Representation of model uncertainties in ECMWF ensembles

ECMWF

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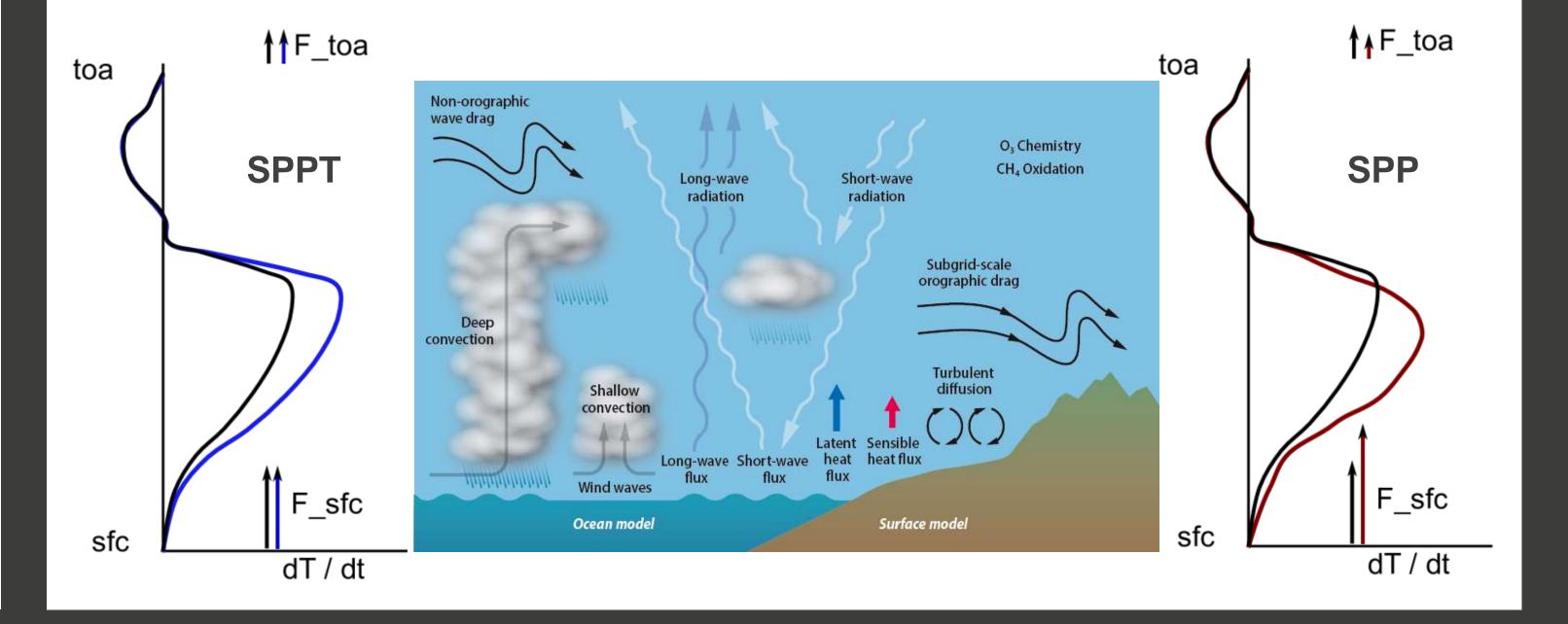
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Future directions @ ECMWF

The coming years are likely to see a further increase in the use of ensemble methods in forecasts and assimilation. This will put increasing demands on the methods used to perturb the forecast model. An area that is receiving greater attention than 5 to 10 years ago is the physical consistency of the perturbations (Leutbecher *et al*, 2016). The development of **SPP** (Ollinaho *et al*, 2016) is an attempt at ECMWF to improve the physical consistency of the perturbations compared to **SPPT** (Palmer *et al*, 2009). Other areas where future efforts will be directed at ECMWF are the expansion of uncertainty representations to the dynamical core and to other components of the Earth system as well as the overall computational efficiency of representing model uncertainty (MU, Leutbecher *et al*, 2016).

