climate change initiative

CLIMATE MODELLING USER GROUP

CMUG Phase 1 Work on LST-Air Temperature and Vegetation Processes

Robert King, Debbie Hemming

cmug cci

Outline

Three science work packages shown here

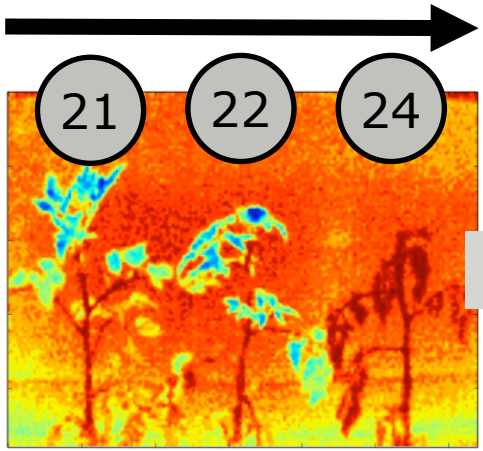
- WP4.8
  - Modelling Vegetation Moisture Stress with Land Surface Temperature (LST) to Air Temperature (Tair) difference,
- WP4.9
  - Application of the LST-Tair metric developed in WP4.8 within ESMValTool to evaluate CMIP6 earth system models,
- WP4.10
  - Comparison of vegetation variations – satellite products and models.

And their link to

- WP5.3 and WP5.4
  - ESA CCI LST diagnostic in ESMValTool.

