Evaluation and probabilistic assessment of vegetation contribution to seasonal climate prediction in EC-Earth

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Outline

Motivations

- Relevance of vegetation effects for climate prediction
- Lack of sensitivity to vegetation variability in state-of-the-art climate prediction systems and Earth System Models

Methodology and model setup

- Inclusion of an effective vegetation cover as a function of vegetation Leaf Area Index (LAI) in EC-Earth
- Experiment setup

Results

- Probabilistic skill assessment
- European Summer heat wave of 2003

Conclusions

Implementation of effective vegetation cover (Ceff) as a function of vegetation Leaf Area index

Effective fractional vegetation cover

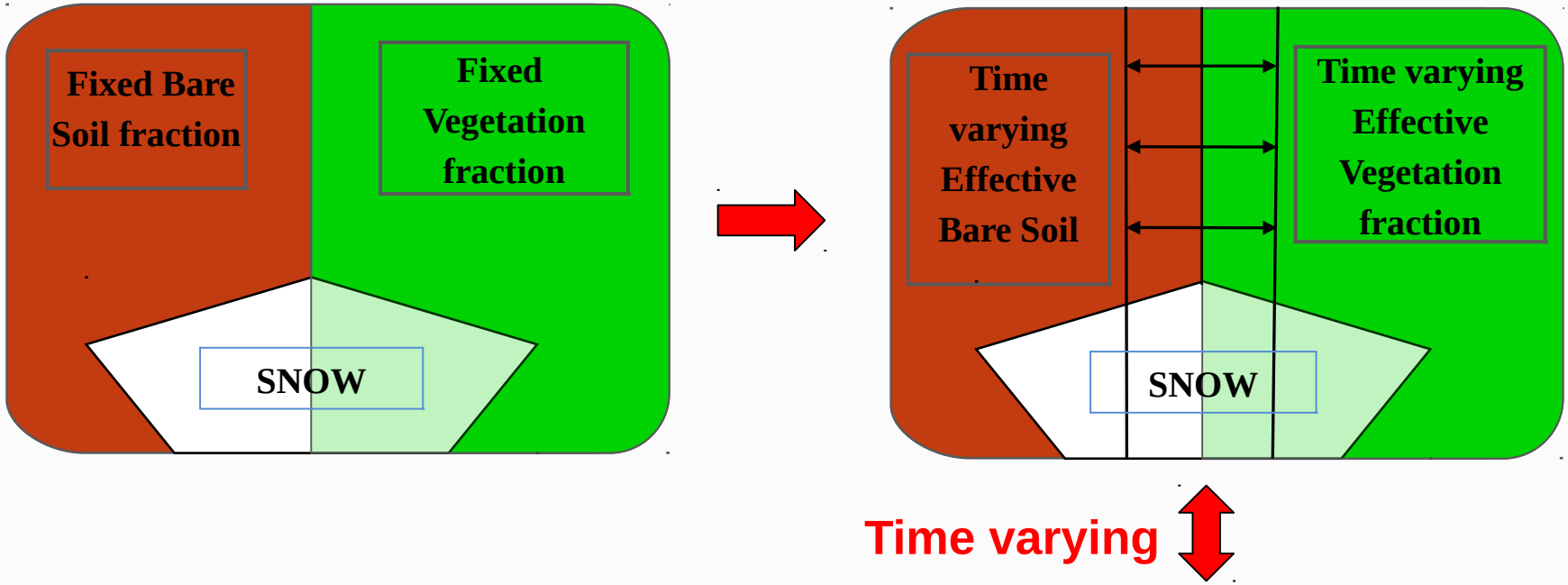
$Cv_{eff}[t] = Cv_L(LAI_L[t])*A_L + Cv_H(LAI_H[t])*A_H$

$A_{L,H}$ Max fractional coverage

Bare soil fraction

$bareS[t] = 1-Cv_{eff}[t]$

$Cv_{L,H}[t] = 1-\exp(-0.5*LAI_{L,H}[t])$ Vegetation density



Time varying

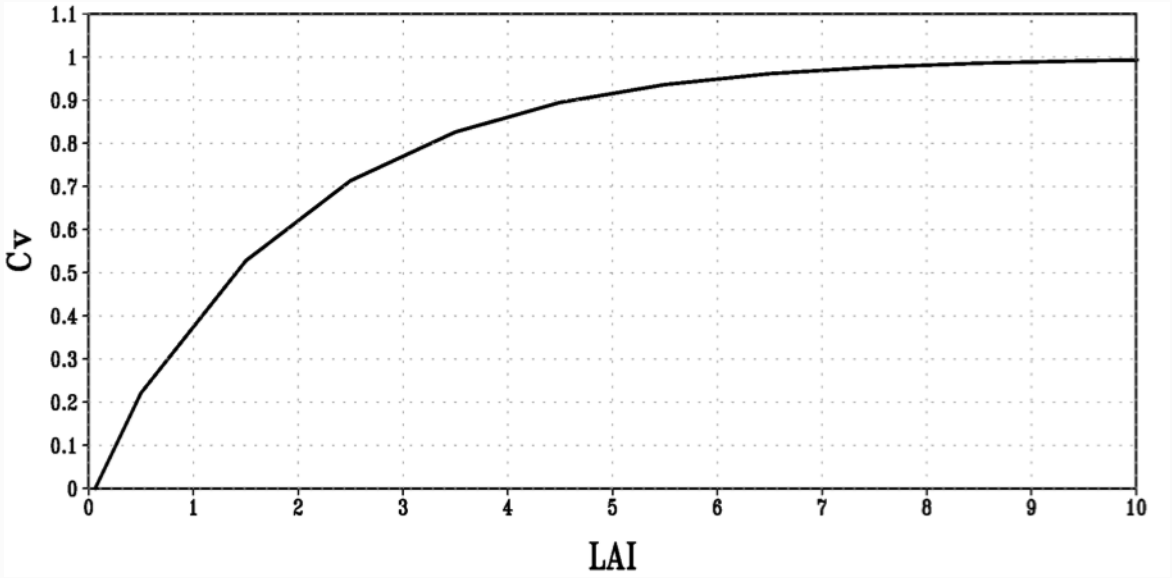
i. **Evapotranspirating surfaces**

i. **Roughness length**

i. The contribution of root density of each vegetation-type to the **Field Capacity**

ii. Surface **Albedo**

Implementation of effective vegetation cover as a function of vegetation Leaf Area Index



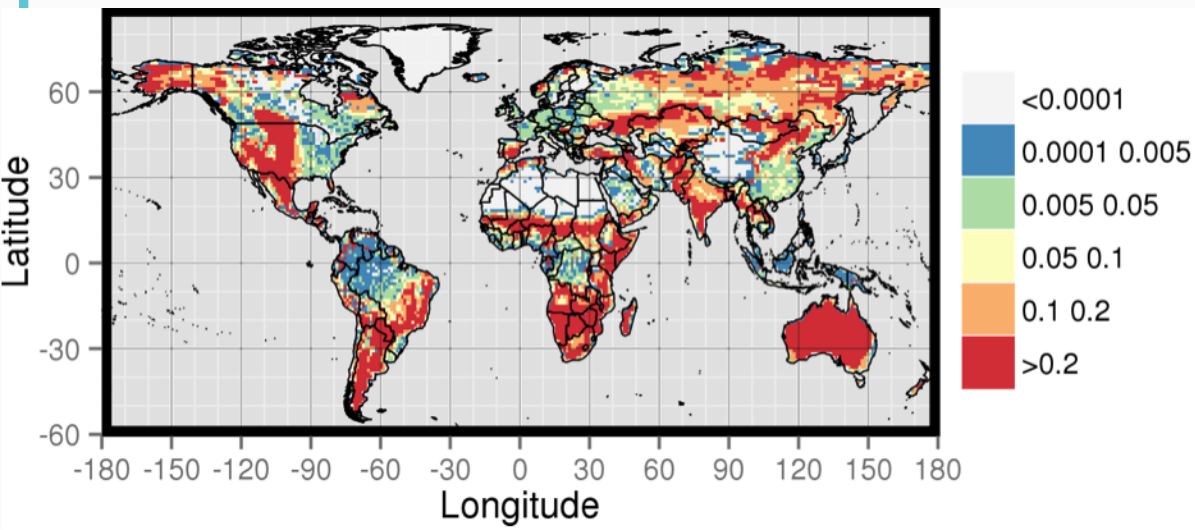
Lambert-Beer formulation for Cv as a function of LAI

