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A parameterisation for sea-breeze enhancement of convective rainfall in a global model

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Background

Tropical rainfall variability is strongly dominated by the diurnal and seasonal cycle, and in coastal regions (such as the Maritime Continent) diurnal precipitation variability is thought to be dominated by land-sea breeze circulations. However most global models are too coarse to resolve such small-scale circulations and therefore their associated impacts on rainfall. We have developed a simple sea breeze parameterisation which was tested in a single column model in earlier work. We now show preliminary results from implementing the scheme in a global model.

Parameterisation description

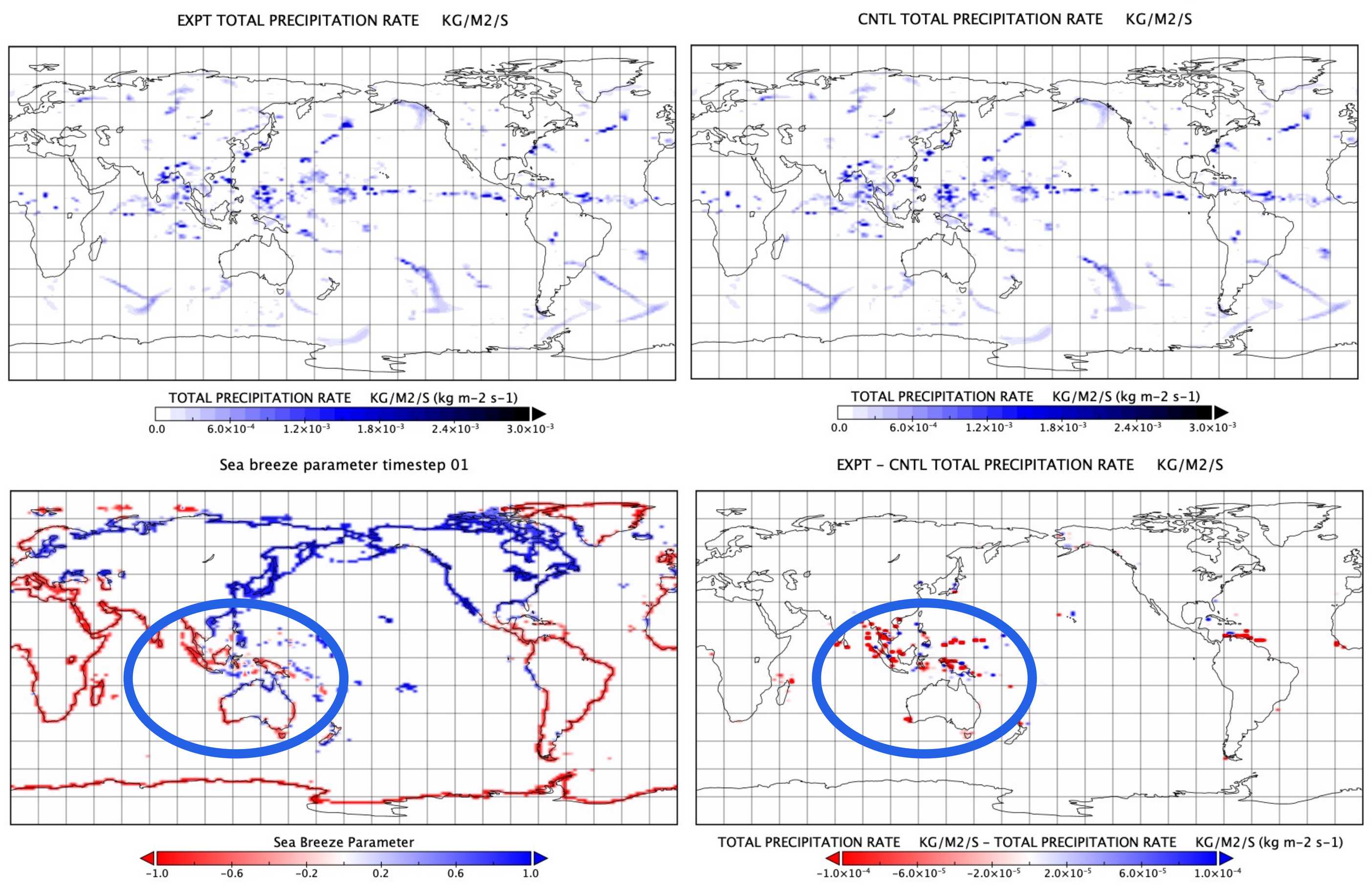
1. Coastal tiling used to determine average land vs average ocean thermal contrast at each coastal grid point.
2. If ocean-land thermal contrast exceeds +/-0.75 K, sea/land breeze conditions are diagnosed.
3. Sea breeze parameter defined at each grid point as thermal contrast above 0.75K threshold, scaled between [-1,1] (+/- value : sea/land breeze).
4. +1K (sea breeze) warming or -1K (land breeze) cooling applied to surface parcel in convection scheme (whilst keeping parcel relative humidity constant).

