Progress Towards Understanding and Predicting Weather and Short-term Climate Extremes at NASA's Global Modeling and Assimilation Office

To be presented at the
APEC Climate Symposium
"Climate prediction and applications: building adaptive capability to extreme climate events"

20-24 June 2010
APEC Climate Center
Busan, Republic of Korea

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[1]NASA/GMAO; [2]UMBC/GEST

GMAO Activities Addressing Climate Extremes

- High Resolution Global Atmospheric Modeling
  - Focus on weather/climate linkages:
  - Examples: tropical storms, snow storms
- Global Coupled Modeling
  - Sub-seasonal to decadal prediction
  - Contributions to national and international consolidated forecasts, IPCC
- Reanalysis – MERRA
  - Diagnosing variability from weather to decadal time scales
  - Example: stationary Rossby Waves and the 2003 European Heat Wave

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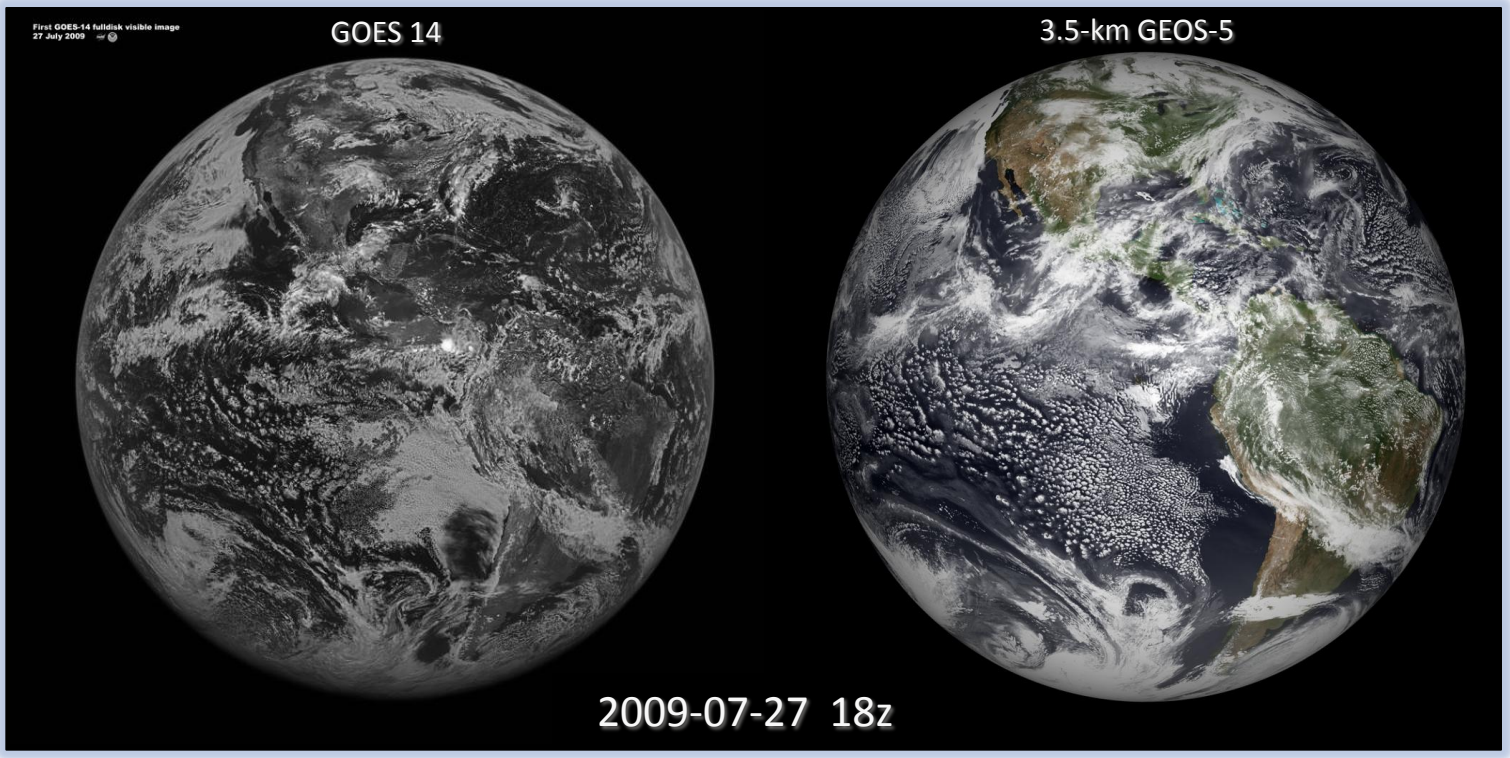
GEOS-5 → GEOS-6 development

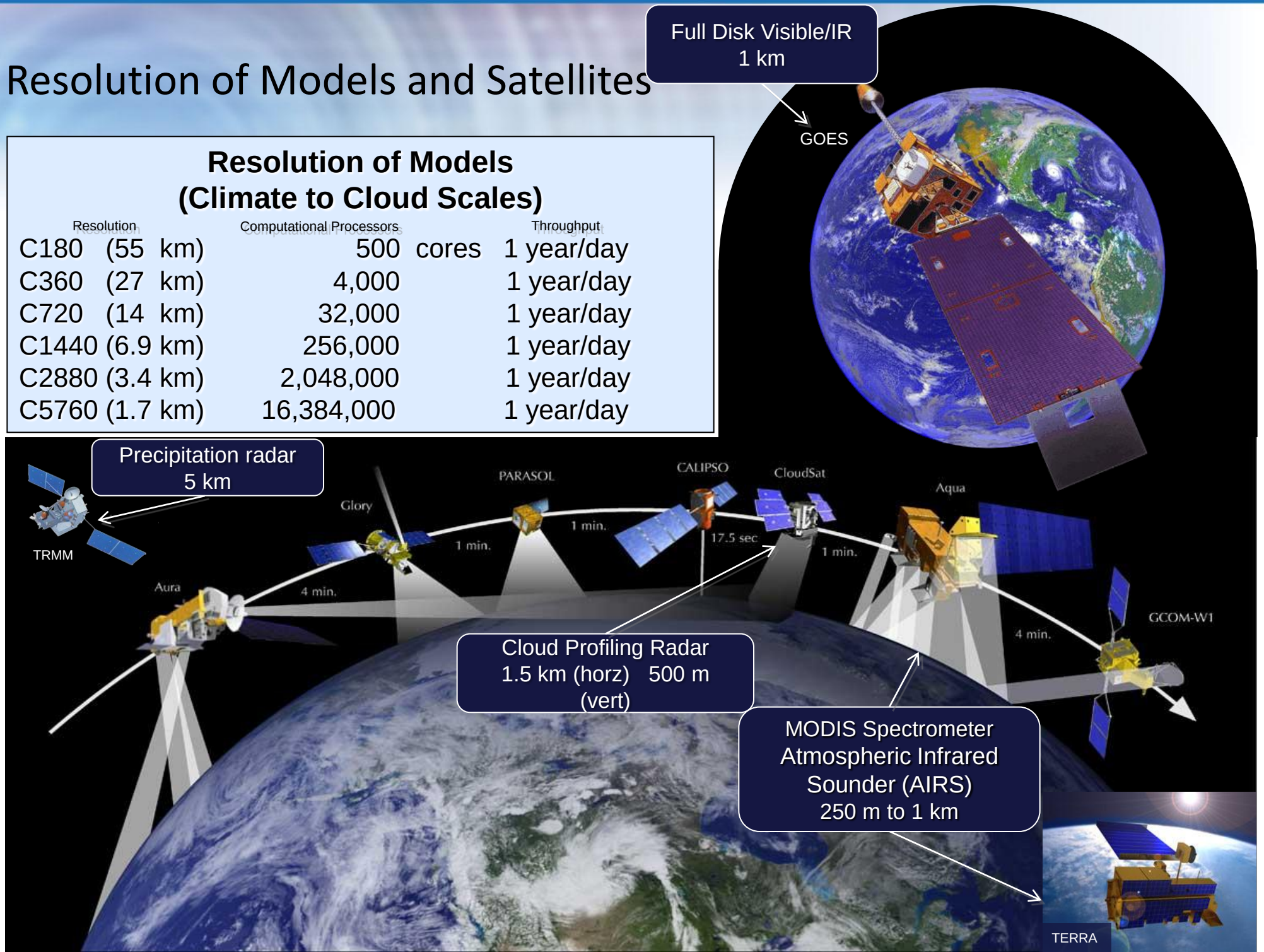
- Non-hydrostatic global modeling
  - Exploration of global cloud permitting resolutions (14- to 3.5- km)
  - Resolving regional impacts of meso-scale features (tropical convection, hurricanes, marine layer stratocumulus, and cumulus cloud streets/vortices)
  - Pursuit of cloud resolving (< 1-km) with explicit cloud micro-physics
  - Maintaining consistency with the large-scale circulation of the global climate in a single atmospheric model



Resolution of Models and Satellites

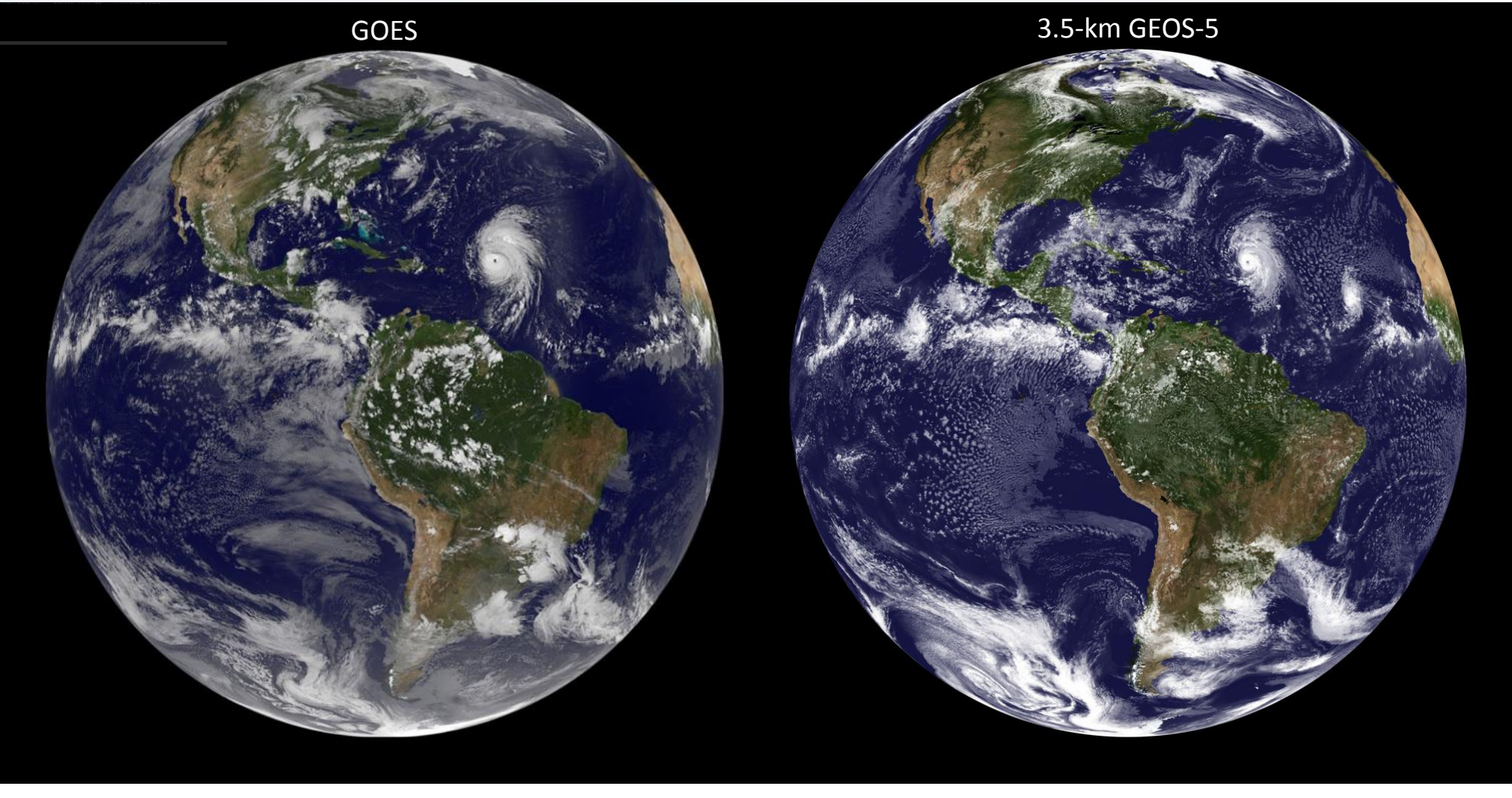
Resolution of Models (Climate to Cloud Scales)

Resolution	Computational Processors	Throughput
C180 (55 km)	500 cores	1 year/day
C360 (27 km)	4,000	1 year/day
C720 (14 km)	32,000	1 year/day
C1440 (6.9 km)	256,000	1 year/day
C2880 (3.4 km)	2,048,000	1 year/day
C5760 (1.7 km)	16,384,000	1 year/day