$$Cv_{L,H}[t] = 1-\exp(-0.5*LAI_{L,H}[t])$$

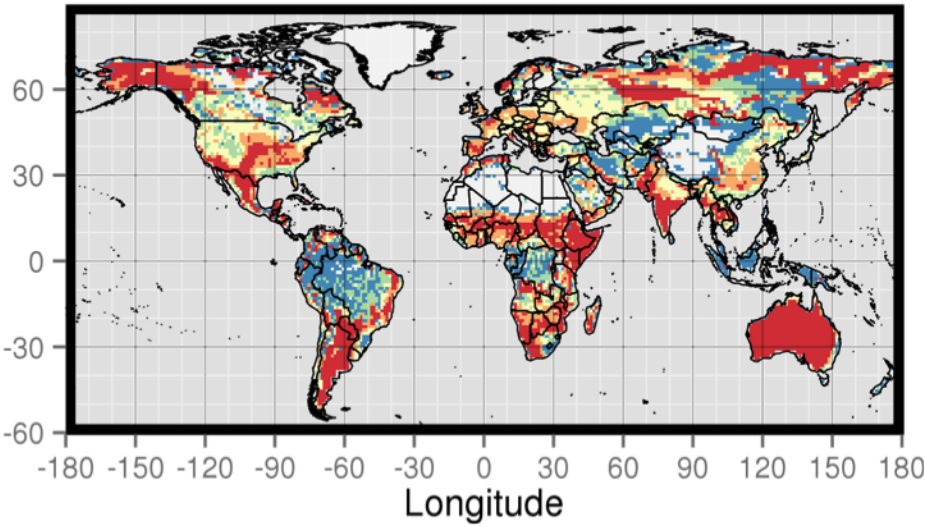
Smith et al. (2011)

Implemented effective cover interannual variability (std dev)

JJA Cv_{eff}



DJF Cv_{eff}



Experiment setup

- Model version: EC-Earth 2.4 with dynamic relation between LAI and vegetation cover;
- **Vegetation**: prescribed from LAI3g observational dataset (Zhu et al. 2013);
- 10 members ensemble, Start dates: 1 May, 1 November, Forecast length: 7 months;
- Period: 1982-2009
- Initial conditions *:
  - Land surface and atmosphere: ERA-INTERIM (10 members);
  - Ocean and sea ice: NEMOVAR/ORAS4 (5 members);
- **Control experiment**: same but with constant LAI.

* Du et al. (2012), Guemas et al. (2014)

Improved Sensitivity to vegetation variability in EC-Earth

RECENT PAPER PUBLISHED:

- Alessandri A., Catalano F., De Felice M., van den Hurk B., Doblas-Reyes F., Boussetta S., Balsamo G., Miller P. A., 2017: Multi-scale enhancement of climate prediction over land by increasing the model sensitivity to vegetation variability in EC-Earth. Clim. Dyn., 49, 1215-1237, doi:10.1007/s00382-016-3372-4

-Implementation of effective vegetation cover as a function of vegetation Leaf Area index
-deterministic skill assessment

Probabilistic skill measures

Brier score $BS = Rel - Res + UNC$ → overall accuracy

Sharpness $$Sh = \sqrt{\frac{1}{n}\sum_{i=1}^{I} N_i (y_i - \bar{y})^2}$$ → signal of the predictions

Discrimination $$d = \left| \mu_{y|o_1} - \mu_{y|o_0} \right|$$ → ability to produce different forecasts for different outcomes of the predictand

Resolution $$Res = \frac{1}{n}\sum_{i=1}^{I} N_i [p(o_1|y_i) - \bar{o}]^2$$ → degree to which the forecasts sort the corresponding conditional observations into different groups

Reliability $$Rel = \frac{1}{n}\sum_{i=1}^{I} N_i [y_i - p(o_1|y_i)]^2$$ → correspondence of the forecasts to the average observation

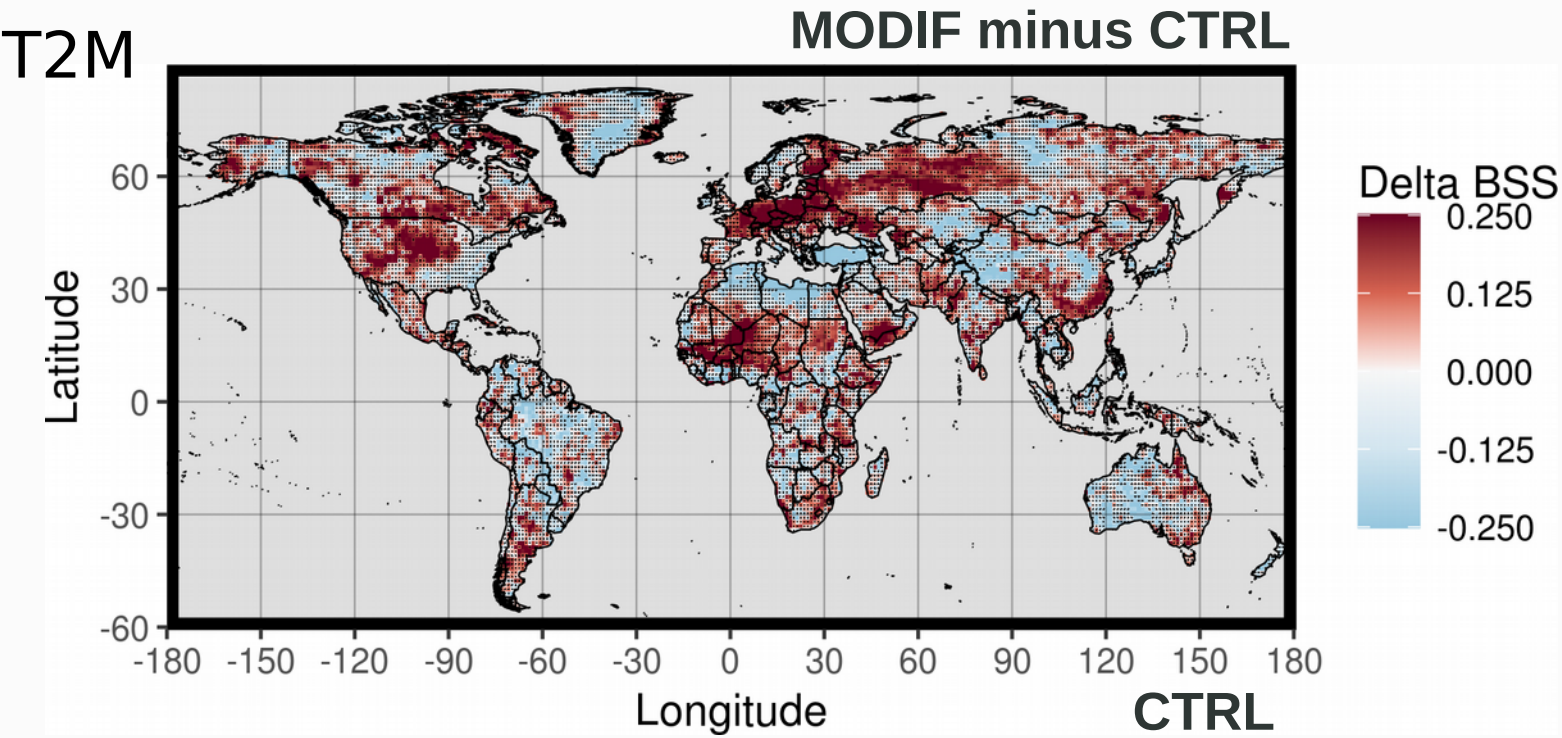
Skill Scores: $$BSS = 1 - \frac{BS}{BS_{clim}} \qquad ResSS = \frac{Res}{BS_{clim}} \qquad RelSS = 1 - \frac{Rel}{BS_{clim}}$$

