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Simulation of heavy precipitation events with the COSMO model

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LM User Seminar, 6 March 2007, Langen



Outline



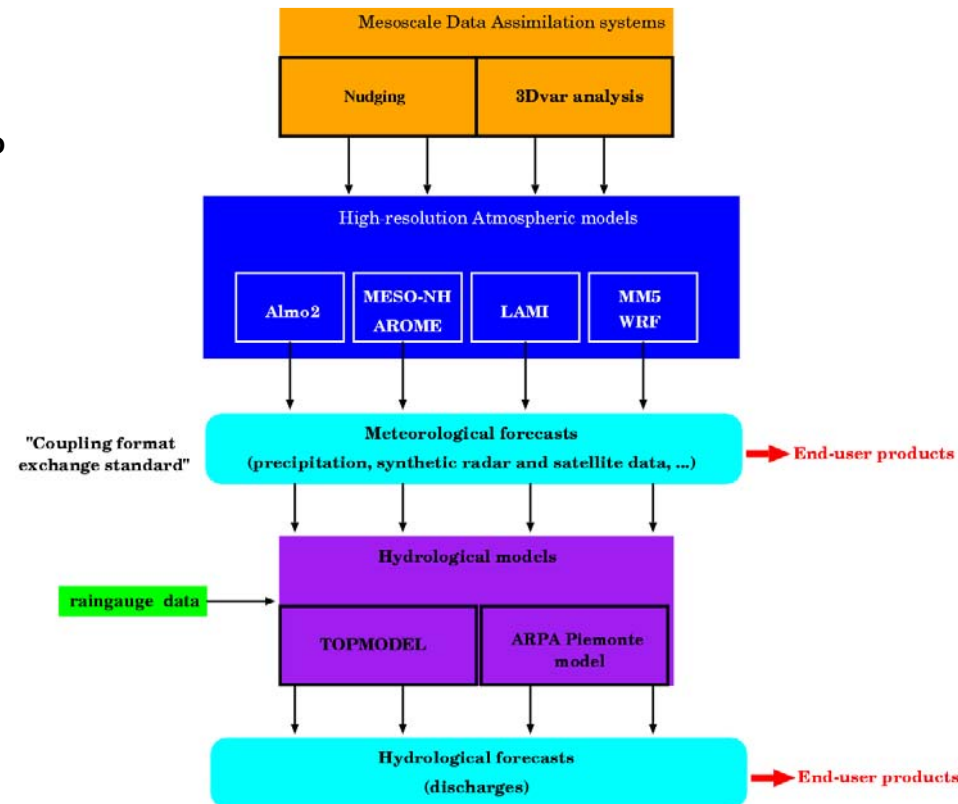
- PREVIEW WP 4340: Very Short Range Flash-Flood Laboratory
- Description of Piemonte and Cévennes test cases
- COSMO model set up
- Results of COSMO model sensitivity studies
 - different horizontal resolutions
 - different initial conditions
 - simulations with z coordinates
- Comparison of precipitation simulated using COSMO, Meso-NH and MM5
- Conclusions and Outlook



PREVIEW WP 4340: Flash flood laboratory



- PREvention, Information and Early Warning: integrated project within FP 6, aim: development and use of new geo-information services for risk management
- Aim of WP 4340: Improvement of flash-flood forecast over medium basins (100-1000 km²) based on next-generation high-resolution NWP models
- Partners: Meteo France (FR); Laboratoire d'étude des transferts en hydrologie et environnement (FR); ARPA Piemonte (IT); National Observatory of Athens (GR); Noveltis (FR)
- Subthemes:
 - Value of the high-resolution NWP precipitation forecast
 - Two-way/one-way coupling
 - Verification approaches and inter-comparison facilities

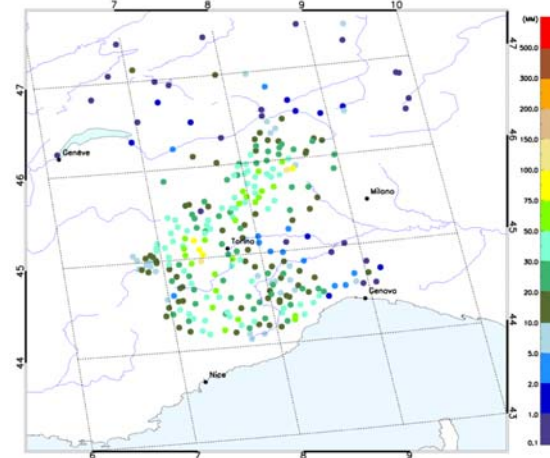
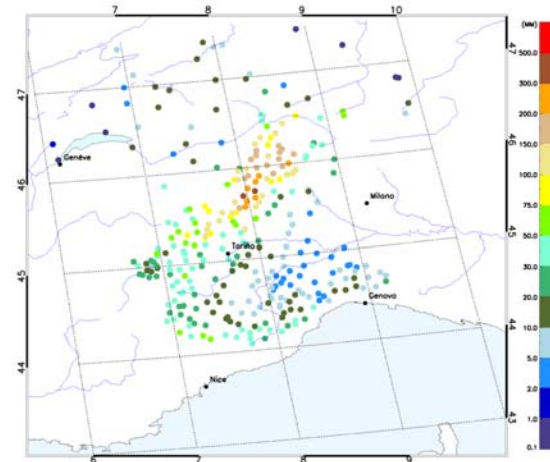




Strong precipitation events in the Piedmont region, 4-5 Jun 2002 and 1 Sep 2002



- 4-5 Jun 2002
 - Heavy precipitation and thunderstorms in the north-western part of Piedmont, local rainfall maximum of 400 mm/24h
 - Southerly flow resulting in high humidity followed by cold air advection
- 1 Sep 2002
 - Heavy showers and thunderstorms in the region around Turin, local rainfall maximum around 130 mm
 - Easterly flow resulting in high humidity, low over southern Italy causing cold air advection

