Mechanisms for summer temperature response to solar forcing over the last millennium in Europe

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Background and motivations

- Summer temperature response to radiative forcing is uncertain (Christensen et al. 2007 [1]).
- Large warming over the Mediterranean area due to the soil moisture-temperature positive feedback (Seneviratne et al. 2010 [2])
- Large spread among models concerning the area of action of this feedback (Boé and Terray 2008 [3])
- Data from the last 50 years are not sufficient to assess the robustness of this response to radiative forcing in the real world.
- Guiot et al. (2010 [4])) produce a spatial reconstruction of summer temperature over Europe (Fig. 1).

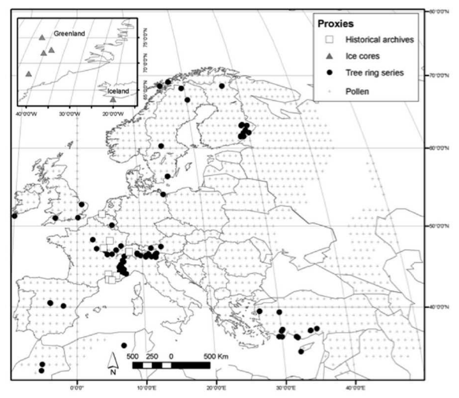

FIGURE 1: Data used in the spatial reconstruction from Guiot et al. (2010)

Can the last millennium be used to evaluate the sensitivity of summer temperature variability in climate models?

Experimental design

We use a 1000-yrs simulation from CNRM-CM5 climate models covering years 1001-2000 with different forcing (Swingedouw et al. 2010 [6]):

- Solar variations from Crowley et al. (2000)
- Volcanoes from Ammann et al. (2007)
- Land use changes from year 1700 (Ramankutty and Folley, 1999), constant before.

We focus on the summer season (April to September, which is the growing season for the proxies from Guiot et al.).
We do not consider the ocean gridpoints in the model.
We use a 13 years cut-off value filtering.

