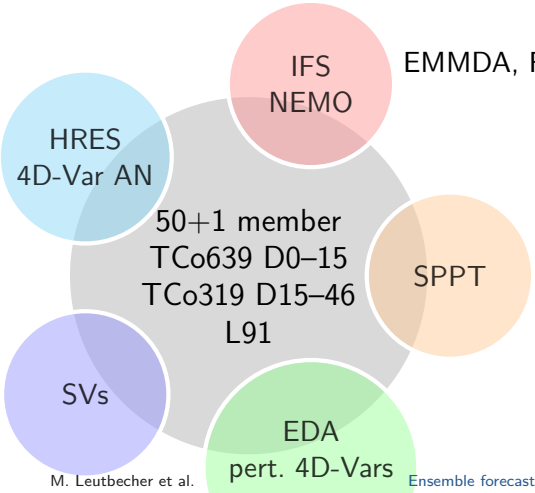
Ensemble forecasting at ECMWF

Martin Leutbecher, Zied Ben Bouallègue, Simon Lang, Sarah-Jane Lock and Frédéric Vitart

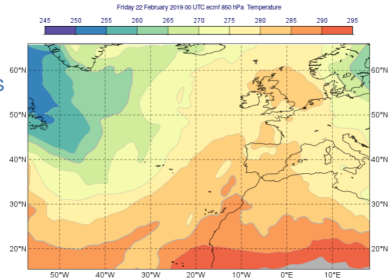
EMMDA, Feb. 2020



Initial conditions

T850hPa

HRES Analysis 00 UTC



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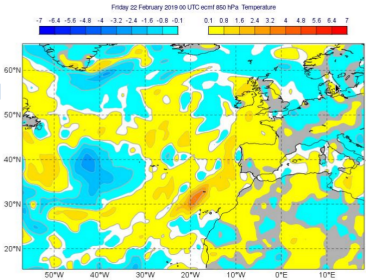
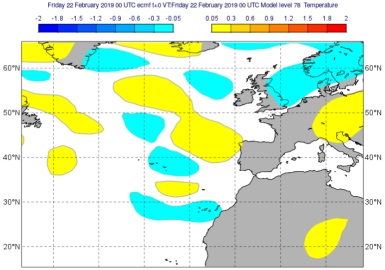
EDA-Pert 1



SV-Pert 1



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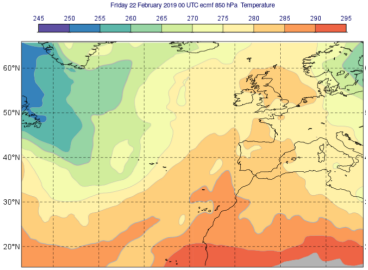
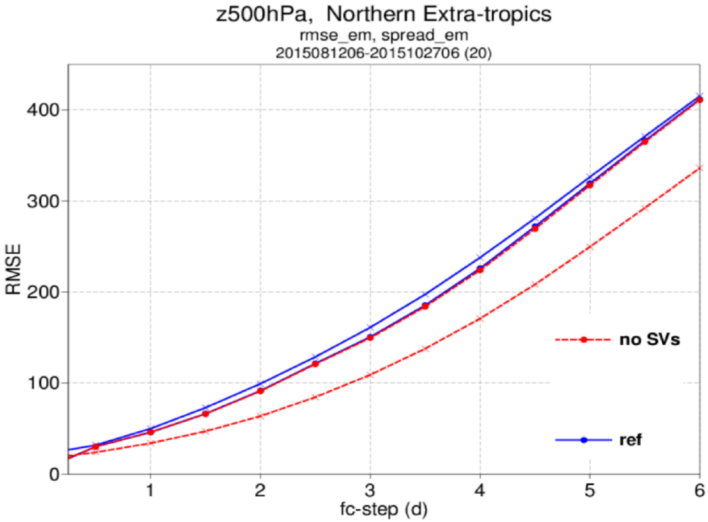
Initial conditions for ENS member 1



