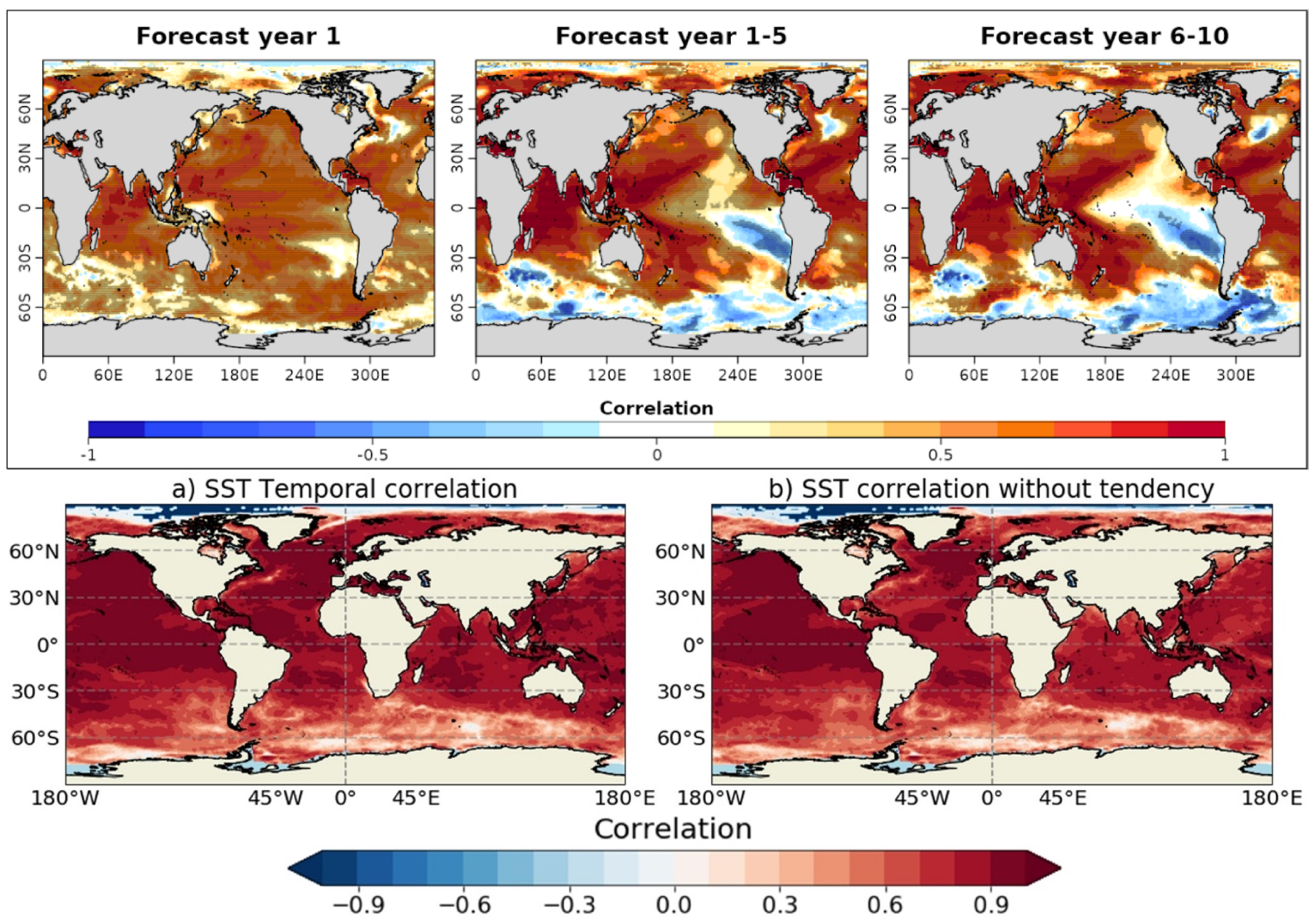
# CMUG WP4 Science Highlights

## Overview

Work Package 4 of the CMUG investigates the new ways to exploit CCI products in MIP experiments. For this summary the main focus is put on the consistency of observational/re-analysis products in the context of CMIP model evaluation. Specifically, we find long (five to 10 year) predictability of the SST, in particular in regions where re-analysis products agree (Topic1 ). We further find that Heat Wave (HW) indices are about as constrained in CMIP6 as in re-analysis data (Topic 2). Topic 3 illustrates characteristic impact of a biom on the heat exchange/soil moisture cycle, which will be used for model evaluation. Topic 4 is about the consistency of Arctic Sea Ice Area observations on different time scales to find the optimal temporal averaging scale. Over all this work helps to refine objectives for model evaluation for a meaningful assessment.

