IASCLIP Modeling and Prediction

Inputs from:

Working Group A

(Diagnostics and Prediction: K. Mo, M. Jury, R. Fu, S. Schubert, J. Schemm)

&

Working Group B

(Model Development: V. Misra, S. C. Chou, B. Kirtman, B. Mapes, C. Wang)

Outline

- **Significance of the Western Hemisphere Warm Pool**
- **Climate models and AWP**
  - NCEP CFS (V. Misra, S. Chan, R. Wu, E. Chassignet)
  - IPCC AR4 20C3M (V. Misra, S. Chan, A. Clement)
- **Extremes and WHWP**
  - Drought (S. Schubert)
  - Tropical cyclone activity(J. Schemm, L. Long, T. LaRow, T. Knutson)
- **Reanalysis**
  - MERRA (B. Mapes)
  - CFSR&R (K. Mo)
- **Conclusion**

Significance of WHWP

- Provides an anchor for boreal summer season predictability over the US
- Has connection to climate extremes: seasonal droughts, seasonal and even possibly decadal tropical cyclone activity in the Atlantic
- Is part of a wider general circulation that has remote connections: e.g. southeast Pacific, Amazon

Seasonal predictability of the AWP

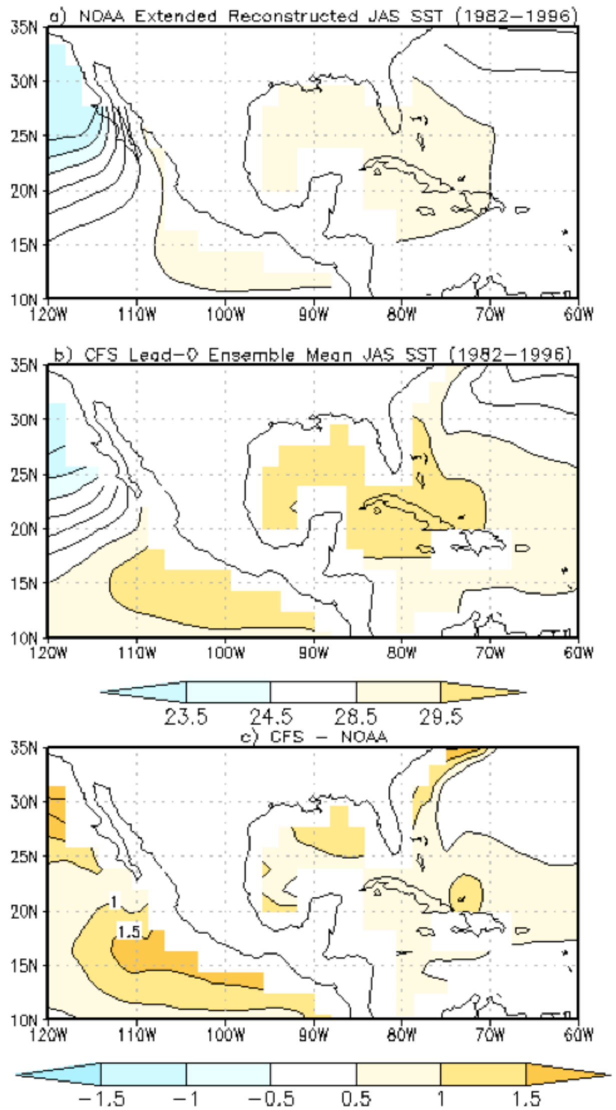
V. Misra, S. Chan (FSU, Dept. of Meteorology & COAPS)

CFS Seasonal hindcasts:

- 23 years(1981-2003)
- 15 ensemble members, starting from every month
- 9 month long integration

CFS Multi-decadal integration

- 4 ensemble members
- Integration period: 32 years

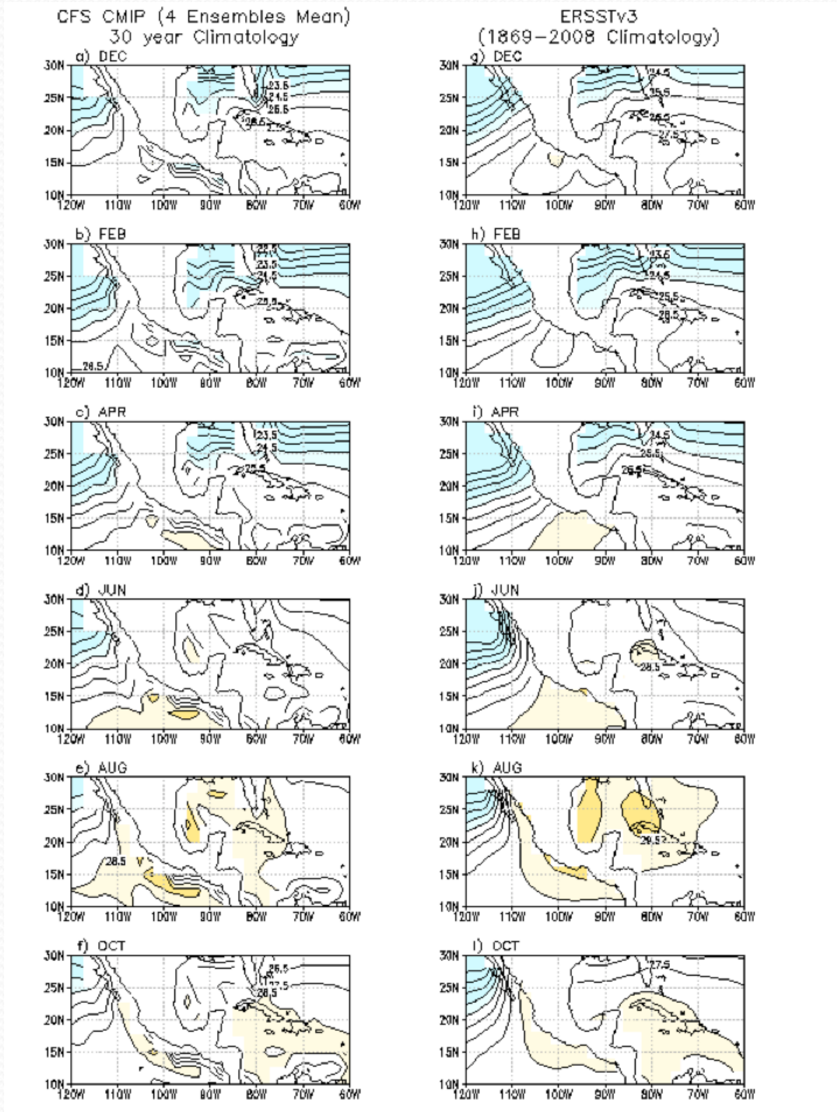


ERSSTV3

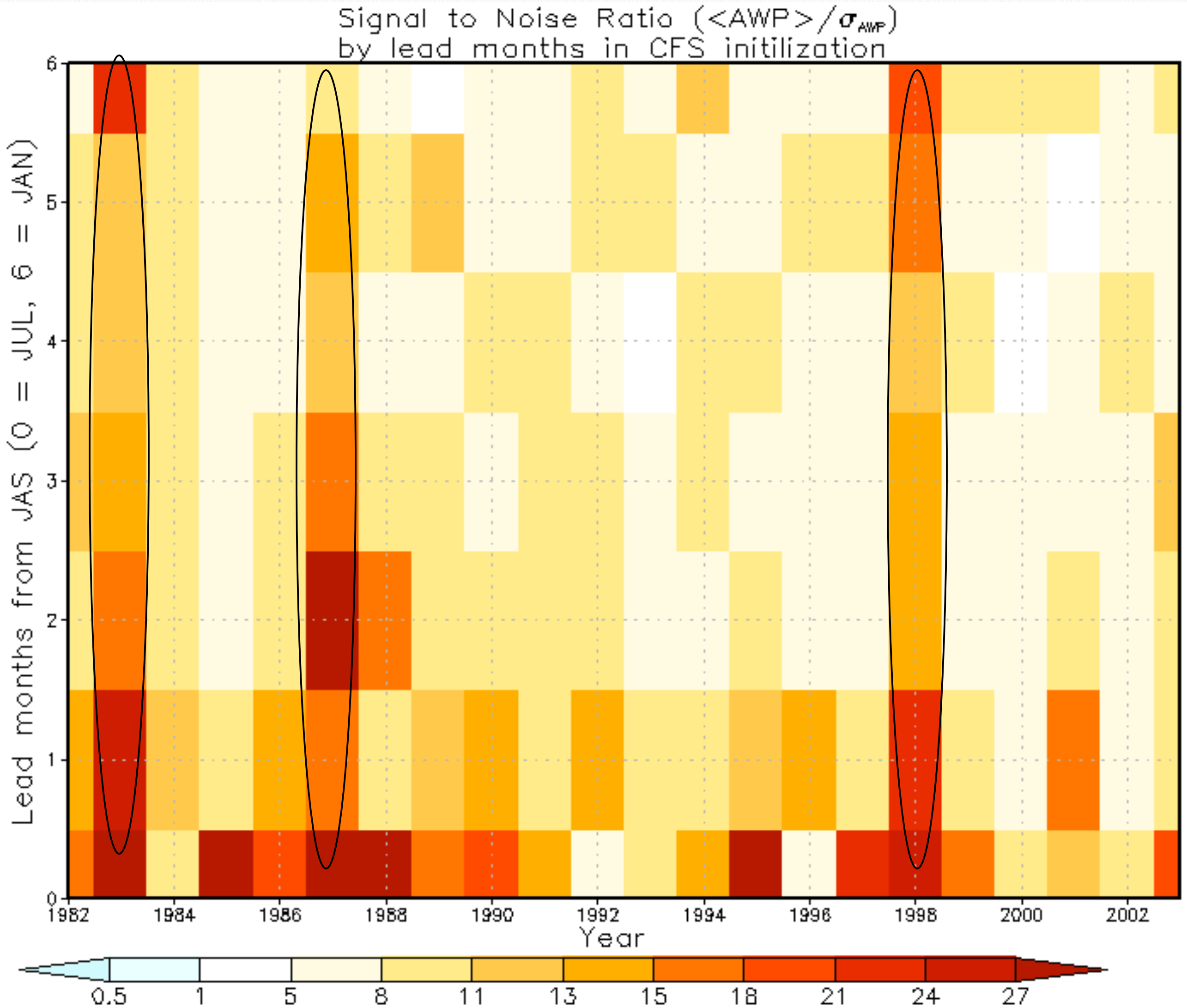
CFS Lead time 0

Errors

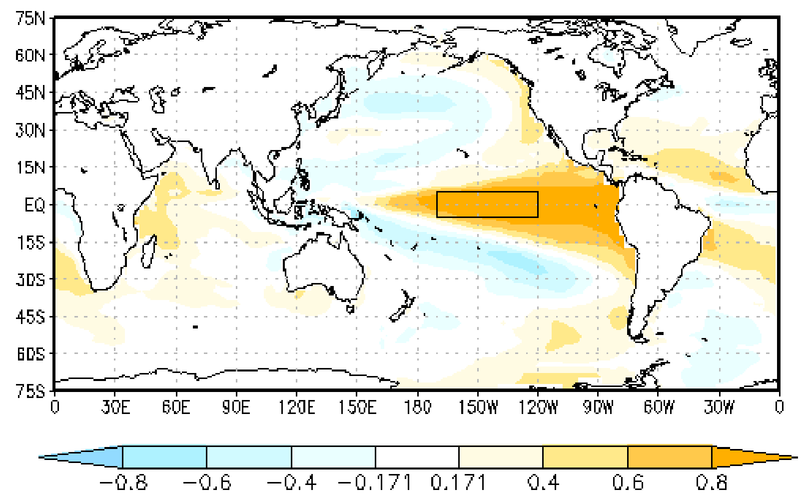
The climatological JAS mean SST



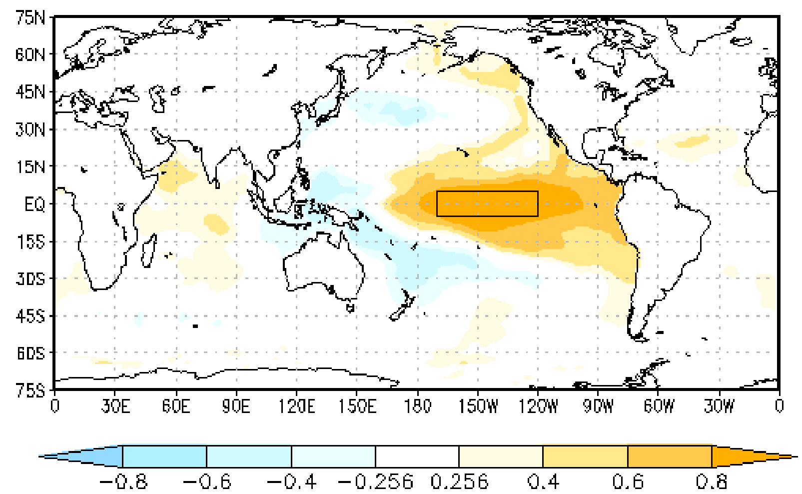
The climatological annual cycle of SST over the WHWP



Signal to noise ratio of JAS AWP area

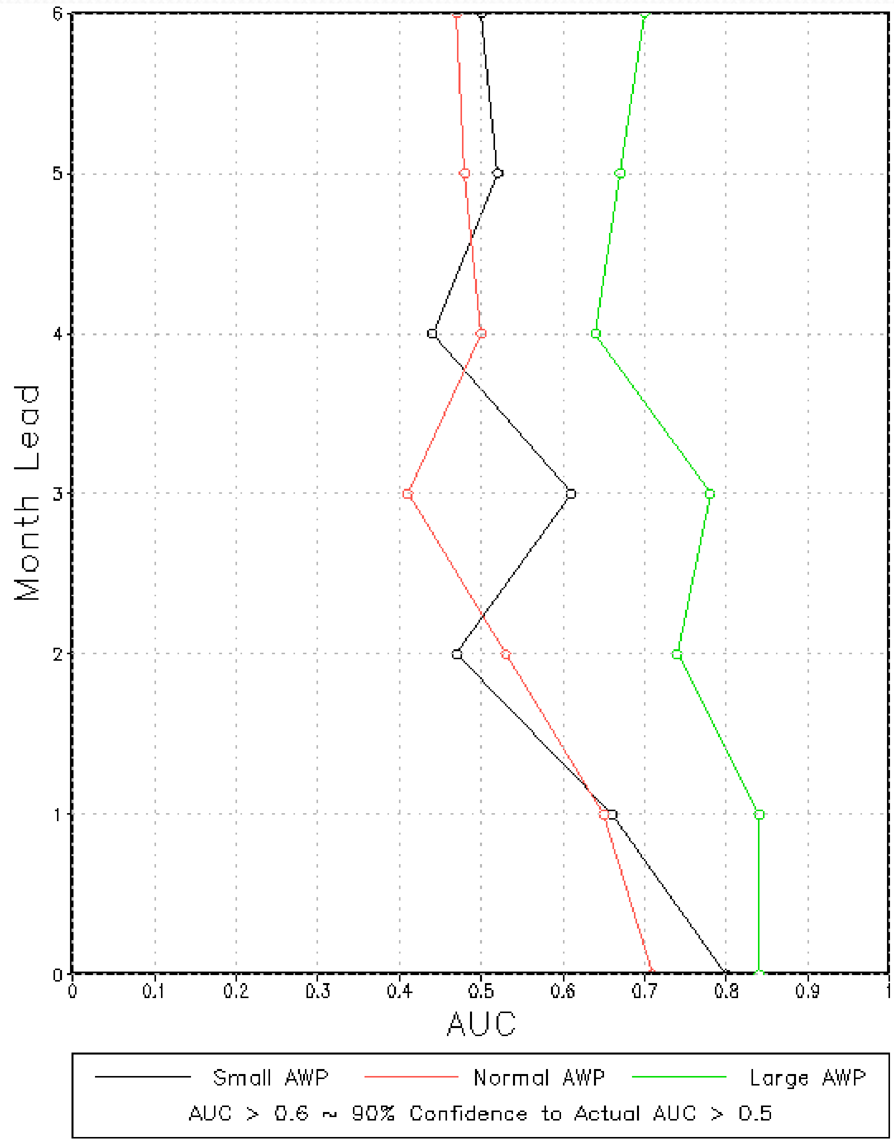


CFS LT

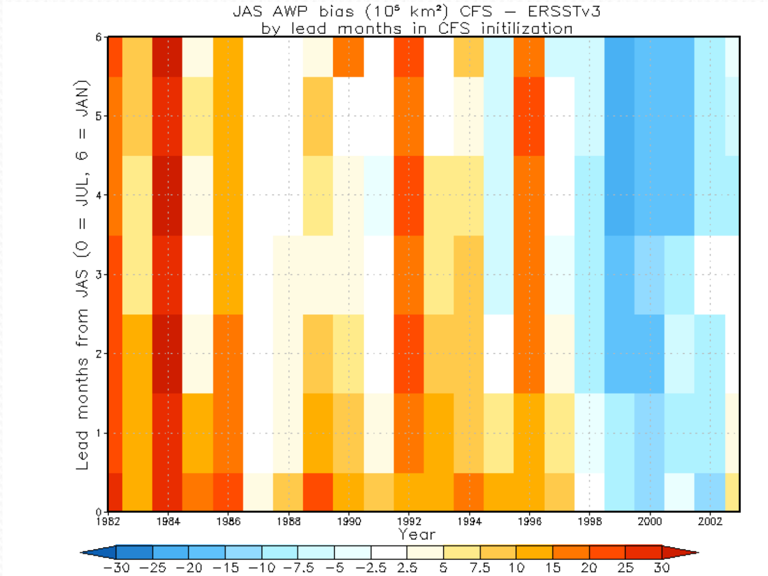


ERSSTV3

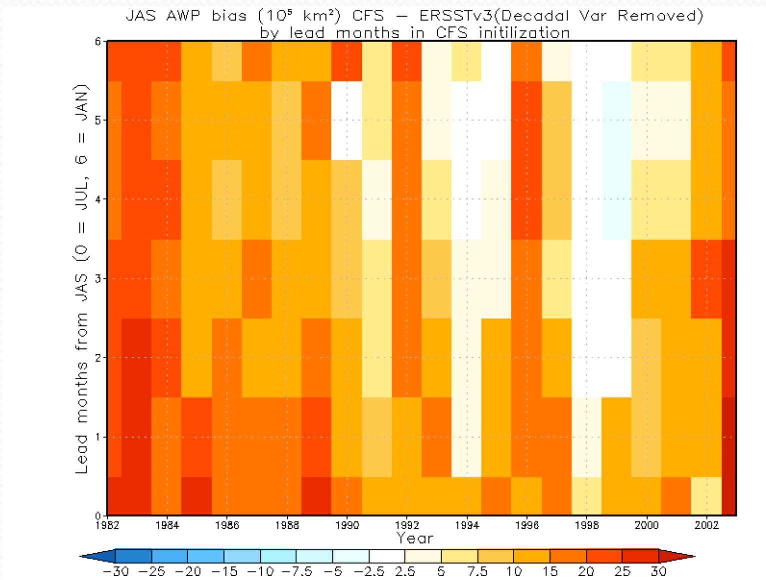
The JAS Nino3.4 SST index correlations with global SST



