Can we constrain *regional summer* near-surface temperature projections?

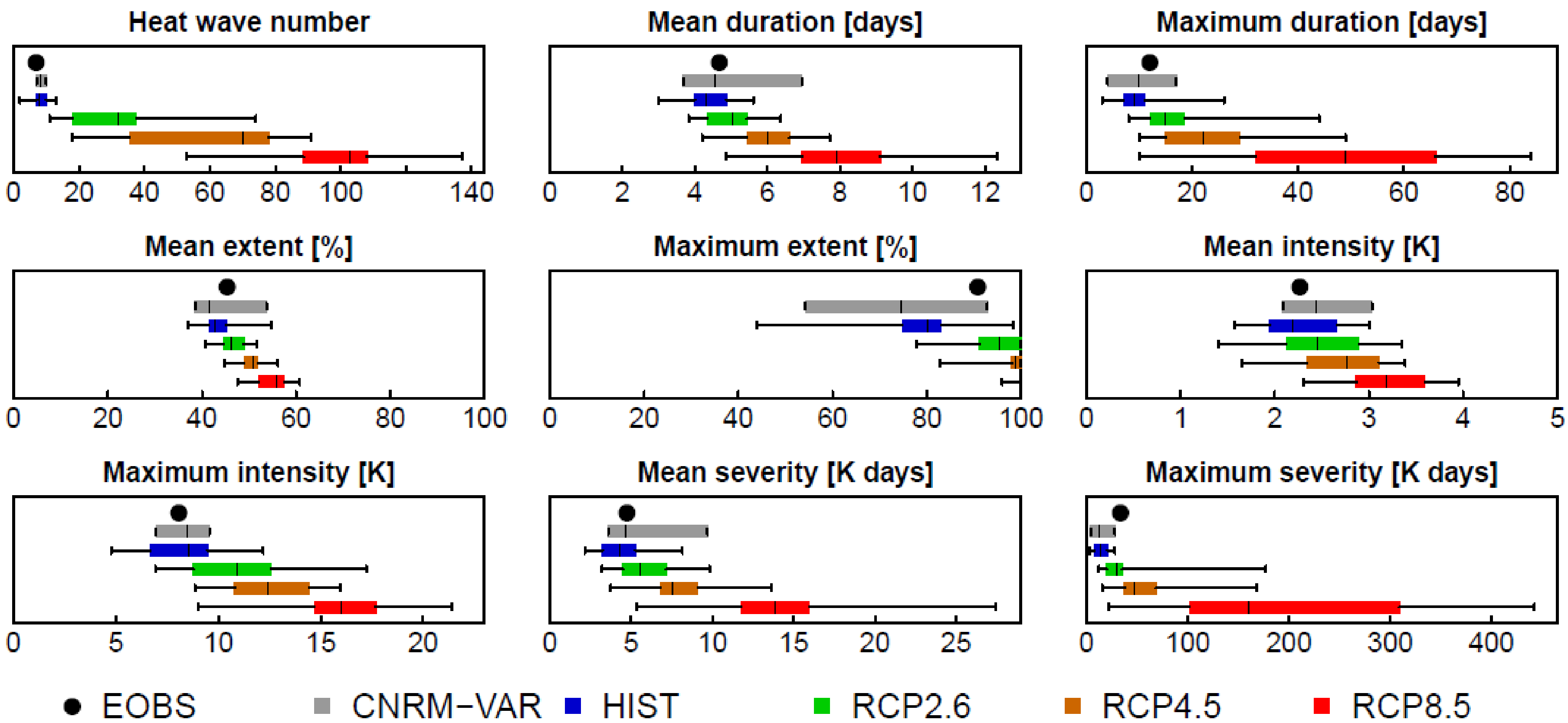
A North American case study

Hervé Douville

Météo-France/CNRM-GAME

herve.douville@meteo.fr

Response of European heat waves in CMIP5



RCP scenarios from 19 models

Schoetter et al. (to be submitted)

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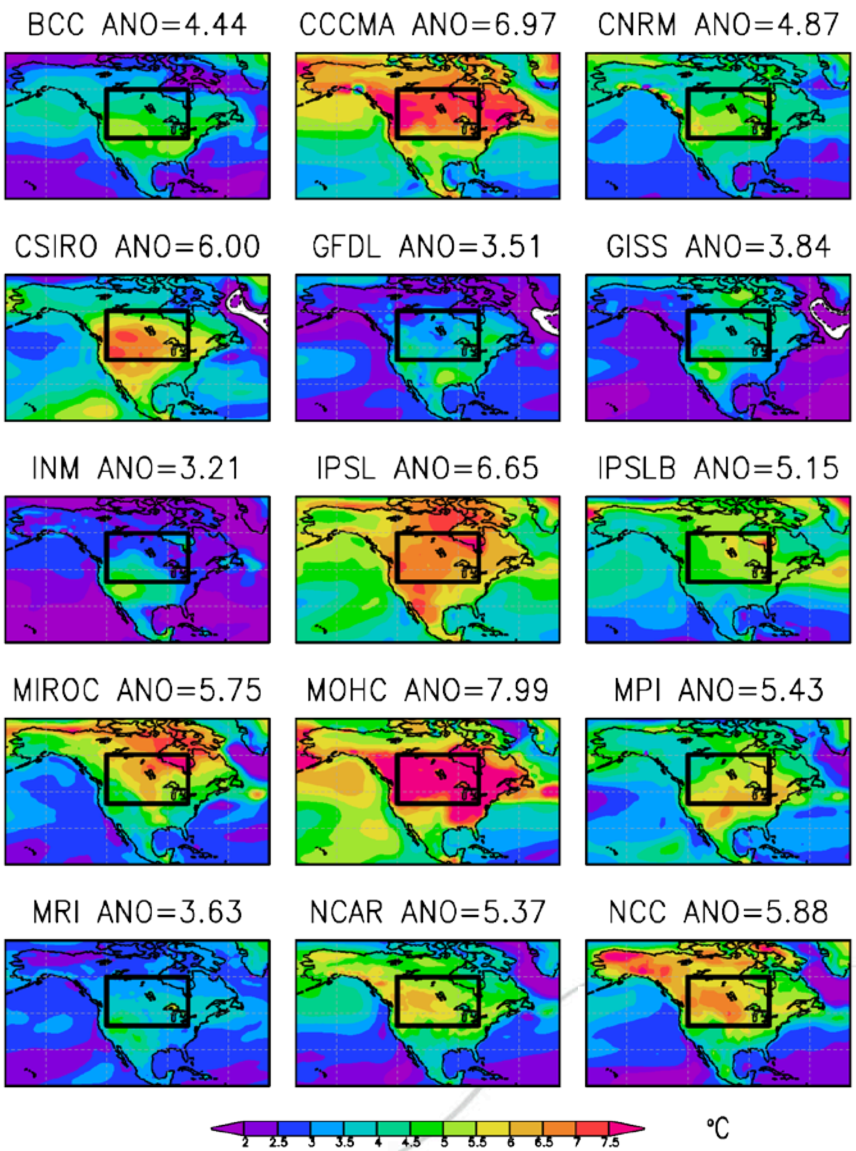
Motivations

- Uncertainties in regional temperature change are even stronger than in global warming (e.g. Cattiaux et al. 2013);
- Changes in extreme temperature events are strongly related to seasonal mean regional temperature changes (e.g. Peings et al. 2013, Schoetter et al., submitted);
- **A regional and seasonal approach might be more effective for constraining climate change (e.g. Hall and Qu 2006) given the spatial heterogeneity of (i) model biases, (ii) non-GHG radiative forcings and (iii) internal climate variability;**
- Besides radiative feedbacks, changes in summer land surface temperature are also controlled by surface heat fluxes (e.g. Seneviratne et al. 2013).

A North American case study

Projected JJAS T2M anomalies 2071-2100 (RCP8.5) vs 1979-2008 (Douville et al., in preparation)

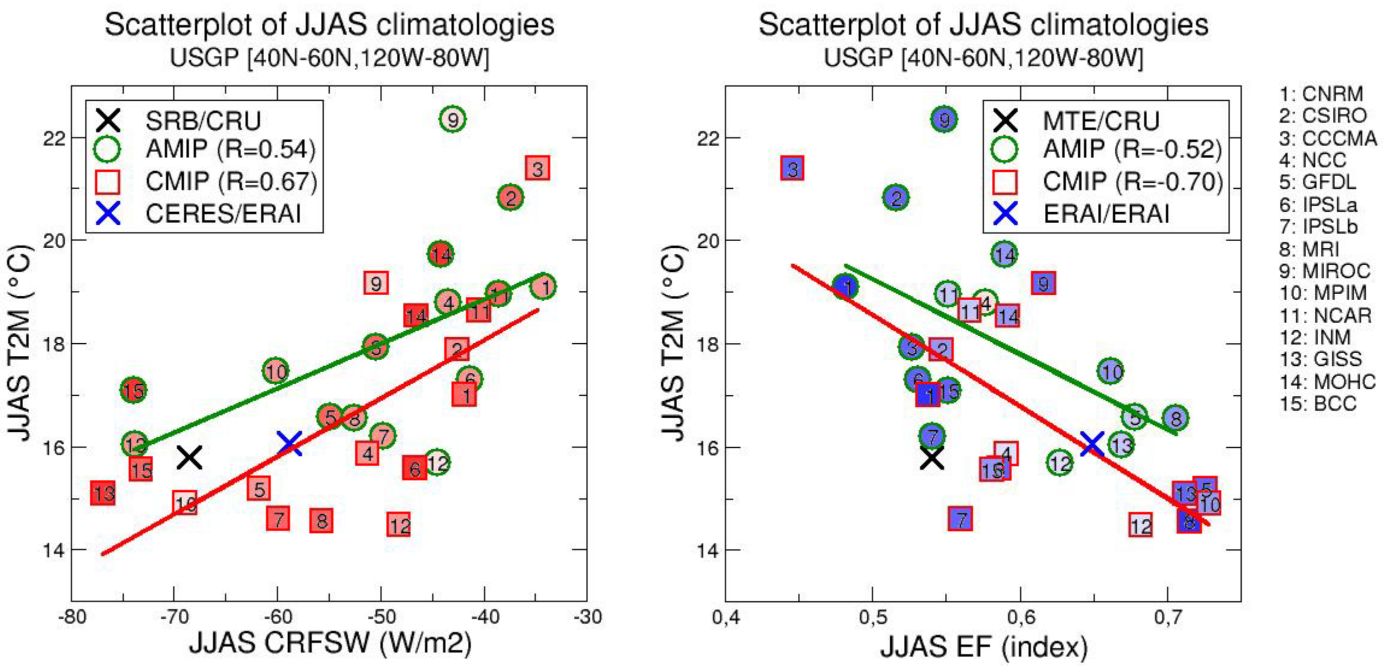
- Large inter-model spread in both the biases and anomalies of summer near-surface temperatures
- North America is a « hot spot » for land-atmosphere coupling (e.g. Koster et al. 2006)