## Topic 1: Decadal Climate Prediction Project - Skill assessment




An extensive skill assessment of the EC-Earth decadal prediction system (Ref 1) has been performed, the SST skill for three forecast horizons is shown in Figure 1; Predictions show high levels of skill even for lead times of six to ten years. However, some regions show significantly negative ACCs which could indicate initialization shocks (e.g. the North Atlantic), problems with oscillation frequencies (e.g. ENSO) or model drift effects. The consistency between the observational products used for skill verification (ESA L4, HadISSTv1.1 and ERSST) is addressed in Figure 1, bottom. It shows that the minimum point-wise correlation between the 3 products is generally very large, and that it is unrelated to the presence of a warming trend.

Figure 1: **Top:** Anomaly correlation coefficient (ACC) for the annual sea surface temperature in the CMIP6 decadal prediction system with EC-Earth for forecast years 1 (left panel), 1-5 (middle panel) and 6-10 (right panel). The ACC is computed for the period of 1982-2020 between the model ensemble mean and the mean of three observational products. Stippling indicates a 95% significance level. **Bottom:** Minimum point-wise correlation between the three observational datasets for the raw (left) and linearly detrended (right) annual mean SST.

## Topic 2: Heat Waves (HW) in CMIP6

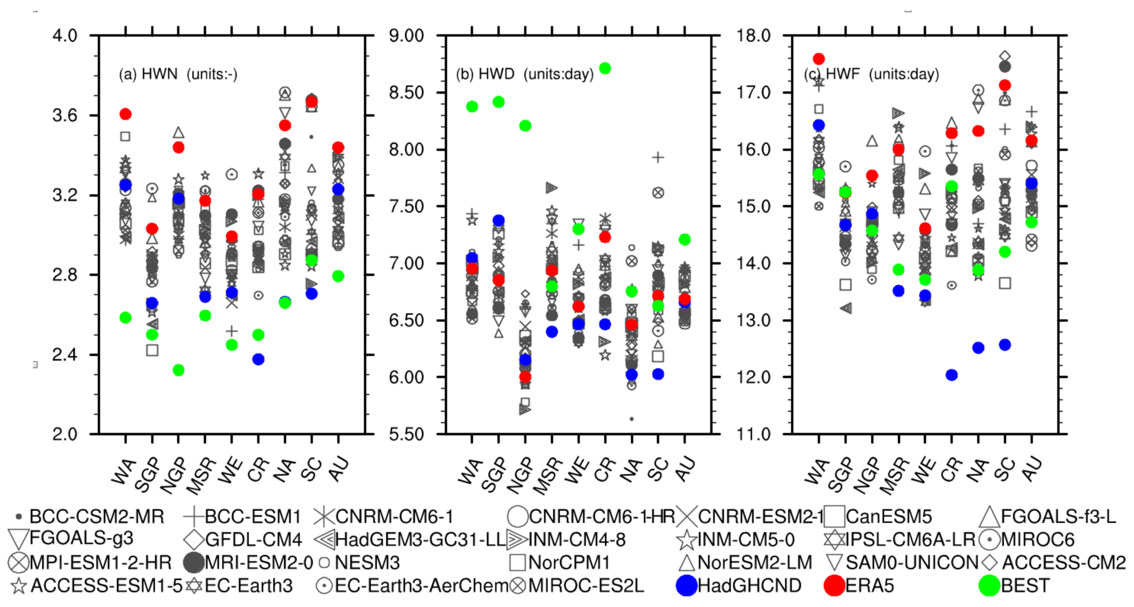


Figure 2: Selected HW indices computed using AMIP models (markers) and observations (colored) during the 1979-2014 period over 9 regions in North America (WA, SGP, NGP), Europe (MSR, WE, CR), East Asia (NA, SC) and Australia (AU), Ref. 2.

