Surface variables assimilation using FASDAS algorithm: effects on COSMO-I2 RUC forecast

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Outline

- Introduction
  - Motivation
  - FASDAS technique
  - Status of previous experiments
- Verifications
  - Rapidly Updating Cycle (RUC)
  - Experiment setup
  - Forecast performances
- Conclusions

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Taking advantage of 2 metres observations

COSMO land-surface and data assimilation

- model implemented features: possibility of assimilating 2 metres observations, but this doesn't affects the soil
- Soil state analysis: in Italy no soil moisture analysis

COSMO-I2 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

Important points

- 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

Fluxes Adjusting Surface Data Assimilation System (FASDAS) short description

General description

- Nudging based, integrates the assimilation of screen level observations
- Explicit coupling between temperature and humidity increments in the atmospheric levels and soil state

Soil state increments calculations

- Nudging of atmospheric temperature and humidity implies a correction of turbulent SH and LH fluxes
- Soil temperature explicit correction proportional to the land surface energy balance terms correction
- Land surface water storages moisture corrected proportionally to the LH flux correction
- The greater the contribution to the LH, the greater the correction

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

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

Recalling that

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

then

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

Influence on soil of fluxes correction: temperature

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

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

$\psi_a \equiv (\Delta q_a/\Delta t)/q_a$: normalization

$E = E_{dir} + E_{can} + \sum_{layers} E_{trasp}$: evapotranspiration

Adjusting the water balance components

Evaluation of the correction of the water balance components

$$E_{\zeta}^{N} = \left(\frac{E_{\zeta}}{E}\right)\psi_{a}\left(\frac{H_{q}^{N}}{\rho_{w} L}\right)$$

ξ = surface, vegetation, soil layers

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

FASDAS in COSMO-I2

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:

$$\Delta E = \left(H^N_{\theta,S} - H^N_{q,S}\right)\Delta t$$

Energy thresold to reach the snow melting point:

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

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

$$\Delta z_{sn,new} = \Delta z_{sn,old} - \frac{\Delta E - \Delta E_0}{L_{sn}\rho_{snow}} \qquad \Delta w_{1,new} = \Delta w_{1,old} - \frac{\Delta E - \Delta E_0}{L_{sn}\rho_w}$$

COSMO-I2 assimilation using FASDAS

Previous experiments framework (Marco Galli, 2012)

- Operational COSMO-I2 configuration
- Analysis mode: no forecast, only assimilation cycle
- Continuous assimilation cycle
- Comparison of no assimilation runs, ufficial assimilation runs and FASDAS assimilation runs

FASDAS produces more balanced analysis with respect to the land surface turbulent energy fluxes

Open points

- To assess the quality of the forecasts of the COSMO model if the soil is interested by the assimilation using FASDAS
- Surface precipitation estimated by radar to restrict precipitation errors at the soil level

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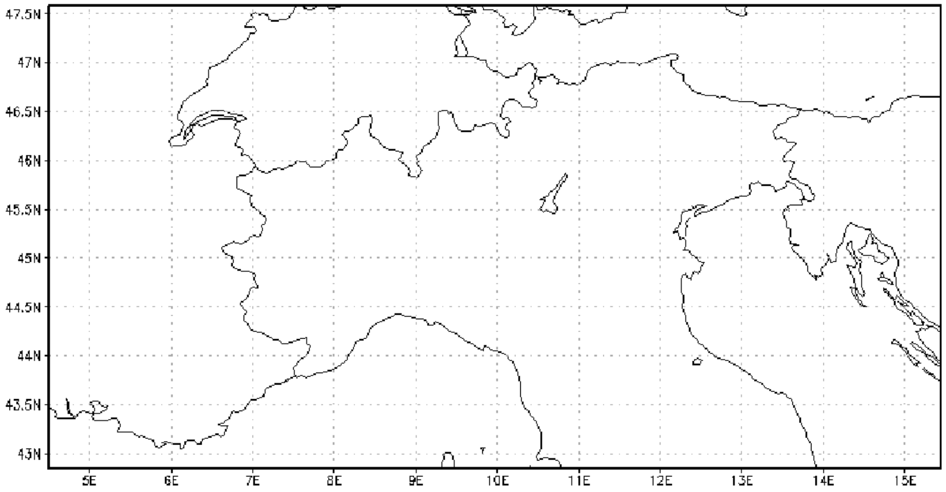
Rapidly Updating Cycle (RUC): ARPA Emilia-Romagna model setup

General description

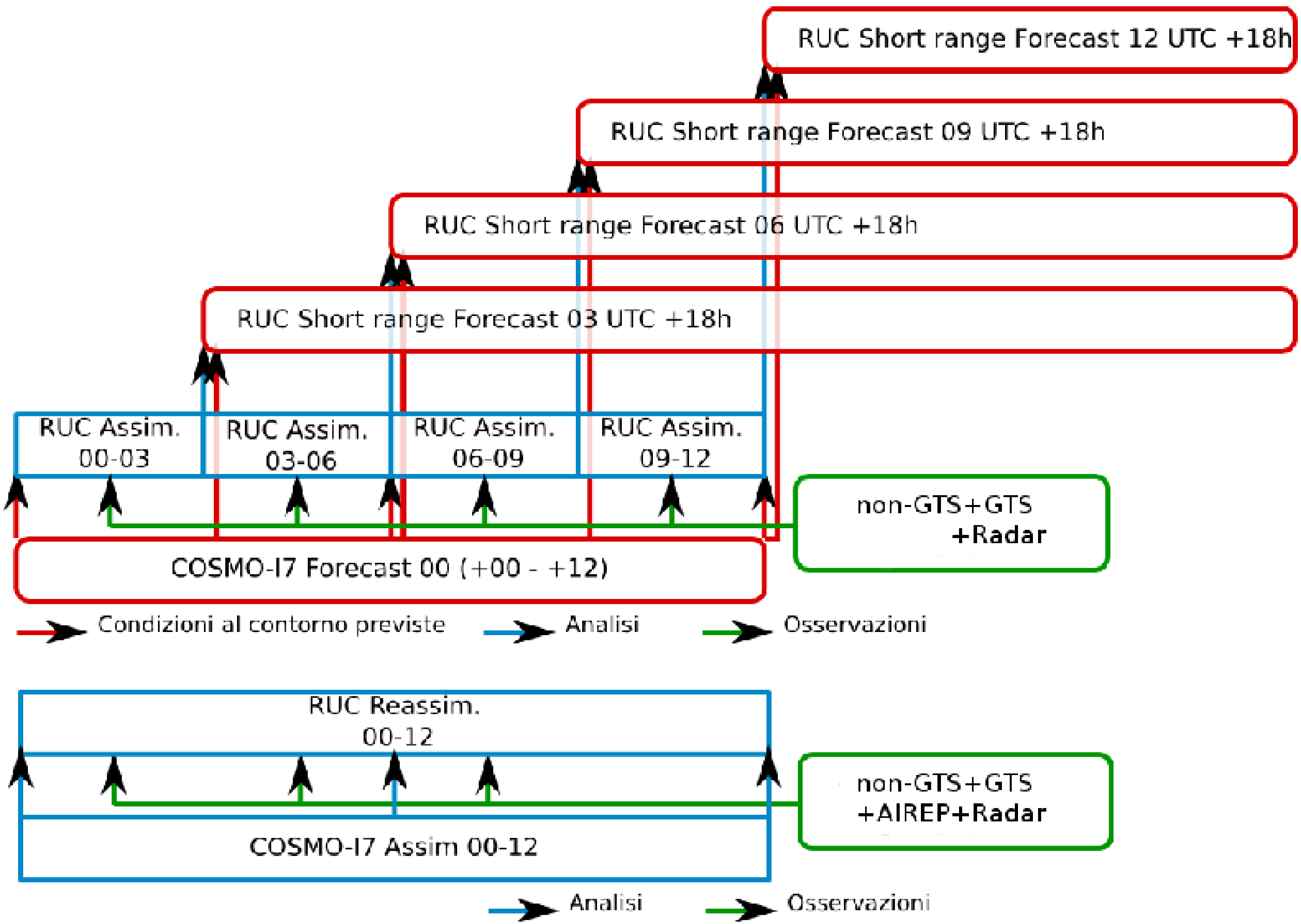
- Integration area: Northern Italy, surrounding the Alps
- Grid step 2.8 km
- Boundary conditions from the operational COSMO-I7



Observations used in the assimilation

- Nudging: SYNOP, SHIP, TEMP, AIREP, the same as COSMO-I7/COSMO-I2, but split in 3-hour "packs" and with a shorter cutoff (about 1h30'), provided by CNMCA
- Latent heat nudging: 15' surface precipitation estimated by radar, composite provided by the Italian National Civil Protection Department

