# Reanalysis at NCEP

## Recent Developments,
## Current Efforts,
## Future Plans

Bob Kistler
IMSG/EMC/NCEP

Representing EMC and CPC staff, contractors and visiting scientists

# Thanks to NCEP colleagues

- EMC – Bill Lapenta, acting director
  - Suru Saha, Daryl Kleist, Jack Woollen, Dave Behringer, S. Moorthi, Haixia Lui, Glenn White, Xingren Wu
- CPC – Wayne Higgins, director
  - Arun Kumar, Craig Long, Wanqui Wang, Leigh Zhang, Wesley Ebisuzaki, Yan Xue, Muthu Chelliah

# In Memory of…

NCEP from 1967 – 2010

"Father" of the Global Spectral Model

The National Centers for Environmental Prediction
Environmental Modeling Center
Welcomes You To Commemorate

**Dr. Joseph G. Sela**

Tuesday, June 29, 2010, 10:00a.m.-12:00 p.m.
World Weather Building, 5200 Auth Road, Camp Springs, Maryland 20746, Room 707

*His Special Contribution to "History and Science"*

NCEP point of contact: Jordan.Alpert@noaa.gov

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# Scripps News

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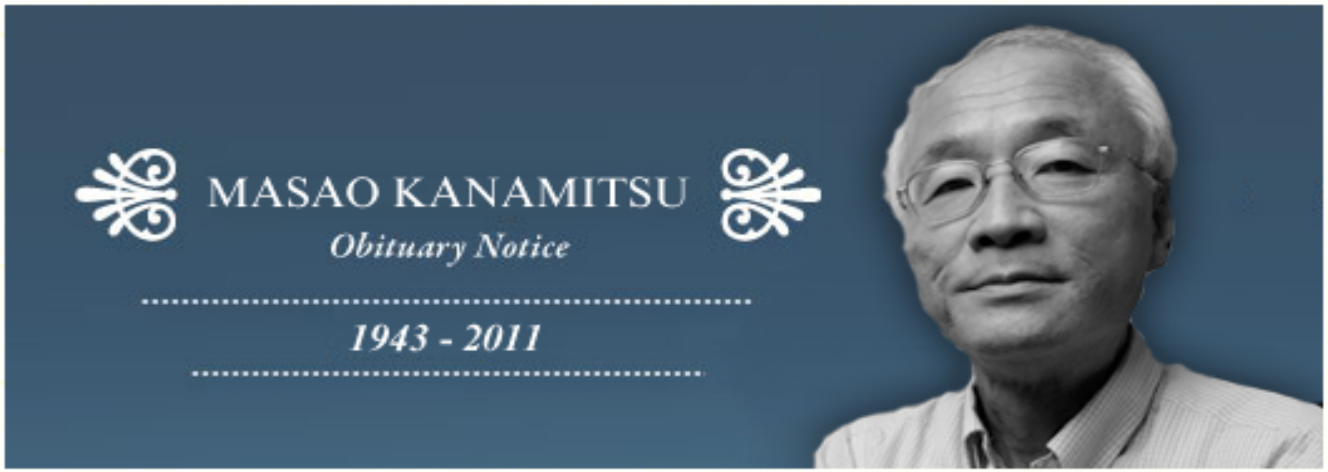



**Wednesday, August 24, 2011**

Obituary Notice:

**Obituary: Climate Modeling Pioneer: Masao Kanamitsu**

*Co-authored one of the most cited papers in geosciences history*

**Scripps Institution of Oceanography / University of California, San Diego**

Masao Kanamitsu, whose pioneering efforts transformed the ability of scientists to detect climate patterns over the course of decades, died of cancer Aug. 17 at his home in Del Mar, Calif. He was 67.

http://scrippsnews.ucsd.edu/Releases/?releaseID=1184

# Reanalysis at NCEP outline…

## Recent Developments (since IRC3), Current Efforts, Future Plans

- CFSRR
  - Climate Forecast System Reanalysis (CFSR)
  - CFSv2 – Reforecast Model
  - Hindcast and operational seasonal (9 mo.) prediction model
  - Identified strengths and weaknesses

- CFSR Lite (CFSRL)
  - Low resolution development system
  - Addresses weaknesses of CFSR

# CFSR and CFSv2 model

- **Operational Implementation of the new system: Spring 2011**

- **CFSv2 Model**
  - Reforecasts and opnl. Seasonal fcsts.
  - Monte Carlo Independent Column Approximation (McICA) implementation of the Rapid Radiative Transfer Model (RRTM) adapted from AER, Inc.
    - Proved to be the "best available" assimilation model for CFSRL

# CFSR Publications

## Identified strengths & weaknesses

- Saha, S., et al. (2010), Bull. Am. Meteorol. Soc.
  - The NCEP Climate Forecast System Reanalysis,
- Higgins, R. W., V. E. Kousky, V. B. S. Silva, E. Becker, and P. Xie (2010), J. Clim.,
  - Intercomparison of daily precipitation statistics over the United States in observations and in NCEP reanalysis products,
- Chelliah, M., W. Ebisuzaki, S. Weaver, and A. Kumar (2011), J. Geophys. Res.
  - Evaluating the tropospheric variability in National Centers for Environmental Prediction's climate forecast system reanalysis,
- Chen, M., W. Wang, and A. Kumar (2010), J. Clim.
  - Prediction of monthly-mean temperature: The roles of atmospheric and land initial conditions and sea surface temperature,
- Mo, K., L. N. Long, Y. Xia, S.-K. Yang, J. E. Schemm, and M. Ek (2011), J. Hydrometeorol.
  - Drought indices based on the Climate Forecast System Reanalysis and ensemble NLDAS,
- Wang, W., P. Xie, S. H. Yoo, Y. Xue, A. Kumar, and X. Wu (2011), Clim. Dyn.
  - An assessment of the surface climate in the NCEP climate forecast system reanalysis,
- Xue, Y., B. Huang, Z.-Z. Hu, A. Kumar, C. Wen, S. Behringer, and S. Nadiga (2011), Clim. Dyn
  - An assessment of oceanic variability in the NCEP climate forecast system reanalysis,
- Wen et al., 2012: *J. Climate*,
  - Ocean-Atmosphere characteristics of Tropical Instability Waves Simulated in the NCEP Climate Forecast System Reanalysis.
- **Li Zhang, Arun Kumar, and Wanqiu Wang (2012), J. Geophys. Res**
  - **Influence of changes in observations on precipitation: A case study for the Climate Forecast System Reanalysis (CFSR)**

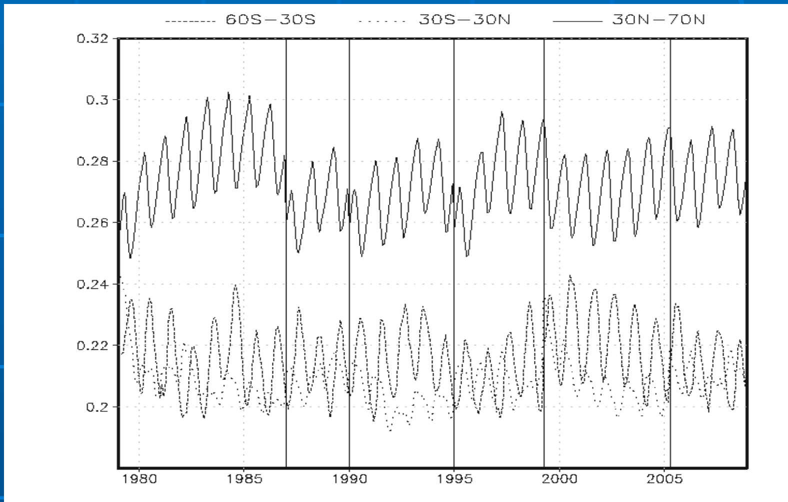
# CFSR Strengths

- High resolution and hourly output
- Period from 1998 >
- Examples
  - Depiction of synoptic rainfall
  - MJO Intraseasonal Rainfall
  - Tropical Instability Waves (TIW)
  - Better NWP Initial Conditions

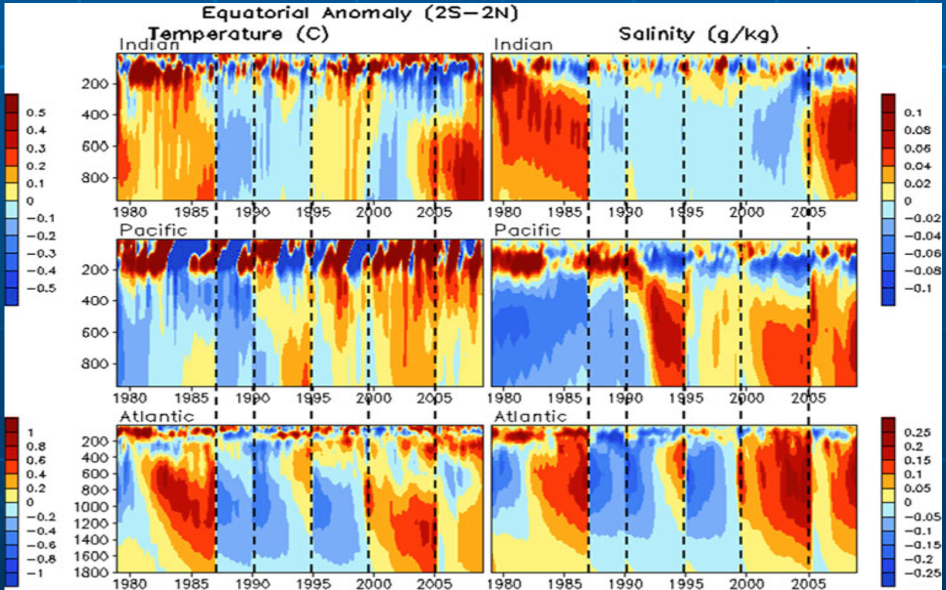
# CFSR Weaknesses

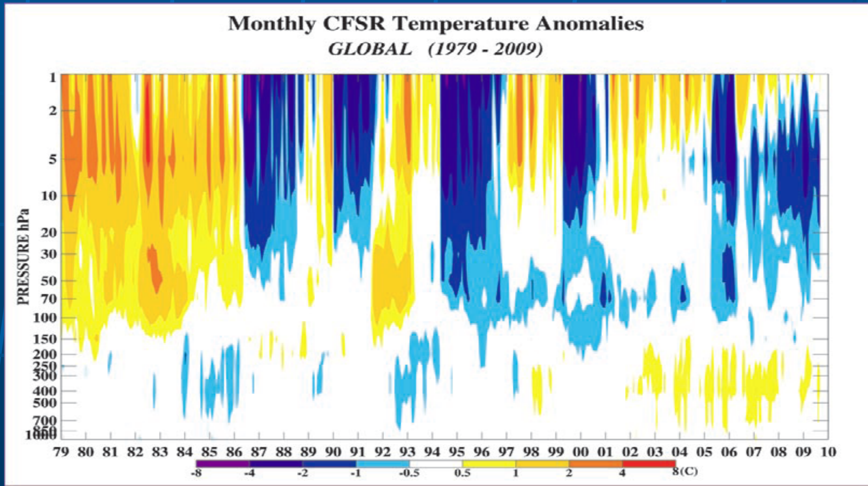
- Stream boundaries
  - Ocean
  - Soil Moisture
  - stratosphere

Soil Moisture



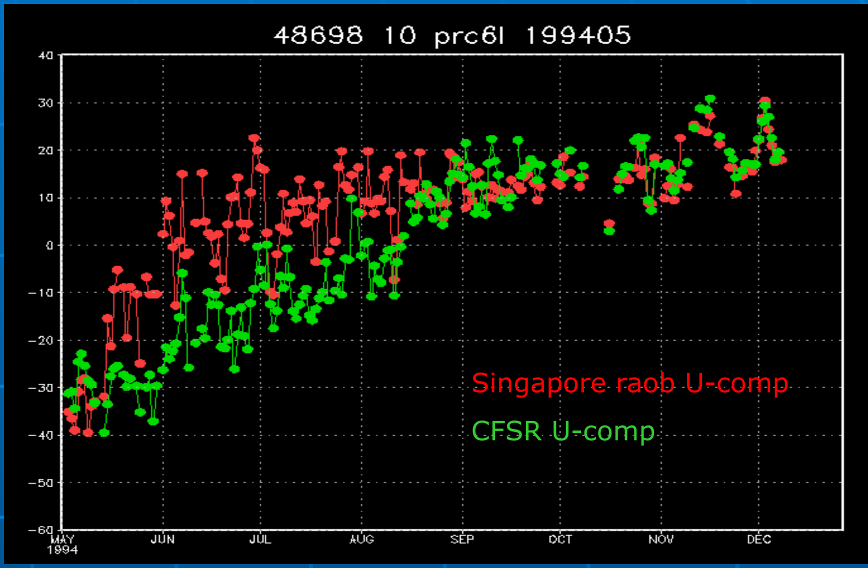

Sub-Surface Ocean Temperature

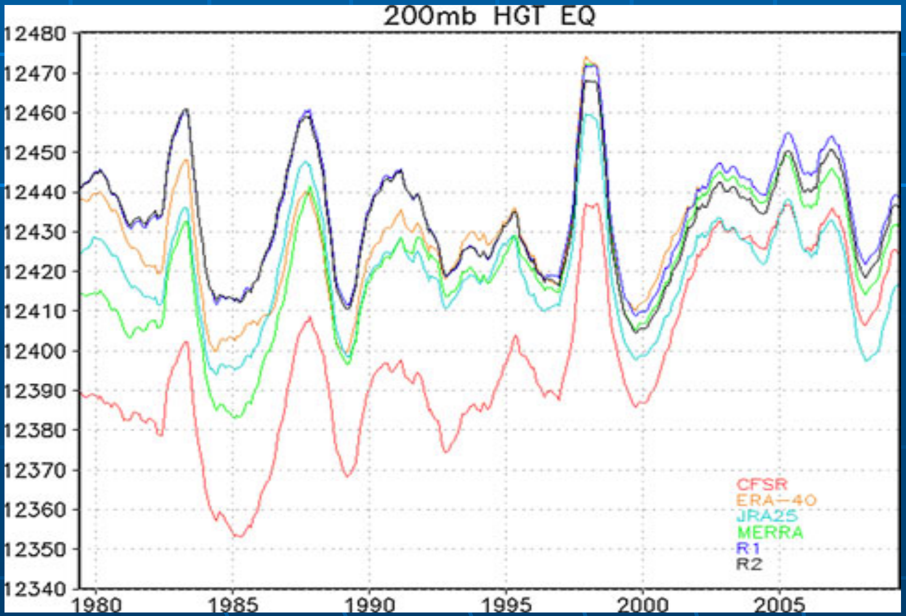


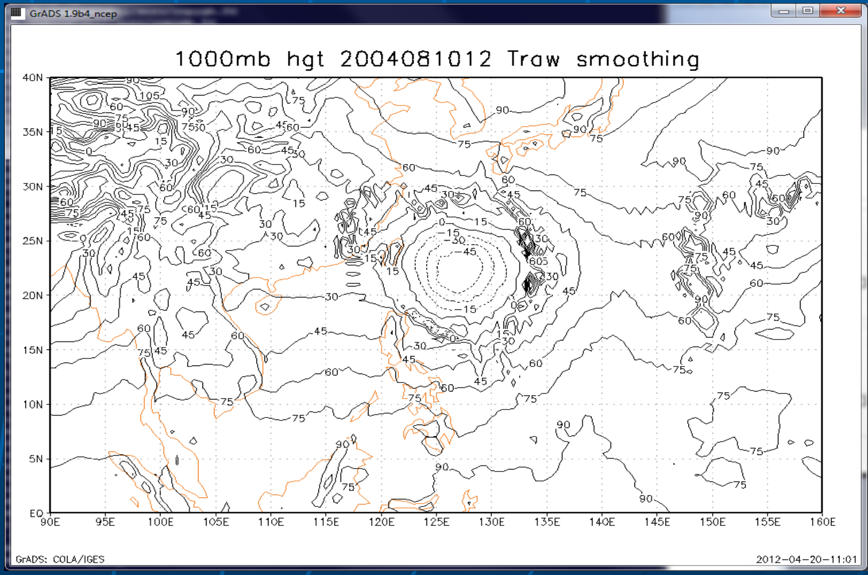



# CFSR Weaknesses

- Tropical issues
  - QBO
  - TC noise
  - Fit to tropo. Obs



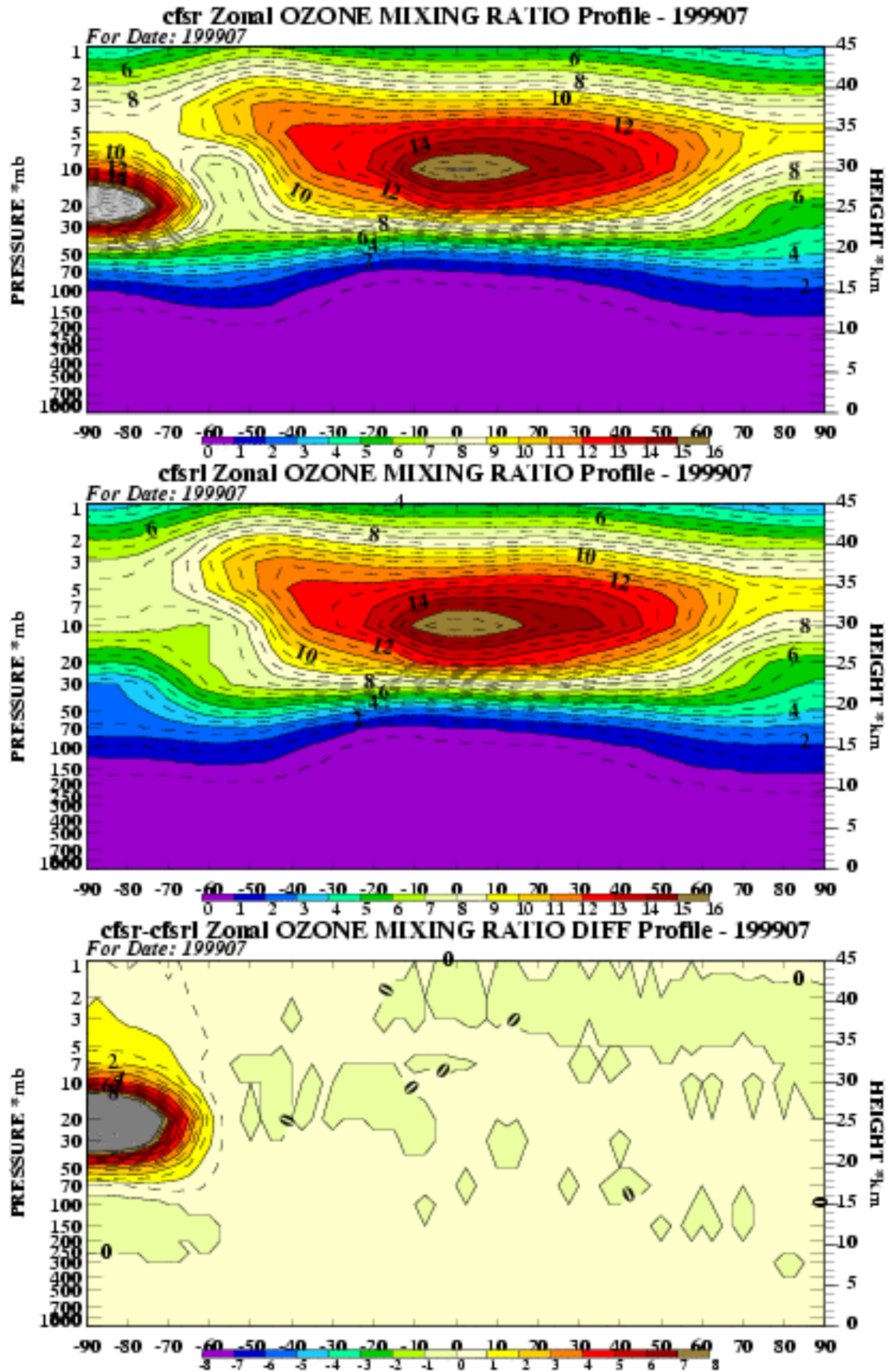



Assimilation of IR ozone channels produced a large profile anomaly in the lower polar stratosphere in the winter hemisphere.