WP4.8 & 4.9: LST – Air Temperature Difference

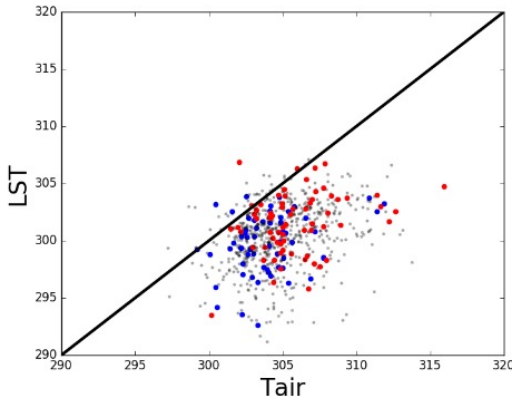
Leaf Temp Increases



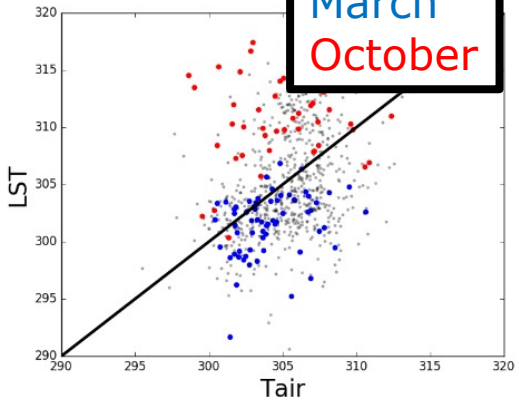
Air: 22

Moisture Stress Increases

Effect visible at leaf-level and satellite/model grid box scales



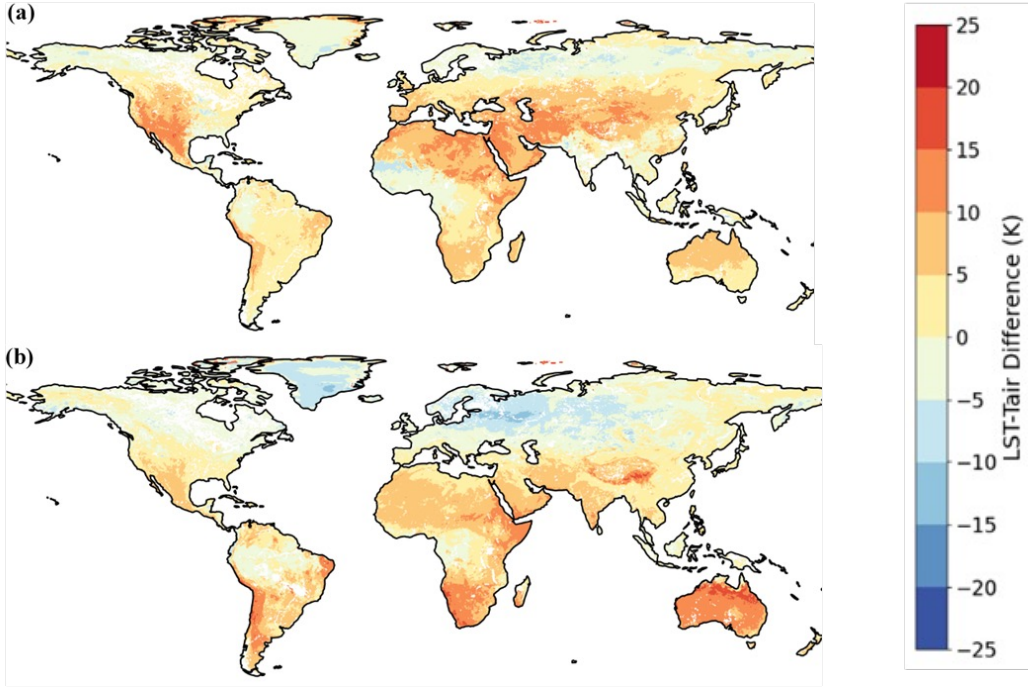
North West



North East

WP4.8: LST – Air Temperature Difference

- LST – Air Temperature (Tair) shows variation across biomes and seasons,
- Driven by radiation, vegetation, soil moisture… changes,
  - Top July 2003,
  - Bottom January 2004.



CCI LST (Aqua MODIS), ERA5-Land Tair

WP4.8: Relationship to Soil Moisture

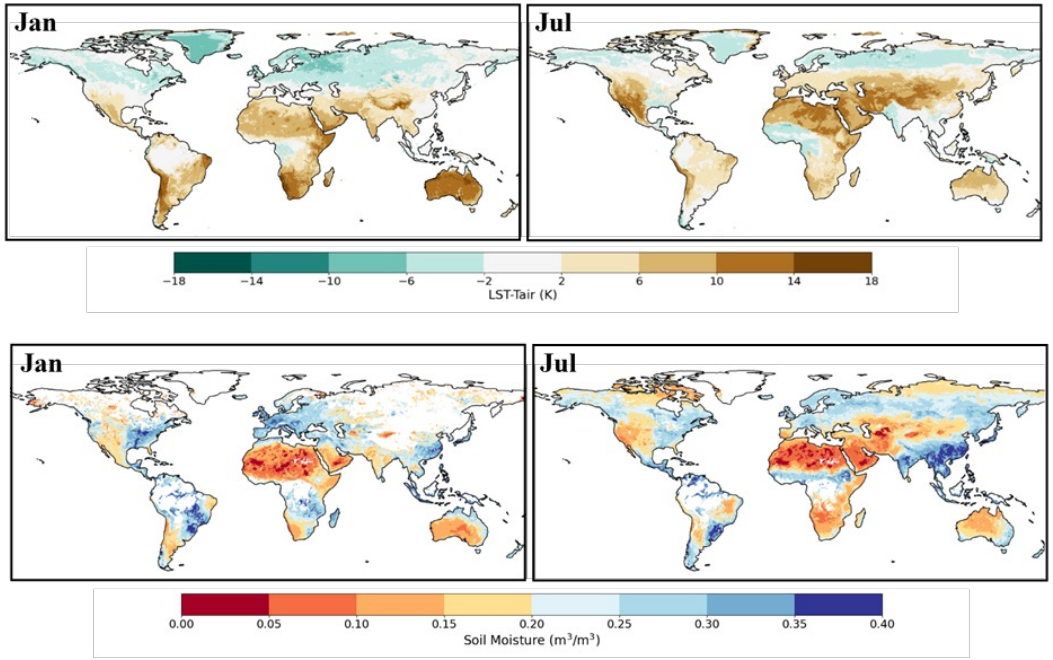
LST – Tair and Soil Moisture show similarities in their large-scale seasonal cycles.

Figure is the January and July climatologies (2003-2013).

Shows a qualitative indication of a broad negative relationship.

+ve = LST>Tair
e.g., NH mid-latitude summer.

-ve = LST<Tair
e.g., NH mid-latitude & boreal winter.



