Case study reproducibility in a convection-permitting WRF multi-physics ensemble: the role of internal variability

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CGL2015-66583-R
BES-2016-078158
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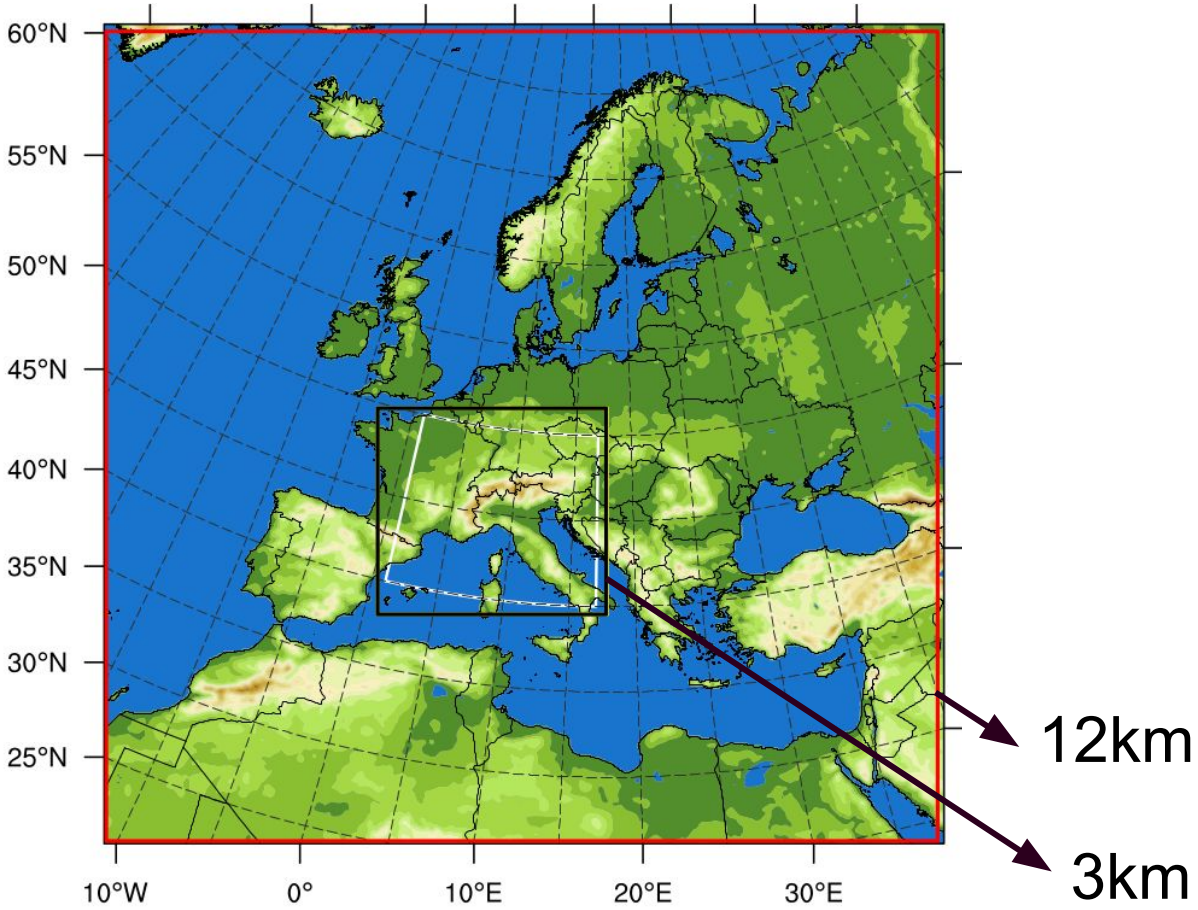
Origin of the study

CORDEX FPS on “Convective phenomena at high resolution over Europe and the Mediterranean”



Coppola et al. (2018) “A first-of-its-kind multi-model convection permitting ensemble for investigating convective phenomena over Europe and the Mediterranean”. *Climate Dynamics*.

Origin of the study

CORDEX FPS on “Convective phenomena at high resolution over Europe and the Mediterranean”

Preliminary experiment.

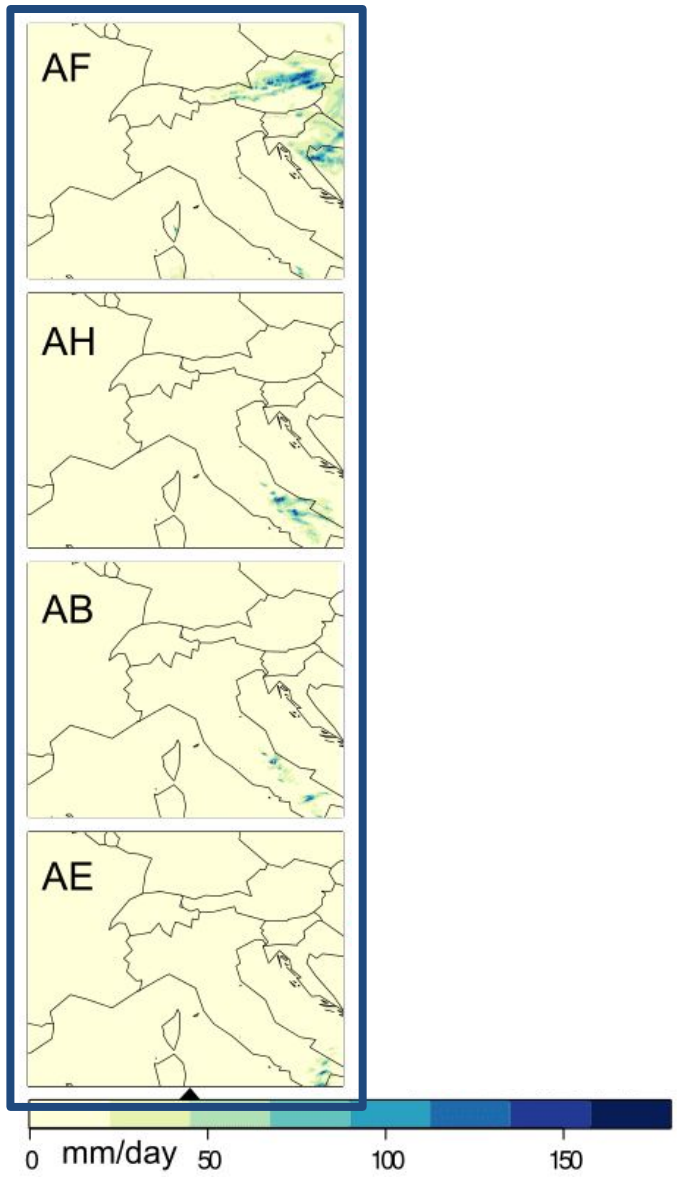
Weather-like vs Climate mode. Assessing three heavy precipitation events:

- “Foehn”: 2-7 November 2014
- “IOP 16”: 23-28 October 2012
- “Austria”: 20-27 June 2009

Coppola et al. (2018) “A first-of-its-kind multi-model convection permitting ensemble for investigating convective phenomena over Europe and the Mediterranean”. *Climate Dynamics*.

