



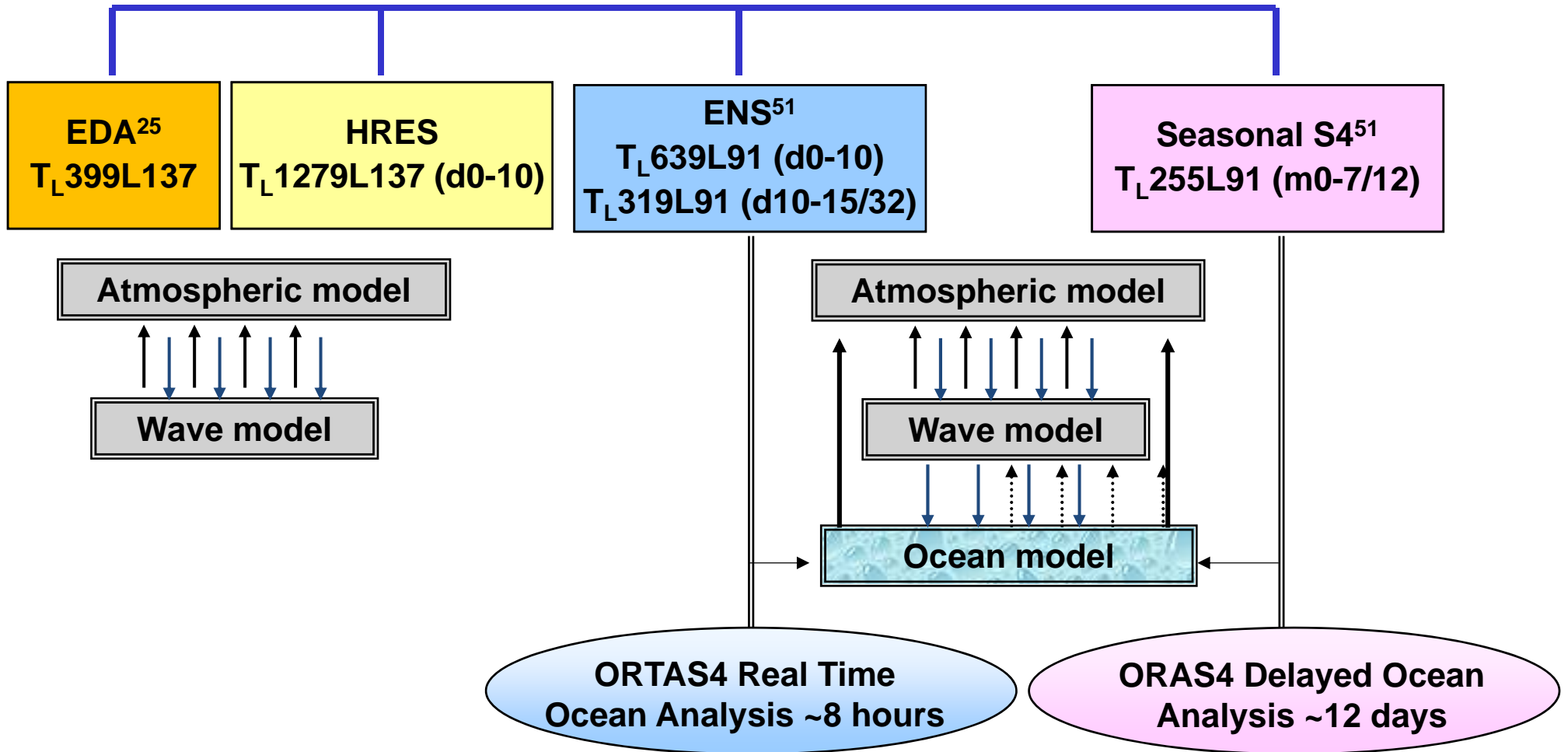
ECMWF medium-range/monthly ensemble

Roberto Buizza

European Centre for Medium-range Weather Forecasts



The ECMWF Integrated Forecasting System (IFS)





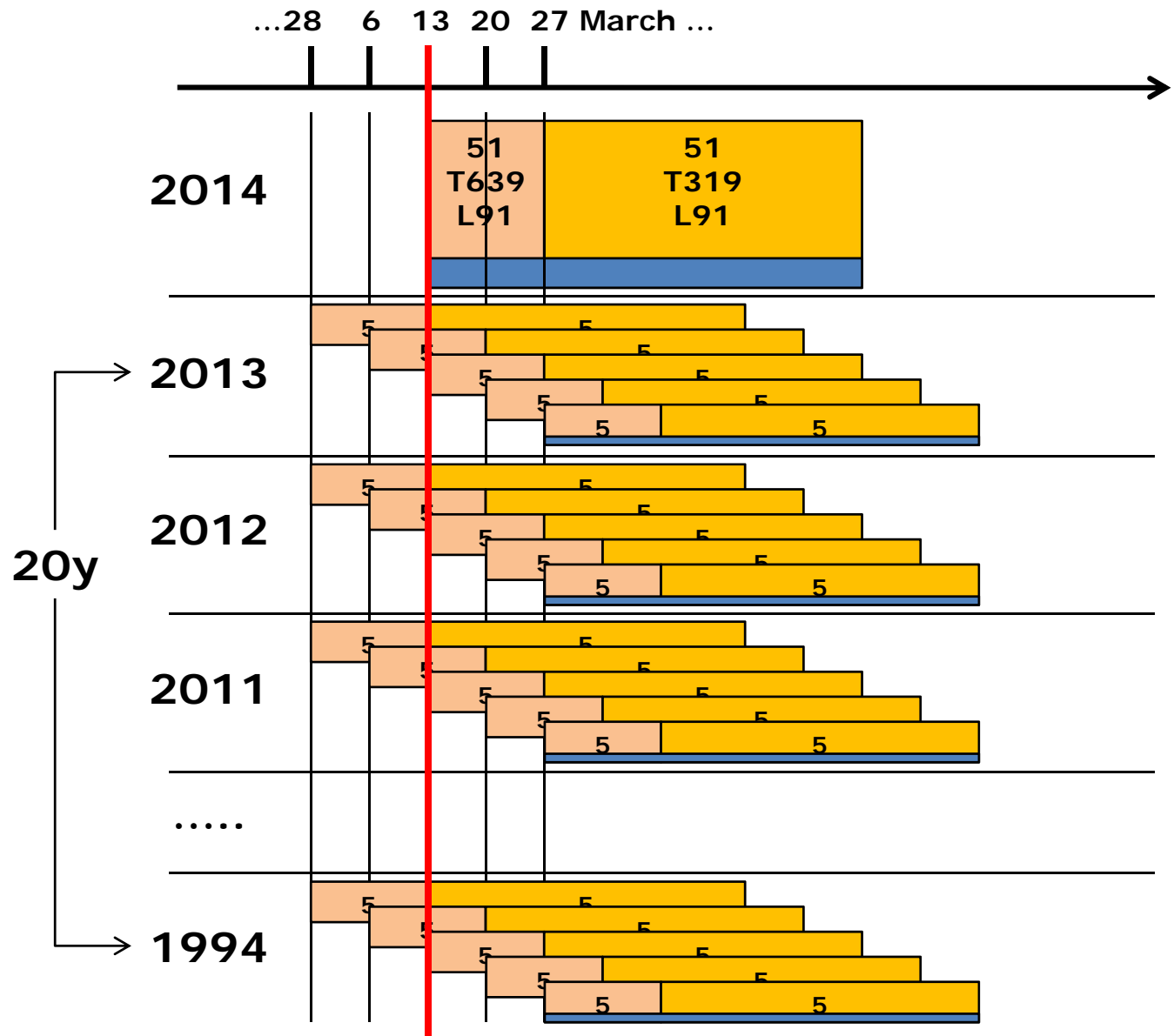
The ENS re-forecast suite to estimate the M-climate

Following *Thomas Hamill* work, a re-forecast suite is part of all ECMWF ensemble systems. Each day, the M-climate is estimated using

500 EPS re-forecasts:

- 20 years (1994 – 2013)
- 5 ICs (-14d,-7d,0,+7d, +14d)
- 5 members

Some of the ENS products (e.g. the Extreme Forecast Indices) are bias corrected and/or calibrated using the model climate.





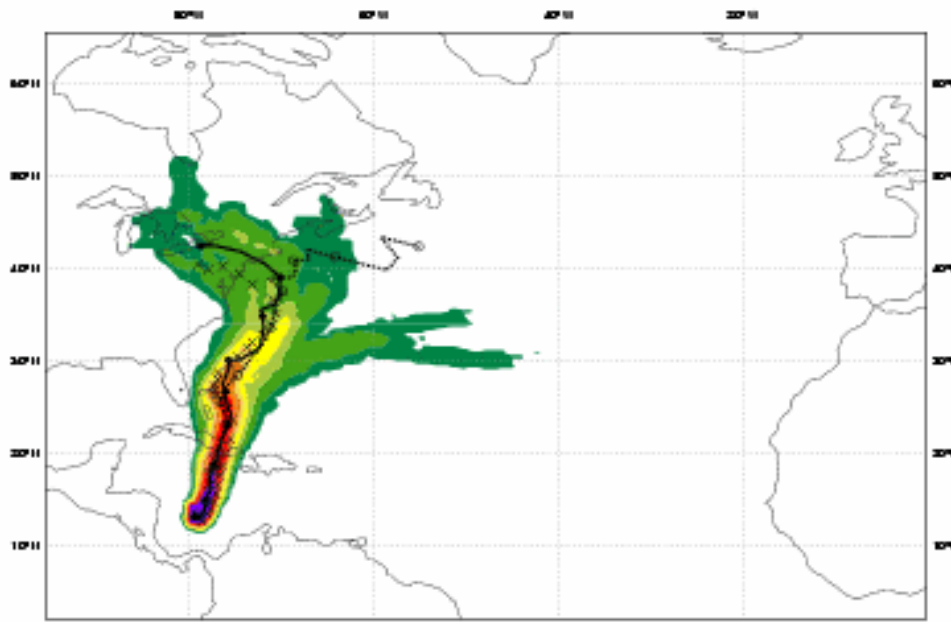
ENS to provide probabilities of weather scenarii

Date 20121023 00 UTC @ECMWF

Probability that SANDY will pass within 120 km radius during the next 240 hours

tracks: solid=OPER; dot=Ens Mean [reported minimum central pressure (hPa) 998]

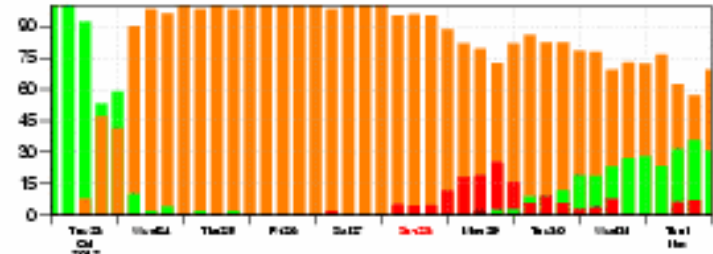
■ 0-10 ■ 10-20 ■ 20-30 ■ 30-40 ■ 40-50 ■ 50-60 ■ 60-70 ■ 70-80 ■ 80-90 ■ 90-100%



