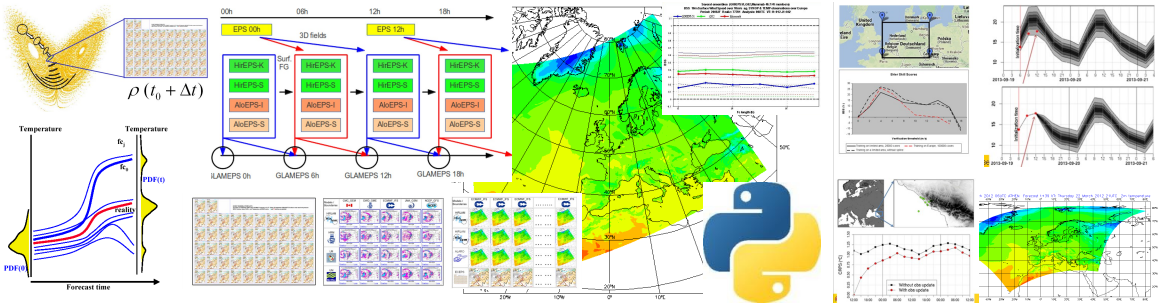
GLAMEPS and HarmonEPS

Carlos Santos (AEMET)
Reunión PREDIMED 2014A
Palma de Mallorca, 5-6 Junio 2014



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GLAMEPS Team 2014: Sibbo van der Veen, Alfons Callado, Pau Escriba, Thomas Nipen, Maurice Schmeits, John Bjørnar Bremnes, Dorien Lugt, Lisa Bengtsson, Andrew Singleton, Kai Sattler, Ole Vignes, Ulf Andrae, Xiaohua Yang, Alex Deckmyn and Inger-Lise Frogner
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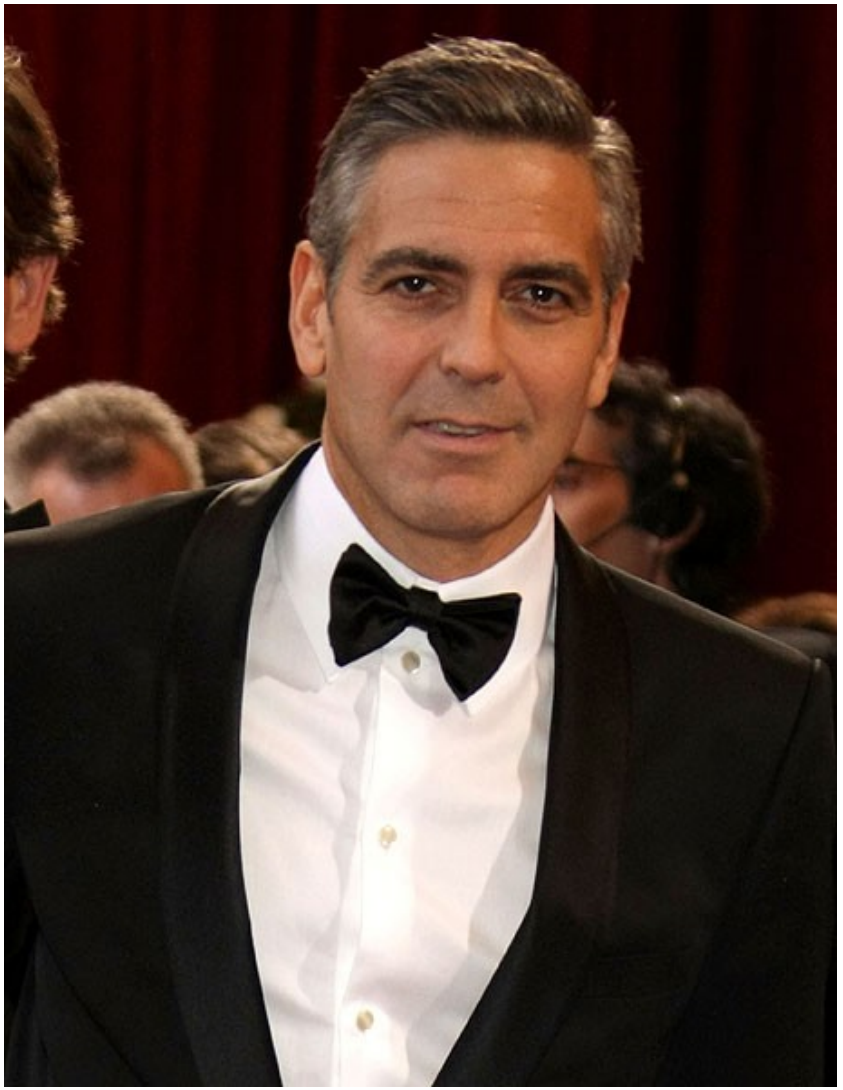
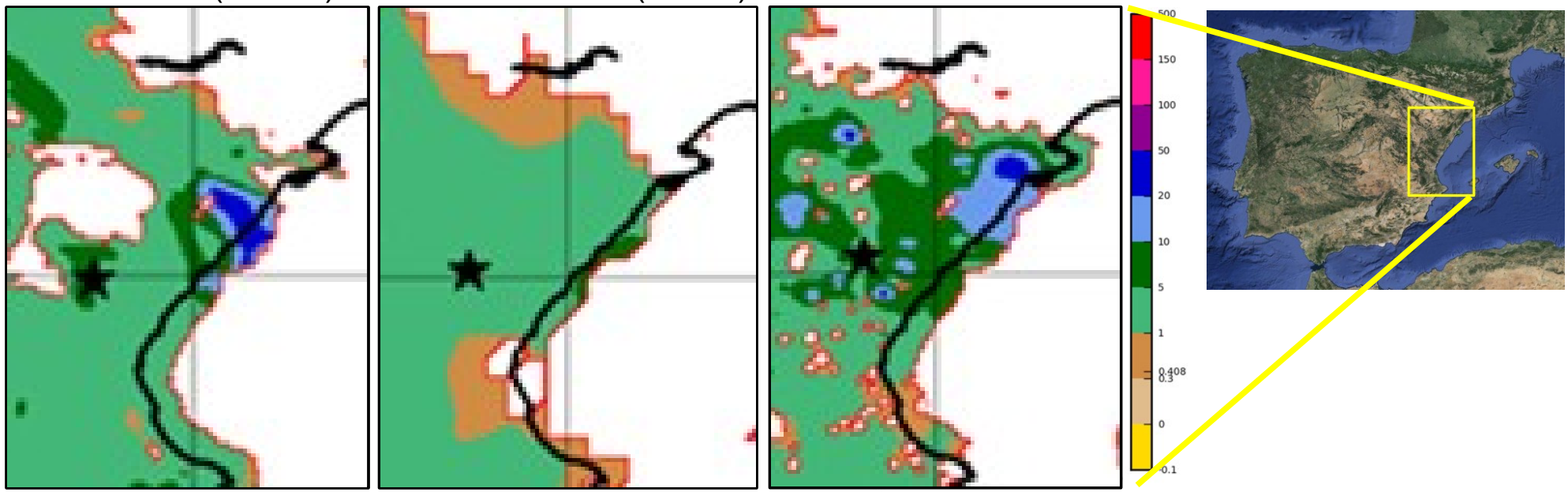
Are models perfect?

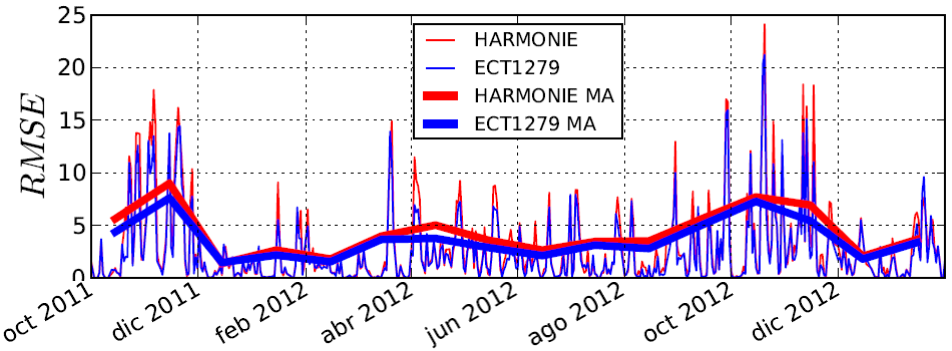


Double penalty problem

HARMONIE (2.5 km) ECMWF T1279 (16 km) OBSERVATIONS

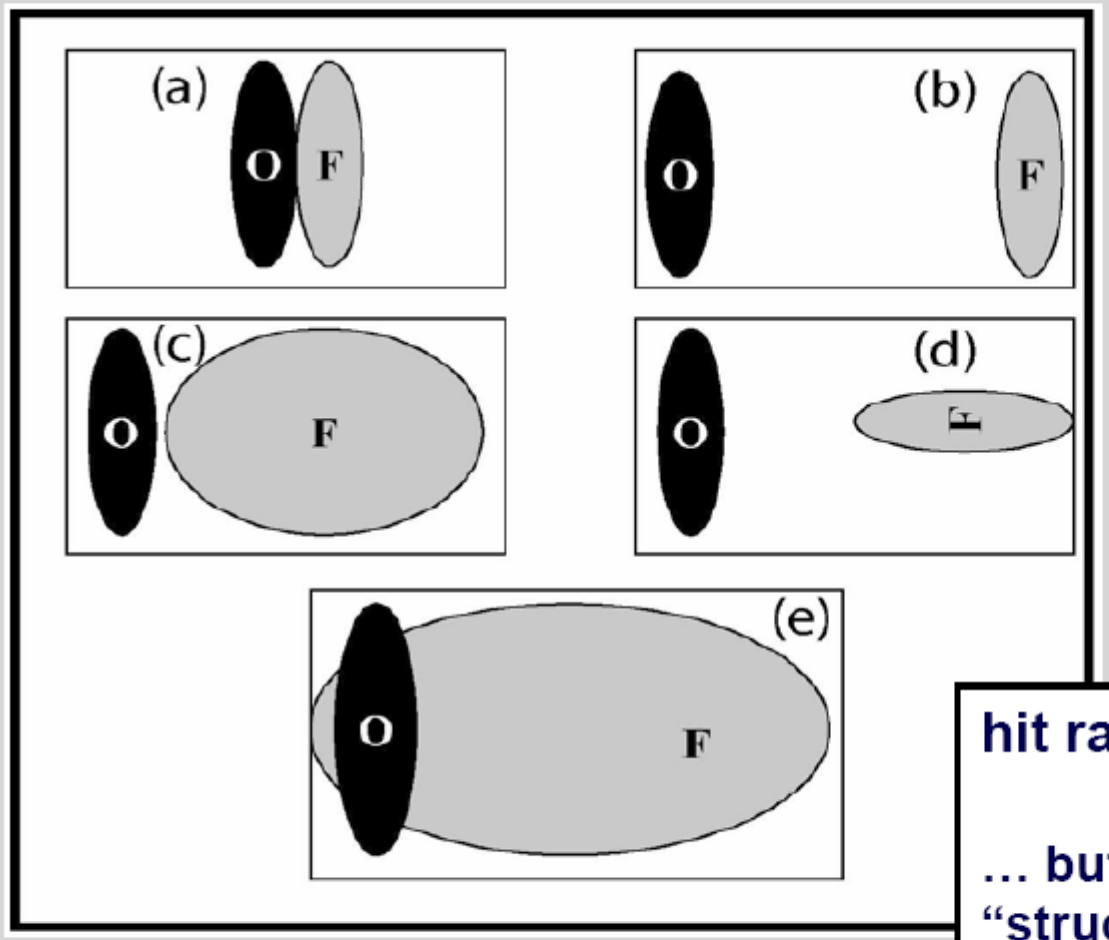


***MSE* = 8.9** ***MSE* = 6.8** ***MSE* = 0**



Double penalty

Problematic aspects of grid point based error scores



Davis et al. 2006 (MWR)

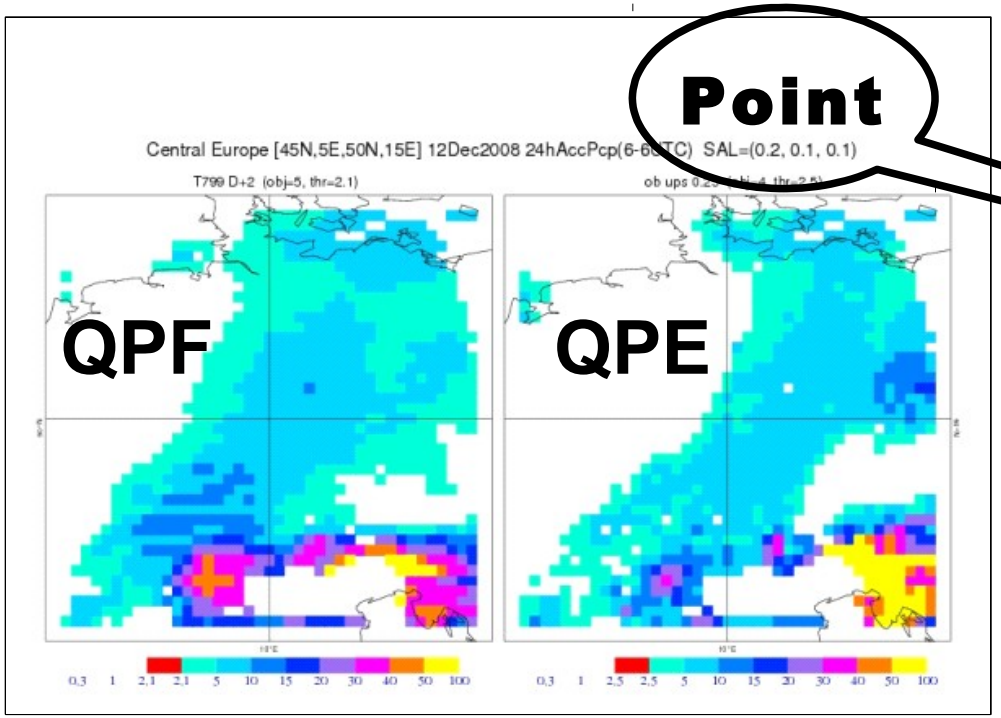
hit rate = 0

… but (a) is "better" than (b)-(d)

