Comparison of Cloud and Radiation Variability Reported by Surface Observers, ISCCP, and ERBS

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Outline

- brief satellite data description
- upper-level cover and “satellite view” low-level cover from surface cloud observations
- “cloud cover radiative forcing” anomalies
- regional and zonal mean cloud variability and trends
- possible reasons for disagreement between cloud and radiation datasets

Processing of ISCCP Data

- All ISCCP cloud types with tops above the 680 mb level were combined into the category of “upper-level” (mid+high) cloud
- All ISCCP cloud types with tops below the 680 mb level were combined into the category of low-level cloud
- Monthly 2.5°×2.5° values were averaged to seasonal or 72-day 5°×10° or 10°×10° values

Processing of ERBS Data

- ERBS all-sky OLR and RSW were adjusted for variations in satellite altitude
- 36-day data were used to avoid aliasing of the diurnal cycle by the precessing satellite
- 36-day 10°×10° values were averaged to seasonal or 72-day values
- sampling is poor at higher latitudes due to low-inclination orbit

EECRA Upper-Level Cloud Cover

- surface observers report total cloud cover (N) and cloud cover of the lowest layer (N_h)
- use random overlap to calculate upper-level cloud cover $N_U = (N - N_h) / (1 - N_h)$
- if low overcast and non-drizzle precipitation, assign N_U to 1 (nimbostratus is diagnosed)
- it is frequently not possible to separately calculate mid- and high-level cloud cover

Random Overlap Assumptions

- upper-level cloud covers the same relative fraction of sky where it is obscured by lower clouds as where it is not obscured
- average upper-level cloud cover is the same for when low-level cloudiness is overcast as when low-level cloudiness is not overcast (unless non-drizzle precipitation)
- the second assumption is more questionable, but better alternatives are not obvious

EECRA Low-Level Cloud Cover

- the "satellite view" of low-level cloud cover is the difference between total and upper-level cover: $N_L = N - N_U = N_h \times (1 - N) / (1 - N_h)$
- the difference between surface-viewed sky dome cover and satellite-viewed earth cover can be substantial for low cumuliform clouds

Processing of EECRA Data

- individual surface-observed cloud cover values were averaged to seasonal or 72-day 5°×10° or 10°×10° values

- steps were taken to avoid biases due to non-uniform spatial and temporal sampling and a minor code change in 1981

Cloud Cover Radiative Forcing Anomalies

- radiative effects of surface-observed cloud cover variability can be quantified in terms of “cloud cover radiative forcing” (CCRF) variability

- CCRF anomalies are anomalies in radiation flux solely due to anomalies in cloud cover

- albedo, emissivity, and other cloud and atmospheric properties are treated as constants

Assumptions of CCRF Estimation

- radiation flux varies linearly with changes in upper and/or low cloud cover
- LW CRF per unit upper cover is constant at each grid point (with seasonal cycle)
- low clouds have no effect on LW
- SW CRF per unit upper cover and SW CRF per unit low cover are constant at each grid point (with seasonal cycle)

Estimation of CCRF Anomalies

LW CCRF anomaly =

upper-level cloud cover anomaly ×

climatological LW CRF per unit upper cover

SW CCRF anomaly =

upper-level cloud cover anomaly ×

climatological SW CRF per unit upper cover +

“satellite view” low-levelcover anomaly ×

climatological SW CRF per unit low cover

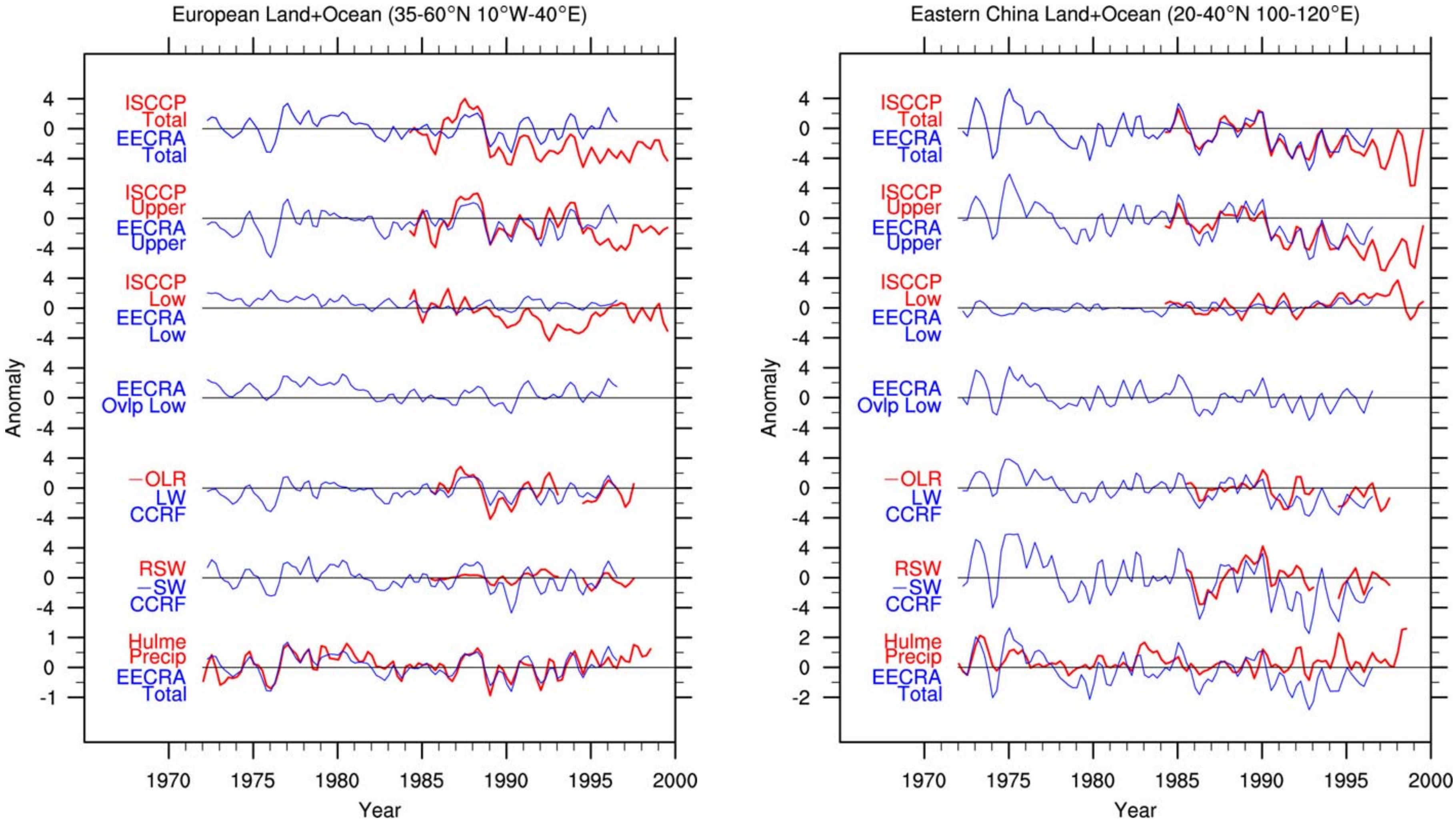
Calculation of Climatological CRF

- LW CRF is obtained from ERBE for 1985-89
- ISCCP visible mean upper-level and mean low-level optical thicknesses are converted to albedo values for 1985-89
- ISCCP visible cloud albedo is scaled by ERBE cloud albedo to convert to broadband
- upper-level and low-level cloud albedo are multiplied by insolation to obtain upper-level and low-level SW CRF

