Ensemble Operational Configuration, Performance, and Planned Upgrades

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GLOBAL

Recent upgraded / planned specification

- Configurations
  - Meteo France: Plan to increase ensemble size
  - RHMC: Plan to increase ensemble size and model resolution
  - ECMWF: Plan to introduce 50 member EDA
  - NCEP: Plan to extend forecast length from 16 to 35/55 days, change horizontal resolution from 34/55km to 25km
  - CPTEC: Increase horizontal resolution to 60km
- Model change
  - DWD: Introduce ICON-EPS
  - CPTEC: Upgrade of model version
  - JMA and BoM: Plan to upgrade (JMA: introduce the latest global model, BoM: change from UM8.2 to UM10.6)
  - NCEP: Plan to upgrade to FV3
  - NRL and CPTEC: Plan to introduce Earth System Model

Recent upgraded / planned specification

- Initial perturbation
  - Meteo France: EDA
  - RHMC: Plan to introduce EnsDa and/or LETKF
  - Met Office: Plan to replace ETKF with En-4DEnVar
- Usage
  - Meteo France: Plan to automate end-user weather forecast
  - NRL: International Cooperative for Aerosol Prediction
  - NCEP: Benefit to social and economic impact
  - BoM: Volcanic ash dispersion

NCEP GEFS Status

	V11 (Dec. 2015)	V12 (Q2FY2020)
GFS Model	Semi-Lagrangian, 2015	FV3 (GFSv15)
Horizontal Resolution	T_L574 (34km)/T_L382 (55km)	C384 (25km)
Vertical resolution	L64 (hybrid)	L64 (hybrid)
Daily frequency	00, 06, 12 and 18UTC	00, 06, 12 and 18UTC
Forecast length	16days	35 days
Members	Control + 20 pert members	Control + 30 pert members
Computational Cost	300 nodes (in peak)	~1000-1200 nodes (in peak)
Execution time	~ 60 min	~60 min
Output resolution	0.5^O x 0.5^O and 1^O x 1^O	0.25^o x 0.25^o and 0.5^o x 0.5^o
Output frequency	3h the first 8 days; 6h the rest	3h the first 10 days; 6h the rest
Initial perturbations	EnKF f06	EnKF f06
Model uncertainty	STTP	SKEB, SPPT (and SHUM)
Tropical storm	Relocation for all members	Relocation for all members
Reforecast	EMC offline – 20 years	30 years (1989-2018)
Implementation	December 2nd 2015	Q2FY2020

Example: Operational ICON-EPS products

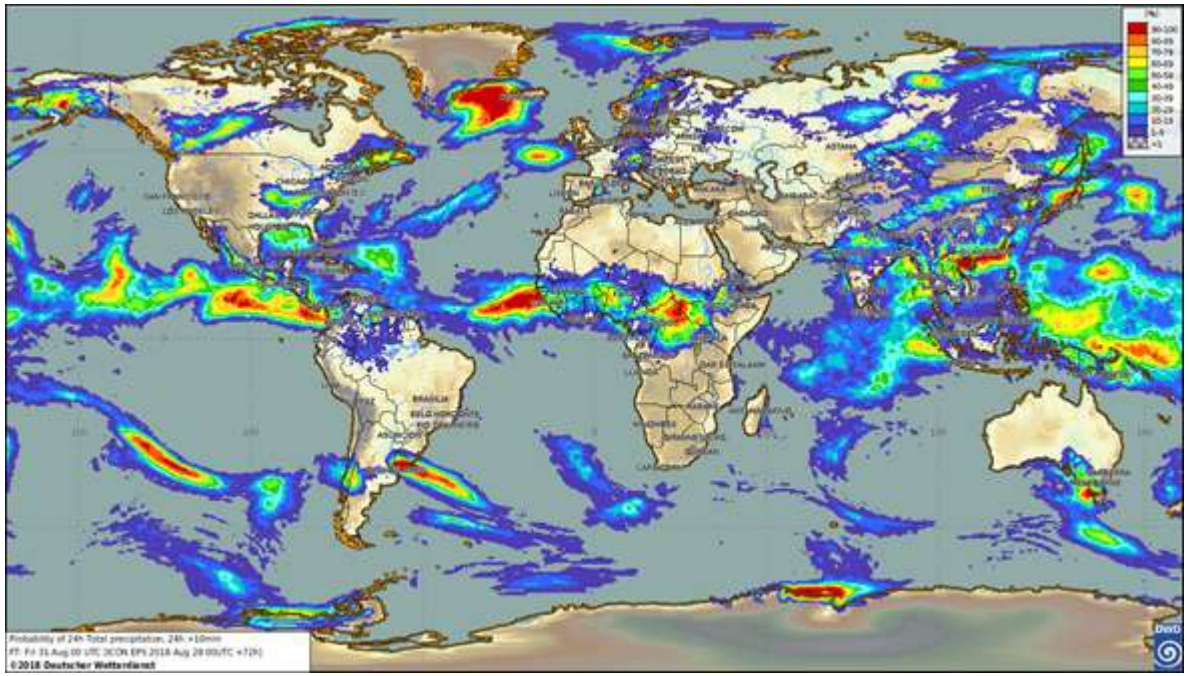
Global: 0,5° opendata.dwd.de : weather/wmc/icon-eps

www.dwd.de/DE/leistungen/wmc/wmc.html

EU: 0,25° charts available in NinJo at DWD

new: Probability of Turbulence (EDPP)

24h Probability of Precipitation >10mm
2018-08-28 00:00 UTC +72h



1. Mean and extreme values

- Unweighted mean of all members
- Spread of all members
- Minimum of all ensemble members
- Maximum of all ensemble members

2. Percentiles

i.e. physical values of a forecast parameter (e.g. T_2M,. . .), which define the perc=10,25,50,75,90 [%] parts of the ensemble distribution.

3. Exceedance Probabilities

- Probability of event above lower limit
- Probability of event below upper limit

Operational global (weather) EPS

Center	Resolutions	FC Range	Members	Initial perturbation, DA	Model Uncertainty	B.C.	Note
ECMWF (Europe)	TCo639L91 TCo319L91 18/32km	15d 46d	51	SV(Total energy norm) + EnDA	SKEB is terminated and Stochastic physics (SPPT) revised SPPT	coupling to ocean model, EDA-based land-surface pert. in ENS Ics	Hindcast dataset increased
Met Office (UK)	20kmL70	7d	17+1 44 for DA 50 for EDA	ETKF En-4D-EnVar	Random Parameters (RP2) ->retire SKEB2 + SPT	SST, Soil moisture and deep soil temperature	
Meteo France (France)	T798(C2.4) L90	4d	35->50	SV (Total Energy Norm)+ EnDA (randomly chosen)	A new set of 10 physical packages, new model pert.	N SURFEX and pert.	
HMC (Russia)	T169L31 SLAV 25-30km	10d	12+2->22	Breeding EnDA and/or LETKF	N SPPT	N SST pert.	Control is produced by 2 models.
NCEP (USA)	TL574L64 TL382L64 ->25km (FV3)	8d +8d 35d	21->31,51	EnKF + Tropical storm relocation	stochastic pert. to account for random model errors SKEB, SPPT, SHUM, process based param.	N Stochastic pert. of land, couple with ocean	Dynamical core: Euler to Semi-Lgrangian
NRL/FNMOC (USA)	T359L60	16d	21 80 for Ini. Pert.	local ET SST pert.	SKEB-mc Multi physics ensemble	N SST initial pert. ocean, ice, wave coupling	Part of the U.S. multi-model ensemble
CMC (Canada)	0.35° L45	16d	20	Ensemble KF	stochastic pert. of physical tendencies and SKEB, further pert. to the physics	new method to evolve SST and sea-ice	
DWD (German)	40km	180h	40	LETKF	Change convection scheme Stochastic representation	SST random pert.	ICON

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

Operational global (weather) EPS

Center	Resolutions	FC Range	Members	Initial perturbation, DA	Model Uncertainty	B.C.	Note
CPTEC/INPE (Brazil)	TQ213L42	15d 30d	15	EOF-based perturbation EnKF, Hybrid 3D-Var	N	N	Couple with earth system model
BoM (Australia)	~60kmL70 33km	10d	18				UM8.2->10.6
JMA (Japan)	TL479L100 TL479L100 TL319L100	11d 18d 34d	27 13 13	SV(Total energy norm) +LETKF (pert. Inflation)	Stochastic perturbation of physics tendency	Rev, SST and sea ice Pert. on SST	Update model
CMA (China)	T213 L31	10d	15	SV	SPPT	N	
KMA (Korea)	~40kmL70 32km (p)	12d	24 44	ETKF Hybrid Ensemble 4D-Var	Random Parameters (RP2) and SKEB2.	N	

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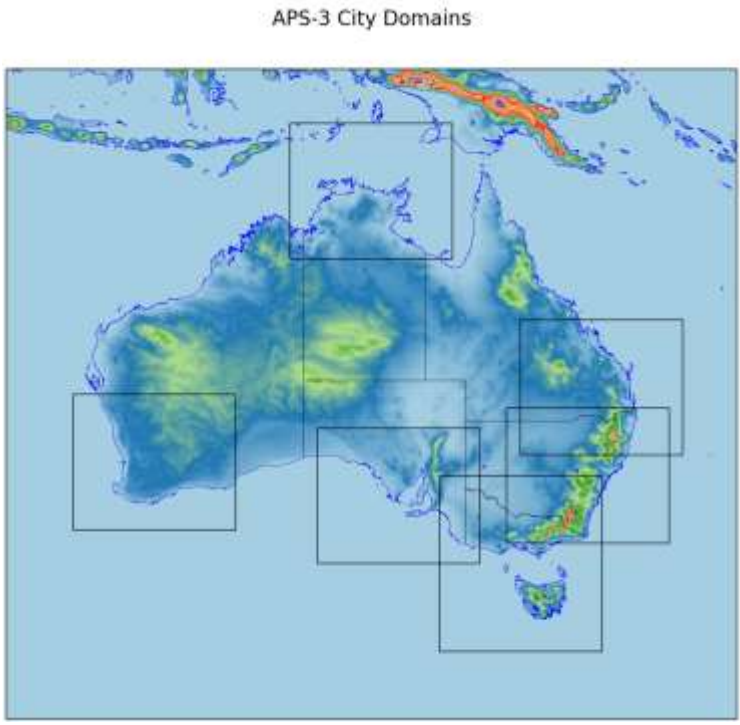
REGIONAL

Recent upgraded / planned specification

- Configurations
  - Meteo France: Plan to increase ensemble size, extend forecast length, increase from 2 to 4 times per day
  - JMA: Increase ensemble size from 11 to 21, 1 to 4 times per day
  - BoM: Six domains at 2.2km resolution based on MOGREPS-UK with 12-18 members
  - Met Office: Hourly cycling and using time-lagging
  - CMC: Increase horizontal resolution and vertical levels
- Move to operational system
  - NRL: COAMPS variable resolution is being transitioned to operation
  - RHMC: Plan to operate in 2019
  - JMA: Plan to operate in 2019
- Usage
  - NRL: COAMPS-TC is a part of U.S. multi-model ensemble

