Recent activities related to EPS (operational aspects)

Junichi Ishida and Carolyn Reynolds

Ayrton Zadra (CMC), Camila Cosset (CPTEC), Michael Baldauf (DWD), Jean-Noël Thépaut (ECMWF), Masayuki Nakagawa (JMA), Dong-Joon Kim(KMA), François Bouyssel (Meteo France), Keith Williams (Met Office), Yuejian Zhu (NCEP), Carolyn Reynolds (NRL)

23-26 Mar. 2015, College Park, U.S.A

WGNE-30

GLOBAL

Operational global (weather) EPS

Black: current, Red: recent upgrade, green: planned or research

Center	Resolutions	FC Range	Members	Initial perturbation, DA	Model Uncertainty	B.C.
ECMWF (Europe)	TL639L91 TL319L91 18/36km (p)	10d +5d	51	SV(Total energy norm) + EnDA	SKEB and Stochastic physics update of backscatter scheme	coupling to ocean model, EDA-based land-surface pert. in ENS ICs
Met Office (UK)	33kmL70 21km (p)	7d	11+1 18/24 (p)	ETKF En-4D-EnVar (p), 4D-EnVar (p)	Random Parameters (RP2) and SKEB2.	N Coupling to ocean (p)
Meteo France (France)	TL538(C2.4) L65	4d	35	SV (Total Energy Norm)+ EnDA	different packages, randomly used	N
HMC (Russia)	T169L31 25-30km (p)	10d	12+1+1	Breeding EnVar DA (r)	N SPPT (p)	?
NCEP (USA)	T254L42 T190L42 T_L573/382L64 (p)	8d +8d 35d (p)	45	Ensemble Transform with Rescaling	stochastic pert. to account for random model errors SKEB, SPPT, SHUM (p)	N Stochastic pert. of land, couple with ocean (p)
NRL/FNMOC (USA)	T159L42 T359L60 (p)	16d	20	local ET Hybrid 4D-Var (r)	N SKEB-mc (p)	N SST initial pert. (p) ocean, ice, wave coupling (r)
CMC (Canada)	0.6° L40	16d	20	Ensemble KF	stochastic pert. of physical tendencies and SKEB further pert. to the physics	new method to evolve SST and sea-ice
CPTEC/INPE (Brazil)	T126 L28	15d	15	EOF-based perturbation	N	N
BoM (Australia)	~60kmL70	10d	24	ETKF	Random Parameters (RP2) and SKEB2.	N
JMA (Japan)	TL479 L60 TL479L100 (p)	11d 18d (p)	27	SV(Total energy norm) Reduce tropical initial pert. (p)	Stochastic perturbation of physics tendency	N Rev, SST and sea ice (p)
CMA (China)	T213 L31	10d	15	bred vector method	N	N
KMA (Korea)	~40kmL70 32km (p)	12d	24 44	ETKF Hybrid Ensemble 4D-Var	Random Parameters (RP2) and SKEB2.	N

Summary of Operational global EPS

- Ensemble approach is now mainstream in operational NWP
  - Almost all centres
- Developed / developing of model uncertainty (e.g. SPPT)
  - ECMWF, MO, MF, HMC, NCEP, NRL, CMC, BoM, JMA, KMA
- Plan of increasing horizontal / vertical resolution
  - ECMWF, Met Office, RHMC, NCEP, NRL, JMA
- Further treatment of lower boundary condition (e.g. couple to ocean, SST or ice perturbation)
  - ECMWF, Met Office, NCEP, NRL, CMC

EXTRA SLIDES (GLOBAL)

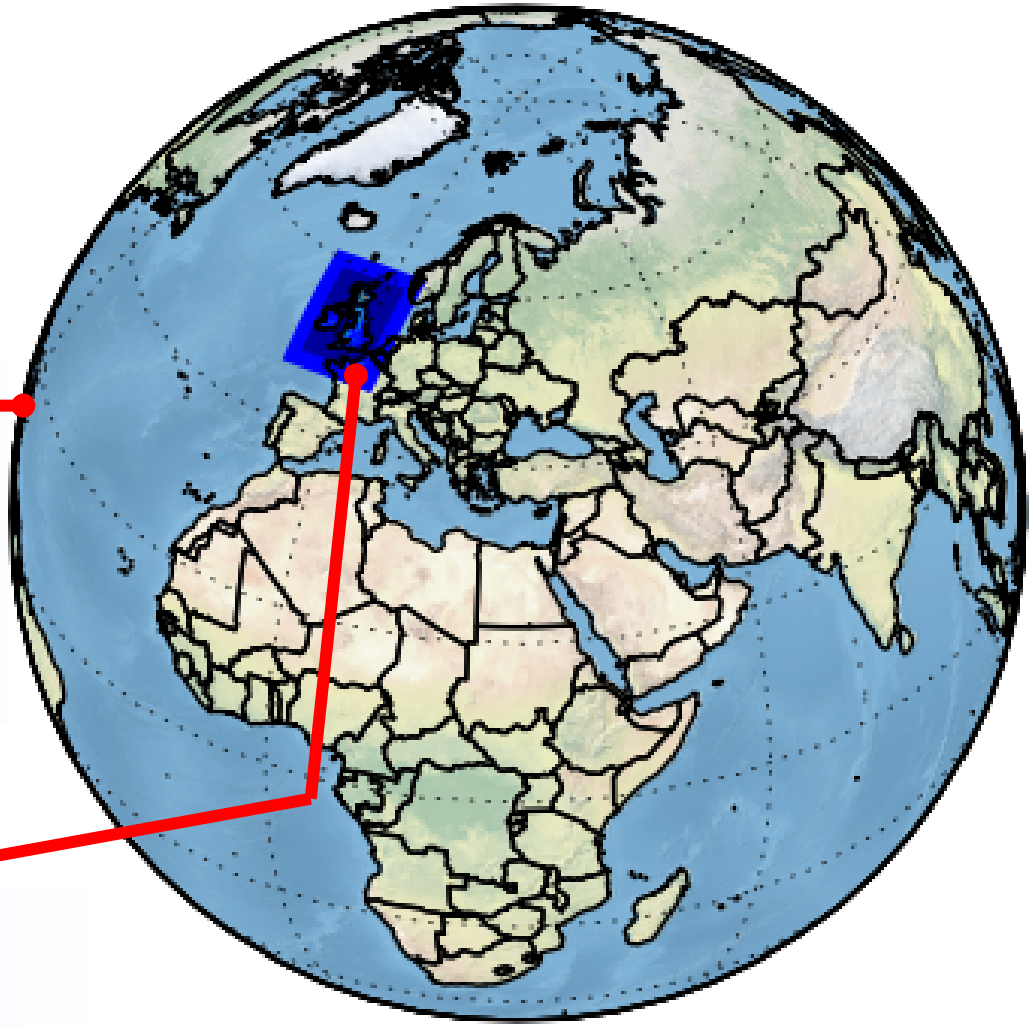
Implementations & plans

- Nov 2013 (cycle 40r1)
  - Coupling with ocean model NEMO from initial time
  - L62 (5hPa top) to L91 (0.01hPa top)
- Apr 2014 (cycle 41r1)
  - minor update of backscatter scheme (orog. GWD removed)
- 2015 Resolution upgrades

	Now (D0-10/D10+)	upgraded
Atmosphere (IFS)	32/64 km	18/36 km
Ocean (NEMO)	1deg L42	¼ deg L75
Waves (WAM)	0.50 deg	0.25/0.36deg
waves (freq,dir)	(30,24) / (25,12)	(36,36) /(30,24)

- 2014/15: Extension of leg B to 45 days planned

Ensemble NWP model suite



MOGREPS-G

- 33km 70 Levels
- 7 day forecast 4 times/day
- 12 members
- 24 member lagged products

MOGREPS-UK

- 2.2km 70 Levels
- 36 hour forecast 4 times/day
- 12 members

©

MOGREPS-G Future Plans

- Routinely upgrade science in-line with Global Atmosphere process to maintain consistency with deterministic models
- Spring 2016:
  - Upgrade horizontal resolution 33km -> 21km
  - Increase forecast members 11 -> 18/24 (to support convective-scale models out to at least 48-60hrs) [note: ensemble size in ETKF is 44]
- Spring 2017:
  - Increase ensemble size from 44 -> ~200 members (forecast members to stay around 18-24)
  - Upgrade 4d-Hybrid-Var DA to 4d-En-Var (subject to research results outperforming current system)
  - Replace ETKF ensemble perturbation scheme with En-4d-En-Var
- 2017/18:
  - Include coupled ocean-atmosphere model in all global configurations

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Ensemble prediction at RHMC

Global:

Models: spectral T169L31, semi-Lagrangian SLAV

Membership: 14 members, 12 perturbed T169L31,
2 controls T169L31 and SLAV

Resolution: ~70 km

240h forecast once a day at 12 UTC

Operational since January 2015

Plans:

- Introduction of high-resolution control runs (~25-30 km) (2015)
- Increase of EPS size (greater contribution of SLAV) (2015, a greater increase in 2016 after a new computer is installed)
- Introduction of SPPT (2015-2016)
- Development of the system based on EnVar DA (2016)