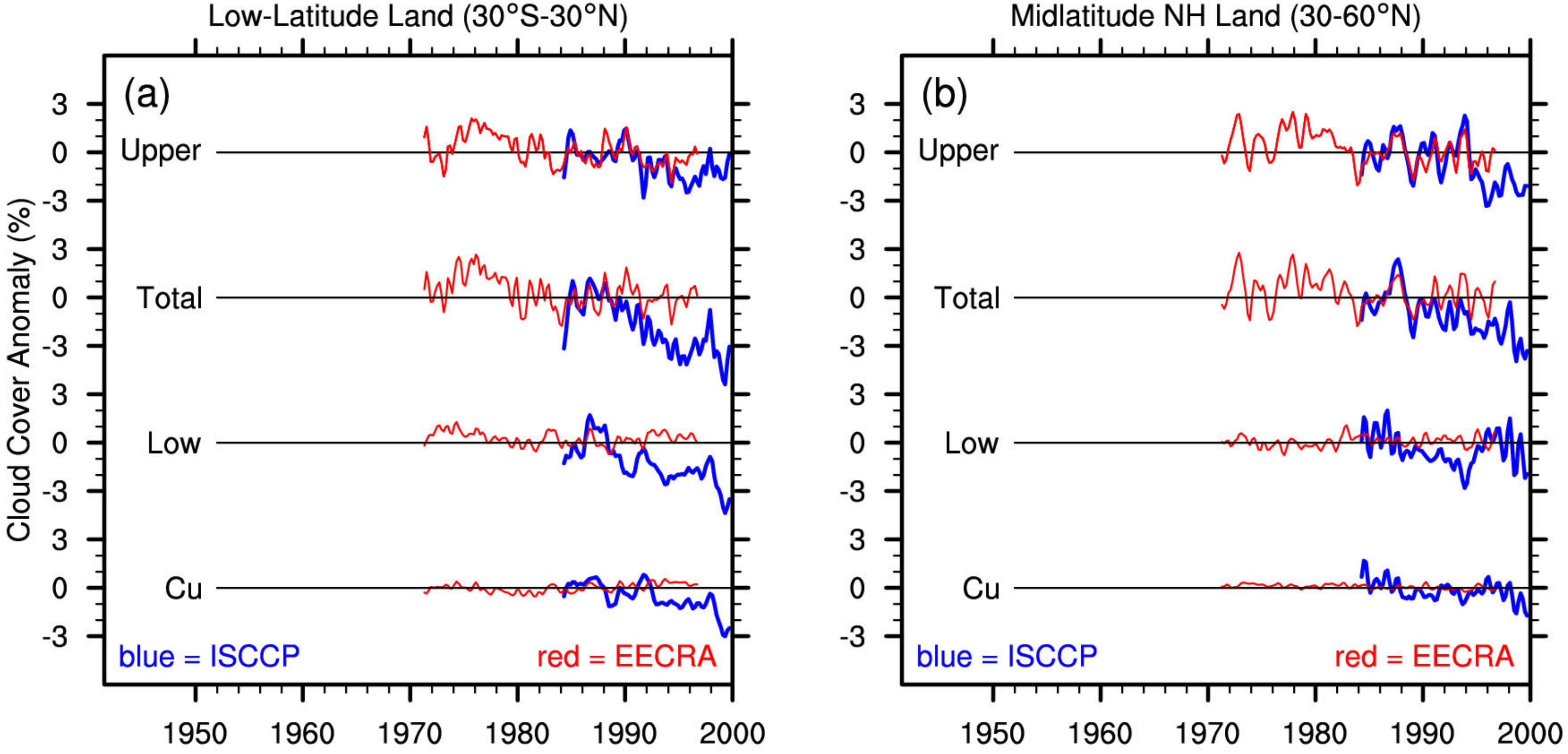
Satellite-Surface Cloud Comparison

- EECRA vs. ISCCP total cloud cover, upper-level cloud cover, and “satellite view” low-level cloud cover
- CCRF anomalies estimated from surface-observed cloud cover vs. all-sky flux anomalies reported by ERBS