Model configuration

- UM GA10.7 (atmosphere-only), N96. Gregory Rowntree convection scheme.
- EXPT: Experiment run (sea breeze parameterisation coupled to convection scheme).
- CNTL: control run (no coupling to convection).
- Two sets of simulations:
  i. 10-day runs initialised 01 Nov 1998, total precipitation output every timestep (20 mins).
  ii. 3-month DJF mini-ensemble runs initialised 01/02/03 Nov 1998, November discarded from analysis as spin-up. Total precipitation output every 3 hours.

First timestep precipitation effects

Reduction in rain in tropics where sea breeze parameter is negative

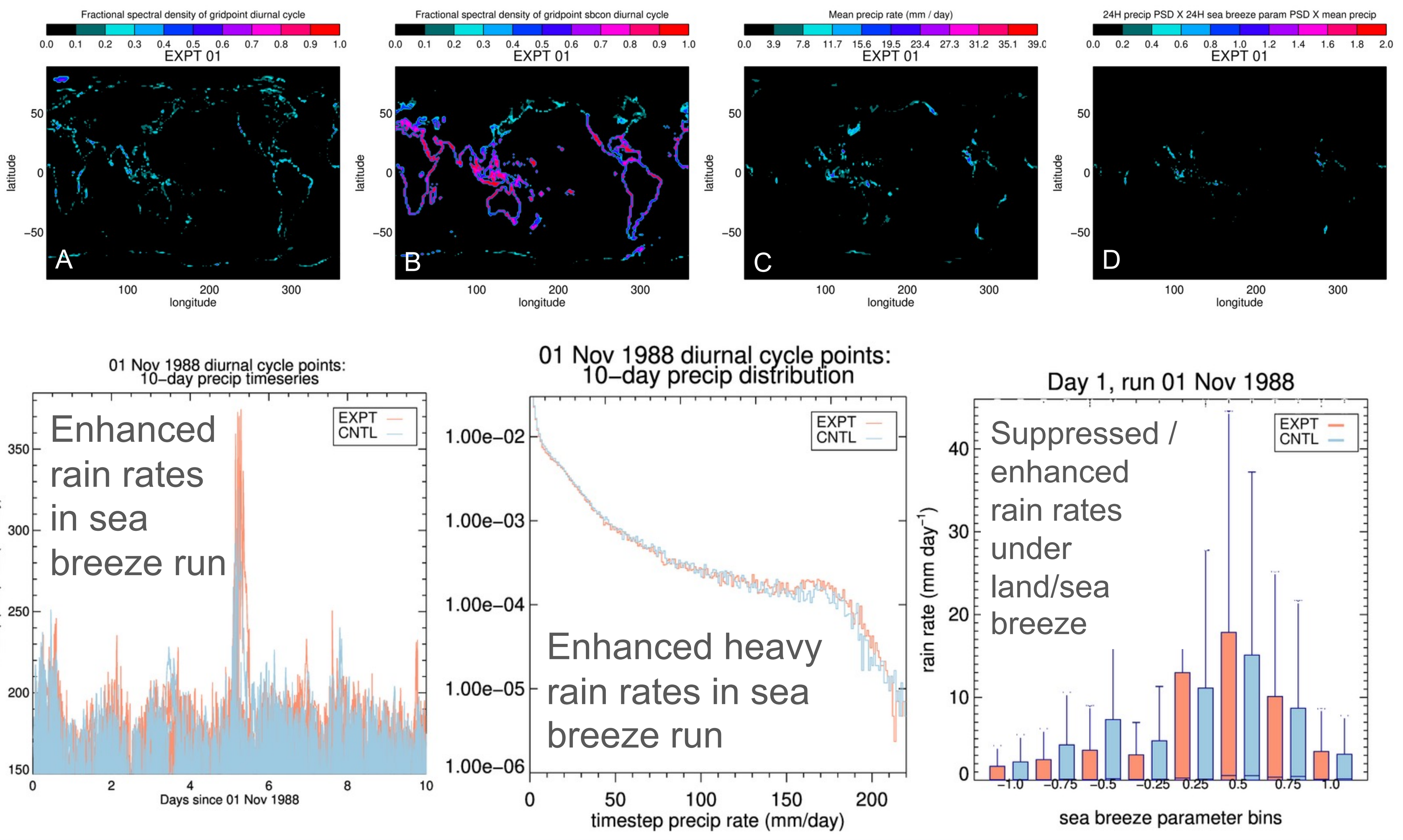


Positive sea breeze parameter: sea breeze conditions (➔ convection enhanced)
Negative sea breeze parameter: land breeze conditions (➔ convection suppressed)

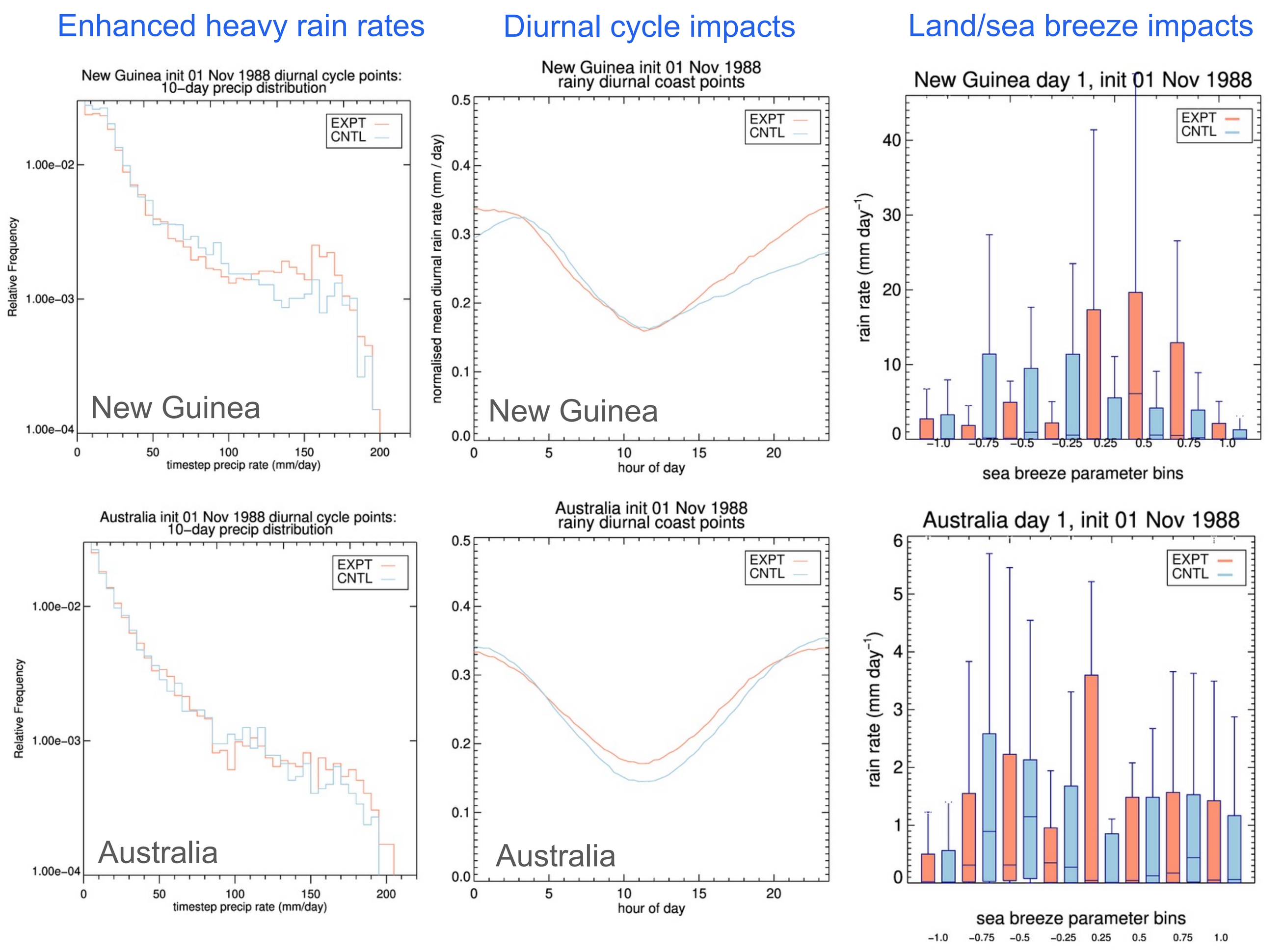
Global effects, 10-day run: rainy diurnal cycle sea breeze coastal points

