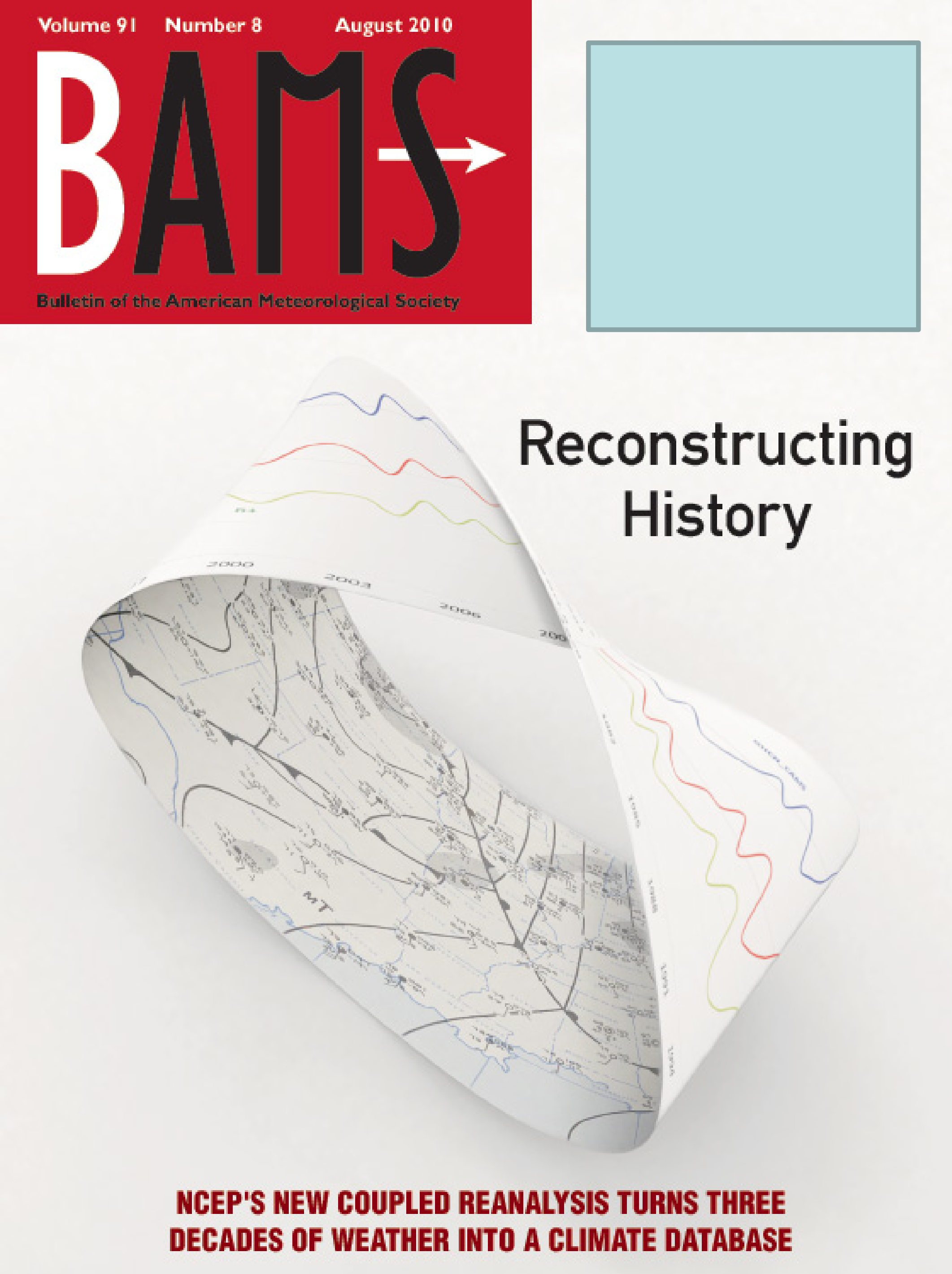
(1) Suru Saha: Re-analyses and re-forecasts as predictability tools.

(2) Huug van den Dool: Use of re-analyses and re-forecasts for the calibration of long-range predictions

- CFSR
- CFSRR, both seasonal and 45 days
- Predictability

- Run into countless issues, MME, cross-validation, prediction of extremes



The NCEP Climate Forecast System Reanalysis

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, Mitch Goldberg

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doi: 10.1175/2010BAMS3001.1

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

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

An upgrade to the coupled atmosphere-ocean-seaice-land NCEP Climate Forecast System (CFS) is being planned for Dec 2010.

This upgrade involves changes to 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 seaice 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**

For a new CFS implementation (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 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 3 layer 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:

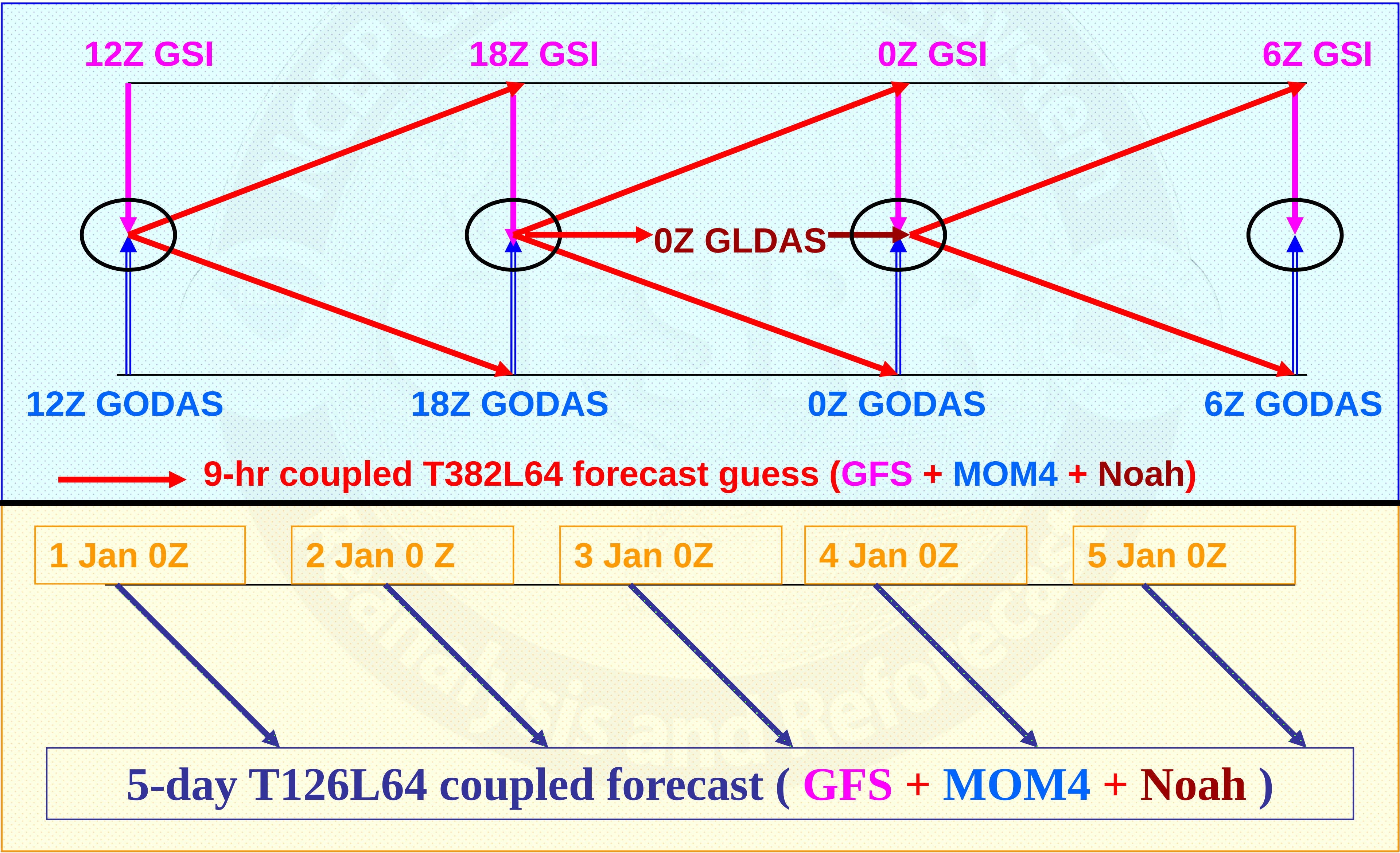
Much higher horizontal and vertical resolution (T382L64) of the atmosphere (earlier efforts were made with T62L28 resolution)

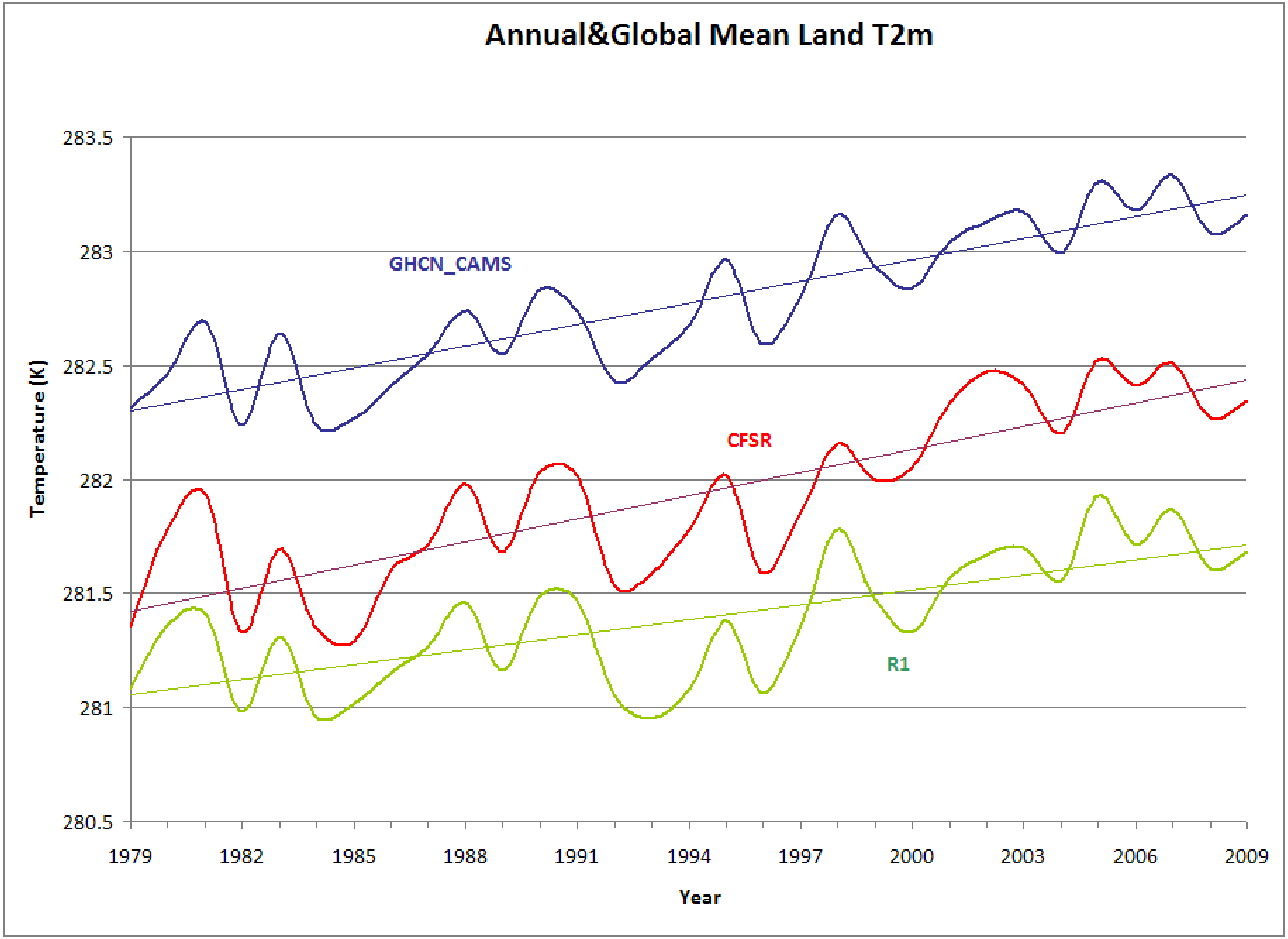
The guess forecast was generated from a coupled atmosphere – ocean – seaice - land system

Radiance measurements from the historical satellites were assimilated in this Reanalysis

To conduct a Reanalysis with the atmosphere, ocean, seaice and land coupled to each other was a novelty, and will hopefully address important issues, such as the correlations between sea surface temperatures and precipitation in the global tropics, etc.

ONE DAY OF REANALYSIS

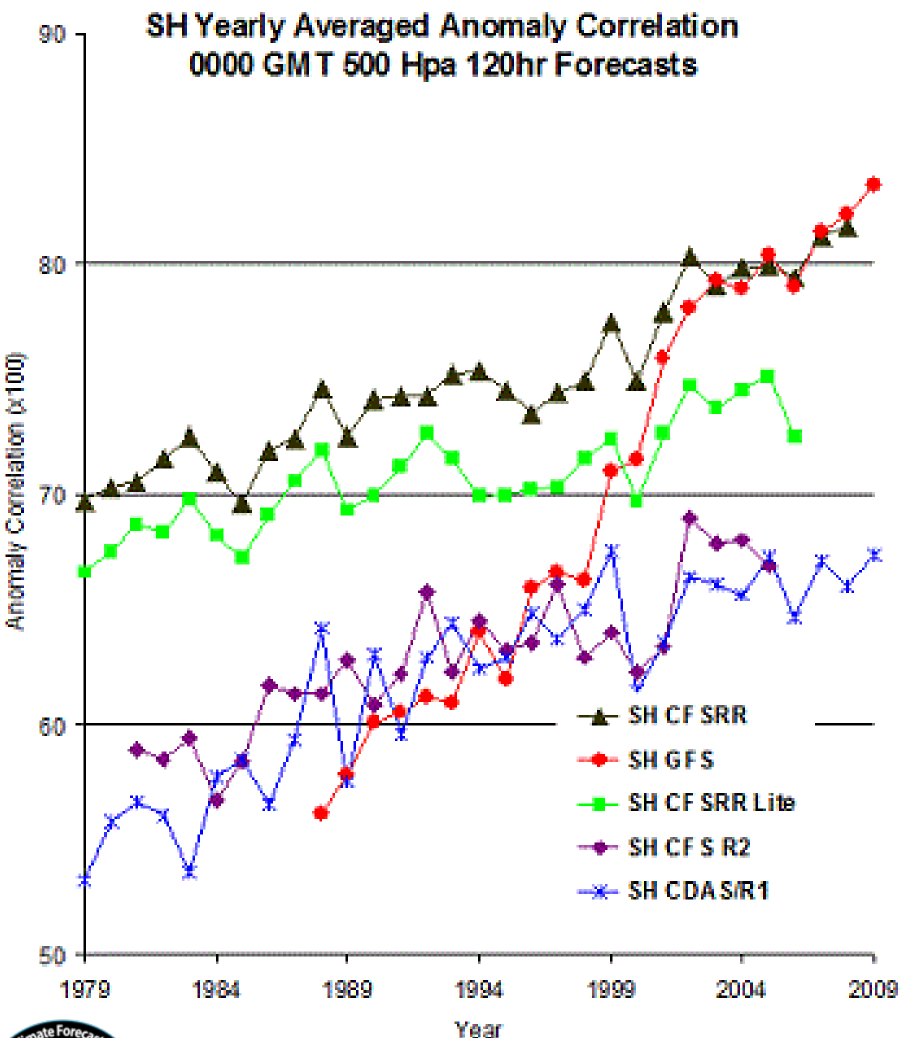


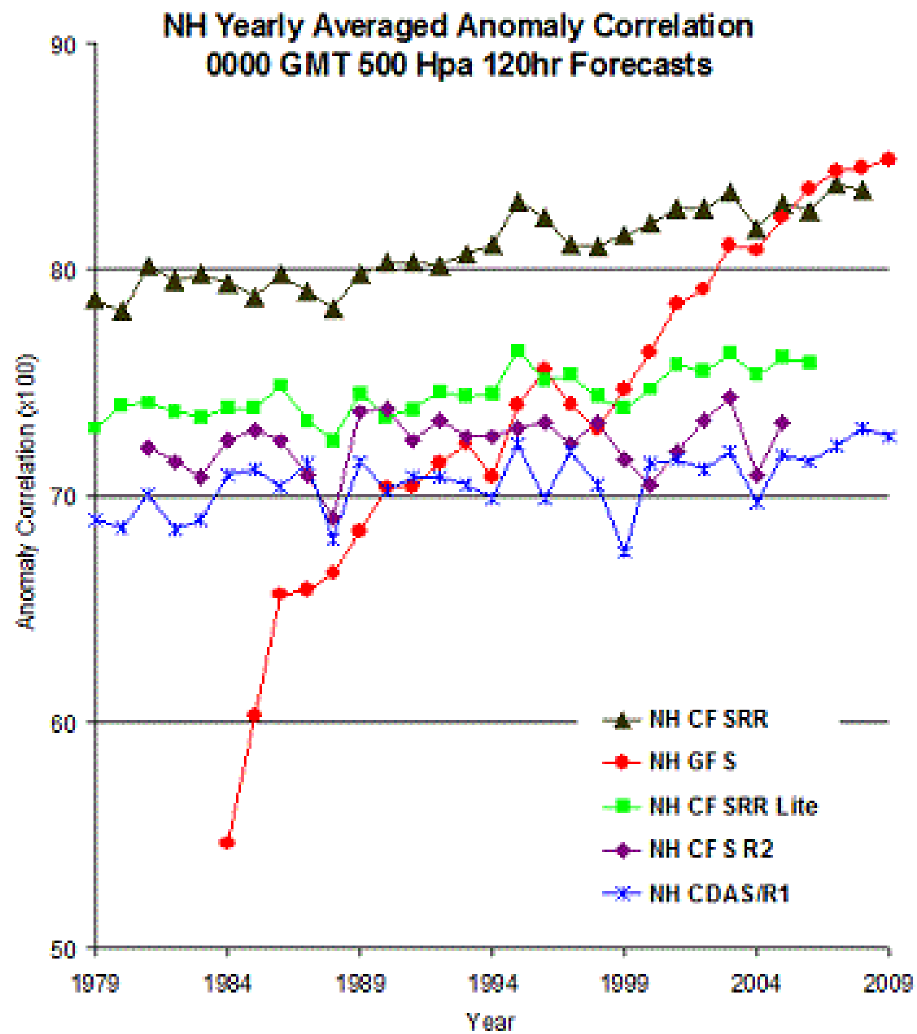


The linear trends are 0.66, 1.02 and 0.94K per 31 years for R1, CFSR and GHCN_CAMS respectively. (Keep in mind that straight lines may not be perfectly portraying climate change trends).

Courtesy: Huug van den Dool

5-day T126L64 forecast anomaly correlations

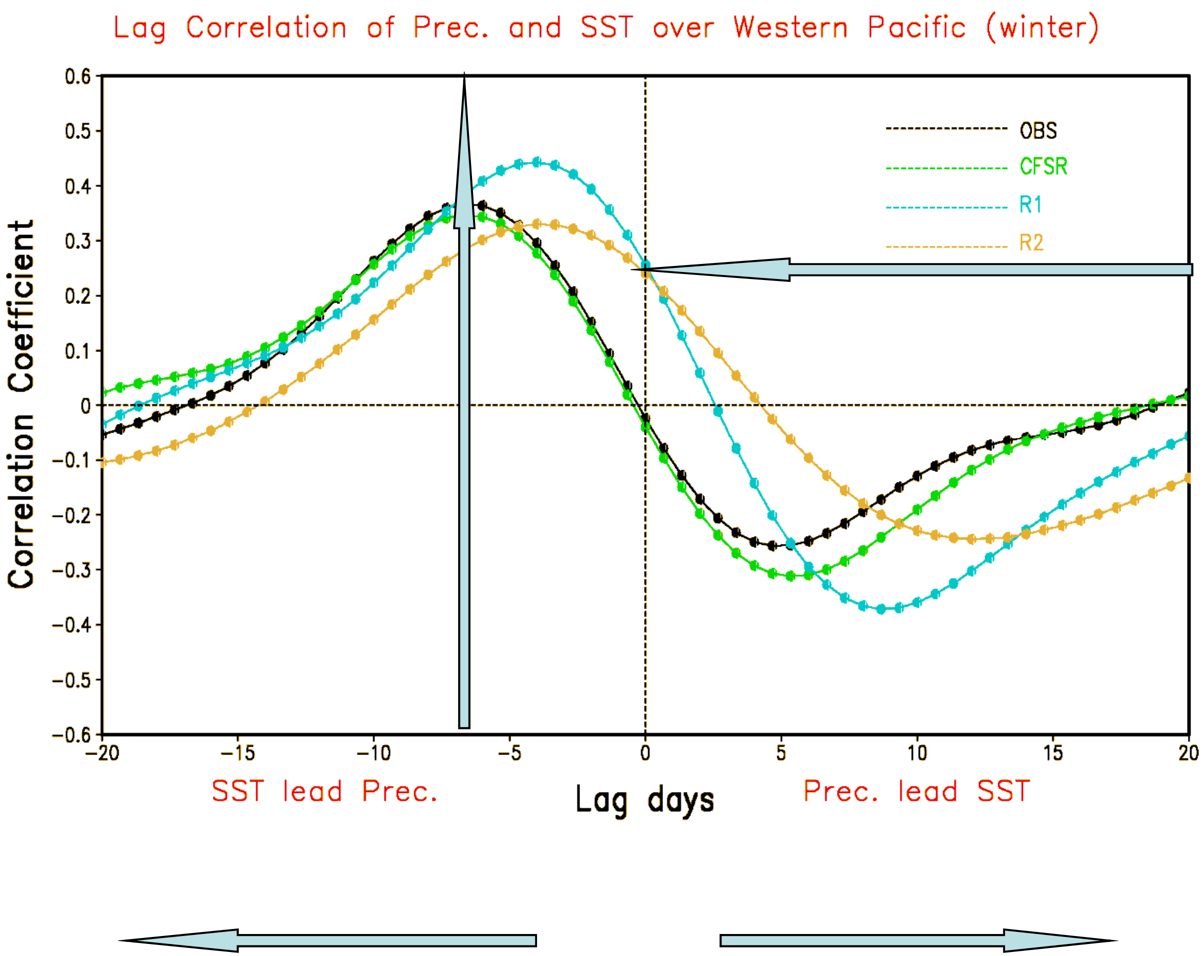




Courtesy: Bob Kistler

SST-Precipitation Relationship in CFSR

Precipitation-SST lag correlation in tropical Western Pacific



Response of Prec. To SST increase : warming too quick in R1 and R2

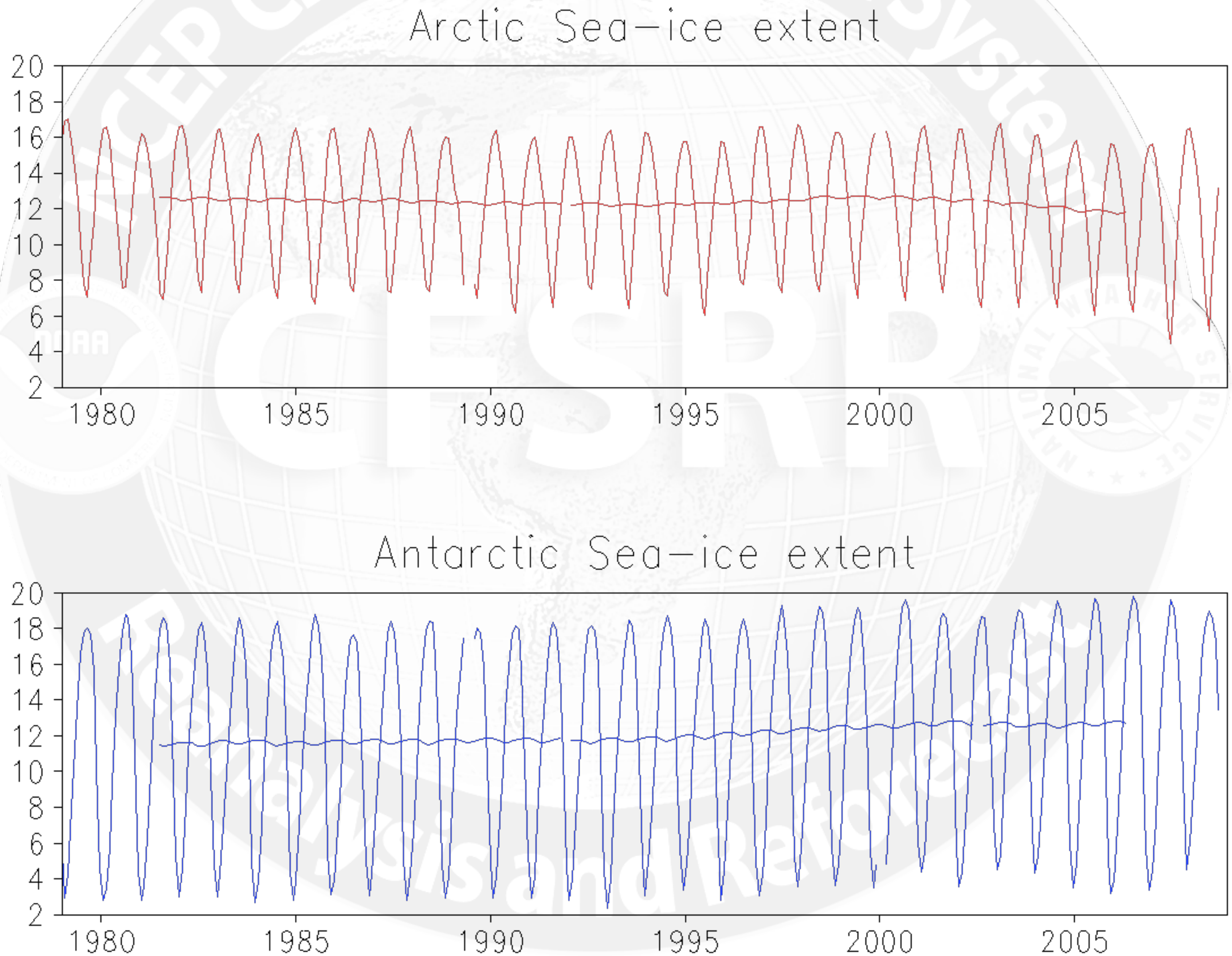
simultaneous positive correlation in R1 and R2

Courtesy: Jiande Wang

Monthly mean Sea ice extent (10^6 km^2)

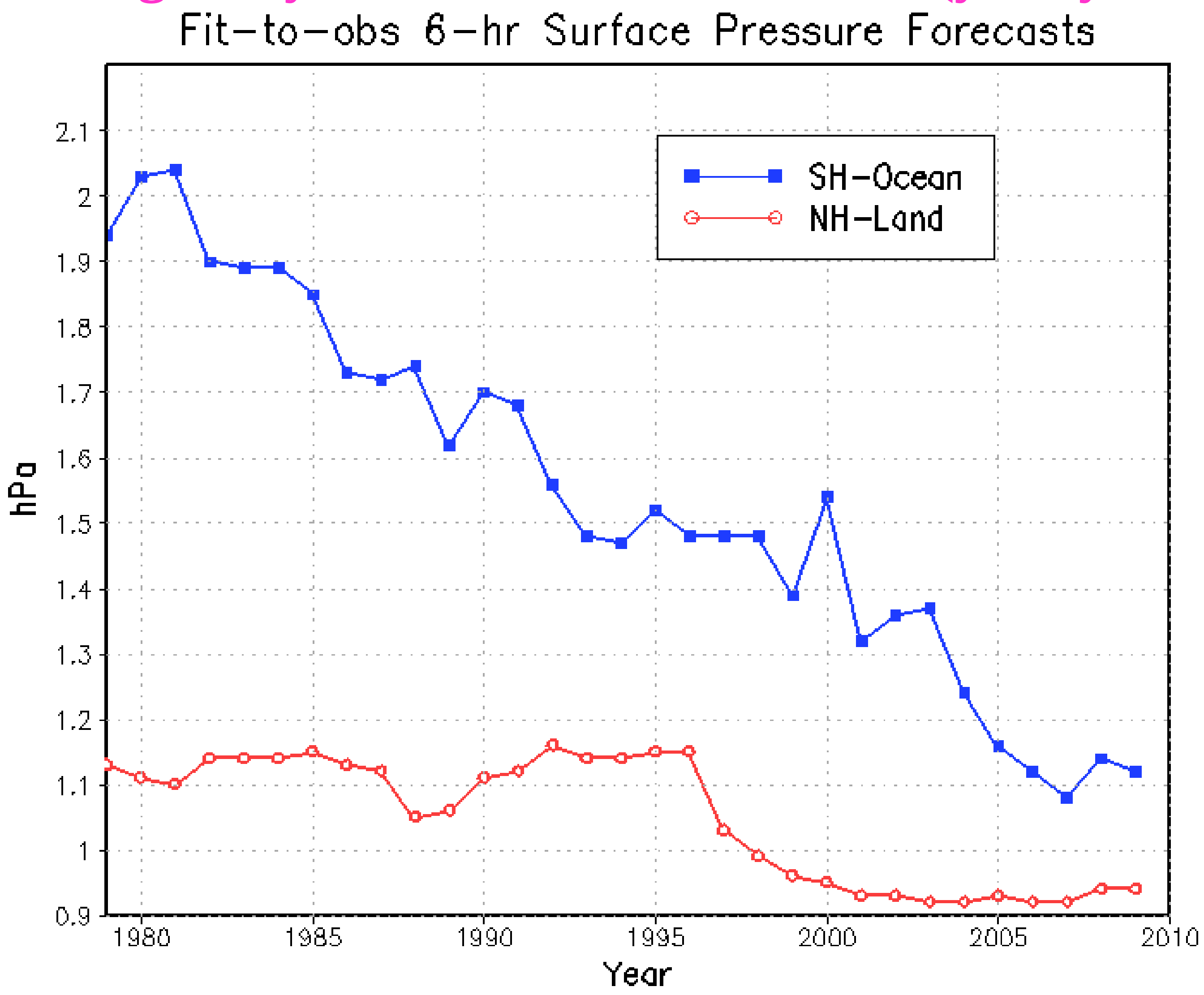
for the Arctic (top) and Antarctic (bottom) from CFSR (6-hr forecasts).

