An Update on Experimental Climate Prediction and Analysis Products being Developed at NASA's Global Modeling and Assimilation Office

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NASA/GFSC

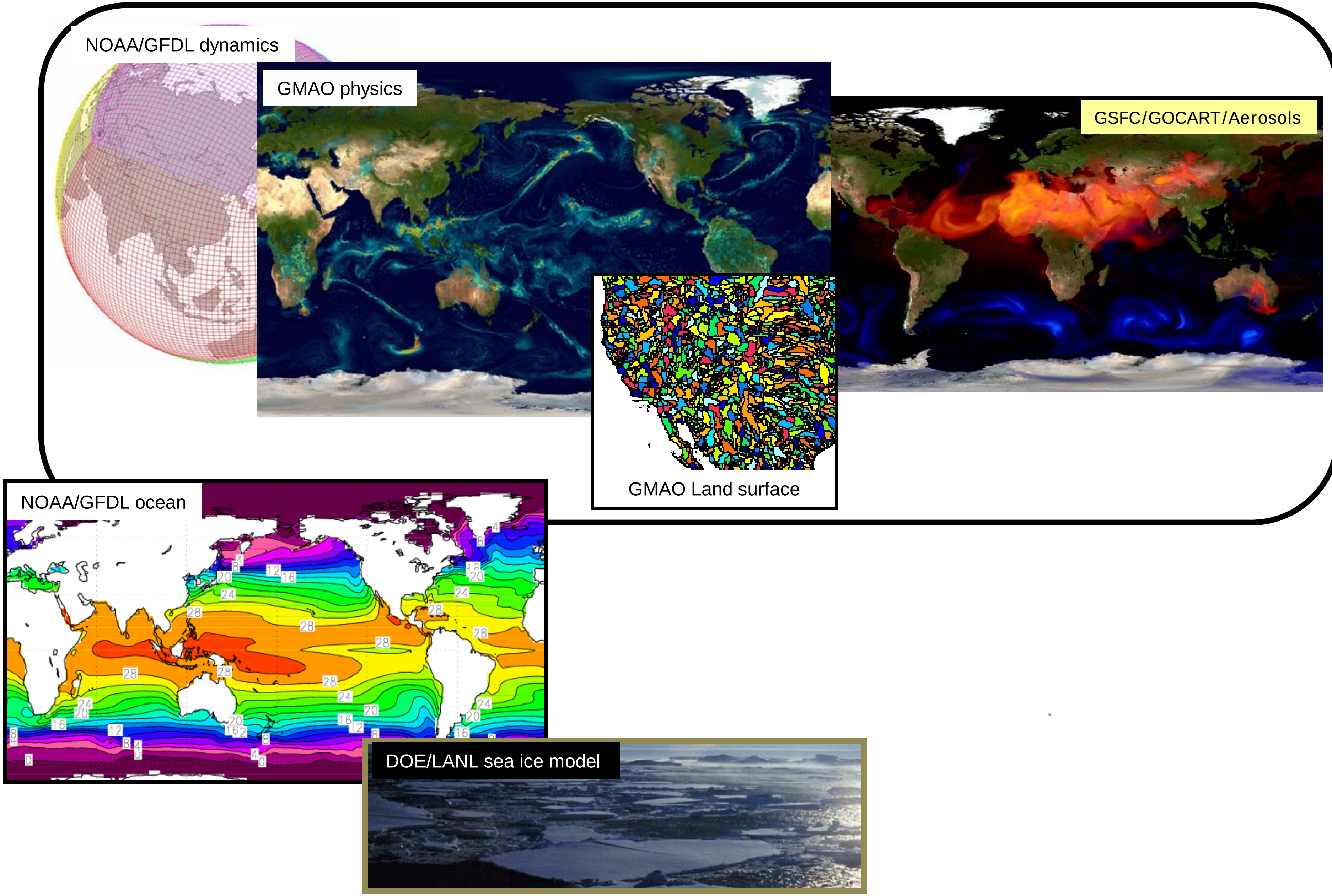
APEC Climate Symposium
"Harnessing and Using Climate Information for Decision Making"

17-20 October 2011
Honolulu, Hawaii

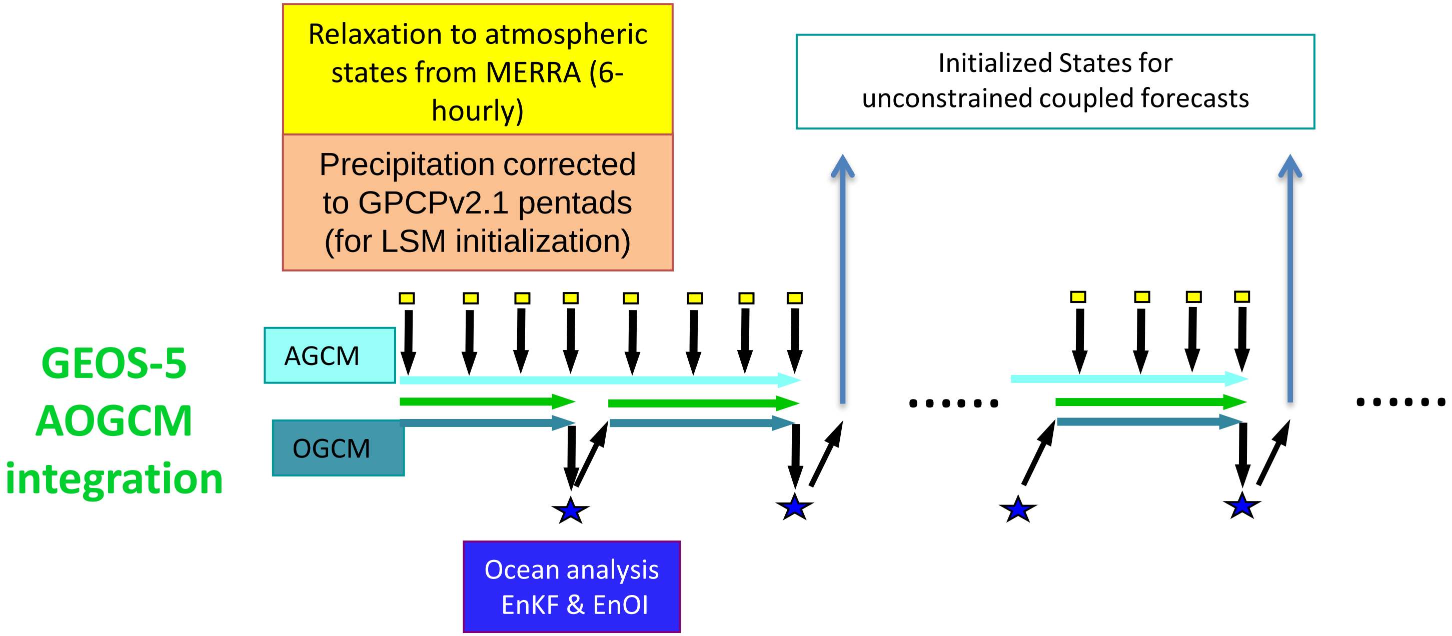
Outline

- GMAO Prediction and Analysis Products
  - GEOS-5 Model
    - Coupled S-I: US National MME (and APCC MME)
    - AGCM High resolution simulations
  - MERRA Reanalysis
    - atlas of extremes
- WCRP effort: working towards a GDEWS
  - coordination with APCC
  - some science (attribution of heat waves)

GEOS-5 AOGCM


NOAA/GFDL dynamics
GMAO physics
GSFC/GOCART/Aerosols
GMAO Land surface
NOAA/GFDL ocean
DOE/LANL sea ice model

GEOS-5 Coupled analysis cycle for Initialization of ISI Predictions



Seasonal Hindcast/Forecast Schedule (as per CPC)

Blue – dates at which 4 additional ensemble members are produce from breeding or simple differences
Pink – critical dates, as forecasts for these might not be ready by due date specified by CPC as 8th of month;
Nominally ten 9-month predictions per month
Hindcasts generated in the same way for each month 1981-2010

MID JANUARY release

Month	Day
12	12
12	17
12	22
12	27
1	1
1	6

MID FEBRUARY

Month	Day
1	11
1	16
1	21
1	26
1	31
2	5

MID MARCH

Month	Day
2	10
2	15
2	20
2	25
3	2
3	7

MID APRIL

Month	Day
3	12
3	17
3	22
3	27
4	1
4	6

MID MAY

Month	Day
4	11
4	16
4	21
4	26
5	1
5	6

MID JUNE

Month	Day
5	11
5	16
5	21
5	26
5	31
6	5

MID JULY

Month	Day
6	10
6	15
6	20
6	25
6	30
7	5

MID AUGUST

Month	Day
7	10
7	15
7	20
7	25
7	30
8	4

MID SEP

Month	Day
8	9
8	14
8	19
8	24
8	29
9	3

MID OCT

Month	Day
9	8
9	13
9	18
9	23
9	28
10	3

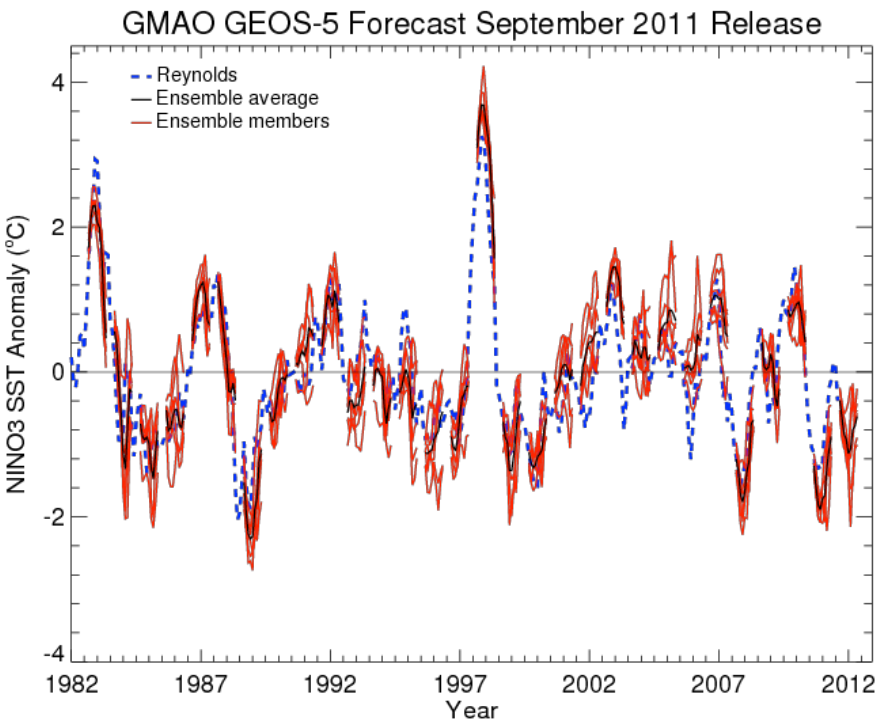
MID NOV

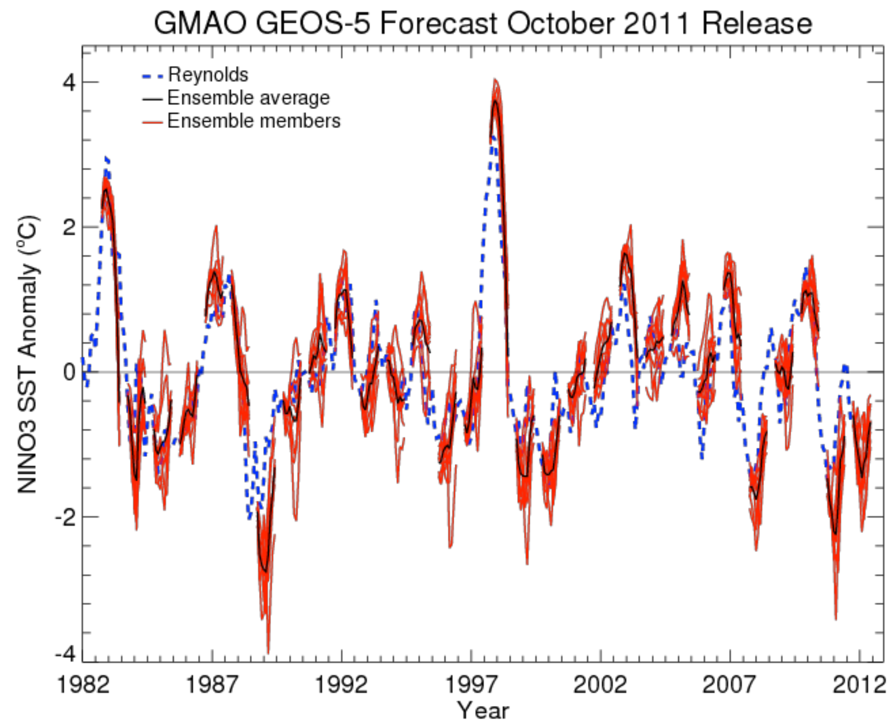
Month	Day
10	8
10	13
10	18
10	23
10	28
11	2
11	7