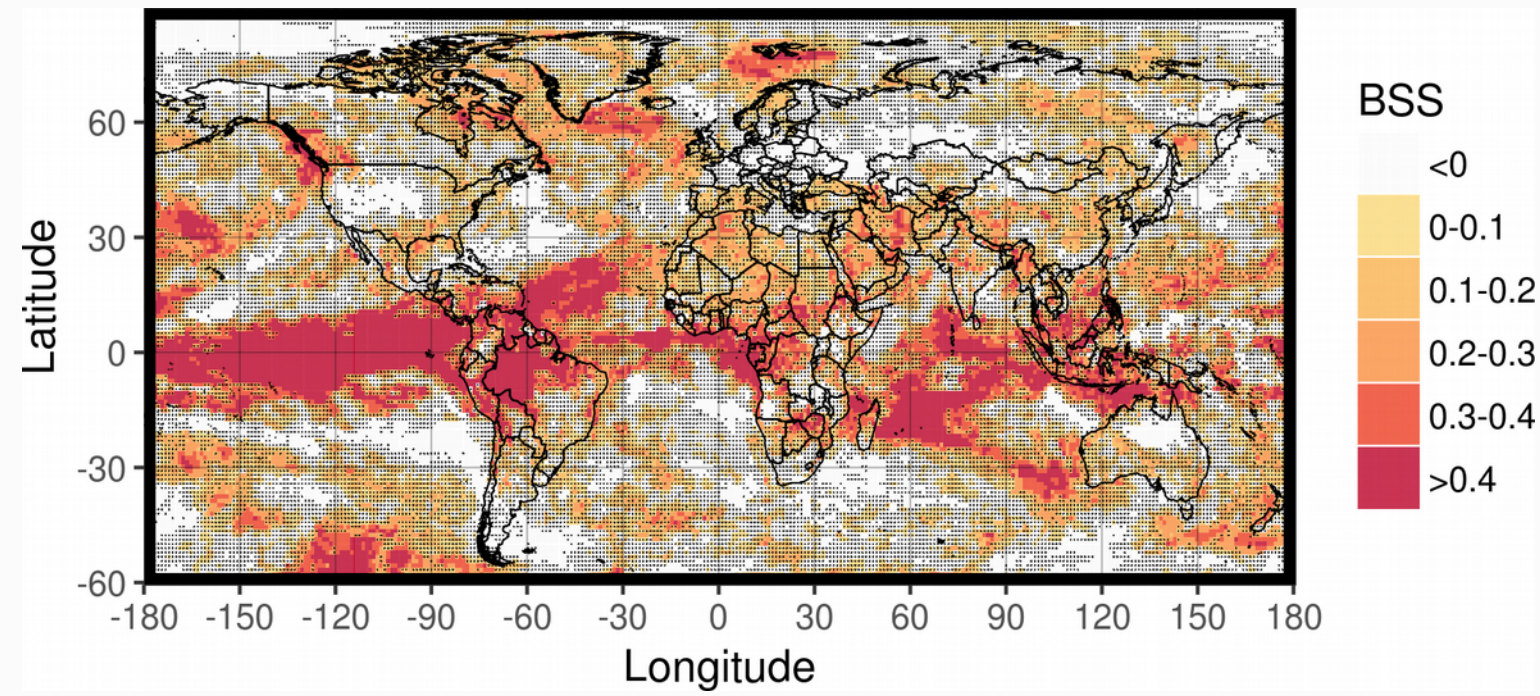
Seasonal hindcasts - 1st Nov start date
BSS differences (MODIF-CTRL) vs ERA-Interim

T2M

WINTER DJF

upper tercile





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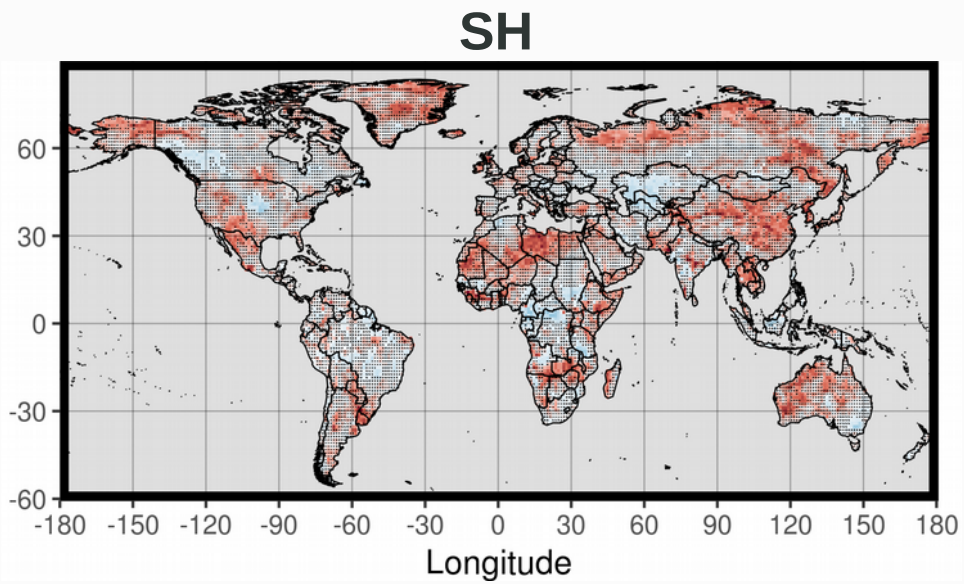
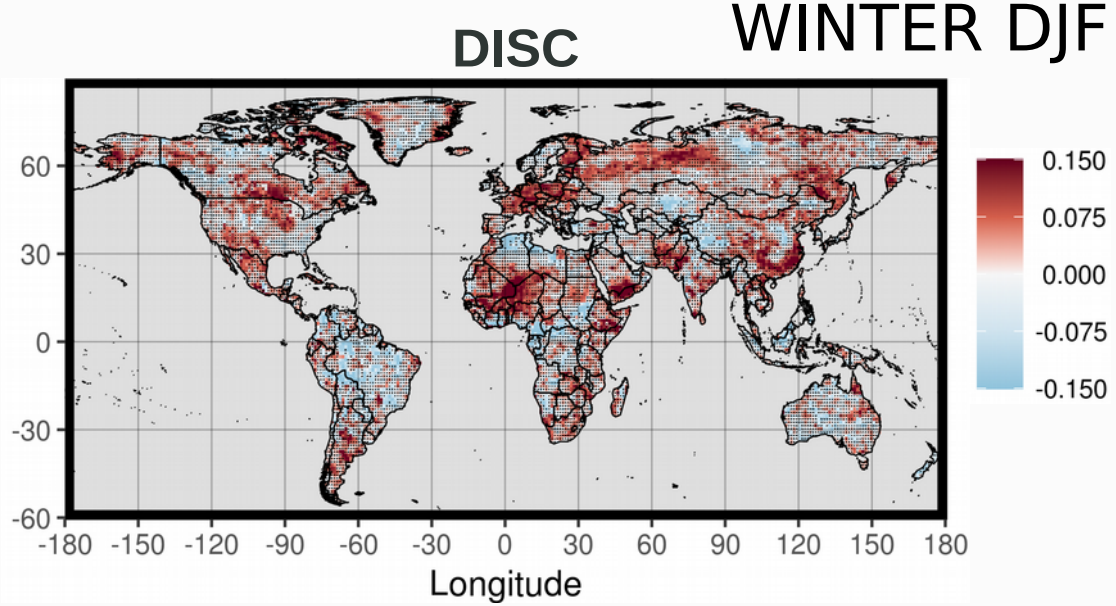
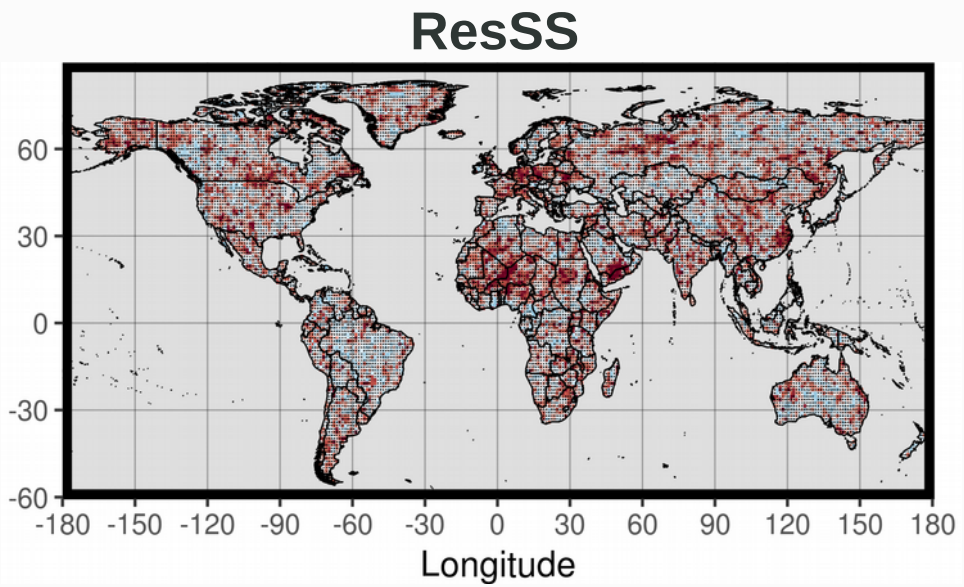
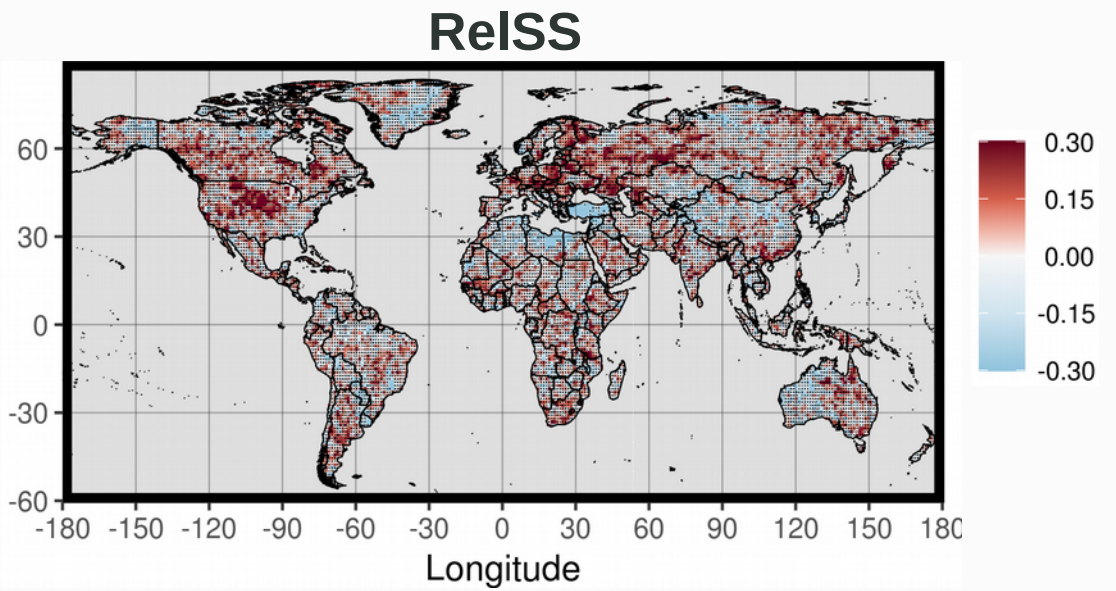
Seasonal hindcasts - 1st Nov start date
T2M differences (MODIF-CTRL) vs ERA-Interim

