Using ESA CCI ECVs to provide support for and guide national and international climate action

Policy relevant work being carried out within the ESA Climate Change Initiative (CCI) Climate Modelling User Group (CMUG)

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The role of CMUG

CMUG's role is to integrate across the Climate Change Initiative (CCI) and facilitate communication between the ECV projects and the climate modelling, research and service communities. CMUG feeds back user requirements and assessments of the ECV datasets to ESA CCI projects; carries out research on applications of ECVs in climate modelling and climate system understanding; and promotes policy-relevant applications of ECVs. CMUG's three primary objectives are on the right.

1. Support integration within CCI programme
2. Foster exploitation of satellite-derived ECVs
3. Assess quality and impact of CCI ECVs

ESMValTool

CMUG works to include ESA CCI ECV datasets in the Earth System Model validation tool: ESMValTool, an open-source community-developed diagnostics and performance metrics tool for the evaluation and analysis of Earth System Models (ESMs). Diagnostics and performance metrics within ESMValTool allow tailored analysis for the evaluation of models with ESA CCI data.
https://esmvaltool.org/

Existing CCI datasets are updated within ESMValTool, and new datasets are added, such as recent implementation of CCI snow and permafrost datasets.

CMUG Vegetation Phenology Study

This study, conducted by the Met Office Hadley Centre and CMCC (Euro-Mediterranean Center on Climate Change), investigates the relationship between vegetation phenology and land-atmosphere interactions using multiple ESA Climate Change Initiative (CCI) datasets. Leaf Area Index (LAI) serves as a proxy for vegetation activity and undergoes a dedicated processing workflow to remove uncertain observations, reduce noise, fill temporal gaps, and generate continuous time series suitable for phenological analysis. Figure 1 summarises this workflow, which combines uncertainty filtering, anomaly detection, interpolation, and smoothing to prepare satellite-derived LAI data for the detection of growing season characteristics and comparison with other Essential Climate Variables.

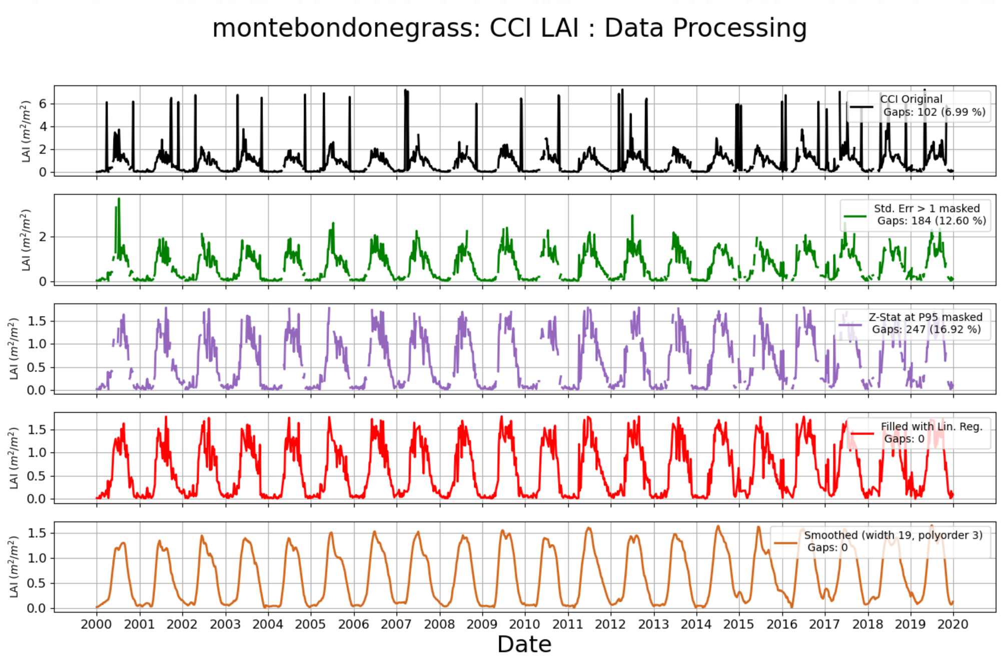


Figure 1: Processing chain applied to CCI_LAI data to prepare it for phenology metric calculations, shown for a single gridbox at Monte Bondone. (Top, black line) Raw CCI_LAI data is first filtered using the standard error (second line, green), then further noise is reduced using a z-score filter (middle, purple line). Gaps are filled using linear regression (penultimate line, red), and the time series is finally smoothed using a Savitzky-Golay filter (bottom, orange).

