Analysis of the sensitivity of the precipitation forecast with respect to changes in the COSMO model parametrizations:

Case study: Emilia Romagna 10 April 2005

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**ARPA-SIM**

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Outline

- Description of the meteorological event;

- COSMO 3.19 – sensitivity experiments;

- COSMO 4.0 - sensitivity experiments;

- Summary of the results;

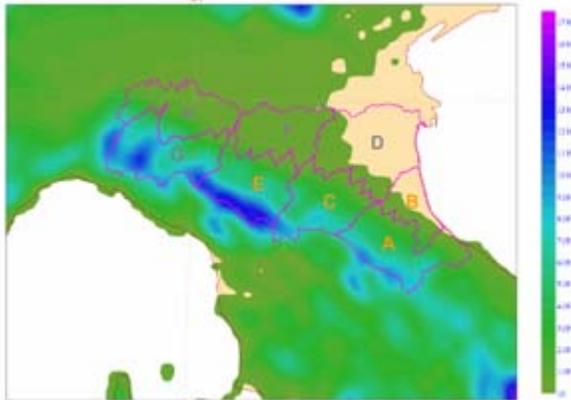- A comparison between the two control versions;

- Conclusions.

Motivation:

Bias distribution of COSMO forecast precipitation (>20 mm) per wind direction

blue= overestimation

red = underestimation
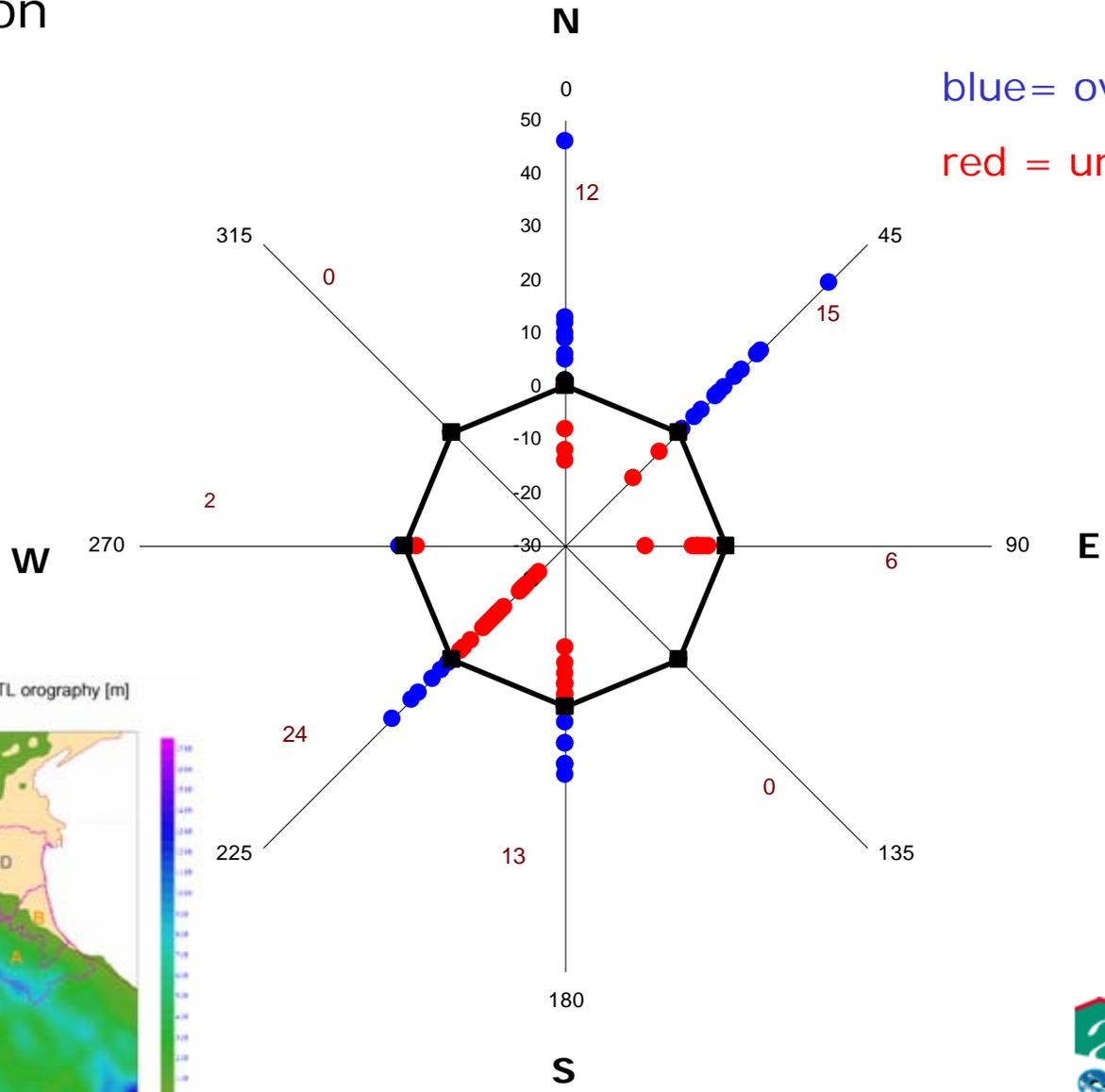
Motivations

❖ even when the synoptic situation is correctly forecasted, the QPF issued by the mesoscale NWP model can be affected by large errors

❖ in this case, one important point to be investigated is the role of the limited-area model parametrisations in affecting the forecast error

Motivations

➢ The "QPF" COSMO Priority Project is born to deal with this problem and it aims to:

❖ test the QPF sensitivity to changes in model parametrizations;

❖ diagnose critical model aspects (microphysics, PBL, convection…..) to be tackled to improve QPF;

❖ verify possible improvements in situations in which the operational COSMO model was poorly performing;

❖ define an experimental test-bed to evaluate the best model upgrades;

ECMWF MSLP analysis 11/04/2005 00UTC
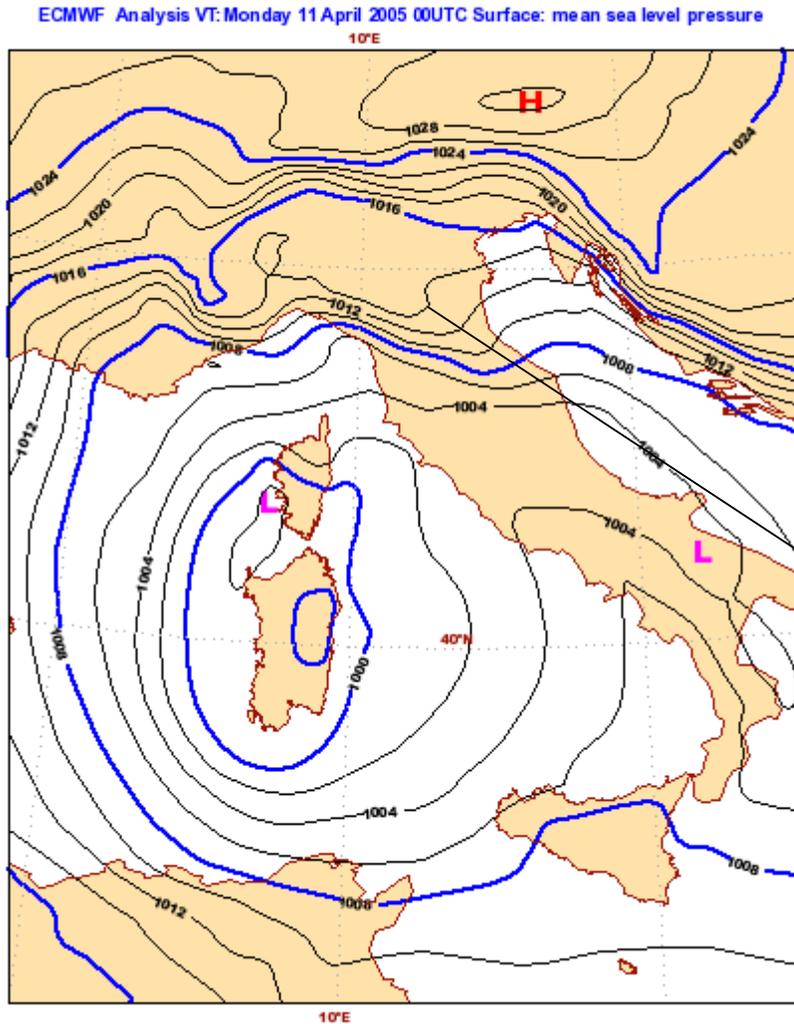
A Mediterranean cyclone over Tyrrhenian Sea linked to an occluded front determines an eastward flux with strong "bora" wind. Heavy precipitation occurs over the Emilia Romagna region (target area, TA).

ECMWF Analysis VT: Monday 11 April 2005 00UTC Surface: mean sea level pressure
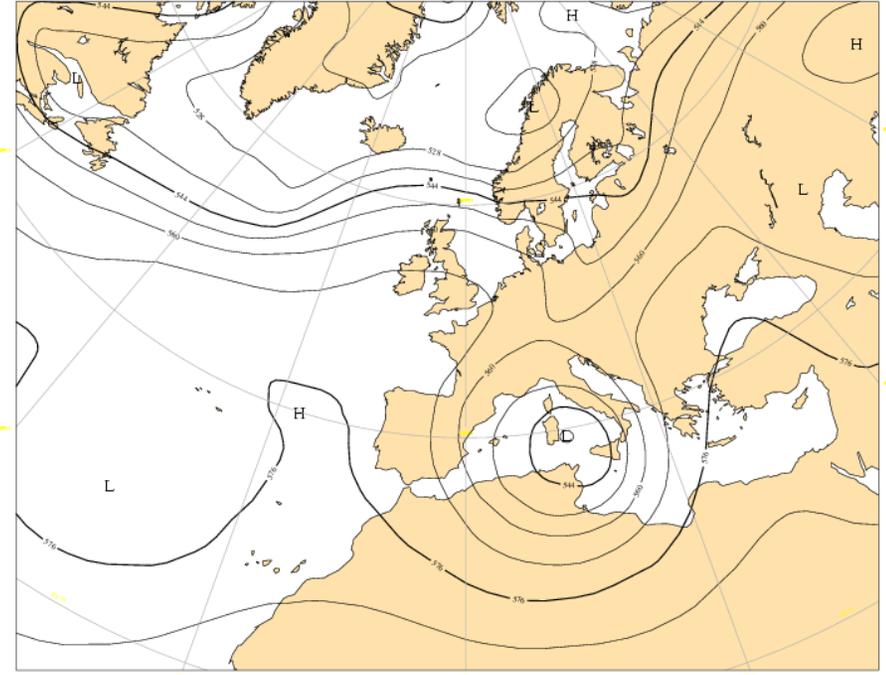
Emila-Romagna's warning areas and CRTL orography [m]
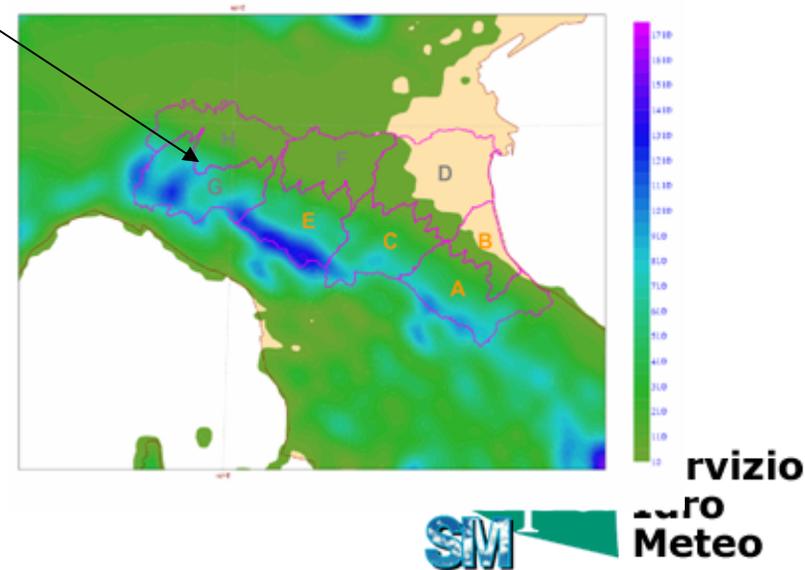
ECMWF Z500 analysis 10/04/2005 and 11/04 2005 00 UTC