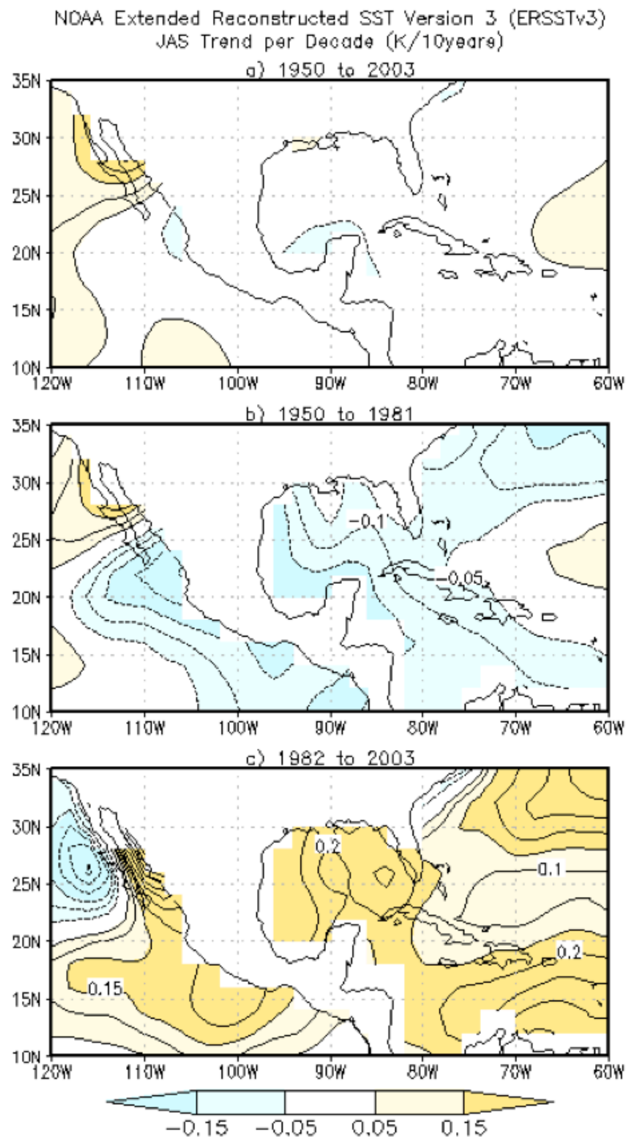
The Area Under the Relative Operating Curve



JAS AWP area errors



JAS AWP area errors after high pass (> 6yr) filter of observed SST

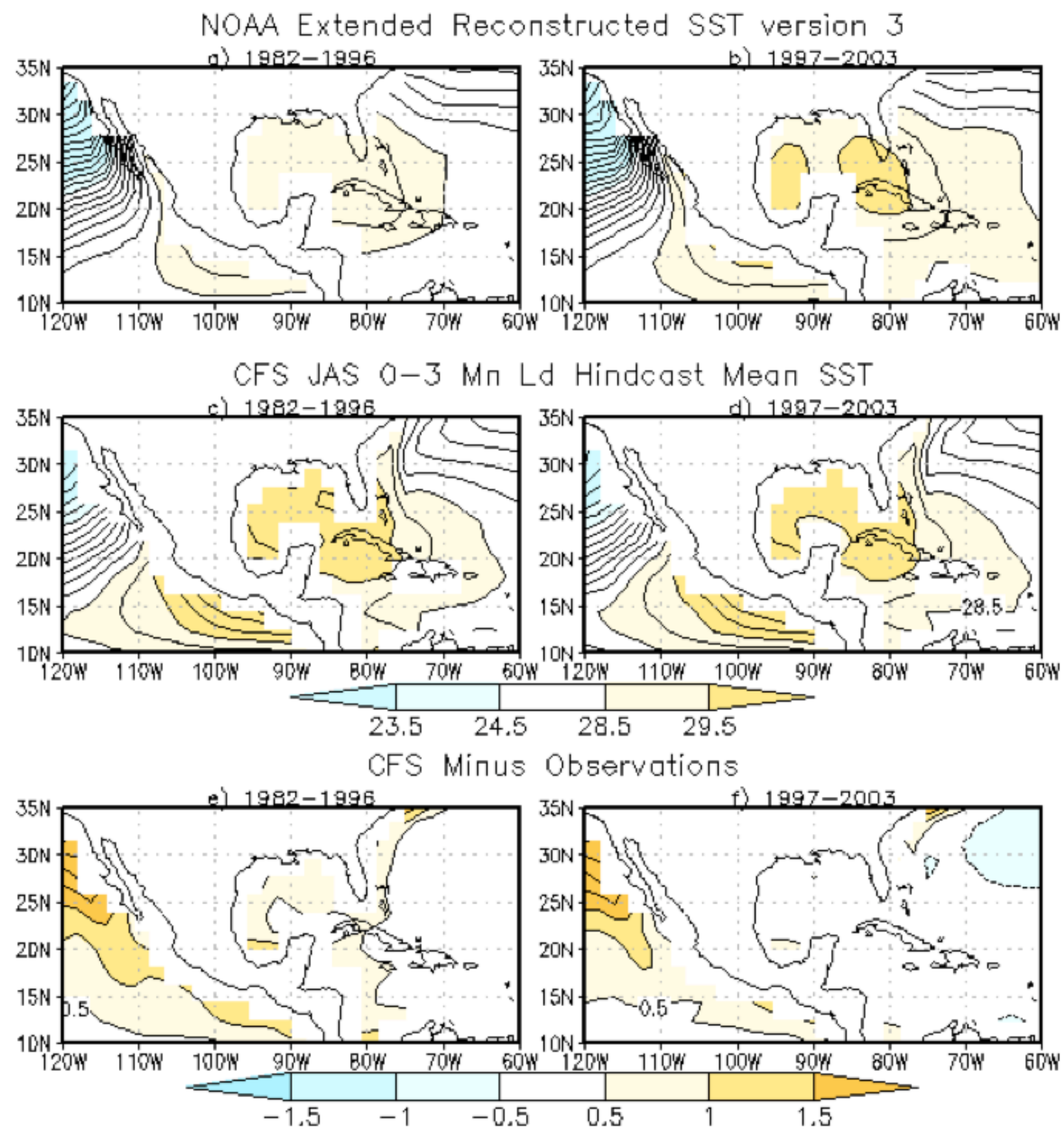


1950-2003

1950-1981

1982-2003

Observed linear trend (per decade) in the July-August September SST



Climatological July-August-September (JAS) seasonal mean SST

Summary

- CFS (hindcasts and CMIP type) integrations display reasonable AWP
- CFS hindcasts have useful skill for large AWP and skill up to one month lead for normal and small AWP (for the period 1981-1996)
- ENSO influence on AWP is relatively strong in CFS, which is unsupported by observations
- Decadal variations in AWP are not captured in CFS hindcasts

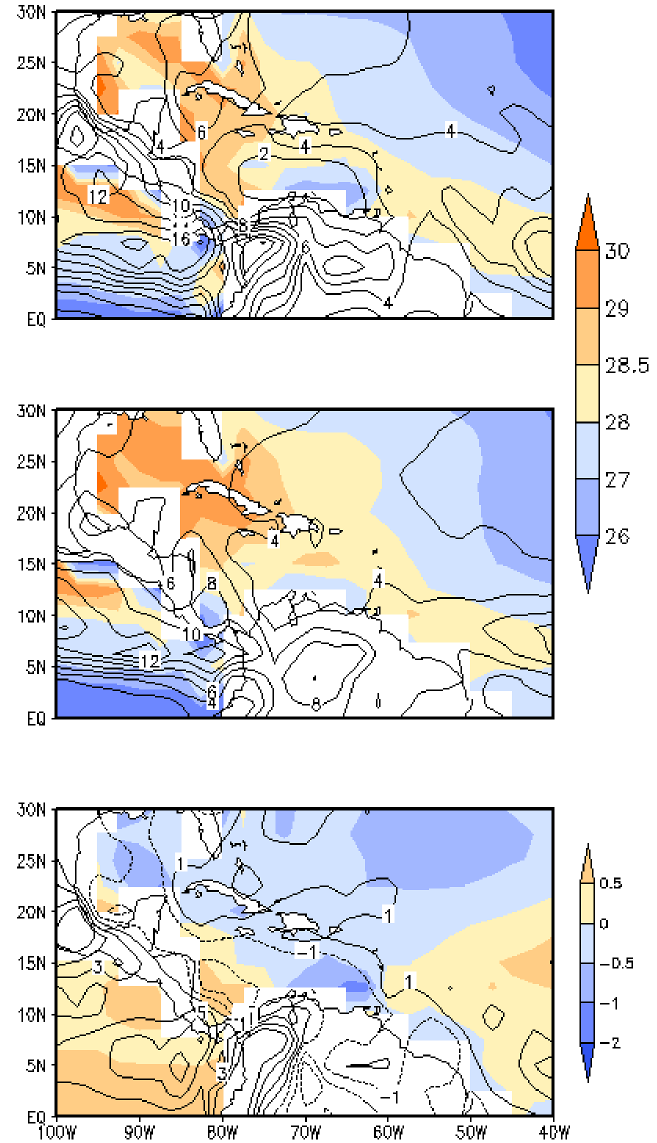
Air-sea interaction over the AWP in the NCEP CFS

V. Misra, S. Chan, R. Wu, E. Chassignet
(Dept. of Meteorology, COAPS, COLA)

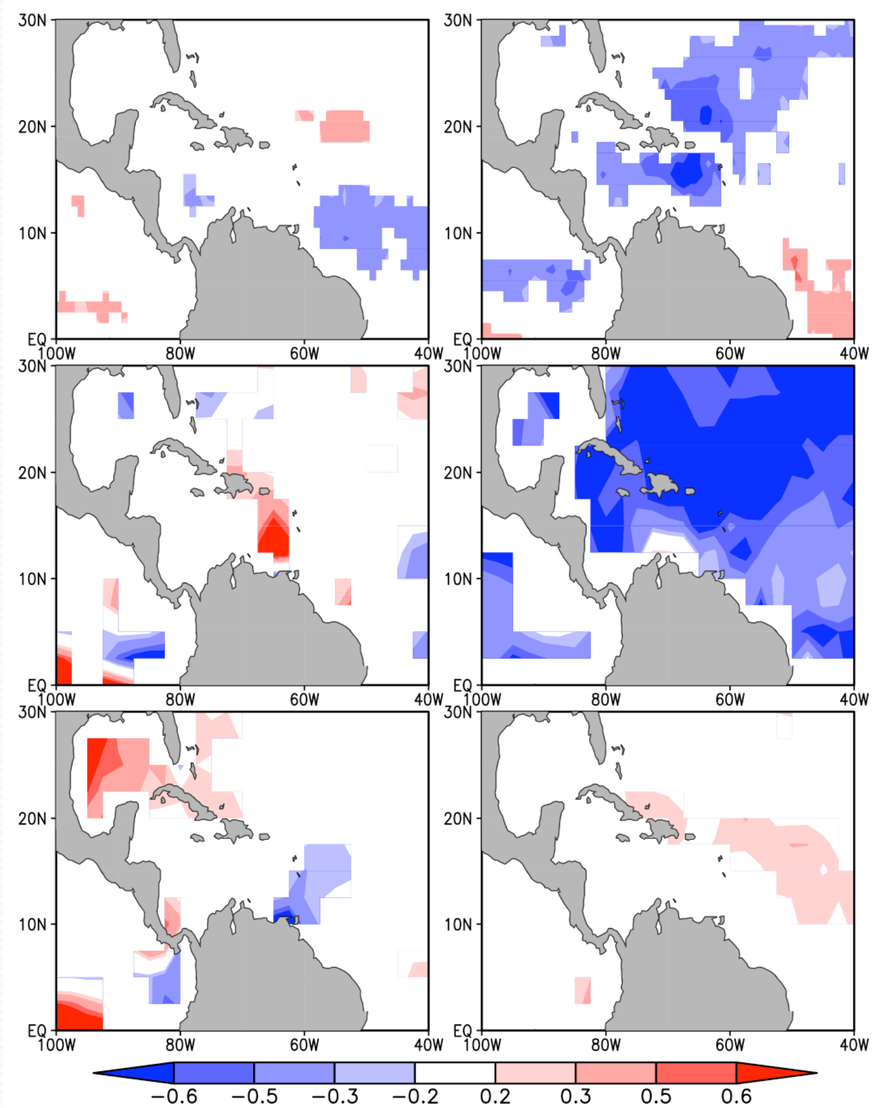
CFS

ERSST-V2

Errors



The climatological mean JAS SST and rainfall contours

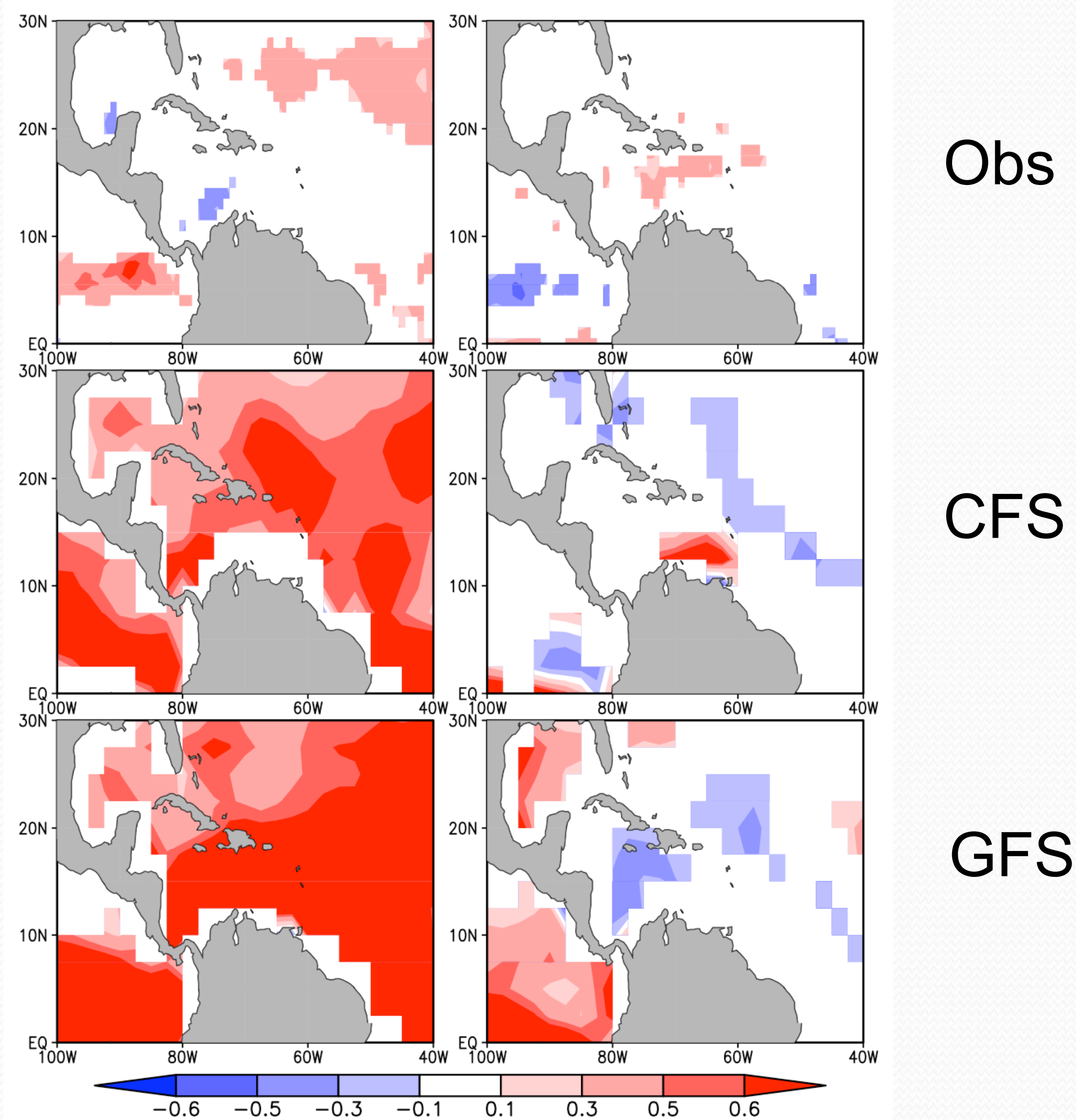


Obs

CFS

GFS

LHF-SST correlations   LHF- $\frac{\partial SST}{\partial t}$ correlations



LHF-(q_s-q_a) correlations LHF-$|\overrightarrow{V_{10m}}|$correlations

Summary

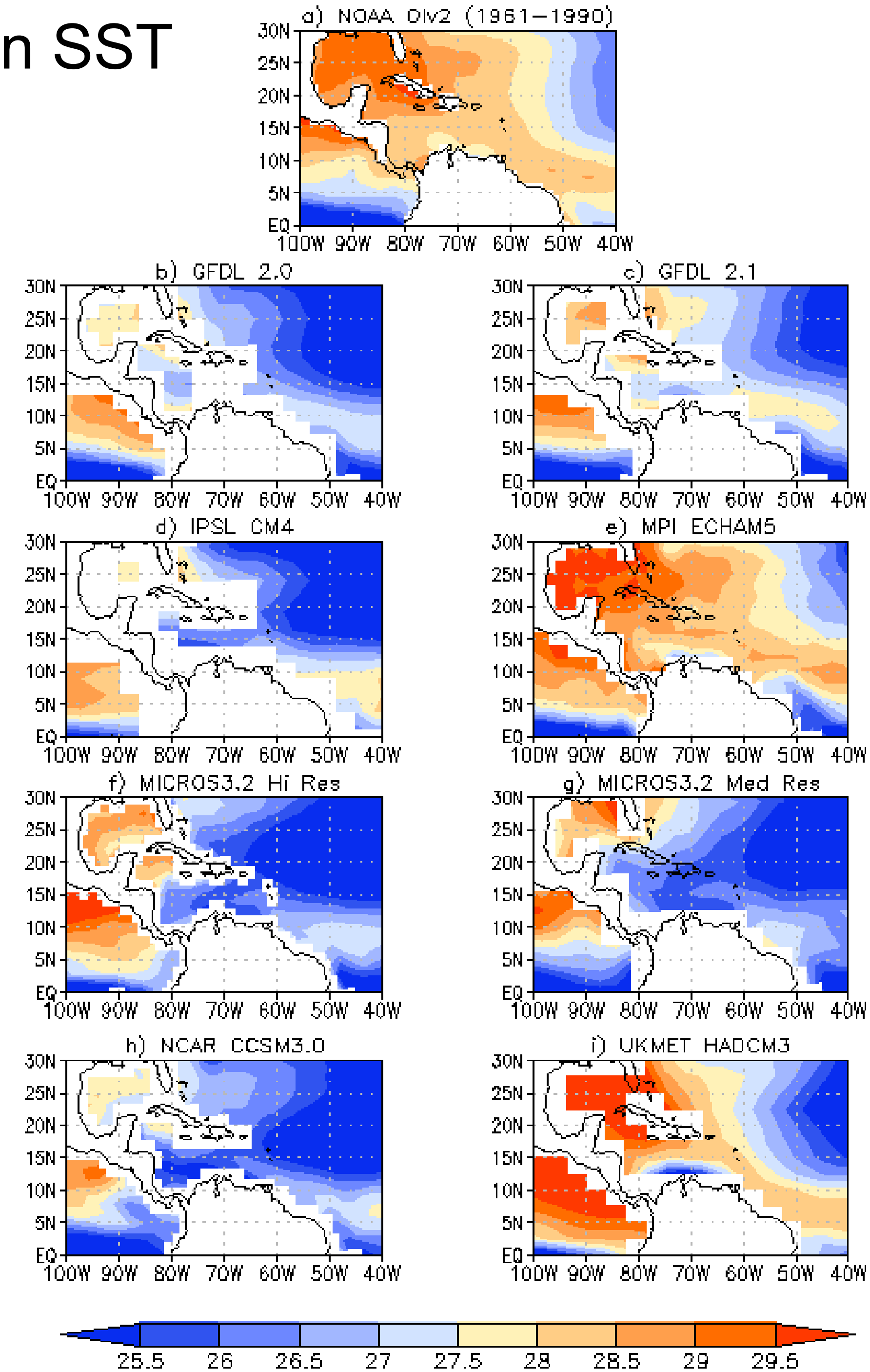
- Observations indicate that atmospheric fluxes force SSTA over AWP--at least over the northwest tropical Atlantic
- CFS captures this feature reasonably but GFS does not==> air-sea coupling important for AWP
- PBL problems in CFS/GFS: LHF over dependent on air-sea humidity difference and under-dependent on surface winds