Singular vectors and reliability



ens. mean RMSE

ens. stdev

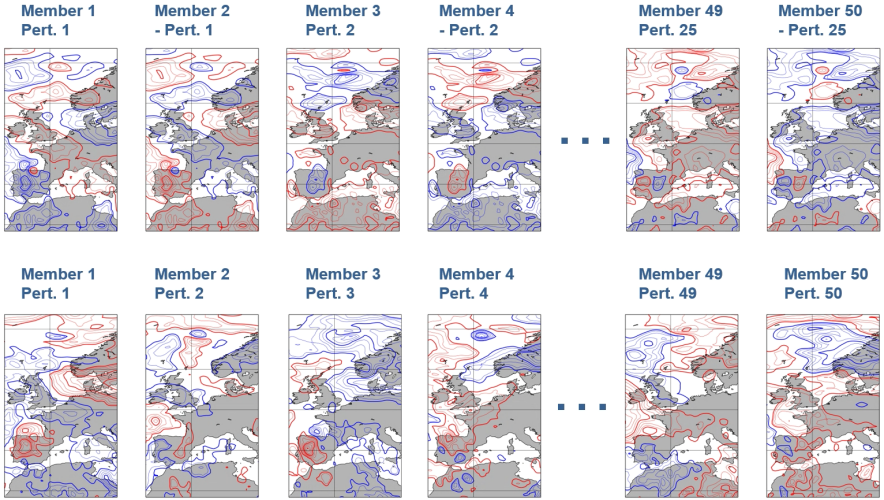
EDA and SPPT generate spread also in the directions of the leading SVs. Just not enough though.

When to stop using SVs? See Leutbecher, M. and Lang, S. T. (2014) QJ

Exchangeable initial conditions

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

z500hPa



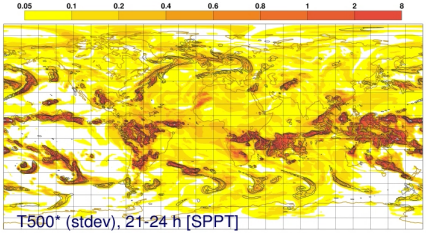
New:
Perturbations from new 50-Member EDA

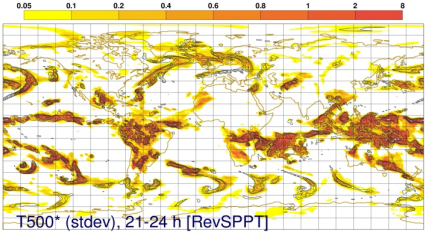
implemented in June 2019

see Lang et al., ECMWF newsletter Nr. 158

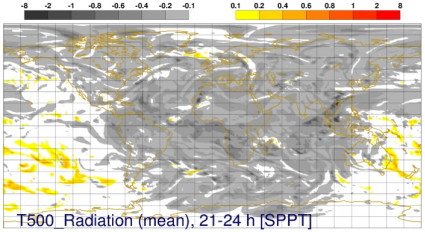
Leutbecher (2018), `https://doi.org/10.1002/qj.3387`

Stochastically Perturbed Parametrization Tendencies





temperature tendency perturbations due to SPPT only (K/3h, shading)
precipitation (ens. mean, .5/1/2/4/8/... mm, black contours)
2015011000, t=+21–24 h

