Republic of Turkey
Ministry of Forest and Water Affairs
Meteorological Service

A new mesoscale short-range ensemble system compiled with ARW multi-physics and clustered ECMWF-ENS: scientific description and some preliminary results

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Outline

- ***What*** are the basic ingredients of an ensemble system?
- ***How*** this new ensemble system is configured?
- Highlights of some preliminary results
- Concluding remarks

What are the basic ingredients of an ensemble system?

1. Ensemble of ICs/LBCs to address uncertainties in data
2. Multi-physics and stochastic approaches to account for model uncertainties
3. An ensemble data assimilation system to give flow-dependent flavour

Advance Research WRF (ARW) Ensemble Capabilities

- Multi-physics options
- Stochastic physics: stochastic kinetic energy backscatter *(Berner et al. 2011)*
- Physics perturbations *(Hacker et al. 2011)*
- Hybrid (*3DVar+ETKF*) data assimilation *(Demirtas et al. 2009)*

ARW Based 10-member Ensemble System Compiled with Multi-Physics and Representative Members of Clustered ECMWF-ENS

Ensemble Configurations Employed in This Study

- Low resolution ensembles: 10km (control forecast+ 10 members)
  1. ARW run with ECMWF-ENS ICs/BCs: 10 members
     - Default: The first 10 members of 50 *ECMWF-ENS*
     - Selecting 10 members out of 50: determined by a clustering technique

  2. One of the following ARW multi-physics ensembles with ECMWF-ENS' control forecast for providing ICs/BCs
     - ARW phy1 ensembles
     - ARW phy2 ensembles
     - ARW phy3 ensembles

  3. Hybrid: ECMWF-ENS and ARW physics ensembles combined
     - Default or representative members of clusters and a chosen ARW multi-physics (phy1, phy2 and phy3) ensembles

- High resolution ensembles: 4.5km (control forecast+ 10 members)

  – ARW multi-physics ensembles run with ECMWF-HRES ICs/BCs:
     - ARW phy1 ensembles
     - ARW phy2 ensembles
     - ARW phy3 ensembles

Note that *ARW phy1*, *phy2* and *phy3* groups are not mixed up in the same run, they are employed separately to test their performance.

ARW Multi-Physics Ensembles (phy1)

Member	PBL	Sfc. L. Phy	LSM	Mic.physics	Cu.Phy	LW Rad.	SW Rad.
1	YSU	MO	Thermal	Kessler	KF	RRTM	Dudhia
2	MYJ	MOJ	Noah	Ferrier	KF	RRTM	Dudhia
3	MYJ	MOJ	Thermal	WSM6	BM	RRTM	CAM
4	MYJ	MOJ	Noah	Kessler	BM	CAM	Dudhia
5	MYJ	MOJ	Noah	Lin	GD	CAM	CAM
6	YSU	MO	Noah	WSM5	KF	RRTM	Dudhia
7	MYJ	MOJ	Noah	WSM5	GD	RRTM	Dudhia
8	YSU	MO	RUC	Lin	BM	CAM	Dudhia
9	YSU	MO	RUC	Ferrier	BM	RRTM	CAM
10	MYJ	MOJ	RUC	Thompson	GD	CAM	CAM

Older version options with varying LW and SW radiation schemes

ARW Multi-Physics Ensembles (phy2)

Member	PBL	Sfc. L. Phy	LSM	Mic.physics	Cu.Phy	LW Rad.	SW Rad.
1	MYNN	MYNN	Noah	Thompson	KF	RRTM	Goddard
2	QNSE	QNSE	Noah	Thompson	Grell 3D	RRTM	Goddard
3	MYJ	MOJ	Noah	Morrison	KF	RRTM	Goddard
4	YSU	MO	RUC	Morrison	New SAS	RRTM	Goddard
5	YSU	MO	Noah	Milbrandt-Yau	KF	RRTM	Goddard
6	ACM2	Pleim-Xiu	Pleim-Xiu	Milbrandt-Yau	Tiedtke	RRTM	Goddard
7	YSU	MO	Noah	WDM5	KF	RRTM	Goddard
8	QNSE	QNSE	Noah	WDM6	KF	RRTM	Goddard
9	YSU	MO	Noah	WDM5	Tiedtke	RRTM	Goddard
10	YSU	MO	Noah	WDM6	Grell 3D	RRTM	Goddard

Some new options, but LW and SW radiation options are the same for all.

ARW Multi-Physics Ensembles (phy3)

Member	**PBL**	**Sfc. L. Phy**	**LSM**	**Mic. physics**	**Cu.Phy**	**LW Rad.**	**SW Rad.**
1	MYNN	MYNN	Noah	Thompson	KF	RRTMG	RRTMG
2	QNSE	QNSE	Noah	Thompson	Grell 3D	RRTMG	RRTMG
3	MYJ	MOJ	Noah	Morrison	KF	RRTMG	RRTMG
4	YSU	MO	RUC	Morrison	New SAS	RRTMG	RRTMG
5	YSU	MO	Noah	Milbrandt-Yau	KF	RRTMG	RRTMG
6	ACM2	Pleim-Xiu	Pleim-Xiu	Milbrandt-Yau	Tiedtke	RRTMG	RRTMG
7	YSU	MO	Noah	WDM5	KF	RRTMG	RRTMG
8	QNSE	QNSE	Noah	WDM6	KF	RRTMG	RRTMG
9	YSU	MO	Noah	WDM5	Tiedtke	RRTMG	RRTMG
10	YSU	MO	Noah	WDM6	Grell 3D	RRTMG	RRTMG

Similar to phy2, but radiation is set to RRTMG for both LW and SW.

