RegCM4 CP core: the challenge to explore climate by the new non hydrostatic version of the ICTP regional climate model

E. Pichelli, E. Coppola, G. Giuliani, F. Giorgi

Thanks for contributing to
I. Guettler, L. Srnec from DHMZ
M. Belda, T. Halenka from Charles UNIV.

Ninth ICTP Workshop on the Theory and Use of Regional Climate Models

Trieste 28 May - 8 June 2018

RegCM NON-Hydrostatic core

No hydrostatic approximation and the vertical momentum equation resolved.

$$p(x,y,z,t) = p_0(z) + p'(x,y,z,t),$$

$$T(x,y,z,t) = T_0(z) + T'(x,y,z,t),$$

$$\rho(x,y,z,t) = \rho_0(z) + \rho'(x,y,z,t).$$

Horizontal momentum equations
Heat equation
Mass continuty equation

Vertical momentum equation

Subgrid phenomena parameterizations (turbolence, microphysics, convection, radiation, soil exchange of moist and energy....)

High or very high horizontal resolution

Depending on resolution some **sub-grid** phenomena can be **explicitly resolved**, other still need to be **parameterized**, possibly enhancing degree of closure and/or representing more **sophisticatedly**.

Atmospheric convection

Mechanism of redistribution of energy

Free convection:
Buoyancy (thermal initiation).

Forced convection:
mechanisms other than thermodynamic that favor vertical instability: wind shear, low level convergence, terrain mechanical acceleration, …

Moist convection leads to **cumulus formation** (**latent head release and moist condensation**) and thunderstorm development

Scales: few meters to tens **km** horizontally and vertically over **short time ranges** (30 minutes on average to go from Initiation to dissipation for thunderstorms)

Cumulus formation inside a model

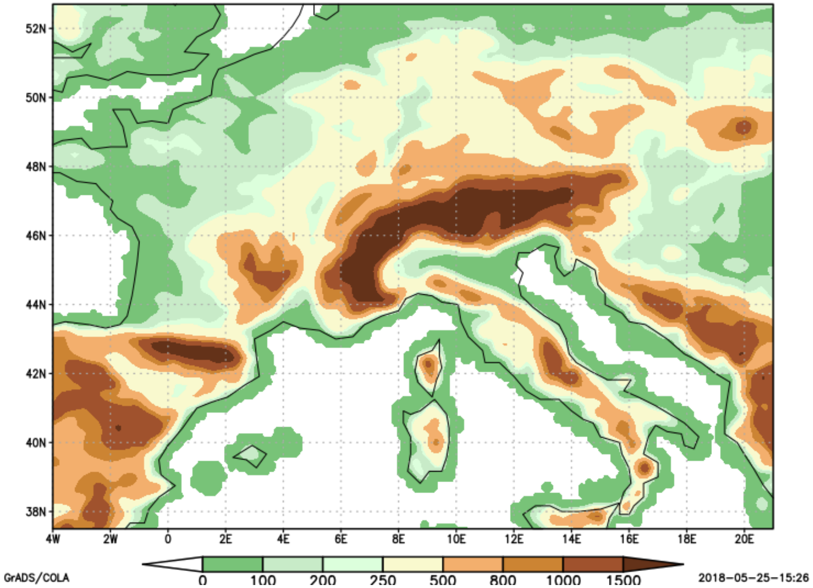
Dx < 3-5km
→ parameterization needed

Dx > 3-5km
→ Cumulus formation explicitly resolved

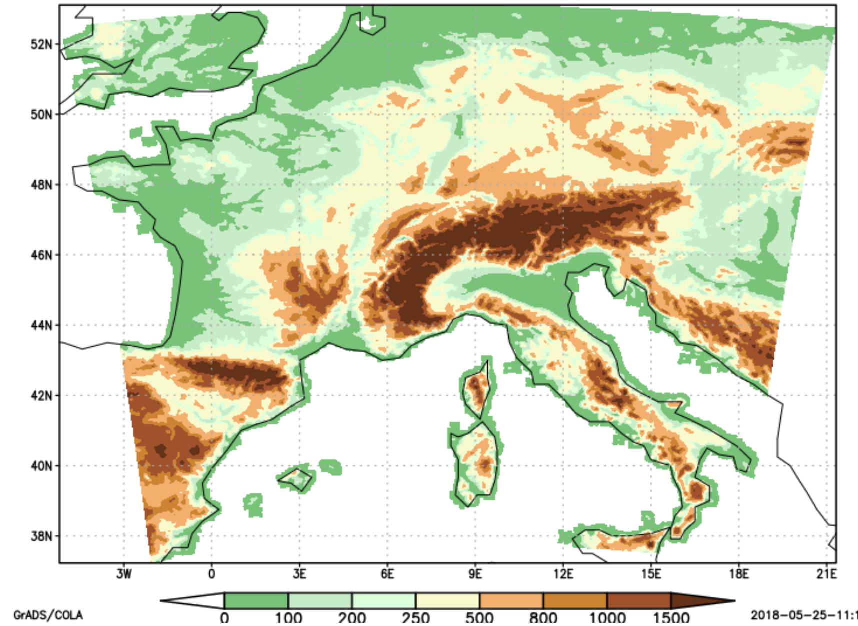
Convection Permitting core

Ex. enhanced resolution

12 Km



3 Km



More complex orography resolved → **advantage** to better represent interactions at the mesoscale

→ **disadvantage** steeper gradients can induce to numerical instabilities not easily manageable

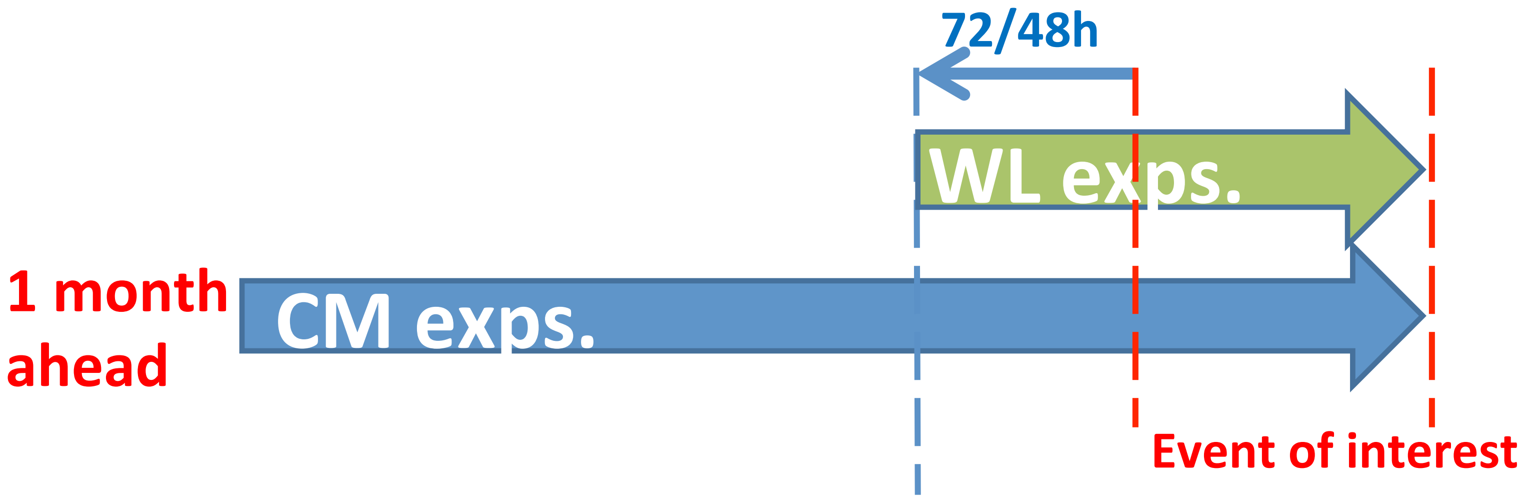
Ex. **gravity waves** (extremely important in the dynamics of mesoscale circulation!!) can be artificially **reflected** at the top of the domain and amplified thus adding **artificial information** and also turning to unstable solutions (ex. too high w)

How we can manage unstable solutions due to W excess

→ reducing Dt
→ using Upper layer Rayleigh dumper for the vertical velocity (reduces the w close to the top, relaxing on BC)
→ enhancing the β coefficient, dumping for high frequency acoustic modes

```
&nonhydroparam
ifupr = 1,         ! Upper radiative boundary condition (Klemp and Durran,
                   ! Bougeault, 1983)
nhbet = 0.1,       ! Ikawa beta parameter (0.=centered, 1.=backward)
                   ! determines the time-weighting, where zero gives a
                   ! time-centered average and positive values give a bias
                   ! towards the future time step that can be used for
                   ! acoustic damping. In practice, values of
                   ! nhbet = 0.2 - 0.4 are used (MM5 manual, Sec. 2.5.1)
nhxkd = 0.1,       ! Time weighting for weighting old/new pp
ifrayd = 1,        ! Upper levels Rayleigh damper to BCs
rayndamp = 5,      ! Number of top levels to apply
rayalpha0 = 0.001, ! Rate alpha0
rayhd = 10000.0,   ! Damping scale depth
```

EURO-CORDEX FPS-CP test-cases ex.