Next GEFS (V11.0.0) configuration

- Model
  - Current: GFS Euler model (V9.0.1)
  - Plan: GFS Semi-Lagrangian model (V10.0.0)
- Horizontal resolution
  - Current: T254 (~52km) for 0-192 hours, T190 (~70km) for 192-384 hours
  - Plan: T_L574 (~34km) for 0-192 hours, T_L382(~52km) for 192-384 hours
- Vertical resolution
  - Current: L42 hybrid levels
  - Plan: L64 hybrid levels to match with GFS and DA
- Computation cost:
  - Current: 84 nodes (+ post process) for 55 minutes
  - Plan: 300 nodes (first 35 minutes), 250 nodes (2^{nd} 30 minutes)
- Output:
  - Current: every 6-hr for 1*1 degree pgrb files
  - Plan: every 3-hr for 0.5*0.5 degree pgrb files
- Schedule:
  - Feb. 2015 – deliver codes/scripts to NCO
  - Apr. 2015 – implementation (WCOSS-phase II)

GEFS Plan

- Increase model resolution and membership
- Introduce other stochastic schemes
  - Stochastic Kinetic Energy Backscatter (SKEB)
    - Represents processes absent from model
  - Stochastic Perturbed Physics Tendencies (SPPT)
    - Designed to represent the structural uncertainty (or random errors) of parameterized physics. Biggest impact for tropics
  - Stochastically-perturbed boundary layer HUMidity (SHUM)
    - Designed to represent influence of sub-grid scale humidity variability on the the triggering of convection
  - Stochastic perturbed land-surface
- Extend GEFS to 35 days
  - Coupling with ocean/ice model, or alternate method

NRL Global Ensemble Forecast System

- Current system: NAVGEM T239L50, 20-mem, 2xday to 16 days. ET initial perturbation method with obs-based analysis error variance estimates.
- Upgrades 2015-2016: Incorporation of model uncertainty.
  - Stochastic forcing with moisture convergence mask (SKEB-mc) in operational testing
  - SST initial perturbations, diurnal cycle, persistent anomaly capability (2016)
  - T359L60 (2016)
  - Hybrid 4D-Var system currently being developed for transition to operations (2016)
- Long-term plans: Coupled atmo-ocean-ice-wave system for subseasonal to seasonal applications

Canadian centre: recent developments in the Global Ensemble Prediction System (GEPS)*

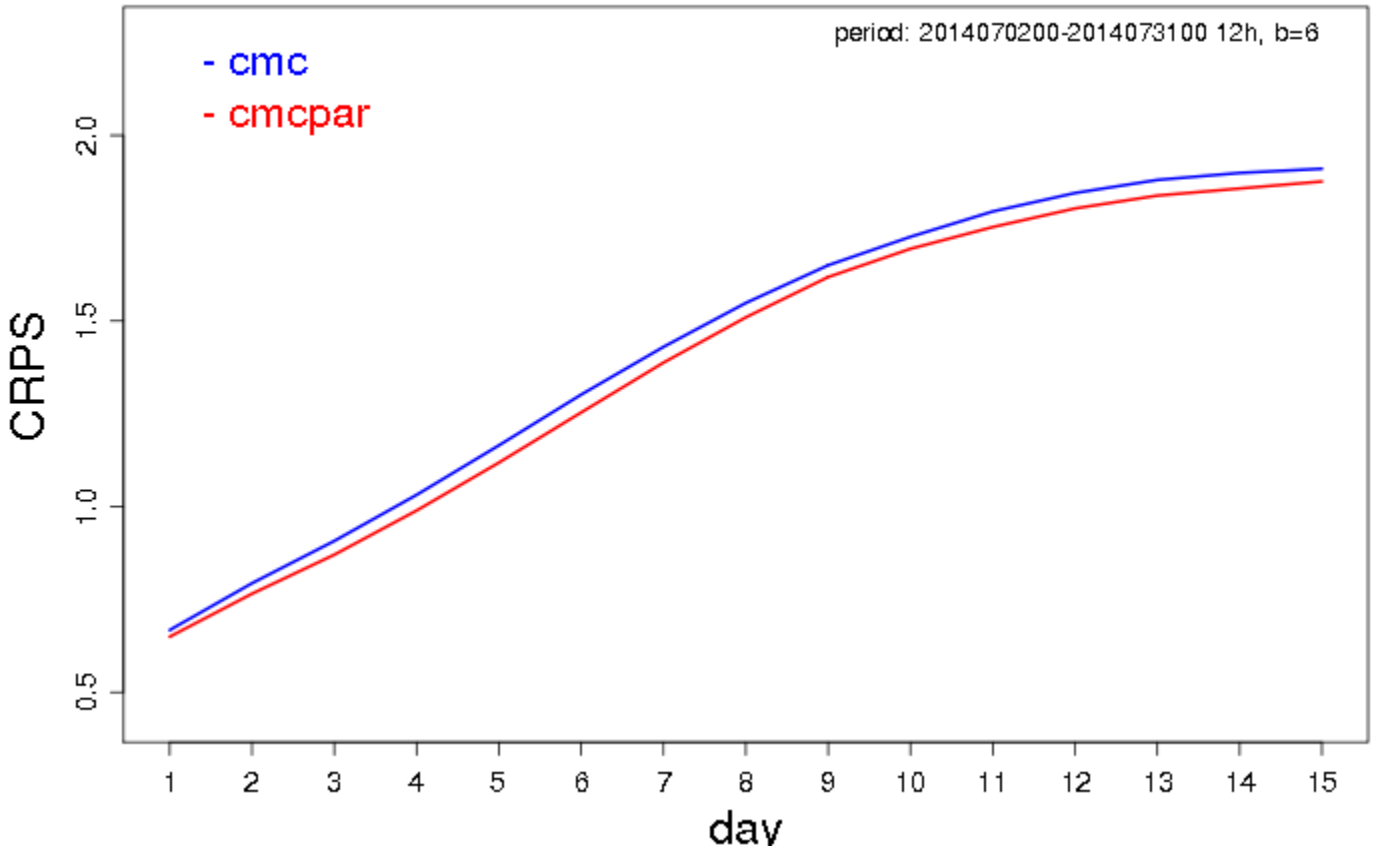
Main changes to the forecast component

- *horizontal resolution: 66 → 50 km*
- *time step: 20 → 15 min*
- *new method to evolve SST and sea-ice fields*
- *further perturbations to the physics (e.g. orographic blocking bulk drag coefficient, thermal roughness length over oceans)*

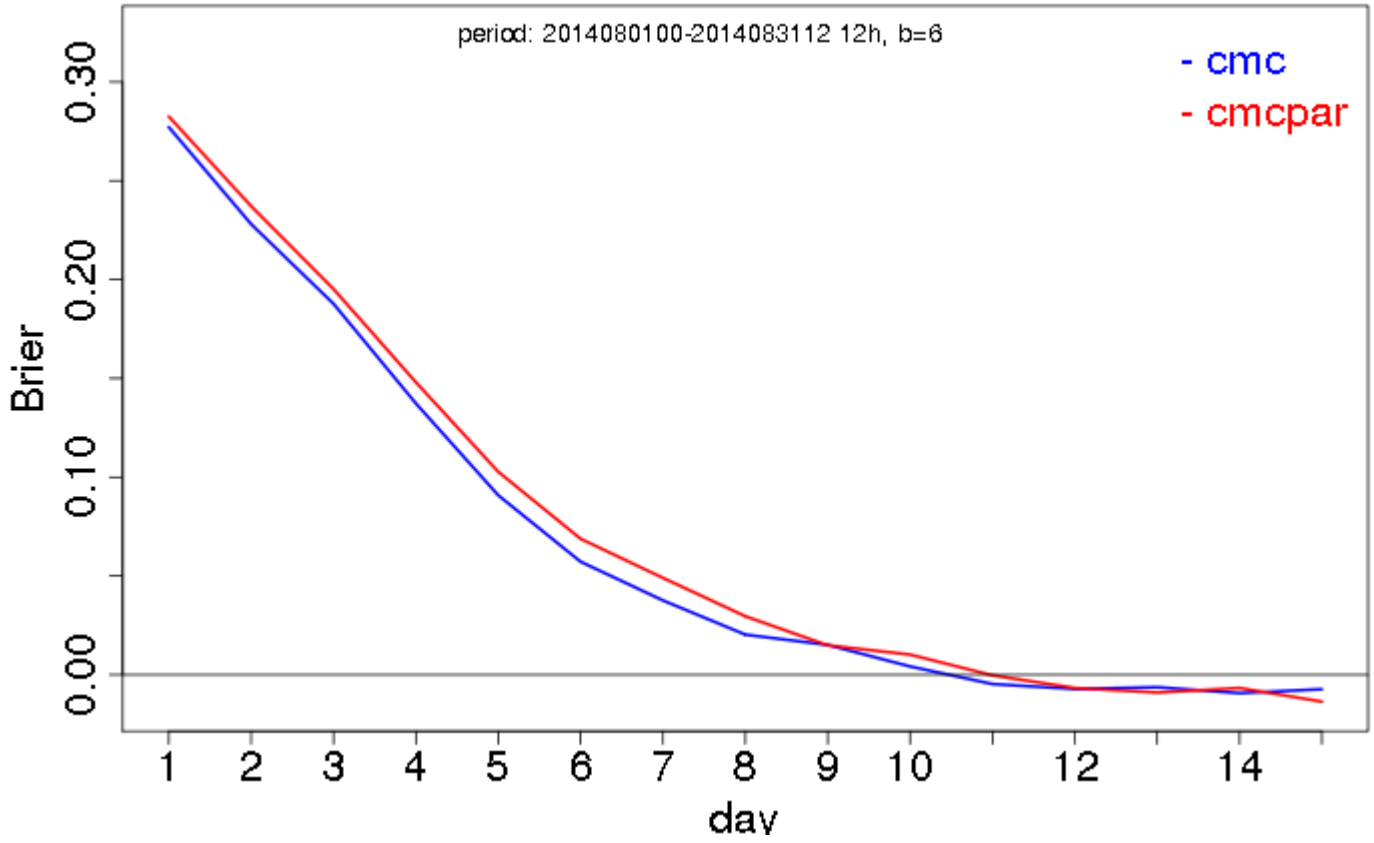
Overall 6-h improvement in forecast skill for atmospheric variables.

