Design of the 30-year NCEP CFSRR

T382L64 Global Reanalysis
and
T126L64 Seasonal Reforecast Project
(1979-2008)

Suru Saha and Hua-Lu Pan, EMC/NCEP

With Input from

Stephen Lord, Mark Iredell, Shrinivas Moorthi,
David Behringer, Ken Mitchell, Bob Kistler,
Jack Woollen, Huug van den Dool, Catherine Thiaw and others

For a new Climate Forecast System (CFS) implementation

Two essential components:

A new Reanalysis of the atmosphere, ocean, sea-ice and land over the 31-year period (1979-2009) is required to provide consistent initial conditions for:

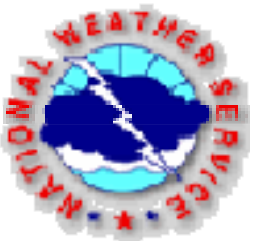
A complete Reforecast of the new CFS over the 29-year period (1981-2009), in order to provide stable calibration and skill estimates of the new system, for operational seasonal prediction at NCEP

For a new CFS implementation (contd)

1. Analysis Systems :	**Operational GDAS: Atmospheric (GADAS)-GSI Ocean-ice (GODAS) and Land (GLDAS)**
2. Atmospheric Model :	**Operational GFS**
	New Noah Land Model
3. Ocean Model :	**New MOM4 Ocean Model**
	New Sea Ice Model

For a new CFS implementation – Reanalysis (contd)

1. **An atmosphere at high horizontal resolution (spectral T382, ~38 km) and high vertical resolution (64 sigma-pressure hybrid levels)**
2. **An interactive ocean with 40 levels in the vertical, to a depth of 4737 m, and high horizontal resolution of 0.25 degree at the tropics, tapering to a global resolution of 0.5 degree northwards and southwards of 10N and 10S respectively**
3. **An interactive sea-ice model**
4. **An interactive land model with 4 soil levels**



There are three main differences with the earlier two NCEP Global Reanalysis efforts:

- **Much higher horizontal and vertical resolution (T382L64) of the atmosphere (earlier efforts were made with T62L28 resolution)**
- **The guess forecast will be generated from a coupled atmosphere – ocean – seaice - land system**
  - **Novelty for addressing important issues, such as the correlations between sea surface temperatures and precipitation in the global tropics, etc.**
- **Radiance measurements from the historical satellites will be assimilated in this Reanalysis**

UPGRADES TO THE ATMOSHERIC / SURFACE MODELS

- **Hybrid vertical coordinate (sigma-pressure)**
- **Noah Land Model : 4 soil levels. Improved treatment of snow and frozen soil**
- **Sea Ice Model : Fractional ice cover and depth allowed**
- **Sub grid scale mountain blocking**
- **Reduced vertical diffusion**
- **RRTM long wave radiation**
- **ESMF (3.0)**

SOME TEST UPGRADES TO THE ATMOSHERIC MODEL

- **Enthalpy**
- **MODIS Albedo**
- **AER RRTM Shortwave Radiation (likely)**
- **Ferrier-Moorthi Microphysics**
- **New Boundary Layer Parameterization**
- **New Shallow Convection**
- **New Aerosol Treatment**
- **New Convection Scheme (RAS)**
- **New convective gravity wave drag formulation**
- **Inclusion of historical CO2, solar cycle and volcanic aerosols (likely)**

GSI – NCEP's New Generation Analysis System

John Derber[1], Lidia Cucurull[2], Daryl Kleist[3], Xu Li[3], Curtis Marshall[3], Dave Parrish[1], Manuel Pondeca[3], Jim Purser[3], Russ Treadon[1], Paul vanDelst[2], Wan-Shu Wu[1]

[1] NOAA/NWS/NCEP/EMC, [2] UCAR, [3] SAIC

Courtesy : Russ Treadon, EMC

Assimilated data types

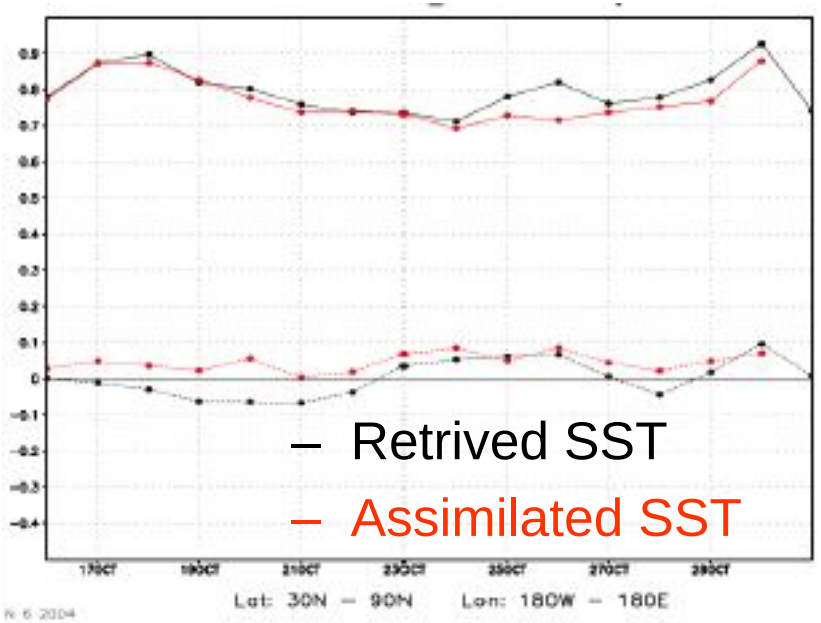
- All data types currently assimilated by SSI may also be assimilated by GSI
  - Sondes, ship reports, surface stations, aircraft data, profilers, etc
  - Cloud drift and water vapor winds
  - TOVS, ATOVS, AQUA, and GOES sounder brightness temperatures
  - SBUV ozone profiles and total ozone
  - SSM/I and QuikScat surface winds
  - SSM/I and TMI rain rates

Courtesy : Russ Treadon, EMC

GSI development: Analysis variables

- SST analysis
  - Physical retrieval from AVHRR T_b data
  - Option to add / assimilate in-situ SST data

Slight, but consistent reduction in rms and bias fits to independent buoy SST data



Courtesy : Russ Treadon, EMC

GSI development: New radiance data

- Aqua AIRS/AMSU-A
  - Operational as of 12 UTC, 31 May 2005
  - Future improvements
    - Examine all FOVs to determine warmest spots
    - Use MODIS data for cloud detection
- SSM/I
  - Use of T_b data reduces model moisture bias
  - Forward model for emissivity includes effects of surface winds
    - Assimilation of SSM/I T_b data can affect surface winds
    - Could (should) turn off assimilate of SSM/I wind product