MID DEC

Month	Day
11	12
11	17
11	22
11	27
12	2
12	7

September and October Hindcasts (Nino3)



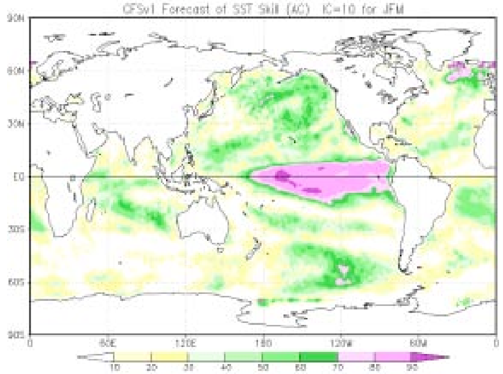


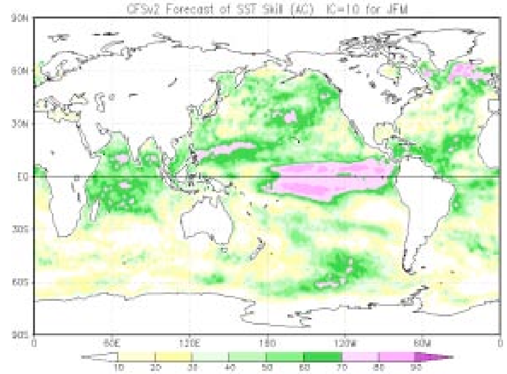
"National" MME

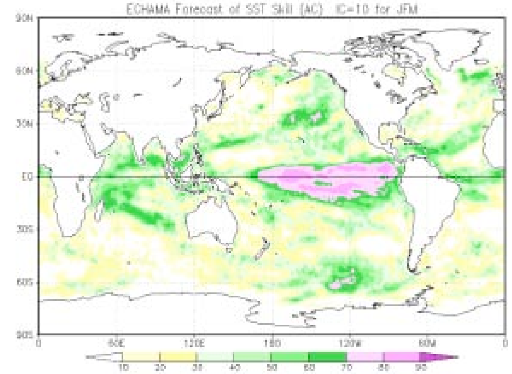
Model	Hindcast Period	Ensemble Size	Lead Times	Arrangement of Ensemble Members	Contact and reference
CFSv1	1981-2009	15	0-8 Months	1st 0Z +/-2 days, 21st 0Z +/-2d, 11th 0Z+/- 2d	Saha (Saha et al. 2006)
CFSv2	1982-2009	24(28)	0-9 Months	4 members (0,6,12,18Z) every 5th day	Saha (Saha et al. 2010)
GFDL-CM2.2	1982-2010	10	0-11 Months	All 1st of the month 0Z	Rosati (Zhang et al. 2007)
IRI-ECHAM4-f	1982-2010	12	0-7 Months	All 1st of the month 0Z	DeWitt (DeWitt 2005)
IRI-ECHAM4-a	1982-2010	12	0-7 Months	All 1st of the Month 0Z	DeWitt (Dewitt 2005)
CCSM3.0	1982-2010	6	0-11 Months	All 1st of the Month 0Z	Kirtman (Kirtman and Min 2009)
GEOS5	1981-2010	10	0-9 Months	1 Member every 5th day, 4 additional at end of month	Schubert (Vernieres et al. 2011)

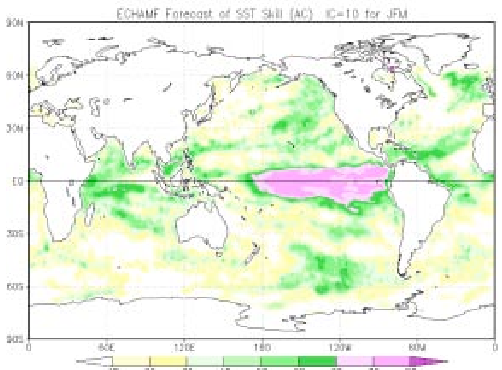
NOAA CTB effort

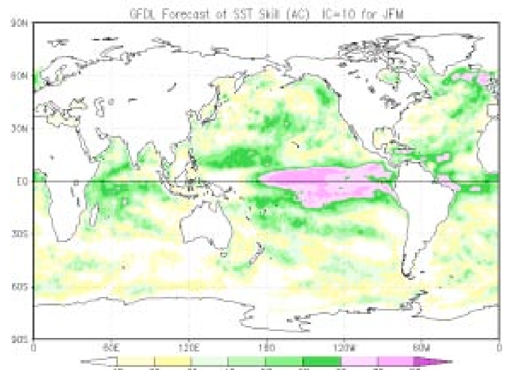
Oct Starts: Season 3 SST forecast (JFM) – Hindcast Correlations based on 1982 - 2011

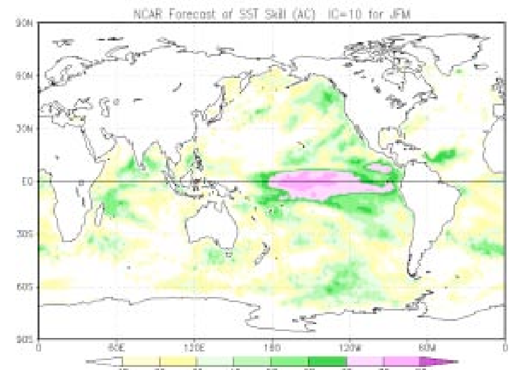




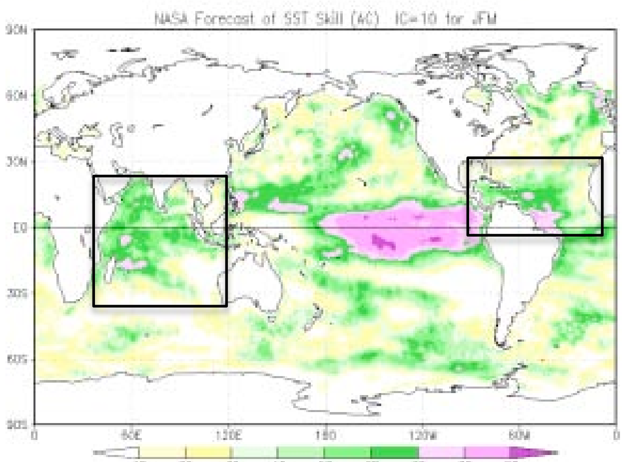


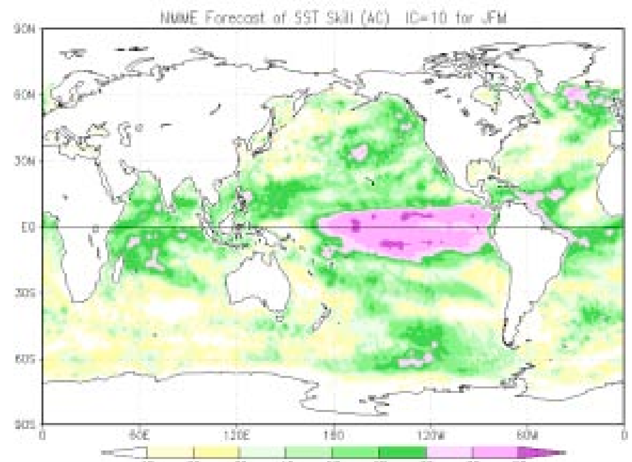






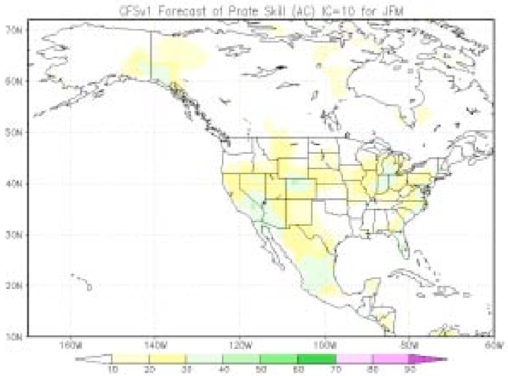
GEOS-5

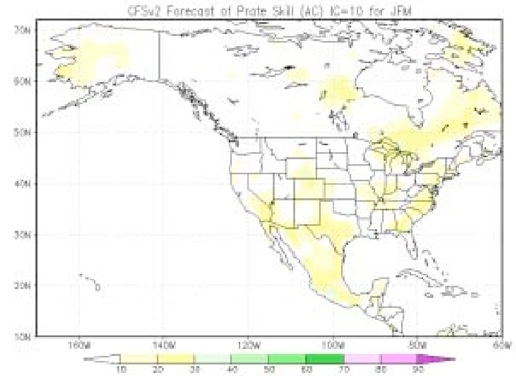


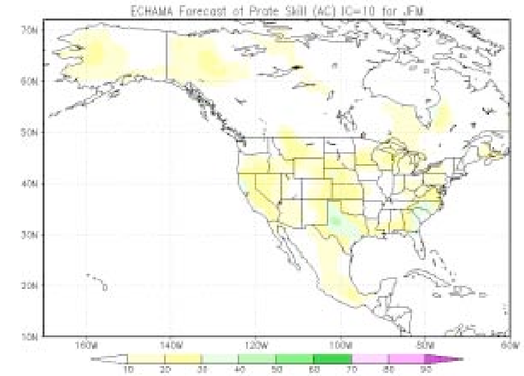


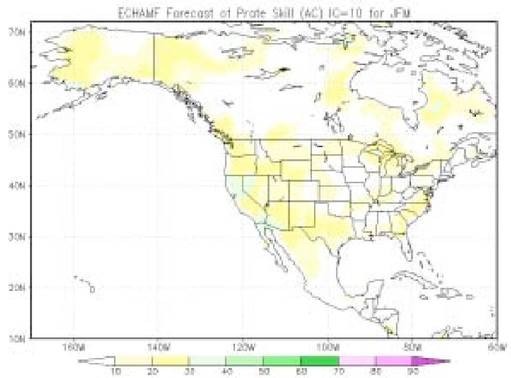
MME

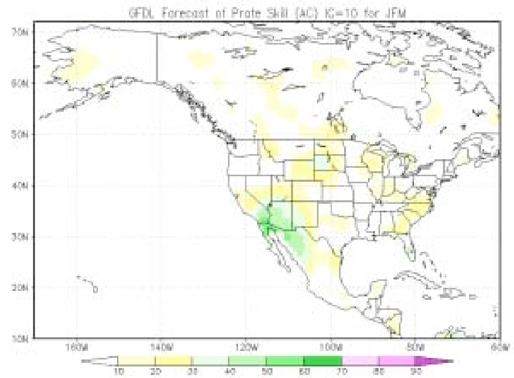
Oct Starts: Season 3 Precip forecast (JFM) – Hindcast Correlations based on 1982 - 2011