WINTER DJF









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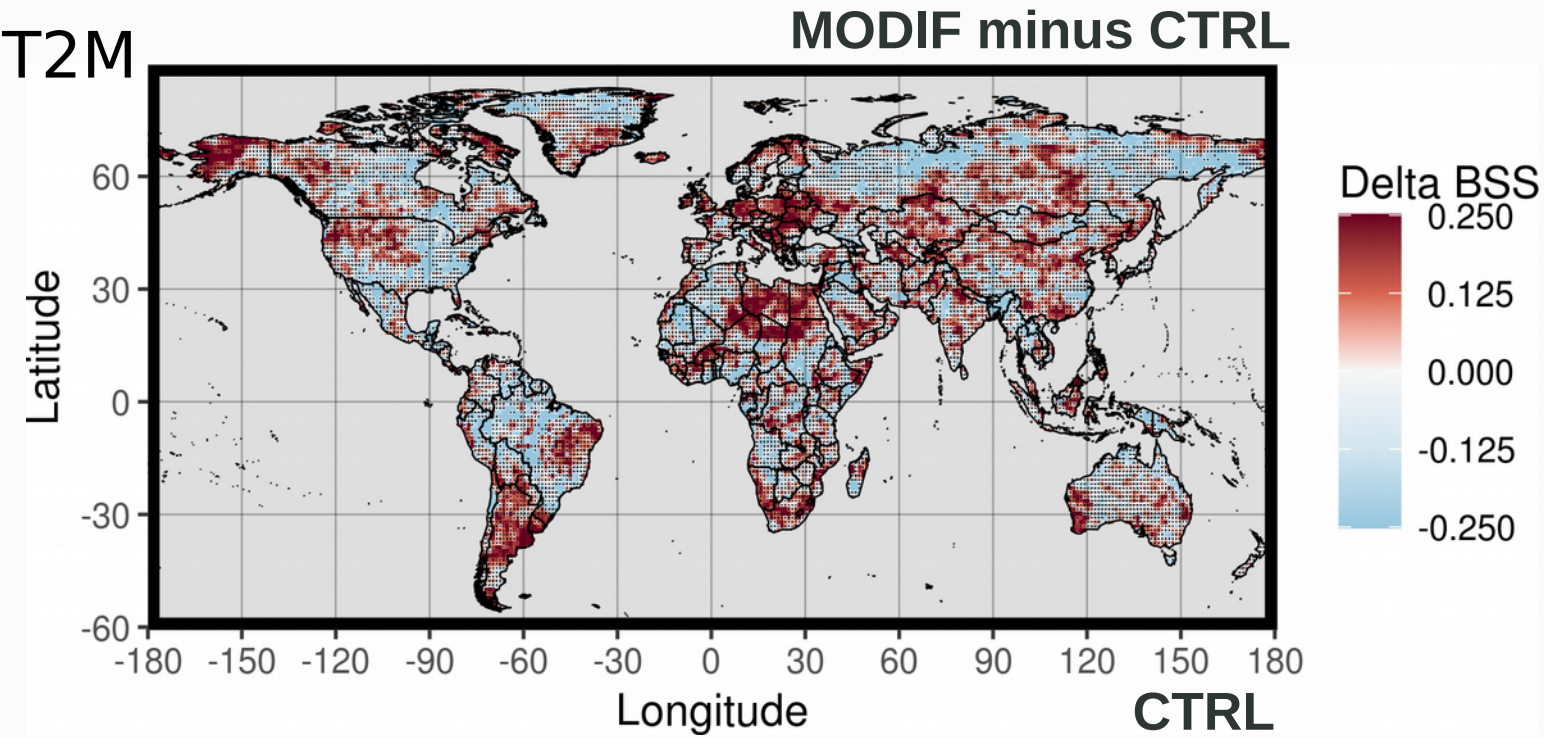
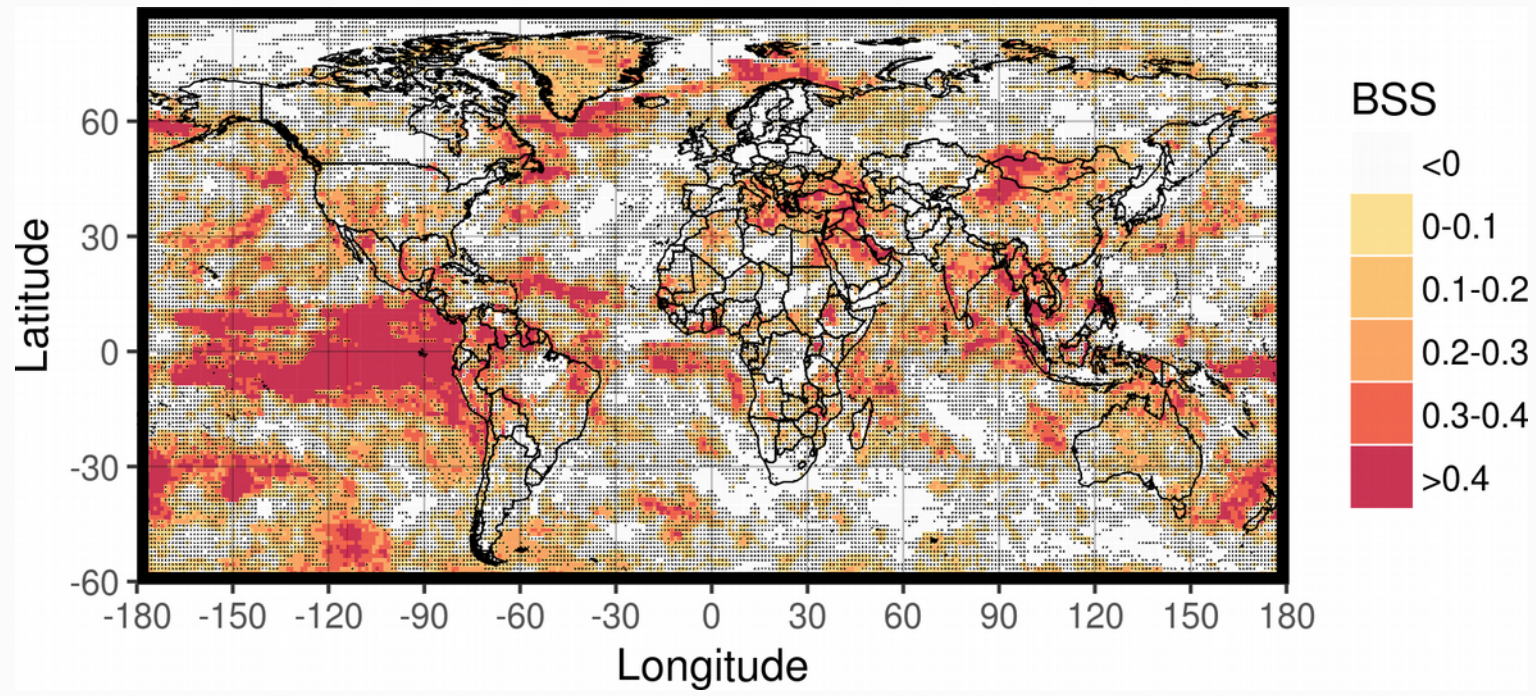
Seasonal hindcasts - 1st May start date
BSS differences (MODIF-CTRL) vs ERA-Interim