WP4.8: Case Study - 2003 European Heatwave

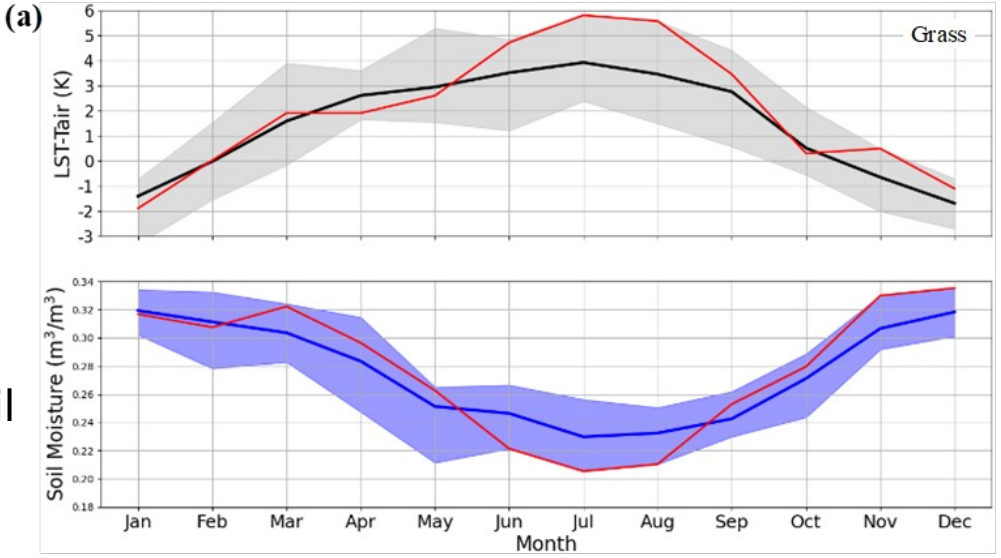
- The 2003 European heatwave was an extreme heat and drought event, eg Vandentorren et al. 2004, Fischer et al. 2007.
- Lead to strong land-surface responses and feedbacks on local climate, including low soil water content, reduced evapotranspiration and latent cooling, and increased sensible heat fluxes
- This resulted in amplification and persistence of the heatwave and drought conditions
- Use France as a case study of how LST – Tair can be used to detect heatwaves
- Concentrate on three biomes/plant functional types (Aggregated from CCI Land Cover)
  - Grass – only show these results here
  - Broadleaf Trees (BT)
  - Needleleaf Trees (NT)

Vandentorren, S. et al. 2004 Mortality in 13 French Cities During the August 2003 Heat Wave. American Journal of Public Health. 94(9), 1518.
Fischer, E.M. et al. 2007 Soil moisture-atmosphere interactions during the 2003 European summer heat wave. Journal of Climate. 20(20), 5081-5099.

WP4.8: Case Study - 2003 European Heatwave

- Monthly climatology of LST-Tair and Soil Moisture
- Examine this for the three biomes Grass, Broadleaf Tree & Needleleaf Tree

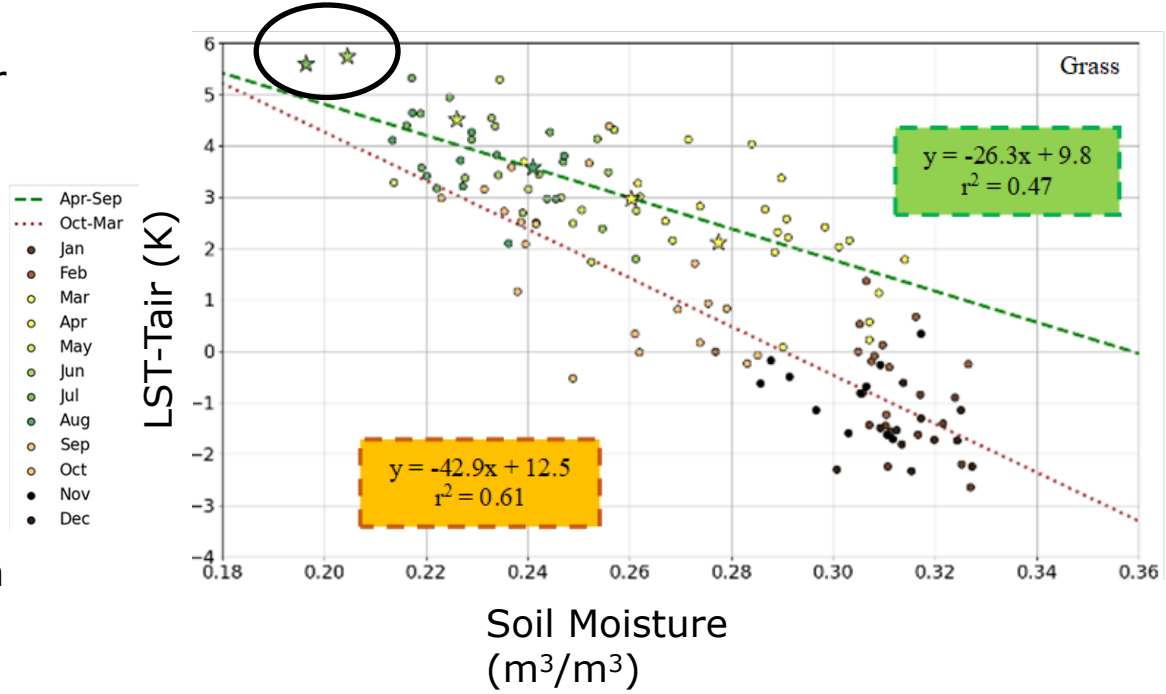
- Black: LST – Tair
- Blue: CCI Soil Moisture
- Shading: Range 2003-2013
- Red: 2003 for both LST-Tair and Soil Moisture
- Summer 2003 shows the maximum of LST-Tair and minimum of Soil Moisture.



