Supplementary material to: Stochastic daily rainfall generation in tropical islands with complex topography

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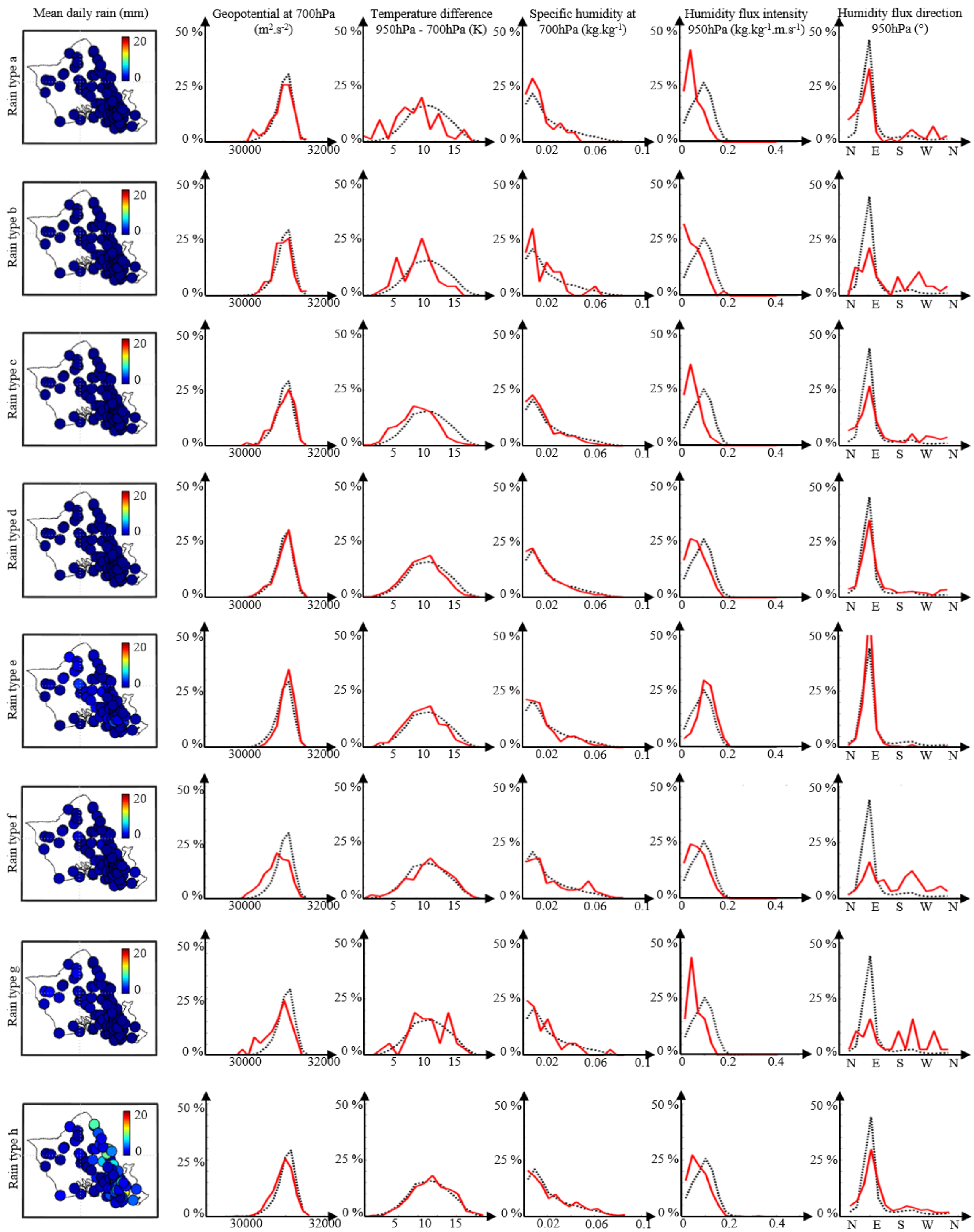
