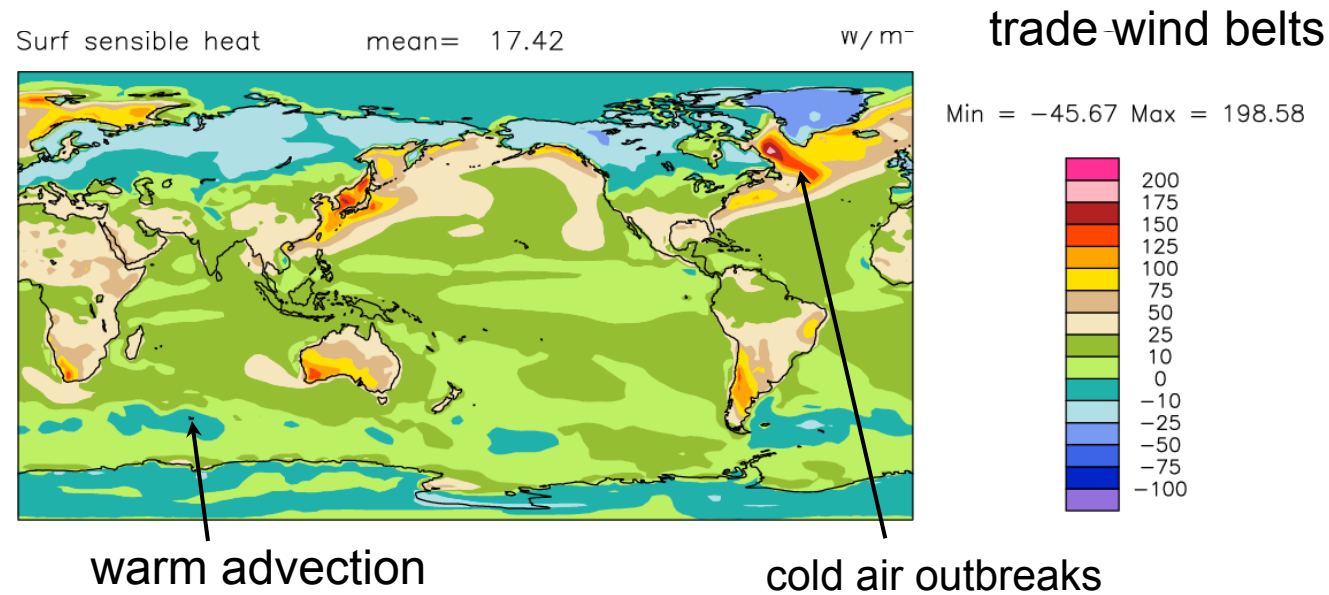
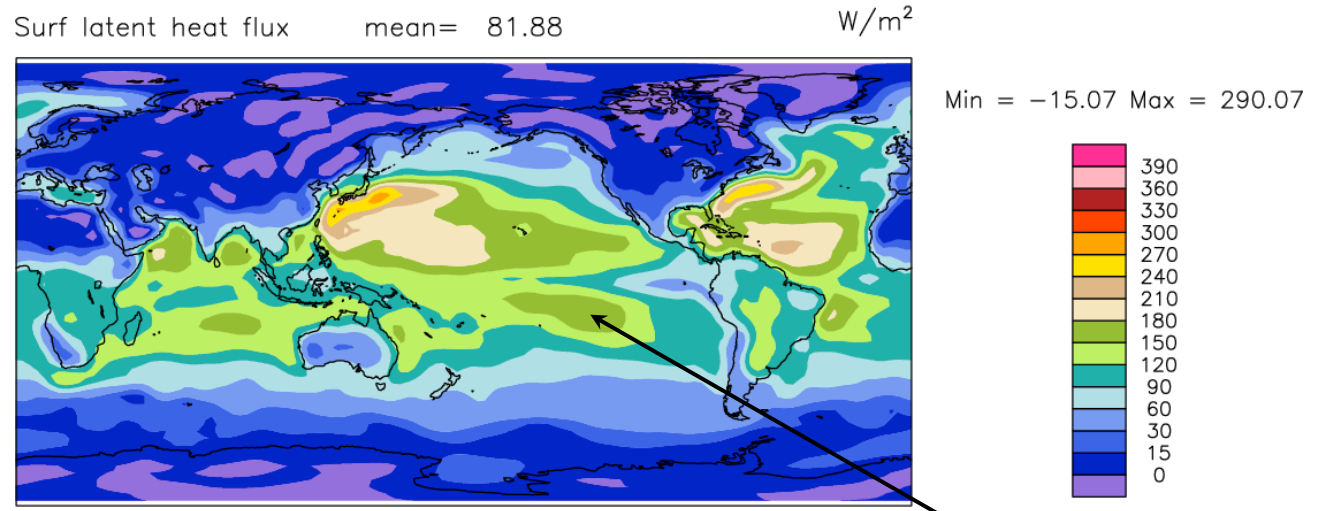
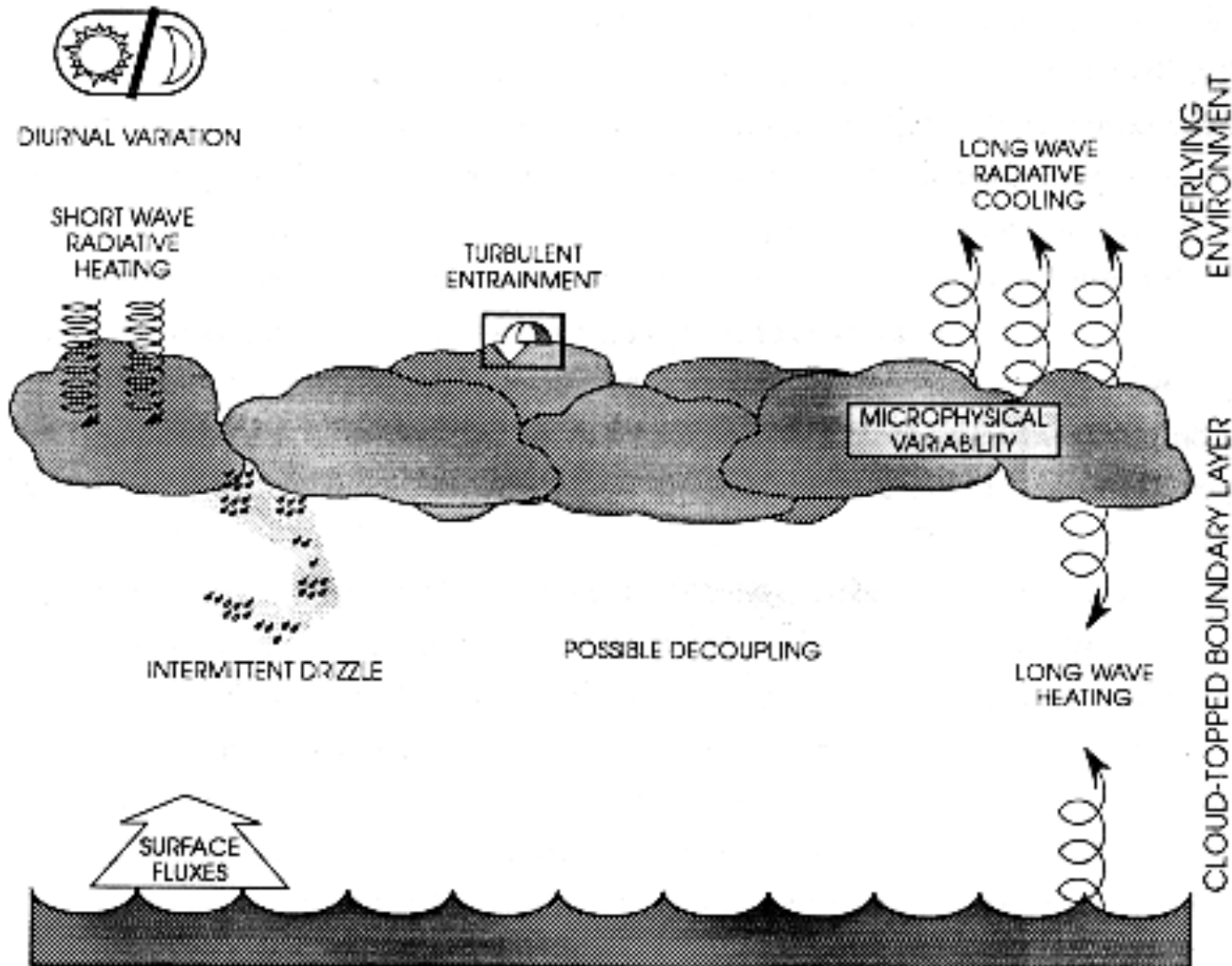


