# Decadal potential predictability of soil water, vegetation, and wildfire frequency over North America

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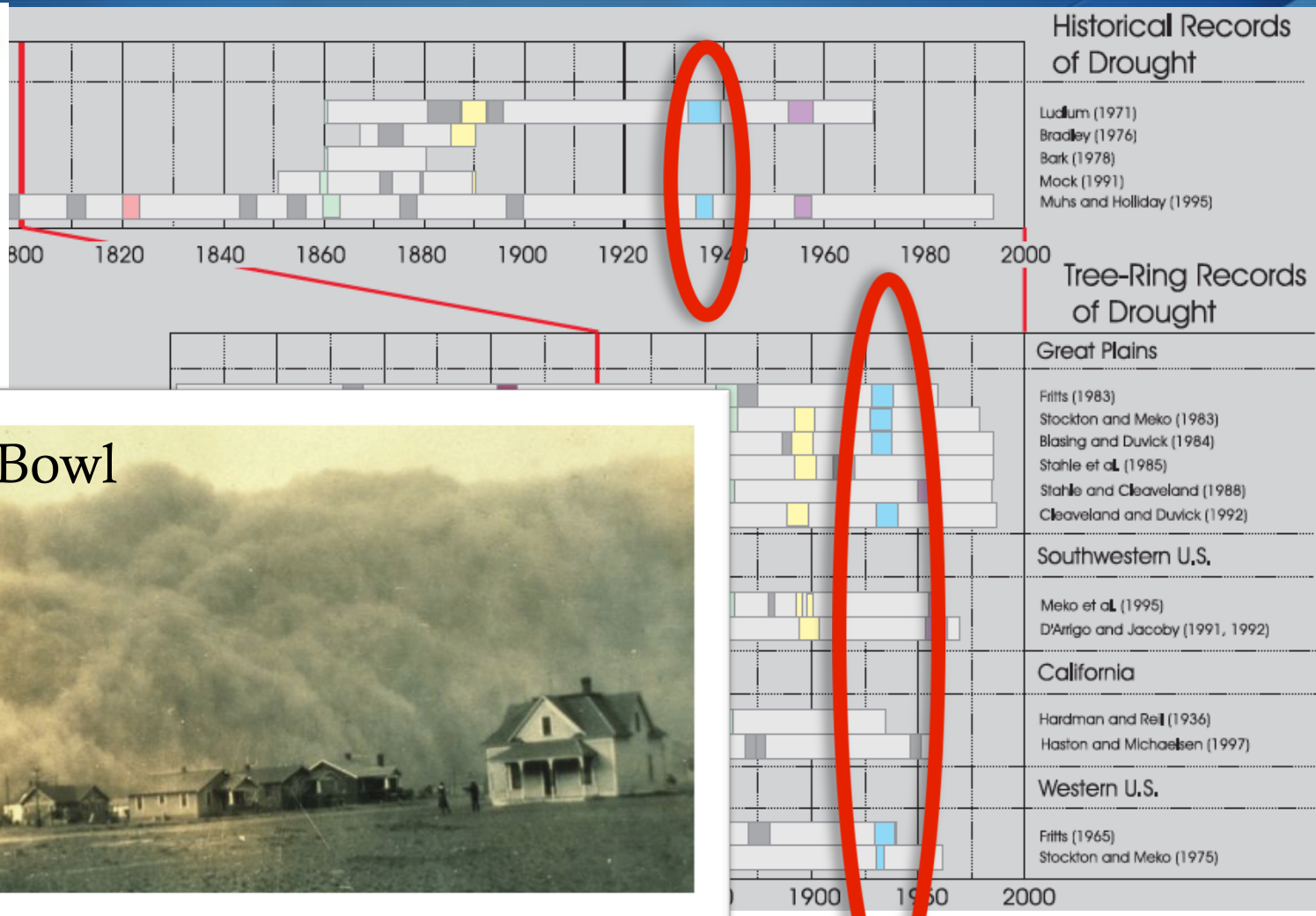
INTERNATIONAL PACIFIC RESEARCH CENTER

Community Earth System Model

# Mega-droughts in US historical records



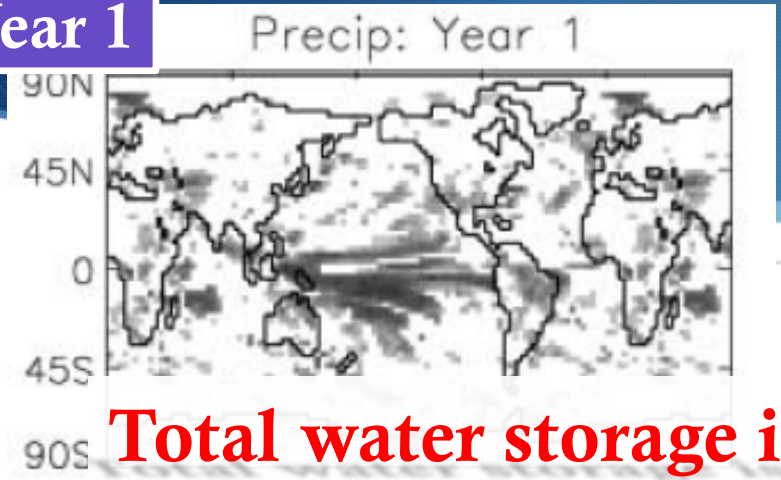




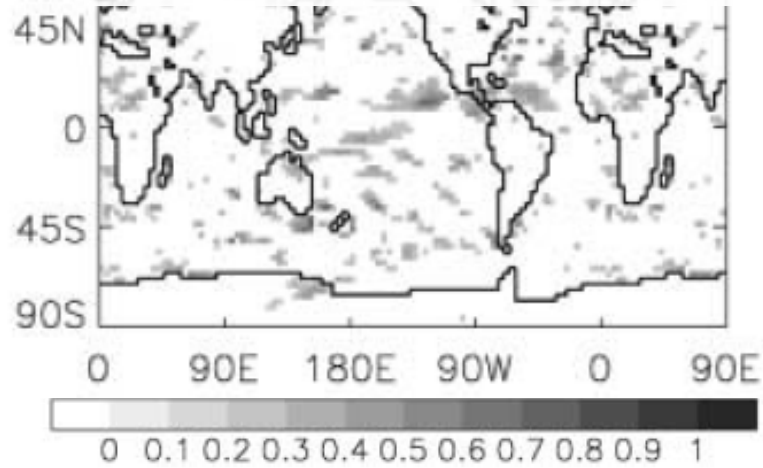
Woodhouse and Overpeck (1998)