10/04/2005 00 UTC
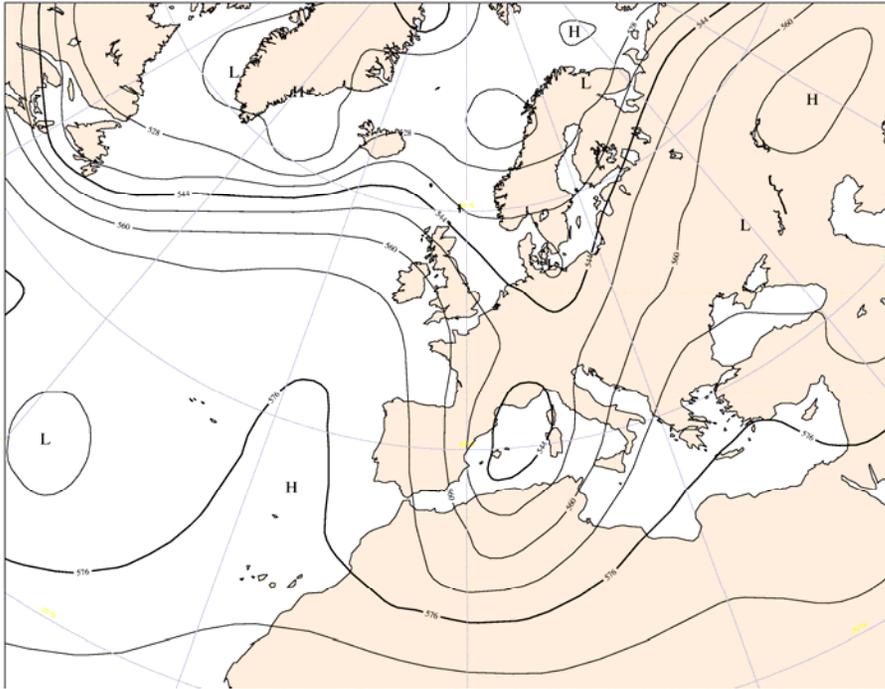
11/04/2005 00 UTC
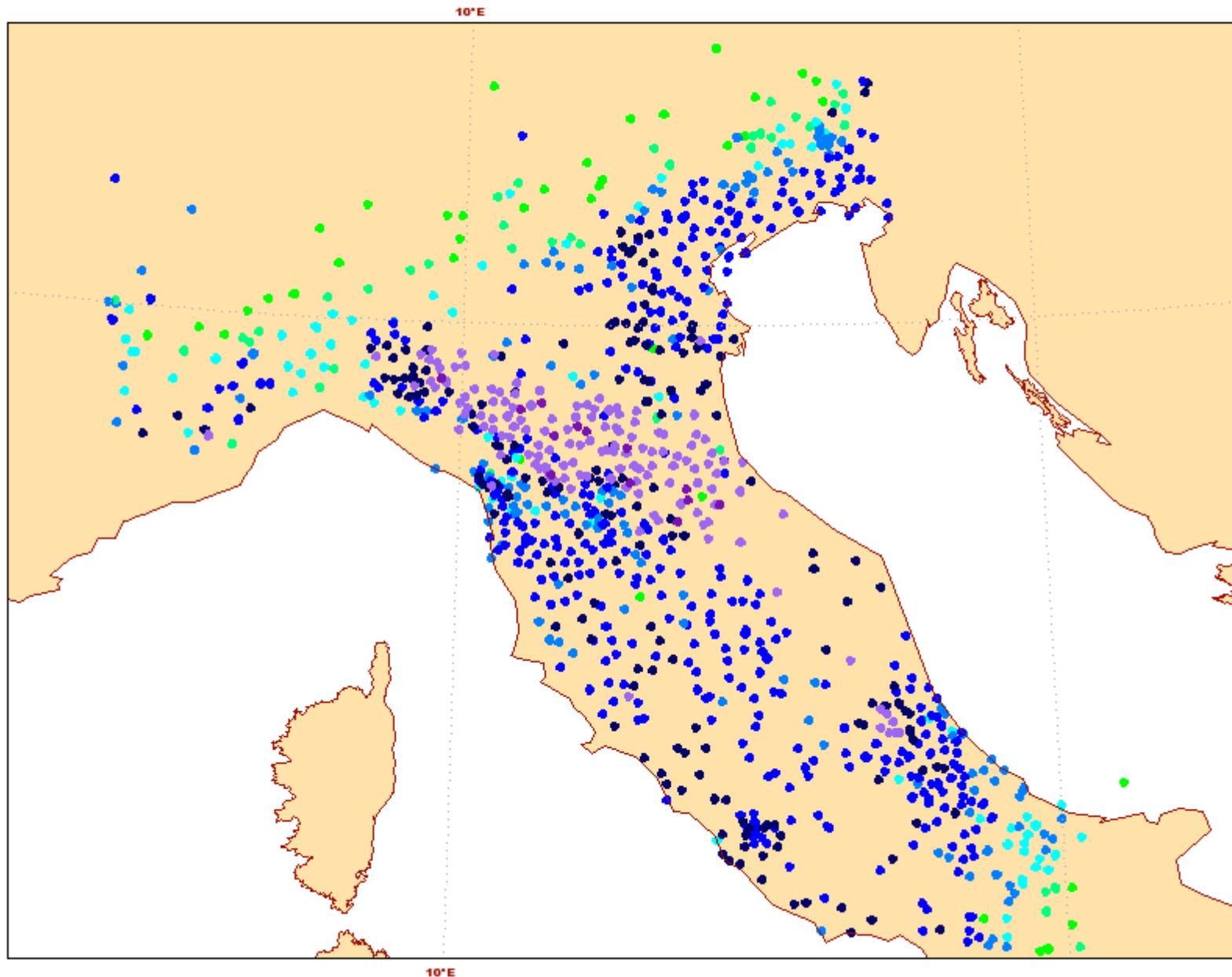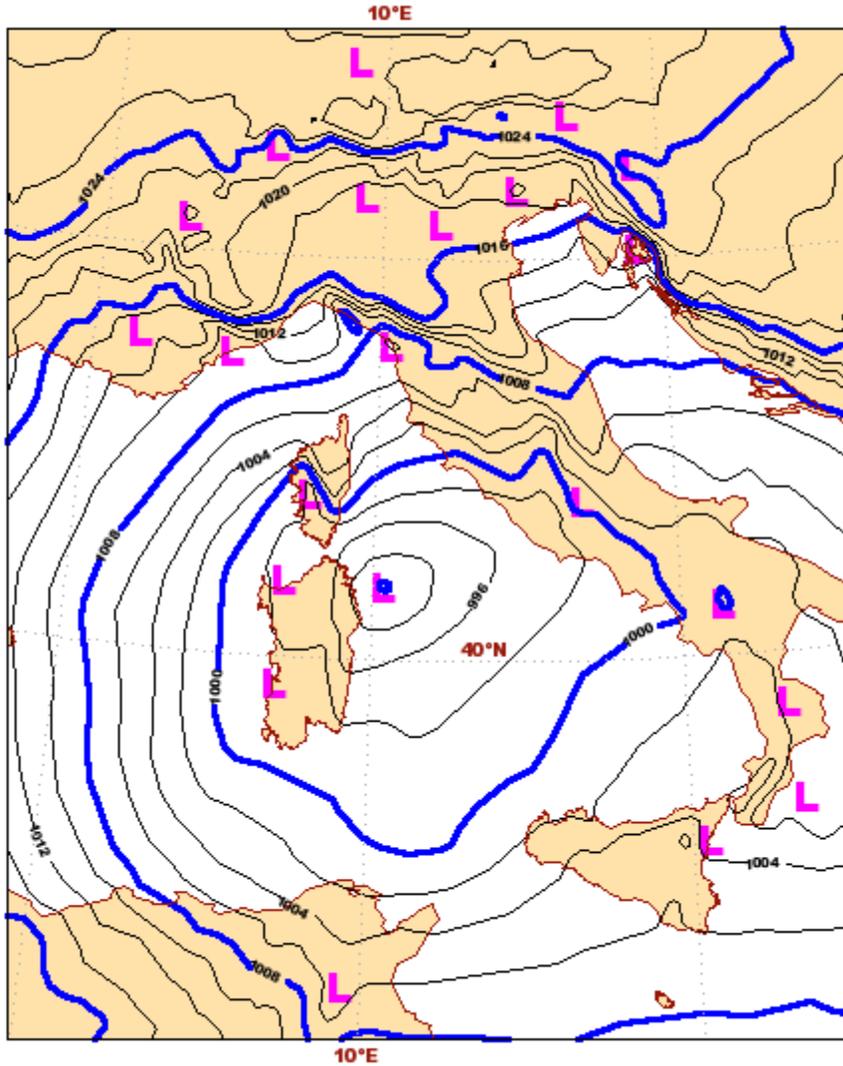
Total precipitation observed during 10/04/2005 00-24

0.1 - 1   1 - 2   2 - 5   5 - 10   10 - 20   20 - 40   40 - 80   80 - 120
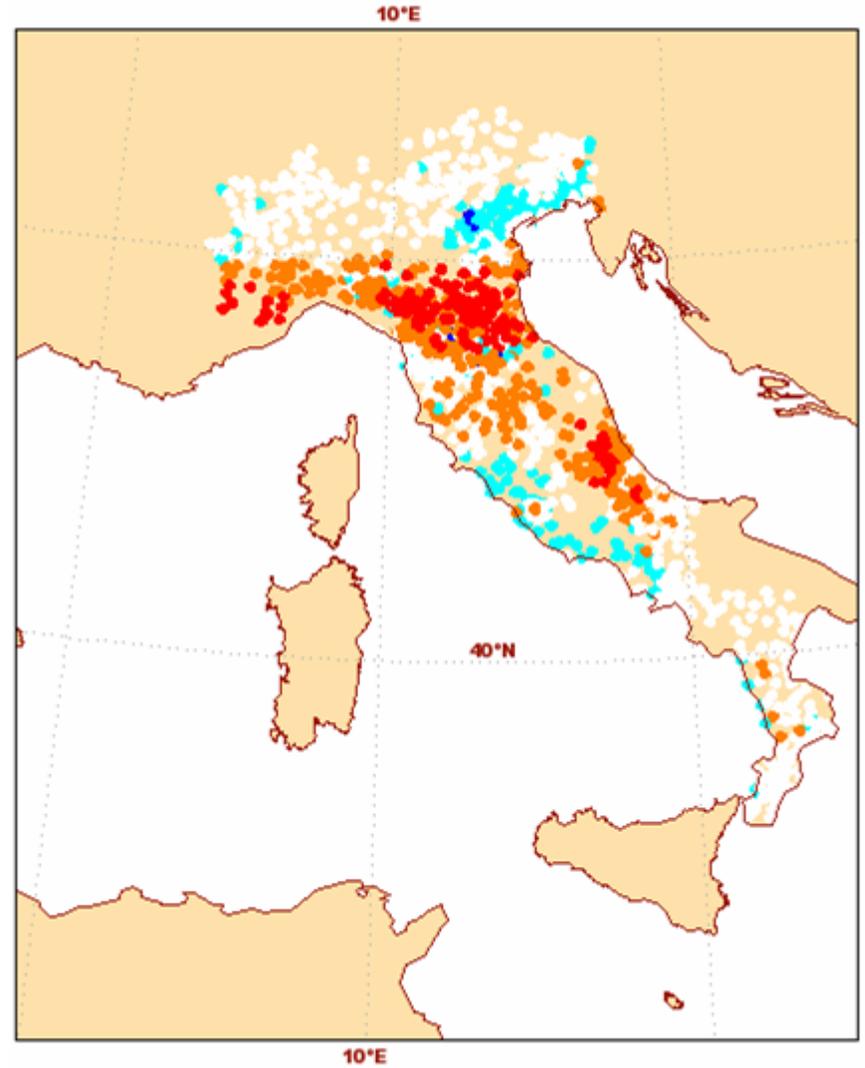
COSMO MSLP FC+24h

Difference between COSMO 10/04/2005 00UTC FC+24h TP and observed for 10/04/2005 [mm/24h]

List of the sensitivity experiments with COSMO 3.19

sea01	increase/decrease of the scaling factor of the laminar
sea40	sublayers over sea
qv090	increase/decrease of atmospheric water vapor mixing ratio
qv110	by 10%
micro1	modified microphysics
micro2	
micro3	
conmod	modified convection
conoff	
conkfb	
rlam01	decrease/increase of the scaling factor of the laminar
rlam50	sublayers for scalars

DIFFERENCES IN 24h TP (EXPERIMENTS-CONTROL), temperature profile and QC and QI cloud contents
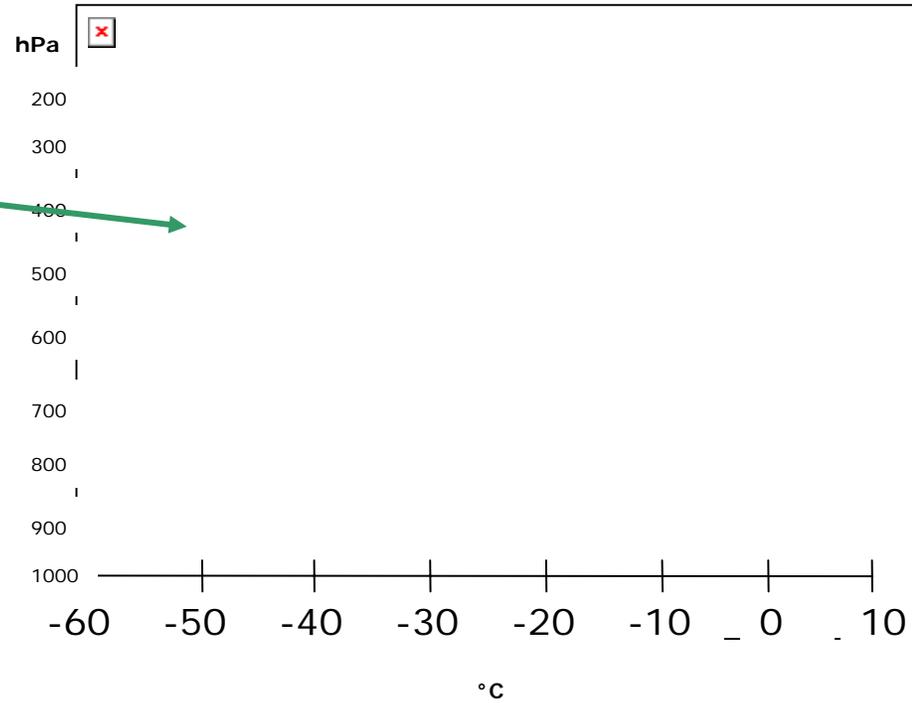
Difference map in TP between the exp and the ctrl version 3.19

SEA01:
Increased vertical exchange of heat and moisture over sea, rat_sea=1

_COMP Accum of 0 Fcsts VT: 00UTC 10 April 2005 to 00UTC 20050411 Surf: sea01 - ctrl/TP

Difference map in TP between the exp and the ctrl version 3.19

SEA40
Decreased vertical exchange of heat and moisture over sea, rat_sea=40
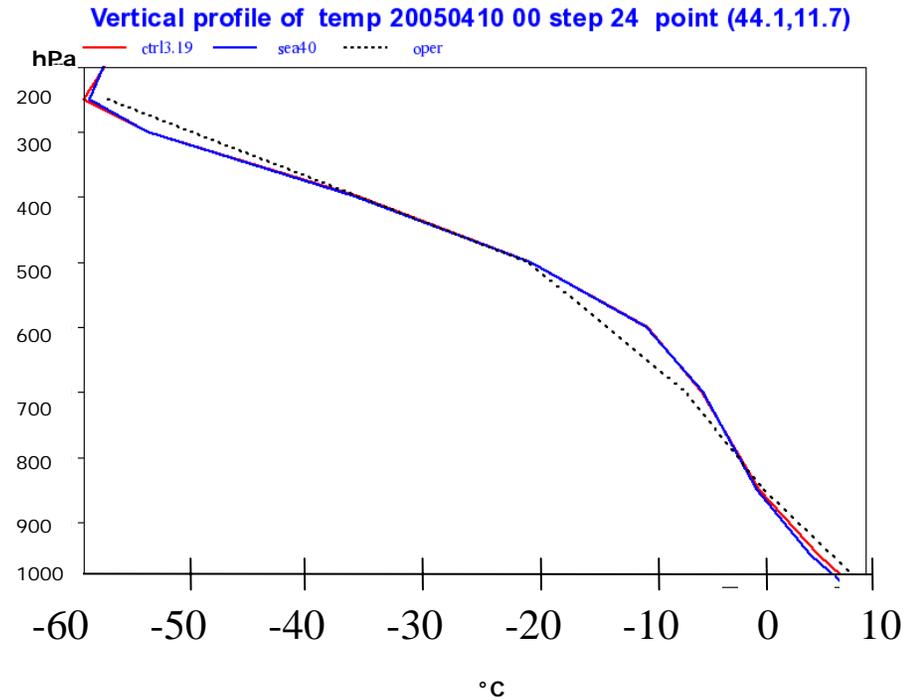
_COMP Accum of 0 Fcsts VT: 00UTC 10 April 2005 to 00UTC 20050411 Surf: sea40 - ctrl/TP