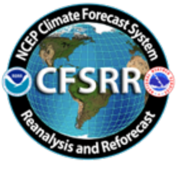
5-year running mean is added to detect long term trends.



Courtesy: Xingren Wu

The fit of 6 hour forecasts of instantaneous surface pressure against irregularly distributed observations (yearly averages)

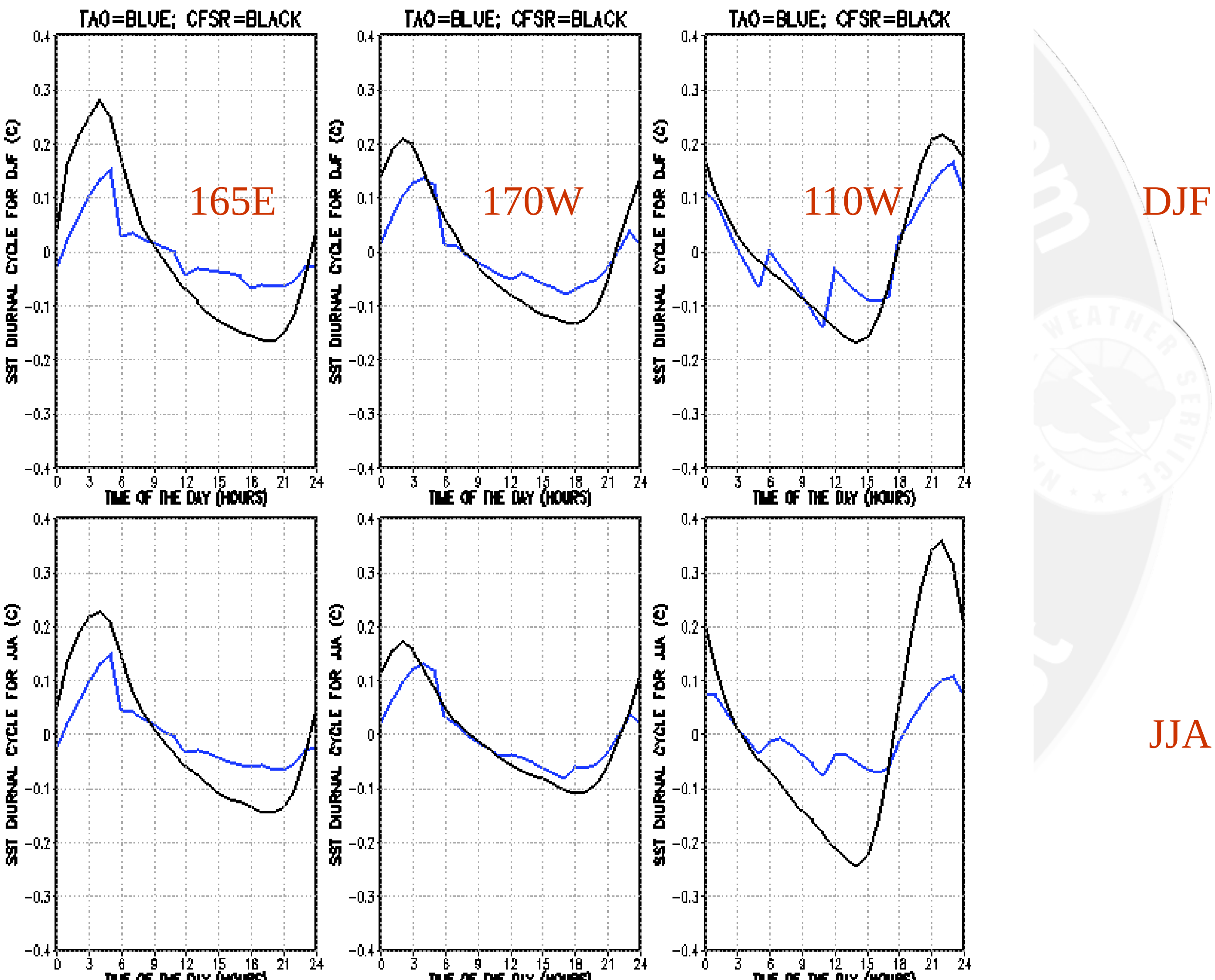




Courtesy: Huug van den Dool

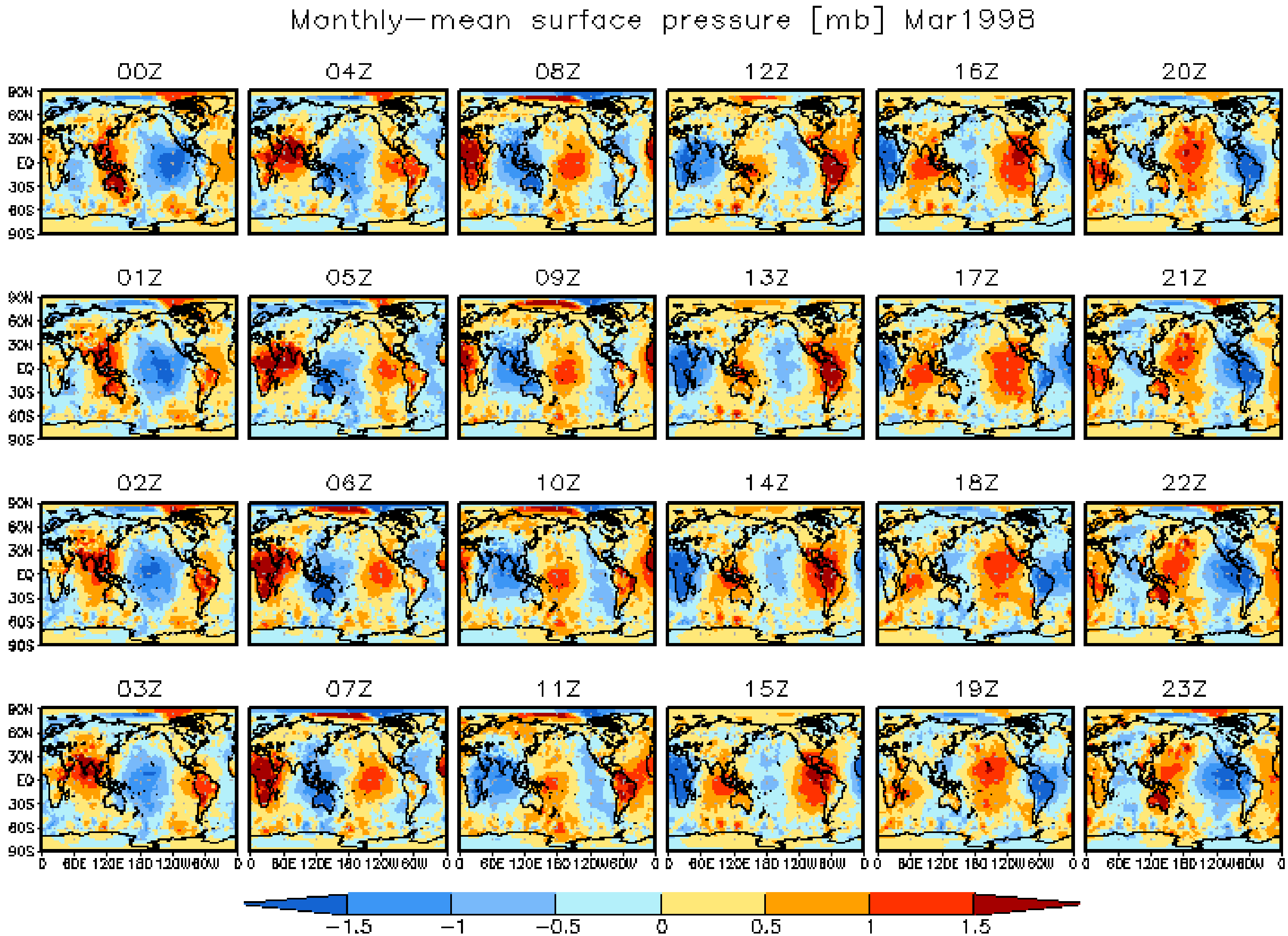
The Diurnal Cycle of SST in CFSR

The diurnal cycle of SST in the TAO data (black line) and CFSR (blue line) in the Equatorial Pacific for DJF (top three panels) and JJA (bottom three panels).



Courtesy: Sudhir Nadiga

Monthly mean hourly surface pressure with the daily mean subtracted for the month of March 1998

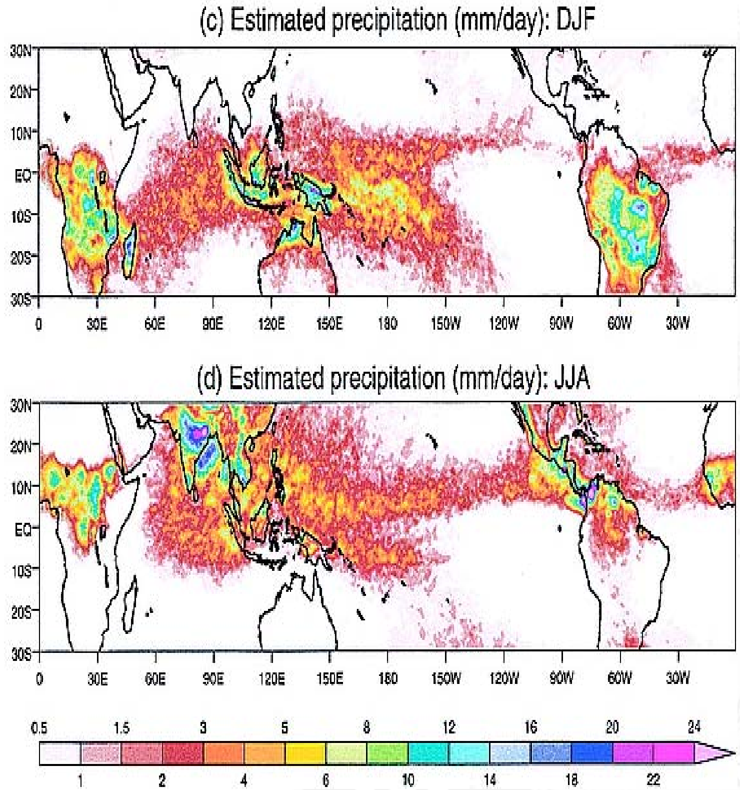


Courtesy: Huug van den Dool

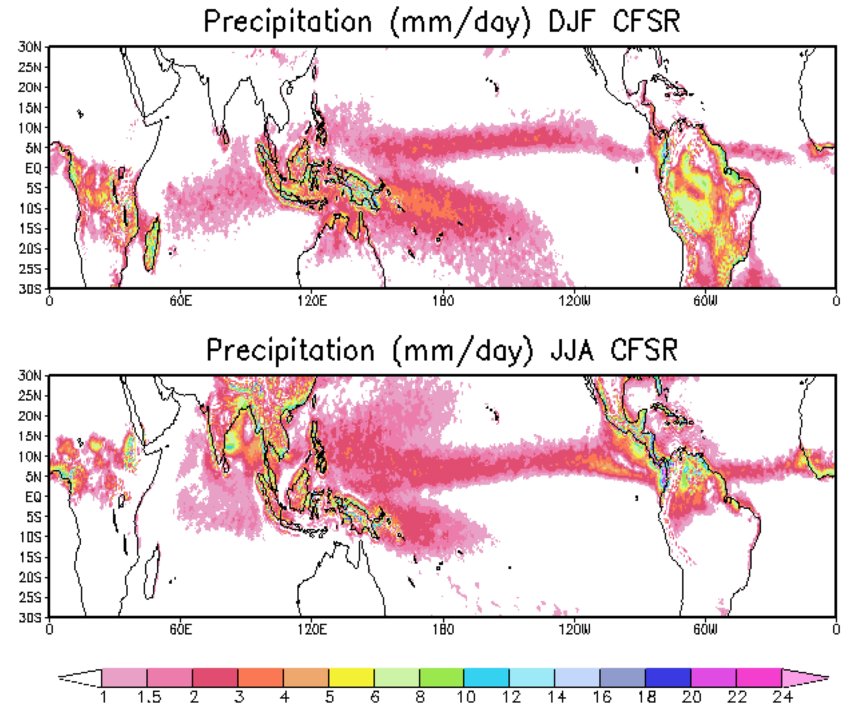
The amplitude of the diurnal cycle

(1^{st} harmonic) in precipitation (mm/day)

Gang and Slingo, 2001



CFSR

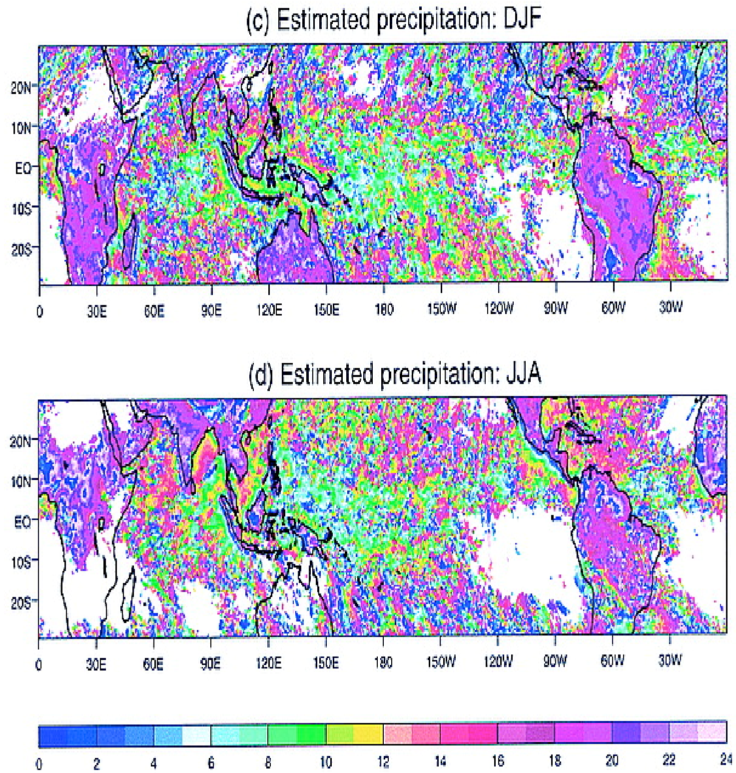


CFSR distribution is quite good, but amplitude is smaller than 'Slingo' (estimated from 3 hourly data)

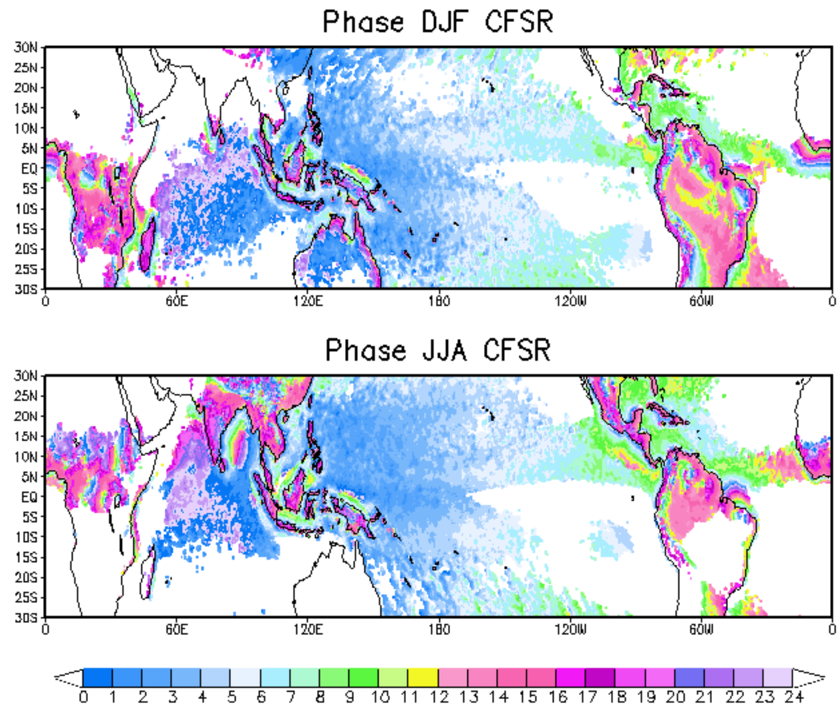
The phase of the diurnal cycle

(1^{st} harmonic) in precipitation (hour – local time)

Gang and Slingo, 2001



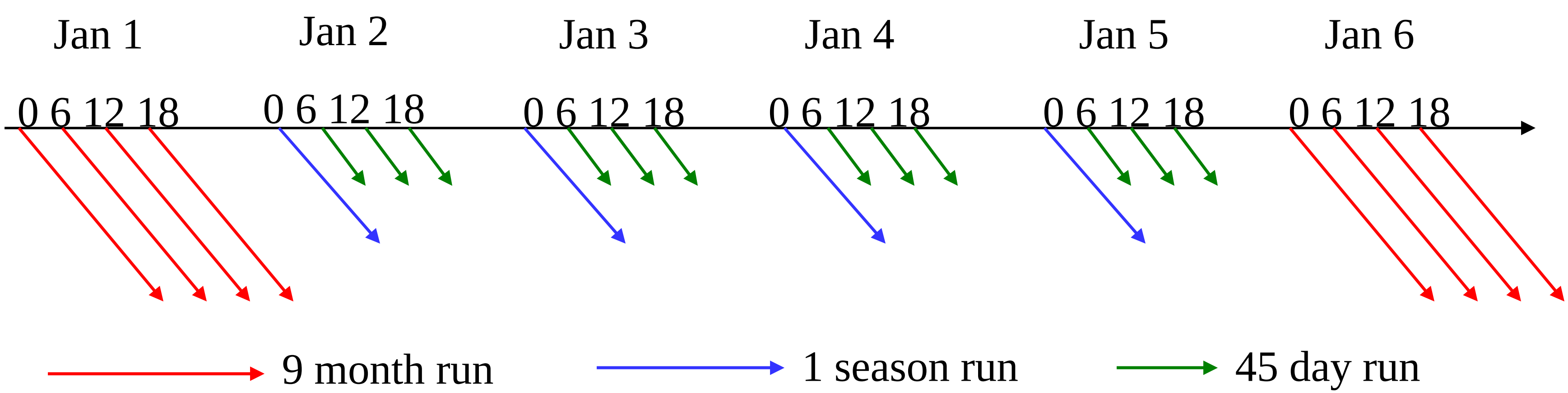
CFSR



CFSR distribution of phase is quite good, just less detail than 'Slingo' (estimated from 3 hourly data)

Hindcast Configuration for next CFS

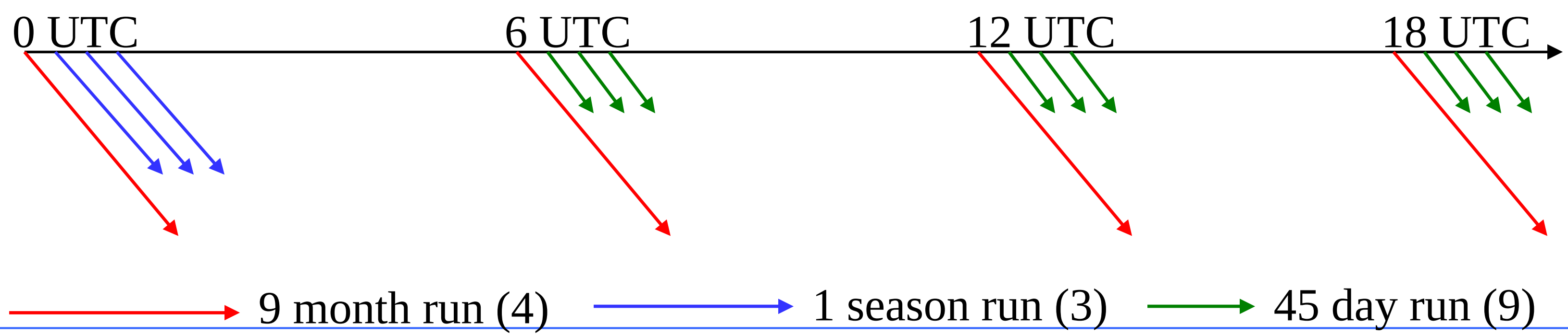
- 9-month hindcasts will be initiated from every 5th day and will be run from all 4 cycles of that day, beginning from Jan 1 of each year, over a 28 year period from 1982-2009 This is required to calibrate the operational CPC longer-term seasonal predictions (ENSO, etc)
- There will also be a single 1 season (123-day) hindcast run, initiated from every 0 UTC cycle between these five days, over the 12 year period from 1999-2010. This is required to calibrate the operational CPC first season predictions for hydrological forecasts (precip, evaporation, runoff, streamflow, etc)
- In addition, there will be three 45-day (1-month) hindcast runs from every 6, 12 and 18 UTC cycles, over the 12-year period from 1999-2010. This is required for the operational CPC week3-week6 predictions of tropical circulations (MJO, PNA, etc)
- **Total number of years of integration = 9447 years !!!!!**



Courtesy: Suru Saha

Operational Configuration for next CFS

- There will be 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.
- In addition to the control run of 9 months at the 0 UTC cycle, there will be 3 additional runs, out to one season. These 3 runs per cycle will be initialized as in current operations.
- In addition to the control run of 9 months at the 6, 12 and 18 UTC cycles, there will be 3 additional runs, out to 45 days. These 3 runs per cycle will be initialized as in current operations.
- There will be a total of 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.



Courtesy: Suru Saha

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

Email : cfs@noaa.gov

Comparison of Seasonal Prediction CFSv1 (ops) and CFSv2 (next upgrade)

9-MONTH HINDCASTS

27 years: 1982-2008; 10 initial months.

→ Results shown for all 10 months, but maps only for 2 months

May ICs

CFSv1 : 15 members (Apr 9 - May 3)

CFSv2: 6x4=24 members (Apr 11, Apr 16, Apr 21, Apr 26, May 1 and May 6; 4 cycles each)

Sample size: 648 for CFSv2; 406 forCFSv1.

Nov ICs

CFSv1 : 15 members (Oct 9 – Nov 3)

CFSv2: 7x4=28 members (Oct 8, Oct 13, Oct 18, Oct 23, Oct 28, Nov 2 and Nov 7; 4 cycles each)

Sample size: 756 for CFSv2; 406 for CFSv1.

