Applications: forecaster perspective, training

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Met Office

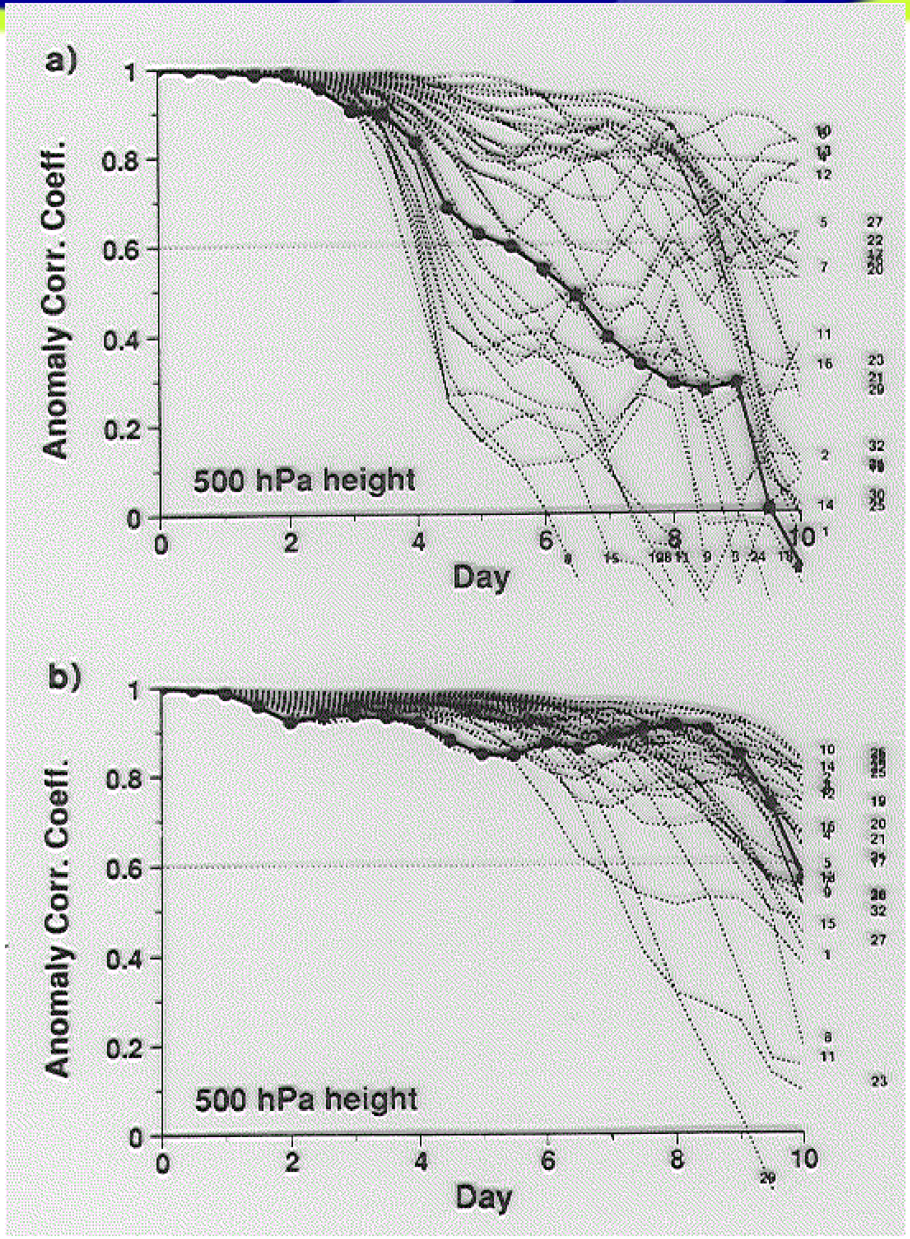
Also, Chair, WMO CBS Expert Team on Ensemble Prediction

Thanks to: Anders Persson, Pierre Eckert, many others.

Outline

- Use of ensembles in forecast operations
- Severe Weather/extreme events
- Presentation of Ensemble outputs and Probabilities
- Training
- What does TIGGE offer?

Information Potential

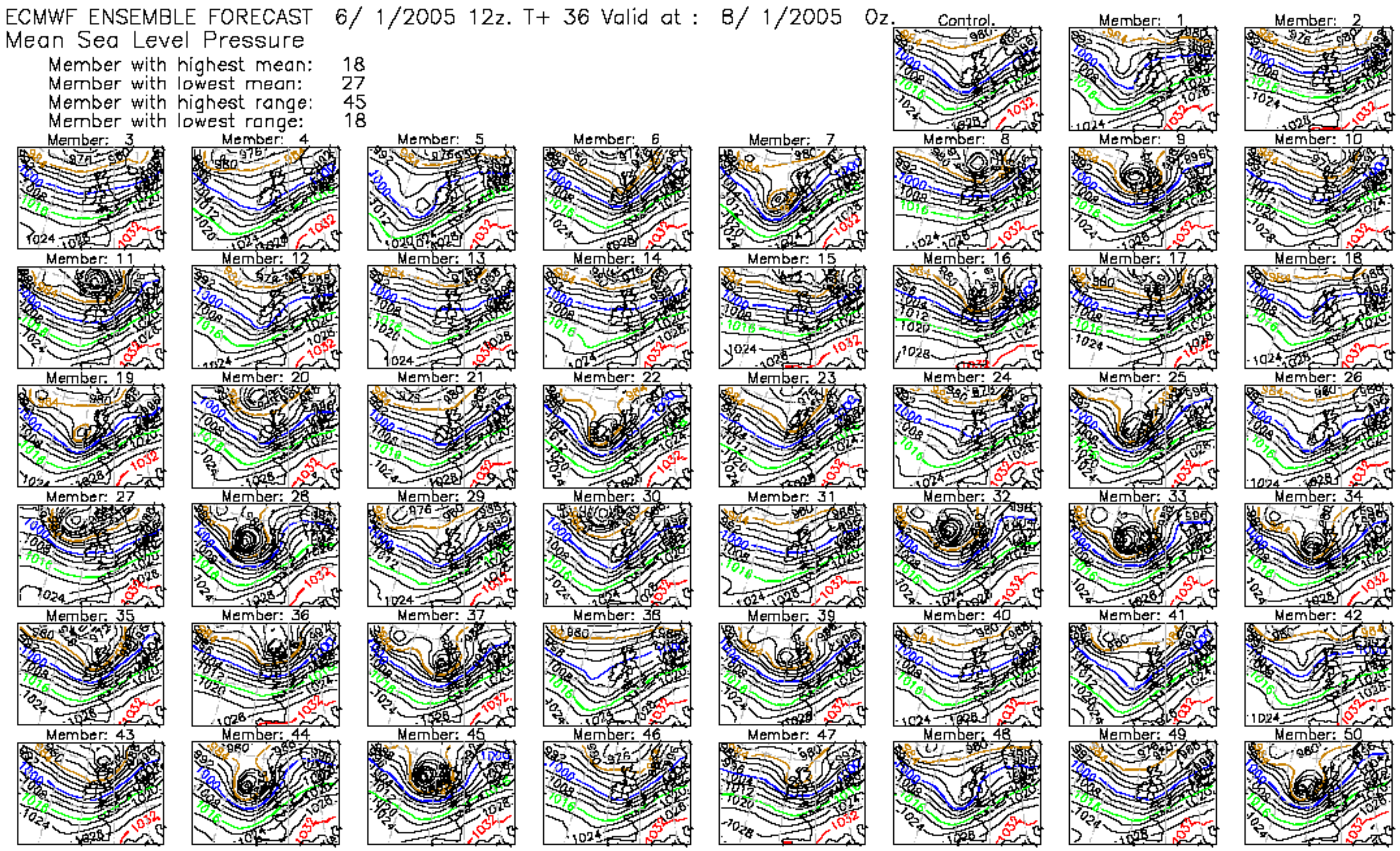


- ACC>0.6 indication of useful forecast
- Two graphs show variable predictability
- Many EPS members more skilful than control (solid line)
- Need to develop ways to extract information from best members, without knowing which they are
- Ensemble prediction systems (EPS) allow us to assess the *flow-dependent* predictability

Figure from Molteni *et al*, 1996

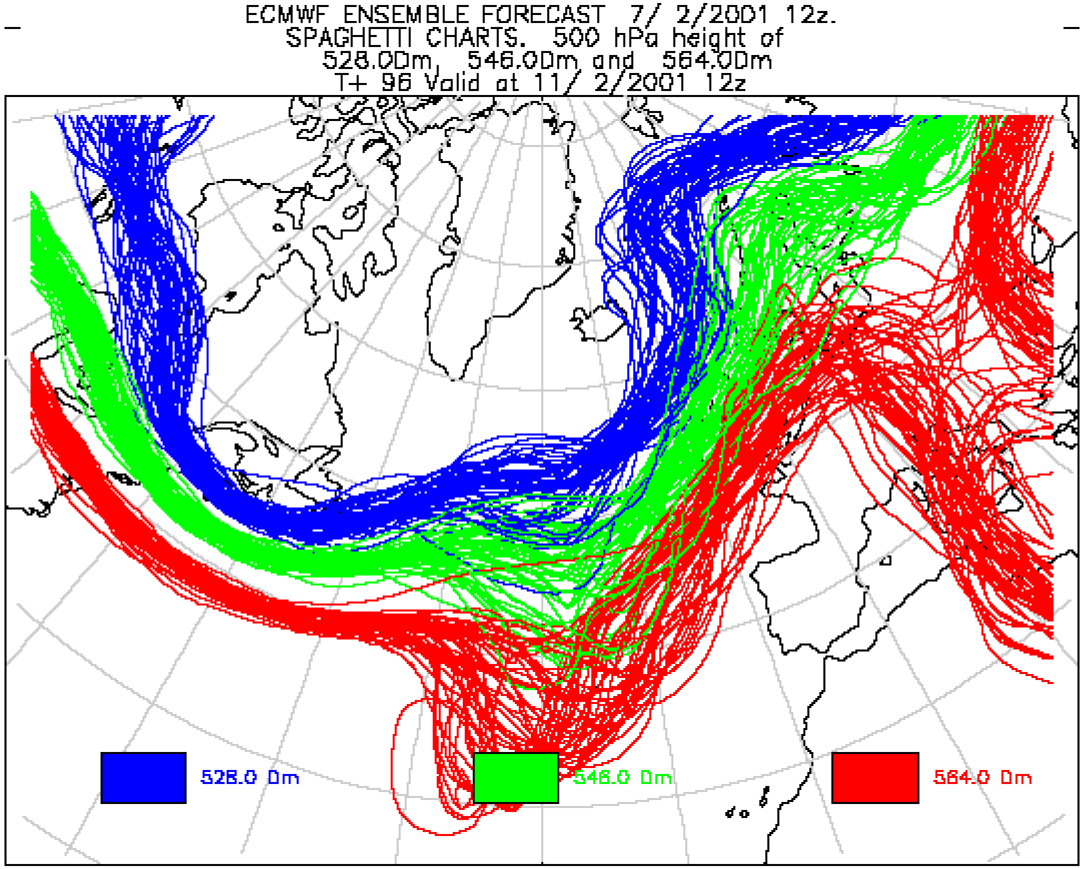
Use of Ensembles in Forecast Operations

Ensemble prediction System (EPS)