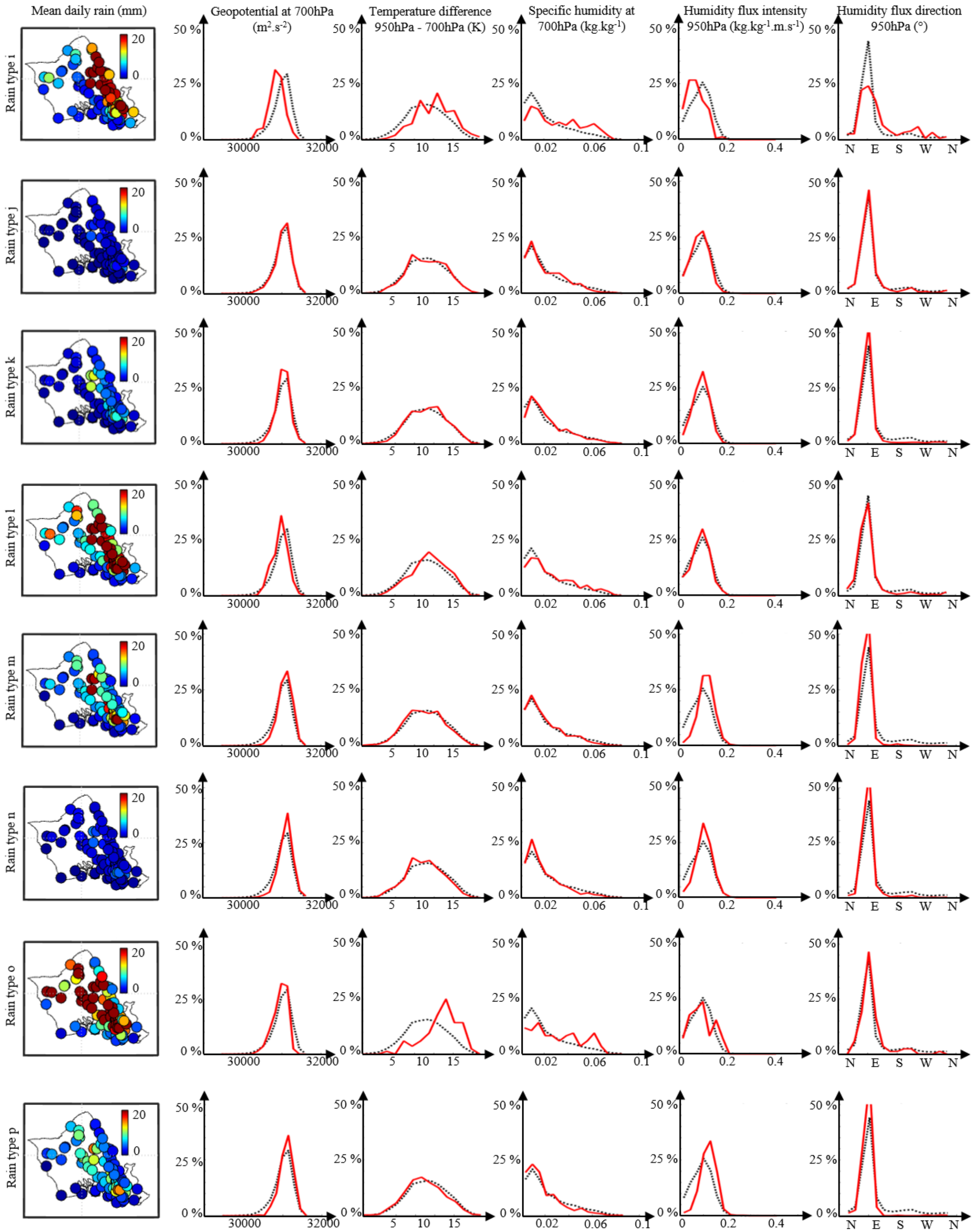
1 Supplementary material 1: Relationships between rain types and meteorological covariates in the island of O‘ahu




