Improving the analysis of the COSMO model by the assimilation of 2 metres observations

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Outline

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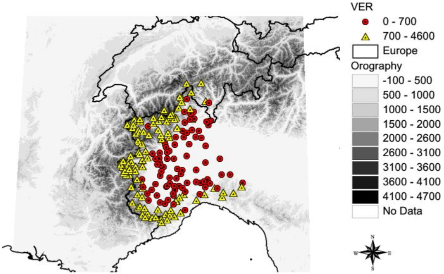
Taking advantage of the many stations in Piemonte

Goal of the work

- Few GTS observations points over Piemonte region
- Much denser station network owned by ARPA
- Take advantage for enhancing COSMO analysis production



Current COSMO-I2 configuration

- Very high resolution grid (2.8 km)
- Only temperature assimilation makes simulation differ significantly
- 2m temperature is not used operationally

COSMO land-surface and data assimilation

COSMO model implemented features

- Possibility of assimilating 2 metres observations (temperature, humidity,. . .)
- Assimilation of 2 metres observations affects directly the atmospheric state but not the soil

Soil state analysis

- Germany: variational soil moisture analysis from 2 metres temperature observations once a day
  - Indipendent procedure
  - Not part of official COSMO package
- Italy: no soil moisture analysis

COSMO performance with the standard assimilation of 2m temperature

- Temperature is positively affected
- Relative humidity and wind are neutrally or slightly negatively affected
- Soil-atmosphere turbulent energy fluxes show a neutral or a slighlty negative effect
- Temperature profiles at +12h forecast time are negatively affected for 00 UTC runs, positively affected for 12 UTC runs

The most important point

- The benefits of the assimilation of 2m temperature are very short lasting during the model forecast
- Need to introduce some “long memory” element in the DA system: the soil

Outline

Fluxes Adjusting Surface Data Assimilation System (FASDAS)

Alapaty et al. (2001, 2008)

Problem statement

Errors in PBL description are reduced if T2m and Q2m assimilation does not have heavy consequences on the equilibrium of the model

$$\frac{\partial \alpha}{\partial t} = \mathcal{M}(\alpha, z, t) + N_\alpha \left(\hat{\alpha} - \alpha\right) \equiv \frac{\partial \alpha^{\mathcal{M}}}{\partial t} + \frac{\partial \alpha^{N}}{\partial t}$$

Recalling that

$$\frac{\partial \alpha}{\partial t} = -\frac{H_1^\alpha - H_S^\alpha}{\rho C \Delta z}$$

then

$$H^{\alpha,N} = \rho C_\alpha \left(\frac{\partial \alpha^N}{\partial t}\right) \Delta z$$

Influence on soil of fluxes correction: temperature

$$\Delta T_g^N = \left(\frac{\partial T_g^N}{\partial t}\right)\Delta t = (H_{\theta,S}^N - H_{q,S}^N)\frac{\Delta t}{C_g}$$

A positive (negative) adjustment of H_q causes a reduction (growth) of T_g, because it is a function of the saturation vapour pressure calculated at T_g

Warning

The fluxes are adjusted so that T2m and Q2m converge towards observed values. The fluxes are altered to allow the atmospheric structure in a realistic way, regardless of the reason of errors in simulated T2m and Q2m.

Putting together soil moisture correction and 2m DA

State of art (including COSMO soil moisture operational analysis)

- Many data assimilation tecniques attribute the main source of T2m errors in wrong estimates of soil moisture
- Sometimes errors in T2m values are due to indipendent model errors and not to the data assimilation scheme; in this case, the correction of soil moisture would be an additional source of problems

Preliminary definitions

- q_a: mixing ratio of surface layer (a measure of humidity)
- Δq_a: time change in mixing ratio in surface layer due to mixing
- $\psi_a \equiv \Delta q_a / q_a$: normalization
- $E = E_{\mathrm{sfc}} + E_{\mathrm{can}} + \sum_{\mathrm{layers}} E_{\mathrm{trasp}}$: evapotranspiration

Adjusting the water balance components

Evaluation of the correction of the water balance components

$$E_{\xi}^{N} = \left(\frac{E_{\xi}}{E} \right) \psi_a \left(\frac{H_q^N}{\rho_w L} \right)$$

$\xi =$ surface, vegetation, soil layers

Then sum the terms obtained from this step to the appropriate water balance equations (soil layers, vegetation,. . .)

