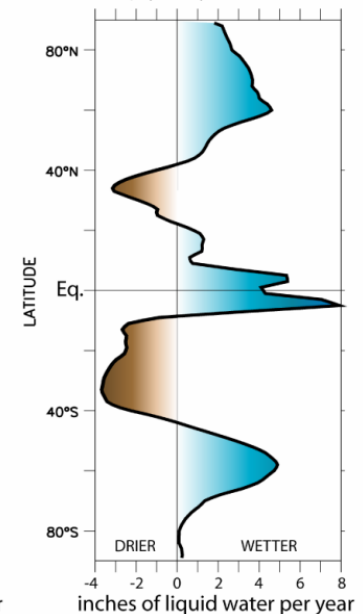
Adapted from Held and Soden (2006, *J. Clim.*)

Figure by N. Naik., LDEO/Columbia

LONGITUDINALLY AVERAGED
1950–2000 PRECIPITATION
as modeled by NOAA/GFDL CM2.1



LONGITUDINALLY AVERAGED
21st Cy PRECIPITATION CHANGE
as projected by NOAA/GFDL CM2.1

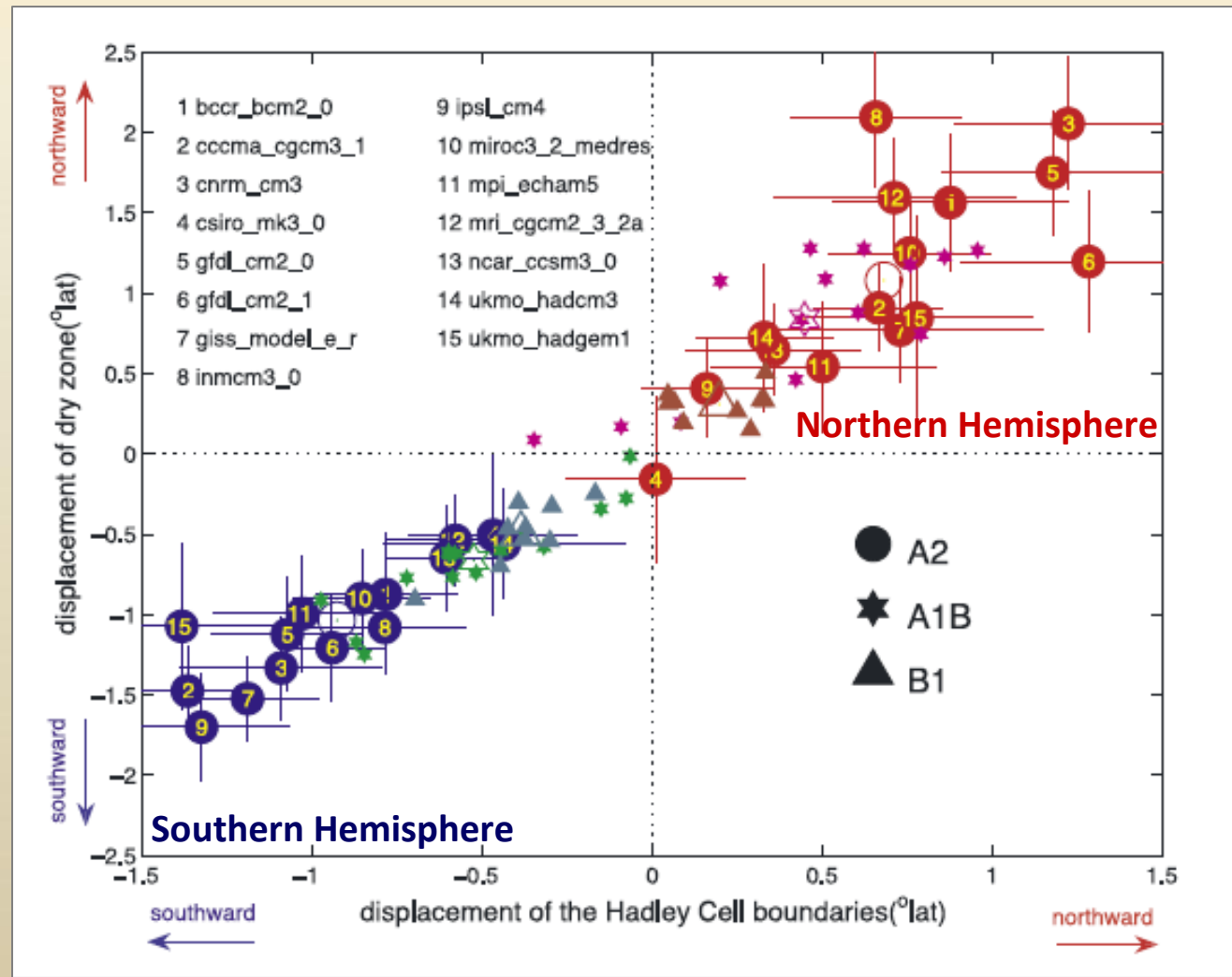


Adapted from Held and Soden (2006, *J. Clim.*)



