The Diurnal Cycle of Precipitation: A Comparison of State-of-the-Art Observations and Models

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Model and Observation Products

	Model CNRM-ESM2-1 r1i1p1f2	Observations NASA GPM IMERG
Background	DECK AMIP experiment simulation	Multi-satellite retrievals
Spatial Resolution	~1.4° x ~1.4°	0.1° x 0.1°
Temporal Resolution	1 hour	Half-hour
Period	1979-2008	2000-Present
Variable	Precipitation Flux	Surface Precipitation Rate

Novelties of analysis:

- First global evaluation of CMIP6 representation of the diurnal cycle
- First analysis of interannual variability of the diurnal cycle

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Determining the Diurnal Cycle

Methodology

- Convert model variable to surface precipitation rate
- Match spatiotemporal resolutions of products
- Produce 5D histogram using JJA data
  - [lat (ϕ), lon (λ), rain rate (R), year (y), hour (t_{UTC})]
- Compute accumulation for chosen period of years

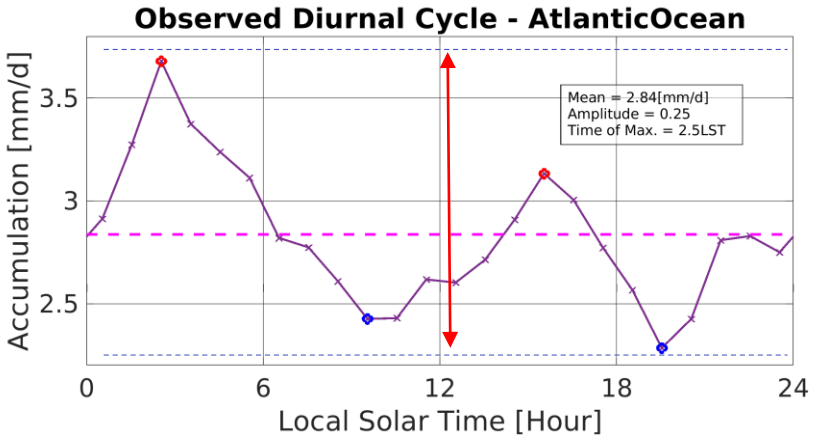
$$P(\phi, \lambda, t_{UTC}, y) = \frac{\sum_{R_i \geq 0} N_i R_i}{\sum_{R_i \geq 0} N_i}$$

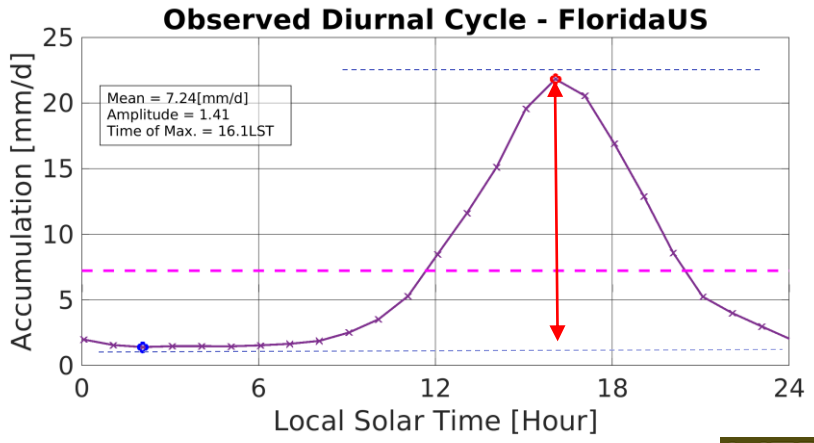
Note: N is the count for the ith rain rate bin.