FASDAS in COSMO

Direct assimilation

- Quality control and weight the 2m data (not reported for brevity)
- Assimilation of T2m and Q2m (observation nudging of the atmospheric fields)
- Estimation of fluxes adjustment

Indirect assimilation

- Calculation of weighting factor for latent heat flux (ψ_a)
- Weight evapotranspiration terms
- Partition the weighted adjustment of evaporation
- Sum the water balance corrections in the appropriate equations
- Add the fluxes adjustment to the predicted ones

In case of snow

Modification of the snow energy balance:

$$\Delta E = (H_{\theta,S}^{N} - H_{q,S}^{N})\Delta t$$

Energy thresold to reach the snow melting point:

$$\Delta E_0 = (T_0 - T_{sn})\rho_{sn} c_{sn} \Delta z_{sn}$$

If $\Delta E < \Delta E_0$, only snow warming
Otherwise, snow starts to melt and top soil layer moisture must increase:

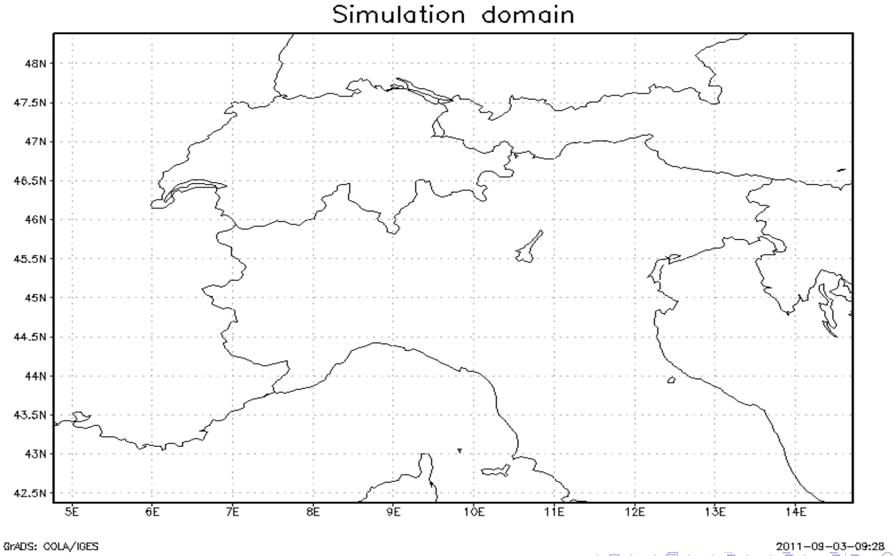
$$\Delta z_{sn,new} = \Delta z_{sn,old} - \frac{\Delta E - \Delta E_0}{L_{sn}\rho_{sn}}$$

$$w_{1,new} = w_{1,old} + \frac{\Delta E - \Delta E_0}{L_{sn}\rho_w}$$

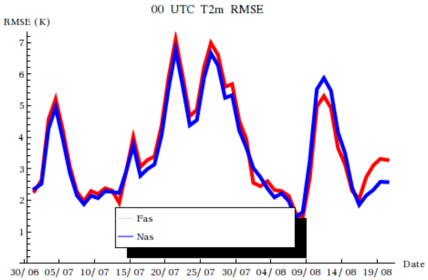
Experiment framework

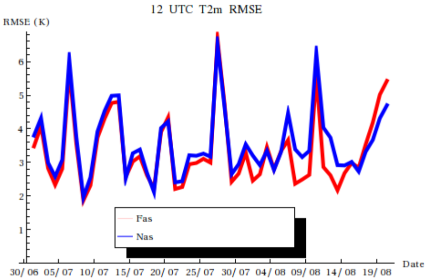
- Operational COSMO-I2 configuration
  - Exception: multilayer soil scheme
- Analysis mode: no forecast, only assimilation cycle
- Continuous assimilation cycle
- Performed at 00 UTC and 12 UTC, for the previous 12 hours
- Comparison of no assimilation runs (NAS), official assimilation (ASS), and FASDAS (FAS)
- ARPA weather station half used for assimilation, half for verification

