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)

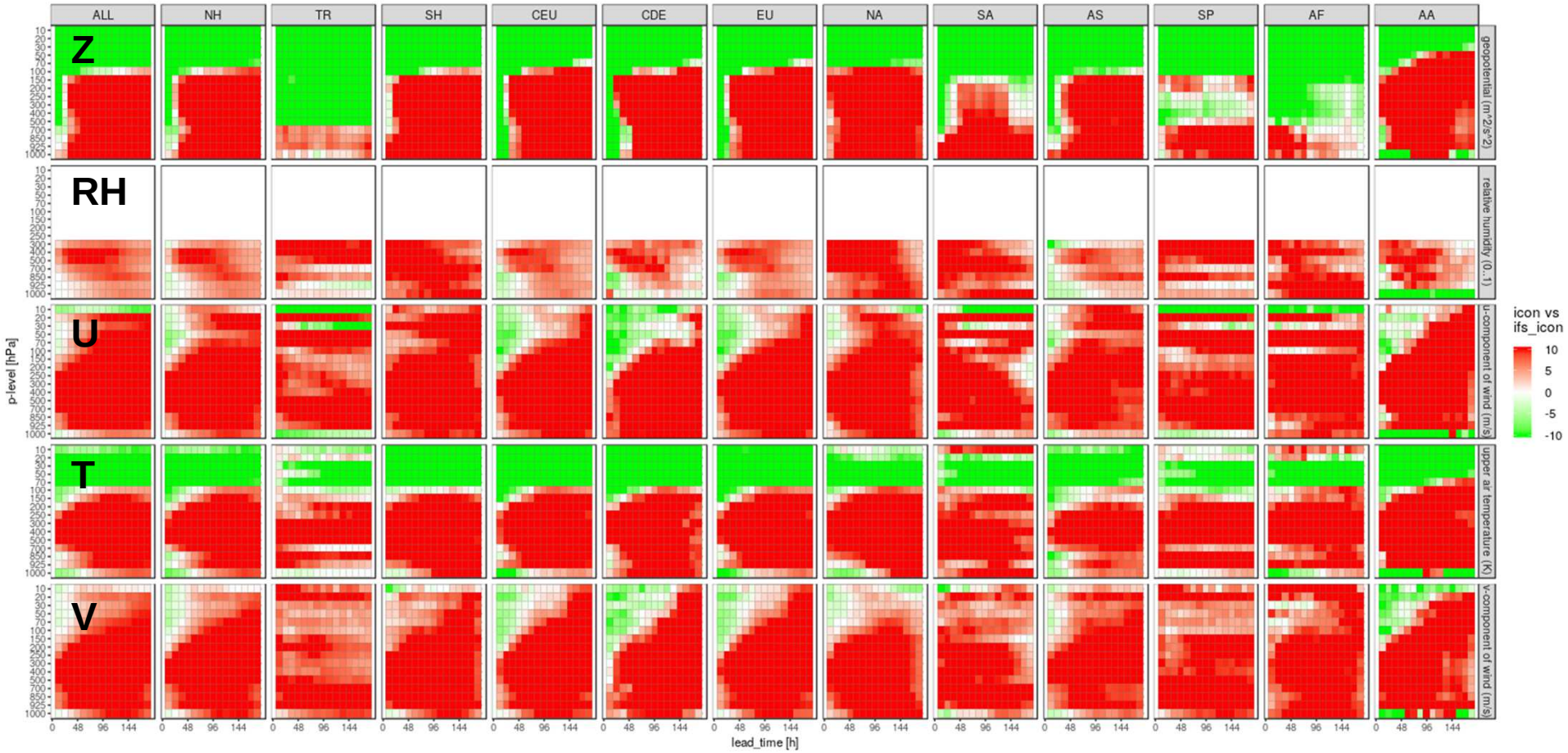
→ EDA → Evaluation → Outlook

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

- LETKF (Localized Ensemble Transform Kalman Filter, Hunt et.al. 2007)
- 40 Members (-> 80 Members)
- 3h Assimilation Cycle
- 40 km (20 km Europa)
- **Covariance Inflation**
  - multiplicative factor
  - additive Inflation $+0{,}25B_{3dVar}$ (NMC Method)
  - „relaxation to the prior“
  - SST 1°K random perturbations with spatial correlations of 100km/1000km and 1 day

ICON-EPS better

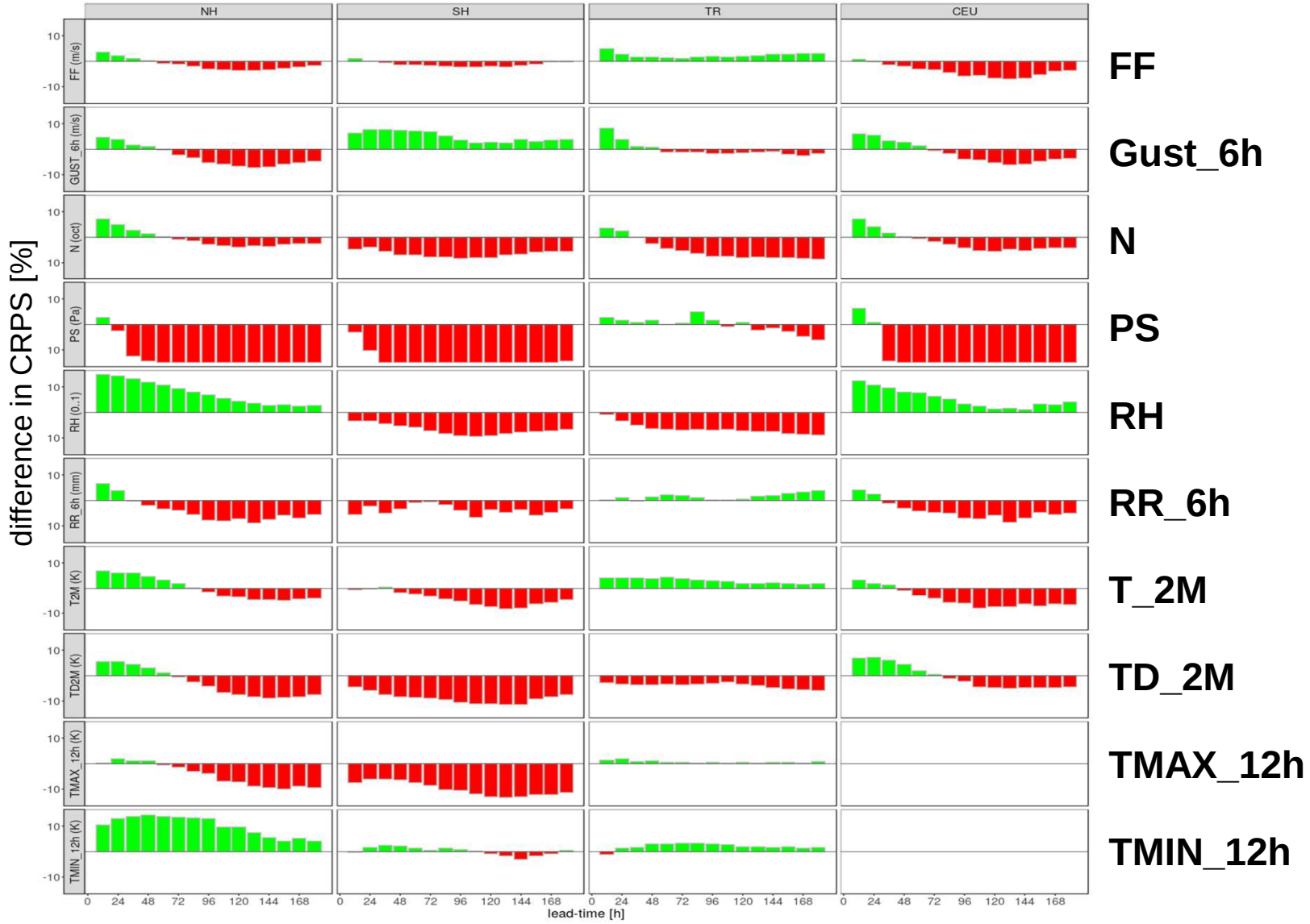
Verification against Observations November 2017



color: difference in CRPS [%]

ICON-EPS better

Verification against Observations November 2017



FF

Gust_6h

N

PS

RH

RR_6h

T_2M

TD_2M

TMAX_12h

TMIN_12h

extreme Gusts 6h

0-48h 479 Fälle %

Helpful?	**yes**	285	**59,5**
	no	73	**15,2**
	ok	117	**24,4**
	nothing	4	**0,8**
Comparison	**ECMWF**	**68**	**14,2**
	ICON	**91**	**19,0**
	No added value	299	**62,4**
	nothing	23	**4,8**