Tropical Convection & Hurricane Bill

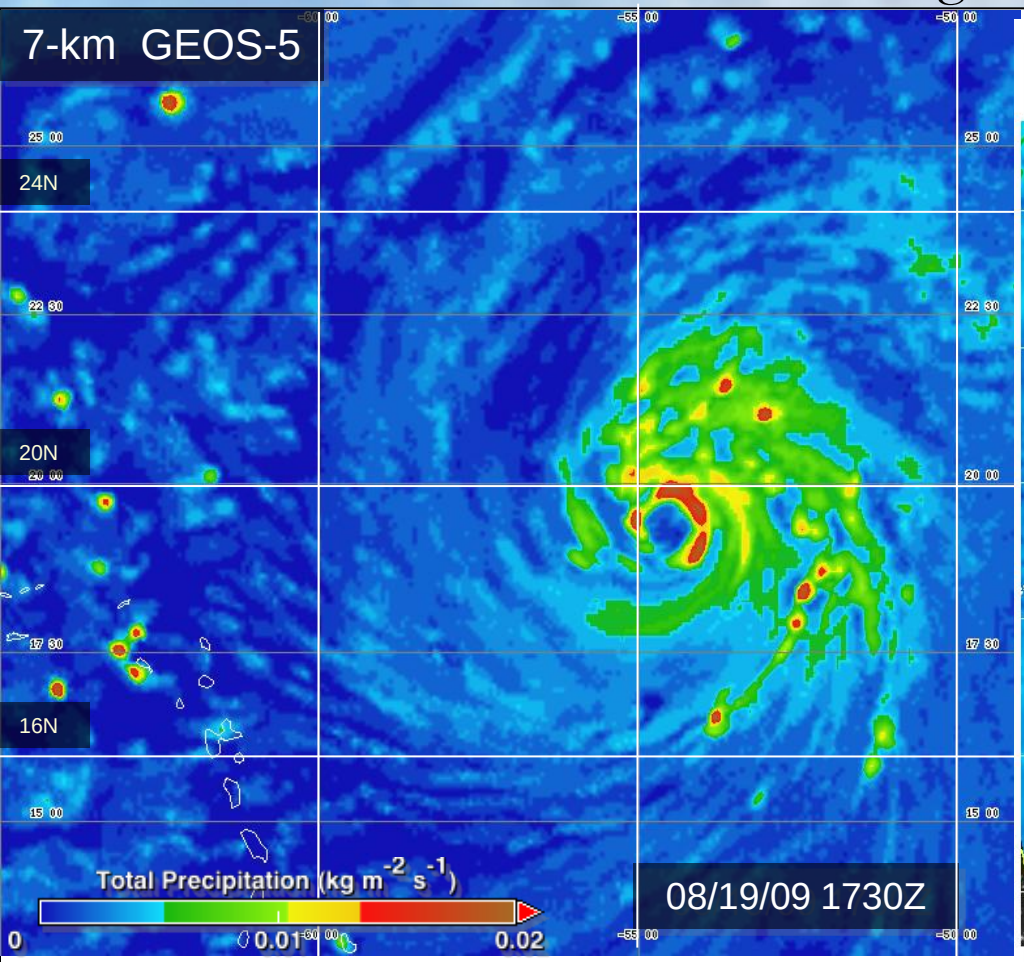
72-hr forecast Initialized 2009-08-16 21z

