



The new ECMWF VArIable Resolution EPS (VAREPS)

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The current 15-day VAREPS

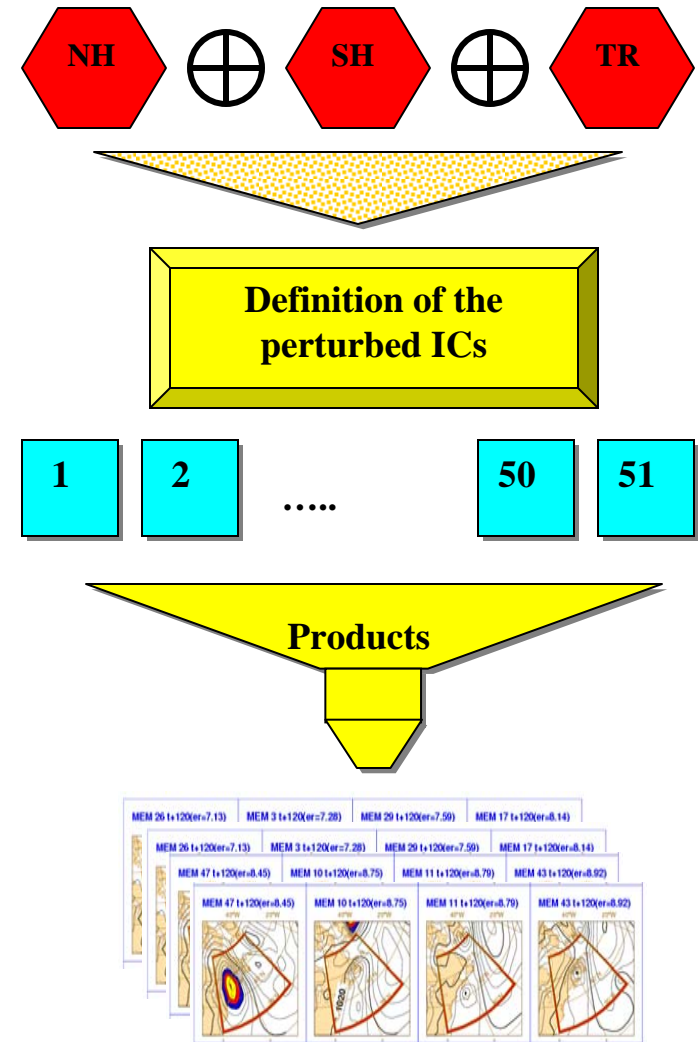
The Ensemble Prediction System consists of 51 forecasts run with variable resolution:

- $T_{L399L62}$ (~50km, 62 levels) from day 0 to 10
- $T_{L255L62}$ (~80km, 62 levels) from day 10 to 15.

The EPS is run twice a-day, at 00 and 12 UTC.

Initial uncertainties are simulated by perturbing the unperturbed analyses with a combination of T42L62 singular vectors, computed to optimize total energy growth over a 48h time interval (OTI).

Model uncertainties are simulated by adding stochastic perturbations to the tendencies due to parameterized physical processes.





Since May '94 the EPS configuration changed 15 times

Between Dec 1992 and Sep 2006 the ECMWF system changed several times: ~50 model cycles (which included changes in the model and DA system) were implemented, and the EPS configuration was modified 15 times.

Date	Description	Singular Vectors's characteristics					
		HRES	VRES	OTI	Target area	EVO SVs	sampl
Dec 1992	Oper Impl	T21	L19	36h	globe	NO	sim
Feb 1993	SV LPO	"	"	"	NHx	"	"
Aug 1994	SV OTI	"	"	48h	"	"	"
Mar 1995	SV hor resol	T42	"	"	"	"	"
Mar 1996	NH+SH SV	"	"	"	(NH+SH)x	"	"
Dec 1996	resol/mem	"	L31	"	"	"	"
Mar 1998	EVO SV	"	"	"	"	YES	"
Oct 1998	Stoch Ph	"	"	"	"	"	"
Oct 1999	ver resol	"	L40	"	"	"	"
Nov 2000	FC hor resol	"	"	"	"	"	"
Jan 2002	TC SVs	"	"	"	(NH+SH)x+TC	"	"
Sep 2004	sampling	"	L40	"	"	"	Gauss
Jun 2005	rev sampl	"	"	"	"	"	"
Feb 2006	resolution	"	L62	"	"	"	"
Sep 2006	VAREPS	T42	L62	48h	(NH+SH)x+TC	YES	Gauss

Forecast characteristics				
HRES	VRES	Tend	#	Mod Unc
T63	L19	10d	33	NO
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"
TL159	L31	"	51	"
"	"	"	"	"
"	"	"	"	YES
"	L40	"	"	"
TL255	"	"	"	"
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"
TL399	L62	10d	"	"
TL399(0-10)+TL255(10-15)	L62	15d	51	YES



Key characteristics of the 9 Operational Global EPSs

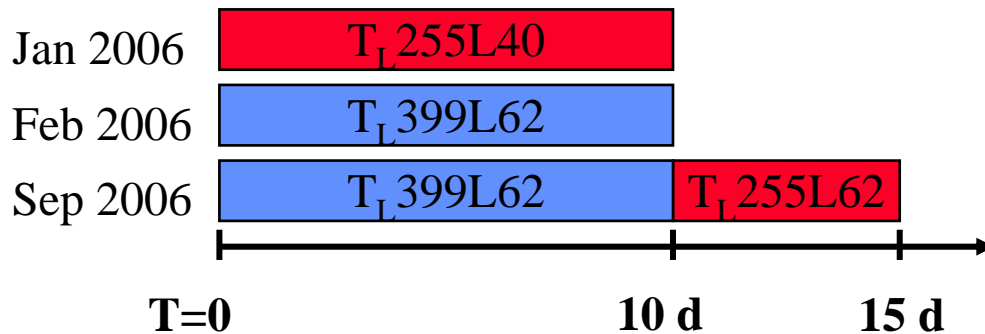
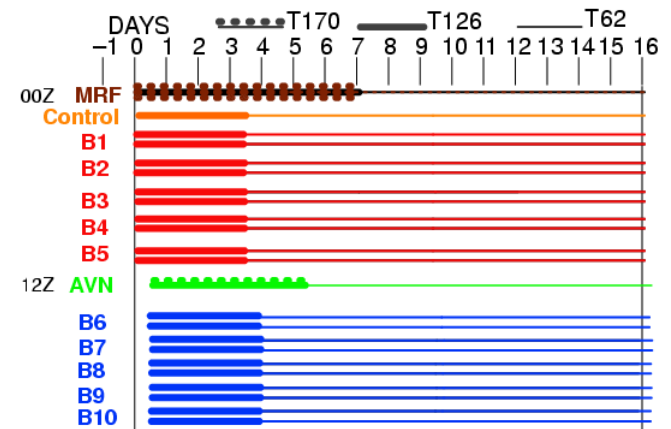
From 12/09/06, ECMWF joined 3 other centres (CPTEC, MSC, NCEP) capable to provide 15-day operational global ensemble forecasts.

