Waves to Weather
Project A1: “Upscale impact of diabatic processes from convective to near-hemispheric scale”

An estimation of intrinsic limits of predictability using ICON and a stochastic convection scheme

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DWD-CUS Offenbach, 7.3.2017

Outline

Questions

- What is the **intrinsic limit** of **predictability** that is imposed by the convection?
- What is the **relevance** of this limit for nowadays weather prediction systems?
- How much room is there for further **improvement**?

Outline

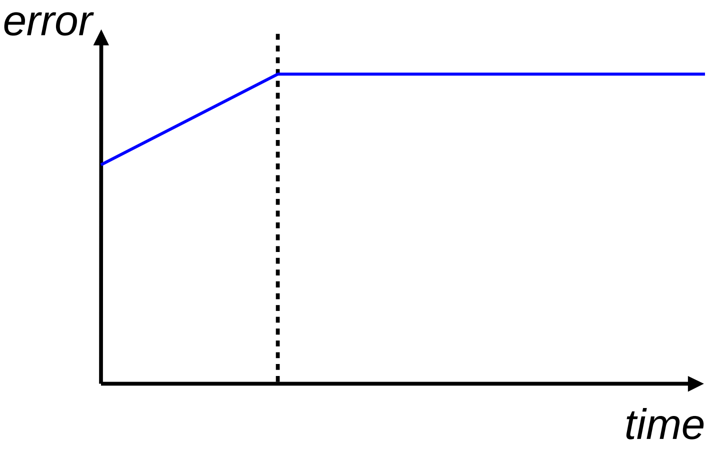
- Introduction
- Experimental setup
- Results

Introduction

Practical and intrinsic predictability

Practical predictability

Limit of prediction with currently available models and procedures



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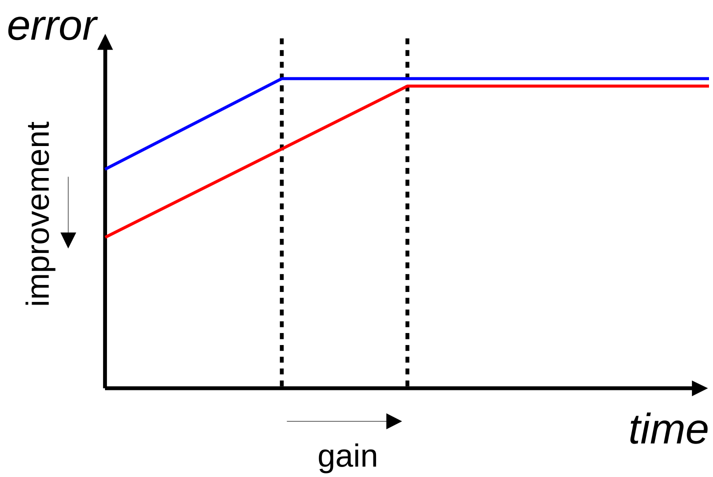

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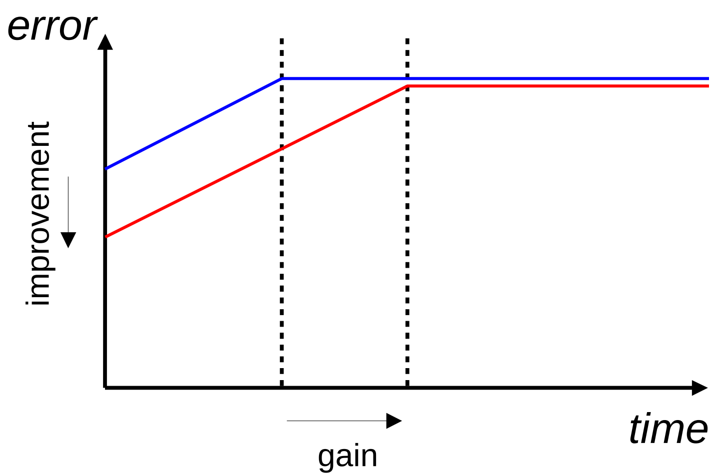
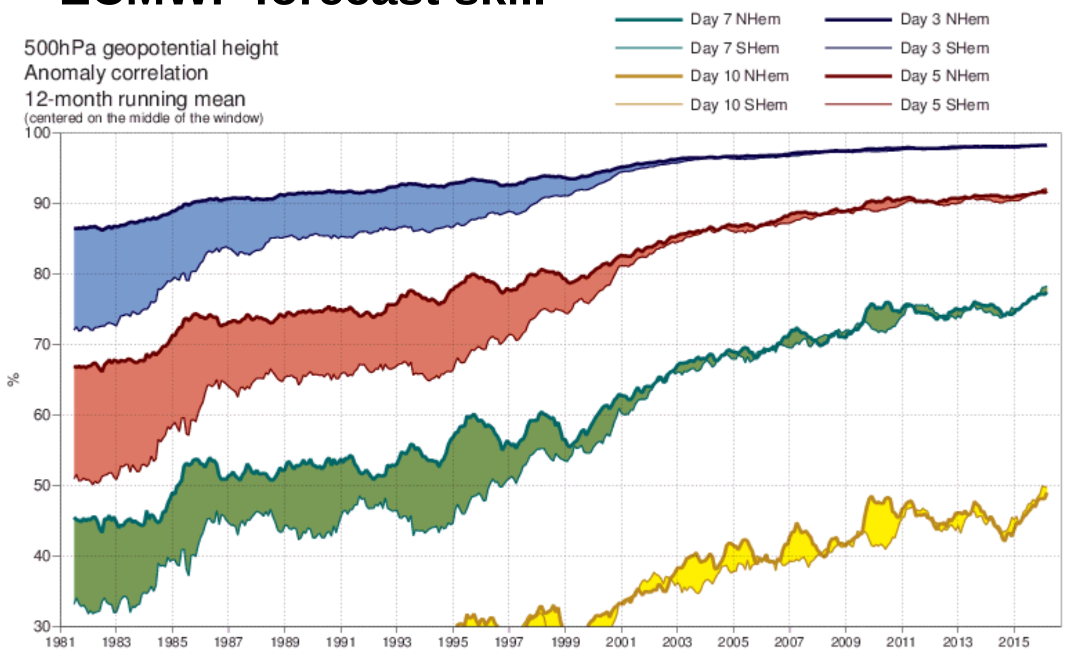


ECMWF forecast skill



Improvement: 1 forecast-day per decade

Practical and intrinsic predictability

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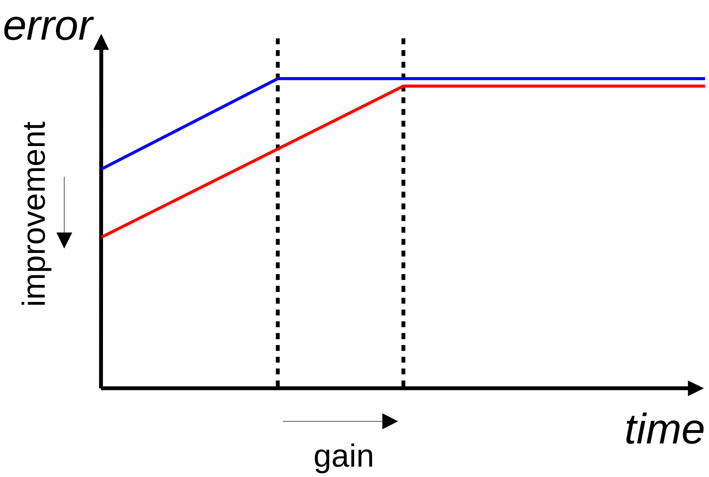
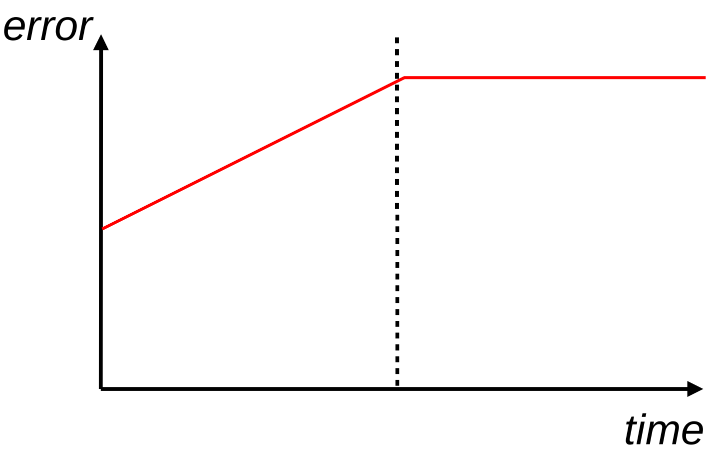


Intrinsic predictability

Limit of prediction with perfect procedures and knowledge of the initial state



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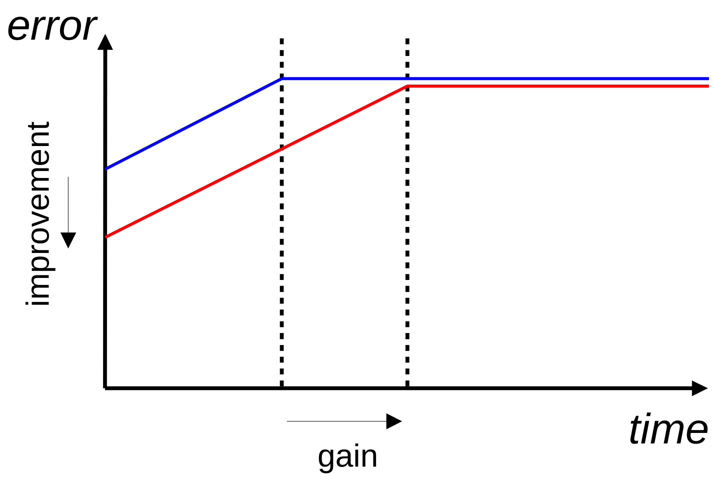