Vertical profile of temp 20050410 00 step 24 point (44.1,11.7)

Difference map in TP between the exp and the ctrl version 3.19

QV090:
Reduction of atm water vapor mixing ratio by 10% in cloud free regions
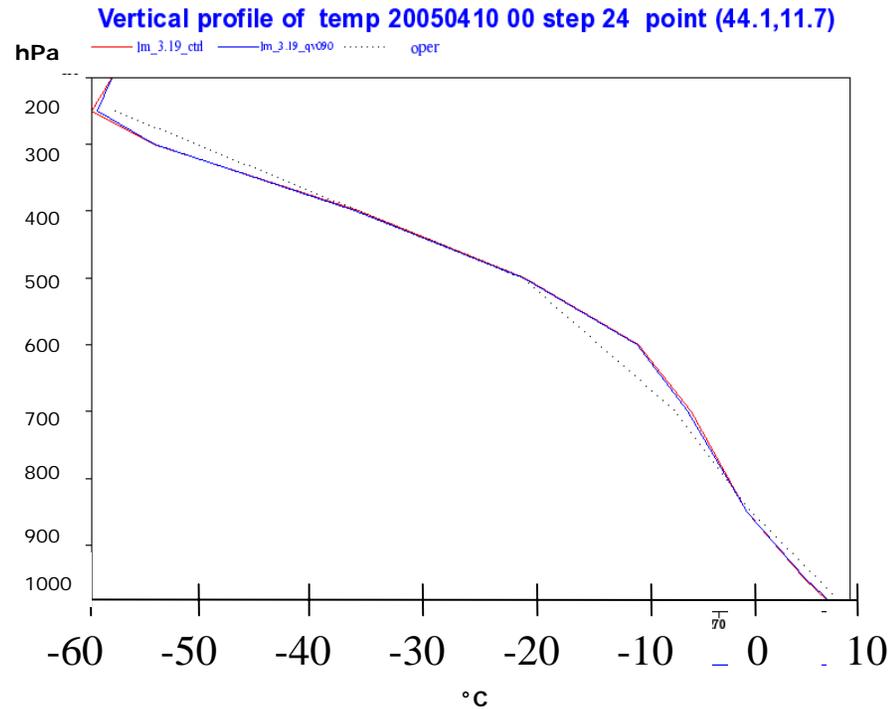
_COMP Accum of 0 Fcsts VT: 00UTC 10 April 2005 to 00UTC 20050411 Surf: qv090 - ctrl/TP

Vertical profile of temp 20050410 00 step 24 point (44.1,11.7)

Difference map in TP between the exp and the ctrl version 3.19

QV110
Increase of atm water vapor mixing ratio by 10%

_COMP Accum of 0 Fcsts VT: 00UTC 10 April 2005 to 00UTC 20050411 Surf: qv110 - ctrl/TP

Vertical profile of temp 20050410 00 step 24 point (44.1,11.7)

hPa   — lm_3.19_ctrl   — lm_3.19_qv110   ······· oper

Difference map in TP between the exp and the ctrl version 3.19
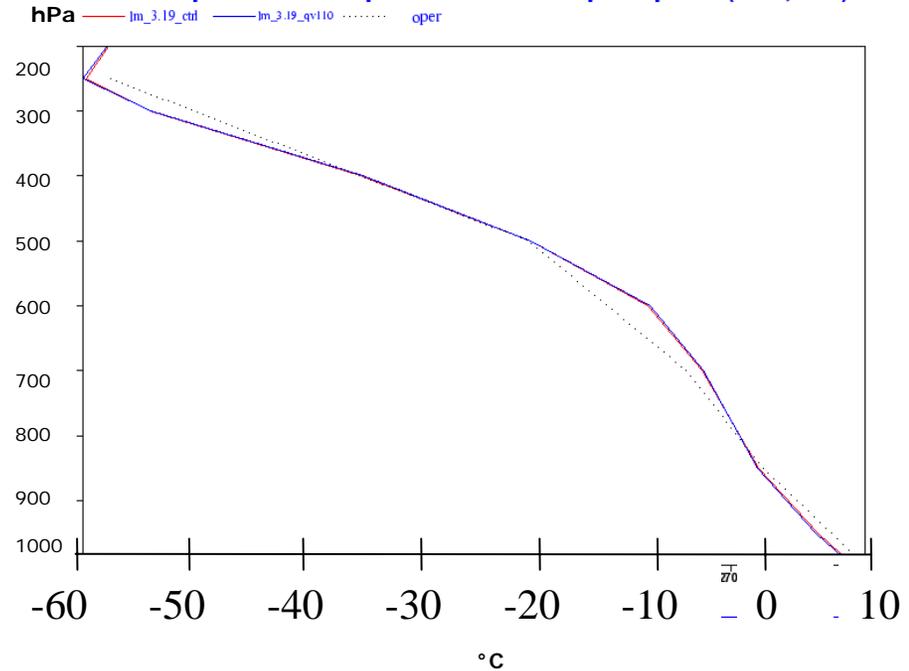
Micro1:
Modified microphysics with new cloud autoconversion scheme.

_COMP Accum of 0 Fcsts VT: 00UTC 10 April 2005 to 00UTC 20050411 Surf: micro1 - ctrl/TP

Vertical profile of specific cloud ice content, grid scale 20050410 00 step 24 point (44.1,11.7)

ctrl3.19_QI   lm_3.19_QC   Micro1_QI   Micro1_QC
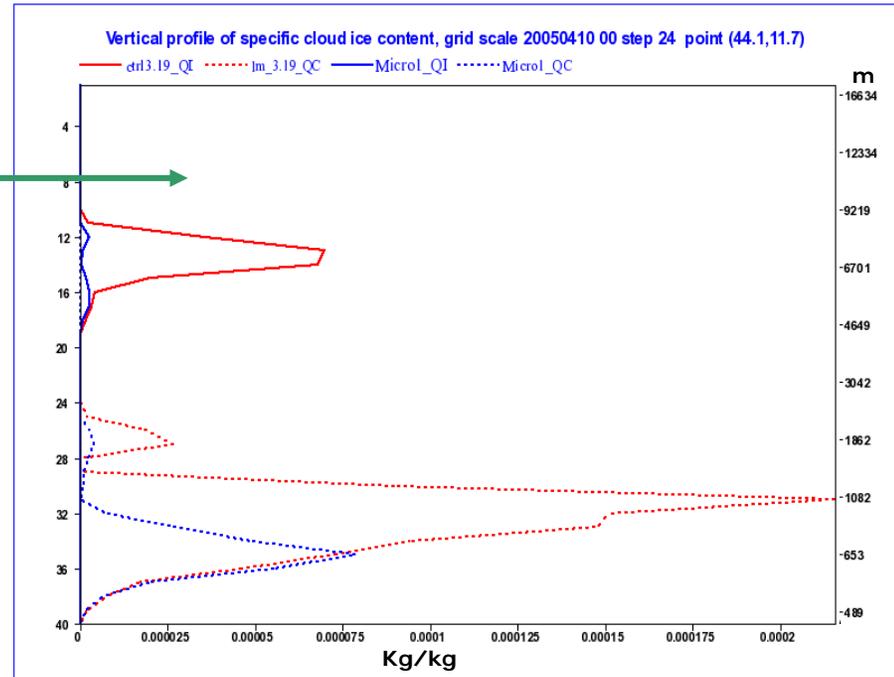
Blu = micro1   Red = ctrl 3.19
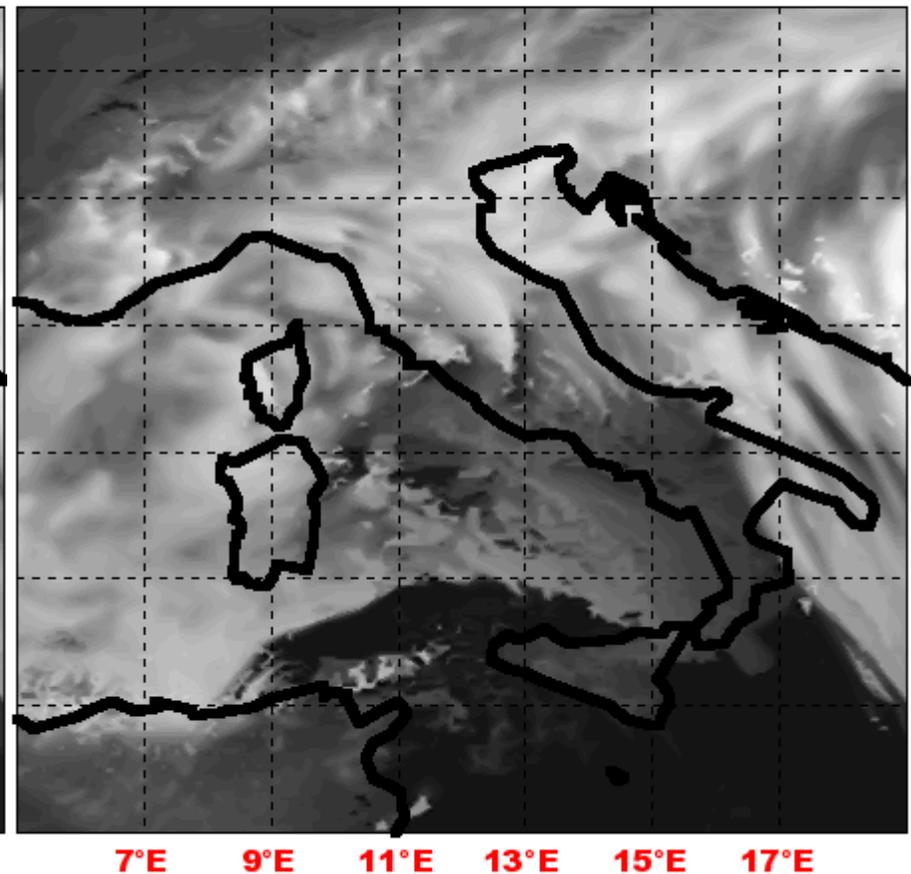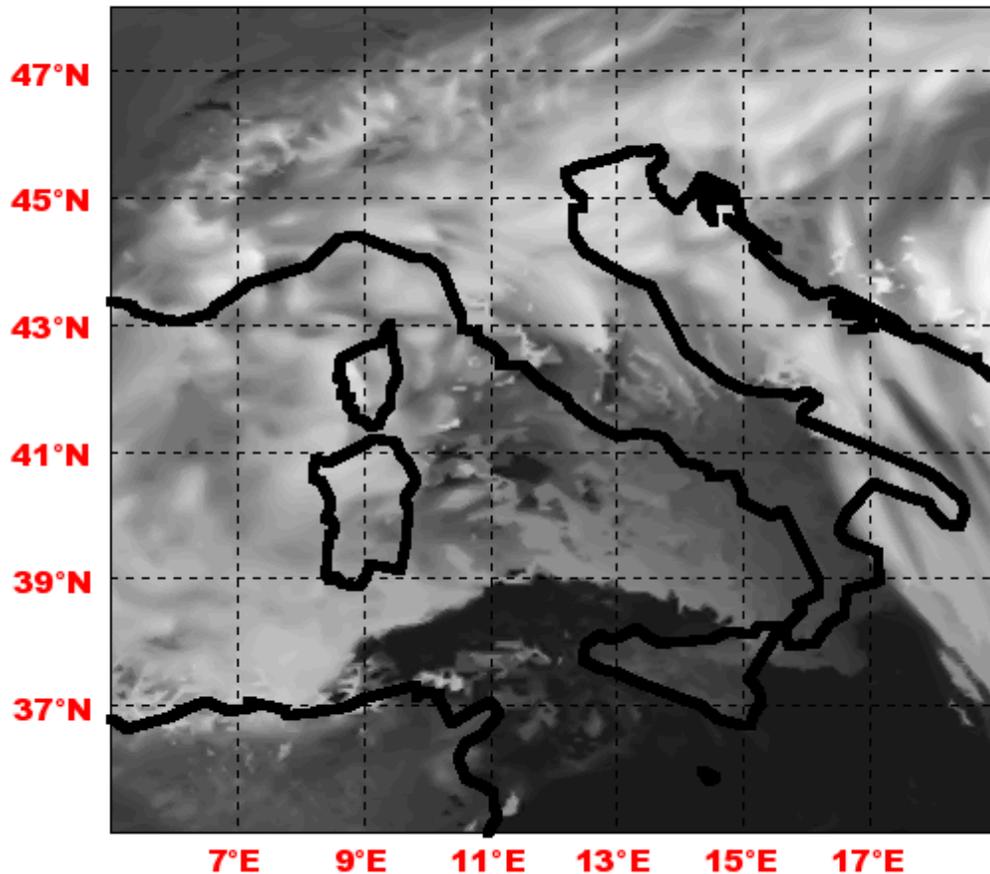
—   QI   .....   QC

