Evaluating current convection-permitting ensembles for past high-impact weather events in Italy: results from the SPITCAPE Special Project

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Goal of the SPITCAPE ECMWF Special Project

- assess the added value of **convection-permitting (CP) ensembles** with respect to global ones in reforecasting past **high-impact weather** events

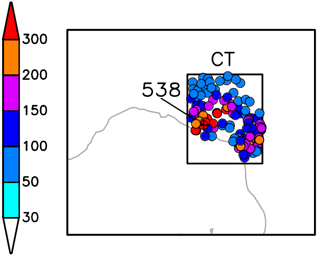
Further goals

- estimate the strengths/limitations of the simple **dynamical downscaling** method to initialise CP models (WRF-ARW, MESO-NH and MOLOCH) nested in the ECMWF global ensemble (horiz res $\simeq$ 20 km)
- contribute to the debate about the reliability of the three CP models with respect to:
  - the accuracy of the results
  - the computational costs

Cinque Terre (**CT**) - 25/Oct/2011

north-western Italy

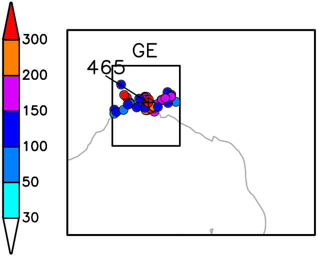
– Severe weather over complex orography
– Mesoscale Convective System (MCS)
– Maximum rainfall rates $> \frac{150mm}{1-hour}$ and $\frac{450mm}{12-hour}$



Genoa (**GE**) - 4/Nov/2011

north-western Italy

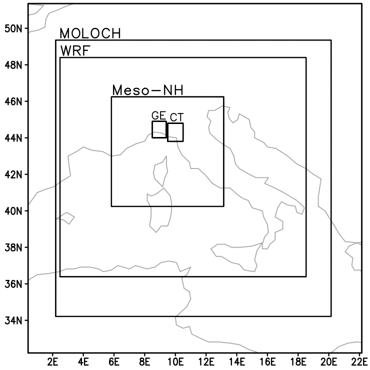
– Self-regenerating and quasi-stationary V-shaped MCS
– Maximum rainfall rate $> \frac{390mm}{6-hour}$ (returning period $\simeq$ 200 ys)
– low-level convergence lines triggered auto-regenerating convective cells



Re-forecast of CT and GE - Global Model

- ECMWF ENS ensemble forecasts
- IFS model cycle 41r2 (March 2016)
- grid spacing $\simeq$ 20 km
- forecast lengths: +72-hour, +60-hour, +48-hour, +36-hour

Re-forecast of the CT and GE cases - CP models



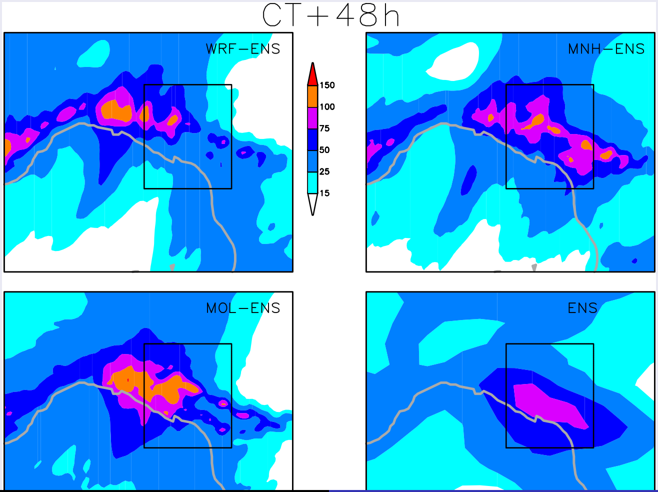
Recent versions of:

- WRF-ARW @ 3 km
- Meso-NH @ 2.5 km
- MOLOCH @ 2.5 km

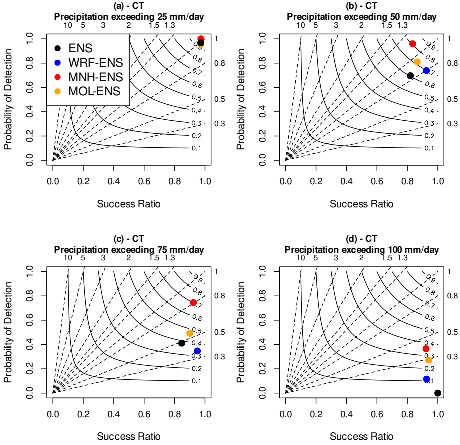
Model	Rows×Cols	Levels	Grid points	Δt
WRF-ARW	400 × 440	55	≃ 9.7 million	18 sec
Meso-NH	225 × 270	52	≃ 3.1 million	6 sec
MOLOCH	502×614	50	≃ 15.4 million	30 sec

