The new ECMWF Variable Resolution Ensemble Prediction System (VAREPS)

Roberto Buizza, Jean-Raymond Bidlot, Nils Wedi, Manuel Fuentes, Mats Hamrud, Graham Holt, Tim Palmer and Frederic Vitart, European Centre for Medium-Range Weather Forecasts

1 The rationale of variable resolution ensemble prediction

Since the early 1990s, global ensemble prediction systems (EPSs) have become part of the operational suites at many weather prediction centres (*Palmer et al* 1993, *Molteni et al* 1996, *Houtekamer et al* 1996a and 1996b, *Toth & Kalnay* 1993 and 1997). Since then, forecasters have been given access not only to single but also to probabilistic products, the former usually generated by a single high-resolution integration and the latter by an ensemble of low-resolution integrations of the same model. At ECMWF, for example, at the time of this workshop (November 2005) the forecasting system was based on:

- A single, T_L511L61 10-day integration, starting from a TL511L61 analysis
- An ensemble of 51 T_L255L40 10-day integrations, one (the control forecast) starting from a T_L255L40 truncation of the T_L511L61 analysis (the control analysis), and 50 starting from the control analysis perturbed by adding initial perturbations generated using T42L40 singular vectors (*Buizza & Palmer 1995)* and integrated using a stochastic scheme designed to simulate random model errors due to physical parameterisations (*Buizza et al* 1999)

Although each global system has been developed following a different approach to simulate observation, initial and model uncertainties (for a comparison between the ensemble systems operational at ECMWF, BMRC-Melbourne, MSC-Canada and NCEP-Washington, see *Bourke et al* 2004 and *Buizza et al* 2005), all of them are based on a limited number, say O(10), integrations of low-resolution versions of the state-of-the-art numerical weather prediction models used to produced single, high-resolution forecasts. Computing resources' availability has been one of the constraints that have limited the ensemble size to few tens and have made it unfeasible to run the ensemble systems with the same resolution as the single, high-resolution these operational ensemble systems.

Theoretically, the rationale behind VAREPS is that during a numerical integration high-wave-number (i.e. small) scales are resolved only up to the forecast range when keeping them has a positive impact of the forecast quality, and they are not resolved when their impact is smaller. Technically, this can be achieved by running the first part of the forecast with a higher resolution than the second part (e.g. spectral truncation T_L399 up to forecast day 7, and then T_L255), thus using relatively more computing resources in the early forecast range than in the long forecast range. The computing resources 'saved' by reducing the horizontal resolution in the second half of the forecast range can be used not only to increase the resolution in the first half, but also to extend the ensemble forecast range. This approach to ensemble prediction is not new, since it has been used at NCEP since inception of their ensemble prediction system (*Toth et al* 2002).

This report briefly summarizes the results presented at the 10th workshop on Operational Meteorological Systems, held at ECMWF in November 2005. Appendix A shows all the material presented during the talk.

2 The new ECMWF VAREPS

The new VAREPS aims to increase the value of the ECMWF ensemble system in two ways: in the short forecast range, by providing more skilful predictions of small-scale, severe events, and in the long forecast range by extending the range of skilful products from 10 to 15 days.

In this work, a VAREPS system with spectral truncation applied at forecast day 7 is compared with three constant-resolution EPSs (Table 1). All these ensembles have been run using the same model versions (IFS model cycles 28r3) starting from the same initial conditions and using the same initial perturbations.

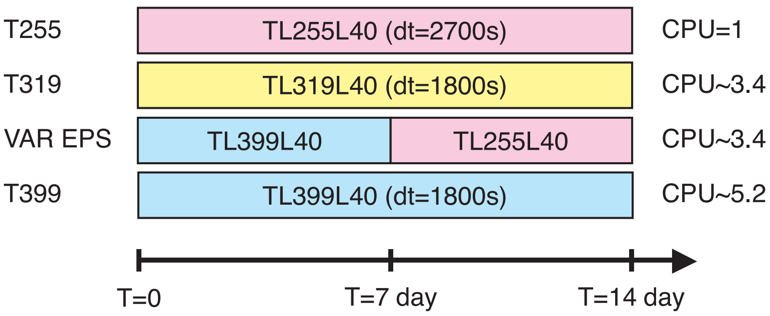

Table 1. Schematic of the VAREPS and the constant-resolution EPS configurations. Note that in terms of computing resources, VAREPS and a T319-EPS have very similar costs.

3 VAREPS average results

Average results based on 45 cases (spanning different years and covering both cold and warm seasons, and different ranges of synoptic situations) have indicated that compared to the operational, T_L255-EPS, VAREPS will give more skilful predictions. In particular, VAREPS will provide:

- In the short range (i.e. in this configuration up to forecast day 7):
  - More accurate synoptic scale prediction of temperature at 850 hPa (T850) and geopotential height at 500 hPa (Z500), with predictability gains of probabilistic forecasts of between 2 and 6 hours
  - More accurate precipitation predictions, with predictability gains of probabilistic forecasts of 5-10-20 mm/d of between 6 and 12 hours
  - More accurate prediction of severe weather events, such as hurricanes or intense extra-tropical storms, with up to 50% reductions of intensity and position errors of mean sea level pressure (MSLP) local minima
- In the long range (i.e. in this configuration between forecast day 7 and 15):
  - Skilful ensemble-mean and probabilistic predictions of Z500 and T850 anomalies

Results have also indicated that compared to the similar-cost, constant-resolution T_L319 EPS, in the 1st week (day 0-7) VAREPS outperforms the T_L319 EPS in the prediction of total precipitation, but the two systems perform similarly in the prediction of T850 and Z500. In the 2nd week (day 7-15) the two systems perform rather similarly.

The rank-sum Mann-Whitney-Wilcoxon (RMW, see, e.g., *Wilks* 1995) test, with bootstrapping, has been used to estimate the significance of the difference between the systems' performances: considering VAREPS and the T_L319-EPS, the difference has a RMW<20% only up to forecast day 4.

4 Impact of increased resolution in the early forecast range

The performance of VAREPS and the constant-resolution ensembles (Table 1) have been compared also for some severe weather events cases. Results have indicated that compared to the old T_L255 system, the higher resolution VAREPS (i.e. T_L399) system provides more accurate predictions. In particular:

- **Hurricane Katrina (29 August 2005)** – Comparison of t+84, +96 and +108h forecasts indicates that VAREPS (i.e. T_L399 resolution) gives a more accurate cyclone intensity prediction, with VAREPS forecasts being, correctly, deeper in the region of the storm development (~50% reduction in average absolute intensity error). This has a substantial positive impact on probabilistic predictions of MSLP minima, wind speed and significant wave height.
- **Hurricane Stan (6 October 2005)** – Comparison of +72, +96, +120 and +144h forecasts indicates that VAREPS (i.e. T_L399) gives a more accurate precipitation prediction, especially for higher thresholds (above 25 mm/d). (It is worth pointing out that in this case, VAREPS forecasts of the cyclone are not 'deeper', suggesting that the use of higher resolution does not systematically lead to 'deeper', more intense cyclones.)
- **UK storms (27 Oct 2002 and 12 Jan 2004)** – For both storms, comparison of +72h forecasts indicates that VAREPS (i.e. T_L399) forecasts are more accurate in locating the low pressure system (5% reduction in position error), while differences in intensity are small. This has a small positive impact on the probabilistic prediction of wind speed. For the 2nd storm, VAREPS forecast are better capable to predict the development and propagation of two small-scale vortices located at very short distance.
- **Intense precipitation over Europe (15 Oct 2000 and 12 Aug 2002)** – For both floods, VAREPS probabilistic precipitation forecasts are slightly more accurate (Brier scores are ~5% lower).

5 VAREPS implementation plan

VAREPS will eventually link the medium-range ensemble prediction with the monthly ensemble prediction system, thus providing ECMWF users with a seamless ensemble forecast ranging from day 0 to 32.

In the first phase of the ensemble system upgrade, VAREPS will be implemented with a truncation applied at forecast day 10 instead of 7, and it will be extended up to forecast day 15. The decision to truncate the forecasts at day 10 instead of day 7 is mainly technical, and it has been taken to allow users who do not have enough resources to modify their post-processing/product generation programmes to still be able to use the ECMWF ensemble up to forecast day 10. Clearly, users will still need to adapt their software to be able to use ensemble forecasts beyond forecast day 10, since these forecast fields will have different characteristics (e.g. resolution, file size, ..). The decision to extend the forecast up to forecast day 15 instead of 14 has been to facilitate the TIGGE (THORPEX Interactive Grand Global Ensemble) research project.