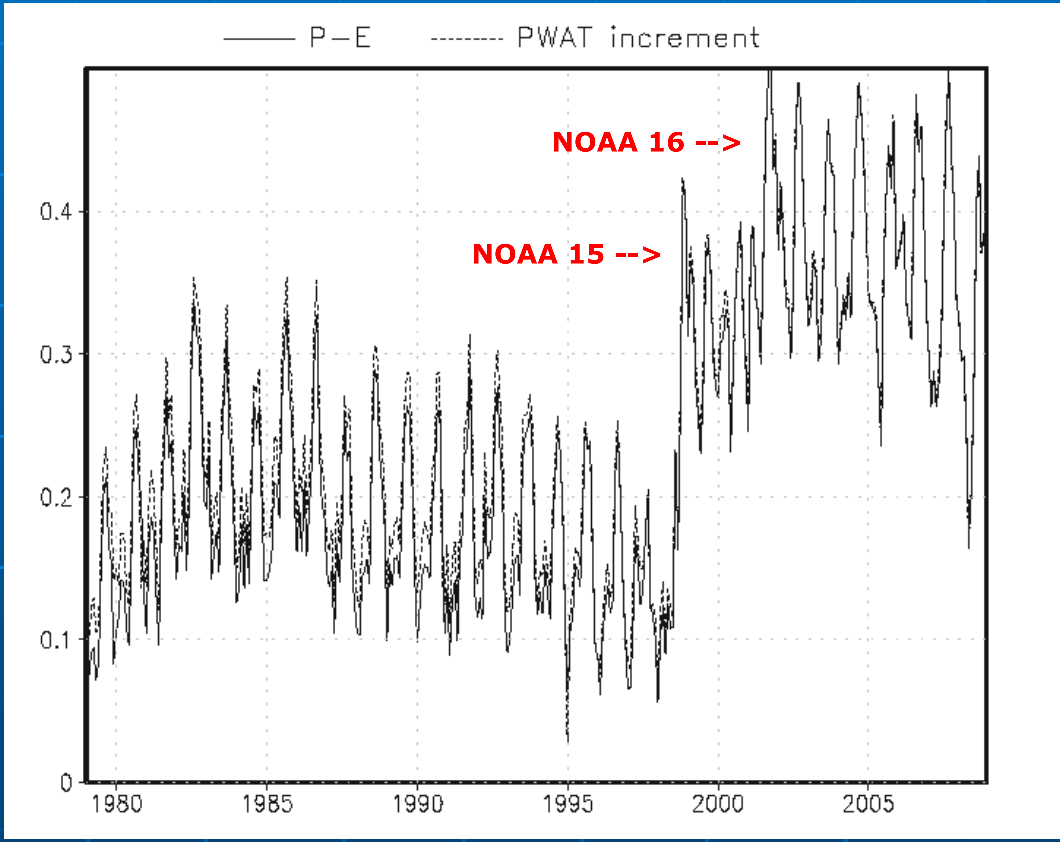
Not assimilating these channels poleward of 60° improves the profile in the polar region.

Craig.Long@noaa.gov



# CFSR Weaknesses

- TOVS > ATOVS
  - AMSU-A
  - NOAA-15 Oct 1998
  - NOAA-16 Feb 2001




**Li Zhang, Arun Kumar, and Wanqiu Wang (2012), J. Geophys. Res**
**Influence of changes in observations on precipitation:**
**A case study for the Climate Forecast System Reanalysis (CFSR)**

# Reanalysis at NCEP outline

## Recent Developments (since IRC3),
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  - CFSv2 – Reforecast Model
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  - Lower resolution development system
  - Addresses identified weaknesses of CFSR

# CFSR-lite (CFSRL) addressing CFSR weaknesses

- T126 (vs T382) single stream. 1979-> ~18mo's
- Tropical background errors
  - MERRA inflation example
  - Improve troposphere and stratosphere in TOVS period
- Corrected satellite bias correction & ob error
- Tropical Cyclone (TC)
  - Fixed relocation bug
  - Assimilate TC central pressure
  - Improved detection and relocation
- Adopted CFSv2 as assimilation model

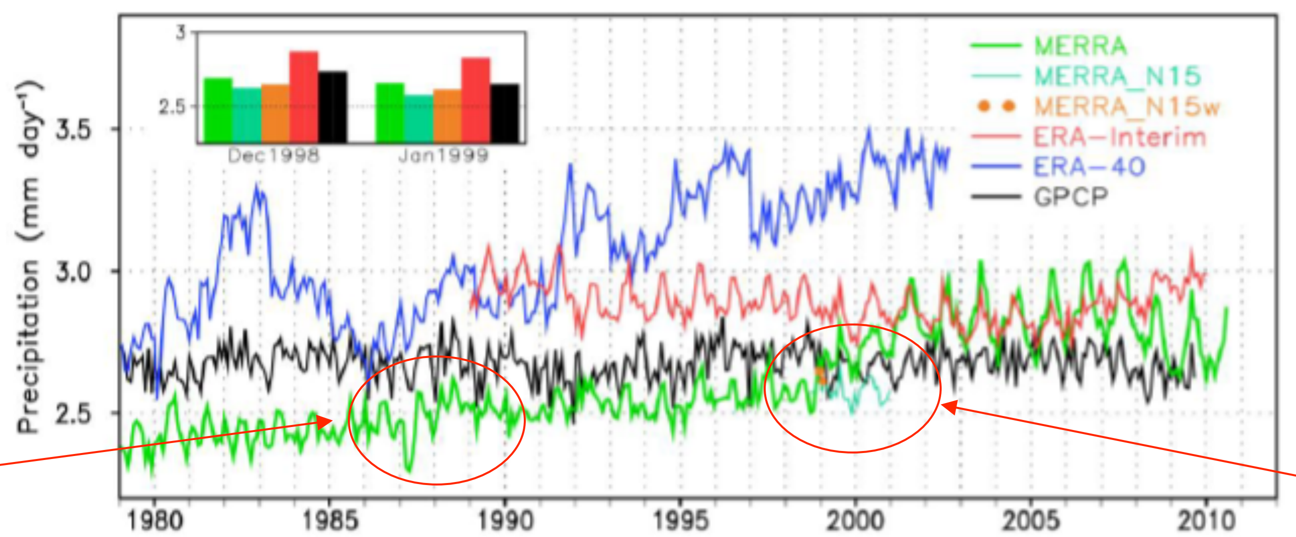
# CFSRL status

- 13 months on NOAA R&D Vapor – Feb 2011:Mar 2012
  - Pre-empted 1 month for 2011 tropical outlook forecasts
  - Limited to only 1 stream

- Assimilation prediction model
  - Anticipated opnl. CFS/GFS coupled system (unification mindset)
    Ran 1979-1986 years to assess first stream boundary
    Ocean was improved, but…
    Clouds, fluxes worse than CFSR model
    QBO was still inferior to R1, ERA-I, MERRA
  - CFSv2 seasonal prediction model as assimilation model
    The McICA radiation interaction tuned at T126L64 led to
    better clouds and fluxes than the CFSR model

- 1998-1999 TOVS > ATOVS transition
  - Gained insight from MERRA and ERA-I, CPC AMIP
  - Ran an impact test of revised moisture radiances (upcoming slides)

# MERRA Global Precip.
# Fig 18 in Basilovich, 2011




MERRA AMSUA tests

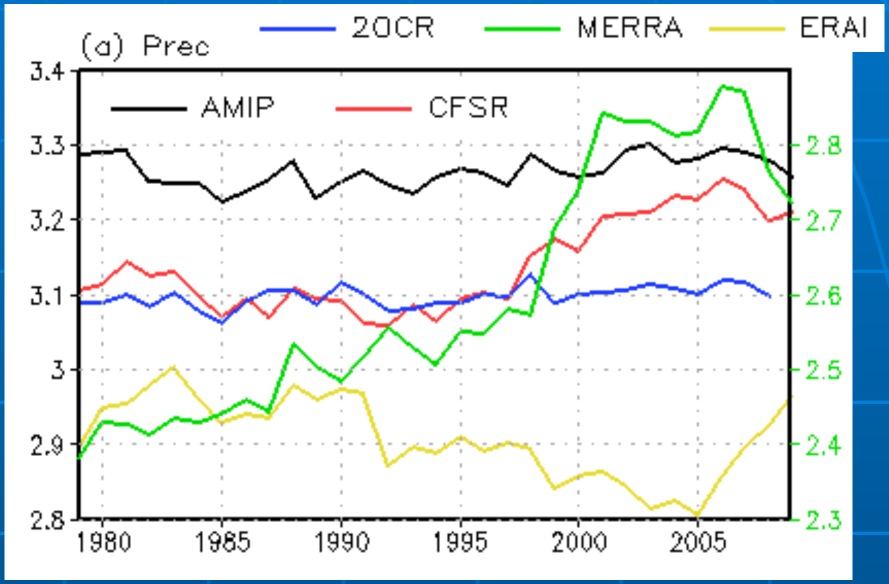
SSMI start

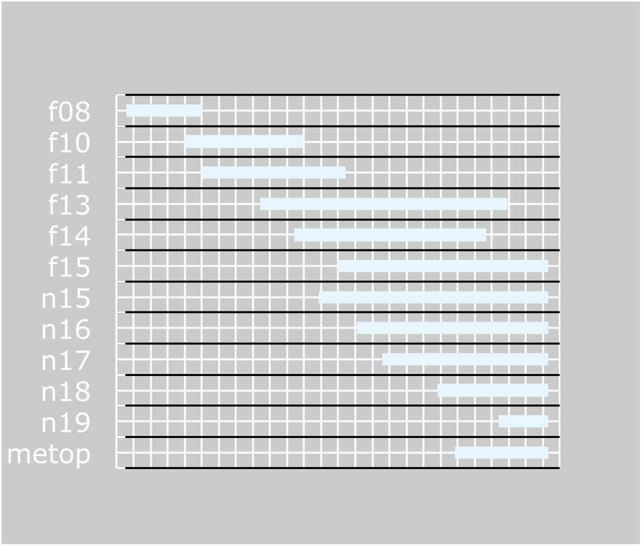
AMSUA start

FIG. 18. Time series of global monthly mean precipitation (mm day$^{-1}$) for MERRA, ERA Interim and ERA-40, compared against GPCP. In addition to the time series from the MERRA distribution, two short data withholding experiments are shown. MERRA_N15 is from an experiment withholding all AMSU-A data from NOAA-15, and MERRA_N15w withhold only the AMSU-A window channels, 1-3 and 15. For clarity, the inset shows the monthly mean values for December 1998 and January 1999.

# Summarizing Instruments in ERA-I, MERRA, and CFSR

- ERA-I
  - 7 ch's SSMI (starts in 1987)
  - Excluded AMSU-A Window ch's 1,2,3,15
- MERRA
  - 7 ch's SSMI
  - All AMSU-A ch's
- CFSR
  - no SSMI
    - More on next slide…
  - All AMSUA ch's



# NCEP & SSMI

- Tested assimilation of SSMI Total Column Water Vapor product in SSI in 1990's
  - Not successful
    - Cold model bias produced excessive rainfall
  - Did use the sfc wind speed product

- SSMI radiances tested in 2004 by Okamota and Derber(MWR,2006) in early GSI
    - SSMI infrastructure in GSI for use by MERRA
    - Never implemented into GDAS
      - Excess moisture in tropics,
      - Precluded by higher priorities
    - Therefore not assimilated in CFSR

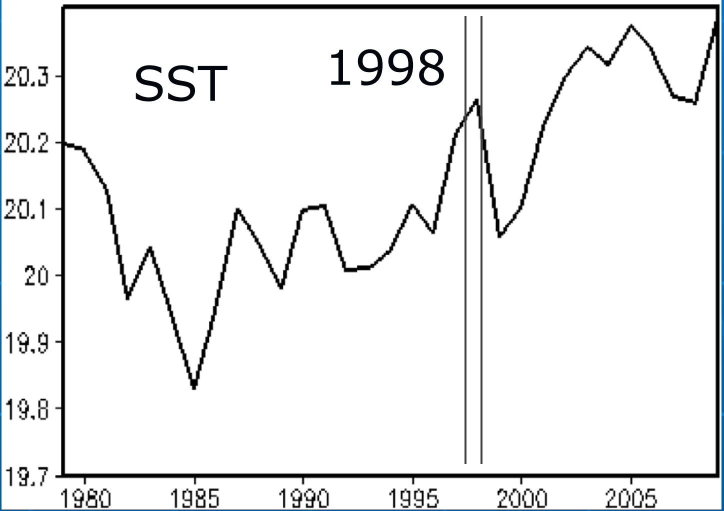
# TOVS->ATOVS transition 1998-1999

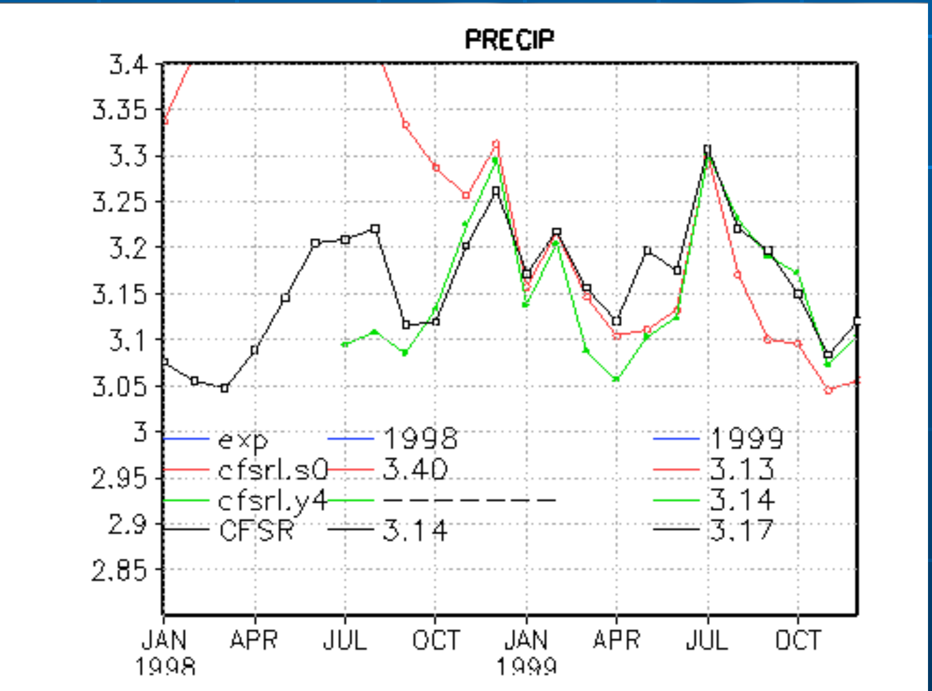
- From insight of MERRA and ERA-I…
- With 2 months  left on Vapor…
- Ran a impact test of the ERA-I config
  - Control (pry4) – CFSR configuration
    - No SSMI, All AMSU-a channels
    - July 1998-Dec 1999
  - Test (prs0) – ERA-I config
    - With SSMI, no AMSUA window channels
    - Jan 1998-Dec 1999

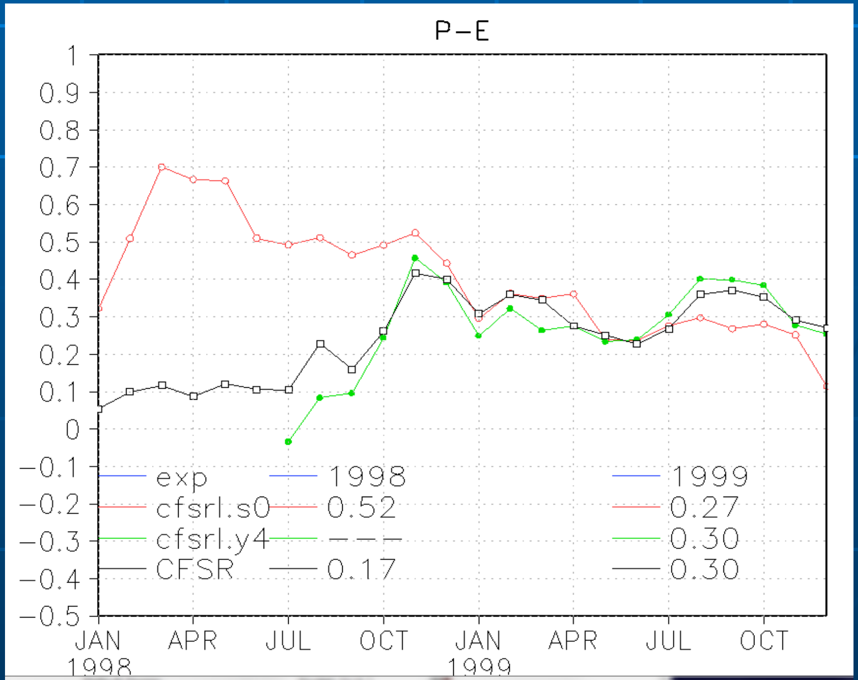
# SSMI in 1998

What caused the excess precip?

- El Nino
- Sat Bias Correction spinup problems
- Model cold bias
- Combinations ???



# Influence of changes in observations on precipitation: A case study for the Climate Forecast System Reanalysis (CFSR)

Li Zhang, Arun Kumar, and Wanqiu Wang (JGR, 2012)

AMIP Sequence

CFSR -> AMIP

1. Cold bias
2. Excess precip
3. Atmos dries
4. Obs SST & land increase evap

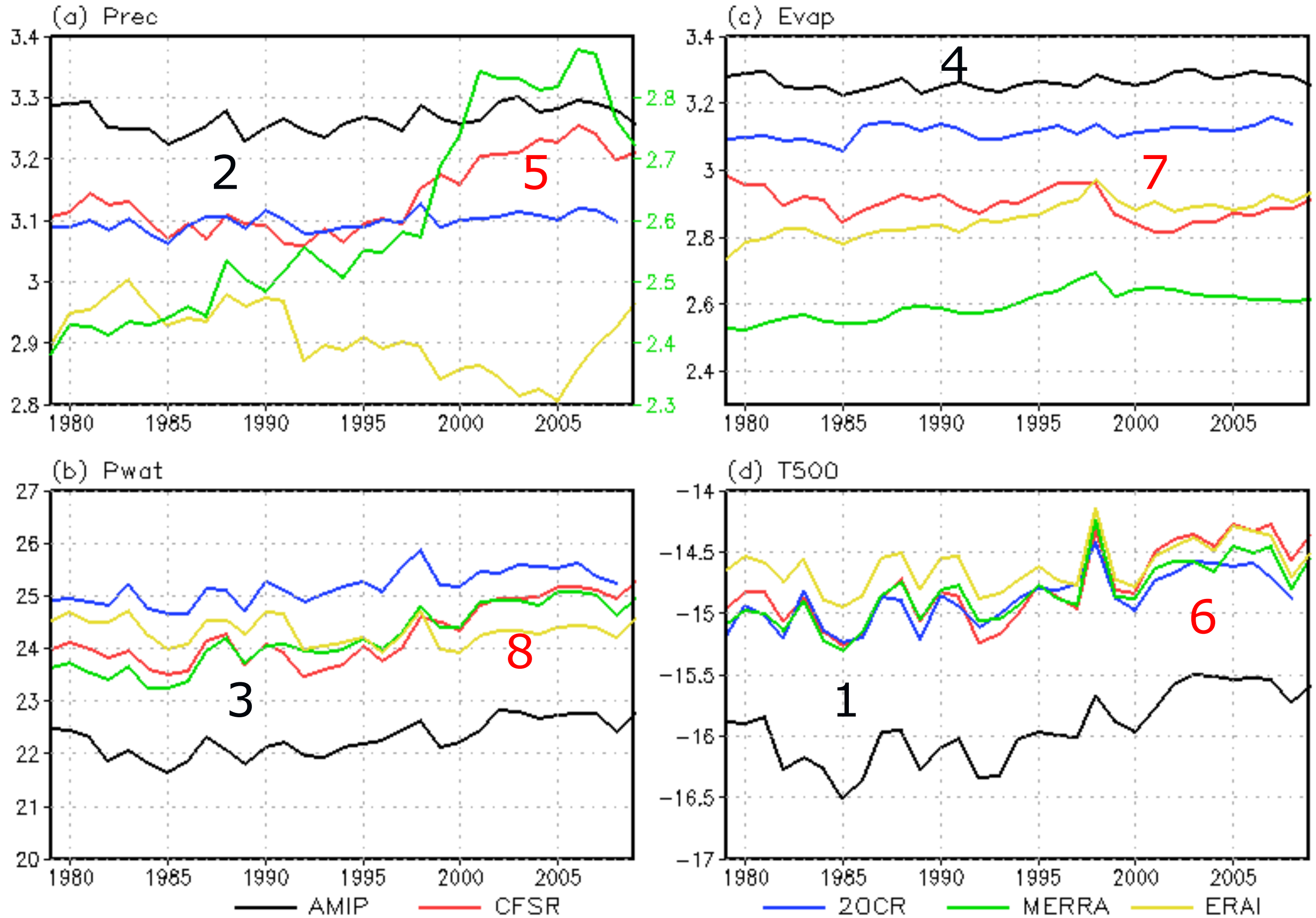
Within CFSR 1998->

Same seq. occurs

ANL –> F06

AMSU-A wdw. ch's

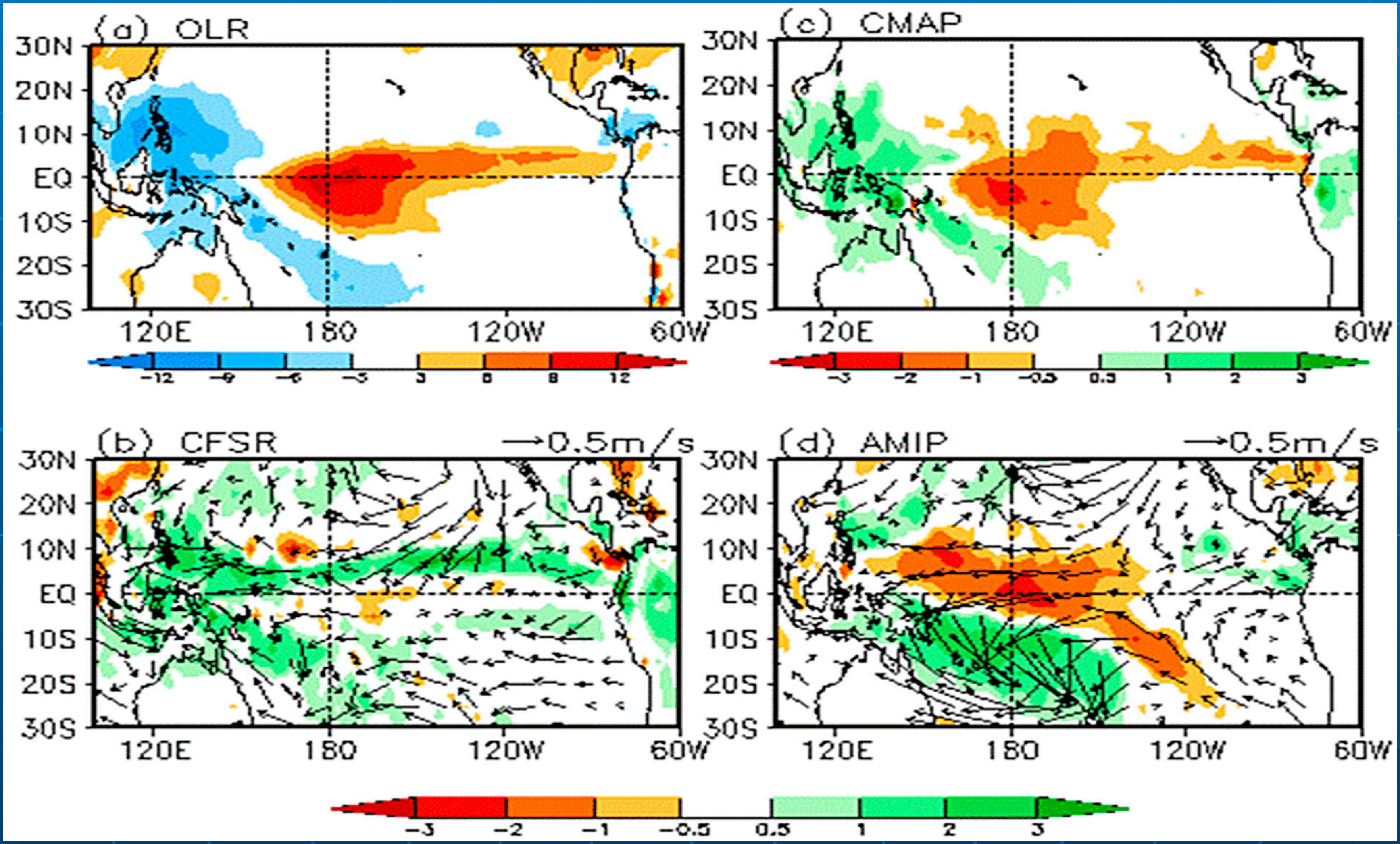
5. Precip is amplified
6. Temp increases
7. Evap decreases
8. Atmos. moistens