hit rate > 0

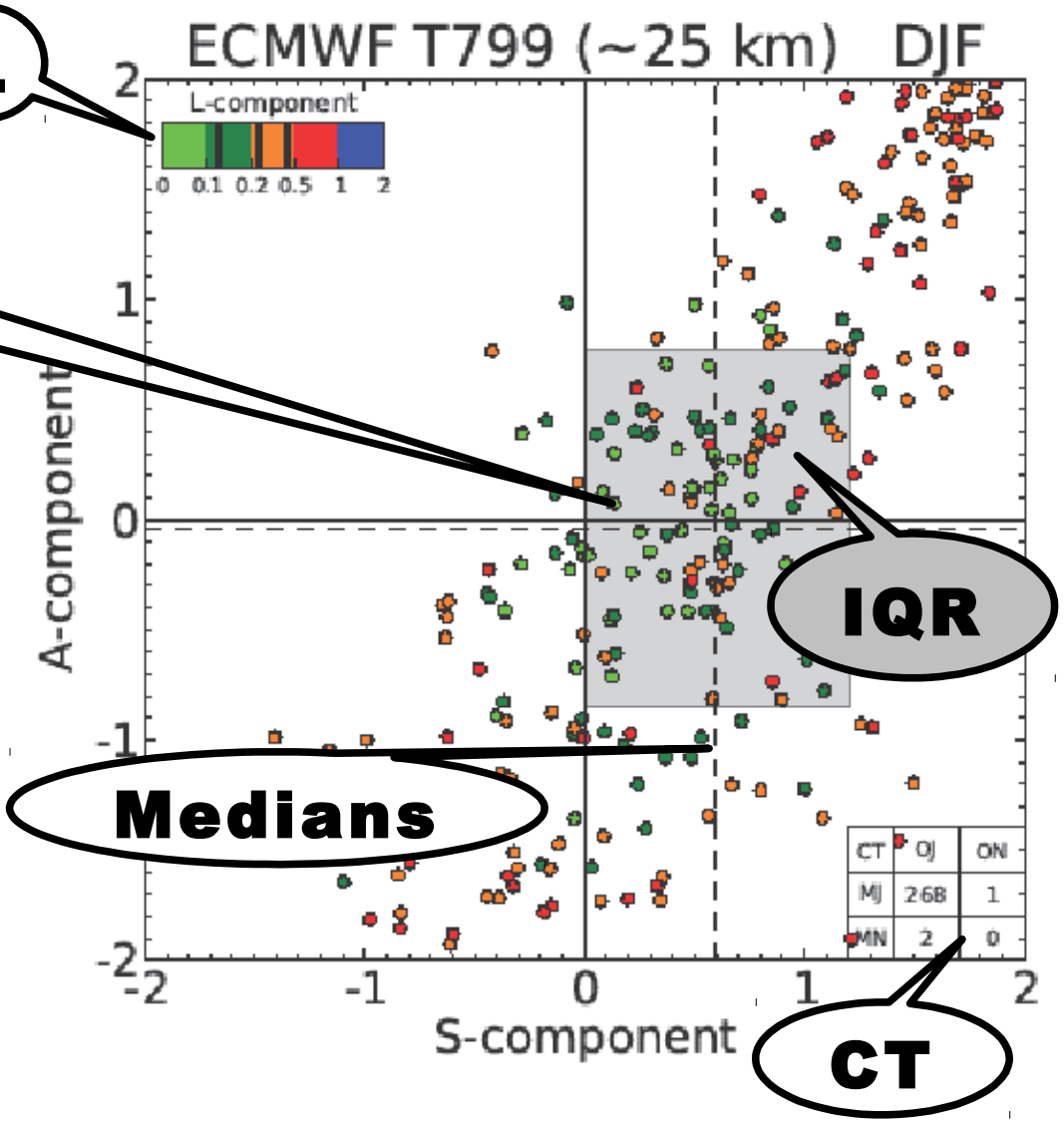
… but forecast has not the right "structure"

SAL plot



Point

L

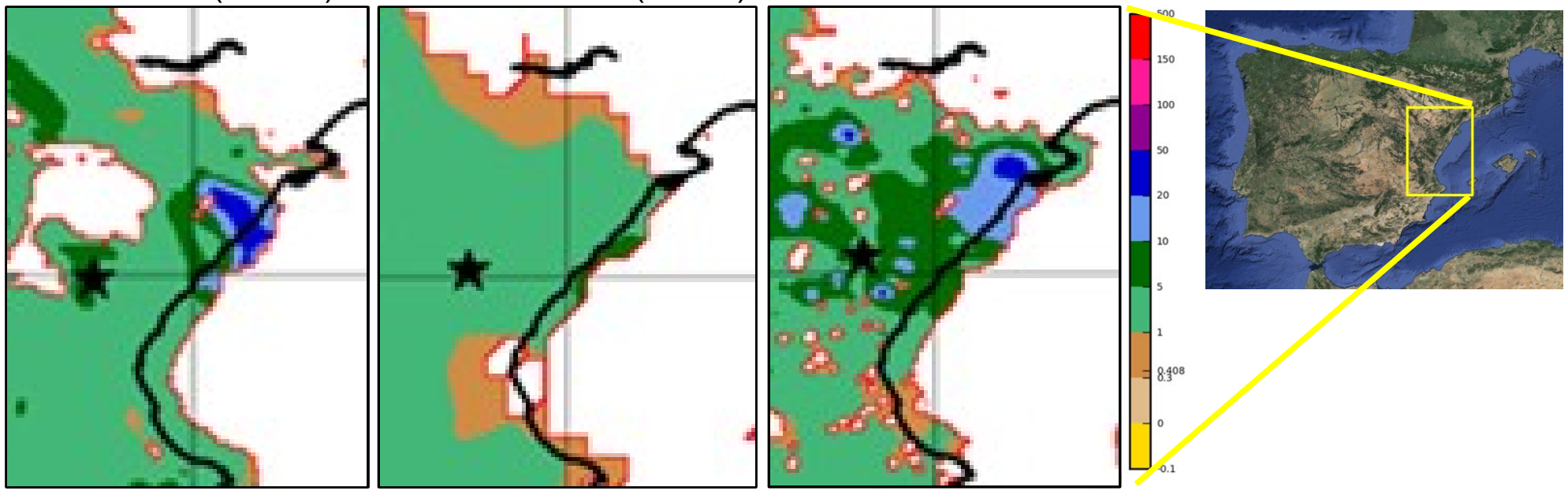


S:	Structure	-2 … objects too small or too peaked	0 Perfect	+2 objects too large or too flat
A:	Amplitude	-2 … averaged QPF under-estimated	0 Perfect	+2 averaged QPF over-estimated
L:	Location		0 Perfect	+2 wrong location of Total Center of Mass (TCM) and / or of objects relative to TCM

Quantitative, explicit and accumulative information about different aspects of QPF performance

Double penalty problem

HARMONIE (2.5 km) ECMWF T1279 (16 km) OBSERVATIONS

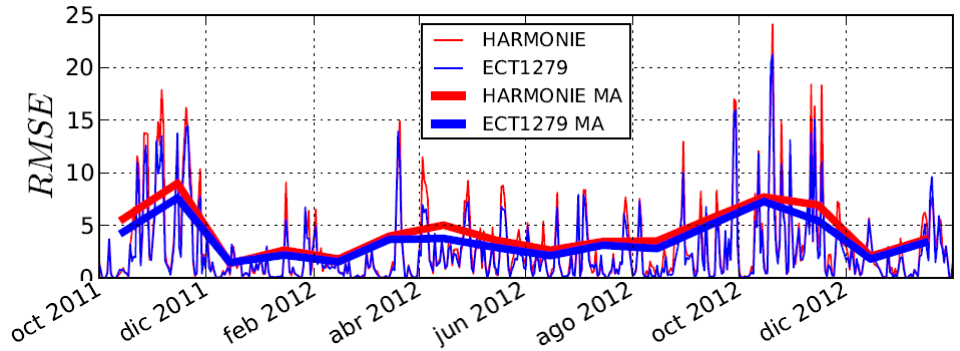


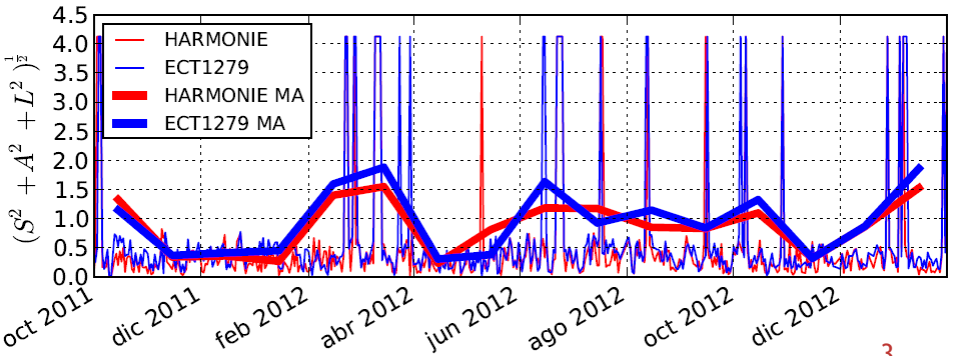
MSE = 8.9
S = 0.07
A = 0.07
L = 0.03

MSE = 6.8
S = 0.5
A = - 0.3
L = 0.1

MSE = 0
S = 0
A = 0
L = 0

MSE, S, A, L = 0
perfect forecast

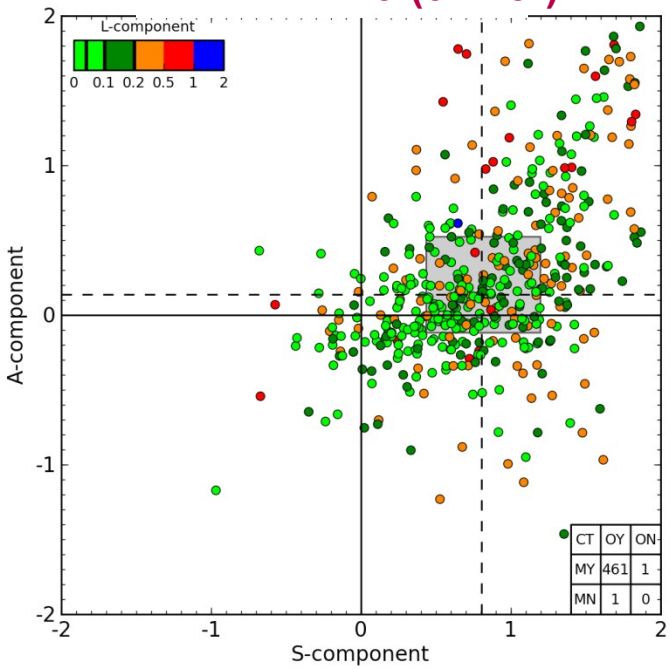




MODEL COMPARISON

Oct2011-Jan2013

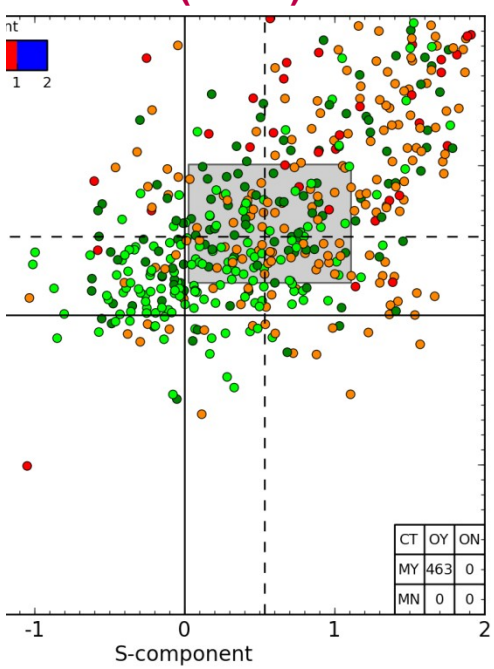
ECMWF T1279 (0.125º)



S = 0.8
A = 0.14
L = 0.10

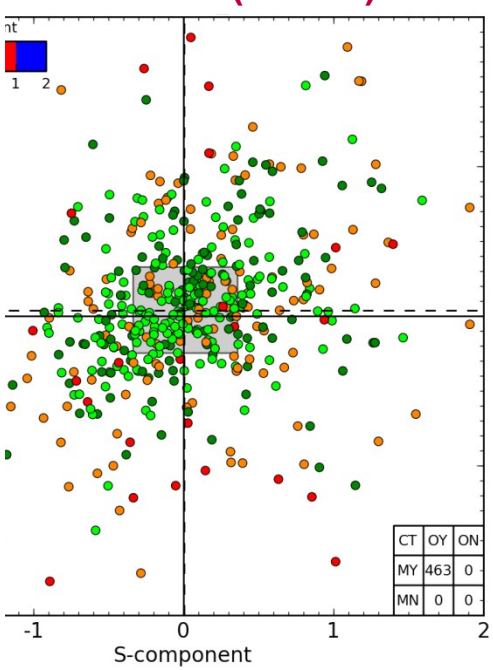
1 False Alarm
1 Missing Event

HNR (0.05º)



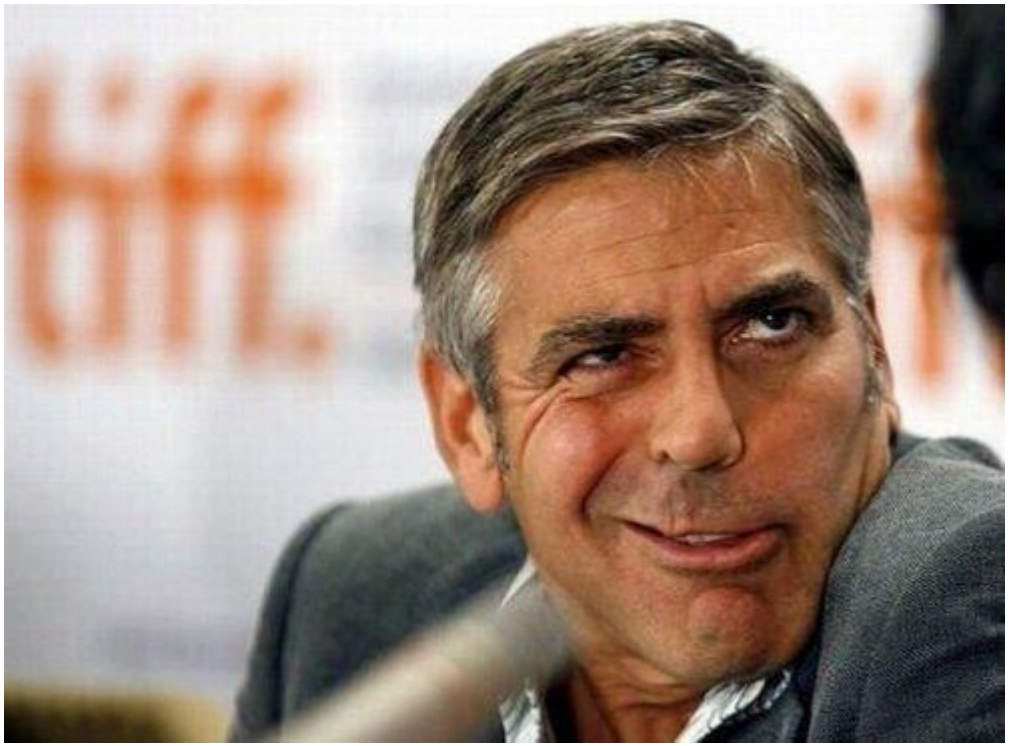
S = 0.5
A = 0.5
L = 0.17

HARMONIE (2.5km)