1. Calculate power spectra of sea breeze parameter and of coast-masked precipitation at each grid point.
2. Extract fractional power spectral density of both fields at the 24-hour mode to identify coastal grid points with and strong diurnal precip cycle (Fig A) and a sea breeze (Fig B).
3. Multiply 24h precip fractional power by the 24h sea breeze fractional power to suppress points where diurnal precip signal is strong but sea breeze signal is weak.
4. Multiply by mean rain rate (Fig C) at grid point to enhance regions with strong precip and suppress points with weak precip (Fig D).

Identifying rainy grid points with a diurnal precipitation cycle and a land-sea breeze:



Regional effects, 10-day run, rainy diurnal sea breeze points



Day 1 precipitation distribution binned by sea breeze parameter. Suppressed rain rates under land breeze, enhanced rain rates under sea breeze.

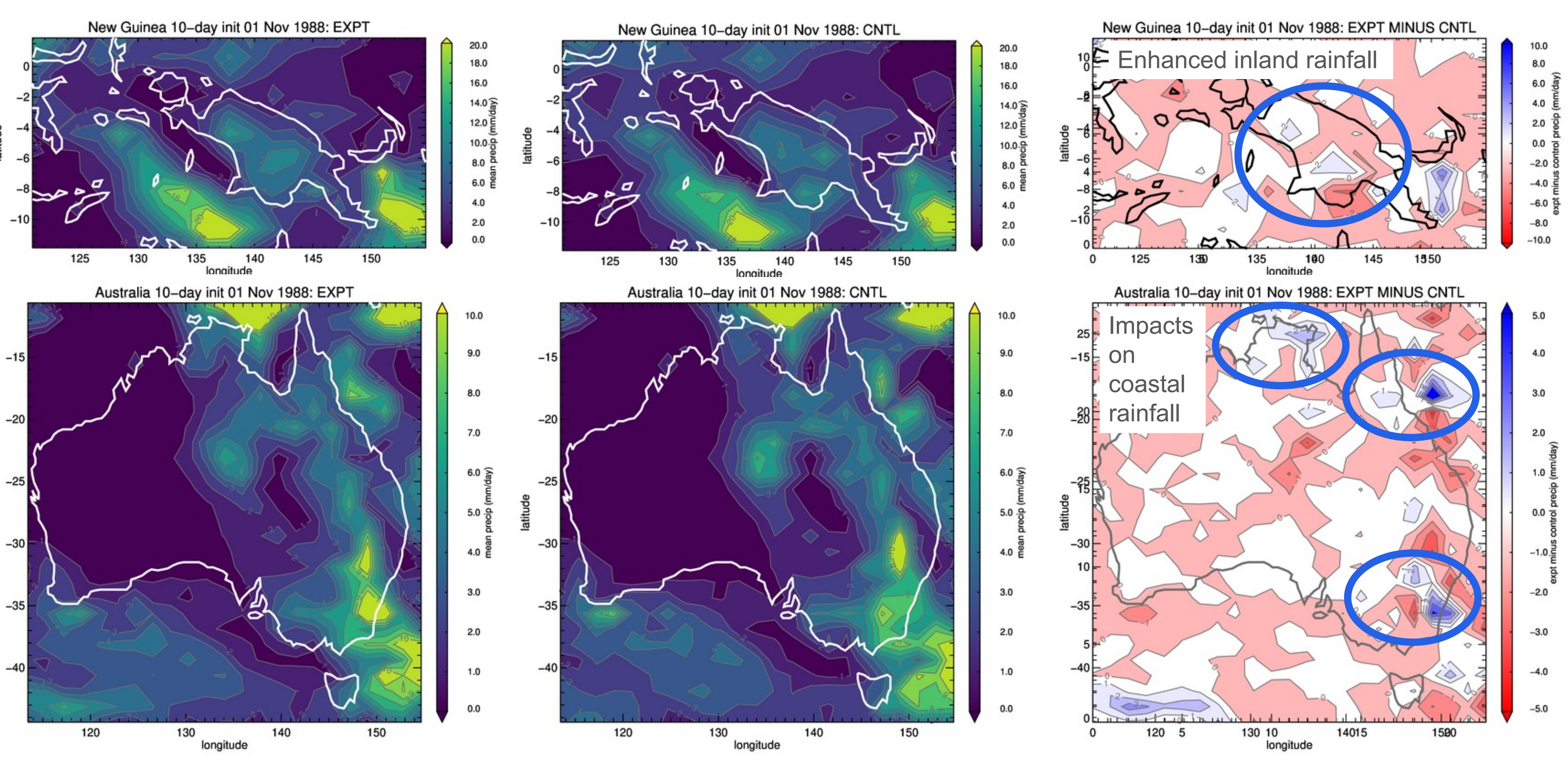
Asymmetric response.