•AMIP and 20CR did not assimilate moisture sensitive radiances

Precipitation and 10m surface wind

**difference 1999–2009 minus 1987–1997**




Ocean coupling - 10 m winds drive the ocean circulations

# Reanalysis at NCEP outline

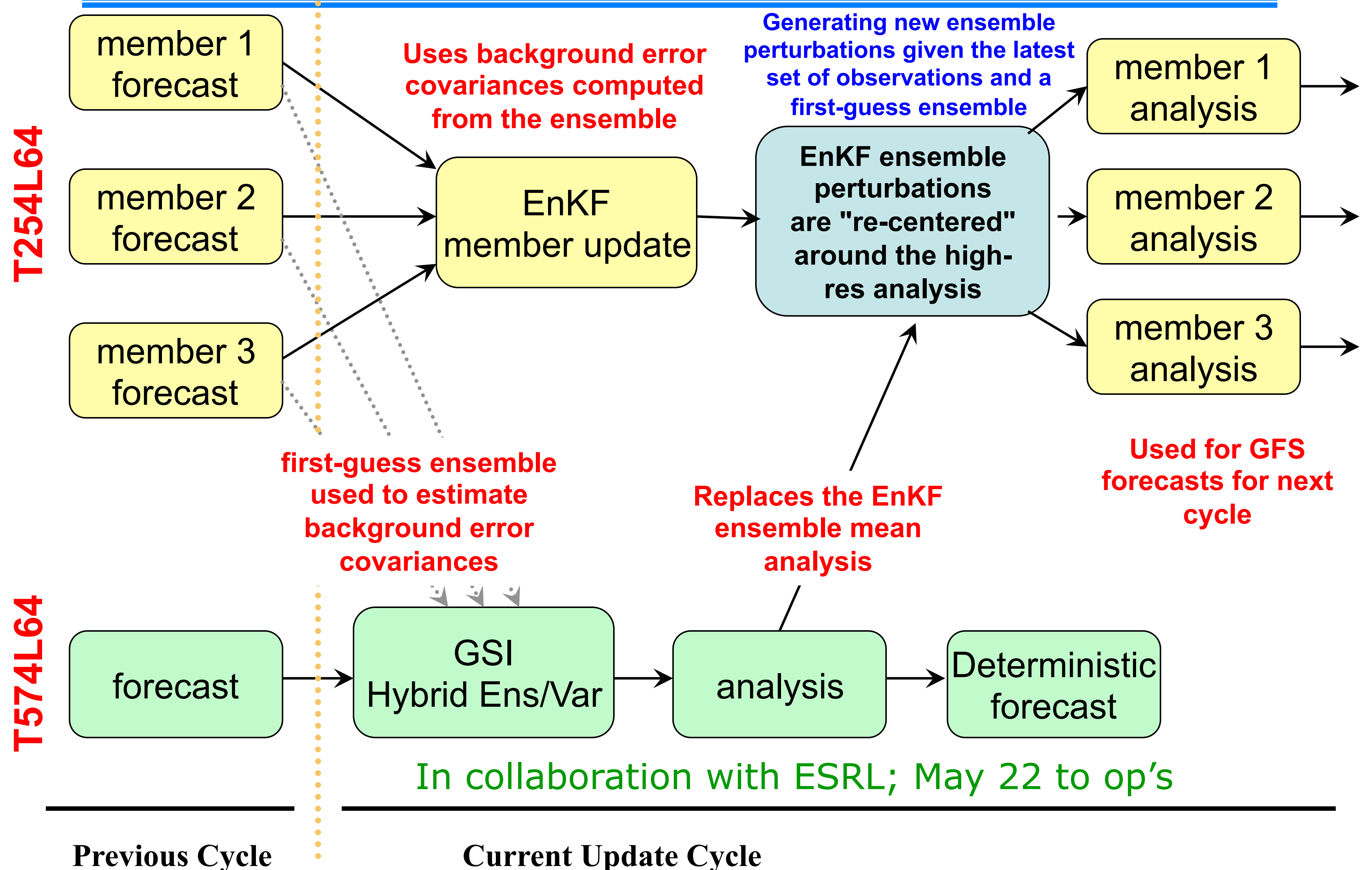
## Recent Developments,
## Current Efforts,
## Future Plans

GDAS developments

NCEP and NOAA Computing

Proposed NOAA strategy

# Dual-Resolution Coupled Hybrid 3D-VAR/EnKF




In collaboration with ESRL; May 22 to op's

Presented 20 April 2012

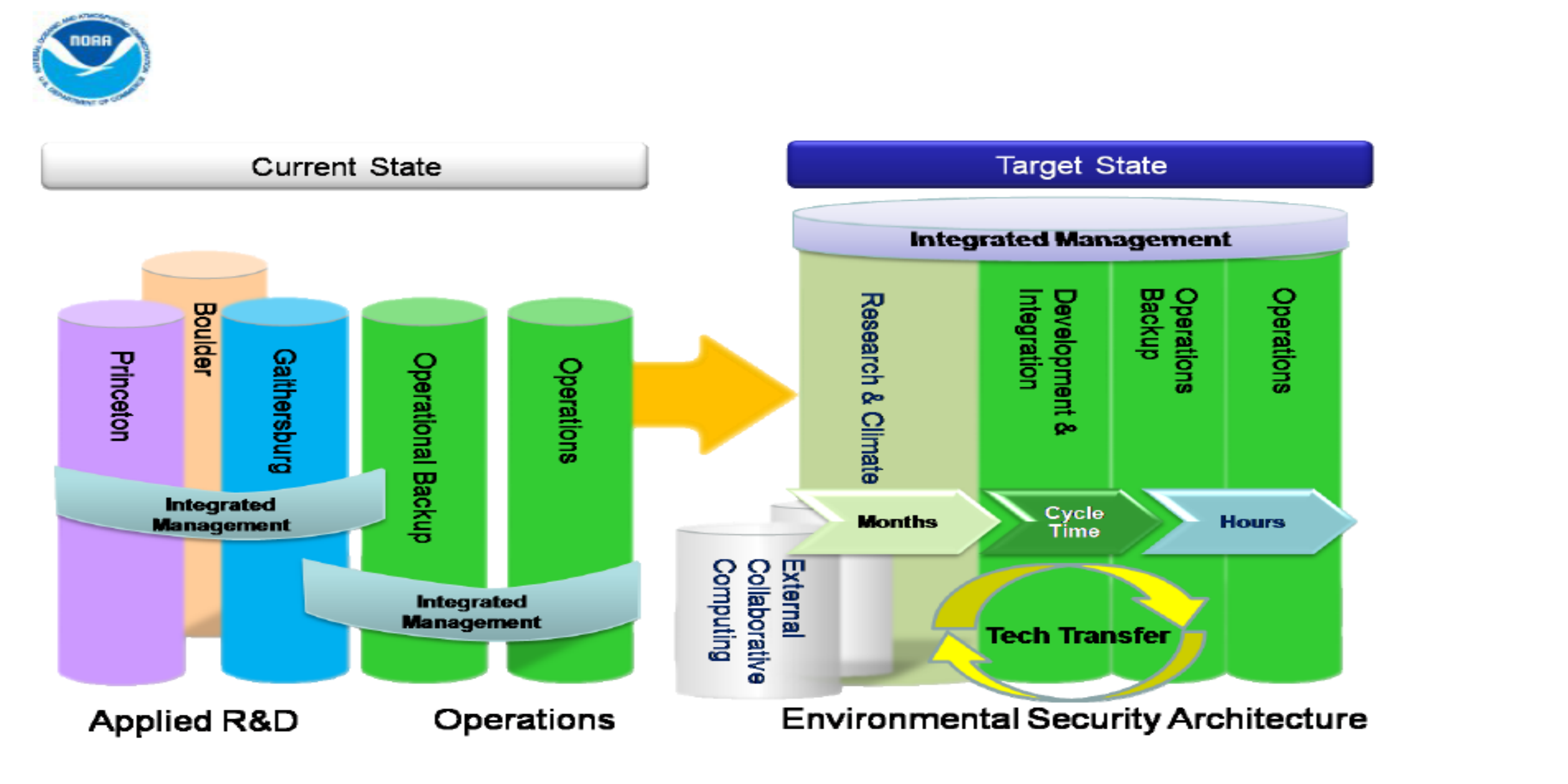
# Cloudy Radiance Assimilation

Min-Jeong Kim, Emily Liu, Yanqiu Zhu, Will McCarty (GMAO)

- Large numbers of radiances contain cloud (and precipitation) signal.
- If cloudy radiances can be properly used, potential for significant improvement in forecasts of temperature, wind, moisture and cloud fields.
- Initially addressing simpler problem with microwave and non-precipitating clouds
- Planned for initial operational implementation in the next next global GSI upgrade (Spring – Fall 2013)
- Reanalysis challenge– apply to MSU and SSMI

# NOAA R&D Computing

- CFSR
  - ibm mist
- CFSv2
  - ibm stratus / cirrus
- CFSRL follow-on
  - GAEA (cray)
- R1 replacement
  - WCOSS (ibm*)



# GAEA, T-Jet, Zeus, and WCOSS are 4 different OS/chipsets !

| HPC System | Accts | Allocation | Allocation Used | Projects |
|---|---|---|---|---|
| GAEA | 37 | 6.2% (5.04M Core Hours per month) | ~10% | • Develop next version of CFS capability - Saha<br>• **Advanced Data Assimilation for Reanalysis - Saha**<br>• Ocean Model Development - Tolman<br>• GEFS Development - Zhu |
| T-Jet | ~13 | HWRF –<br>6000 Cores<br><br>DA –<br>3000 Cores | HWRF –<br>6000 Cores for 6 Weeks in Q2FY12<br><br>DA –<br>3000 Cores in Q2FY12 | • HFIP Regional Model Ensemble – Tallapragada<br>• HFIP Real-time Demo - Tallapragada<br>• Eulerian GFS control run and Semi-Lagrangian GFS experimental run for 2011 summer season – Yang<br>• HFIP Hurricane and Hybrid EnKF - Tong<br>• ETR and Hybrid EnKF comparisons – Zhu |
| Zeus | 110 | 44% of system | 80% | • Global Model Development - Moorthi<br>• Regional Model Development - DiMego<br>• Climate Model Development - Saha<br>• Ocean Model Development - Tolman<br>• Data Assimilation Development - Derber<br>• GEFS Development – Zhu |
| Jibb and S4 | 2 | N/A | N/A | • Porting of HYCOM runs - Tolman |
| UCSD San Diego | 1 | Mass Store Only | Mass Store Only | • Developed 30 year Hindcast database using WAVE Model - Chawla |

# A NOAA Climate Reanalysis Strategy

Arun Kumar, Gil Compo,
Bob Kistler, Jeff Whitaker, Jack Woollen

Earth System Research Laboratory
Serving Society through Science

# *An overview of the proposed NOAA's climate reanalysis effort*

- The key concept:
  - both NCEP and ESRL (that comprises the core of the NOAA's reanalysis expertise) will work with the same model and data assimilation infrastructure (e.g., GFS, Hybrid EnKF, observational data base, boundary conditions).
  - Specific details within the infrastructure that will be pursued by NCEP or ESRL can differ with minimal duplication of resources.
  - This strategy promotes significant enhancements of portability, communication, leveraging of expertise in all the aspects of the common infrastructure for the climate reanalysis.

# An overview of the proposed NOAA's climate reanalysis effort, cont.

Within the "common infrastructure" paradigm:

- NCEP will focus on the 1948-present with goals of replacing R1
- AMIP runs will test efforts to eliminate the exisiting cold bias
- ESRL will focus on a sparse-input based climate reanalysis back to the $19^{th}$ century.
- NCEP and ESRL will collaborate on the configuration of the hybrid data assimilation system where ESRL has considerable expertise, particularly for the pre-satellite period
- Hybrid assimilation can allow for uncertainties in the :
  - atmospheric boundary conditions, such as SSTs and sea ice
  - radiative forcings, such as solar variability
  - CO2, and volcanic aerosols
  - offline analysis fields, such as snow cover and precipitation
- Within this framework there is a natural opportunity to utilize OSE approaches to clarify issues introduced by qualitative and quantitative changes in observing systems throughout the historical record

# First Priority

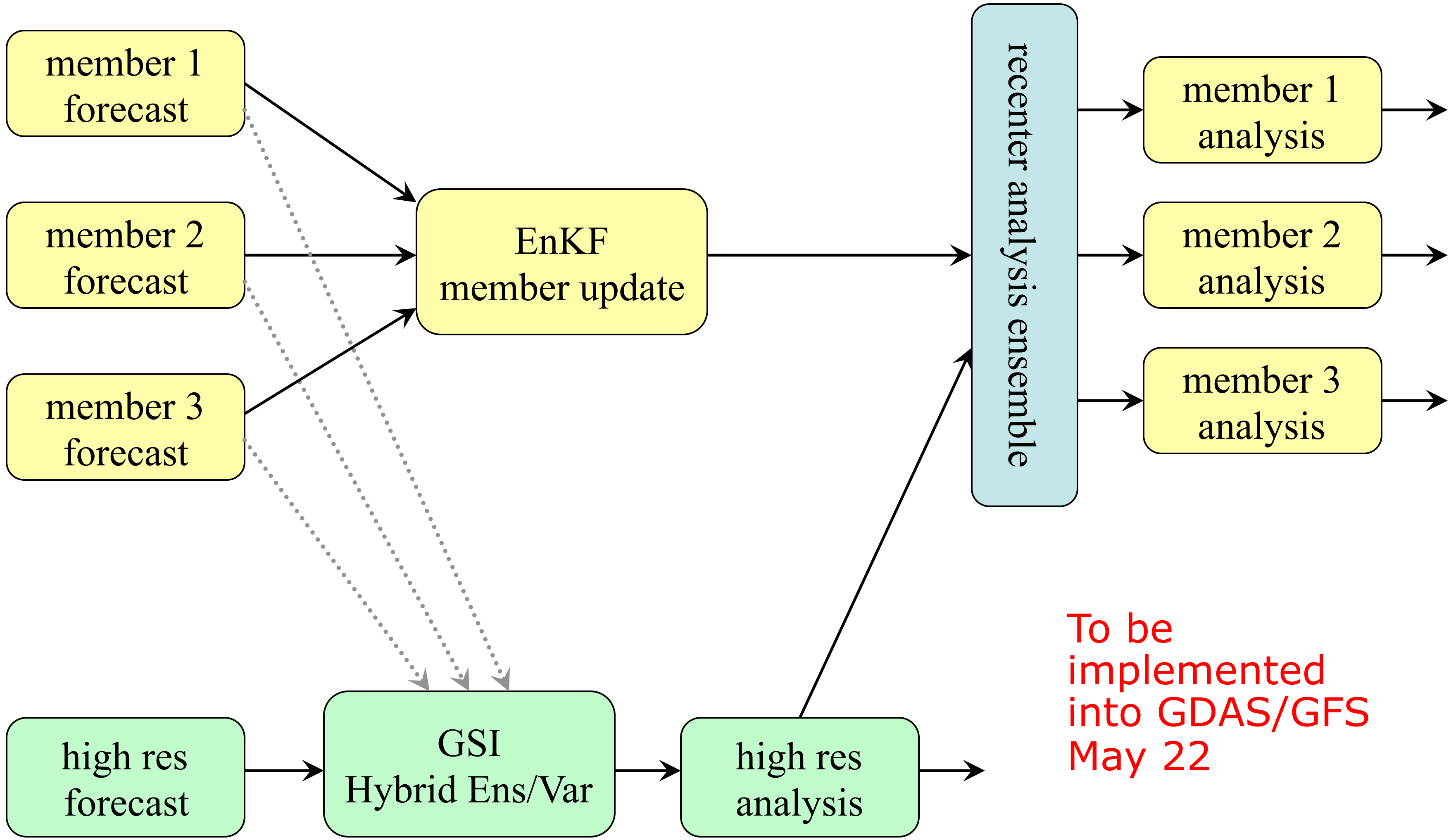
- The critical problem to be solved..
- And it's not just a reanalysis issue
  - e.g. Next generation CFS (CFSv3)
- *The Cold bias of the prediction* model
  - It distorts the entire water cycle
    - Assimilation of H2O sensitive radiances
    - Clouds
    - Almost all radiative fluxes
    - Precipitation

# Thank you !

# Extra slides

# Dual-Res Coupled Hybrid

In collaboration with Jeff Whittaker NOAA/ESRL



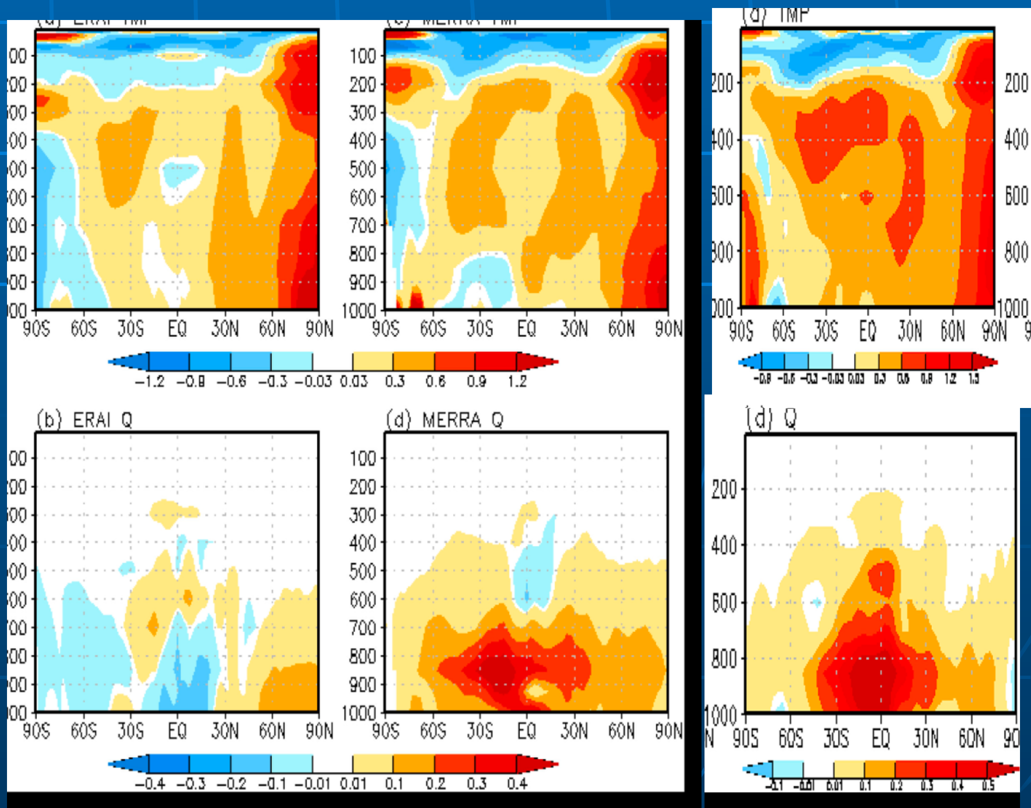

To be implemented into GDAS/GFS May 22

# Zhang et. al. : the hypothesized causes for changes in the precipitation utilize different mechanisms

In the case of CFSR and MERRA a wetter analysis after 1998 drifting to a colder, drier model state (AMIP) leading to an increase in precipitation

for ERA-I a warmer atmosphere after 1998 requiring less precipitation for the model to drift to a warmer mean state

ERA-I MERRA CFSR



# *Defining NOAA requirements for an ongoing climate reanalysis effort*

- Maintain the corporate memory that has been developed as part of the past reanalysis efforts in NOAA
- As models and data assimilation systems improve, and as historical data bases expand, climate reanalysis effort needs to be repeated at a regular interval.
- The international Global Climate Observing System and the US Global Change Research Program, to which NOAA is an essential contributor, call for long-term reanalysis datasets with quantified uncertainties
- A sustained climate reanalysis effort can also spur improvements in all these areas as well (leading to benefits in NWP & climate forecasting)
- The is a need to update the current generation of reanalysis that is used for real-time climate monitoring in NOAA, NCEP/NCAR R1.