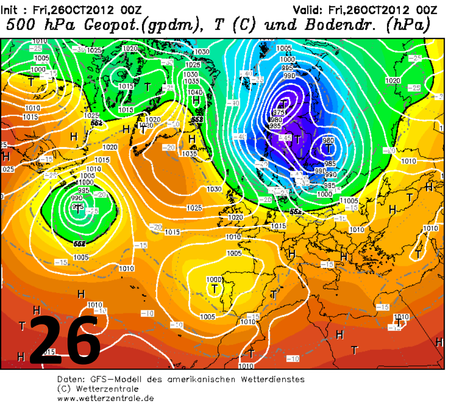
Preliminary exercise among many different NWPM and RCM to explore potentialities of climate CP simulations…while waiting for long runs

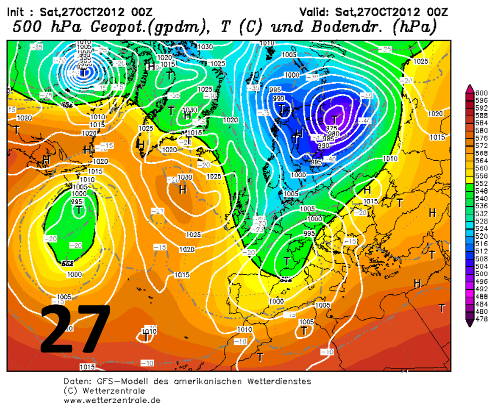
WL simulations → investigate RCMs in their new CP cores (not trivial!!)

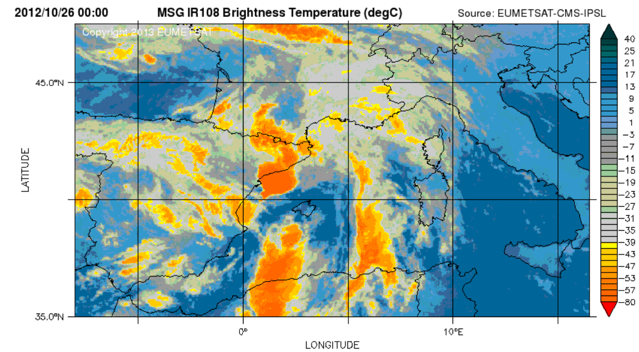
CM simulations → assess the multi-model ensemble potentialities

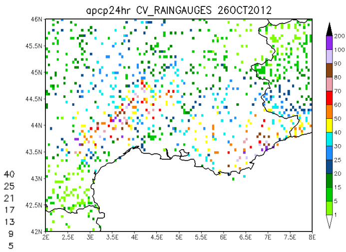
→ investigate NWPMs over long range scale

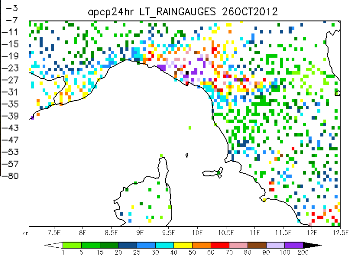
TEST CASES



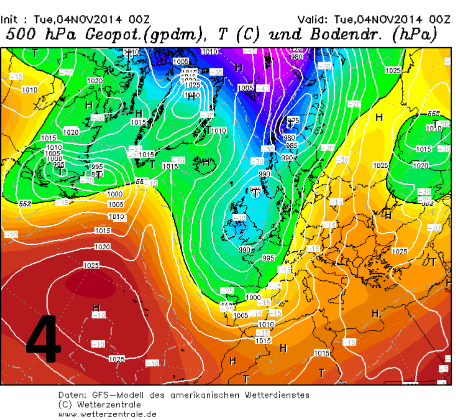


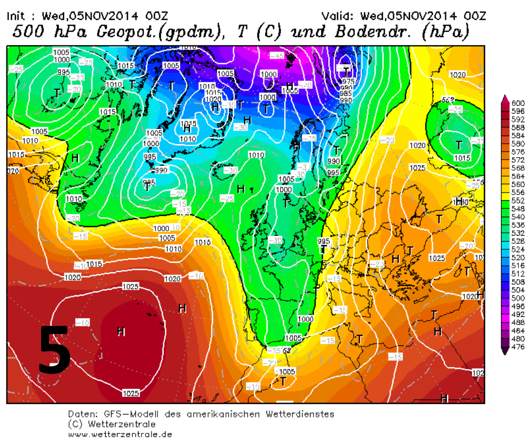


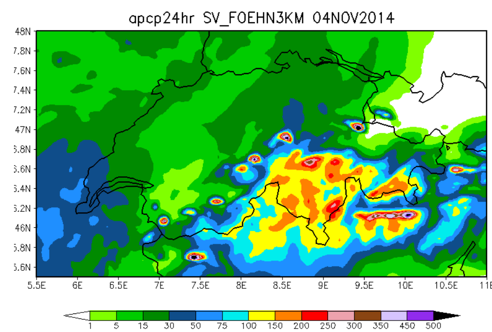




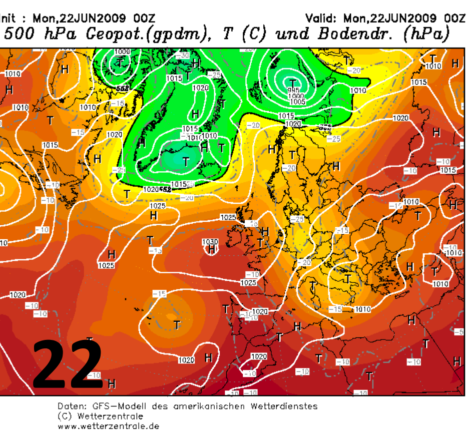
HyMeX-IOP16
(Oct. 2012)

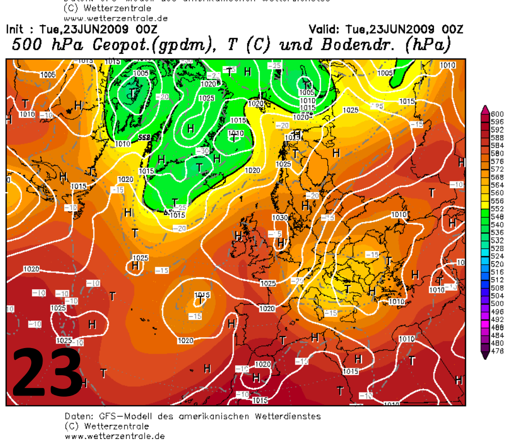


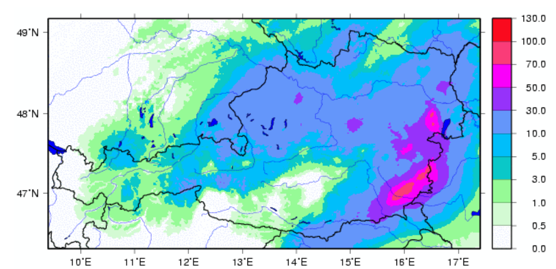




Foehn case
(Nov. 2014)

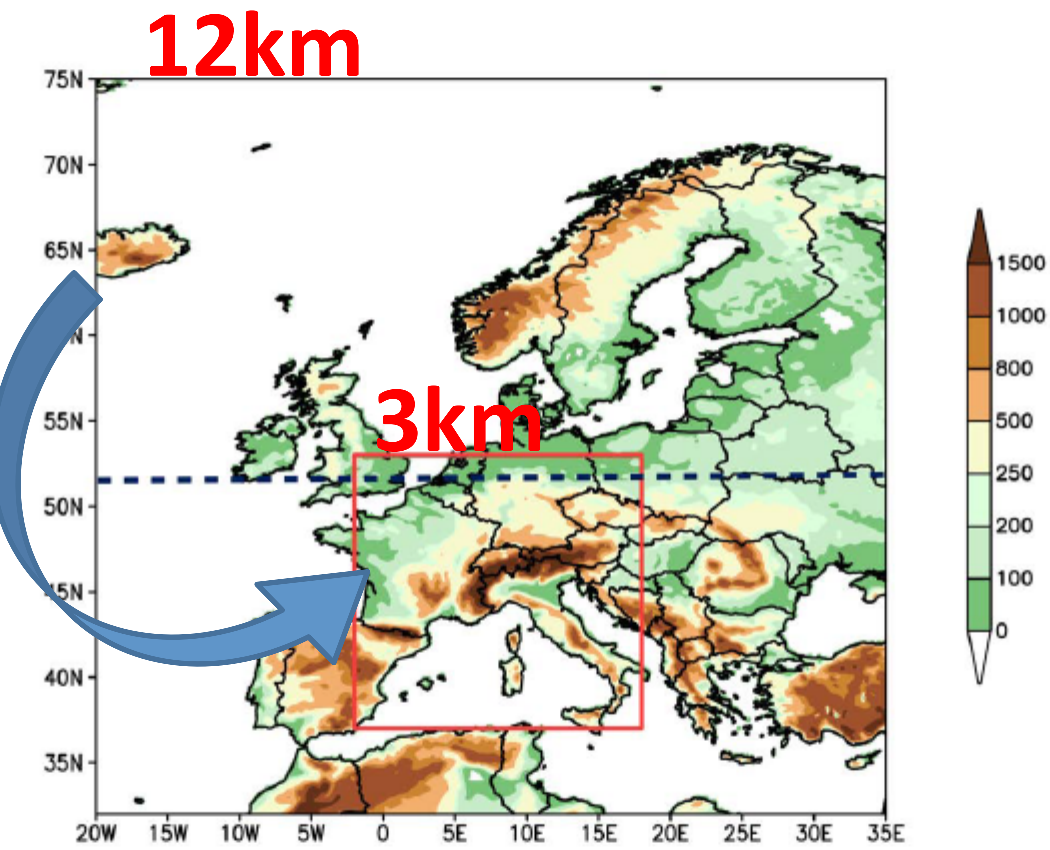






Austria case
(June 2009)

EURO-CORDEX FPS-CP protocol



RegCM	
12 Km	3 Km
Hydrostatic core	Non-hydro.
23 v-levels	41 v-levels
ERA-Int IC-BC	12KM IC-BC
530x530	575x605

Preliminary assessments for RegCM simulations

→HPE from complex mesoscale interactions are less easly captured by CM exps.

