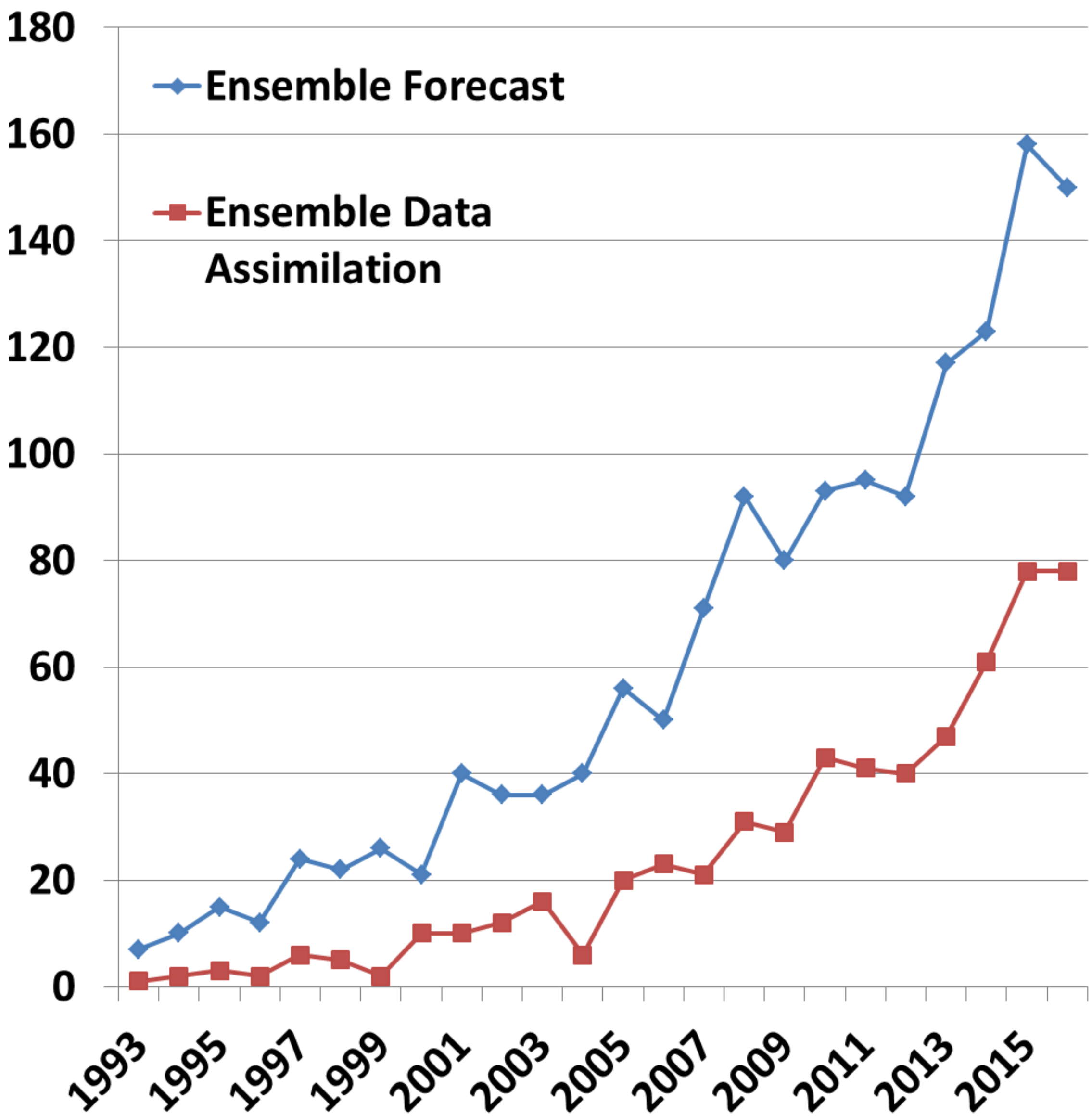
Current Issues and Challenges in Ensemble Forecasting

Carolyn Reynolds (NRL) and Junichi Ishida (JMA)
With contributions from WGNE members

32nd WGNE
Exeter, UK, 9-12 October 2017

- **Recent Trends in Ensemble-Related Research**
- **Initial Perturbations**
- **Model Uncertainty**
- **Lateral/Lower Boundary Uncertainty**
- **Weather/Climate Interface (S2S)**
- **Impacts (TCs, Hydrology)**
- **Ensemble Structure**