Data (Focus on JJAS mean climate)

- 15 CMIP5 models: **AMIP & Historical** (1979-2008), **RCP8.5** (2071-2100) and **1%CO2** (yrs 19-48 & 111-140) simulations
- 1 realization per model but internal climate variability is estimated using 5 members of CNRM-CM5 (Historical and RCP8.5)
- Gridded observations & reanalyses: **T2M** (CRU_TS3), **CRFSW** (CERES & SRB), **EF**=LE/(LE+H) (MTE Jung et al. 2009 & ERAI), **RH2M** (NCEP2) and **SMI** (normalized Soil Moisture Index, ERAI-Land Balsamo et al. 2013)
- 3 sets of metrics: climatology, interannual variability (correlations based on detrended seasonal anomalies), and recent trends (1979-2012 linear fits)
- Poor man's constraint: exclude the least realistic model out of the 15 independent models for each metric showing a *significant* (p-value < 5% => R>0.51) statistical link with the projected temperature anomalies

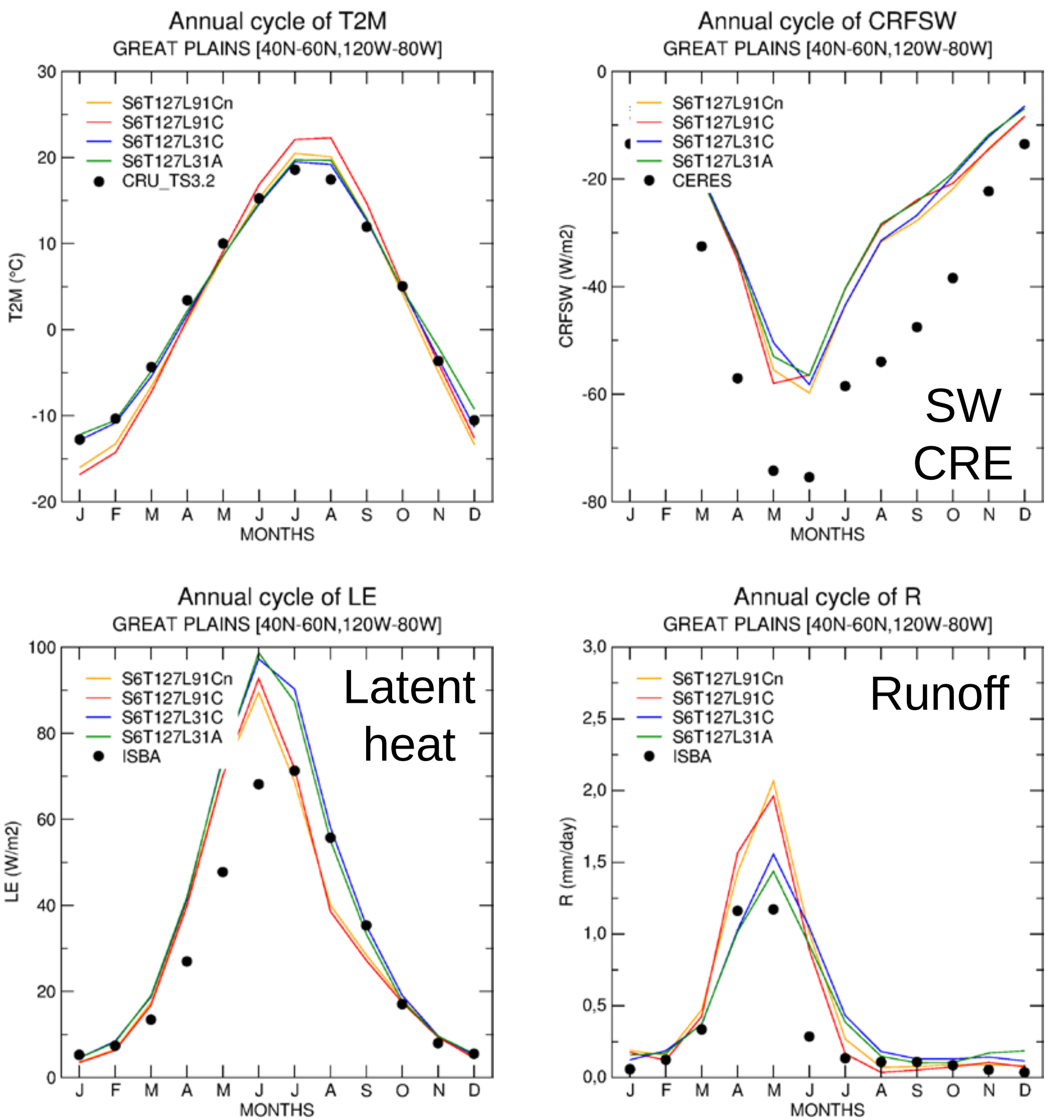
Scatterplots of climatologies: AMIP & HIST



Symbols are filled with colors that denote the spatial correlation (inside the domain) between X and Y

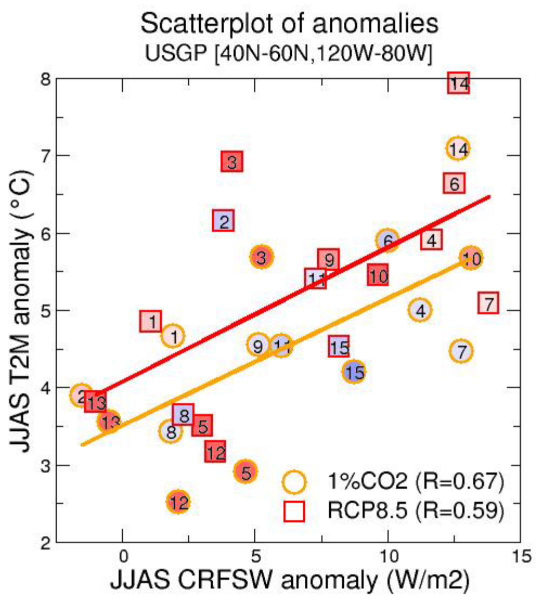
- ❑ Large errors in both cloud and land surface processes contribute to summer temperature biases (even more obvious in CMIP)
- ❑ Temperature biases are generally stronger in AMIP than in CMIP
- ❑ « Observed » SW CRE and EF are very uncertain
- ❑ What is the main driver of temperature biases?

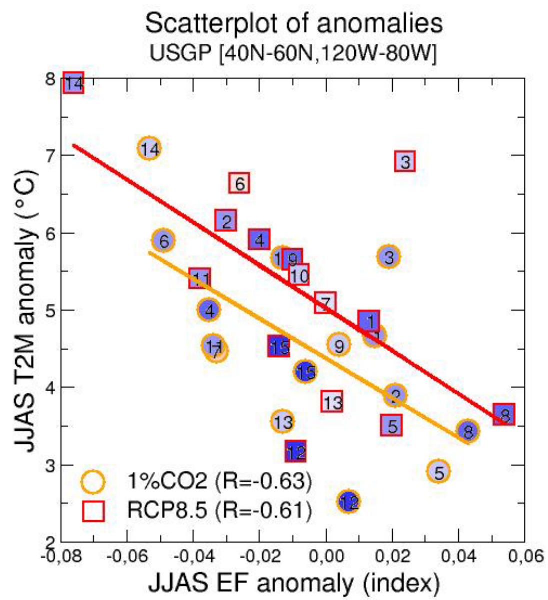
T2M biases in the CNRM AGCM



- ❑ 4 AMIP simulations:
- - ARPv5 (old physics)
- - ARPv5 with improved (MODIS) surface albedo
- - ARPv6 (new physics)
- - ARPv6 nudged towards ERA-Interim dynamics
- ❑ Increased precipitation intensity in ARPv6 leads to stronger runoff, lower evapotranspiration and higher JJAS temperature + dynamical amplification due to a thermal low effect

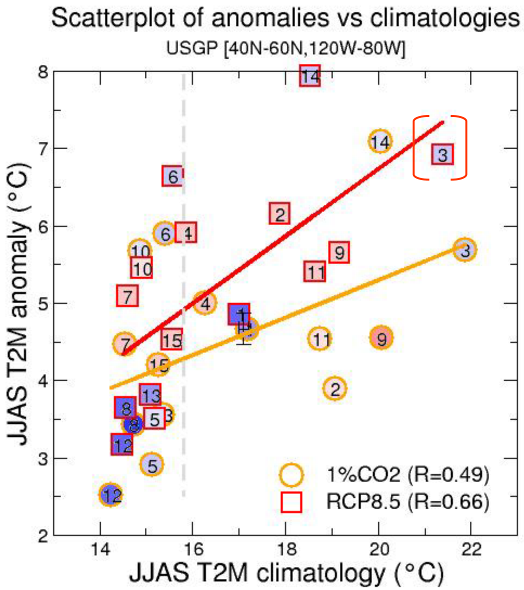
Scatterplots of anomalies: 1%CO2 & RCP8.5