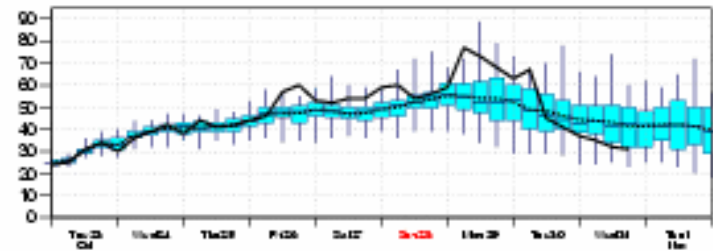
List of ensemble members numbers forecast Tropical Cyclone Intensity category in colours: TD [up to 33] TS [34-63] HR1 [64-82] HR2 [83-95] HR3 [>95 kt]

+02h	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
+06h	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
+12h	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
+18h	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
+24h	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
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+54h	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
+60h	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50

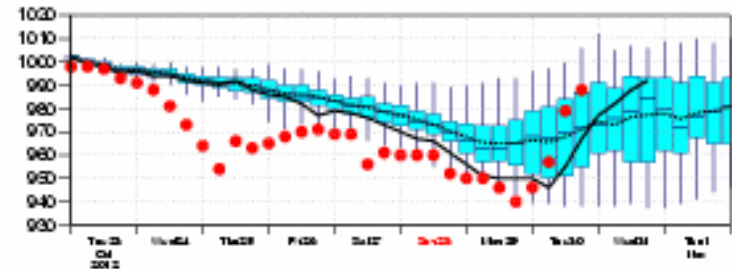
Probability (%) of Tropical Cyclone Intensity falling in each category
 TD [up to 33] TS [34-63] HR1 [64-82] HR2 [83-95] HR3 [>95 kt]



10m Wind Speed (kt) solid=OPER; dot=Ens Mean



Mean Sea Level Pressure in Tropical Cyclone Centre (hPa) solid=OPER; dot=Ens Mean



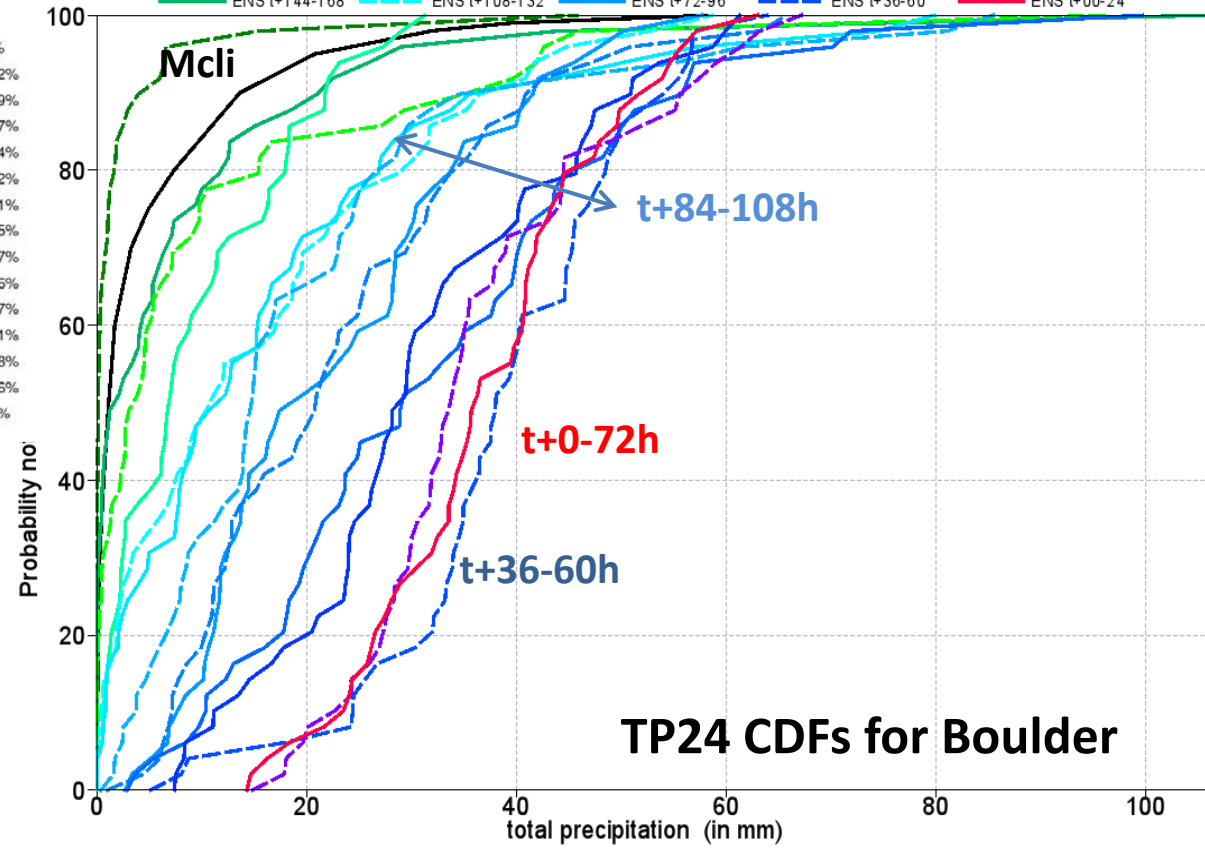
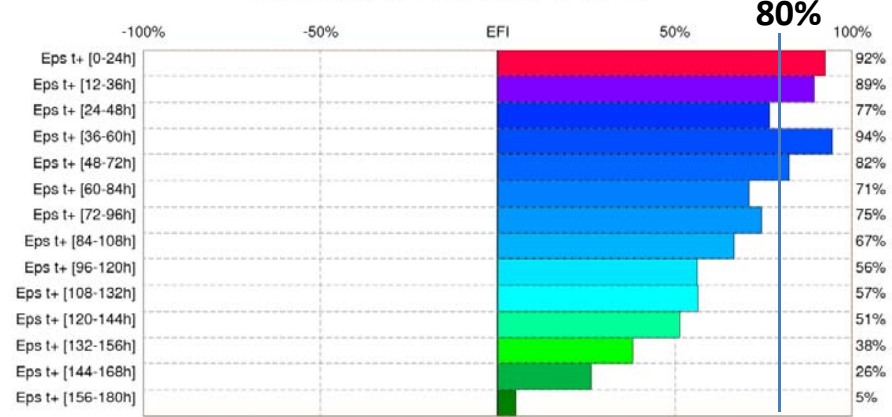


ENS to identify rare events

Extreme Forecast Index for total precipitation at 40.02N -105.29W
Thursday 12 September 2013

Cumulative Distribution Functions for total precipitation at 40.02°/-105.29° VT: 12/09/2013 00UTC - 13/09/2013 00UTC

M-clim t+24-48	ENS t+132-156	ENS t+96-120	ENS t+60-84	ENS t+24-48
ENS t+156-180	ENS t+70-144	ENS t+84-108	ENS t+48-72	ENS t+12-36
ENS t+144-168	ENS t+108-132	ENS t+72-96	ENS t+36-60	ENS t+0-24



Boulder, 12-13 Sep 2013.

This plot shows EFI fcs for TP24 valid for the 24-hours between 00 UTC of 12 and 13 September 2013.

EFI was increasing approaching the date.

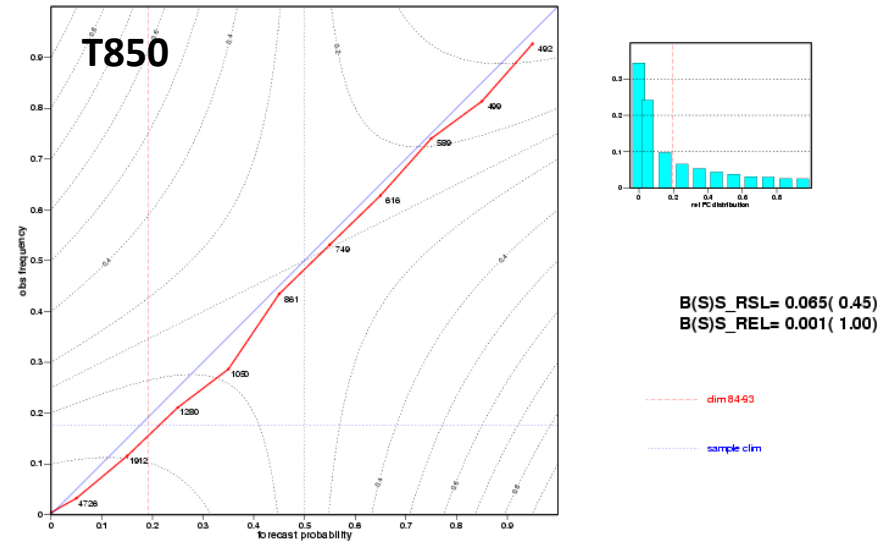
(From Ivan Tsonevski)



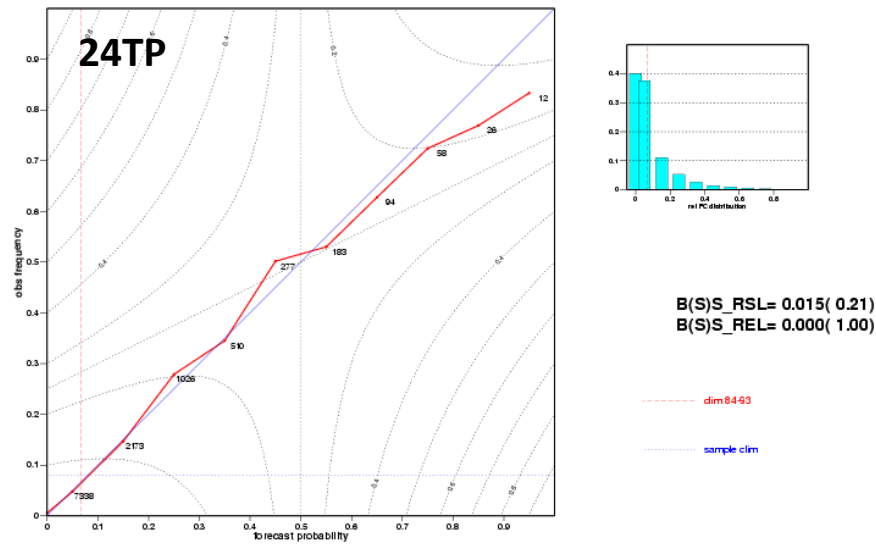
How do they perform? Ensembles must be reliable

Reliability is a key property that probabilistic forecasts must have.