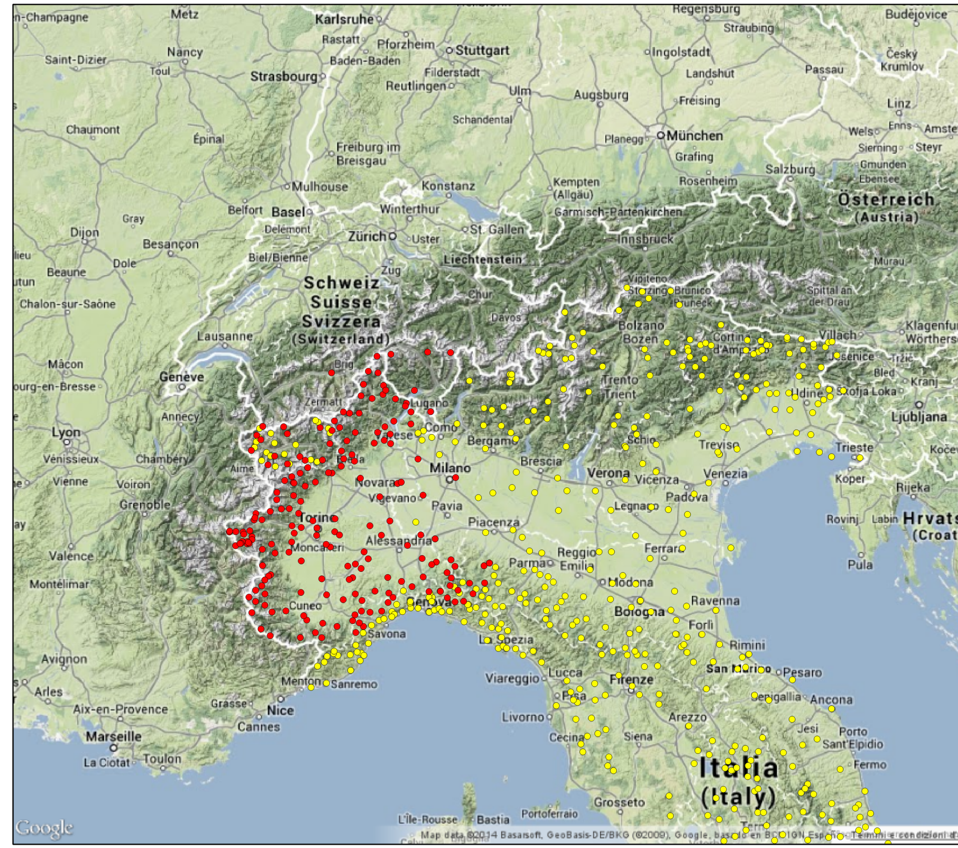
Rapidly Updating Cycle (RUC): diagram of the operational suite



Rapidly Updating Cycle (RUC): ARPA Piemonte model setup

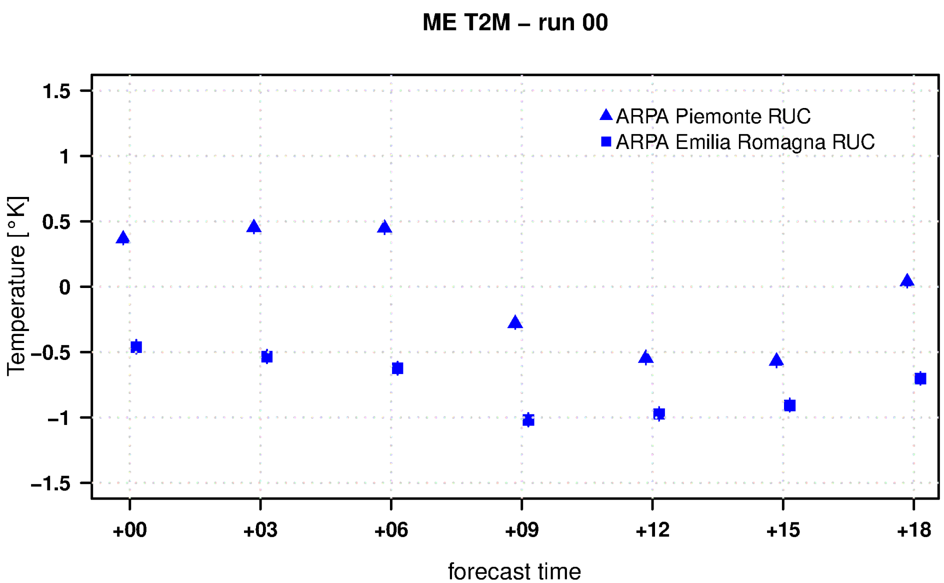
The ARPA Piemonte RUC modelling system differs in two components

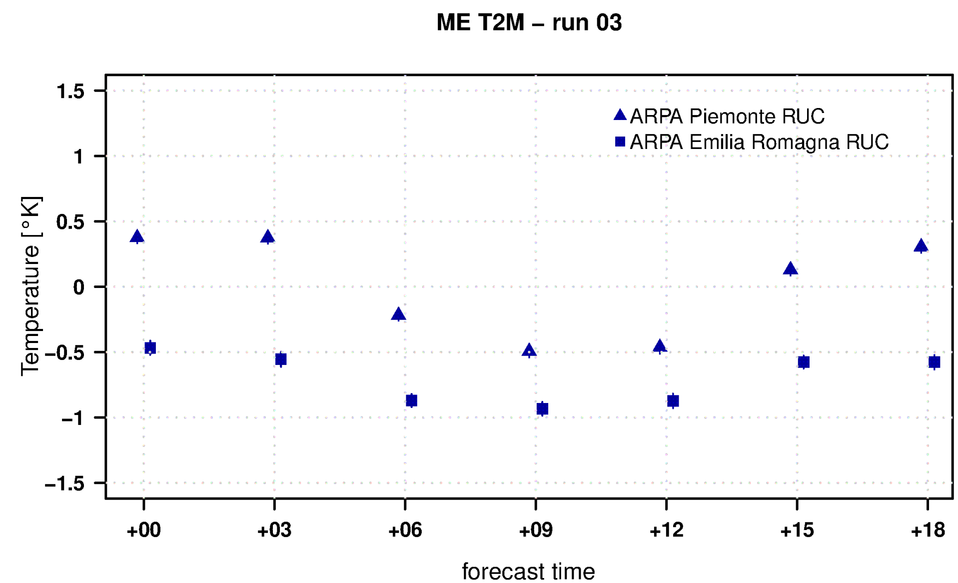
- the assimilation of T2m coming from the high density weather stations network of ARPA Piemonte and Italian National Civil Protection Department
- FASDAS scheme implemented inside COSMO code

