Process-based improvement of climate prediction in EC-Earth ESM

Franco Catalano[1], Andrea Alessandri[1,2], Matteo De Felice[1,3]
1 Agenzia Nazionale per le nuove Tecnologie, l'energia e lo sviluppo sostenibile (ENEA), Italy
2 Royal Netherlands Meteorological Institute (KNMI), The Netherlands
3 Joint Research Centre (JRC), European Commission, Petten, Netherlands

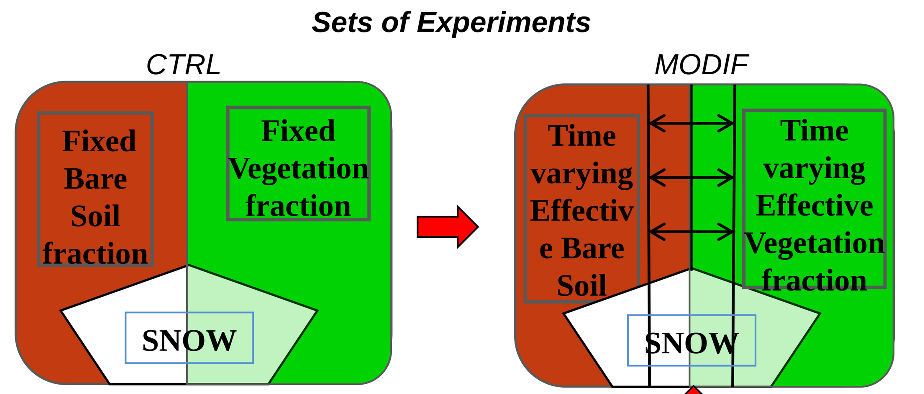
contact: franco.catalano@enea.it
https://impatti.sostenibilita.enea.it/people/franco-catalano

Motivation

Novel observational global datasets of land-surface variables are expected to significantly enhance understanding and representation of land surface processes representation in Earth System Models (ESMs). The observational analysis (Catalano et al. 2016) unveiled novel important observational constraints that has driven the development of new process-based parameterizations in HTESSEL (i.e. the land-surface model included in the EC-Earth ESM).

1. Improved vegetation representation in EC-Earth

The EC-Earth (Hazeleger et al., 2012) Earth system model is based on the seamless development of the operational seasonal forecast system of ECMWF.

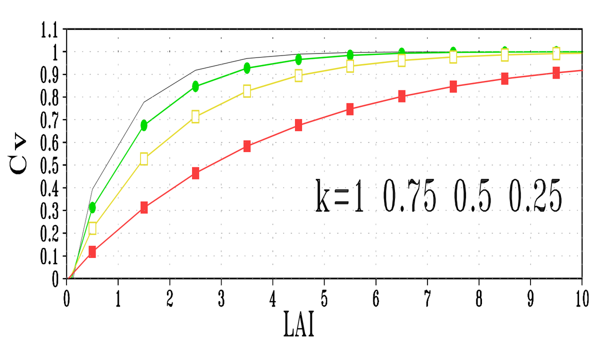


EC-Earth model components
- IFS atmosphere + HTESSEL land surface
- NEMO ocean + LIM3 sea-ice
- LPJ-GUESS vegetation

i. **Evapotranspirating surfaces**
ii. **Roughness length**
iii. The contribution of root density of each vegetation-type to the **Field Capacity**
iv. Surface **Albedo**

Improved Vegetation Representation

To represent the effective sub-grid vegetation fractional cover (Cv) that can vary seasonally and interannually as a function of leaf development and canopy growth we included an exponential dependence of the vegetation density to the LAI (Alessandri et al. 2017).