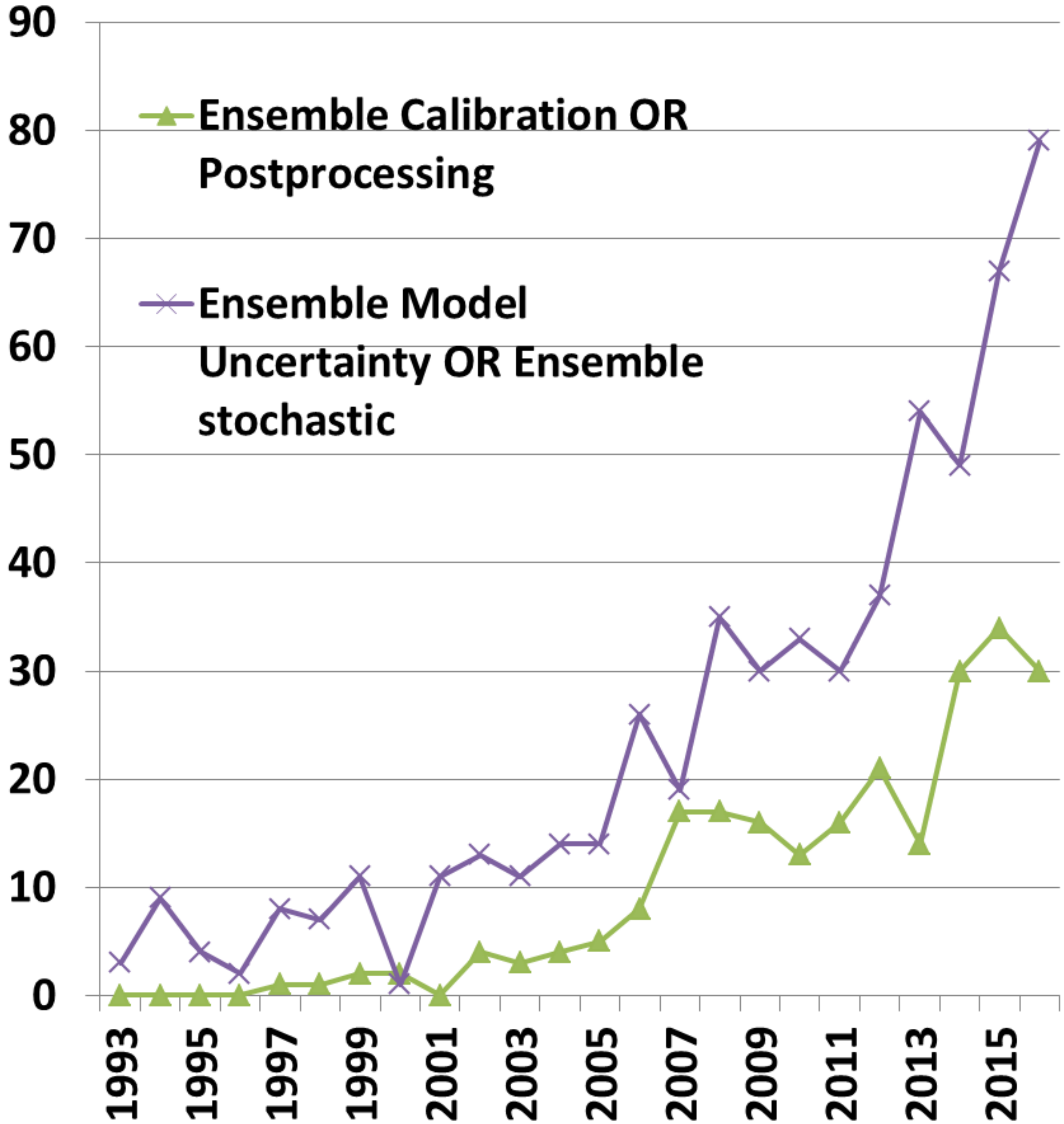
*Number of Article/Year with These Words in the Abstract**



Research in ensemble forecasting and ensemble data assimilation continues to be active.

***AMS journals only**

Number of Article/Year with These Words in the Abstract*



Research in model uncertainty continues to grow rapidly.

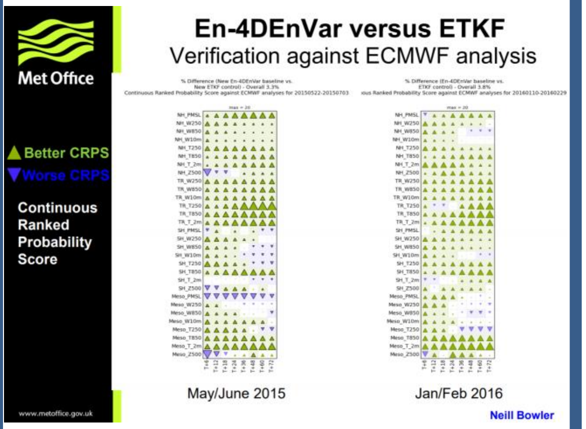
Interest in calibration and post-processing also substantially larger than in the early 2000s.