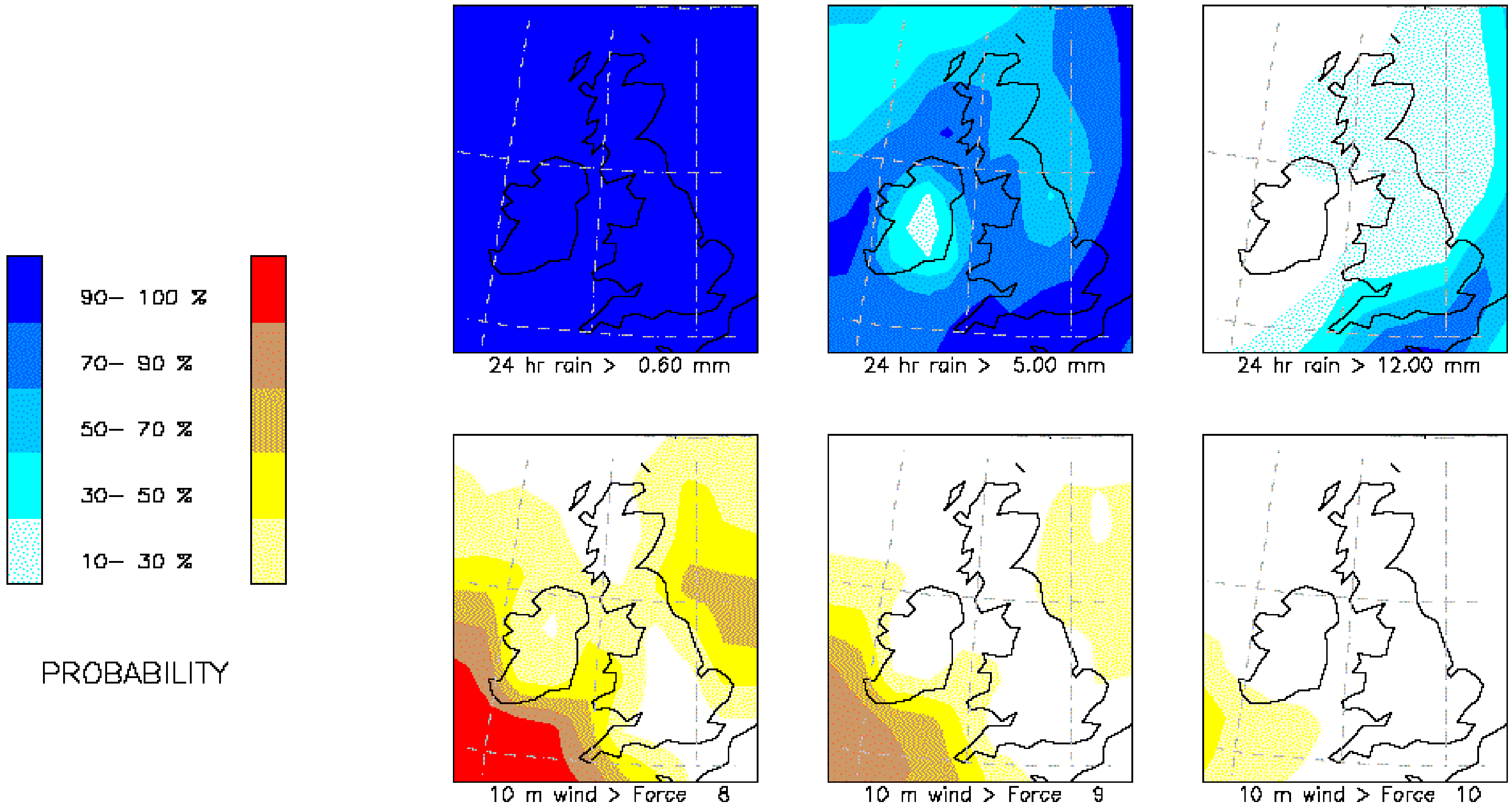
- Example from ECMWF 51-member medium-range ensemble
- TIGGE offers possibility of even more information

Spaghetti Chart



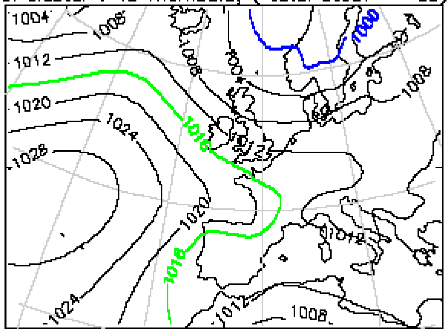
Contoured Grid-point Probabilities

- Rain and wind probabilities



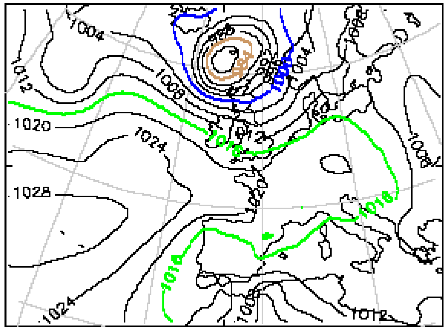
Tools for summarising information

Central cluster : 45 members, (total stdev= 69)



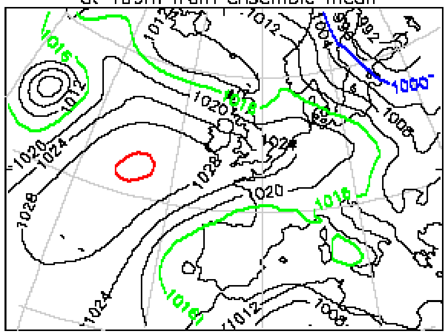
Mean Sea Level Pressure :
14/ 5/2000 12Z. T+144 Valid at : 20/ 5/2000 12z.

EPS Member 8 extreme of tube 1 (3 members)
at 111m from ensemble mean



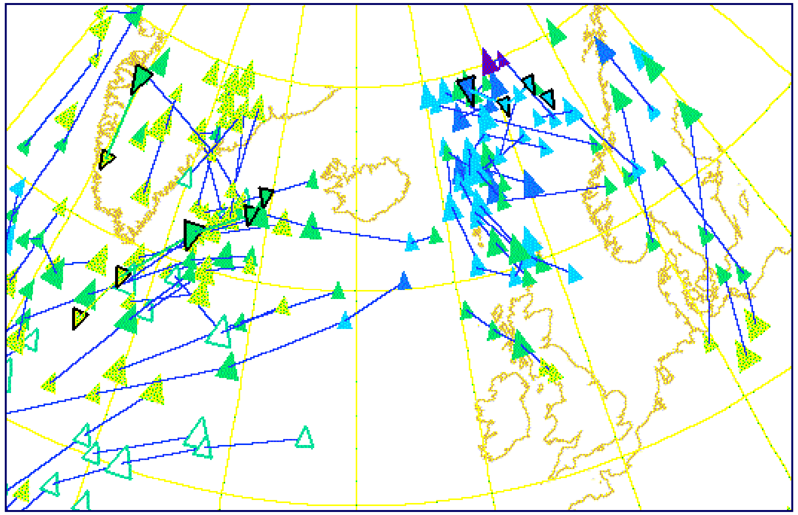
Mean Sea Level Pressure :
14/ 5/2000 12Z. T+144 Valid at : 20/ 5/2000 12z.

EPS Member 46 extreme of tube 2 (1 member),
at 109m from ensemble mean



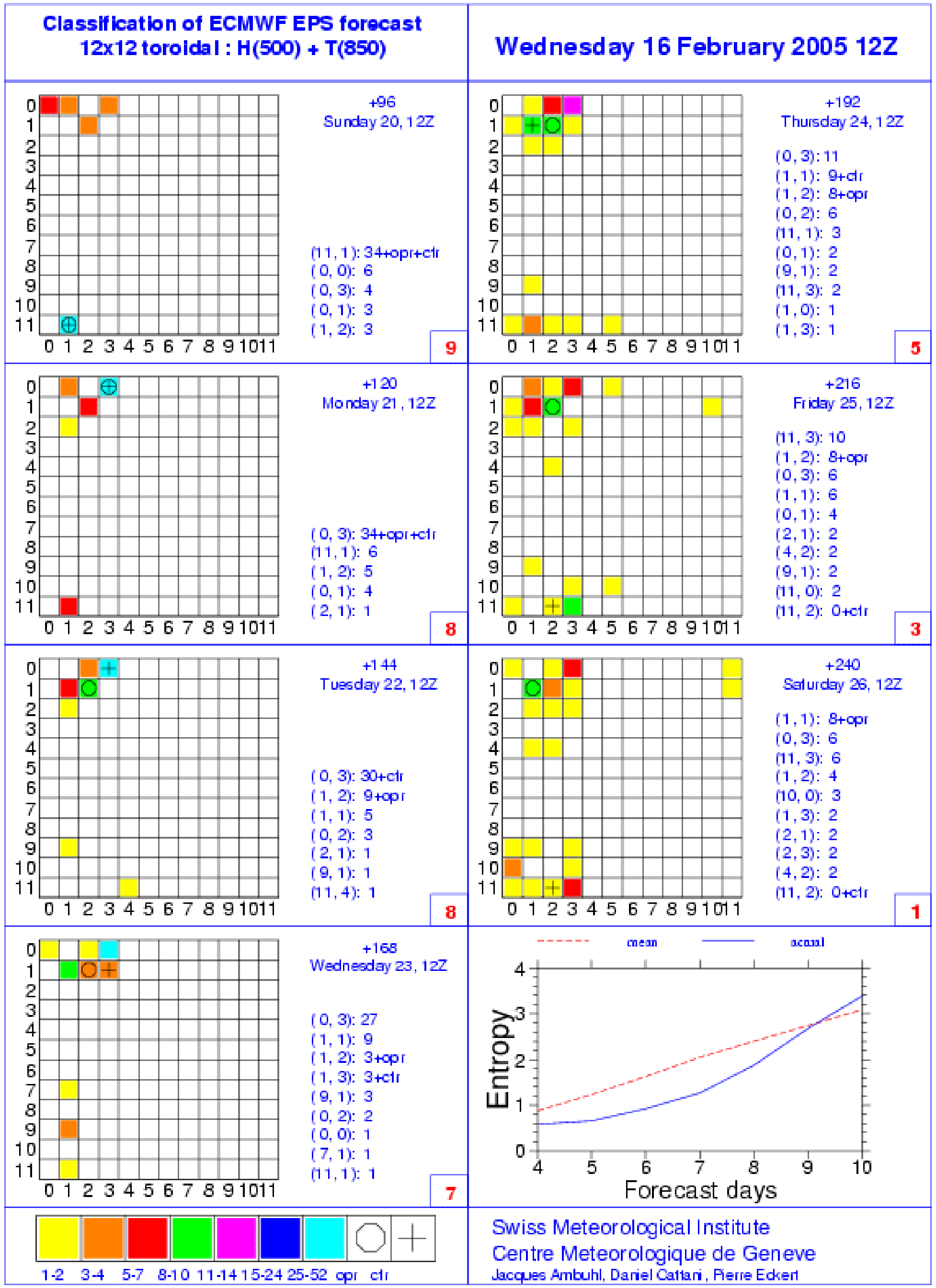
Mean Sea Level Pressure :
14/ 5/2000 12Z. T+144 Valid at : 20/ 5/2000 12z.

