



Ensemble Prediction Systems at ECMWF

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European Centre for Medium-Range Weather Forecasts

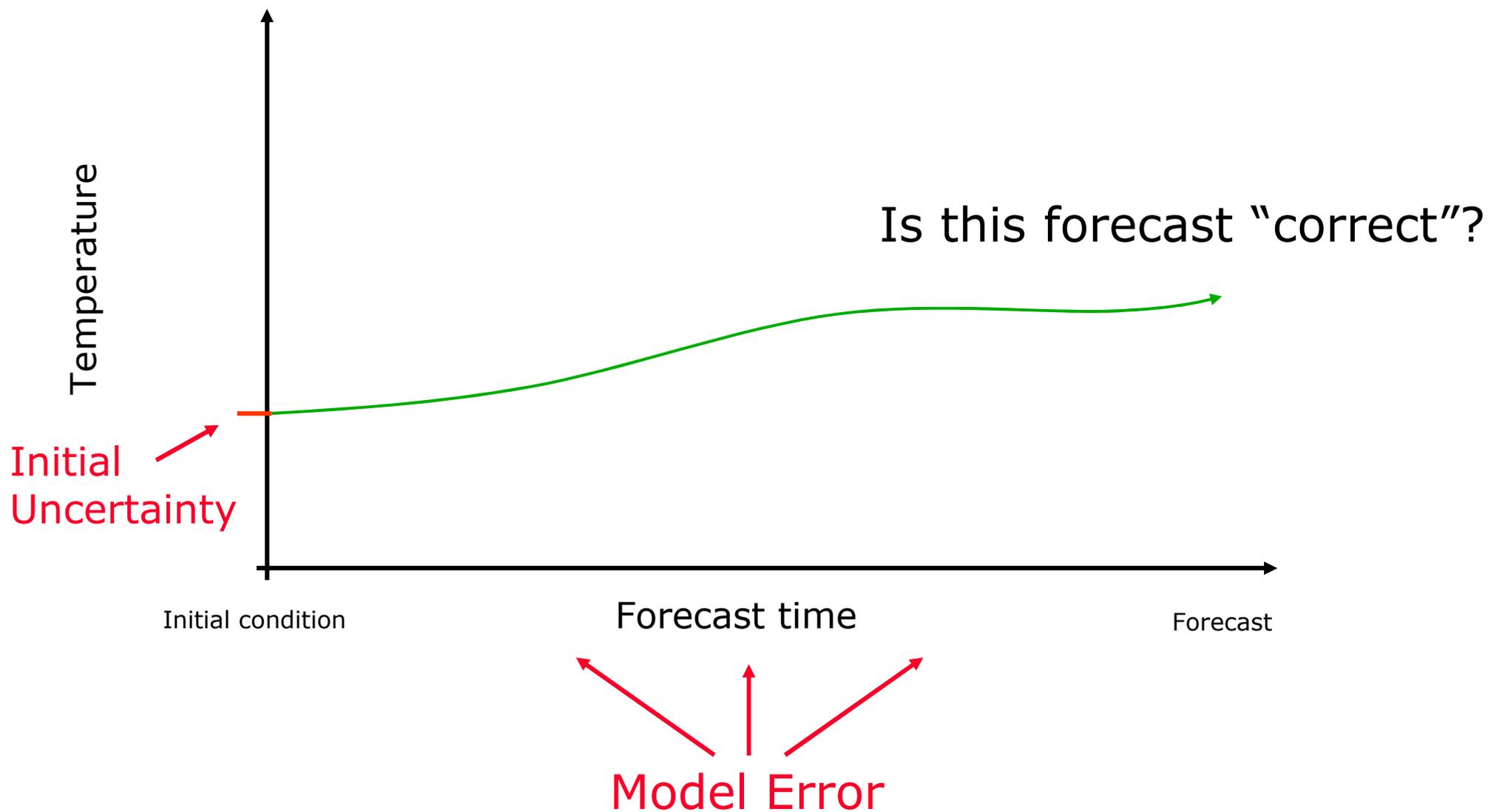


Questions

- **What is an Ensemble Prediction System (EPS)?**
 - multiple forecasts from slightly different initial conditions
 - enables probabilistic forecasts
- **Why do we need an EPS and probabilistic forecasts?**
 - to account for uncertainties in initial conditions and model error
 - to support user specific decision-making processes
- **Which systems exist at ECMWF?**
 - medium-range: up to 15 days
 - monthly: up to 4 weeks
 - seasonal: up to 6 months

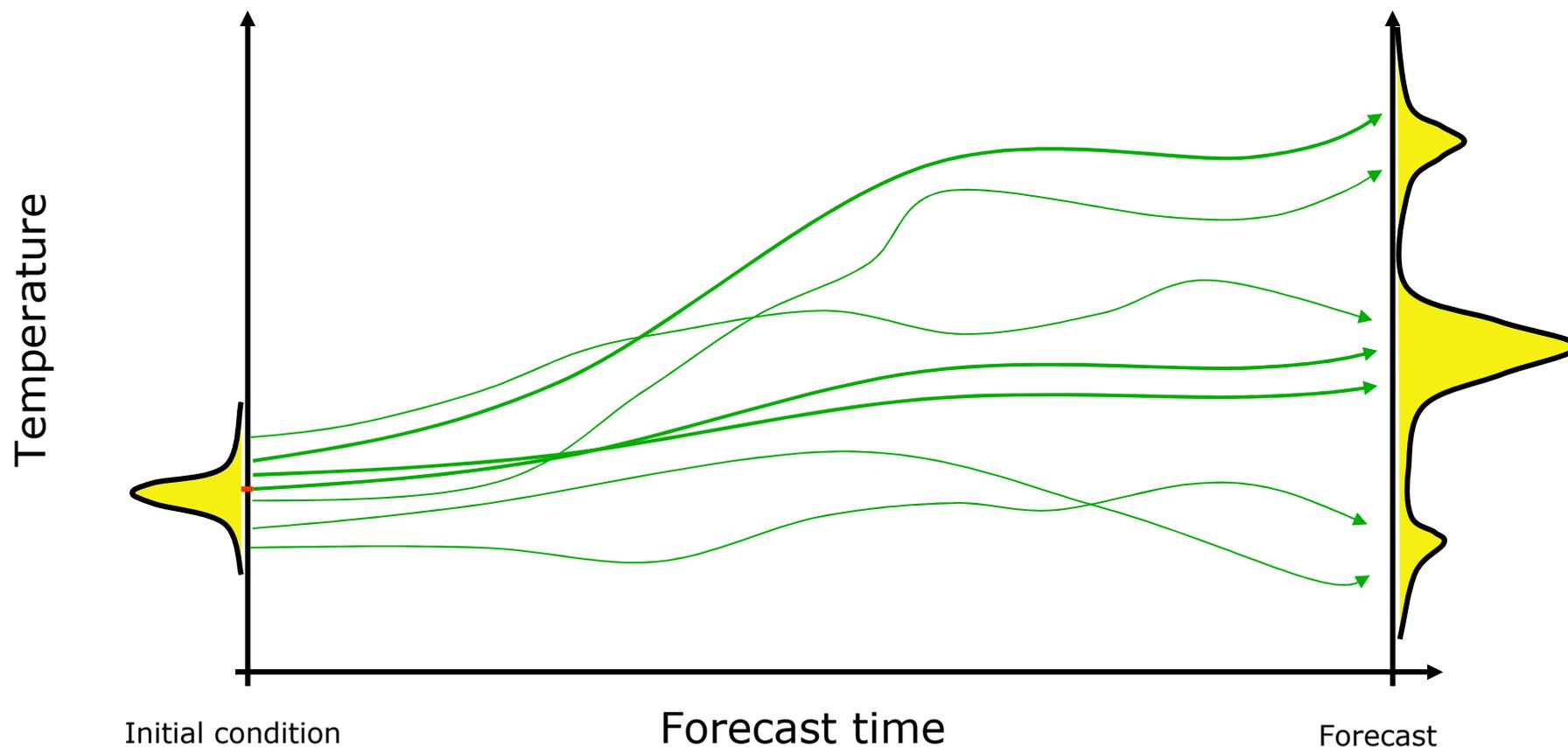


Deterministic Forecasting





Ensemble Forecasting

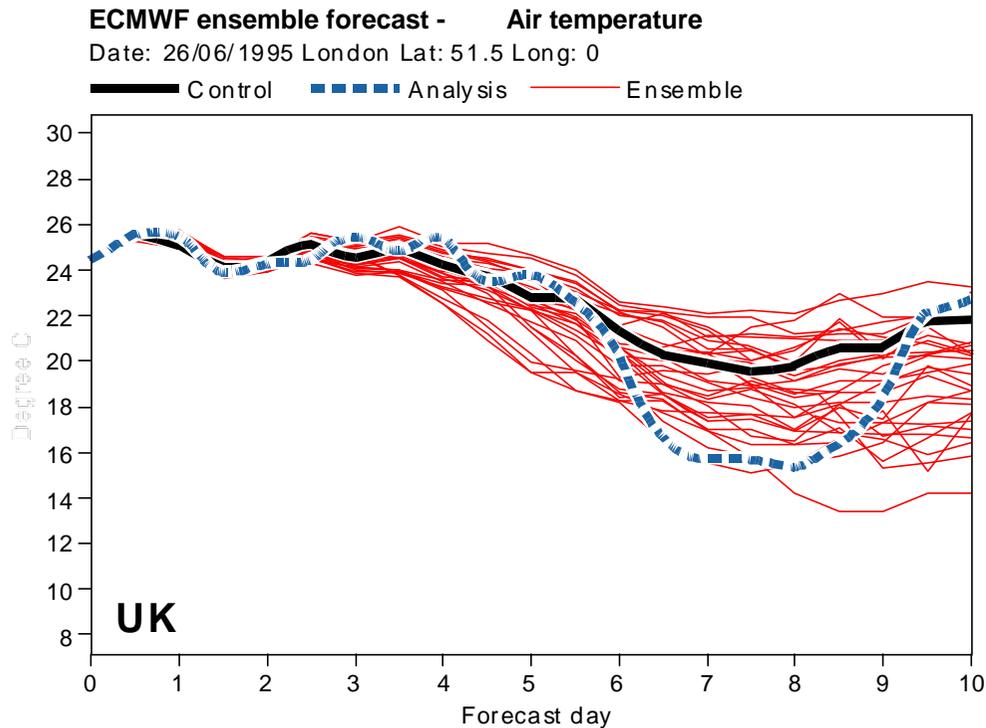


Complete description of weather prediction in terms of a Probability Density Function (PDF)