The ensemble upgrade from the T_L255L40 system operational in November 2005 to VAREPS will take place in three phases (Table 2):

- **Phase 1, Feb 2006:** from T_L255L40(d0-10) to T_L399L62(d0-10)
- **Phase 2, Q2 2006:** from T_L399(d0-10) to VAREPS [T_L399(d0-10)+T_L255(d10-15)]
- **Phase 3, 2006/2007:** Work to link VAREPS(d0-15) with the monthly system will continue, with the goal to implement a seamless d0-32 VAREPS as soon as feasible

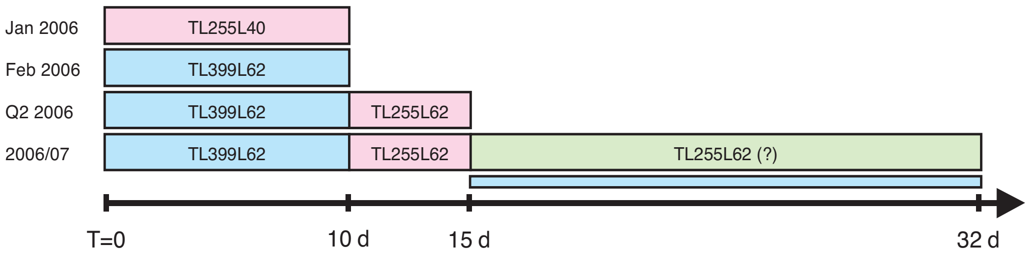

Table 2. Schematic of the VAREPS implementation plan.

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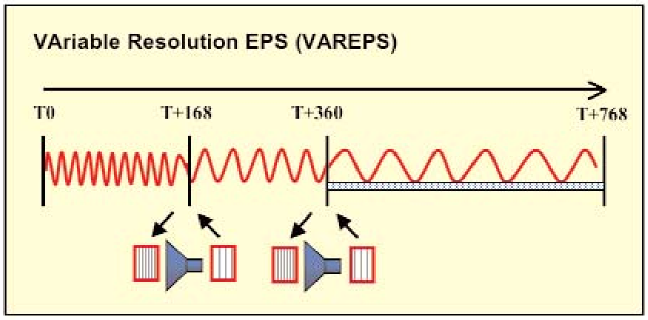

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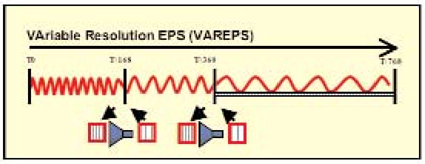
Why VAREPS?

VAREPS aims to increase the value of the current EPS in two ways:

- up to fc d7, by providing more skilful predictions of small-scale, severe events
- after fc d7, by extending the range of skilful products from 10 to 15 days

VAREPS will also provide the first 2-legs of ECMWF planned seamless ensemble system, which will be extended initially to one month, and then to a longer forecast time.

The key idea behind VAREPS is to resolve small-scales in the forecast up to the forecast range when resolving them improves the forecast, but dropping them when their impact is negligible.



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Summary with key conclusions

1. **Expected average impact of EPS upgrade**
   – Results based on the comparison of Z500 and total precipitation predictions (46 cases, 51mem) indicate that in the 1st week VAREPS will deliver gains of up to 12h, and in the 2nd week it will give users access to skilful probabilistic forecasts.

2. **Impact of EPS upgrade on severe weather forecasts**
   – In the 1st week, VAREPS(T399) will deliver more accurate predictions of intense cyclonic developments (both in terms of intensity and position), wind speed, significant wave height and precipitation.

3. **The future: a seamless ensemble system from day 0 to day 32**
   – The first cases of 3-leg VAREPS have been completed. The configuration planned to be implemented in Q1/2006 will (most probably) be:
   - Day 0- 7: $T_L399L62^{DT1800s}$
   - Day 6-15: $T_L255L62^{DT2700s}$
   - Day 15-32: $T_L255L62^{DT2700s}$ coupled with ocean model

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Outline

1. **Expected average impact of EPS upgrade**

2. **Impact of EPS upgrade on forecasts of severe weather**
   – Hurricane Katrina (29 August 2005)
   – Hurricane Stan (6 October 2005)
   – UK storms (27 Oct 2002 and 12 Jan 2004)
   – Intense precipitation over Europe (15 Oct 2000 and 12 Aug 2002)

3. **The future: a seamless ensemble system from day 0 to day 32**

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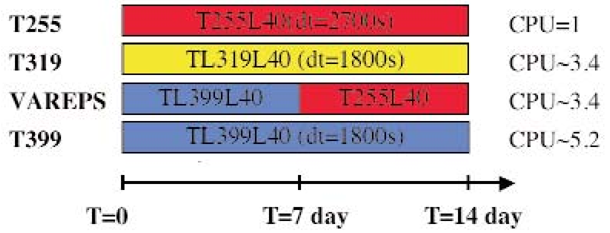
1. EPS configurations tested with 51-members

Ensembles have been run in the following 4 configurations:



Ensembles have been compared 45 cases (20 cases from warm and 25 from cold seasons, model cycle 28r3).

Average results are based on the comparison of 500 hPa geopotential height (Z500), 850 hPa temperature and total precipitation (TP) forecasts. Case studies have also considered significant wave height and 850hPa wind.

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1. Expected average impact of EPS upgrade

Average results and case-studies indicate that VAREPS will give:

- **In the 1st week (day 0-7):**
  - More accurate synoptic scale prediction of T850 and Z500, with predictability gains of probabilistic forecasts of ~2-6h
  - More accurate precipitation predictions, with predictability gains of probabilistic forecasts of 5-10-20 mm/d of ~6-12h
  - More accurate prediction of severe weather events, such as hurricanes or intense extra-tropical storms, with up to 50% reductions of intensity and position errors of MSLP local minima
- **In the 2nd week (day 7-15):**
  - Skilful ensemble-mean and probabilistic predictions of Z500 and T850 anomalies

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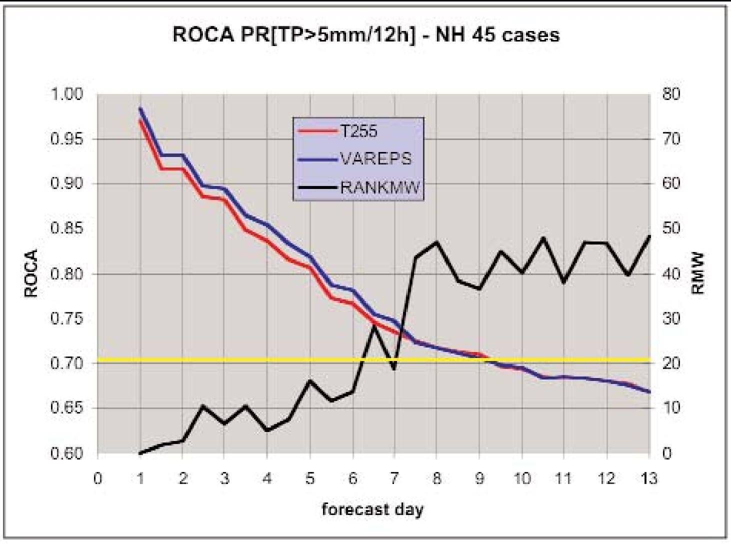
1. Expected impact of EPS upgrade: π[TP12≥5mm]



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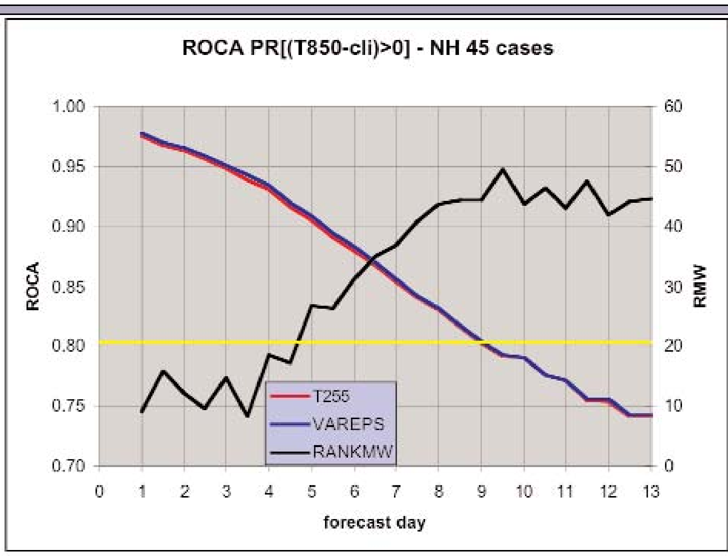
1. Expected impact of EPS upgrade: π[(T850-cli)>0]



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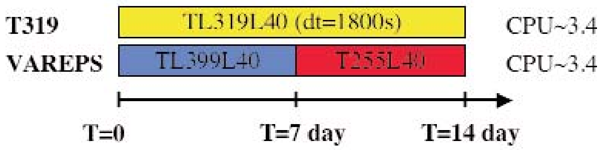
1. Expected average impact of EPS upgrade

How does VAREPS compare with an equal-cost, constant-resolution system?