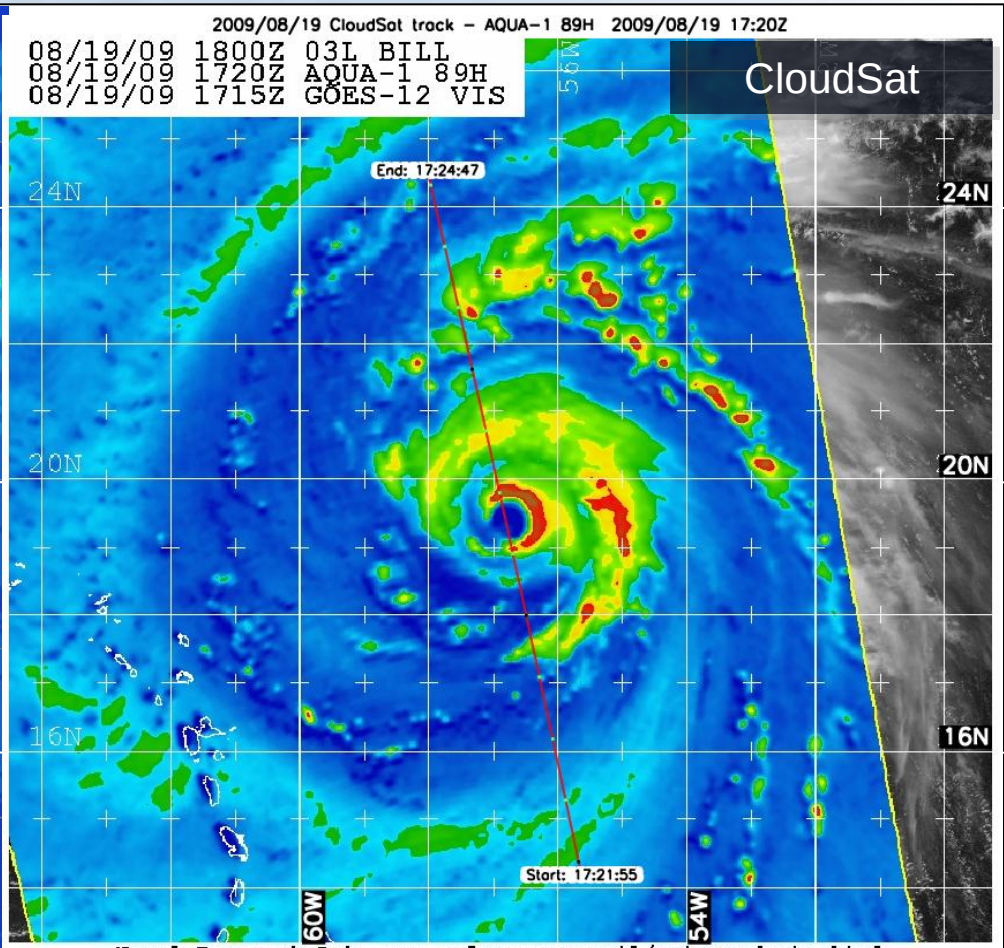


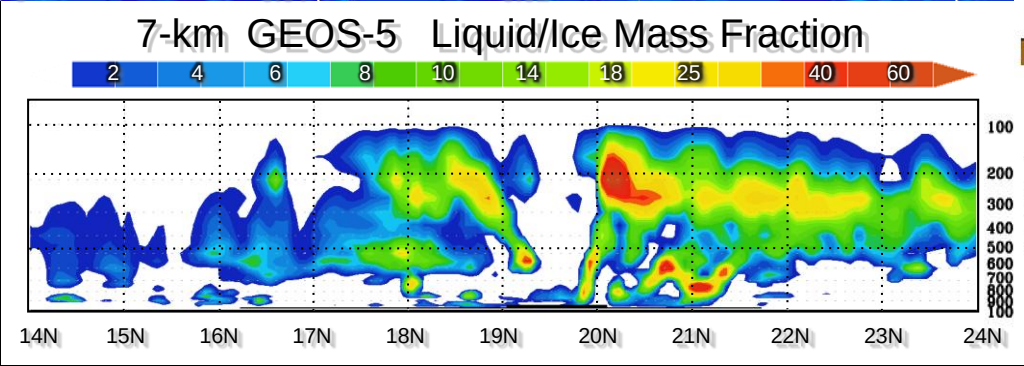
Hurricane Bill

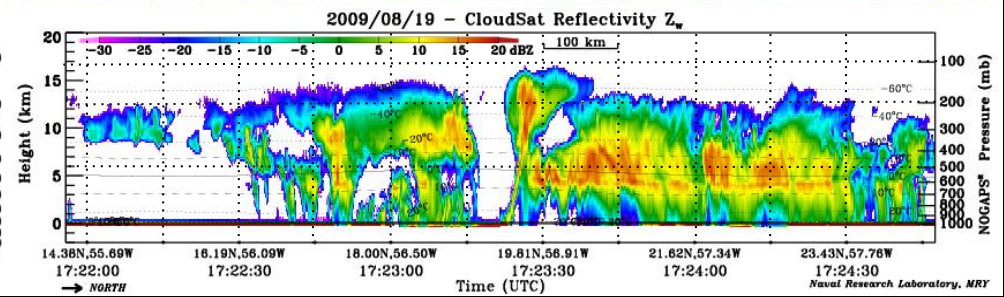
August 2009

69-hr forecast Initialized
2009-08-16 21z



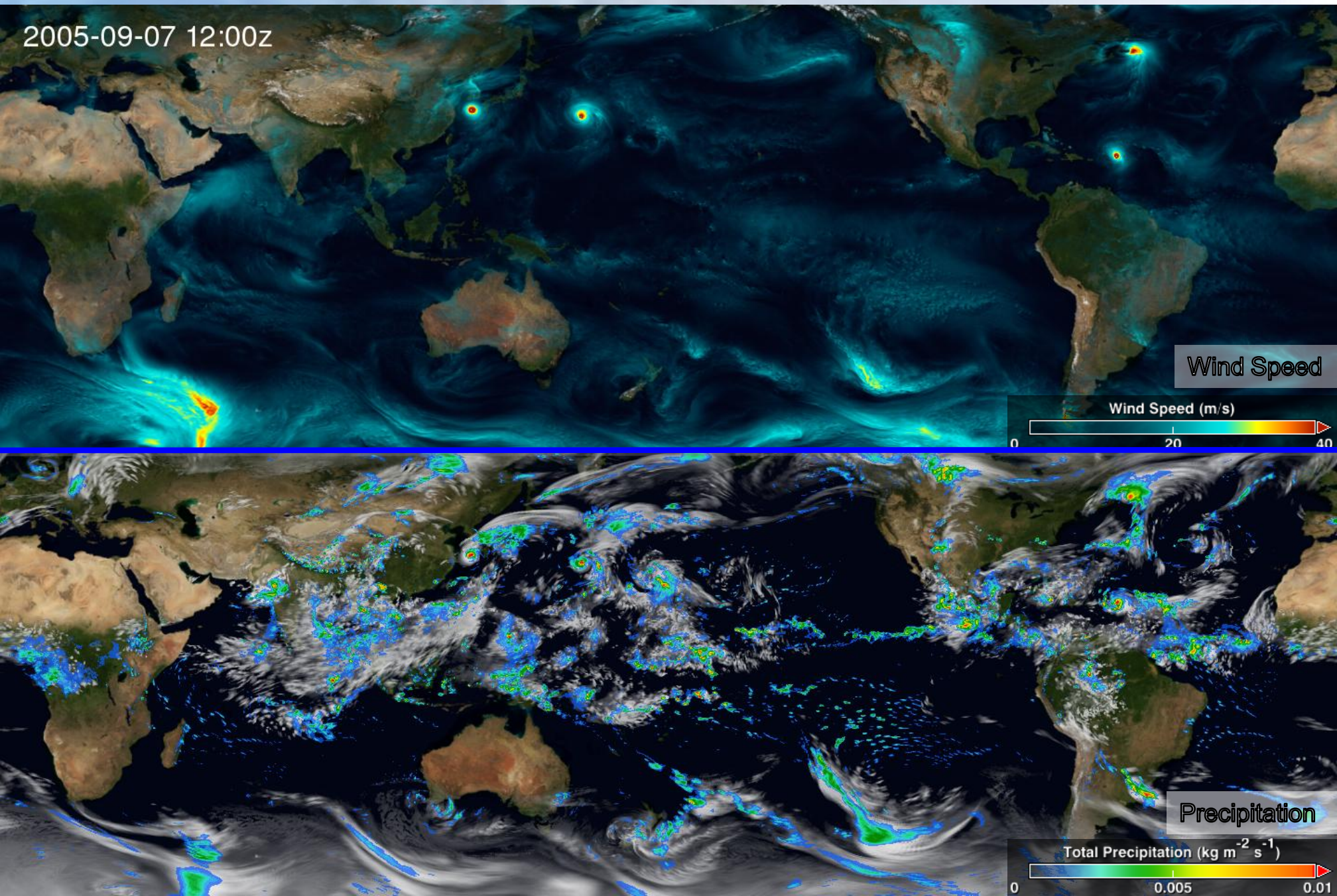




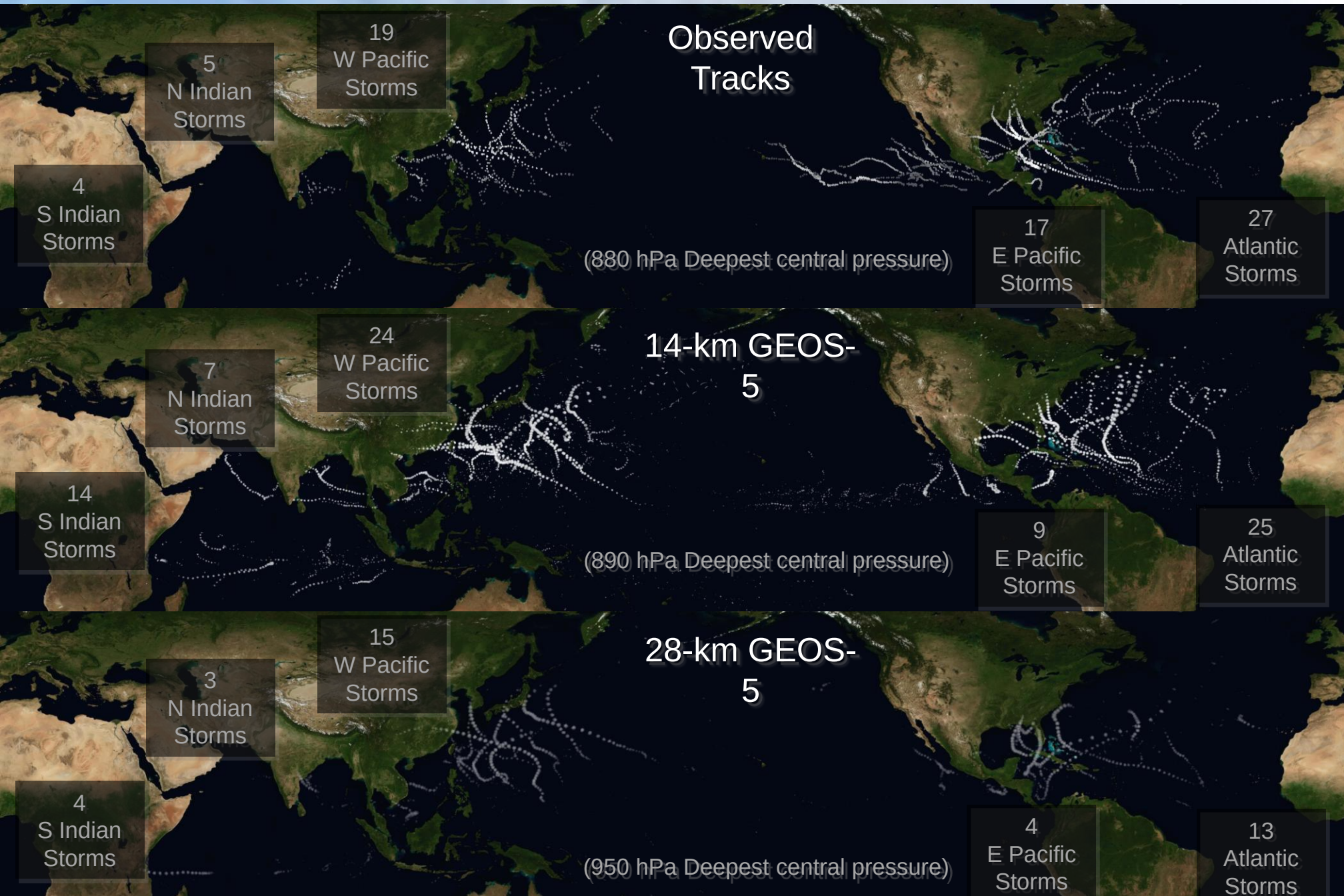


2005 Climate and Tropical Cyclones

14-km



Global Tropical Cyclone Tracks 2005 (May-Dec)



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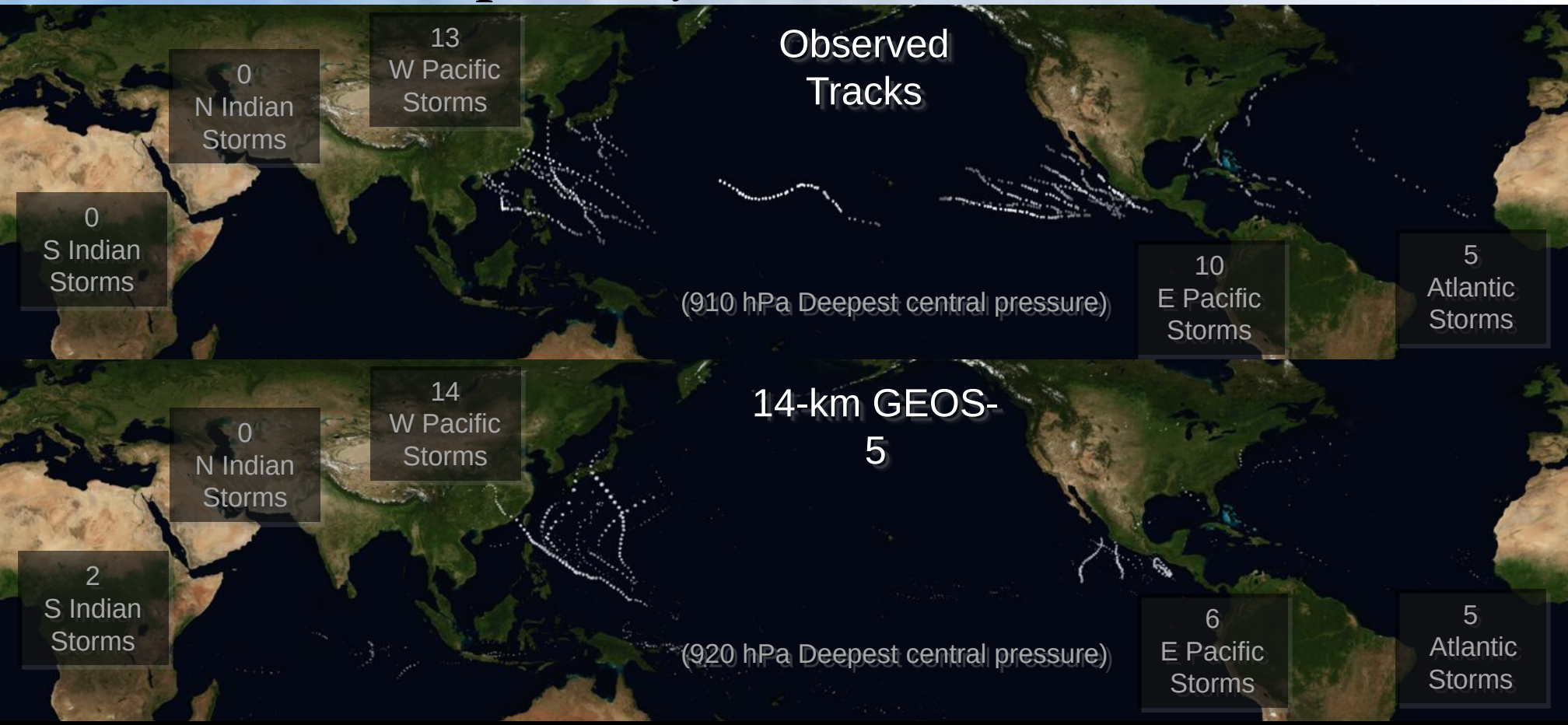


US 2010 East Coast Snow Storms

'Snowmageddon'

Boyds, MD

6 February

16 inches (41 cm)

10 February

19inches (48 cm) new snow

As of February 11: Baltimore (**72.3 inches** [183.6 cm], Philadelphia (**70.3 inches** [178.6 cm]

History of US East Coast Snow Storms

- **Seasonality of Number of Storms:**
  - *Nov -2; Dec -7; Jan - 12;* ***Feb -22****; Mar-10; Apr-2*
- **Impact of ENSO phase (# of storms):**
  - *ENSO Warm: 22, Neutral: 26, Cold: 5*
- **Impact of NAO:**

Composites for ten snowiest months

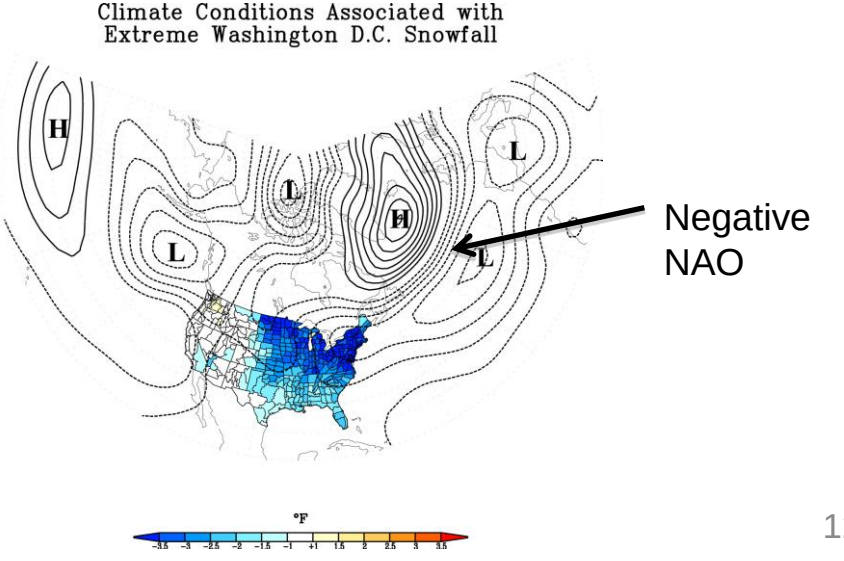


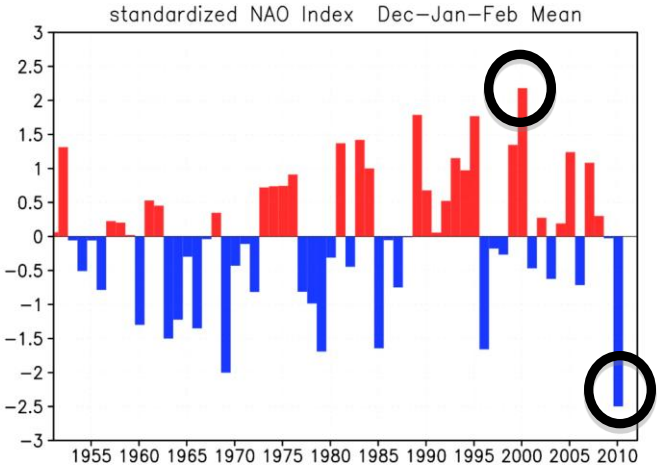
Figure: *The December-January-February 2010 anomalies in 500-mb height (contours) and U.S. surface temperature. Composites for* ten snowiest months in each of the three winter months December, January, and February since 1891. *Anomalies are determined relative to the period 1971-2000 . Contour interval is 20m.*

NOAA Attribution Team
This expert assessment is a consolidated effort of the National Oceanic and Atmospheric Administration (NOAA). Lead author and contact is Martin Hoerling (martin.hoerling@noaa.gov).