Mean daily rain (mm)
Geopotential at 700hPa (m².s⁻²)
Temperature difference 950hPa - 700hPa (K)
Specific humidity at 700hPa (kg.kg⁻¹)
Humidity flux intensity 950hPa (kg.kg⁻¹.m.s⁻¹)
Humidity flux direction 950hPa (°)
Rain type i
Rain type j
Rain type k
Rain type l
Rain type m
Rain type n
Rain type o
Rain type p
20
0
50 %
25 %
0 %
30000
32000
5
10
15
0.02
0.06
0.1
0
0.2
0.4
N
E
S
W
N

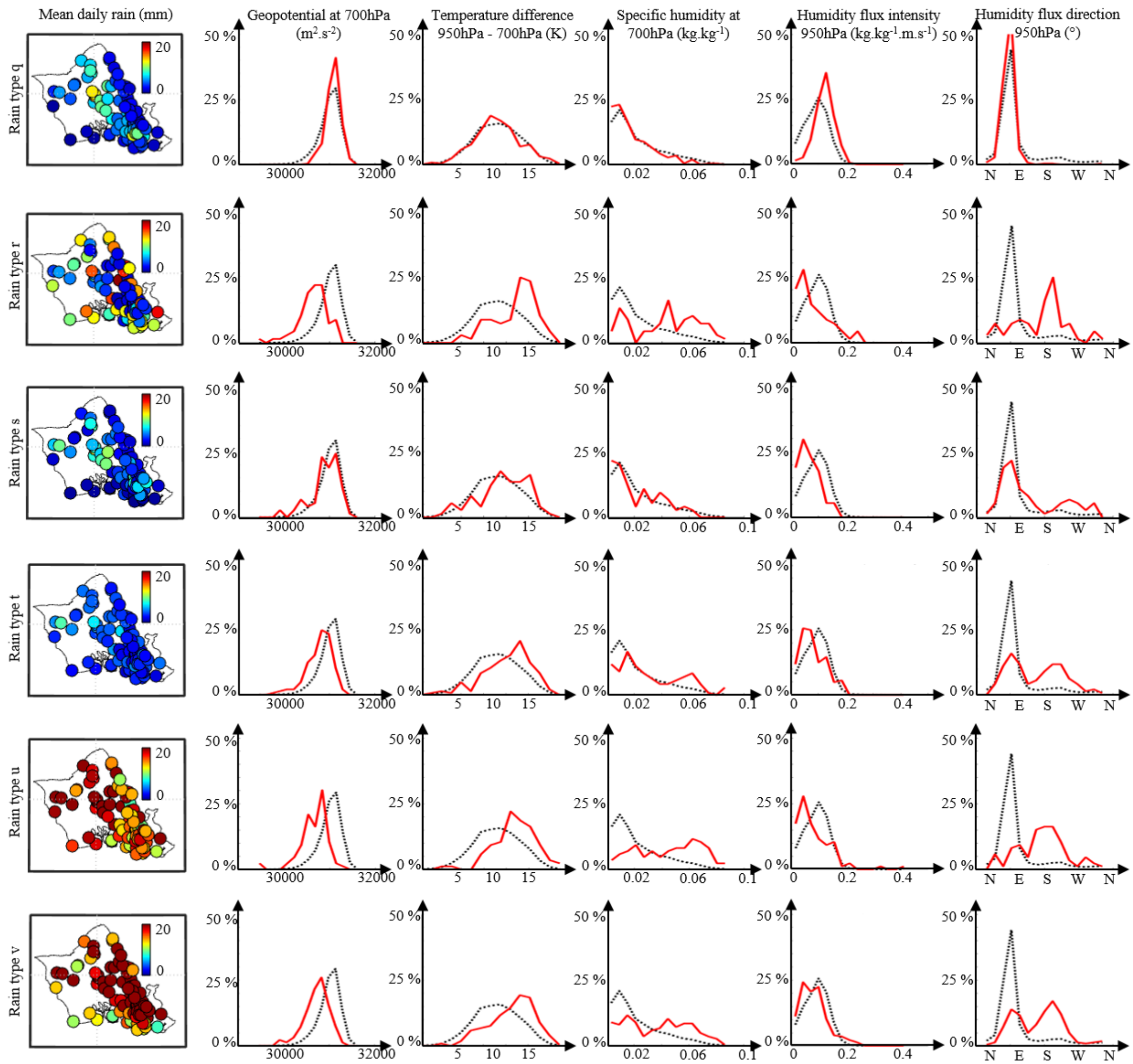


Figure SM1.1: Meteorological covariates observed concurrently with each rain type in the island of O‘ahu. First row: spatial pattern of observed mean daily rain. Second row: geopotential height at 700 hPa. Third row: temperature difference between 950 hPa and 700 hPa. Fourth row: specific humidity at 700 hPa. Fifth and sixth rows: intensity and direction of the specific humidity flux (i.e., wind multiplied by specific humidity) at 950 hPa. In rows 2–6, the red line denotes the pdf for the covariate at hand for the rain type of interest, and the dashed black line denotes the pdf of the same covariate for the entire dataset (i.e., encompassing the 22 rain types).