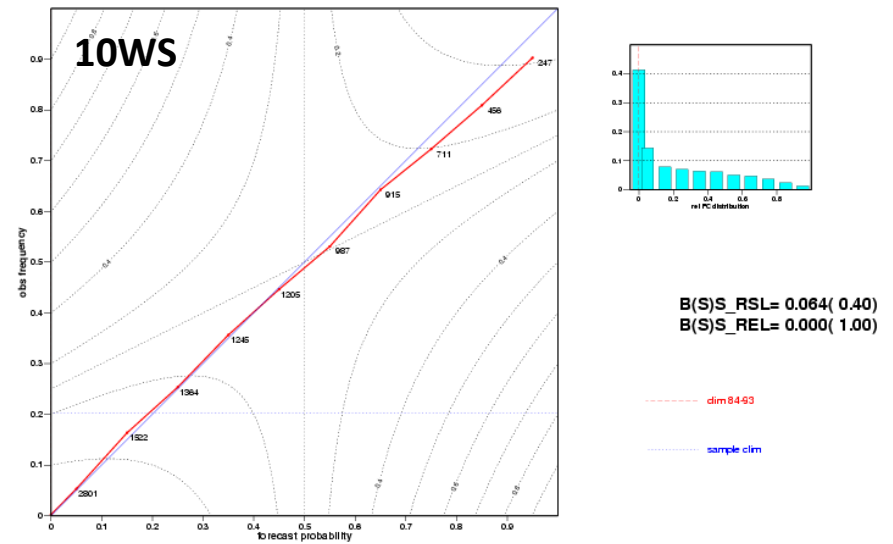
Oct12-Dec12 t + 144 Europe an T850 anomaly It -4 K
BrSc = 0.080 LCB rSkSc= 0.45 Uncertainty= 0.145



Oct12-Dec12 t + 144 Europe an 24h-precip gt 10 mm
BrSc = 0.057 LCB rSkSc= 0.21 Uncertainty= 0.073



Oct12-Dec12 t + 144 Europe an 10m wind speed gt 10 m/s
BrSc = 0.097 LCB rSkSc= 0.52 Uncertainty= 0.162

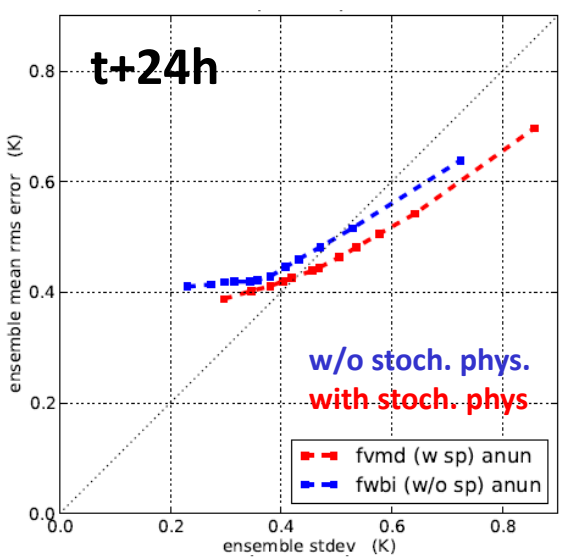




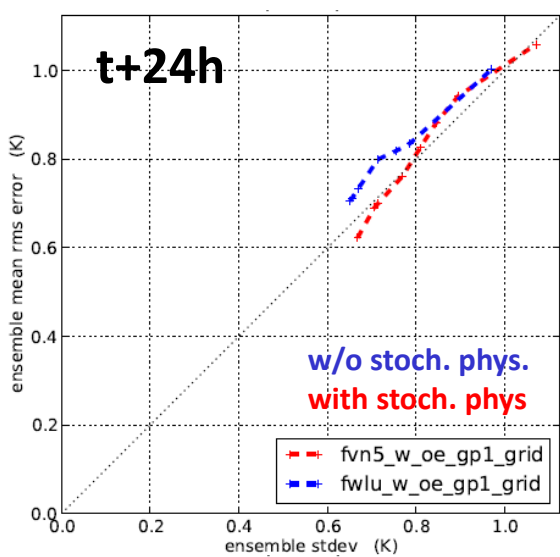
How do they perform? Ensembles must be reliable

ENS reliability is sensitive to verification field (analysis or obs).

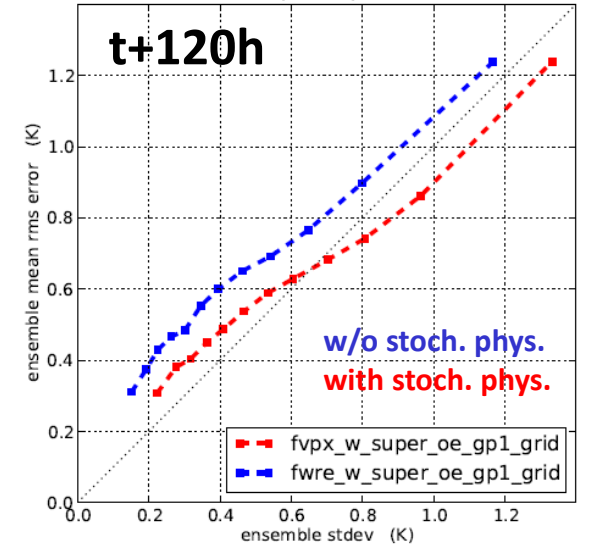
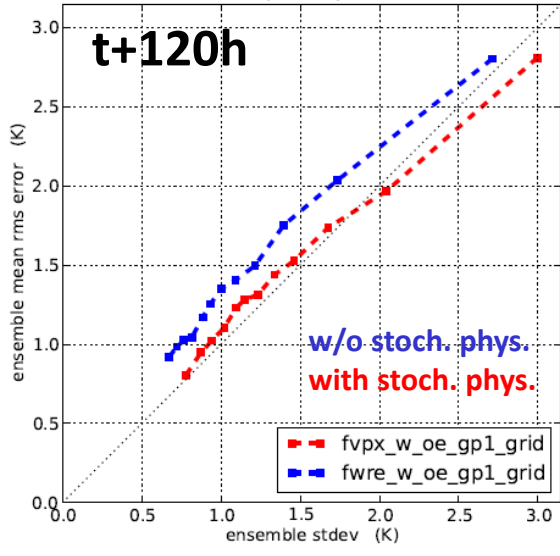
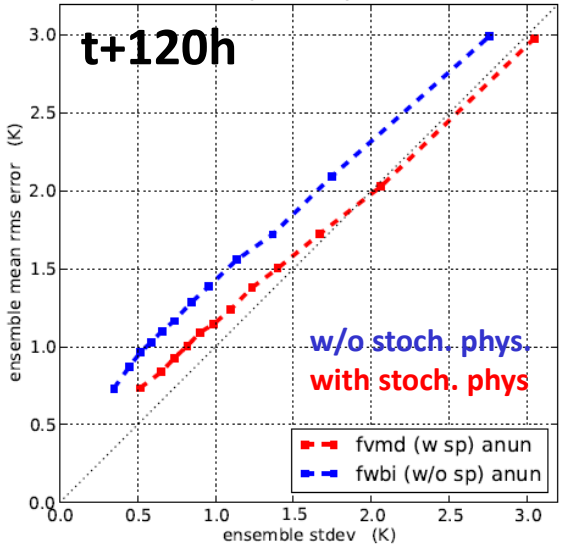
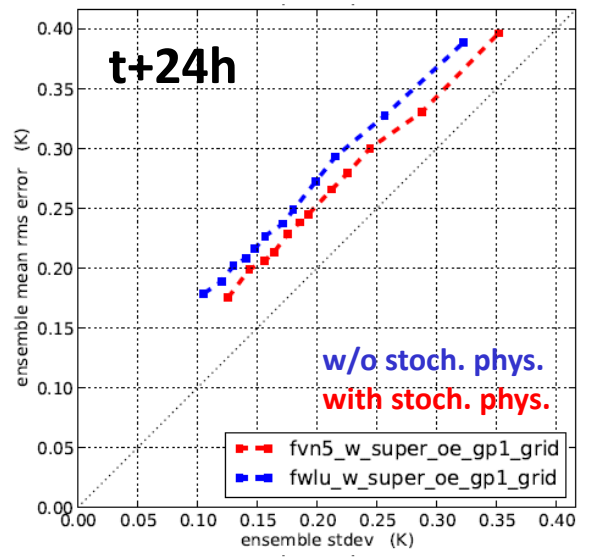
NH T500 – fc v analysis



NH T500 – fc v radiosondes



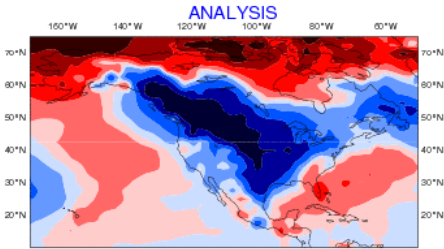
NH T500 – fc v AMSUA



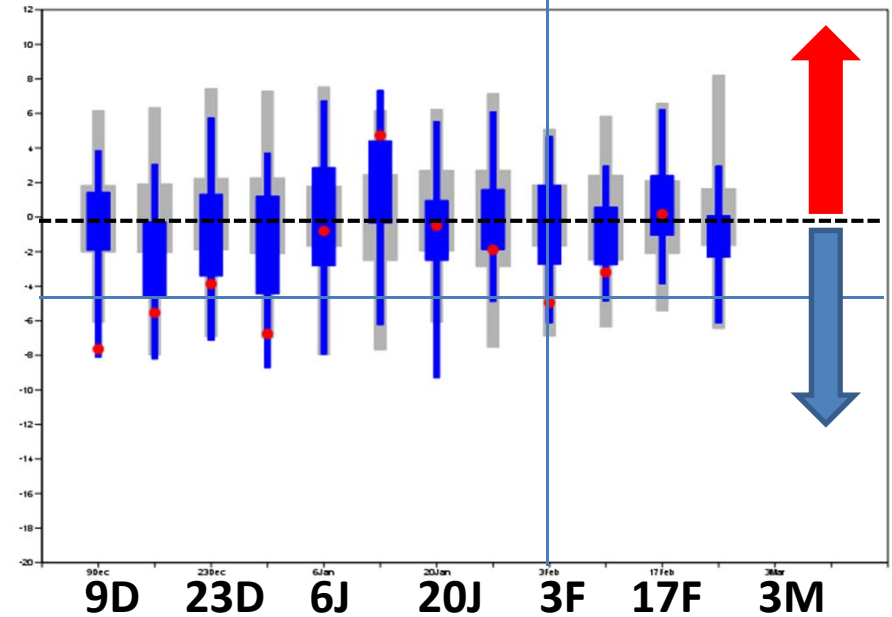
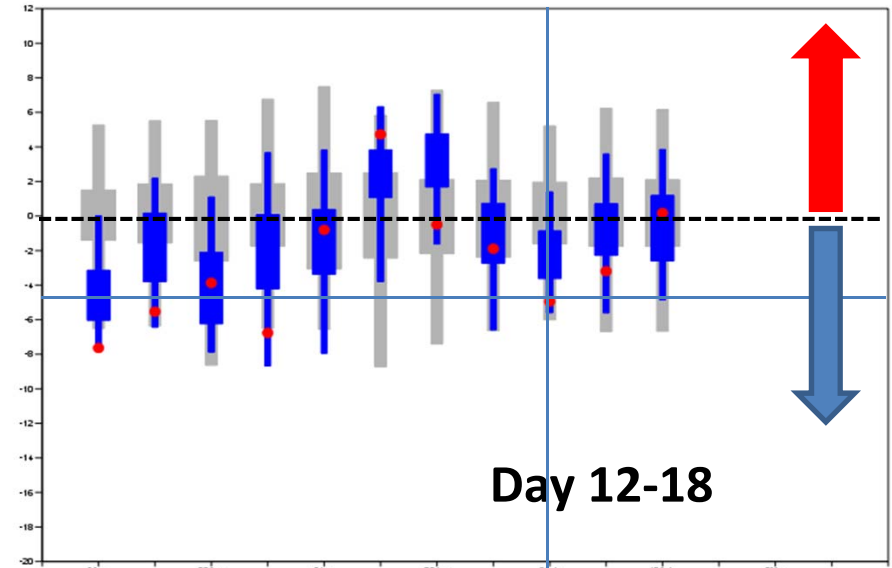
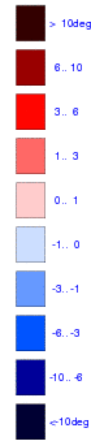
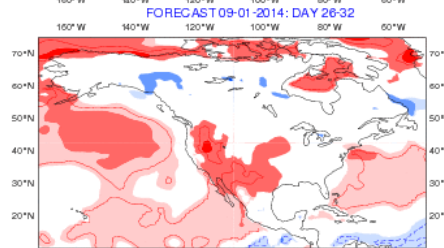
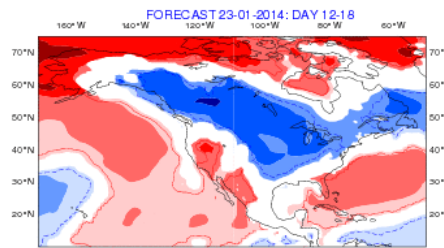
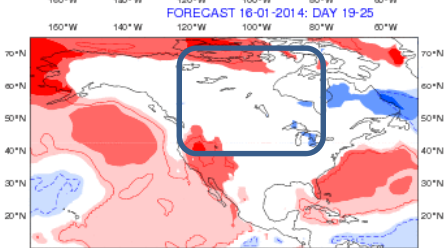
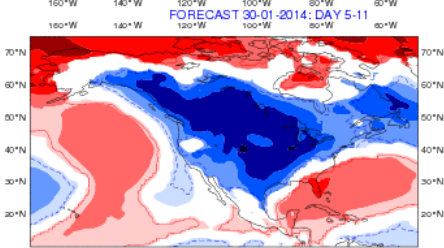
(From M Yamaguchi)



