M. Denhard, A. Rhodin, J. T. Ambadan, H. Anlauf, A. Fernandez del Rio, A. Cress, G. Zängl, H. Frank, T. Hanisch, C. Primo, F. Fundel, M. Buchhold, R. Potthast

ICON-EPS

operational suite (since 18th January 2018)

- 40 Member
- Global, 40 km / ICON-EU Nest, 20 km
- **00/12 UTC ✉ +180h / 06/18UTC ✉ +120h**
- **03/09/15/21 UTC ✉ +30h** Boundary Conditions for COSMO-DE-EPS
- Perturbing physics tuning parameters (fixed during the forecast)
- Initial condition perturbations by global EDA (LETKF)

✉ EDA at DWD ✉ Spread Skill relation ✉ Outlook

ICON global Ensemble Data Assimilation

Andreas Rhodin, Harald Anlauf, Ana Fernandez del Rio, Alexander Cress, Roland Potthast

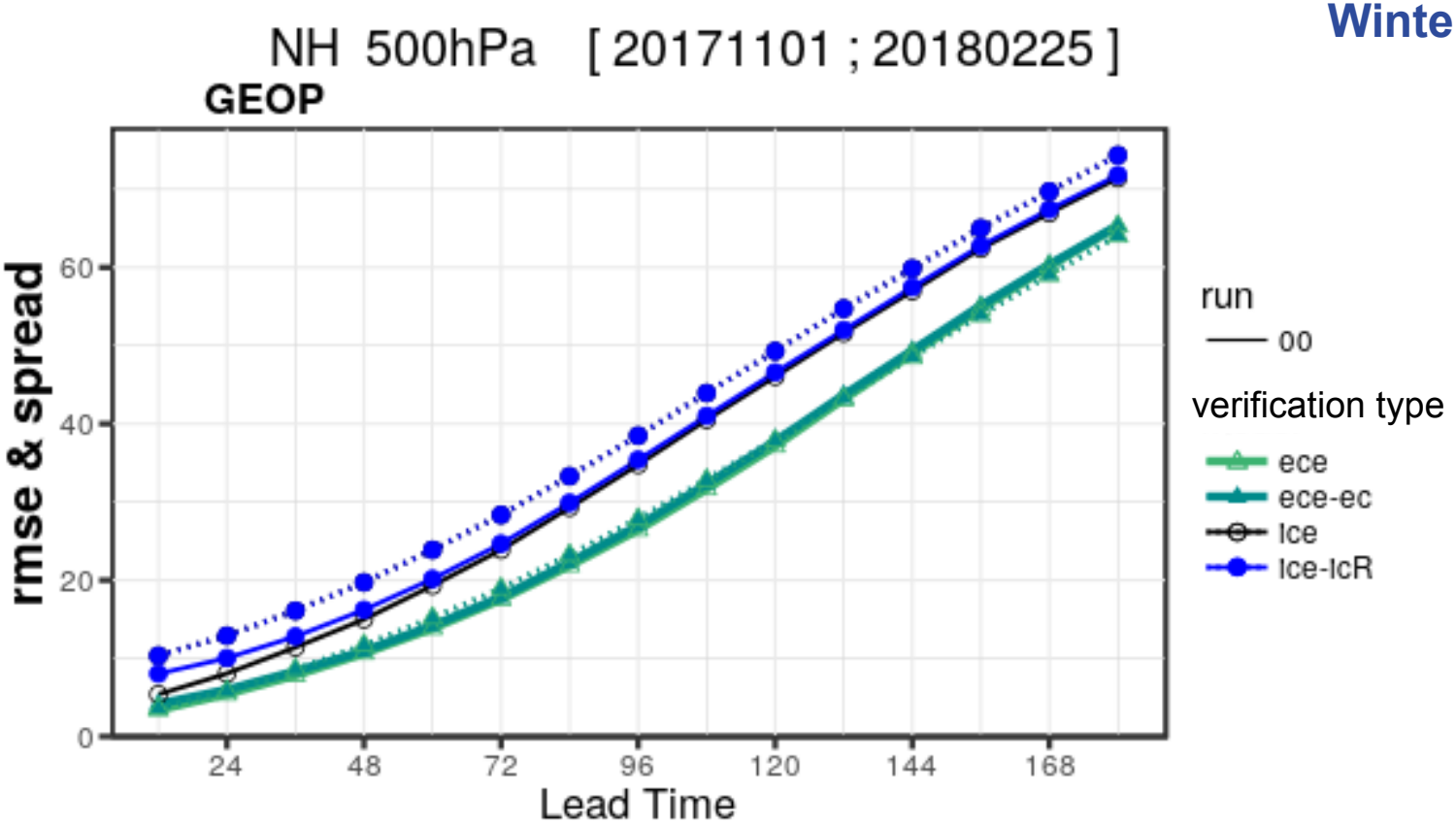
- LETKF (Localized Ensemble Transform Kalman Filter, Hunt et.al. 2007)
- 40 Members (-> extend to 80 Members)
- 3h Assimilation Cycle
- 40 km (20 km Europa)
- **Covariance Inflation**
  - **multiplicative factor (0.9 to 1.5)**
    Houtekamer et al. (2005): online estimate of spread and ensemble mean RMSE in observation space
  - **additive Inflation + 0,25B$_{3dVar}$** *length scales 300 km , 150km (RH)*
  - **„relaxation to the prior“ (0.75)** *Zhang et al. (2004)*
  - **SST random perturbations** *1°K, correlations of 100km/1000km and 1 day*

How do these perturbations grow during the forecasts ?

