

High-resolution ensemble precipitation simulations over a small domain with complex topography



Ioannis Sofokleous¹, Adriana Bruggeman¹, Corrado Camera², George Zittis³

¹ *Energy, Environment and Water Research Center, The Cyprus Institute, Nicosia, Cyprus*

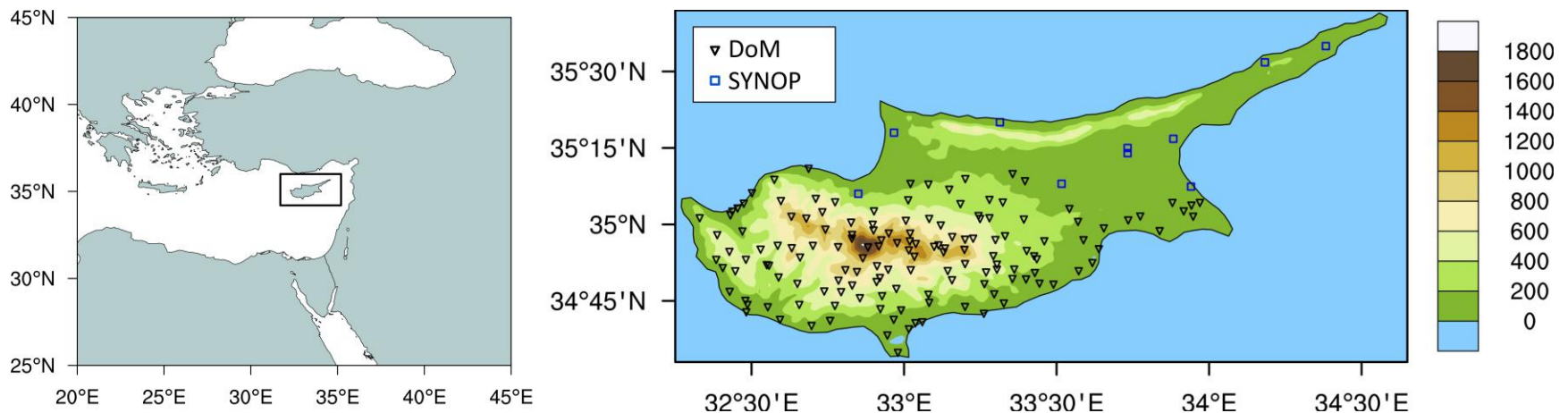
² *Dipartimento di Scienze della Terra "A. Desio" University of Milan, Milan, Italy*

³ *Climate and Atmosphere Research Center, The Cyprus Institute, Nicosia, Cyprus*



Objective

- This study aims to select an ensemble of the Weather Research and Forecasting model (WRF) for high-resolution hydrological applications
- Different dynamical downscaling options are evaluated:
 1. Domain configurations (3)
 2. Initialization frequencies (2)
 3. Physics parameterizations (18 combinations - members)
- Five evaluation metrics for daily and sub-daily (30 min) precipitation and a Composite Scaled Score (CSS) are used
- A stepwise evaluation approach is followed for a 3-month simulation period
- Study area: Cyprus in the Eastern Mediterranean



Stepwise Evaluation Method

Simulation experiments	# experiments	Calibration period
Step 1 3 domain setups × 1 initialization × 18 members × 1 month	54	Jan 2012
Step 2 1 domain setup × 2 initializations × 18 members × 2 months	72	Jan 2012, May 2012
Step 3 1 domain setup × 1 initialization × 18 members × 3 months	54	Oct 2011, Jan 2012, May 2012

Model configurations tested		
Domain setup 12-4-1 6-1a 6-1b	Initialization frequency 5-days 30-days	Physics parameterisations 18 members

Method: Evaluation measures

For daily amounts

1. Bias (mm)
2. Mean Absolute Error (mm)
3. Modified Nash-Sutcliffe Efficiency
4. Kling-Gupta Efficiency

For 30-min amounts > 15mm (extreme events)