ENS to predict anomalies weeks ahead



Analysis and ECMWF EPS-Monthly Forecasting System
2-metre Temperature anomaly
Verification period: 03-02-2014/TO/09-02-2014
ensemble size = 51, climate size = 100
Shaded areas significant at 10% level
Contours at 1% level



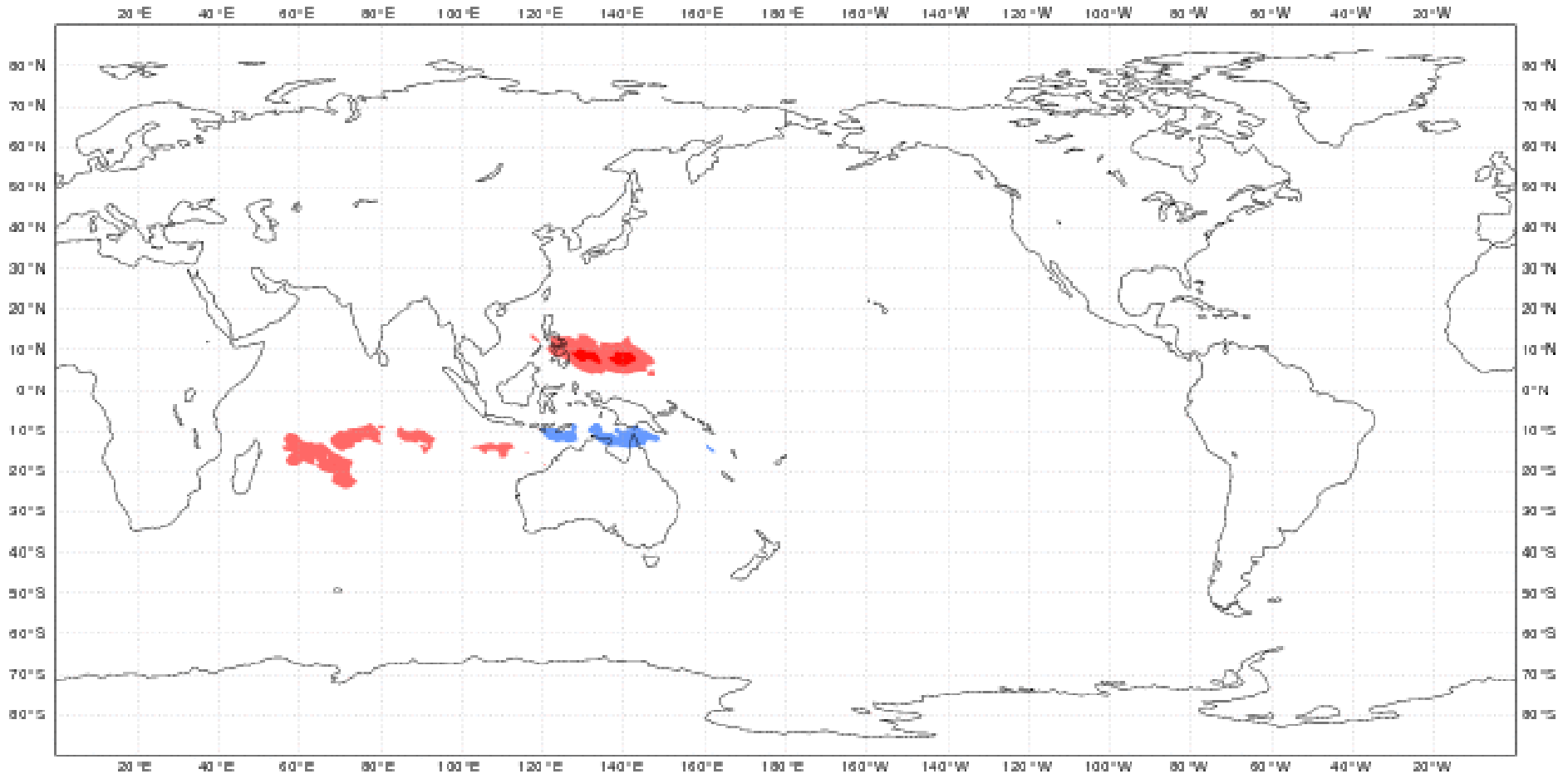
This plot shows ENS weekly anomaly forecasts over North America in D13-JFM13 (the right panels show average 2mT over (120-60W;40-70N)).



ENS to predict TC genesis (anomalies) weeks ahead

Weekly Mean Anomaly of Tropical Cyclone Strike Probability. Date: 20140320 0 UTC t+(432-600)
Probability of a TC passing within 300km radius

Legend for probability anomalies:
-100--40 (black), -40--30 (dark blue), -30--20 (blue), -20--10 (light blue), -10--10 (white), 10--20 (light red), 20--30 (red), 30--40 (dark red), 40--100 (black)





How do the ensembles perform? HRES, ENS-C, ENS-M

500hPa geopotential

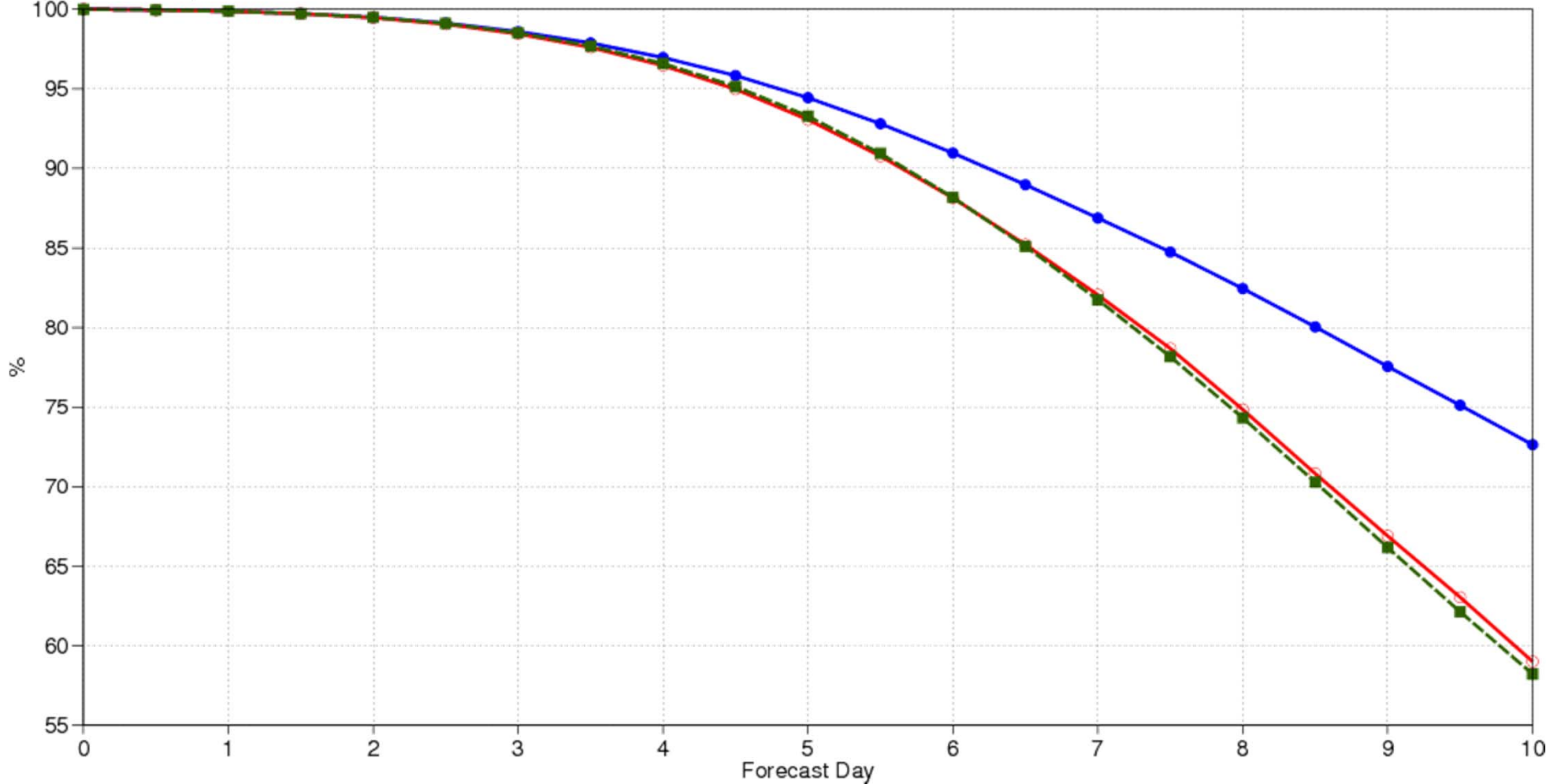
Anomaly correlation

NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)