To address this question, the following two (almost) equal-cost ensemble systems have been compared:



- In the 1st week (day 0-7): VAREPS is better than T319 in predicting TP (the difference has RMW<20% up to forecast day 4) but there is a very small difference for T850 and Z500
- In the 2nd week (day 7-15): VAREPS and T319 perform similarly

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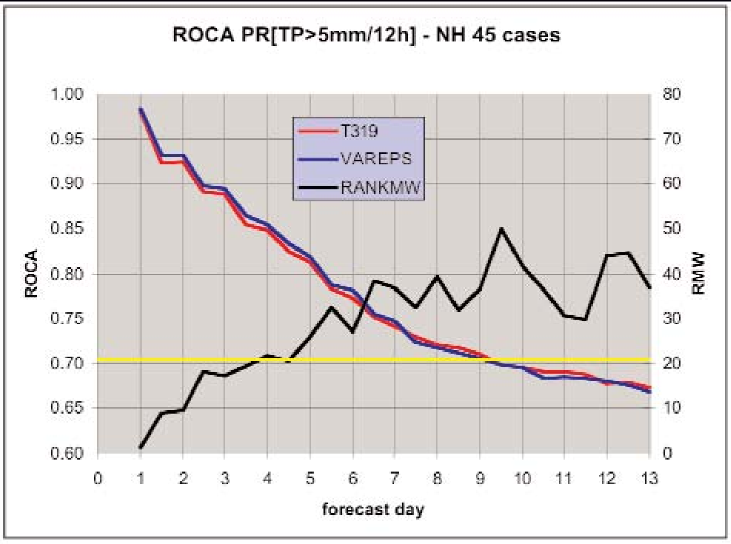
1. Expected impact of EPS upgrade: π[TP12≥5mm]



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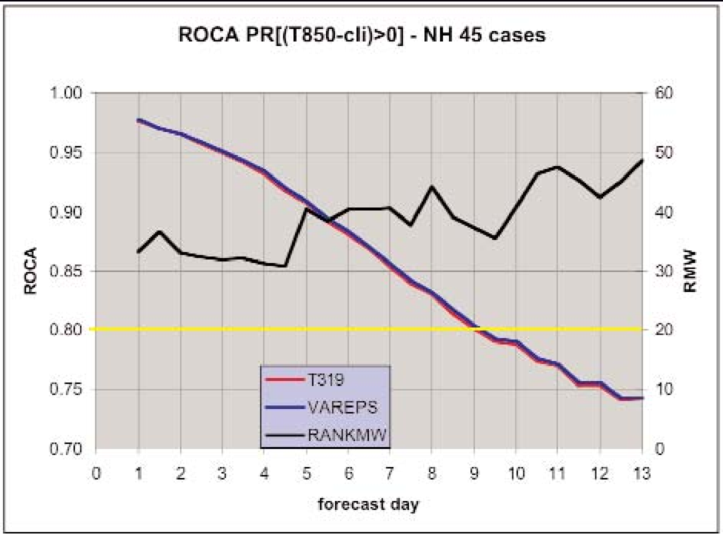

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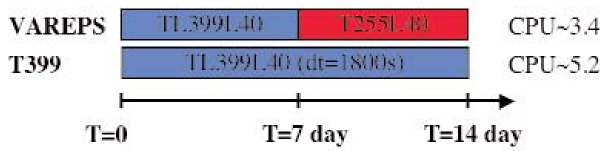
1. Expected average impact of EPS upgrade

How does VAREPS compare with a more expensive, constant-resolution system?

To address this question, the following two equal-cost ensemble systems have been compared:



- In the 2nd week (day 7-15): T399 is better than VAREPS in predicting TP (but it is worth pointing out that the differences have RMW≥20%, and that the 0.70 ROCA threshold is crossed at forecast day 10)

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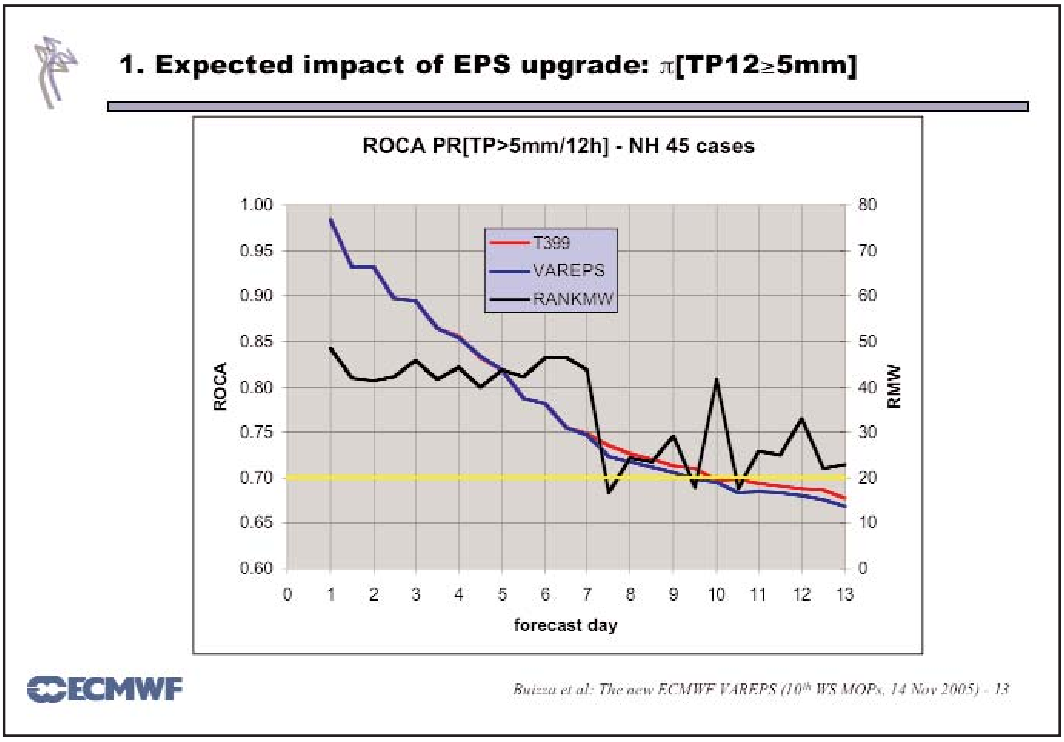
1. Expected impact of EPS upgrade: π[TP12≥5mm]
ROCA PR[TP>5mm/12h] - NH 45 cases
T399
VAREPS
RANKMW
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forecast day
ECMWF
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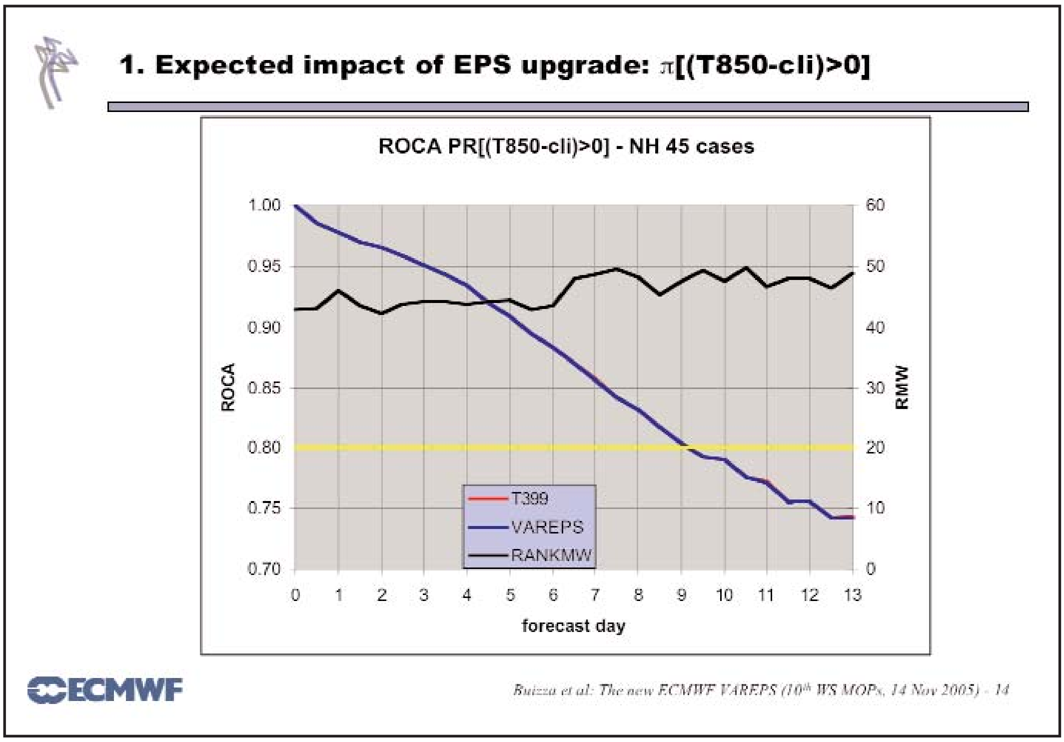
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Outline