# Predictability of precipitation

**Year 1**



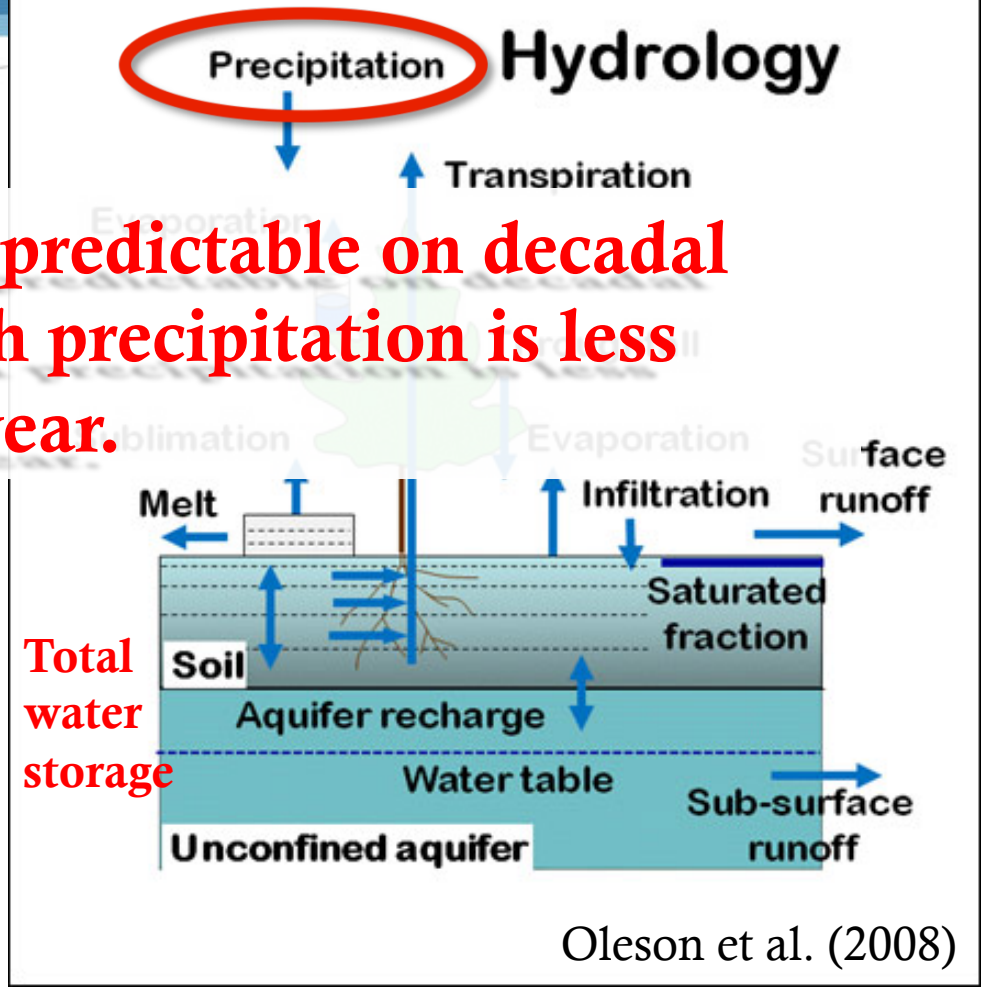

**Year 5**




Collins (2002)

**Total water storage is predictable on decadal timescales even though precipitation is less predictable beyond 1 year.**

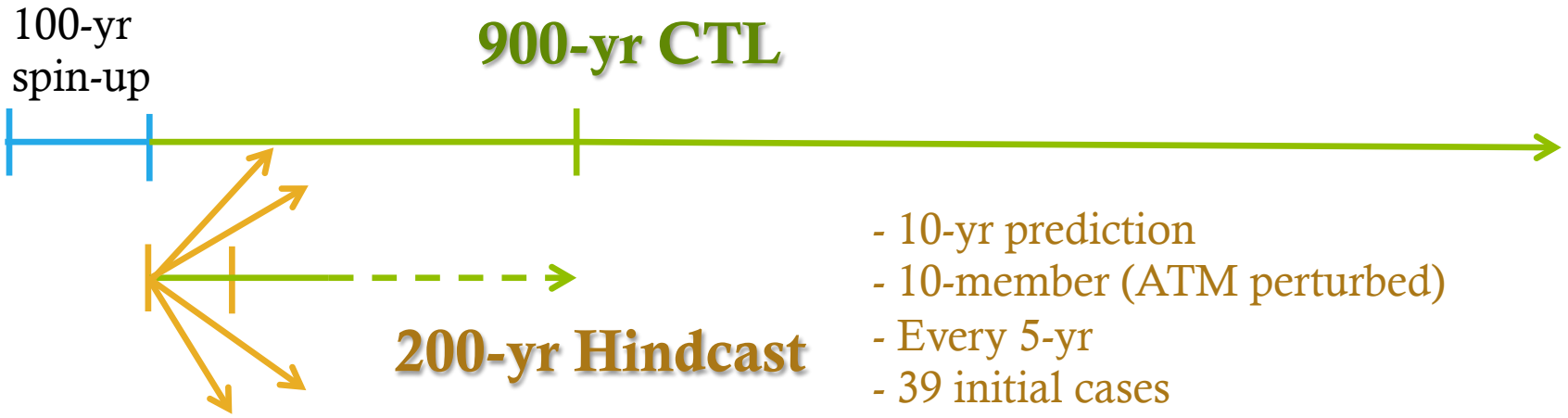
**CLM4**




Oleson et al. (2008)

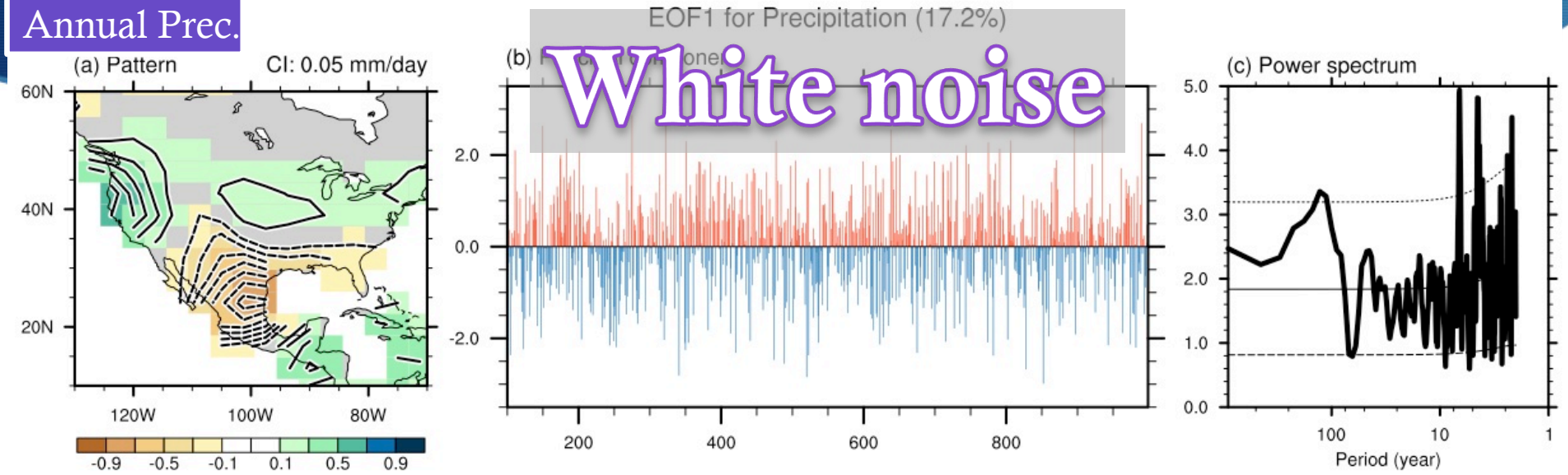
# Model experiment

- Low-resolution version of CESM 1.0.3 (Shields et al. 2012)
  - ATM & LND: T31 L26
  - OCN & SEA ICE: 3 x 3 L60
- A 900-year-long pre-industrial control simulation (+100-yr spinup)
- Hindcast experiment for 200-yr CTL run.

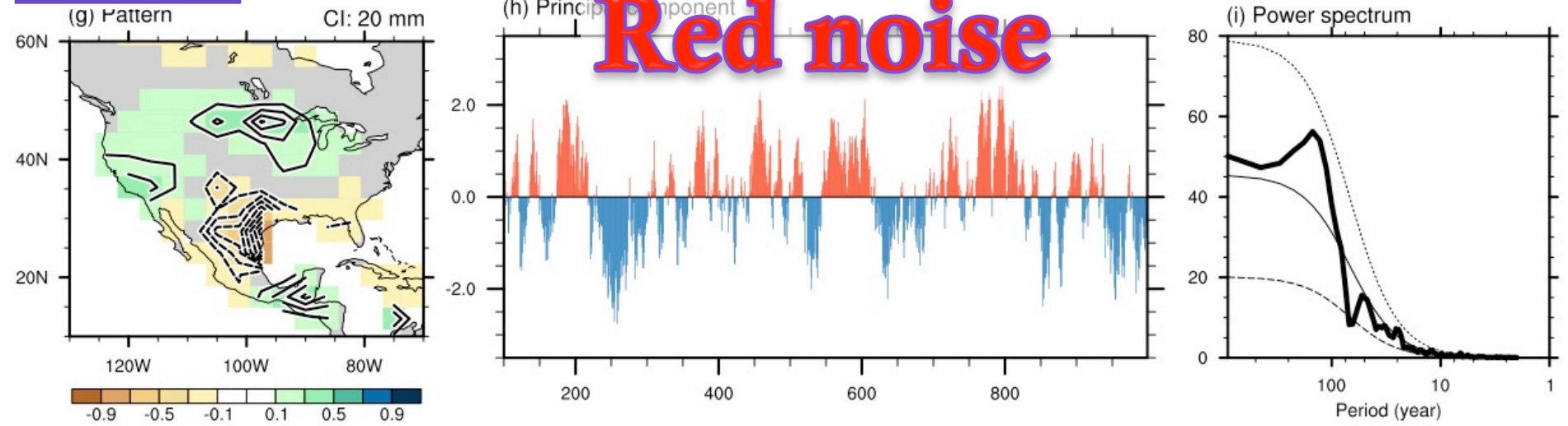


# EOF1 for prec. and soil water

Annual Prec.




