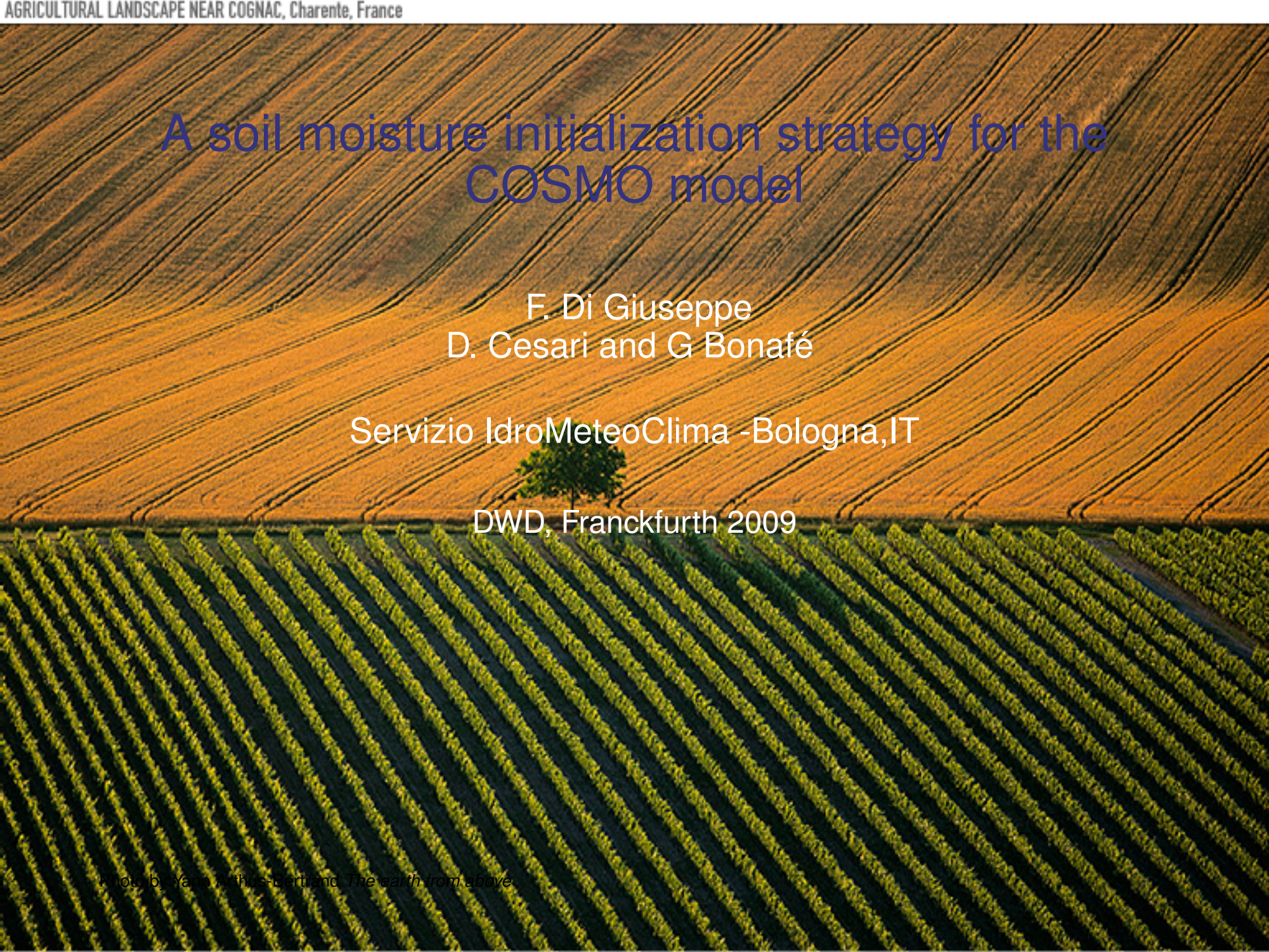


A soil moisture initialization strategy for the COSMO model

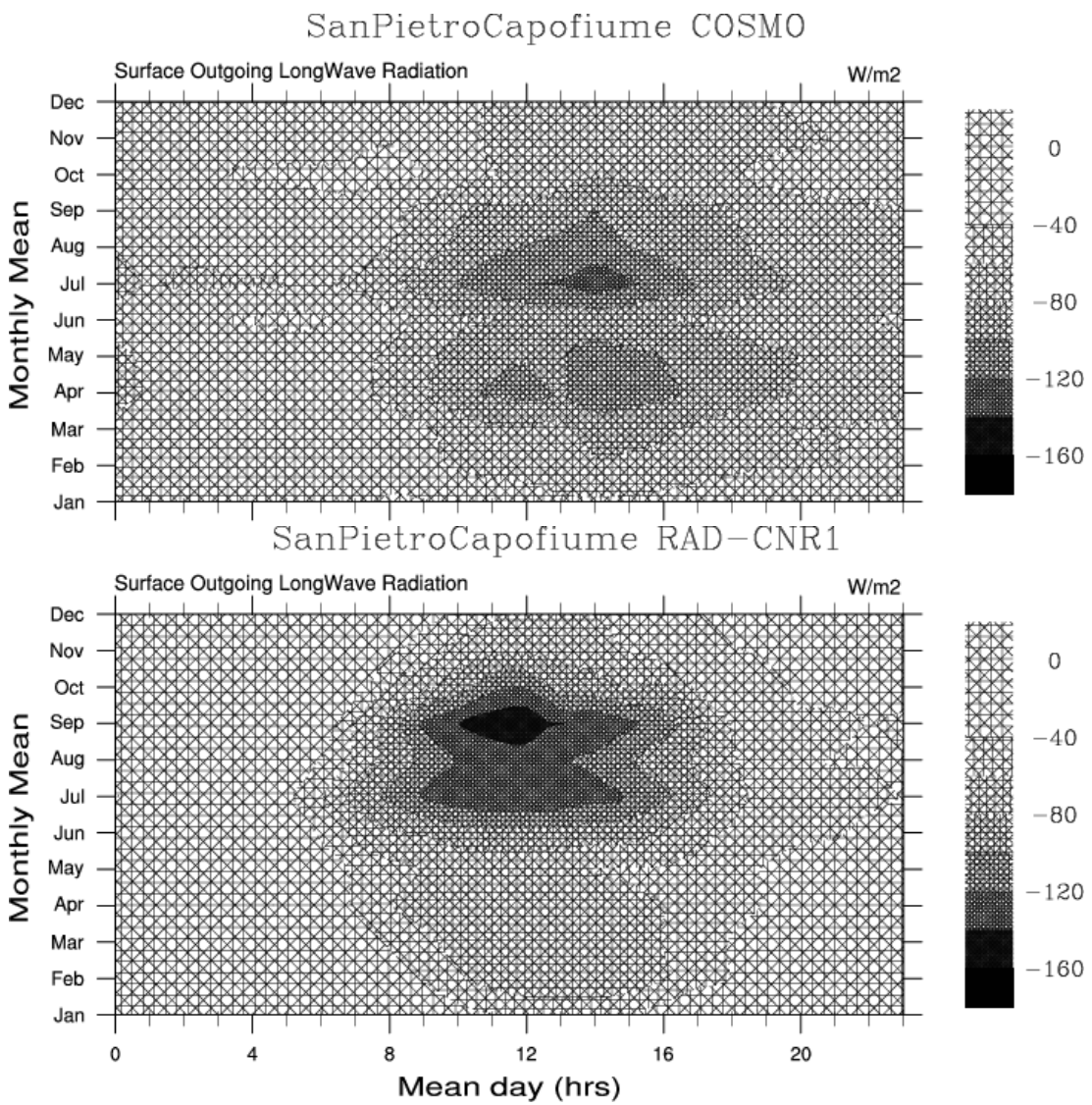
F. Di Giuseppe
D. Cesari and G Bonafé

Servizio IdroMeteoClima -Bologna,IT

DWD, Franckfurth 2009

Photo by Yann Arthus-Bertrand *The earth from above*

Diagnosis of the problem: ECMWF initialization



- Shift in the diurnal cycle later in the afternoon
- Too large LW emission during night which shows a temperature warm bias at nighttime too small LW during daytime.

