Marine low clouds and inversion strength

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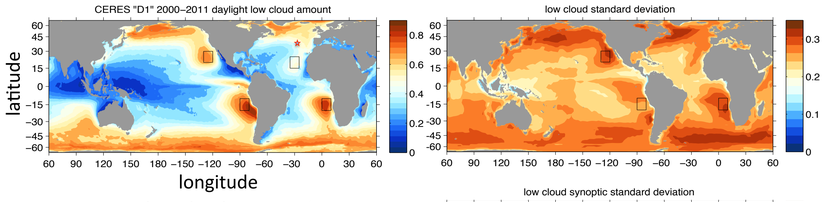
Low clouds cool the climate by reflecting sunlight, shading the ocean surface, and emitting thermal radiation at a warm temperature. Marine low cloud amount is correlated to lower tropospheric stability (θ_{700hPa}-θ_{sfc}) on seasonal and interannual time scales (Klein and Hartmann 1993). Low cloud parameterizations in many models are activated by lower tropospheric stability criteria. Estimated inversion strength (EIS, Wood and Bretherton 2006) measures inversion strength using standard analysis levels. A stronger inversion is presumed to limit entrainment of dry air into the boundary layer, aiding cloud formation and limiting cloud evaporation. As surface climate warming would reduce inversion strength and thus cloud amount, the control of the inversion strength on marine low cloud represents a positive climate feedback. *We investigate the low cloud-EIS relation* on sub-daily to interannual time scales with 26-years of ISCCP D1 adjusted low cloud fraction (Rossow and Schiffer 1999, Clement et al. 2009) and EIS from NCEP reanalysis. We find:

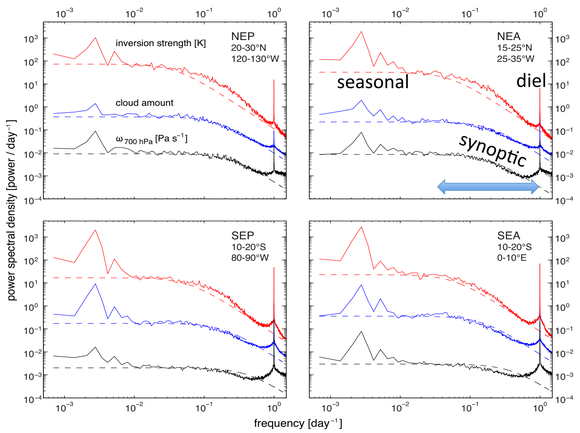
1. **Synoptic variability** is responsible for most EIS-low cloud covariance throughout the subtropics and midlatitudes. Negative synoptic covariance (unstable-cloudy) is found at 45-60° latitude. Synoptic storm structure explains the midlatitude covariance.
2. The **seasonal** EIS-low cloud (stable-cloudy) correlation (Klein and Hartmann 1993) dominates only in the southeastern tropical Atlantic and Pacific Oceans. *Beware of using Klein-line low cloud parameterizations on timescales other than seasonal.*
3. **Diurnal and interannual** low cloud-EIS covariance are 10x smaller than seasonal or synoptic variability.
4. Synoptic **covariance of low cloud with *downward* vertical velocity** is found in midlatitude storm tracks, especially over the western north Pacific and Atlantic Oceans.

The seasonal inversion strength variations explain a small fraction of low cloud variance around the globe. The processes responsible for marine low cloud correlations should be considered carefully when extrapolating these correlations to climate feedbacks.



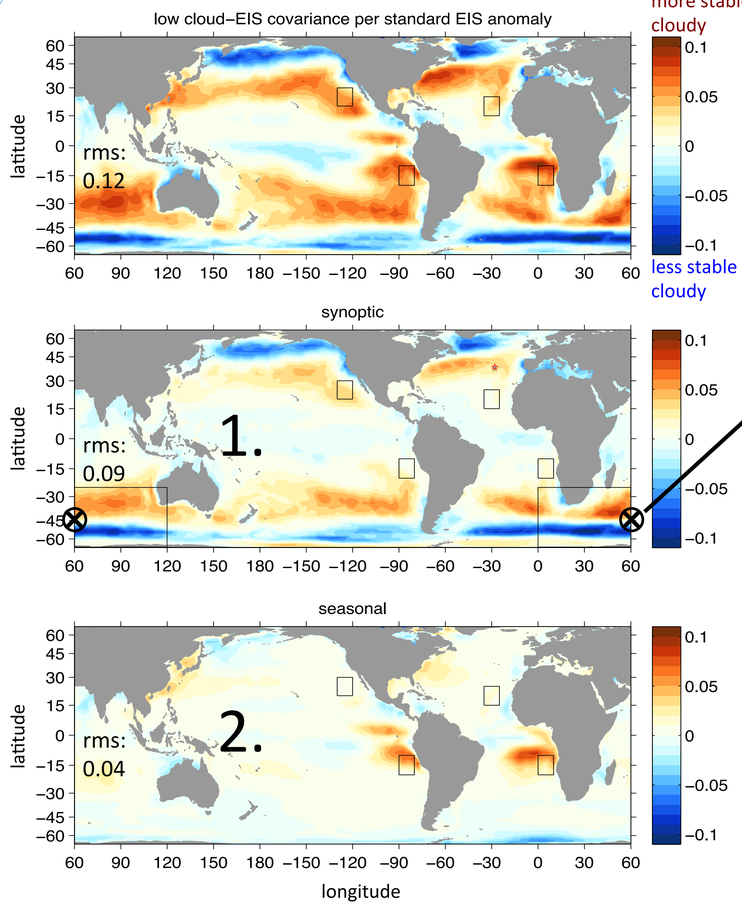
Top: Mean low cloud amount (CERES daylight-only) shows subtropical marine stratiform cloud decks near the Klein and Hartmann (1993) stratus regions (squares). Low cloud is defined to have cloud top below 560 hPa to include clouds in deep boundary layers.