5. Hit rate * Bias ratio, for Bias ratio < 1 (underestimation)

or

Hit rate / Bias ratio, for Bias ratio > 1 (overestimation)

For relative performance of ensemble members

6. Composite Scaled Score (CSS): ranges from 0 (best performance) to 1 (worst performance) and combines the values of the five evaluation measures

$$CSS_i = \frac{1}{N_s} \sum_{s=1}^{N_s} \left(\frac{x_{s,i} - x_{s,worst}}{x_{s,best} - x_{s,worst}} \right)$$

i: index of member (1-18)

s: index of evaluation measure (1-5)

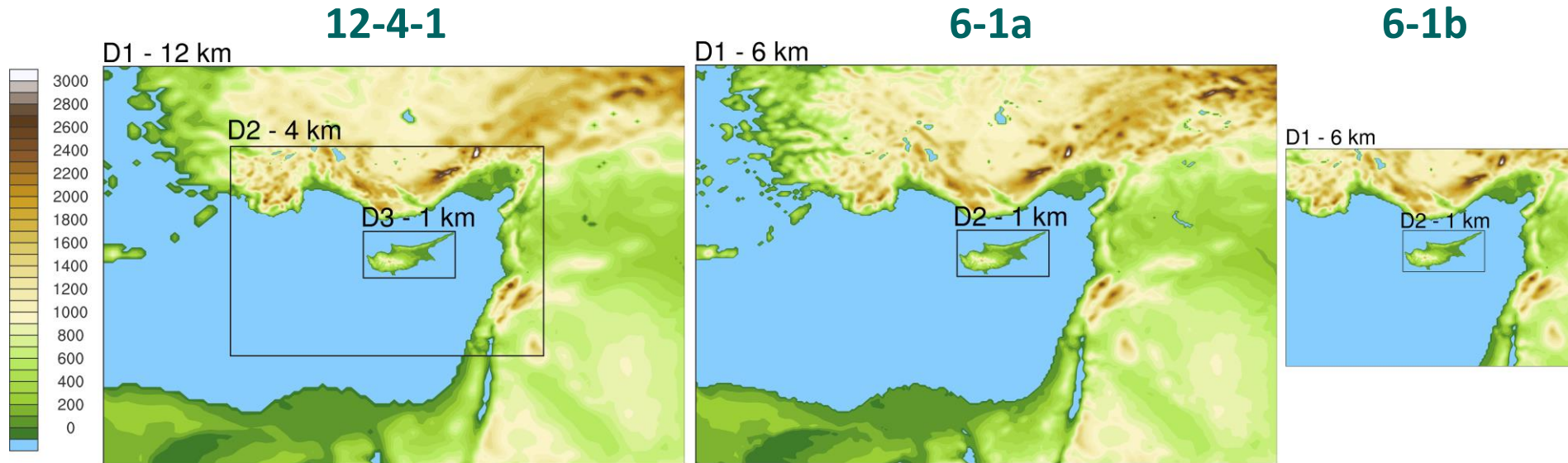
N_s : Number of evaluation measures (5)