Monthly Means vs mean day for 2 years data (2007-2008). The observations are recorded by the

The problem of soil (moisture) initialization

* There are almost no suitable measurements for operational initialization.
  - In situ observations are rare and heterogeneous.
  - Remotely sensed surface soil moisture database are available with mostly daily frequency (AMSRU-E, ASCAT) but the detected radiation is directly linked only to the model's uppermost soil layer and therefore can only provide partial information. Moreover soil moisture retrieval from microwave frequencies requires accurate specification of the vegetation cover and soil type at the pixel location which is not usually available with the desired precision.
* Small representativity of soil moisture. [Western *et al.*(1998)] showed that the correlation length for soil moisture can be as small as 10 cm
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Diagnostic Study

Three soil moisture initialization methods are compared for the September-October-November 2008 period.

- *Initialization by interpolation from the ECMWF soil moisture analysis (ECMWF)*. Atmospheric prognostic variable are from COSMO analysis, while prognostic soil and temperature humidity are interpolated from ECMWF as are diagnostic variables (QV_S, T_{SNOW}, W_{SNOW}, Q_I);
- *Free running soil moisture (COSMO)*. The initialization is performed using the soil moisture field from a previous COSMO run. After the first few days of start up it should represent the equilibrium between precipitation increase in soil wetness and evaporation from bare soil and transpiration from plant;
- *Variational soil moisture analysis using surface 2M synop observation(SMA)*. The method implemented is the one of Martin Lange, in which adjoin of the soil moisture increments with respect to the T_{2m} is parameterised.

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Verification dataset

The verification dataset is composed of three sources;

1. Surface flux measurements collected by the EU-funded research project CARBOEUROPE Integrated Project (CEIP)
2. Data collected at the the ARPA-SIMC meteo station located at SanPietroCapofiume (SPC) in the middle of the Italian Po Valley.
3. synop network comprising more the 400 stations with 3 hourly measurements

The CARBOEUROPE project has the aim of quantifying the relationship between carbon fluxes and vegetation characteristics. Therefore, great attention has been posed to locate observing stations over different land use/cover types. Measurements[1] are recorded since 2004 half-hourly on more than one hundred Eddy flux stations over Europe
SanPietroCapofiume meteo station is an intensive observation meteo station managed by ARPA-SIMC. In addiction to the conventional meteorological measurements including SYNOP and TEMP since 2007 is operating a Time-Domain Reflectometer (TDR) which measures soil water content and temperature profiles at 8 unevenly spaced levels below the ground between 10 and 100 cm.