2 Supplementary material 2: Model assessment for the island of Tahiti

2.1 Observation dataset and rainfall climatology

The island of Tahiti is located in the South Pacific (lon = 149.5°W, lat = 17.6°S, area = 1042 km^2, max altitude = 2241 m) in French Polynesia. It has been selected to complement the case study of O‘ahu because Tahiti experiences a wetter climate (mean annual rain exceeding 10000 mm/year at Mt Mauru, Fig. SM2.1) with a strong rain seasonality caused by the proximity of the South Pacific Convergence Zone (SPCZ) [*Laurent et al.*, 2019] [*Brown et al.*, 2020]. The SPCZ crosses Tahiti during (austral) summer (November–April), which leads to a marked wet season (Fig. SM2.3) [*Hopuare et al.*, 2015]. Despite the above differences in rain intensity and seasonality, O‘ahu and Tahiti share similar patterns of orographic rain enhancement because both have significant topography and are exposed to a tropical marine climate. Hence, the windward (northeast) and high altitude slopes of Tahiti tend to be wetter than their leeward and lowland counterparts. In terms of rain generation processes, Tahitian precipitation is dominated by orographic rains triggered by easterly trade winds [*Laurent et al.*, 2019], complemented by a significant contribution from regional atmospheric disturbances driven by the Madden-Julian Oscillation (MJO) [*Hopuare et al.*, 2018].

To explore the features of Tahitian rainfalls, we use an 11-year dataset covering the period 2004–2014 and encompassing 26 rain gauges operated by the French weather agency (Météo France) and Direction of Equipment of Tahiti (Groupement d'Etudes et de Gestion du Domaine Public de Polynésie Française [GEGDP]). This dataset has been compiled and quality controlled by [*Pheulpin*, 2016] and occasional gaps were filled for the present study using the non-parametric vector sampling approach [*Oriani et al.*, 2020].

2.2 Rain types in Tahiti

Applying the rain typing approach introduced in Sect. 2.2.3 to the above dataset leads to 11 rain types for the period 2004–2014 (Fig. SM2.1). Scrutinizing the spatial patterns of mean daily rainfall (Fig. SM2.1), seasonality of rain type occurrence (Fig. SM2.1), and relationships with meteorological covariates (Fig. SM2.2) led us to pool rain types into three hyperclasses (H1-3) that can be linked to the three main rain generation processes in the area.

(H1) Almost dry days (Fig. SM2.1, rain types a–c): during these days, most rain gauges report no rain and no gauge reports more than 5 mm/day on average. In terms of weather conditions, these types are associated with a stable atmosphere and low moisture influx (Fig. SM2.2).

(H2) Trade wind days (Fig. SM2.1, rain types d–g): these types display well-defined spatial patterns of rain accumulation caused by orographic lifting and are associated with a relatively stable atmosphere and an important influx of moisture under the influence of east-northeasterly trade winds (Fig. SM2.2).

(H3) Regional atmospheric disturbance days (Fig. SM2.1, rain types h–k): these days correspond to relatively widespread rains with latitudinal gradients; two sub-categories can be identified. The first one encompasses rain types h–j that occur mostly during the wet season (November–April) and are associated with low pressure, unstable atmosphere, weak trade wind inversion, and weak northerly winds (and therefore moisture influx). These types probably correspond to convective rains caused by the interactions between the MJO and the crossing of the SPCZ over Tahiti. The second category encompasses a single type (type k) and is associated with southeasterly winds. This type probably corresponds to “Maraamu” events (Tahitian name [Laurent et al., 2019]), i.e., days with unusual southeasterly trade winds. This type has been placed in the disturbance hyperclass (H3) category because it is relatively rare, but, with the exception of wind direction, the associated meteorological covariates are close to those of trade wind days (Fig. SM2.2).

The pooling of rain types in three hyperclasses with names similar to the ones used for the O‘ahu case study should not hide the differences in rain generation processes between the two islands. Hence, while orographic rain enhancement by orographic lifting probably follows relatively similar processes in both islands (although modulated by differences in island morphology), disturbance related precipitations are produced by very different processes: mid-latitude or sub-tropical weather systems in the case of O‘ahu; and purely tropical effects caused by the transit of the SPCZ in the case of Tahiti.