SUMMER JJA

upper tercile

T2M





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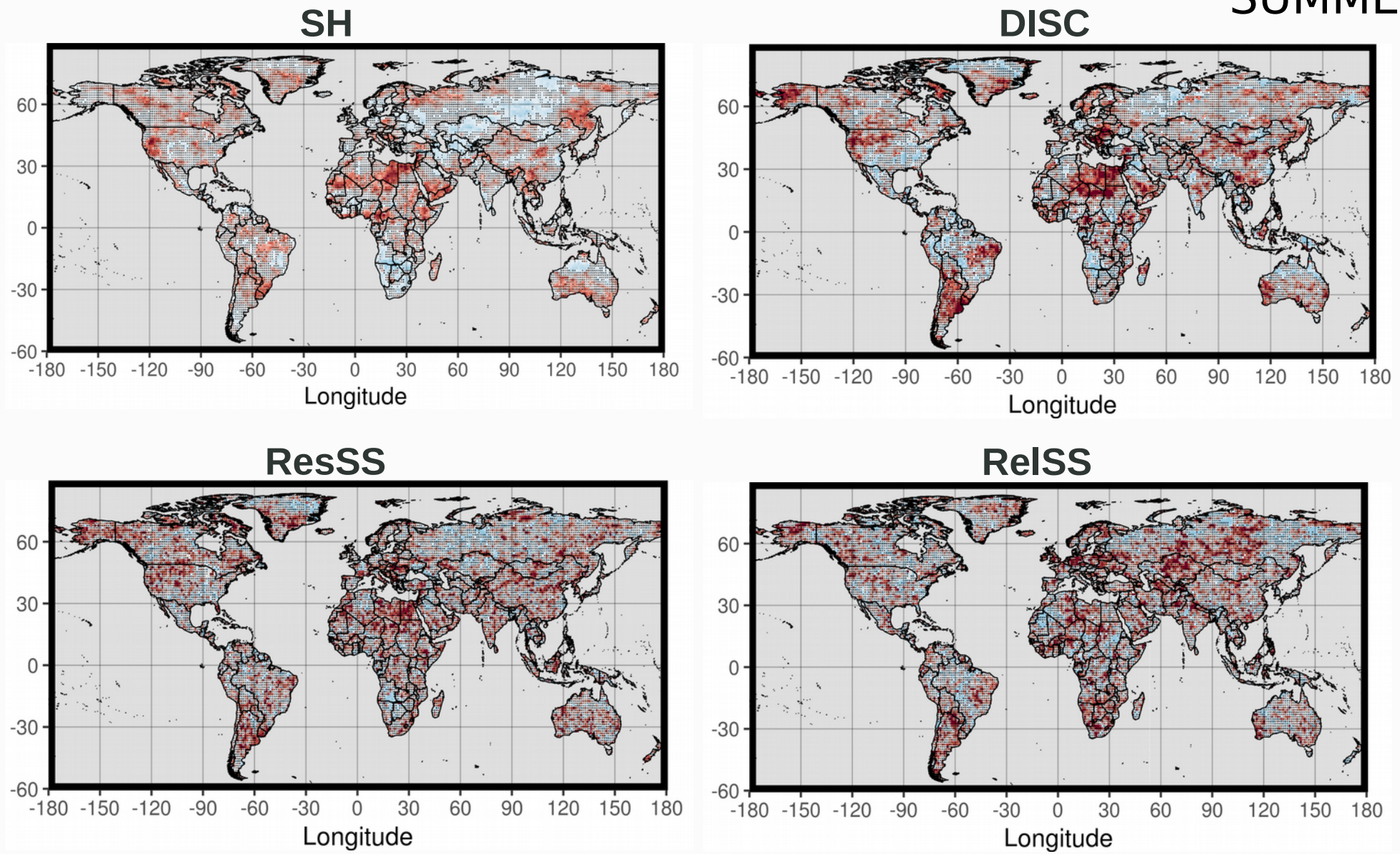
Seasonal hindcasts - 1st May start date
T2M differences (MODIF-CTRL) vs ERA-Interim