<i>Updated 2 April 2007</i>	BMRC	CMA	CPTEC	ECMWF	FNMOCC	JMA	KMA	MSC	NCEP
	Australia	China	Brazil	Europe	US	Japan	Korea	Canada	US
simul model syst uncert	NO	NO	NO	NO	NO	NO	NO	YES (16 models)	NO
simul model random uncert	NO	NO	NO	YES (stoch ph)	NO	NO	NO	YES (16 models)	NO
simul observation error	NO	NO	NO	NO	NO	NO	NO	YES (rand pert)	NO
initial pert strategy	SVs	SVs & BVs	EOF-based	SVs	BVs	BVs	BVs	analyses cycl	BVs
hor-resol init pert	TL42	?	T126	TL42	T119	T106	T63	TL149	T126
Initial perturbed area	ExTR (<20S, >20N)	?	TR (45S:30N)	ExTR (<30S, >30N) + upto 6 TR-area	Globe	?	NH+TR (>20S)	Globe	Globe
hor-resol forecasts	TL119	T213	T126	TL399(0-10) TL255(10-15)	T119	T106	T213	TL149	T126
top of the model (hPa)	10	?	3	5	1	0.4	0.4	10	3
forecast length (days)	10	10	15	15	10	9	10	16	16
# runs per day (UTC)	2 (00,12)	2 (00, 12)	2 (00,12)	2 (00,12)	1 (00)	1 (12)	2 (00, 12)	2 (00, 12)	4 (00,06,12,18)
# pert mem per run	32	14	14	50	16	50	16	16	20
# ens mem per day	66	30	30	102	17	51	34	34	84



Variable resolution (NCEP, ECMWF and FNMOC)

Between 2000 and 2006, NCEP ran their 16-day individual integrations with **variable resolution**, with a T126 resolution up to forecast day 3.5 and T62 afterwards. In 2006, NCEP concluded that a T62 resolution was too low, and thus decided to increase the resolution between day 3.5 and 16 to T126, i.e. reversing to a constant resolution system.



In 2006, ECMWF decided to extend the forecast length of its ensemble system to 15 days, but using a **variable resolution** approach, with a T_L399 resolution between forecast day 0 and 10 and T_L255 from day 10 to 15.

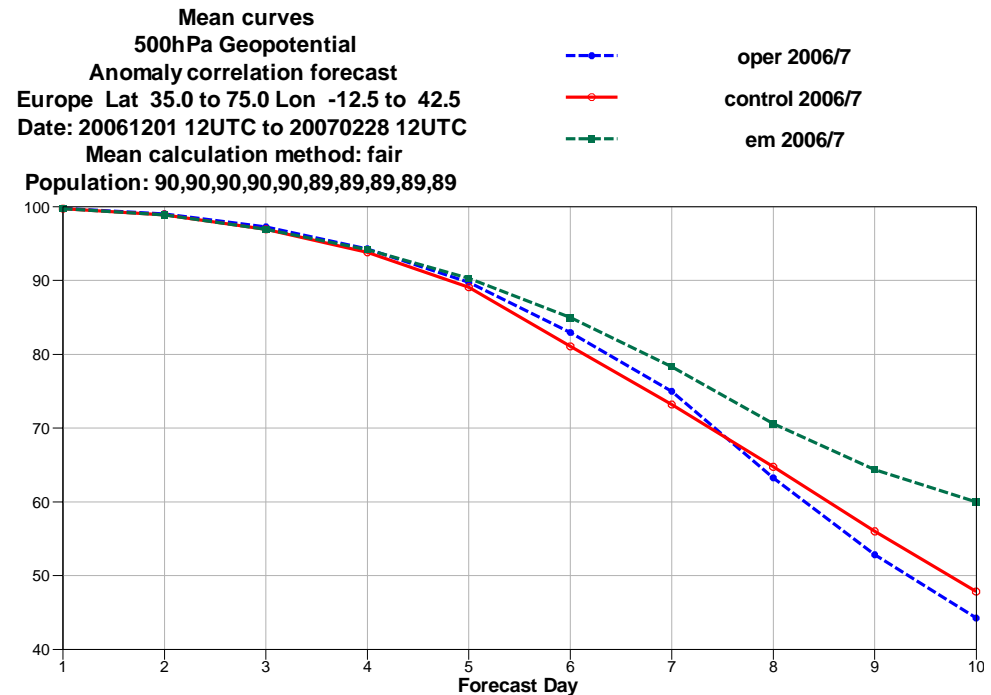
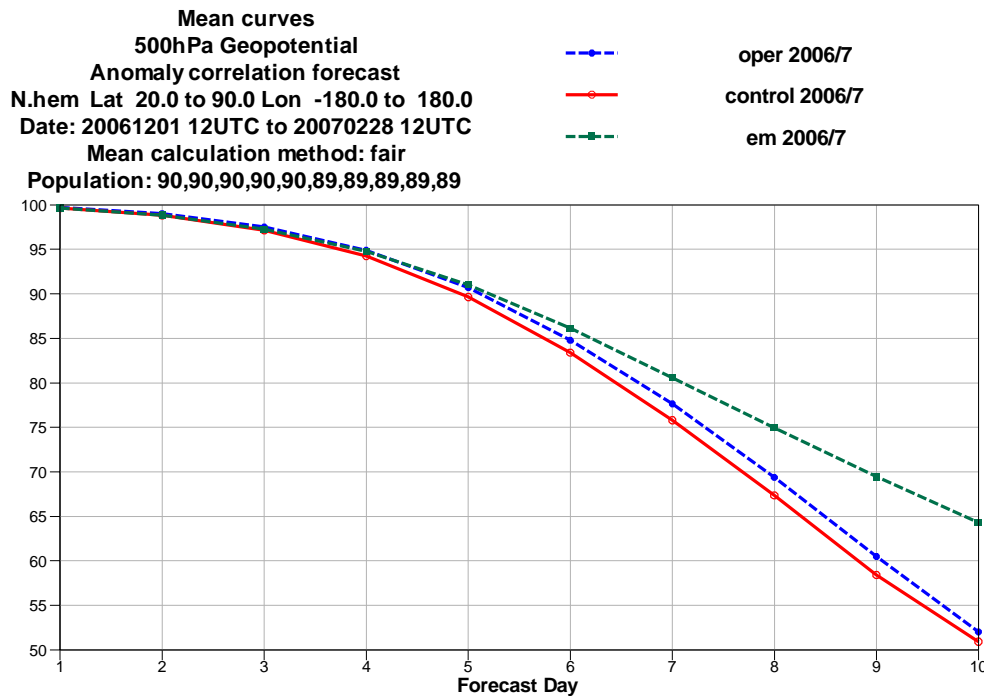
FNMOC ensemble also uses a variable resolution: T_L159 from day 0 to 3.5, and T_L119 from day 3.5 to 10.