60-108h 604 Fälle %

Helpful?	**Yes**	297	**49,2**
	no	132	**21,9**
	ok	174	**28,8**
	nothing	1	**0,2**
Comparison	**ECMWF**	**98**	**16,2**
	ICON	**61**	**10,1**
	no added value	429	**71,0**
	nothing	16	**2,6**

Extreme Precipitation Events

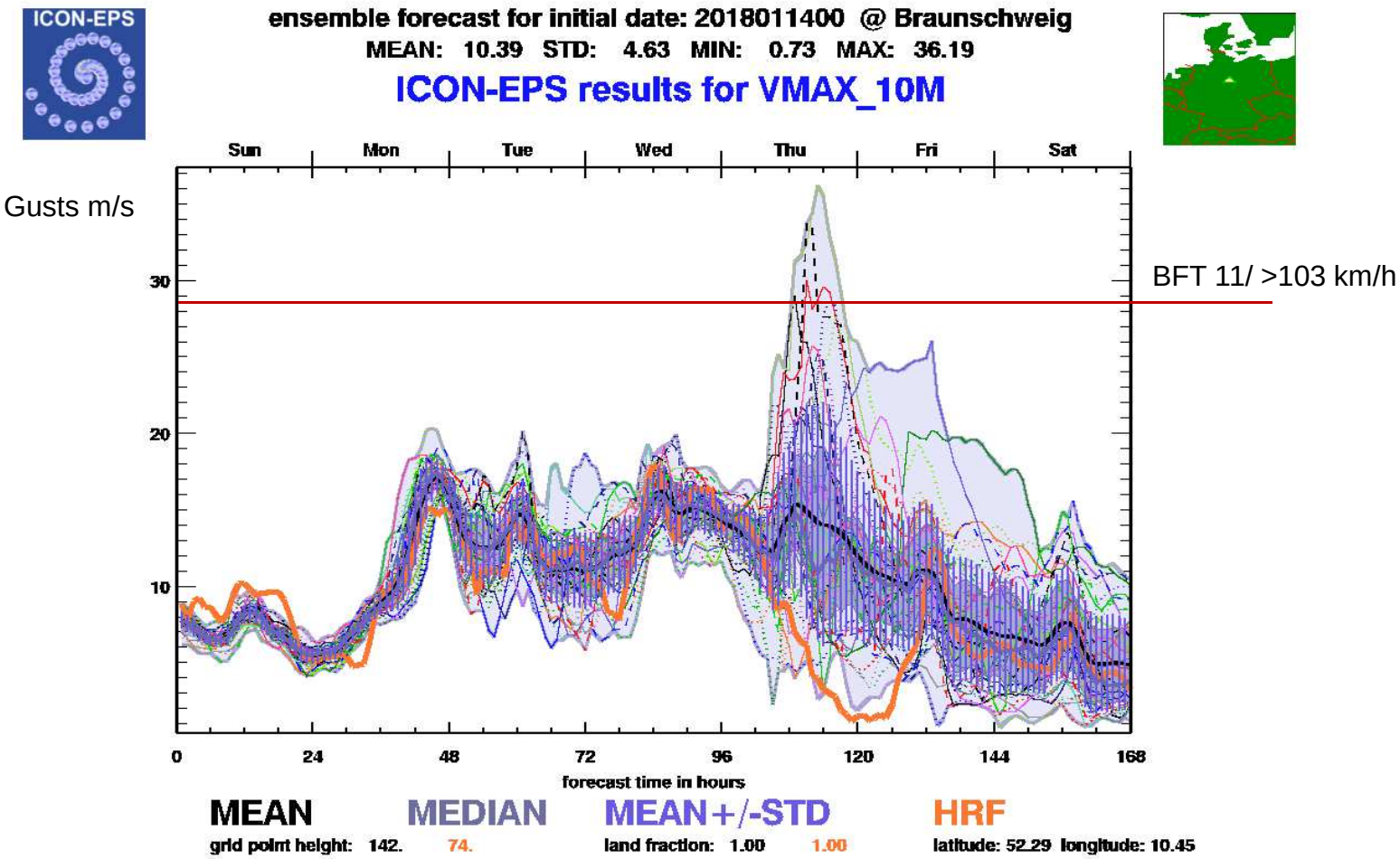
0-48h 61 cases %

Helpful?	**yes**	23	**37,7**
	no	23	**37,7**
	ok	13	**21,3**
	nothing	2	**3,3**
Comparison	**ECMWF**	**8**	**13,1**
	ICON	**7**	**11,5**
	No added value	39	**63,9**
	nothing	4	**6,6**

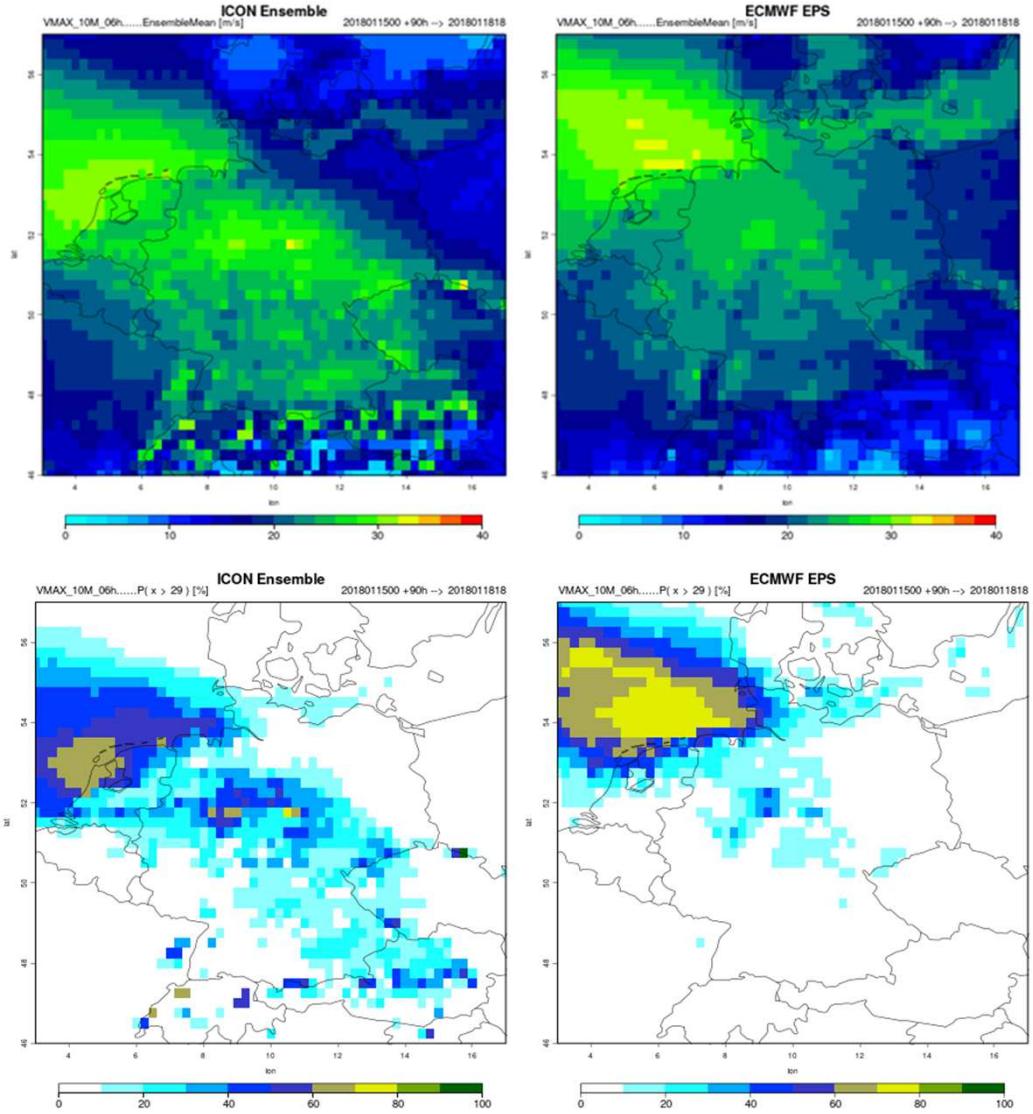
60-108h 91 cases %

Helpful?	**yes**	20	**22,0**
	no	54	**59,3**
	ok	17	**18,7**
	nothing	0	**0,0**
Comparison	**ECMWF**	**13**	**14,3**
	ICON	**12**	**13,2**
	No added value	62	**68,1**
	nothing	4	**4,4**

6h wind gusts Braunschweig



ICON-EPS ECMWF-EPS



20180115 00UTC

(+90h)

→ 20180118 18UTC

Ensemble mean

P(x > 29m/s)

ICON-EPS products with fieldextra

EU-Nest:
0,25°lat/lon

www.dwd.de
-> ICON database reference manual

in preparation: global products

Table 9.4.: Available output fields for ICON-EPS: **Probability Products**.