Verification against analysis, 1.5° lat/lon

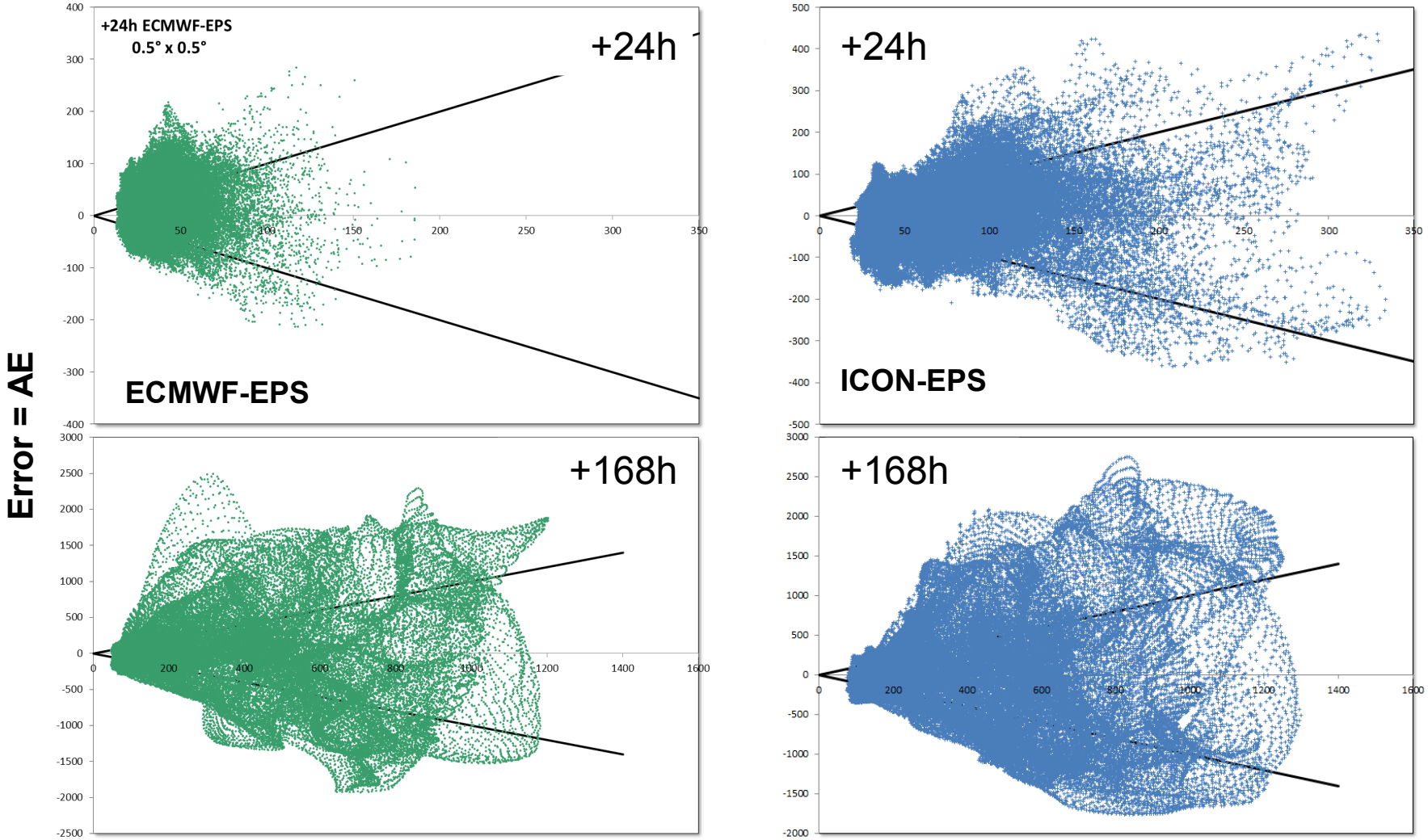
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Winter



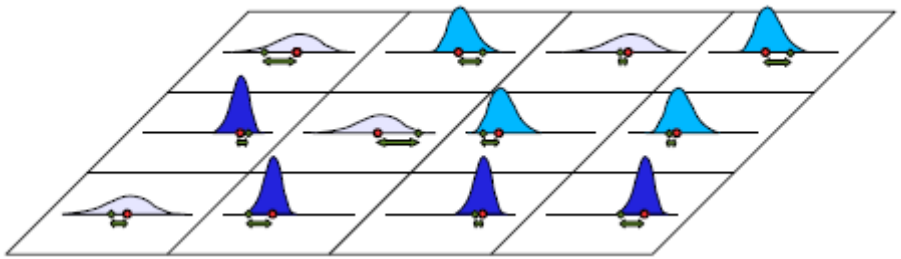
ice = ICON-EPS
ece = ECMWF-EPS
icR = ICON hres Routine analysis
ec = IFS hres analysis

30. September 2016 500hPa Geop. 0,5°x 0,5°



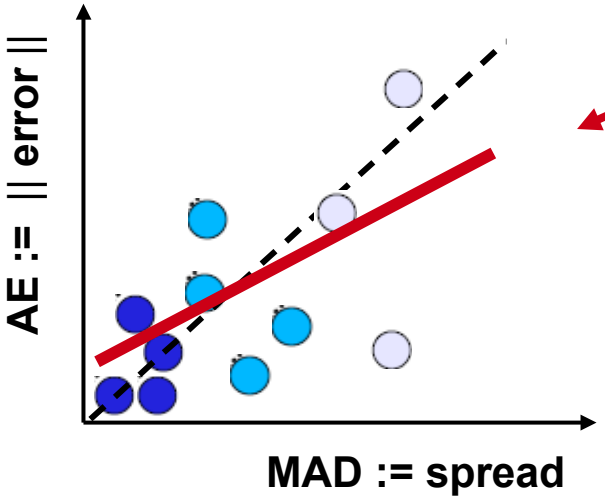
Spread-Skill Reliability

Leutbecher, M., 2009: Diagnosis of Ensemble Forecasting Systems, ECMWF

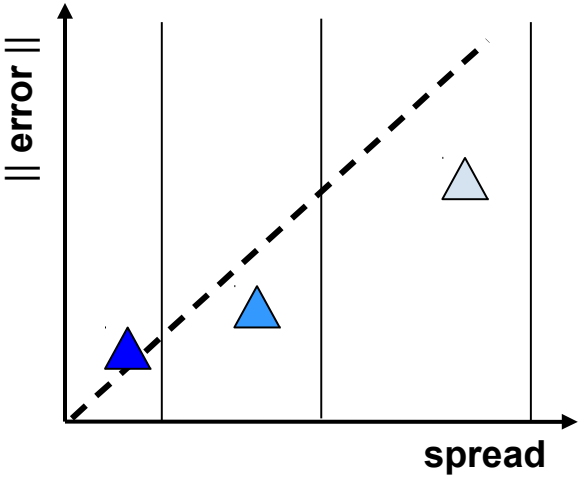


Barker (1991)
Scherrer et al. (2004)
Grimit and Mass (2007)
Eckel et al. (2012)
van Schaevbroeck and Vannitsem (2016)