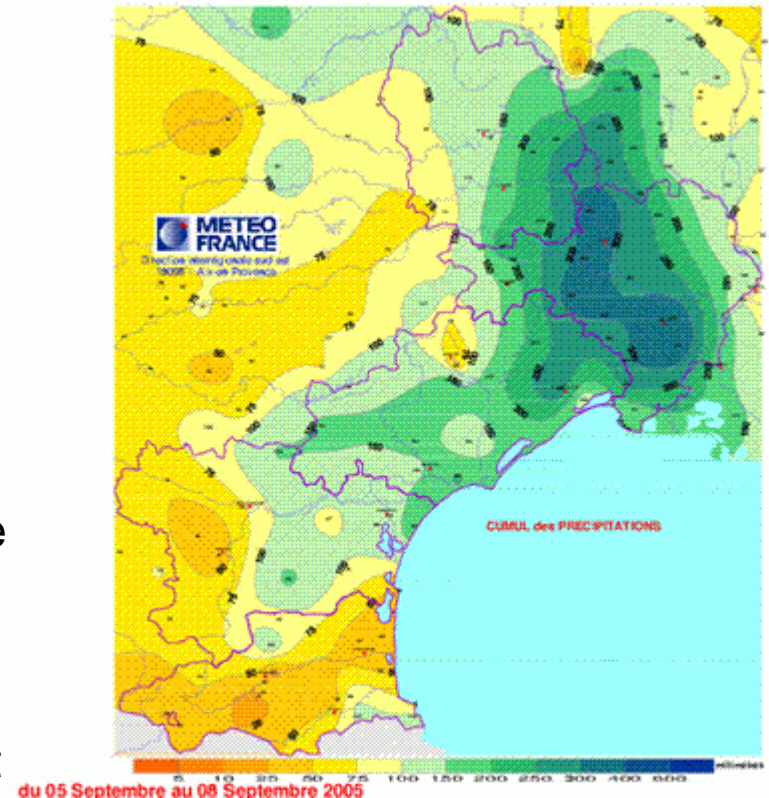




Strong precipitation events in Cévennes region 5-9 Sep 2005



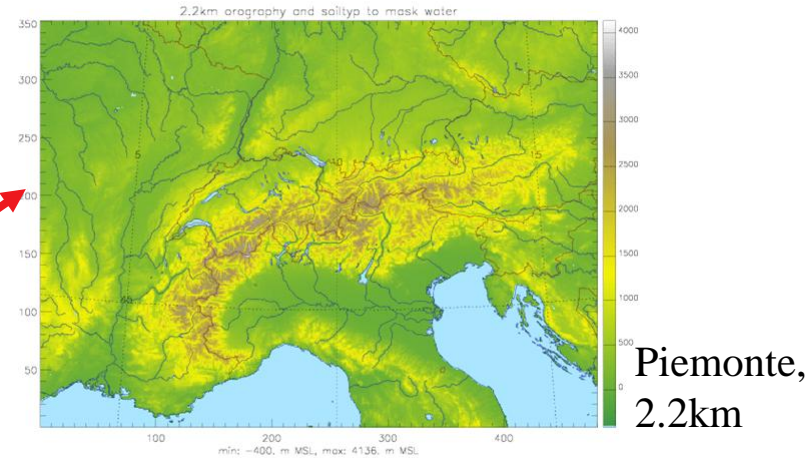
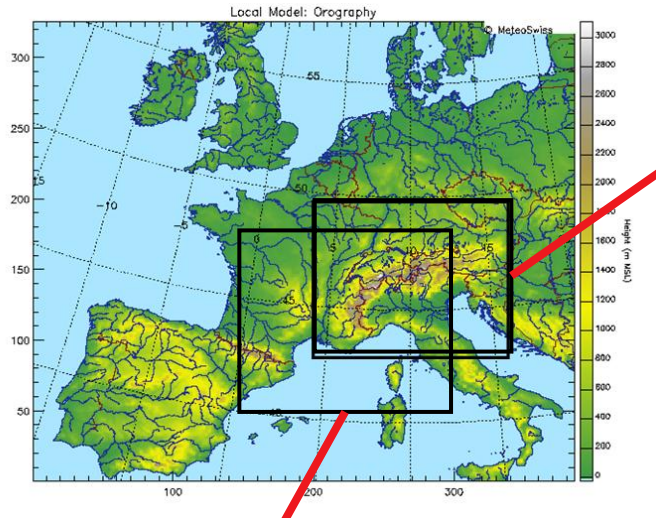
- 5-9 Sep 2005
 - Heavy showers and thunderstorms in the Cévennes region, 3d accumulated rainfall of about 300 mm
 - Frontal passage with convective precipitation in the first part of the period, southerly flow creating favourable condition for convection in the second part



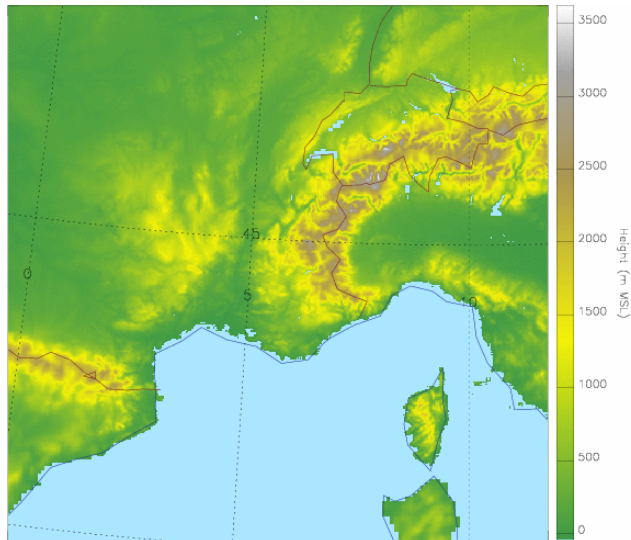
Accumulated rainfall, 5-7 Sep 2005



Model setup



- Horizontal grid sizes 7km and 2.2km, 45 vertical levels
- Interpolated initial values and boundary values forecasts from IFS
- 24h runs every 12 hours:
 - Piedmont case studies:
 - 4.6.2002, 00 - 5.6.2002, 12
 - 1.9.2002, 00 - 1.9.2002, 12
 - Cévennes case study:
 - 5.9.2005, 00 – 9.9.2005, 12



Cévennes,
2.2km

Simulation of heavy precipitation events with the COSMO model

S. Dierer



Results of sensitivity studies



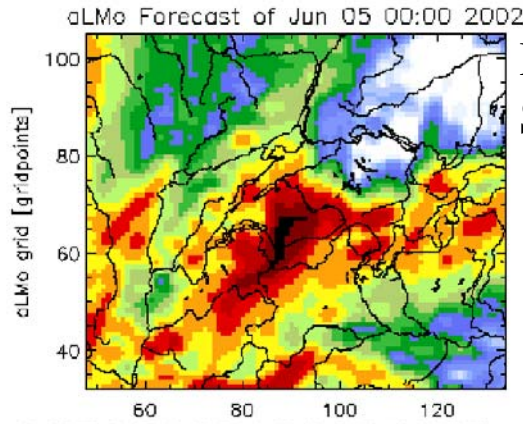
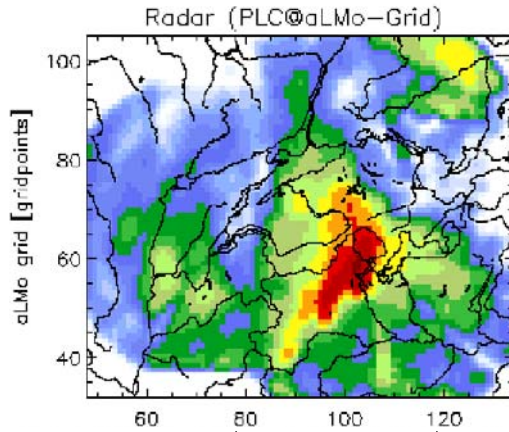
Impact of horizontal grid size, Piedmont region, 05 Jun 2002: Simulated and radar measured 24h precipitation



Radar

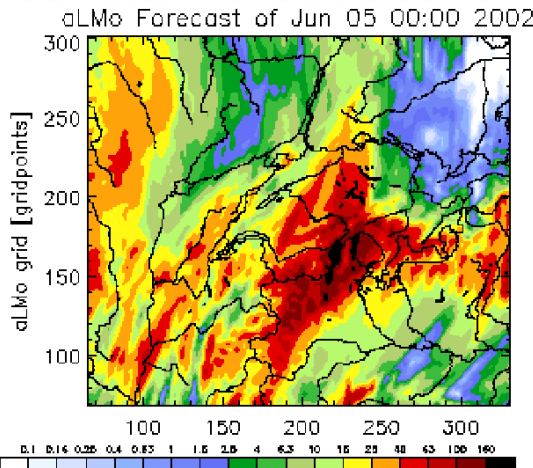
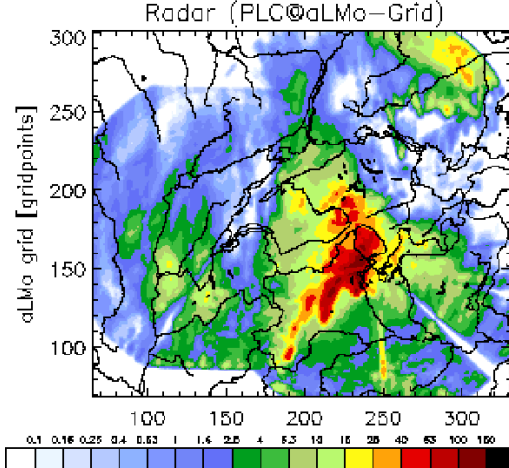
aLMo

7km
grid



Bias: 14 mm
Std: 24 mm

2.2km
grid



Bias: 16 mm
Std: 20 mm

Threat score

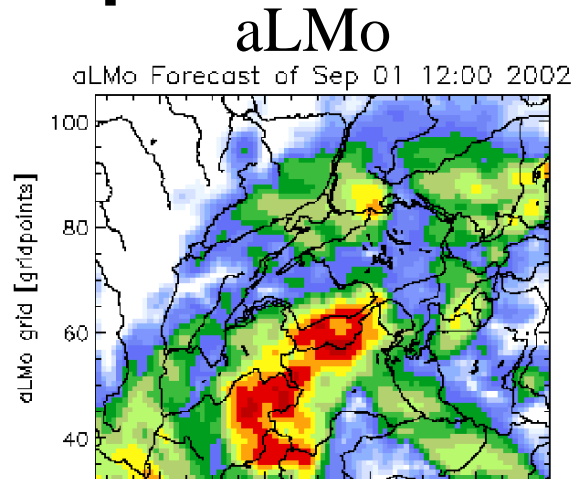
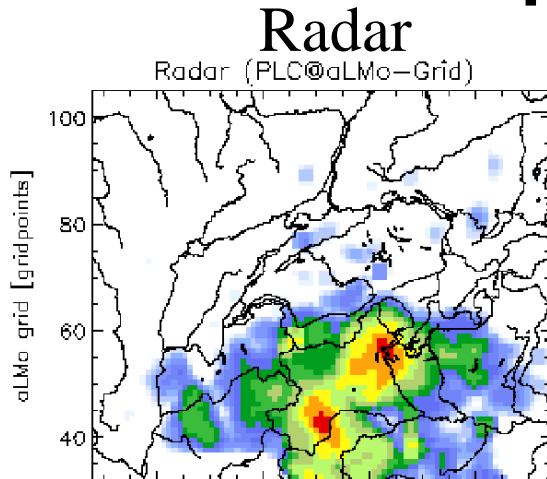
| Thres. [mm] | c | f |
|-------------|------|------|
| 0.1 | 0.78 | 0.80 |
| 1 | 0.55 | 0.58 |
| 2.5 | 0.39 | 0.39 |
| 16 | 0.12 | 0.12 |
| 40 | 0.03 | 0.13 |