Selecting Among ECMWF-ENS 50 Members: Cluster Analysis

Widely Used Cluster Analysis Techniques:

- Non-Hierarchical clustering
  - K-means
- Hierarchical clustering
  - Complete Linkage (farthest neighbour clustering)
  - Ward’s method (a.k.a. minimum variance method)

The *complete linkage technique* is used in this study to form clusters and select representative members. (It is adapted from ARPA-SIMC, but implementation differs.)

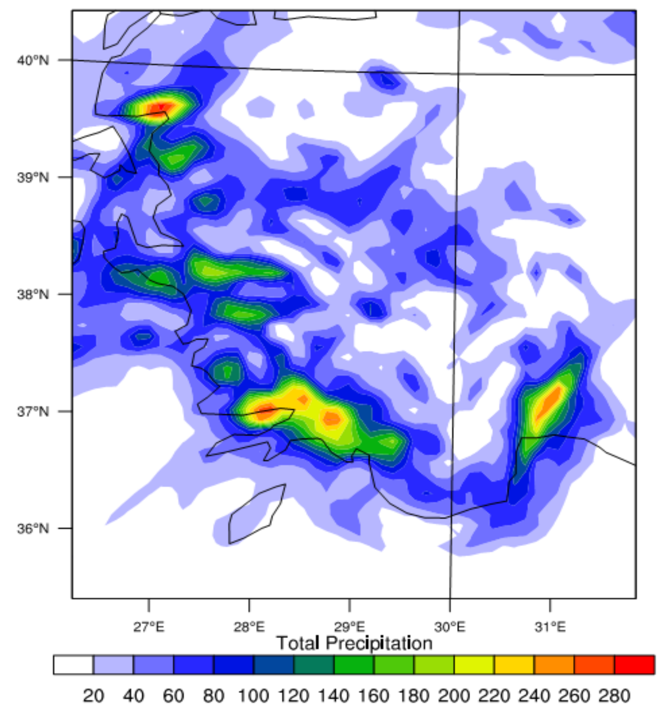
Some Preliminary Results (snapshots)

High Impact Weather:

A Mediterranean case study:
Severe flash-flooding in Antalya on 10th October 2011

Observed Precip on 10th October 2011

- Muğla: *169mm (recorded historical high!)*
- ***Antalya (36.9N-30.8E):***
  - 00-06UTC: 5.6 mm
  - 06-12UTC: 46.6 mm
  - ***12-18UTC: 231.6 mm***
  - 18-00UTC: 13.4 mm
  - ***24hrs total precip: 297.2mm***



So, we are to examine whether our ensembles get 6hrs accumulated precipitation (from 12UTC to 18UTC) reasonable in the first place, then look at its 24hrs accumulated precip.

Predictability by horizontal resolution…

- Coarse resolution: 10km
- Finer resolution: 4.5km

Predictability by forecast range…

- 24hrs in advance: It was forecast, but somewhat under estimated! (Not included in this presentation)
- 72hrs in advance
  - Some 4.5km ensemble runs over estimate total precipitation
  - 10km ensemble runs are more modest!

Performance of Ensembles (t+72)

- Low resolution ensembles: 10km
  1. ECMWF-ENS based ARW ensemble runs:

     Under estimates both in default and representative members of ECMWF-ENS (hereafter RM of ECMWF-ENS).

  2. ARW multi-physics ensembles
     - Phy1: Under-estimates
     - Phy2: Some members get 6hrs intense rain and total precip close to obs
     - Phy3: Similar or slightly better than Phy2

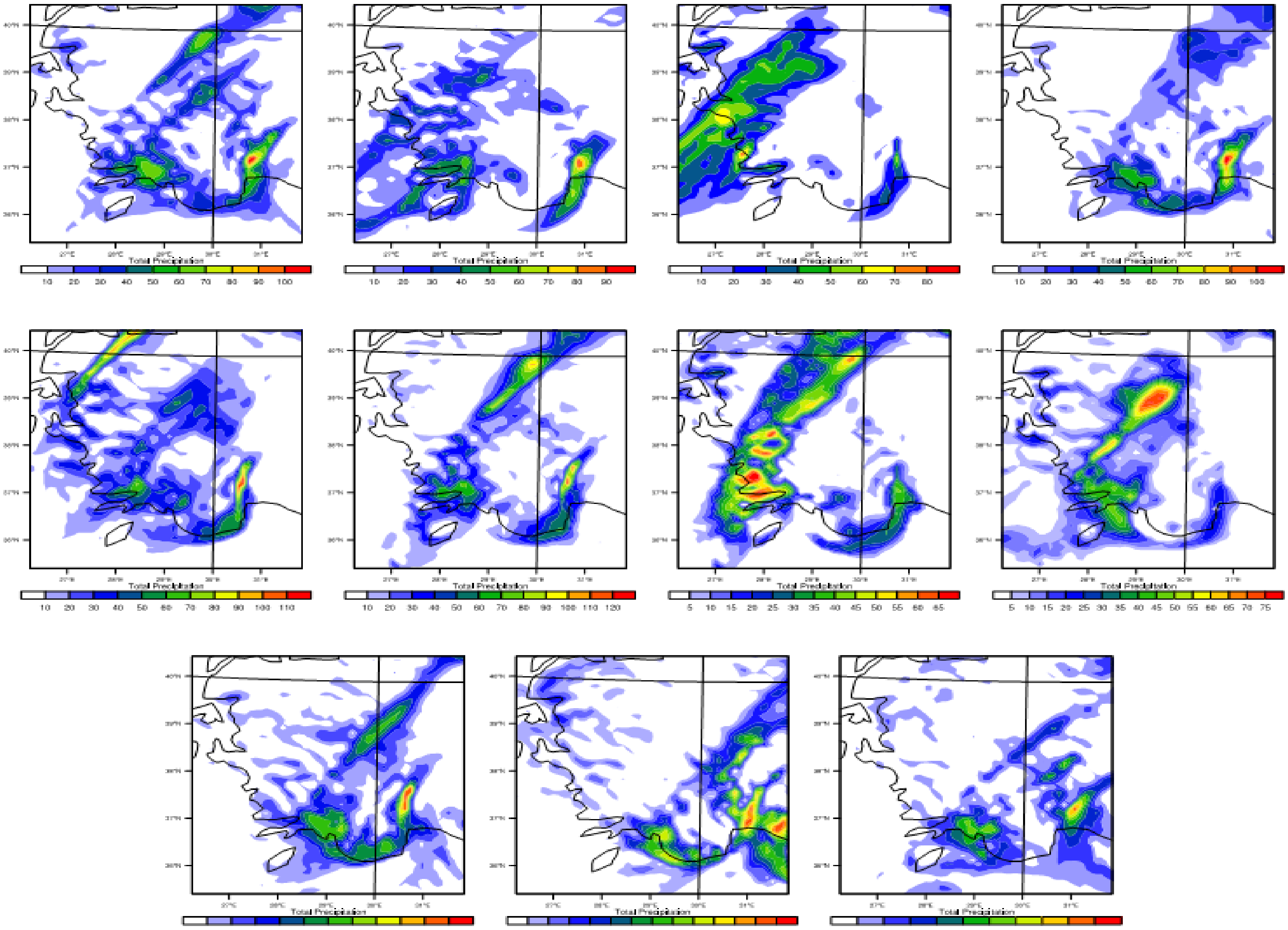
  3. Hybrid: ECMWF-ENS and ARW multi-physics ensembles combined