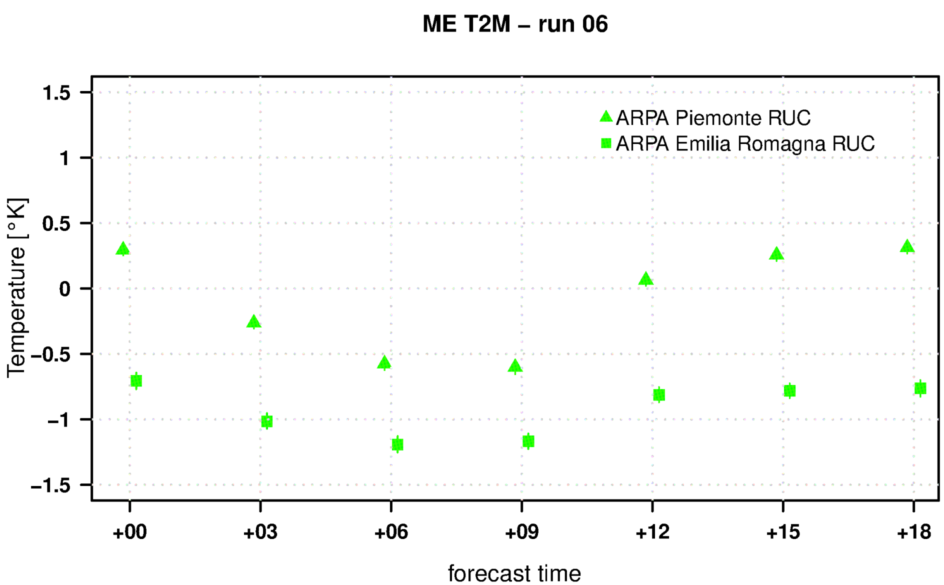


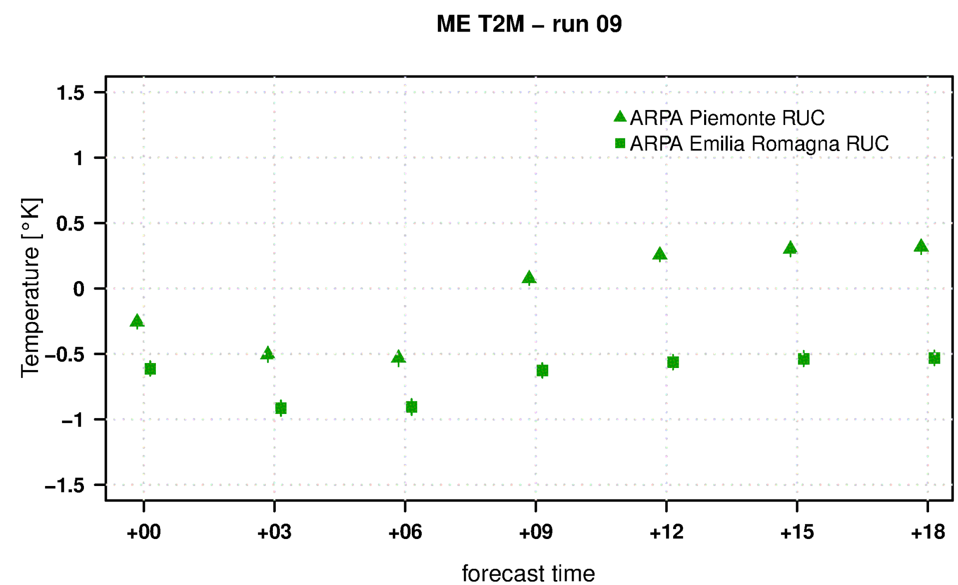
- verification from january to may
- observed data from a subset of verification stations not used for assimilation (stations inside the 0-500 m range)