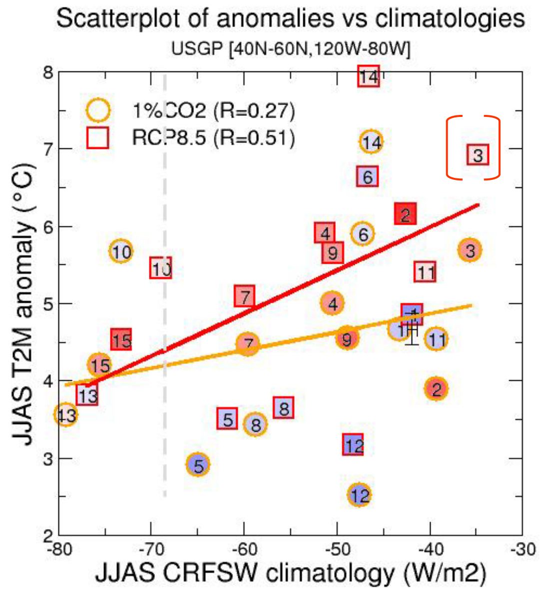


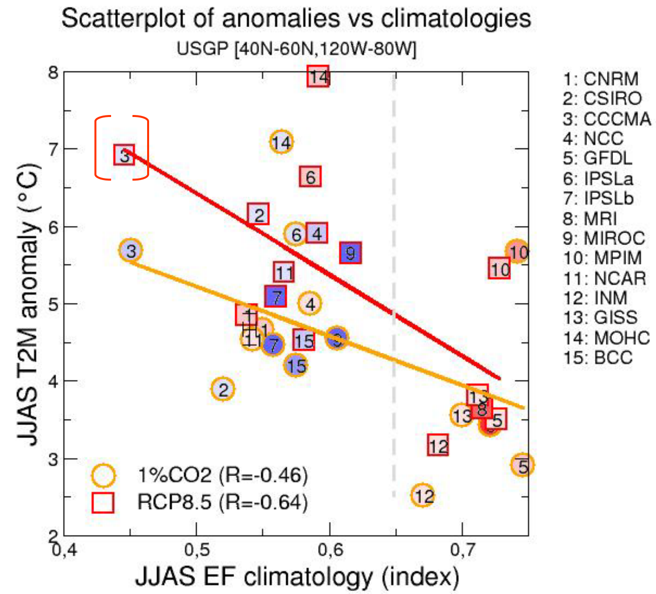


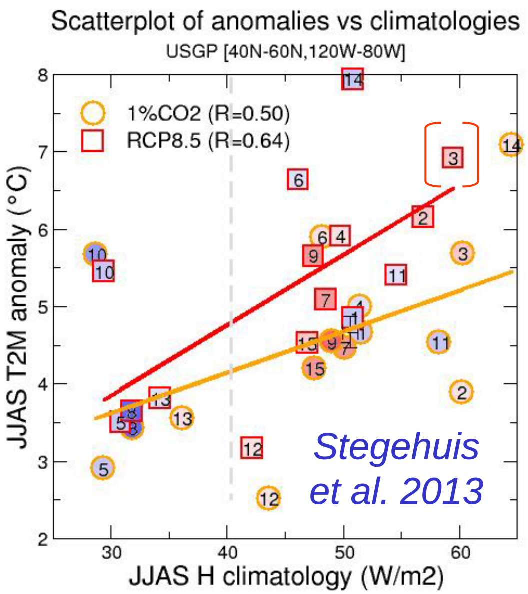
- ❑ Both SW CRE and EF also seem to contribute to the inter-model spread in temperature anomalies (note that models disagree about the sign of the EF response)
- ❑ The statistical links are robust: (i) statistically significant (p-value < 5%), (ii) found in both RCP8.5 scenarios and 1%CO2 experiments and (iii) consistent with the spatial variability of T2M anomalies within most CMIP5 models

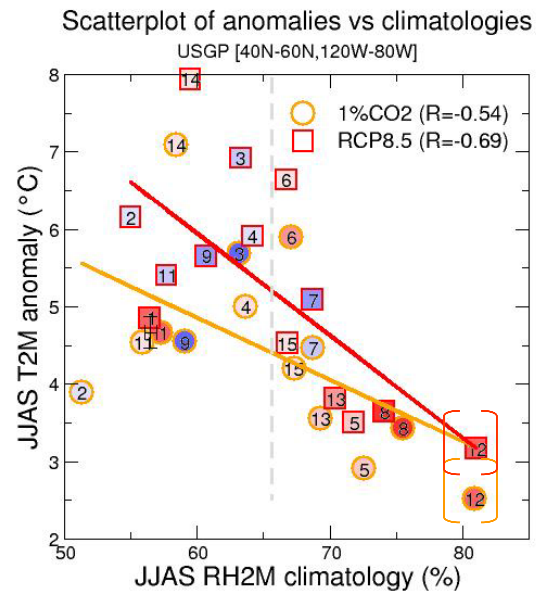
Biases vs anomalies: 1%CO2 & RCP8.5





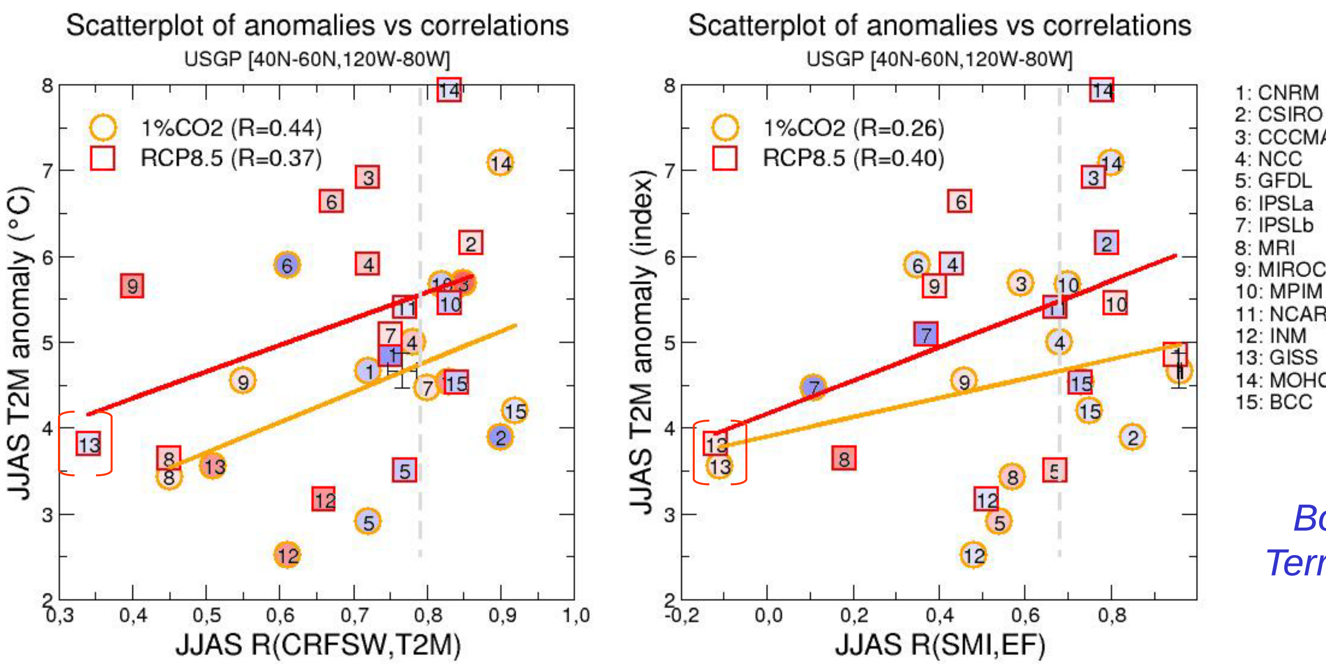






- ❑ Robust links with both cloud and land surface processes
- ❑ Consistent between RCP8.5 & 1%CO2
- ❑ One realization per model is enough

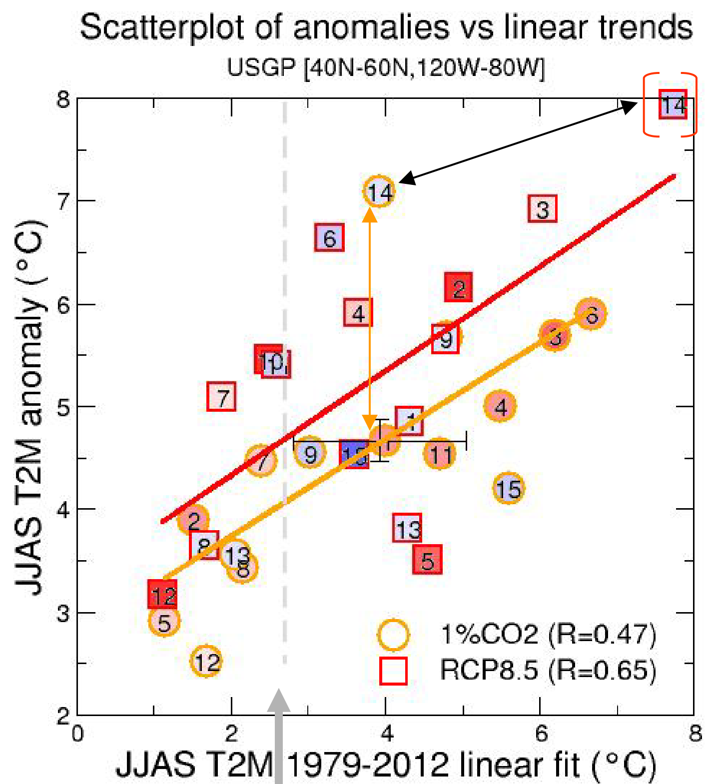
R(X,Y) vs anomalies: 1%CO2 & RCP8.5



Boé and Terray 2014

- Interannual correlations are robust metrics (1 realization per model is enough) but (not surprisingly) they do not necessarily represent strong constraints on projected summer temperatures
- Yet, they are useful to detect « unusual behaviours » (e.g. GISS that show a too weak influence of SW CRE on T2M and a wrong-sign correlation between soil moisture and EF).