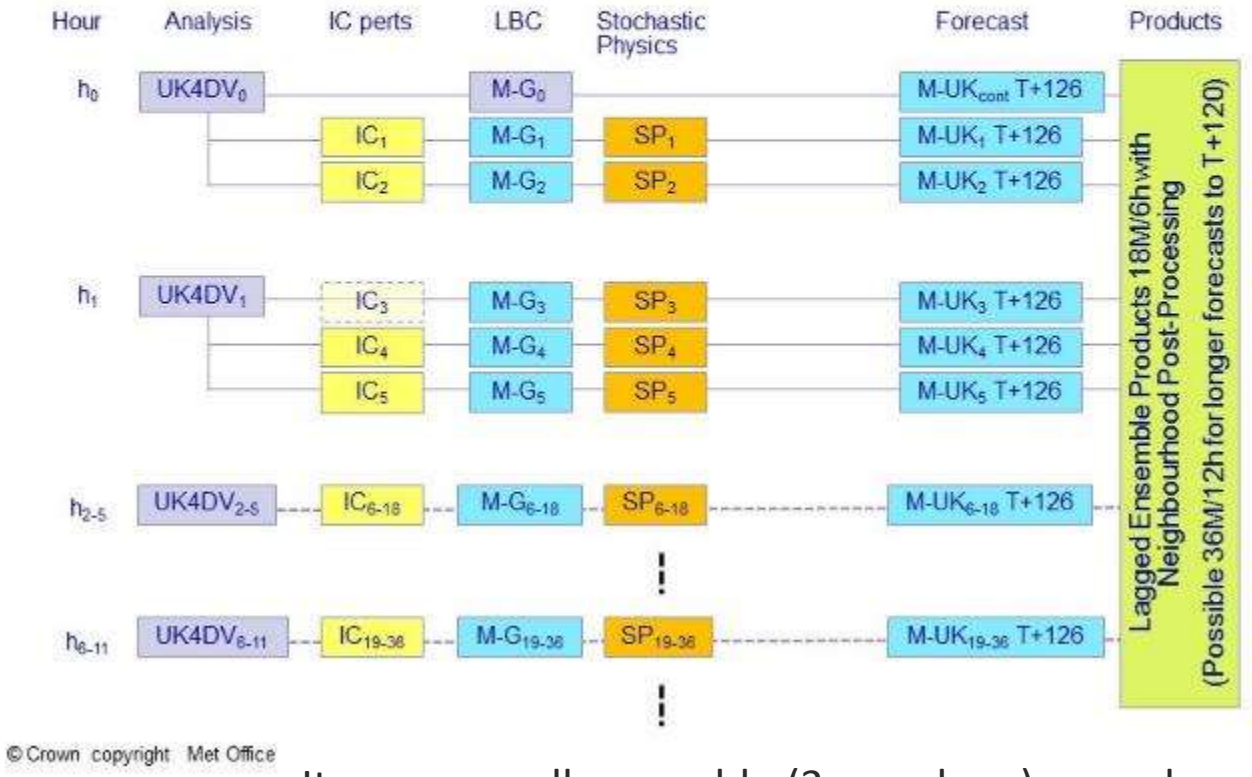
BoM NWP Ensembles – Status / Plans

- Operational Ensembles will be part of upcoming "APS**3**" suite
  - City-scale:
    - "CE**3**" is in development, planned for operations Q2-2019
    - Six domains (right) at 2.2km resolution
    - Based on PS39 MOGREPS-UK, but RA1-M and RA1-T physics used on different domains
    - 12-18 members (compute permitting), 36-hour FCs, four times a day
    - Planned for operations Q2-2019



From early 2019:
Hourly cycling, which includes 18 members runs to T+120.

Hourly ensemble schematic



This takes advantage of UKV now running hourly 4DVar and the recent increase in number of global ensemble members

It runs a small ensemble (3 members) every hour and use time-lagging to create a larger ensemble (18 members per 6h cycle)

Operational regional EPS

Center	Resolutions	FC Range	Members	Initial perturbation, DA	Model Uncertainty	B.C.	Note
Met Office (UK)	2.2kmL70 1.5kmL70-120	54h	11+1 18/24	High Resolution Analysis + global EPS Convective ensemble DA	Stochastic physics using random parameter	Perturbing parameters in JULES	UM Hourly operation
Meteo France (France)	2.5km	45-51h	12->16	Deterministic Analysis + Pert. From 3.2km ensemble assimilation	SPPT	Pert. of surface LBC selection with clustring	AROME
DWD (German)	2.8km	27h 45h	20 40	IFS, GMS, GME, GSM Ensemble DA based on LETKF	Increase Pert. Parameters	Global ICON EPS, soil moist pert.	COSMO
HMC (Russia)	2.2km	48h	10	COSMO-S14-EPS	N SPPT, Addutuve model-error pert.	COSMO-S14-EPS	Test-operation COSMO
JMA (Japan)	5kmL76	39h	20+1	SV(Total energy norm) Hybrid DA	N Pert. tendency	JMA global EPS Perturbed SST	Test-operation
NCEP/SREF (US)	16kmL41		1+12, 1+12	Multi analysis	Variety of physics scheme	Stochastic soil moisture	Frozen
NRL/FNMOC (US)	4km	120h	10+1	Perturbed synoptic scales Perturbed Rankine Vortex	N	GEFS/NAVGEM with synoptic perturbations	COAMPS-TC In all basins
NRL/FNMOC (US)	45/15/5km	72h	20+1	Downscaling from global ensemble	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
CMA (China)				Multi Scale Blending (GEPS and LETKF)	RP	Global EPS	UM
KMA (Korea)	3kmL70	45h	23+1	Downscale from Global EPS LETKF	RP	Global EPS	UM

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

EXTRA SLIDES
CONTRIBUTION FROM MANY CENTERS

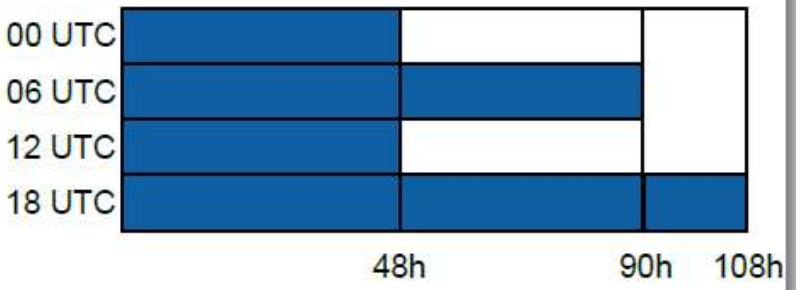
Arpege-EPS status and plans : operational aspects

General characteristics

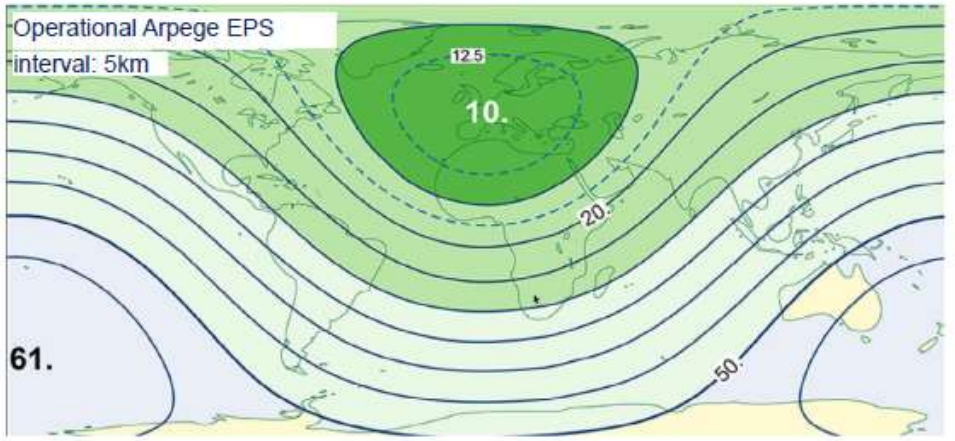
- 35 members
  including a control member

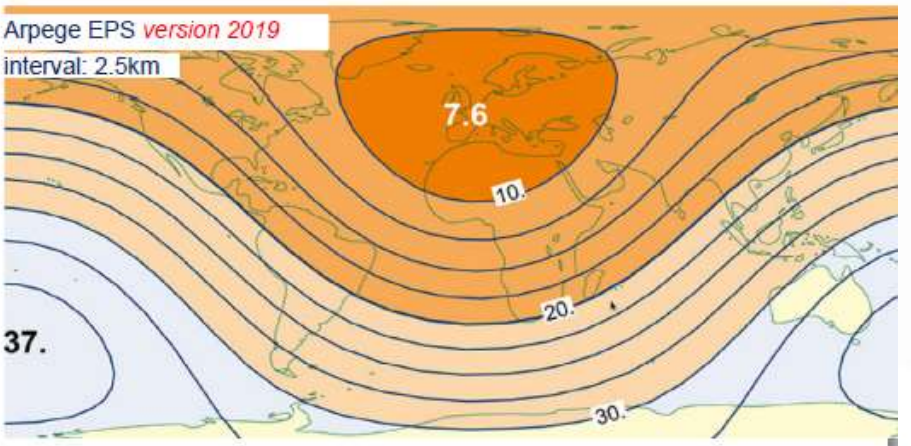
  provide boundary conditions to Météo-France LAM EPS PEARO *(F. Bouttier, L. Raynaud)*

- Running 4 times a day



- Forecasts resolution :





Arpege-EPS status and plans : operational aspects

Initialization procedure

- using background states from the EDA of Météo-France randomly choosen :
  AEARP, 25 members, T399C1
  (L. Berre, G. Desroziers)

next version (2019)	50 members T499C1

- singular vectors computed over 7 areas (rescaled by σ_b)

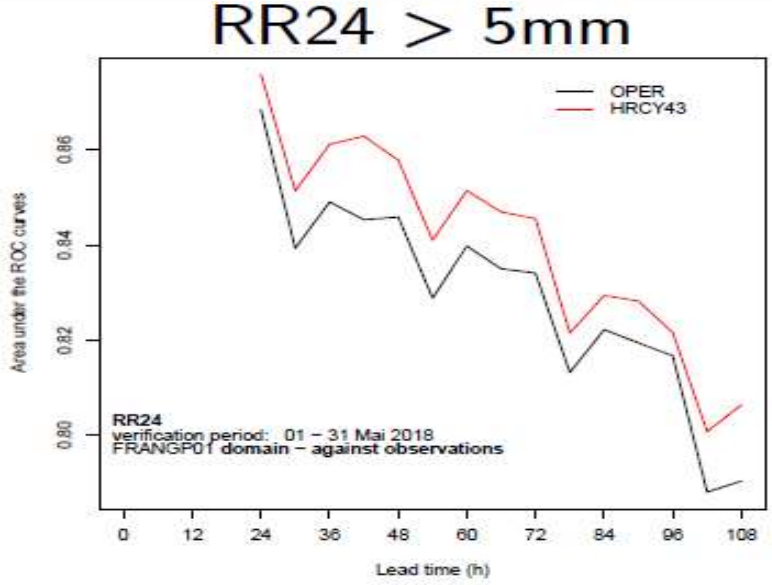
area	OTI(h)	res.	norm
ATEUR	18	TI95	TE
HNC et HS	24	TI95	TE
4xTROP	18	TI95	KE

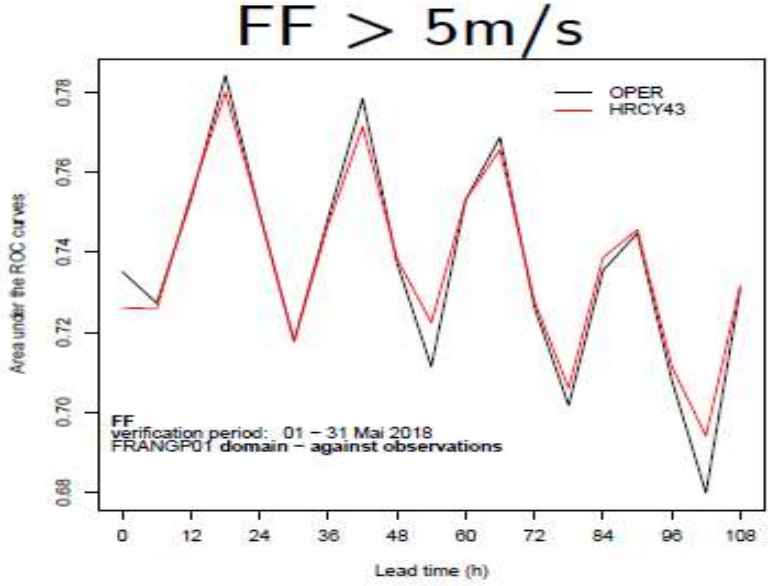
- Initial perturbations are not symetric.