- Tubing (left) identifies most probable and most extreme forecasts
- Clustering groups together similar forecasts
- Cyclone Tracking shows low centres



Classification of the enemble (MeteoSuisse)

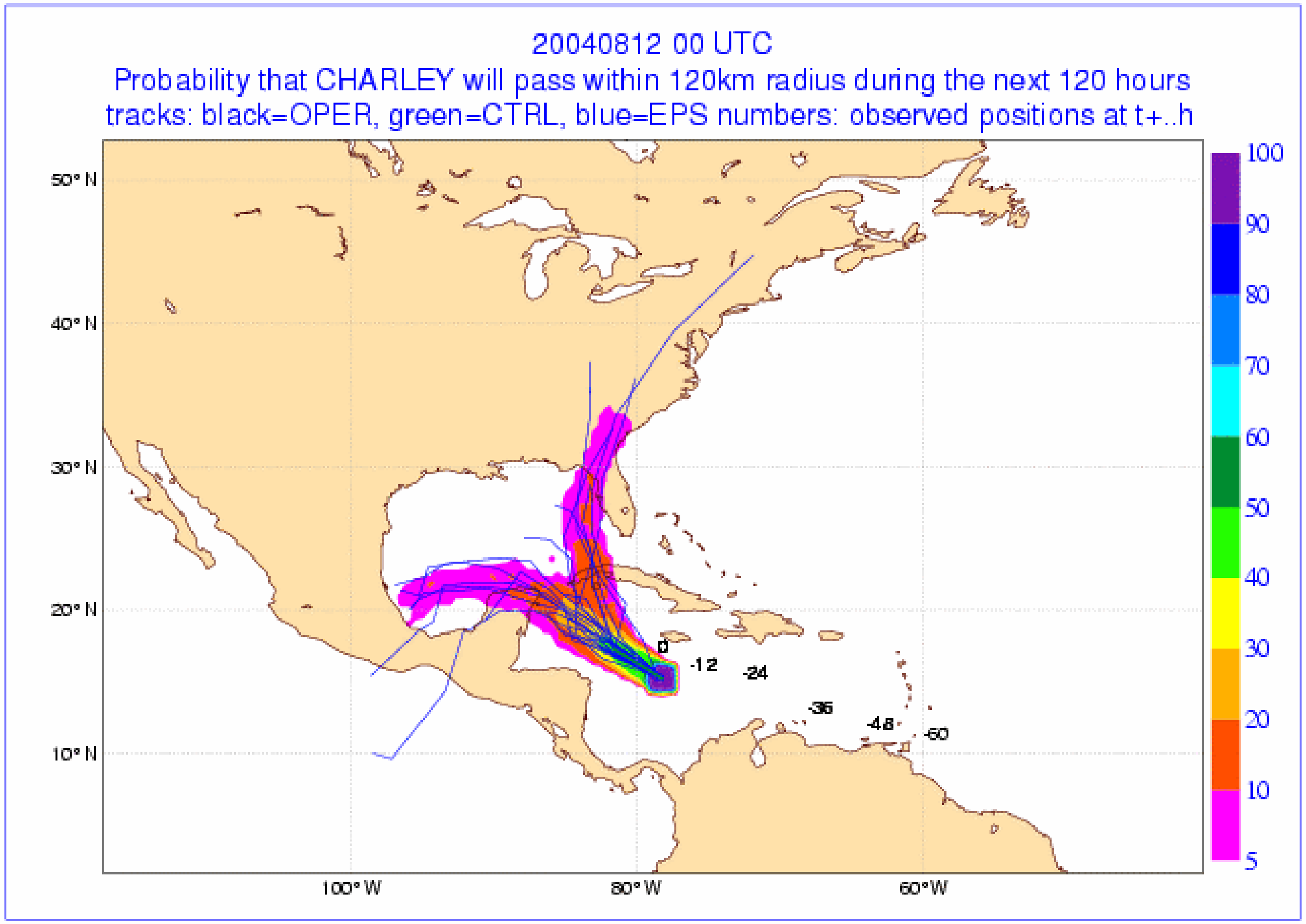
- Each member of the ensemble is classified
- It is possible to visualise the spread of the ensemble on the synoptic scale
- Disorder can be quantified with the entropy
- A confidence index can be computed



Slide courtesy of Pierre Eckert, Meteo-Suisse.

Tropical Cyclones

- Graphics of:
  - tracks
  - strike probabilities
- Alerts of areas at risk
  - Quantifies risk

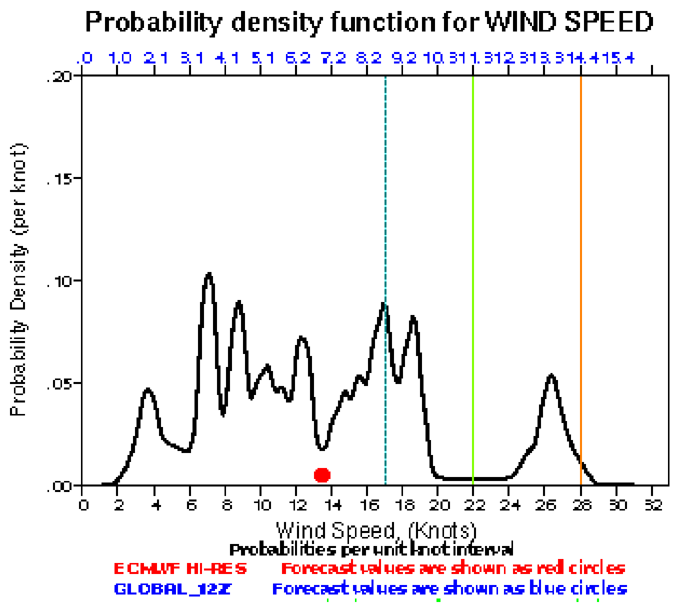


Site-Specific Probabilities

Data Time: 12Z on 25 April 2001
Forecast Time: T+96
Verifying Time: 12Z on 29 April 2001

LERWICK (S. SCREEN)
03005

Recalibrated Kalman Filtered data



Probabilities calculated from 51 ensemble members

WS >= 17 kn (F5)	.28
WS >= 22 kn (F6)	.13
WS >= 28 kn (F7)	.01
WS >= 34 kn (F8)	.00
WS >= 41 kn (F9)	.00
WS >= 48 kn (F10)	.00
WS >= 56 kn (F11)	.00

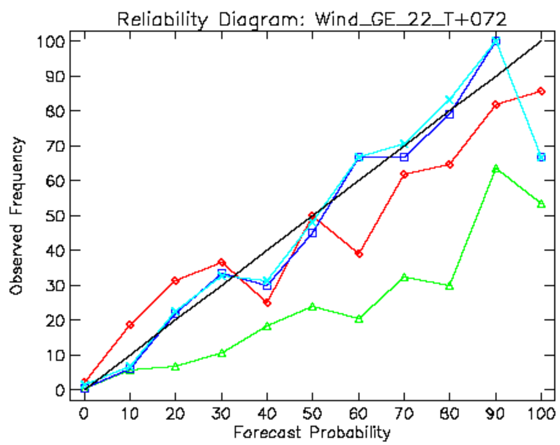
Beaufort

Force	knots	m/s
1	1-3	0.3-1.5
2	4-6	1.6-3.3
3	7-10	3.4-5.4
4	11-16	5.5-7.9
5	17-21	8.0-10.7
6	22-27	10.8-13.8
7	28-33	13.9-17.1
8	34-40	17.2-20.7

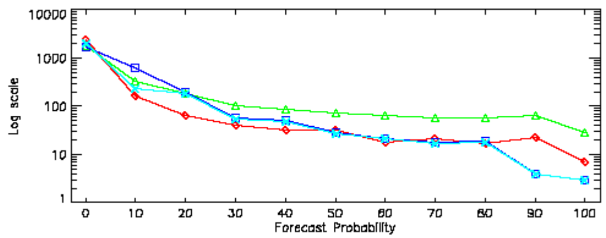
- Site-specific weather parameters can be extracted from each EPS member to create probability forecasts
- Site-specific bias corrections can be applied

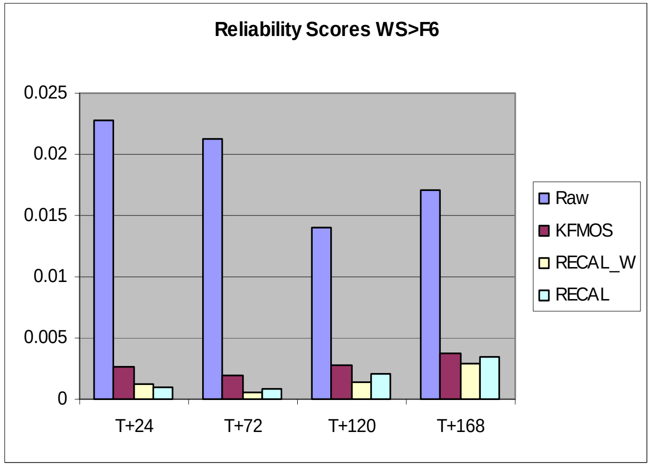
Wind speed pdf (recalibrated)

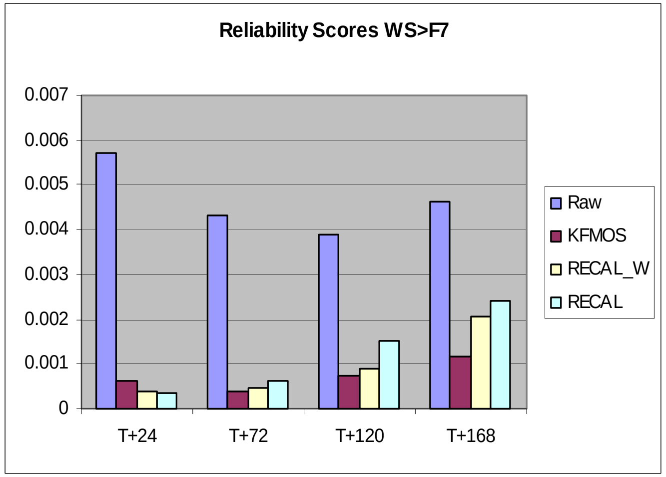
Verification -WS>Force 6 at T+72



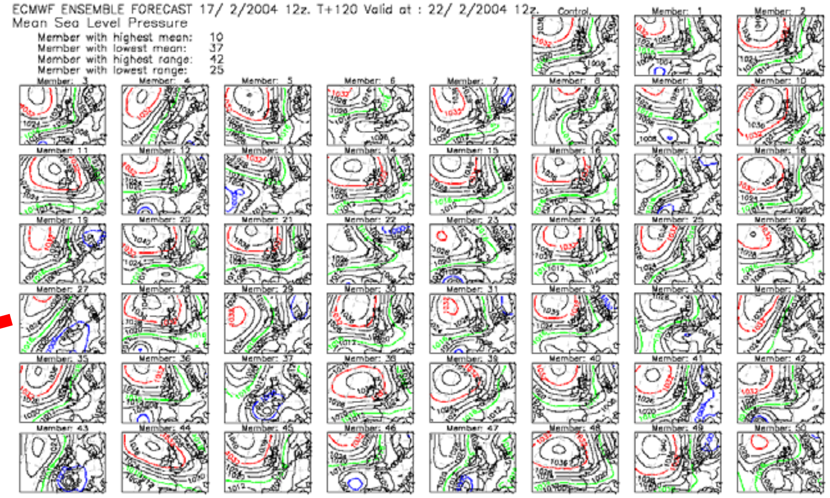
KFMOS	Reliability Score
KFMOS	0.00201257
RAW	0.0213004
RECAL	0.000799934
RECAL_W	0.000624931



