A comparison between 4D-VAR and cycling 3D-VAR methods for the simulation of a severe weather event in Central Italy. Preliminary results.

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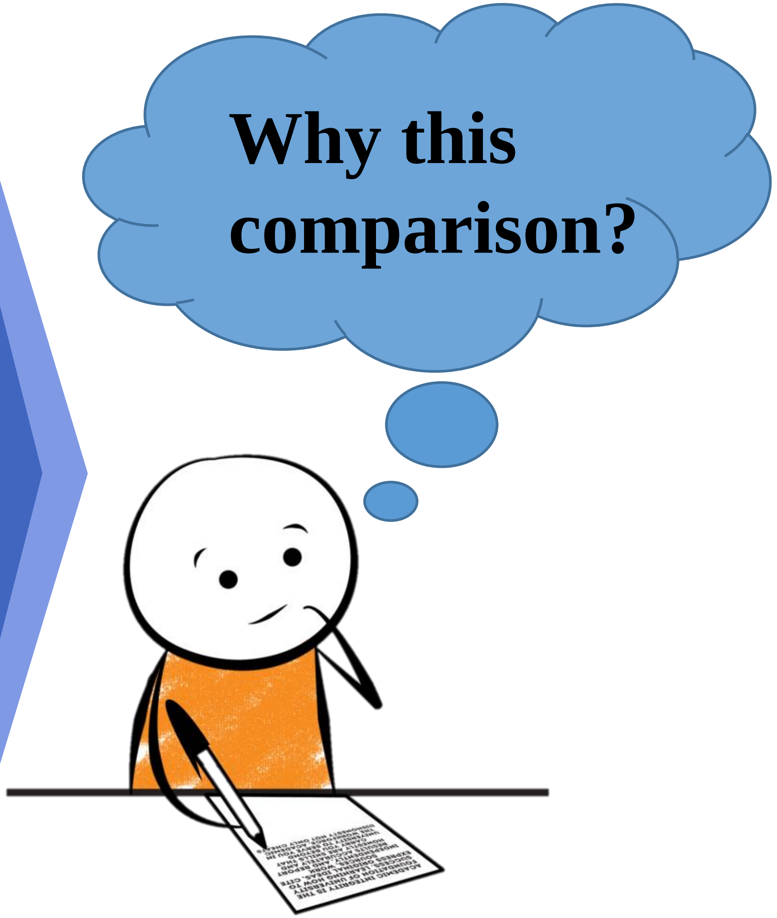
Outline

- Aim
- Case study description
- WRF model setup
- Numerical simulations
- Results
- Conclusions and future plans

Aim



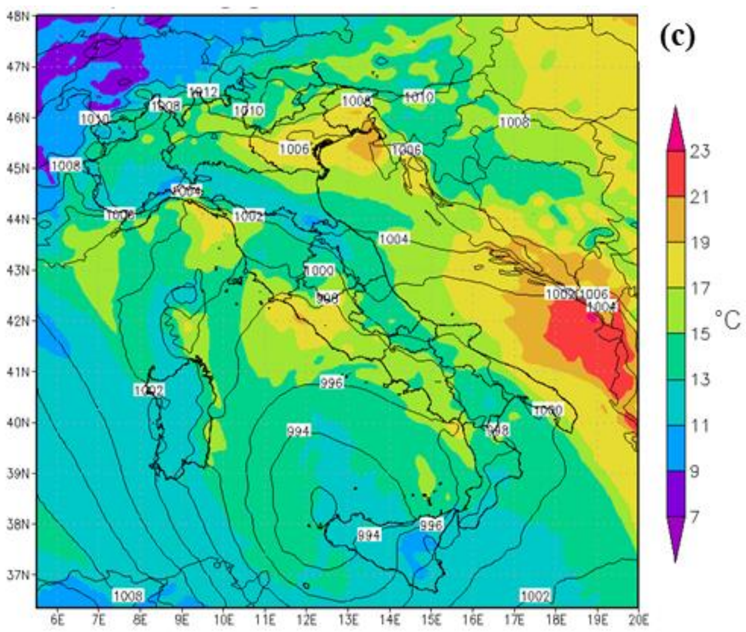
Several works (Mazzarella et al., 2019; Choi et al., 2013; Wang et al., 2013; Sun and Wang, 2013; Huang et al., 2009) prove the positive impact of 4D-VAR in rainfall forecast but, the need to resolve the tangent linear and adjoint model makes this technique computationally too expensive.

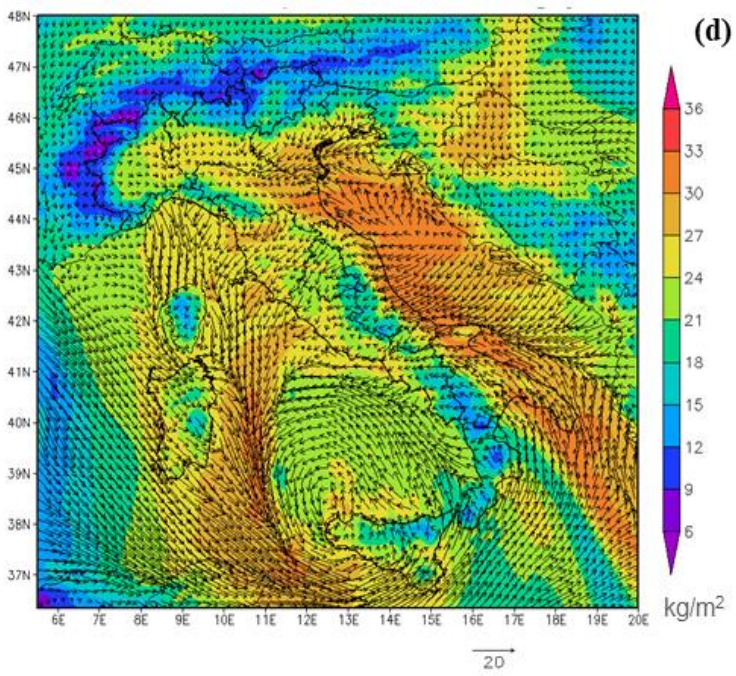
To the aim of exploring a more reasonable method, a comparison between a cycling 3D-VAR, that needs less computational resources, and 4D-VAR techniques is performed for a severe weather event occurred in Central Italy