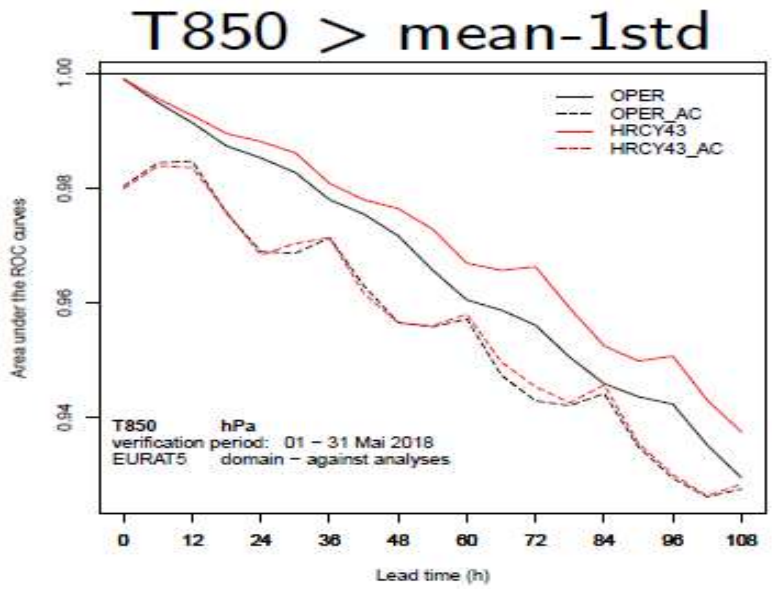
Model error

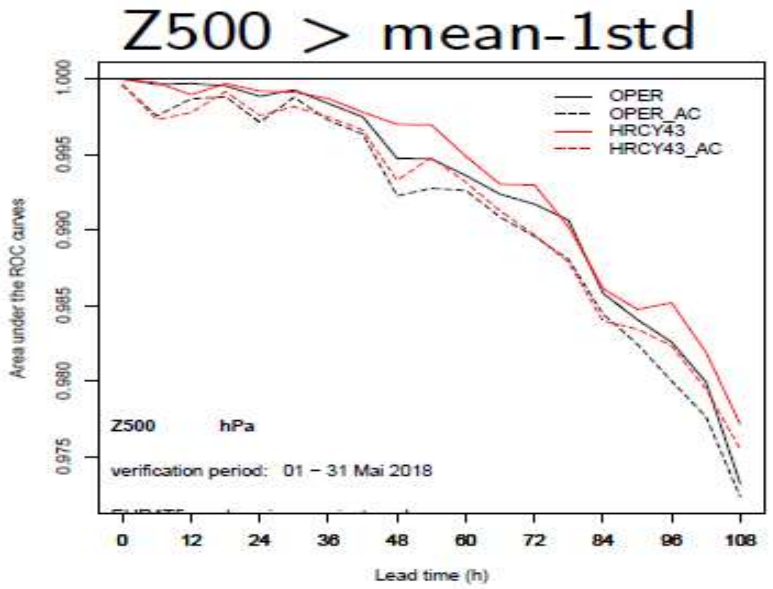
- using a set of 10 physical packages including that of operational ARPEGE model. Playing on different physical schemes :
  - sallow convection and deep convection
  - vertical diffusion
  - solar radiation
  - different types of cloud recovery

Arpege-EPS status and plans : operational aspects





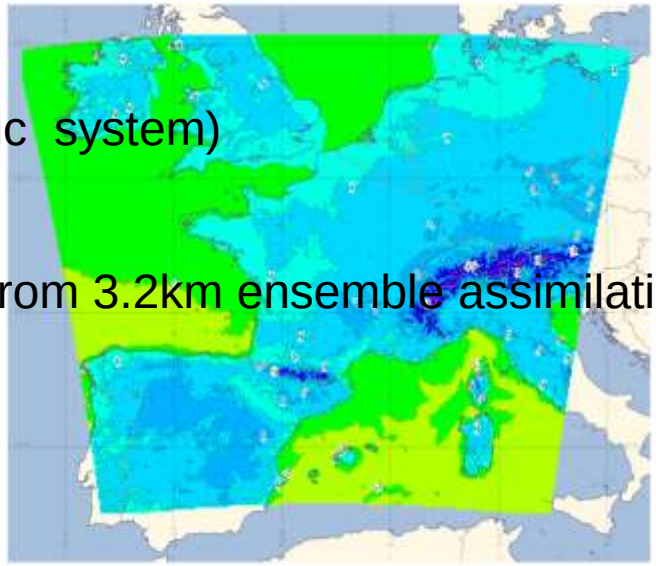




Arome-France EPS (PEARO) status and plans : operational aspects

Current (Sept 2018)

- operational production, 12 members, 4x/day
- Arome model at 2.5kmL90 (vs 1.3km deterministic system)
- max forecast range: 45 to 51 hours
- Initial Conditions : deterministic analysis + perts from 3.2km ensemble assimilation
- Lateral Boundaries : PEARP global ensemble
- Model perturbations : SPPT + surface schemes



Recent changes (Spring 2018)

- from 2 to 4 ensembles per day, extended forecast ranges
- ICs changed from PEARP to **ensemble assimilation** = much better short ranges up t
- revised LBC selection with **new clustering algorithm** = reduced synoptic-scale overd

Planned changes (2019-2020)

- increase **ensemble size** from 12 to 16 members
- use ensemble to automate end-user weather forecasts

METEO FRANCE

US Navy Global Ensembles:

- Current configuration:
  - T359L60 (37 km) 21 member ensemble run at 00Z and 12Z out to 16 days. 80-member 6-h ensemble forecasts are run every 6 hours to produce the initial perturbations, but only 20 members (plus one control) are run out to 16 days.
  - Stochastic Kinetic Energy Backscatter is employed to account for model uncertainty.
  - Part of the National Unified Operational Prediction Capability multi-model ensemble.
- Plans:
  - Testing initial SST perturbations and a simple SST diurnal cycle model for 2019.
  - Also testing a multi-physics ensemble.
  - Navy Earth System Model (global atmosphere-ocean-ice coupled) forecast system, with a 16-member ensemble run weekly out to 45 days, planned for operations in 2019. This system is contributing to the NOAA SubX multi-model ensemble.

US Navy Mesoscale Ensembles:

- COAMPS-TC ensemble:
  - 11 members at 4 km resolution for TCs in all basins.
  - Undergoing pre-operational testing by October.
  - Part of the multi-model ensemble with HWRF

- COAMPS ensemble capability (variable resolution) is being transitioned to operations. Initially it will used in a downscaling way with cold starts from the global NAVGEM ensemble.

NRL: Multi-model Tropical Cyclone Ensemble: COAMPS-TC, NOAA HWRF, and NOAA HMON: Hurricane Harvey

Rapid Intensification Validation: Harvey (09L) Multi-model Example

0 - 24 h Probability of RI (%)

Initial Time	COAMPS-TC	HWRF	HMON	Combo
22/18z	0	0	0	0
23/00z	0	0	0	0
23/06z	0	0	0	0
23/12z		0	9	3
23/18z	9	0	0	2
24/00z	18	33	9	23
24/06z	82	67	27	60
24/12z	82	100	100	95
24/18z	55	38	82	53
25/00z	9	10	73	26
25/06z	0	0	9	2

Prob of RI (%)
0 - 32
33 - 65
66 - 99
100

No forecast

RI validated for 24 h windows beginning at 23/12z through 25/00z

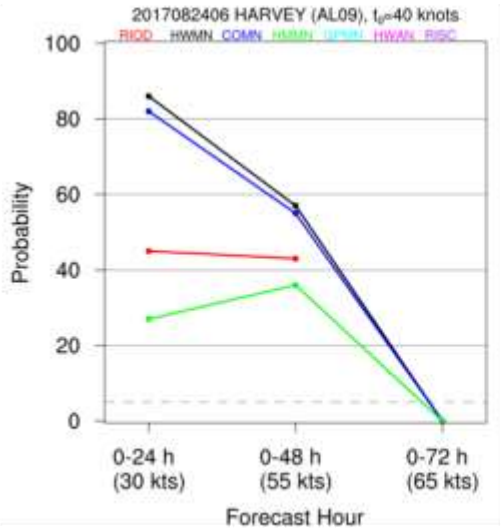
- Three ensembles gave very low probabilities of RI at 23/12z and 23/18z, when Harvey was a 30 kt TD
- In subsequent forecasts, the probability of RI markedly increased, reaching 95% for the combined ensemble at the 24/12z initial time (when Harvey was a 55 kt TS)
- Combined ensemble probability of RI was still > 50% for the 24/18z initial time, but decreased to 26% at 25/00z. Harvey was 75 kt hurricane at both times.

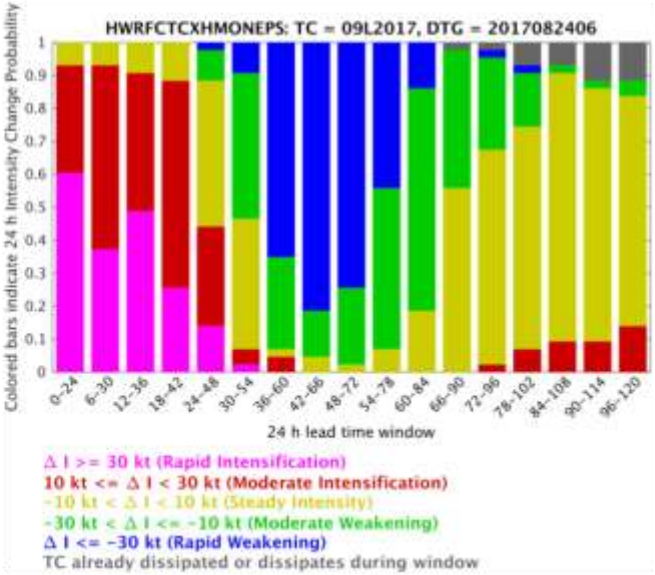
Multi-model ensemble recognized the Harvey was likely to rapidly intensify before making landfall in Texas (26/03z)

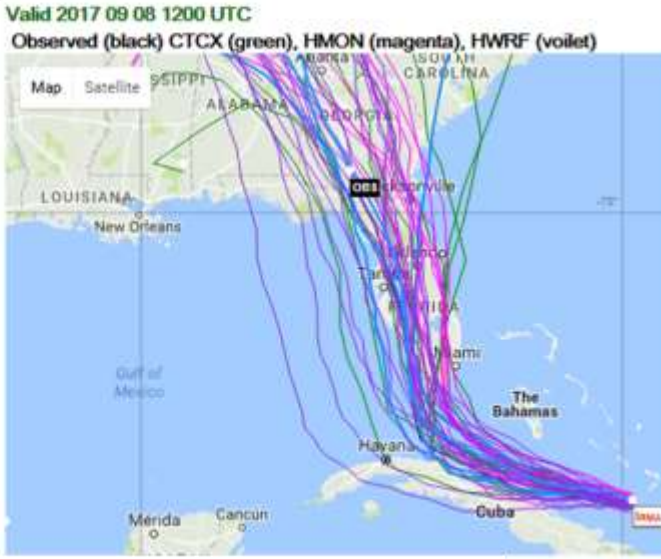
NRL COAMPS-TC
Future Plans

Objectives for FY18+:

- Keep running the real-time demo system for the Atlantic and Eastern Pacific
- Continued contribution to HFIP multi-model ensemble
- Continued product development (e.g. R34 products, clustering), interfacing with JTWC and NHC







NRL: International Cooperative for Aerosol Prediction Multi-Model Ensemble (ICAP-MME)

