Climate sensitivity and the Southern Ocean: the effect of the "too few, too bright" model cloud problem

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FORCeS
Constrained aerosol forcing for improved climate projections
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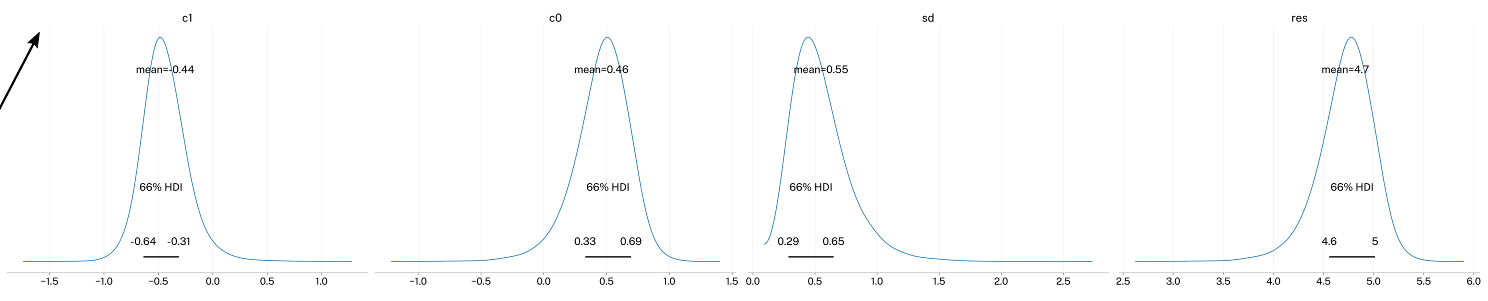
- **The "too few too bright" problem (TFTB) means that model clouds cover too small area but have too high albedo – a compensating error.**
- **How does this bias impact model climate sensitivity?**
- **We looked at the Southern Ocean (SO) and global ocean impact, using satellite measurements as an observational constraint.**
- **We employed a multivariate regression approach based on Markov chain Monte Carlo (MCMC).**
- **Constraining climate sensitivity based on cloud fraction/brightness in the SO and over global ocean yields equilibrium climate sensitivity (ECS) in a likely (66%) range 4.6–5°C and 3.7–5.2°C in CMIP6 (respectively) and 3.7–4.4°C in CMIP5. These results are preliminary.**

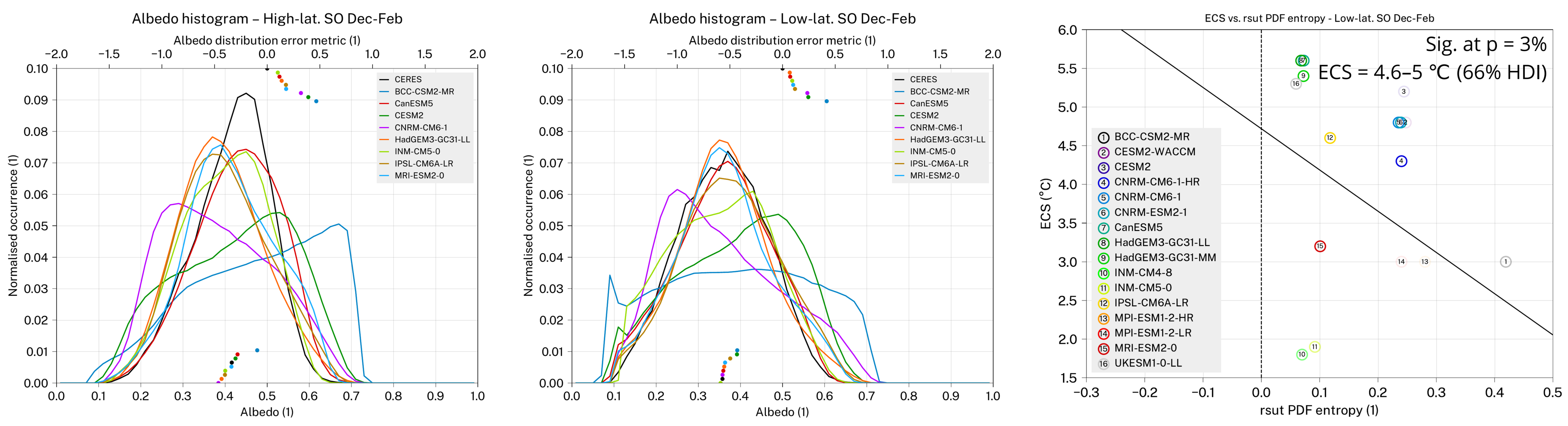
Southern Ocean

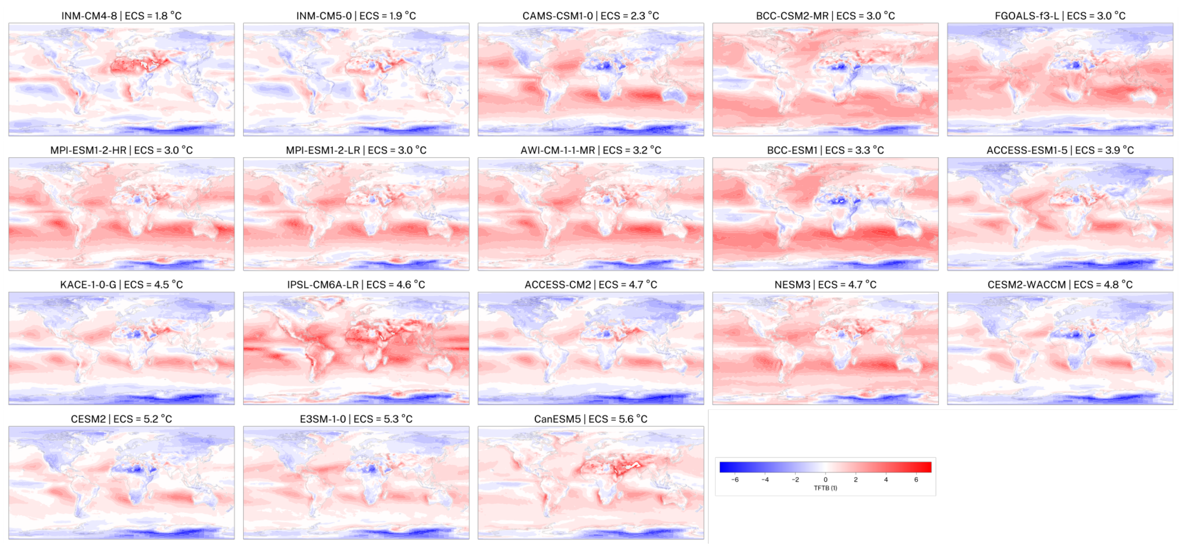
- CMIP6 models display probability density function (PDF) of daily albedo wider than observations (CERES). In models more extreme cloud scenes are more common than in reality. This occurs in both low-latitude (45–55°S) and high-latitude (55–65°S) Southern Ocean.
- When this bias is parametrised with the entropy of the PDF of top of atmosphere (TOA) outgoing radiation (rsut), models with greater bias show lower ECS than models with lower bias.
- This linear relationship is significant at p = 3%, and constraints ECS to 4.6–5°C (66% highest density interval; HDI).

Bayesian linear regression y = c0 + c1*x with Cauchy-distributed residual error, simulated with PyMC.



Cloud albedo PDF in models and observations in high- and low-lat. SO.

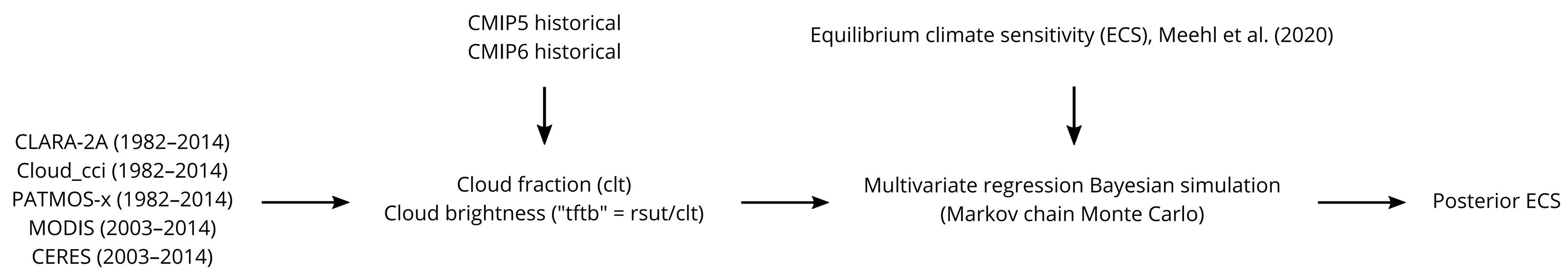




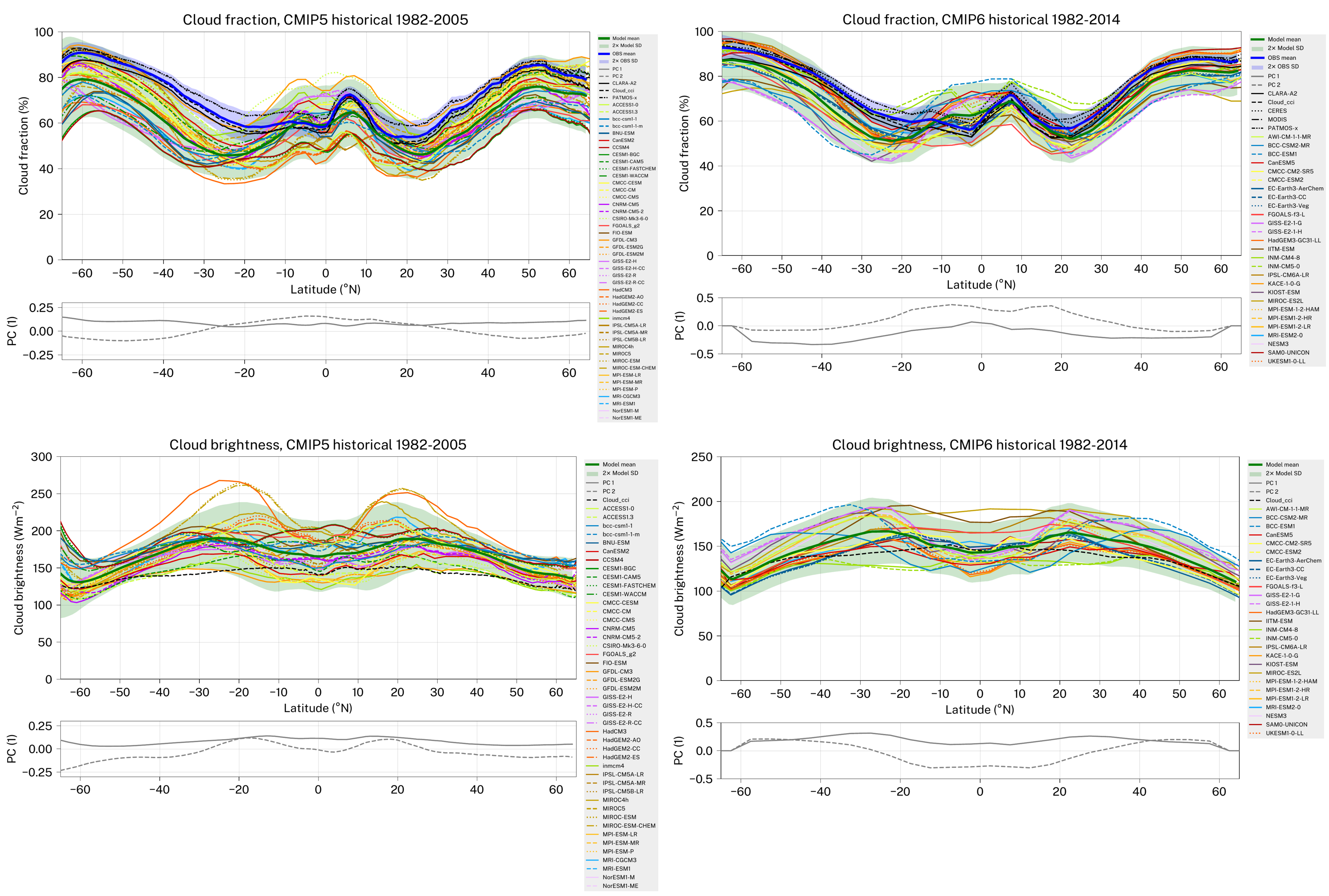
Global ocean

- We used historical satellite data (CLARA-2A, Cloud_cci, PATMOS-x, MODIS and CERES) from 1982 to 2014 to link biases in cloud fraction brightness over the ocean to model ECS in CMIP5 and CMIP6.
- Models are biased low in cloud fraction (clt) and high in cloud brightness (rsut/clt used here as a proxy for cloud brightnes).
- We calculated principal components (PC) of variability of cloud fraction and cloud brightness across models. We used projection of fields on these PCs as predictors in a multivariate regression.
- Some of the 1st and 2nd PC of cloud fraction and cloud brightness are significantly linearly related to model ECS (p-value between 0.1% and 4%).
- Multivariate regression simulated using MCMC constraints the ECS to 3.7–4.4°C and 3.8–5.1°C likely range (66% HDI) in CMIP5 and CMIP6, respectively.

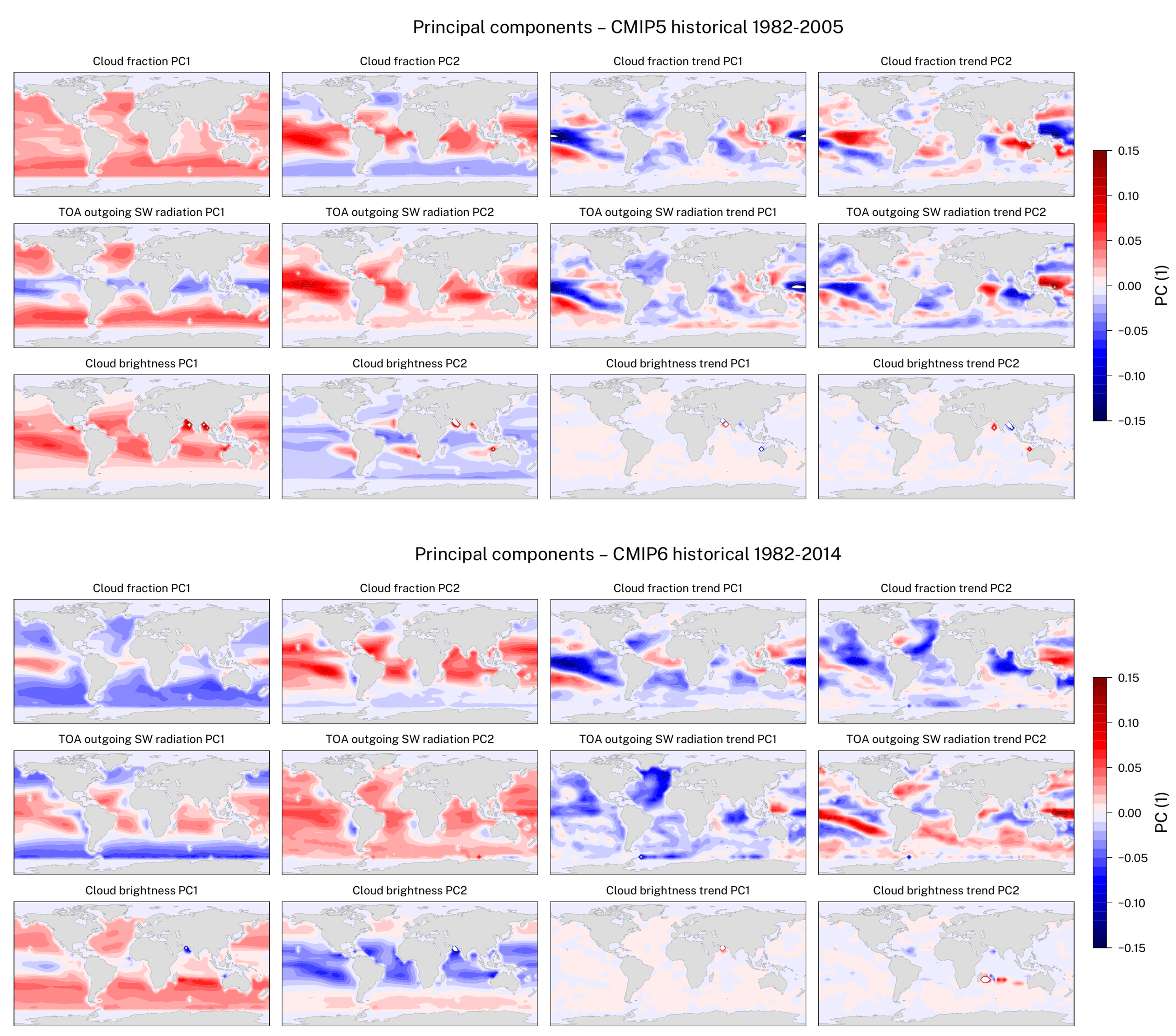
Schematic of the analysis.



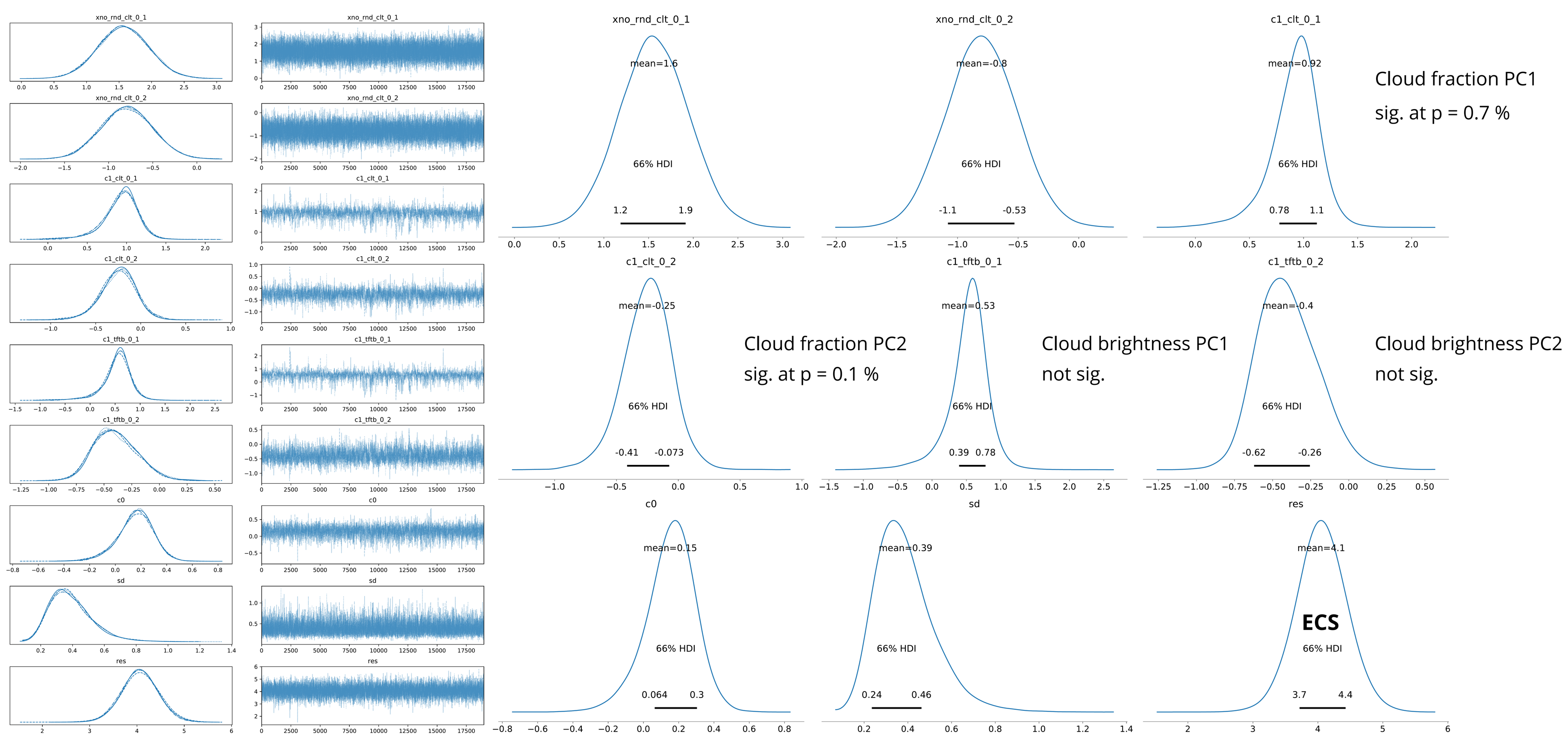
Cloud fraction and cloud brightness in CMIP5 and CMIP6 models and satellite observations.



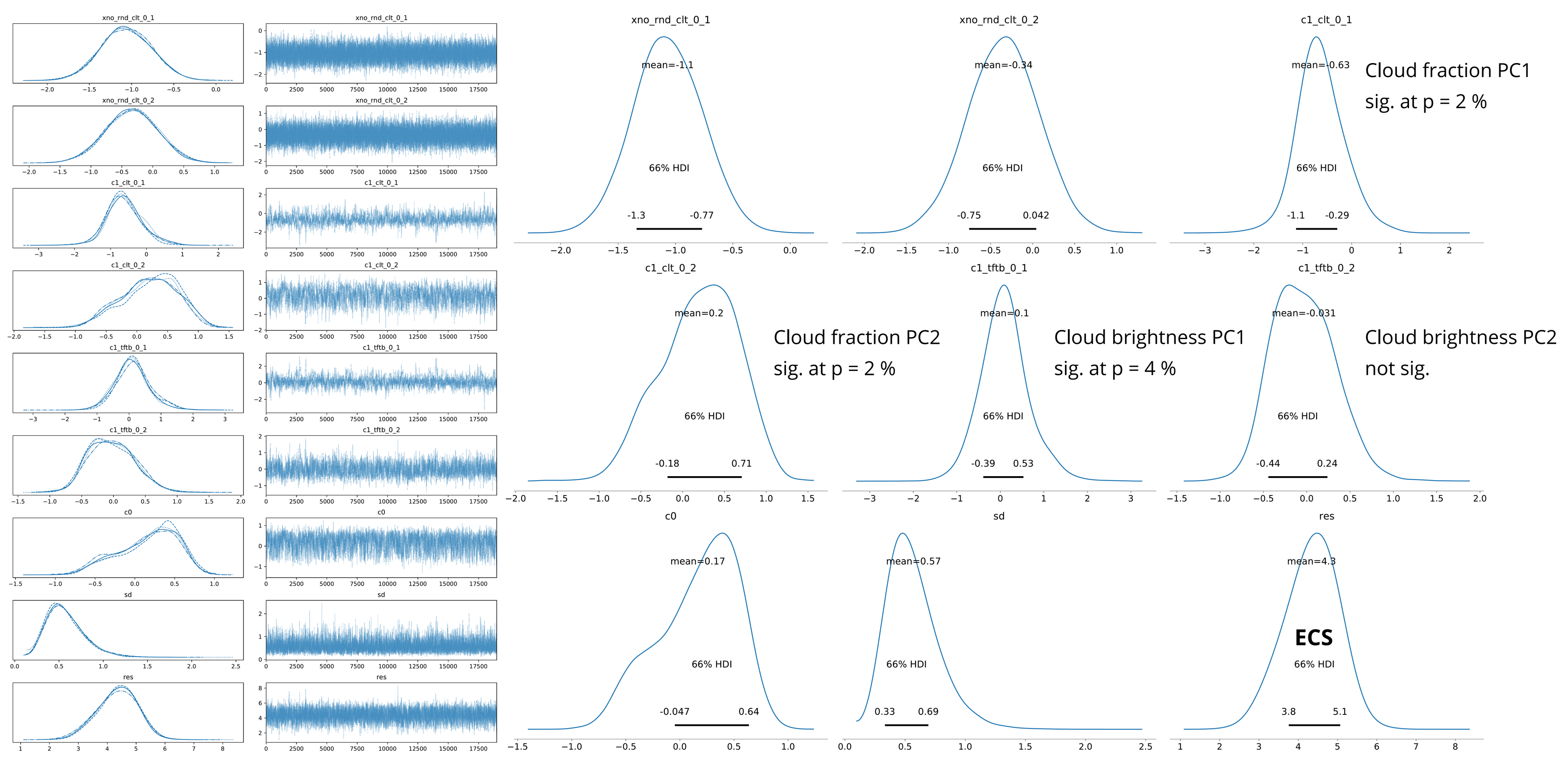
First two principal components of variability of cloud fraction and cloud brightness acress models.



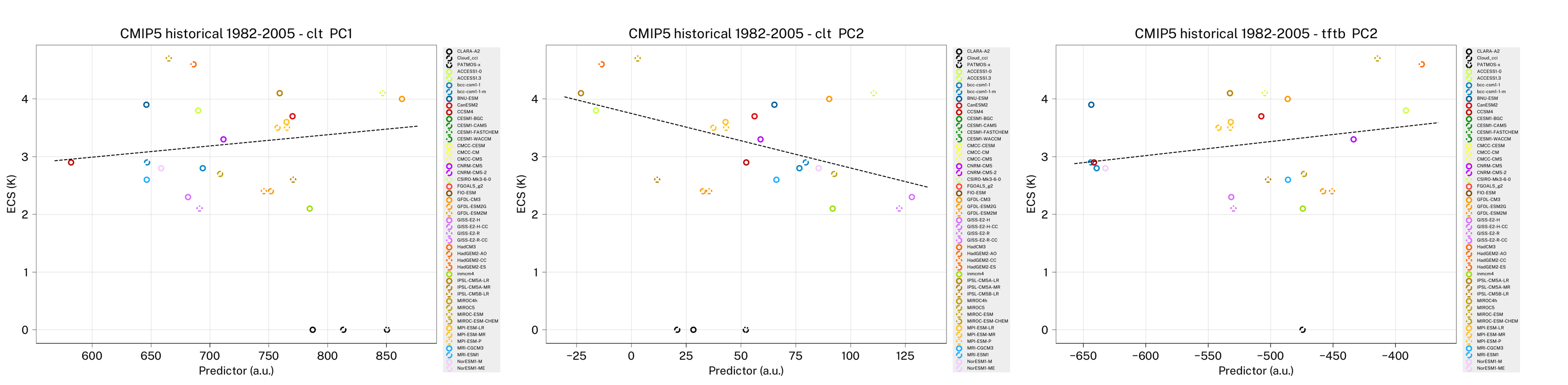
CMIP5 1982–2005
Posterior distributions of the multivariate regression y = c0 + [c1]*[x].



CMIP6 1982–2014
Posterior distributions of the multivariate regression y = c0 + [c1]*[x].



Significant linear regression components.



Significant linear regression components.