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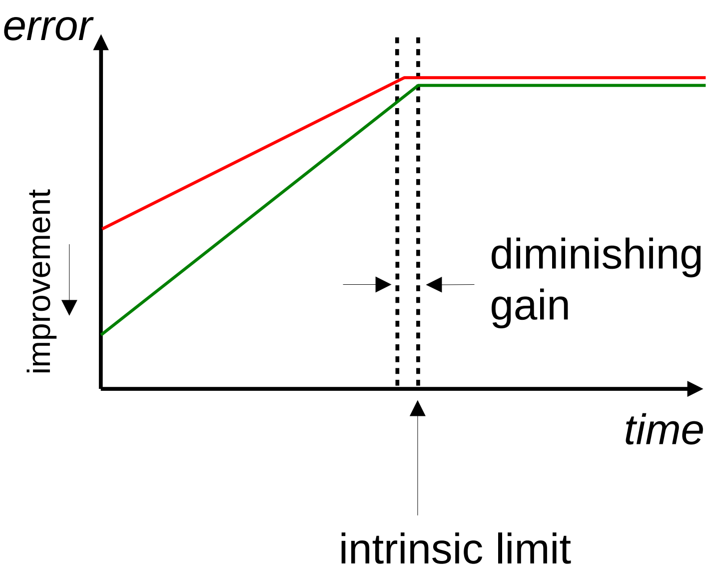
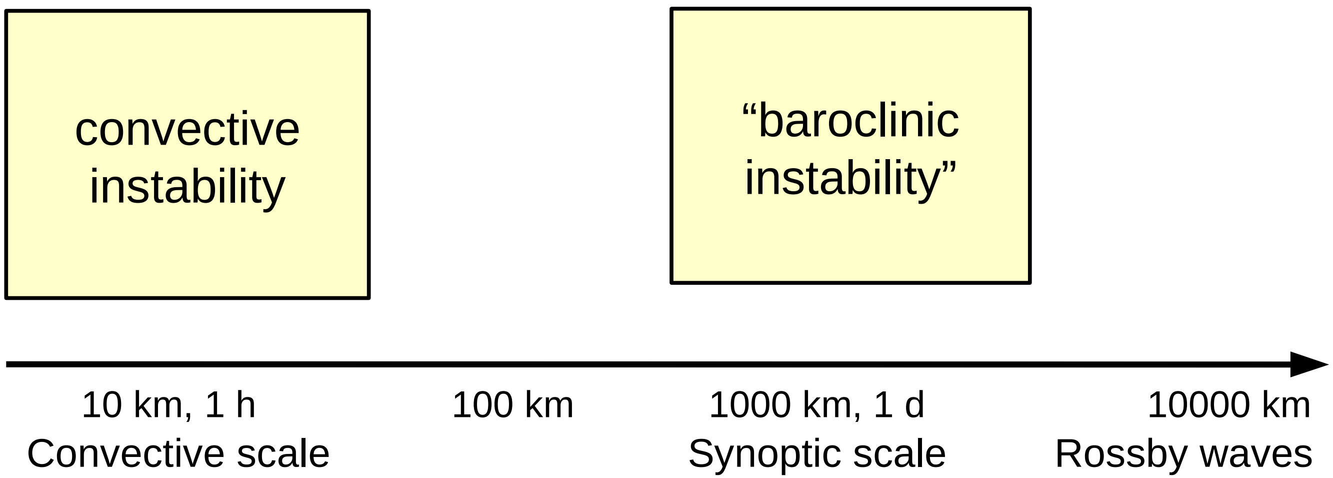


Intrinsic limit of predictability via scale interaction



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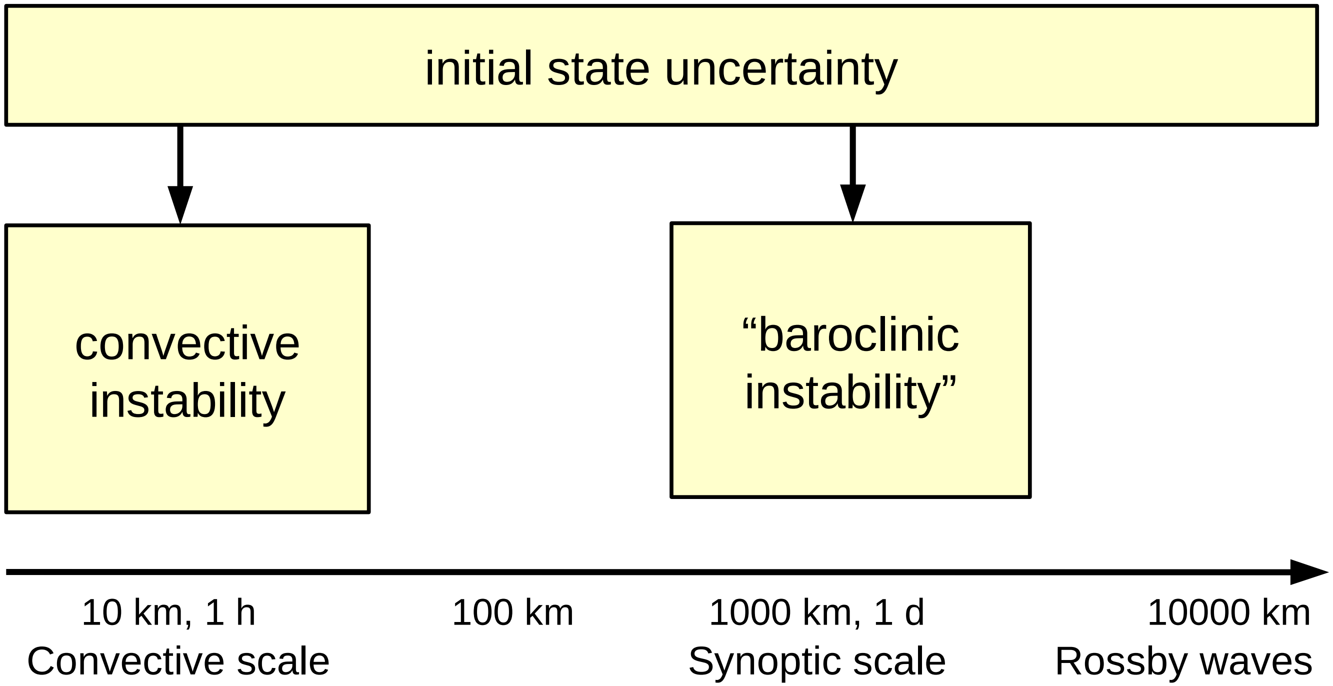

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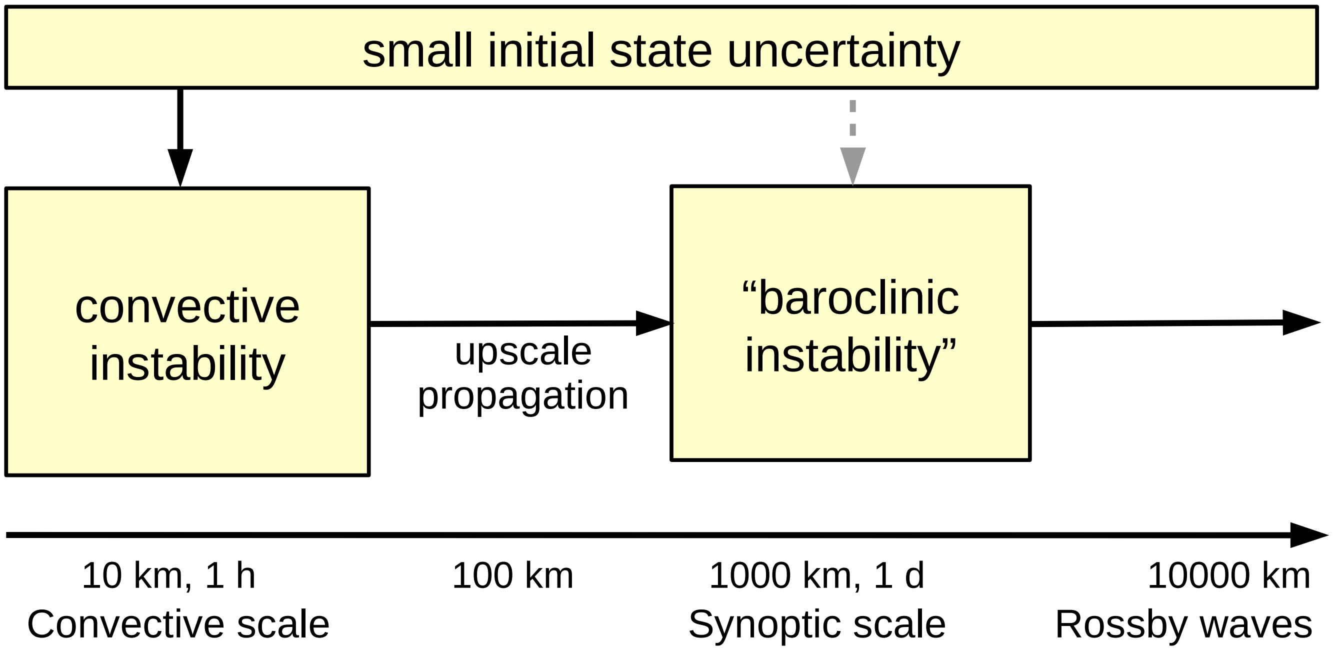