CURRENT ICAP OPERATIONS - as of May 2018

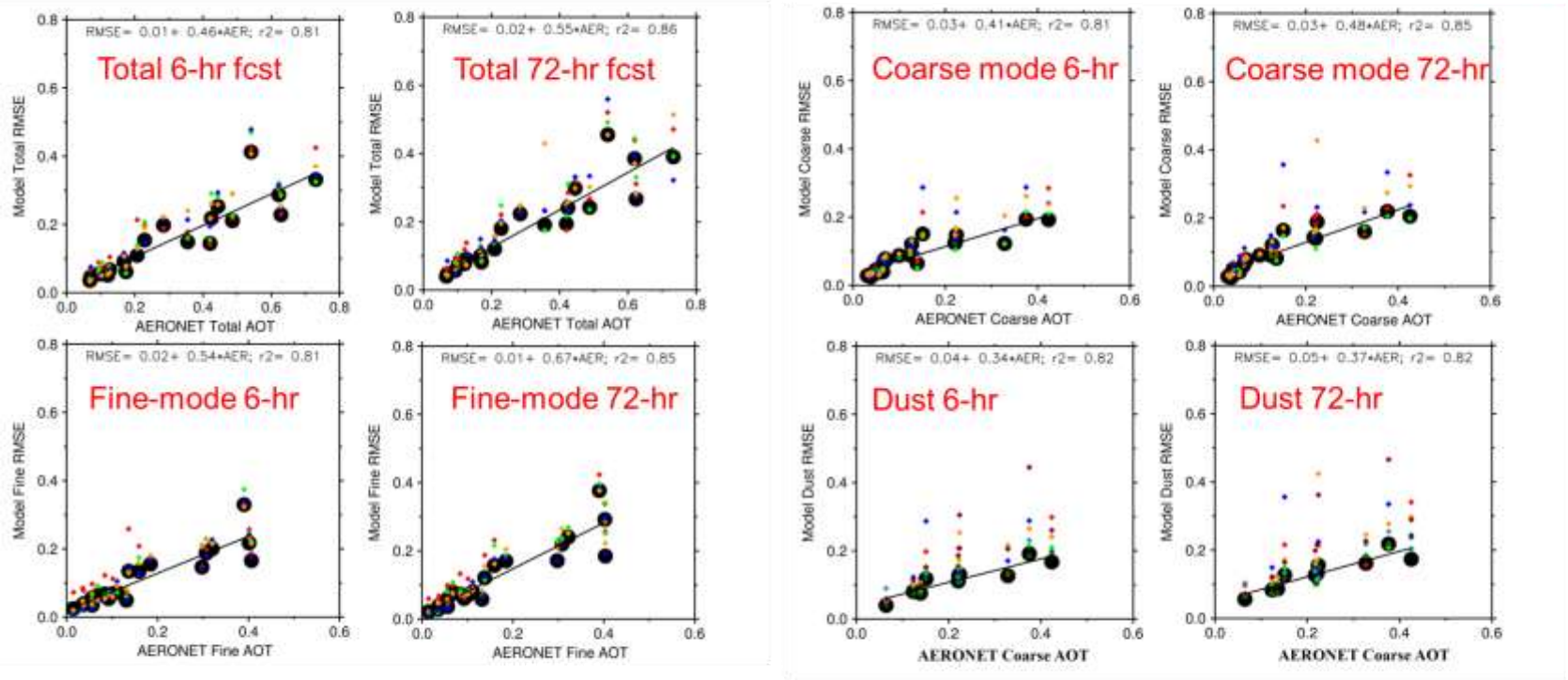
Organization	BSC	Copernicus/ ECMWF	JMA	Meteo France	NASA	US Navy	NOAA	FMI	UKMO
Model	MONARCH	CAMS	MASINGAR	MOCAGE	GEOS-5	NAAPS	NGAC	SILAM	MetUM
Status	QO	O-24 hrs	QO	O	QO	O	O	O	O
Meteorology	Inline NMMB	Inline IFS	inline AGCM	Offline ARPEGE	Inline GEOS-5	Offline NAVGEM	Inline GFS	Offline IFS	Inline UM
Resolution	1.4x1 (0.7x0.5)	0.4x0.4	0.375x0.375	1x1	0.25x0.31	0.33x0.33	1x1	0.5x05	0.35x0.23
levels	24 (48)	60	40	47	72	60	64	60	70
DA	LETKF^{p}	4DVar	2DVar LETKF^{p}	2018	2DVar +LDE	2DVar 3DVar, EnKF^{p}	NA	3Dvar^{p}, 4Dvar^{p}, EnKF^{p}	4DVar
Assimilated Obs	DAQ MODIS+DB	DAQ MODIS DT+DB PMAp	MODIS L3, AHI^{p}, CALIOP^{p}	NA	Neural Net MODIS	DAQ MODIS, AVHRR^{p} VIIRS^{p} CALIOP^{p}	NA	NA	MODIS Dust AOT
Species	Dust, Sea Salt BC, OC (POA,SOA) Sulfate	BC, OC Dust Sea Salt Sulfate	BC, OC Dust Sea Salt Sulfate	BC, OC Dust Sea Salt Sulfate, Nitrate, Ammonium	BC, OC Dust Sea Salt Sulfate Nitrate	Anthro+bio B. B. Smoke Dust Sea Salt	Dust BC, OC Sea Salt Sulfate	BC, Dust, OC, Sea Salt, Sulfate, Nitrate, B.B. Smoke	Dust
Size Bins	8 (dust, salt) bulk for others	3 (dust, salt), bulk for others	10 (dust, salt), bulk for others	6	5 (dust, SS), 2(BC, OC), 3(NI*), bulk sulfate	bulk	5 (dust, SS), 2(BC, OC), bulk sulfate	4 (dust), 5 (SS), 3 (B.B. Smoke), 2 (sulfate), bulk for others	2
Antho. & Biogenic Emission	HTAPv2.1 (anthro), MEGANv2.04 (biogenic)	MACCity (anthro), MEGAN (biogenic)	MACCity	MACCity (anthro.) MEGAN-MACC (biogenic)	EDGAR V4.1/4.2, AeroCom Phase II, GEIA	MACCity, BOND, POET	EDGAR V4.1, AeroCom Phase II, GEIA	MACCity, STEAM, MEGANE, HTAP(Coarse PM)	NA
Bio. Burn. Emissions	GFAS	GFAS	GFAS	GFAS	QFED	FLAMBE	GBBEPx	GFAS, IS4FIRES	NA

- The ICAP-MME is run daily w/ 1x1 deg res at 00Z for 6 hrly fcasts out to 120 hrs w/ a 1-day latency.
- Modal AOT (550nm) and dust AOT (550nm) data in NetCDF is available publically.
- Green means proposed. Red means changes occurred last year. "p" means prototype.

NRL: International Cooperative for Aerosol Prediction Multi-Model Ensemble (ICAP-MME)

June 2016 – May 2017 ICAP MME AOD validation with AERONET

Black dot is MME

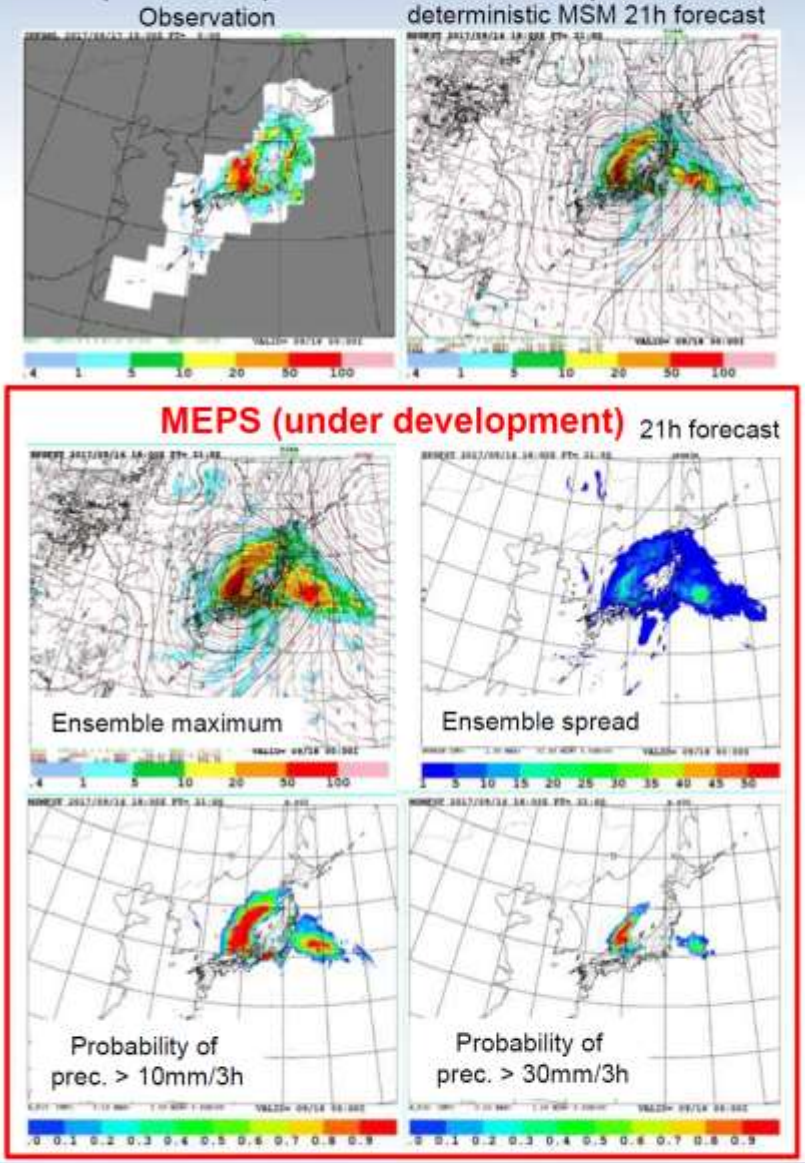


- ICAP MME (consensus) is overall the top performer for all modes.
- Similar result as in Sessions et. al. (2015)

Meso-scale Ensemble Prediction System (MEPS)

- **Purpose**
  - Providing uncertainty and probability information of operational deterministic MSM
- **Ensemble forecast**
  - Forecast model : ASUCA (as in MSM)
  - Resolution : 5km (as in MSM)
  - Ensemble size: 21
    - 20 perturbed runs + 1 control run
- **Perturbation**
  - Initial : Singular vector (SV)
  - Lateral boundary : Global SV
  - Physics and lower boundary
    - Under development
- **Current Status**
  - Test period (since March 2015)
  - Operated 4 run/day
  - currently studying
    characteristics of MEPS forecasts
    utilization methods of MEPS results
- **Future Plan**
  - Full operation in 2019

Example of 3-h prec. forecast :16 Sep. 2017 00UTC



Upgrade plan of the operational global EPS at JMA

- Upgrades in the physical processes of the Global EPS model based on the latest JMA-GSM
  - Adopting GSM implemented in July 2017 for deterministic forecasting, keeping the consistency among deterministic and ensemble forecasting models
- Upgrades in LETKF-based perturbations
  - Use of inflated perturbation derived from the ensemble of 6-hour forecasts instead of analyses
    - Mitigating underdispersiveness at initial conditions
    - Focusing efforts in improving the characteristics of 6-hour forecasts, which will be used for hybrid DA.
  - Adjustment of the scale of horizontal/vertical localization in the LETKF

EPS work at DWD

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

- **Operational global ICON-EPS products since January 2018**
  - **After two years of EPS evaluation phase**
- **Tuning changes in the convection scheme in order to reduce temperature bias dipole in the tropics**
  - **Bias dipole: too cold in lower troposphere, too warm in middle troposphere; problem affects EPS and deterministic forecasts, but CRPS is even more sensitive to it than RMSE in deterministic system**
  - **Most important changes affect downdrafts, with reduced initial downdraft mass flux at LFS and increased entrainment**
- **Ongoing developments for improved stochastic representation of model errors**

Example: Operational ICON-EPS products

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Global: 0,5° opendata.dwd.de : weather/wmc/icon-eps

www.dwd.de/DE/leistungen/wmc/wmc.html

EU: 0,25° charts available in NinJo at DWD

new: Probability of Turbulence (EDPP)

24h Probability of Precipitation >10mm
2018-08-28 00:00 UTC +72h

1. Mean and extreme values

- Unweighted mean of all members
- Spread of all members
- Minimum of all ensemble members
- Maximum of all ensemble members

2. Percentiles

i.e. physical values of a forecast parameter (e.g. T_2M,. . .), which define the perc=10,25,50,75,90 [%] parts of the ensemble distribution.