Date: 20131201 00UTC to 20140228 00UTC

oper_an od 0001 | Mean method: fair

- oper fc 00UTC,12UTC
- enfo cf 00UTC,12UTC
- enfo em 00UTC,12UTC





How do the ensembles perform? HRES, ENS-C, ENS-M

500hPa geopotential

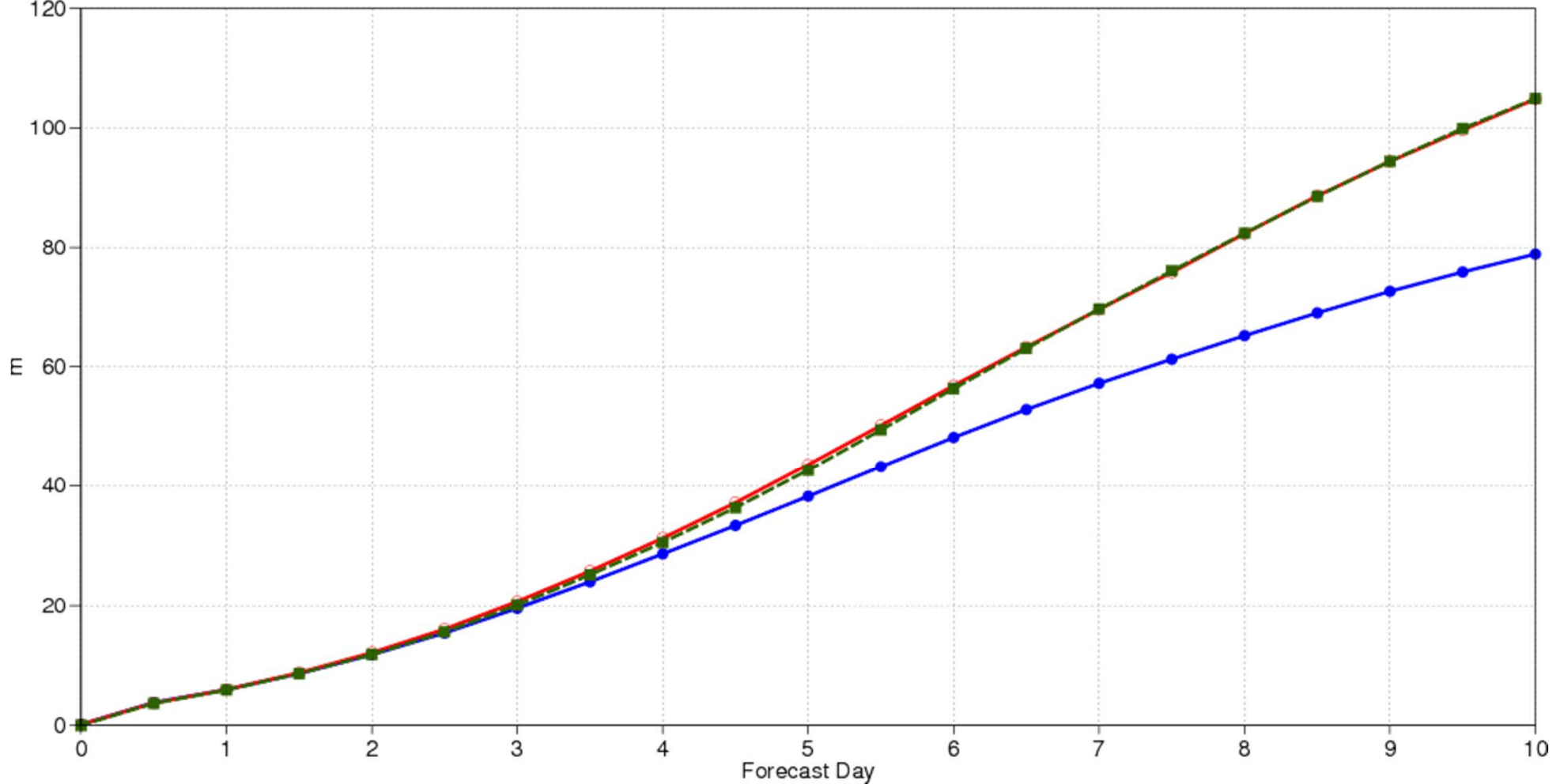
Root mean square error

NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)

Date: 20131201 00UTC to 20140228 00UTC

oper_an od 0001 | Mean method: fair

- oper fc 00UTC,12UTC
- enfo cf 00UTC,12UTC
- enfo em 00UTC,12UTC





How do the ensembles perform? ENS-C, ENS-M, ENS-std

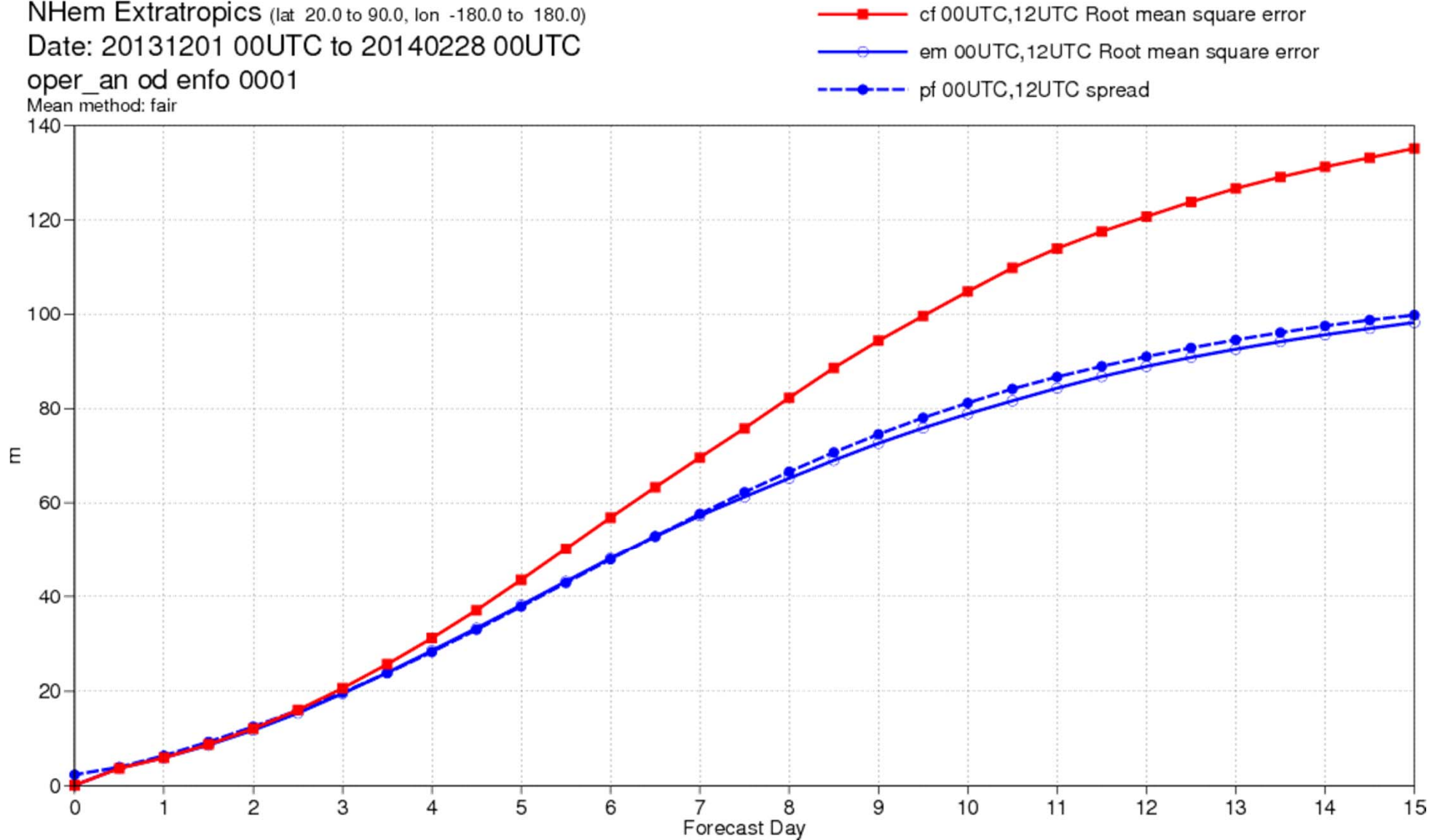
500hPa geopotential

NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)

Date: 20131201 00UTC to 20140228 00UTC

oper_an od enfo 0001

Mean method: fair



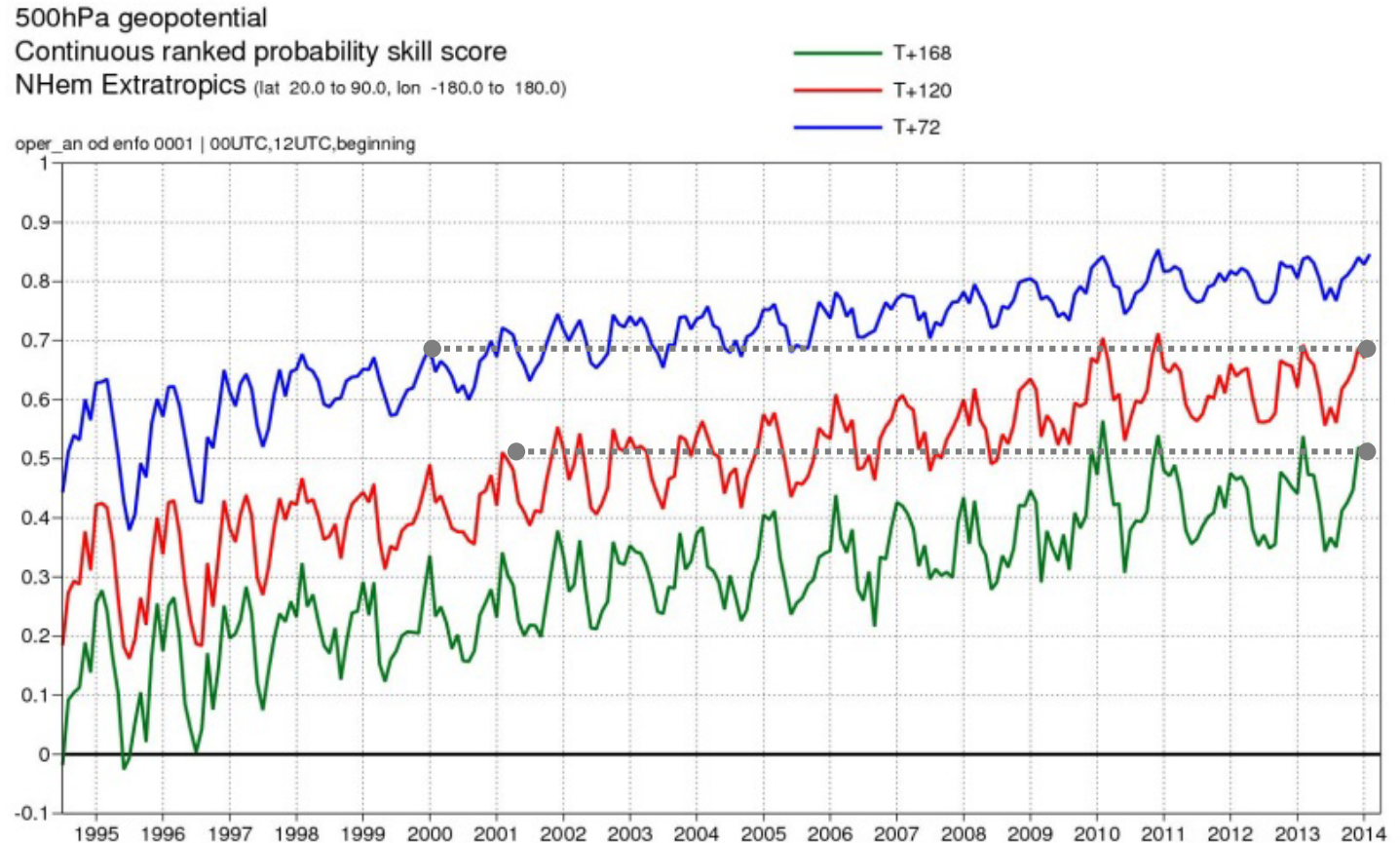


How do ensembles perform? Scores' trends CRPSS Z500 NH

Scores' trends can be used to monitor progress.

This plot shows that for upper-level fields over the NH extra-tropics, performance has been improving continuously.

Results indicate predictability gains of 1.5-2.0 days per decade.