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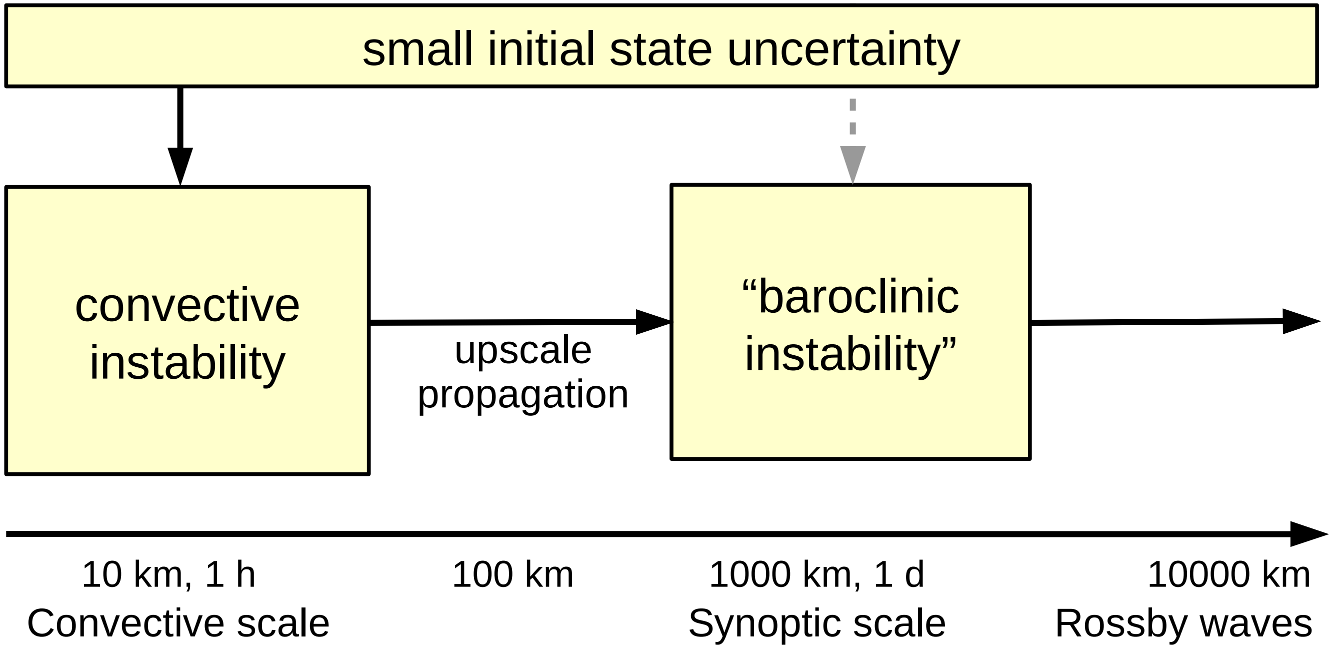
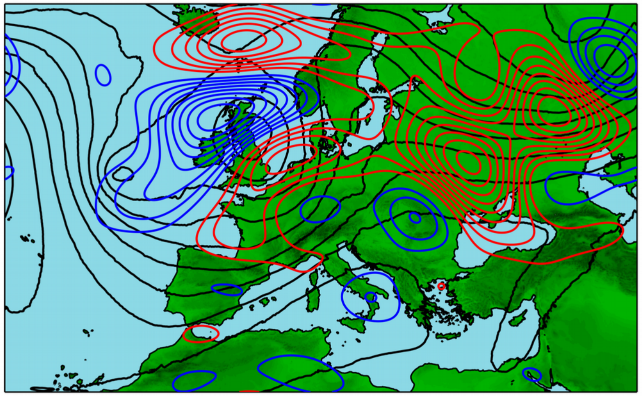


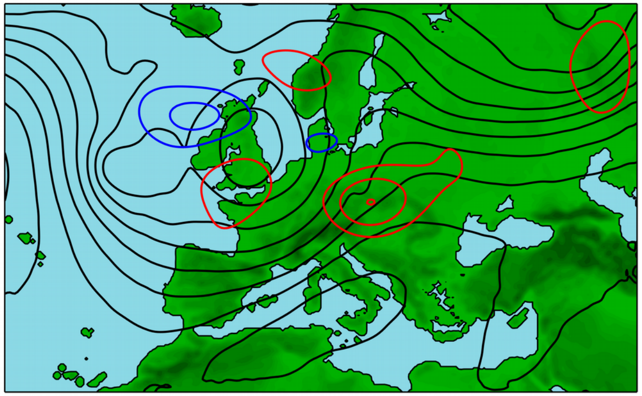
- Quick amplification (≈ 1h) of errors at **convective scale** and subsequent upscale propagation sets the **intrinsic limit** of predictability (Lorenz 1969, Sun and Zhang, 2016)
- Estimate requires a **global model** with an accurate representation of **convection**, but CRM is too expensive
- Is a coarser resolution and a **convection scheme** good enoug?

Error growth case study with COSMO (Selz and Craig, 2015a+b)

2.8 km resolution,
no conv-scheme



28 km resolution,
Tiedtke conv.



- Conventional convection schemes do not amplify errors near the convective scale sufficiently → **overconfidence**

Errors in 500hPa geopot after 60h (color)

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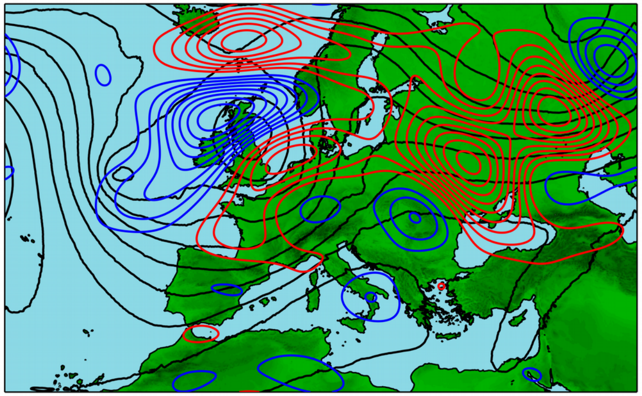

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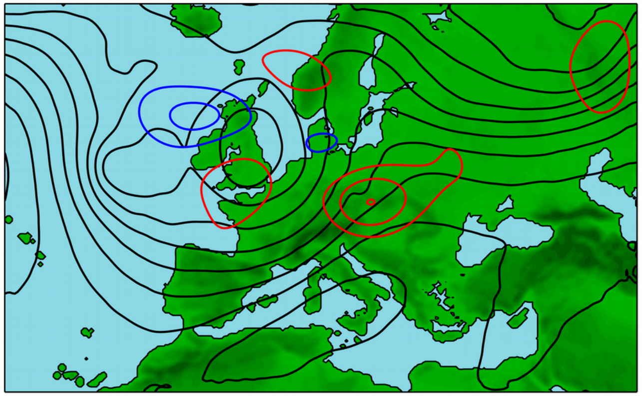
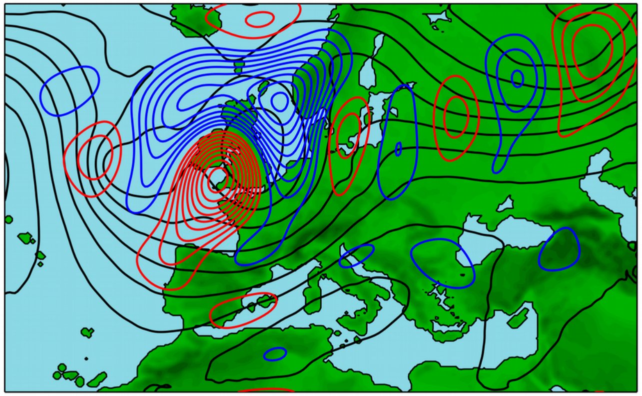


28 km resolution,
Plant-Craig stochastic conv.

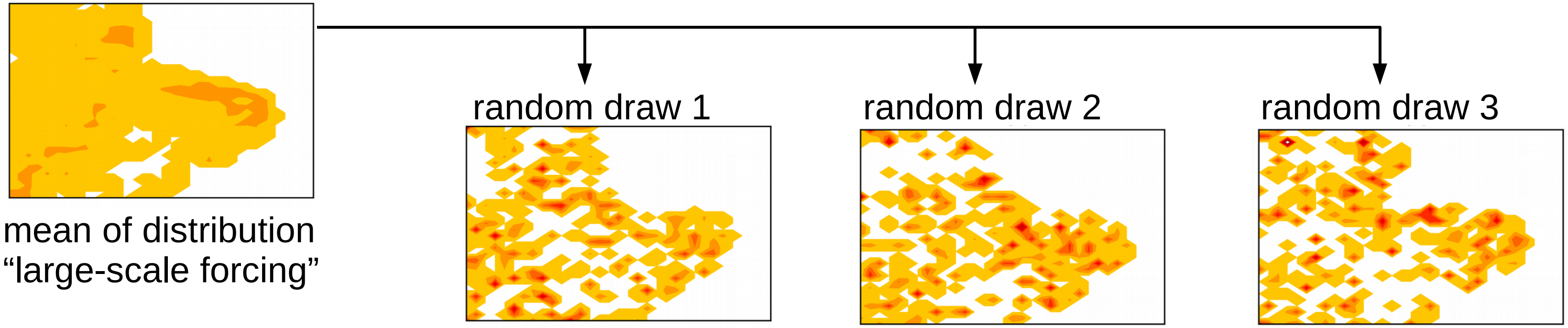


- Conventional convection schemes do not amplify errors near the convective scale sufficiently → **overconfidence**
- The Plant-Craig stochastic convection scheme showed **similar errors** than the convection-permitting reference run

Errors in 500hPa geopot after 60h (color)

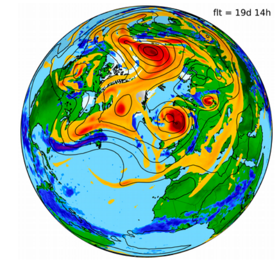
Plant-Craig scheme: basic idea

- Closure assumption determines the **mean of a distribution**
- Clouds are **drawn randomly** from this distribution
- **Ensemble of different realizations** (microstates) consistent with the large-scale forcing can be generated