T799, EPS-control and EM in winter '07, NH and EU

Over NH (left), on average in winter '07 (D06/JF07) the T799 performed better than the EPS control and worse than the EPS-mean (EM). For example, the difference in the time ACC reaches 0.75 between the T799 and the EPS-control was ~4h, and between the T799 and the EM was ~18h.

Over Europe (right), the difference between the T799 and the EPS control was smaller, while the EPS-mean kept its lead.

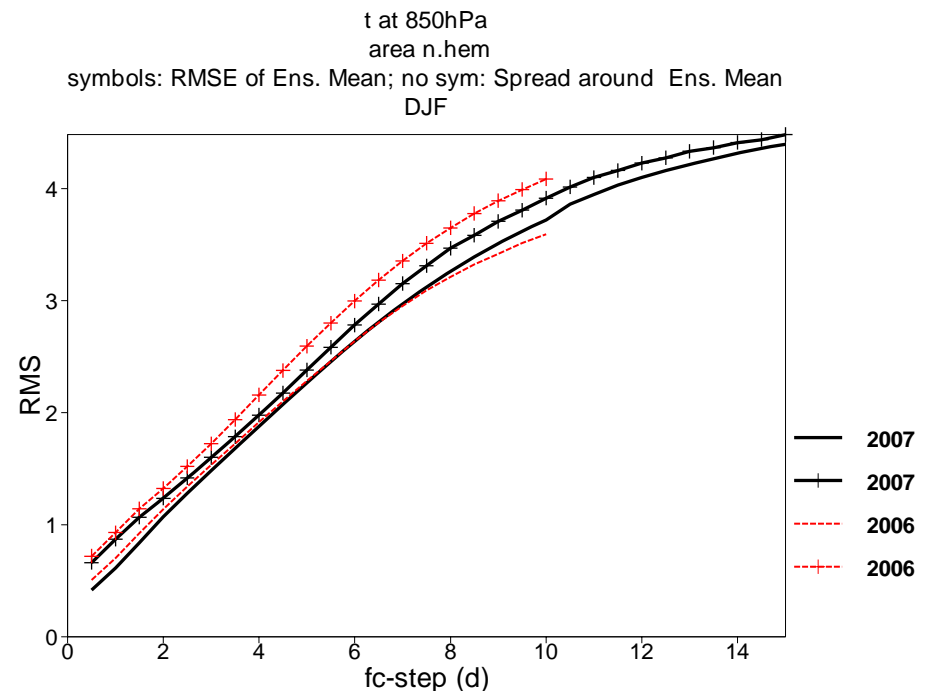
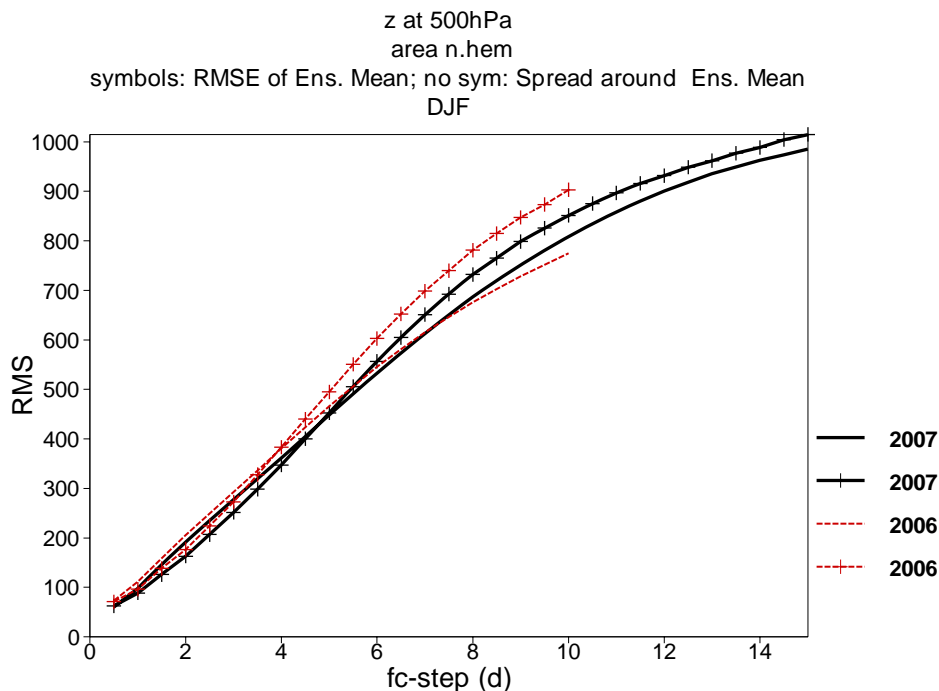




EPS std and EM-error in winter '06 and '07 NH

Compared to winter 2006, in winter 2007 the ensemble had a lower EM error (lines with symbols), up to fc day 5 a slightly lower std, a smaller spread under-estimation beyond fc day 5 and an overall closer match between std and EM-error.

This figure compares the ensemble std and the error of the ensemble-mean for winter 2006 and 2007 for Z500 (left) and T850 (right) over NH.