ERA40 surface fluxes (DJF)



Cloud-topped BL processes



Siems et al. 1993

Some marine boundary-layer cloud types

WMO cloud classification:

http://www.srh.noaa.gov/jetstream/synoptic/clouds_max.htm#max

Fractostratus



Stratus (St)



Stratocumulus (Sc)



Cu under Sc



Cumulus (Cu)



Cumulonimbus



Marine boundary layer clouds from space

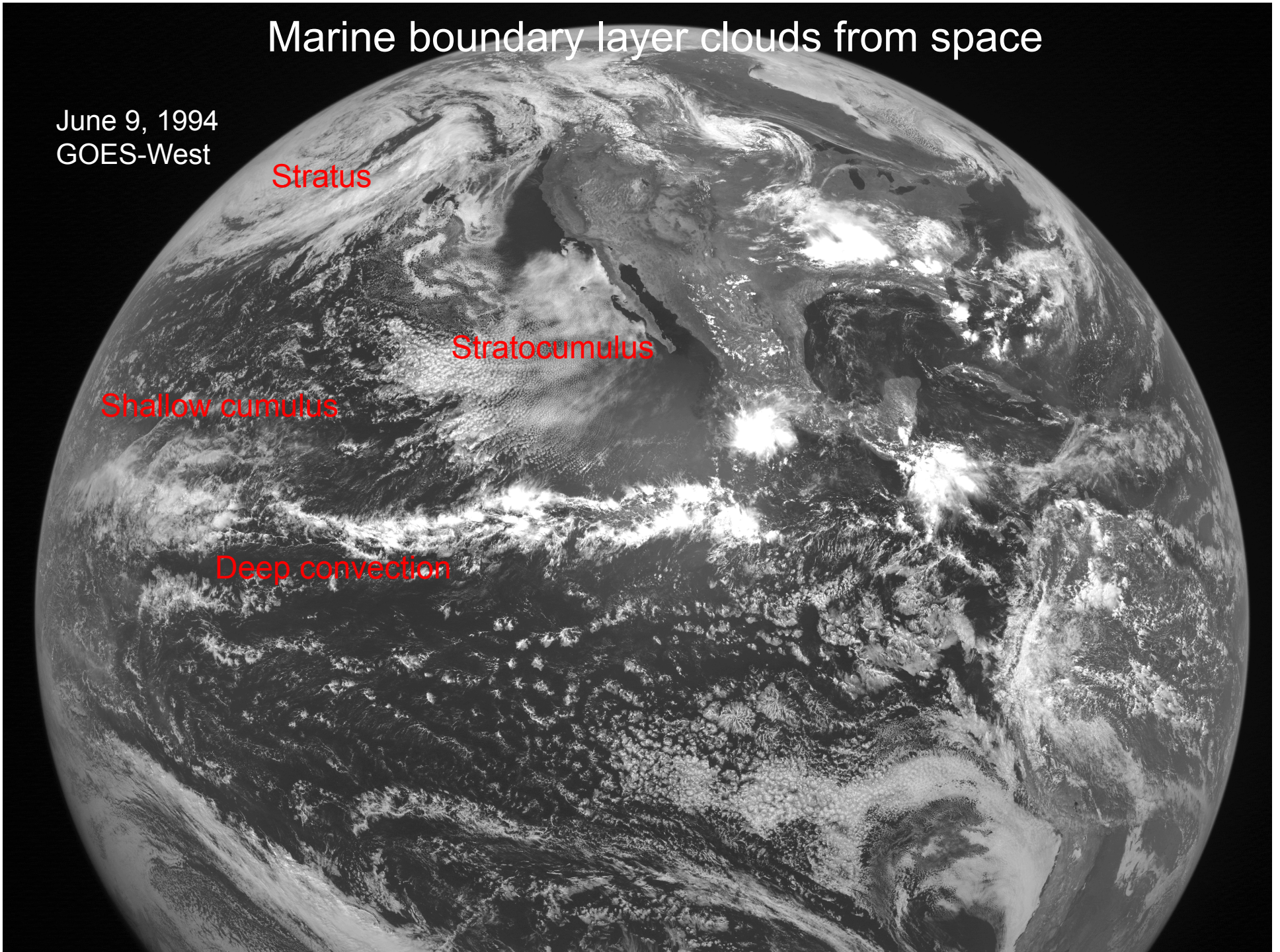
June 9, 1994
GOES-West

Stratus

Stratocumulus

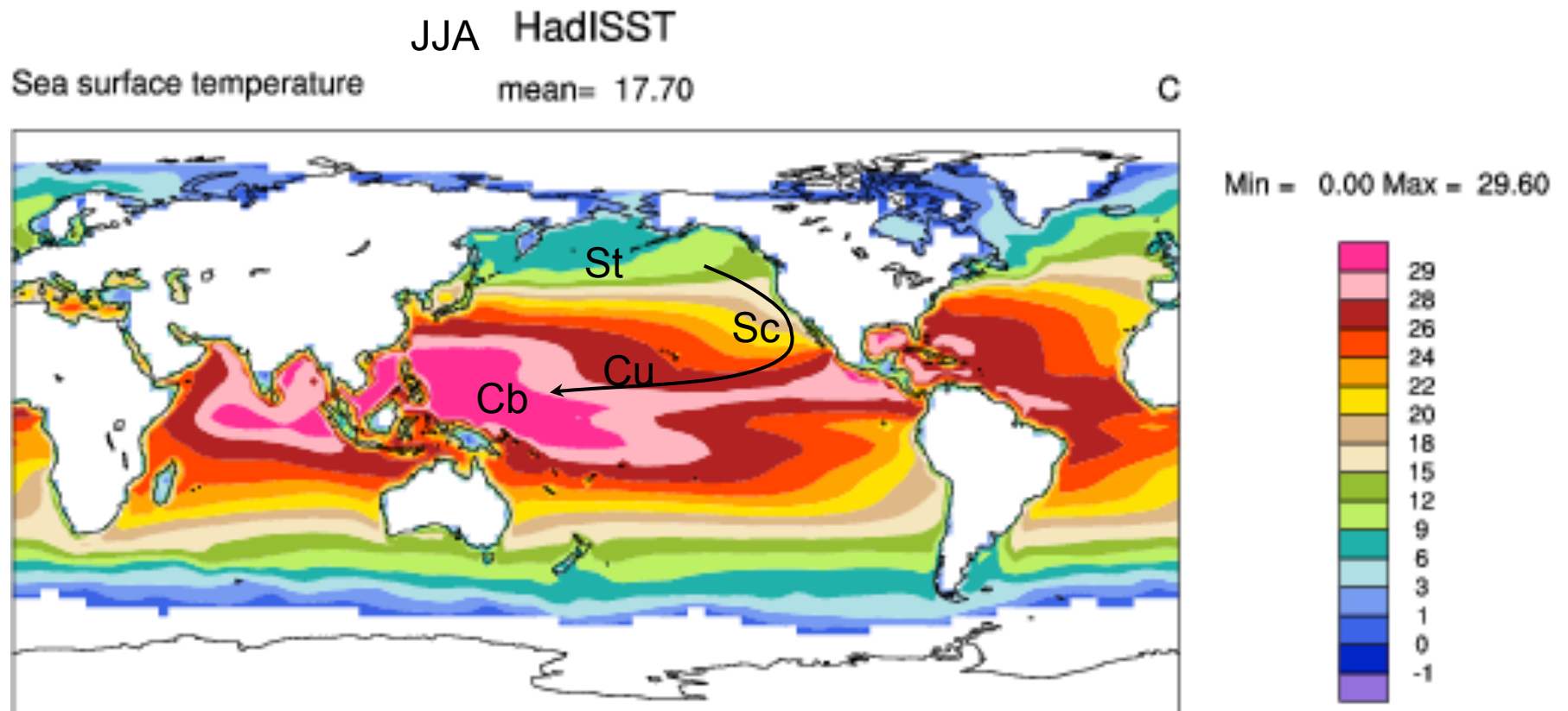
Shallow cumulus

Deep convection

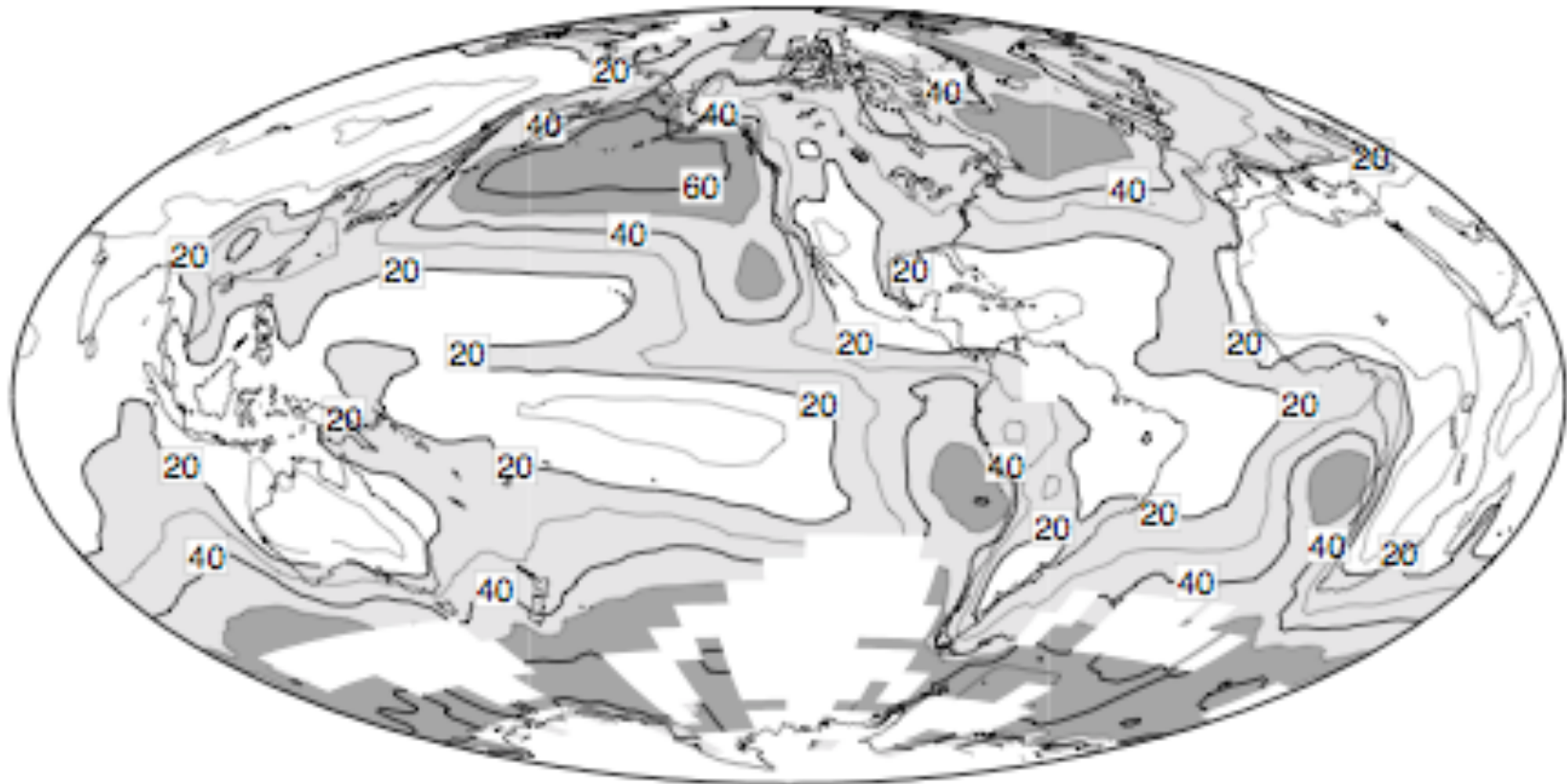


Observations over the oceans