S = 0.006
A = 0.04
L = 0.12

- S ▭ improvement at higher resolutions
- A ▭ not correlated with resolution.
- L ▭ without significant variability with resolution



“Our models are not perfect”

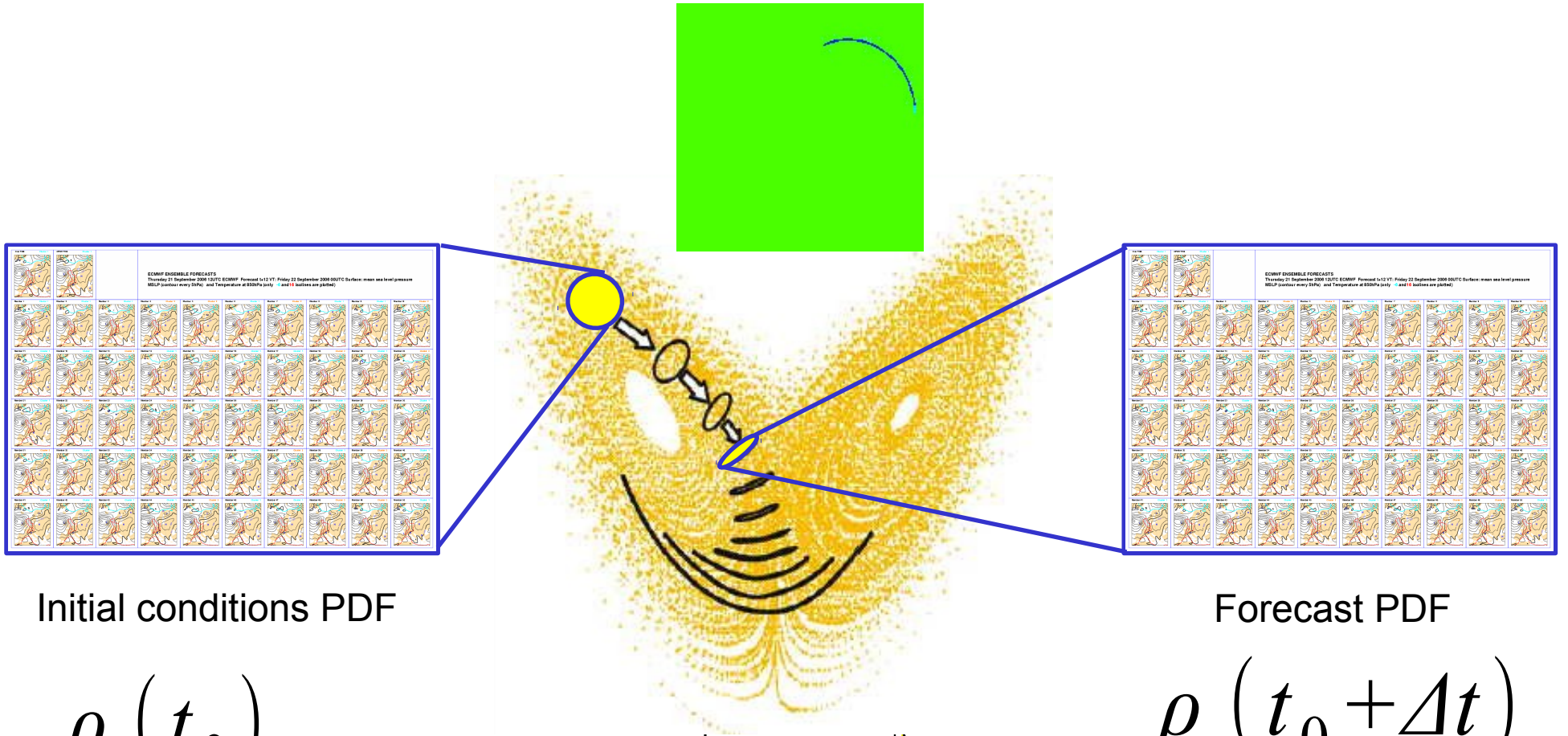
Lenny Smith,
Ensemble Conference
Toulouse, Nov 2012

That's why we use ensembles

Outline

- Are models perfect? SAL
- Predictability, probabilistic forecasts, EPSs
- ECMWF-EPS, AEMET-SREPS, GLAMEPS
- GLAMEPS
- GLAMEPS v1 (current)
- Performance
- GLAMEPS v2 (2014)
- Harmon EPS
- Conclusions
- References

What is an Ensemble Prediction System?