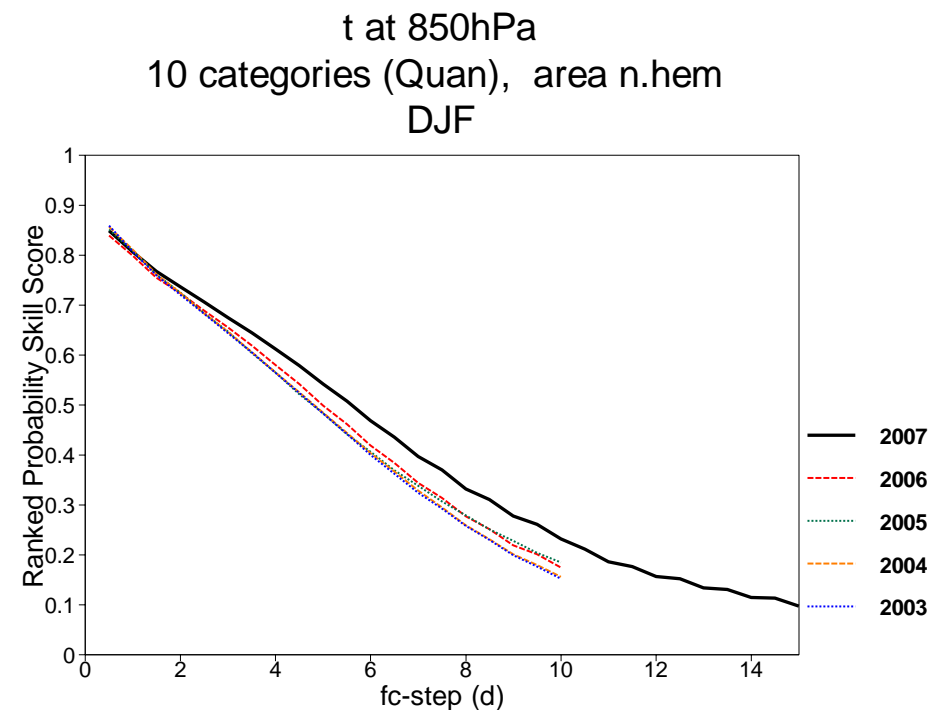
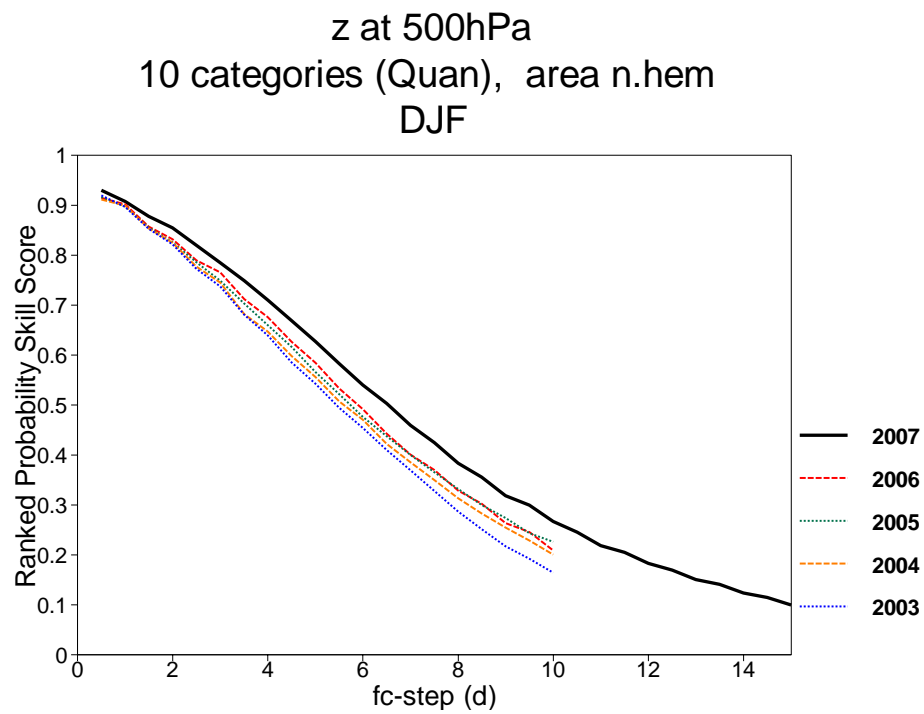




EPS RPSS winter '06 and '07 NH

Compared to the previous four winters, in 2007 the ensemble showed overall best performance.

This figure compares the RPSS for winters 2003-2007 for Z500 (left) and T850 (right) over NH.

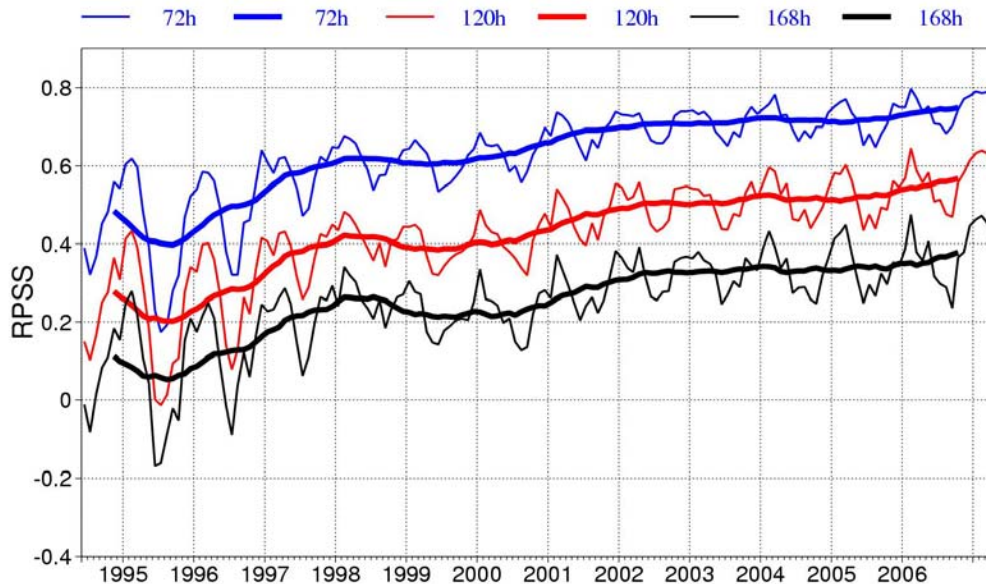




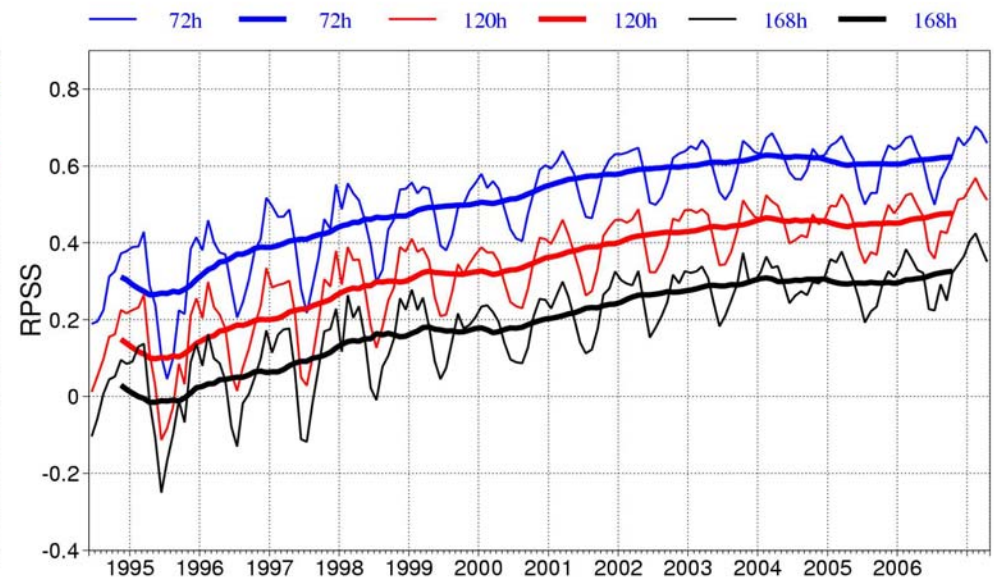
Trends in ensemble RPSS for Z500 and T850 over NH

The RPSS for the probabilistic prediction of Z500 and T850 anomalies indicates that during the past 10 years ensemble predictability has increased. A linear-trend estimate indicates gains in predictability of more than 2 days per decade.