The consistency of HW regional indexes in AMPI models and three re-analysis products is investigated in Figure 2. While there is a comparable spread between the models as there is between the regions, the re-analysis results have just as much dispersion. Compared to HadGHCND re-analysis, AMIP and Historical simulations show a larger spatial but smaller temporal extend in heat waves (Figure 3). The impact of warming scenarios on HW days becomes evident in Figure 3 where in historical simulations most of Western Europe experiences 40 to 50 HW days. For a limited warming of 1.5K this increases to about 100 day, 100 to 130 days for 2K, and 130 to 160 HW days for 3K warming.

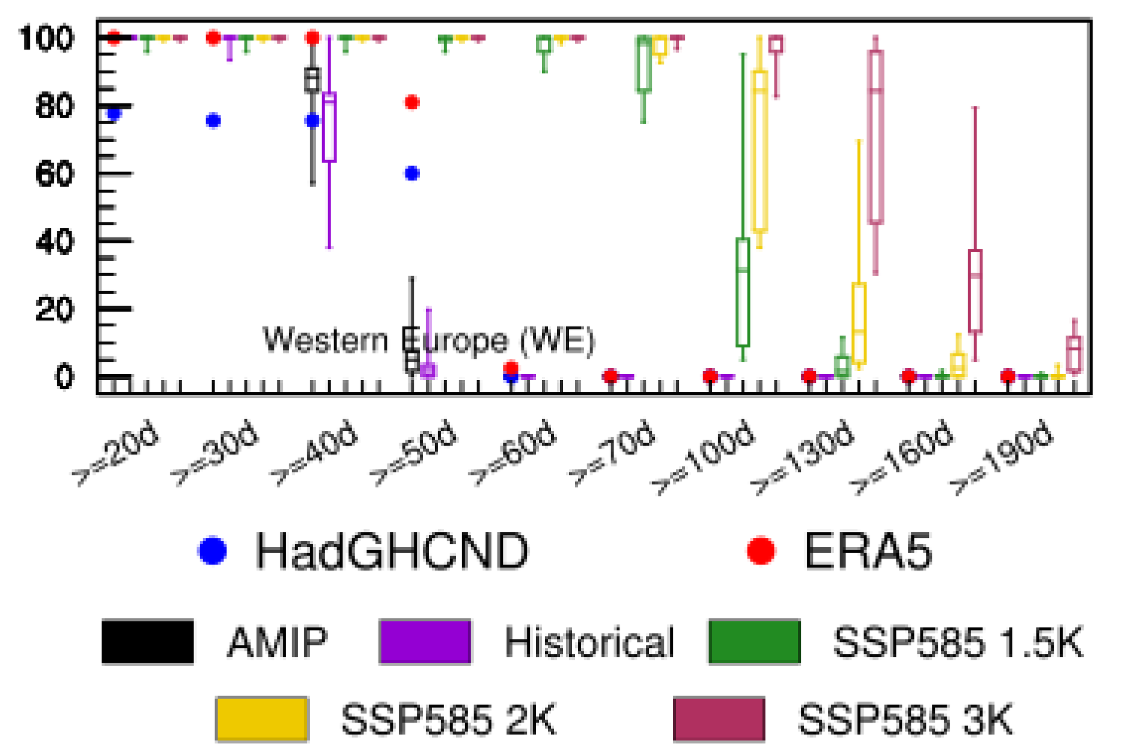



Figure 3: Spatial percentage of the Western Europe region surpassing a threshold on yearly HW days by climate scenario, Ref. 2.