Impact of horizontal grid size, Piedmont region, 01 Sep 2002: Simulated and radar measured 24h precipitation

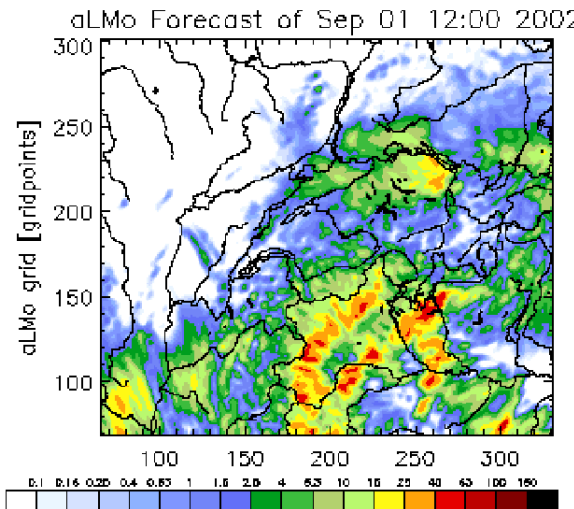
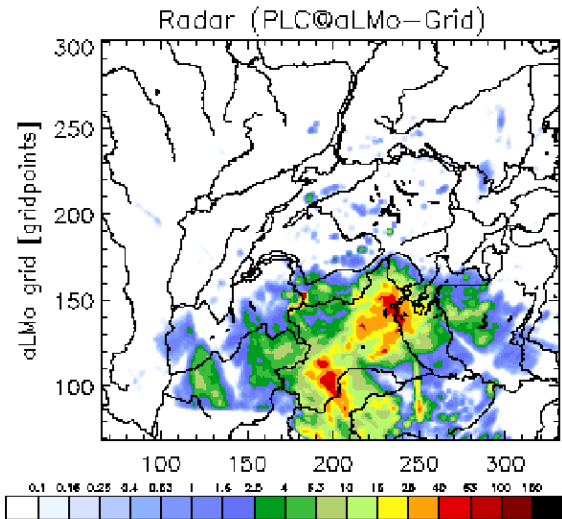


7km
grid



Bias: 4.2 mm
Std: 11 mm

2.2km
grid



Threat score

| Thres. [mm] | c | f |
|-------------|------|------|
| 0.1 | 0.39 | 0.40 |
| 1 | 0.27 | 0.35 |
| 2.5 | 0.22 | 0.31 |
| 16 | 0.05 | 0.17 |
| 40 | 0.00 | 0.01 |

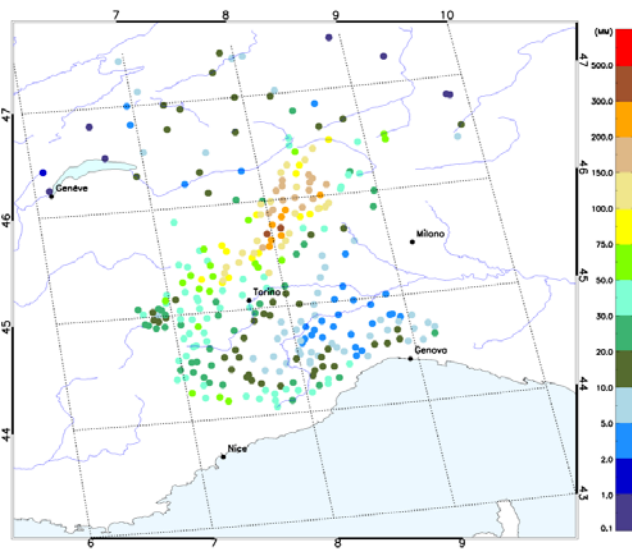
Bias: 2.2 mm
Std: 7 mm



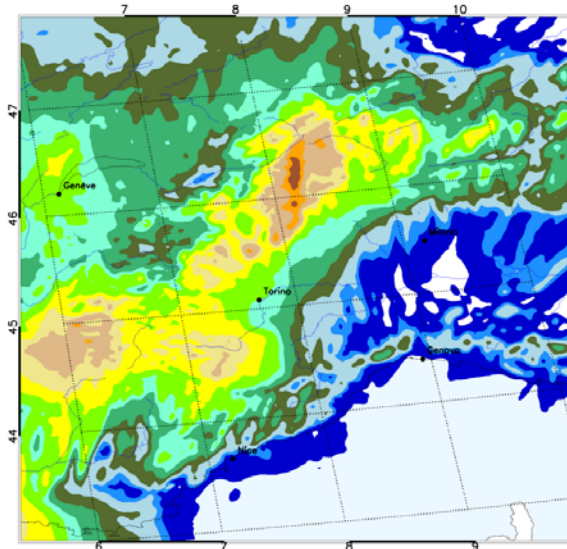
Impact of initial conditions



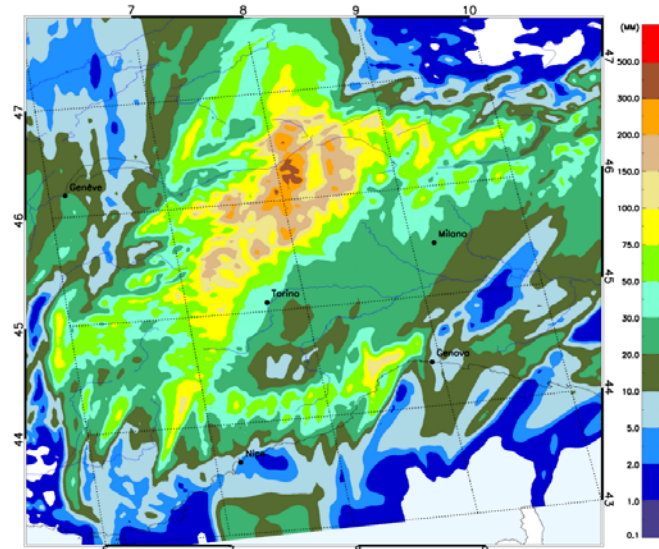
Impact of initial conditions, 05.06.2002, 00: 18h precipitation



