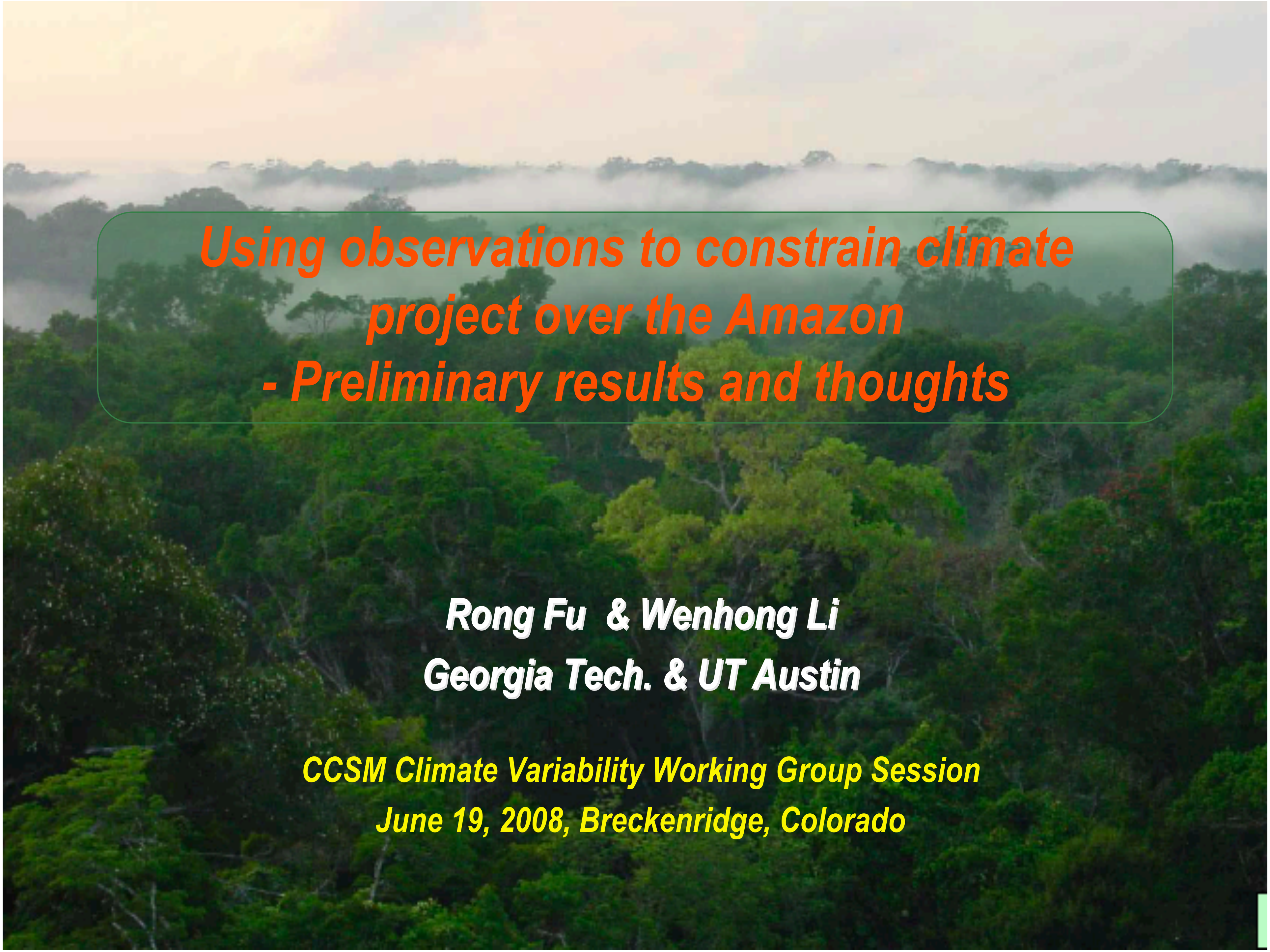

Using observations to constrain climate project over the Amazon - Preliminary results and thoughts

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CCSM Climate Variability Working Group Session