2 metres temperature description performance

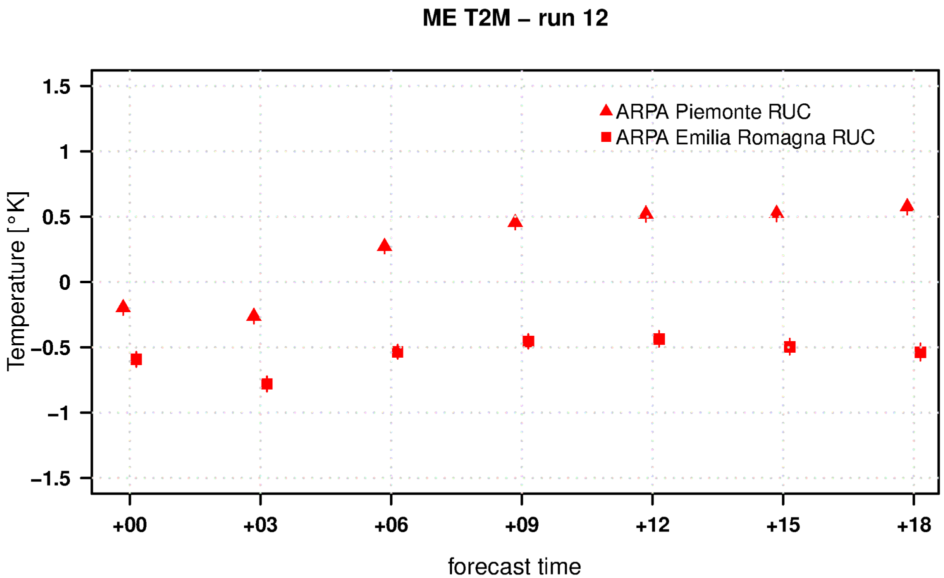


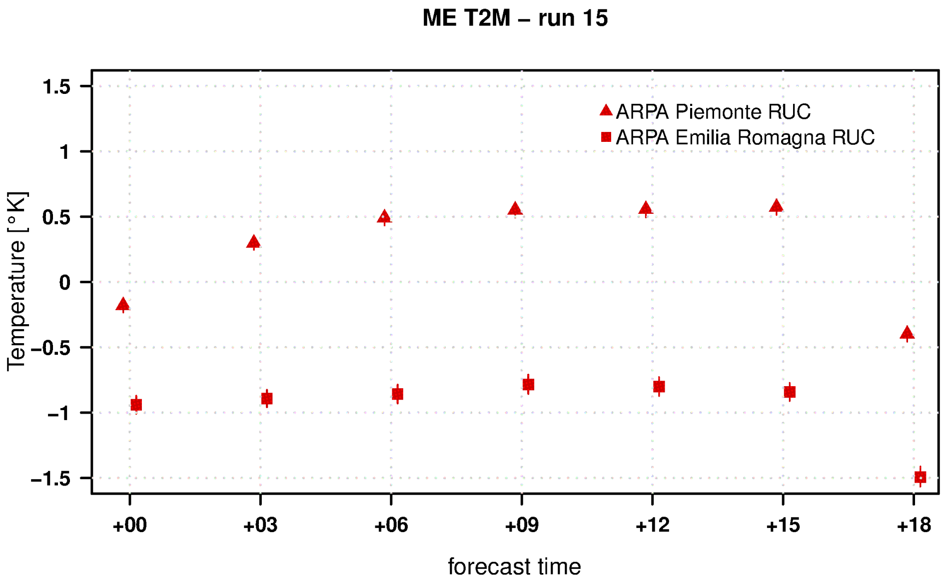


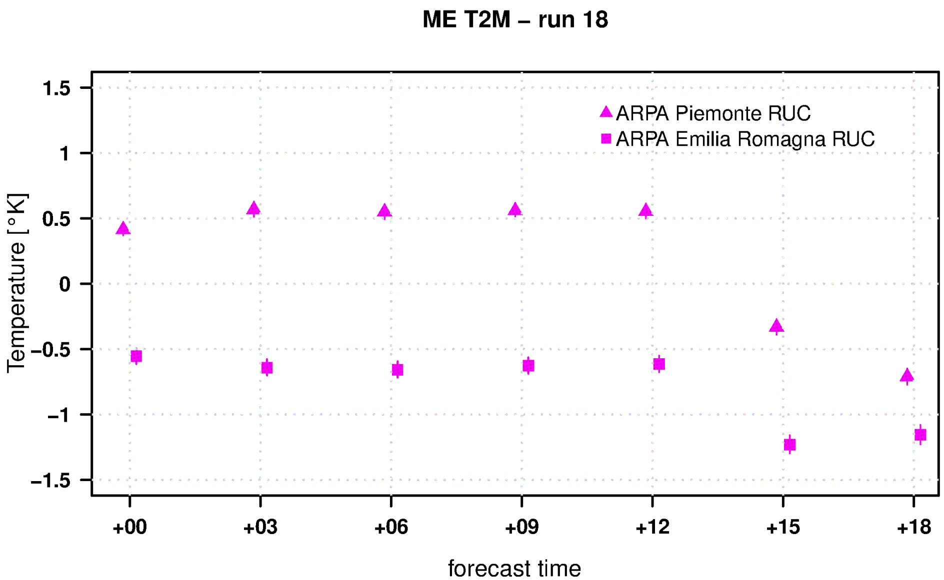


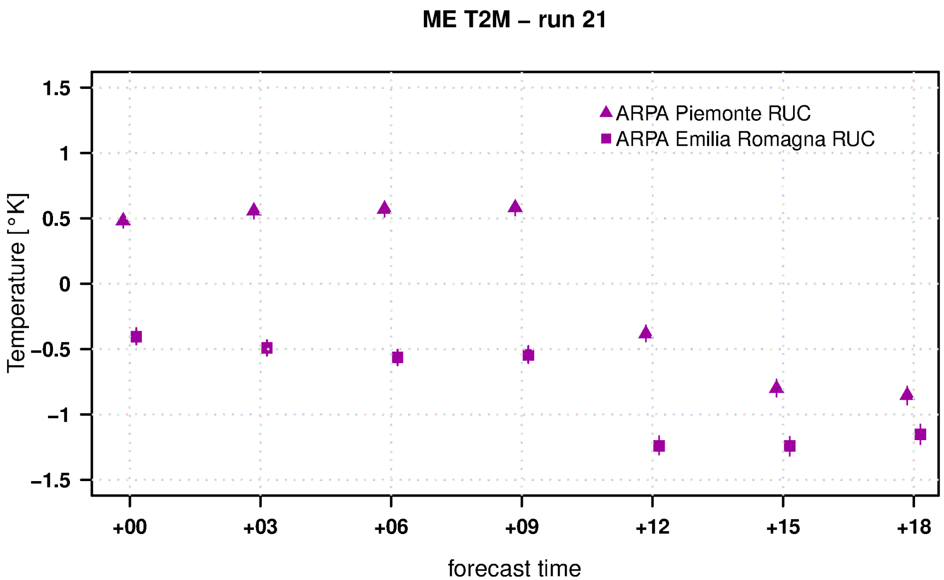


2 metres temperature description performance

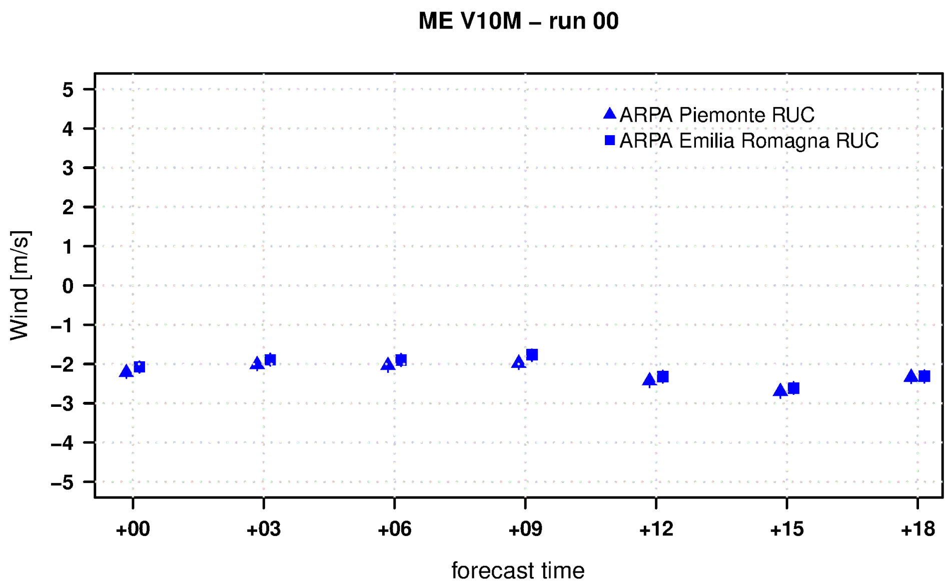


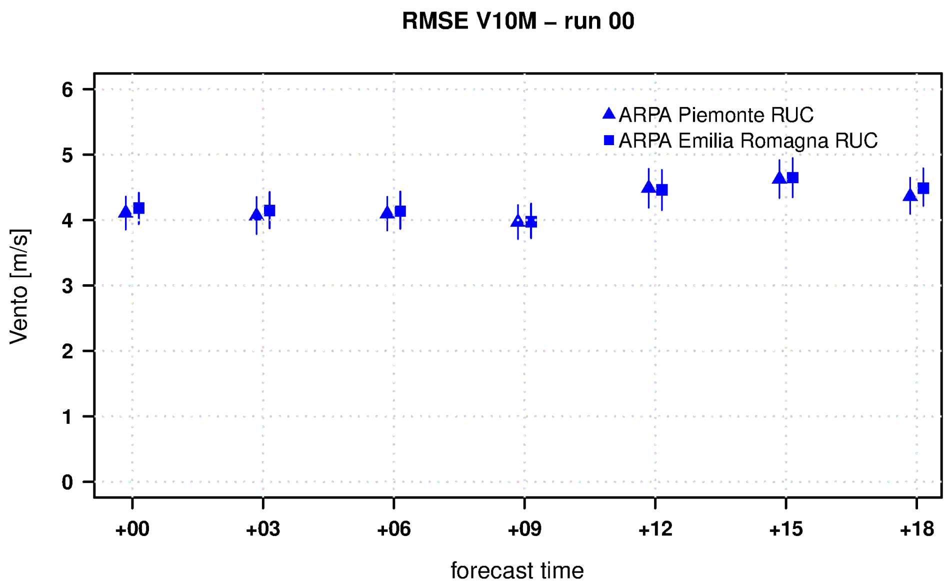