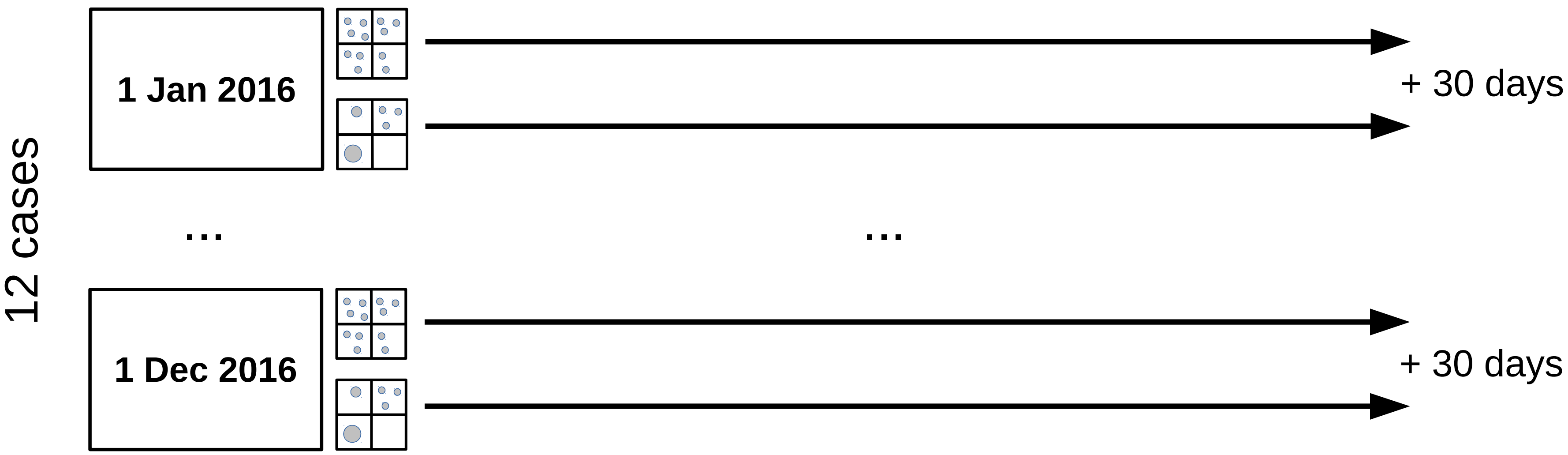


Experimental setup

Experimental - setup



- **Global ICON** simulations (40km resolution)
- **30 days** forecast lead time
- **12 recent cases** (1st of each month in 2016)
- **Plant-Craig convection scheme** to estimate convective-scale uncertainty
- IFS ensemble (50 members) as reference for current forecasting abilities