Implemented effective cover interannual variability (std dev)

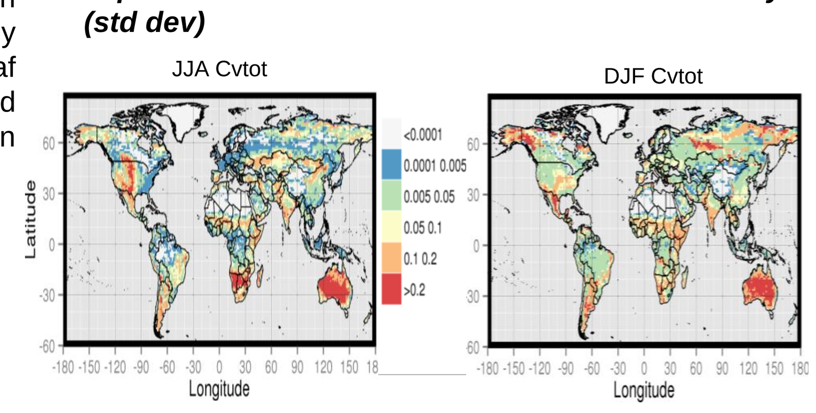


Figure 1: Interannual standard deviation of (left) summer and (right) winter mean Cv in the MODIF experiment.

2. Skill enhancement of seasonal forecasts due to realistic vegetation representation

A set of hindcasts has been performed for the period 1982-2010. The realistic representation of vegetation variability leads to a significant improvement of the skill in predicting 2m temperature during winter (DJF) and precipitation during summer (JJA) over land at seasonal time-scales (Alessandri et al. 2017).

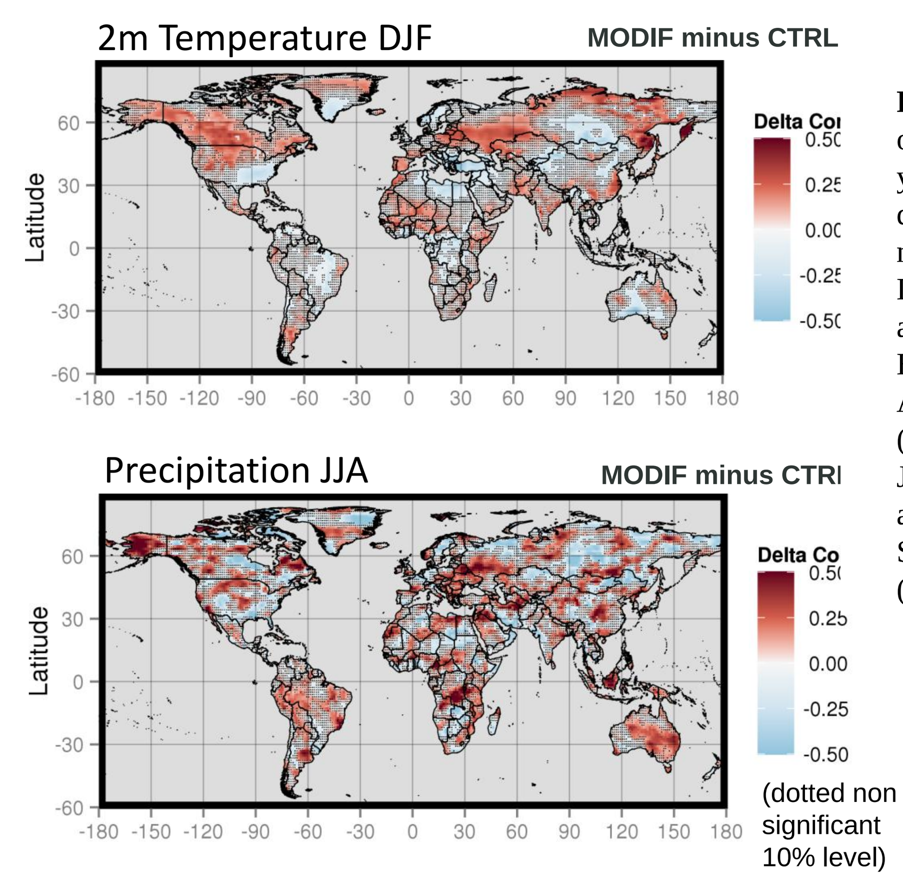


Figure 2: MODIF minus CTRL correlation difference for 1-month lead (upper) boreal winter 2m Temperature and (lower) boreal summer Precipitation. Reference data is ERA-INTERIM for temperature and GPCP for precipitation. Dotted areas did not pass test for statistical significance at 10% level.