Results: CT ensemble mean (forecast length is +48-hour)

daily cumulated precipitation is underestimated



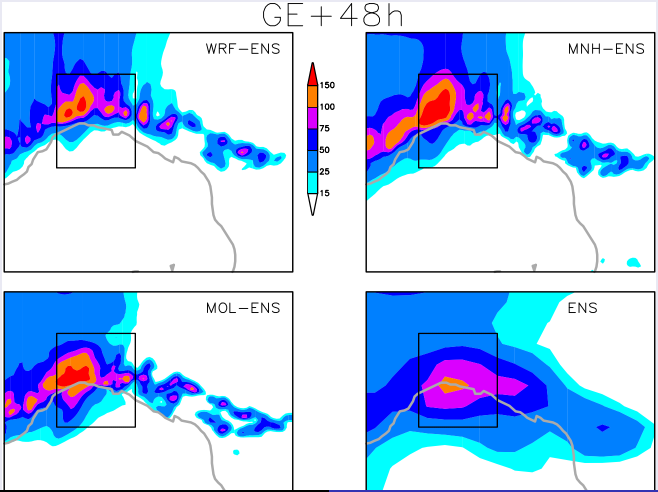
Results: CT performance diagrams



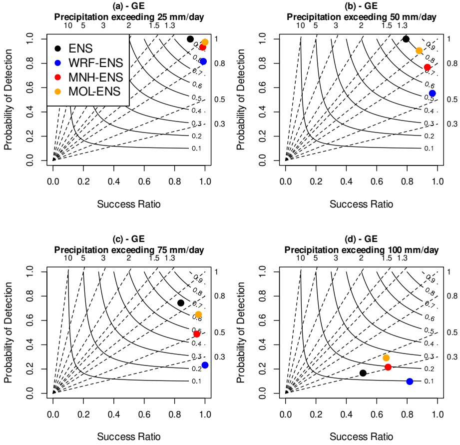
- Meso-NH (• symbol) provides more skillful predictions
- ENS (• symbol) as good as CP models $\leq$75 mm
- poor skills for all models for thresholds $\geq$100 mm

Results: GE ensemble mean (forecast length is +48-hour)

daily cumulated precipitation is underestimated

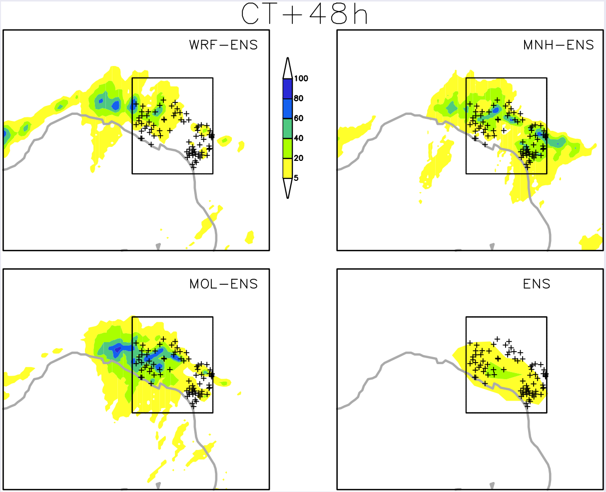


Results: GE performance diagrams



- ENS (•) & MOLOCH (•) outperform the other models
- ENS (•) comparable/better than CP models for ≤75 mm
- poor skills for all models for ≥100 mm

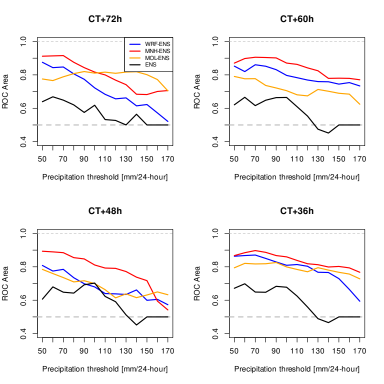
Results: CT prob of precipitation (PoP) >100 mm