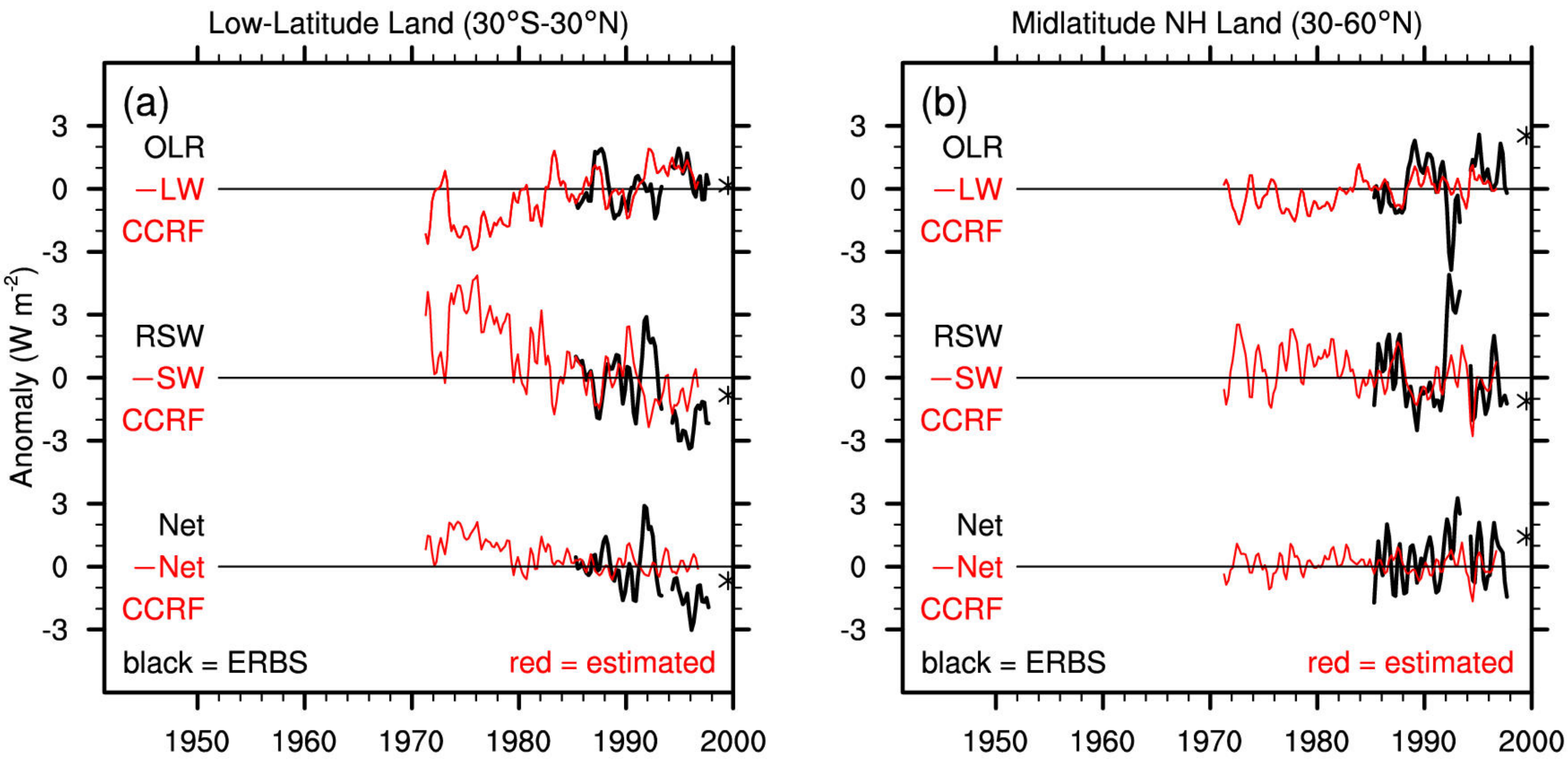
Two Regional Comparisons



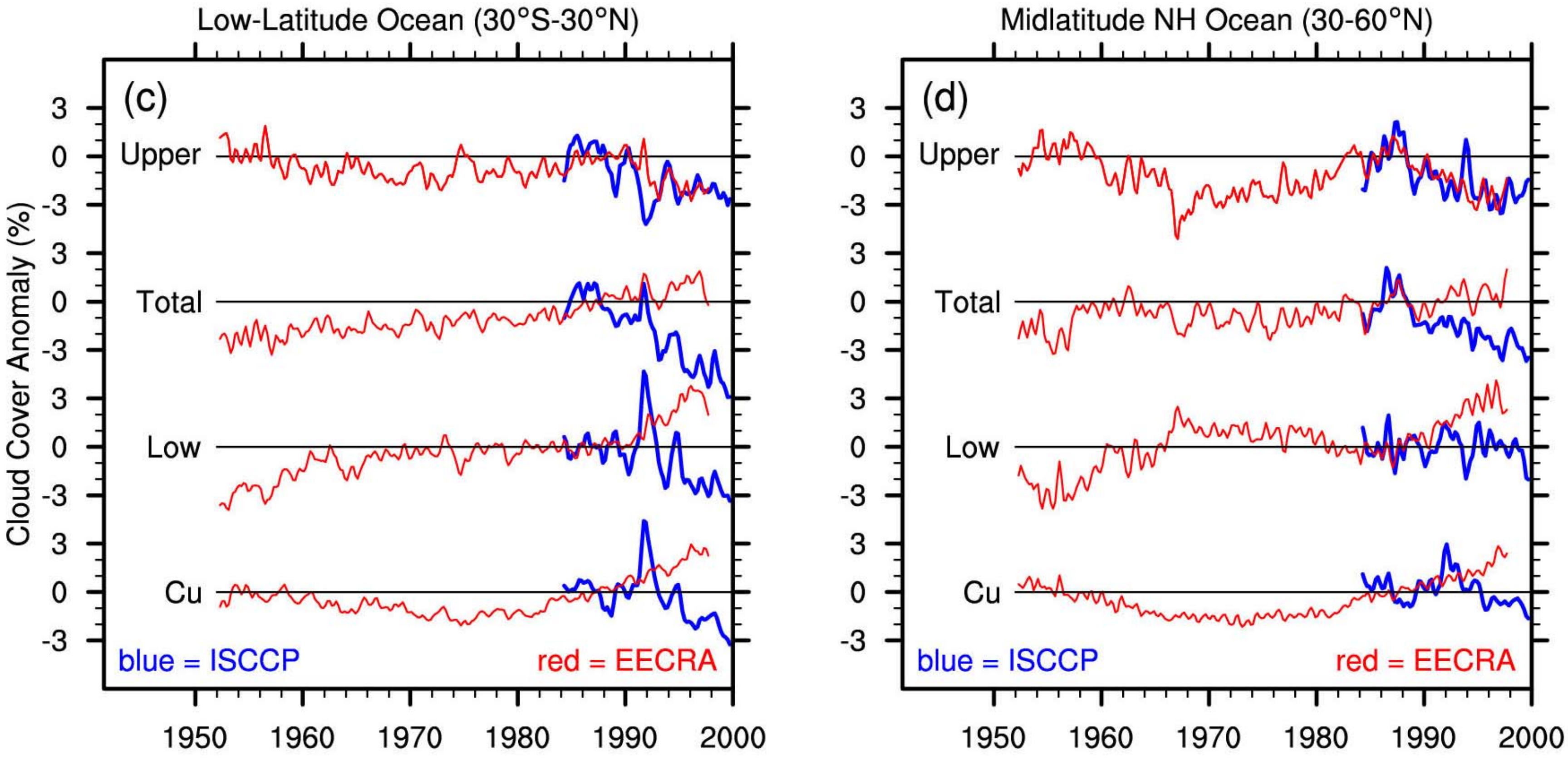
Zonal Mean Land ISCCP Comparison



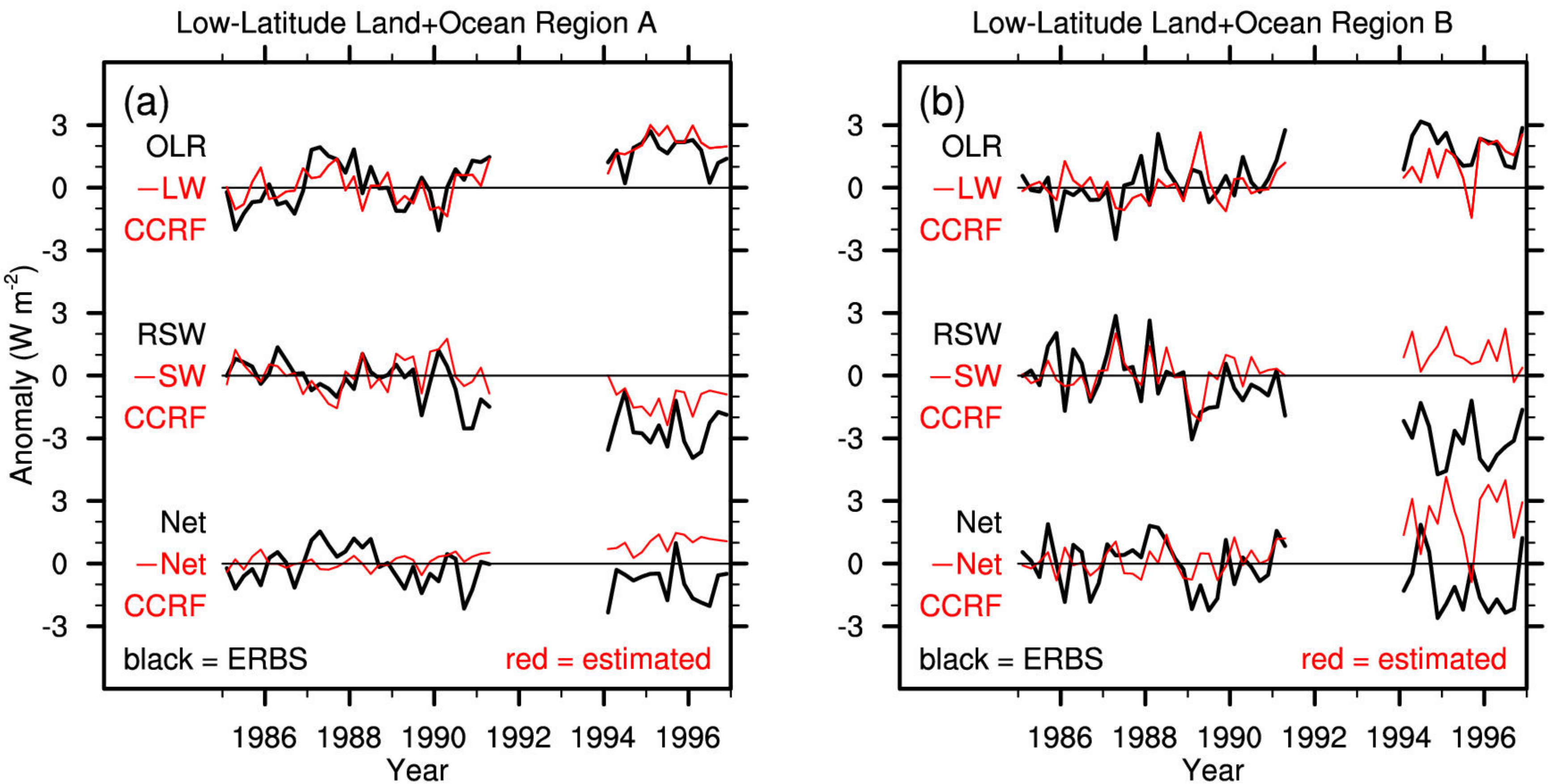
Zonal Mean Land ERBS Comparison



Zonal Mean Ocean ISCCP Comparison



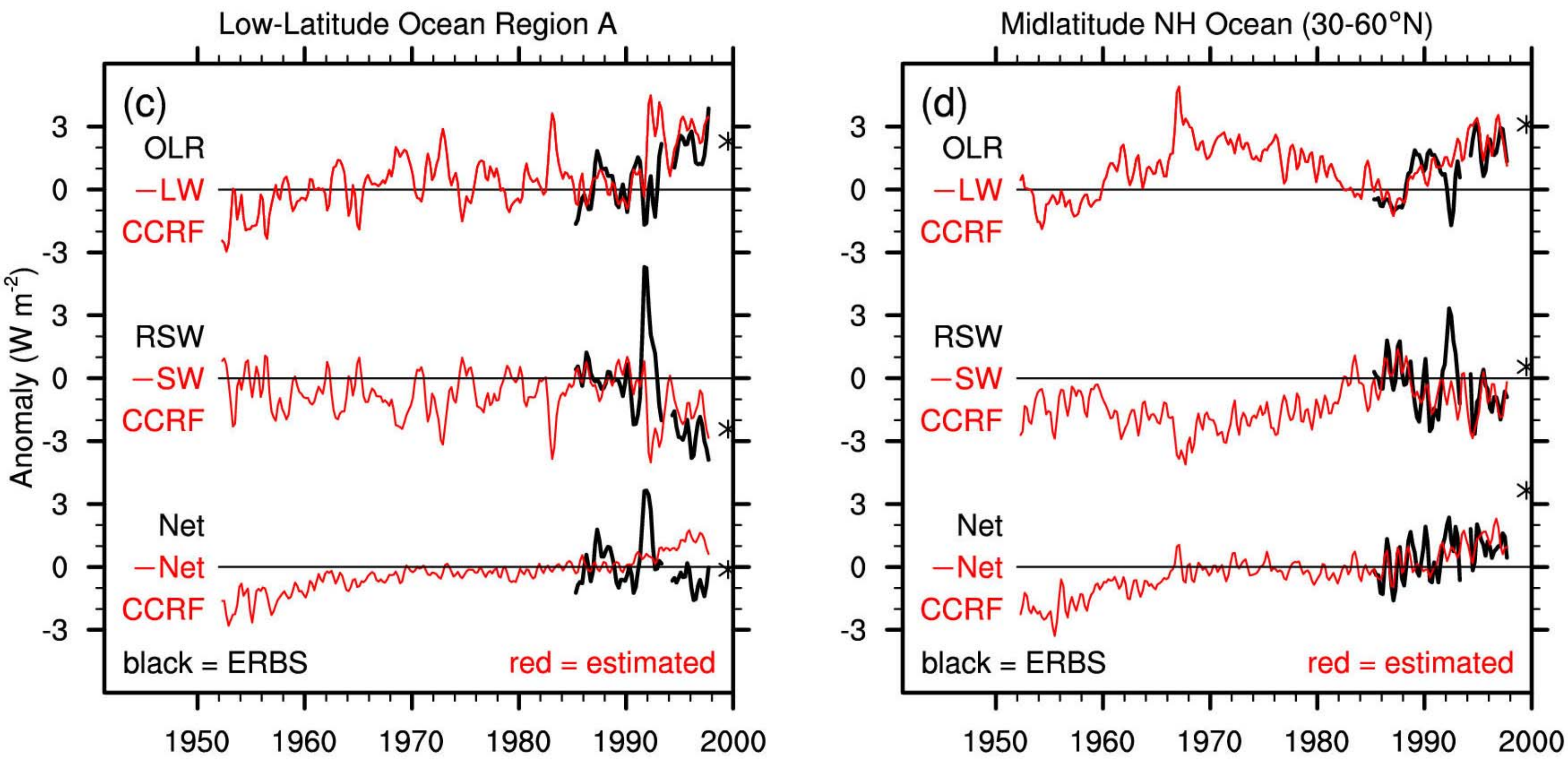
Tropical Land+Ocean ERBS Comparison



tropical Indo-Pacific

tropical Atlantic and eastern Pacific