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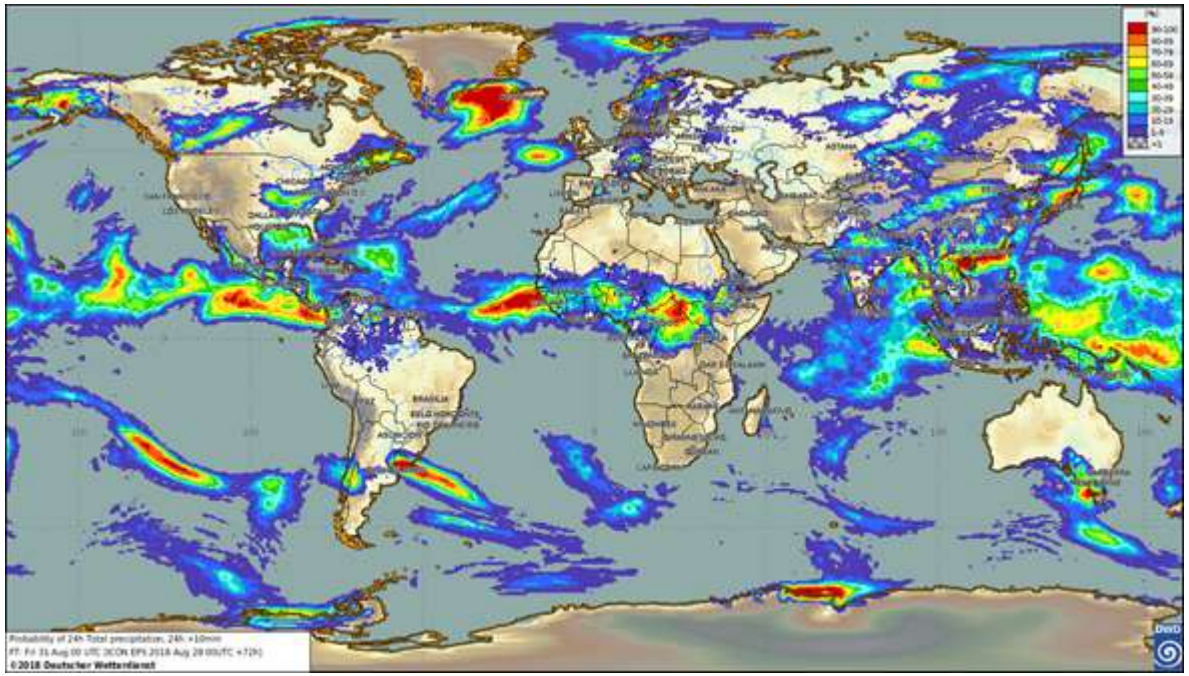
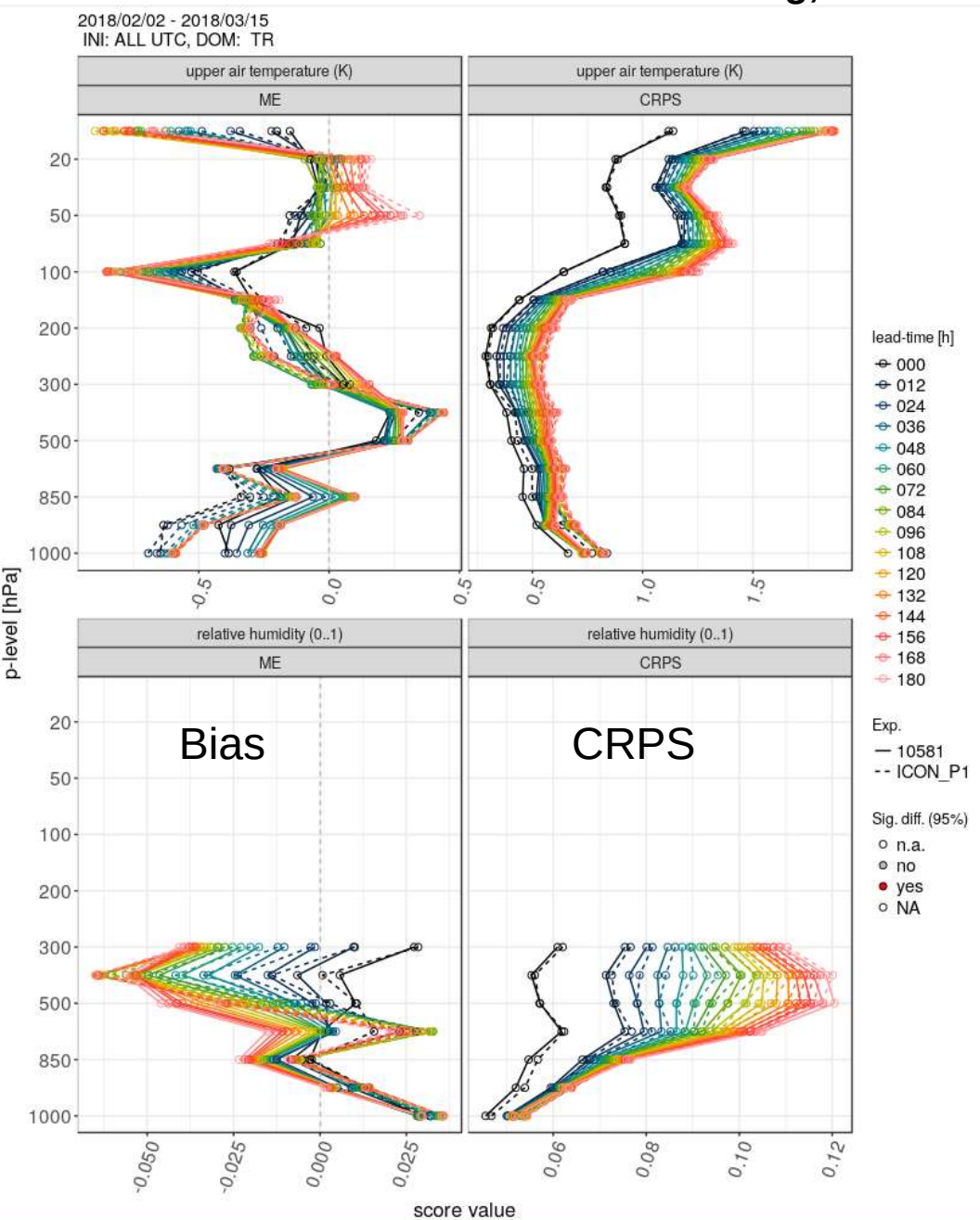
- Probability of event above lower limit
- Probability of event below upper limit

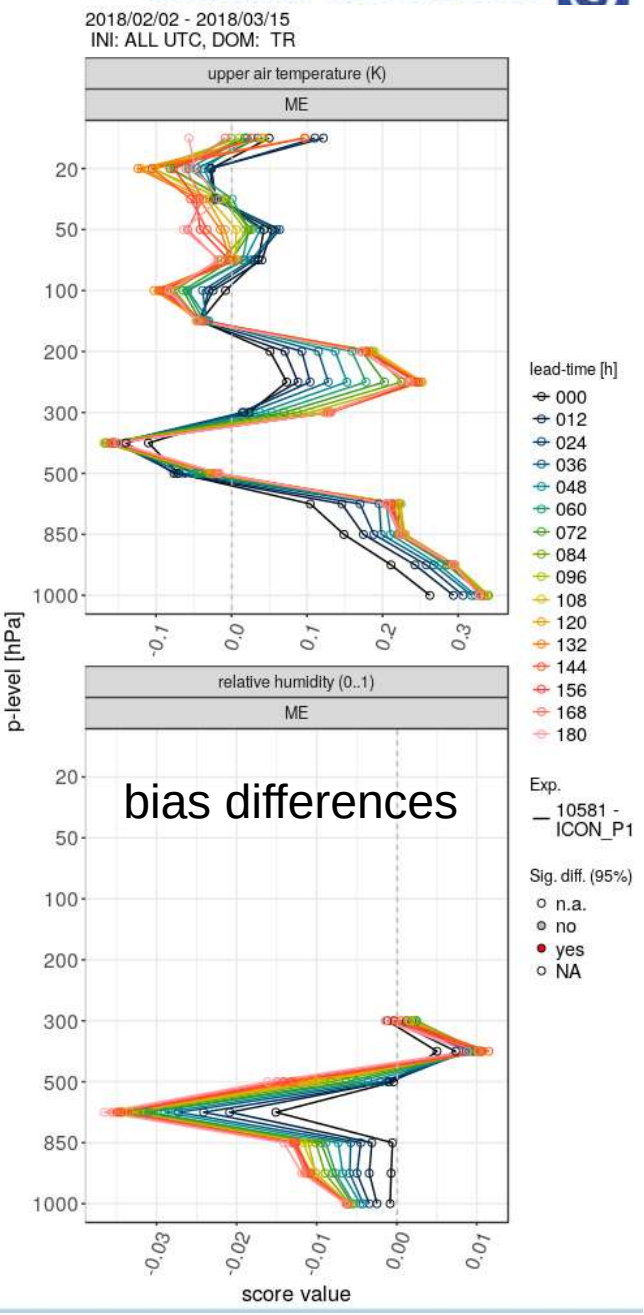


T and RH in the tropics: radiosonde verification

solid lines: with convection retuning, dashed lines: reference

Deutscher Wetterdienst





Australian Government
Bureau of Meteorology

BoM NWP Ensemble Development (Sept 2018)

Michael Naughton, Shaun Cooper

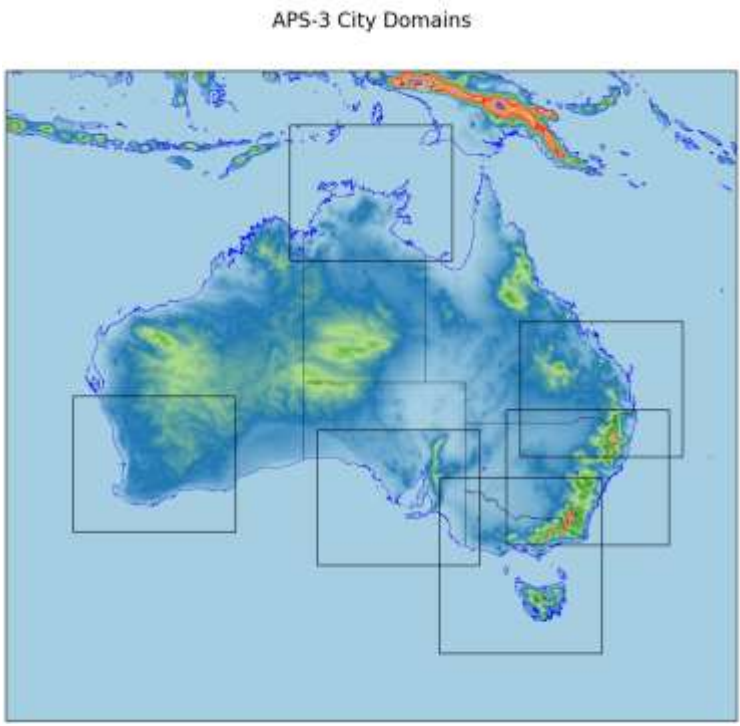
<Firstname>.<Lastname>@bom.gov.au

BoM NWP Ensembles – Status / Plans

- Bureau is developing **global** and *city-scale* ensembles: ACCESS -- **GE** and *CE*.
- As with nearly all ACCESS NWP systems, based on analogous UKMO systems (MOGREPS, etc)
- Current **operational** NWP suite ("APS**2**") has no ensemble systems.
  - The APS**2**-dev version of GE ("GE**2**") continues to be run as a research demonstration real-time trial.
  - Relatively old now: UM 8.2, N216 (60km) resolution
- **Operational** Ensembles will be part of upcoming "APS**3**" suite
  - Global:
    - "GE**3**" is in development, planned for operations Q1-2019
      - integral component of global modelling now, due to hybrid-VAR
    - UM 10.6, N400 (33km) resolution (UKMO PS39 model and DA components)
    - 18 members (though subject to compute cost)

