THE NCEP CLIMATE FORECAST SYSTEM Version 2

Implementation Date: 18 Jan 2011

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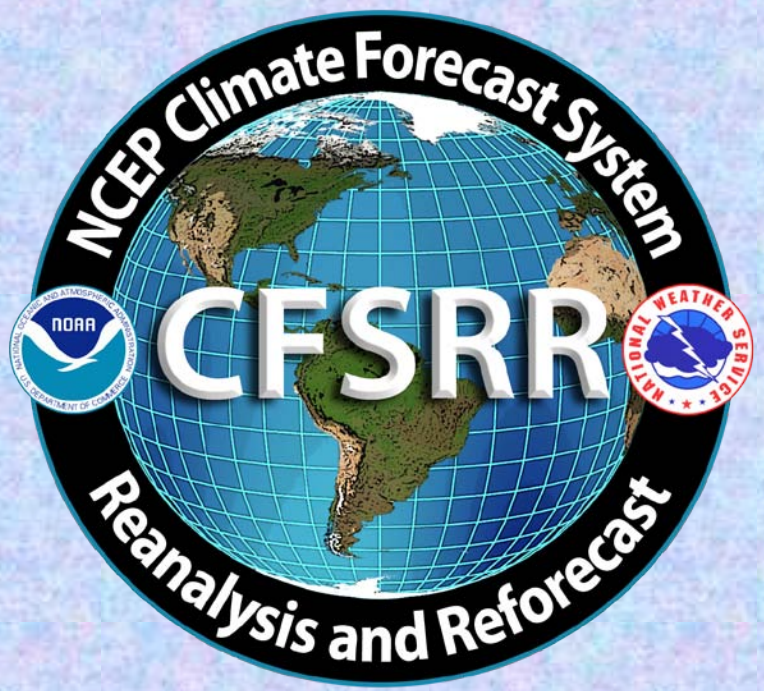

THE ENVIRONMENTAL MODELING CENTER

NCEP/NWS/NOAA

Suranjana Saha, Shrinivas Moorthi , Hua-Lu Pan, Xingren Wu, Jiande Wang, Sudhir Nadiga, Patrick Tripp, Robert Kistler, John Woollen, David Behringer, Haixia Liu, Diane Stokes, Robert Grumbine, George Gayno, Jun Wang, Yu-Tai Hou, Hui-ya Chuang, Hann-Ming H. Juang, Joe Sela, Mark Iredell,, Russ Treadon, Daryl Kleist, Paul Van Delst, Dennis Keyser, John Derber, Michael Ek, Jesse Meng, Helin Wei, Rongqian Yang, Stephen Lord, Huug van den Dool, Arun Kumar, Wanqiu Wang, Craig Long, Muthuvel Chelliah, Yan Xue, Boyin Huang, Jae-Kyung Schemm , Wesley Ebisuzaki, Roger Lin, Pingping Xie, Mingyue Chen, Shuntai Zhou, Wayne Higgins, Cheng-Zhi Zou, Quanhua Liu, Yong Chen, Yong Han, Lidia Cucurull , Richard W. Reynolds, Glenn Rutledge, and Mitch Goldberg, 2010: ***The NCEP Climate Forecast System Reanalysis.*** BAMS, 90, 1015-1057.

Saha et al, 2011: The NCEP Climate Forecast System Version 2, to be submitted for publication to the Journal of Climate.

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Thanks to Suru Saha, Huug van den Dool, Steve Lord, Bob Kistler, John Ward for slides

Operational CFS Status (CFS V.1)

- **Implemented in 2004 (V.1)**
  - GFS2003 + GFDL MOM3
  - Direct atmosphere-ocean coupling once a day in forecast
  - Daily four 9-month forecasts
- **Initial State**
  - Atmosphere and ocean driven by old Reanalysis (R2)
- **Calibration**
  - Hindcast 1981 to 2008 (15 members each month) using the same system completed prior to implementation
- **Product heavily used by CPC**
  - CPC blends all forecasts based on the skill estimates
  - Major forecast improvements have resulted

- CFS gained converts from climate folks who did not believe dynamic models can have any skills in seasonal forecasts
- Skill in predicting the ENSO indices (it seems every model can predict strong events six months in advance)
- Skill in US temperature and precipitation prediction is low and lower

CFS Reanalysis & Reforecast (CFSRR V.2)

- **Goals**
  - Improve 3-6 week forecasts and seasonal prediction skill
    - Incorporate latest technologies (atmosphere, ocean, land surface models and data assimilation)
    - Improve end-to-end consistency between hindcasts and forecasts
    - Include historical CO2 changes, solar cycle and volcanic ash (CWL)

- **EMC-CPC collaboration**
  - EMC – system design and execution
  - CPC – diagnostic monitoring and evaluation
  - Many problems discovered and fixed due to close working relationship

- ***CFSRR v.3—2017???***

For a new Climate Forecast System (CFS) implementation

Two essential components:

A new Reanalysis of the atmosphere, ocean, seaice 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 28-year period (1982-2009), in order to provide stable calibration and skill estimates of the new system, for operational seasonal prediction at NCEP

- **improvements to 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)**
  Reanalysis T382, 64 levels
  CDAS T574, 64 levels
  Forecasts T126, 64 levels

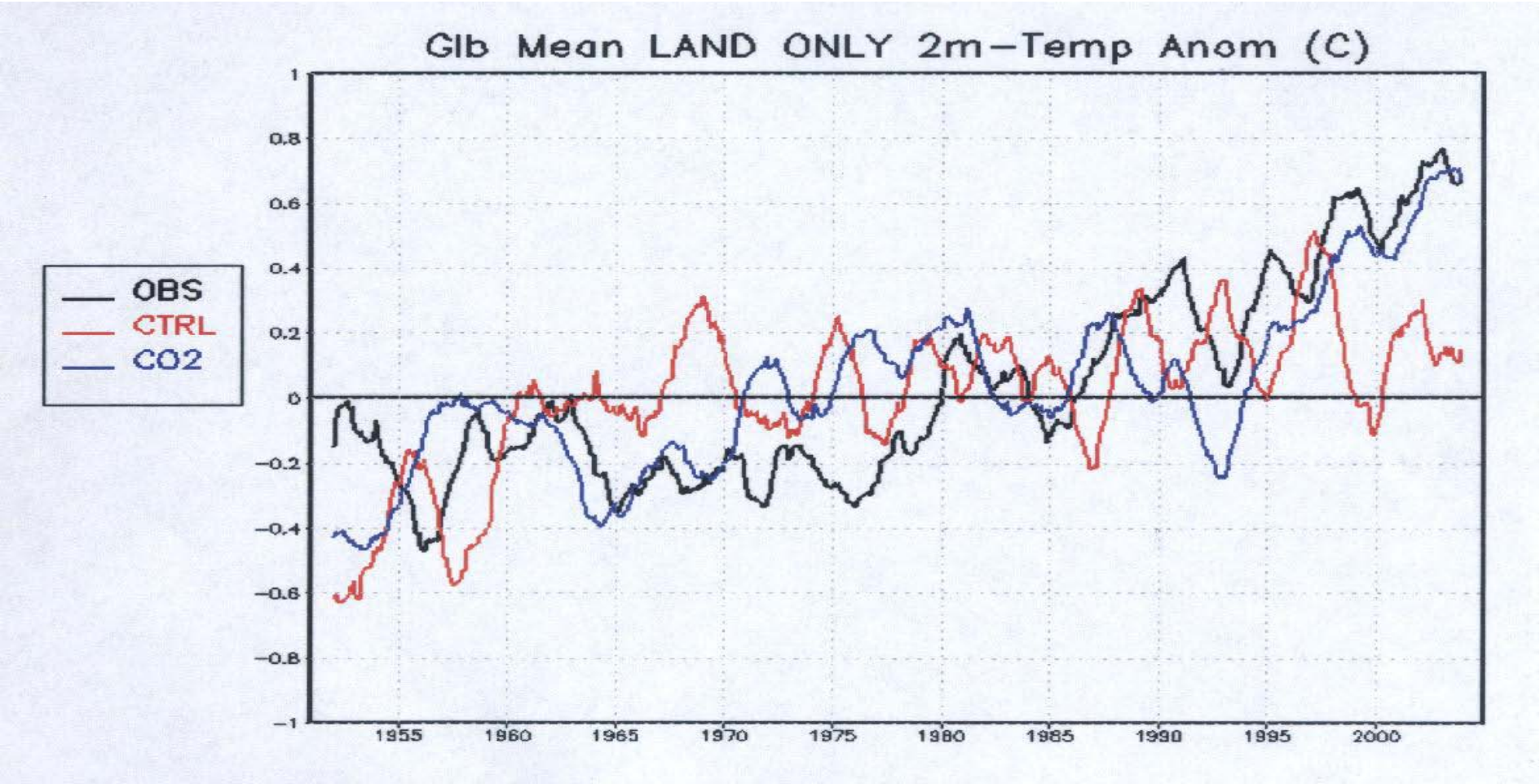
- **improvements to the ocean and ice with the NCEP Global Ocean Data Assimilation System, (GODAS) and a new GFDL MOM4 Ocean Model with an interactive Sea Ice Model**
  40 levels in the vertical, to a depth of 4737 m, 0.25^{o} at the tropics, tapering to a global resolution of 0.5^{o} polewards of 10N and 10S