Total Water

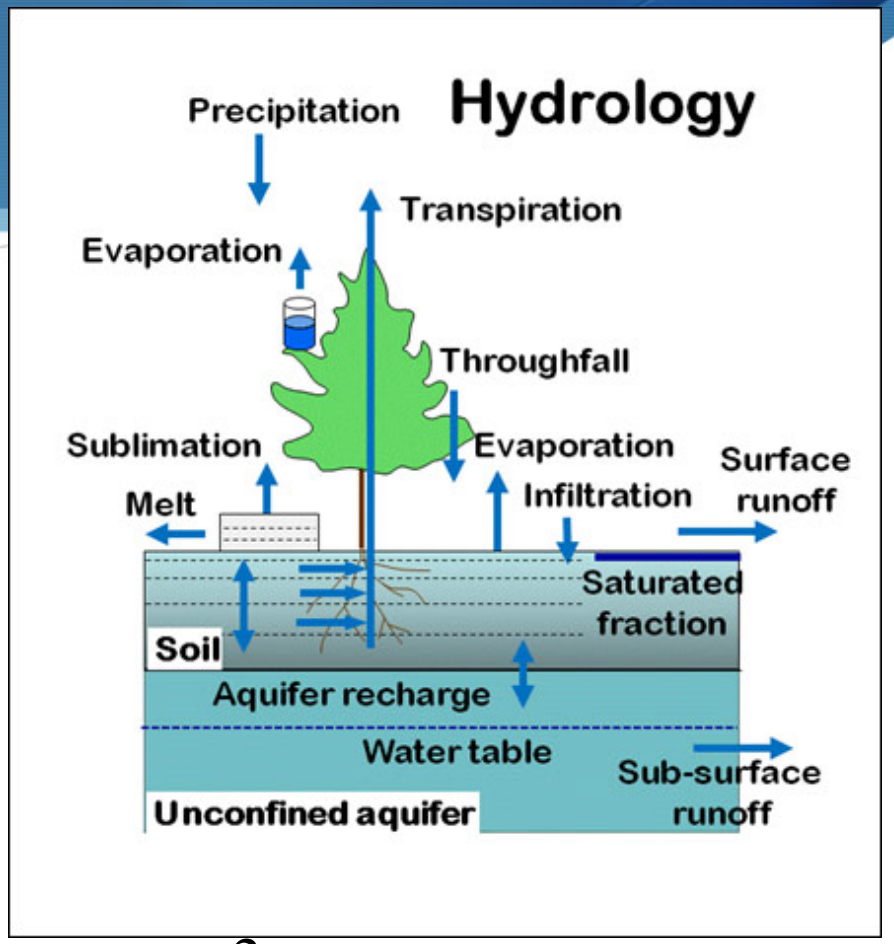


# Water budget in soil layer

$$\frac{\partial W}{\partial t} = P - E - R + S$$

$$\approx -\lambda W + P(t)$$

Delworth and Manabe (1988)




AR1 process

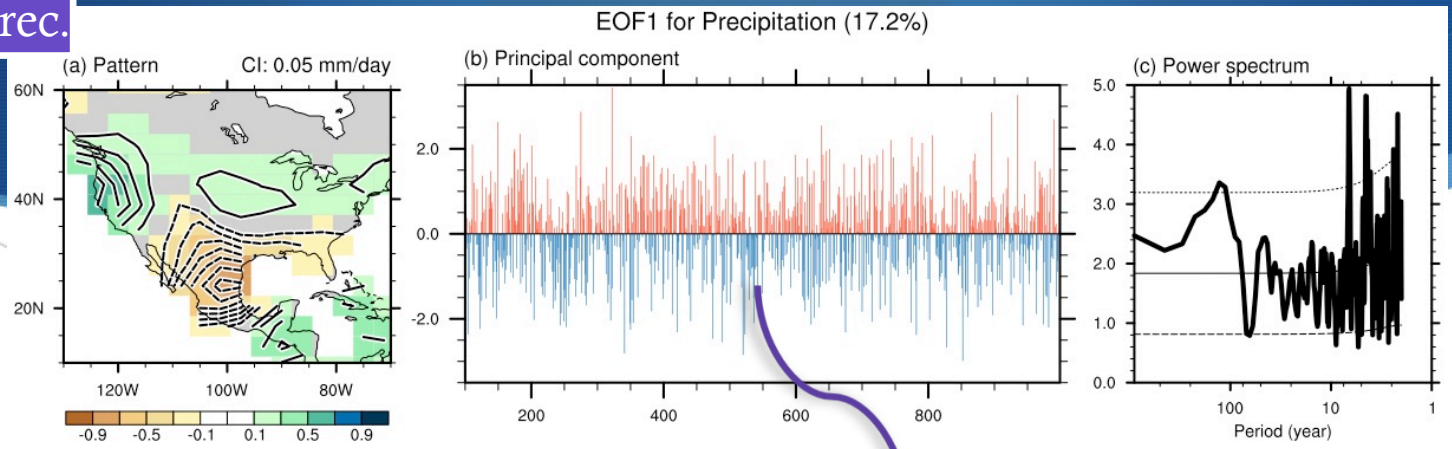
$$W_{i+1} = \alpha W_i + \varepsilon_i$$

$$= \varepsilon_i + \alpha\varepsilon_{i-1} + \alpha^2\varepsilon_{i-2} + \alpha^3\varepsilon_{i-3} + \cdots$$

Soil layer acts as an integrator of precipitation: the filtering effect

# AR1 process

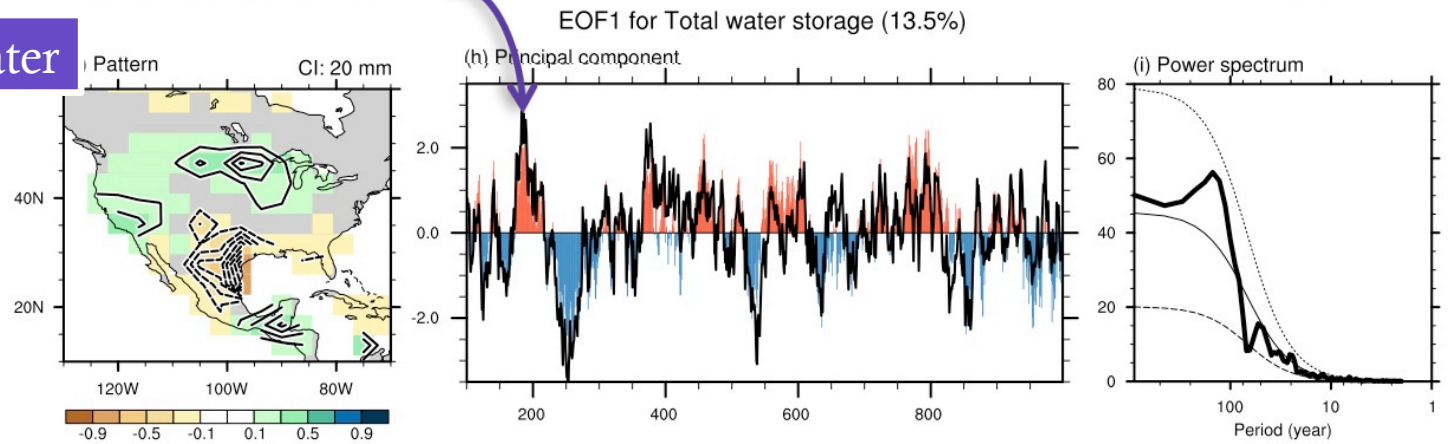
Annual Prec.




$$W_{i+1} = \alpha W_i + \varepsilon_i$$

α: Auto-correlation with 1-yr lag

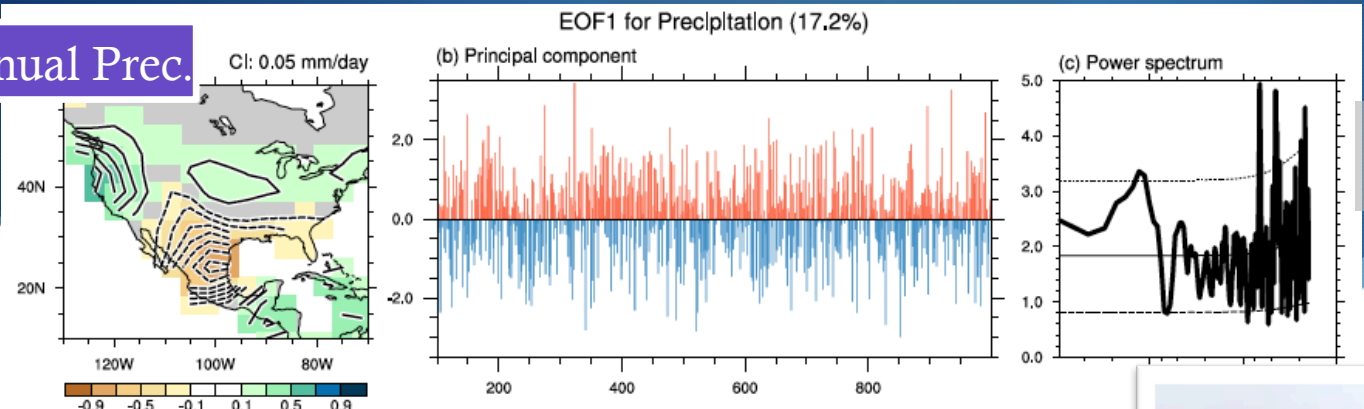
Total Water




—— AR1 process estimated from precip.