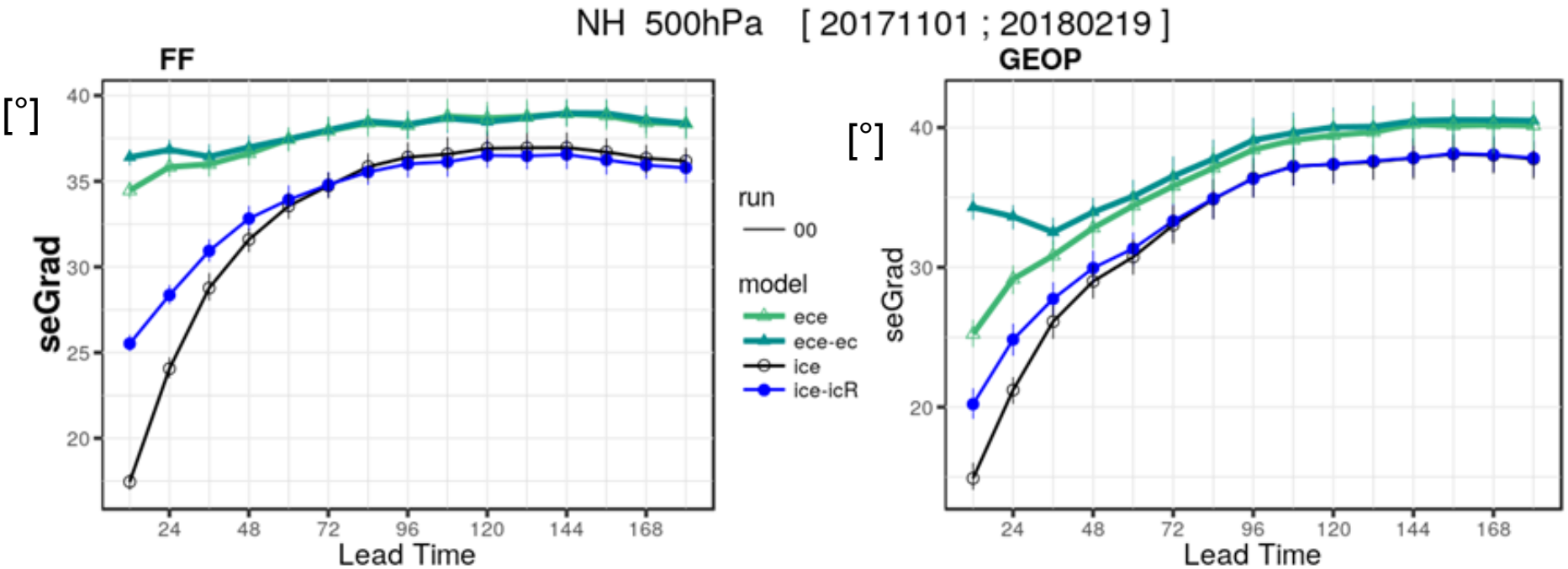
Linear Regression Model



Σ



Spread-Skill Reliability



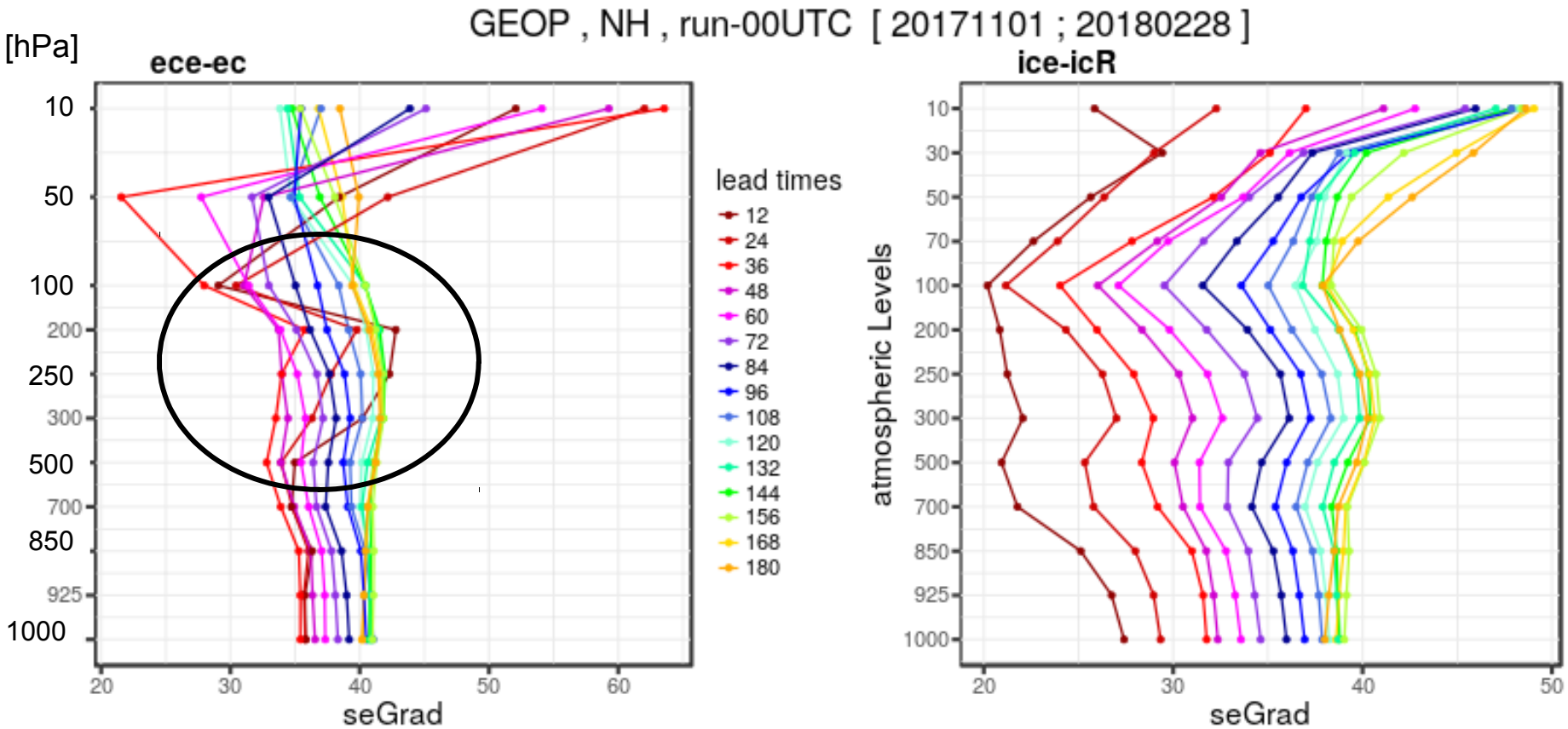
Improve the Spread-Skill Reliability in the short range

ice = ICON-EPS
ece = ECMWF-EPS
icR = ICON hres Routine analysis
ec = IFS hres analysis