1. **Expected average impact of EPS upgrade**

2. **Impact of EPS upgrade on forecasts of severe weather**
   - Hurricane Katrina (29 August 2005)
   - Hurricane Stan (6 October 2005)
   - UK storms (27 Oct 2002 and 12 Jan 2004)
   - Intense precipitation over Europe (15 Oct 2000 and 12 Aug 2002)

3. **The future: a seamless ensemble system from day 0 to day 32**

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2. Case studies: key conclusions

❖ **Hurricane Katrina (29 August 2005)**

- Comparison of +84, +96 and +108h forecasts indicates that VAREPS(T399) gives a more accurate cyclone intensity prediction, with VAREPS forecasts being on average deeper (~50% reduction in average absolute intensity error). This has a substantial positive impact on probabilistic predictions of MSLP minima, wind speed and significant wave height.

❖ **Hurricane Stan (6 October 2005)**

- Comparison of +72, +96, +120 and +144h forecasts indicates that VAREPS(T399) gives a more accurate precipitation prediction, especially for higher thresholds (above 25 mm/d).

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2. Case studies: key conclusions

- **UK storms (27 Oct 2002 and 12 Jan 2004)**
  - For both storms, comparison of +72h forecasts indicates that VAREPS forecasts are more accurate in locating the low pressure system (5% reduction in position error), while differences in intensity are small. This has a small positive impact on the probabilistic prediction of wind speed.
  - For the 2nd storm, VAREPS forecast are better capable to predict the development and propagation of two small-scale vortices located at very short distance.
- **Intense precipitation over Europe (15 Oct 2000 and 12 Aug 2002)**
  - For both floods, VAREPS probabilistic precipitation forecasts are slightly more accurate (Brier scores are ~5% lower).

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2. Hurricane Katrina: 26-29 August 2005

- Katrina was one of the strongest storms of the last 100y
- Sustained winds at landfall of 140mph, and minimum central pressure recorded of 920hPa (3rd lowest recorded for a land-falling Atlantic storm in the US)
- Developed initially as a tropical depression southeast of the Bahamas on 23 Aug
- Cat-I when landed in Florida
- Reached maximum intensity (Cat-V) on 28 Aug
- Cat IV at landing

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2. Hurricane Katrina: impact

- Loss of life is still unknown but likely to be in the 100s
- 80% of New Orleans was under flood water on 31 Aug due to levee failures from Lake Pontchartrain
- Oil production in the Gulf of Mexico was reduced by 1.4mbd (down to only 5% of daily production)
- Power shortages affected over 1.7m people (*source: NCDC*)
- Costs to the insurance and reinsurance industries estimated to be ~$40-60bn (*source: FT*) (for comparison, Andrew damages adjusted for inflation were $25bn)

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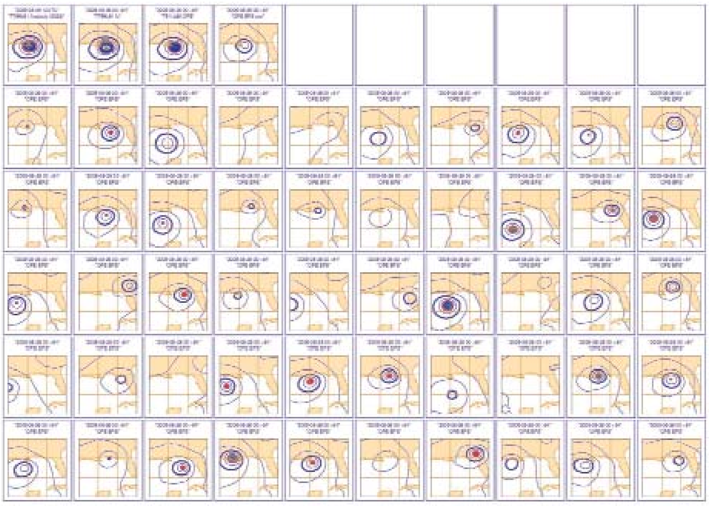
2. Kat: T255 EPS from OPEan, 2005-08-26 00 +84h

- Top row: T799 an, T799 fc, T511 fc, EPS control
- Other rows: EPS perturbed members 1 to 50

(All but T799 fcs started from T511 OPE analysis, T799 fc started from T799 analysis.)

Each panel shows MLSP with a 5hPa contour interval and shading for values below 990hPa.



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2. Kat: VAREPS(T399) from OPEan, 2005-08-26 00 +84h

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- Other rows: EPS perturbed members 1 to 50

(All but T799 fcs started from OPE T511 analysis.)

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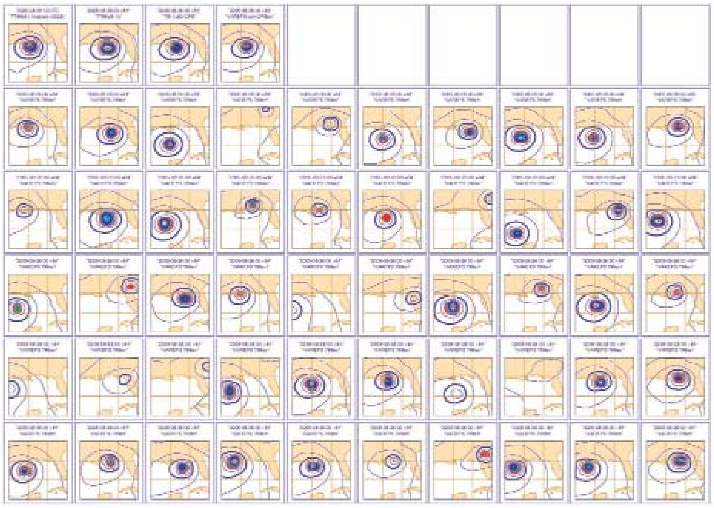

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2. Kat: intensity and position error in +84h MSLP pert-mem

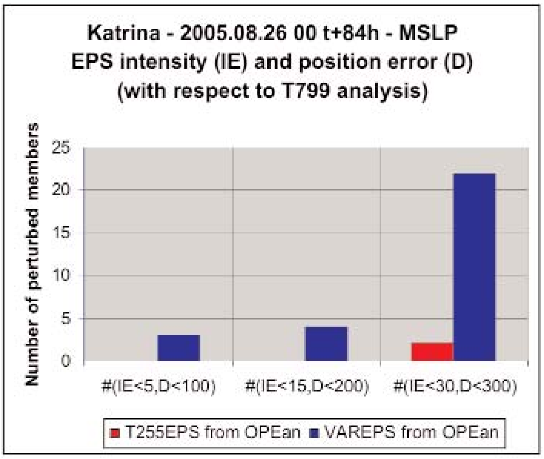
The three sets of bars show the number of perturbed members with intensity (IE) and position (D) errors inside three categories:

- IE<5hPa and D<100km
- IE<15hPa and D<200km
- IE<30hPa and D<300km

(with respect to T799 analysis)

Two ensemble configurations are compared:

- T255 from OPEan (T511L60)
- VAREPS (T399) from OPEan



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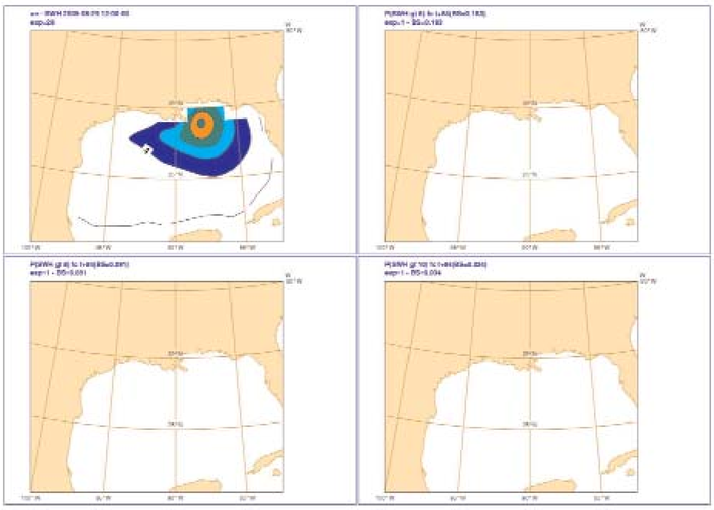
2. Kat: SWH prob in T255 from OPEan in +84h fcs

The top-left panel shows the significant wave height (SWH) in the T799 analysis (cont interval is 2m).