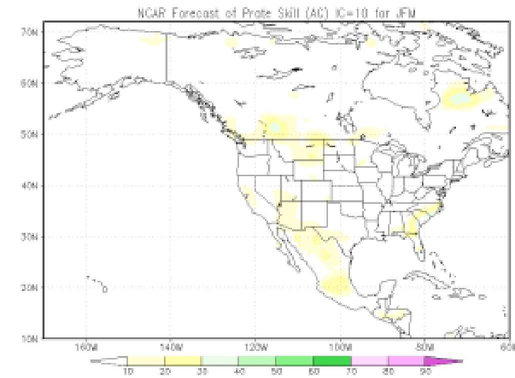




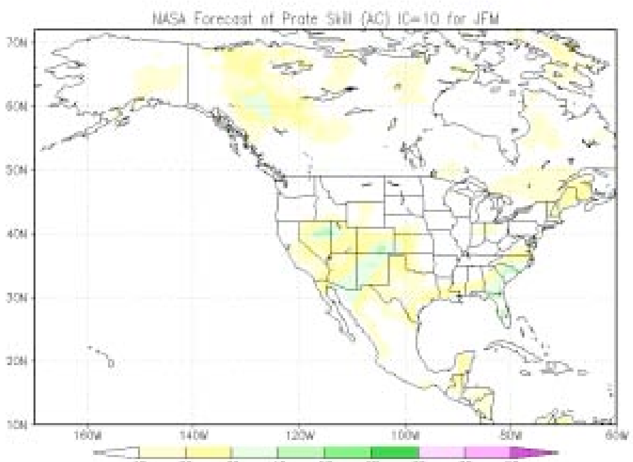


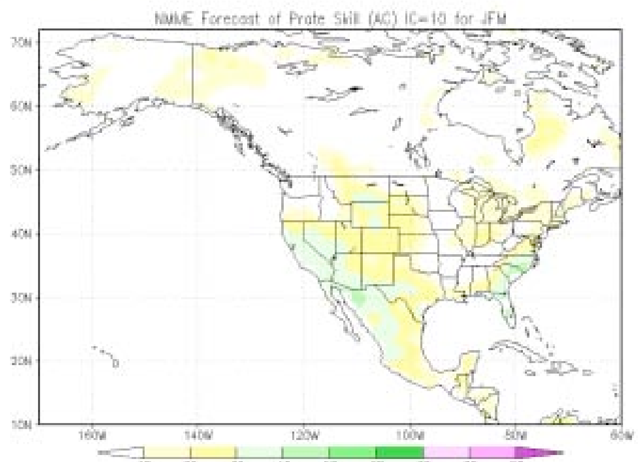






GEOS-5





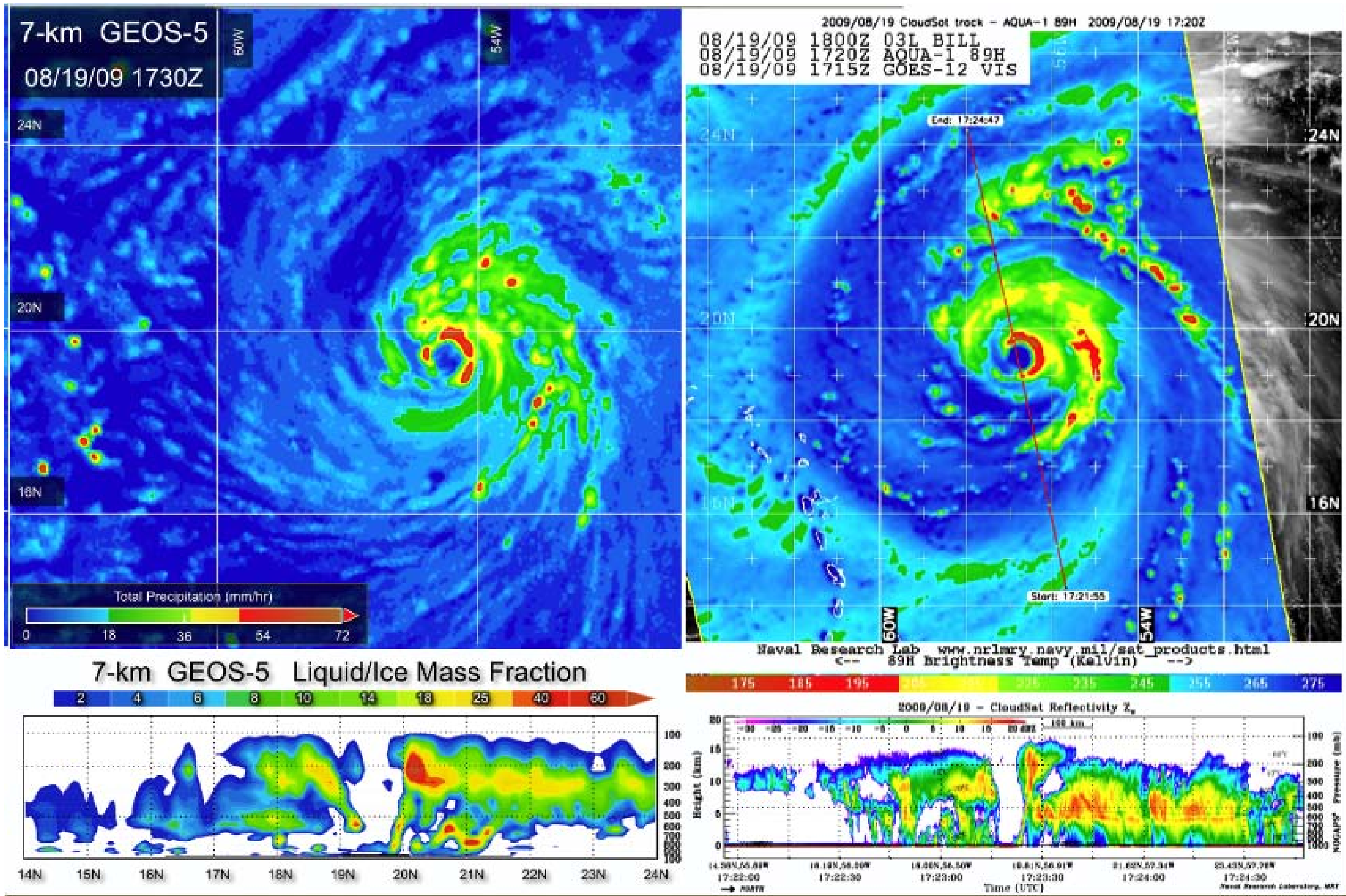
MME

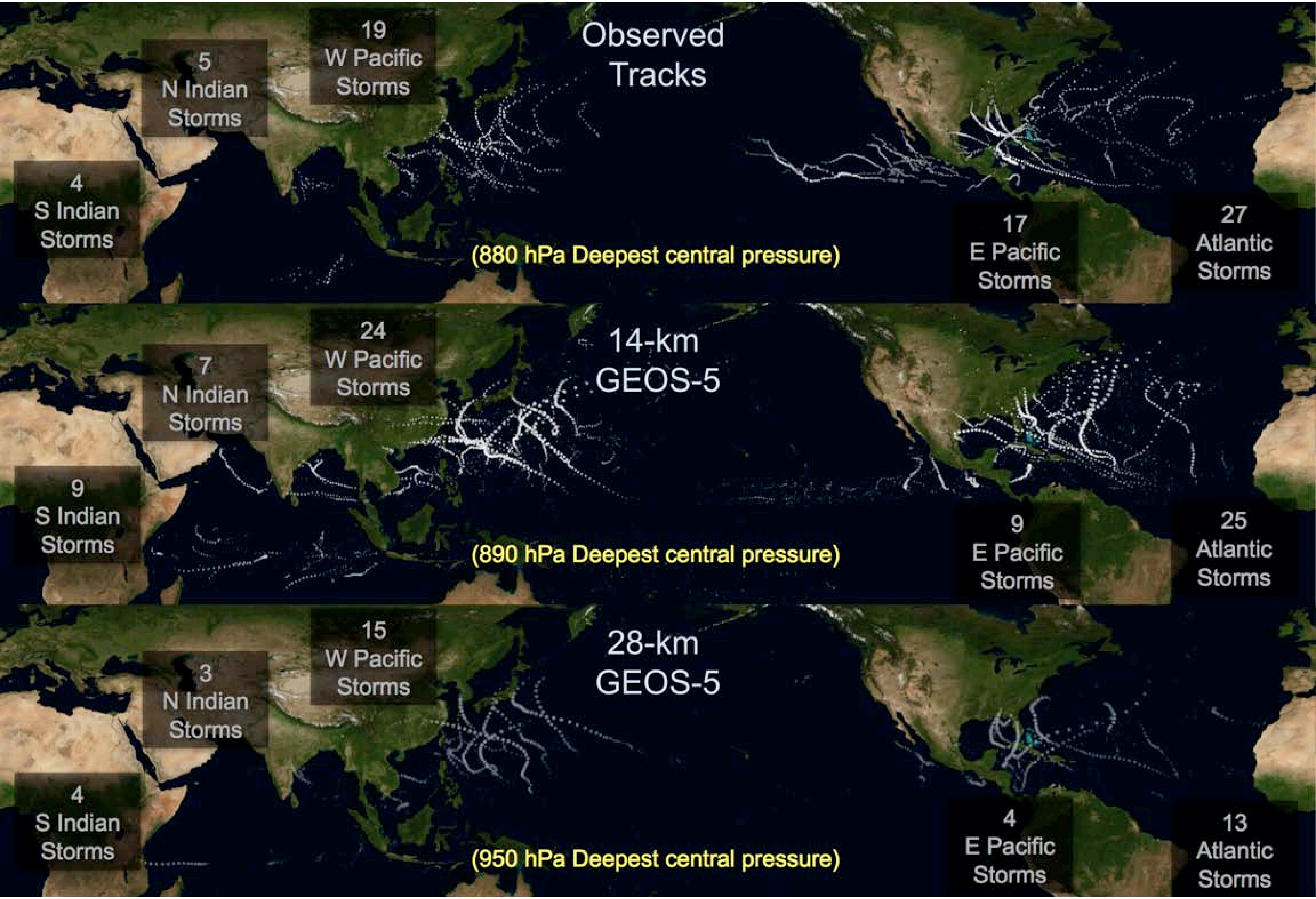
High Resolution AGCM Runs

- ½ degree AMIP (Young-Kwon Lim)
- ¼ degree attribution (2010 Snow storms, Chang et al 2011; spring storms/flooding and precursors to tornadic activity)
- 3.5 – 14km: focus on tropical storms(Putman and Suarez 2011)

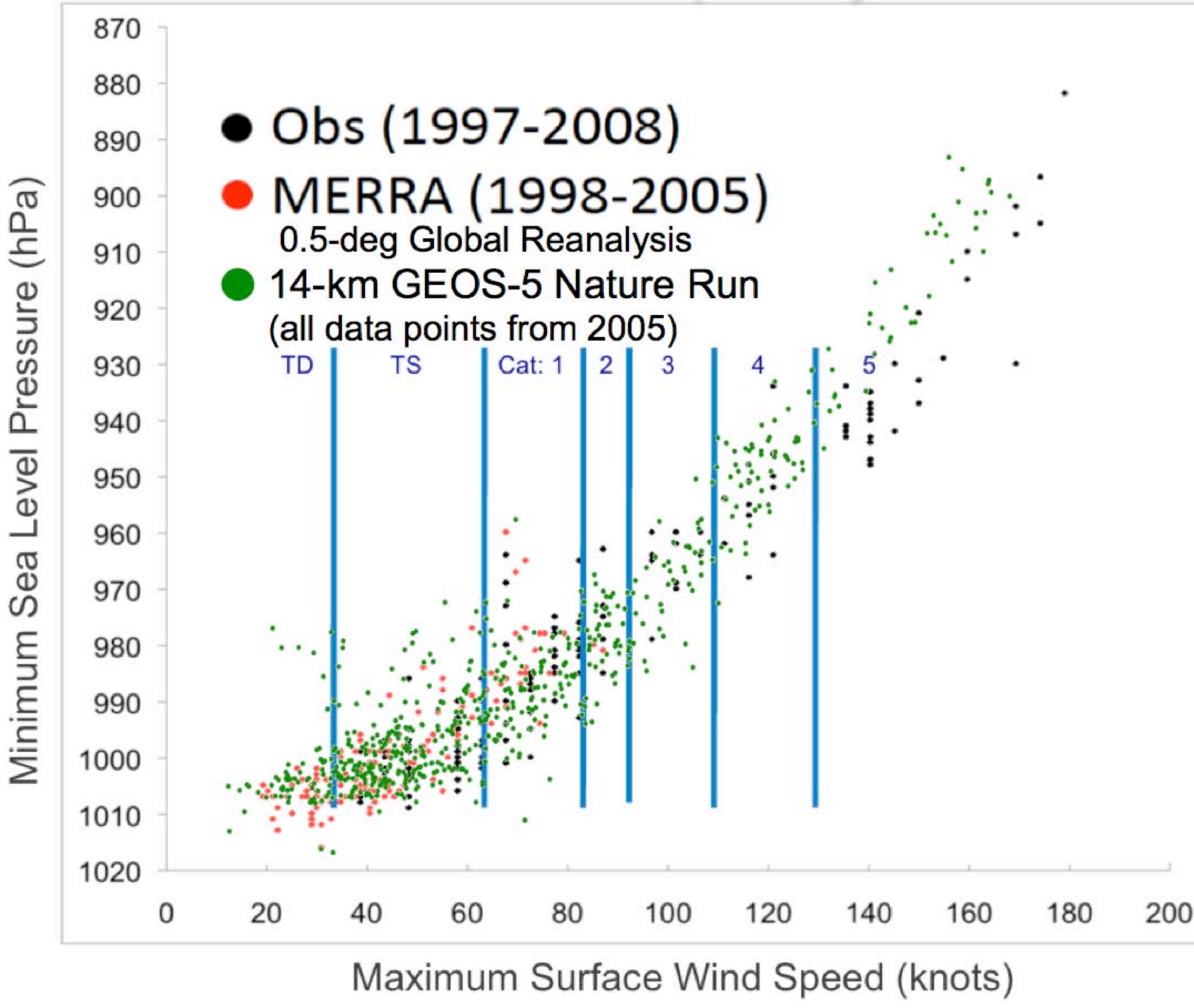
7 km GEOS-5

Observations





Observed Tracks
19 W Pacific Storms
5 N Indian Storms
4 S Indian Storms
(880 hPa Deepest central pressure)
17 E Pacific Storms
27 Atlantic Storms
14-km GEOS-5
24 W Pacific Storms
7 N Indian Storms
9 S Indian Storms
(890 hPa Deepest central pressure)
9 E Pacific Storms
25 Atlantic Storms
28-km GEOS-5
15 W Pacific Storms
3 N Indian Storms
4 S Indian Storms
(950 hPa Deepest central pressure)
4 E Pacific Storms
13 Atlantic Storms