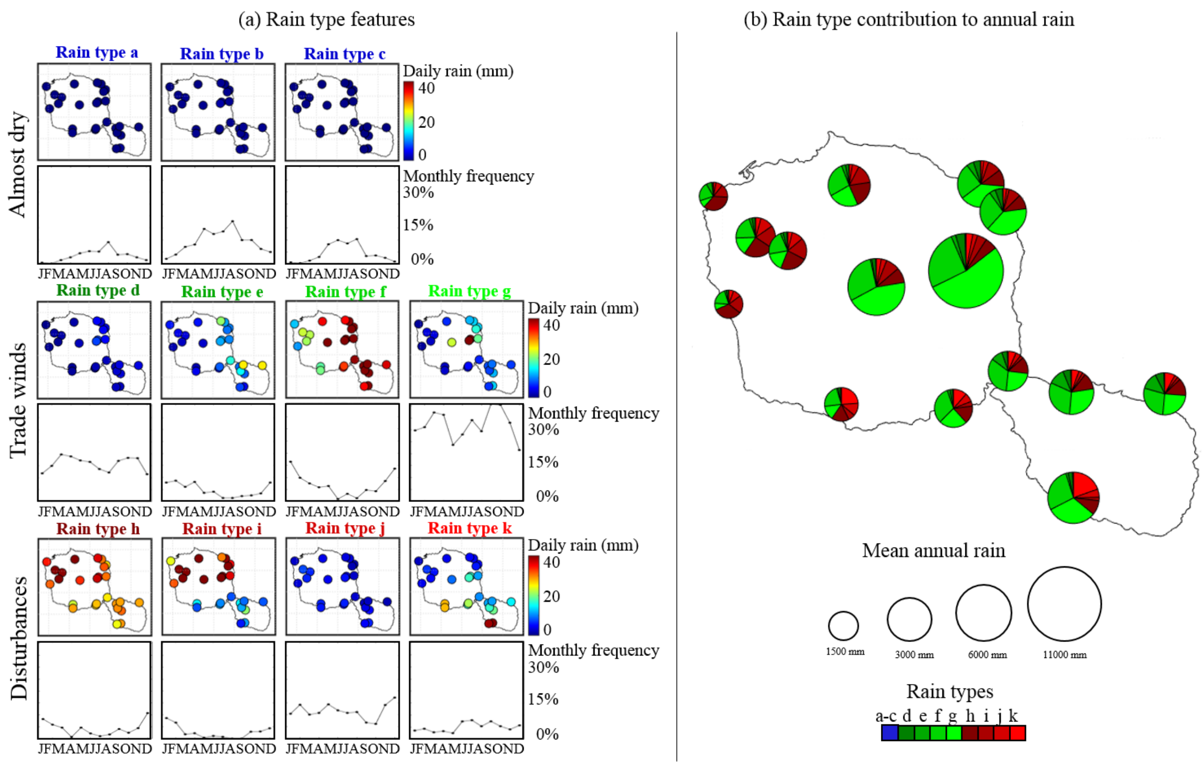
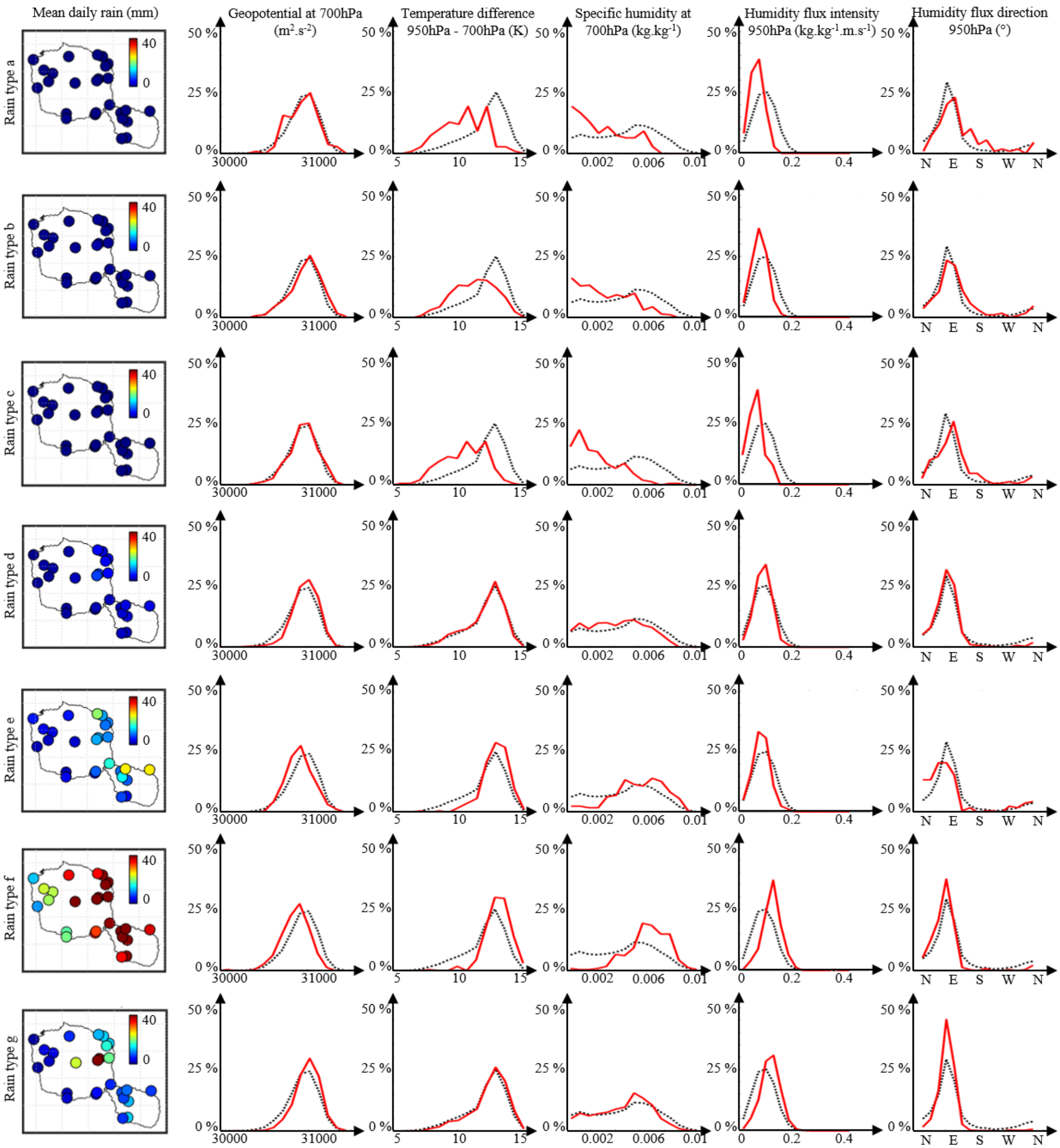


