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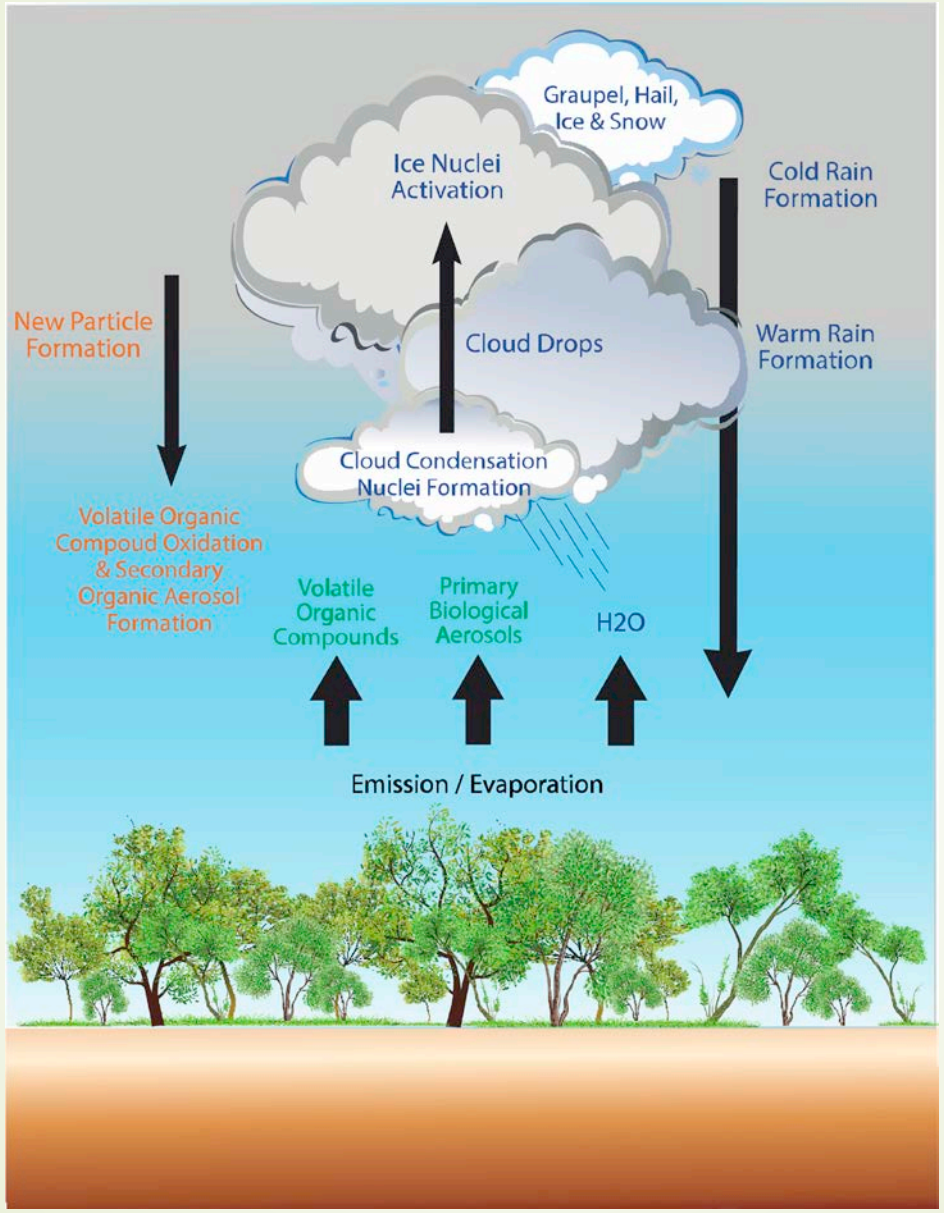
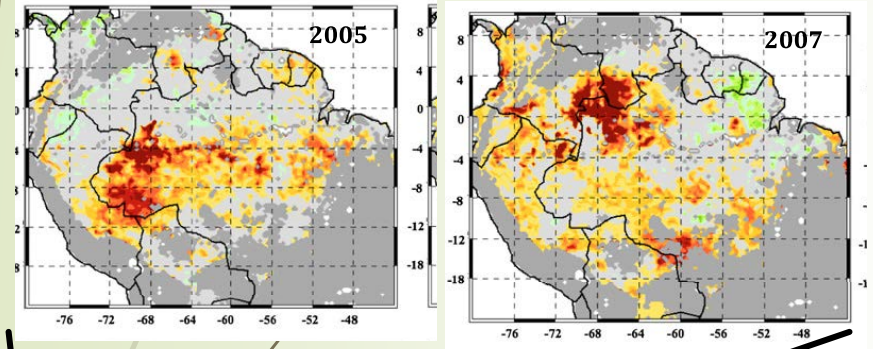
OCO-2 Science Team Meeting
CalTech, March 20th, 2018

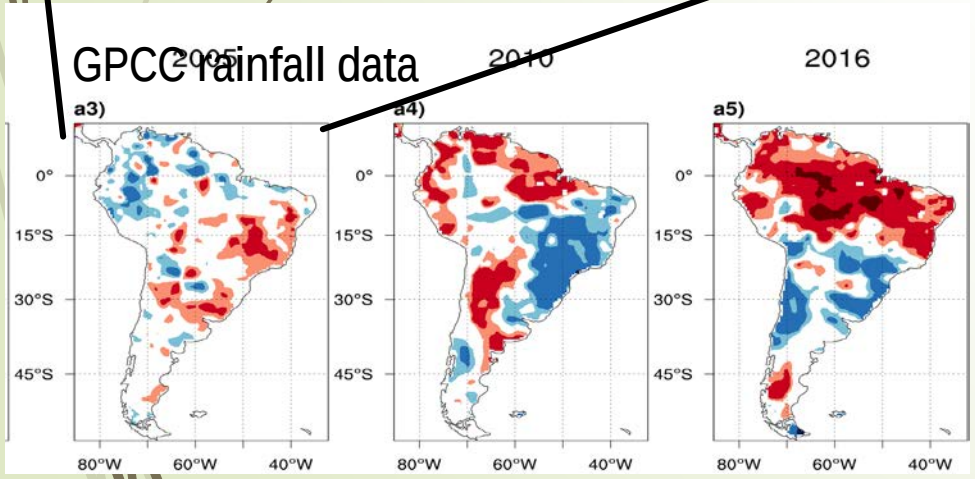

Graupel, Hail, Ice & Snow
Ice Nuclei Activation
Cold Rain Formation
New Particle Formation
Cloud Drops
Warm Rain Formation
Cloud Condensation Nuclei Formation
Volatile Organic Compoud Oxidation & Secondary Organic Aerosol Formation
Volatile Organic Compounds
Primary Biological Aerosols
H2O
Emission / Evaporation

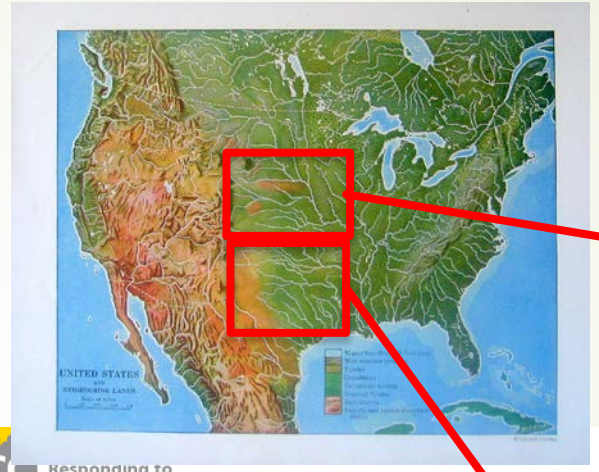
?

Strong needs for creditable climate prediction/projection

Impact of 2005 drought Saatch et al. 2012







RTCC Responding to Climate Change

Brazil faces water rationing amid worst drought in 84 years

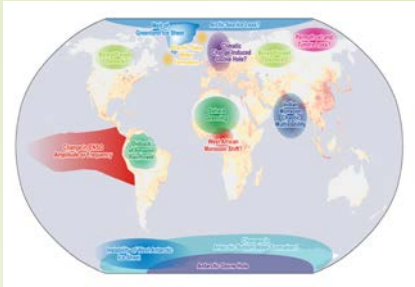
Last updated on 16 February 2015, 3:50 pm

Citizens of Sao Paulo are to have their tap water cut off five days a week in a bid to manage the supply crisis