[1] data available at www.carboeurope.org

Overview of the period at SPC location

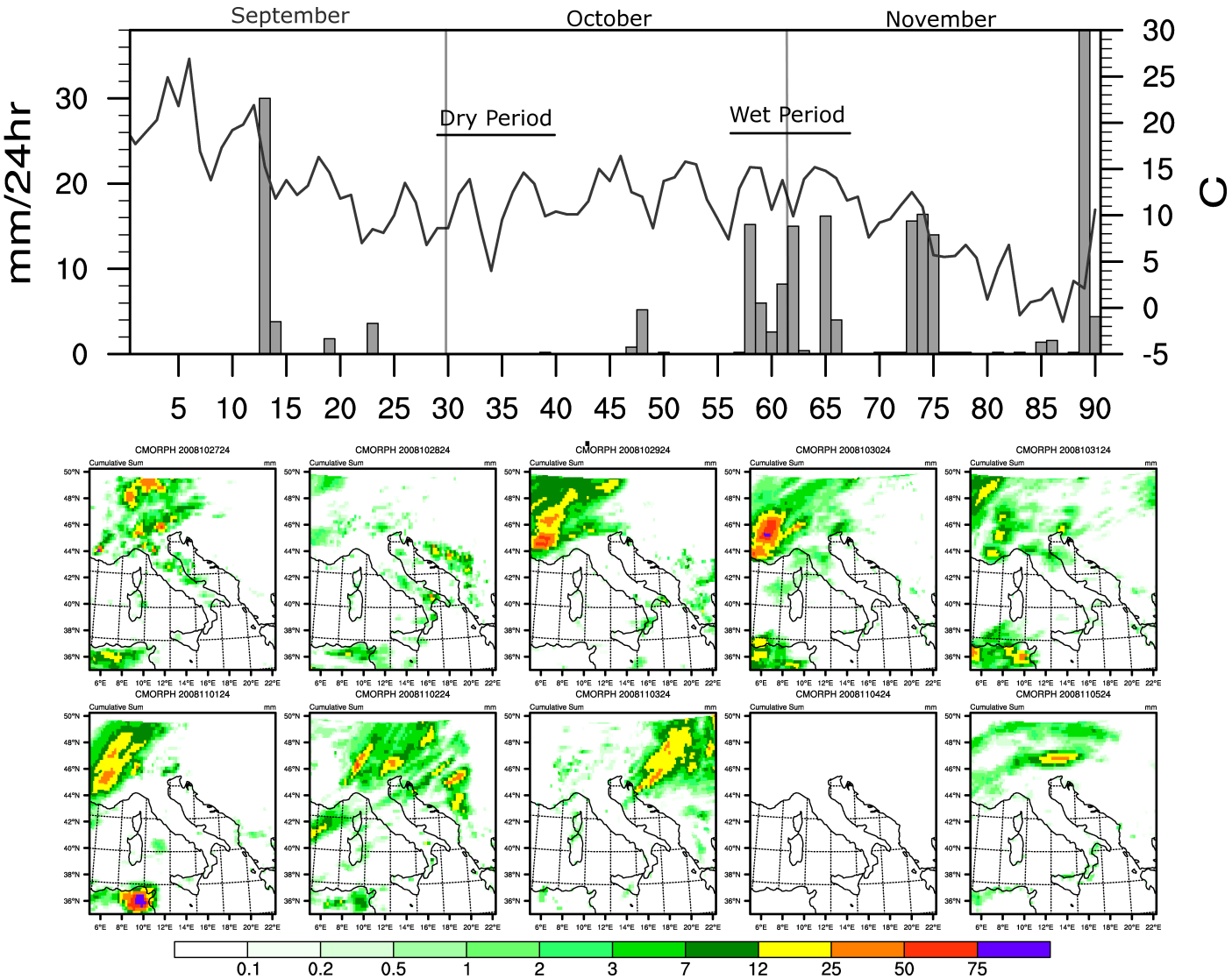
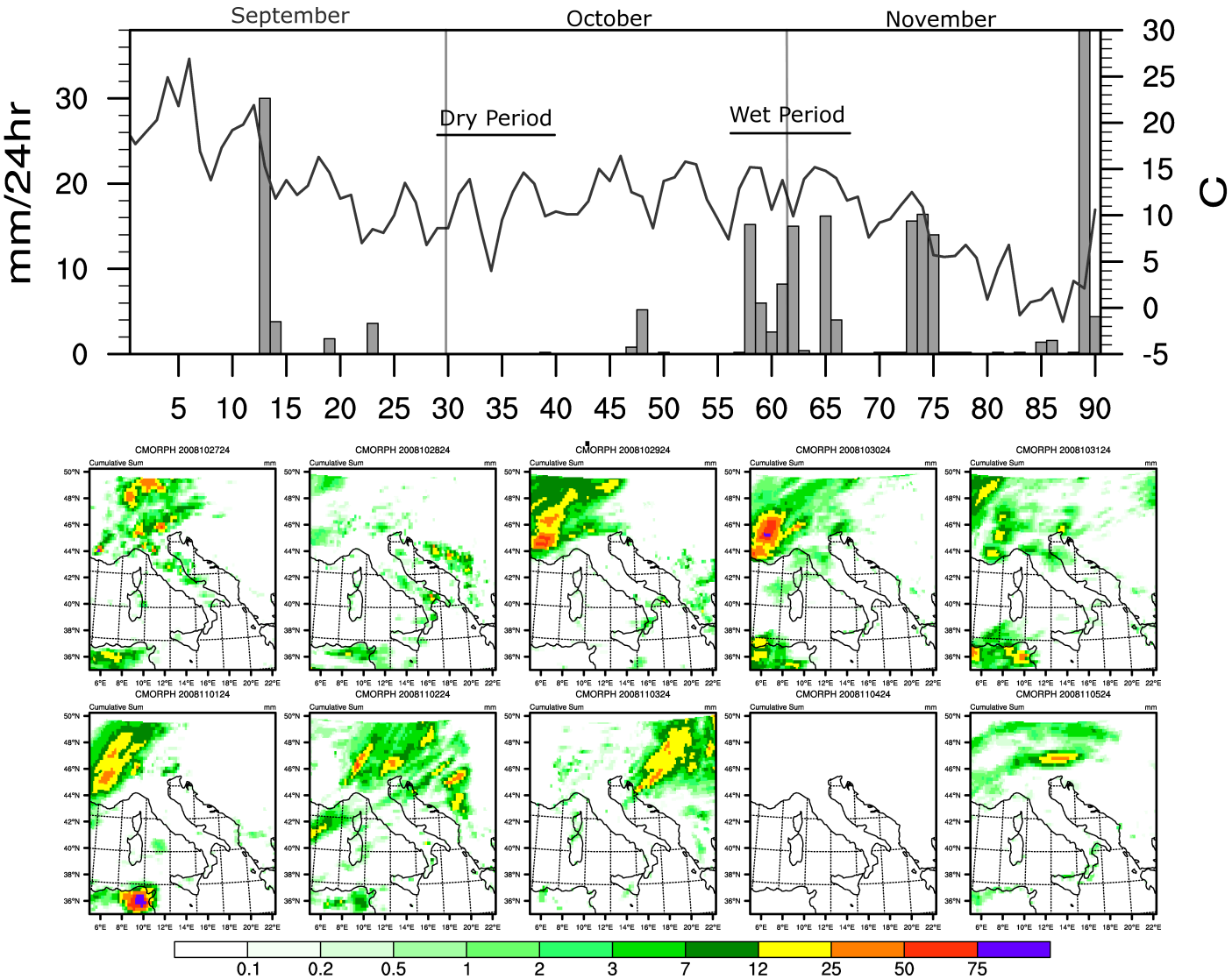


Figure: Observed daily precipitation during the wet period: CMORPH database

Overview of the period at SPC location



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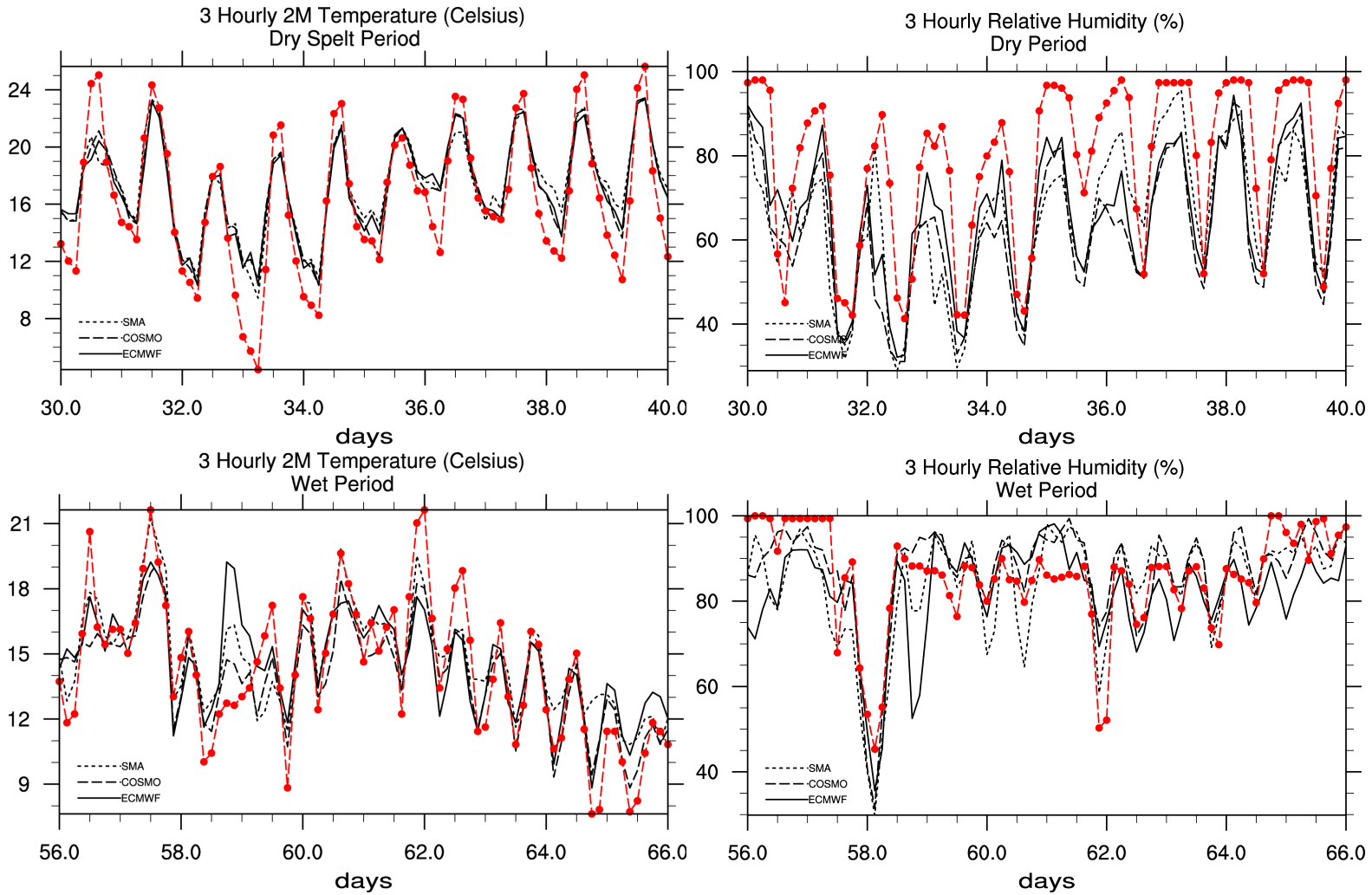
Surface temperature and humidity biases