Diurnal Parameters

- Mean
- Amplitude (= $\frac{Max - Min}{2\ x\ Mean}$)
- Time of Maximum & Minimum
- Number of Peaks
  - Peak identified when Prominence x Width > 0.1 x Mean x 2h

IMERG observations – JJA 2000-2018





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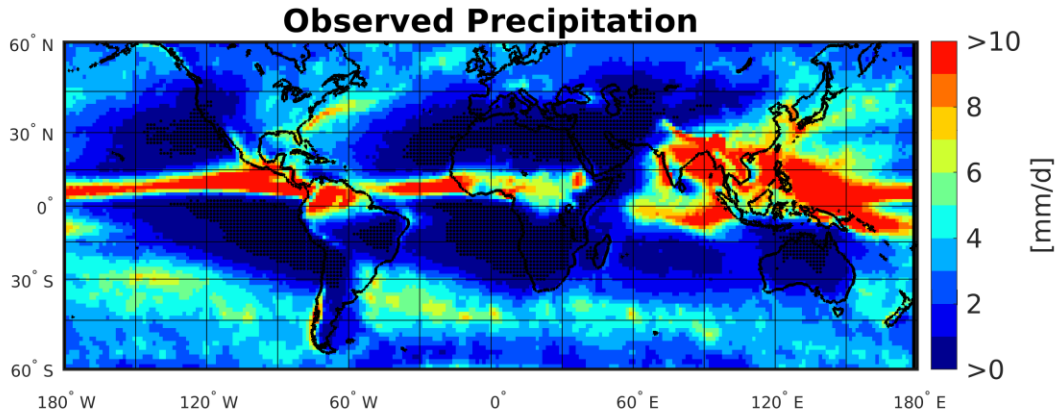
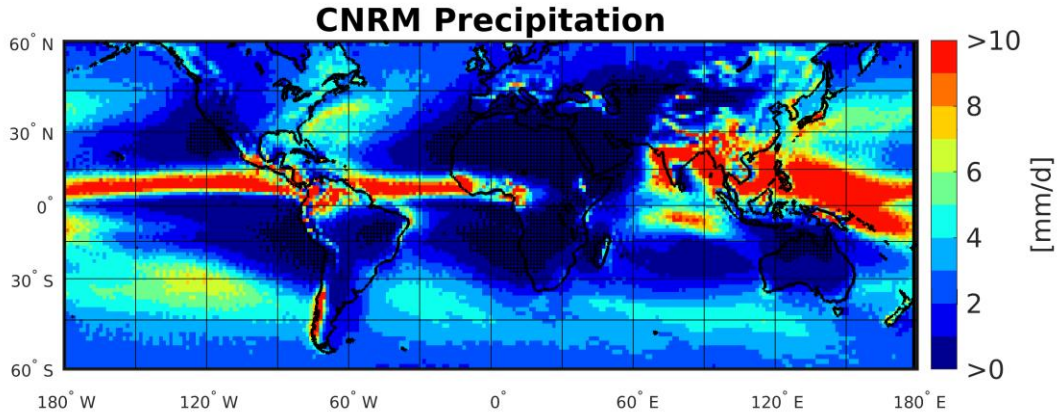
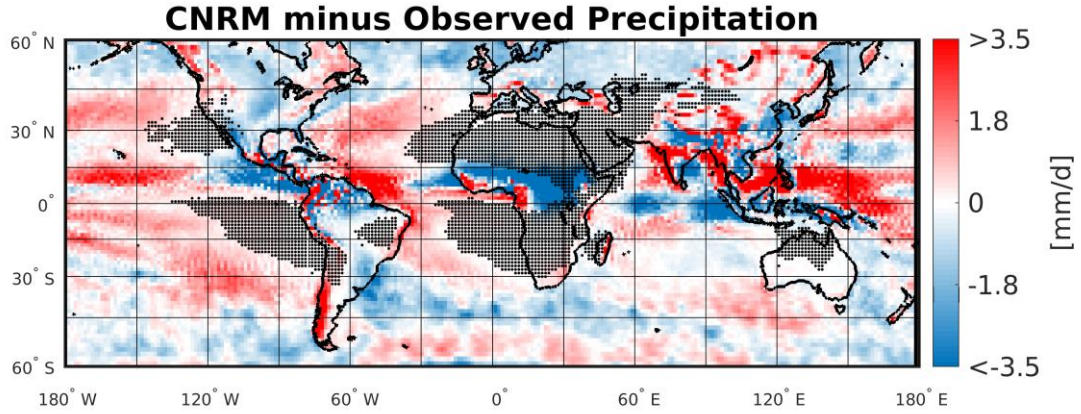
Evaluation of the Diurnal Cycle

IMERG observations JJA 2000-2018; CNRM-ESM2-1-AMIP simulation JJA 1979-2007







Black dots – Arid regions

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Mean Precipitation

- IMERG observations depict the pattern of mean precipitation accumulation.