Obs (1997-2008)
MERRA (1998-2005)
0.5-deg Global Reanalysis
14-km GEOS-5 Nature Run
(all data points from 2005)
TD
TS
Cat: 1
2
3
4
5
Minimum Sea Level Pressure (hPa)
870
880
890
900
910
920
930
940
950
960
970
980
990
1000
1010
1020
0
20
40
60
80
100
120
140
160
180
200
Maximum Surface Wind Speed (knots)

Atlas of Extremes

- Compares MERRA and CFSR and various observational datasets
- VAMOS Working Group on extremes
  http://gmao.gsfc.nasa.gov/research/subseasonal/atlas/Extremes.html (Developed at GMAO by Young-Kwon Lim)
- Characterizing extremes for the recent past over the Americas

Characterizing extremes for the recent past over the Americas

This webpage displays the rainfall and temperature characteristics for the last three decades over the Americas. Geographical distribution and time series of the values displayed on this webpage are climatology (seasonal & daily), rainfall frequency, temporal variation of the monthly precipitation in terms of the Standardized Precipitation Index (SPI), return values of extreme-related quantities from daily precipitation, and temperature extreme indices. The SPI is presented here to give an indication of what the precipitation amount is in relation to normal, and whether the individual locations experience wet/drought condition. Return values have been calculated for the daily maximum precipitation, the number of heavy rainfall events, the number of rainy days, and the consecutive dry days per season based on the Generalized Extreme Value (GEV) distribution. Please click the following list to be better informed about the concept of these values and the process of calculation.

Note: Please be aware that this atlas is a beta version. The atlas is still evolving as we learn more about the quality of the data and continue to add additional extreme parameters. We point out in particular that there are substantial regional difference in the quality of the reanalysis products with parts of South America showing considerably less (compare with North America) agreement in the precipitation and surface temperature fields among the reanalysis products and compared with observations (to the extent those are available). Please click Readmefirst for more information.

1. Mean fields

1.1 Seasonal climatology (Precipitation)
MERRA CFSR CPC (US&Mexico) CPC (SA) CDC (SA)
1.2 Seasonal climatology (Temperature)
MERRA (T mean, T max, T min) CFSR (T mean, T max, T min)
1.3 Daily precipitation climatology
1.4 Daily rainfall frequency

Basic climatologies

2. Precipitation extreme indices

2.1 The Number of Extreme Rain Days (Prcp. amount > 90% percentile) Maps
2.2 Maximum Length of Wet Spell (Max. number of consecutive rainy days (rain >= 1mm)) Maps
2.3 Maximum Length of Dry Spell (Max. number of consecutive dry days (rain < 1mm)) Maps

Precipitation extremes

3. Standardized Precipitation Index (SPI)

3.1 SPI maps
3.2 SPI time series
3.3 SPI plots for each season
MAM JJA SON DJF

SPI time series and maps

4. Generalized Extreme Value (GEV) and Return values

4.1 Return value maps
4.2 Return value maps in ENSO phases
El Niño years La Niña years Difference (El Niño - La Niña)

Precipitation return values based on GEV fits, including impact of ENSO

5. Temperature extreme indices

5.1 The Number of Warm Extreme Days (Tmax >= 90% percentile) Maps
5.2 The Number of Warm Extreme Days time series
5.3 The number of Cold Extreme Days (Tmin =< 10% percentile) Maps
5.4 The Number of Cold Extreme Days time series
5.5 Warm Spell Duration Index (WSDI) time series
5.6 Cold Spell Duration Index (CSDI) time series
5.7 The Number of Warm Extreme Nights (Tmin >= 90% percentile) Maps
5.8 The Number of Warm Extreme Nights time series

Various temperature extremes - latest

Datasets used:

1. Modern Era Retrospective-analysis for Research and Applications (MERRA) (1979-2009) from NASA/GSFC/GMAO (0.667x0.5 degree resolution)
2. The Climate Forecast System Reanalysis (CFSR) (1979-2009) from NOAA/NCEP (T382(~0.3125 degree Resolution))
3. NOAA/NCEP/CPC gridded observation (1.0 degree resolution)
3.1 North America (US and Mexico) (1979-2009)
3.2 South America (1978-2007)
4. NOAA/CDC (Liebmann et al. 2005) gridded observation over South America (1979-2005) (2.5 degree resolution)

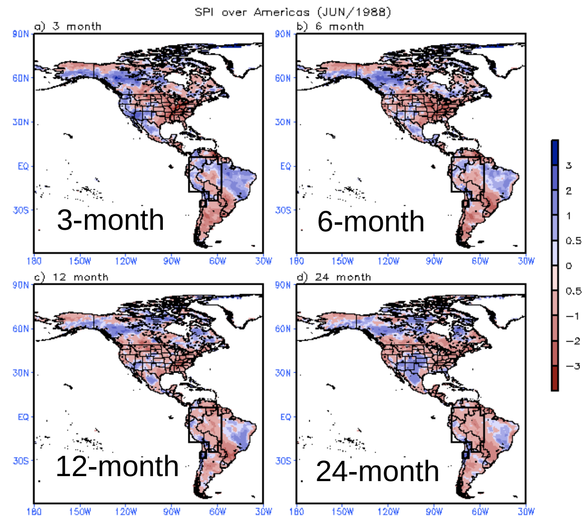
Data sets: MERRA, CFSR, gridded station obs (CPC, CDC)

Standardized Precipitation Index (SPI)

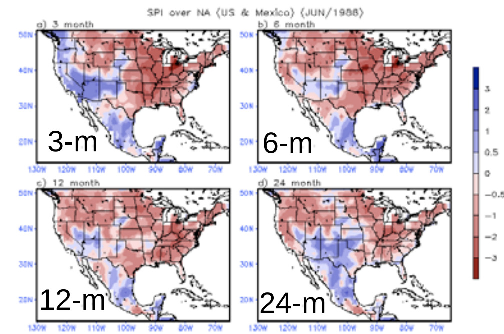
Standardized Precipitation Index time series over 1981-2009 Note: Part of South America where the reanalysis is very low correlated (MERRA, CFSR) with the observational CPC precipitation show some inconsistency with the observational SPI time series. Please be sure to check **Domains for area-averaging** (Domains) before looking at the SPI time series		
1. SW Canada 3 mon. 6 mon. 12 mon. 24 mon.	2. SC Canada 3 mon. 6 mon. 12 mon. 24 mon.	3. SE Ontario (Toronto & near Great lakes) 3 mon. 6 mon. 12 mon. 24 mon.
4. SE Canada (Quebec(Montreal)) 3 mon. 6 mon. 12 mon. 24 mon.	5. US (WA, OR, ID, MT, WY) 3 mon. 6 mon. 12 mon. 24 mon.	6. US (ND, SD, NE, MN, IA) 3 mon. 6 mon. 12 mon. 24 mon.
7. US (WI, IL, IN, MI, OH) 3 mon. 6 mon. 12 mon. 24 mon.	8. US (PA, NY, NJ, CT, MA, RI, NH, VT, ME) 3 mon. 6 mon. 12 mon. 24 mon.	9. US (CA, NV, UT, AZ) 3 mon. 6 mon. 12 mon. 24 mon.
10. US (CO, NM, KS, OK, TX) 3 mon. 6 mon. 12 mon. 24 mon.	11. US (MO, AR, KY, TN) 3 mon. 6 mon. 12 mon. 24 mon.	12. US (WV, VA, MD, DC, DE, NC) 3 mon. 6 mon. 12 mon. 24 mon.
13. US (LA, MS, AL, FL, GA, SC) 3 mon. 6 mon. 12 mon. 24 mon.	14. North American Monsoon (NAM) 3 mon. 6 mon. 12 mon. 24 mon.	15. Mexico 3 mon. 6 mon. 12 mon. 24 mon.
16. C America (Guatemala, Belize, Honduras, El Salvador, Nicaragua, Costa Rica, Panama) 3 mon. 6 mon. 12 mon. 24 mon.	17. Caribbean island countires 3 mon. 6 mon. 12 mon. 24 mon.	18. N Colombia, Venezuela, Tri.&Tobago, N Guyana 3 mon. 6 mon. 12 mon. 24 mon.
19. Ecuador, S Colombia, N Peru 3 mon. 6 mon. 12 mon. 24 mon.	20. S Peru 3 mon. 6 mon. 12 mon. 24 mon.	21. NW Amazon (NW Brazil), S Venezuela 3 mon. 6 mon. 12 mon. 24 mon.
22. NE Amazon (N Brazil), S Guyana, Suriname, French Guiana 3 mon. 6 mon. 12 mon. 24 mon.	23. Amazon (W Brazil) 3 mon. 6 mon. 12 mon. 24 mon.	24. Amazon (NE Brazil) 3 mon. 6 mon. 12 mon. 24 mon.
25. C Brazil 3 mon. 6 mon. 12 mon. 24 mon.	26. SE Brazil 3 mon. 6 mon. 12 mon. 24 mon.	27. E Brazil 3 mon. 6 mon. 12 mon. 24 mon.
28. Bolivia, N Argentina 3 mon. 6 mon. 12 mon. 24 mon.	29. Paraguay, S Brazil 3 mon. 6 mon. 12 mon. 24 mon.	30. Uruguay, SE Brazil 3 mon. 6 mon. 12 mon. 24 mon.
31. Chile, W Argentina (Andes) 3 mon. 6 mon. 12 mon. 24 mon.	32. E Argentina 3 mon. 6 mon. 12 mon. 24 mon.	

SPI June 1988

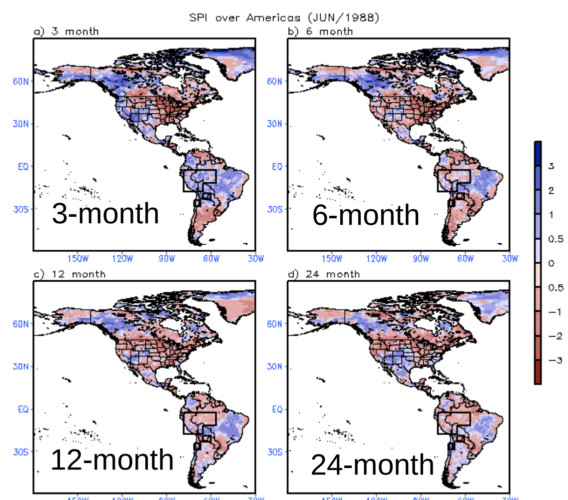
MERRA



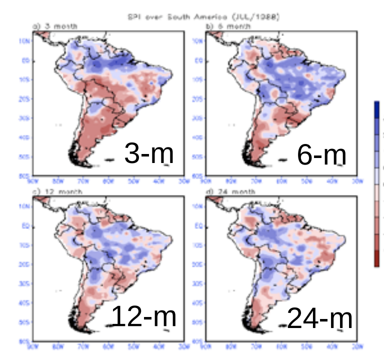
CPC



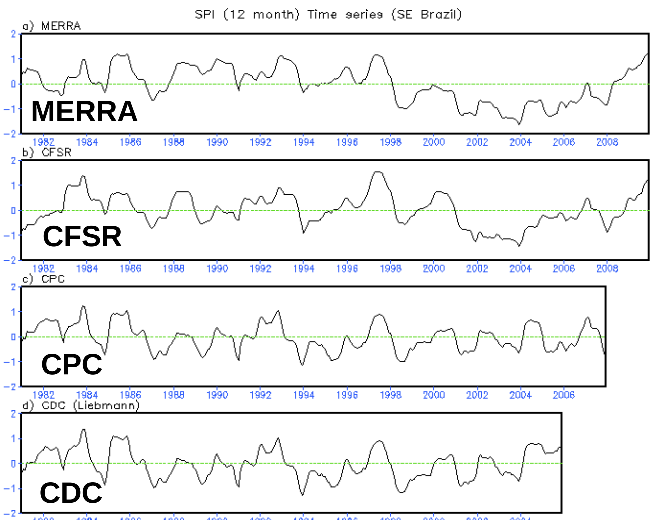
CFSR



CDC



SPI 12 month – SE Brazil



Towards a Global Drought Early Warning System

- Barcelona Drought workshop (March 2011) (http://drought.wcrp-climate.org/workshop/index.shtml)
- Action Items
  - Drought catalog
    - Global assessment of current understanding
  - Experimental global drought early warming system
    - GDEWS workshop: 11-13 April 2012, at ESA-ESRIN, Frascati
  - Coordinated case studies
    - Example: Russian Heat Wave