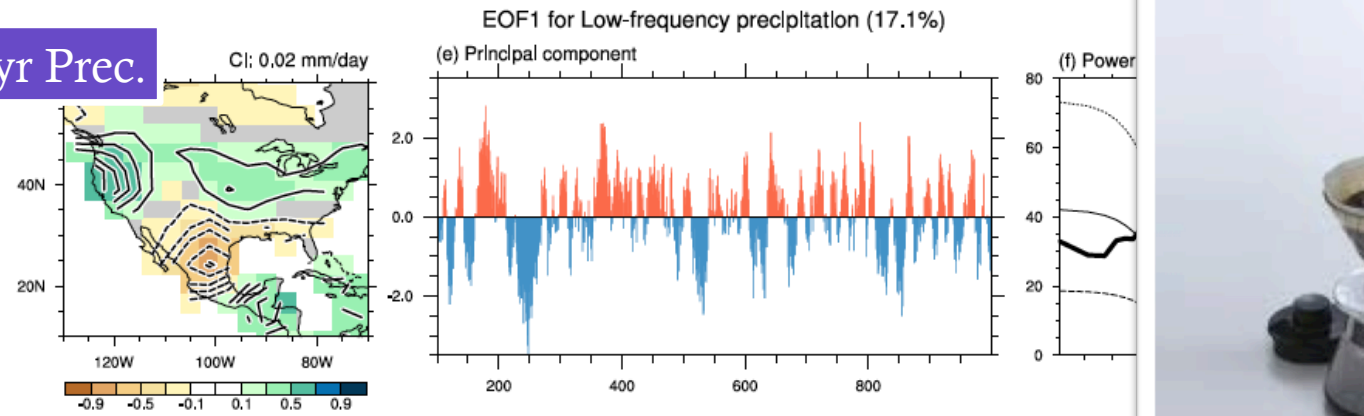
# Soil acts as natural low-pass filter

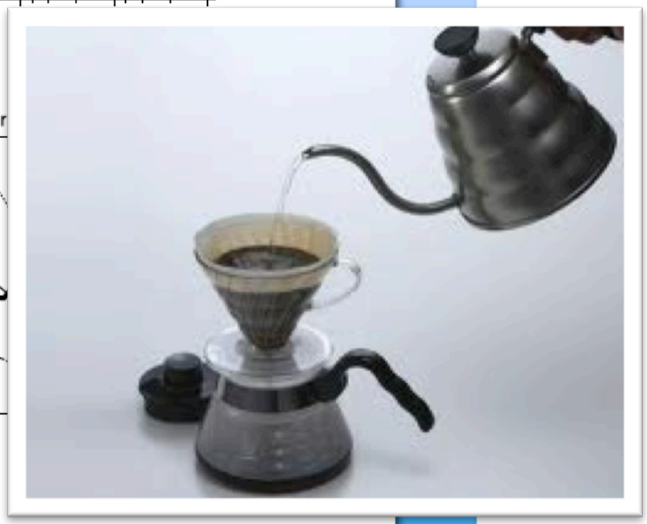
Annual Prec.



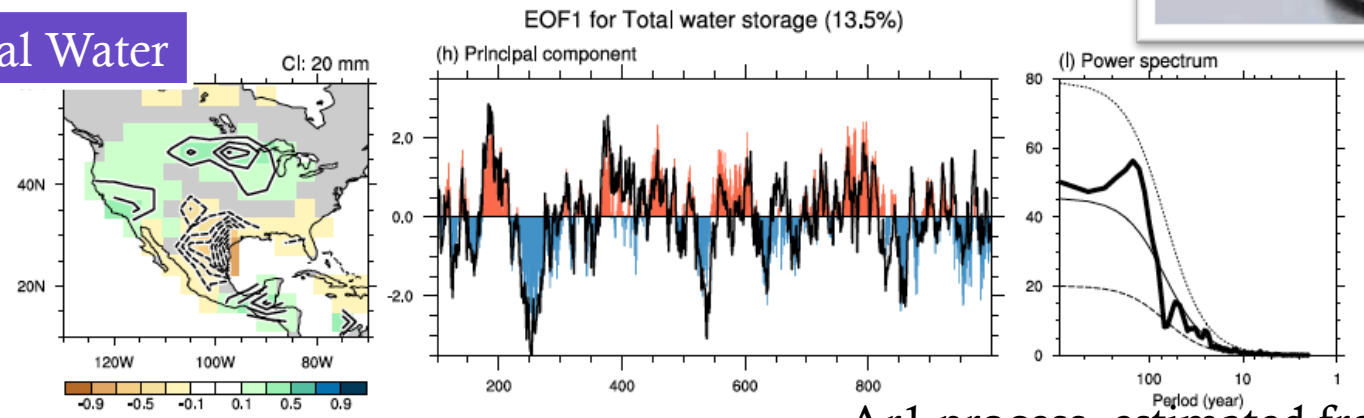

White noise

10-yr Prec.