Zonal Mean Ocean ERBS Comparison

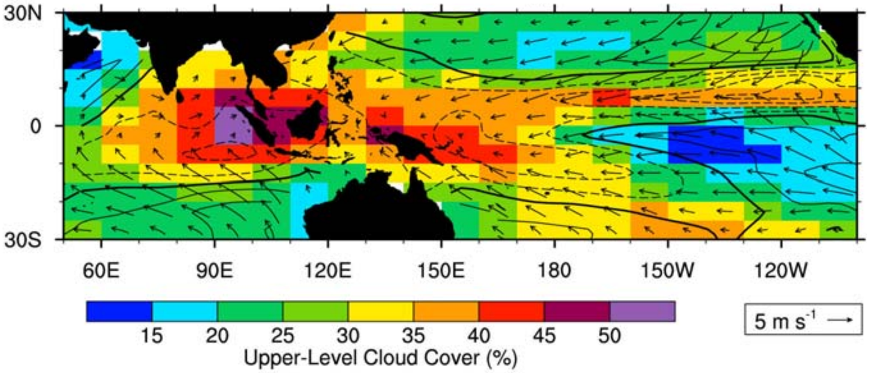


tropical Indo-Pacific

North Atlantic and North Pacific

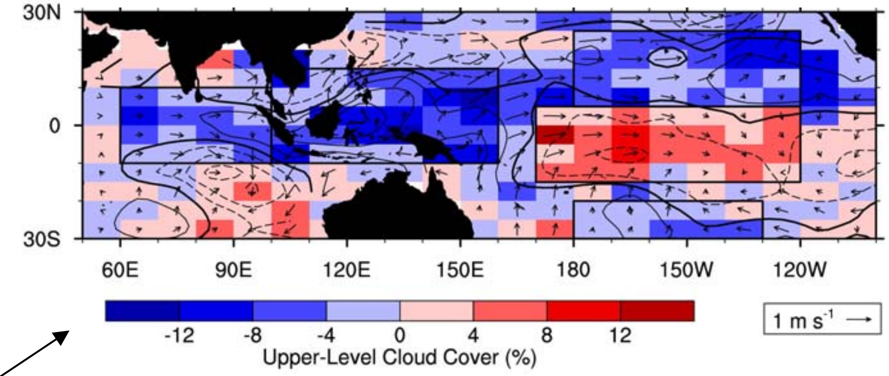
Tropical Indo-Pacific Ocean

Upper Cloud and COADS Divergence



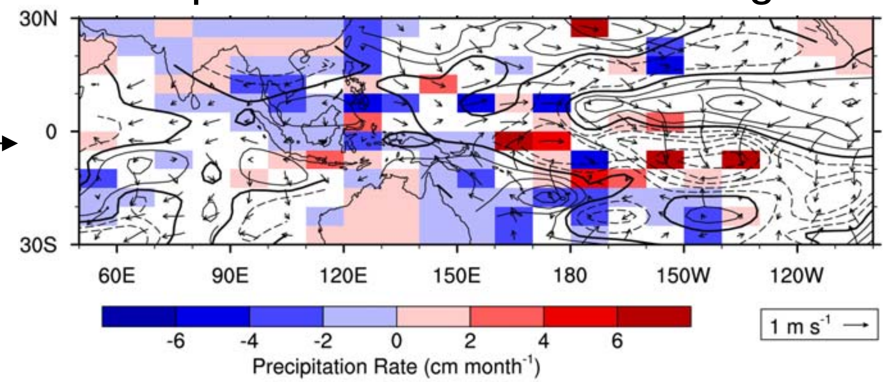
annual climatology

Upper Cloud and SLP-reconstruct Div

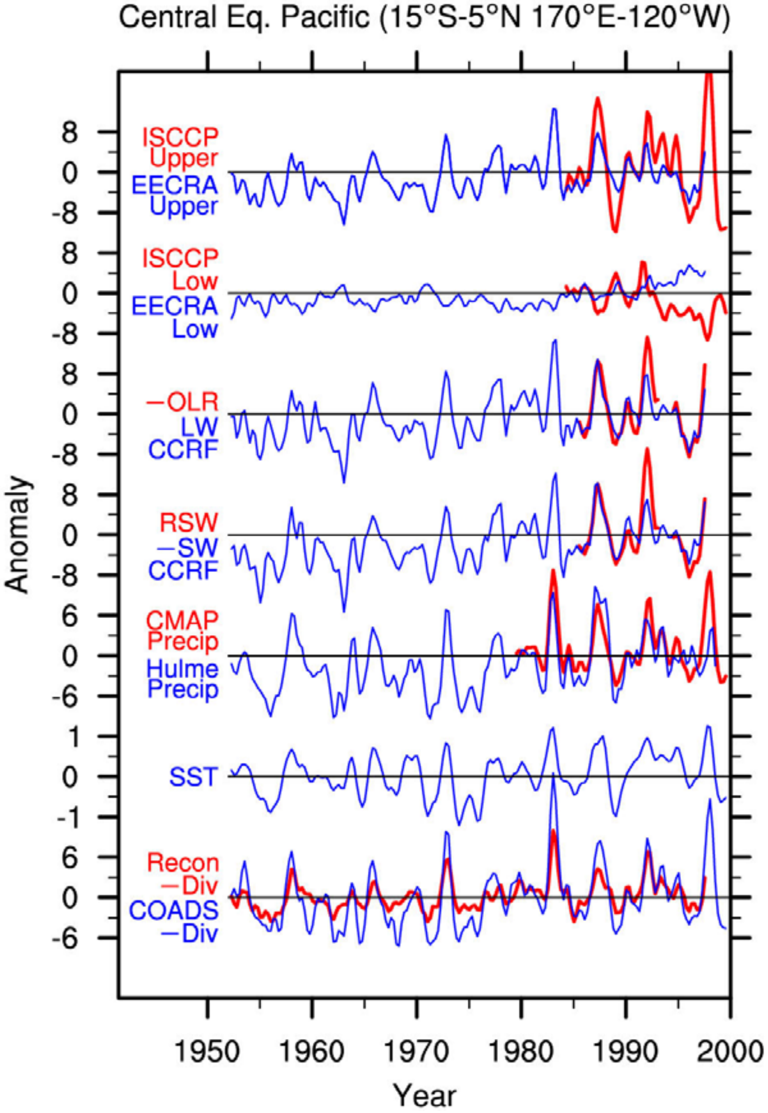


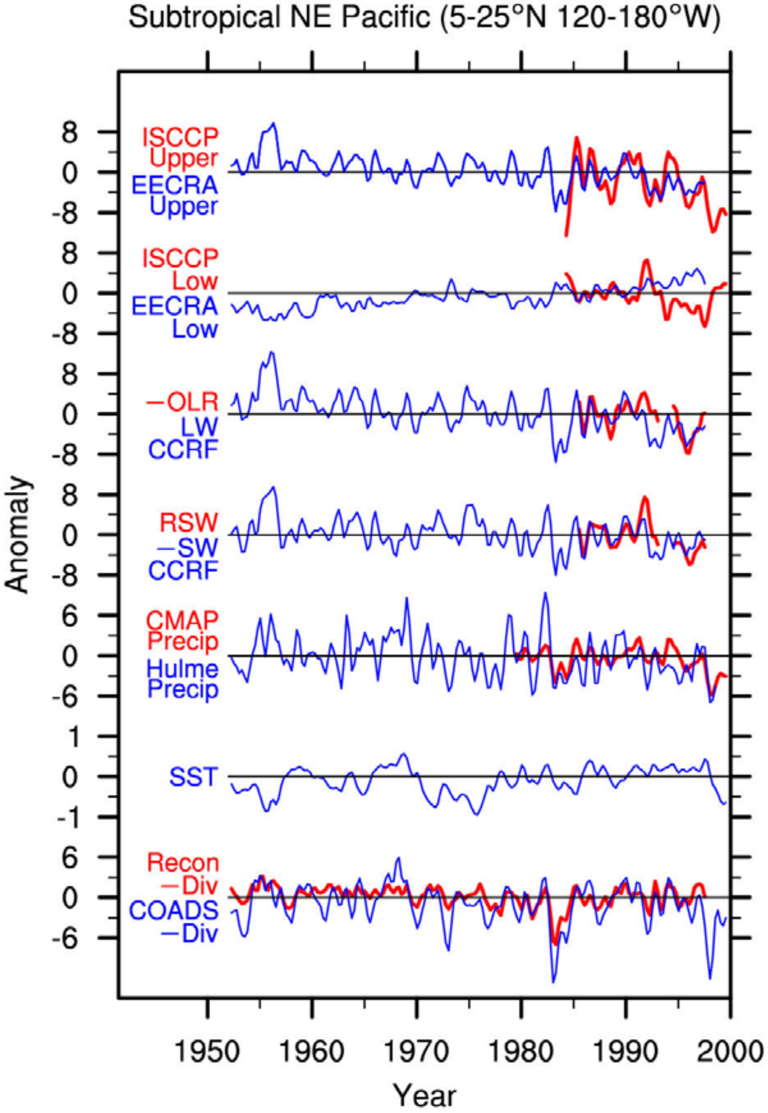