Trends vs anomalies: 1%CO2 & RCP8.5



Observed trend not much affected by the global warming hiatus

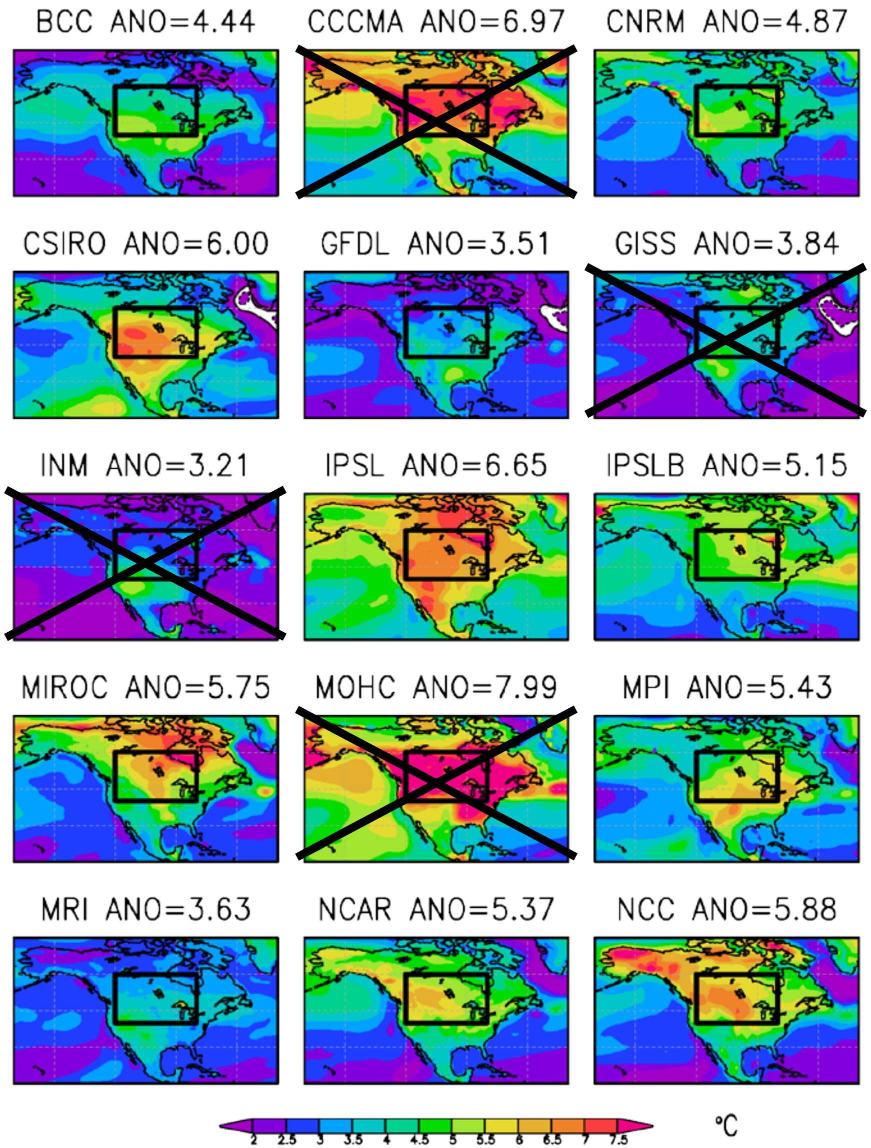
- ❑ Recent linear trends in T2M show significant correlations with projected T2M anomalies and HadGEM2ES is a possible outlier for two reasons:

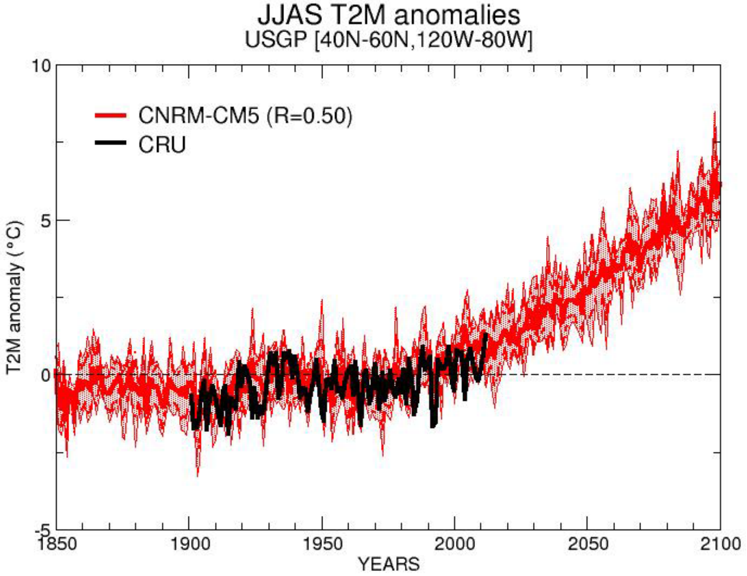
(i) A strong and disputed (e.g. Alkama et al. 2011) CO2 stomatal closure effect on plant transpiration
(ii) A strong and disputed (e.g. Zhang et al. 2013) indirect aerosol effect

- ❑ Both effects are more easily detected (and falsified) at the regional scale but are probably also important at the global scale

- ❑ One realization per model might however not be enough

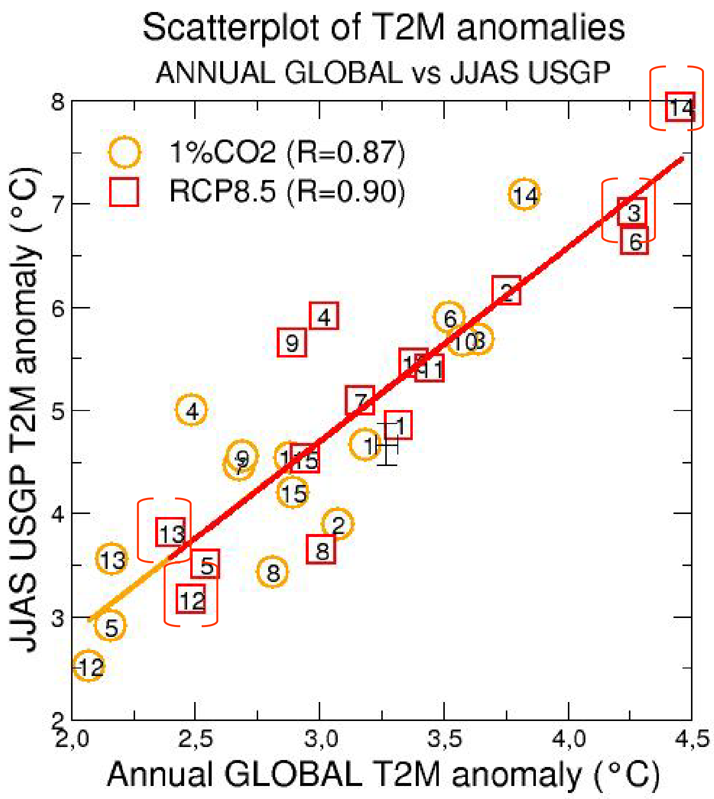
Constraining projections by removing « outliers »





- ❑ 4 out of the 15 CMIP5 models are potential outliers
- ❑ Removing outliers leads to a substantial reduction of the inter-model spread (that here includes the uncertainty due to internal variability)

Global vs regional emergent constraints?



- ❑ Constraining the global warming would be extremely useful to constrain regional climate changes but seems to be very difficult
- ❑ Constraining the regional warming might be easier and would be also very useful to constrain the global warming
- ❑ NB: We only have one globe to constrain regional warming but we have multiple regions to constrain global warming

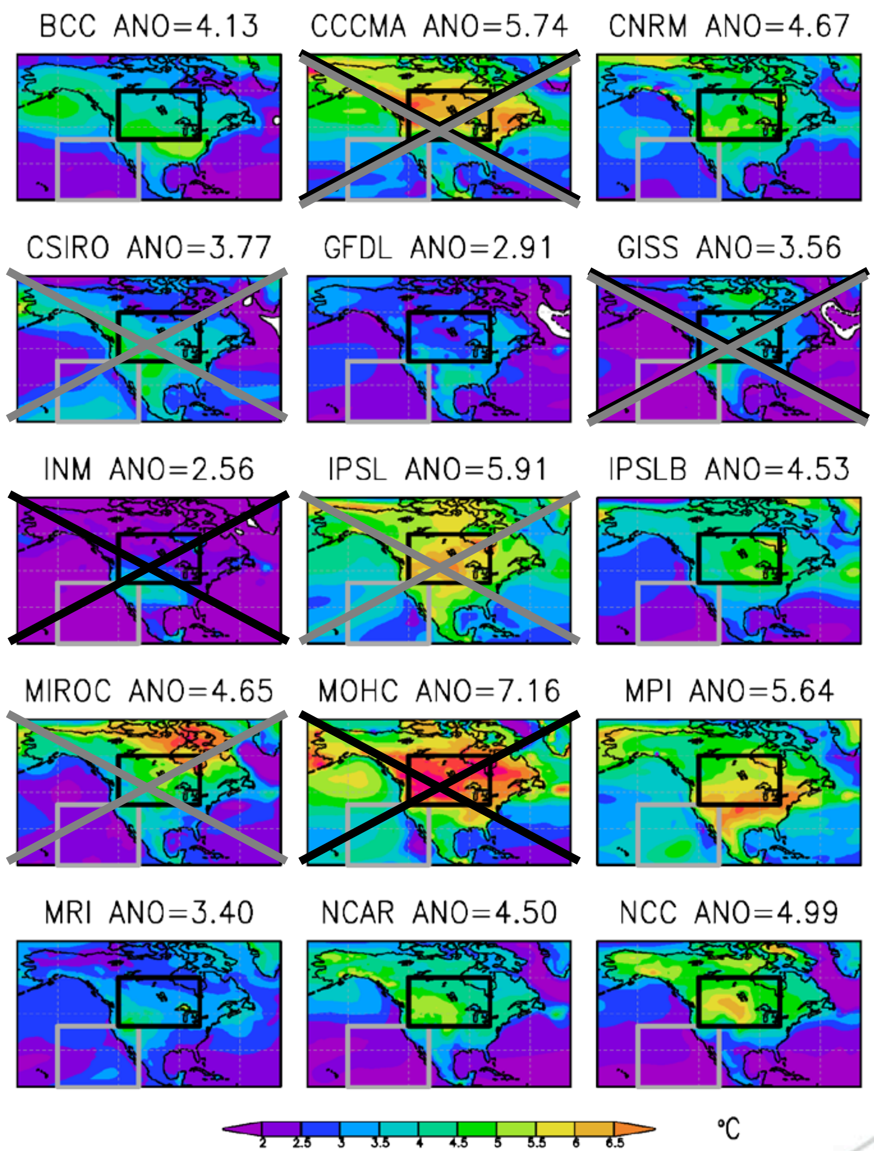
Conclusions

- Biases / uncertainties in present-day / future summer temperature over North America (as well as over Europe) are due to the poor simulation of both cloud and land surface processes;
- Constraining regional and seasonal mean temperature changes is feasible… but using multiple and physically-based metrics (rather than a single magical index);
- Assessing the models ability to simulate trends that cannot be explained by internal climate variability (D&A) will provide more and more efficient metrics.