Key differences between SPPT and SPP

- representation of MU close to the assumed sources of the errors
- physical consistency: e.g. local budgets and flux perturbations
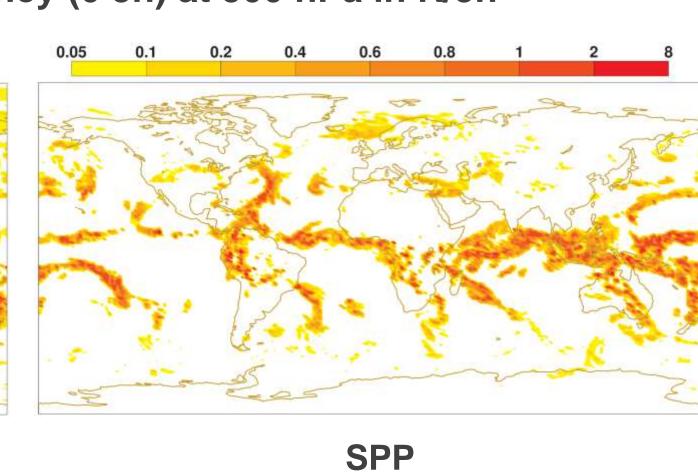- beyond an amplitude error, e.g. in shape of heating profile

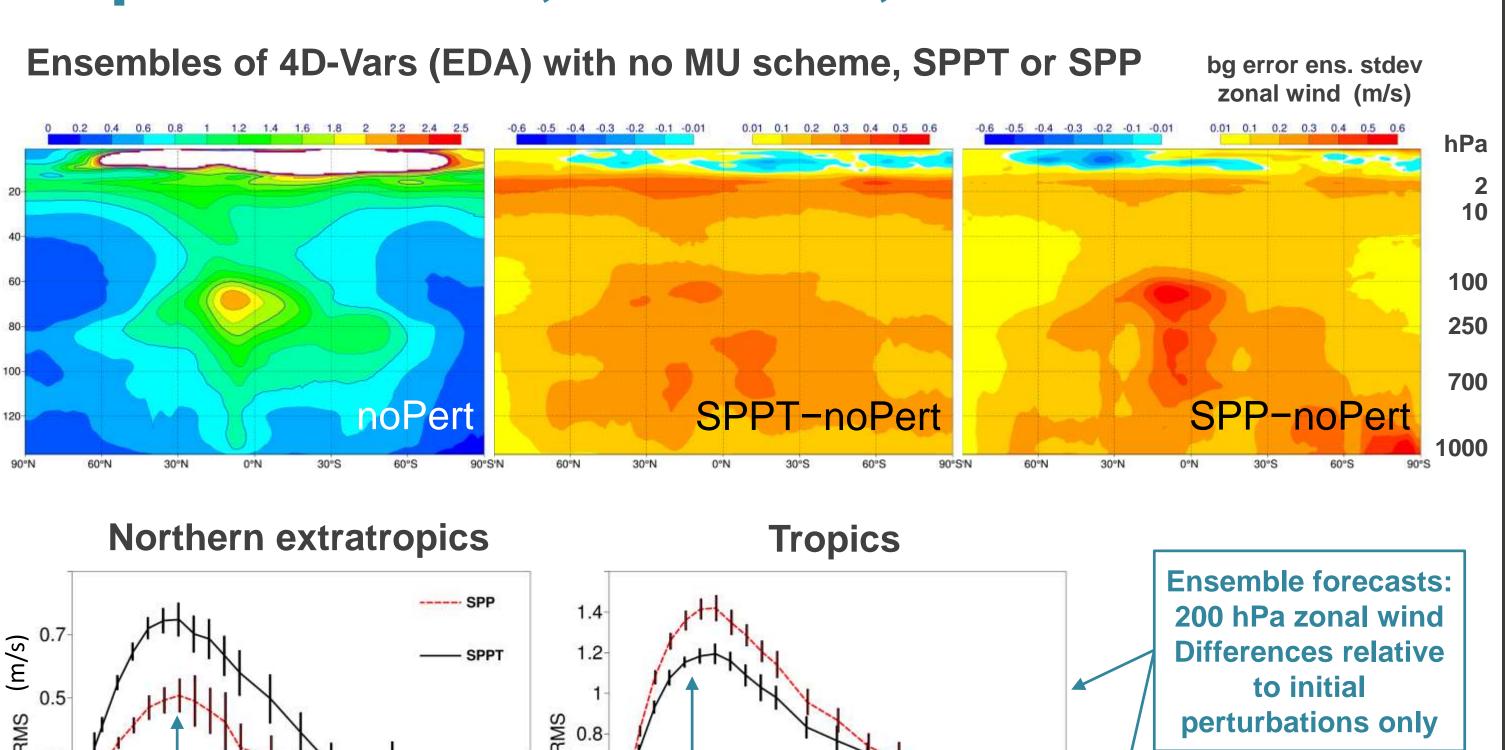## Understanding tendency perturbation differences between SPPT and SPP