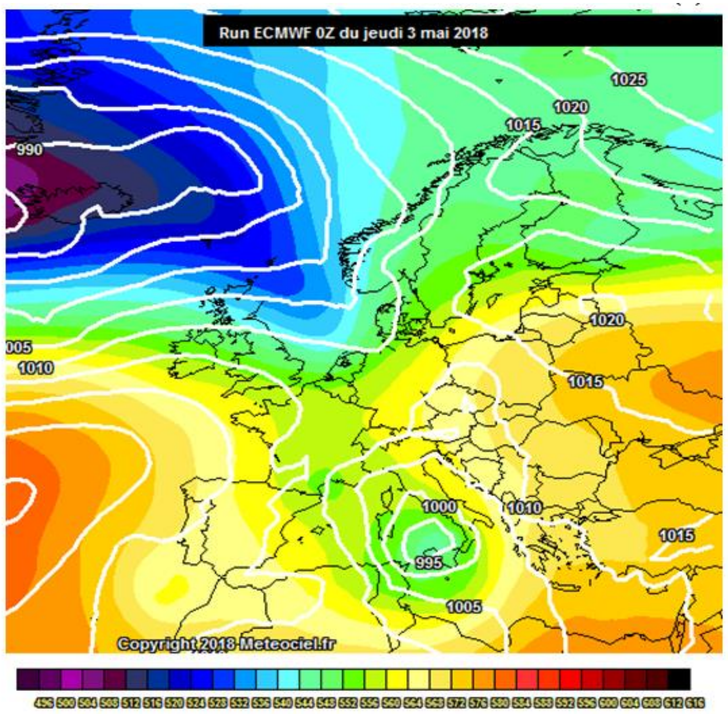
The assimilation methods are evaluated using two different statistical approaches.

Case Study: Synoptic Overview

A stretched trough (with axis oriented from northeastern to southwestern), extending from northwestern Europe to the inland sectors of Algeria, evolved into a cut-off system.
A deep cyclone (992 hPa) located near western side of Sicilia, produced a strong southeasterly flow at upper and medium troposphere levels and easterly winds at lower pressure heights (950 and 1000 hPa) over the Central Adriatic regions.



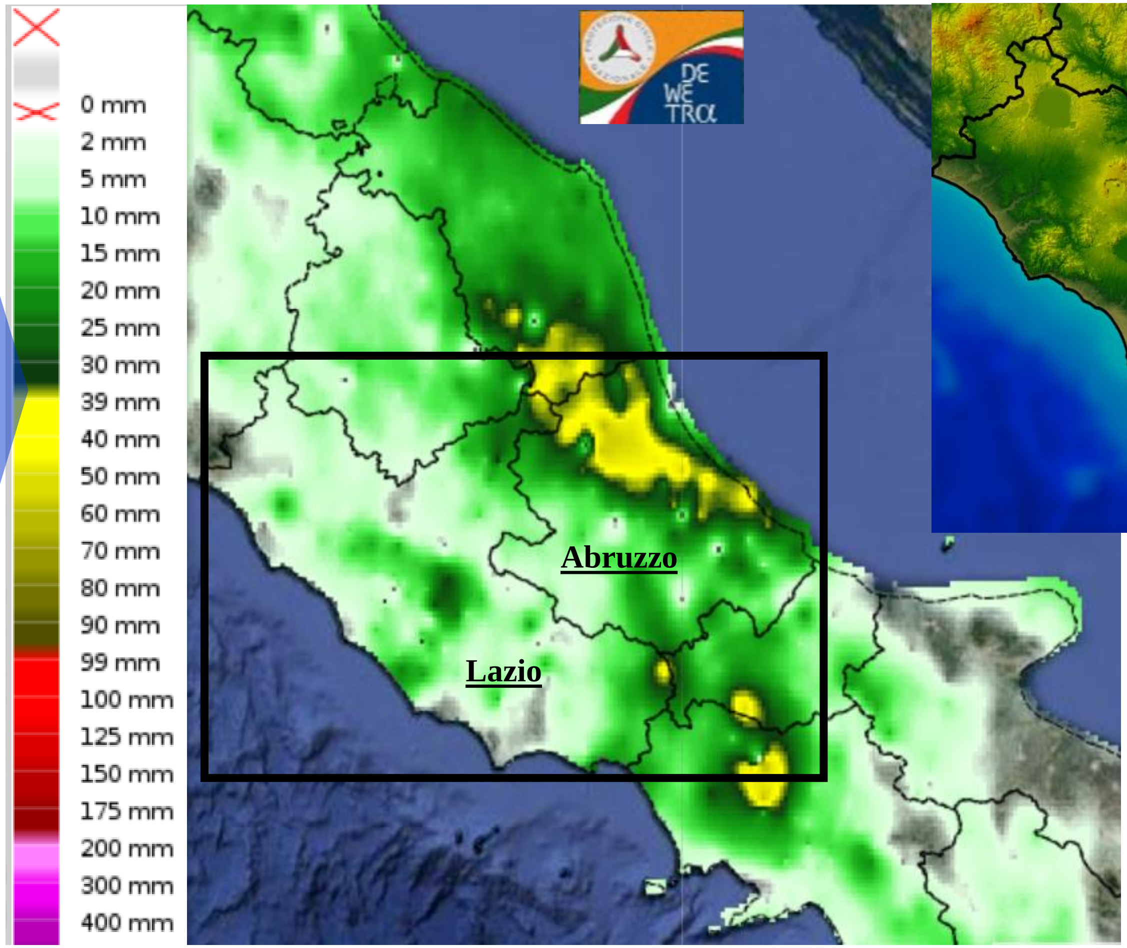




The interaction between the Appennine mountain ridge and the strong winds increased the air column instability, producing heavy precipitations along the Central Adriatic coast.

Case Study: 3 May 2018

12h Accumulated rainfall from 09 UTC to 21 UTC on 3 May 2018



The study area is focused on a complex orography region. The presence of Apennines chain and the interaction with the sea play a key role in precipitation forecast.

Abruzzo and Lazio regions, highlighted by the black rectangle, represent the study area.

Relevant rainfall peaks are observed in the northern Abruzzo: Fano al Corno (54mm), Tossicia (50mm), Arsita (50 mm), Moscufo (48mm).