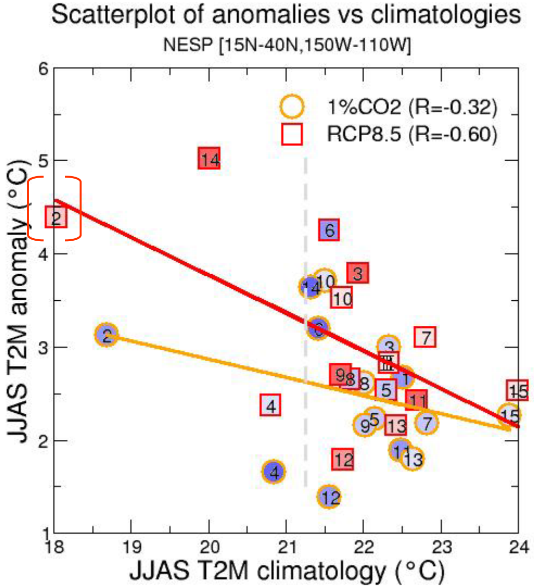
Implications

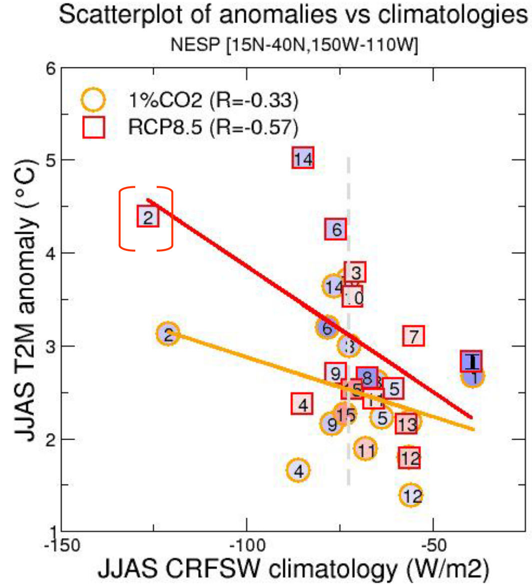
- Running global off-line land surface simulations (e.g. GSWP) driven by observed atmospheric forcings and CO_2 concentrations would be useful for understanding the role of land surface biases and feedbacks in CMIP models (cf. H2020 IMPULSE);
- Improving a sustainable (but not necessarily global) observing system is as important as improving the climate models for narrowing uncertainties in climate projections;
- Having multiple (5?) members in the forthcoming CMIP-DECK experiments (at least for the historical simulations) would be useful to distinguish between model uncertainty and internal variability and for the development of robust emergent constraints.

Prospects: Looking at two « canonical » regions?