WP4.8: Case Study - 2003 European Heatwave

- Monthly pair of LST-Tair and Soil Moisture is shown for 2003-2013,
- Summer (April-September) / Winter (October-March) fits given, show the effect of vegetation & evapotranspiration,

- Difference in slopes suggests the cooling influence from evapotranspiration,
- Consistent with other studies showing low soil moisture was a major contributor to the intensification of the 2003 European heat wave, Fennessy and Kinter, 2011.

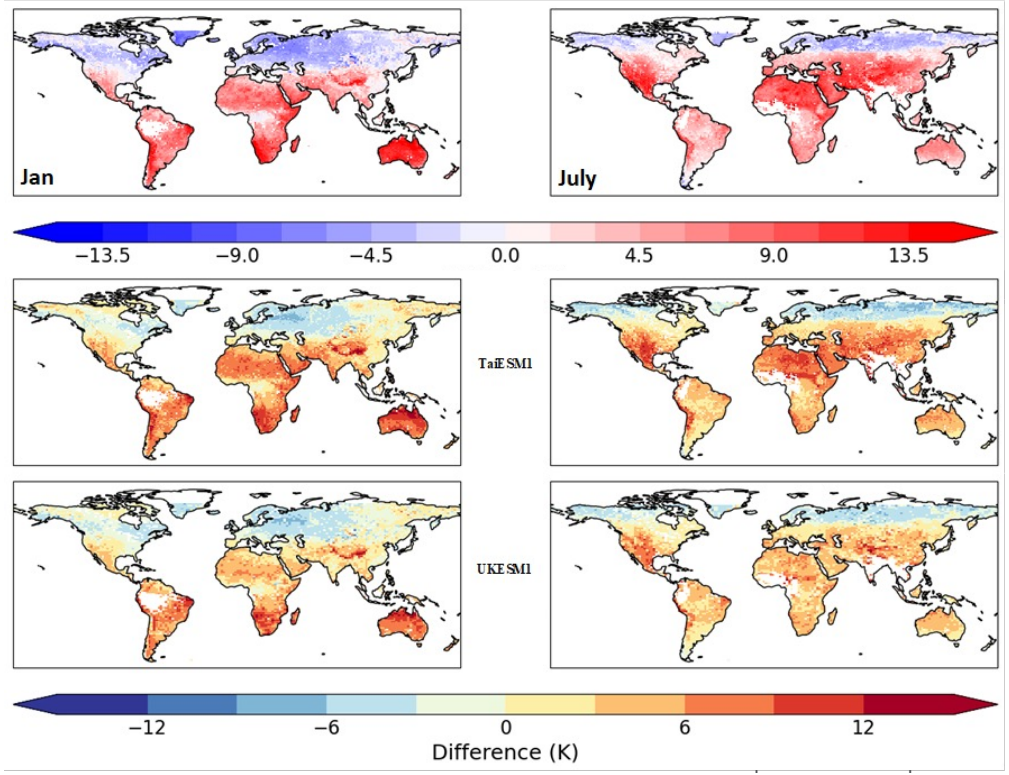


Fennessy, M.J. and Kinter, J.L 2011 Climatic feedbacks during the 2003 European heat wave. Journal of Climate. 24(23), 5953-5967.

WP4.9: Evaluation of CMIP6

With the LST-Tair and Soil Moisture relationship developed, consider the behaviour of the CMIP6 models.
Like with observations, this is a valid relationship over all land points, but we consider only vegetated regions in our analysis.

TaiESM and UKESM can be seen to have different climatological values for LST-Tair.