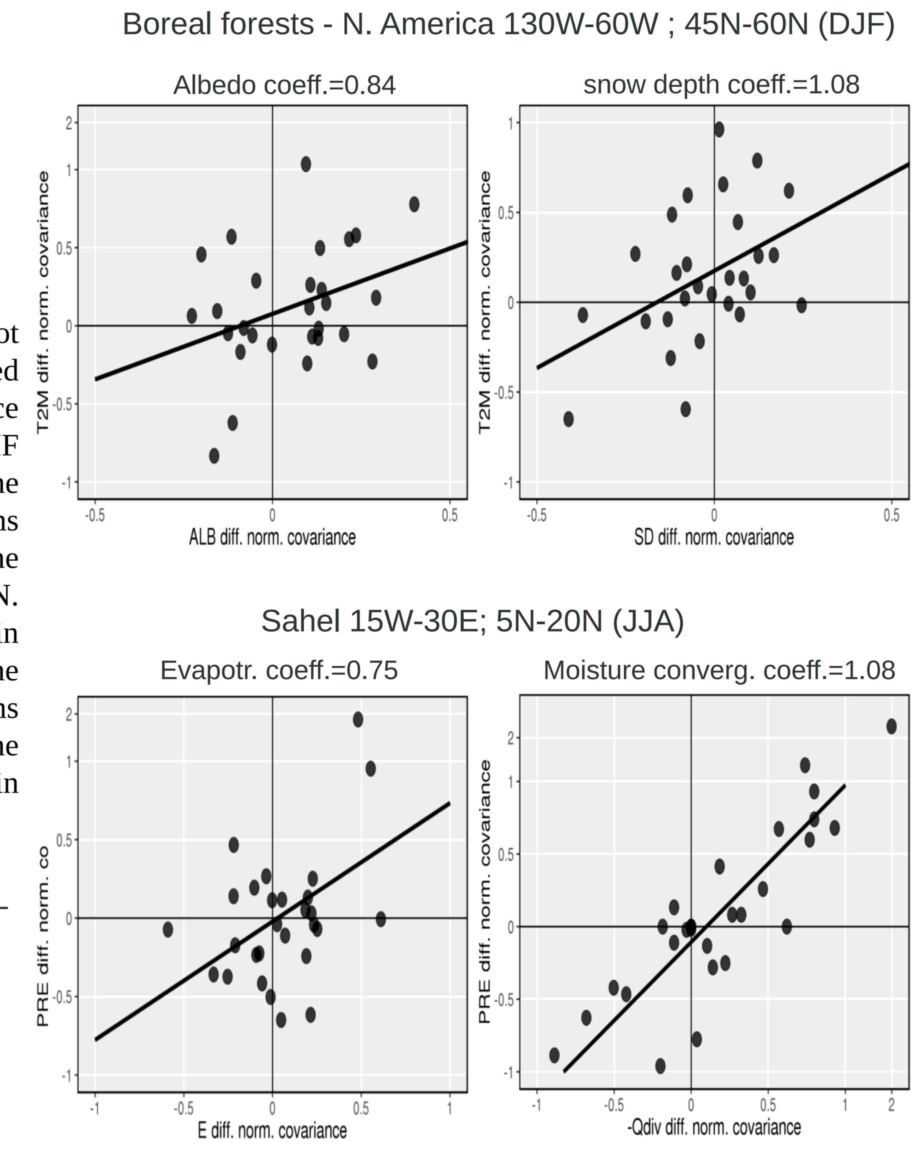


Figure 3: Scatterplot of the normalized yearly covariance differences MODIF minus CTRL for the DJF predictions averaged over the Boreal forests – N. America domain (upper) and for the JJA predictions averaged over the Sahel domain (lower).