Parameter	Description	
T_2M	2m Temperature	
TD_2M	2m Dew Point Temperature	
SP_10M	Wind Speed at 10m	
PMSL	Mean Sea Level Pressure	
CAPE_ML	Convective Available Potential Energy	
CLC*	Cloud Cover (*=T/L/M/H)	
Parameter	**Description**	**Height Level**
T, SP	Temperature, Wind Speed	500/850hPa
Parameter	**Description**	**Accumulation**
T_G	Ground temperature (temperature at sfc-atm interface)	12h
TMAX_2M/TMIN_2M	Max/Min Temperatures	12h, 24h
VMAX_10M	Maximum wind speed at 10m above ground	6h, 12h, 24h
TOT_PREC	Total Precipitation	6h, 12h, 24h, 48h, 72h
SNOW_GSP	Large scale snowfall water equivalent	6h, 12h, 24h

1. Mean and extreme values

- Unweighted mean of all members (deriv = 0)
- Spread of all members (deriv = 4)
- Minimum of all ensemble members (deriv = 8)
- Maximum of all ensemble members (deriv = 9)

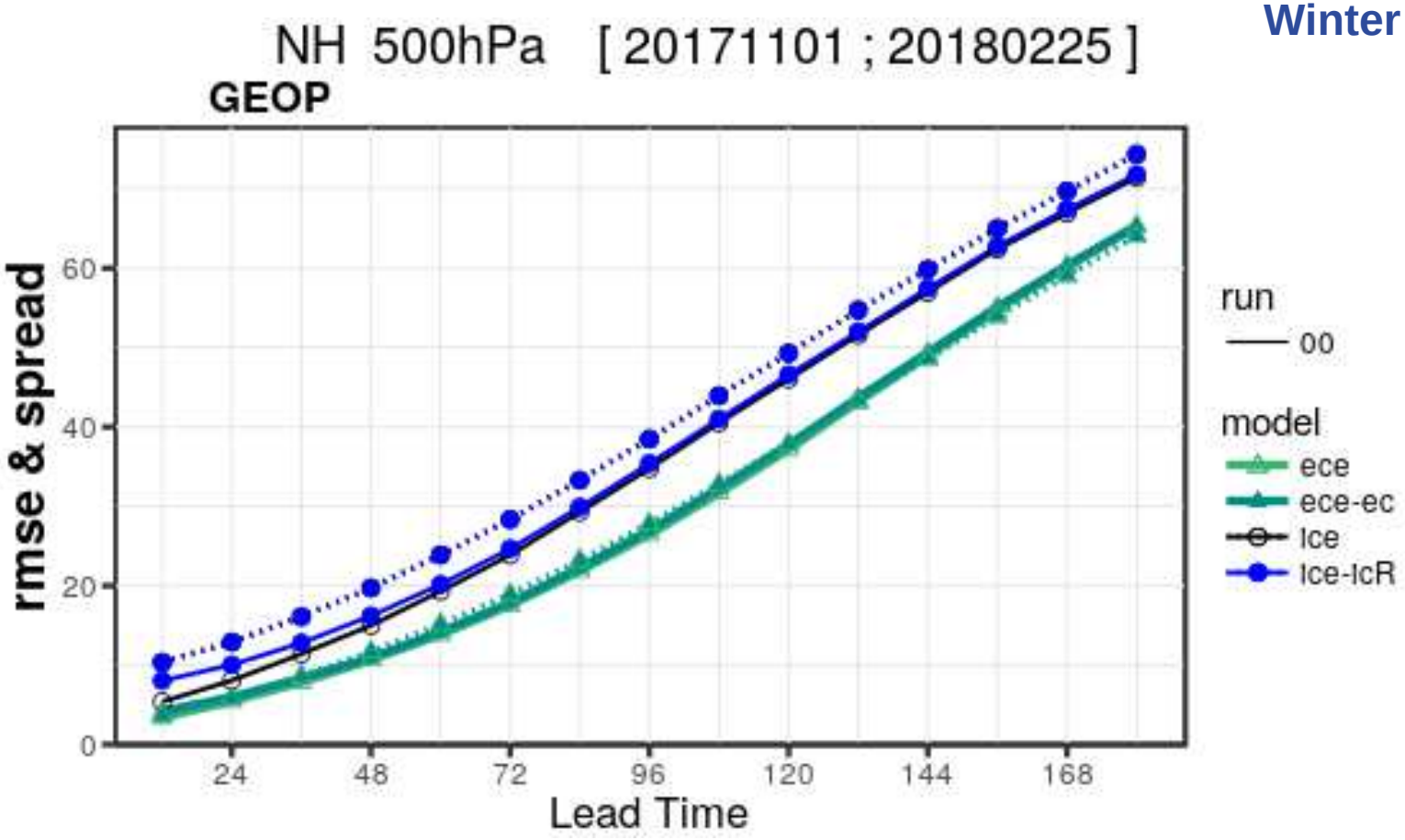
2. Percentiles

i.e. physical values of a forecast parameter (e.g. T_2M,. . .), which define the perc=10,25,50,75,90 [%] parts of the ensemble distribution.

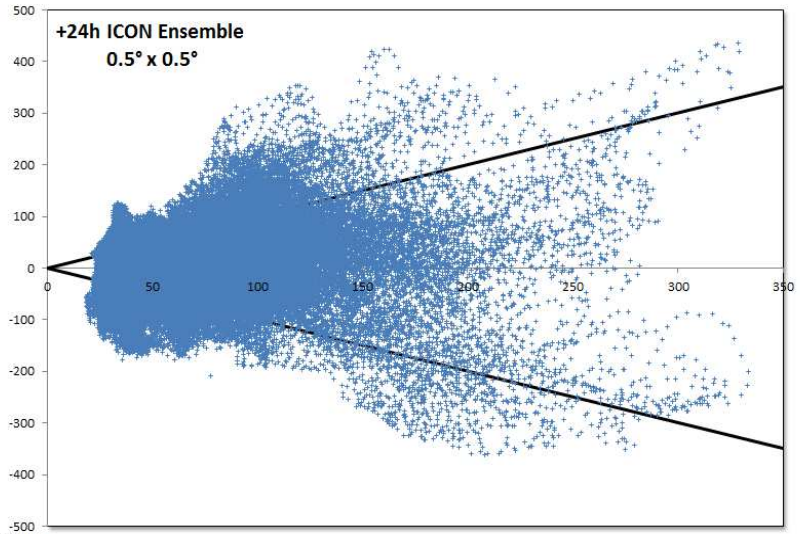
3. Exceedance Probabilities

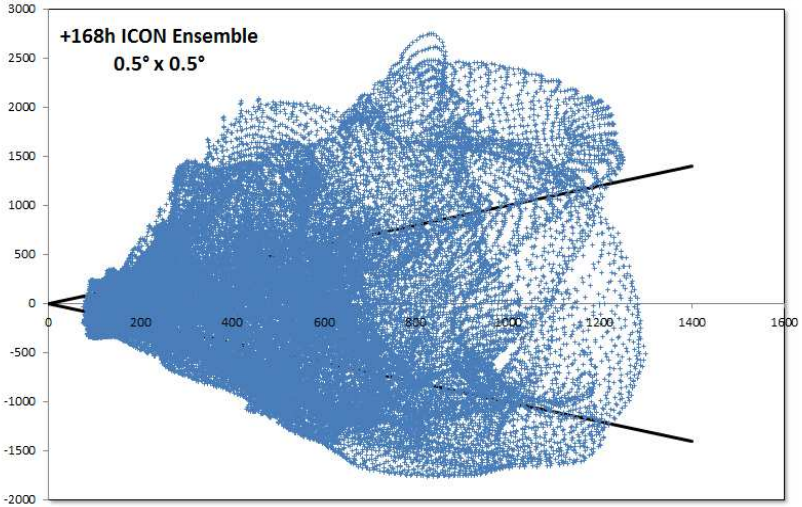
- Probability of event above lower limit (probt=3)
- Probability of event below upper limit (probt=4)