Courtesy : Russ Treadon, EMC

GSI development: New radiance data

- **NOAA – N (18) Summer 2005**
  - **HIRS, AMSU-A, MHS**
  - **Code ready and waiting for data to evaluate**
- **SSM/IS**
  - **QC and bias correction difficulties because FOVs not collocated**
- **AMSR-E (NASA)**
  - **Beginning tests with radiative transfer model**
- **AVHRR and GOES imagery**
  - **Testing underway**

Courtesy : Russ Treadon, EMC

GSI development: CRTM development

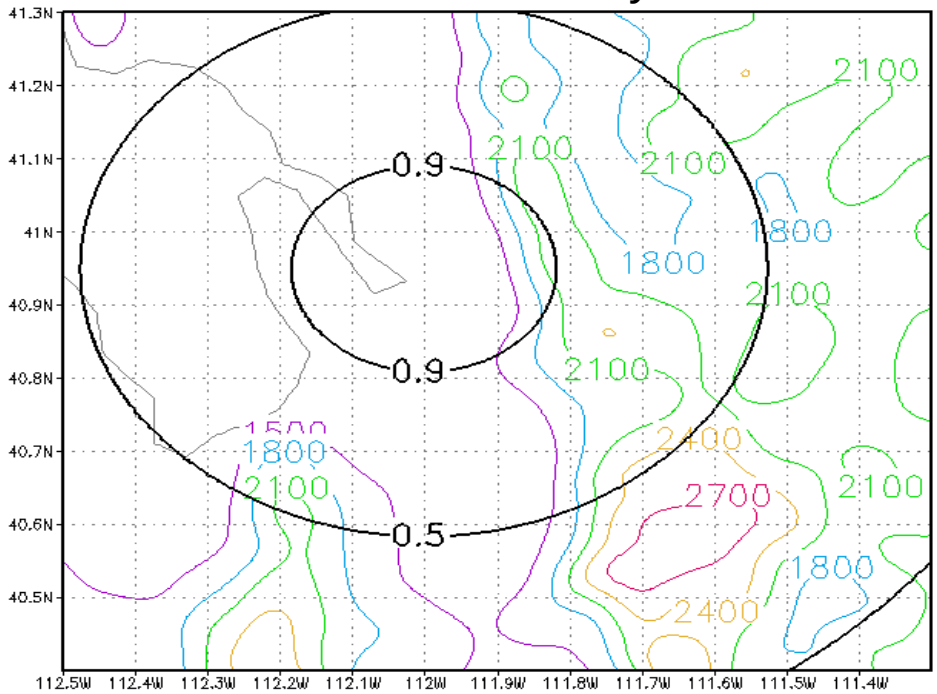
- **Proto-type CRTM with modular design**
  - **Simplifies user interaction with code**
  - **Permits easier evaluation of various algorithms**
- **Soon will include**
  - **Algorithms to handle scattering and absorption from clouds for microwave channels**

Courtesy : Russ Treadon, EMC

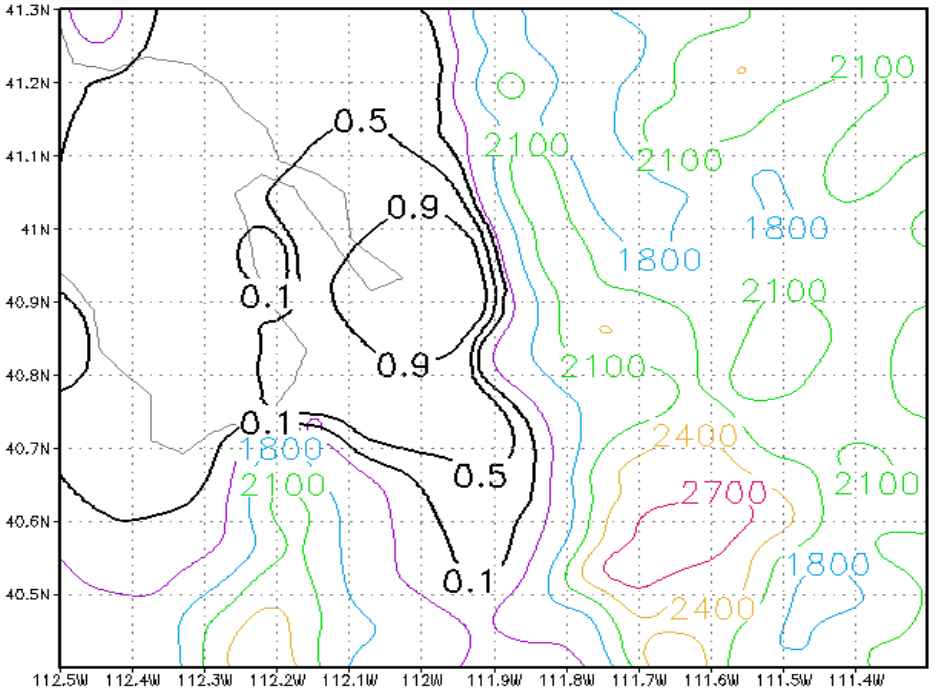
Anisotropic vs Isotropic Error Covariances

