Evaluation of frontal precipitation in CMIP6 models

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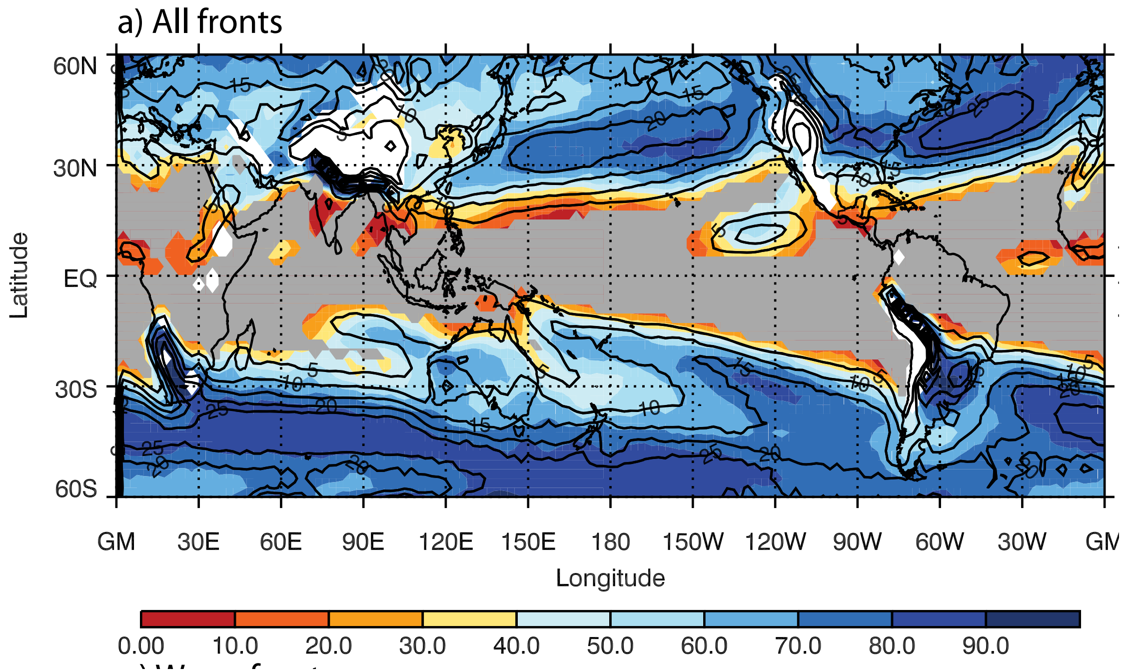
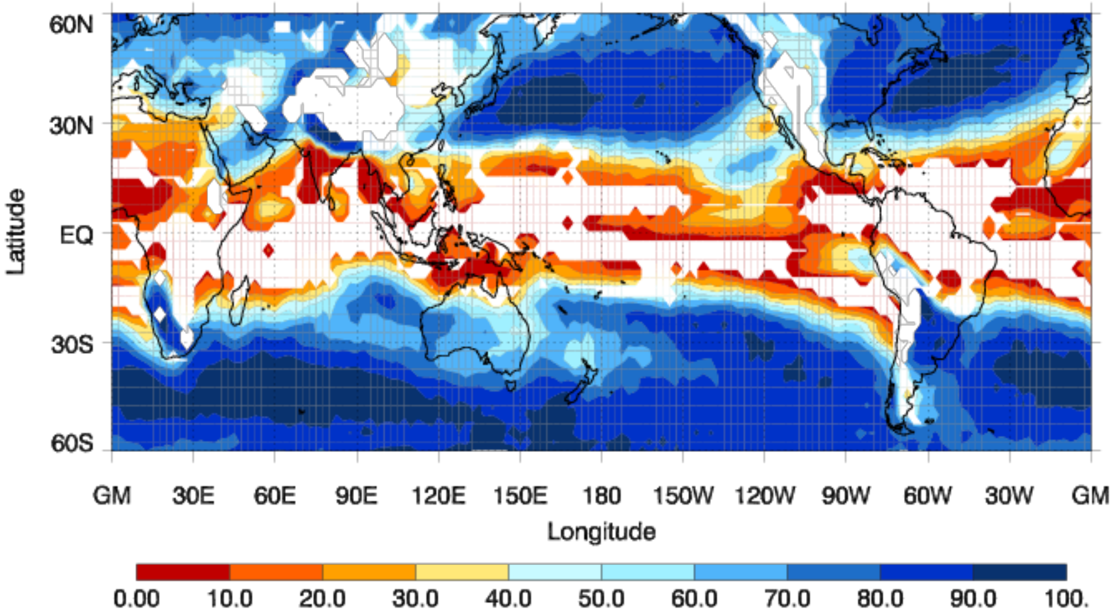
Weather fronts are very important for both total and the extreme precipitation globally