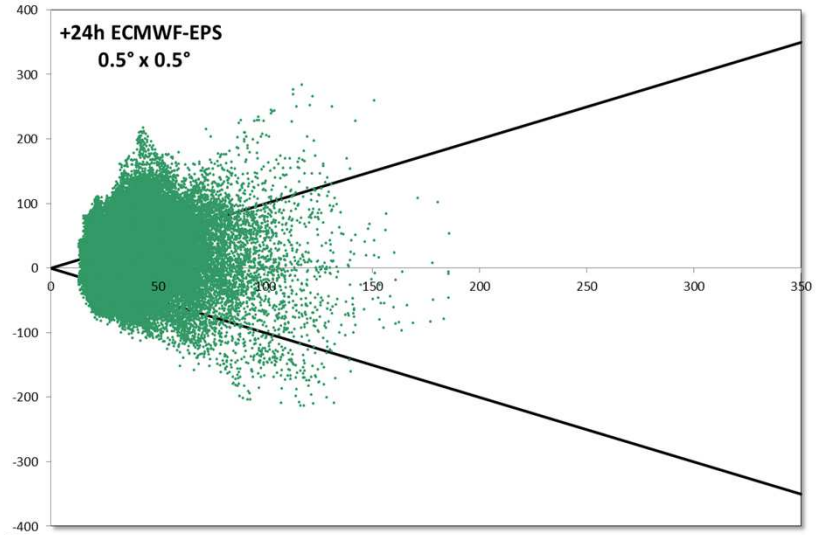
Winter

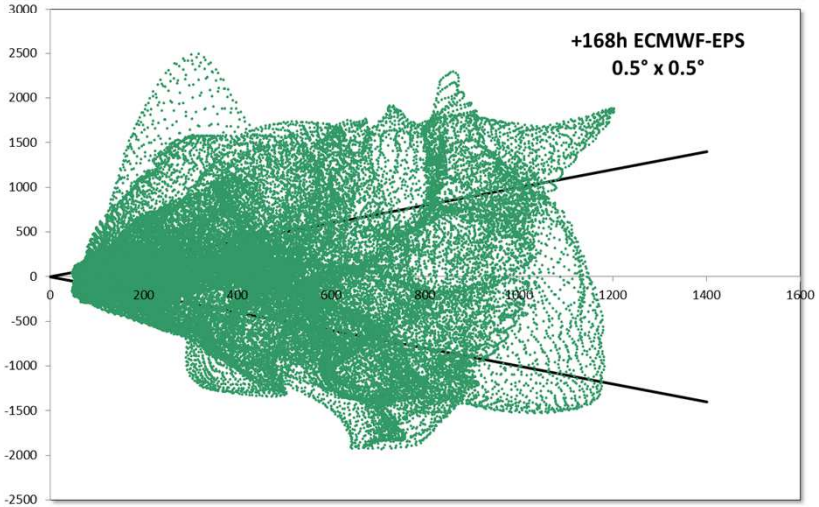

NH 500hPa [20171101 ; 20180225]
GEOP
rmse & spread
0
20
40
60
24
48
72
96
120
144
168
Lead Time
run
00
model
ece
ece-ec
Ice
Ice-IcR