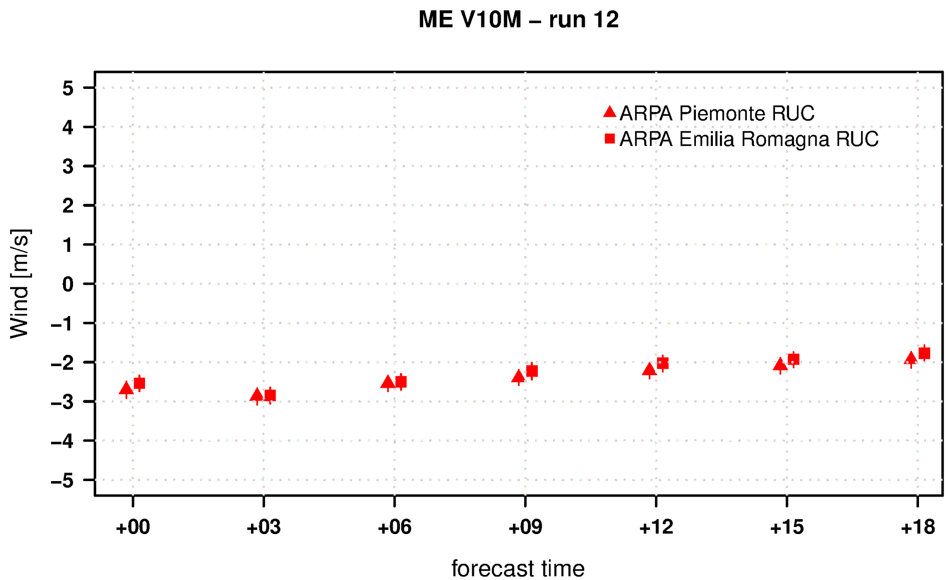


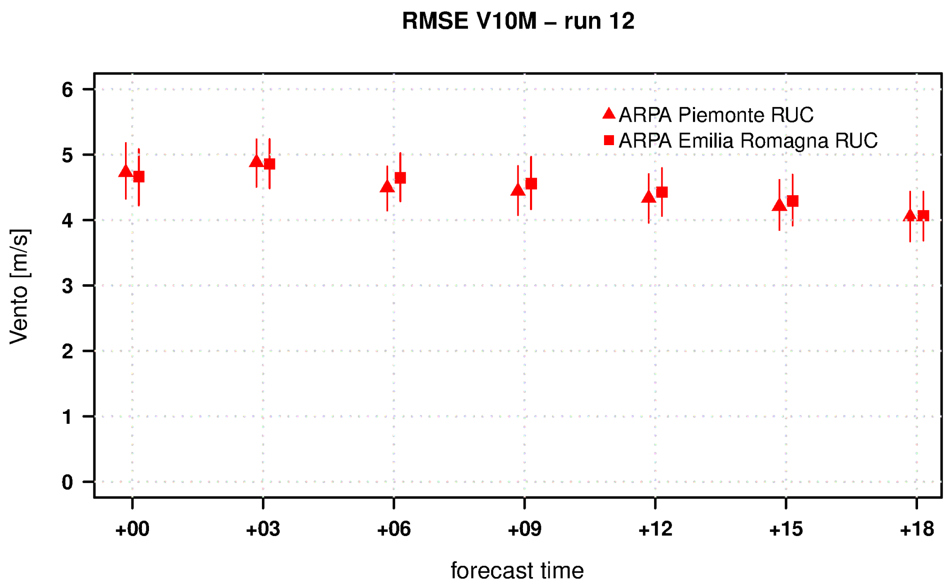


10 metres wind speed description performance

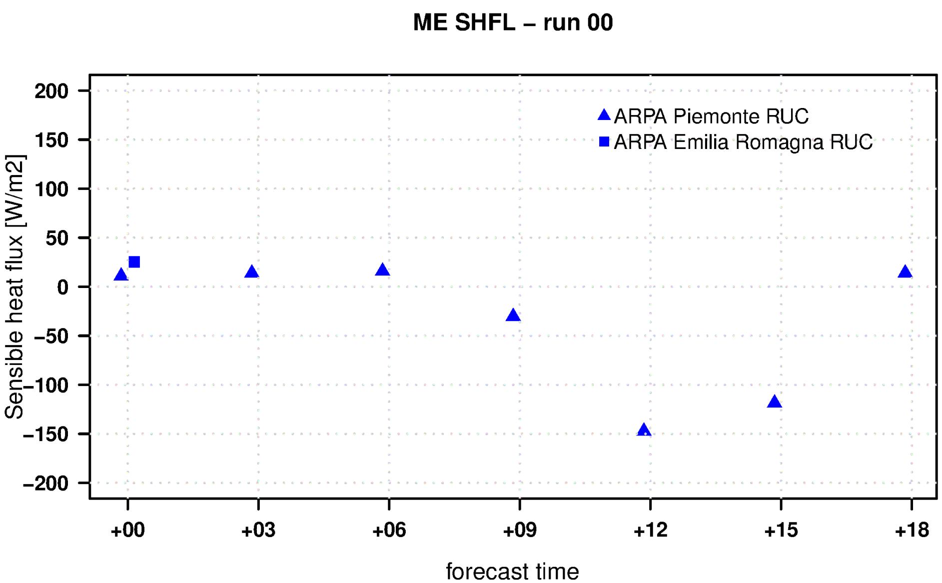


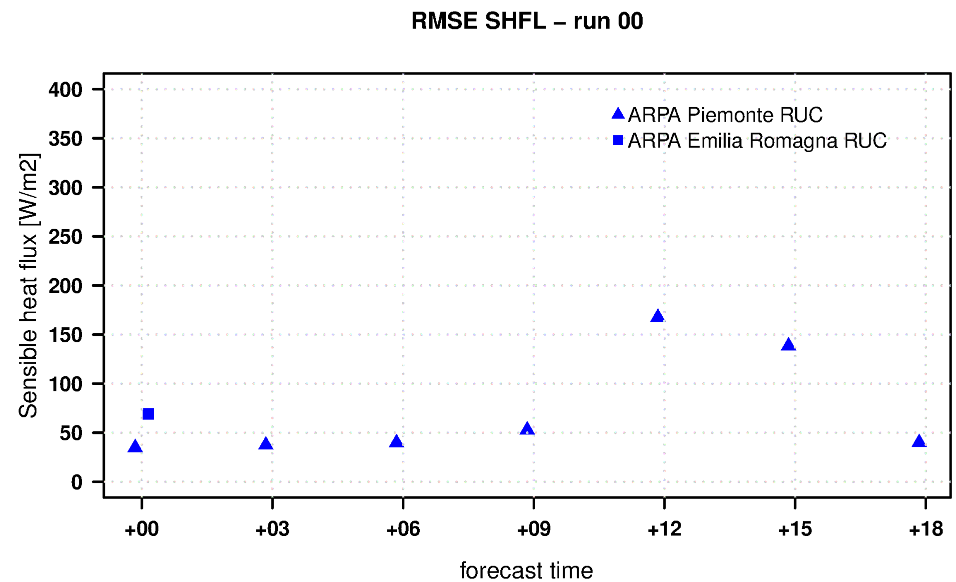


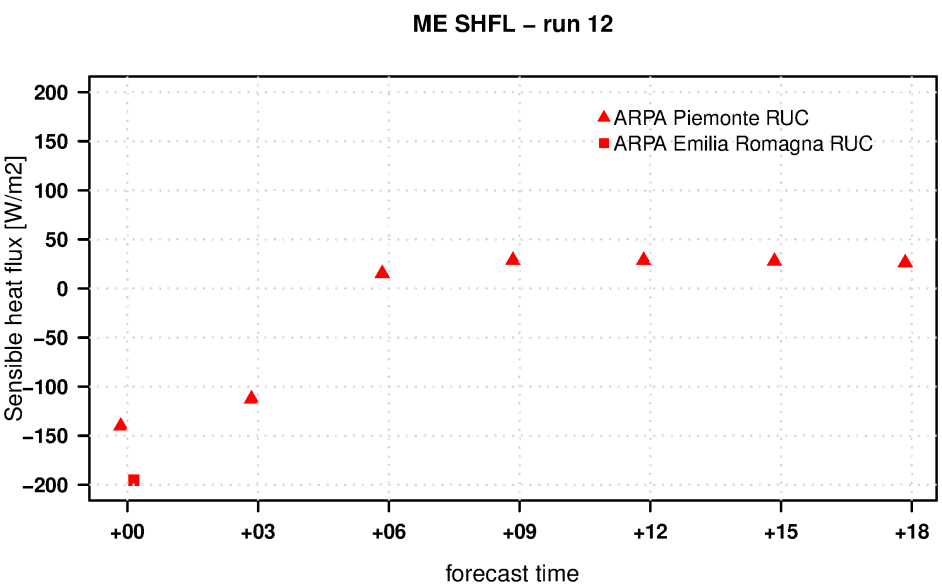


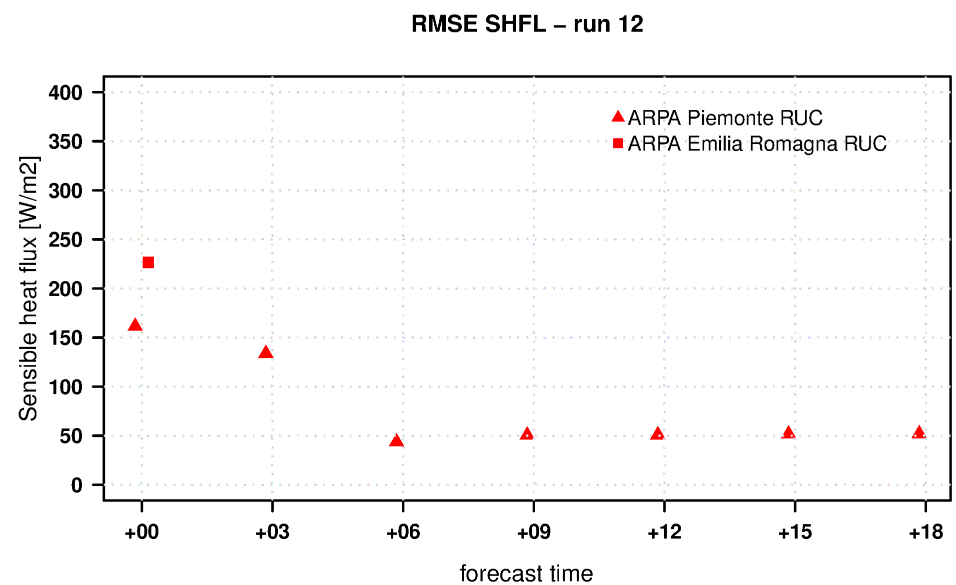


Sensible heat flux description performance