WRF Multi-physics ensemble

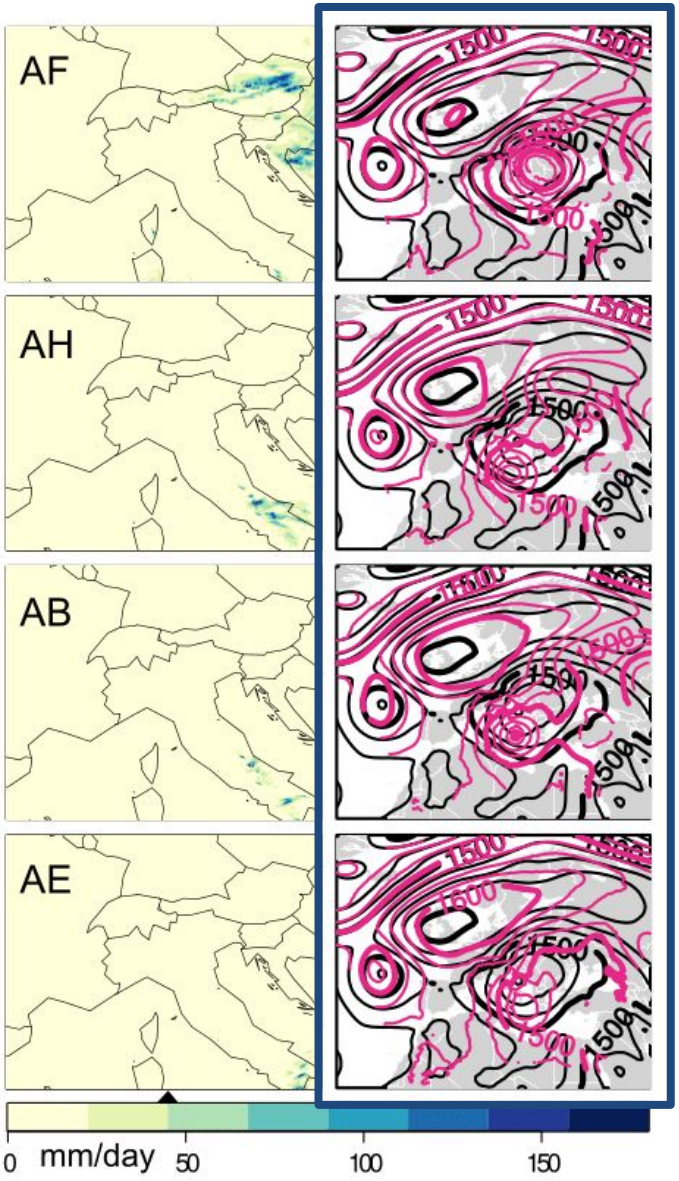
Convection-permitting domain



Large discrepancies between individual ensemble members

WRF Multi-physics ensemble

Parameterized domain

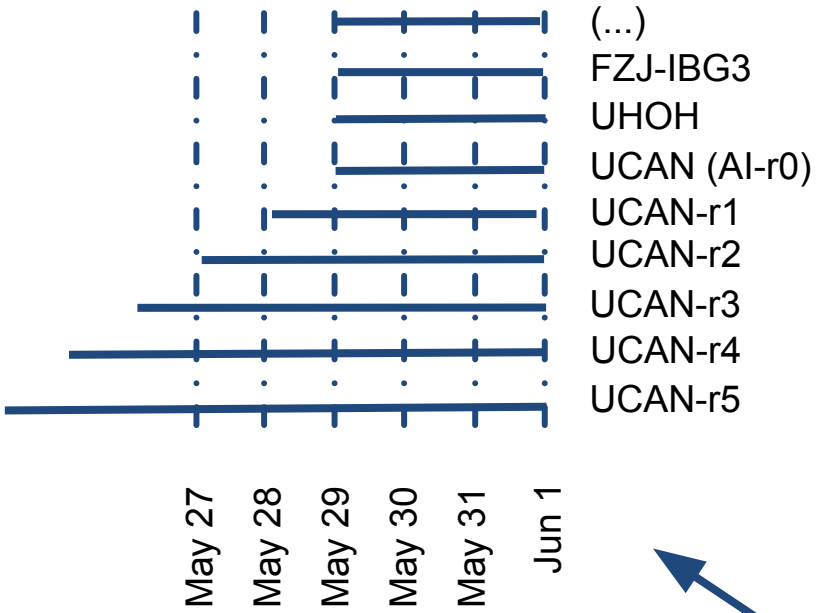


Large discrepancies between individual ensemble members

Differences on the simulated synoptic situation:

Some members reproducing as observed, others simulating an isolated low-pressure system

Multi-Initial conditions ensemble

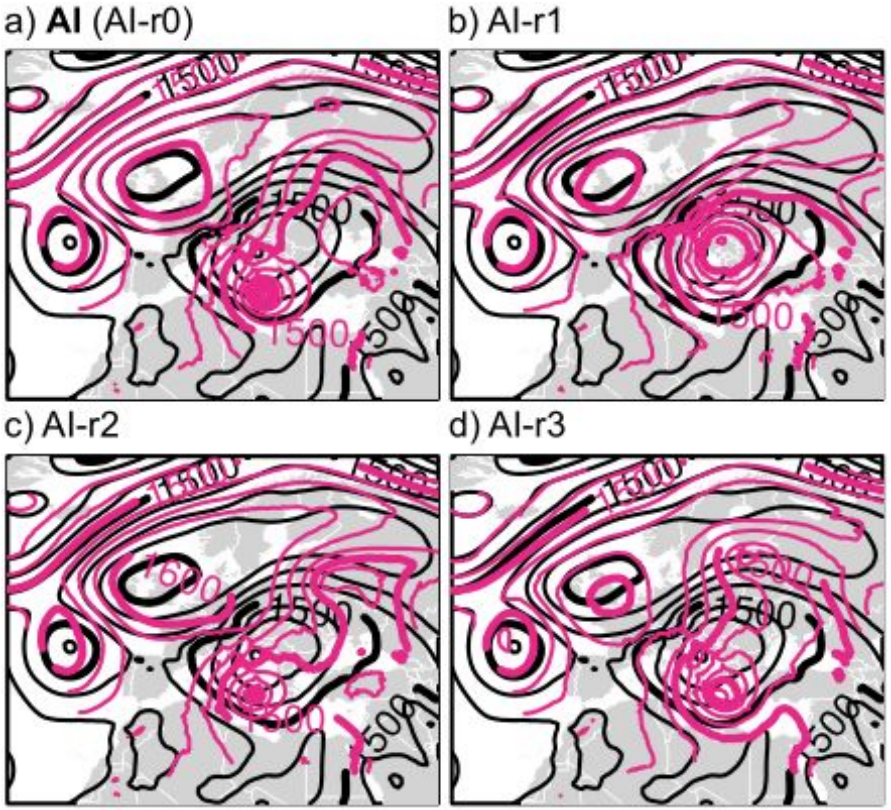


WRF3.8.1

- -AUTH
- -BCCR
- -FZJ-IBG3
- -IDL
- -IPSL
- -NOA
- -UHOH
- -UCAN
  - -r0
  - -r1
  - -r2
  - -r3
  - -r4
  - -r5

Internal variability uncertainty.
Lagged method.

Multi-Initial conditions ensemble



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Again, by only perturbing initial conditions, some members reproduce the circulation as observed, others develop an isolated low pressure system

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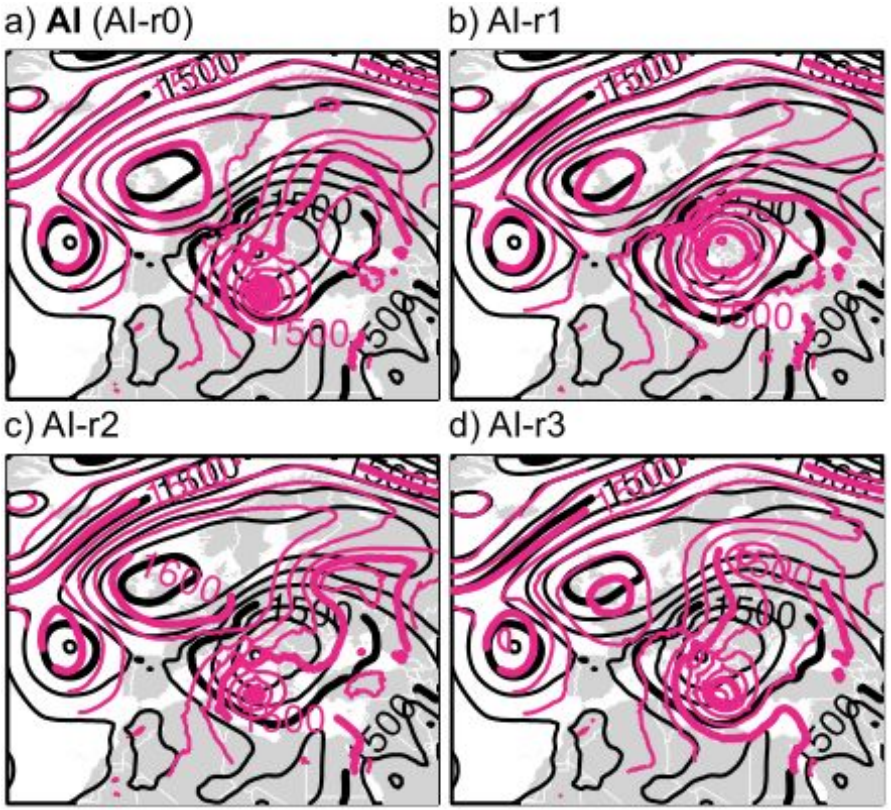

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Internal variability

Methodology

Analysis of the uncertainties
(*Alexandru et al., 2007*)

Inter-member variance:

$$\sigma_X^2(i,j,k,t) = \frac{1}{M-1}\sum_{m=1}^{M}\left(X(i,j,k,t,m) - \langle X\rangle(i,j,k,t)\right)^2$$

X: variable
i,j,k: spatial coordinates
M: total number of ensemble members
t: time
m: ensemble member

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Inter-member variance:

Ensemble mean

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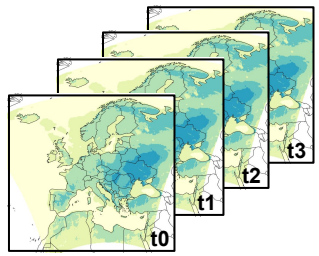