Figure SM2.1: Rain types identified for the island of Tahiti. (a) Spatial distribution and frequency of occurrence of each rain type. (b) Contribution of each rain type to the annual rain accumulation for a selection of 15 gauges spread throughout the island. The color code of the pie charts in (b) is the same as the names of the types in (a).



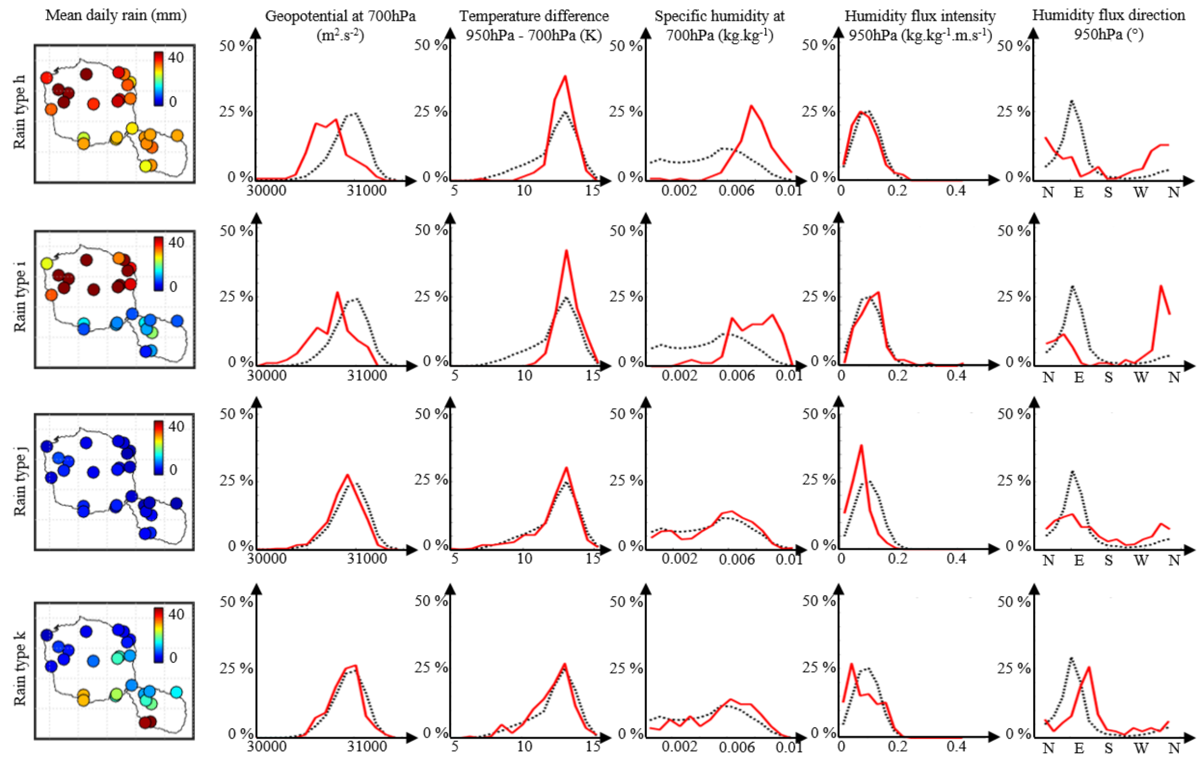


Figure SM2.2: Meteorological covariates observed concurrently with each rain type for the island of Tahiti. First row: spatial pattern of observed mean daily rain. Second row: geopotential height at 700 hPa. Third row: temperature difference between 950 and 700 hPa. Fourth row: specific humidity at 700 hPa. Fifth and sixth rows: intensity and direction of the specific humidity flux (i.e., wind multiplied by specific humidity) at 950 hPa. In rows 2–6, the red line denotes the pdf for the covariate at hand for the rain type of interest, and the dashed black line denotes the pdf of the same covariate for the entire dataset (i.e., encompassing the 22 rain types).

2.3 Model cross-validation for the island of Tahiti

Figures SM2.3 and SM2.4 evaluate the ability of the proposed stochastic rainfall model to simulate site-specific and island-scale statistics, respectively, for the island of Tahiti. Results show that the model performs very well for this island. In particular, note the ability of the model to faithfully reproduce rainfall seasonality, which is a distinctive feature of Tahitian rainfalls when compared to the O‘ahu case study presented in the main text. In addition, contrary to the O‘ahu experiment, the island-scale 11-years extreme precipitation is accurately simulated in the case of Tahiti.