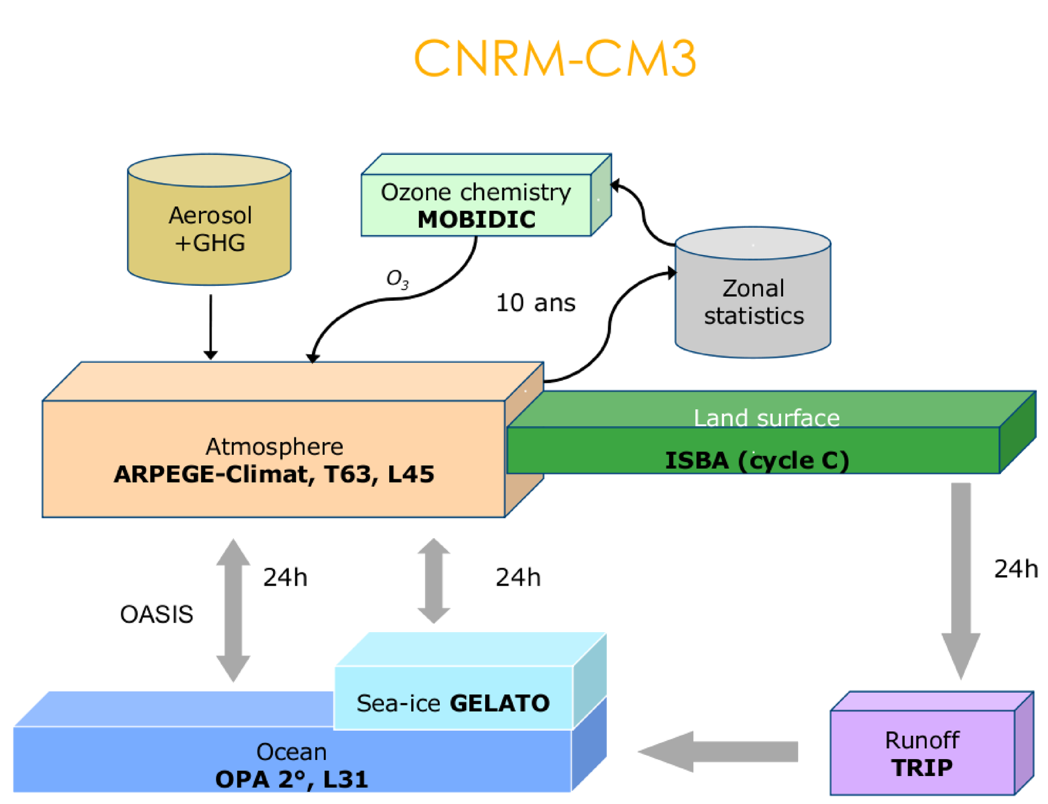

FIGURE 2: Components of the coupled climate model CNRM-CM3

Response to solar forcing

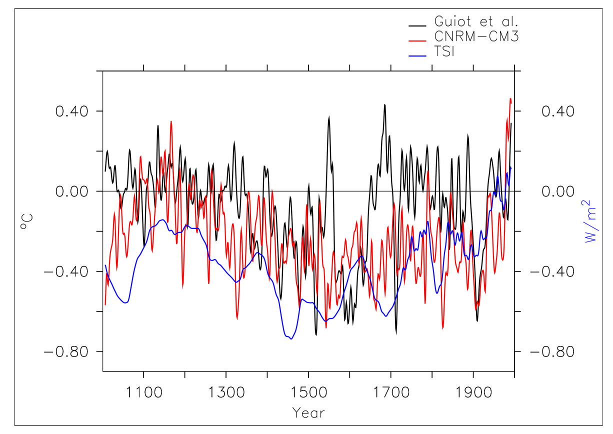

FIGURE 3: Model-data timeseries of summer temperature averaged over Europe and solar variations.

- Correlation of 0.25 between data and model when averaged over Europe.
- Correlation of 0.5 between model and solar index. 0.25 for data and solar index.
- Low frequency agreement increases for some region: Mediterranean area and North Europe. Fewer signal for temperature in Central Europe.
- Similar pattern for spatial regression over solar index.
- When zonally averaged: same minimum and similar amplitude except for the Mediterranean area.

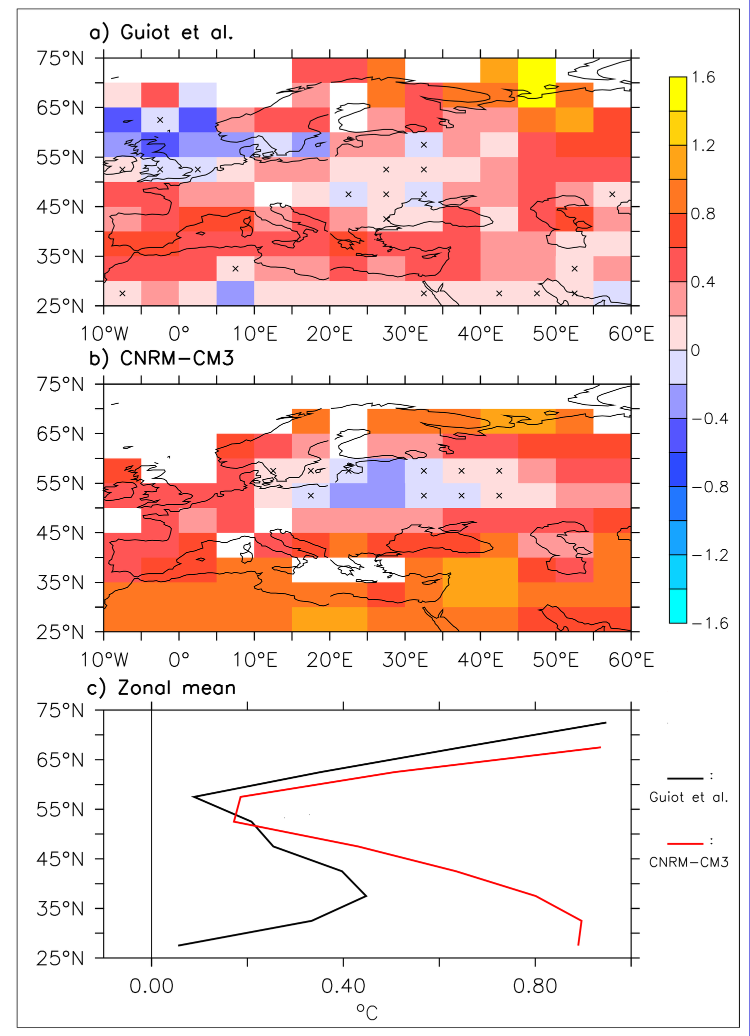

FIGURE 4: Regression of a) data and b) model over the solar forcing. c) Zonal average of a) and b).

Regression on solar forcing in the model

- Forcing of solar variability is almost isotropic over Europe
- Response is strongly anisotropic for clouds and precipitations: large variations over Central Europe.
- Evapotranspiration flux also has strong increase over Central Europe. On the contrary, over the Mediterranean area, the flux is diminished.

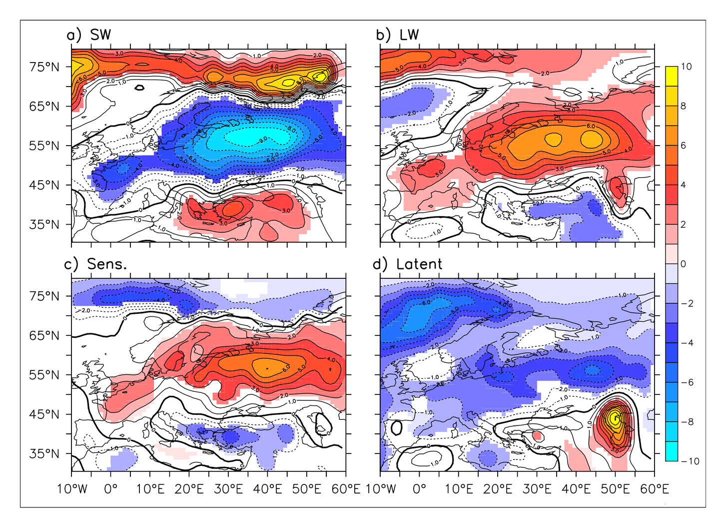

FIGURE 5: Regression on solar forcing of radiative fluxes.

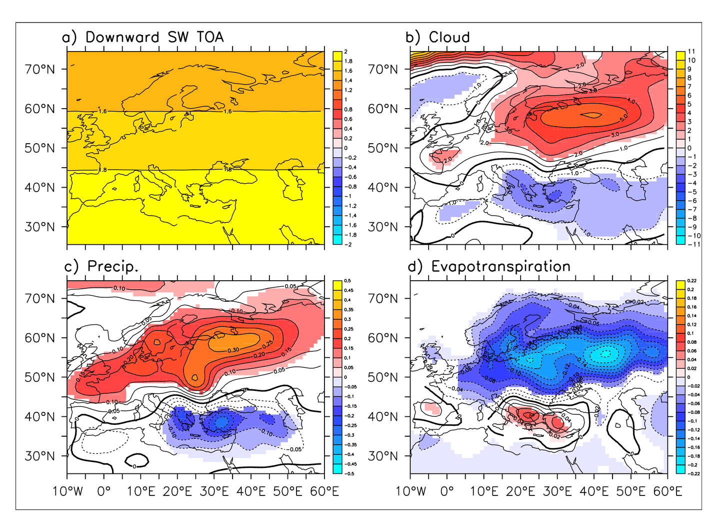

FIGURE 4: Regression on solar forcing

- Changes in latent heat fluxes reflect evapotranspiration modifications.
- Over Central Europe: SW decreases, LW increases, which reflects the modification in cloud cover.
- Over Northern Europe: more SW due to sea ice response (Swingedouw et al. 2010).