*AMS journals only

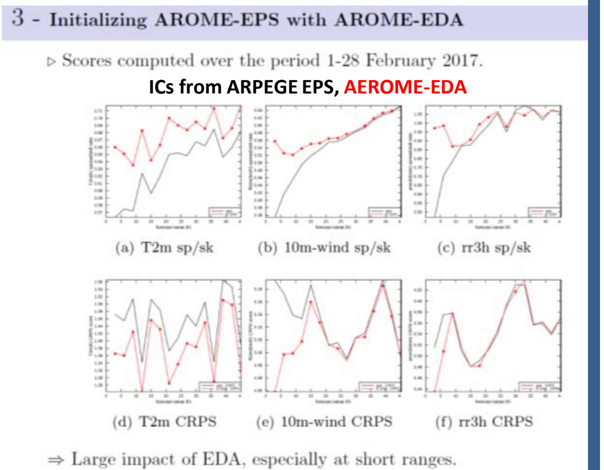
Initial Perturbations: Continued Focus on DA-EPS Consistency

- CMC: IAU replaces digital filter, recentering (global); IAU, intermittent to perpetual DA cycle (regional)
- CPTEC: ENKF/Hybrid 3DVAR
- DWD: SVs of Krylov space, Broyden matrix
- ECMWF: Improved SVS, higher EDA resolution
- JMA: LETKF (global); SVs (regional)
- Met Office: En-4DEnVar, 1.5km lagged MOGREPS-UK
- Meteo France: Regional EDA and 3D-EnVAR
- NRL: Perturbed Obs for atmo-ocean coupled model
- ROSHYDROMET: EnsDA or LETKF

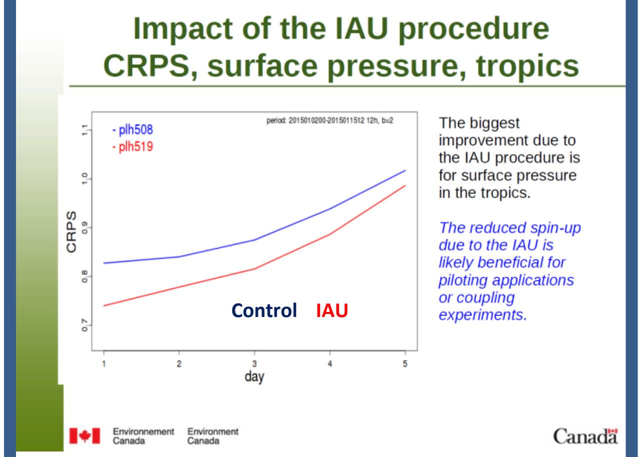
Met Office



Meteo France



CMC



Model Uncertainty: Stochastic Methods, Parameter Variations, AI

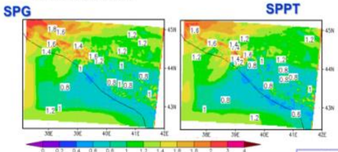
- **CMC: Recycle key physics variables (regional)**
- **DWD: Smoothed Plant-Craig conv. tend., linear model forecast error approximation**
- **ECMWF: Revised SPPT, SPP, consistency in EDA and EPS, SL-advection uncertainty**
- **JMA: Physics perturbations under development**
- **Met Office: SPP, analysis increment additive inflation**
- **MeteoFrance: Regional-SPPT, perturbed parameters, Global- testing SPP**
- **NCEP: From STTP to SKEB + SPPT + SHUM**
- **NRL: Increment perturbations in coupled system**
- **ROSHYDROMET: Stoch. pattern generator**

ROSHYDROMET

SPG vs SPPT

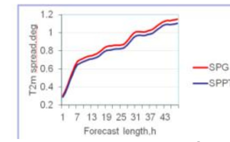
The preliminary results of ensemble computations with SPG look optimistic and require more extensive experimentation

- No computational instabilities
- No outbursts



The spread pattern for SPG and SPPT are a bit different but close

- With SPG the spread grows a little faster than with SPPT, while the skill is nearly similar

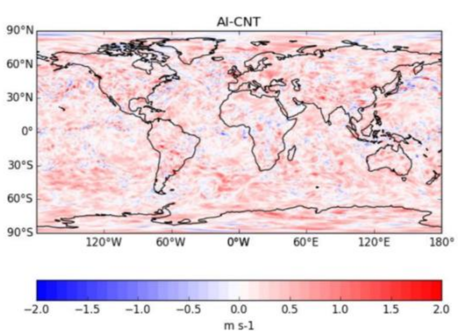


2-m T Spread

C. Piccolo (Met Office)

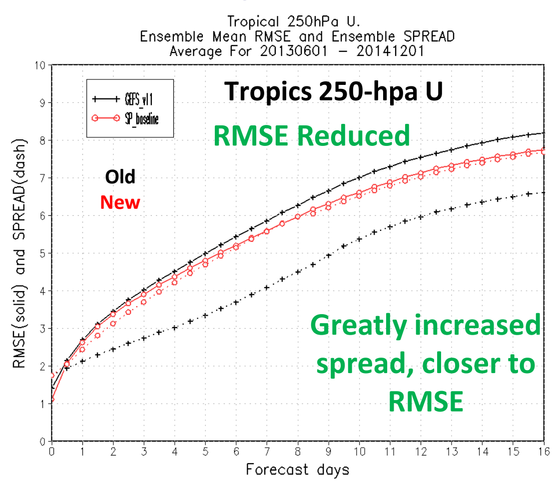
Met Office

Geographical variation of spread at T+6 h (AI - CNT)



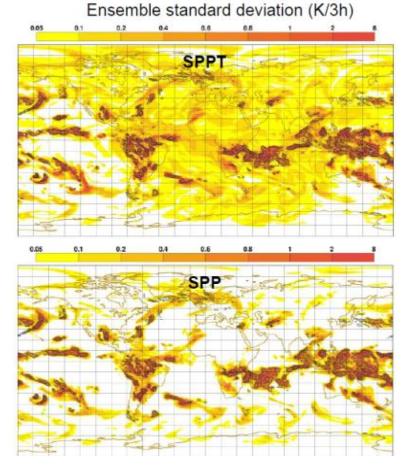
AI introduces more large scale spread across all regions but lacks flow-dependency. It also better represents the error in the SH and tropics.