SUMMER JJA



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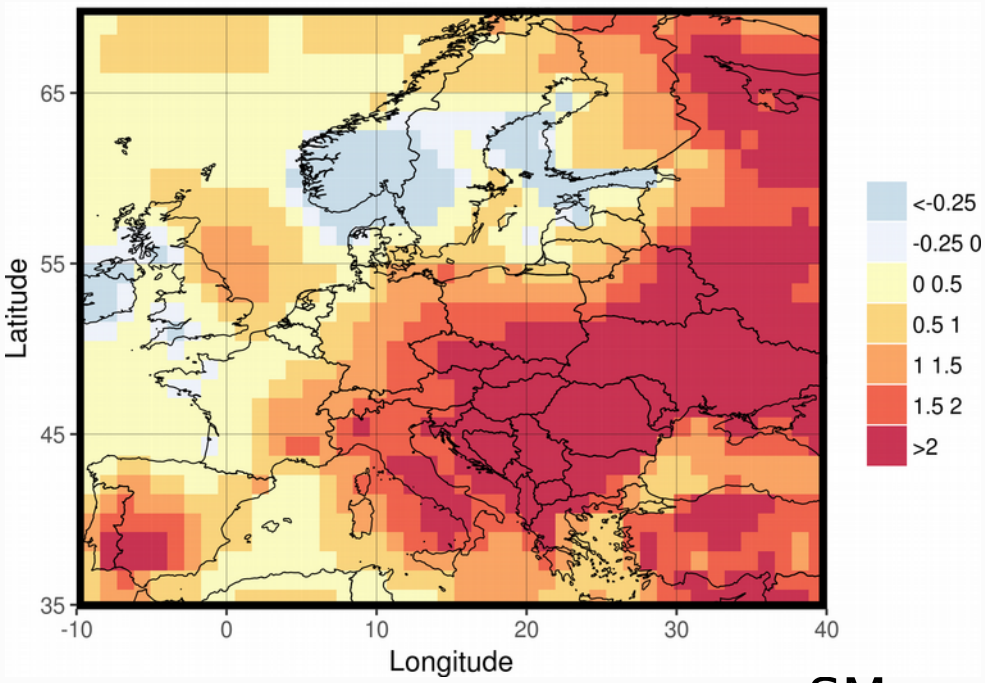
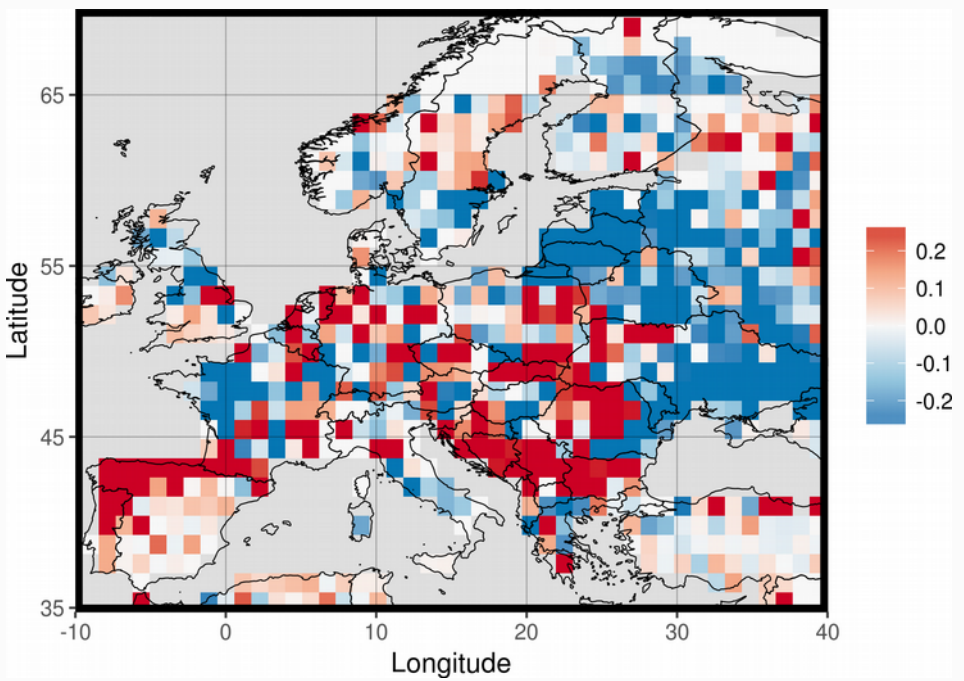
Vegetation-atmosphere feedback contribution to the amplification of 2003 European summer heat wave

European heat wave 2003 – obs anomalies - May

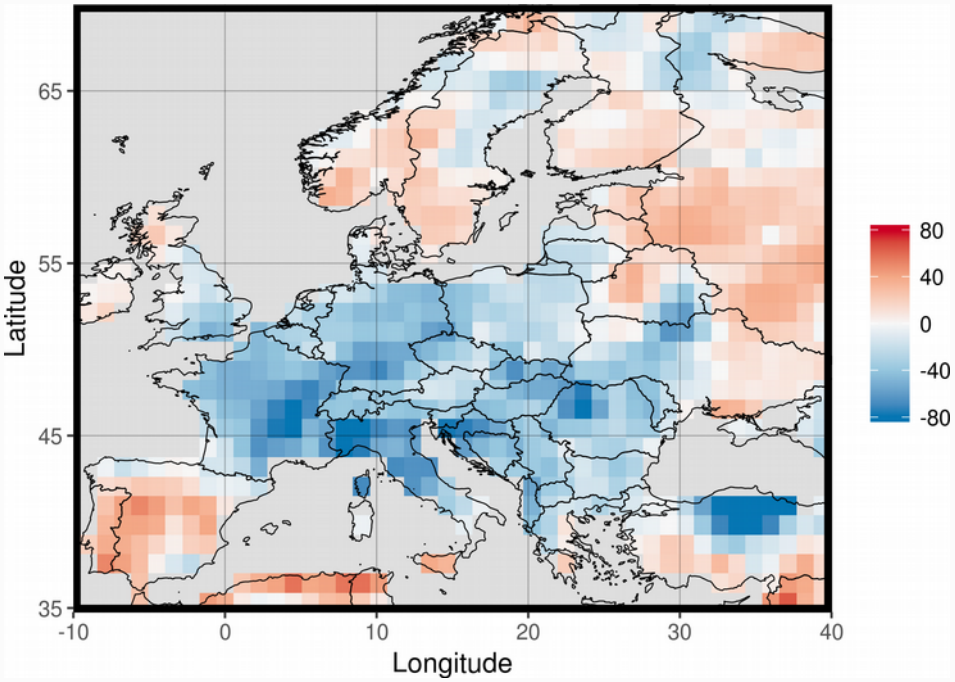
T2M



LAI



SM



Large positive temperature anomaly in may drives:

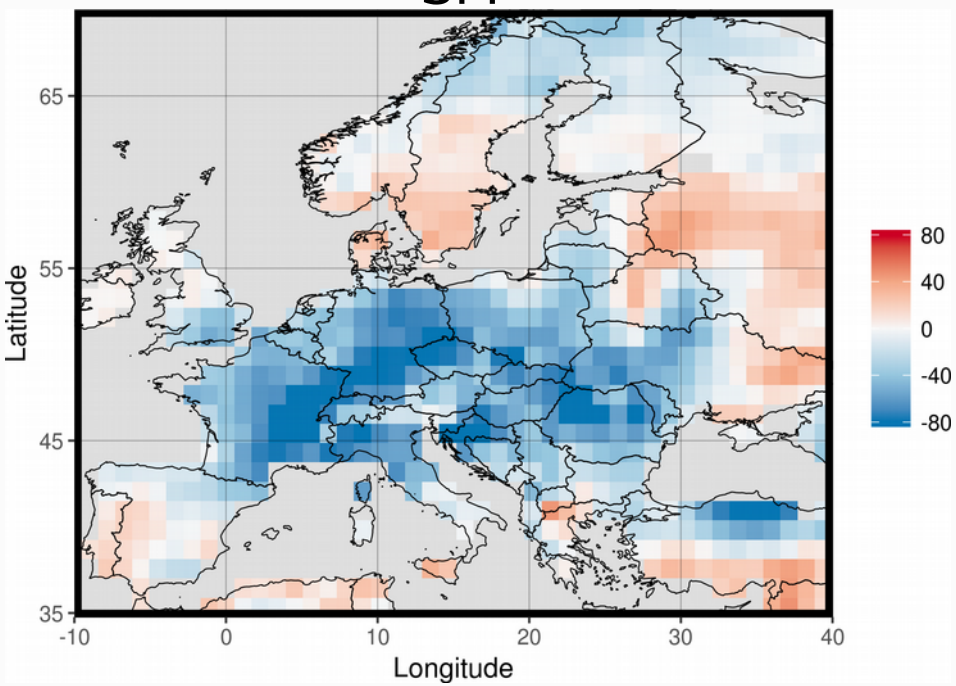
→ early vegetation greenup

→ enhanced evapotranspiration

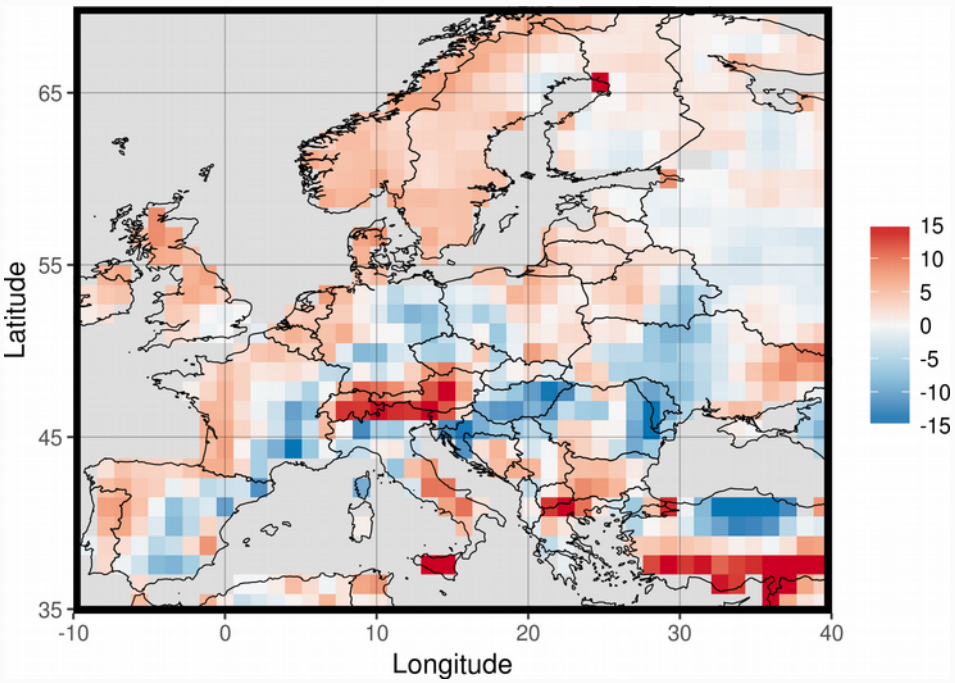
→ enhanced soil drying

European heat wave 2003 – obs anomalies - JJA

SM



SLHF



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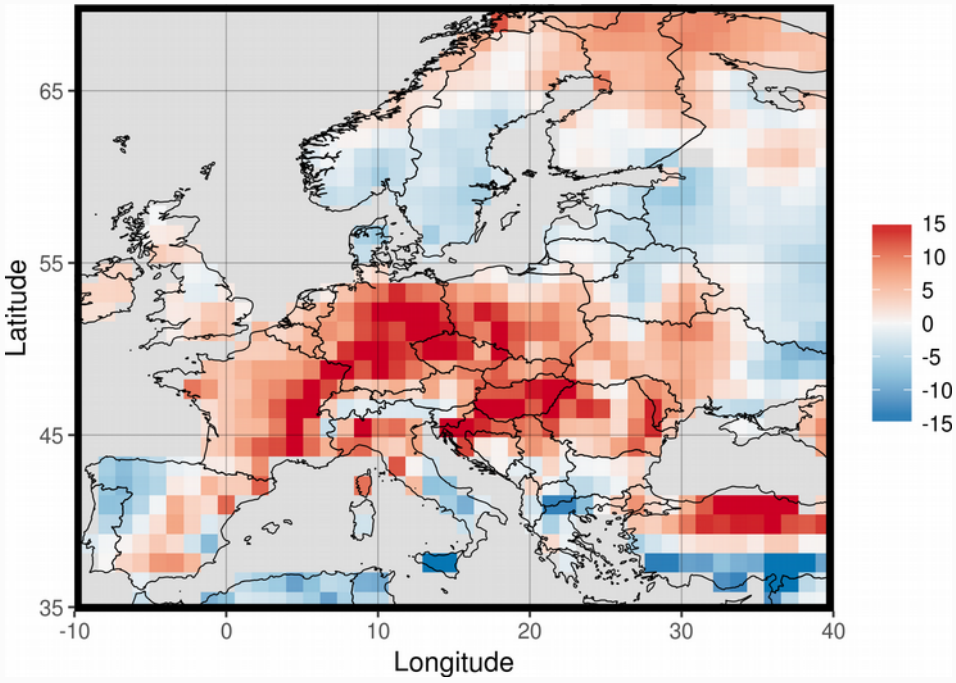


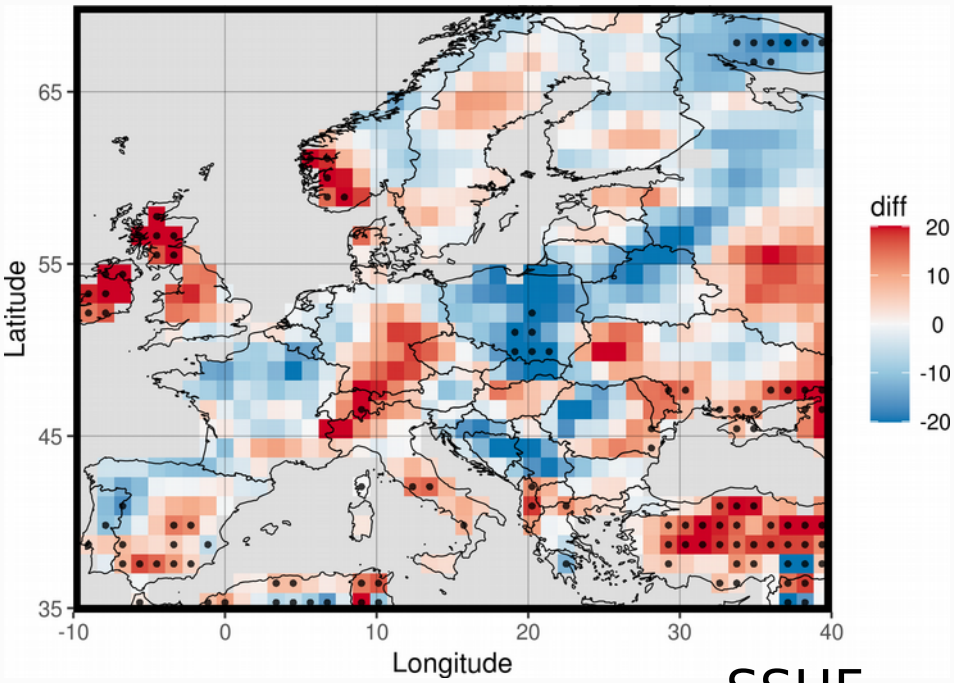
Persistent large negative soil moisture anomaly in JJA changes local surface energy balance:

→ reduced latent heat flux

→ enhanced sensible heat flux

European heat wave 2003 – MODIF-CTRL - JJA

SM



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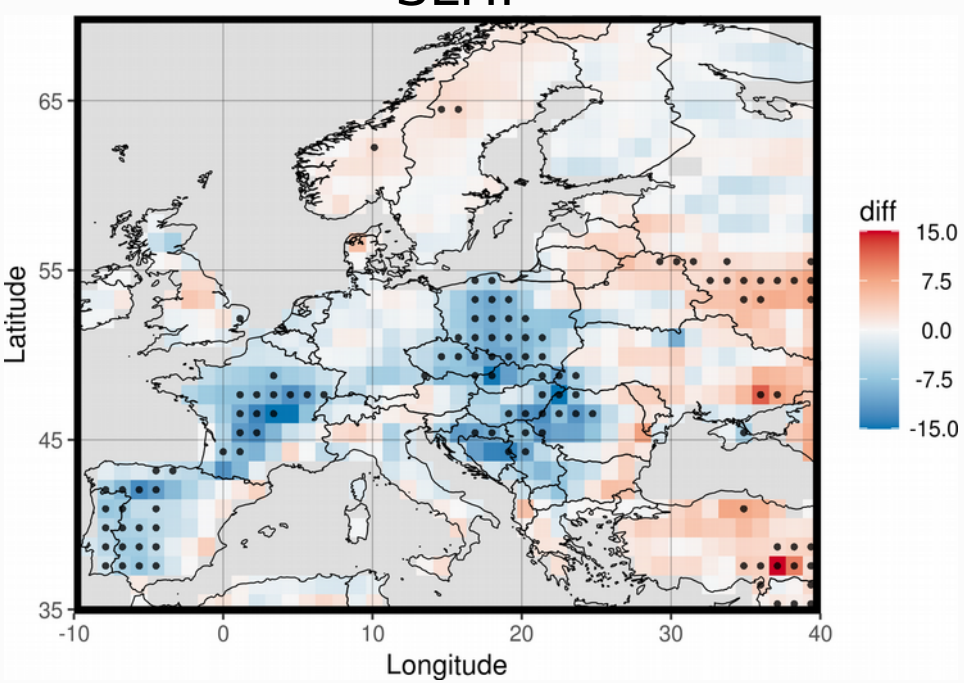