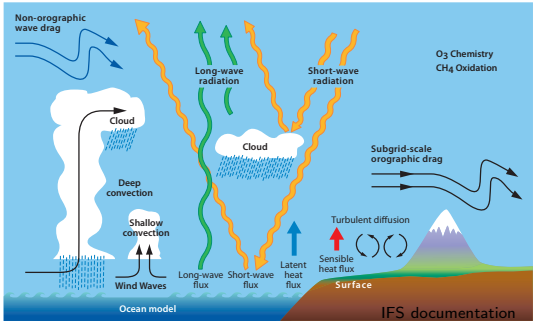


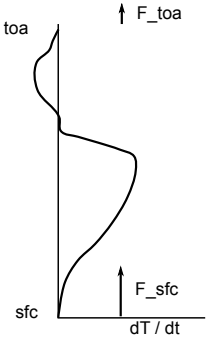
- **More realistic diurnal cycle of tendency perturbations in SPPT** by not perturbing the clear-sky radiative tendency;
- Perturbations in stratosphere and weaker tapering of perturbations in boundary layer
- Same SPPT in ENS and EDA, and cycling of random fields in EDA
- 20% reduced SPPT amplitude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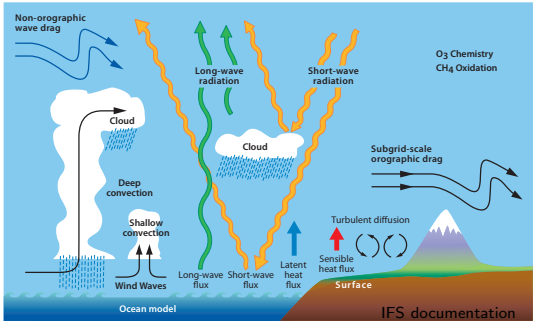

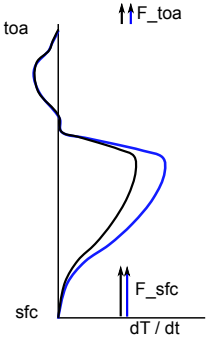

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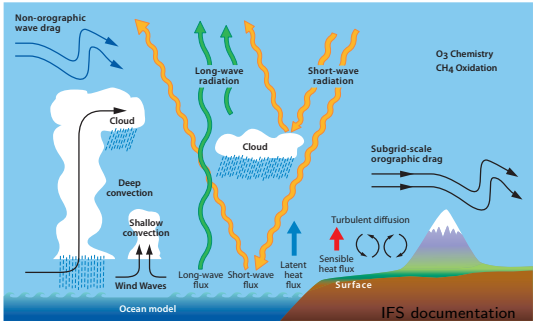
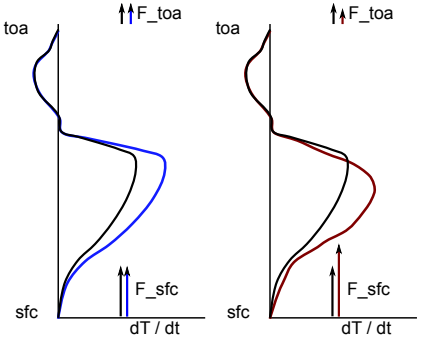




Ongoing research on model uncertainties

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

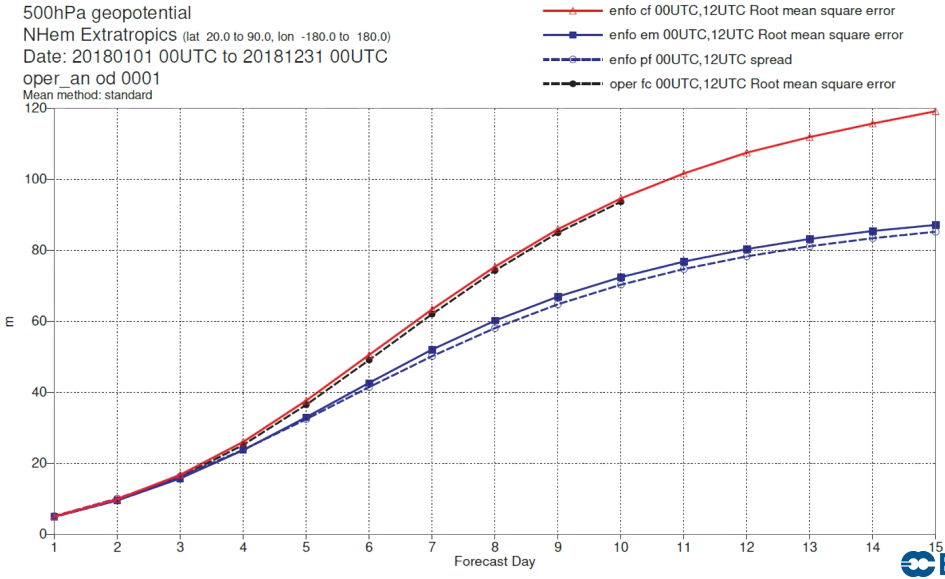
see Ollinaho et al. (2017) and Leutbecher et al. (2017).