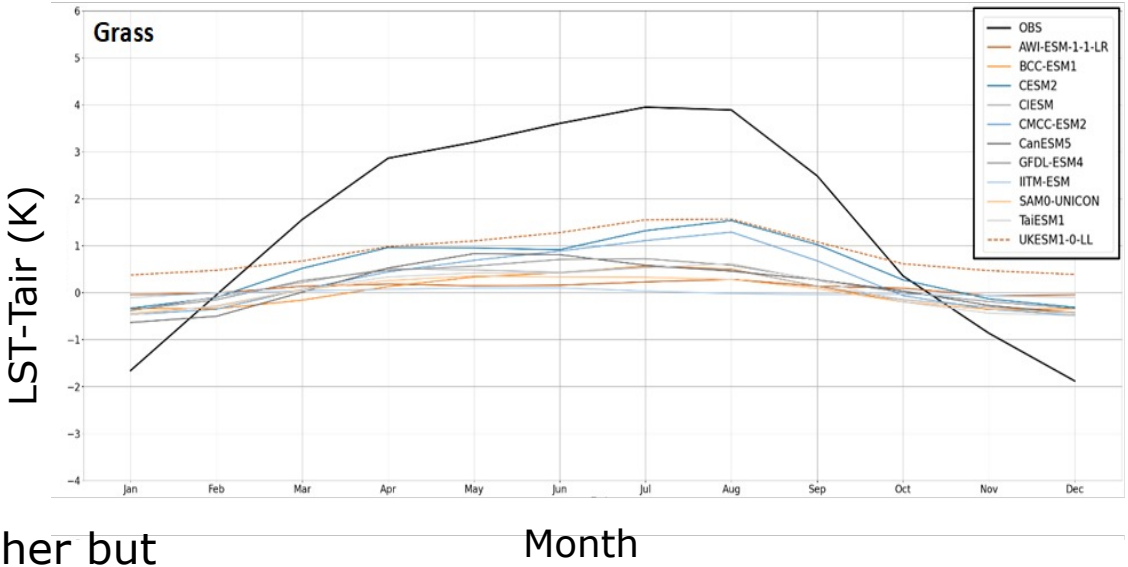


WP4.9: Evaluation of CMIP6

Climatology (2003-2013) of monthly mean LST-Tair for the three biomes studied over France:

- Grass – shown here
- Broadleaf Tree
- Needleleaf

Black is CCI LST and ERA5 Tair
Coloured lines are CMIP6 models

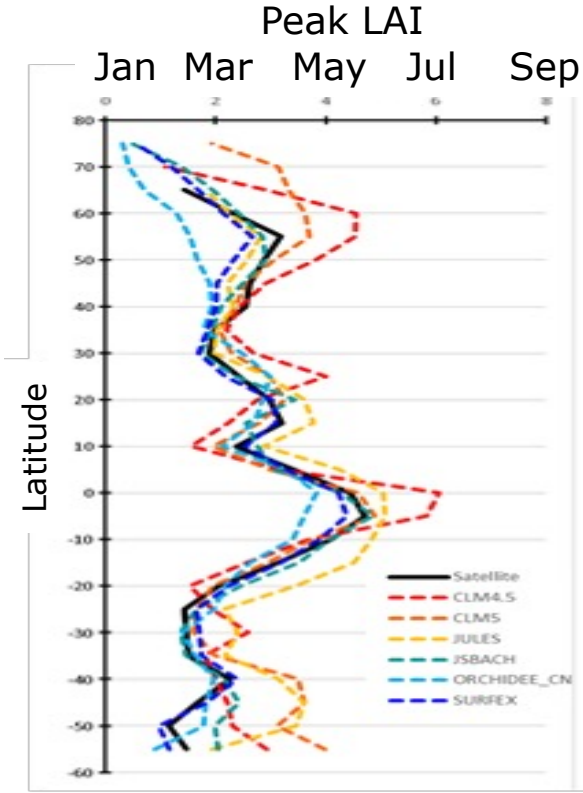


Models are consistent with each other but observations show several degrees variation from the models.

WP4.10: LAI Seasonal Variation

Aim: Compare the timing and magnitude of seasonal variations in vegetation

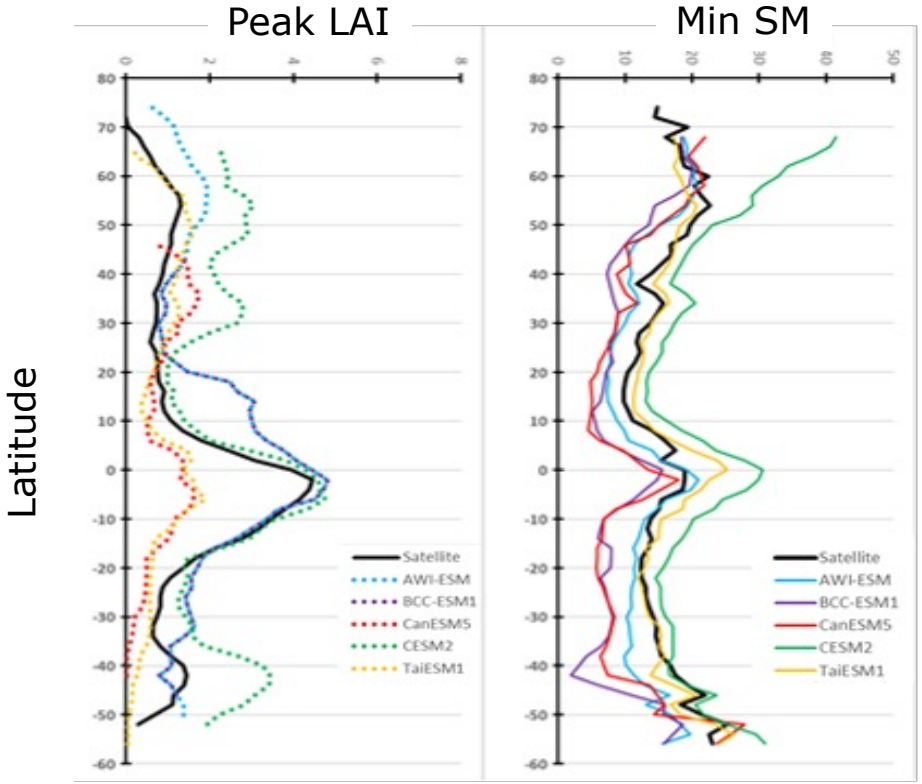
- This is strongly influenced by seasonal climate, particularly moisture availability,
- exert a large-scale influence on processes that exchange heat, mass and momentum between the land and atmosphere,
- This study provides a preliminary evaluation of large-scale variations in vegetation seasonality and soil moisture,
  - historic runs of a range of offline LSMs (used in the EU CRESCENDO project),
  - LAI from Copernicus Global Land Service,
- Leaf Area Index is the primary variable used in LSMs and ESMs for scaling-up from leaf to canopy level processes.