- The CNRM model typically differs the most from the IMERG observations in the tropics:
  - Most regions show overestimates by the model;
  - Some regions, such as central Africa and tropical west coasts, show underestimates.

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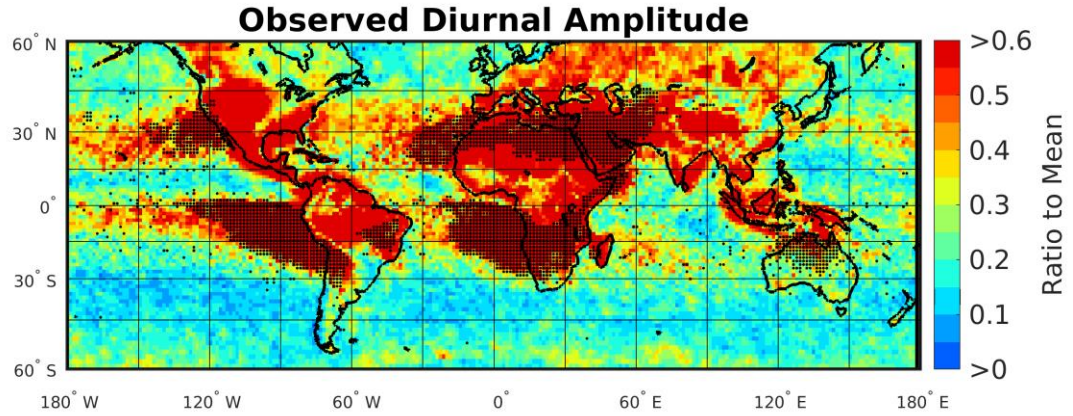