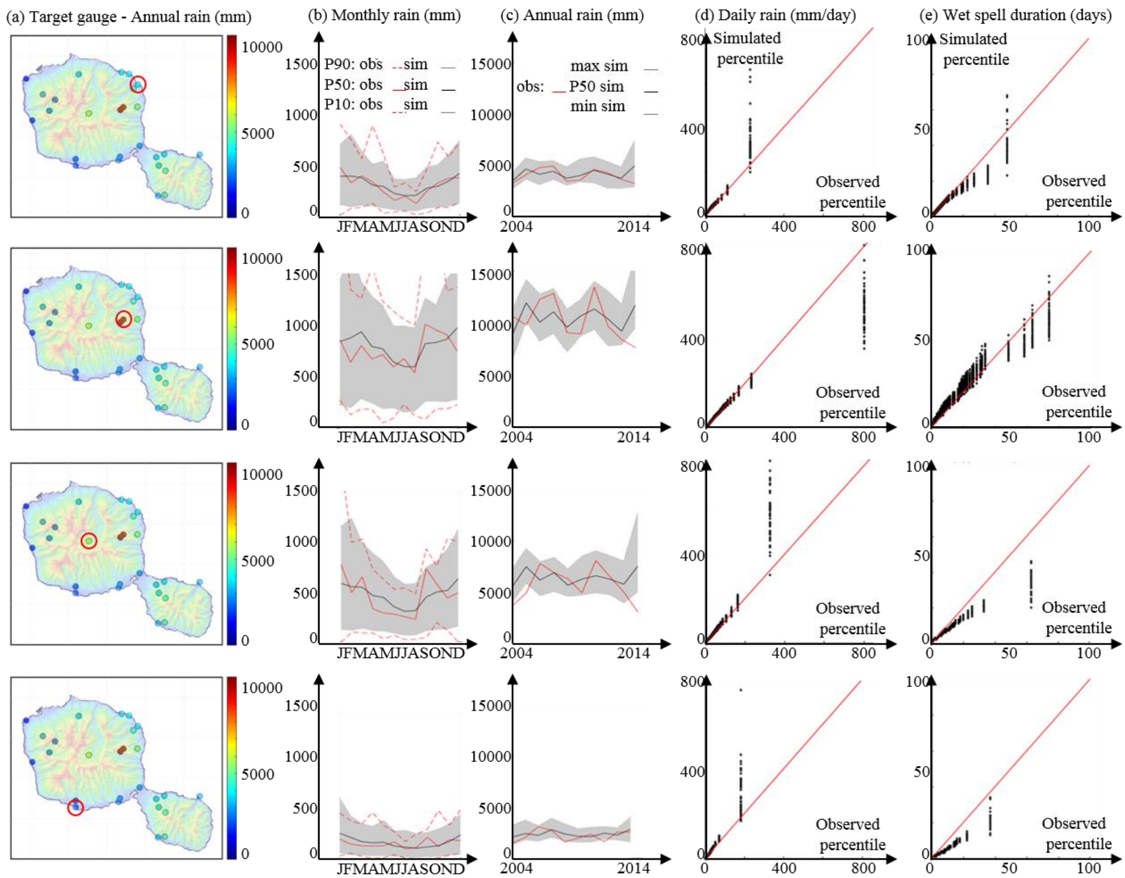


Figure SM2.3: Ability of the model to simulate site-specific rain statistics on Tahiti. (a) Target locations. (b) Observed (black) and simulated (red) monthly rain accumulation. Dashed lines denote quantiles 10% and 90% and solid lines denote the median value. For simulated values, each statistic is estimated as the median across the 50 realizations. (c) Observed (black) and simulated (red) annual rain accumulation. For simulations, dashed lines denote the minimum and maximum of the 50 realizations, and the solid line denotes the median of simulations. (d) The q-q plot of daily rain percentiles. (e) The q-q plot of wet spell duration percentiles.