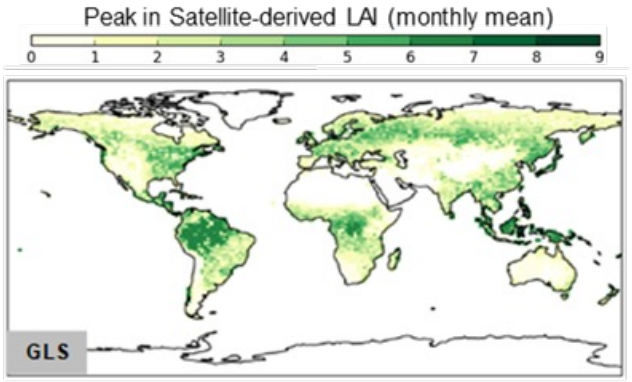
WP4.10: LAI Seasonal Variation

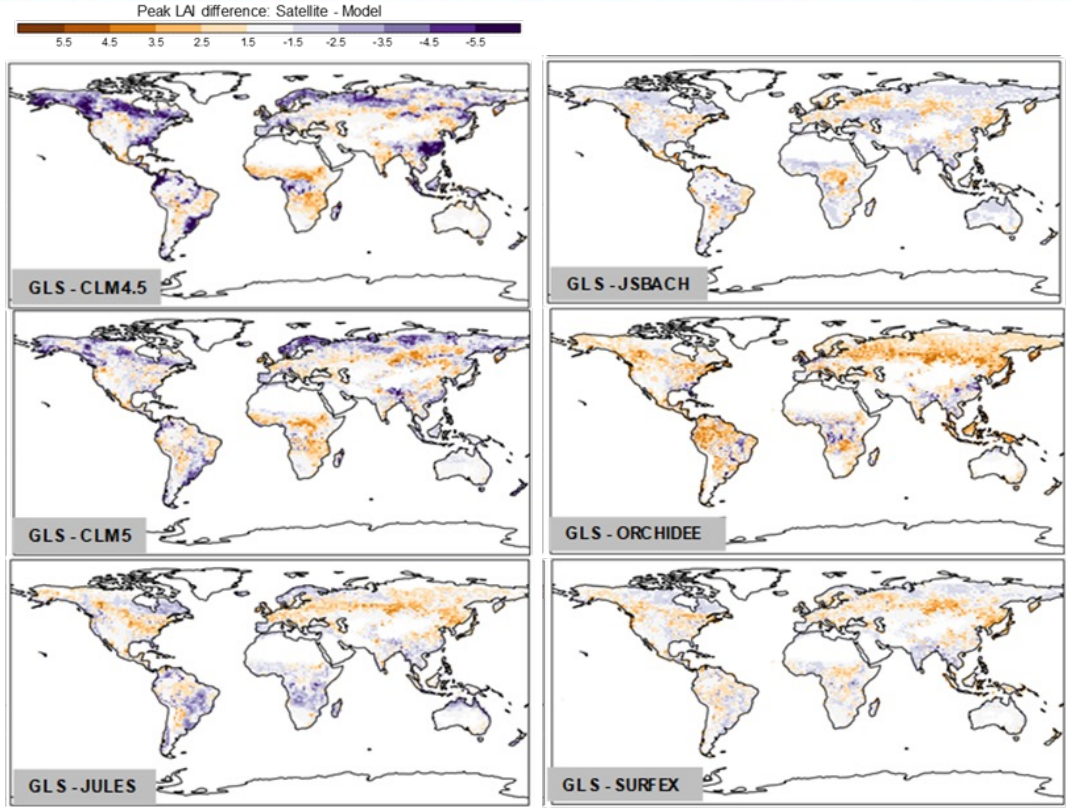
- Peak LAI value and Minimum soil moisture,
- Both from monthly mean values,
- Zonal peaks correspond to the latitude's monthly peak pattern.

