The specification of Leaf Area Index for use in mesoscale weather prediction system

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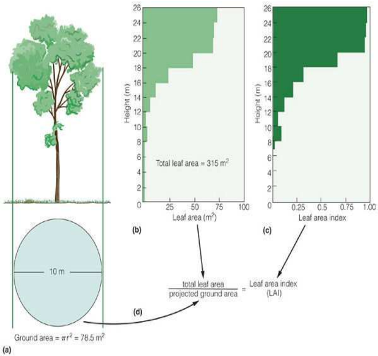
Outline

Vegetation representation in land scheme

Vegetation modify the partitioning between latent and sensible heat flux through the evapotranspiration.
Vegetation amount is represented by only two parameters:



The fractional area (f_a) of vegetation occupying a given pixel

The leaf area index (LAI), defined as the area of leaf surface in a grid cell in comparison to the vegetated part of the grid cell area

As the resolution of regional models approaches the km scales, vegetation fraction will tend to become resolved (either 0 or 1). We have concentrated on the LAI estimation, which gives a measure of the vegetation density.

LAI datasests

Three datasets (approaches) are compared:

- a space and time invariant LAI data set (FIX) Previosily used in COSMO
- a LAI specification based on land cover classes (LCB)
- a dynamical day-by-day LAI specification based on MODIS observations (MOD)

LCB Approach

The land cover approach uses a land usage classification to which vegetation proprierties are associated.
We use:

- CORINE land cover classification produced as outcome of the "Coordination of information on the environment" project by the European Commission.
- LAI min and max values are then assigned to the CORINE land use using the ECOCLIMAP Ploject.
- LAI seasonal variability is simulated by means of an empirical function.

$$LAI(\phi, J_d, \Phi_S) = LAI_{min} + (LAI_{max} - LAI_{min}) \cdot f_V(\phi, J_d) \cdot f_h(\Phi_S)$$

with ϕ geographic latitude, Φ_S geopotential height, f_h a height reduction function and:

$$f_V(\phi, J_d) = max(0.0, min(1.0, C \cdot sin(\pi \cdot max(0.0, (J_d - V_S)/V_l)))) \quad (1)$$

where $J_d(\phi)$ is the current Julian day, $V_S(\phi)$ is the starting Julian day of the vegetation period and V_l is its length.

Table: CORINE classes with prescribed minimum and maximum max LAI values

LAI (min)	LAI (max)	Class
1.21	3.45	Broad-leaved forest
1.67	3.32	Coniferous forest
1.57	3.50	Mixed forest
1.01	2.52	Natural grasslands
1.04	2.44	Moors and heathland
1.13	1.94	Sclerophyllous vegetation
1.09	2.85	Transitional woodland-shrub
0.72	1.98	Beaches, dunes, sands
0.22	0.56	Bare rocks
0.57	1.40	Sparsely vegetated areas
1.36	2.38	Burnt areas
0.04	0.10	Glaciers and perpetual snow
0.85	2.80	Inland marshes
		Salines
		Water courses

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MOD Approach

It uses the Global Leaf Area Index product MOD15A2 whichis a 8-day composite (one year has 45 MODIS days) with a spatial resolution of 1-km on a sinusoidal grid.
Methodology :

1. Creation (2001 - 2006) of annual “climatology”. Procedures of hole filling and quality check based on dataset quality flags
2. Merging of the climatology with the day-by-day observation available trough the free ftp service.
3. Interpolation to the desiderable grid

Comparison between LAI datasets:Spatial distribution

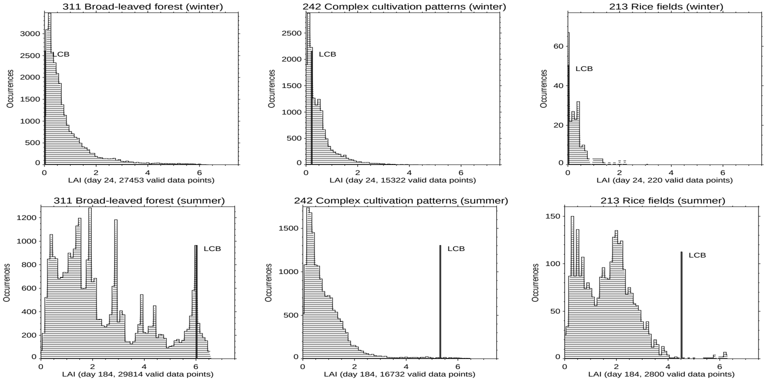

Figure: Leaf Area Index probability density function (PDF) from the MOD dataset. The PDFs are aggregated over a selection of CORINE land cover classes. Two example days are considered: the 24th of January ("winter" case) during plants resting and the 3rd of July ("summer" case) during plants vegetative period. The predicted LCB-LAI values are reported with bars.