1952-1997 trend

Precipitation and COADS Divergence



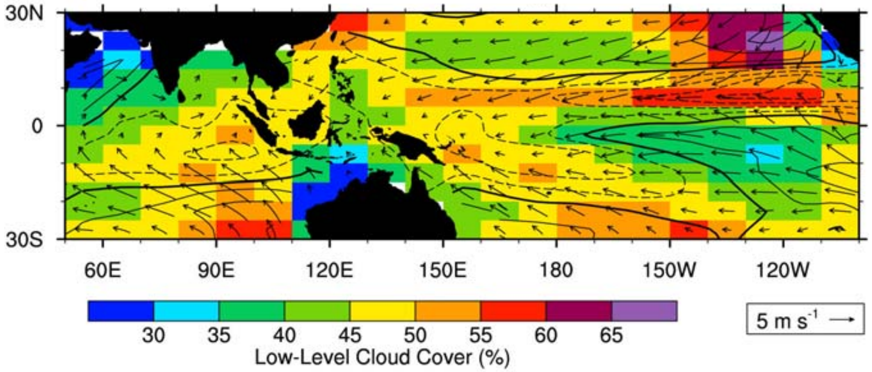
Tropical Indo-Pacific Ocean



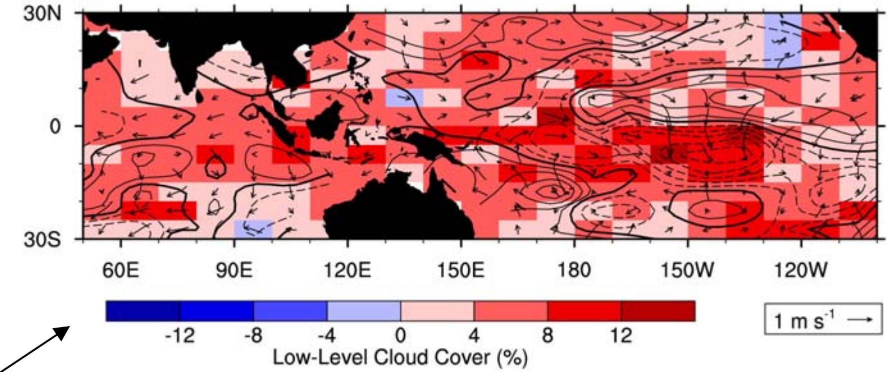


Tropical Indo-Pacific Ocean

"Surface-view" Low-Level Cloud



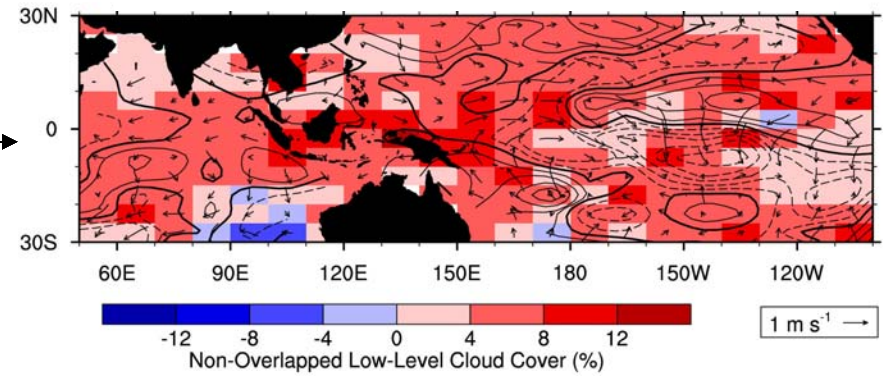
"Surface-view" Low-Level Cloud



annual climatology

1952-1997 trend

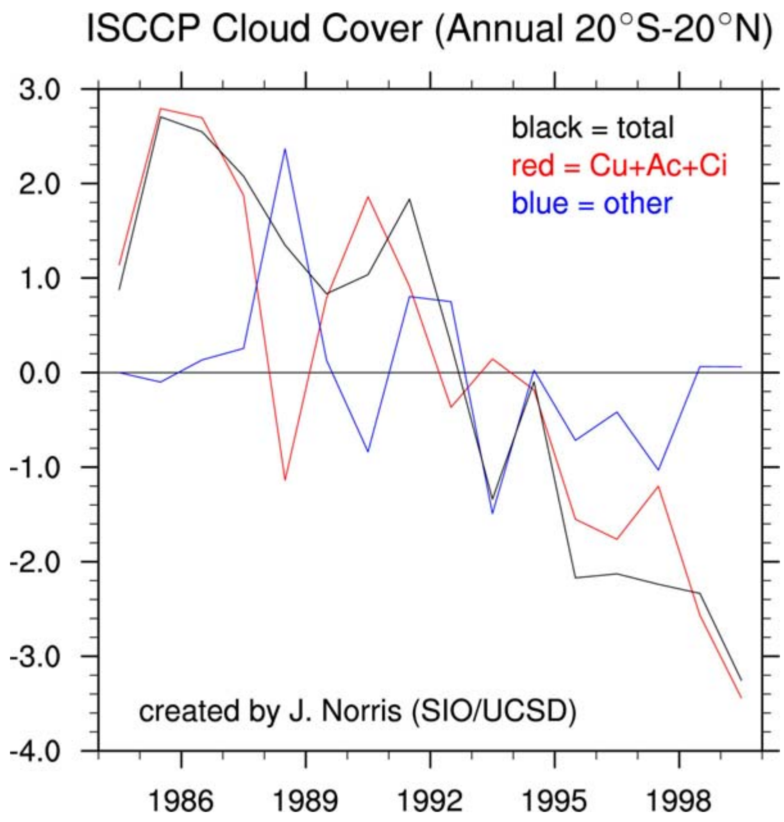
"Satellite-view" Low-Level Cloud