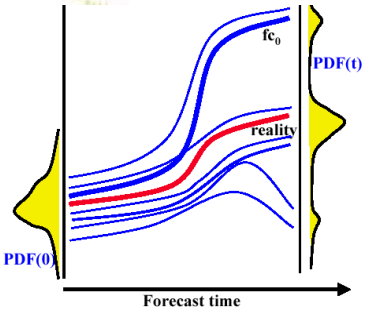


Initial conditions PDF

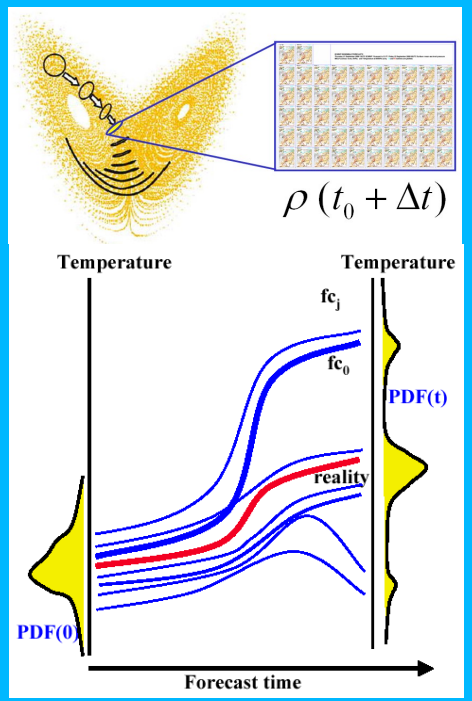
$$\rho\left(t_0\right)$$

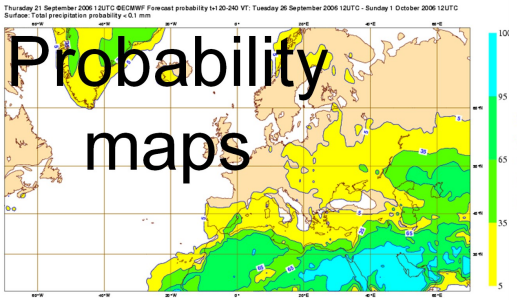
Forecast PDF

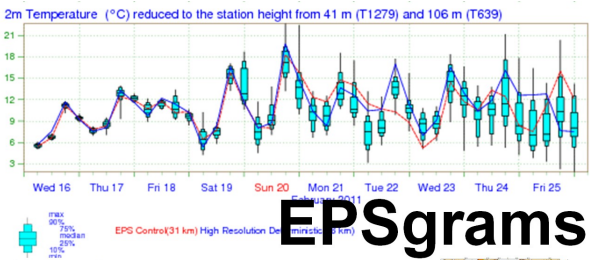
$$\rho\left(t_0+\Delta t\right)$$

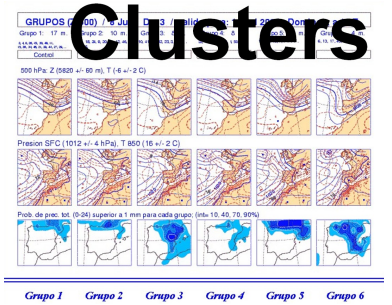


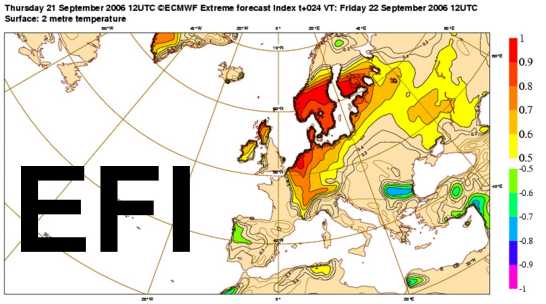
Probabilistic forecasts

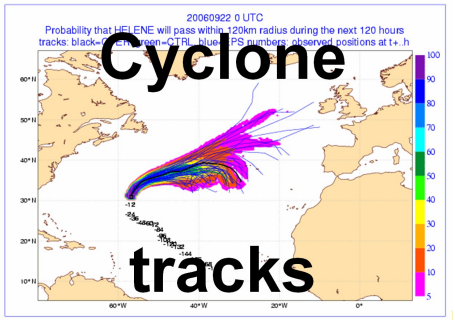




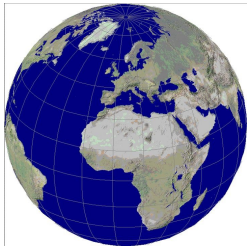








EPSs throughout the World



GCM EPS

ECMWF EPS

(1+50)x32km

SVs+EDA+Stoch

NCEP GEFS

1x50km+20x100km

BVs(Lyapunov)+ETR

MSC

20

Montecarlo, ETKF

NAEFS

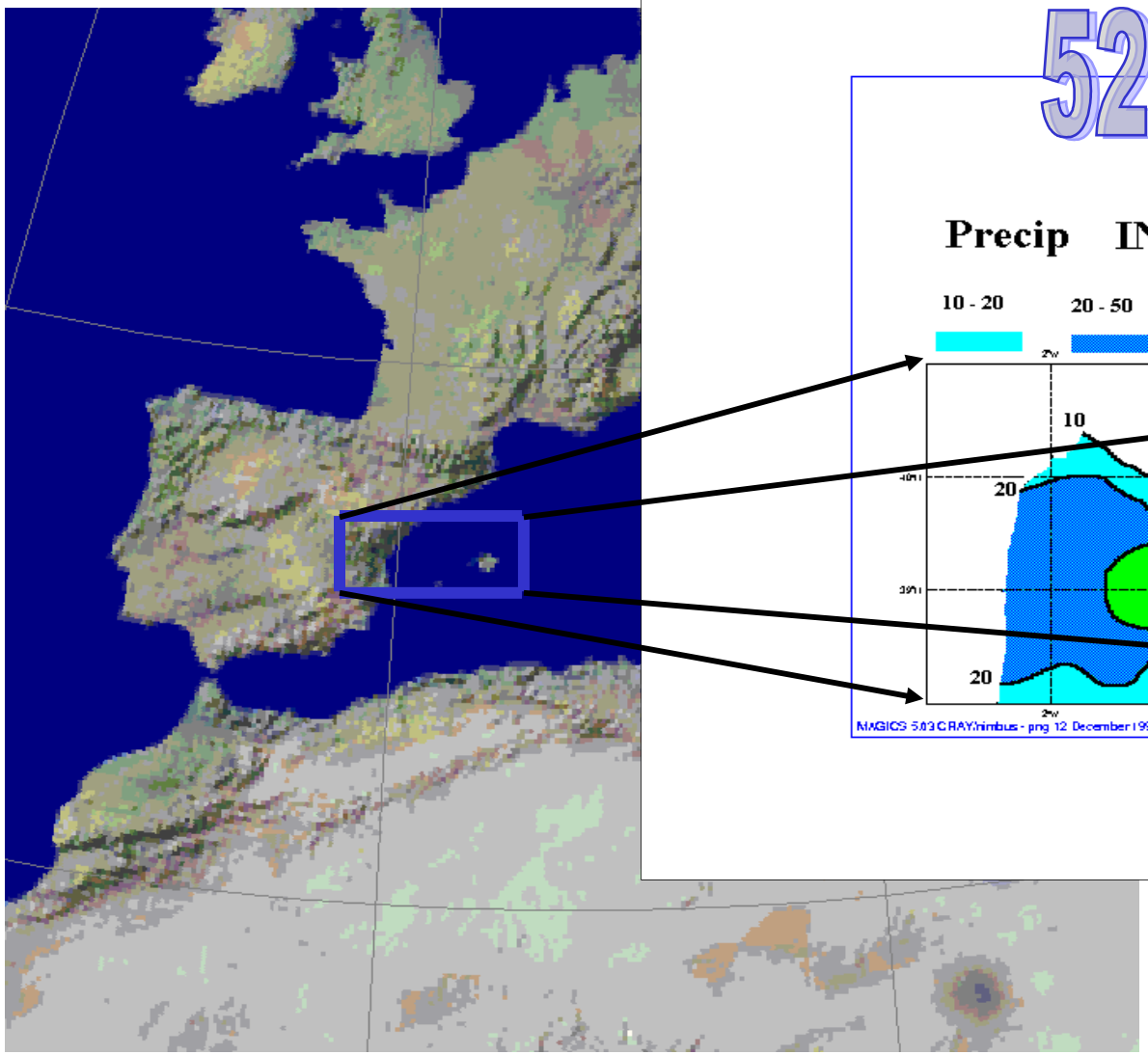
JMA

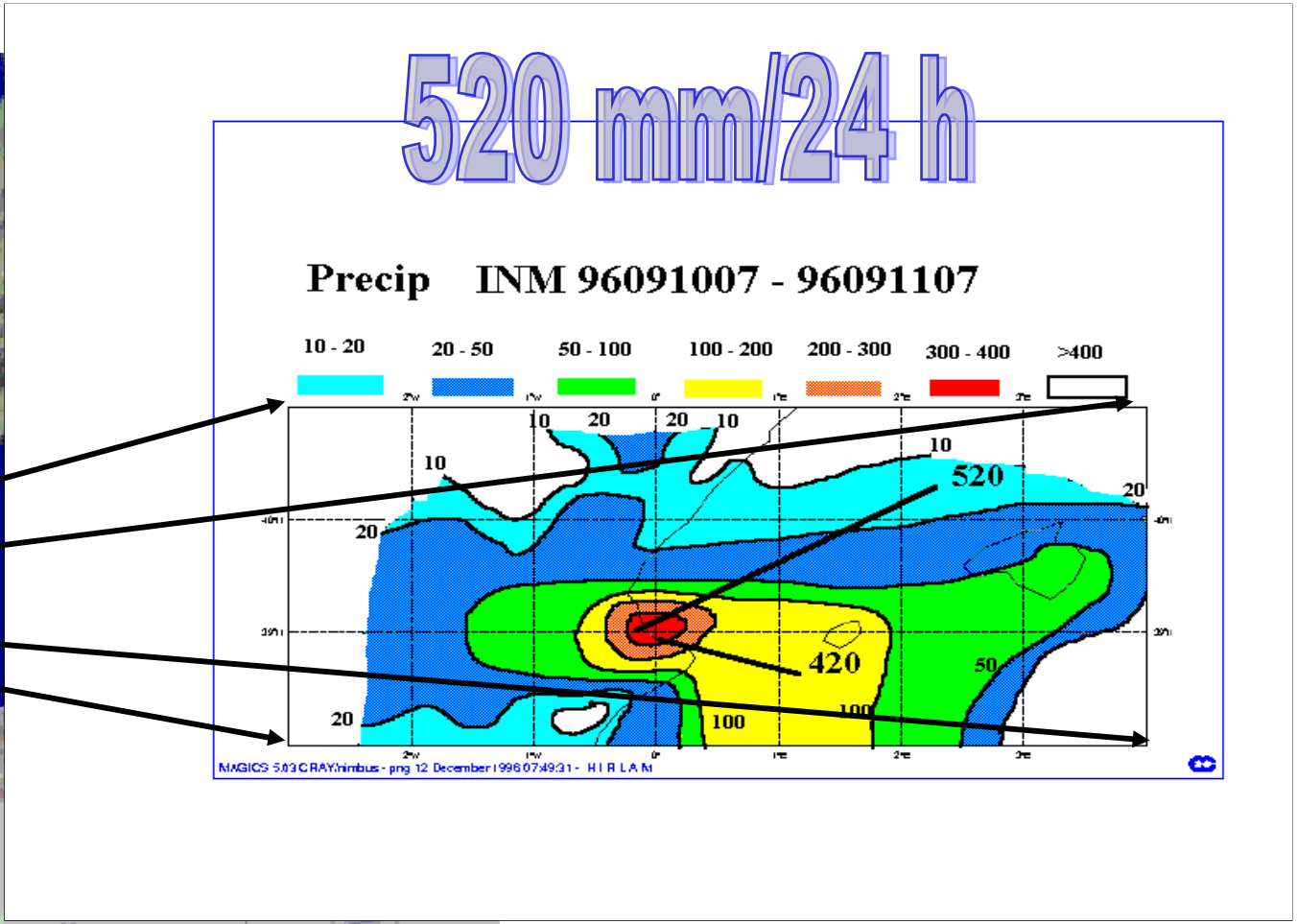
60km

normal+typhoon

UKMO

Why an EPS for SR?



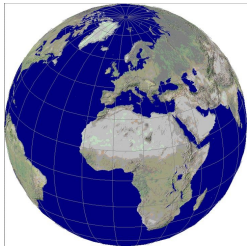


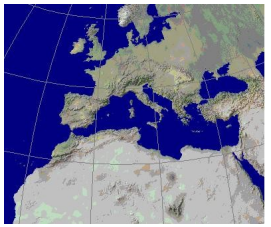
MR: ECMWF EPS

SR: AEMET-SREPS

GLAMEPS

EPSs throughout the World





GCM EPS

ECMWF EPS
(1+50)x32km
SVs+EDA+Stoch

NCEP GEFS
1x50km+20x100km
BVs(Lyapunov)+ETR

MSC
20
Montecarlo, ETKF

NAEFS

JMA
60km
normal+typhoon

UKMO

LAM EPS

AEMET-SREPS
(20)x25km
Mummub

HIRLAM GLAMEPS
(54)x11km
Mum SVs

LACE

COSMO

NCEP SREF
4km

Mesoscale-γ EPS

- Convective scale
- Cloud permitting
- Cloud resolving

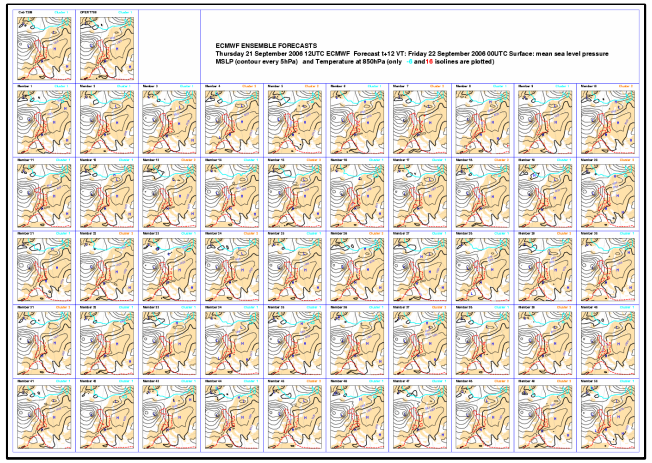
Gamma-SREPS
2.5km
LETKF+SPPT

Harmon EPS
2.5km
LETKF+SPPT

NCEP
Lots of

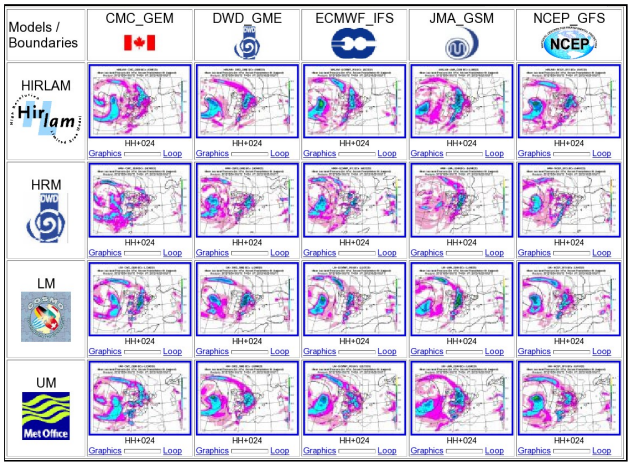
UKMO

ECMWF-EPS



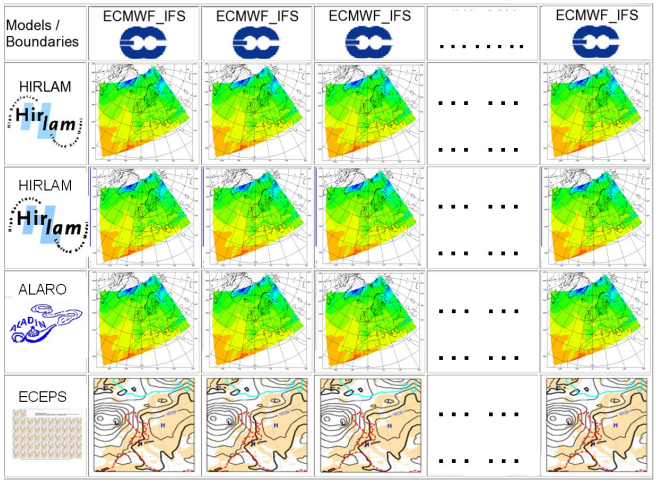
Global
One only model IFS
IC: pert (SVs + EDA)
ME: Stochastic Params
1+50 members
00, 12 UTC
+10d T639 ~ 31km
+15d T399 ~ 50km
L92

AEMET-SREPS



LAM
Multi-model
IC: multi-(ICs+LBCs)
ME: multi-model
4x5 members
00, 12 UTC
+72h
0.25º ~ 25km
L40

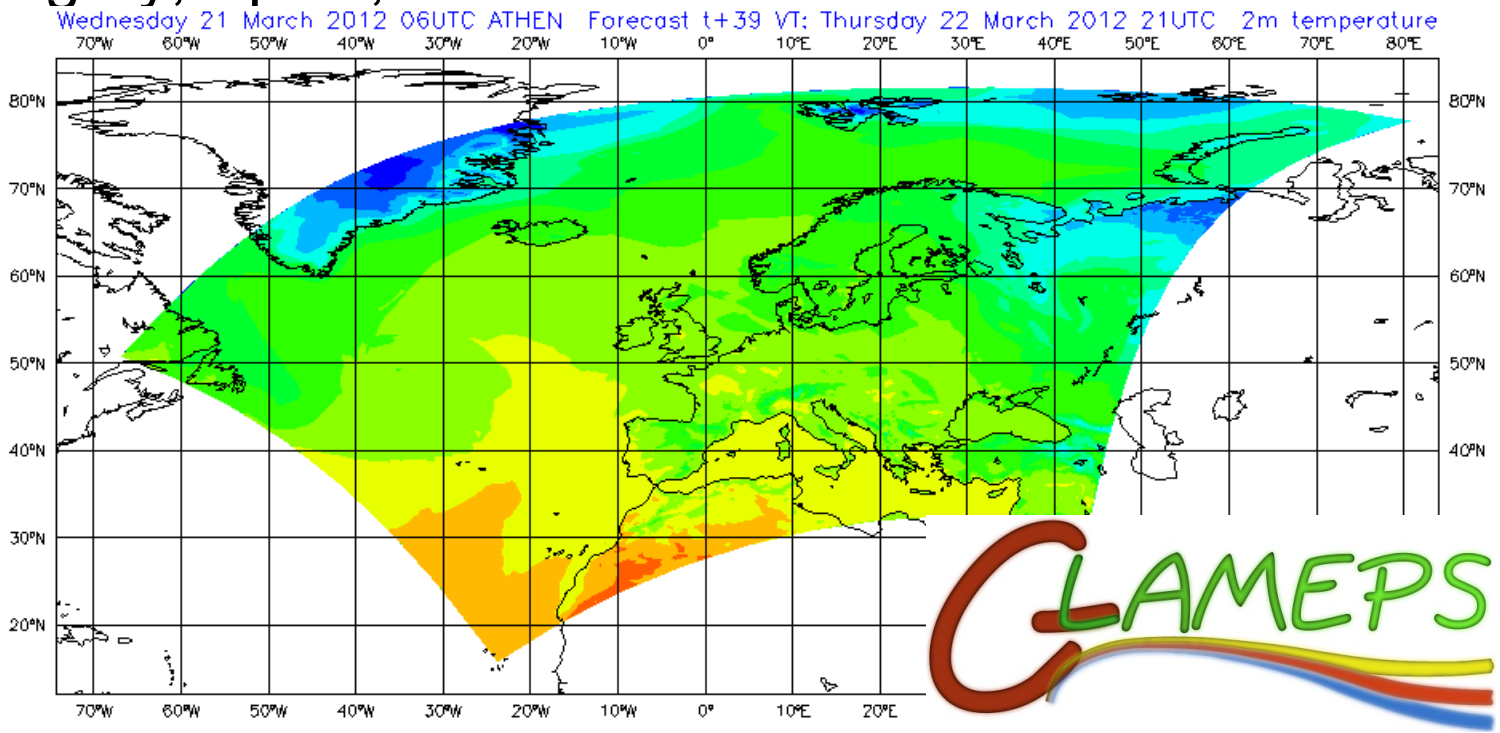
GLAMEPS



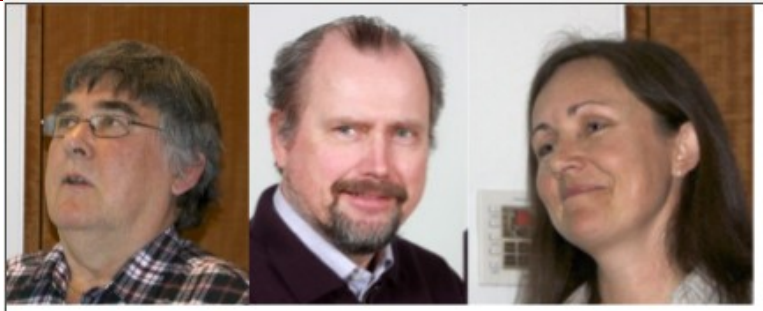
LAM
Multi-model
IC: pert (SVs + EDA)
ME: multi-model
3x(1+12)+14+1members
06, 18 UTC
+54h
0.11º ~ 11km
L40

GLAMEPS

- HIRLAM – ALADIN
- Pan-european ensemble, since 2006
- **G**rand **L**imited **A**rea **M**odel **E**nsemble **P**rediction **S**ystem = GLAMEPS
- Norway, Sweden, Finland, Denmark, Belgium, Netherlands, Hungary, Spain, Ireland



Cast

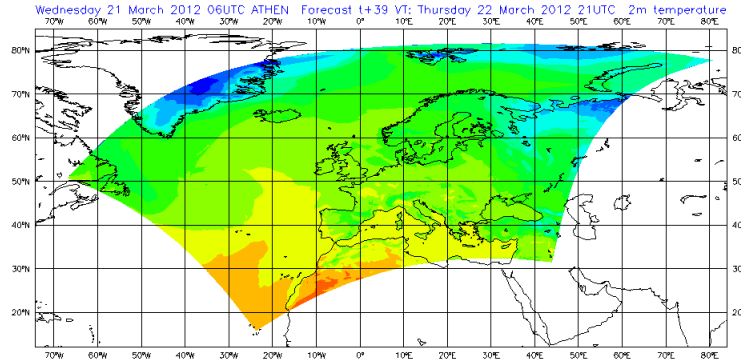


Sibbo van der Veen, Alfons Callado, Pau Escriba, Thomas Nipen, Maurice Schmeits, John Bjørnar Bremnes, Dorien Lugt, Lisa Bengtsson, Andrew Singleton, Kai Sattler, Ole Vignes, Ulf Andrae, Xiaohua Yang, Alex Deckmyn and Inger-Lise Frogner


GLAMEPS v1 (current)

