THE ECMWF PERSPECTIVE

David Anderson

Head of Seasonal and Monthly forecasting section.

Special thanks to Magdalena Balmaseda, Arthur Vidard and Graeme Kelly

ECMWF activities: the atmosphere

- Forecasts for the medium range (10 days). Deterministic forecast and ensemble forecasts.
- The deterministic forecast is made twice per day at TL511.
- An ensemble of forecasts are made at TL255 twice per day. (51 members to provide a pdf).
- Forecasts for a month ahead (coupled atmosphere-ocean model). These are made weekly, 51 member ensemble at TL159.
- Forecasts for seasons ahead (coupled model). These are made monthly, 40 member ensemble at TL95.
- Atmospheric reanalyses (ERA15 1979-1993, ERA40 Sept1957-Aug2002). ERA provides atmospheric initial conditions for both monthly and seasonal hindcasts (needed for calibration and validation). For seasonal, the effect is more indirect than direct. (ERA provides better fluxes for producing better ocean analyses.)
- Ocean reanalyses spanning ERA period. See ENACT later. Ocean reanalyses are needed for calibrating the monthly and seasonal forecasting systems, because of model drift (error).

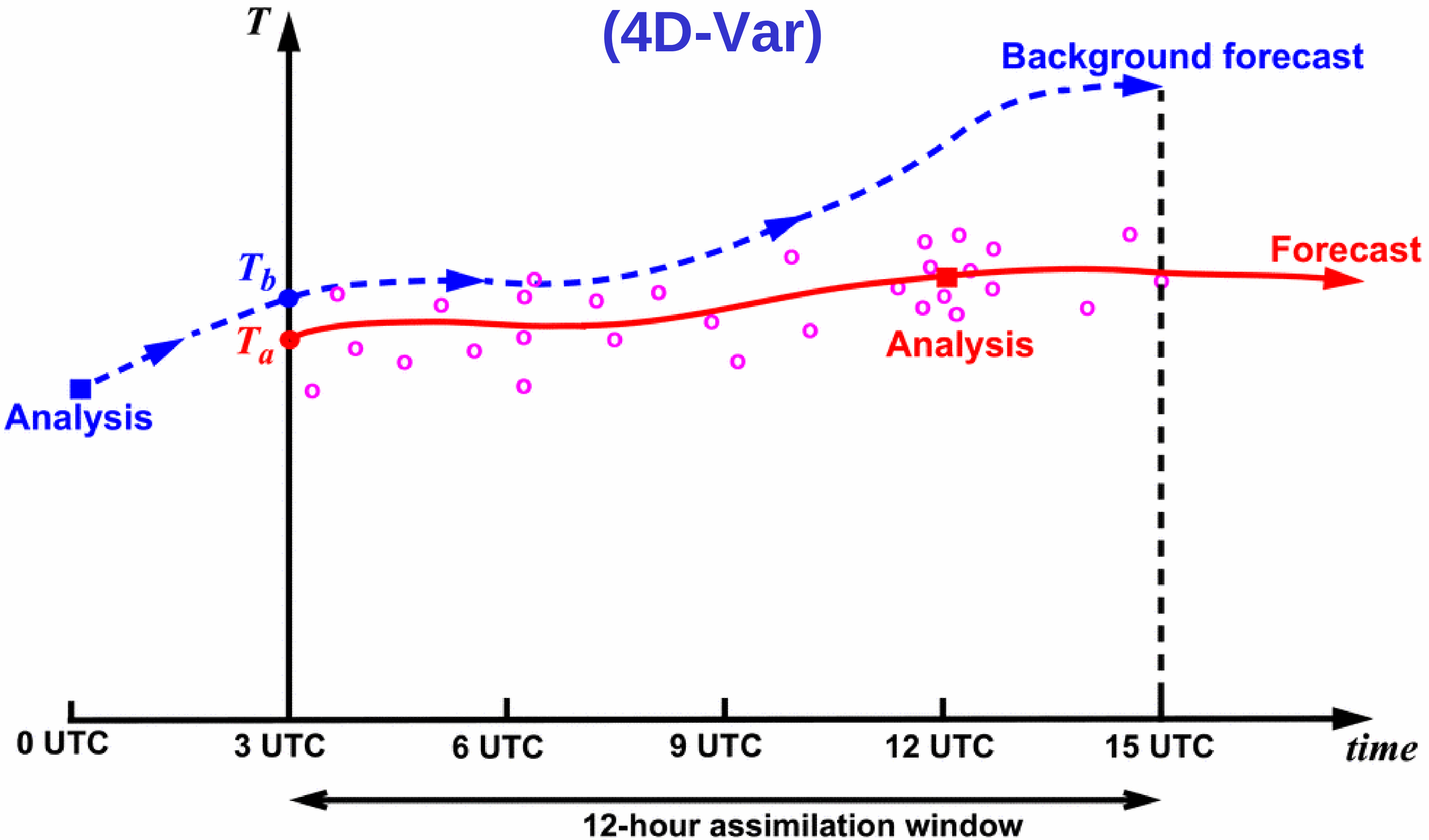
- The atmospheric analysis system is 4d-var.
- This is cutting edge, though some weather centres are now following e.g. Meteo France, UKMO.
- It is expensive. So simplifications have to be made: an incremental approach is used.
- The same atmospheric analyses are used for medium range, EPS, monthly and seasonal forecasts, suitably truncated from T511 to T255, T159, T95 respectively.

- In the early 80’s, the forecast system used 3x as much power as the analysis.
- Now, the analysis takes 3x as much power as the forecast (deterministic, high resolution).
- Of course analysis is also used for EPS, monthly, seasonal, (decadal).

The 4d-var incremental system

- This consists of outer and inner loops.
  - The outer loop defines the trajectory. This is done using the full nonlinear model at highest resolution, currently TL511.
- A tangent linear model is derived, based on the full model but somewhat simplified. An adjoint is derived which is an exact adjoint of the the TL model.
- The cost function is minimised using the TL and its adjoint. The nonlinear outer loop is done only twice (big difference from the ocean strategy).
- The cost function is quadratic, giving faster minimisation.
- The TL and adjoint are at lower resolution. Currently TL159. Estimates are made of the Hessian.
- The window is 12 hours. (There are variants on this which I will not discuss).

Four Dimensional variational data assimilation (4D-Var)



Forecast TL511 (~40km) 60 levels analysis TL159 (~80km)

- Using spectral space makes it more difficult to have a spatially varying correlations e.g. different scales for tropics from extra-tropics.
- Can get low frequency variability generated by changes in the model, the assimilation system or the observing network. Reanalyses can reduce the former two but not the latter since the same version of the model and assimilation system are used throughout. Observing system changes e.g. new satellites coming on stream, can cause problems. See later.
- The strategy for 4d-var is different from e.g. ECCO which uses a long window (10-40 years) but includes other control variables than initial conditions, e.g. forcing fields in the cost function.

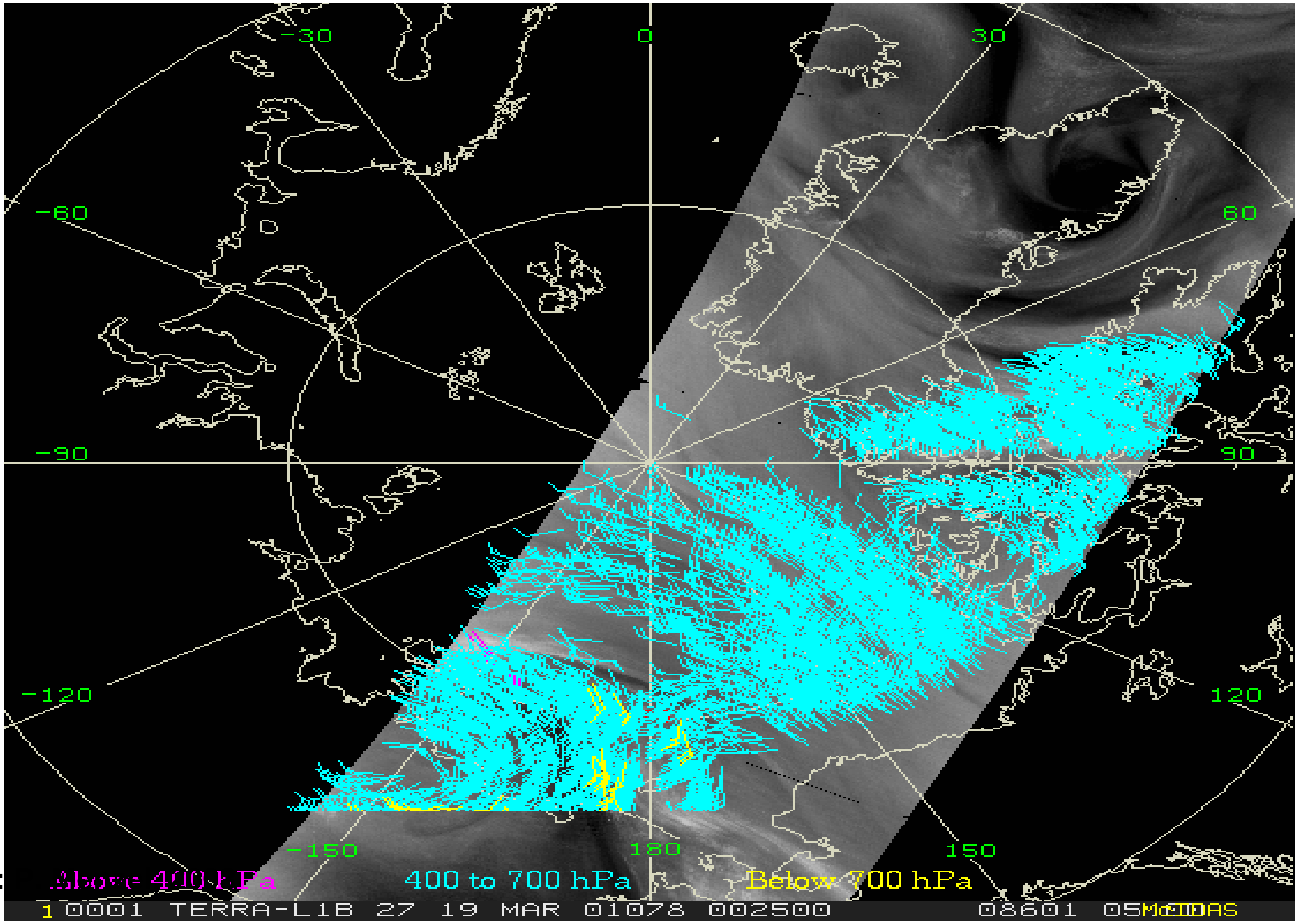
- **Is 4d var worth the extra effort- computational and manpower?** I will show later the impact.
- ERA15 used an OI scheme. (T106)
- ERA40 used a 3d-Var scheme with FGAT (First guess at appropriate time). Resolution is TL159 which gives same surface grid as ERA15.

- Quality control
- This is a highly nonlinear process and an important one. Selecting which observations to accept and with what weight. See tropical cyclone example.
- The analysis system is effectively lower resolution than the forecast model, even when formally the resolution may be the same. As mentioned the analysis resolution is in fact considerably lower than that of the forecast model.
- You also have to deal with sampling error.

Medium range

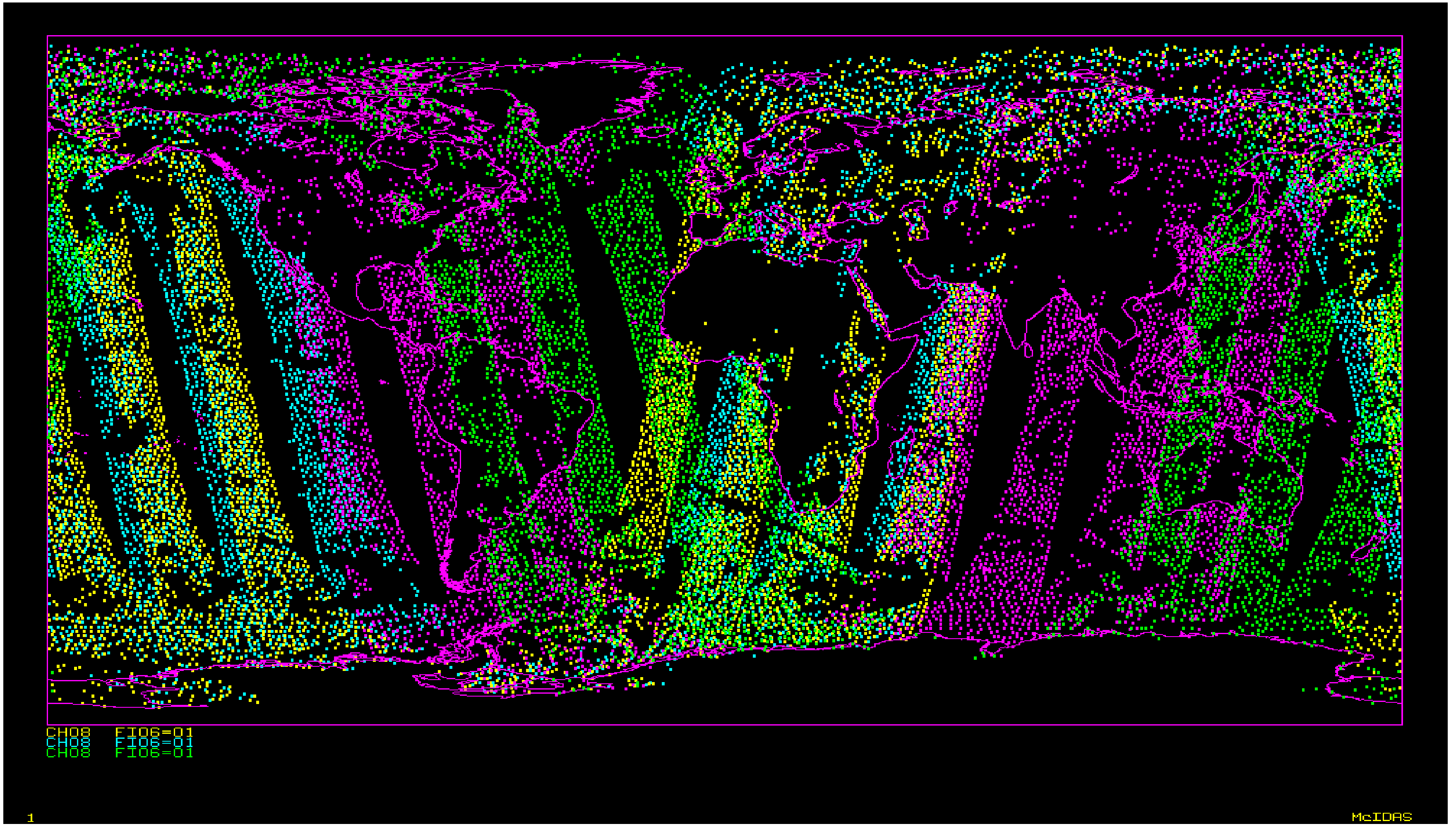
- Currently there is an atmospheric analysis at ‘T511’, approximately 40 km but the atmospheric structure functions are broader than this).
- This is 4d-var using an incremental approach. The outer loop uses the full nonlinear model. There is then an inner loop which uses a tangent linear which is a smoother version of the full model and which runs at a reduced resolution. The adjoint must be the exact adjoint of the TL. Typically one has 50 inner loops to an outer loop. The outer loop updates the trajectory.

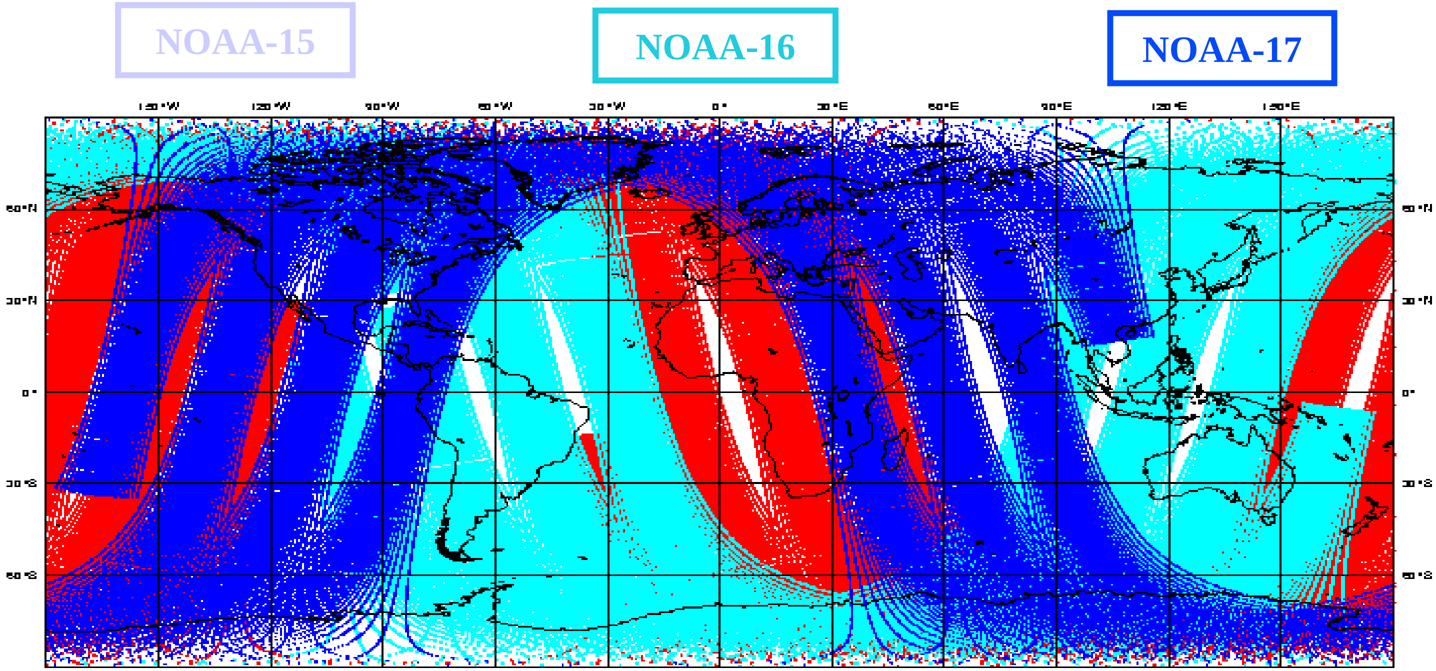
Polar WV winds from MODIS

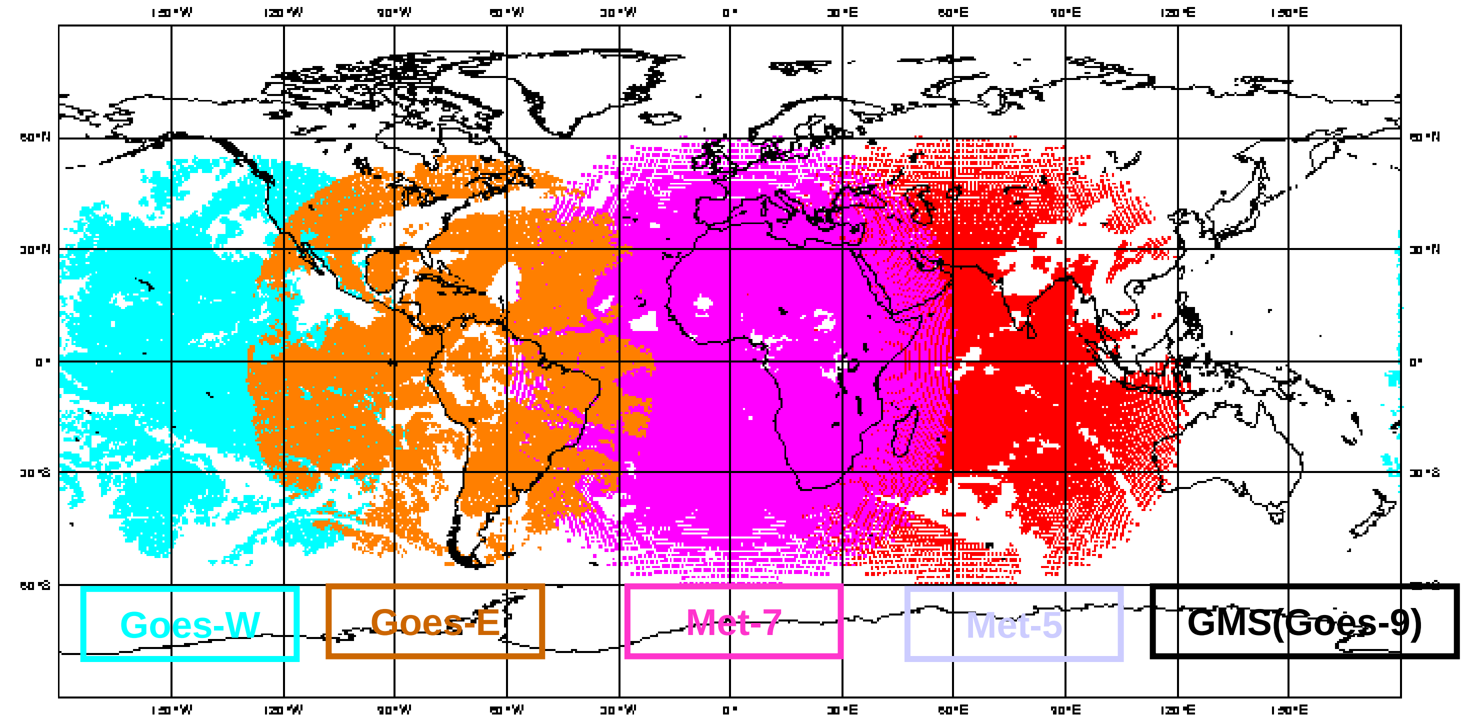


Source:

Four AMSU-A instruments




NOAA-15
NOAA-16
NOAA-17

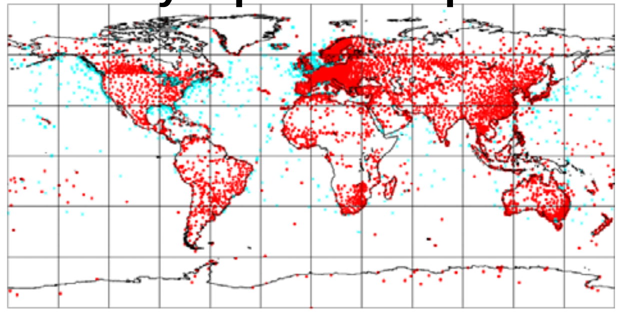

Goes-W
Goes-E
Met-7
Met-5
GMS(Goes-9)

Data coverage

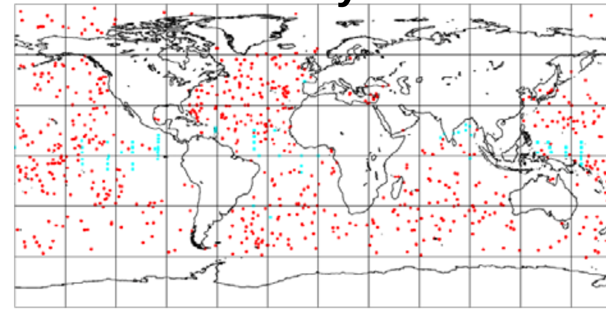
09 – 15 UTC5 September 2003 +

AQUA (Airs,AMSUA) and 5 geo rads.

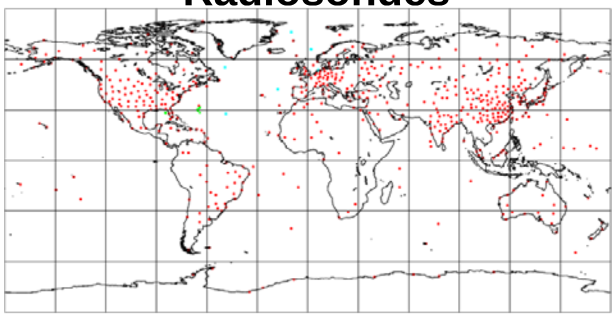
Synops and ships



Buoys

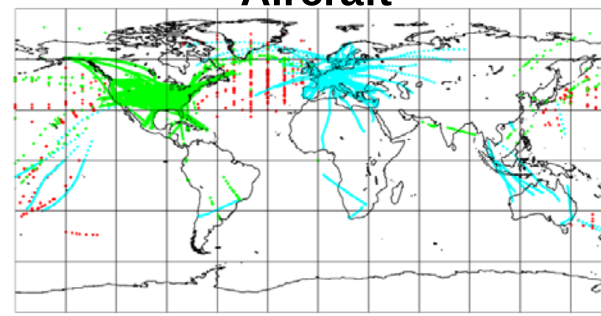


Radiosondes

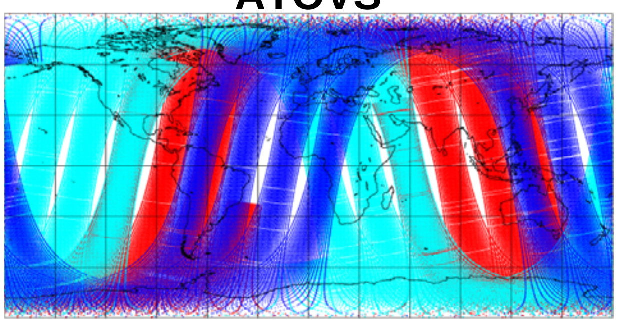


Pilots and profilers

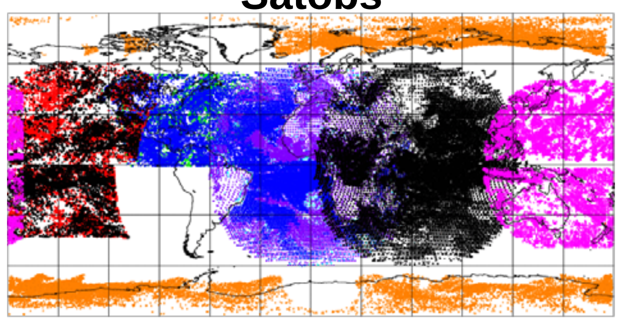
Aircraft



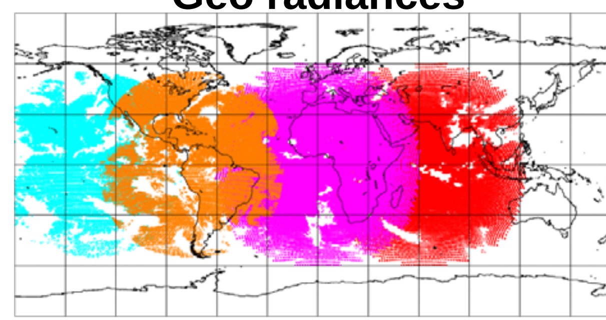
ATOVS



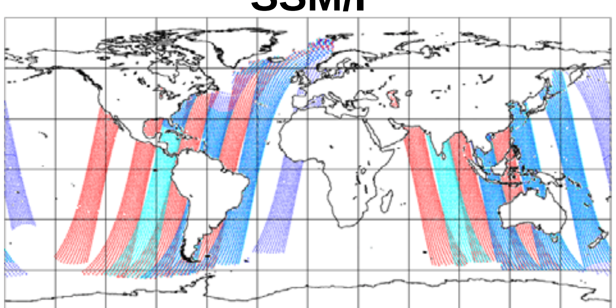
Satobs



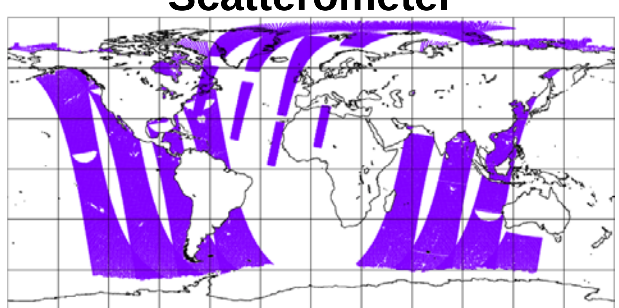
Geo radiances



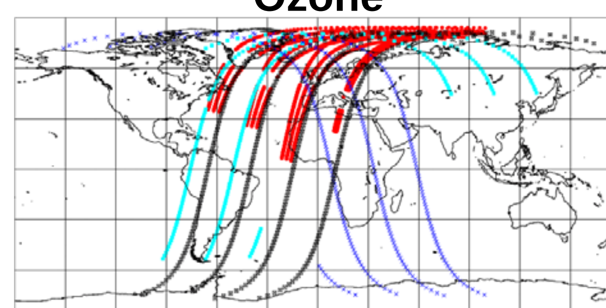
SSM/I



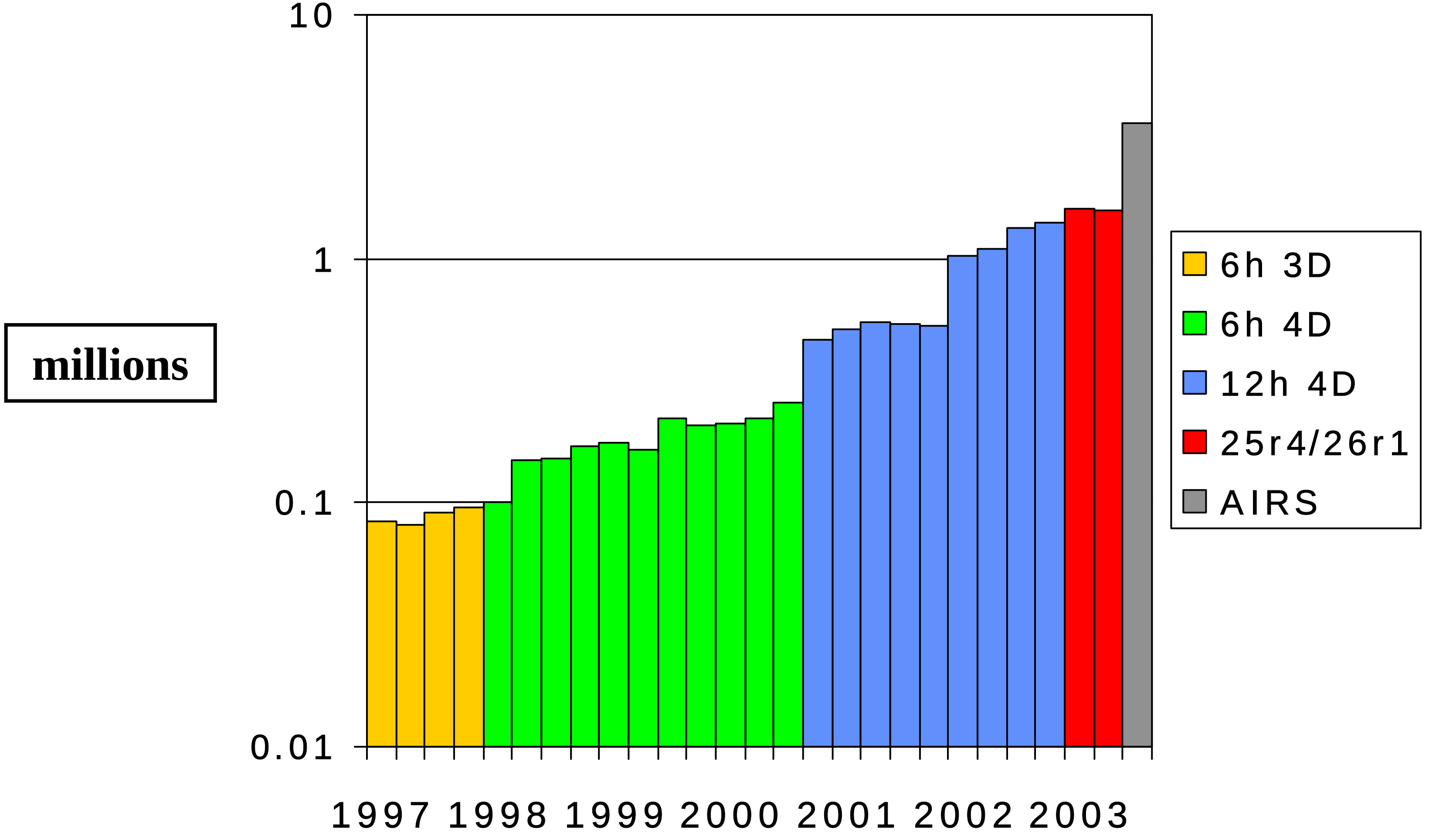
Scatterometer



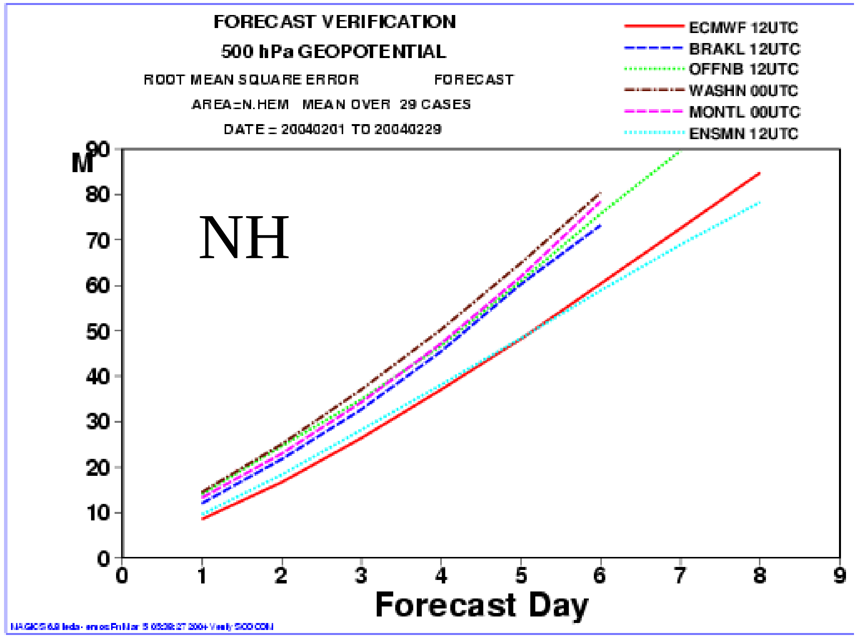
Ozone

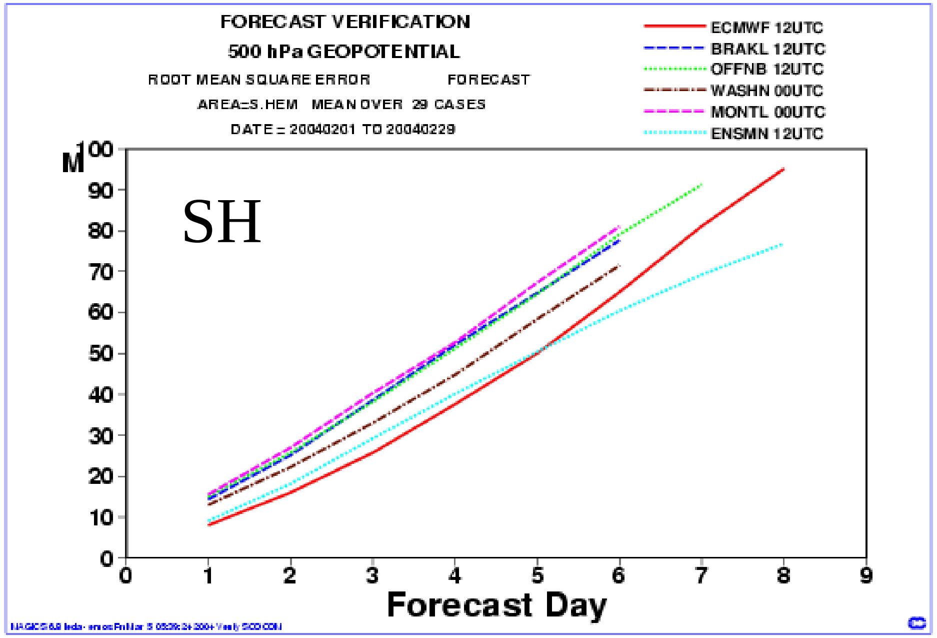


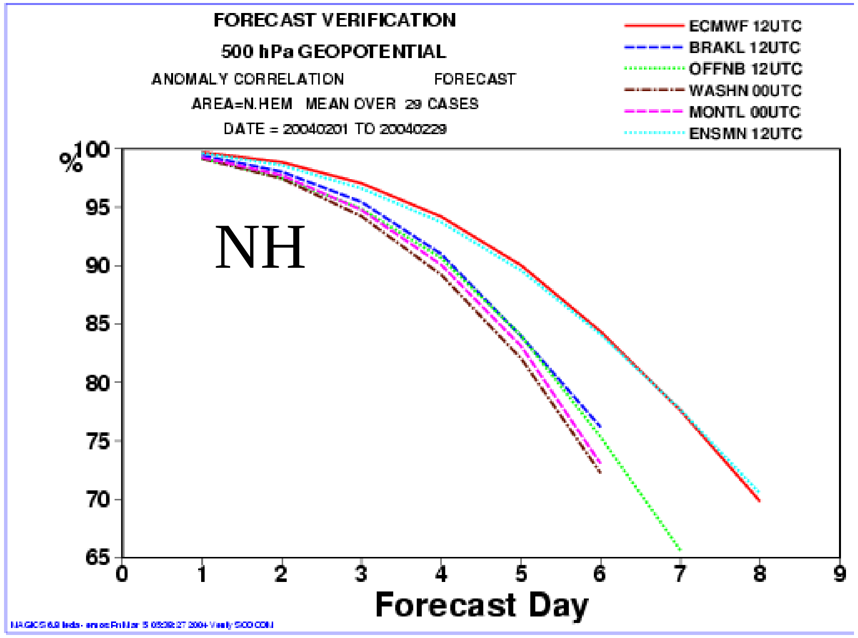
Number of observational data used in the ECMWF assimilation system (with AIRS)