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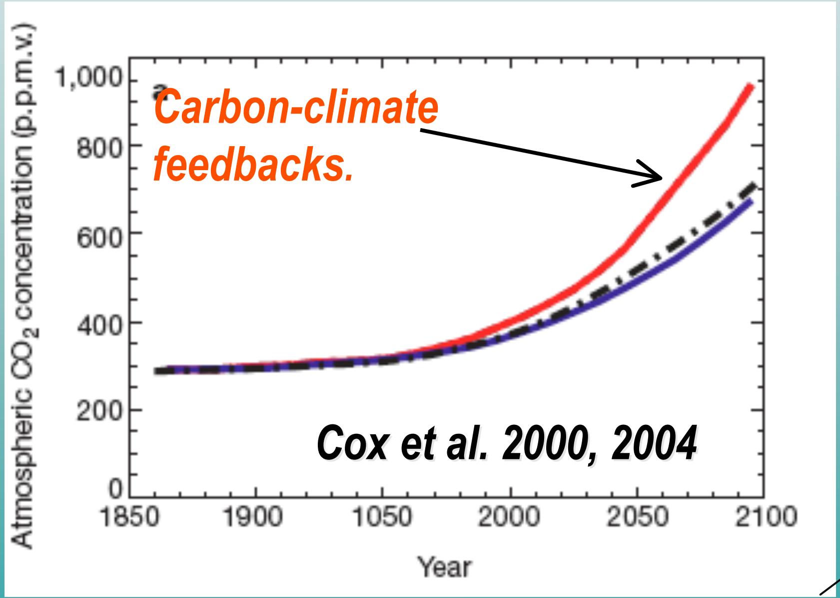
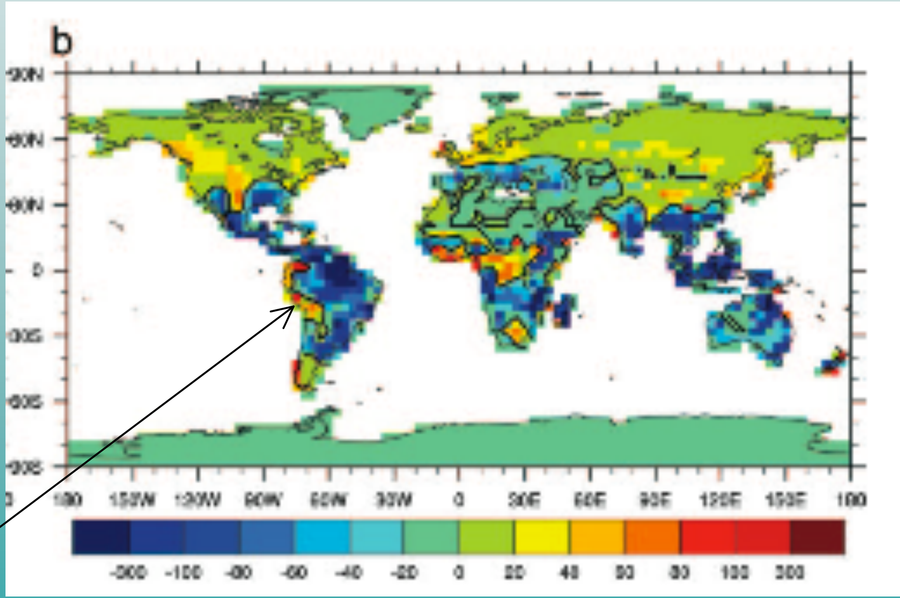
Climate models' projection:

- *Die back of the Amazon rainforest under a double CO_2 scenario contributes to ~70 GtC,*
  - *~33 ppmv additional increase in the global atmospheric CO_2.*
  - *> 10 year of global fossil fuel emission at current emission level*

  (Cox et al. 2004)