- **improvements to the land with the NCEP Global Land Data Assimilation System, (GLDAS) and a new NCEP Noah Land model**

UPGRADES TO THE ATMOSPHERIC MODEL

- **Hybrid vertical coordinate (sigma-pressure)**
- **Noah Land Model : 4 soil levels. Improved treatment of snow/frozen soil**
- **Sea Ice Model : Fractional ice cover and depth allowed**
- **Sub grid scale mountain blocking**
- **Reduced vertical diffusion**
- **ESMF (3.0)**
- **Enthalpy**
- **AER RRTM Longwave radiation**
- **AER RRTM Shortwave Radiation**
- **New Aerosol Treatment**
- **Inclusion of historical CO2, solar cycle and volcanic aerosols**

Testing with CMIP Runs (variable CO2)



OBS is CPC Analysis (Fan and van den Dool, 2008)

CTRL is CMIP run with 1988 CO2 settings (no variations in CO2)

CO2run is the ensemble mean of 3 NCEP CFS runs in CMIP mode

--realistic CO2 and aerosols in both troposphere and stratosphere

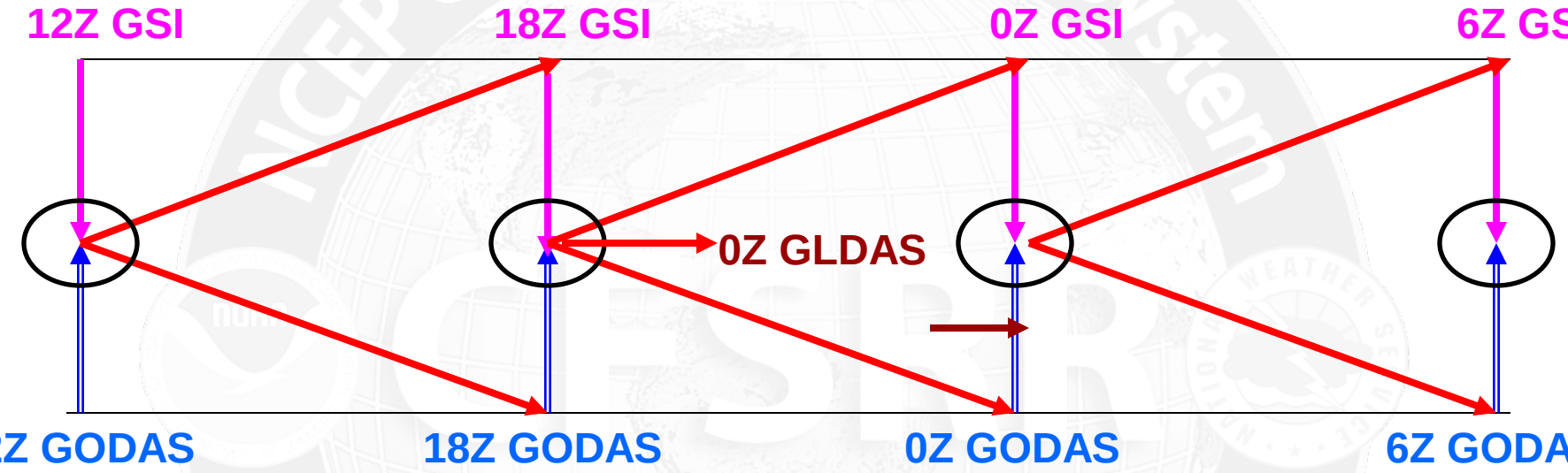
Processing: 25-month running mean applied to the time series of anomalies (deviations from their own climatologies)

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 T62L28)**
- **The guess forecast was generated from a coupled atmosphere – ocean – sea ice - land system**
- **Radiance measurements from the historical satellites were assimilated in this Reanalysis instead of NESDIS temperature retrievals**