RPSS, z500hPa, n.hem, Ensemble



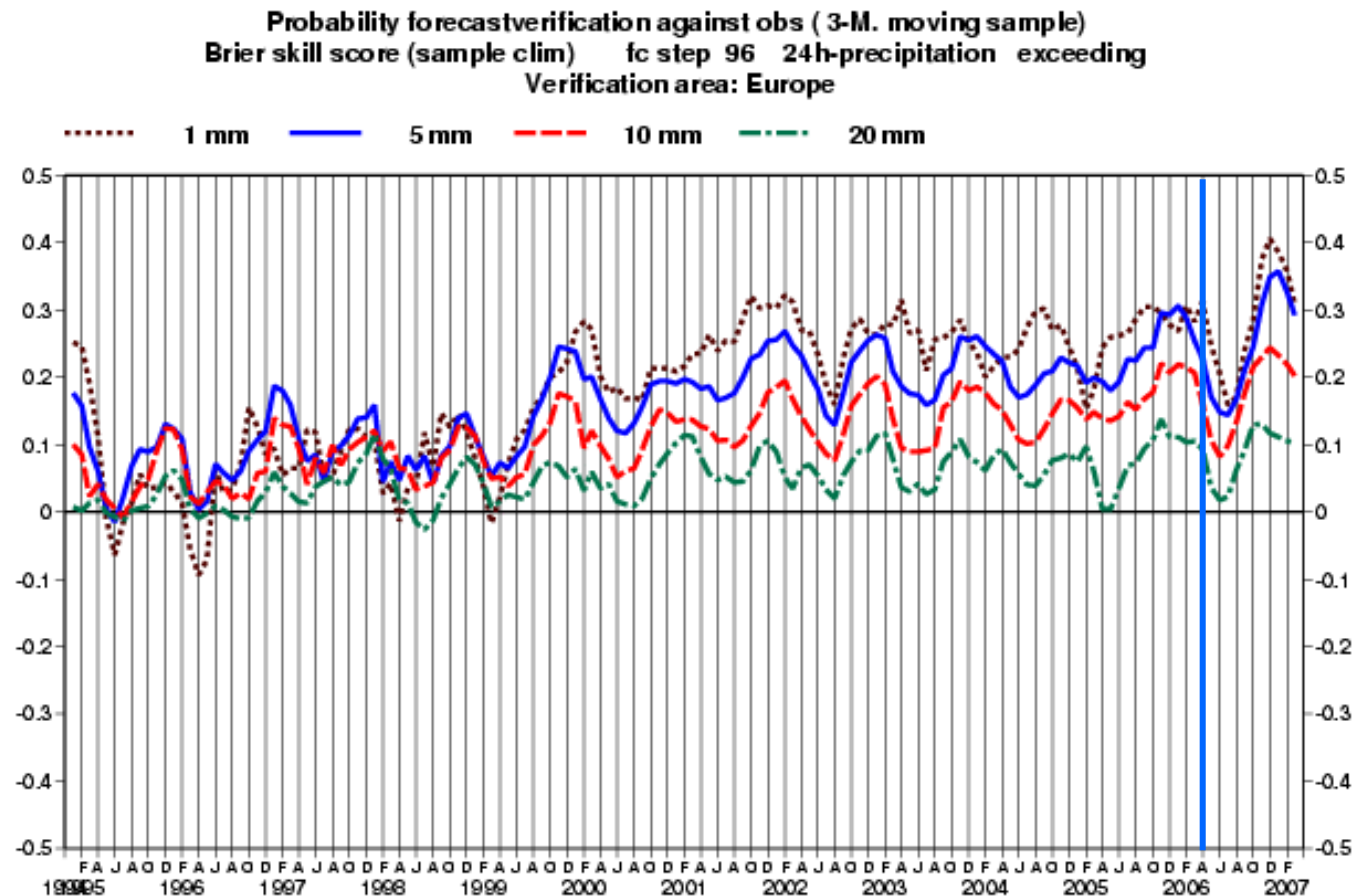
RPSS, t850hPa, n.hem, Ensemble





EPS BSS – +96h TP vs obs EU

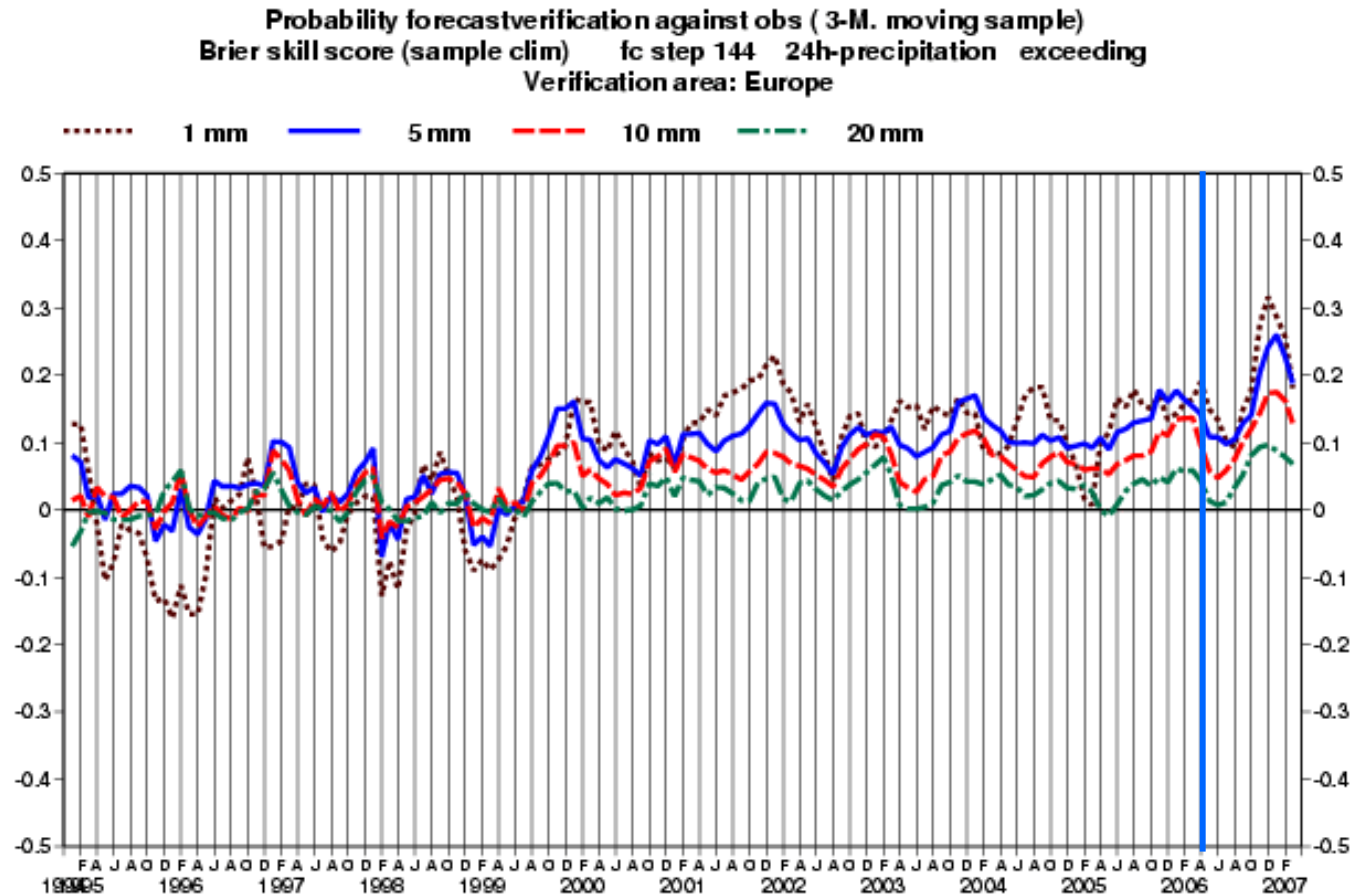
Over Europe, there are some indications that, following the implementation of the T399 EPS on 1 Feb 2006, the BSS of +96-hour forecasts of 24-hour accumulated precipitation (verified against synop observations) has been increasing.