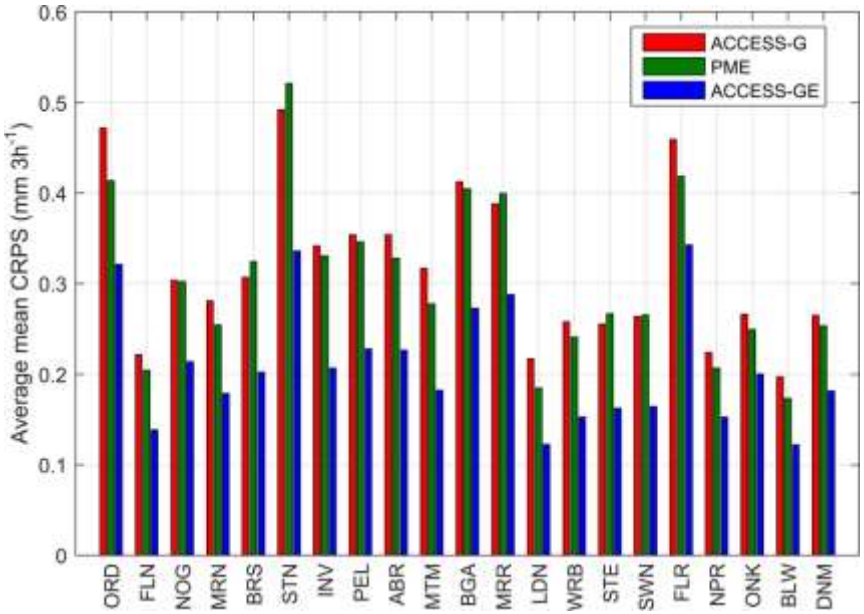
BoM NWP Ensembles – Status / Plans

- Operational Ensembles will be part of upcoming "APS**3**" suite
  - City-scale:
    - "CE**3**" is in development, planned for operations Q2-2019
    - Six domains (right) at 2.2km resolution
    - Based on PS39 MOGREPS-UK, but RA1-M and RA1-T physics used on different domains
    - 12-18 members (compute permitting), 36-hour FCs, four times a day
    - Planned for operations Q2-2019



BoM NWP Ensembles – GE2

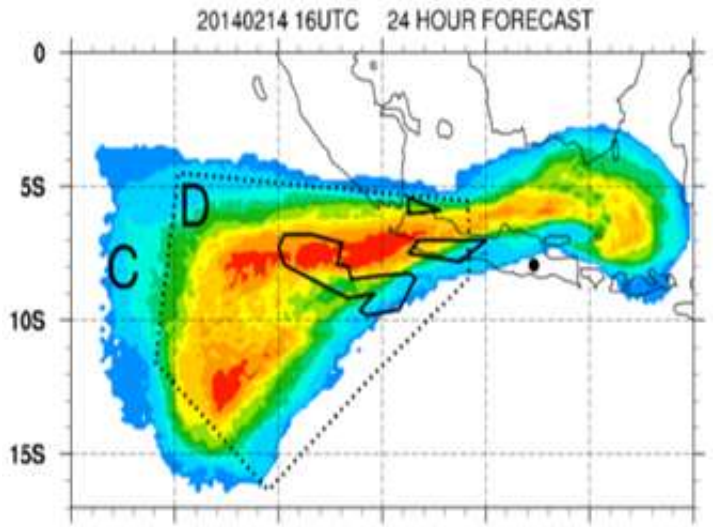
- Research system, but real-time running and supporting demonstrations including:
  - Streamflow forecasts, and volcanic-ash dispersion



(David Robertson, CSIRO)

Average (all lead-times) precip CRPS, across all catchments

PME = Poor Man's Ensemble



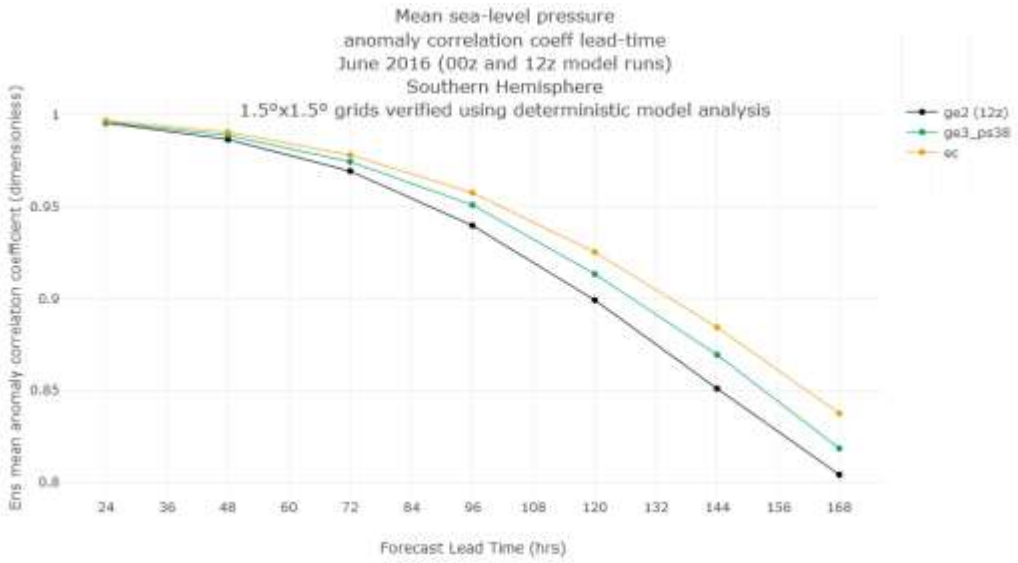
(Richard Dare)

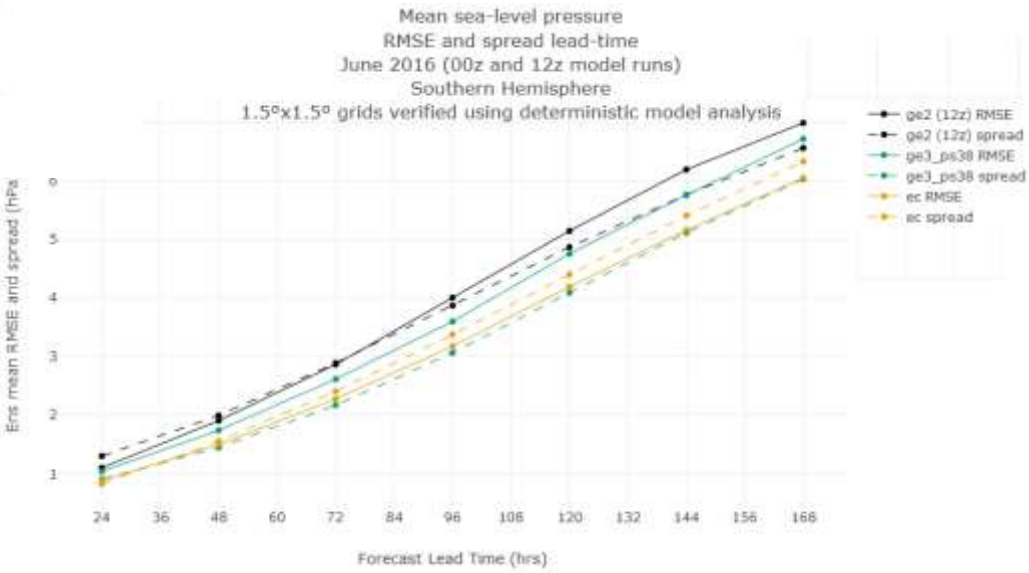
Probability map of ash-concentration amount

GE2 driving HYSPLIT dispersion model

BoM NWP Ensembles – GE3 Trials

➔ Full-resolution (N400) trials still running, but low-res (N216) PS-38 trials encouraging





Global ensemble prediction: **operational**

Global RHMC EPS is operational since January 2015

2 models: spectral T169L31, semi-Lagrangian SLAV

Resolution: ~70 km

14 forecasts: 12 perturbed T169L31 (breeding with regional rescaling) + 2 control: T169L31 and SLAV

240h forecast once a day starting at 12 UTC

Products at www.meteoinfo.ru and www.swfdp-ca.meteoinfo.ru

No changes last year –a new computer was installed only at the end of July 2018

Global ensemble prediction: **plans and research**

- Increase of ensemble size and model resolution next year (M22, T369L63 + SLAV (0.16-0.24)°x0.225°L60)
- Initial perturbations from EnsDa and/or LETKF
- Introduction of soil perturbations

RHMC

Mesoscale ensemble prediction: **regular runs**

- No operational mesoscale EPS now
- A new mesoscale EPS is being developed and is to start operation in 2019

(Moscow region, M15, COSMO 2.2 km L51, 2-day forecasts twice a day, ICs&BCs from ICON-EPS /GEFS)

Mesoscale ensemble prediction: **research in stochastic representation of model-related uncertainty**

A new method AMPT: Additive Model-error perturbations scaled by Physical Tendencies has been developed based on investigation of COSMO model errors and tested using COSMO-Ru2-EPS system (created for the Sochi Olympics).

RHMC

Met Office NWP & climate ensemble systems

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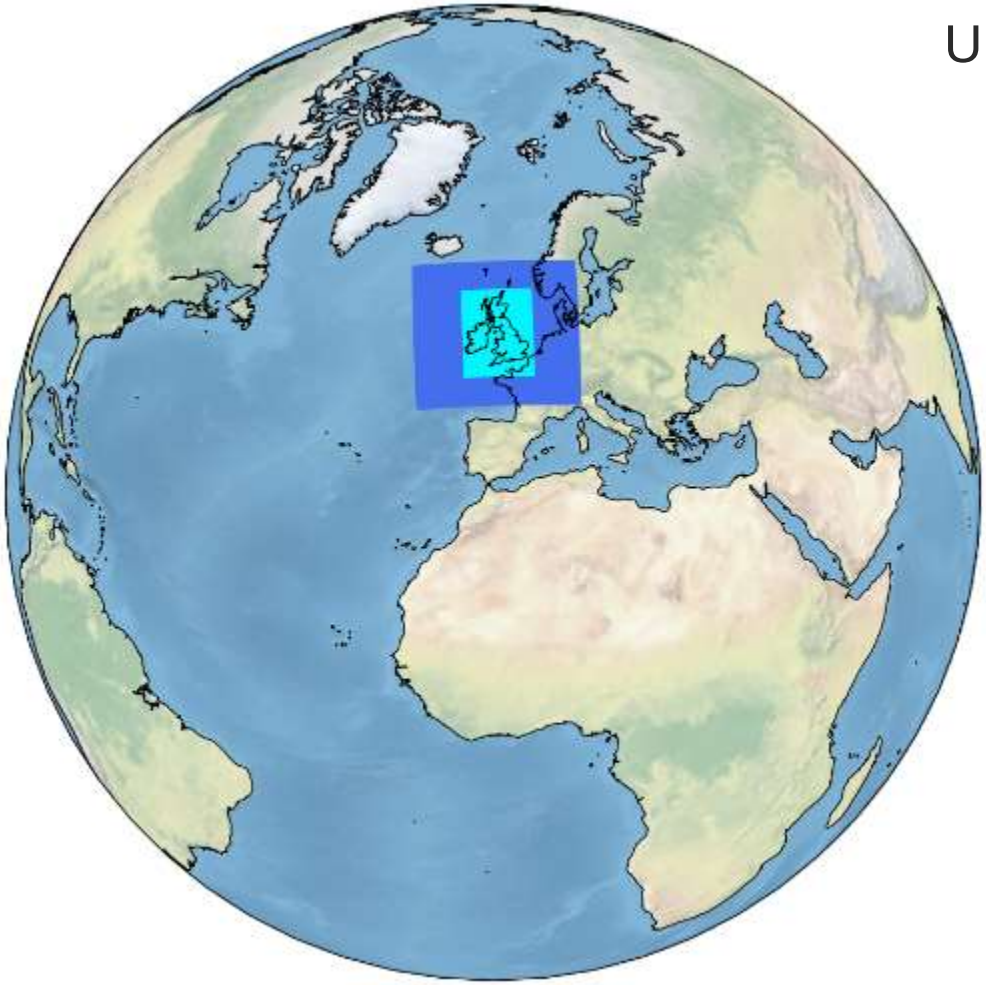
Global NWP ensemble configuration (2018)