MODIF-CTRL Normalized yearly covariance

$$\frac{(x_i'^k y_i'^k)}{[\sum_{j=1}^{n}(x_j'^k)^2]^{1/2}[\sum_{j=1}^{n}(y_j'^k)^2]^{1/2}}$$

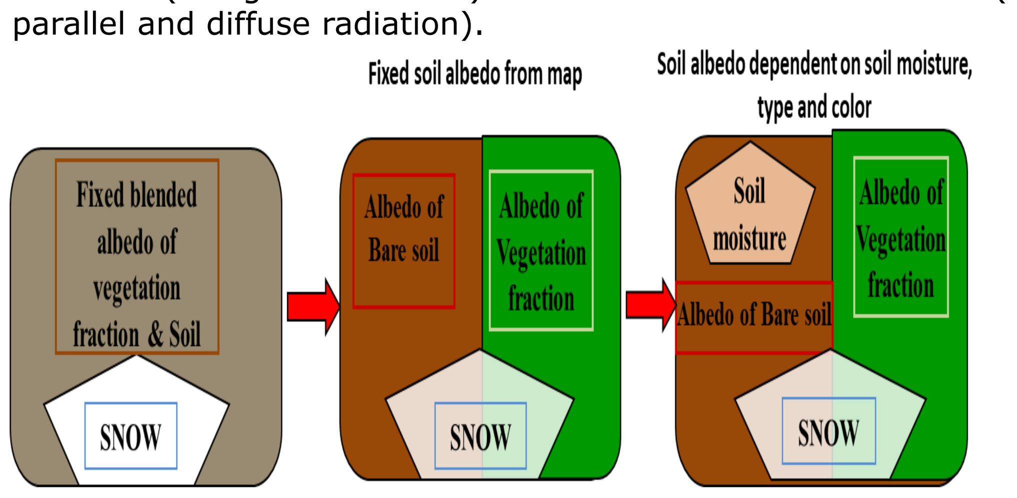
j = each single year,
k = lead time (1 month)

Regression line (coefficient significant at 5% level)

3. New interactive soil albedo in EC-Earth

We introduced realistic soil albedo that can vary seasonally and interannually as a function of soil moisture.

Soil albedo parameters estimated based on the latest available COPERNICUS observational dataset by removing albedo of vegetation fraction (Rechid et al. 2009, Otto et al. 2011). Only grid points with no snow are selected. For each soil class (color and texture) we found a robust (statistically significant) relationship between albedo anomalies and ESA soil moisture (Dorigo et al. 2017) for each of the four SW bands (near-infrared and visible for parallel and diffuse radiation).



$ALB_{soil}[x,t] = ALB_c[x] + ALB_{anom}(texture,color,SM[t])$

- ALB_c is the bare soil albedo map (Rechid et al. 2009, Otto et al. 2011) which represents constant soil albedo space inhomogeneities;

- ALB_{anom} represents soil albedo anomalies, dependent on soil moisture. Parameters of f are estimated separately for each soil texture/color class.

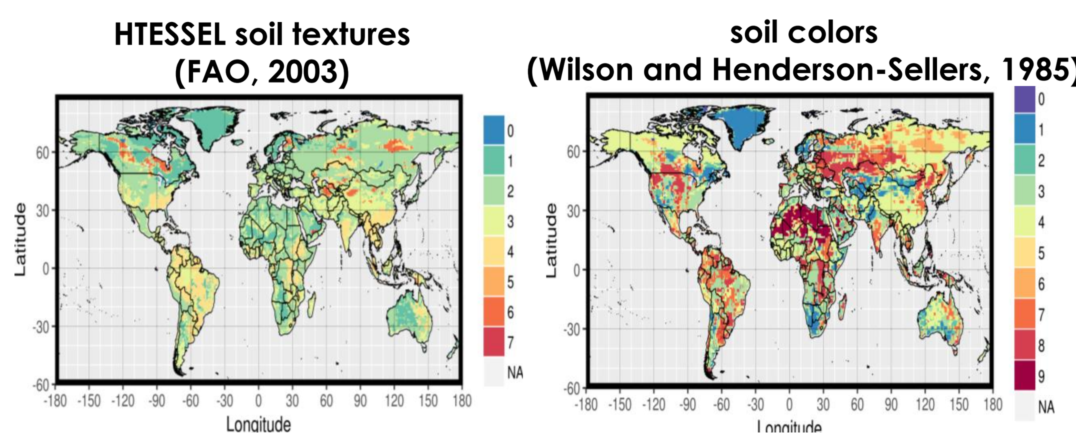


Figure 4: Soil texture and soil color maps used for the discretization.