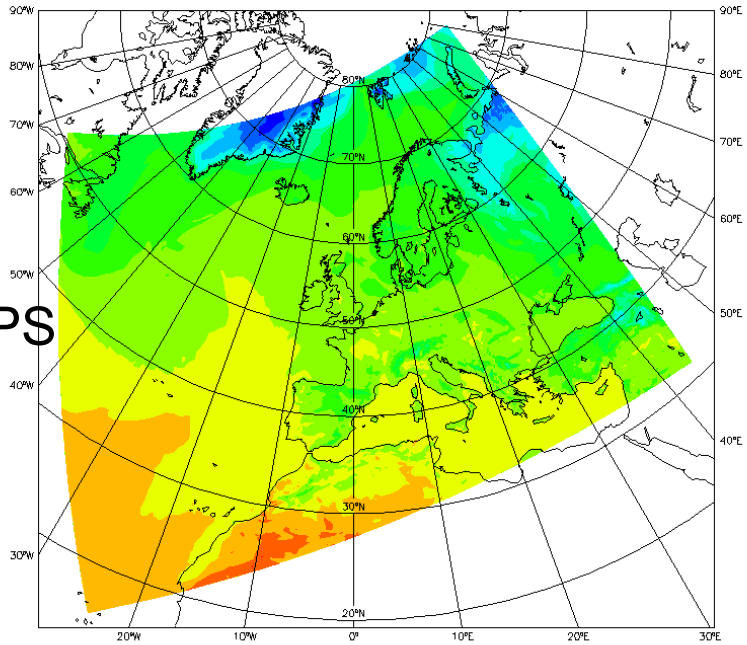
GLAMEPS as a multi-model super-ensemble

- Hirlam_Straco EPS (1+12)
- Hirlam_K.Fritz EPS (1+12)
- Aladin EPS (1+12)
- ECEPS_subset (14)
- ECIFS (1)



Settings

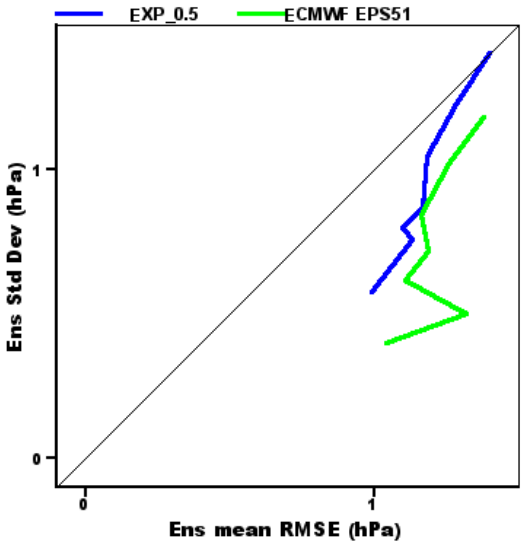
- Short Range: 06,18 UTC (EC 00,12 UTC), T+54
- Aladin: 629x529, 11.8 km, L37
- Hirlam: 646x492, 0.10° (11 km), L40
- ICs: downscaling ECMWF EPS (i.e. SVs + EDA)
- Better performance than ECMWF & AEMET-SREPS
- Runs as Time-Critical Facility at ECMWF

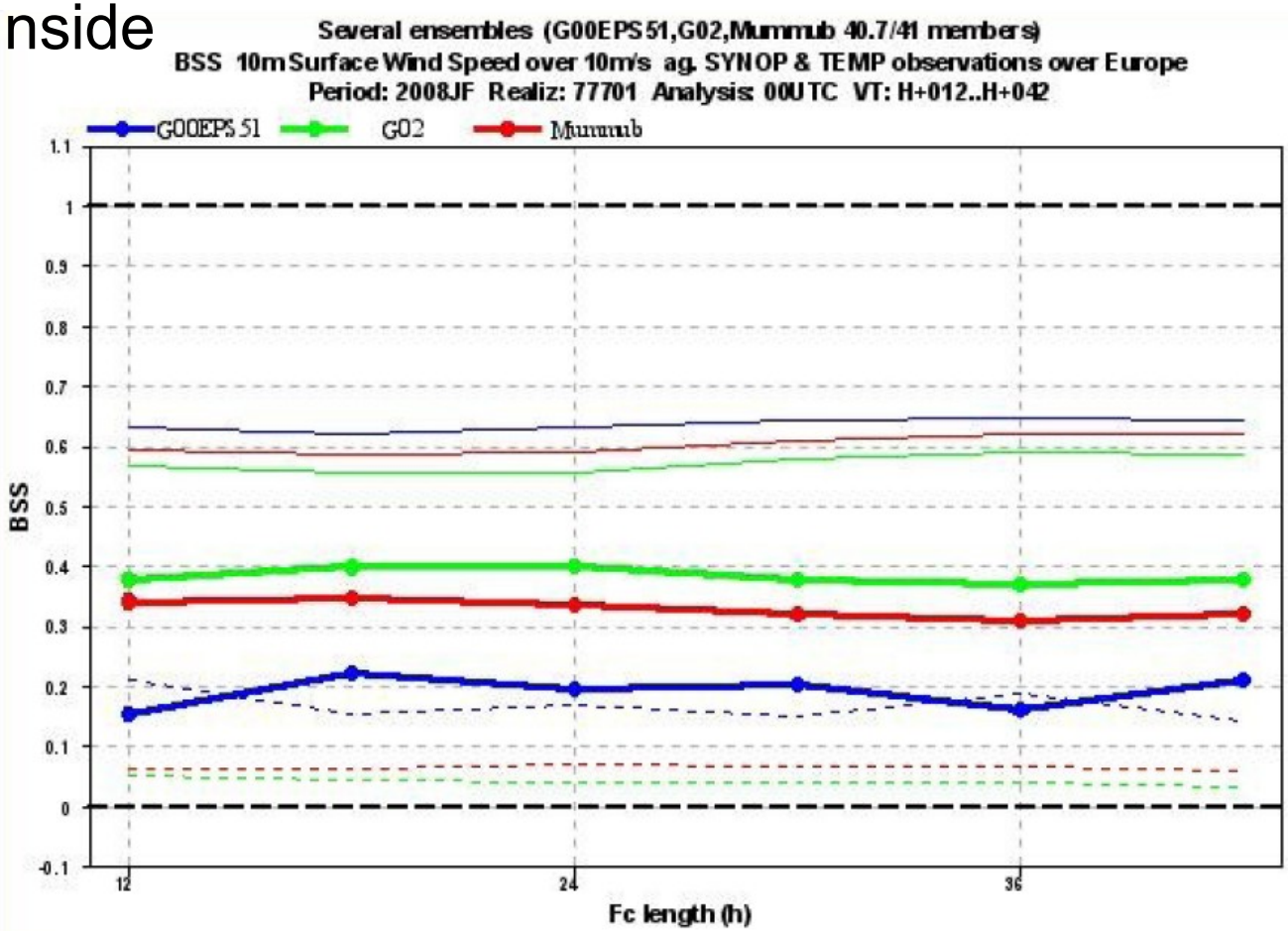


GLAMEPS v1 performance

Higher than ECMWF & AEMET-SREPS

- Multi-model nature
- +perturbations
- ECMWF-EPS subset inside
- Higher resolution

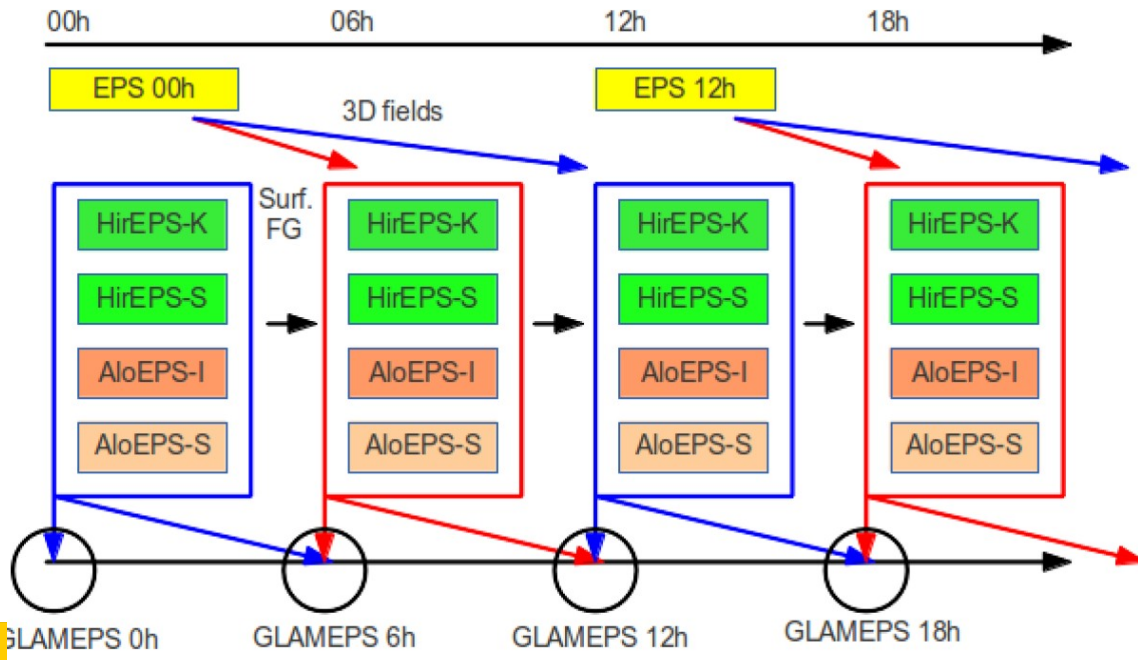




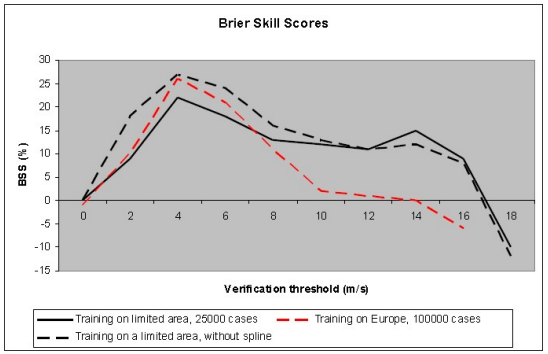
GLAMEPS v2 (2014)

R&D improvements

- Increase the number of Alaro ensemble members (new with Surfex) at expense of the EC EPS members
- 4 times per day (lagged ensembles, 25 new every six hours and 25 from six hours earlier)
- Increased resolution (~8 km).
- Updated model versions
- Including CAPE SV perturbations

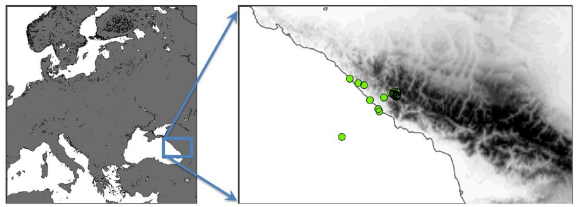


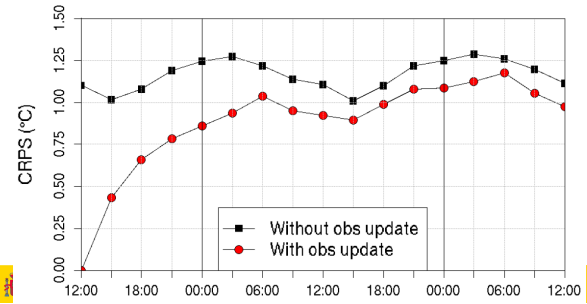
GLAMEPS v2 (2014)



Calibration 10m wind

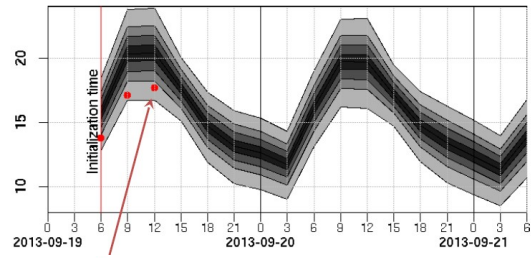
- Statistical post-processing [Extended] Logistic Regression
- Nov 2011 (tr), Dec 2011 (vf), European stations, +18 h
- Predictors: ensemble mean, latitude, longitude, altitude of stations
- Significant improvements both reliability and resolution
- Better results for higher thresholds training on a limited area

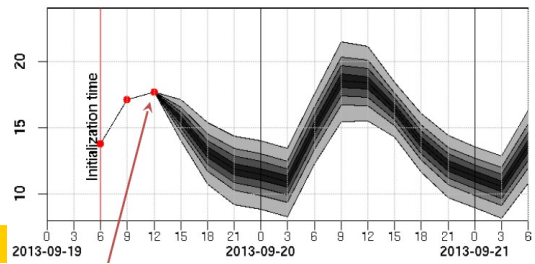




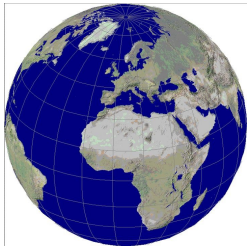
Calibration 2mT

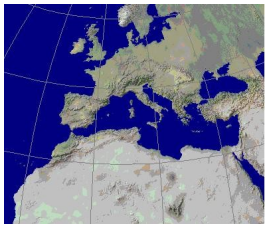
- Sochi Olympics,
- Prob fc for 30 stations
- Frequently updated forecasts





EPSs throughout the World





GCM EPS

ECMWF EPS
(1+50)x32km
SVs+EDA+Stoch

NCEP GEFS
1x50km+20x100km
BVs(Lyapunov)+ETR

MSC
20
Montecarlo, ETKF

NAEFS

JMA
60km
normal+typhoon

UKMO

LAM EPS

AEMET-SREPS
(20)x25km
Mummub

HIRLAM GLAMEPS
(54)x11km
Mum SVs

LACE

COSMO

NCEP SREF
4km

Mesoscale-γ EPS

- Convective scale
- Cloud permitting
- Cloud resolving

Gamma-SREPS
2.5km
LETKF+SPPT

Harmon EPS
2.5km
LETKF+SPPT

NCEP
Lots of

UKMO

Harmon EPS

Transition to γ - mesoscale

- A convection-permitting EPS
- Sub-European and Sochi-area
- 2.5 km resolution
- T+36 lead time
- Full DA and 6 h cycling for the control
- HarmonEPS to be run every 12 h
- Surface assimilation included for every member
- 20 members, 10 members with AROME and 10 with ALARO ~ continue multi-model approach
- IC perturbations: LETKF, comparison with 4DVAR, EDA, ECEPS downscaling
- Model error: SPPT and multi-physics
- CA: A stochastic parameterization for deep convection organization using cellular automata
- LBCs: ECEPS T639 vs ECEPS T1279

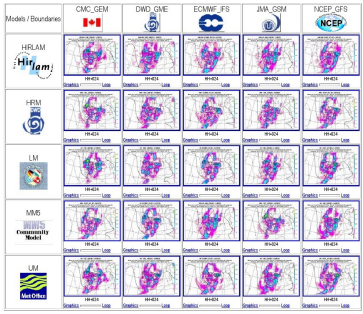
AEMET-SREPS fc tools

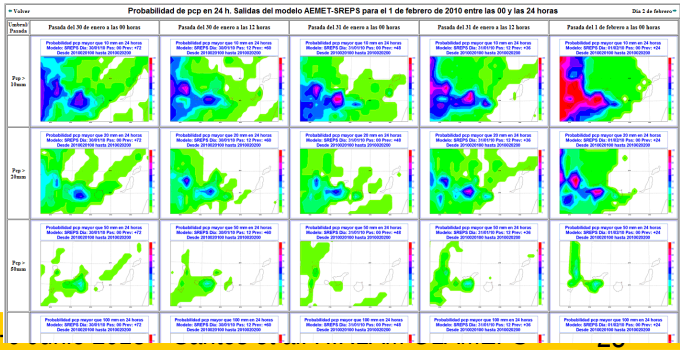
AEMET-SREPS: Buen ejemplo folklórico

- Buen trabajo con eco internacional (pionero en Europa)
- No implantado oficialmente por el carácter no-lineal de la organización

PERO recordad que lo teneis disponible!!!