COSMO generated MSG satellite IR 10.8 image
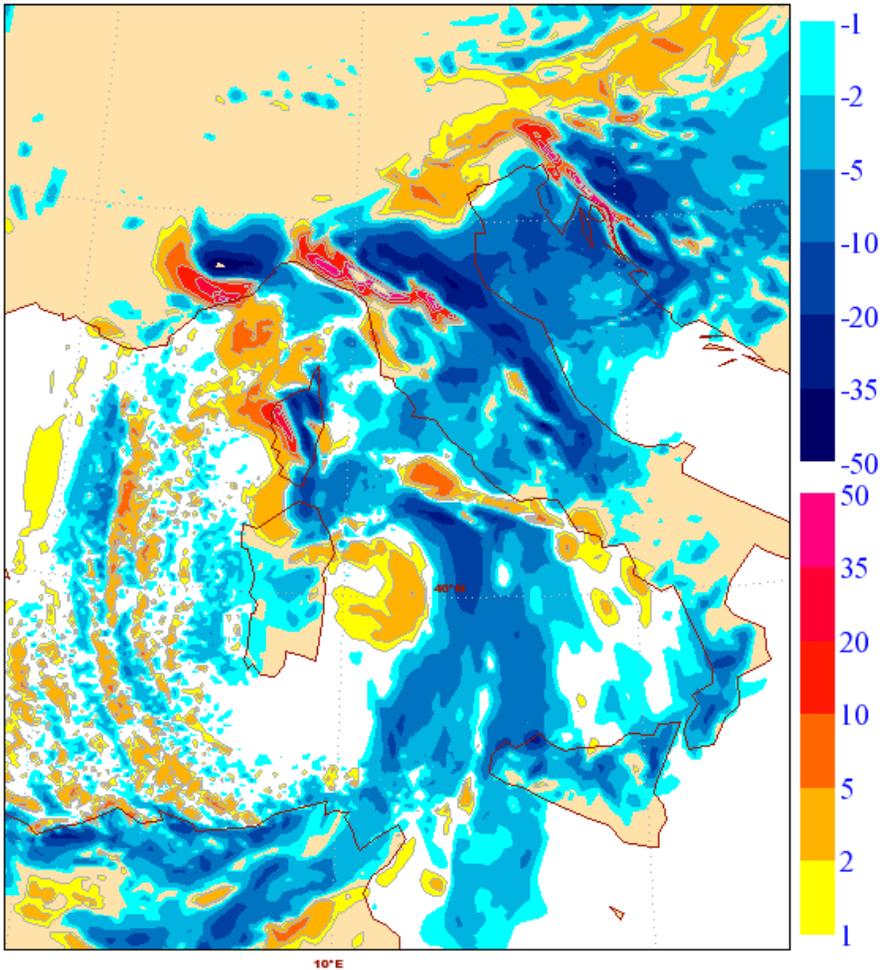

20050410 00UTC   t+24 VT: 20050411 00UTC Surf: micro1/IR10.8

20050410 00UTC   t+24 VT: 20050411 00UTC Surf: ctrl/IR10.8

Difference map in TP between the exp
and the ctrl version 3.19

micro2
Modified microphysics with extreme
changes in snow properties and the
new cloud autoconversion scheme

_COMP Accum of 0 Fcsts VT: 00UTC 10 April 2005 to 00UTC 20050411 Surf:
micro2 - ctrl/TP

Vertical profile of specific cloud ice content, grid scale 20050410 00 step 24 point (44.1,11.7)

Blu = micro2   Red = ctrl 3.19

——   QI   .....   QC

COSMO generated MSG satellite IR 10.8 image

20050410 00UTC   t+24 VT: 20050411 00UTC Surf: micro2/IR10.8

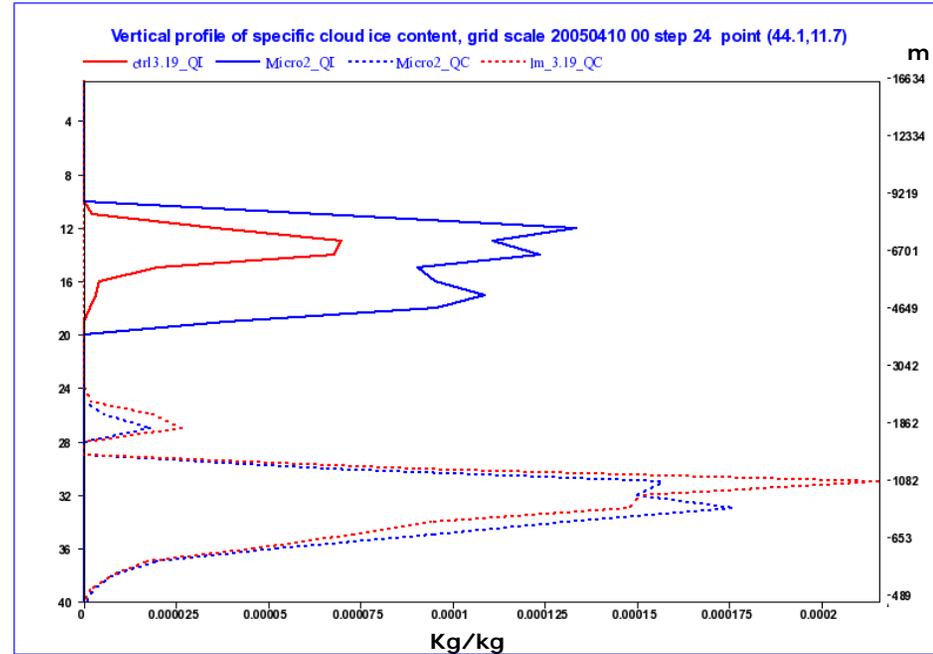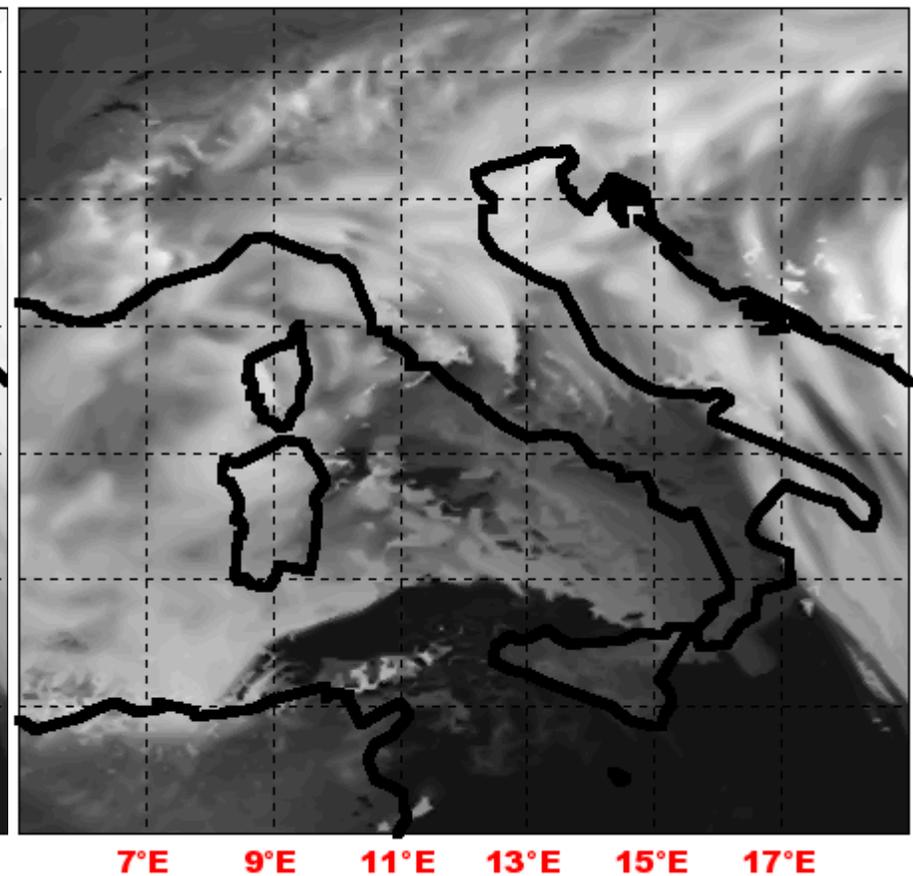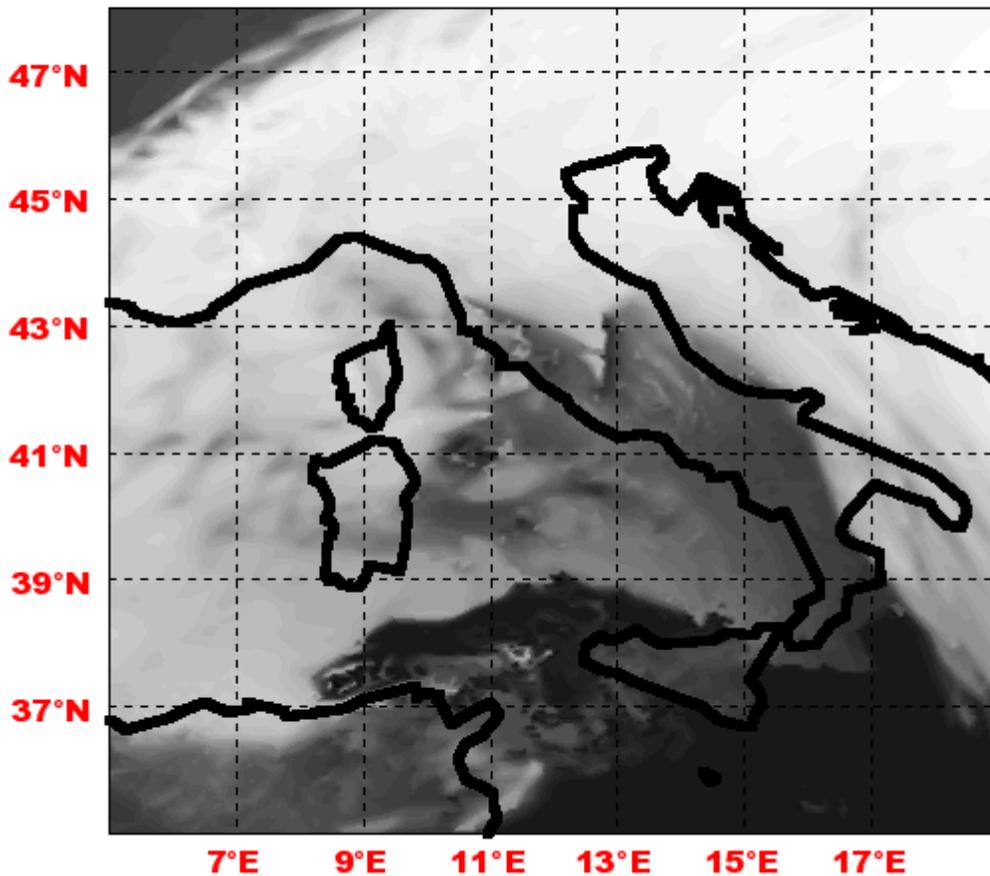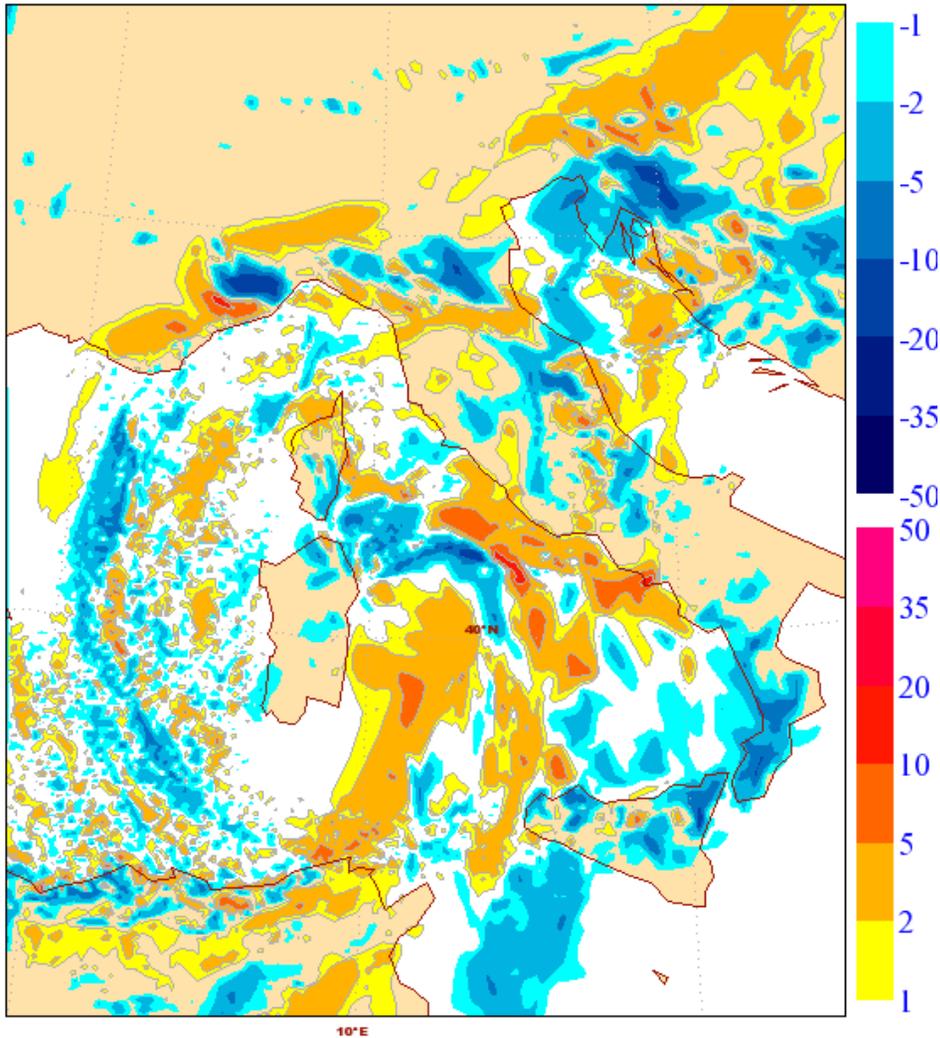20050410 00UTC   t+24 VT: 20050411 00UTC Surf: ctrl/IR10.8

Difference map in TP between the exp and the ctrl version 3.19

micro3
Modified microphysics with moderate changes in snow properties and the new cloud autoconversion scheme

_COMP Accum of 0 Fcsts VT: 00UTC 10 April 2005 to 00UTC 20050411 Surf: micro3 - ctrl/TP

Vertical profile of specific cloud ice content, grid scale 20050410 00 step 24 point (44.1,11.7)

ctrl3.19_QI   Micro3_QI   Micro3_QC   lm_3.19_QC

Blu = micro3   Red = ctrl 3.19

—   QI   .....   QC

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COSMO generated MSG satellite IR 10.8 image