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)
- Variables/areas studied: US T, US P, global and Nino34 SST, global and Nino34 Prate.
- 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
CFSv1v2	15.4	12.2	78.3	57.0	45.4
CFSv1v2-CFSv2	-0.9	+2.7	+1.1	+2.5	+3.2
%tage change	(-5.8%)	(+22%)	(+1.4%)	(+4.4%)	(+7%)

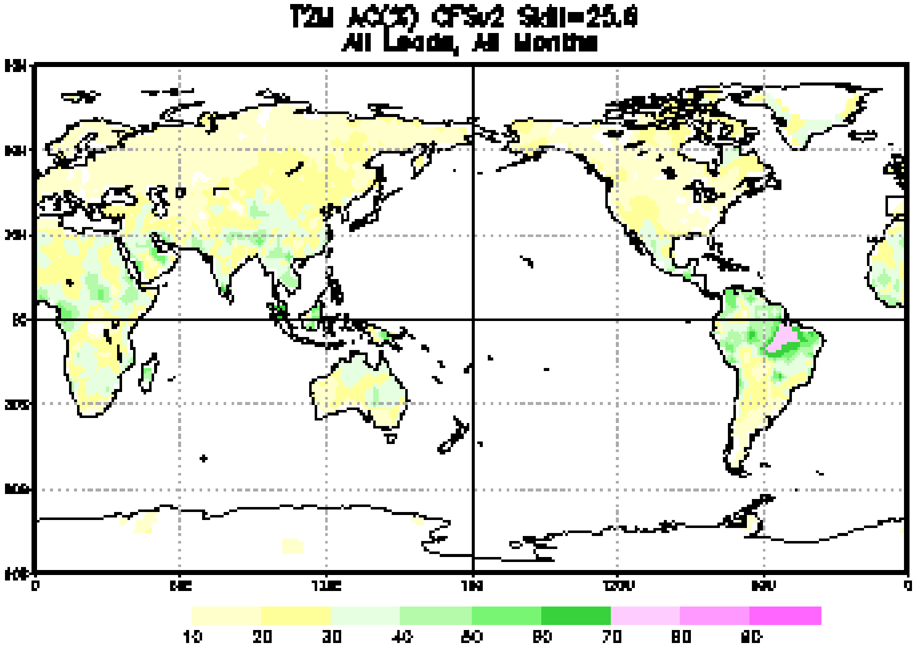
-0.077	0.117	-0.002	0.137	0.159	0.138	0.181	0.172	0	0	-0.075	0.057	8					
-0.023	-0.054	-0.018	-0.084	0.072	0.133	0.12	0.2	0	0	0.095	0	7					
0.023	-0.027	0	0.117	0.231	-0.061	0.185	0.036	0	0	0.18	-0.024	6		US	Tmp2m	v1	1982-2008
0.176	0.052	0.002	-0.069	0.1	0.071	-0.044	0.146	0	0	0.157	0.25	5					
0.277	-0.004	0.069	0.032	-0.01	0.029	0.039	0.054	0	0	0.105	0.211	4					
0.274	0.188	0.19	0.053	0	0.003	0.049	0.114	0	0	0.303	0.26	3					
0.107	0.21	0.256	0.128	-0.031	0.054	-0.044	0.141	0	0	0.191	0.162	2					
0.298	0.164	0.265	0.272	0.154	0.067	0.074	0.009	0	0	0.031	0.118	1	-0.084	-0.007	0.095	0.197	0.303
0.428	0.427	0.433	0.433	0.38	0.367	0.226	0.322	0	0	0.486	0.257	0					
jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	lead	min	ave-sd	ave	ave+sd	max

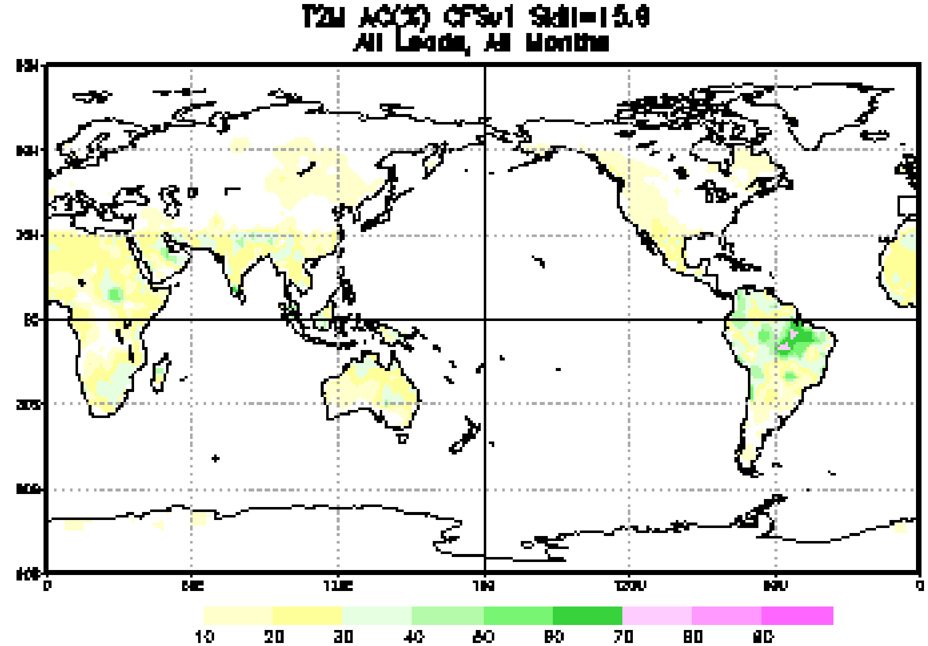
ave is calculated for all starting months and leads 1-8

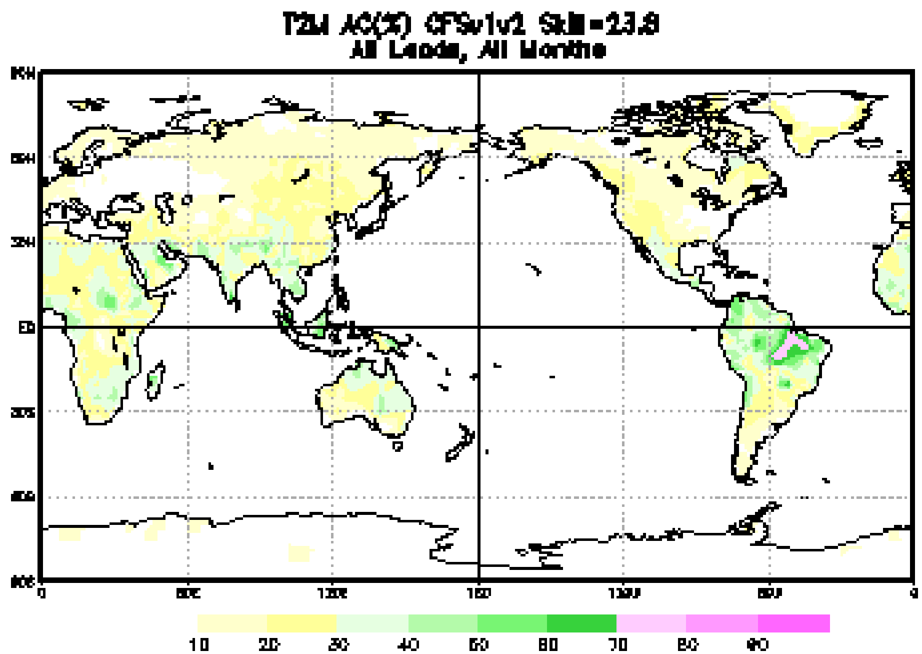
Anomaly Correlation for other Regions
(collaboration with EUROSIP and India)
All Leads (1-8), All Months (10)

Green is good **Red is not good**

Model	US T	Europe T	India T	US P	Europe P	India P
CFSv2	16.3	16.4	48.1	9.5	6.0	18.9
CFSv1	9.5	9.6	2.4	10.3	4.5	18.0
CFSv1v2 CFSv1v2-CFSv2 %tage change	15.4 -0.9 (-5.8%)	15.5 -0.9 (-5.8%)	30.7 -18.1 (-59%)	12.2 +2.7 (+22%)	6.2 +0.2 (+3.2%)	22.8 (+3.9) (+17.1%)

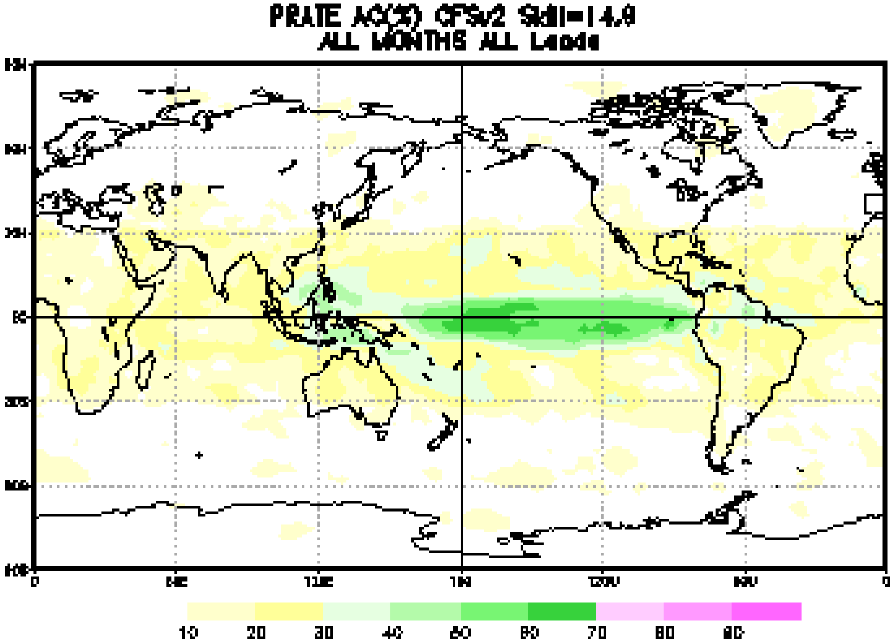


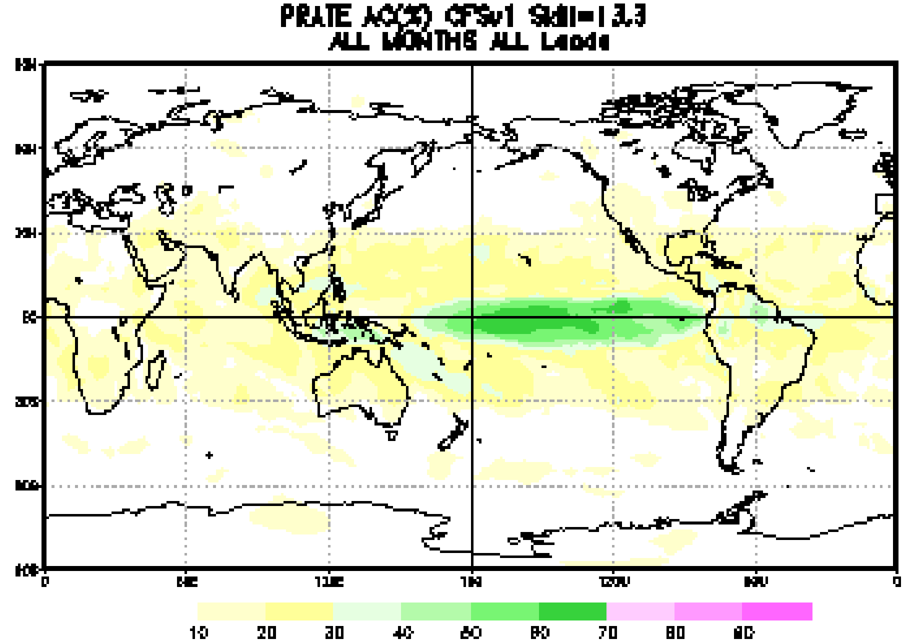


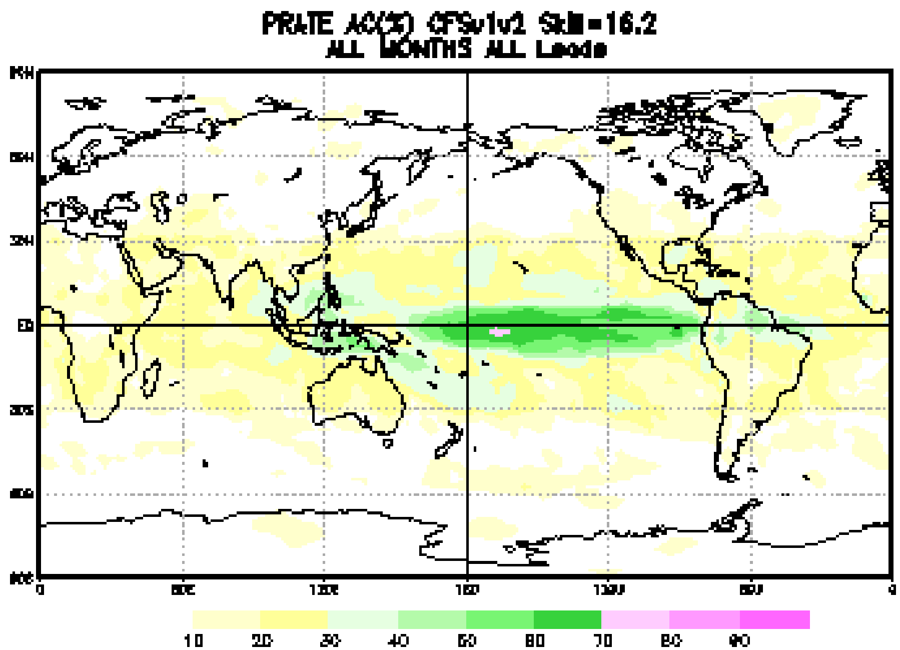


More skill globally for CFSv2

HUUG VAN DEN DOOL, CPC/NCEP/NWS/NOAA

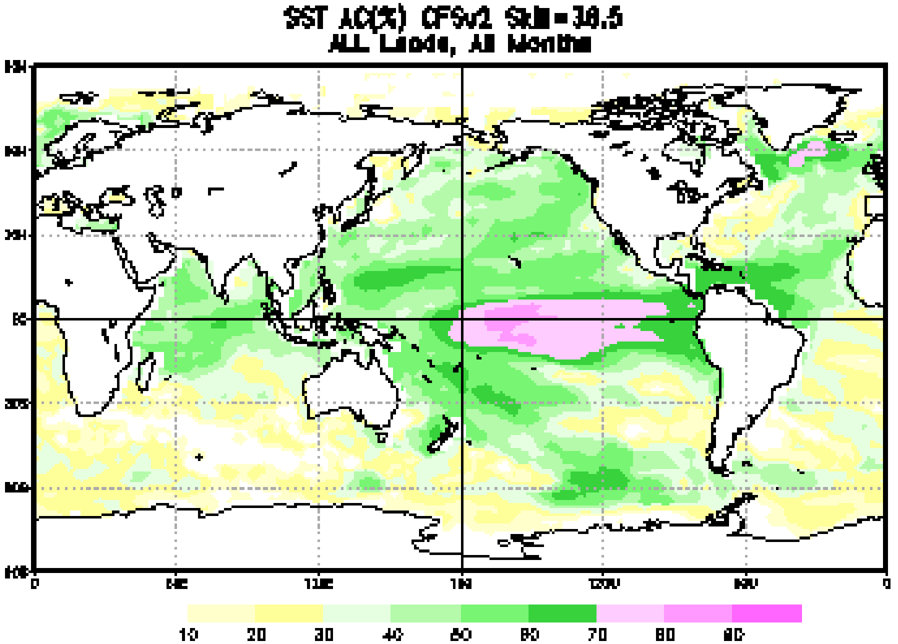


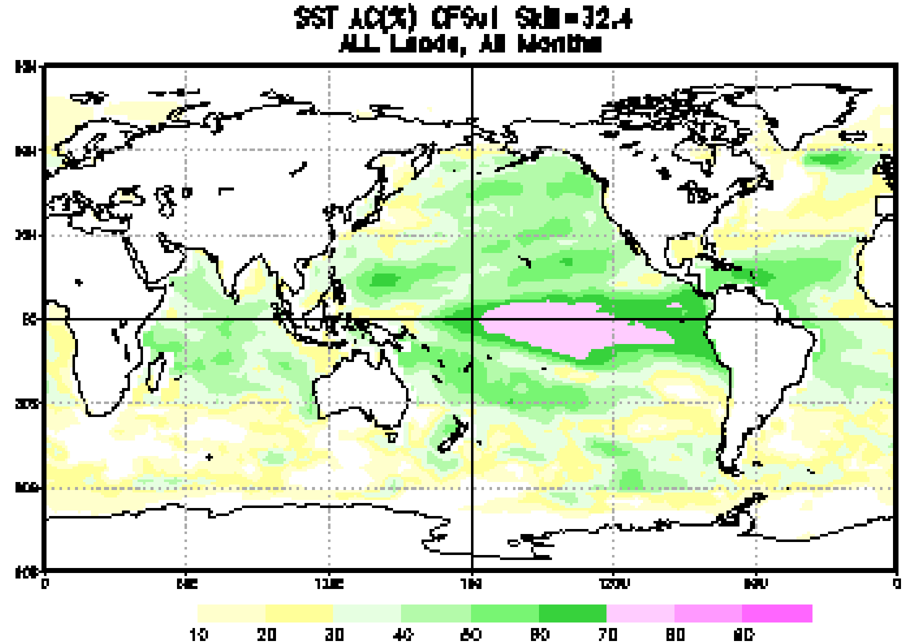


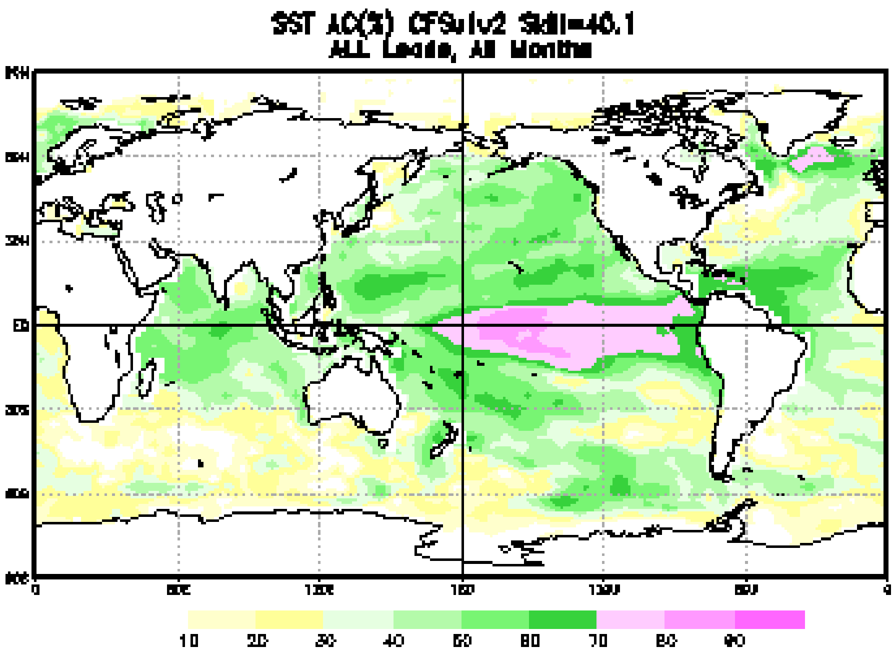


More skill in the western Pacific for CFSv2

HUUG VAN DEN DOOL. CPC/NCEP/NWS/NOAA







More skill west of the dateline and over the Atlantic for CFSv2

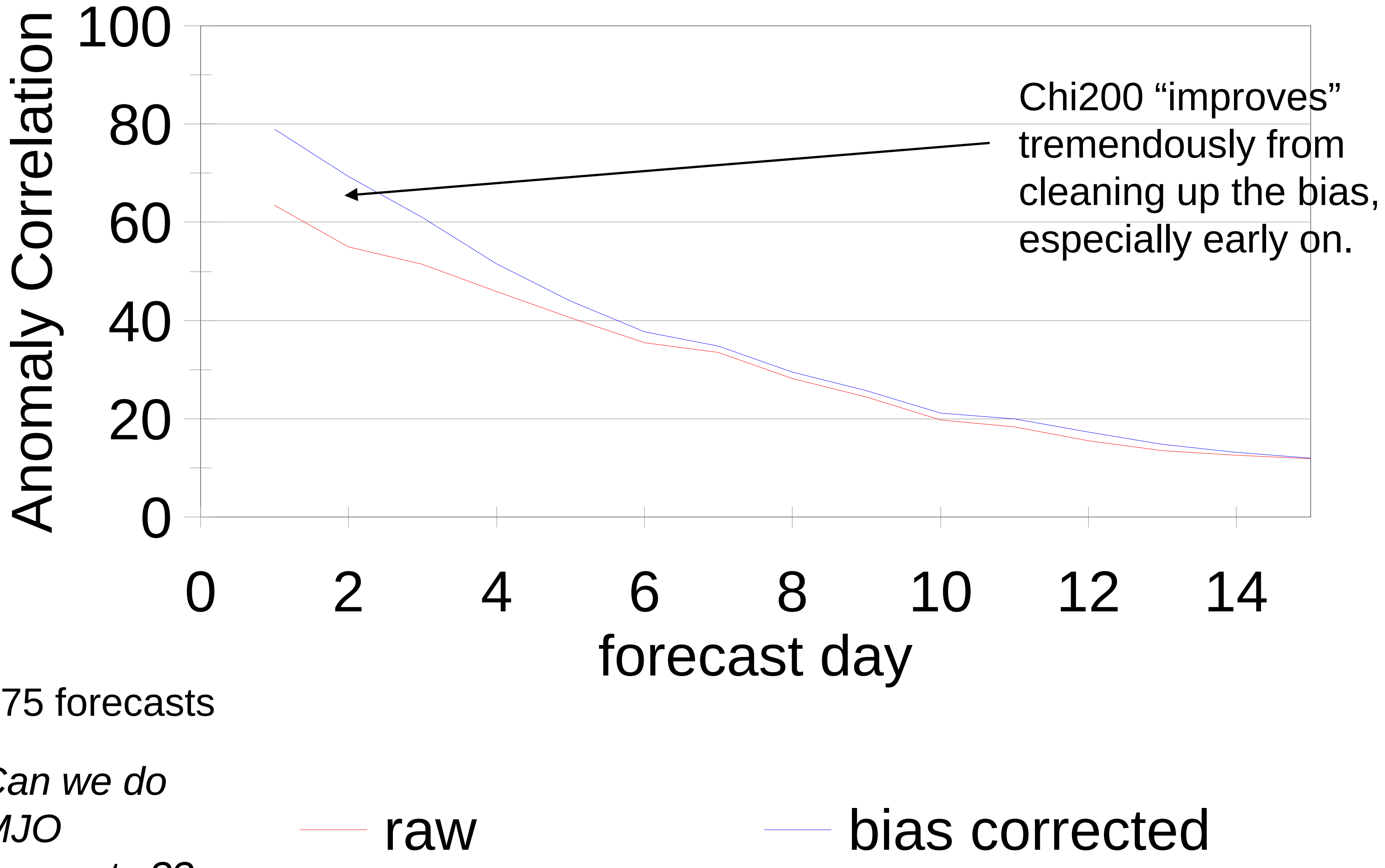
HUUG VAN DEN DOOL, CPC/NCEP/NWS/NOAA

Switch gears to 45 day forecasts from CFSR

Daily CFS Scores

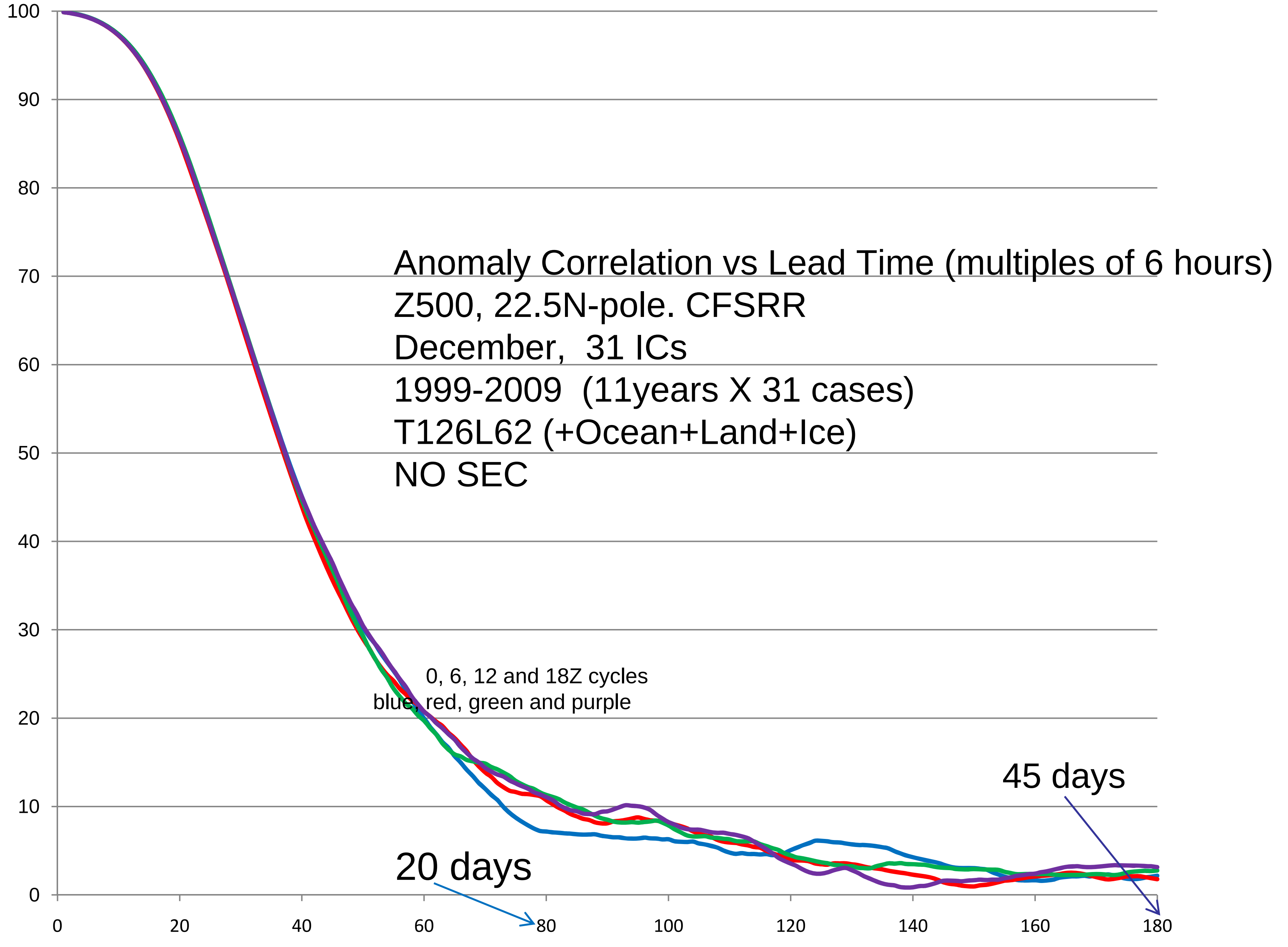
OLD!
v1

CHI200 1981-2005 TR December



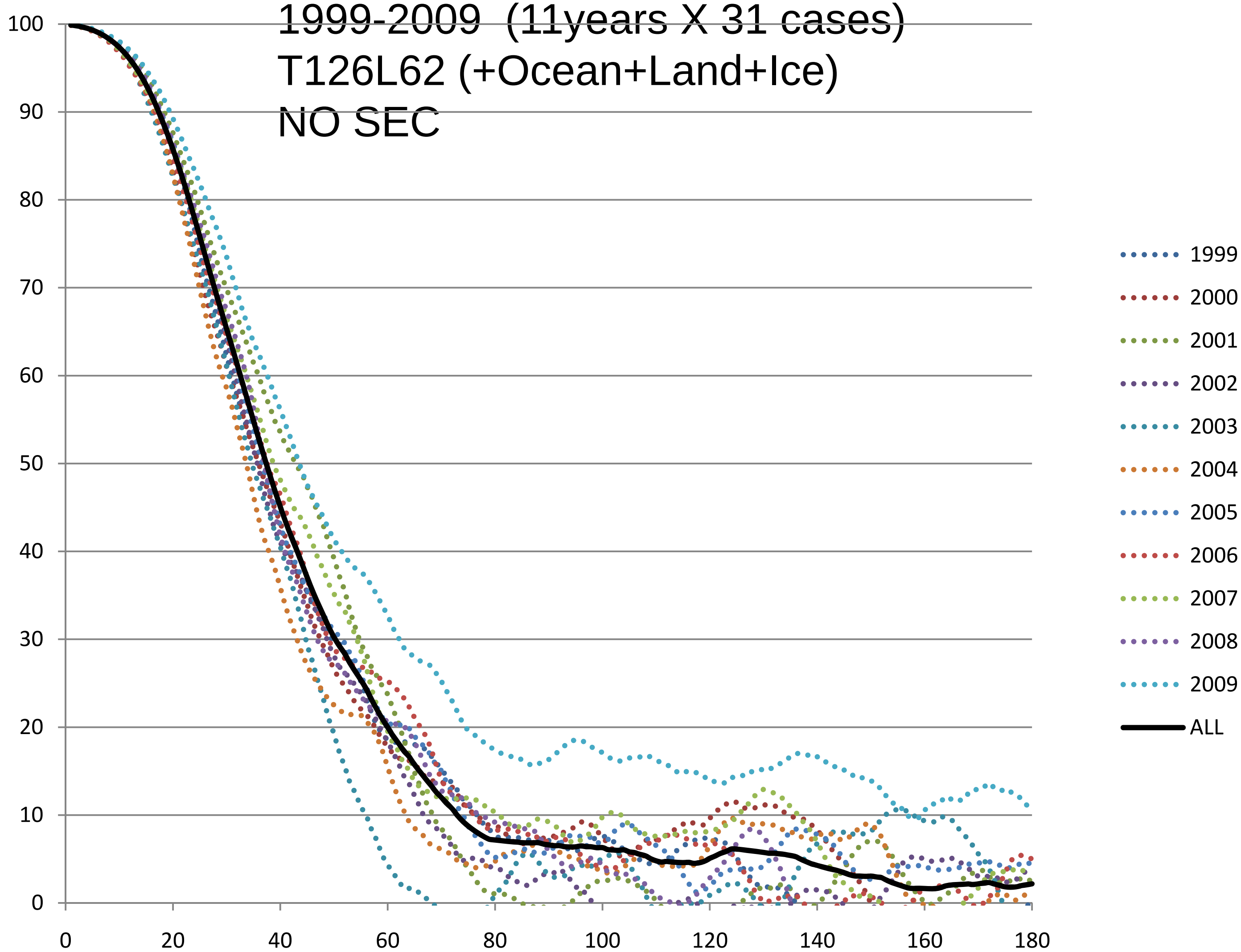
375 forecasts

Can we do MJO forecasts ??