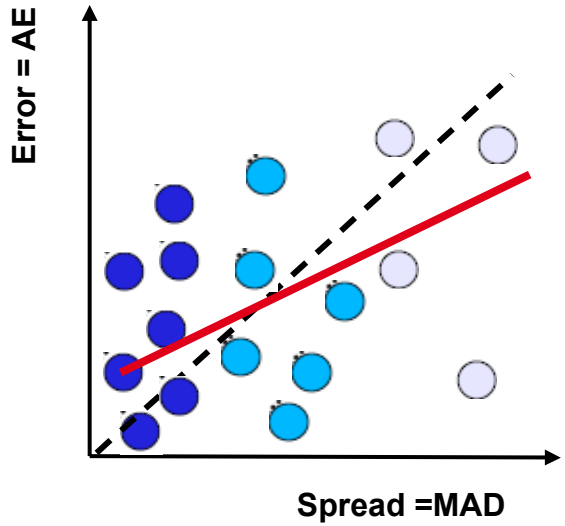
Spread-Skill Reliability

ECMWF-EPS

ICON-EPS

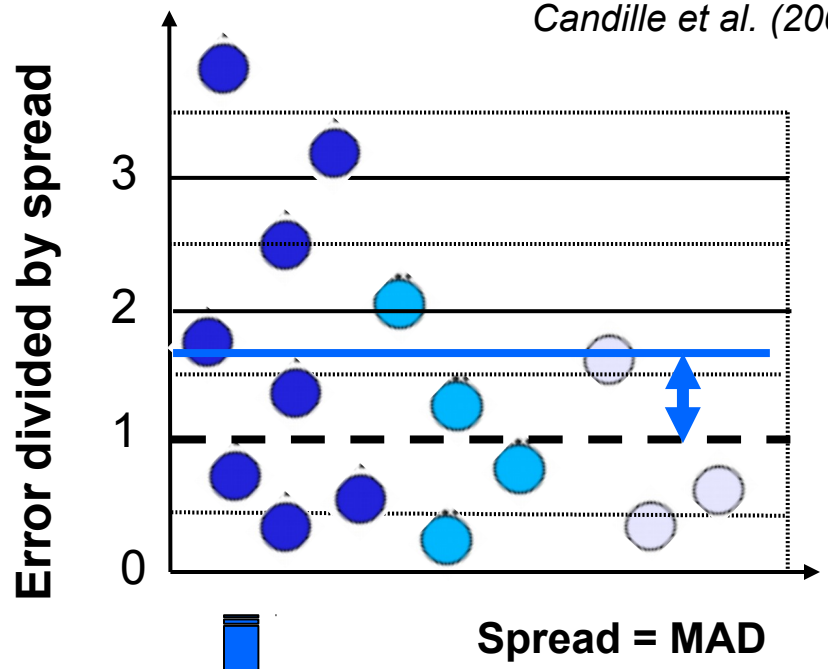


spread error bias



(AE/MAD)

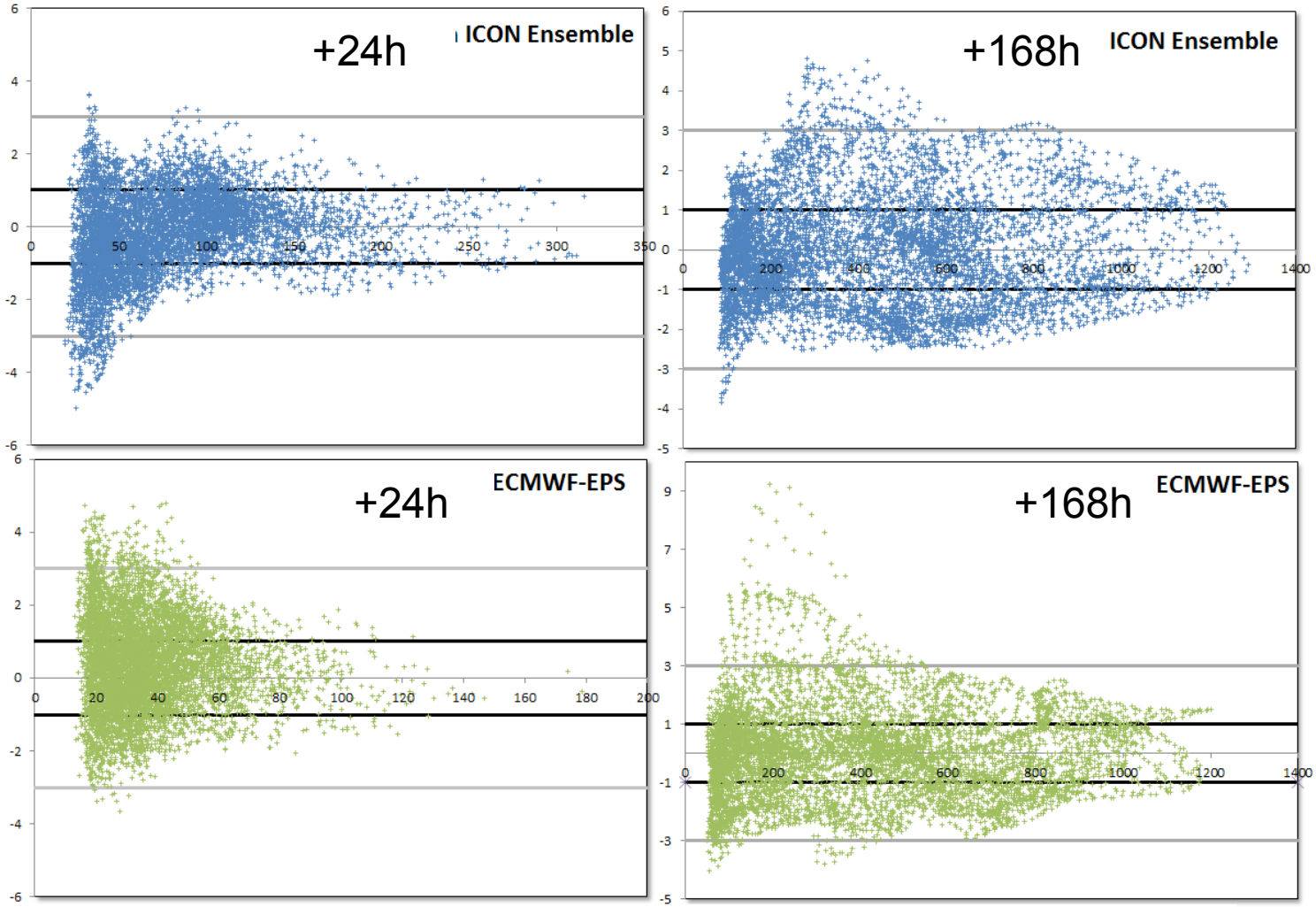
centred error
e.g. *Talagrand et al. (1999)*
Candille et al. (2007)