Error Correlations Plotted Over Utah Topography

Observation influence extends into mountains indiscriminately



Observation influence restricted to areas of similar elevation



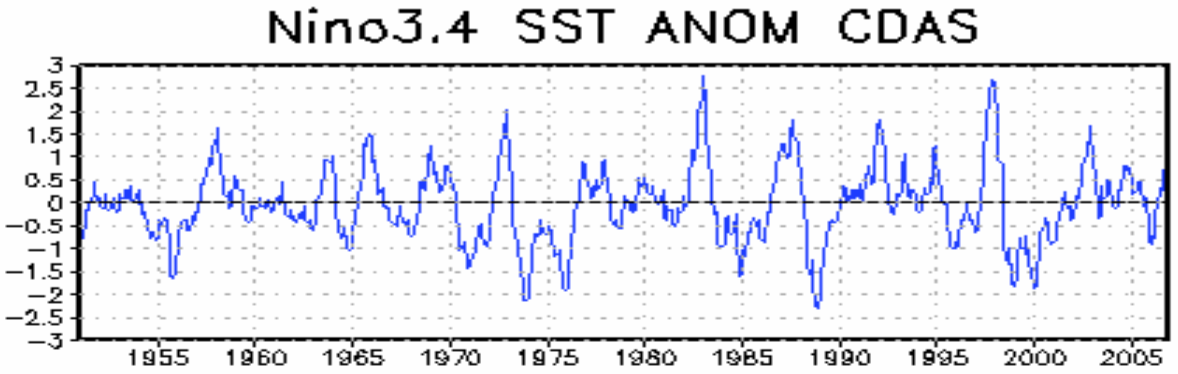
Courtesy : Russ Treadon, EMC

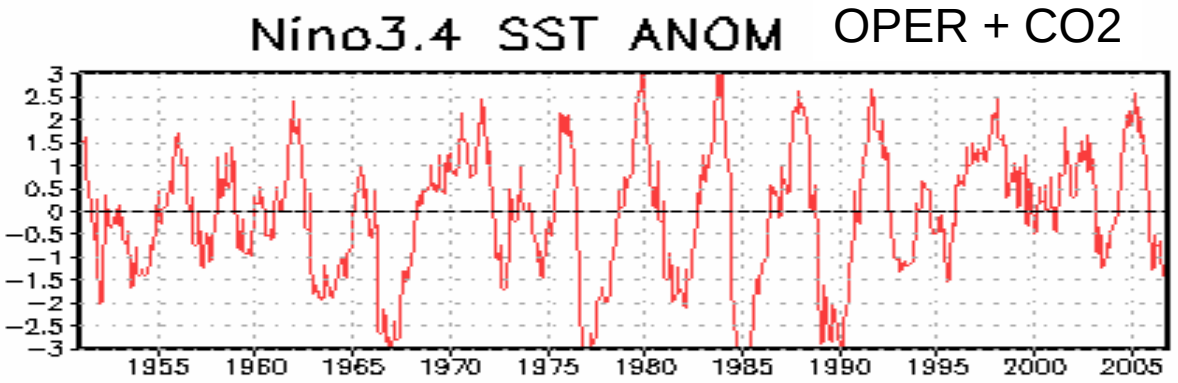
Test and Evaluation of RRTM-SW Radiation

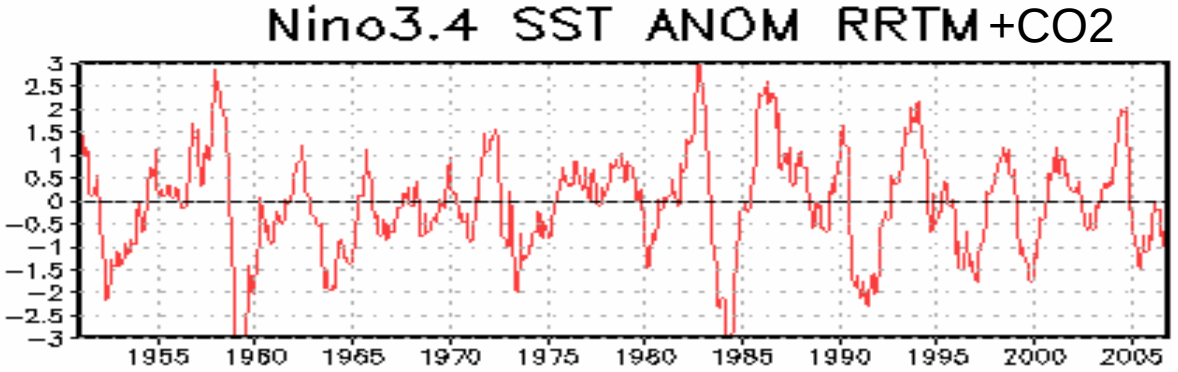
(Rapid Radiative Transfer Model)

1. RRTM-SW radiation scheme has been recoded to fit into GFS/CFS new radiation module structure. In addition, other physical processes such as solar-cycle, aerosol optical effect, historical volcanic aerosol effect, and historical CO2 variation effect, etc are also developed for the experiment.
2. For the experiment, a T126 model (vs current operational GFS) was used starting from ic 01/01/1948 for 60 year runs.
3. Comparison of global mean SST, T2m anomalies, and global map of SST climatology shows promising improvement over the control model.

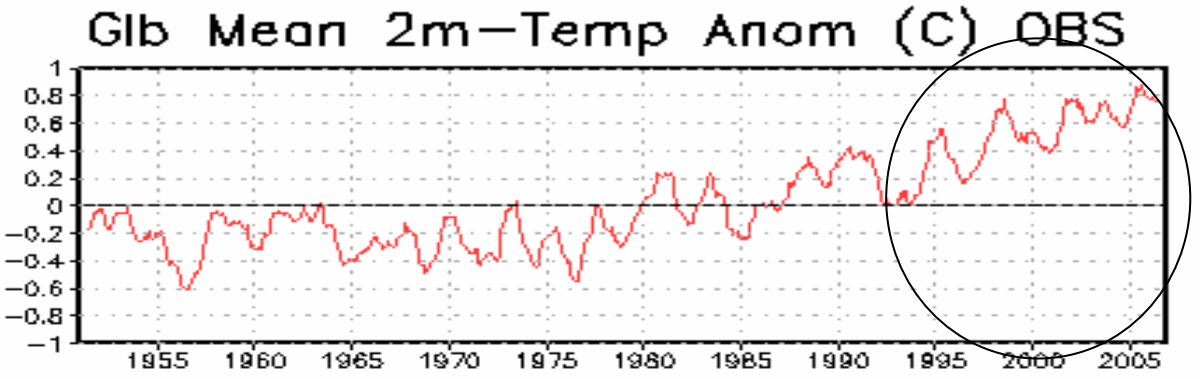
Comparing with CDAS, RRTM run result shows better overall magnitude than the control (OPER) run with NASA short-wave radiation scheme