# For a new Climate Forecast System implementation

## Four essential components:

1. Develop and test an upgraded data assimilation and forecast model to replace R2 , GODAS, and CFSv1
2. Making a new Reanalysis (CFSR) of the atmosphere, ocean, seaice and land over the 32-year period (1979-2010), which is required to provide consistent initial conditions for:
3. Making a complete Reforecast of the new CFS over the 29-year period (1982-2010), in order to provide stable calibration and skill estimates of the new system, for operational subseasonal and seasonal prediction at NCEP (CFSv2 model …more to follow)
4. Operational Implementation of the new system: Spring 2011

# CFSR mindset

- "Had the concepts and experience of R1, NARR"
  - Run reanalysis  with current production system
    - GDAS of 2007 :"New GSI" and GFS with pressure-sigma coordinate
    - GSI allowed flexibility in the treatment of the B – the "background error"
  - Assimilate all historical data

- Deadline to replace CFSv1 upgrade
  - Time went to production with little testing
  - High resolution forced multiple streams with only one year overlaps

- R1 assimilated satellite retrievals
  - Moisture retrievals were always "blacklisted"
  - Only moisture obs were from raobs and dropsondes
  - ATOVS retrievals were retrofit to reproduce TOVS in both content and count
  - SSI background errors
    - were held fixed for 1948 >.
    - Were broader than those of GSi, especially in tropics
  - Did recompute B for the TOVS period – not very different esp. in tropics

- NARR used a prototype regional GSI, focused on North America, and assimilated observed precipitation and focused on conventional obs

- Prototype for CFS GFS merger
  - Run assimilation production resolution high resolution

- Accepted for decades a global atmospheric model with a cold bias

# CFSv2 model

- T126L64 atmosphere / same coupled ocean as CFSR assimilation model
  - Tuned at the same resolution as CFSRL
- Virtual temperature vs enthalpy as prognostic variable (unifies with GFS)
- Marine stratus parameterization
  - Off for seasonal forecasts due to excess stratus and cold SST's
- Parameterization of cumulus convection gravity wave drag
- Monte Carlo Independent Column Approximation (McICA) implementation of the Rapid Radiative Transfer Model (RRTM) adapted from AER, Inc.
  - Separates of calculation of optical characteristics from radiative transfer
  - Addresses the unresolved variability of layered cloud
  - Has proven to be unbiased against independent column approximations
  - Proved to be the "best available" assimilation model for CFSRL
- Two modifications to Noah land surface model
  - New vegetation parameters and rooting depths to increase evapotranspiration
  - Surface runoff parameters were adjusted to increase runoff

# CFSR

- Run with the operational  GDAS of 2007
  - GSI replaced SSI of R1 R2
  - Background errors of 2007
  - Historical satellite systems as was run in op's at the time
    - SSU was added
    - SSMI was excluded as it was operations
- Coupled model –
  - Ocean assimilation GODAS MOM4
  - Ice model
  - Land sfc with cmap prepcipitation
- 6 streams, 1 year overlaps

# NOAA Climate Reanalysis Strategy

- Follow-up to CFSR and 20CR…
- Envision a coordinated "one NOAA" strategy for reanalysis activities
- Implementation  will depend on the availability of necessary resources for staff

# NOAA Climate Reanalysis Strategy

1. *Defining NOAA requirements for an ongoing climate reanalysis effort*
2. *An overview of the proposed NOAA's climate reanalysis effort*
3. *Next steps towards building the NOAA's climate reanalysis effort*

# *An overview of the proposed NOAA's climate reanalysis effort, cont.*

- The initial coordinated climate reanalysis will focus on the atmosphere
  - the systems will not provide initial conditions for seasonal forecasts as CFSR-CFS.v2 did
  - nor will it  attempt to serve as a ocean reanalysis
  - subsequent research will include the prospects for coupled ocean/atmosphere reanalysis before the satellite period.

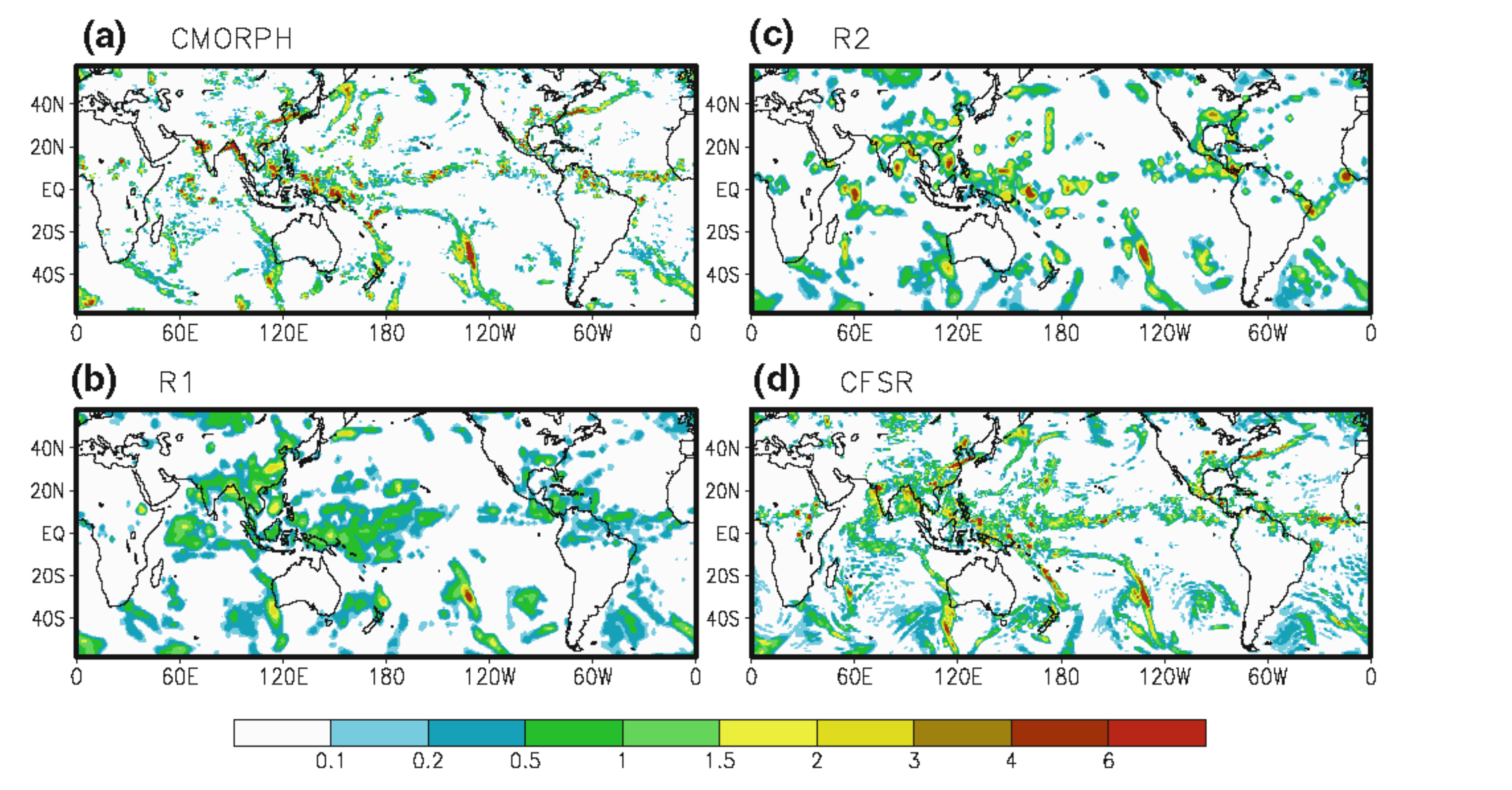
# 3. Next steps towards building the NOAA's climate reanalysis effort

- Management…
  - Present the concept "up the chain"
    - NCEP and ESRL management
    - NOAA CPO program managers.
  - **Serve as point of discussion at Friday's Panel Session**
  - Develop a detailed implementation plan
  - Hopefully, receive funding

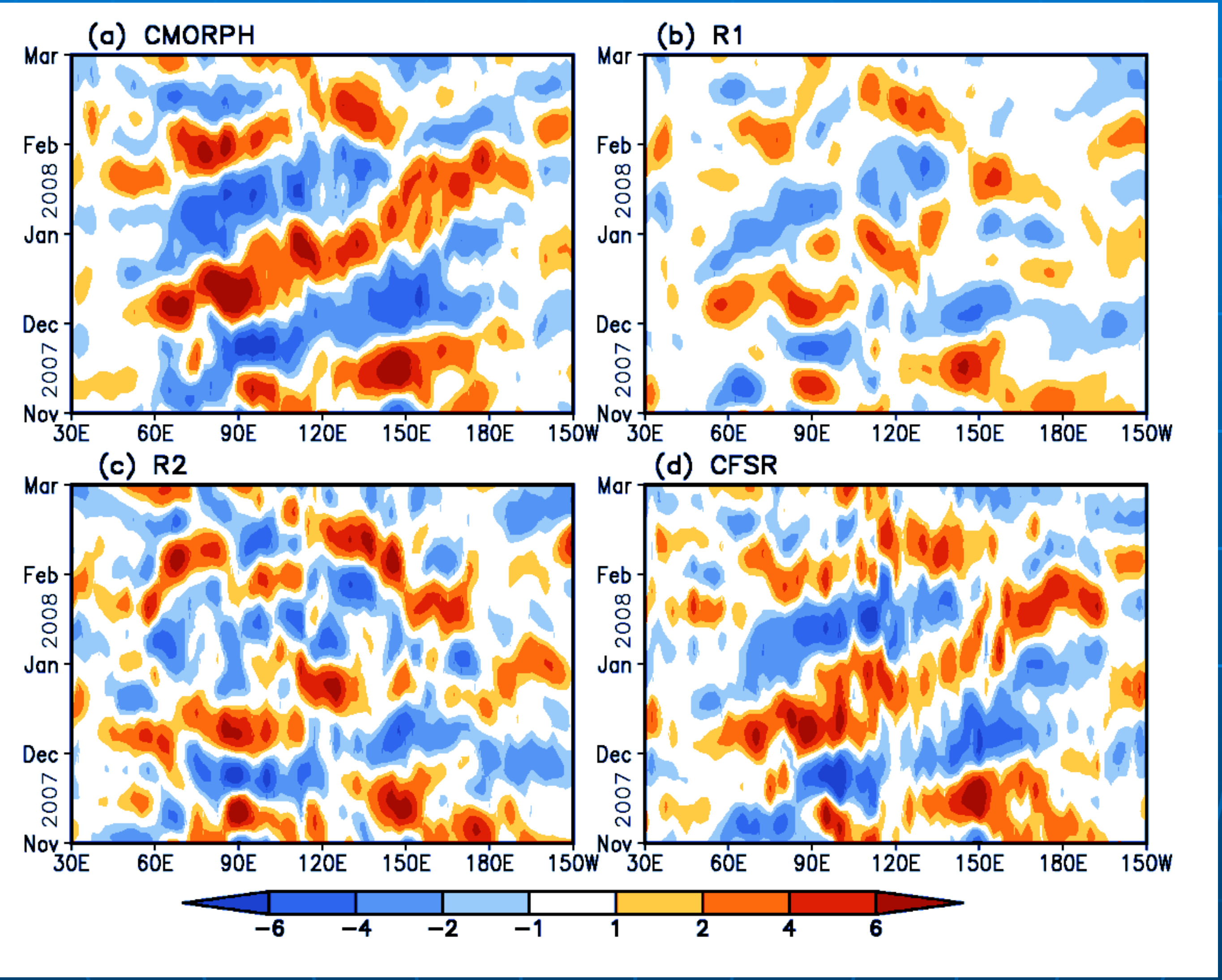
- Develop and test the assimilation system on NOAA R&D system.
  - This effort will leverage on significant progress that has already been made in porting of NCEP modeling systems on Gaea.
  - ESRL's experience of working on multiple platforms, and with the hybrid data assimilation system, will play a key role.
  - Keep the system portable !!!
    - Use version control software to include local machine optimizations
    - Will eventually have to replace R1 on NCEP Weather and Climate Operational Supercomputer System (WCOSS)

# Strength – Depiction of High Frequency Variability

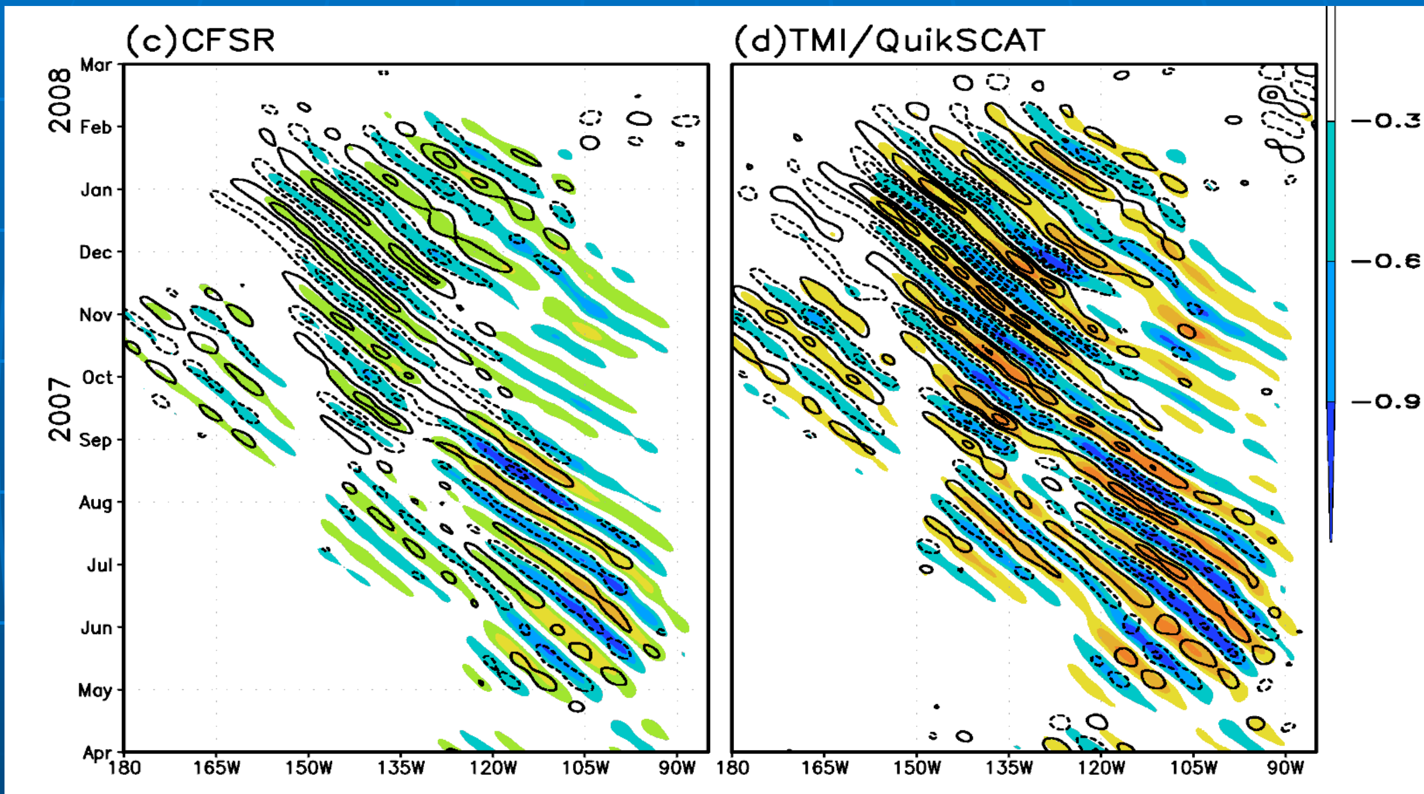
**Rainfall – Synoptic Features**



# MJO Intraseasonal Rainfall

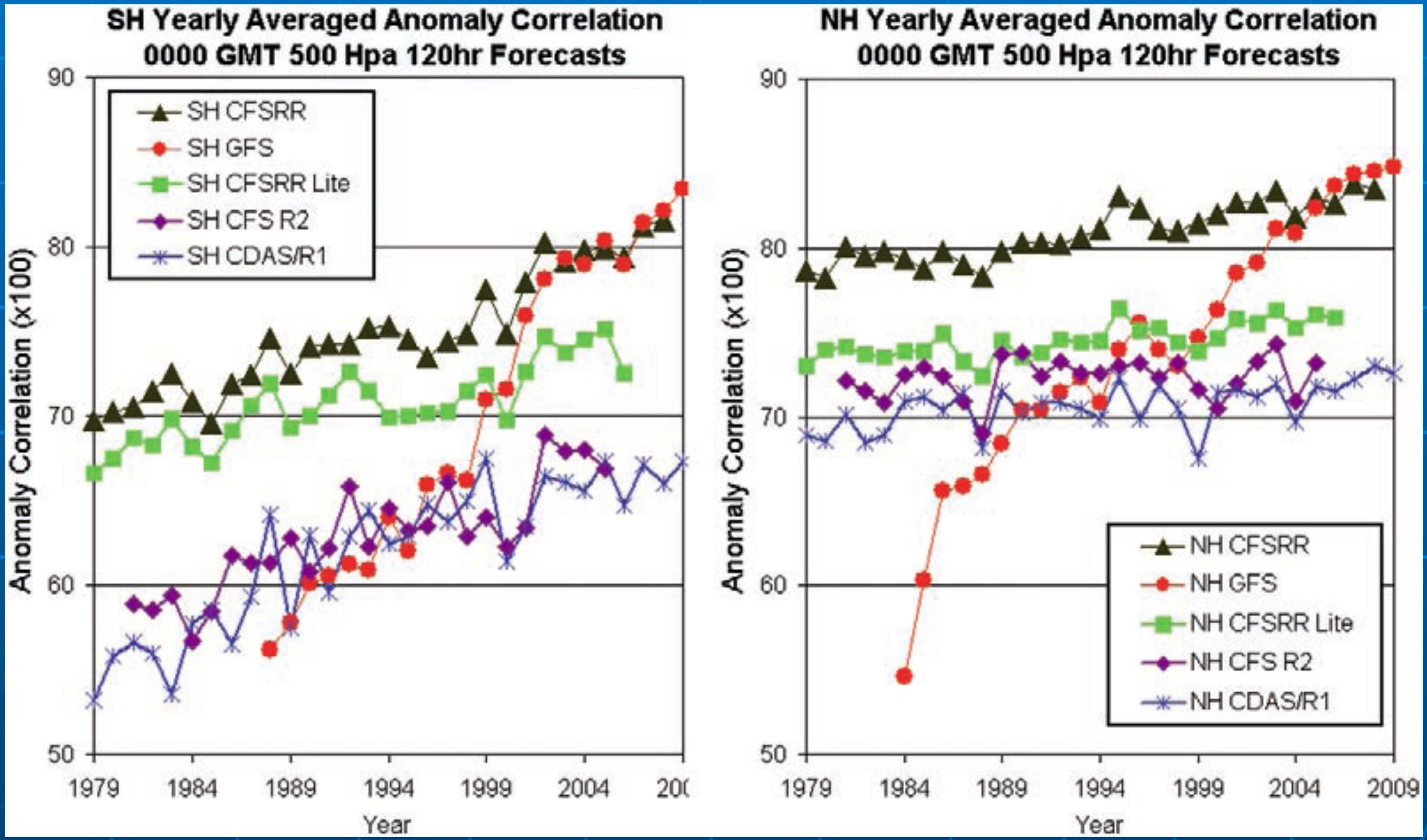


# Tropical Instability Waves (TIW)




SST (Shading) ; 10-M Wind (Contour)

# Better NWP Initial Conditions



# Identified CFSR Weaknesses

- Stream boundaries
  - Ocean
  - Soil
  - stratosphere
- Tropical issues
  - QBO
  - Fit to tropospheric obs.
  - Tropical storms
    - Detection
    - Relocation noise
- TOVS > ATOVS (1998)
  - Moisture Discontinuties
  - Tropical circulation discontinuities

- Stream boundaries
  - High resolution
  - Deadline
  - One year overlaps
- Tropical issues
  - Assimilation window, ob errs
  - GSI Background error
  - Tropical storms
    - Detection
    - Relocation noise
- TOVS > ATOVS (1998)
  - Selection of moist. ob systems
  - GFS cold bias