Comparison between LAI datasets: Annual Modulation

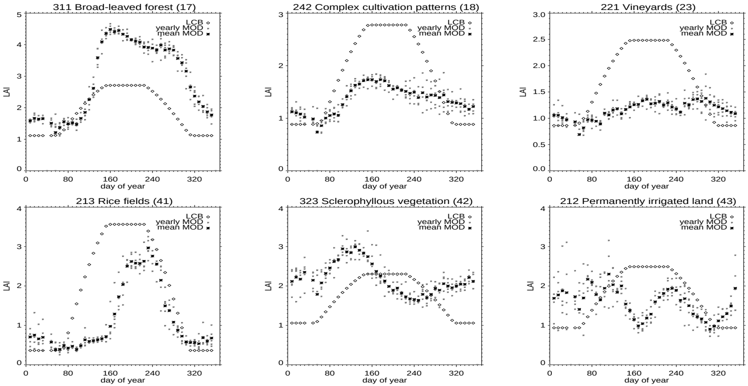

Figure: LAI annual cycle for the MOD and LCB datasets averaged over the CORINE land cover classes.

Comparison between LAI datasets: 2 days experiment

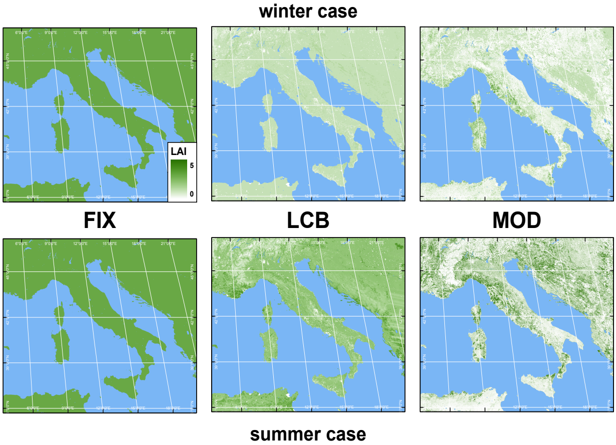

Figure: LAI maps for two example days in winter (19 January 2006) and summer (08 July 2007) using the FIX, LCB and MOD

Comparison between LAI datasets: Predicted Surface Fluxes

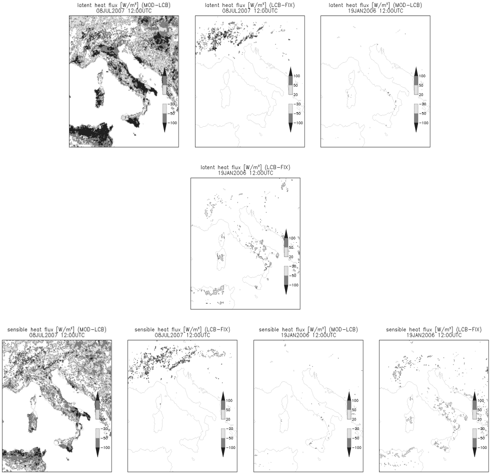

Figure: Differences in latent and sensible heat fluxes MOD-LCB and LCB-FIX. Upper panel: summer case (8 July 2007). Lower panels: winter case (19 January 2006). Differences are plotted at +12 hrs forecast time using the COSMO-I7 regional model.

Dataset Validation: Forecast vs Analysis

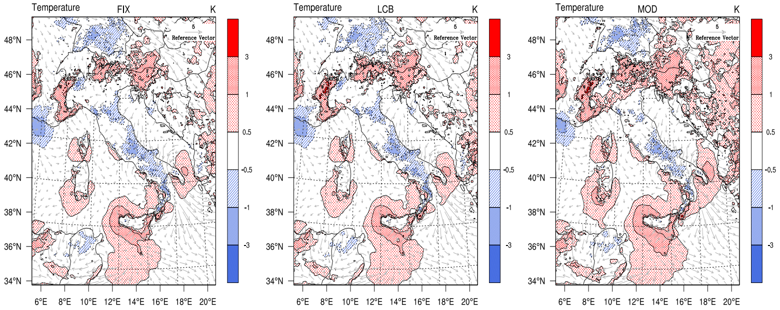

Figure: + 36 hrs forecast mean error (forecast - analysis) for 2m dry temperature using the three different datasets. The underlined arrows represent the mean 10 m wind field for the period considered (1-30 june 2005)