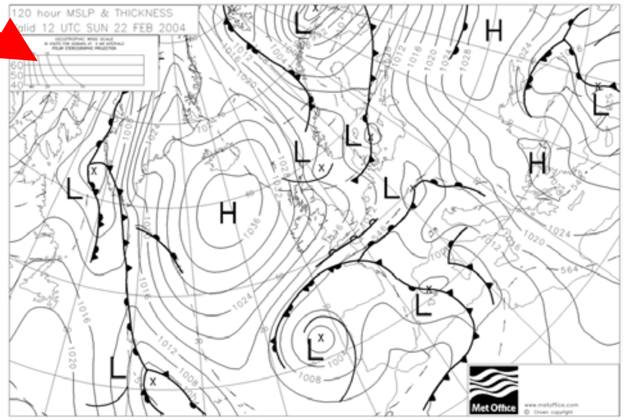




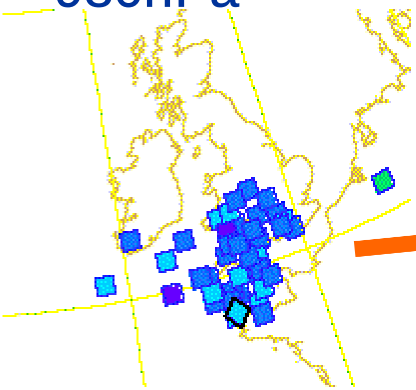
Met Office Operations Centre

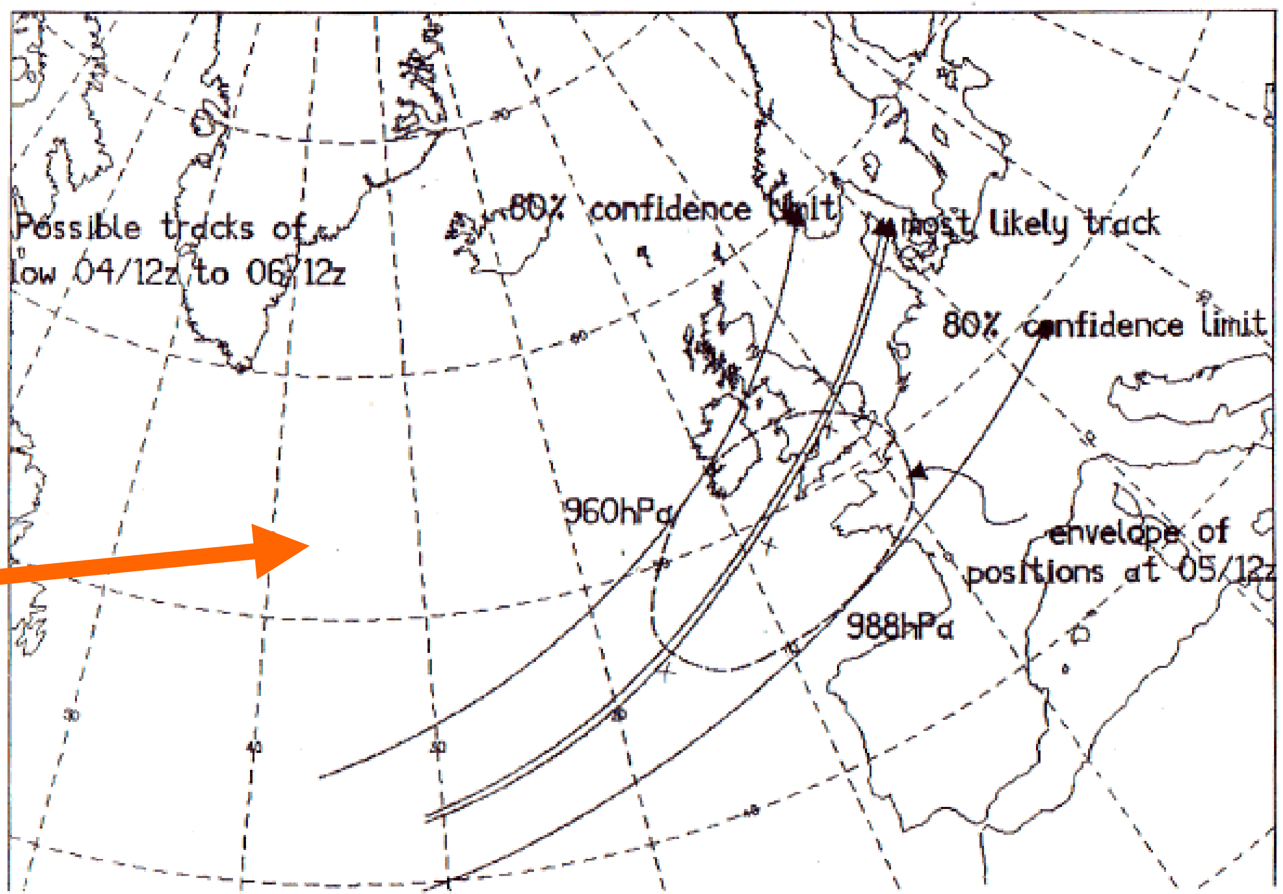


Ops Centre forecaster uses the ensemble to assess the *most probable outcome* before creating the medium-range forecast charts (using field modification software)



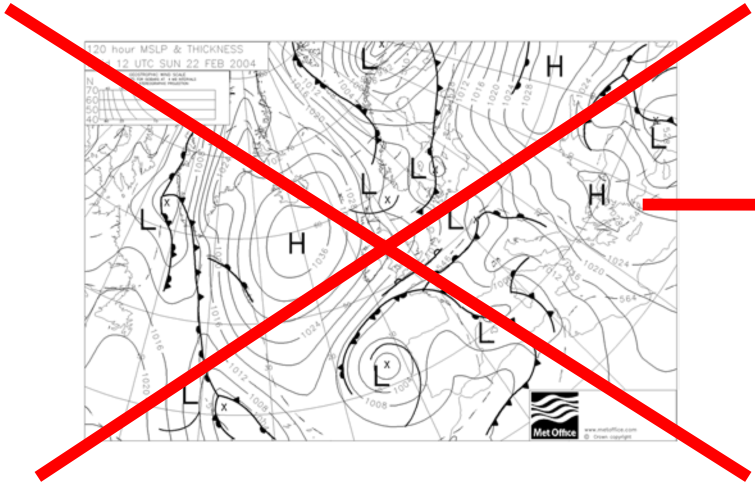
Ensemble
Low
Centres
below
980hPa



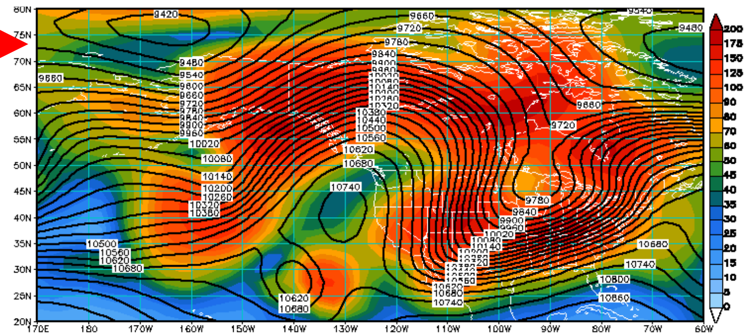


Future Production Systems

- Forecast production needs to change if we are to fully exploit ensembles
  - Ability to use selected ensemble members in forecast production
  - Tools to generate “most probable” outcome (eg field modification)
  - Fully probabilistic products – need more explanation (internet)



Shading might represent:
- 50th or 90th percentile precipitation
- mean WBPT (show predictable fronts only)



Forecast Production with TIGGE

- Still learning how to use ensembles in forecast production
  - Met Office currently considering future production:
    - Select ensemble member?
    - How to make use of probabilistic information?
    - How to describe and present uncertainty?
- Multi-model ensembles present new challenges:
  - Production systems need to take data from different sources
  - How to weight different models?
- NAEFS is a pilot for multi-model production

Severe or Extreme Weather

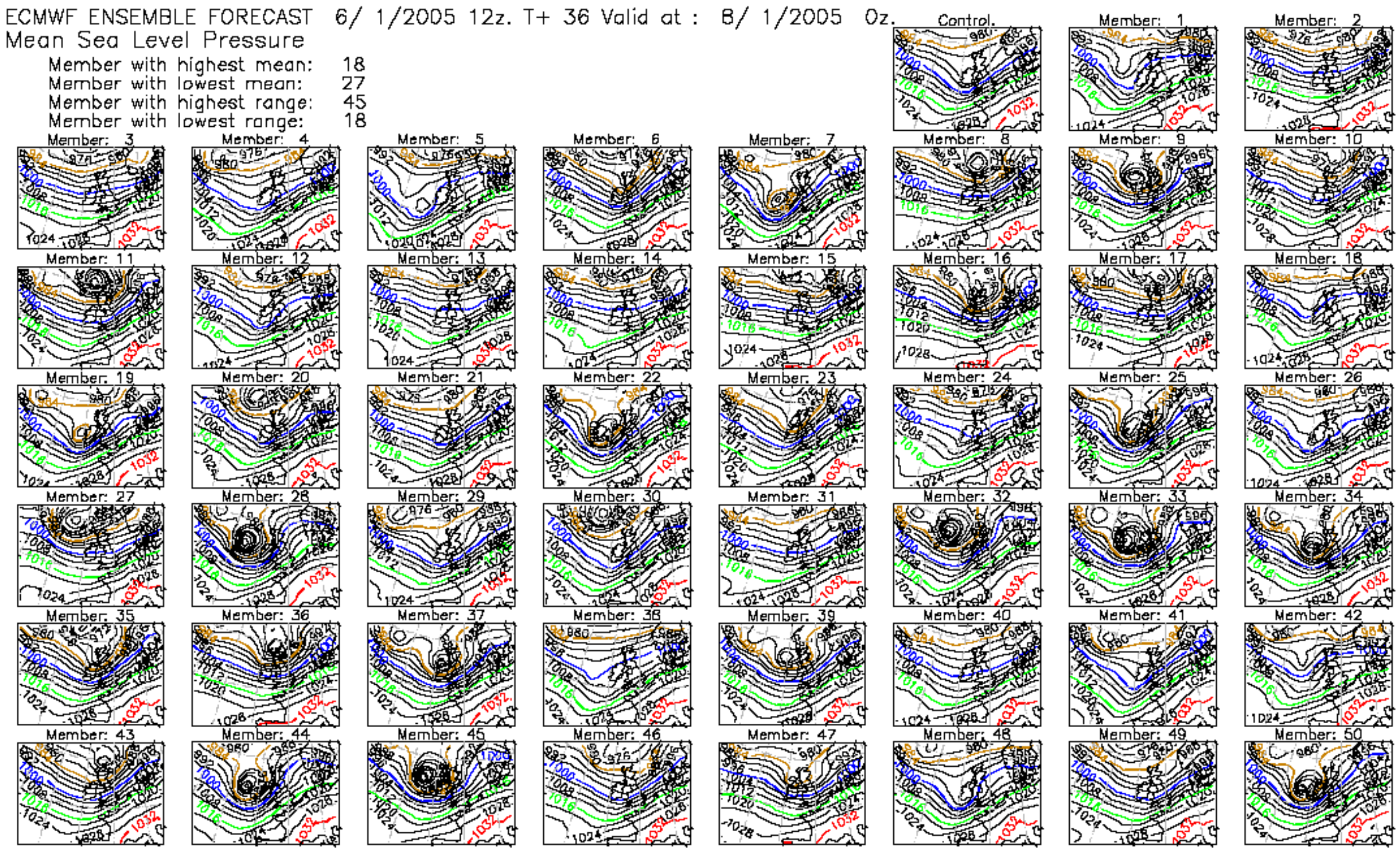
The Challenge of Severe Weather

Focus of THORPEX is on High-Impact Weather

Severe weather well-suited to ensemble approach:

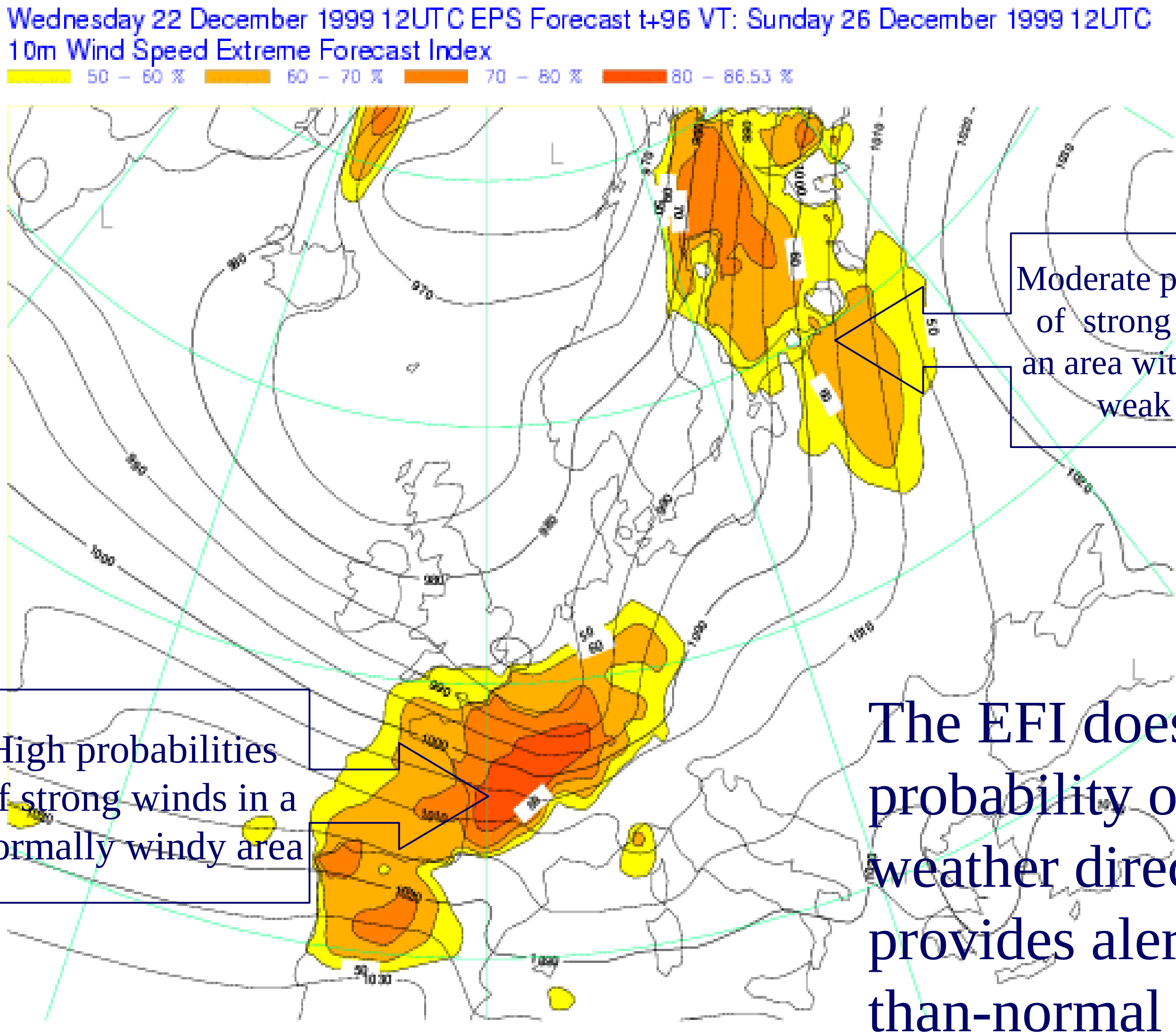
- Development often involves interaction of several elements
- Need to get all these elements right in combination
  - chance of categorical success is low
  - Probability forecasts - expect low probabilities
- Rare events mean few test cases, so difficult to
  - Verify (assess) quality of forecasts
  - Calibrate – correct for systematic errors

Increased uncertainty in extreme events



- This example was for a recent storm over the UK (8 Jan 2005)
- Large uncertainty in details for a 36 hour forecast

Extreme Forecast Index (EFI): 26 Dec 1999

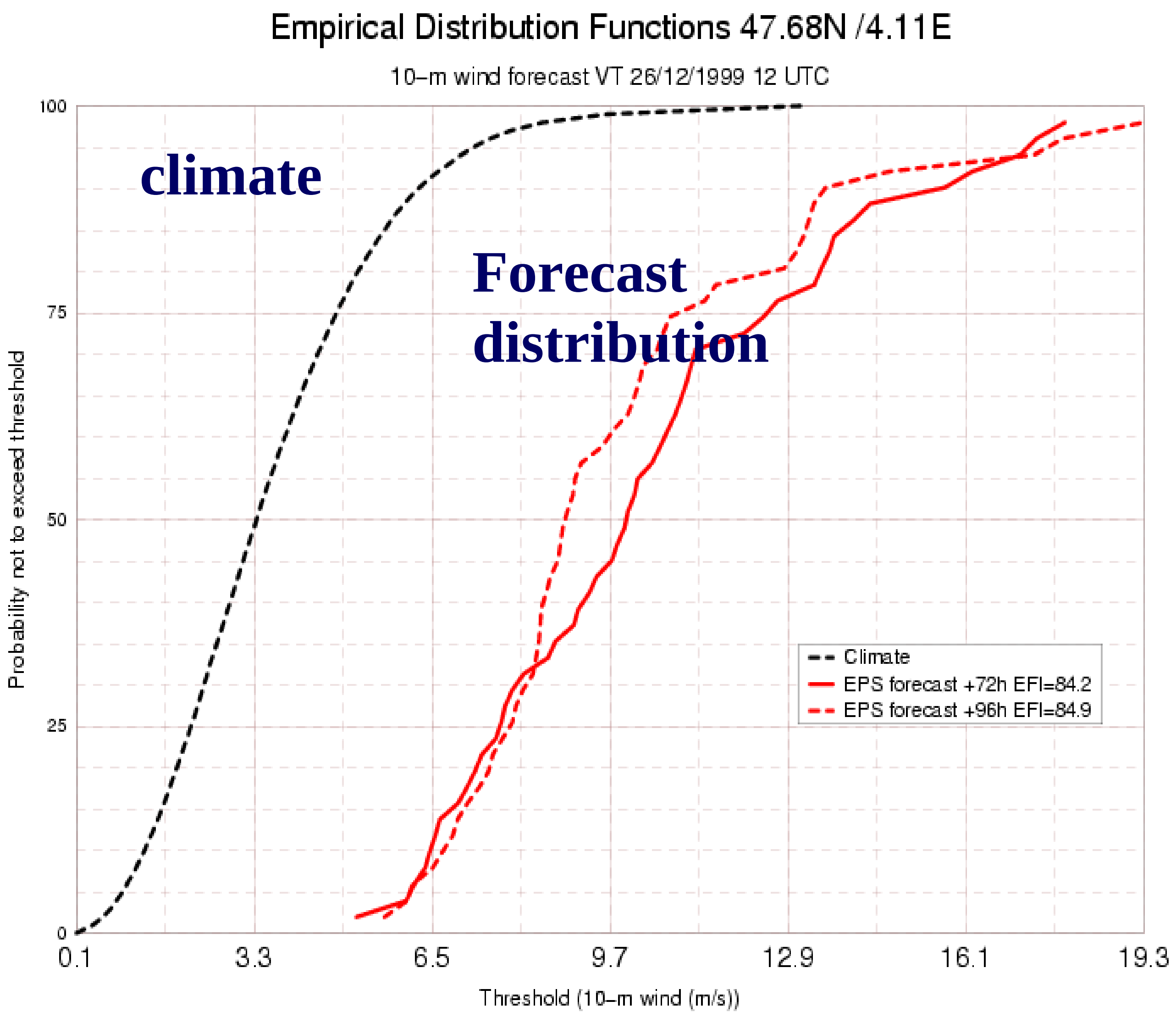


Moderate probabilities of strong winds in a an area with normally weak winds

High probabilities of strong winds in a normally windy area

The EFI does NOT give probability of severe weather directly, but provides alert of higher-than-normal risk.

Wind EFI for northern France 26 Dec 1999



EFI – An Alerting Tool

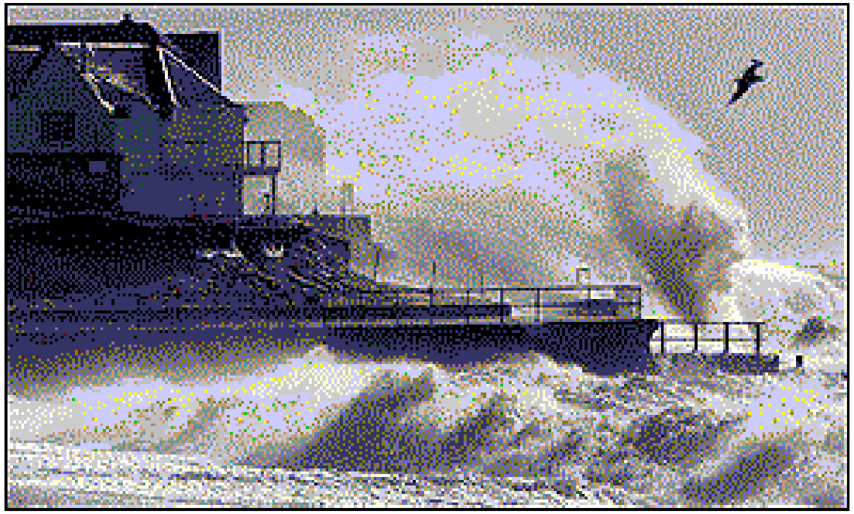
- EFI Alerts forecasters to unusual forecasts
  - Does *NOT* provide probabilities of extreme weather
    - Forecasters not sure how to use it
    - Attempts to interpret as probabilities have had limited success – high false alarm rates
- Need to develop and maintain model climatology
  - For multi-model TIGGE would require climatology for all models
    - TIGGE research could provide initial climate
    - How to maintain with model changes?