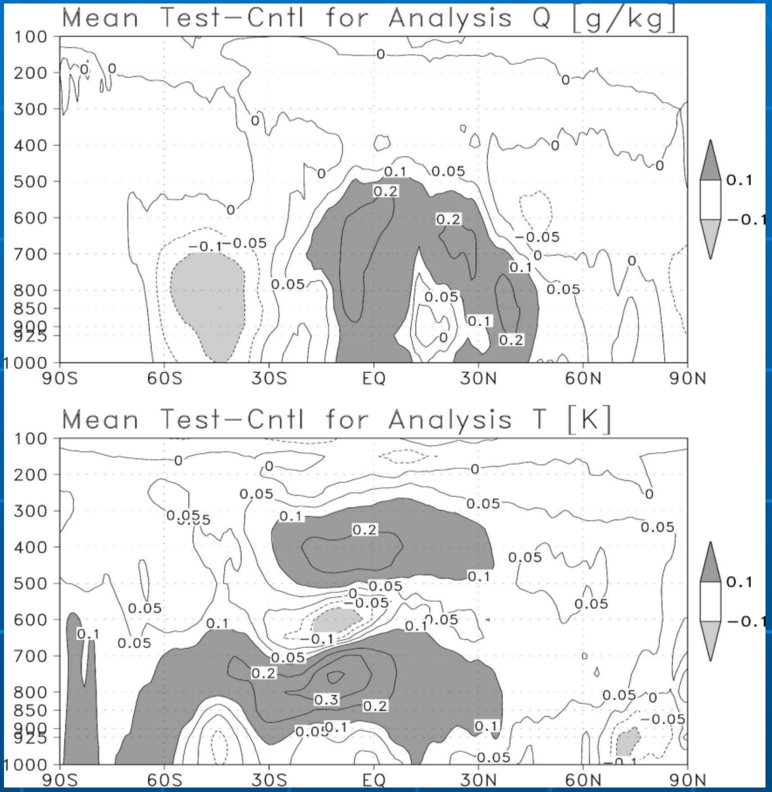
# CFSR-lite (CFSRL) addressing CFSR weaknesses

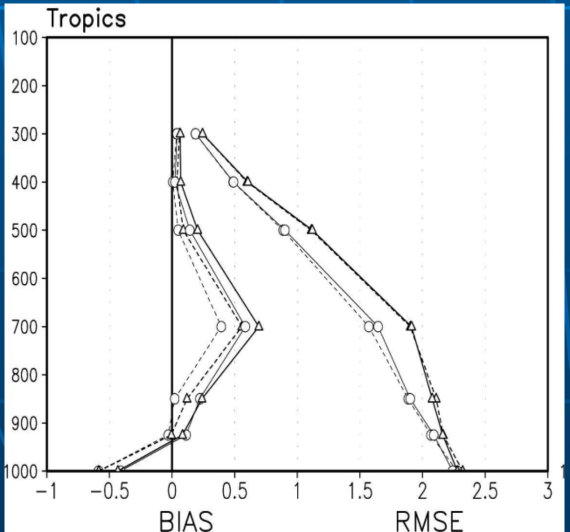
- T126 (vs T382) single stream
  - Focus on monthly mean fields
  - Eliminate stream boundaries
  - Faster execution (~mon/day)
  - More compact archives –
  - Ocean model remains the same
- Tropical background errors
  - MERRA inflation example
  - Improve troposphere and stratosphere in TOVS period
- Corrected satellite bias correction
  - Obs. Error
  - Anchoring top channels
  - Benefit stratosphere
    - SSU ch3
    - AMSU-A ch 14
- Corrected tropical cyclone (TC) relocation bug
  - Eliminates numerical noise,
- Assimilate TC central pressure
  - Improves detection and relocation
- SST analysis 1xdaily vs 4xdaily
  - Removes noise
- Reprocessed microwave radiances
  - Simultaneous nadir overpass cross instrument calibration
  - MSU in 1980's, AMSU for 1998 >
- Incorporate 4 years of coupled prediction model and GSI development
  - 5 day fcst scores = CFSR
  - Slight reduction in model cold bias

# Okamoto and Derber (MWR, 2006)

## Assimilation of SSM/I Radiances in the NCEP Global Data Assimilation System

- Impact test of SSMI radiances
  - July-Aug 2004
  - Both control and test included AMSU-A window channels
- "The assimilation experiments from July to August 2004 show that the SSM/I radiance assimilation adds moisture in the Northern Hemisphere and Tropics and slightly reduces it in the Southern Hemisphere.
- "The moisture added seems to be too much compared to rawinsonde observations, especially in the Tropics."




Higher priority tasks precluded follow-up development and operational implementation

Therefore not assimilated in CFSR

# Global mean SST 60S-60N

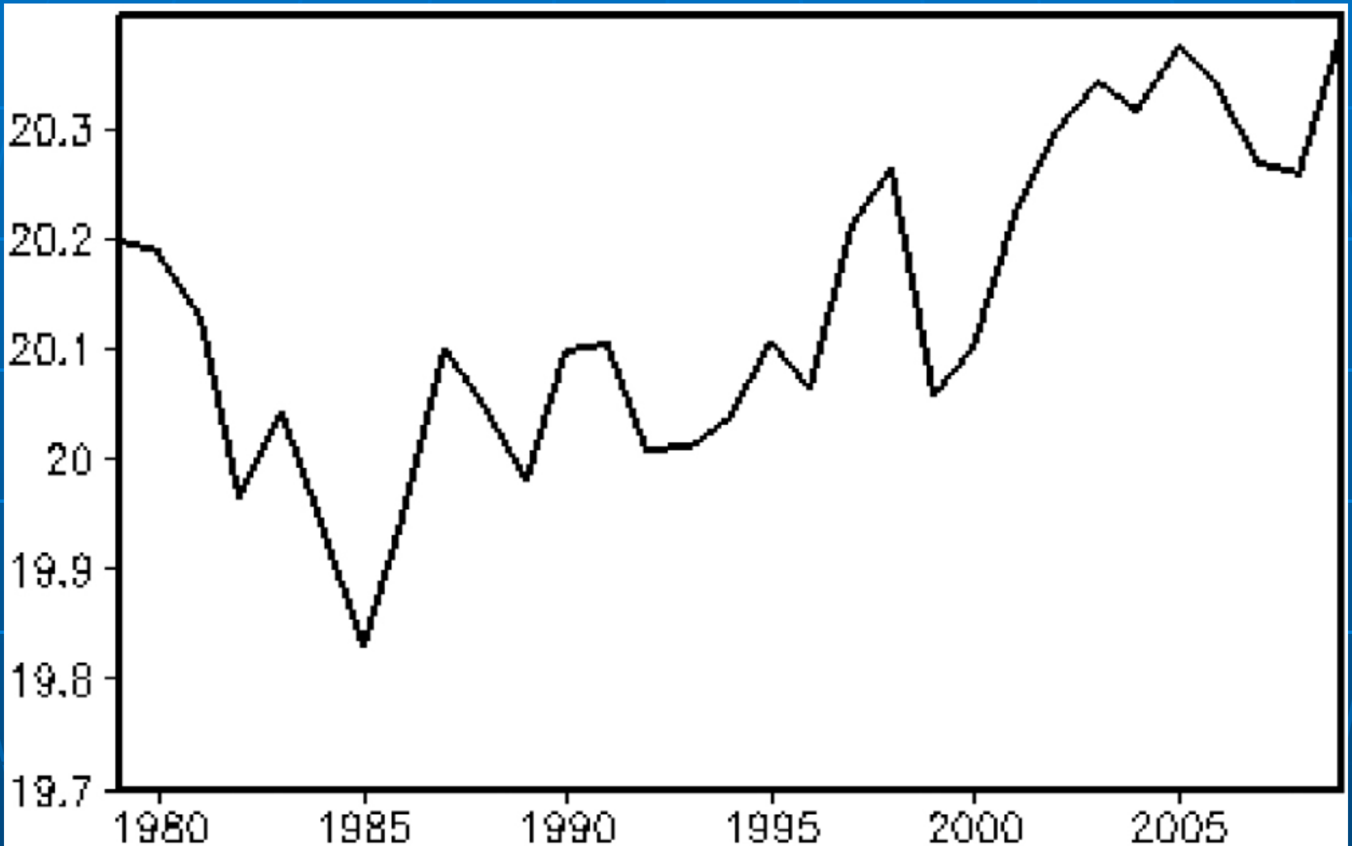
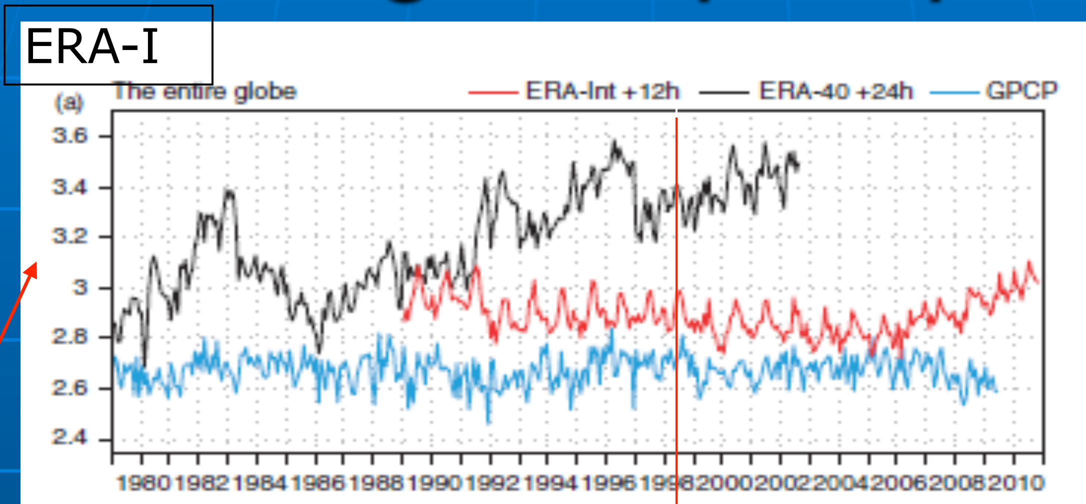
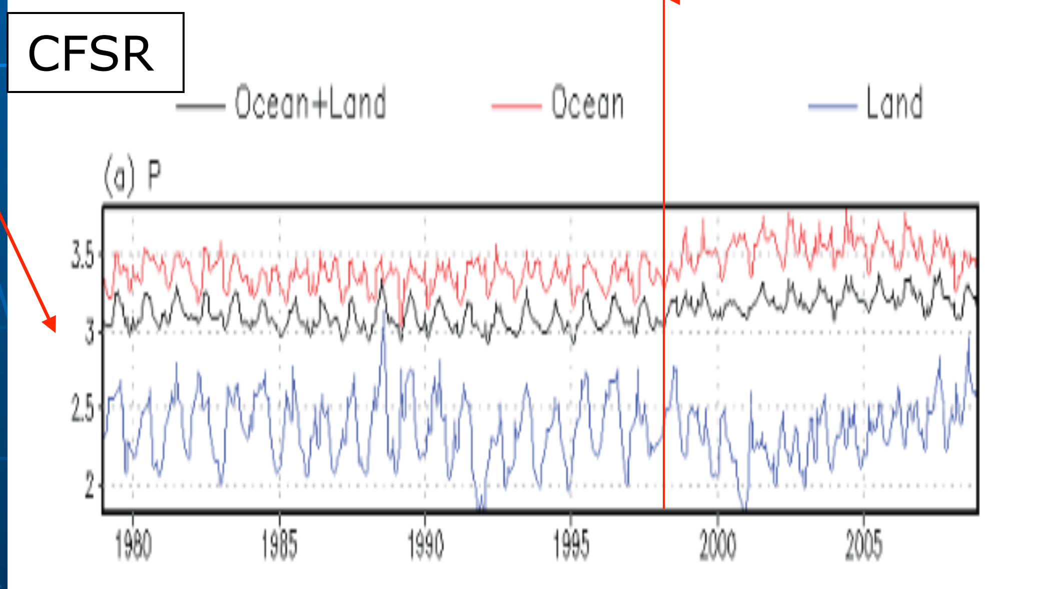



Figure 2. Time series of the annual mean of the sea surface temperature averaged over the global ocean between 60S and 60N for the period of 1979–2009 for the AMIP run.

# ERA-I vs CFSR global precip




ERA-I plot starts after SSMI began in 1987

ATOVS 1998

Scales of mm/day differ

CFSR did not assimilate SSMI

# NCEP CFSR-Lite

- T126  version of CFSR (T382)
- 2011 GSI + CFSv2 model
- Addresses lessons learned from CFSR
- Possible replacement system for NCEP/ NCAR R1 of Kalnay, 1996 and Kistler, 2001
  - 1948 – 1978
  - 1979 –
  - Currently testing the ERA-I SSMI & AMSU-A configuration for 1998-1999

# CFSRL on vapor, continued

- Persuaded skeptical admin's to dedicate 6 nodes
  - 192 processors provided via special job queue
  - maximize job multitasking
  - minimize job queuing
  - optimized coupled prediction model and GSI for maximum speed
    1980's:1 year ~ 8 days
  - backfill with CPC hurricane project jobs to maximize node utilization
    - 24x7 node utilization
- Revamped CFSR archive organization
  - CFSR manually submitted disk cleanup and HPSS jobs were automated
    - T126/1x1 grib resolutions, 6hr freq, larger HPSS tapes permit monthly tarballs
  - Automated observation uploading (CFSRR all on disk…)
  - Rewrote, expanded fit-to-obs monitoring, incorporated multiple comparisons scripting (kudos Jack Woollen)
    CFSRR vs CFSRL, between CFSRL exp's
  - Reorganization permits web plotting on Cirrus/stratus v
    - vapor is outside firewall - file transfers write to web server not permitted

# CFSRL Milestones
## Oct 2010-Oct 2011

- Oct 2010 –
  - port of CFSRR to vapor began
- Nov 2010
  - benchmarked vapor vs stratus
- Dec 2010
  - Began testing assimilation for 197812
- Jan 2011
  - HPSS archive rewritten, tested 197901
- Feb 2011 –
  - Received dedicated nodes
  - Began ozone test for 197901 and 197907
- March 2011
  - Ran CPC requested 1 year Dec 2005 – Dec 2006
    - Uncovered numerous issues to be resolved
  - Optimized coupled prediction model
- April 2011
  - Nodes preempted by the CPC seasonal TC fcsts
  - Intensive debug of fit-to-obs program revealed sensitivity to how ob qc was obtained
  - GSI scripting was optimized and mode more robust
- May 2011
  - Resolved origin of TC noise in CFSRR for CFSRL
  - Created monthly restart tarballs
- June 2011
  - 15 month run (CFSv2 cdas model) ended with discovery of multiple GODAS script errors
- July 2011
  - Upgraded to 2011 GFS coupled model
  - Replaced adhoc RADCOR with adaptive system
  - Added radiation diagnostics from CFSv2 fcst model
- Aug 2011
  - Restarted CFSRL – ran 2 years
  - Added comparison fit-to-ob plots
  - Numerous vapor, HPSS outages into Sep
- Sep 2011
  - Run reach the end of 1983
  - Ran meteosat upgrade test (2 mo's with, 2 without)
  - QBO problems with 1981-2 easterly phase reported
- Oct 2011
  - Relaxed wind qc – little impact on QBO
  - Problem appears to be model
  - Began test of CVSv2 pred model in place of 2011 GFS
- Nov 2011
  - Will pass first CFSRL stream boundary 1985

# CFSRL milestones
# Nov 2011- Apr 2012

- Nov 2011 – test of CFSv2
- Dec revamped QBO processing
- Jan – Mar 2012 1998 -1999 testing
- March 23 – vapor shutdown

# CFSRL on GAEA

- Reanalysis computational paradigm shift:
  - GAEA is not a previous generation operational NWP computer
    - Examples: Cray xmp (R1), asp/bsp (NARR), mist/dew (CFSRL)
  - Not "battle tested" mature hardware and software
    - Was not benchmarked with the NCO production job suite
    - admins not familiar with NCEP computational requirements
    - 12 years on the IBM architecture
  - Hardware initially presented has to be reconfigured
    - No permanent disk space
    - No dedicated processing
  - Awaiting Archive path to HPSS

- Port the end-to-end vapor CFSRL
  - Functioning coupled global data assimilation system,
  - verification codes
  - end-of–month processing
- Equivalent in dedicated vapor resources
  - 192 processors available continuously 24x7
  - Job/code optimization: run at least 1 month per wall day
  - Need to complete ~ 15 years of 1979-2010, all of 1948-1978
- Ability to upload and download from HPSS
  - ~260Gb to be uploaded from GAEA to HPSS ~1xdaily

# CFSRL on GAEA, cont.

- 1948-1978
  - Explore
  - Analyses of snow, ice and precip are degraded or absent
  - CFSRLv1 – as currently configured
  - CFSRLv2 - EnKF hybrid
    - 1948 – 1978 – atmos only
    - 1979 -            - coupled
    - Resolution of proposed CFSv3 prediction (T254 T382 ?)
    - CFSv3 – high resolution multiple stream CFSRv3
    - Concurrent prediction resolution CFSRLv3

# MERRA vs CFSRR

- MERRA focused on “climate”
  - 3 streams with 2 year overlaps
  - No prediction results
- CFSRR focus on seasonal prediction
  - Replace R2
  - 6 streams 1 year overlaps
  - 5 day predictions
    - Demonstrate improvement over R2 as basis for CFSv1

# Available Coupled Models for CFSRL

1. CFSv2 data assimilation model (2007) CFSR model

2. 2012 GFS/GDAS model (2011)
   1. Fluxes are degraded
3. CFSv2 seasonal forecast model

   Will be frozen until CFSv3

   CFSRL would complement

# Evaluating Recently Developed Reanalysis Projects

CFSR, MERRA and ERA-Interim

Time series of global precipitation

Impact  of Observation Systems

Bob Kistler
IMSG/EMC/NCEP
MAPP Webinar Feb 14, 2012

# Evaluating Recently Developed Reanalysis Projects

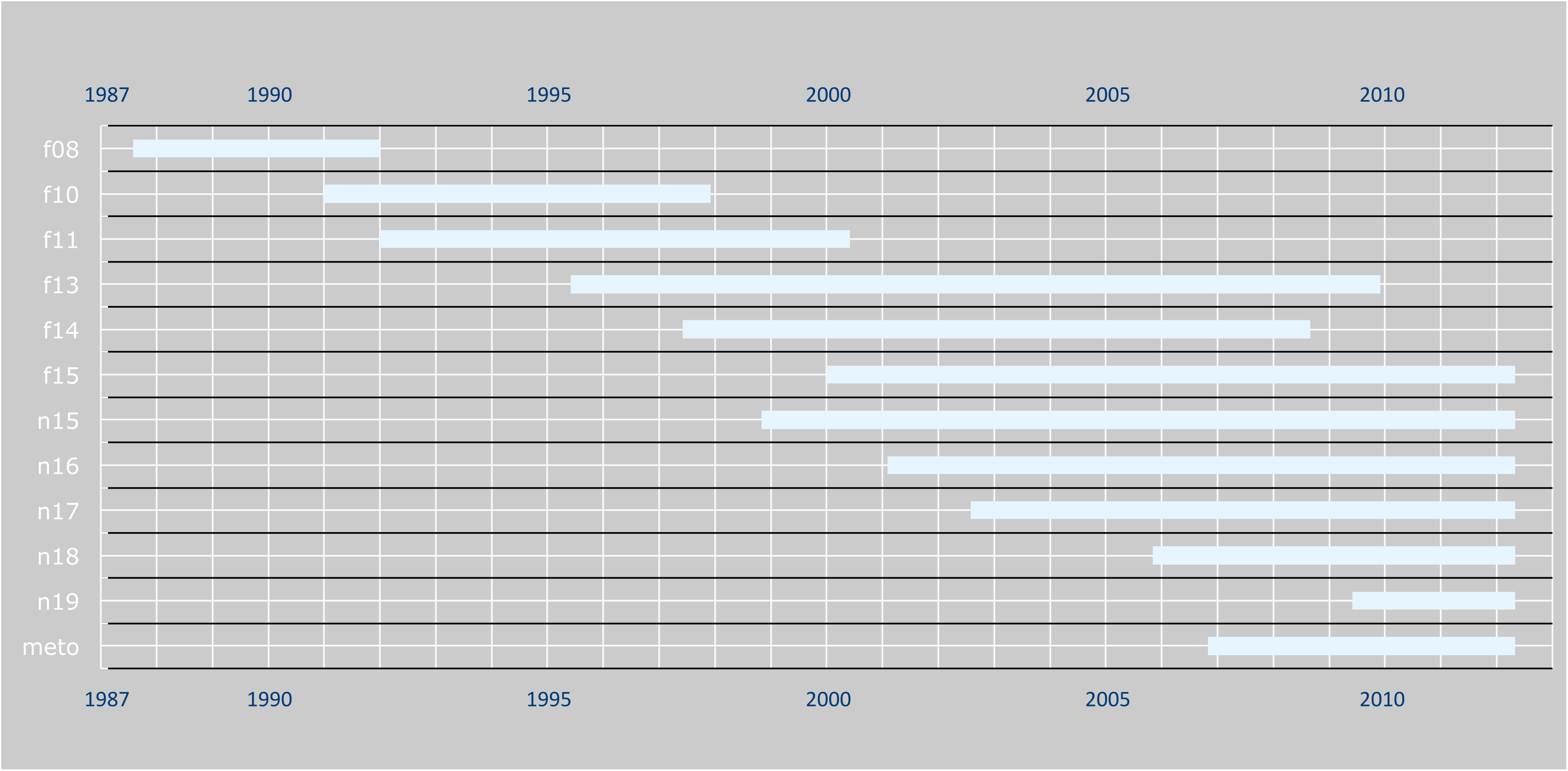
- One of the challenges to the interpretation of reanalysis time series is the impact of observing system changes, in particular:
  - SSMI (beginning in 1987)
  - AMSUA (beginning in 1998)