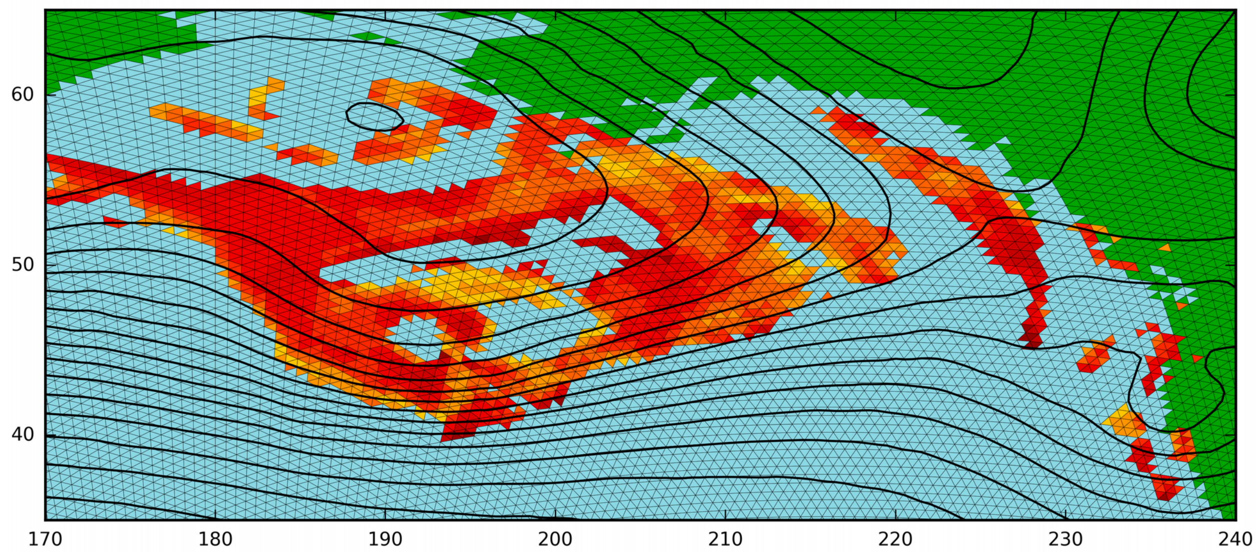


Currently: 2 members, planned: 5 members

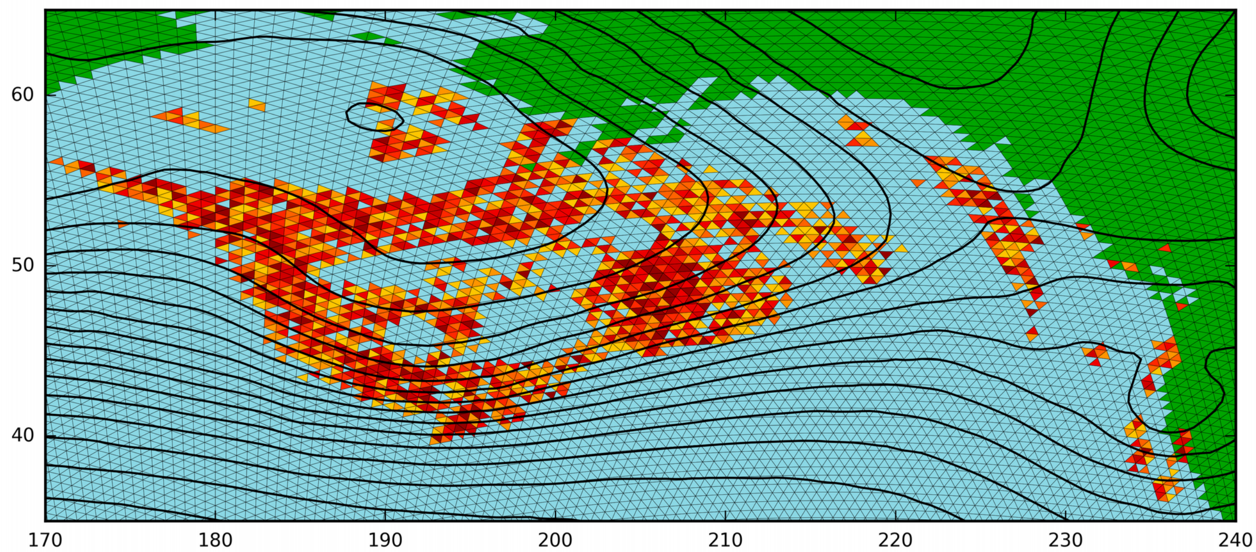
Results

Example: 1 Nov 2016, 01UT, Eastern North Pacific

Closure massflux



Realized massflux, Member #1



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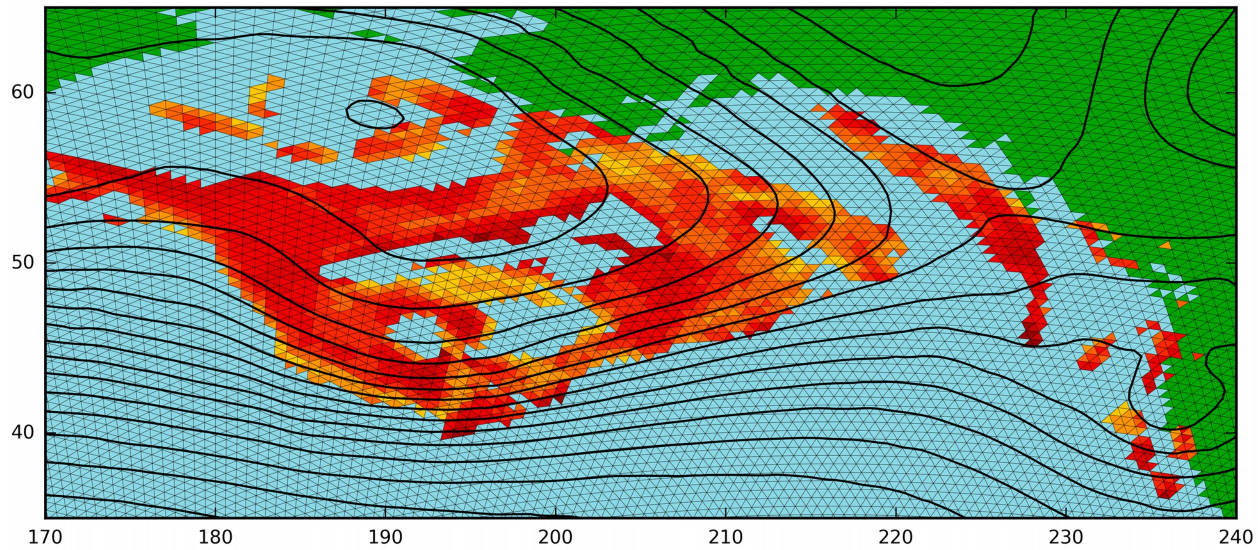
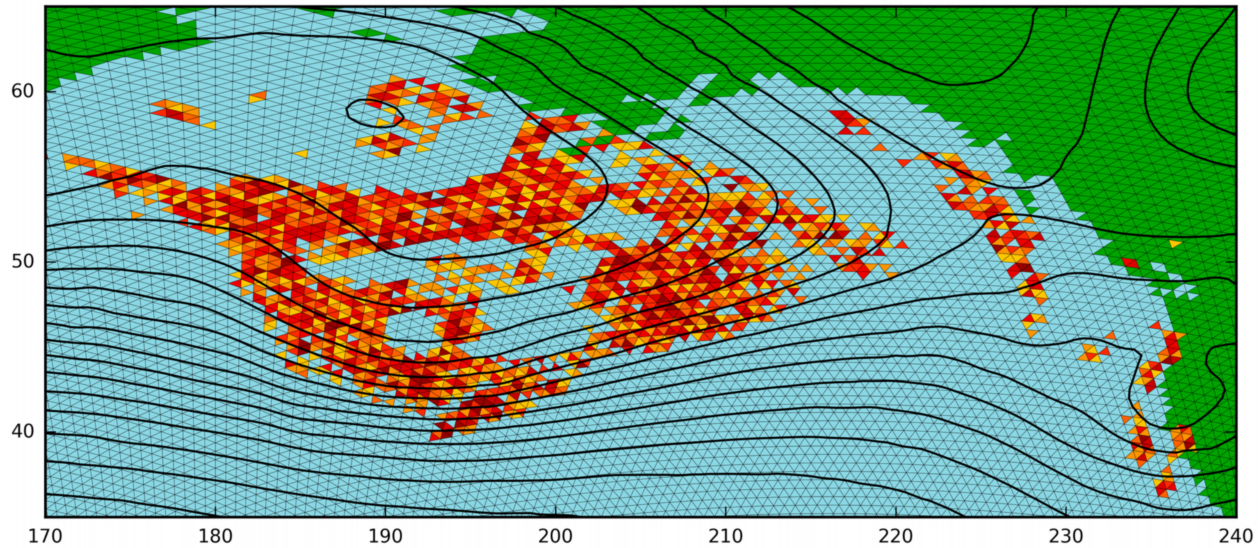
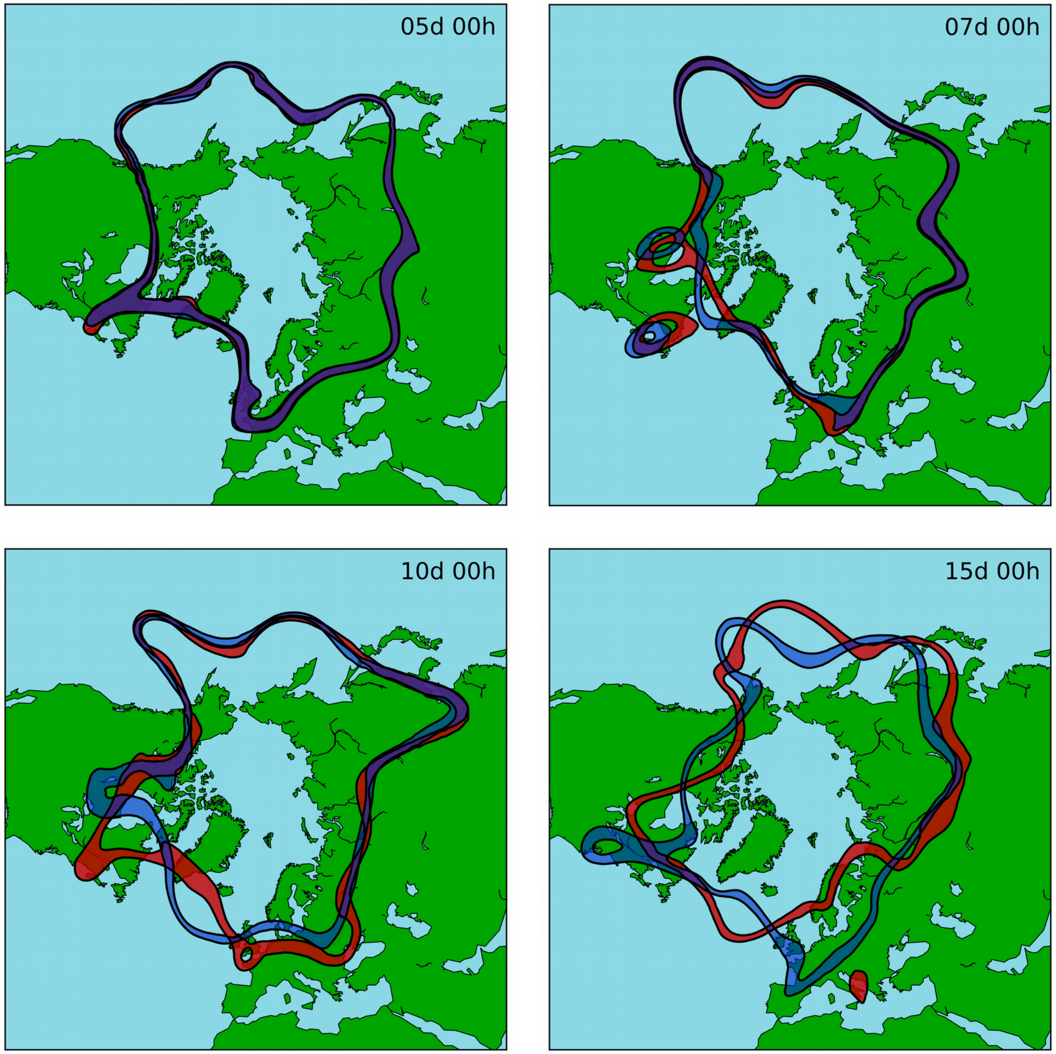


Realized massflux, Member #2



Example: 1 Nov 2016-run, 300 hPa geopotential



Mid-latitude error kinetic energy (EKE) at 300hPa

- Only mid-latitudes (40°-60°)
- Average over all 12 cases
- Average over both hemispheres

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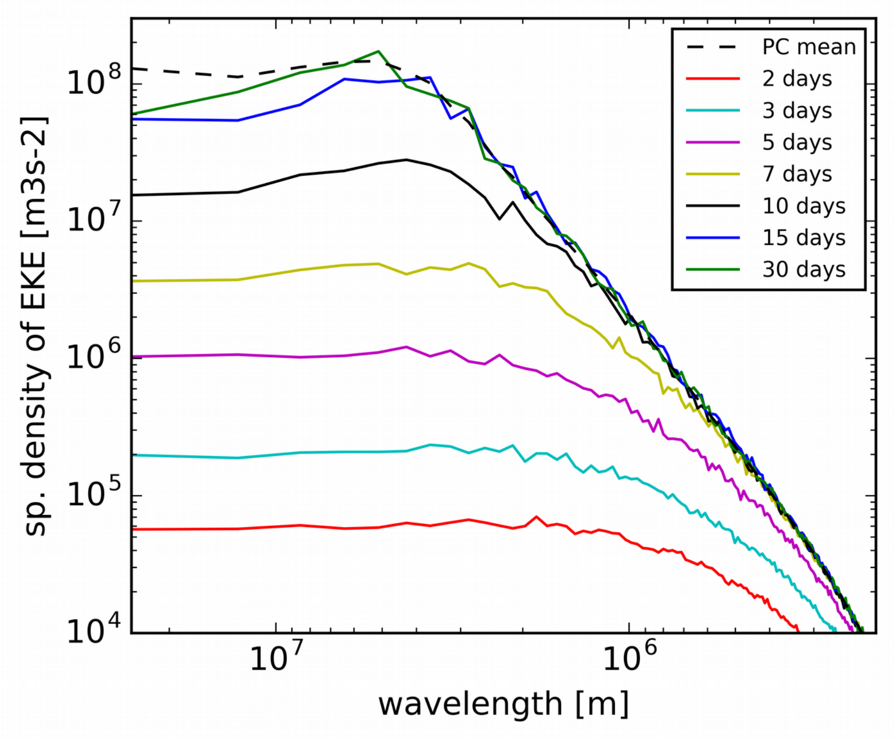
Plant-Craig-Ensemble



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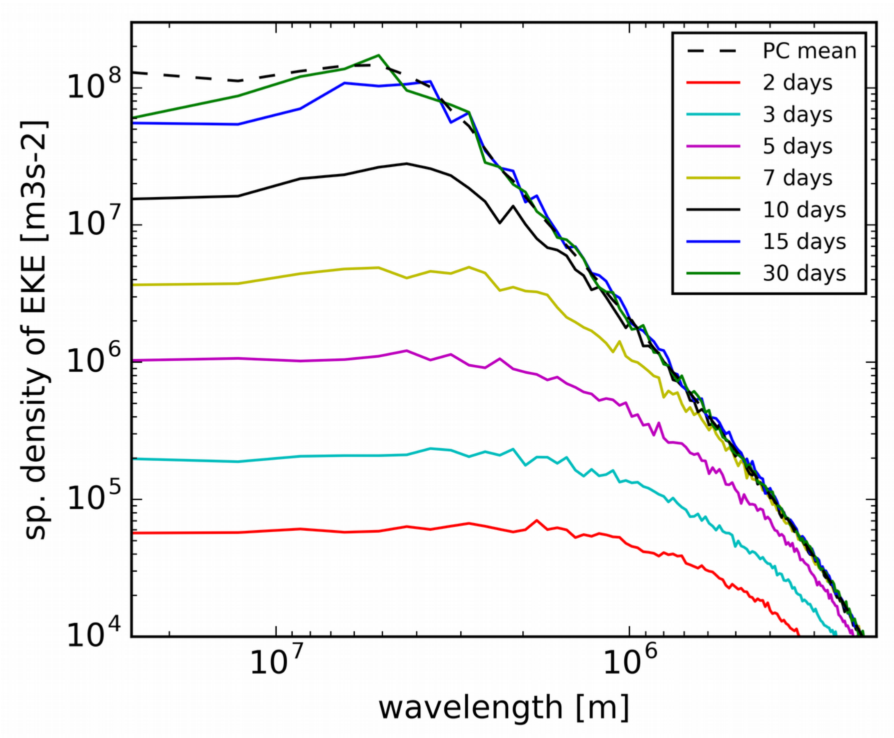
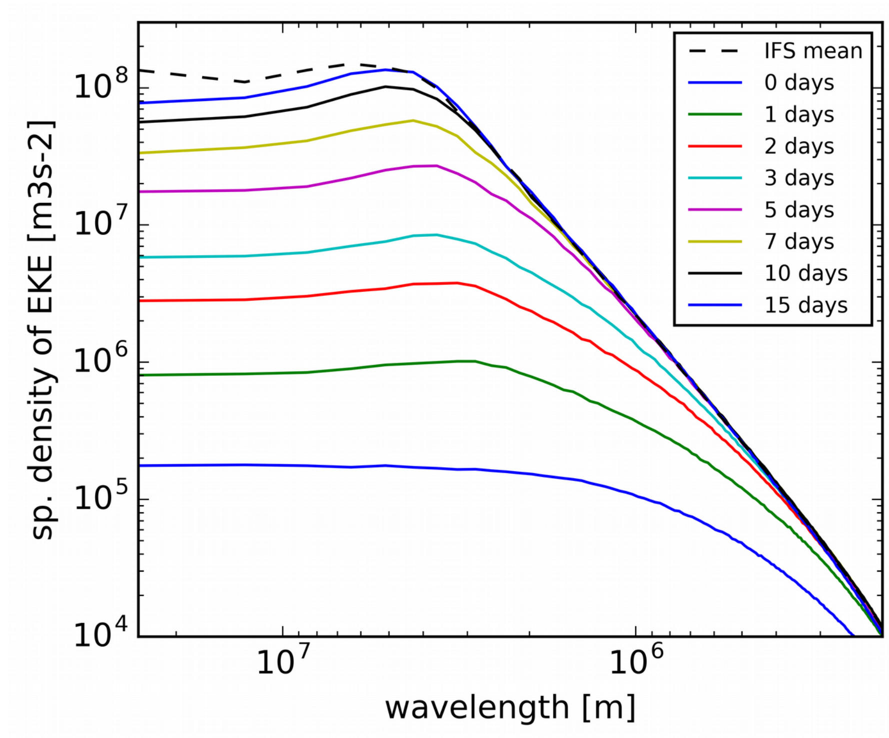