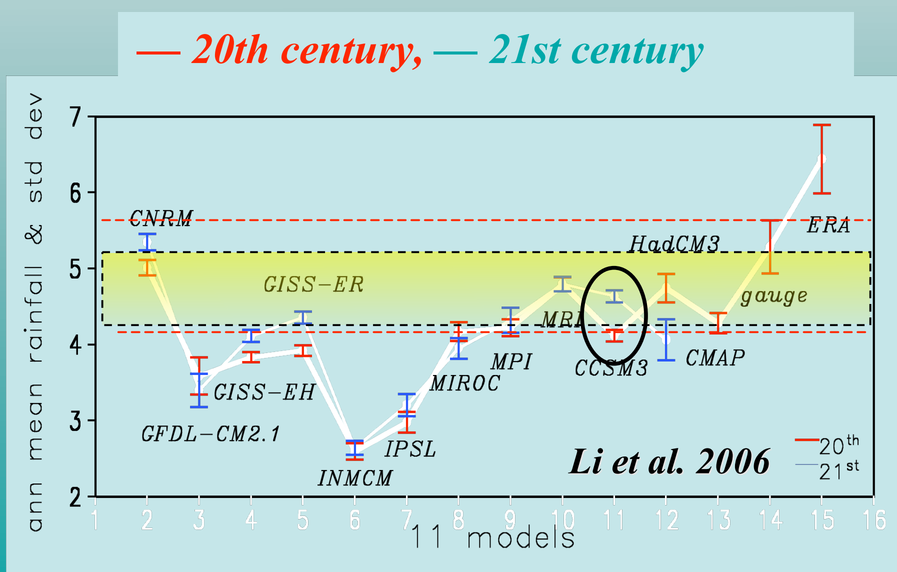
NPP decreases with rainfall

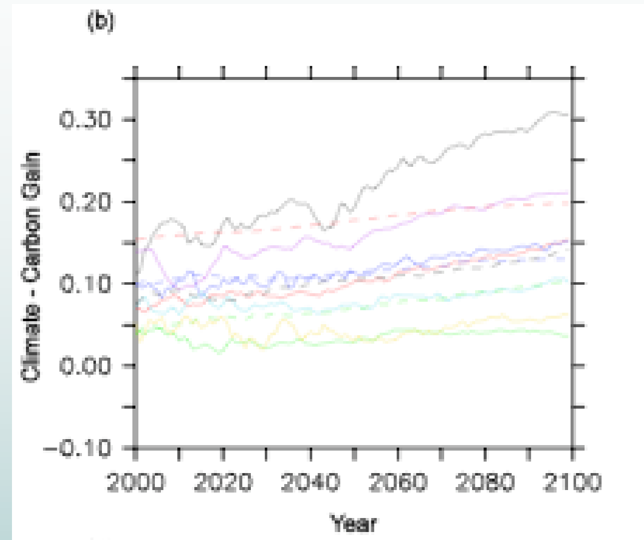
Fung et al. 2005 PNAS

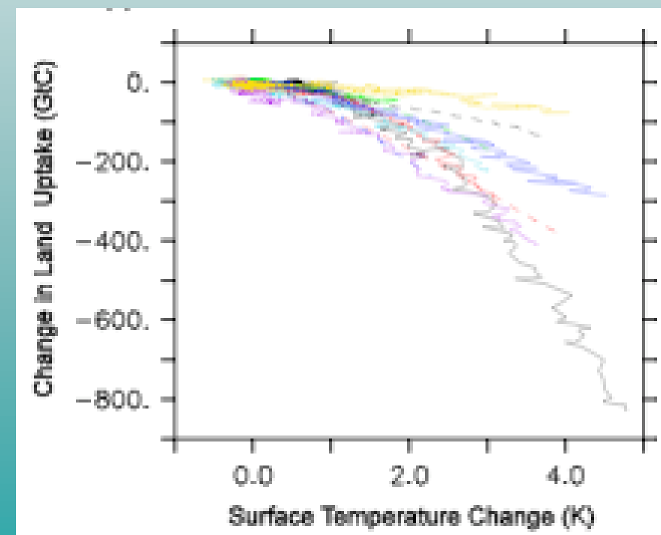
What is the likelihood for "die back" of the Amazon rainforest to occur?

- *The IPCC AR4 models disagree strongly in the projection of future rainfall changes over the Amazon, e.g., 4 models project increase rainfall, 2 models project decrease rainfall, 5 models project no significant change. (Li et al. 2006, JGR);*

- *Uncertainty in projected rainfall changes over tropical land is the main cause of the uncertainty in projected carbon-climate feedback for the 21st century (Friedlingstein et al. 2006).*





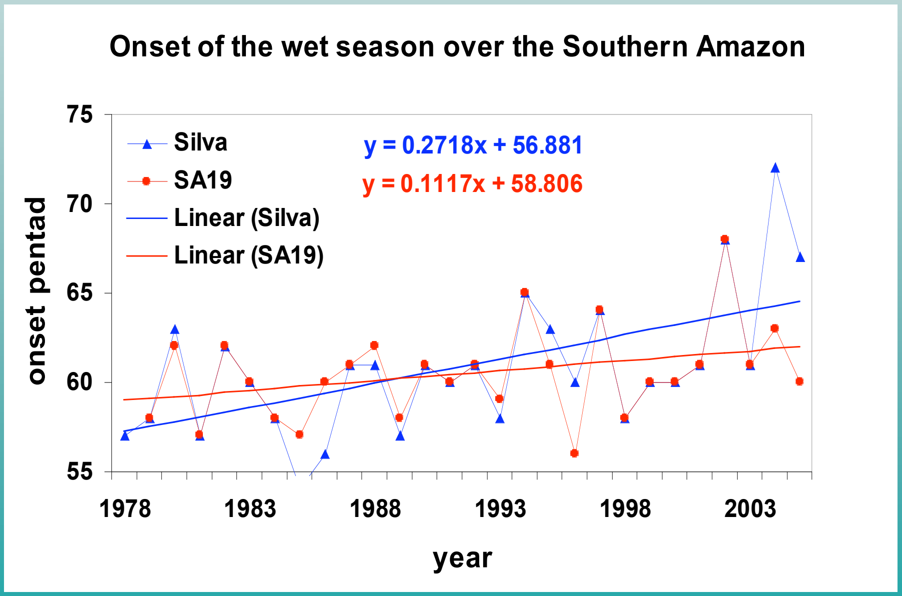


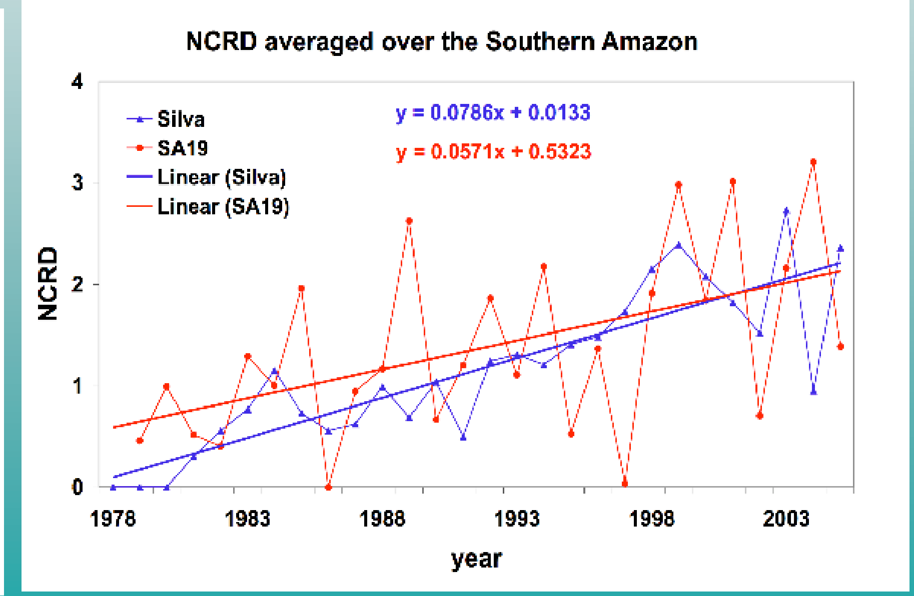
Friedlingstein et al. 2006

- ***Can we use observations to constrain the uncertainty in climate projections?***
  - ***What rainfall change would more realistic models project?***
    - ***However, "good" models for the 20th century do not necessarily provide good projection for the 21st century.***
  - ***How can we use observations to improve the confidence of climate projection over the Amazon?***

Observed rainfall change over the S. Amazon:

- ***Long-term raingauges data suggest a delay of wet season onset and an increase in drought severity over the S. Amazon (5˚-15˚S, 50˚-70˚W) since 1979 (Mann-Kendall test, 95% confidence).***





CMIP3 model simulations used in this analysis:

- 16 modeling group, 23 models/versions from PCDMI.

Table S2: Number of the models, available simulations and trend samples for wet season onset and NCRD trends, respectively, for the four scenarios.

	Pre-Industrial	**Realistic SST for the 20th century**	**Anthropogenic-external forcing for the 20th century**	**The 21st century A1B**
Number of Models	Onset: 21	Onset: 10	Onset: 21	Onset: 18
	NCRD: 22	NCRD: 14	NCRD: 23	NCRD: 22
Number of simulations	Onset: 24	Onset: 20	Onset: 42	Onset: 33
	NCRD: 26	NCRD: 31	NCRD: 70	NCRD:49
Number of trend samples	Onset: 48	Onset: 40	Onset: 84	Onset: 66
	NCRD: 52	NCRD: 62	NCRD: 140	NCRD: 98

Method:

Santer et al. 2007:

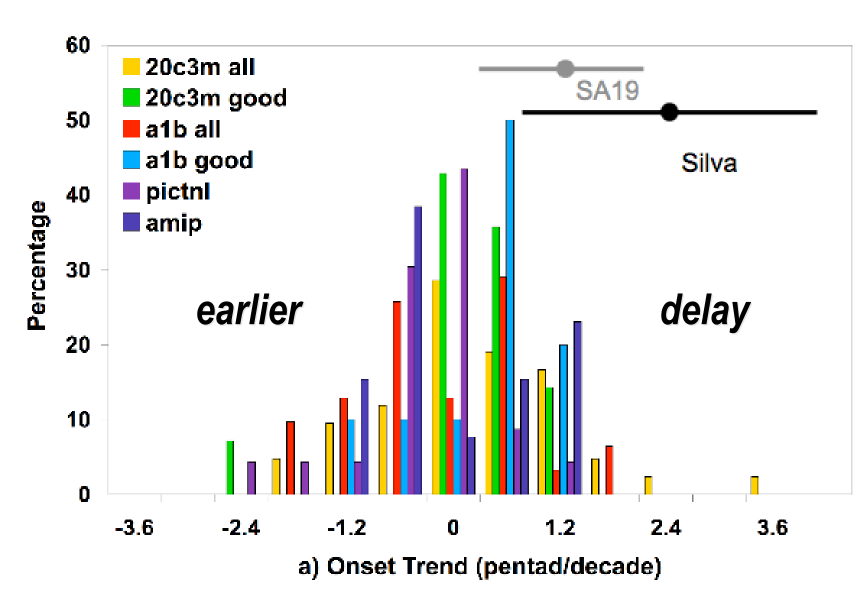
Use as many models and simulations as possible, and increase the pool of model samples by using as many non-overlap periods from each simulation as possible to

- *improve the robustness of the climate signal in the attribution analysis*
- *Increase the statistic significance of the probability of the simulated trends*

Would more realistic models project a more consistent rainfall change over the Amazon?

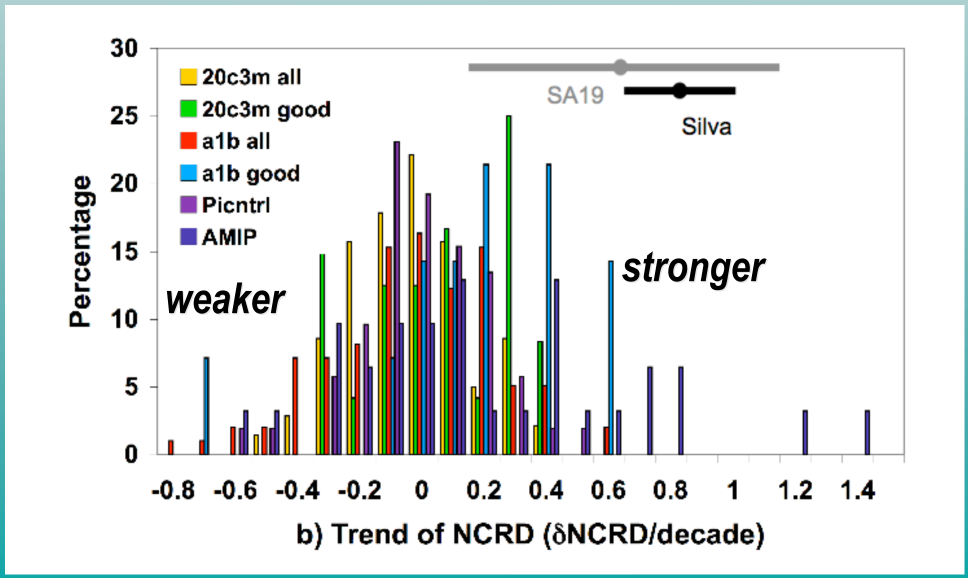
- ***The "good" models are defined as:***
  - ***Onset dates agree with observed climatology and standard deviations within 25% and 50%, respectively.***
  - ***the simulated trends agree with observation in sign***
  - ***For the period of 1979-2000.***
- ***$\chi 2$-test: sample distributions are different (95-99%) except between AMIP and 20C3M all models;***
- ***Yes, more realistic models for the 20th century more consistently (70% chance) project for a delay of wet season onset by 2079-2100.***