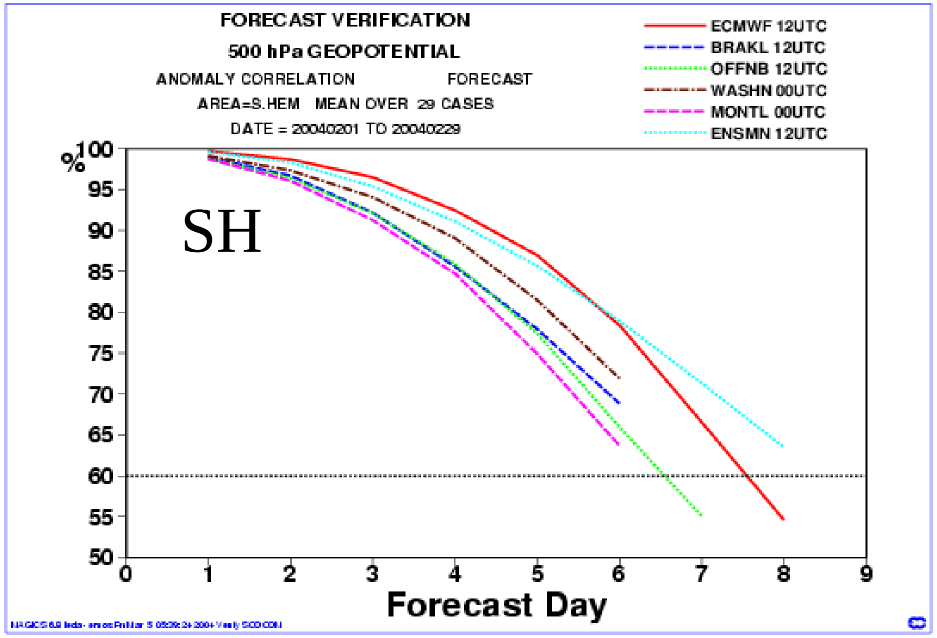


Comparison between centres of 500 hPa ht scores(Feb. 2004)

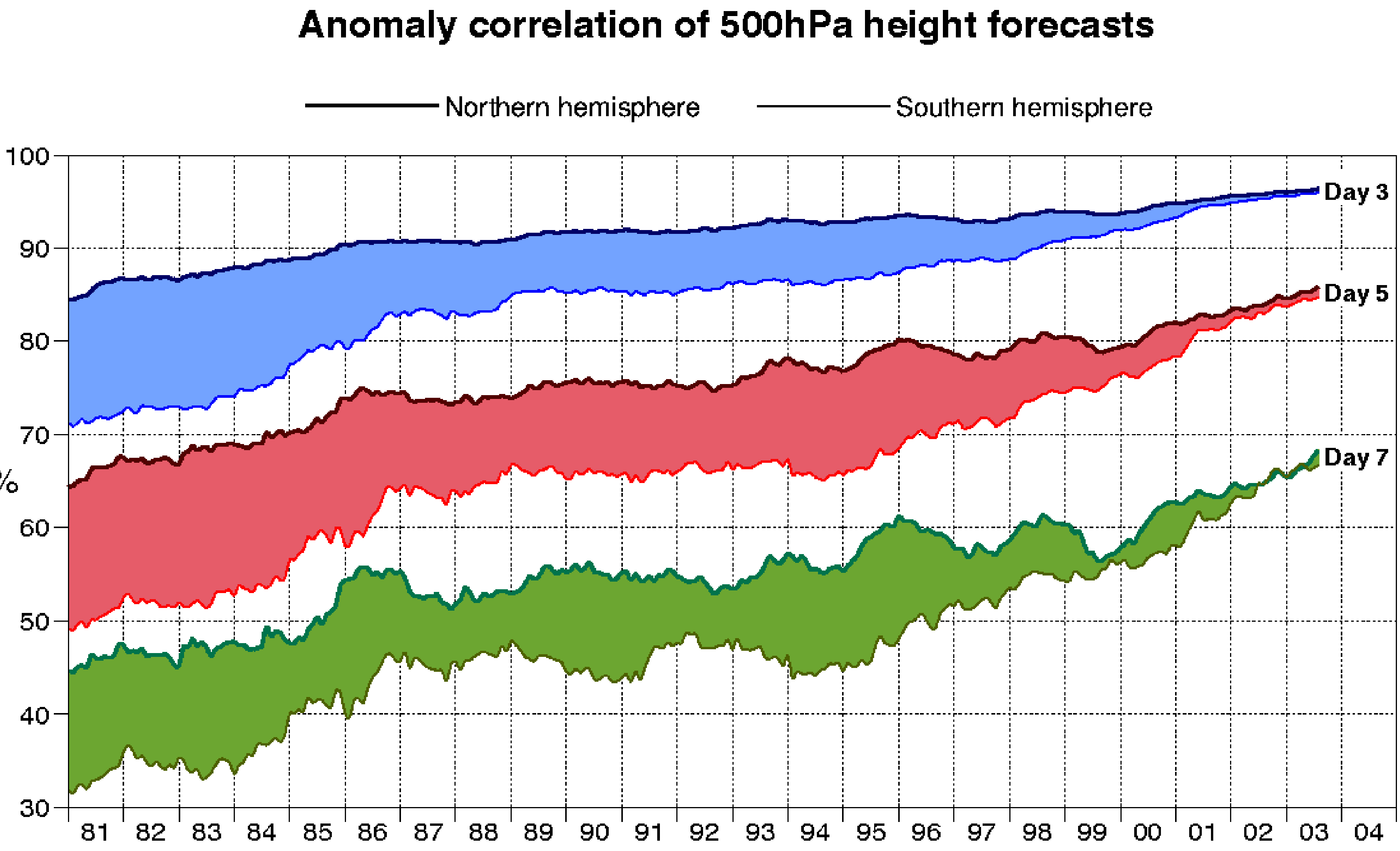


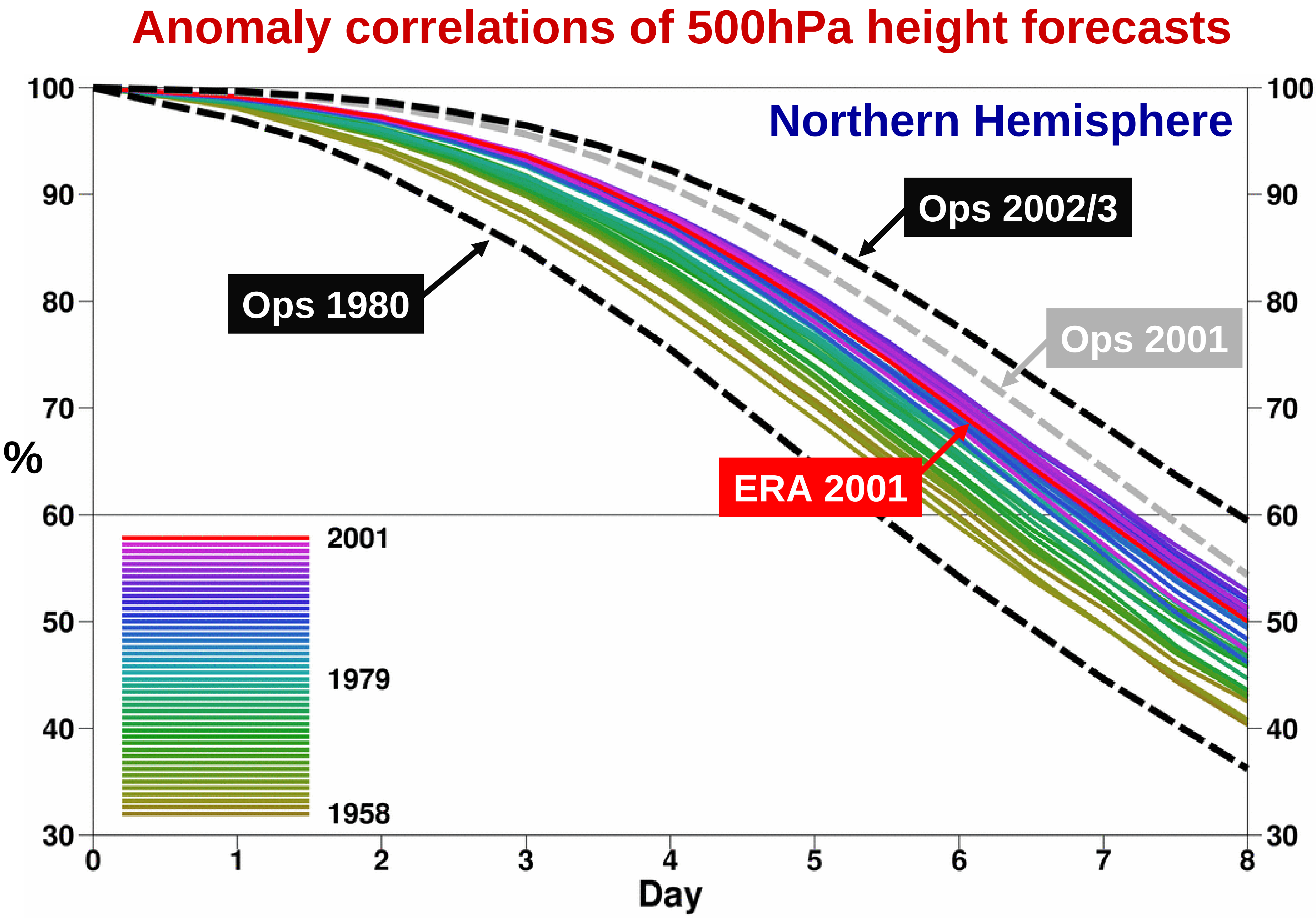






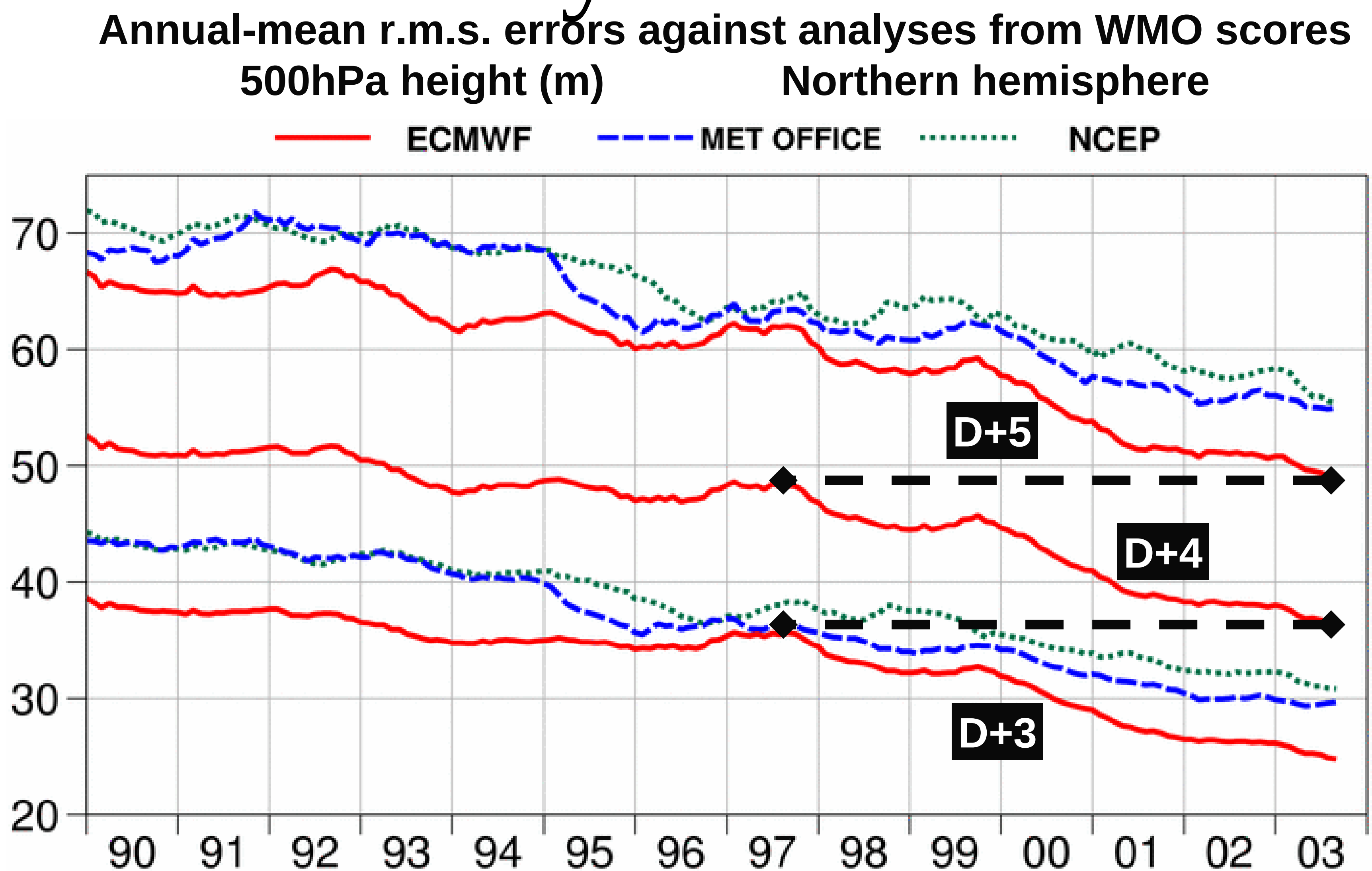
ECMWF forecasts 1981-2003

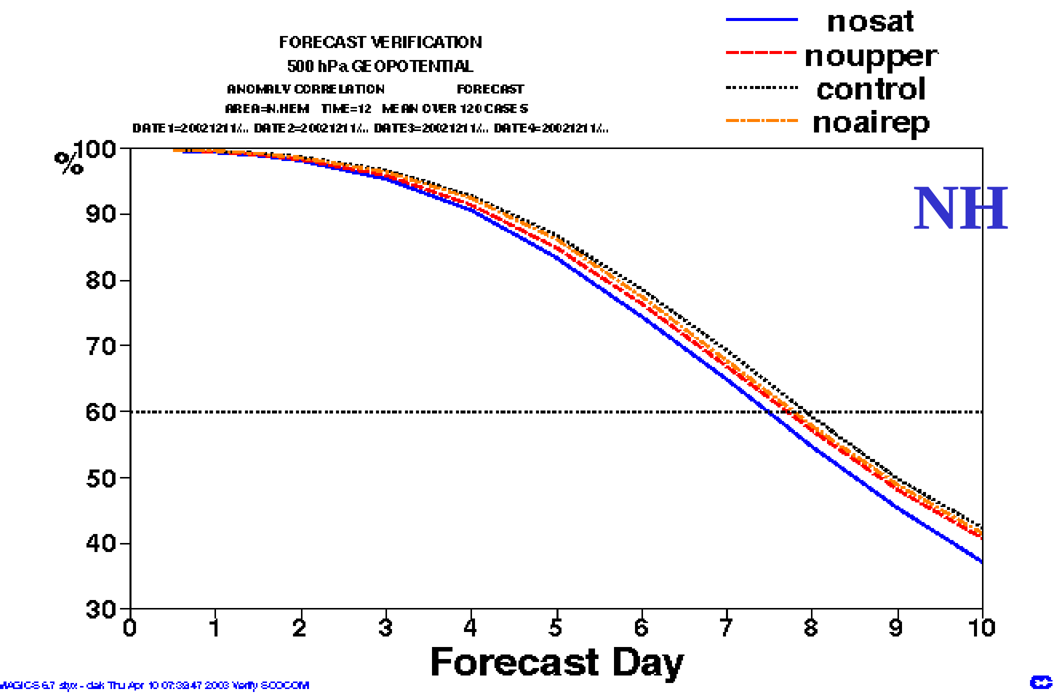


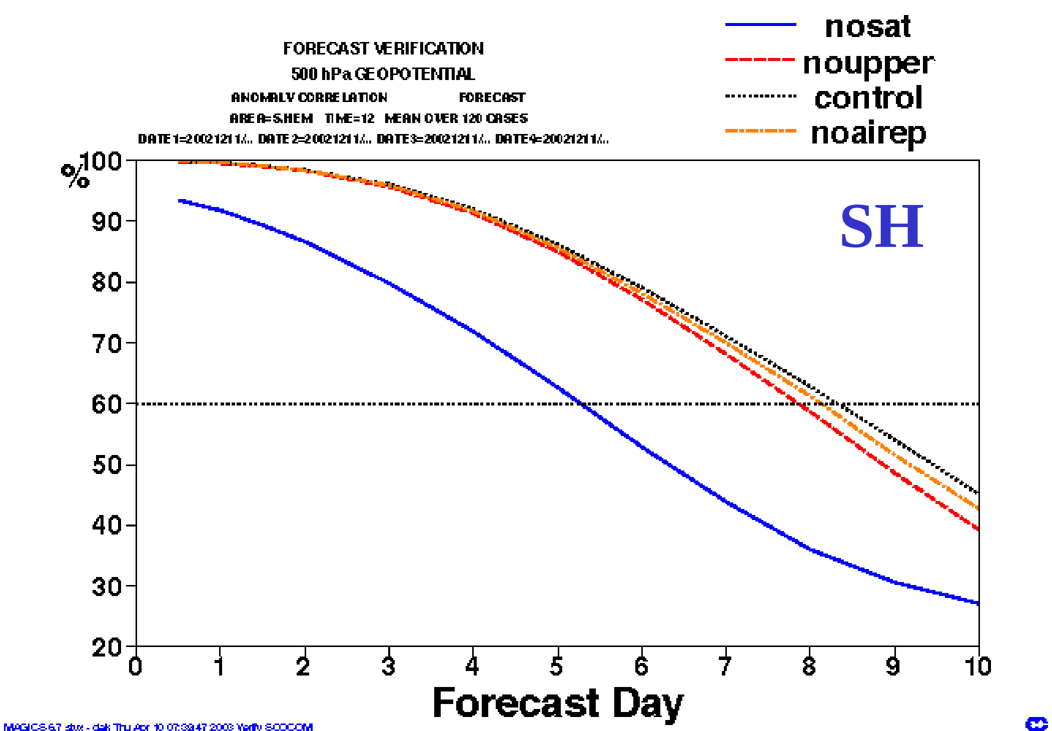


Anomaly correlations of 500hPa height forecasts
Northern Hemisphere
Ops 2002/3
Ops 1980
Ops 2001
ERA 2001
2001
1979
1958
%
Day
100
90
80
70
60
50
40
30
0
1
2
3
4
5
6
7
8

Recent improvement in the accuracy of forecasts





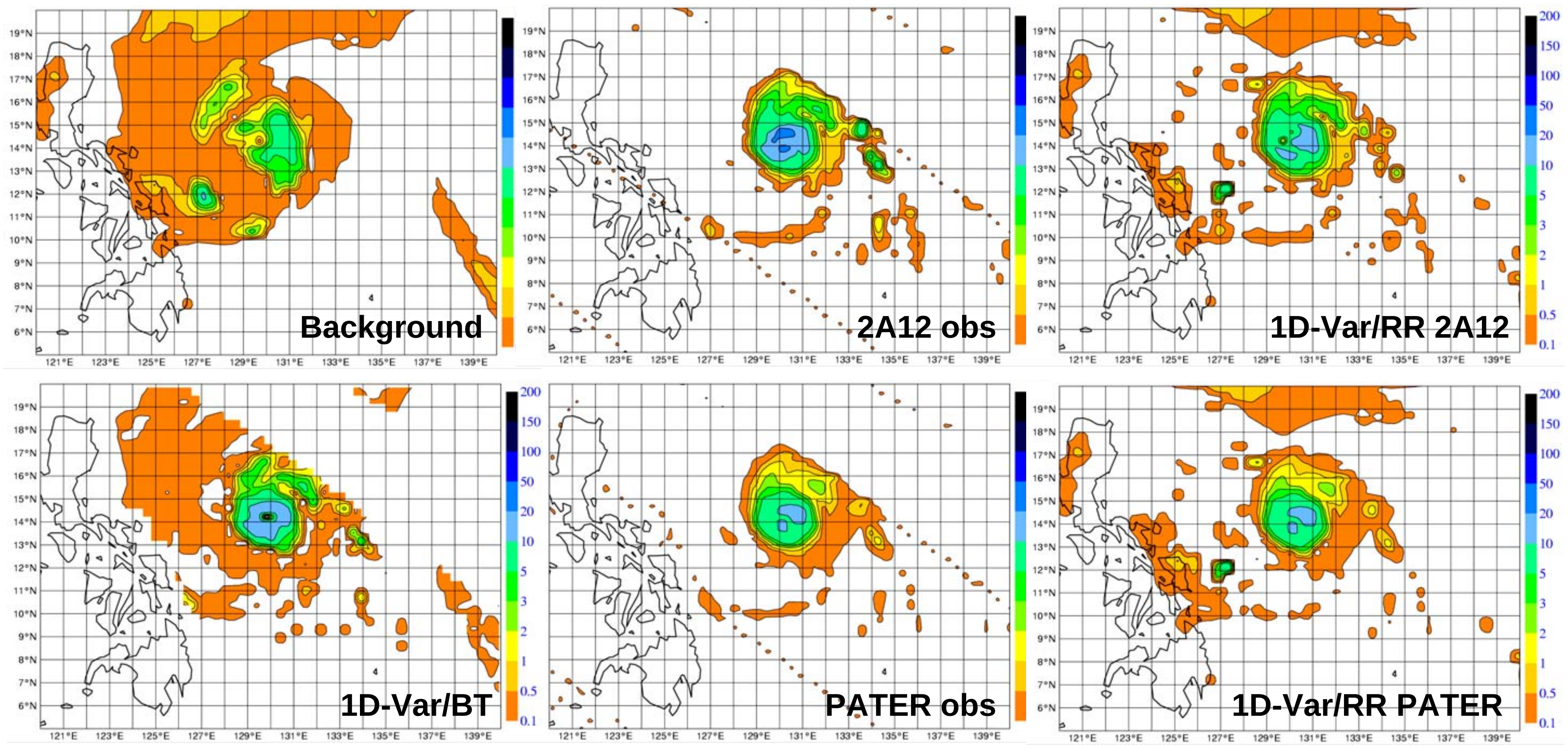


OSE SCORES

(2 summer months + 2 winter months)

Satellites are now the main source of information even in NH

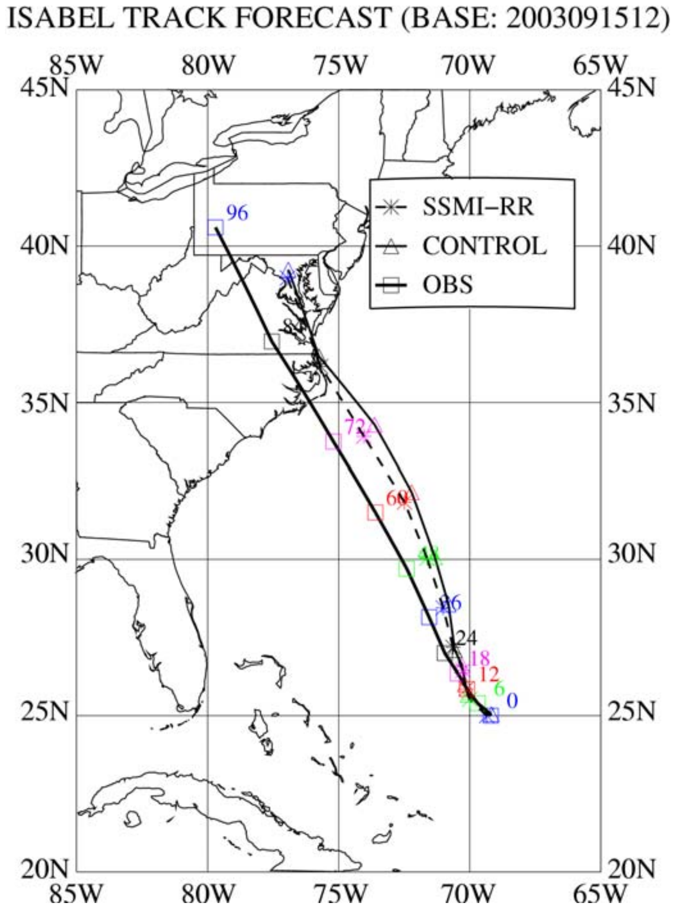
1D-Var results

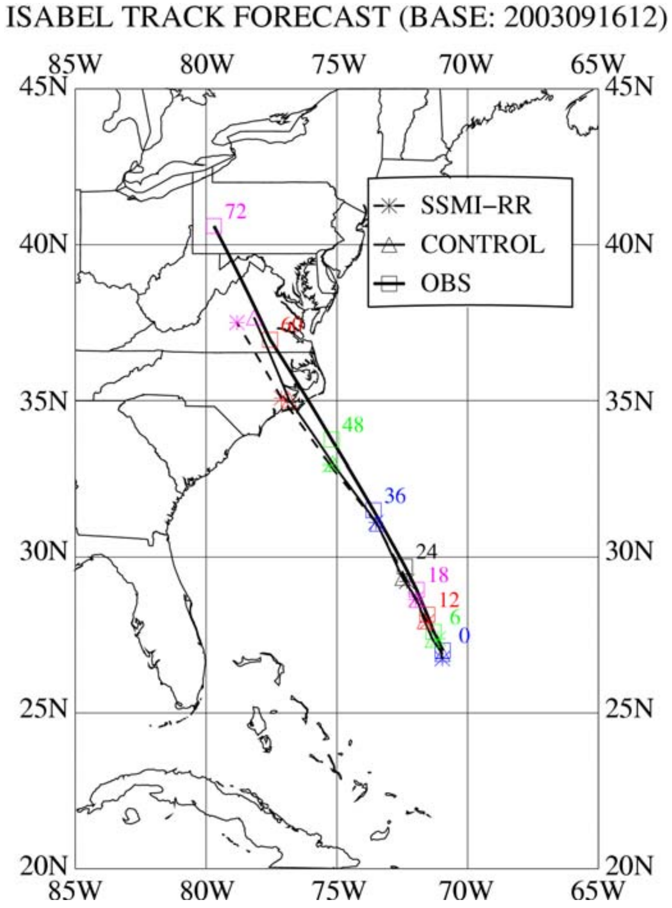


Case of super-typhoon MITAG (5 March 2002 @1200 UTC)
TMI data
Surface rainfall rates (mm hr^{-1})