Proportion of global annual precipitation (from GPCP) associated with fronts identified in ERA-Interim using the method of Berry et al. 2011. *Figure from Catto, J. L., et al. (2012), GRL.*



Proportion of global annual extreme precipitation (defined as events above the 99th percentile from ERA-Interim) associated with fronts identified in ERA-Interim using method of Berry et al 2011. *Figure from Catto, J. L., and S. Pfahl (2013), J. G. R.*

Climate models need to represent the correct precipitation for the correct dynamical reasons

- We wish to contribute to the efforts to evaluate state-of-the-art climate models and to develop a metric based on the evaluation of frontal precipitation. (See Pendergrass et al 2020 for details of the precipitation metrics workshop.)
- To do this we will use the framework developed in *Catto et al 2015.*
- Errors in total precipitation can be decomposed into 2 regimes:
  - frontal and non-frontal

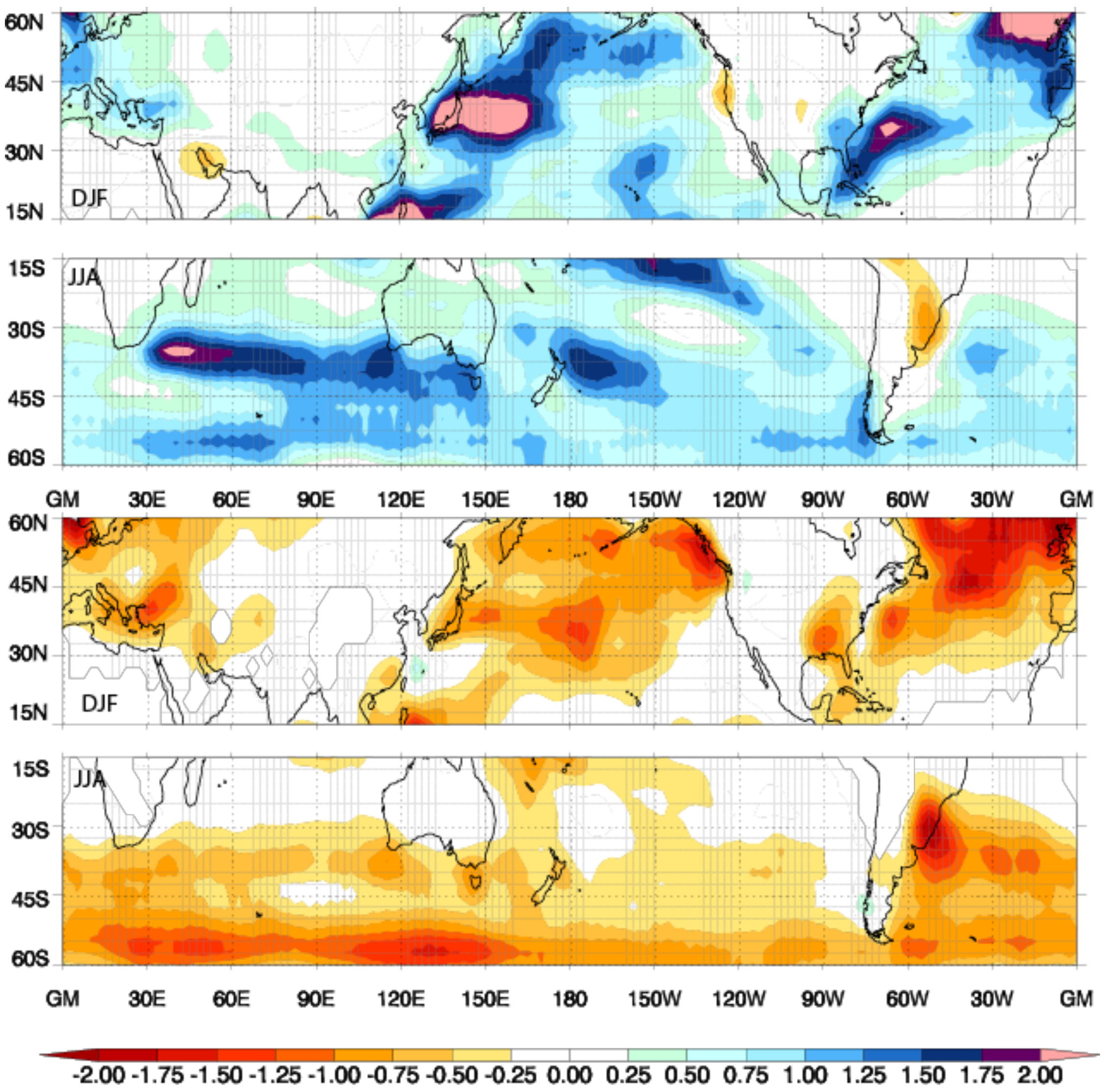
$$E_p = P_m - P_o$$

$$\boxed{E_p = \Delta F_f I_{f,o} + F_{f,o}\Delta I_f + \Delta F_f \Delta I_f + \Delta F_n f I_{nf,o} + F_{nf,o}\Delta I_{nf} + \Delta F_{nf}\Delta I_{nf}}$$

- Where fronts are identified using the method of Berry et al 2011.
  - On 2.5degree resolution data, identify frontal points using a Thermal Front Parameter (TFP; Hewson 1998) based on wet bulb potential temperature at 850hPa.

$$TFP(\theta_w) = -\nabla|\nabla\theta_w| \bullet \left(\frac{\nabla\theta_w}{|\nabla\theta_w|}\right)$$

Demonstration from CMIP5: Representation of winter frontal rainfall

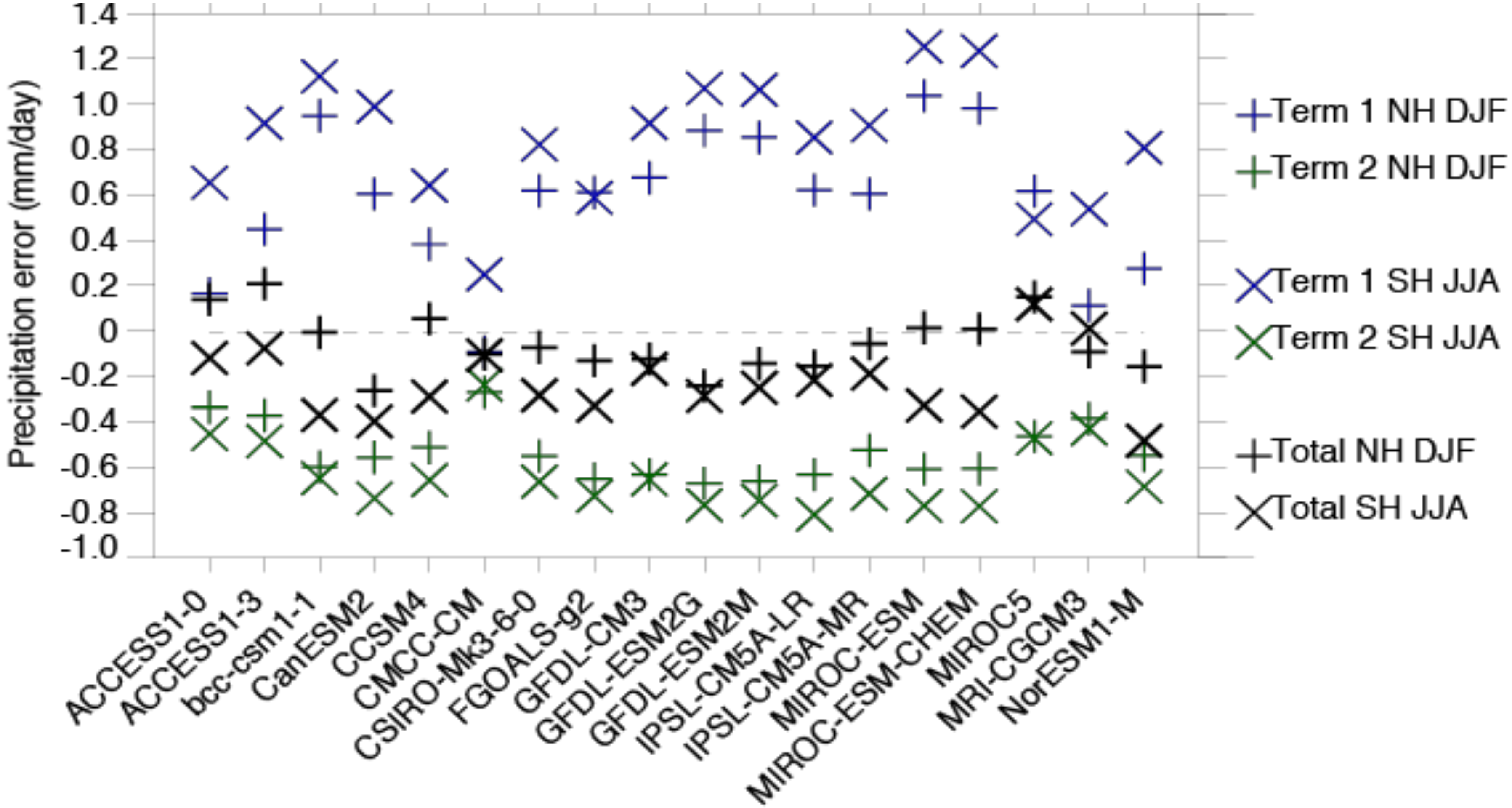


Error decomposition term 1: Contribution to total precipitation bias from errors in frontal precipitation **frequency**. Large positive values.