"+" rain-gauge where precipitation >100 mm was observed

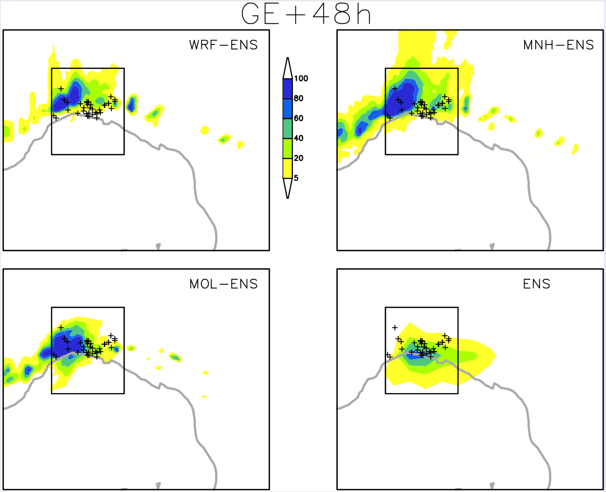
Results: CT PoP verification - ROC Area

X-axis: precipitation thresholds $\in$ [50,170] mm, Y-axis: ROC Area



- CP ensembles outperform ENS (___)
- CP ensembles have similar skills and ROC Area is >0.5 up to 170 mm
- Meso-NH (___) better than MOLOCH (___)/WRF (___)
- ENS (___) ROC Area is <0.5 at about 130 mm

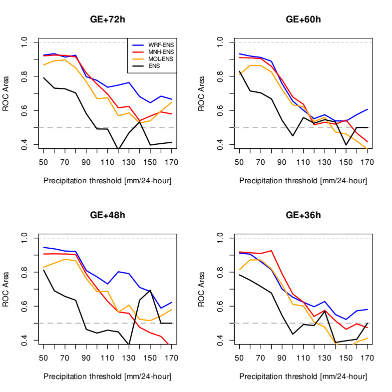
Results: GE prob of precipitation (PoP) >100 mm



"+" rain-gauge where precipitation >100 mm was observed

Results: GE PoP verification - ROC Area

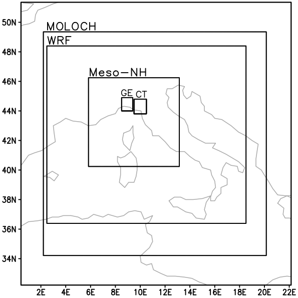
X-axis: precipitation thresholds ∈ [50,170] mm, Y-axis: ROC Area



- CP ensembles outperform ENS (——)
- CP ensembles have similar skills [WRF(——) occasionaly better] and ROC Area is <0.5 at about 120-130 mm
- ENS (——) ROC Area is <0.5 at about 90-100 mm

Final remarks: CP ensemble runtime

Model	Rows×Cols	Levels	Grid points	Δt
WRF-ARW	400 × 440	55	$\simeq$ 9.7 million	18 sec
Meso-NH	225 × 270	52	$\simeq$ 3.1 million	6 sec
MOLOCH	502×614	50	$\simeq$ 15.4 million	30 sec



$$\alpha_{model} \stackrel{def}{=} \frac{\text{Grid points(model)}}{\Delta t(\text{model})}$$

$\alpha_{WRF} \simeq \alpha_{MNH} \simeq \alpha_{MOL}$
$\rightarrow$ runtime depends on model numerics, not on model's domain extent

Final remarks: CP ensemble runtime

Average runtime for a 36-hour long simulation on ECMWF Cray XC40 supercomputer

X-axis: # of nodes/cores, **Y-axis**: runtime (secs)

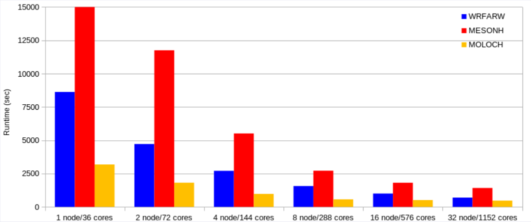


Figure: Number of nodes/cores is doubled at every step

- MOLOCH is the fastest model ($\simeq 3X$ faster than WRF for number of cores ≤ 144, then $\simeq 2X$ faster)
- Meso-NH is the slowest model (better scalability)