Error = AE









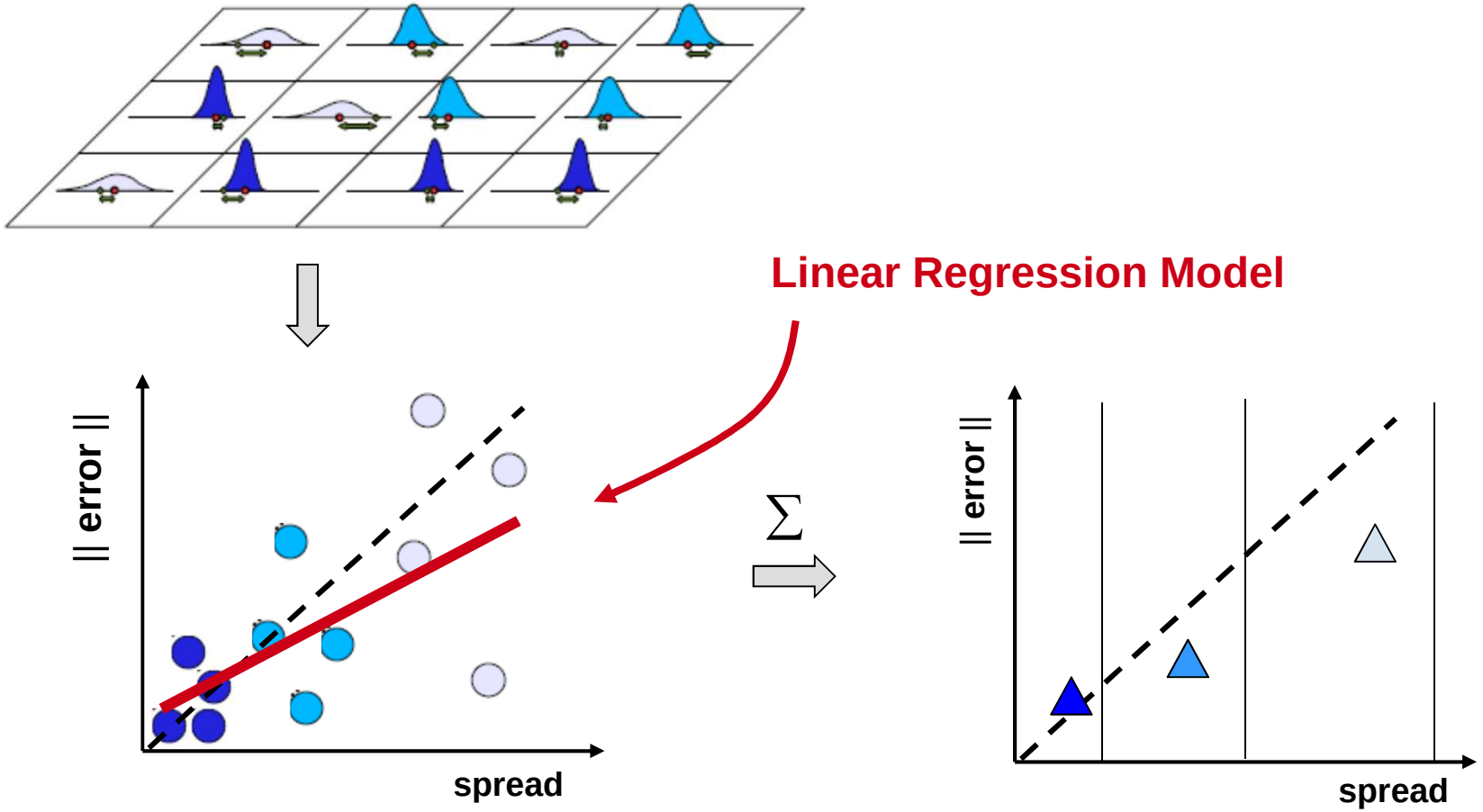
ICON-EPS

Spread = AD

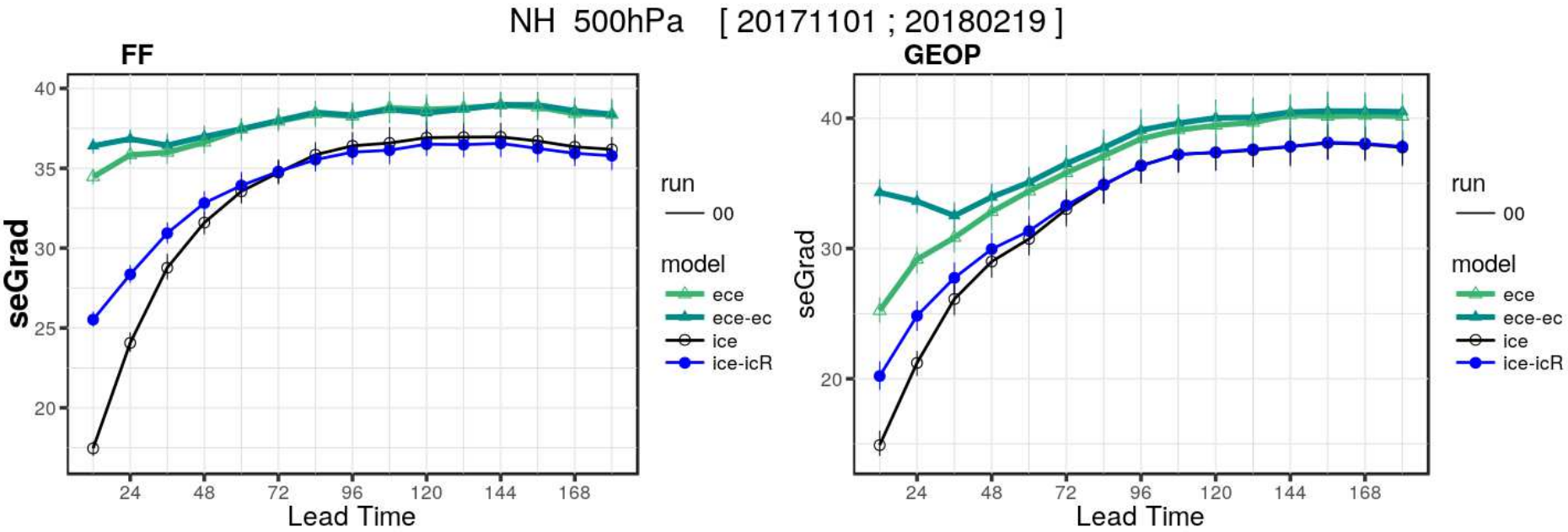
ECMWF-EPS

Spread-Skill Reliability

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

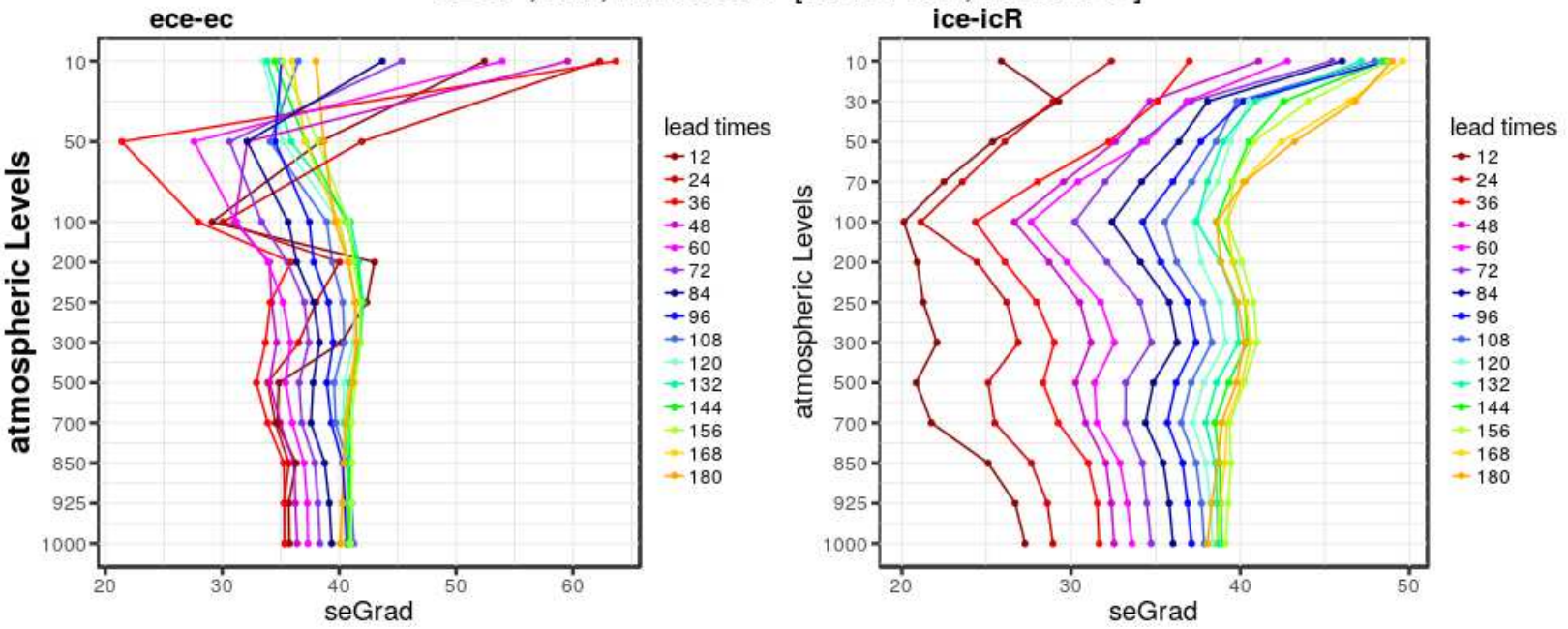


Spread-Skill Reliability



Improve the Spread-Skill Reliability in the short range

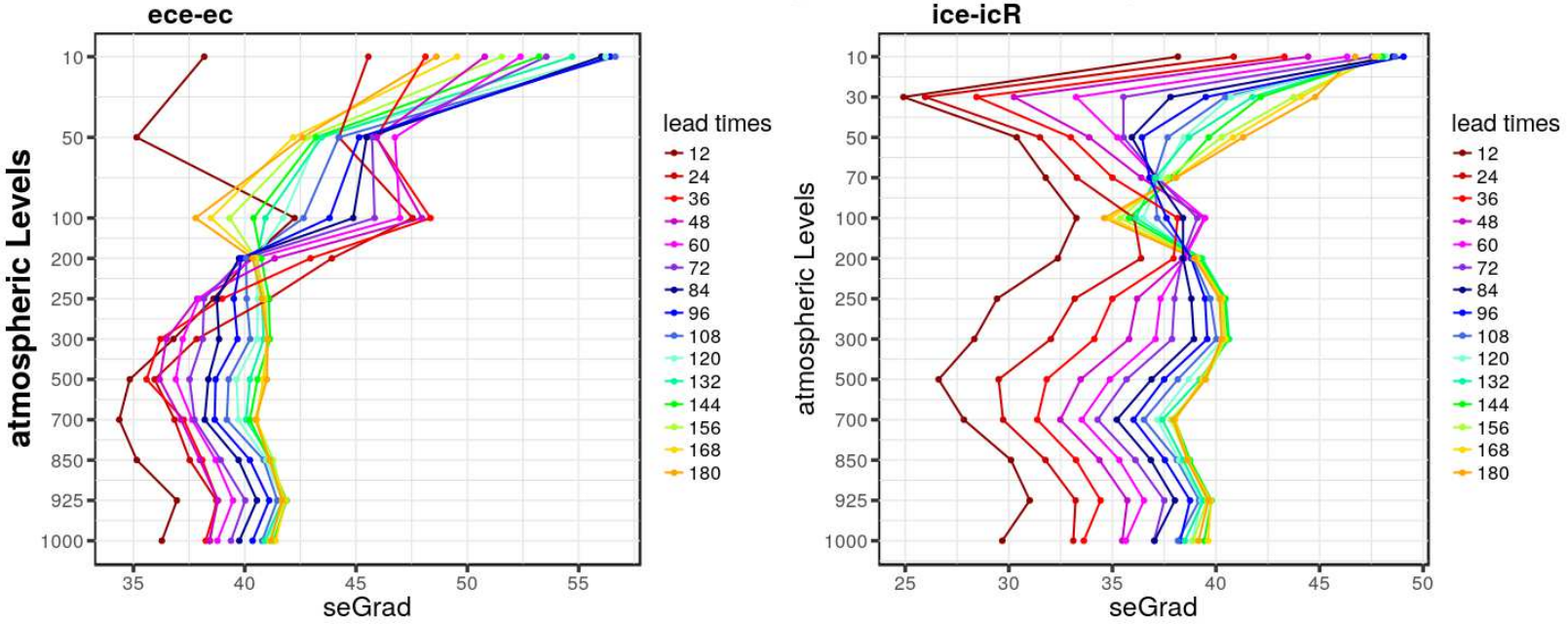
GEOP , NH , run-00UTC [20171101 ; 20180225]