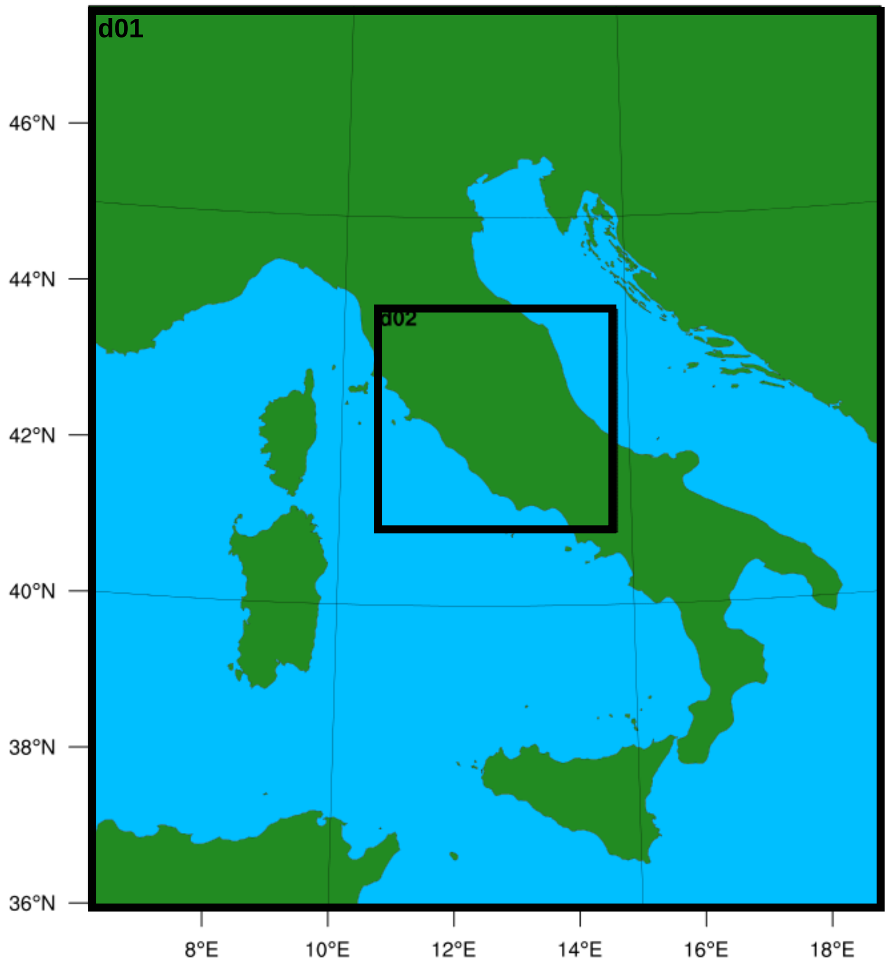
WRF Model Setup

The Weather Research and Forecasting (WRF) model, version 4.0.3, has been used in this study.

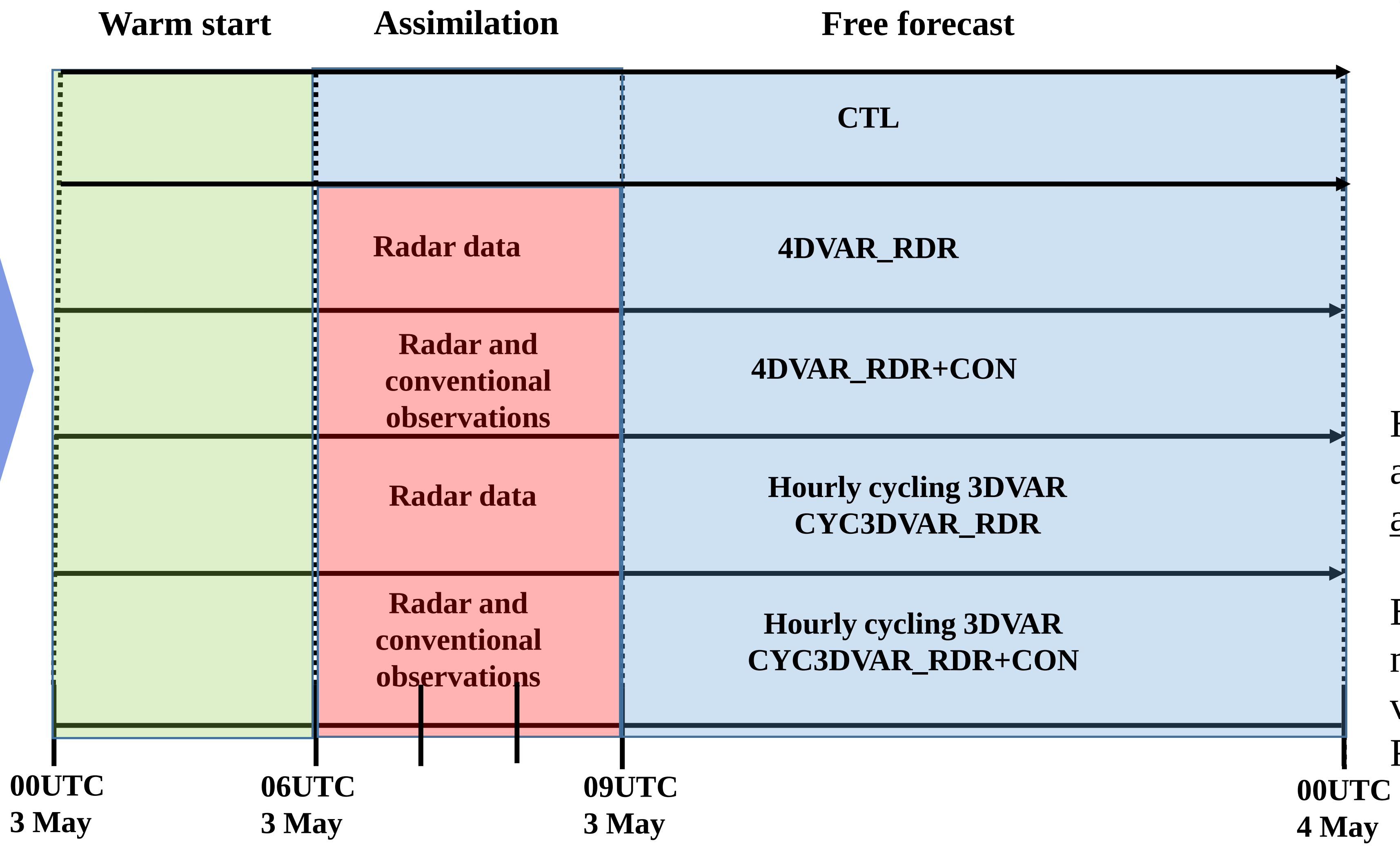
Domain	Horizontal grid dimensions	Horizontal grid spacing	Vertical levels
D01	379x431	3 km	40
D02	340x319	1 km	40

The initial and boundary conditions are provided by ECMWF with 0.125° spatial resolution. A one-way nesting is used.