Observations

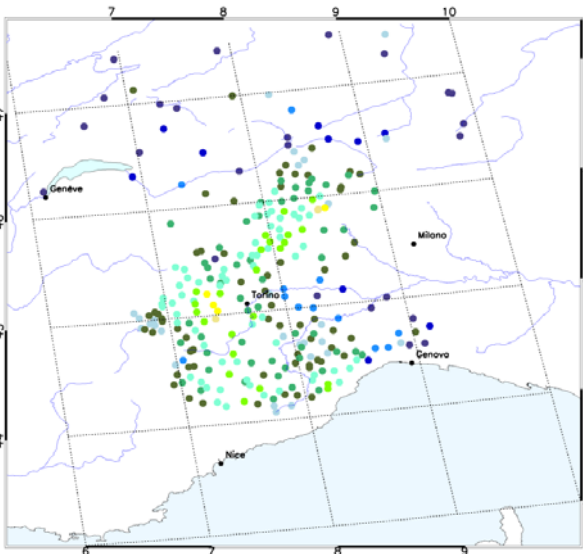


Initial values from
interpolation

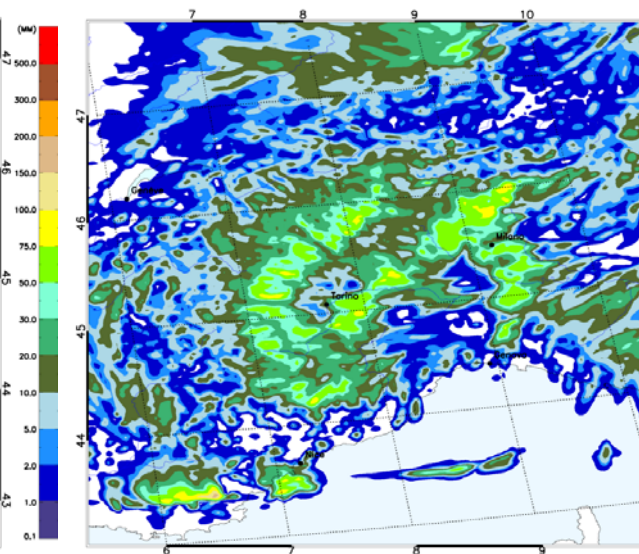


Initial values from
assimilation run

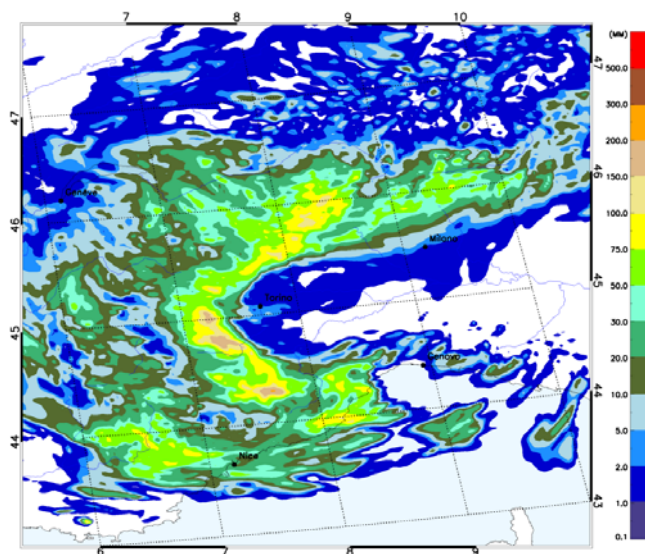
Impact of initial conditions, 01.09.2002, 12: 18h precipitation



Observations



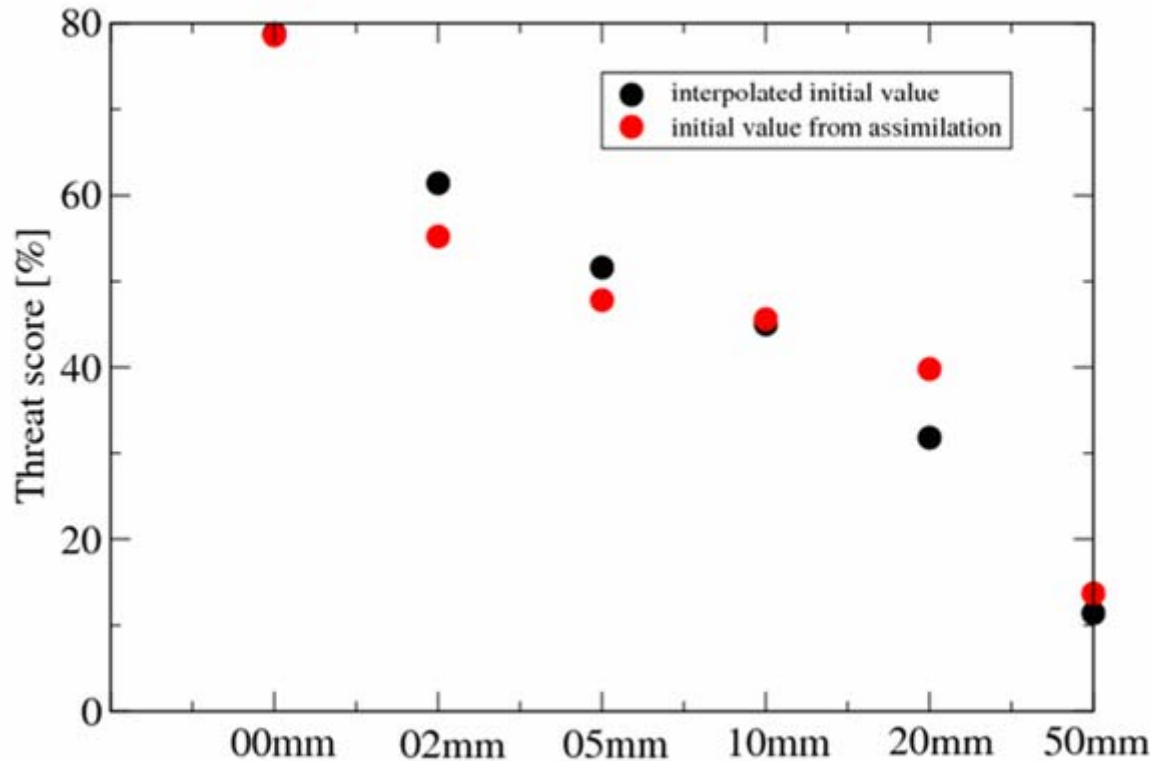
Initial values from
interpolation



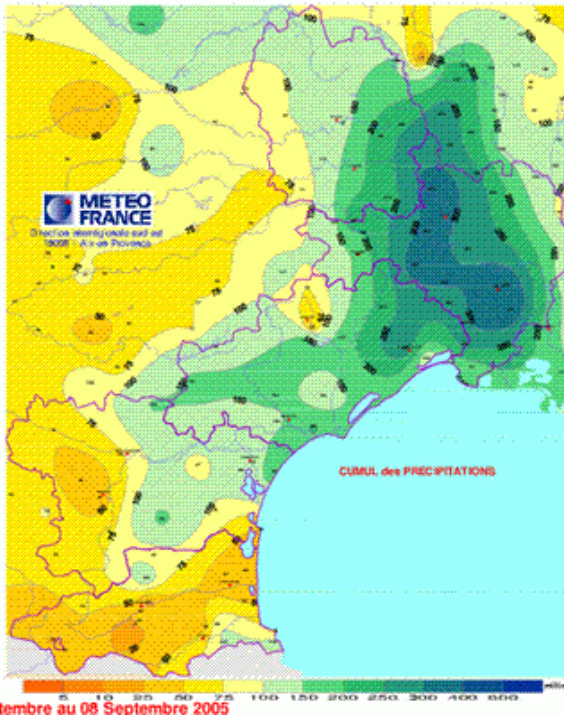
Initial values from
assimilation run



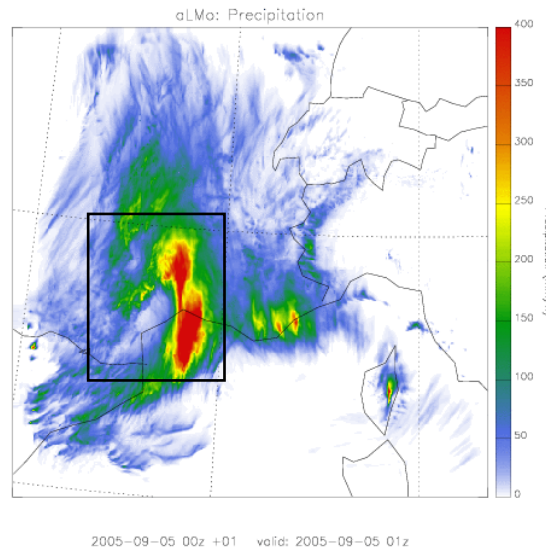
Average threat score of 12h precipitation sums from rain gauges and COSMO simulations for Piemonte cases



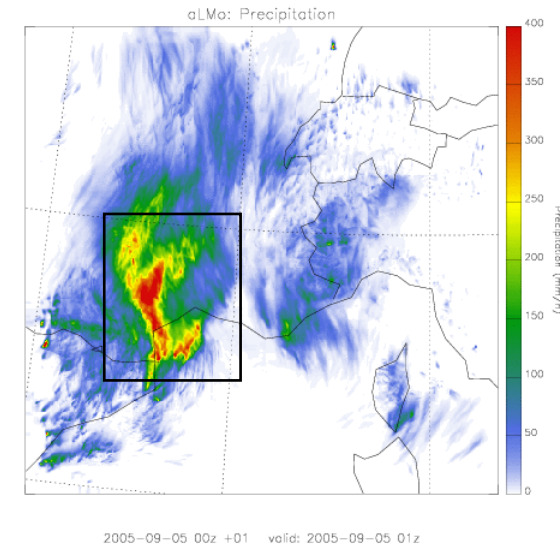
Comparison of 3d accumulated precipitation – rain gauges, model with assimilation and interpolated initial data