Compare Two Different Winters

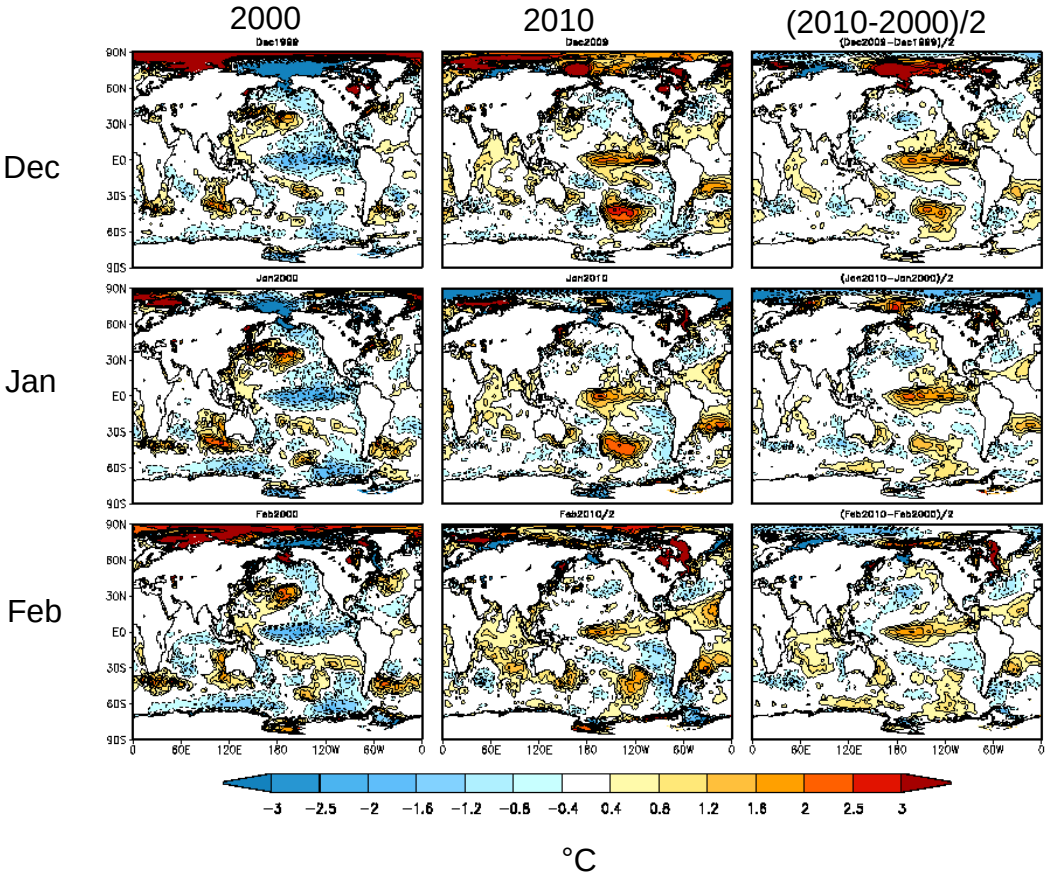
1) **2009/2010: El Nino, negative NAO**

2) **1999/2000: La Nina, positive NAO**



NAO Index*

SST Anomalies



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The Experiments

- **GEOS-5 AGCM**
  - ¼ deg horizontal resolution

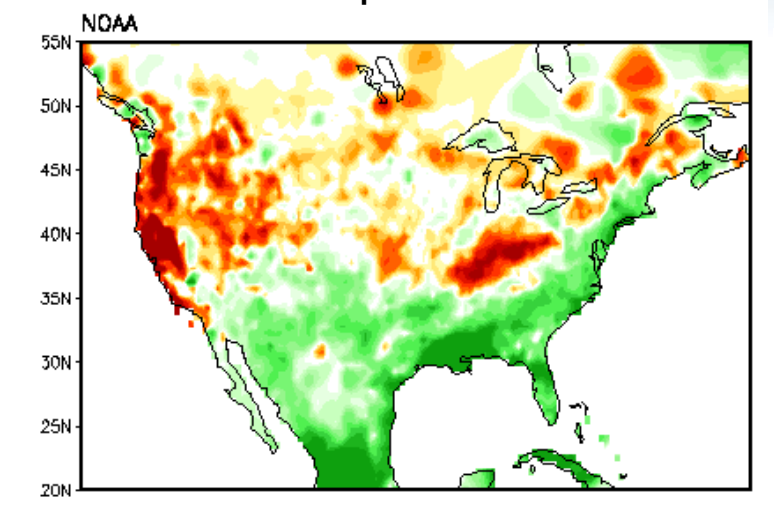
- **50 hindcasts for each winter (1999/00 and 2009/10)**
  - initialized on December 1 and run through end of February
  - forced with observed SST
  - atmospheric Initial conditions from MERRA
  - perturbations computed as scaled differences between two November states 1 day apart

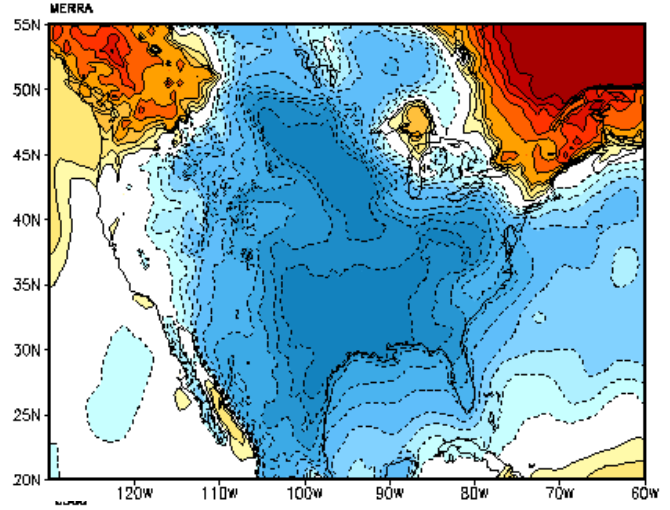
February Response (2010-2000)

Precipitation

T 2m

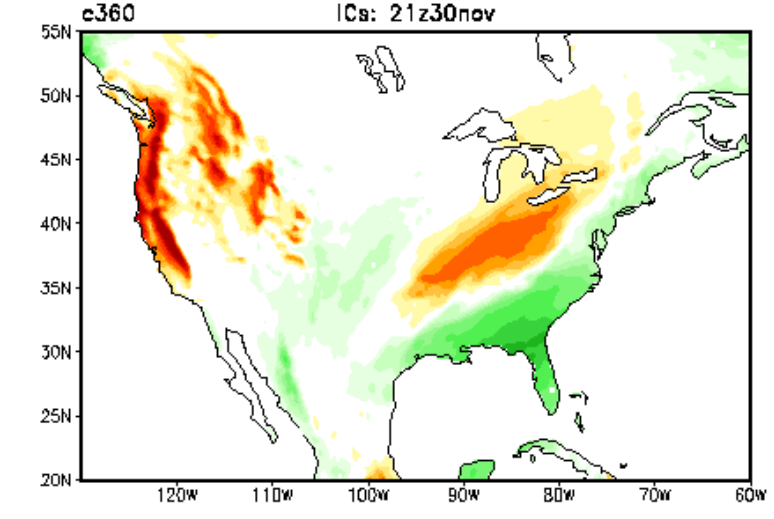
Station Obs

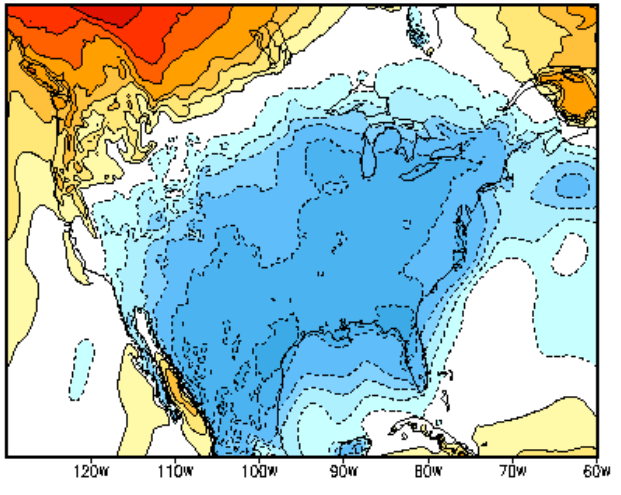




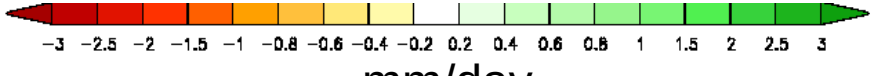
MERRA

Model: ens average

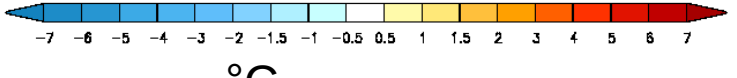




Model: ens average



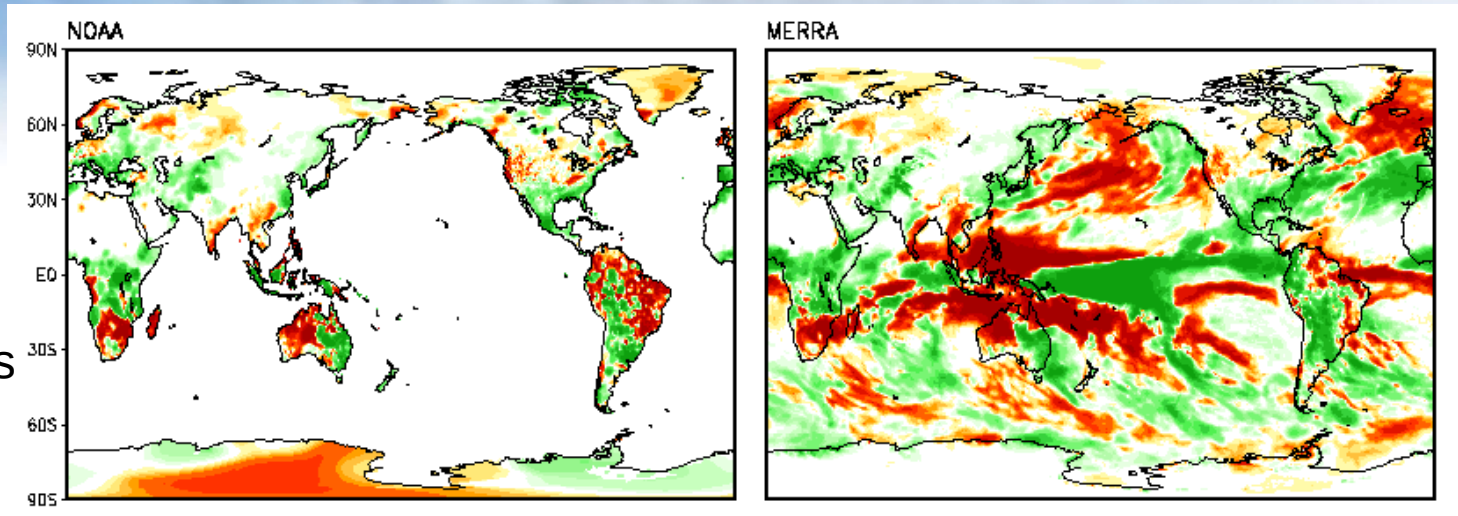
mm/day



°C

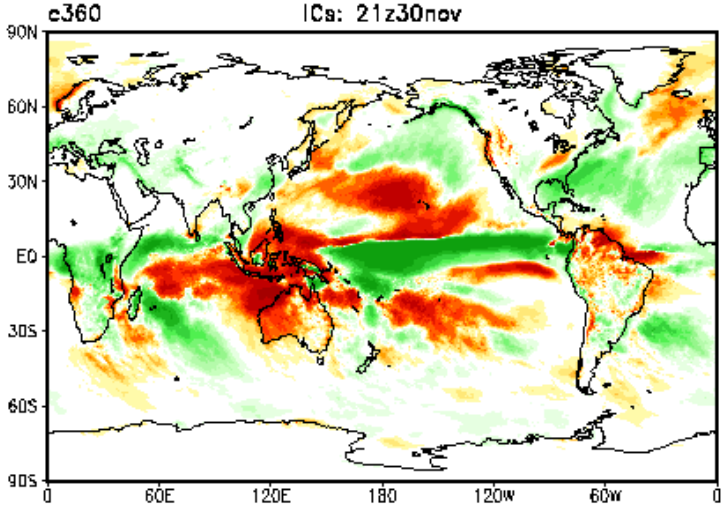
Precipitation (Feb 2010- Feb 2000)

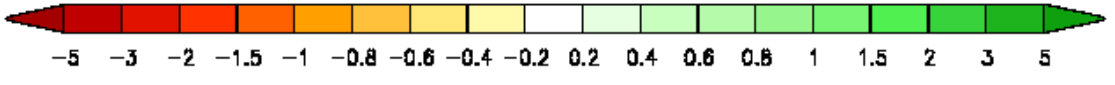
Station Observations



MERRA

Model Ensemble Mean





mm/day

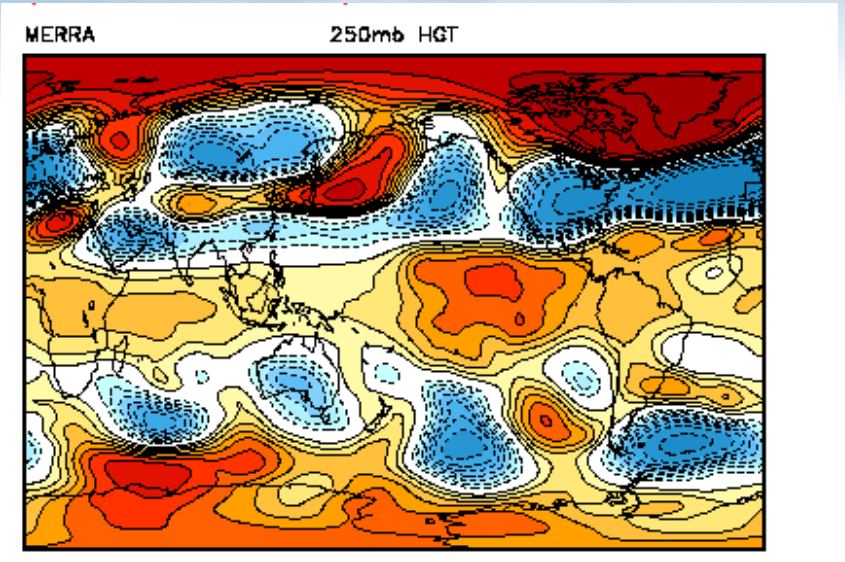
February (2010-2000)