Physics options	D01	D02
Microphysics	WSM6	WSM6
Cumulus	Resolved	Resolved
Planetary boundary layer	MYJ	MYJ
Short-wave radiation	Dudhia	Dudhia
Long-wave radiation	RRTM	RRTM



Numerical Simulations

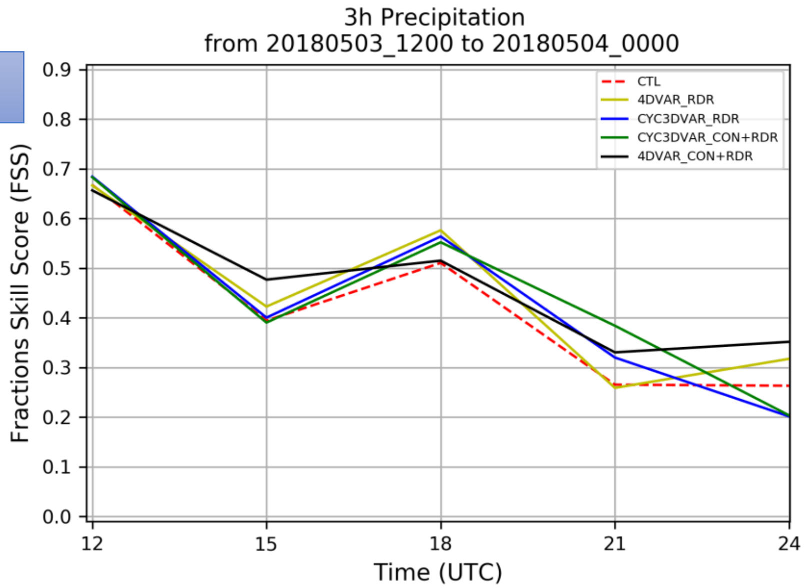


Hourly reflectivity, radial velocity and null echo observations are <u>assimilated in D01 domain (3km)</u>

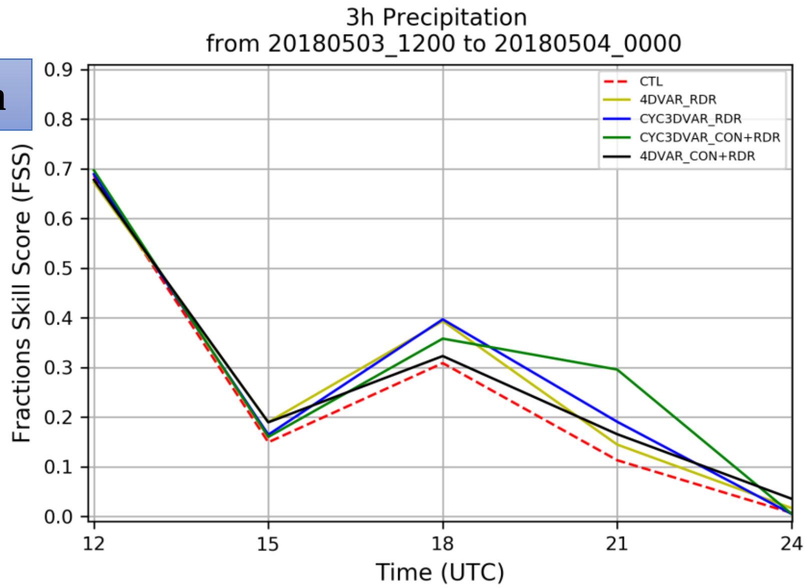
BE matrix is calculated with NMC method. The following control variables are considered u, v, T, RH_s, P_s.

Results

> 3mm/3h



> 5mm/3h

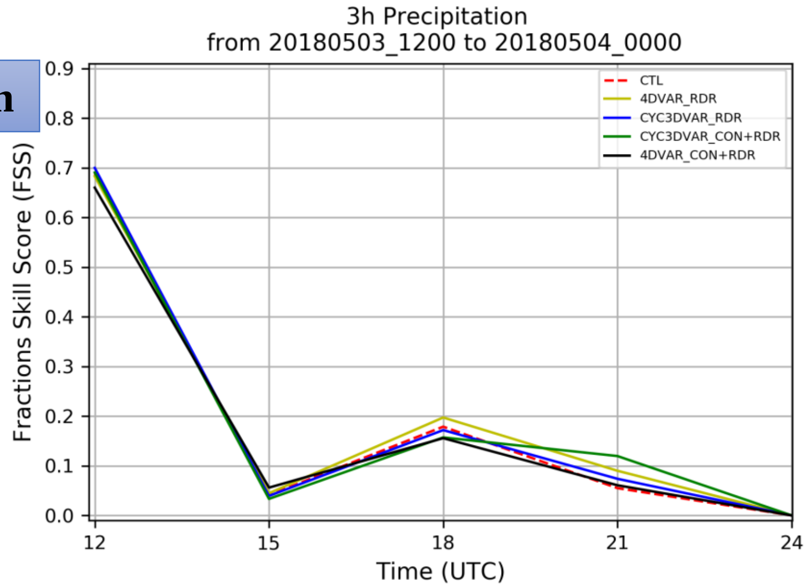


The simulations with cycling 3DVAR and 4DVAR show a positive impact compared to CTL simulation without assimilation.

The improvement of cycling 3DVAR is comparable with 4DVAR.

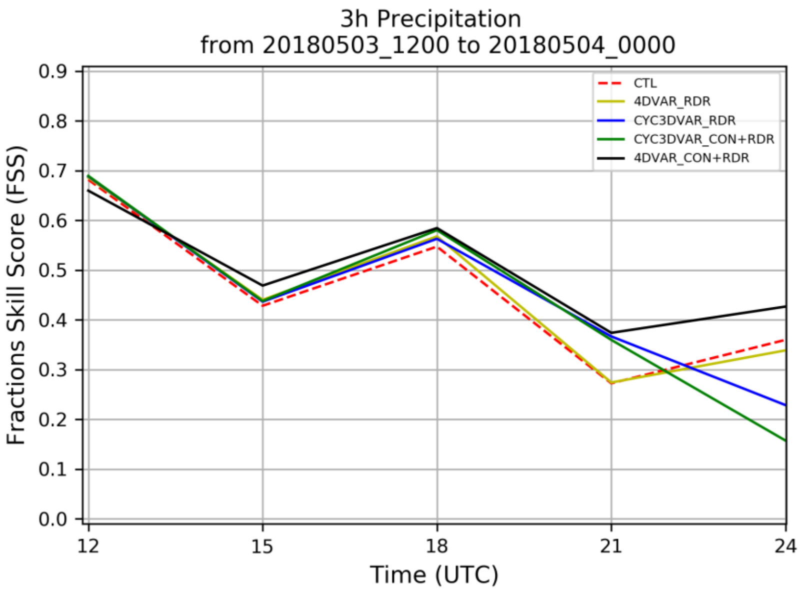
The experiments are carried out using one-way nesting

