Ensemble forecasting at ECMWF

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50+1 member
TCo639 D0–15
TCo319 D15–46
L91

IFS
NEMO

HRES
4D-Var AN

SPPT

SVs

EDA
pert. 4D-Var
Initial conditions

T850hPa

HRES Analysis 00 UTC

EDA-Pert 1

SV-Pert 1

Initial conditions for ENS member 1
Singular vectors and reliability

EDA and SPPT generate spread also in the directions of the leading SVs. Just not enough though.

When to stop using SVs?
Exchangeable initial conditions

Old:
Plus-Minus
Symmetry with Perturbations from 25-Member EDA

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Plus-Minus
Symmetry with Perturbations from 25-Member EDA

New:
Perturbations from new 50-Member EDA

implemented in June 2019

see Lang et al., ECMWF newsletter Nr. 158
Leutbecher (2018), https://doi.org/10.1002/qj.3387
Stochastically Perturbed Parametrization Tendencies

- More realistic diurnal cycle of tendency perturbations in SPPT by not perturbing the clear-sky radiative tendency;
- Perturbations in stratosphere and weaker tapering of perturbations in boundary layer
- Same SPPT in ENS and EDA, and cycling of random fields in EDA
- 20% reduced SPPT amplitude
- **SKEB deactivation** (2.5% saving)

See also Lock et al (2019); https://doi.org/10.1002/qj.3570
Future directions for representation of MU

- represent uncertainty close to the assumed sources of the errors
- physical consistency of perturbation
- e.g. preserve local energy or moisture budget through flux perturbations at surface and at the top-of-the-atmosphere consistent with the tendency perturbation
- beyond an amplitude error, e.g. uncertainty in shape of heating profile
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Ongoing research on model uncertainties

- Stochastically Perturbed Parametrization Tendencies (SPP)
- Quantitative comparison of the tendency perturbations from SPP and SPPT
- Dynamical Core uncertainties

see Ollinaho et al. (2017) and Leutbecher et al. (2017).
Medium-range

- rms error and spread
- TC track error
- ensemble size and spatial resolution
RMS errors of ensemble mean and ensemble spread (both 18 km) and RMSE of 9 km and 18 km deterministic forecasts
Evolution of spread and error

500hPa geopotential
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
Date: 20010101 00UTC to 20181231 00UTC
oper_an od enfo 0001
Mean method: standard

Solid : Error
Dashed : Spread
2001 2008 2018

Forecast Day

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Tropical cyclone track position error and spread

EM mean position error and ENS spread D+3, D+5

Means over periods of 365 days ending on 31 May
Ensemble size and spatial resolution

- Both spatial resolution as well as ensemble size have an impact on the required computational resources
- New supercomputer, what should one do?
- Increase resolution or ensemble size or both?
- Skill optimisation given fixed computational resources but allowing potentially for two resolutions

\[ (k, m) \]

The latter use 4 times as much computational resources.

- See Leutbecher and Ben Bouallégue (2019), https://doi.org/10.1002/qj.3704
Ensemble size and spatial resolution

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- New supercomputer, what should one do?
- Increase resolution or ensemble size or both?
- Skill optimisation given fixed computational resources but allowing potentially for two resolutions
- Here, ensembles \((k, m)\) with \(k\) 29 km resol. members and \(m\) 18 km resolution members. The latter use 4 times as much computational resources.
- see Leutbecher and Ben Bouallègue (2019), https://doi.org/10.1002/qj.3704 and
Extended-range

- Impact of lagging and ensemble size
- Evolution of MJO skill
- Evolution of skill generally
- Revised initial conditions for reforecasts
- see also Vitart et al, (2019)a,b, https://www.ecmwf.int/node/19286, https://www.ecmwf.int/node/18872
Lagging and ensemble size in extended-range
Impact on CRPSS over 20 variables/regions

Lag ensemble defined by 2 attributes:
- Ne: Ensemble size per day (Ne=1 to 51)
- Nd: Number of combined dates (Nd=2 to 5)

- Running legB daily could be an option if daily ensemble size > 20 (+8% cost of legB)
- Using lag ensembles can help improve skill of weeks 2, 3 and 4
- Lag ensemble size should be larger than burst ensemble size
- Optimal number of lag days increases with lead time and in the Tropics

Diff Lag ensemble (Ne,Nd) – Burst (51m)

Day 5-11
Day 12-18
Day 19-25
Day 26-32

40m, 2d
20m, 3d
14m, 4d
13m, 5d
Evolution of MJO skill

MJO Bivariate Correlation

- 0.5
- 0.6
- 0.8

Forecast Day vs. YEAR from 2002 to 2018.
Evolution of skill generally

- The skill of the extended-range forecasts has improved since 2014, particularly in the Tropics.

- In the Northern Extratropics, the improvement is less significant, particularly for the upper tropospheric fields.

Impact of ERA5 (46R1) not included.
Revised initial conditions for reforecasts

Changes introduces in 46R1:

- ERA5 is now used to initialize the re-forecasts
- ERA5 EDA is used to perturb initial conditions
- Land surface is initialized from ERA5 instead of from an offline re-analysis

Impact of coupled data assimilation also investigated
Summary

- Flow-dependent initial perturbations from EDA and SVs: Both components essential to achieve reasonable reliability
- Revision of SPPT brings different flow-dependent representation of model uncertainties through removing spurious diurnal cycle in perturbations
- The desire for physical consistency of perturbations motivates development of alternative schemes that represent uncertainty close to its sources
- Ensemble size and spatial resolution are both important and the configuration providing best skill will depend on the specific application. The next medium-range configuration will probably still have 50 members and a resolution of 9–11 km
- It is planned to have daily extended-range forecasts enabling skill improvements through lagging from week 2 onwards