- Demonstrate with the comparison monthly mean, globally averaged precipitation time series from:
  - NOAA/NCEP:CFSR
    - Saha, et al BAMS, 2010
  - ECMWF: ERA-Interim (ERA-I)
    - Dee, et al QJRMS, 2011
  - NASA/GMAO: MERRA
    - Basilovich, et al JClim, 2011
  - GCPC (independent estimate)
    - http://www.gewex.org/gpcp.html

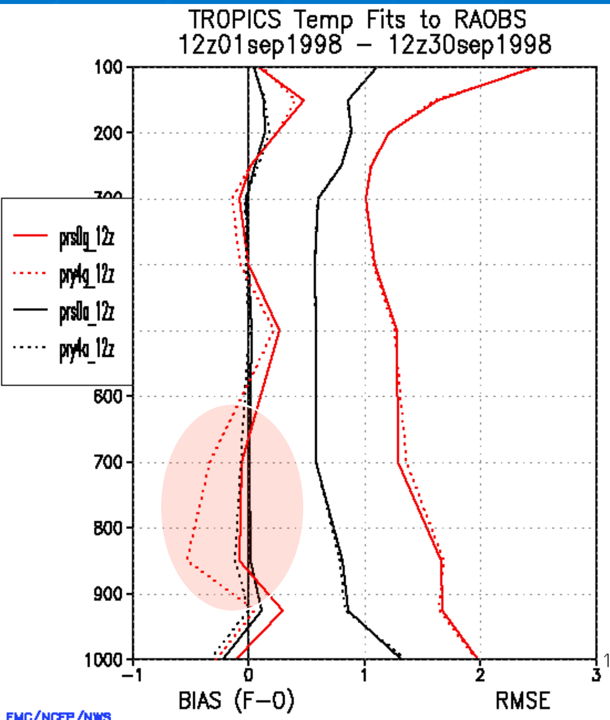
# 13 mo’s CFSRL testing

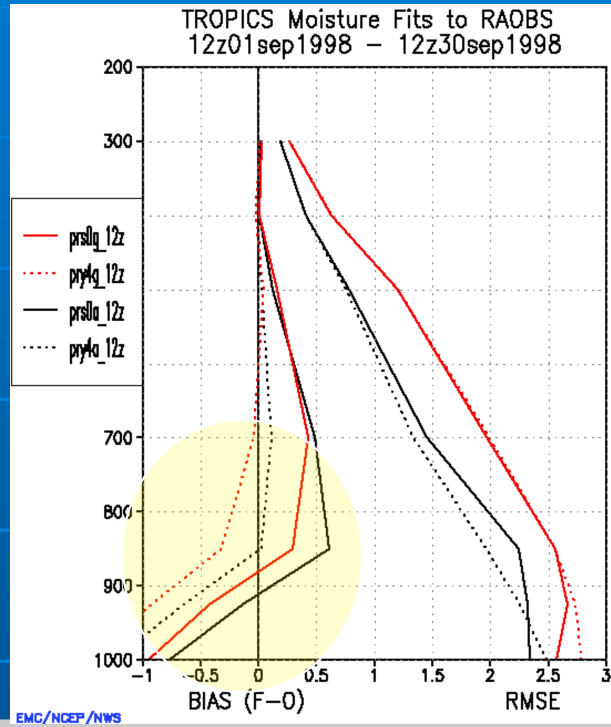
- Control (pry4) July 1998-Dec 1999
  - Same input data as CFSR (no SSMI)
- SSMI assimilation (prs0) Jan 1998-Dec 1999
  - ERA-I AMSU-A configuration
- CFSR (prc3, prc4 streams)
- pry4 vs prc4 –
  - Impact of CFSRL system
- prs0 vs pry4 –
  - 1998 – impact SSMI vs no SSMI
  - 1999 – impact of SSMI vs AMSU-A ch 1-3,15

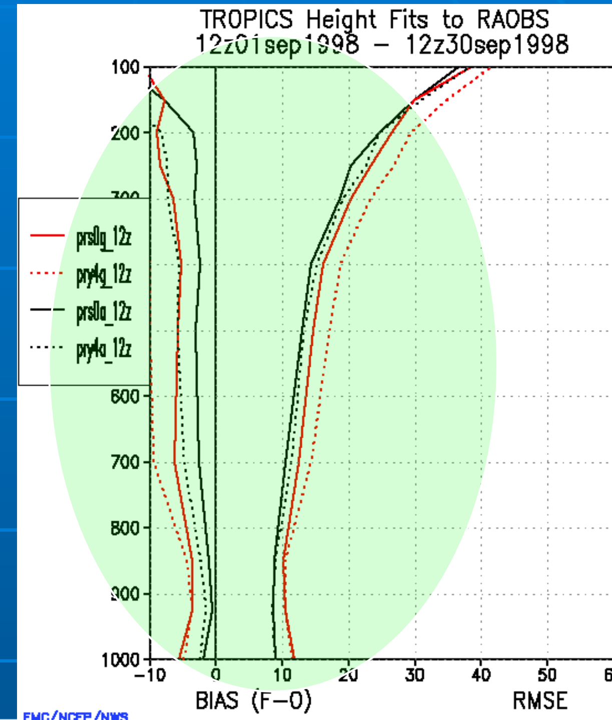
# SSMI and AMSU



# Tropical Troposphere fit-to-raobs Sept 1998 1200 GMT



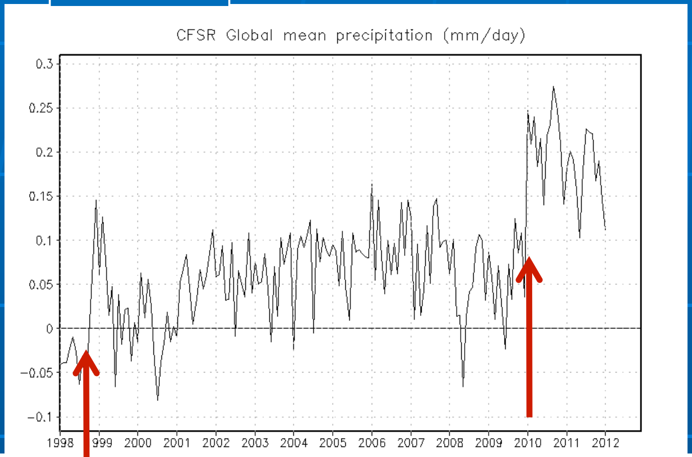



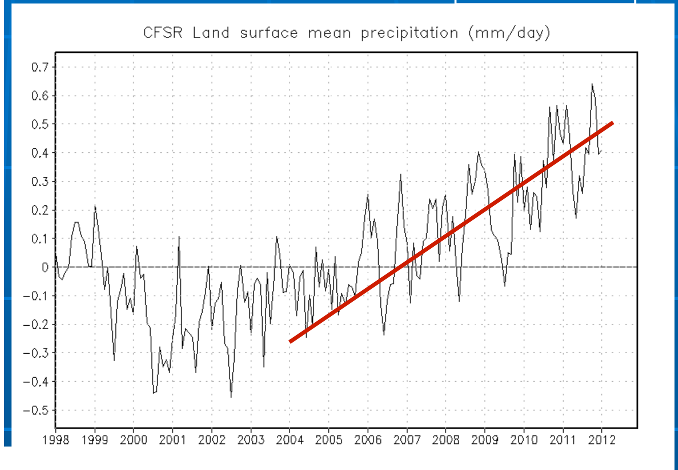

Improved prs0 height bias and rms measure improved integrated virtual temperature – the reduced low level dry bias improvement coupled with the removal of the pry4 guess cold temperature bias 850-600 HPa positively impact the height bias and rms throughout the troposphere, i.e. their combined improvements are more important than the prs0 <850 HPa moist bias.

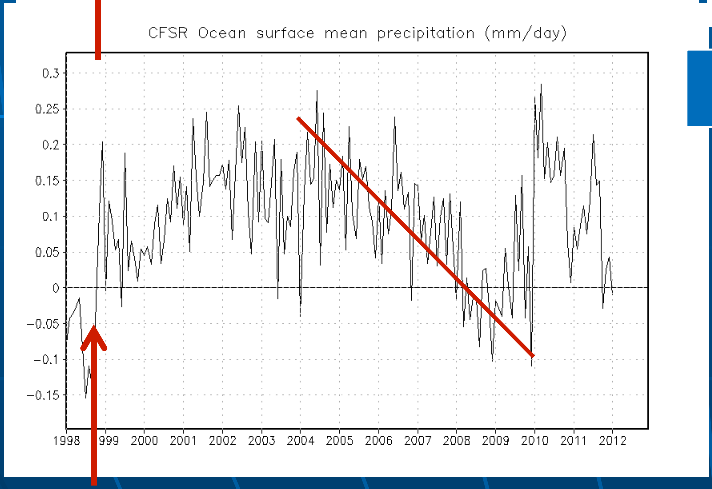
# Some Recent Trends in the CFSR: Precipitation

Global




Land



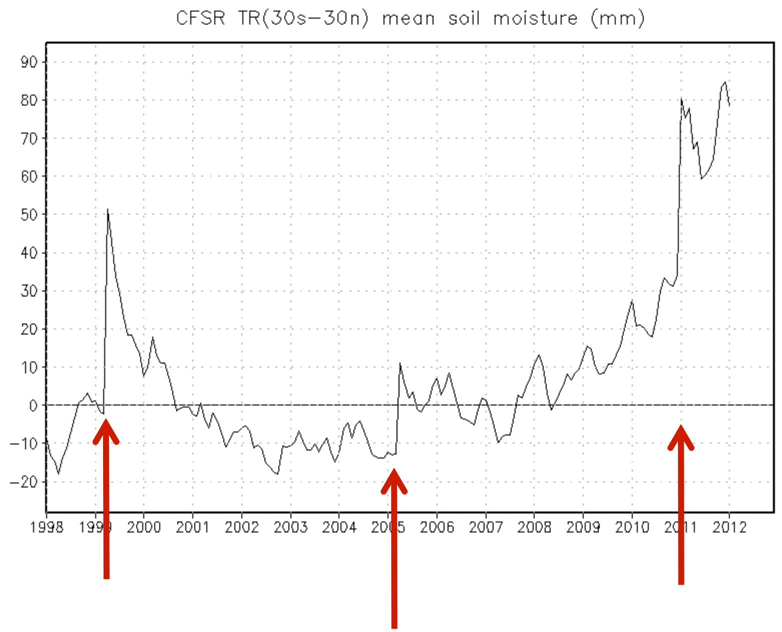




Ocean

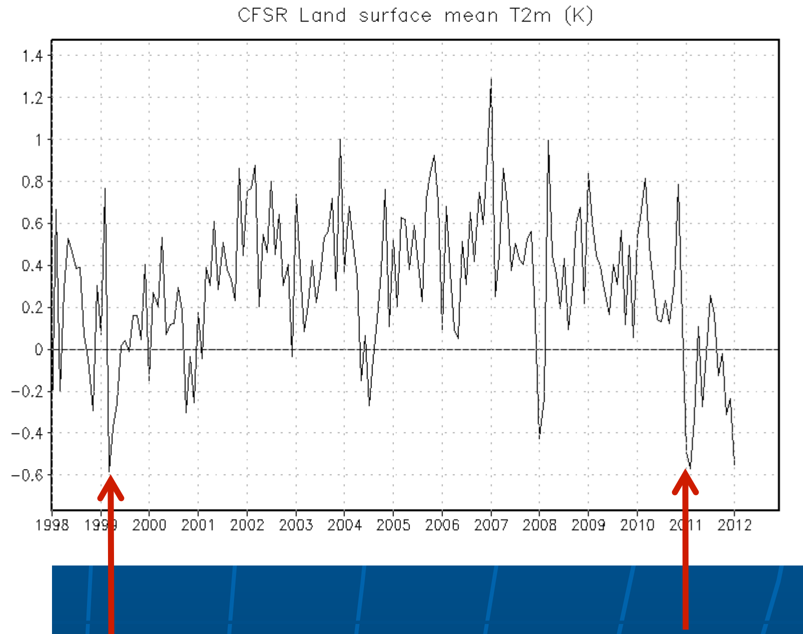
Some change in the CFSR assimilation system ~ 2010! GSI?

# Some Recent trends in the CFSR

SM – Tropical




T2m – Global



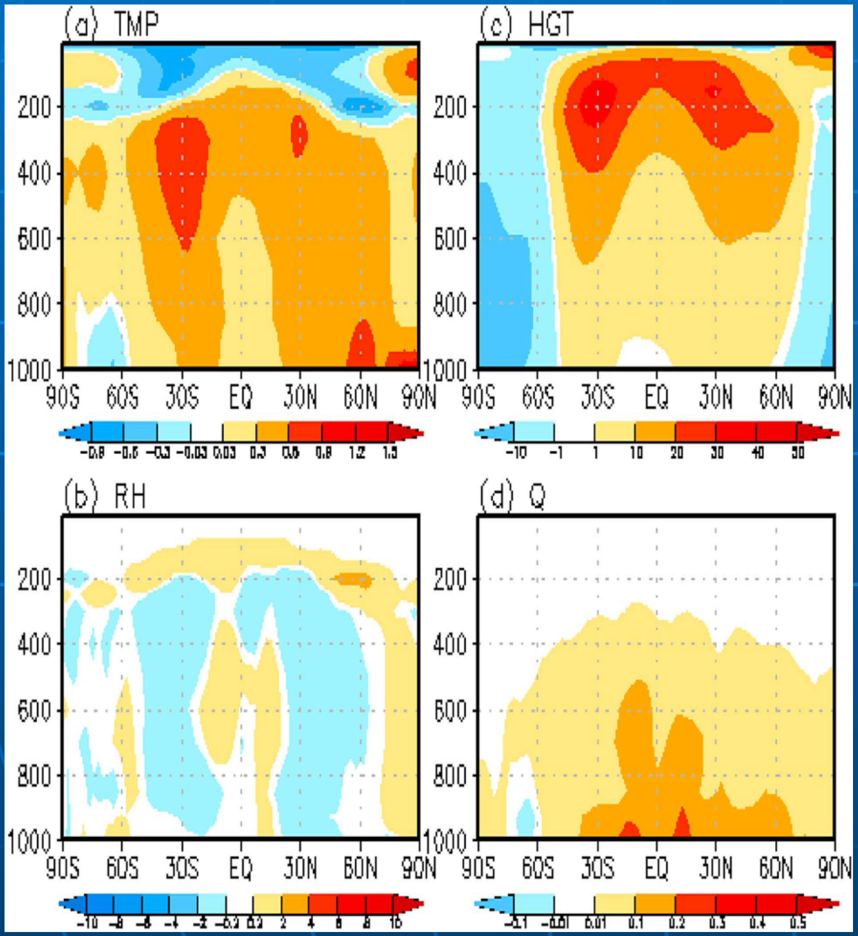

Change in 2011 related to change in the resolution (T384→ T574)?

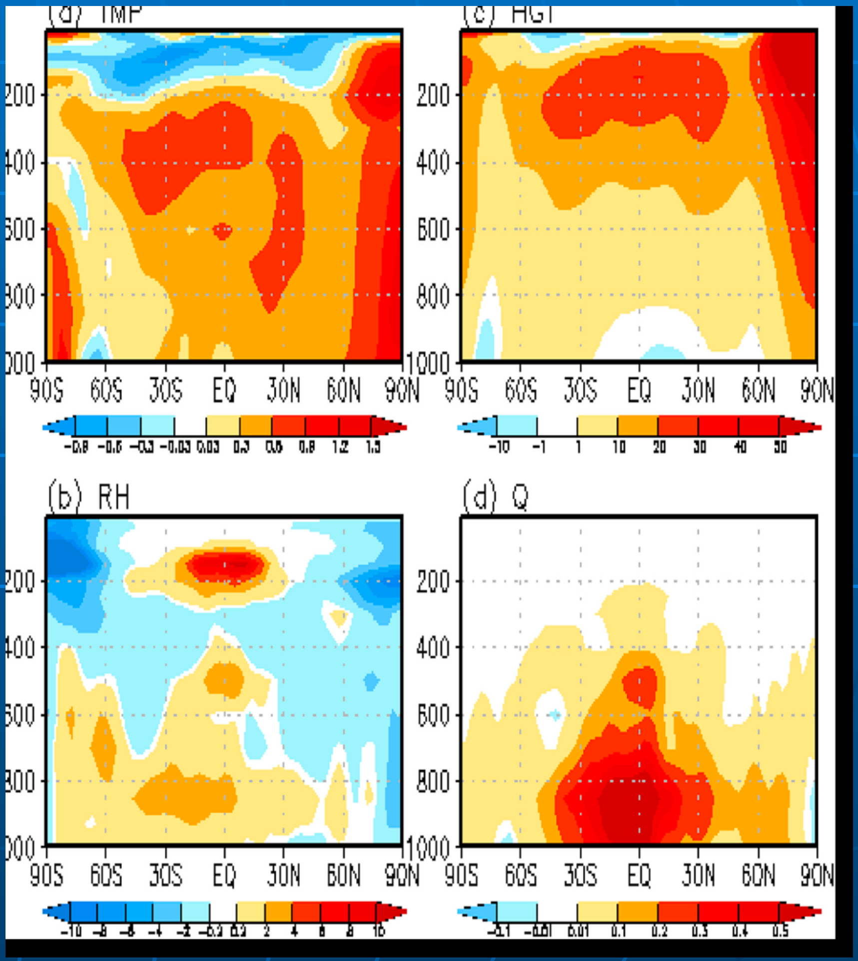
# Influence of Recent Changes?

- Are changes in the real-time CFSR having an influence on the real-time seasonal forecasts (for which anomalies are computed relative to either 1982-2010 or 1999-2010 hindcasts)?
- This happened for the CFSv2 forecasts ~ 1999; Have seen similar issues in CFSv1;
- Not sure, but need to keeping an eye