	Agreement with observations
Pre-industry	14%
AMIP	33%
The 20th century anthrop. forcing (All 23 models) The "good" models	44% 51%
The 21st-A1B (all models) ***The "good" models***	39% (delay) **70% (delay)**



Drought Severity:

- *χ2-test: sample distributions are statistically the same between AMIP and the 20C3M "good models".*
- *SST changes appear to play a major role.*
- *Again, more realistic models for the 20th century project more consistently (72% chance) for an increased drought severity by 2079-2100.*



	Agreement with observations
Pre-industry	22%
AMIP	38%
The 20th century anthrop. forcing (All 23 models) The "good" models	16% 37%
The 21st-A1B (all models) *The "good" models*	27% ↑ 72% ↑

How can we determine the model's ability to provide a creditable projection?

Issues:

- *A good fit to the 20th century does not guaranty a more reliable projection;*
- *Multimodel consensus is not a sufficient criterion for assessing forecast trustworthiness (e.g., Giorgi & Mearns 2002; Shukla et al. 2006).*

How can we determine the model's ability to provide a creditable projection?

- ***Palmer et al, 2008: A seamless prediction:***
  - *There are fundamental physical processes in common to both seasonal forecast and climate change time scales.*
  - *If essentially the same ensemble forecasting system can be validated probabilistically on time scales where validate exist, then we can modify the climate change probability objectively using probabilistic forecast scores on their shorter timescale.*

- ***Observations can help identify these fundamental physical processes***

The process that control the wet season onset over the Amazon on seasonal scale:

surface latent flux ⇑

⇓

surface air buoyancy ⇑

⇓

convective inhibition energy (CINE) ⇓

⇓

Rainfall ⇑, elevated atmospheric heating

Chiang et al. 2001

⇓ ⇑

moisture convergence.