     It is better than 1, but under estimates compared to 2.

- High resolution ensembles with ECMWF-HRES ICs/LBCs: 4.5km
  - ARW phy1: Under estimates
  - ARW phy2: Better than that of phy1
  - ARW phy3: Close to phy2 performance

6hrs acc. precip from 12 UTC to 18 UTC (Only ICs/BCs differ)

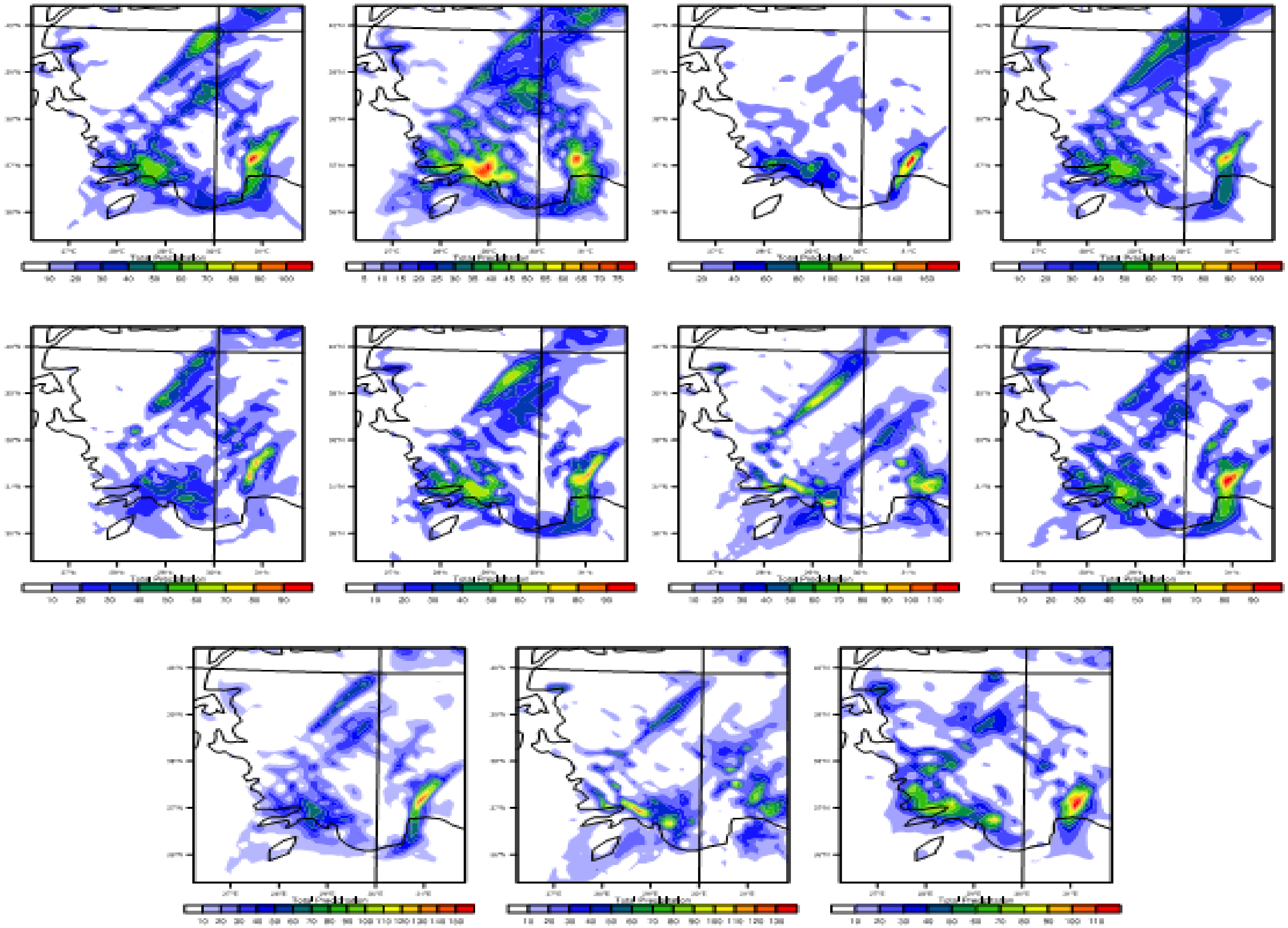
cf



1. ARW (10km) run by using *RM of ECMWF-ENS*

6hrs acc. precip from 12 UTC to 18 UTC (Only physics differ)