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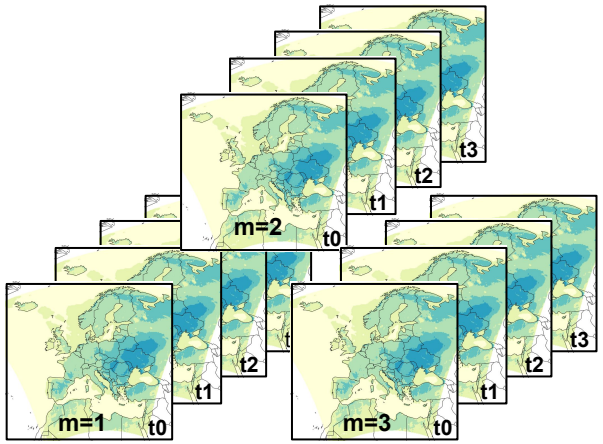

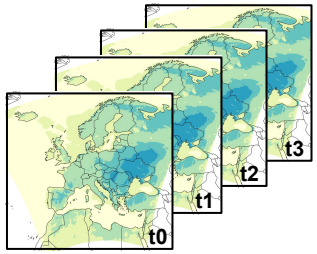

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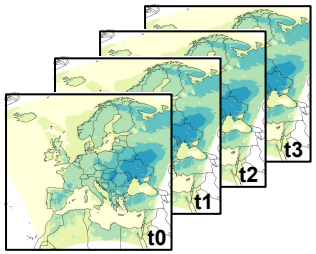

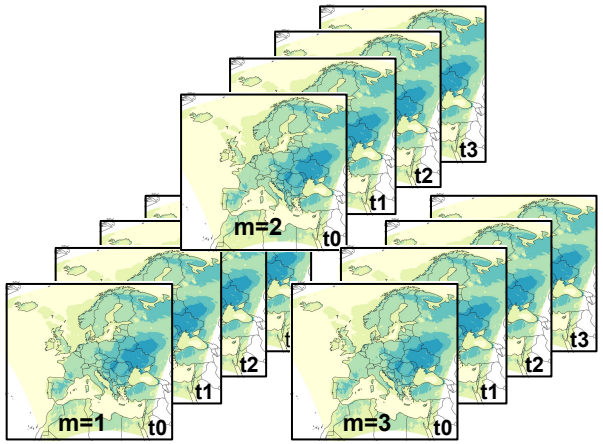

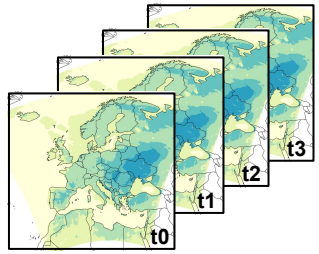

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X: variable
m: ensemble member
M: total number of ens. members
I,J: number of grid cells
t: time
i,j,k: spatial coordinates
N: number of time steps

Spatial distribution of the uncertainty
(Time average)

$$\overline{\sigma_X^2}^{t}(i,j,k) = \frac{1}{N}\sum_{t=1}^{N}\sigma_X^2(i,j,k,t)$$

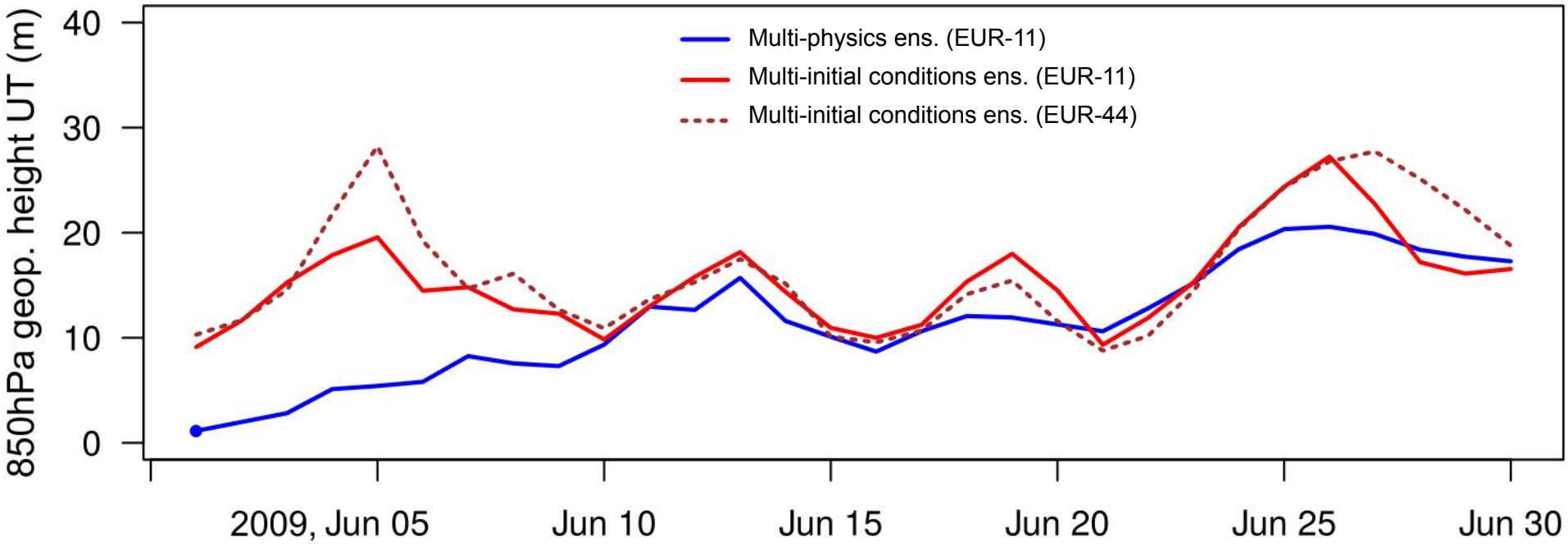
Time evolution of the uncertainty
(Domain average)

$$\overline{\sigma_X^2}^{xy}(k,t) = \frac{1}{I\times J}\sum_{i=1}^{I}\sum_{j=1}^{J}\sigma_X^2(i,j,k,t)$$