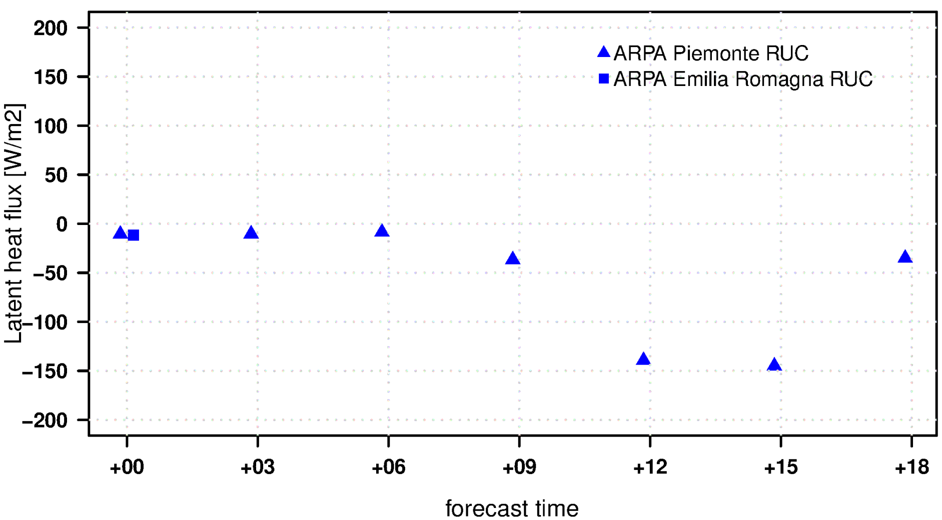




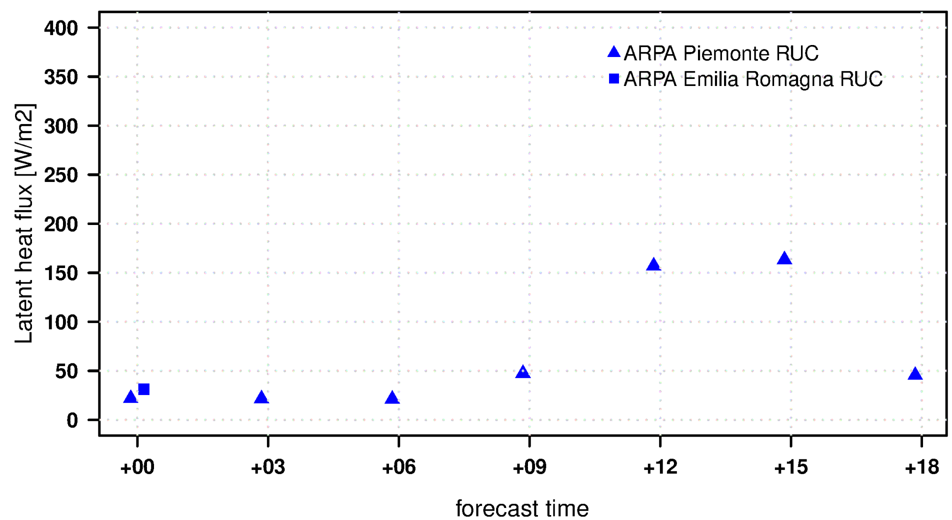


Latent heat flux description performance

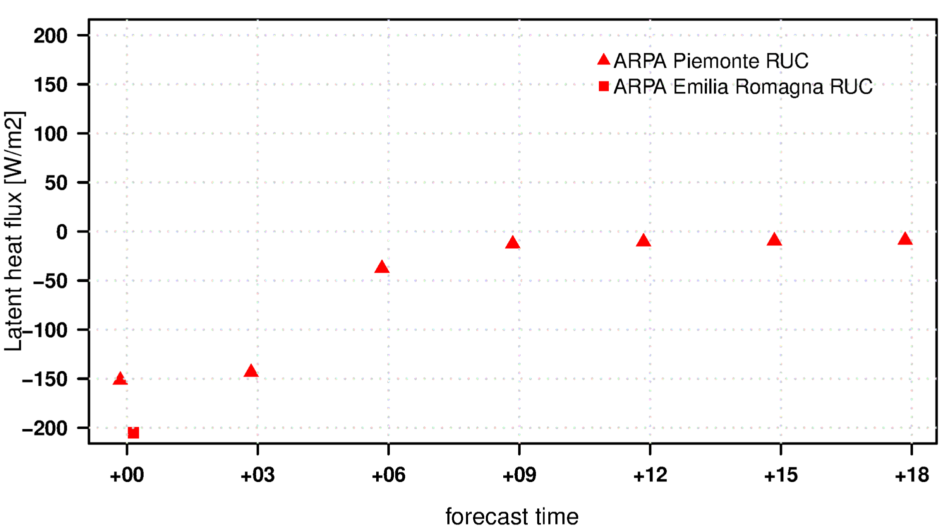
ME LHFL – run 00



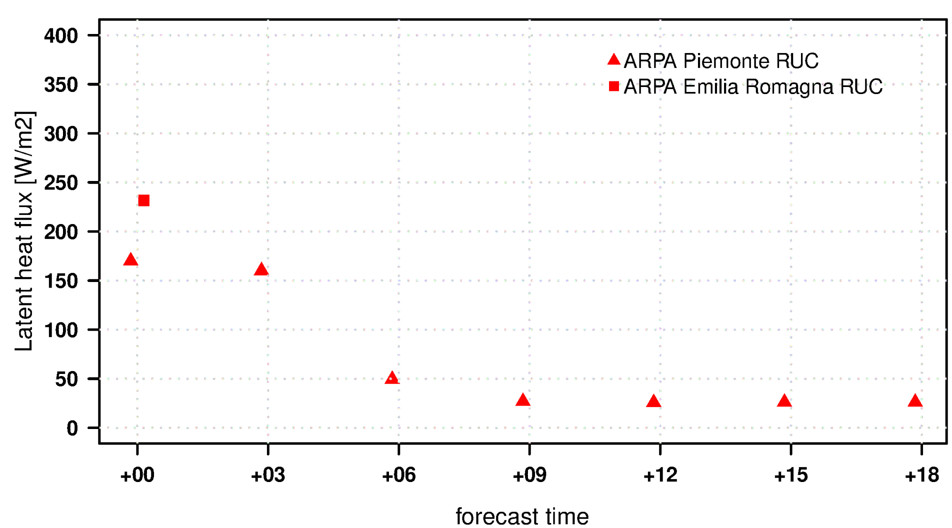
RMSE LHFL – run 00



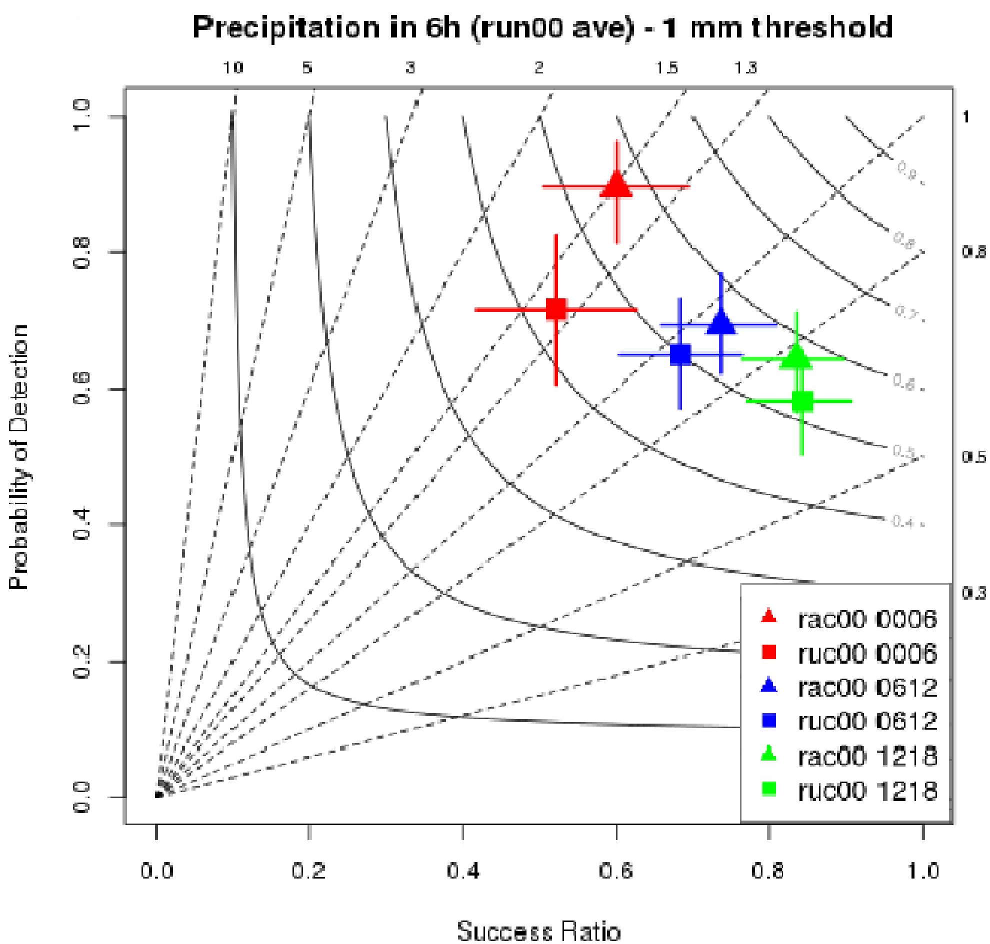
ME LHFL – run 12

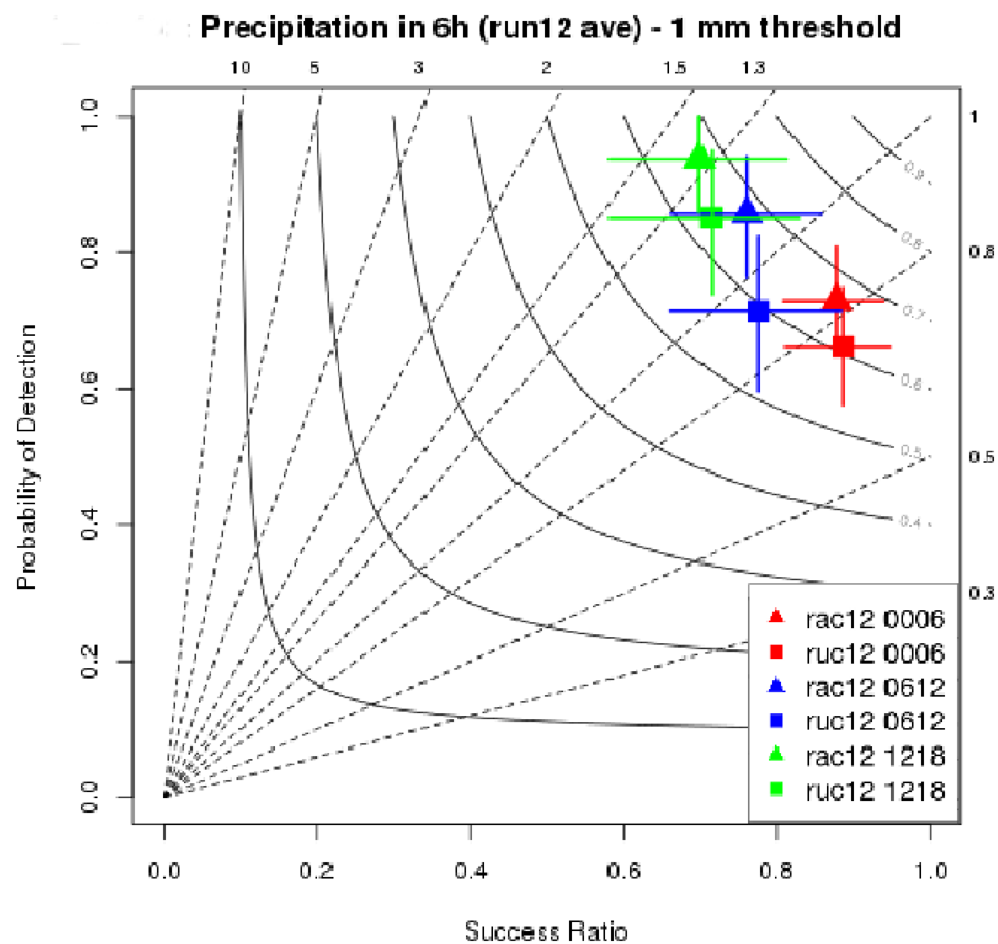