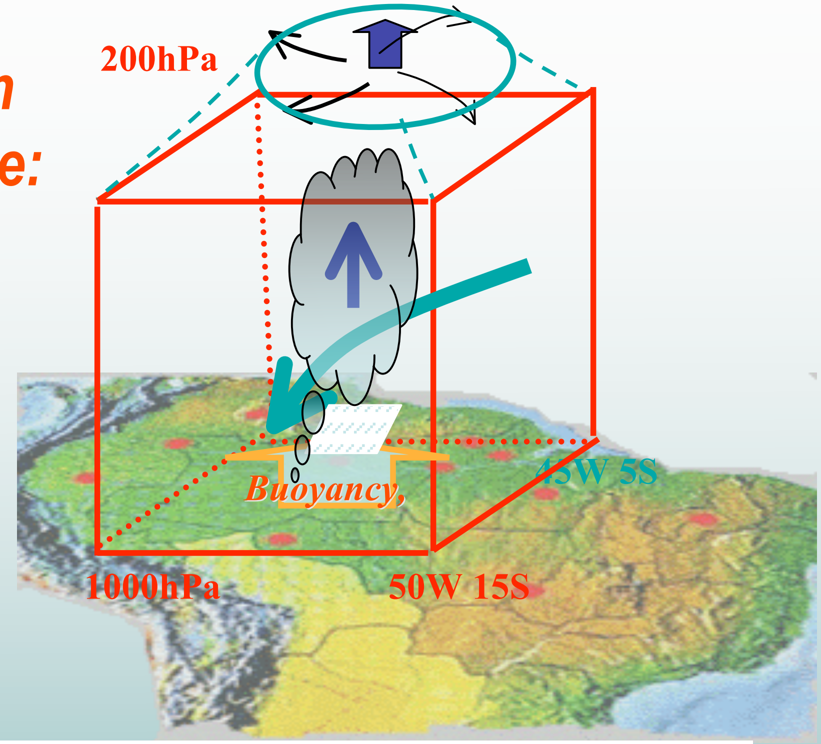
⇓

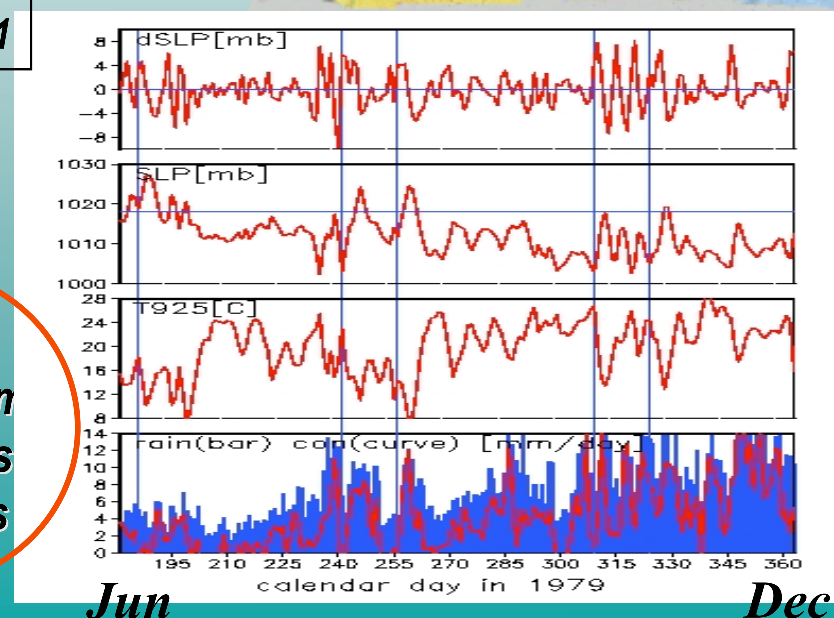
upper troposphere anticyclonic flow

⇓

wet season onset

Trigger mechanism cold fronts incursions





Li and Fu 2004, 2006, J. Climate

What control wet season onset and its interannual and decadal variabilities?

Key factors	Wet season onset	Interannual delay	Decadal scale delay
↑Surface latent flux,	↓CINE, initiate the transition	Pre-seasonal land surface dry anomaly, ↑ Bo, is a main cause.	Drier land surface, reduce CAPE
↑moisture transport⇔↑ rainfall	Accelerate the circulation transition	?	Weaker transport
Extratropical synoptic system incursions	Trigger the large-scale rainfall onset	infrequent and weaker cold fronts	Decrease in frequency of extratropical cold fronts

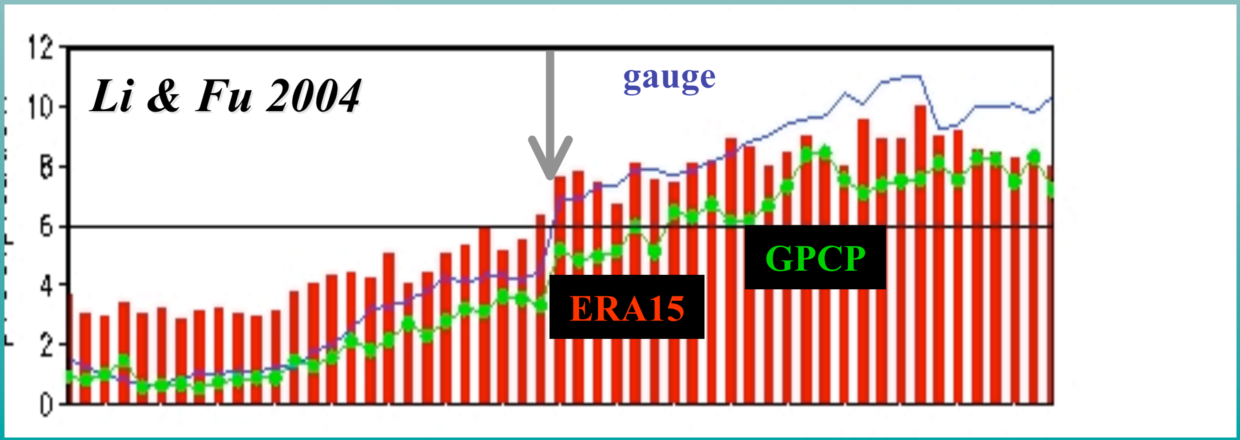
- ***Implication:***
  - ***The climate models that adequately capture the roles of these three key factors in seasonal to decadal variations would be more creditable for their projections of future change of wet season onset over the Amazon.***