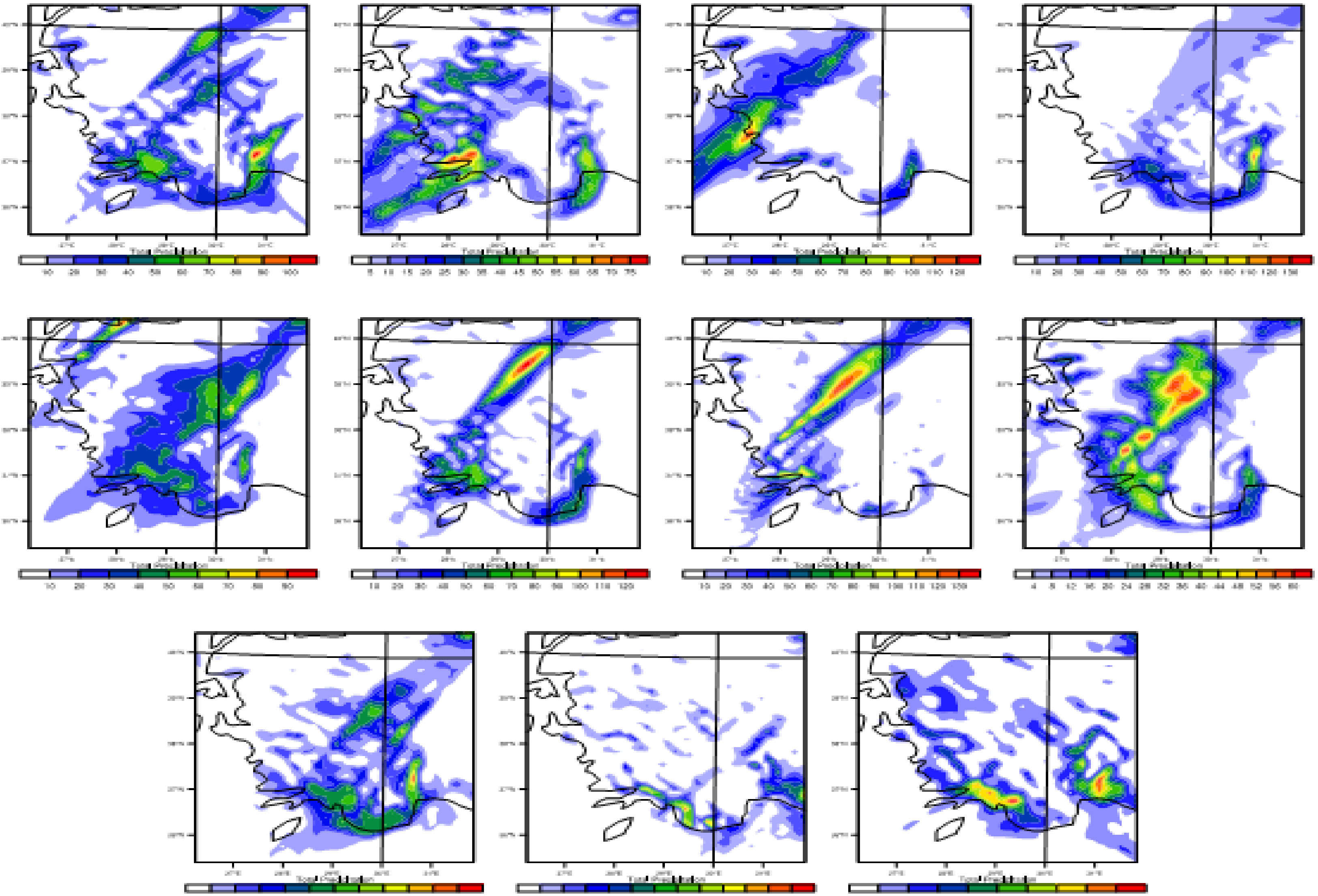
cf



2. ARW (10km) run by using *ECMWF-ENS CF's IC/BCs* and *ARW phy3*

6hrs acc. precip from 12 UTC to 18 UTC (Both physics and ICs/BCs differ)