- Twice daily (00 and 12 UTC), SR: AEMET-SREPS, MR: ECMWF-EPS
- En sur.inm.es y en página ATAP > SREPS
- Migración a mesoescala gamma: γ-SREPS

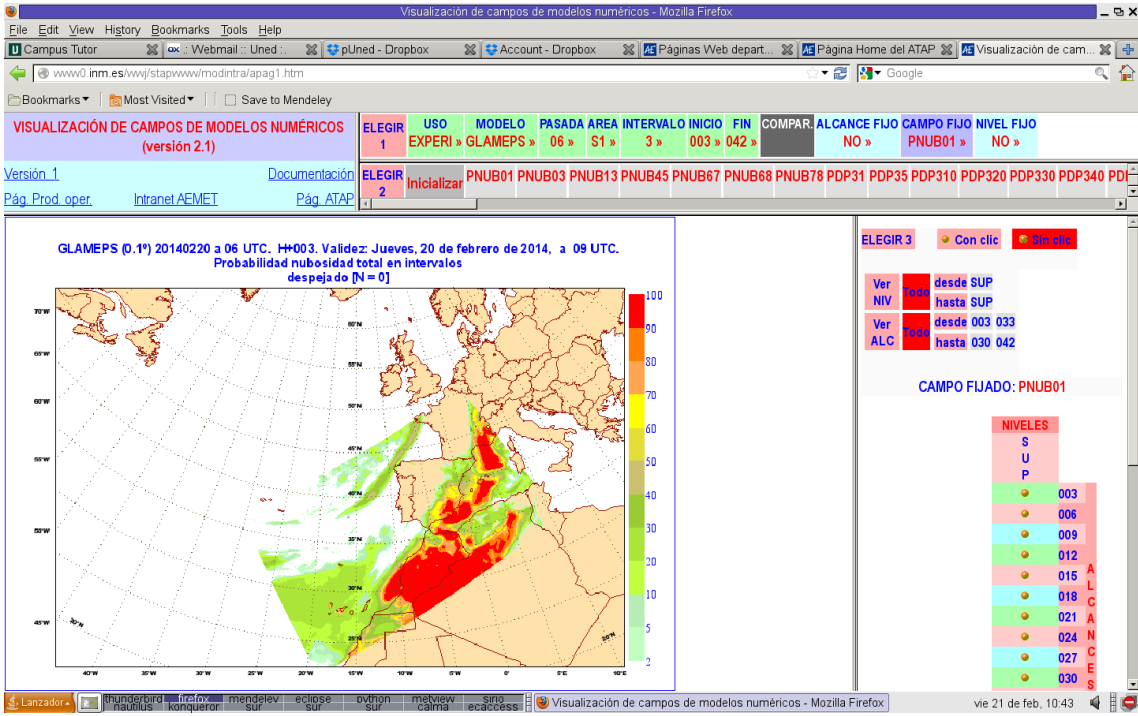


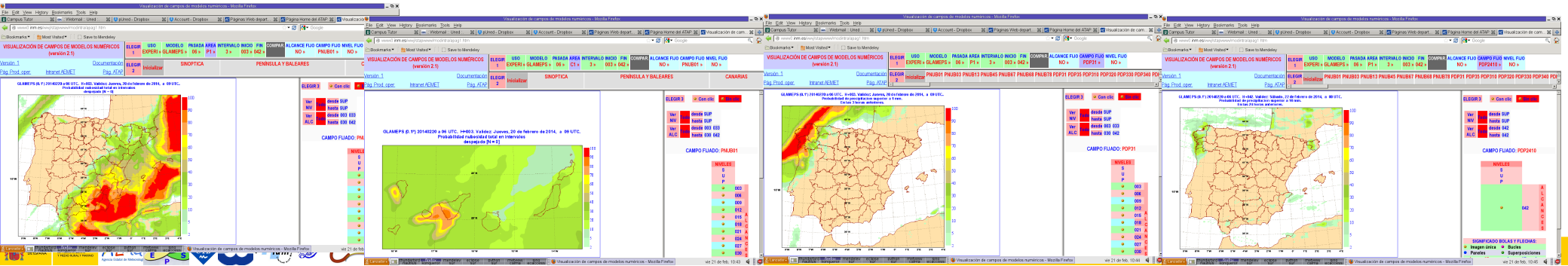


GLAMEPS fc tools

Ya disponible!!!

- Twice daily (06 and 18 UTC)
- Feliciano's web site
- Ensemble 54 miembros
- 10 km
- Península & Canarias

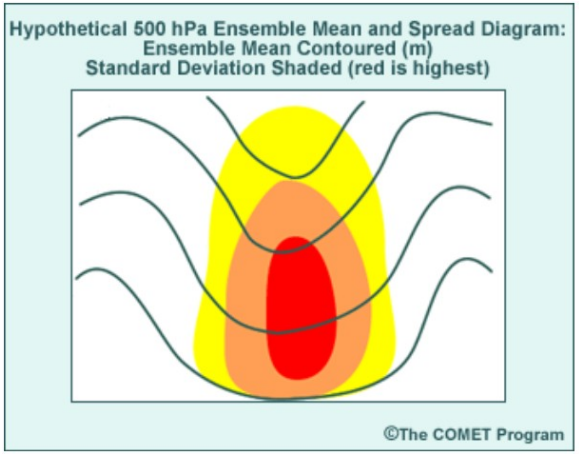


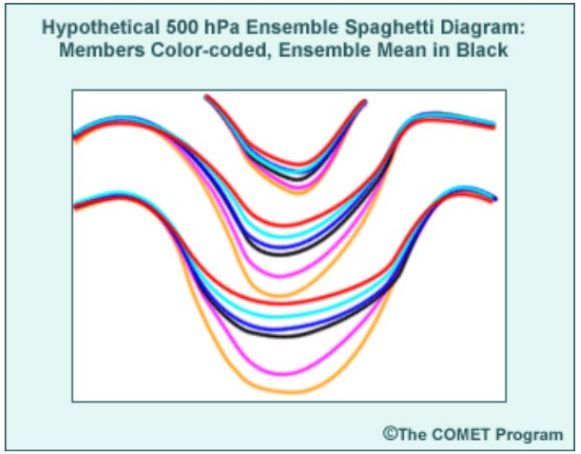


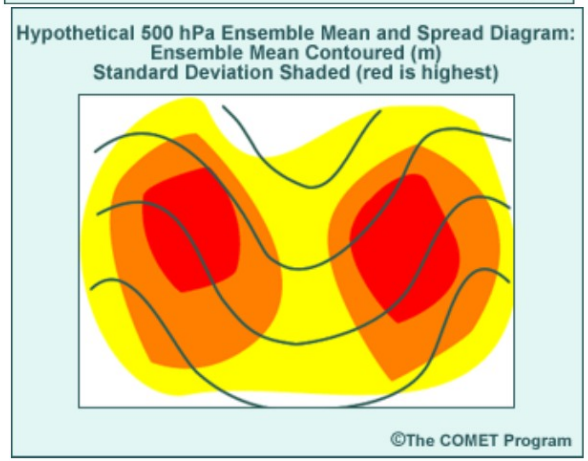
Spread

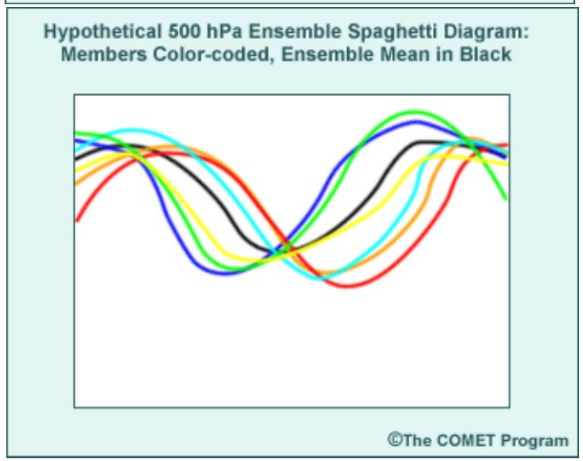
Interpretación

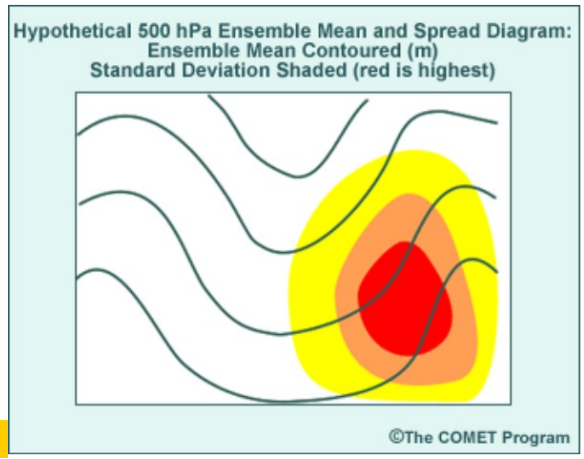
- Sobre eje vaguada, más incertidumbre en **intensidad**
- Corriente arriba y abajo (ambos lados), más incertidumbre en **posición**
- A un lado solamente, características menos predecibles ocultas por el suavizado (menor escala a menudo)