→OR-forcing rain events are generally better reproduced than CE related to more complex mechanisms (CV2 MCS) also by CMs

→ Events related to weak mesoscale forcings are less easily located than ones related to deep large-scale forcings

→ sensitivity to Low-Res driving BC

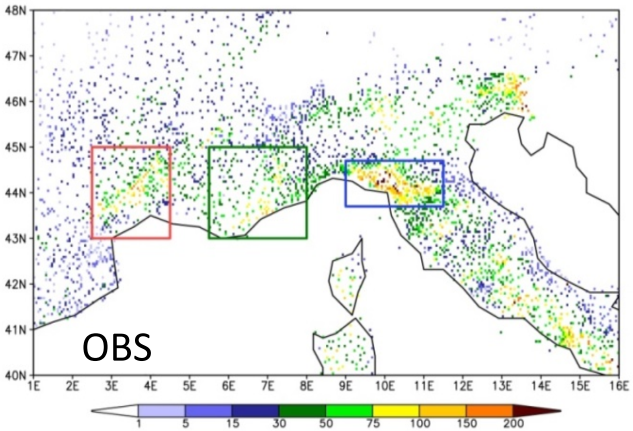
→ sensitivity to Physics schemes

RegCM mini-ensemble

Charles Univ.

DHMZ

	ICTP		DHMZ		CUNI	
DOM.	12 KM	3 KM	12 KM	3 KM	12 KM	3 KM
VERT. LEV.	23	41	41	41	23	41
ICBC	ERA-INT	12KM	ERA-INT	12KM	ERA-INT	12KM
CORE	HYDRO.	NON-HYDRO.	HYDRO.	NON-HYDRO.	HYDRO.	NON-HYDRO.
Micro-PHYS.	SUBEX	WSM5	WSM5	WSM5	SUBEX	NOGH.-THOMP.
PBL	UW	Holtslag	Holtslag	Holtslag	UW	Holtslag
SURFACE	CLM4.5	CLM4.5	BATS	BATS	CLM4.5	CLM4.5
CUMULUS	TIEDKE-tn	Shallow	Grell	NO	TIEDKE-def	Shallow



Event total precipitation for **HyMex-IOP16**

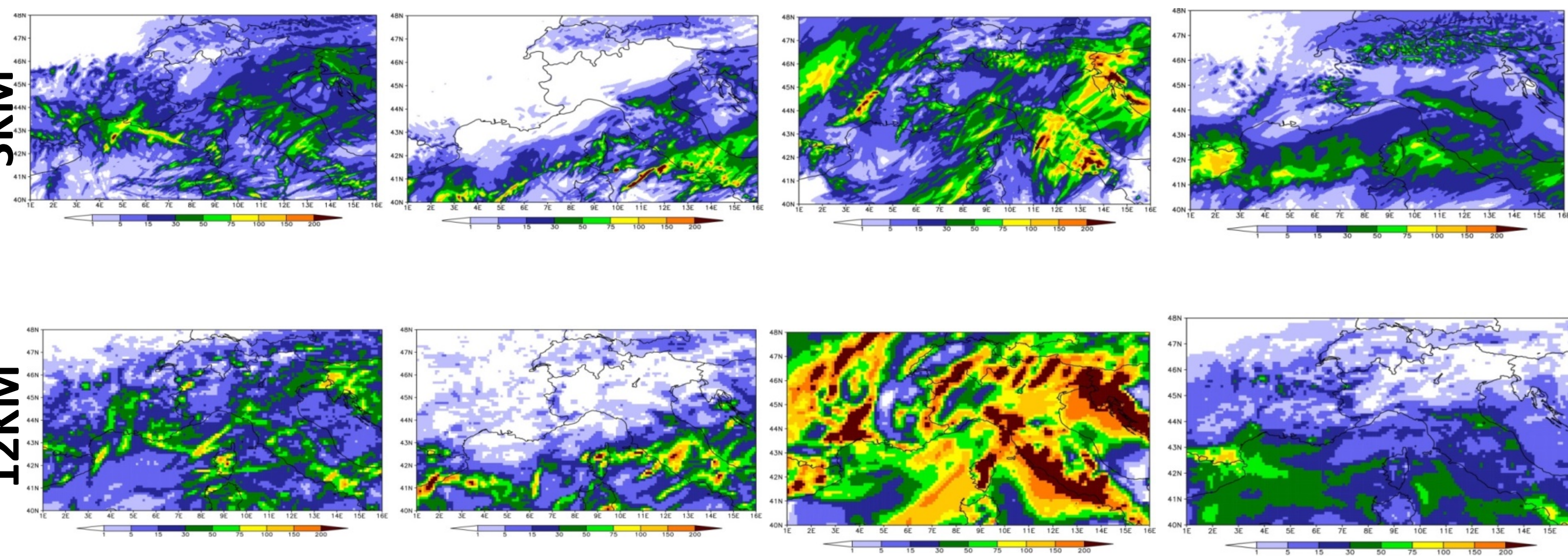
NOTICE

IOP16 case is characterized by **local surface minimum** evolving across WMED, then interacting with deep upper level NA trough.

ICTP-WL ICTP-CM DHMZ-CM CUNI-CM

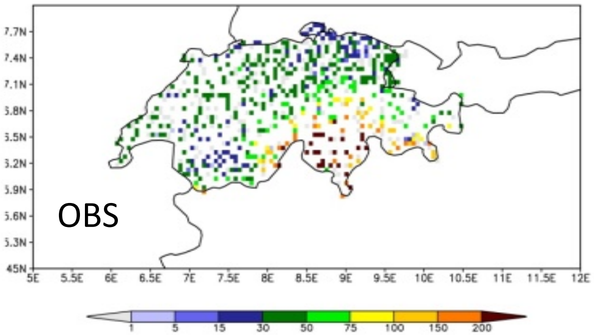
3KM

12KM

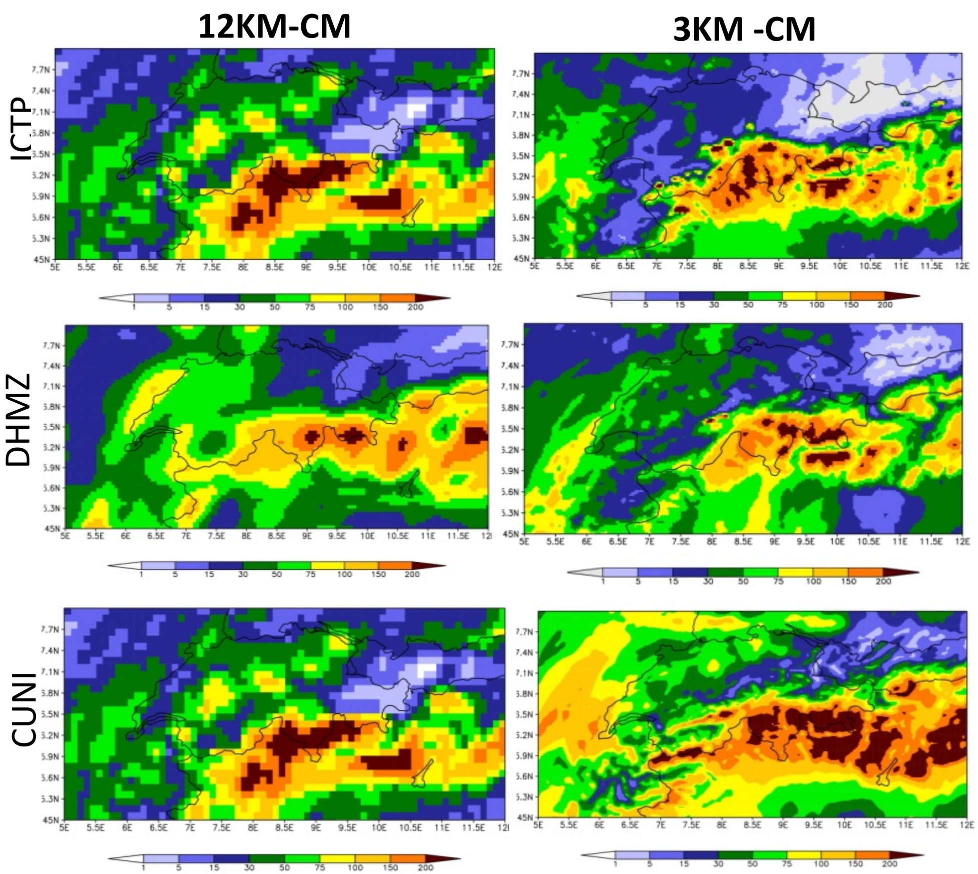


Remarks:

- WL sims. are reasonable and similar among them
- CM sims very much dependent on Physics configuration (ex. BATS too wet)
- Precipitation field at 3km trace the mother domain one → The introduction of sophisticate microphysics (ICTP, CUNI) alone is not enough for a fair performance!!