$$seBias = \frac{1}{N}\sum_{i}^{N}\frac{|e_i|}{MAD_i} - 1$$

30. September 2016 500hPa Geop. 1,5°x 1,5°

AE / AD

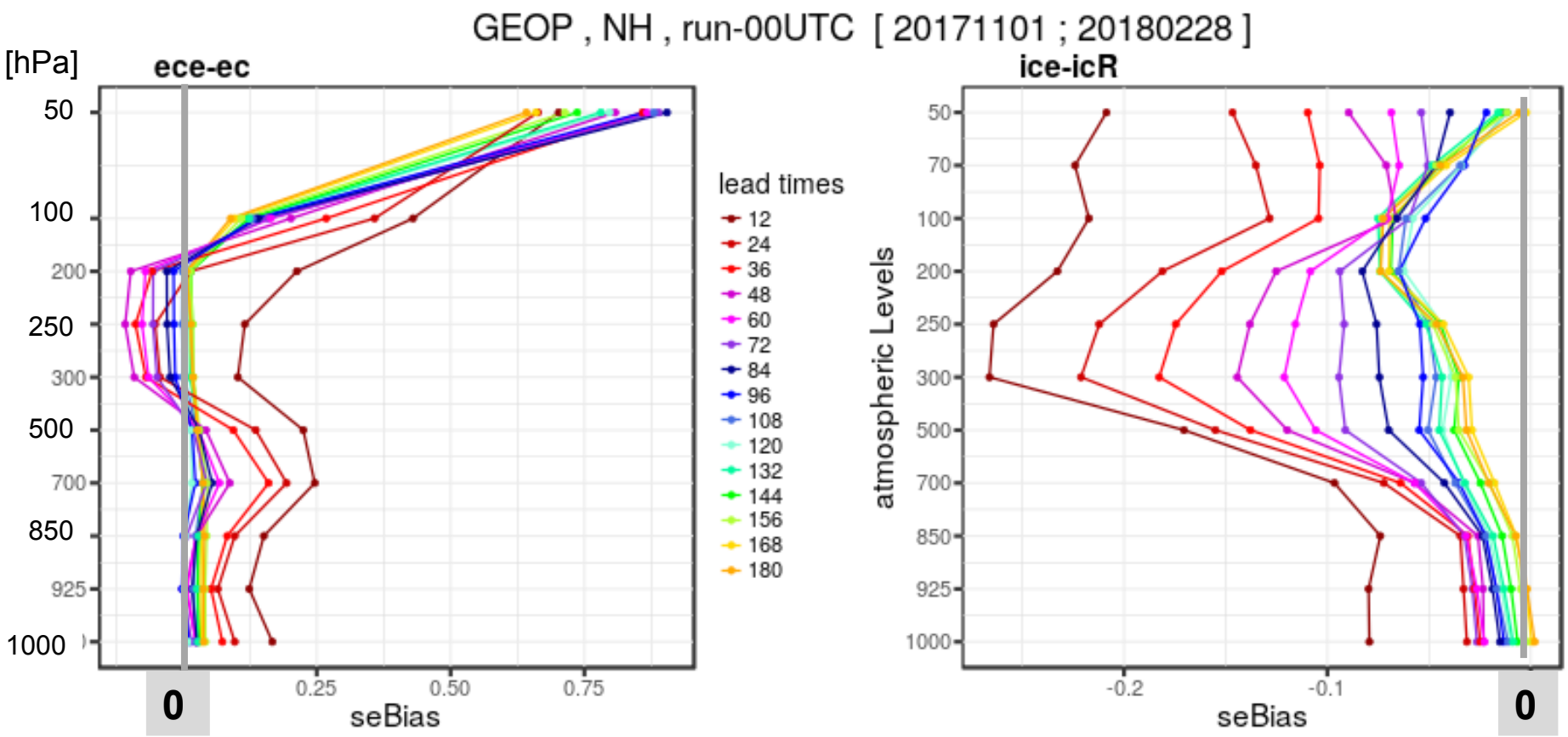


Spread = **MAD**

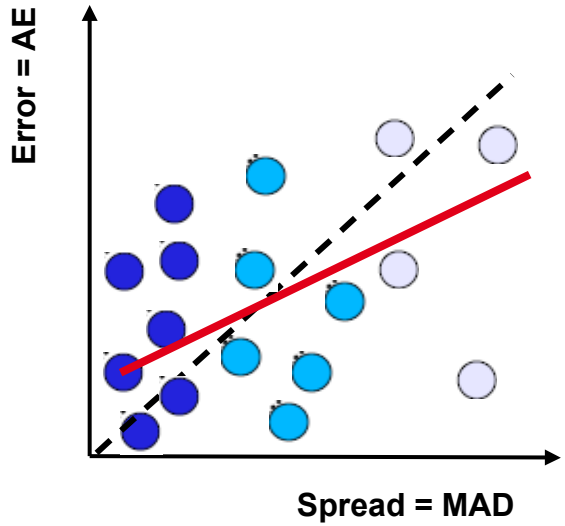
$$seBias = \frac{1}{N}\sum_{i}^{N}\frac{|e_i|}{MAD_i} - 1$$