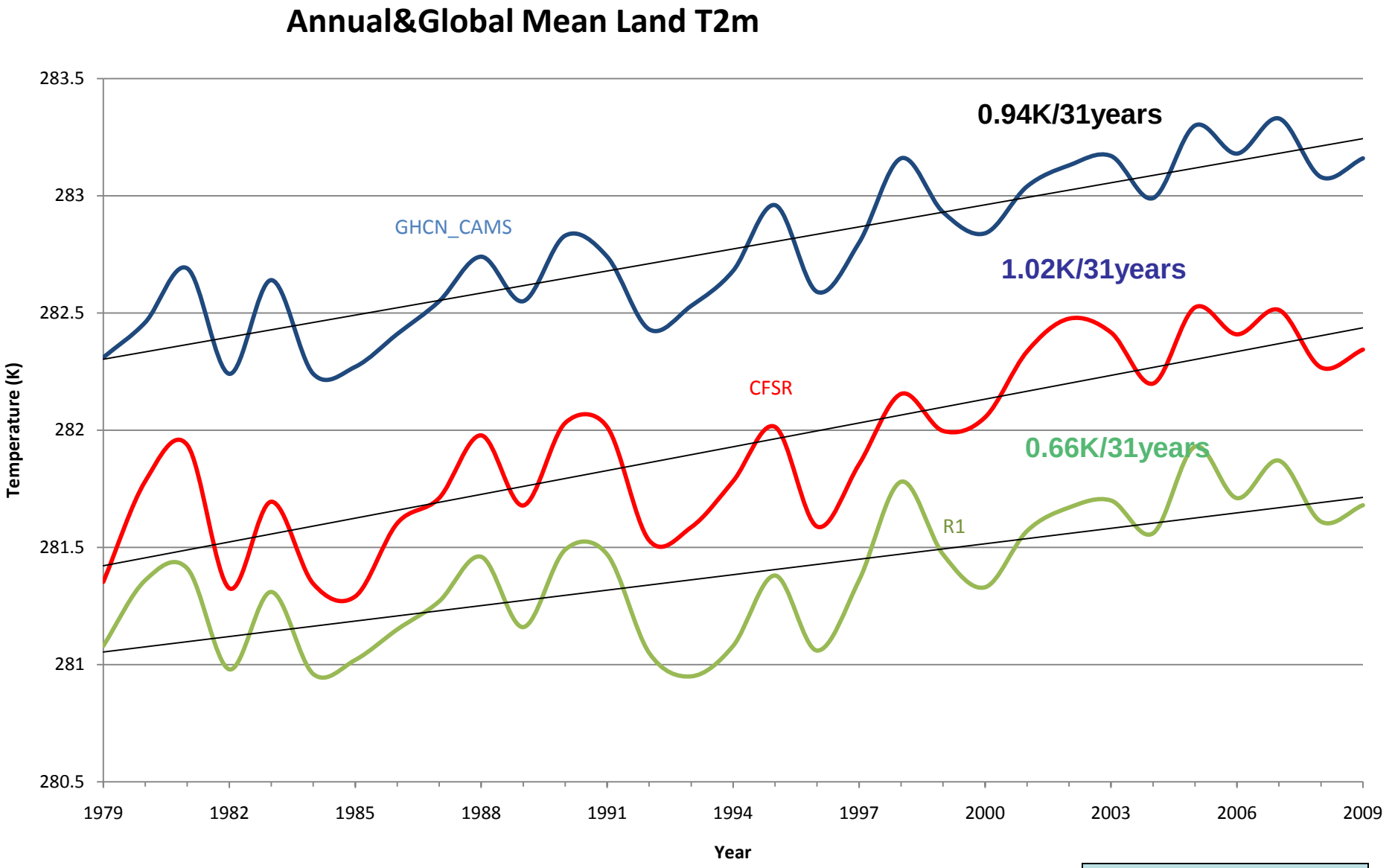
To conduct a coupled Reanalysis was a novelty, and will hopefully address important issues, such as the correlations between sea surface temperatures and precipitation in the global tropics.

ONE DAY OF REAL TIME ANALYSIS



→ 9-hr coupled T382L64 forecast guess (GFS + MOM4 + Noah)

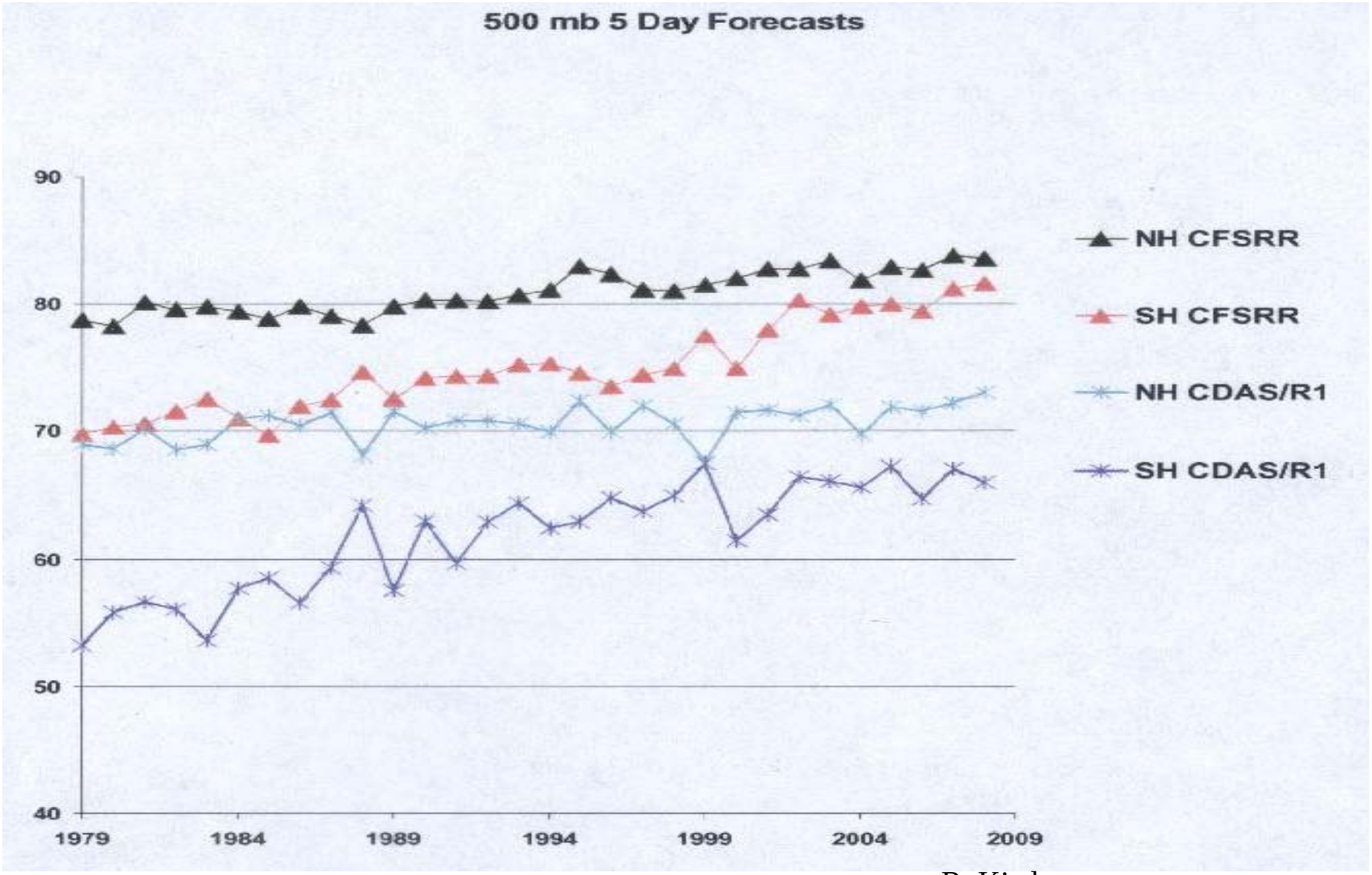
Hourly coupling between atmosphere and ocean