The other panels show the probabilities that:

- SWH>6m (t-right)
- SWH>8m (b-left)
- SWH>10m (b-right)

Prob cont iso are 2/5/10/20/40/60%.



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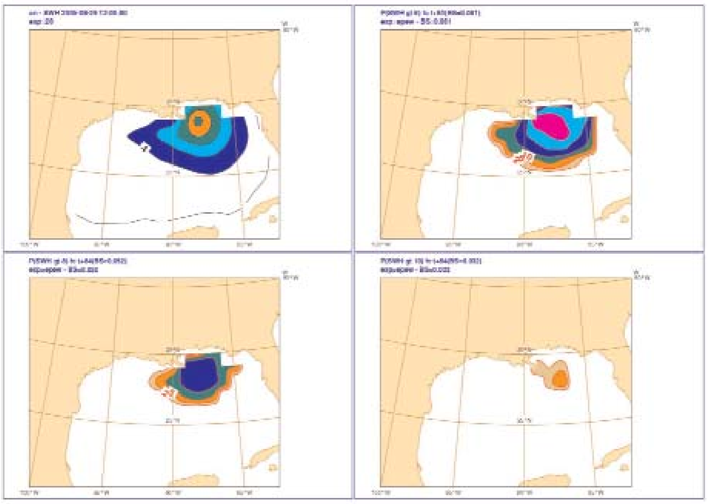
- SWH>10m (b-right)

Prob cont iso are 2/5/10/20/40/60%.



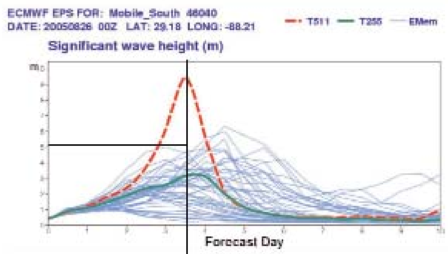
ECMWF

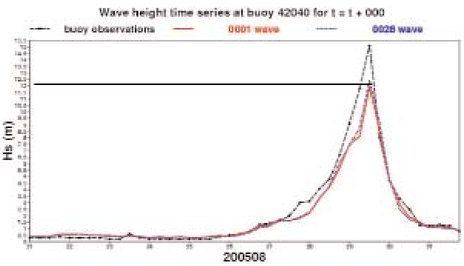
Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 25

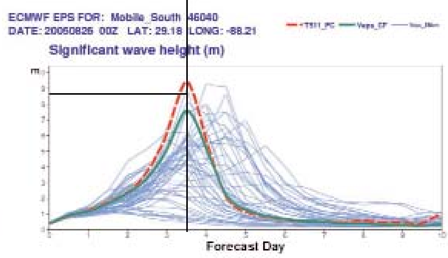
2. Kat: SWH t+84h fcs at buoy, VAREPS and EPS

Buoy 42040 obs for 12UTC of 29 Aug and t+84h forecasts from 26 Aug 00UTC.

Bottom-left panel: buoy measured SWH of 15m. ECMWF analysis at T511 and T799 produced SWH of 12m. EPS forecasts were up to ~5m (top-right), while VAREPS forecasts reached 9m (bottom-right).





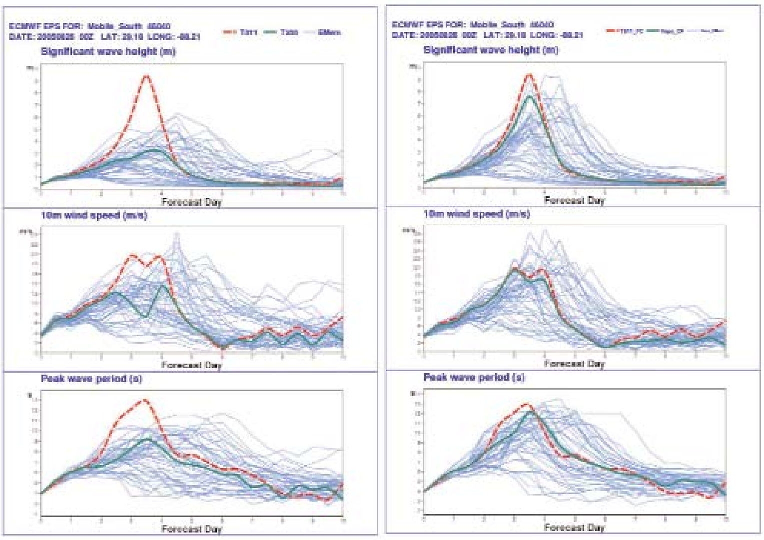


ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 26

2. Kat: t+84h fcs at buoy, VAREPS and EPS

T+84h forecasts from 26 Aug at 00UTC from EPS (left) and VAREPS (right) SWH, 10m wind speed and peak wave period at buoy 42040.



ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 27

2. Kat: intensity and position error in +96h MSLP pert-mem

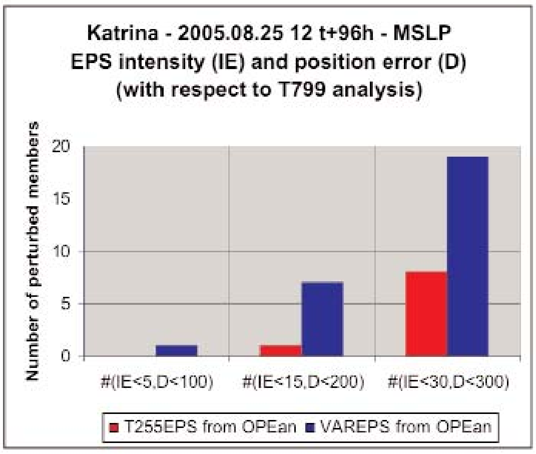
The three sets of bars show the number of perturbed members with intensity (IE) and position (D) errors inside three categories:

- IE<5hPa and D<100km
- IE<15hPa and D<200km
- IE<30hPa and D<300km

(with respect to T799 analysis)

Two ensemble configurations are compared:

- T255 from OPEan (T511L60)
- VAREPS (T399) from OPEan



ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 28

2. Kat: intensity and position error in +108h MSLP pert-mem

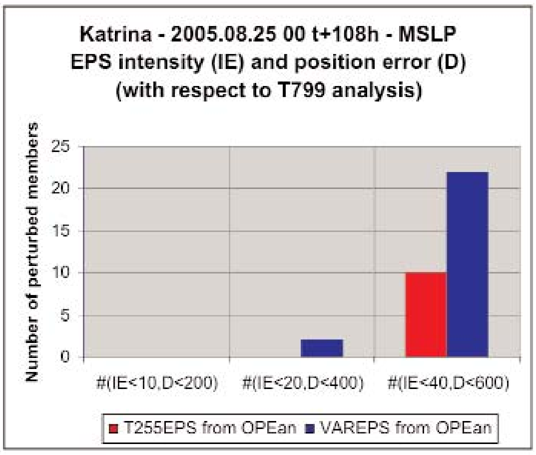
The three sets of bars show the number of perturbed members with intensity (IE) and position (D) errors inside three categories:

- IE<10hPa and D<200km
- IE<20hPa and D<400km
- IE<40hPa and D<600km

(with respect to T799 analysis)

Two ensemble configurations are compared:

- T255 from OPEan (T511L60)
- VAREPS (T399) from OPEan



Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 29

Outline

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3. **The future: a seamless ensemble system from day 0 to day 32**