Mechanism proposed

Seasonal control of evapotranspiration

- Over Central Europe: similar correlation in the observations of the last 50 years (Alkama et al., 2009 [5]) and the model.

evapotranspiration is controled:

- by radiative fluxes (energy input) in winter
- by soil moisture (water reservoir) in summer

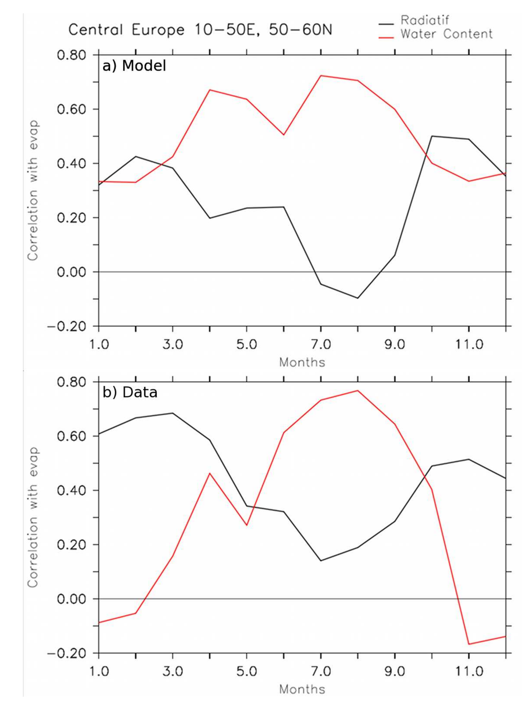

FIGURE 7: Correlation diagram for different months on the x-axis for a) model and b) data of the last 50 years from Alkama et al. (2009)

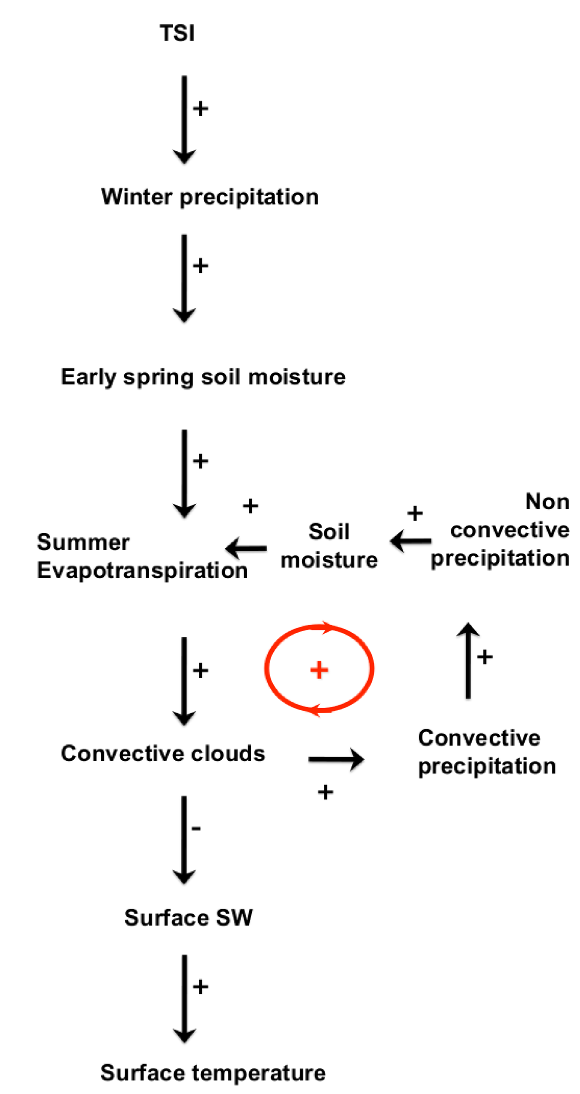

FIGURE 8: Scheme of the mechanisms at play in the center of Europe in the model.

Conclusions

- Spatio-temporal reconstructions can be useful to evaluate climate models low frequency.
- Latitudinal agreement between CNRM-CM3 climate model and data is correct except around the Mediterranean area, where warming is overestimated in the model.
- Deficiency in the response of this region implies carefulness when considering projections over this region using this model.
- Last millennium as a useful test-case for models response to radiative changes (here for evapotranspiration related processes in response to solar forcing)

Solar forcing has a similar signature on surface temperature in summer in model and data, implying evapotranspiration mechanisms

References

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[4] Guiot J., C. Corona, and ESCARSEL members. Growing season temperatures in europe and climate forcings over the past 1400 years. *PLoS ONE*, 5, 2010.

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