EPS BSS – +144h TP vs obs EU

Over Europe, there are some indications that, following the implementation of the T399 EPS on 1 Feb 2006, the BSS of +144-hour forecasts of 24-hour accumulated precipitation (verified against synop observations) has been increasing.





THORPEX and TIGGE

THORPEX key objectives are:

- To increase fundamental understanding of dynamics and predictability of the atmosphere
- To make significant, quantifiable, worldwide improvements in decision-making skills and consequent measurable reduction in societal distress
- To promote and fully exploit advances in NWP, observations, communications and data-assimilation techniques
- To deliver improved global and regional forecasting system with active involvement of developed, developing and least developed nations

TIGGE (the THORPEX Interactive Grand Global Ensemble) is a framework for international collaboration in development and testing of ensemble systems:

- A resource for many THORPEX research projects
- A prediction component of THORPEX Forecast Demonstration Projects
- A prototype future Global Interactive Forecast System



TIGGE: comparison of ECMWF, JMA, NCEP & UKMO EPS

Data have started been archived in the TIGGE (THORPEX Interactive Grand Global Ensemble) database.

The performance of the following four ensemble systems in April 2007 have been compared. Work is in progress to extend the verification period to include more months, and to consider other ensemble systems (e.g. KMA and CMA).

	JMA	ECMWF	NCEP	UKMO
Model error simul	NO	YES	NO	YES
initial pert strategy	BVs	SVs	BVs	ETKF
Ini perturbed area	NH+TR	Globe	Globe	Globe
hor-resol forecasts	T106	TL399(d0-10) > TL255(d10-15)	T126	N144 (~80km)
Vertical levels	40	62	28	38
fc length (days)	9	15	16	15
# pert members	50	50	20	23
# runs per day	1 (12)	2 (00,12)	4 (00,06,12,18)	2 (00, 12)
# mem per day	51	102	84	48

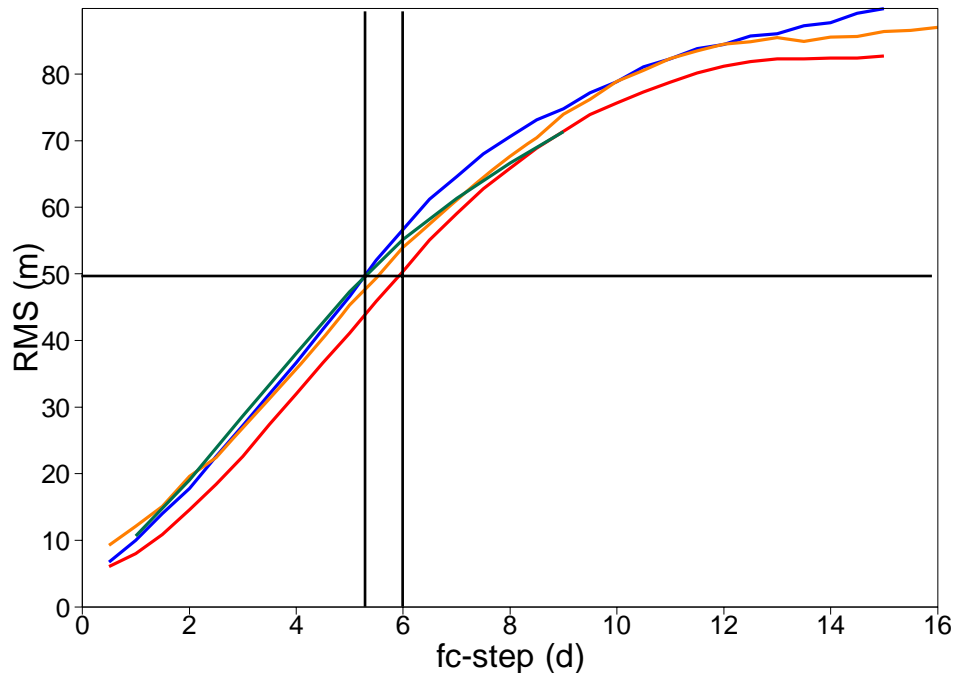
(from Y-Y Park)



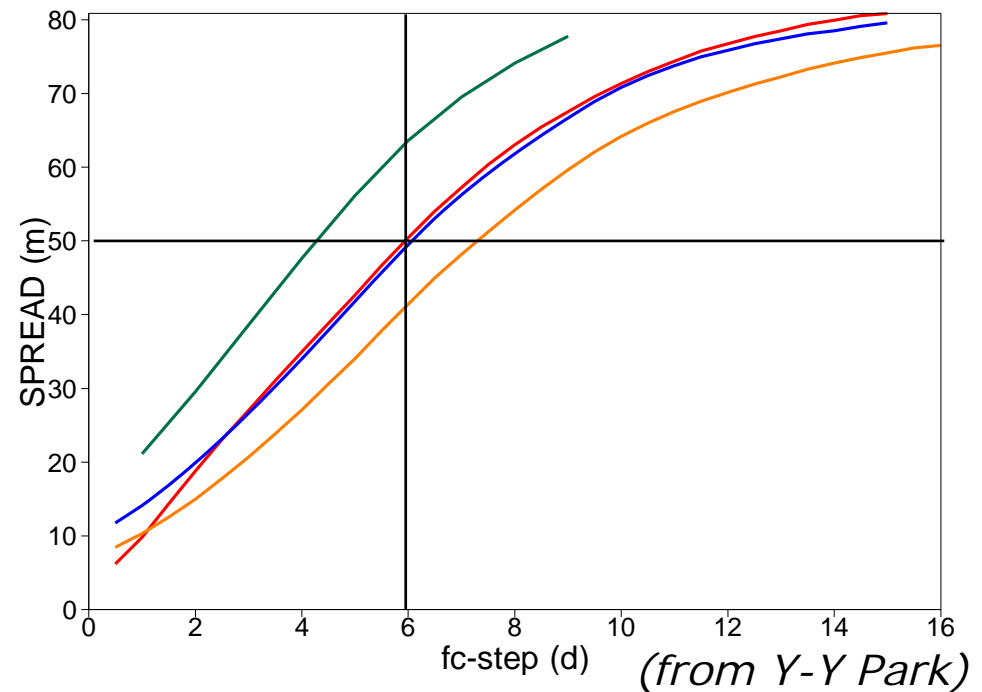
Ensemble std v EM-error – Z500 NH

The ECMWF EM has the lowest RMSE (left). The ECMWF spread is the smallest initially and increases more steeply. In the medium-range, the matching between EM-error and std is best for the ECMWF ensemble.