W. Kolczynski (NCEP)



S. J. Lock (ECMWF)

Ensemble standard deviation (K/3h)



Ensemble mean convective precipitation (mm/3h)

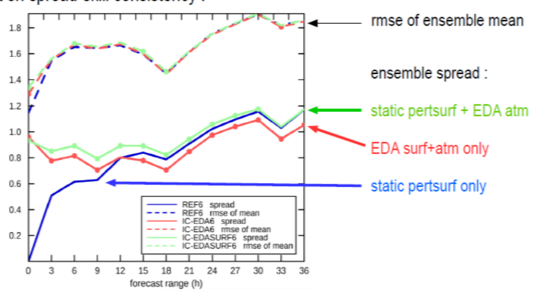
Lateral/Lower Boundary Uncertainty

- **CMC: Regional: SSTs at 10 km, CALDAS (Land DA); Global: Coupling with NEMO**
- **CPTEC: Coupled with Brazilian Earth System Model**
- **DWD: Improved LAM boundary conditions through dynamically consistent initial perturbations in global ensemble**
- **JMA: SST perturbations (global), lower boundary perturbations (regional)**
- **MeteoFrance: Surface variable perturbations**
- **NCEP: Soil temp and moisture extension to SPPT**
- **NRL: SST perturbations, SST diurnal cycle**
- **ROSHYDROMET: Soil perturbations**

C. Reynaud (Meteo France)

AROME surface-model perturbations : static vs EDA

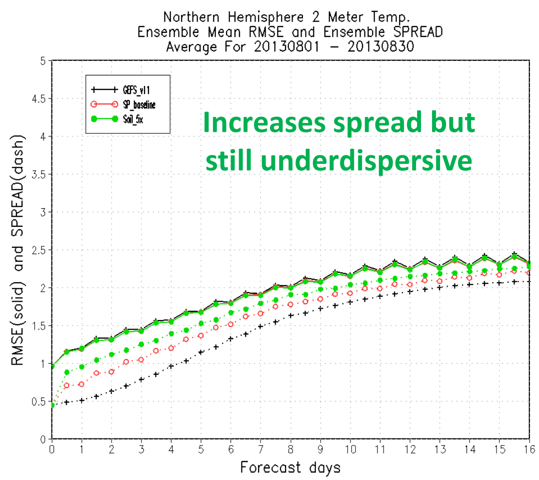
Impact on spread-skill consistency :



EDA ICs good at short ranges, but miss long-lived surface errors.
Static surface-model perturbations alone take time to influence the atmosphere.
The best is a mix of both.
(Ideally, EDA needs a surface perturbation scheme, but long-term surface stability is an issue)

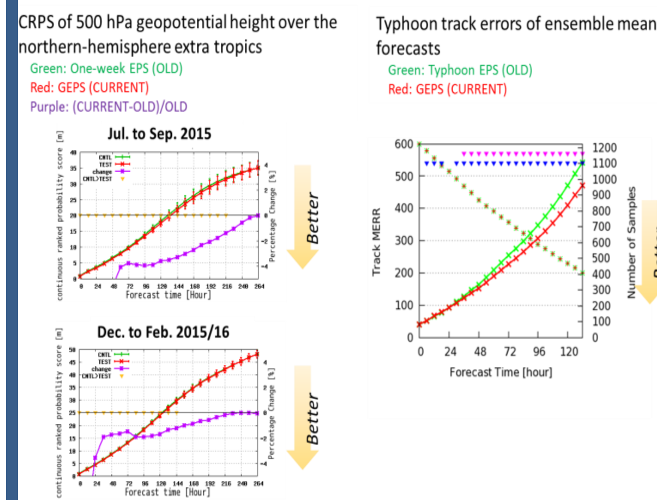
W. Kolczynski (NCEP)

Soil SPPT – 2-m Temp



JMA

Improvements in GEPS forecasts



Weather-Climate Interface: S2S Forecasting

S2S

Sub-seasonal predictions : S2S partners

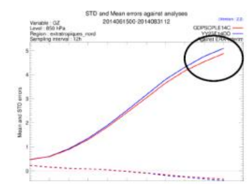
	Time-range	Resol.	Ens. Size	Freq.	Hcsts	Hcst length	Hcst Freq	Hcst Size
ECMWF	D 0-46	T639/319L91	51	2/week	On the fly	Past 20y	2/weekly	11
UKMO	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
NCEP	D 0-44	N126L64	4	4/daily	Fix	1999-2010	4/daily	1
EC	D 0-32	0.6x0.6L40	21	weekly	On the fly	1995-2014	weekly	4
CAWCR	D 0-60	T47L17	33	weekly	Fix	1981-2013	6/month	33
JMA	D 0-34	T319L60	25	2/weekly	Fix	1981-2010	3/month	5
KMA	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
CMA	D 0-45	T106L40	4	daily	Fix	1886-2014	daily	4
CNRM	D 0-32	T255L91	51	Weekly	Fix	1993-2014	2/monthly	15
CNR-ISAC	D 0-32	0.75x0.56 L54	40	weekly	Fix	1981-2010	6/month	1
HMCR	D 0-63	1.1x1.4 L28	20	weekly	Fix	1981-2010	weekly	10