Rain gauges



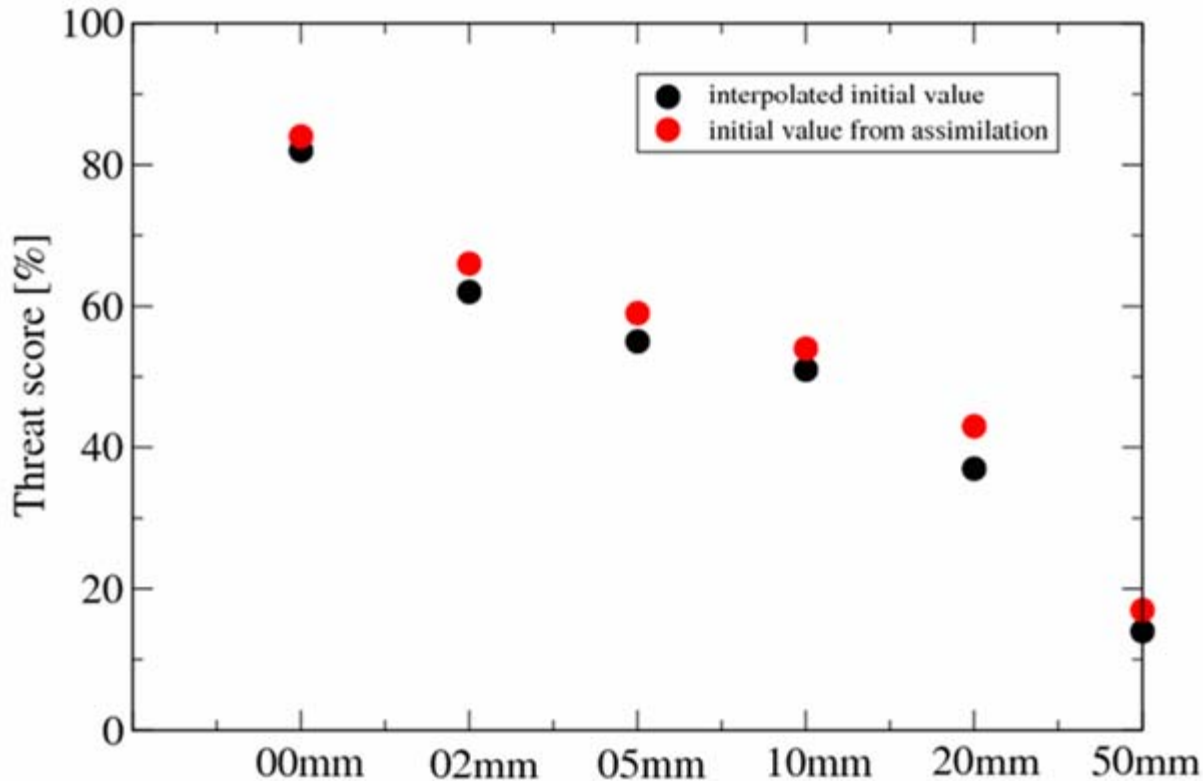
assimilation



interpolated



Average threat score of 12h precipitation sums from rain gauges and COSMO simulations for Cévennes cases





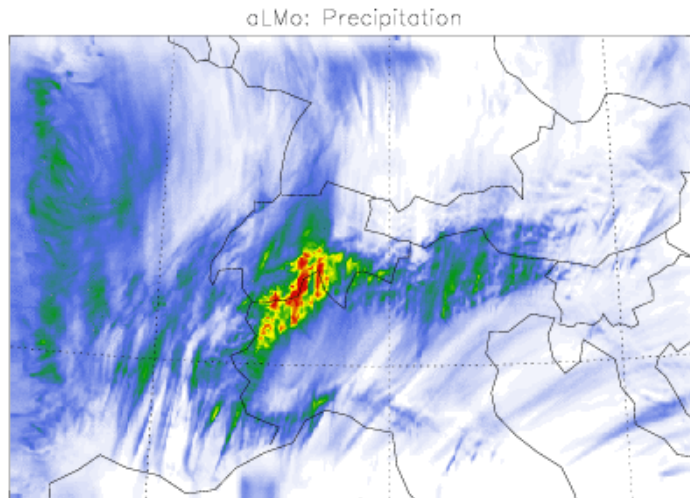
Sensitivity regarding vertical coordinate: z coordinate versus terrain following

Z coordinate version of COSMO model



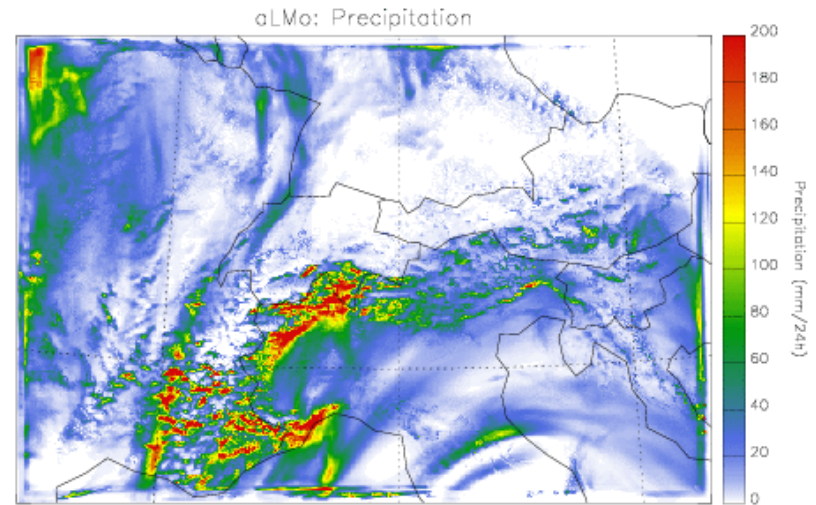
- Dynamics are calculated using z coordinates, physics are calculated using terrain following coordinates
- Version 1.7 of LMZ is used
- “z orography”: V-valleys are filled up
- Some changes of namelist settings are necessary:
 - Leapfrog instead of Runge-Kutta
 - no prognostic rain
- Smaller time steps for stable solution
 - 7km: 15s instead of 72s
 - 2.2km: 5s instead of 20s

Simulated 24h precipitation sum with terrain following and z coordinates: Piemonte test case, 05 June 2002, 00



2002-06-05 00z +24 valid: 2002-06-06 00z

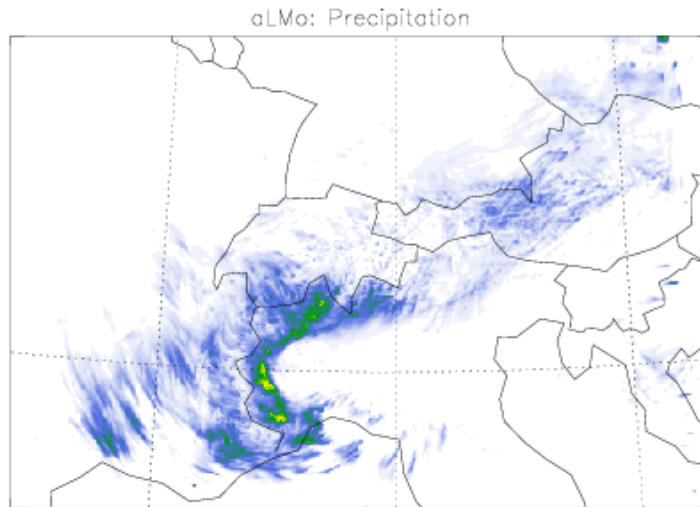
Terrain following
coordinates



2002-06-05 00z +24 valid: 2002-06-06 00z

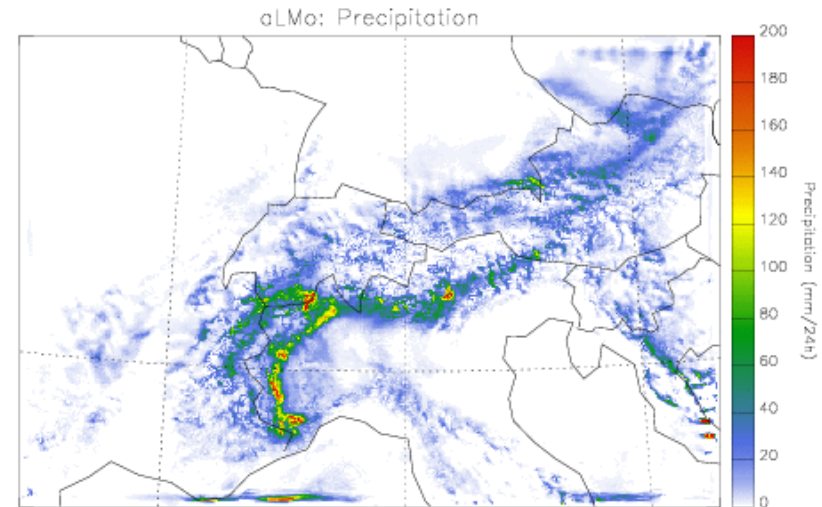
Z coordinates

Simulated 24h precipitation sum with terrain following and z coordinates: Piemonte test case, 01 September 2002, 12