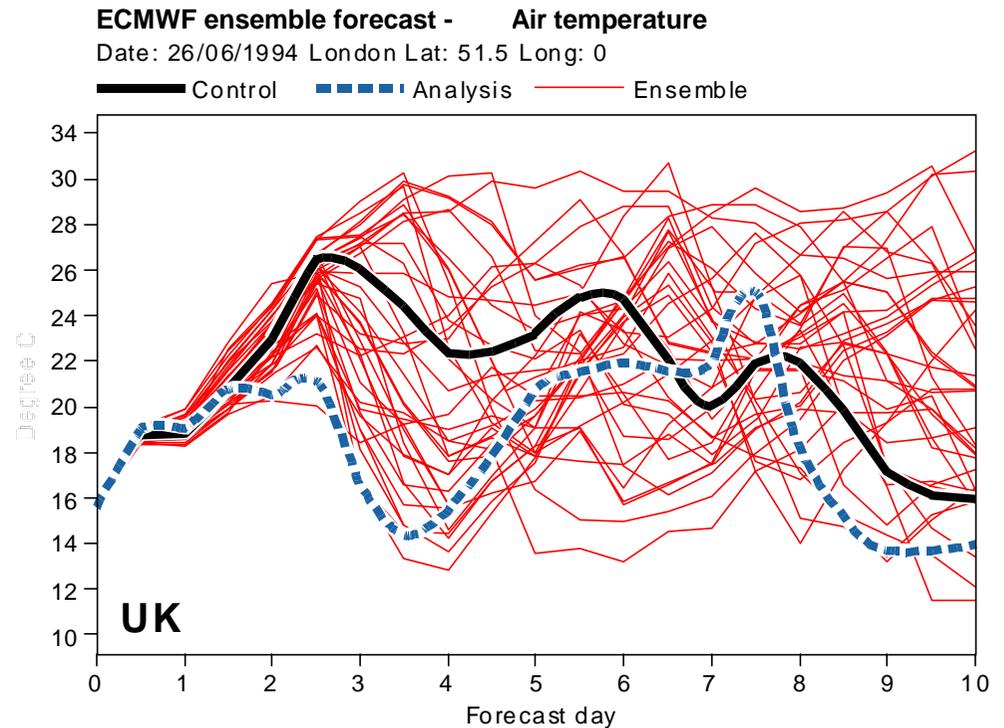


Flow dependence of forecast errors

26th June 1995



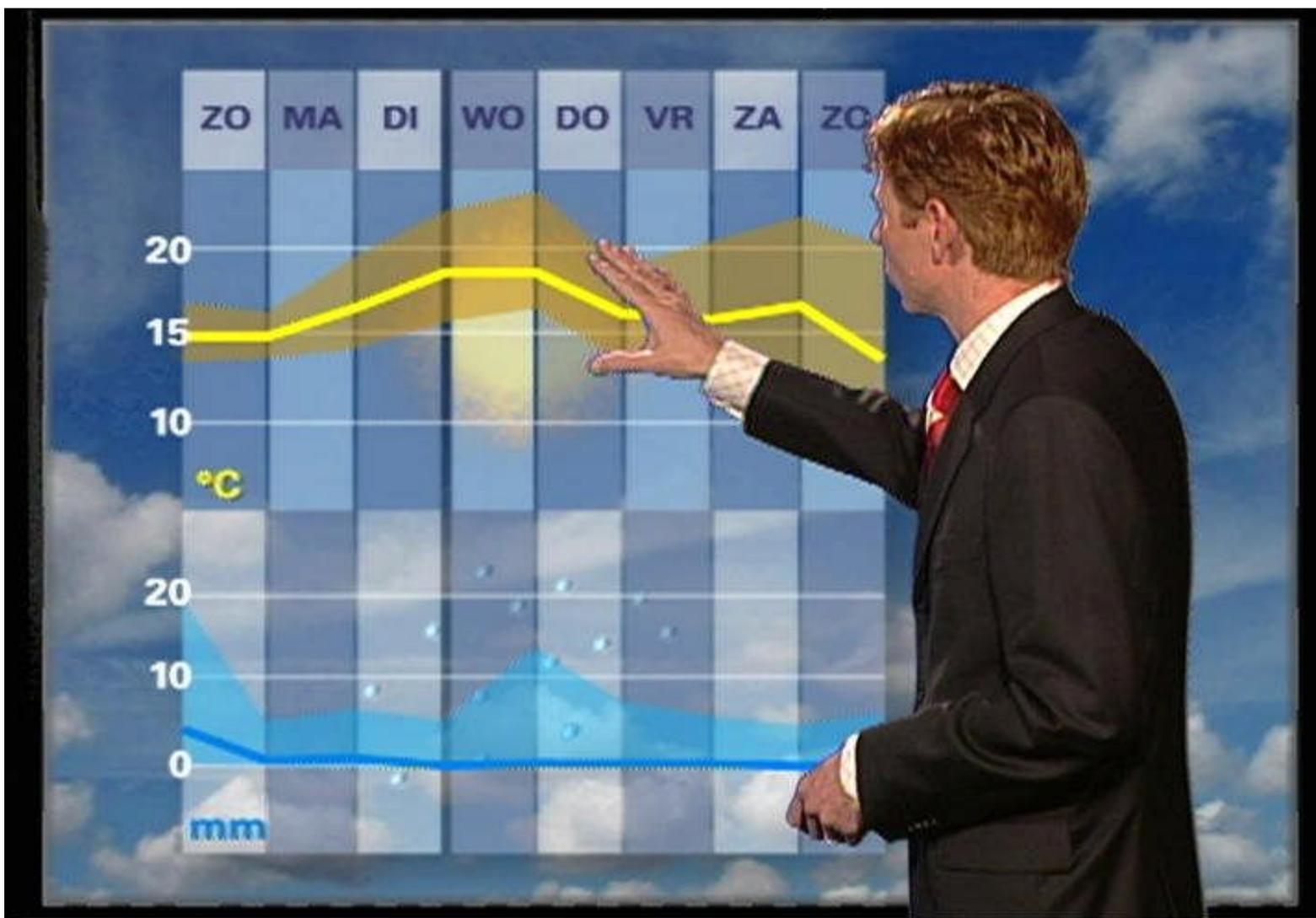
26th June 1994



If the forecasts are coherent (small spread) the atmosphere is in a more predictable state than if the forecasts diverge (large spread)



EPS appearing on Dutch TV



Courtesy of Robert Mureau, KNMI



EPS appearing on German TV

Der 15-Tage-Trend

➤ Video-Link: *Der 15-Tage-Trend, erklärt im Wetter-Beitrag der "Tagesthemen"*

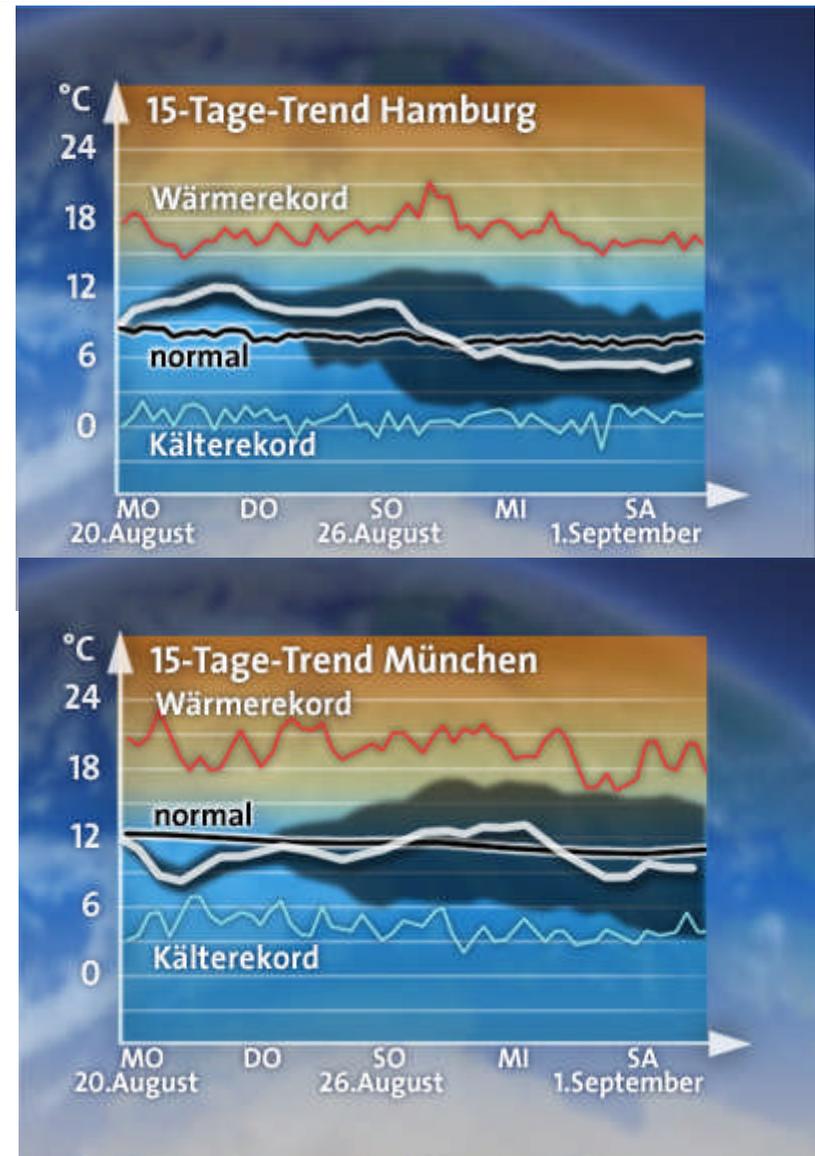
Neu und exklusiv im Tagesthemen-Wetter gibt es nun den 15-Tage-Trend für die Temperatur in 1500 m Meershöhe (Graphiken meistens für Hamburg und München). Das Wetter-Computermodell wird 50 Mal leicht modifiziert. Die Bandbreite der Ergebnisse wird durch den dunkel schattierten Bereich gekennzeichnet, der Mittelwert aller Lösungen durch die helle ausgezogene Linie. Die gestrichelte, mehr oder weniger horizontal verlaufende, markiert den langjährigen Mittelwert für die jeweilige Jahreszeit als Orientierung.

Je schmaler der dunkel schattierte Bereich um die mittlere Vorhersage bleibt, desto gesicherter ist die Vorhersage, das ist meistens für die ersten Vorhersagetage der Fall. Manchmal lassen sich aber wirklich auch Trends über die gesamten 15 Tage ablesen - wenn zum Beispiel der gesamte schattierte Bereich über der gestrichelten Klimadurchschnittslinie bleibt, ist ein Kälteeinbruch sehr unwahrscheinlich. Dies war zum Beispiel im gesamten Dezember 2006 der Fall.