DRY PERIOD: The warm model bias during nigh-time is not compensated by the evident dry humidity bias since the RH is correct during daytime and overestimated during the night.

WET PERIOD: General improvement due to the soil saturation regime. The SMA experiment has problems

Rationale

Problem

Warm and dry bias during night-time is confirmed to be a critical aspect. This produces too much mixing and difficulty in generating a stratified stable boundary layer.

Possible suspects

- SOURCE TERMS ARE WRONG?: Wrong sensible and/or latent heat fluxes?: a too large sensible heat flux and too small latent would explain the lack of low level humidity and the warm model bias;
- TRANSPORT TERMS ARE WRONG?: A wrong coiche of the turbulent diffusion coefficients would produce too much mixing;

Questions to be answered

- Is there a soil moisture analysis method between the three which performs the better in terms of weather forecast?;
- Is there a soil moisture analysis method between the three which provides a realistic estimation of soil moisture?

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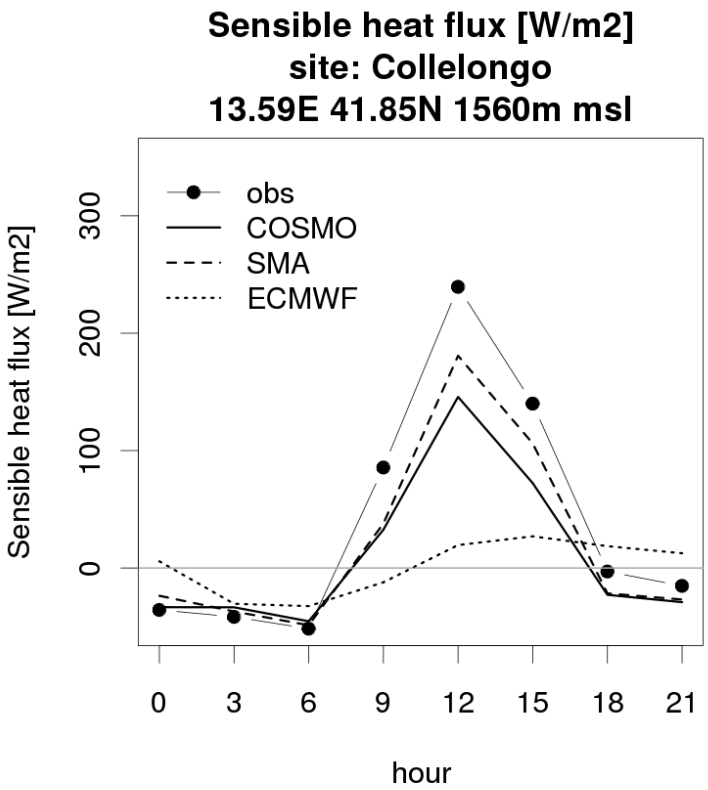
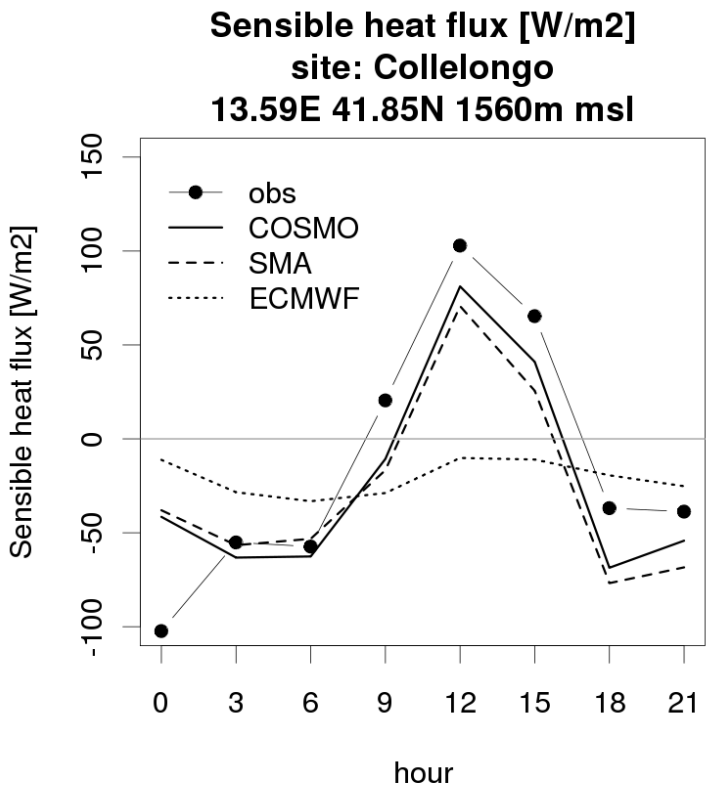
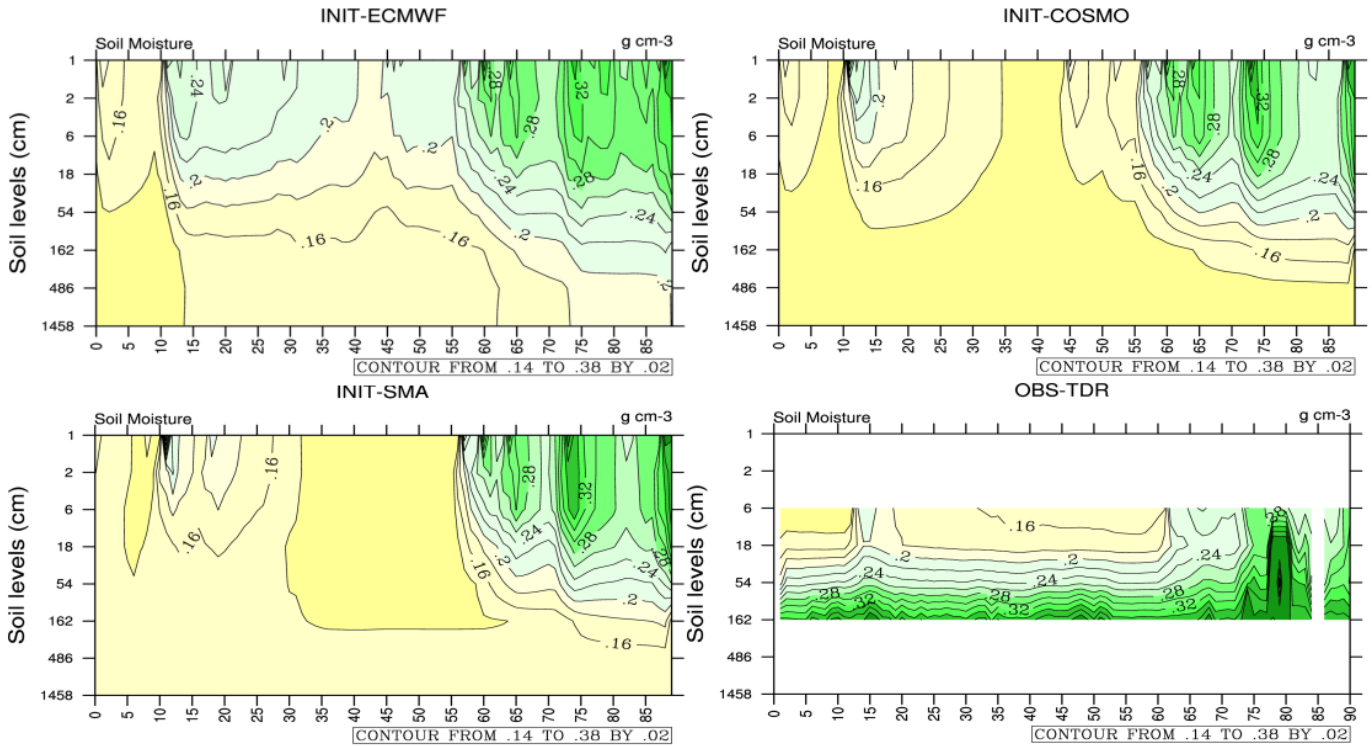
Daily cycle of sensible heat: Model vs Observations