** Material kindly provided by Peter Houtekamer and Normand Gagnon*

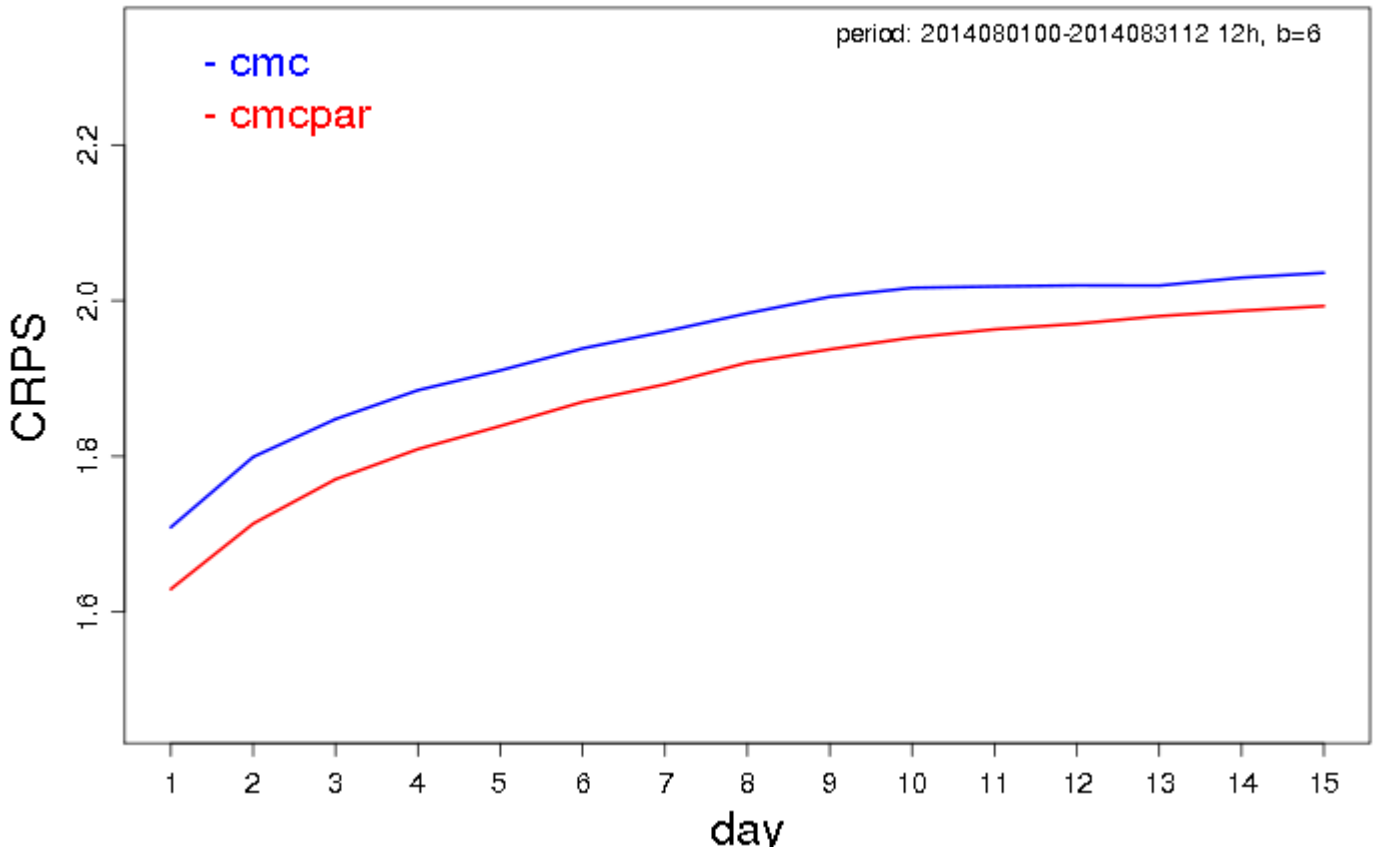
Verification against radiosondes, Temperature at 850hPa Aug 2014 (during parallel suite of new system) old versus new



Precipitation verification over N. America
Brier score, 10-mm threshold
Aug 2014 (during parallel suite of new system)
old versus new



Surface verification
Dew-point depression
Aug 2014 (during parallel suite of new system)
old versus new



CPTEC Ensemble Prediction System

EPS-OPER: Zhang and Krishnamurti (1999)

- EOF based perturbations
- 15 members
- Unperturbed initial condition: NCEP analysis 12 UTC

EPS-MB09: Mendonça and Bonatti (2009)

- Two additional variable (surface pressure and specific humidity)
- Extended analysis region

EPS-MB09 BC: Cunningham et al. (2014)

- Bias is defined as the difference between the control forecast and the analysis and subtracted from each member of the ensemble.

Contrib: Camila Cossetin (camila.ferreira@cptec.inpe.br)

Development – EPS -

- Under development
  - Extension of forecast range up to 432 hours ahead
  - Introduction of the latest version of GSM (TL479L100)
  - Reduction of tropical initial perturbation amplitude
  - Revise of sea surface temperature and sea ice during the time integration
  - Introduction of snow analysis with SSMI data and land cycle system as a land initial condition generator

Current status of global EPS

	2006.07.~2010.12.	2010.12~2011.05	2011.5~2012.6.	2012.6~2013.6	2013.7.~
Model Base	GDAPS (JMA)	UM (UKMO, ver7.5)	UM ver7.7	UM ver7.9	UM ver7.9
Assimilation Method	3D - Var	4D - Var	4D - Var	4D-Var	**Hybrid Ensemble 4D - Var**
Horizontal Resolution	T213 (Gausian grid) 0.5625 degree in lat/lon	N320 (~40km) 0.5625 in lon/ 0.375 in lat.	N320 (~40km) 0.5625 in lon/ 0.375 in lat.	N320 (~40km) 0.5625 in lon/ 0.375 in lat.	N320 (~40km) 0.5625 in lon/ 0.375 in lat.
Vertical levels / top of model	40 / ~0.4 hPa	50 / ~63 km	70 / ~80 km	70 / ~80 km	70 / ~80 km
Initial Times	00,12	00, 12	00,12	00,12	00, 12 (06, 18 for cycled hybrid)
Lead Time	10 days	10 days	10 days	10 days	**12 days**
Output Frequency	6h	6h	6h	6h	6h to 240h,12h to 288
No. of Members	15+1	23+1	23+1	23+1	23+1
Coupled Ocean	No	No	No	No	No
Initial Perturbations	Breeding + factor rotation	ETKF	ETKF	ETKF	ETKF
Model Perturbations	No	RP, SKEB2	RP, SKEB2	RP, SKEB2	RP, SKEB2
Surface Perturbations	No	No	No	SST Perturbation	SST Perturbation

REGIONAL

Operational regional EPS

Center	Resolutions	FC Range	Members	Initial perturbation, DA	Model Uncertainty	B.C.	Note
Met Office (UK)	2.2kmL70	36h	11+1 18/24 (p)	Interpolated from global EPS Convective ensemble DA (p)	SPPT (p)		UM
Meteo France (France)	2.5km	42h	11+1	Rescaled and centered from global EPS EDA or B-based random noise (r)	SPPT	correlated random perturbations of SST, soil moisture/humidity, snow, physiographies	AROME Pre-operation
DWD (German)	2.8km	27h	20 40 (r)	IFS, GMS, GME, GSM Ensemble DA based on LETKF (r)	Pert. Parameters SPPT (r)	IFS, GMS, GME, GSM Add COSMO-LEPS (p) Global ICON EPS (r)	COSMO
HMC (Russia)	2.2km	48h	10	COSMO-S14-EPS	N SPPT (p)	COSMO-S14-EPS	COSMO
JMA (Japan)	5kmL48	39h	10+1 20+1 (p)	SV(Total energy norm) Hybrid DA (r)	N Pert. tendency (r)	JMA global EPS Perturbed SST (r)	JMA-NHM Test-operation
NRL/FNMOC (US)	27/9/3km	120h	10+1	Perturbed synoptic scales Perturbed Rankine Vortex	N	GEFS/NAVGEM with synoptic perturbations	COAMPS-TC
NRL/FNMOC (US)	45/15/5km	72h	20+1	ETKF	Parameter variations	NAVGEM ensembles	COAMPS
CMC (Canada)	15km	72h	20+1	Interpolated from global EPS Improved by global EPS	Stochastic pert. of physics	Global EPS Improved by global EPS	GEM
KMA (Korea)	3kmL70	45h	23+1	Downscale from Global EPS LETKF	RP	Global EPS	UM