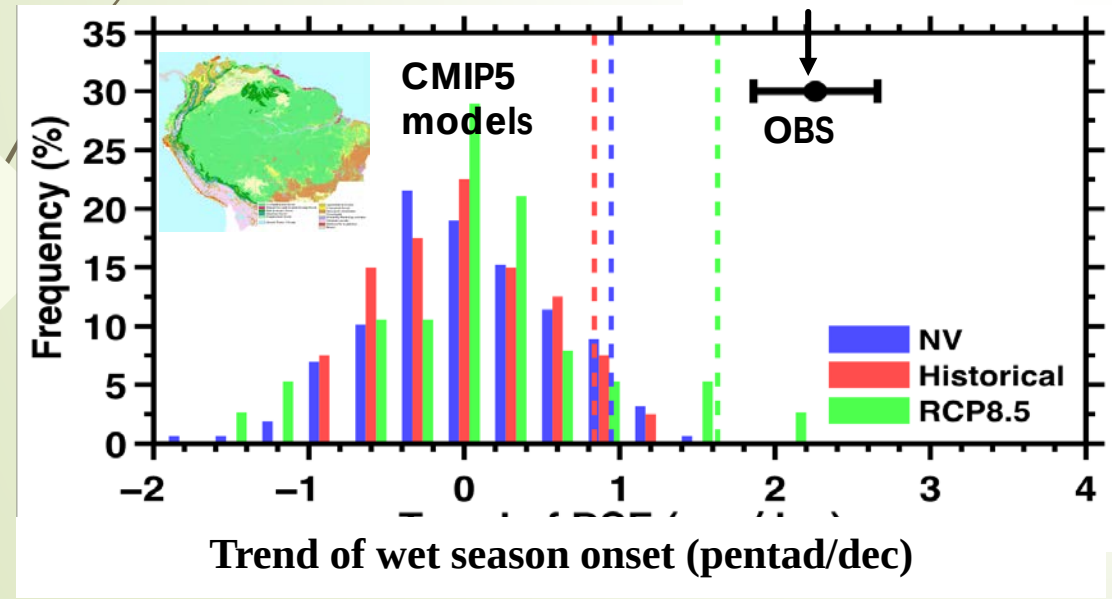
Aerial view of dam in Sao Paulo state (Pic: Flickr/Fernando Stankuns)

- *Is the Amazon rainforest as resilient as projected by the CMIP5 models?*
- *All the CMIP5 models severely underestimate the increase of dry season over the Amazon.*

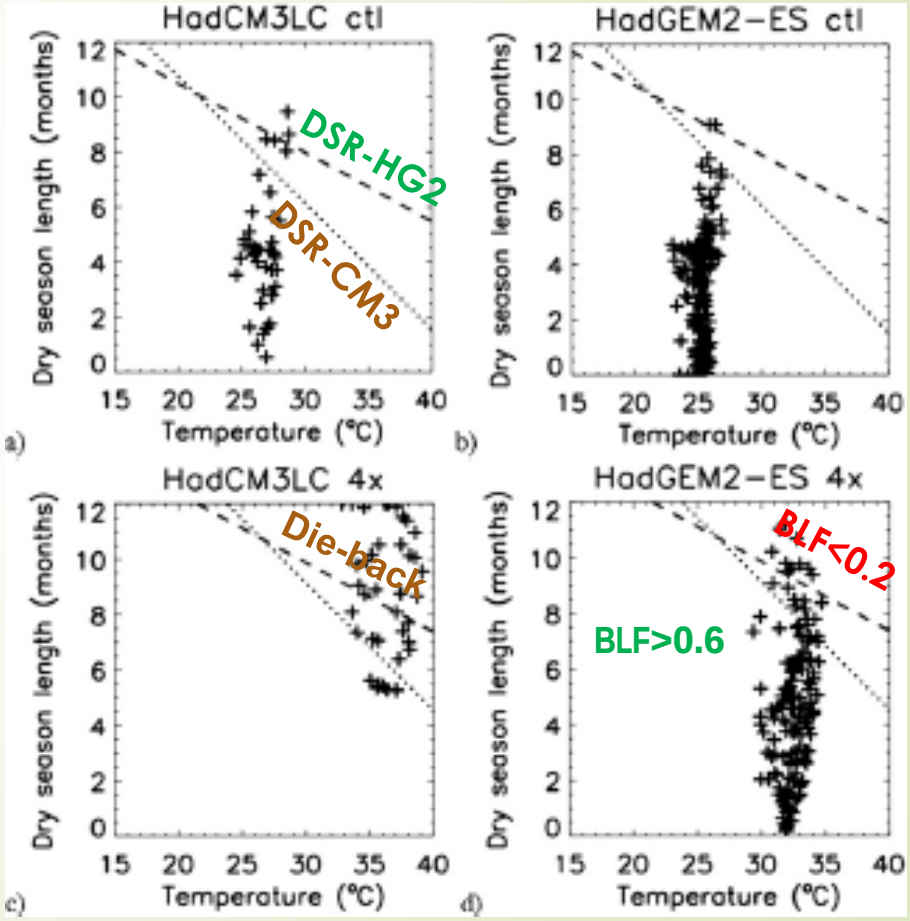
Cox et al. 2000;
Lenton et al. 2008
Hungtingford et al. 2013



Increase of dry season length by ~ 5±2 days/decade



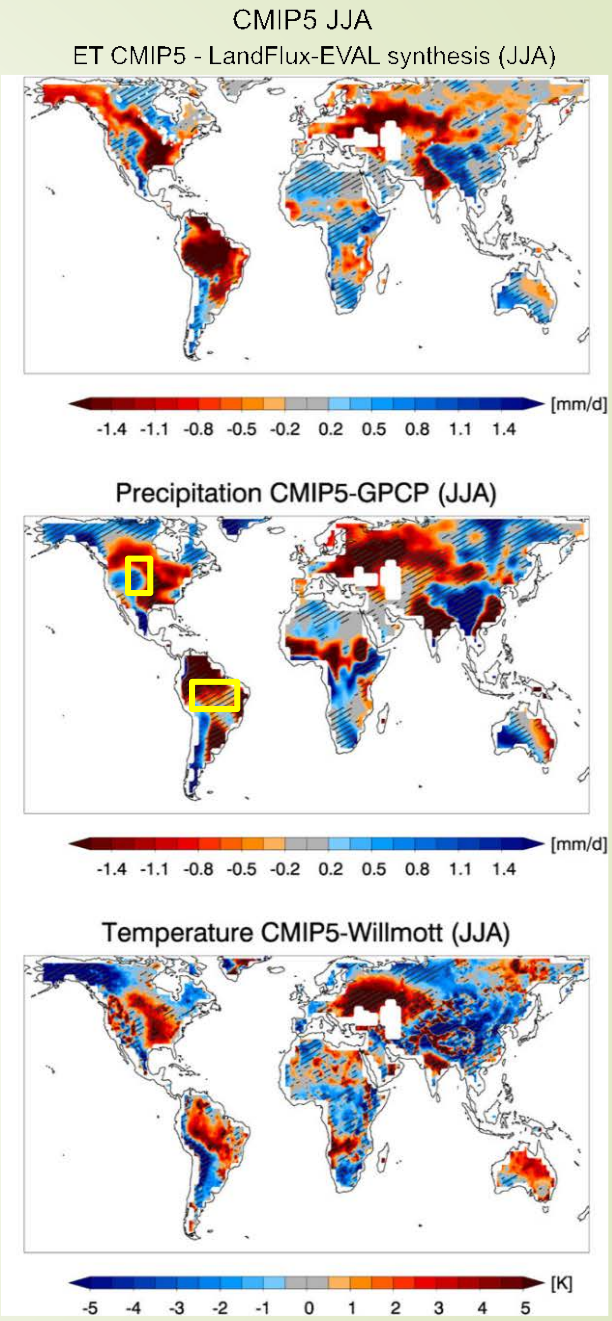
Fu et al. 2013



Good et al., 2013

Major biases in the current ESMs:

- *Warm and dry biases over land surface represent a major bias common to most of the earth system models (Flato et al 2013) need to be addressed by CMIP6 (Stouffer et al. 2017)*
- *Such biases appear to result from deficiencies in representing land surface and/or clouds (Cheruy e tla. 2014; Mueller and Seneviratne 2014).*
- *These dry and warm biases tend to in regions with high biomass, thus have high impacts on terrestrial biosphere*



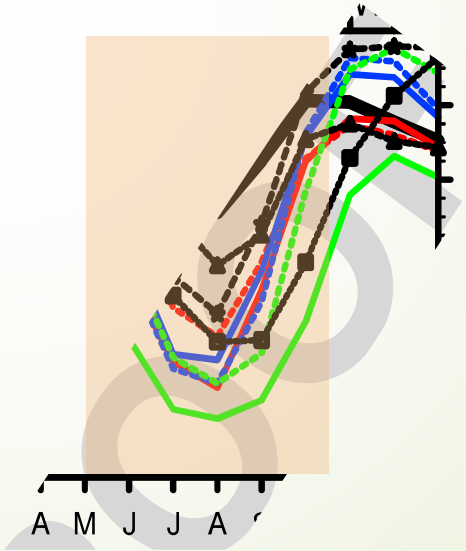
Mueller & Seneviratne 2014

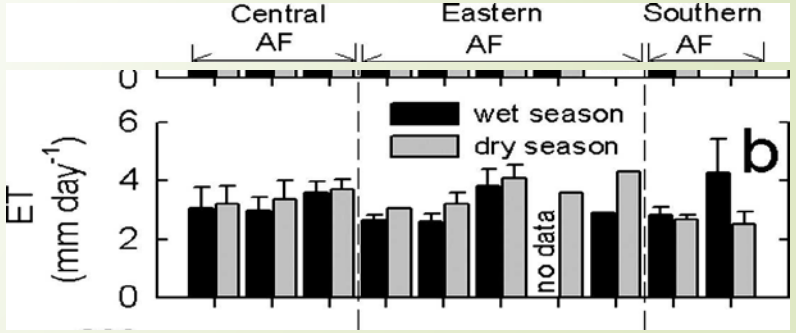
Ecosystem may hold a key for improving water cycle modeling and prediction, especially on seasonal and interannual scales

What cause the dry bias over the Amazon?