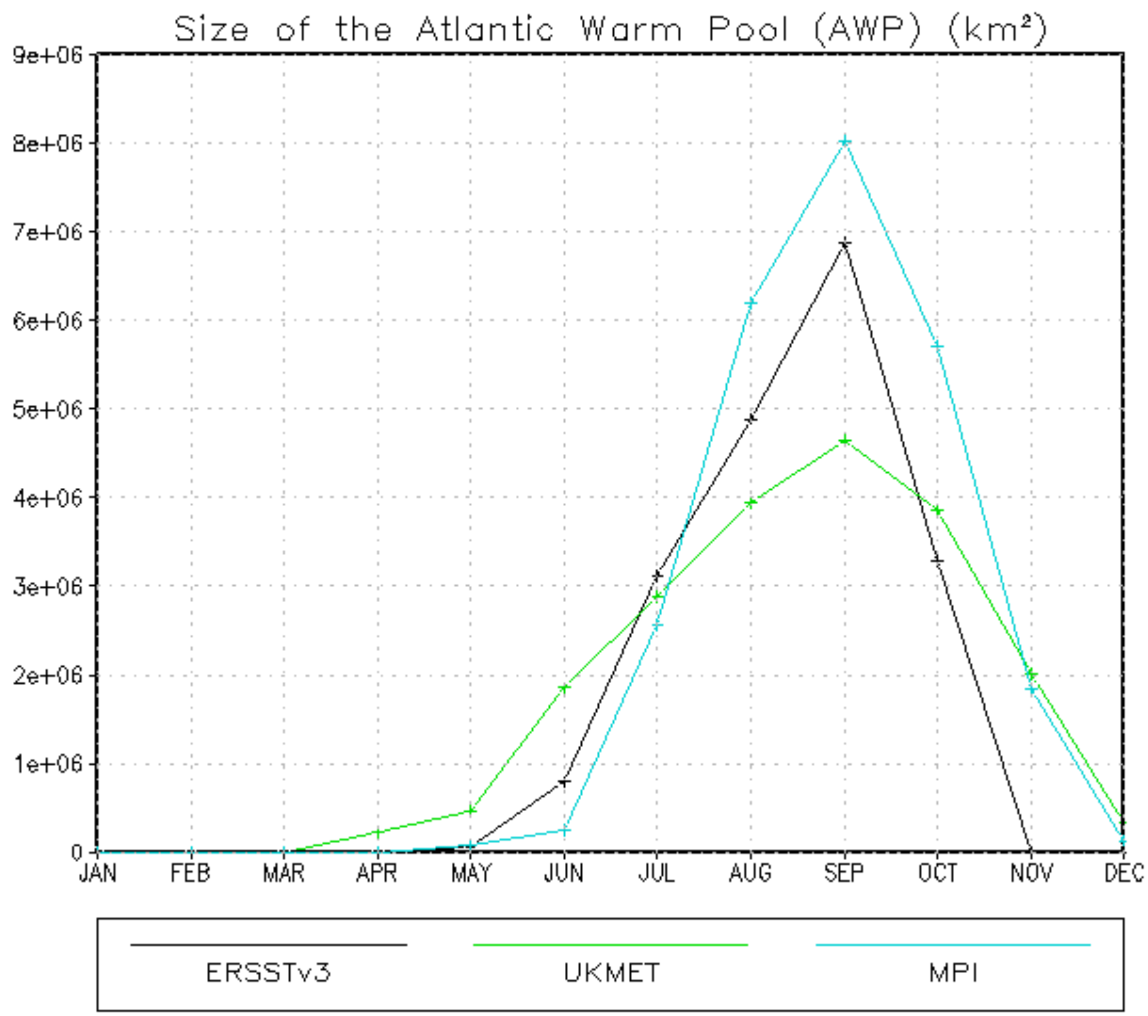
IPCC AR4 model bias

V. Misra, S. Chan, A. Clement, T. Knutson, D. Enfield

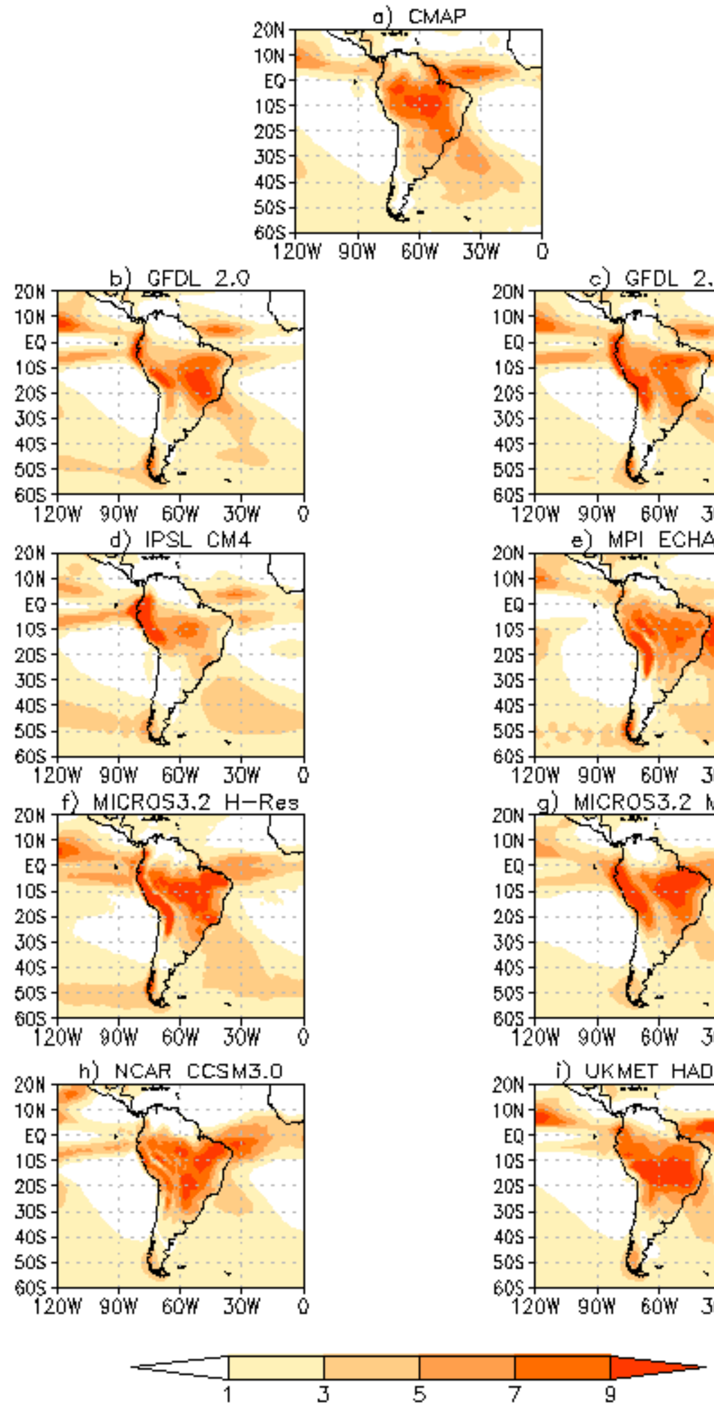
FSU Dept. of Meteorology & COAPS, RSMAS, GFDL, AOML

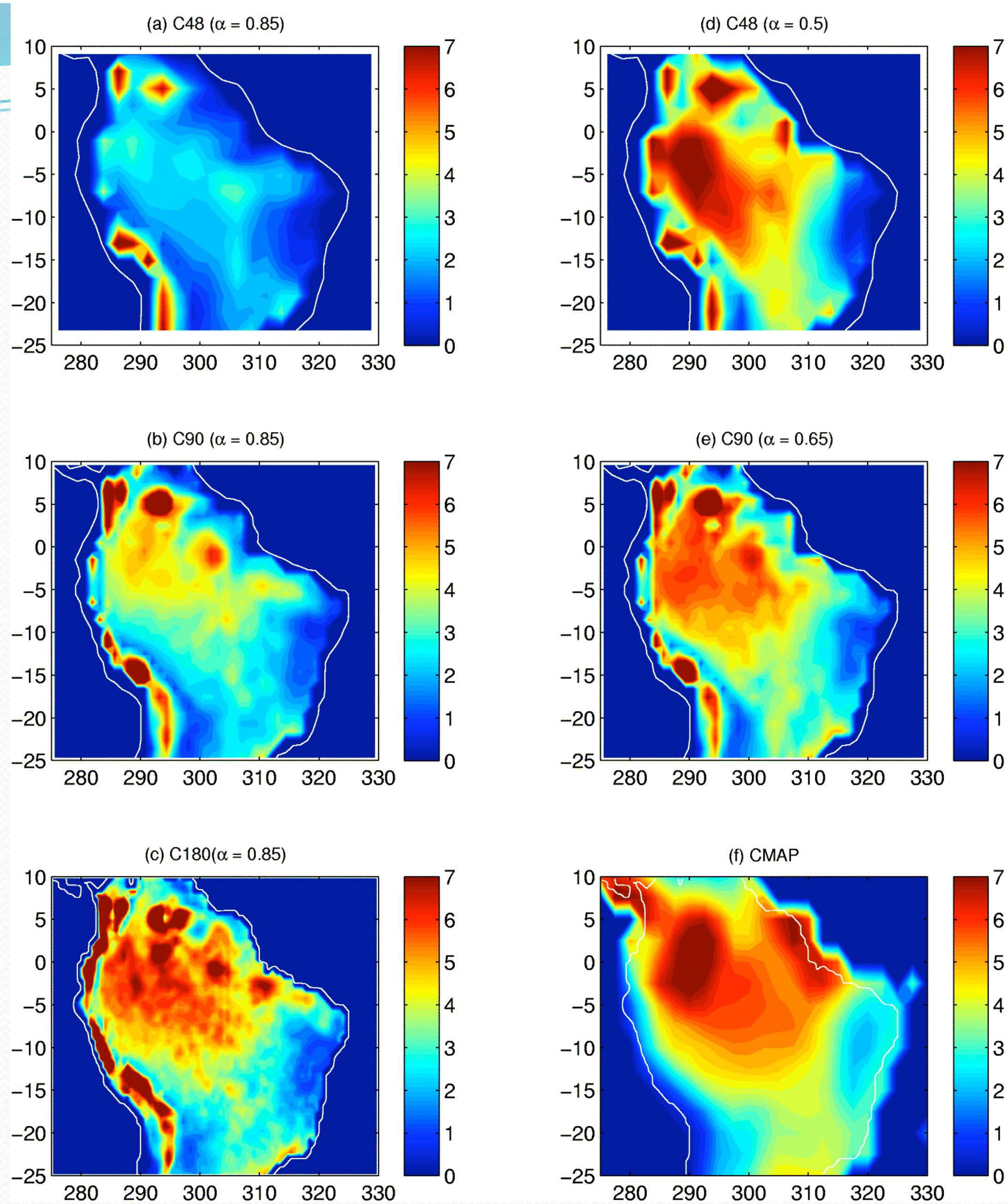
The JAS climatological mean SST



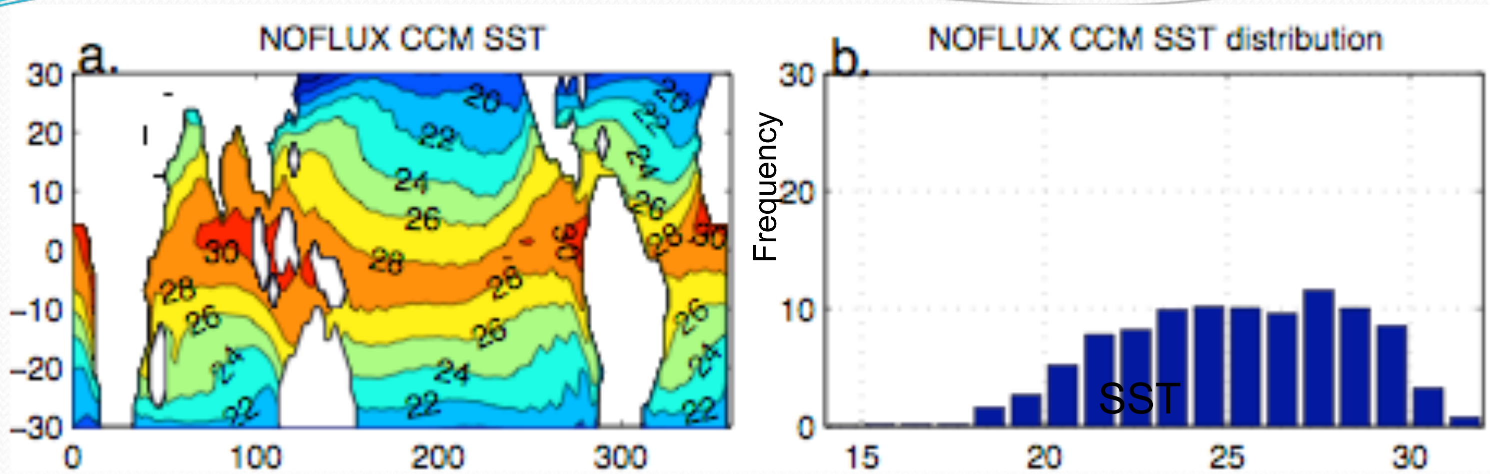

Size of the Atlantic Warm Pool (AWP) (km²)
9e+06
8e+06
7e+06
6e+06
5e+06
4e+06
3e+06
2e+06
1e+06
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
ERSSTv3
UKMET
MPI

The DJF climatological precipitation

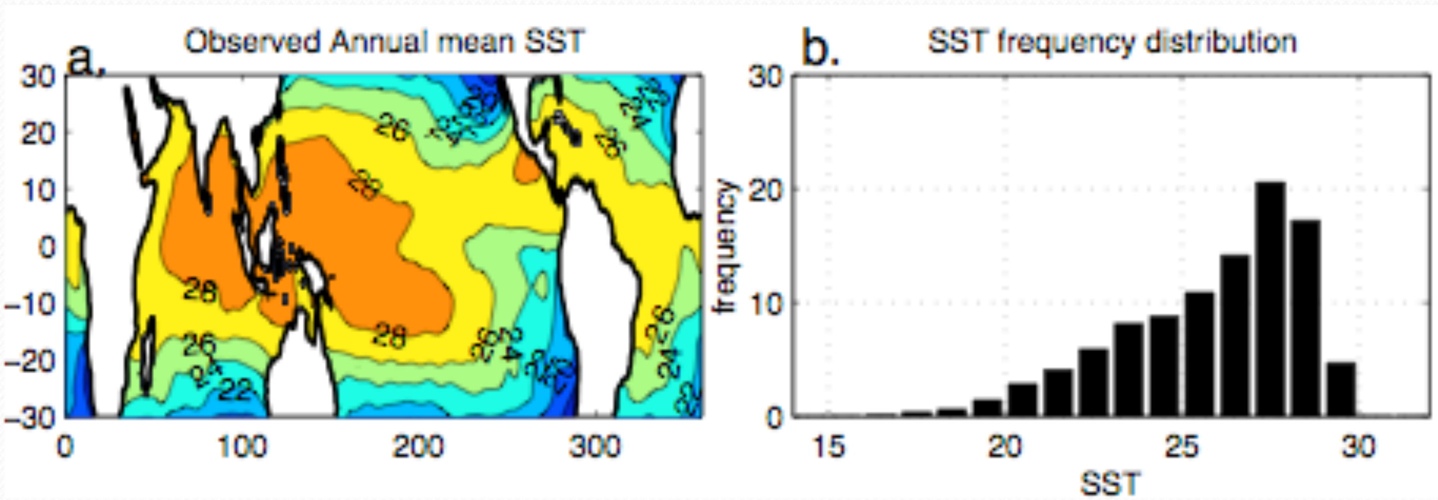




Sensitivity of annual mean Amazon precipitation to resolution and convective entrainment rate



When the **atmosphere** does more of the heat transport (all), the Hadley cell is strong and high windspeeds off the equator erode the warm pool.



When the **ocean** does part of the job (half), the warm pool is spread meridionally and confined to the west via the combination of Ekman + Sverdrup processes.

AWP in the 21st century from AR4

- Most of the IPCC-AR4 projections weaken AMOC
- They warm the North Atlantic by 1º C less than the North Pacific by 2100.
- Despite increase in AWP size by 2100 they project reduced precipitation over the IAS.

Summary

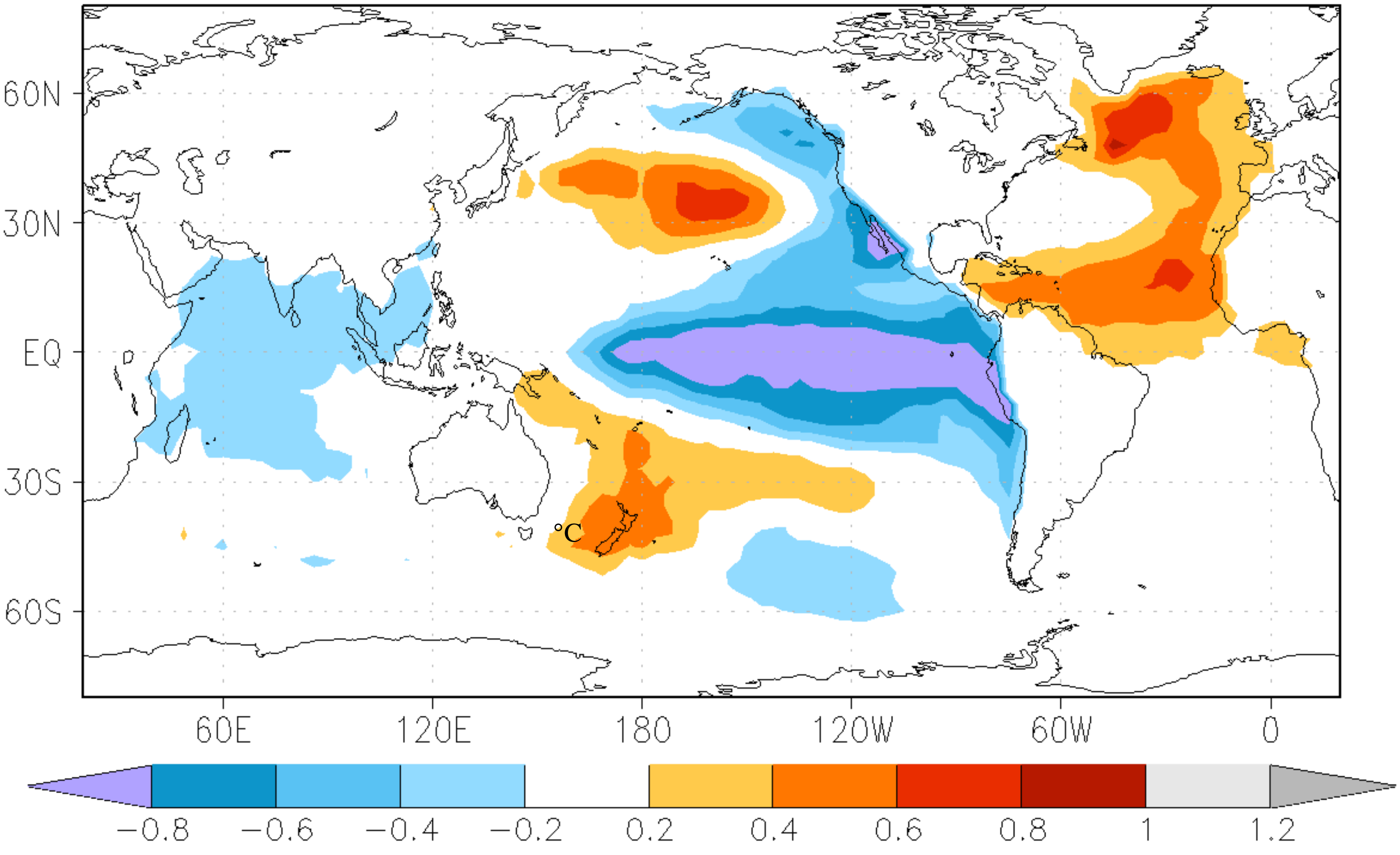
- AWP errors are grave in IPCC-AR4 models
- Could they improve from improving the precipitation over Amazon?
- Is ocean transport erroneous?
- AWP is projected to receive less rainfall than now in late 21st century: Could this be a result of the West Pacific warm pool winning the competition of getting a larger share of organized convection to maintain the general circulation in these models?