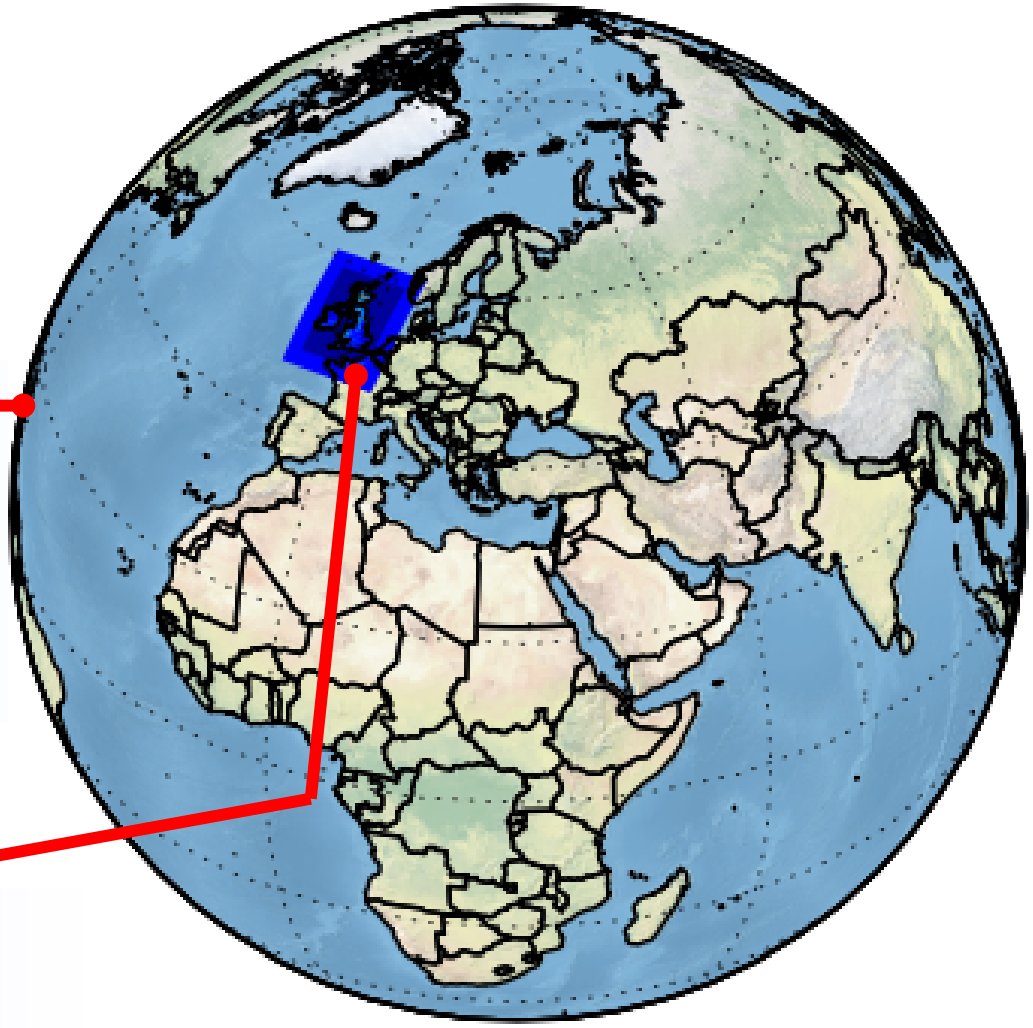
Black: current, Red: recent upgrade, green: planned or research

Summary of Operational regional EPS

- High resolution EPS: same as or bit coarser than deterministic regional model
  - Almost all centres
- Several centers running EPS for research and quasi-operational purposes towards operation in near future
  - Meteo France, NRL, JMA
- Research of Ensemble DA
  - Met Office, DWD, JMA, KMA
- Development of model uncertainty
  - Almost all centres
- Variety of lateral boundary conditions
  - From global ensemble or multiple deterministic global model, with or without perturbation

EXTRA SLIDES (REGIONAL)

Ensemble NWP model suite



MOGREPS-G

- 33km 70 Levels
- 7 day forecast 4 times/day
- 12 members
- 24 member lagged products

MOGREPS-UK

- 2.2km 70 Levels
- 36 hour forecast 4 times/day
- 12 members

©

MOGREPS-UK plans

Short-term

- Use UKV analysis combined with perturbations from MOGREPS-G.
- First phase of stochastic physics – version of "random parameters" scheme suited for MOGREPS-UK.

Longer term – (on new HPC)

- Hourly UK ensemble; combine several runs to make larger lagged ensemble
- Higher resolution (horizontal and vertical)
- Convective-scale ensemble data assimilation (needing much larger ensemble for DA cycling).

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MOGREPS-UK Initial conditions

- Experience with the old regional ensemble (MOGREPS-R) showed benefit of using a higher resolution regional (NAE) analysis, plus global perturbations.
- Does the same carry over to MOGREPS-UK?

Downscaled:

Currently each MOGREPS-UK (2.2km) member starts from a reconfigured MOGREPS-G (N400, 32km) 3-hour forecast.

$x_{UK}=R(x_G)$

Re-centred:

An alternative is to re-centre the MOGREPS-G perturbations around the UKV (1.5km) analysis.

$x_{UK}=x_a+R(x_G)-R(x_G^0)$

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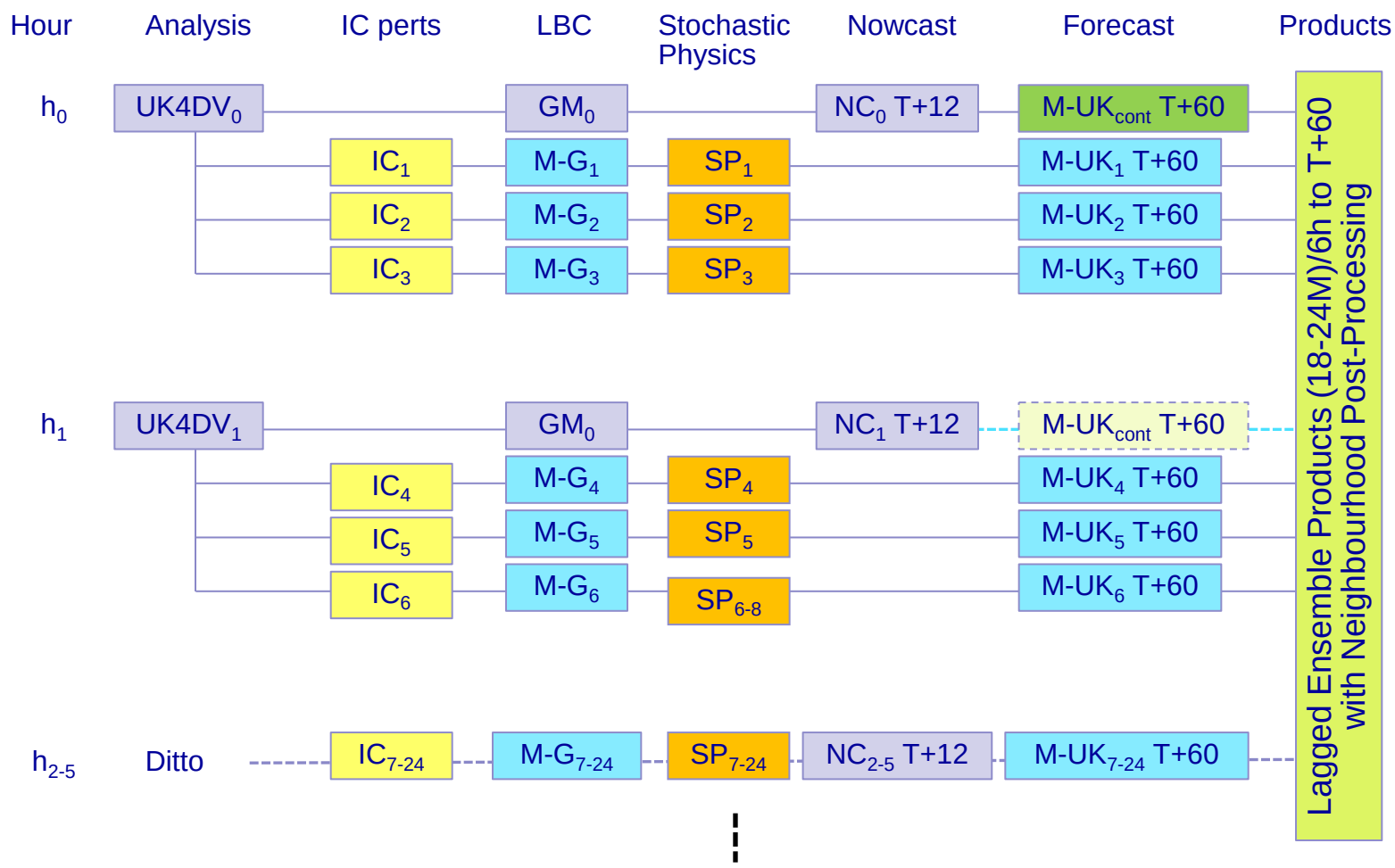
Future Ensemble Organisation

