

Supplement of ‘Machine learning of cloud types shows higher climate sensitivity is associated with lower cloud biases’

Peter Kuma, Frida A.-M. Bender, Alex Schuddeboom, Adrian J. McDonald, and Øyvind Seland

November 2, 2022

In addition to supplementary figures included in this document, these external figures are provided:

- `geo_cto_historical_10_1.png`: The same as Fig. 6, but for a classification into 10 cloud types.
- `geo_cto_historical_10_2.png`: The same as Fig. 7, but for a classification into 10 cloud types.
- `geo_cto_historical_27_1.png`: The same as Fig. 6, but for a classification into 27 cloud types.
- `geo_cto_historical_27_2.png`: The same as Fig. 7, but for a classification into 27 cloud types.
- `geo_cto_abrupt-4xC02_10_1.png`: The same as Fig. S7, but for a classification into 10 cloud types.
- `geo_cto_abrupt-4xC02_10_2.png`: The same as Fig. S8, but for a classification into 10 cloud types.
- `geo_cto_abrupt-4xC02_27_1.png`: The same as Fig. S7, but for a classification into 27 cloud types.
- `geo_cto_abrupt-4xC02_27_2.png`: The same as Fig. S8, but for a classification into 27 cloud types.
- `validation_10.png`: The same as Fig. 3, but for a classification into 10 cloud types.
- `validation_27.png`: The same as Fig. 3, but for a classification into 27 cloud types.
- `geo_cto_xval_10.png`: The same as Fig. 4, but for a classification into 10 cloud types.
- `geo_cto_xval_27.png`: The same as Fig. 4, but for a classification into 27 cloud types.

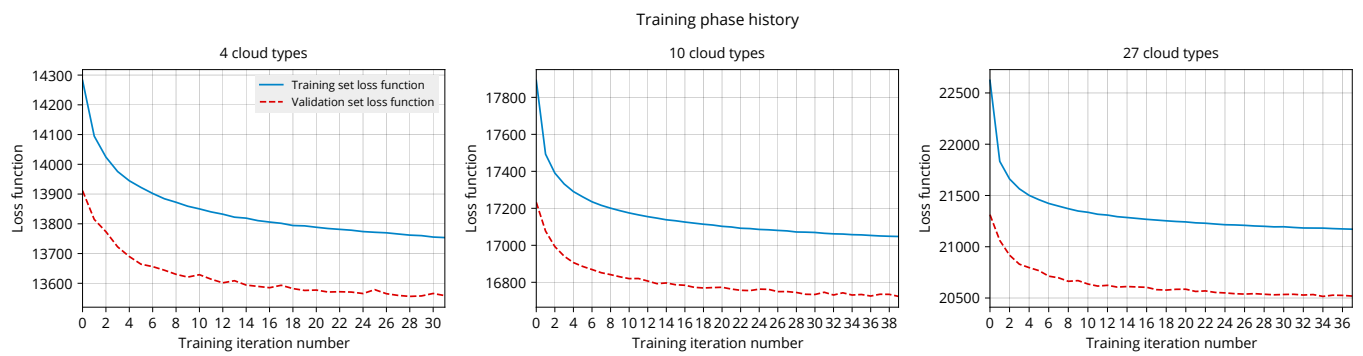


Figure S1: Training phase loss function evolution for the training and validation set for the ANN of 4, 10 and 27 cloud types.