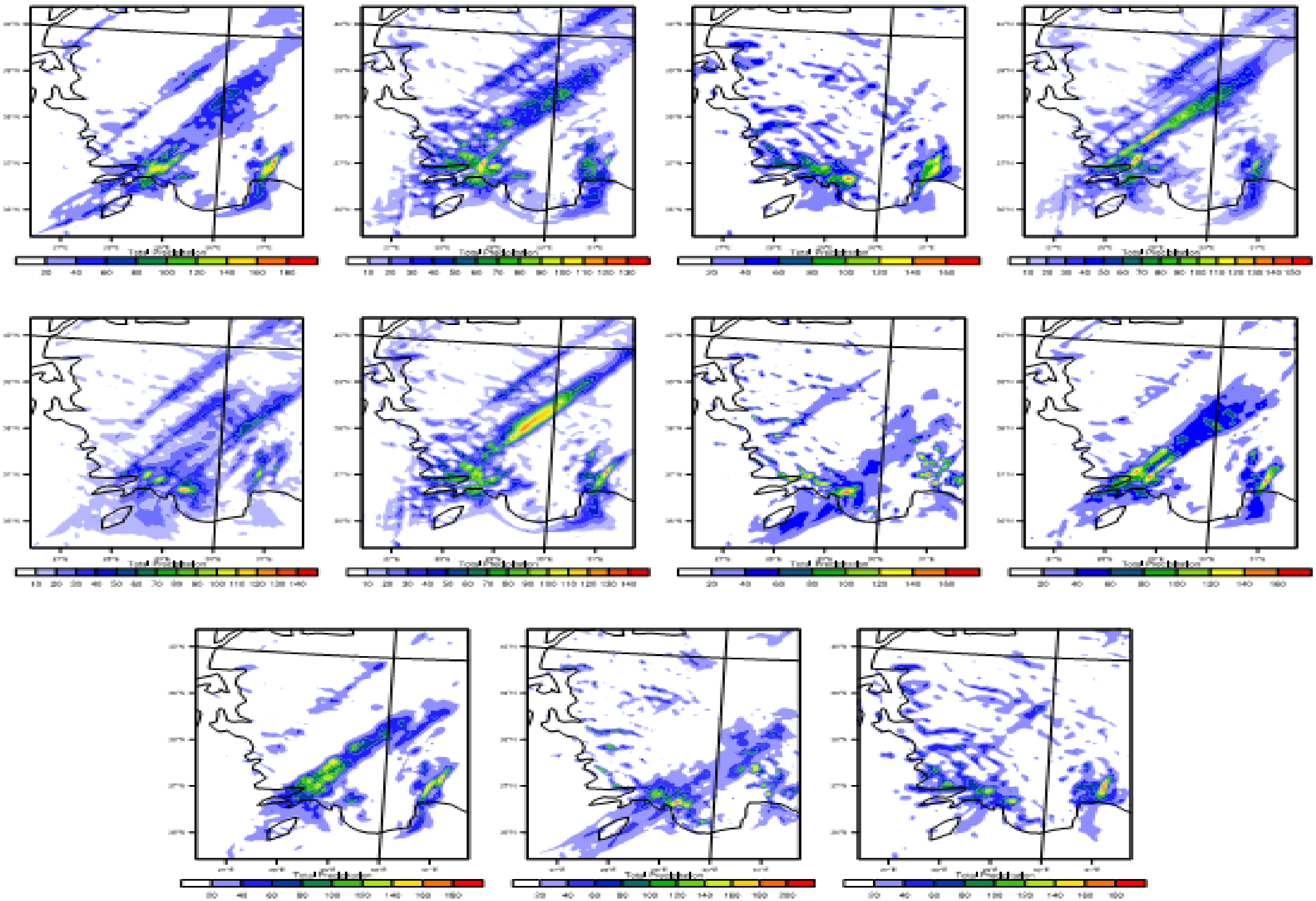
cf



3. Hybrid: *RM of ECMWF-ENS and ARW phy3*

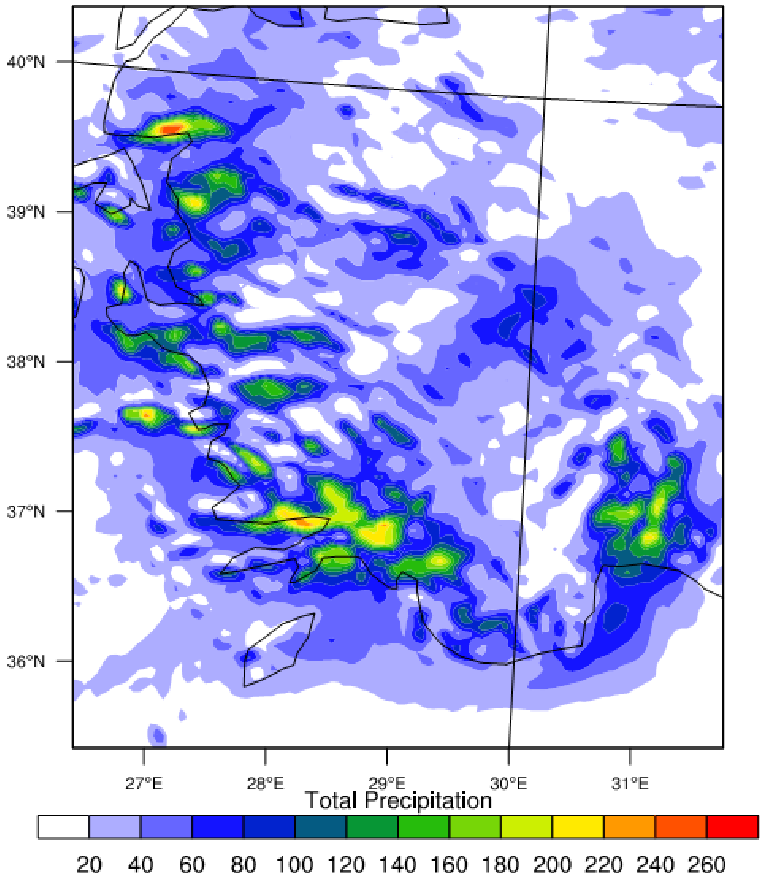
6hrs acc. precip from 12 UTC to 18 UTC (Only physics differ)