LEFT (Dry Period), RIGHT (wet Period). In the ECMWF run the sensible heat flux is positive during night (too much thermal inertia). The other two experiments try to compensate for this effect.

Mechanism I: too little soil moisture available for evapo-transpiration



There is a water reservoir at the lower levels (root zone 1m depth) which is not accounted for in the model. In reality this makes available extra moisture for evaporation

Mechanism II: too fast response of soil moisture to precipitation forcing

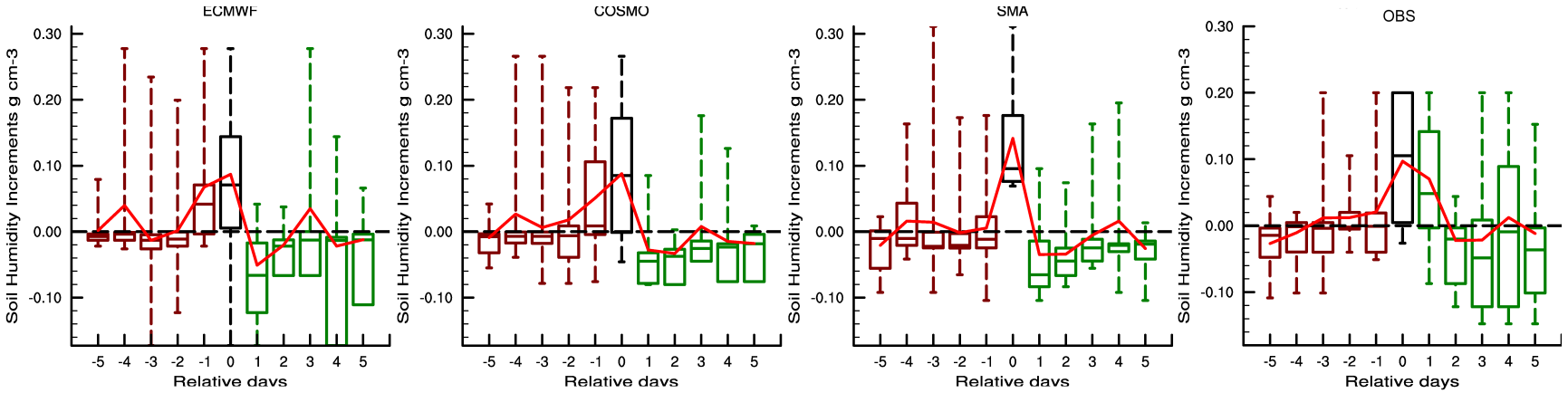
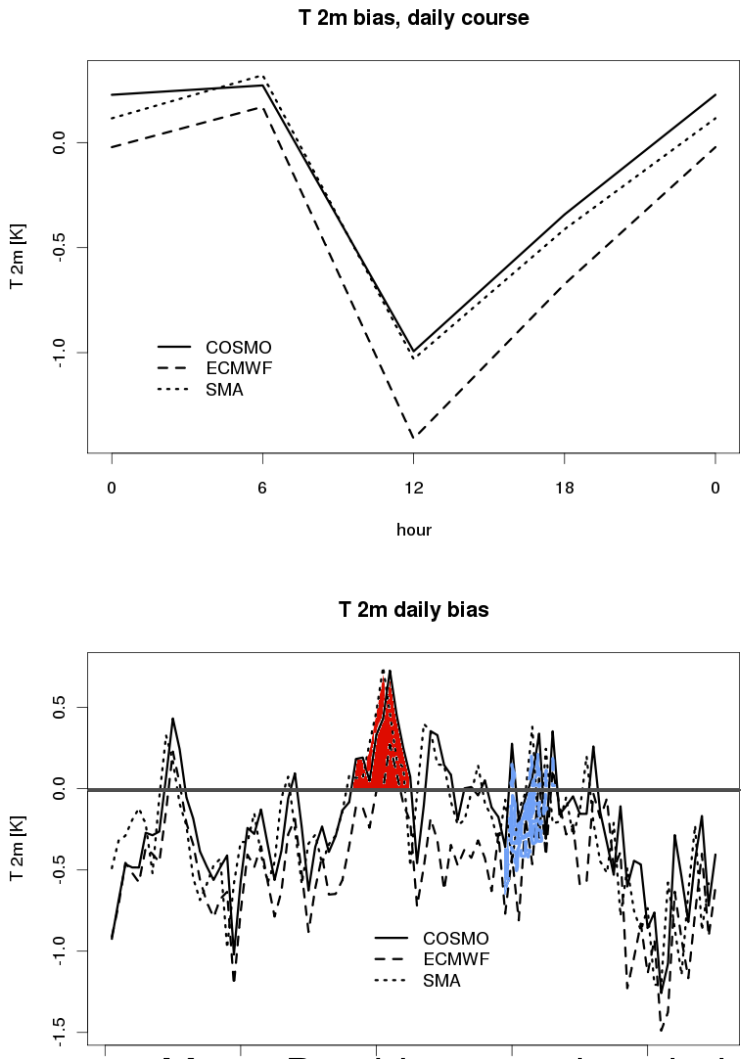


Figure: Precipitation vs soil moisture increments composite analysis at 10 cm depth. Day 0 is marked if daily integrated precipitation ¿ 5 mm. Then daily soil moisture increments are calculated over the first 10 cm soil depth