Qualitative differences in response in the two regions:

New Guinea: strong enhancement / suppression of rain across range of sea / land breeze values.

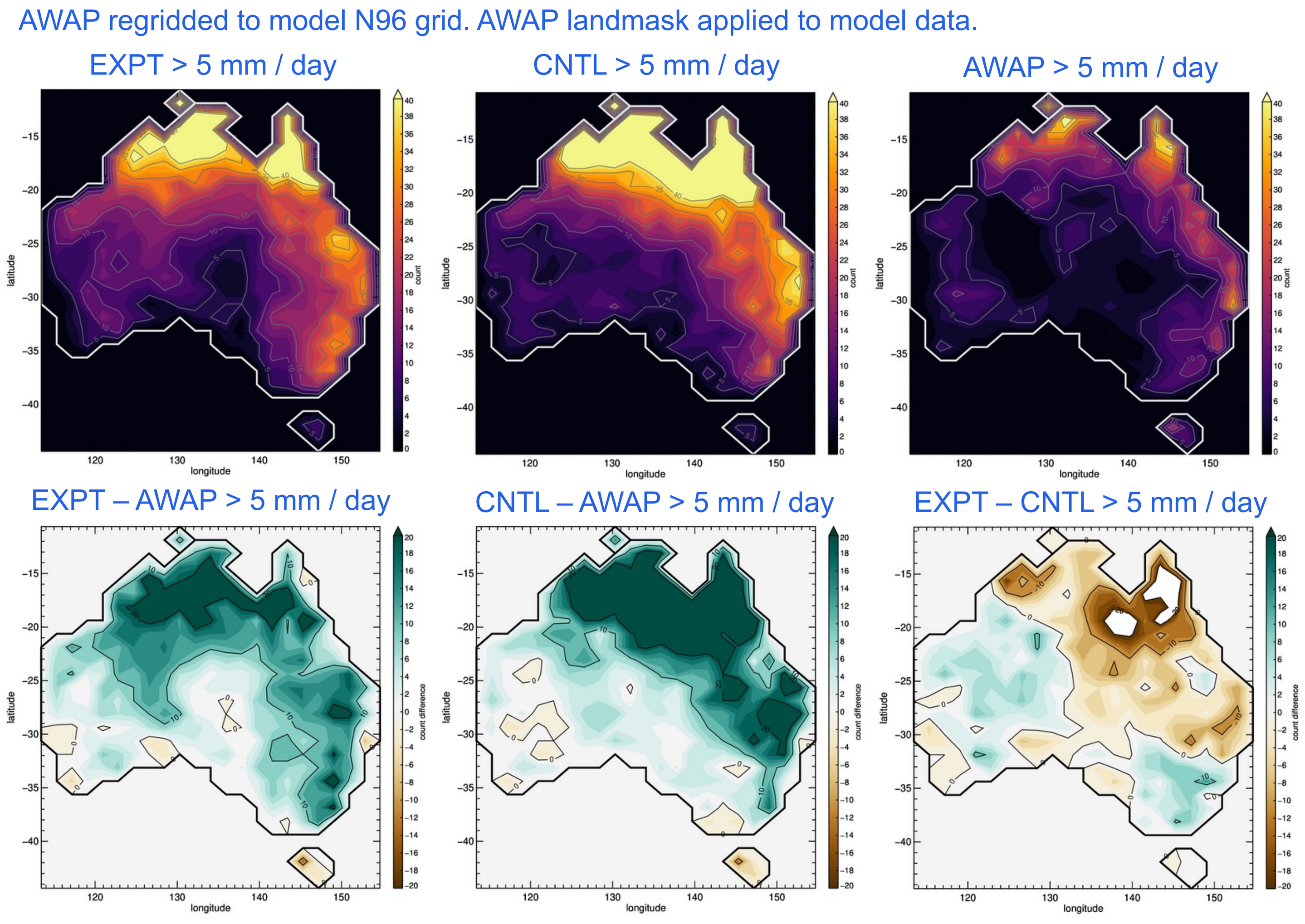
Australia: strongest rain enhancement seen for weakest sea breeze values.