convective precip. (mm/3h)   ensemble mean T tendency (0 3h) at 500 hPa in K/3hC

radiation

net physics
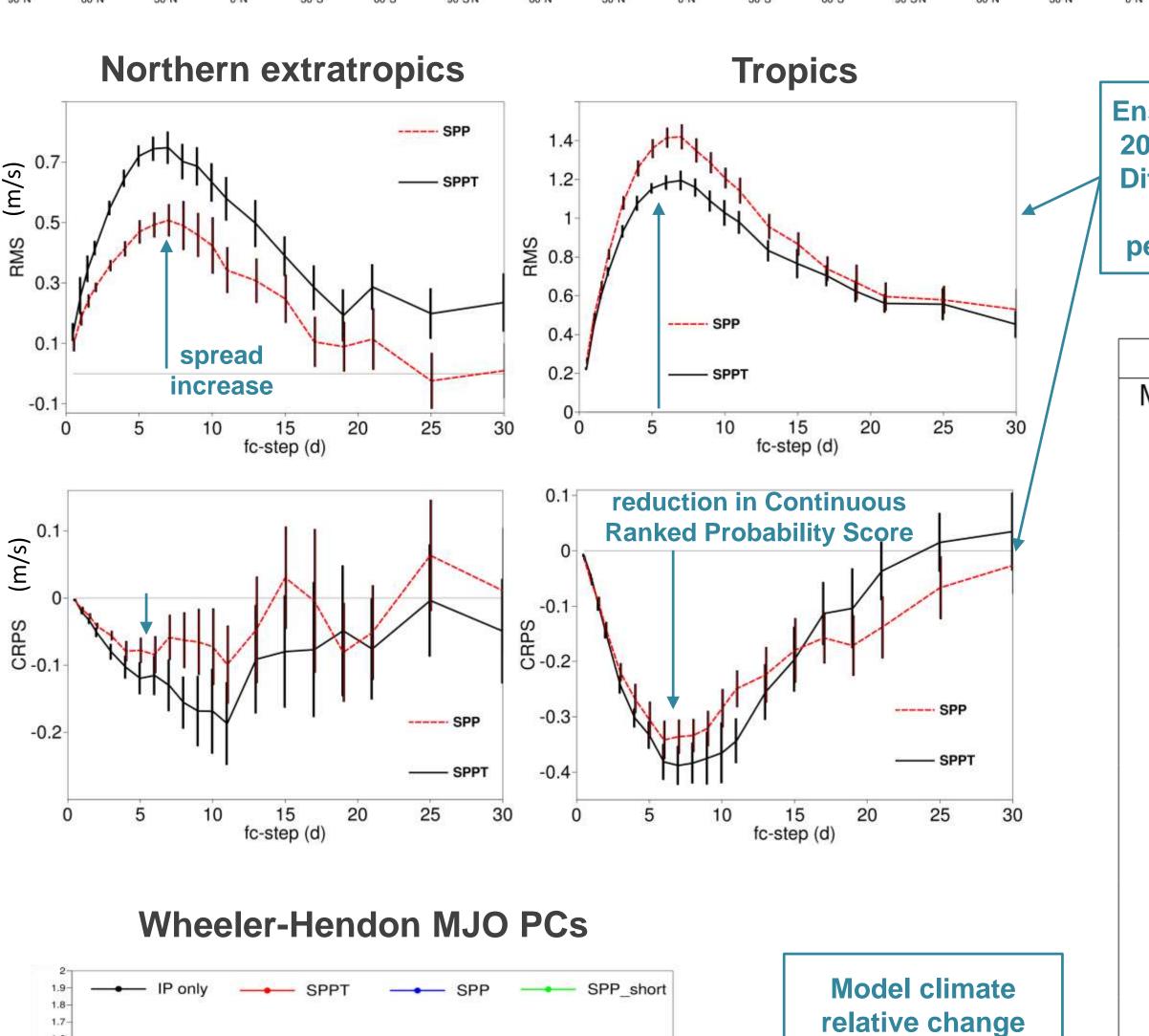
ensemble stdev T tendency (0 3h) at 500 hPa in K/3h