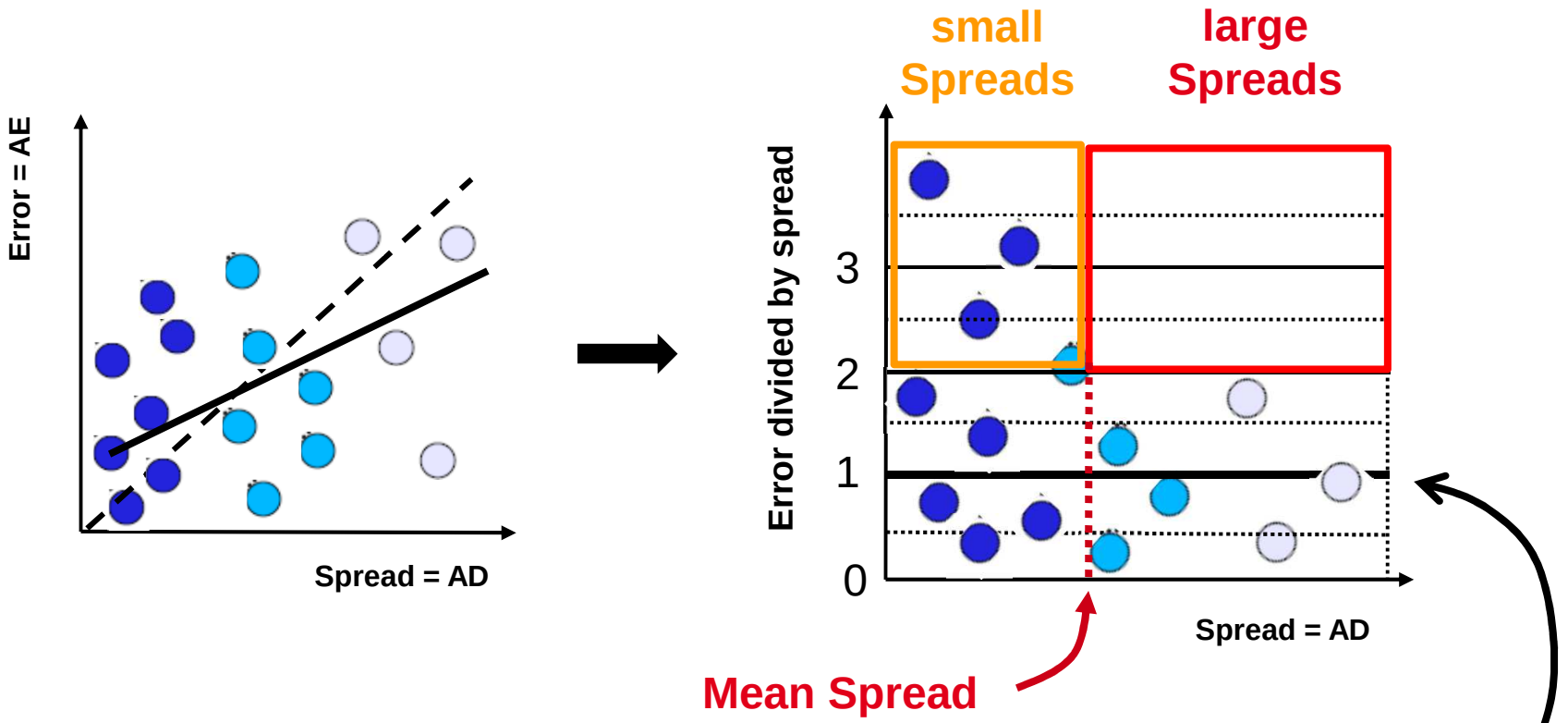
ECMWF-EPS

ICON-EPS

FF , global , run-00UTC [20171101 ; 20180219]

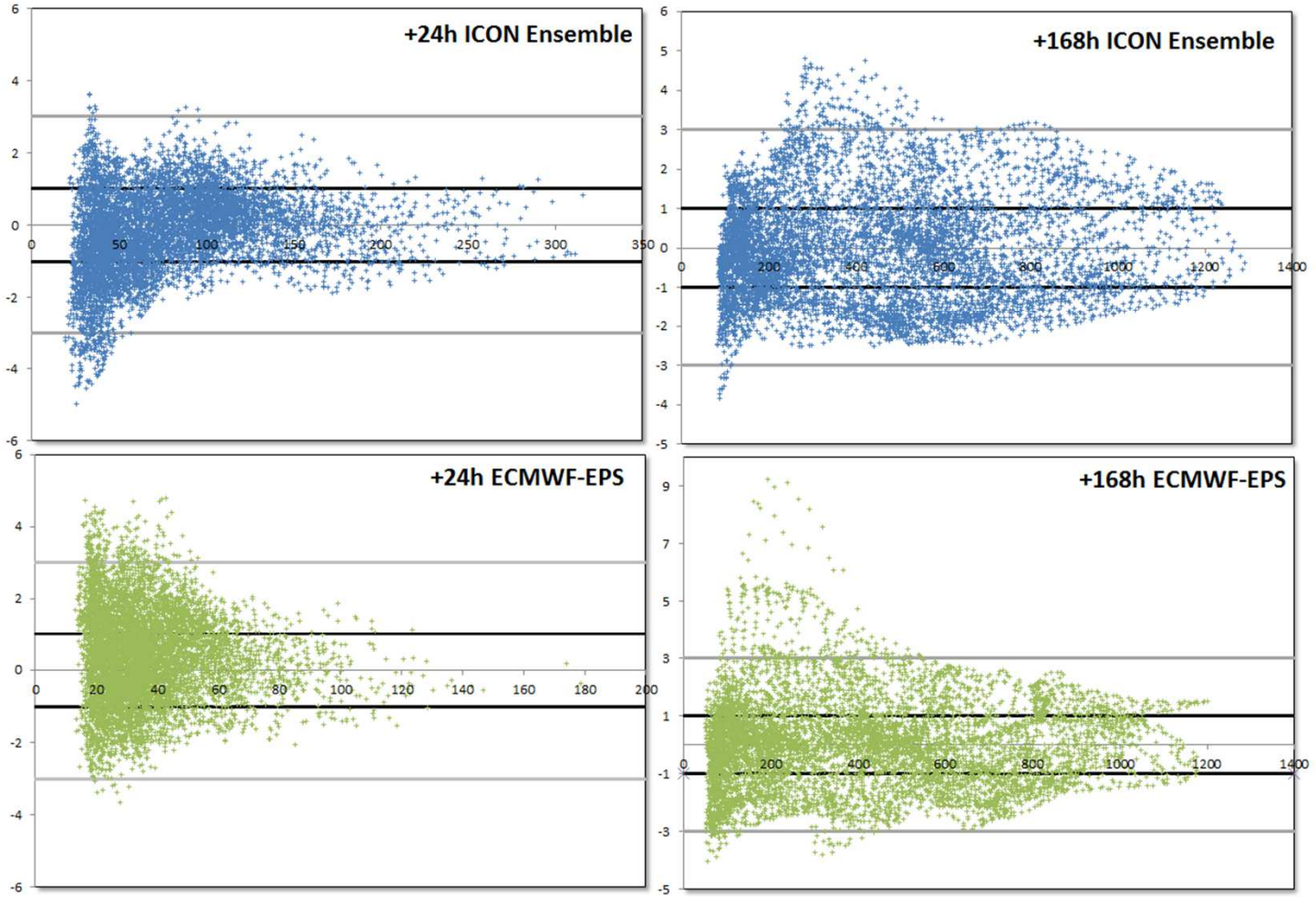


conditional on spread



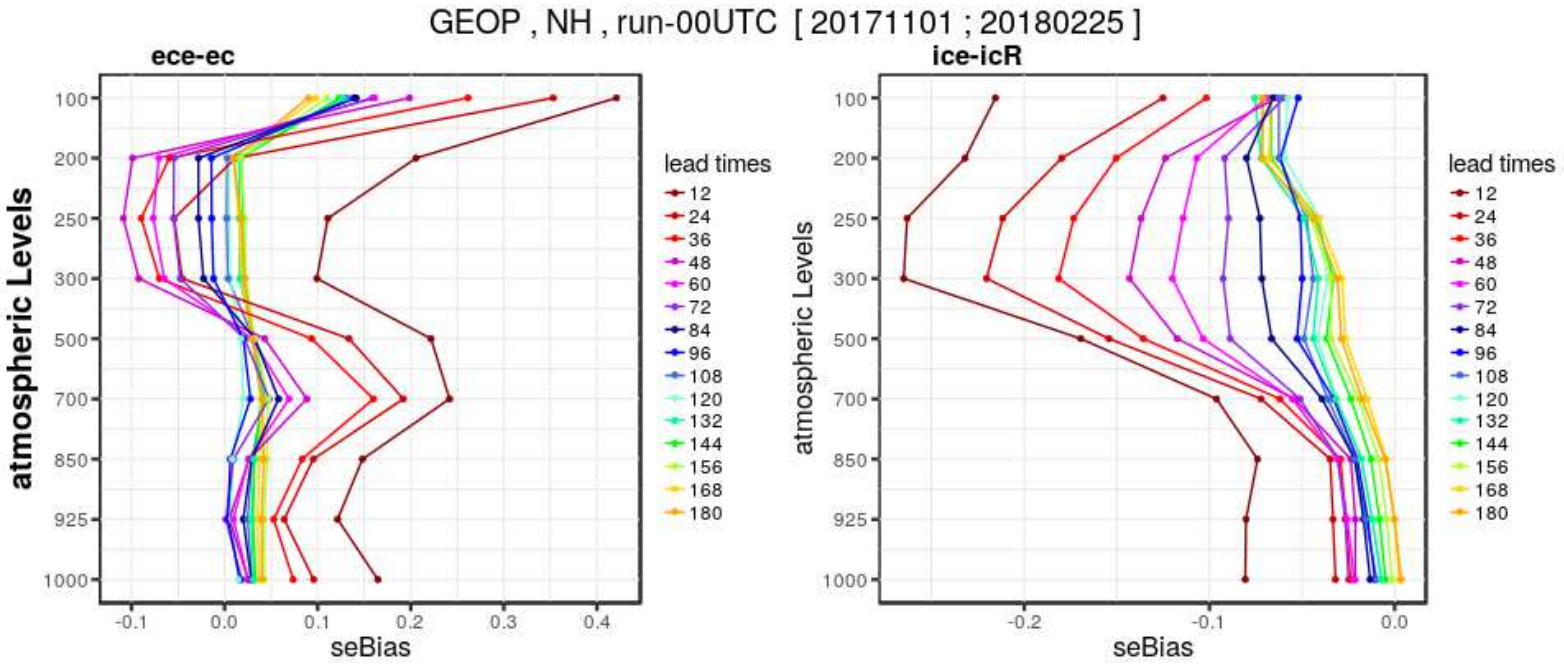
$$seBias = \frac{1}{N}\sum_{i}^{N}\frac{|e_i|}{AD_i} - 1$$