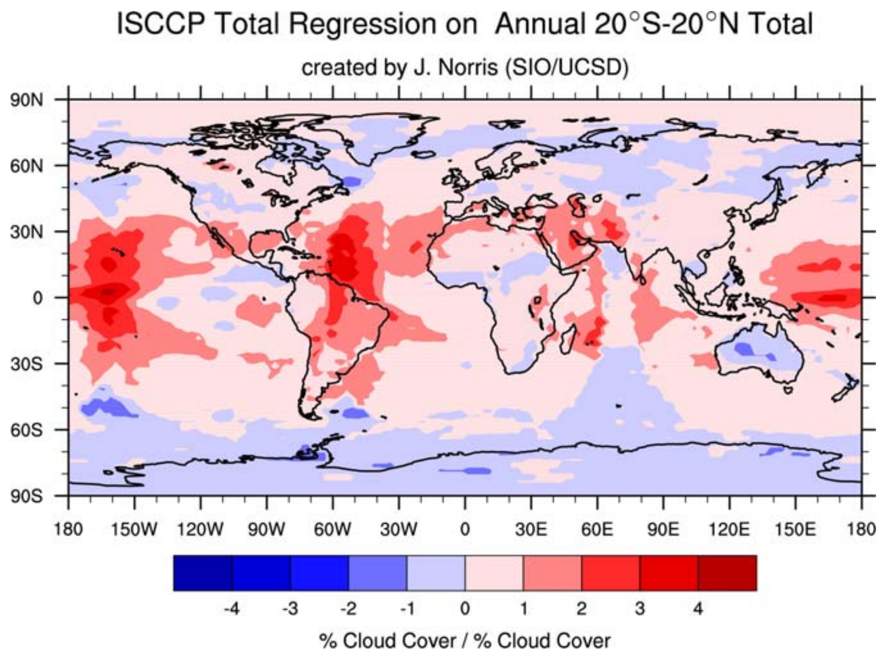


Satellite-Surface Comparison Results

- EECRA, ISCCP, and ERBS show similar upper-level cloud cover and OLR trends
- EECRA and ISCCP show different low-level and total cloud cover trends
- EECRA and ERBS show different SW CCRF and RSW trends over low-latitude oceans
- EECRA upper-level cloud trends are similar to circulation trends over the tropical Indo-Pacific, but low-level cloud trends are not