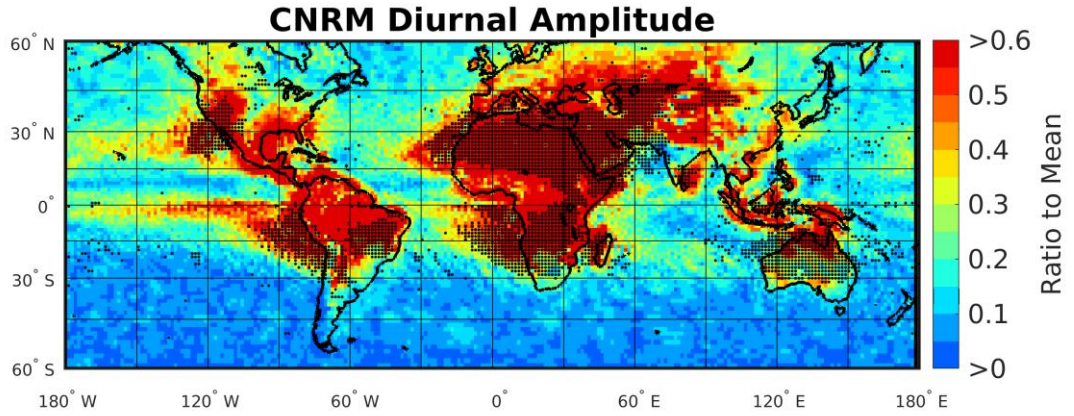

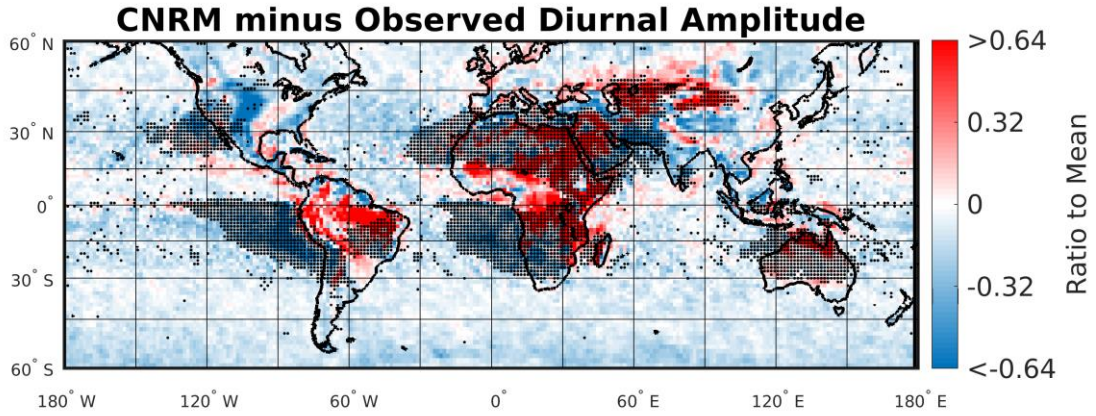

Black dots – Arid regions & interannual variability exceeding ±50% of amplitude

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Diurnal Amplitude

- IMERG observations highlight that stronger amplitudes (> 30% of the diurnal mean) are found over land than over ocean (< 30% of the diurnal mean in the regions where mean > 3mm/day).
- The CNRM model generally slightly underestimates the normalised amplitude over ocean.
- Over land, there are stronger differences compared to ocean:
  - Strongest overestimates by the model in central Africa and South America;
  - Strongest underestimates by the model over western US.

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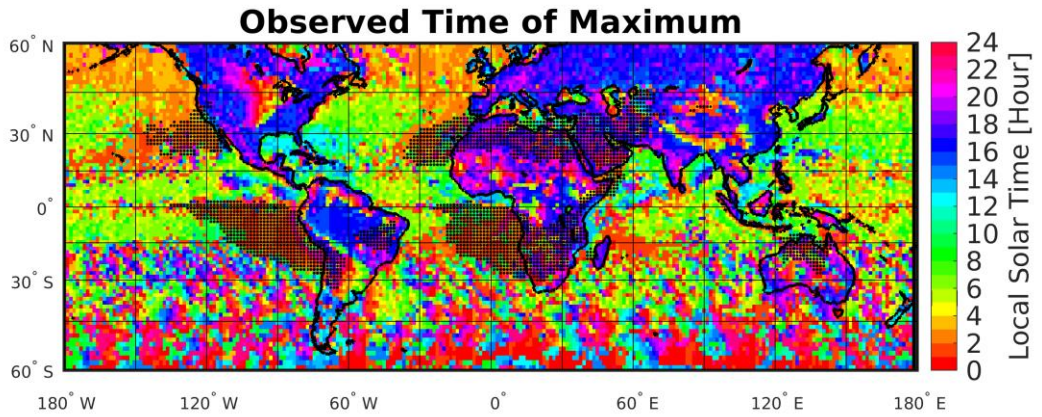