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

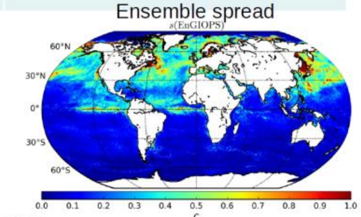
CMC

Coupled GEPS-NEMO

Modification	Impact
Coupling of GEPS forecasts to GIOPSf component	- Improved ice and SST evolution for GEPS - Potential impact on ensemble spread - New monthly ensemble ice-ocean forecast products (for CIS)



Ensemble spread



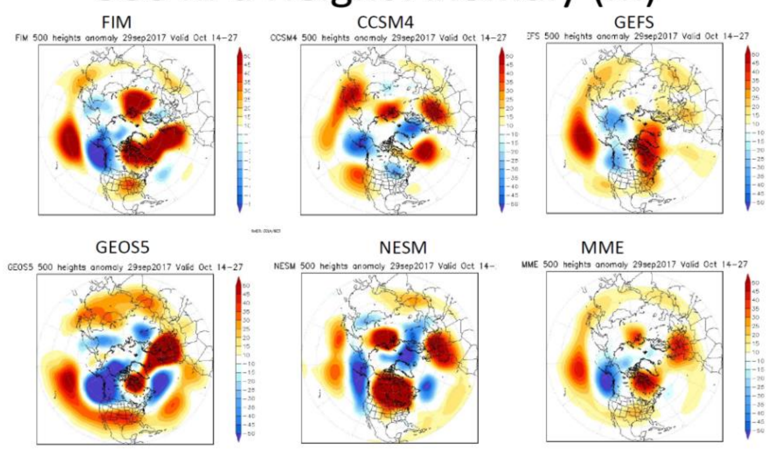
Environment Canada Environnement Canada

Page 12 – 17-9-18

Canada

North American Multi-model Ensemble (NMME) /SubX

500 hPa Height Anomaly (m)



Sea Ice Prediction Network US Navy Contribution

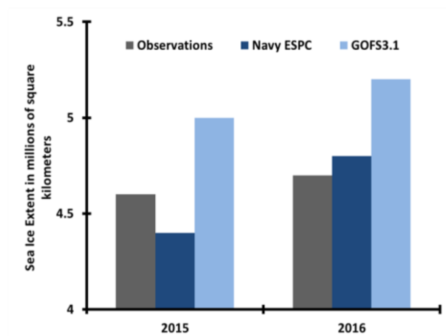
Navy Global Coupled System

- 10 member time-lagged ensemble starting one day apart at 12Z starting from the last 10 days July.

Navy Global Ocean-Ice System (GOFS)

- 10 member ensemble using the same initial conditions for each member, but different atmospheric years

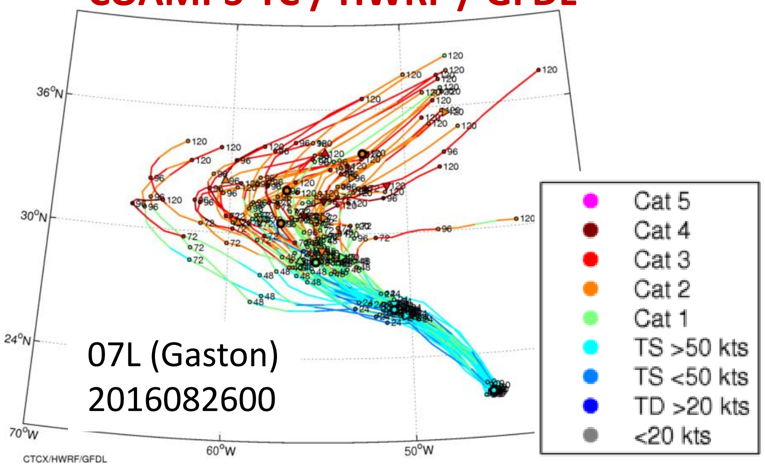
Coupled atmosphere-ocean improves performance over using atmospheric forcing from previous years



Impacts: Tropical Cyclone Ensemble Forecasting

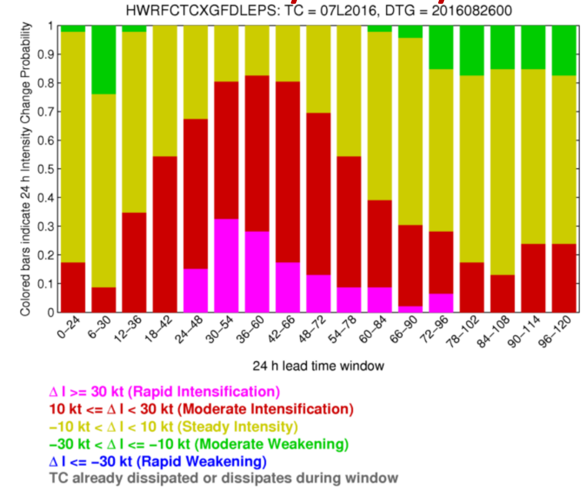
HFIP Multi-model Ensemble Integrated Intensity-Track Information

COAMPS-TC / HWRF / GFDL

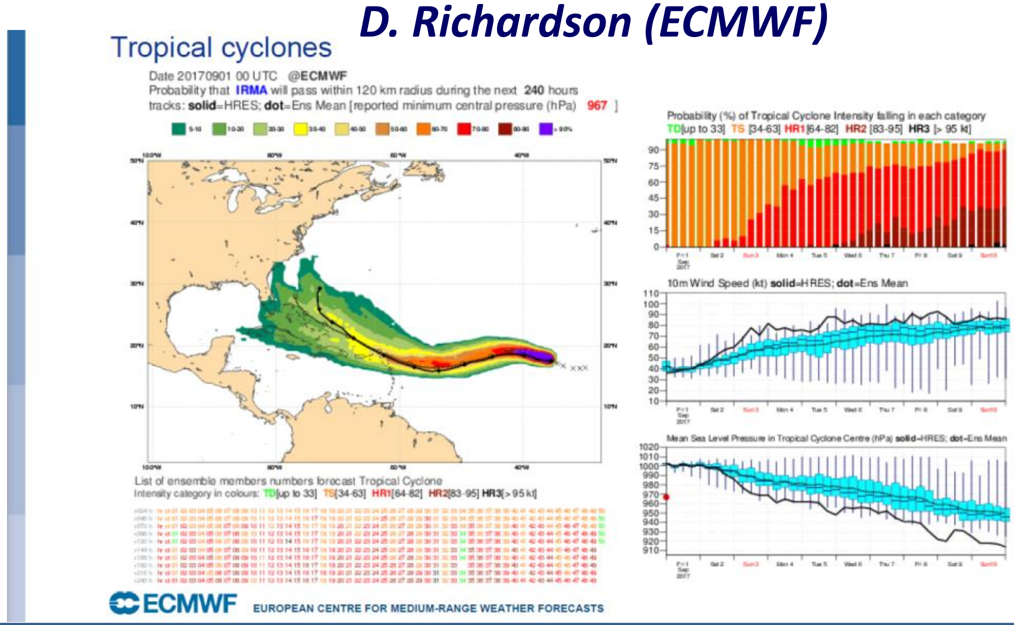


HFIP Multi-model Ensemble 24-h Intensity Change Probability

COAMPS-TC / HWRF / GFDL



D. Richardson (ECMWF)



Impacts: Hydrology, Extreme Weather, Renewable Energy

H. Clocke (U. Reading)

HEPEX a community of research and practice to advance hydrologic ensemble prediction

HEPEX *Hydrologic Ensemble Prediction Experiment* began in 2004 at an ECMWF workshop jointly organized with the US National Weather Service (NWS) & the European Commission (EC).

It continues to connect the research community, forecasters and forecast users and facilitates the exchange of ideas, data, methods and experience.

Find out more: **www.hepex.org**


HEPEX Workshop, 6-8 June 2016, Quebec, Canada

HEPEX Chairs are:
Maria-Helena Ramos (IRSTEA, France)
QJ Wang (University of Melbourne , Australia)
Fredrik Wetterhall (ECMWF, UK)
Andy Wood (UCAR, USA)

11

h.l.cloke@reading.ac.uk

University of Reading

- The theme for the 2018 HEPEX workshop is '**breaking the barriers**' to highlight current challenges facing ensemble forecasting researchers and practitioners and how they can be overcome:
- using ensemble forecasts to improve decisions in practice,
- extending forecasts in space (including to ungauged areas) and across lead-times, from short-term to sub-seasonal to seasonal forecast horizons,
- using ensemble forecasts to maximise economic returns from existing water infrastructure (e.g. reservoirs), even as inflows and demand for water change,
- using ensemble forecasts to improve environmental management of rivers,
- applying ensemble forecasts for agriculture,
- searching for better/new sources of forecast skill,
- balancing the use of dynamical climate and hydrological models with the need for reliable ensembles,
- communicating forecast quality and uncertainty to end users.

h.l.cloke@reading.ac.uk

WEXICOM Freie Universität Berlin · Forschungsforum Öffentliche Sicherheit · DKKV · Max-Planck-Institut für Bildungsforschung / Max Planck Institute for Human Development · Hans-Ertel-Zentrum für Wetterforschung · Deutscher Wetterdienst · DWD

➔ **Weather warnings: from EXtreme event Information to COMunication and action**

- Research project of the **Hans-Ertel-Zentrum** (funded by DWD)
- Inter- and **transdisciplinary approach** involving meteorology, social sciences, and psychology
- **Ultimate goal is to facilitate transparent and effective communication of risk and uncertainties to specific user groups**
- Using the DWD's fire brigade information system (FeWIS) as a testbed, the project will implement **different ways of communicating probabilistic weather information**
- Use of this **information will be analyzed in terms of usage and preferences** to determine whether and how risk-based warnings can help emergency managers to reduce the risk of loss and damage

ECMWF Predictability Seminar, 13.09.2017 - Slowly but surely... 12

R. Hagedorn (DWD)

Closing the gap

Deutscher Wetterdienst – Wetter und Klima aus einer Hand · DWD

➔ Main goal of Division on Product Development and Customer Relations at DWD

- **Enhancing the importance and utility of weather information and (probabilistic) forecast products for the user by…**
  - Collecting user requirements
  - Consolidating requirements and possibilities
  - Planning, coordinating and conducting new developments
  - Supporting users to integrate weather information into their own decision support systems
- **Fostering the dialogue between users and developers in particular on integrating probabilistic information**

ECMWF Predictability Seminar, 13.09.2017 - Slowly but surely... 8

ECMWF Annual Seminar 11-14 Sept. 2017
Ensemble Prediction: Past, Present and Future

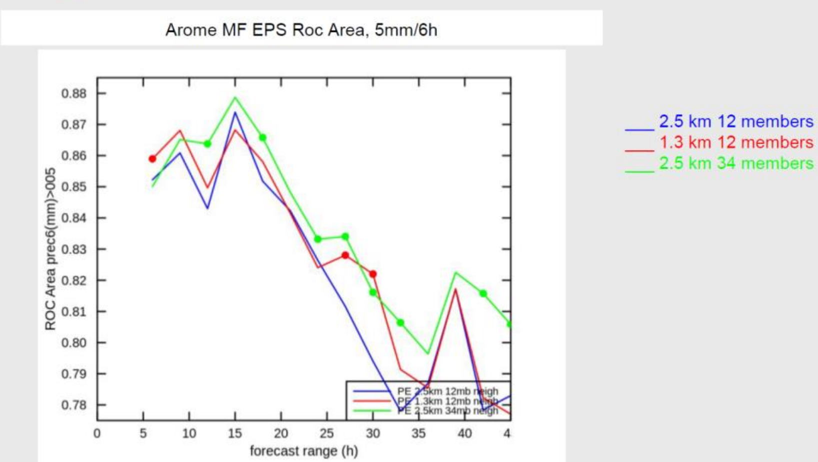
Structure of Ensemble Systems:

Panel Discussion: F. Bouttier, R. Hagedorn, S. J. Lock, L. Raynaud, T. Stockdale (moderator)

- User/metric dependent
    - Higher resolution for short forecasts*
    - More members for DA, extreme events, long forecasts
- Lagged forecasts a success at Met Office
- Use small ensembles, "fair" scores, for R&D

I.-L. Frogner (Norwegian Met Institute) showing results from Meteo France, Met Office

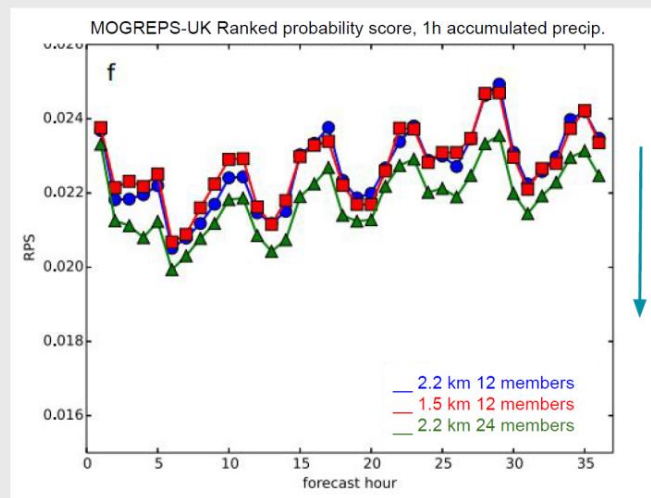
Higher resolution or more members?



Raynaud and Bouttier, 2017

Norwegian Meteorological Institute

Higher resolution or more members?



MOGREPS- UK: Hagelin et al, 2017

Norwegian Meteorological Institute

ECMWF Annual Seminar 11-14 Sept. 2017
Ensemble Prediction: Past, Present and Future

Structure of Ensemble Systems:

Panel Discussion: F. Bouttier, R. Hagedorn, S. J. Lock, L. Raynaud, T. Stockdale (moderator)

- **User/metric dependent**
  - **Higher resolution for short forecasts***
  - **More members for DA, extreme events, long forecasts**
- **Lagged forecasts a success at Met Office**
- **Use small ensembles, "fair" scores, for R&D**

C. Ferro (U. Exeter)

Adjust scores to the desired ensemble size

Fair scores are unbiased estimates of the scores that would be obtained if the ensemble size were infinite.

We also have unbiased estimates of the scores that would be obtained for any ensemble size, M.