Time evolution of the uncertainties

One-month uncertainties

Geopotential height at 850hPa



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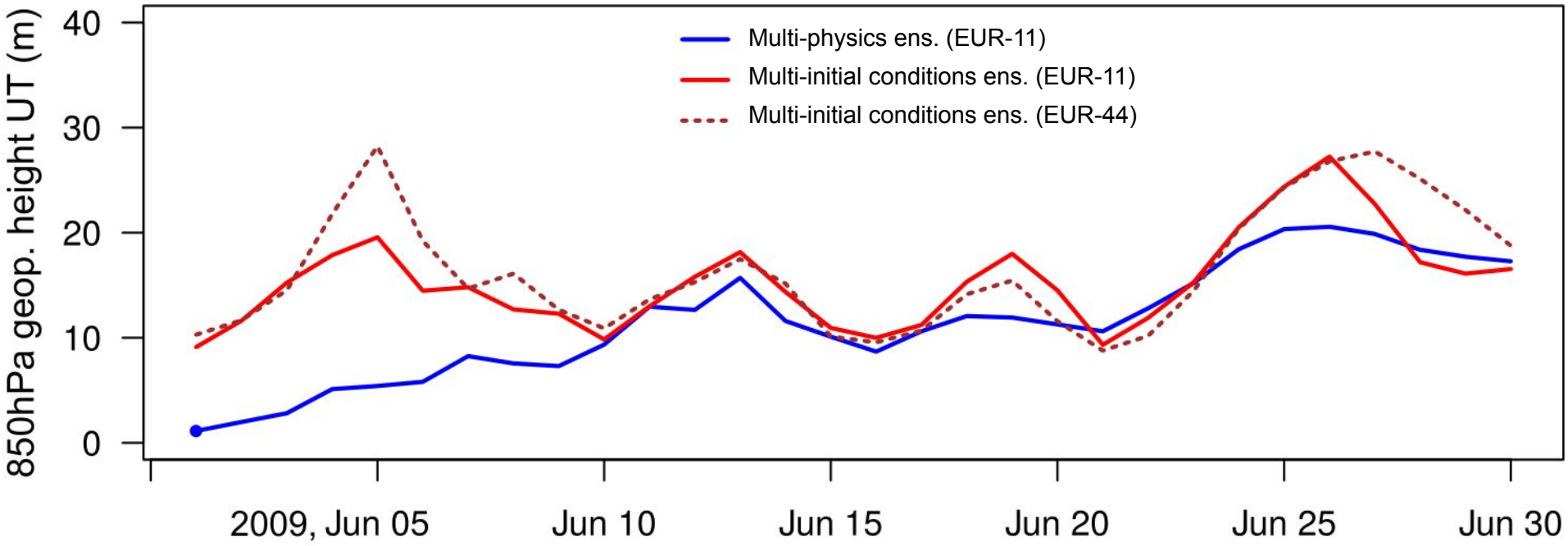
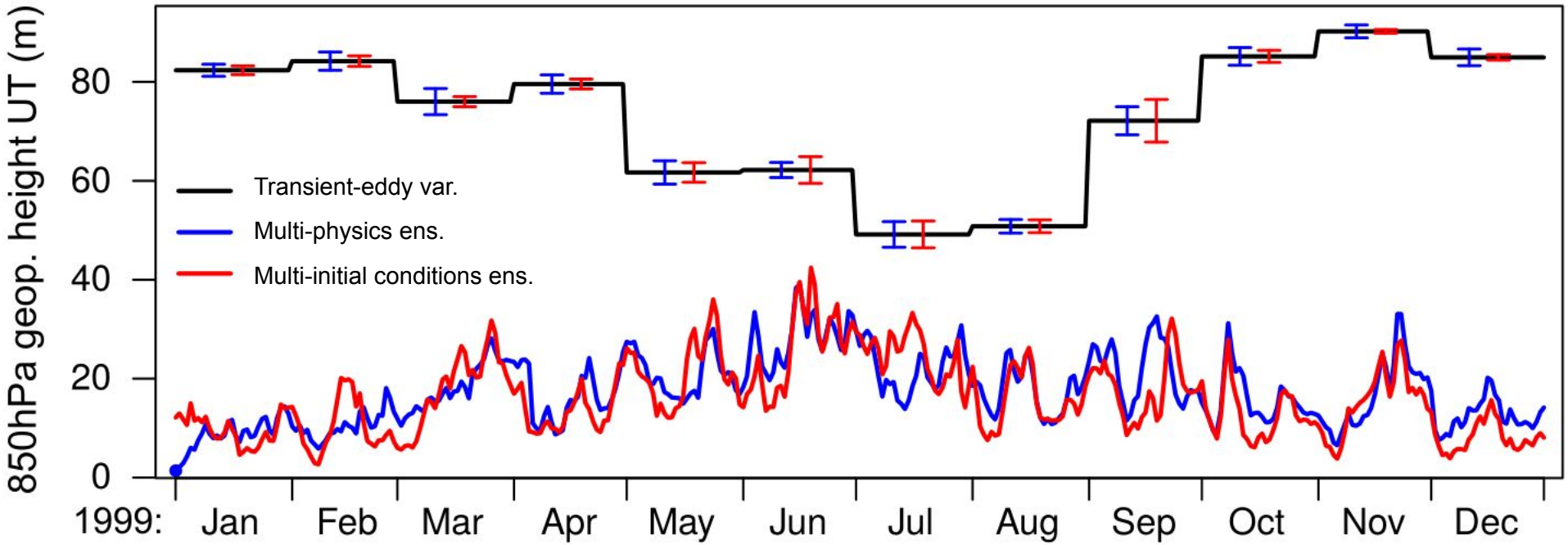


Physical parameterizations (**multi-physics ensemble**) introduce smaller differences among members than those from the Internal variability (**multi-initial conditions ensemble**)

Time evolution of the uncertainties

One-year uncertainties

Geopotential height at 850hPa



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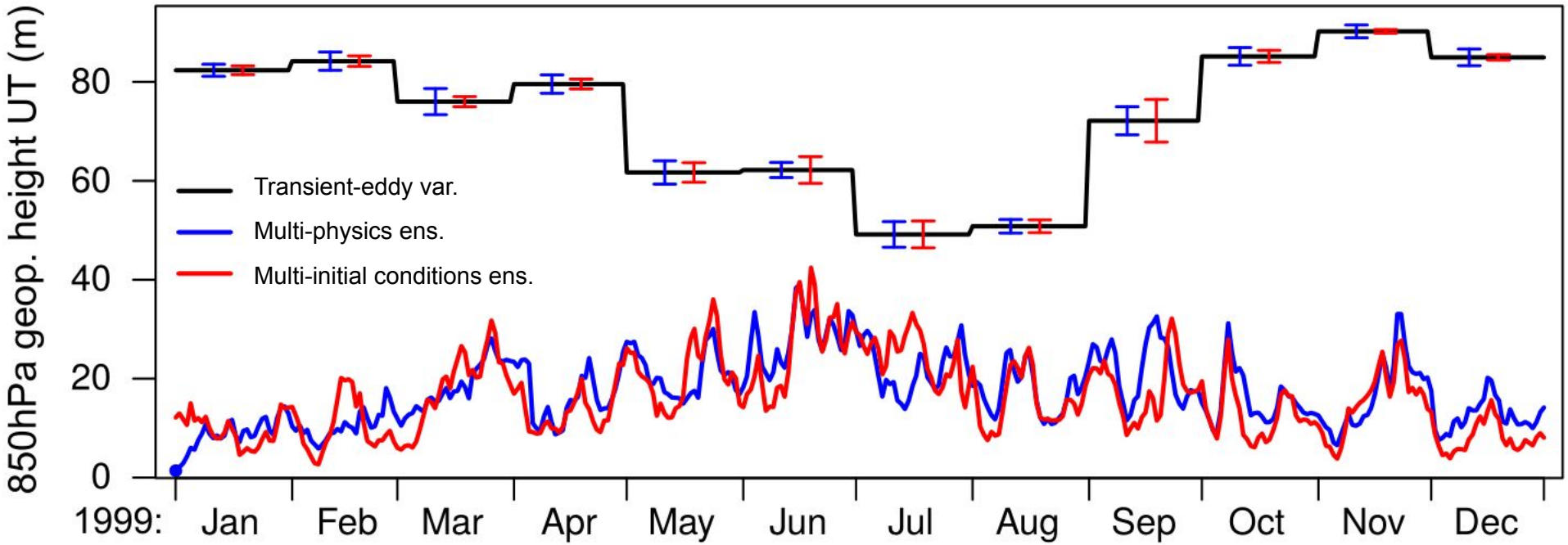

Differences introduced by physical parameterizations are amplified and assimilated into the system as perturbations of initial conditions

Time evolution of the uncertainties

One-year uncertainties

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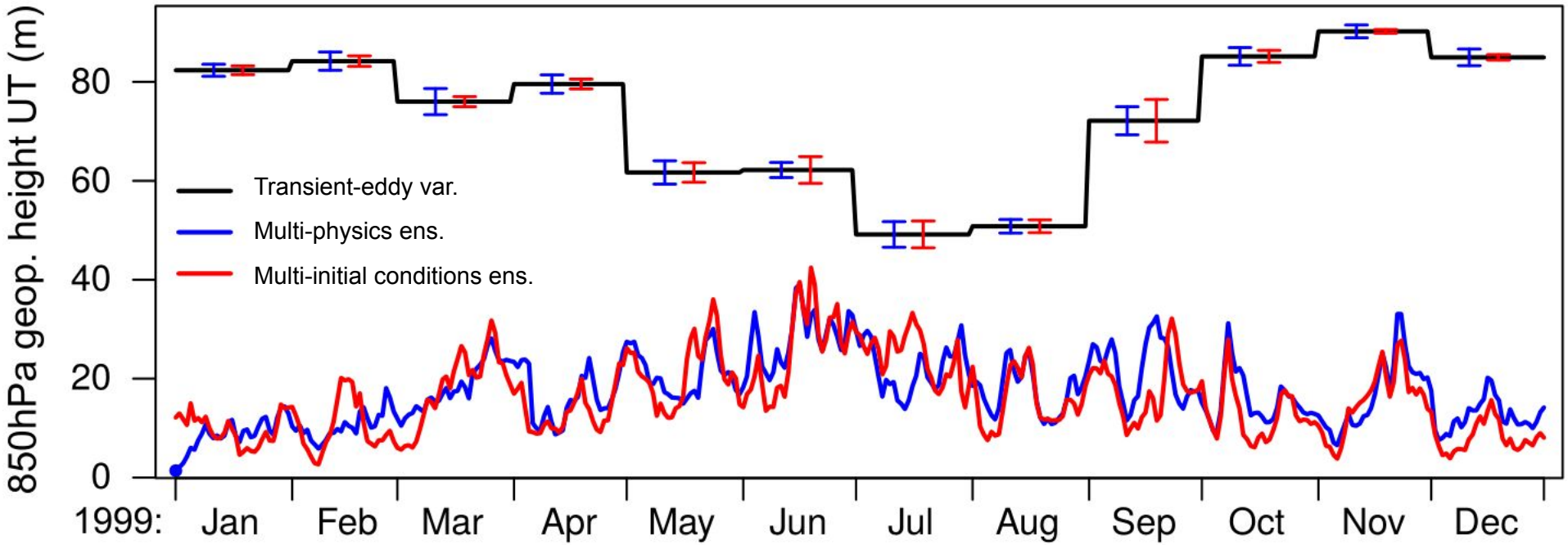