z at 500hPa (cf_as_ref) RMSE of Ens. Mean
cases 20070401-20070426_N26, area n.hem
ecmwf_vt12 ukmo_vt12 ncep_vt12 jma_vt12



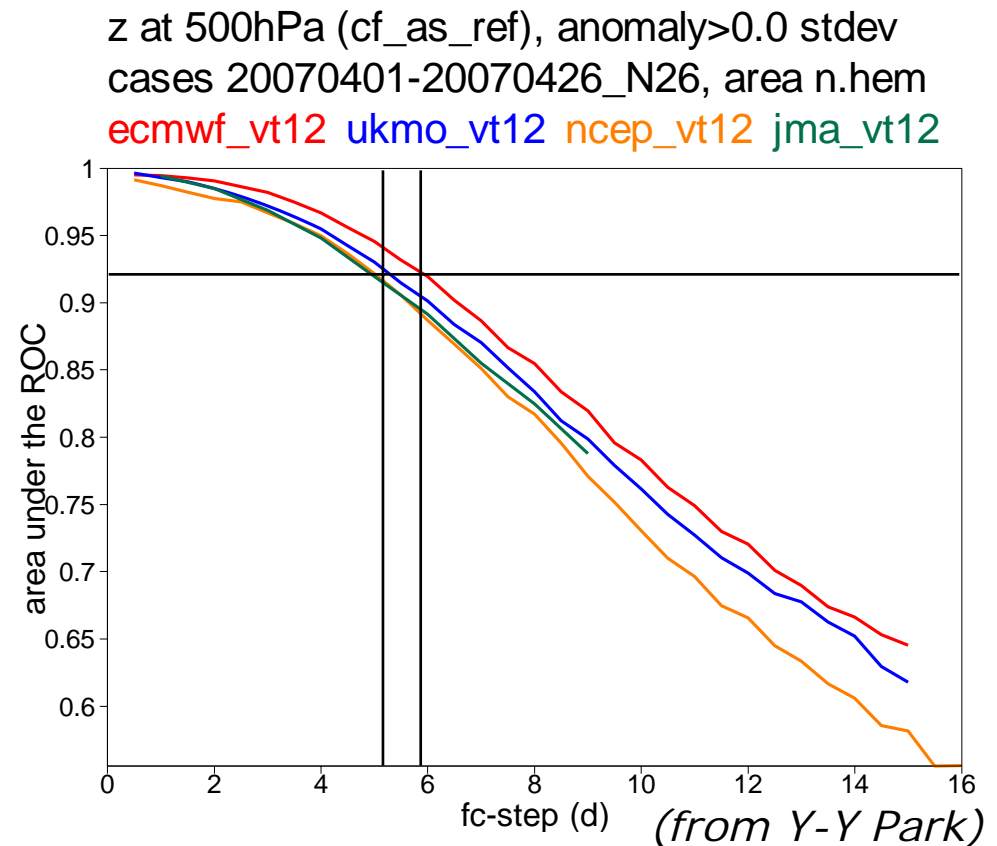
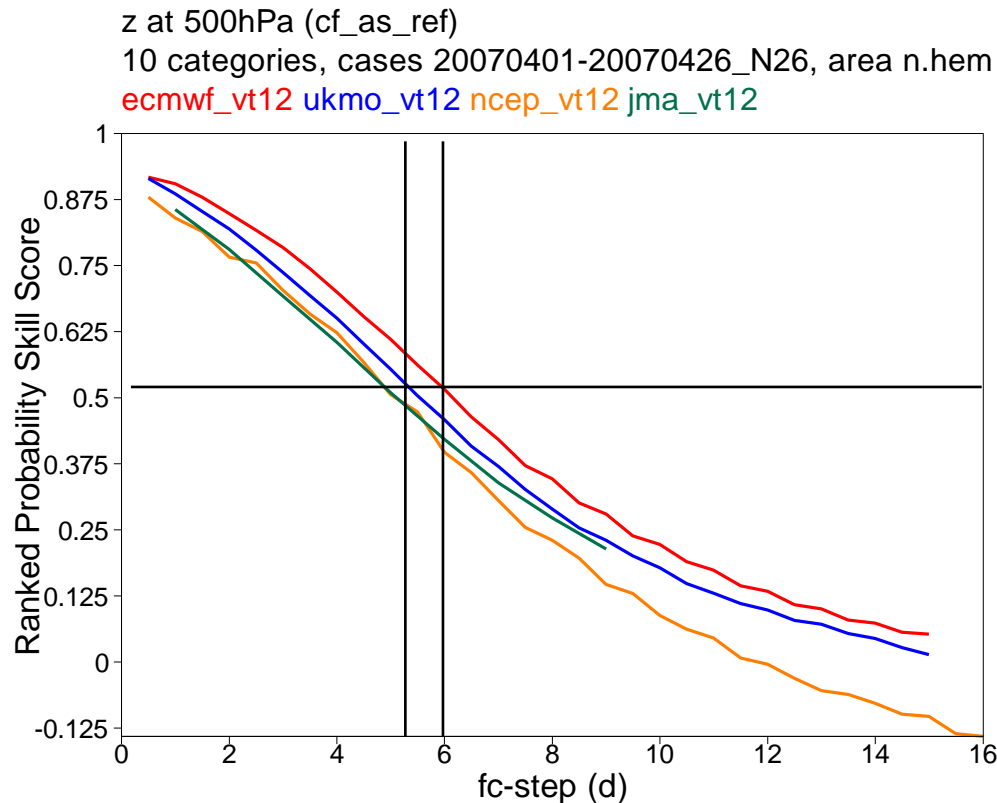
z at 500hPa (cf_as_ref) Spread around Ens. Mean
cases 20070401-20070426_N26, area n.hem
ecmwf_vt12 ukmo_vt12 ncep_vt12 jma_vt12