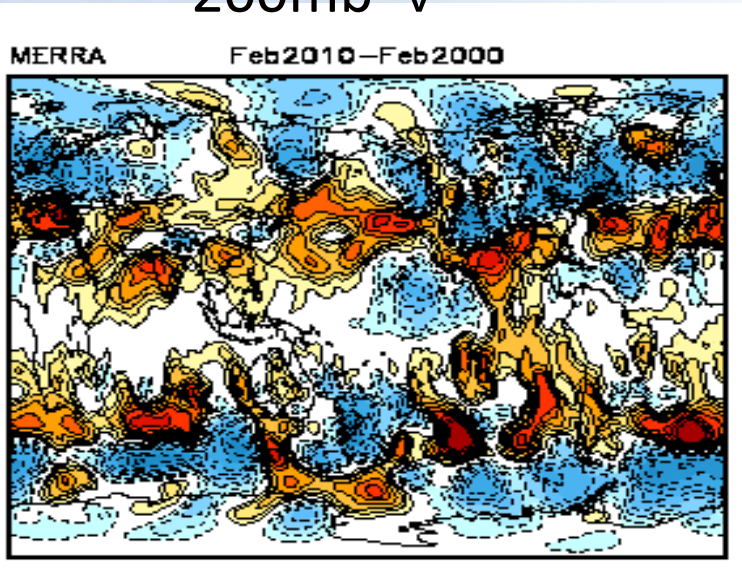
250mb Z

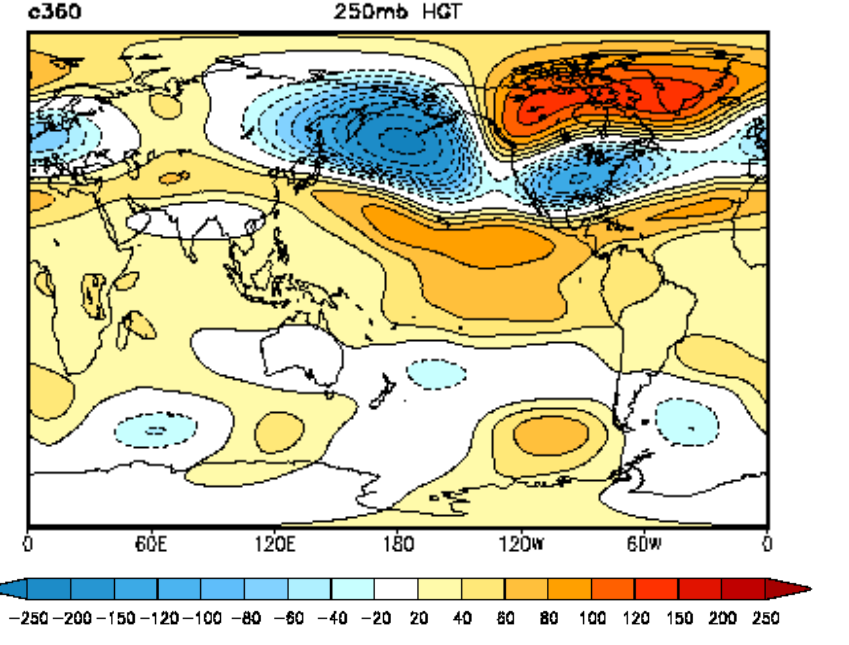
200mb V'^2

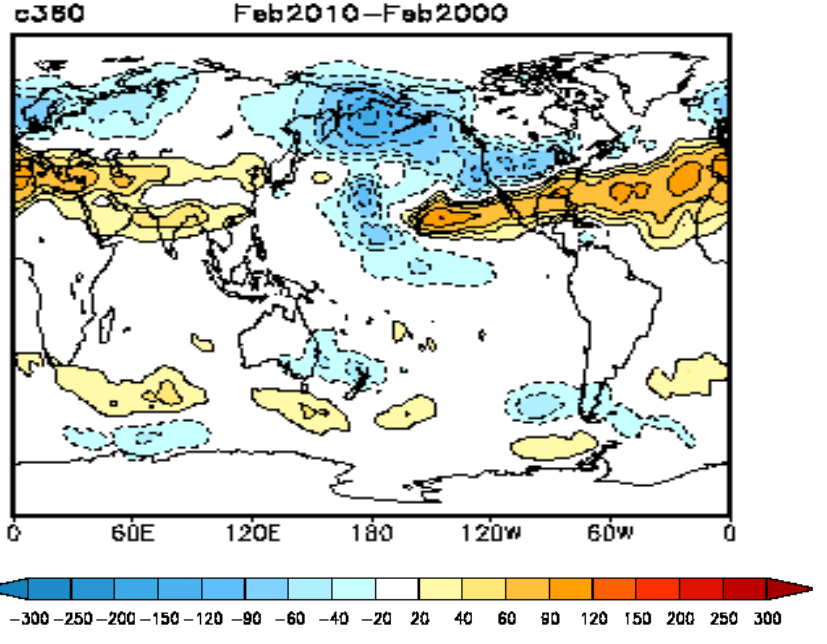
MERRA

Model Ensemble Mean









Results

- GEOS-5, when forced with observed SST appears to reproduce the overall enhanced storminess on the US east coast/southeast and elsewhere (e.g., over parts of southern Europe)
- Currently looking into the role of the SST in the different ocean basins
- Also looking in more detail into the intra-ensemble variability and the snow storms produced by the model

MERRA - NASA's Reanalysis of the Satellite Era

Modern **E**ra **R**etrospective-analysis for **R**esearch and **A**pplications

http://gmao.gsfc.nasa.gov/merra

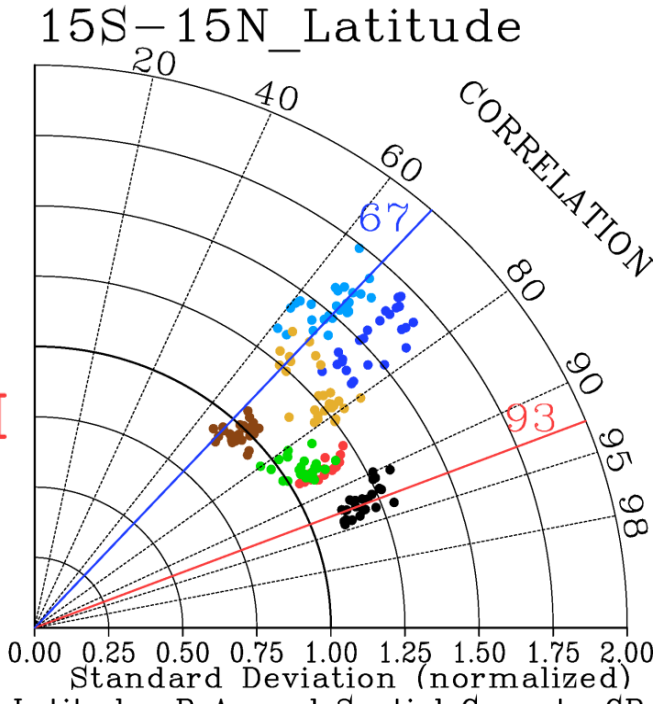
MERRA System

A reprocessing of atmospheric observations from 1979 to present using the GEOS-5 Data Assimilation System

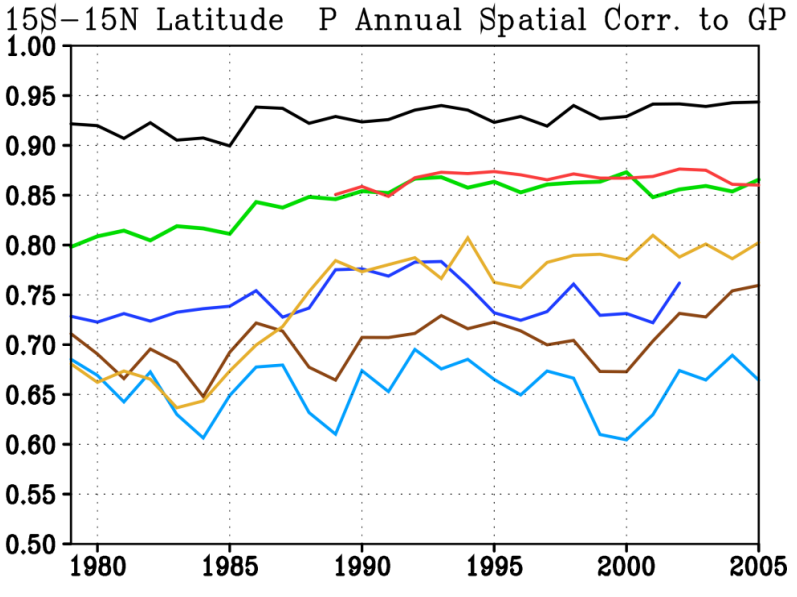
- System version: GEOS-5.2.0
- 1979 – present
- 1/2° × 2/3° × 72L
- 3 Processing Streams

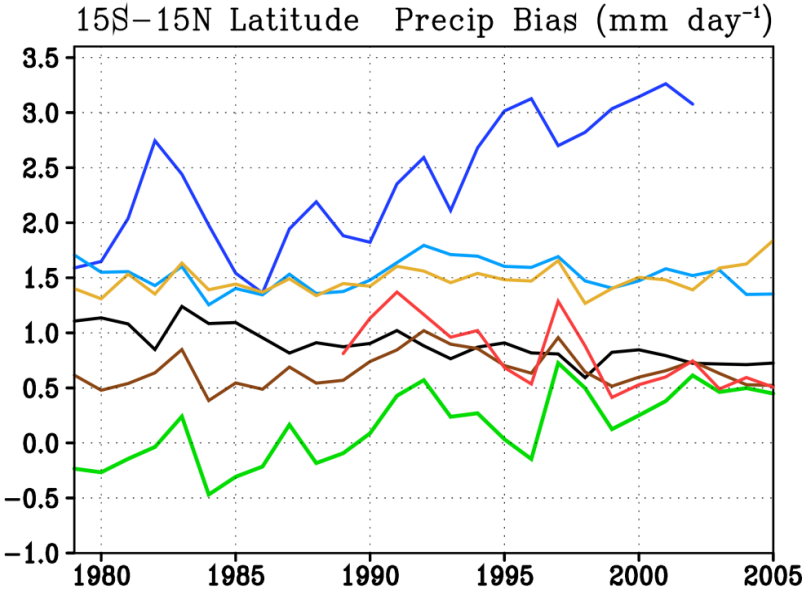
Spatial Variability of Precipitation

CMAP
ERA40
NR1
NR2
JRA25
INTERIM
MERRA



- Tropical precipitation drives the global comparison
- *Some notable improvements since the earlier reanalyses*
- Taylor diagrams show the skill reproducing a reference data set
- GPCP is the reference
- Annual means, 1979-2005



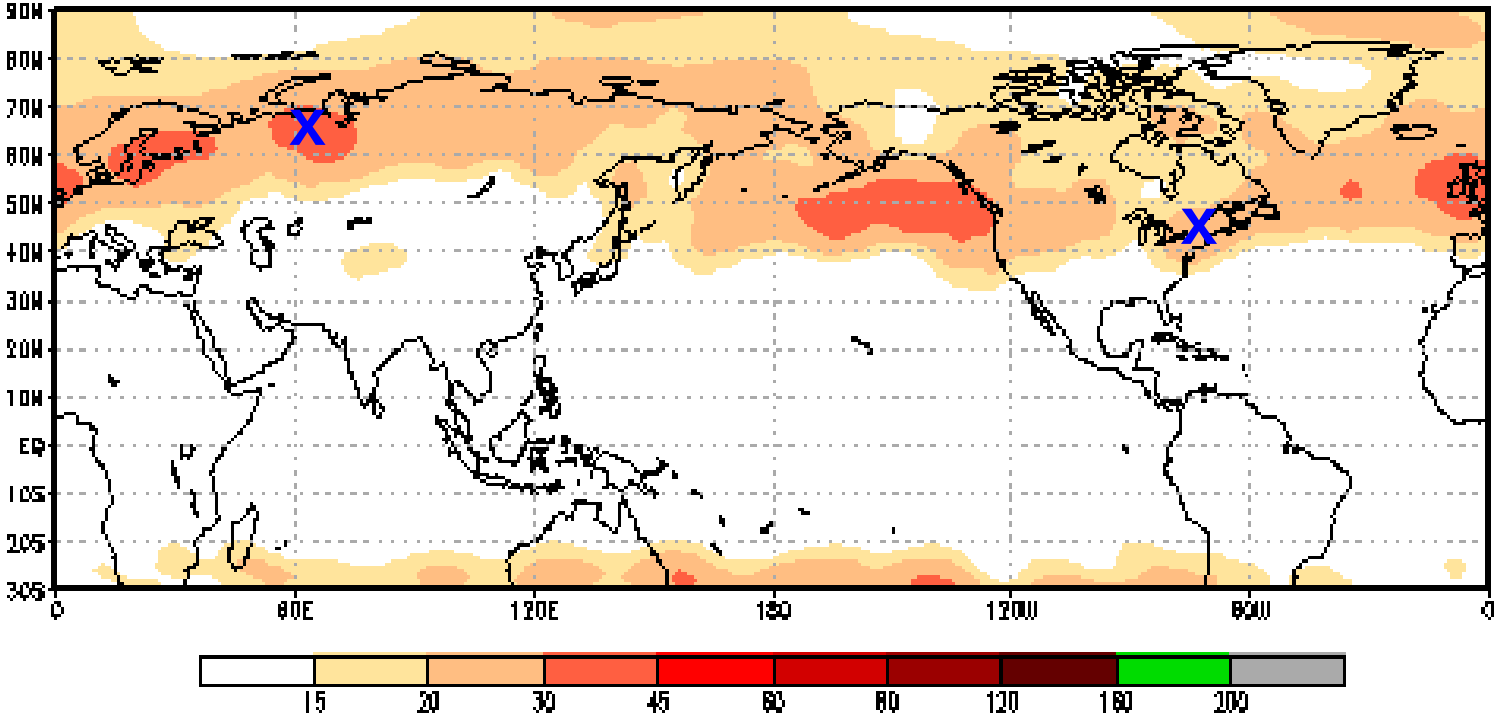


2003 European Heat Wave

A MERRA-Based Analysis

Variance of V250mb (JJA 1979-2008)

(30-90 day filter)