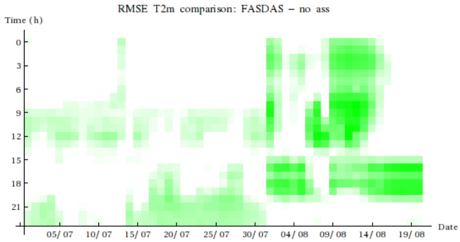
The domain of the simulations



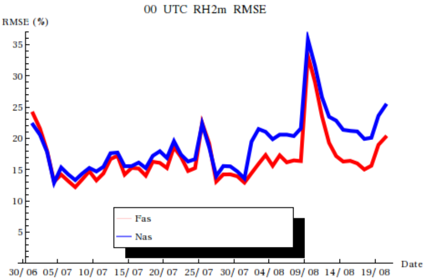
2 metres temperature description performance

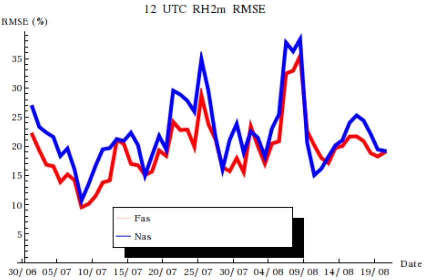


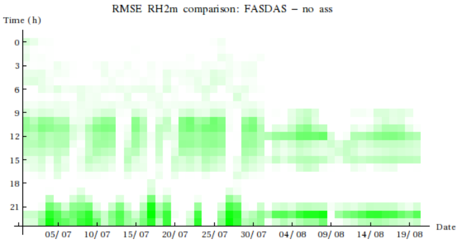




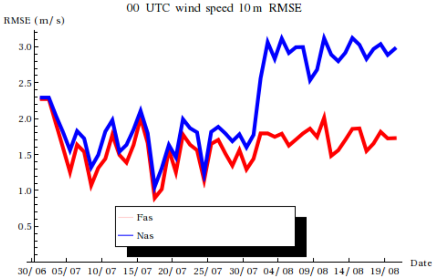
2 metres relative humidity description performance

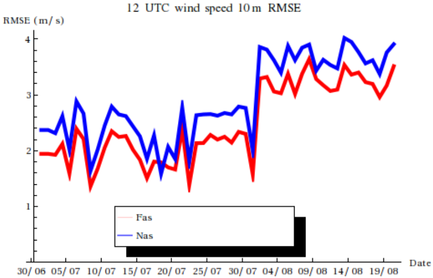


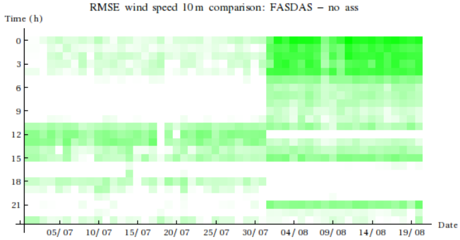




10 metres wind speed description performance

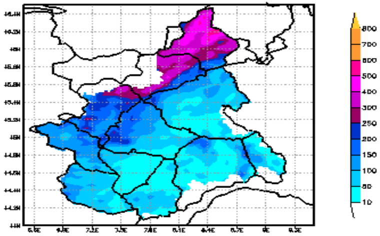




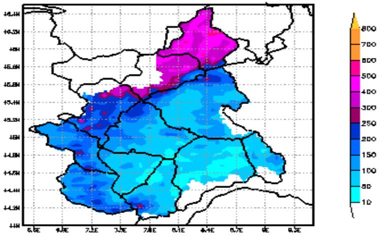


Rain description performance (July)