Total Water



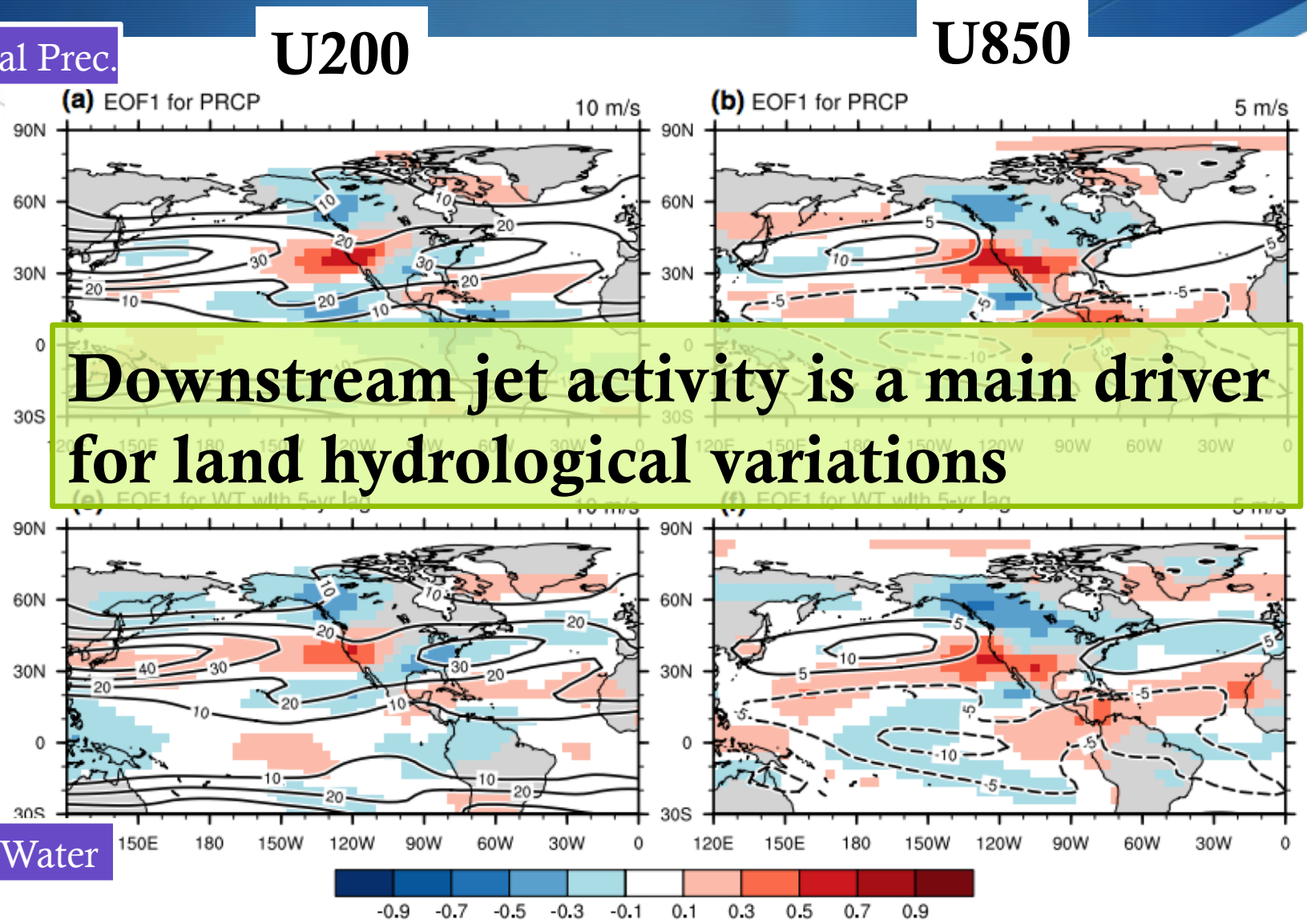

Red noise

—— Ar1 process estimated from precip.

# Relationship between the land hydrology and the westerly jet

Annual Prec.