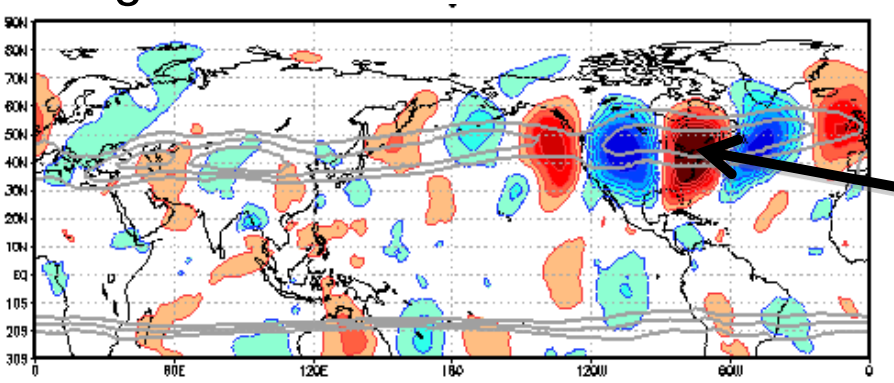


$(m/s)^2$

One- point lead/lag Correlation (V250mb)

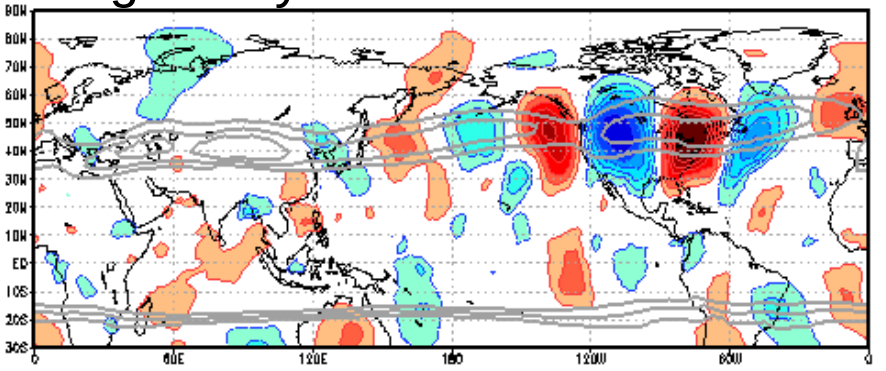
(30-90 day filter, JJA 1979-2008)

Lag 0

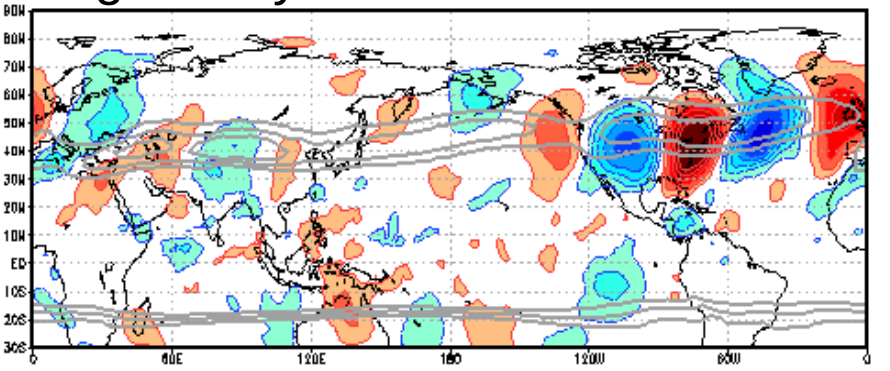


Base point

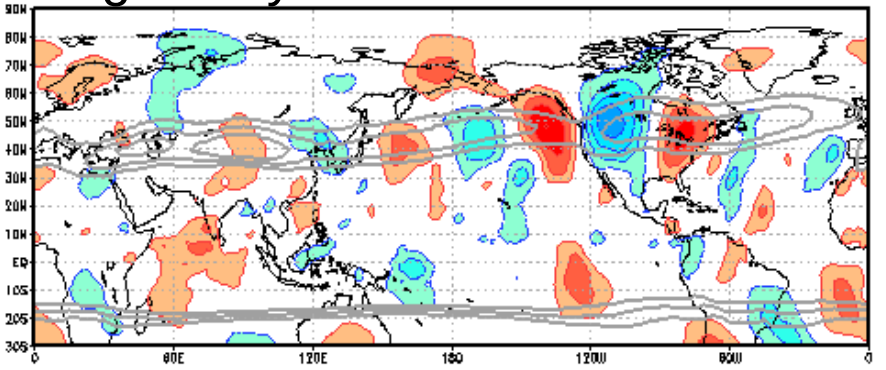
Lag -4 days



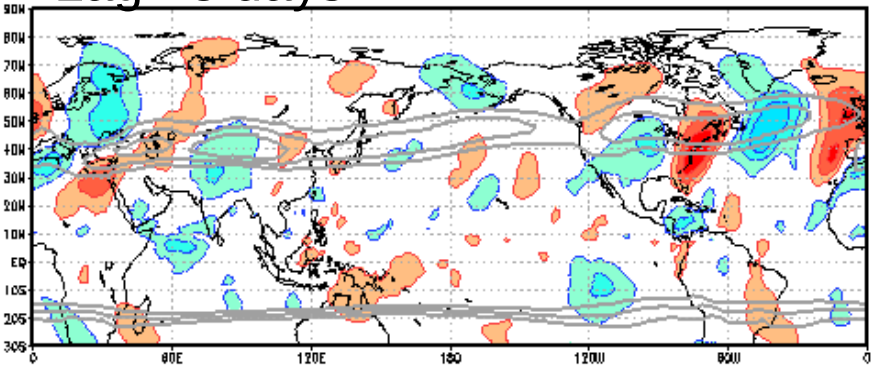
Lag +4 days



Lag -8 days



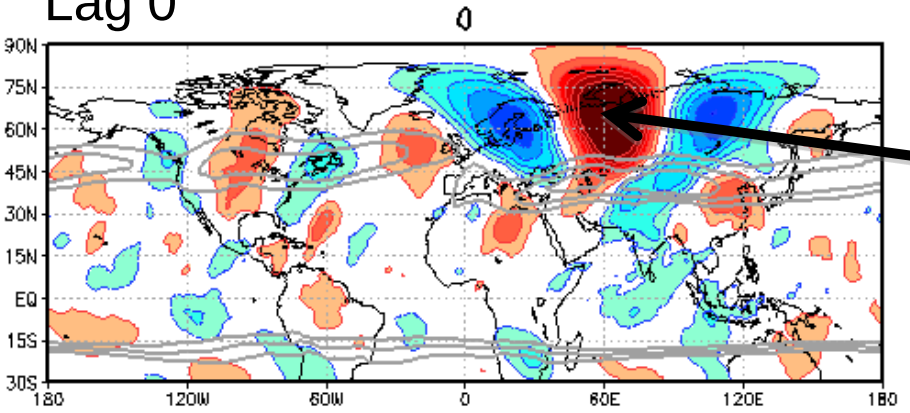
Lag +8 days



One- point lead/lag Correlation (V250mb)

(30-90 day filter, JJA 1979-2008)

Lag 0



Base point

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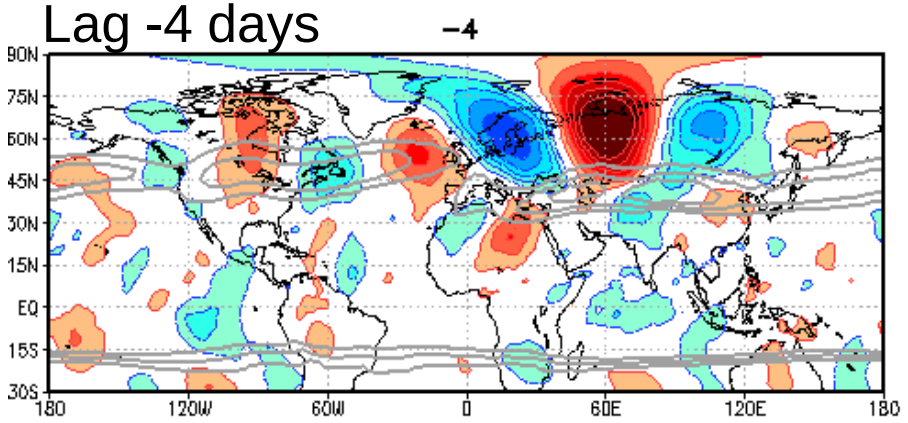
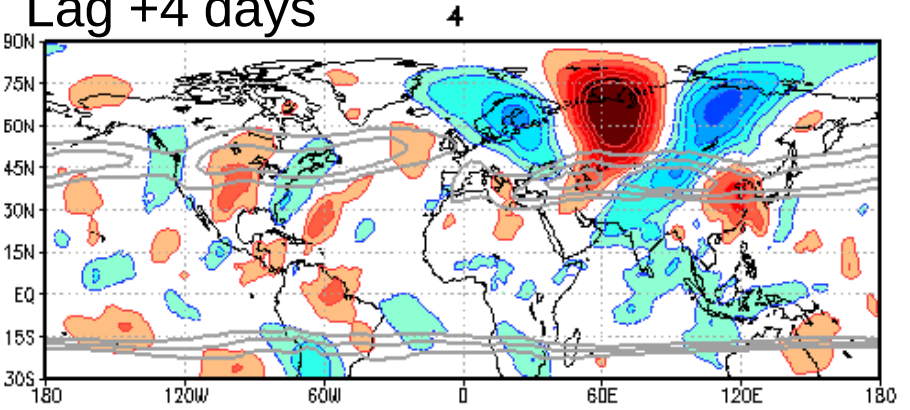
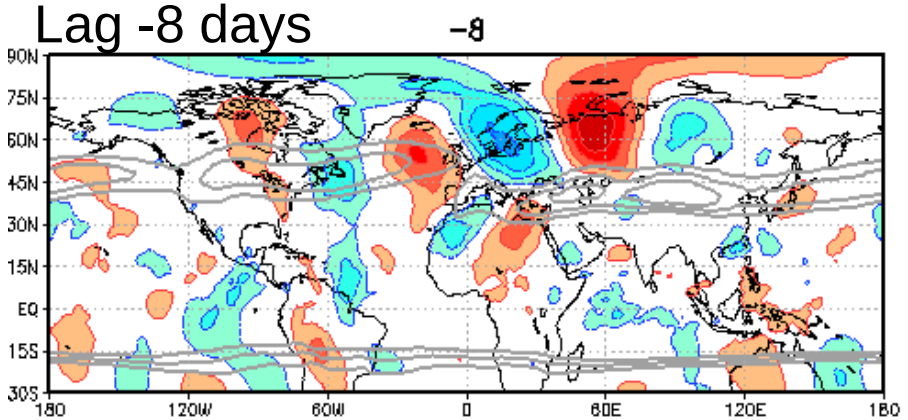