Right: ISCCP standard deviation of low cloud amount (~0.3) is dominated by synoptic variations, with a 0.1 contribution from the seasonal cycle in the southern stratus decks.



Interannual to diurnal power spectra of ISCCP adjusted cloud, EIS, and 700 hPa pressure velocity in the tropical stratus regions. Considerable energy lies in the broad synoptic band around 10-day period.

We separate EIS and low cloud amount covariance into orthogonal interannual, seasonal, synoptic, and diurnal bands.

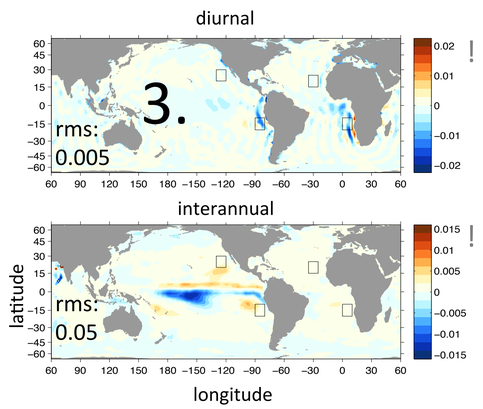


Covariance of ISCCP adjusted low cloud with EIS. Positive values (red) in the subtropics and eastern tropical Atlantic and Pacific Oceans indicate cloud amounts are greater for more stable conditions. Negative values (blue) poleward of 45° latitude show cloud amount increases for unstable conditions.

- Synoptic (1-30 day) covariance is responsible for most of the total covariance (positive and negative) poleward of ±15° latitude, including in the stratus regions.
- In the deep tropics, seasonal covariance of cloud and EIS is responsible for much of the total covariance, especially over the eastern tropical Pacific and Atlantic Oceans.

Amplitudes are normalized to represent cloud fraction anomalies associated with a standard deviation of EIS.

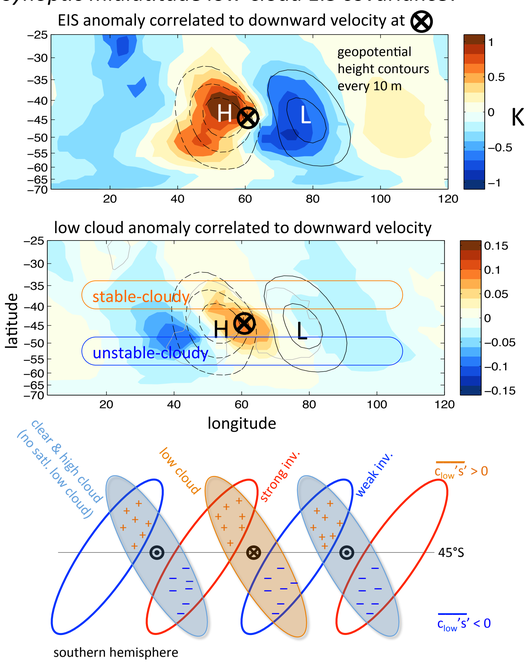
Low cloud variations associated with diurnal and interannual variations of EIS are small.

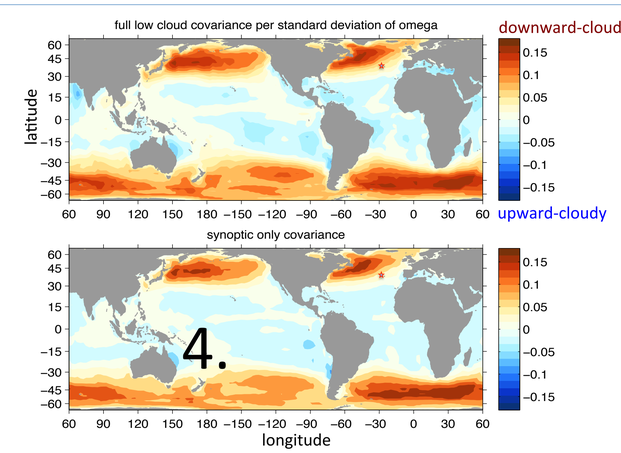


What is responsible for the synoptic midlatitude low-cloud EIS covariance?

Synoptic patterns of EIS and low cloud regressed on downward 700-hPa pressure velocity at 44°S, 61°E (cross).

The EIS regression on pressure velocity tilts northeast-southwest in the southern hemisphere, while low cloud amount tilts northwest-southeast. Thus more low clouds are found in stable conditions equatorward of 45° and more low clouds are found in unstable conditions poleward of 45°, explaining the synoptic low cloud-EIS correlation (1) at left.





Low clouds increase ~0.15 for a standard downward anomaly of 700 hPa pressure velocity (ω_{700}) in midlatitudes, especially the western Pacific and Atlantic storm tracks, and the Atlantic and Indian Southern Ocean.

Low cloud response to vertical velocity is weak outside the midlatitudes, with clouds increasing slightly for upward motion outside of tropical convergence zones.

References

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