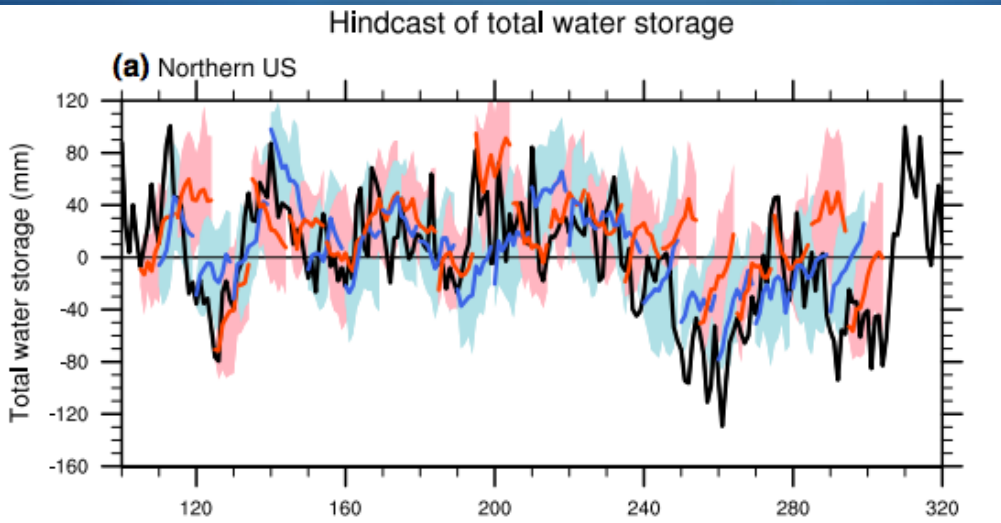
Total Water

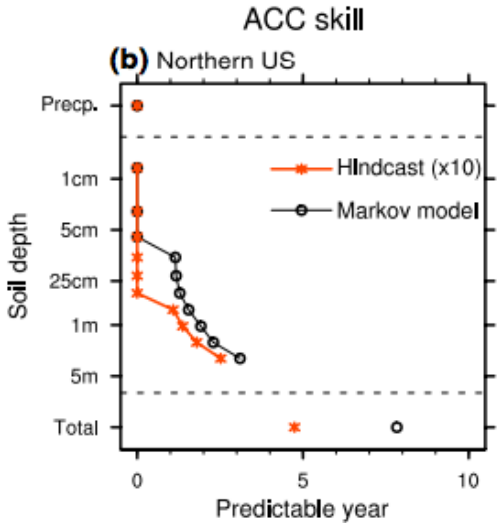


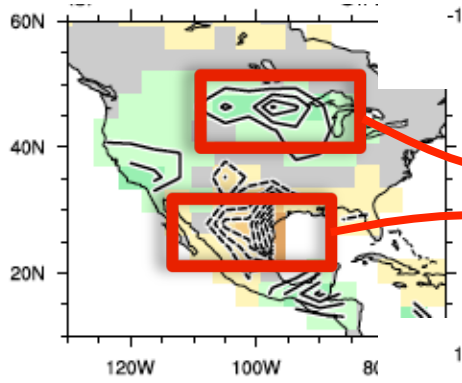

**Downstream jet activity is a main driver for land hydrological variations**

# Can we really predict the total water variations on decadal timescales?

# Hindcast exp. for total water storage

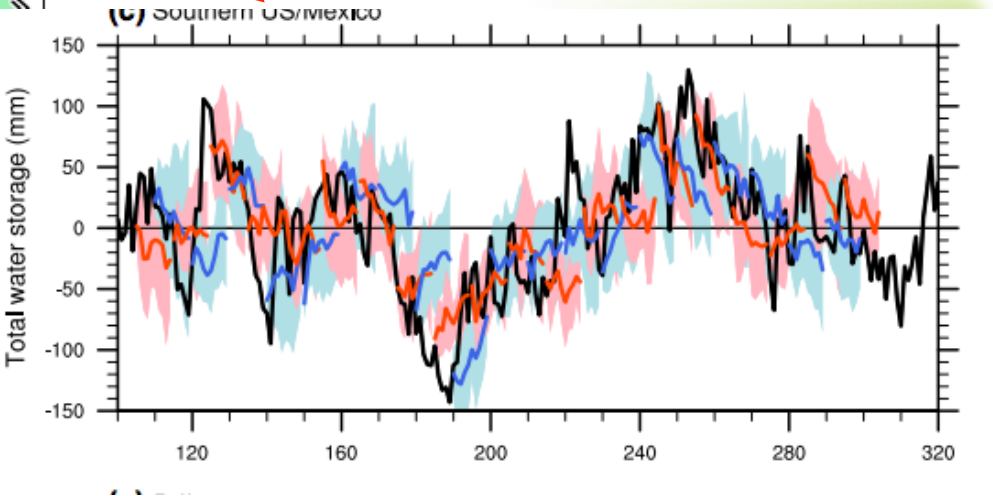


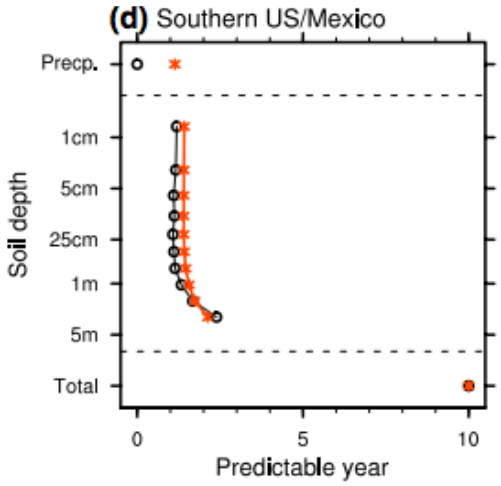




CTL run

Hindcast



# Decadal land predictability: ACC skill

100 105 110 115 CTL run

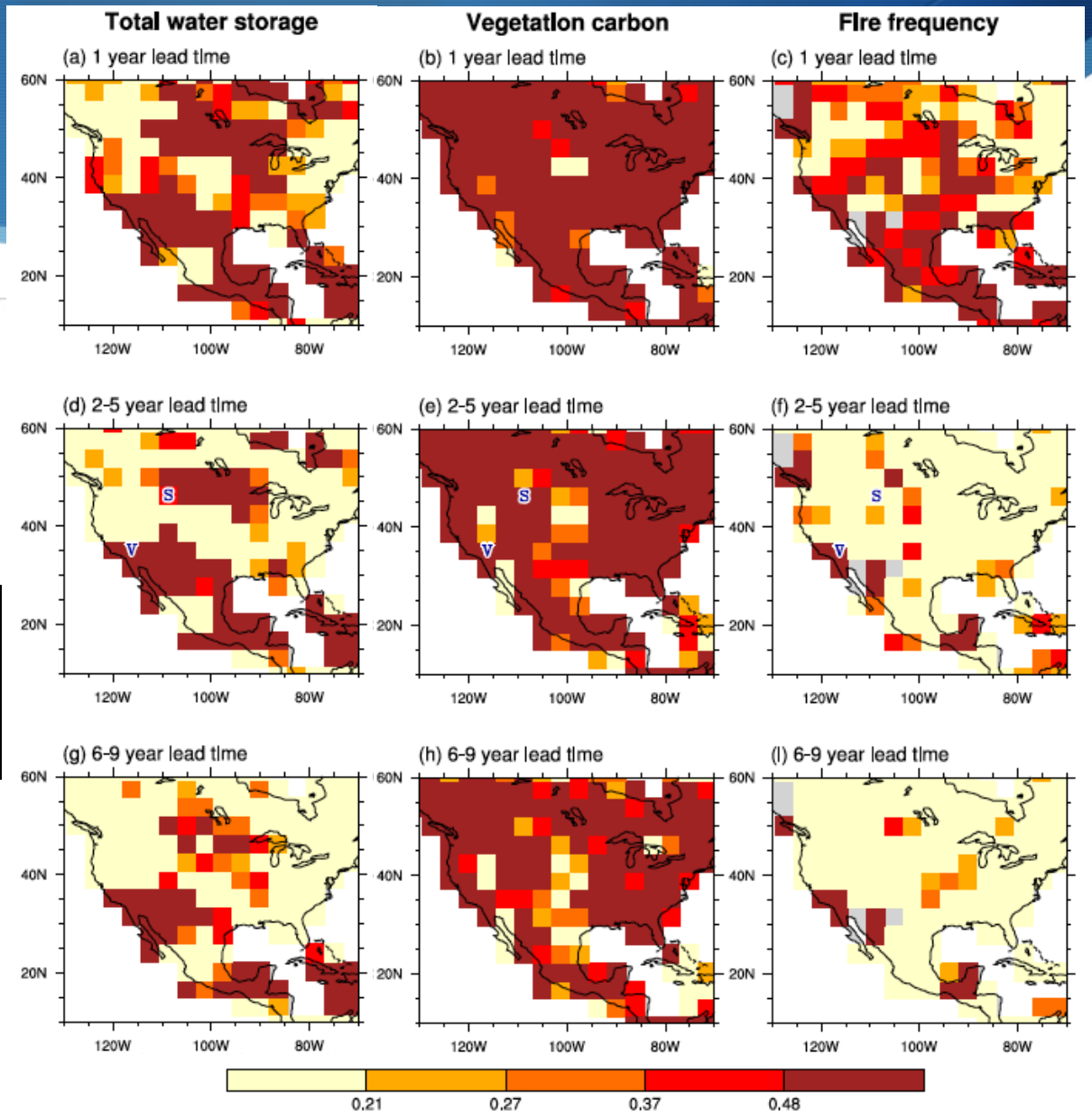
HCST run
(39 cases)

. . . .