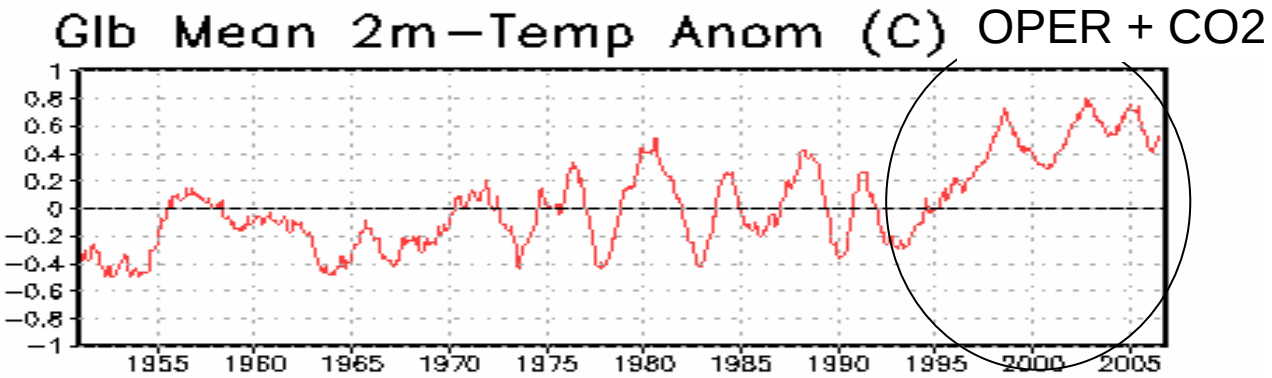


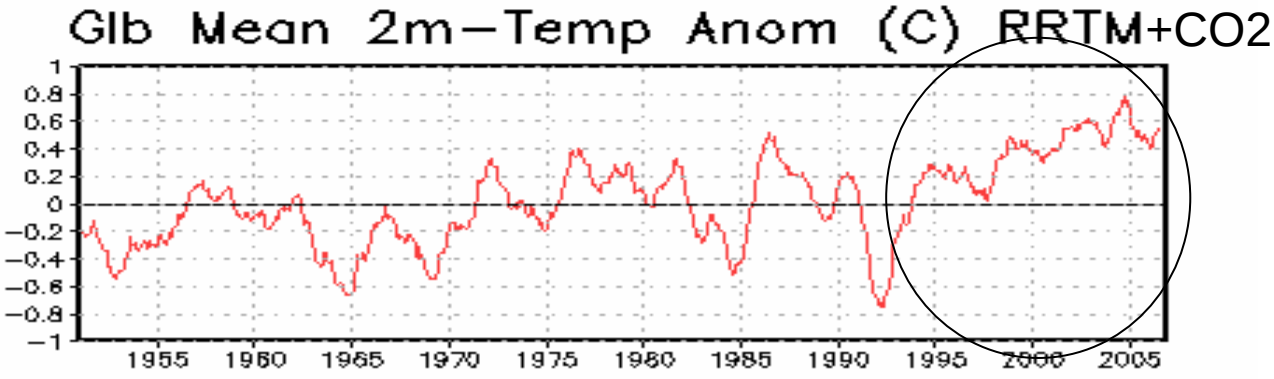




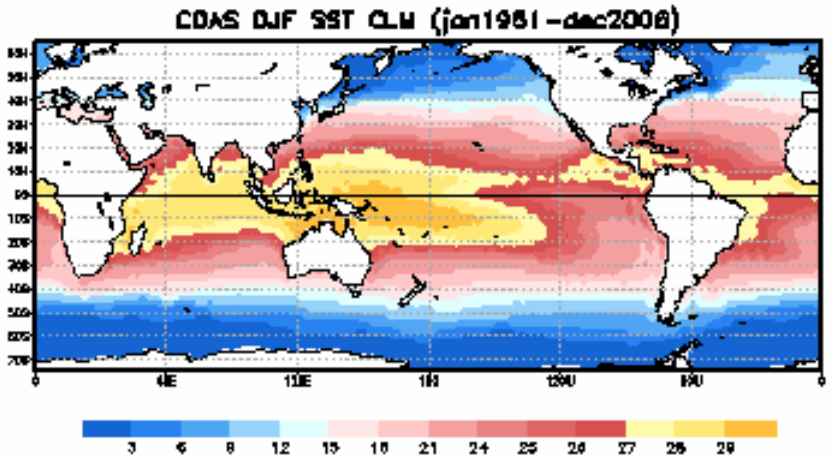
Both model runs show CO2 effect from 90's and beyond.