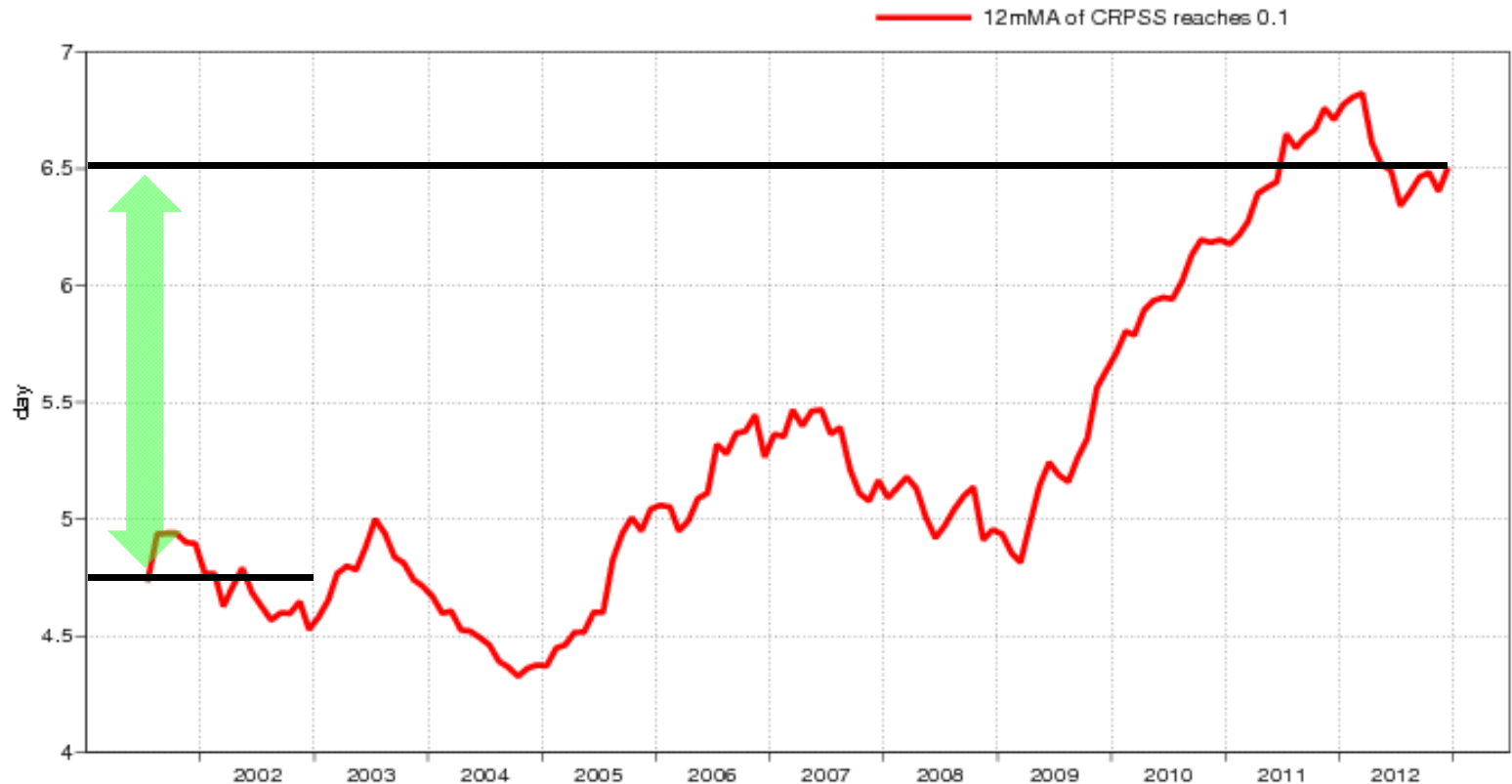
How do ensembles perform? Scores' trends CRPSS TP24 EU

Similar, although smaller in size, improvements can be seen by looking at 24h total precipitation, with skill gains of about 1.75 days between 2001 and 2012.

The plot shows the forecast lead time when CRPSS crosses a 10% value.

ECMWF EPS 12UTC forecast skill

total precipitation
Continuous ranked probability skill score
Europe (lat 35.0 to 75.0, lon -12.5 to 42.5)

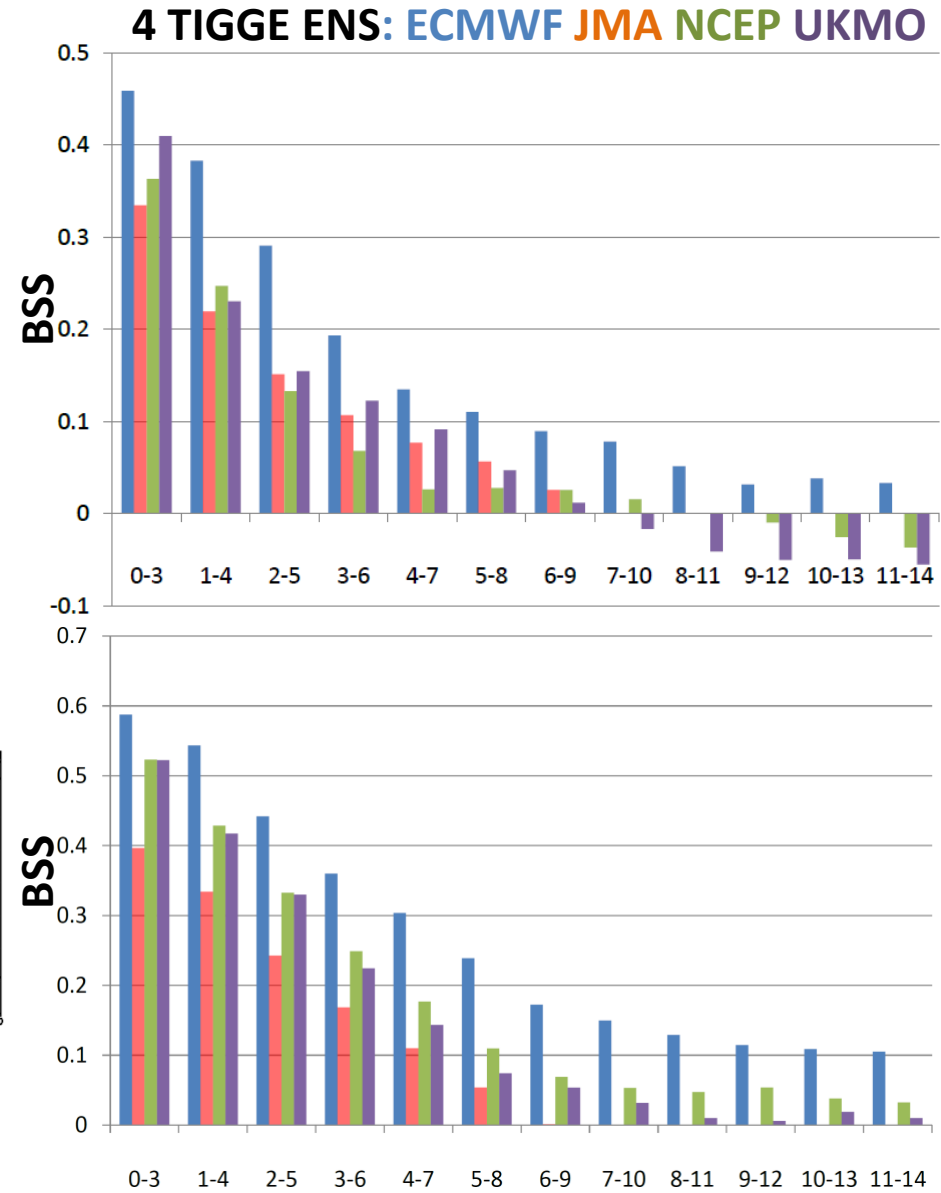
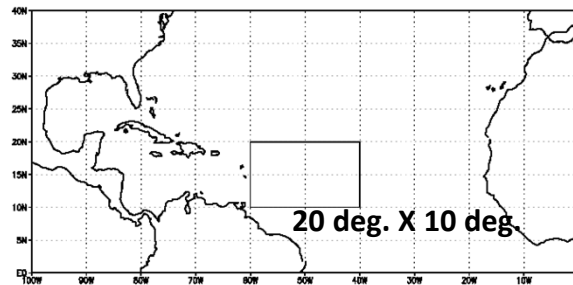
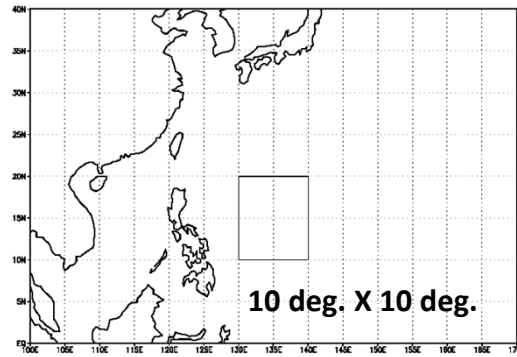




How do they perform? Ensembles must be reliable

TIGGE-based results for Jul-Oct 2012. TC tracking data have been created with the ECMWF vortex tracker (Vitart et al. 1997, JC). Verified TCs are storms with a 'Tropical Storm' intensity or stronger (>35 knots).

Verification Areas



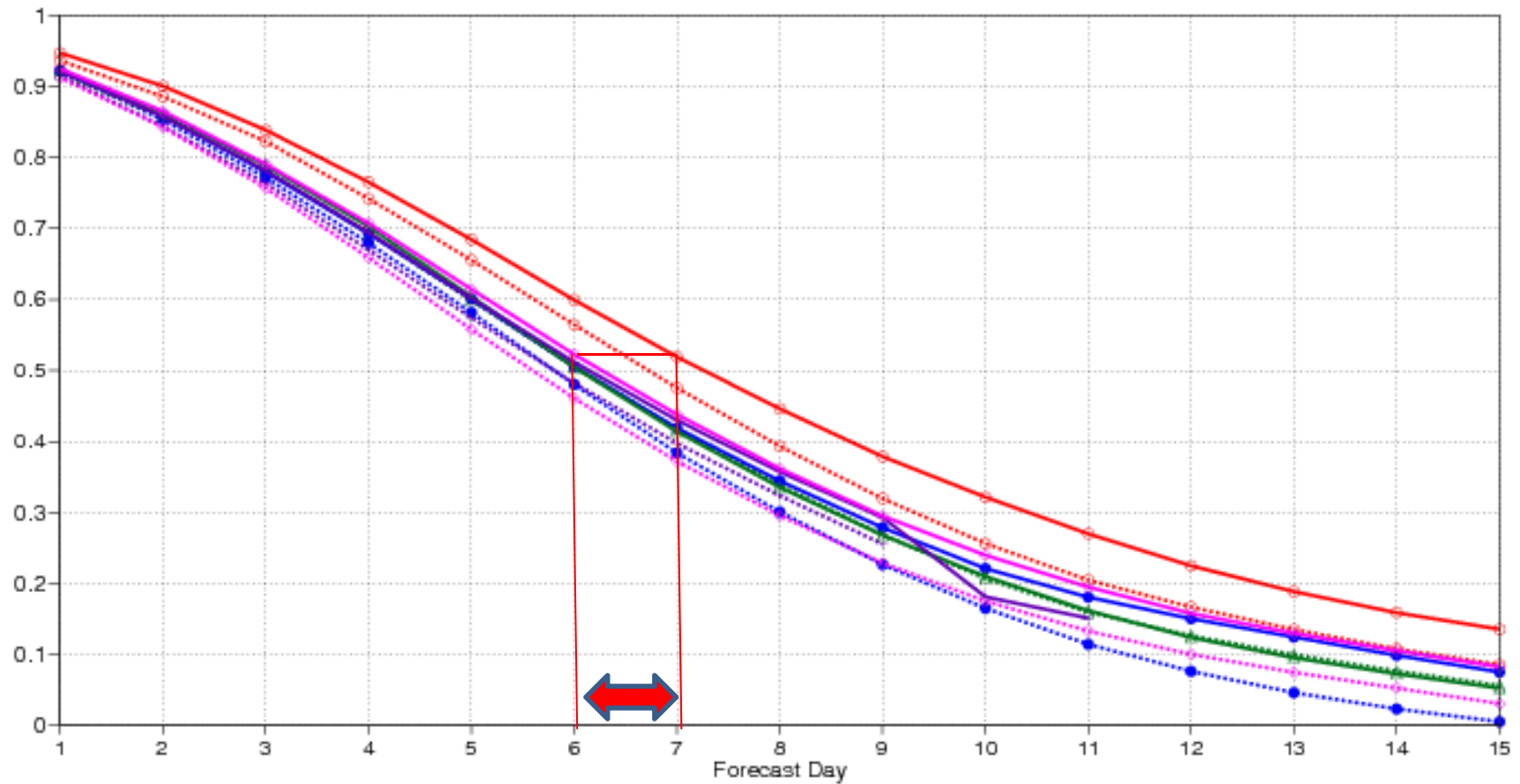
(From M Yamaguchi)