# (1999-2009) minus (1987-1997)

## AMIP CFSR



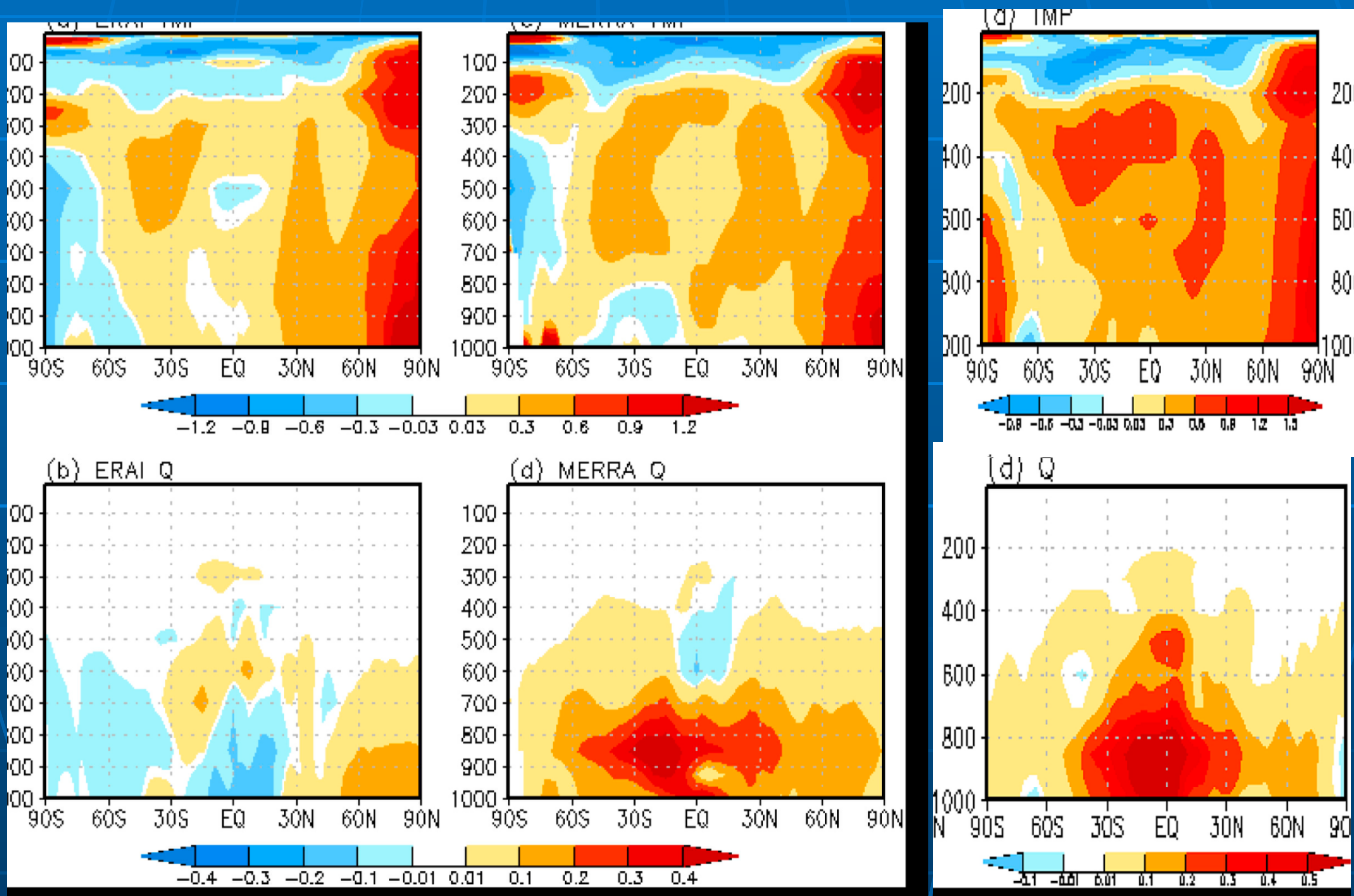

CFSR larger T,Q, + trend than AMIP

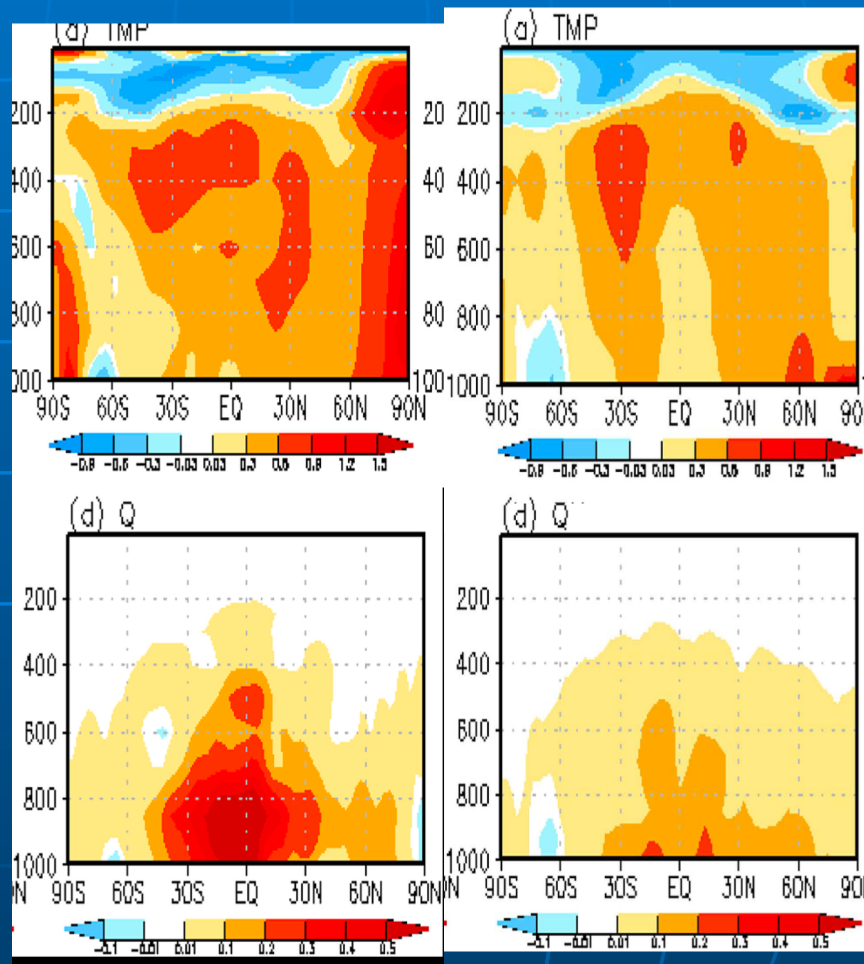
# (1999-2009) minus (1987-1997)

## ERA-I MERRA CFSR

TMP

Q




(a) TMP
200
400
600
800
1000
90S 60S 30S EQ 30N 60N 90N
-0.8 -0.6 -0.3 -0.03 0.03 0.3 0.6 0.8 1.2 1.5
(a) TMP
200
400
600
800
1000
90S 60S 30S EQ 30N 60N 90N
-0.8 -0.6 -0.3 -0.03 0.03 0.3 0.6 0.8 1.2 1.5
(d) Q
200
400
600
800
1000
90S 60S 30S EQ 30N 60N 90N
-0.1 -0.01 0.01 0.1 0.2 0.3 0.4 0.5
(d) Q
200
400
600
800
1000
90S 60S 30S EQ 30N 60N 90N
-0.1 -0.01 0.01 0.1 0.2 0.3 0.4 0.5

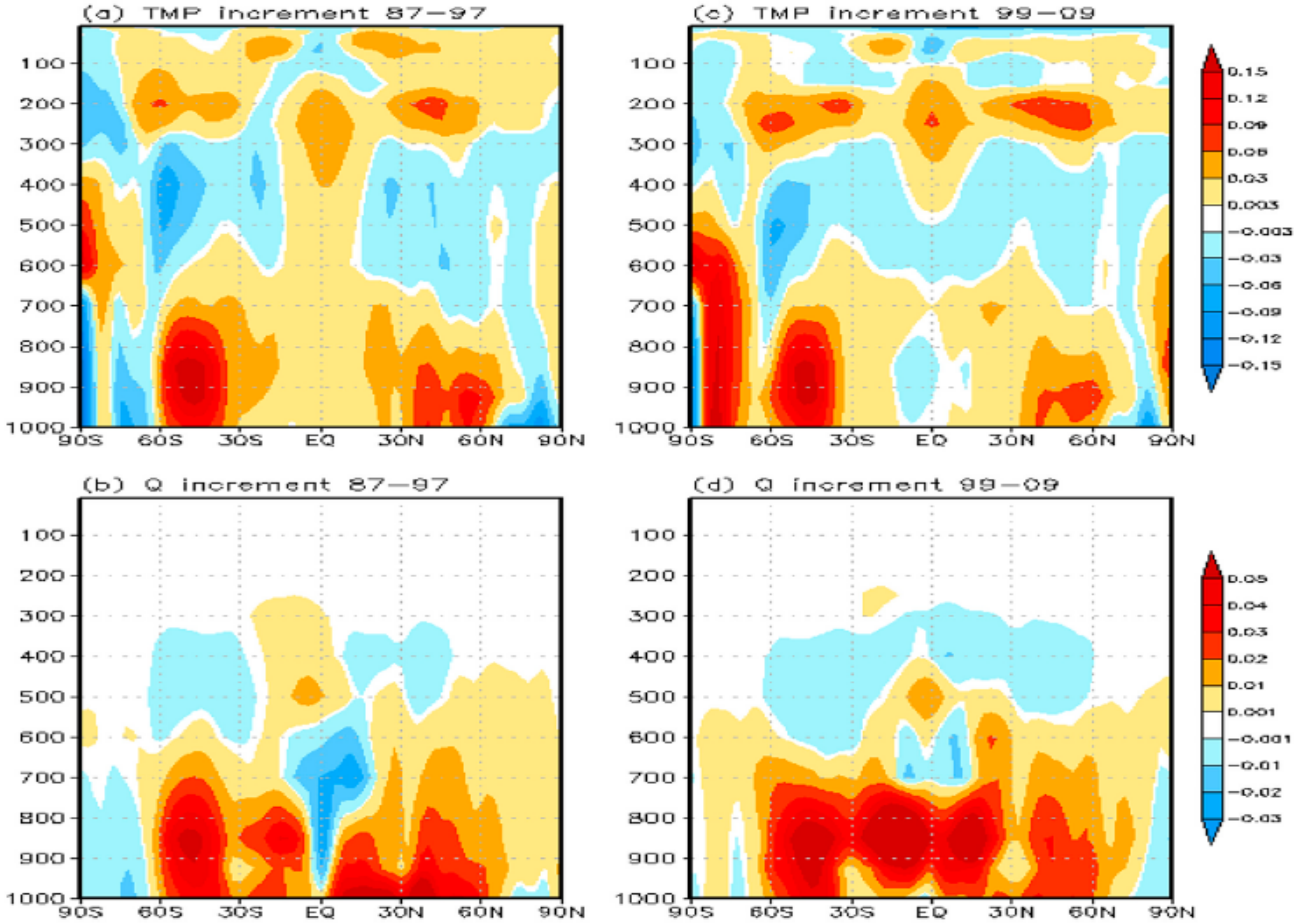
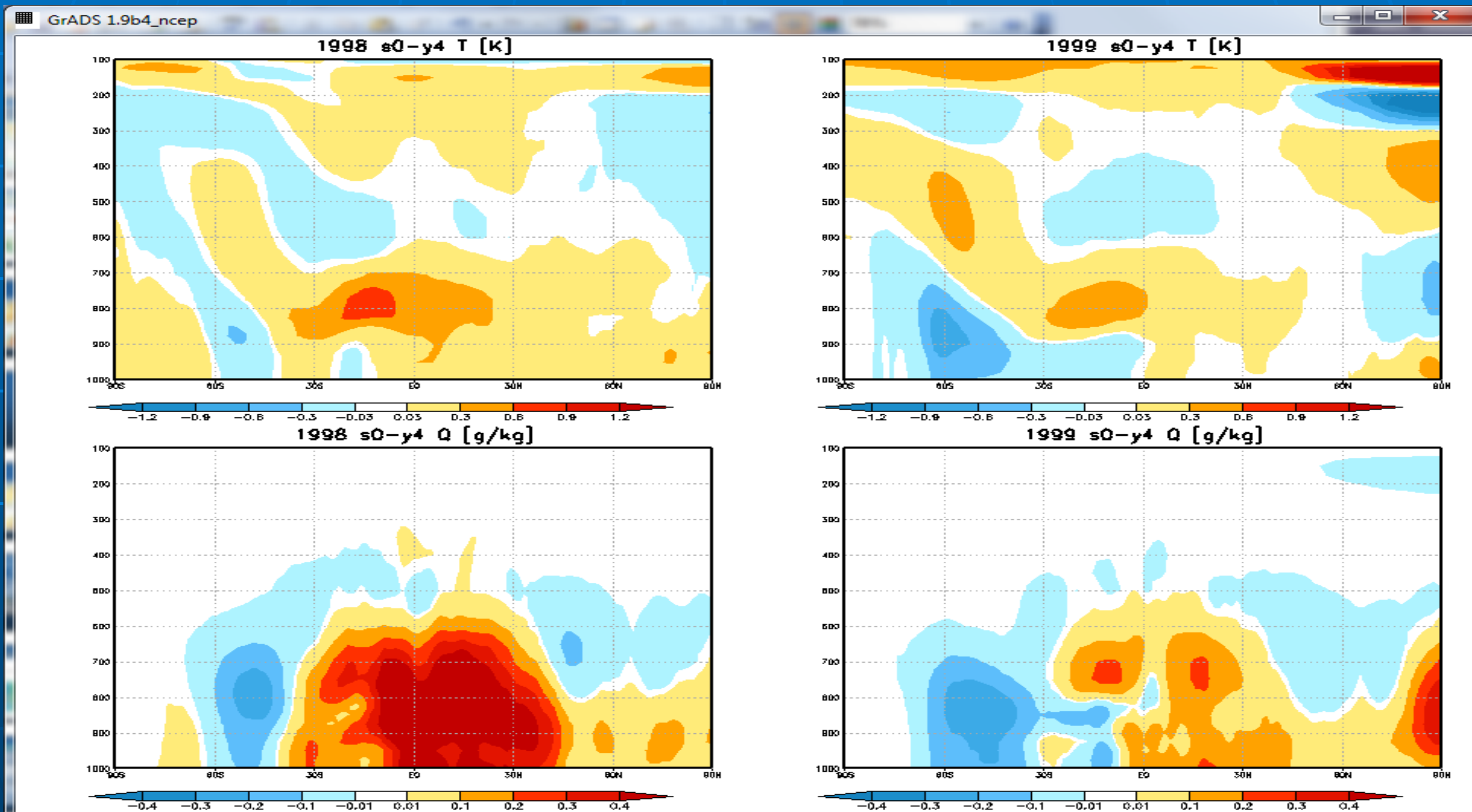
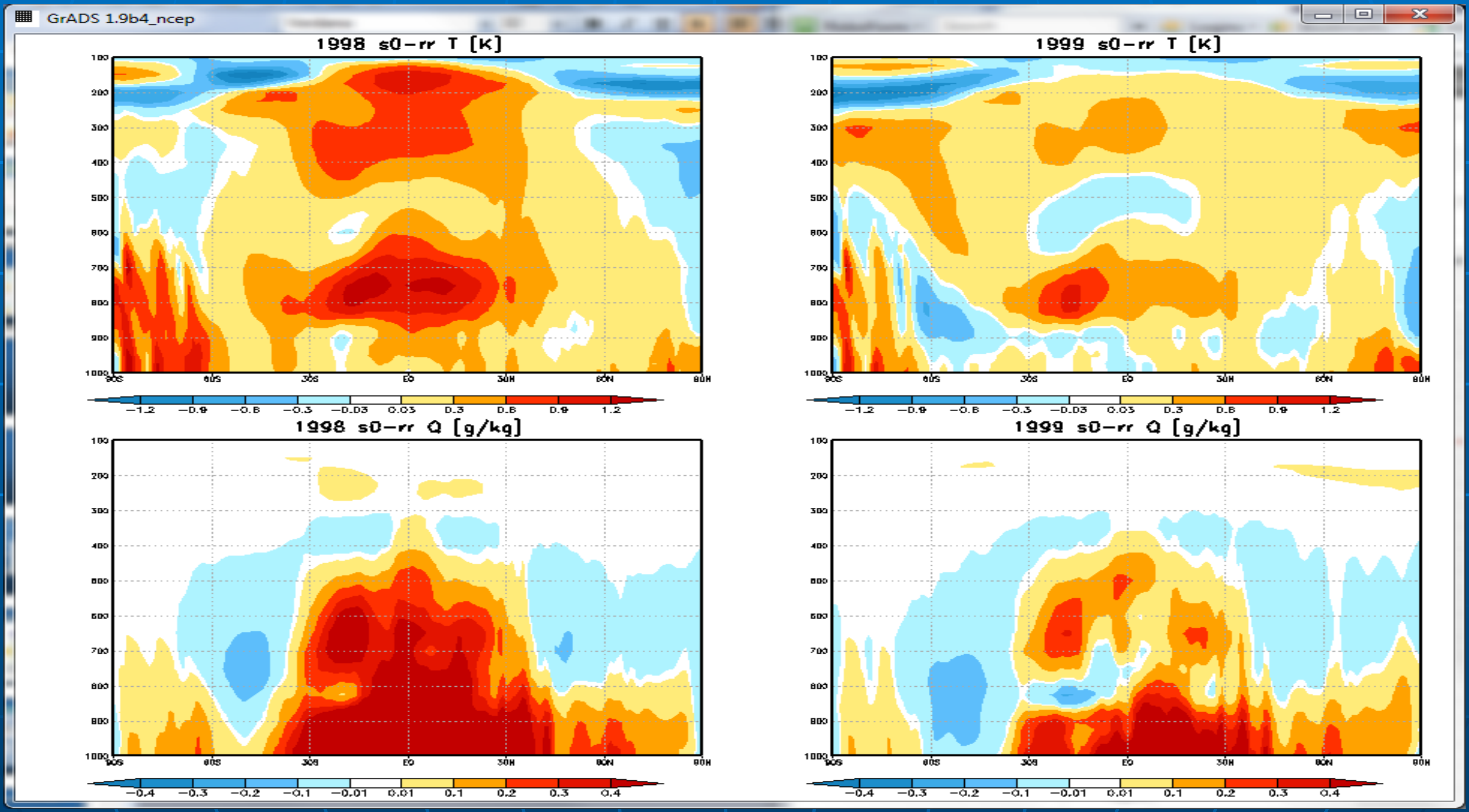


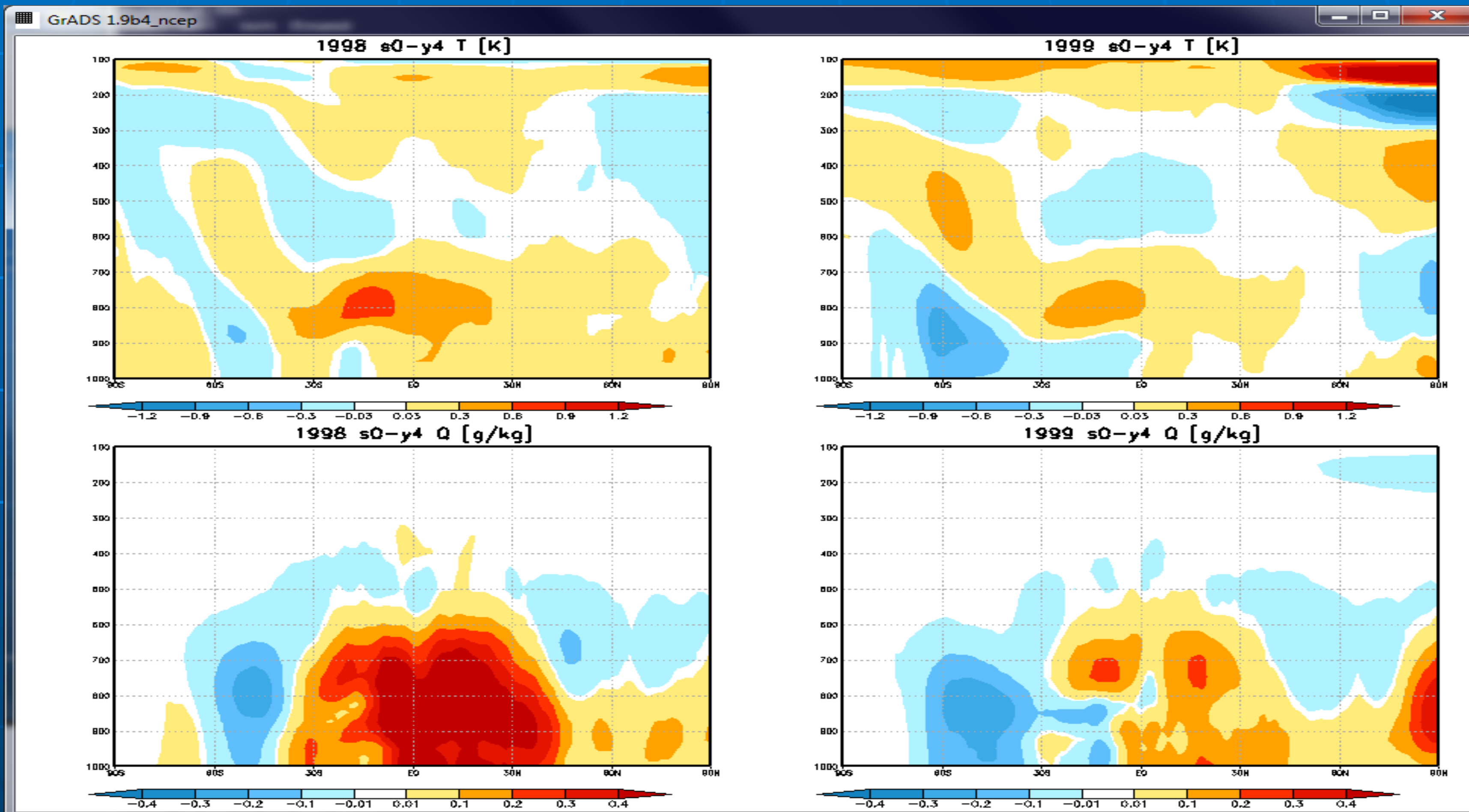

**Figure 7.** The zonal mean for CFSR for (a) temperature increment during the period of 1987–1997, (b) specific humidity increment during 1987–1997, (c) temperature increment during the period of 1999–2009, and (d) specific humidity increment during 1999–2009.