Early Warnings of Severe Weather (UK)

Met Office issues Early Warnings up to 5 days ahead - when probability ≥60% of disruption due to:

- **Severe Gales**
- **Heavy rain**
- **Heavy Snow**

- Forecasters Provided with alerts and guidance from EPS



Early Warning outputs

RECOMMEND ISSUE OF A WARNING

Probability % of event by region between 1800 07 JAN 2005 and 1200 08 JAN 2005

Prob. of event occurring anywhere in the UK is 80%

N. Scotland	33%
E. Scotland	49%
S.W. Scotland	51%
N. Ireland	37%
N.W. England	55%
N.E. England	59%
Midlands	45%
Wales	33%
S.W. England	41%
Cen. S. England	51%
S.E. England	33%
E.Anglia/Lincs	39%

Event: SEVERE GALES - gusts of at least 70mph

T+ 18	36 12 10 11 47 30 24 34 1	18%
T+ 24	13	2%
T+ 30	16	2%
T+ 36	16 8 34 6 36 50 37 35 47 21 29 11 22 12 23 30 13 49 43 14 32 0	43%
T+ 42	34 45 50 44 28 33 25 9 39 47 19 32 7 48 37 5 27 21 22 29 26 18 12 0 42 16 38 36 40	57%
T+ 48	28 32 20 9 44 33 7 42 22 45 1 25 5 50 27	30%
T+ 54	5 34 37 32	8%
T+ 60	32	2%
T+ 66	16	2%
T+ 72	27	2%
T+ 78	27 50	4%
T+ 84	50 13 2 47 6	10%
T+ 90	50 13 48 28	8%
T+ 96	33 25 5	6%
T+102	8 25	4%
T+108	3	2%
T+114	--	
T+120	--	
T+126	--	
T+132	--	
T+138	4	2%
T+144	41 21	4%
T+150	--	
T+156	--	
T+162	26	2%
T+168	26	2%

Use of Ensemble in this case

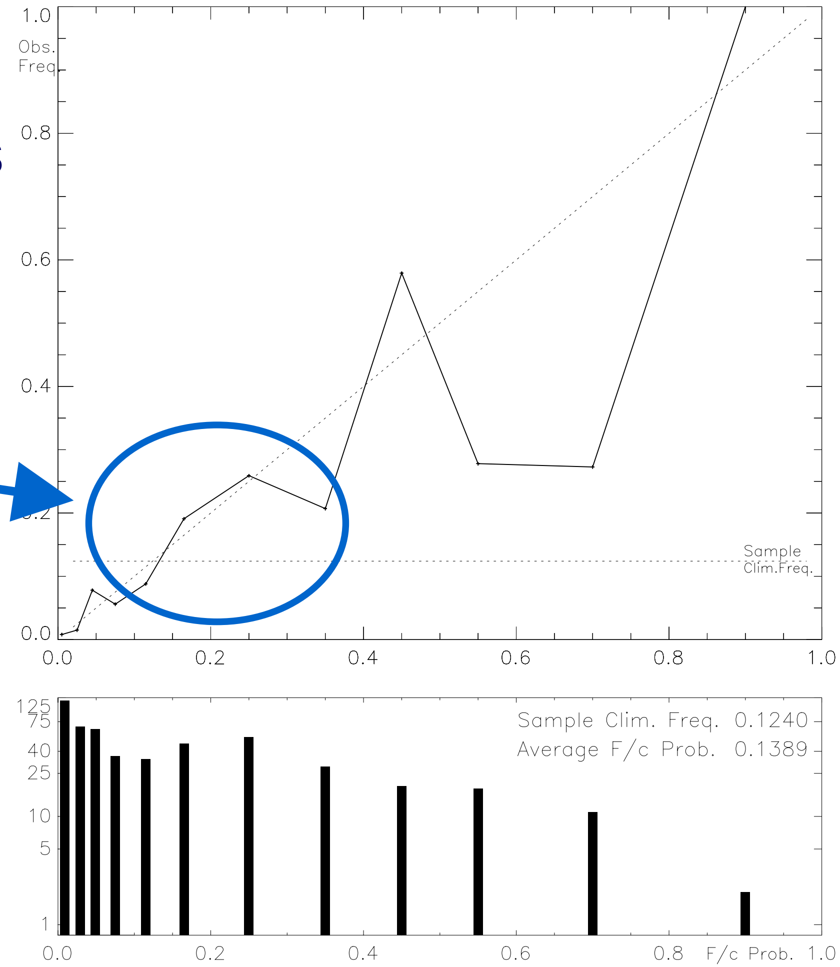
- Ensemble gave early indication of risk of severe storm
  - Lots of uncertainty
  - Probability higher than normal
  - First-Guess Early Warning gave very strong signal
    - 30% risk of exceptionally severe gales (very high for this category)
  - Early warning was issued giving probabilities
    - Risk and uncertainty was described in forecasts to public and emergency services
  - Result was excellent forecast for storm-force winds
    - Heavy rainfall was predicted but did not get very extreme amounts in Carlisle.

Verification

- Good relationship between forecast probability and frequency of occurrence
- Most severe events *can be* forecast, but at *low probabilities*

- False alarms
  - For each correct low probability warning, several false alarms are also issued

Obs freq



f/c prob

Benefits of TIGGE for Severe Weather

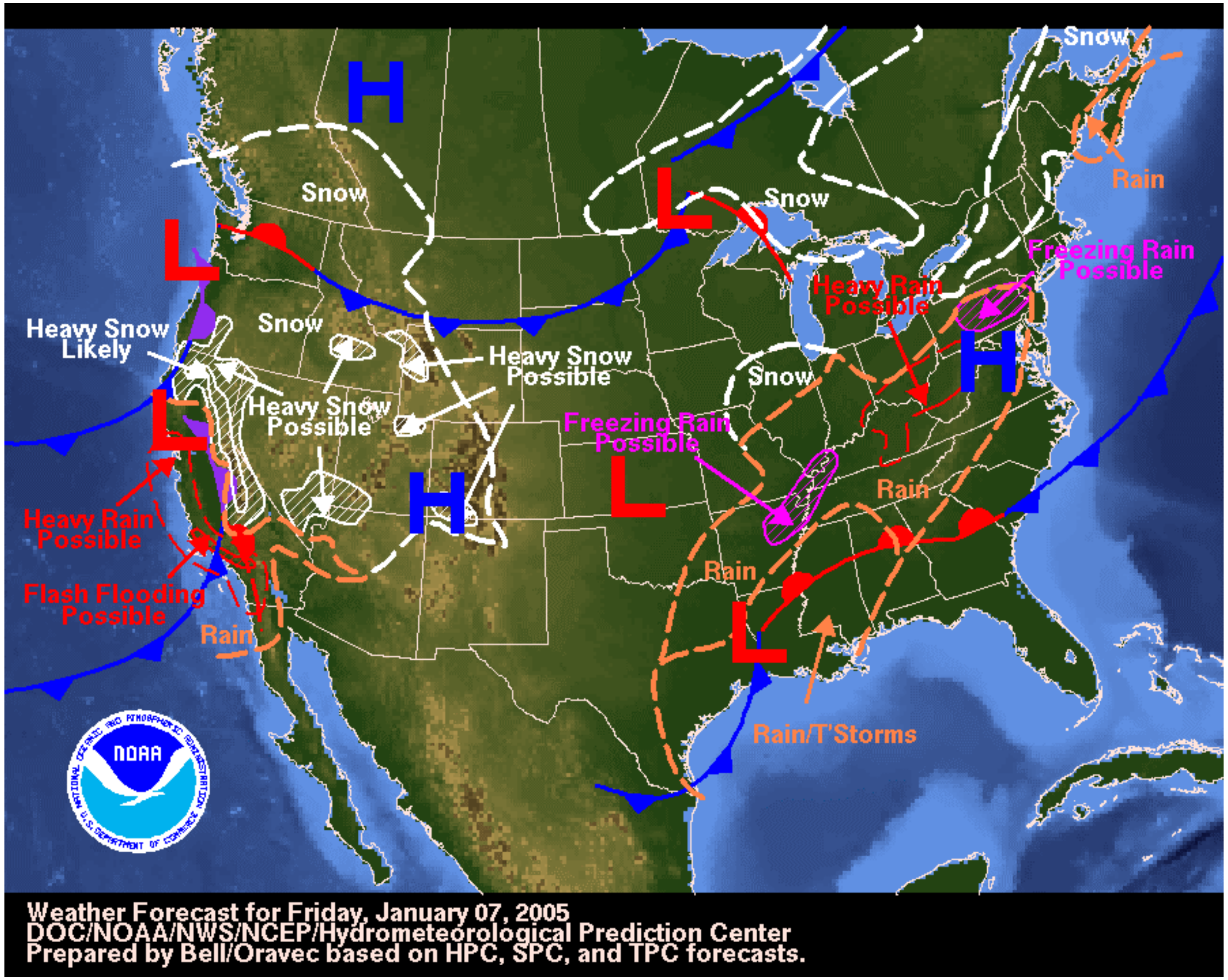
- Better chance of capturing event
  - Larger Ensemble
  - More diverse perturbations

- Shared resource to support forecasting and disaster mitigation for the whole Globe

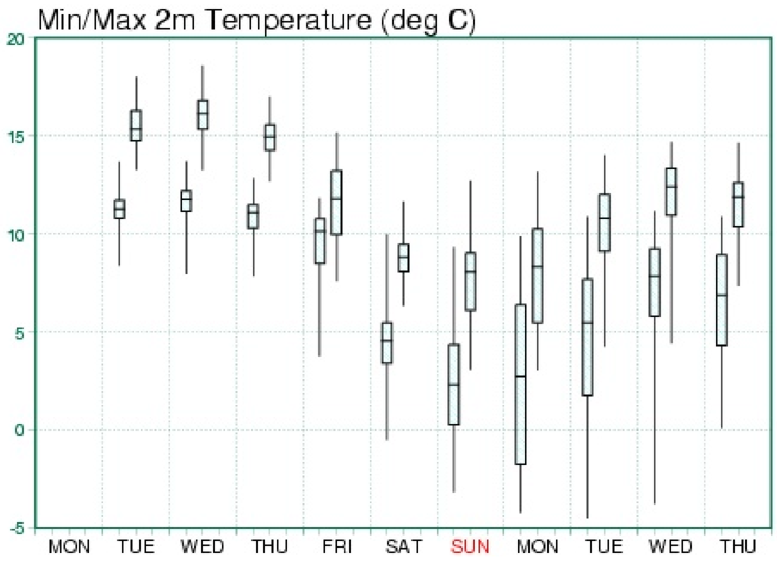
Presentation of Ensemble Outputs/Probabilities