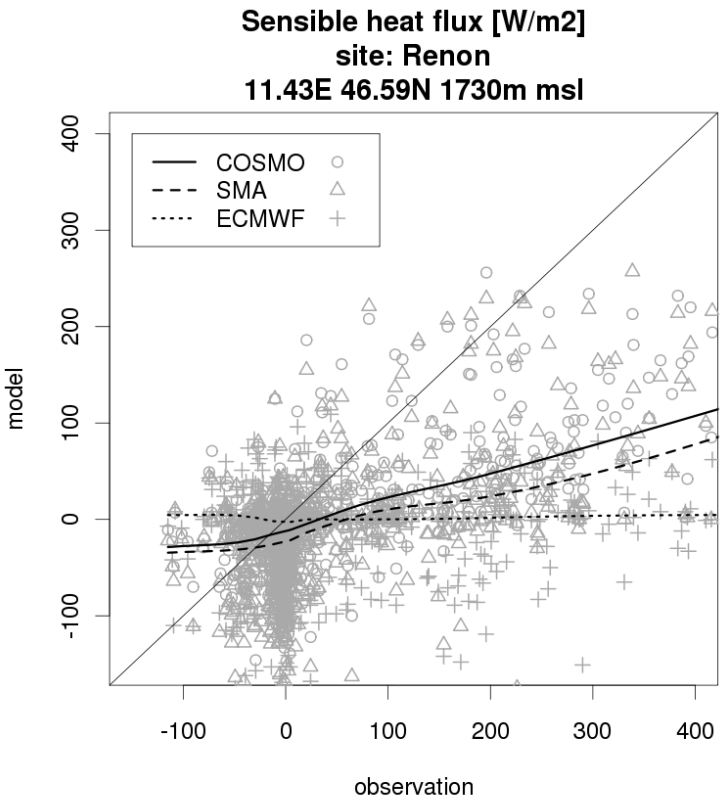
Surface T_{2m} Scores

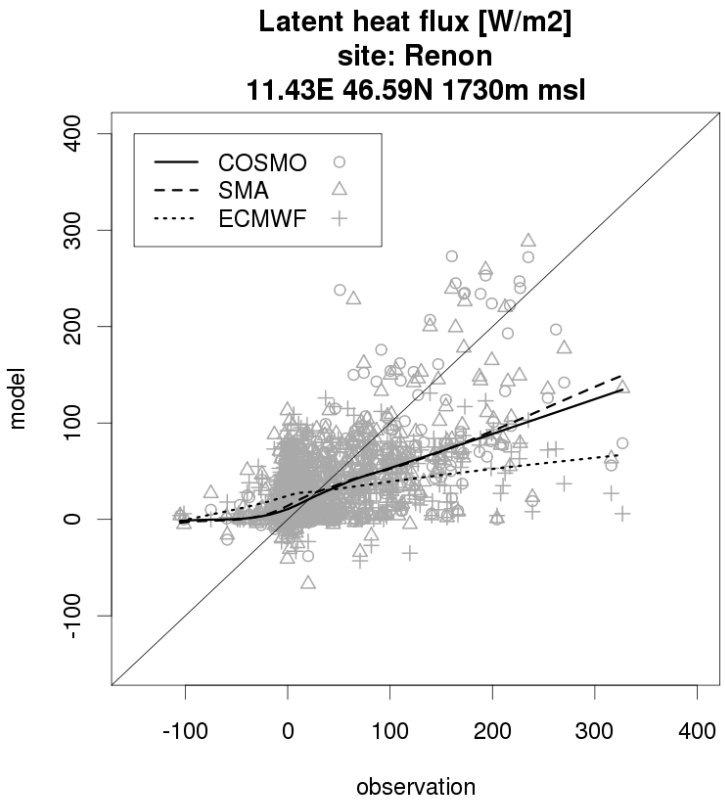


Upper part: Mean-Day bias over the whole SON 2008 period. Lower part: Time Series of the daily bias

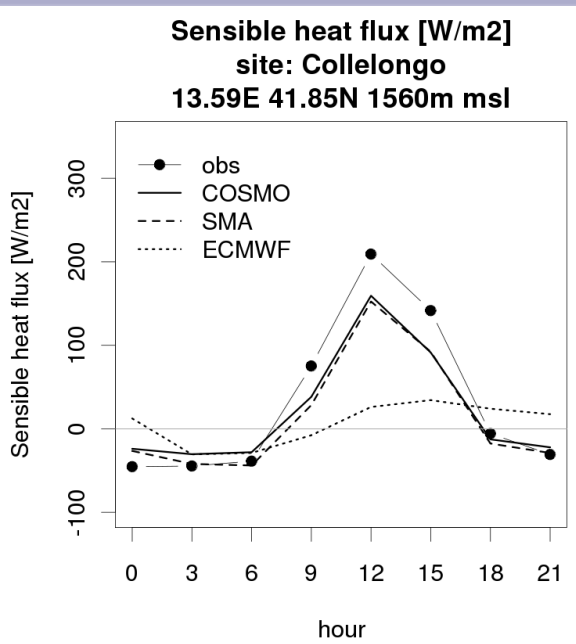
- COSMO is equivalent to SMA in terms of T_{2m} bias
- In general the model performs better in rainy conditions
- Warm bias during dry period mainly controlled by the nighttime bias.

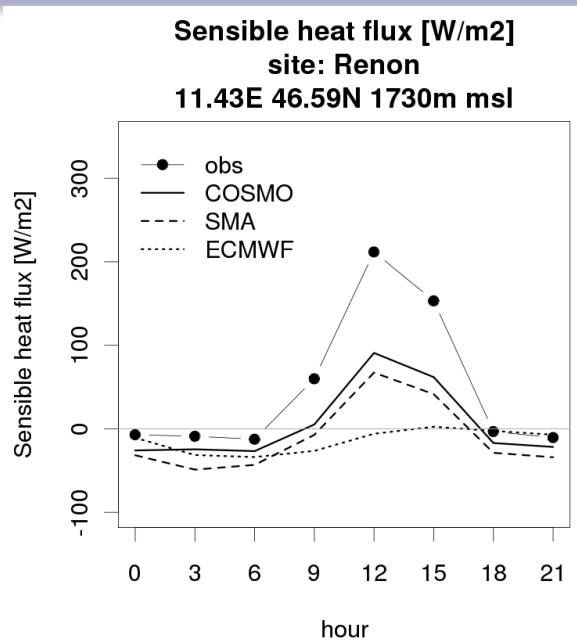
Surface fluxes comparison





Daily Cycle


Sensible heat flux [W/m2]
site: Collelongo
13.59E 41.85N 1560m msl
obs
COSMO
SMA
ECMWF
Sensible heat flux [W/m2]
-100
0
100
200
300
0
3
6
9
12
15
18
21
hour