- LSMs have broad agreement in zonal 'shape' but magnitude varies
  - Both LAI and SM.



WP4.10: LAI Seasonal Variation



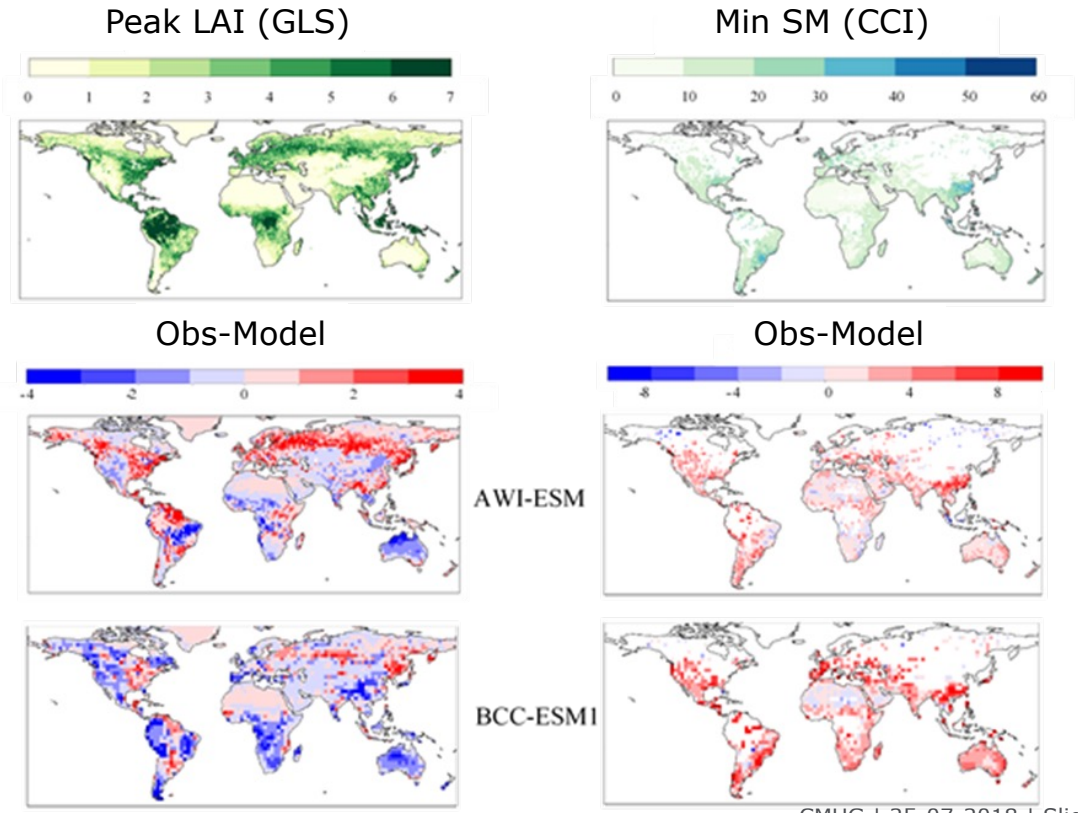


Climatology of LAI Peak (satellite) compared to LSM value
Shown is difference in months
Significant variation spatially and temporally between the different models.

WP4.10: LAI Seasonal Variation

Climatology of Peak LAI and Minimum Soil Moisture (2003-2014).
Only showing two ESMs (not LSMs).