SPPT   SPP

Impact on EDA, ens. fc^sts, model climate
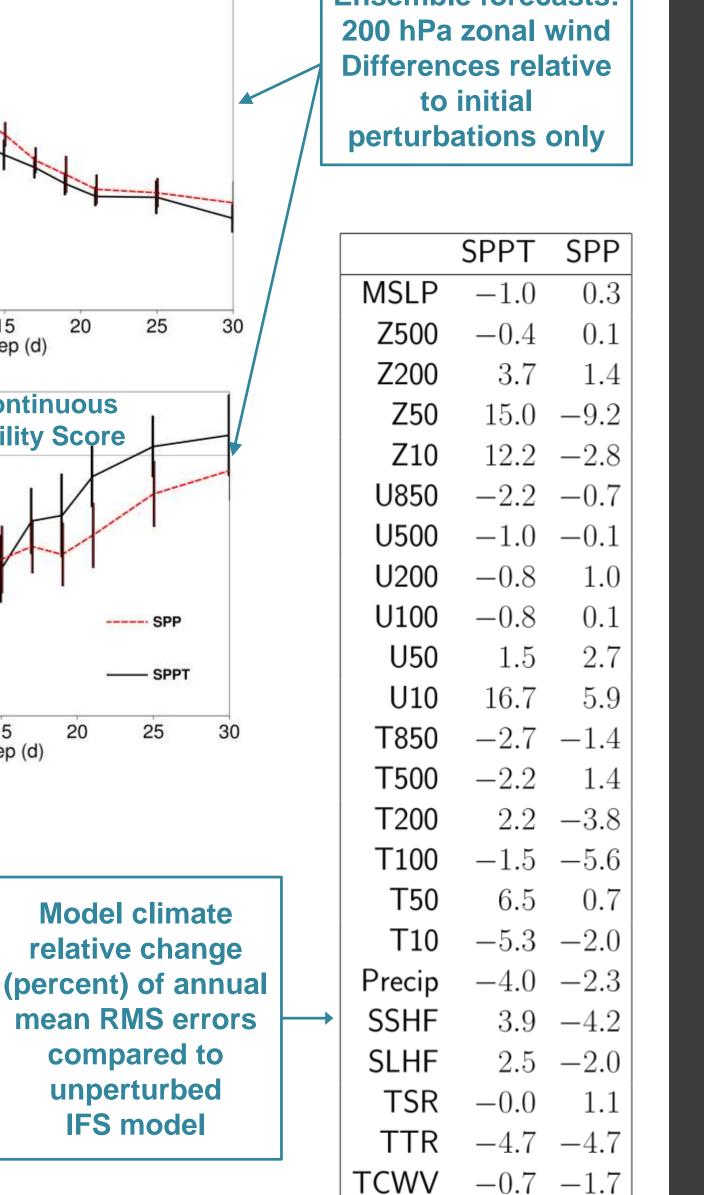
Ensembles of 4D-Vars (EDA) with no MU scheme, SPPT or SPP   bg error ens. stdev zonal wind (m/s)