20050410 00UTC   t+24 VT: 20050411 00UTC Surf: micro3/IR10.8

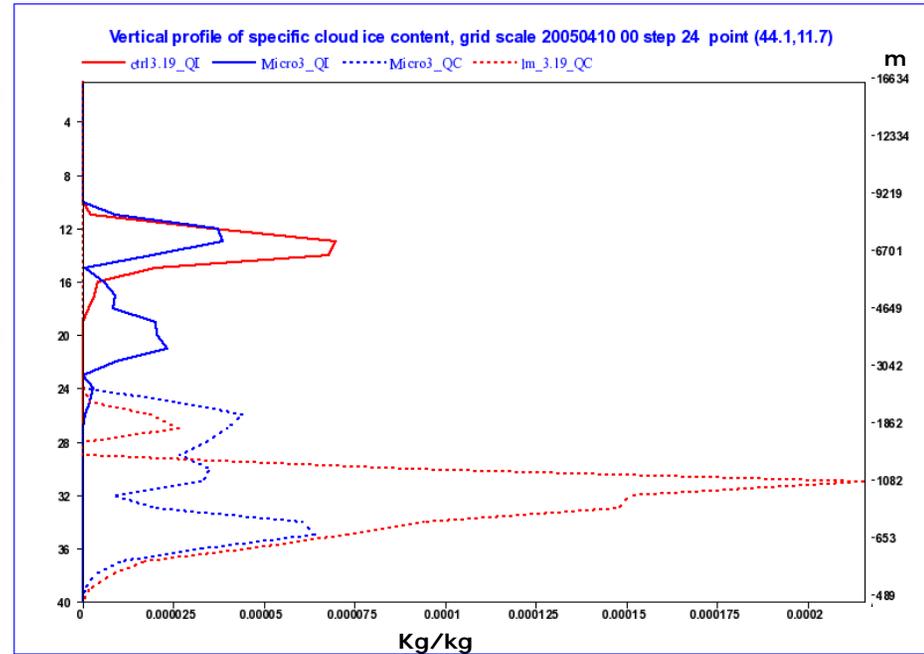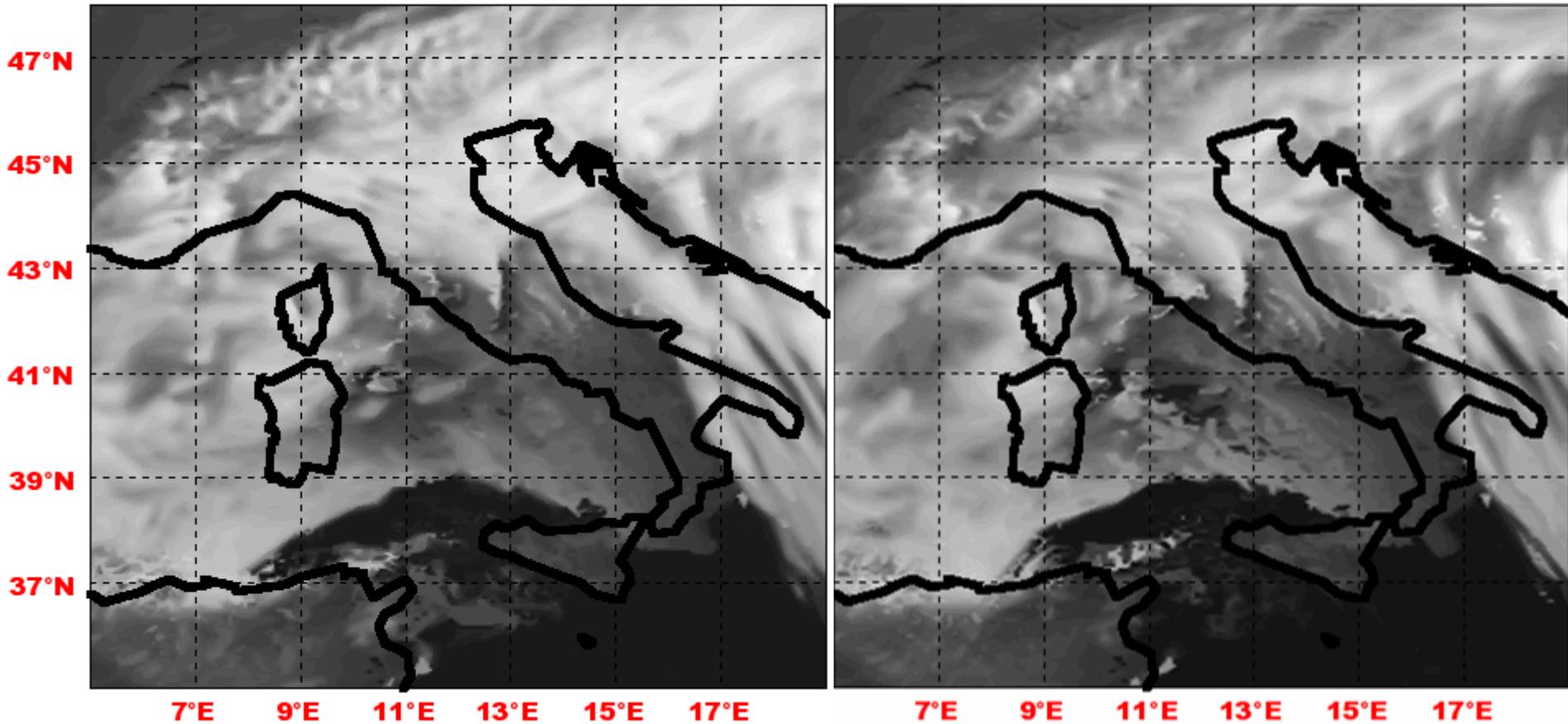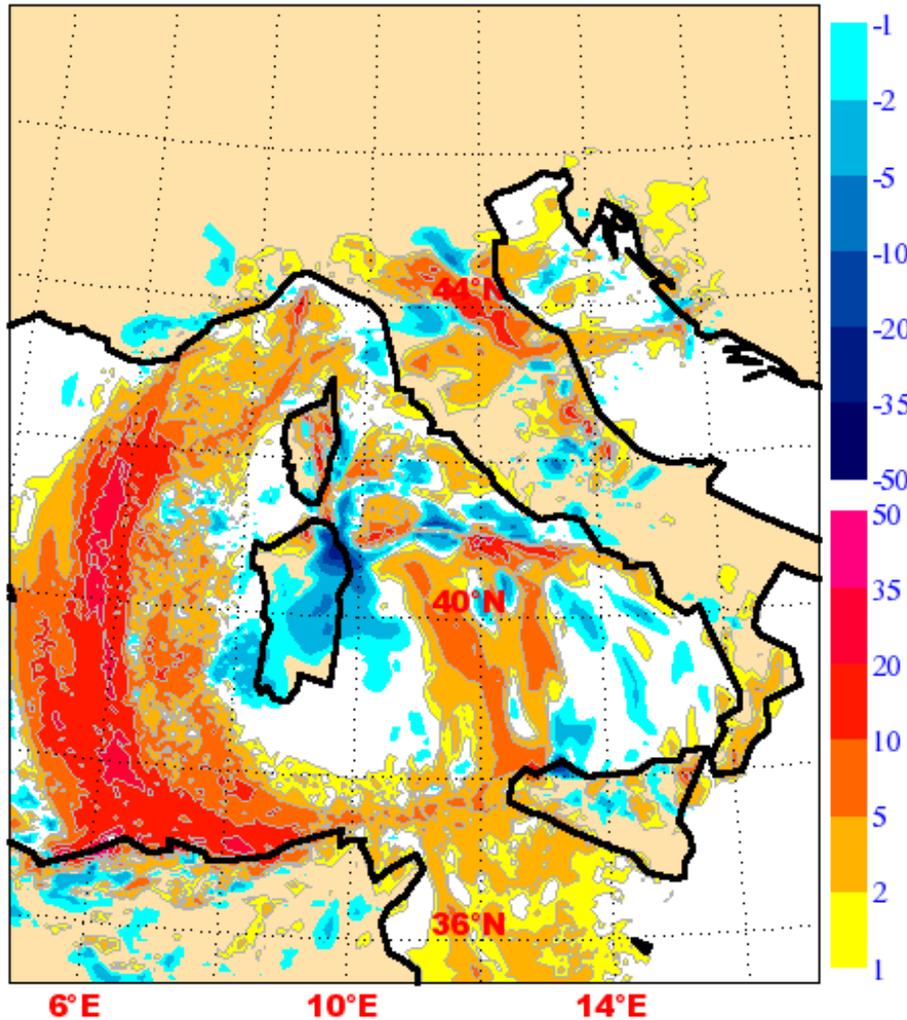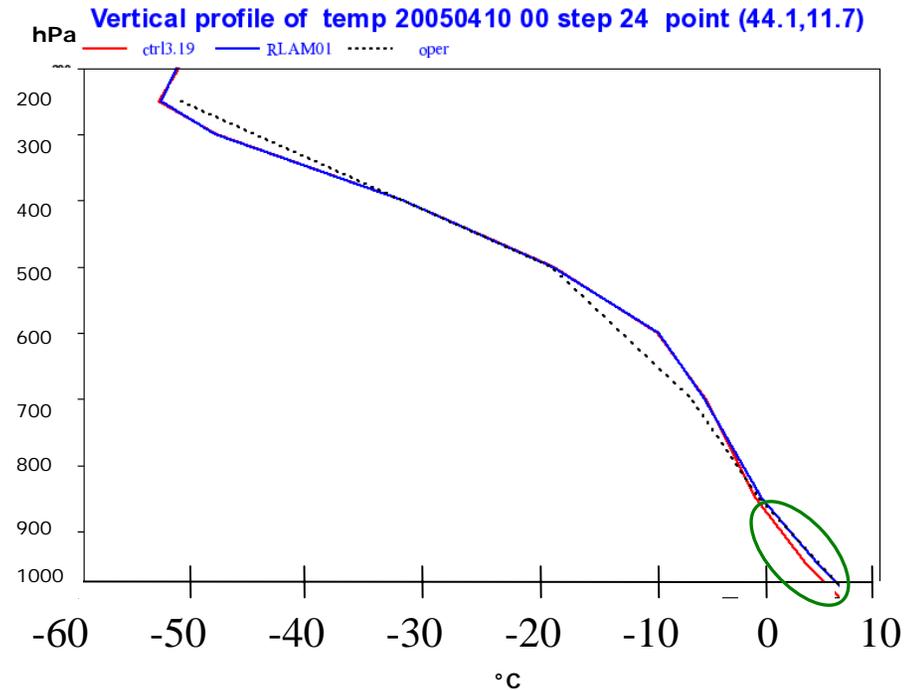20050410 00UTC   t+24 VT: 20050411 00UTC Surf: ctrl/IR10.8
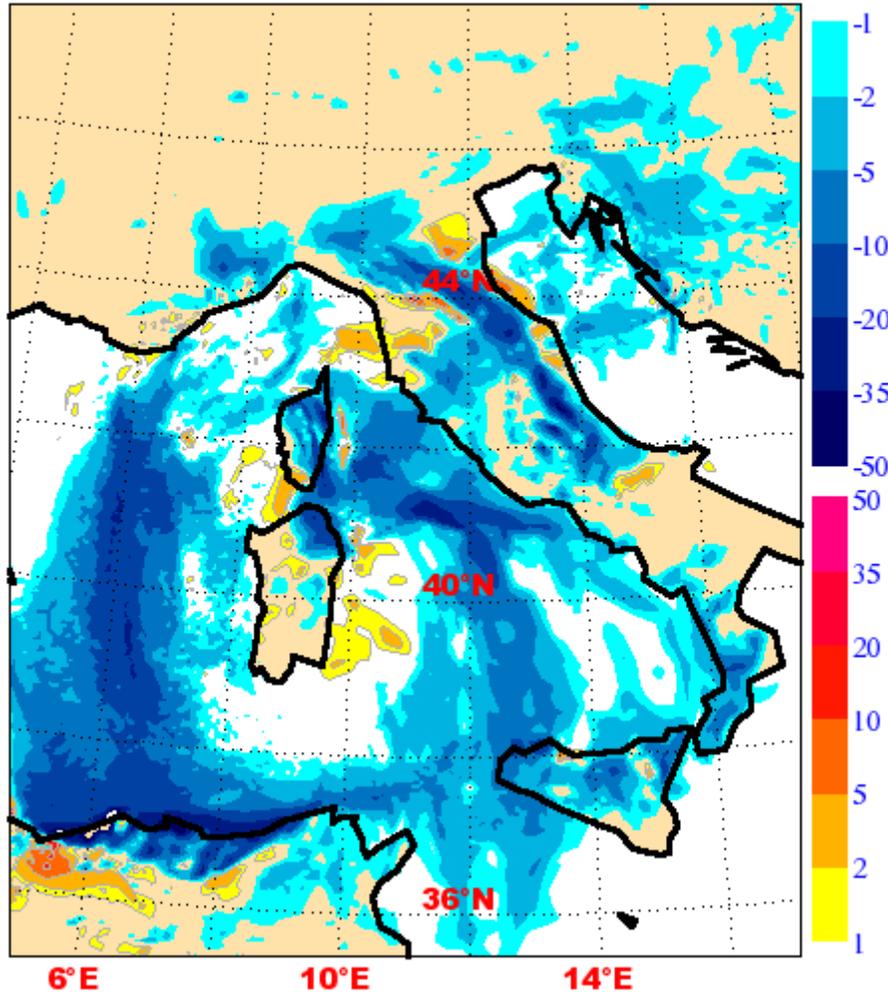
Difference map in TP between the exp and the ctrl version 3.19

Rlam 01:
decreased scaling factor of the laminar sublayer for scalar (increased exchange of heat and moisture).

_COMP Accum of 0 Fcsts VT:00UTC 10 April 2005 to 00UTC 20050411 Surf: rlam01 - ctrl/TP

Vertical profile of temp 20050410 00 step 24 point (44.1,11.7)

ctrl3.19   RLAM01   oper

Difference map in TP between the exp and the ctrl version 3.19

Rlam50:
increased scaling factor of the laminar sublayer for scalar (decreased exchange of heat and moisture.