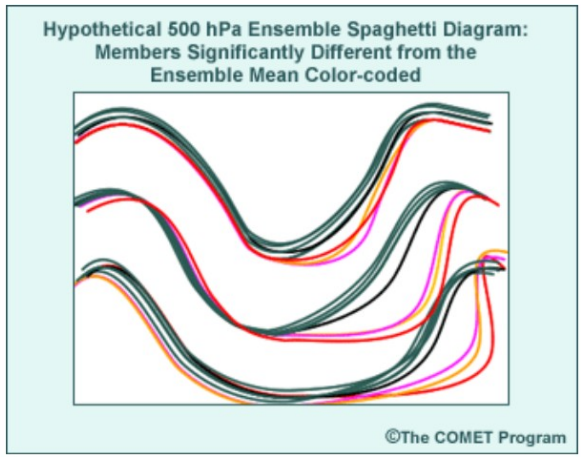




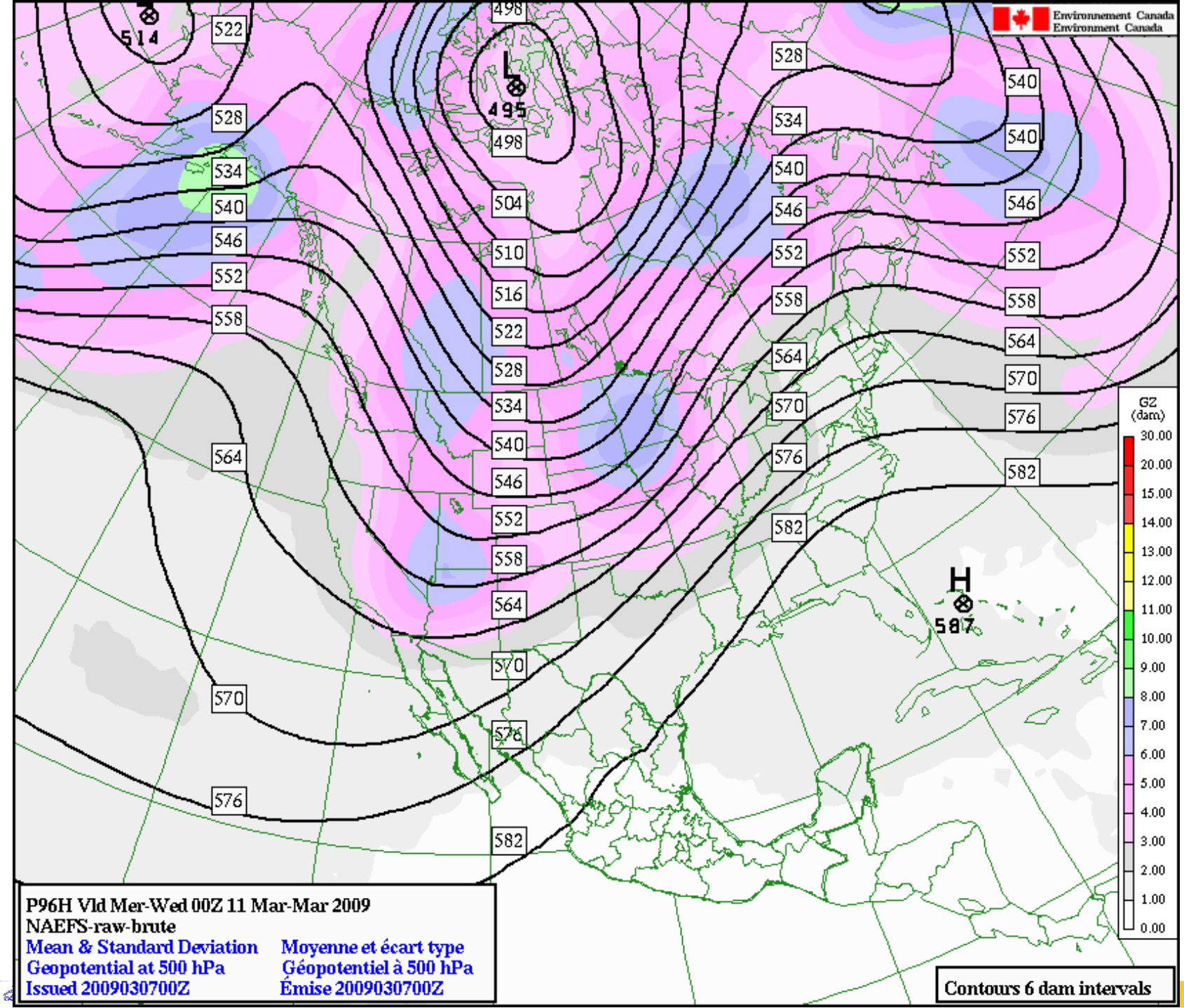








Spread: ejemplo



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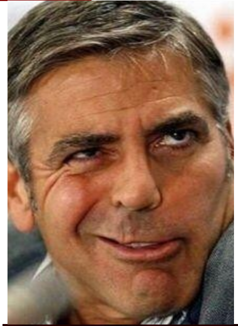
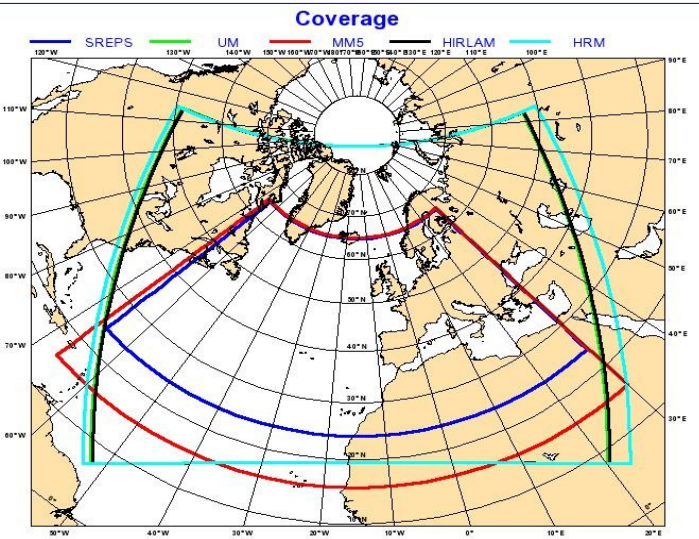


Gracias

Bonus slides

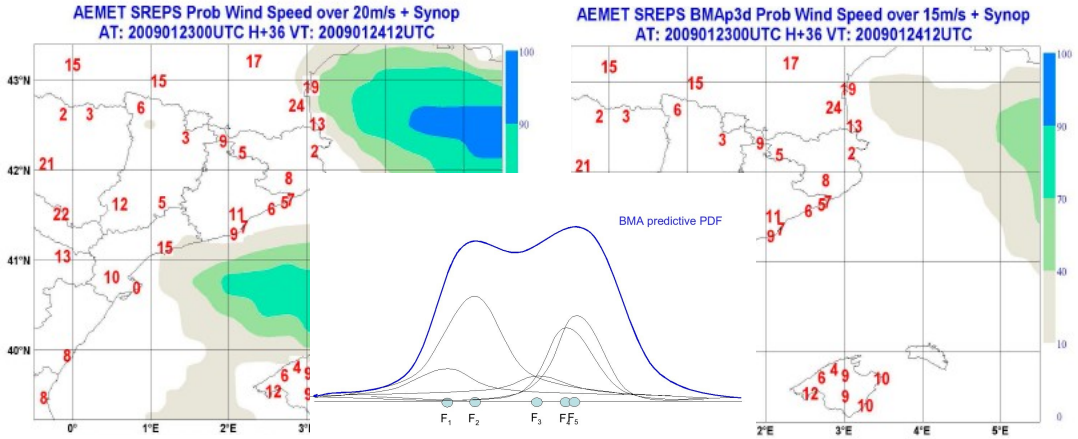
AEMET - SREPS

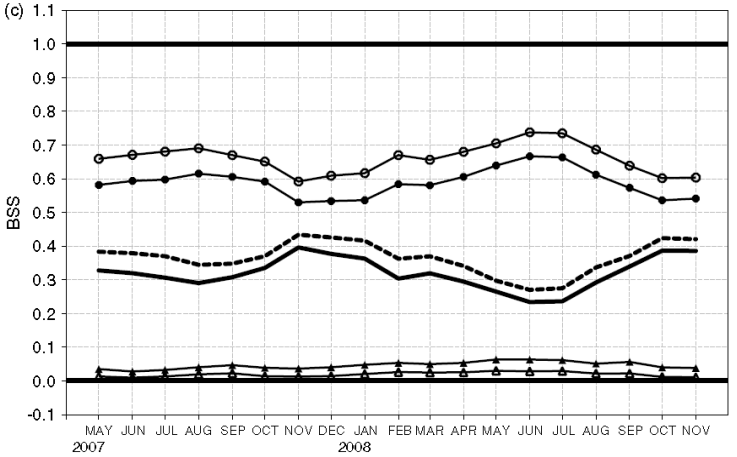


Models / Boundaries	CMC_GEM	DWD_GME	ECMWF_IFS	JMA_GSM	NCEP_GFS
HIRLAM	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop
HRM	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop
LM	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop
UM	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop	HH+024 Graphics Loop

- Multi-model, Multi-ICs, Multi-LBCs
- Twice a day (00,12 UTC) up to T+72
- 4 LAMs x 5 GCMs = 20 members
- 0.25º ~ 25 km

More research





Statistical calibration

Several works were done using Bayesian Model Averaging (BMA, Raftery, 2004) to calibrate the ensemble PDF with the observations. Albeit improving the accumulation scores, **extreme events are still an issue** (Escribà et al., 2011).

Observational uncertainty

In forecast verification it has been traditionally assumed that the observation error is negligible when compared with the forecast error. Though this assumption can be consistent for long forecast ranges, in a more general framework observations are described together with their uncertainty, **avoiding underestimation of EPS performance**. In this context, *Observational Probability* method (Candille and Talagrand, 2008) was extended for precipitation (Santos and Ghelli, 2012).

AEMET- γ -SREPS

Research phase

- SREPS (25 km) $\rightarrow$ γ-SREPS (2.5 km)
- **Convergence with GLAMEPS:** staff and efforts, but an independent suite
- Road map: 2012-2013 research phase

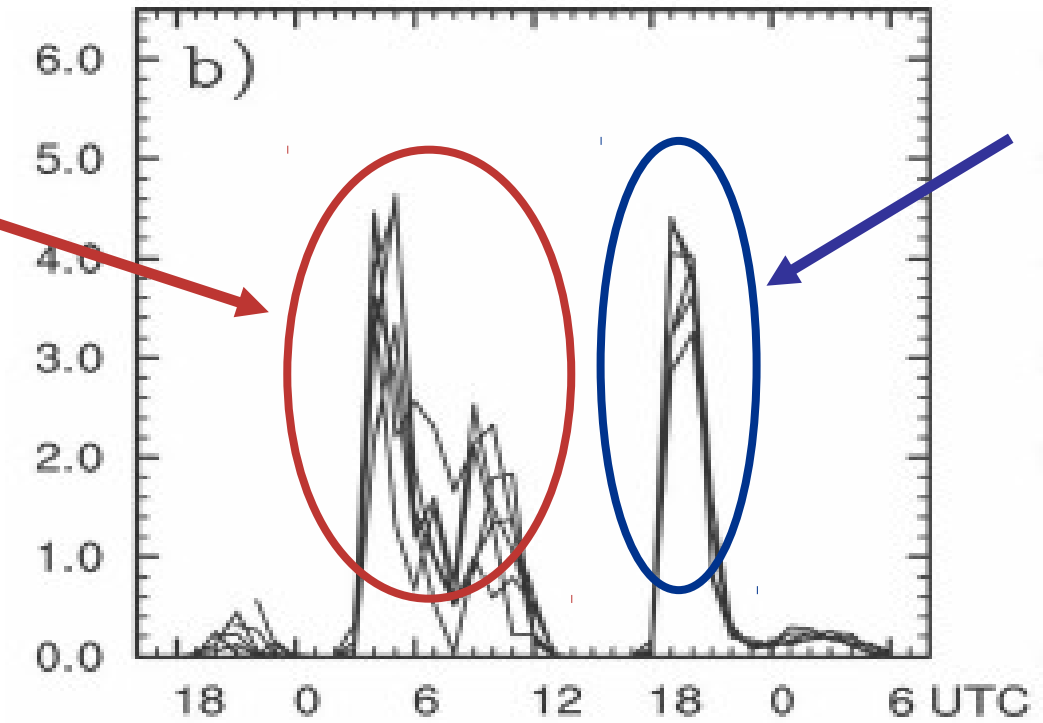
Research lines

- **Predictability issues** at convective scale are different than at synoptic/mesoscale
- Starting point: HARMONIE as base model
- Sampling uncertainties: SPPT (model), LETKF (ICs), LBCs
- Case studies: according to scale
- Feature-based verification: MODE
- Python wrapping

Predictability issues at convective scale

Predictability limits at convective-scales and their influence to higher scales (Hohenegger & Schär, 2007)

1-hour Accumulated Precipitation



First meso-γ-scale Less predictability

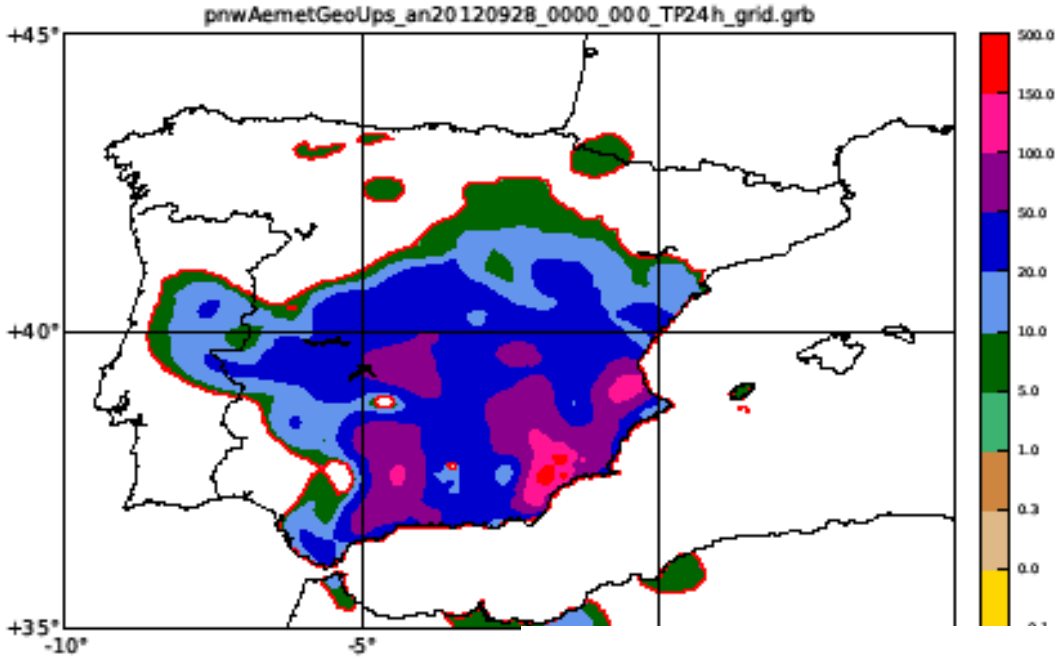
Later meso-β-scale More predictability

Convective instability

Pre-frontal convection

Cold front

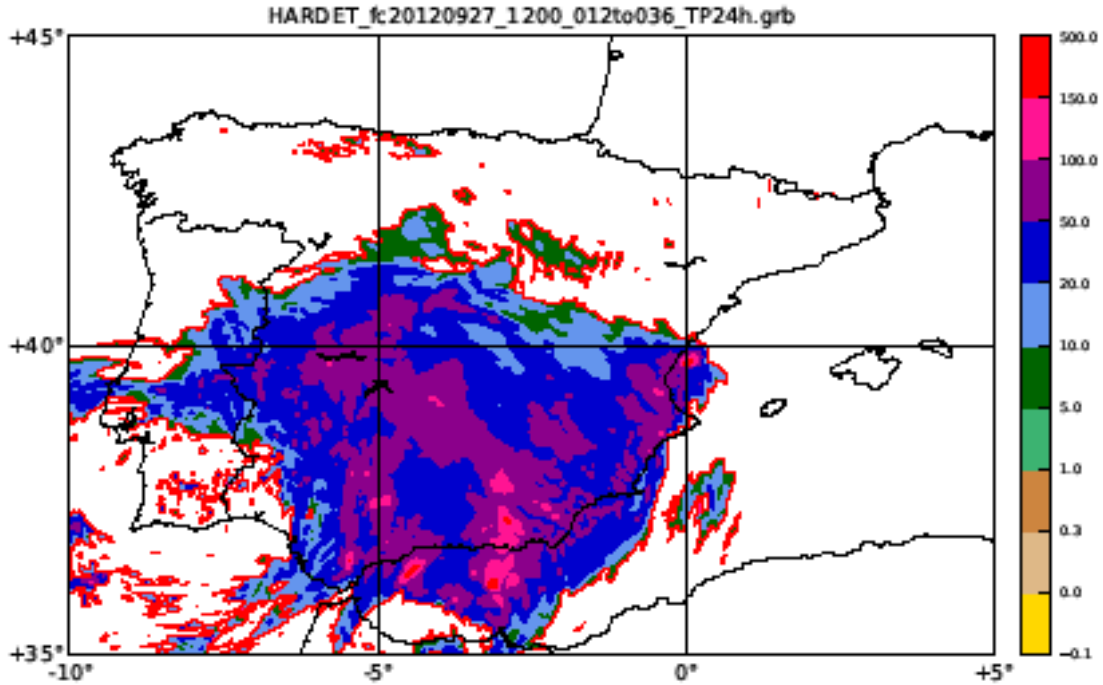
Baroclinic instability



HARMONIE in HYMEX/ IOP8 2012-09-28

Obs

Mod



Acknowledgements

·J.A. García-Moya was the alma mater for many years and had to leave the group due to external non-linear forcing dynamics. I ask you for a warm applause for him.