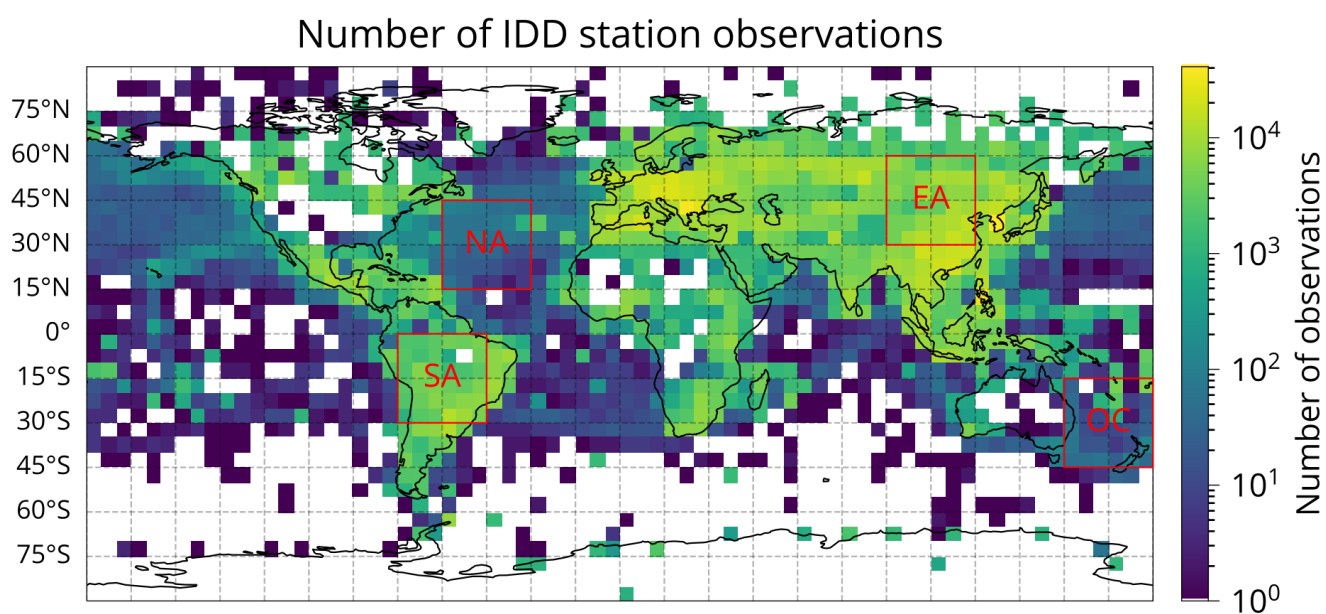


Figure S2: Number of observations in the IDD dataset on a $5^\circ \times 5^\circ$ grid as a total over the years reserved for validation (2007, 2012 and 2017). The highlighted regions are the validation regions: North Atlantic (NA), East Asia (EA), South America (SA) and Oceania (OC).

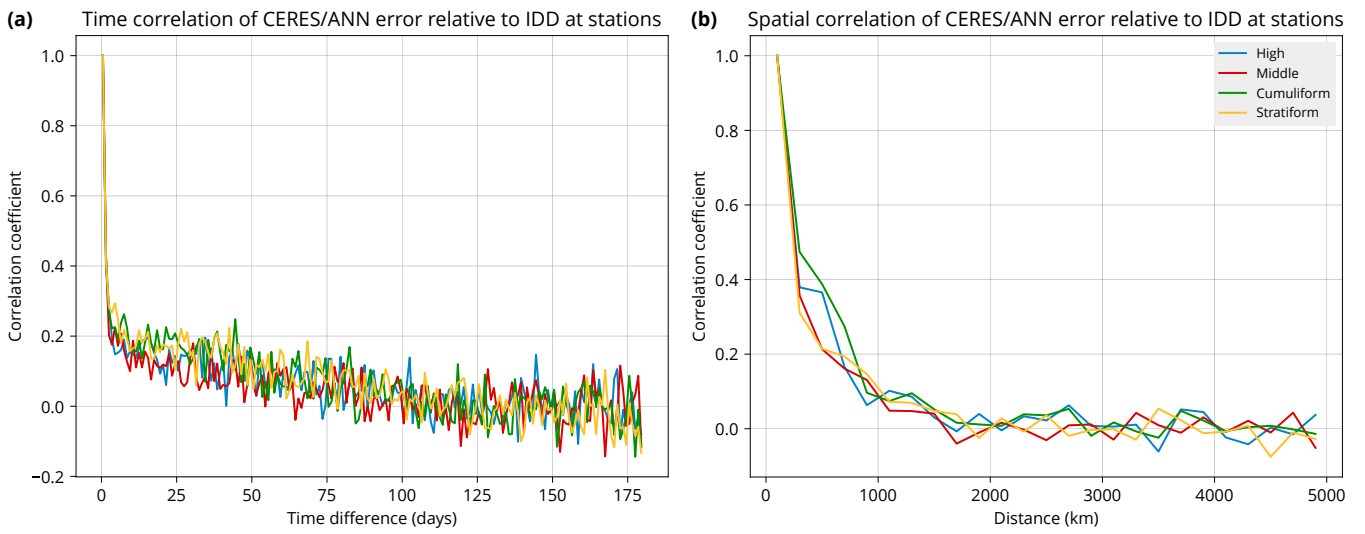


Figure S3: Temporal **(a)** and spatial **(b)** correlation of error in CERES/ANN cloud type occurrence probability relative to IDD at stations. The correlation is calculated from 100000 randomly selected points in year 2007. This year was not used for training the ANN. In the temporal correlation, two points at the same location by different (random) times are compared. In the spatial correlation, two points on the same day but different (random) locations are compared.