cf

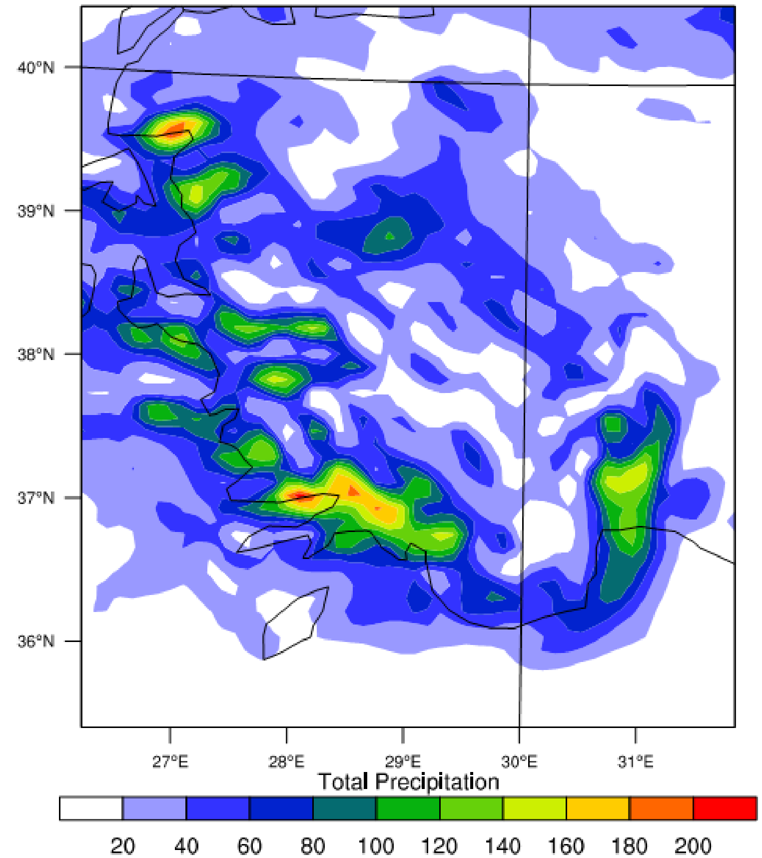


ARW (4.5km) run by using *ECMWF-HRES'* ICs/BCs and *ARW phy3*

Ensemble mean

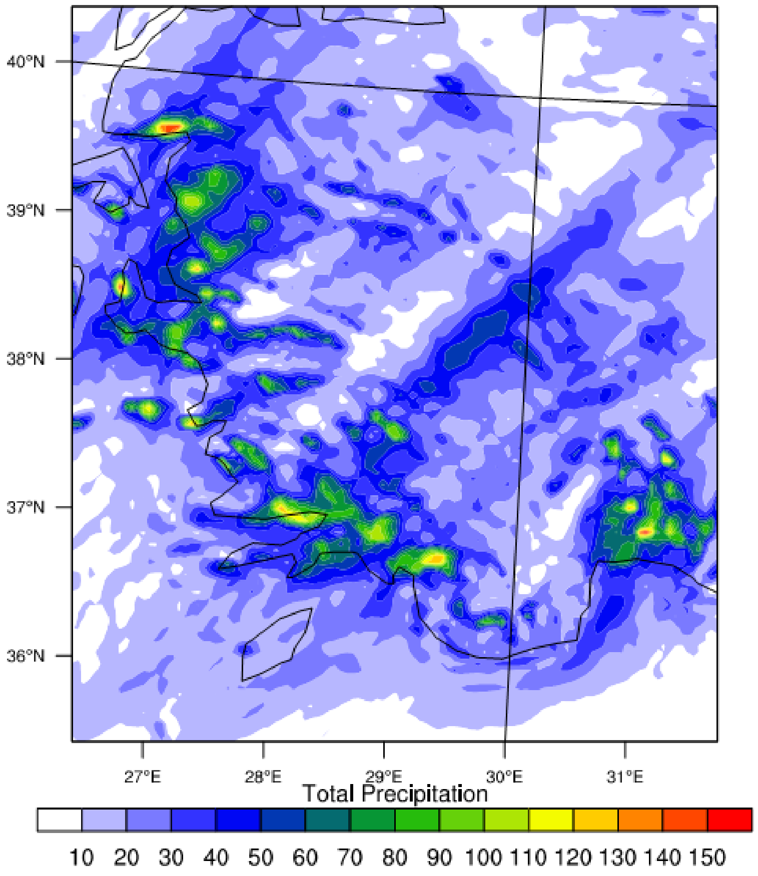


4.5km *ARW phy3* ens

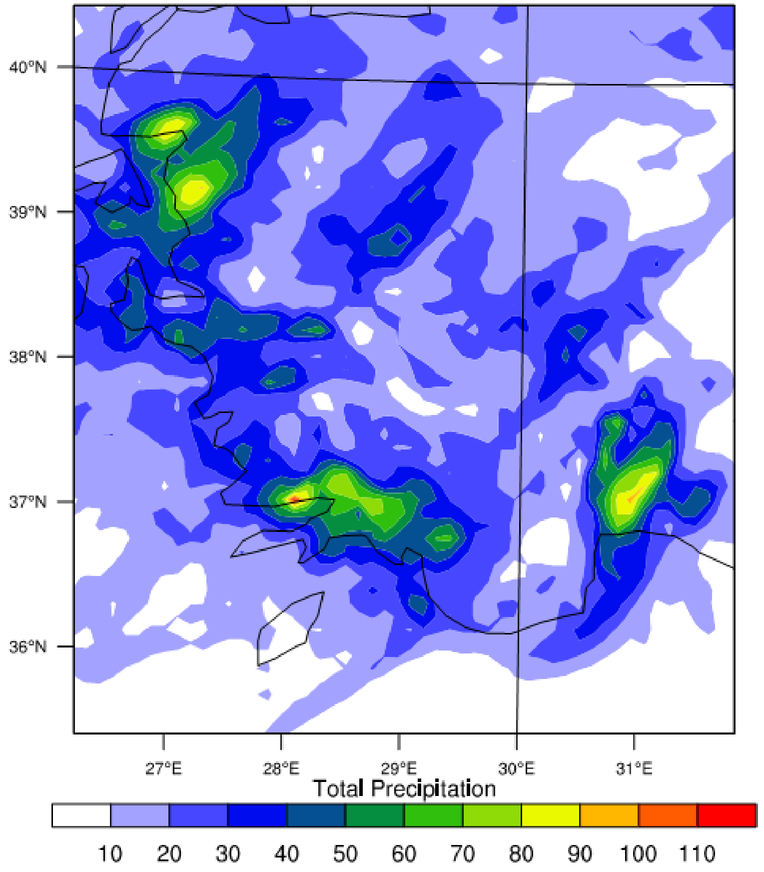


10km *ARW phy3* ens