2002-09-01 12z +24 valid: 2002-09-02 12z

Terrain following
coordinates

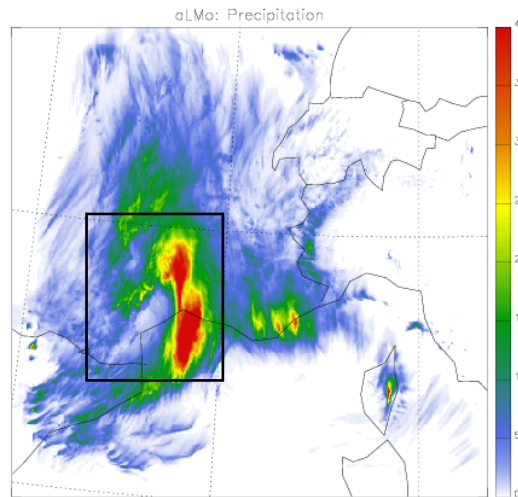
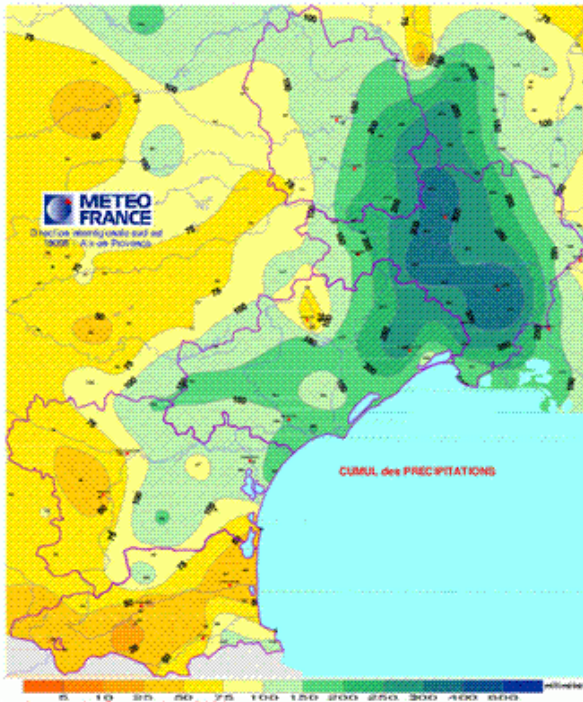


2002-09-01 12z +24 valid: 2002-09-02 12z

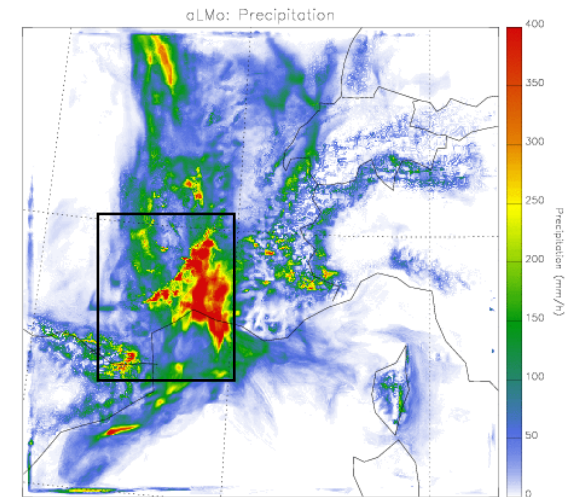
Z coordinates



Comparison of 3d accumulated precipitation – rain gauges, model with terrain following and z coordinates



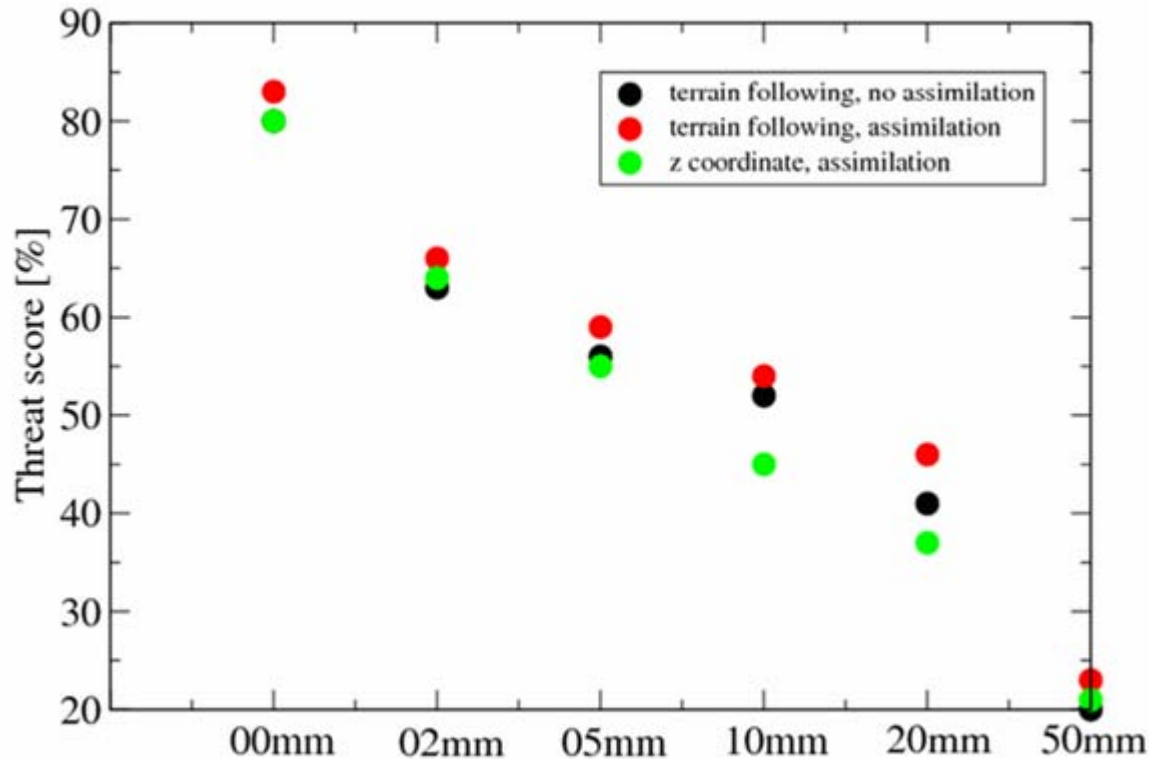
2005-09-05 00z +01 valid: 2005-09-05 01z



2005-09-05 00z +01 valid: 2005-09-05 01z



Average threat score for all COSMO simulations with terrain following and z coordinates





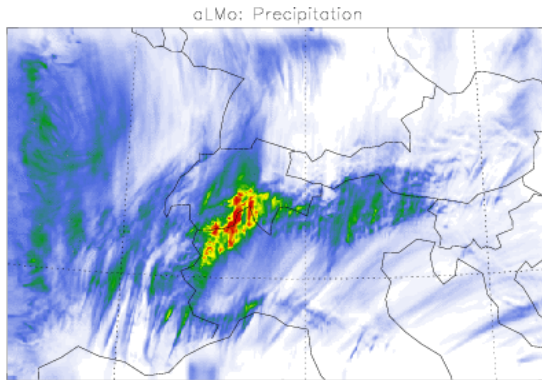
Piemonte case study, 05 June 2002, 00: explaining the differences



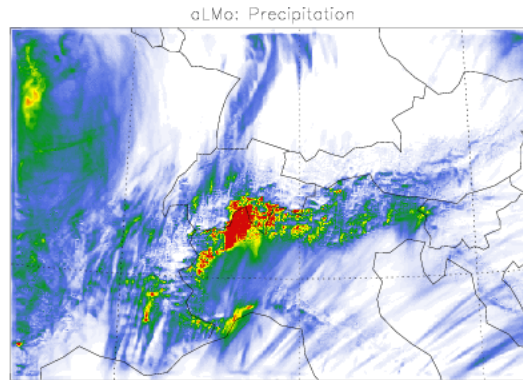
Terrain-following,
reference

Terrain-following,
z-settings + z-orography

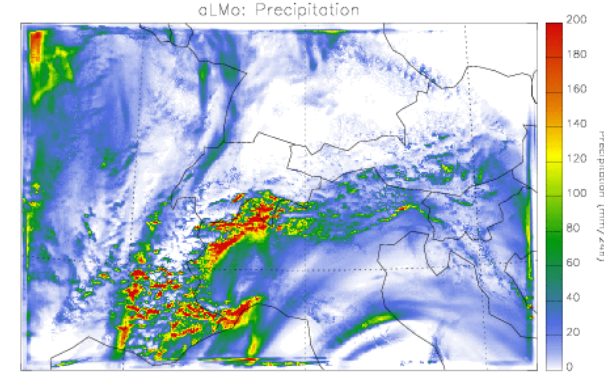
z coordinates



2002-06-05 00z +24 valid: 2002-06-06 00z



2002-06-05 00z +24 valid: 2002-06-06 00z



2002-06-05 00z +24 valid: 2002-06-06 00z

-Runge Kutta

-dt(7km)=72s / dt(2.2km)=20s

-Prognostic precipitation

-Leapfrog

-dt(7km)=15s / dt(2.2km)=5s

-No prognostic precipitation

Threat score for 4 simulations with terrain following and z coordinates using same settings