Dataset Validation: Synop Observations

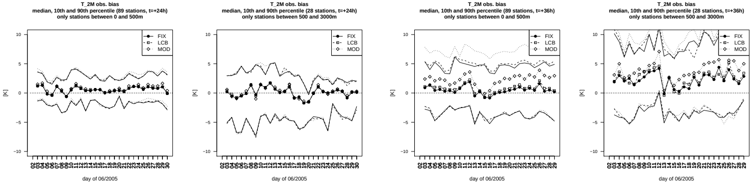

Figure: Screen level dry temperature biases for two different forecast times at +24hrs (midnight) and +36 hrs (noon). Around 100 synop stations are used which cover the Italian territory. The available observations are split into mountain station (above 500 m) and valley stations (below 500 m)

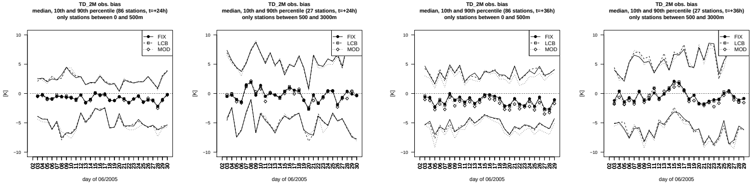

Figure: dew-point temperature.

Dataset Validation: Surface Fluxes

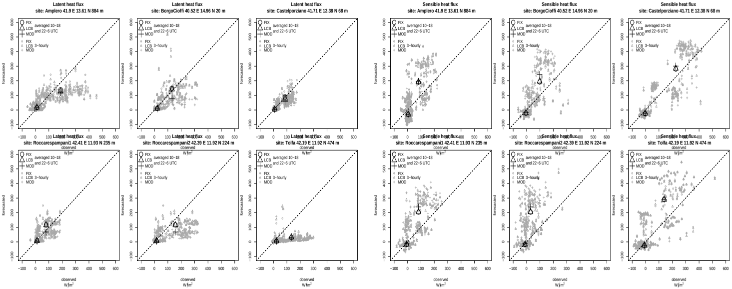

Figure: Turbulent fluxes observational bias. Oversized markers are for mean biases

Table: Available LAI measurements at selected CARBOEUROPE sites and the corresponding estimations using the three LAI datasets.

Code	name	lat	lon	H (m)	land use	FIX	LCB	MOD	OBS	Obs. Per
IT-Amp	Amplero	41° 54' 14"	13° 36' 18"	884	grassland	3.00	2.26	1.42	1.43	ave.Jun20
IT-BCi	BorgoCioffi	40° 31' 25"	14° 57' 26"	20	cropland	3.00	2.76	0.89	2.7	ave.Jun20
IT-Cpz	Castelporziano	41° 42' 18"	12° 22' 33"	68	forest	3.00	2.64	1.69	–	–
IT-Ro1	Roccarespampani 1	42° 24' 29"	11° 55' 48"	234	oak	3.00	2.92	1.44	–	–
IT-Ro2	Roccarespampani 2	42° 23' 24"	11° 55' 15"	223	oak	3.00	2.92	1.44	–	–
IT-Tol	Tolfa	42° 11' 22"	11° 55' 17"	473	shrub	3.00	3.05	2.99	–	–

Conclusions

- The intercomparison between the three datasets has shown that the MOD approach is the only one able to capture the expected vegetative cycle typical of the Mediterranean soil
- Using land-use based LAI as in the LCB dataset does not introduce a significant variability in comparison to the unrealistic FIX database
- On a one month validation period COSMO showed to correctly predict the incoming energy at the surface. Nevertheless COSMO land scheme is unable to partitioning it between latent and sensible heat fluxes, being the first always underestimated and the latter always overestimated.
- The MOD LAI exacerbate these biases showing the limitation of improving only one parameter. In one case in which LAI predictions were in almost perfect agreement with the observation the forecast of surface heat fluxes confermed the same biases being the expected improvements offset by the too low soil moisture initialization.