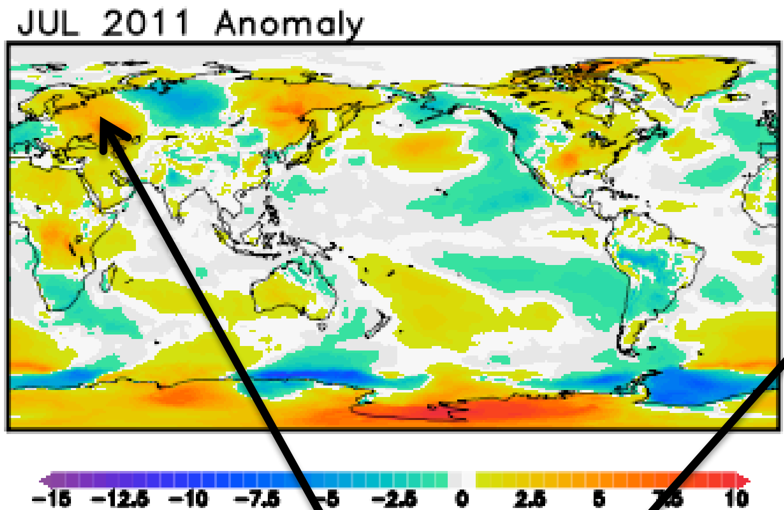
July: Russian Heat Wave and Fires

- Central Russia …. with temperatures above 30°C for an entire month.
- “The central city of Volgograd was Russia’s hottest city with temperatures hovering above 40° Celsius (104 F) for the past few days, hotter than Cairo, Tashkent, Tehran and New Delhi.” The extreme heat is causing the former permafrost tundra to smolder and burn.
- Across Russia, “the emergencies ministry used 18 planes and 38 helicopters in an effort to douse a total of 220 wildfires, including 28 major blazes covering nearly 12,000 hectares,” a Moscow-based spokeswoman told AFP. “A major fire started in the southern Rostov region on Tuesday causing two days of explosions of World War II-era shells embedded in a local forest.”

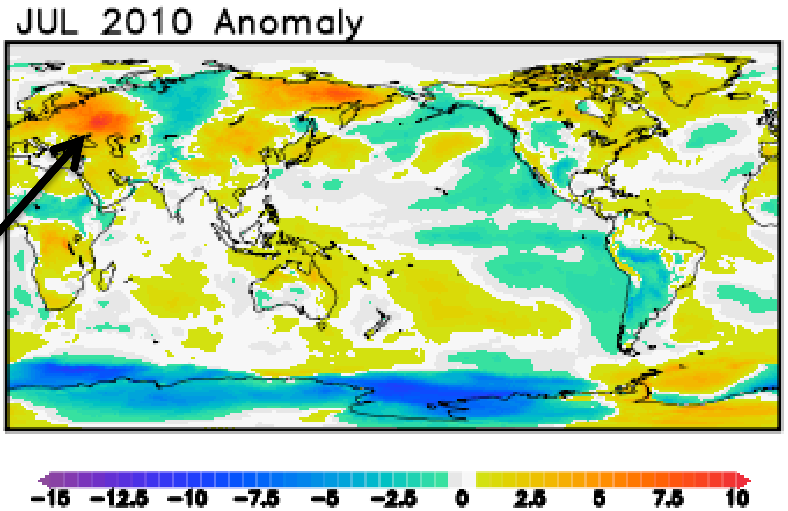
MERRA
Atlas

Temperature at 2 meters

July 2011



July 2010



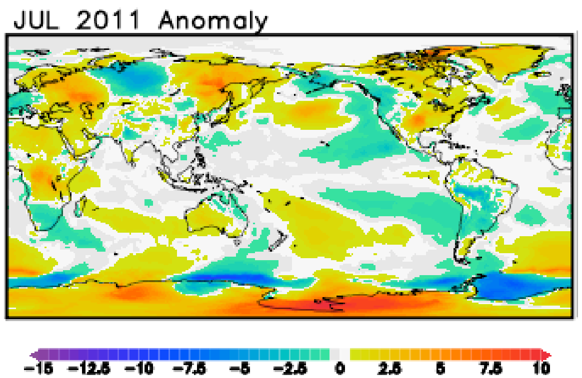
°C

Russian Heat Waves

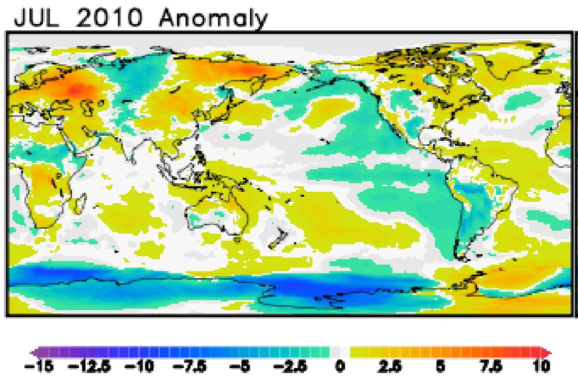
MERRA
Atlas

Temperature at 2 meters

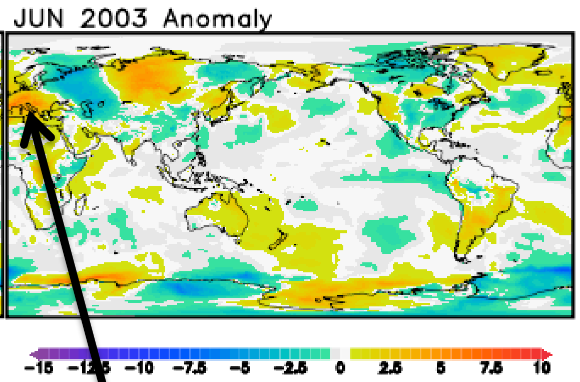
July 2011



July 2010



June 2003



°C

European Heat Wave

Leading Rotated EOFs
Monthly JJA V250mb

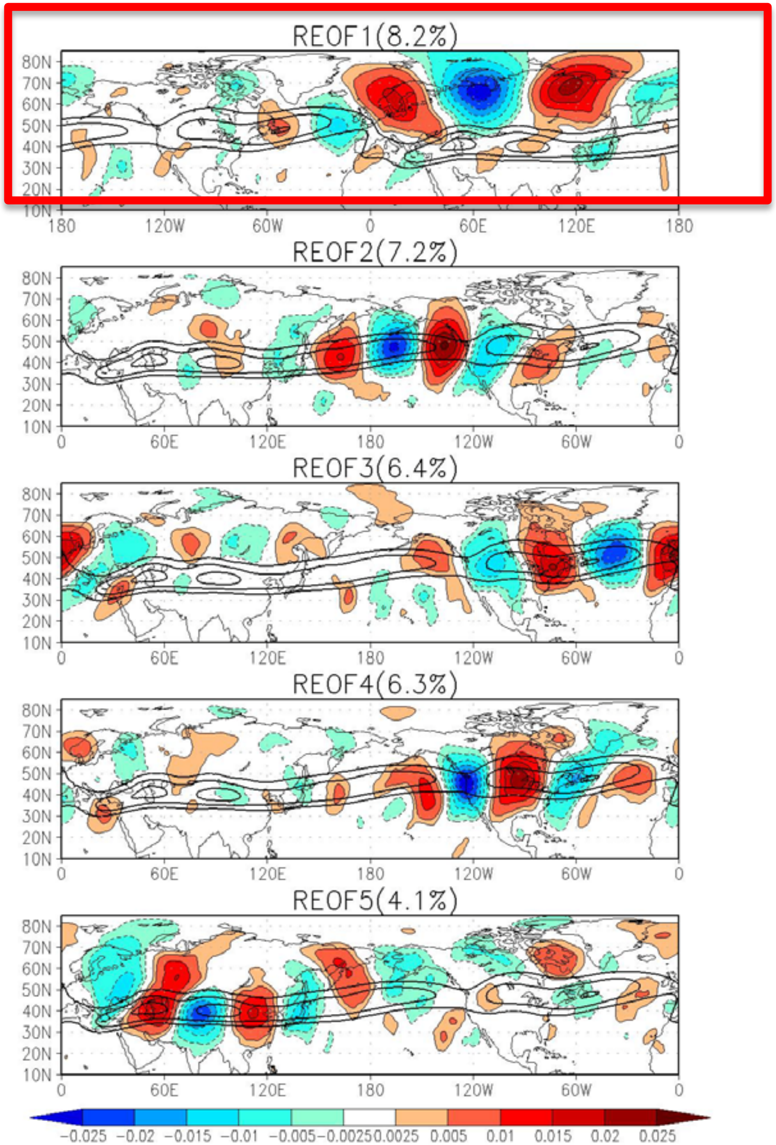
REOF 1

REOF 2

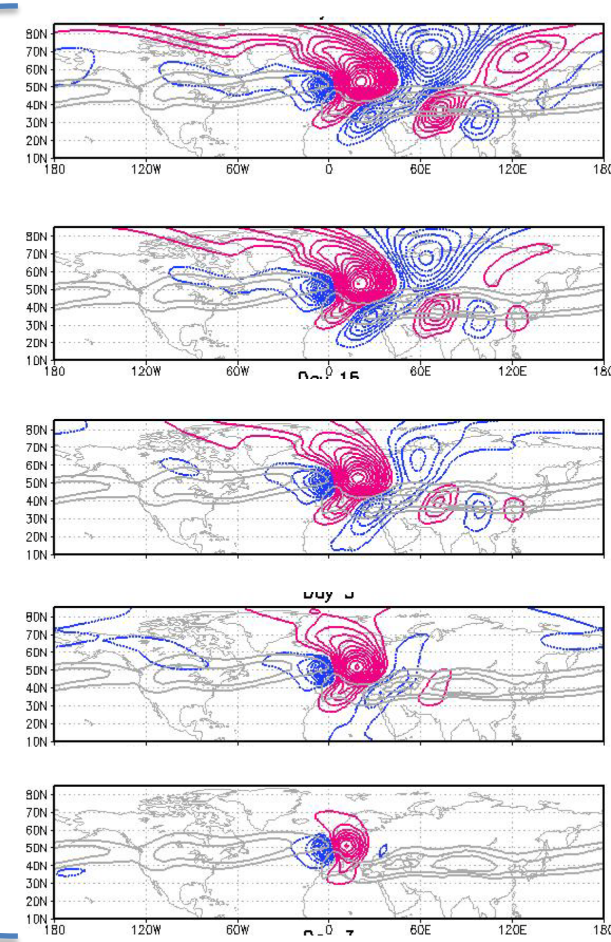
REOF 3

REOF 4

REOF 5



SWM response of the eddy v-wind at σ=0.257 to an idealized vorticity source at 0E, 50N



Day 20

Day 10

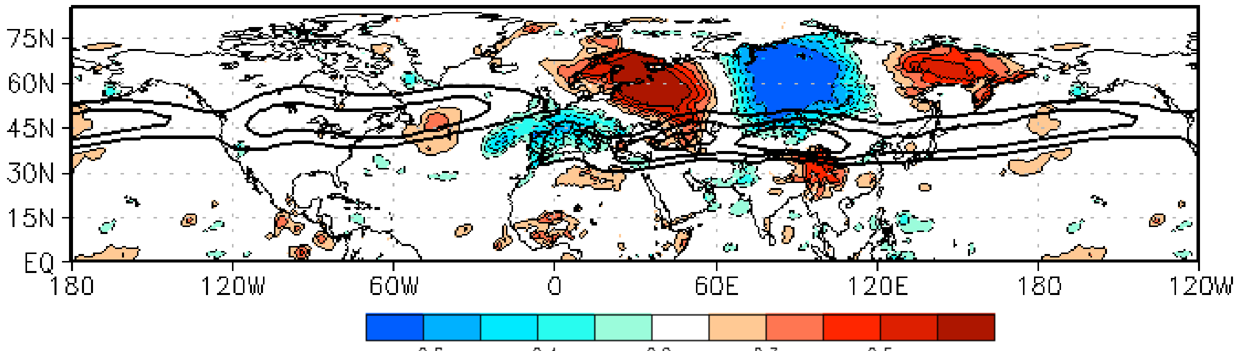
Day 5

Day 3

Day 1

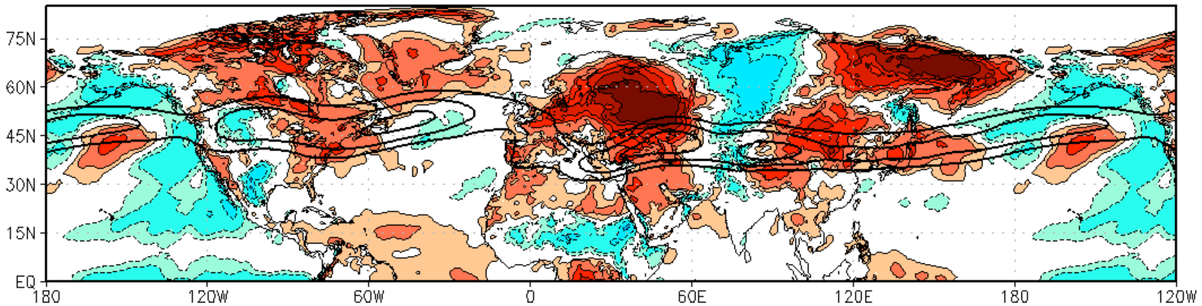
MERRA Base State: JJA 1979-2010

V250mb REOF 1 Correlated with T2m (Monthly JJA)