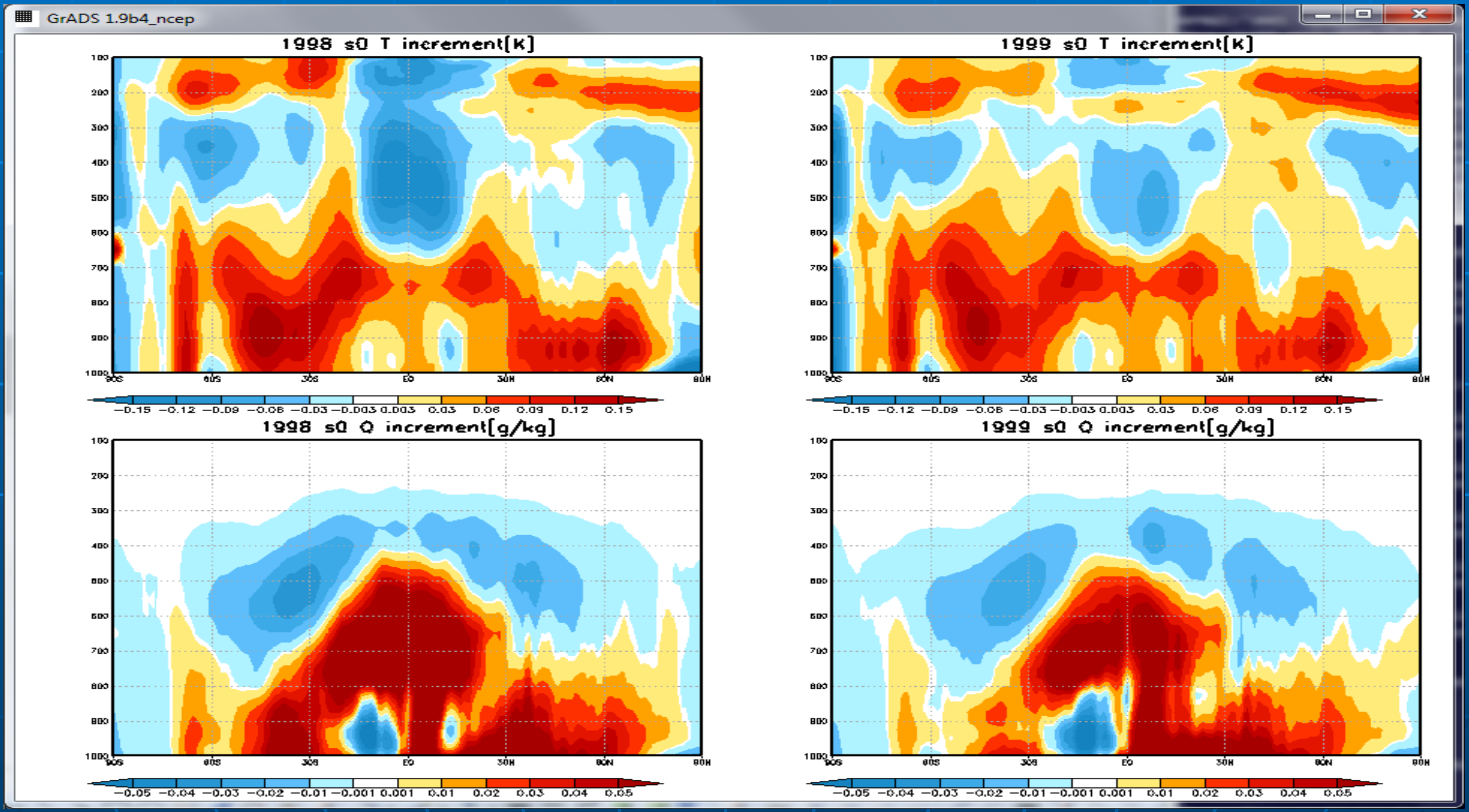
Equatorial cold, moist model bias in the absence of AMSU-A/SSMI

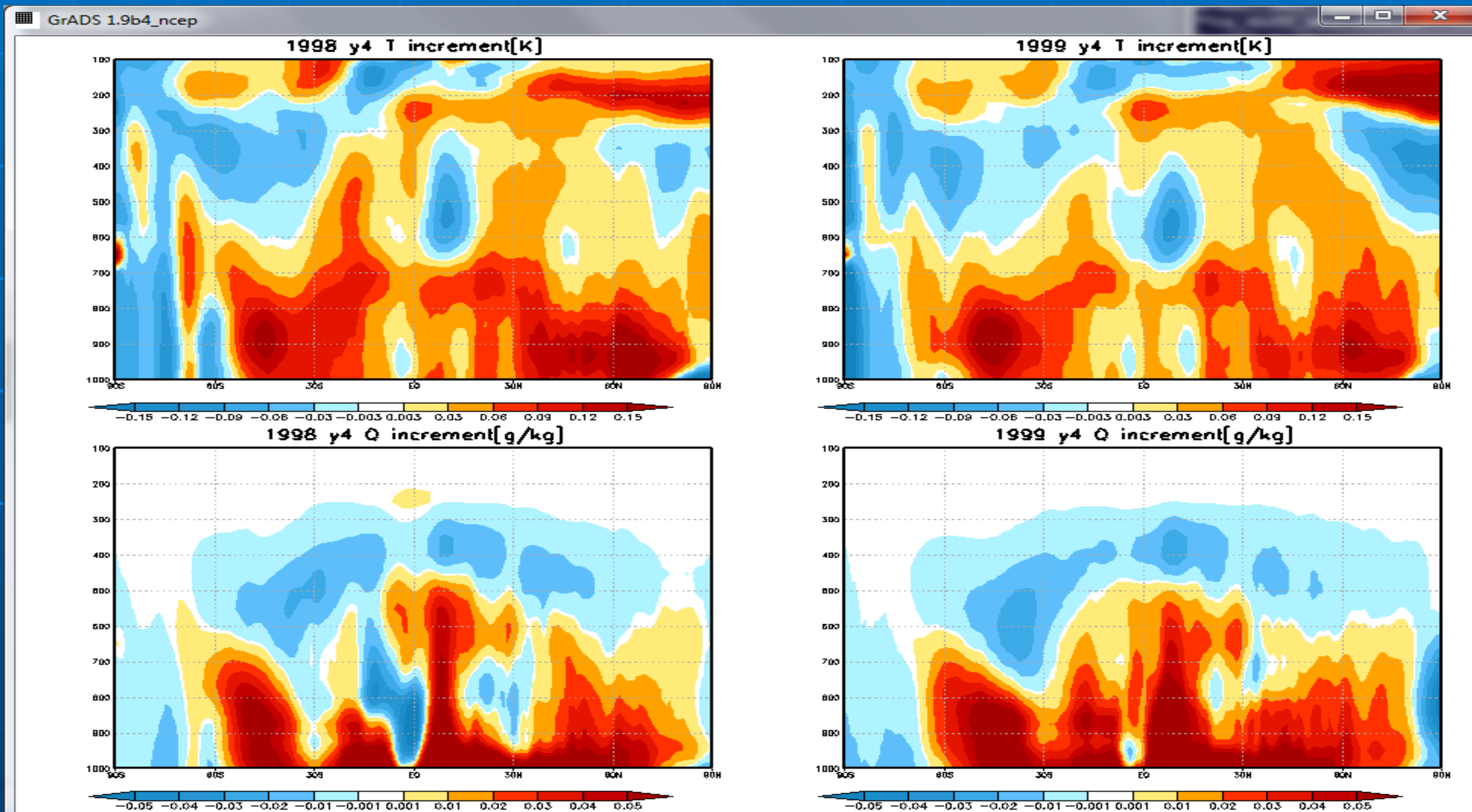
Equatorial warm bias driven by precip caused by AMSU-A radiances

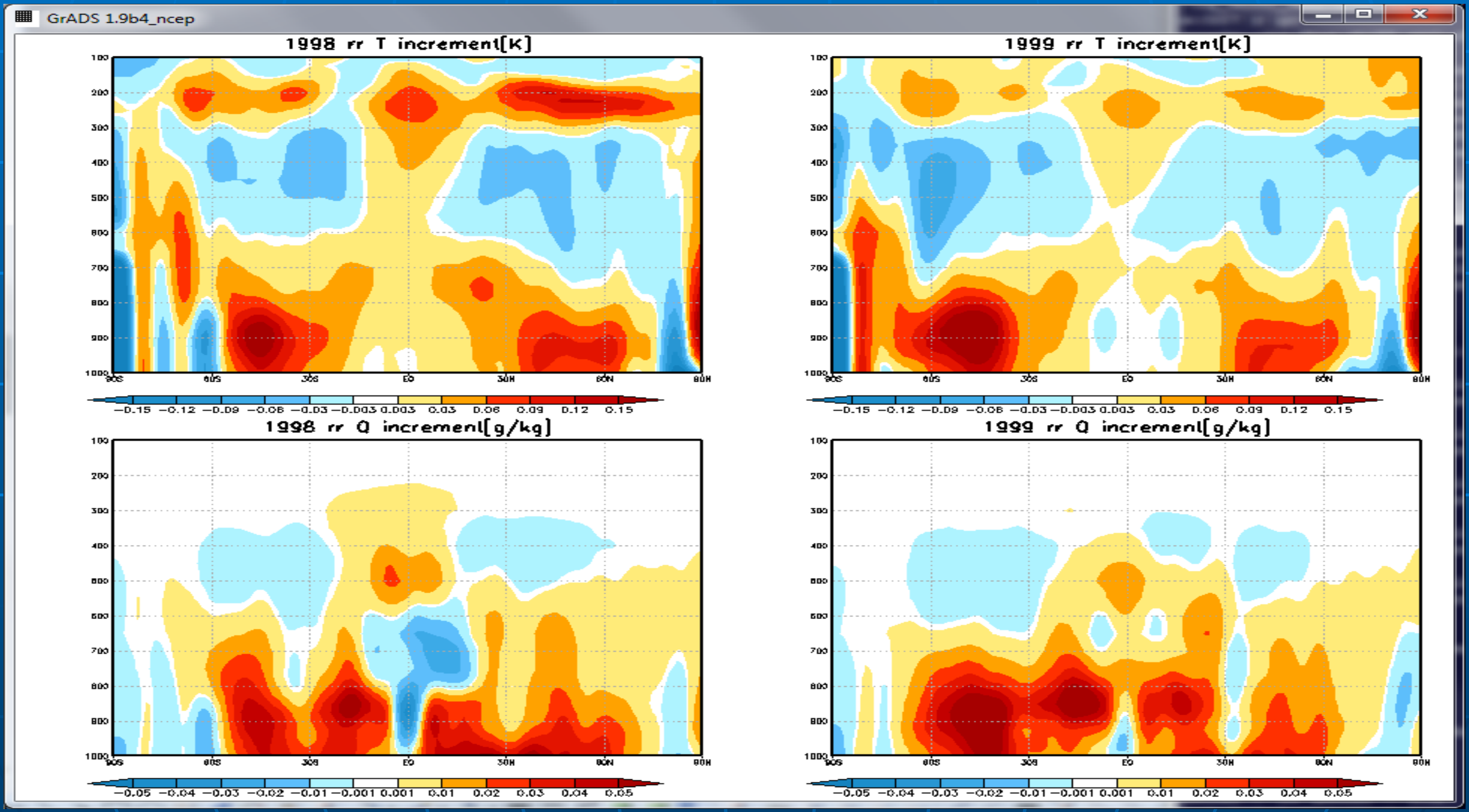

GrADS 1.9b4_ncep
1998 s0-y4 T [K]
1999 s0-y4 T [K]
-1.2 -0.9 -0.6 -0.3 -0.03 0.03 0.3 0.6 0.9 1.2
1998 s0-y4 Q [g/kg]
1999 s0-y4 Q [g/kg]
-0.4 -0.3 -0.2 -0.1 -0.01 0.01 0.1 0.2 0.3 0.4


GrADS 1.9b4_ncep
1998 s0-rr T [K]
1999 s0-rr T [K]
1998 s0-rr Q [g/kg]
1999 s0-rr Q [g/kg]
-1.2 -0.9 -0.6 -0.3 -0.03 0.03 0.3 0.6 0.9 1.2
-0.4 -0.3 -0.2 -0.1 -0.01 0.01 0.1 0.2 0.3 0.4

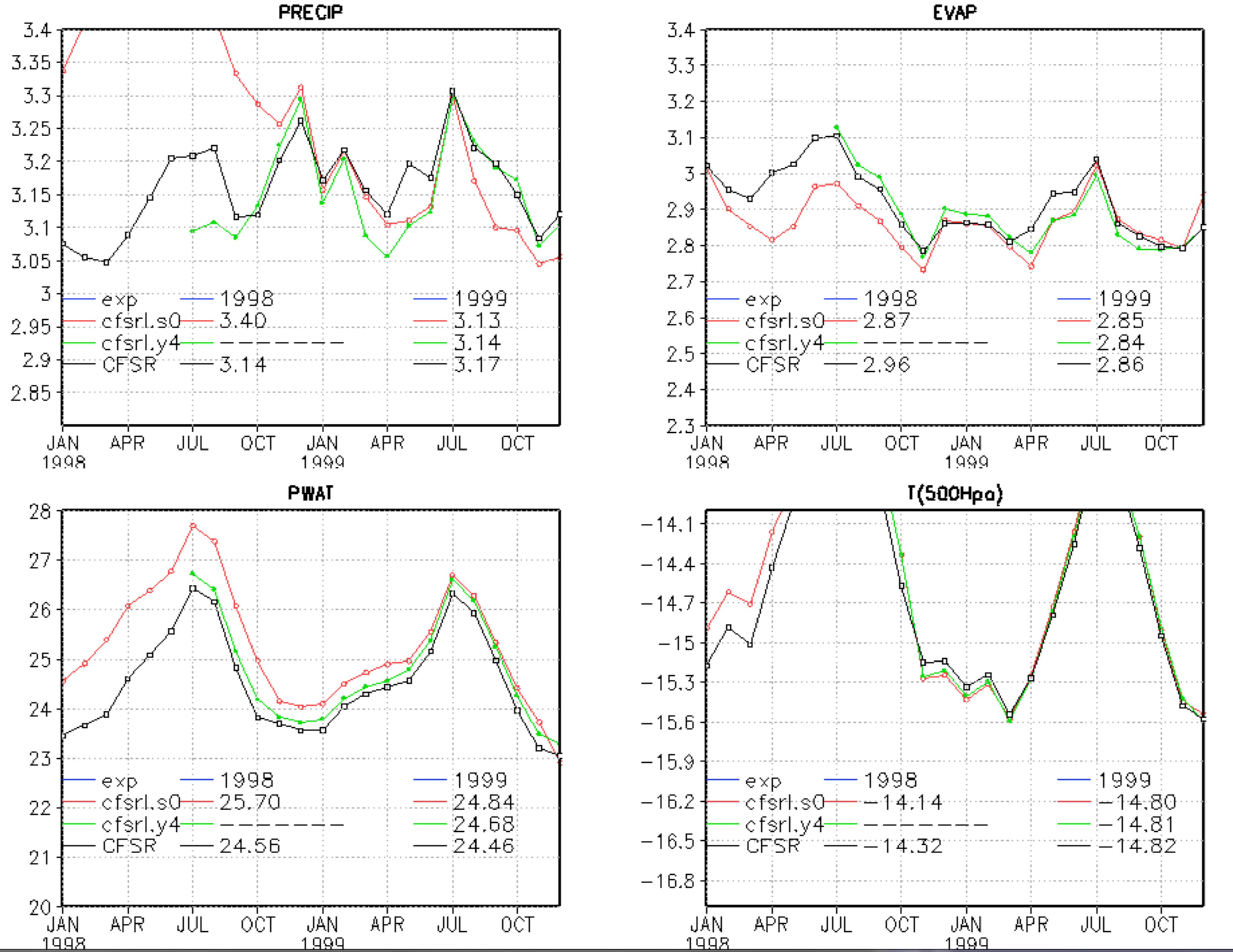

GrADS 1.9b4_ncep
1998 s0-y4 T [K]
1999 s0-y4 T [K]
100 200 300 400 500 600 700 800 900 1000
90S 60S 30S EQ 30N 60N 90N
-1.2 -0.9 -0.6 -0.3 -0.03 0.03 0.3 0.6 0.9 1.2
1998 s0-y4 Q [g/kg]
1999 s0-y4 Q [g/kg]
-0.4 -0.3 -0.2 -0.1 -0.01 0.01 0.1 0.2 0.3 0.4


GrADS 1.9b4_ncep
1998 s0 T increment[K]
1999 s0 T increment[K]
1998 s0 Q increment[g/kg]
1999 s0 Q increment[g/kg]
-0.15 -0.12 -0.09 -0.06 -0.03 -0.003 0.003 0.03 0.06 0.09 0.12 0.15
-0.05 -0.04 -0.03 -0.02 -0.01 -0.001 0.001 0.01 0.02 0.03 0.04 0.05


GrADS 1.9b4_ncep
1998 y4 T increment[K]
1999 y4 T increment[K]
-0.15 -0.12 -0.09 -0.06 -0.03 -0.003 0.003 0.03 0.06 0.09 0.12 0.15
1998 y4 Q increment[g/kg]
1999 y4 Q increment[g/kg]
-0.05 -0.04 -0.03 -0.02 -0.01 -0.001 0.001 0.01 0.02 0.03 0.04 0.05
100 200 300 400 500 600 700 800 900 1000
90S 60S 30S EQ 30N 60N 90N



GrADS 1.9b4_ncep
1998 rr T increment[K]
1999 rr T increment[K]
1998 rr Q increment[g/kg]
1999 rr Q increment[g/kg]


PRECIP
exp
cfsrl.s0
cfsrl.y4
CFSR
1998
3.40
---------
3.14
1999
3.13
3.14
3.17
EVAP
exp
cfsrl.s0
cfsrl.y4
CFSR
1998
2.87
---------
2.96
1999
2.85
2.84
2.86
PWAT
exp
cfsrl.s0
cfsrl.y4
CFSR
1998
25.70
---------
24.56
1999
24.84
24.68
24.46
T(500Hpa)
exp
cfsrl.s0
cfsrl.y4
CFSR
1998
-14.14
---------
-14.32
1999
-14.80
-14.81
-14.82
JAN
APR
JUL
OCT
1998
1999

# Reanalysis at NCEP outline

## Recent Developments, Current Efforts, Future Plans

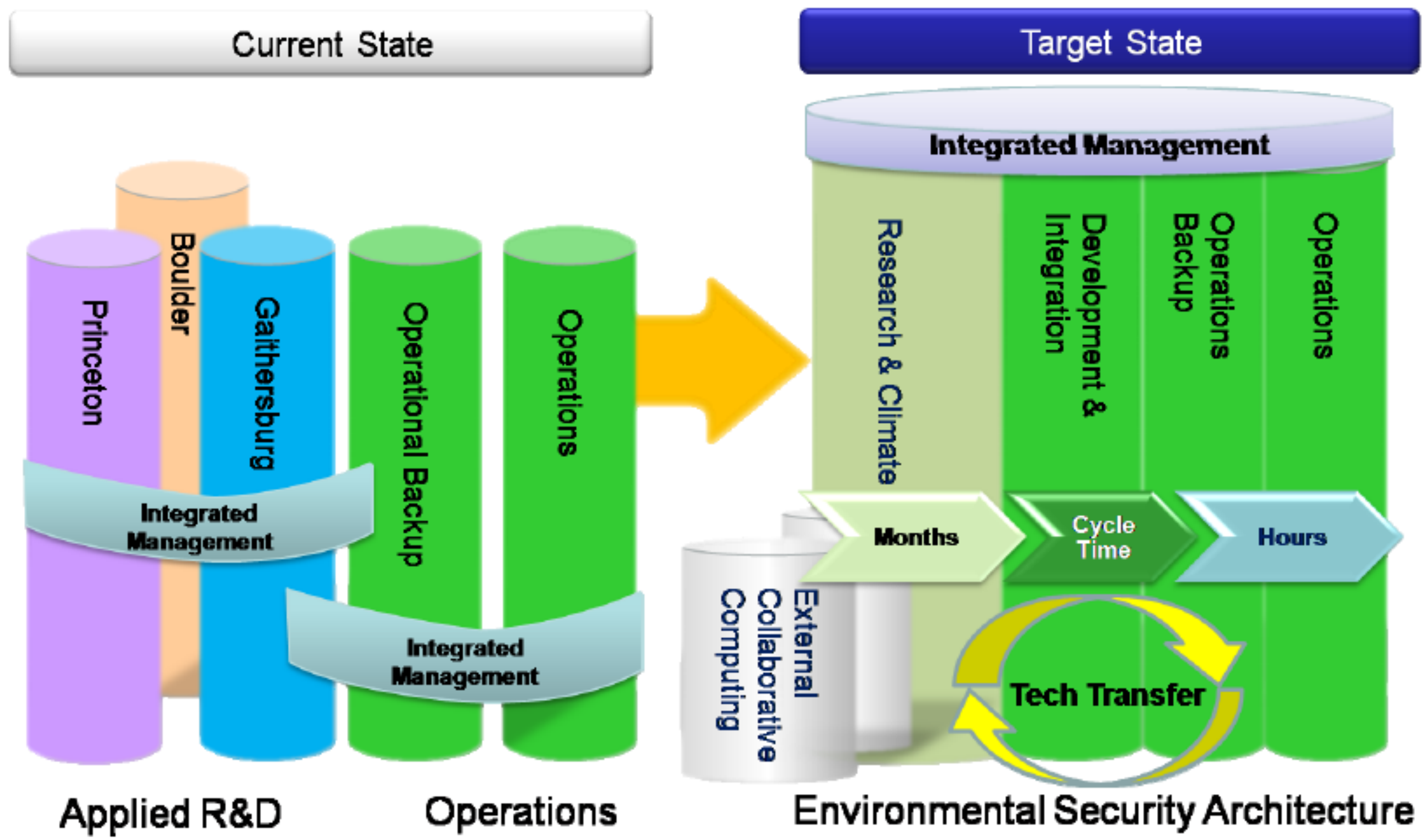
**Implementation of the Hybrid/3dvar-Enkf for GFS**

David Parrish, Russ Treadon, Mike Lueken,
Darly Kleist, Jeff Whittaker (ESRL)

**Cloudy Radiance Assimilation**

Min-Jeong Kim, Emily Lui, Yanzui Zhu, Will McCarty(GMAO)

# NOAA Computing Transition



# CFSR Weaknesses

- Stream boundaries
  - Ocean
  - Soil
  - Stratosphere
- Tropical issues
  - QBO
  - TC noise
  - Fit to tropo. Obs
- TOVS > ATOVS
- Issues with solutions
  - (Jack Woollen talk)
  - Single low-res stream
  - GSI
    - Adjust background err.
    - Treatment of obs
  - Bug fixes
- More Problematic
  - Moisture
  - GFS Model Cold Bias

# *An overview of the proposed NOAA's climate reanalysis effort, cont.*

- NCEP and ESRL envision a set of hierarchical climate reanalysis streams.
  - **AMIP**
  - **Surface data based reanalysis**
  - **Conventional data based reanalysis**
  - **Satellite era reanalysis**
- The hierarchical aspect involves staggered parallel execution of reanalysis streams in increasing order of complexity
- Results from basic streams may be used to bias correct, detrend, or otherwise adjust inputs into runs at the next higher complexity level