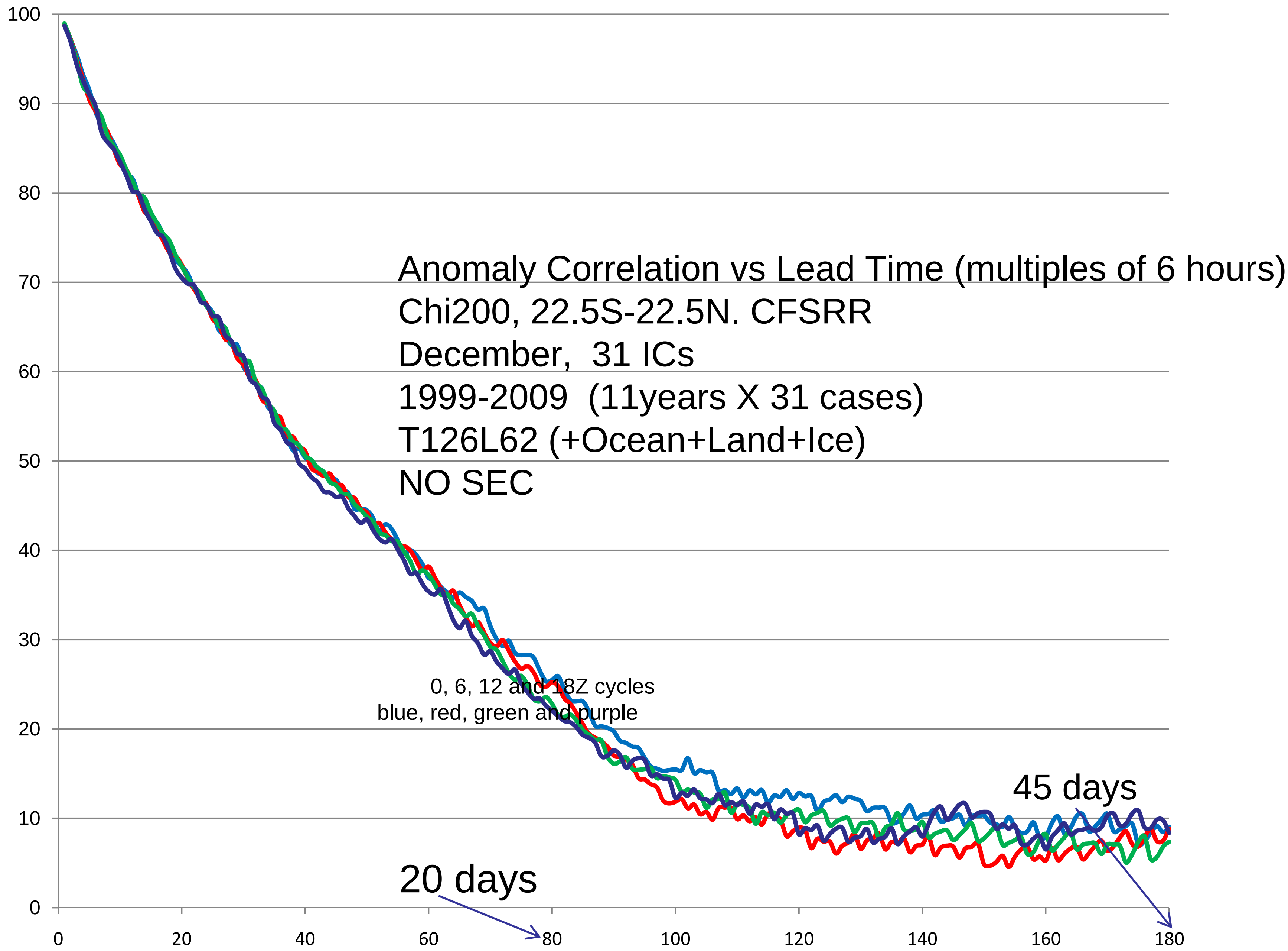


Anomaly Correlation vs Lead Time (multiples of 6 hours)
Z500, 22.5N-pole. CFSRR
December, 31 ICs
1999-2009 (11years X 31 cases)
T126L62 (+Ocean+Land+Ice)
NO SEC
0, 6, 12 and 18Z cycles
blue, red, green and purple
20 days
45 days
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180

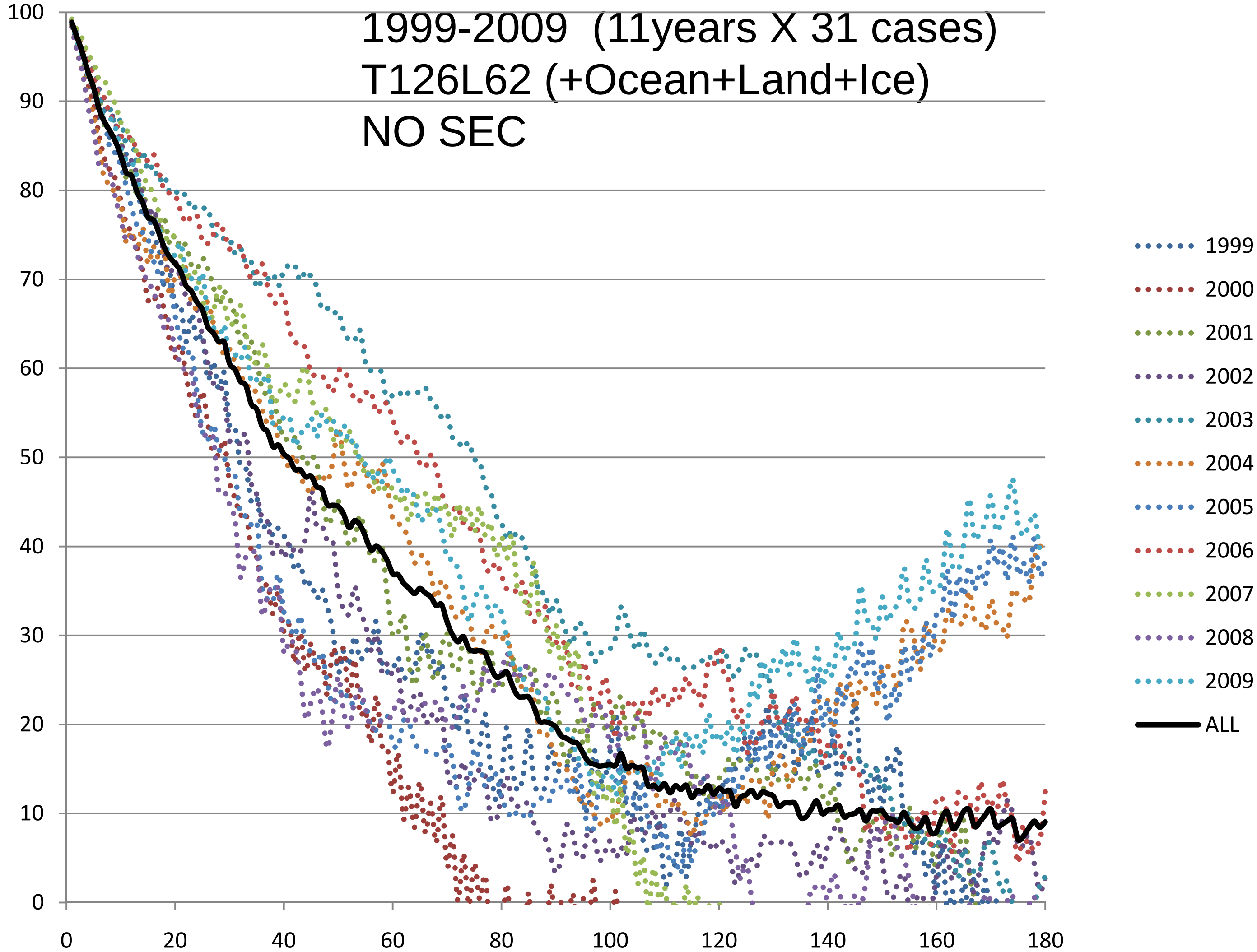
Anomaly Correlation vs Lead Time (multiples of 6 hours)
Z500, 22.5N-pole. CFSRR
December, 31 ICs
1999-2009 (11years X 31 cases)
T126L62 (+Ocean+Land+Ice)
NO SEC



Is 2009 a bit special?


Anomaly Correlation vs Lead Time (multiples of 6 hours)
Chi200, 22.5S-22.5N. CFSRR
December, 31 ICs
1999-2009 (11years X 31 cases)
T126L62 (+Ocean+Land+Ice)
NO SEC
0, 6, 12 and 18Z cycles
blue, red, green and purple
45 days
20 days
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180

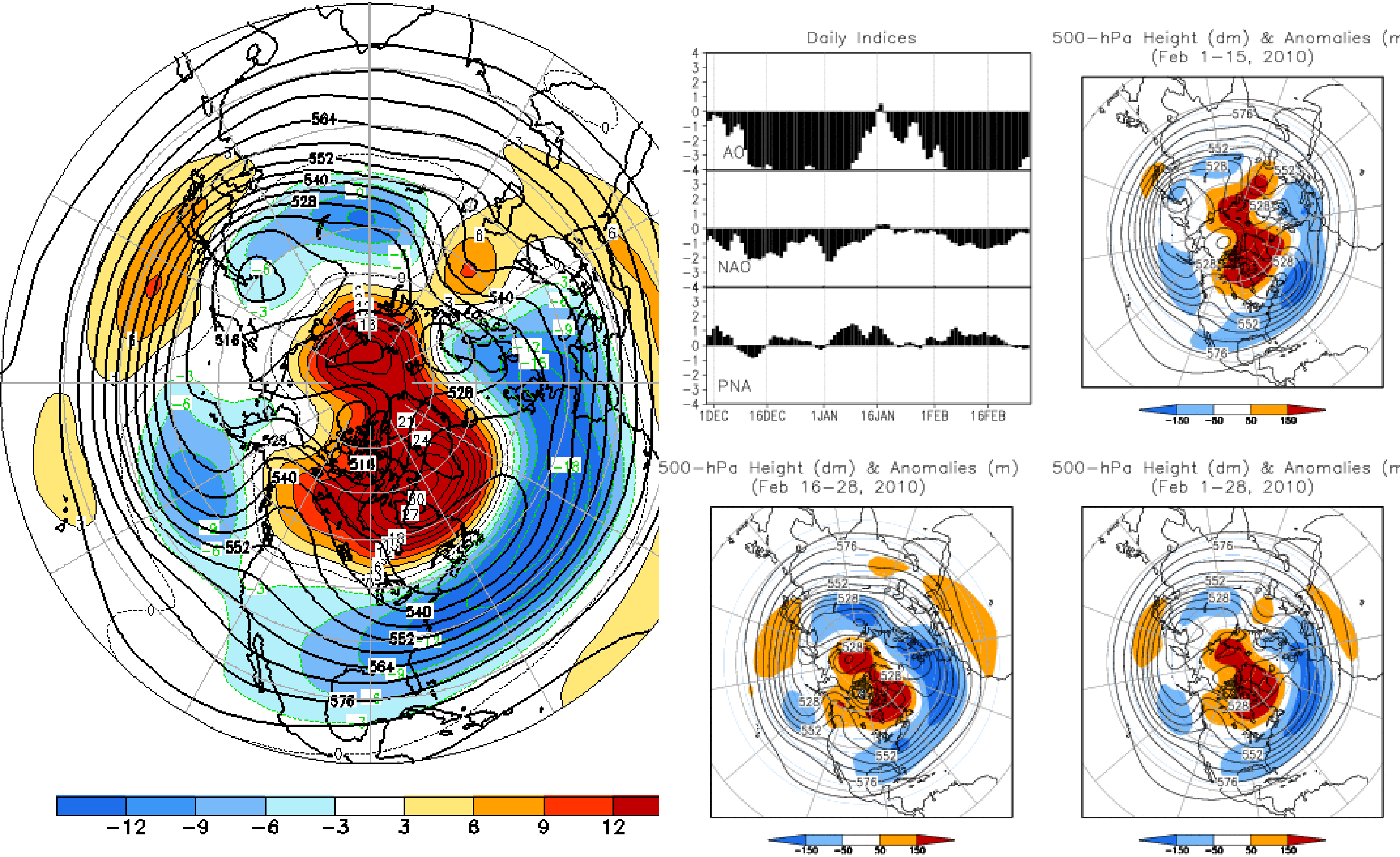
Anomaly Correlation vs Lead Time (multiples of 6 hours)
Chi200, 22.5S-22.5N. CFSRR
December, 31 ICs
1999-2009 (11years X 31 cases)
T126L62 (+Ocean+Land+Ice)
NO SEC

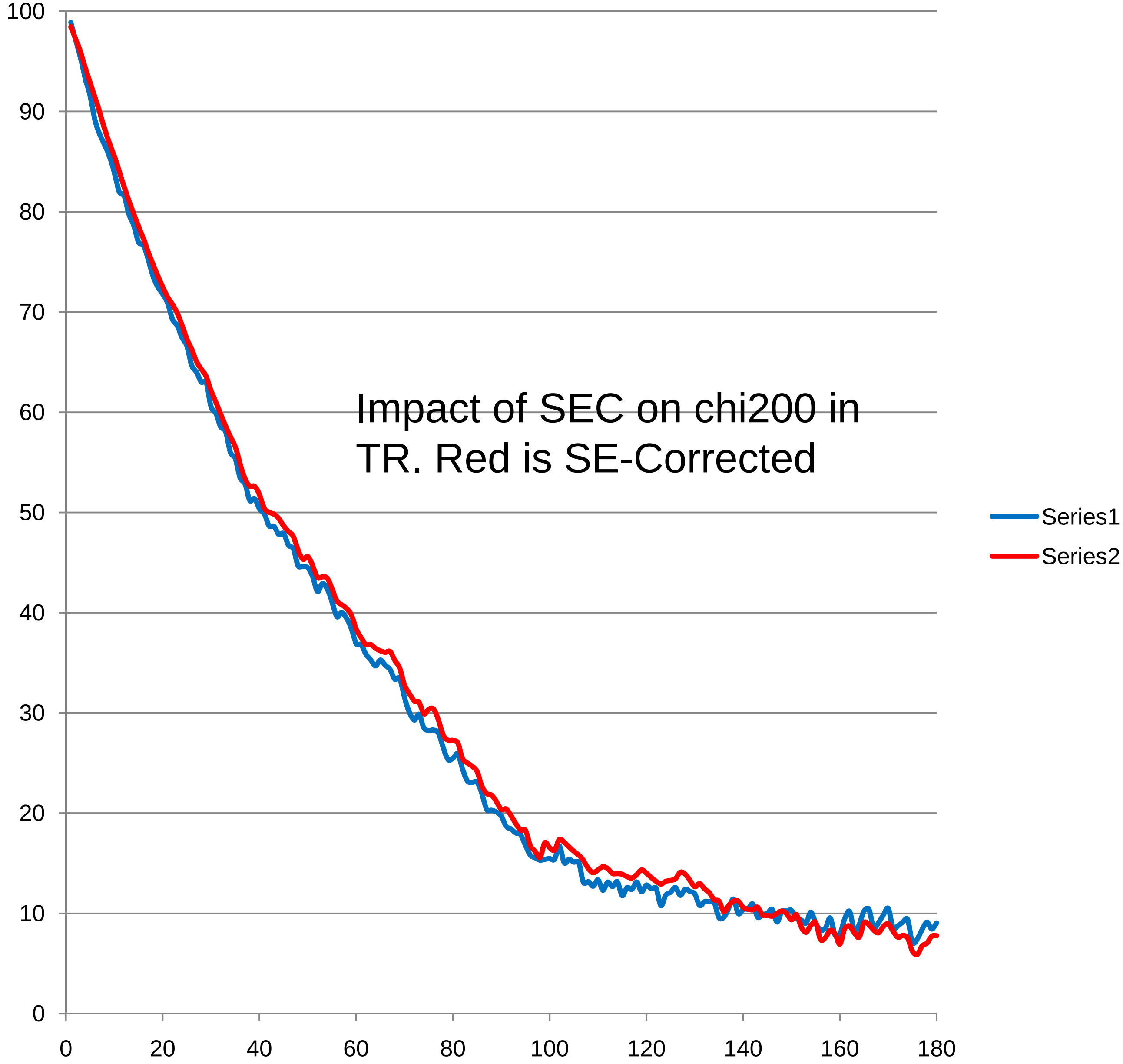


Is 2009 a bit special?

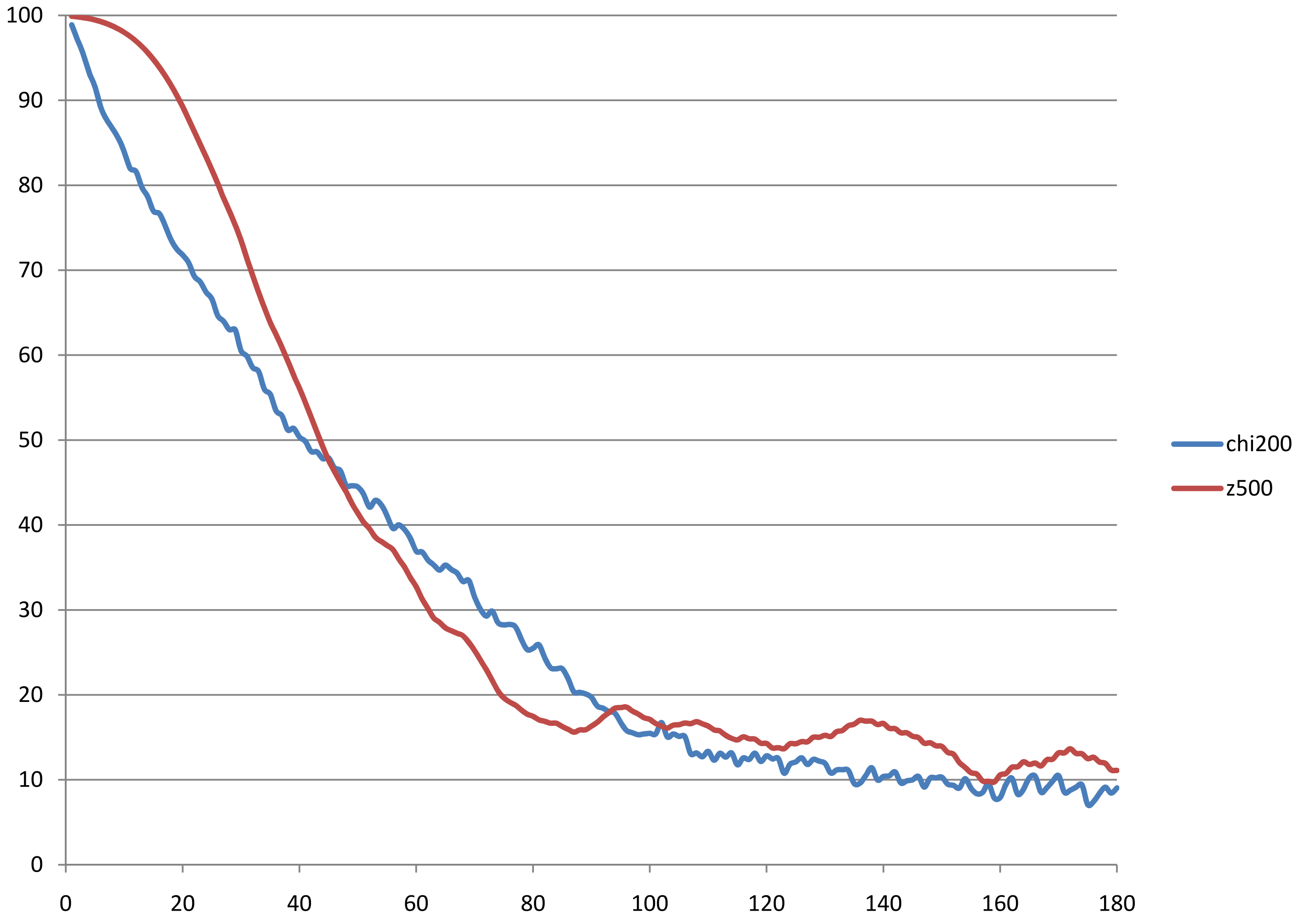
February 2010

500-hPa Height and Anomaly



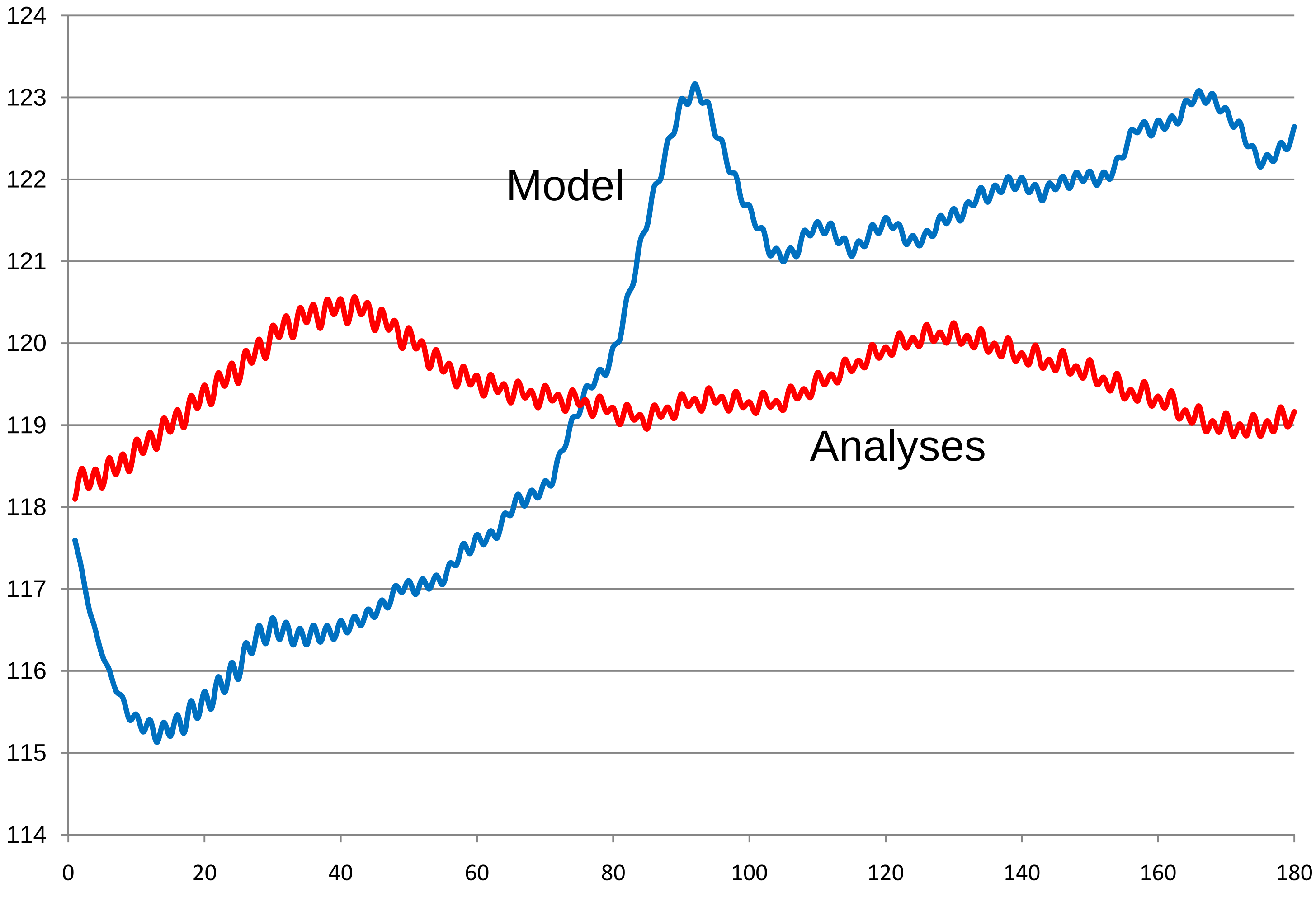


100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
Impact of SEC on chi200 in TR. Red is SE-Corrected
Series1
Series2