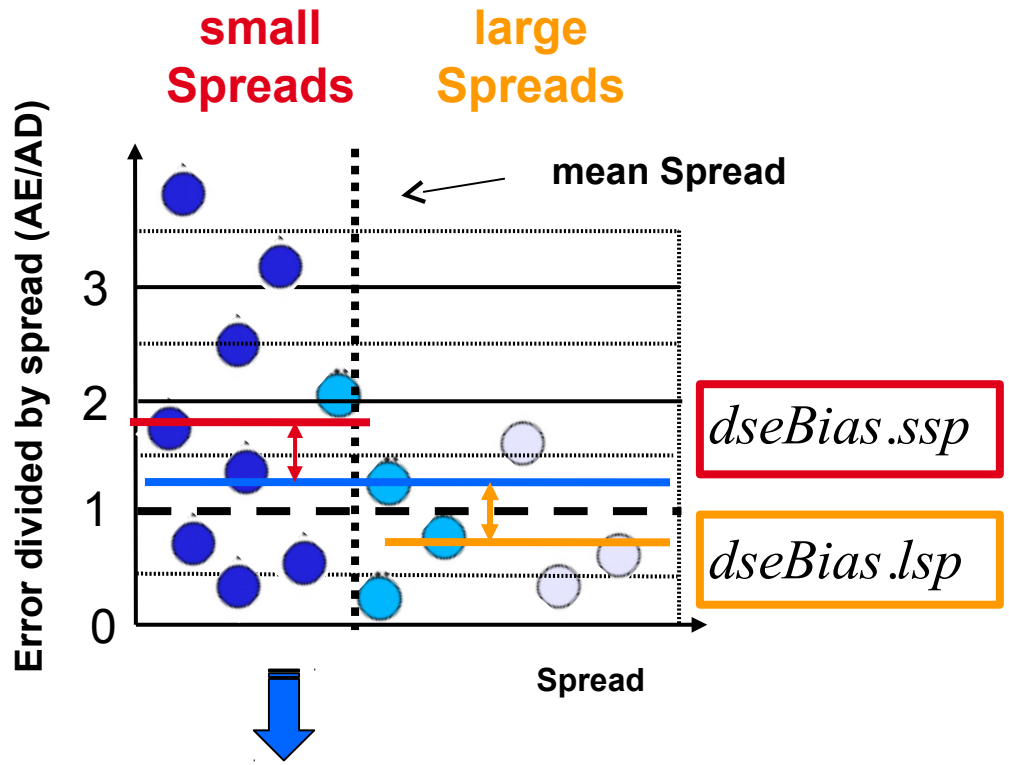
ECMWF-EPS

ICON-EPS



conditional on spread





$$seBias = \frac{1}{N}\sum_{i}^{N}\frac{|e_i|}{MAD_i} - 1$$

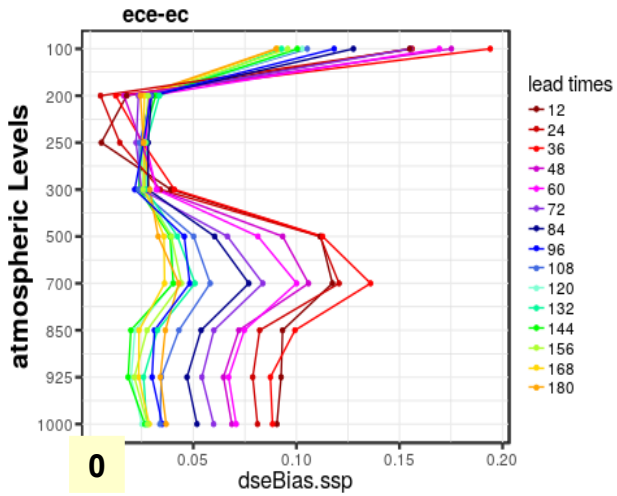
dseBias.ssp *dseBias.lsp*

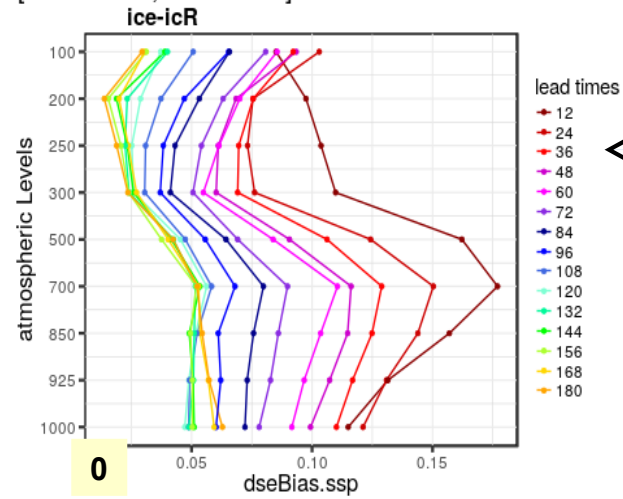
ECMWF-EPS **ICON-EPS**

GEOP , NH , run-00UTC [20171101 ; 20180225]