RMSE LHFL – run 12



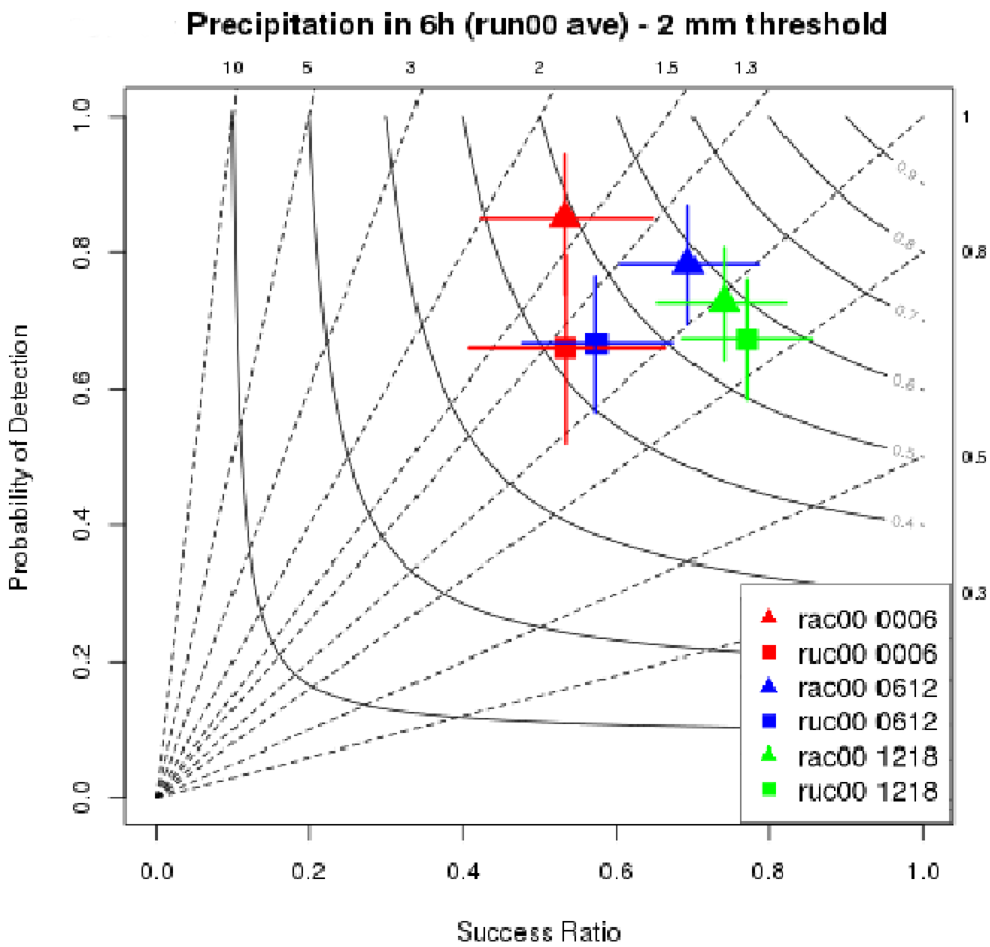
Rain description performance

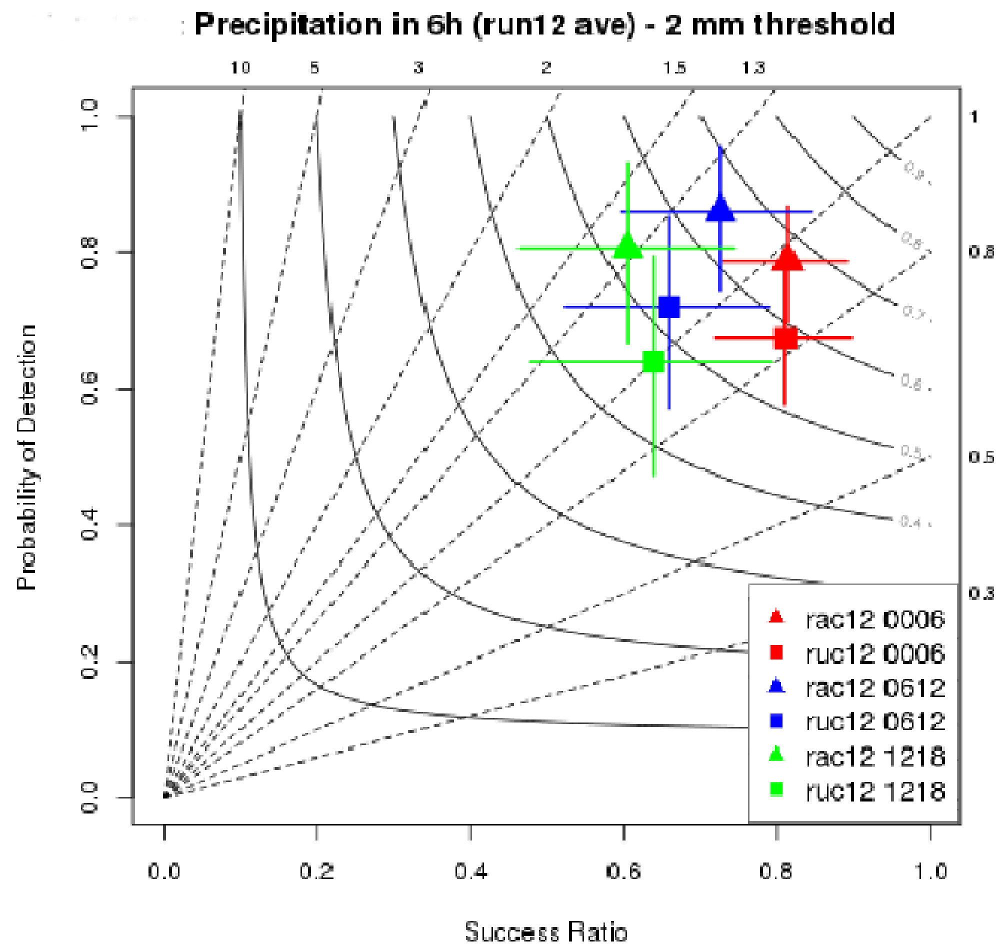




legends RAC stands for ARPA Piemonte system, RUC for ARPA Emilia Romagna system

Rain description performance





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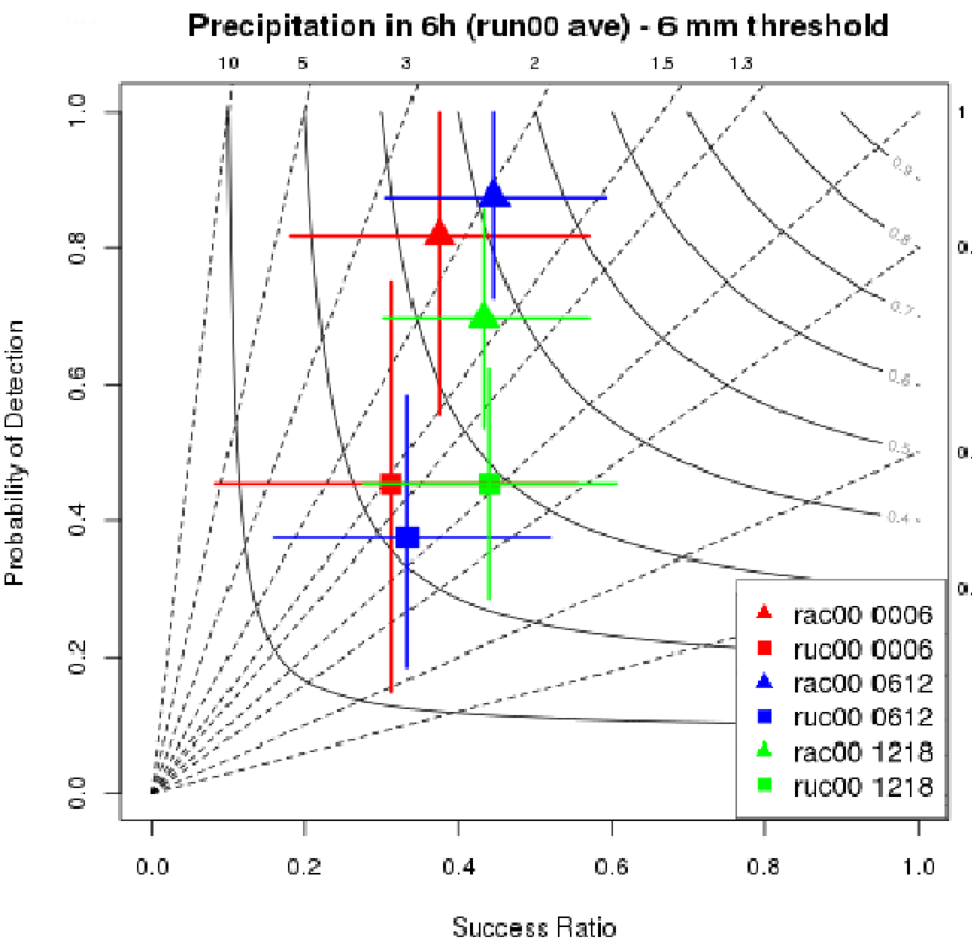