IASCLIP Modeling and Prediction Issues Related to Drought

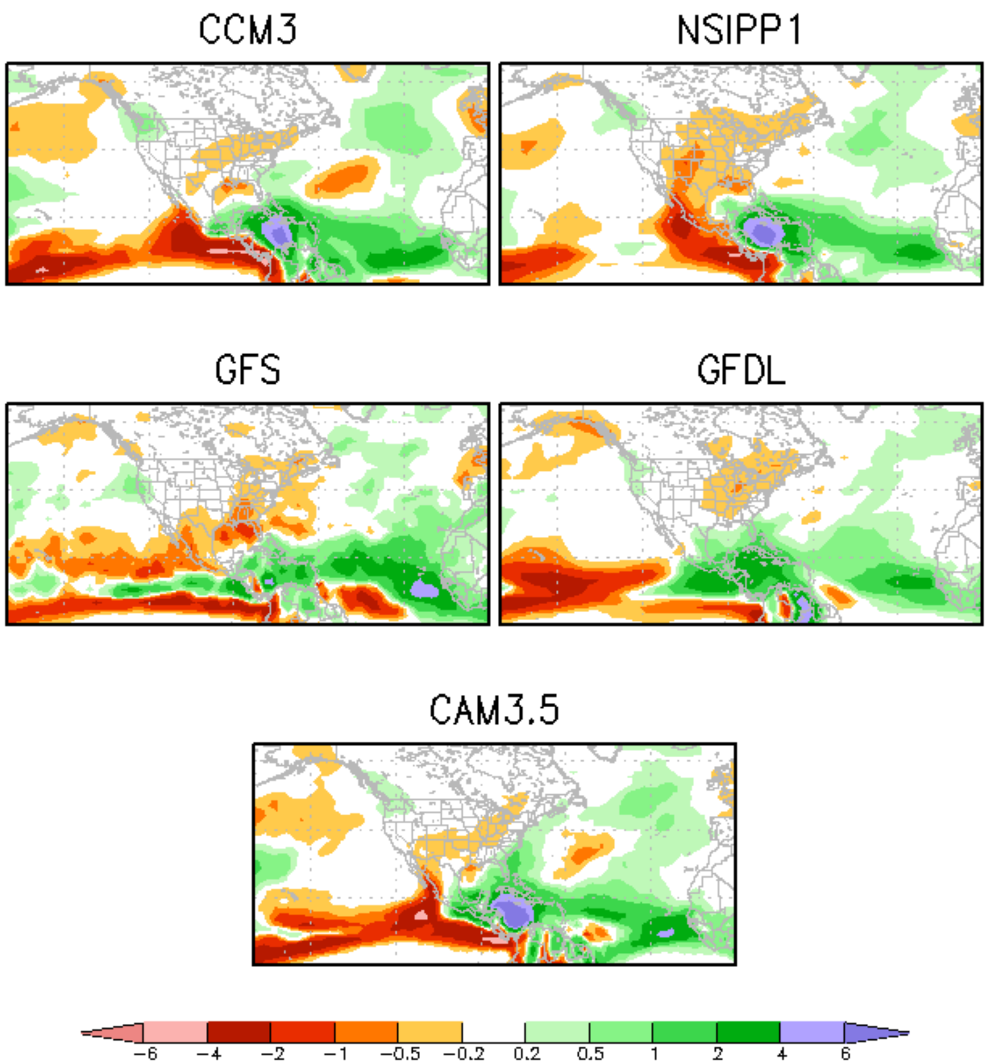
S. Schubert NASA/GMAO

- Some results from the USCLIVAR drought working group model simulations
- Each model was forced with the same idealized SST anomalies consisting of the leading REOFs of the annual mean SST
- Some notes on the forcing:
  - The SST forcing anomalies are added to a climatological annual cycle (the anomalies themselves have no annual cycle - they are held fixed)
  - The REOFS are computed form annual mean SSTs based on the period 1901-2004
- As an example we show some results from forcing the models with the combination of a cold Pacific and warm Atlantic: this combination seems to produce the greatest drought response over the US
- We highlight here some of the uncertainties in the response to SST anomalies (as measured by the differences in the model responses) with a focus on North America and the IAS region during SON
- Further information about the simulations may be found at:
  - http://gmao.gsfc.nasa.gov/research/clivar_drought_wg/index.html

Optimal SST Forcing for US Drought

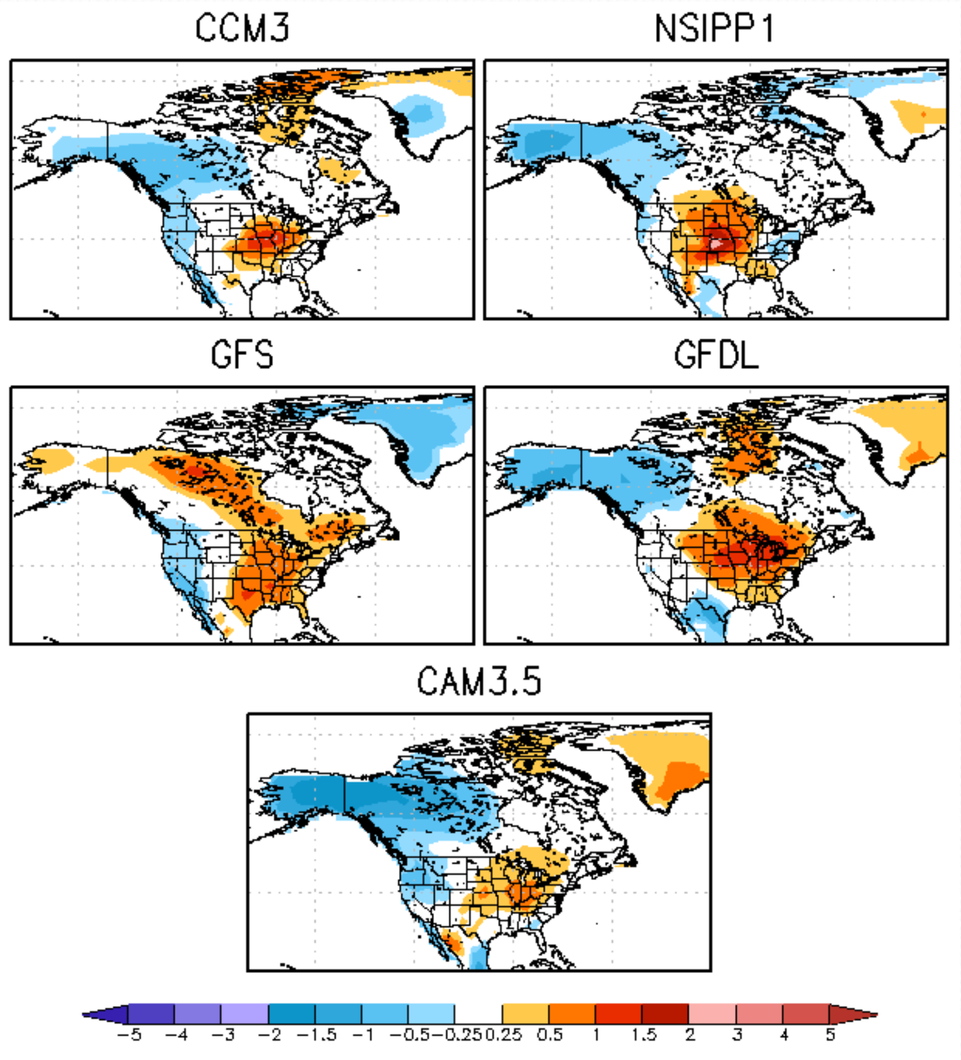


Precipitation Response (mm/day) During SON



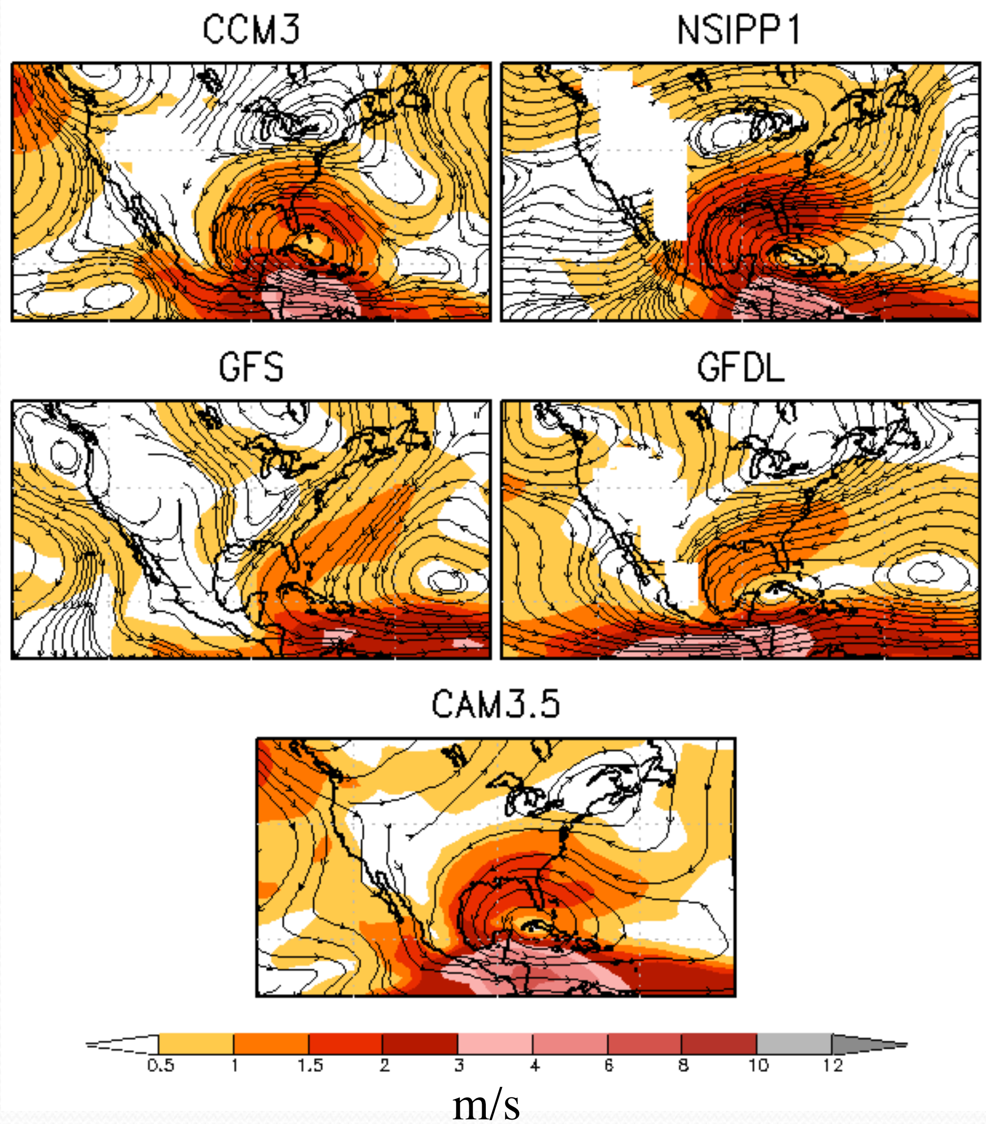
mm/day

Surface Temperature Response (°C) During SON

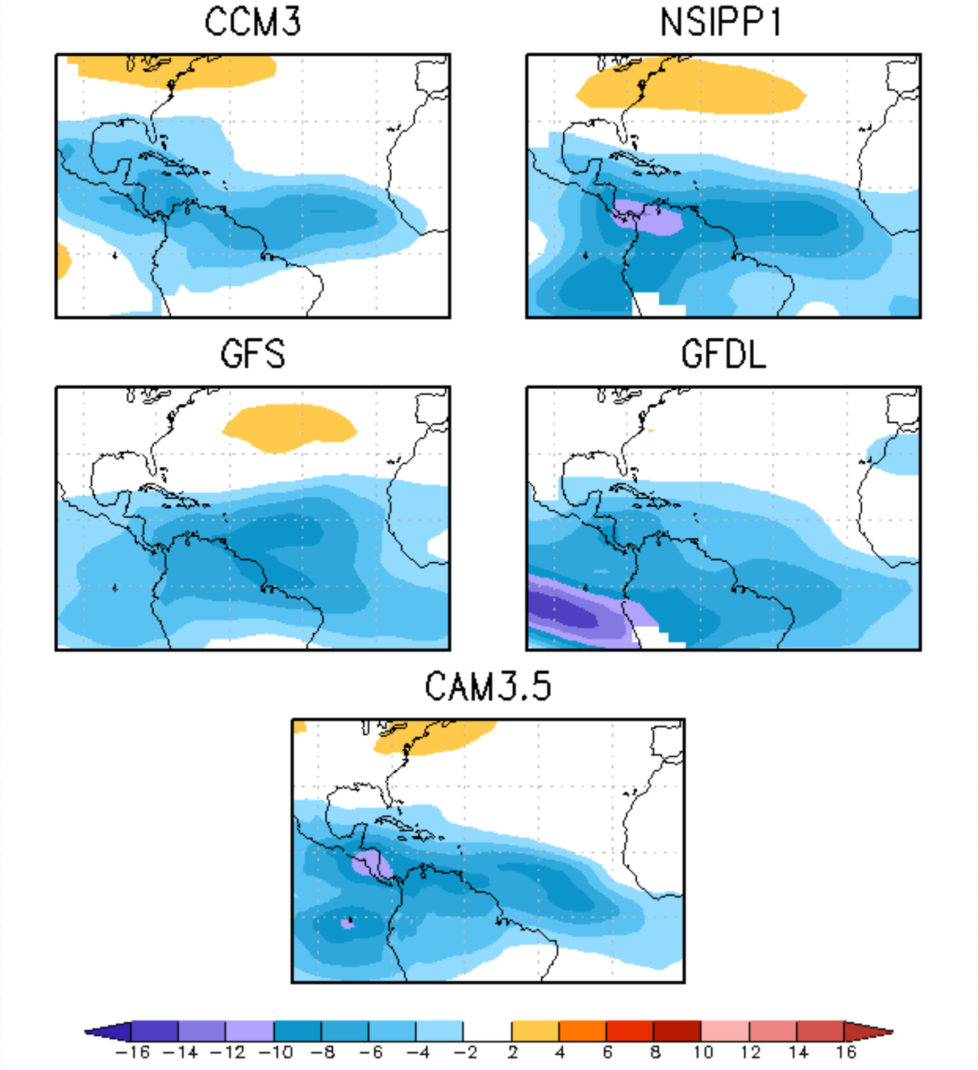


°C

850mb Wind Speed (m/s) and Streamlines During SON



200mb - 850mb U-wind (m/s) Response During SON



m/s

Summary

- For cold Pacific and warm Atlantic SSTA:
- A robust signal of drought over US
- More model uncertainty in P than in Ts
- Weakening of the NASH uniform across models but with subtle differences
- Increased easterly vertical shear over MDR

IASCLIP Modeling and Prediction Issues Related to Hurricanes

J. Schemm, L. Long, T. Knutson, T. Larow
(NCEP, GFDL, COAPS)

CFS T382 Hurricane Season Experiments

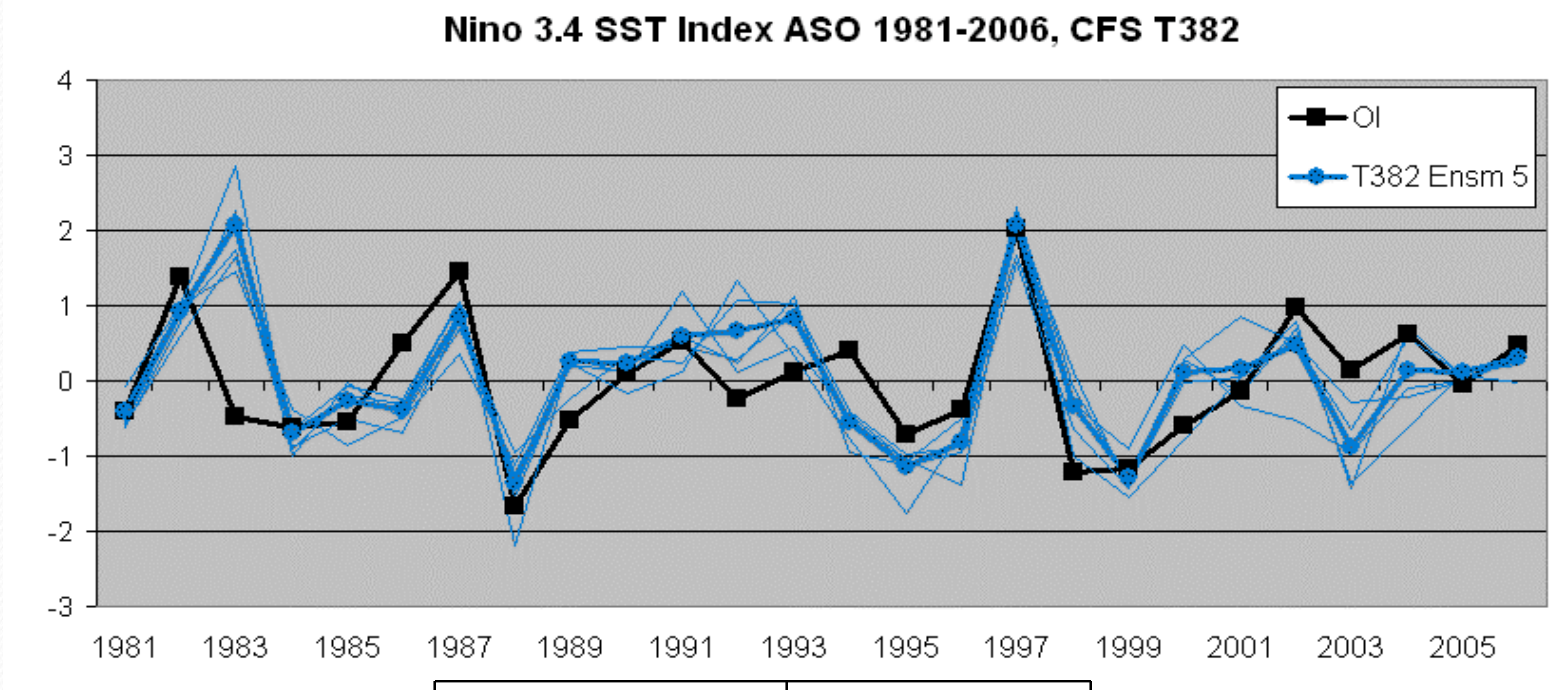
1. One of the FY07/08 CTB internal projects

2. AGCM - 2007 operational NCEP GFS in T382/L64 resolution
   LSM - Noah LSM
   OGCM - GFDL MOM3

3. All runs initialized with NCEP/DOE R2 and NCEP GODAS.
   Initial conditions at 0Z, Apr. 19-23 for 1981-2008.
   Forecasts extended to December 1.