AE / AD

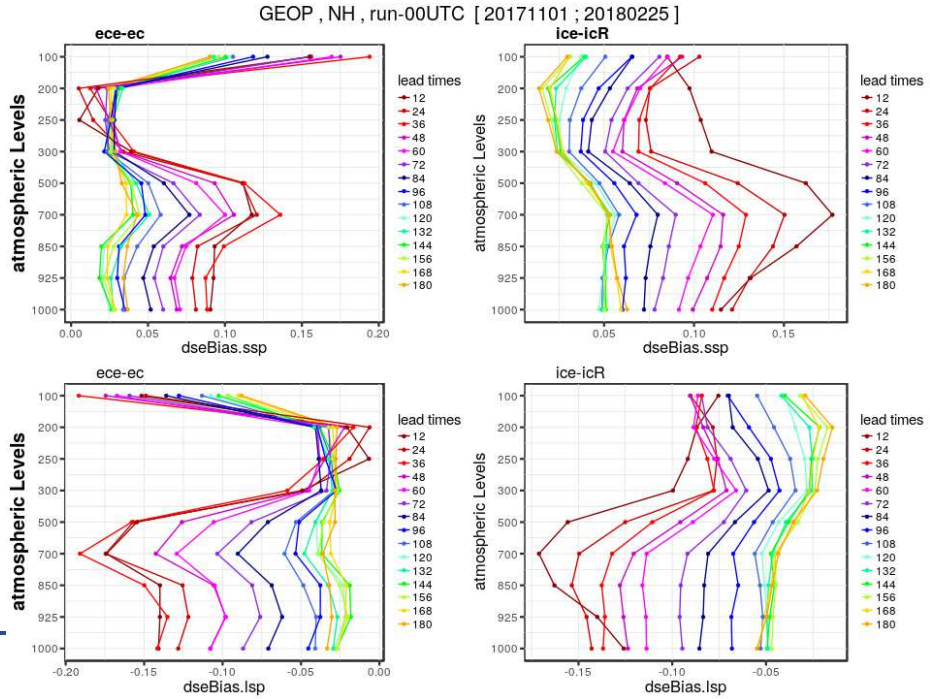


500hPa Geopotential

Spread = **AD**



ECMWF-EPS



ICON-EPS

Philipps Universität Marburg

Jens Winkler, Tobias Heckel, Svenja Seip, Bernhard Schmitt

Initial Perturbations

Arnoldi Approximation

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

$\mathbf{H}$ model for $\mathbf{A}$ ⇨ Singular Vectors of $\mathbf{H}$

Initial Perturbations

Broyden Update

$$\dot{x} = f(x)$$

$$\frac{d\dot{x}}{dt} \rightarrow d\dot{x} = \frac{\partial f(x)}{\partial x} dx \rightarrow d\dot{x} = \frac{\partial f(x)}{\partial x} \dot{x} dt$$

finite differences $$\dot{x}_{t+1} - \dot{x}_t = \frac{\partial f(x)}{\partial x} \dot{x}_t \delta t$$

Secant Equation

$$\dot{x}_{t+1} = \left(\mathbf{I} - \frac{\partial f(x)}{\partial x} \delta t \right) \cdot \dot{x}_t \quad \Leftrightarrow \quad y = \mathbf{B}_{t+1} \cdot s$$