- *Wet season: dry bias can be removed by improving representation of mesoscale convection, cloud microphysics, boundary layer.*
- *Dry and transition seasons: Inadequate representation of the plants' control on ET likely contributes to the dry bias and late wet season onset common in CMIP5 models.*

CAM5





Negron Juarez et al. 2007

Zhang et al. 2017, JGR-A

- *Moisture availability is required for the occurrence of rainfall*
- *Plants transpiration is the main source of moisture in the atmosphere during the dry (June-August) to the transition (September-October) seasons.*

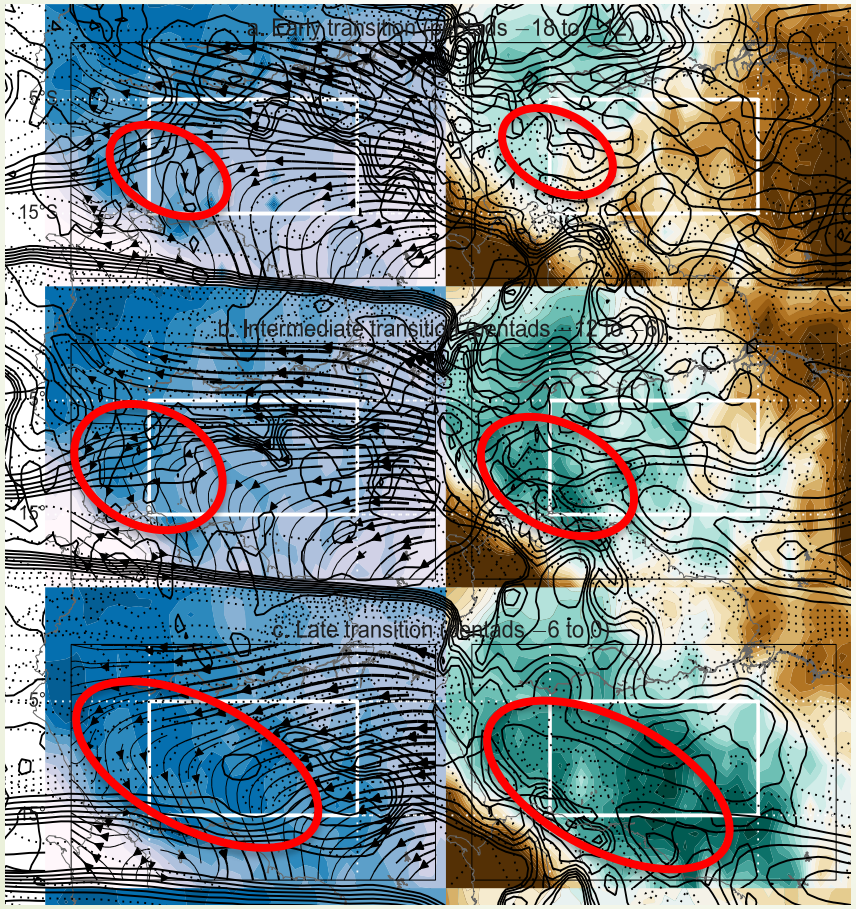
Wind and humidity

δD ‰, moisture convergence

2-3 mons before the onset

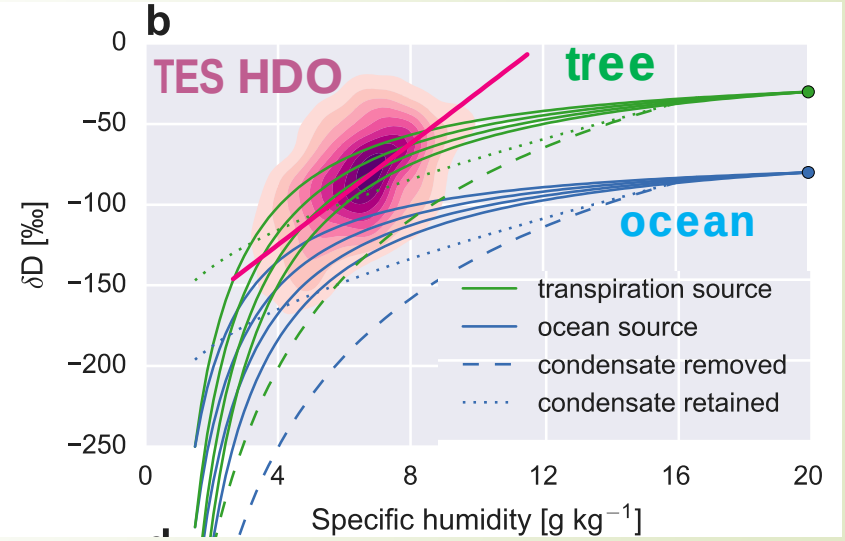
1-2 mons before the onset

0-1 mons before the onset



AIRS

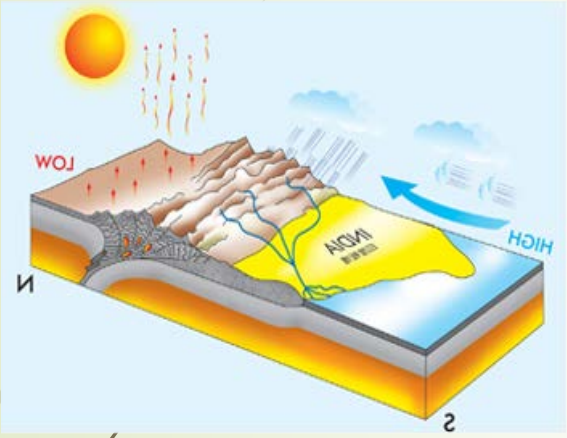
Aura/TES

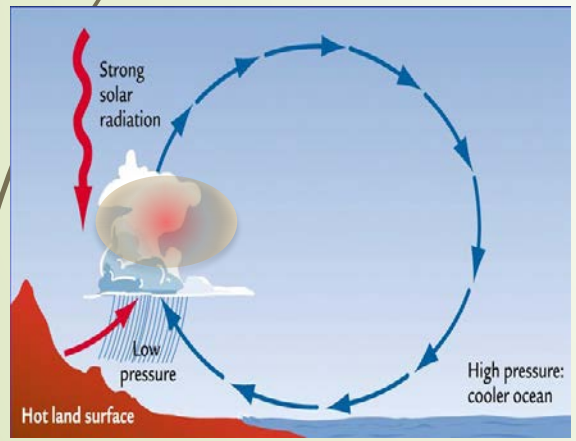


Wright et al. 2017

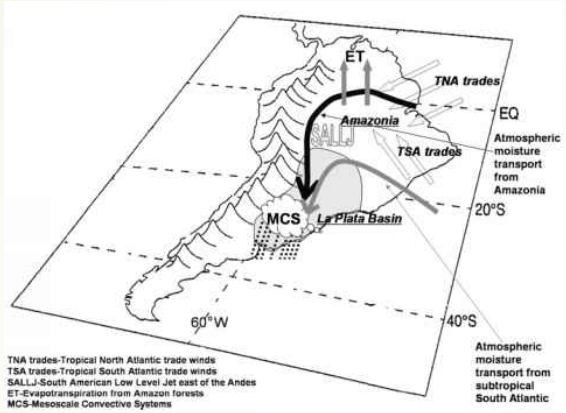
How do rainforests initiate wet season onset?

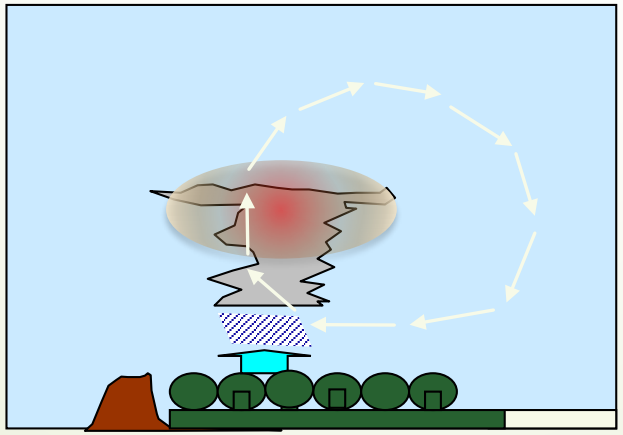
Classic monsoon:





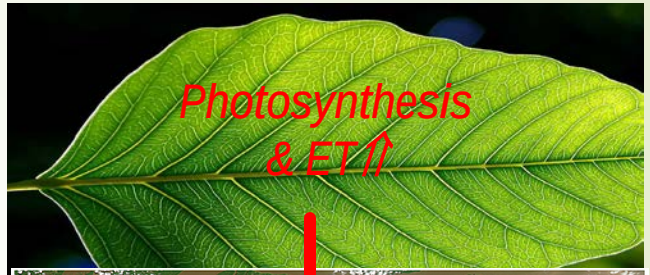
South American Monsoon

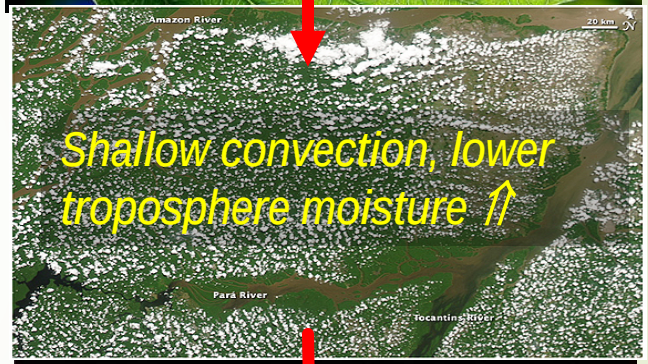


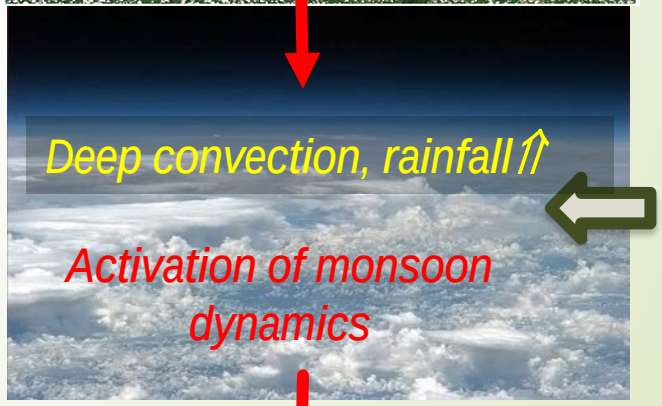


Silva Dias et al (1983); DeMaria (1985), Kleeman (1989), Lenter and Cook (1997), Fu et al. 1999; Li and Fu 2004, Wright et al. 2017

Processes involved







cold fronts incursions lifts surface air

Wet season onset

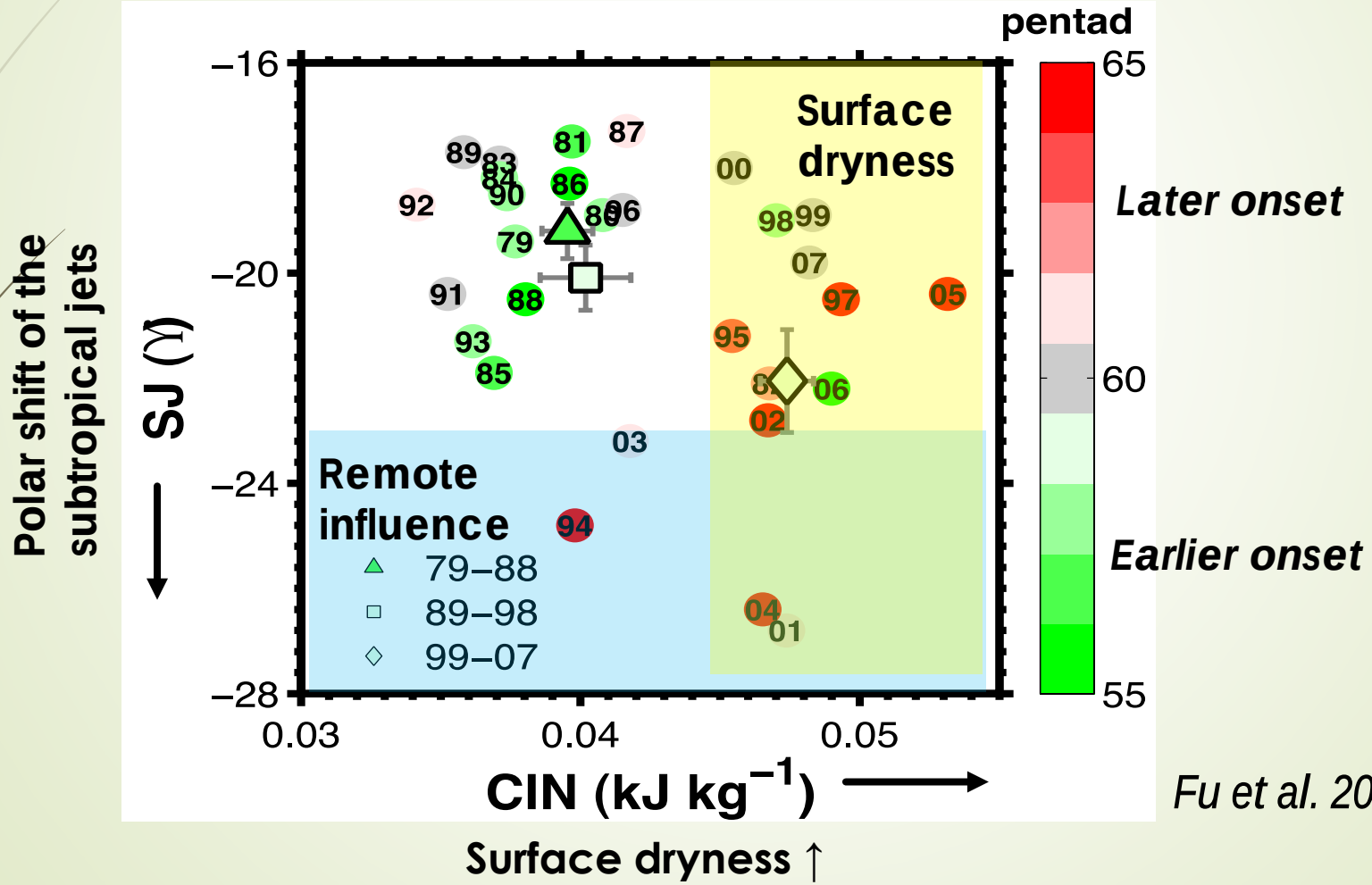
Why is the dry bias strongest during the transition season over the Amazon?

- Underestimate ET,
- Increase ET during late dry season is central for wet season onset.

CMIP5 models

Yin et al. 2013, Climate Dynamics

➡ *Surface dryness contributes more than remote forcing to the delay of wet season onsets*



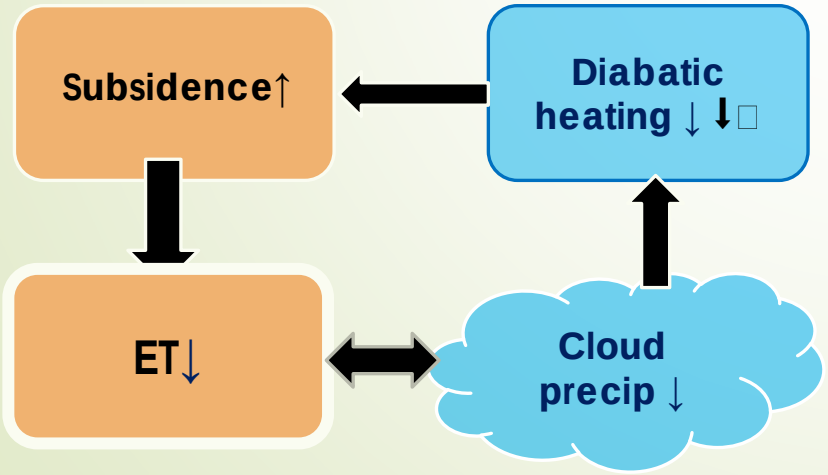
Fu et al. 2013, PNAS

What processes cause the delay of wet season onset?

In tropical or subtropics about the atmospheric boundary layer:

$$\underbrace{\cancel{\frac{\partial \bar{T}}{\partial t}}}_{\substack{\text{local}\\ \text{temperature}\\ \text{change}}} = \underbrace{\frac{\bar{Q}}{C_p}}_{\substack{\text{Diabatic}\\ \text{heating}}} - \underbrace{\left(\frac{p}{p_0}\right)^{\kappa} \bar{\omega}\frac{\partial \bar{\theta}}{\partial p}}_{\substack{\text{vertical}\\ \text{advection}}} - \underbrace{\cancel{\bar{v}\cdot\nabla_p \bar{T}}}_{\substack{\text{temperature}\\ \text{advection}}} - \underbrace{\left(\frac{p}{p_0}\right)^{\kappa} \cancel{\frac{\partial}{\partial p}}\left(\overline{\omega'\theta'}\right)}_{\substack{\text{transient vertical}\\ \text{sensible flux}}} - \underbrace{\cancel{\nabla_p \cdot \left(\overline{v'T'}\right)}}_{\substack{\text{transient}\\ \text{horizontal}\\ \text{advection,}\\ \text{covergence}}}$$

$$\boxed{\bar{\omega} \approx -A\bar{Q}} \qquad where\ A = \frac{\left(\frac{p_0}{p}\right)^{\kappa}}{Cp\left|\frac{\partial \bar{\vartheta}}{\partial p}\right|}$$