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 30

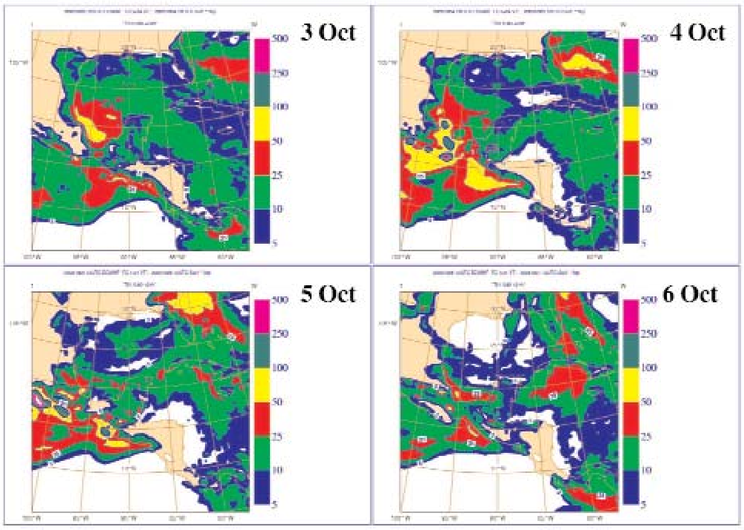
2. Hurricane Stan: 6-7 October 2005

- 11 October 2005 - The death toll from mudslides and flooding triggered by Hurricane Stan in Guatemala has risen to 652. It is estimated that as many as 98,000 Guatemalan residents have suffered property damage as a result of the disaster.
- The footage of Guatemala and El Salvador is reminiscent of Hurricane Katrina - except the victims this time around are farmers and villagers, and the homes destroyed were not located along Bourbon Street, but on the Central American countryside. More disastrously, though, these homes were not made of concrete, but rather of mud and clay. Hurricane Stan, though not as potent as Katrina, has had an equally devastating effect, as the infrastructure in these countries is not designed to resist a hurricane.

ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 31

2. Stan: TP24h in T511 fcs from 12UTC of 3-4-5-6 Oct 2005

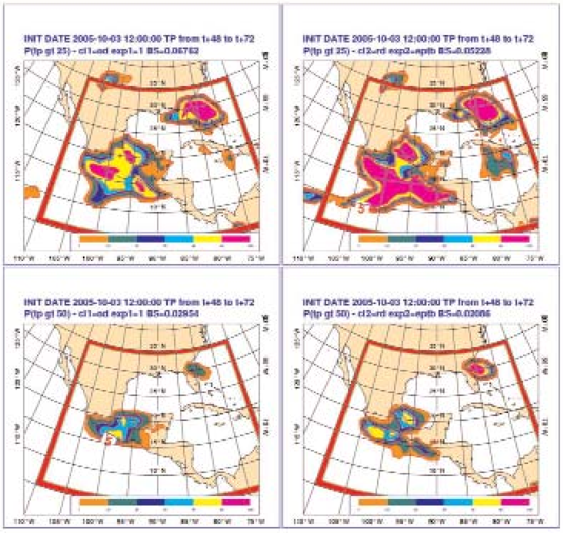


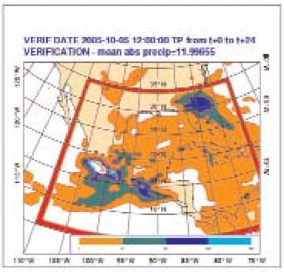
ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 32

2. Stan: PR(TP24>thr) in +72h forecasts valid for 6 Oct 12Z

Panels to the right: t+72h forecasts of PR[TP24>25mm] (top) and PR[TP24>50mm] (bottom) started at 12Z of 3 Oct in the T255 (left) and VAREPS (right) ensembles. The bottom panel shows precipitation verification defined as the T511 t+24h TP.



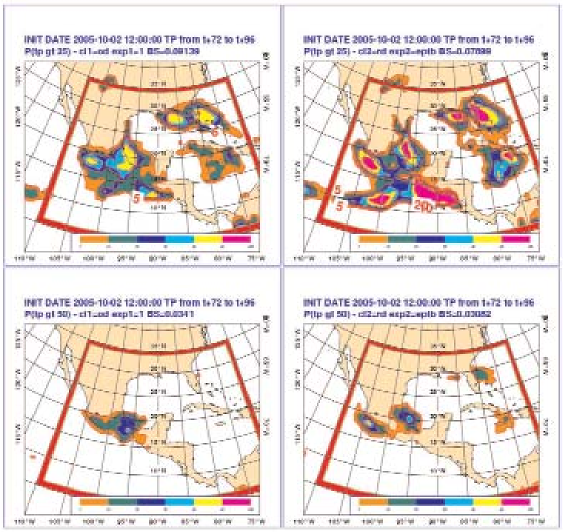


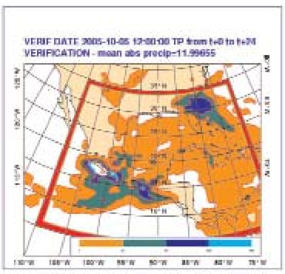
ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 33

2. Stan: PR(TP24>thr) in +96h forecasts valid for 6 Oct 12Z

Panels to the right: t+96h forecasts of PR[TP24>25mm] (top) and PR[TP24>50mm] (bottom) started at 12Z of 2 Oct in the T255 (left) and VAREPS (right) ensembles. The bottom panel shows precipitation verification defined as the T511 t+24h TP.



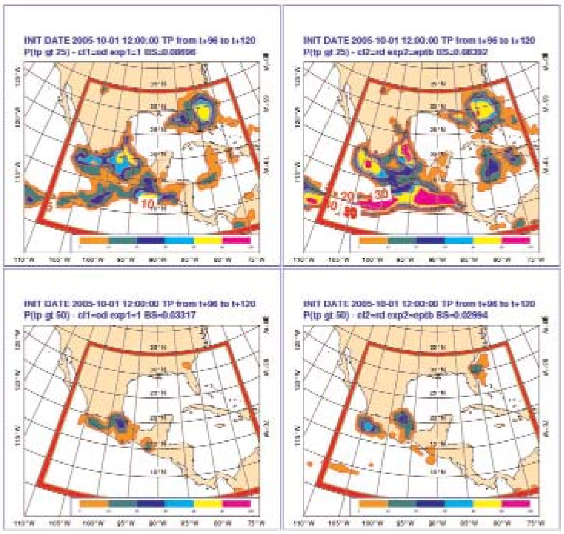


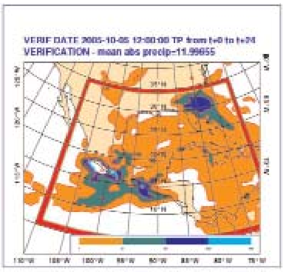
ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 34

2. Stan: PR(TP24>thr) in +120h forecasts valid for 6 Oct 12Z

Panels to the right: t+120h forecasts of PR[TP24>25mm] (top) and PR[TP24>50mm] (bottom) started at 12Z of 1 Oct in the T255 (left) and VAREPS (right) ensembles. The bottom panel shows precipitation verification defined as the T511 t+24h TP.





ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 35

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3. **The future: a seamless ensemble system from day 0 to day 32**

ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 36

2. UK storm 1: 27 October 2002, 12 UTC

From the UK MetOffice News Releases:

- *24 October 2002.* Severe gales are forecast to hit much of England and Wales on Sunday (27 Oct). The south-west, southern England and Wales will take the brunt of the storm, the Met Office is warning. Damaging gusts of up to 80 m.p.h. are expected on exposed coasts and hills and up to 70 m.p.h. over inland areas. The winds will be strong enough to blow over trees and could cause structural damage.

- *27 October 2002.* Storm warnings issued late last week came true today as winds in excess of 80 m.p.h. hit parts of England and Wales. The Atlantic storm crossed Ireland overnight, then the Isle of Man and northern England this morning, en route to the North Sea this afternoon. A wind of 96 m.p.h. was recorded earlier today at Mumbles near Swansea and many areas saw gusts of 60 to 80 m.p.h. In terms of wind speed, it was the biggest storm since late October 2000 when the Isle of Wight recorded 100 m.p.h. winds and 90 m.p.h. winds affected coastal parts of south-west England and south Wales.

ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 37

2. UK storm 1: intensity/position err in +72h MSLP pert-mem

The three sets of bars show the number of perturbed members with intensity (IE) and position (D) errors inside three categories:

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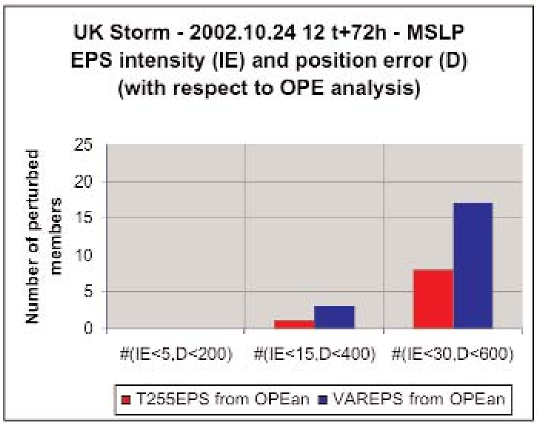


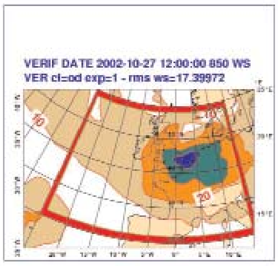
ECMWF

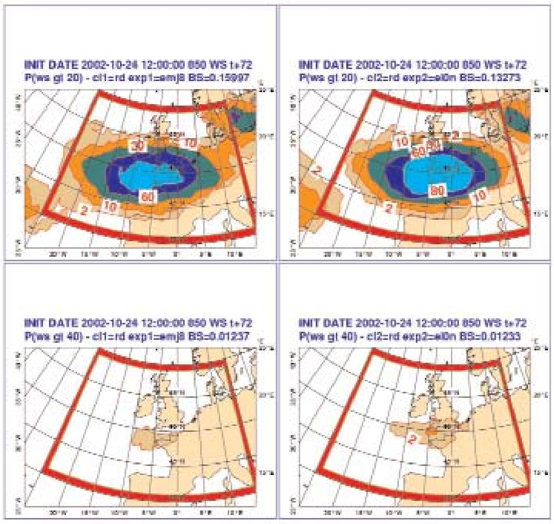
Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 38

2. UK storm 2: PR(850WS>thr) in +72h forecasts

Panels to the right: t+72h forecasts of PR[WS>20m/s] (top) and PR[WS>40m/s] (bottom) started at 12Z of 24 Oct in the T255 (left) and VAREPS (right) ensembles.

The bottom panel shows the wind-speed in the analysis.





ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 39

2. UK storm 2: 12 January 2004, 12 UTC

From the UK MetOffice News Releases:

- *9 January 2004*. Heavy rain and gales are expected to return to Britain early next week, the Met Office is warning. Forecasters are warning of the potential for stormy conditions across the country with winds of 70 m.p.h. across southern and western parts during Monday (12 Jan), with gusts possibly as high as 100 m.p.h. in exposed areas. There is also the possibility of heavy snowfall adding to the difficult conditions for northern areas.

- *14 January 2004*. The Met Office has issued a statement saying the snow that has hit Wales, the Midlands and Eastern England today came from a weather system which was particularly difficult to forecast. The prolonged and heavy rain turned readily to snow as temperatures fell further than expected. Conditions are expected to improve later today, but further wintry conditions can be expected for some areas over the next few days.

ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 40

2. UK storm 2: intensity/position err in +72h MSLP pert-mem

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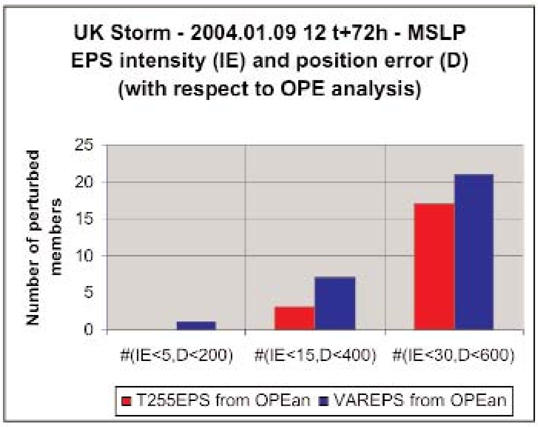
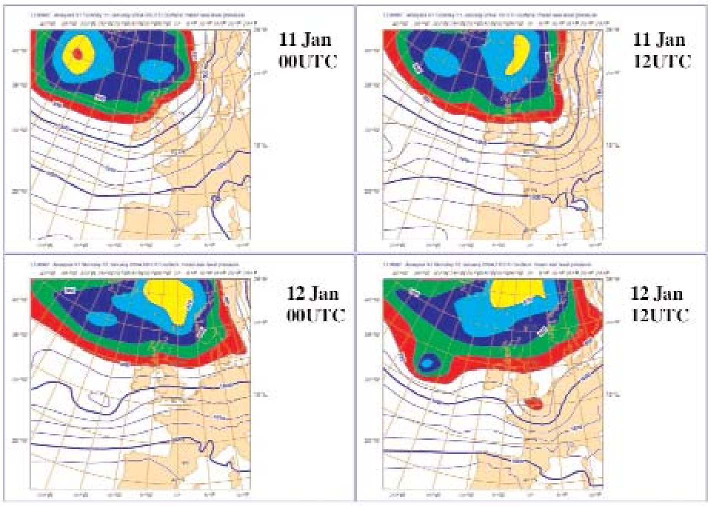


ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 41

2. UK storm 2: 12 January 2004, 12 UTC

Difficult situation to predict, due to the rapid development and propagation of two cyclones within a short distance.



ECMWF

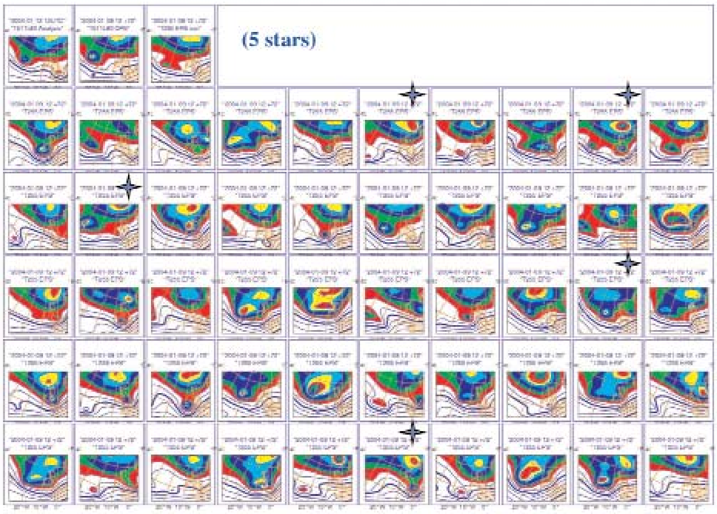
Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 42

2. UK storm 2: T255 EPS from OPEan, 2004-01-09 12 +72h

- Top row: T511 an, T511 fc, EPS control
- Other rows: EPS perturbed members 1 to 50

(All fcs started from T511 OPE analysis.)

Each panel shows MLSP with a 5hPa contour interval and shading for values below 990hPa.



ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 43

2. UK storm 2: VAREPS from OPEan, 2004-01-09 12 +72h

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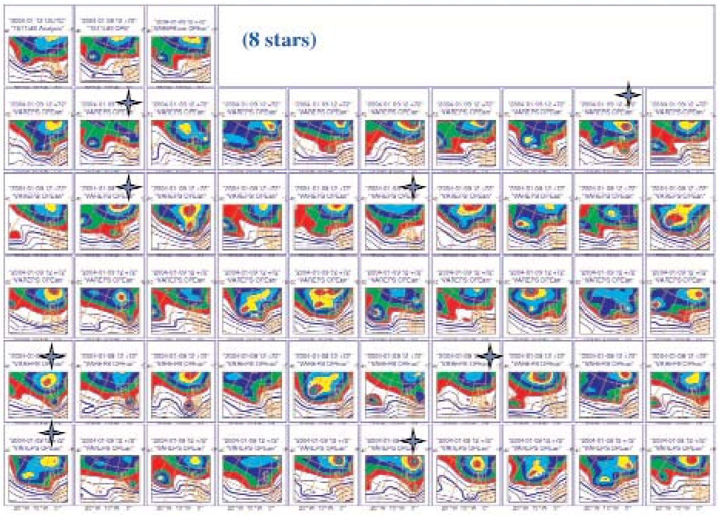


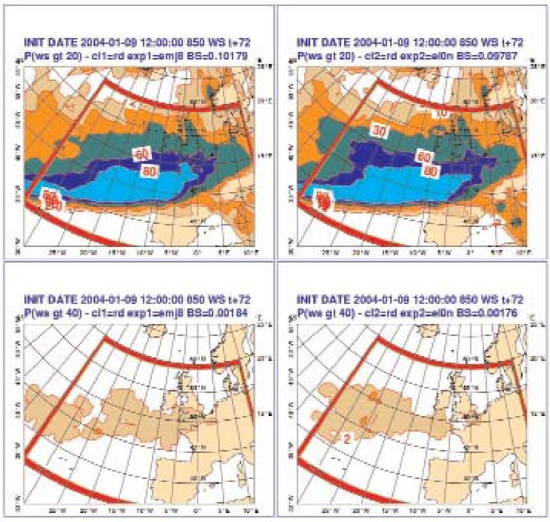
ECMWF

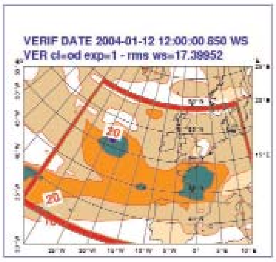
Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 44

2. UK storm 2: PR(850WS>thr) in +72h forecasts

Panels to the right: t+72h forecasts of PR[WS>20m/s] (top) and PR[WS>40m/s] (bottom) started at 12Z of 9 Jan in the T255 (left) and VAREPS (right) ensembles.