Ensemble RPSS and ROCA – Z500 NH

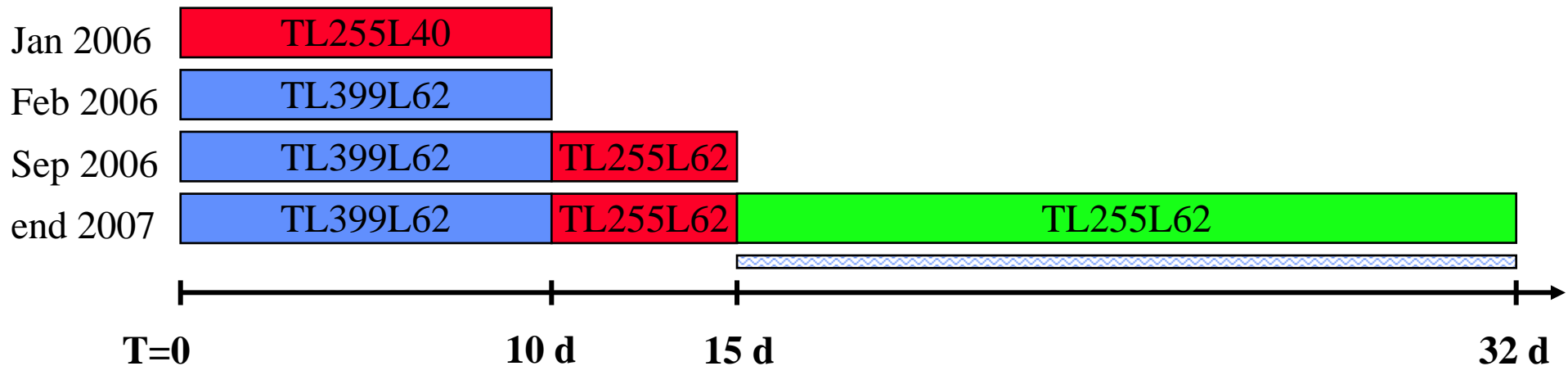
The ECMWF ensemble provides the most skilful probabilistic fcs. At fc day 6, e.g., differences in RPSS (left) and ROCA (right) between ECMWF and the 2nd best system amounts to ~18 hours in predictability.





The future extension of the ECMWF ensemble system

- Until 1 Feb '06, the EPS had 51 10-day forecasts at T_L255L40 resolution
- On the 1st of Feb '06, the 10-day EPS resolution was upgraded to T_L399L62
- On the 12th of Sep '06, the new Variable Resolution EPS (VAREPS) was introduced, and the ensemble forecast range was extended to 15 days
- The next change will be to link the 15-day VAREPS with the monthly forecast system will continue, with the goal to implement a seamless d0-32 VAREPS





Conclusion

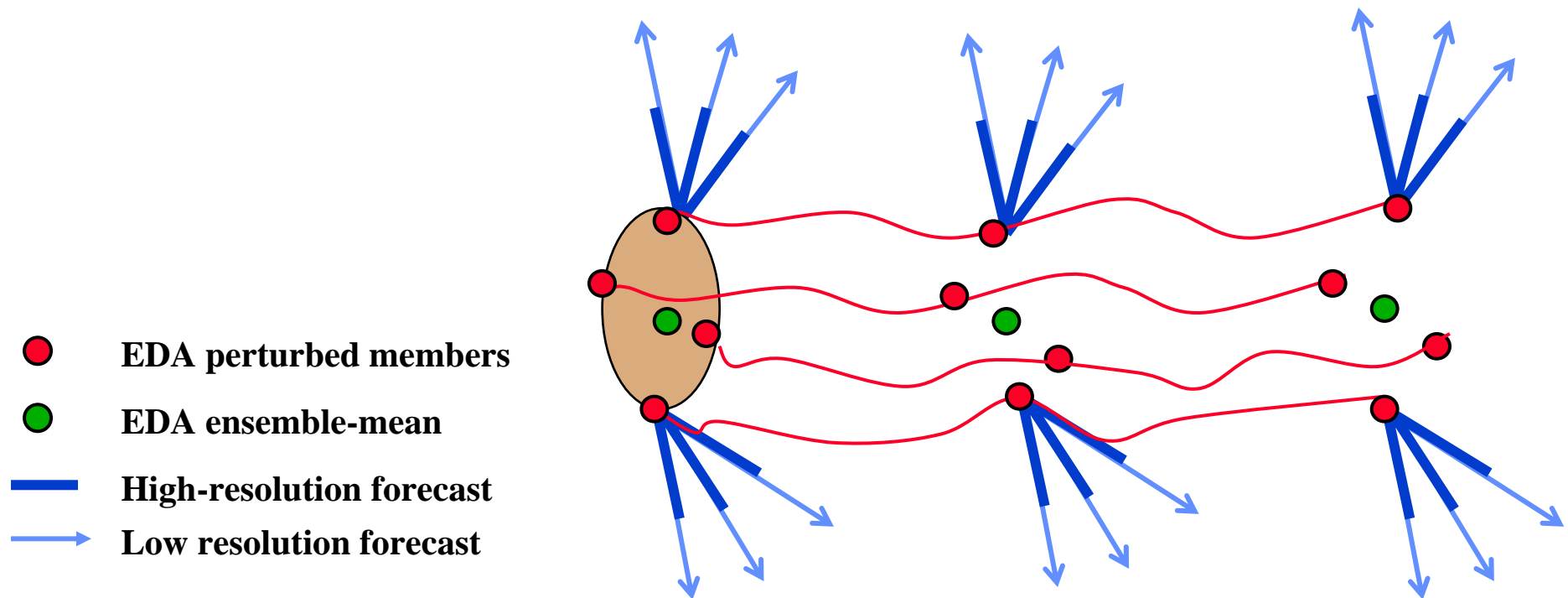
- A complete description of weather prediction can be stated in terms of an appropriate probability density function (PDF). Ensemble prediction appears to be the only feasible method to predict the PDF beyond the range of linear growth. Ensemble prediction can be used not only to identify the most likely outcome, but also to assess the probability of occurrence of maximum acceptable losses.
- The new ECMWF VAREPS includes 50 perturbed and 1 unperturbed 15-day forecasts with variable resolution [$T_L399L62(0-10) + T_L255L62(10-15)$], ran twice a day (00 and 12 UTC).
- In winter 06/07, the new 15-day VAREPS has shown to have a better tuned ensemble spread, and compared to the previous winters, the ensemble Z500 probabilistic predictions had the highest skill. Data started been archived in the TIGGE database. Preliminary results based on month (April 2007) indicates that in terms of Z500 and T850 over NH, the skill of the ECMWF ensemble system is superior to the skill of the NCEP, UKMO and JMA ensembles.



The future probabilistic analysis & forecasting system

Ensemble Data Assimilation (EDA) may be used in the future to generate the EPS initial perturbations. A future EPS configuration could include:

- N-member EDA (e.g. N=11)
- N*M member EDA-SV EPS, $T_L399(d0:10) + T_L255(d10:15)$ (e.g. M=51)
- ICs from each perturbed members and/or the EDA ensemble-mean





Selected bibliography on the ECMWF ensemble system

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