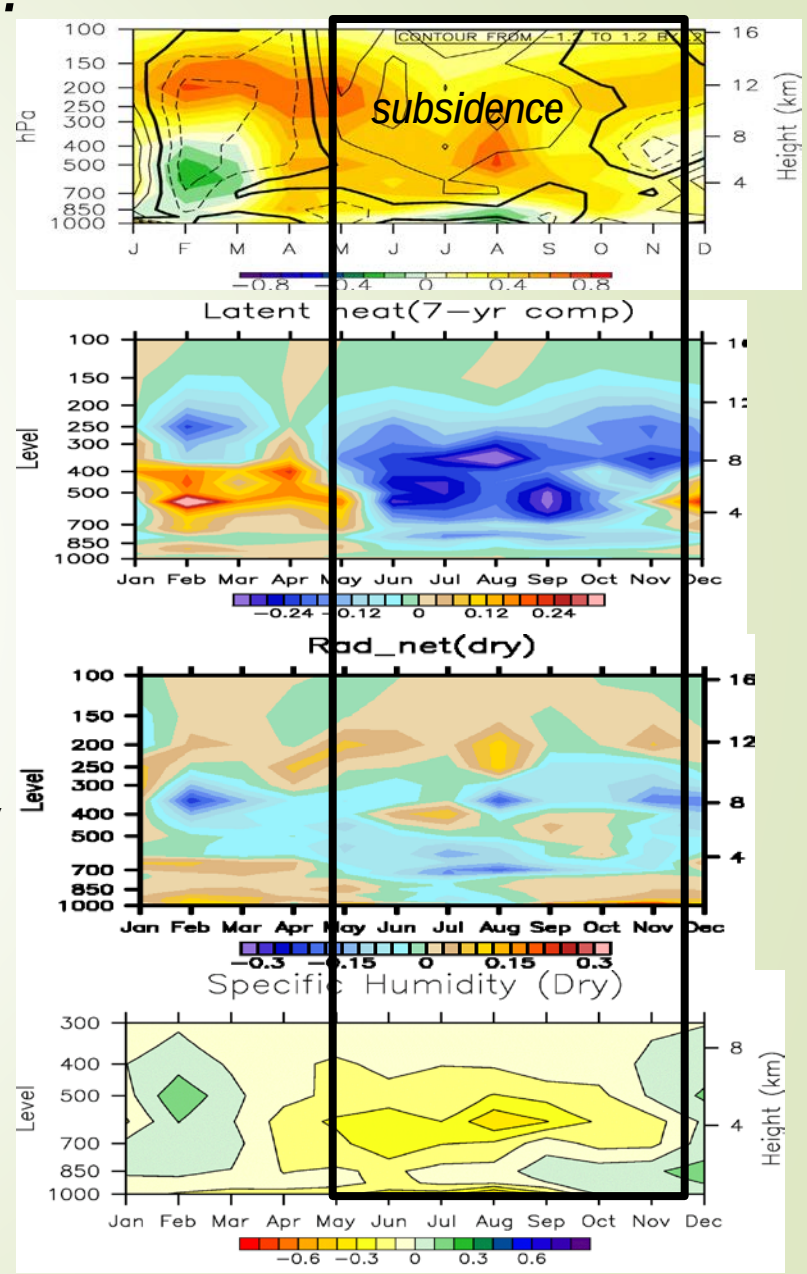
MERRA Reanalysis

Anomalous Subsidence& Anticyclonic circulation

Reduced Latent heat (Rainfall)

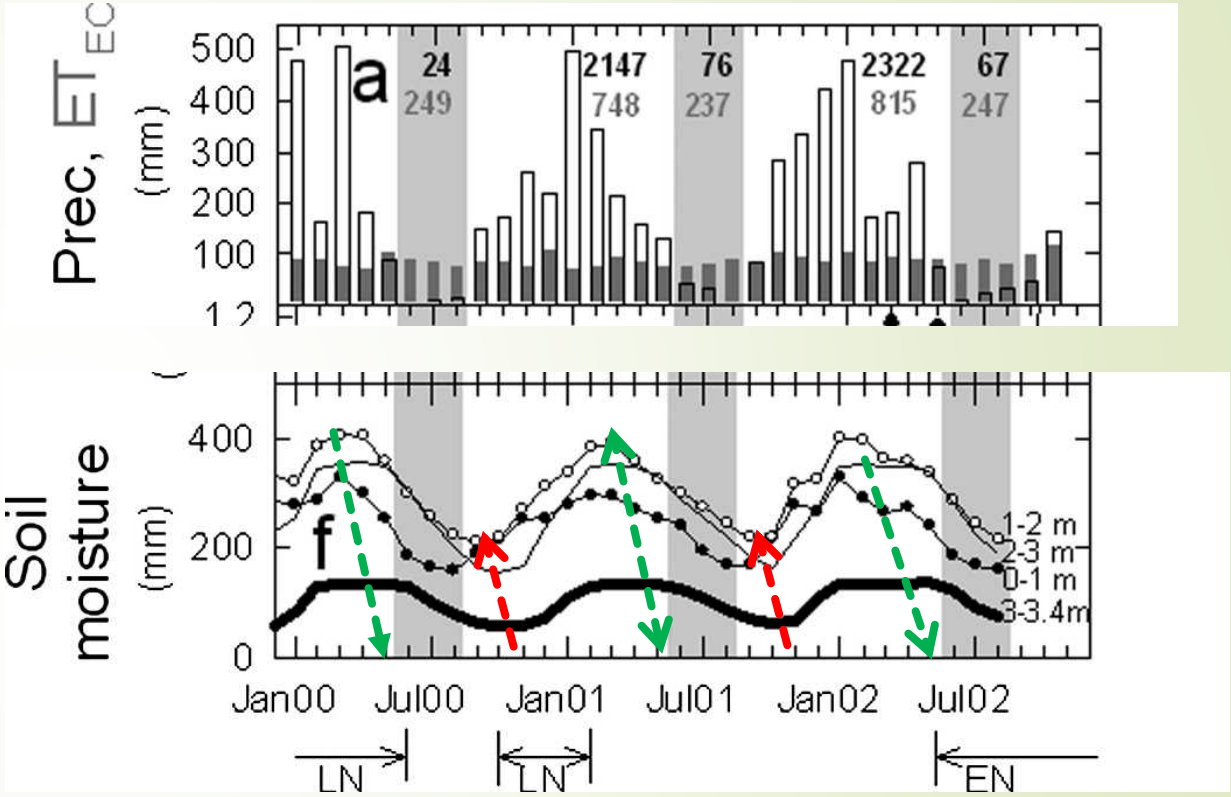
Reduced Radiative heating (low clouds)

Dry surface



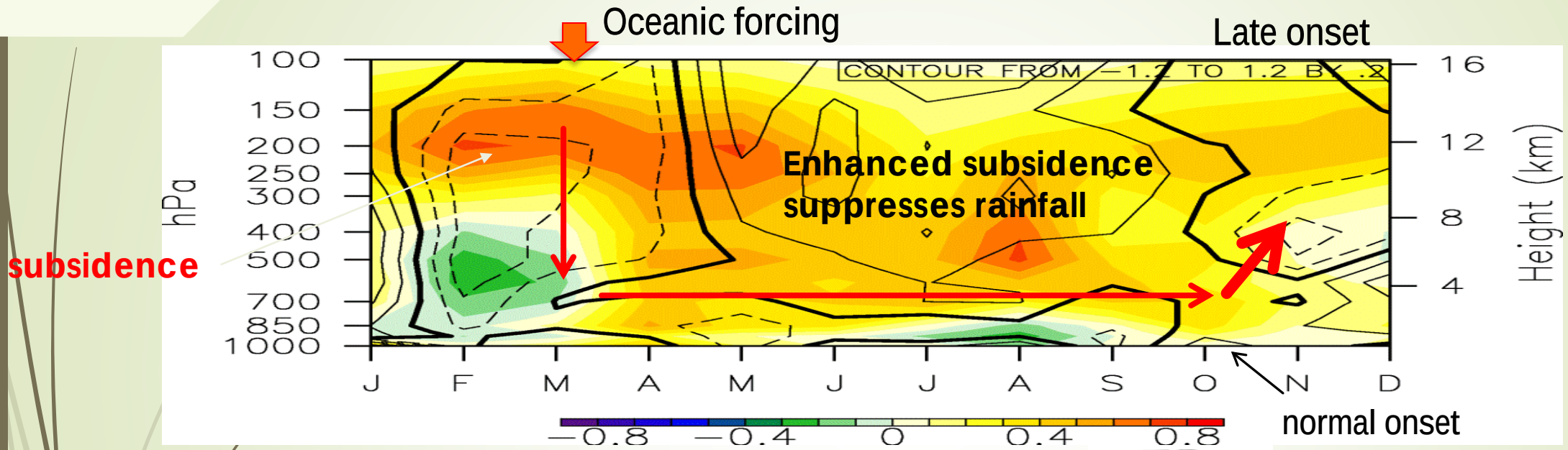
Why does the delayed wet season onset start with rainfall reduction in the previous wet season?