The bottom panel shows the wind-speed in the analysis.





ECMWF

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3. **The future: a seamless ensemble system from day 0 to day 32**

ECMWF

2. Flood over Central Europe: 12 August 2002

PRAGUE, 13 august (CNN) - Powerful floods have now killed 94 people across Europe, including five new deaths in Germany on Wednesday. About 50,000 Prague residents have been evacuated, including those in the historic Old Town, as emergency workers continued laying sandbags along the rising River Vltava and outside buildings.

Eight people have died in the floods in the Czech Republic but damage to the city's medieval buildings cannot be assessed until the levels of muddy water, covering many first and second floors, recede. Workers were fighting to save the 14th century Charles Bridge, one of the city's most popular landmarks.

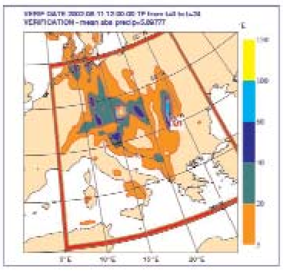
ECMWF

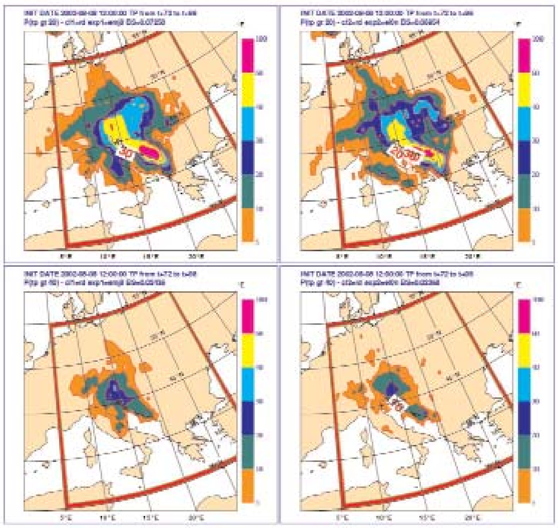
Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 47

2. Flood of Aug 2002: PR(TP24>thr) in +96h forecasts

Panels to the right: t+96h forecasts of PR[TP24>20mm] (top) and PR[TP24>40mm] (bottom) started at 12Z of 8 Aug in the T255 (left) and VAREPS (right) ensembles.

The bottom panel shows precipitation verification defined as the T511 t+24h TP.





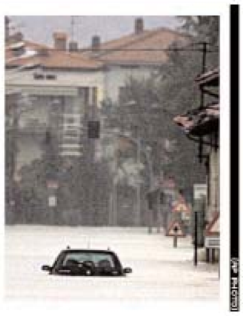
ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 48

2. Flood over Switzerland and Italy: 15 October 2000

GONDO, Switzerland (Reuters) - The 13 people still missing after a mudslide ravaged the village of Gondo on the Swiss-Italian border are assumed to be dead, the local police said on Sunday.

Heavy rains were causing problems elsewhere in Switzerland and northern Italy. Lake Maggiore flooded part of Lugano and in the Valais many train connections were cancelled as tracks were blocked or under water.

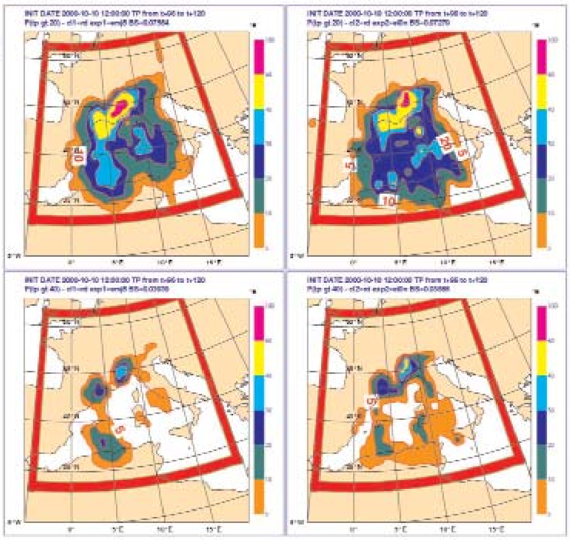


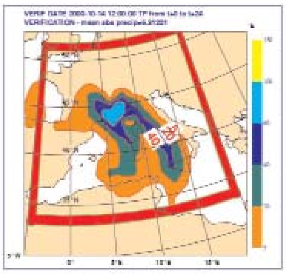
ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 49

2. Flood of Oct 2000: PR(TP24>thr) in +120h forecasts

Panels to the right: t+120h forecasts of PR[TP24>20mm] (top) and PR[TP24>40mm] (bottom) started at 12Z of 10 Oct in the T255 (left) and VAREPS (right) ensembles. The bottom panel shows precipitation verification defined as the T511 t+24h TP.





ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 50

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ECMWF

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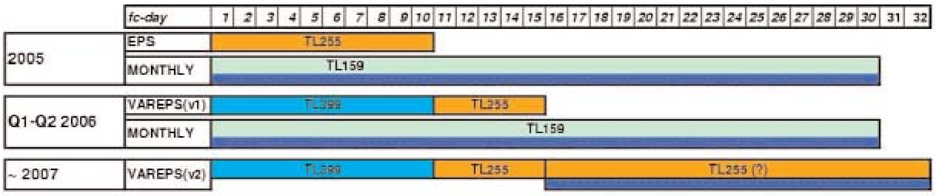
3. The future

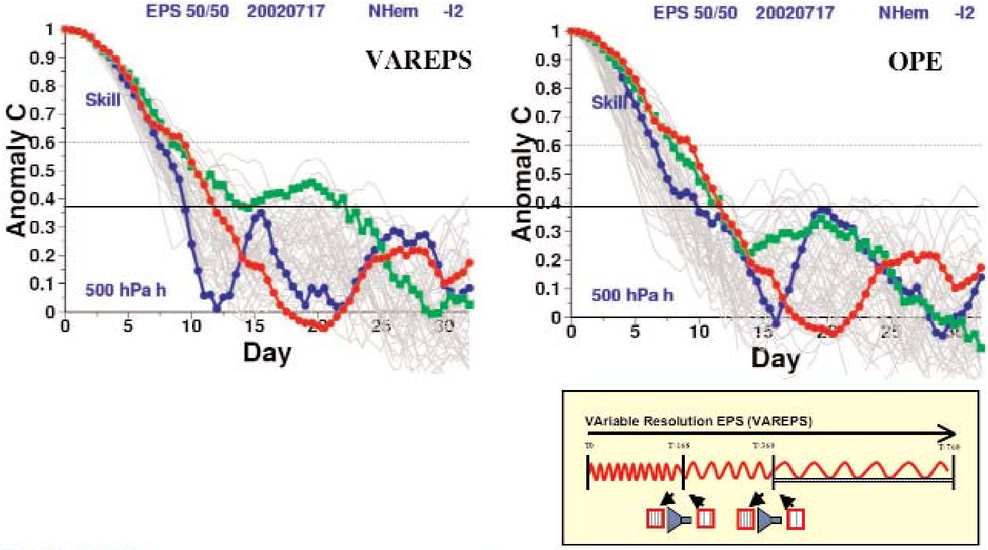
- Research tests of VAREPS have been completed successfully, and all required code modifications have been inserted in the new model cycle (30R1)
- VAREPS is expected to be implemented in Q1-Q2/2006: the exact date will depend on progress on the high-resolution e-suite
- The EPS will be upgraded in two steps: first from T255L40(d0-10) to T399L62(d0-10), and then from T399L62(d0-10) to VAREPSL62(d0-15)
- In 2006 work to test linking VAREPS(d0-15) with the monthly forecast system will continue, with the goal to implement a seamless d0-32 VAREPS



ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 52

3. CY29R2 first case of a 3-legs VAREPS (17 July 2002)



ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 53

.. thank you very much for your attention …

ECMWF

Buizza et al: The new ECMWF VAREPS (10th WS MOPs, 14 Nov 2005) - 54