4. Tropical cyclone detection and tracking methods by Camargo and Zebiak (2002)

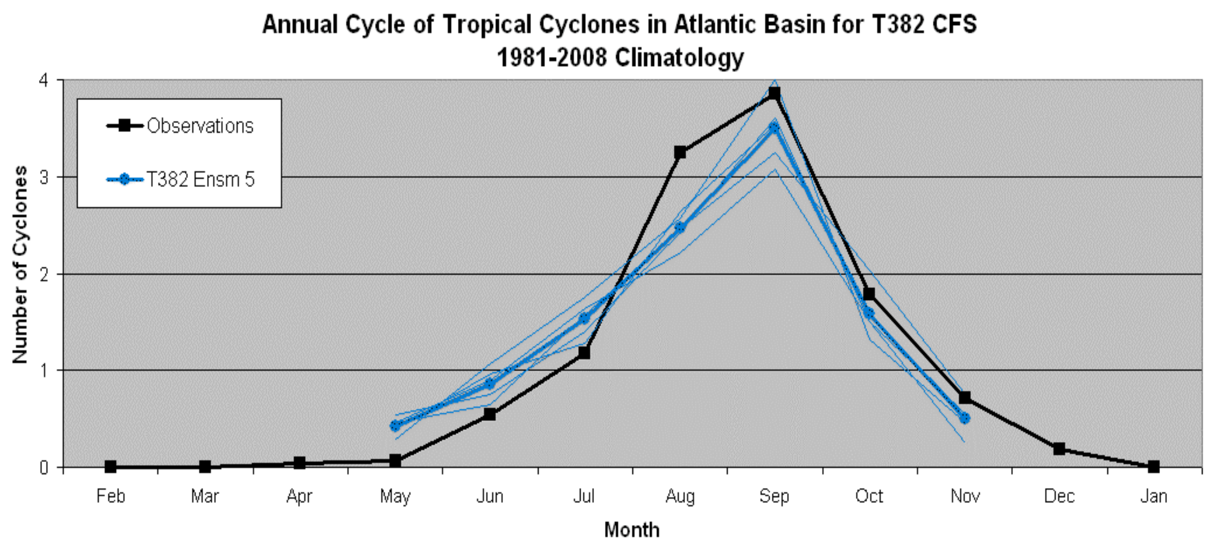
ASO Nino 3.4 SST Index

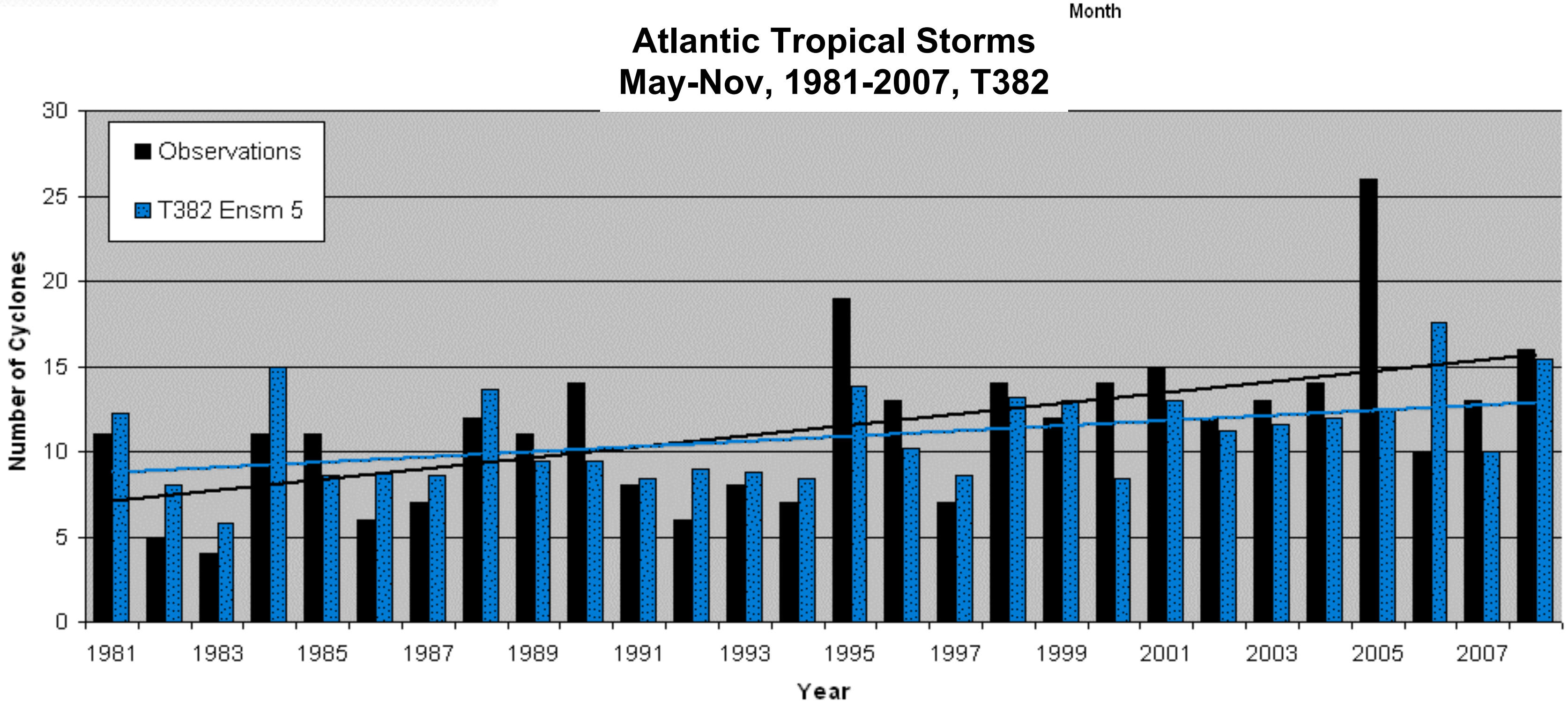


T382	Correlations
IC=0419	0.69
IC=0420	0.60
IC=0421	0.63
IC=0422	0.45
IC=0423	0.56
April Ensm 5	0.63

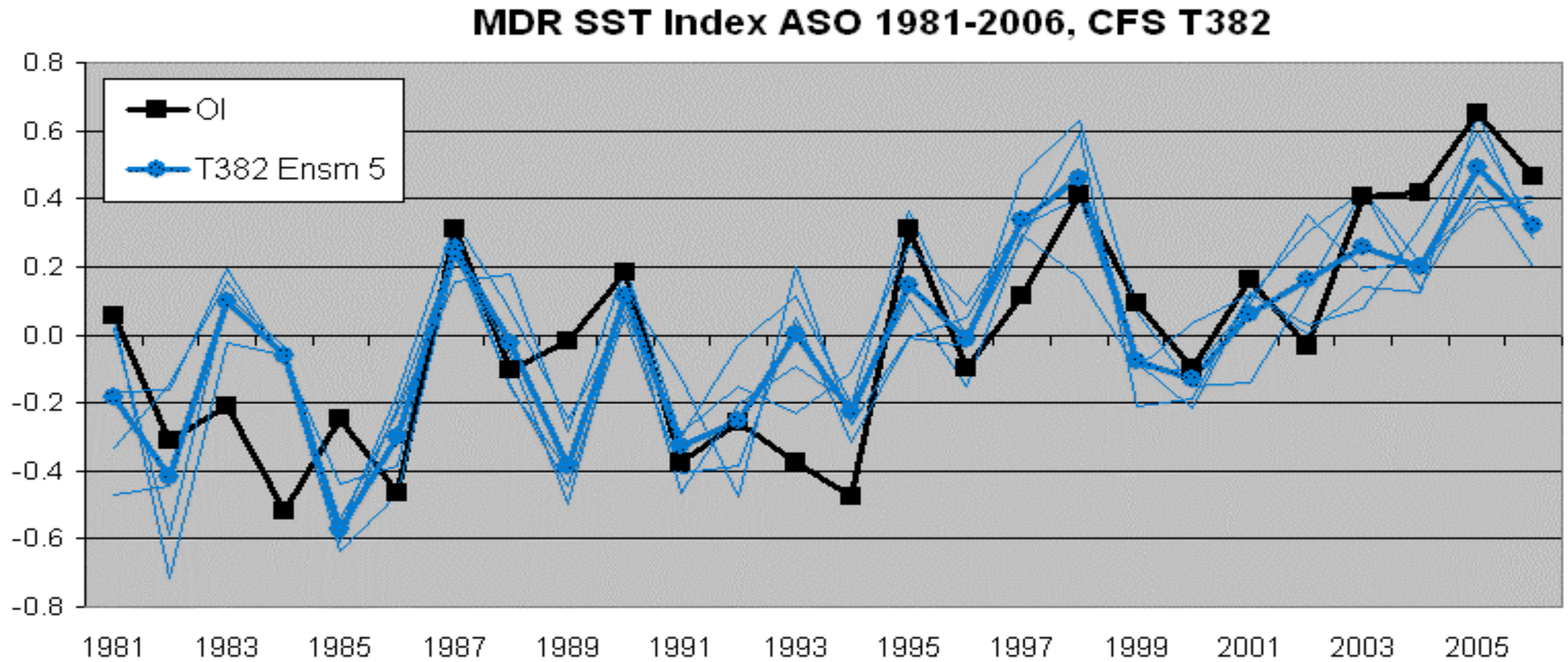
Red = Statistically Significant at 0.95

Atlantic Basin





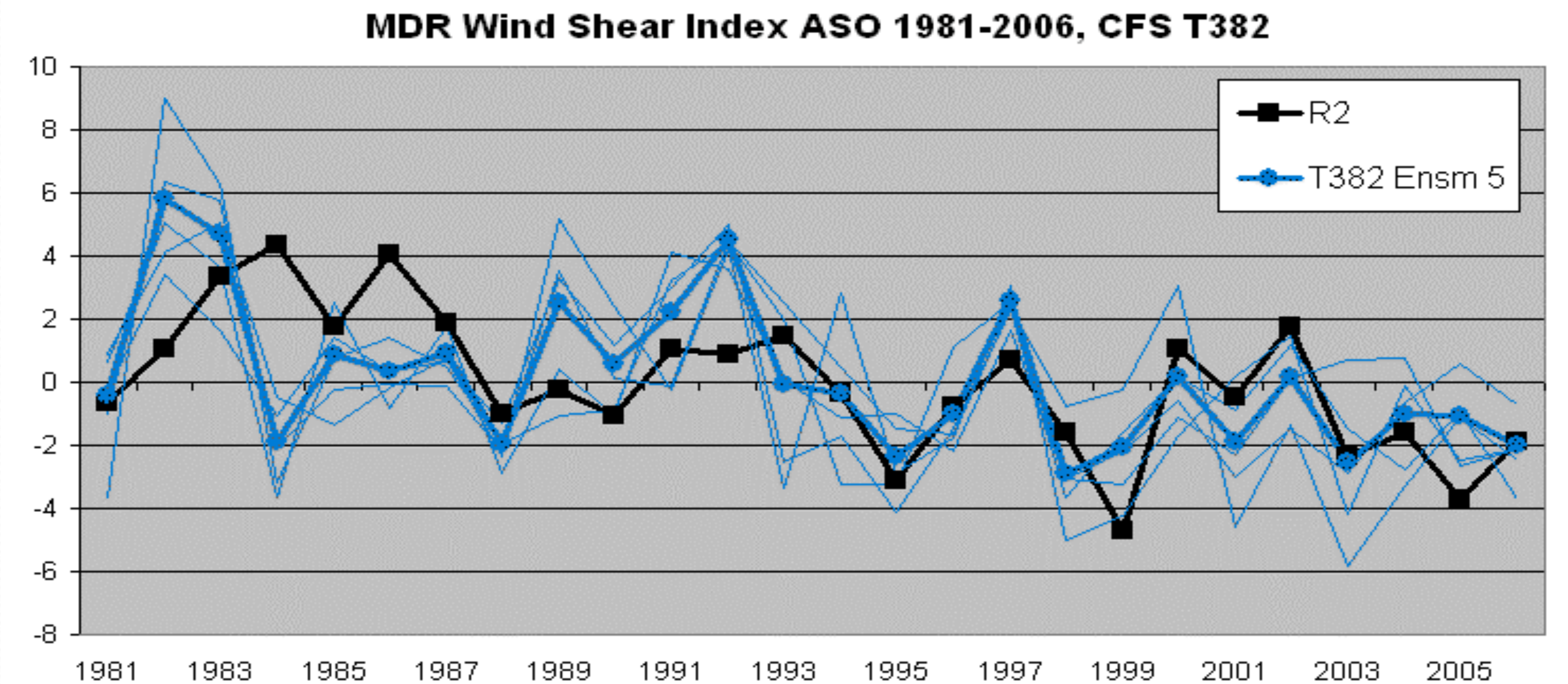
ASO Atlantic MDR SST Index



T382	Correlations
IC=0419	0.64
IC=0420	0.65
IC=0421	0.77
IC=0422	0.71
IC=0423	0.72
April Ensm 5	0.77

Red = Statistically Significant at 0.95

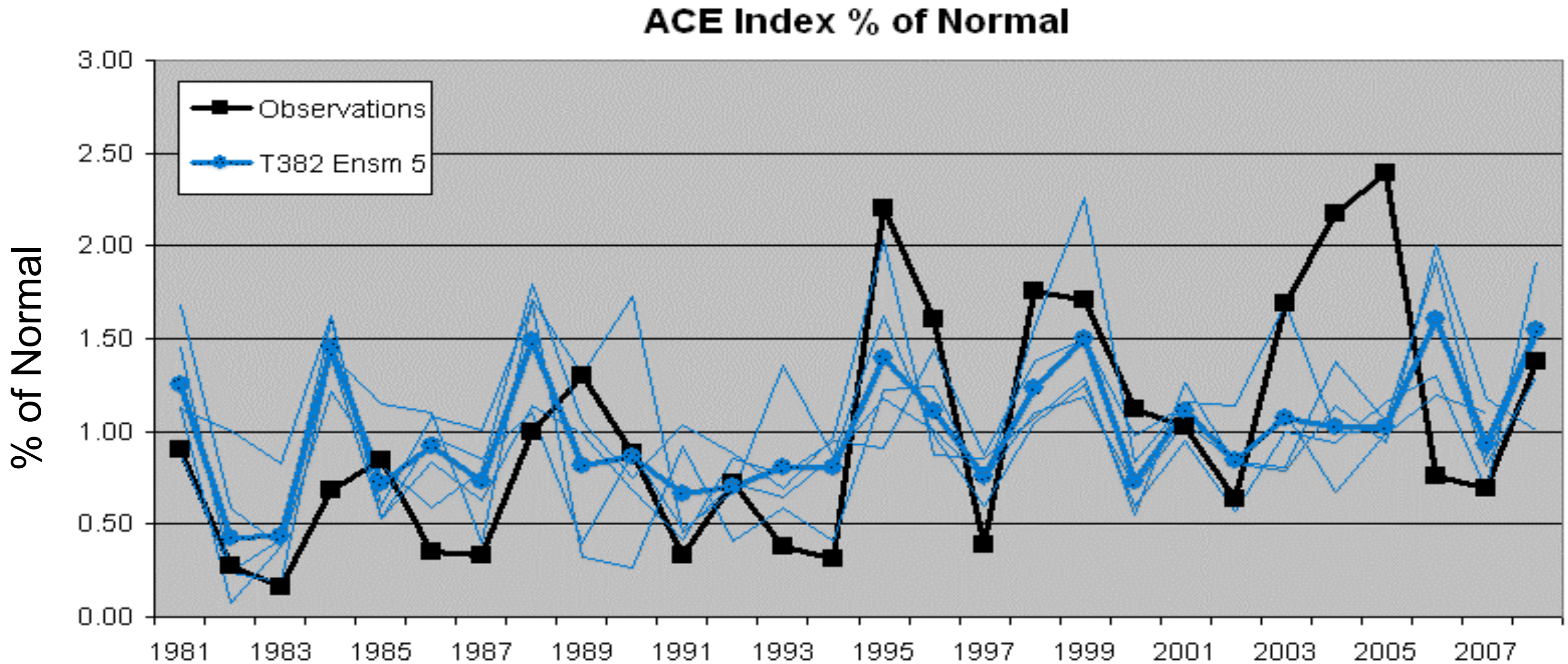
ASO Atlantic MDR Shear Index



T382	Correlations
IC=0419	0.47
IC=0420	0.39
IC=0421	0.47
IC=0422	0.40
IC=0423	0.41
April Ensm 5	0.50