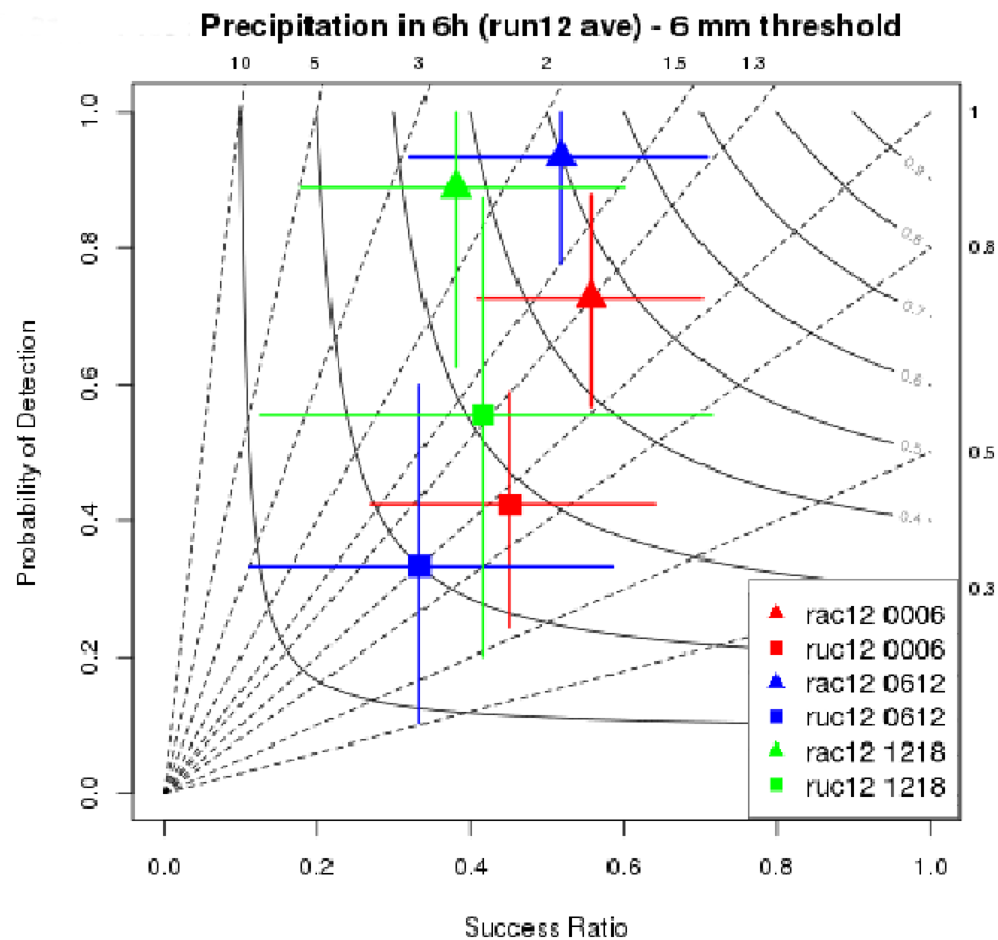

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Outline

Summary and future plans

Introduction of FASDAS in the COSMO observation nudging code

- more balanced analysis with respect to the land surface turbulent energy fluxes
- direct introduction of soil in the analysed fields
- better feedback on the model forecasts at the surface with better values of T2m and precipitation estimates compared to an operational configuration of the COSMO model

Future plans

- FASDA in the test chain at ARPA Emilia-Romagna (COSMO-I2 or COSMO-I7)
- FASDAS and LETKF: possible future? (science-plan 7.3 points 2-3)

Thank you for the attention

$$ME = \frac{1}{N}\sum_{i=1}^{N}\left(P_i - O_i\right)$$

range: -∞, ∞ valore ideale: 0

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(P_i - O_i\right)^2}$$

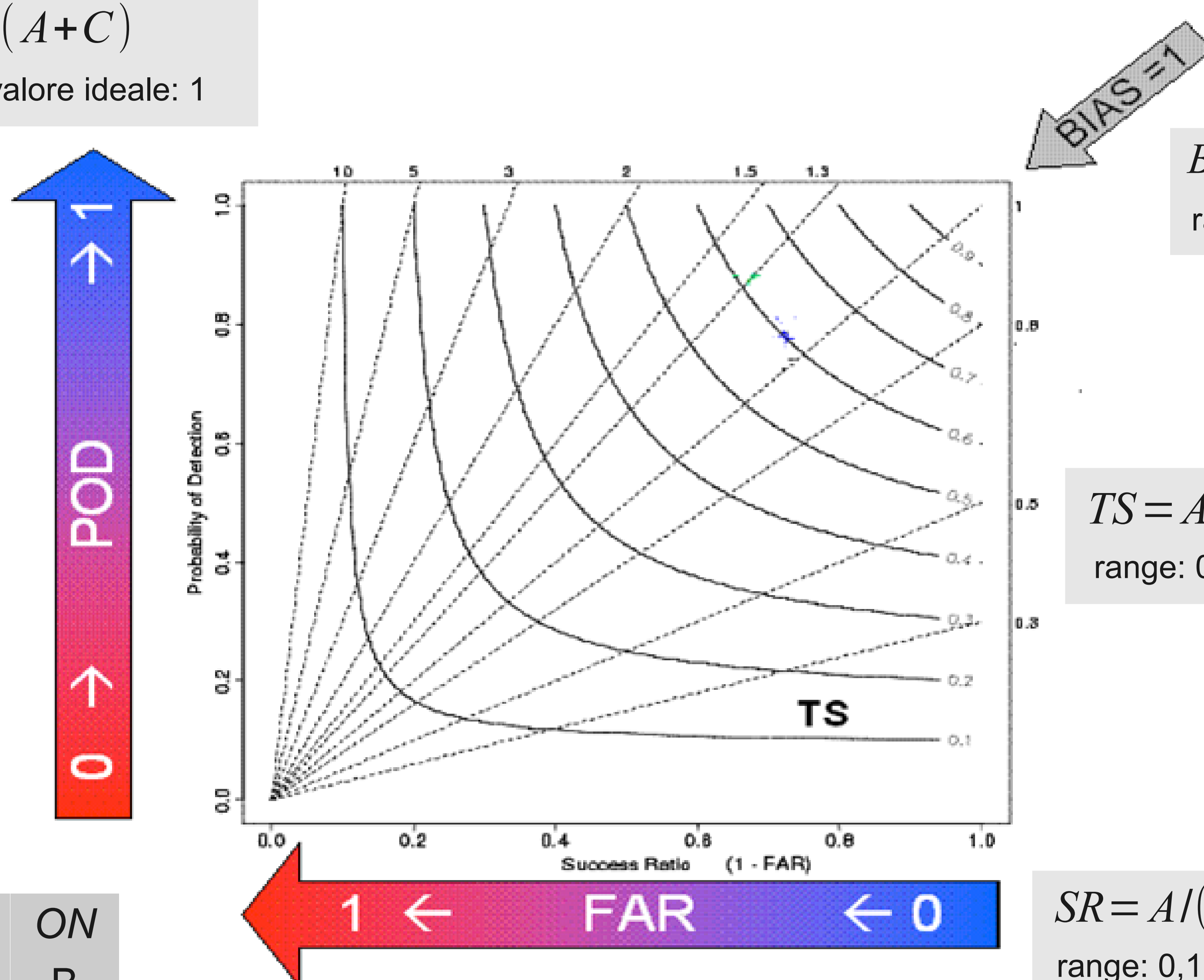
range: 0, ∞ valore ideale: 0

$$POD = A/(A+C)$$

range: 0,1 valore ideale: 1

$$BIAS = (A+B)/(A+C)$$

range: 0, ∞ valore ideale: 1



$$TS = A/(A+B+C)$$

range: 0,1 valore ideale: 1

$$SR = A/(A+B)$$

range: 0,1 valore ideale: 1

	OY	ON
FY	A	B
FN	C	D