$x_{s,i}$: Value of evaluation measure s for member i

$x_{s,worst}$: Worst value of the measure for all members

$x_{s,best}$: Best value of the measure for all members

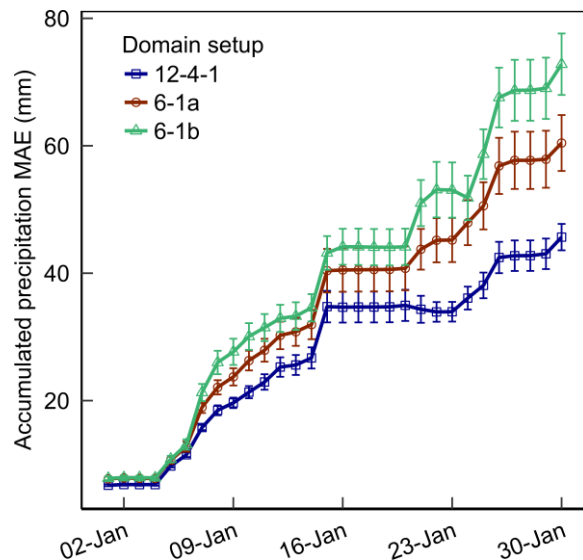
1. Domain configurations



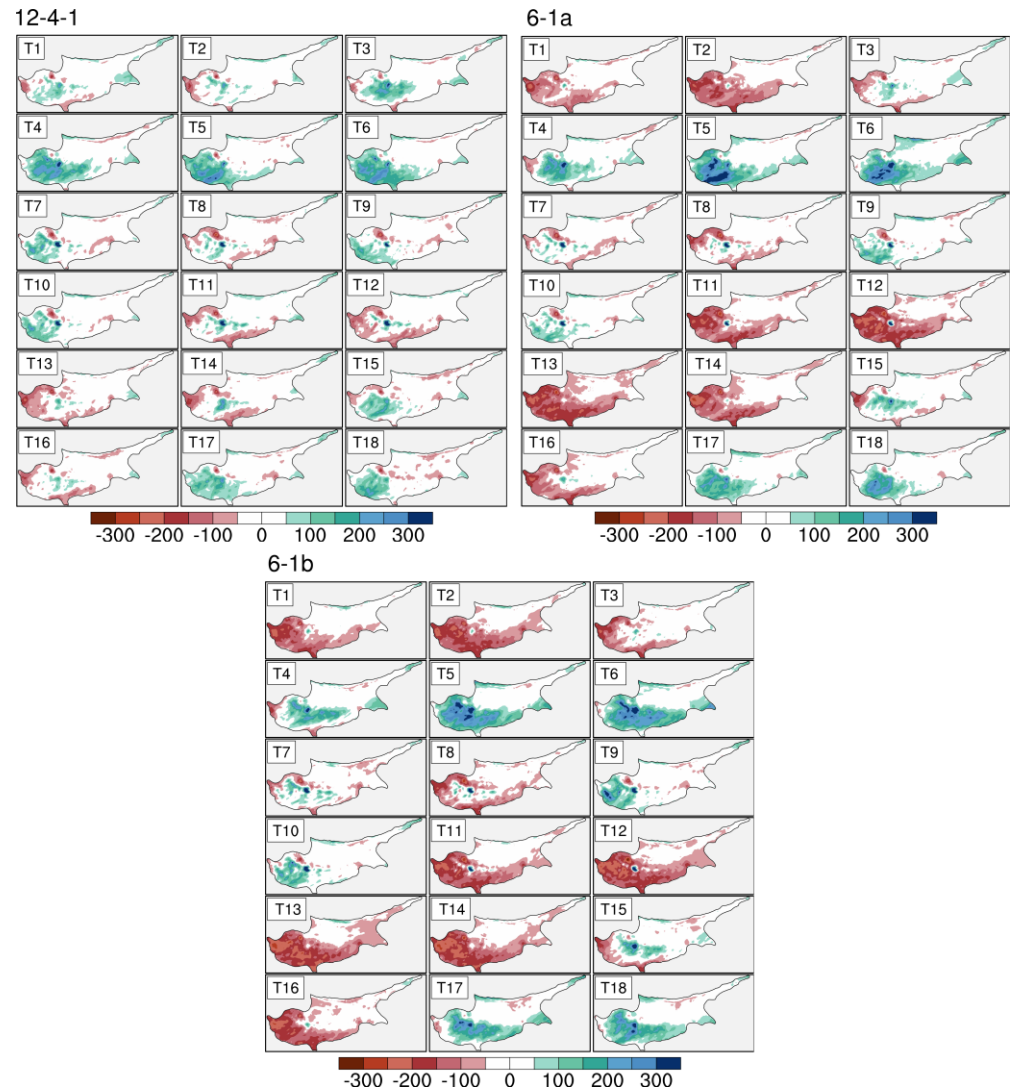
WRF precipitation is initially evaluated for three domain setups and 18 members for January 2012