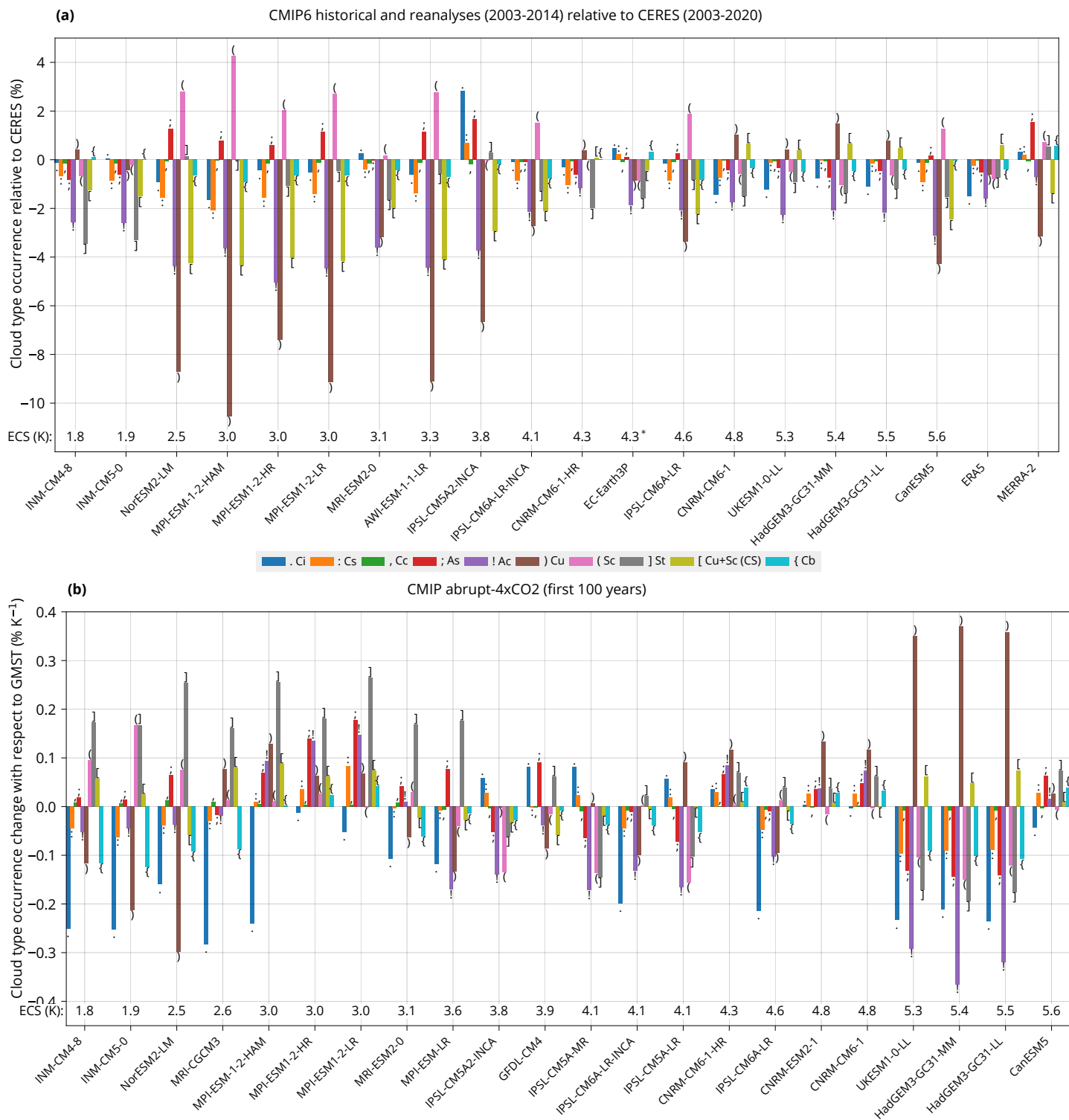


Figure S4: The same as Fig. 9, but for a classification of 10 cloud genera.

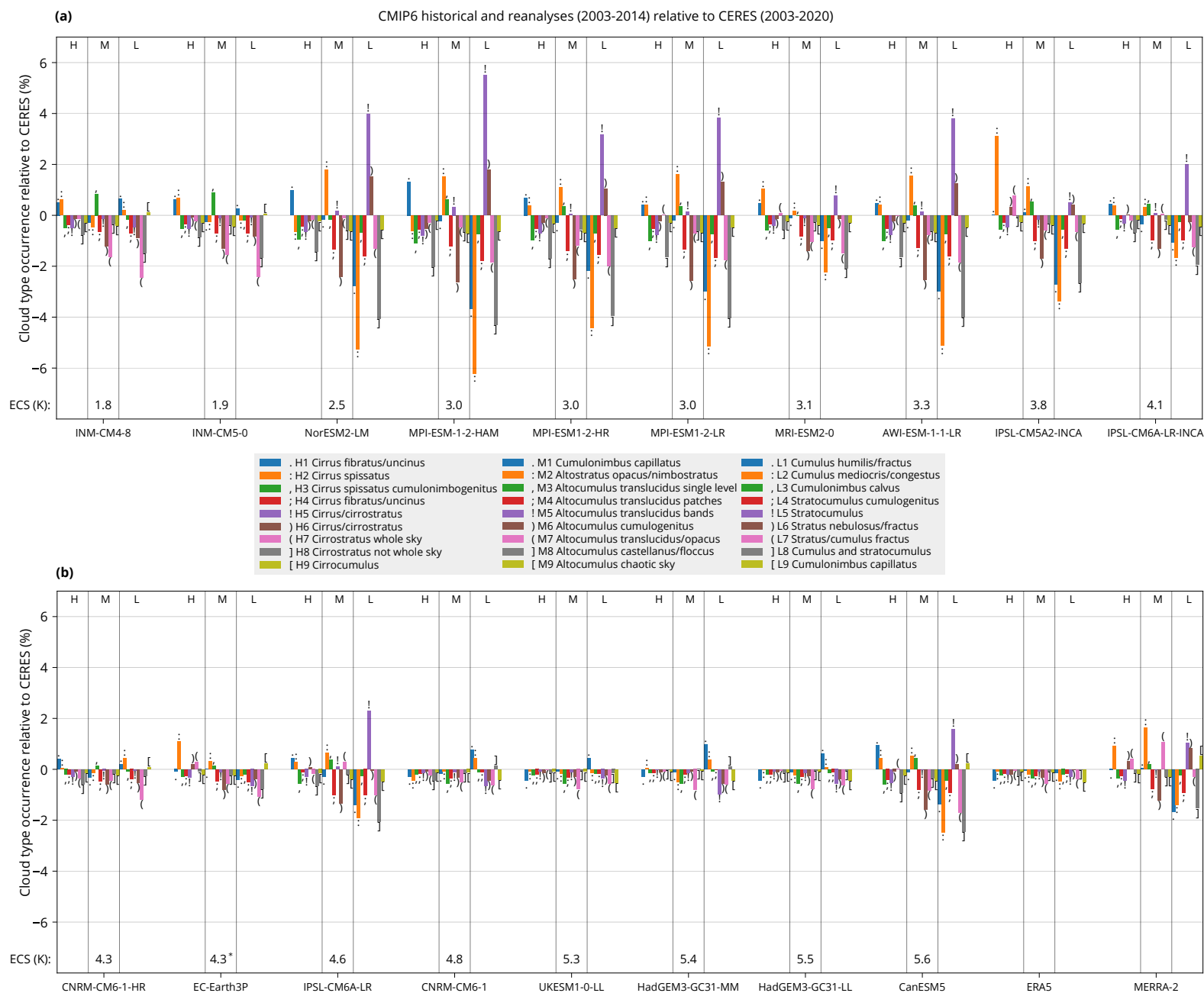


Figure S5: The same as Fig. 9, but for a classification of 27 cloud genera/species in the historical experiment. **(b)** is a continuation of **(a)**.



Figure S6: The same as Fig. 9, but for a classification of 27 cloud genera/species in the abrupt-4xCO₂ experiment. **(b)** is a continuation of **(a)**.

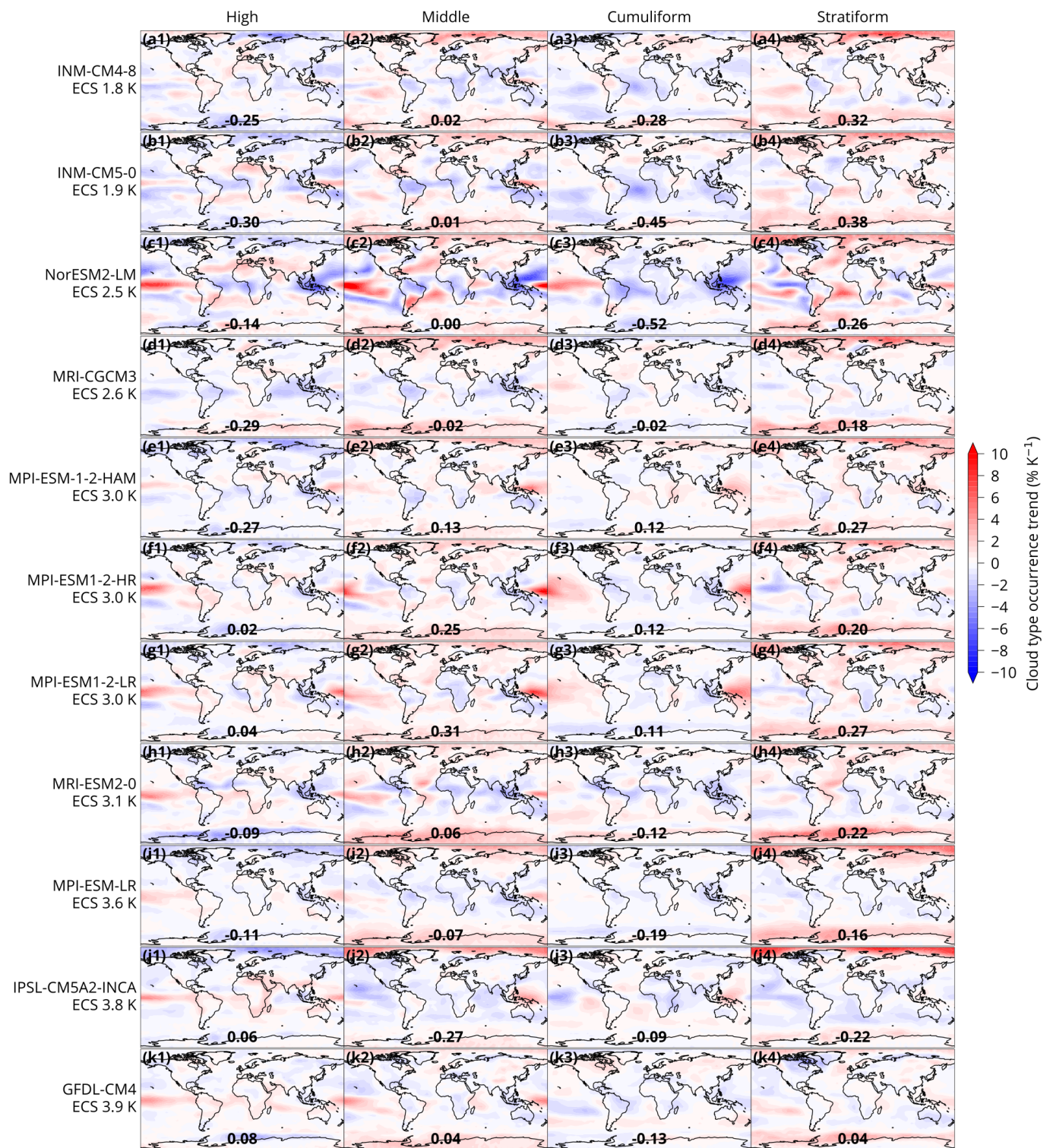


Figure S7: The same as Fig. 6, but for change of cloud type occurrence with GMST in the abrupt-4xCO₂ experiment. Numbers in the lower centre are the global mean.

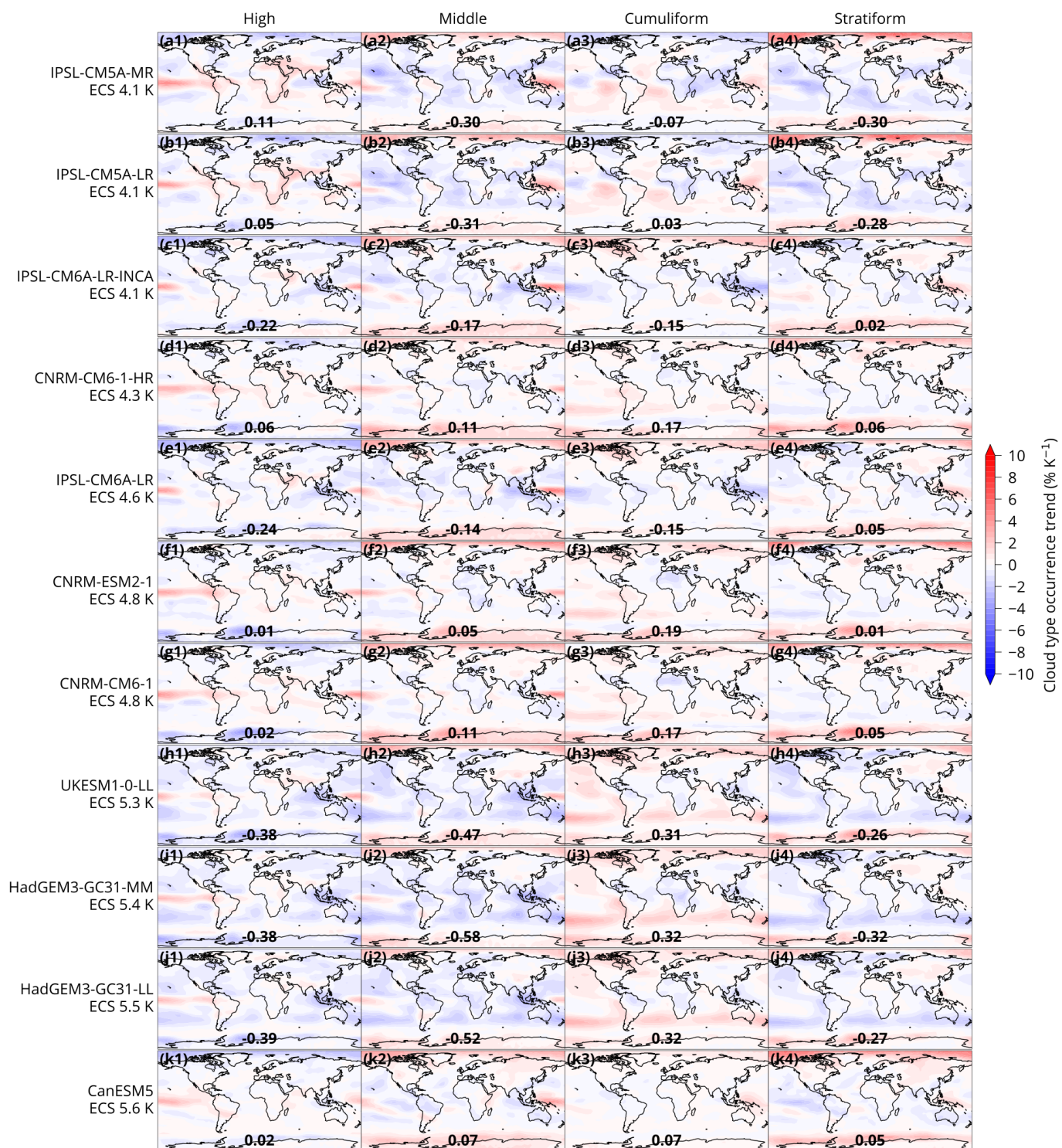


Figure S8: Fig. S7 continued.

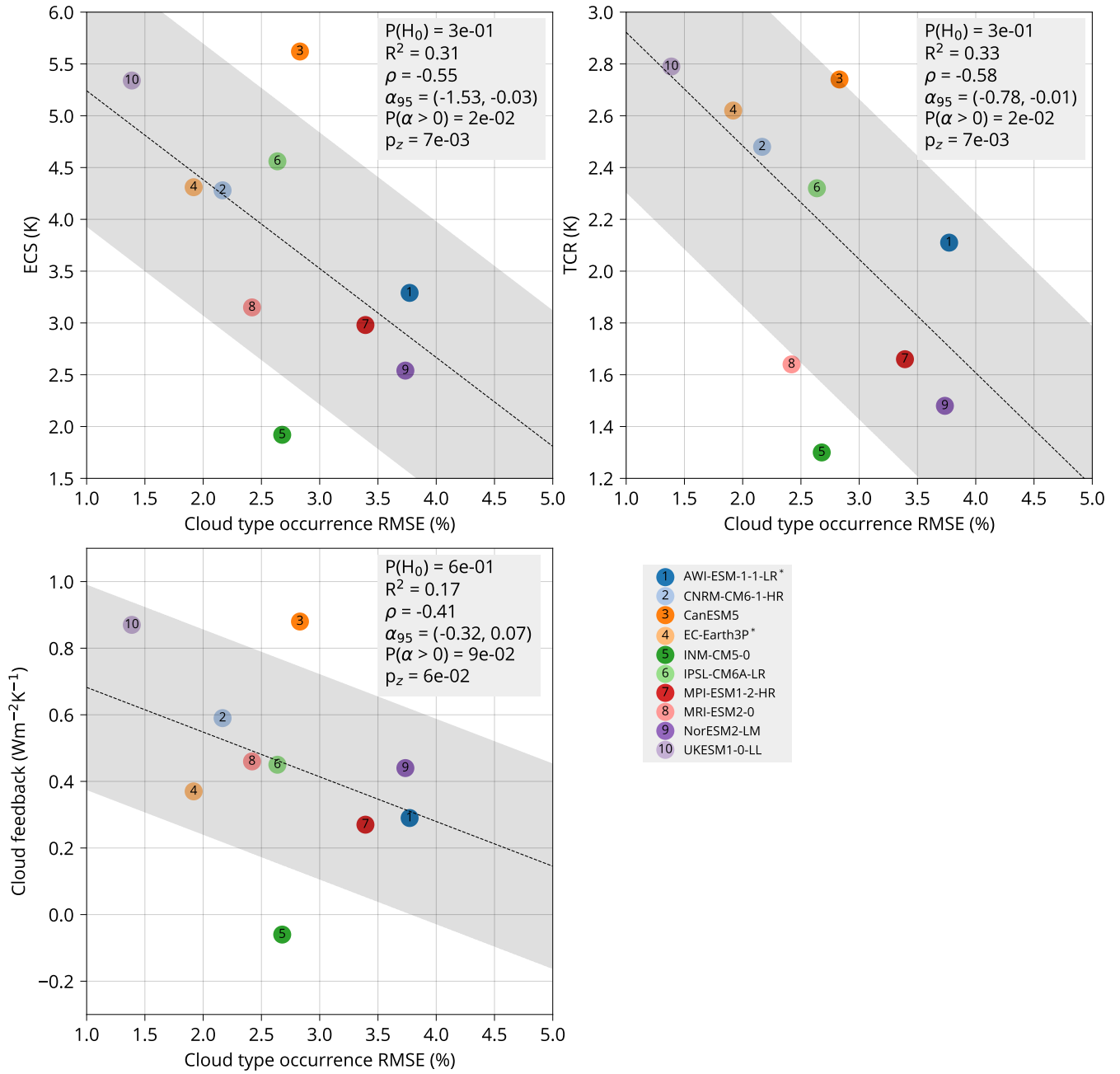


Figure S9: The same as Fig. 12, but calculated with a reduced set of independent models as a sensitivity test.

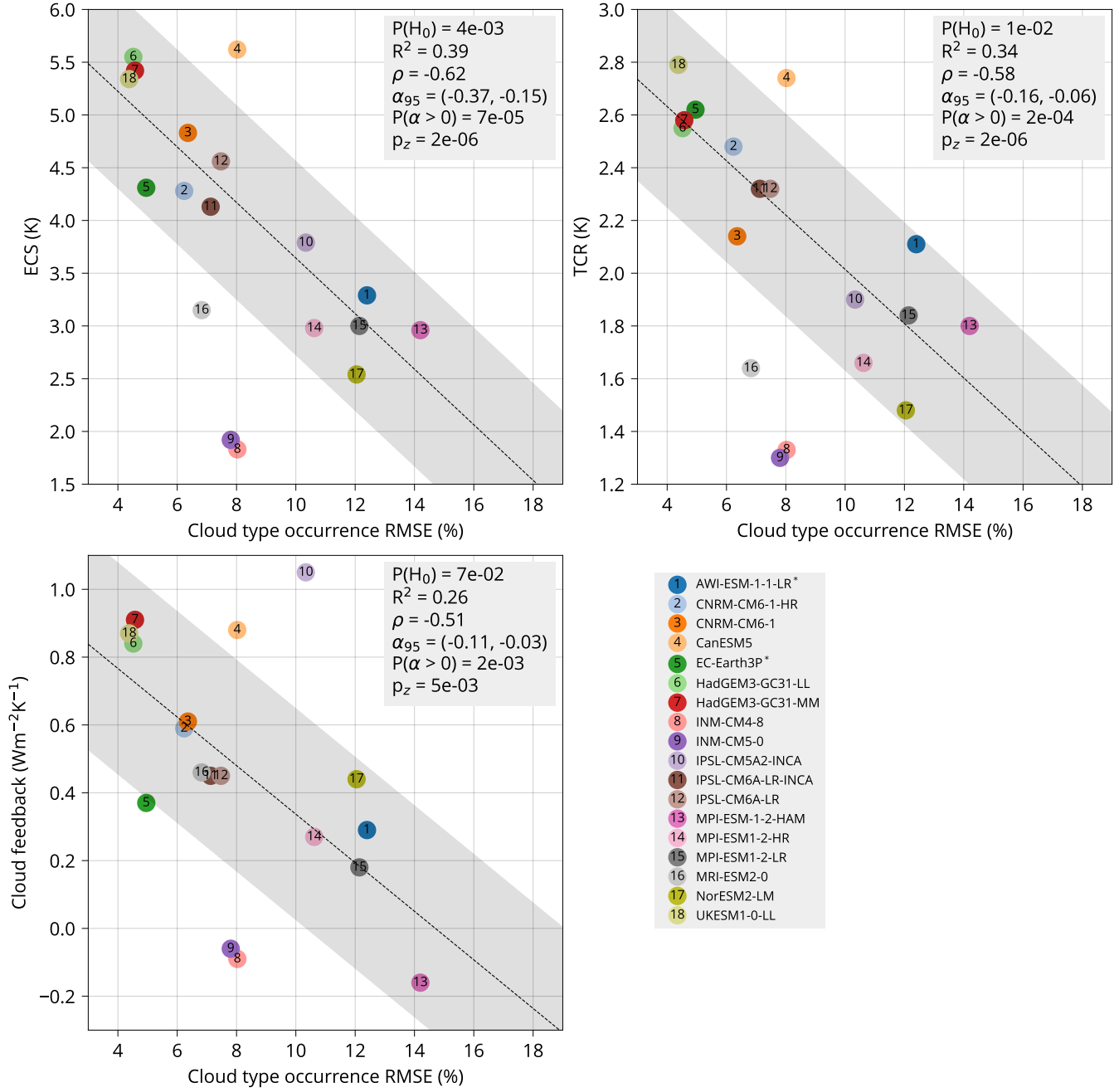


Figure S10: The same as Fig. 12, but calculated from a classification into 4 cloud types.

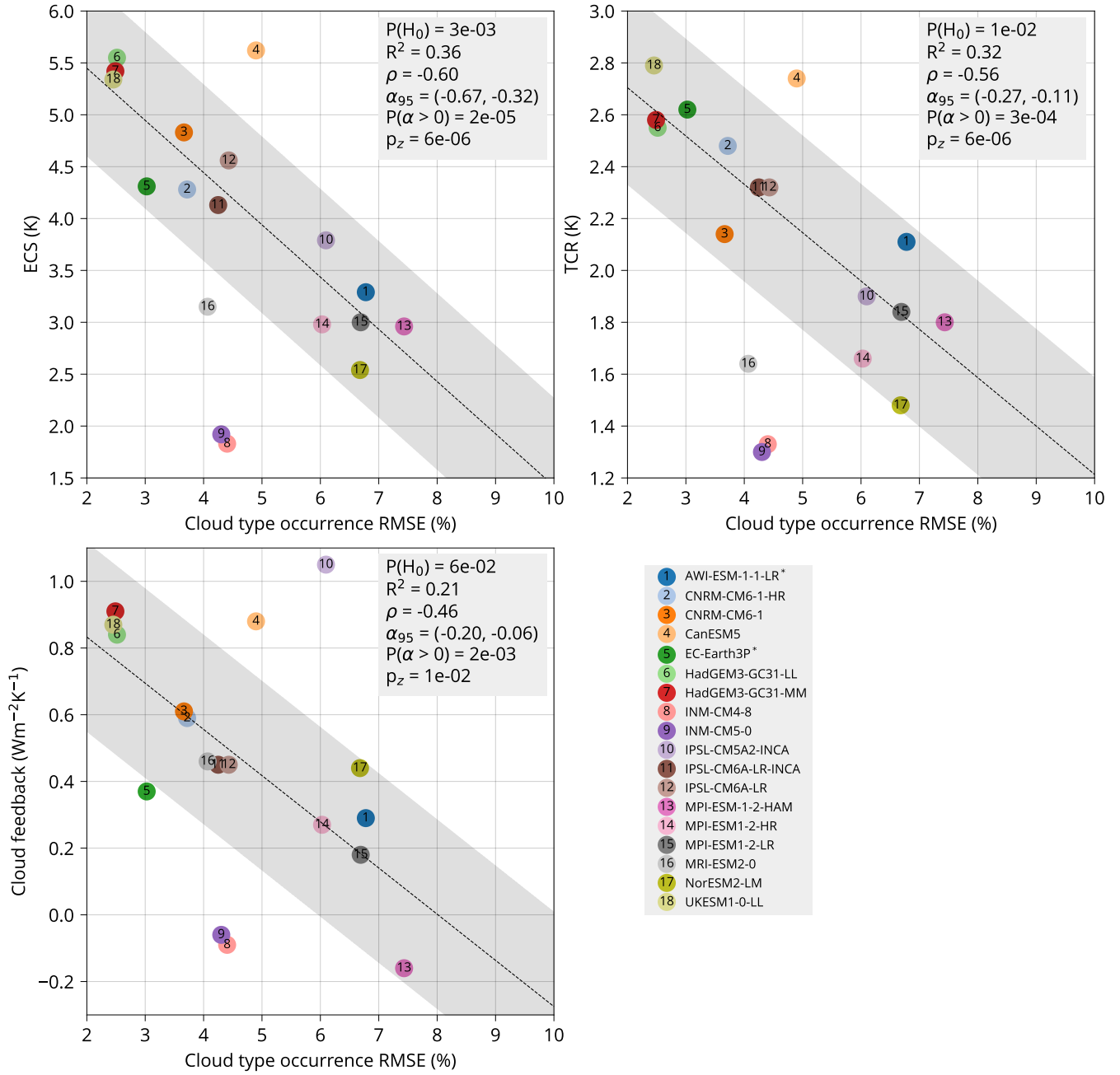


Figure S11: The same as Fig. 12, but calculated from a classification into 10 cloud types.

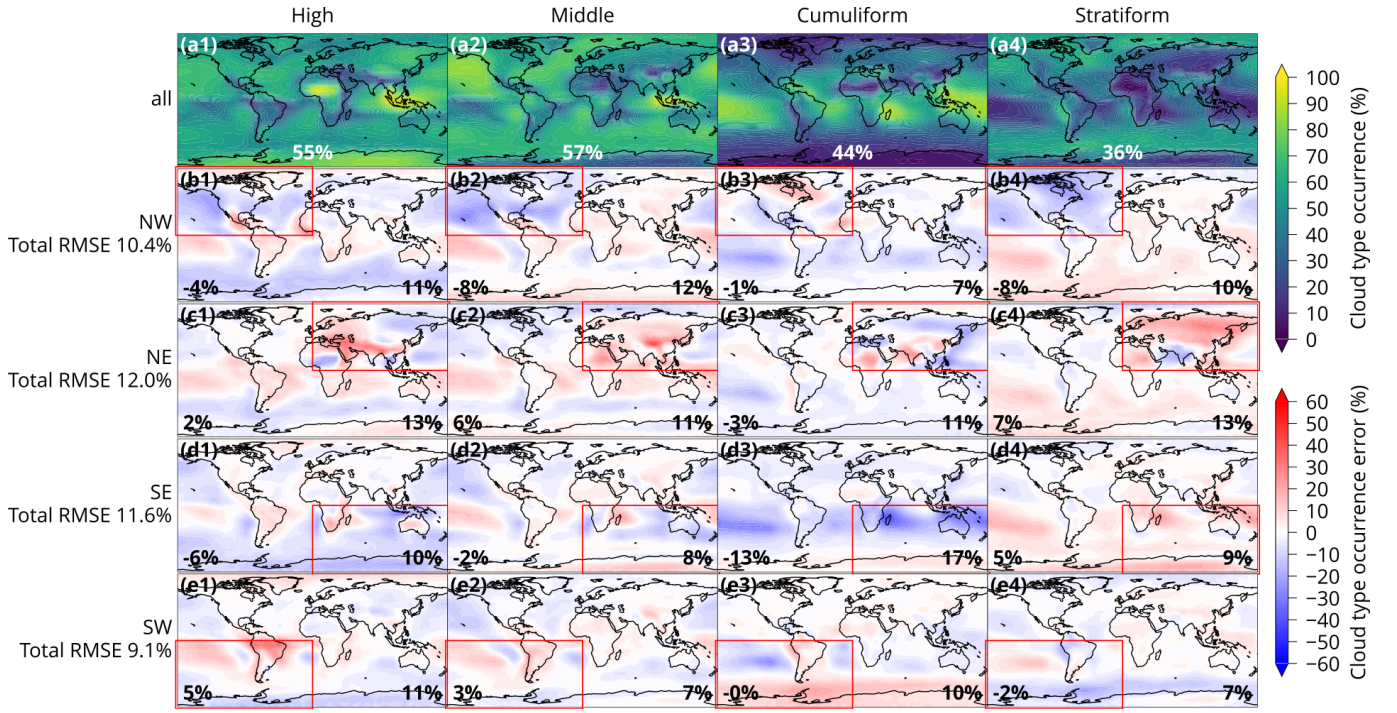


Figure S12: The same as Fig. 3, but showing values relative to the reference artificial neural network (ANN) trained on the whole globe (the first row). The numbers in the lower left and lower right in each plot in (b–e) are the mean error and root mean square error (RMSE) between the all-time mean of the validation ANN (b–e) and the reference ANN (a). The total RMSE is the square root of the sum of mean square errors corresponding to the individual cloud types in the row. The numbers in the centre of the reference ANN plots (a) are the global area-weighted mean.