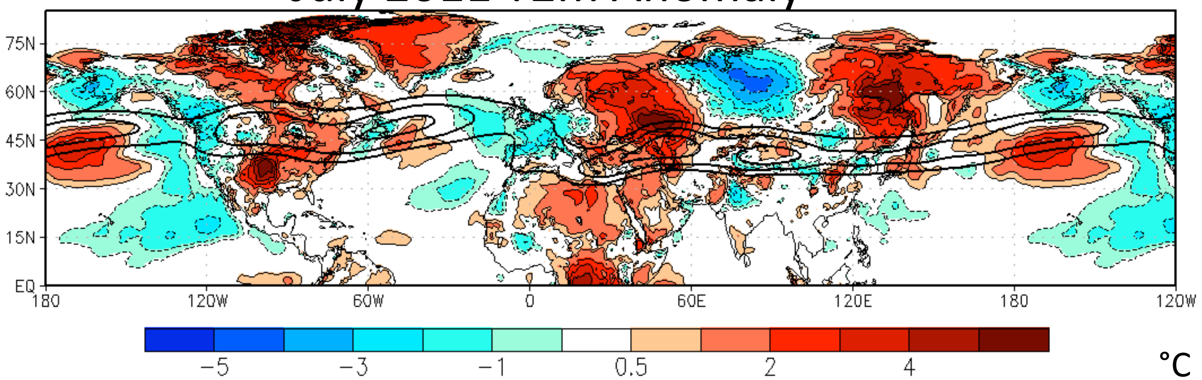


1979-2005

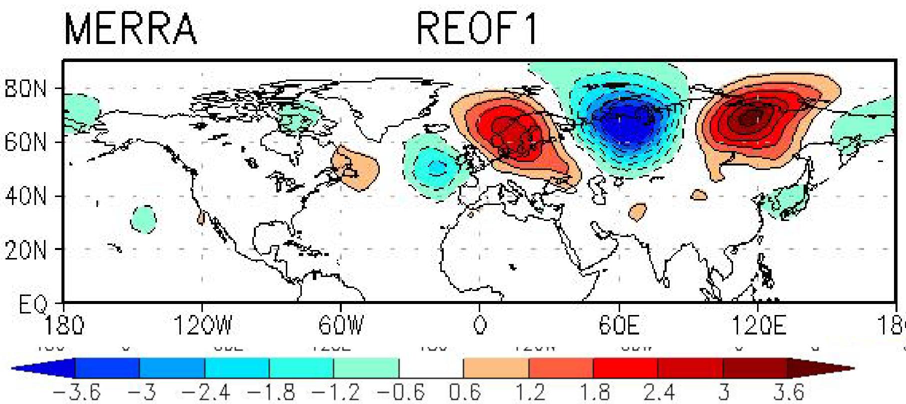
July 2010 T2m Anomaly



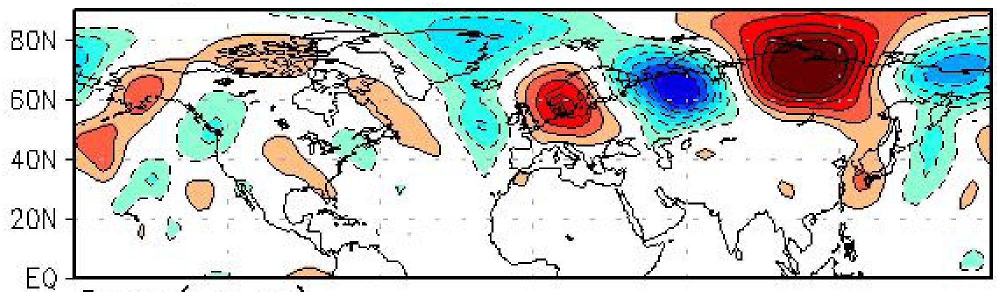
July 2011 T2m Anomaly



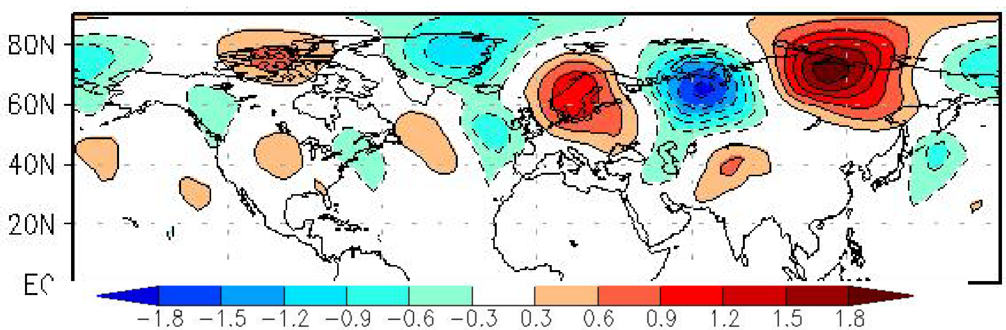
What Forces This Wave?



Stationary Wave Model (total forcing)

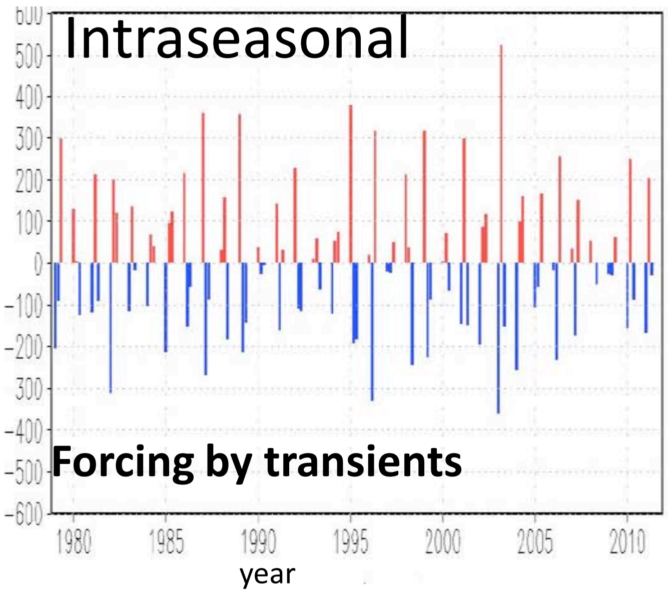


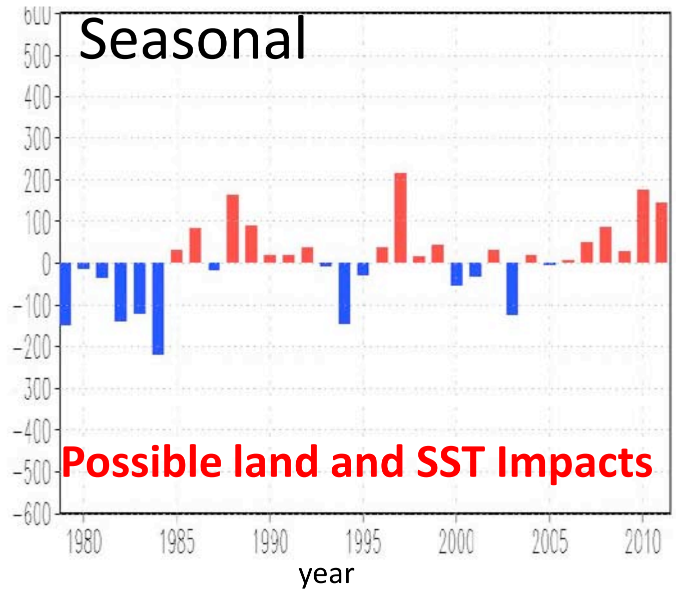
Stationary Wave Model (vorticity transients)

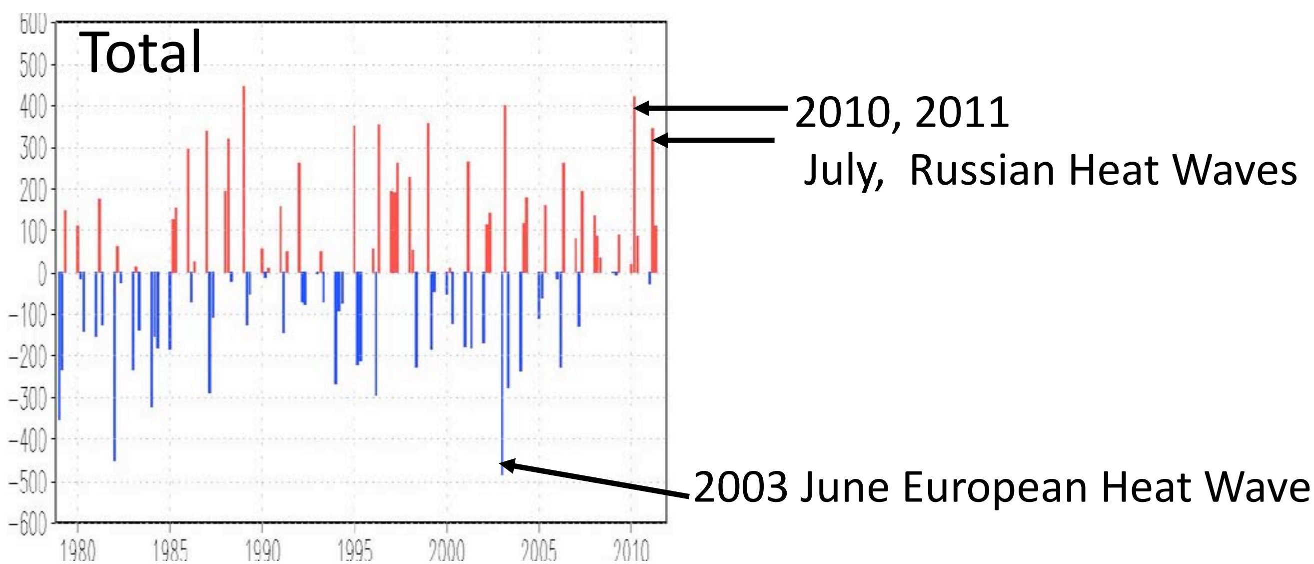


At subseasonal time scales vorticity transients are the main forcing

v250mb REOF 1 (PC, JJA 1979-2011)







Examine Impact of Land and SST on 2010 Russian Heat Wave

GEOS-5 AGCM experiments (1°) :

1) initialized 1 May, 20 ensemble members, observed SST
2) initialized 1 May, 20 ensemble members, climatological SST
3) initialized 1 January, 40 ensemble members, observed SST

- Land and Atmosphere initialized from MERRA
- Anomalies wrt the mean of 4 ensemble members run for each year 1982-2000