Regional effects, 10-day run, mean rain (all points)



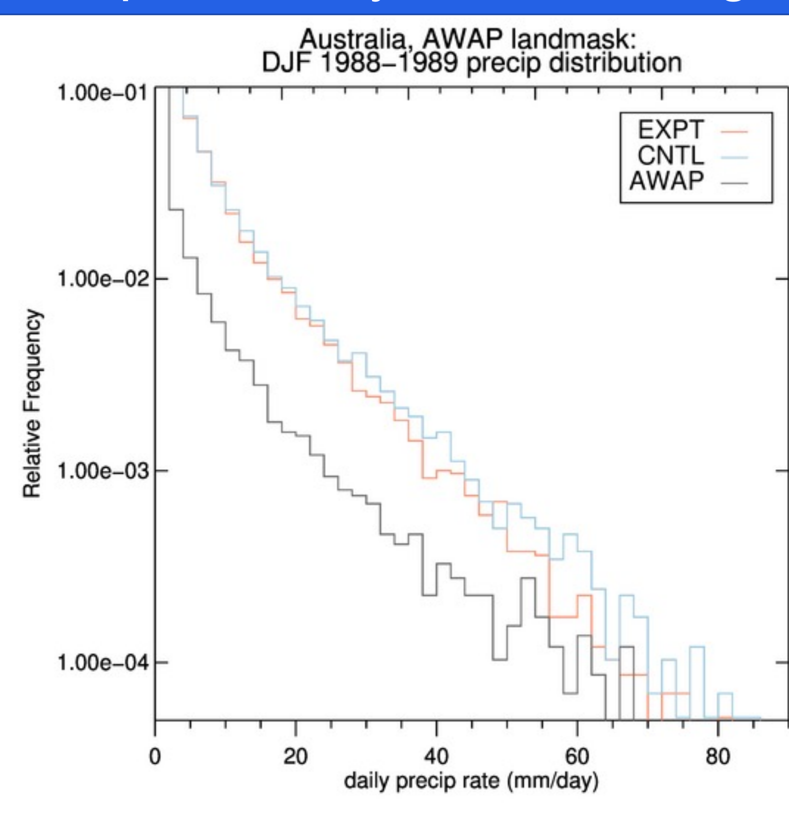
Australian seasonal effects (DJF 3-member model ensemble means) and preliminary evaluation against AWAP gridded daily rainfall observations

AWAP regridded to model N96 grid. AWAP landmask applied to model data.



Both global model configurations overdo the moderate-to-heavy rain, but the sea breeze version reduces the bias in north Australia and improves the frequency and spatial distribution along the east coast.

The reduction in the moderate-to-heavy rain wet bias in the sea breeze runs mainly comes from a reduced frequency of the 5mm (and more)/day rain days in the north and northeast, with an increase in the southeast.



Note: NOT rainy diurnal coastal points as in previous 10-day analysis of timestep rain. Here we show daily mean rain distribution over entire AWAP land region.

Seasonal daily mean rain distribution across all of Australia shows ***reduced*** overprediction of high intensity rainfall in sea breeze run compared to AWAP observations.

Recall: short timescale timestep rain analysis of only rainy diurnal sea breeze coastal points showed ***increased*** heavy rain in sea breeze run.

Indicates longer-timescale feedback processes that lead from increased coastal rainfall to a reduction in overly intense rain in other regions.

Next steps

- Tunable parameter testing:
  i. land-ocean thermal contrast used to define sea breeze conditions.
  ii. strength of thermal perturbation made to convection scheme surface parcel.
- Should sea / land breeze coupling to convection be symmetric or asymmetric?
- Evaluation against rainfall observations in Australia (especially tropical north and east coast).
- Evaluation against high-resolution convection-permitting TerraMaris simulations in Maritime Continent.
- Analysis of feedback processes from convective to seasonal scale.

References: Bergemann, M., Jakob, C., & Lane, T. P. (2015). Global detection and analysis of coastline- associated rainfall using an objective pattern recognition technique. Journal of Climate, 28(18), 7225–7236.
Jones, D., Wang, W., & Fawcett, R. (2009). High-quality spatial climate data-sets for Australia. Australian Meteorological and Oceanographic Journal, 58, 233–248.