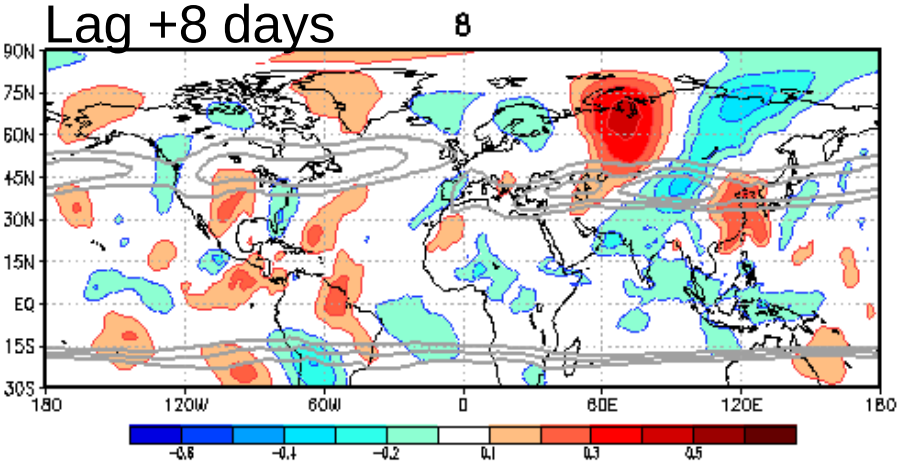
Lag +4 days



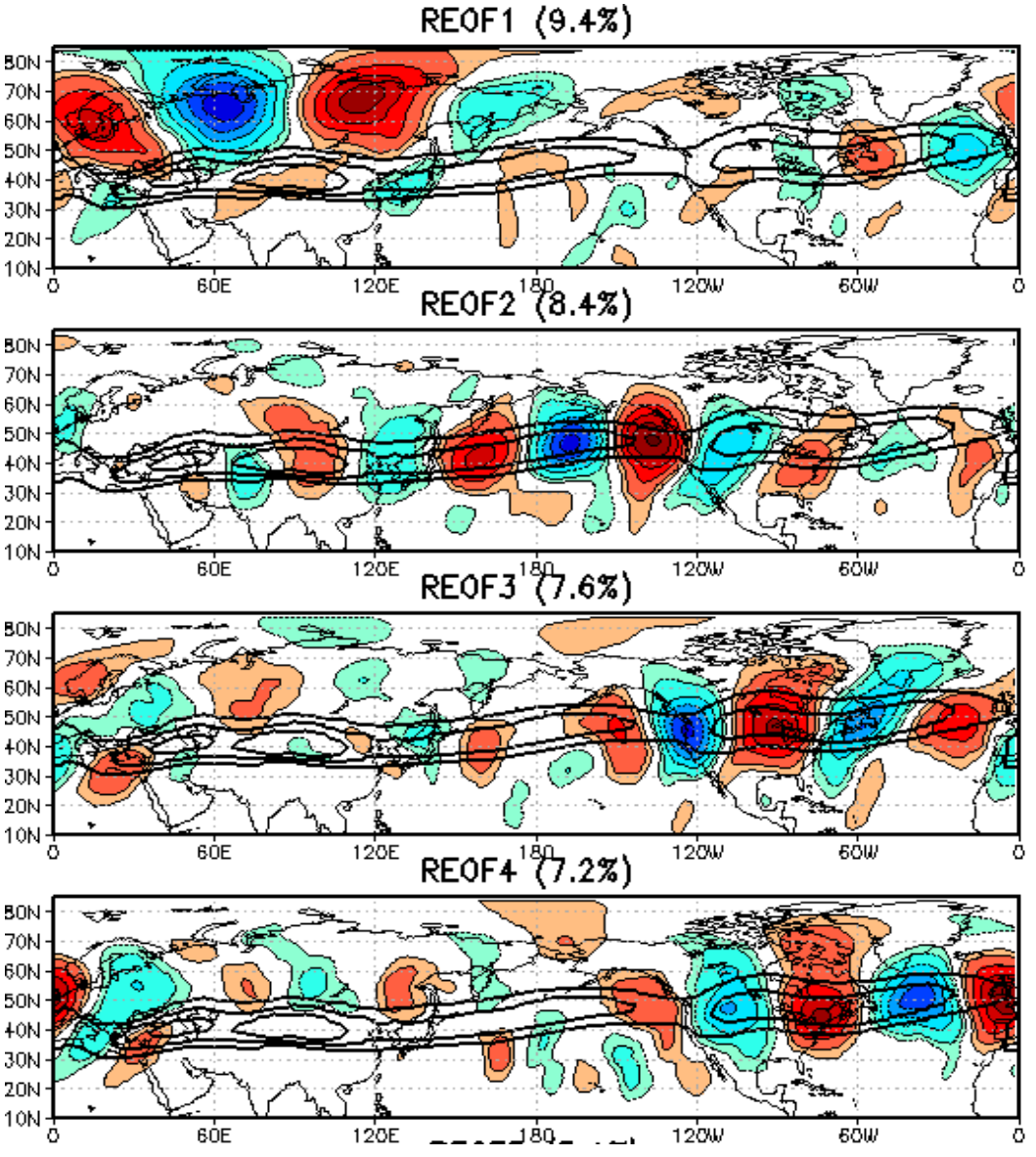
Lag -8 days



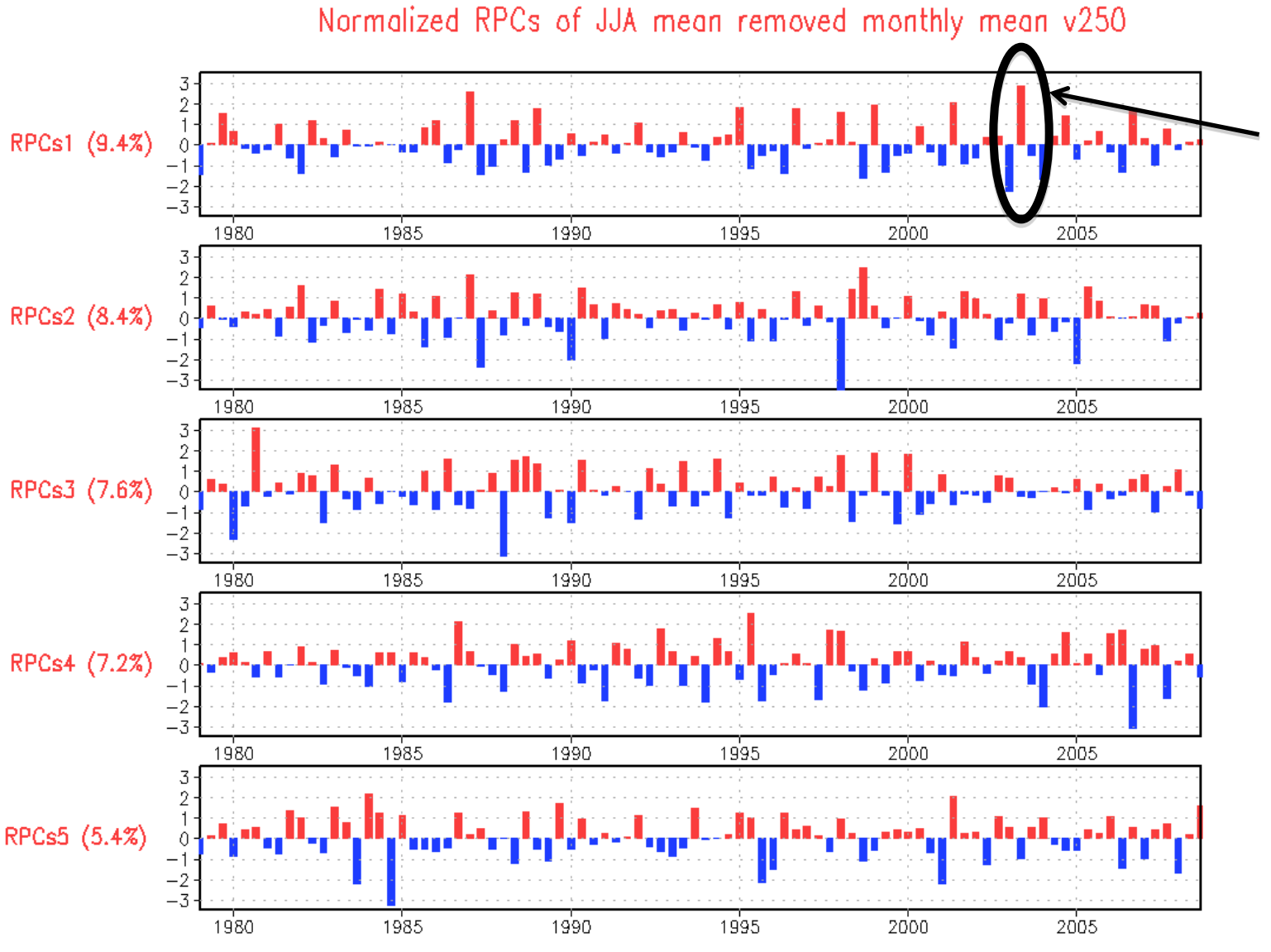
Lag +8 days



Leading Rotated EOFs of Intraseasonal (Monthly JJA) V250mb



Leading Normalized Rotated PCs (Intraseasonal Monthly JJA)