How do the ensembles perform? TIGGE ENS

500hPa geopotential
Continuous ranked probability skill score
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
DecJanFeb

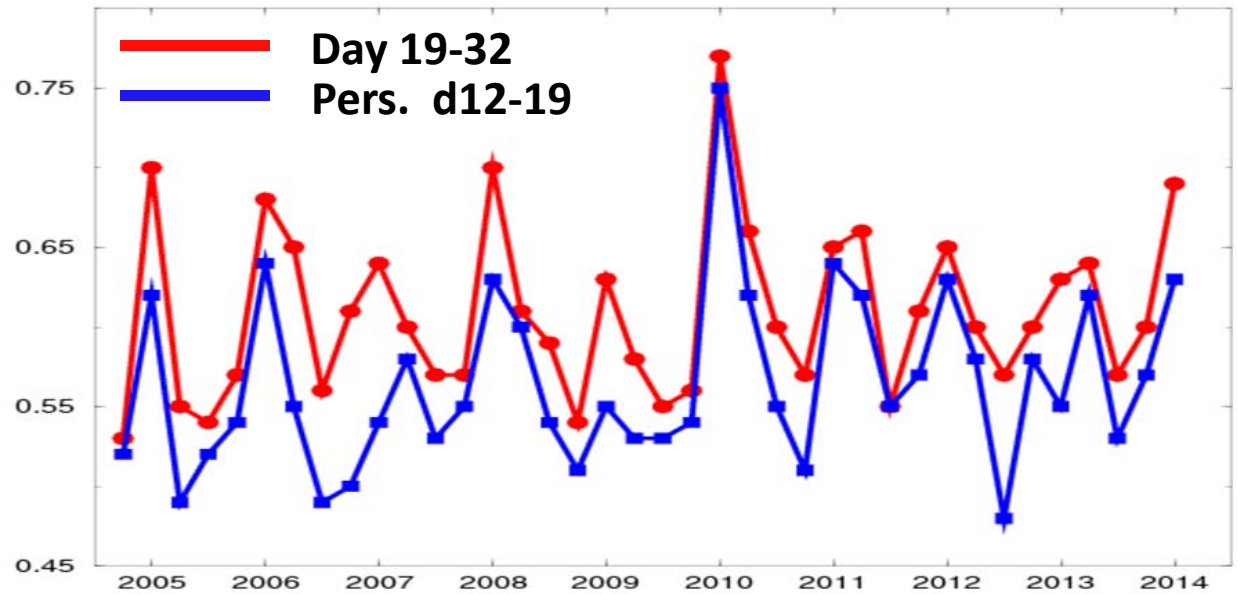
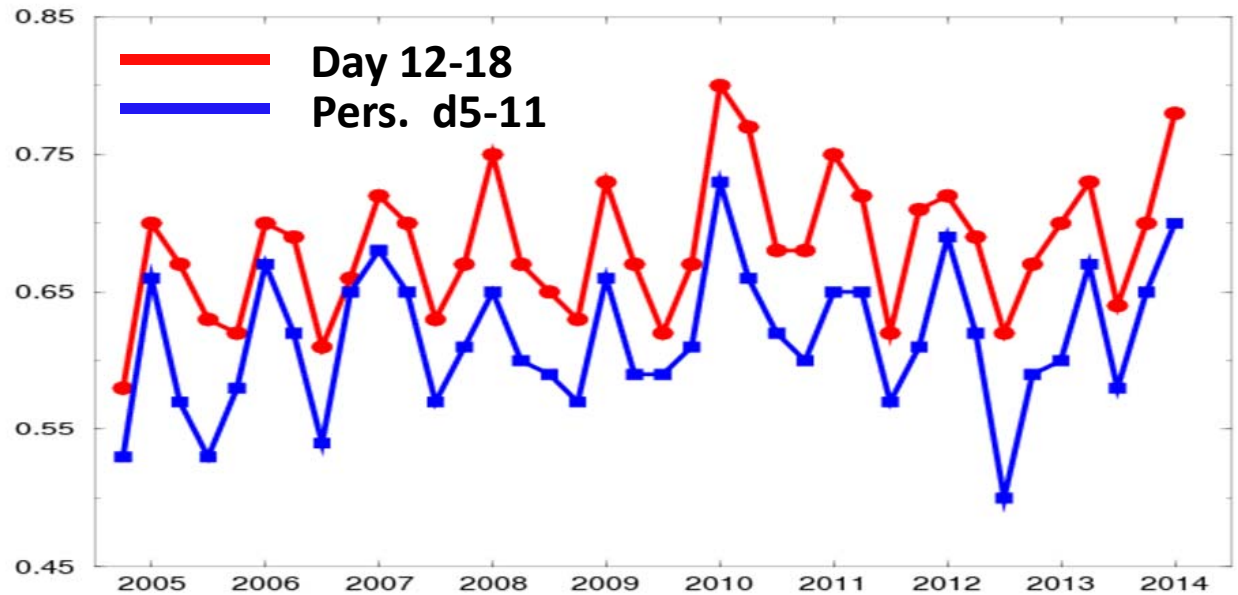
- DJ F2013 CMC
- DJ F2013 JMA
- DJ F2013 NCEP
- DJ F2013 UKMO
- DJ F2013 ECMWF
- DJF2014 CMC
- DJF2014 JMA
- DJF2014 NCEP
- DJF2014 UKMO
- DJF2014 ECMWF





How do the ensembles perform? ROCA[PR(2mT>U3)] NH

ROC score for prob. Fc of 2-meter temperature in the upper tercile.



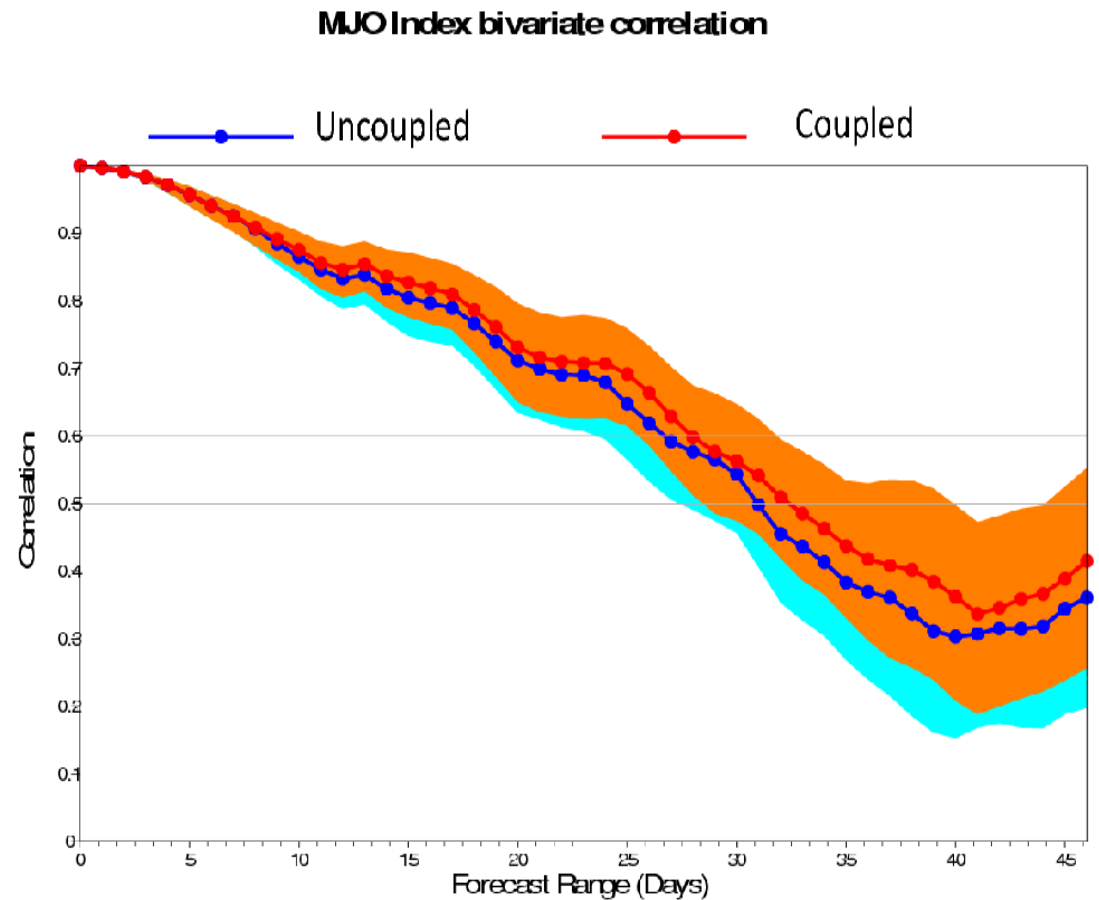


Nov 2013: ENS coupling from d0 to a better marine model ...

Nov 2013: **coupling from initial-time** to a new version of the ocean model (NEMO), with 1-way wave-currents coupling, improved skill, especially in the monthly time-range.

Work is progressing to introduce a better, unified wave-currents-sea-ice model (LIM). The new model based on NEMO is under testing at higher resolution, ORCA_025_Z75.

In 2014 we will complete a 1/4 degree NEMOVAR re-analysis, and we will then implement the 1/4 model first in ENS, and then in the seasonal system (S5, planned for 2016/17).