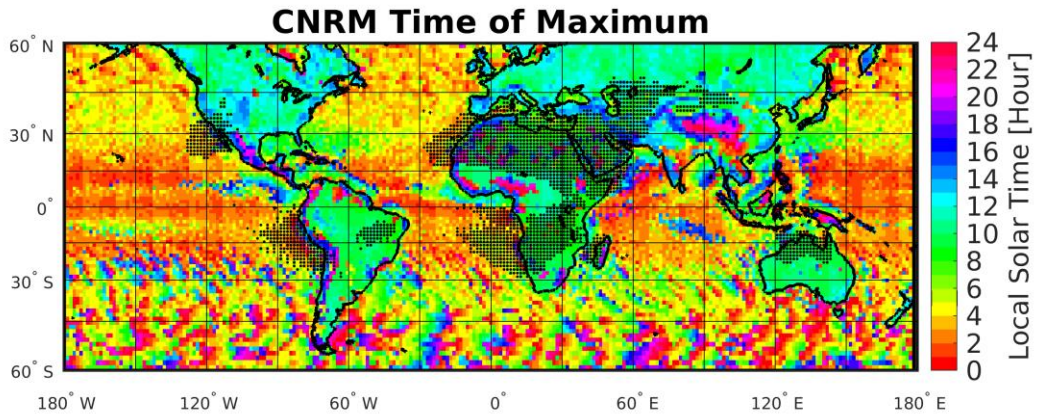

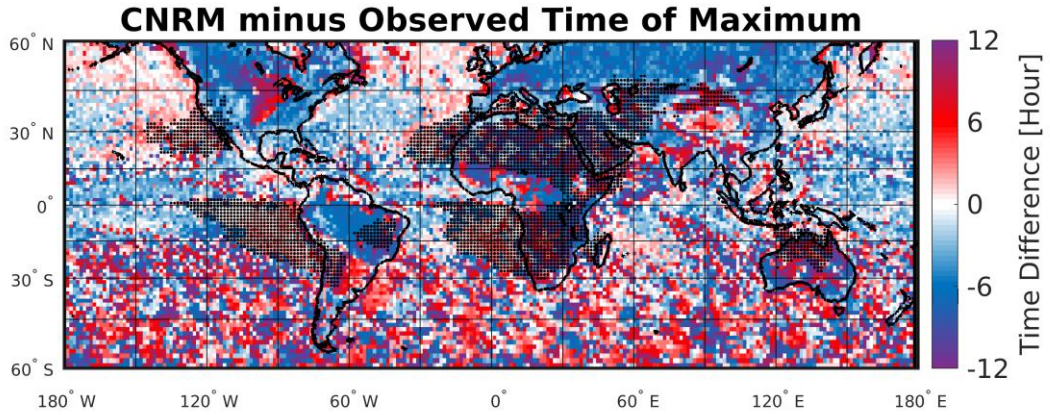

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Time of Maximum

- The IMERG observations show that precipitation generally maximises at:
  - ~16-24 LST over land;
  - ~2-10 LST over open ocean (tropics and northern hemisphere);
  - ~7-13 LST over coastal ocean.

- Note that regions where the phase pattern is quite noisy (over southern hemisphere ocean where season is winter) corresponds to regions where the diurnal amplitude is weaker (less than 30% of the mean).

- The CNRM model typically lags behind the observed time of maximum over land, and to a reduced extent over northern hemisphere ocean.

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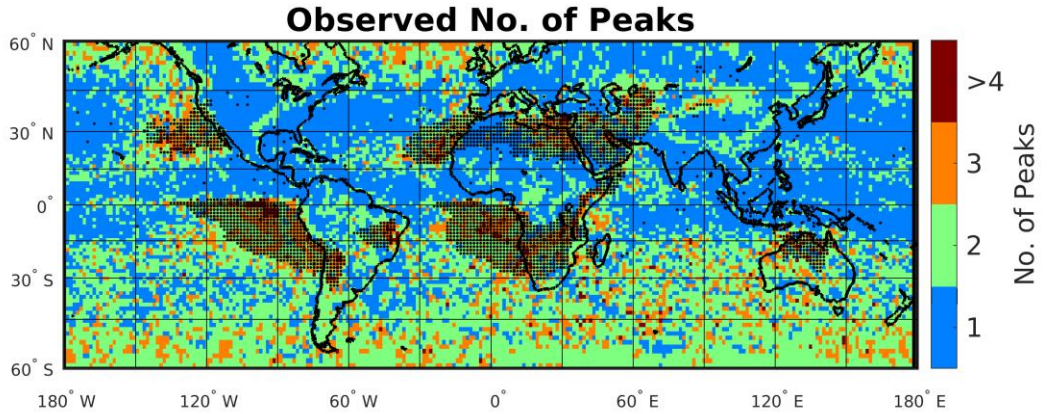