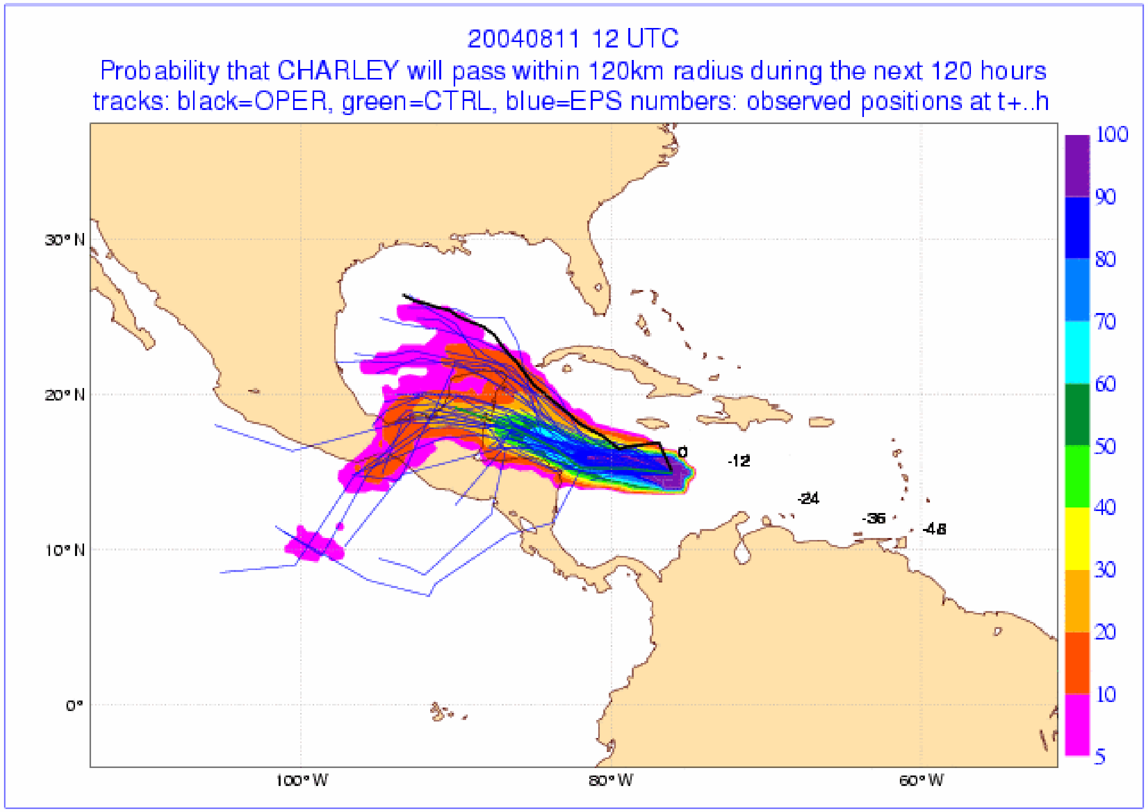
1D-Var+4D-Var SSM/I-RR Assimilation

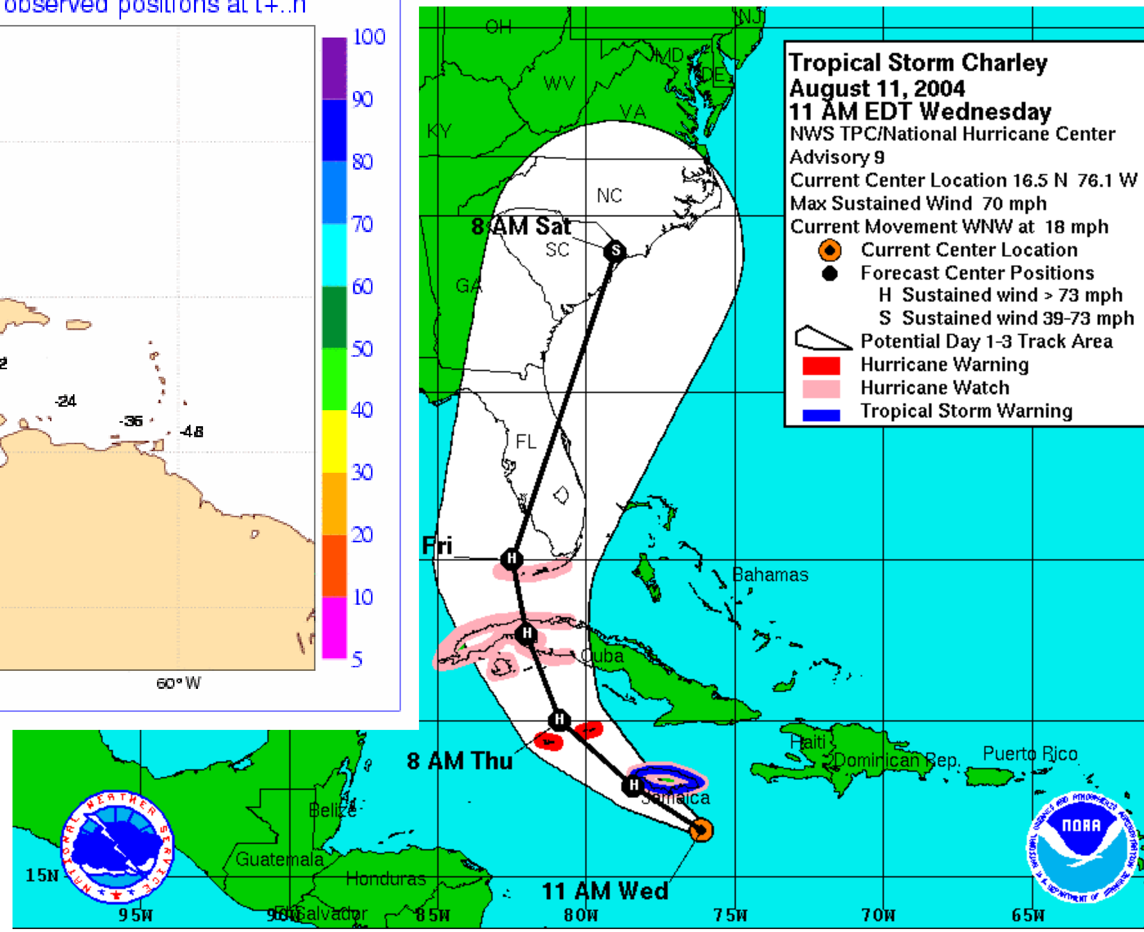
Hurricane ISABEL





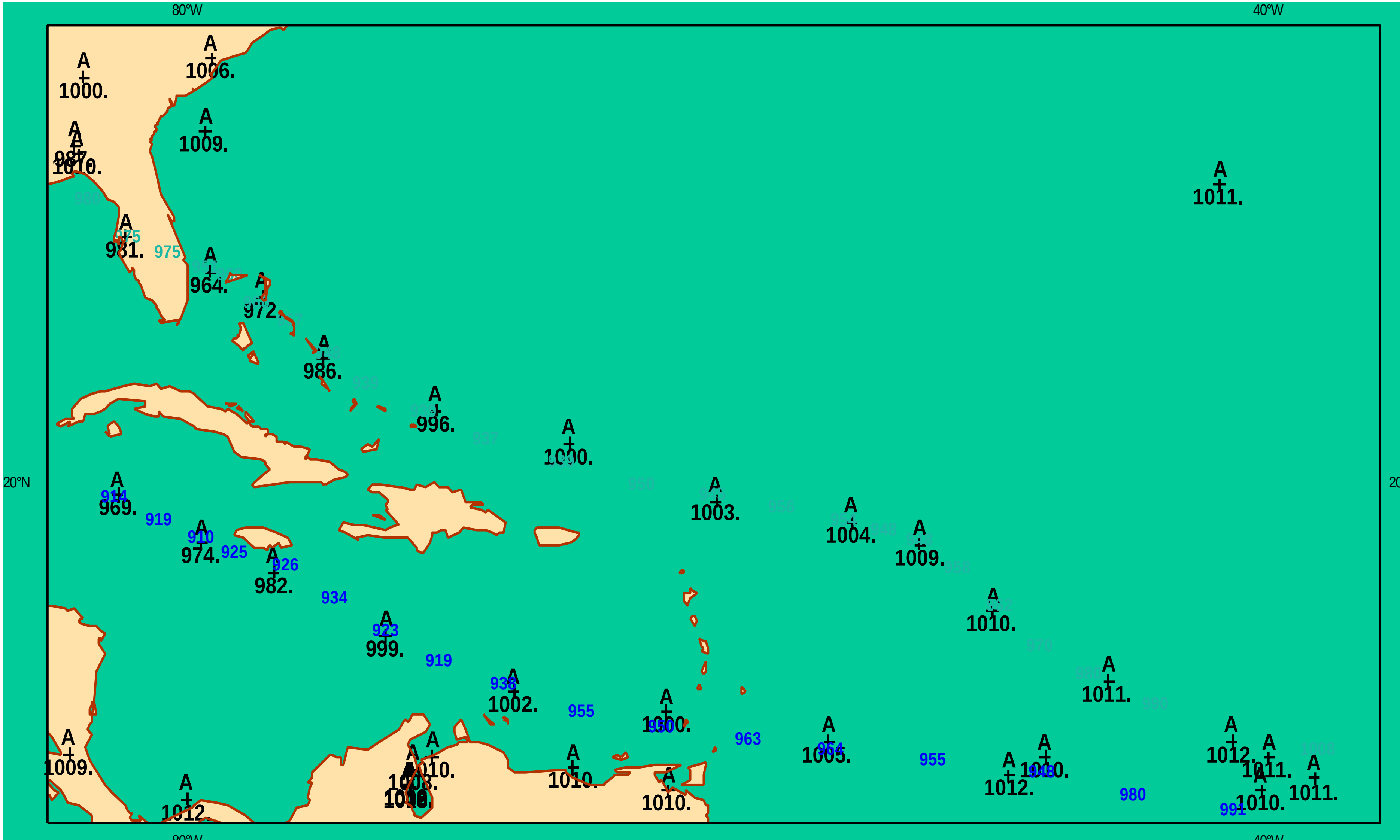
Verification of TCs Charley





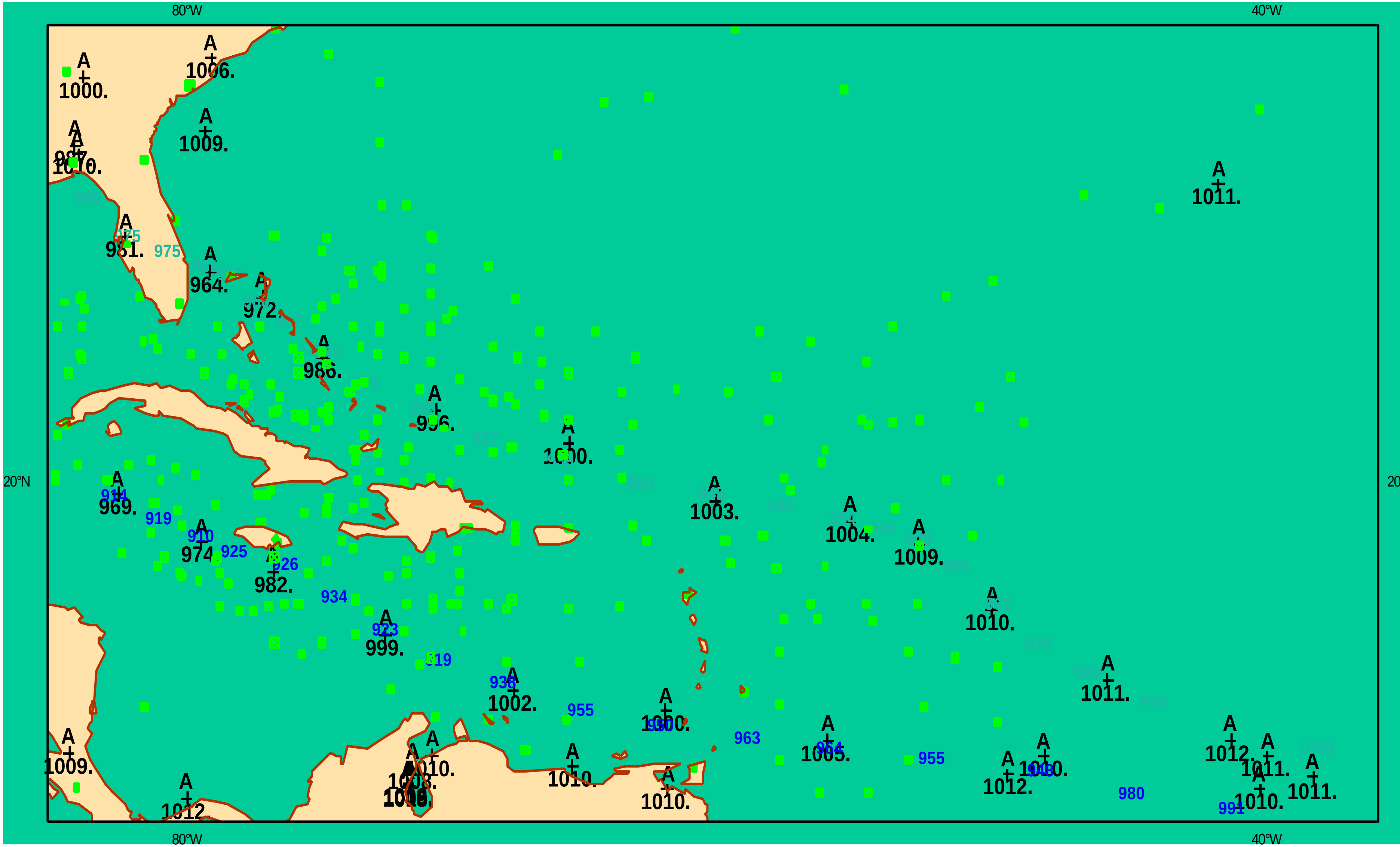
From Federico Grazzini. Slide shows poor forecast trajectory of TC cyclone Charley (small scale TC). Why?

Observed (green/blue) and analysed (A) positions of Frances and Ivan

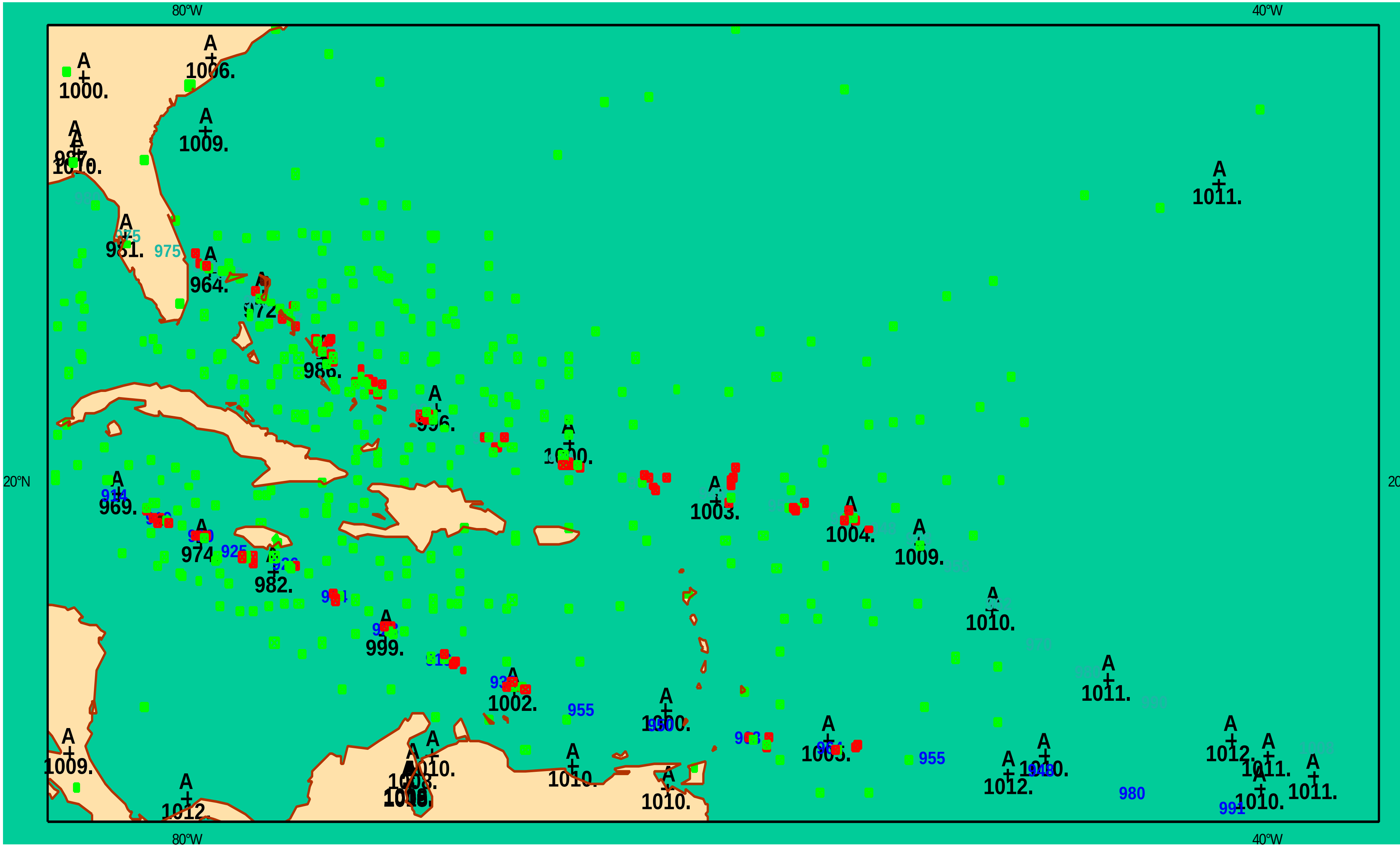


Central pressure not deep enough. Scale of analysis leads to rejection of data. Also central pressure is point value, model is box-average. Difference can be 76mb.

Frances and Ivan plus dropsondes coverage at 250 hPa (25/08 – 13/09)

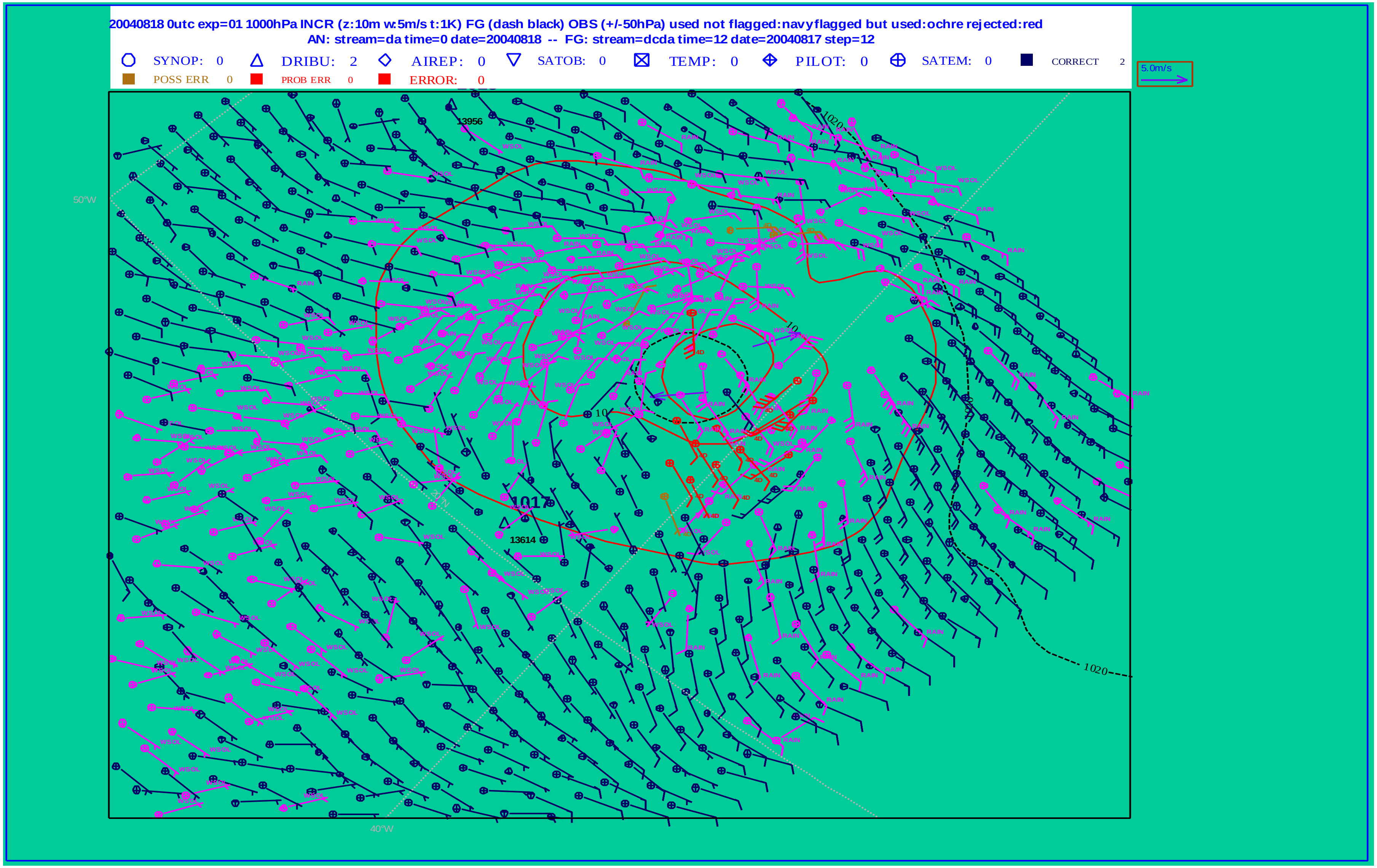


Frances and Ivan plus dropsondes coverage at 700 hPa (25/08 – 13/09)



Red indicates rejected data.

QSCAT passage on the same system



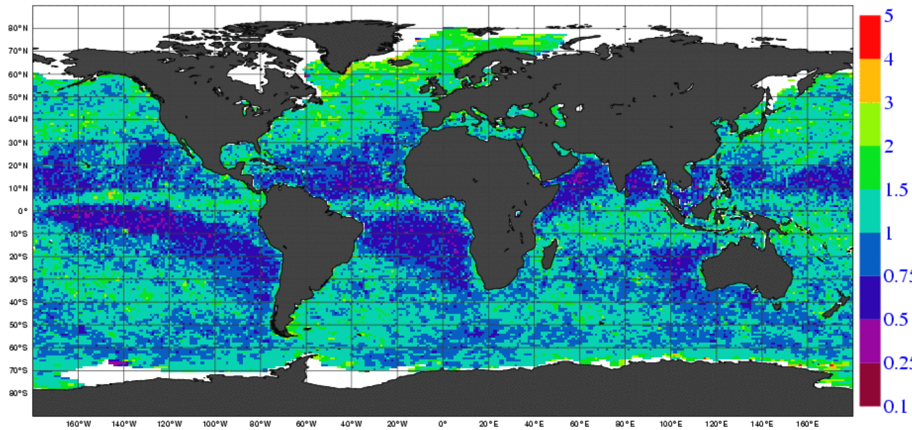
Discussion/Summary

- Dropsonde coverage is increasing and for the last three cyclones was very large.
- Upper level obs were all successfully assimilated
- Eyewall low level observations were rejected by large departures with the FG (some with potential high influence)

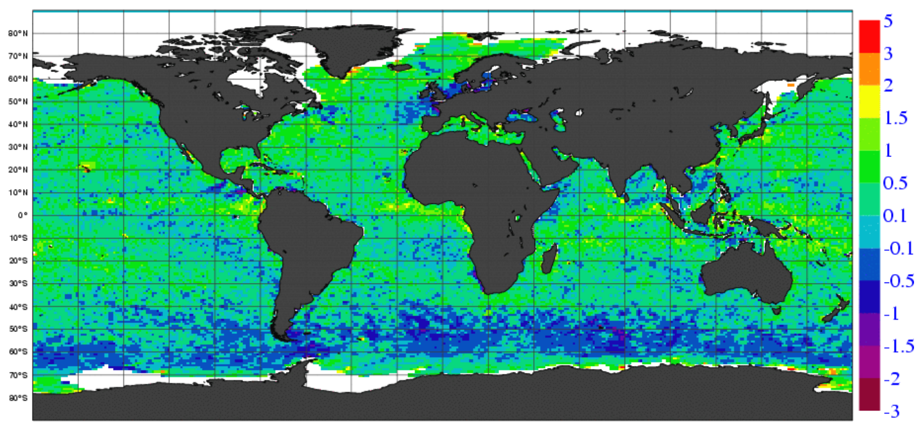
- Often the analysis is weakening the system already present in FG. Sometimes minimization problems are evident.
- For Frances and Ivan (very large and intense cyclones) it took ~7days to have a cyclone below 1000 hPa in the analysis

50-km QuikSCAT versus ECMWF Analysis

STDV (QSCA50 vs ANALYSIS), 10-metre 30min, in m/s.
average from 2002020200 to 2002022818
GLOB:1.06 NHEM:1.23 TROP:0.96 SHEM:1.07



BIAS (QSCA50 vs ANALYSIS), 10-metre 30min, in m/s.
average from 2002020200 to 2002022818
GLOB:0.25 NHEM:0.39 TROP:0.34 SHEM:0.09

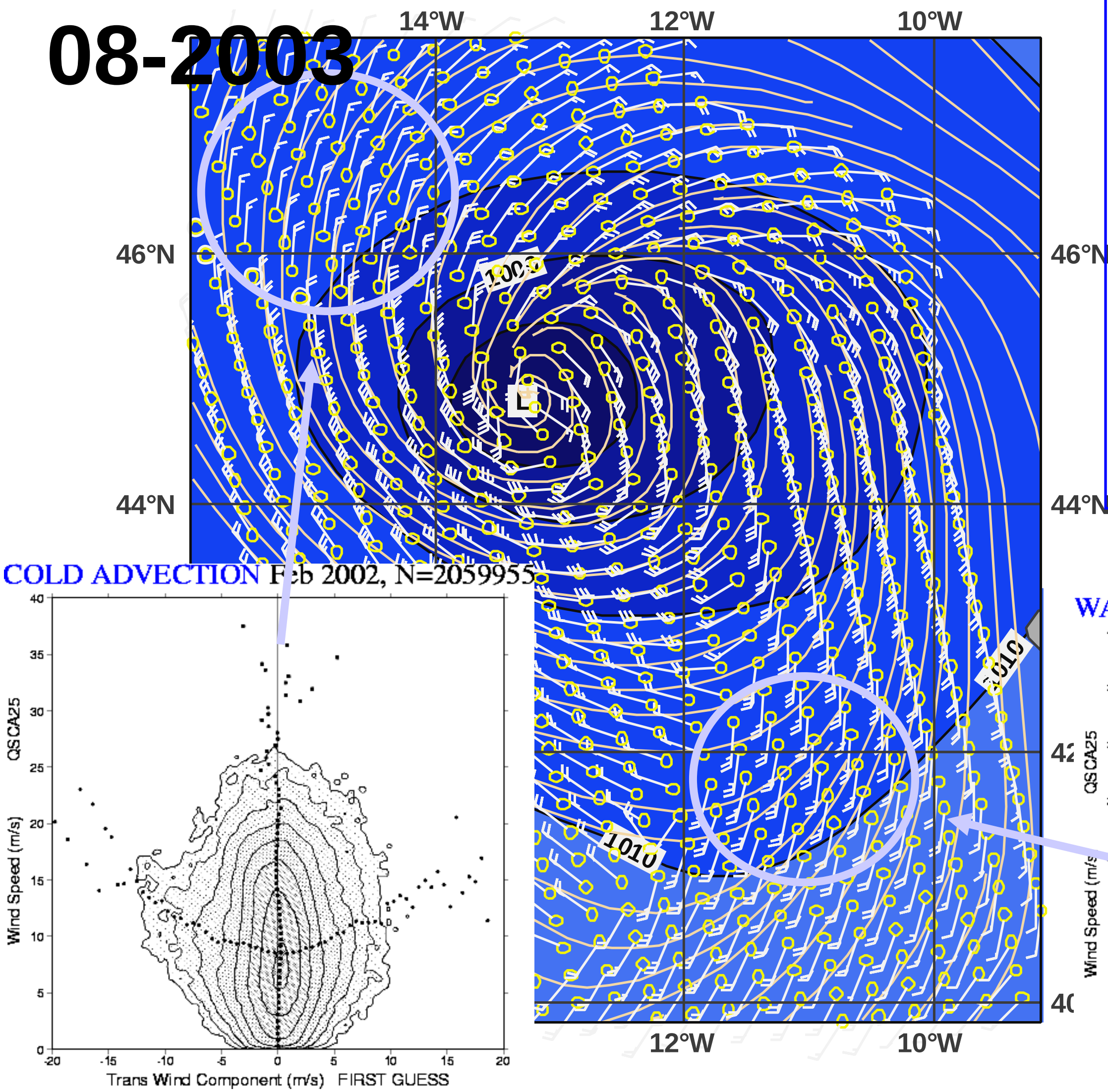


- **February 2002**
- **Collocation error:**
  15 minutes
  20 km
- **50km product:**
  Winds 4% Reduced
- **Data is assimilated:**
  Cost reduced by 32 %
- **Large regional differences**
  ITCZ + 2m/s
  ACC - 1m/s

Hans Hersbach

Lack of cross-isobar flow

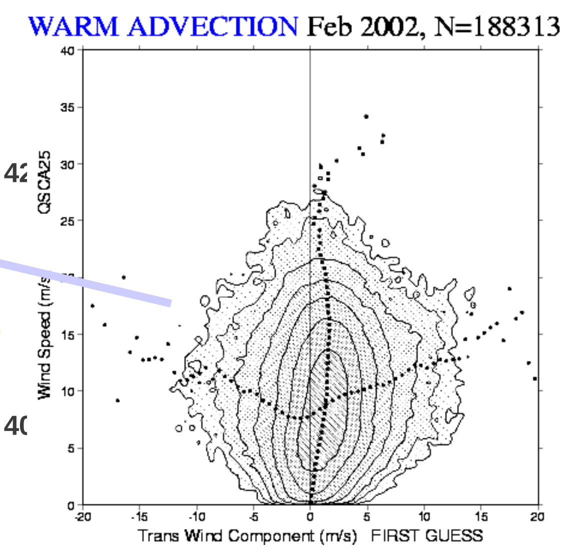
ERS-2 27-08-2003

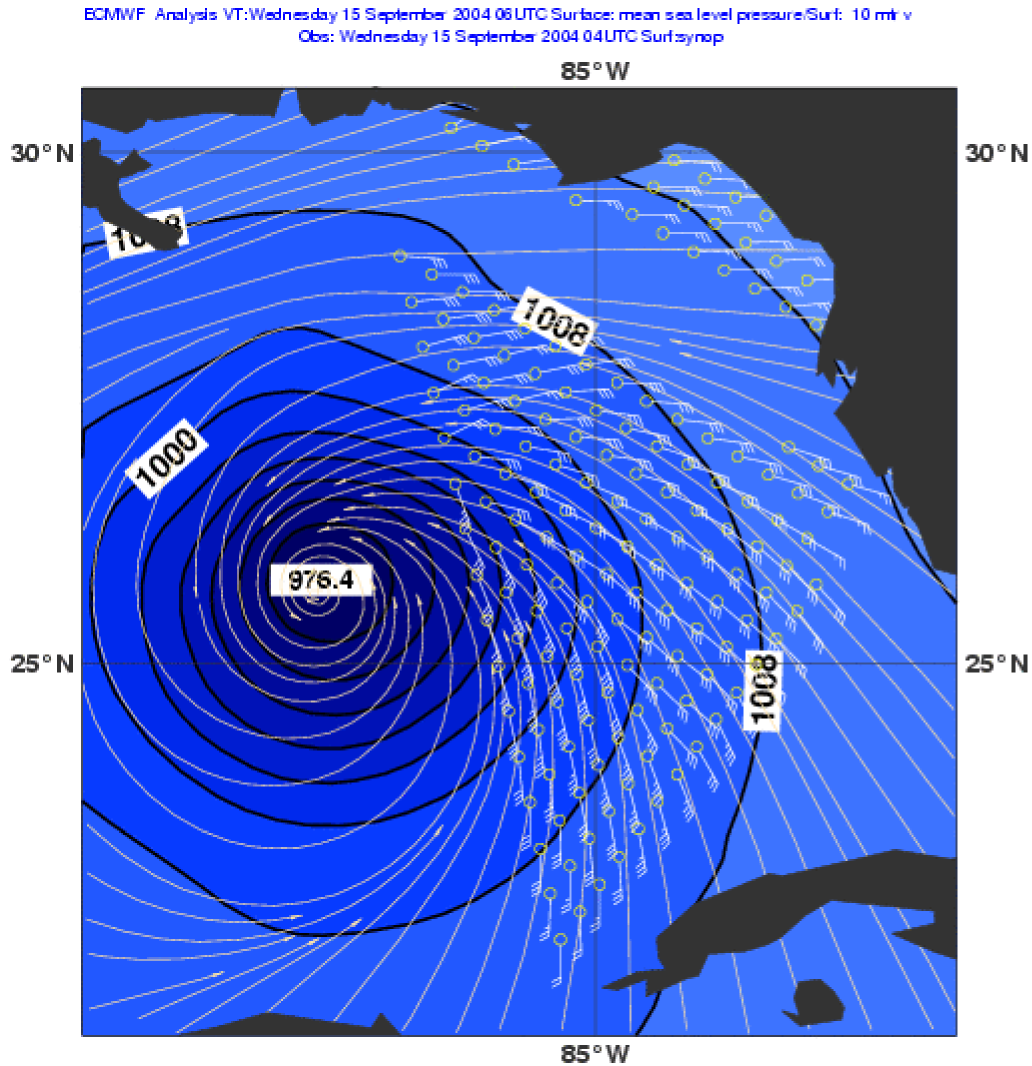


Present in ECMWF model
Lack of sondes veer, backing
Hollingsworth 1994

Also for MetOffice,
Charlie, Sable *(Andrew Brown)*

QuikSCAT, vs ECMWF & NCEP
Difference warm/cold advection



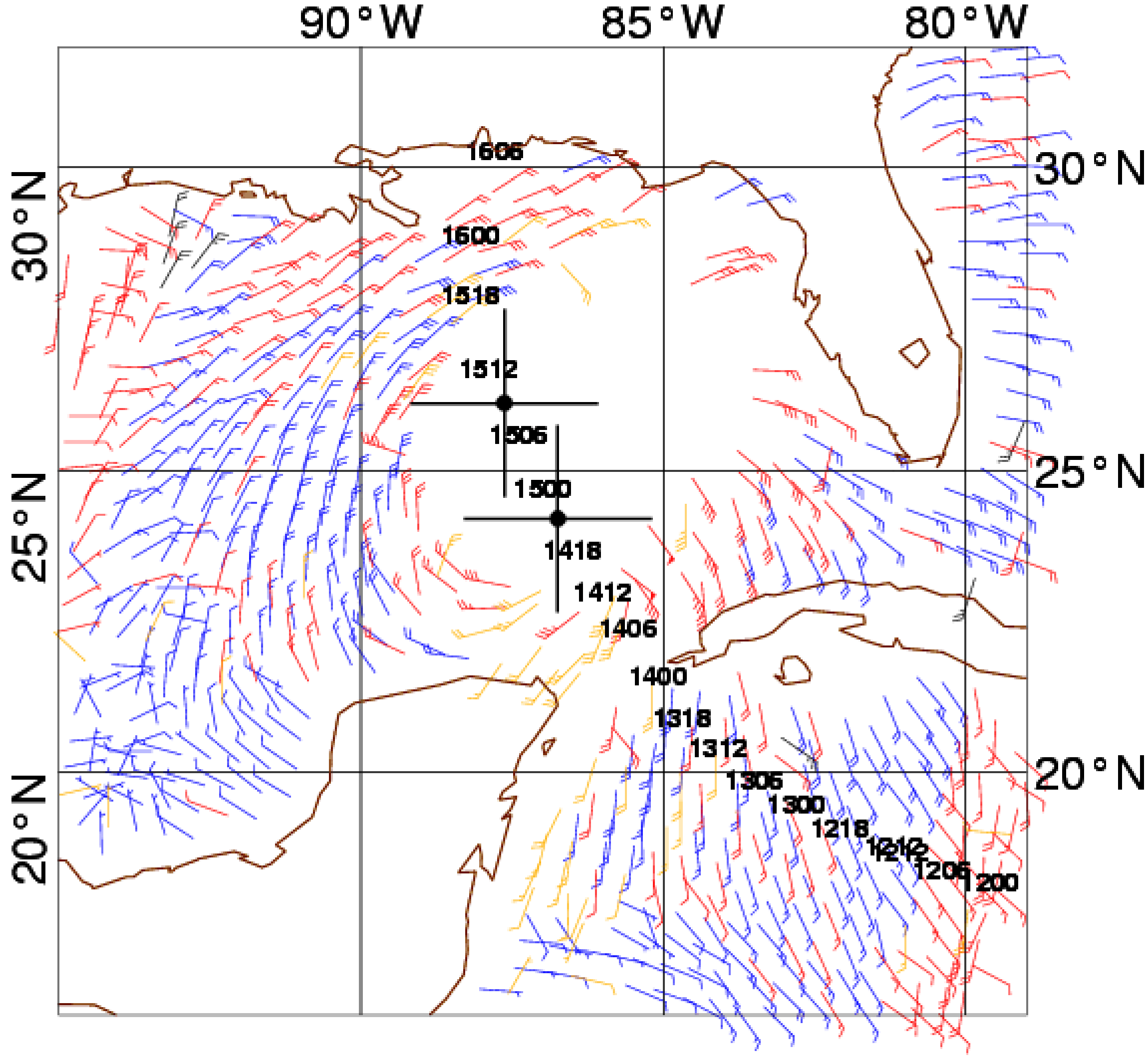


ERS-2 is still working in limited regions. Less rain contamination than Q-scat.

Note left-most vectors

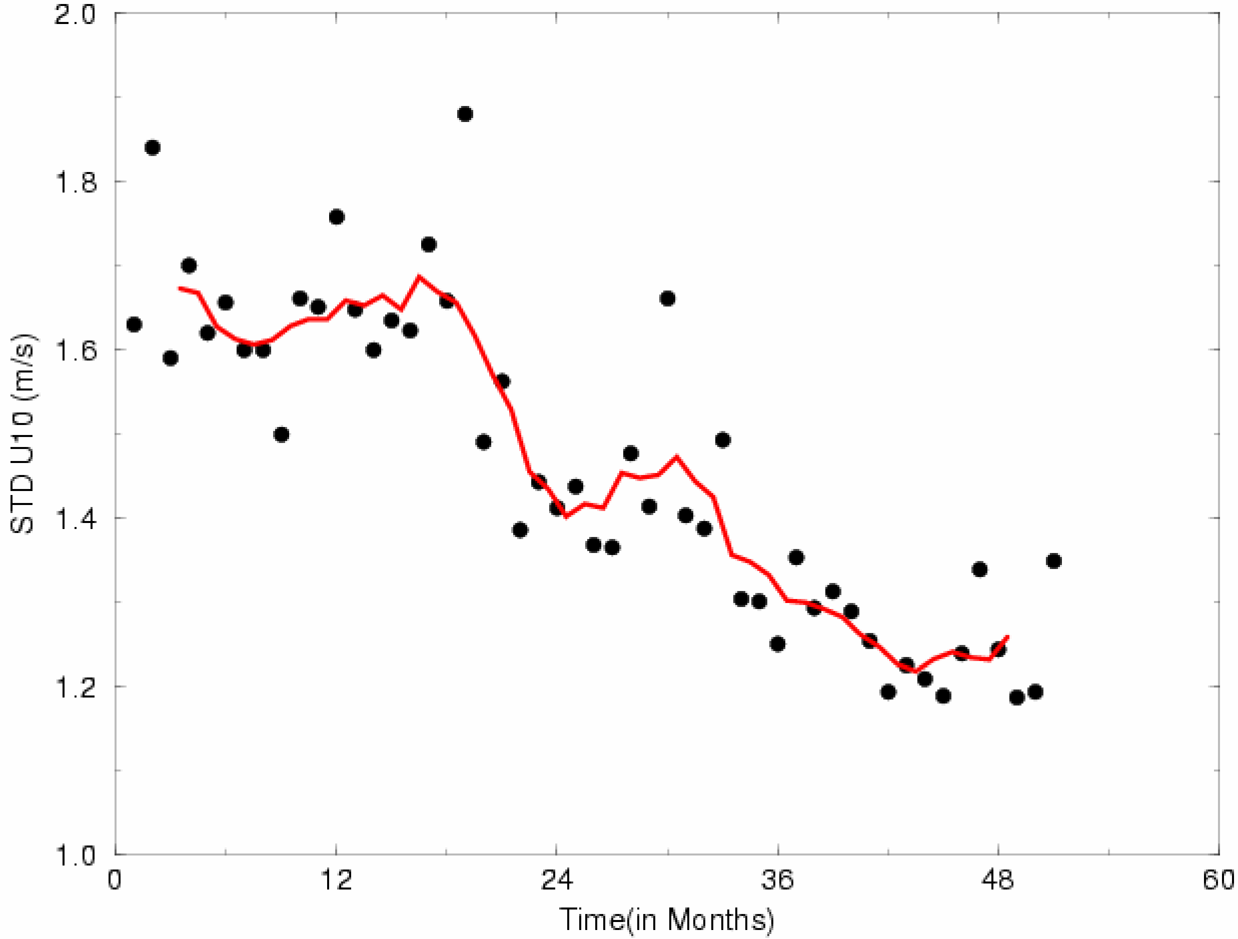
QSCAT 50km (0001, DCDA): IVAN

Ambig. closest to ana, from 2004 0914 2259 to 2004 0915 0001



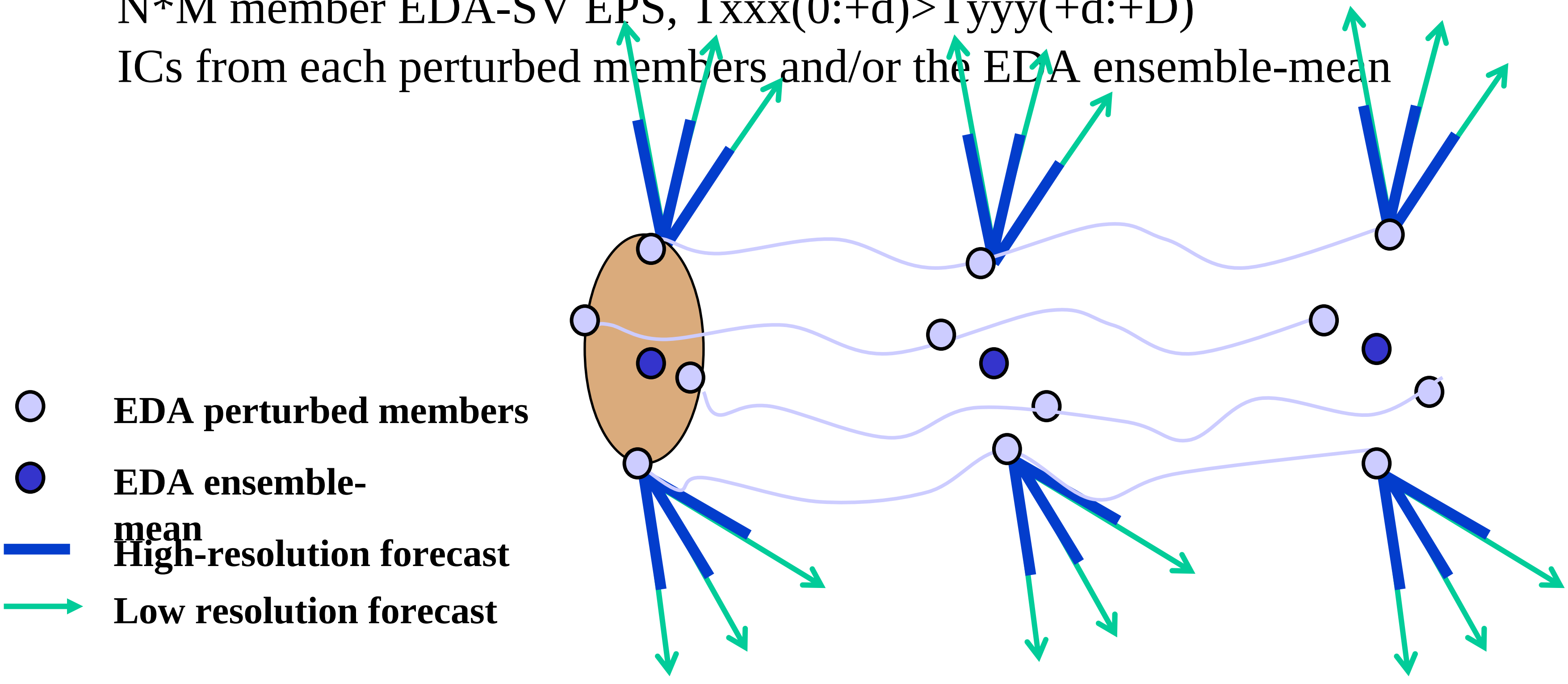
Tropical random wind speed error versus time

Period: August 1995 until December 1999



EDA: towards a probabilistic analysis & forecast system?