Sensible heat flux [W/m2]
site: Renon
11.43E 46.59N 1730m msl
obs
COSMO
SMA
ECMWF
Sensible heat flux [W/m2]
-100
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200
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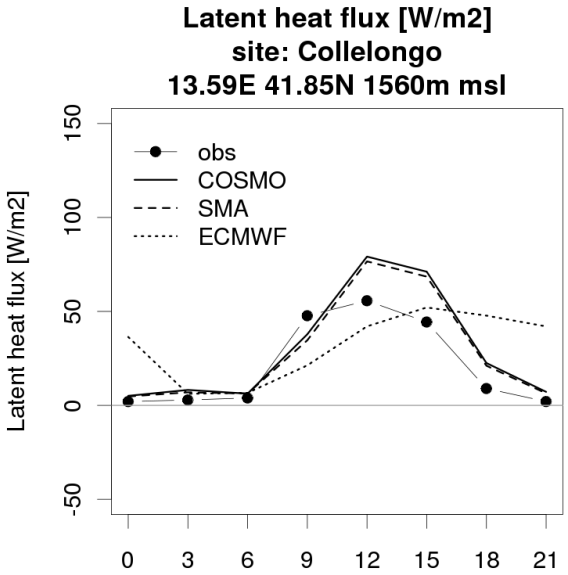
Latent heat flux [W/m2]
site: Collelongo
13.59E 41.85N 1560m msl
obs
COSMO
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Latent heat flux [W/m2]
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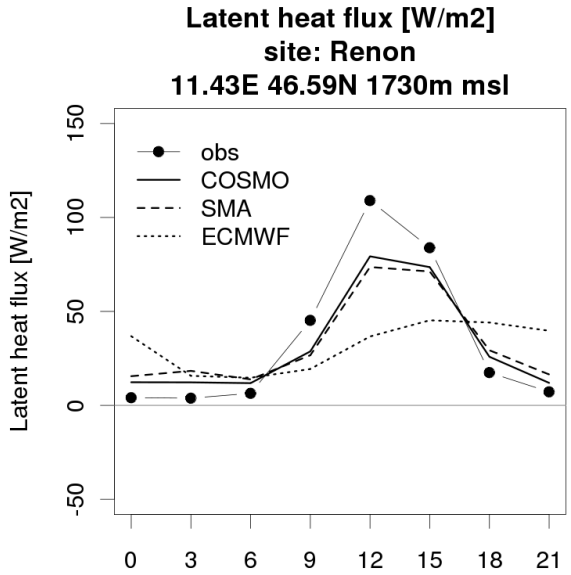
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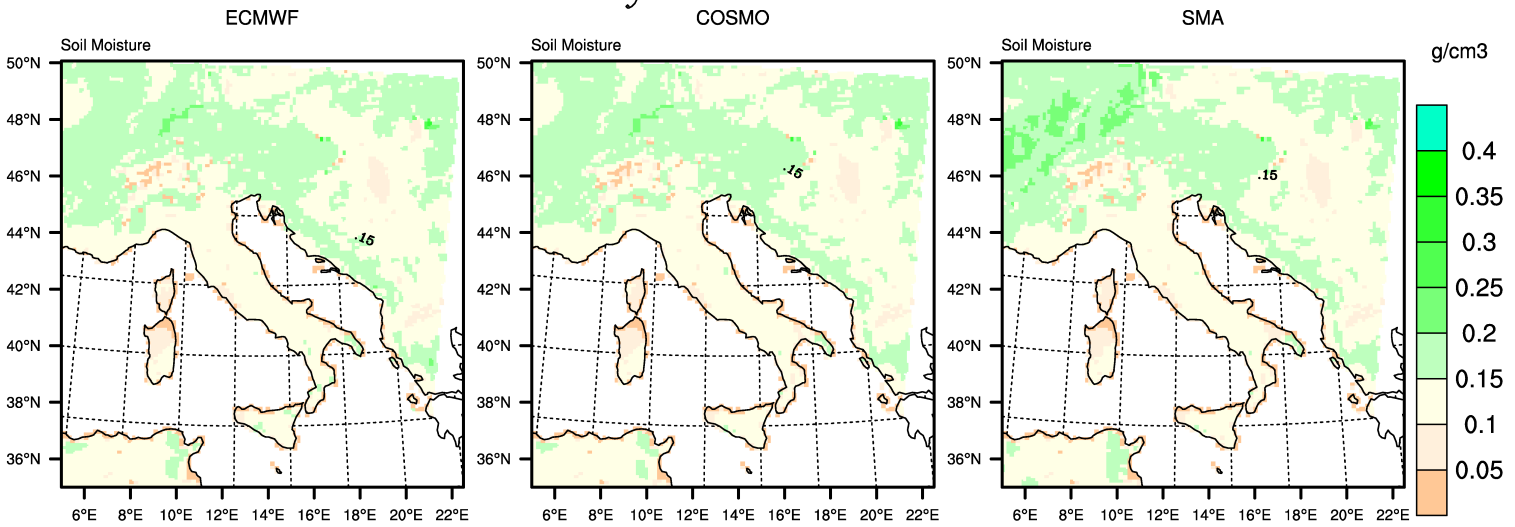
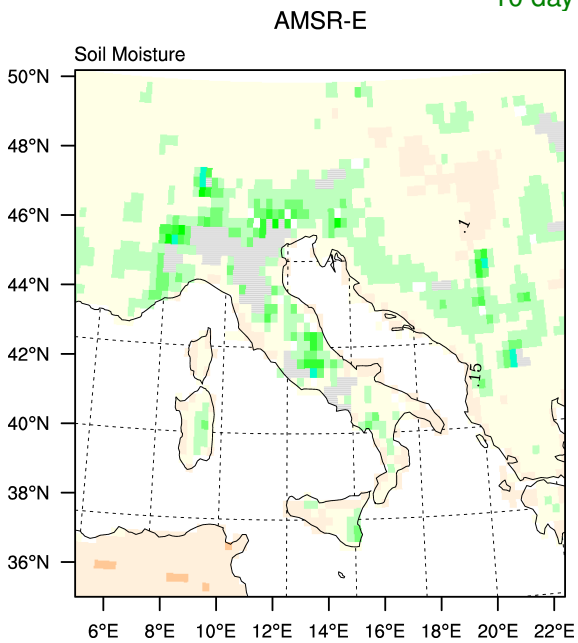
Soil mois