Wider Tropics: Wider Dry Zones

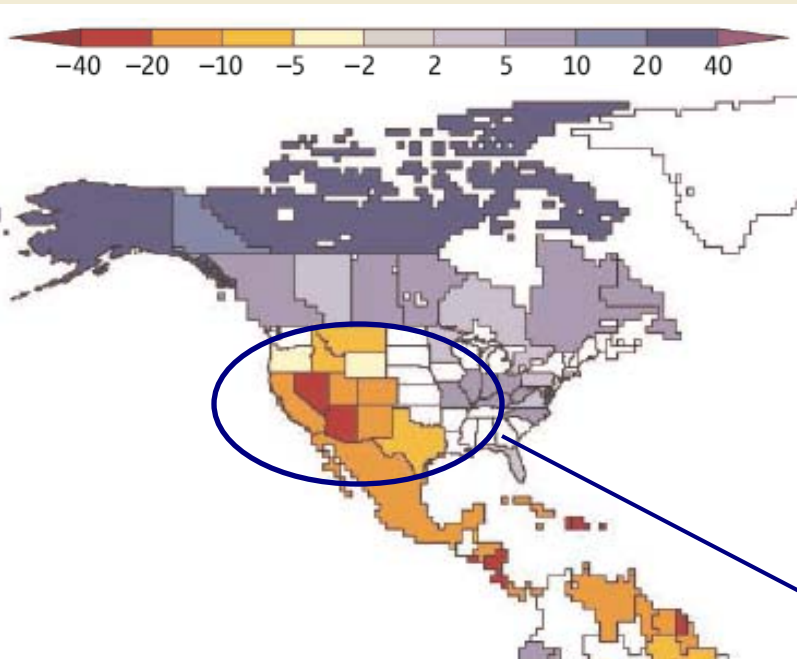
Poleward shift of descending branch of Hadley Circulation is associated with a poleward shift of dry zones.



Lu, Vecchi and Reichler (2007, GRL)

U.S. Southwest Projected to Get Drier

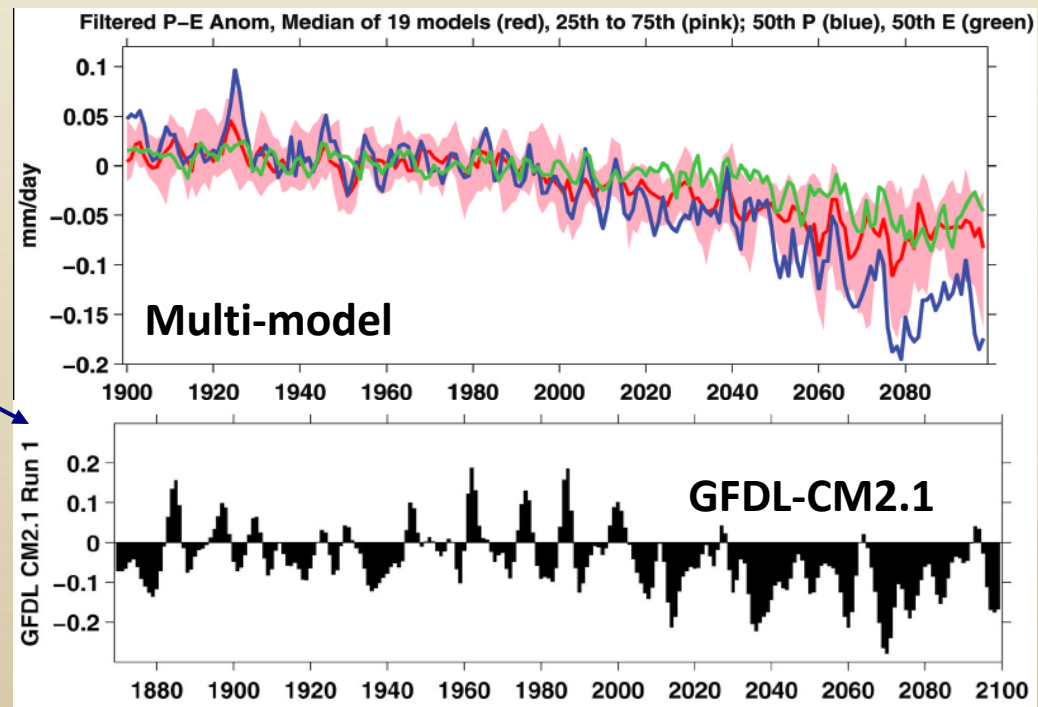
21st Century Projected
% Change in Runoff



Milly et al (2008, Science)

“Dry-get-drier” and expansion of dry zones contribute to drying.

Change in SW US Precip. minus Evap.



Seager et al (2007, Science)

Response of the Tropical Climate System to Warming

Weakening of tropical circulation, largely Walker Circulation

- Detection/attribution studies on Walker Circulation
- Sets stage for changes in El Niño
- Associated with Atlantic wind shear changes (hurricane-relevant)

Wet-get-wetter, dry-get-drier

Poleward expansion of Hadley Circulation

- Dynamical and thermodynamic constraints on rainfall
- Associated with subtropical drying (including SW-U.S.)

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