> 7mm/3h



Results

> 3mm/3h



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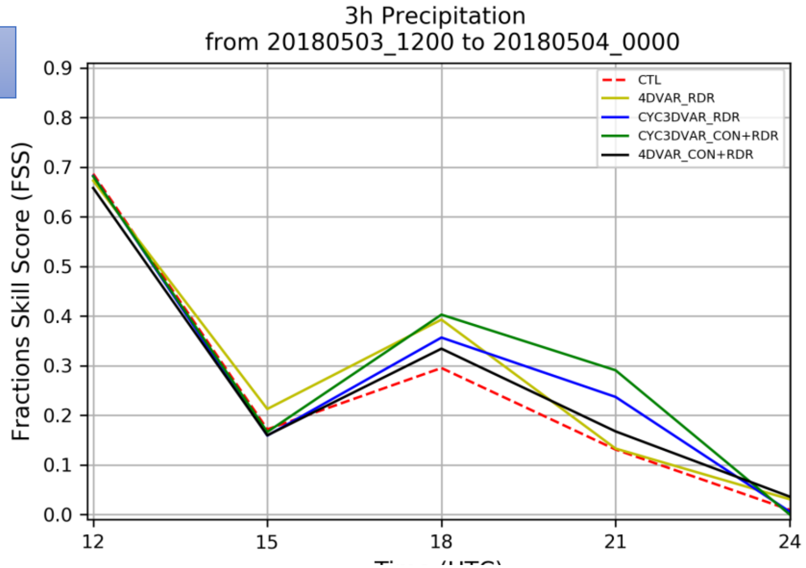

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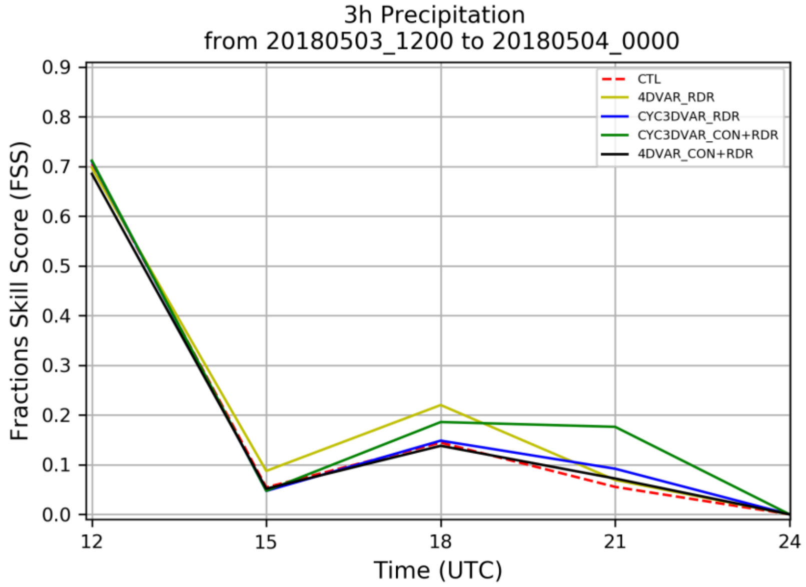
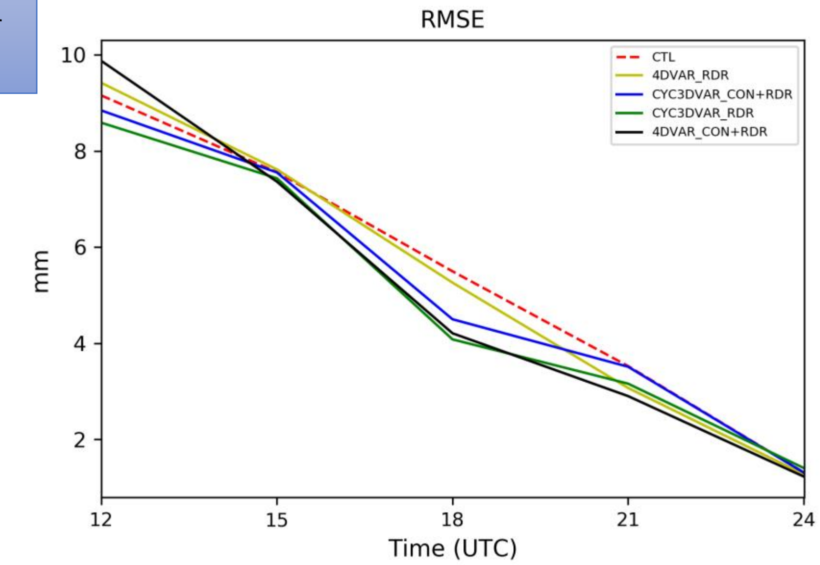


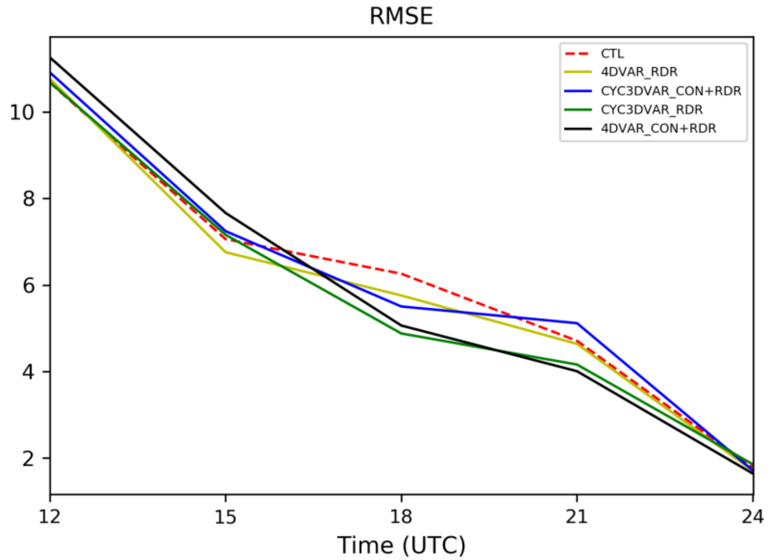
The FSS is also calculated in the study area over D01 domain (3km).
The results confirm the good impact of both assimilation methods. And in addition, the cycling 3DVAR and 4DVAR show a similar behaviour.