Ensemble spread



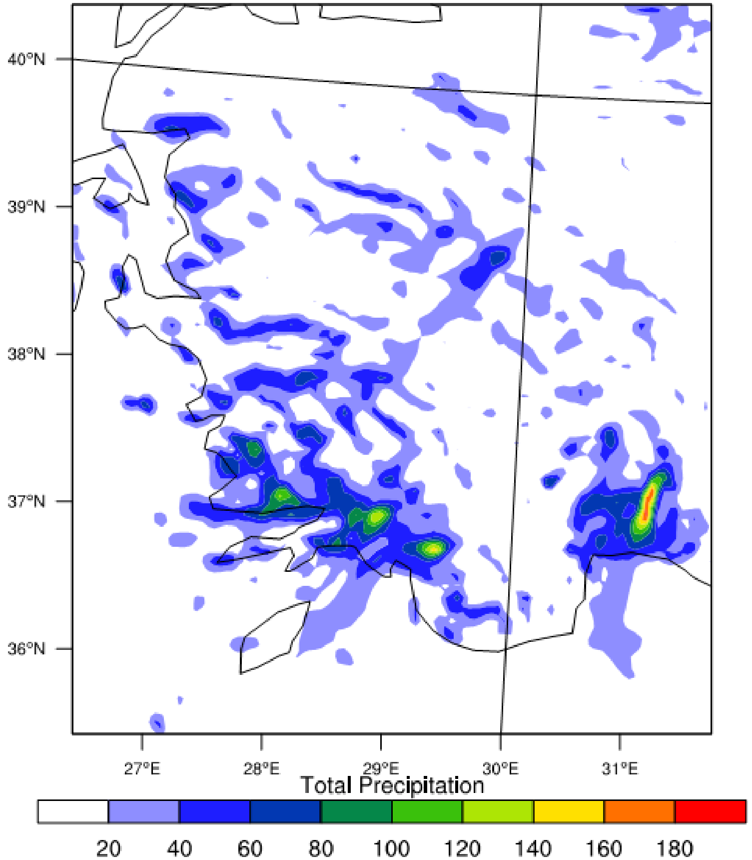
ARW (4.5km) *phy3* ens



ARW (10km) *phy3* ens

Observed 6hrs Total Precip (18UTC-12UTC): 232mm

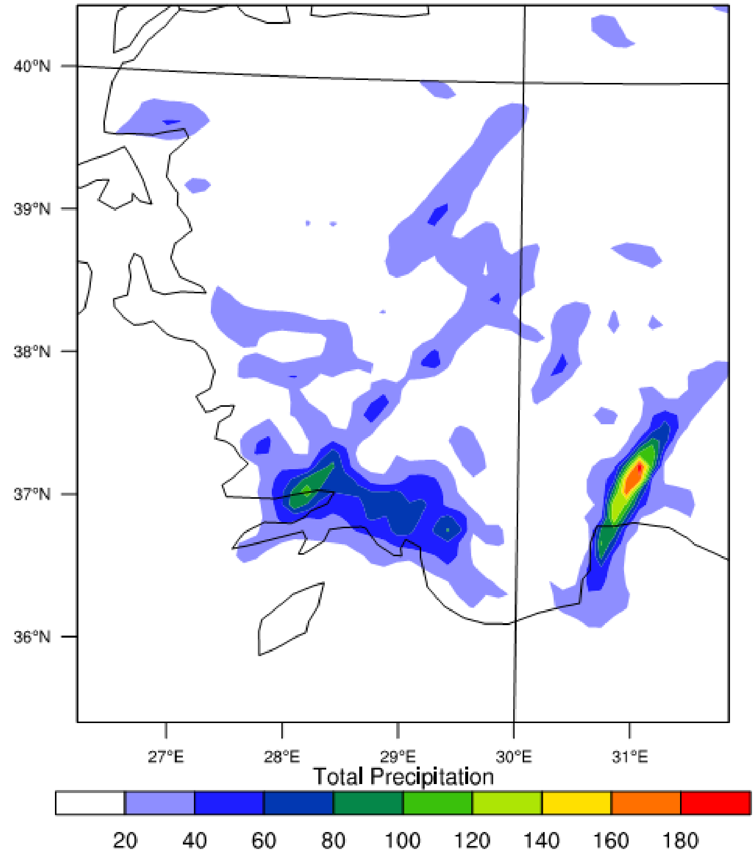
(t+66) Forecast max: 188 mm



4.5km run 6hrs total precip (18UTC-12UTC)