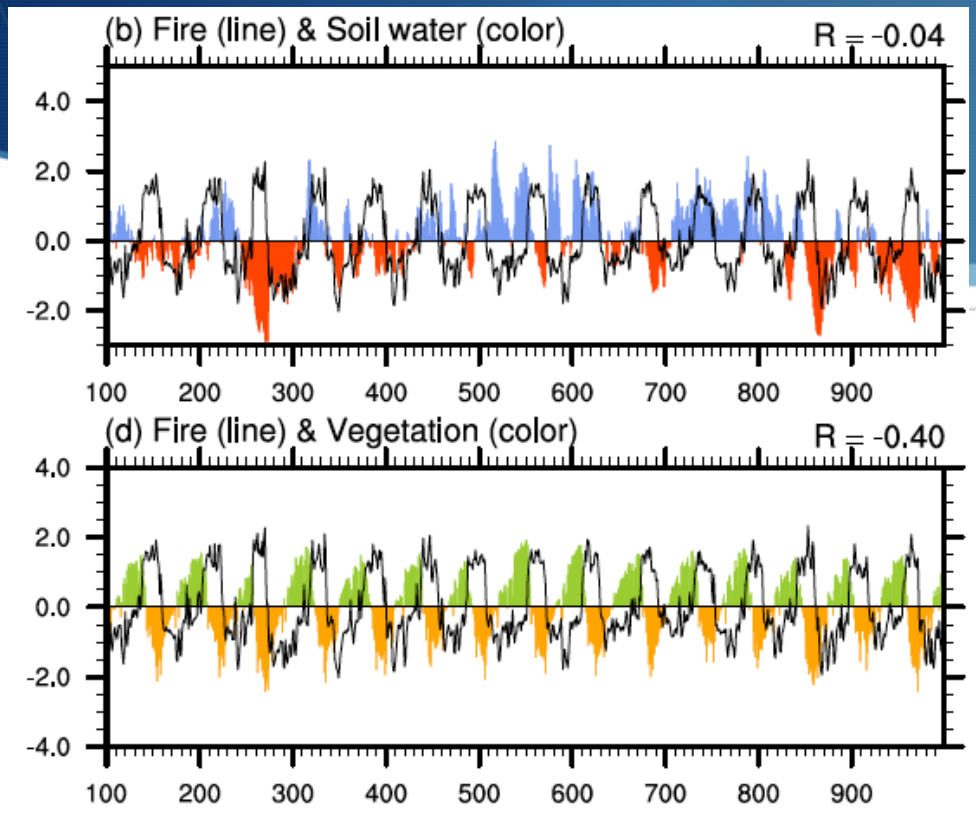
Vegetation

Fire

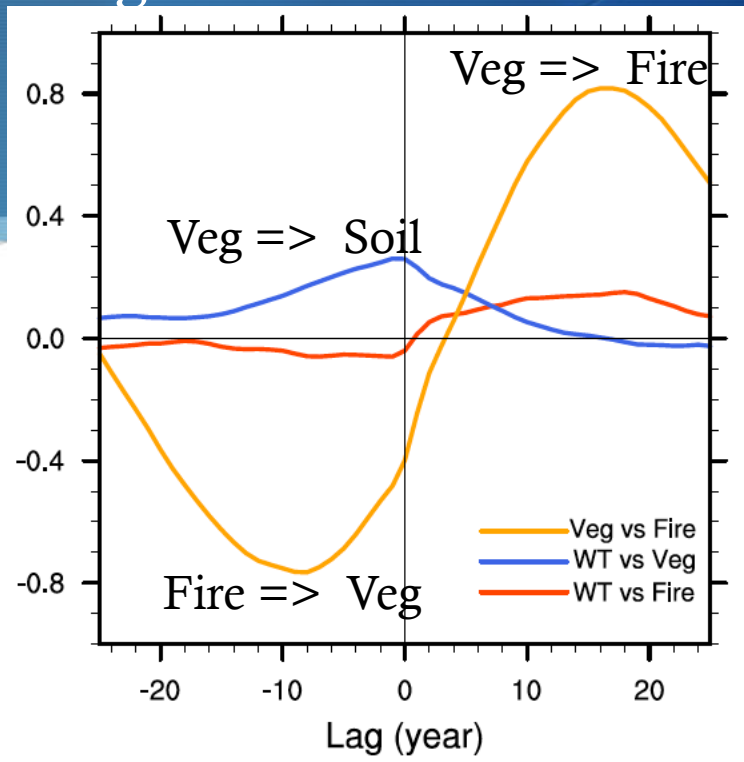
Soil water



# Vegetation regime




Lag correlation coefficients

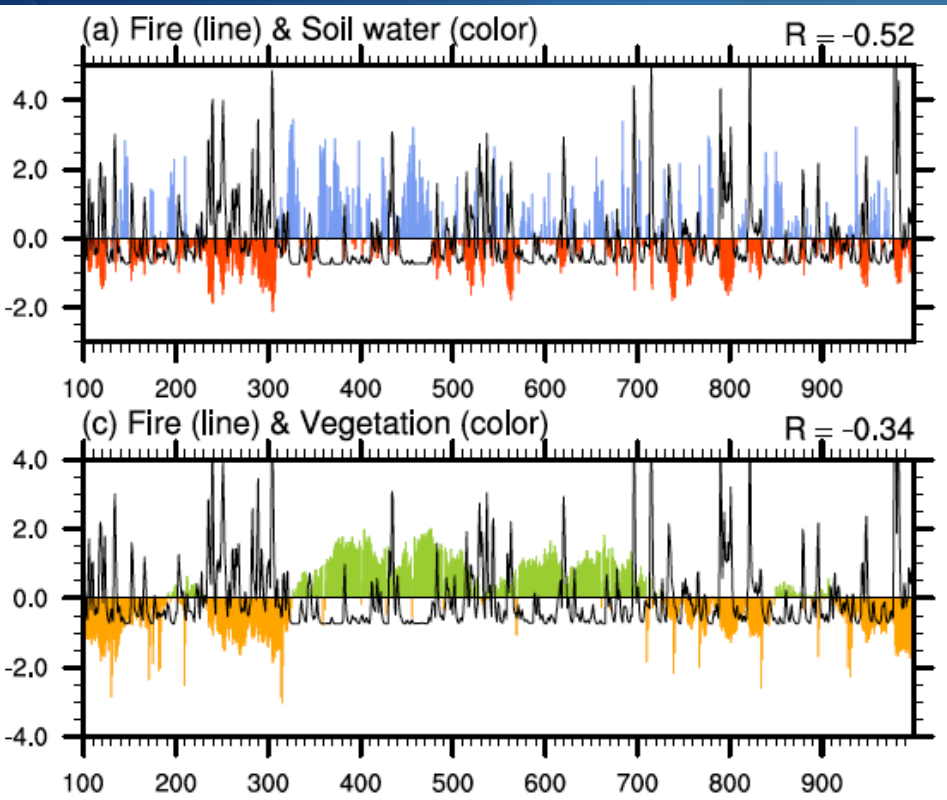


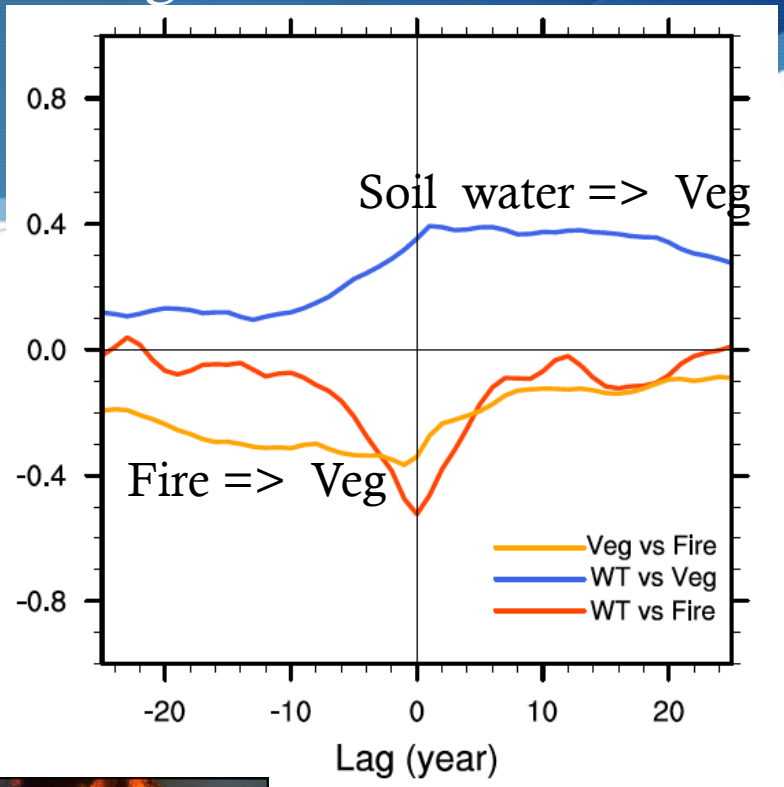




# Soil water regime

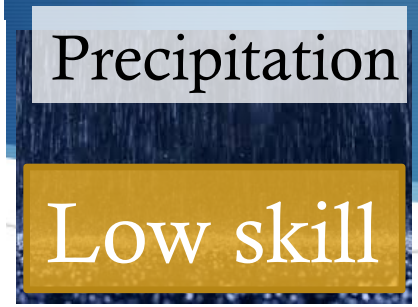
## Lag correlation coefficients






# Schematic view of droughts in CESM

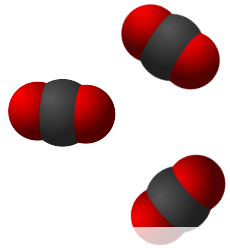


Moisture constrain

Mortality

Fuel availability

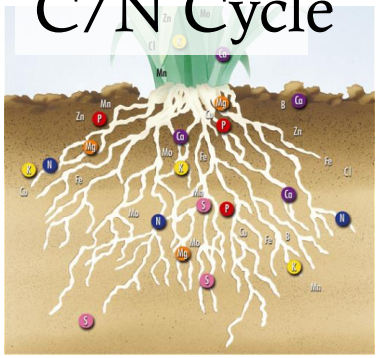

Decadal Predictability



C/N Cycle

Photosynthesis

Evapotranspiration

# Conclusion

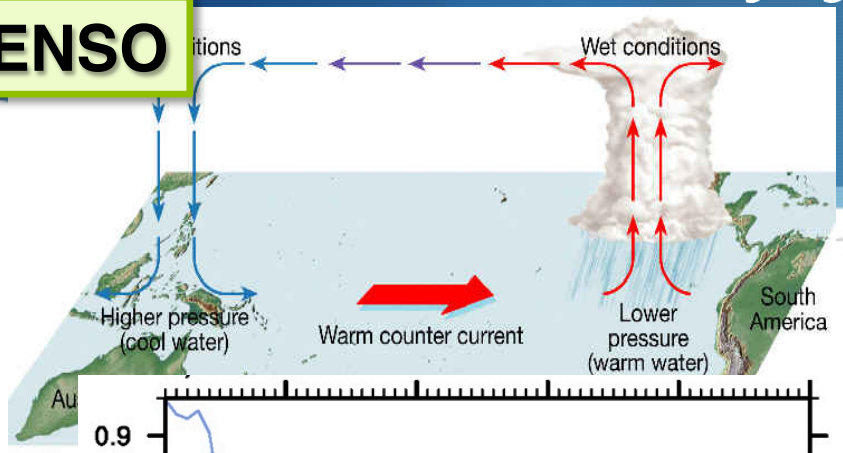
- Annual mean precipitation is less predictable beyond 1-year.
- Changes in total water storage are potentially predictable on decadal timescales due to the long-term persistent memory of soil and aquifer water.
- Skillful decadal predictions of soil water storage, carbon stock, and wildfire frequency are feasible with proper initialization of soil conditions.

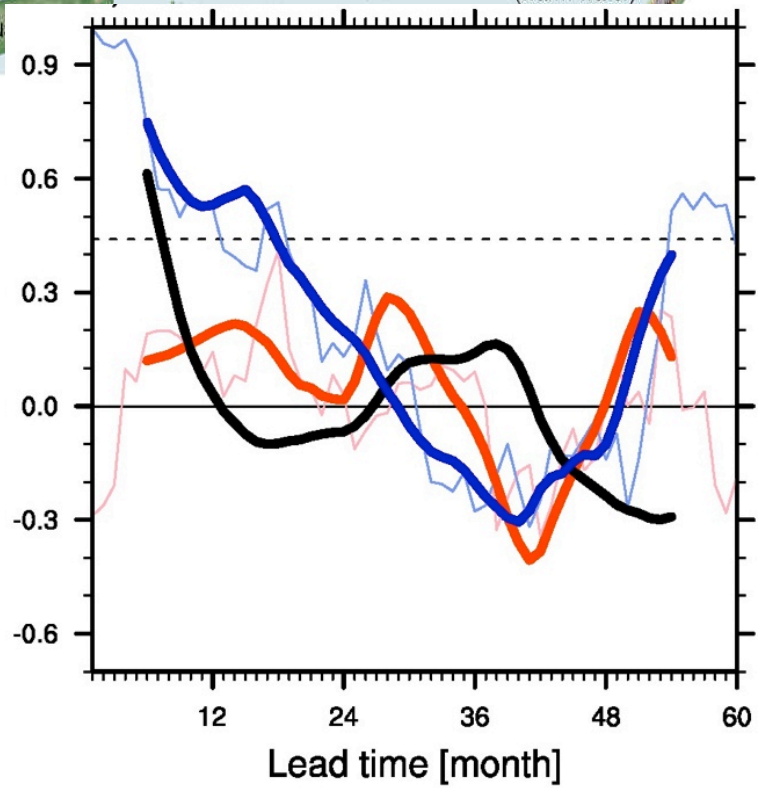
Chikamoto et al. (2015): **Decadal predictability of soil water, vegetation, and wildfire frequency over North America.** *Clim. Dyn.*, online, doi:10.1007/s00382-015-2469-5.