| | 00mm | 02mm | 05mm | 10mm | 20mm | 50mm |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|
| 02090112 | | | | | | |
| tf version | 81 | 63 | 64 | 59 | 56 | 19 |
| lmz | 89 | 85 | 79 | 61 | 57 | 27 |
| 05090512 | | | | | | |
| tf version | 73 | 63 | 61 | 51 | 31 | 11 |
| lmz | 74 | 61 | 58 | 54 | 32 | 15 |
| 05090612 | | | | | | |
| tf version | 77 | 73 | 66 | 57 | 50 | 34 |
| lmz | 91 | 83 | 74 | 62 | 56 | 30 |
| 05090712 | | | | | | |
| tf version | 54 | 52 | 56 | 51 | 40 | 04 |
| lmz | 59 | 37 | 37 | 32 | 31 | 12 |

Threat score for 4 simulations with terrain following coordinates, reference and “old” settings



| 02090112 | 00mm | 02mm | 05mm | 10mm | 20mm | 50mm |
|-------------|------|------|------|------|------|------|
| set1 | 85 | 75 | 72 | 67 | 62 | 25 |
| old setting | 81 | 63 | 64 | 59 | 56 | 19 |
| 05090512 | | | | | | |
| set1 | 80 | 73 | 69 | 61 | 45 | 11 |
| old setting | 73 | 63 | 61 | 51 | 31 | 11 |
| 05090612 | | | | | | |
| set1 | 93 | 87 | 84 | 80 | 76 | 45 |
| old setting | 77 | 73 | 66 | 57 | 50 | 34 |
| 05090712 | | | | | | |
| set1 | 62 | 49 | 54 | 64 | 52 | 04 |
| old setting | 54 | 52 | 56 | 51 | 40 | 04 |



Comparison of COSMO, Meso NH and MM5 for Piemonte case studies June and September 2002

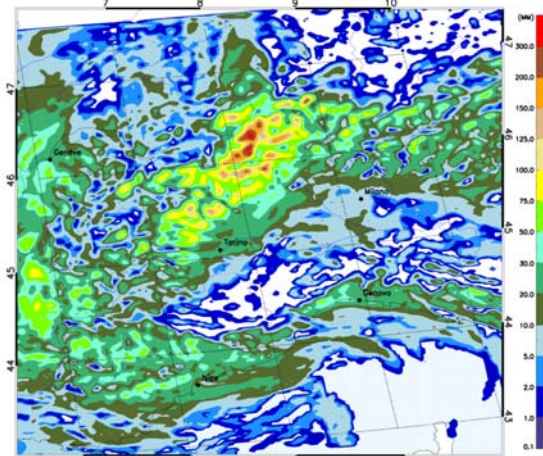
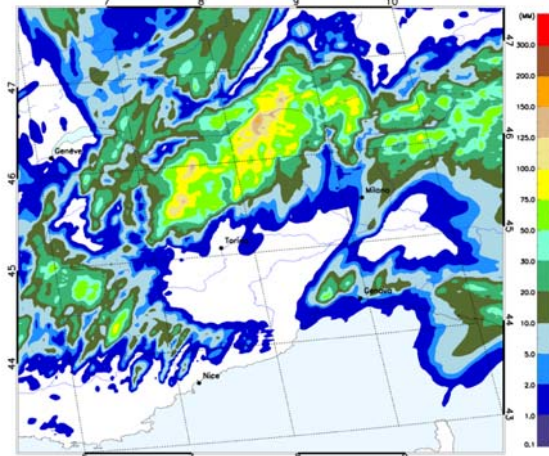
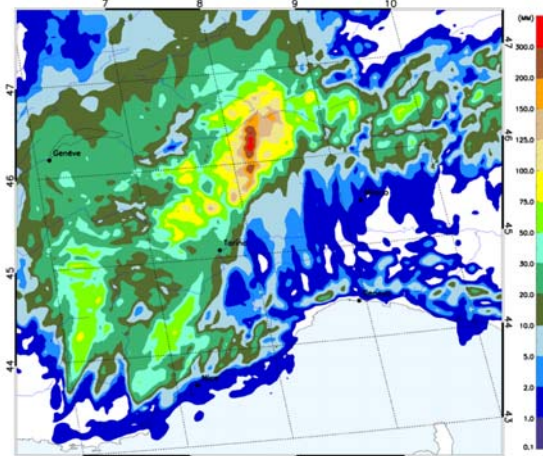
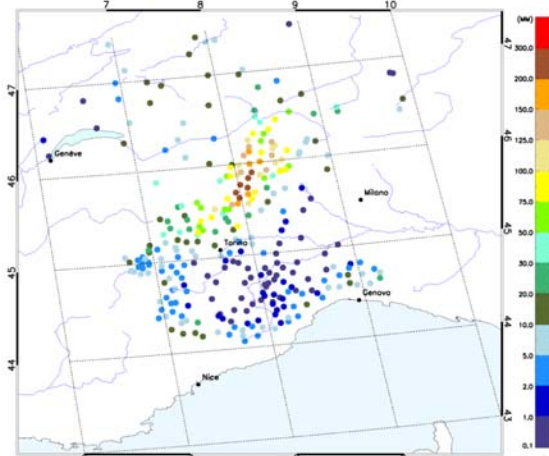


Results of aLMo, Meso-NH and MM5, Piedmont, 5 Jun 2002: 12h precipitation



Obs.

aLMo Bias: 0.99 mm, RMSE: 38.5 mm



Bias: 0.44 mm,
RMSE: 42 mm

Meso-NH

MM5

Bias: 0.72 mm, RMSE: 38 mm

Threat score

| Thresh. [mm] | aLMo | Meso-NH | MM5 |
|--------------|------|---------|------|
| 0 | 0.92 | 0.66 | 0.81 |
| 2 | 0.72 | 0.59 | 0.72 |
| 5 | 0.67 | 0.60 | 0.70 |
| 10 | 0.61 | 0.59 | 0.61 |
| 20 | 0.66 | 0.52 | 0.68 |
| 50 | 0.49 | 0.27 | 0.44 |

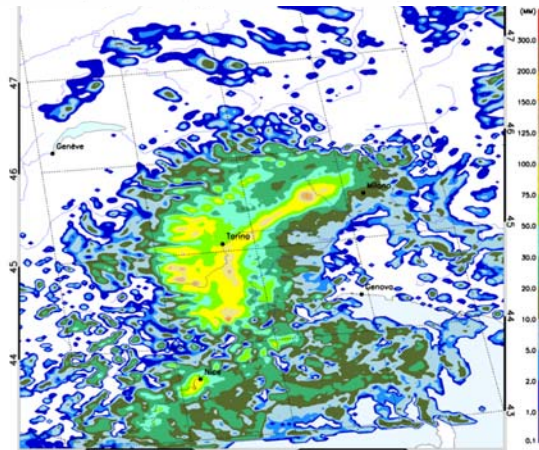
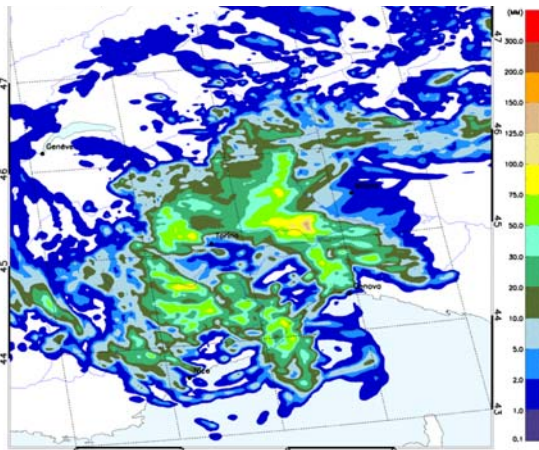
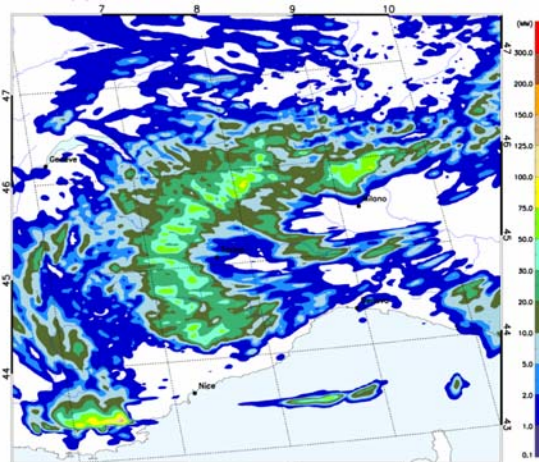
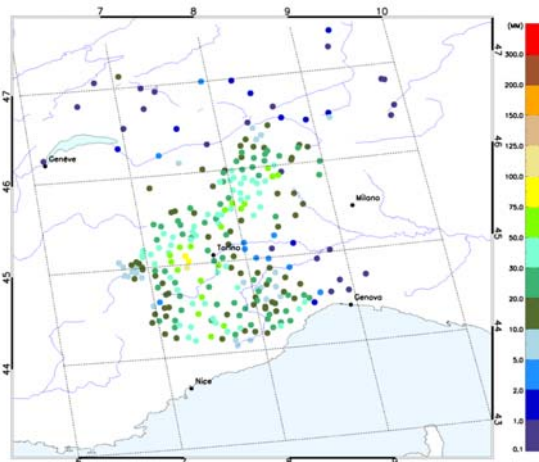