Event total precipitation for **FOEHN** case

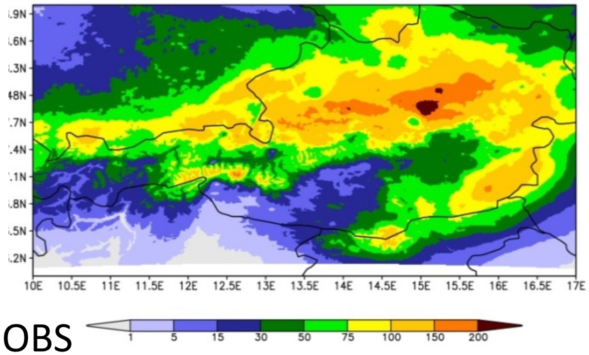


All the simulations behaves similarly in terms of precipitation, but a wet tendency of Nogherotto microphysics is found.

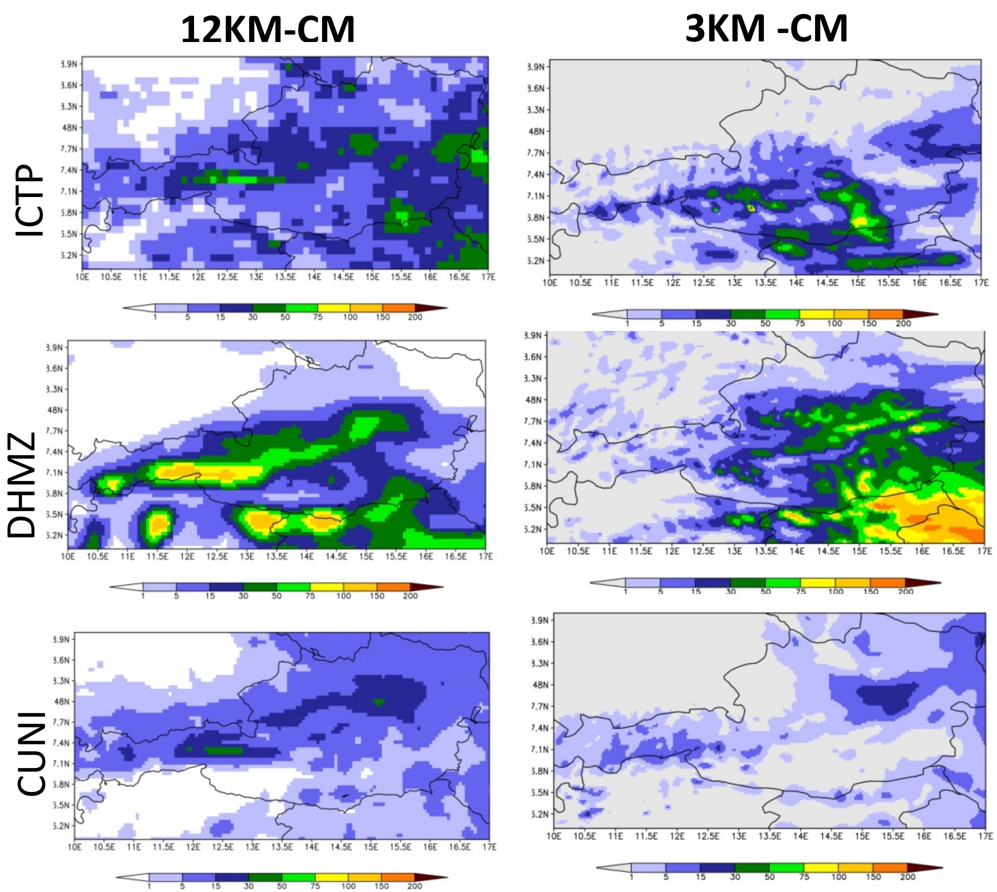
3km modulates the signal respect the 12km, correctly locating maxima.

NOTICE

Foehn case is characterized by **strong upper levels large scale driving conditions** (deep NA trough).



Event total precipitation for **AUSTRIA** case



All the simulations show a dry tendency over the area of interest (shared with their feeding 12 km), but the analysis over the whole 3km domain show that all the simulations **shift the rain event** across the Balkans or southward of Austria because of a **mis-location of the cut off low driving the event**.

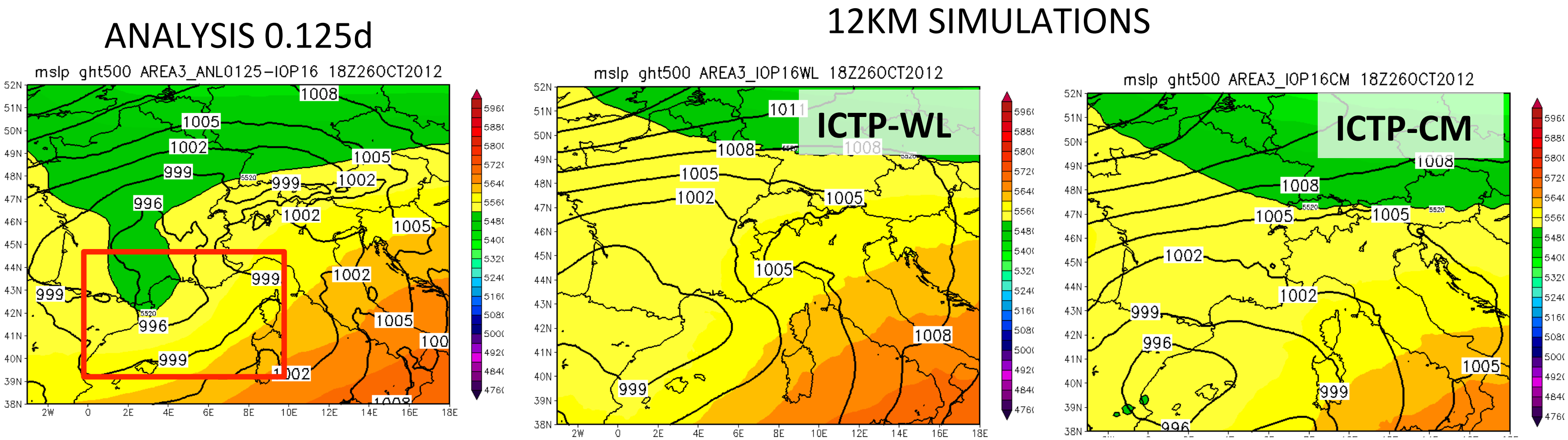
NOTICE

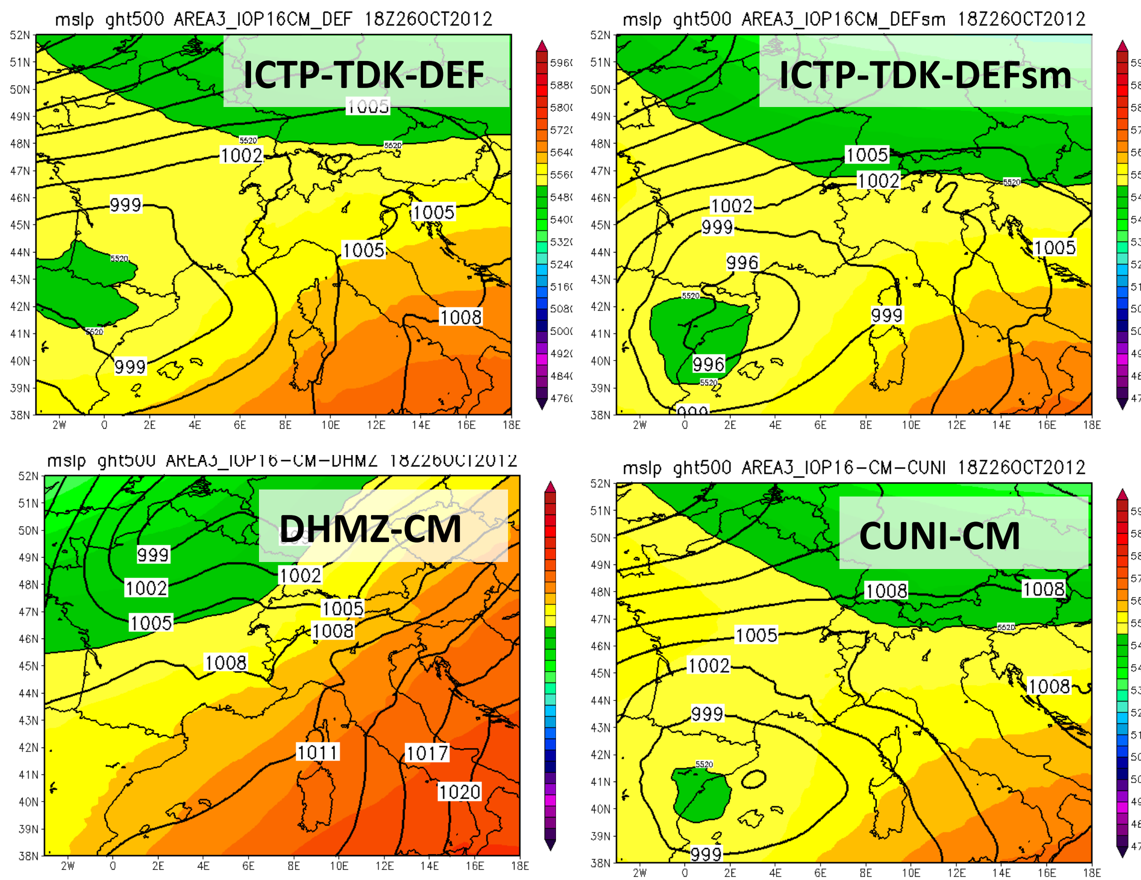
Austria case is characterized by **weak** large scale driving conditions **with upper-level local minimum** evolving across Adriatic Sea.

