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Supporting Information for

Observationally Constrained Cloud Phase unmasks Orbitally Driven Climate Feedbacks

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Supplementary Methods

The “SLF1” and “SLF2” simulations in this study are based on the “CALIOP-SLF1” and “CALIOP-SLF2” simulations from Tan et al., 2016, in which modeled supercooled liquid fraction (SLF) were matched to observational data. The original simulations had a small cool bias and so we modified the cloud tuning values in these simulations in order to improve the climate (Table S1).

We use a pre-industrial model configuration (i.e. land mask, ice sheets, greenhouse gases, vegetation and aerosols). Following the methodology of Erb et al., 2013, we perform idealized simulations in which only obliquity is modified to a low (Lo) value of 22.079° and a high (Hi) value of 24.480° representative of the past 600 Kyr. DEF, SLF1 and SLF2 are run with Lo and Hi obliquity (six simulations) for a minimum of 350 years or until the top-of-atmosphere (TOA) energy budget is $> 0.3 \text{ Wm}^{-2}$. These simulations are long enough to capture broad changes in the atmosphere and surface ocean but are not long enough for the oceans to fully respond to the obliquity forcing. The final 50 years of the simulation are used for climate computations. All results are presented as Lo-Hi anomalies as this convention reduces northern hemisphere (NH) summer insolation, which is conducive to NH glaciation.

Figure S1. Figure S1. Seasonal variations in column-integrated liquid and ice presented as Lo-Hi anomalies for total grid box. Column 1 shows DEF, column 2 SLF1 and column 3 SLF2 for a-c) cloud liquid water path (LWP), d-f) ice water path (IWP) and g-j) total cloud water path (TWP). Units are g/m^2 .

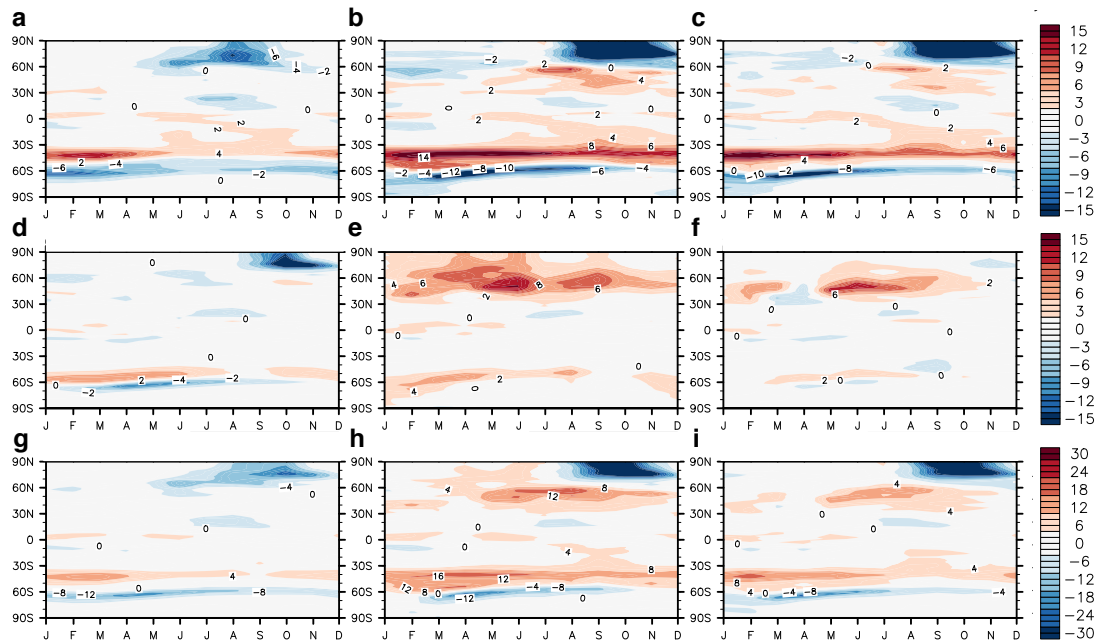


Figure S2. Net cloud feedbacks calculated using the International Satellite Cloud Climatology Project satellite simulator (ISCCP). a) DEF, b) SLF1 and c) SLF2. Feedbacks due to changes in cloud amount (CLD) are shown in orange, cloud optical depth (COT) in green, cloud top pressure (CTP) in blue, a residual component (RES) in magenta and total feedbacks (TOT) shown in black.

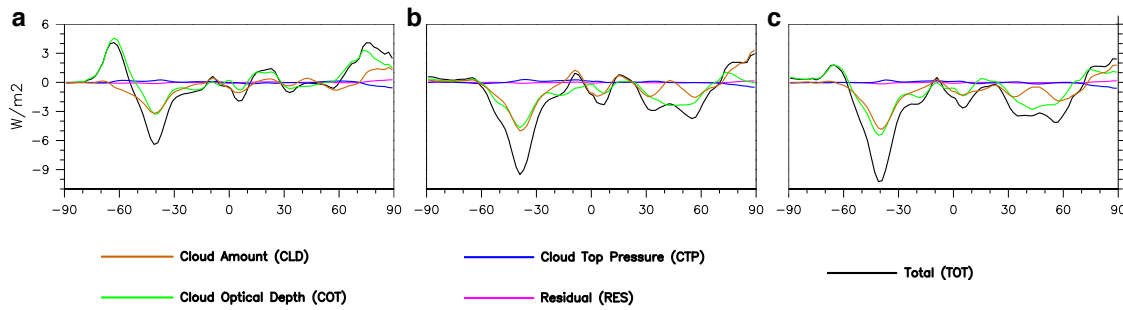


Table S1. Tuning values used for simulations presented in this work. Our values are shown in bold. Values used in Tan et al., 2016 are shown in *italics* and default values shown in parenthesis

	SLF1	SLF2
rhminl	0.9175 (0.8) <i>0.8725</i>	0.8925 (0.8) <i>0.8475</i>
rhminh	0.8 (0.8) <i>0.8</i>	0.99 (0.8) <i>0.99</i>