➔CFSR has less bias than R1, relative to GHCN_CAMS

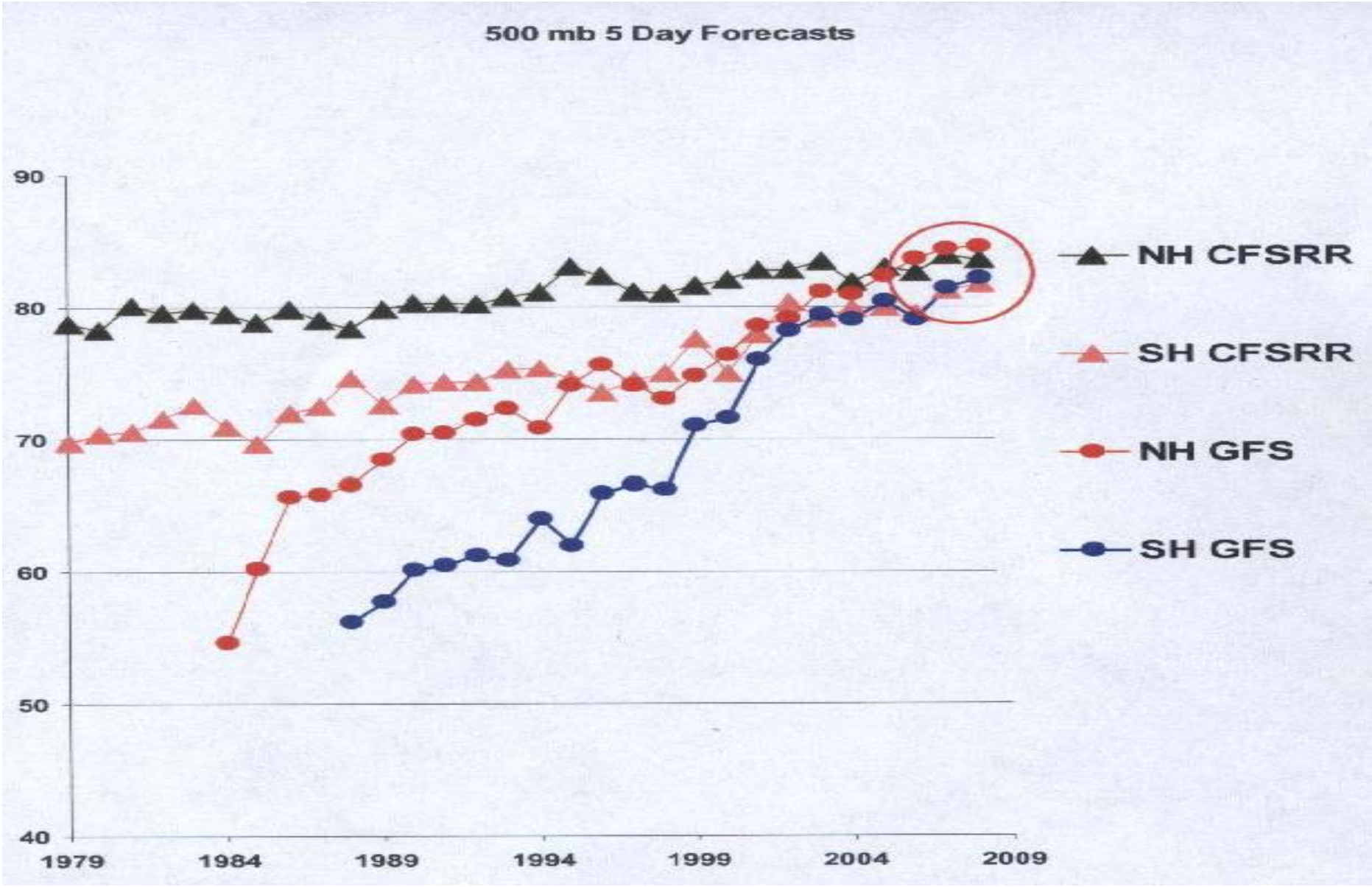
➔Upward trend in CFSR larger than in R1, more like GHCN_CAMS

NWS/CPC
H. Vandendool



R. Kistler

- CFSRR—2008 frozen system—T382, 64 layers, radiances
- R1—1995 frozen system—T62, 28 layers, NESDIS retrievals



R. Kistler

- CFSRR—2008 frozen system—T382, 64 layers, radiances
- GFS—operational model over the years

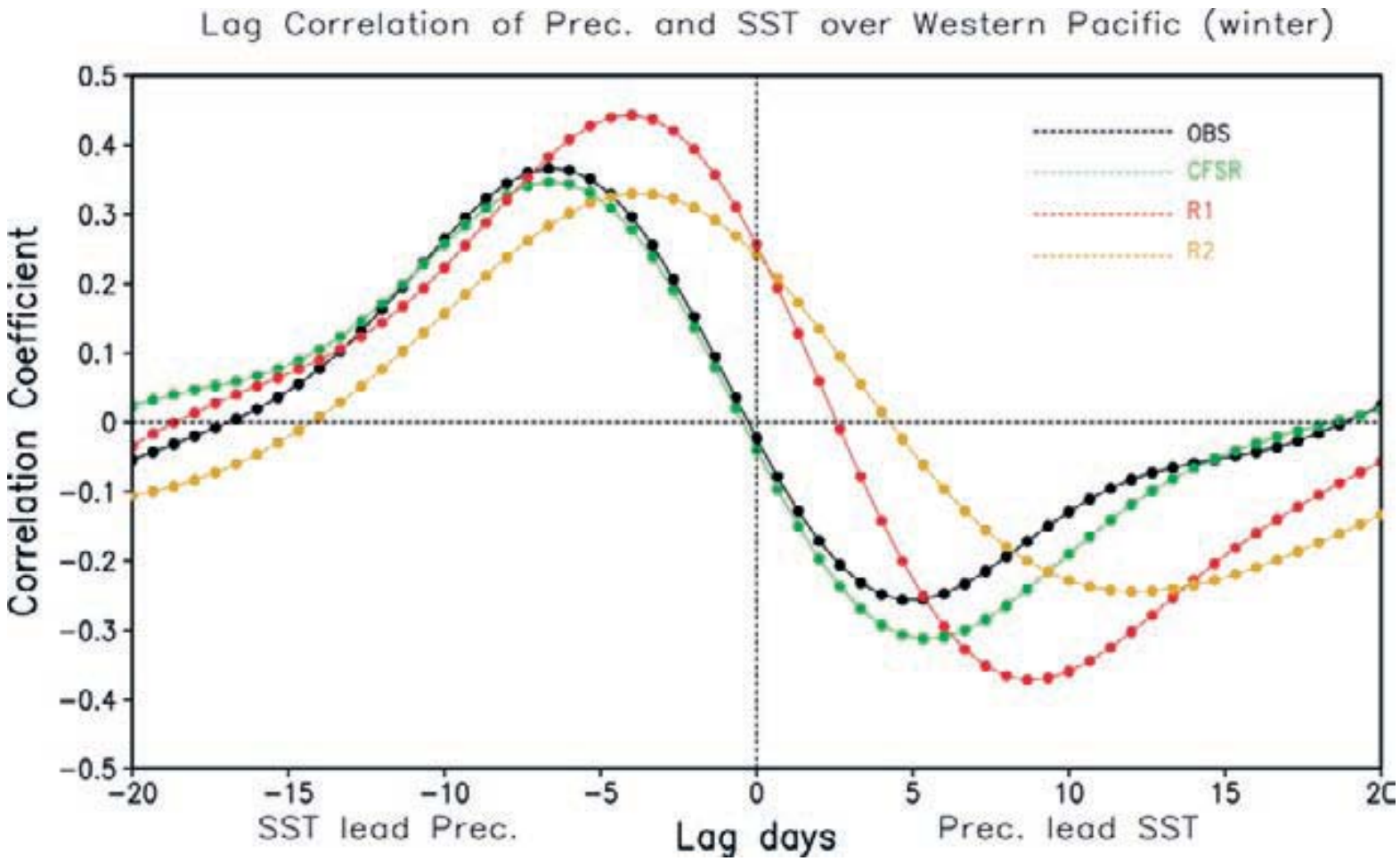
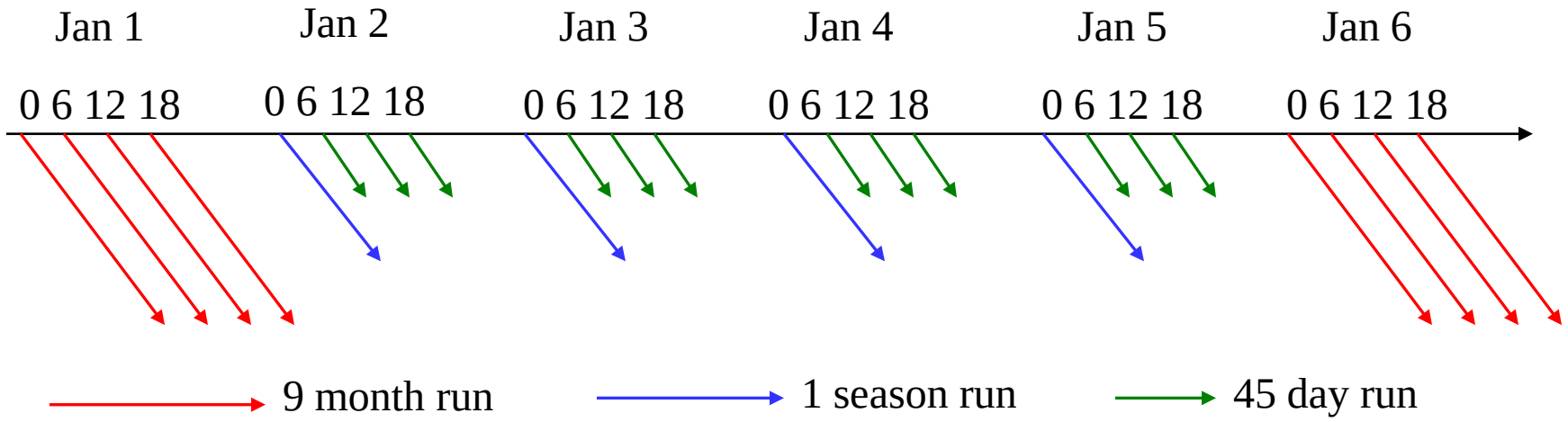