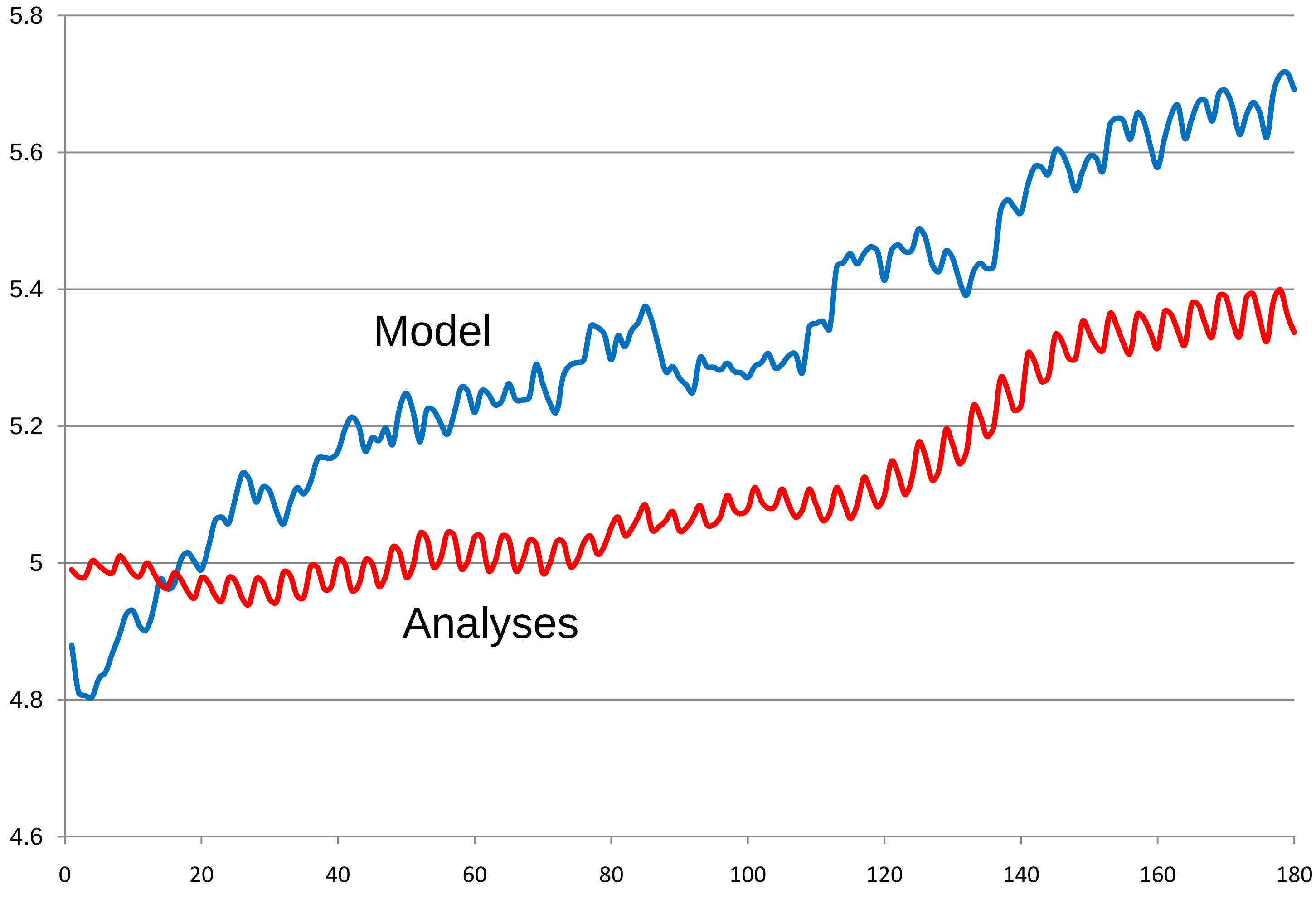


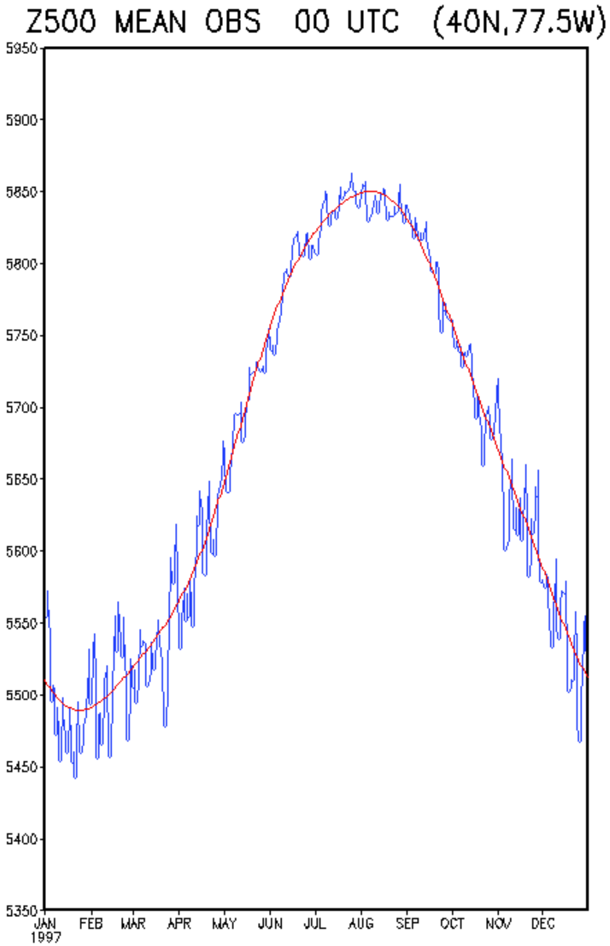
Early error growth in z500 (chi200)
dominated by internal (systematic)

Standard deviations of 500 mb height



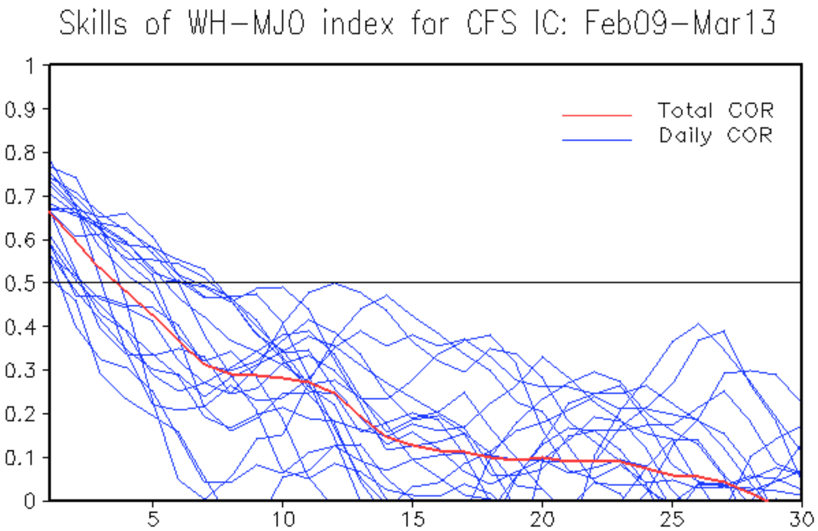
Standard deviations of 200 mb chi

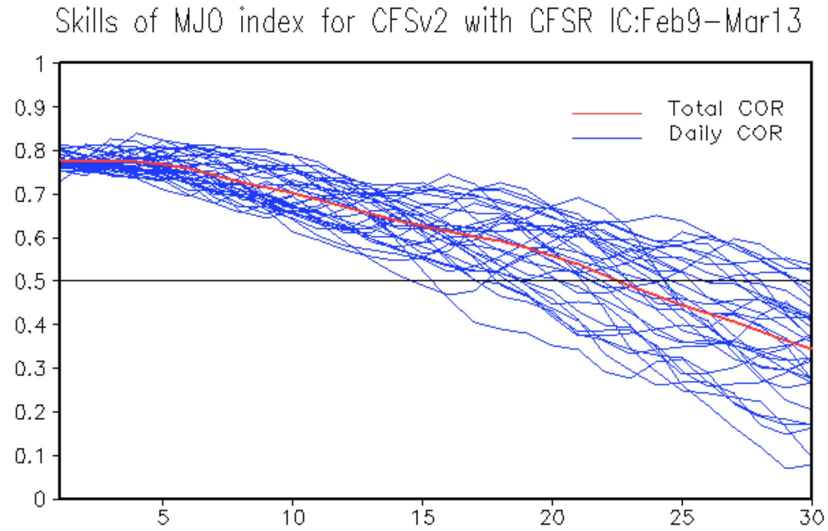


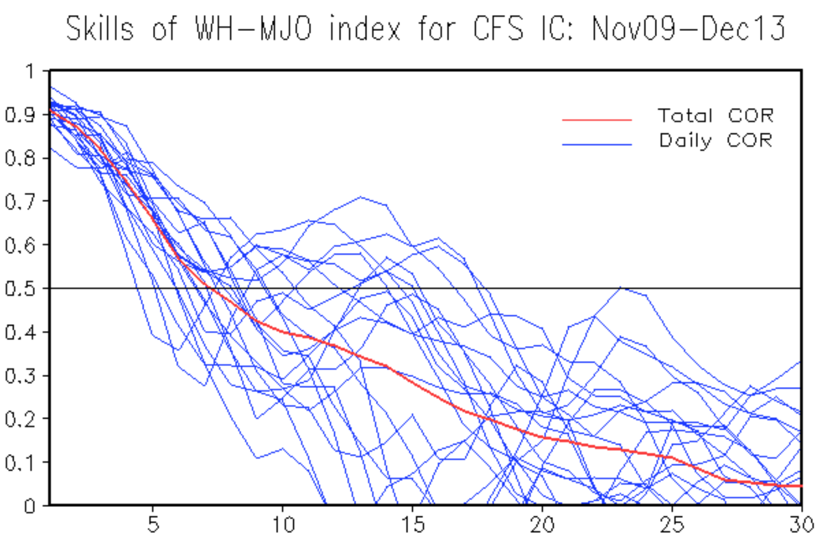


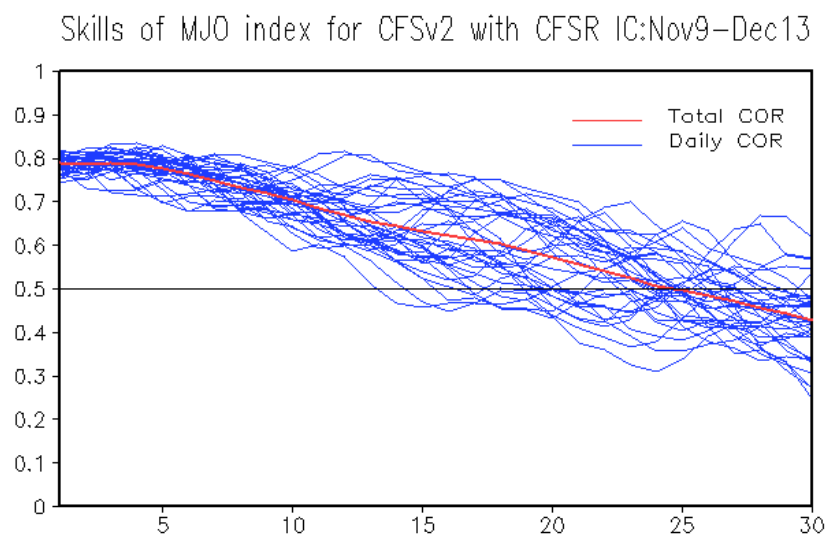
The observed climatological annual cycle of the 500mb geopotential height at a grid point close to Washington, DC, is shown as a smooth red curve based on four harmonics. The 24-yr mean values as calculated directly from the data are shown by the blue curves. Unit is m. (Johansson, Thiaw and Saha 2007)

OLD v1 | New v2









Period 1982 - 2008

Courtesy: Qin Zhang

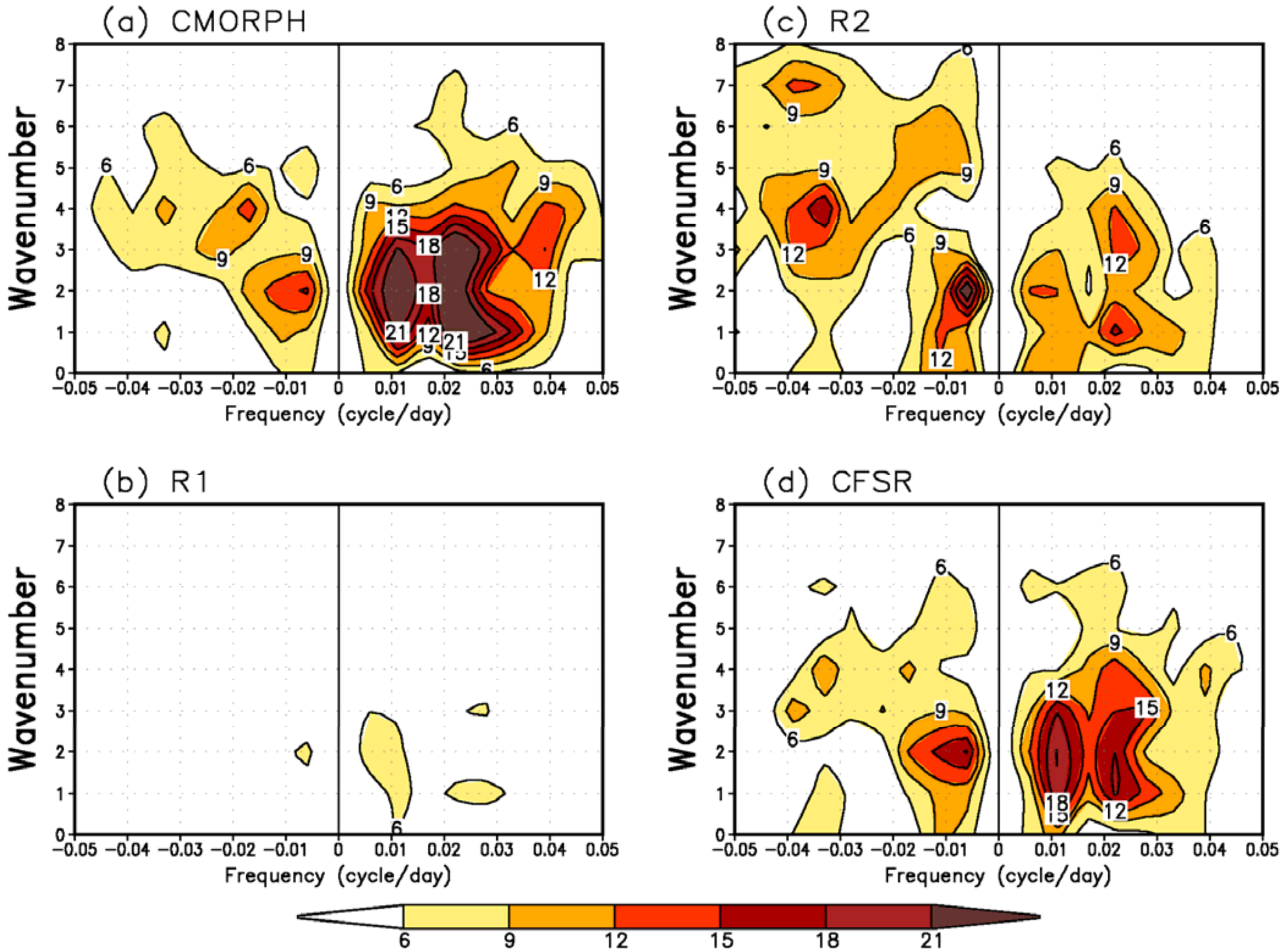


Fig. 1 Wavenumber-frequency spectra of 10S-10N average of raw daily–mean anomalies of precipitation. (a) CMORPH, (b) R1, (c) R2, and (d) CFSR. The unit is 0.0001 $mm^2 days^{-2}$. Contours are shaded starting at 6 with an interval of 3.

Courtesy: Jiande Wang et al

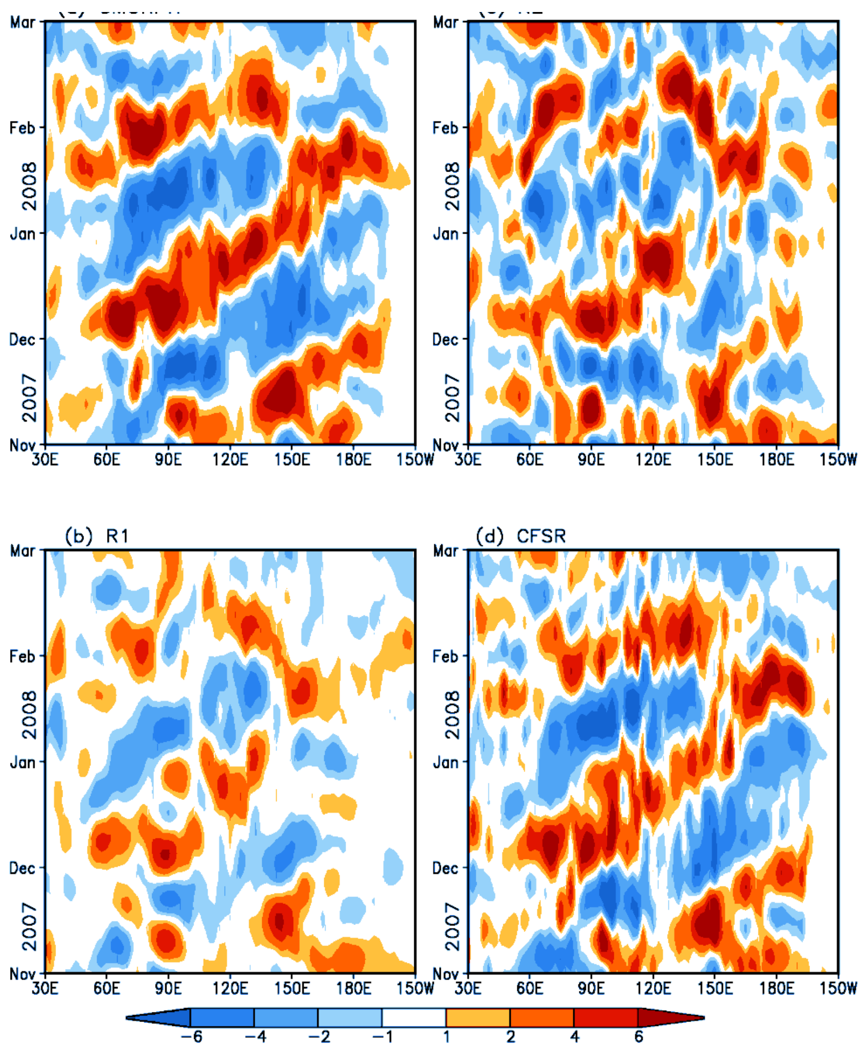


Fig. 2. Time evolution of 10S-10N average intraseasonal precipitation for 01Nov2007-01mar2008.
The anomalies are shaded starting at -6, -4, -2, -1, 1 2 4 and 6 mm/day.

Courtesy: Jiande Wang et al

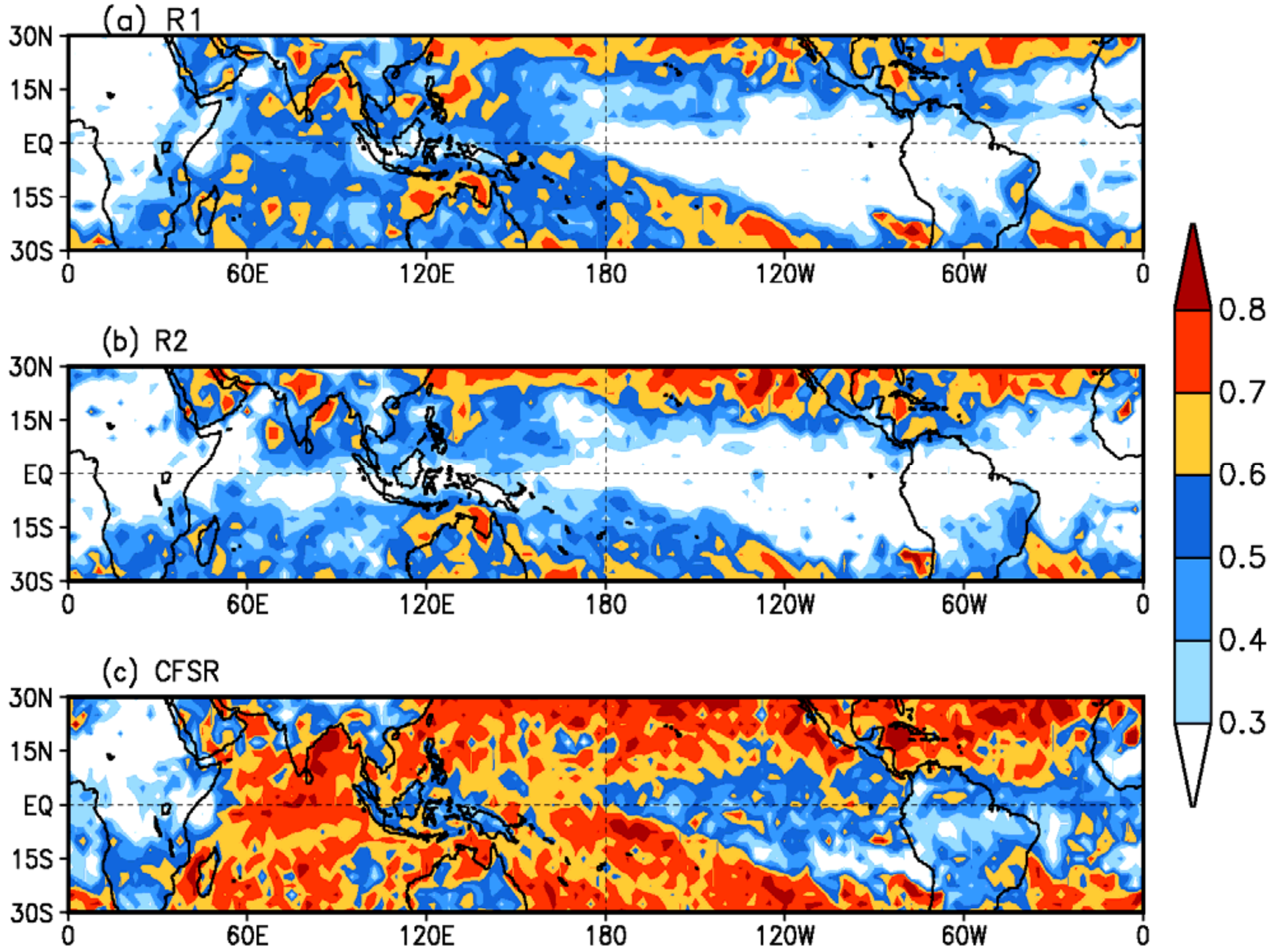


Fig. 3 Correlation of intraseasonal precipitation with CMORPH. (a) R1, (b) R2, and (c) CFSR. Contours are shaded starting at 0.3 with 0.1 interval.