The hypothesis is that the 12 km is driving the CP-domain through BC

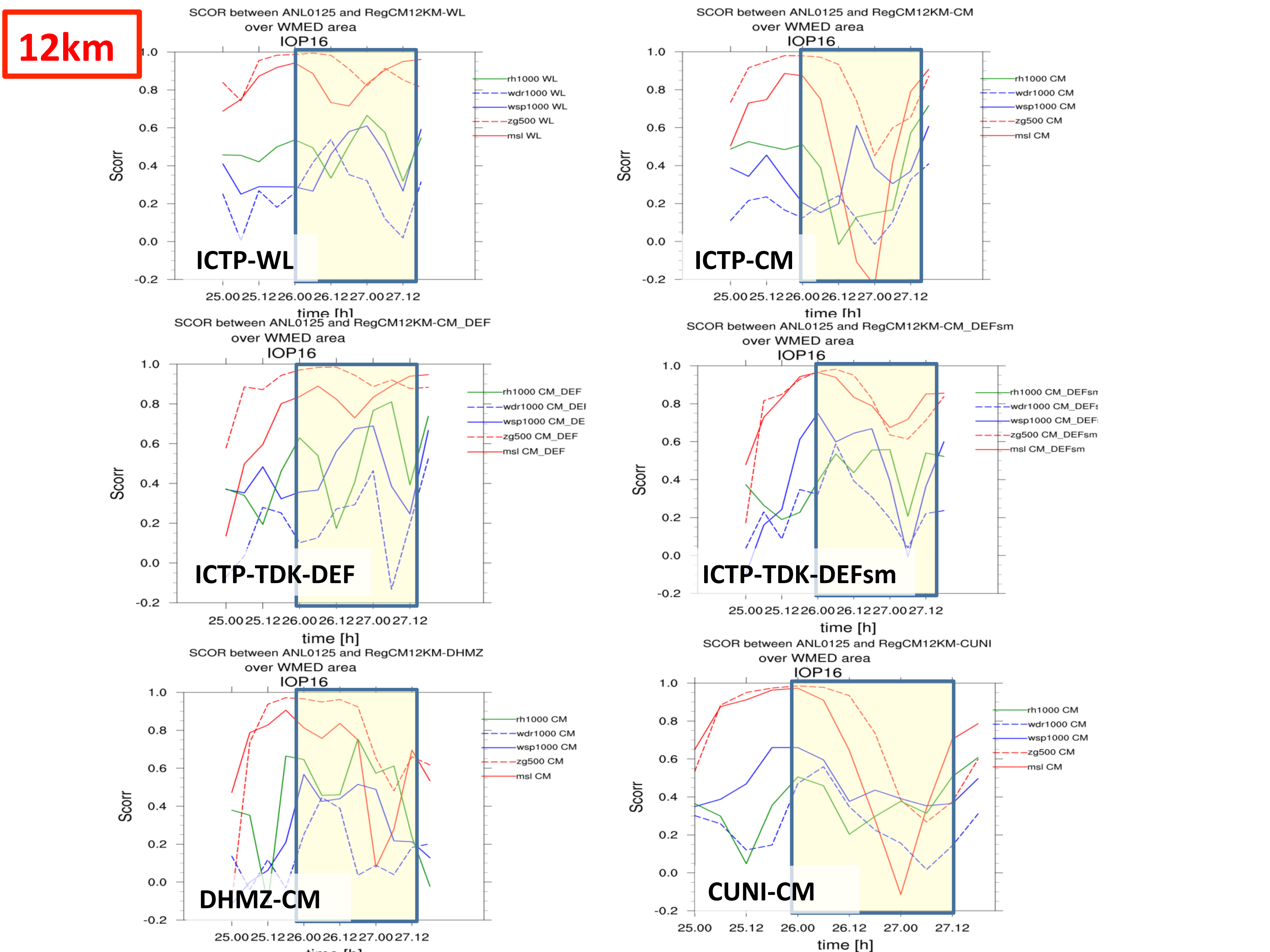
+ 2 more simulations:

	ICTP	
DOM.	12 KM	3 KM
VERT. LEV.	23	41
ICBC	ERA-INT	12KM
CORE	HYDRO.	NON-HYDRO.
Micro-PHYS.	SUBEX	WSM5
PBL	UW	Holtslag
SURFACE	CLM4.5	CLM4.5
CUMULUS	TIEDKE-tn	Shallow
TDK-DEF	Tuning 12 km domain better matching monthly stats.	
TDK-DEF-SM	Idem + Soil Moisture Init.	