- Transition from Sc - shallow Cu - deep Cu as temperature of sea-surface rises compared to that of mid-troposphere.



Annual Stratus Cloud Amount



Klein and Hartmann (1993), from surface observations

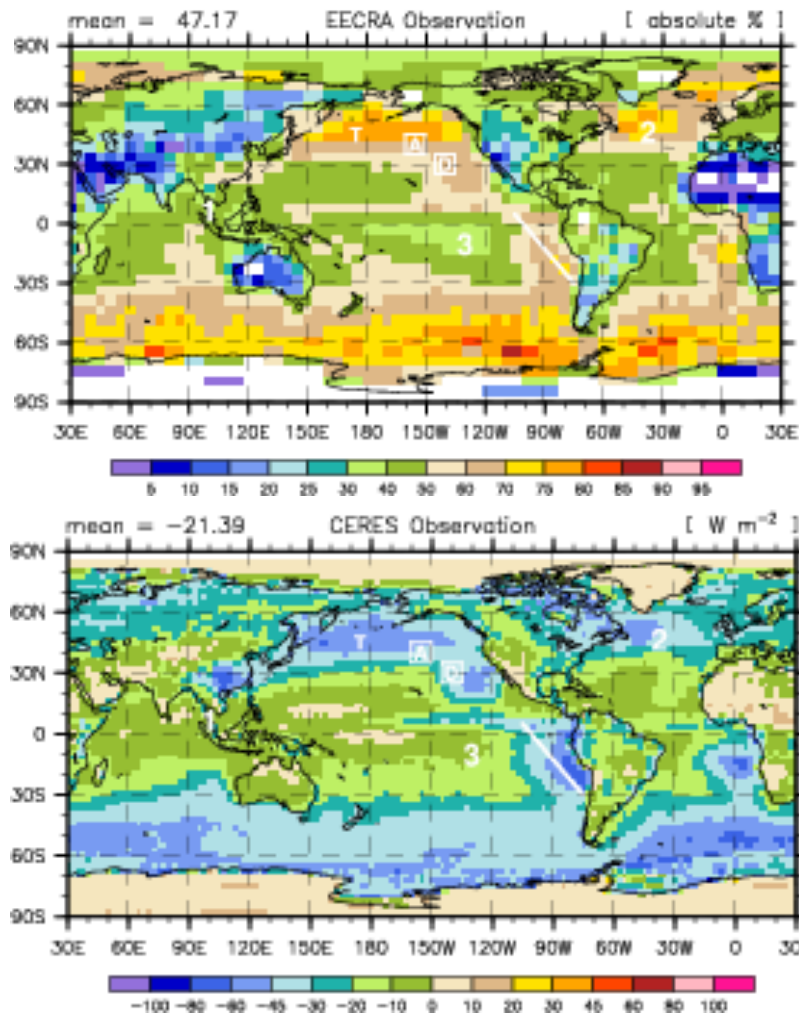
‘stratus’ = stratus + stratocumulus + fog

Boundary-layer cloud amount and cloud radiative effect

Low
cloud
amount
(%)

correlated
with...

Net CRE
[W m⁻²]



CRE = change in net
(shortwave+longwave)
radiation into TOA due to
clouds.

BL clouds reflect sunlight but
are too warm to much affect
outgoing longwave radiation,
producing a negative SWCRE
and little LWCRE, for negative
net CRE.