N-member EDA
N*M member EDA-SV EPS, Txxx(0:+d)>Tyyy(+d:+D)
ICs from each perturbed members and/or the EDA ensemble-mean



Ensemble Data Assimilation

The objectives of the study (based on 14-days TL159L31 3D- and 4D-Var) were:

- **to investigate the impact of perturbations on the initial state, the observation and the diabatic tendencies on analysis fields;**
- **to analyze the possible use of initial perturbations generated from Ensemble Data Assimilation in the EPS.**

Results have indicated that:

- **the average distance between each perturbed analysis and the ensemble-mean of an 11-member OBST-EDA is about 30% smaller than the corresponding distance between analyses from 4 different centers (ECMWF, UKMO, DWD, NCEP).**

- **the use of only EDA-based perturbations would deteriorate the EPS performance. The joint use of EDA- and SV-based perturbations EPS did not improve the results.**

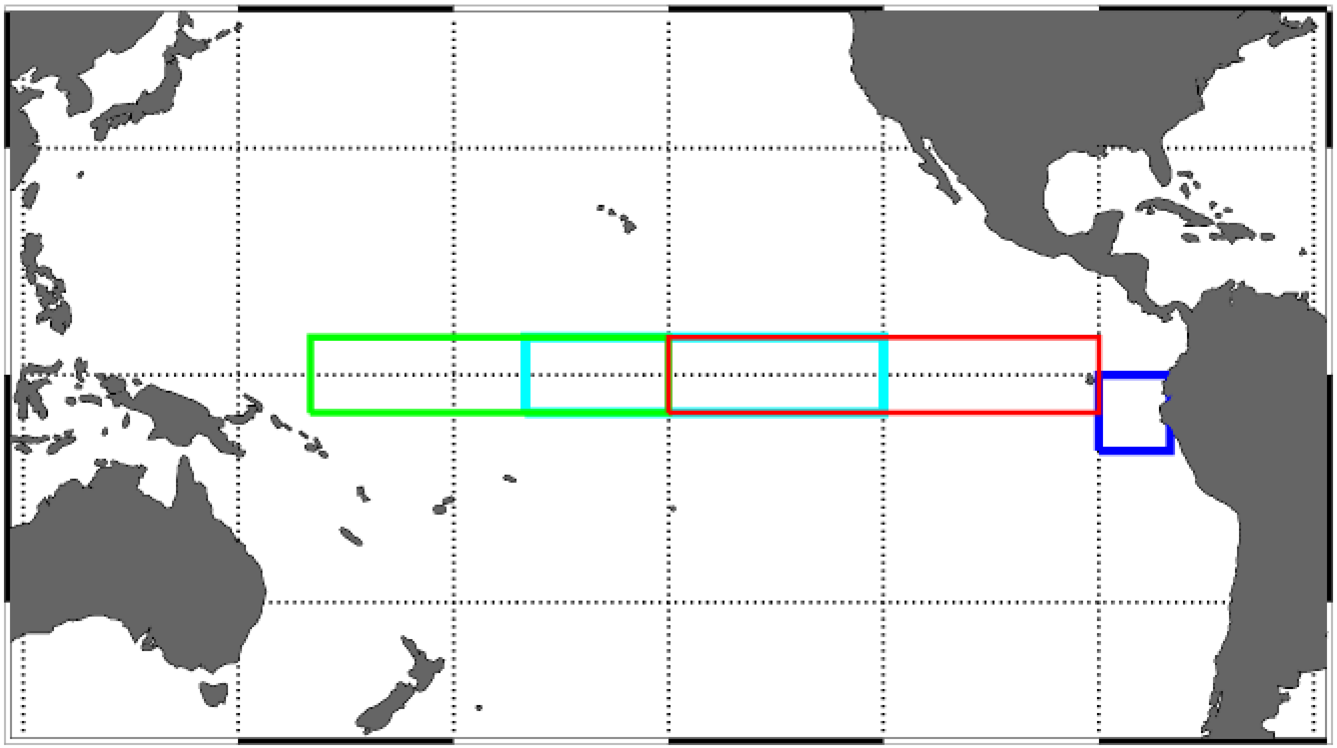
ECMWF perspective: the ocean

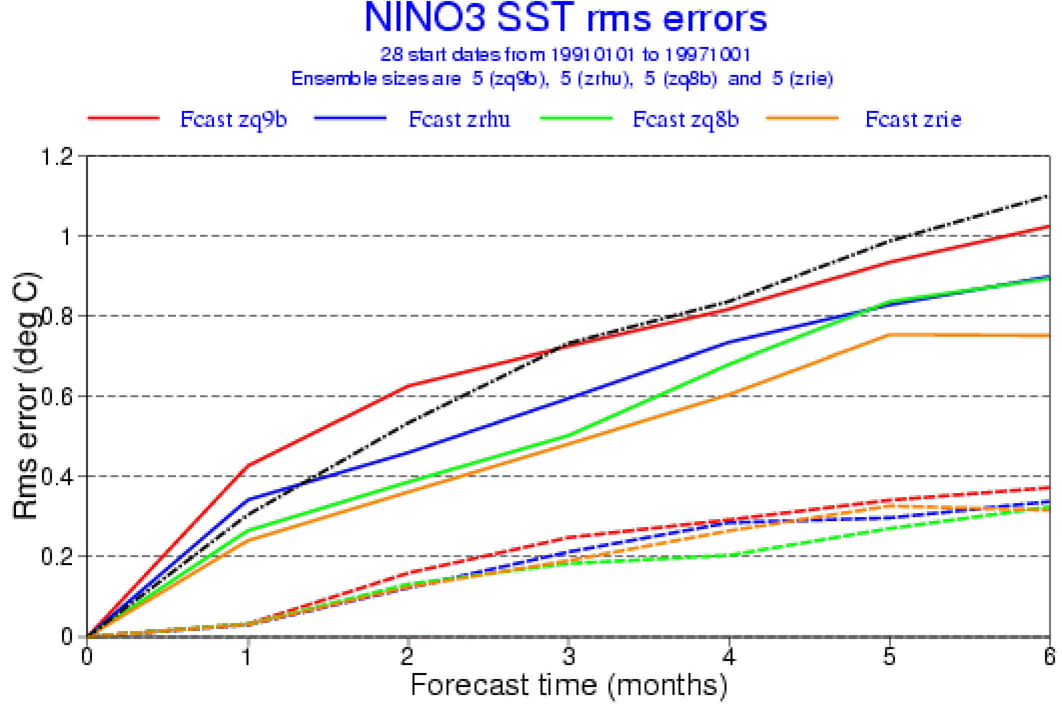
- Ocean analyses and reanalyses used for
- Forecasts for a month ahead
- Forecasts for seasons ahead
- Forecasts for years ahead (ENACT, ENSEMBLES)
- Forecasts of medium range using a coupled model (to be assessed as part of MERSEA)

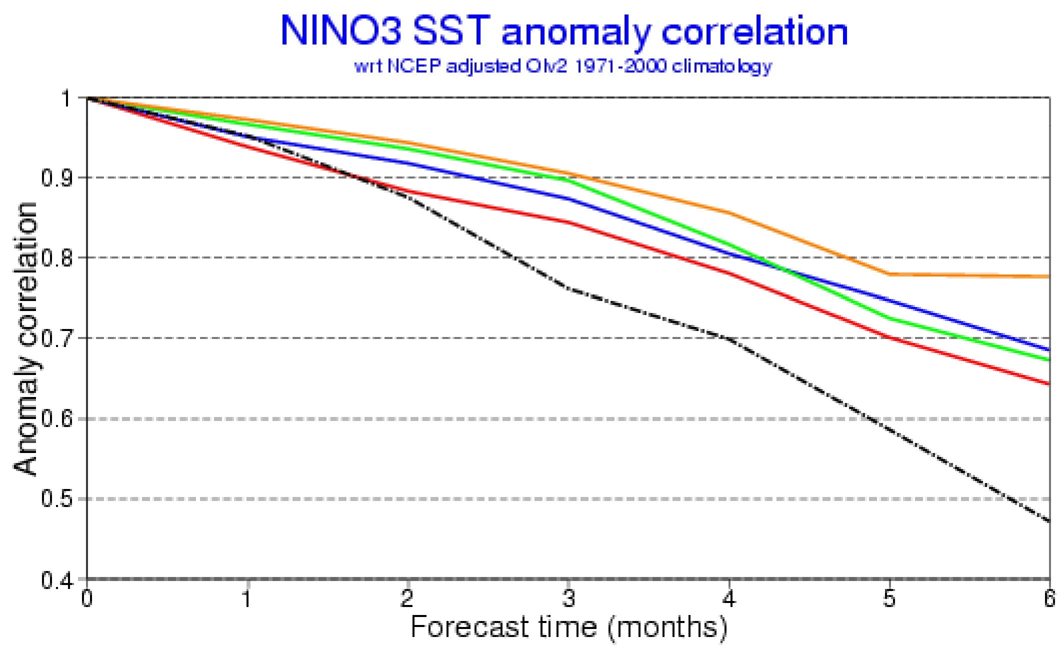
Coupled model initialisation.

- Currently this is done by a data analysis of both media separately. Maybe it should be done together.
- Maybe the reanalysis should involve an adjustment to SST.
- Multi-annual forecasts might need a different strategy to monthly forecasts. (Deeper ocean with fewer data).

Nino3.4, Lon = [-170, -120], Lat = [-5, 5]
Nino12, Lon = [-90, -80], Lat = [-10, 0]
Nino4, Lon = [160, -150], Lat = [-5, 5]
Nino3, Lon = [-150, -90], Lat = [-5, 5]



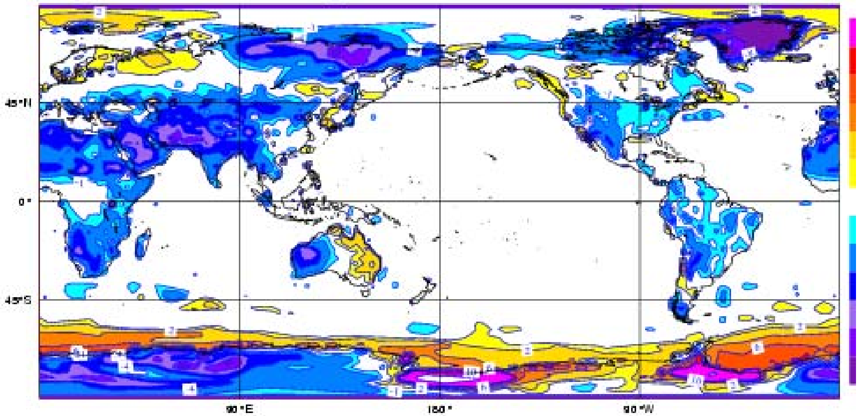




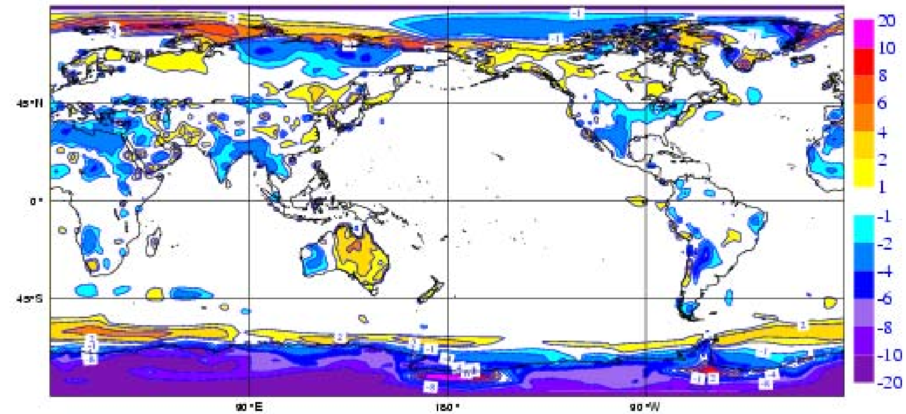
- Spread and rms error for 4 different sets of experiments. The red and blue have no data assimilation, the other two (green and gold do). This system underestimated the uncertainty in ocean initial conditions: only one analysis stream was run.

- Previous slide seems like good news vis-à-vis ocean data assimilation.
- **Forecasts are better with d.a. than without.**
- The impact of different wind products is less with d.a. than without: i.e. data assimilation can offset errors in the winds.

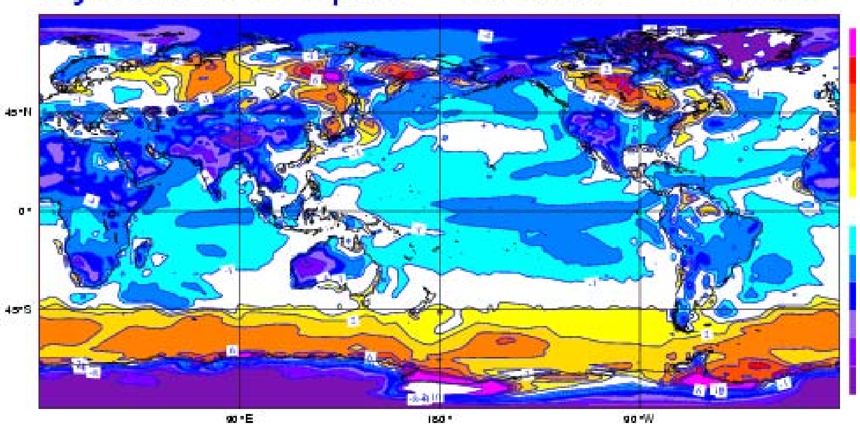
System 1 coupled - month 1 - sstbias



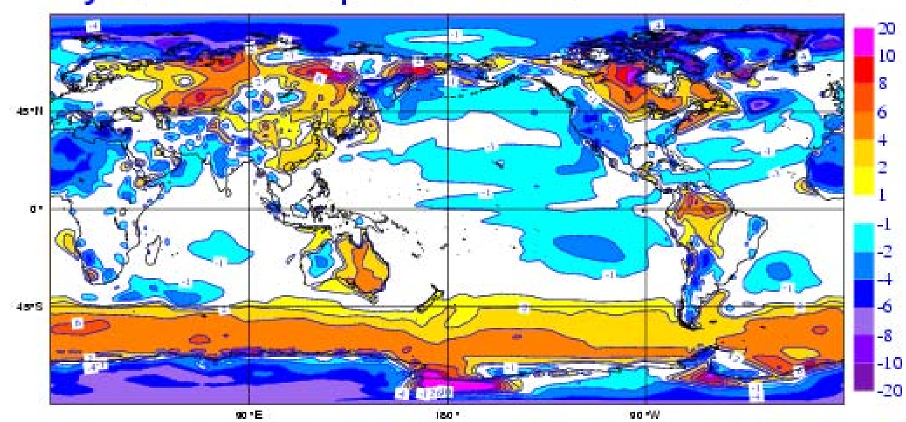
System 2 coupled - month 1 - sstbias



System 1 coupled - month 6 - sstbias



System 2 coupled - month 6 - sstbias



Seasonal Forecast INITIALIZATION

OCEAN INITIALIZATION

- <u>Relaxation to observed SST (~2 days)</u>
- <u>OI of subsurface T, every 10 days</u>
- <u>10 days assimilation window</u>
- Saliniy Updates (T-S scheme)
- Velocity Updates (geostrophy)
- Subsurface 3D relaxation to T and S Levitus 98 (~18 months)
- Daily forcing for mass, momentum, and heat from NWP
- Wind perturbations (SOC-ERA, monthly values)
- <u>11 days behind real time</u>

ENSEMBLE GENERATION

- 40-member ensemble forecast
- 5 different ocean analysis
    - Perturbations to the subsurface
- 40 SST perturbations
    - Reynolds 2dvar-OI
    - Temporal resolution
- Stochastic physics

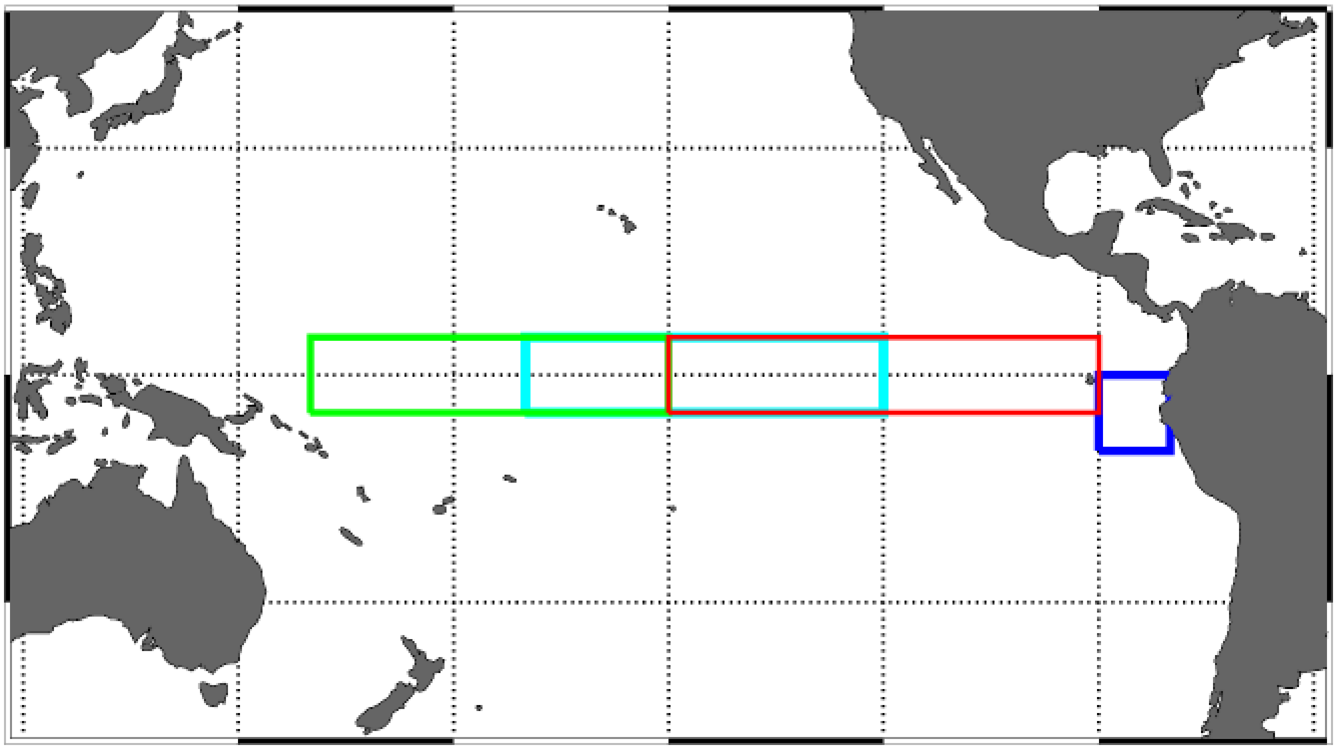
Atmosphere Initialization

- ERA 15 (1987-1993)
- NWP 1994 onwards

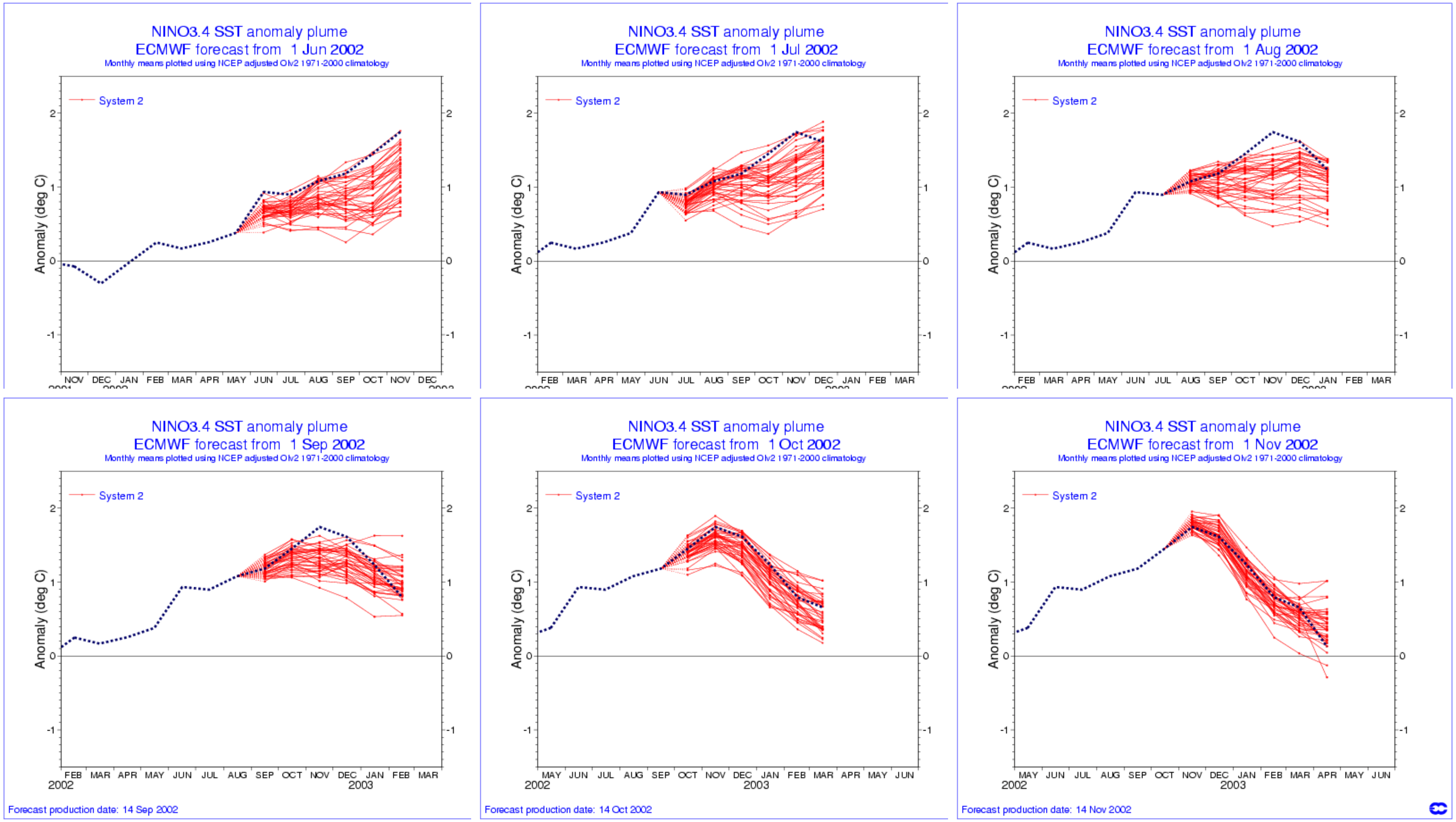
Ensemble generation strategy

- Perturb winds during analysis
- Perturb SSTs at start of forecasts
- Include stochastic physics throughout integration
- How do these compare individually and collectively and with the LA (lagged average) approach used for example in S1?
- **How much does data assimilation control spread?**
- **Is the ensemble spread large enough?**
- Is there skill in the ensemble spread?

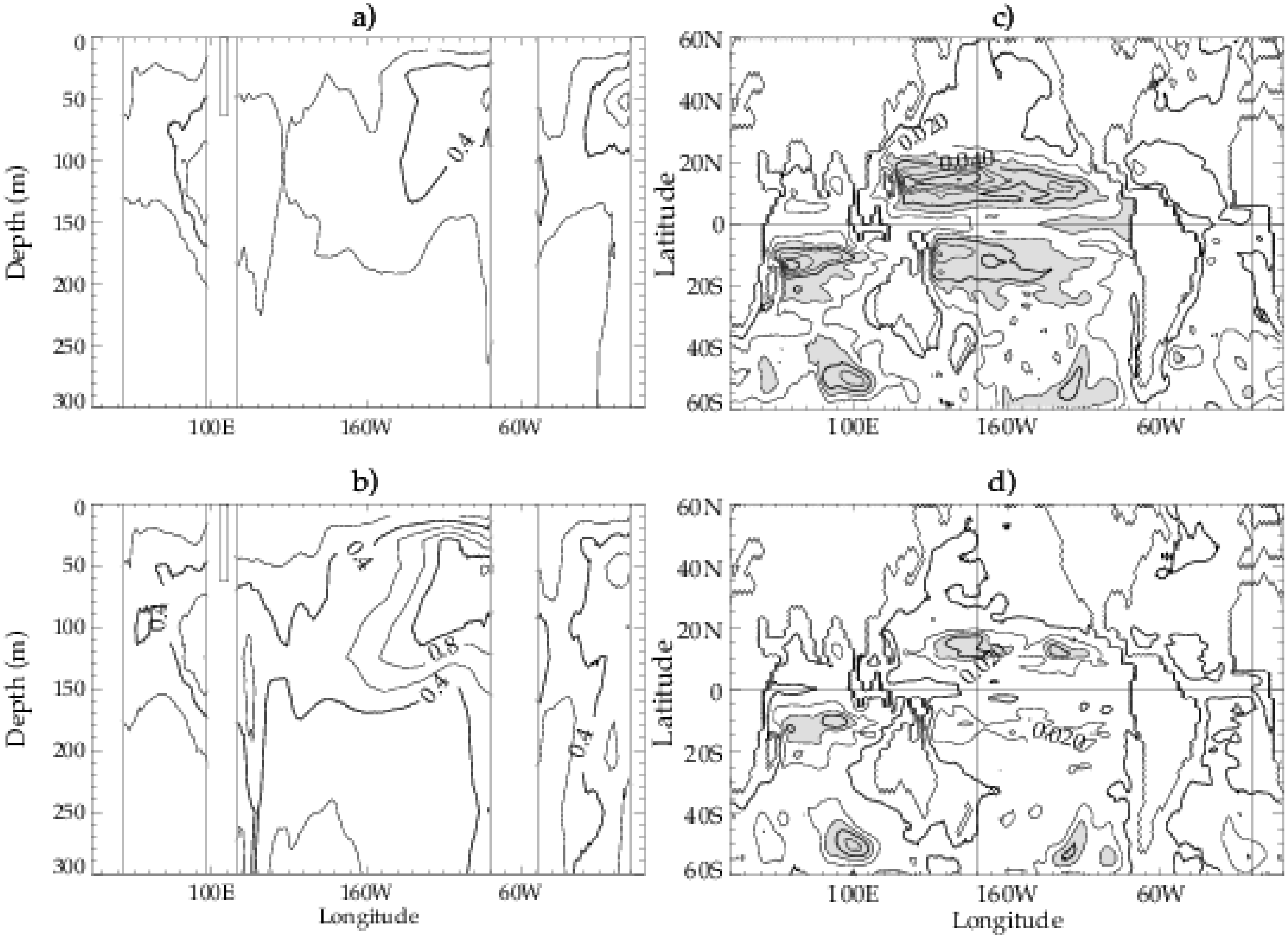
Nino3.4, Lon = [-170, -120], Lat = [-5, 5]
Nino12, Lon = [-90, -80], Lat = [-10, 0]
Nino4, Lon = [160, -150], Lat = [-5, 5]
Nino3, Lon = [-150, -90], Lat = [-5, 5]



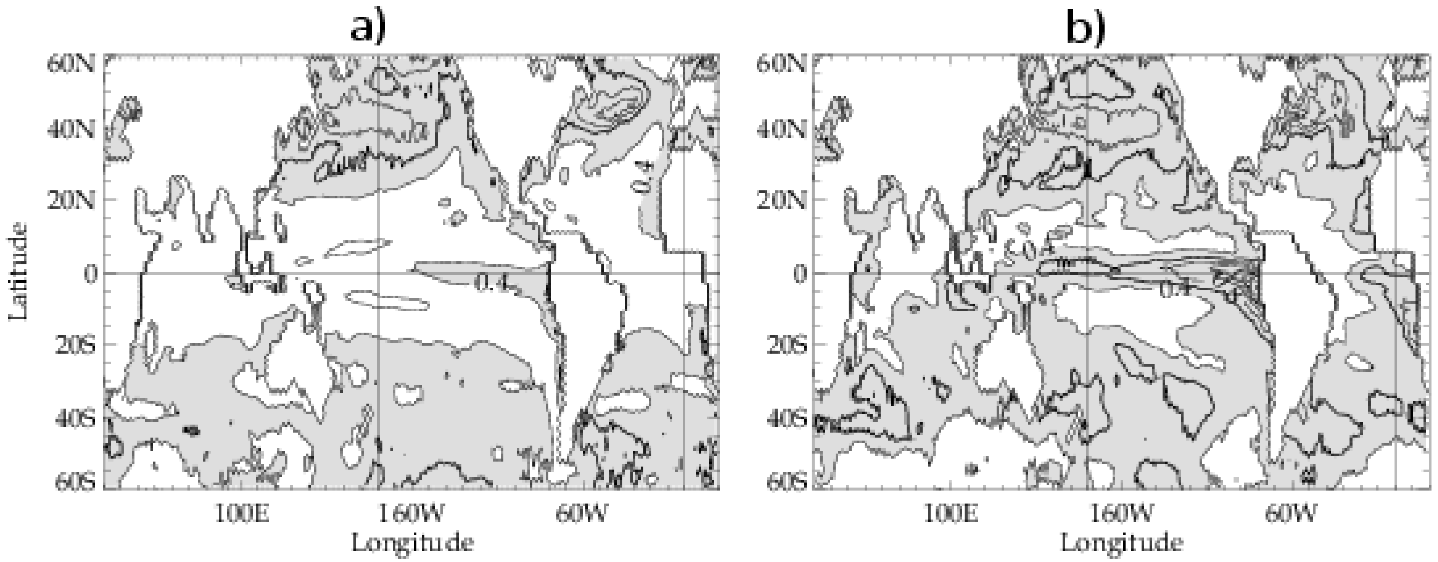
Validation of Nino3.4 forecasts from System-2

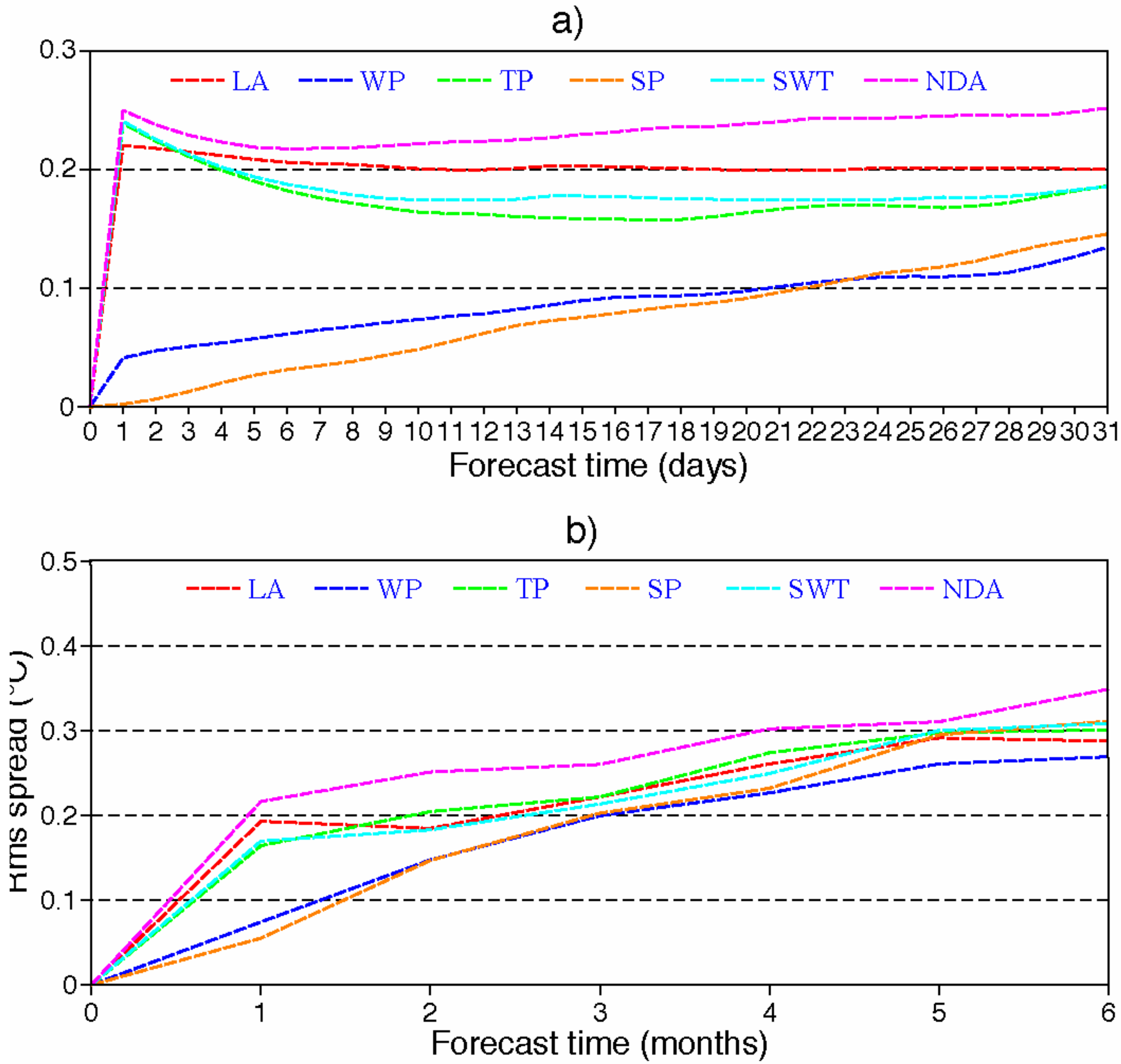


Plot of rms from analyses using wind perturbations with and without ocean data assimilation