IFS-Ensemble



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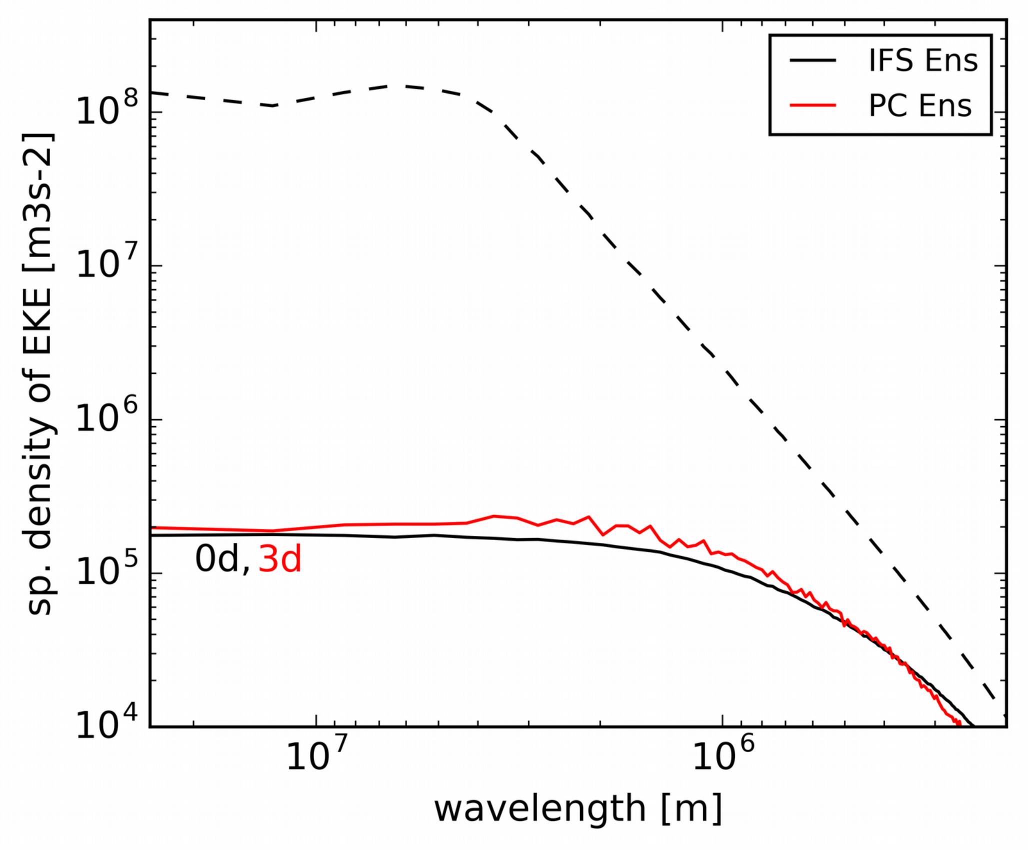

- IFS initial condition uncertainty compares to 3 days of upscale error growth

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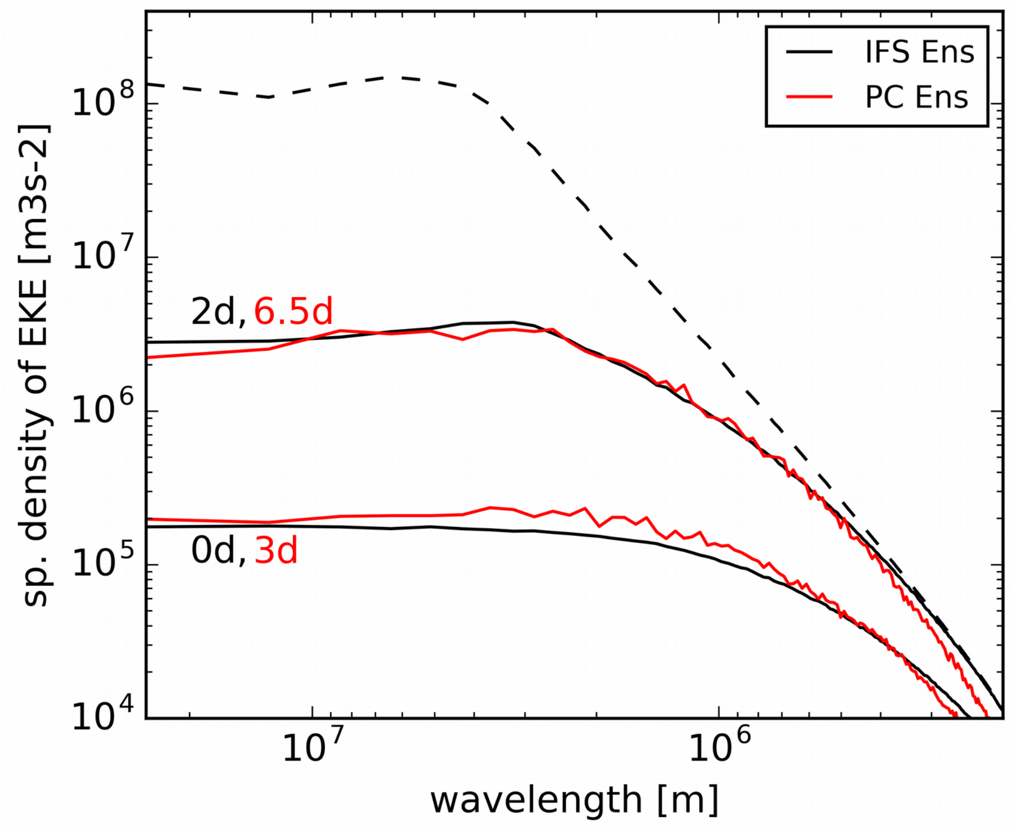

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- IFS error grows faster (inflation by singular vectors and SPPT)

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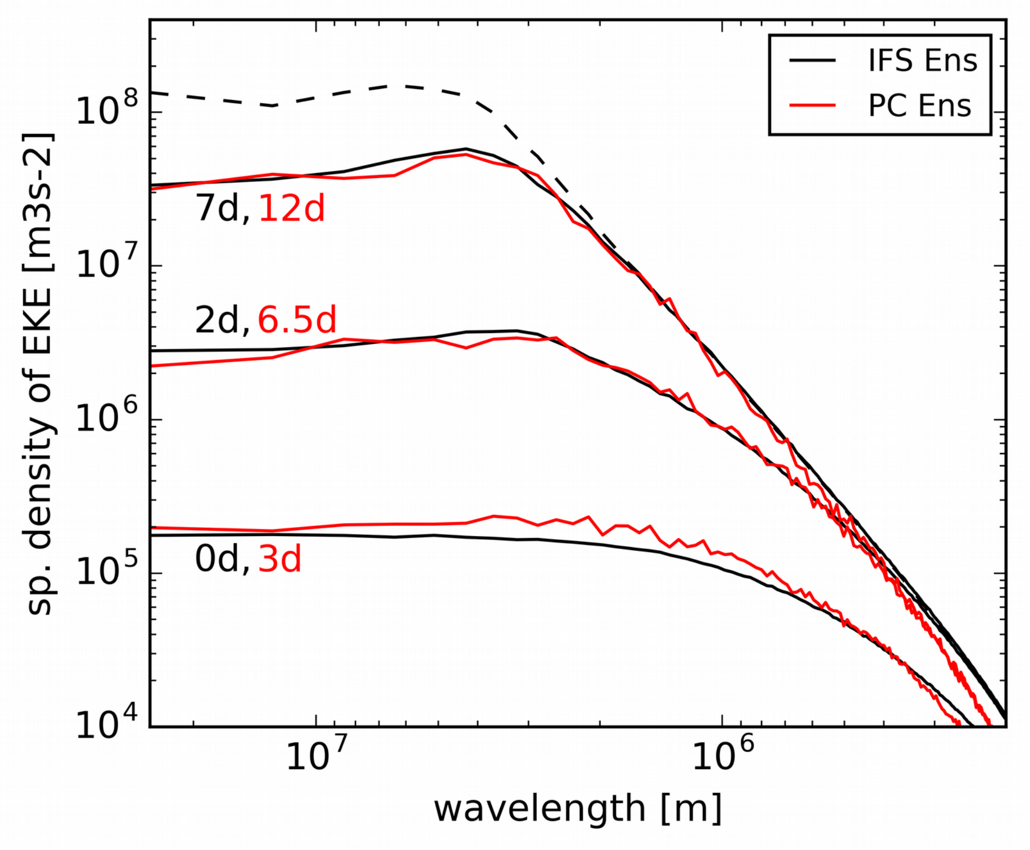