Medium-range

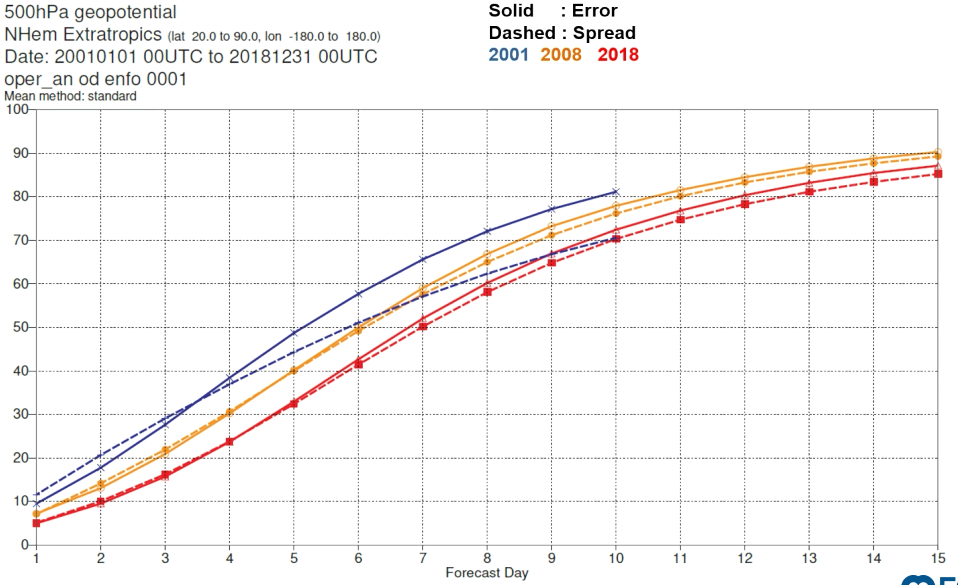
- rms error and spread
- TC track error
- ensemble size and spatial resolution

RMS errors of ensemble mean and ensemble spread

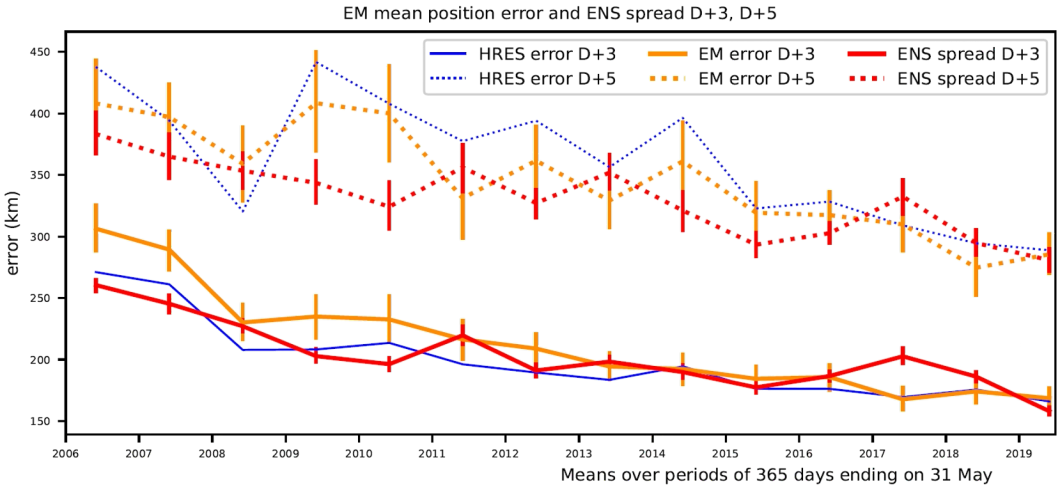
(both 18 km) and RMSE of 9 km and 18 km deterministic forecasts