- E. Kalnay (Univ Maryland) for her grip at the beginning of the project.
- For their support on LAMs, ICs or BCs we give specific mention to J. Bornemann and K. Mylne from UKMO, D. Majewski, M. Gertz and M. Denhard from DWD, C. Marsigli, A. Montani and U. Schättler from the COSMO Consortium. Metview Team (ECMWF) support was essential.
- Precious discussions were held with A. Ghelli, M. Leutbecher, R. Buizza (ECMWF), M. Göeber (DWD), P. Nurmi (FMI), P. Doblas-Reyes (IC3), V. Homar, R. Romero (UIB), O. García, B. Navascués, J. A. López, A. Chazarra, J. Calvo and I. Martínez (AEMET).
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- In GLAMEPS project, K. Satler (DMI) help with technical issues has been always critical.
- We would also like to acknowledge ECMWF member and cooperating states (and also to A. Ghelli, ECMWF) for providing their climate network precipitation data.
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- This work is partially funded by project PREDIMED CGL2011-24458 from the former Spanish Ministry of Science and Innovation.

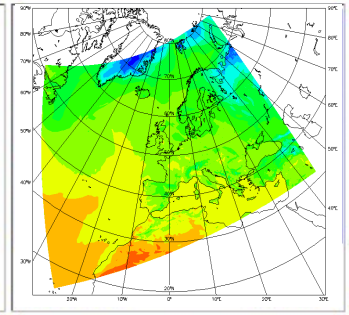
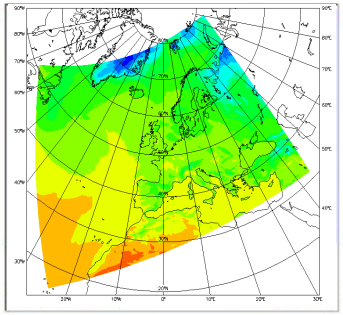
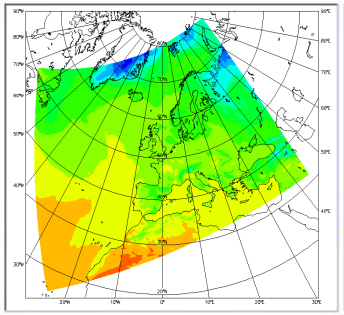
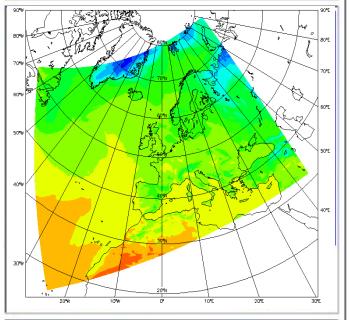
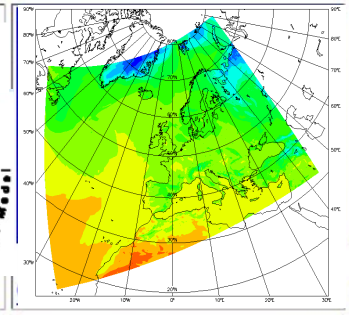
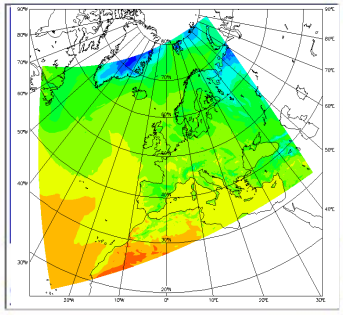
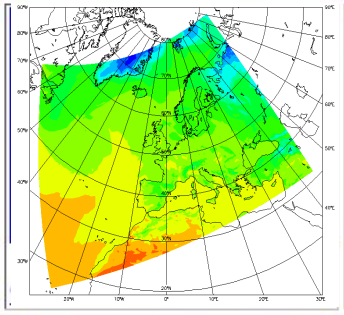
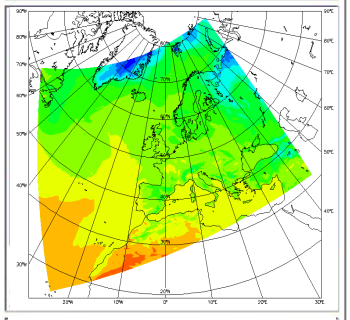
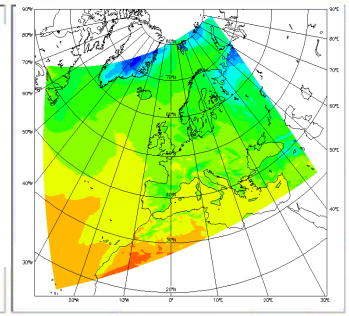
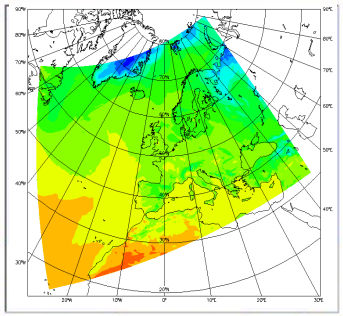
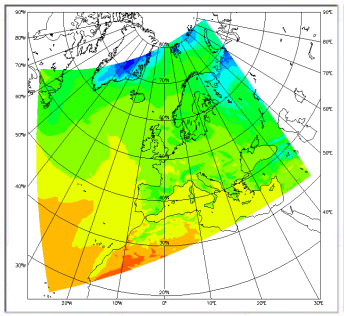
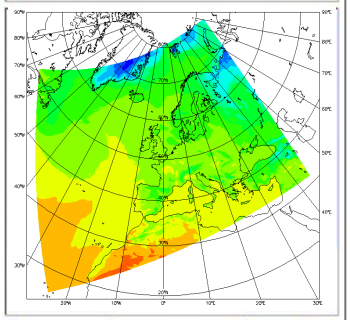
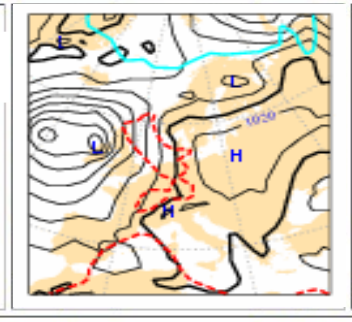
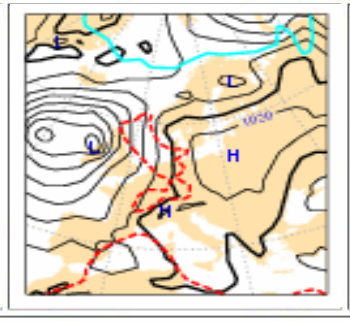
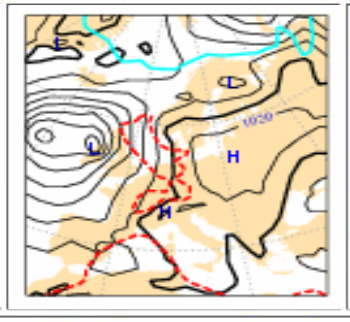
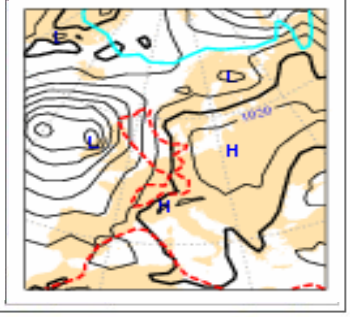
ECMWF resolutions

ECMWF Operational Model Resolution (< 26 Jan 2010)

- Det: T799L91 25 km GG 0. 25º in MARS
- Eps: T399L62 50 km GG 0.5º in MARS

ECMWF Operational Model Resolution (> 26 Jan 2010)

- Det: T1279L91 16 km GG 0.125º in MARS
- Eps: T639L62 31 km GG 0.25º in MARS

Models / Boundaries	ECMWF_IFS	ECMWF_IFS	ECMWF_IFS	...	ECMWF_IFS
HIRLAM				...	
HIRLAM				...	
ALARO				...	
ECEPS				...	

Harmon EPS: Uncertainty strategies

Initial condition perturbations:

- Perturbations from EC EPS
- Humidity perturbations: humidity in SVs, use of MSG cloud mask
- Later LETKF/EnVAR/4DEnVAR

Lateral boundary perturbations:

- Tested EPS (T639) vs EPS (T1279)
- Difference between deterministic runs / SLAF

Model error

- Multi-model
- SPPT
- physics parameter perturbations
- Introduce "stochastic physics" on process level, rather than multiplying the total physical tendencies
- Use Cellular Automata (CA)

Ground surface uncertainties

GLAMEPS verification numbers 2011

How many files?

- 4 sub-ensembles, 12+1[+1+1] each ~ 54 members
- 00 and 12 UTC = 2 run times
- 3/TO/42/BY/3 = 13 forecast steps
- 54·2·13 = **1378 daily files**

How many parameters inside?

- Intermediate output set: z500, t500, t850, mslp, 10mW, gusts, 2mT, AccPcp, etc = 18 params
- Minimum verif set: z500, t850, mslp, 10mW, gusts, 2mT, AccPcp = 8 params

Data volume to process daily?

- Intermediate set: 11 Mb/file ~ **30 Gb**
- Minimum verif set: 5 Mb/file ~ 18 Gb

Data volume to process?

- ~ 540 Gb monthly,
- ~ 1500 Gb seasonally
- ~ **10 Tb yearly**

Who to compare with?

- ECMW EPS = 1 set of graphs
- Deterministic HARMONIE (not here) = x2

Deterministic verification (a minimum)

- Bias & RMSE for any member + ensemble mean = 2 daily (or season) graphs

Probabilistic verification: large scale flow

- Dynamical fields typically z500, t500, t850, mslp: spread-skill + talagrand = 8

Probabilistic verification: weather parameters

- 2mT, wind, AccPcp: here come the thresholds!!!
- E.g. prob (pcp>=0.3,1,5,10…) = x5, x10
- Reliability, Sharpness, ROC, RV = x3
- BS, BSrel, BSres, BSS, BSSrel, BSSres[and decompositions?] = x3
- DRPS, CRPS, DRPSS, CRPSS [and decompositions?] = x2

The number of possible verification graphs grows up to 10 000 → we need to select a summary of information to show

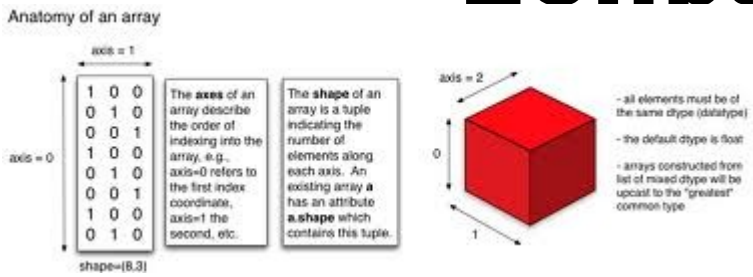
Verification Software

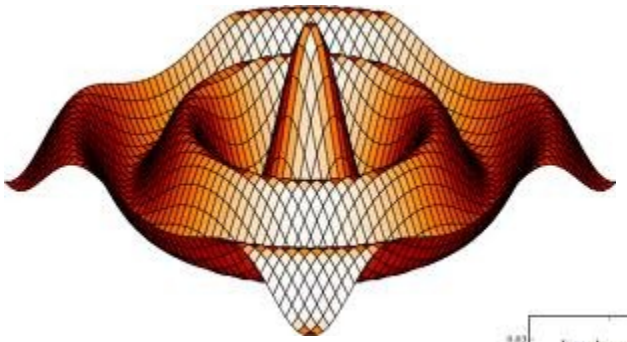
·No hay paquetes de verificación completos ni estandarizados (de hecho no hay un sistema abstracto estándar de verificación)

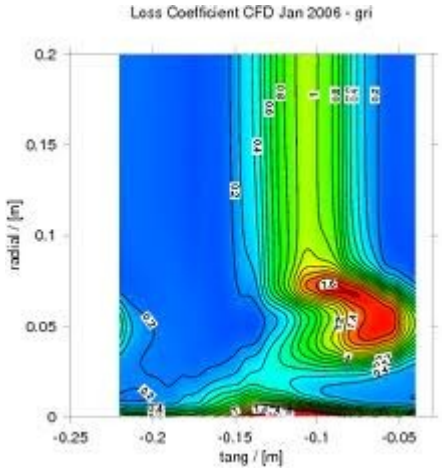
- Inmensos volumen y diversidad de datos: GRIB, netCDF, BUFR, etc
- Volumen / complejidad colosales de metadatos: SQL o similar
- Entorno de desarrollo
- Lenguaje de programación OO
- Soporte array, estadístico, geográfico, gráfico, plug-in de C++/Fortran

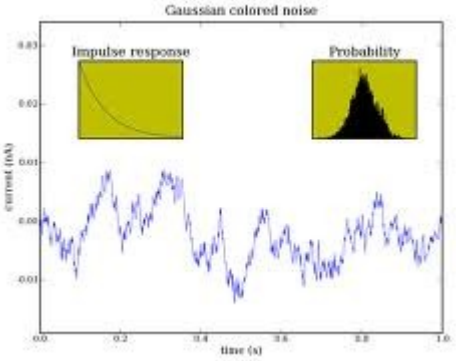
- Algunas opciones
  - Model Evaluation Toolkit (MET, NCAR)
  - Paquete de verificación R (CRAN)
  - **MetPy+Verify** (ECMWF pero no liberado)
- Python
  - Ofrece ventajas descritas arriba
  - Niveles scripting / alto / medio / bajo
  - Utilizado en NCEP / NCAR / NSSL (Wicker 2005: Improving Scientific Productivity using Python: An Example from an Ensemble Data Assimilation System in Meteorology)

Python development: NumPy, SciPy, matPlotLib, MYSQLdb, Eclipse



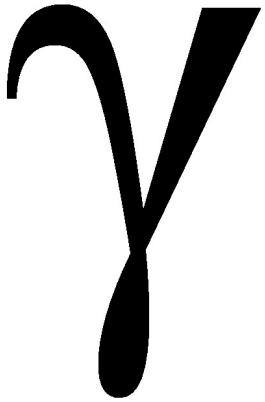






Conference

Title of the talk



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