Error decomposition term 2: Contribution to total precipitation bias from errors in frontal precipitation **intensity**. Large negative values.

From [Catto et al 2015]

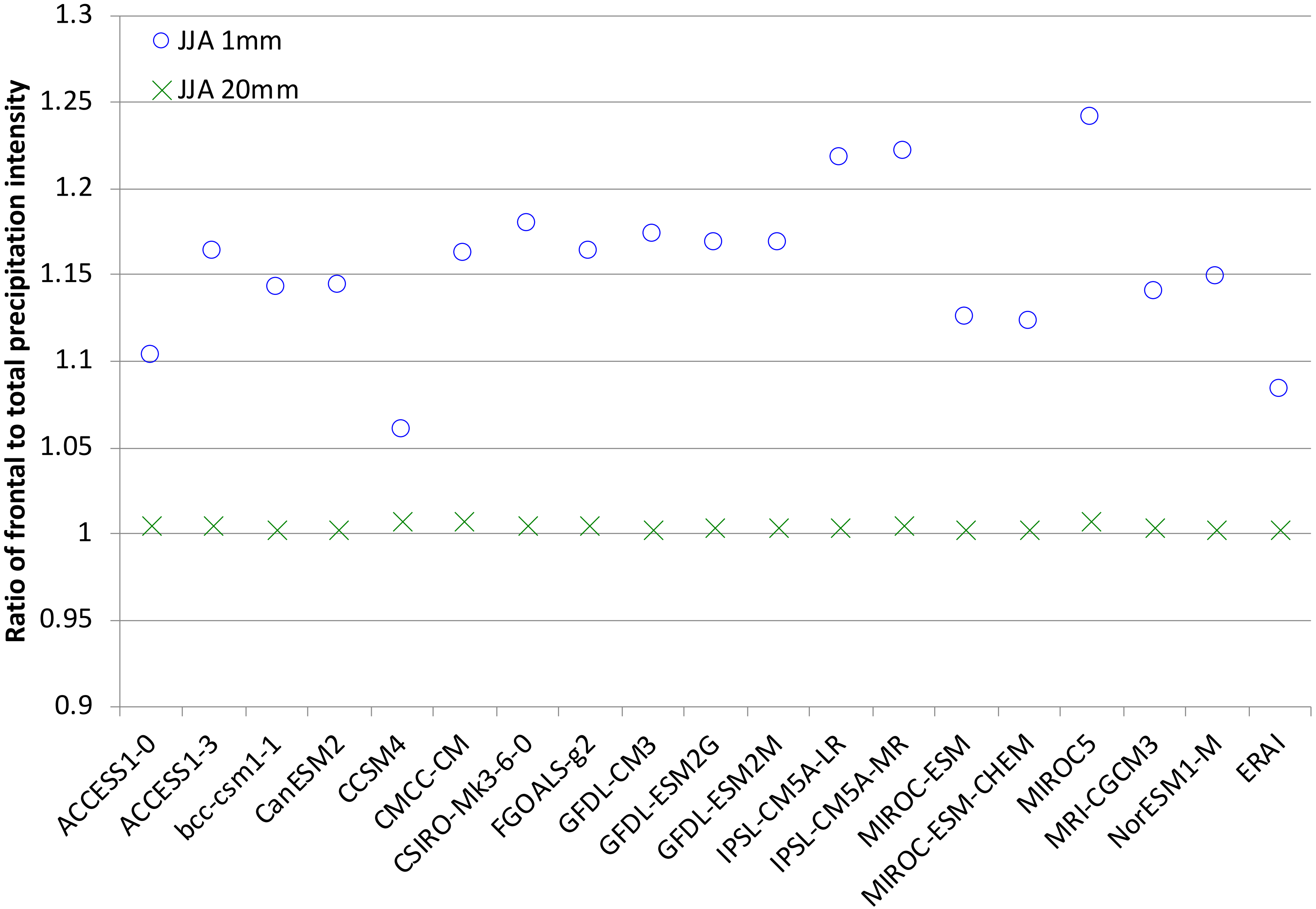
Demonstration from CMIP5: Compensating errors



Average values of the decomposition terms for the NH DJF and SH JJA.