- ***Our best hope for the next step:***
  - ***Identify the "good" models using the seamless prediction approach.***

Wet season onset:

- ***The jump from persistently lower rainrate to persistently higher rainrate relative to the annual mean.***

- ***Define the onset date: The pentad before which rain rate is less than its climatological annual mean value during 6 out of 8 preceding pentads and after which rain rate is this rainfall threshold during 6 out of 8 subsequent pentads (Marengo et al. 2001; Liebmann & Marengo 2001)***



External forcings in the 20th century simulations:

G: Well-mixed greenhouse gases
O: Tropospheric and stratospheric ozone
SD: Sulfate aerosol direct effects
SI: Sulfate aerosol indirect effects
BC: Black carbon
OC: Organic carbon
MD: Mineral dust
SS: Sea salt
LU: Land use
SO: solar irradiance
VL: Volcanic aerosols

20C3M

Model	G	O	SD	SI	BC	OC	MD	SS	LU	SO	VL
CCSM3	Y	Y	Y	-	Y	Y	-	-	-	Y	Y
GFDL-CM2.0	Y	Y	Y	-	Y	Y	-	-	Y	Y	Y
GFDL-CM2.1	Y	Y	Y	-	Y	Y	-	-	Y	Y	Y
GISS-EH	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
GISS-ER	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
MIROC3.2(medres)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
MIROC3.2(hires)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
MIUB/ECHO-G	Y	-	Y	Y	-	-	-	-	-	Y	Y
MRI-CGCM2.3.2	Y	-	Y	-	-	-	-	-	-	Y	Y
PCM	Y	Y	Y	-	-	-	-	-	-	Y	Y
BCCR-BCM2.0	Y	-	Y	-	-	-	-	-	-	-	-
CCCma-CGCM3.1(T47)	Y	-	Y	-	-	-	-	-	-	-	-
CCCma-CGCM3.1(T63)	Y	-	Y	-	-	-	-	-	-	-	-
CNRM-CM3	Y	Y	Y	-	Y	-	-	-	-	-	-
CSIRO-Mk3.0	Y	-	Y	-	?	?	?	?	?	?	-
ECHAM5/MPI-OM	Y	Y	Y	Y	-	-	-	-	-	-	-
FGOALS-g1.0	Y	-	Y	?	-	-	-	-	-	-	-
GISS-AOM	Y	-	Y	-	-	-	-	Y	-	-	-
INM-CM3.0	Y	-	Y	-	-	-	-	-	-	Y	-
IPSL-CM4	Y	-	Y	Y	-	-	-	-	-	-	-
HadCM3	Y	Y	Y	Y	-	-	-	?	-	-	-
HadGEM-run1	Y	Y	Y	Y	Y	Y	-	Y	Y	-	-
HadGEM-run2	Y	Y	Y	Y	Y	Y	-	Y	Y	Y	Y
INGV-SXG	Y	Y	Y	-	?	?	?	?	-	?	?
CSIRO-Mk3.5	Y	-	Y	-	-	-	-	?	?	-	-

- Good models for CWD: GFDL CM2.0, hadCM3 INGV-SXG, Miroc3.2-medres
- Good models for onset: BCCR-BCM2.0, CCCMA-CGCM3.1(T47),NCAR-CCSM,CNRM-CM3,GISS
- AOM,Miroc3.2-medres, Miroc3.2-hires, ECHAM5/MPI-OM, and NCAR-PCM