_COMP Accum o10 Fcsts VT:00UTC 10 April 2005 to 00UTC 20050411 Surf: rlam50 - ctrl/TP

Vertical profile of temp 20050410 00 step 24 point (44.1,11.7)
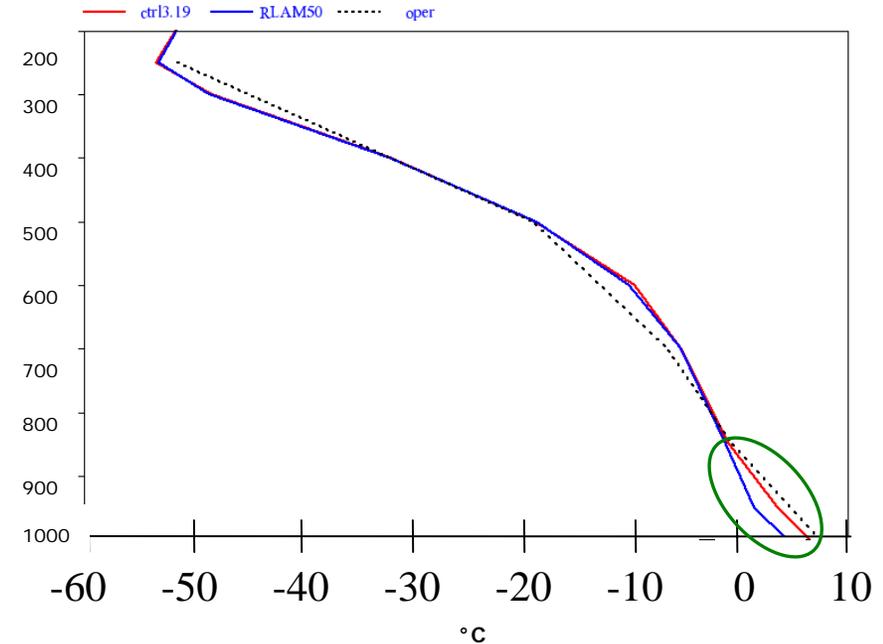
Summary

| Experiment code	Impact on the TP forecast
sea01	Strong increase of TP associated with mistral and bora winds. Increase overestimation in the TA.
sea40	Same as Sea01 but opposite in sign. Decrease of overestimation in TA.
qv090	Strong decrease of TP in the frontal area; substantial reduction in the TA.
qv110	General worsening in the TA.
micro1	Negligible impact
micro2	Very strong impact on the stratiform precipitation Overall positive reduction of TP in the TA.
micro3	Slight better in the TA. Mixed effect elsewhere.
conmod	Decrease TP in the cold air mass, negligible elsewhere. Slight deterioration.
conoff	Negligible impact
conkfb	Negligible impact
rlam01	Increase TP almost everywhere
rlam50	Decrease TP almost everywhere

SENSITIVITY EXPERIMENTS WITH COSMO VERSION 4.0

Main changes between the two model versions
v 3.19 (ctrl) VS v 4.0 (ctrl)

Cosmo v. 4.0 : changes in the microphysics scheme were taken from a combination of previous experiments micro2 and micro3: reduction in drizzle content and increase in cloud water and ice content is expected as well as a better characterization (increase) of precipitation transport to the lee side of mountains.

COSMO v 4.0 ctrl MSLP FC+24h
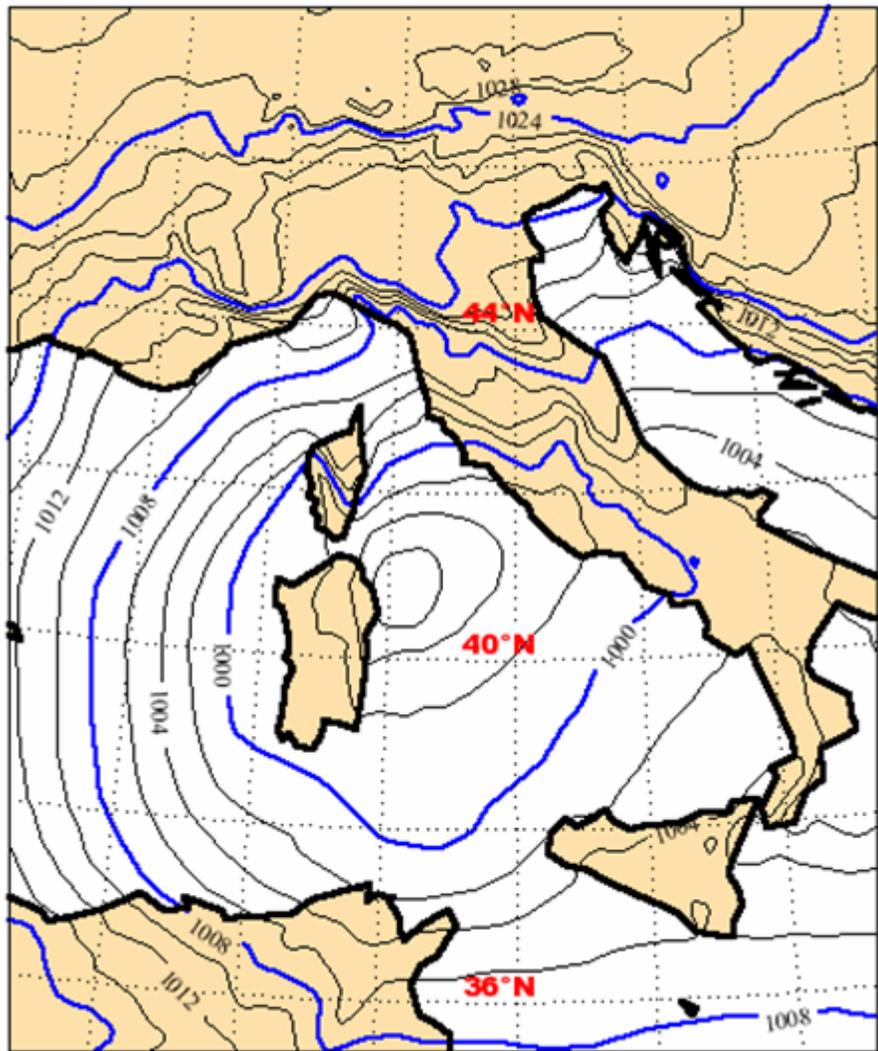
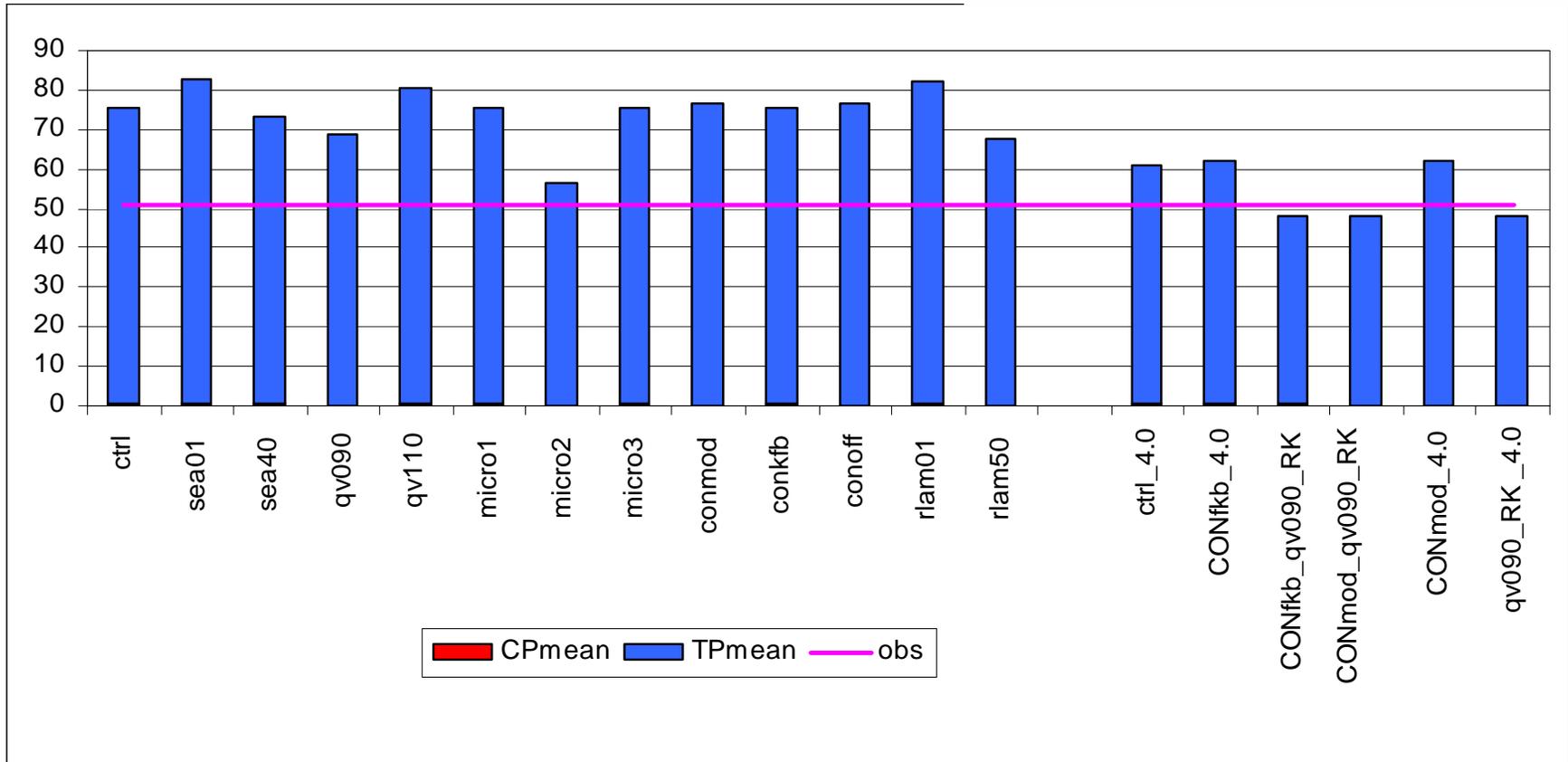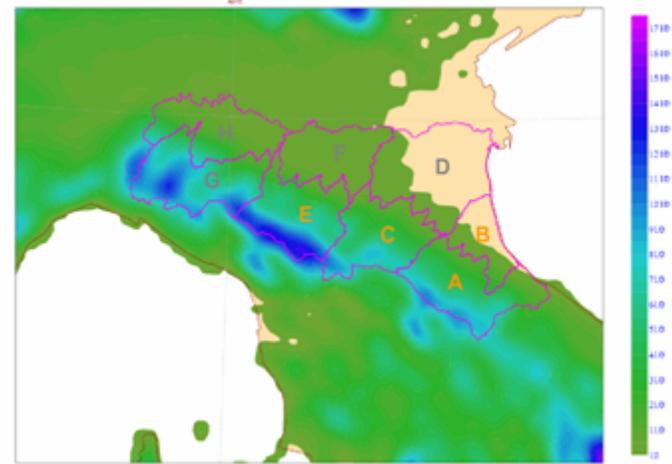## Difference between COSMO 4.0 ctrl 10/04/2005 00UTC FC+24h TP and observed for 10/04/2005 [mm/24h]
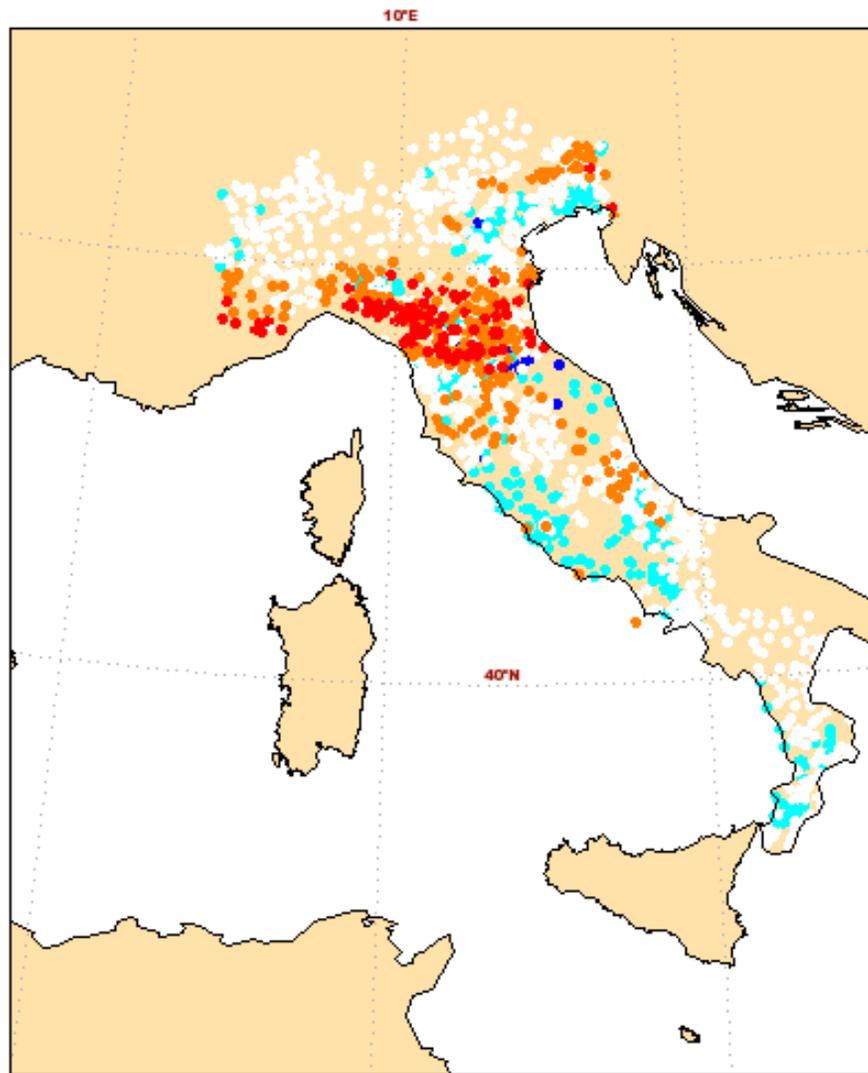
List of the experiments with COSMO 4.0 (second sensitivity experiments)

❖ <u>CTRL:</u> Model version 4.0

❖ <u>QV090</u> + Runge Kutta: Reduction of the initial humidity by 10% and Runge Kutta scheme;

❖ <u>CONkfb</u>: Kain-Fritsch/Becthold convection scheme;

❖ <u>QV090+ RK + CONkfb</u>: KFB convection scheme and reduction of the initial humidity by 10%;

❖ <u>ConMod</u>: new modification of the convection scheme, QC and QI calculated by the convection scheme are now transferred to the grid scale fields;