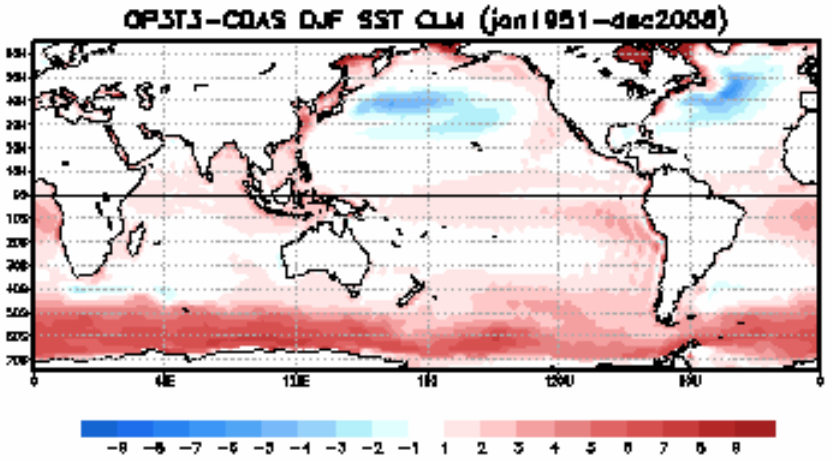




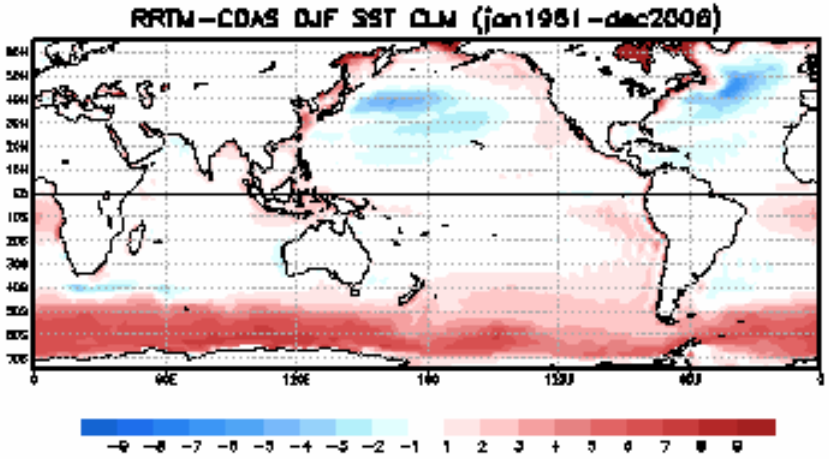
CDAS CLIMATE



BIAS IN OPER + CO2

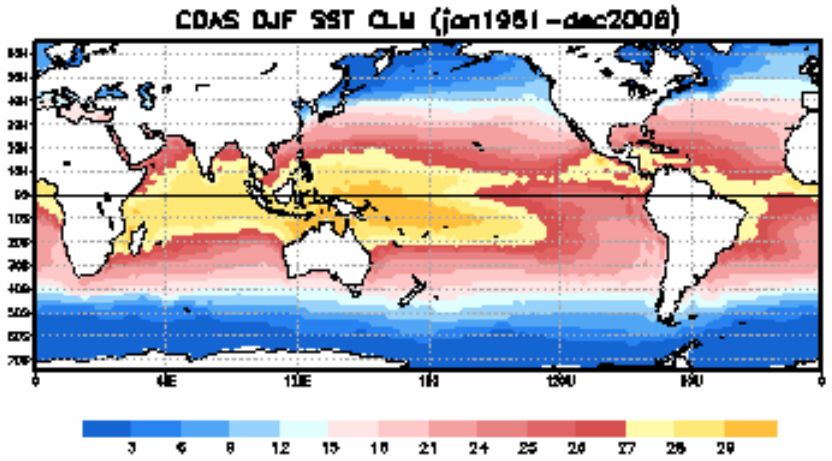


BIAS IN RTMA+CO2

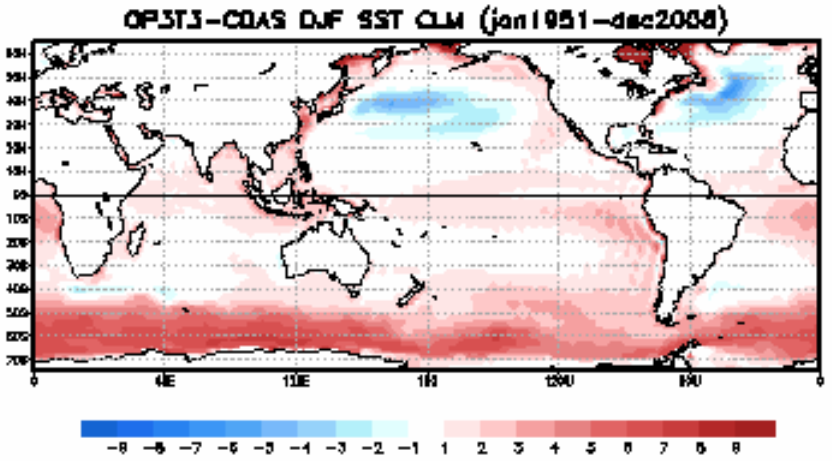


RRTM run shows reduced SST warm bias

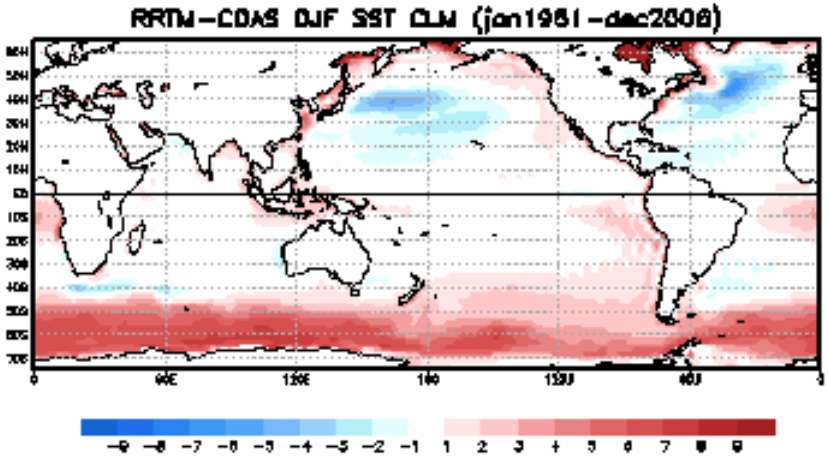
CDAS CLIMATE



BIAS IN OPER + CO2



BIAS IN RTMA+CO2



RRTM run shows reduced SST warm bias

An upgrade to the coupled atmosphere – ocean - sea-ice - land
NCEP Climate Forecast System (CFS) is being planned for Jan 2010.

This upgrade involves changes to both **DA & MODELING** of all components of the CFS, namely:

- improvements to the data assimilation of the **ATMOSPHERE** with the new NCEP Gridded Statistical Interpolation Scheme (GSI) and major improvements to the physics and dynamics of operational NCEP Global Forecast System (GFS)
- improvements to the data assimilation of the **OCEAN AND ICE** with the NCEP Global Ocean Data Assimilation System, (GODAS) and a new GFDL MOM4 Ocean Model
- improvements to the data assimilation of the **LAND** with the NCEP Global Land Data Assimilation System, (GLDAS) and a new NCEP Noah Land model

4 Simultaneous Streams

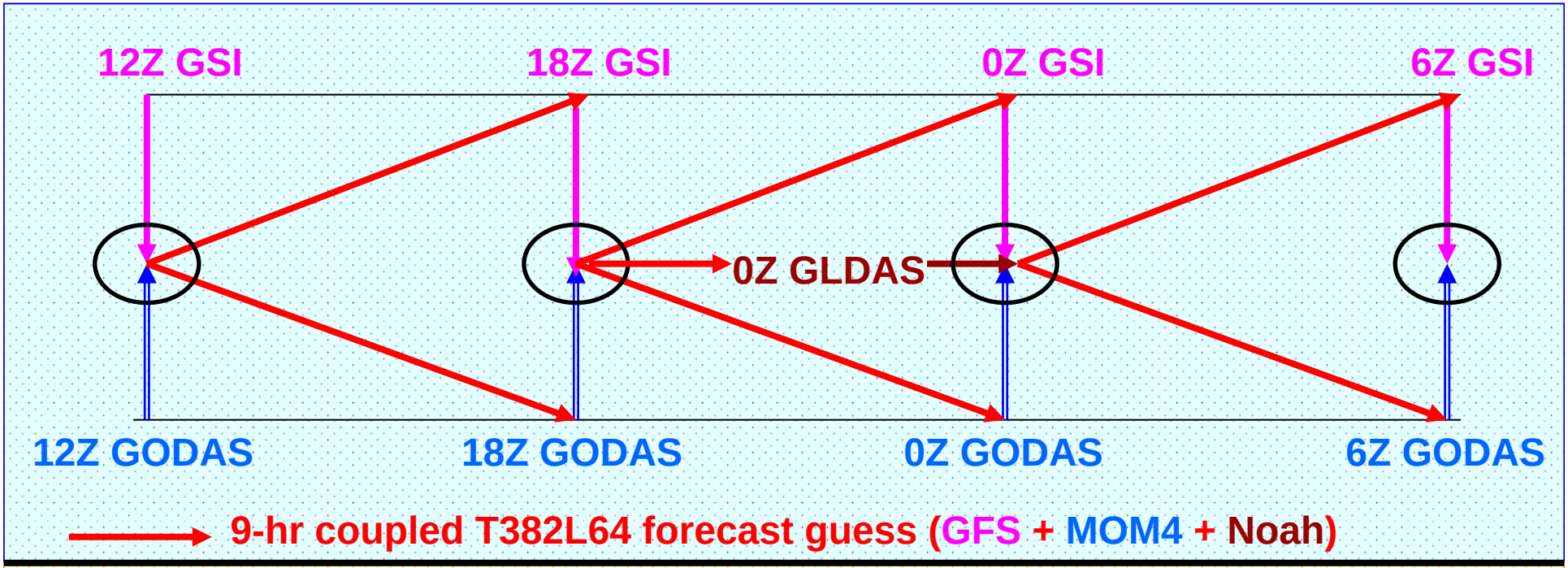
- Jan 1979 – Sep 1986 — 8 years
- Apr 1986 – Oct 1993 — 7 1/2 years
- Apr 1993 – Oct 2000 — 7 1/2 years
- Apr 2000 – Dec 2009 — 10 years