Plot of rms spread and error in SST for months 3-5. Spread is too small



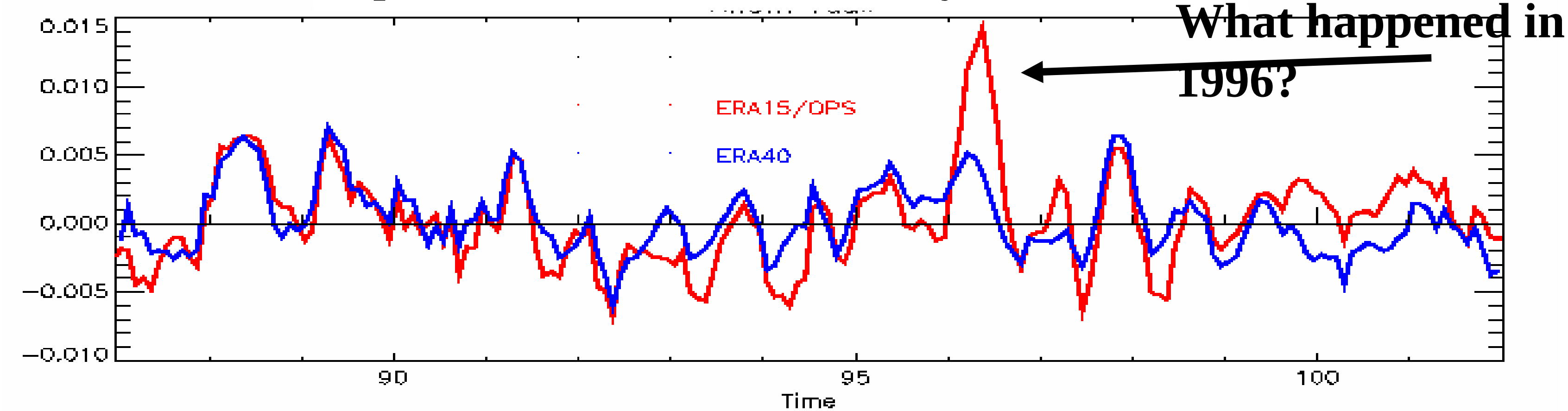


Spread from various contributions: wind, SST stochastic physics, all of above, LA, data assimilation

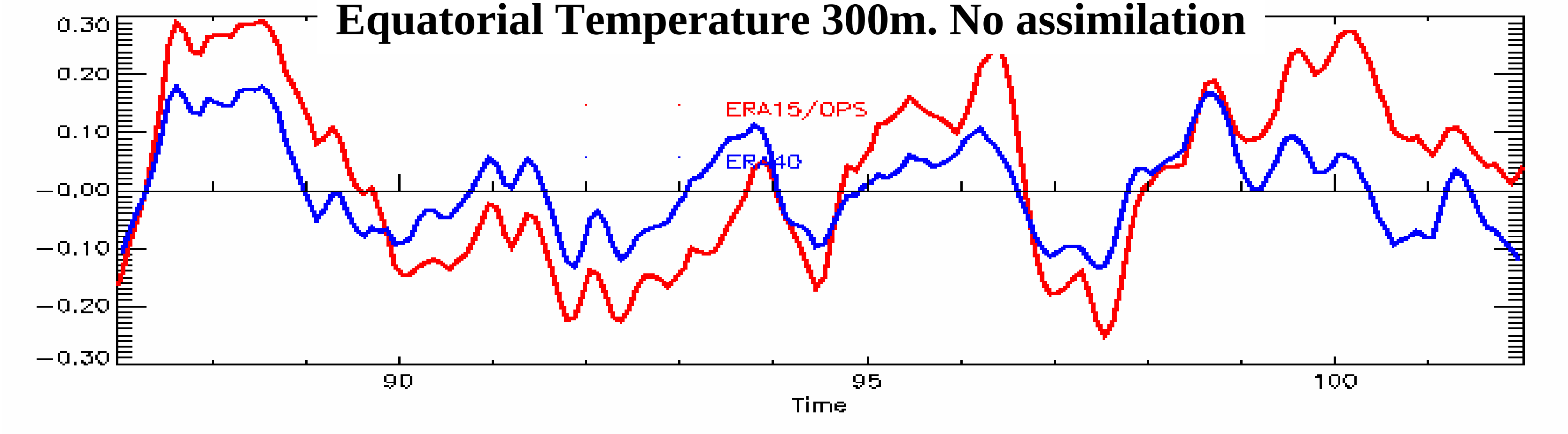
ERA15/OPS versus ERA40

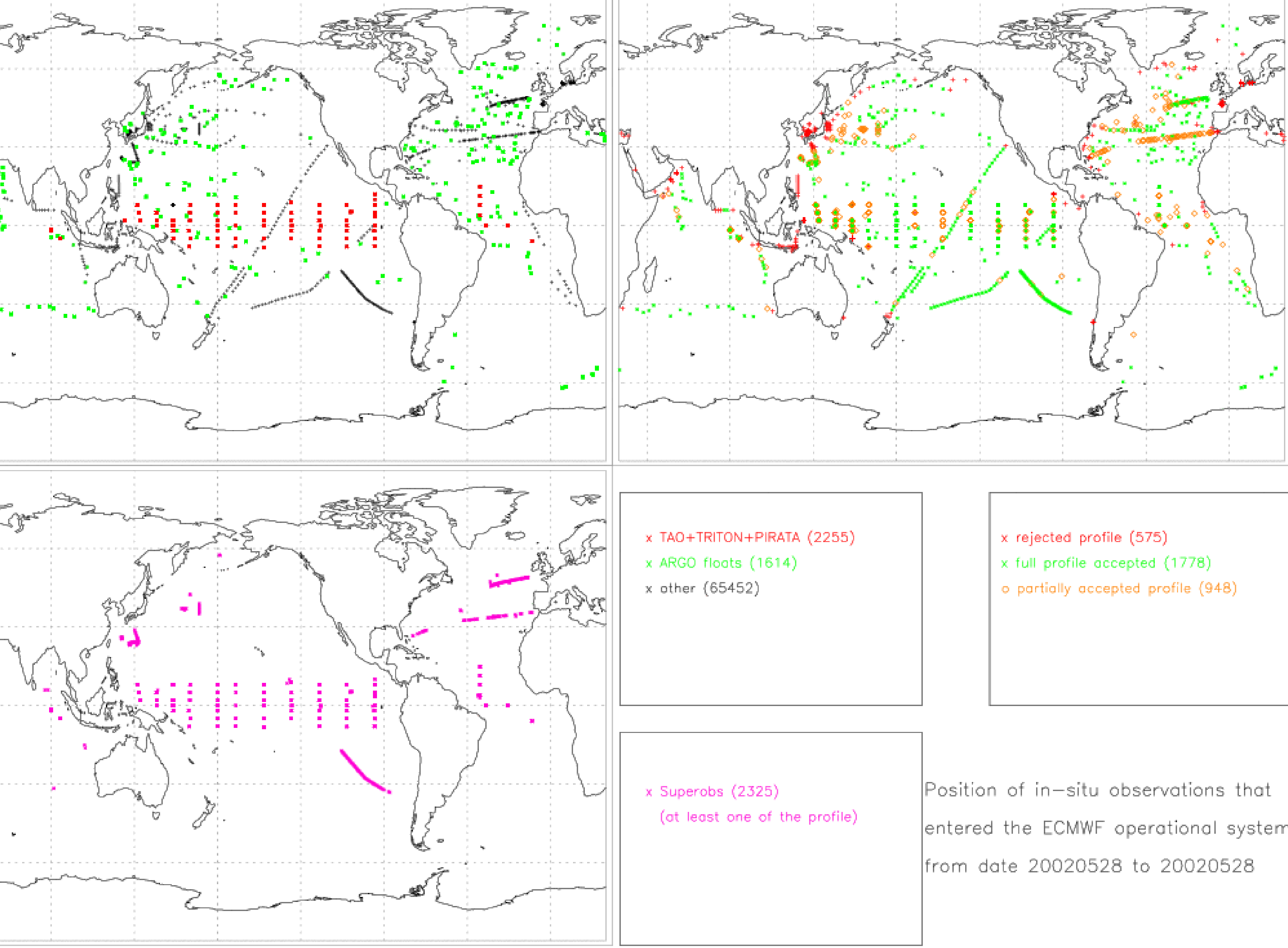
Uncertainty in Surface fluxes=Uncertainty in ocean state

Equatorial Wind Stress Anomaly



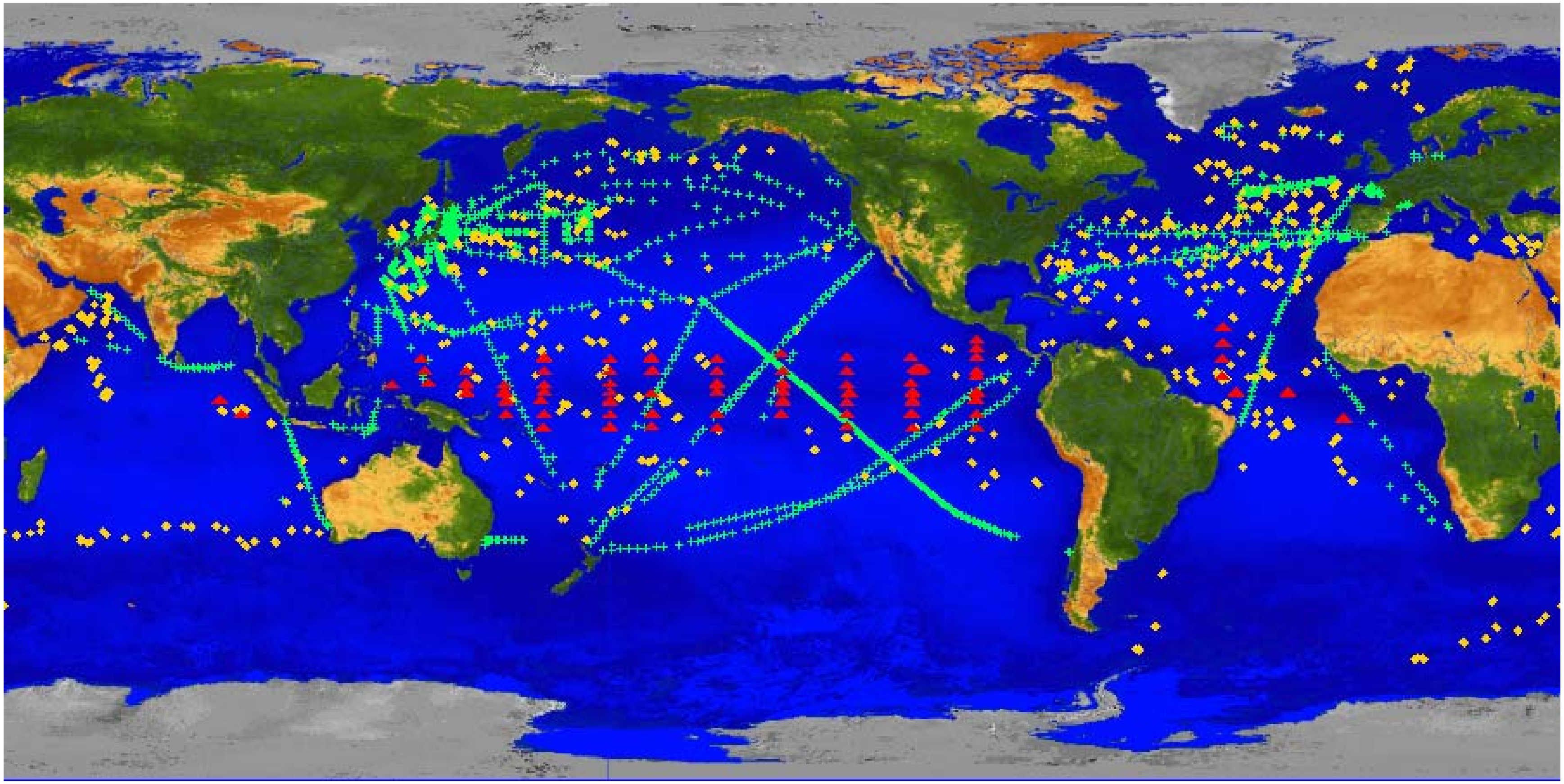
Equatorial Temperature 300m. No assimilation



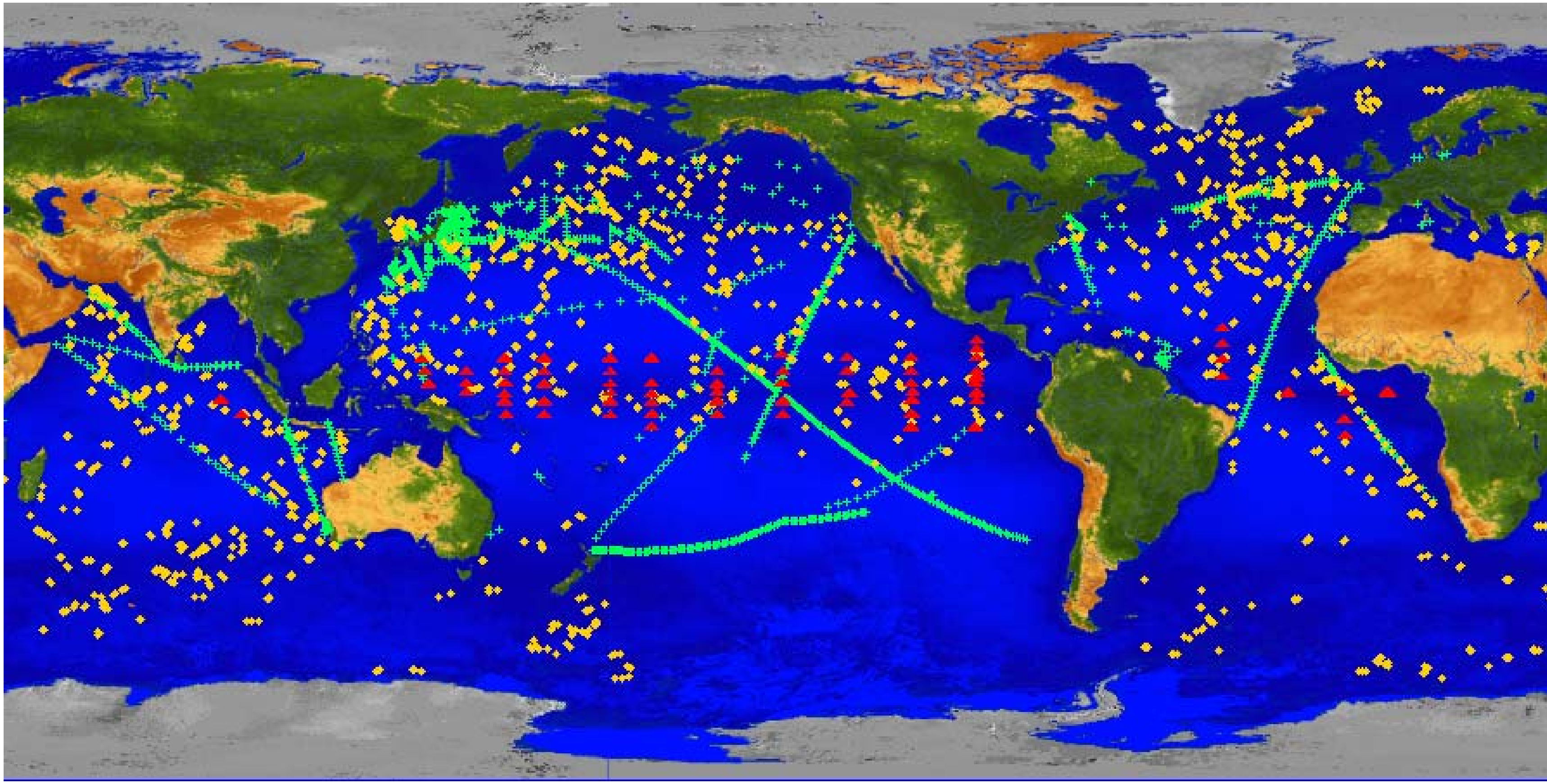


x TAO+TRITON+PIRATA (2255)
x ARGO floats (1614)
x other (65452)
x rejected profile (575)
x full profile accepted (1778)
o partially accepted profile (948)
x Superobs (2325)
(at least one of the profile)
Position of in-situ observations that
entered the ECMWF operational system
from date 20020528 to 20020528

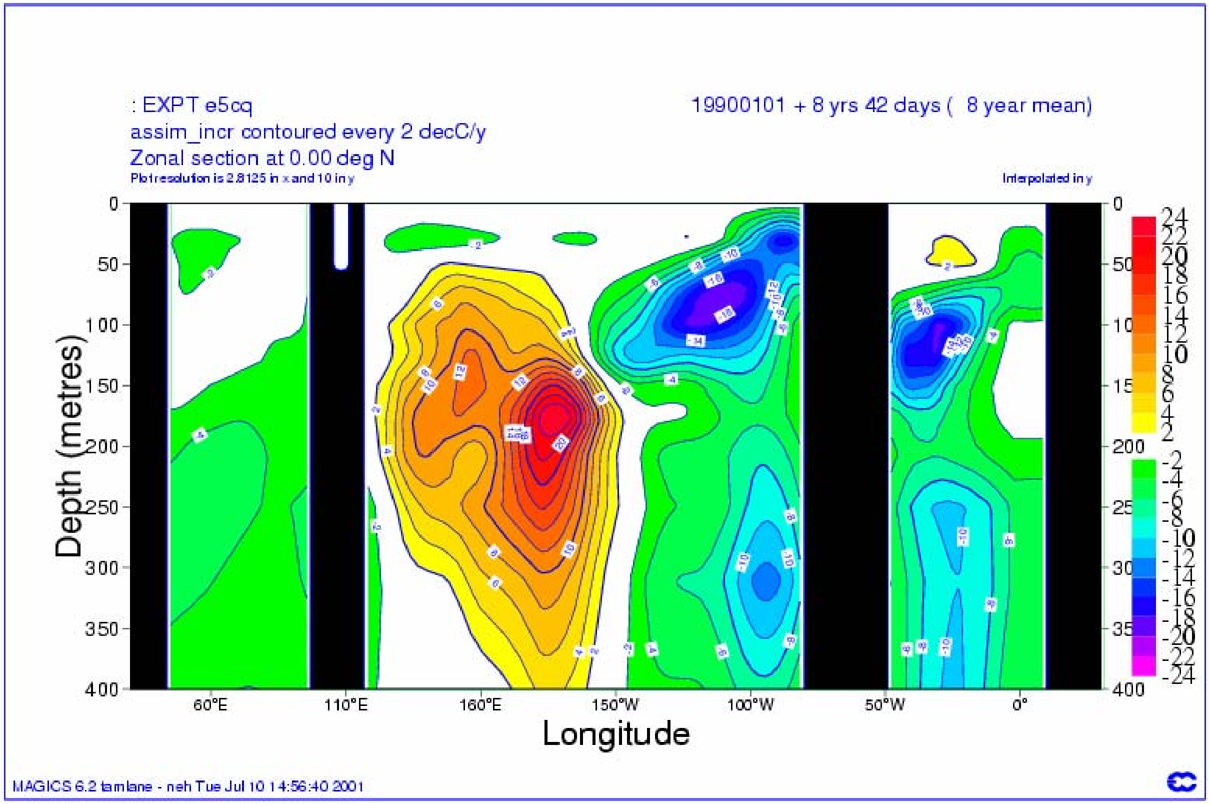
Data coverage for May 2002

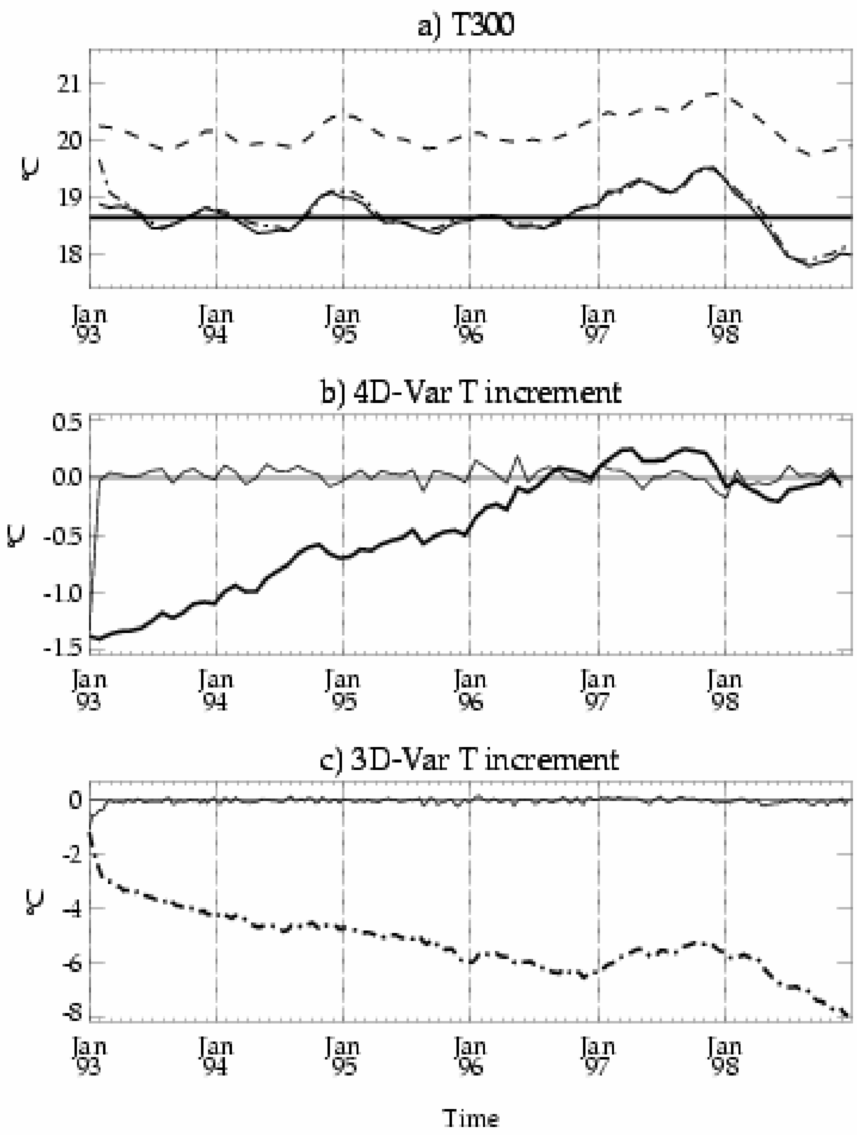


Data coverage for May 2003



Assimilation Increments





Systematic error in other systems

Weaver el al, MWR 2003

Time evolution of increment:

OPA 4D-var

OPA 3D-var

Balanced Currents Method *Burgers et al, JPO 2002*

$$\eta_a = \eta_b + Q\,;\, \vec{u}_a = \vec{u}_b + \delta\vec{u}$$

- To update currents / the velocity increment is partially in geostrophic balance with the density increments:

$$Q = Q_\eta + Q_e ; Q_e = \alpha Q ; 0 \le \alpha \le 1$$

$$\delta u = -\frac{g}{f}\frac{\partial \alpha Q}{\partial y} \quad ; \delta v = \frac{g}{f}\frac{\partial \alpha Q}{\partial x}$$

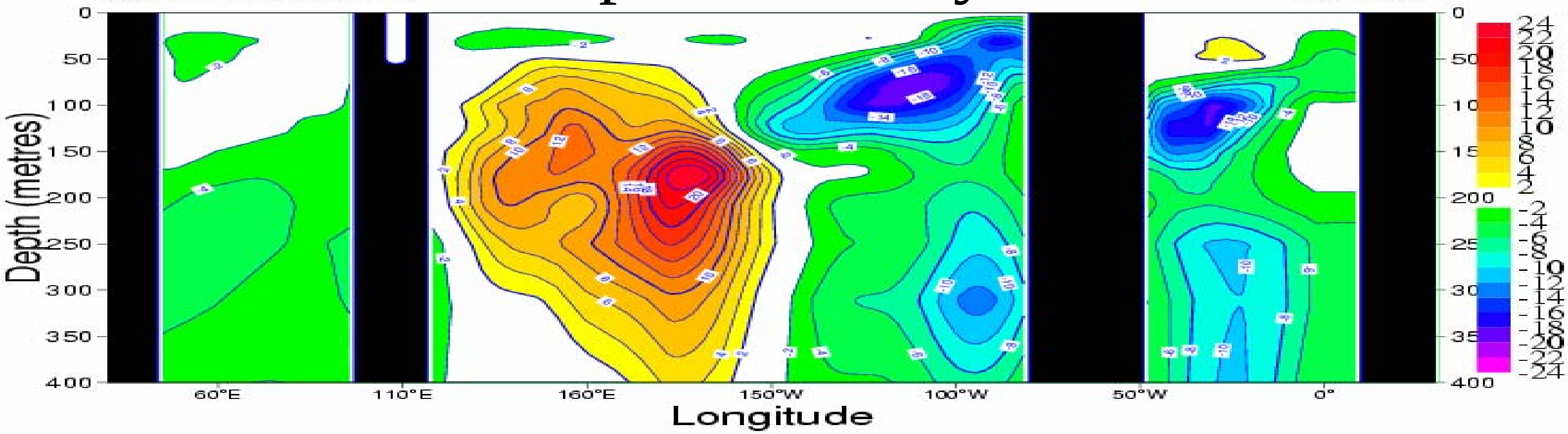
- At the Equator:

$$\delta u = -\frac{g}{\beta}\frac{\partial^2 \alpha Q}{\partial y^2} \quad ; \delta v = 0$$

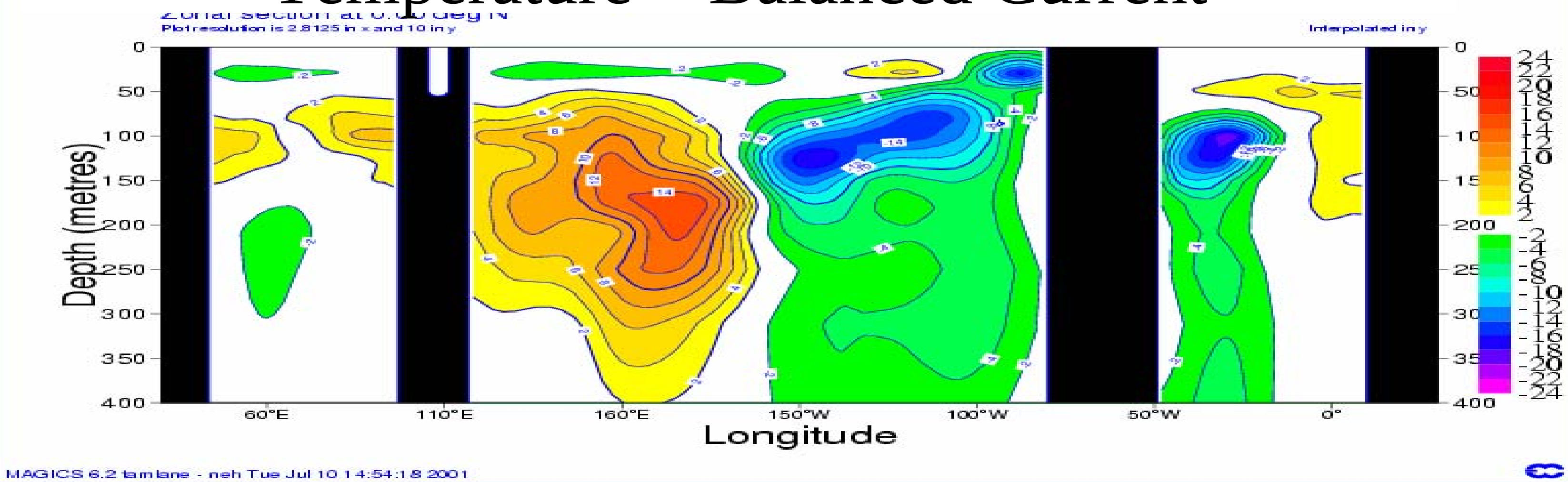
α may depend on z

Temperature Increments

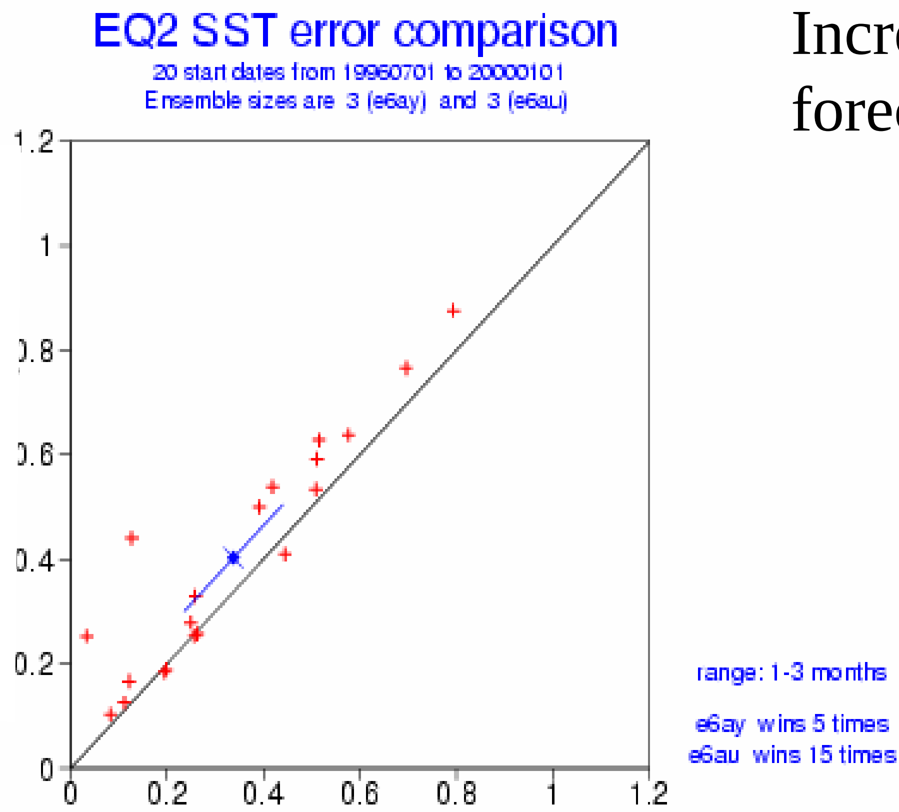
Temperature only



Temperature + Balanced Current



Velocity Increments help forecast statistics



Assim

Assim + Velocity increments

MERSEA

- An EU project to develop high resolution global and regional ocean analyses for operational applications.
- Science:
- Use a global 0.25 deg ocean model and analysis for seasonal forecasting (T159). (Quite expensive) Test the impact of ocean resolution. (MF, INGV, ECMWF)
- Use a global 0.25 deg ocean model and analysis for medium range forecasting (T511). ECMWF

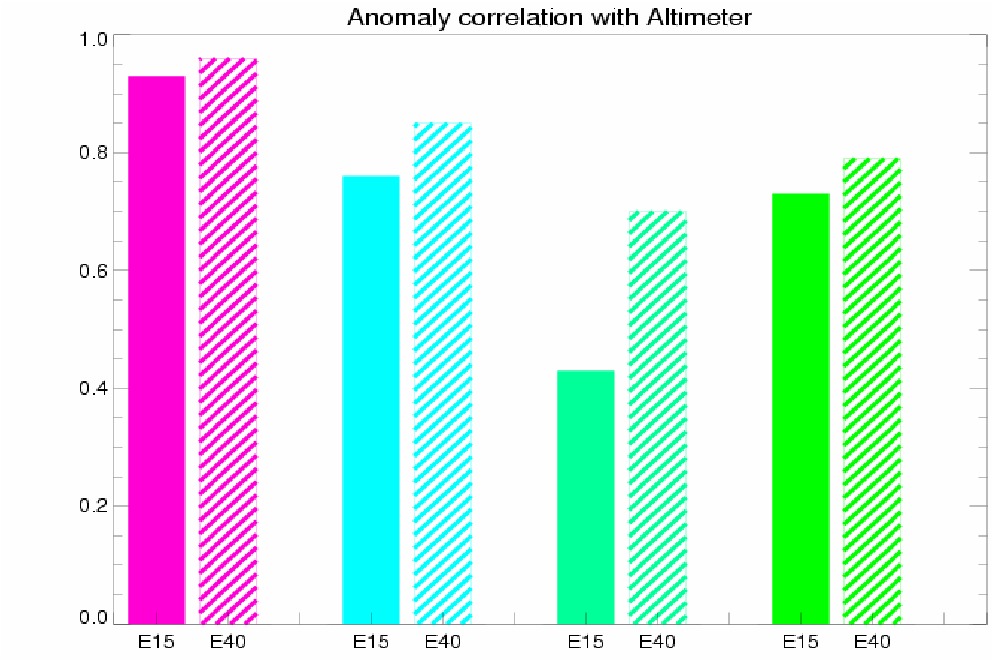
Quality of interannual variability: ERA40 v ERA15/OPS

Correlation of SL with Altimeter data

Equatorial Areas

ERA15/OPS = solid bars

ERA40 = dashed bars



EastPac WestPac Eq Atl Eq Ind

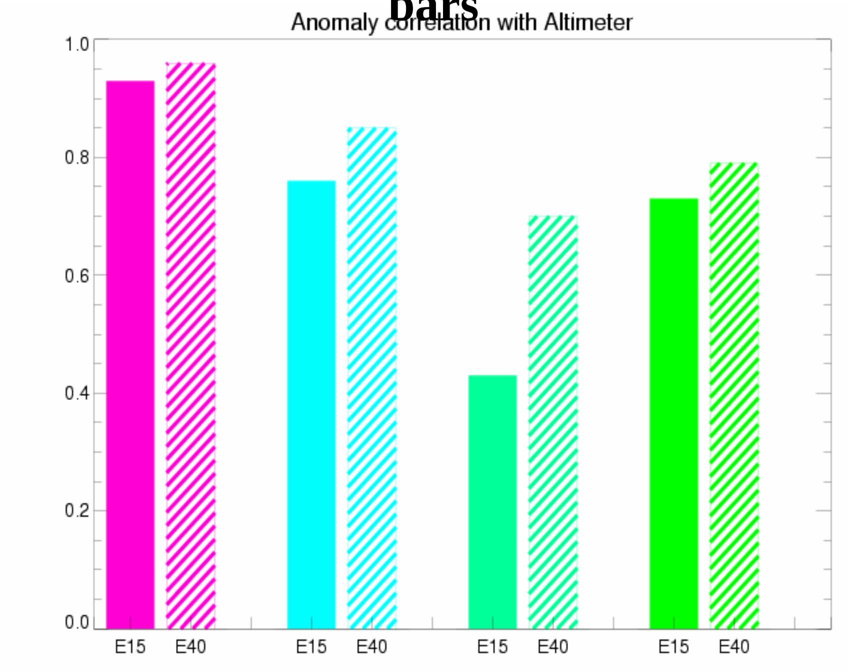
Quality of interannual variability: ERA40 v ERA15/OPS