1. Domain setups

→ Least errors in WRF simulated precipitation are found with the 12-4-1 domain setup



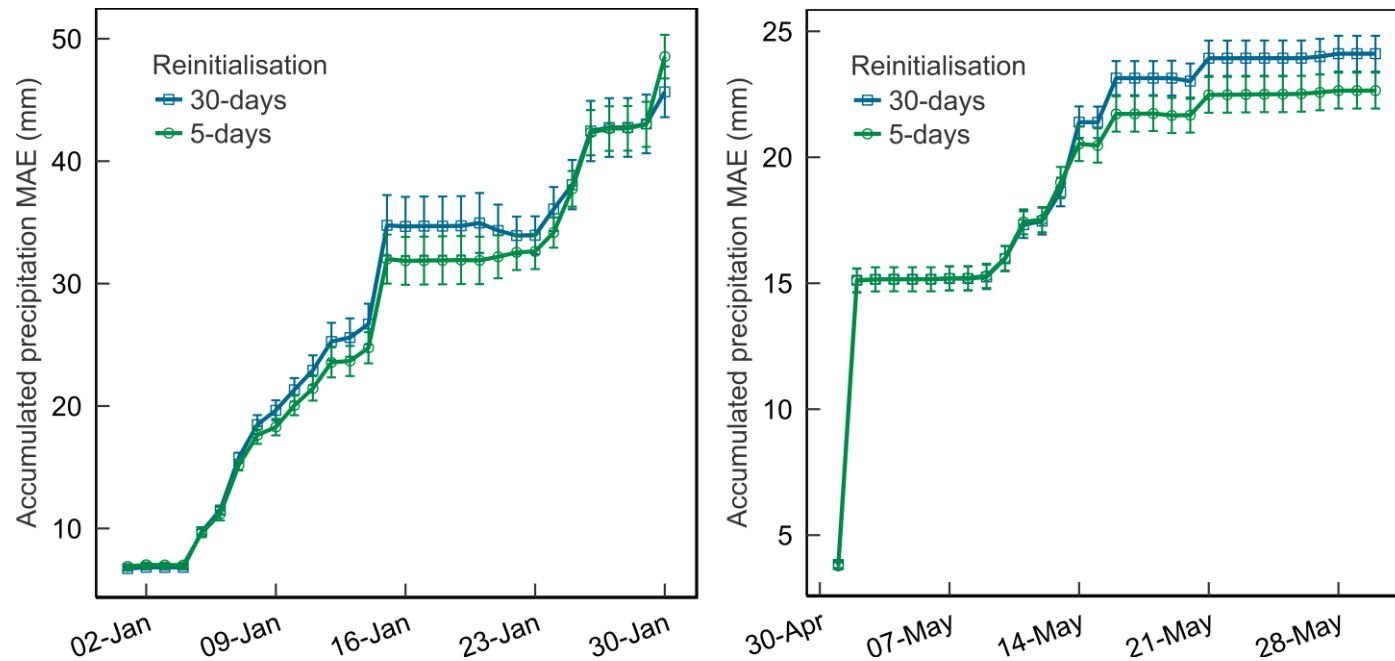
Average value and standard deviation of MAE of accumulated precipitation (mm) for 18 members for January 2012.