4. Preliminary evaluation of the improved soil albedo representation

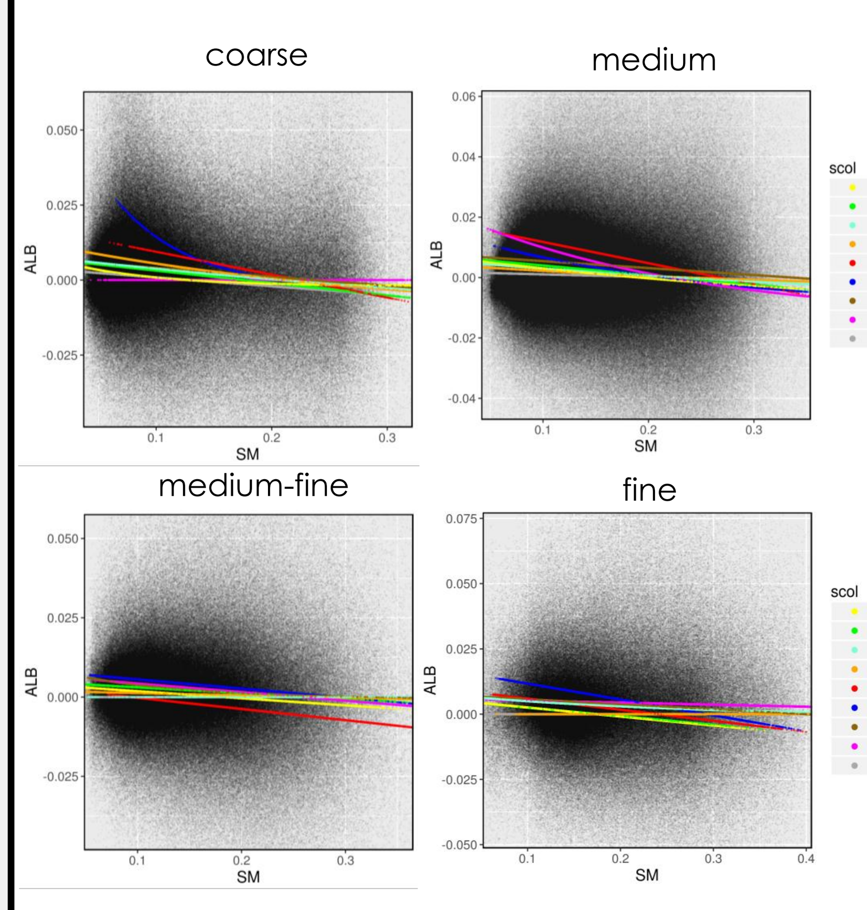


Figure 5: Scatterplots of soil albedo anomalies vs soil moisture. Comparison of estimates for each soiil texture/color (colored curves) with observations (black dots). Near infrared parallel component