**Impact of ocean variability on downstream jet activity is still an open question.**

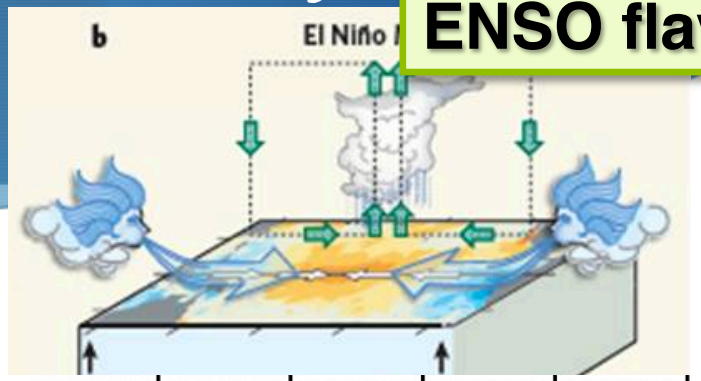
# Possible climate forcing to the westerly jet activity

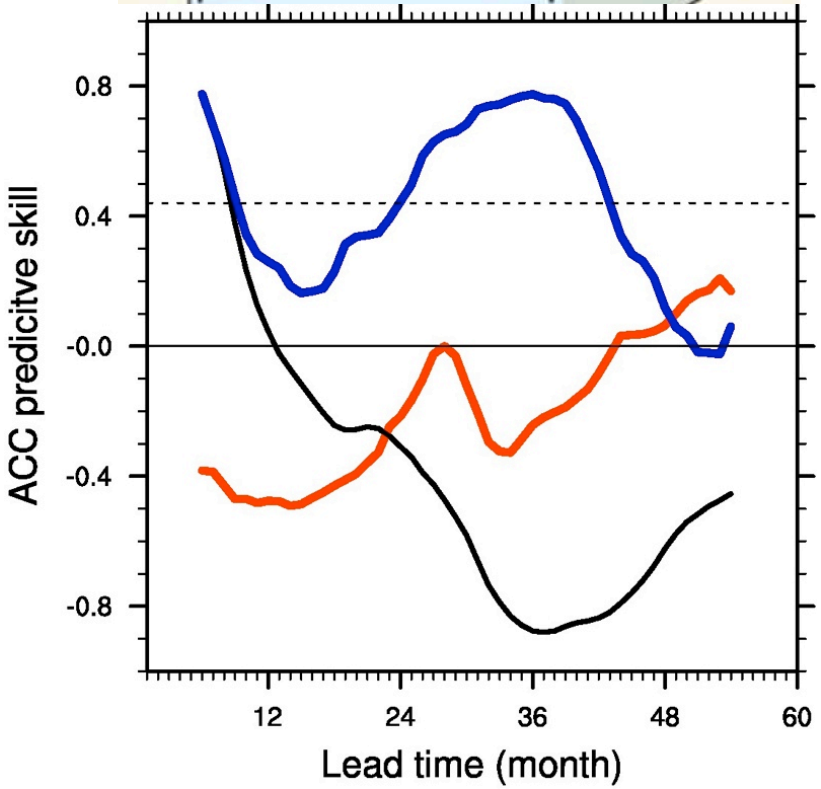
**ENSO**



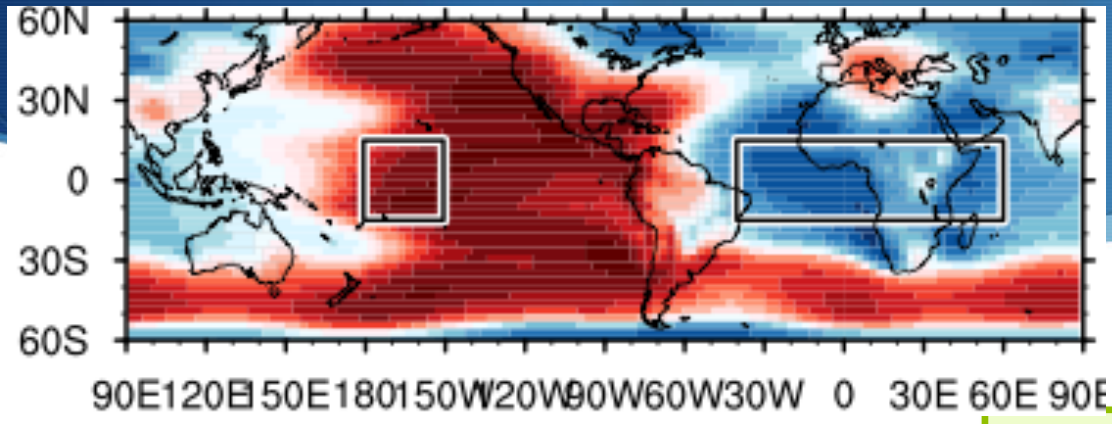



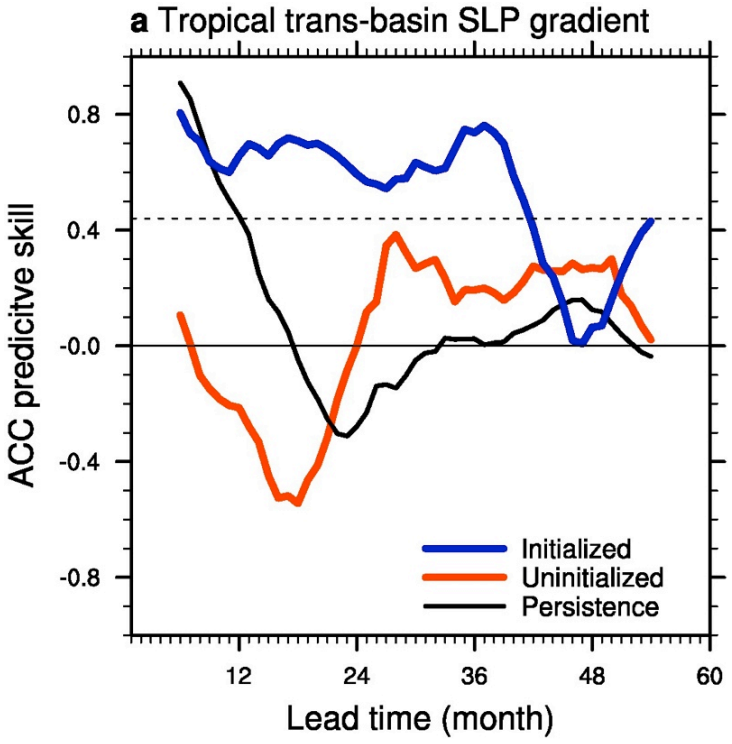

**ENSO flavor**



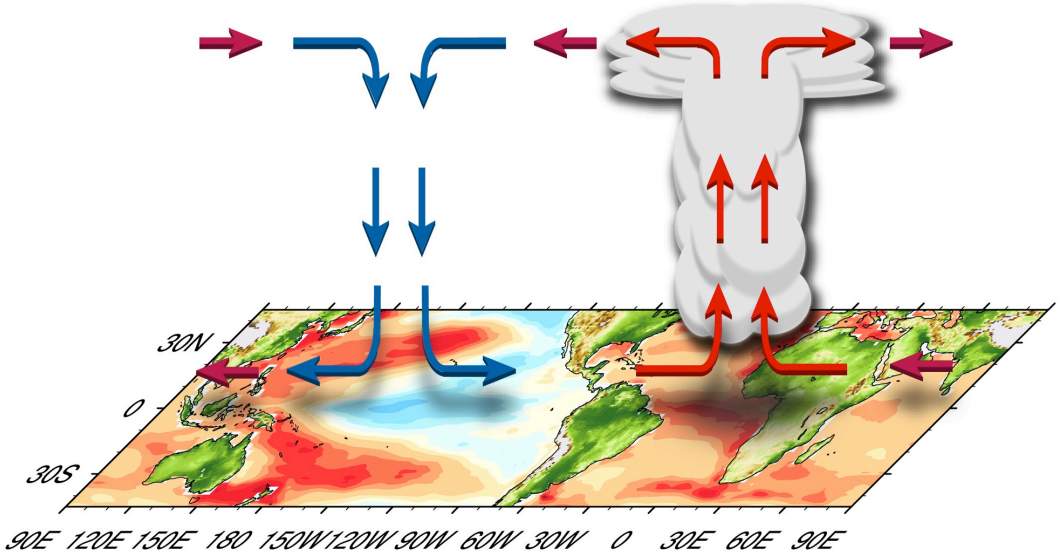



# Multi-year memory of the tropical climate




**Trans-Basin Variability**




Chikamoto et al. (2015) *Nature Comm.*