Correlation of SL with Altimeter data

Equatorial Areas

ERA15/OPS = solid bars

ERA40 = dashed bars

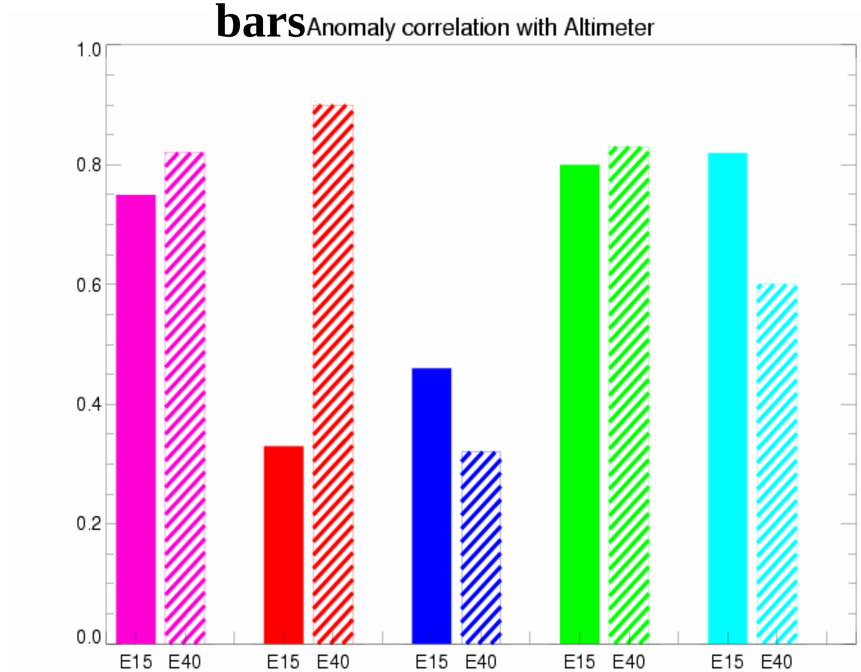


EastPac WestPac Ind Eq Atl Eq

Atlantic Ocean

ERA15/OPS = solid bars

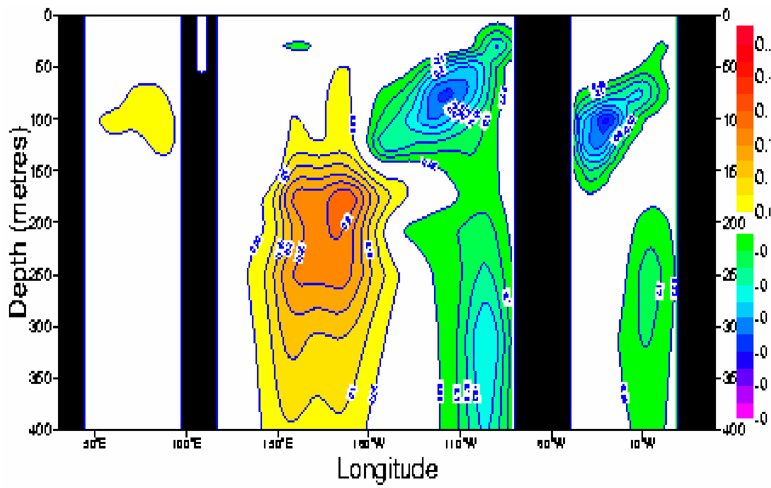
ERA40 = dashed bars



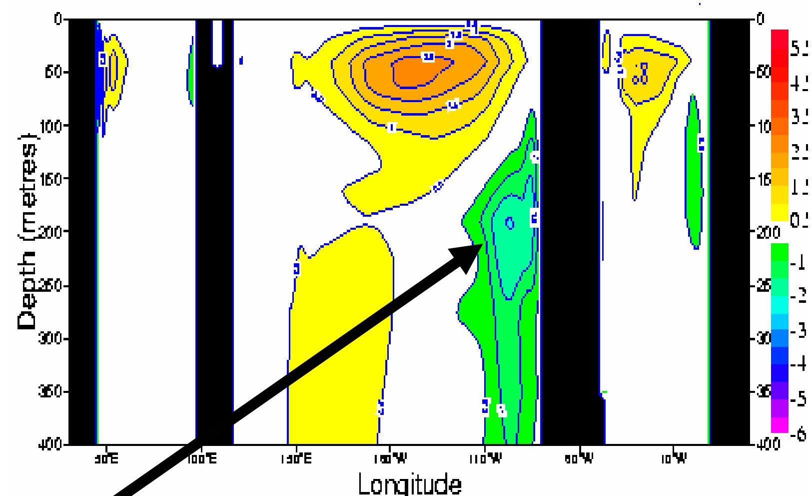
Atl3 NsTrAtl SsTrAtl Natl DIPOLE

BIAS correction schemes

Average Assimilation Increment



Vertical Velocity



1. **Presence of Systematic error**
2. **Part of the error is induced by the DA method**
3. **Possibility of bias estimation and on-line correction?**

- **A generalized bias correction scheme has been formulated**
- **It allows a slow time evolution of the “bias-term”.**
- **Tests with different covariance formulations**

a)Impact of Gain Matrix and Balance Constraints

Assim incr (C.I=0.05 C/10 days)

Experiment E0

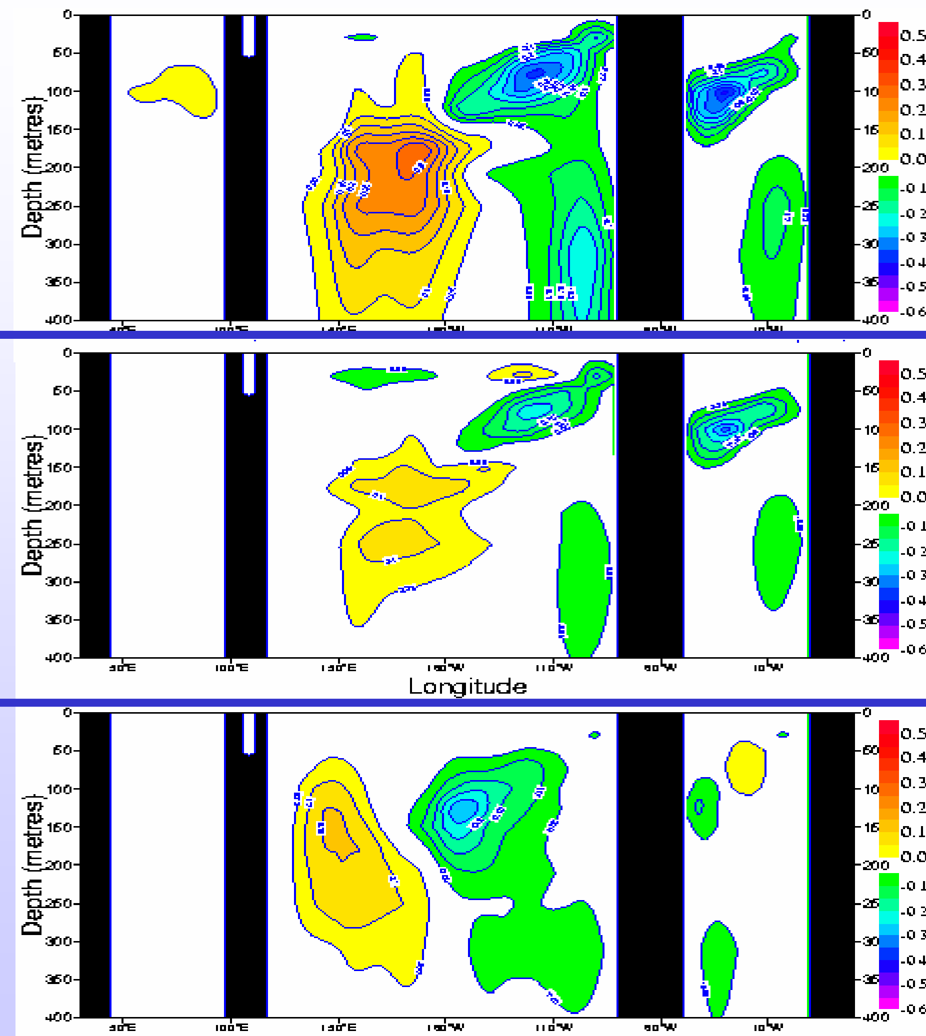
No bias correction

Experiment Eu

Correcting bias in pressure gradient

Experiment ET

Correcting bias in Temperature



b)Impact of Gain Matrix and Balance Constraints

Vertical velocity (C.I=0.5m/day)

Experiment E0

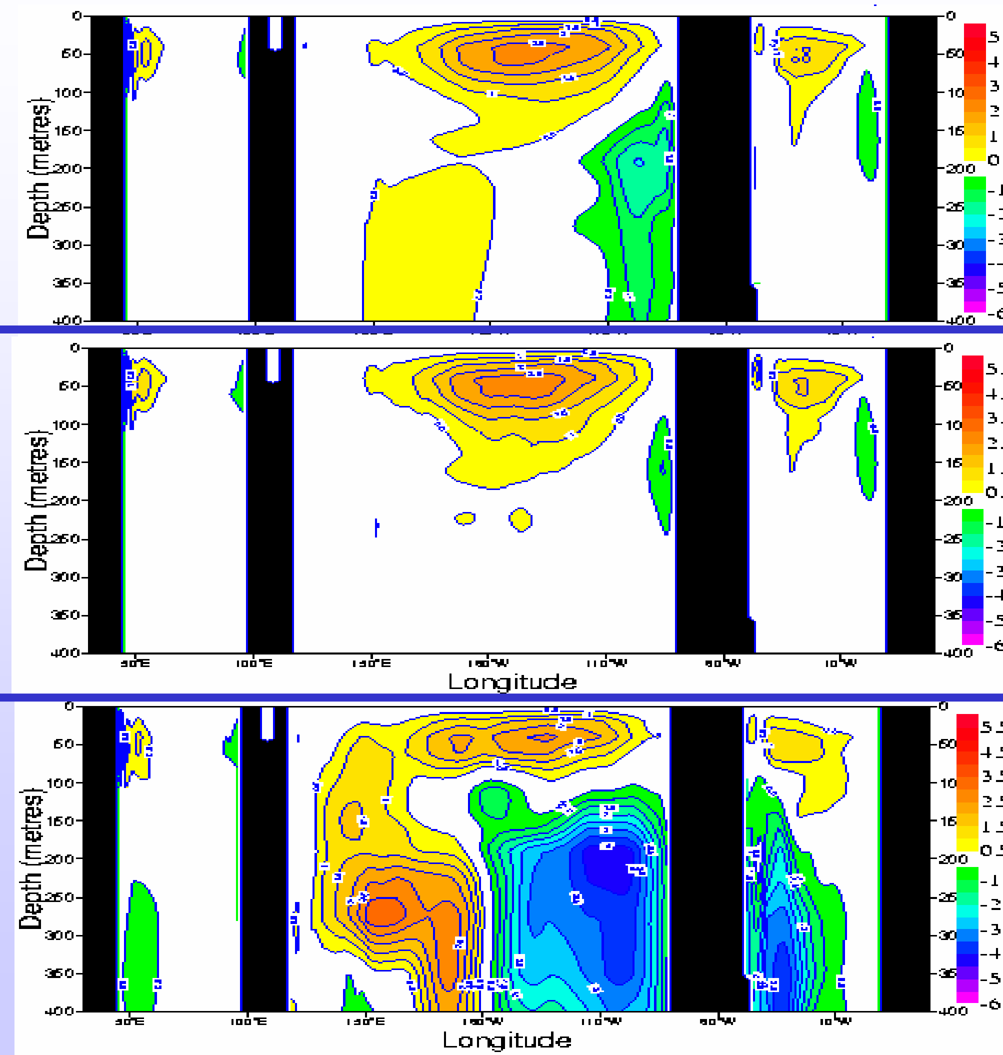
No bias correction

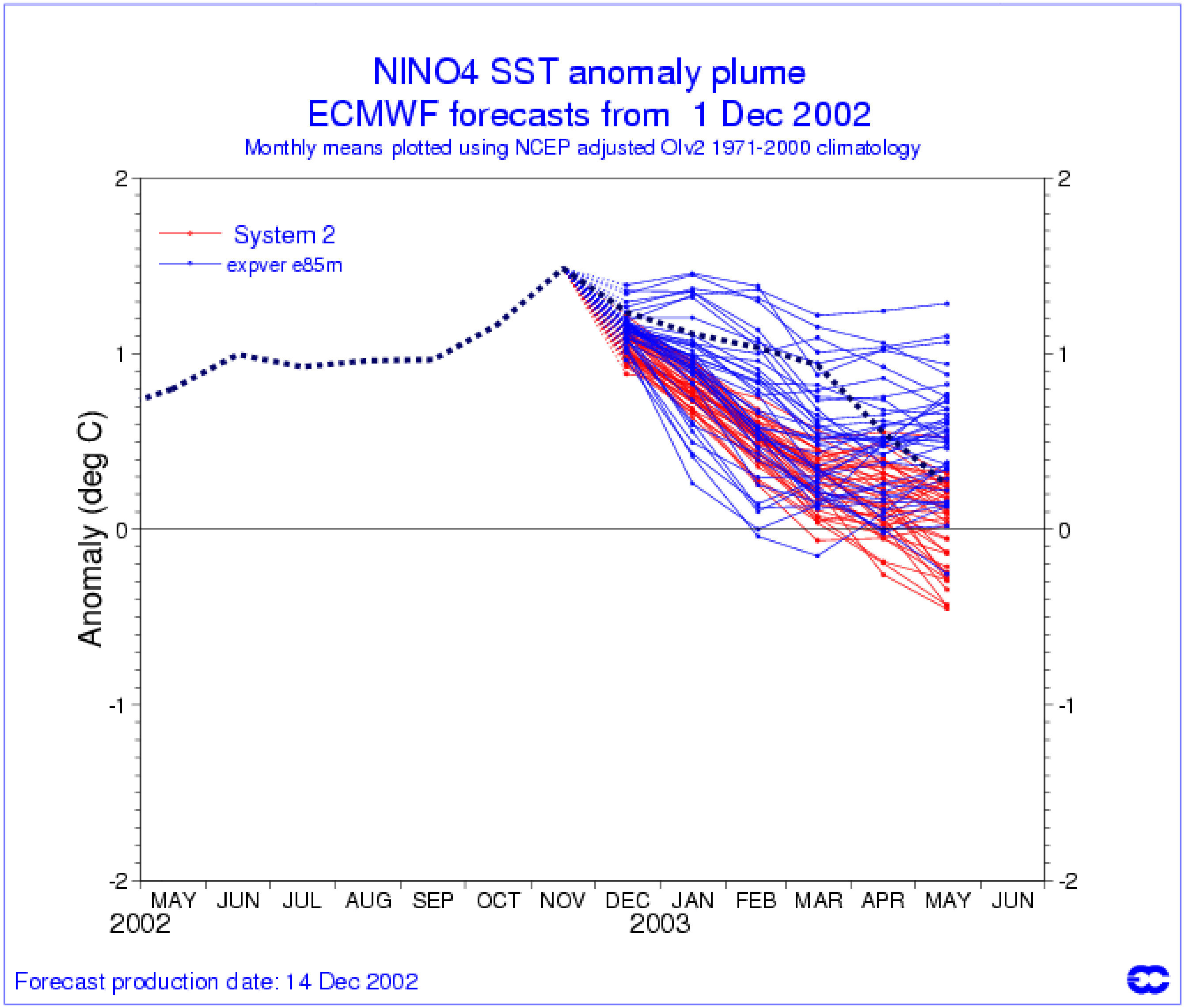
Experiment Eu

Correcting bias in pressure gradient

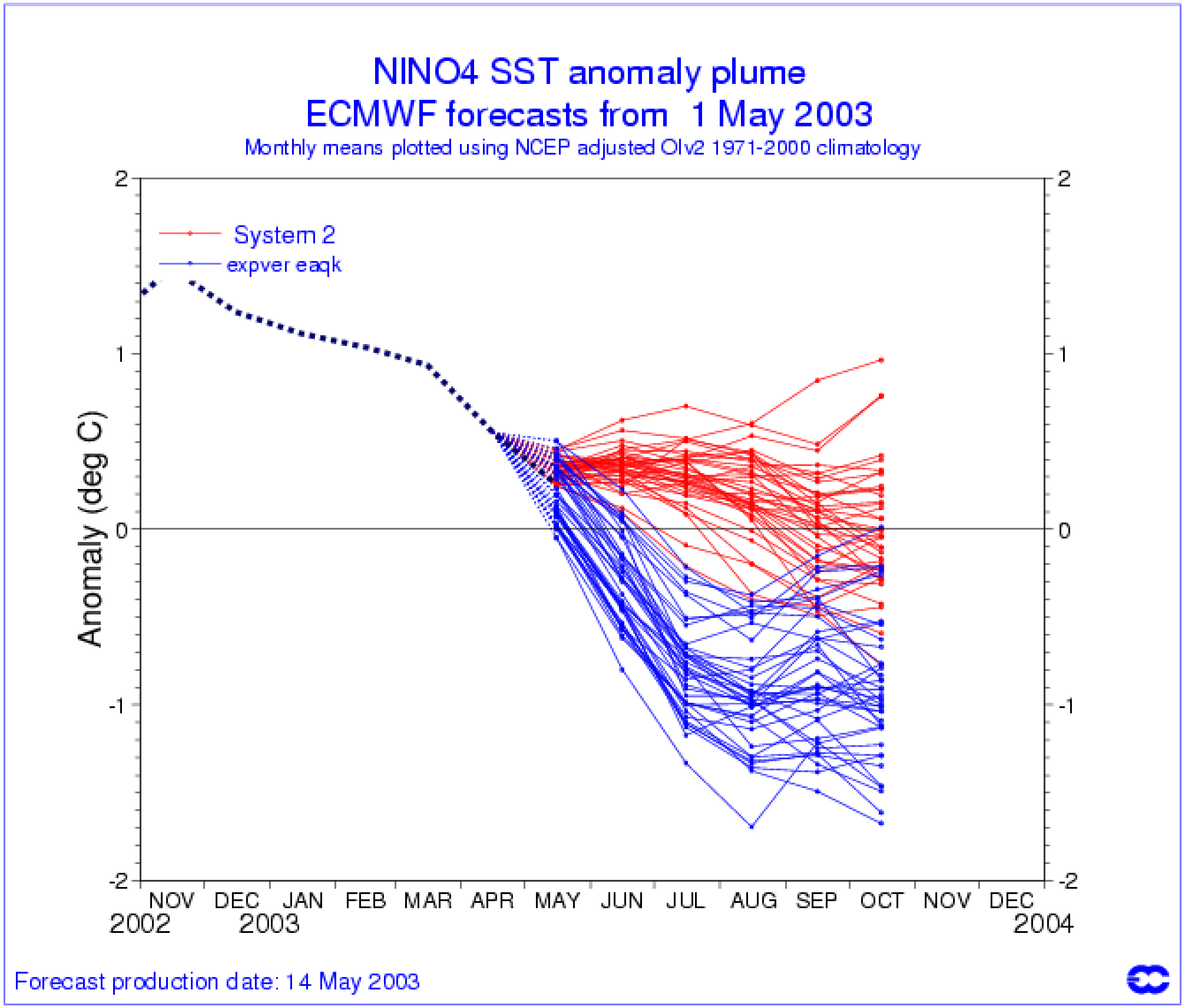
Experiment ET

Correcting bias in Temperature

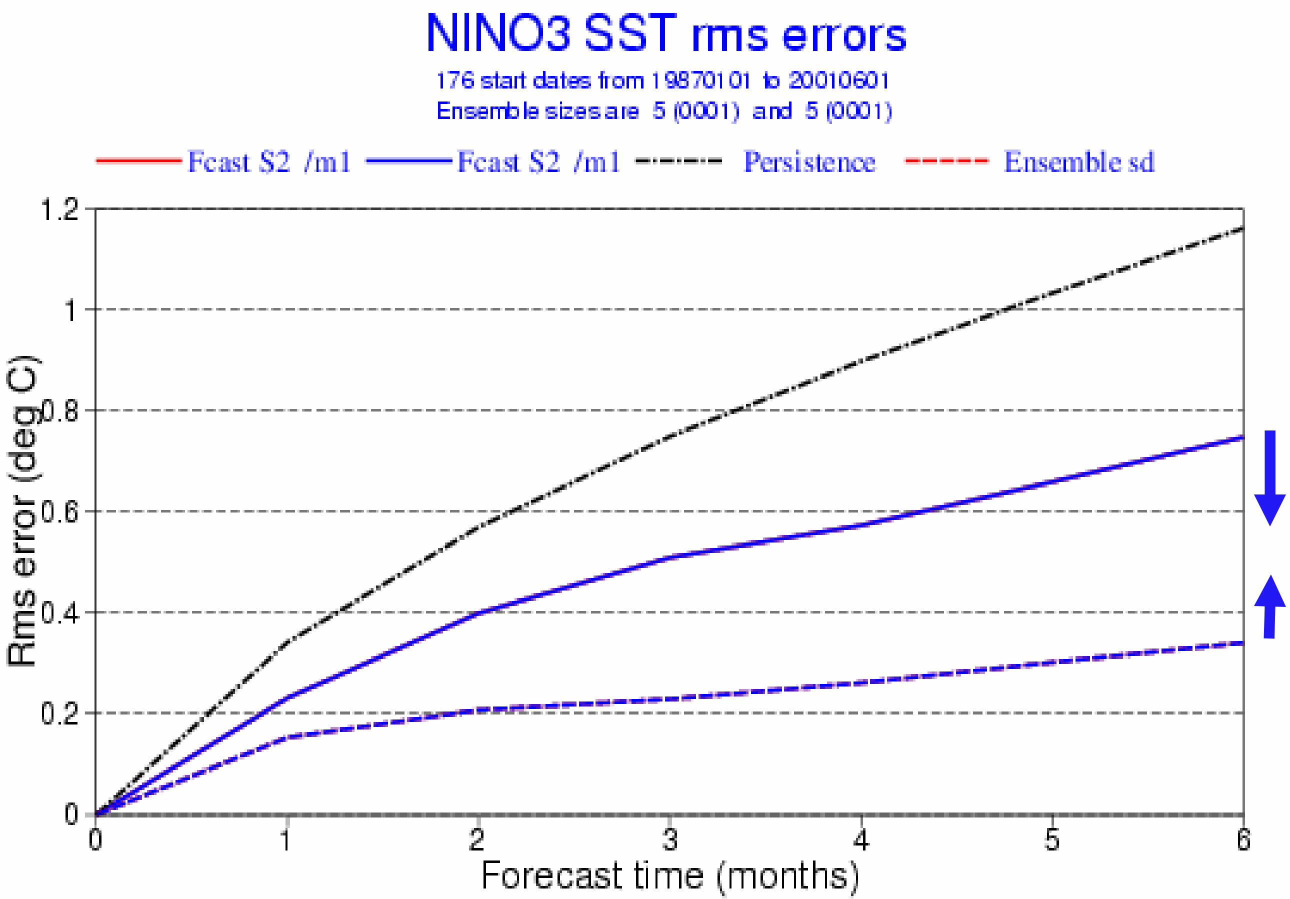




NINO4 SST anomaly plume
ECMWF forecasts from 1 Dec 2002
Monthly means plotted using NCEP adjusted OIv2 1971-2000 climatology
System 2
expver e85m
Anomaly (deg C)
2
1
0
-1
-2
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
2002
2003
Forecast production date: 14 Dec 2002



NINO4 SST anomaly plume
ECMWF forecasts from 1 May 2003
Monthly means plotted using NCEP adjusted OIv2 1971-2000 climatology
System 2
expver eaqk
Anomaly (deg C)
2
1
0
-1
-2
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
2002
2003
2004
Forecast production date: 14 May 2003



Forecast System is not reliable:

RMS > Spread

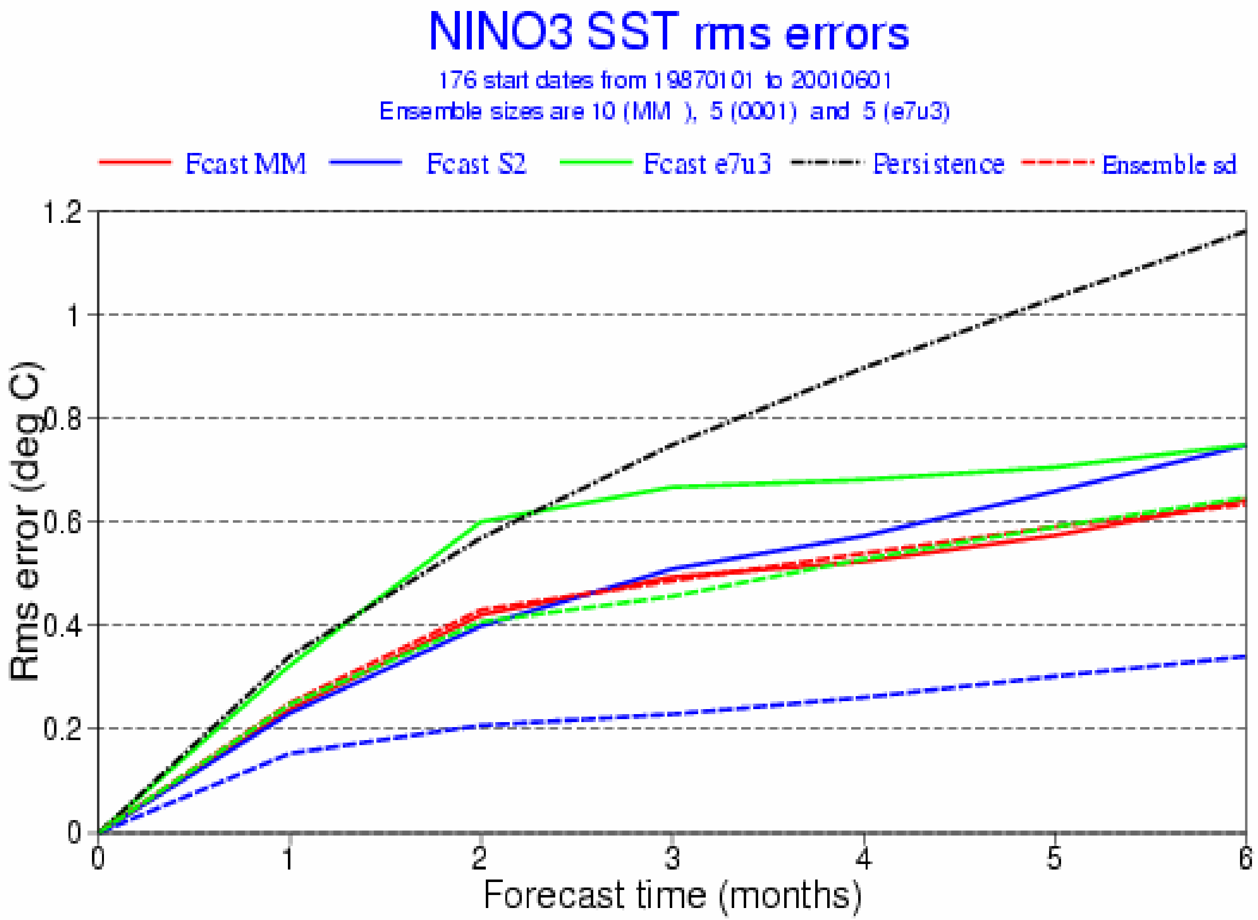
A) Can we reduce the error? How much?

(Predictability limit)

***B)*Or can we only increase the spread?**

A) Improve the ensemble generation: Need to sample model error

B) Improve calibration: A posteriori use of all available information



ECMWF

UKMO

Multi-Model

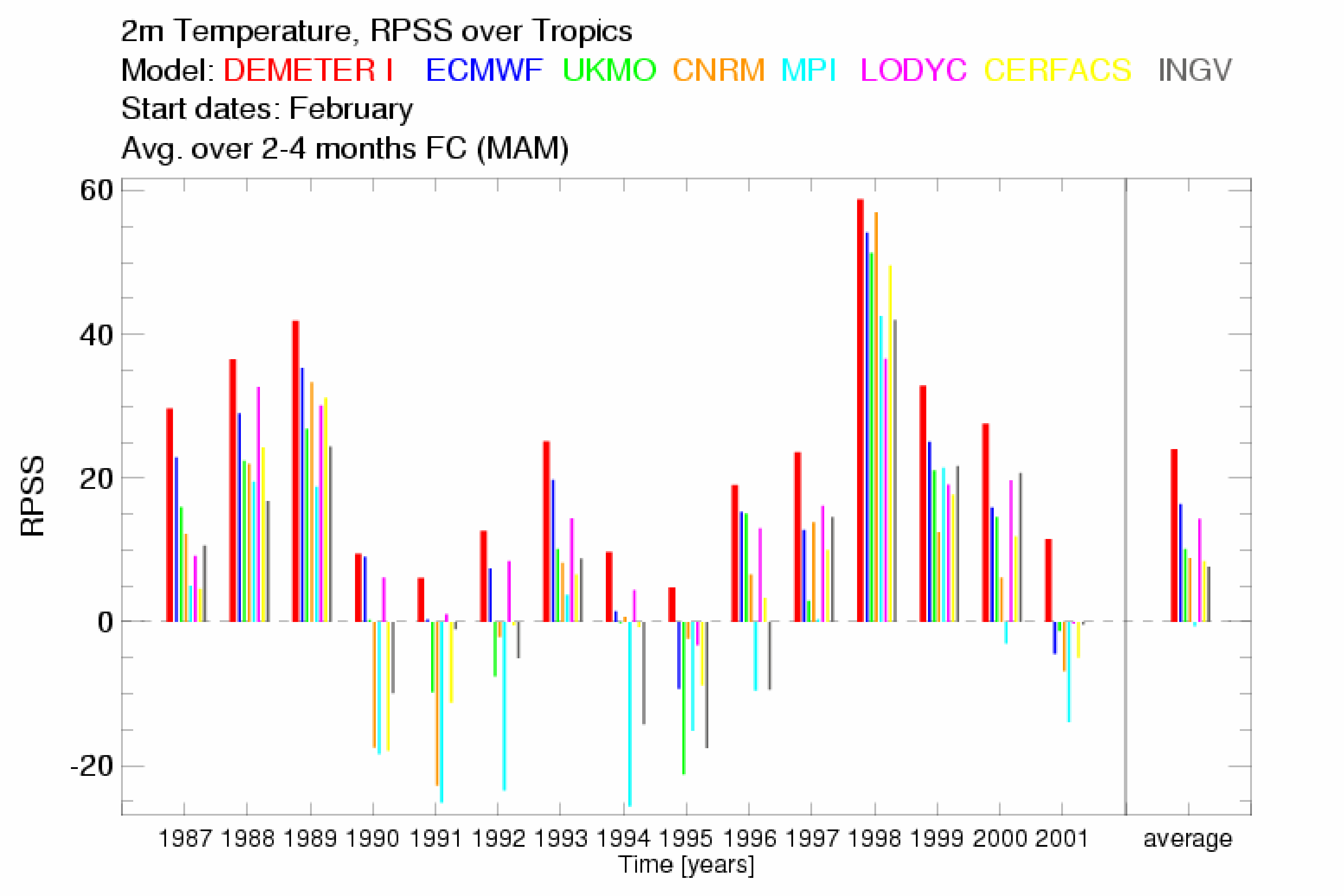
Multi-model:

RMS=SPREAD !!

and RMS is reduced

DEMETER

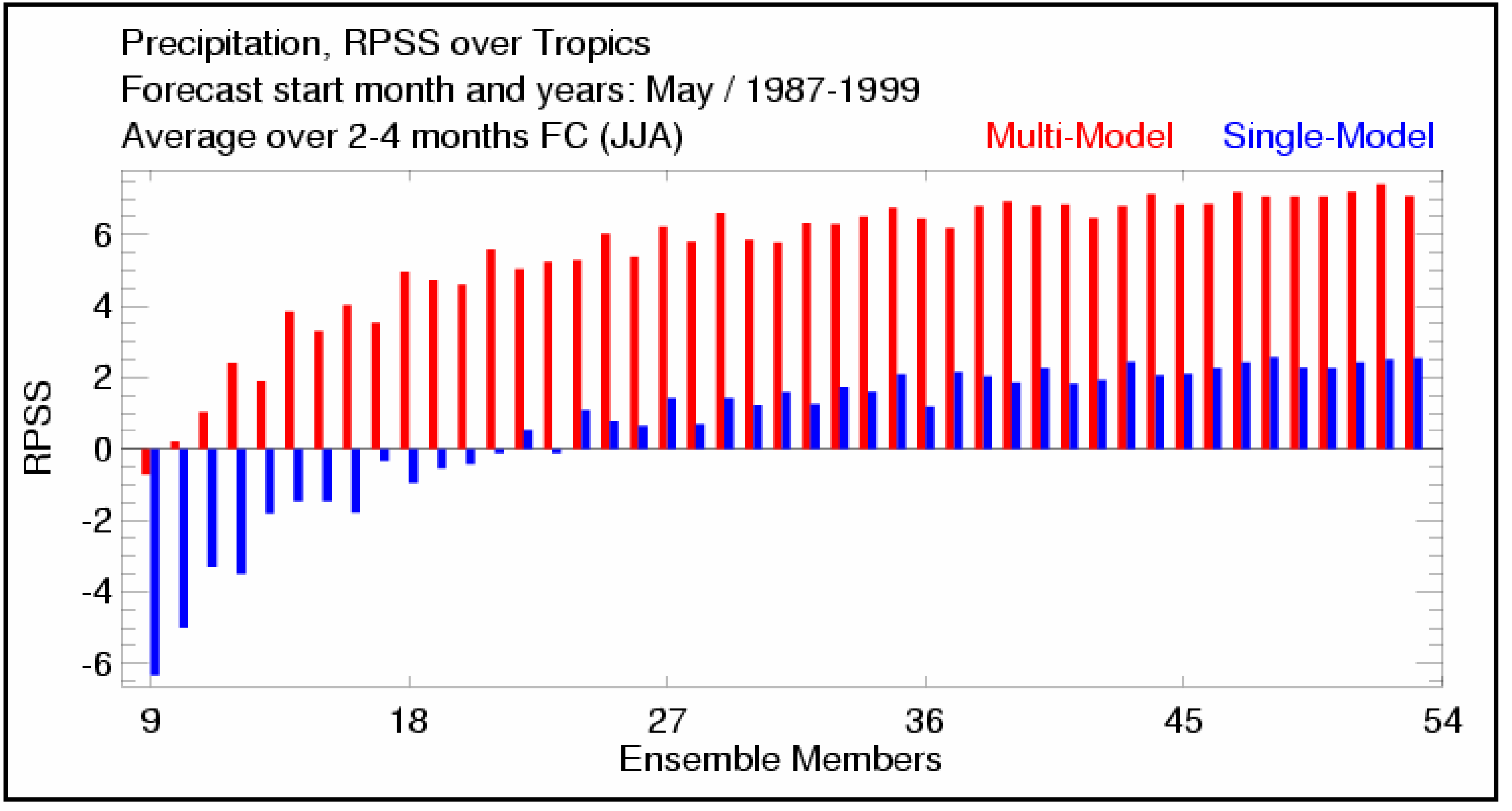
Development of a European Multi-Model Ensemble System for Seasonal to Interannual Prediction



http://www.ecmwf.int/research/demeter

ensemble size versus multimodel

From DEMETER

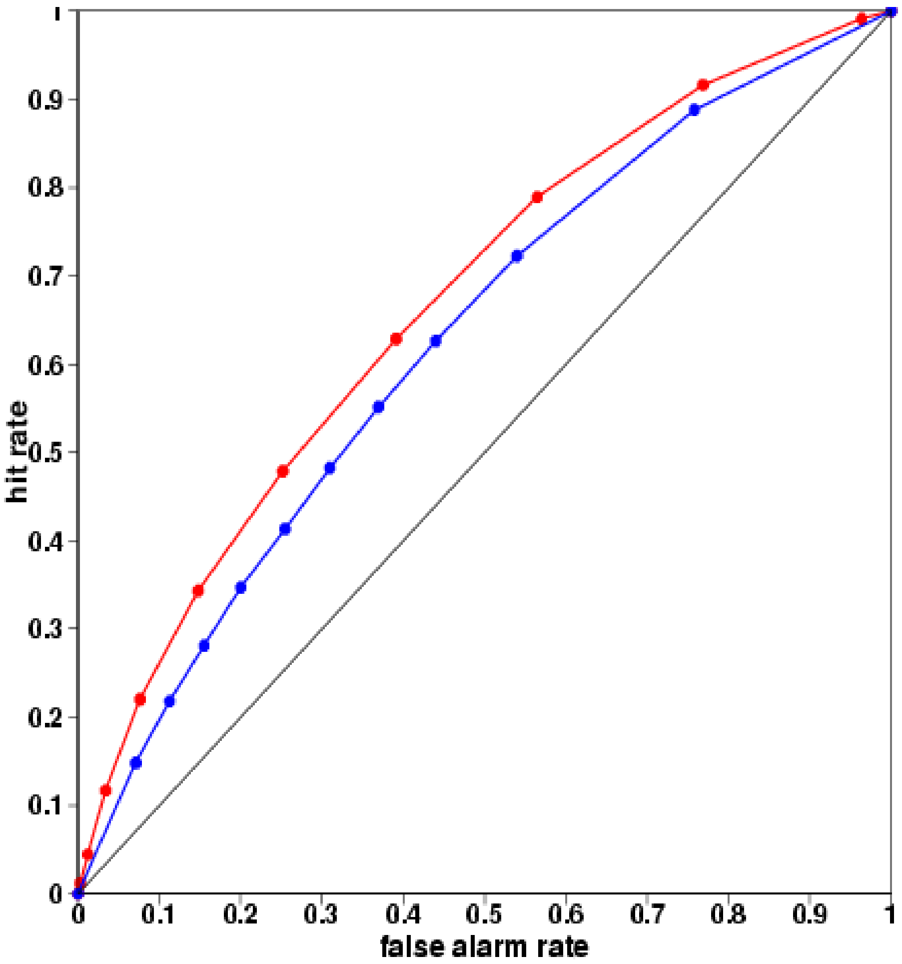


Provided by Doblas-Reyes

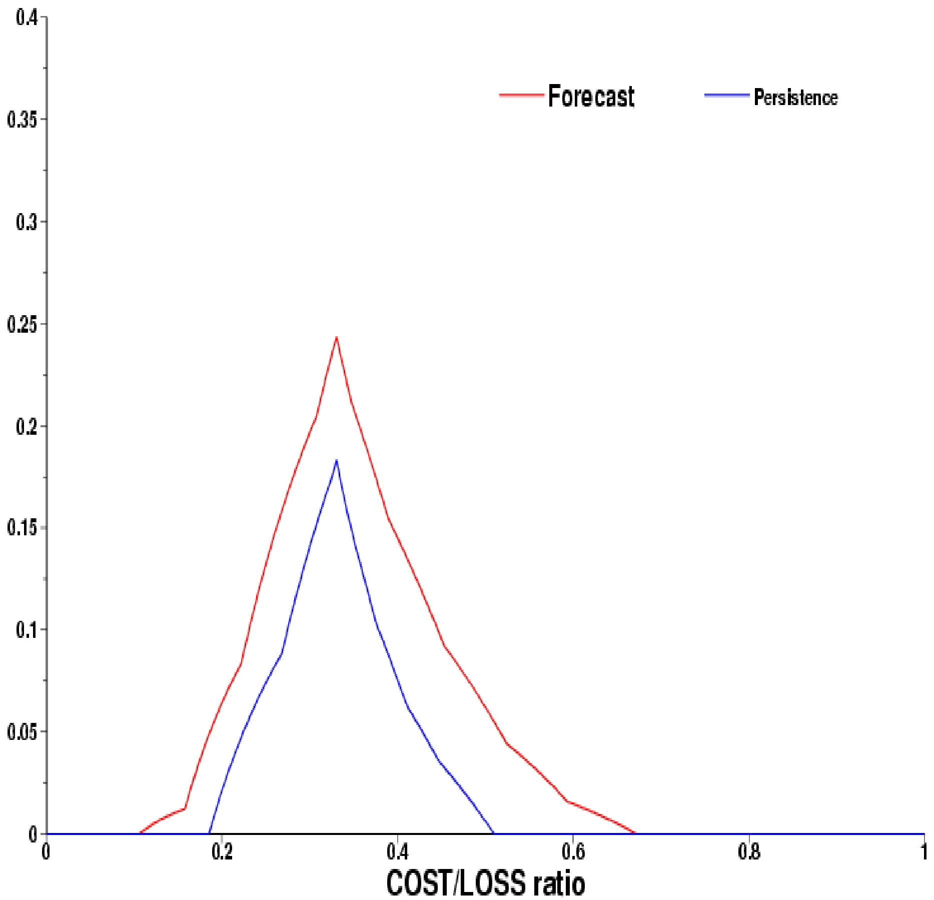
Comparison with Persistence of day 5-11 probabilities