Red = Statistically Significant at 0.95

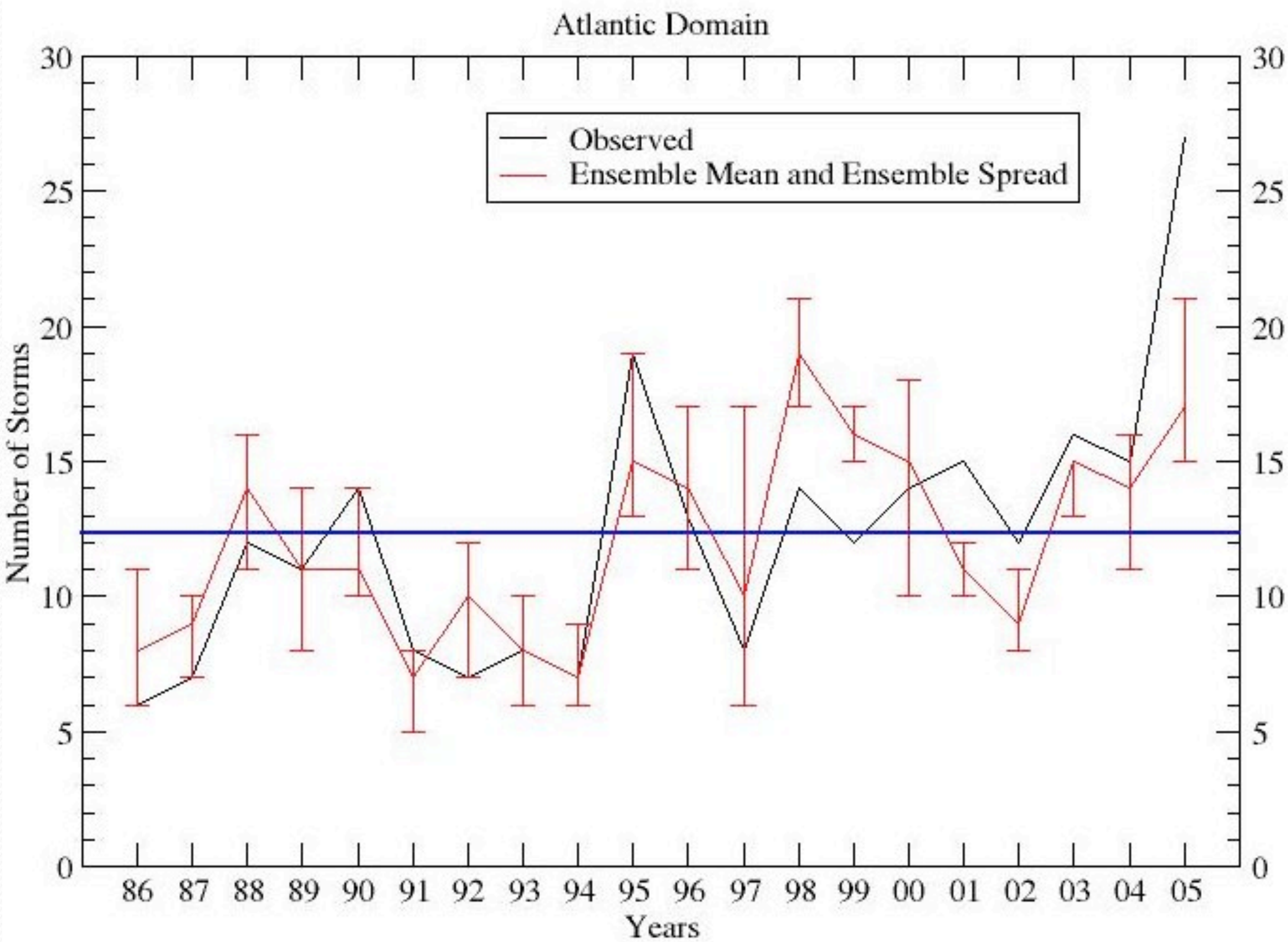
Atlantic Basin ACE Index



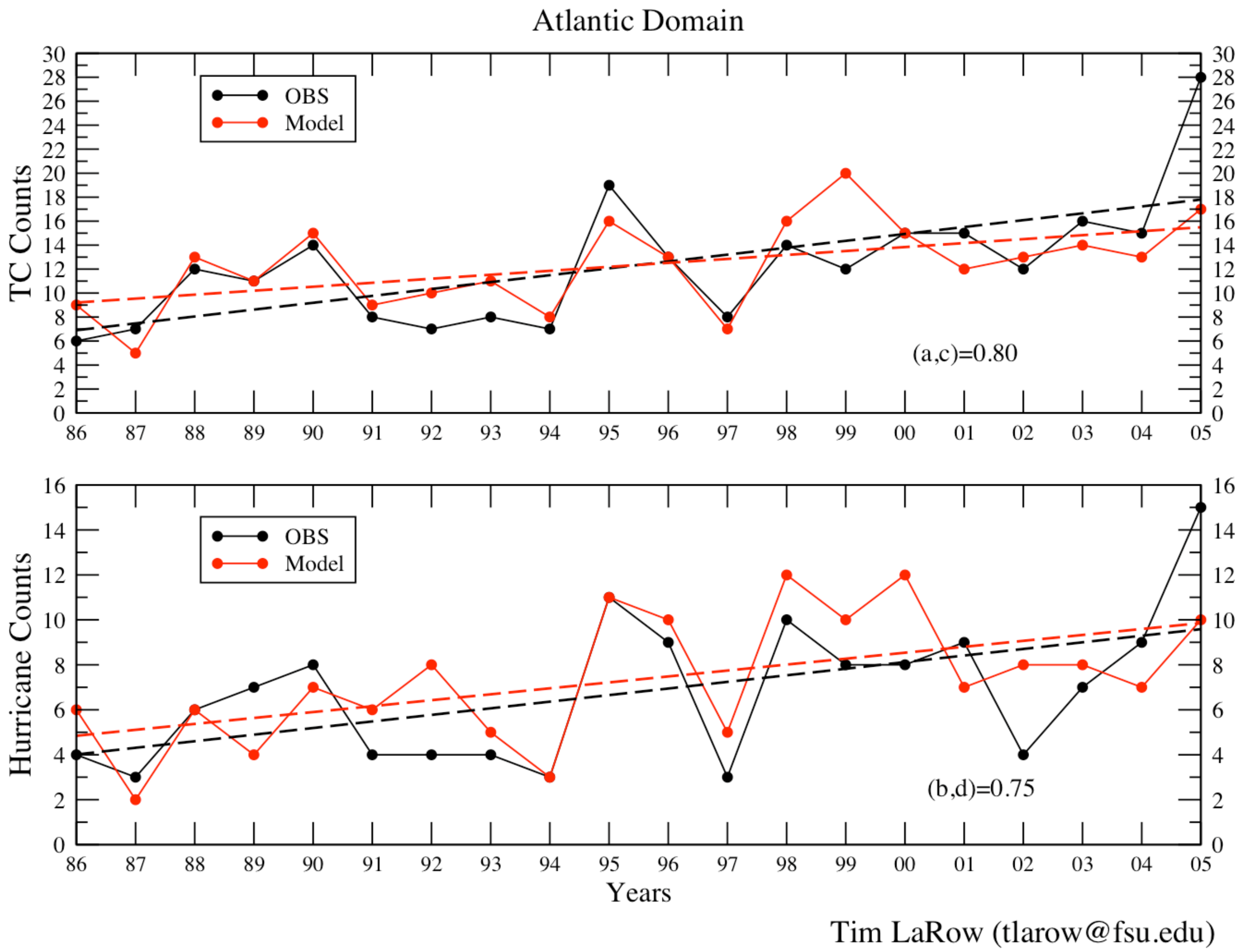
N=27 N=13 N=13

Correlations	Total	81-93	94-06
IC=0419	0.47	0.05	0.23
IC=0420	0.58	0.70	0.15
IC=0421	0.28	0.00	0.48
IC=0422	0.49	0.70	0.30
IC=0423	0.59	0.88	0.60
April Ensm 5	0.62	0.70	0.38

Red = Statistically Significant at 0.95

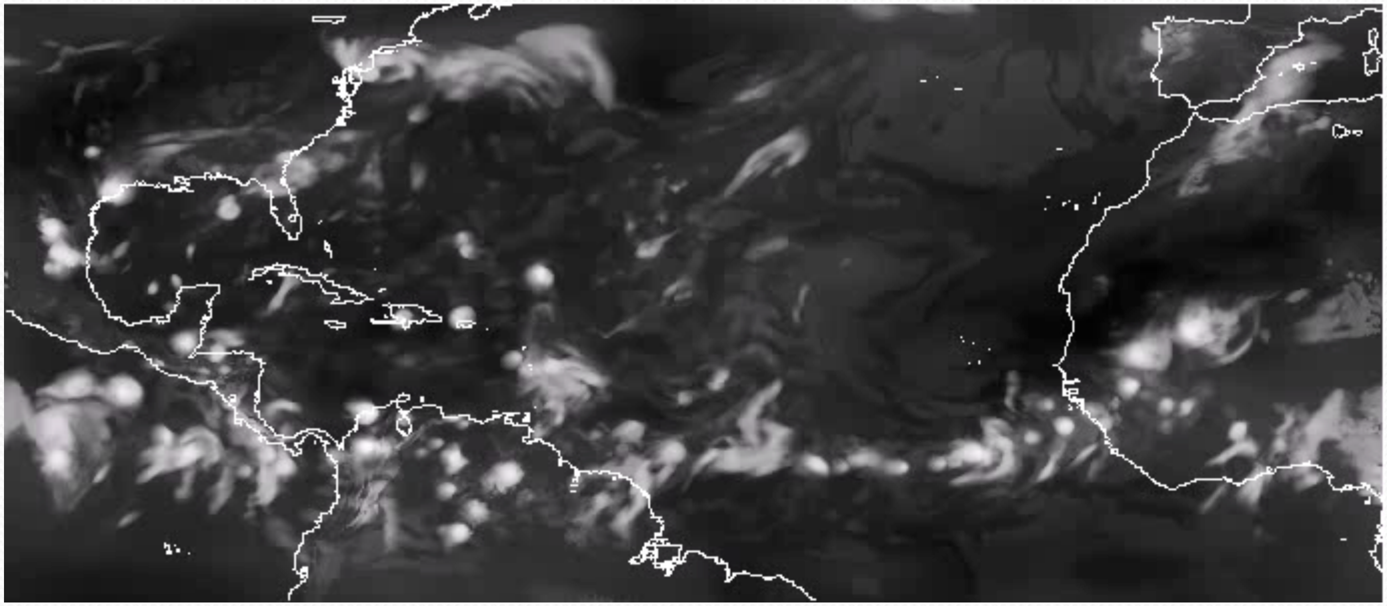


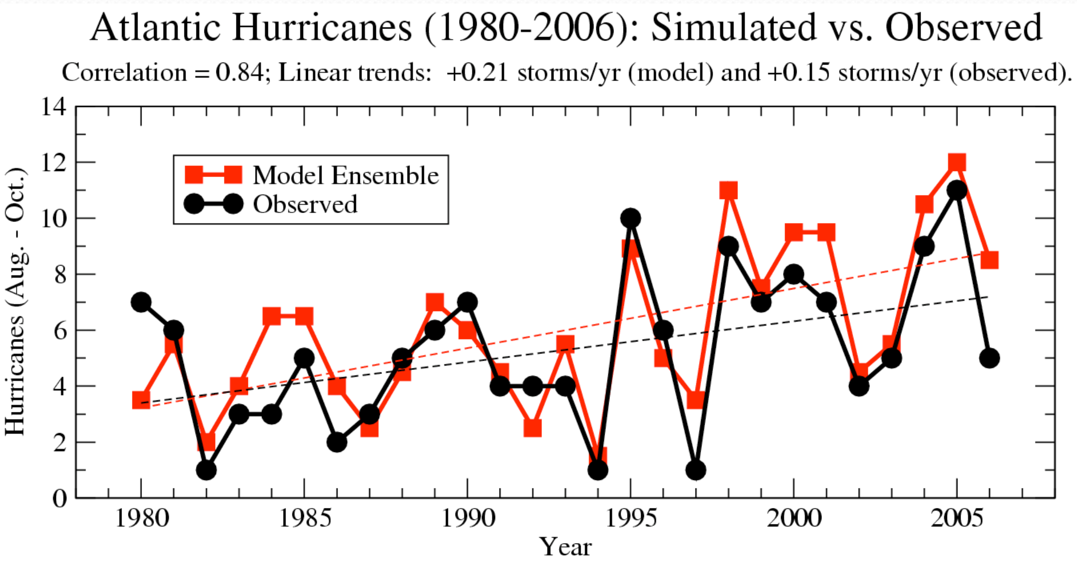
FSU GSM forced with observed SST



FSU GSM with CFS bias corrected SST

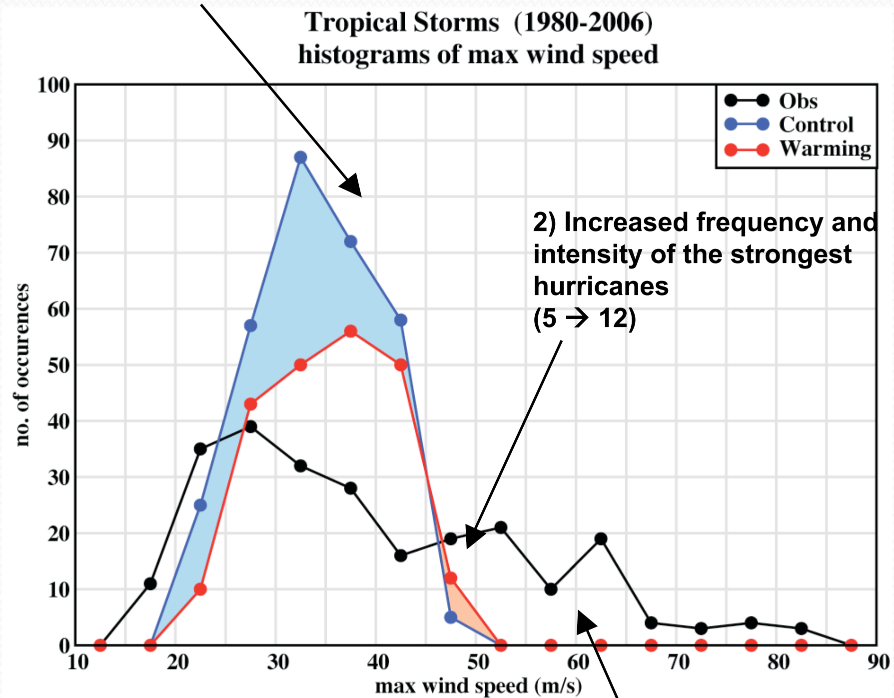
GFDL Zetac Model: 18-km grid regional model for Atlantic hurricane season simulations, nudged toward large-scale (wave 0-2) NCEP Reanalyses





The regional model projects a *decrease* in Atlantic hurricane and tropical storm *frequency* for late 21st century, downscaling from an IPCC A1B climate change scenario (18-model ensemble):

1) Decreased frequency of tropical storms (-27%) and hurricanes (-18%).

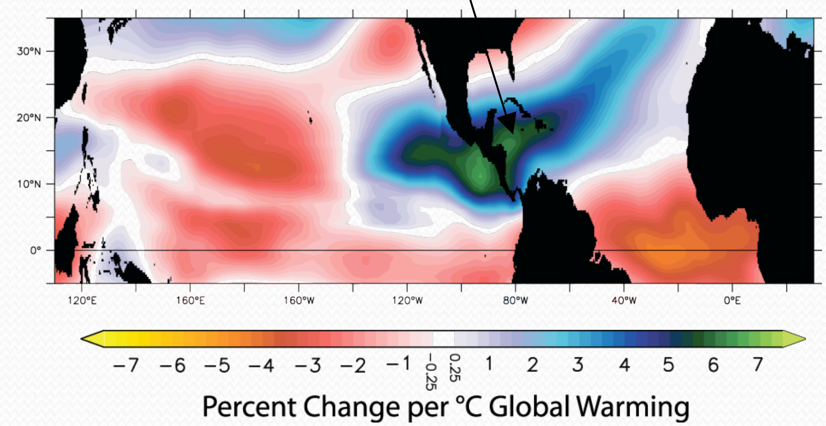


2) Increased frequency and intensity of the strongest hurricanes (5 → 12)

3) Caveat: the regional model does not simulate hurricanes as strong as those observed.

Source: Knutson et al., *2008*, Nature Geoscience.

Global models project increased vertical wind shear over the (warmer) Caribbean



Source: Vecchi and Soden, *Geophys. Res. Lett.*, (2007)

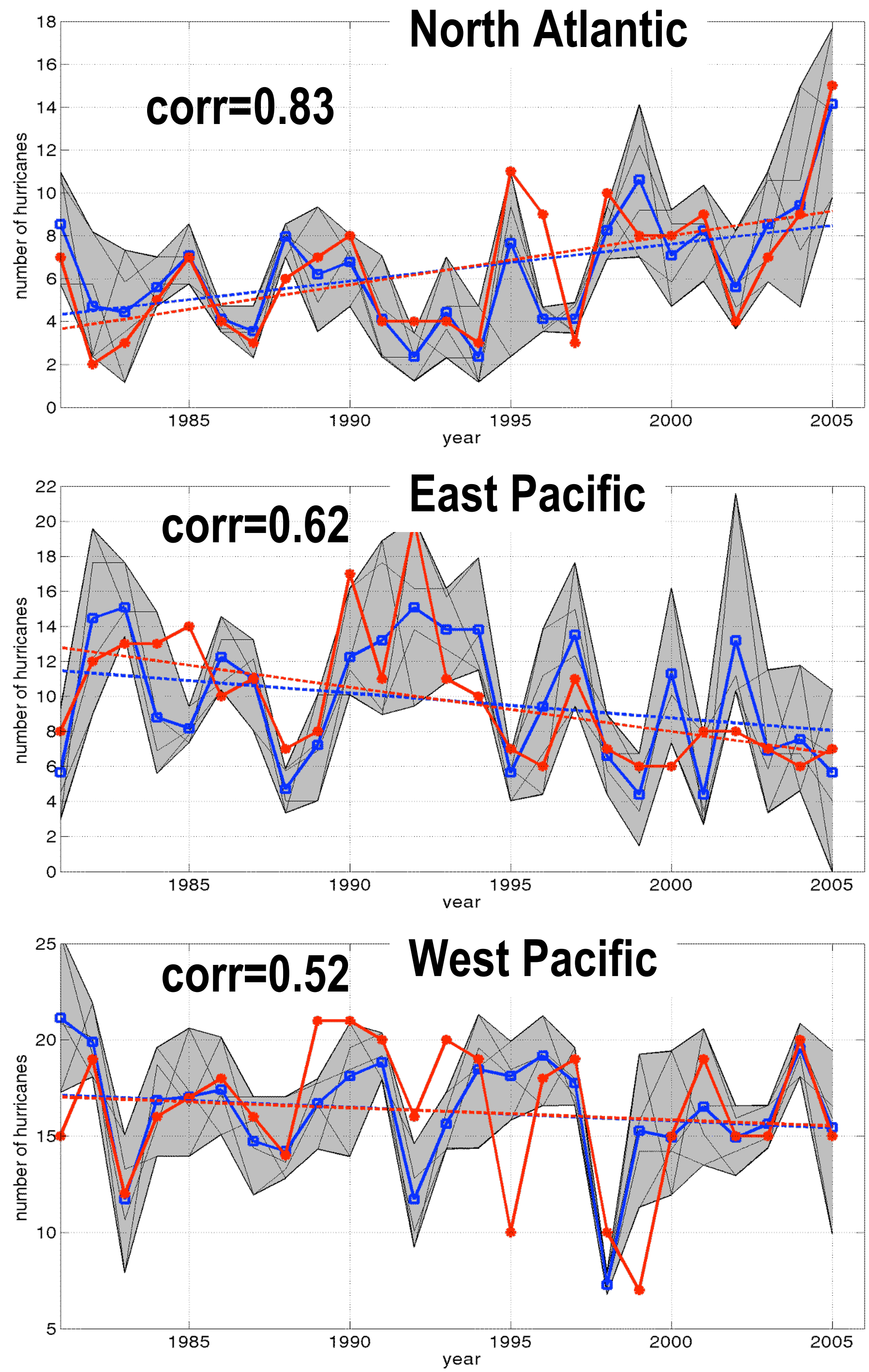
50-km grid global model with observed SSTs

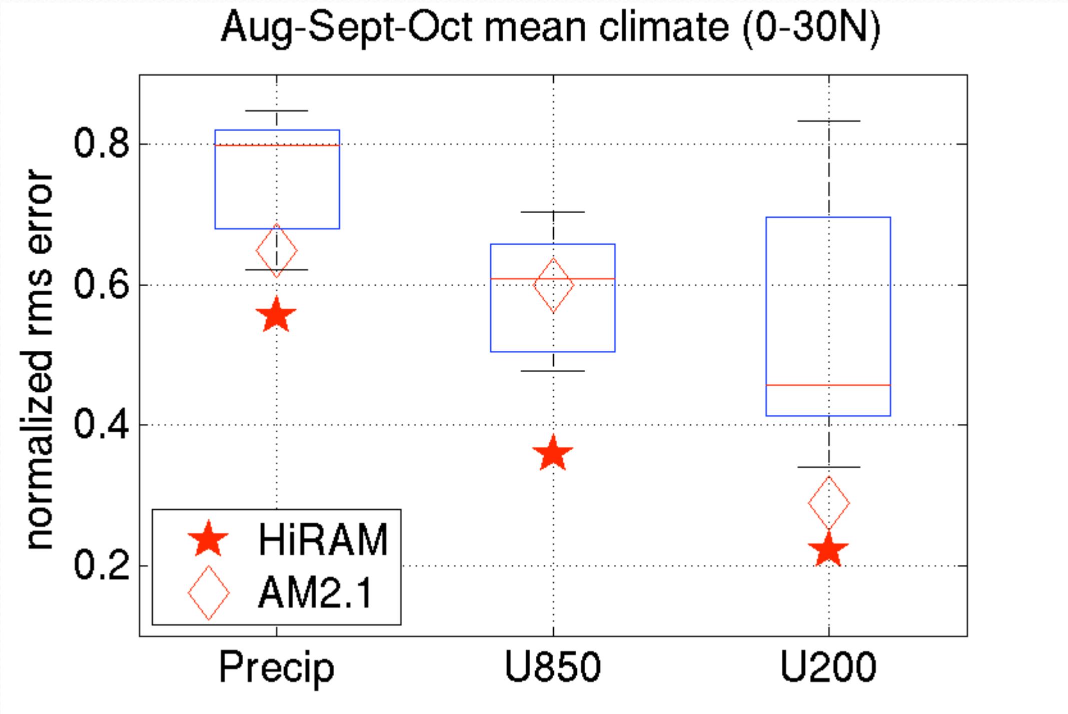
red: observations
blue: HiRAM ensemble mean
shading: model uncertainty

Hurricane counts for each basin are normalized by a time-independent multiplicative factor

The correlation for the South Pacific is ~0.3 and insignificant for the Indian Ocean

Zhao et al, submitted to J. Climate, 2009.





Aug-Sept-Oct mean climate (0-30N)
normalized rms error
0.8
0.6
0.4
0.2
HiRAM
AM2.1
Precip
U850
U200

Summary

- CFS at T382 resolution exhibits robust climatological seasonal cycle of tropical cyclone.

- Warming trend and intensification of hurricane activity in the Atlantic basin captured in the CFS hindcasts,uncoupled versions of the new GFDL model (50 km), FSU GSM (T126).

- CFS-T382, FSU GSM display fair level of skill in predicting interannual variability of seasonal storm activities based on the limited number of forecast runs.