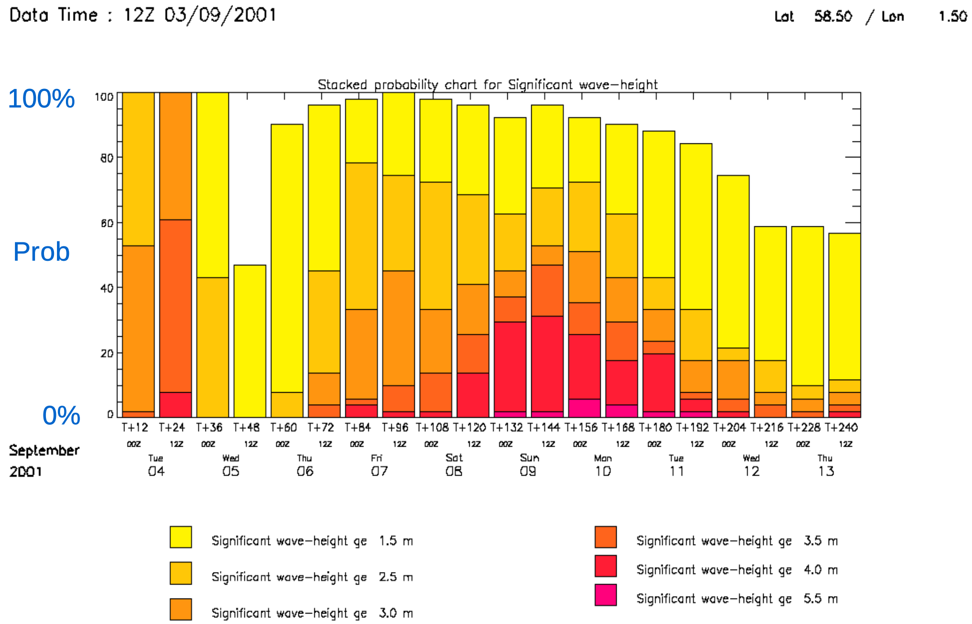
Example Summary of Ensemble Risks

- Threats assessment produced by forecasters in US



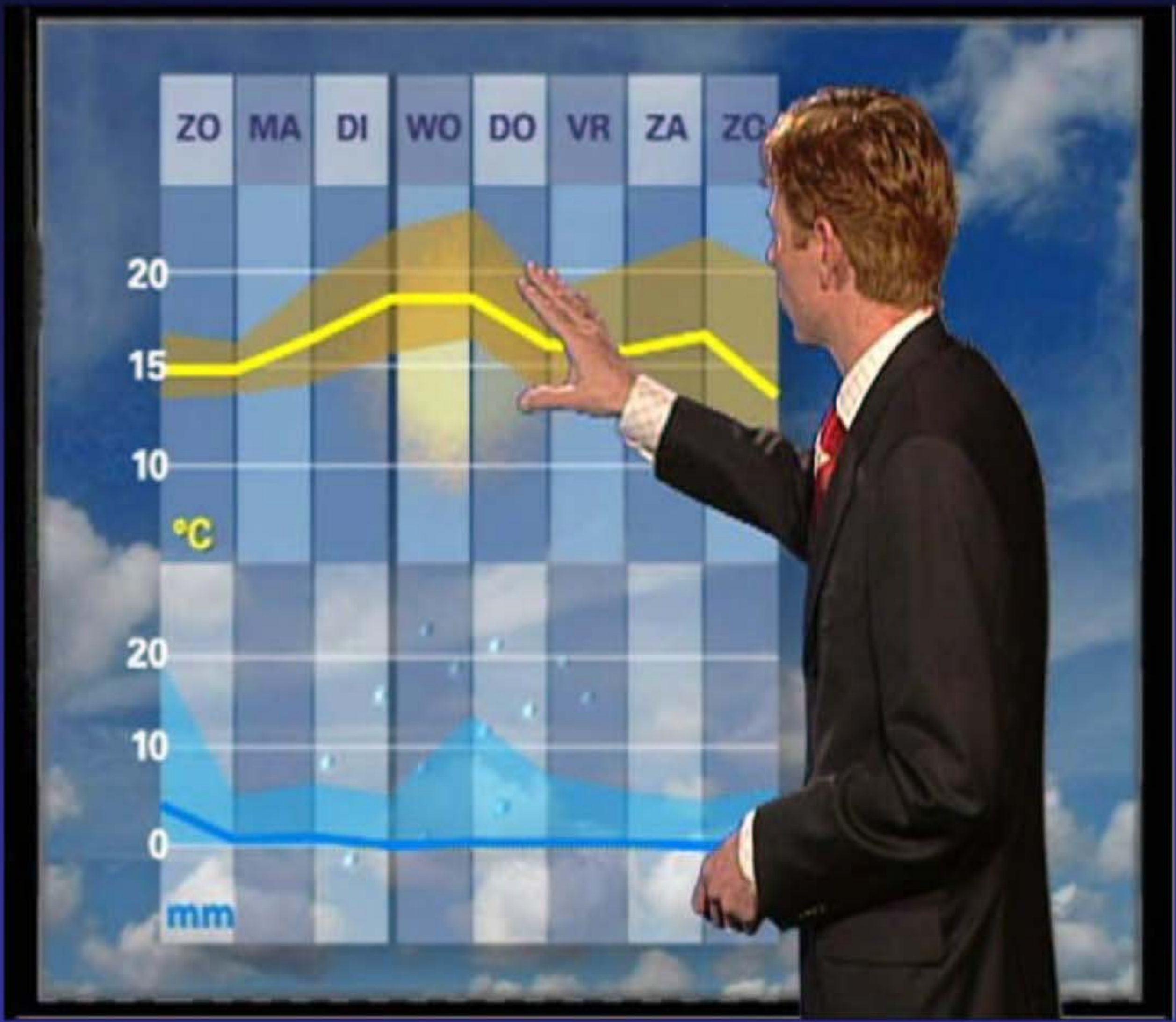
Site-specific Products for the Risk Manager





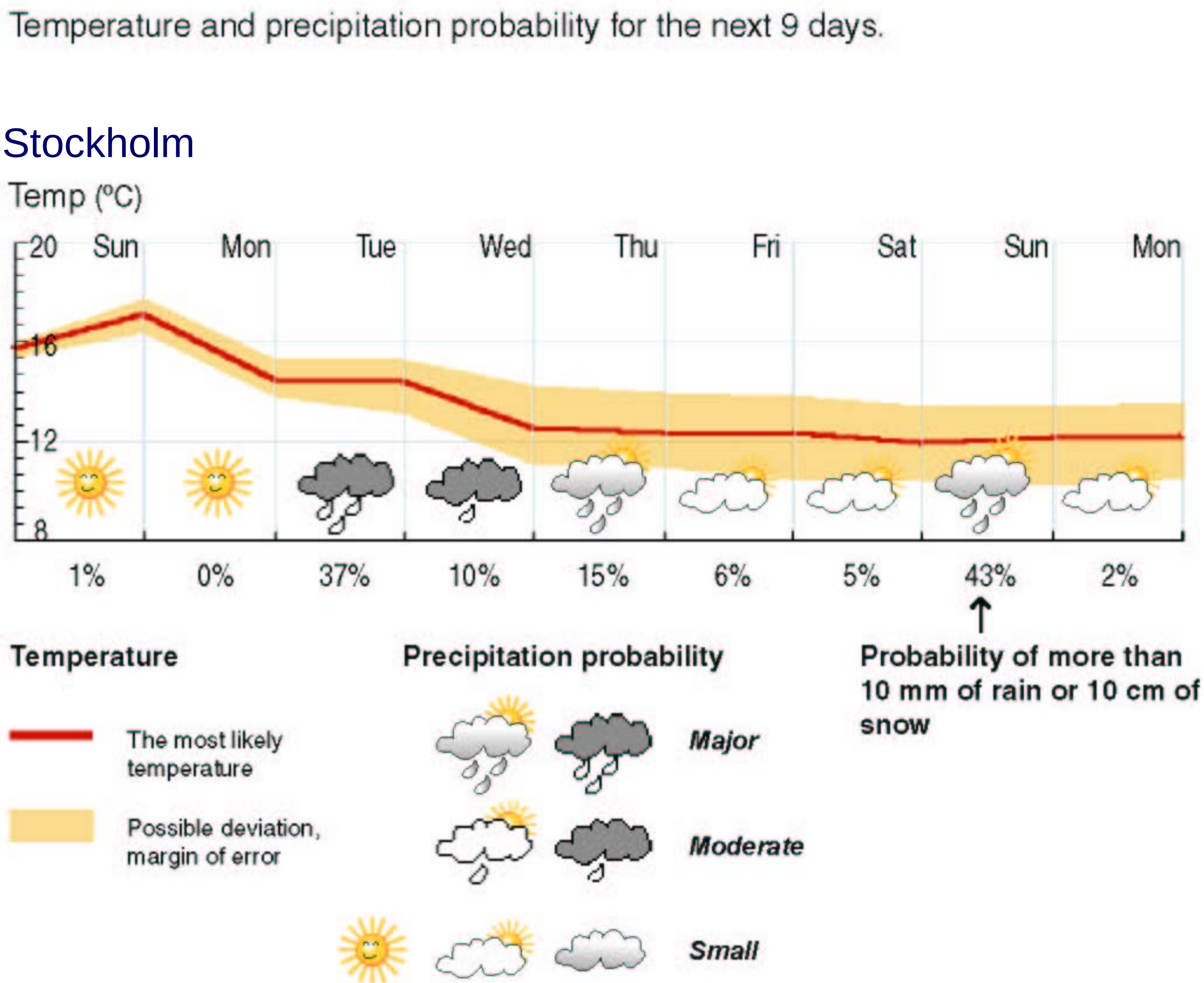
- Plot of ensemble spread
- Probability graph for multiple severity thresholds

EPS appearing on Dutch TV



Courtesy of Robert Mureau, KNMI.

Epsgram produced by the Swedish Meteorological and Hydrological Institute and published by newspapers, in this case a newspaper in Poland



Slide courtesy of Anders Persson, SMHI.

Confidence Index Example: national TV

Slide courtesy of Pierre Eckert, Meteo-Suisse.