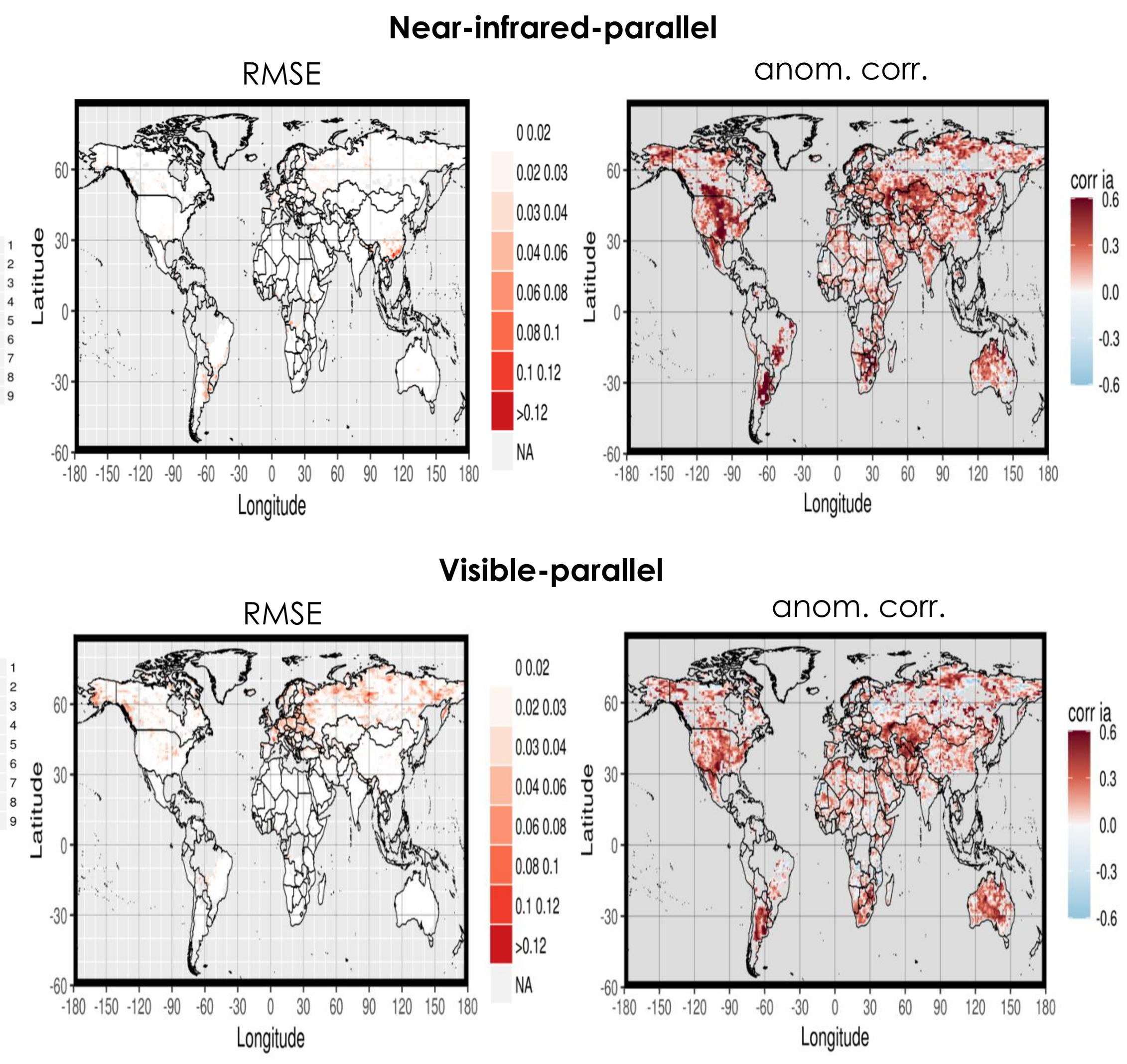


Figure 6: RMSE and anomaly correlations of soil albedo estimates for near infrared parallel (upper) and visible parallel (lower) components. Reference data is GLCF GLASS albedo (Liu et al. 2013)) after removal of vegetation fraction.

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5. Summary and Conclusions

The interactive representation of vegetation cover as a function of LAI (MODIF), replacing the original constant vegetation (CTRL), leads to multi-scale enhancements in EC-Earth:

-Over middle-to-high latitudes, due to the time-varying shadowing of tree vegetation on the albedo of snow covered surfaces.

-Over transitional land surface hot spots, mainly related to improved performance in predicting evapotranspiration and in partitioning surface fluxes.

The interactive representation of soil albedo as a function of soil moisture, replacing the original constant bare soil albedo leads to global enhancement of land-surface variability