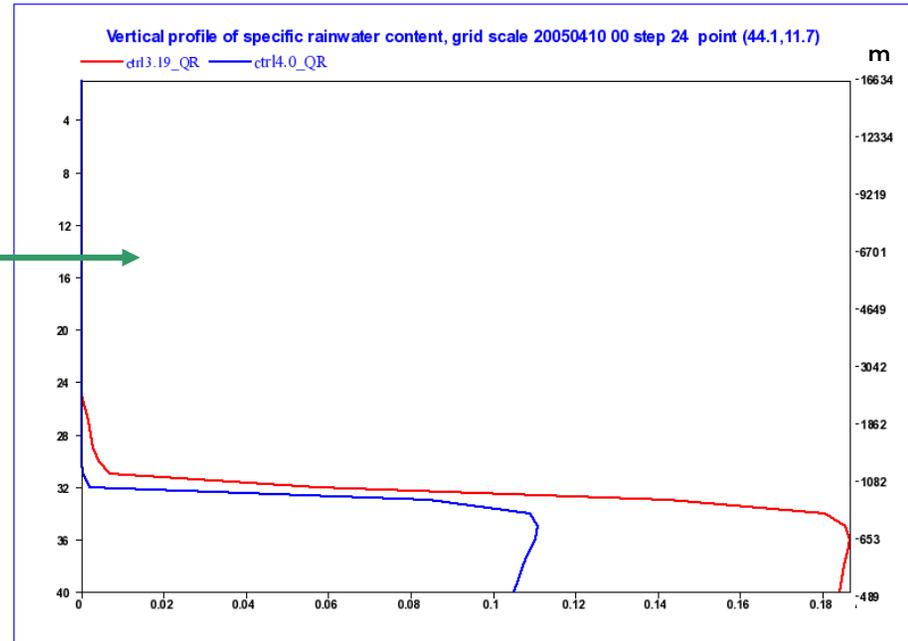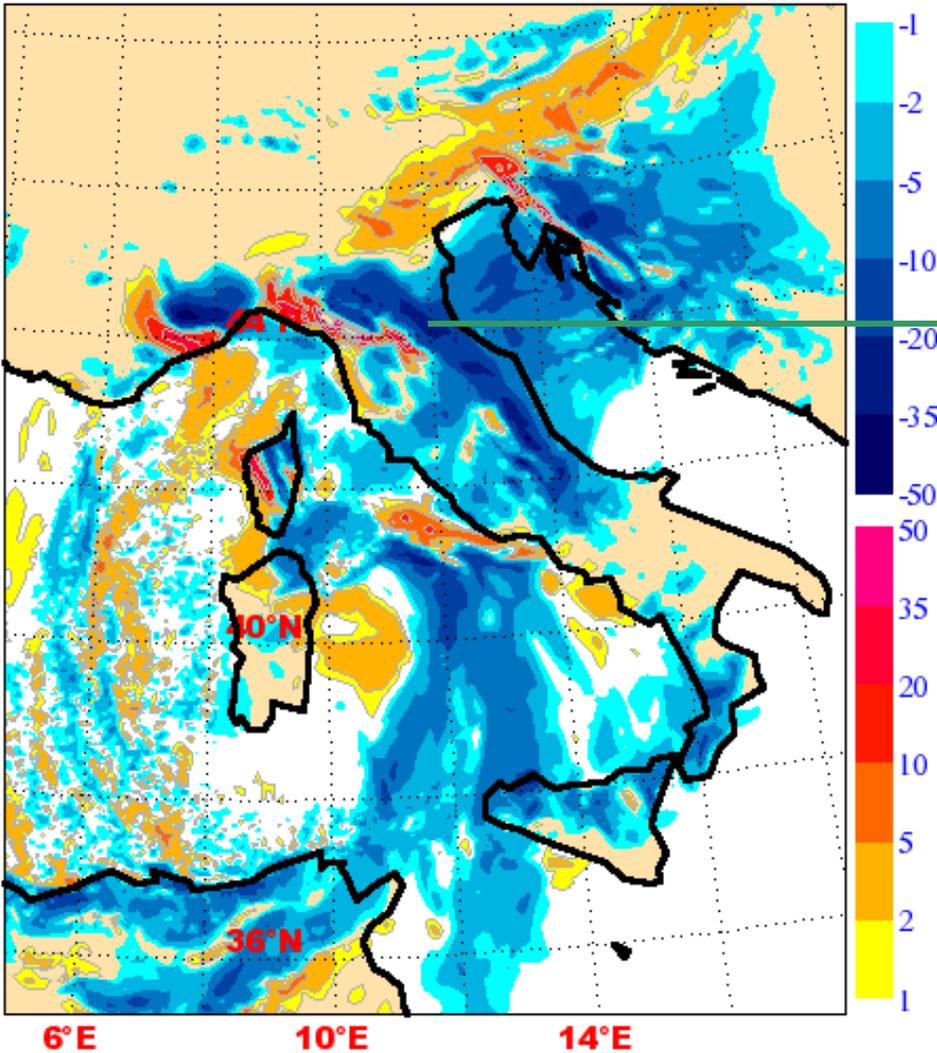❖ <u>QV090 + RK+ ConMod</u>: a variation in the experiment CONmod with reduction of initial humidity by 10%;

Summary of the experiments:

Emila-Romagna's warning areas and CRTL orography [m]

Legend: CPmean (red) — TPmean (blue) — obs (magenta line)

Categories: ctrl, sea01, sea40, qv090, qv110, micro1, micro2, micro3, conmod, conkfb, conoff, rlam01, rlam50, ctrl_4.0, CONfkb_4.0, CONfkb_qv090_RK, CONmod_qv090_RK, CONmod_4.0, qv090_RK_4.0

Differences map in TP between the ctrl 4.0 and the ctrl 3.19

Specific rainwater content

_COMP Accum of 0 Fcsts VT:00UTC 10 April 2005 to 00UTC 20050411 Surf: ctrl_lm4p0 - ctrl/TP

Vertical profile of specific rainwater content, grid scale 20050410 00 step 24 point (44.1,11.7)

ctrl3.19_QR   ctrl4.0_QR

Blue =ctrl 4.0   Red = ctrl 3.19

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Ctrl 4.0-obs
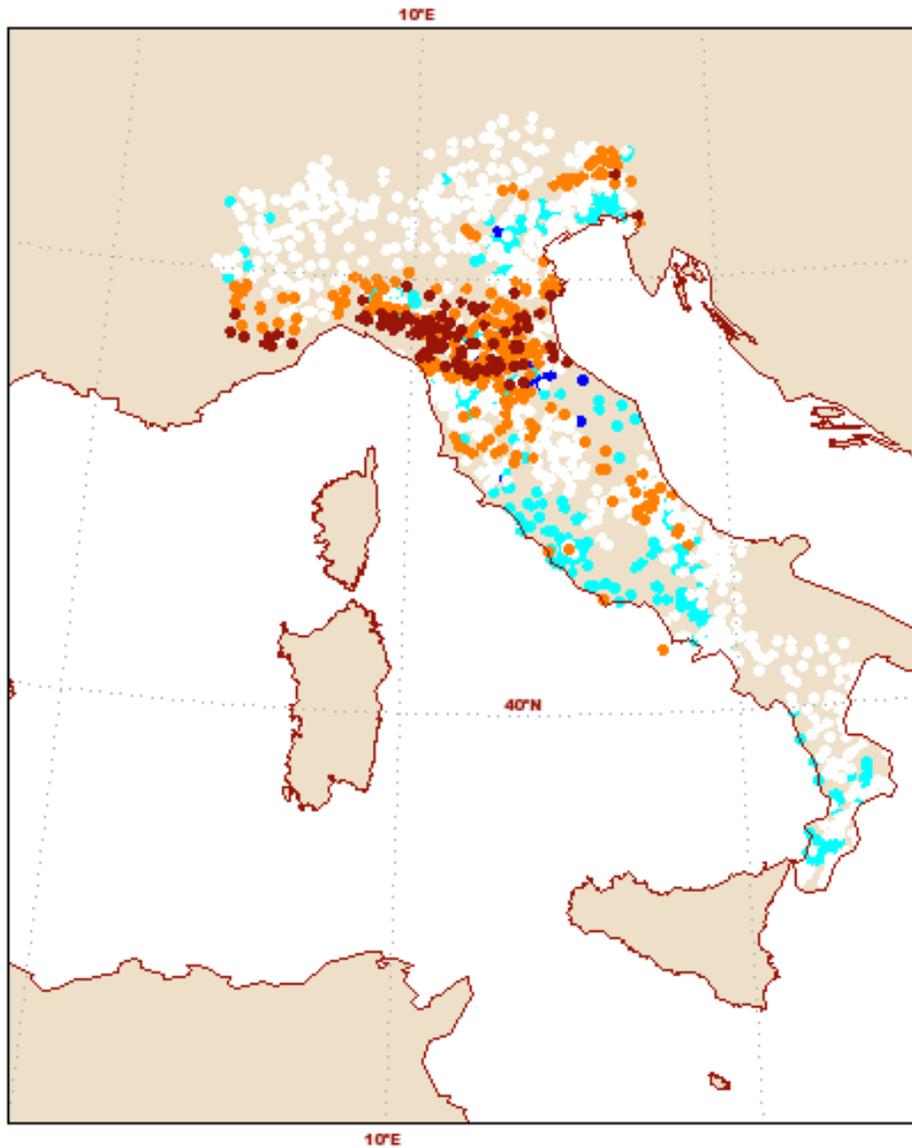
Ctrl 3.19-obs
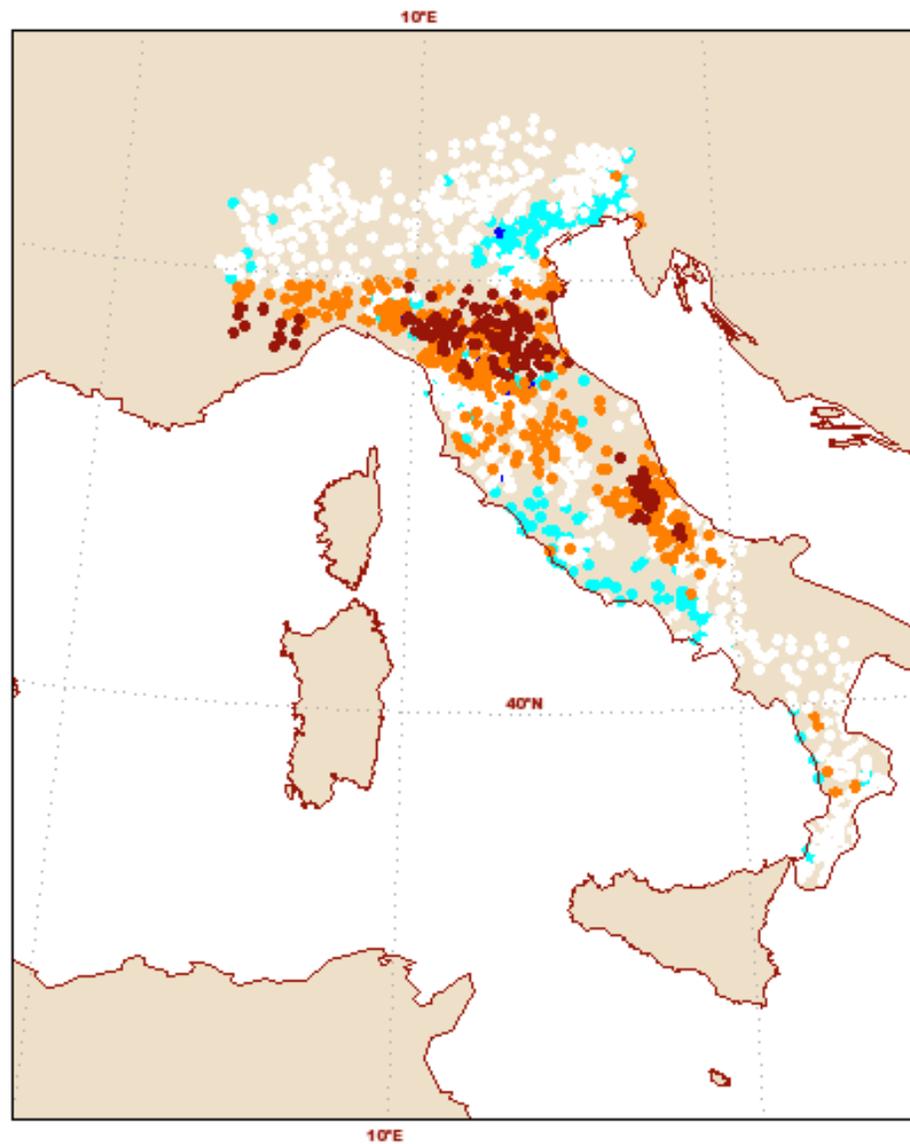
COSMO generated MSG satellite IR 10.8 image
on the left control run 4.0 and on the right the control run 3.19
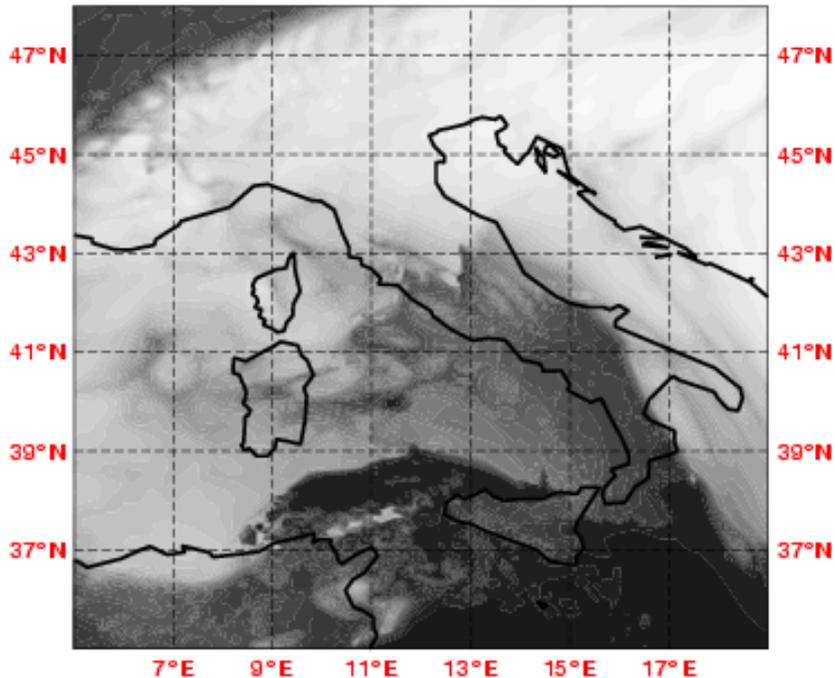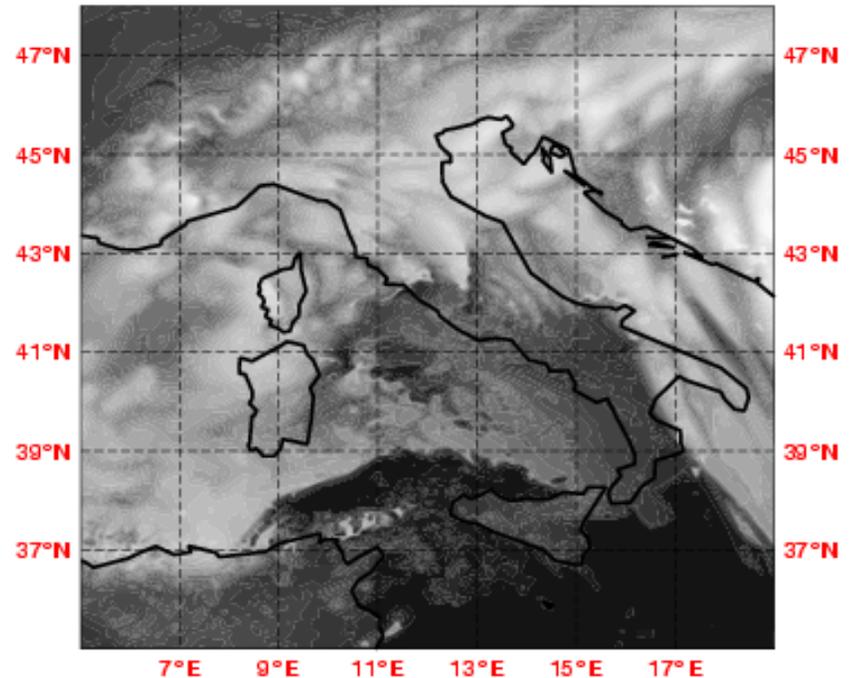
Ctrl 4.0