MétéoSuisse

Example: Prévision plein air

Précipitations	Période et intensité (forte / faible à modérée)	12h	12h	12h	12h	12h
	Fréquence, localisation	-	intermittentes	intermittentes	résiduelles	-
	Quantité moyenne (l/m^2)	0	5-10	5-10	2	0
	Prob. plus de 1 l/m^2	nulle	forte	forte	faible	nulle
	Prob. plus de 10 l/m^2	nulle	modérée	modérée	faible	nulle
	Limite des chutes de neige (m)	300	300	300	300	300
Température de l'air à 2 m du sol min/max(°C) à 1000 m		-8 / -3	-7 / -1	-6 / -3	-6 / -2	-9 / -2
Indice de confiance (sur 10)		8	7	7	6	6

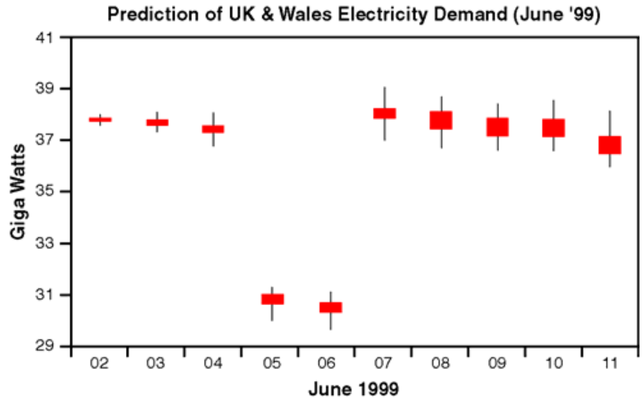
MétéoSuisse

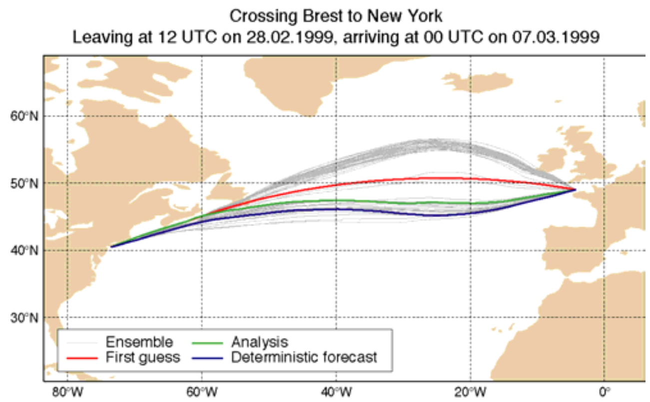
Slide courtesy of Pierre Eckert, Meteo-Suisse.

Advanced Applications

Ensembles of Outcome Models

- Ensembles can be used to drive outcome models, eg.:
  - Hydrology
  - Wind energy
  - Ship-routing
- Few examples in real use yet but some applications in hydrology:
  - EFAS (JRC, Italy)
  - COSMO-LEPS
  - SMHI

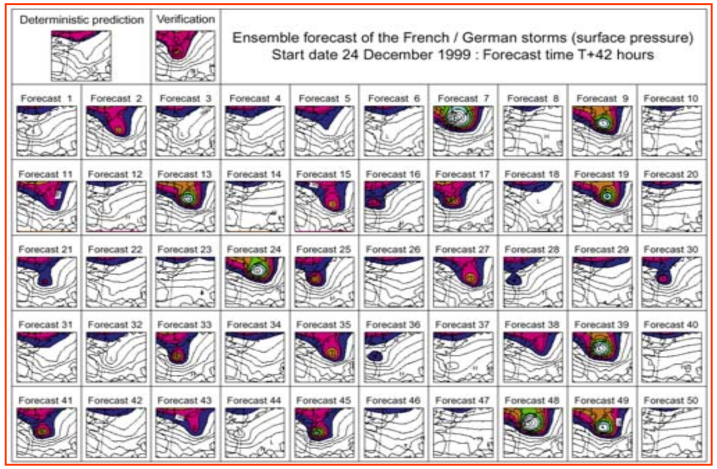




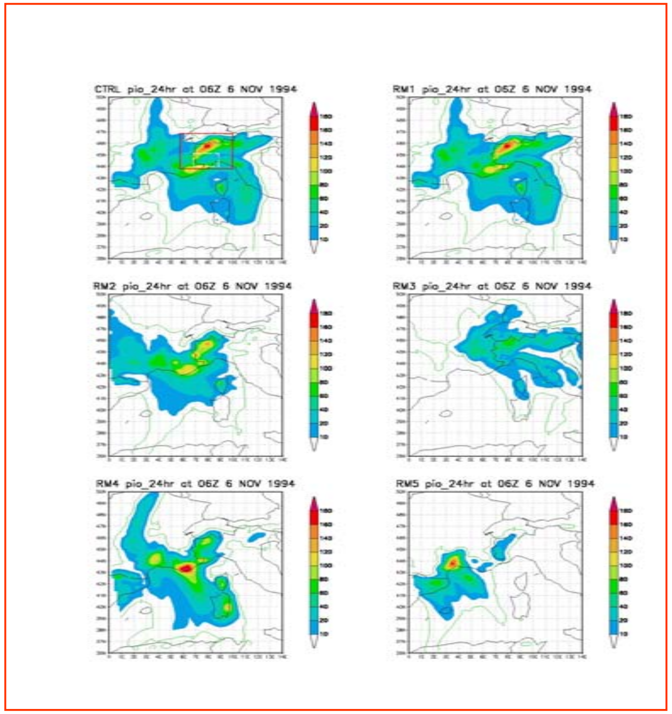
PROBABILISTIC

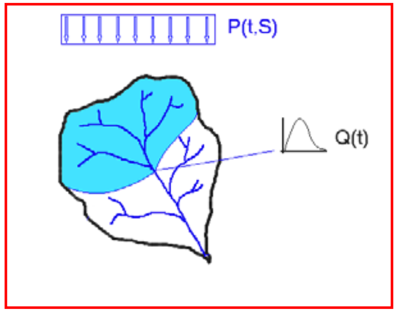
Single Site

EPS

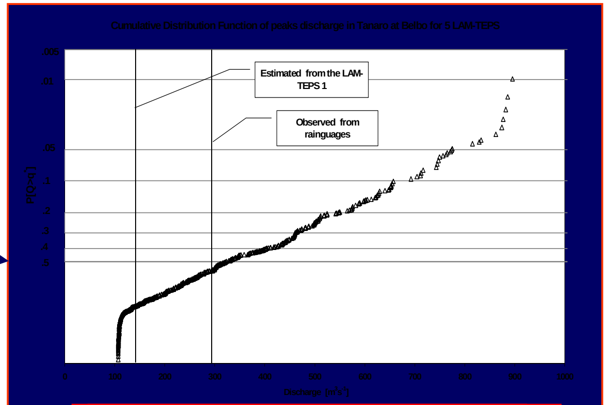


LEPS





DHM



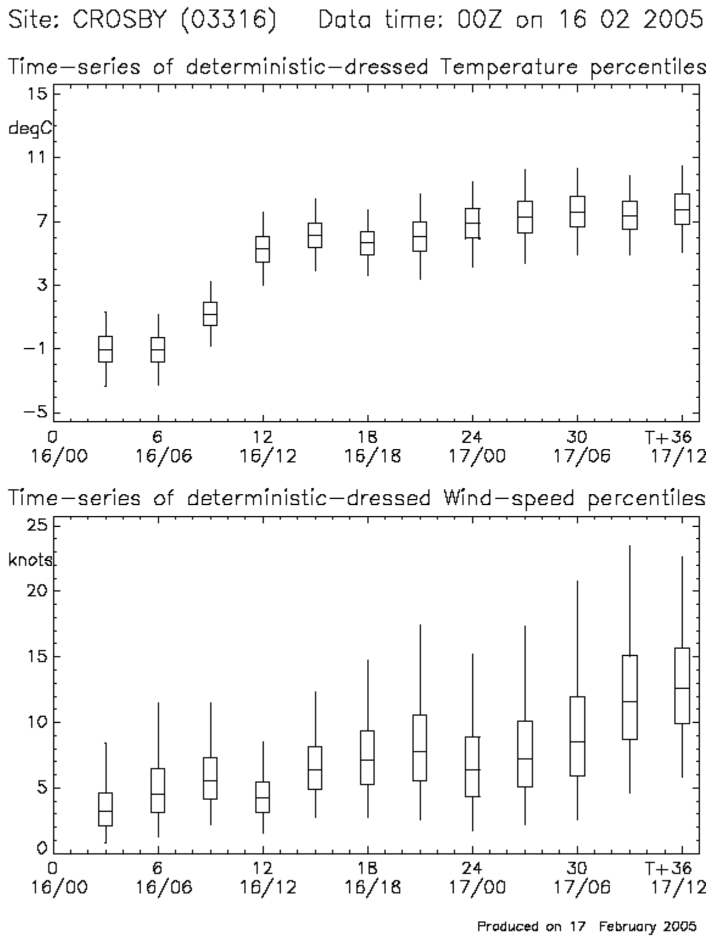
CDF of peak discharges

Thanks to Roberto Rudari, CIMA, Genova.

Probability Forecasts – an alternative view

- *"…meteorology … hung up on how to use ensembles… seems to think you need the whole ensemble to produce a probability forecast… which is rubbish"* Steve Jewson, RMS.

- Meteograms on right generated from deterministic model plus gaussian error stats (transformed in wind case)
  - Cheap and reliable
  - Benchmark for ensembles
    - Need to prove that EPS spread adds value
- **But** ensemble provides :
  - Relationship between parameters
  - Full meteorological scenarios



Training

(Re-)Training Forecasters

- Change way forecasters think
  - Predictability central – get away from determinism
  - Improving deterministic
- Changing Role
  - Forecast consultants
  - Interpretation of automated forecast
  - Advising on decision-making
- Integrate into basic training
- WMO provides training for members
  - Workshops to “Train the trainer” (Brasilia, Shanghai)
  - Why and how to use

(Re-)Training Users

- Change the way users think
  - Think they need deterministic to make decisions
  - Reasons for uncertainty – a little science!
  - Cost/loss for decision-making
- Consultancy
  - Need to understand users' decision-making
  - Demonstrations of extra information
    - Example - *Wind farm "game"*
- Some customers easier than most
  - Offshore oil – engineers
  - Finance and Insurance – statisticians

TIGGE

So what does TIGGE offer for future forecasting?

Use of Global Multi-model Ensembles

- Multi-model ensembles (eg TIGGE, NAEFS) are *expected* to offer best quality probability forecasts. Can we use them?
  - Need to harmonize output formats of all fields from all models used – *TIGGE – NAEFS is a good pilot*
  - All centres need to modify forecast production systems to use this common format – *possible?! – NAEFS pilot again*
  - Huge data volumes to exchange – model levels (eg. profiles)
  - Cost implications are huge – 10y+ programme?
- Other benefits – backup, resilience, global resource …
- Big question: Will the extra skill (over good single-model EPS) justify the costs?

Conclusions – Ensembles

- We can never get rid of uncertainty - ensembles allow us to
  - Quantify it –
    - add *Error Bars* to our forecasts
    - Produce alternative scenarios
    - Assess risks of severe events
  - Reduce it –
    - Assess most probable outcomes
- Exploiting benefits is a challenge. Need to:
  - Rethink production processes
  - Change the way we present forecasts
- Cheaper alternatives for some applications

Conclusions - TIGGE

- TIGGE (or its operational descendent) could offer:
  - Best available probability forecasts
  - Shared resource for the benefit of mankind
- Difficulties of exploiting this should not be underestimated:
  - Probabilistic forecast production and presentation
  - Data exchange of 3-D fields
  - Harmonization of data formats
  - Re-engineering of forecast production in *all* centres
  - Stable models/ calibration datasets for optimum use
- Will the benefits justify the costs?
  - Key question for THORPEX research

Questions?