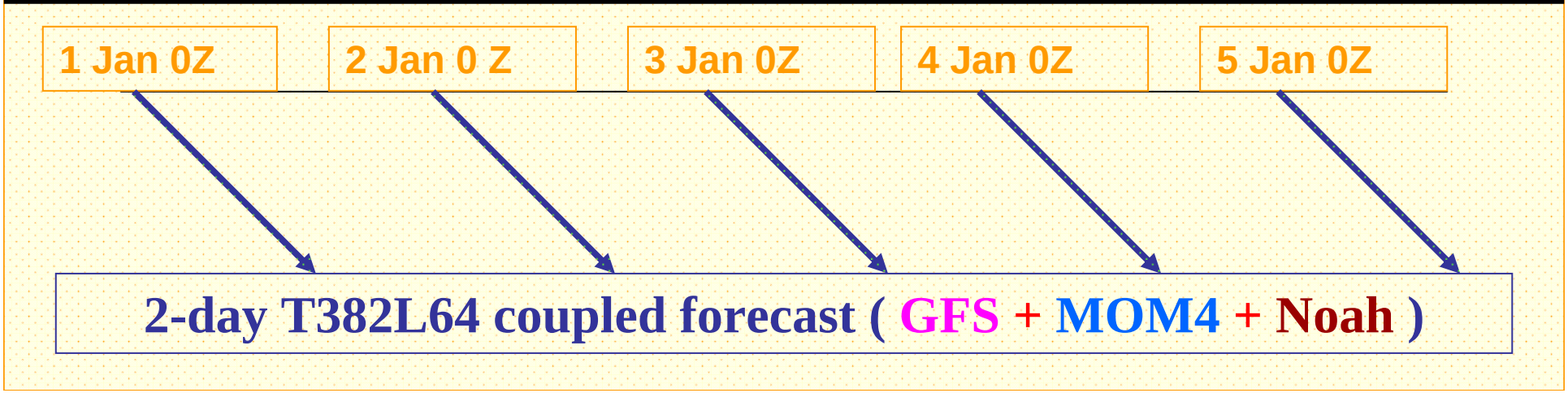
6 month overlap for ocean and land spin ups

Reanalysis to cover 31 years (1979-2009) + 21 overlap months

Reforecasts to cover 28 years (Jan 1982 – Dec 2009)

ONE DAY OF REANALYSIS

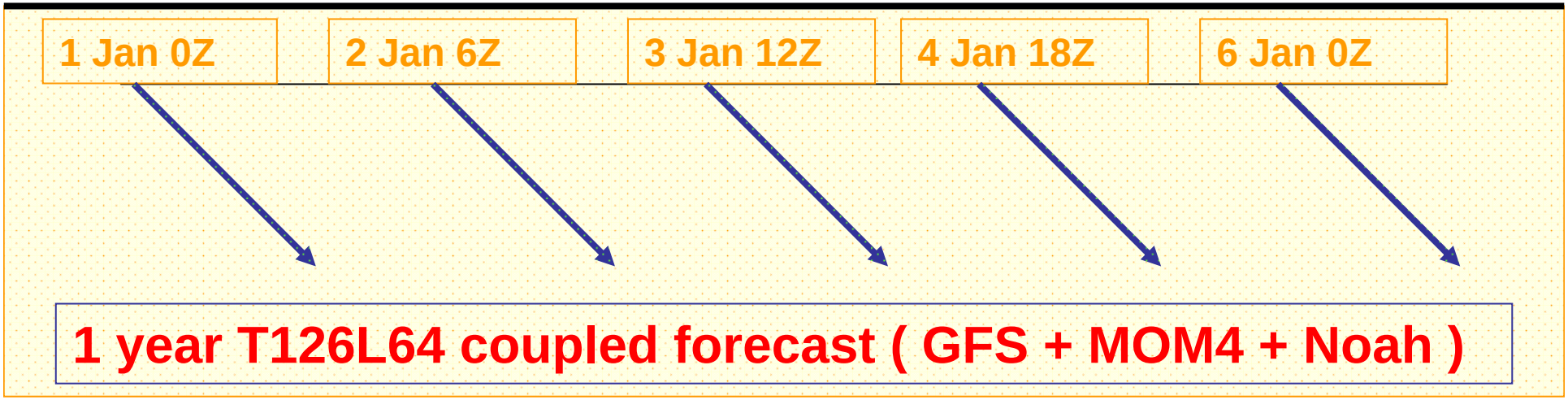




ONE DAY OF REANALYSIS

- **Atmospheric T382L64 (GSI) Analysis at 0,6,12 and 18Z, using radiance data from satellites, as well as all conventional data**
- **Ocean and Sea Ice Analysis (GODAS) at 0,6,12 and 18Z**
- **From each of the 4 cycles, a 9-hour coupled guess forecast (GFS at T382L64) is made with hourly coupling to the ocean (MOM4 at 1/4º equatorial, 1/2º global)**
- **Land (GLDAS) Analysis using observed precipitation with Noah Land Model at 0Z**
- **Coupled 2-day forecast from initial conditions from every 0Z cycle, will be made with the T382L64 GFS with hourly coupling to the ocean (MOM4 at 1/4º equatorial, 1/2º global) for sanity check.**

CFS REFORECASTS



Coupled one-year forecast from initial conditions 30 hours apart will be made for 2 initial months (April and October) with the T126L64 GFS with hourly coupling to the ocean (MOM4 at 1/4º equatorial, 1/2º global). Total number of forecasts = 28 x 2 x 30 = 1680

For each cycle, there will be approximately 7 members per month, with a total of 210 members over a 30-year period. This ensures stable calibration for forecasts originating from each cycle, for a given initial month

SOME NOTES

PROPOSED TIME LINE FOR COMPLETION OF CFSRR

- **January to December 2008**: Begin Reanalysis Production and Evaluation for the full period from 1979 to 2008 (30 years)
- **January to December 2008**: Begin CFS Retrospective Forecast runs for 2 initial months: October and April, and evaluate the monthly forecasts as well as the seasonal winter (Lead-1 DJF) and summer (Lead-1 JJA) forecasts.
- **January to October 2009**: Continue running the CFS Reforecasts (for the rest of the 10 calendar months)
- **November 2009**: Begin computing calibration statistics for CFS daily, monthly and seasonal forecasts.

January 2010: Operational implementation of the next CFS monthly and seasonal forecast suite.