All the models have large positive contributions to the precipitation error from the errors in frontal precipitation frequency, and compensating negative contributions from the errors in frontal precipitation intensity.

Demonstration from CMIP5: Frontal amplification factor



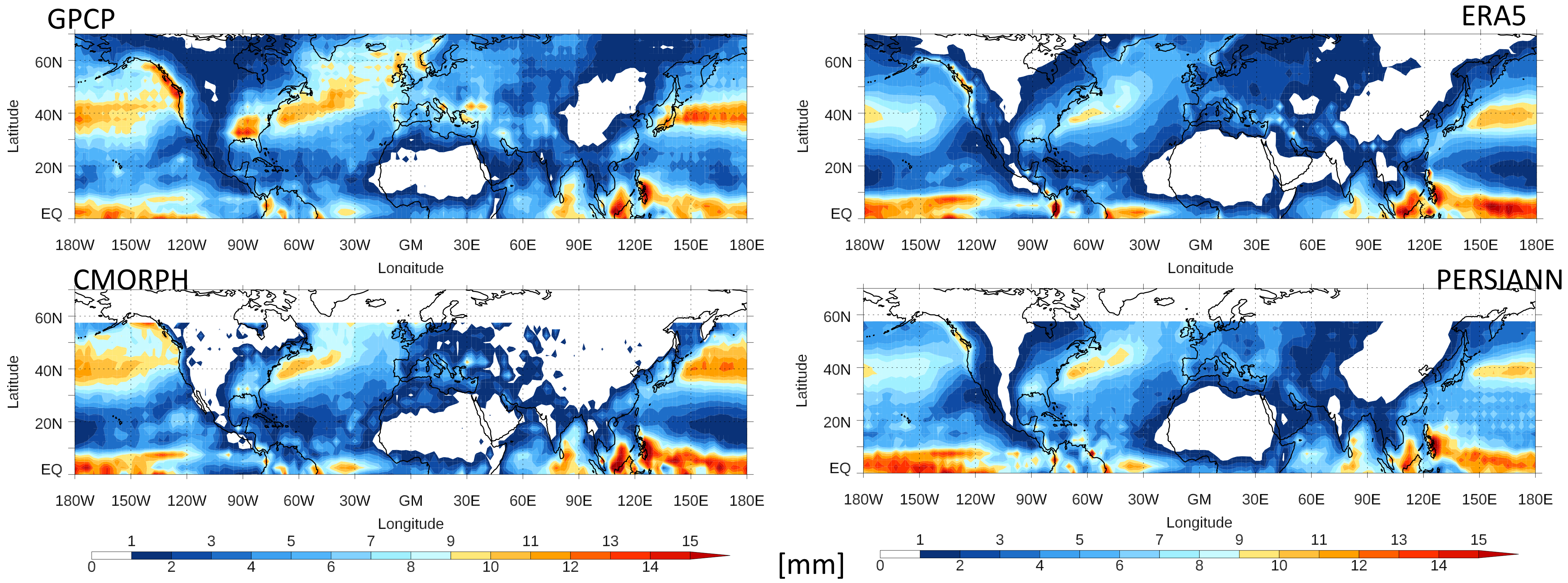
The frontal amplification factor is the ratio of the mean frontal precipitation intensity to the mean precipitation intensity. This has been calculated for all precipitation above 1mm and all precipitation above 20mm (shown here for the SH JJA). For low intensity precipitation, models overestimate the amplification associated with fronts.

At very high intensities, the models better capture the amplification from fronts.

Adapted from [Catto et al 2015]

Considering observational uncertainty

- Initial work to investigate the range of frontal precipitation characteristics in different observational or reanalysis datasets. Fronts have been identified from ERA5 data.
- Using data from the [FROGS]() dataset. Figures show the average intensity of precipitation when a front is present. Highest intensity seen in GPCP and CMORPH and lower in ERA5.



Conclusions and Future Work

- We have a framework within which to evaluate the CMIP6 models that has been demonstrated for the CMIP5 data in Catto et al 2015.
- It will be important to consider a range of observations in the evaluation to capture the uncertainty with differing dataset.
- Next steps will be to apply the methodology to DECK simulations from CMIP6 for which the 6-hourly pressure level data are available along with daily precipitation.
- Produce metrics based on the decomposition of precipitation errors into frontal and non-frontal precipitation.

References

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