Results

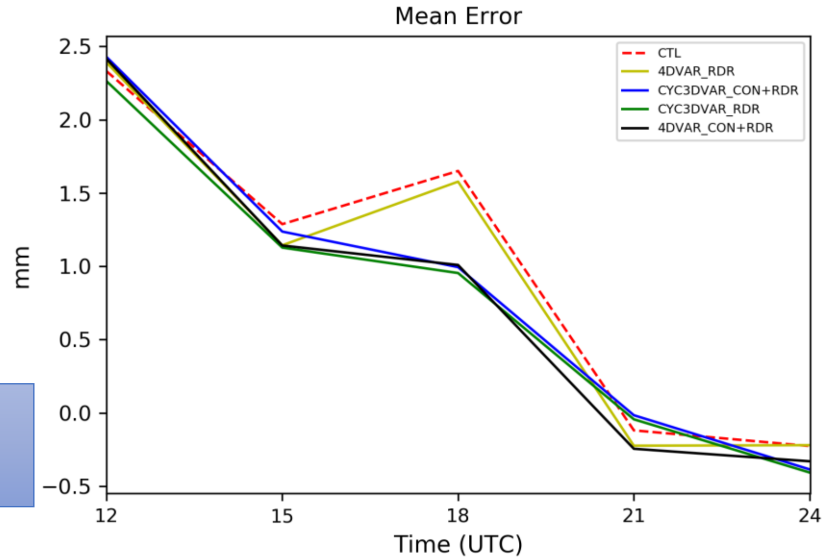
Domain D01
3 km

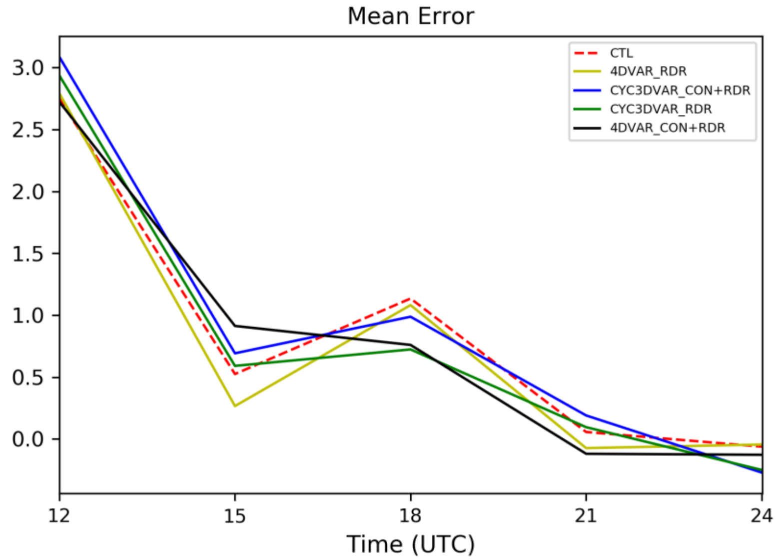


Domain D02
1 km



The good results of assimilation are confirmed by RMSE ad Mean Error. These index are independent from threshold values.