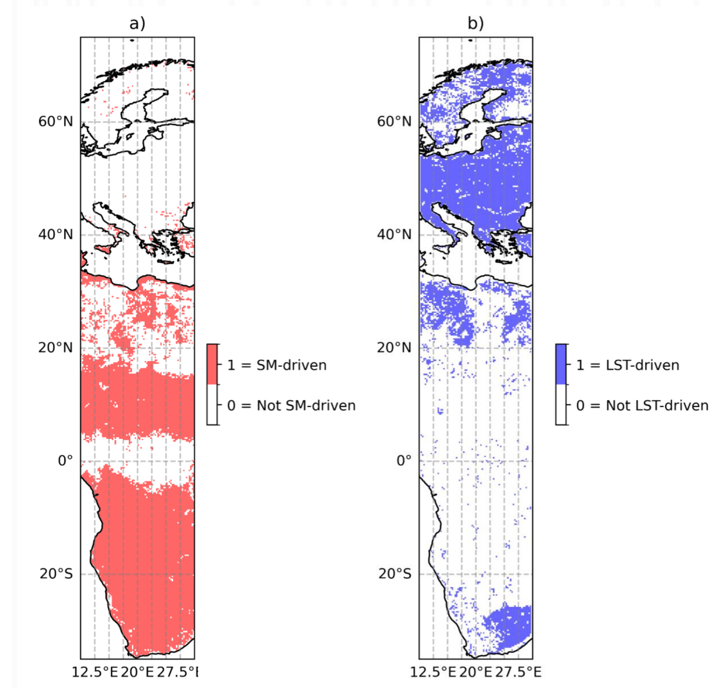
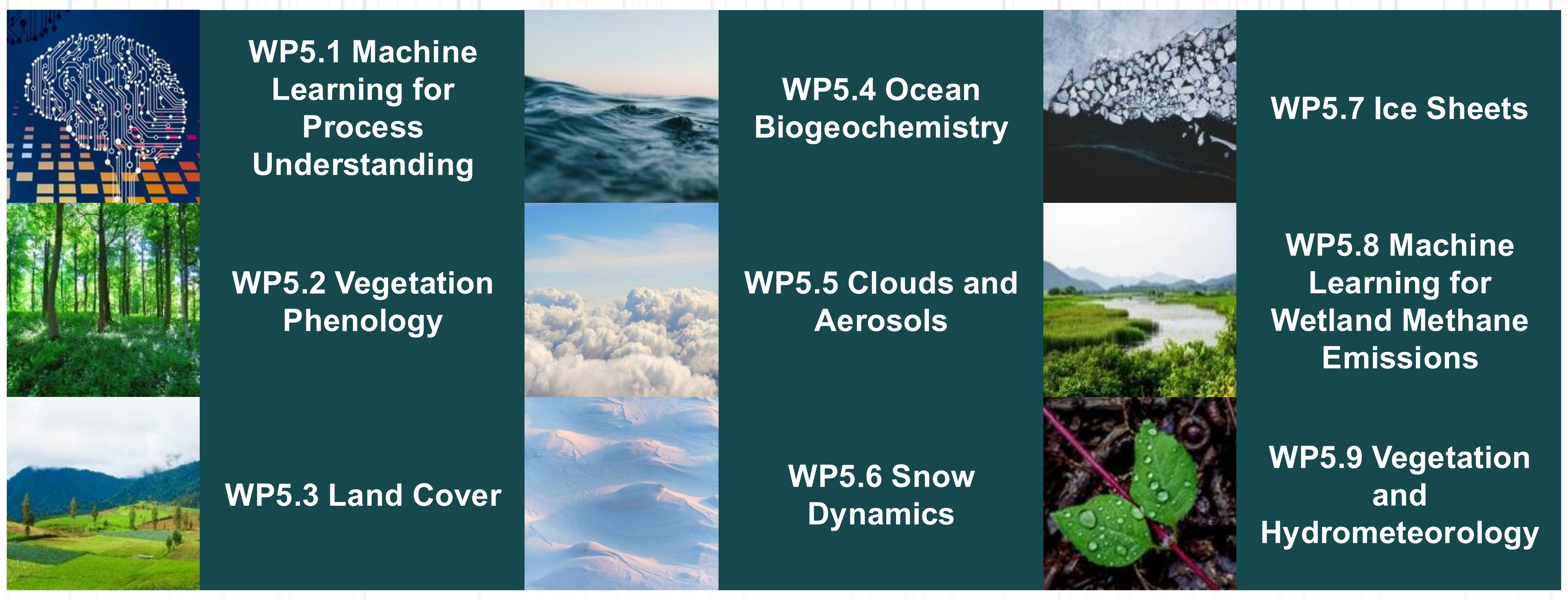


Figure 2: Regions where vegetation phenology is primarily driven by (a) soil moisture and (b) land surface temperature. Classification is based on at least two of three indicators: favourable climatological conditions, a positive correlation with Leaf Area Index (LAI), and a positive lagged relationship in which changes in soil moisture or temperature precede vegetation growth.

The processed LAI data are combined with soil moisture and land surface temperature observations to investigate the environmental controls on vegetation growth. Correlations, time-lag relationships, and climatological thresholds are used to identify regions where vegetation phenology is primarily driven by water availability or temperature. Figure 2 reveals distinct large-scale patterns, with moisture-driven ecosystems concentrated in semi-arid regions and temperature-driven ecosystems dominating many temperate and boreal environments. These results demonstrate how multiple ESA CCI datasets can be integrated to improve understanding of land-atmosphere interactions, vegetation responses to climate variability, and the processes that regulate the timing of the growing season.

CMUG Scientific Studies



CMUG Ocean Biogeochemistry study

This study evaluates how ESA CCI-derived physical and biogeochemical observations affect global ocean physical–biogeochemical reanalyses in the Met Office and Barcelona Supercomputing Center seasonal forecasting systems. Figure 3 shows that Met Office primary production is sensitive to the assimilation configuration: physics assimilation increases column-integrated primary production, largely through altered transport and nutrient supply, while adding OC-CCI chlorophyll assimilation modifies the spatial pattern and gives the closest agreement with the BICEP observation-based primary production product. The results highlight both the potential value of satellite biogeochemical assimilation and the need for model-specific multivariate balancing schemes, as subsurface and multivariate updates can improve impact but may also degrade model skill if poorly constrained.

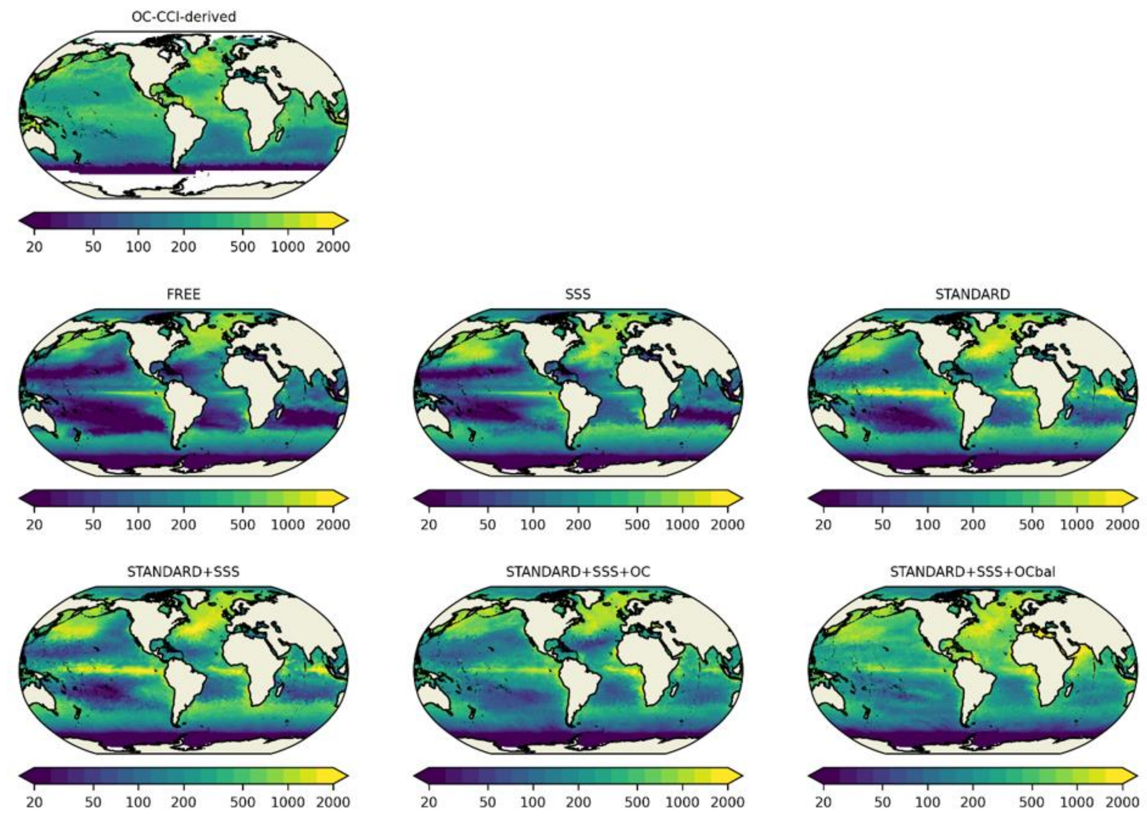


Figure 3: Monthly mean column-integrated primary production for June 2019 from each MO run and the BICEP product derived from OC-CCI data.