Hourly UK4DV nowcast

19-24M/6h MOGREPS-UK Nested in 18-24M MOGREPS-G

Potentially ***all*** at 1.5km resolution



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The AROME EPS - progress & plans

AROME-France-EPS in preoperational mode :

- 12 members at 2.5km resolution (vs 1.3km for deterministic AROME-France)
- 42-hour range production starts at 09 and 21UTC
- Perturbations:
  - **lateral boundary conditions:** selected from the 35-member global PEARP ensemble (using clustering) (PEARP has 10 km resolution)
  - **initial upper-air:** rescaled & centered perturbations from PEARP
  - **initial surface:** correlated random perturbations of SST, soil moisture/humidity, snow, physiographies
  - **model error:** SPPT (stochastic perturbation of physics tendencies)
- Current research:
  - coupling between initial, lateral and surface perturbations
  - better ICs (using EDA or B-based random noise)
  - dispersion-preserving clustering of LBCs
  - post-processing :
  - precipitation calibration, neighbourhood methods and economic value
  - coupling to flood prediction models & aircraft trajectory planning

DWD's Ensemble Prediction System

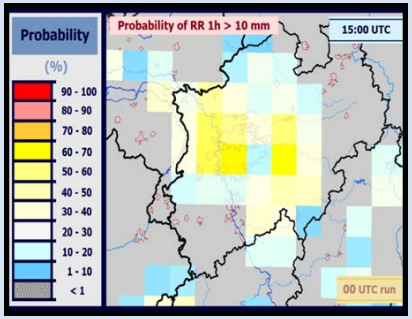
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

COSMO-DE-EPS

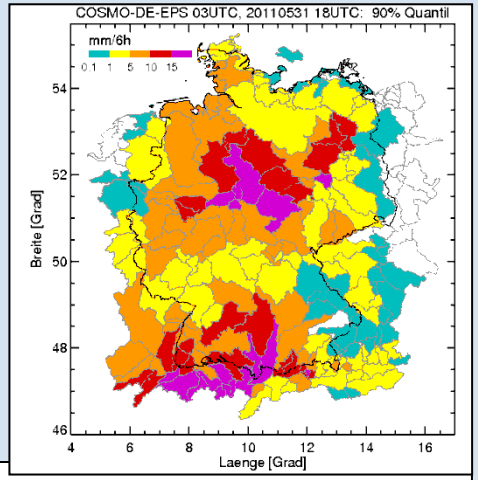
- Ensemble based on COSMO-DE, convection permitting
- Variation of initial conditions, boundaries and model physics, multi model input
- Grid spacing: 2.8 km
- 20 ensemble members
- Forecasts 0 - 27 hours, 8 runs per
- Operational since May 2012

- weather warnings
- hydrological forecasts

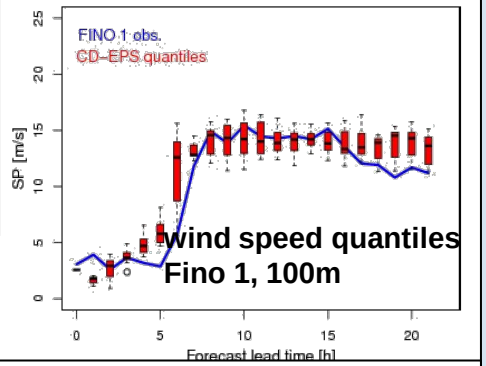
Prob. of precip. > 10mm/h



Precip. 90% quantil

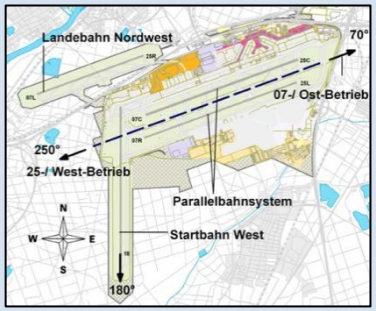


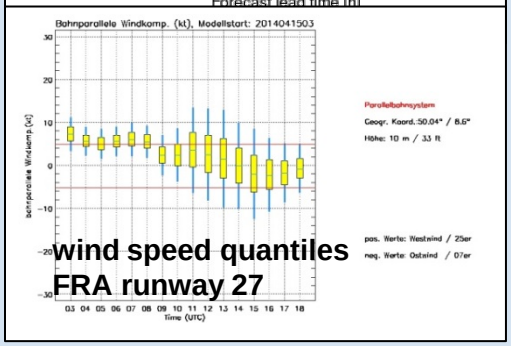
- renewable energies:



- airport weather

runway tail and crosswinds



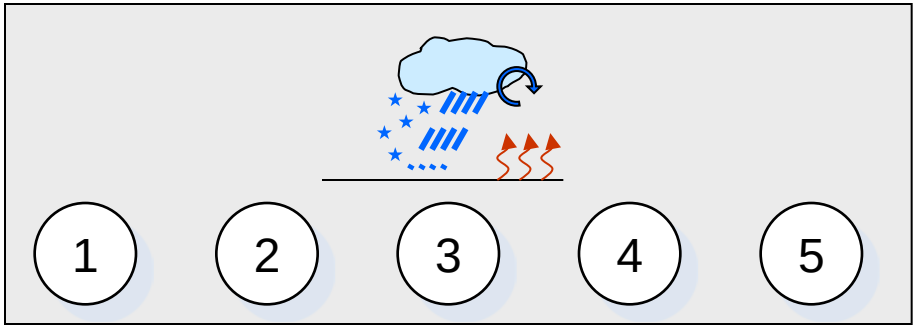


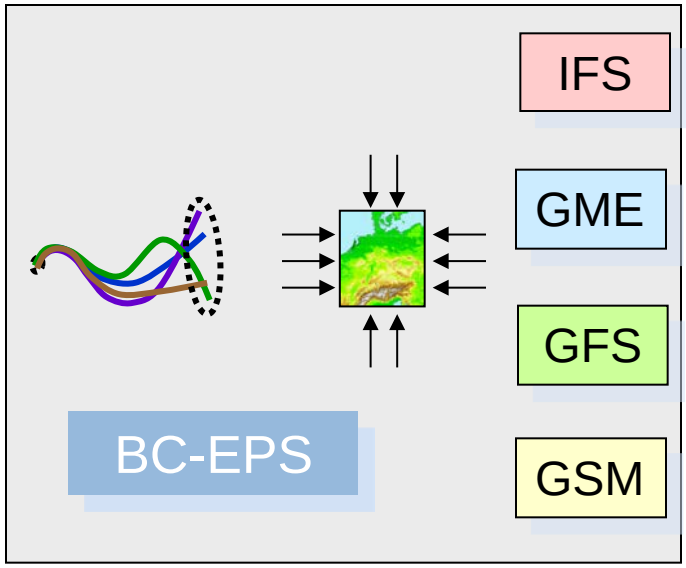
DWD's Ensemble Prediction System

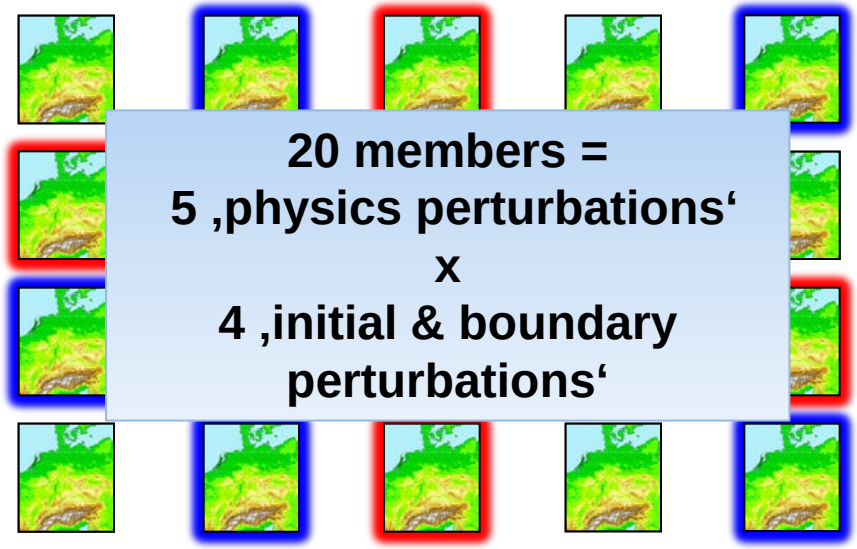
Members 1 - 20 (operational setup)