Bestreicht allerdings der schattierte Bereich die ganze Graphik von extrem kalt zu extrem warm, dann ist wirklich nicht mal eine Trendvorhersage möglich - dann wissen Sie, dass wir nichts wissen und Sie am besten wie immer am folgenden Abend schauen, ob sich ein eindeutiger Trend abzeichnet.

15-Tage-Vorhersagen sind für jeden Ort der Welt und nicht nur für Temperaturen, sondern auch für Niederschlagsmengen und Windstärken verfügbar. Bei Fragen wenden Sie sich bitte an:

➤ wetter@DasErste.de





Goal of Ensemble Prediction

- Represent uncertainty of prediction
 - Ensemble Spread should
 - o capture “truth” (spread \sim RMS error)
 - o indicate range of uncertainty
- Move from deterministic to probabilistic forecast



Why Probabilities?

- Open air restaurant scenario:
 - open additional tables: £20 extra cost, £100 extra income (if $T > 24^{\circ}\text{C}$)
 - weather forecast: 30% probability for $T > 24^{\circ}\text{C}$
 - what would you do?
- Test the system for 100 days:
 - $30 \times T > 24^{\circ}\text{C} \rightarrow 30 \times (100 - 20) = 2400$
 - $70 \times T < 24^{\circ}\text{C} \rightarrow 70 \times (0 - 20) = -1400$
$$\begin{array}{r} 2400 \\ -1400 \\ \hline +1000 \\ \hline \hline \end{array}$$
- Employing extra waiter (spending £20) is beneficial when probability for $T > 24^{\circ}\text{C}$ is greater 20%
- The **higher/lower** the cost loss ratio, the **higher/lower** probabilities are needed in order to benefit from action on forecast



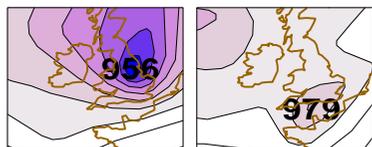
ECMWF's Ensemble Prediction System

- Account for **initial uncertainties** by running ensemble of forecasts from slightly different initial conditions
 - **singular vector** approach to sample perturbations with maximum amplification rate
- **Model uncertainties** are represented by **stochastic physics**
 - multiply model parameterization tendencies by “random numbers”
- EPS runs twice daily (00 and 12 UTC)
 - 1 control + 50 perturbed forecasts from (perturbed) analysis
 - resolution day1-10: T_L399L62 (50km), day9-15: T_L255L62 (80km)
- EPS products
 - stamp maps, clusters, probability maps, EFI, EPSgrams,...

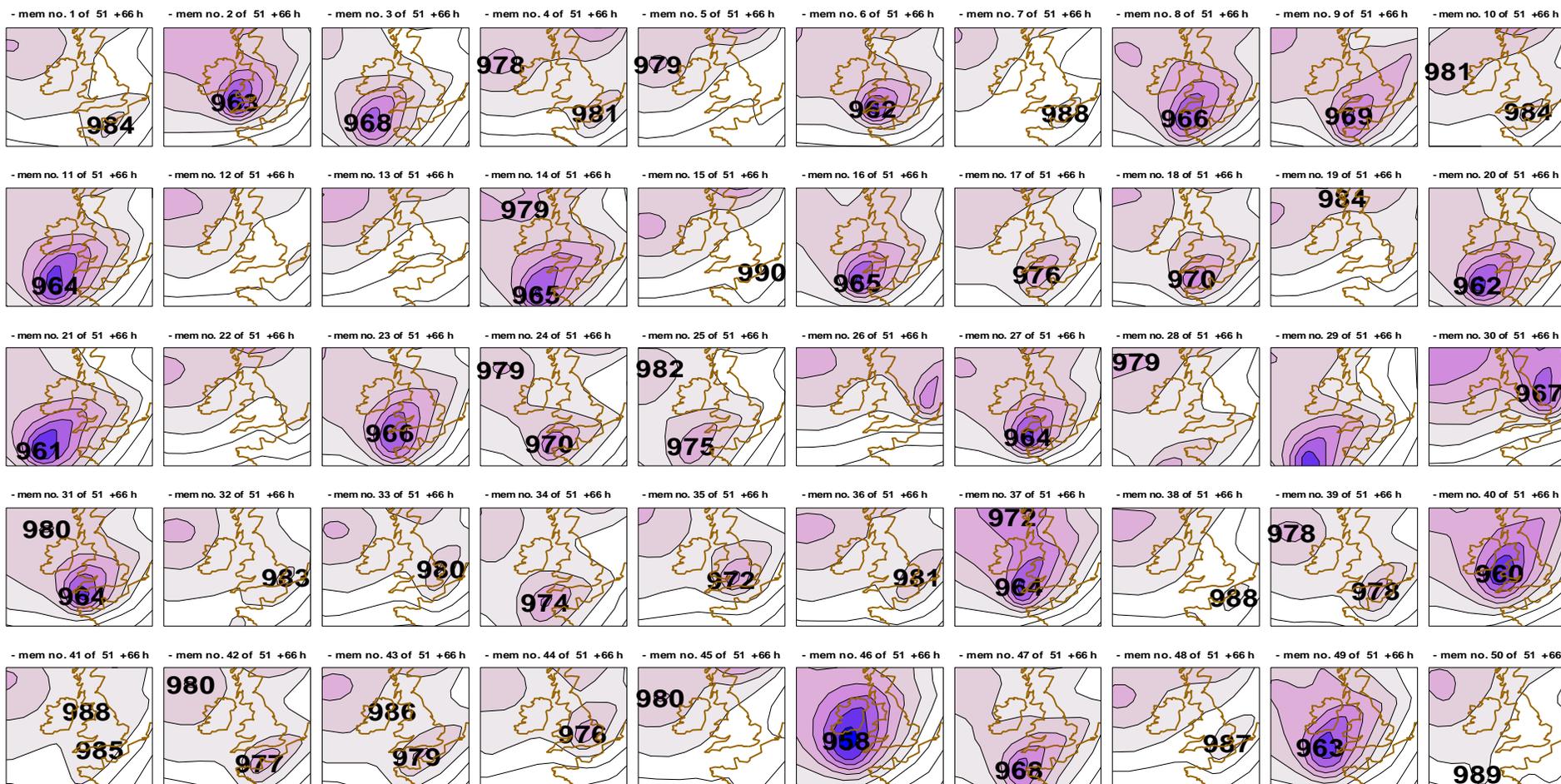


EPS products: stamp maps

AN 19871016, 06GMT EPS Cont FC +66 h



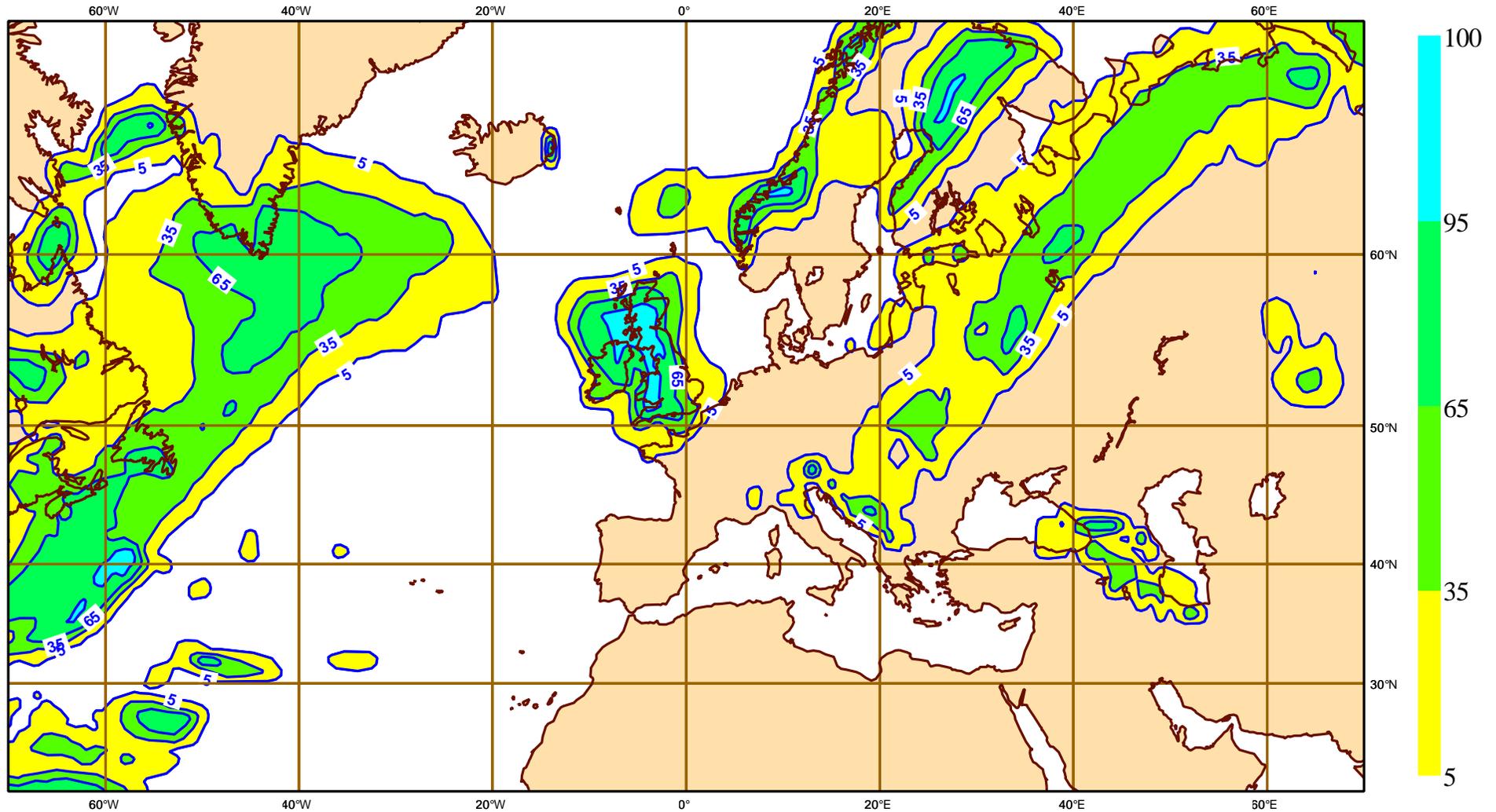
Mean sea level pressure (5hPa) VT: 16 Oct 1987, 6 UTC
TL399 ensemble, TL95 moist SVs with $t_{opt}=24h$