Evolution of spread and error



Tropical cyclone track position error and spread



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

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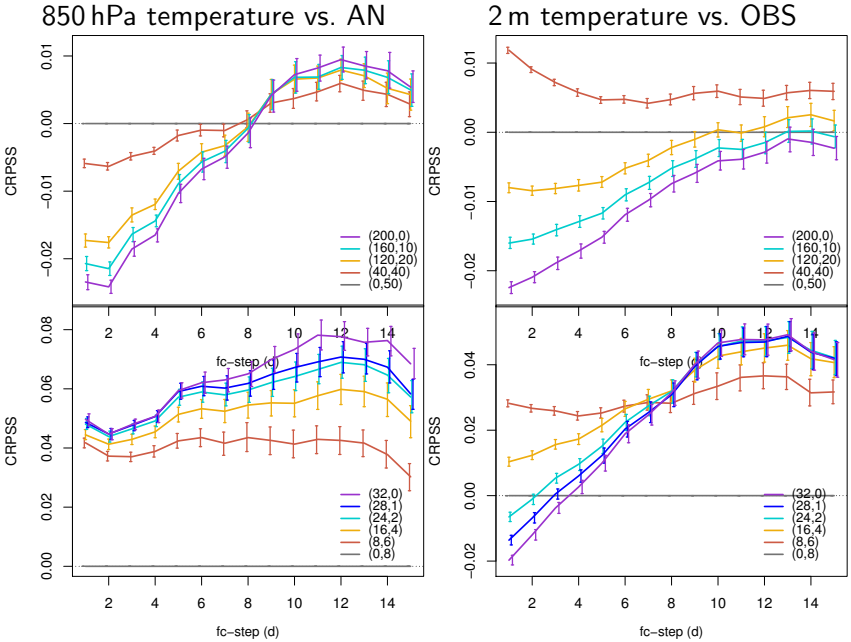
- Skill optimisation given fixed computational resources but allowing potentially for two resolutions
- Here, ensembles (k, m) with k 29 km resol. members and m 18 km resolution members. The latter use 4 times as much computational resources.
- see Leutbecher and Ben Bouallègue (2019), `https://doi.org/10.1002/qj.3704` and
- Ben Bouallègue et al. (2019) `https://doi.org/10.1080/16000870.2019.1697165`

Dual-resolution ensembles



Extended-range

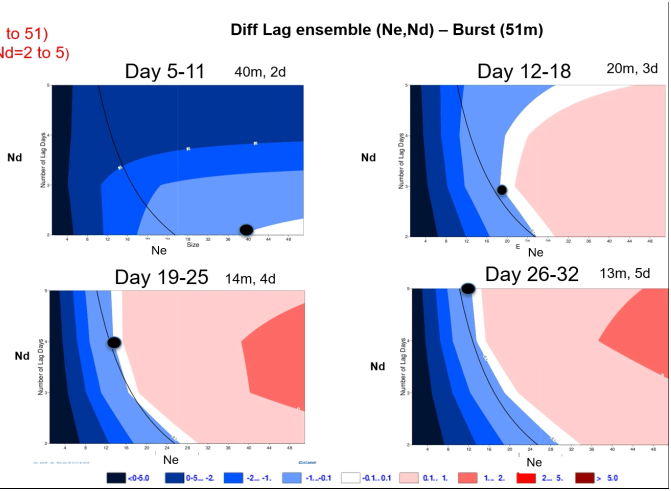
- Impact of lagging and ensemble size
- Evolution of MJO skill
- Evolution of skill generally
- Revised initial conditions for reforecasts
- see also Vitart et al, (2019)a,b, `https://www.ecmwf.int/node/19286`, `https://www.ecmwf.int/node/18872`