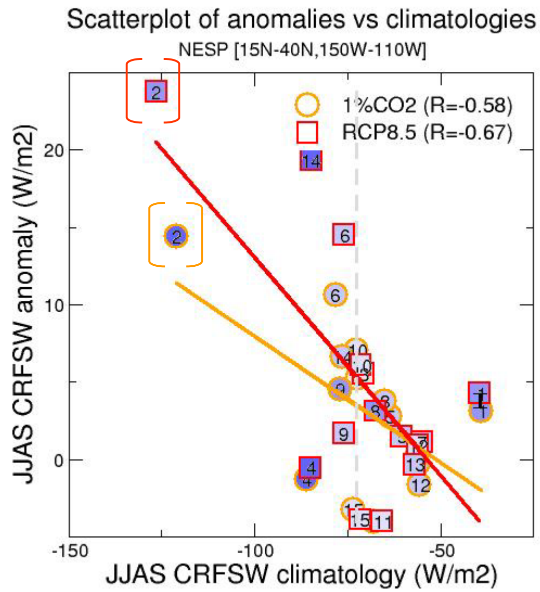


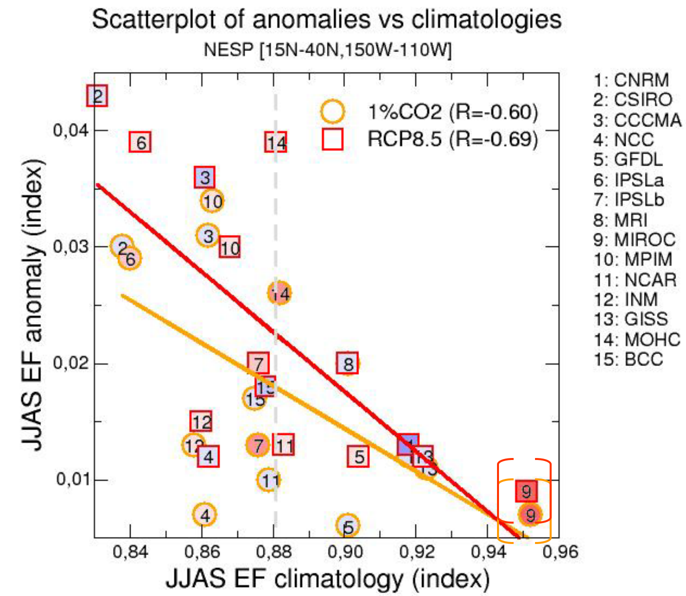
Climatol. vs anomalies: 1%CO2 & RCP8.5



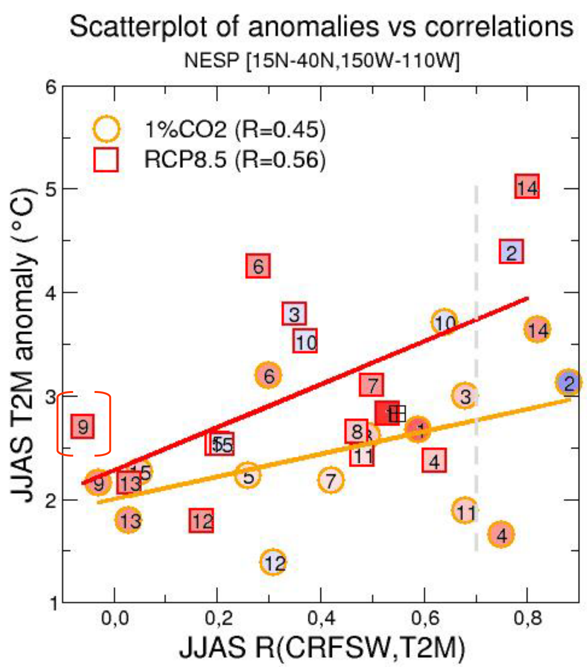


Outliers: CSIRO (& MIROC?) models



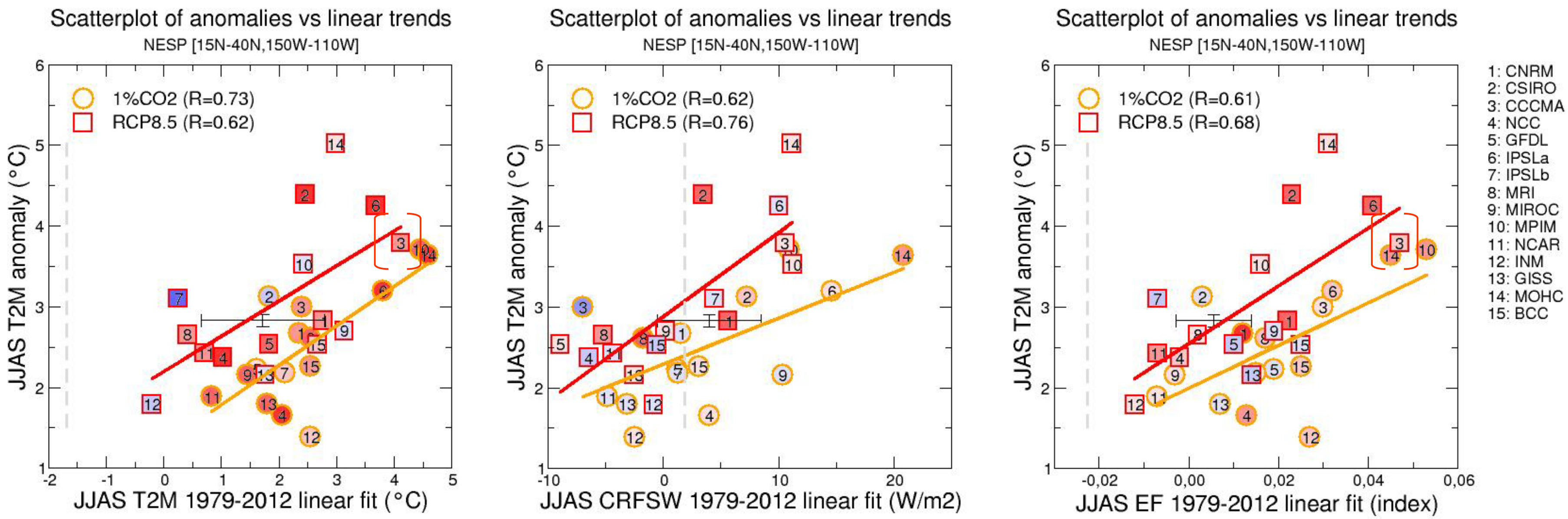


R(X,Y) vs anomalies: 1%CO2 & RCP8.5



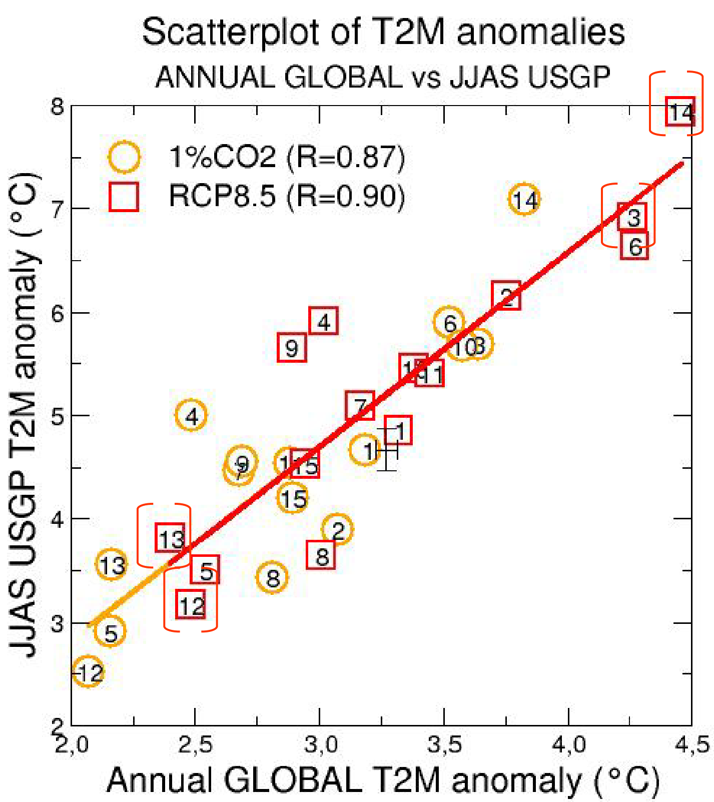
Outliers:
MIROC (and GISS?) models

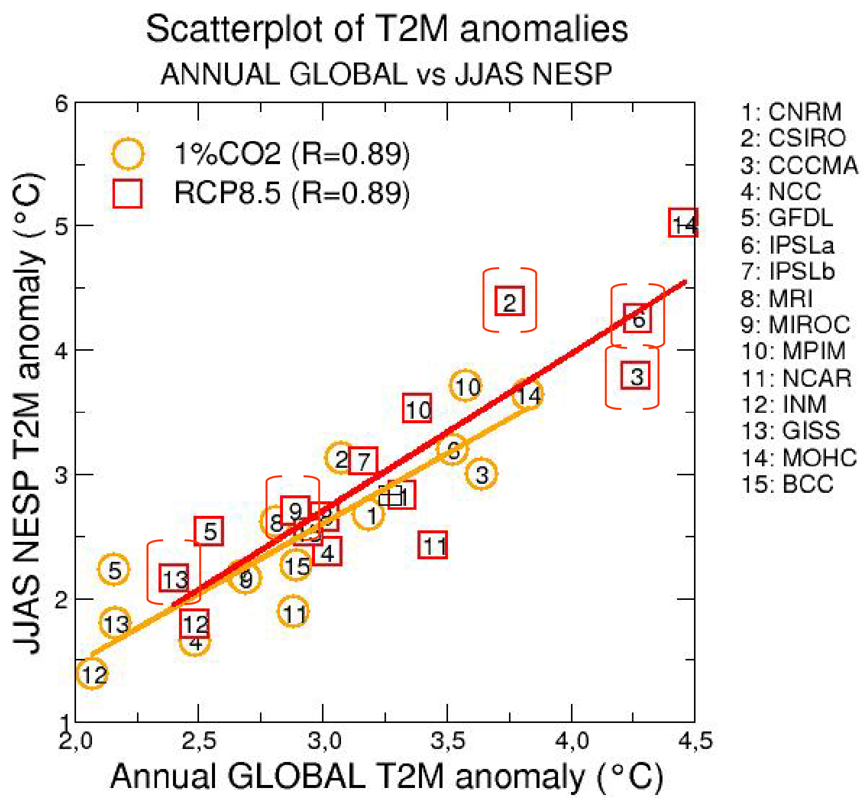
Trends vs anomalies: 1%CO2 & RCP8.5



Outlier:
CCCMA (and
IPSL?) models

Prospects: Looking at other regions?





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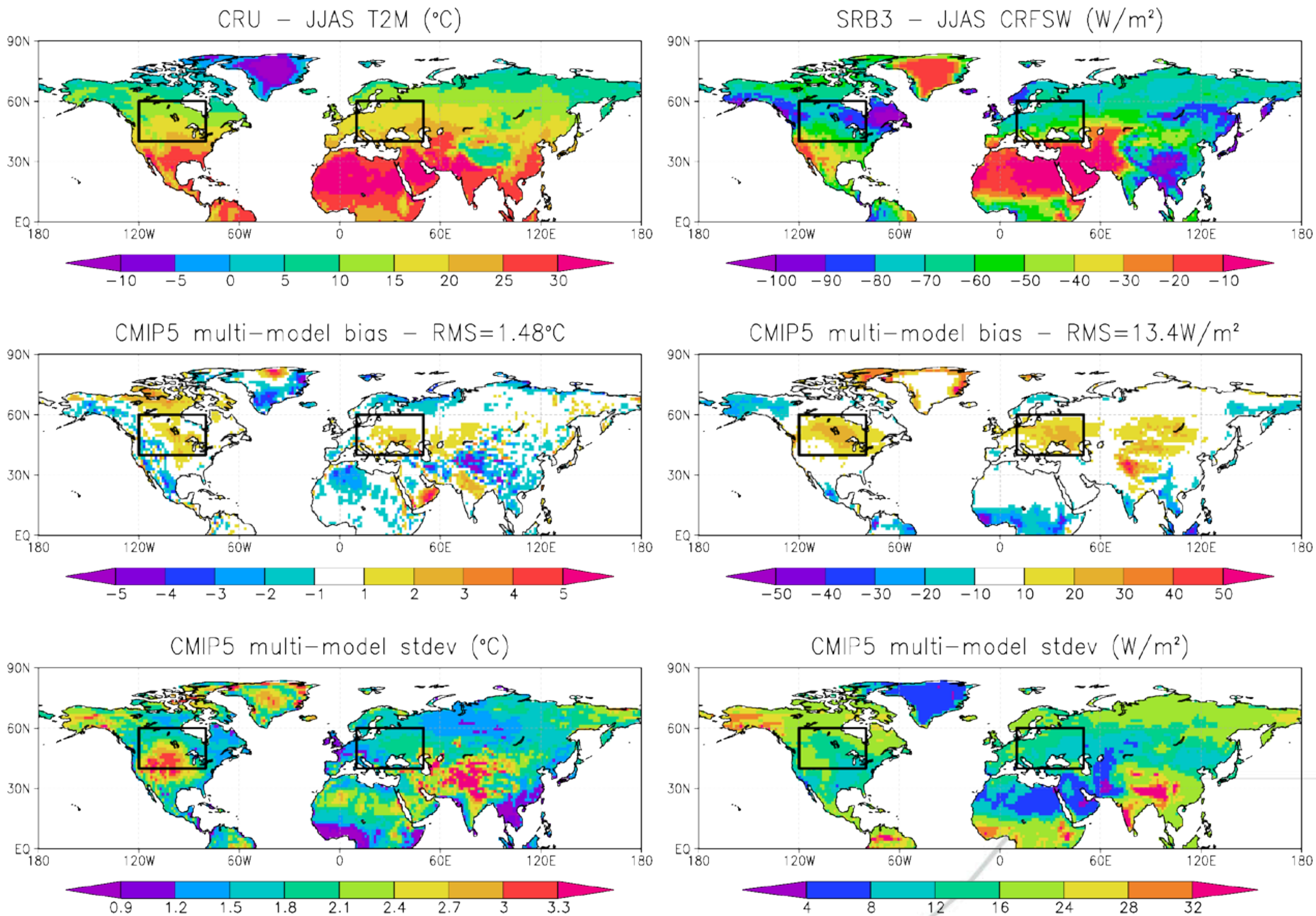
T2M (left) & CRFSW (right) biases: HIST

Obs

MME mean bias

MME bias stdev

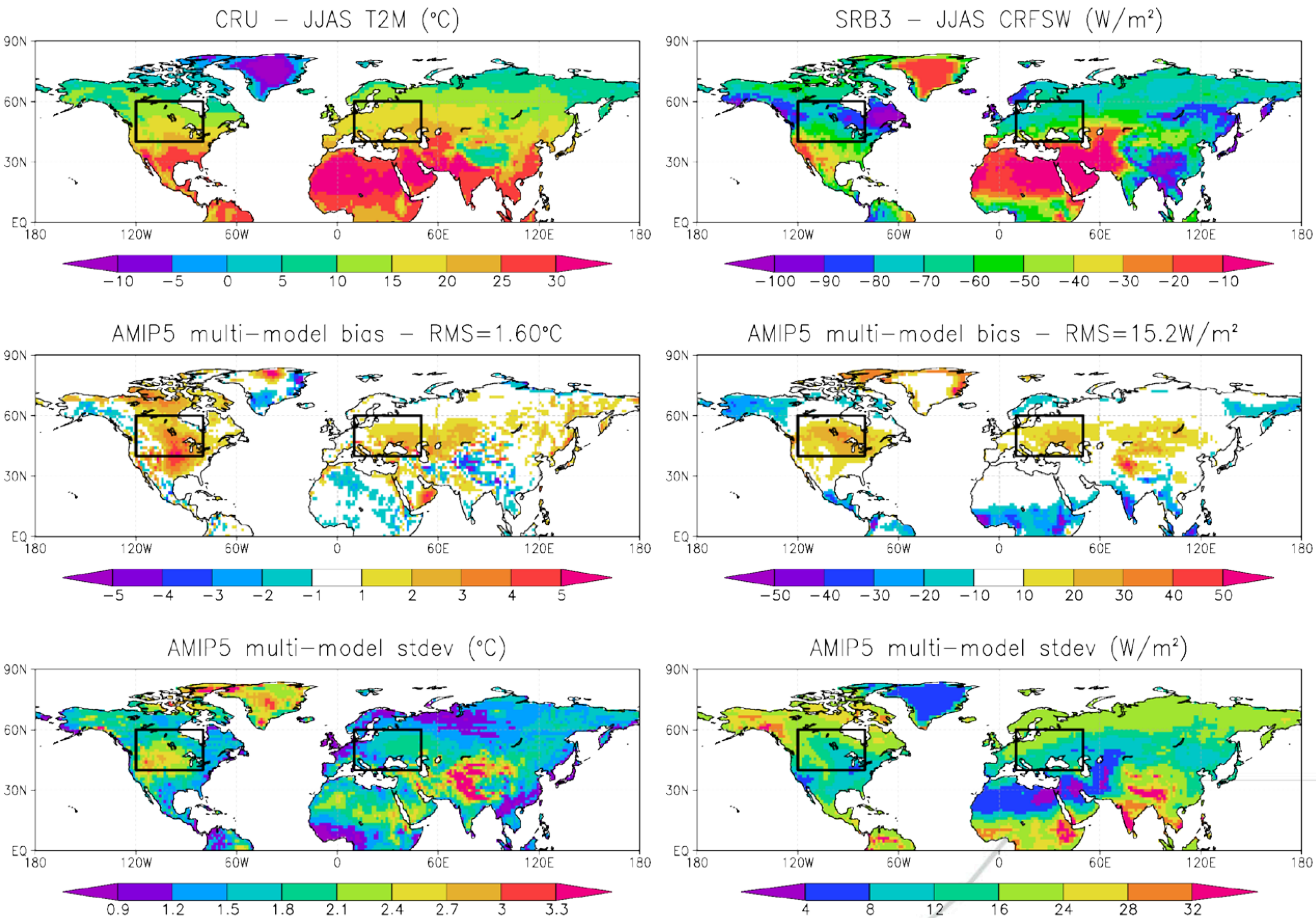


T2M (left) & CRFSW (right) biases: AMIP

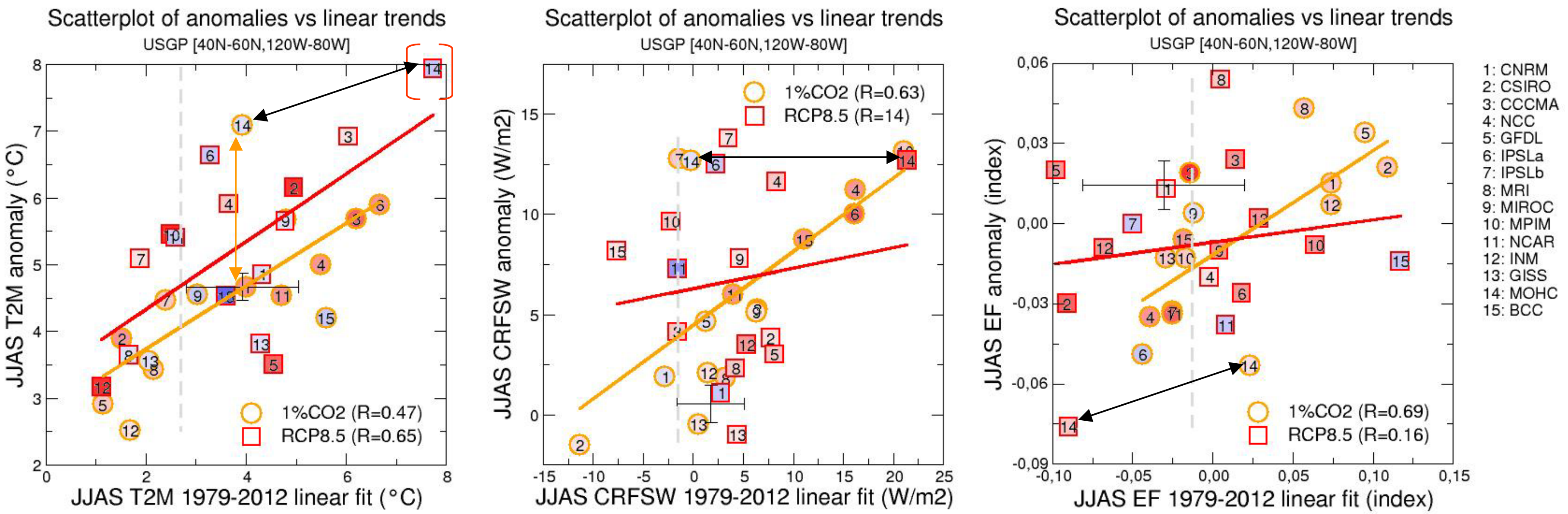
Obs

MME mean bias

MME bias stdev

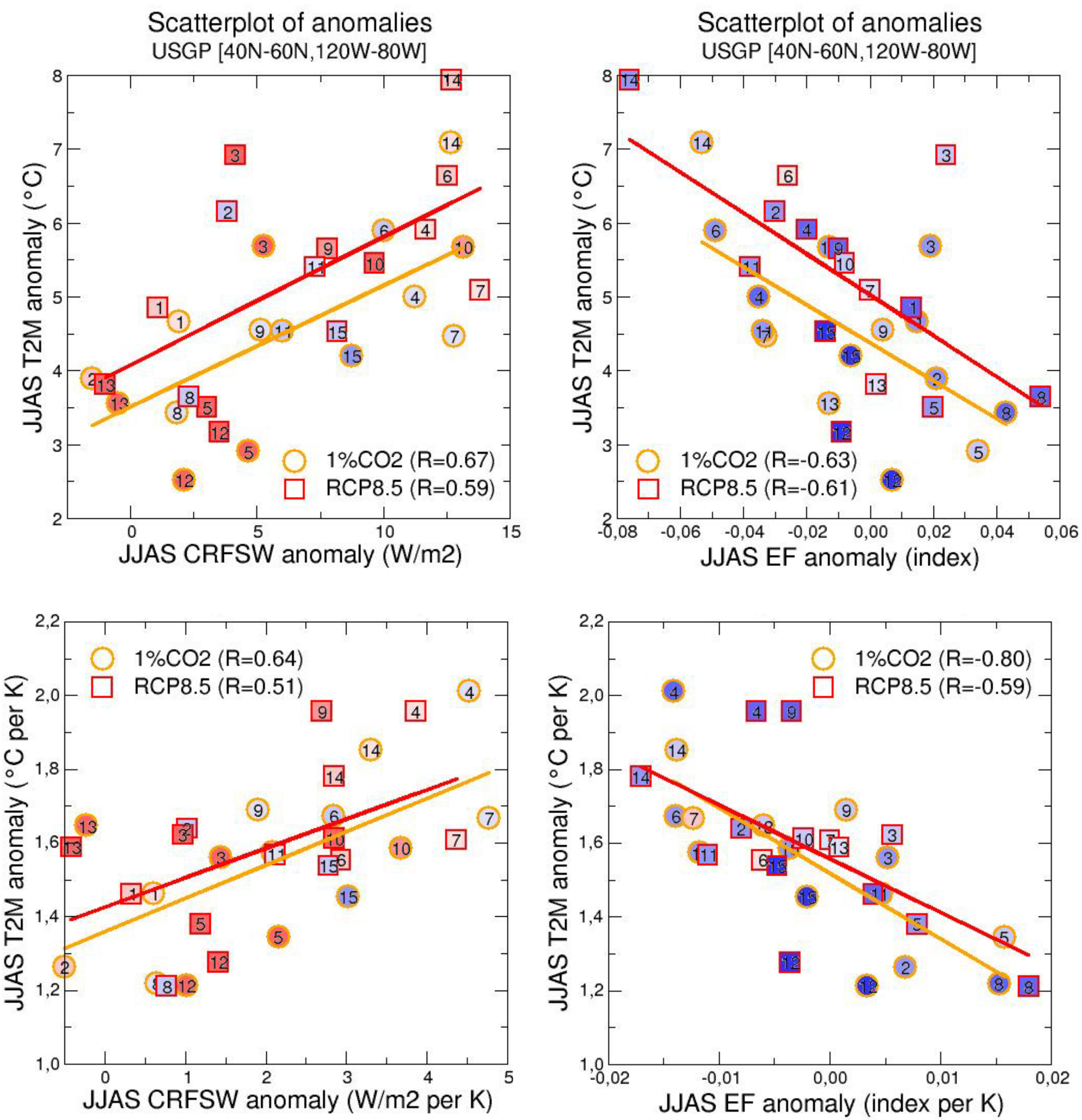


Trends vs anomalies: 1%CO2 & RCP8.5



- ❑ Recent linear trends in T2M show significant correlations with projected T2M anomalies (especially in RCP8.5) and HadGEM2ES (with a strong indirect aerosol effect and a strong CO2 physiological effect on surface evapotranspiration) appears as an outlier
- ❑ Also true for CRFSW and EF in 1%CO2 experiments (less clear in RCP8.5 due to model-dependent radiative effects of anthropogenic aerosols) but large uncertainties in both « observed » and simulated trends (one realization per model is not necessarily enough)

Scatterplots of anomalies: 1%CO2 & RCP8.5



- Both SW CRE and EF contribute to the inter-model spread of T2m anomalies
- The statistical links are robust (i.e. statistically significant and found in both RCP8.5 and 1%CO2 expts)
- Also true for scaled anomalies