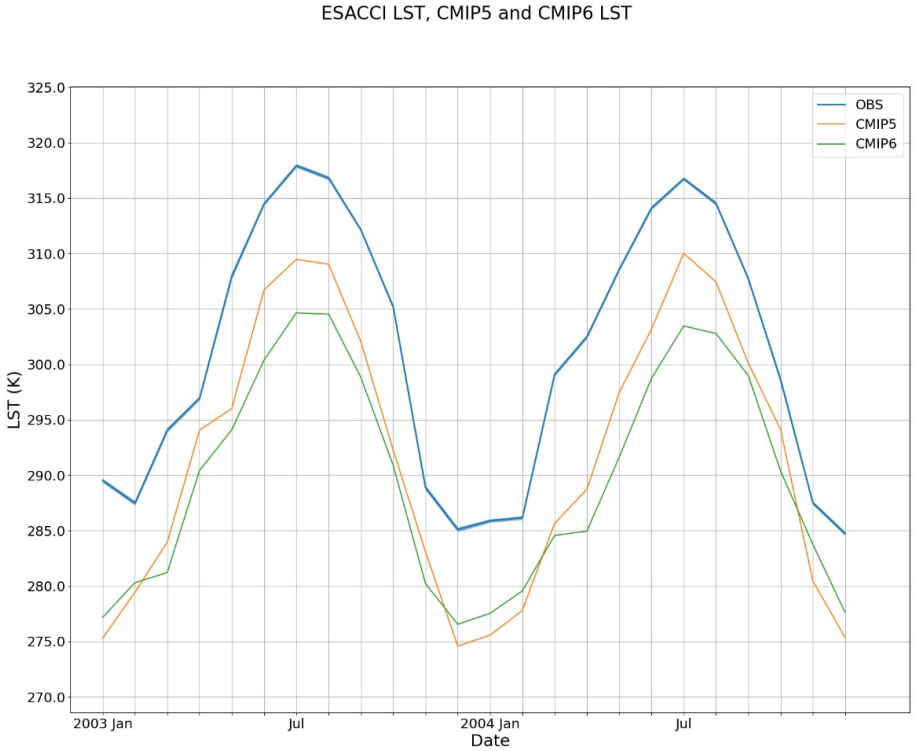
LAI in the CMIP6 ESMs show large (about -4 to +4) differences to the climatology, and show spatial inconsistencies across ESMs.



WP5.3 & WP5.4: Using Uncertainties

- Propagate the individual uncertainty components to get area “average” uncertainty,
- Created an ESMValTool diagnostic to evaluate CMIP5 and CMIP6 models against the CCI LST product,

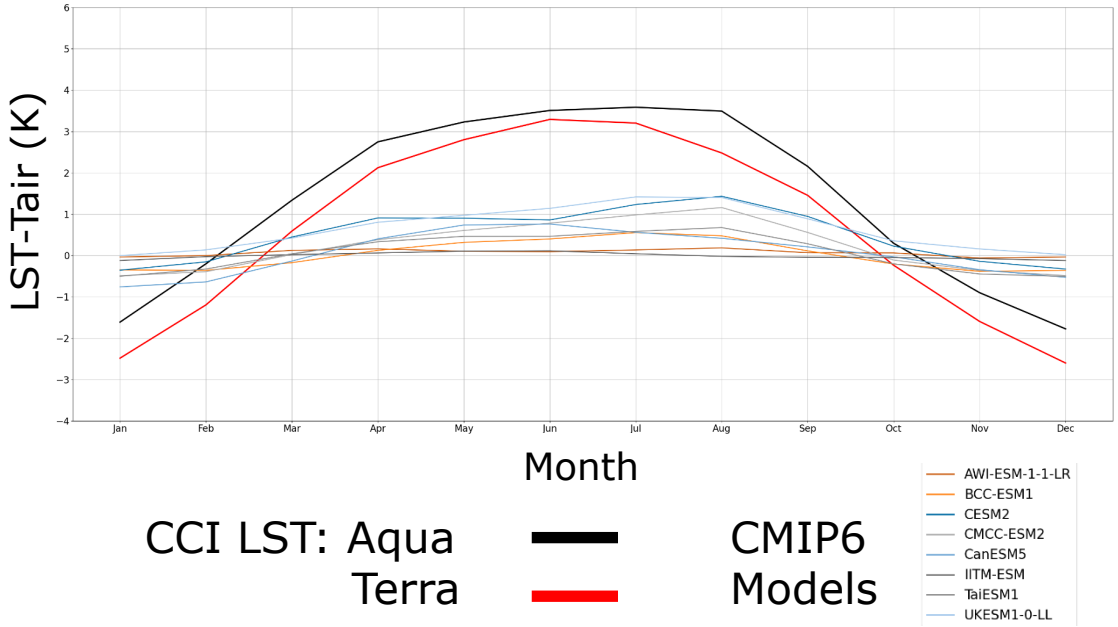
- Region of shrubland in California, HadGem2 and UKESM, with CCI LST + uncertainty.



Choice of Platform

- LST work chose Aqua MODIS,
- Overpass time ~1330 Local coincides with peak vegetation activity,
- Consider Terra MODIS ~1030L overpass…
- Care needs to be taken when choosing satellite product for model evaluation.

France Grassland Climatology (2003-2013)



Summary

- LST to Air Temperature difference can be used as a measure of vegetation stress,
- LST-Tair is out of phase with soil moisture,
- 2003 European Heatwave shows in LST-Tair,
- Different satellite LST platforms give a different evaluation against CMIP6 models.

- LAI and Soil Moisture peaks/minimums are linked,
- Link can be used to evaluate CMIP6 models' vegetation processes,
- Large differences seen between different CMIP6 models.