CMUG Cloud and Aerosol study

This study, led by ECMWF, BSC and DLR, assesses how ESA CCI aerosol and cloud observations support Earth system model assimilation and evaluation. ECMWF tests aerosol and cloud optical depth assimilation in IFS-COMPO, while BSC evaluates SLSTR aerosol assimilation in the MONARCH dust model. The study uses ESMValTool to compare model outputs with satellite observations. Figure 4 focuses on the BSC experiments, showing how MONARCH dust optical depth changes after assimilation and how the analysis compares with ESA-CCI dust optical depth observations. The results show that assimilation reduces the average MONARCH dust optical depth and brings the analysis closer to the ESA-CCI dust optical depth product.

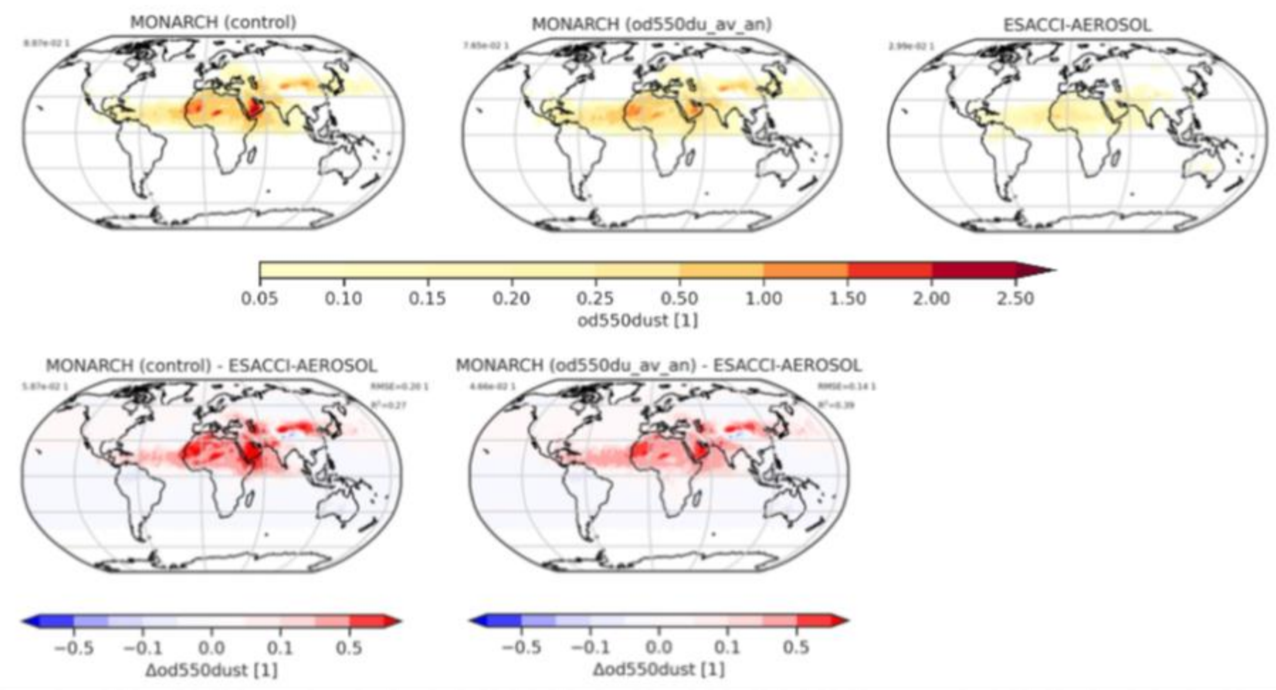


Figure 4: Monthly averages of dust optical depth (DOD) at 550 nm computed using ESMValTool: MONARCH control simulation (FR experiment in table 2 of Escribano et al. 2024) in the top left map, MONARCH analysis (SLSTR-px3 experiment in table 2 of Escribano et al. 2024) in the top middle map, ESA-CCI (SLSTR SU 1.12) in the top right map. In the bottom: average differences between the control simulation and ESA-CCI (left map), average differences between the analysis and ESA-CCI (middle map). Spatial RMSE and squared correlation (R2) are displayed on the right of differences maps.

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