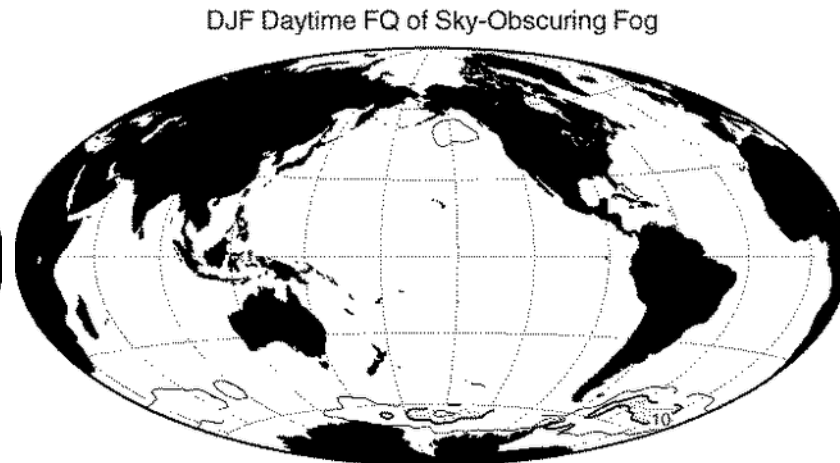
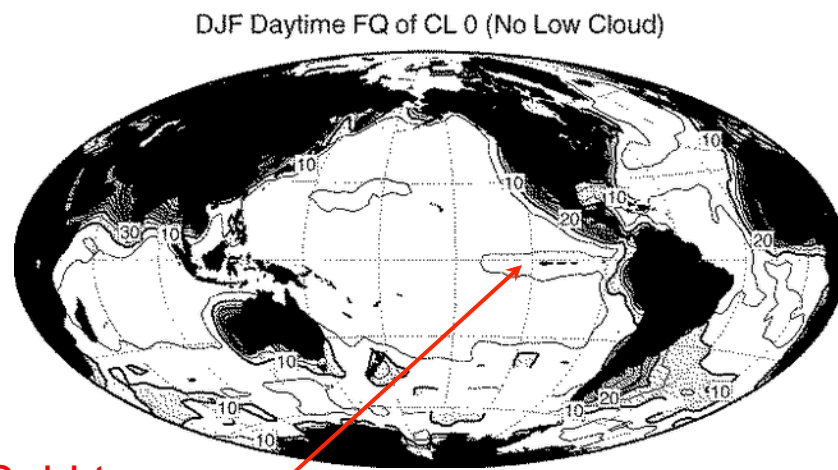
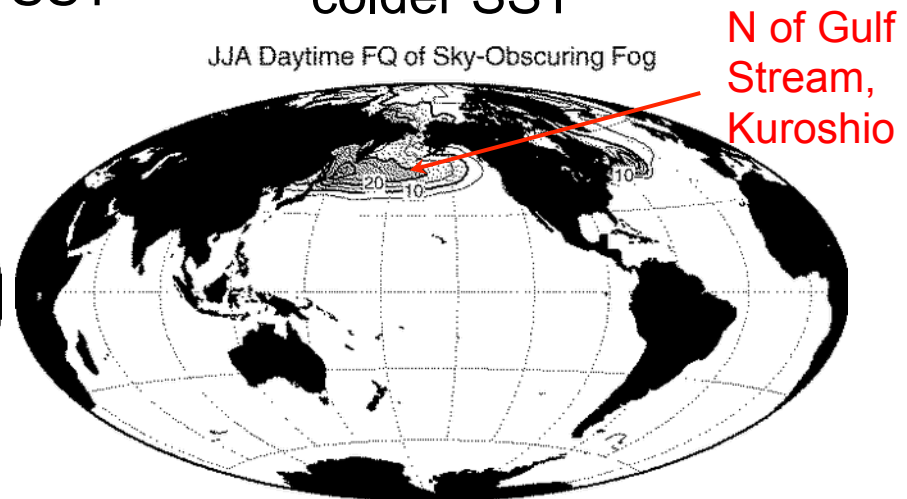
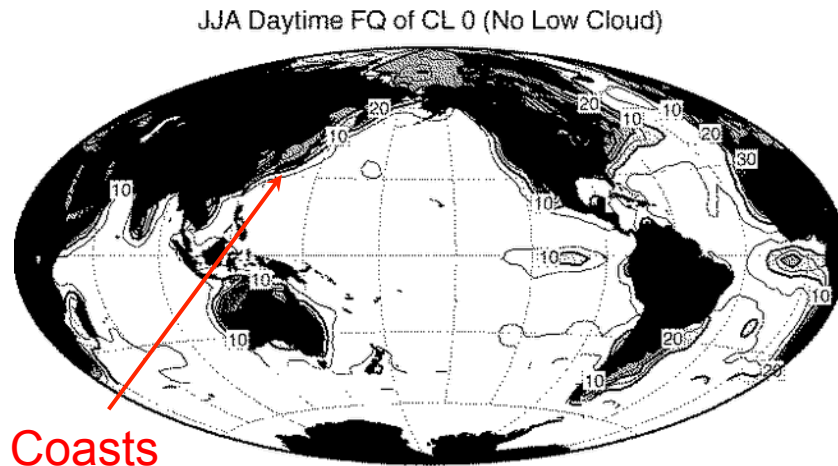
- Marine boundary-layer cloud is the most radiatively important cloud type for the current climate.

Warren surface cloud climatology

- <http://www.atmos.washington.edu/CloudMap>
- 45 years of routine ship observations

advection from warm land to cold SST

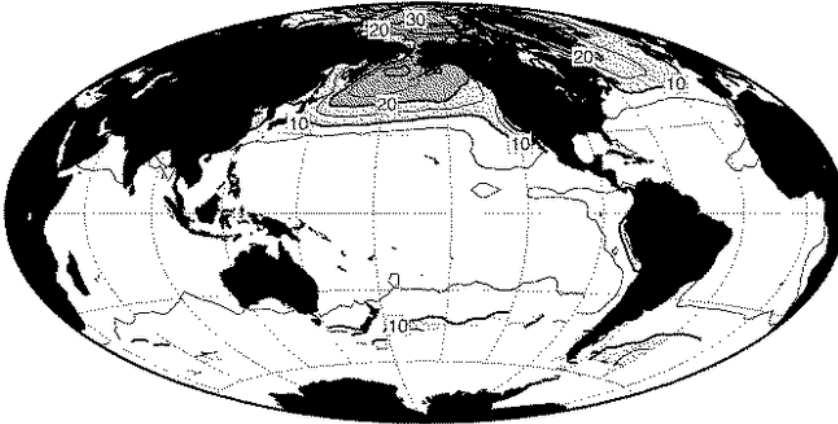
advection from warm to much colder SST



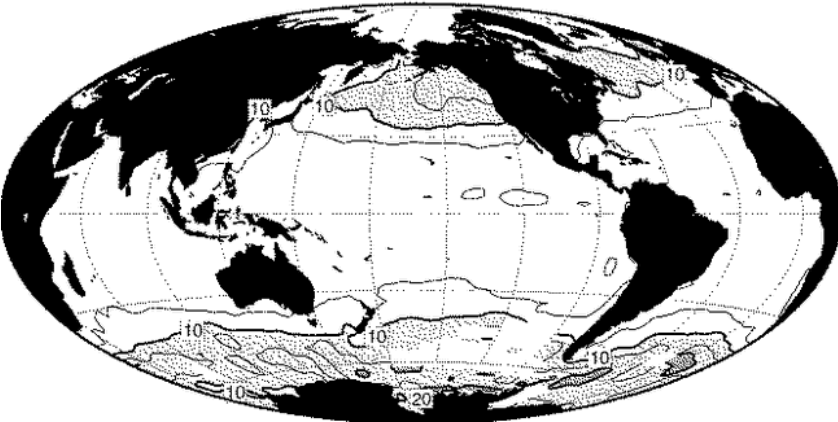
Cold-ocean MBL cloud types

Weak air-sea temperature differences

JJA Daytime FQ of CL 6 (Fair-Weather Stratus)

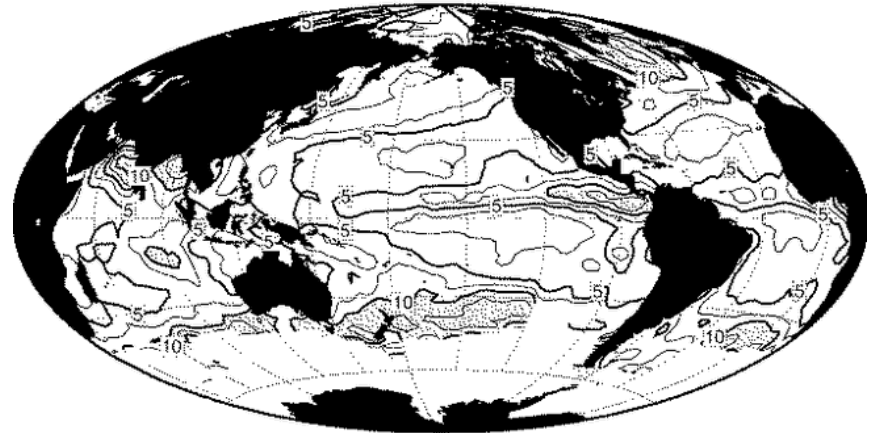


DJF Daytime FQ of CL 6 (Fair-Weather Stratus)