Ctrl 3.19

Specific cloud ice and water contents over model level
Ctrl 3.19 (red) and ctrl 4.0 (blue) point (44.1,11.7)
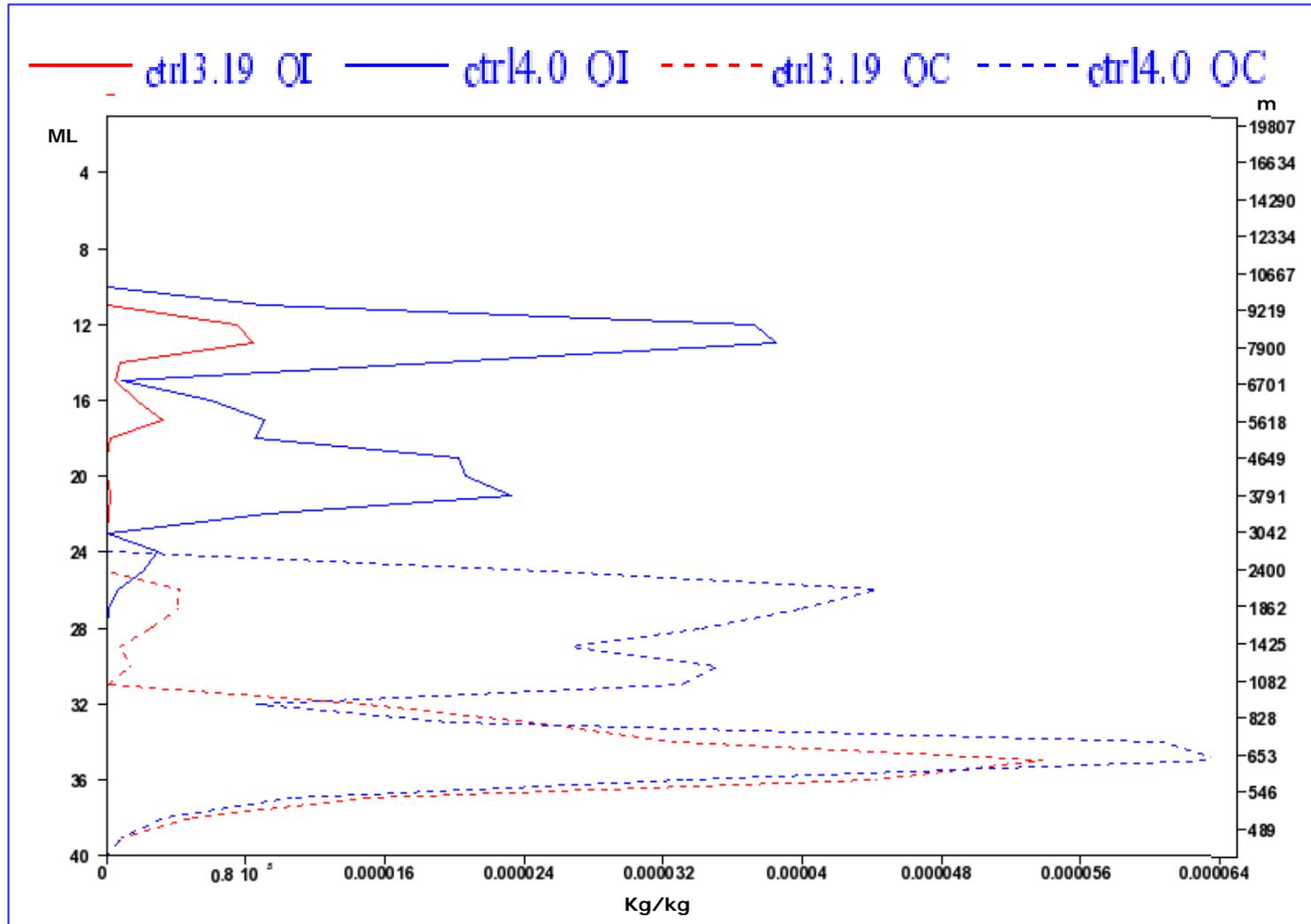
Conclusions

• for the experiments with version 3.19, the major impact is due to the change in the microphysics (micro2, micro3), and in the physical parameters that control the exchange of heat and moisture (rlam01, rlam50, sea01, sea40);

• the introduction of version 4.0 improves the forecast by reducing the overestimation of precipitation. This can be due to the fact that the new scheme lead to a slower formation of rain and to the fact that the species remain in the atmosphere;

• the QPF project proved to be a very useful test bed for the model upgrade, permitting an evaluation over a variety of events and areas.
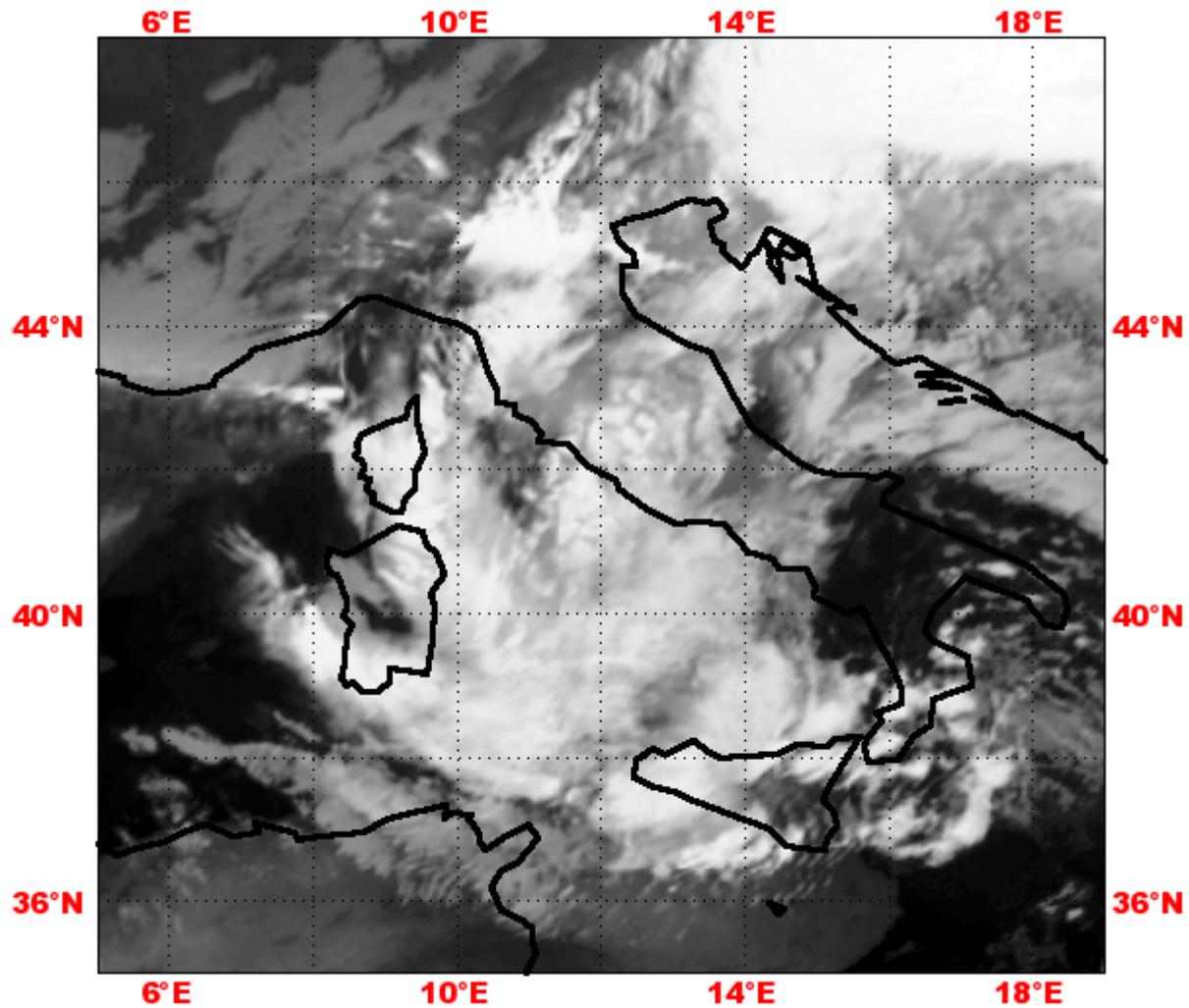
Future work

• the new model version 4.0 decreases the precipitation in the overestimation case

• but what would be the model behaviour in an underestimation event?

• this will be investigated for a case where precipitation was underestimated by old version, but we expect that the better characterization of precipitation transport to the lee side of mountains leads to an improvement of the forecast as well.
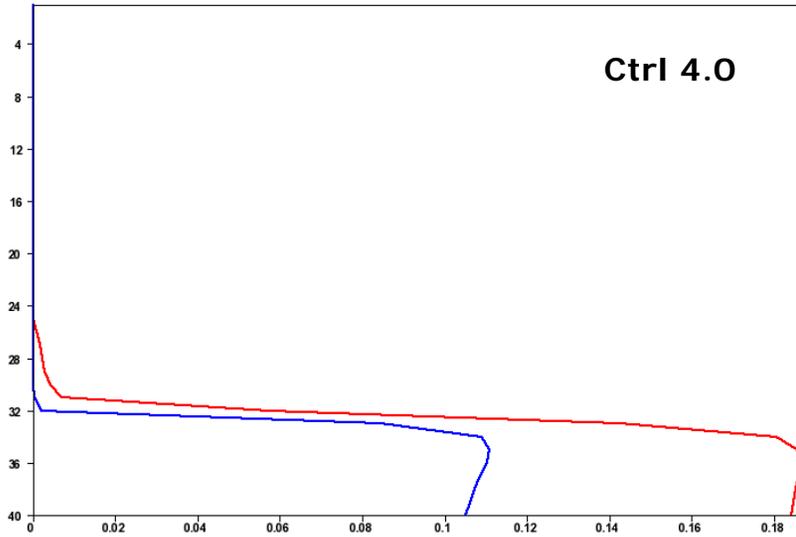
...to be continued

Slide di supporto

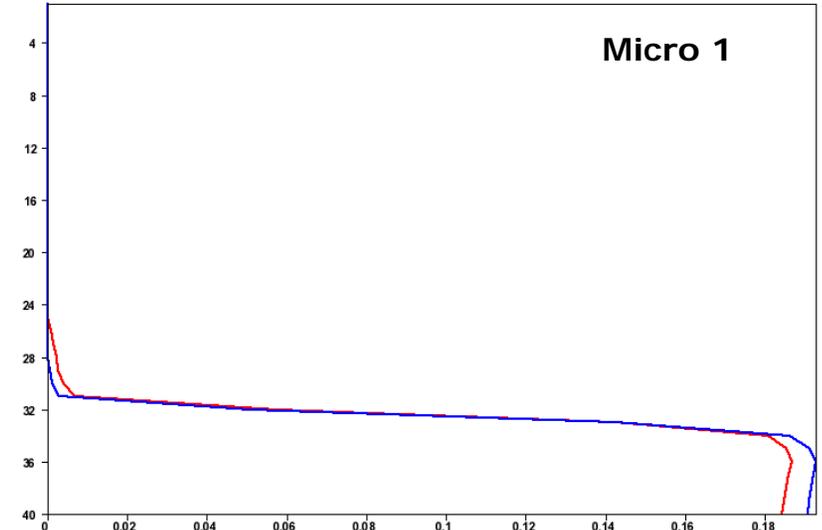Satellite First Infrared Band Sunday 10 April 2005 2345UTC

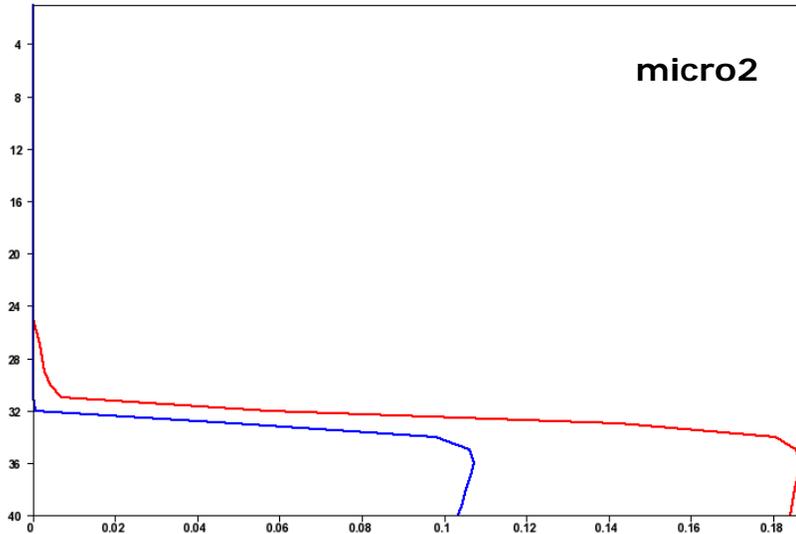Vertical profile of specific rainwater content, grid scale 20050410 00 step 24 point (44.1,11.7)