Uncertainty estimation in modern reanalysis systems

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Introduction/rationale

- Uncertainty estimation is an added value to any meteorological analysis/forecasts → it is not different in reanalysis
- In many of the available reanalysis datasets uncertainty estimates are not available so far
- At ECMWF CERA-20C and ERA5 include uncertainty estimation based on a 10-member EDA (Ensemble of Data Assimilations) system
- The main objective of the present talk is to give an overview about the reliability diagnostics for CERA-20C and ERA5 and give some hints about the use of EDA for reanalysis uncertainty estimation

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Spread-skill relationship (ensemble reliability)

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- In a well-calibrated ensemble the ensemble spread should match the skill of the ensemble mean (spread-skill relationship, optimally diagonal line in a scatterplot)
- Some questions about the ensemble reliability:
  - Can the raw ensemble spread from EDA be directly used for the uncertainty estimation?
  - How to quantify the skill, i.e. what is the verification truth?
  - Should the errors in the analysis/observation be considered?
  - What guidelines can be given to the reanalysis users for the use of EDA uncertainty information?

Some practical considerations

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- CERA-20C and ERA5 include a 10-member EDA ensemble for computing the background errors (see relevant talks earlier this conference)
- Verification truth: high resolution IFS analysis (OPER), ERA-Interim, observations taking into account their respective errors
- In ERA5 the skill of the high-res product (rather than that of the ensemble mean) is of interest
- In ERA5 there are various additional EDA spread characteristics available (e.g. scaled ensemble spread, forecast spread)

Choice of verification truth + use of analysis/observation errors

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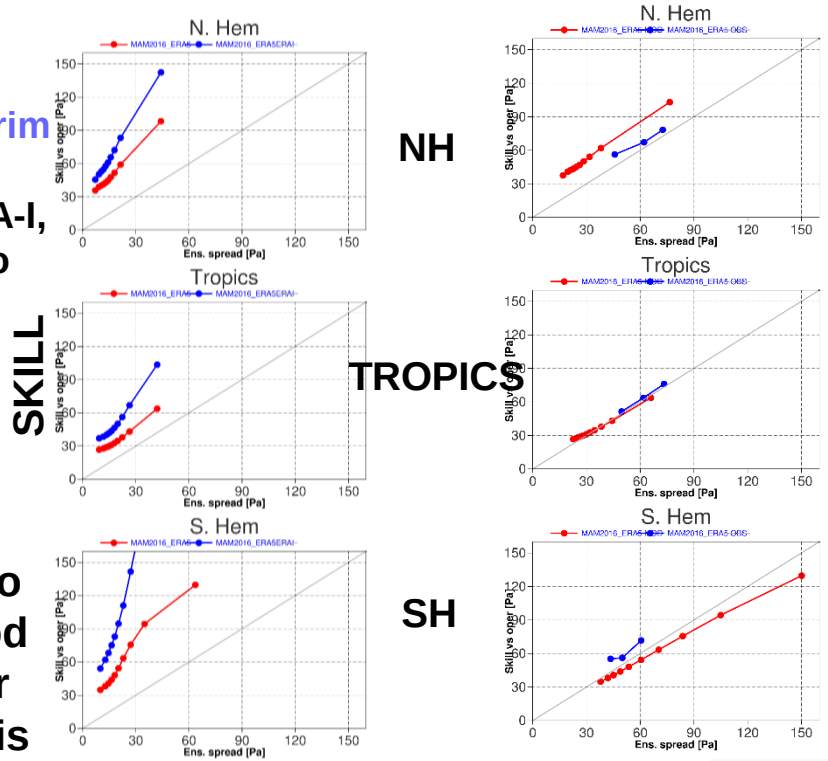
ERA5 raw MSLP spread-skill for spring, 2016

Skill=ERA5 vs OPER
Skill=ERA5 vs ERA-Interim

Errors in reference (ERA-I, OPER) NOT taken into account

Looks better when verifying against operations, but it also depends on the period chosen (i.e. for older periods ERA-Interim is a better truth)



Skill=ERA5 vs OPER
Skill=ERA5 vs Observations

Errors in reference (OPER, obs) ARE taken into account

Very good reliability (slightly better against observations)

Yamaguchi et al., 2016 (QJ)
Saetra et al., 2004 (MWR)

SPREAD

MODEL SPACE | **MODEL VS. OBS. SPACE**

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Surface pressure spread-skill for 2010 (against observations taking into account the observation errors)

NH

TROPICS

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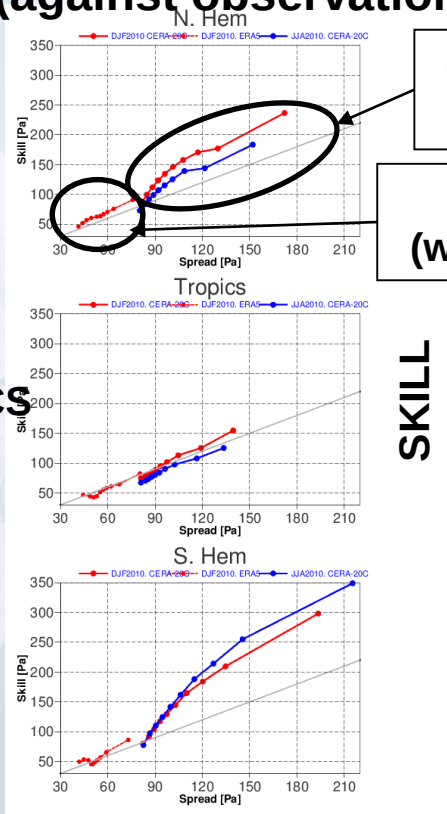

CERA-20C: summer and winter, 2010

ERA5 (winter, 2010)

SKILL

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CERA-20C has a reasonably good reliability, though ERA5 is much better (better resolution and more observations)

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Surface pressure spread-skill for 1979 and 2016 spring against observations

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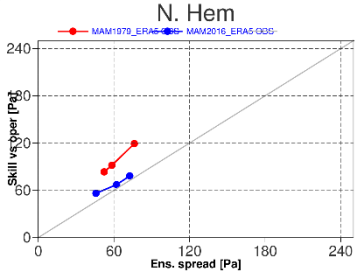

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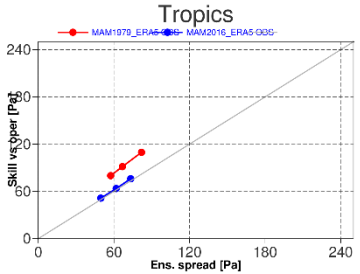

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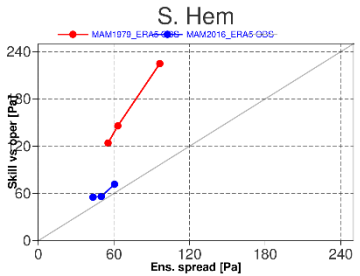

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1979 is under-dispersive especially at the Southern Hemisphere (it is anyway expected that the reliability depends on the time period too)

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Summary, conclusions, discussions

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- The spread-skill relationship of both CERA-20C and ERA5 reanalysis systems seems satisfactory (especially ERA5)
- It is absolutely essential to take into account analysis/observation errors in the production of proper spread-skill relationship
- Though guidance to the ERA5 users might not be straightforward
  - We will provide our diagnostic results
  - And provide recommendations what to use and in what aspects the users should be careful at
  - Feedbacks are welcome
- Next steps: extend the results for more variables and more periods

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