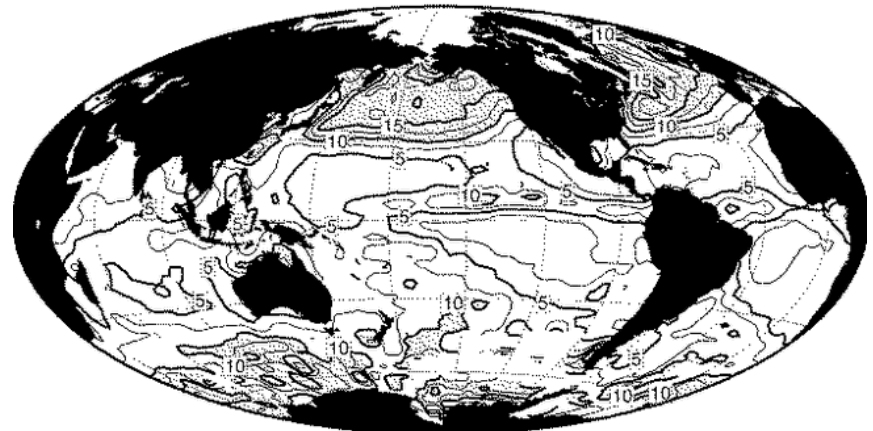


Deep storm systems

JJA Daytime FQ of CL 7 (Bad-Weather Stratus)



DJF Daytime FQ of CL 7 (Bad-Weather Stratus)

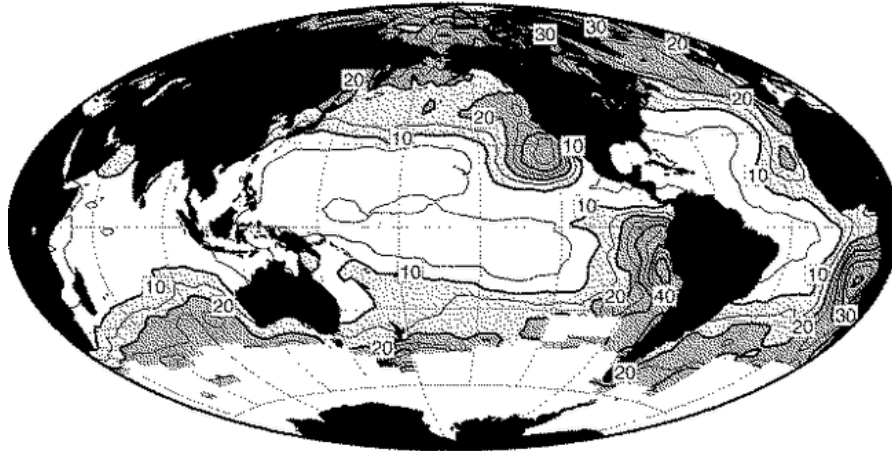


Norris et al. (1998, *J Climate*)

Cool-ocean MBL cloud types

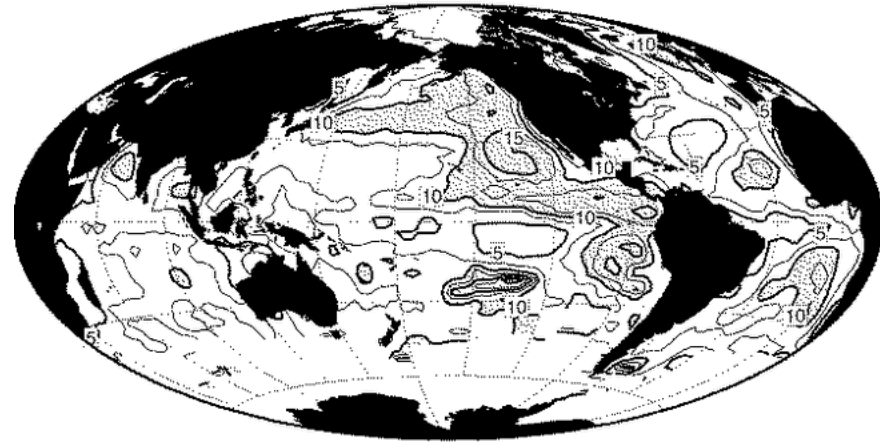
Cold advection, cool SST

JJA Daytime FQ of CL 5 (Ordinary Stratocumulus)

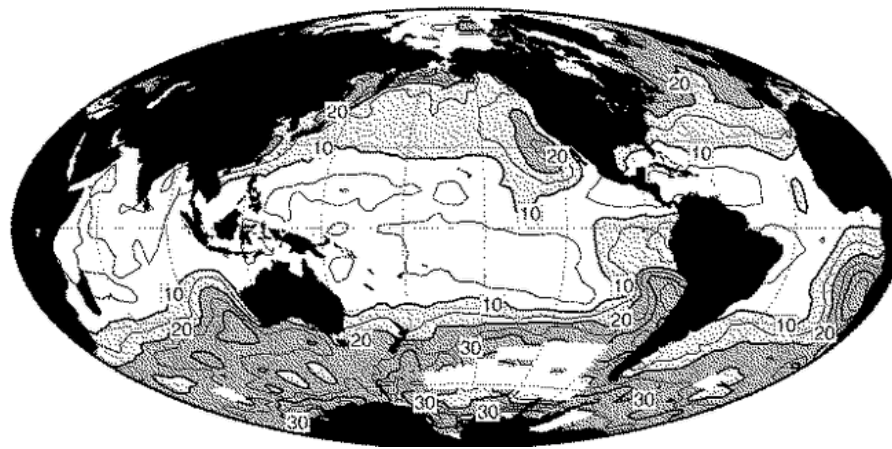


Cold advection, medium SST

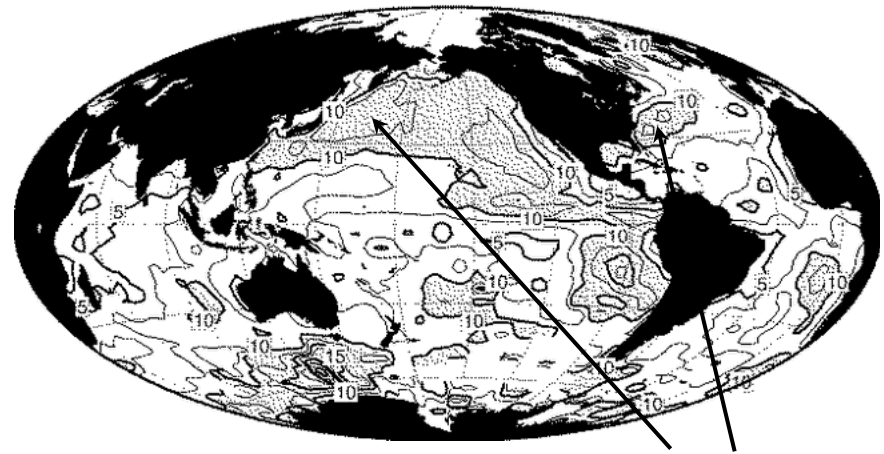
JJA Daytime FQ of CL 8 (Cumulus under Stratocumulus)



DJF Daytime FQ of CL 5 (Ordinary Stratocumulus)