Fig. 27. Temporal lag correlation coefficient between precipitation and SST in the tropical western Pacific (averaged over 10° S–10° N, 130° –150° E) in R1 (red), R2 (brown), CFSR (green), and observation (black). GPCP daily precipitation and Reynolds ¼° daily SST are used as observational data. Negative (positive) lag in days on the x axis indicates the SST leads (lags) the precipitation. Data for the boreal winter (Nov–Apr) over the period 1979–2008 are bandpass filtered for 20–100 days after removing the climatological mean.

Hindcast Configuration for next CFS

- 9-month hindcasts initiated from every 5th day from all 4 cycles of that day, beginning from Jan 1 of each year, over a 28 year period from 1982-2009
- This is required to calibrate the operational CPC longer-term seasonal predictions (ENSO, etc)
- A single 1 season (105-day) hindcast run, initiated from every 0 UTC cycle between these five days, over the entire period.
- This is required to calibrate the operational CPC first season predictions for hydrological forecasts (precip, evaporation, runoff, streamflow, etc)
- Three 45-day (1-month) hindcast runs from every 6, 12 and 18 UTC cycles.
- This is required for the operational CPC week3-week6 predictions of tropical circulations (MJO, PNA, etc)
- In all, a total of 40,880 hindcasts made (the equivalent of running the CFS for over 14,000 yrs !!)



Definitions and Data

- AC of ensemble average monthly means
- GHCN-CAMS (validation for Tmp2m)
- CMAP (validation for Prate)
- OIv2 (validation for SST)
- 1982-2008 (27 years)
- All starting months (minus Sep and Oct)
- Common 2.5 degree grid
- v1 (15 members), v2 (24/28 members)
- Two climos used for all variables within tropics
  30S-30N: 1982-1998 and 1999-2008
  Elsewhere: 1982-2008