„+“ soil moisture anomaly

„-“ soil moisture anomaly







Current Research:
Extension to 40 Members

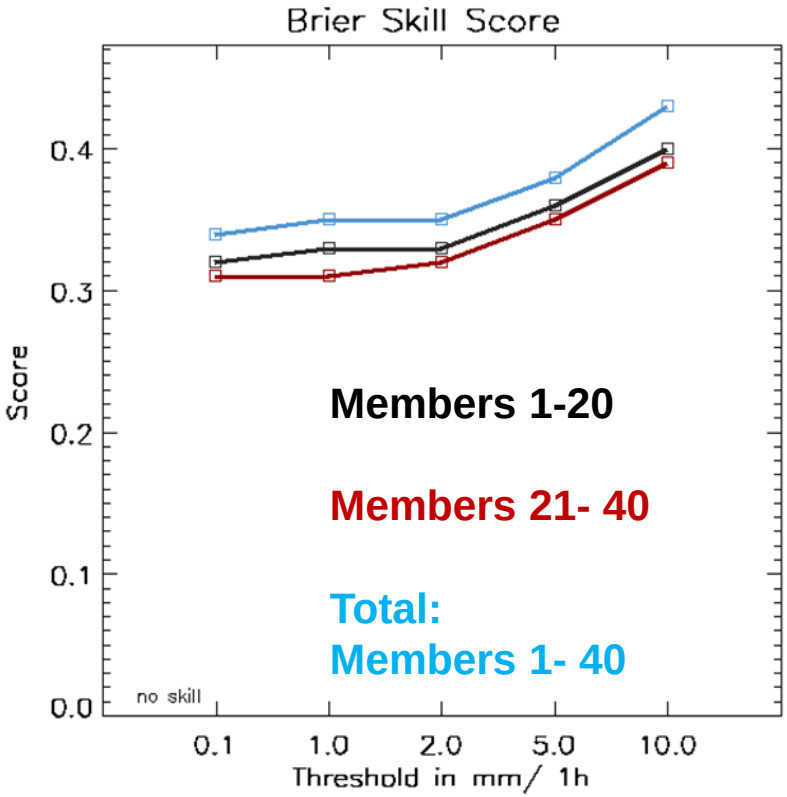
➔ **increase number of boundary forecasts**

current setup: **4** x 5 =
20 members

future setup: **8** x 5 =
40 members

➔ **the 4 additional boundary forecasts:**
selected members from COSMO-LEPS ensemble
(driven by the global ECMWF ENS)

Verification Results (precipitation)



Future plans

- ➔ operational use of KENDA for IC perturbations
- ➔ add new physics perturbations or alternative perturbation methods (e.g. stochastic physics)
- ➔ use of global ICON EPS for BC perturbations

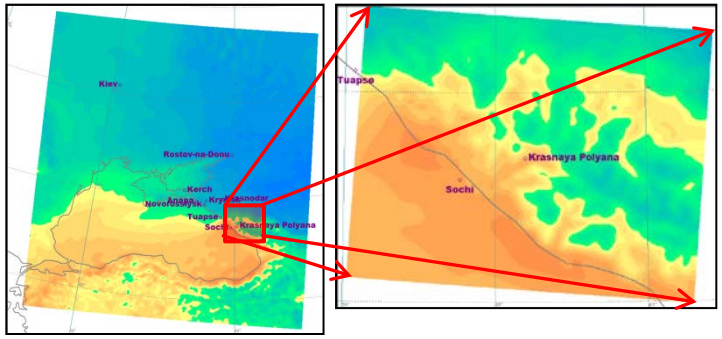
Ensemble prediction at RHMC

Regional:

Model: COSMO

Membership: 10 members

Resolution: 2.2 km



IC&BCs from COSMO-S14-EPS (a clone of COSMO-LEPS for Sochi region, developed and managed by ARPA-SIMC, Italy) , 7 km resolution

48h forecasts twice a day at 00 and 12 UTC

Has been developed for the Sochi region and ran operationally till May 2014

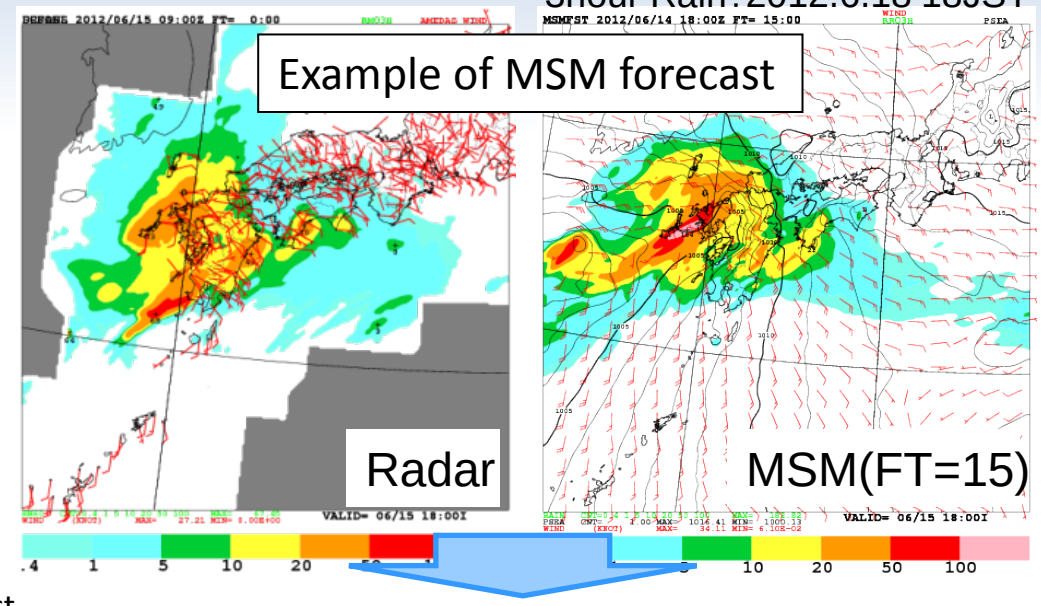
Research: SPPT effect on forecast skill and ensemble spread (using Sochi data)

Plans: development of convection-permitting EPS based on COSMO model for Moscow region (and for the polar region if computer available)

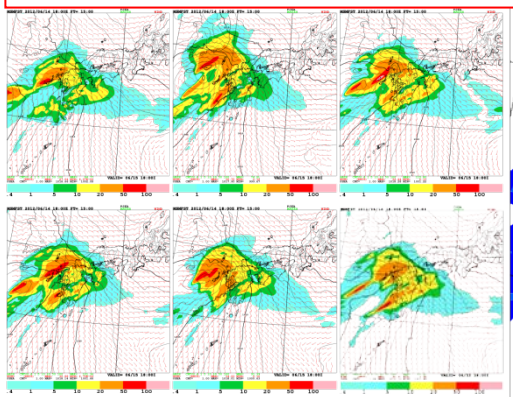
Mesoscale Ensemble Prediction System (MEPS) at JMA

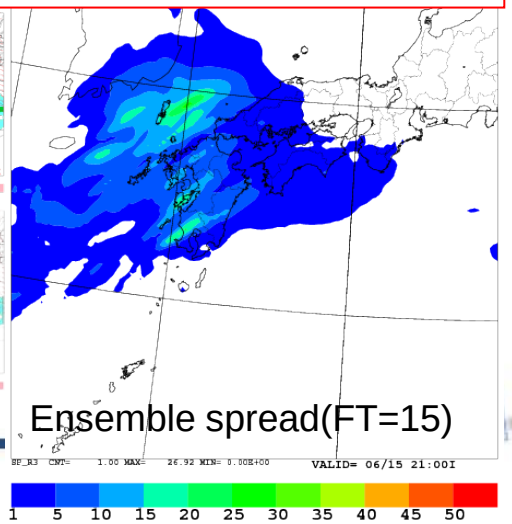
- **Purpose**
  - Uncertainty and probability information of MSM
- **Schedule**
  - Test operation is planned to start at the end of FY2014
- **Ensemble forecast**
  - Forecast model : JMA-NHM (Saito et al. 2006)
  - Resolution : 5km
  - Ensemble size: 11
    - 10 perturbed forecasts + 1 control forecast
- **Perturbation**
  - Initial : Singular vector (SV)
  - Lateral boundary : Global EPS
    - Based on SV
  - Physics and lower boundary
    - Under development
- **Current Status**
  - Daily experiment once a day with initial and lateral boundary perturbations

3hour Rain : 2012.6.18 18JST



Meso-scale Ensemble Prediction System (MEPS)


Perturbed forecasts(FT=15)