250 hPa →

small Spreads

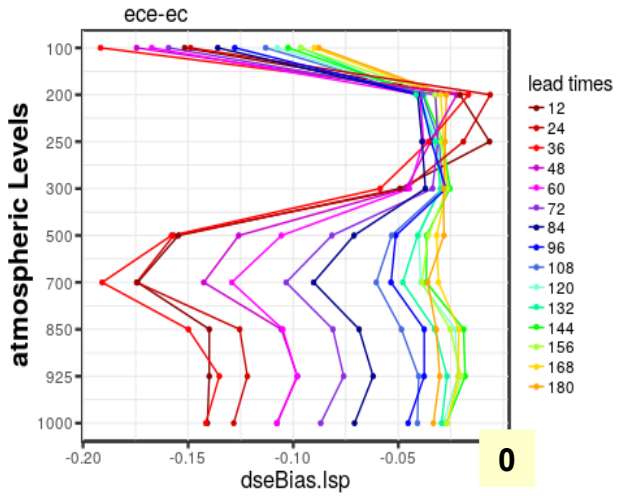


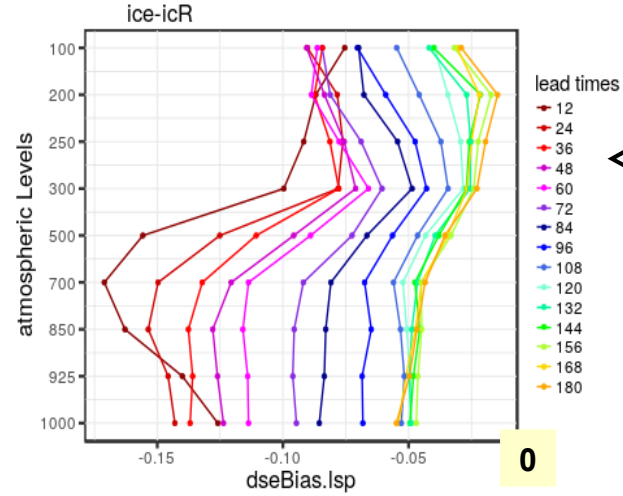


← 250 hPa

250 hPa →

large Spreads

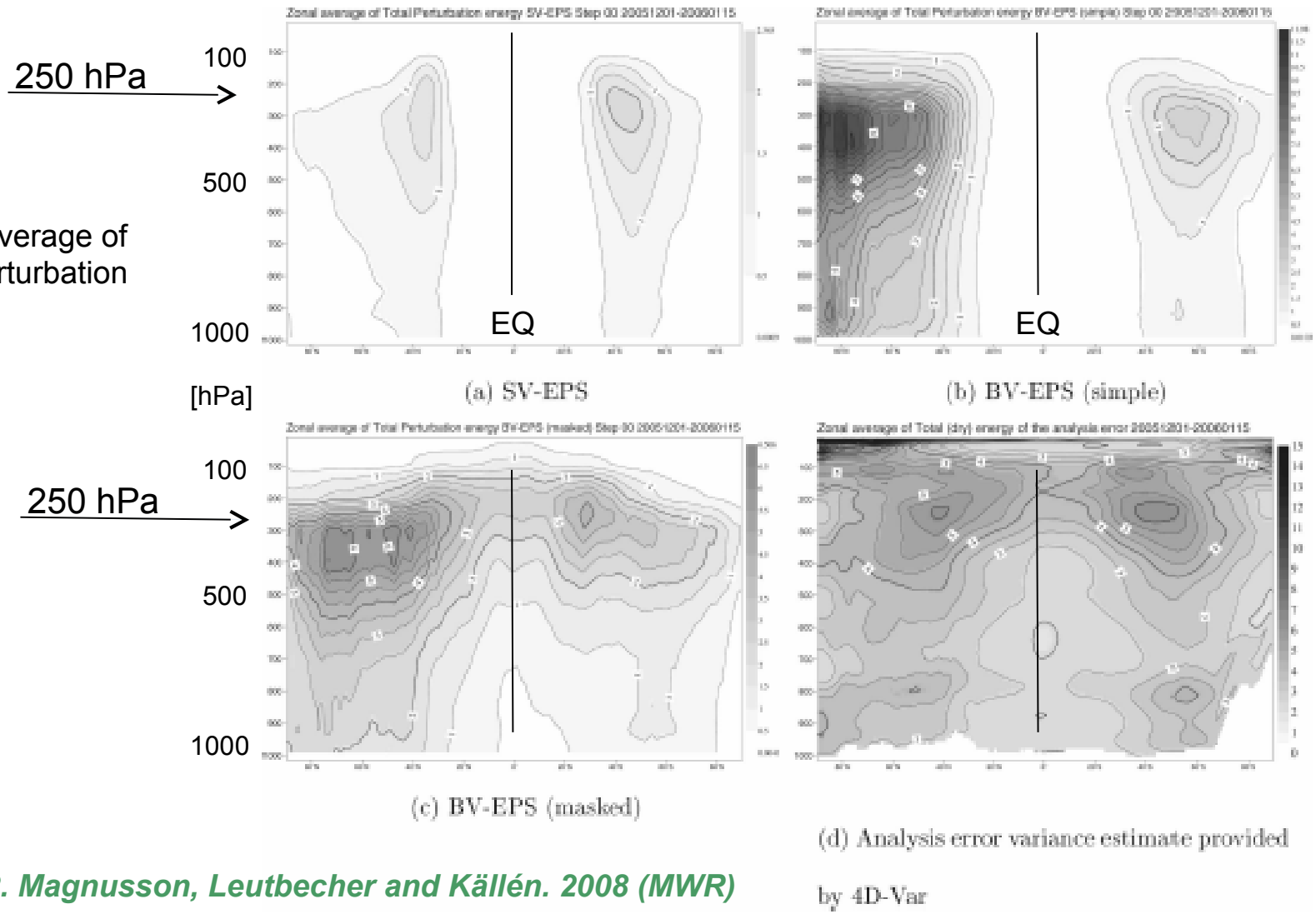




← 250 hPa

Mean initial perturbation

Zonal average of total perturbation energy



(a) SV-EPS

(b) BV-EPS (simple)

(c) BV-EPS (masked)

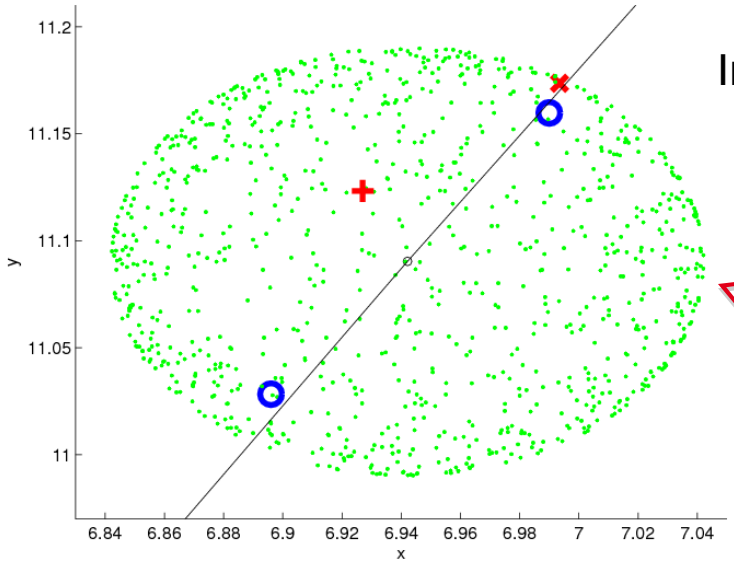
(d) Analysis error variance estimate provided by 4D-Var