Total precipitation bias (mm) for January 2012

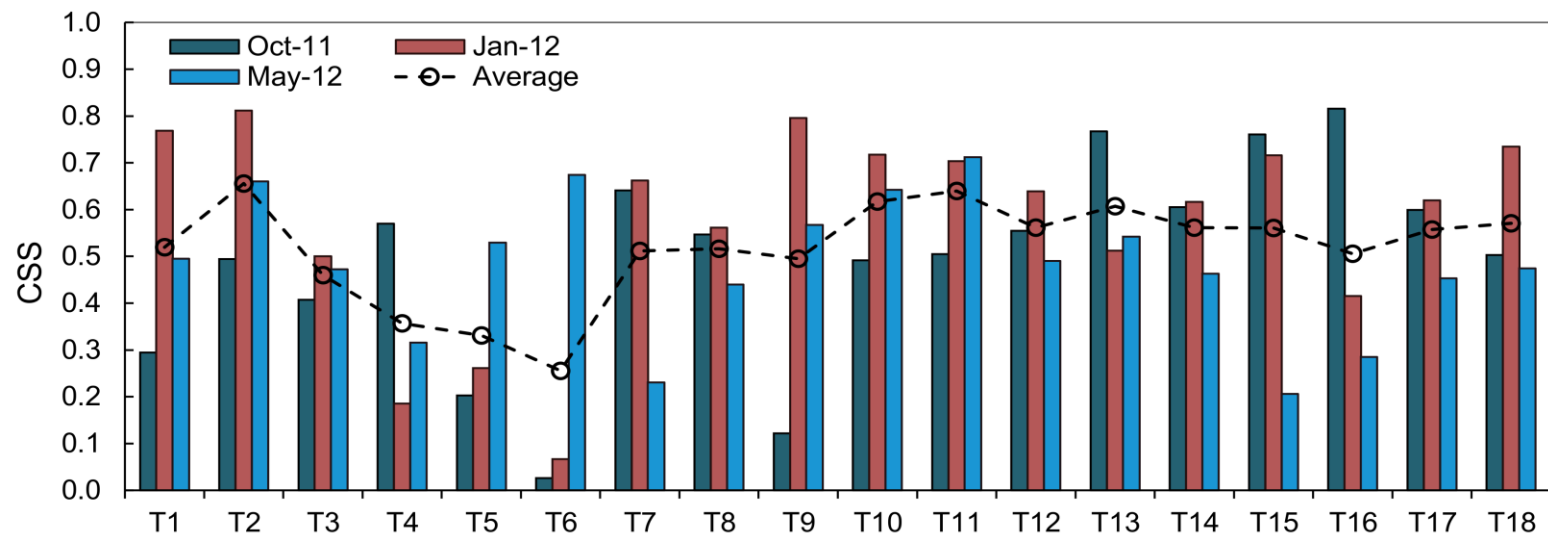
2. Initialization frequencies

→ The shorter initialization frequency (5-days) leads to similar WRF performance with the longer frequency (30-days)



Average value and standard deviation of MAE of accumulated precipitation (mm) for 18 members for January and May 2012.