Differences introduced by physical parameterizations are amplified and assimilated into the system as perturbations of initial conditions

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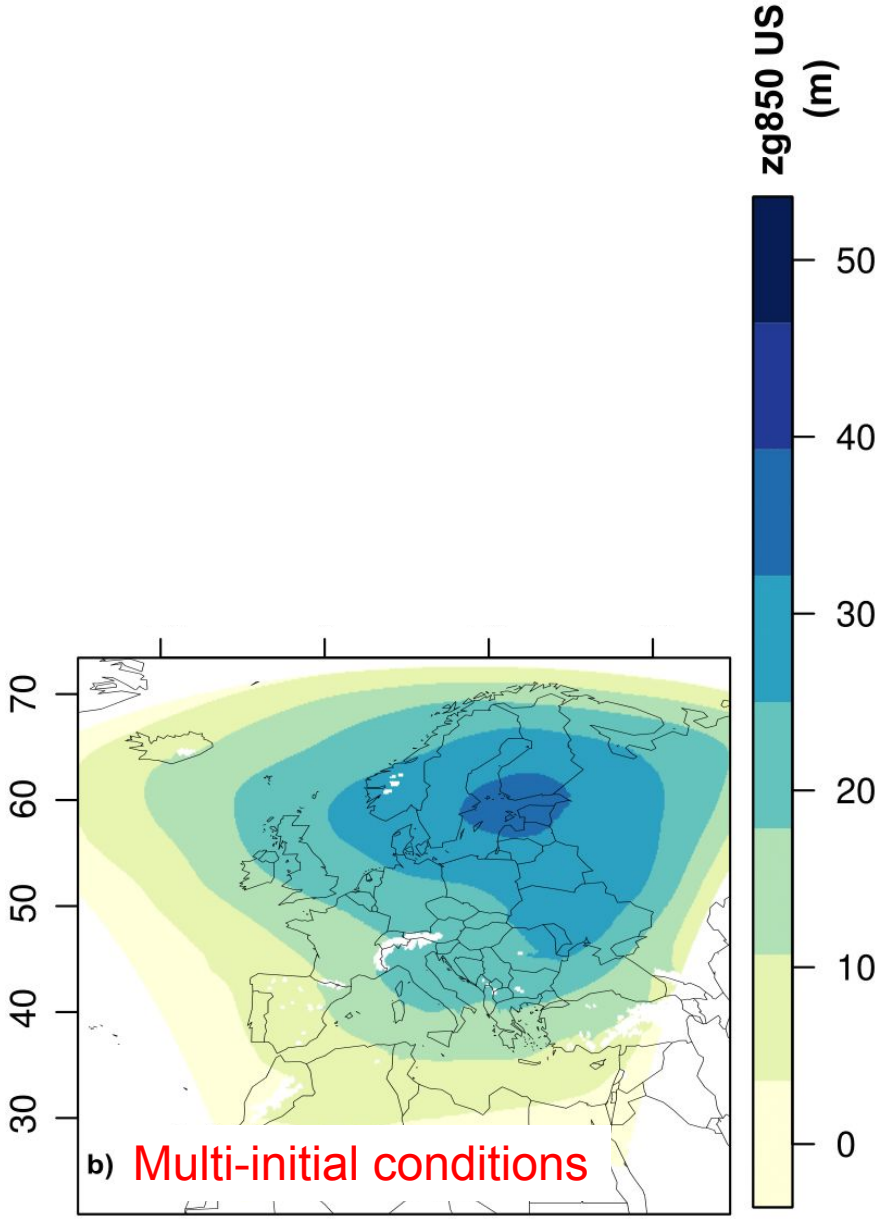
Multi-physics uncertainty could be explained by the **Internal Variability**

Spatial distribution of the uncertainties



One-year uncertainties
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$$\overline{\sigma_X^2}^t(i,j,k) = \frac{1}{N}\sum_{t=1}^{N}\sigma_X^2(i,j,k,t)$$

In space, similar patterns. Only **multi-physics uncertainty** slightly larger than **Internal variability**

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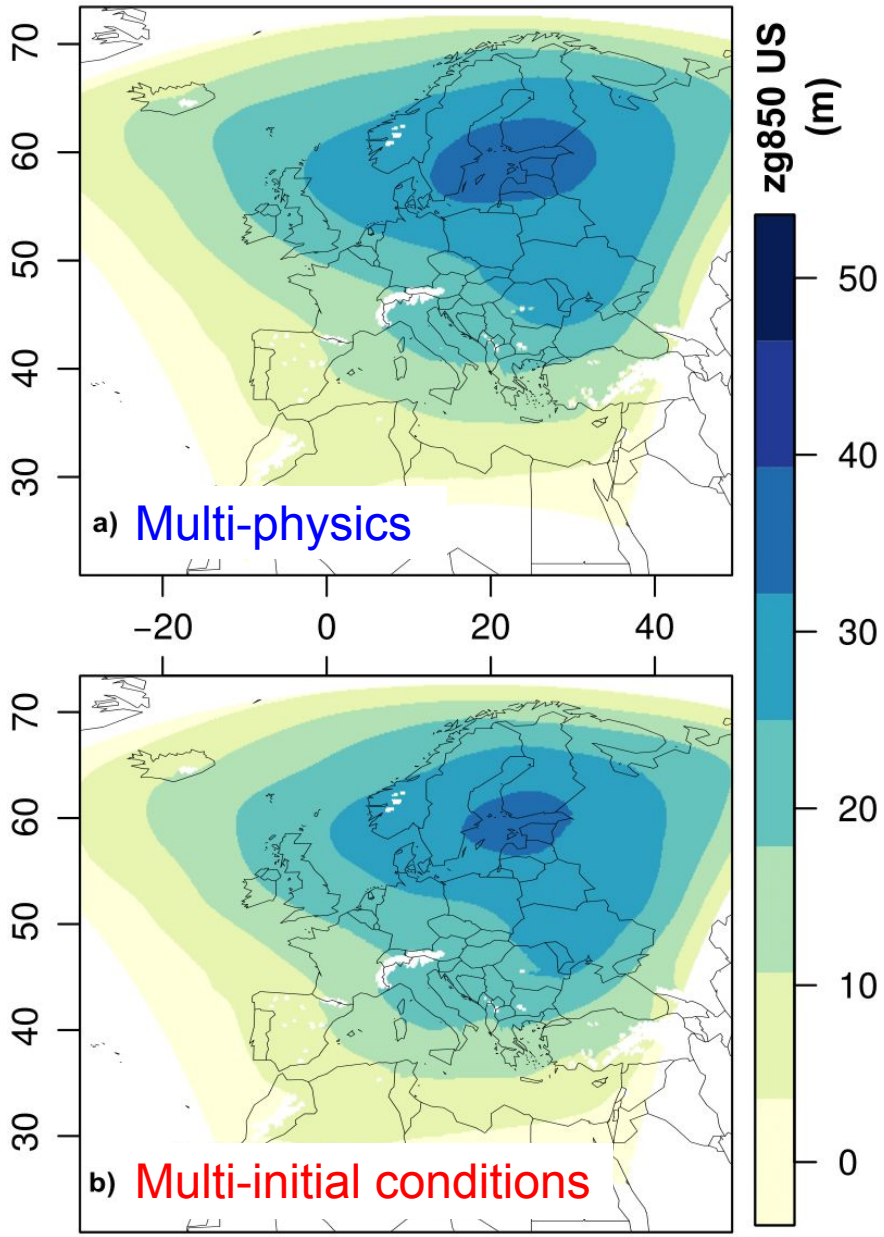