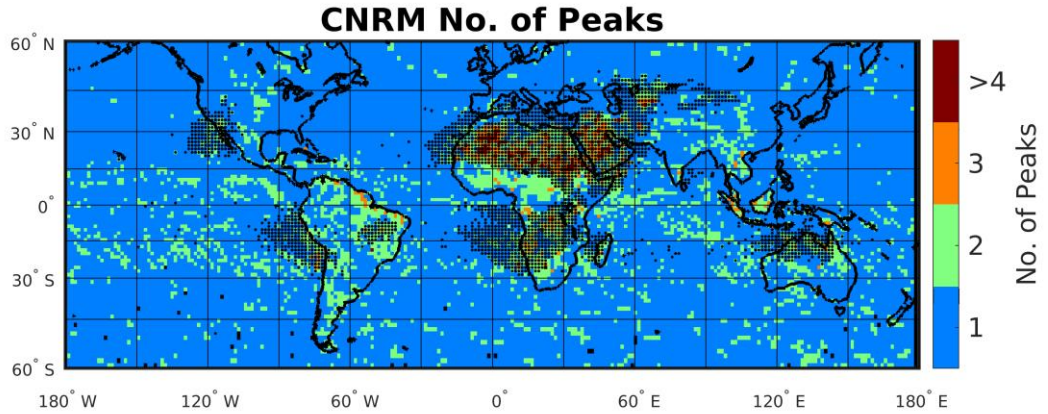

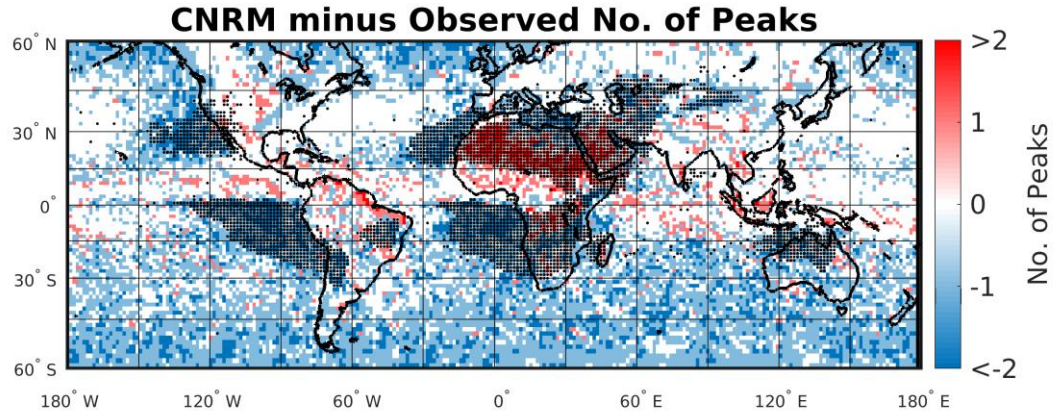

Black dots – Arid regions & interannual variability exceeding ±0.5 peaks

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Number of Peaks

- Observations suggest that there is typically one prominent peak in the diurnal cycle in the tropics and northern hemisphere (where the season is summer).
- The model typically agrees with the observations in these regions, but simulates one peak in the other regions where the observations suggest that there are multiple peaks.
- Such findings are dependent on the criterion selected for identifying prominent peaks (see slide 3 for the criterion).

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Future Work

- Extend the analysis to more CMIP6 model simulations:
  - Differences between AMIP simulations from different models;
  - Differences between AMIP and historical simulations;
  - Impacts of higher resolution models.

- Determine the effects of El Nino Southern Oscillation on the diurnal cycle of precipitation.

- Could sample diurnal cycle by dynamical regime to remove some of the interannual/month-to-month variability in the location of the convection.

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Citations

- NASA IMERG:
  - Data: G. J. Huffman, D. T. Bolvin, D. Braithwaite, K. Hsu, R. Joyce, and P. Xie, 2019. *Integrated Multi-satellitE Retrievals for GPM (IMERG), Level 3B-HHR, Version 6B. NASA's Precipitation Processing System.* Subset used: June 2000 – May 2019, accessed 25 October 2019, ftp://arthurhou.pps.eosdis.nasa.gov/gpmdata/YYYY/MM/DD/imerg.
  - Algorithm document: George J Huffman, David T Bolvin, Dan Braithwaite, Kuolin Hsu, Robert Joyce, Christopher Kidd, Eric J. Nelkin, Soroosh Sorooshian, Jackson Tan, and Pingping Xie, 2019. NASA Global Precipitation Measurement (GPM) Integrated Multi-satellitE Retrievals for GPM (IMERG). Algorithm Theoretical Basis Document, Version 6, page 38. Accessed 3 February 2019, https://pmm.nasa.gov/ sites/default/files/document_files/IMERG_ATBD_V06.pdf.

- CNRM-CERFACS CNRM-ESM2-1:
  - Data: R. Seferian, 2018. *CNRM-CERFACS CNRM-ESM2-1 model output prepared for CMIP6 CMIP amip*. Version 20191022. Earth System Grid Federation. https://doi.org/10.22033/ESGF/CMIP6.3924. Dataset licenced under CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/).
  - CMIP6 overview article: Veronika Eyring, Sandrine Bony, Gerald A Meehl, Catherine A Senior, Bjorn Stevens, Ronald J Stouffer,and Karl E Taylor, 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) Experimental Design and Organization. Geoscientific Model Development (Online), 9(LLNL-JRNL-736881).