Courtesy: Jiande Wang et al

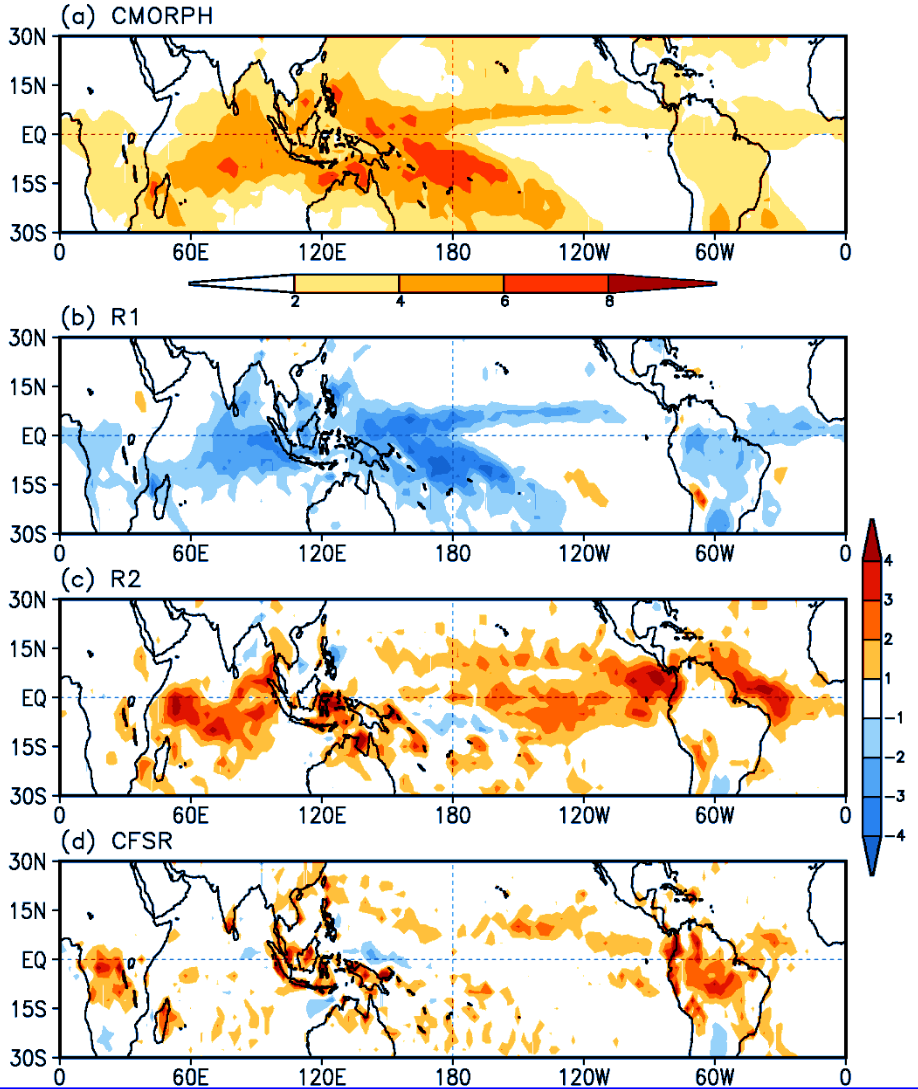
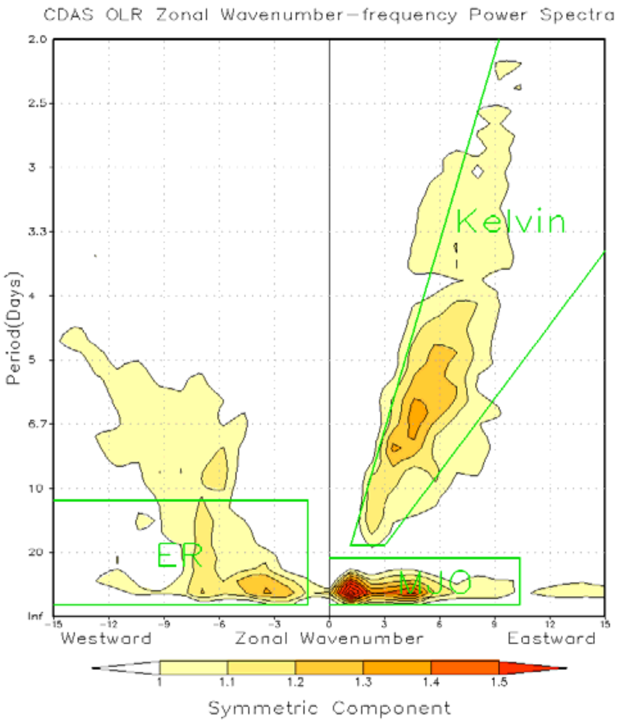
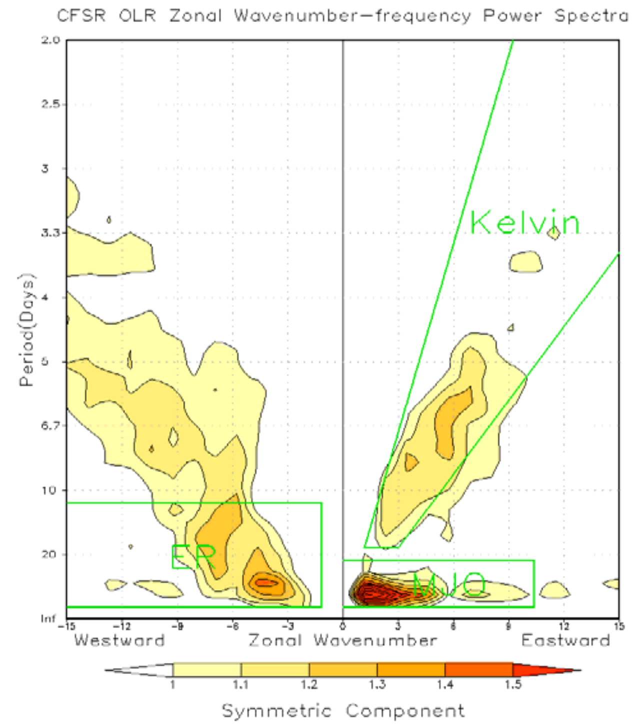
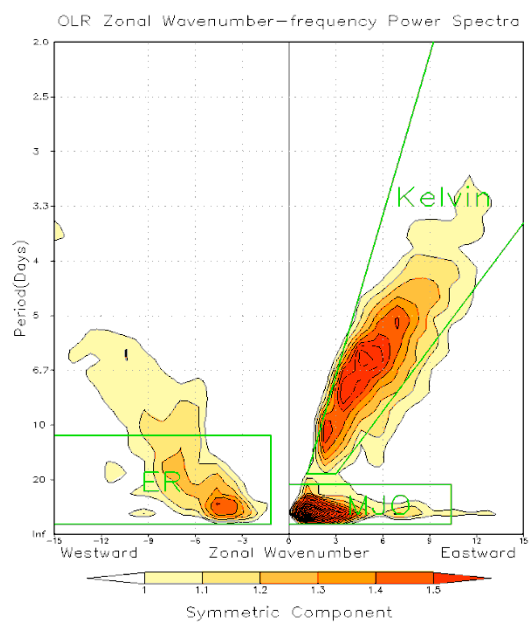


Fig. 4. (a) Standard deviation of intraseasonal rainfall anomalies from CMORPH. (b) differences in standard deviation of intraseasonal rainfall anomalies between R1 and CMORPH. (c) As in (b) except for R2. (d) As in (b) except for CFSR. Contours are shaded at an interval of 2 mm/day in (a) and 1 mm/day in (b), (c) and (d) with values between -1 and 1 plotted as white.

Courtesy: Jiande Wang et al


CDAS OLR Zonal Wavenumber−frequency Power Spectra
Period(Days)
2.0
2.5
3
3.3
4
5
6.7
10
20
Inf
-15
-12
-9
-6
-3
0
3
6
9
12
15
Westward
Zonal Wavenumber
Eastward
Kelvin
ER
MJO
1
1.1
1.2
1.3
1.4
1.5
Symmetric Component


CFSR OLR Zonal Wavenumber−frequency Power Spectra
Period(Days)
2.0
2.5
3
3.3
4
5
6.7
10
20
Inf
-15
-12
-9
-6
-3
0
3
6
9
12
15
Westward
Zonal Wavenumber
Eastward
Kelvin
ER
MJO
1
1.1
1.2
1.3
1.4
1.5
Symmetric Component


OLR Zonal Wavenumber−frequency Power Spectra
Period(Days)
2.0
2.5
3
3.3
4
5
6.7
10
20
Inf
-15
-12
-9
-6
-3
0
3
6
9
12
15
Westward
Zonal Wavenumber
Eastward
Kelvin
ER
MJO
1
1.1
1.2
1.3
1.4
1.5
Symmetric Component

MME (CFS and CCSM)

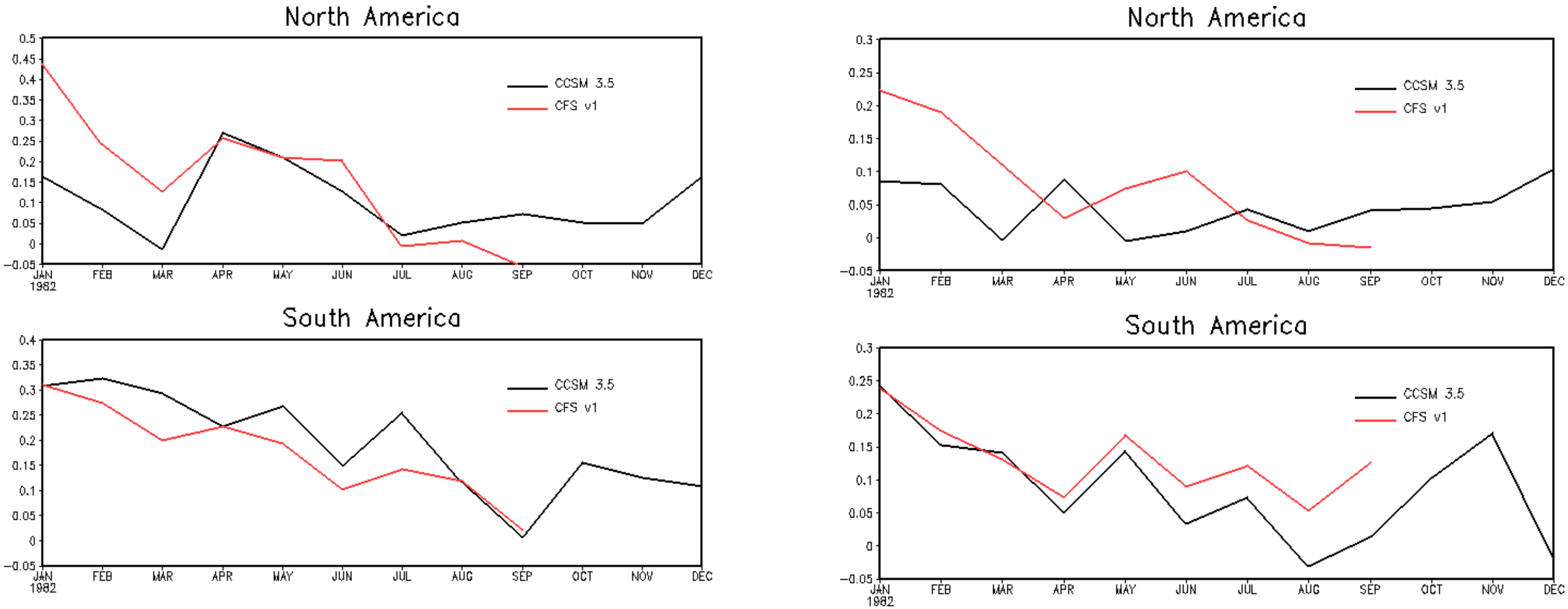


Fig.2 Anomaly Correlation of forecast for T2M (left) and PRATE (right) as a function of lead time (in months) for North America and South America. Black lines denote AC for CCSM and red lines for CFSv1 forecasts.

Evaluation of CCSM and operational CFS for monthly forecasts of precipitation and temperature over the Americas*

Malaquías Peña, Huug van den Dool, Emily Becker, and Ben Kirtman

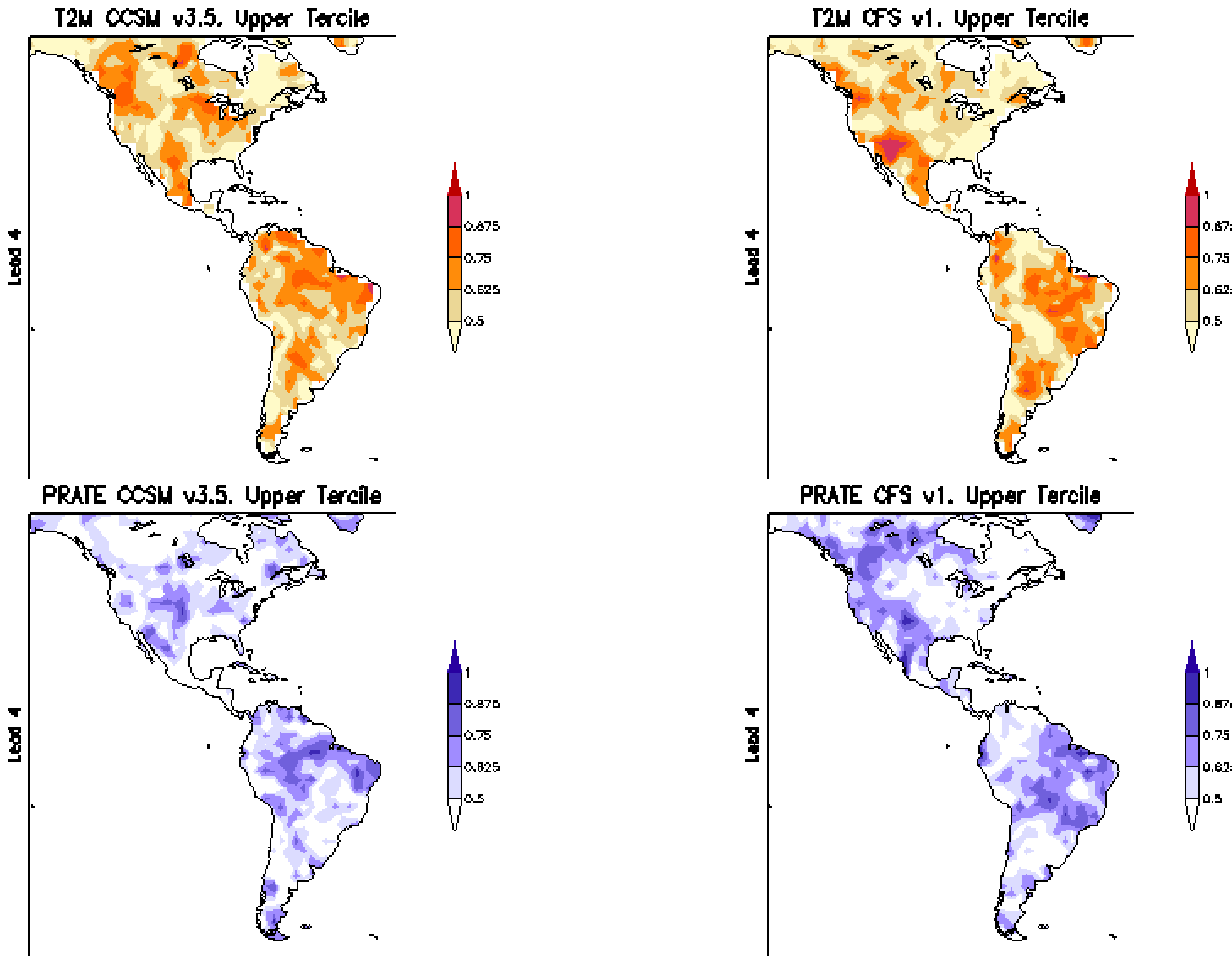


Fig.5 Area below the Relative Operating Curve. Three classes (terciles) of events were analyzed.Only the upper terciles is shown for T2M (top) and PRATE (bottom). Values above 0.5 means the forecast is able to anticipate the event with more skill than a random forecast. Values above 0.6 are generally considered useful.

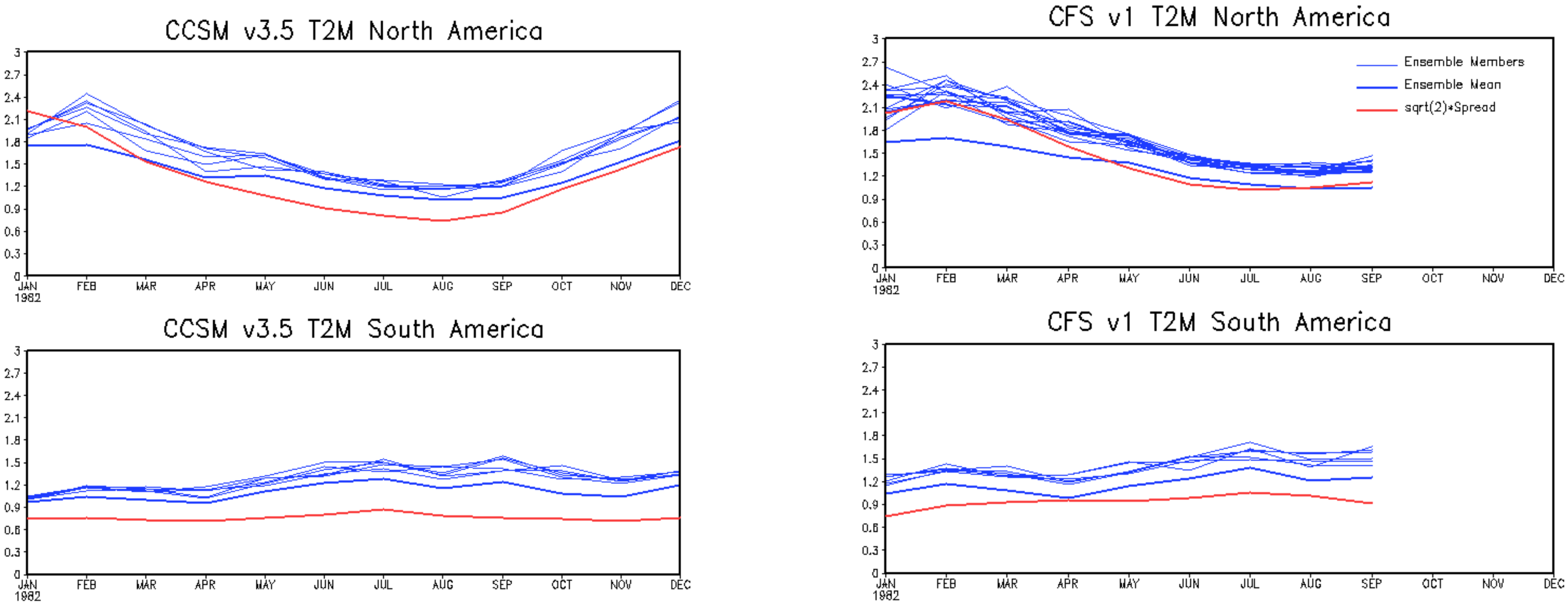


Fig 4. RMSE (after SE error correction) and ensemble spread as a function of lead time for CCSM (left panels) and CFS (right panels). Most of the errors are near saturation by the end of lead 0, thus the RMSE basically reflects the seasonality of the forecast error variance.

MME and extremes prediction

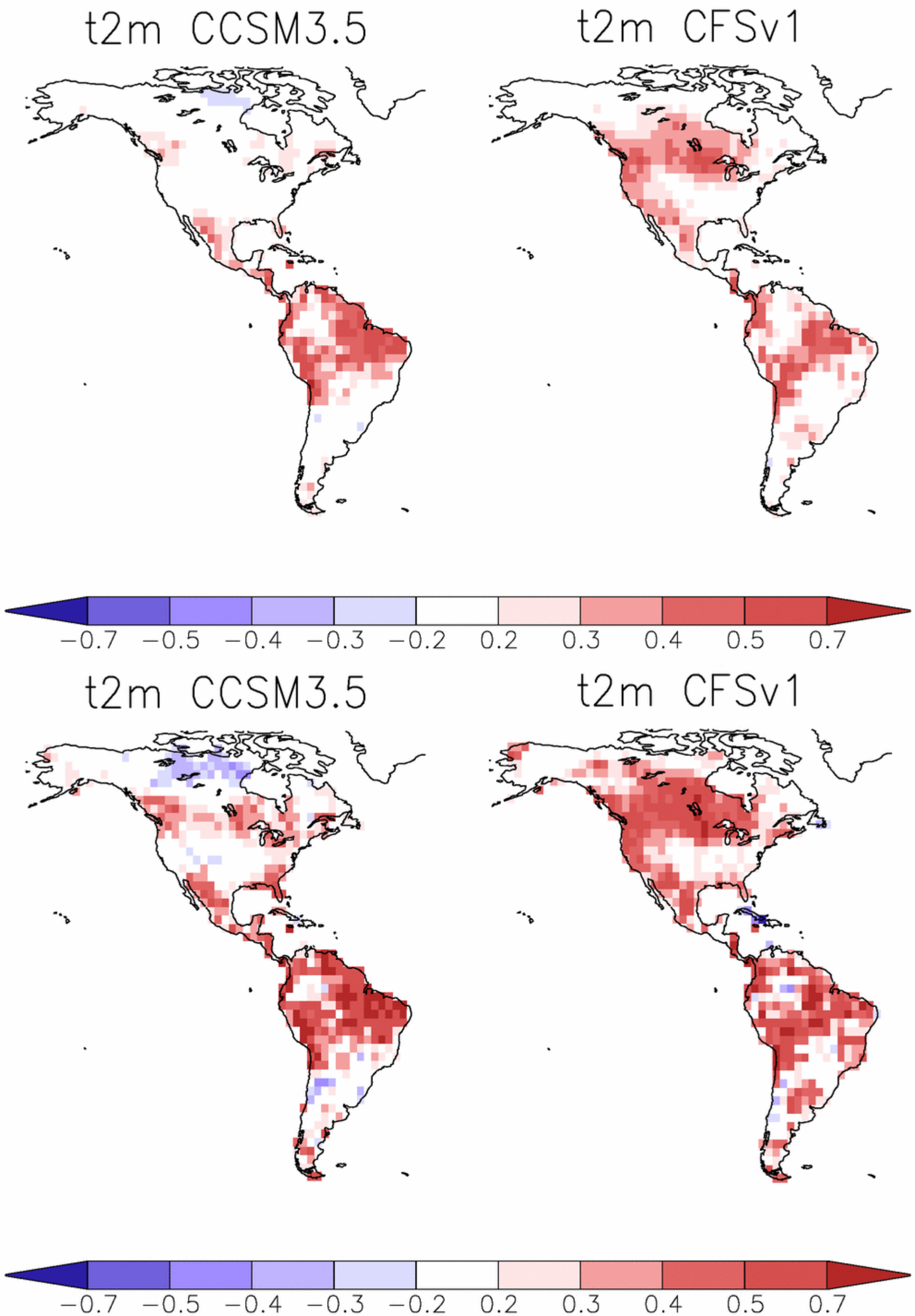
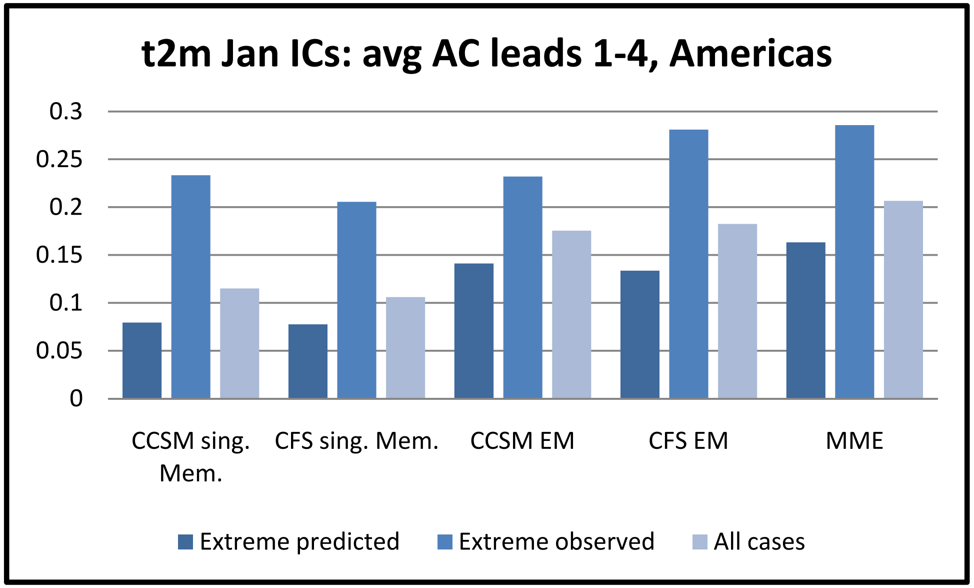
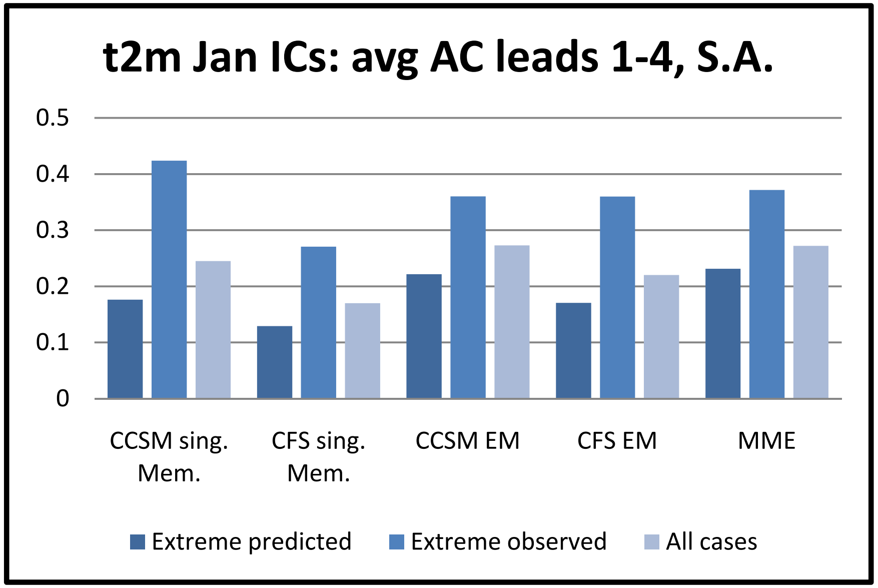
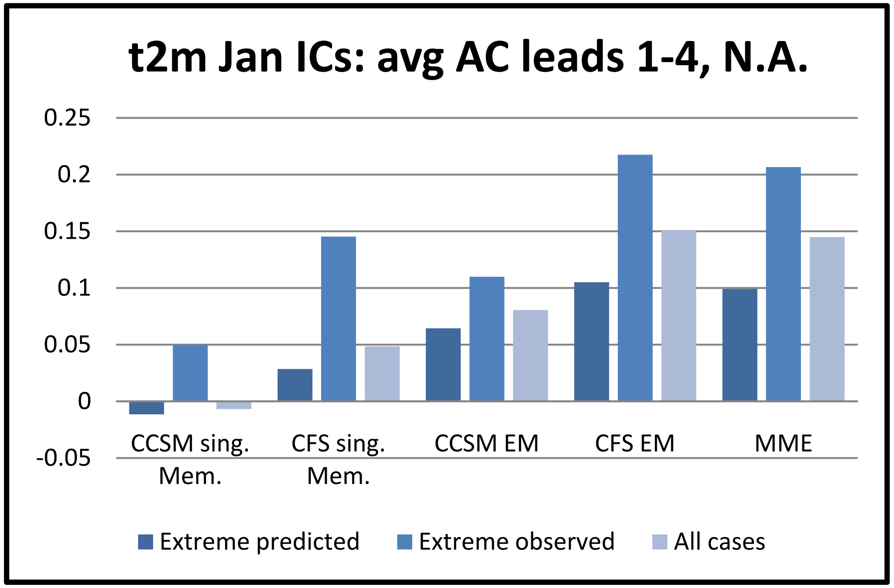
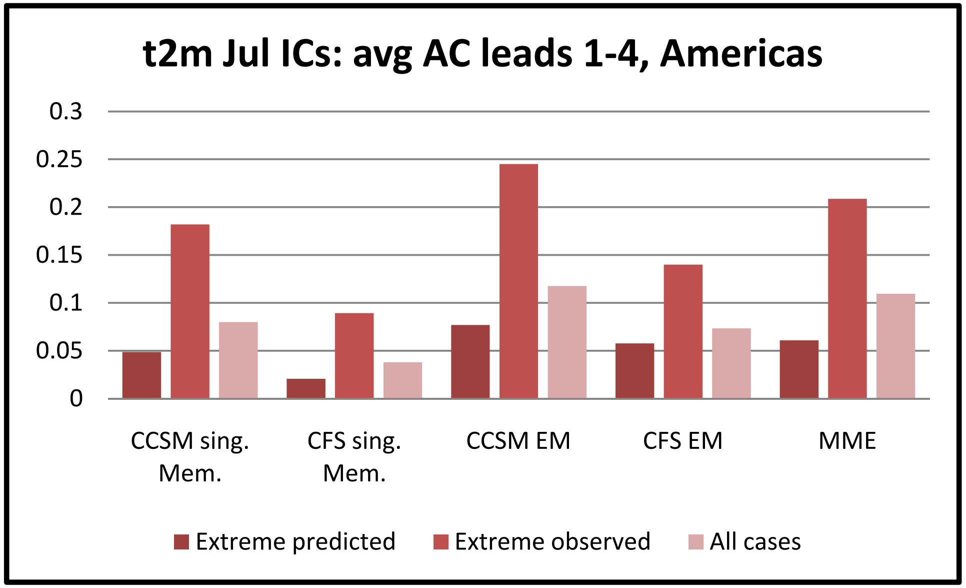