ARW phy3 ens

(t+66) Forecast max: 197mm

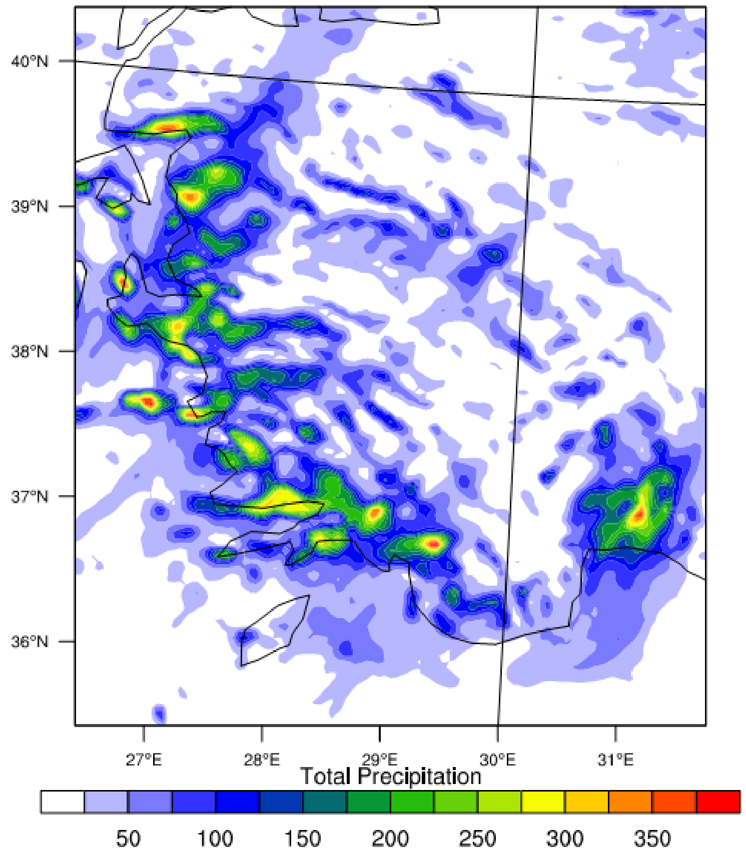


10km run 6hrs total precip (18UTC-12UTC)

*ARW phy*3 ens

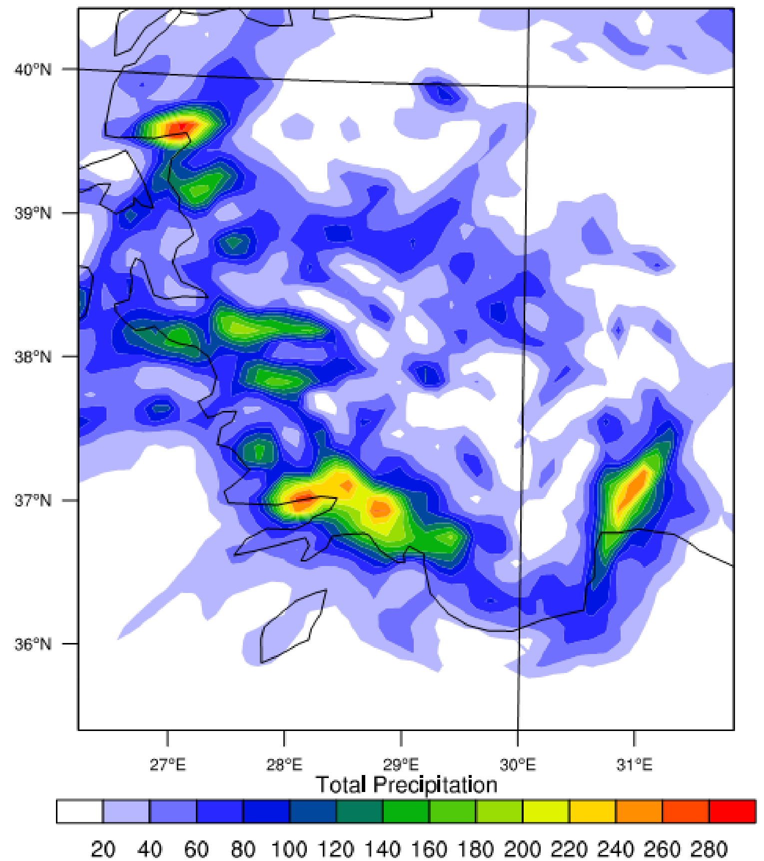
Observed 24hrs Total Precip: 297mm

(t+72) Forecast max: 360 mm



4.5km run total precip (24hrs)

(t+72) Forecast max: 262 mm



10km run total precip (24hrs)

Concluding Remarks

- ARW model based short range ensemble system can generate combinations of ensemble members to address uncertainties in data and in the model.
- It is very helpful to employ a cluster analysis technique to select representative members among 50 ECMWF-ENS members.
- Depending on a case in question, ARW multi physics based ensembles may perform better than an ensemble run that uses control forecast physics with ECMWF-ENS.
- High resolution (<5km) ARW physics ensembles may not be as sustainable as coarse resolution ensembles when using multi-physics options, since some physics options may core dump!
- Predictability doesn't always increase with the latest ICs/BCs, considering ICs/BCs of earlier runs could also be very beneficial.
- It is only one case study for the time being, there being so much to be done…..

Thanks for attending…

Acknowledgements: I am grateful to the ECMWF for providing the related datasets/computer resources, NCAR for making ARW publicly available and ARPA-SIMC for sharing with me their cluster algorithm.