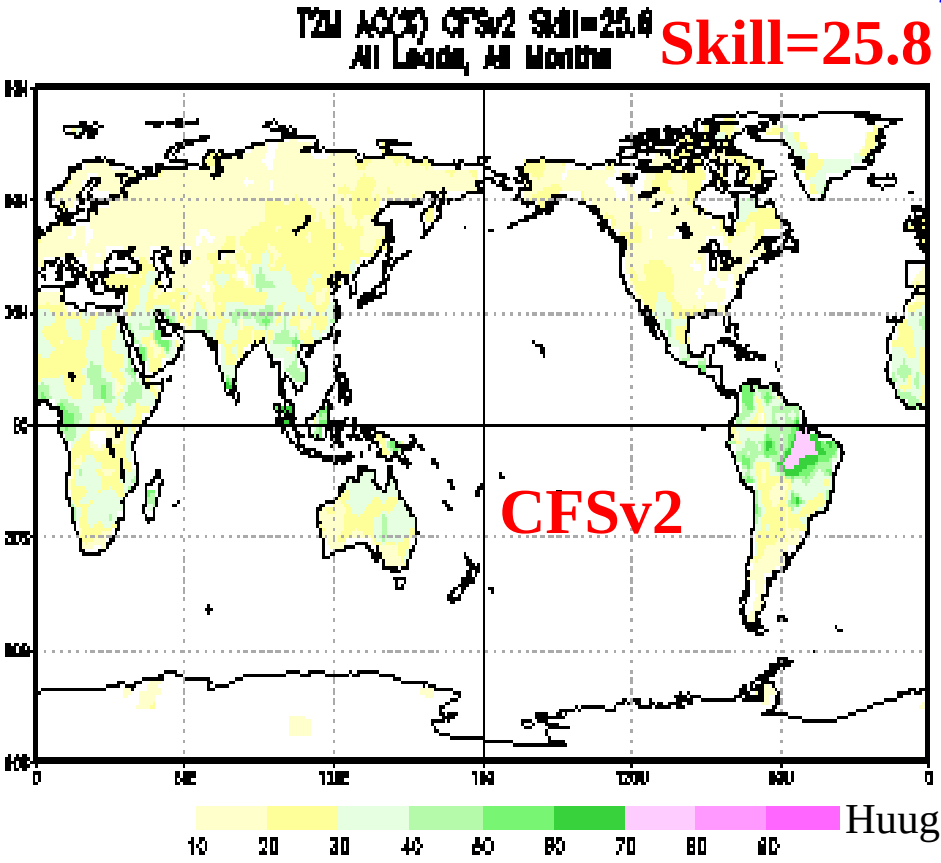
THE BOTTOM LINE FOR CPC

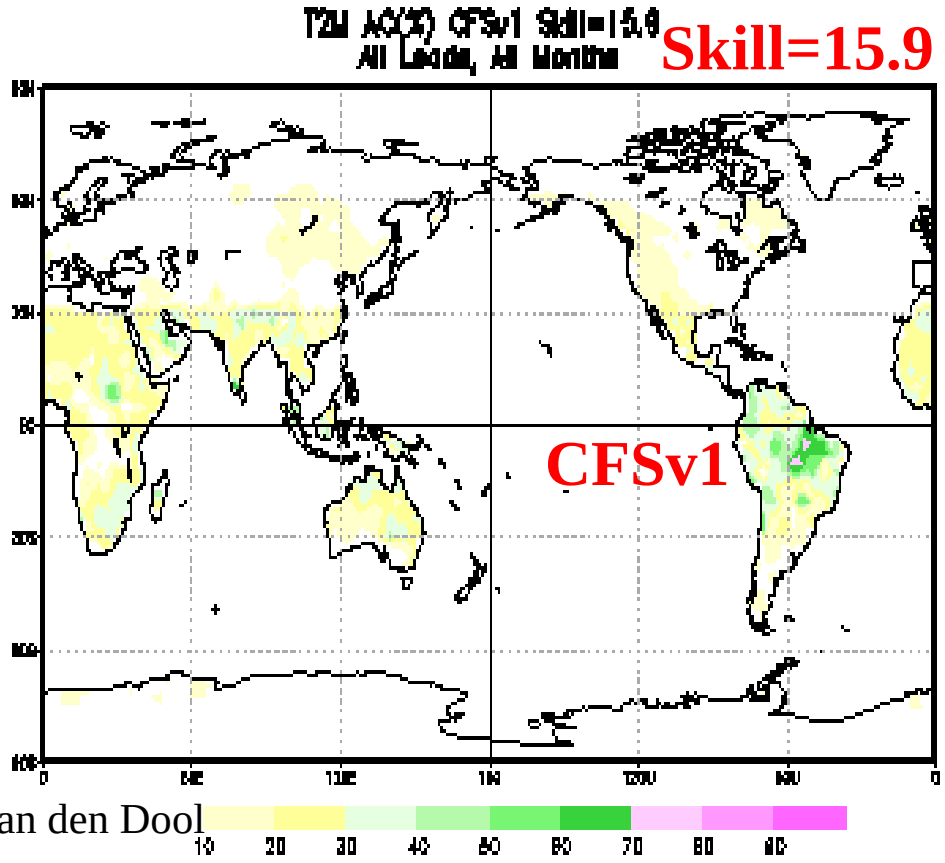
Anomaly Correlation: All Leads (1-8), All Months (10)

Green is good **Red is not good**

Model	US T	US P	Nino34 SST	Nino34 Prate	Global SST (50N-50S)
CFSv2	16.3	9.5	77.2	54.5	42.2
CFSv1	9.5	10.3	71.8	52.8	37.7

Anomaly correlation

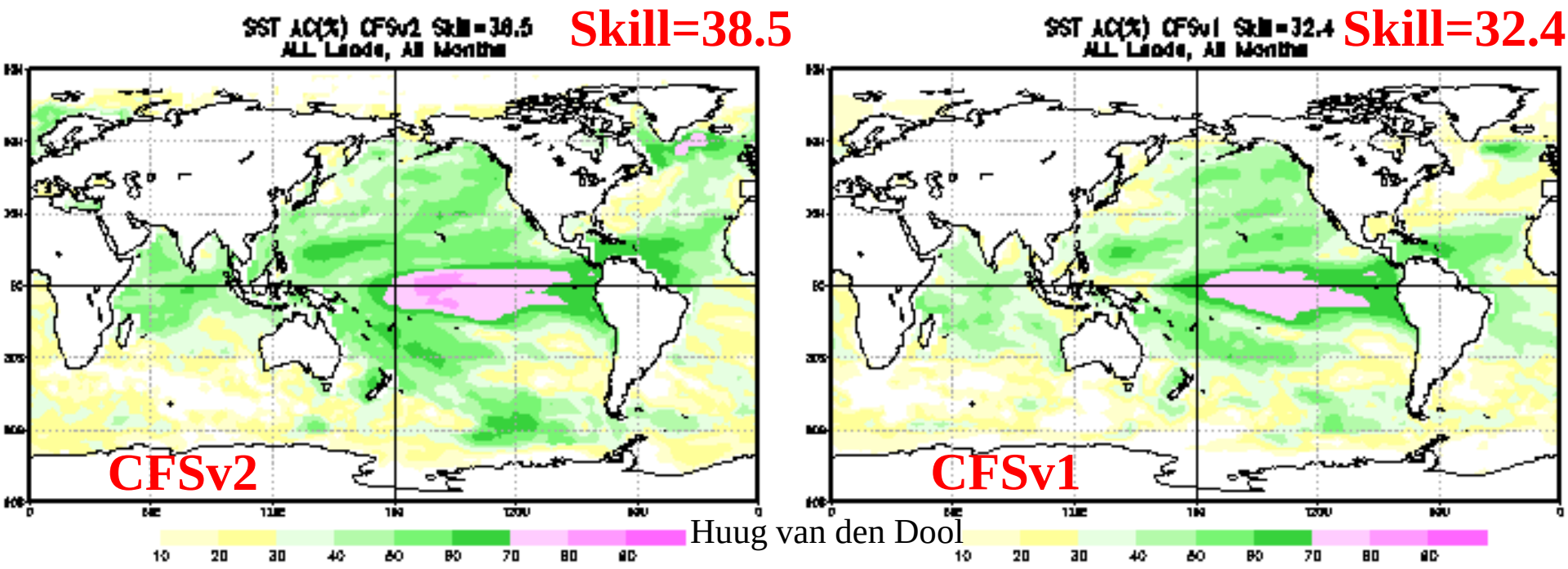




Huug van den Dool

2-meter Temps:

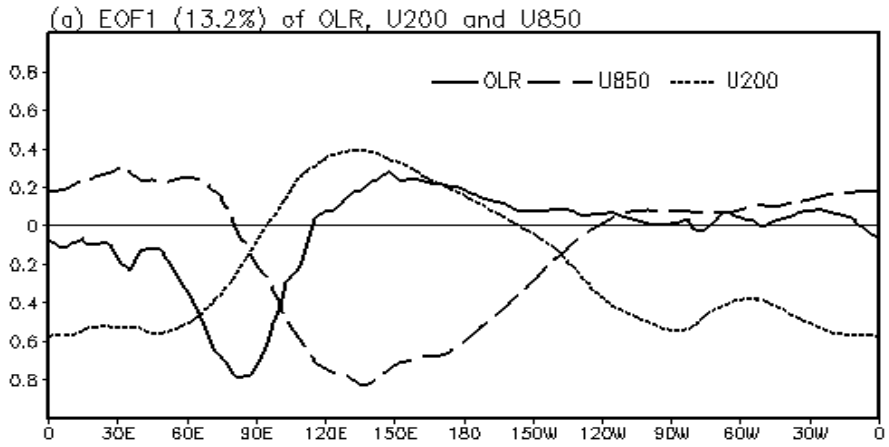
Increase in global skill for CFSv2 over land areas at all leads, for both ICs, against CFSv1, probably due to the incorporation of CO2 changes.

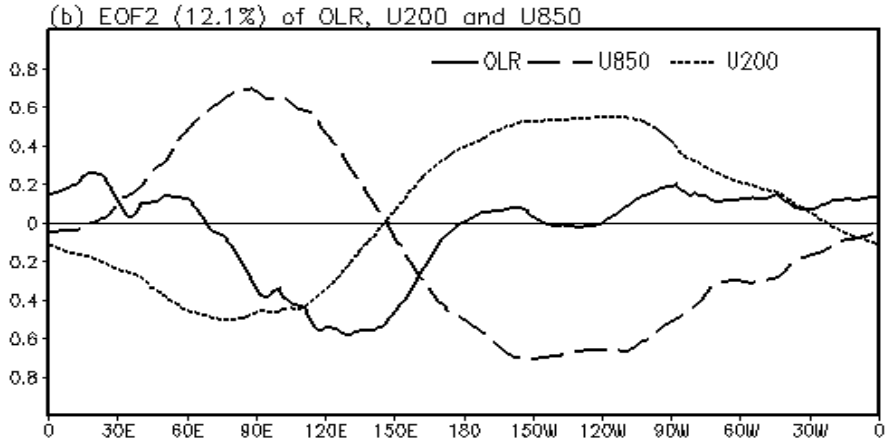


Sea Surface Temps:

- For Nov ICs, there is more skill at the longer leads for CFSv2 than the operational CFS (no spring barrier ?)
- There appears to be some interesting skill in CFSv2 in high latitude NW Atlantic (Labrador, Greenland) for both initial months. The sea-ice model???