## Topic 3: LST minus $T_{AIR}$ and veg. moisture stress

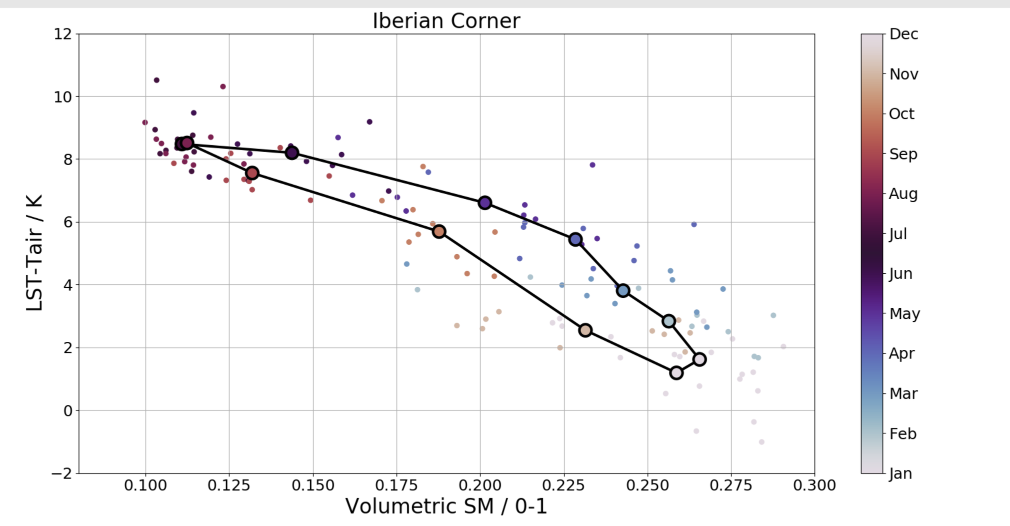



Figure 4: Relationship between the monthly mean LST minus air T difference (LST-airT) and near surface soil moisture for a region of cropland in southern Portugal. Data sources: CCI LST (Aqua), CCI SM (Active product) and ERA 5.

Figure 4 shows a clear negative relationship between the LST-airT and near surface soil moisture (SM) for a region dominated by cropland. Changes in leaf transpiration are a likely mechanism for this behaviour, and is expected to vary across biomes. This work will quantify this relationship across large biome scales using satellite observations to evaluate it in climate/Earth System Models.