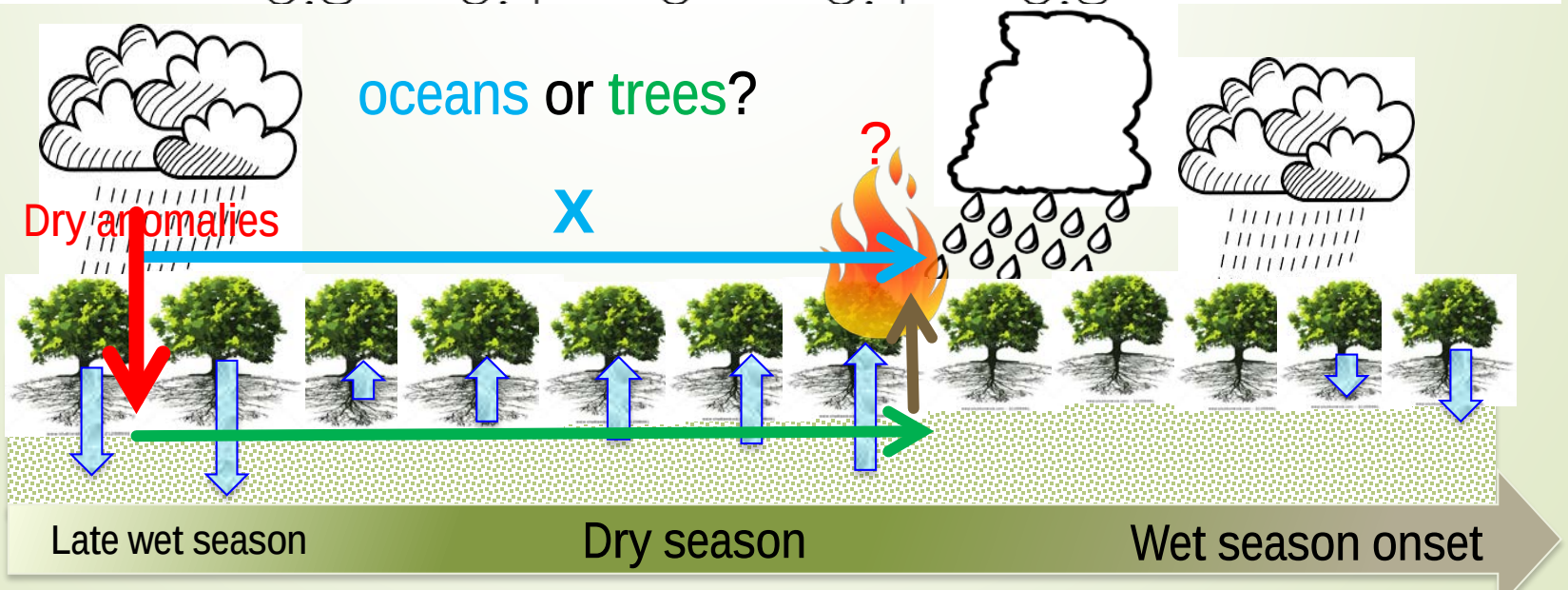
- *ET is less influenced by dry season rainfall than by wet season rainfall*
- *Zoot zone soil moisture, recharged by rainfall in previous wet season (Dec-May), influences ET in Aug-Oct,*
- *Allowing strong Pacific and Atlantic SSTA during wet season (Dec-May) to influence ET and rainfall during following dry season (JJA) and wet season onset in fall (SON).*



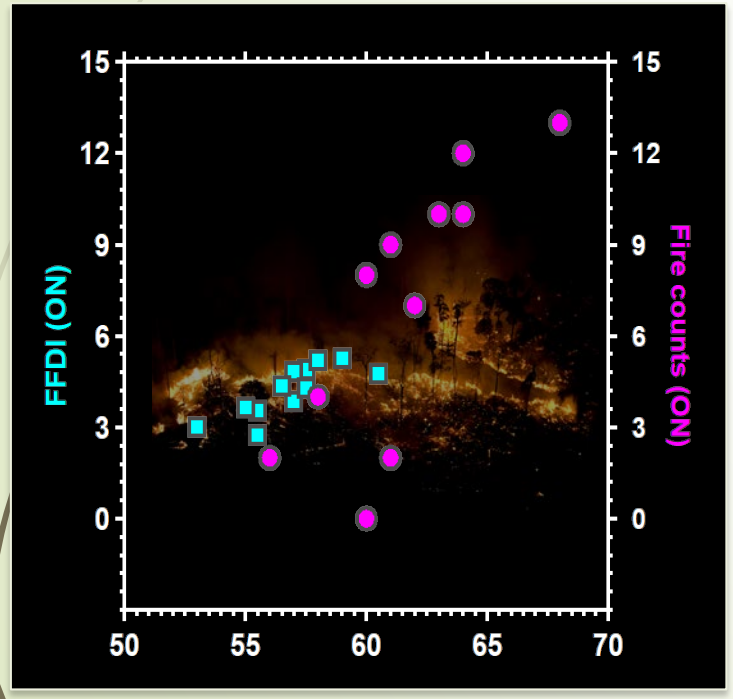
Negrón Juarez et al. 2007

What causes persistent (6-mons) dry anomalies?

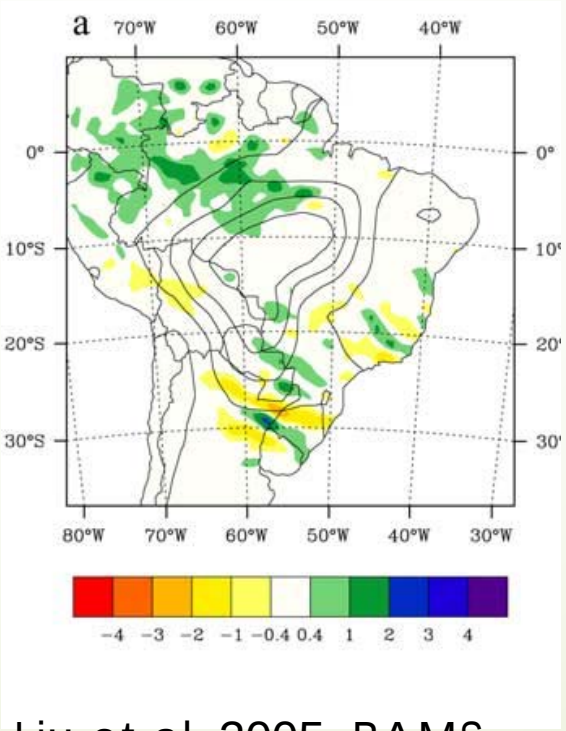




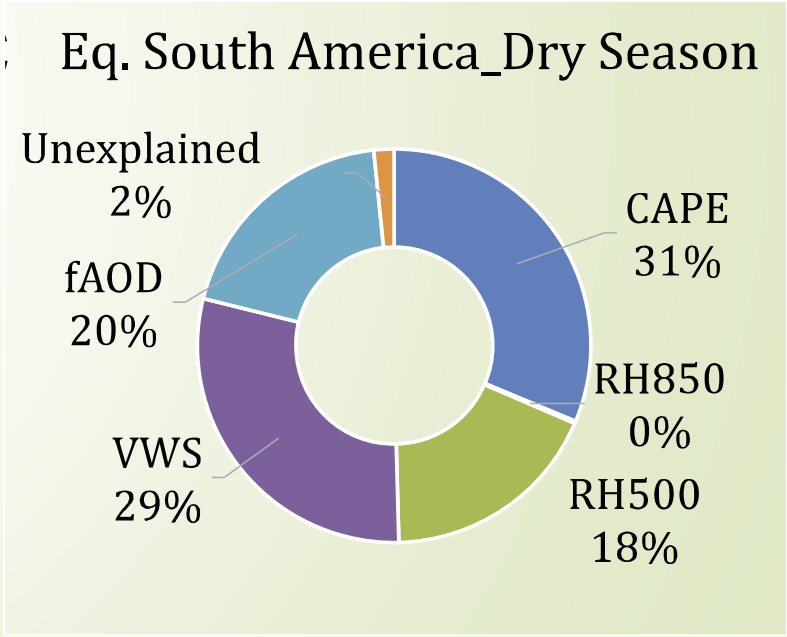
- *Dry anomalies increase fire activities*
- *Fires produce biomass aerosols, which in turn, delay of wet season onset and amplify rainfall variability*



Fu et al. 2013, PNAS



Liu et al. 2005, BAMS,
Zhang et al. 2009, GRL

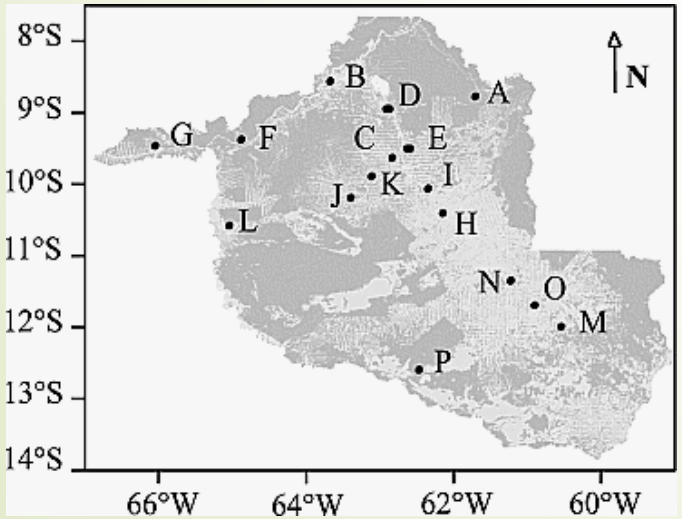


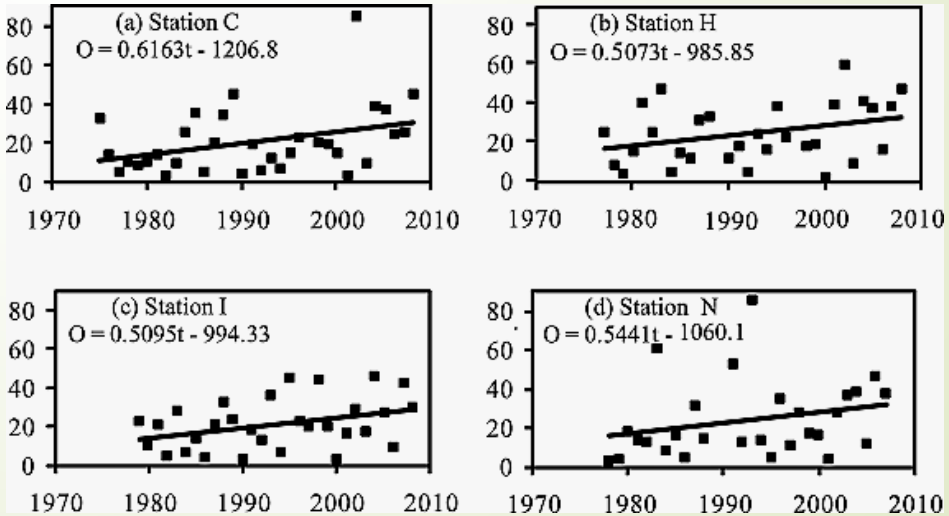
Chakraborty et al. 2016, PNAS

- *Landuse reduces dry season ET and can delays wet season onset*

Butt et al. 2011:

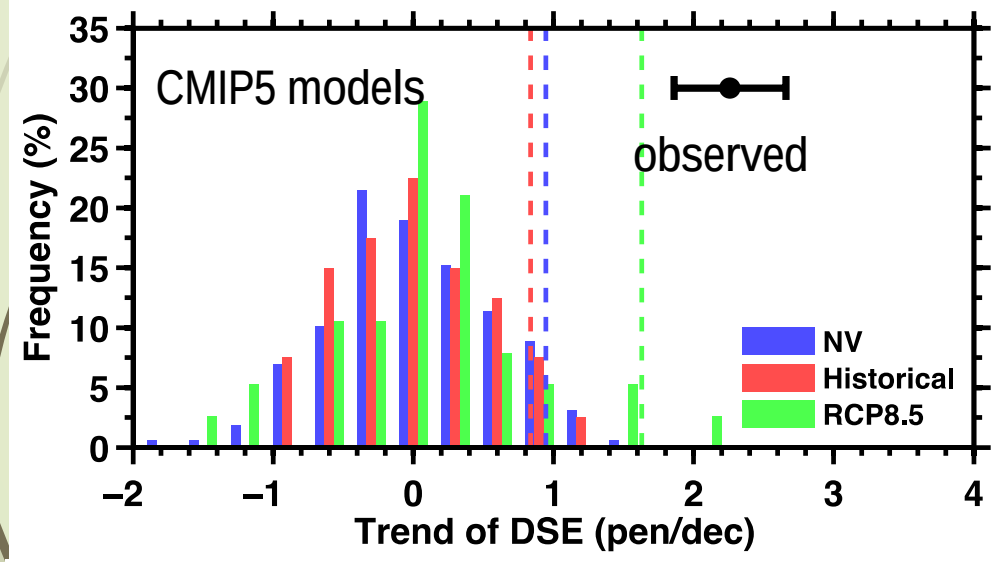
- **wet season onset in the deforested areas have shown significant delay since late 1970s.**





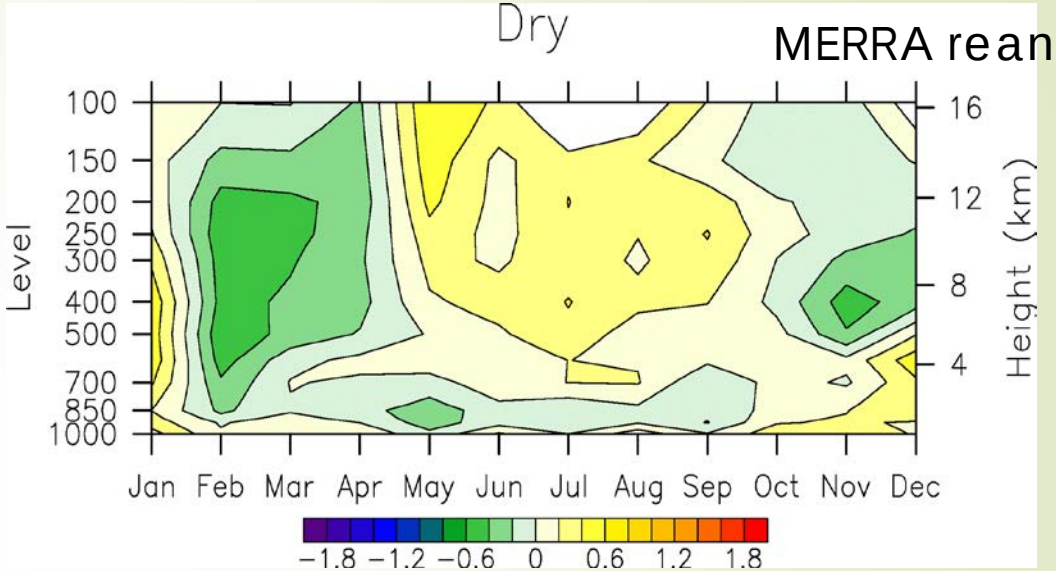
Why do climate models fail to predict delay of wet season onset over Amazon?

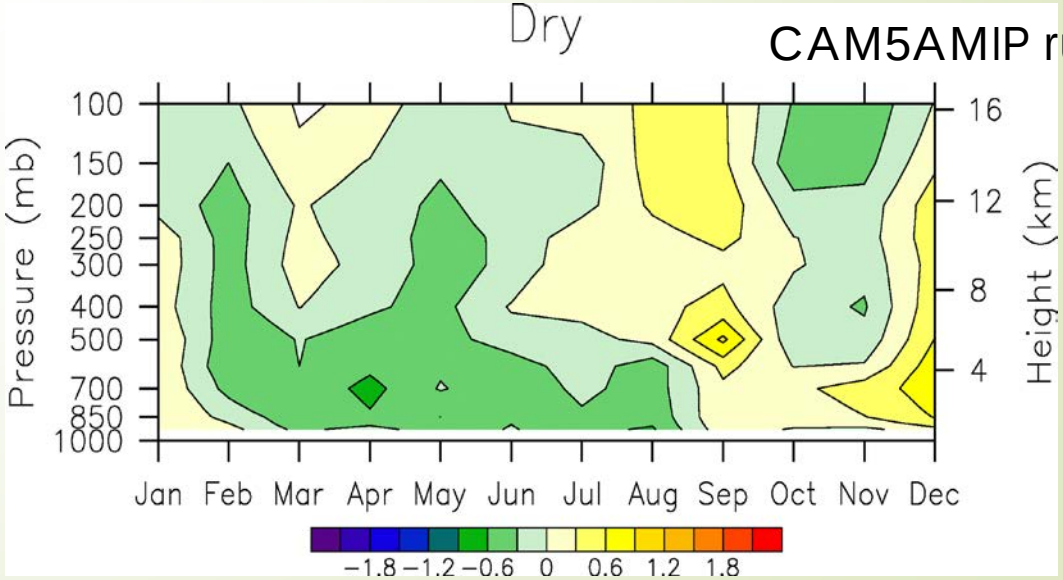
- *Do not capture the inter-seasonal drought memory due ecosystem-atmospheric interaction.*
- *Result from instantaneous external forcing*



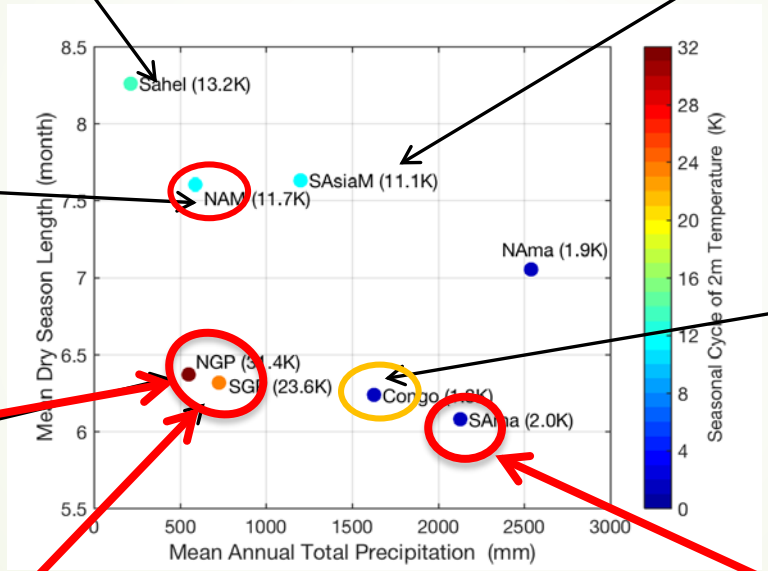
Trend of wet season onset (5 days/dec)