Days 12-18 N. Extratropics 2mtm in upper tercile

ROC score: 0.67 0.62



Potential Economic Value



Monthly Forecast

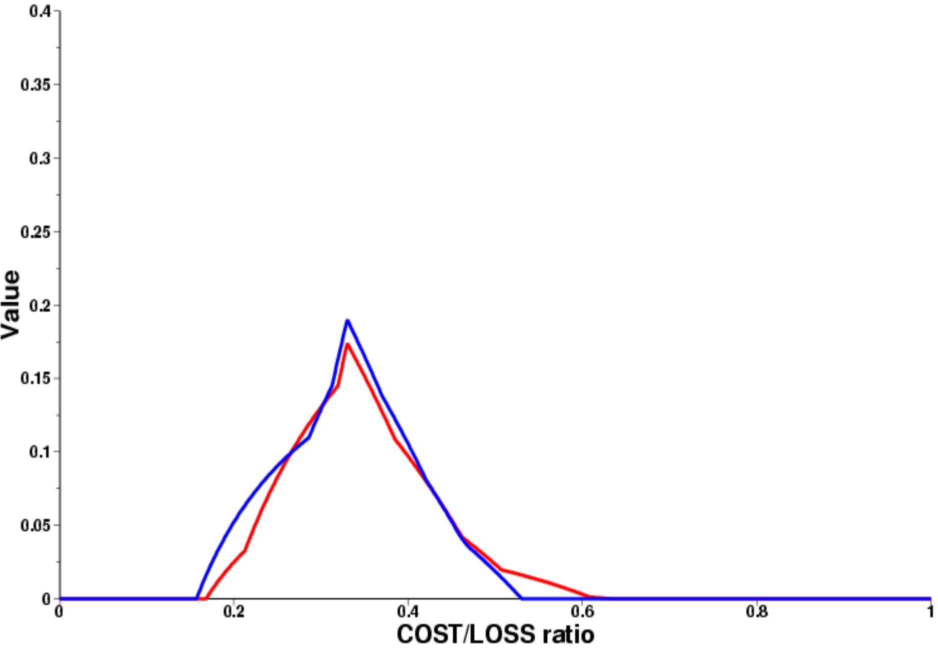
Persistence

Potential Economic Value.
Days 12-18

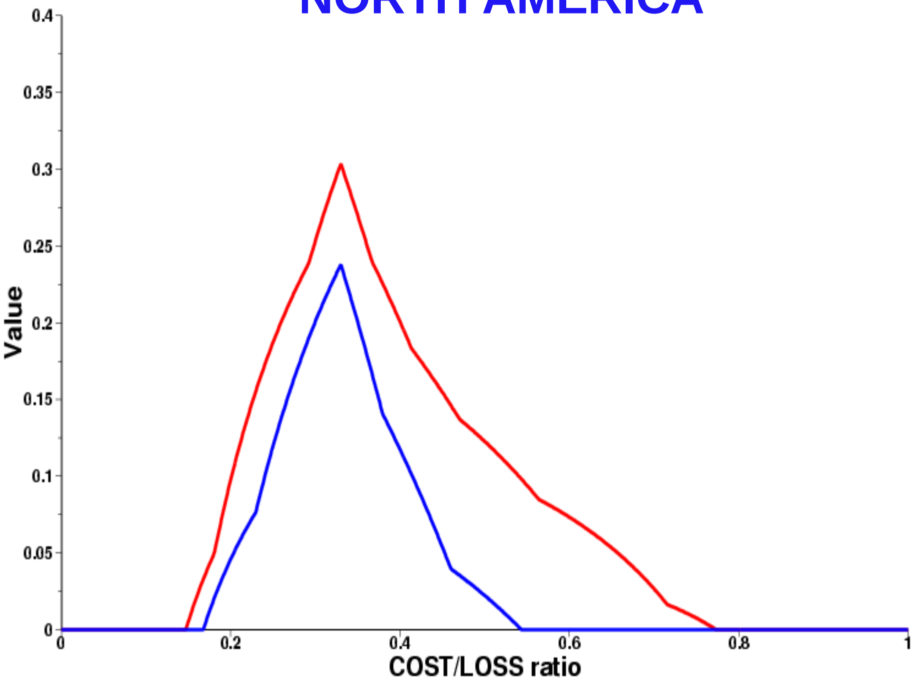
2m-temp in upper tercile

Monthly Forecast — Persistence of days 5-11 probabilities

EUROPE

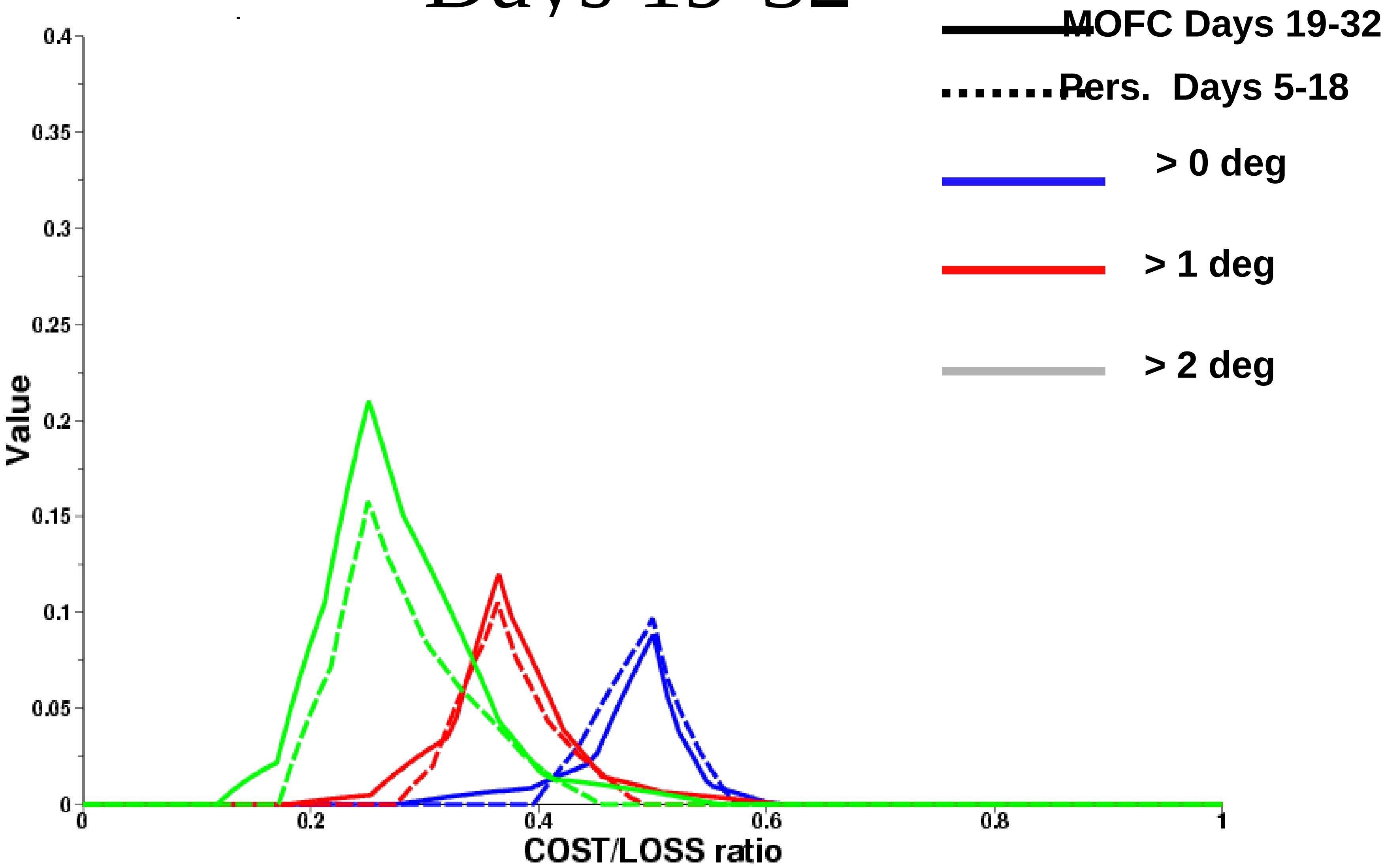


NORTH AMERICA



2m-temperature. N. Extra.

Days 19-32

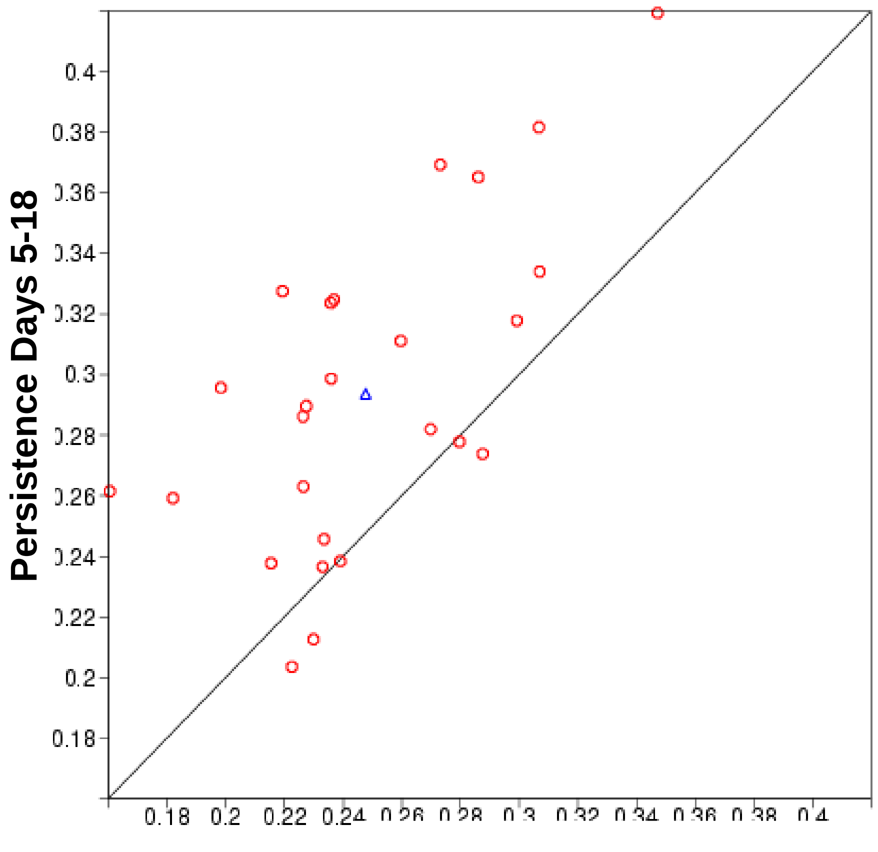


Brier Score N. Extratropics

2m-temp in upper tercile

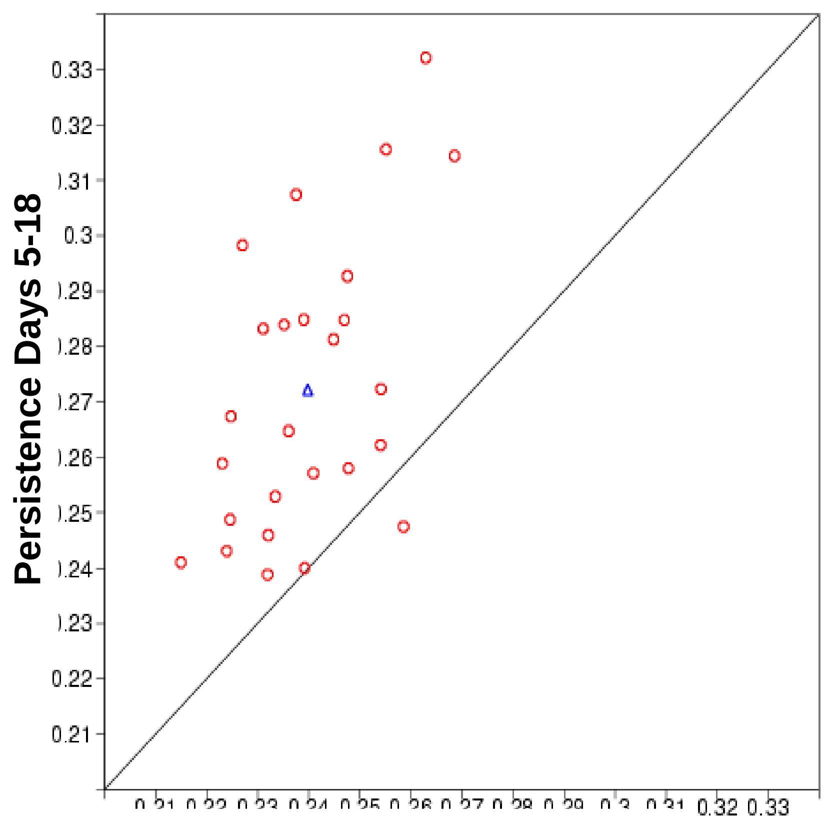
MOFC/PERS: 21/5

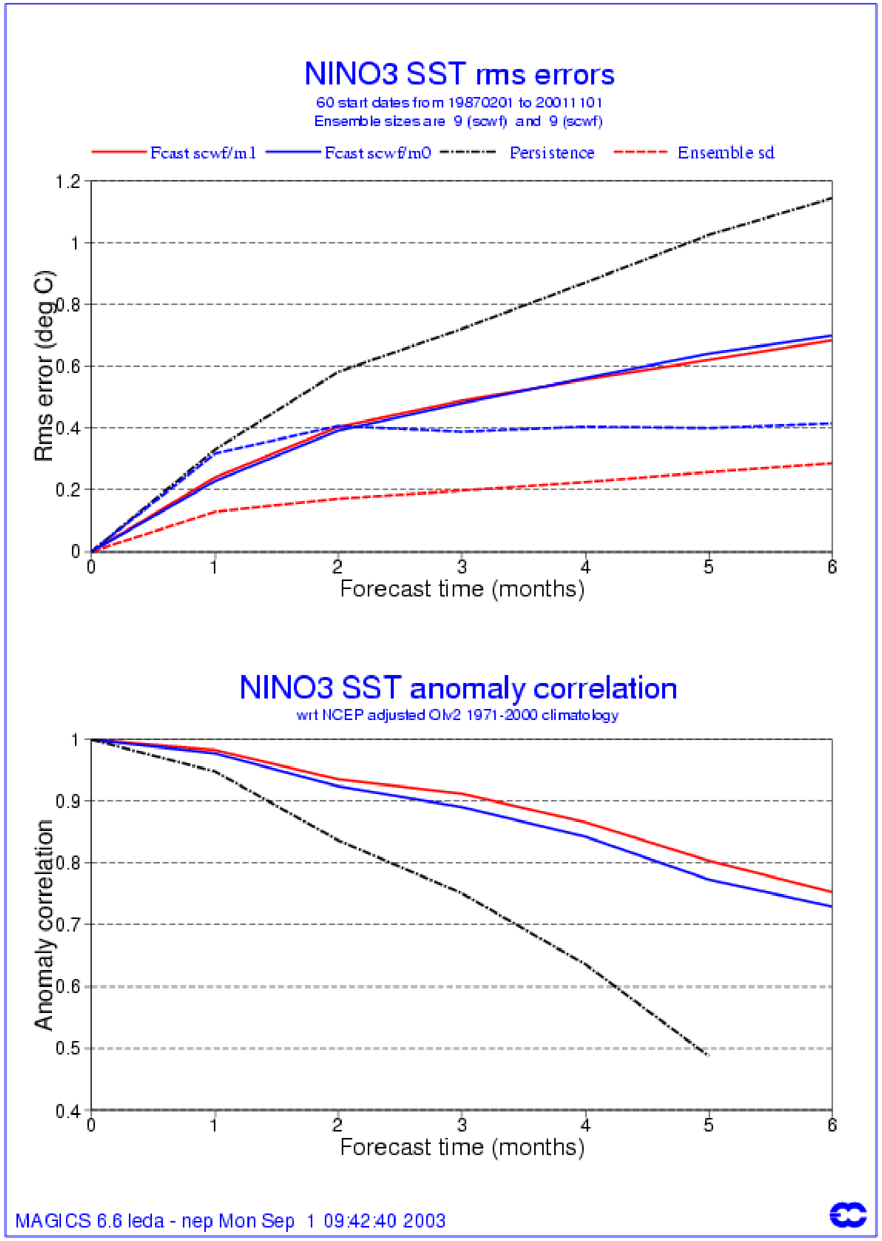
(si



Precip in upper tercile

MOFC/PERS: 25/1 (sign:99%)

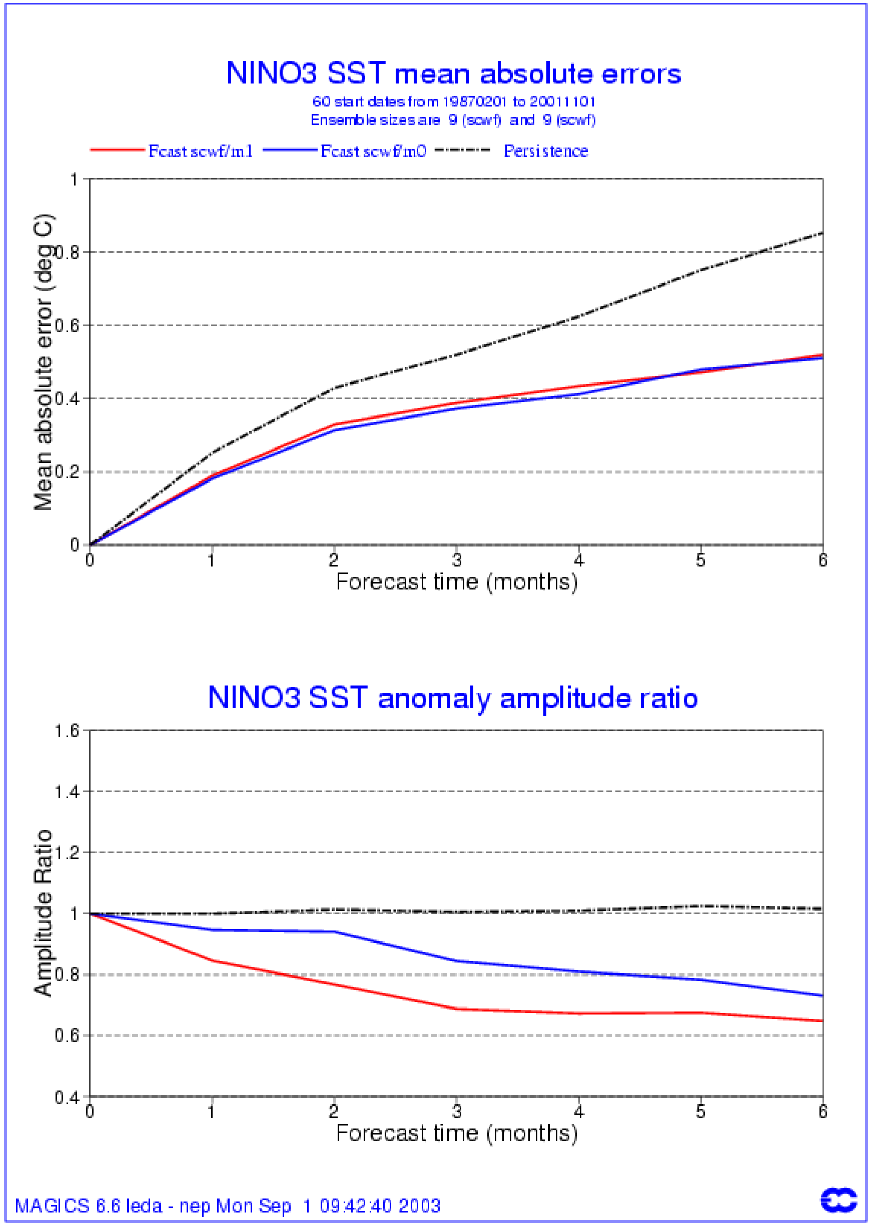




- Comparison of da and no da forecast skill for the Nino3 region.
- The skill is comparable, but the spread is much larger in the case of no da.

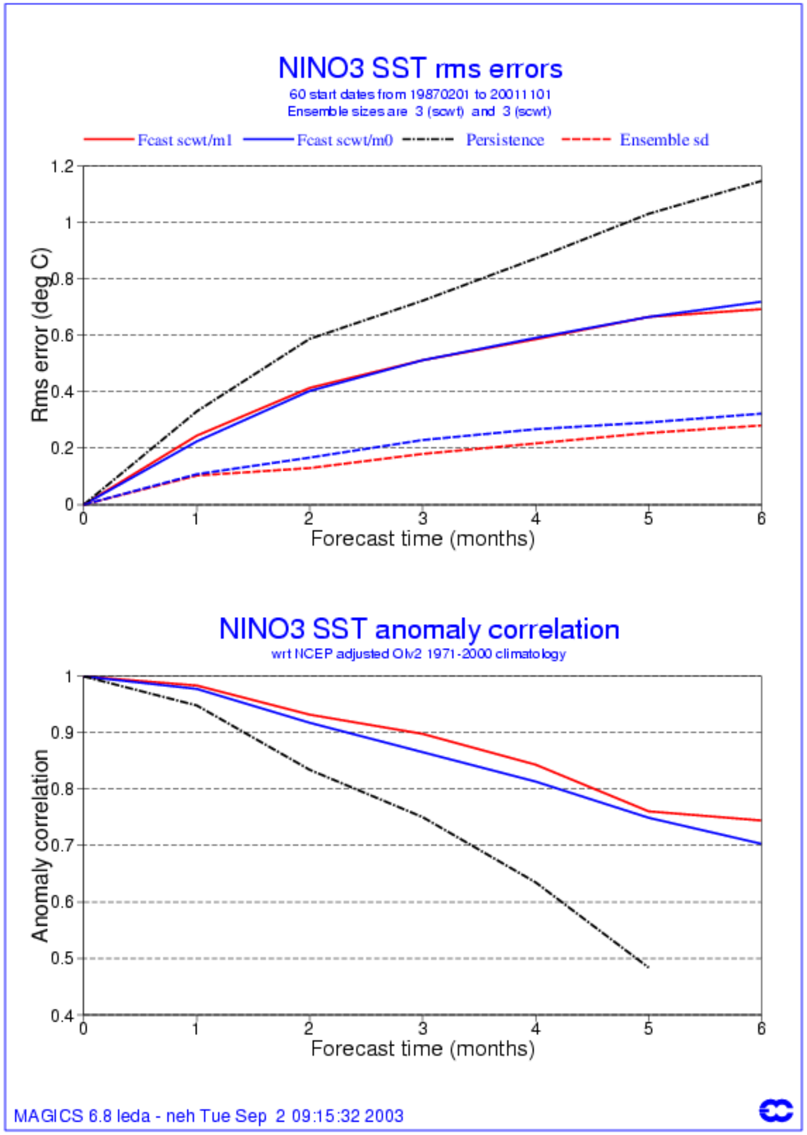
- Demeter ensemble: 9 members, 3 with no wind perturbations, 3 +, 3-

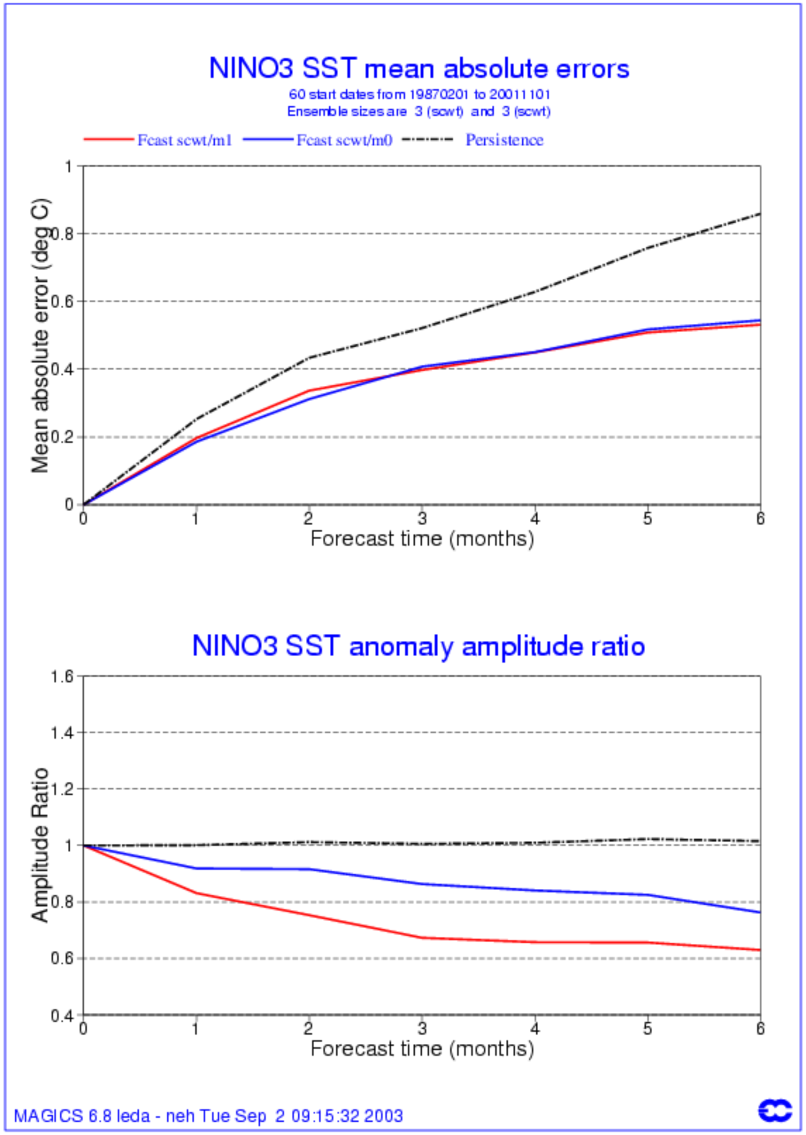
DEMETER assimilation and no assimilation. 9 members, 4 seasons, 15 years



- The amplitude ratio is reduced in the case of data assimilation. Is this because the spread in the no data assimilation case is too large? This can be checked by looking only at hindcasts without wind perturbations.

The spread is comparable between the two experiments (da, no da), but still the amplitude ratio is reduced in the da case, likely showing the impact of mean state. The correlation is higher in the da case.

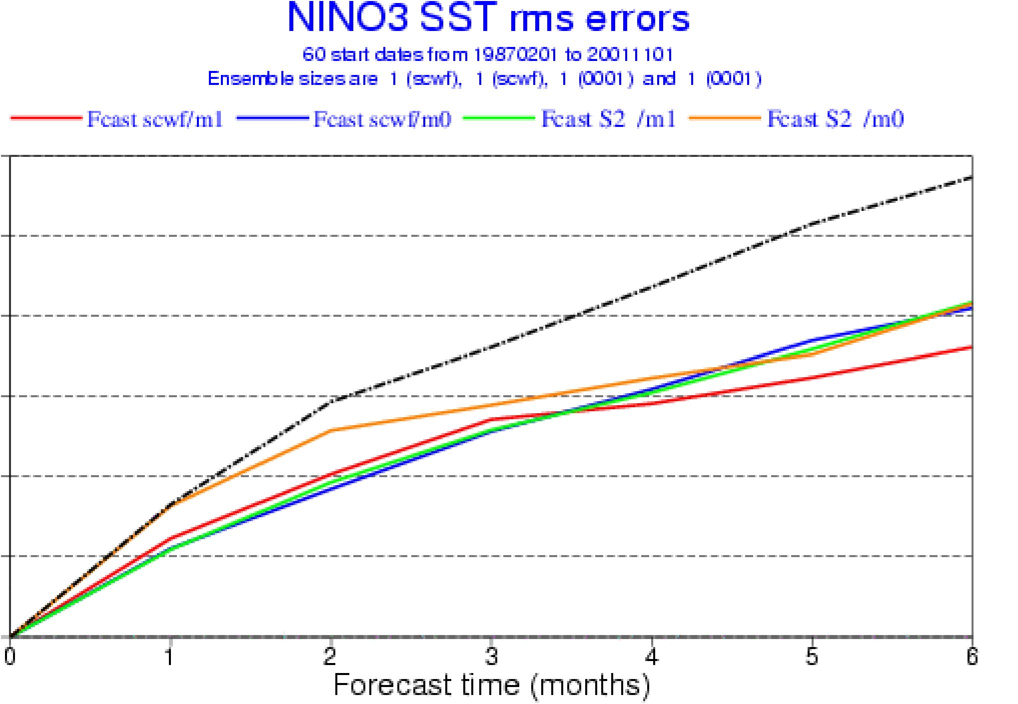


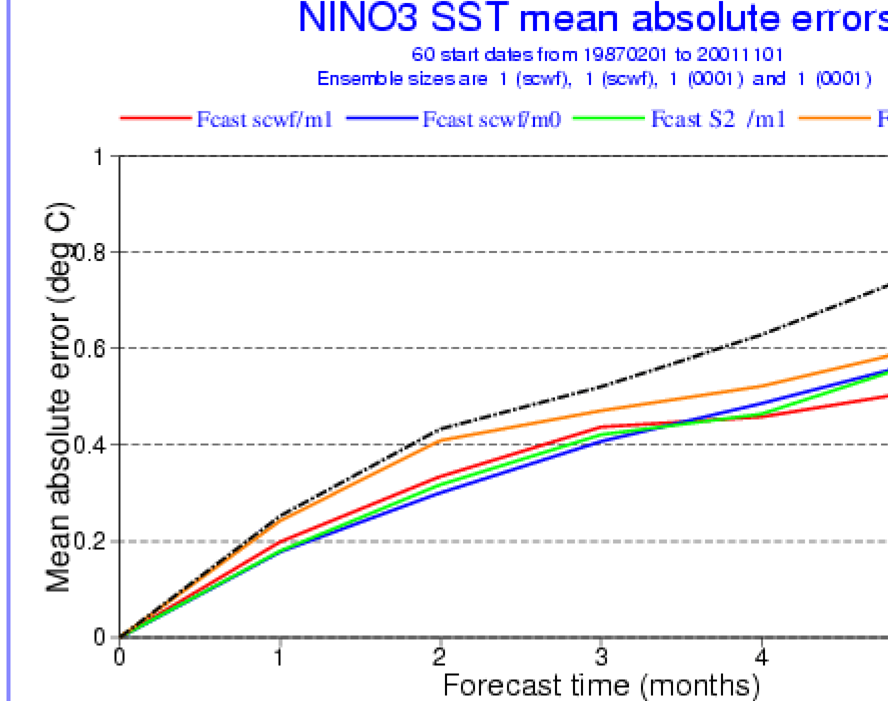


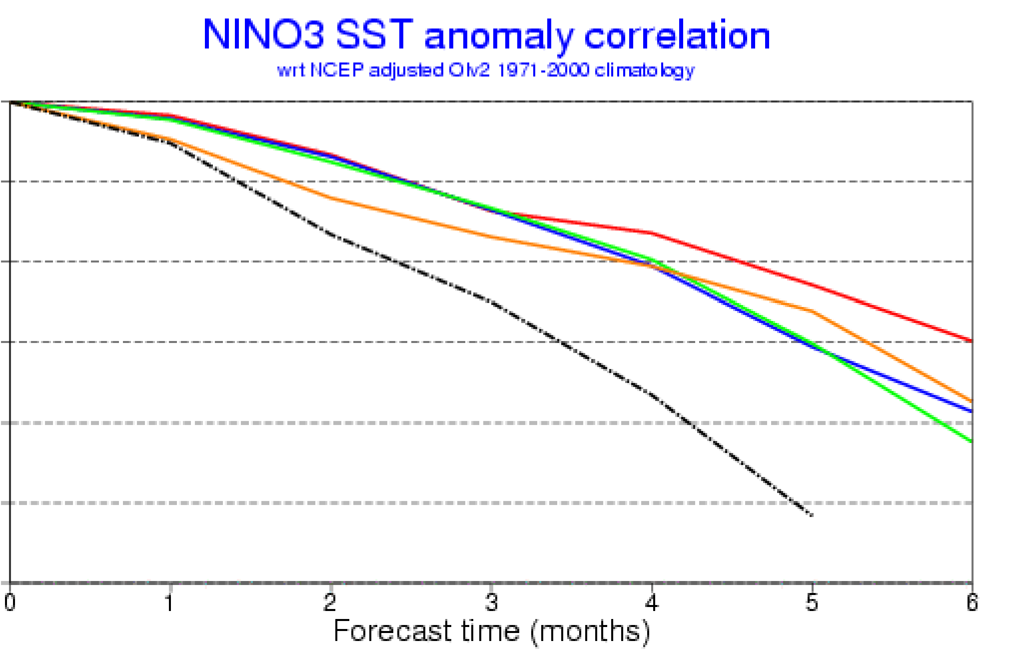
Data assimilation, no da revisited using S2 and Demeter

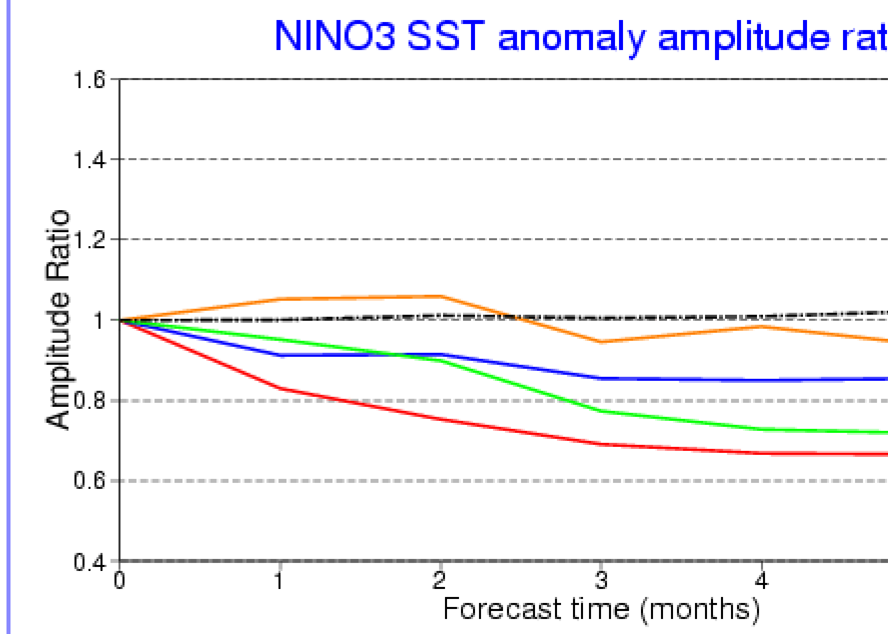
- The next slide will compare S2 and Demeter hindcasts. The coupled models are the same.
- The ocean initial conditions are different: S2 uses ERA15/Ops winds while Demeter uses ERA40 stresses. The latter is thought to be the better product since it is a more uniform product produced using the same atmospheric assimilation system throughout.