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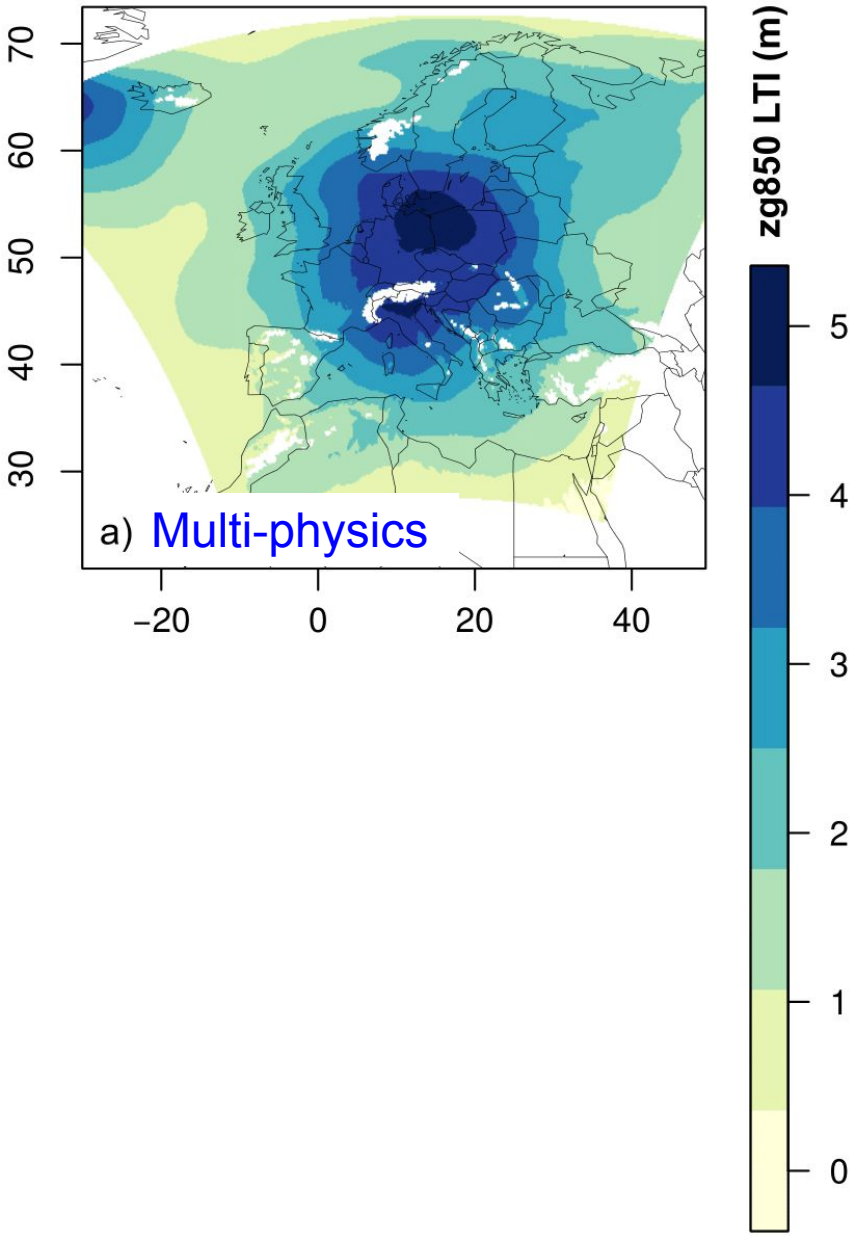
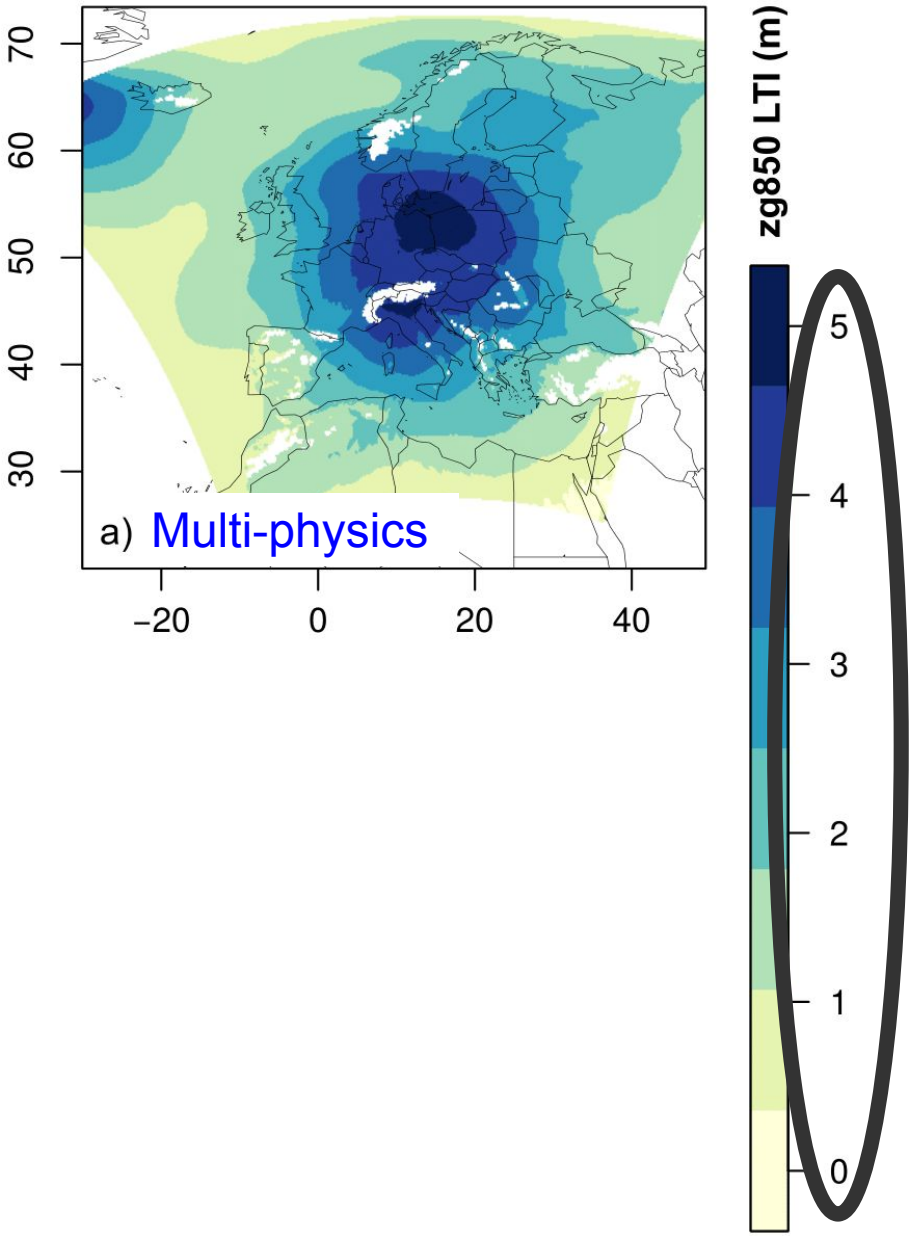
Long-term impact (Climatologies)



Geopotential height at 850hPa
Long-term systematic effect of physical parameterizations

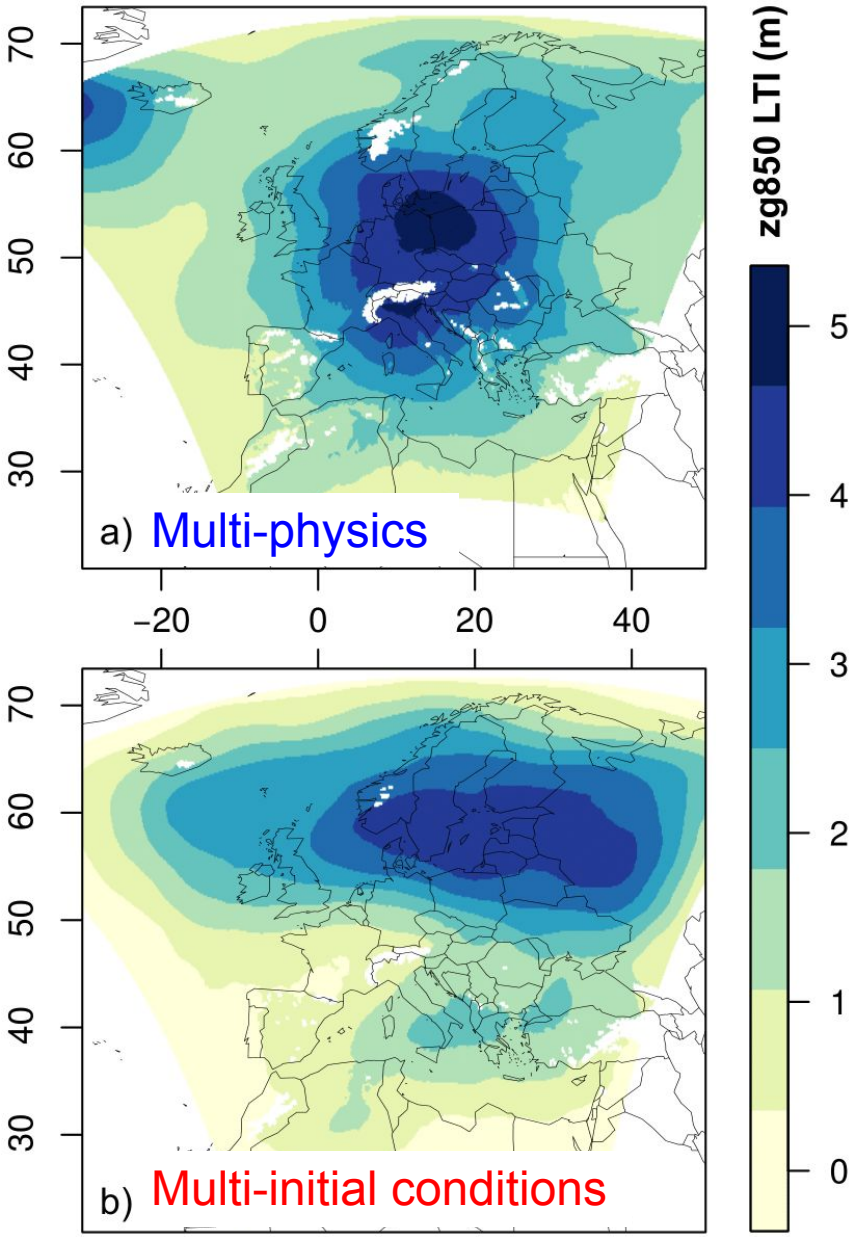
Long-term impact (Climatologies)