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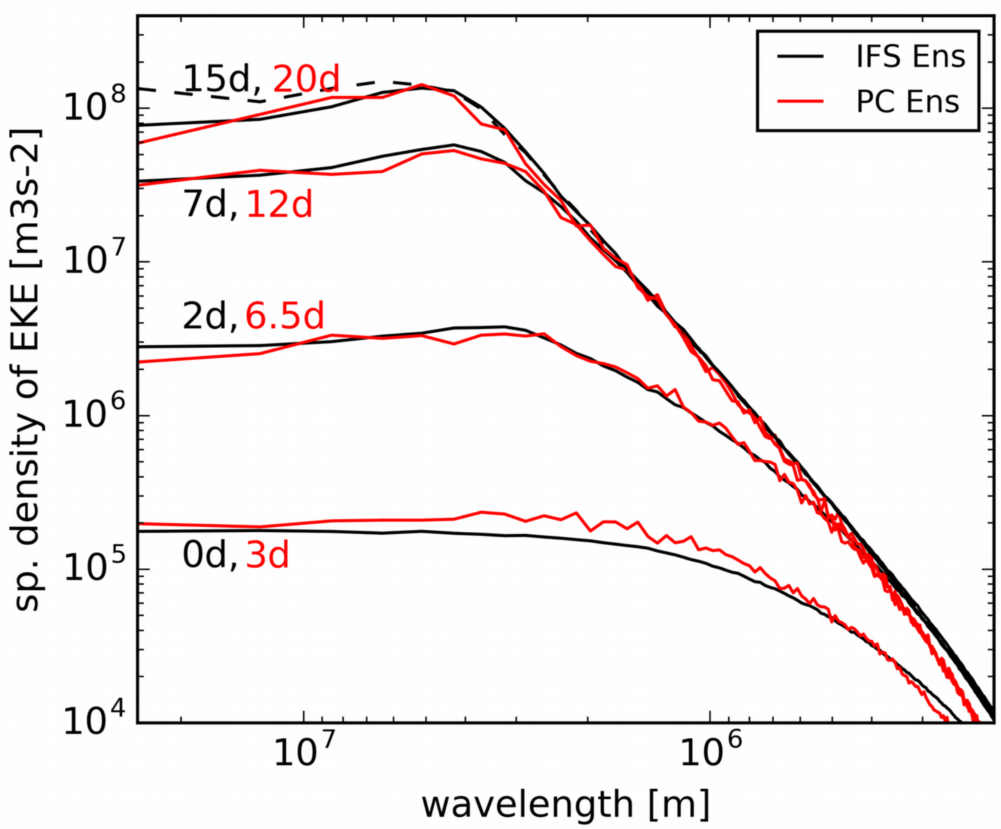
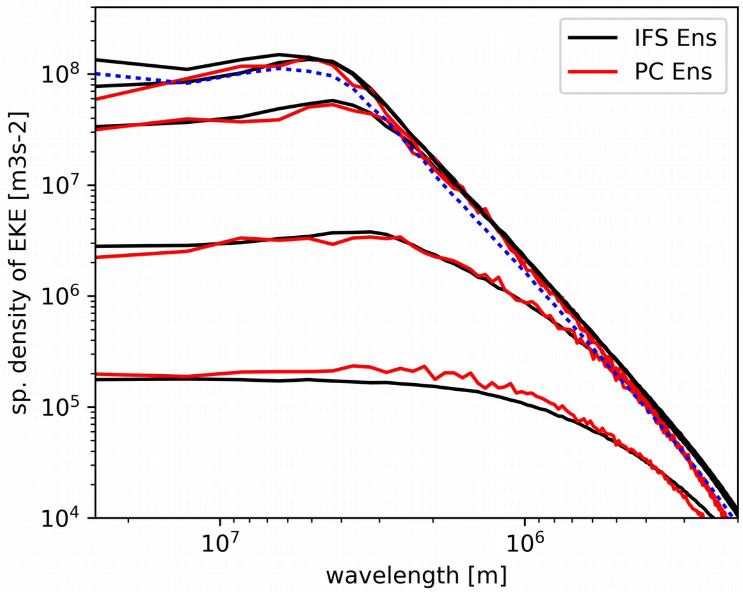


- IFS initial condition uncertainty compares to 3 days of upscale error growth
- IFS error grows faster (inflation by singular vectors and SPPT)
- Time gap extends to ca. 5-6 days

Predictability time from 75% threshold

Define a threshold (75%):



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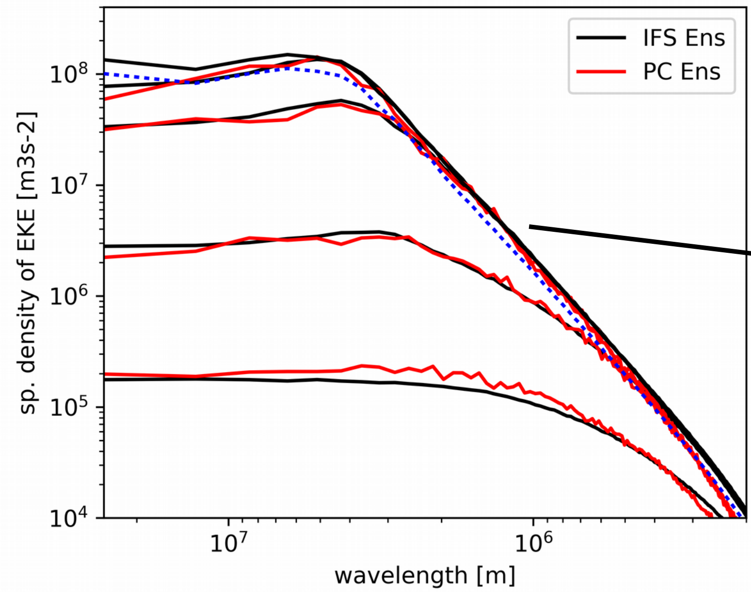
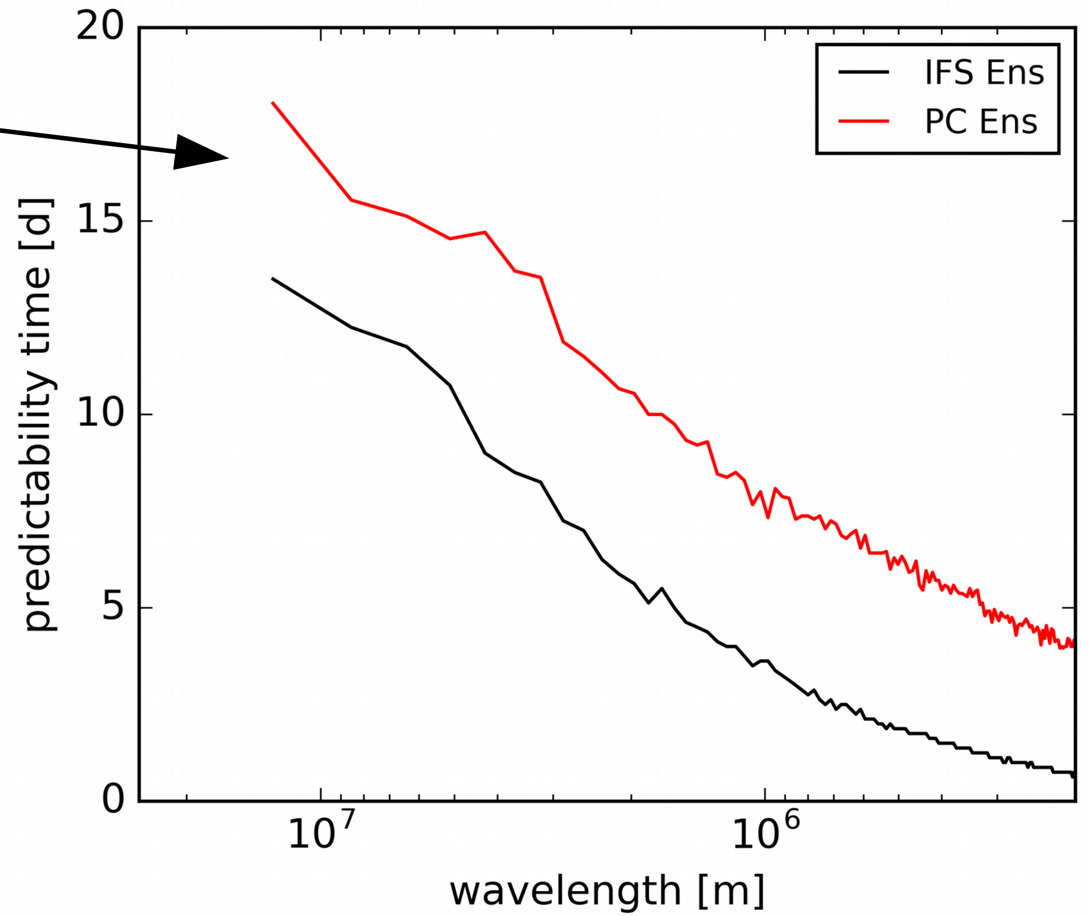