2003 Monthly Anomalies (V250mb)

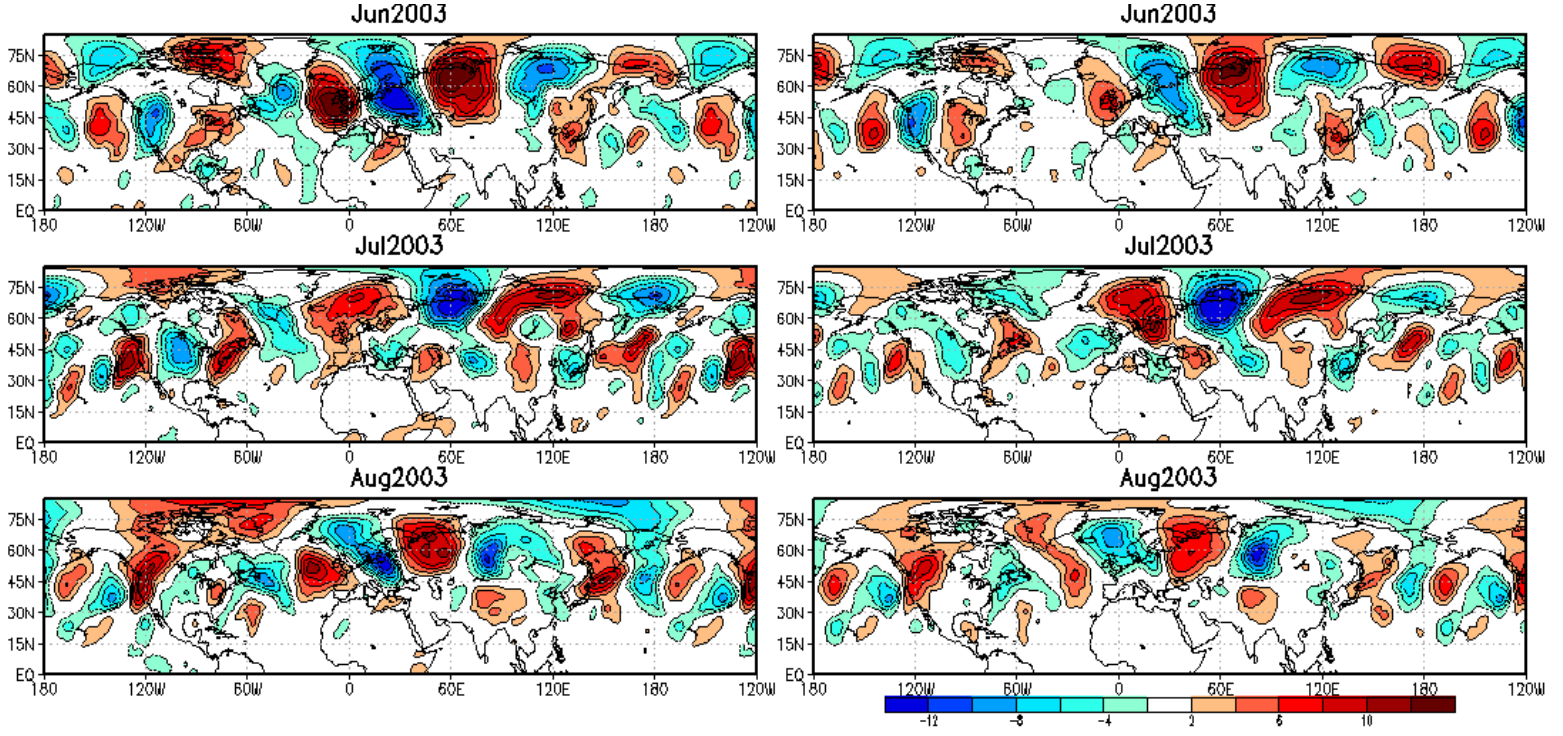
Interannual

Intraseasonal

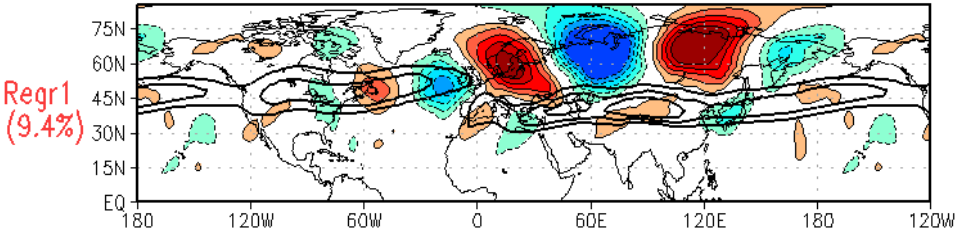
June

July

Aug



REOF 1 – Regression with V250mb



2003 European Heat Wave Monthly Anomalies (MERRA)

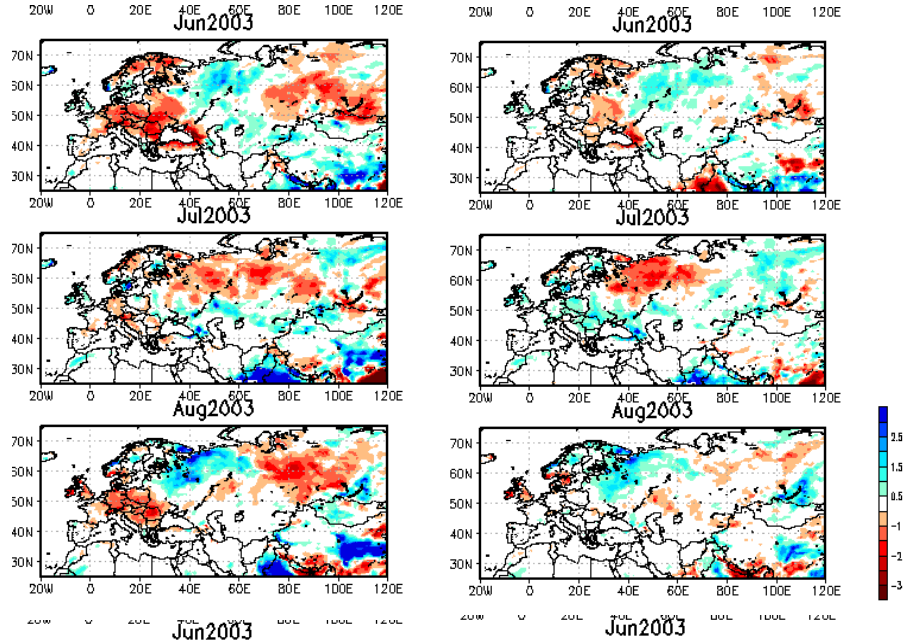
Interannual

Intraseasonal

Jun

Jul

Aug

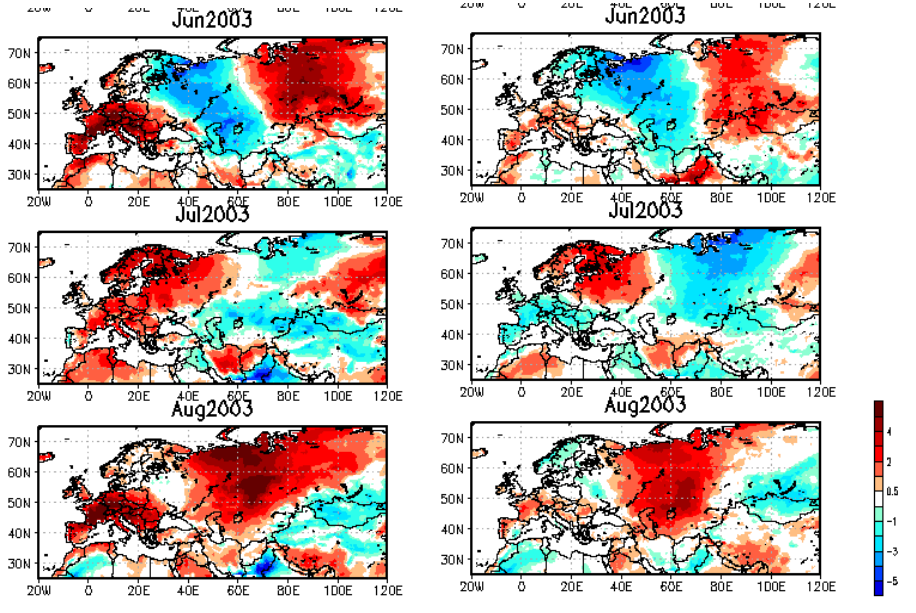


Precipitation mm/day

Jun

Jul

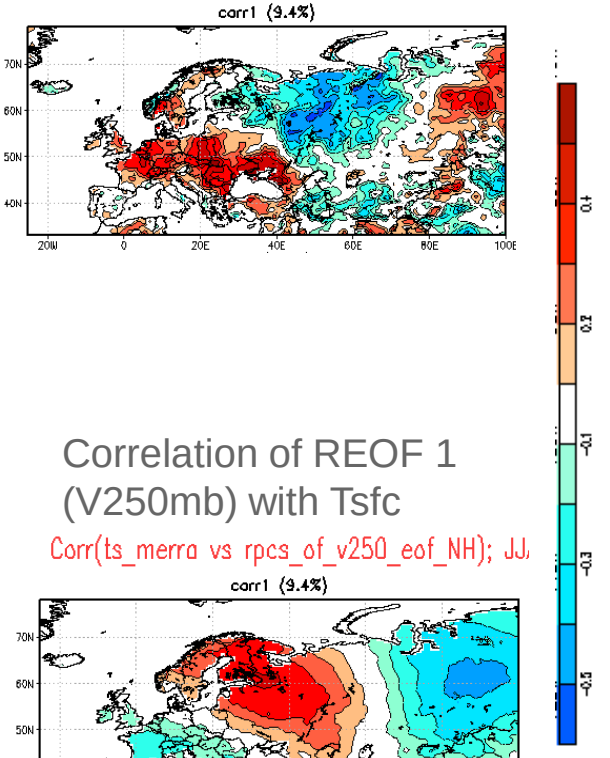
Aug



Temperature °C

Correlation of REOF 1 (V250mb) with Precip

Corr(pr_merra vs rpcs_of_v250_eof_NH); JJ



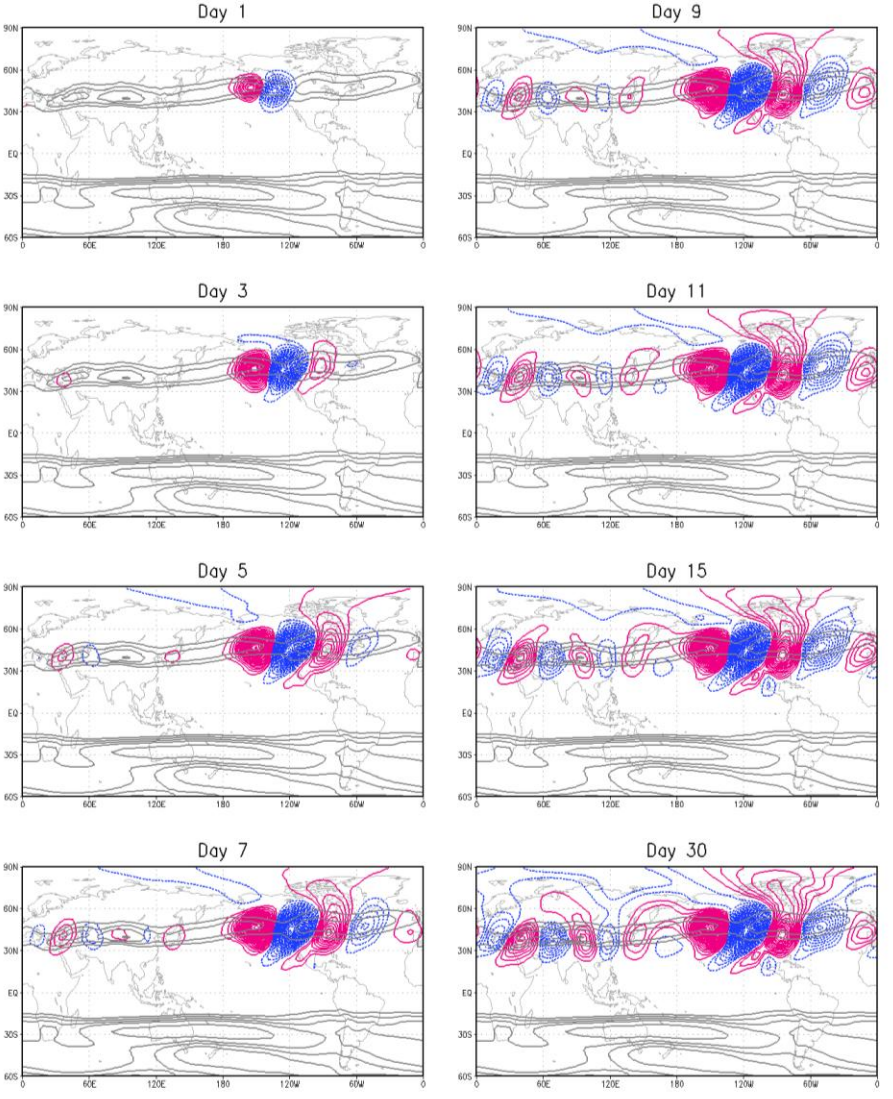
Correlation of REOF 1 (V250mb) with Tsfc

Corr(ts_merra vs rpcs_of_v250_eof_NH); JJ

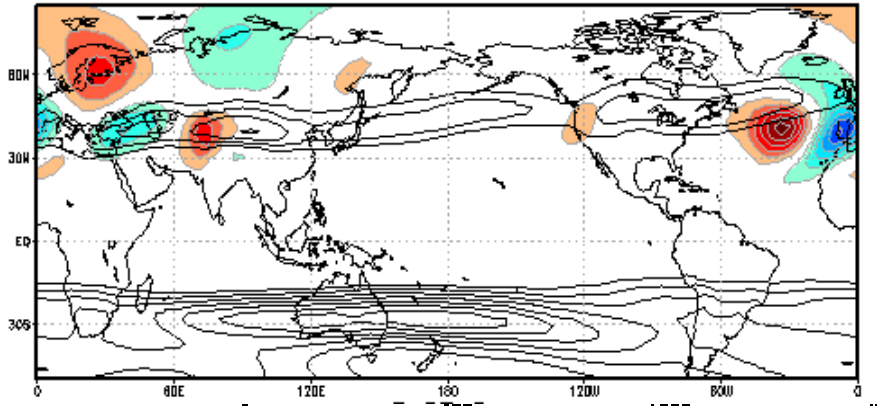
Preliminary Work With Stationary Wave Model (SWM)

Evolution of Eddy V-wind σ=.257 (Heating at 210E, 45N)

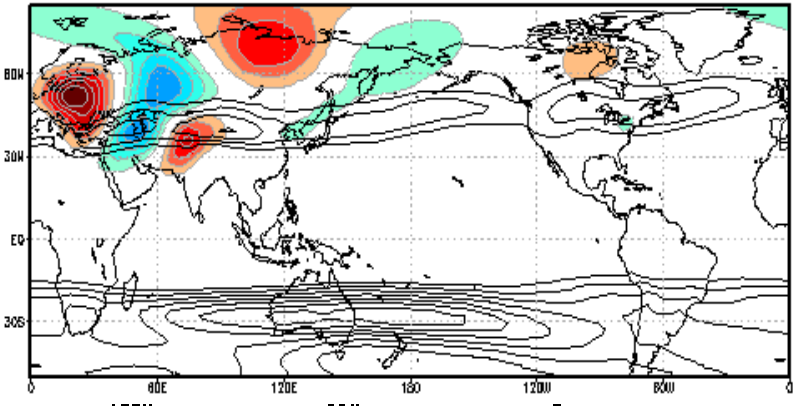
MERRA JJA Base State



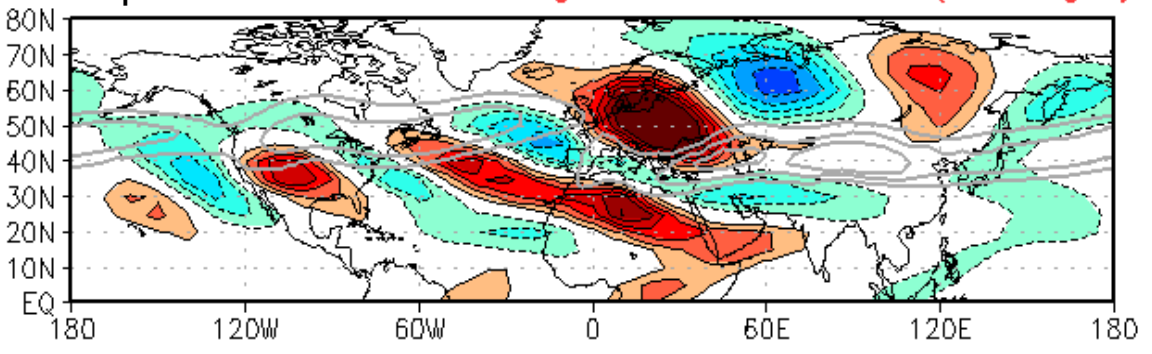
SWM Response to Idealized Heat Source at 330E, 40N



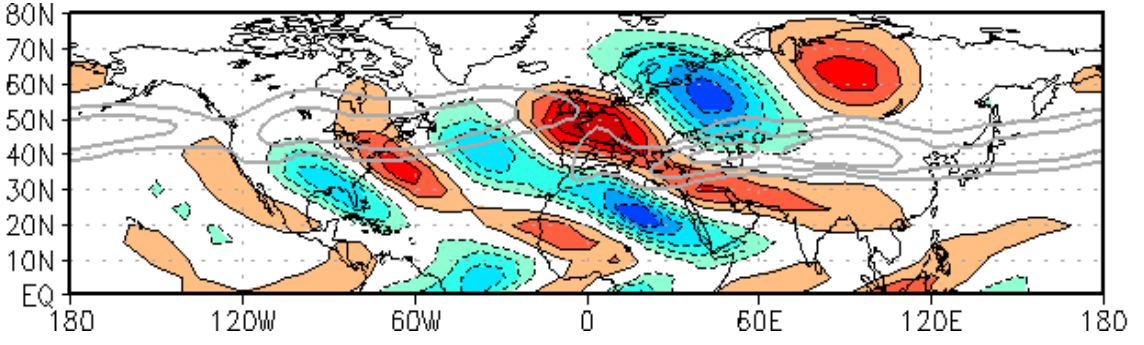
SWM Response to Idealized Heat Source at 20E, 50N



"Optimal" Heat Source Pattern for REOF 1



"Optimal" Vorticity Source Pattern for REOF 1



Conclusions

- Stationary Rossby Waves appear to play a significant role in modulating monthly precipitation and Tsfc in (northern) middle latitudes during JJA

- In particular, the wave associated with the leading REOF of V250mb appears to have played substantial role in modulating (perhaps even initiating) the extreme 2003 European heat wave.

Summary

- The GMAO is developing ultra-high resolution (working toward cloud resolving) global models and data assimilation systems to facilitate:
  - addressing weather/climate issues (e.g., changes in hurricane activity and other extreme weather)
  - assimilating high resolution satellite observations
- Currently running ¼ deg (25km) routinely and exploring global cloud-permitting resolutions (14- to 3.5- km)