Geopotential height at 850hPa
Long-term systematic effect of physical parameterizations

Careful: order of magnitude smaller

Long-term impact (Climatologies)



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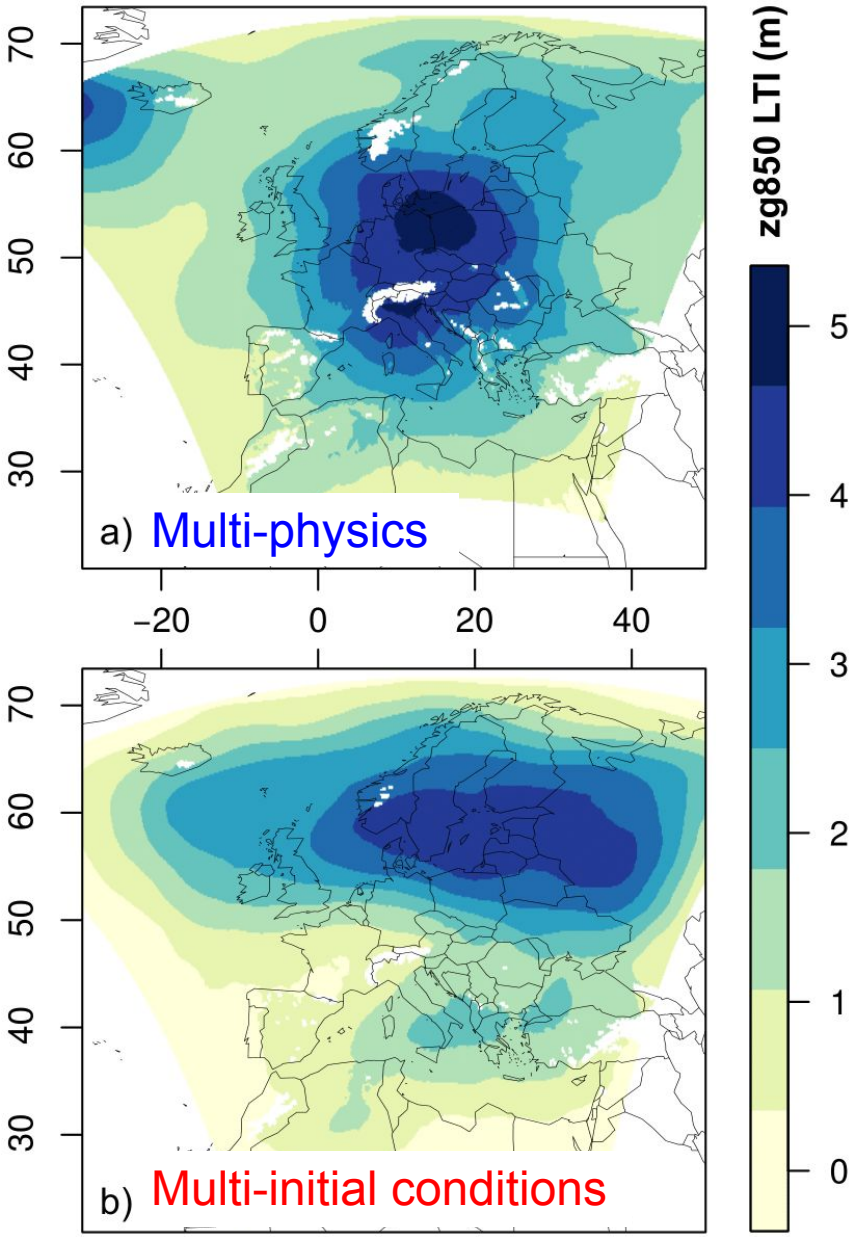

Geopotential height at 850hPa
Long-term systematic effect of physical parameterizations

Different patterns but comparable magnitude

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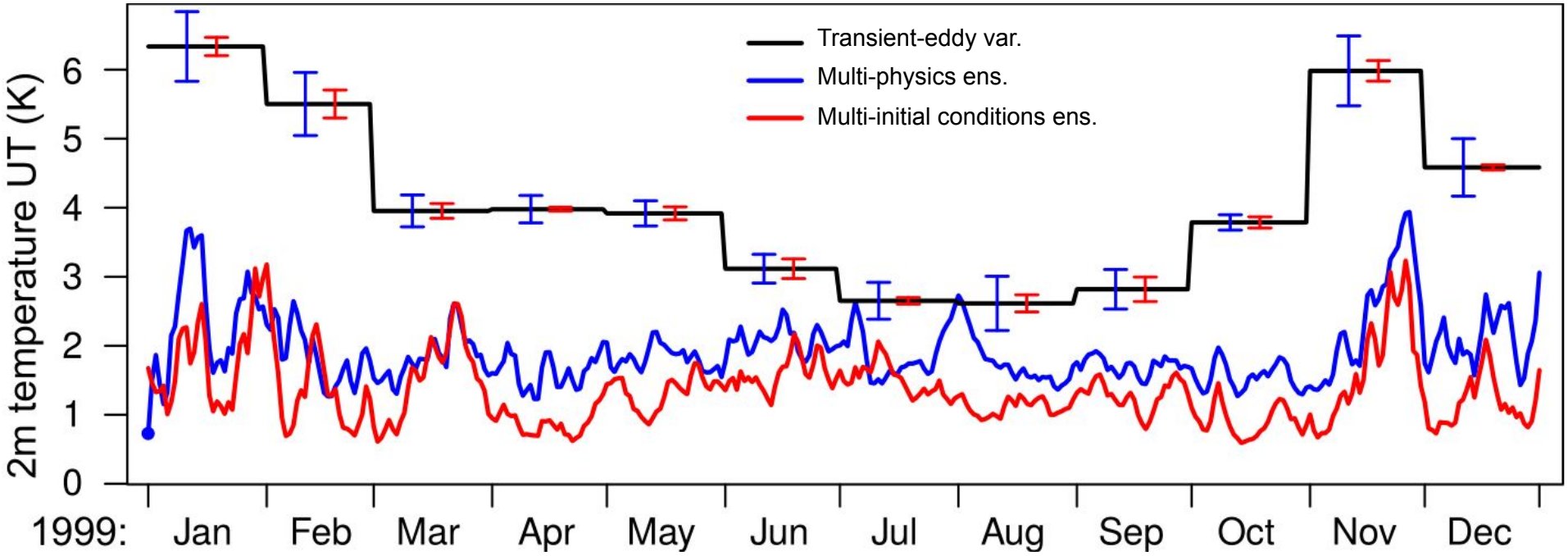
It seems that for circulation variables, one-year is not enough to distinguish the systematic effect of the physical parameterizations