Results of aLMo, Meso-NH and MM5, Piedmont, 1 Sep 2002: 12h precipitation



Obs.

aLMo Bias: 0.42 mm, RMSE: 20.5 mm



Threat score

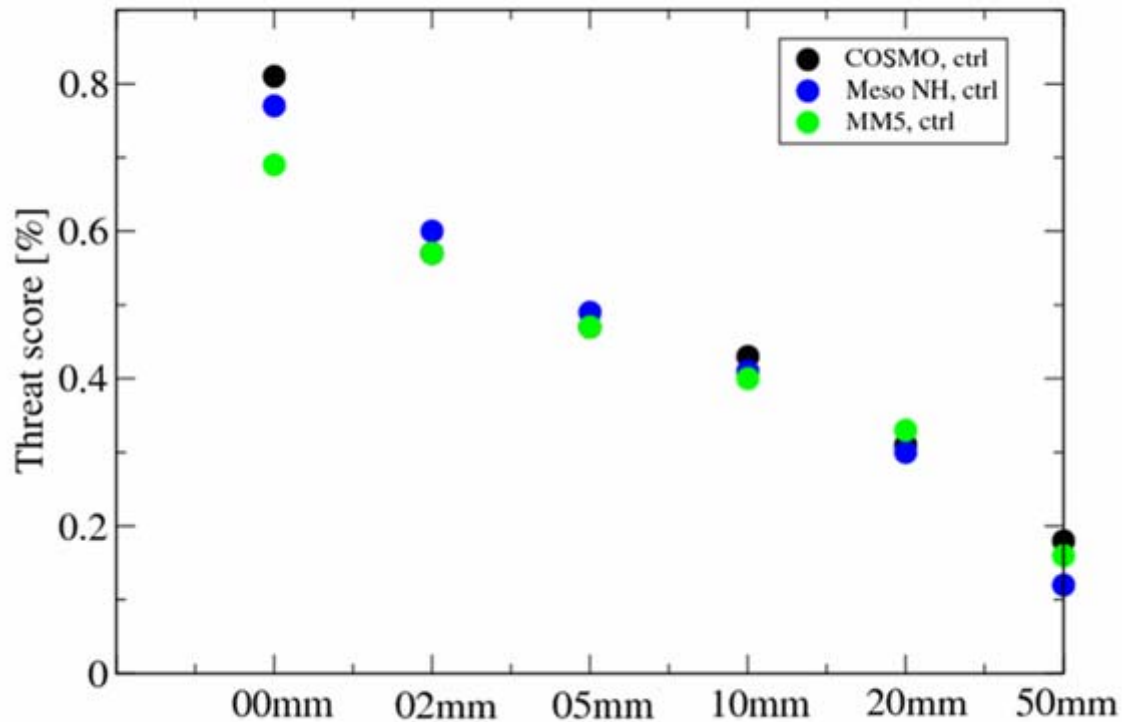
| Thresh. [mm] | aLMo | Meso-NH | MM5 |
|--------------|------|---------|------|
| 0 | 0.87 | 0.87 | 0.84 |
| 2 | 0.72 | 0.78 | 0.83 |
| 5 | 0.62 | 0.65 | 0.72 |
| 10 | 0.46 | 0.50 | 0.63 |
| 20 | 0.23 | 0.25 | 0.48 |
| 50 | 0.00 | 0.08 | 0.11 |

Bias: 0.59 mm, RMSE: 21 mm

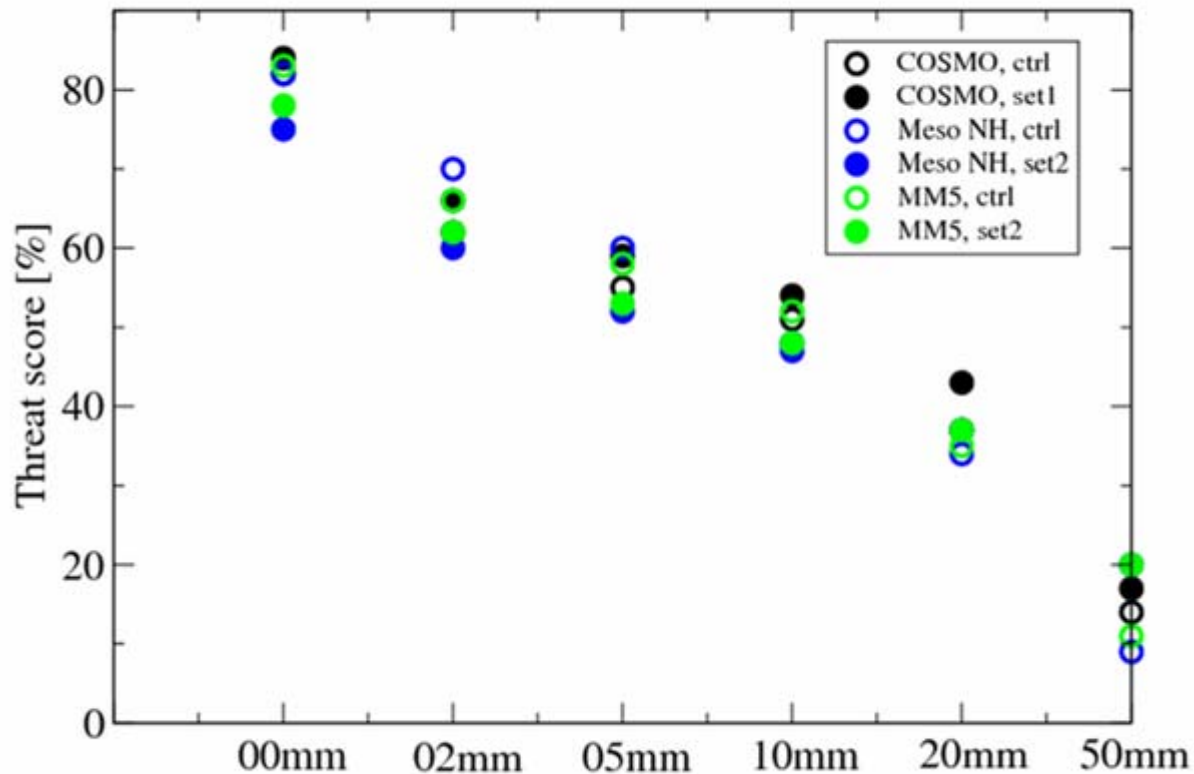
Meso-NH MM5 Bias: 0.92 mm, RMSE: 20.6 mm



Threat scores for aLMO, Meso-NH and MM5 for 12h precipitation of 5 simulations for the Piedmont region



🇨🇭 Average threat score of 12h precipitation sums from rain gauges and COSMO, Meso NH and MM5 simulations for Cévennes cases





Conclusions and Outlook



- Amount of precipitation overestimated in 7 km and 2.2 km runs, still precipitation simulation in good agreement with measurements
- Improved placement with higher resolution, but pattern and precipitation amount remain similar
- Vertical resolution showed hardly any effect
- Initial conditions from assimilation run improved simulation of precipitation for the Cévennes cases, but had small effect for the Piemonte cases
- Use of z coordinates seems to improve precipitation forecast compared to runs with terrain following coordinates with same setting, but runs with prognostic precipitation and Runge-Kutta can not be performed and a very small time step has to be used
- Comparison of COSMO model, Meso NH and MM5
 - big differences for single cases
 - for Piedmont and Cévennes cases average result quality is similar