EPS products: probability maps

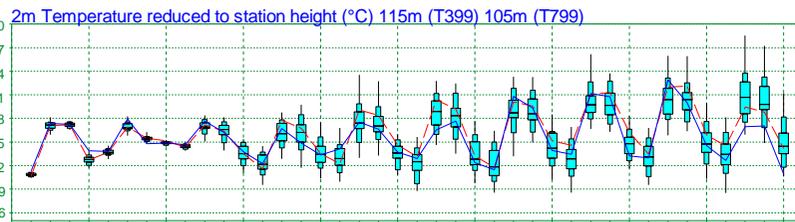
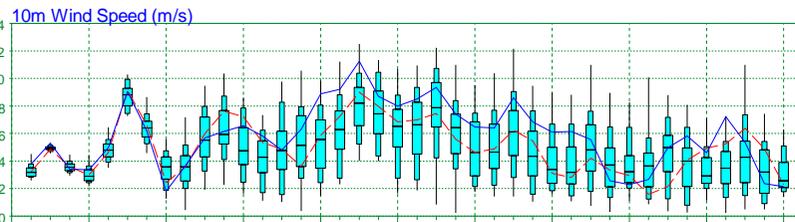
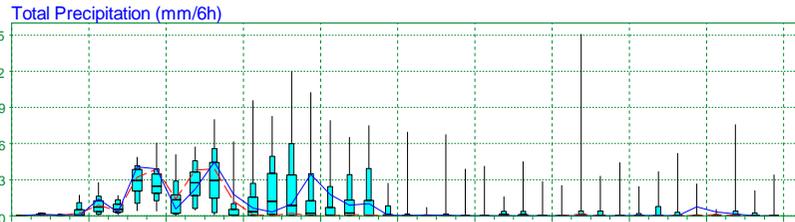
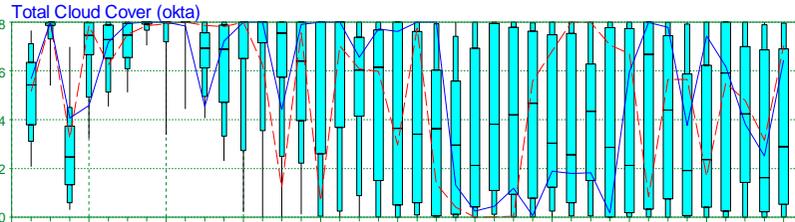
Thursday 16 August 2007 12UTC ©ECMWF Forecast probability t+036-060 VT: Saturday 18 August 2007 00UTC - Sunday 19 August 2007 00UTC
Surface: Total precipitation of at least 5 mm





EPS products: EPSgram

EPS Meteogram
Reading (48m) 51.46°N 1.33°W
Deterministic Forecast and EPS Distribution Friday 17 August 2007 00 UTC



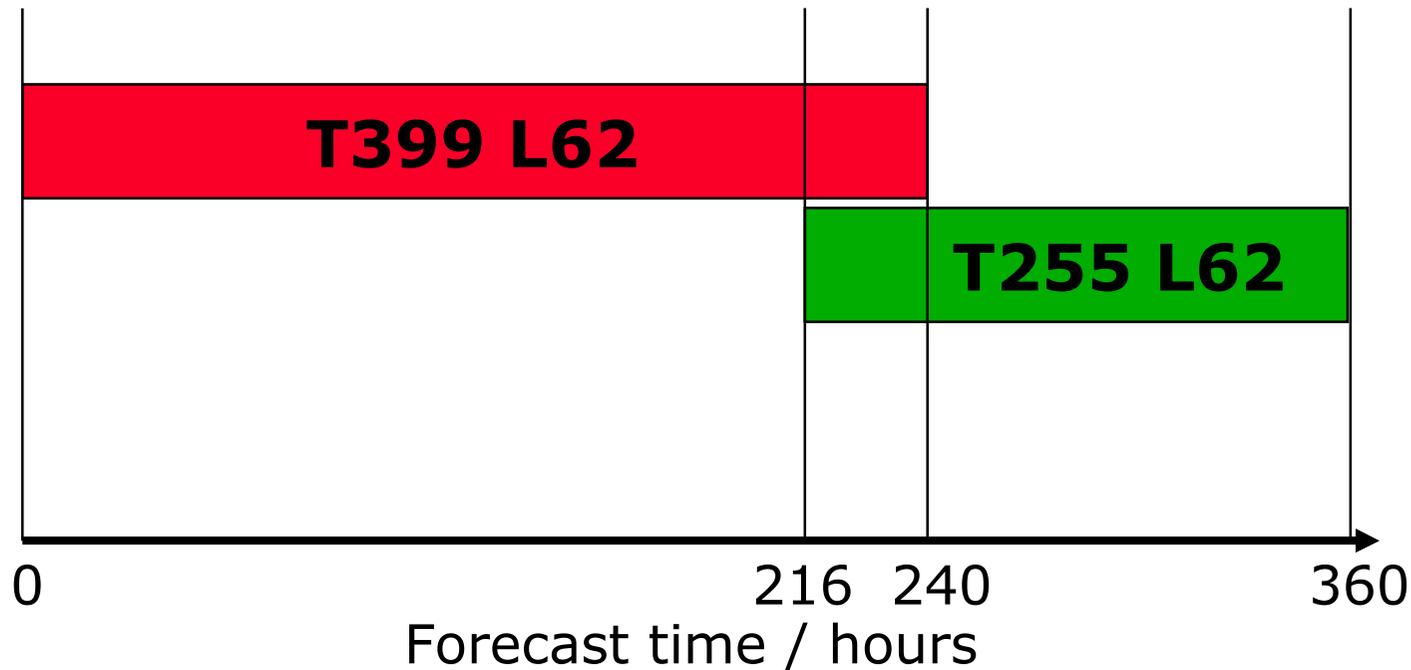
max
90%
75%
median
25%
10%
min

— T799 OPS — T399 CTRL



28/11/2006: VarEPS

- VarEPS concept
 - higher resolution at beginning of forecasts
 - lower resolution at longer lead times

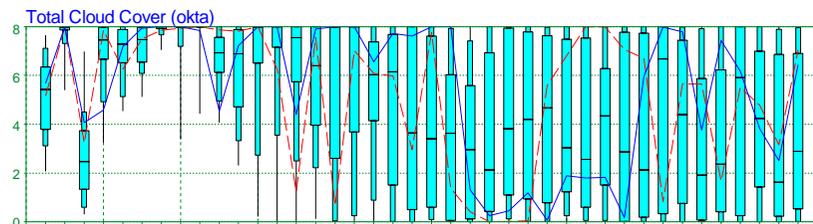


See also:
ECMWF Technical Memorandum No. 499

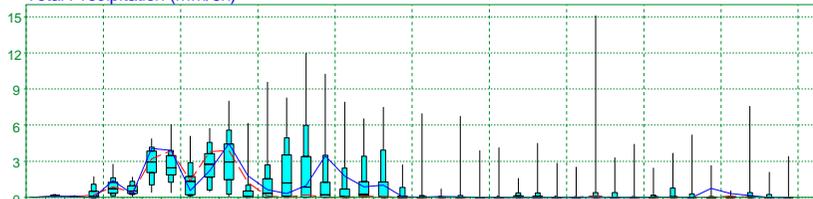


EPS products: EPSgram

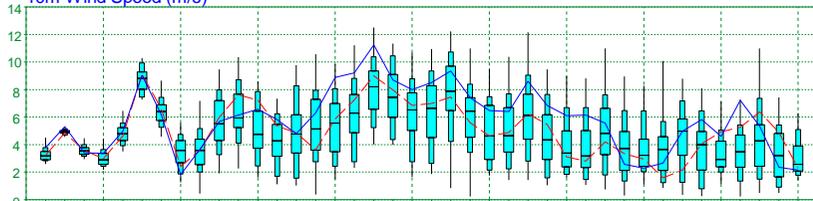
EPS Meteogram
Reading (48m) 51.46°N 1.33°W
Deterministic Forecast and EPS Distribution Friday 17 August 2007 00 UTC



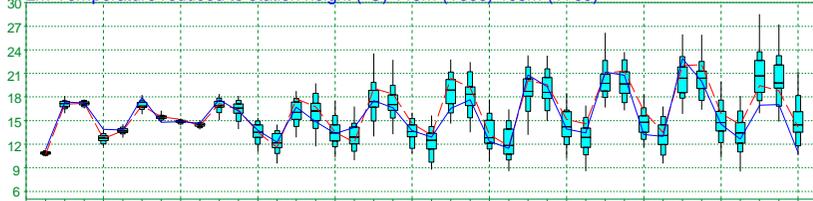
Total Precipitation (mm/6h)



10m Wind Speed (m/s)

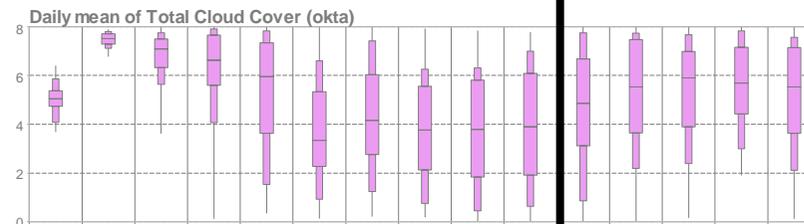


2m Temperature reduced to station height (°C) 115m (T399) 105m (T799)

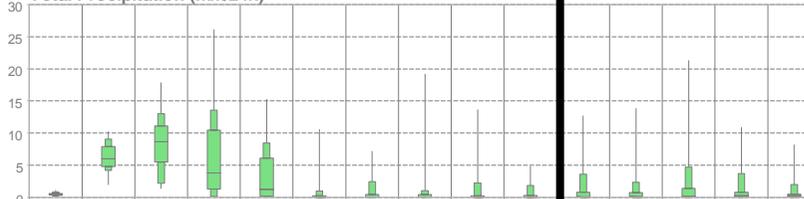


max 90% 75% median 25% 10% min
— T799 OPS — T399 CTRL

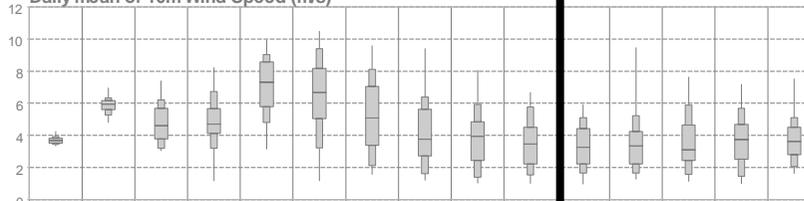
EPS Meteogram
Reading (48m) 51.58°N 1°W
Extended Range Forecast based on EPS Distribution Friday 17 August 2007 00 UTC