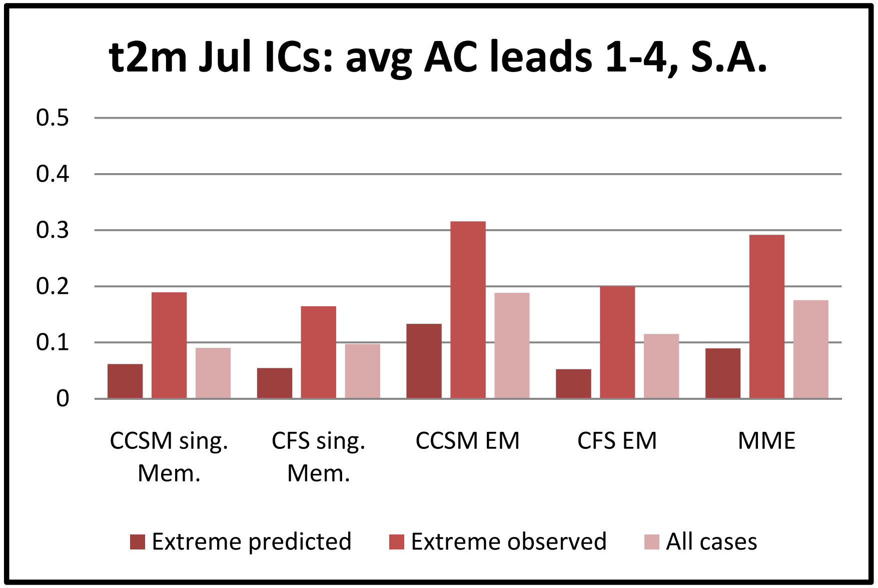
Fig 3. Anomaly correlation of ensemble mean forecasts for leads 0 to 4 combined for (top; threshold=0) all cases and for (bottom; threshold=1 S.D.) anomalies whose amplitude exceed 1 standard deviation with respect to the monthly mean. Note the higher AC scores for high amplitude anomalies. For both models there is an increase of AC as the threshold increases

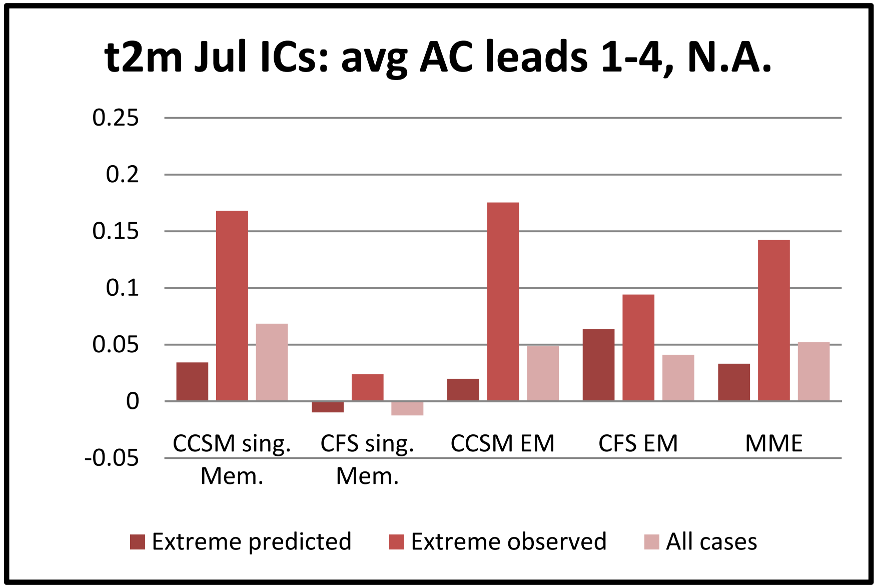

t2m Jan ICs: avg AC leads 1-4, Americas
0.3
0.25
0.2
0.15
0.1
0.05
0
CCSM sing. Mem.
CFS sing. Mem.
CCSM EM
CFS EM
MME
Extreme predicted
Extreme observed
All cases


t2m Jan ICs: avg AC leads 1-4, S.A.
0.5
0.4
0.3
0.2
0.1
0
CCSM sing. Mem.
CFS sing. Mem.
CCSM EM
CFS EM
MME
Extreme predicted
Extreme observed
All cases

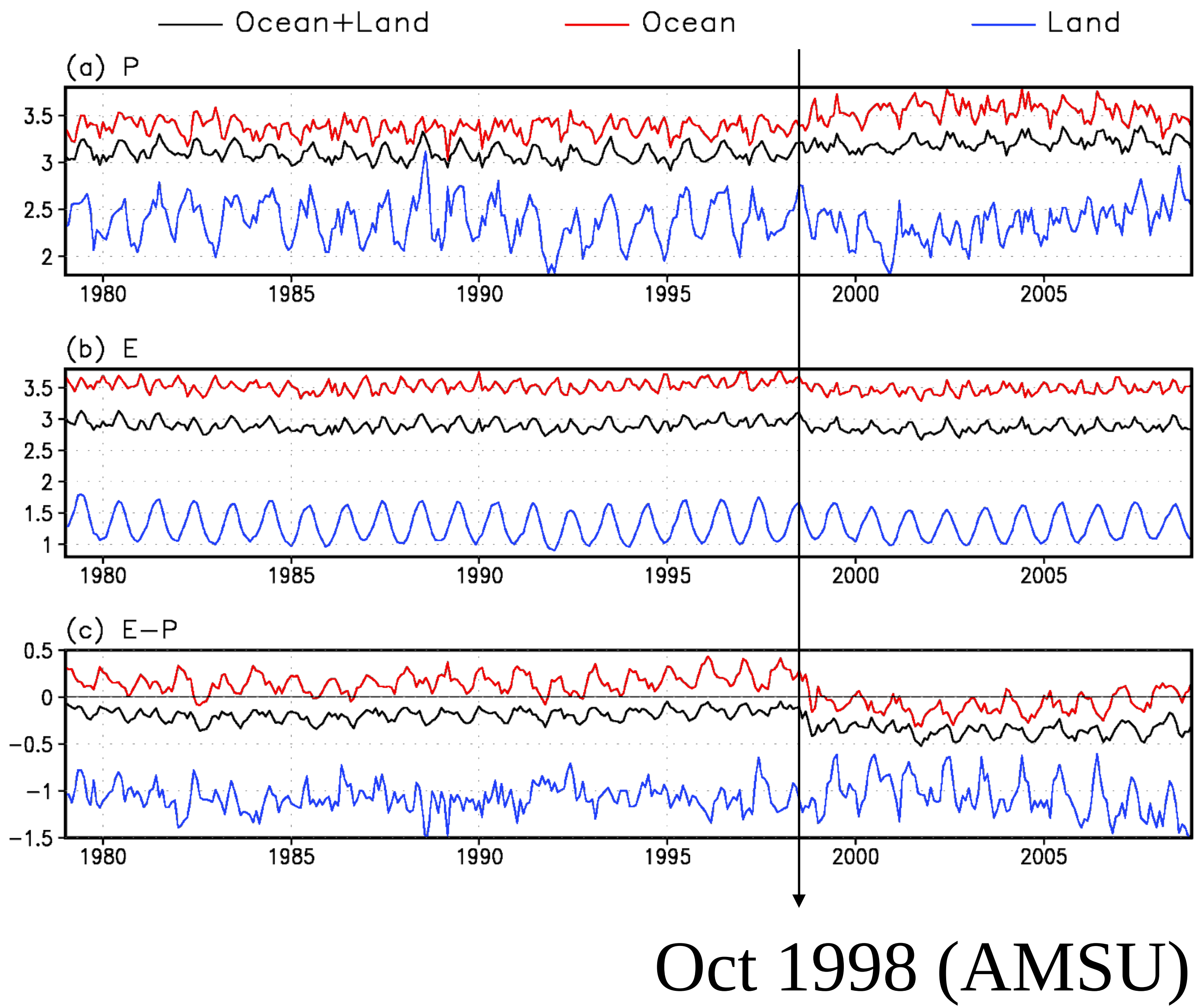

t2m Jan ICs: avg AC leads 1-4, N.A.
0.25
0.2
0.15
0.1
0.05
0
-0.05
CCSM sing. Mem.
CFS sing. Mem.
CCSM EM
CFS EM
MME
Extreme predicted
Extreme observed
All cases


t2m Jul ICs: avg AC leads 1-4, Americas
0.3
0.25
0.2
0.15
0.1
0.05
0
CCSM sing. Mem.
CFS sing. Mem.
CCSM EM
CFS EM
MME
Extreme predicted
Extreme observed
All cases


t2m Jul ICs: avg AC leads 1-4, S.A.
0.5
0.4
0.3
0.2
0.1
0
CCSM sing. Mem.
CFS sing. Mem.
CCSM EM
CFS EM
MME
Extreme predicted
Extreme observed
All cases


t2m Jul ICs: avg AC leads 1-4, N.A.
0.25
0.2
0.15
0.1
0.05
0
-0.05
CCSM sing. Mem.
CFS sing. Mem.
CCSM EM
CFS EM
MME
Extreme predicted
Extreme observed
All cases

Is everything perfect with CFSR?? NO!



Ocean+Land
Ocean
Land
(a) P
3.5
3
2.5
2
1980
1985
1990
1995
2000
2005
(b) E
3.5
3
2.5
2
1.5
1
(c) E−P
0.5
0
−0.5
−1
−1.5
Oct 1998 (AMSU)

Use 2 climatology's for the SST and PRATE

bias correction in CFSv2

1. For all hindcasts from Jan 1982 to Dec1998, use 1982-1998 climo (17 years)
2. For all hindcasts from Jan 1999 to Dec 2008, use 1999-2008 climo (10 years)

About Predictability

Some points I would like to raise:

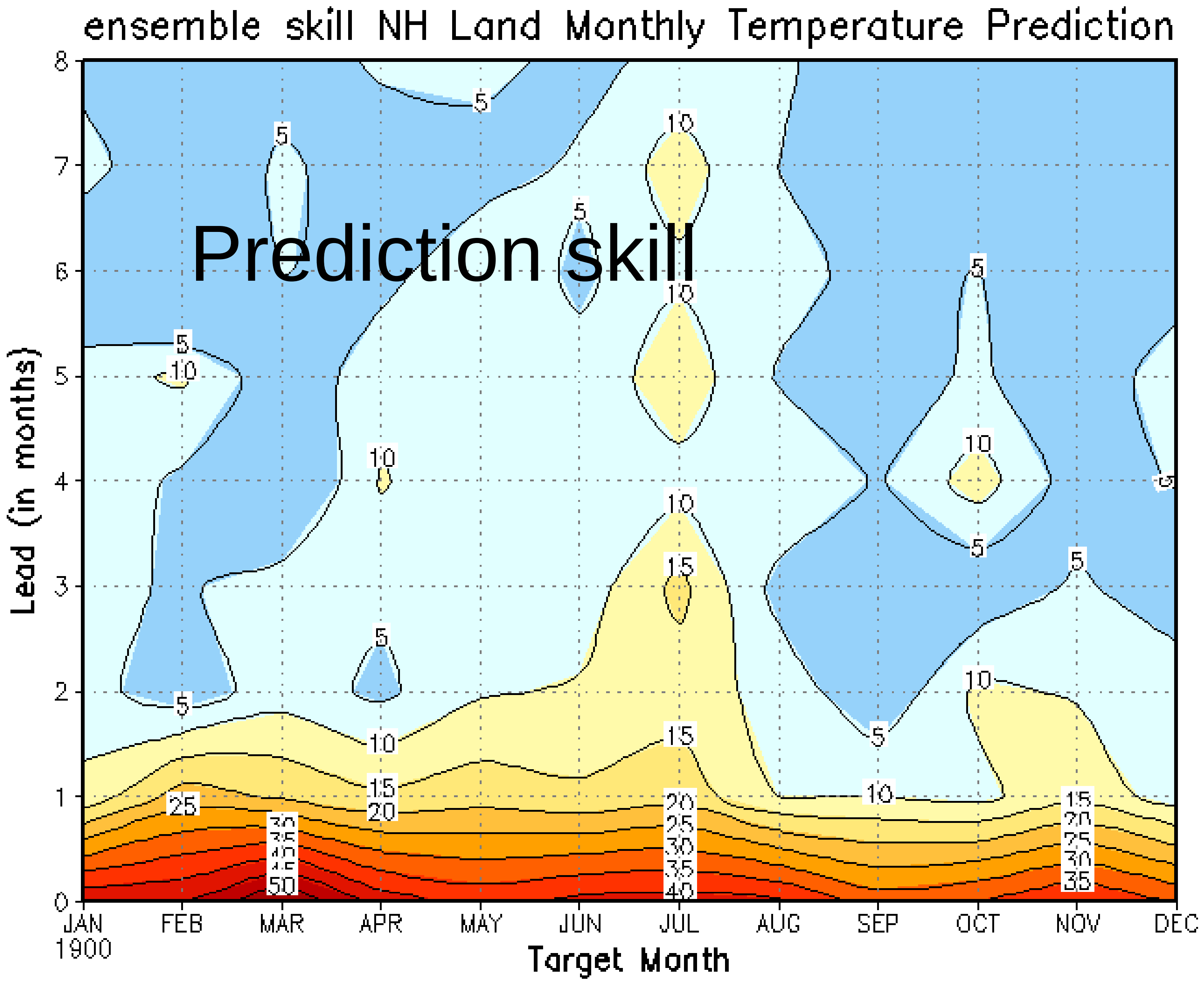
- An acceptable definition of predictability, and procedures to calculate it. Also a list of test/requirements for a dynamical model to pass, before predictability estimates are to be taken seriously.

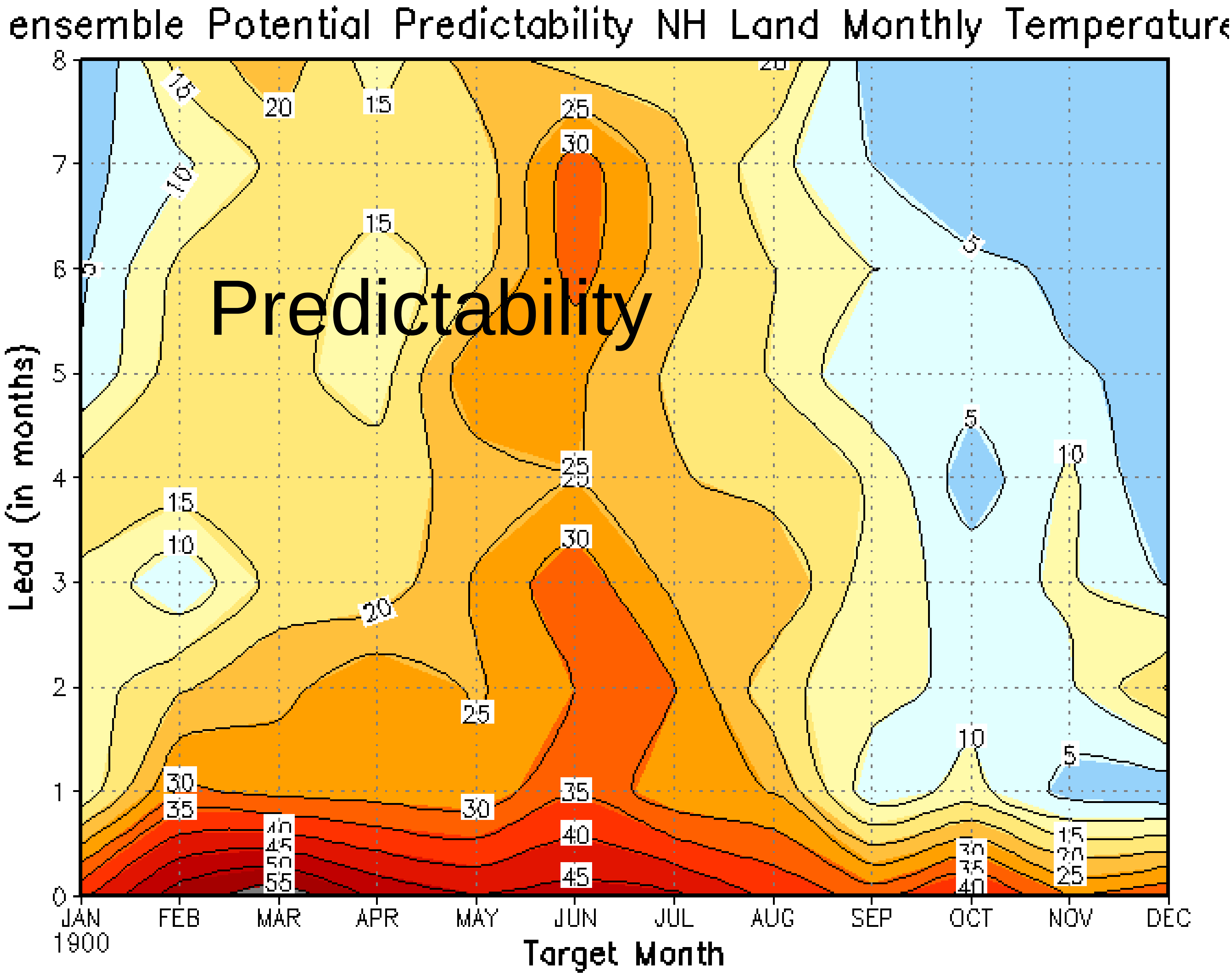
2) Prediction skill and Predictability, in tier-1 system, in T, P and in the erstwhile lower boundary conditions of tier-2 systems, such as SST and soil moisture (w) will be shown now.

- → Predictability (theoretical/intrinsic) is a ceiling for prediction skill

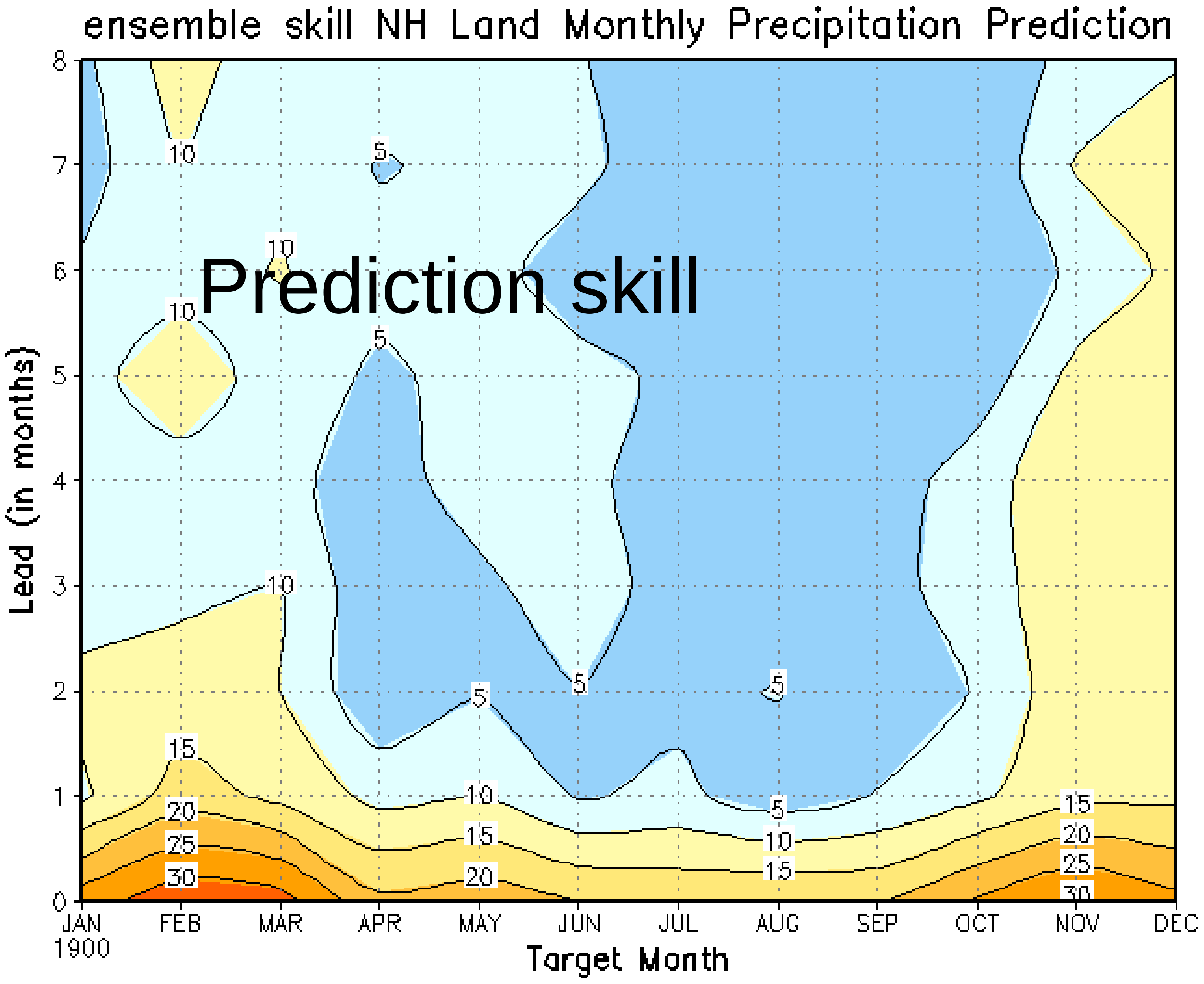
- → In systems like 1-tier CFS: there is only predictability of the 1st kind.

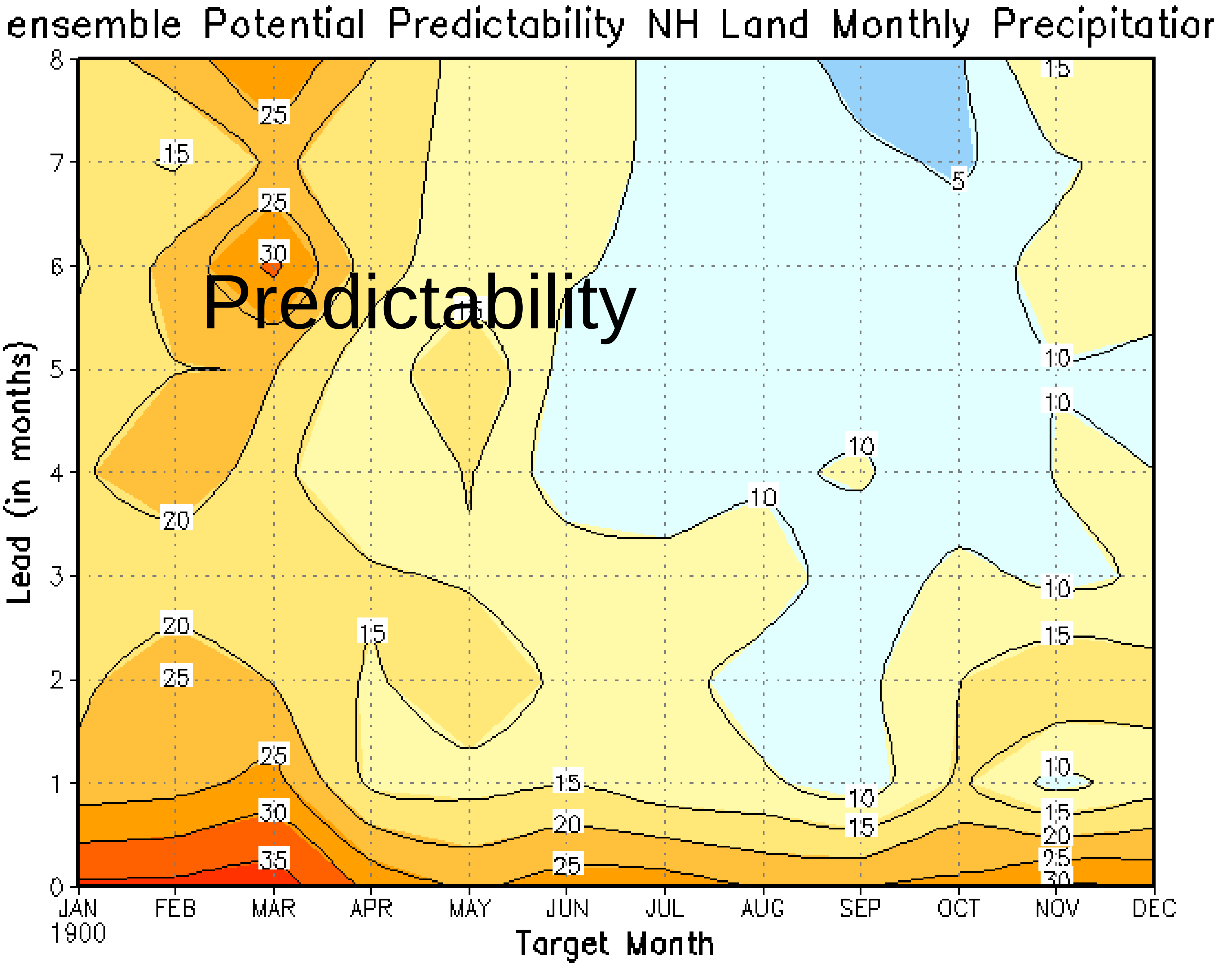
So: We are left with study of hindcasts and estimates of predictability of the first kind (including SST,w).


ensemble skill NH Land Monthly Temperature Prediction
Prediction skill
Lead (in months)
Target Month
JAN
1900
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
0
1
2
3
4
5
6
7
8