Example: Adjusted Brier score,

$$\mathrm{BS} - \frac{(1 - m/M)F(t)\{1 - F(t)\}}{m - 1}.$$

Example: Adjusted CRPS,

$$\mathrm{CRPS} - \int \frac{(1 - m/M)F(t)\{1 - F(t)\}}{m - 1}\,dt.$$

These can be used to predict the effects of changing ensemble size and to compare ensembles of different sizes.

Use proper scores to rank probability forecasts.

Avoid calculating scores for only extreme outcomes.

Use weighted scores to focus on extreme outcomes.

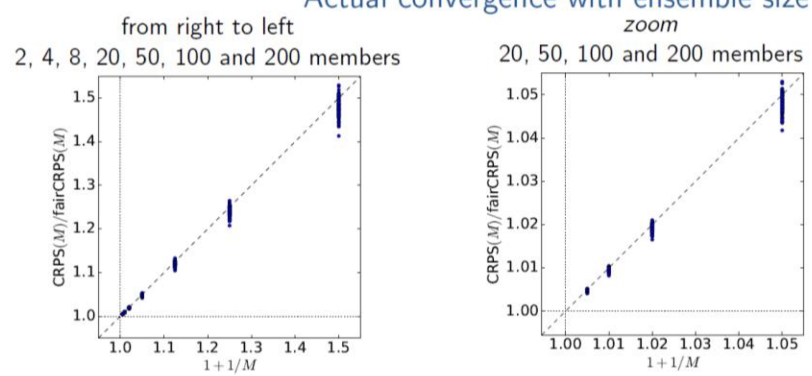
Use (weighted) fair scores to rank ensemble forecasts.

Adjust scores to account for different ensemble sizes.

Avoid misinterpreting 'better' scores for rare events.

M. Leutbecher (ECMWF)

Actual convergence with ensemble size



- Data from 200 member TCo399 IFS experiment, JJA2016
- 120 data points for each ensemble size
- 15 lead times × 4 variables (z500, T850, u850, u200) × 2 regions (NH and SH extratropics)
- 50 and 200 members are 2% and 0.5% worse than ∞, respectively

ECMWF

- **Operational ensemble forecasts:** 50 members are too few — let's increase the ensemble size to ...
- **Research & Development:** Small ensembles are highly efficient. Two to four members may be enough for standard evaluations (provided exchangeability in the ensemble generation and use of fair scores)

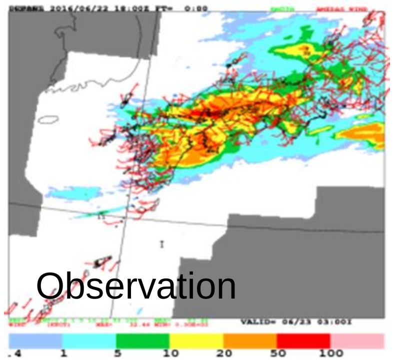
Extra Slides

Implementation of ASUCA L76 in MEPS

Replacement of MEPS forecast model (Jul. 2017)

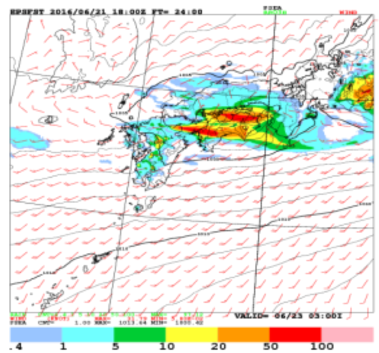
- JMA-NHM L48 => ASUCA L76
- configuration of ASUCA identical to deterministic MSM
  => evaluation of uncertainties in MSM forecasts with IC and BC pert.
- Improvement in forecast skills from each member and ensemble mean.

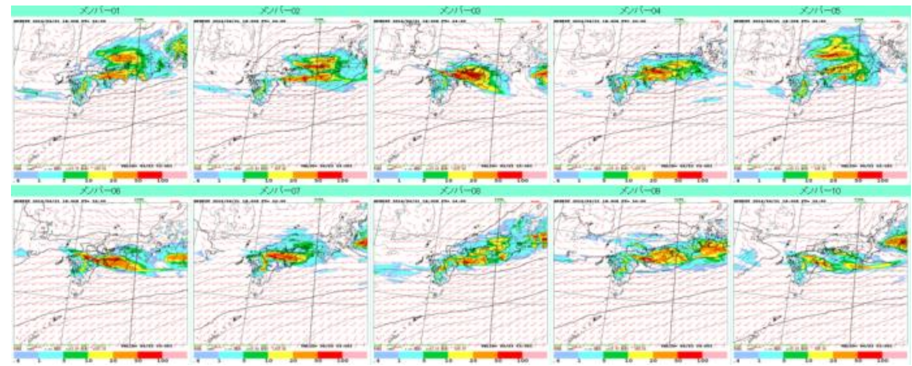
3h-accumulated precipitation at 22 Jun. 2016 18UTC



Observation

Old MEPS
JMA-NHM L48





prec. > 10mm/3h: too localized
prec. > 50mm/3h: too much

Perturbed runs take over characteristic of forecast from their own control run.

improved prec. forecast

New MEPS
ASUCA L76