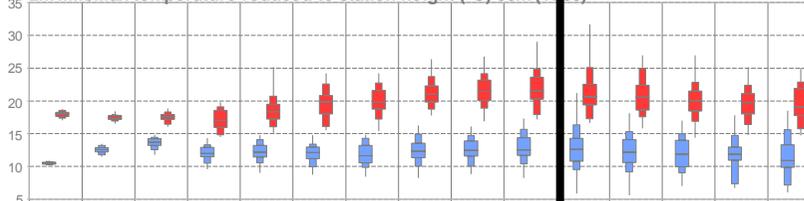
Total Precipitation (mm/24h)



Daily mean of 10m Wind Speed (m/s)



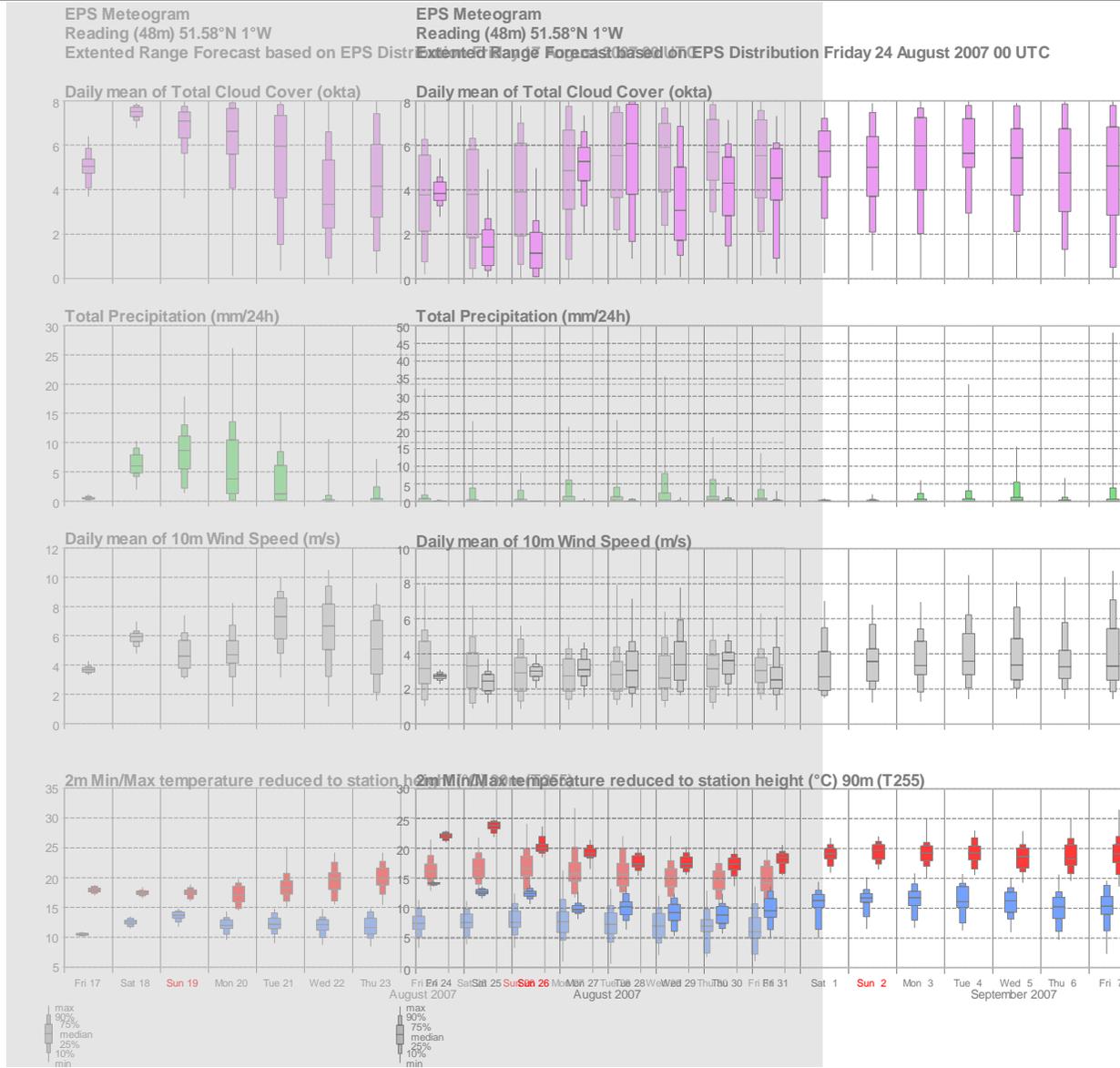
2m Min/Max temperature reduced to station height (°C) 90m (T255)



max 90% 75% median 25% 10% min



EPS products: EPSgram





The extended range EPS

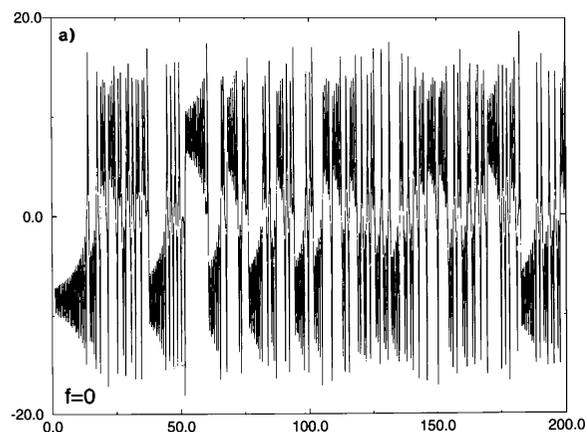
Can we predict further ahead than 10-15 days?