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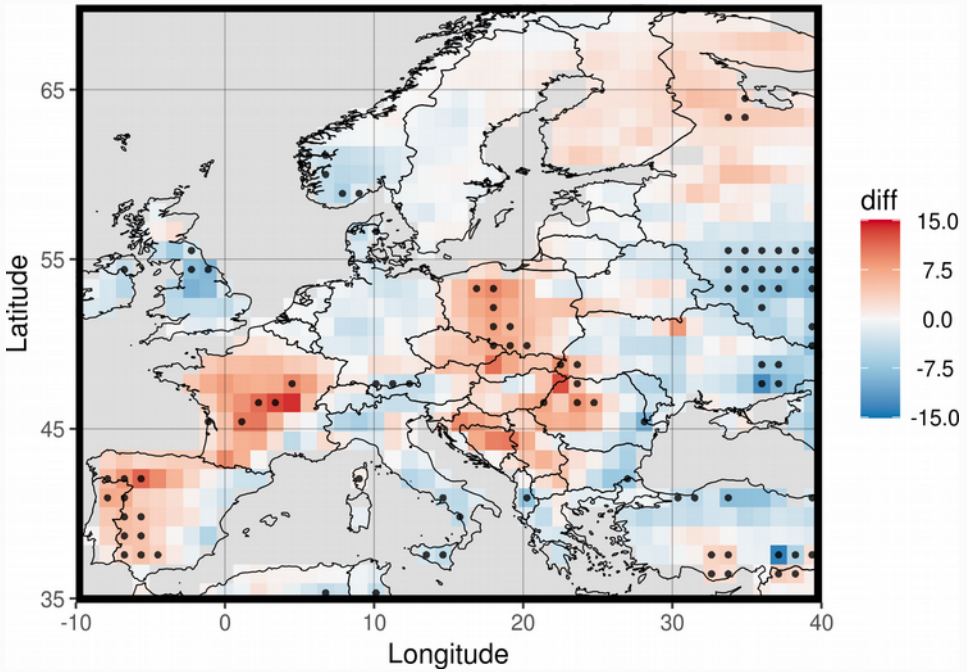


Vegetation variability in MODIF contributes to enhance the positive feedback on the surface energy balance:

→ enhanced soil drying

→ reduced latent heat flux

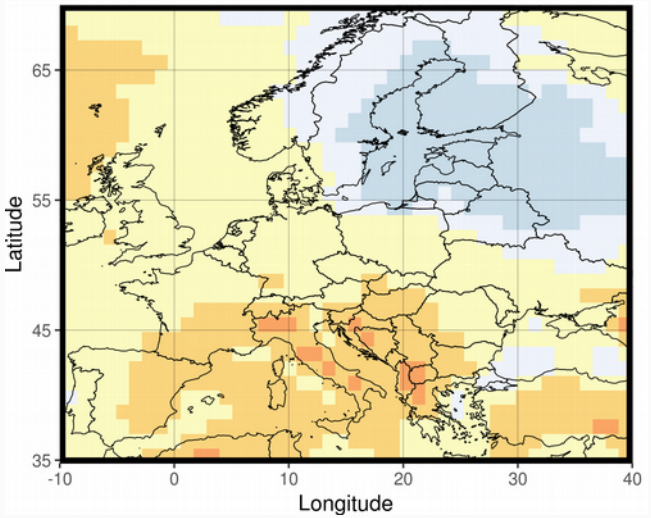
→ enhanced sensible heat flux

(dotted significant 10% level)

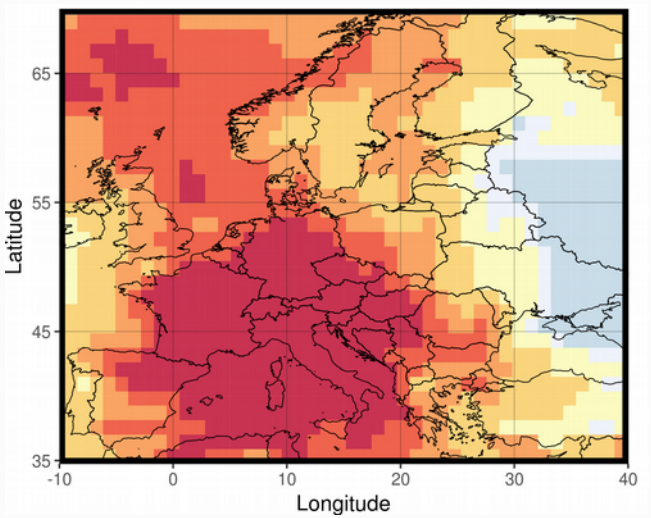
European heat wave 2003 – forecast improvement

T2M anomaly - JJA

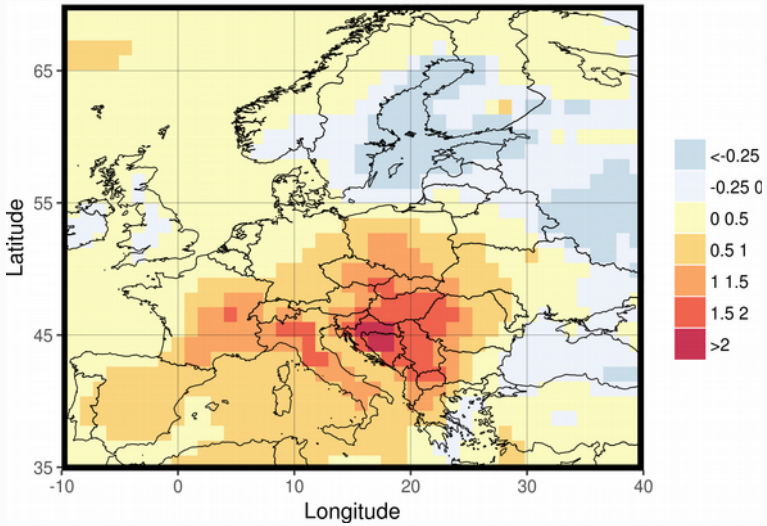
CTRL



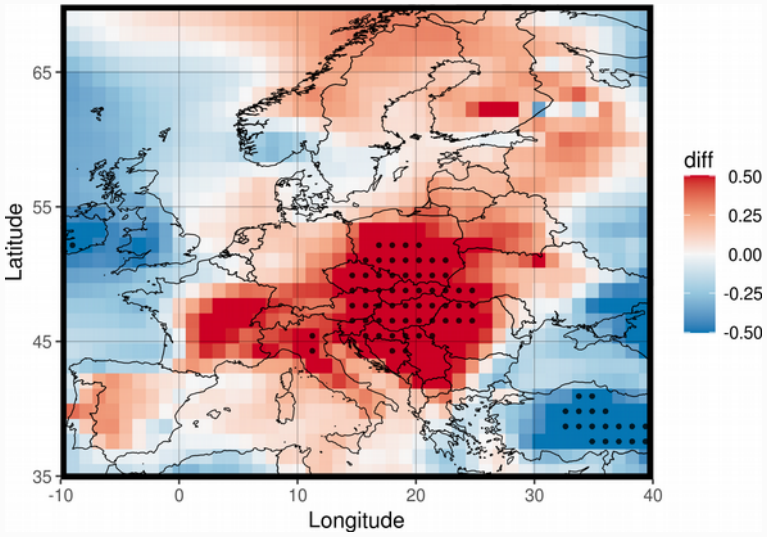
OBS



MODIF



MODIF - CTRL



(dotted significant 10% level)

Conclusions

- We implemented in EC-Earth a time-varying effective vegetation cover as a function of Leaf Area Index
  - Realistic representation of vegetation cover has noticeable effects on EC-Earth variability and change leads to enhancements of seasonal climate predictions
  - Significant improvement of model probabilistic skill, especially over regions characterized by strong land-atmosphere coupling
  - Particular improvement of Brier skill score for T2M in DJF over: boreal forests of North America and Asia, Great Plains, Europe, Sahel, South-East Asia
  - In JJA the sensitivity is larger over: Europe, Great Plains, Sahel, South America, Nordeste, Central Asia
  - Probabilistic skill improvement is mostly related to local increase of Discrimination and Reliability
- Vegetation variability has a positive feedback on surface temperatures in 2003 European summer heat wave
  - Realistic representation of vegetation cover leads to significant improvement in the prediction of the heat wave