Figure 2. Magnusson, Leutbecher and Källén. 2008 (MWR)

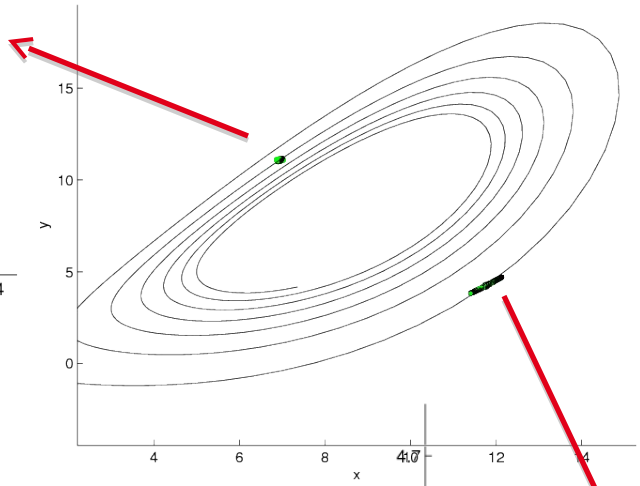
Perturbation methods Lorenz-63

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

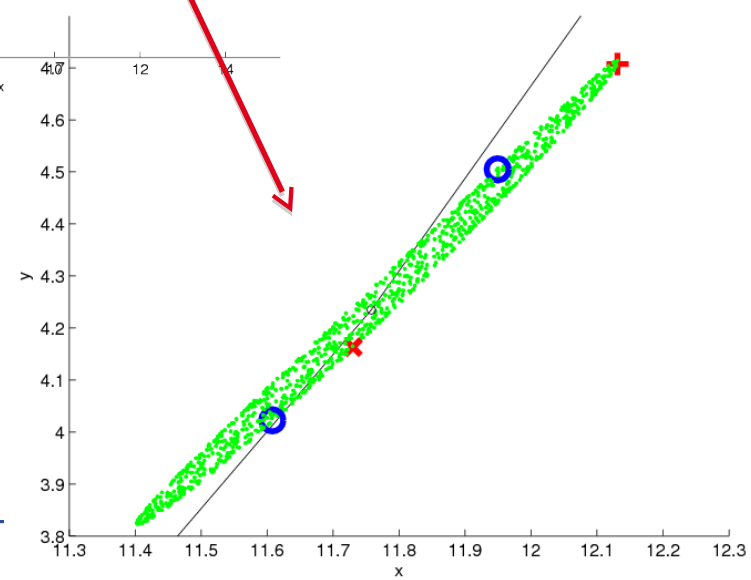
by Linus Magnusson



Initial point



After 1 time unit



- Random pert.
- ✚ 1st SV
- ✖ 2nd SV
- ○ BV

random **Initial Perturbations**

from the tangent linear subspace of growing perturbatuions

$$\underbrace{\mathbf{A}}_{n\times n}\ \underbrace{\mathbf{Q}}_{n\times m} = \underbrace{\mathbf{Q}}_{n\times m}\ \underbrace{\mathbf{H}}_{m\times m} + \boldsymbol{\varepsilon} \qquad m << n$$

Krylov subspace computed by Arnoldi Algorithm

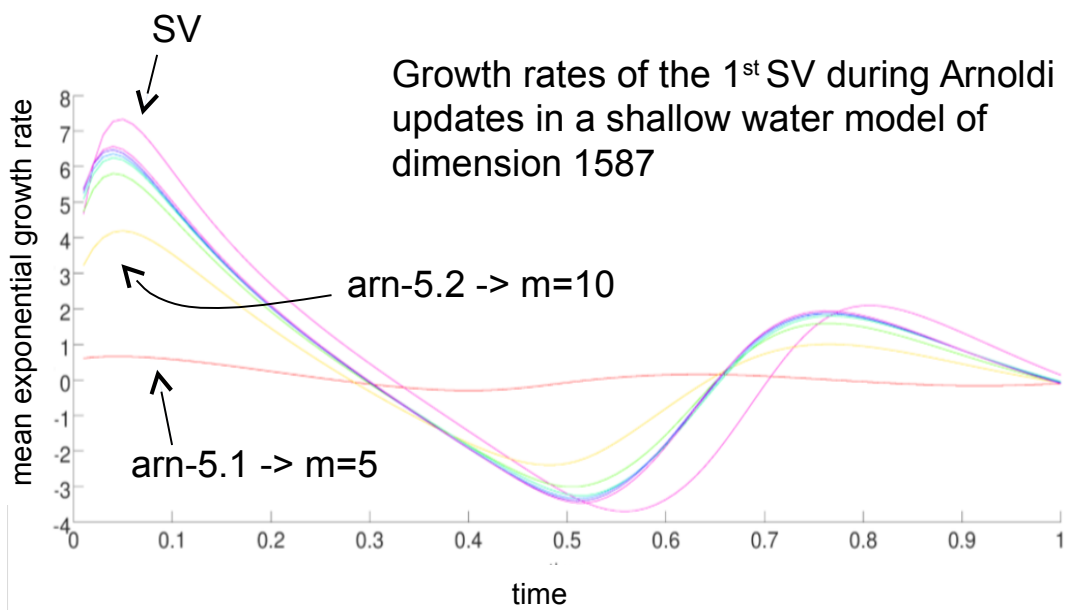
Tangen Linear Operator

$\mathbf{H}$ model for $\mathbf{A}$

Singular Vectors of

$\mathbf{H}$

Growth rates of the 1st SV during Arnoldi updates in a shallow water model of dimension 1587



Summary & Outlook

Spread Skill Relation is not reliable during the first days of the forecast

- **Singular Vector perturbations for the short range using Arnoldi Iteration**

ICON-EPS is operational since 18th January 2017

International Contributions

WMO – Verification

TIGGE (Thorpex Interactive Grand Global Ensemble) ?

Documentation

The spread skill properties of the global ICON Ensemble

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in preparation