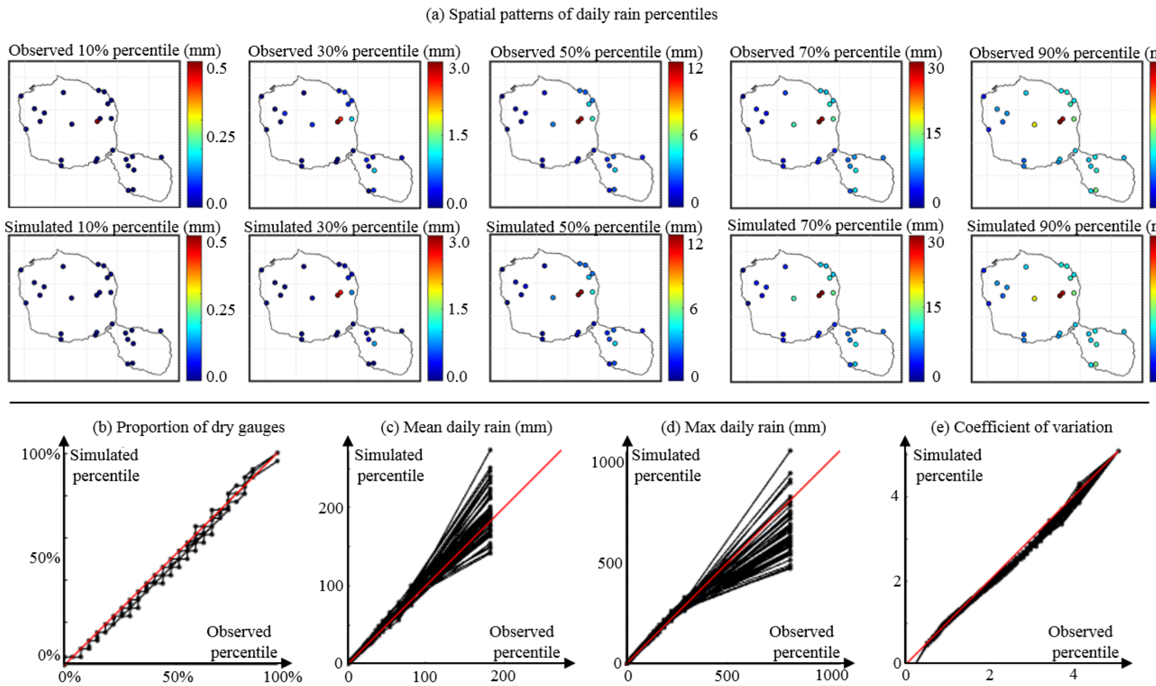


Figure SM2.4: Assessment of island-scale statistics simulation in Tahiti. (a) Spatial patterns of observed (upper row) and simulated (lower row) percentiles of daily rain accumulation. From left to right: 10%, 30%, 50%, 70% and 90% percentiles. (b–d) The q-q plots of key rain statistics aggregated over the whole rain gauge network: (b) proportion of dry gauges; (c–d) mean and max daily rain; (e) coefficient of variation.

References

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