Modern-Era Retrospective-Analysis for Research and Applications [MERRA] reanalysis:
lessons about process errors in the IASCLIP region

Brian Mapes

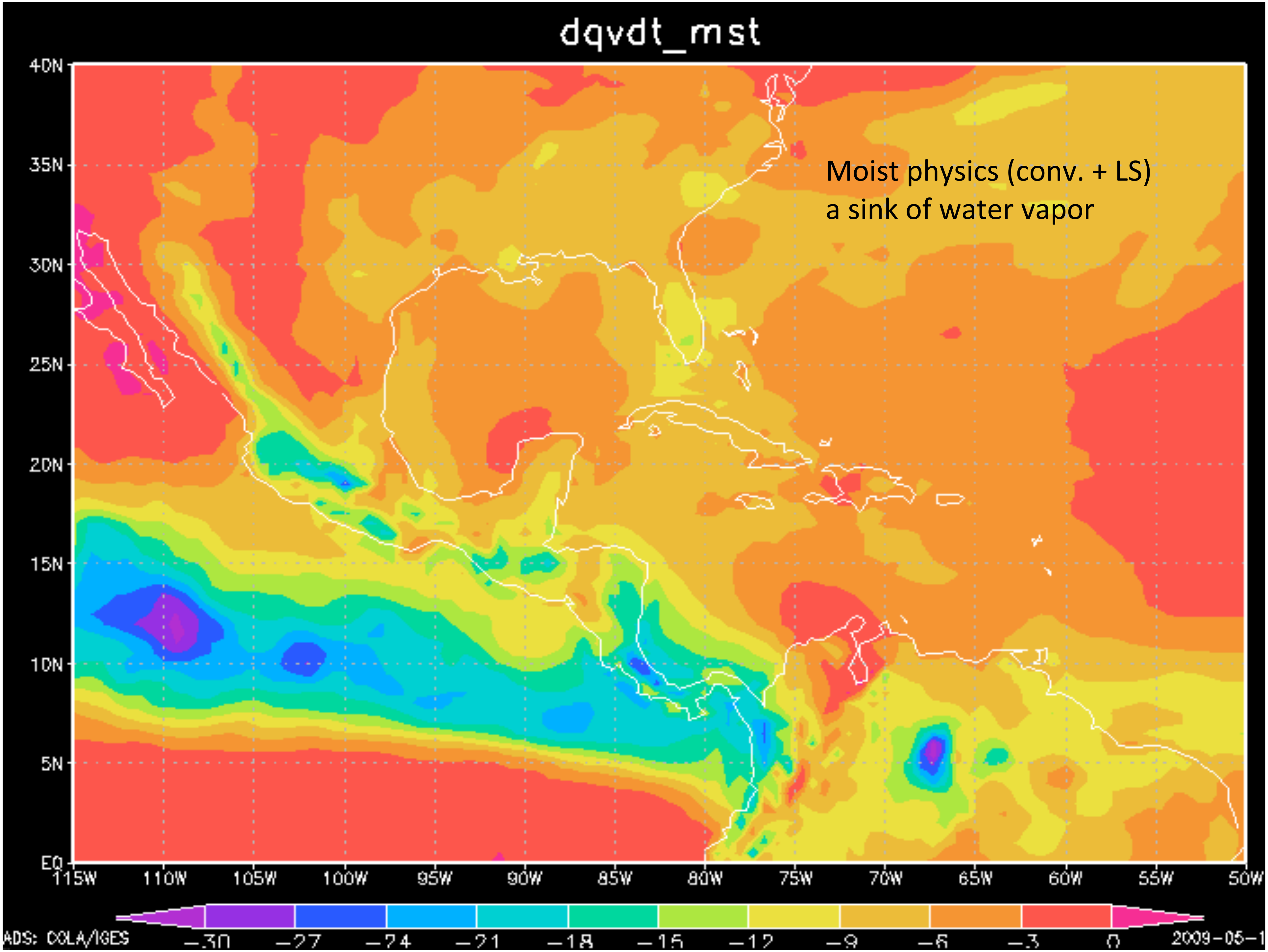
NASA's MERRA reanalysis

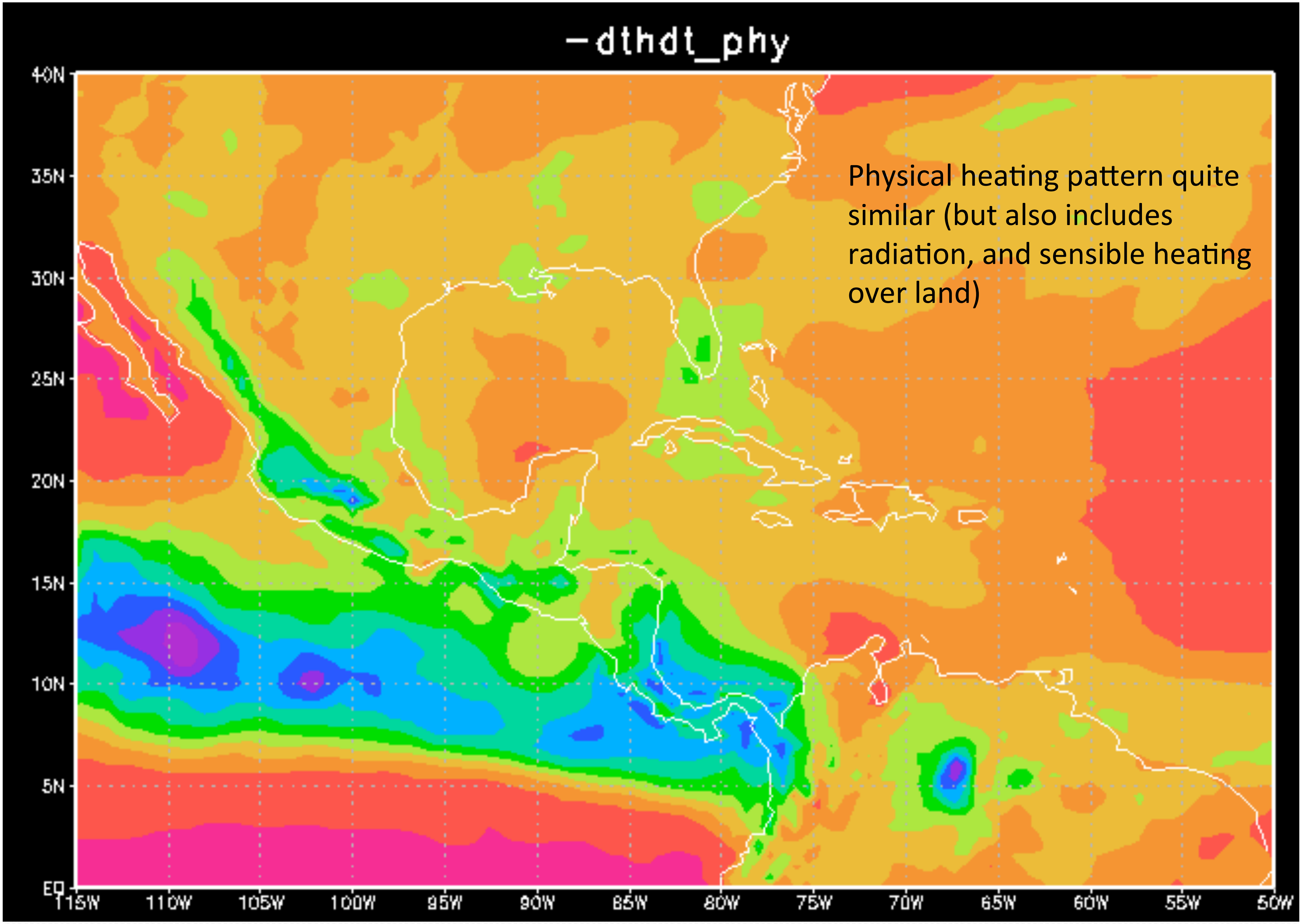
- "GEOS-5" GCM
- 1979-present planned (90% completed)
- ½ x 2/3 degree analysis
- analysis tendency fields are part of the MERRA dataset: these measure the ways in which the model fields need to be 'nudged' to keep the time evolution on track.
- Since dynamical tendencies are close to correct (flow and gradients are obs/analyzed),

- Analys. Tend. ~ -(phys. Error)

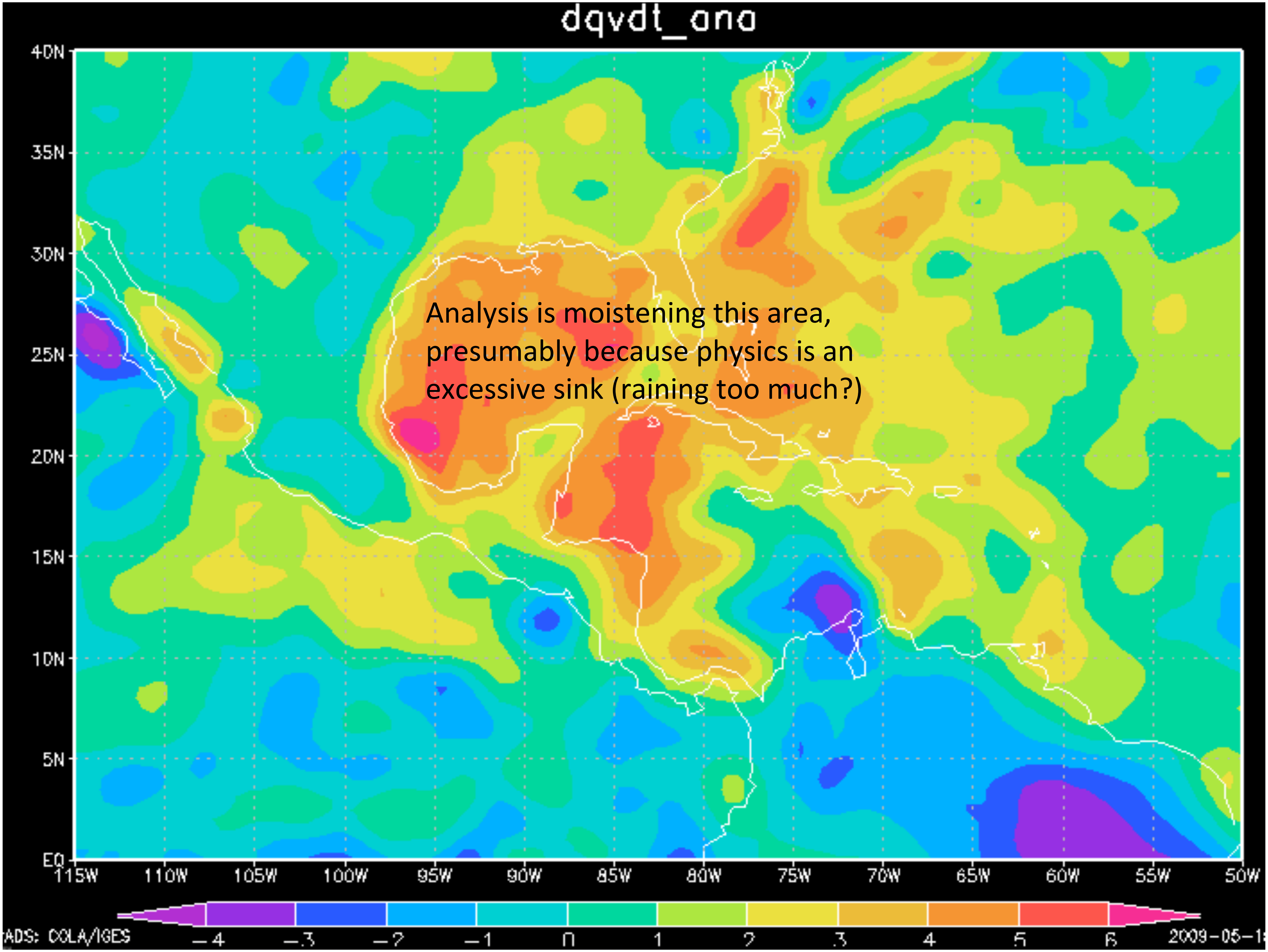
Vertically integrated tendency fields:

- Mst = moist physics (conv+LS)   (for qv)
- Phy = all physics schemes   (for theta)
- Ana = analysis tendency   (~ –phys. error)


dqvdt_mst
Moist physics (conv. + LS)
a sink of water vapor
40N
35N
30N
25N
20N
15N
10N
5N
EQ
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
65W
60W
55W
50W
-30
-27
-24
-21
-18
-15
-12
-9
-6
-3
0
GrADS: COLA/IGES
2009-05-1



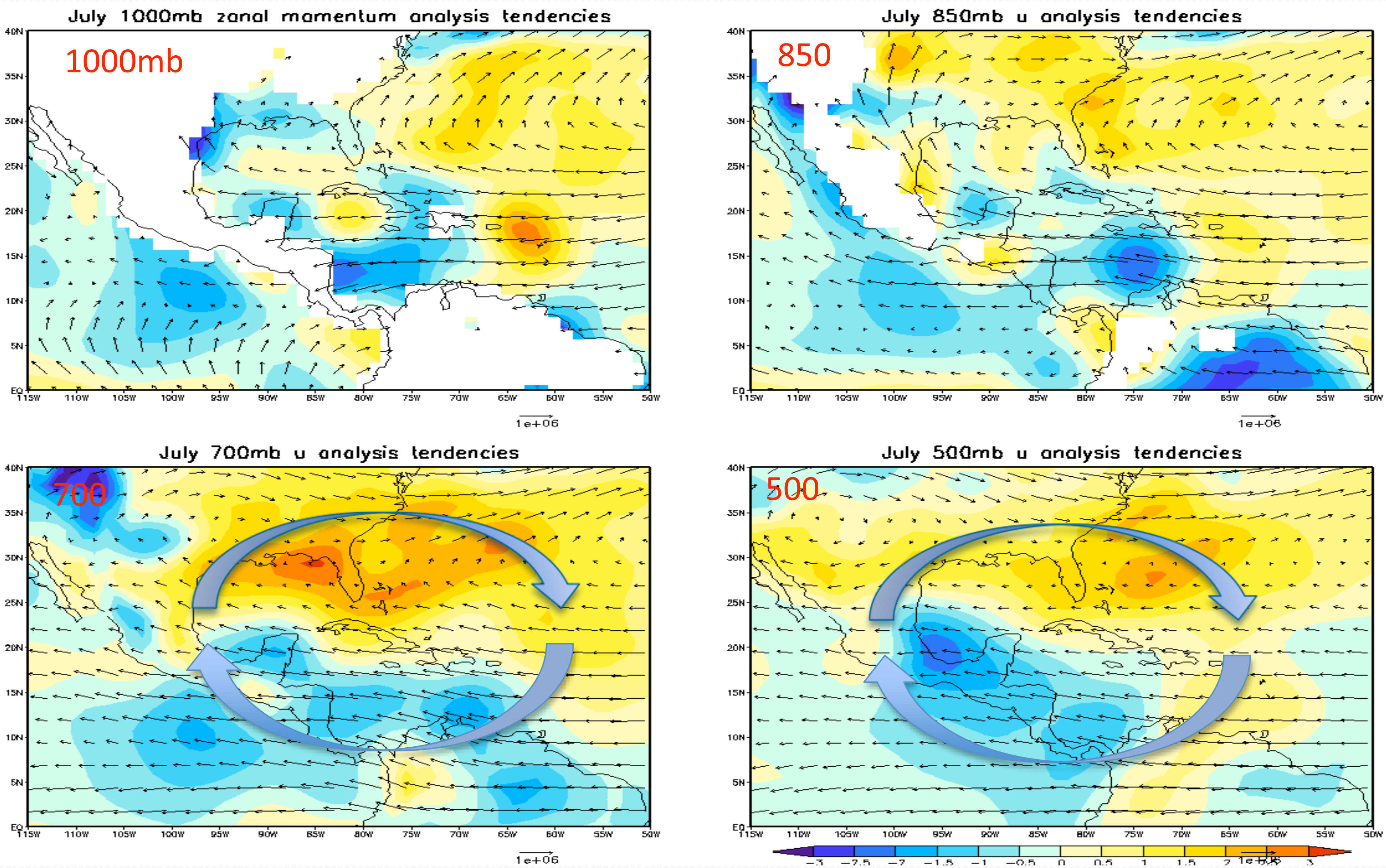
-dthdt_phy
40N
35N
30N
25N
20N
15N
10N
5N
EQ
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
65W
60W
55W
50W
Physical heating pattern quite similar (but also includes radiation, and sensible heating over land)


dqvdt_ana
Analysis is moistening this area, presumably because physics is an excessive sink (raining too much?)
40N
35N
30N
25N
20N
15N
10N
5N
EQ
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
65W
60W
55W
50W
-4
-3
-2
-1
0
1
2
3
4
5
6

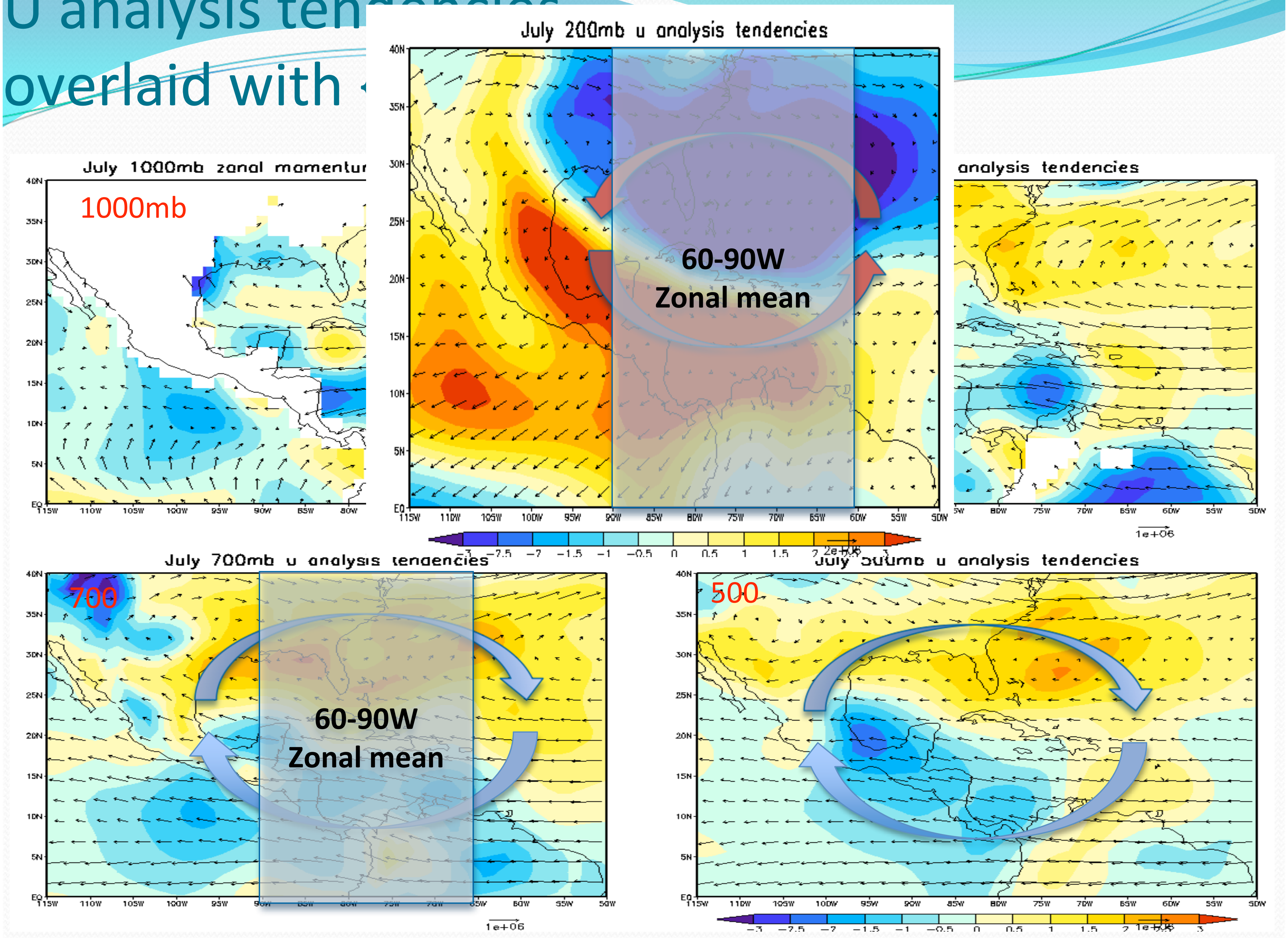
T tendencies make more sense vertically resolved

- T is a structural variable (mass field in geostrophic balance)
- Also have analysis tendencies of u,v
- Are the analysis increments of T and wind dynamically related?