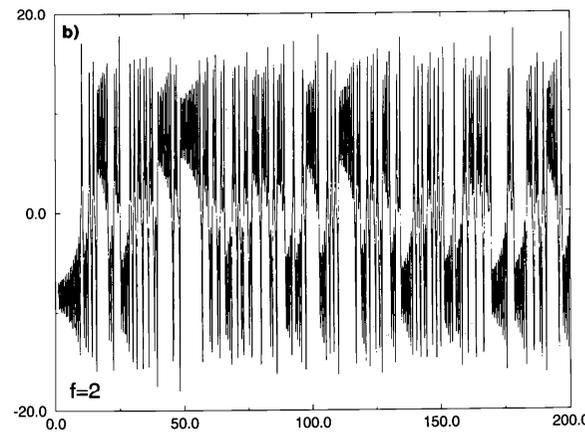
Additional external forcing

Add external stable forcing f to Lorenz (1963) equations

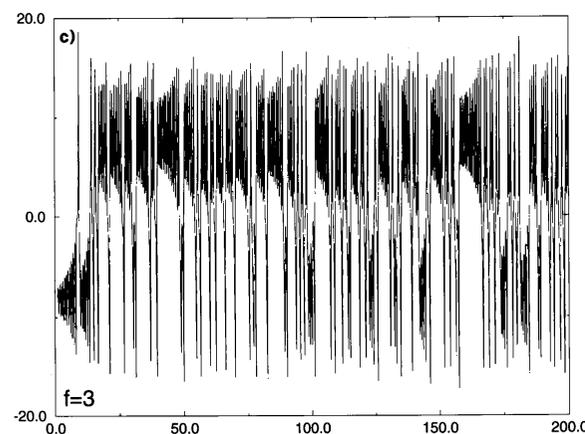
$f=0$



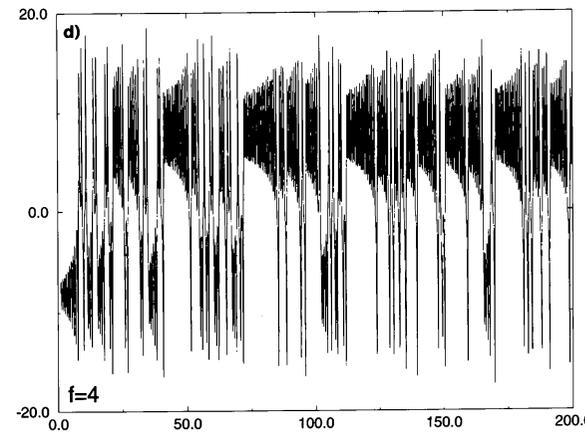
$f=2$



$f=3$



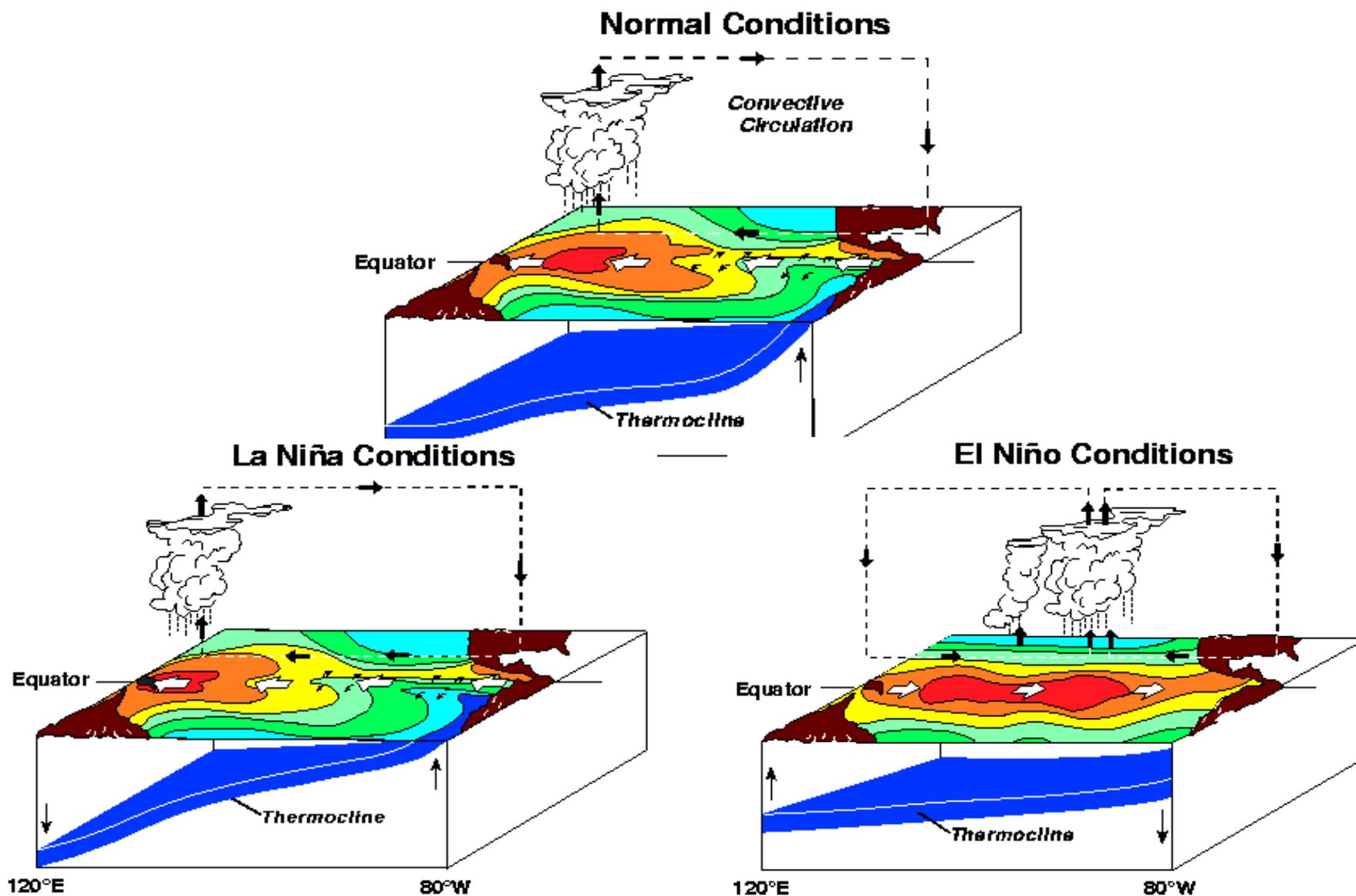
$f=4$



The influence of f onto the PDF of the state vector is predictable



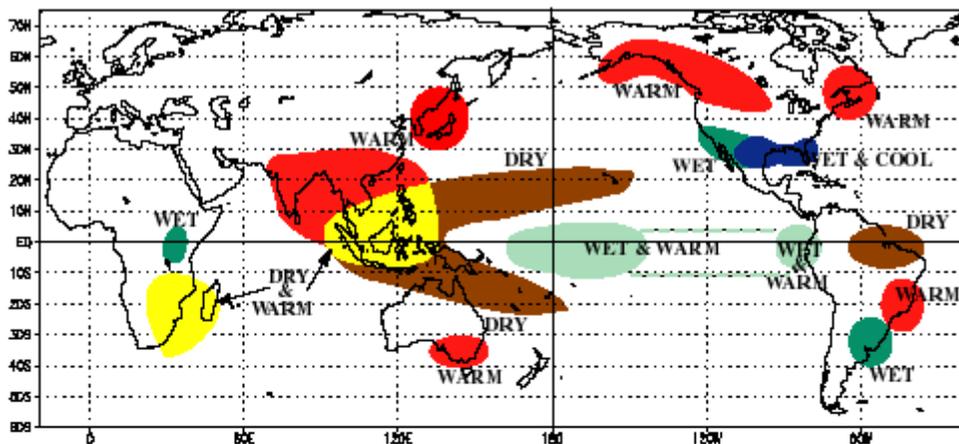
Ocean / atmosphere coupling in the tropical Pacific



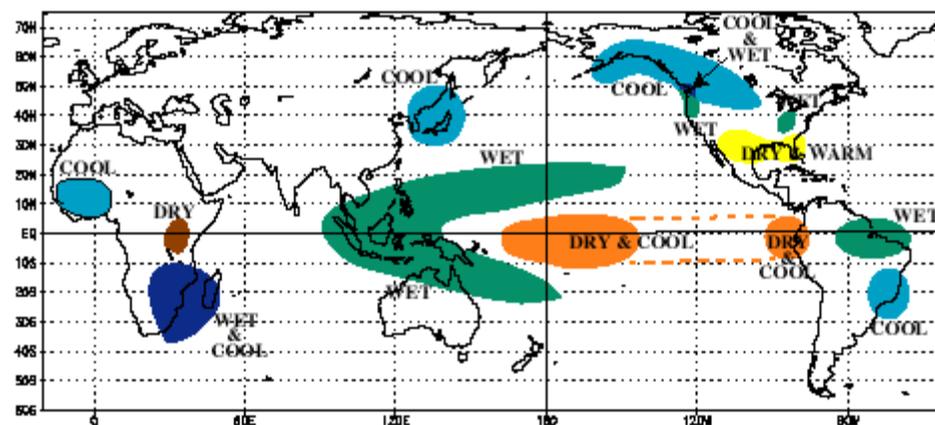


Global Impact of El Niño / La Niña

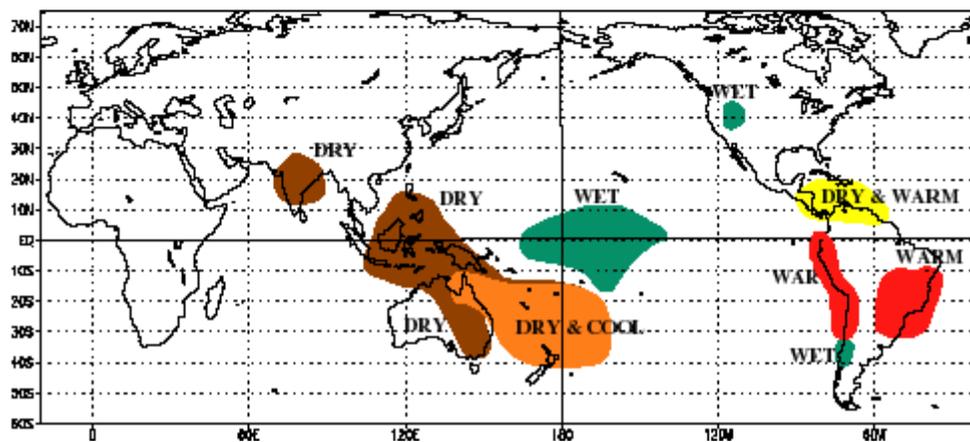
WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



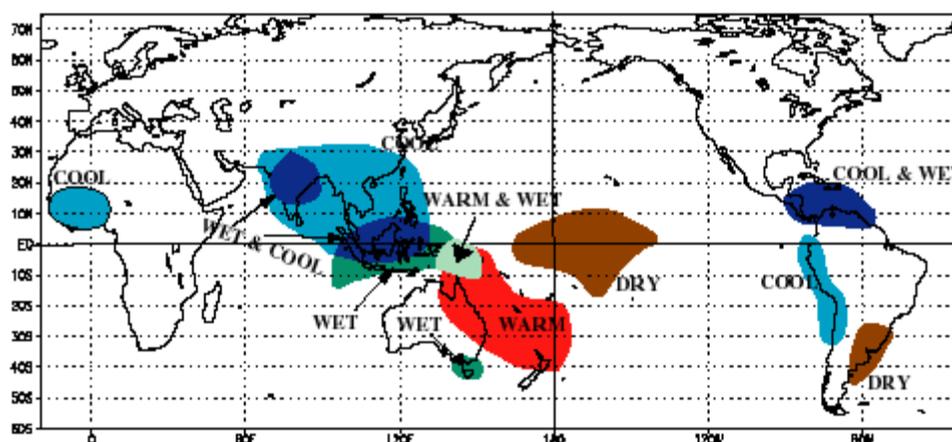
COLD EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



WARM EPISODE RELATIONSHIPS JUNE - AUGUST



COLD EPISODE RELATIONSHIPS JUNE - AUGUST



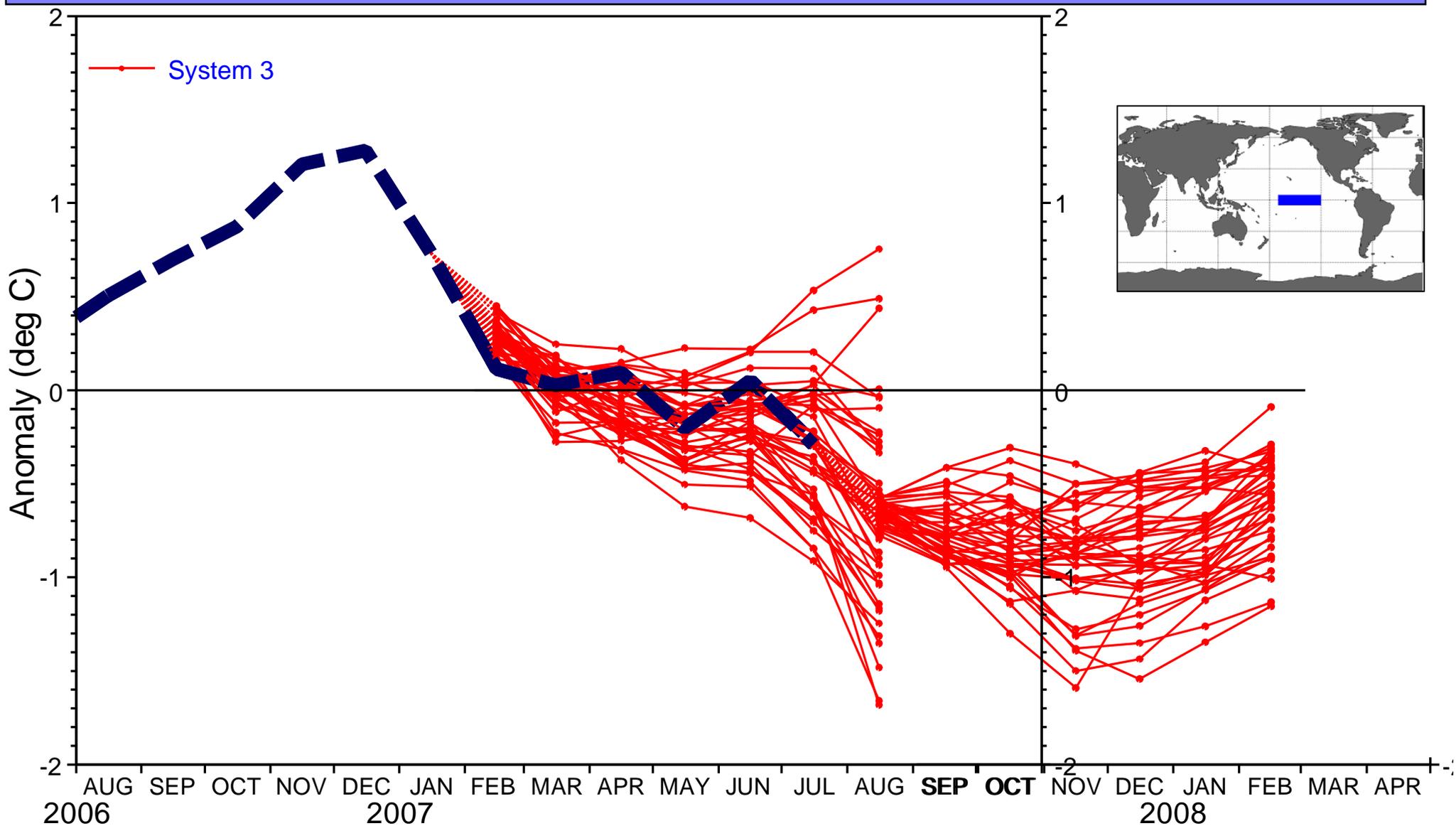


Seasonal Forecast System

- Experimental program started in 1995
- Success of the system led to operational implementation
- Coupled Atmosphere-Ocean model
- Production of seasonal forecast every month
 - Initialize ocean and atmosphere with operational analyses
 - Ensemble generation:
 - o 5 ocean analyses with different wind stress perturbations
 - o 40 SST perturbations
 - Run 41-member ensemble of 6-month integrations TL159L62
 - Consider predicted PDF vs. climatology