Time evolution of the uncertainties

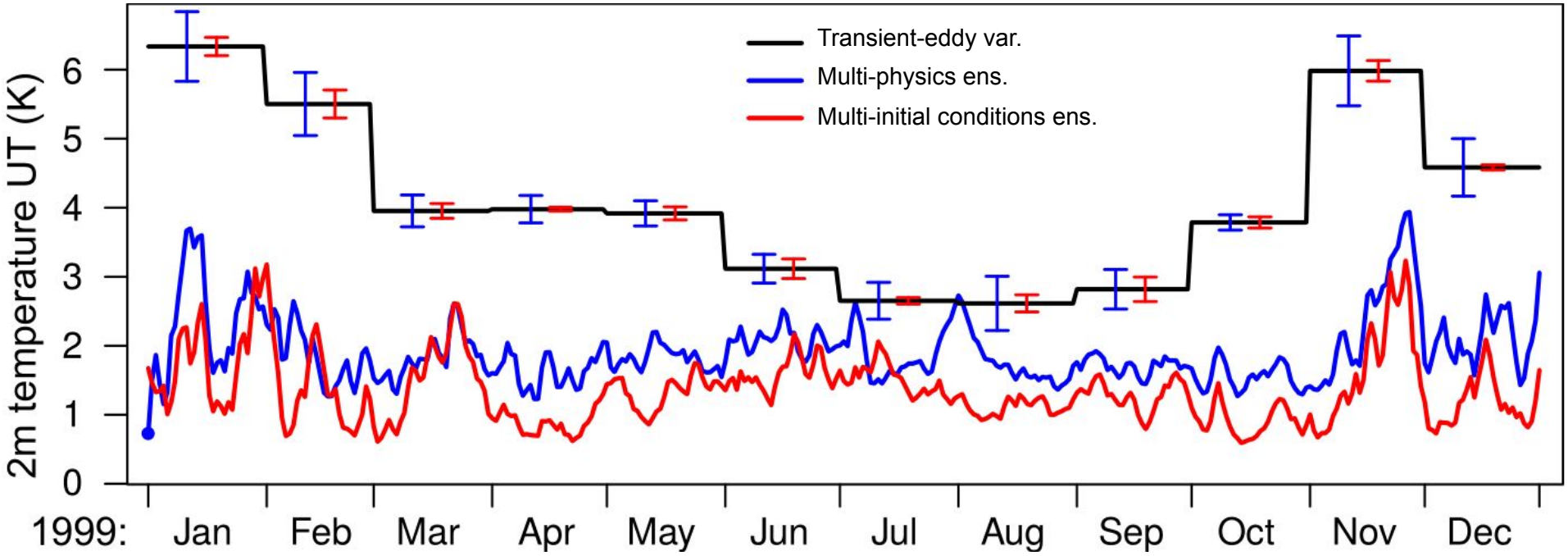
One-year uncertainties

Surface temperature



Time evolution of the uncertainties

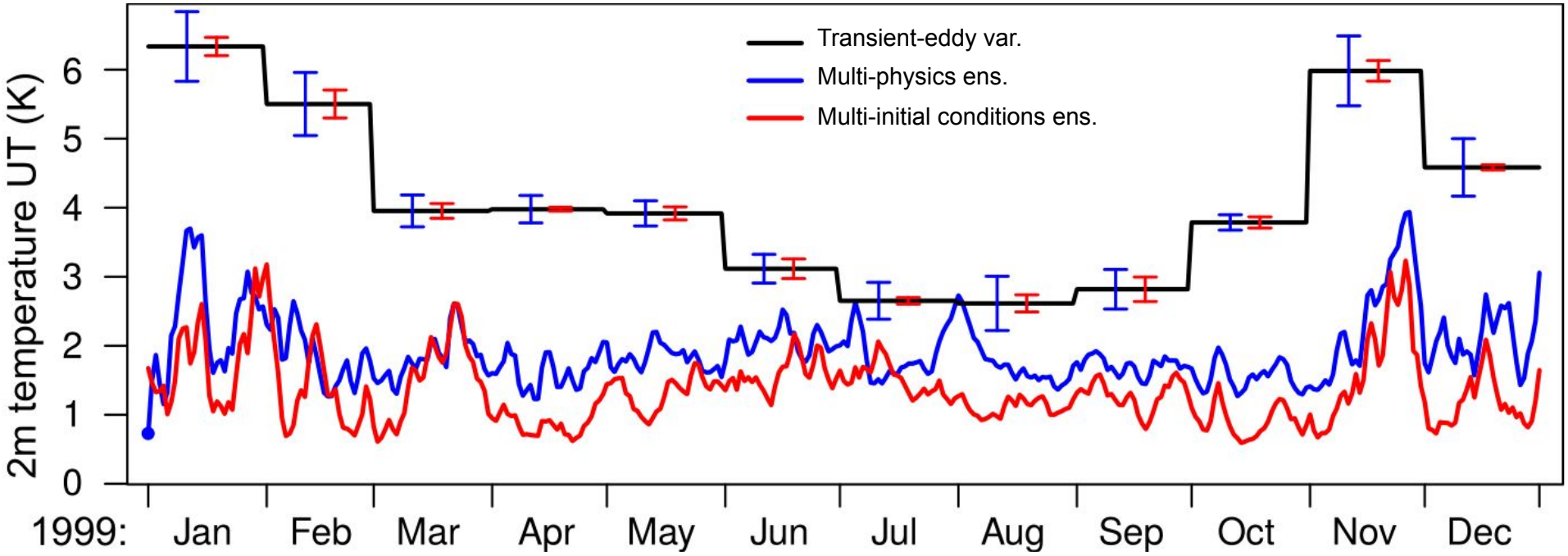
One-year uncertainties
Surface temperature



For surface temperature, **multi-physics uncertainty** is higher than **Internal variability**

Time evolution of the uncertainties

One-year uncertainties
Surface temperature



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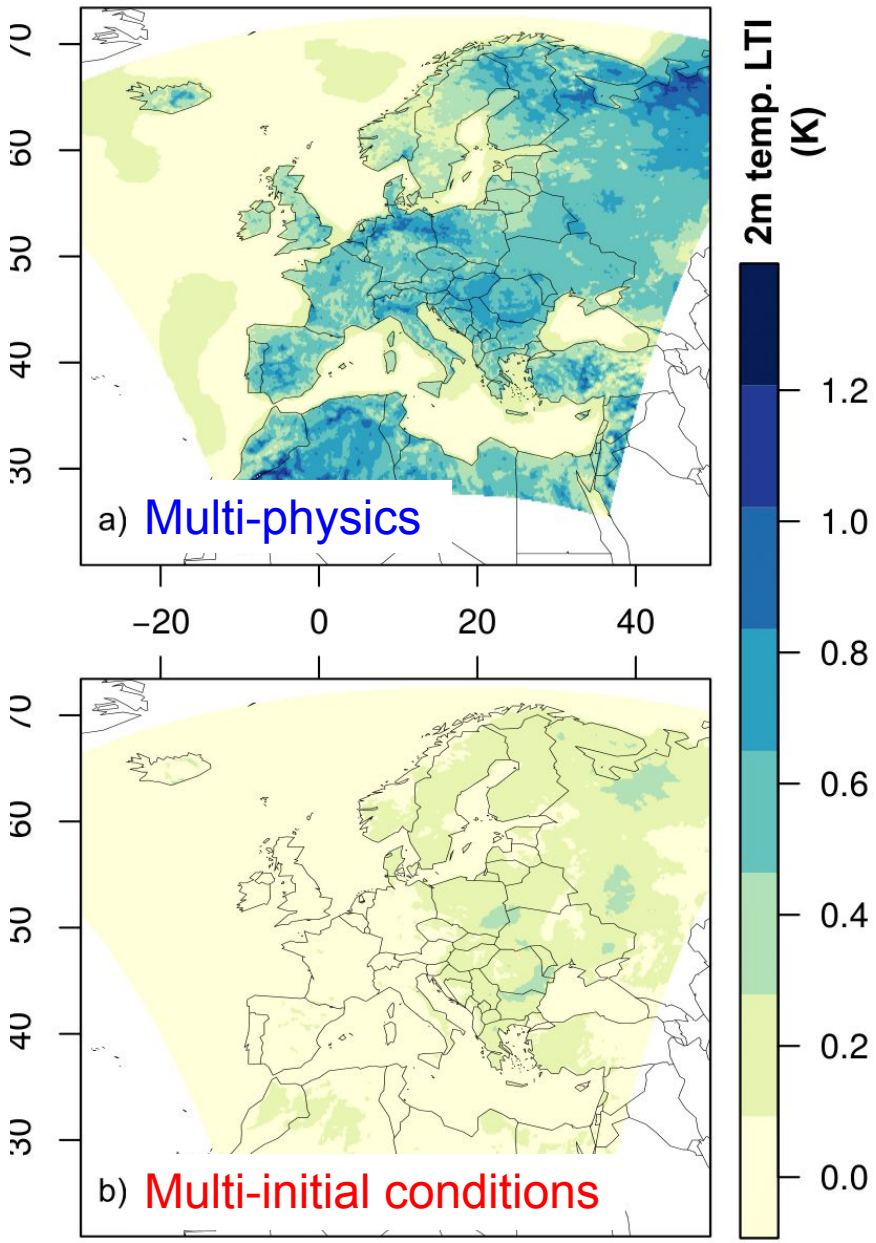
It would be more feasible to discern both uncertainties in variables more controlled by parameterizations

Long-term impact (Climatologies)



Surface temperature
Long-term systematic effect of physical parameterizations

Magnitude in multi-physics is well above the magnitude of internal variability

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For surface variables, one year could suffice to discern the systematic effect of the physical parameterizations

Conclusions

- Internal variability is dependant on the area, domain, season, variable and model
- Differences between ensemble members could be explained by the Internal Variability
- It seems that it is more feasible to discern these uncertainties when studying surface variables, rather than circulation variables
- One-year would be not enough to distinguish the systematic effect from the physical configurations in circulation variables
- Physics sensitivity studies should take into account the role of the Internal Variability

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Thank you

Spatial distribution of the uncertainties

One-year uncertainties
Surface temperature