- For S2, the data assimilation (green) leads to better forecasts than the no-da case (gold).
- For Demeter, using ERA40 winds, the importance of data assimilation is reduced.


NINO3 SST rms errors
60 start dates from 19870201 to 20011101
Ensemble sizes are 1 (scwf), 1 (scwf), 1 (0001) and 1 (0001)
Fcast scwf/m1
Fcast scwf/m0
Fcast S2 /m1
Fcast S2 /m0
0 1 2 3 4 5 6
Forecast time (months)


NINO3 SST mean absolute errors
60 start dates from 19870201 to 20011101
Ensemble sizes are 1 (scwf), 1 (scwf), 1 (0001) and 1 (0001)
Fcast scwf/m1
Fcast scwf/m0
Fcast S2 /m1
Mean absolute error (deg C)
0 0.2 0.4 0.6 0.8 1
0 1 2 3 4
Forecast time (months)


NINO3 SST anomaly correlation
wrt NCEP adjusted OIv2 1971-2000 climatology
0 1 2 3 4 5 6
Forecast time (months)


NINO3 SST anomaly amplitude rat
Amplitude Ratio
0.4 0.6 0.8 1 1.2 1.4 1.6
0 1 2 3 4
Forecast time (months)

Problems in existing ocean DA systems:

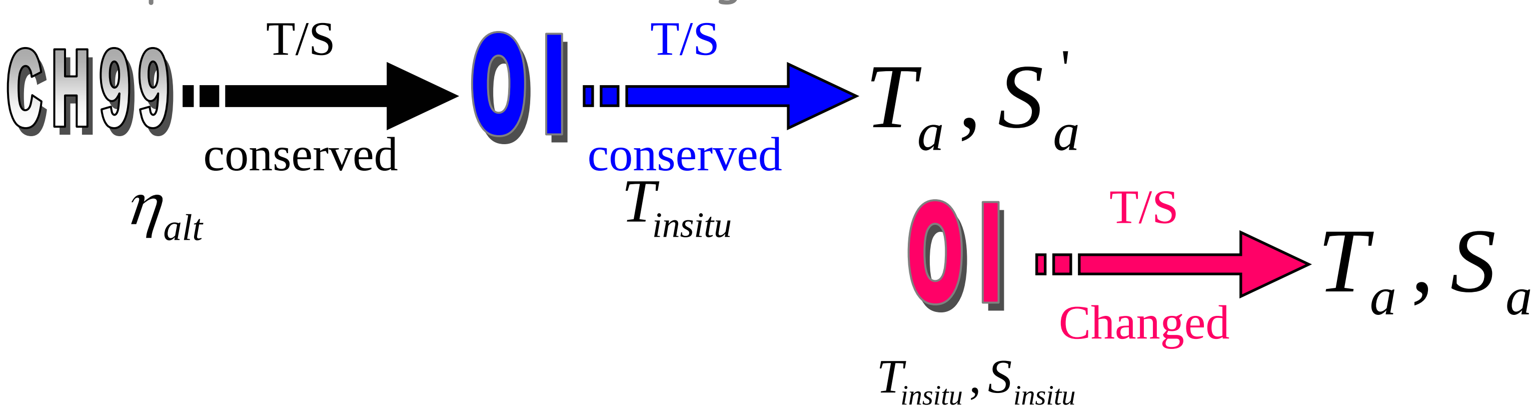
- Systematic error:
  - How optimal is the analysis?
  - spurious time variability: If observation are not homogeneous in space/time
  - Can it be estimated and corrected?
- Deficient multivariate covariances:
  - Unconstrained variables can get worse

assimilation of Salinity

Motivations:

- Known drift in salinity
- SofT scheme has improved not enough
- Number of salinity data recently increased (ARGO)

Idea: perform a second OI using T+S data to correct the T/S relationship



Assimilation of S(T) not S(z)

$$S_a(T_a) = S_a'(T_a) + \mathrm{K}'(S_o(T_o) - \mathrm{H}S_b(T_o))$$

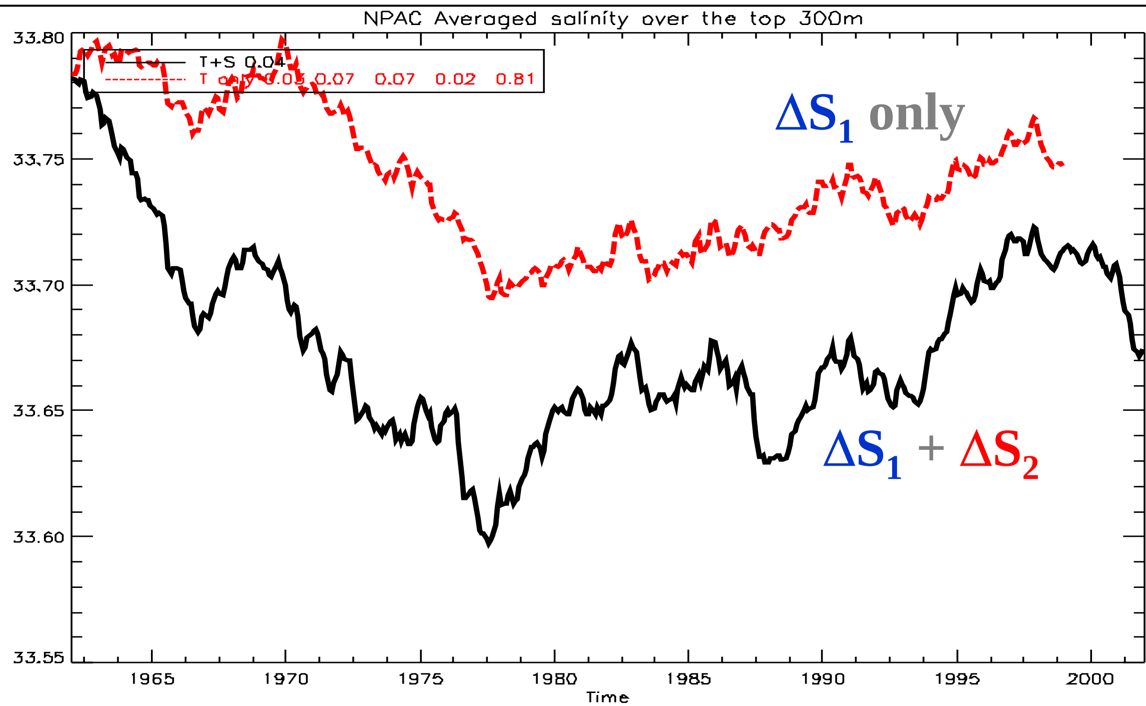
$$\mathrm{K}' \approx e^{-\frac{r^2}{R^2}} \cdot e^{-\frac{(T_a - T_o)^2}{T_R^2}}$$

assimilation of Salinity

New S(T) assimilation leads to 2 increments

(1) Balancing increment ΔS_1 associated with T assimilation keeps S(T) unchanged (already operational in system II, Troccoli et al 2002)

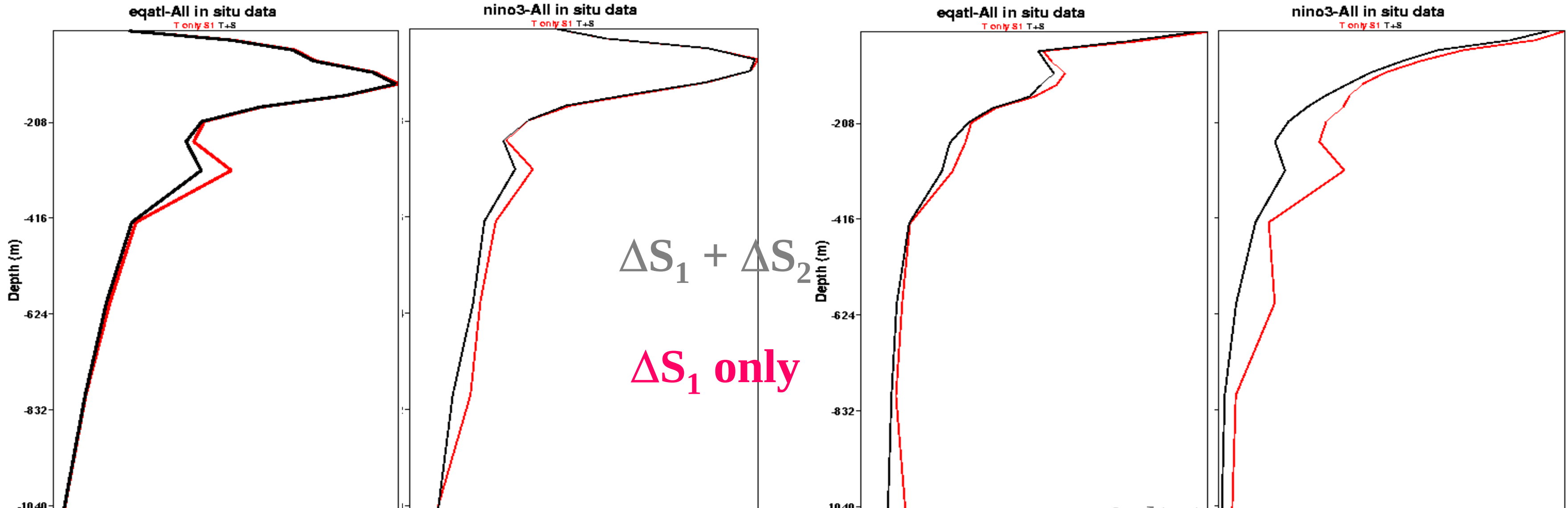
(2) Salinity assimilation increment ΔS_2 associated with observed S(T) changes (under test, 40 year assimilation complete)



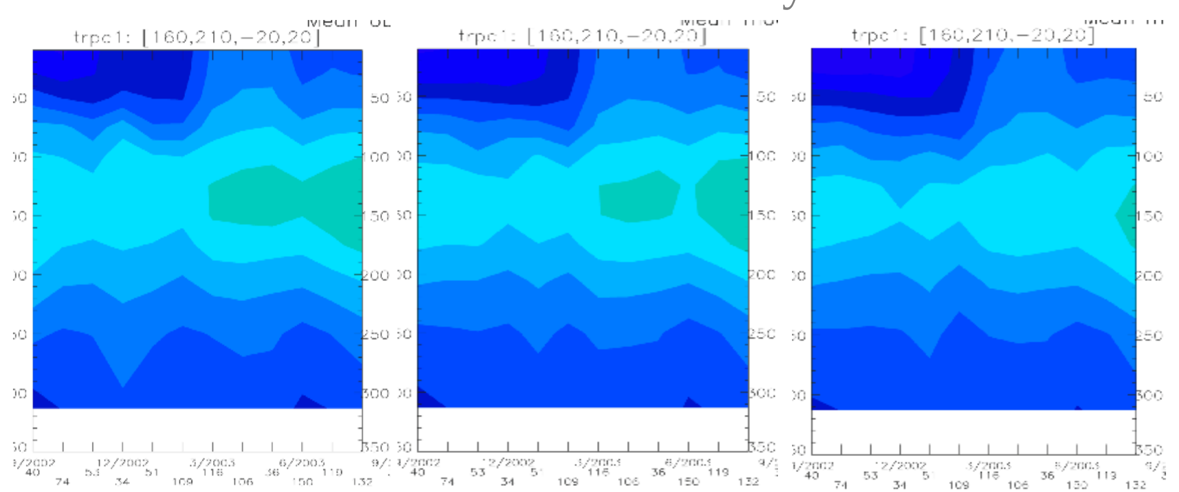
Mean Salinity Top 300m

assimilation of Salinity

Rms difference with data over 15 years:

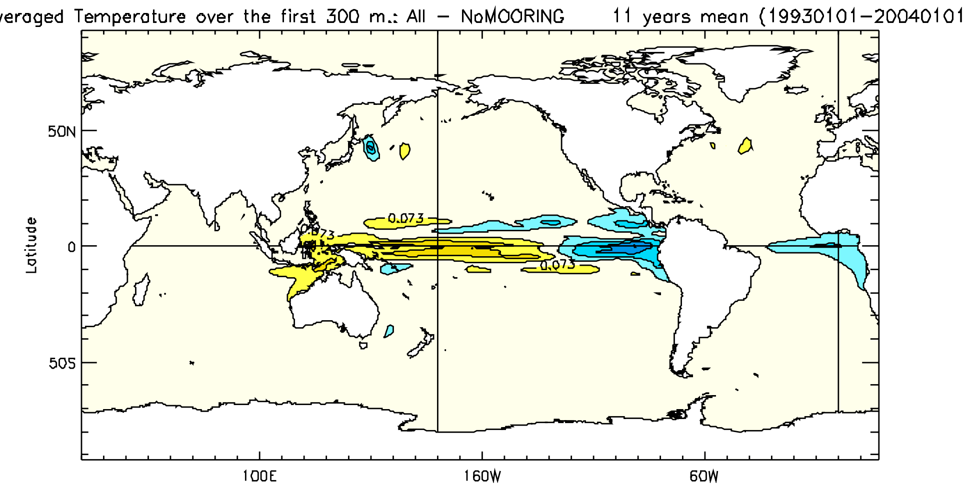


Mean Salinity
top 300m
Trop Pac box

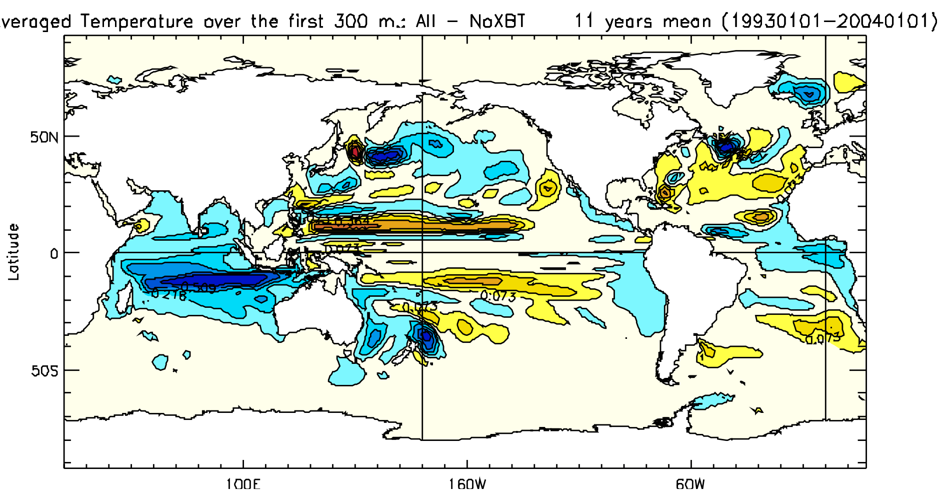


Observing System Experiments

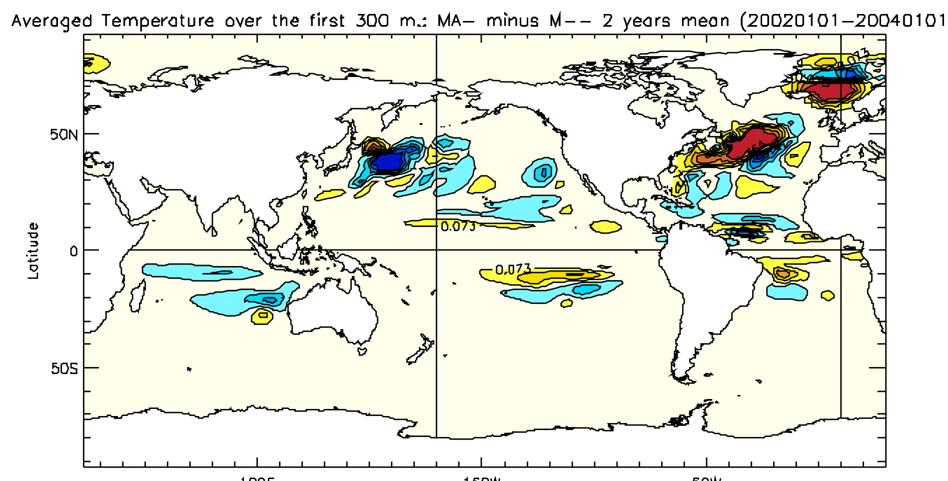
The Three main components of the in situ observing network have been withdrawn one after the other from our system, in order to assess their impact.
Figures show the impact on the mean temperature over the first 300m from:



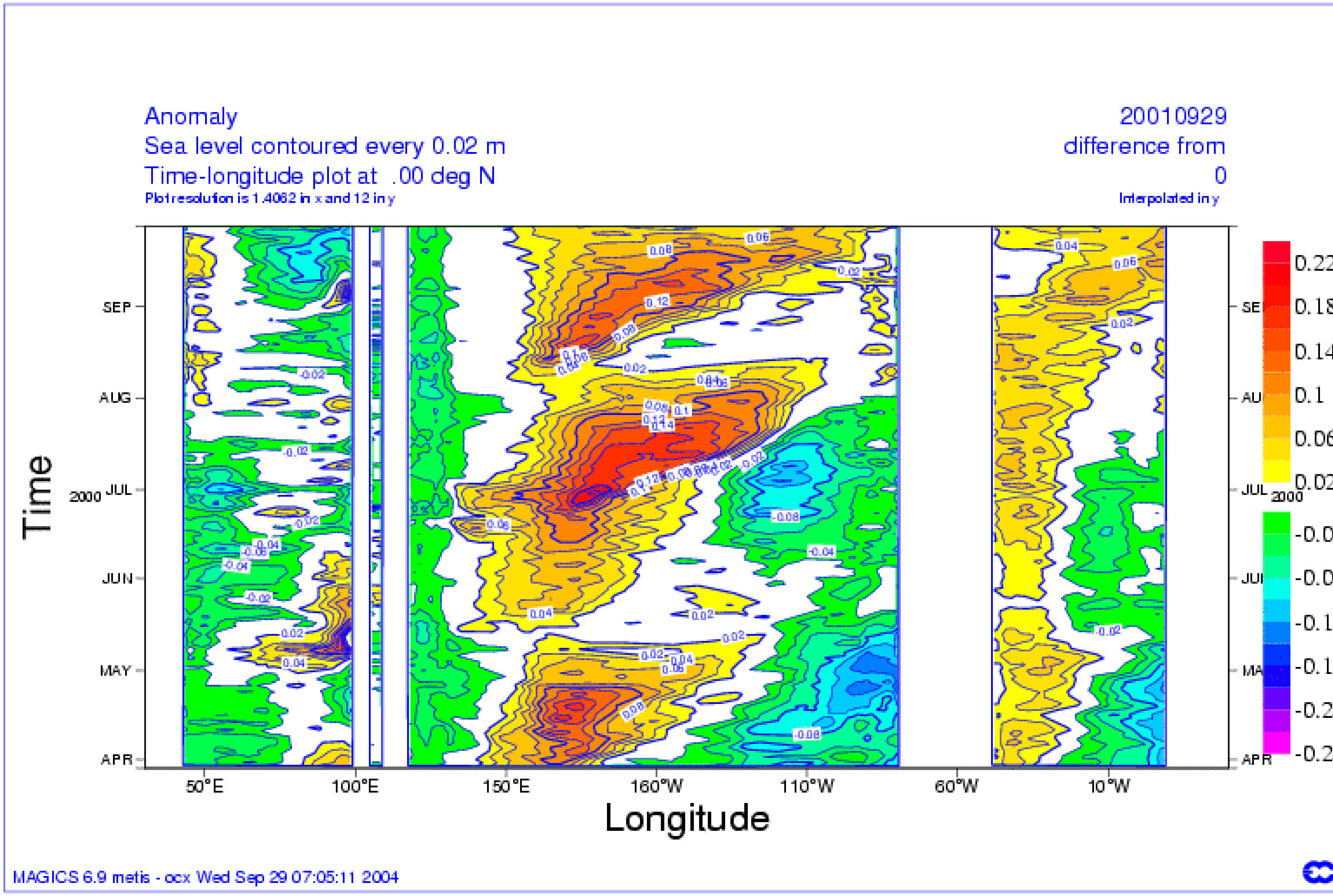
MOORINGS

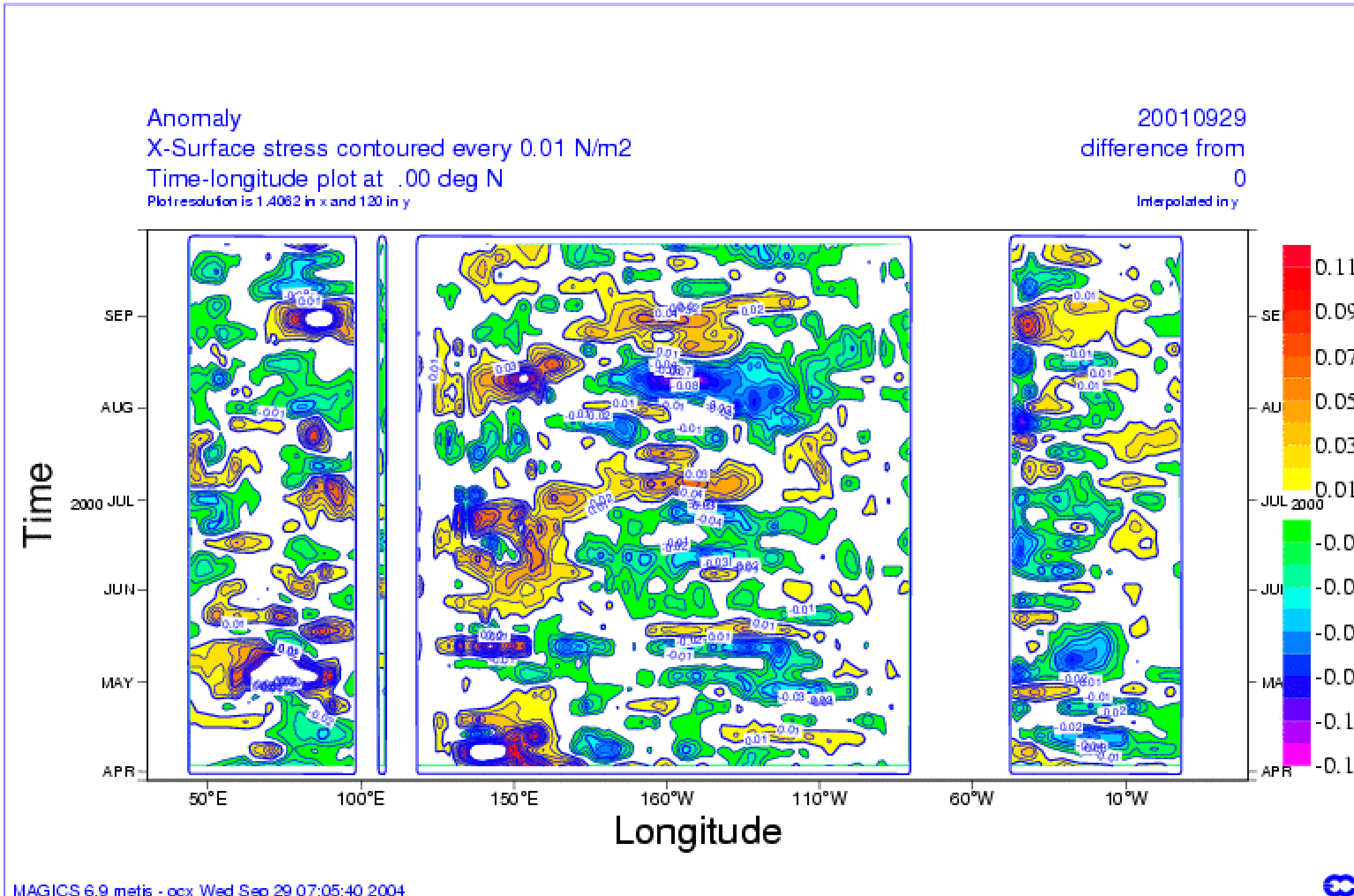


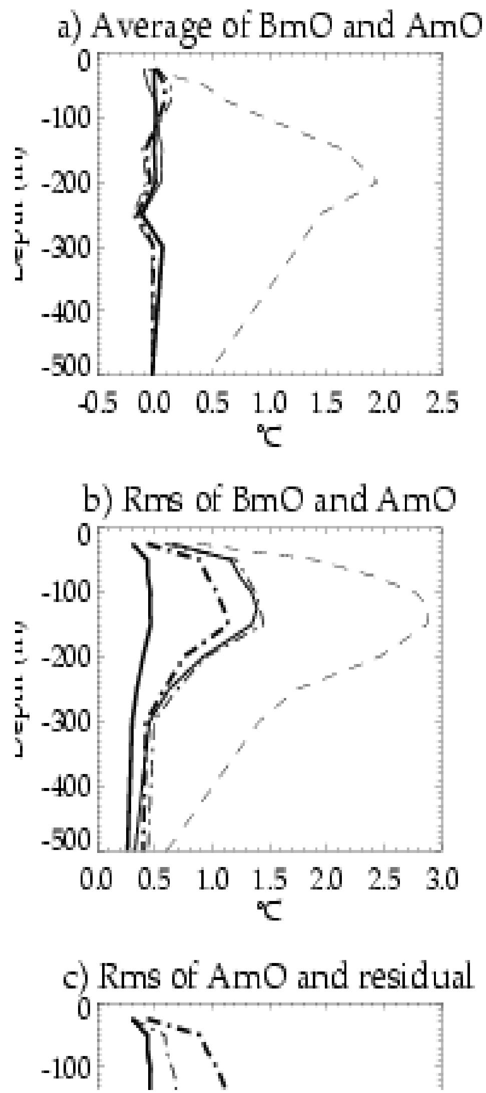
XBTs

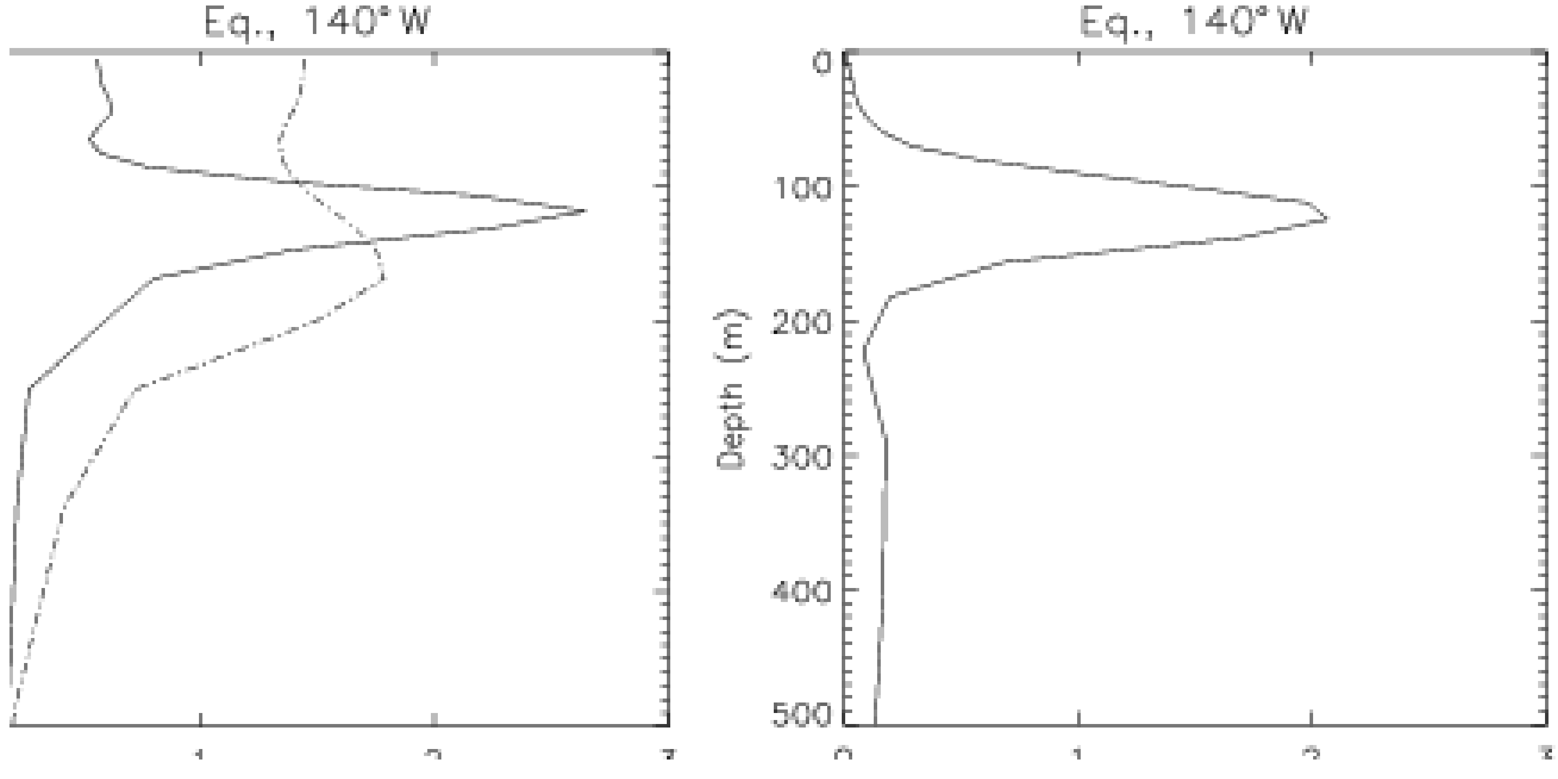


Argo floats

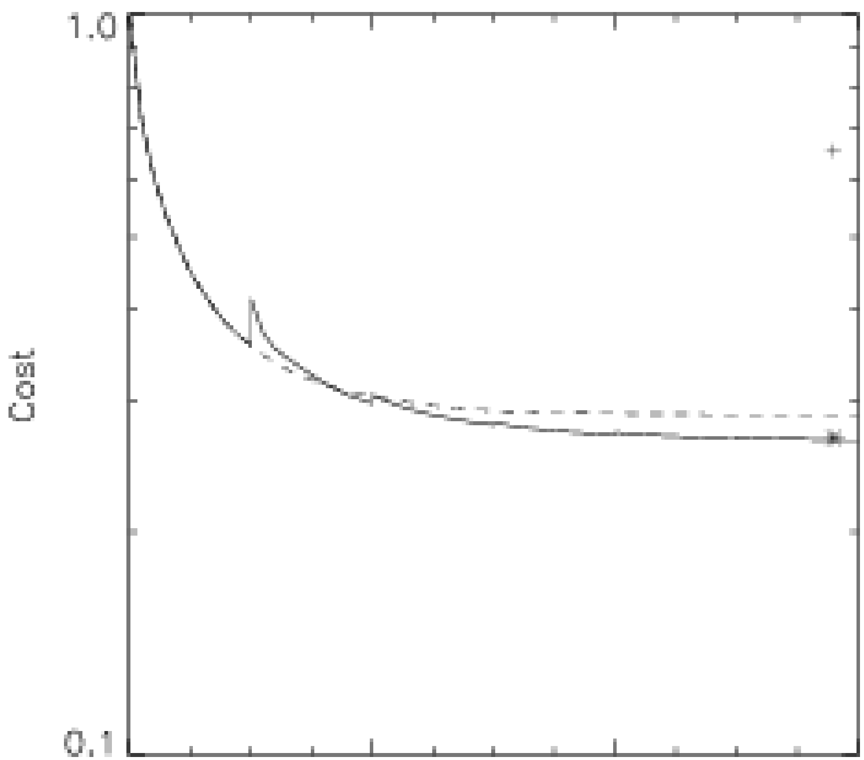

Anomaly
Sea level contoured every 0.02 m
Time-longitude plot at .00 deg N
Plot resolution is 1.4062 in x and 12 in y
20010929
difference from
0
Interpolated in y
Time
Longitude
SEP
AUG
JUL
2000
JUN
MAY
APR
50°E
100°E
150°E
160°W
110°W
60°W
10°W
0.22
0.18
0.14
0.1
0.06
0.02
-0.04
-0.08
-0.12
-0.16
-0.2
-0.24
MAGICS 6.9 metis - ocx Wed Sep 29 07:05:11 2004


Anomaly
X-Surface stress contoured every 0.01 N/m2
Time-longitude plot at .00 deg N
Plot resolution is 1.4062 in x and 120 in y
20010929
difference from
0
Interpolated in y
Time
SEP
AUG
2000 JUL
JUN
MAY
APR
50°E
100°E
150°E
160°W
110°W
60°W
10°W
Longitude
0.11
0.09
0.07
0.05
0.03
0.01
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
MAGICS 6.9 metis - ocx Wed Sep 29 07:05:40 2004


a) Average of BmO and AmO
0
-100
-200
-300
-400
-500
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
°C
b) Rms of BmO and AmO
0
-100
-200
-300
-400
-500
0.0
0.5
1.0
1.5
2.0
2.5
3.0
°C
c) Rms of AmO and residual
0
-100



Eq., 140° W
Eq., 140° W
Depth (m)
0
100
200
300
400
500
0
1
2
3



1.0
Cost
0.1