MJO Identificati





Wheeler and Hendon (2004)

→ Multivariate EOF analysis using OLR, 850 hPa / 200 hPa zonal wind

→ <u>Data pre-filtering:</u>

1. Seasonal cycle removed

2. ENSO variability removed

3. Latest 120day mean removed

→ The first two PCs are called Real-time Multivariate MJO indices (RMM1, RMM2)

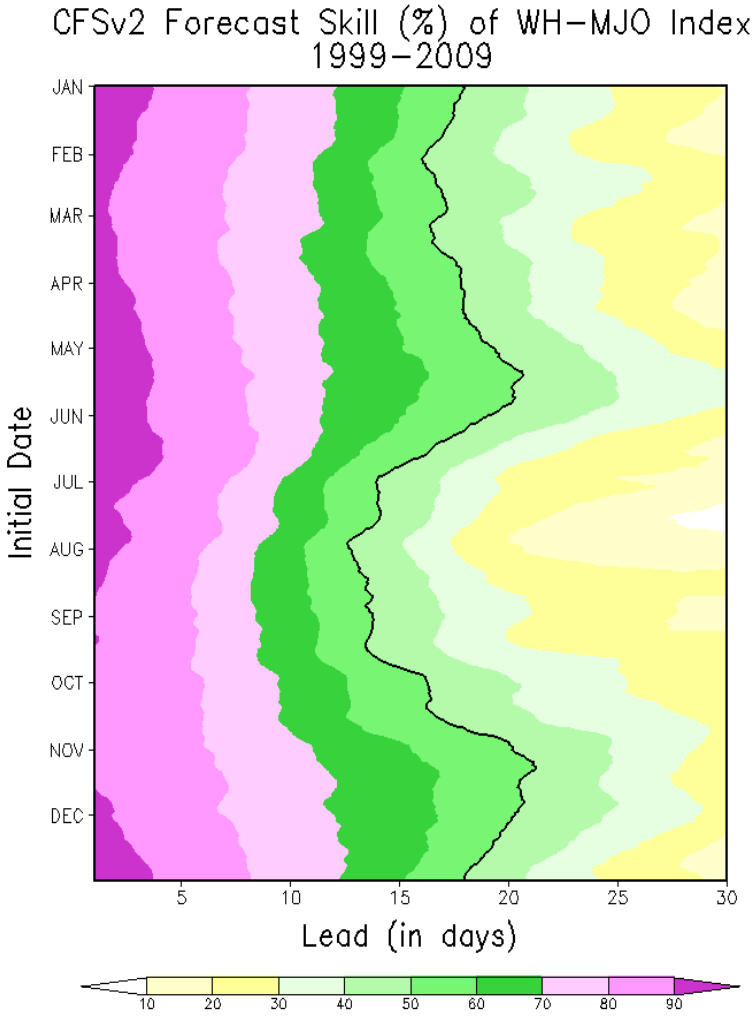
MJO Forecast Skill Definition

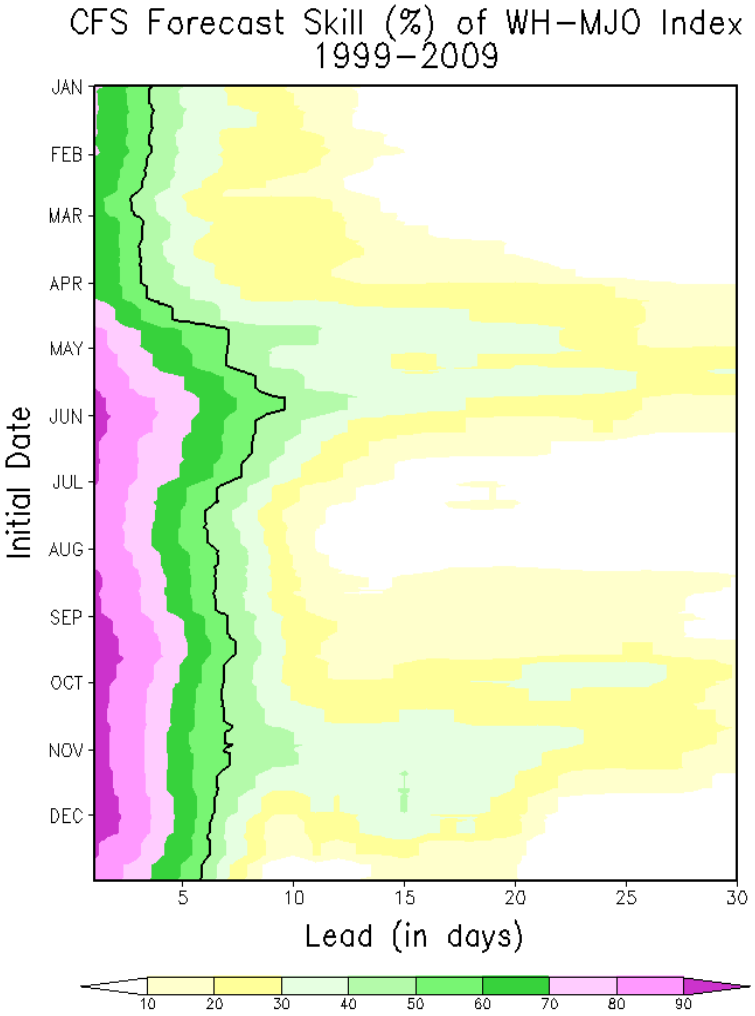
- Bivariate correlation (COR) metrics according to Lin et al (2008):

$$\mathrm{COR}(\tau) = \frac{\sum_{i=1}^{N} [a_{1i}(t)b_{1i}(t) + a_{2i}(t)b_{2i}(t)]}{\sqrt{\sum_{i=1}^{N} [a_{1i}^2(t) + a_{2i}^2(t)]}\sqrt{\sum_{i=1}^{N} [b_{1i}^2(t) + b_{2i}^2(t)]}}, \quad (1)$$

where $a_{1i}(t)$ and $a_{2i}(t)$ are the observed RMM1 and RMM2 at day t, and $b_{1i}(t)$ and $b_{2i}(t)$ are their respective forecasts, for the ith forecast with a τ-day lead. Here, N is the number of forecasts. COR(τ) measures the skill in forecasting the phase of the MJO, which is insensitive to amplitude errors. COR(τ) is equivalent to a spatial pattern correlation between the observations and the forecasts when they are expressed by the two leading combined EOFs.