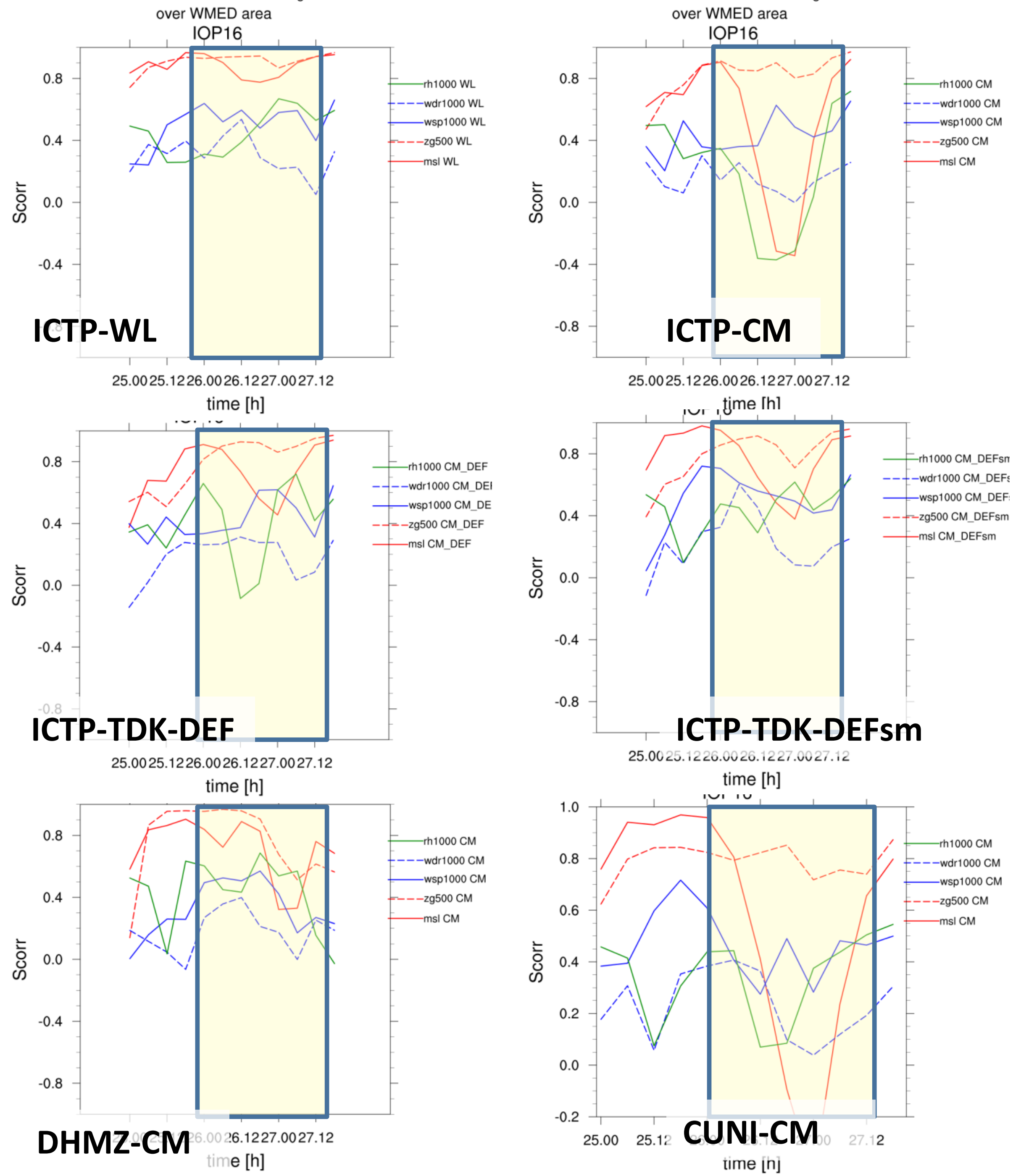




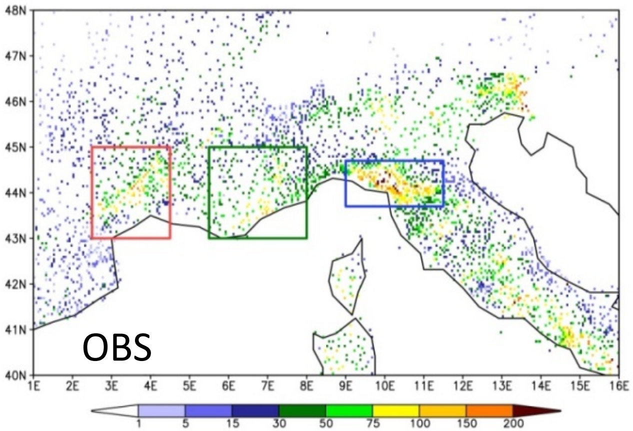
Mean sea level pressure (black lines) and **geopotential height at 500hPa** (colors) from ECMWF-analysis (top-left) and the model simulations at 12 km on Oct. 26th, 2012 at 18UTC.


12km
SCOR between ANL0125 and RegCM12KM-WL
over WMED area
IOP16
rh1000 WL
wdr1000 WL
wsp1000 WL
zg500 WL
msl WL
ICTP-WL
SCOR between ANL0125 and RegCM12KM-CM
over WMED area
IOP16
rh1000 CM
wdr1000 CM
wsp1000 CM
zg500 CM
msl CM
ICTP-CM
SCOR between ANL0125 and RegCM12KM-CM_DEF
over WMED area
IOP16
rh1000 CM_DEF
ICTP-TDK-DEF
SCOR between ANL0125 and RegCM12KM-CM_DEFsm
over WMED area
IOP16
rh1000 CM_DEFsm
zg500 CM_DEFsm
msl CM_DEFsm
ICTP-TDK-DEFsm
SCOR between ANL0125 and RegCM12KM-DHMZ
over WMED area
IOP16
rh1000 CM
wdr1000 CM
wsp1000 CM
zg500 CM
msl CM
DHMZ-CM
SCOR between ANL0125 and RegCM12KM-CUNI
over WMED area
IOP16
rh1000 CM
wdr1000 CM
wsp1000 CM
zg500 CM
msl CM
CUNI-CM
Scorr
time [h]
25.00
25.12
26.00
26.12
27.00
27.12

3km



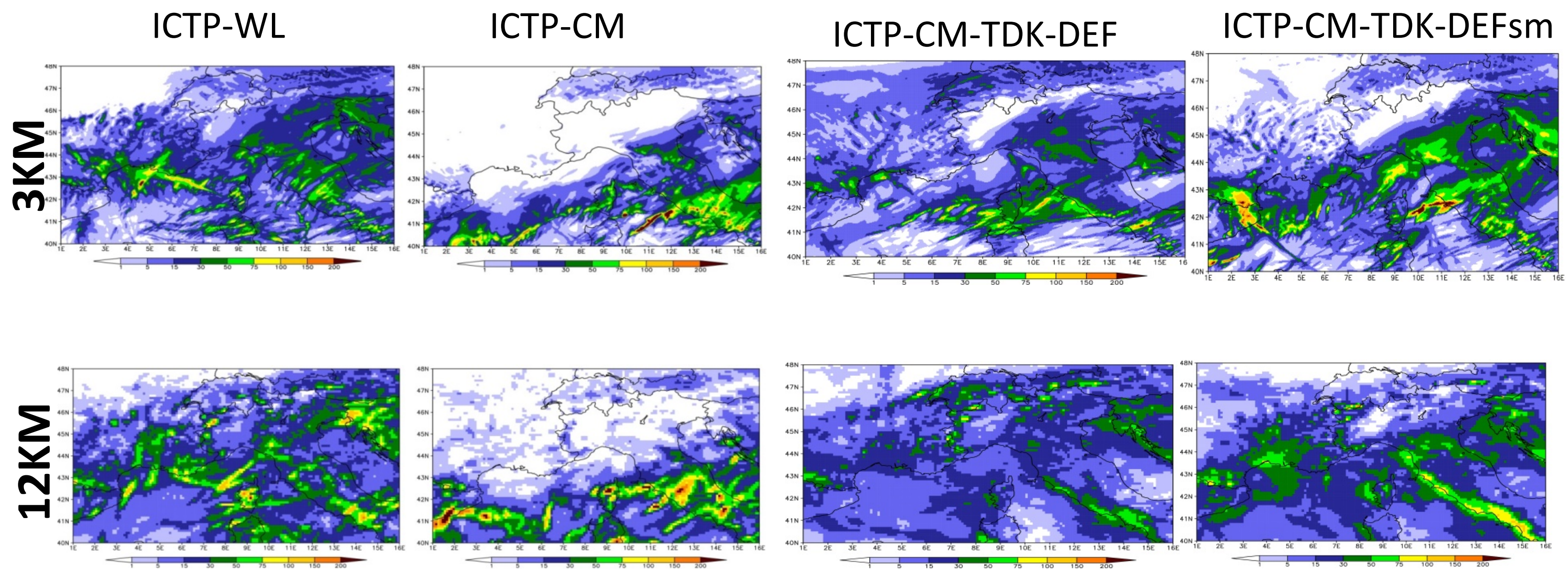
over WMED area
IOP16
rh1000 WL
wdr1000 WL
wsp1000 WL
zg500 WL
msl WL
Scorr
ICTP-WL
time [h]
over WMED area
IOP16
rh1000 CM
wdr1000 CM
wsp1000 CM
zg500 CM
msl CM
ICTP-CM
rh1000 CM_DEF
zg500 CM_DEF
msl CM_DEF
ICTP-TDK-DEF
zg500 CM_DEFsm
msl CM_DEFsm
ICTP-TDK-DEFsm
DHMZ-CM
CUNI-CM
25.00
25.12
26.00
26.12
27.00
27.12



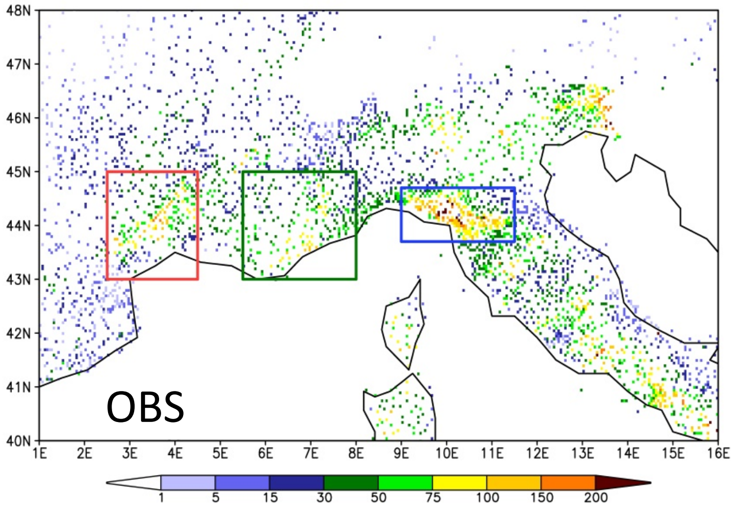
Event total precipitation for **HyMex-IOP16**

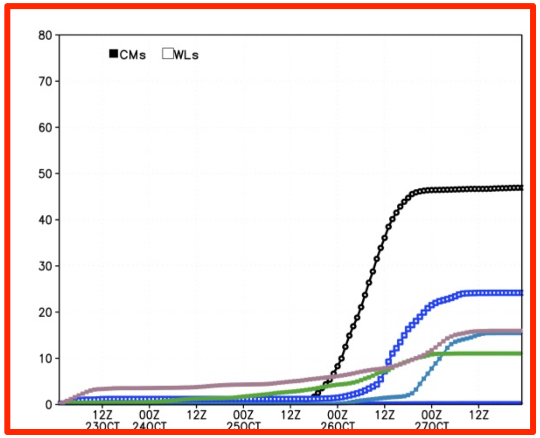
NOTICE

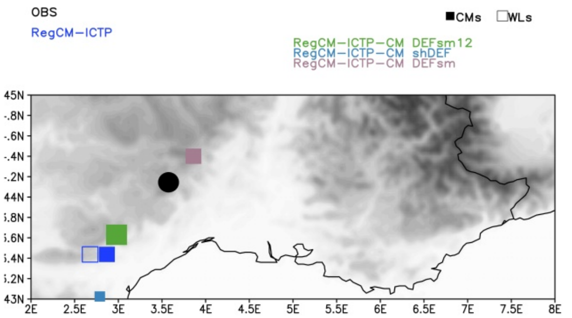
IOP16 case is characterized by **local surface minimum** evolving across WMED, then interacting with deep upper level NA trough.