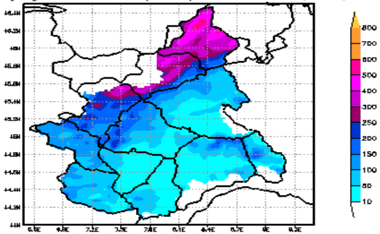
July cumulated precipitation FAS (mm)



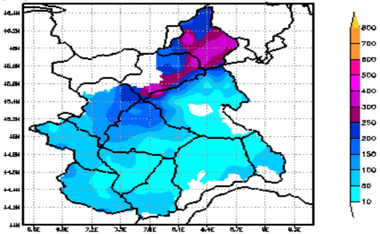
July cumulated precipitation NAS (mm)



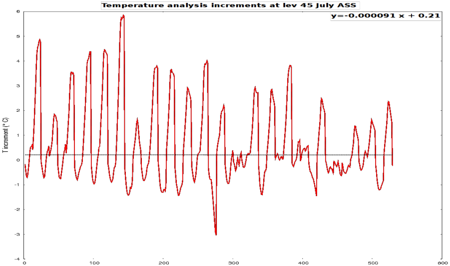
July cumulated precipitation ASS (mm)

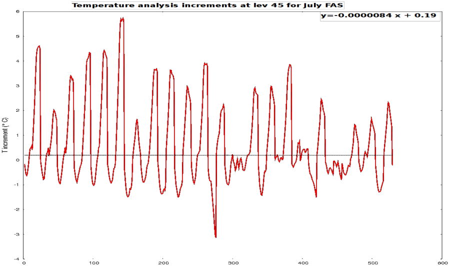


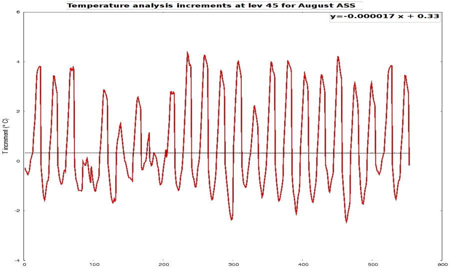
July cumulated precipitation OBS (mm)

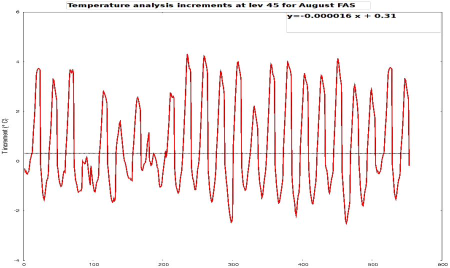


Time trend of lowest level temperature increments









Further developments

Calibration of FASDAS

- Proper tuning of the parameters that take part in the scheme
  - Thickness of soil layer which is temperature corrected
  - Artificially adjusting soil moisture more for the top soil layers than the deeper ones
- Choosing when to apply the scheme
  - Weather regimes
  - Time of the day
- Choosing how often to apply the scheme

Completing the soil moisture analysis

- Use radar and rain gauges data to correct errors in soil moisture due to bad precipitation representation

Outline

Conclusions

- Deficiencies in the assimilation by nudging to the surface observations
- Development of FASDAS
- Tests on the official operational model
- Good results running COSMO and FASDAS for every surface variable

Thank you for the attention

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Any questions, comments, suggestions,...?

References

- Kiran Alapaty, Dev Niyogi, Fei Chen, Patrick Pyle Anantharman Chandrasekar and Nelson Seaman, **Development of the Flux-Adjusing Surface Data Assimilation System for Mesoscale Models**, Journal of Applied Meteorology and Climatology, 2008
- Kiran Alapaty, Nelson L. Seaman, Devdutta S. Niyogi,Adel F. Hanna, **Assimilating Surface Data to Improve the Accuracy of Atmospheric Boundary Layer Simulations**, Journal of Applied Meteorology and Climatology, 2001