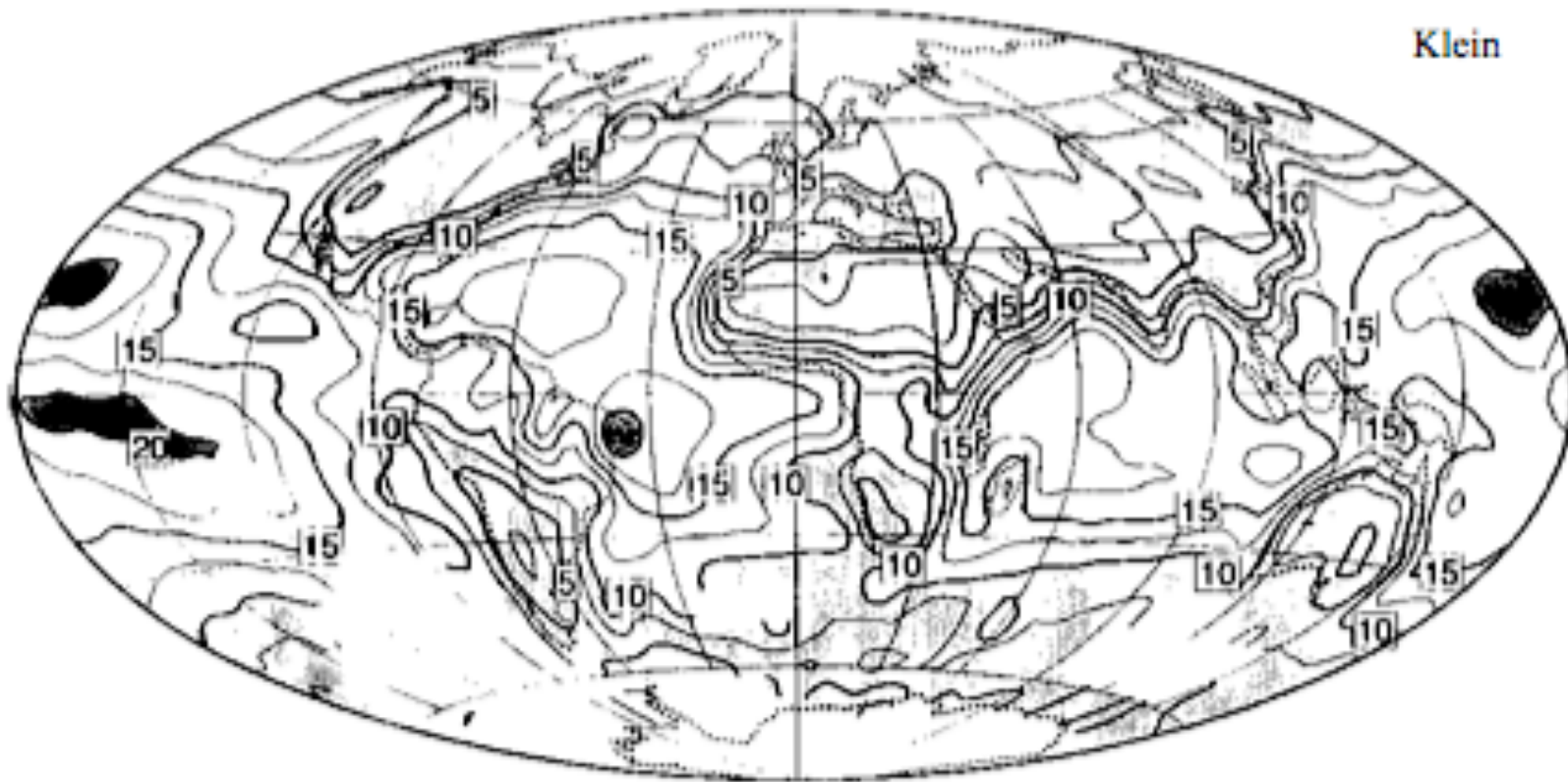
DJF Daytime FQ of CL 8 (Cumulus under Stratocumulus)



Cumulus Cloud Amount

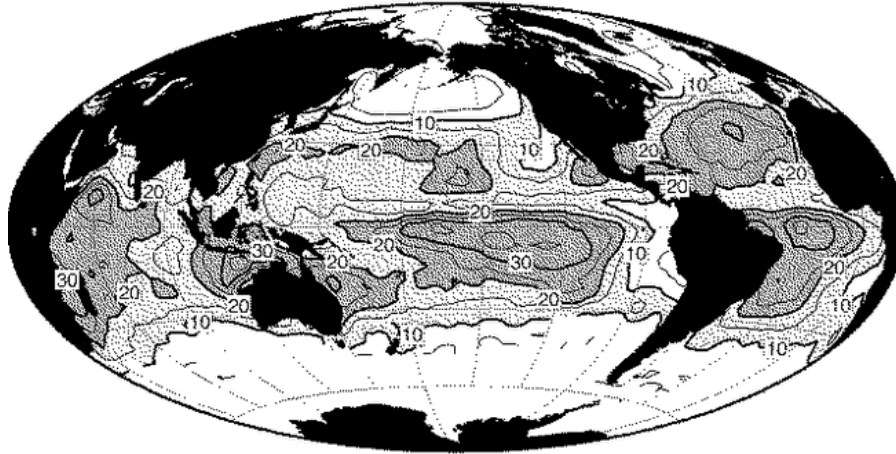
cumann.2

Klein

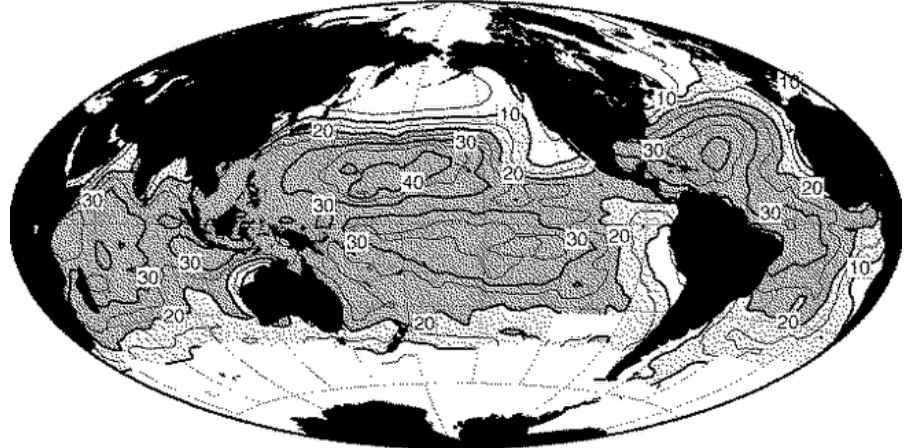


Cumulus-topped MBLs

JJA Daytime FQ of CL 1 (Small Cumulus)

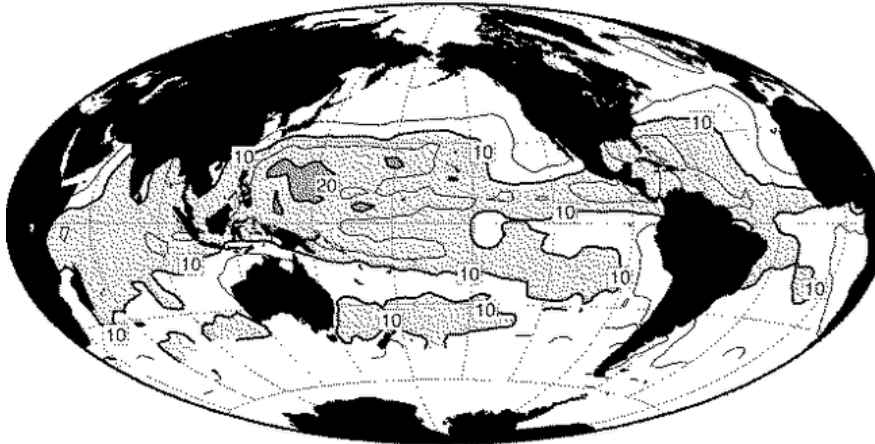


JJA Daytime FQ of CL 2 (Moderate and Large Cumulus)