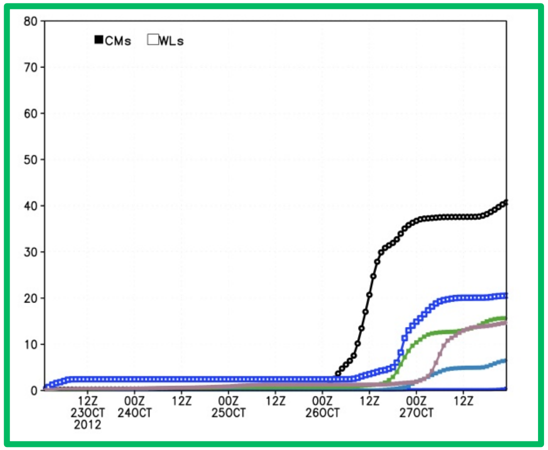


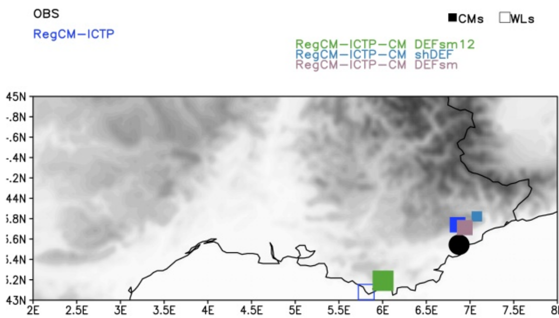
AAVE-RAIN T-SERIES

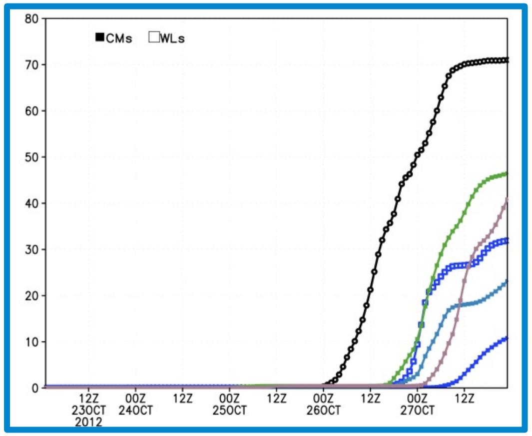


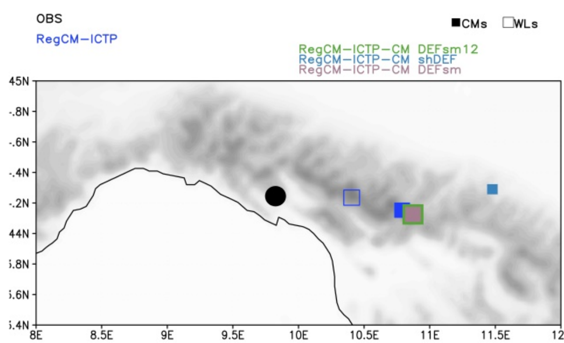












OBS

CNTR

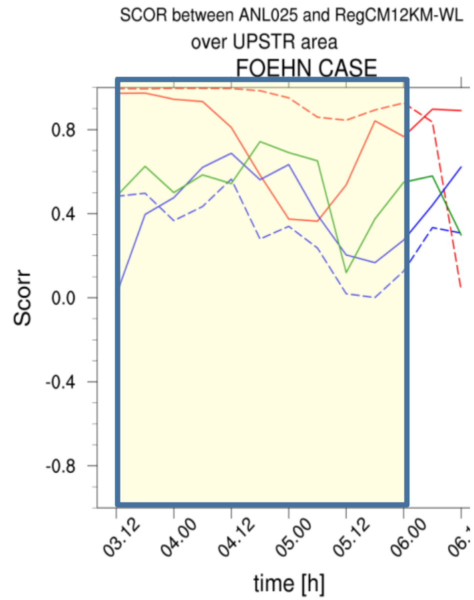
ICTP-CM-TDK-DEF

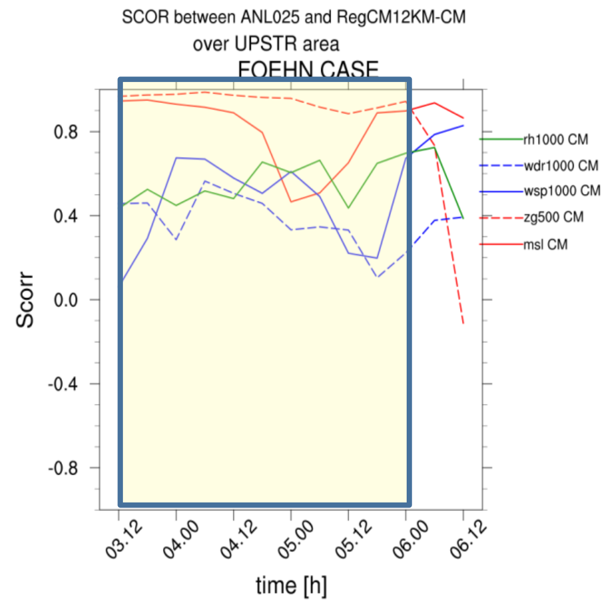
ICTP-TDK-DEF-SM

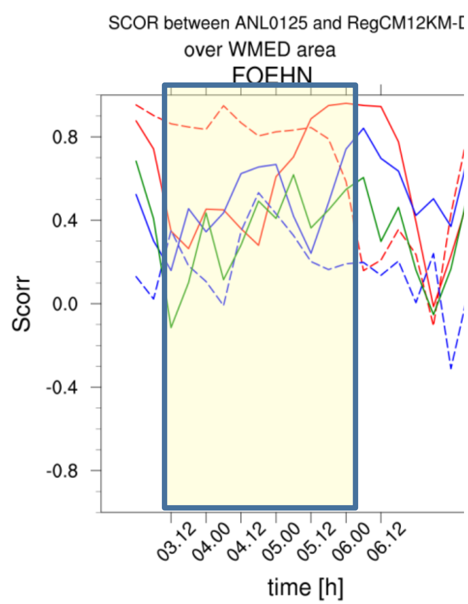
TDK-DEF-SM3

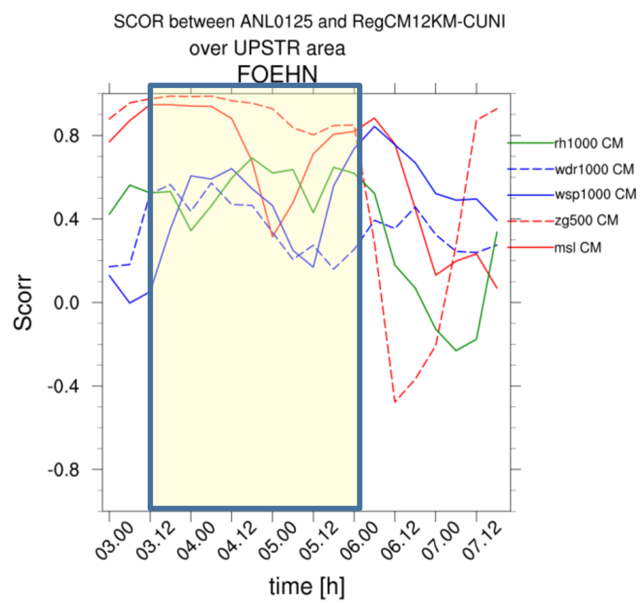
FOEHN CASE 12km

Foehn case is characterized by **strong upper levels large scale driving conditions** (deep NA trough).