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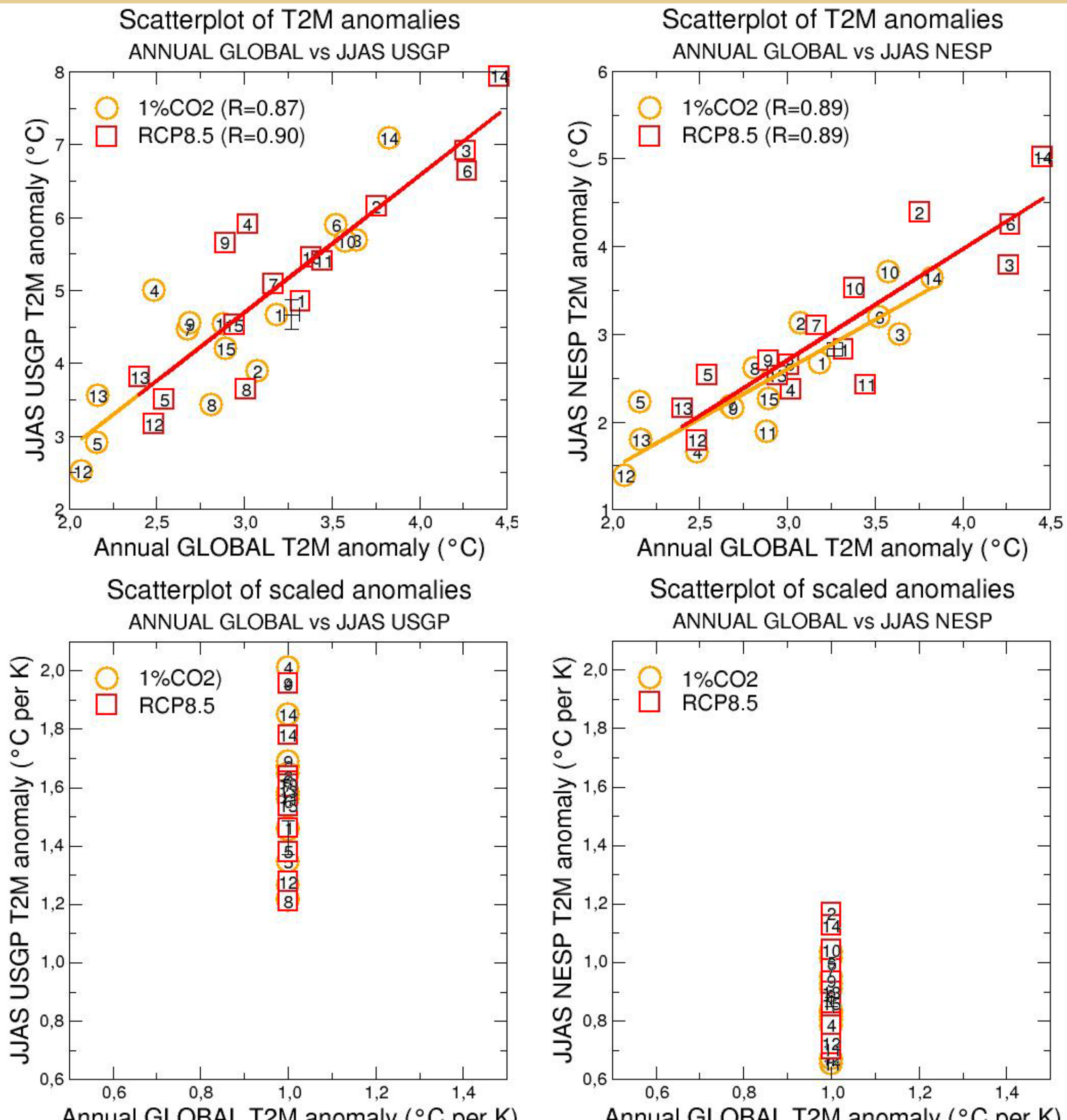
Effect of scaling on the intermodel spread



1: CNRM
2: CSIRO
3: CCCMA
4: NCC
5: GFDL
6: IPSLa
7: IPSLb
8: MRI
9: MIROC
10: MPIM
11: NCAR
12: INM
13: GISS
14: MOHC
15: BCC

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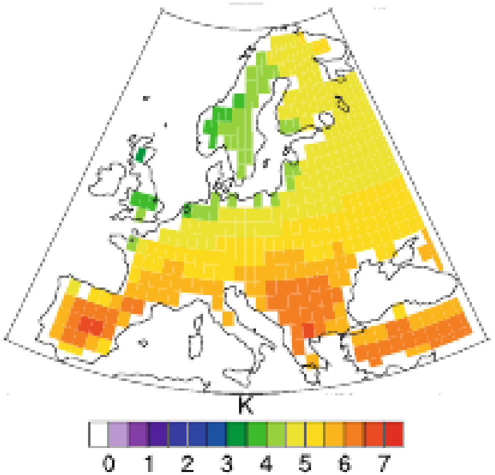
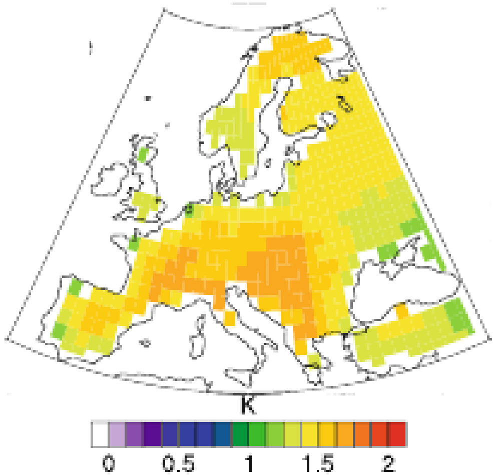
JJAS warming over Europe in CMIP5

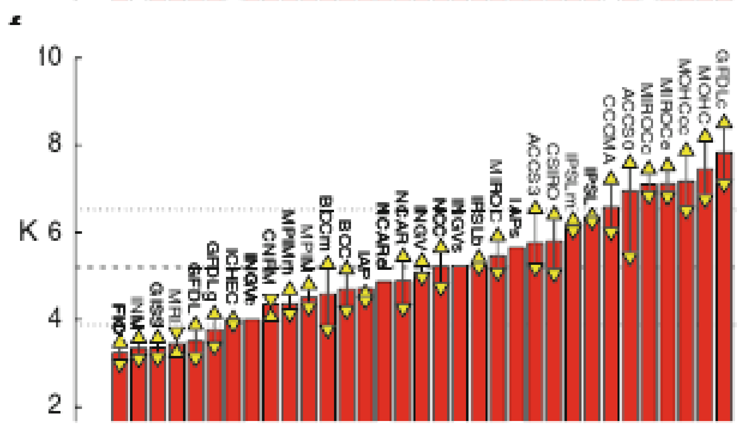
MME mean



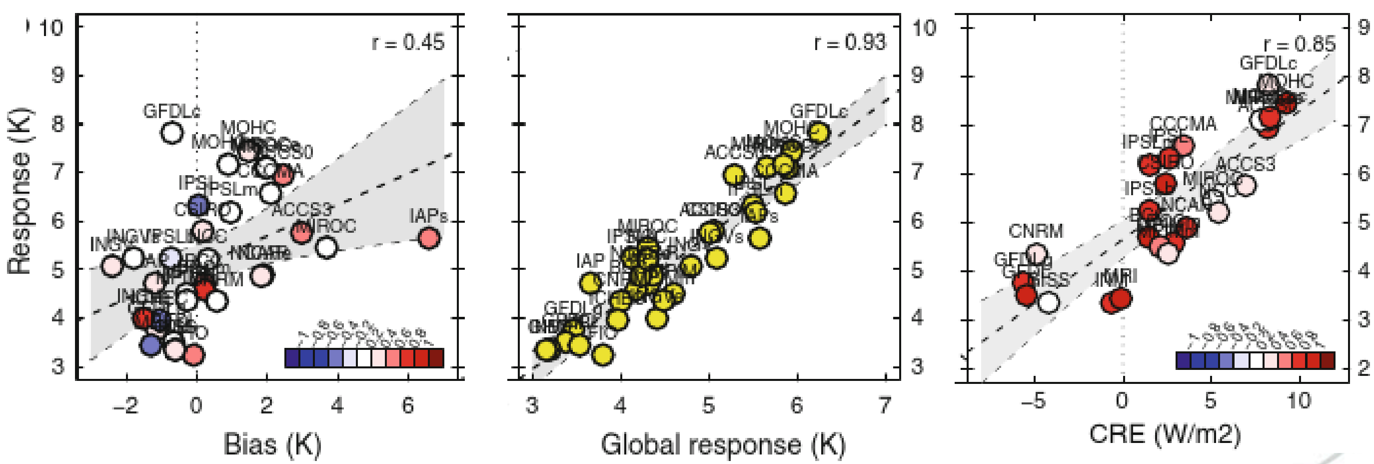
MME stdev



Spatial average for each model



Inter-model spread in European warming as a function of…



RCP8.5 scenarios from 33 models

Cattiaux et al. 2013

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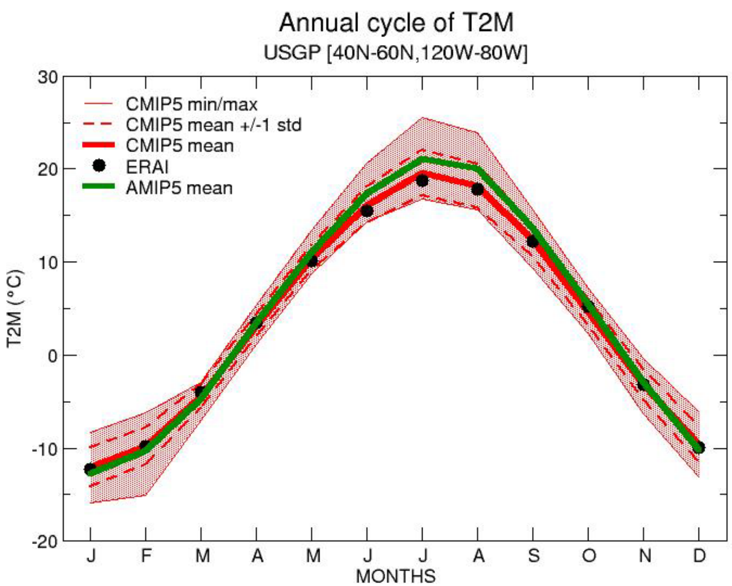
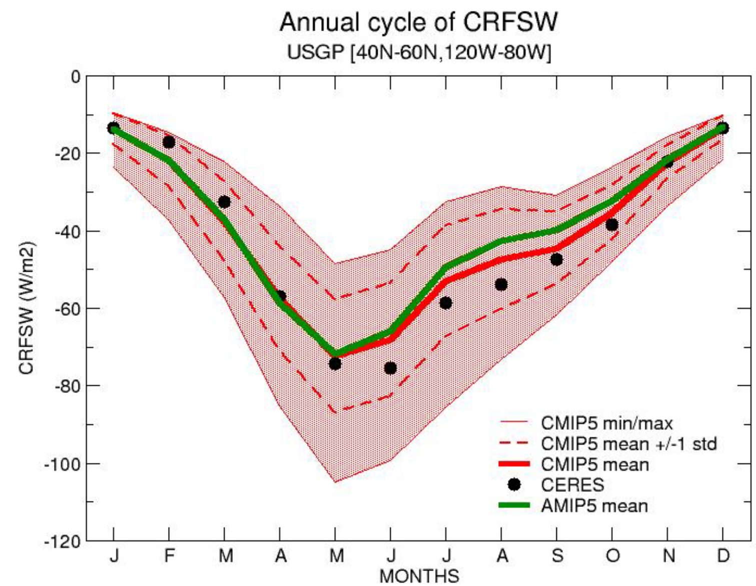
Seasonal dynamics of T2M biases





- ❑ The MME warm bias appears in June, in line with a lack of SW cloud radiative cooling
- ❑ It is then amplified by an underestimation of the evaporative fraction