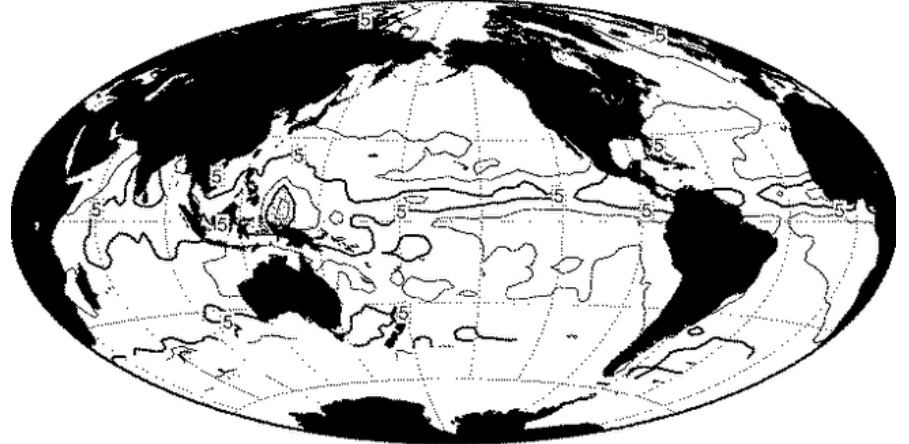


Norris et al. (1998, *J Climate*)

JJA Daytime FQ of CL 3 (Cumulonimbus without Anvil)

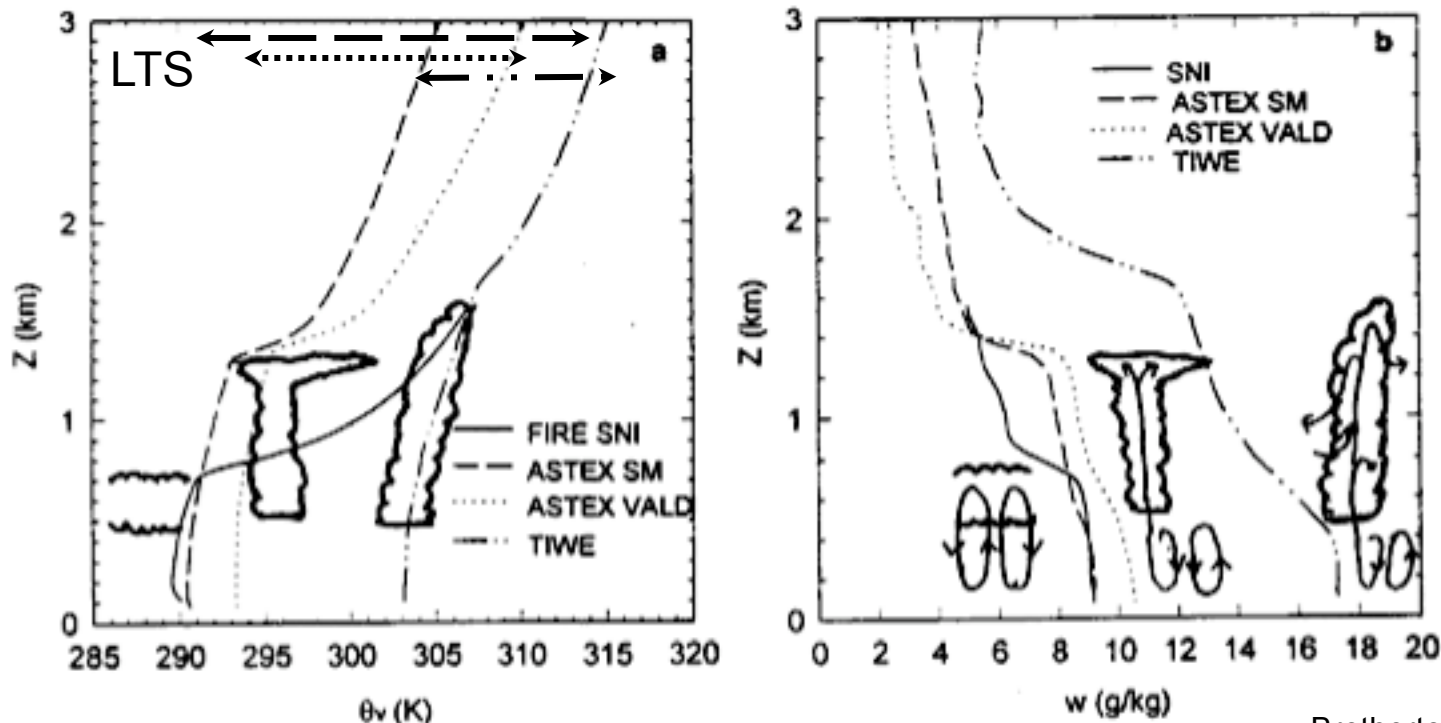


JJA Daytime FQ of CL 9 (Cumulonimbus with Anvil)



Over warm oceans, Cu-topped MBLs > 70% of time.

Subtropical PBL soundings



Bretherton 1997,
after Albrecht et al. 1995

Figure 3. Composite soundings of (a) θ_v and (b) q_t from four CTBL experiments from Albrecht et al. (1995). Sketches of the typical boundary layer cloud structure observed in (left to right) FIRE (July 1987, 33 N, 120 W, SST = 289 K, Cloud Fraction = 0.83), ASTEX (June 1992, SM: 37 N, 25 W, SST = 291 K, CF = 0.67; VALD: 28 N, 24 W, SST = 294 K, CF = 0.40), and TIWE (December 1991, 0 N, 140 W, SST = 300 K, CF = 0.26) are overlaid. In (b), the air motions that accompany the clouds are also sketched.

- Sc and St clouds favored by strong, low inversions, which go with large lower tropospheric stability.

Measures of lower-tropospheric stratification

Lower tropospheric stability (Klein&Hartmann 1993)

$$LTS = \theta_{700} - \theta_{1000}$$

Estimated Inversion Strength (Wood&Breth 2006)