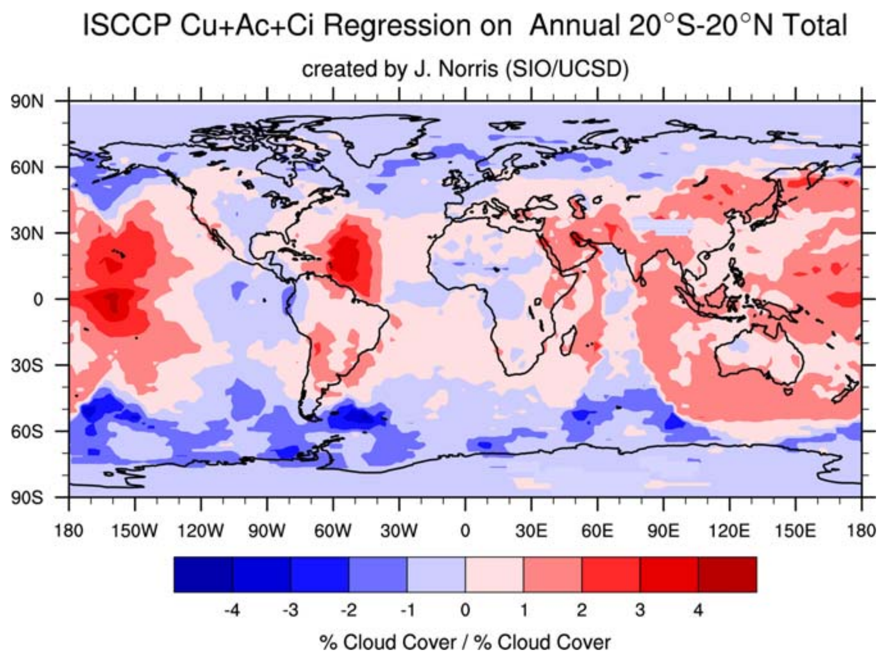
ISCCP Total Cloud Cover Trend

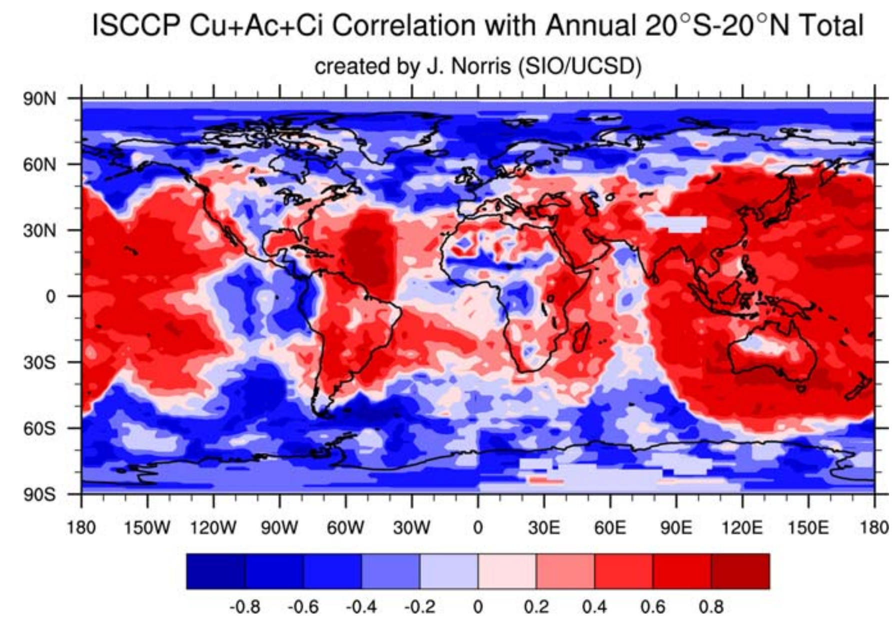




largest decreases at limbs of geostationary satellites

ISCCP Optically Thin Cloud Cover





trends in optically thin cloud cover primarily responsible for total cloud cover trend

cloud variability has substantial coherence within geostationary satellite footprints