Nino-3.4 SST anomaly plumes

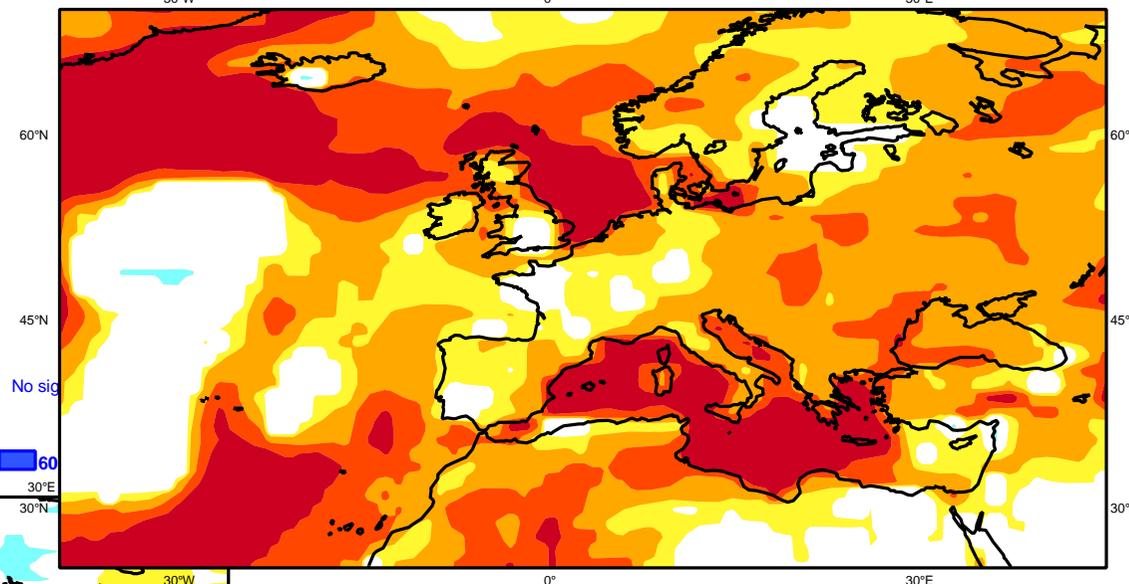
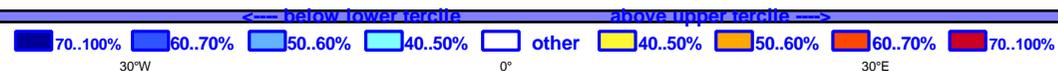




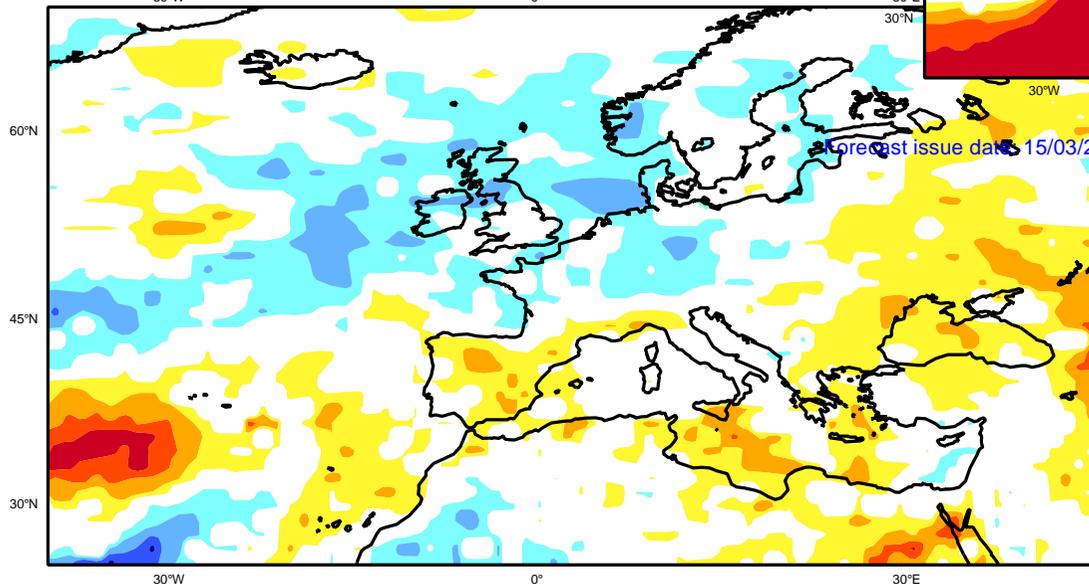
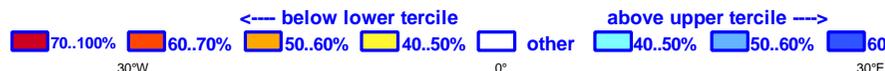
In Hindsight...

ECMWF Seasonal Forecast
Prob(most likely category of 2m temperature)
Forecast start reference is 01/03/07
Ensemble size = 41, climate size = 275

System 3
JJA 2007
No significance test applied



ECMWF Seasonal Forecast
Prob(most likely category of precipitation)
Forecast start reference is 01/03/07
Ensemble size = 41, climate size = 275



My "private" forecast from 10/04/2007:

- "normal to nice" summer in Europe
- avoid Mediterranean and/or Eastern Europe if you don't like warmer and drier than normal

Forecast issue date: 15/03/2007



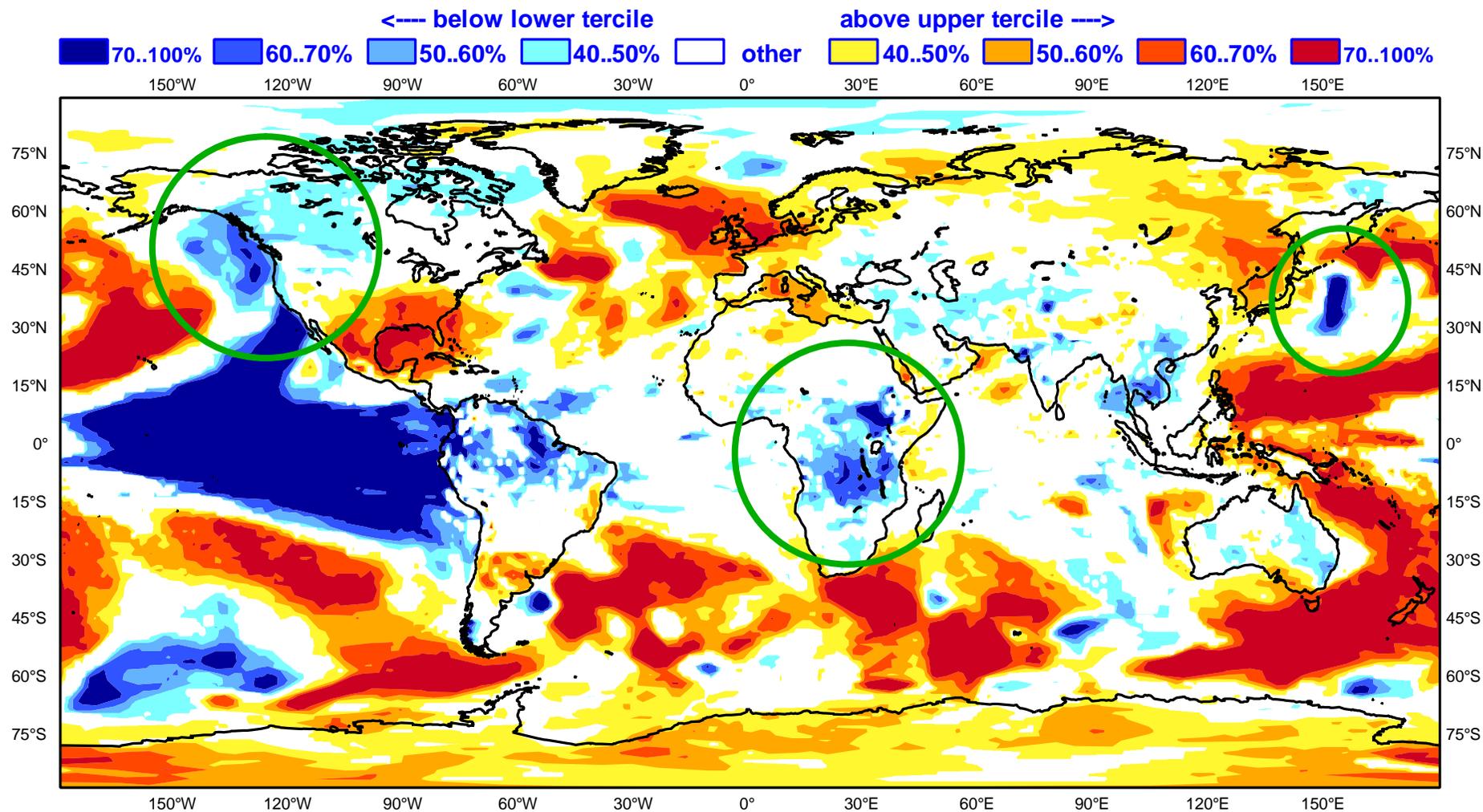


ECMWF Seasonal Forecast Prob(most likely category of 2m temperature)