noPert   SPPT−noPert   SPP−noPert

Northern extratropics   Tropics

Ensemble forecasts: 200 hPa zonal wind Differences relative to initial perturbations only

spread increase

reduction in Continuous Ranked Probability Score

Wheeler-Hendon MJO PCs

IP only   SPPT   SPP   SPP_short

RMS error

ensemble stdev

Model climate relative change (percent) of annual mean RMS errors compared to unperturbed IFS model

	SPPT	SPP
MSLP	−1.0	0.3
Z500	−0.4	0.1
Z200	3.7	1.4
Z50	15.0	−9.2
Z10	12.2	−2.8
U850	−2.2	−0.7
U500	−1.0	−0.1
U200	−0.8	1.0
U100	−0.8	0.1
U50	1.5	2.7
U10	16.7	5.9
T850	−2.7	−1.4
T500	−2.2	1.4
T200	2.2	−3.8
T100	−1.5	−5.6
T50	6.5	0.7
T10	−5.3	−2.0
Precip	−4.0	−2.3
SSHF	3.9	−4.2
SLHF	2.5	−2.0
TSR	−0.0	1.1
TTR	−4.7	−4.7
TCWV	−0.7	−1.7
T2m	0.2	0.5
SST	−3.1	−1.6

Discussion

Initial uncertainties
- optimality
- IC uncertainty depends on MU
- MJO: coupled DA↔MU

Seamlessness
- consistent representation of MU
- no re-centring of ensemble ICs
- reduced need for singular vectors

Estimating MU (parameters)
- weak-constraint 4D-Var
- coarse-graining of high-res simulations
- observations and EDA verification

Computational efficiency
- reduced precision efforts
- resolution versus ensemble size
- efficiency of random fields

Unrepresented sources of uncertainty

Atmospheric processes
- phase transitions
- background aerosol
- vertical mixing: unstable BL, above BL

Dynamical core
- PDE → SPDE
- solution error in semi-Lagrangian

Land surface
- skin layer conductivity
- soil moisture: hydr. params.
- vegetation→albedo/ evatrans.

Ocean/ sea ice
- subgrid-scale mixing
- sea ice rheology

References

Leutbecher, M, Lock, S-J, Ollinaho, P, Lang, STK and CoAuthors, 2016: Stochastic representations of model uncertainties at ECMWF: State of the art and future vision. ECMWF Tech. Memo. **785** (Q.J.R. Meteorol. Soc. Accepted Author Manuscript. doi:10.1002/qj.3094)

Ollinaho, Pirkka, Sarah-Jane Lock, Martin Leutbecher, Peter Bechtold, Anton Beljaars, Alessio Bozza, Richard M. Forbes, Thomas Haiden, Robin J. Hogan and Irina Sandu, 2016: Towards process-level representation of model uncertainties: Stochastically Perturbed Parametrisations in the ECMWF ensemble, Q.J.R. Meteorol. Soc. **143:** 408–422. doi:10.1002/qj.2931

Palmer, T.N., R. Buizza, F. Doblas-Reyes, T. Jung, M. Leutbecher, G.J. Shutts, M. Steinheimer and A. Weisheimer, 2009: Stochastic parametrization and model uncertainty. ECMWF Tech. Memo. **598**.