Radiation Flux from ISCCP

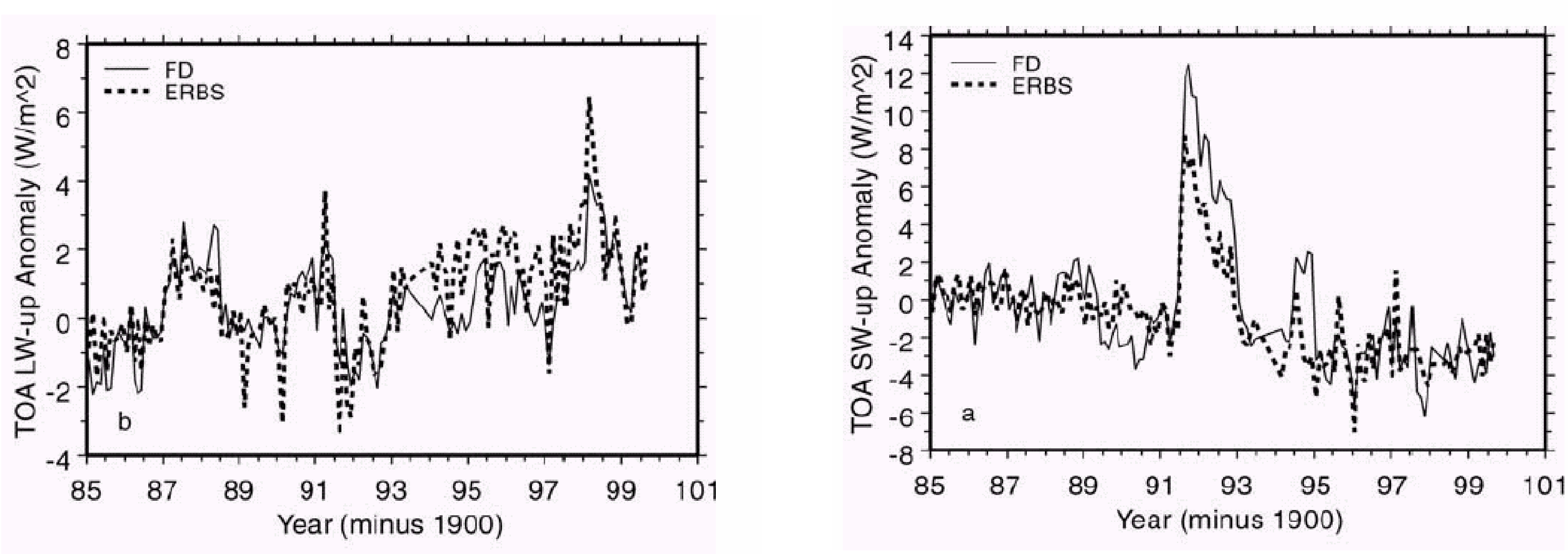


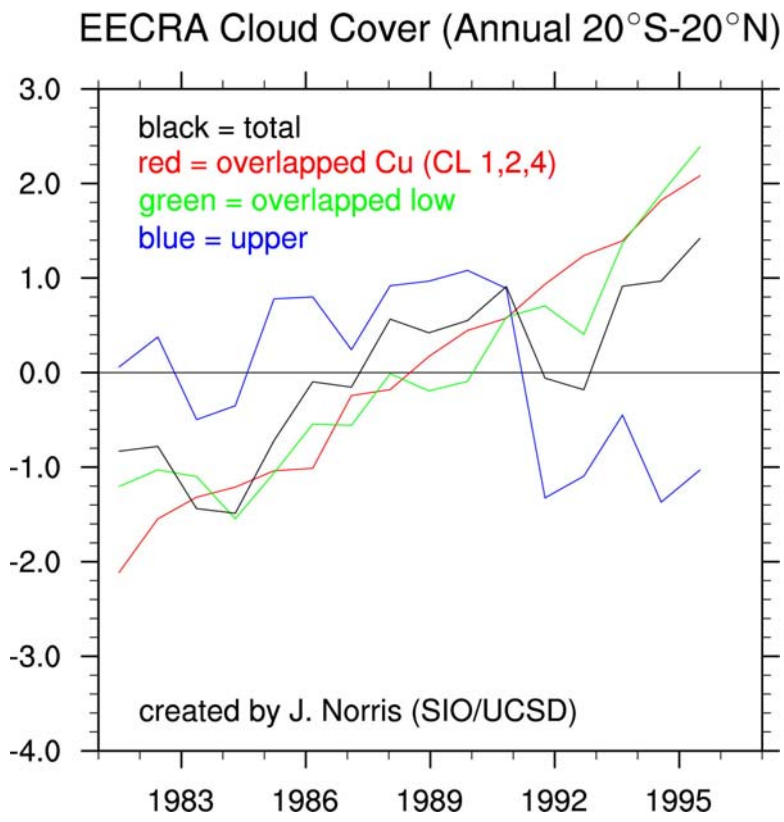
Figure 6. TOA flux anomaly time series for ISCCP-FD and ERBS for (a) $S\uparrow_t$, (b) $L\uparrow_t$ and (c) N_t. Values are 36-day averages for the zone, 20°S to 20°N, with mean seasonal cycle removed and the average for 1985–1989 set to zero. See comparison statistics in Table 7.

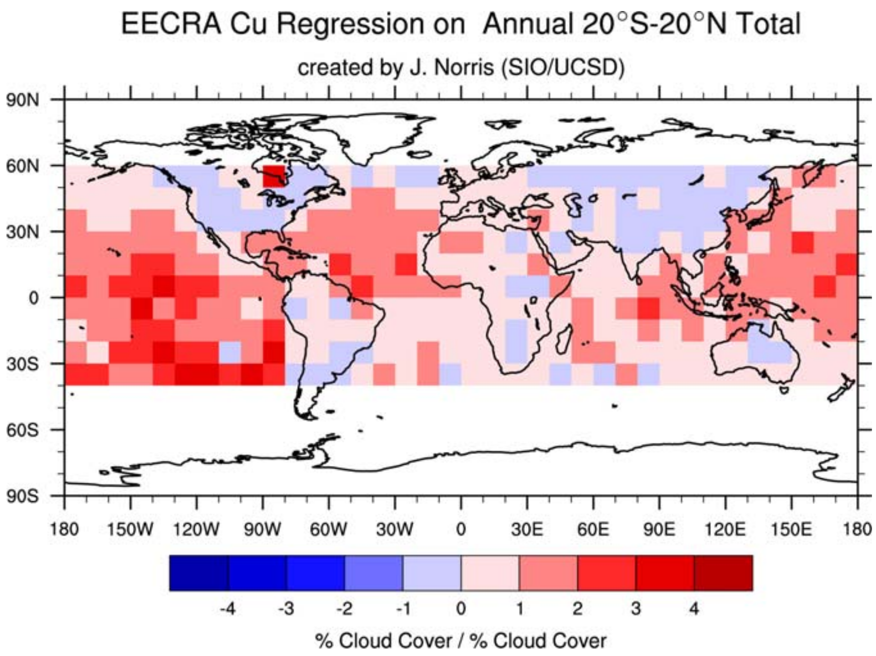
from Zhang et al. (JGR 2004)

ISCCP Artifacts vs. Agreement with ERBS

- artifacts occur for the optically thinnest clouds, i.e., those with least radiative impact
- a change in effective detection threshold could produce apparent variability in thin clouds
- satellite movement produces apparent variability due to ISCCP cloud overestimate at high viewing angles (G. Campbell, CIRA).
- calibration issue for footprint artifact?

Surface Total Cloud Cover Trend





increasing total cover primarily due to increasing cumulus

Artifacts in Surface Cloud Observations

- artifacts can result from unidentified changes in observing procedure or archival errors
- it is difficult to identify potential artifacts in ocean observations (ships travel everywhere)
- surface/satellite disagreement may result from different observing methods (especially for Cu)
- any low-level cloud artifact present in EECRA somehow does not affect the calculation of upper-level cover via random overlap

EECRA and ERBS can be Reconciled If…

- the albedo of low-level clouds reported by surface observers has decreased
- low cloud types with less than average albedo increased and types with more than average albedo have decreased
- cumulus seen by surface observers have grown “taller” but not “wider”
- absorbing aerosol has a substantial influence on ERBS RSW

Conclusions

- comparison of multiple datasets suggests observations of decadal variability/trends are reliable for many regions
- surface cloud observations corroborate 1985-1997 decadal tropical cloud/radiation change
- zonal mean upper-level cloud cover has decreased over land since 1971 and ocean since 1952
- ENSO-like upper cloud trend pattern over the Indo-Pacific since 1952

Future Work

- documentation of regional variability and trends in cloud cover and CCRF

- comparison with precipitation and surface radiation data

- investigation of potential artifacts in surface cloud data