Impact of Land/atmosphere and SST

Impact of SST

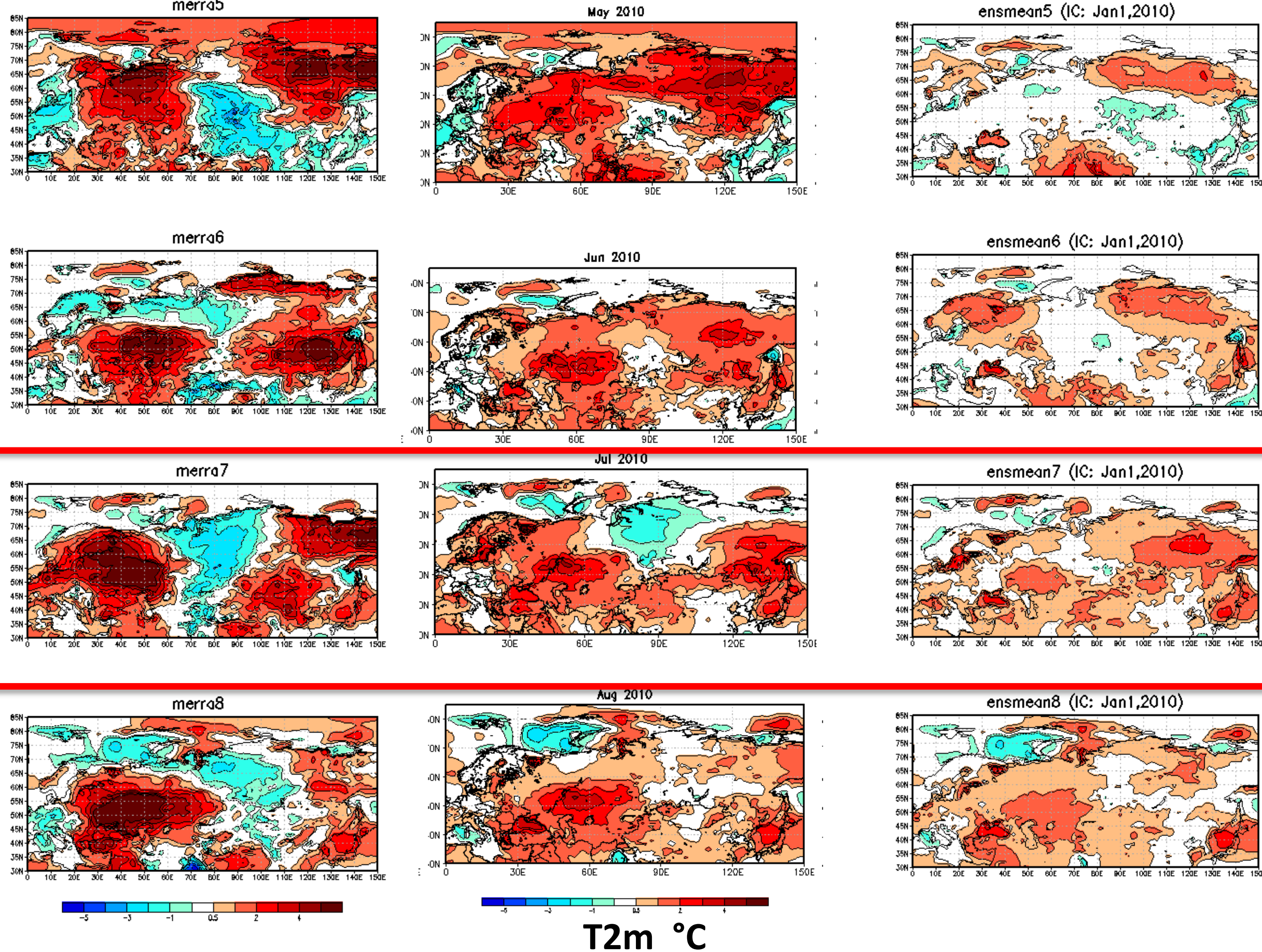
MERRA	IC (May1,2010)- Perturbation runs: 20	IC (Jan1,2010) Perturbation runs: 40

May

June

July

August

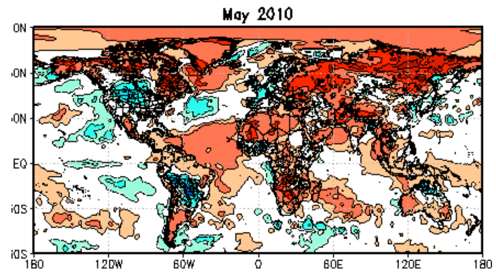


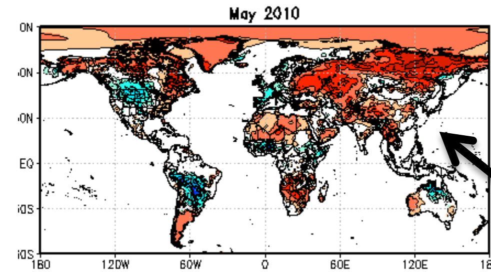
T2m °C

AGCM Observed SST (IC May 1)

AGCM Climate SST (IC May 1)

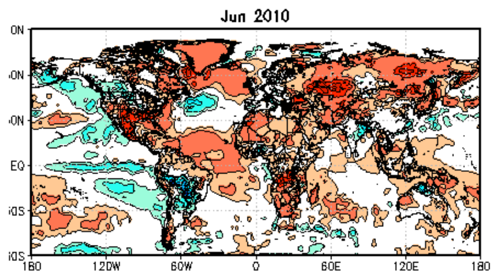
May 2010

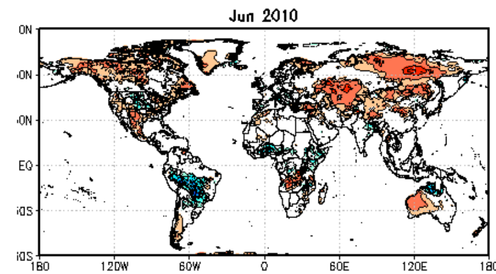




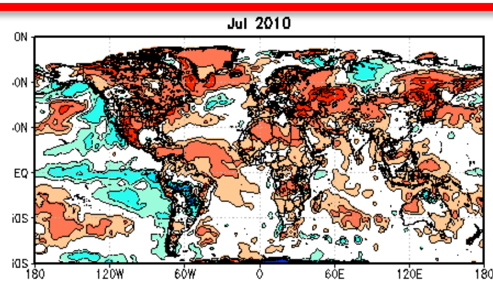
Impact of Land and Atmospheric Initial conditions and land feedbacks

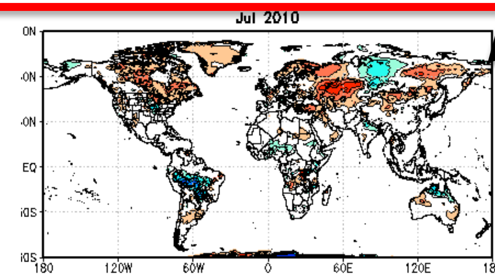
June 2010



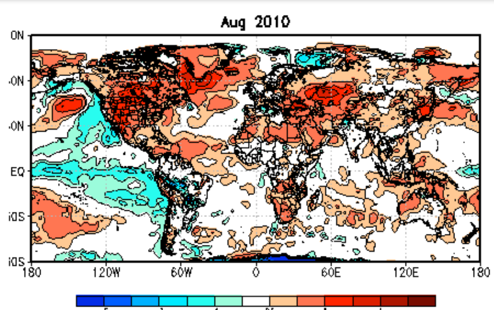


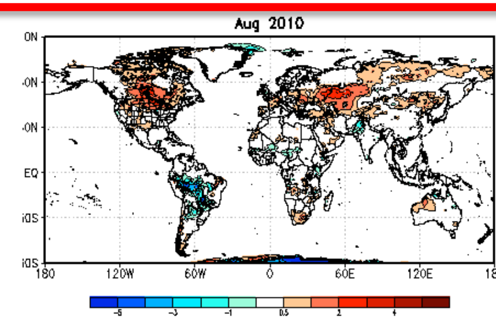
July 2010





August 2010





V250mb
m/s

AGCM Observed SST (IC May 1)

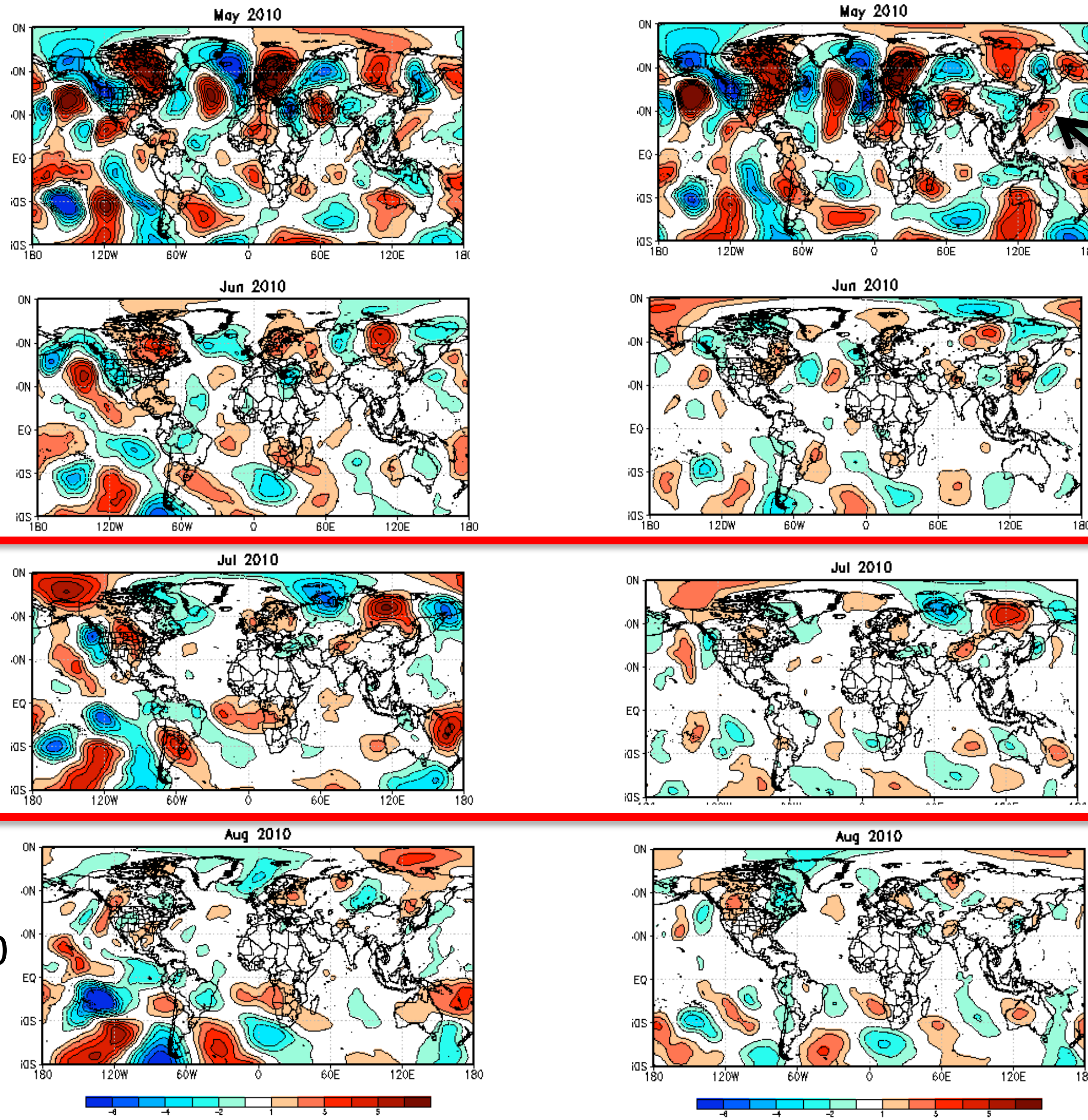
AGCM Climate SST (IC May 1)

May 2010

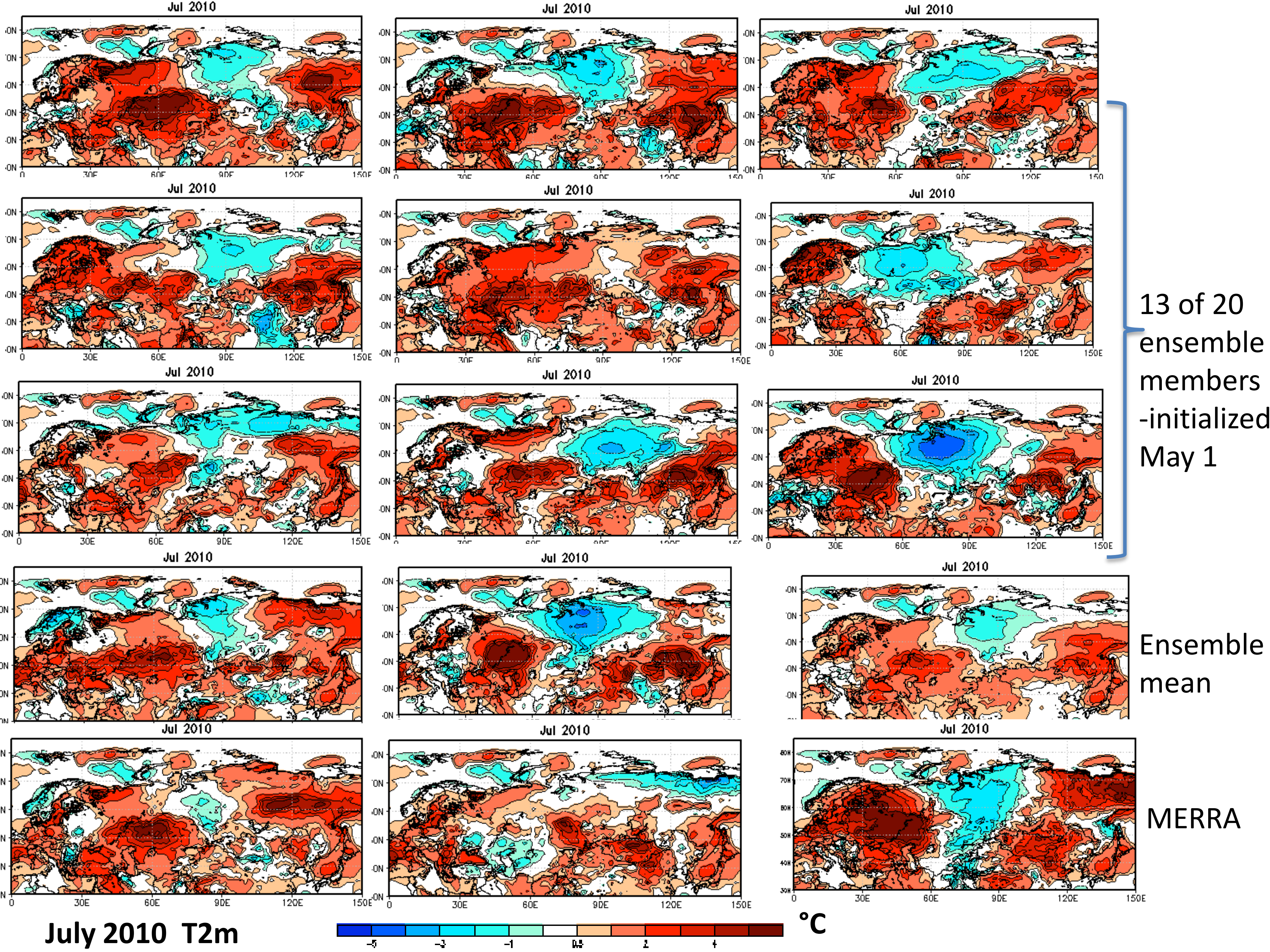
June 2010

July 2010

August 2010



Impact of Land and Atmospheric Initial conditions and land feedbacks


Jul 2010
13 of 20 ensemble members -initialized May 1
Ensemble mean
MERRA
0 30E 60E 90E 120E 150E
July 2010 T2m
-5 -3 -1 0.5 2 4
°C

2010/11 Russian Heat Waves: Preliminary Conclusions

- A summertime recurring Rossby Wave over Eurasia (forced by sub-monthy vorticity transients) gets amplified and becomes stationary
- SST anomalies appear to play a role in preconditioning (warming and drying the land)
- Land feedbacks appear to play a role in maintaining the Rossby wave

Concluding Remarks

- The GEOS-5 model is being used in a wide range of applications
  - Prediction at subseasonal to decadal time scales
  - High resolution (attribution of extremes, data assimilation)
  - Reanalysis (MERRA, working towards an IESA capability)

- GMAO will continue to contribute to MME efforts
  - APCC and new US national effort

- Invite APCC involvement in efforts to develop a GDEWS

Extra Slides

GEOS-5 AGCM for ISI Prediction

- Finite volume dynamical core (Lin, 2004)
  - 1°x1.25°x72 layers
- Convection: Relaxed Arakawa-Schubert (Moorthi and Suarez, 1992)
  - Modified after Sud and Walker (1999) to compute rainout from updraft
  - Stochastic Tokioka (1988) trigger
- Prognostic Cloud/Microphysics: Bacmeister et al. (2006)
- Boundary Layer: Lock (2000) and Louis (1982)
  - Use larger of K values from the two schemes
  - Lock scheme suppressed in presence of wind shear
  - Louis turbulent length scale from (diagnosed from K profile) PBL depth
- Radiation: Shortwave – Chou and Suarez (1999), Longwave – Chou et al. (2001)
- Surface Layer: Monin-Obukov of Helfand and Schubert (1995)
- Gravity Wave Drag Scheme based on McFarlane (1987) and Garcia and Boville (1994)
- Interactive Aerosol from GOCART model
- Chemistry
  – GHGs, ozone: relaxation to time evolving specified zonal means consistent with IPCC

The GEOS-5 OGCM for ISI Prediction

- MOM4
  - Version 4.1 patch 1
  - ½°x½°x40 levels (1/4° equatorial refinement), tri-polar grid
  - B-grid, Z-coordinate (geopotential option)
  - KPP vertical mixing
  - Laplacian horizontal diffusion and friction
- Diurnal skin layer (Price)
- Sea ice: CICE (Los Alamos National Laboratory)

GEOS ODAS-2

- ODAS-2 can be run as an Ensemble Kalman Filter (EnKF) with state-dependent multivariate background error covariances or as an Ensemble OI (EnOI) with static multivariate background error covariances
  - EnKF: 20 member ensemble
  - EnOI: Static ensemble of 20 EOFs from time series of differences in 20-member ensemble AOGCM simulation

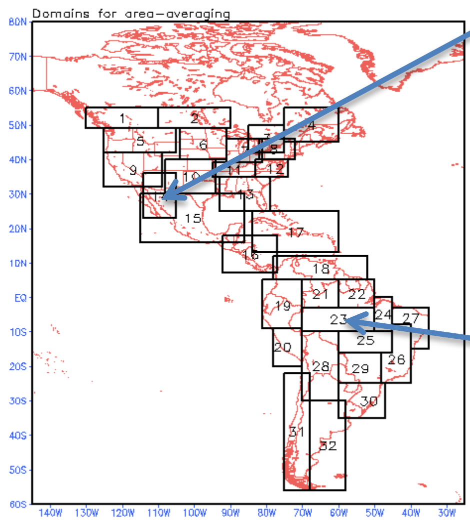
- T and S profiles (Buoys, XBTs, CTDs, Argo) and Reynolds SST are assimilated daily.
- XBT temperature profiles have been corrected according to Levitus et al. (2009).
- For XBTs and Buoys, synthetic salinity profiles are generated from Levitus & Boyer S(T)
- Climatological SSS is assimilated to compensate for errors in fresh water input from precipitation and river runoff.
- Sea Level Anomalies are from AVISO.
- Analysis is also constrained by Levitus & Boyer climatological temperature and salinity – correction made to first guess fields before assimilation of other real-time data – univariate.
- Multivariate covariances correct T and S, not currents.

Climatology – Annual Cycle of Daily Precipitation

Daily precipitation amount climatology (1979-2009) (domain averaged)

Daily precipitation climatology [mm/day] Domains for area-averaging (Click here~.)		
1. SW Canada	2. SC Canada	3. SE Ontario (Toronto & near Great lakes)
4. SE Canada (Quebec(Montreal))	5. US (WA, OR, ID, MT, WY)	6. US (ND, SD, NE, MN, IA)
7. US (WI, IL, IN, MI, OH)	8. US (PA, NY, NJ, CT, MA, RI, NH, VT, ME)	9. US (CA, NV, UT, AZ)
10. US (CO, NM, KS, OK, TX)	11. US (MO, AR, KY, TN)	12. US (WV, VA, MD, DC, DE, NC)
13. US (LA, MS, AL, FL, GA, SC)	14. North American Monsoon (NAM)	15. Mexico
16. C America (Guatemala, Belize, Honduras, El Salvador, Nicaragua, Costa Rica, Panama)	17. Caribbean isand countries	18. N Colombia, Venezuela, Tri.&Tobago, N Guyana
19. Ecuador, S Colombia, N Peru	20. S Peru	21. NW Amazon (NW Brazil), S Venezuela
22. NE Amazon (N Brazil), S Guyana, Suriname, French Guiana	23. Amazon (W Brazil)	24. Amazon (NE Brazil)
25. C Brazil	26. SE Brazil	27. E Brazil
28. Bolivia, N Argentina	29. Paraguay, S Brazil	30. Uruguay, SE Brazil
31. Chile, W Argentina (Andes)	32. E Argentina	

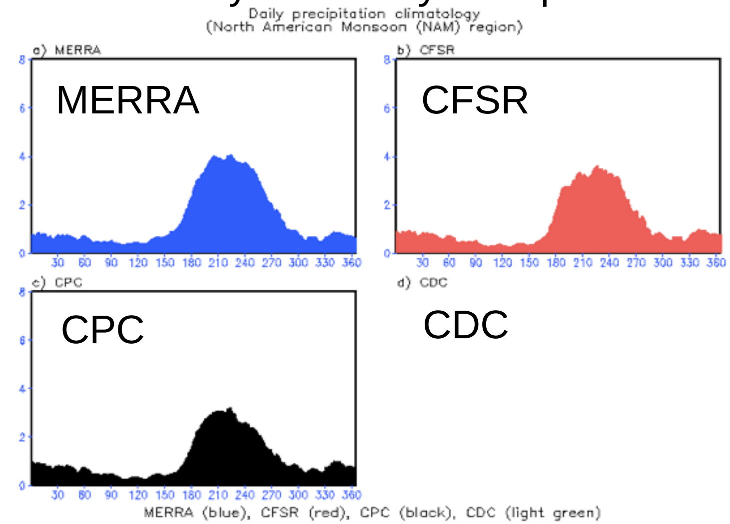
Choice of Regions



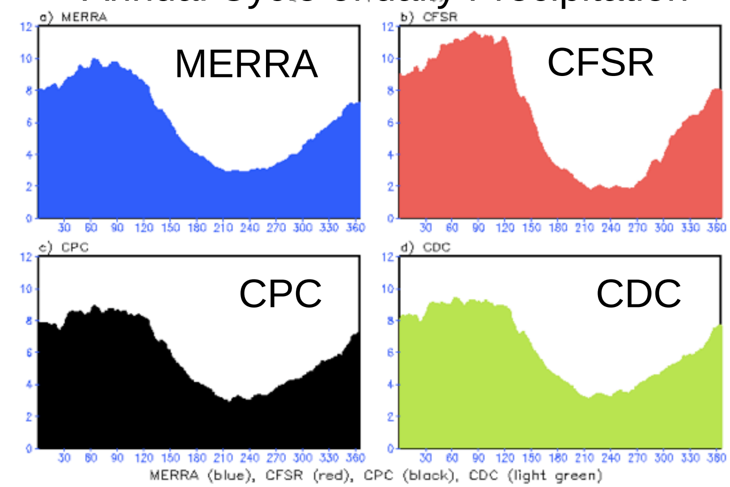
NAM

W. Brazil

Annual Cycle of daily Precipitation



Annual Cycle of daily Precipitation



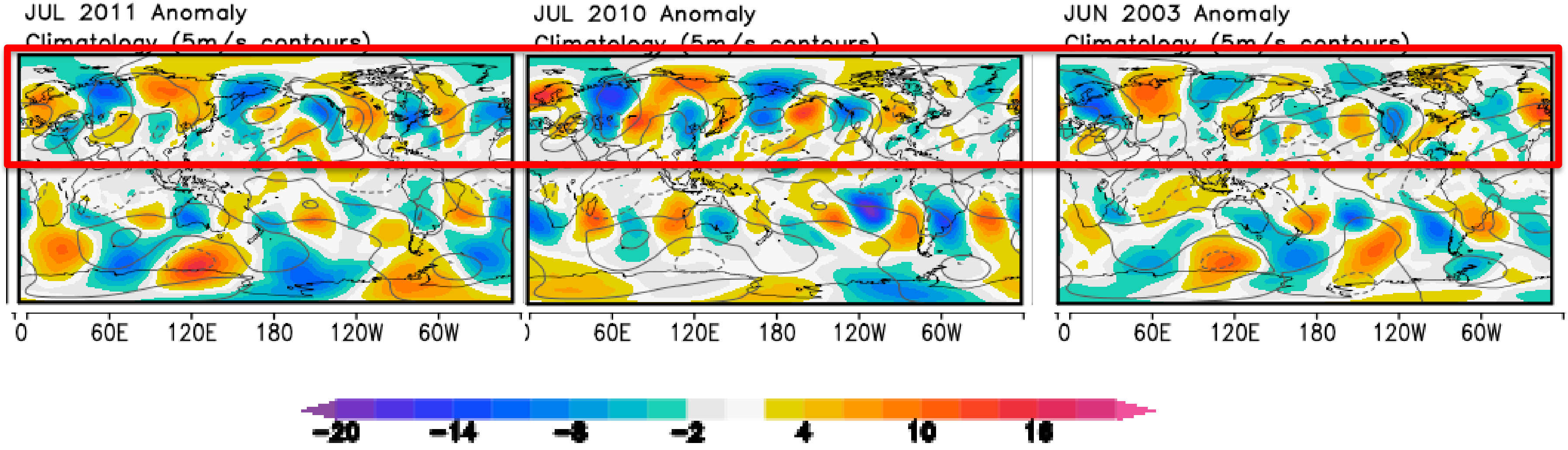
MERRA
Atlas

V250mb Anomalies

July 2011

July 2010

June 2003



m/s