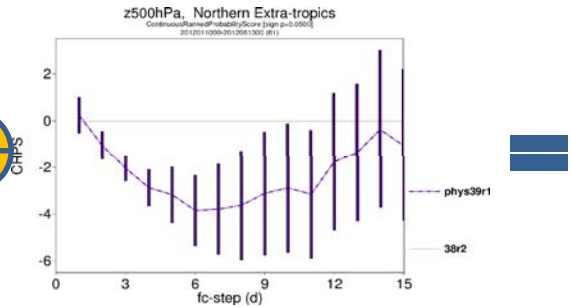
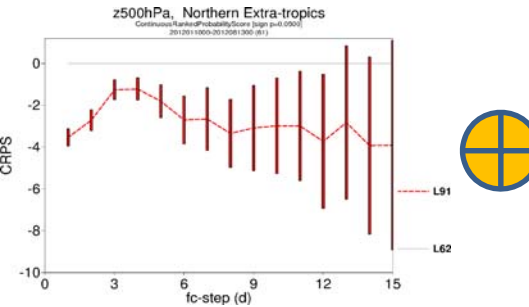
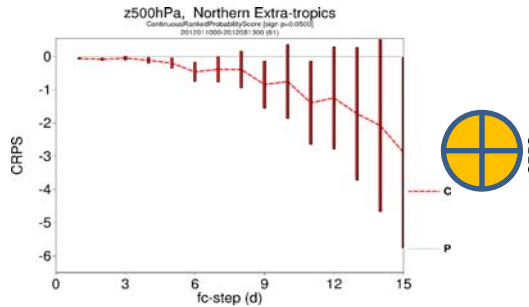


(From F Vitart)



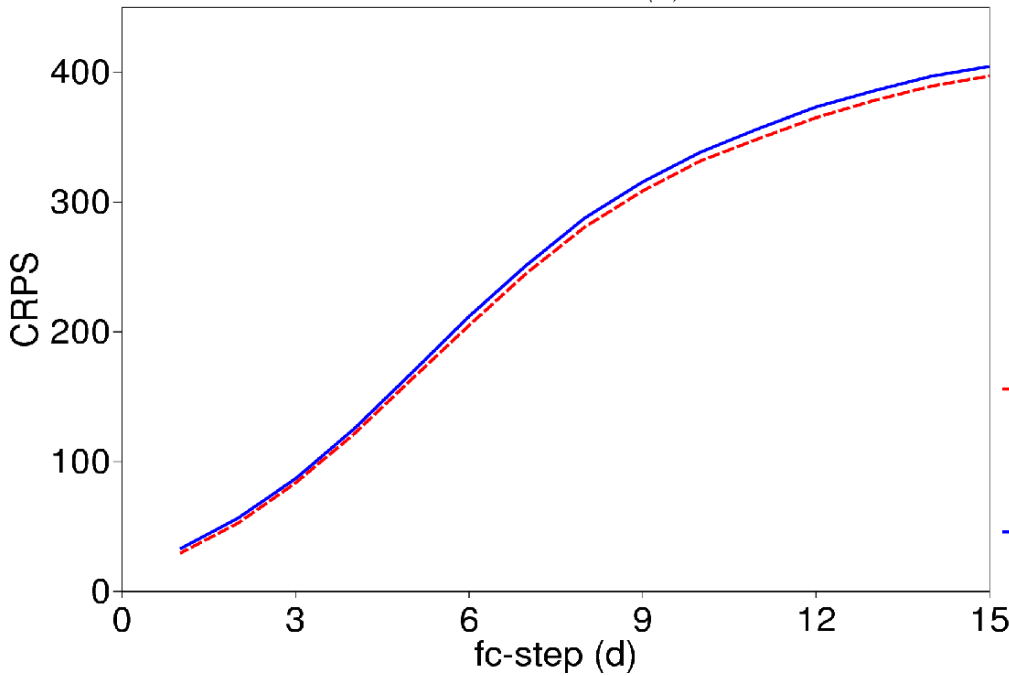
Nov 2013: ENS coupling d0, L62>L91, new physics+SKEB

Results based on 61 cases (JFM12, JJA12); 38r2 analyses and EDA perturbations.



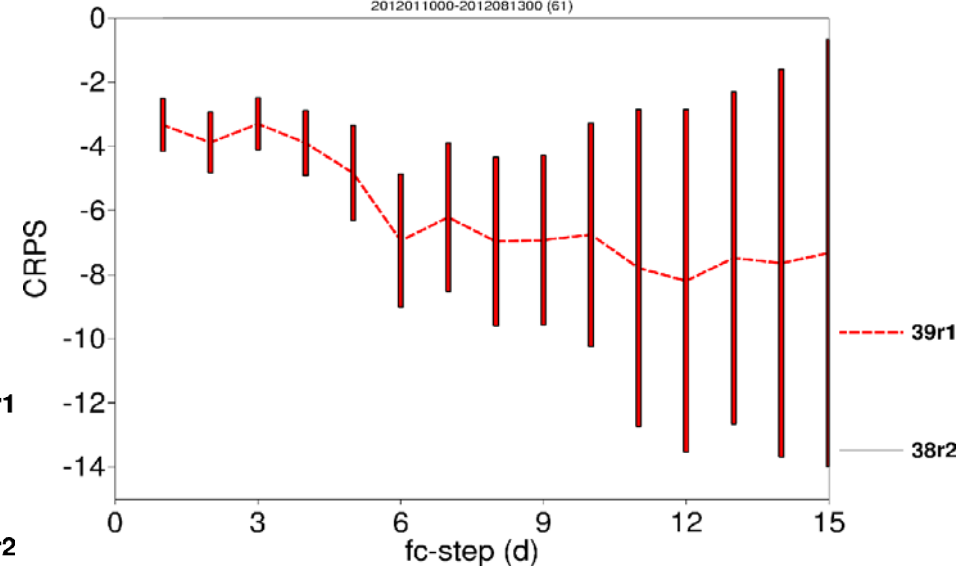
z500hPa, Northern Extra-tropics

ContinuousRankedProbabilityScore
2012011000-2012081300 (61)



z500hPa, Northern Extra-tropics

ContinuousRankedProbabilityScore [sign p=0.0500]
2012011000-2012081300 (61)



(From M Leutbecher)



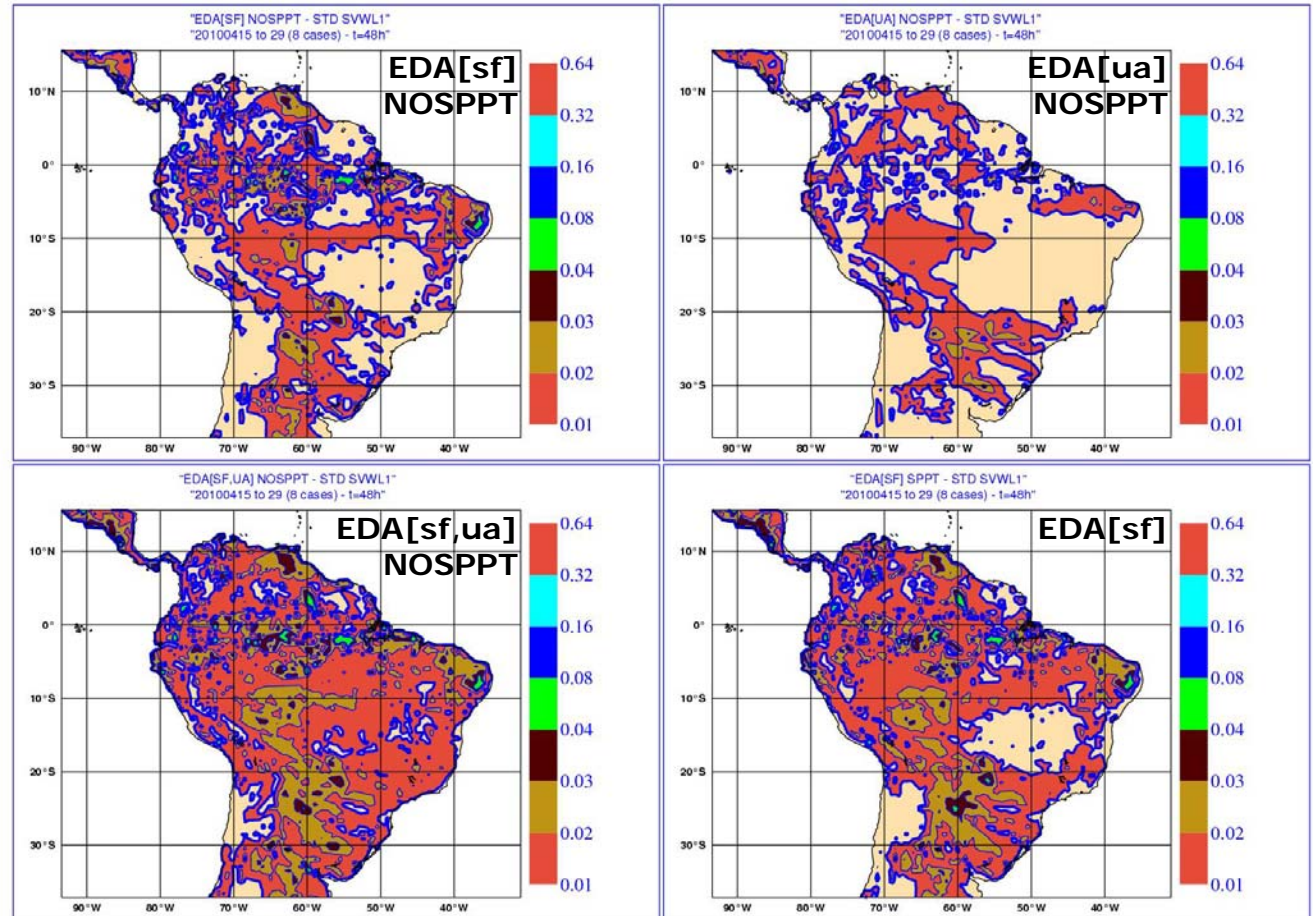
Nov 2013: EDA-based land-surface pert. in ENS ICs

Initial perturbations improved by coupling more the ensemble of analyses and forecasts.

Nov 2013: EDA-based surface initial perturbations introduced in ENS.

Preliminary results indicate increased reliability in the short forecast range, due to small spread improvements.

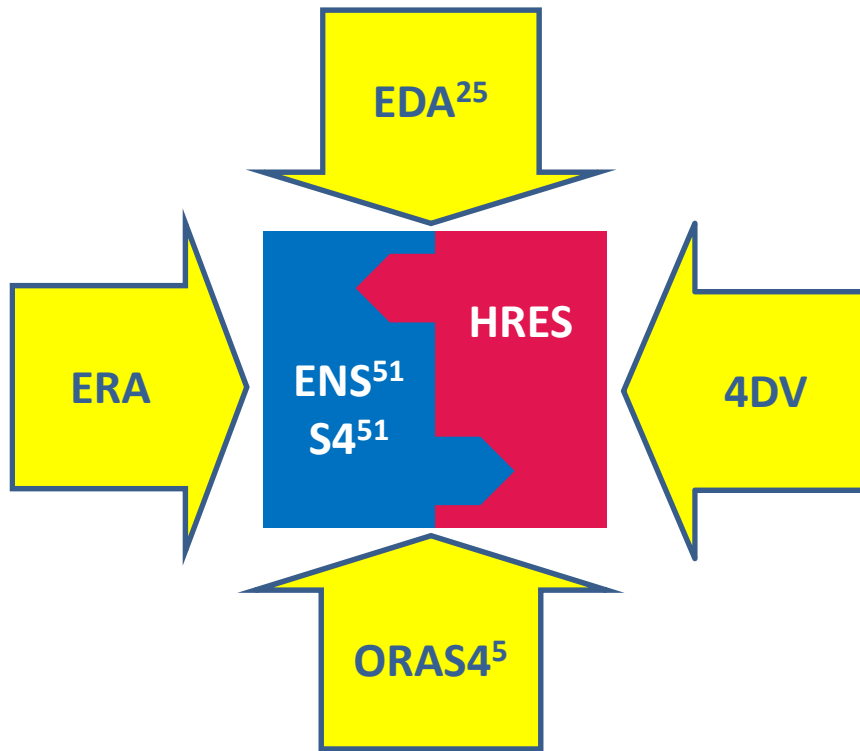
SWVL1 – std(t=48h)





The future: moving towards a more integrated approach

Today



PDF(0) << 4DV+EDA+ORAS4
 PDF(0) << ERA+ORAS4 (past)
 PDF(T) << HRES+ENS/S4

The future



PDF(0) << coupled analysis and re-analysis (past) stream
 PDF(T) << medium/long range stream