気象庁
Japan Meteorological Agency

NRL COAMPS Ensemble Forecast Systems

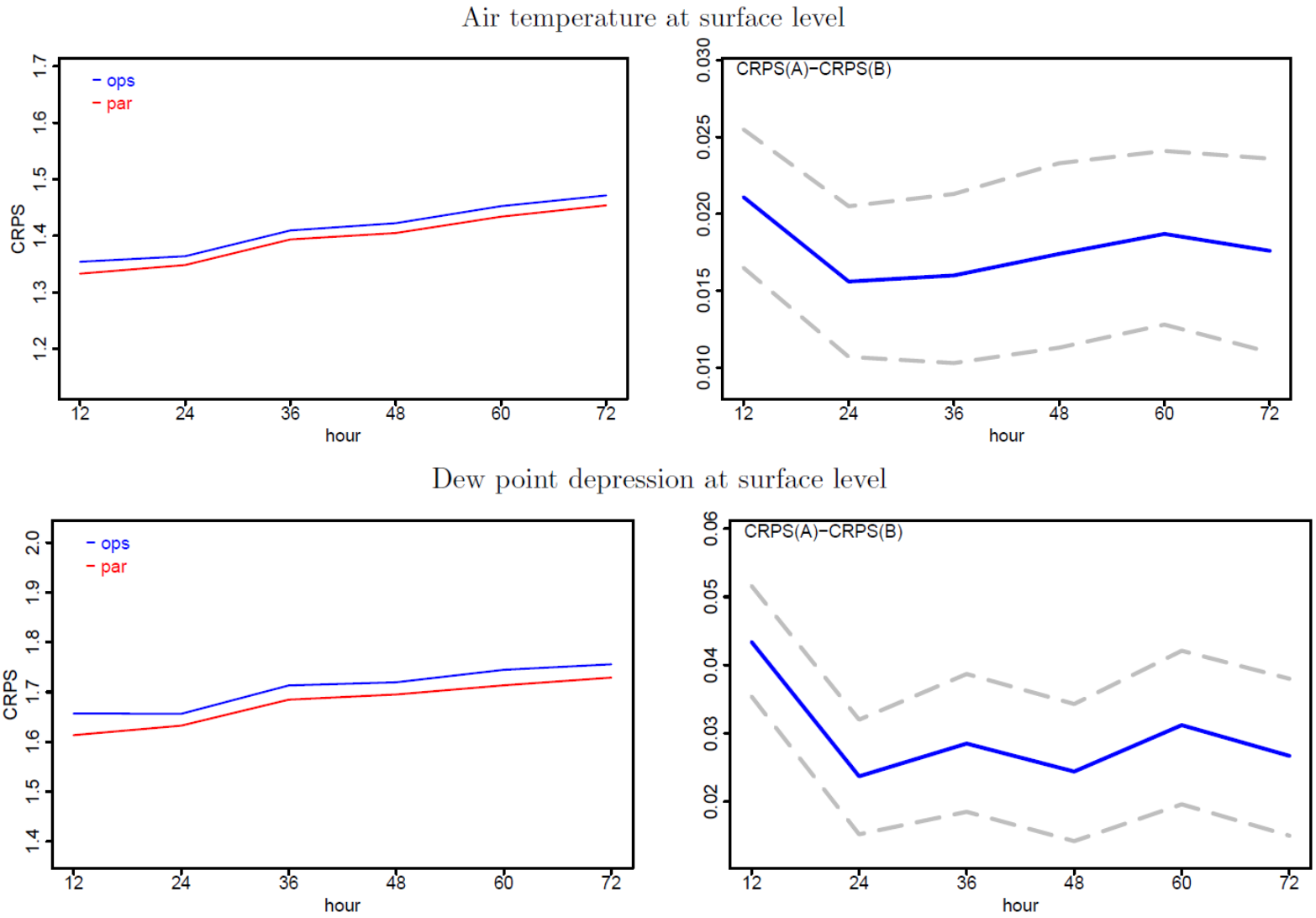
- Ensemble Transform with perturbed physics parameters
- EnKF within DART for COAMPS-TC (27, 9, 3 km, 10-mems, part of the NOAA Hurricane Forecast Improvement Project Multi-model Ensemble)
- Applications:
    - Coupled dispersion modeling (Fukushima)
    - Coupled atmosphere-ocean ensembles (Hydrological cyclone in the Mediterranean Experiment)
    - Tropical Cyclone applications (HOAA HFIP, ONR)
    - DoD tactical applications (refractivity)

Canadian centre: recent developments in the Regional Ensemble Prediction System (REPS)*

- *Main change consisted in **improvements to the analysis and lateral boundary conditions** – provided by the global ensemble (GEPS) which underwent a major upgrade.*
- ***CRPS scores**, both at the surface and the upper air, show **significant improvements**. Most of the improvements are from the reliability component.*
- ***Brier precipitation scores also show improvements** at all thresholds and at all leads times, especially below 15 mm.*
- *The new system is a bit more over dispersive.*
- *Some scores shown in next slides.*

** Material kindly provided by Amin Erfani, Ronald Frenette, Normand Gagnon and Martin Charron*

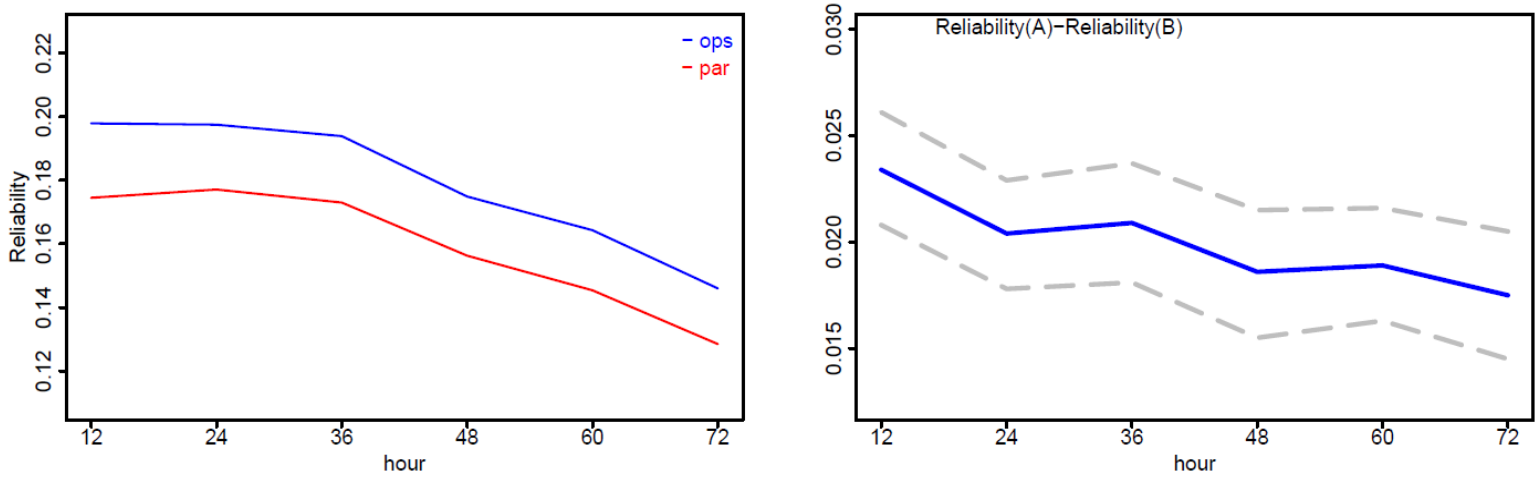
Comparison of CRPS scores near surface between old and new system



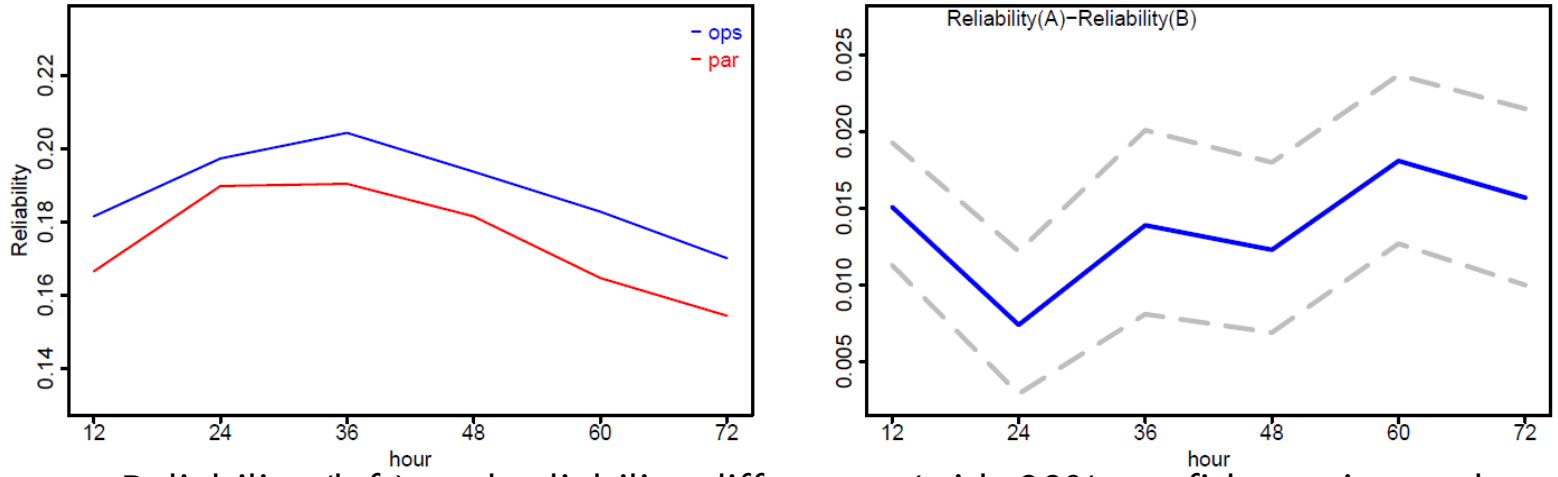
CRPS (left) and CRPS difference (with 90% confidence intervals, right) between the REPS 2.0.1 (blue) and REPS 2.1.0 (red).