Computer resource issue

- **We were anticipating the arrival of the upgrade to Haze to add the 44 nodes needed.**
- **Haze upgrade is delayed until June or July 2008.**
- **The Reanalysis completion date may slip 6 months or more, due to this delay.**
- **Requesting more dedicated nodes from Haze and Mist (22 nodes each)**

HUMAN REQUIREMENTS

Project Managers

Suru Saha and Hua-Lu Pan

REANALYSIS

6 people (TBD) managing 4 streams and rotating through

REFORECASTS

3 people (TBD) managing 4 streams and rotating through

Internal Advisory Panels

SCIENTIFIC : Huug van den Dool, Mark Iredell, Shrinivas Moorthi, Glenn White, Ken Mitchell, Dave Behringer, Stephen Lord and others

TECHNICAL : Bob Kistler, Jack Woollen, Catherine Thiaw, Diane Stokes and others

DATA and DIAGNOSTICS: Wesley Ebisusaki, Wanqiu Wang, Jae Schemm and others

CFSRR Science Advisory Board

- **Dr. Jeffrey Anderson, NCAR**
- **Dr. Saki Uppala, ECMWF**
- **Dr. Rick Rosen, NOAA/CPO**
- **Dr. Lars Peter Riishojgaard, JCSDA**
- **Dr. James Carton, University of Maryland**
- **Dr. Eric Wood, Princeton University**
- **Dr. Mark Serreze, University of Colorado**
- **Dr. Gabriel Lau, NOAA/GFDL**
- **Dr. Gil Compo, NOAA/ESRL**
- **Dr. Huug van den Dool, NOAA/CPC**

Collaborators

- **NOAA/CPC is a full partner and is actively involved in the monitoring of the Reanalysis**
- **NOAA/NCDC is a full partner and is actively involved in the archival of the Reanalysis**
- **We are starting to talk to NCAR to provide additional data for university researchers**

SOME NOTES - 1

DATA ARCHIVAL

Using 1 TB tapes, we would need more than 1500 tapes to make the master copy (with second copy parity, maybe 15% more ?)

EMC does not have the resources to do any data distribution, except that CPC will be provided with whatever data they need for their operational CFS predictions.

NCDC/NOAA has decided to be a partner in the archival and distribution of both the CFS Reanalysis and Reforecasts, through their NOMADS system. They will work with EMC to siphon all data, while it is being generated in real time and make it available to the community in mid 2009.

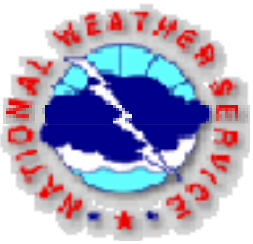
SOME NOTES - 2

REANALYSIS WITH CONVENTIONAL DATA

CPC may be interested in using the same CFS Reanalysis system, but with conventional data only (no satellite data) to go back to 1948, and continue into the future with the same system.

This Reanalysis may be more homogeneous over a longer period (60+ years) and be more suitable for CPC's monitoring of the atmosphere, land and ocean.

EMC will help in this endeavor.



Email : cfs@noaa.gov

Website : http://cfs.ncep.noaa.gov

BACKGROUND

Computer resources for CFSRR

- **Needs 88 nodes to run four streams of the Reanalysis starting January 2008.**
- **On Haze, we have 22 dedicated nodes (8 cdev nodes and 14 ctb nodes) to accelerate implementation)**
- **On Zephyr, we have 16 dedicated nodes.**

Justification

- **90% of the climate modeling work is in the preparation for the Reanalysis and the Reforecast**
- **Routine CFS production runs take very little (2-3%) of the total CCS resource budgeted for climate, which is 30% of the machine**

T382L64 CFS REANALYSIS AND T126L64 REFORECASTS

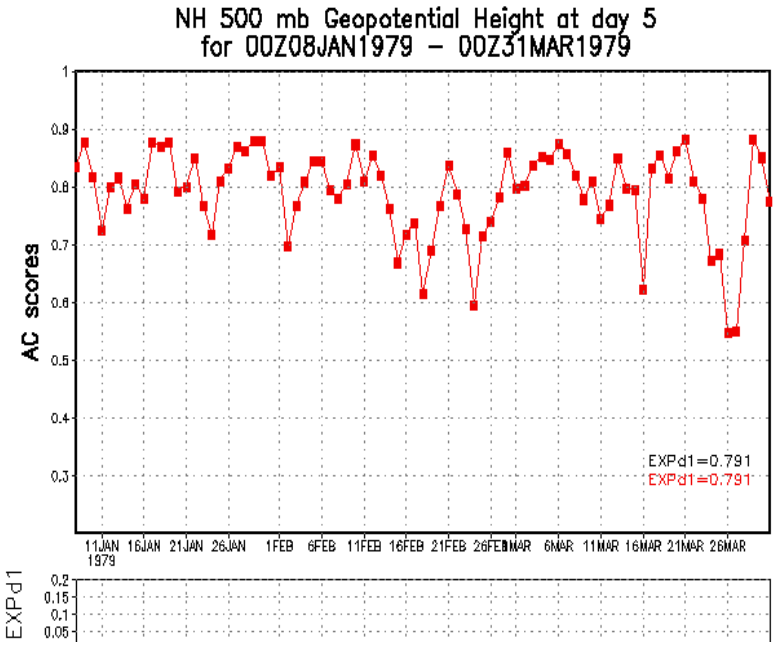
	IBM Power 5	
Specs for 4 days of T382L64 Reanalysis, including a 2-day T382L64 forecast every cycle (4 simultaneous streams)	88 nodes, 160 minutes Will take 1 calendar year (on HAZE upgrade)	
Specs for 8 one-year coupled reforecasts (T126L64) (2 per stream)	16 nodes, 24 hours Will take 8 calendar months to complete 2 initial months (on ZEPHYR)	
Total Disk Space	100 TB	
Total Mass Store (HPSS) Space	1.5 PB	