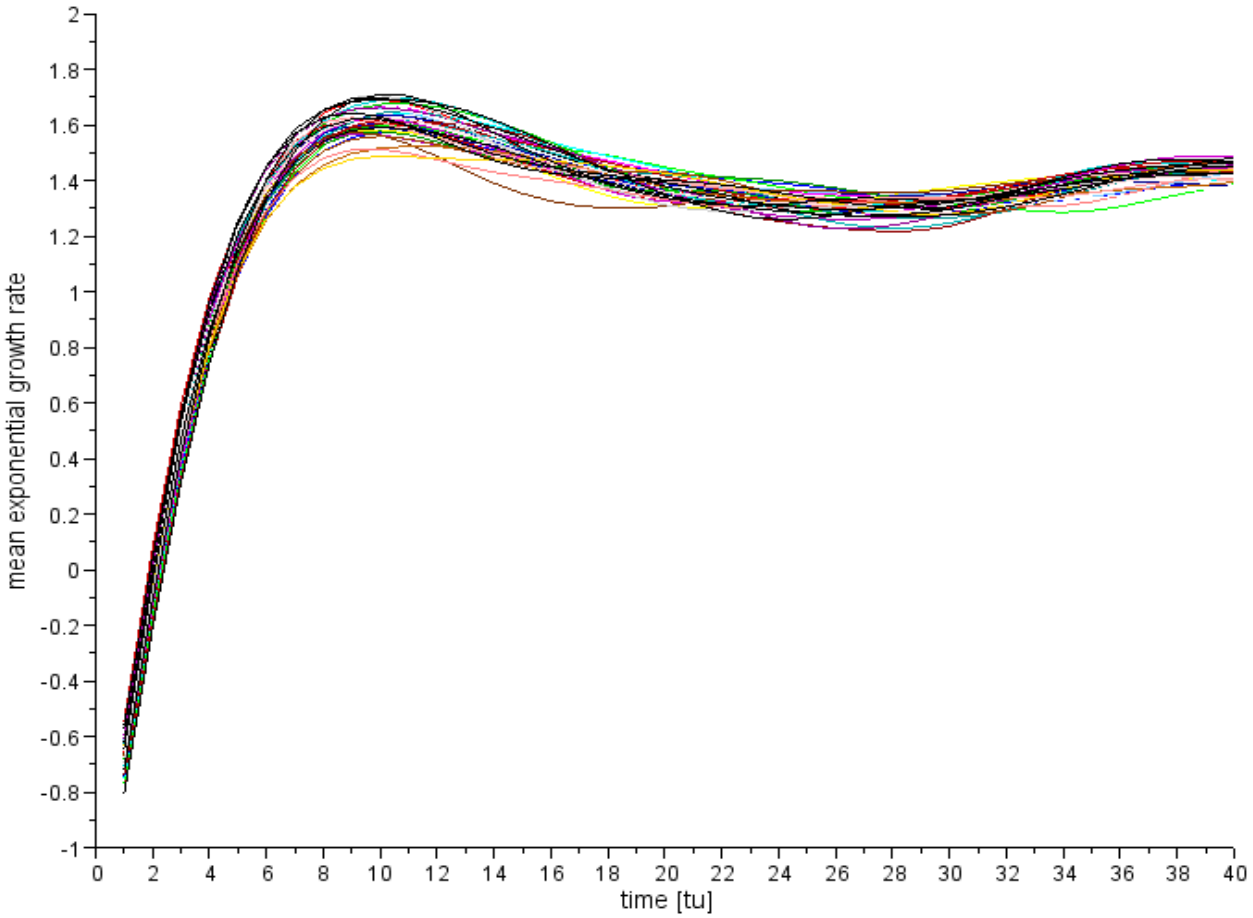
Lorenz96

Growth rate

Random Perturbations

1000 samples

N=40

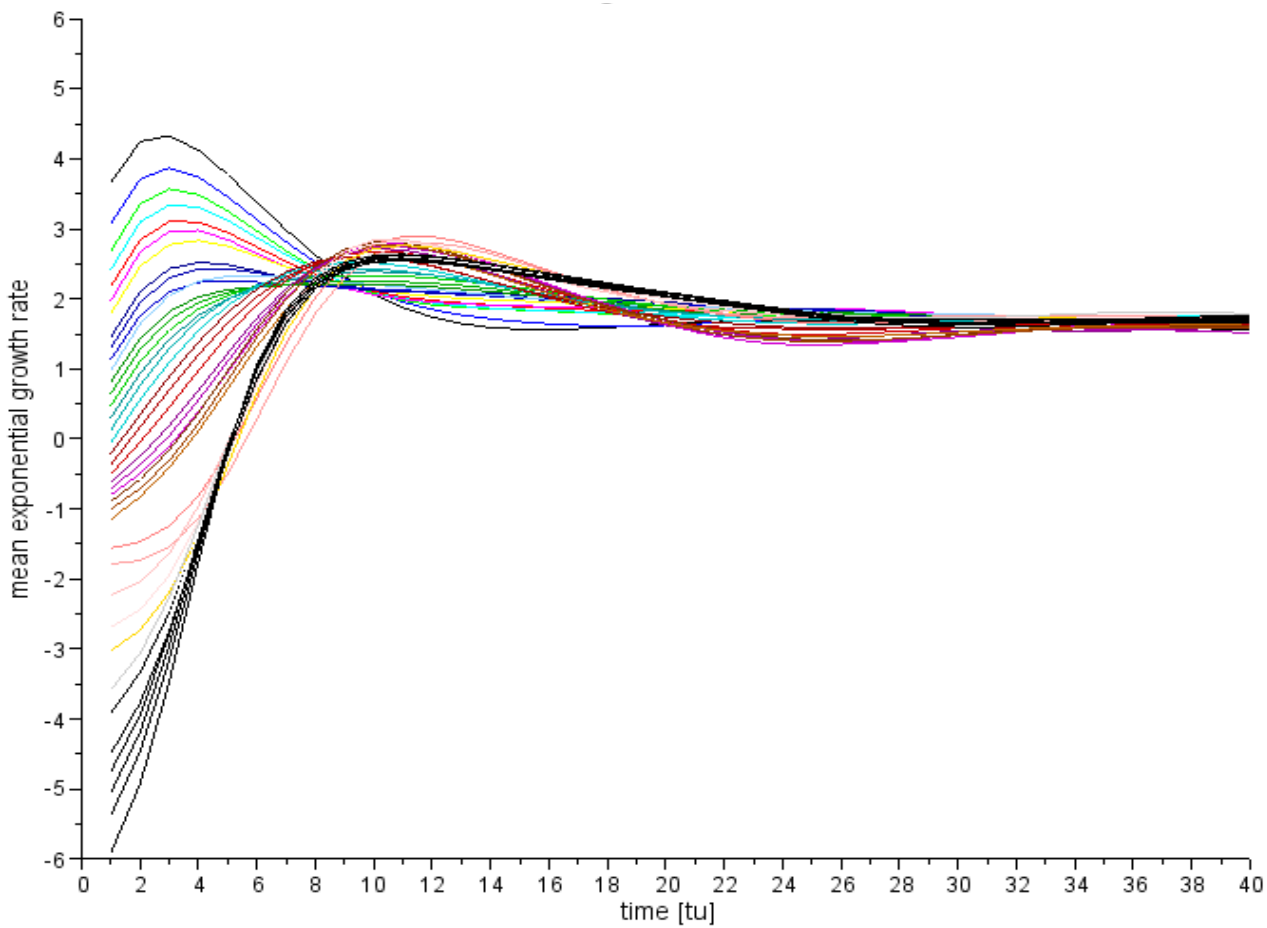


Lorenz96

Growth rate

Singular Vectors

1000 samples
N=40



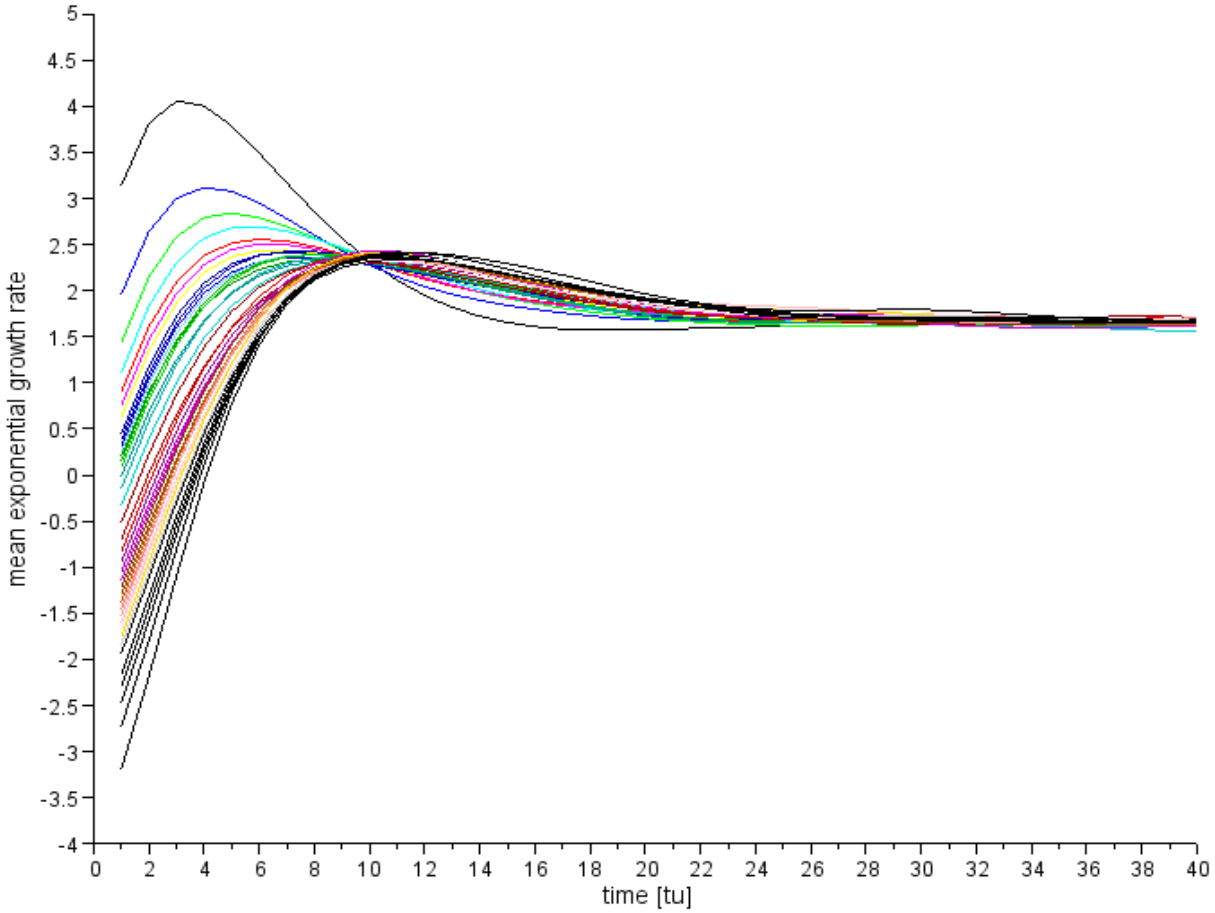
Lorenz96

Broyden Update

1000 samples

N=40

Growth rate



Summary

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

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

Global Ensemble MOS

S. Trepte, R. Hess

Cooperation with ECMWF

Zusammenarbeit mit ECMWF

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

	Topic / Action points	DWD responsible	ECMWF reponsible
1.	**Verification:** Estimation of observation error and investigations on the spread-skill reliability	F. Fundel M. Denhard	To be defined
2.	**Initial Condition perturbations:** New Singular Vector (SV) approximations for the short range in ICON and comparison to the ECMWF SVs	M. Denhard J. Winkler	M. Leutbecher S. Lang
3.	**Stochastic Parameterization:** Tests of the Plant-Craig extension in the Tiedtke-Bechthold convection parametrization scheme in ICON.	G. Zängl M. Denhard	To be defined
4.	**Model error representation:** Implementation of the new EM-scheme in ICON and comparison to SPPT and SPP at ECMWF.	T. Heppelmann, M. Sprengel M. Köhler, C. Gebhardt,	S.J. Lock M. Leutbecher
5.	**Diagnostics:** Collaboration with ECMWF on the effects of model error schemes in global Ensembles.	E. Machulskaya	