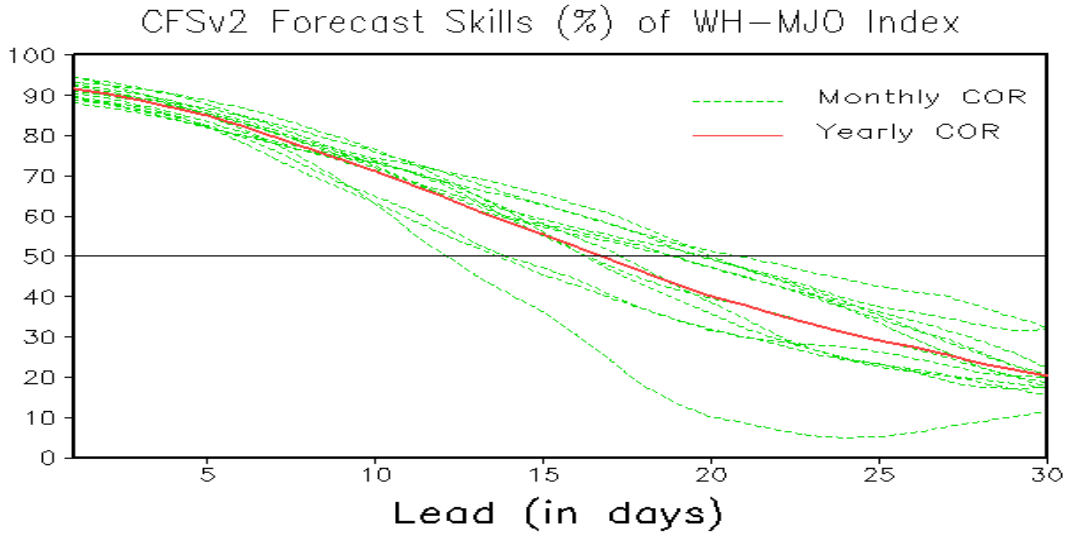
Forecast Skill of WH-MJO index

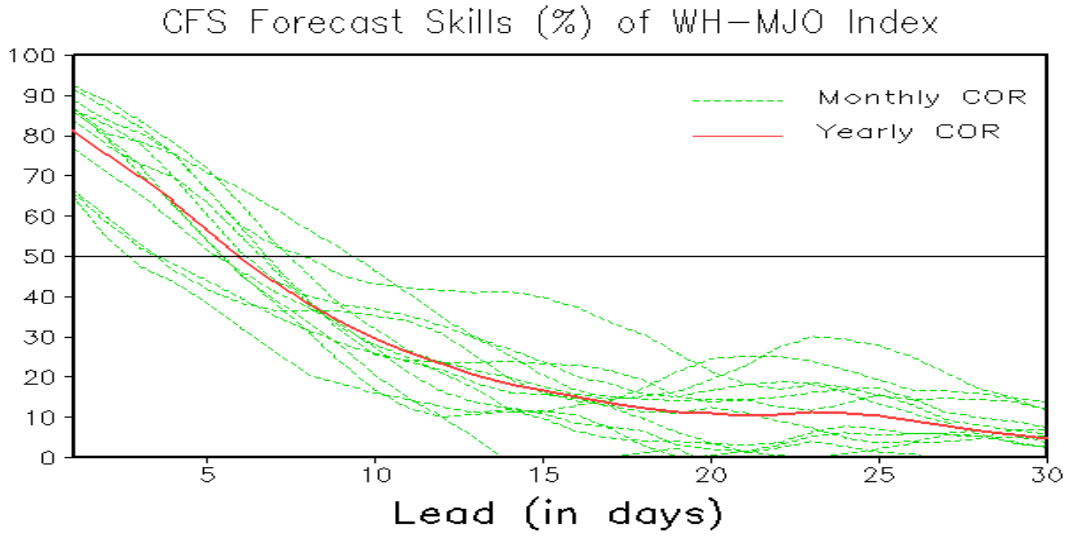




Courtesy Qin Zhang – NCEP/CPC

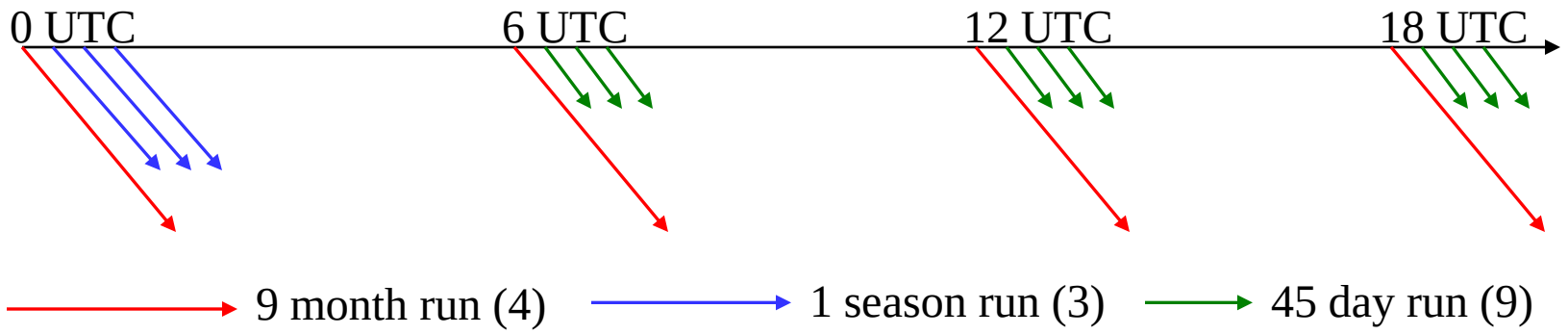
Forecast Skill of WH-MJO index





Operational Configuration for next CFS

- 4 control runs per day from the 0, 6, 12 and 18 UTC cycles of the CFS real-time data assimilation system, out to 9 months.
- At the 0 UTC cycle, 3 additional runs, out to one season.
- At the 6, 12 and 18 UTC cycles, 3 additional runs, out to 45 days.
- 16 CFS runs every day, of which 4 runs will go out to 9 months, 3 runs will go out to 1 season and 9 runs will go out to 45 days.



NOMADS
The NOAA Operational Model Archive and Distribution System

CFSRR Data Access at NCDC

http://nomads.ncdc.noaa.gov/NOAAReanalysis/cfsrr
http://dss.ucar.edu/pub/cfsr.html

Access via the NOAA Operational Model Archive and Distribution System (NOMADS).

- Tier 1 “Hi-Priority” Monthly means and selected hourly time series data on disk

- Fast access and Bulk order Capabilities: http (wget, etc.) ftp, ftp4u (grib subsetting).

- Bulk Order Capability Limited by # of Simultaneous requests. Wait time tbd

- CFS Reanalysis and Re-Forecasting complete

CFS Version 2 upgrade scheduled for 18 January 2011

- Forecast component will be frozen (T126L64)
  - Assimilation component will evolve with GFS and GSI
- CFS Data Assimilation fully coupled version of T574 GFS/GSI
- GSI upgrade scheduled for early March
- CDAS is being tested with the new GSI
  - If impact neutral, CDAS will switch to new GSI in March
  - Old GSI remains for CDAS, until negative impacts resolved
- R2 , GODAS to be discontinued Jul.1, 2011
- Rerunning CFSR at T126 L64 in single stream from 1979 to 2010.
- R1 (NCEP/NCAR) will continue until CFSR finishes 2010
- Same frozen system will be run from 1948 until 1980 with one year overlap

Issues

- Is coupled data assimilation useful at this stage?
- Is the high resolution atmosphere analysis important?
- How to merge efforts for week 1-2 forecasts with week 3-4 forecasts and seasonal forecasts?

Future (how far away?)

- Coupled high resolution data assimilation for weather and climate
- Coupled weather and climate forecasts with decreasing resolution as the range of forecast increases
- Periodic reanalysis and reforecast for both weather and climate forecasts