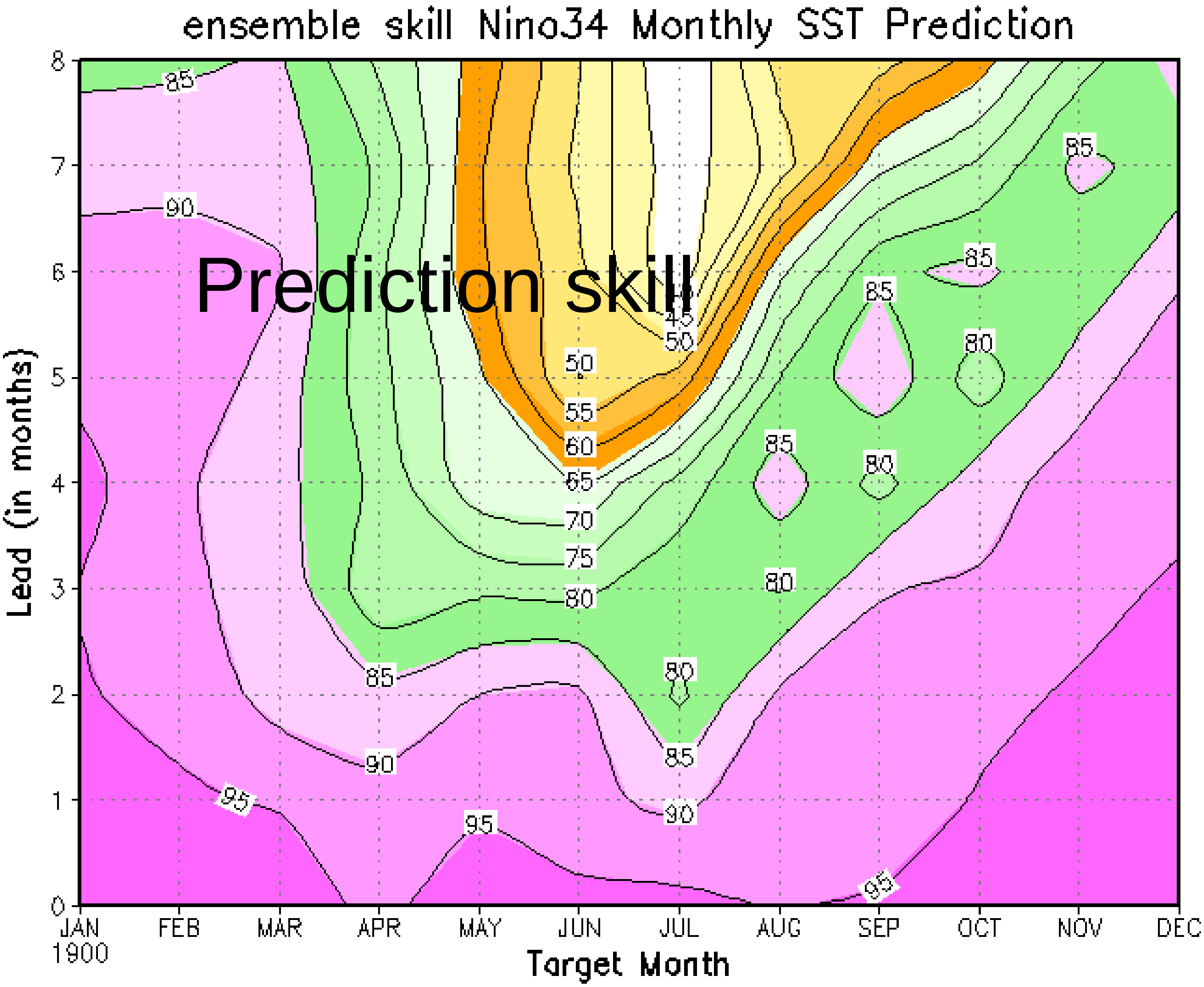

ensemble Potential Predictability NH Land Monthly Temperature
Predictability
Lead (in months)
0
1
2
3
4
5
6
7
8
JAN
1900
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Target Month

Prediction skill

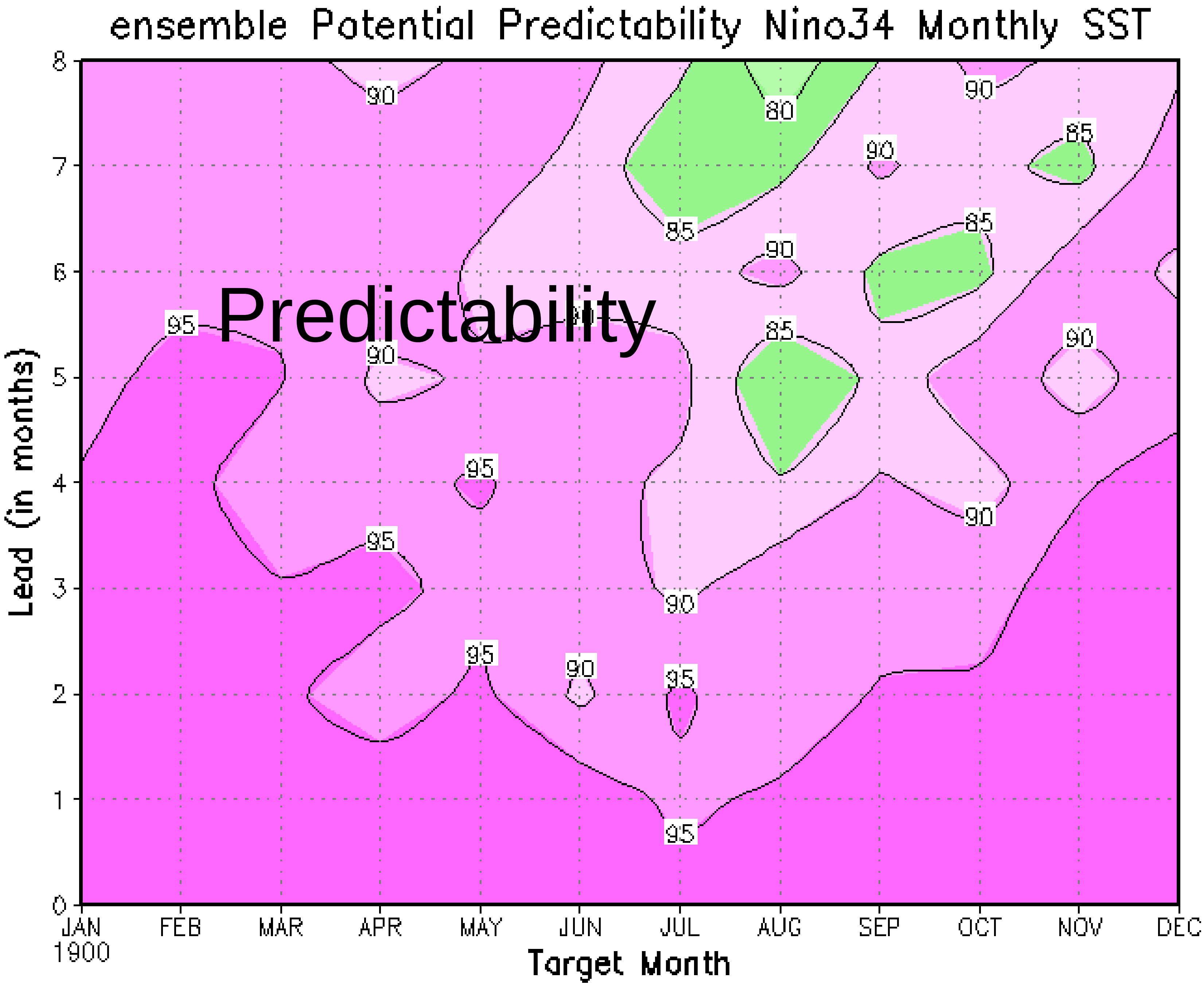


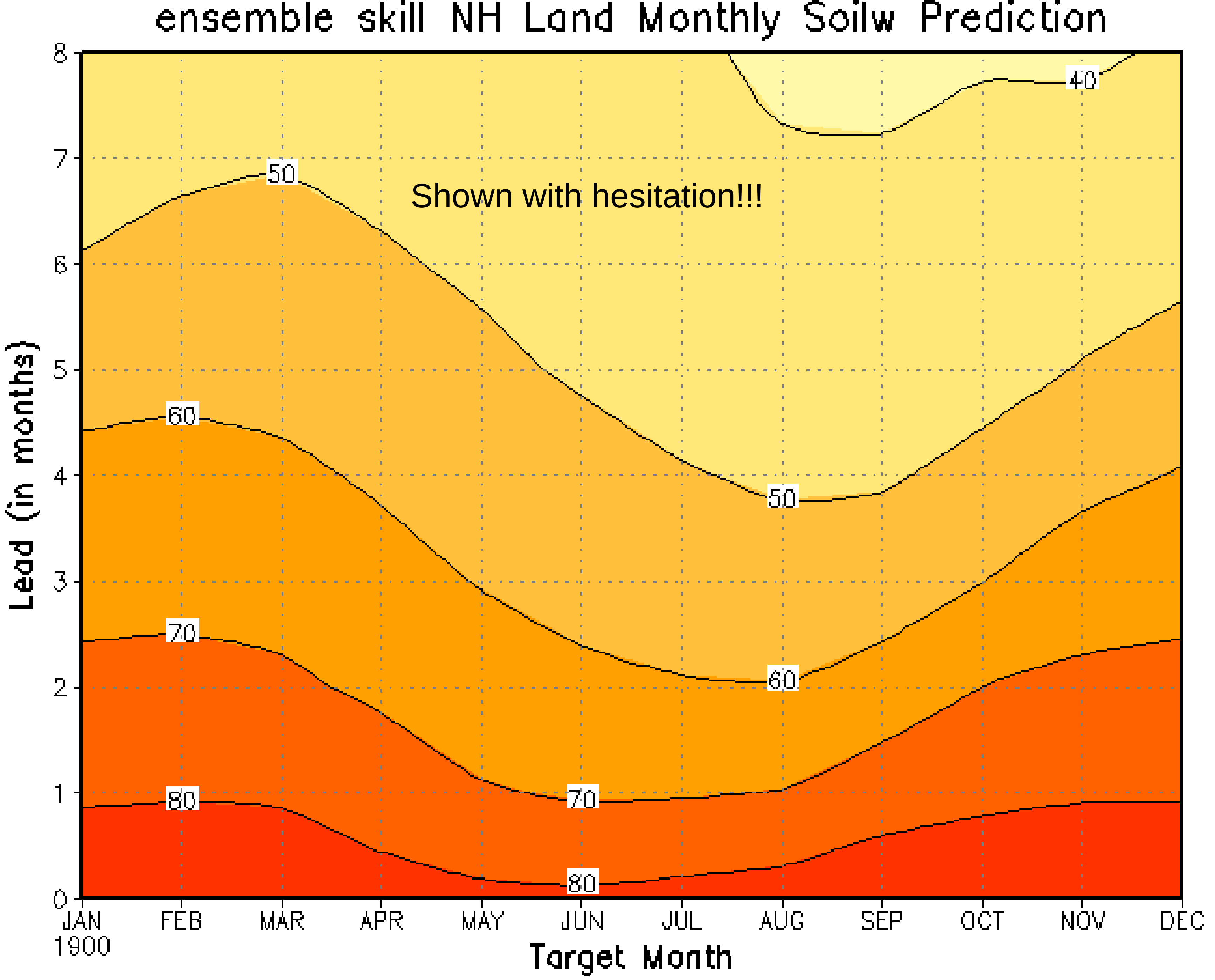


ensemble Potential Predictability NH Land Monthly Precipitatior
Predictability
Lead (in months)
Target Month
JAN 1900
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

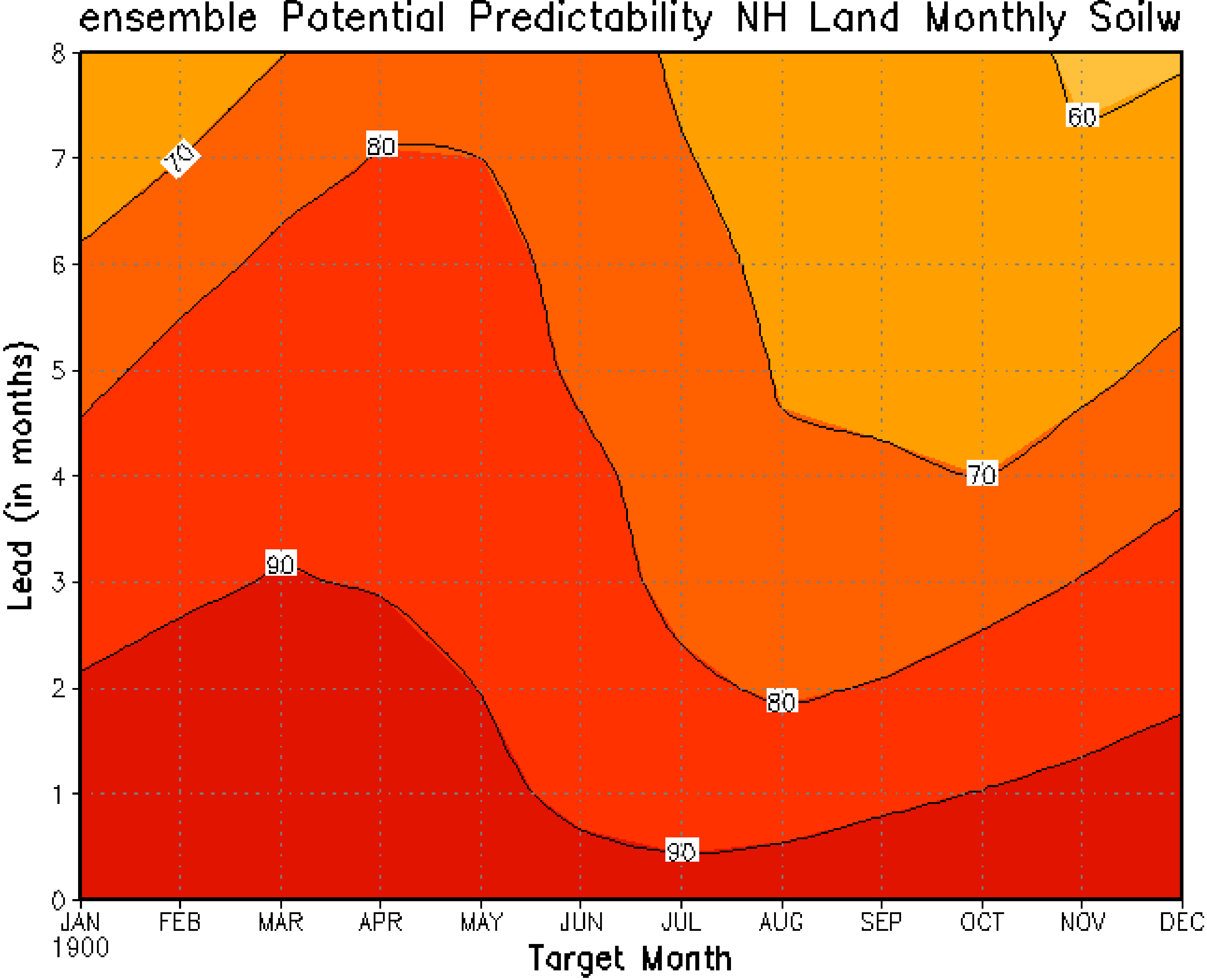

ensemble skill Nino34 Monthly SST Prediction
Prediction skill
Lead (in months)
0
1
2
3
4
5
6
7
8
JAN 1900
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Target Month
45
50
55
60
65
70
75
80
85
90
95

Predictability





ensemble skill NH Land Monthly Soilw Prediction
Shown with hesitation!!!
40
50
60
70
80
50
60
70
80
8
7
6
5
4
3
2
1
0
Lead (in months)
JAN
1900
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Target Month



ensemble Potential Predictability NH Land Monthly Soilw
Lead (in months)
Target Month
JAN 1900
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
0
1
2
3
4
5
6
7
8
60
70
80
90

Huug van den Dool, CPC

"Experimentation with Methods for the Multi-Model Ensemble Approach for Seasonal Prediction"

IRI, March, 27, 2008

M. Peña Mendez and H. van den Dool, 2008:
Consolidation of Multi-Method Forecasts at CPC.
JCLIM 2008.

Unger, D., H. van den Dool, E. O'Lenic and D. Collins, 2009:
Ensemble Regression.

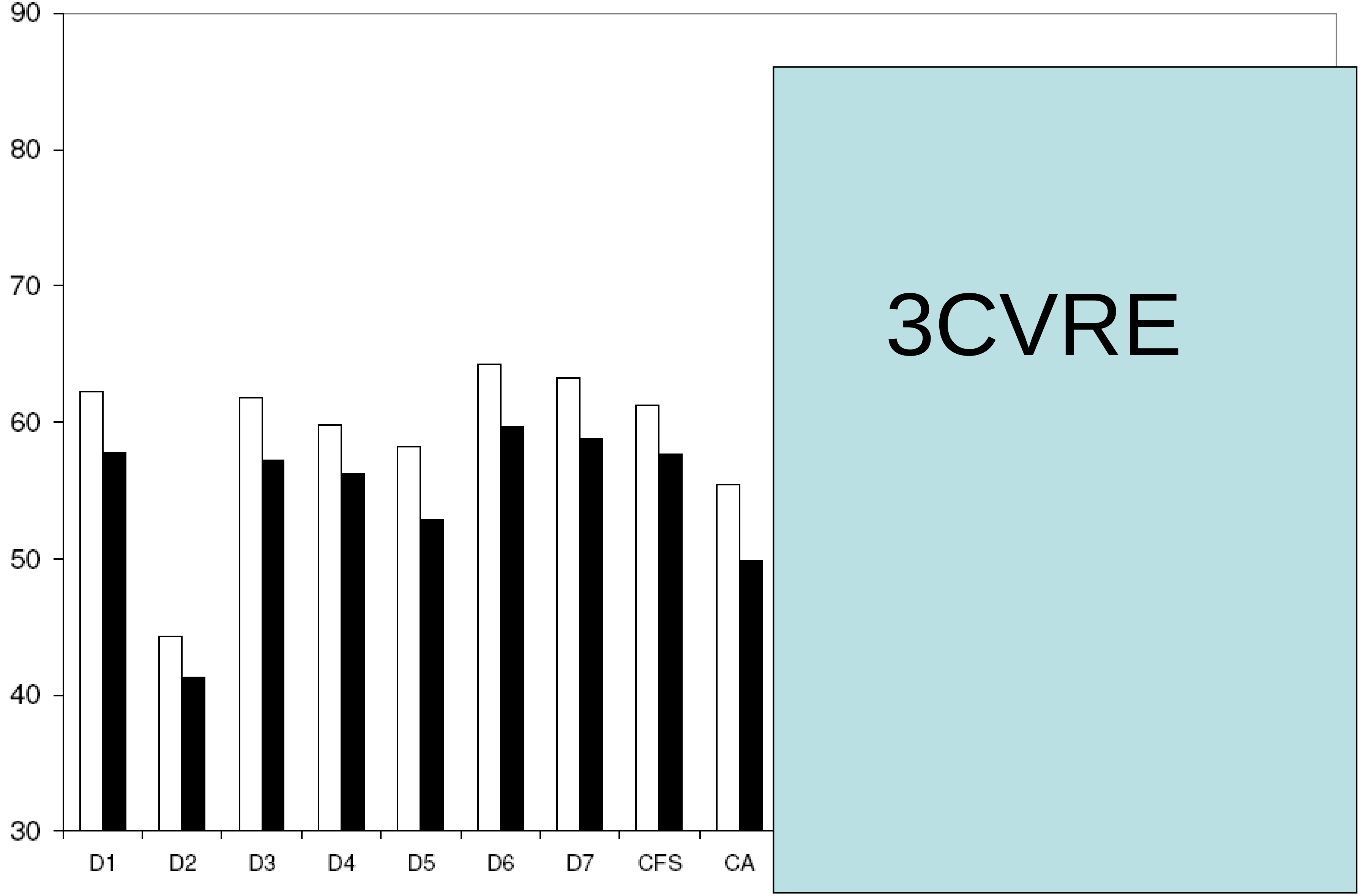
(1) CTB, (2) why do we need 'consolidation'?

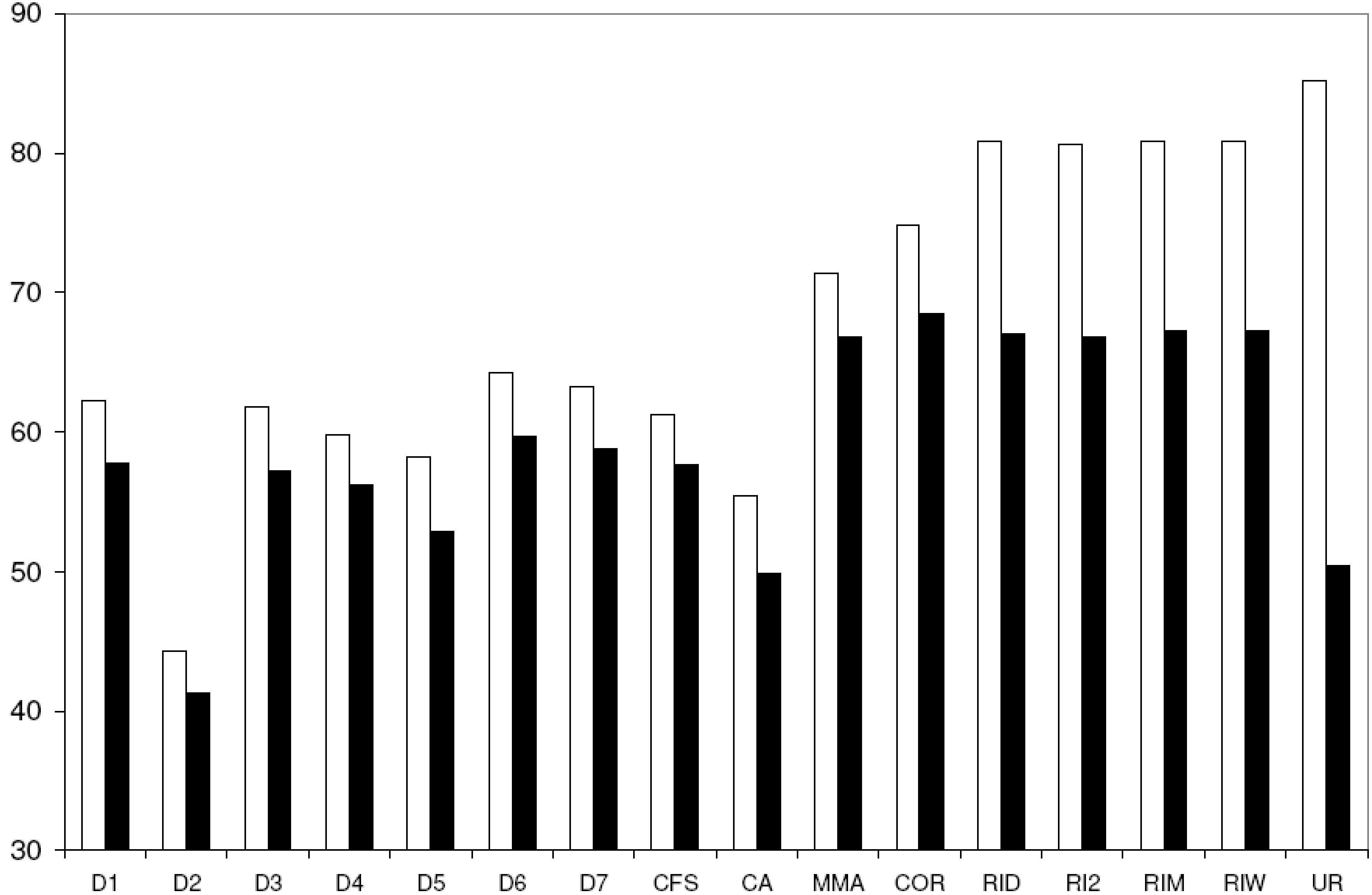
Table 2 Summary of consolidation techniques and corresponding weights

Acronym	Method	Weight
MMA	Multi-Model ensemble Average	
COR	Correlation	
UR	Unconstrained Regression	
RID	Ridging	
RI2	Double pass Ridging	
RIM	Ridging with MMA constraint	
RIW	Ridging with weighted mean constraint	

Table 2 Summary of consolidation techniques and corresponding weights

Acronym	Method	Weight
MMA	Multi-Model ensemble Average	$\alpha = K^{-1}\mathbf{1}$, where $\alpha = (\alpha_1, \alpha_2, \ldots, \alpha_K)$, K = number of participating models and $\mathbf{1}$ is a column vector of size K and all elements equal to 1
COR	Correlation	$\alpha_1 = \frac{1}{f}\frac{\sum_{t=1}^{N}\zeta_{it}o_t}{\sum_{t=1}^{N}\zeta_{it}^2} = \frac{b_i}{fa_{ii}}$, where $f = \sum_{i=1}^{K}\frac{b_i}{a_{ii}}$, ζ_{it} is the training timeseries forecast of i-th model, b_i is the covariance function between model i and observations, and a_{ii} is the variance of model i.
UR	Unconstrained Regression	$\alpha = \mathbf{A}^{-1}\mathrm{b}$, where $\mathbf{A} = \mathbf{Z}^T\mathbf{Z}$, $\mathrm{b} = \mathbf{Z}^T\mathrm{o}$ and $\mathbf{Z} = (\zeta_{it})$, $t=1,..N$, $i=1,..K$,
RID	Ridging	$\alpha = (\mathbf{A} + \lambda\mathbf{I})^{-1}\mathrm{b}$, λ is such that $\sum_{i=1}^{K}\alpha_i^2$ is small and $\alpha_i \geq -0.01$, $i=1,..,K$.
RI2	Double pass Ridging	First pass is regular RID; then set to zero any $\alpha_i < 0$, $i=1,..,K$; then carry out a second RID.
RIM	Ridging with MMA constraint	$\alpha = (\mathbf{A} + \lambda\mathbf{I})^{-1}\left(\mathrm{b} + \frac{\lambda}{K}\mathbf{1}\right)$ (Delsole 2007)
RIW	Ridging with weighted mean constraint	$\alpha = (\mathbf{A} + \lambda\mathbf{I})^{-1}(\mathrm{b} + \lambda\,\alpha^{COR})$, where $\alpha_i^{\mathrm{COR}} = \frac{1}{f}\left(\frac{\mathrm{b_i}}{a_{ii}}\right)$, are the COR regression coefficients


90
80
70
60
50
40
30
D1
D2
D3
D4
D5
D6
D7
CFS
CA
3CVRE


90
80
70
60
50
40
30
D1
D2
D3
D4
D5
D6
D7
CFS
CA
MMA
COR
RID
RI2
RIM
RIW
UR

Meaning of 3CVRE

- When doing Cross Validation: Leave 3 years out (3 as a minimum)
- R: Leave 3 years out, namely the test year plus two others chosen at Random, see example
- E: Use ‘External’ observed climatology, not an observed climatology that changes in response to leaving out a particular set of 3 years.

Probability Anomaly Correlation

- Meaning of good-old anomaly correlation
- Minimize the MSE (since Gauss)
- Now on to minimizing the Probability Score
- This leads to the Probability Anomaly Score.
- Damping, inflation, (re)calibration etc

THANK YOU