Standardized stream function for late wet onset years



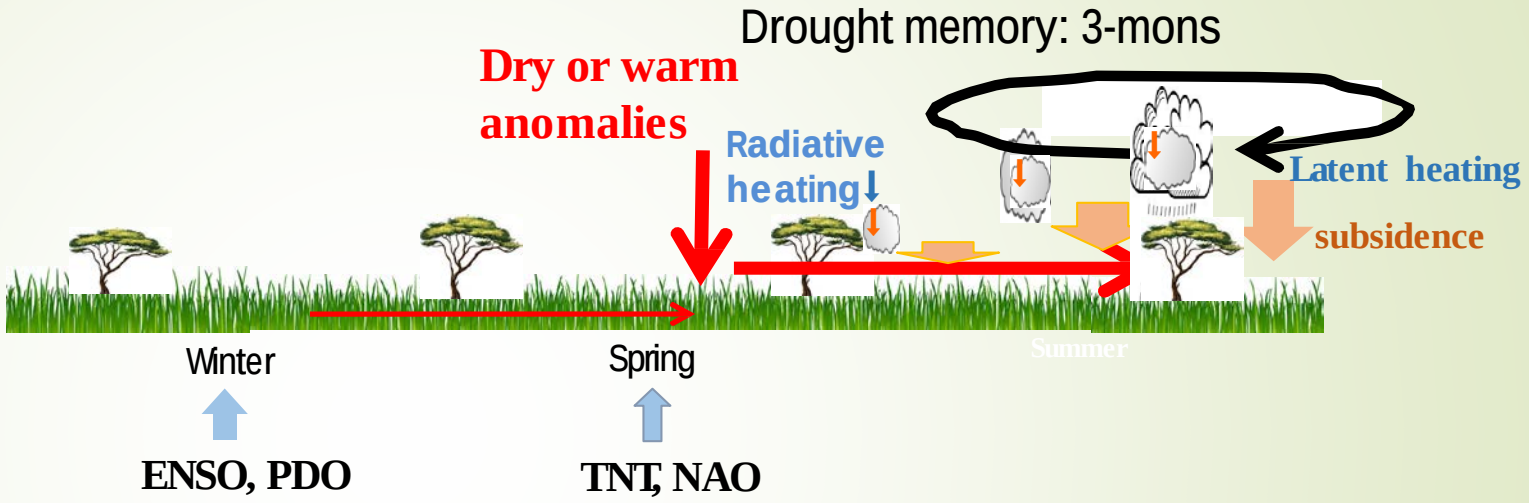


- *Are there simple rules about vegetation influence on water cycle behind different climate and vegetation conditions?*

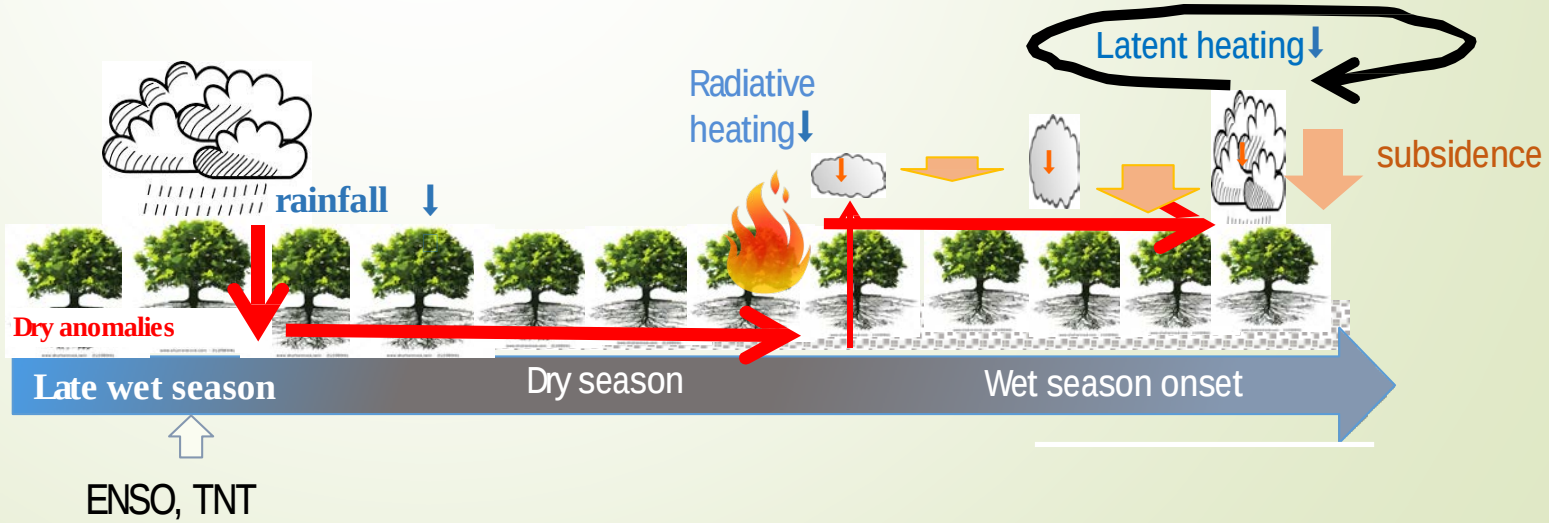


Root zone and soil moisture availability may dominate vegetation influence drought persistence and predictability in different climate and vegetation regimes

Shallow soil moisture - atmospheric feedbacks - US Great Plains



Deep soil moisture ground water - atmospheric feedbacks - S. Amazon

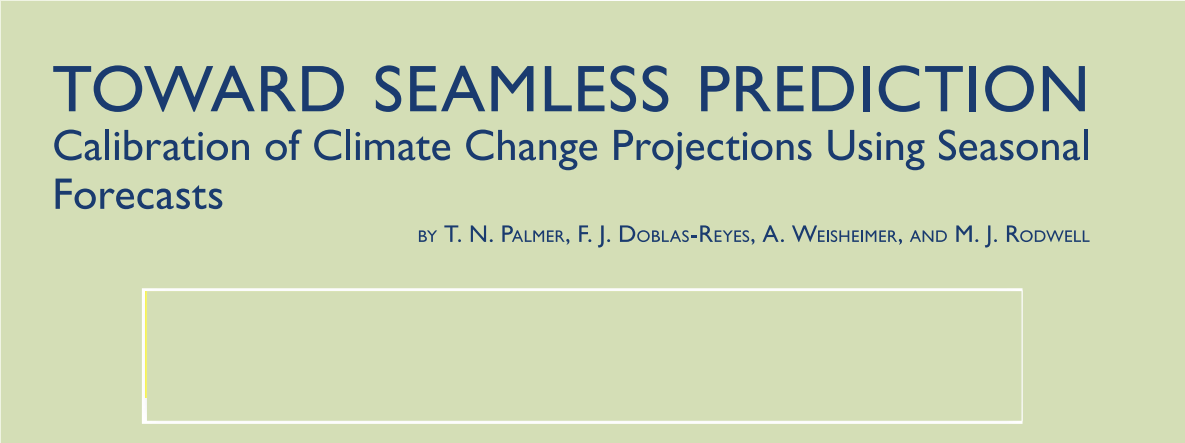


Main points

- *Land surface/ecosystem not only respond to, but also actively influence water cycle on seasonal, interannual to decadal time scales, especially drought and delay of rainy season.*
- *Ecosystem modeling is not only central for future carbon-climate projection, but also important for improving seasonal to interannual predictions of water cycle, especially drought, in today's climate.*

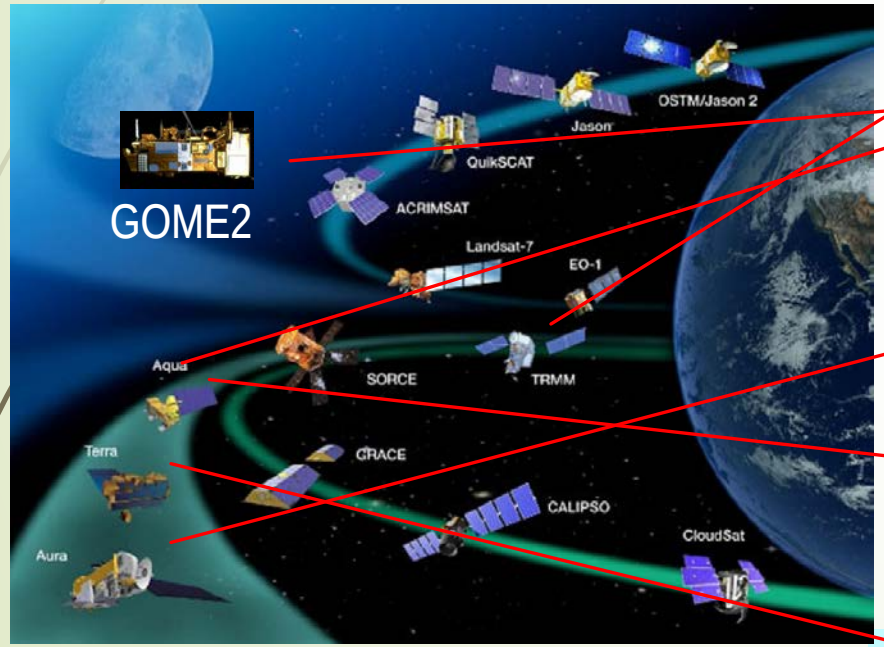
Questions to be addressed by this workshop:

- *How can we integrate observations more effectively in models?*
- *How do we couple biosphere and land models to other model components in ESMs?*



Apply coupled ecosystem-climate models to hindcast or forecast seasonal and interannual carbon and water cycles and vigorously evaluate the models skills provides an effective way to quantify uncertainty and calibrate/improve some of the key processes behind the carbon-water feedback, and to improve the trustworthiness of future projection.

- *Develop metrics & multi-emergent constraint for jointly evaluate carbon and water cycles and satellite simulators*
- *Enable and engaging research community to evaluate the prediction skills*



Datasets: TRMM, CERES, MODIS, AIRS, AURA/TES, GOME2, *GFFD3*, ERA-I

Wright et al. 2017, PNAS