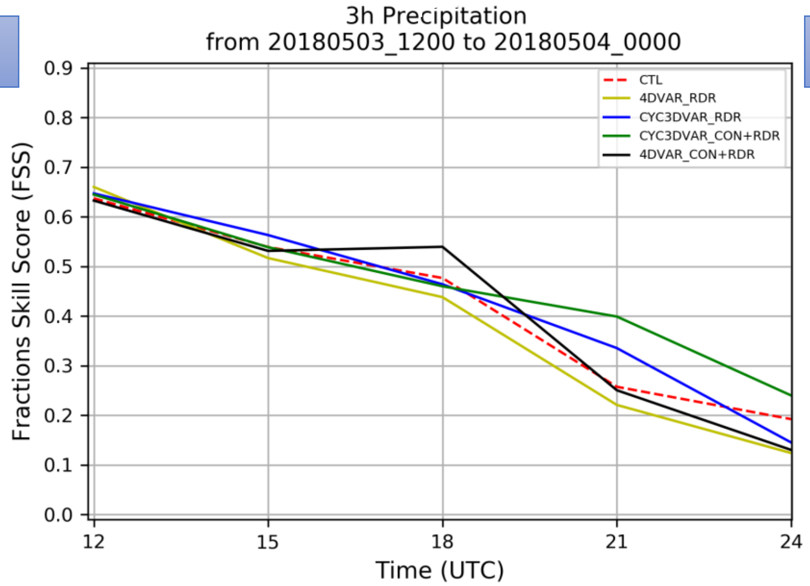


Domain D01
3 km

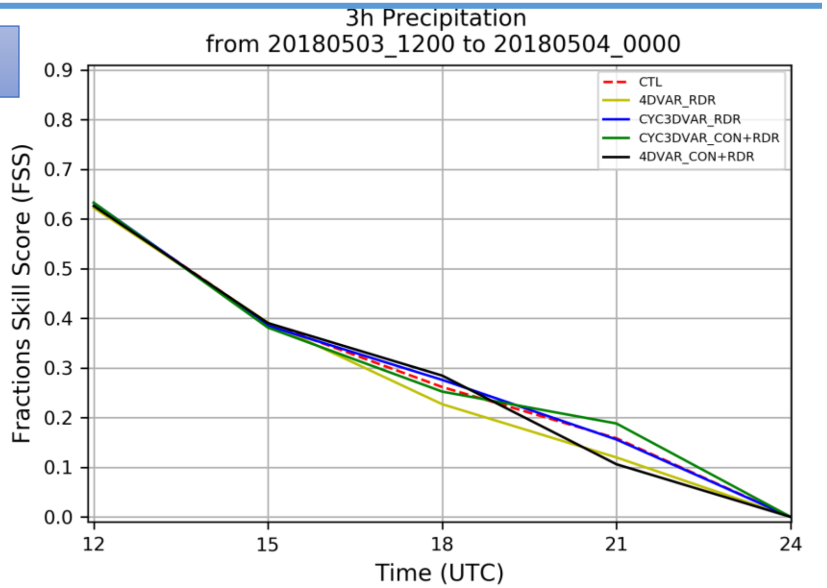
Domain D02
1 km

Results

> 3mm/3h

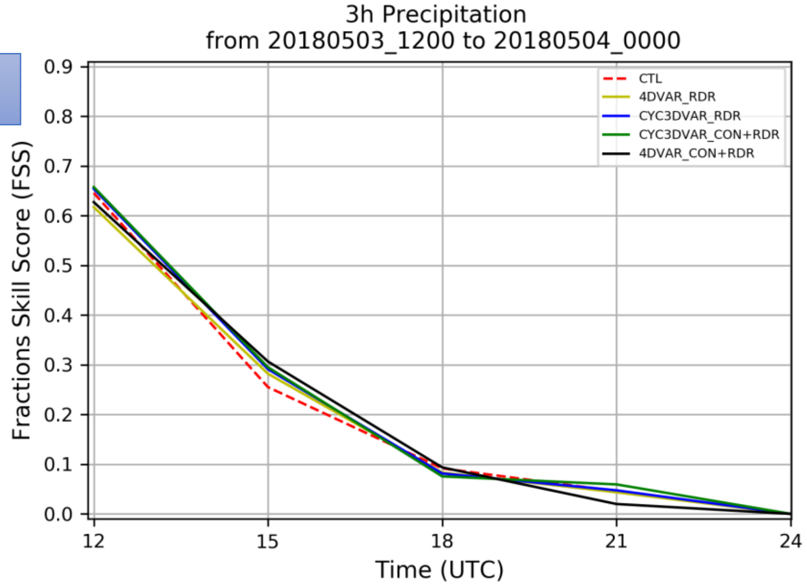


> 5mm/3h



What happens when the two-way nesting is used?

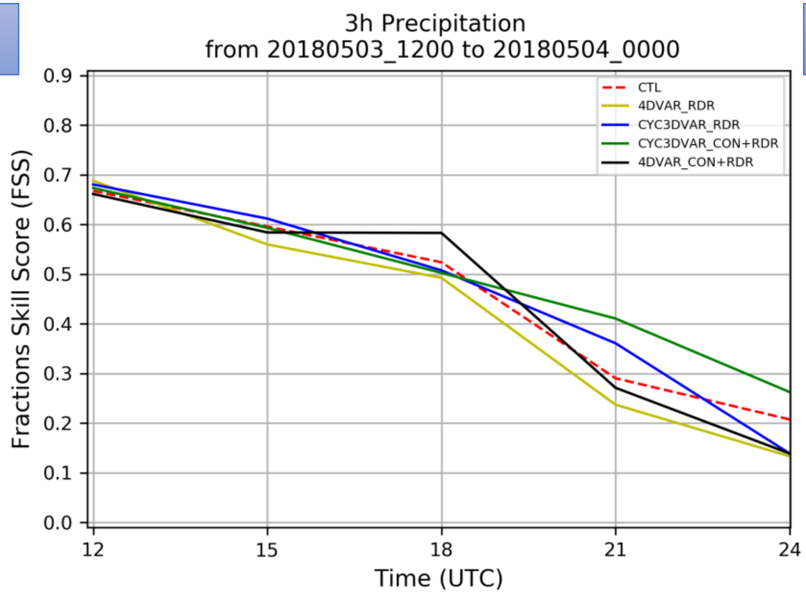
> 7mm/3h



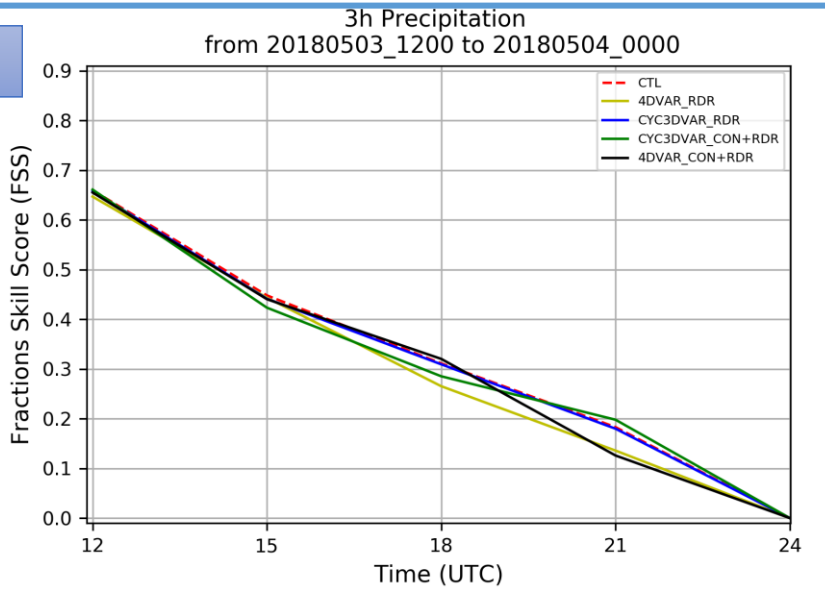
The impact of assimilation is reduced with two-way nesting. Why does this behaviour occur?
The assimilation is only performed over low resolution domain. Consequently, the continuous interaction between inner and mother domains may produce noise which reduces the performance of data assimilation.

Results

> 3mm/3h

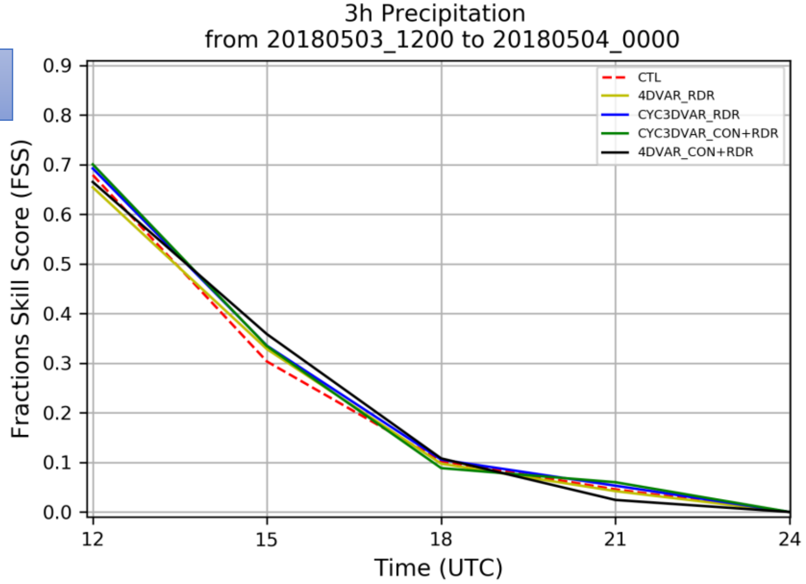


> 5mm/3h



What happens when the two-way nesting is used?