System 3
DJF 2007/08

Forecast start reference is 01/08/07
Ensemble size = 41, climate size = 275

No significance test applied



Forecast issue date: 15/08/2007



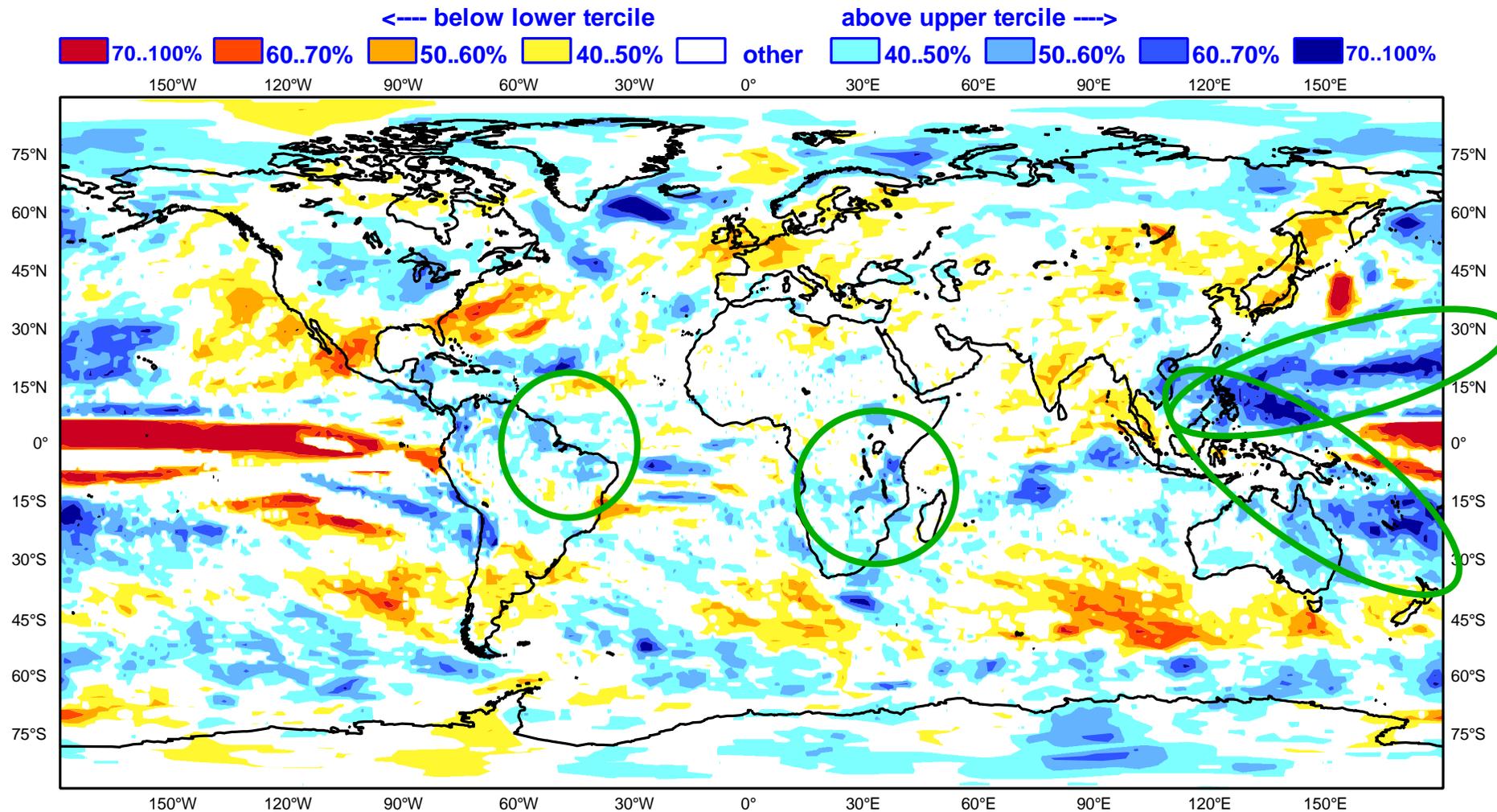


ECMWF Seasonal Forecast Prob(most likely category of precipitation)

System 3
DJF 2007/08

Forecast start reference is 01/08/07
Ensemble size = 41, climate size = 275

No significance test applied



Forecast issue date: 15/08/2007



3rd EUMETCAL workshop, 29-31 Aug 2007: *Ensemble Prediction at ECMWF*



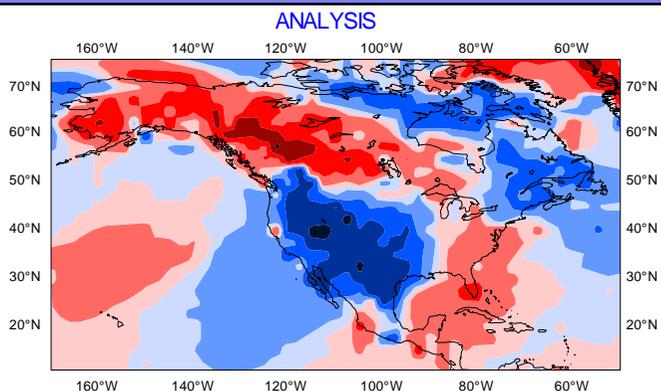


Monthly Forecast System

- Experimental program started in March 2002 to fill the gap between medium range (10 days) and seasonal scale
- Coupled Atmosphere-Ocean model
- Operational production of monthly forecast once a weeks
 - Initialize ocean and atmosphere with operational analyses
 - Ensemble generation:
 - o atmospheric perturbations as in medium-range EPS
 - o oceanic perturbations as in seasonal forecast system
 - Run 51-member ensemble of 32 day integrations TL159L40
 - Consider predicted PDF vs. climatology

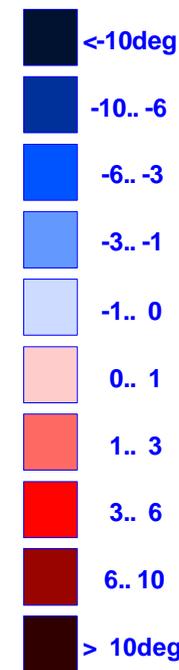
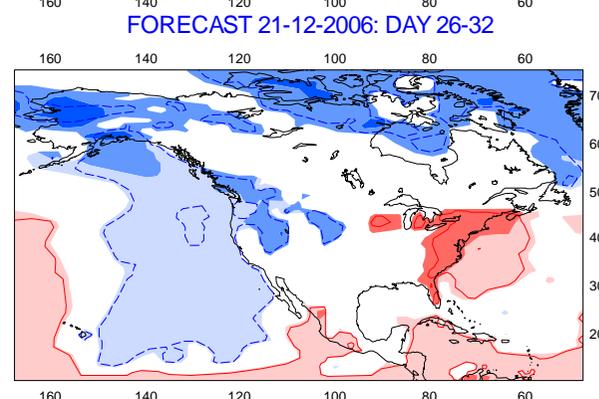
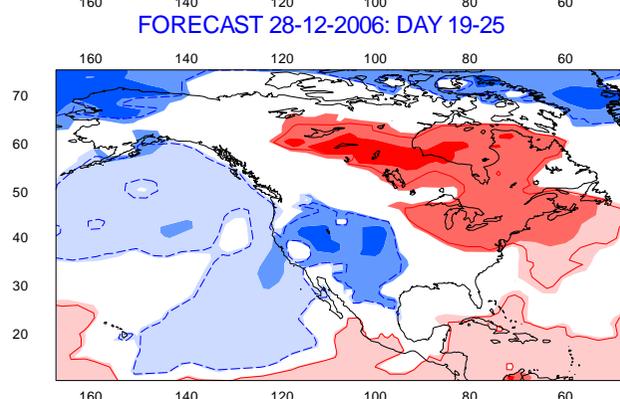
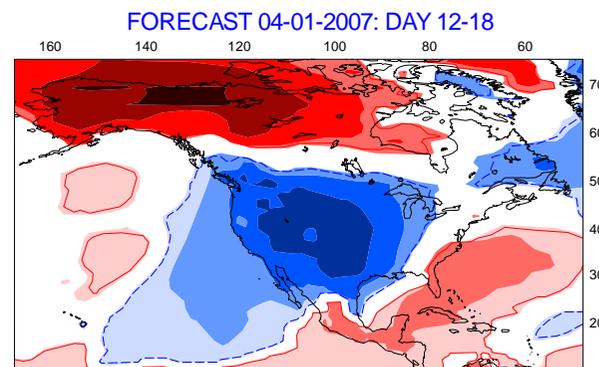
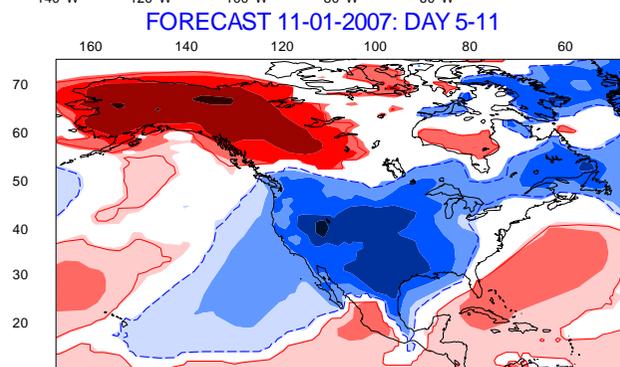


Example of Blocking: 15-22 Jan 2007



Analysis and ECMWF Monthly Forecasting System
2-meter Temperature anomaly
Verification period: 15-01-2007/TO/21-01-2007

ensemble size = 51 , climate size = 60
Shaded areas above 90% significance
Solid contour at 95% significance





ECMWF EPS systems

- Medium-range ensemble prediction system (15 days)
 - T_L399 62 levels (day0-10), T_L255 62 levels (day9-15)
 - control + 50 perturbed members
- Monthly forecast system (4 weeks)
 - T_L159 40 level (atm.), 1.4 ° x 0.3-1.4°, 29 vertical levels (ocean)
 - 51-member ensemble
- Seasonal forecast system (6 month)
 - T_L95 40 level (atm.), 1.4 ° x 0.3-1.4°, 29 vertical levels (ocean)
 - 40-member ensemble

Aim to establish seamless probabilistic ensemble system



Still Questions?

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 - multiple forecasts from slightly different initial conditions
 - enables probabilistic forecasts
- **Why do we need an EPS and probabilistic forecasts?**
 - to account for uncertainties in initial conditions and model error
 - to support user specific decision-making processes
- **Which systems exist at ECMWF?**
 - medium-range: up to 15 days
 - monthly: up to 4 weeks
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