MOGREPS-G technical details	
Resolution	1280x960 regular lat/lon grid-points = 20km (in mid-latitudes)
Vertical levels + Time-step	70 levels (model top 80 km) and Time-step = 7.5min
Science configuration	GA6.1 – Walters *et al* (2017)
Ensemble size of long forecasts	17 perturbed members + control member. Recommended use is to lag the latest two cycles, giving 36 members.
Forecast length + frequency	17 pert + 1 control = 18 members to 7-days every 6 hours
Initial conditions	Interpolated from high-resolution deterministic analysis
Initial condition perturbations	Ensemble Transform Kalman Filter (using 44 members)
Stochastic physics	SKEB + Stochastic Perturbation of Tendencies (SPT) (Sanchez et al, 2016, doi:10.1002/qj.2640)
Surface perturbations	Sea-surface temperature, soil-moisture and deep soil-temperature (Tennant and Beare, 2014)

ETKF Replacement Project - 2018

- Aim: To replace the ETKF with a more sophisticated (and more sustainable) ensemble update. To go operational in 2019.
- ETKF – transform the ensemble perturbations using information from the latest observations
  - Sophisticated adaptive inflation scheme
  - Simple localisation
- En-4DEnVar – perform data assimilation for each member using VAR code
  - Sophisticated localisation
  - Simple inflation (based on relaxation to prior, given less need for inflation)
- **Changes to Stochastic Physics include:**
  - **Retirement of Random Parameter Scheme**
  - **Introduce Stochastic Perturbed Tendencies (SPT) (already includes SKEB)**
  - **Introduce analysis increment additive inflation (AI) – see next slide**

Regional NWP ensemble configuration (MOGREPS-UK).



Until end 2018:

- 12 members
- 54 h forecast length
- Runs 4 cycles per day at 03, 09, 15 and 21 UTC
- 2.2 km resolution on the inner domain, 4 km in the variable resolution zone
- Boundary conditions from the Met Office global ensemble, MOGREPS-G
- Initial conditions for each ensemble member are provided by the deterministic UK model (UKV) analysis with perturbations from MOGREPS-G added to these

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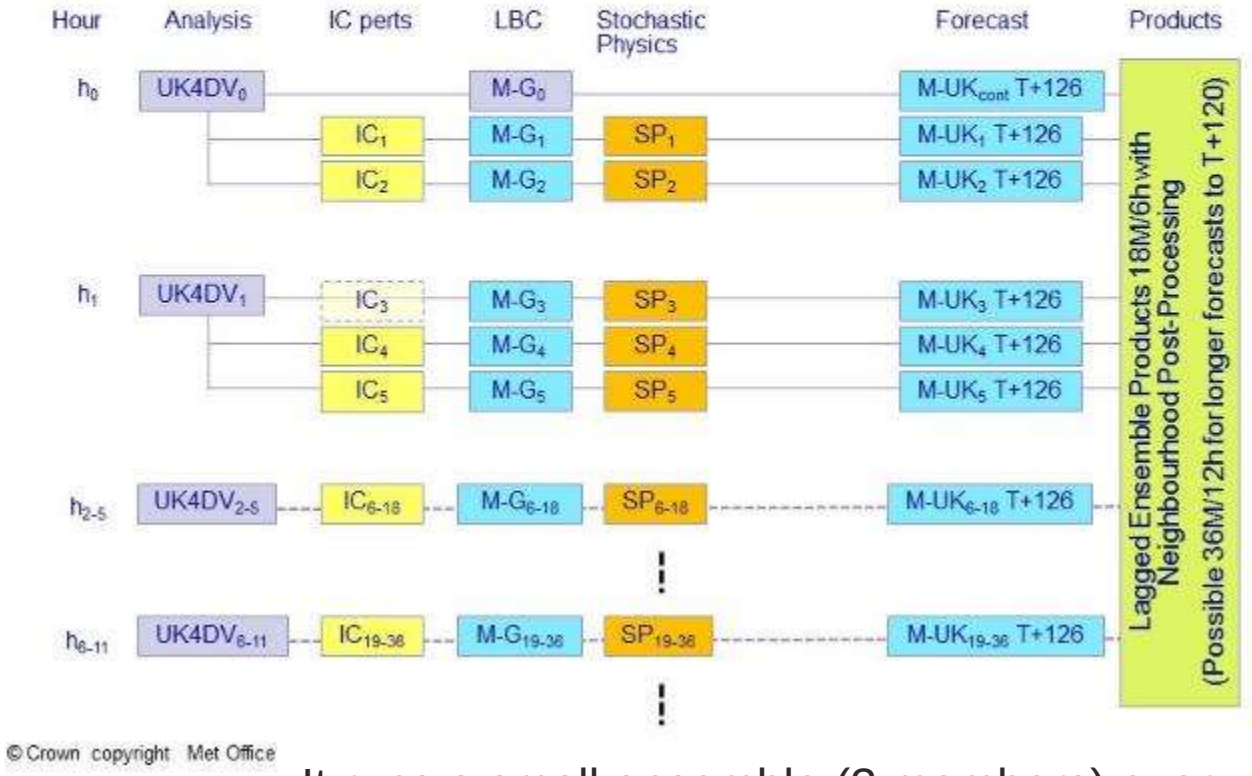
From early 2019:
Hourly cycling, which includes 18 members runs to T+120.

Hourly ensemble schematic



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This takes advantage of UKV now running hourly 4DVar and the recent increase in number of global ensemble members

It runs a small ensemble (3 members) every hour and use time-lagging to create a larger ensemble (18 members per 6h cycle)

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Seasonal ensemble (GloSea)

- Resolution:
  - Atmosphere: 60km L85
  - Ocean ¼ degree L75
- Hindcasts:
  - 1993 – 2015
  - 4 start dates per month, 3 members per start date, each run to 7 months
- Forecasts:
  - Each day run 2 members to 7 months + 2 members to 2 months
- Initialisation:
  - Nemovar for ocean
  - Met Office NWP analysis for atmosphere
- Routinely upgrade science in-line with Global Atmosphere process to maintain consistency with other Met Office global models.

Stochastic physics: SKEB
Testing SPT

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Decadal ensemble (DePreSys)

- Resolution:
  - Atmosphere: 60km L85
  - Ocean ¼ degree L75
- Hindcasts:
  - 1960 – present day
  - Start date 1st November every 2 years
  - 10 members out to 5 years
- Forecasts:
  - Start 1st November each year
  - 10 members out to 5 years
- Initialisation:
  - Weakly coupled, nudging to Smith and Murphy (2007) ocean T & S; sea ice from HadISST
- Routinely upgrade science in-line with Global Atmosphere process to maintain consistency with other Met Office global models.

Stochastic physics: SKEB
Testing SPT

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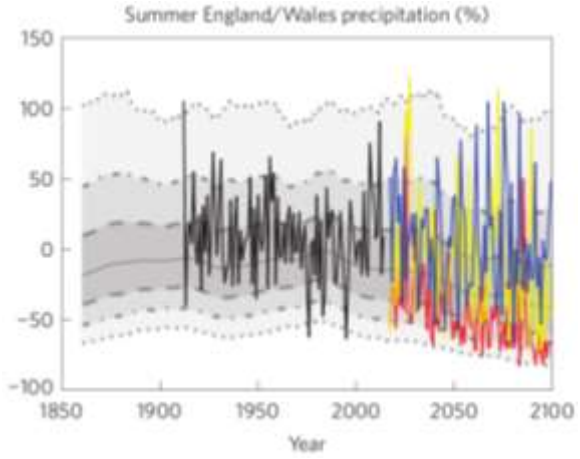
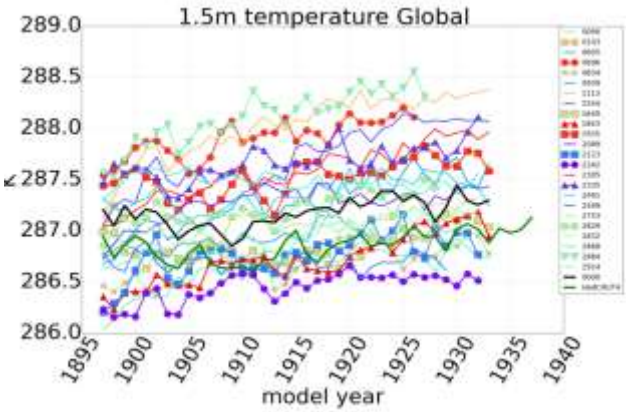
UK Climate Change Projections 2018





Probabilistic projections are used for risk assessment and must comprehensively sample the key uncertainties.

Plausible and diverse GCM realisations used to understand climate variability and extremes under a warming climate. Also used to:

- Drive regional and impacts models
- Connect regional scale to global drivers

Stochastic physics: SKEB + Stochastic Perturbation of Tendencies (SPT)

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Representation of model uncertainties revised in 2018

Revision in medium-range and extended range ensemble forecasts and EDA implemented in June 2018 (cycle 45r1):

- SKEB has been switched off due to marginal impact of current configuration
- SPPT revised (cf. last year's WGNE slides)
  - Perturbations to (total phys. ten.)−(clear-sky rad. ten.) instead of (total phys. tendency)
  - Boundary layer tapering closer to surface
  - No tapering in stratosphere
  - 20% reduction of stdev of random fields
- Consistent model uncertainty representation in ensemble of data assimilation and ensemble forecasts

Planned changes for 2019 (cycle 46r1)

- 50 member EDA
- Exchangeable initial conditions (+/- symmetry of initial perturbations will be abandoned)

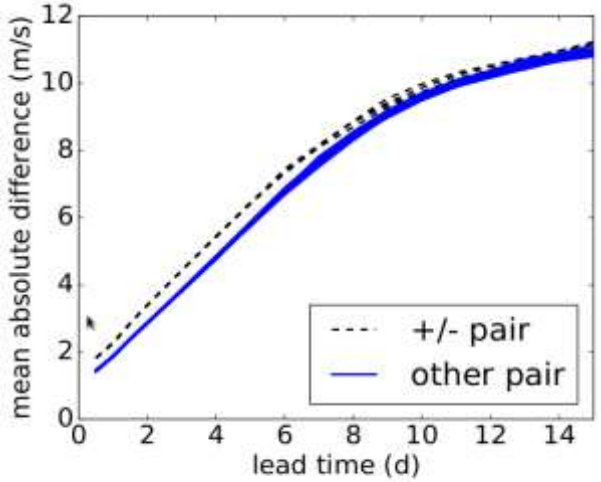


Figure 3. Mean absolute difference of different pairs of ensemble forecasts versus lead time for 200 hPa zonal wind in the northern extratropics.