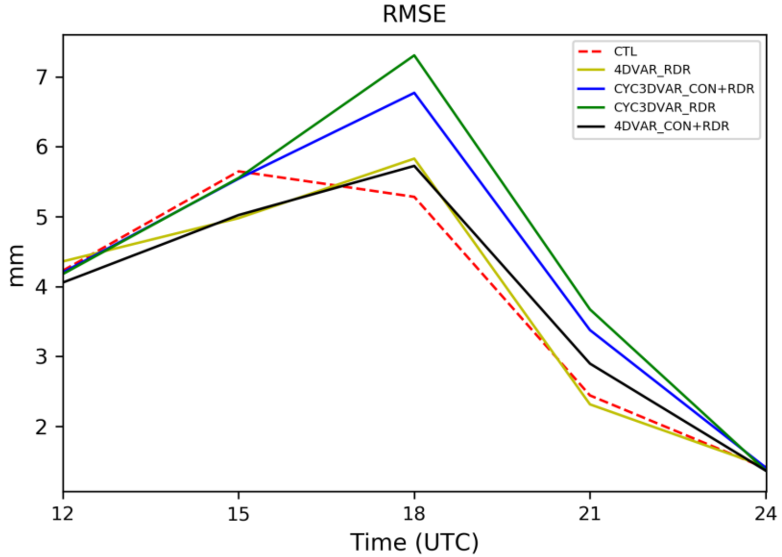
> 7mm/3h

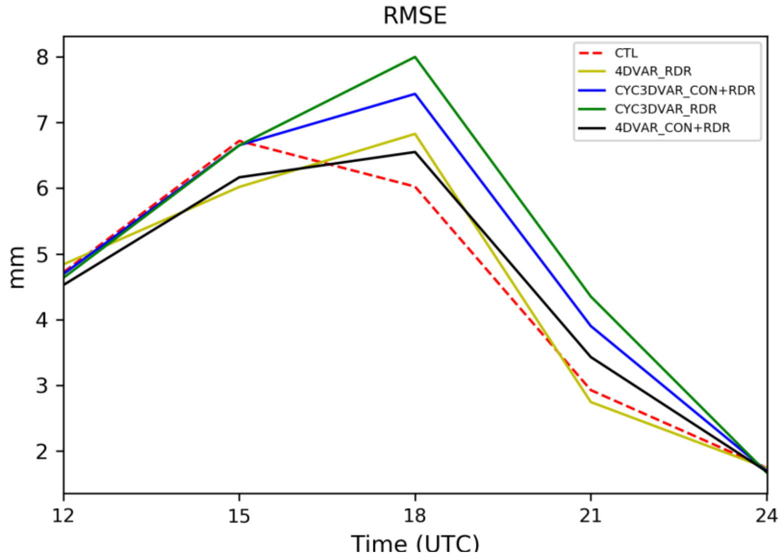


The FSS calculated in low resolution domain show a similar behaviour. The results confirm the worsening in terms of FSS compared with CTL simulation without data assimilation.

Results

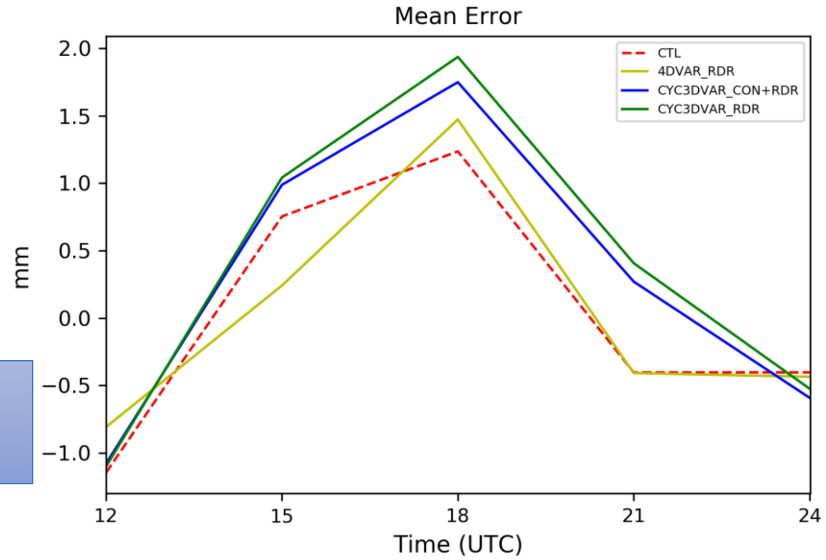
Domain D01
3 km

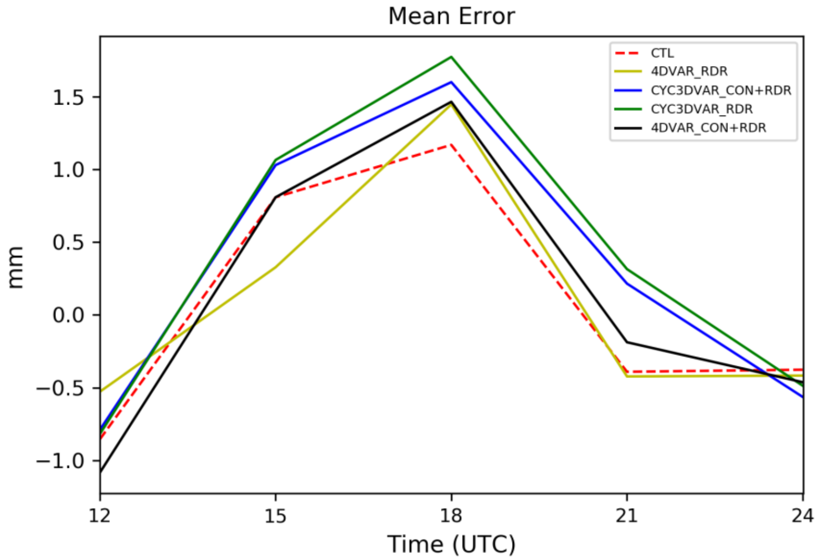




Domain D02
1 km

The RMSE and Mean Error confirm the poor results with two-way nesting





Domain D01
3 km

Domain D02
1 km

Conclusions

- Cycling 3DVAR and 4DVAR methods improve the precipitation forecast;
- The impact of cycling 3DVAR and 4DVAR is comparable;
- The two-way nesting reduces the impact of assimilation.

Future Plans

- Investigate the impact of data assimilation in two-way nesting;
- Repeat the 3DVAR simulations assimilating data in high resolution domain. 4DVAR is too computationally expensive for 1km spatial resolution!
- Add a new case study.

Thank you for your attention

Any questions?

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