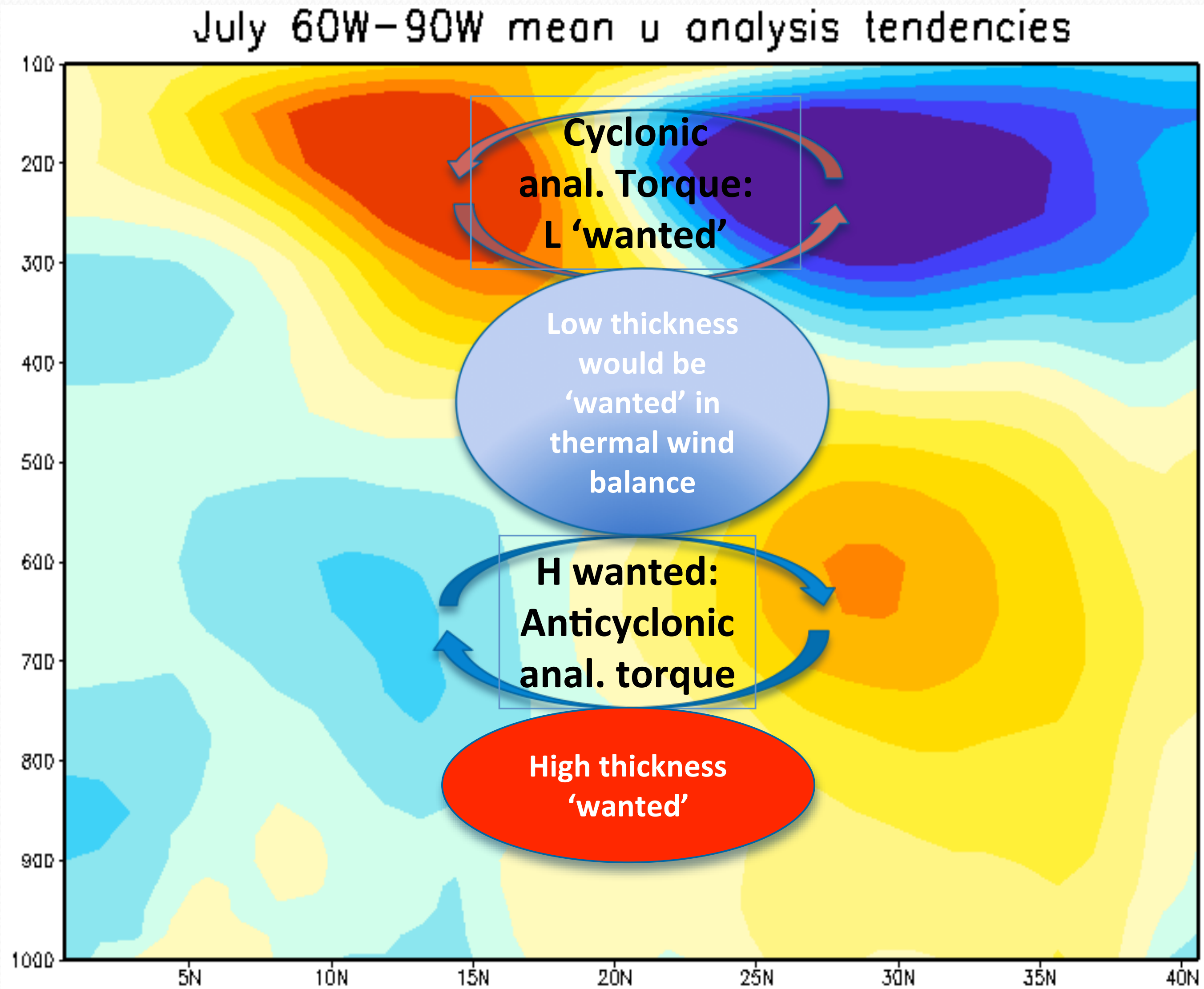
U analysis tendencies overlaid with {u,v} vectors



U analysis ten
overlaid with

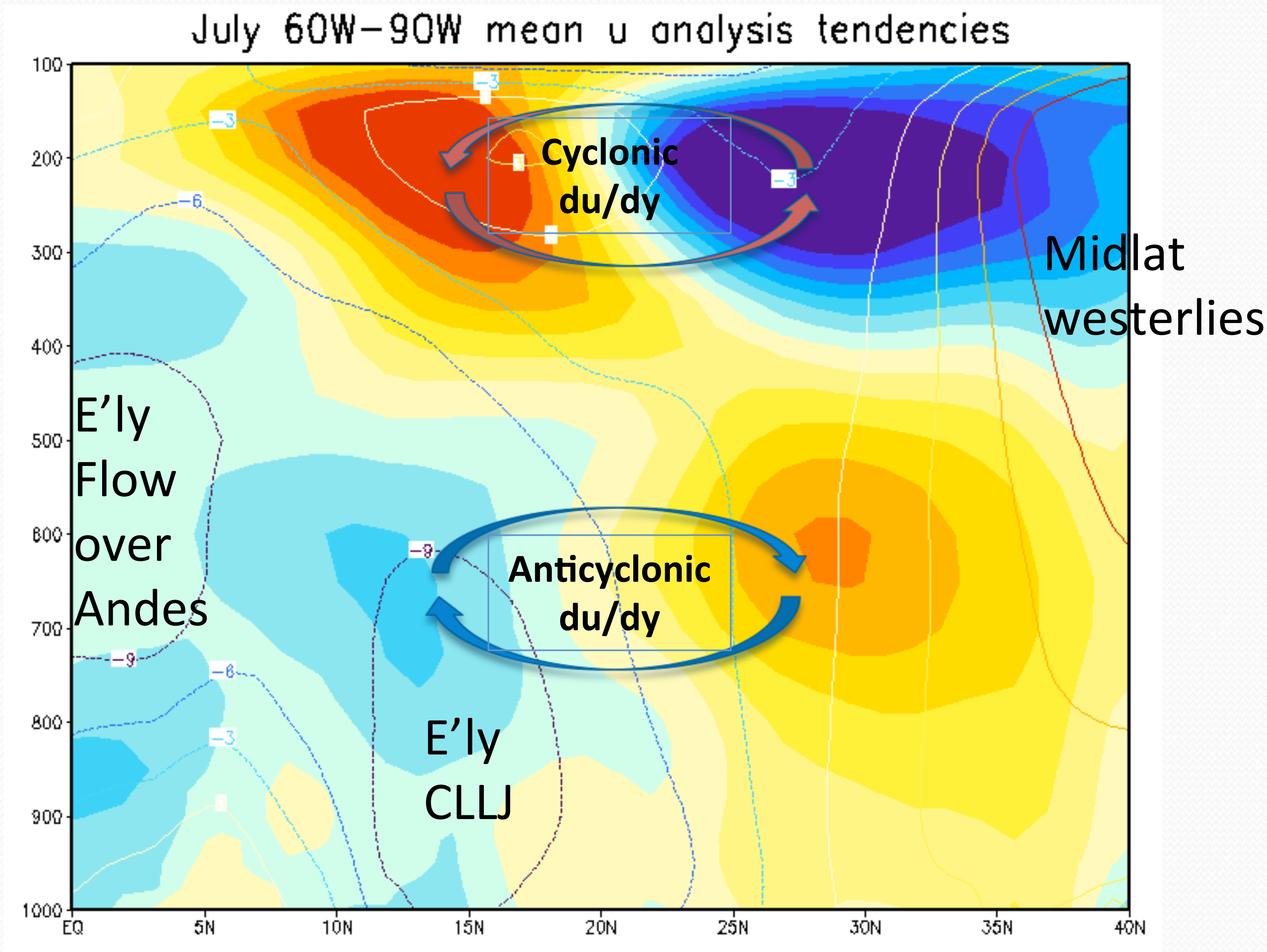


U analysis tendency:

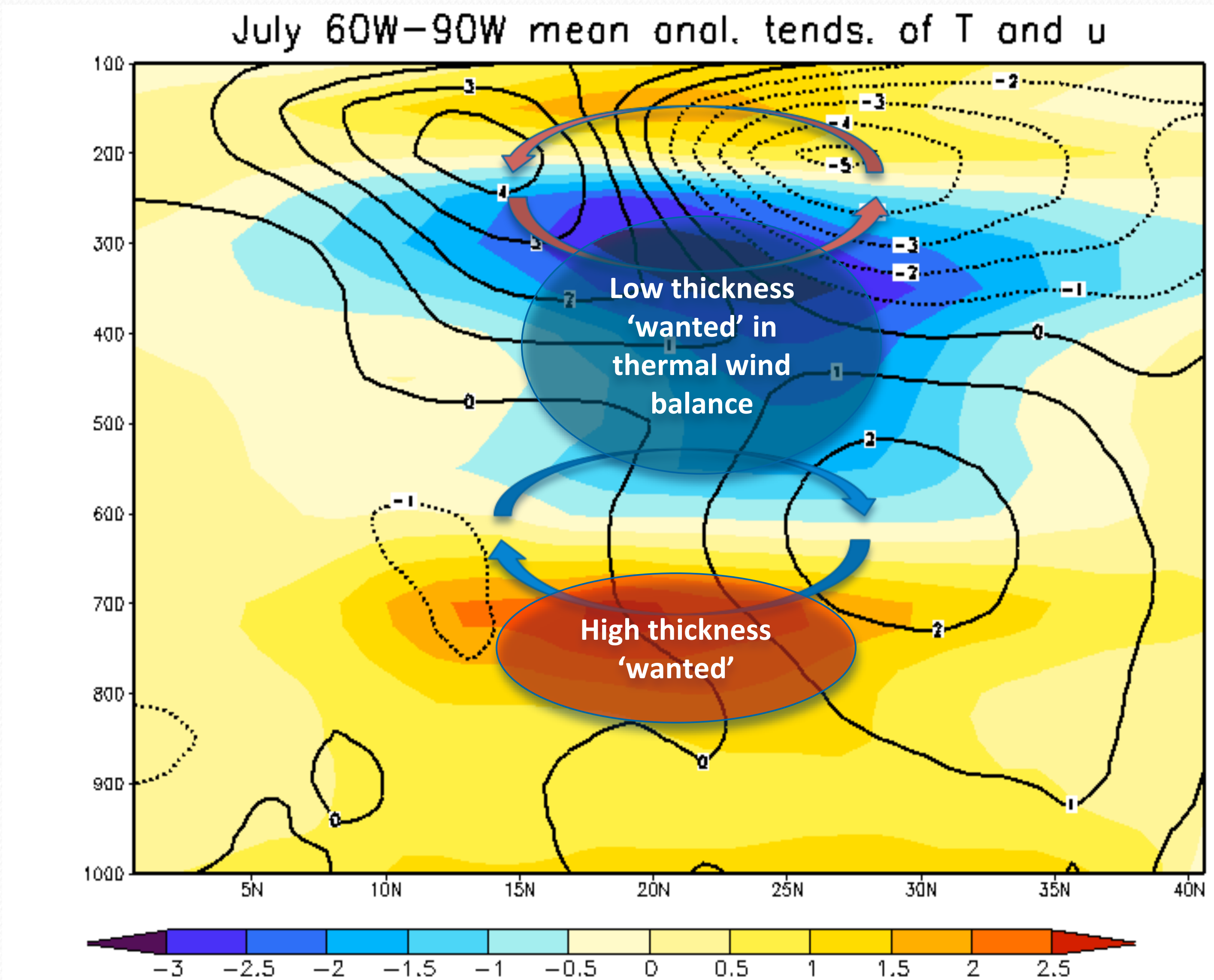


U wind analysis tendency profile

open contours are mean u

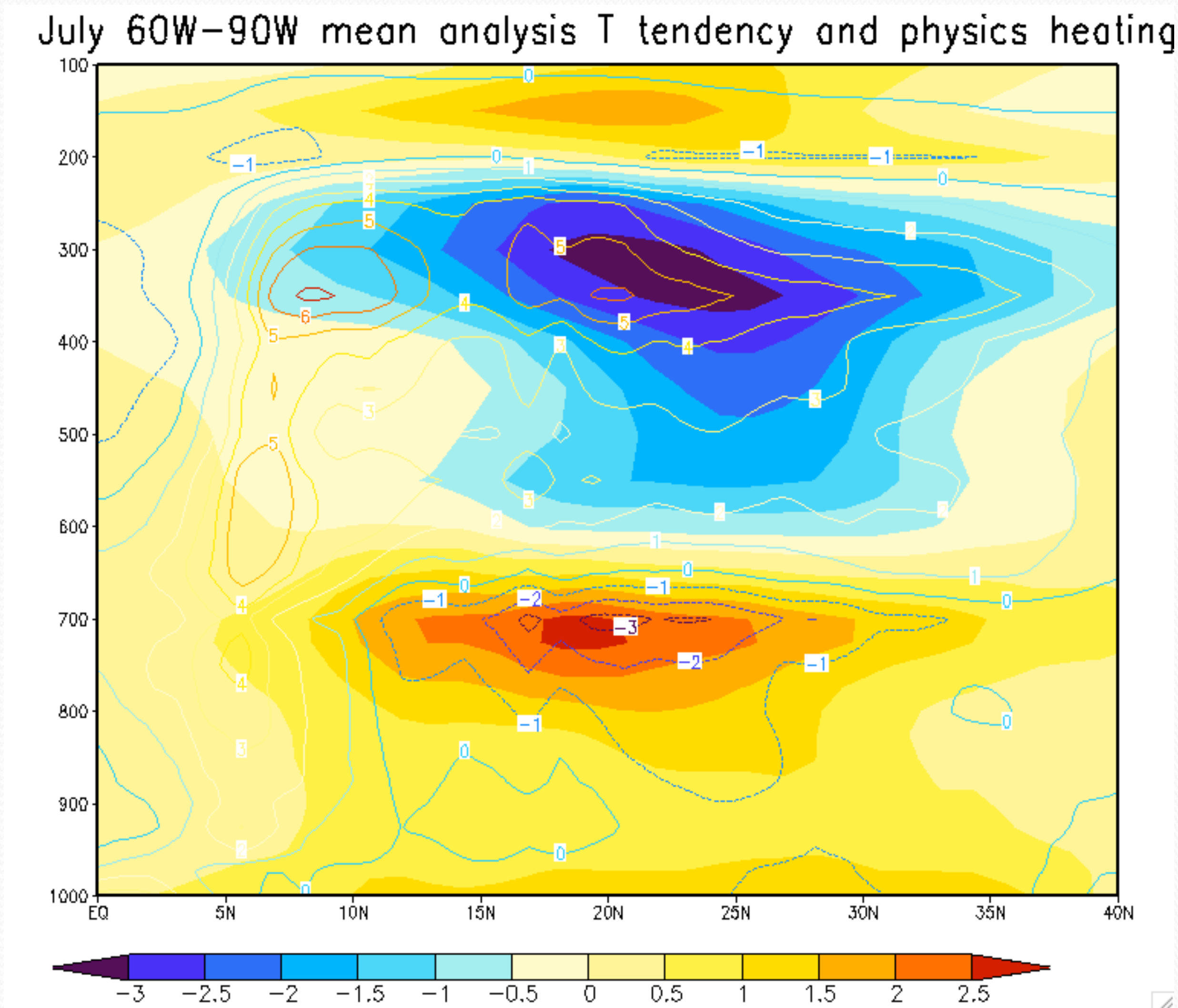


T analysis tendency agrees!

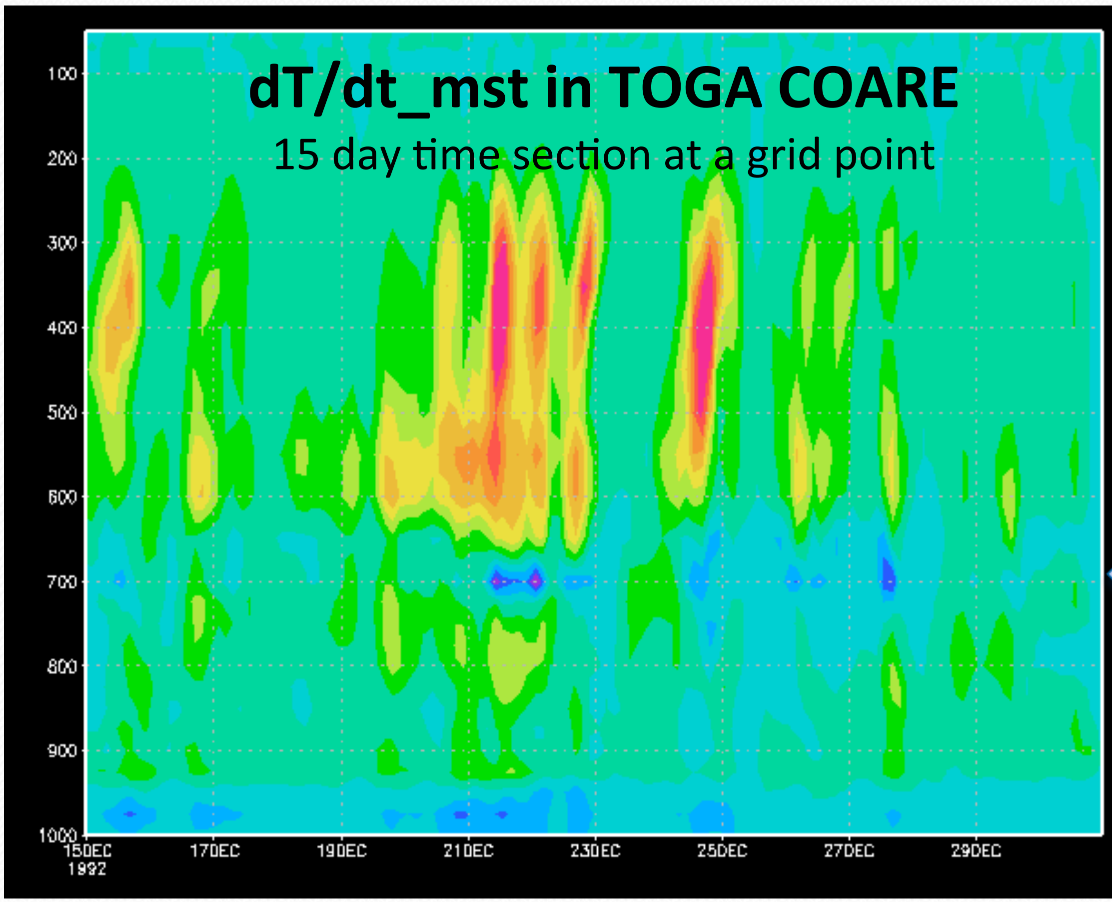


“too much” of deep convective heating

with its peculiar characteristic profile



GEOS-5 model's peculiar heating profile in tropical deep convection



Strange cooling spike at 700 is re-evap of precip

Summary

- Analysis *tendencies* ~ model process errors.
  - How are routine observations having to nudge this model to keep its state realistic & on track?
- IAS summer errors: too much deep convection in GEOS5
  - seen in excessive PW sink, fought by anal. Tendency
  - also in excessive (fought by analysis) circs. driven by
  - Too much of model's deep convective heating
    - with its hokey Q_1 profile → PV error profile 'fingerprint'

CFSR&R

K. Mo, NCEP/CPC

CFSRR- CFS reanalysis and seasonal reforecast project

- An ocean-atmosphere-land coupled system
- Atmosphere: T382L64 GFS
- Ocean: GFDL MOM4 ocean model (0.250 in the tropics and 0.50 globally)
- Land GLDAS Noah model with 4 soil layers
- Time: Jan1979-2009 and will continue in real time
- Data will be distributed after 6 months of completion (2010)
- Monitoring in CPC will switch from CFS to CFSRR
- NCEP will have a web site monitoring the Pan American Oceanic and atmospheric conditions_VAMOS unifying theme

Conclusions

- NCEP CFS is promising over IAS but has some typical problems of air-sea interaction bias, over bearing influence of ENSO
- Decadal variations in AWP not captured in CFS hindcasts
- IPCC-AR4 display some grave errors over AWP
- Robust signal of US drought, increased easterly shear over MDR, from cold Pacific and warm Atlantic
- Dynamical seasonal prediction of TC activity is showing encouraging results--new GFDL (HiRAM) Model is promising
- 21st century climate is projected to have reduced TC activity despite increased size of AWP?
- Analysis tendencies in MERRA reflect model bias: GEOS5 rains too much over IAS region
- CFSRR is coming out in 2010