Comparison of reliability scores near surface between old and new system

Air temperature at surface level

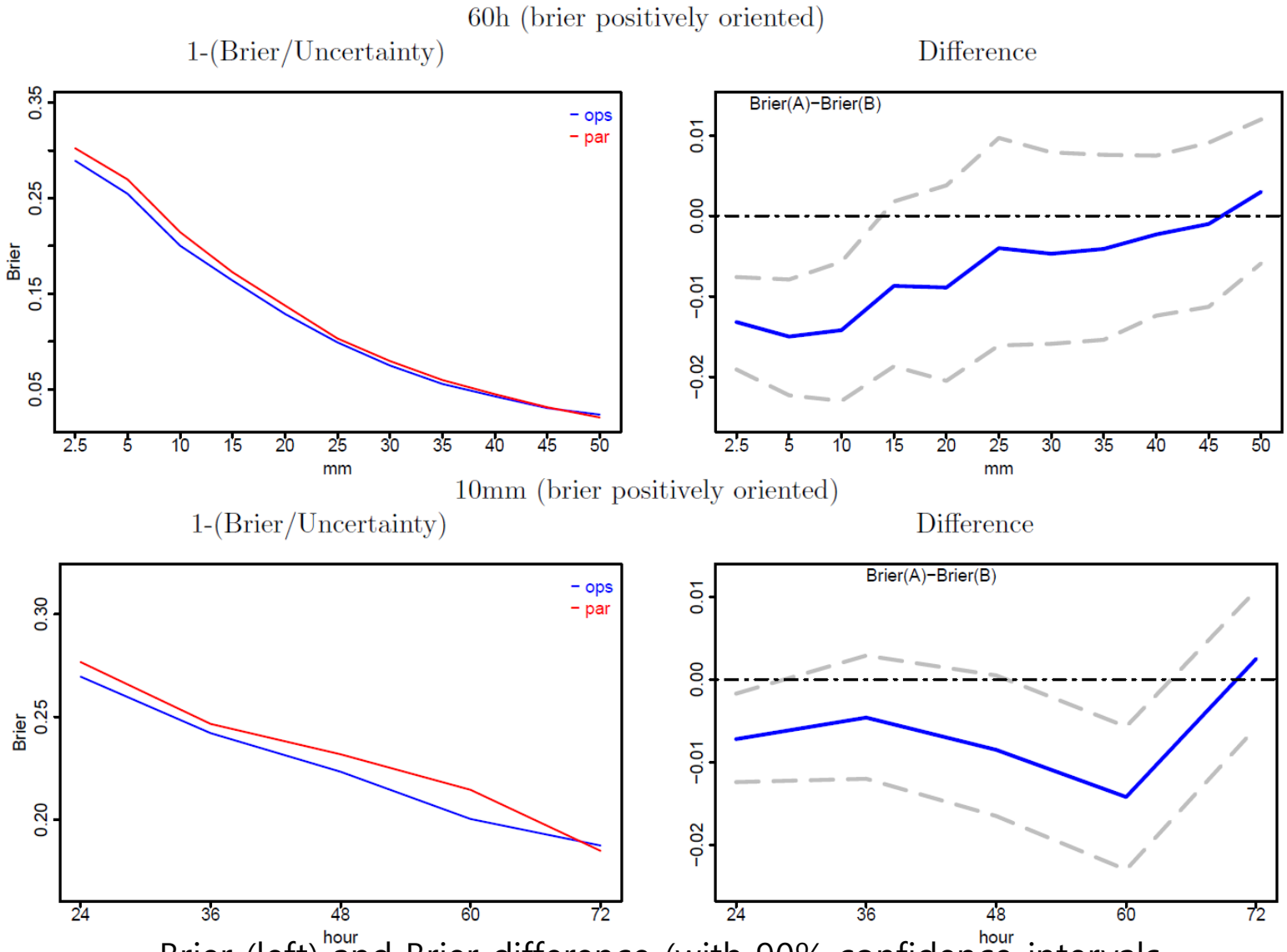


Dew point depression at surface level



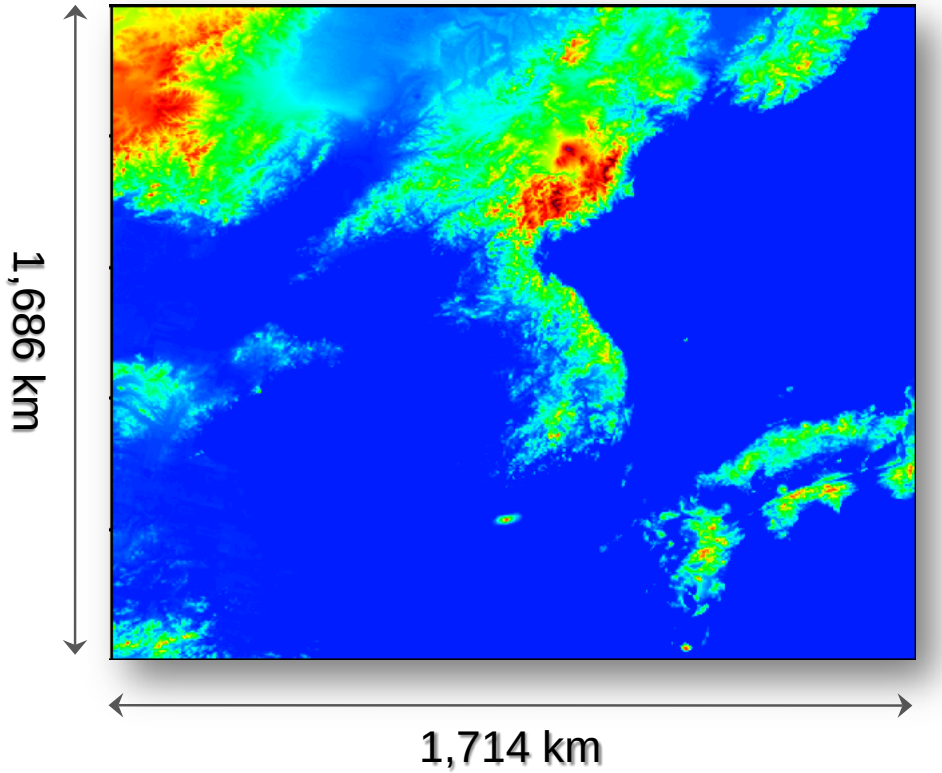
Reliability (left) and reliability difference (with 90% confidence intervals, right) between the REPS 2.0.1 (blue) and REPS 2.1.0 (red).

Comparison of Brier scores at 60h between old and new system



Brier (left) and Brier difference (with 90% confidence intervals, right) between the REPS 2.0.1 (blue) and REPS 2.1.0 (red).

Local ENsemble prediction System (LENS)



- The integration area covers the Korean peninsula including oceans and parts of adjacent countries such as China and Japan.
- The 3 km horizontal grid spacing and 70 vertical levels of top 40km altitude are employed.
- Simple downscaling of global Ensemble prediction system (N320L70, ~40km) will be adapted for IC/BC.

EPSG vs. LENS

	EPSG (global)	LENS (local)
Model Base	UM ver8.2	UM ver8.2
Assimilation Method	**Hybrid Ensemble 4D - Var**	**No / LETKF**('16)
Horizontal Resolution	N400 (~40km)	~3km
Vertical levels / top of model	70 / ~80 km	70 / ~40 km
Initial Times	00, 12 (06, 18 for cycled hybrid)	03, 15
Lead Time	12 days	45 hours
Output Frequency	6h to 240h,12h to 288	1h
No. of Members (+control)	23+1	**11+1 / 23+1**
Coupled Ocean	No	No
Initial Perturbations	**ETKF**	**From EPSG**
Model Perturbations	**RP, SKEB2**	**RP**
Surface Perturbations	SST Perturbation	No

Future plans of KMA EPSs

❖ Global EPS

- Implement of a new dynamical core (ENDGAME) of the model
- Increasing the horizontal resolution (40km -> 32km)
- Increasing the ensemble member (23 -> 44) [to be decided]

-> (Near) Real-time experiment and evaluation (‘15)

Operational Implementation (‘16)

❖ Convective scale EPS

- Developing a convective scale EPS to provide short-range probabilities of high impact weather over local area

-> (Near) Real-time experiment and evaluation (’14~)

Operational Implementation (Q4 ‘15)

- Further development to use initial perturbations from ensemble data assimilation(LETKF) (‘16)