See https://doi.org/10.1002/qj.3387

- Radiation time step in medium-range ensemble consistent with unperturbed high-resolution forecast

NCEP Ensemble Systems

Yuejian Zhu
Ensemble team leader
Environmental Modeling Center
NCEP/NWS/NOAA

September 2018

NCEP GEFS Status

	V11 (Dec. 2015)	V12 (Q2FY2020)
GFS Model	Semi-Lagrangian, 2015	FV3 (GFSv15)
Horizontal Resolution	T_L574 (34km)/T_L382 (55km)	C384 (25km)
Vertical resolution	L64 (hybrid)	L64 (hybrid)
Daily frequency	00, 06, 12 and 18UTC	00, 06, 12 and 18UTC
Forecast length	16days	35 days
Members	Control + 20 pert members	Control + 30 pert members
Computational Cost	300 nodes (in peak)	~1000-1200 nodes (in peak)
Execution time	~ 60 min	~60 min
Output resolution	0.5^O x 0.5^O and 1^O x 1^O	0.25^o x 0.25^o and 0.5^o x 0.5^o
Output frequency	3h the first 8 days; 6h the rest	3h the first 10 days; 6h the rest
Initial perturbations	EnKF f06	EnKF f06
Model uncertainty	STTP	SKEB, SPPT (and SHUM)
Tropical storm	Relocation for all members	Relocation for all members
Reforecast	EMC offline – 20 years	30 years (1989-2018)
Implementation	December 2nd 2015	Q2FY2020

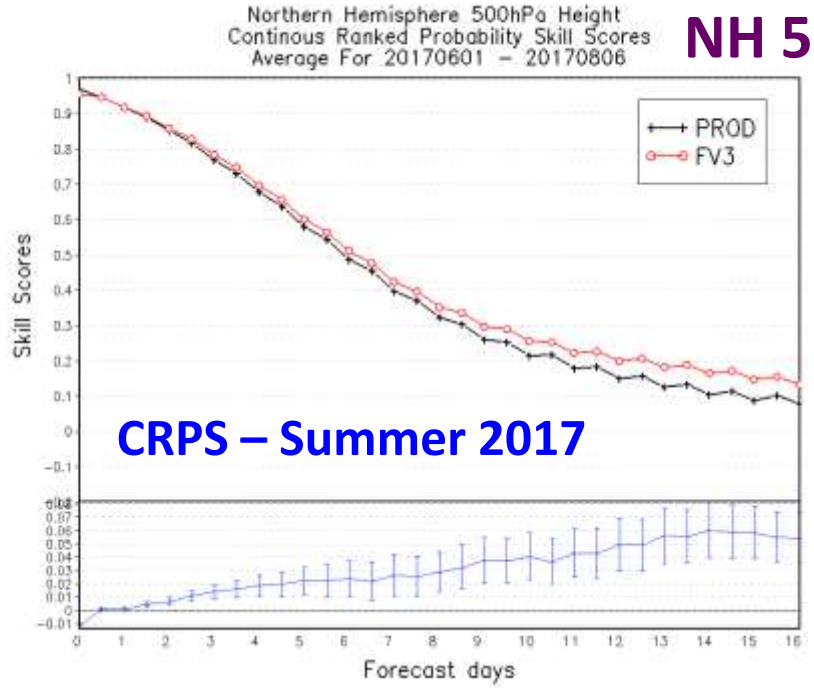
Cost and benefit of **GEFSv12** upgrade

- Implementation cycling – 2 years (actually 4+ years from last implementation)

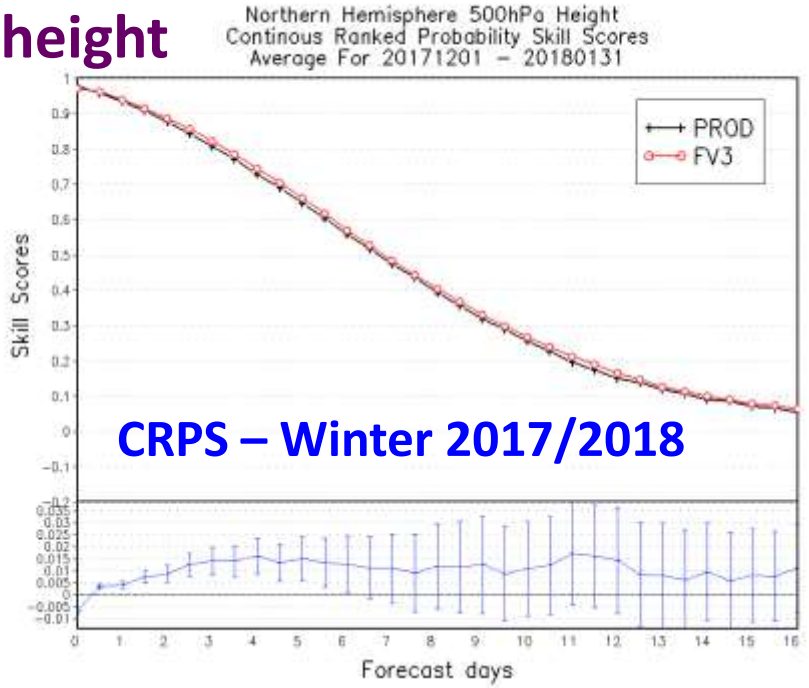
- Computation cost (example)
  - GEFSv11 - ~320 nodes for 1 hour (one cycle) – 34km/55km (day 1-16)
  - GEFSv12 - ~1000 nodes for 1 hour (one cycle)- 25km (day 1-16)
  - Nearly 3-4 times resource increasing for upgrade (higher resolution)

- Benefit and improvement (based current retrospective runs)
  - Significantly improve NH 500hPa height CRPS/AC score
    - All lead-time for summer
    - First week for winter
  - Significantly improve tropical winds for both summer and winter
    - 850hPa and 250hPa
    - Reduce error and increase spread
  - Significantly improve CONUS precipitation forecast
    - CRPS
    - BSS – Reliability and Resolution
  - **Benefit – social and economic impact?**

NH 500hPa height

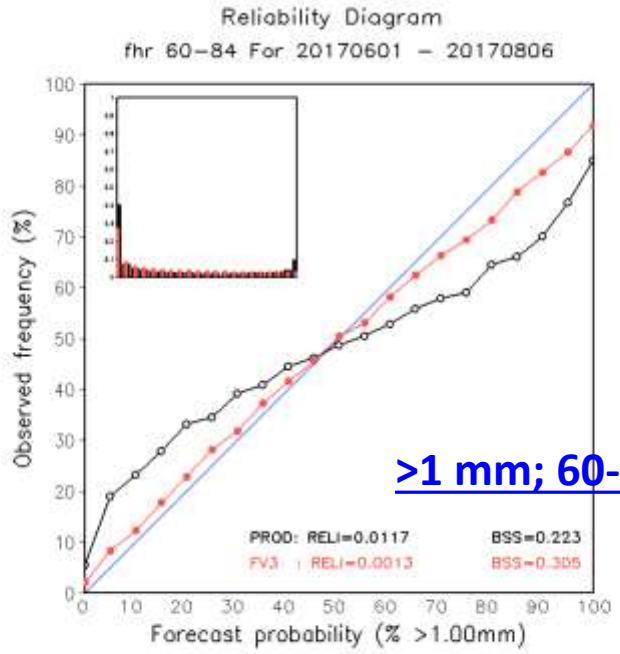


CRPS – Summer 2017



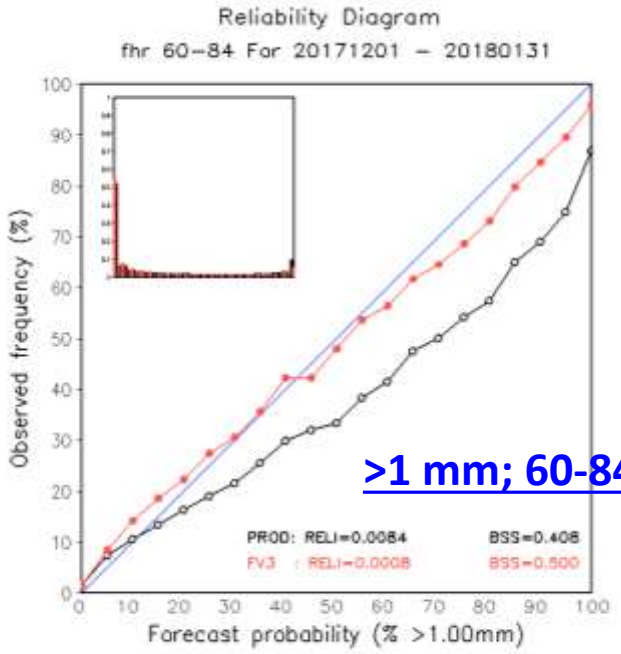
CRPS – Winter 2017/2018

CONUS Precipitation



>1 mm; 60-84 hrs

Summer



>1 mm; 60-84 hrs

Winter

YAN LUO, NOAA/NWS/NCEP/EMC

YAN LUO, NOAA/NWS/NCEP/EMC

GEFS (v13) Plan

- Atmospheric model
  - GFS v16
  - Advanced physics
- Coupling system
  - Fill coupling with Ocean, Land, Sea-ice, Wave and Aerosol
  - Data assimilation?
- Ensemble configuration
  - Initial perturbations – EnKF analysis from early cycle run
  - Increase model resolution and membership (resource dependency)
  - Forecast lead – 55 days to cover CPC monthly forecast
  - Model perturbations – process based perturbed parameterization
- Support package
  - Reanalysis?
  - Reforecast for 30 years
- Target implementation time
  - 2022

Short-Range Ensemble Forecast (SREF) System

- Two model systems
  - NMMB, WRF_ARW
- Resolutions
  - Horizontal – 16 km
  - Vertical - 41 levels (model top?)
- Ensemble membership
  - NMMB – 1 control, 12 perturbed forecast
  - WRF_ARW – 1 control, 12 perturbed forecasts
- Enhanced IC diversity:
  - Mix use of multi analyses (NDAS, GFS and RAP) for each model core
  - Blending of GEFS and SREF IC perturbations for all members
- Enhanced physics diversity:
  - More variety of physics schemes
  - Stochastic flavor in physics parameters (GWD and soil moisture)
- Implement – Oct. 21 2015
- Current status
  - **System has been frozen, has no further development**

The CPTEC Ensemble Prediction System

Current Status and Future Plans

Carlos Bastarz - CPTEC/INPE

August, 2018

Updates and Future Plans

Completed:

- Update the model version to the BAM (Brazilian Global Atmospheric Model), which is the next generation of the current global model and increase model resolution to TQ0213L042 (~60 km);

Sensibility Tests:

- Verification of the perturbation regions (South/North Hemispheres, Tropics and Southern/Northern South America);
- Verification of the Ensemble Size X Model Resolution;
- As the number of layers has been increased, it is necessary to tune the vertical profile of the humidity standard deviation to use within the EOF perturbations reweight.

Short-term:

- Forecast bias correction.

Mid/long term plan (to be defined):

- Couple with the BESM (Brazilian Earth System Model);
- Introduce the perturbations from an EnKF (from a hybrid 3dEnsVar data assimilation cycle – already tested).

Updates and Future Plans

www.cptec.inpe.br

Hybrid 3DVar data assimilation (hybrid background error covariance matrix):

- Unification of the deterministic data assimilation system for NWP (7 days) and the EPS system (15 days), taking advantage of the updated forecast ensemble of analysis to extend the forecasts range up to 15 days;
- The hybrid 3DVar system is being tested (at this stage, TQ0062L028) and yielded positive results for deterministic NWP (the ensemble forecasts still have to be properly evaluated).