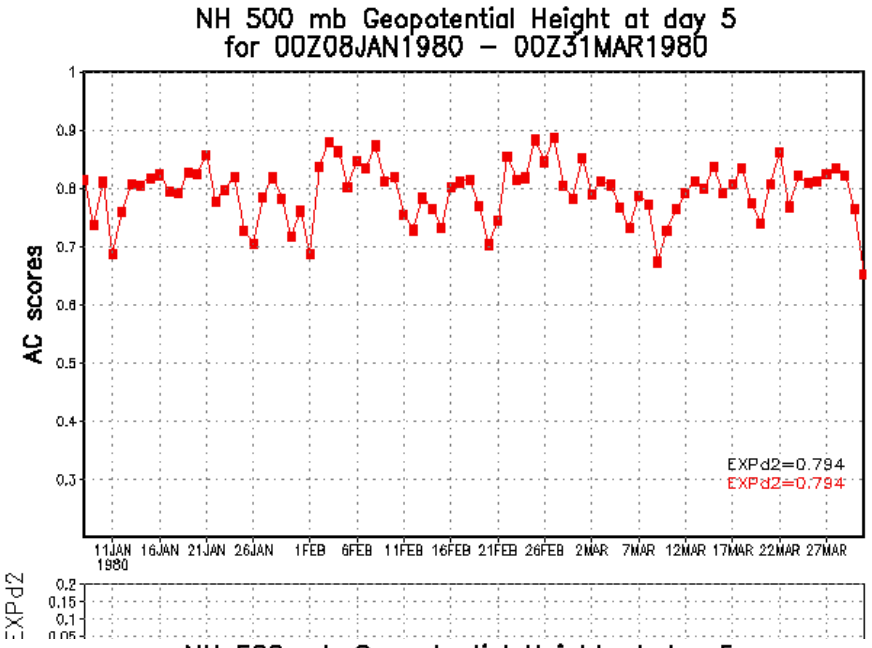
Reforecast

- **The CFS Reforecast is scheduled to start in Jan 2009, pending the upgrade of Dew and Mist.**

Status

- **New format and improved SBUV ozone data**
- **SSU radiance data need calibration for drift of cell pressures**
- **Satellite radiance bias correction estimates for each new satellite needs a 3-month run of the full coupled GDAS at T382L64. There are 10-15 satellites to cover**
- **Making a T62L64 atmospheric only Reanalysis is underway to go through all atmospheric data from 1979 - 2007**


NH 500 mb Geopotential Height at day 5
for 00Z08JAN1979 – 00Z31MAR1979
AC scores
EXPd1=0.791
EXPd1=0.791
11JAN 16JAN 21JAN 26JAN 1FEB 6FEB 11FEB 16FEB 21FEB 26FEB 2MAR 7MAR 11MAR 16MAR 21MAR 26MAR
1979
EXPd1


NH 500 mb Geopotential Height at day 5
for 00Z08JAN1980 – 00Z31MAR1980
AC scores
EXPd2=0.794
EXPd2=0.794
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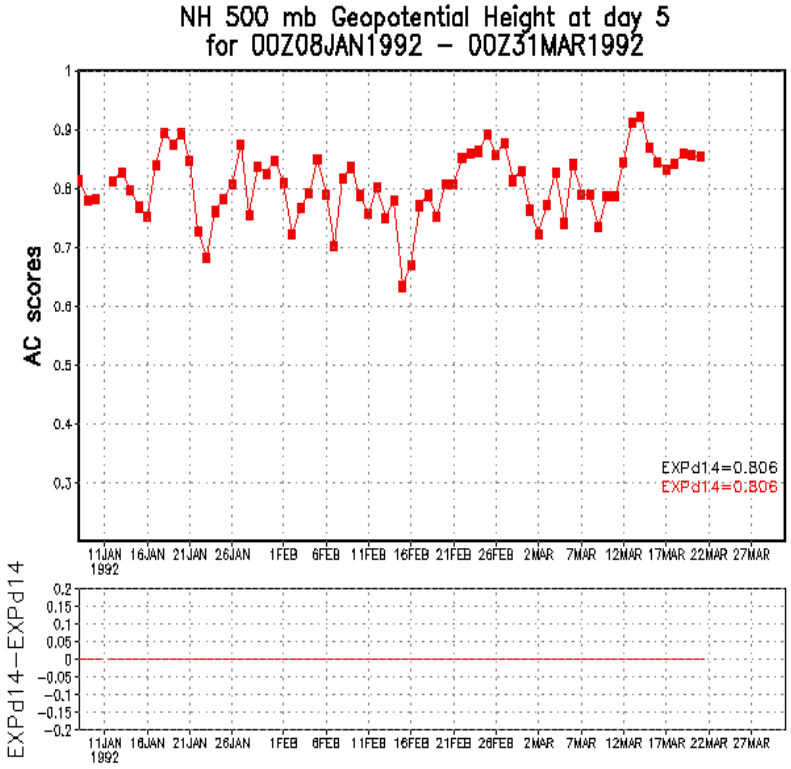
1980
EXPd2


NH 500 mb Geopotential Height at day 5
for 00Z08JAN1992 – 00Z31MAR1992
AC scores
EXPd14=0.806
EXPd14=0.806
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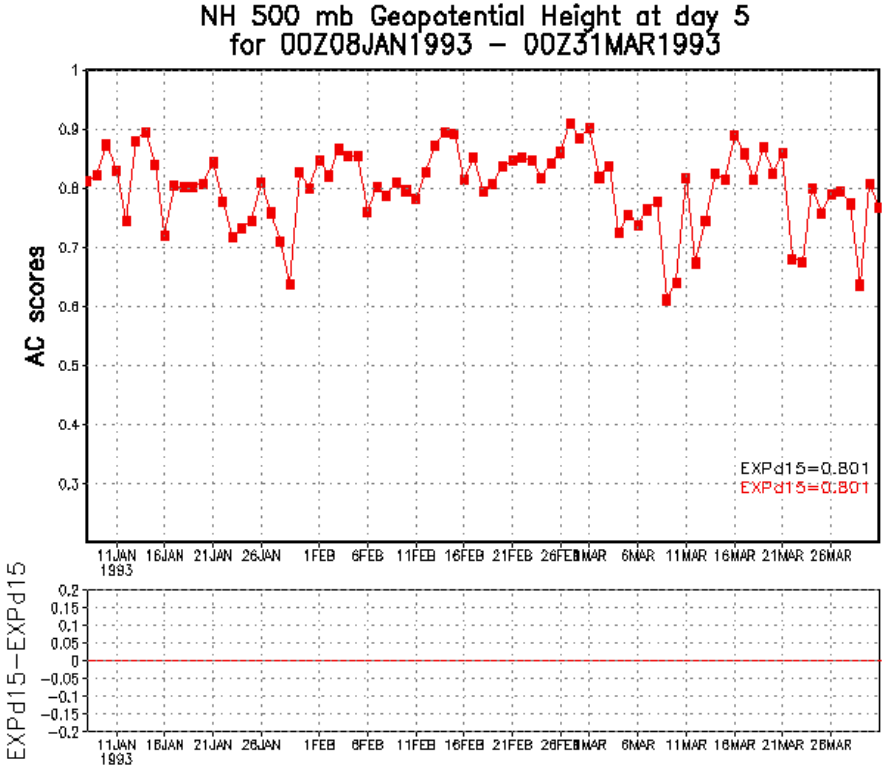
1992
EXPd14–EXPd14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for 00Z08JAN1993 – 00Z31MAR1993
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1993
EXPd15–EXPd15