3. Physics parameterizations – Composite Scaled Score

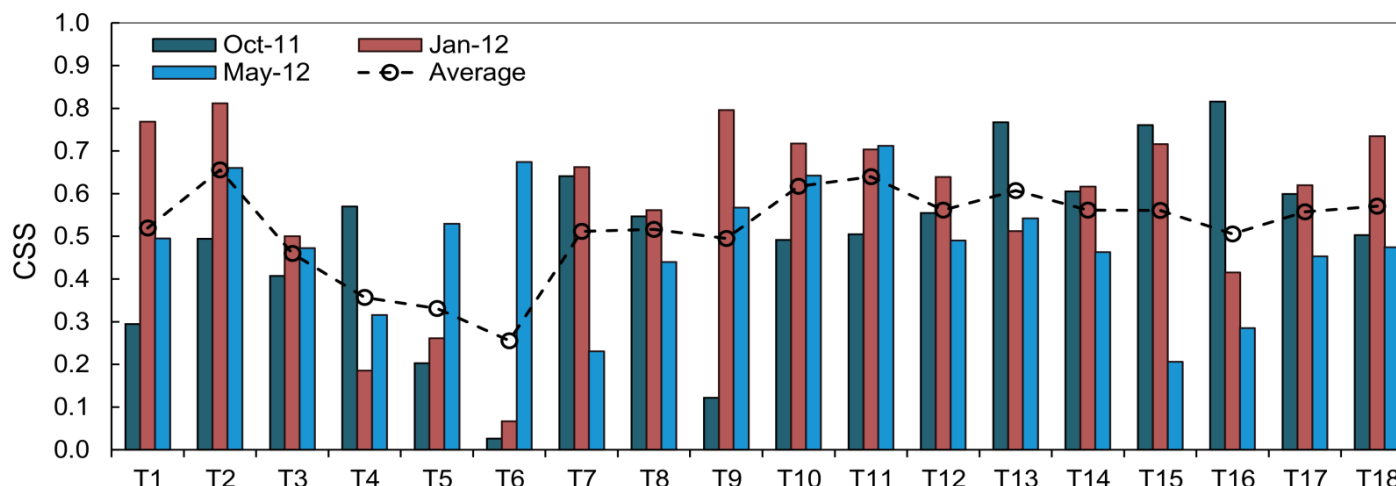


Microphysics	6						5					16						
Cumulus	2	1		3		1	3		2			1		3				
PBL	2	1	2	1	2	1	1	2	2	1	2	1	1	2	1	2	1	2
Surf. Layer	2	91	2	91	2	91	91	2	2	91	2	91	91	2	91	2	91	2

The Composite Scaled Score (CSS) for 18 members (T1-T18) for October 2011 and January and May 2012 and the average CSS for the three months

- ¹Microphysics:** 5 – Ferrier 6 – WRF Single Moment-6 16 – WRF Double Moment-6
²Cumulus: 1 – Kein-Fritch 2 – Betts-Miller-Janjic 3 – Grell-Freitas
³Planetary Boundary Layer: 1 – Yonsei University 2 – Mellor Yamada Janjic
⁴Surface Layer: 2 - Eta Similarity 91 - MM5 similarity

3. Physics parameterizations – Composite Scaled Score



Microphysics	6						5					16						
Cumulus	2		1		3		1		3		2			1		3		
PBL	2	1	2	1	2	1	1	2	2	1	2	1	1	2	1	2	1	2
Surf. Layer	2	91	2	91	2	91	91	2	2	91	2	91	91	2	91	2	91	2

- **Microphysics:** Ferrier (T7-T12, CSS=0.56) and WRF-Double-Moment-6 (T13-T18, CSS=0.56) outperform WRF-Single-Moment-6 (T1-T6, CSS=0.43)
- **Cumulus:** Betts-Miller-Janjic (CSS=0.59) outperforms Kein-Fritch (CSS=0.49) and Grell-Freitas (CSS=0.47)
- **Surface layer/ Boundary layer:** Different members with the same schemes achieve different CSS. E.g. T2 with CSS=0.66 and T6 with CSS=0.26 for Yonsei University/MM5-similarity
- **Top five members:** T2, T10, T11, T13, T18 with average CSS>0.58

Summary

→ **A stepwise evaluation approach for high resolution, dynamical downscaling of ERA5 was developed and tested for a small, topographically complex domain (Cyprus) :**

1. Precipitation with a three-nested domain setup outperforms the two-nested domain setup with similar size ($1488 \times 1248 \text{ km}^2$) and a two-nested domain setup with smaller size ($826 \times 768 \text{ km}^2$)
2. Short initialization frequency (5-day) and monthly initialization lead to similar model performance. The same is not true for larger domain setups according to previous studies
3. A Composite Scaled Score (CSS), which combines the values of multiple evaluation metrics, makes the evaluation of WRF simulations more comprehensive than single metric evaluation.