Mean Soil Moisture – 1 cm depth
Dry Period

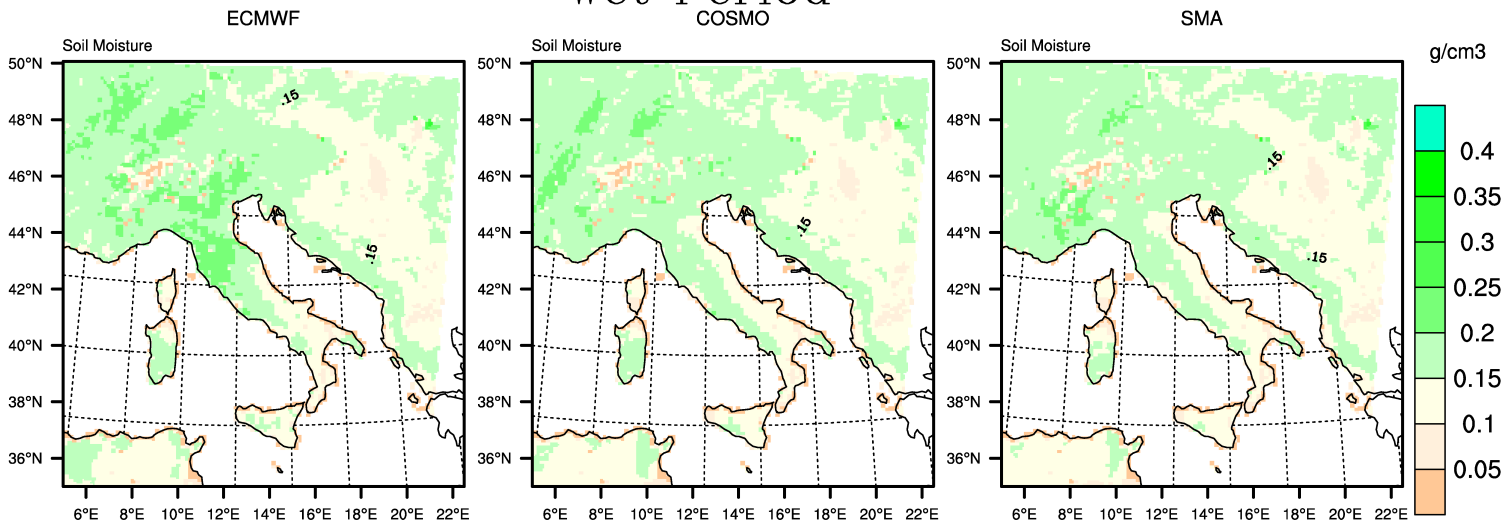


10 day mean during the dry period

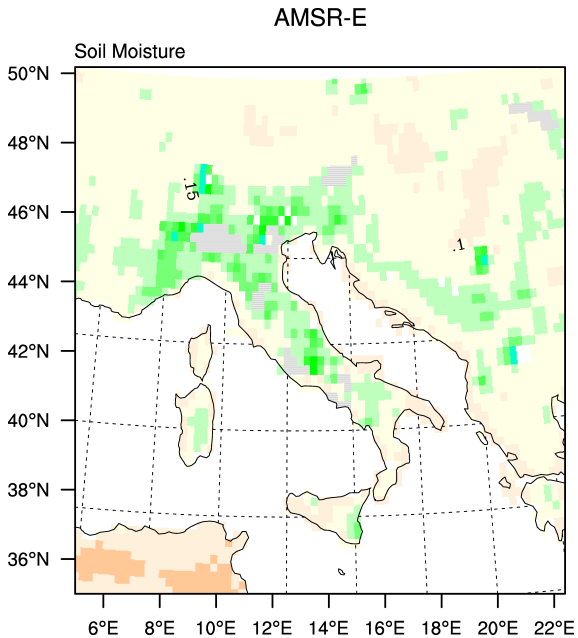


- underestimation of soil moisture over Italy and overestimation in the Northern Part of Europe
- Spots over the Alps are classified as rock

Soil mois



10 day mean during the wet period



- soil moisture increase as a direct consequence of precipitation flow from the west
- ECMWF is the most moist of all three runs which confirms the high thermal inertia of this kind of initialisation

Conclusions

General

More evident PBL problems at night and in prolonged dry conditions when the model is characterised by a warm and dry bias.
The clear effect is that the PBL is too mixed so that stable stratified conditions are difficult to achieve with negative consequences in the forecast of inversions, fog, ...
The causes found are:

1. too little humidity in the soil (especially in the root zone) at least for Italy also comparing with the AMSRU-E dataset;
2. too fast response of the soil model to dry-up the ground after a precipitation event;
3. sensible heat flux over-estimated, latent under-estimated;

Soil Moisture analysis

None of the soil moisture analysis is able to capture the “real soil moisture”. It would be difficult to use these analysis in hydrological applications for example.
Nevertheless, the COSMO experiment seems the one able to produce the lowest T_{2m} biases and the best surface fluxes estimation.

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Variational analysis of effective soil moisture from screen-level atmospheric parameters: Application to a short-range weather forecast model.
Quarterly Journal of the Royal Meteorological Society, **125**(559).

Effect of precipitation

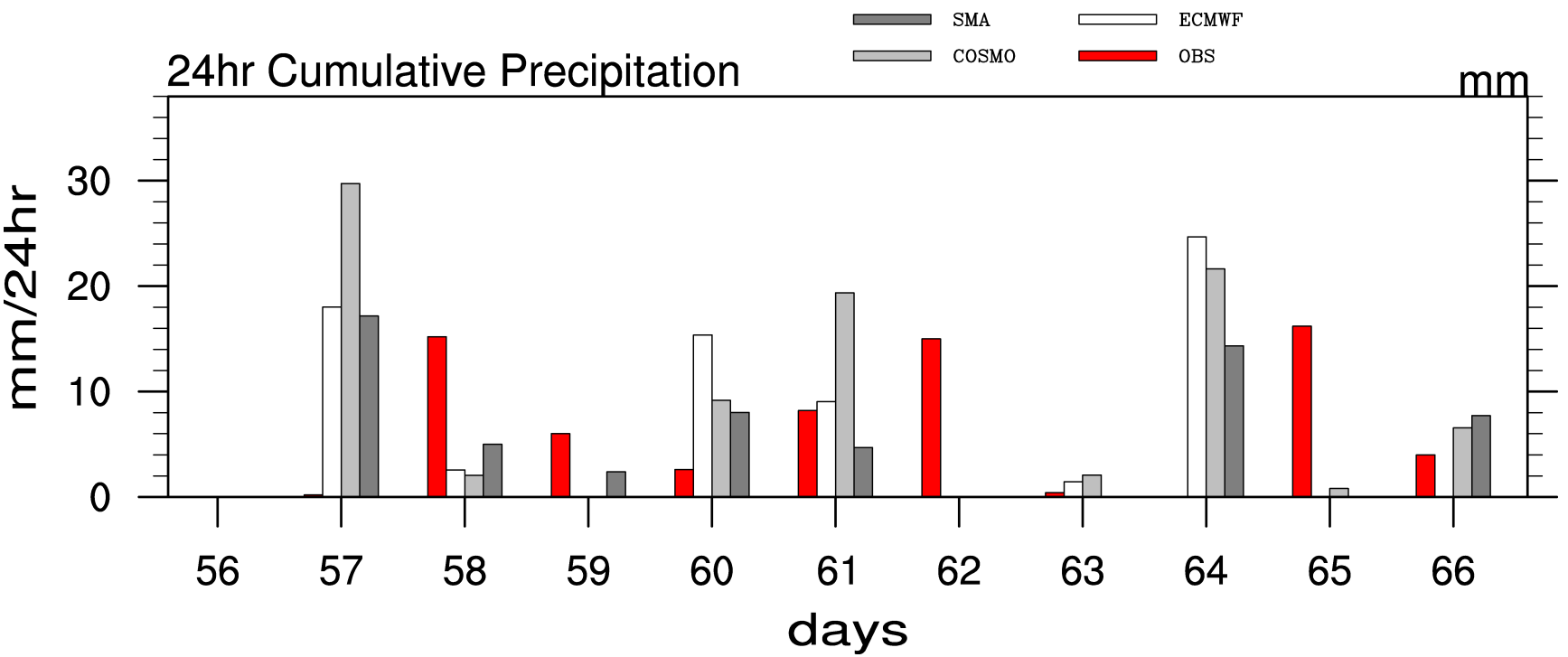

Figure: