An observational perspective on the cloud feedback: from inter-annual variability to global climate change

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1. Introduction

Several observational and numerical studies have shown that increased low cloud cover in subtropical stratus regions (i.e. stratocumulus and stratus cloud types) is associated with cold SST, high LTS (or EIS, i.e. Estimated Inversion Strength), strong large-scale atmospheric subsidence and surface winds divergence. These inter-relationships can be interpreted as arising from a positive feedback among clouds, SST and atmospheric circulation (Clement et al. 2009).

- Do fluctuations in low cloud cover amplify the internal variability of climate?
- Are there further implications for the global climate change?

This study examines correlations between observations of clouds, SST and atmospheric circulation on multiple timescales. The main findings are that cloud radiative forcing amplify SST on inter-annual timescales and the low-level cloud feedback has been positive for the years 1954-2008. The feedback is calculated from observations of clouds from ships that have been corrected for a spurious global increase in cloud cover and compared to satellite retrievals of cloud fraction (ISCCP and Patmos-x).

2. Datasets

Cloud cover: Archive of ship-based reports compiled by Hahn and Warren that covers the years 1954-2008 (EECRA), ISCCP corrected cloud cover and radiative fluxes (provided by J. Norris) and Patmos-x corrected cloud fraction retrievals (provided by A. Evan). The tropical mean annual mean has been removed to cloud observations from ships prior to calculations because an unknown artifact introduces a spurious positive trend globally (Figure 1 and Norris 1998, Deser et al. 2010). Corrected data are in good agreement with ISCCP retrievals for most part of the oceans (Figure 2).

SST: Hadley center reanalysis (HadISST).

Surface winds (10 m): NCEP/NCAR reanalysis.

Latent heat flux (10 m): NCEP/NCAR reanalysis.

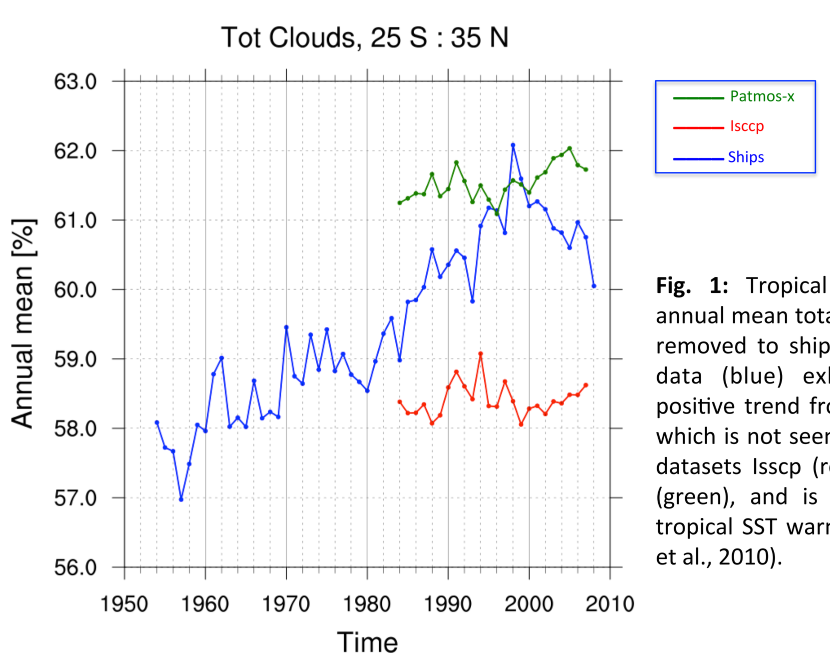

Fig. 1: Tropical mean (25S:35S) annual mean total cloud anomalies removed to ships raw data. Ships data (blue) exhibit a spurious positive trend from 1954 to 2008, which is not seen in the other two datasets Isscp (red) and Patmos-x (green), and is inconsistent with tropical SST warming trend (Deser et al., 2010).

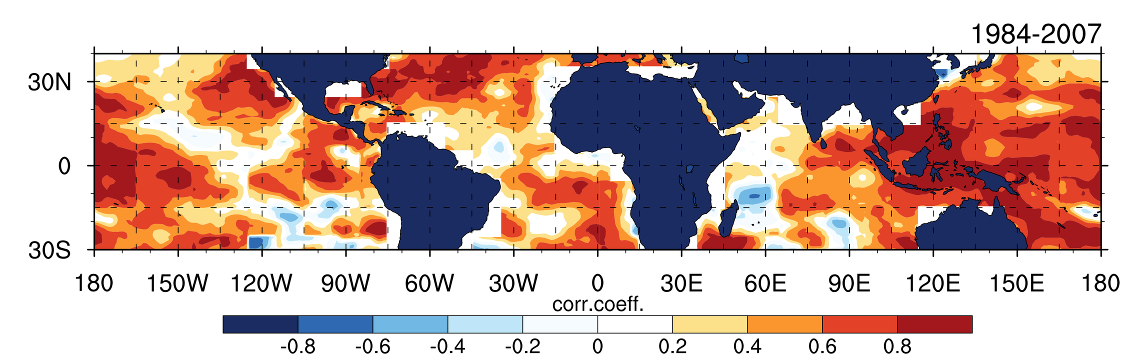

Fig. 2: Linear correlation between total cloud inter-annual anomalies of ISCCP and corrected observations from ships for the years 1984-2007. A 1-2-1 smoothing is applied.

3. Subtropical stratus regions

Lead-lag correlations of monthly mean anomalies show that clouds and surface winds lead SST in subtropical stratus regions (Figure 3).

The sign of the correlations indicate that weaker surface winds and reduced cloud cover precede warmer SST. Weaker surface winds decrease the latent heat flux from the ocean, while reduced cloud cover increases solar radiation flux at the surface. Both processes favor warmer SST, but while the latent heat flux becomes a damping (i.e. negative feedback) for large SST anomalies, cloud radiative forcing (estimated as SW flux at TOA) is positive for a longer time (Figure 4).

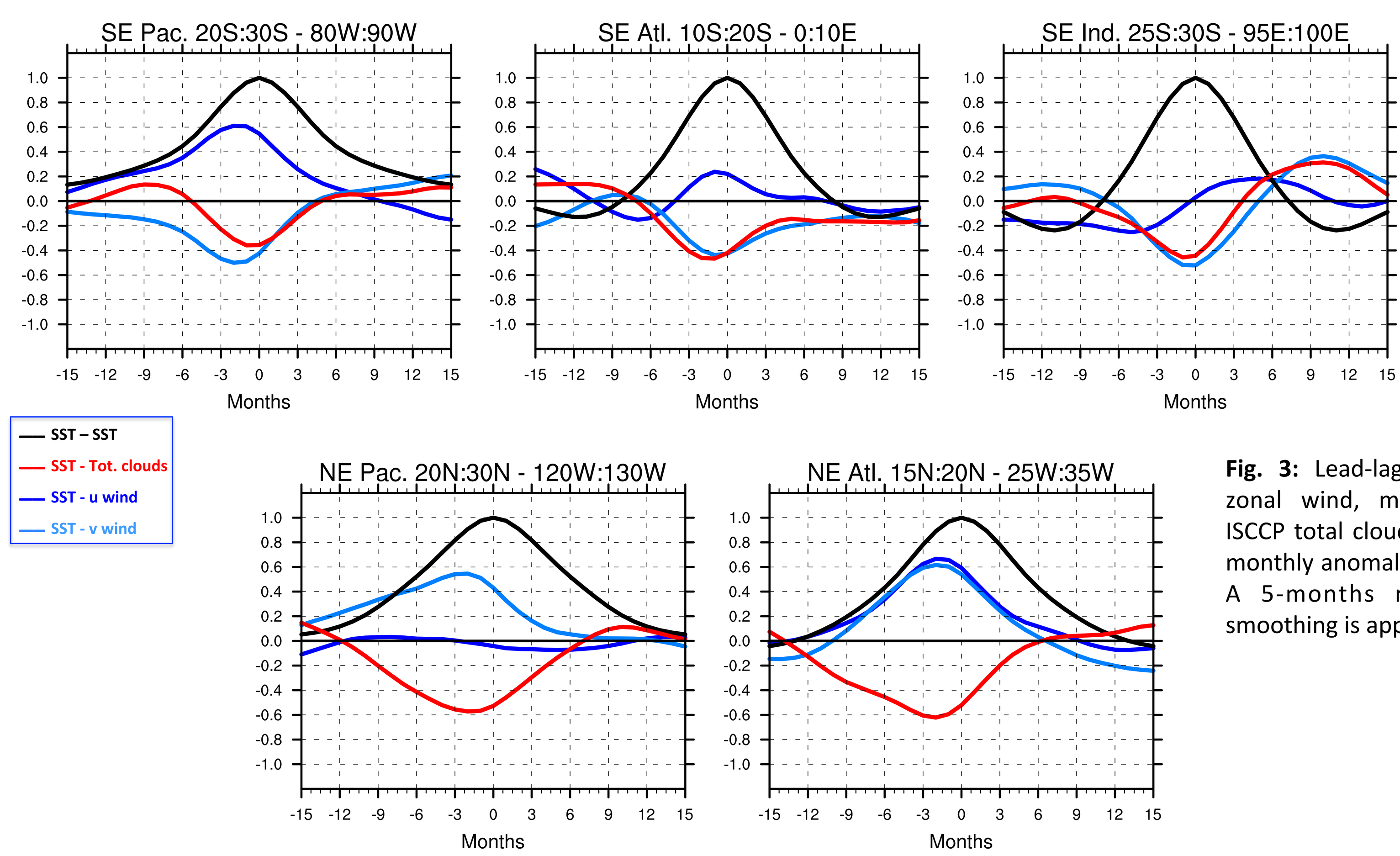

Fig. 3: Lead-lag correlation of zonal wind, meridional wind, ISCCP total cloud cover and SST monthly anomalies (1984-2007). A 5-months running mean smoothing is applied.

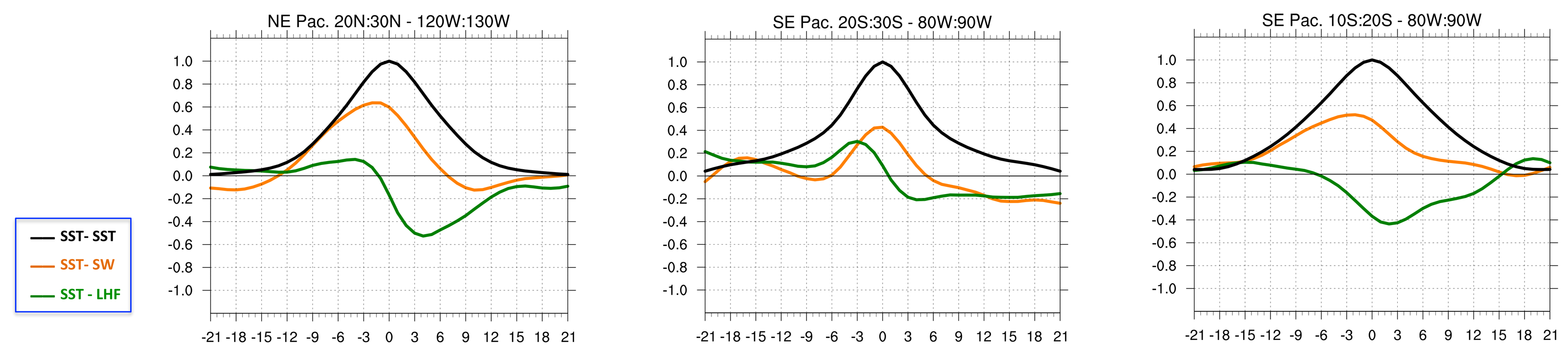

Fig. 4: Lead-lag correlation of SW net radiation flux at TOA, latent heat flux at surface and SST monthly anomalies. Heat fluxes are positive downward. A 5-months running mean smoothing is applied.

4. ENSO-like events (1984-2007)

Composites of warm and cold ENSO-like events show a large-scale response of cloud cover over the eastern equatorial Pacific and subtropical stratus regions. ENSO-like events are defined as local maxima of the Nino 3.4 SSTA index that are also greater than one standard deviation of the index. Composites of SSTA, surface winds and cloud cover are obtained by averaging all ENSO-like events.

The clouds response in stratus regions to warm events is a reduction of cloud cover (Figure 5, left column), and an increase in cloud cover during cold events (Figure 5, right column). This suggests that a regional positive feedback between clouds and SST further reinforces SST anomalies during ENSO-like events.

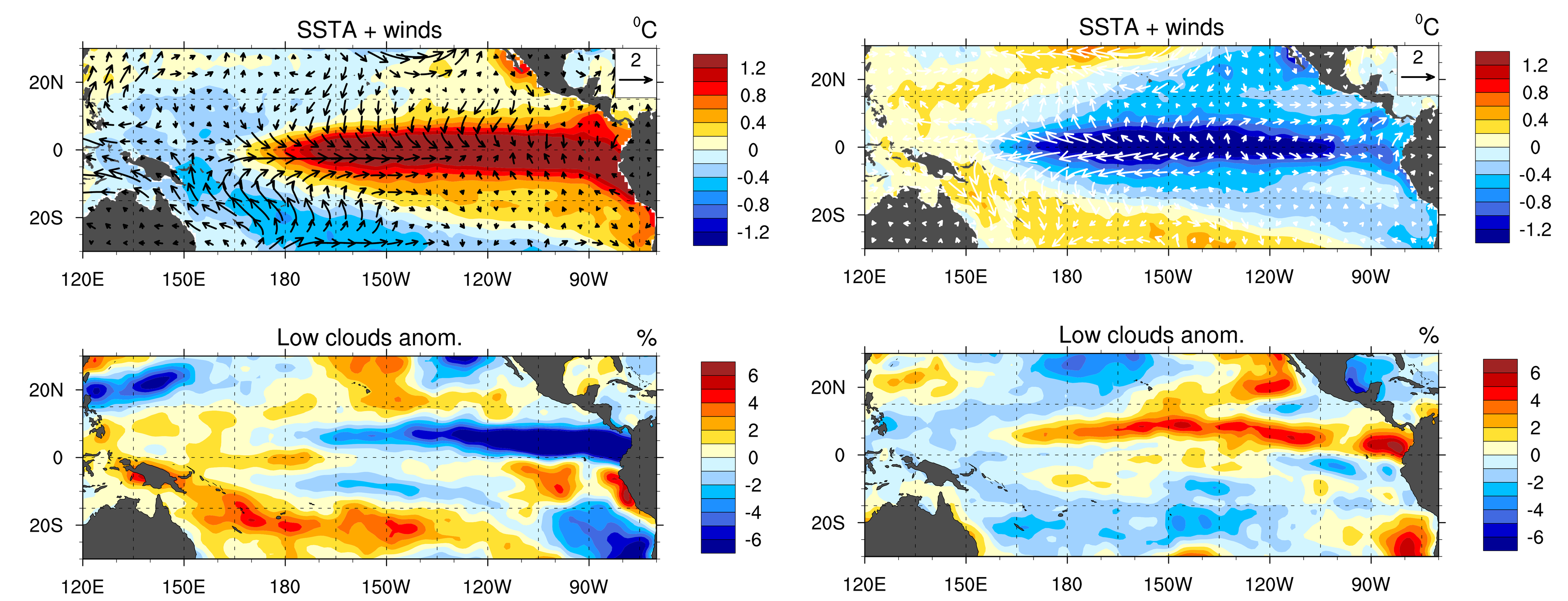

Fig. 5: Composites of ENSO-like warm (left) and cold (right) events. Top: SST and surface winds monthly anomalies. Bottom: ISCCP low-level cloud cover monthly anomalies. All data are de-trended.

5. Global climate change

Ships observations show a negative trend in both low-level and total cloud cover (1954-2008) over three major subtropical stratus regions. An estimate of the cloud feedback is made based on the change in CRF (cloud radiative forcing) divided by change in SST for the period 1954-2008 and is obtained from regression of ISCCP net radiative fluxes at TOA on cloud cover. This empirical estimate suggests a fairly strong positive low-level cloud feedback in those regions.

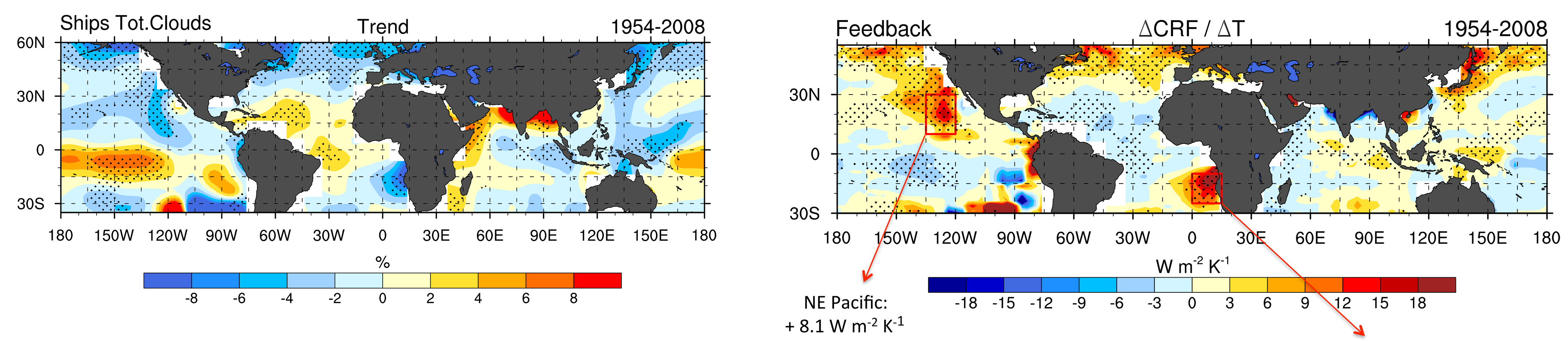

Fig. 6: Left: Trend in total cloud cover (1954-2008) from corrected ships observations. Right: Estimate of the total cloud feedback. Stippling indicates areas that are statistically significant at the 95% level of a two-tailed t-test.

6. Conclusions

Lead-lag correlations of monthly mean anomalies show that latent heat flux damps SST anomalies in the stratus regions, while cloud radiative forcing contributes to warm SST anomalies (i.e. a positive feedback) for longer time.

On inter-annual timescales clouds response to warm and cold events in the tropical Pacific amplify SST anomalies.

An empirical estimate of the cloud feedback reveals a large positive feedback over three major stratus regions for the period 1954-2008.

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