## Topic 4: Optimal temporal scales for model evaluation

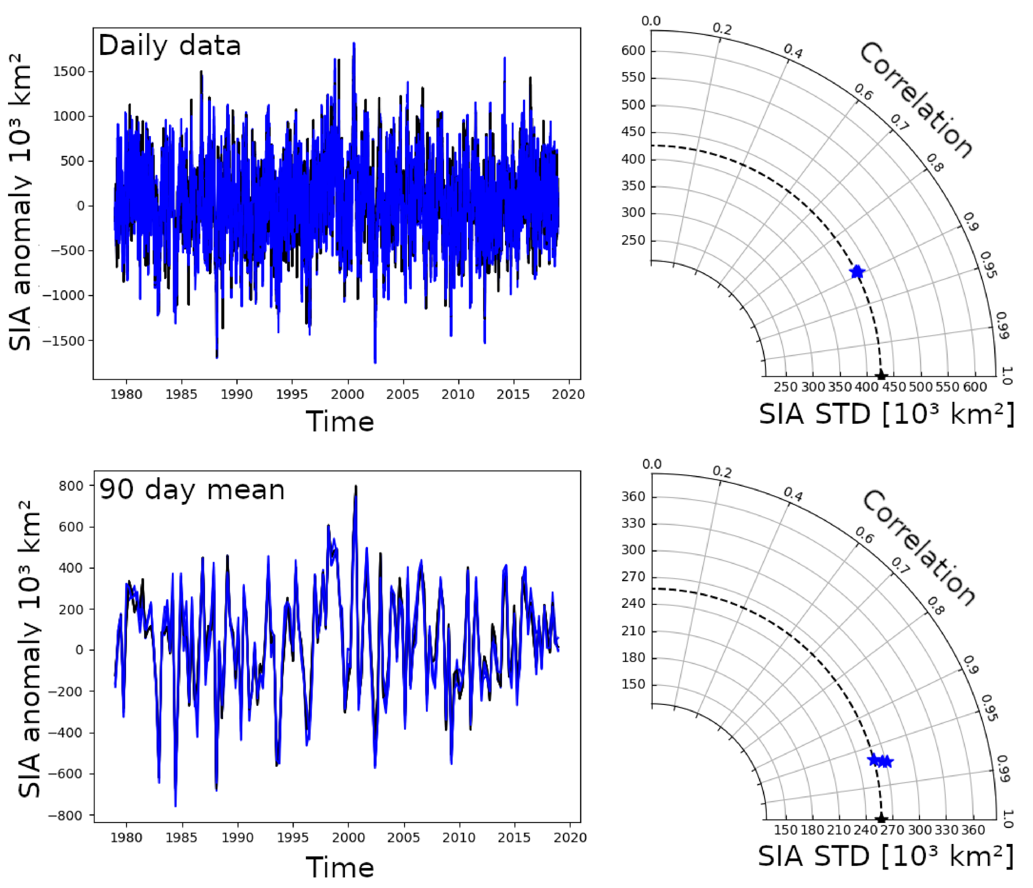



Figure 5: Sea Ice Area anomaly time series from four satellite products on the left and corresponding Taylor diagram (standard deviation vs. correlation) on the right. Based on daily data (top) and 90 day averages (bottom).

To the optimal temporal scale for averaging the Arctic Sea Ice Area (SIA) reduces the observational error while preserving most of the real signal. For a lack of ground truth, we investigate (Figure 5) how the inter-product agreement (correlation) increases with increasing averaging periods. For averaging periods below about 30 days, the cross product errors reduce quickly while for longer averaging periods only the SIA standard deviation (i.e. the signal) is reduced (Figure 6). The results from observations agree with statistical model results where the observational uncertainty temporal scale is about 20% to 30% of the variability temporal scale.

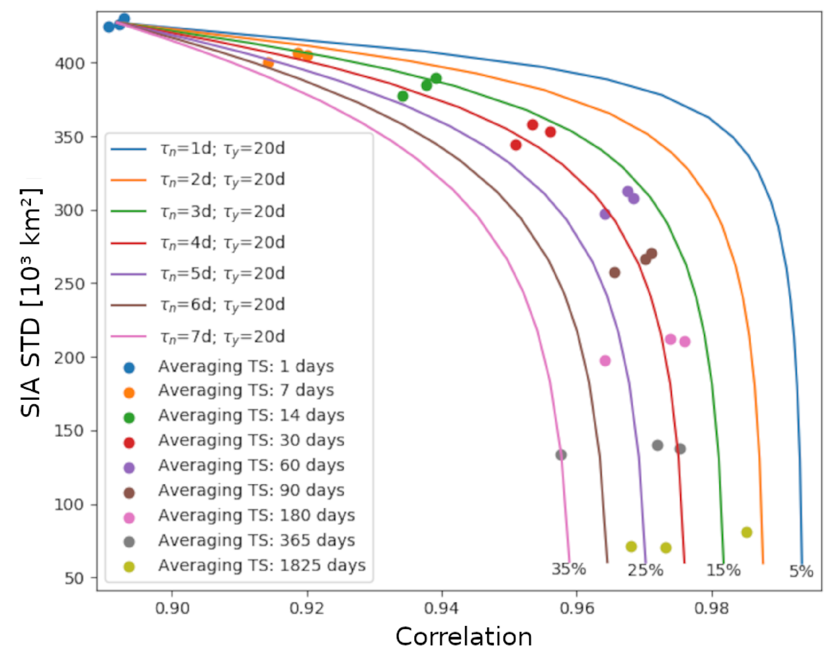



Figure 6: Sea Ice Area standard deviation of NASA Bootstrap, NASA Merged and OSISAF passive microwave algorithms and corresponding correlation towards SIA anomaly based on NASA Team algorithm. Lines correspond to analytical results from AR(1) processes for the SIA variability and errors with different temporal correlation length scales, for comparison.

## References


1. **Bilbao, R., Wild, S., Ortega, P., et al.** (2021): Assessment of a full-field initialized decadal climate prediction system with the CMIP6 version of EC-Earth, *Earth Syst. Dynam.*, 12, 173-196, doi:/10.5194/esd-12-173-2021.

2. **Zhao, Al-Yaari, Cheruy** (In preparation): Heatwave characteristics and uncertainties in historical and future climate based on the CMIP6 models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