$$EIS = LTS - \Gamma_{ma,850}(z_{700} - z_{LCL})$$

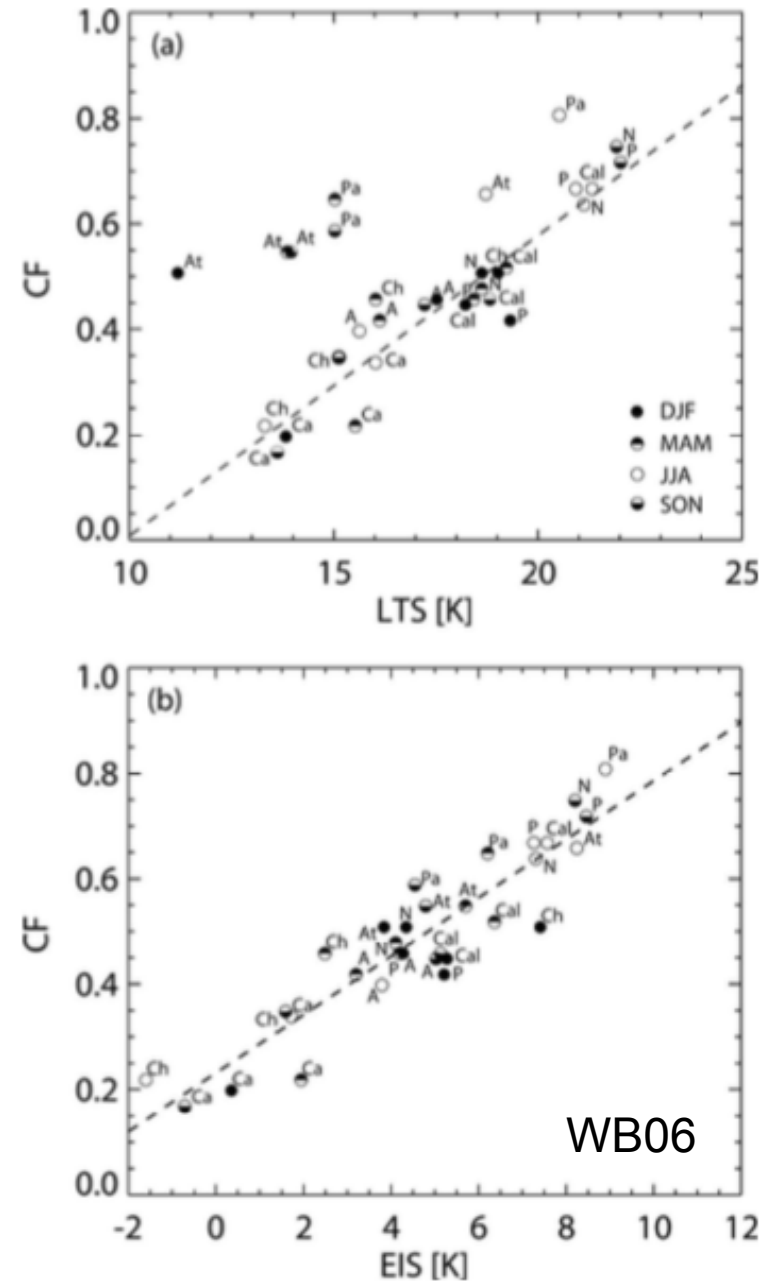
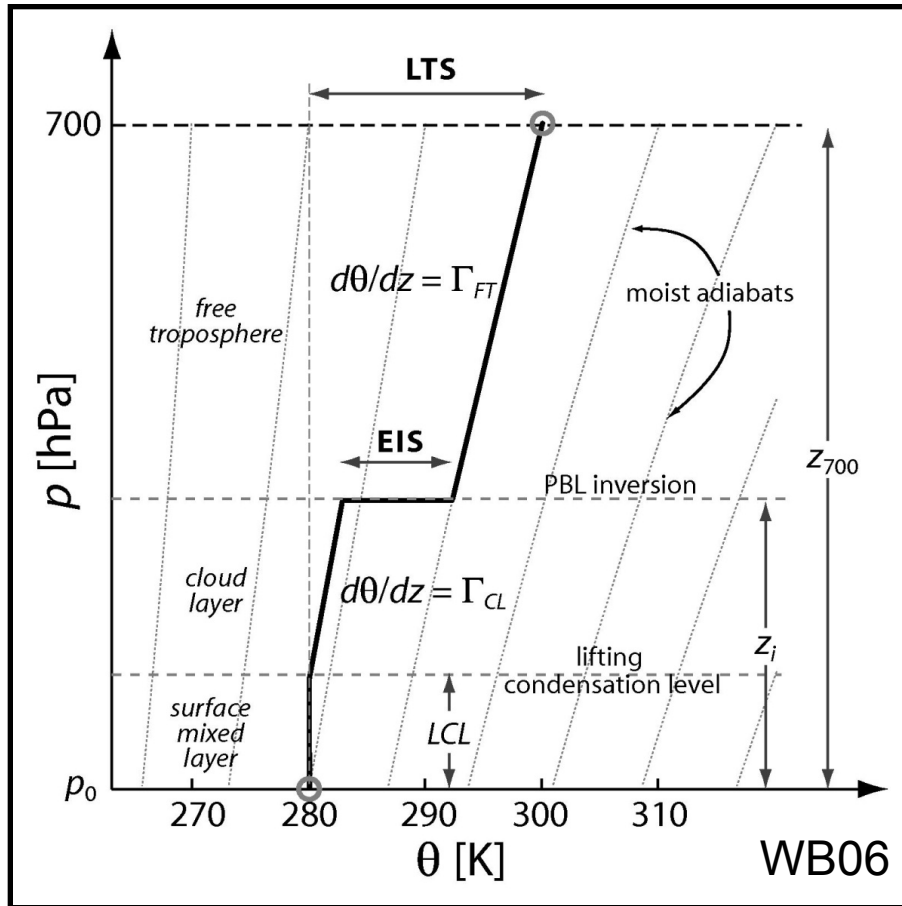
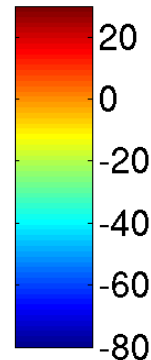
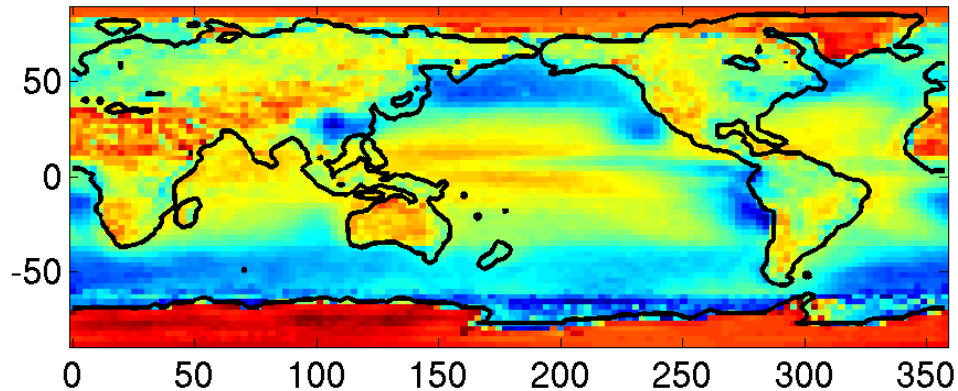


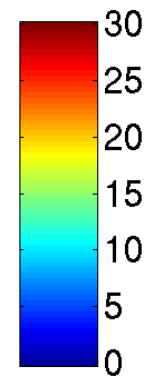
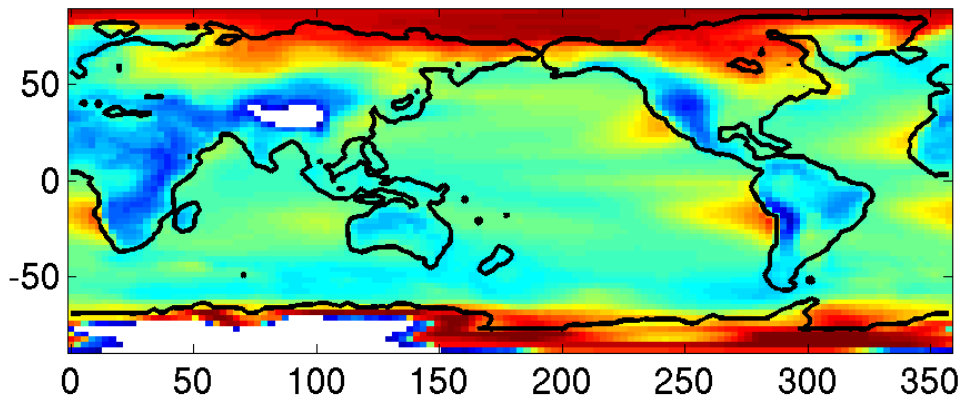
FIG. 6. Relationship between (a) LTS and low cloud amount, and (b) EIS and low cloud amount, for seasonal means at the locations described in Table 1. All seasons/regions where LTS > 10 K are plotted.

ERBE Net Cloud Forcing, W/m^2



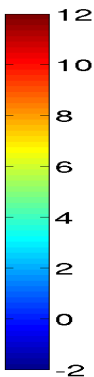
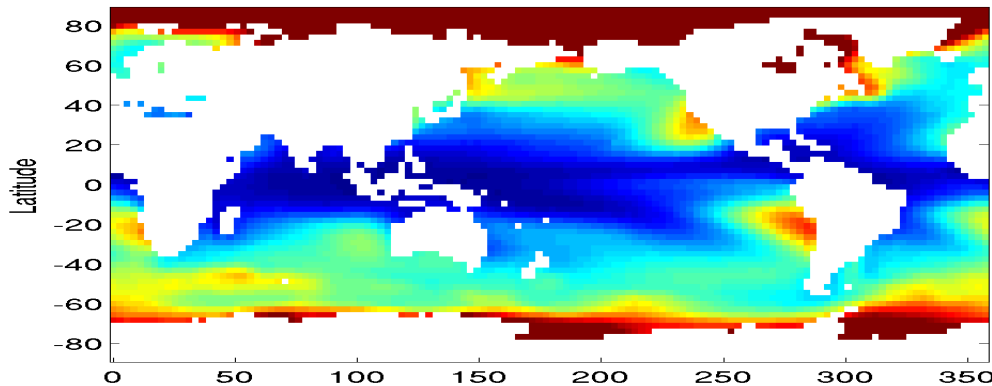
EIS correlated to low cloud everywhere, LTS correlated to low cloud in low latitudes

LTS, K



Lower tropospheric stability correlated with low-latitude marine low cloud (Klein and Hartmann 1993)

ERA-40 EIS



EIS also captures midlat BL cloud underlying a cooler free troposphere: EIS is a more 'temperature-invariant' predictor of low cloud response to stratification change.