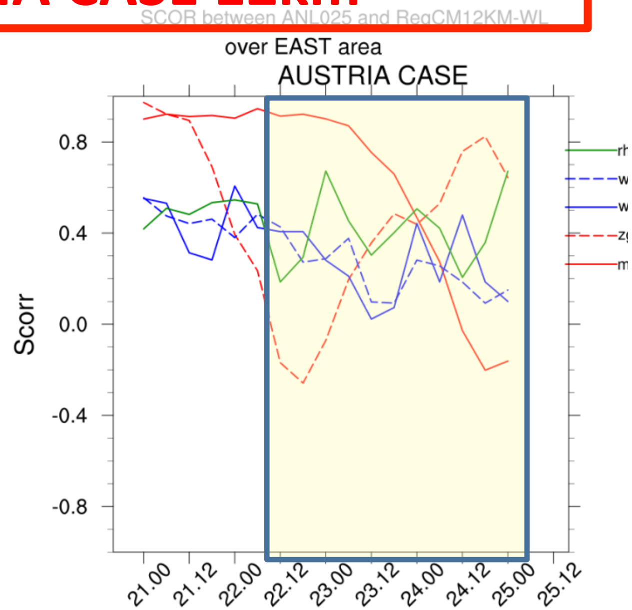


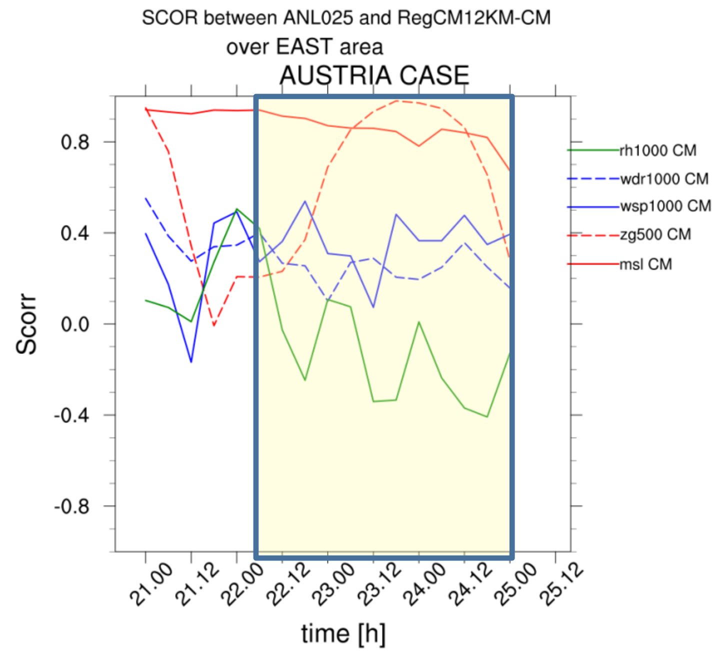


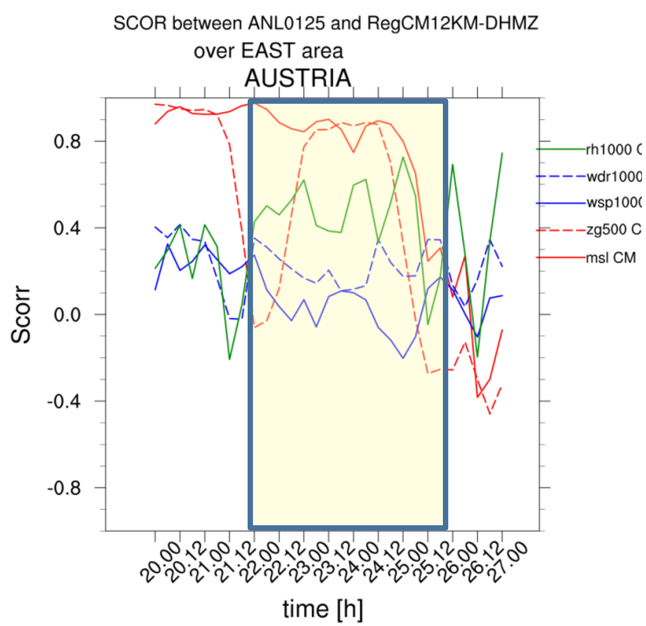


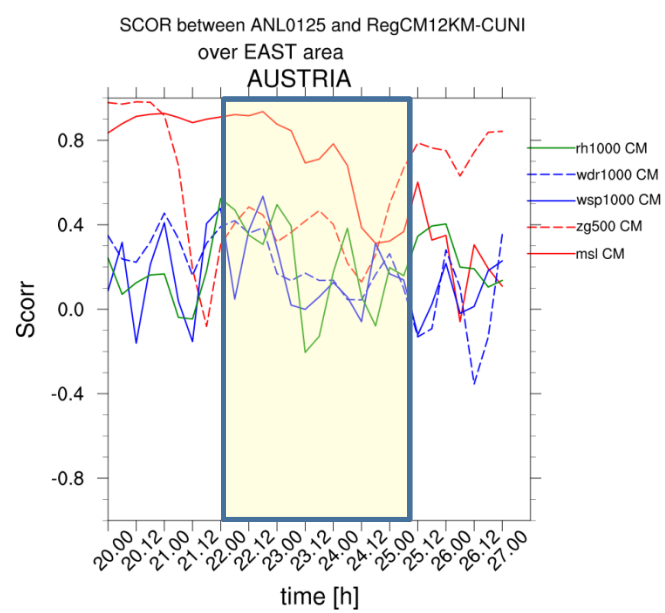


AUSTRIA CASE 12km



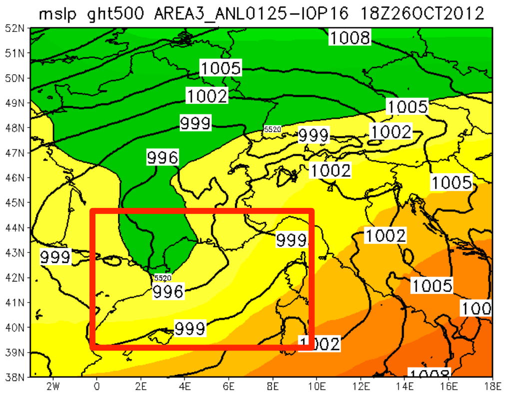




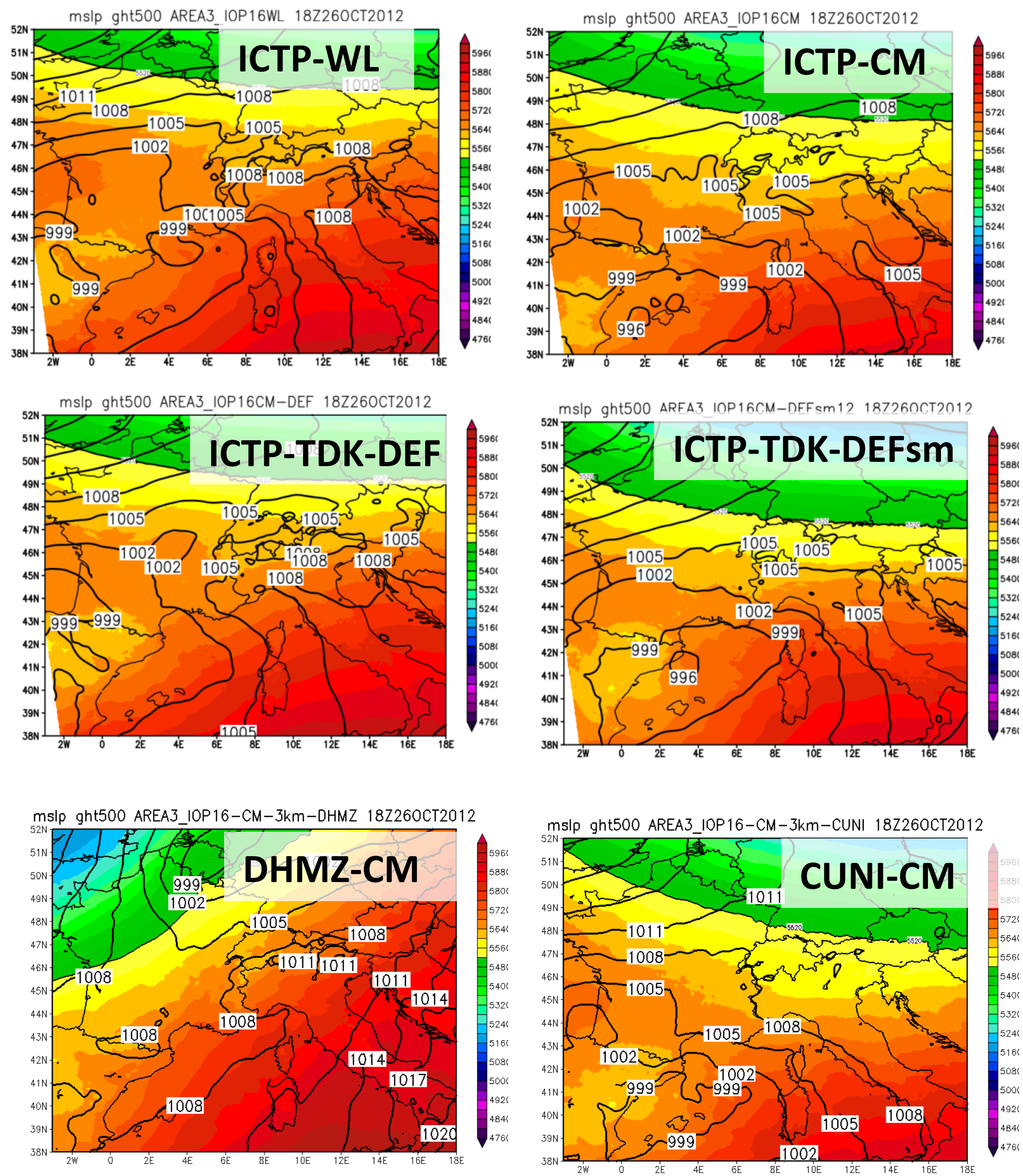


Austria case is characterized by **weak** large scale driving conditions **with upper-level local minimum** evolving across Adriatic Sea.

ANALYSIS 0.125d



3KM SIMULATIONS



TAKE HOME MESSAGE

- When running at high resolution, dynamical down-scaling is suggested through intermediate low resolution domain/s
- Choose as large as possible … nd the area of interest to a … ions
- Use filters fo … nstabilities if you run in or …
- Take care of fi … domains to have the best … strong influence CP-core performances, especially in case of complex interactions between large and meso-scale mechanisms

Thank You!

SIDE NOTE:

- using same core for all level of nesting (ex. both 12 and 3 km non-hydro) should much improve model performances