Predictability time for each scale



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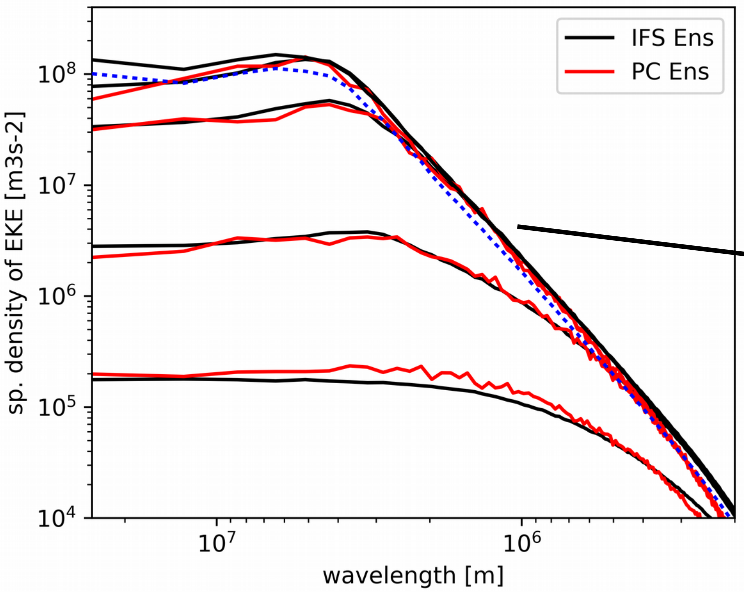

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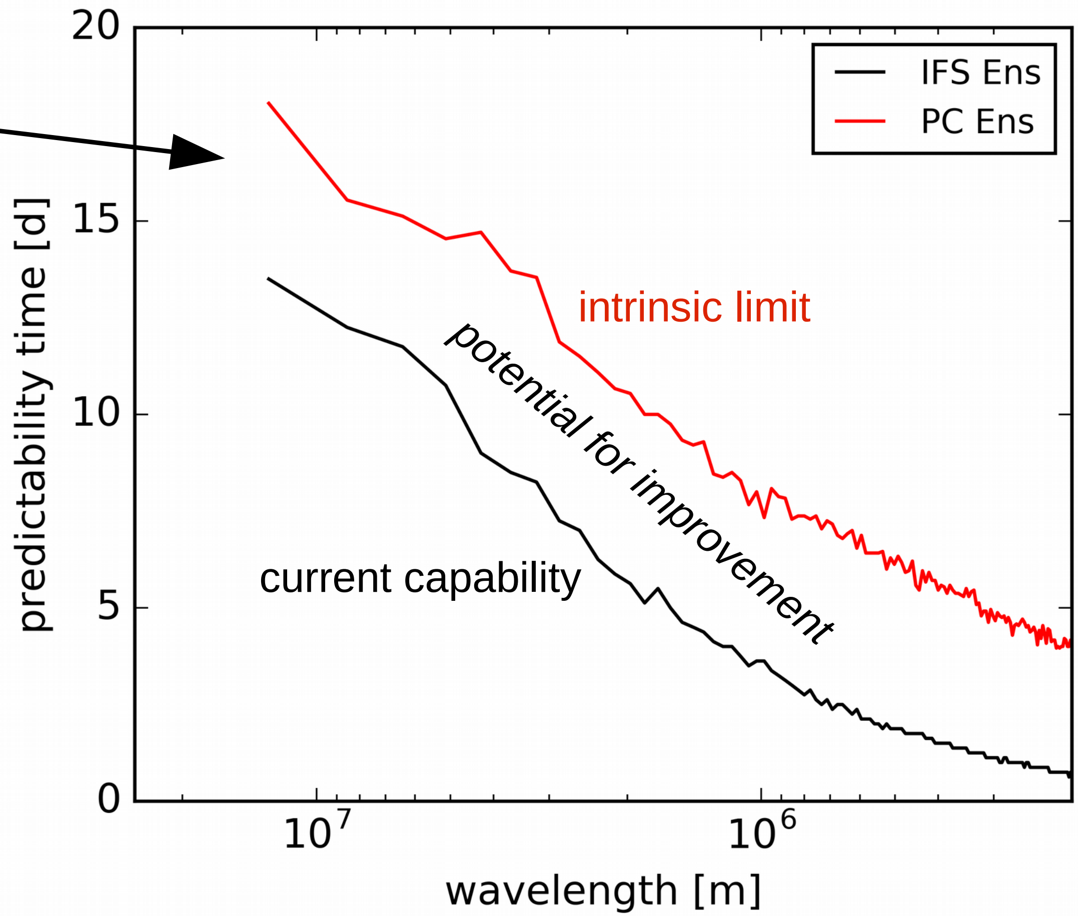
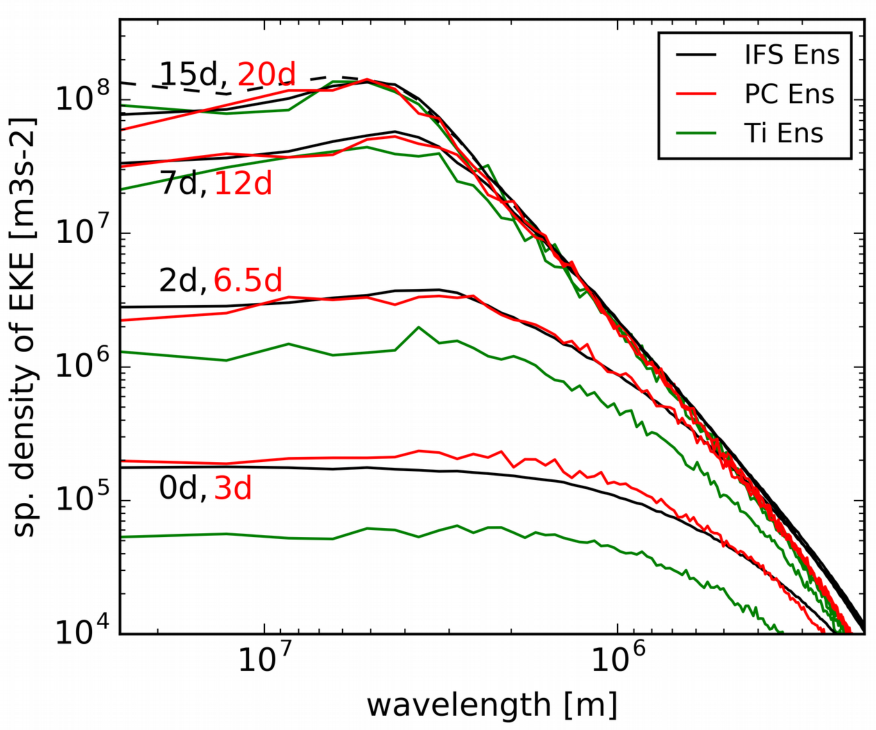


Tiedtke-ensemble for comparison

Error kinetic energy



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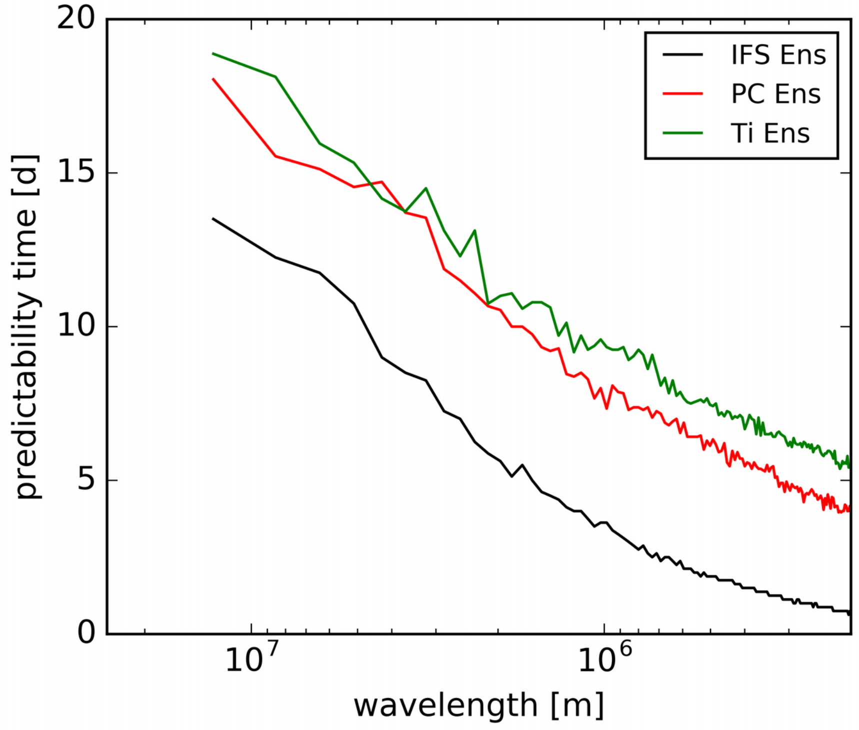

- Tiedtke scheme gives longer intrinsic predictability estimates (overconfidence)
- Difference gets smaller for large modes and long predictability times

Conclusions

- **Upscale propagation time** from convective scale to planetary scale has been estimated to **around 15-20 days**
- The error growth in the PC-ensemble estimates the **intrinsic predictability limit** since predictability of convection cannot be extended beyond its intrinsic limit of O(10 hours)
- Forecasts of current ECMWF forecasting system can be improved by **5-6 days** for the largest scales:
  3 days through **perfecting the initial conditions**
  2-3 days through **perfecting the model (?)**
- The **Tiedtke** convection scheme **overestimates** the intrinsic predictability at Mesoscale and synoptic scale but not (much) at planetary scale

Generalization of pairwise error measures for an ensemble

Difference Total Energy

$$(u_1-u_2)^2 \longrightarrow \frac{1}{N^2-N}\sum_{i\neq j}(u_i-u_j)^2$$

$$=\frac{2}{N-1}\sum_i (u_i-\bar{u})^2=2\cdot Var(u)$$

$$DTE=Var(u)+Var(v)+\frac{c_p}{T_r}Var(T)$$

Error Kinetic Energy

$$\frac{1}{2}|\tilde{u}_1-\tilde{u}_2|^2 \longrightarrow \frac{1}{N^2-N}\sum_{i\neq j}\frac{1}{2}|\tilde{u}_i-\tilde{u}_j|^2$$

$$=\frac{1}{N-1}\sum_i|\tilde{u}_i-\bar{\tilde{u}}|^2=\frac{N}{N-1}\left(\frac{1}{N}\sum|\tilde{u}_i|^2-|\frac{1}{N}\sum\tilde{u}_i|^2\right)$$