Lagging and ensemble size in extended-range

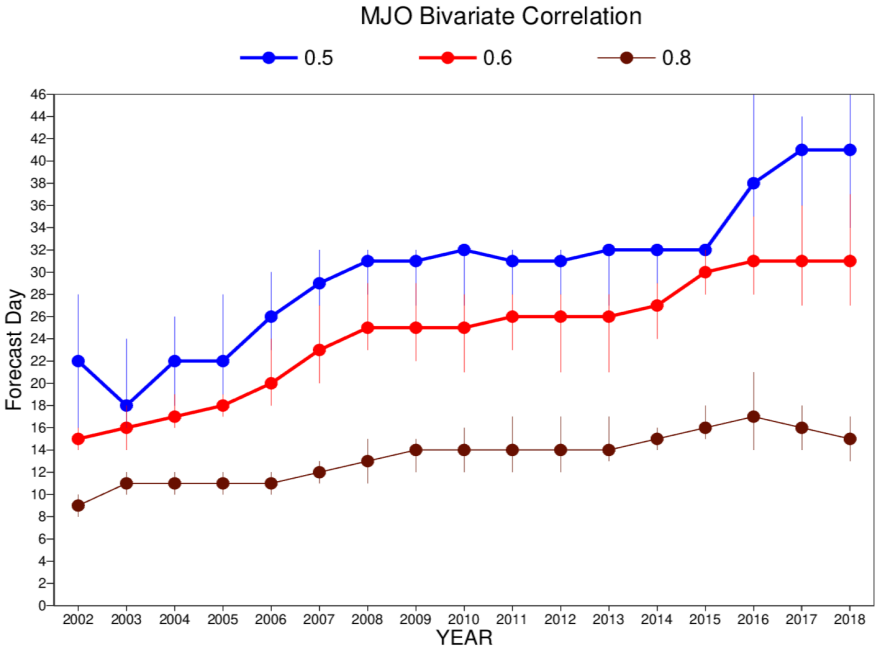
Impact on CRPSS over 20 variables/regions

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



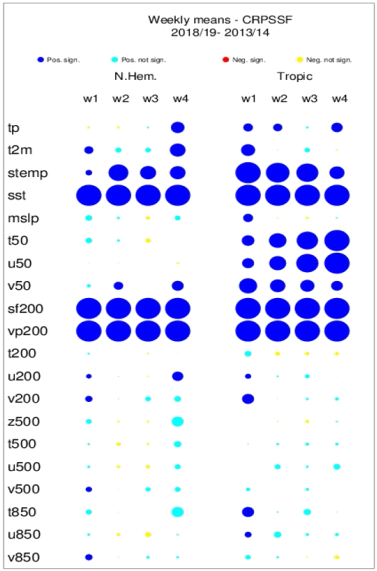
Evolution of MJO skill



Evolution of skill generally

Scorecard 2018/19 vs 2013/14

Rfcst period 1999-2012

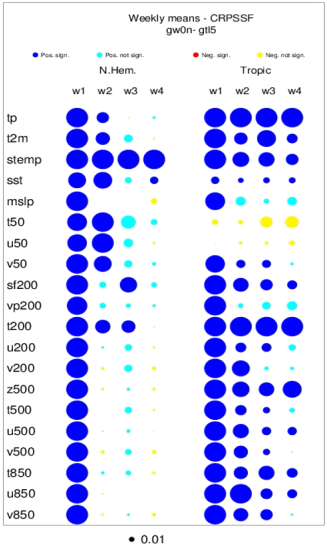


- The skill of the extended-range forecasts has improved since 2014, particularly in the Tropics
- In the Northern Extratropics, the improvement is less significant, particularly for the upper tropospheric fields

Impact of ERA5 (46R1) not included

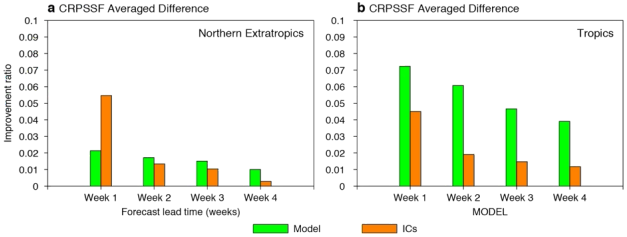
Revised initial conditions for reforecasts

Scorecard
ERA5 vs EI initialization



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