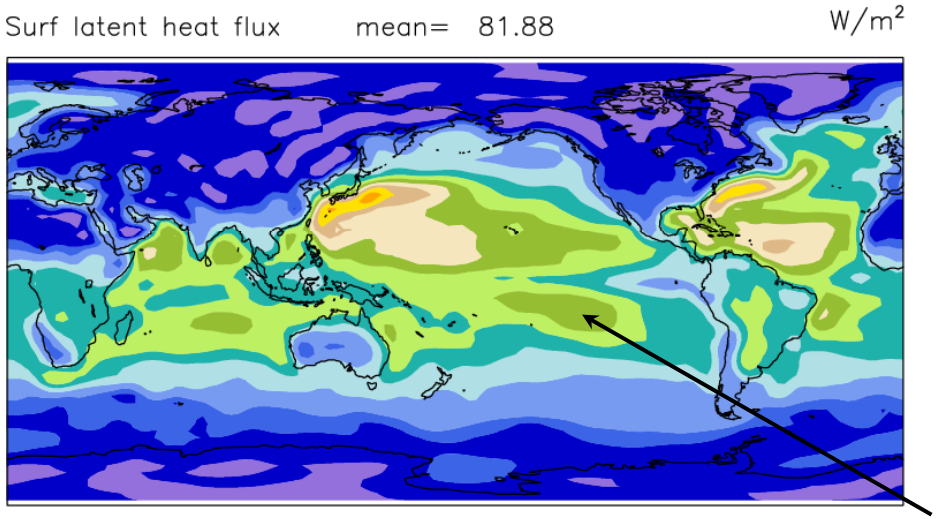
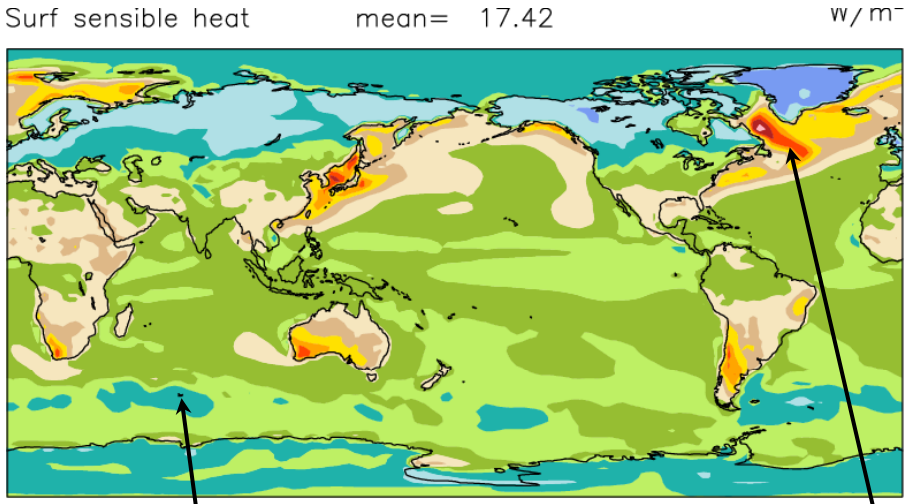
Surface fluxes (DJF)



trade-wind belts



warm advection

cold air outbreaks

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)

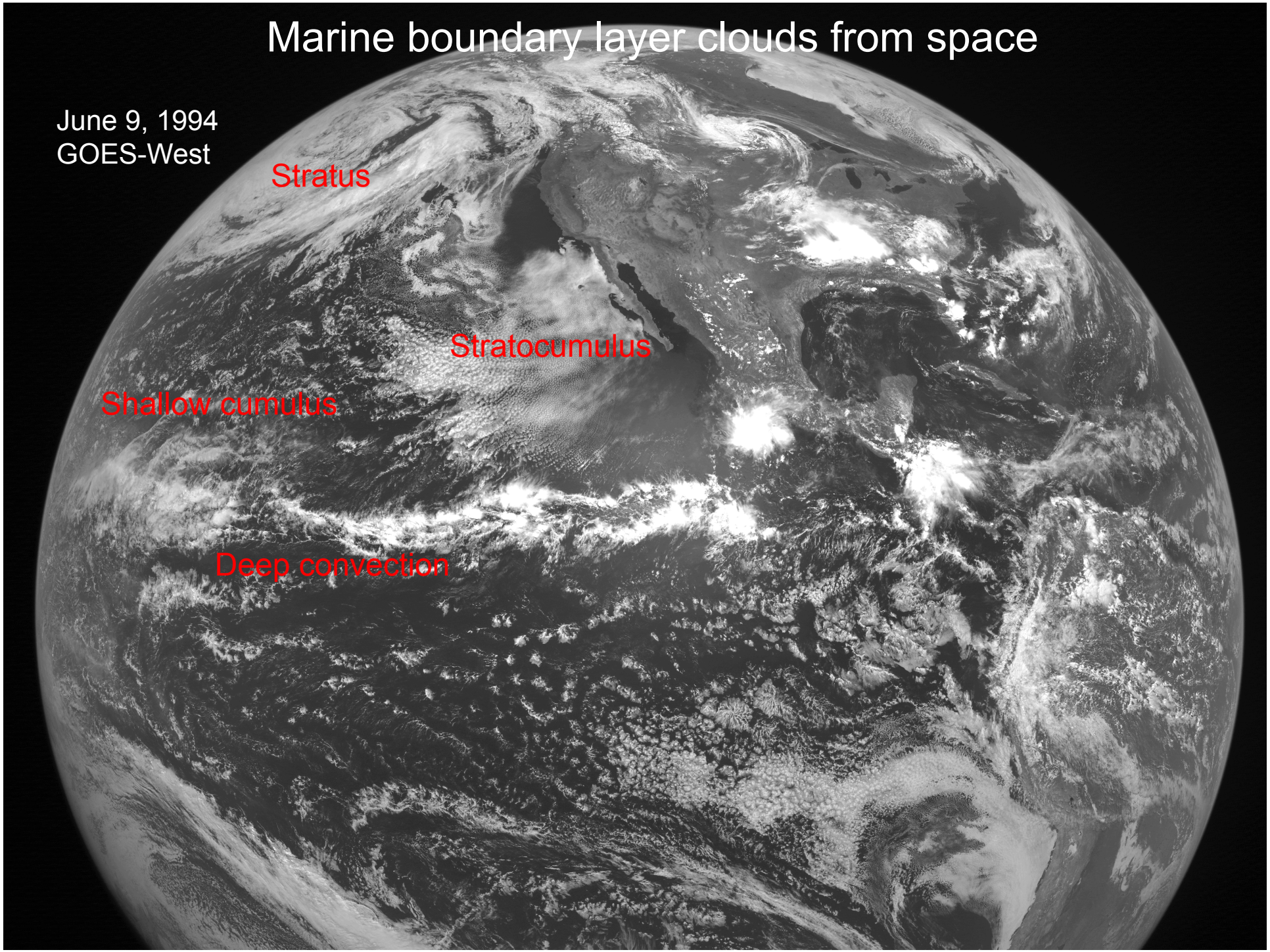
Cu under Sc

Cumulus (Cu)

Cumulonimbus

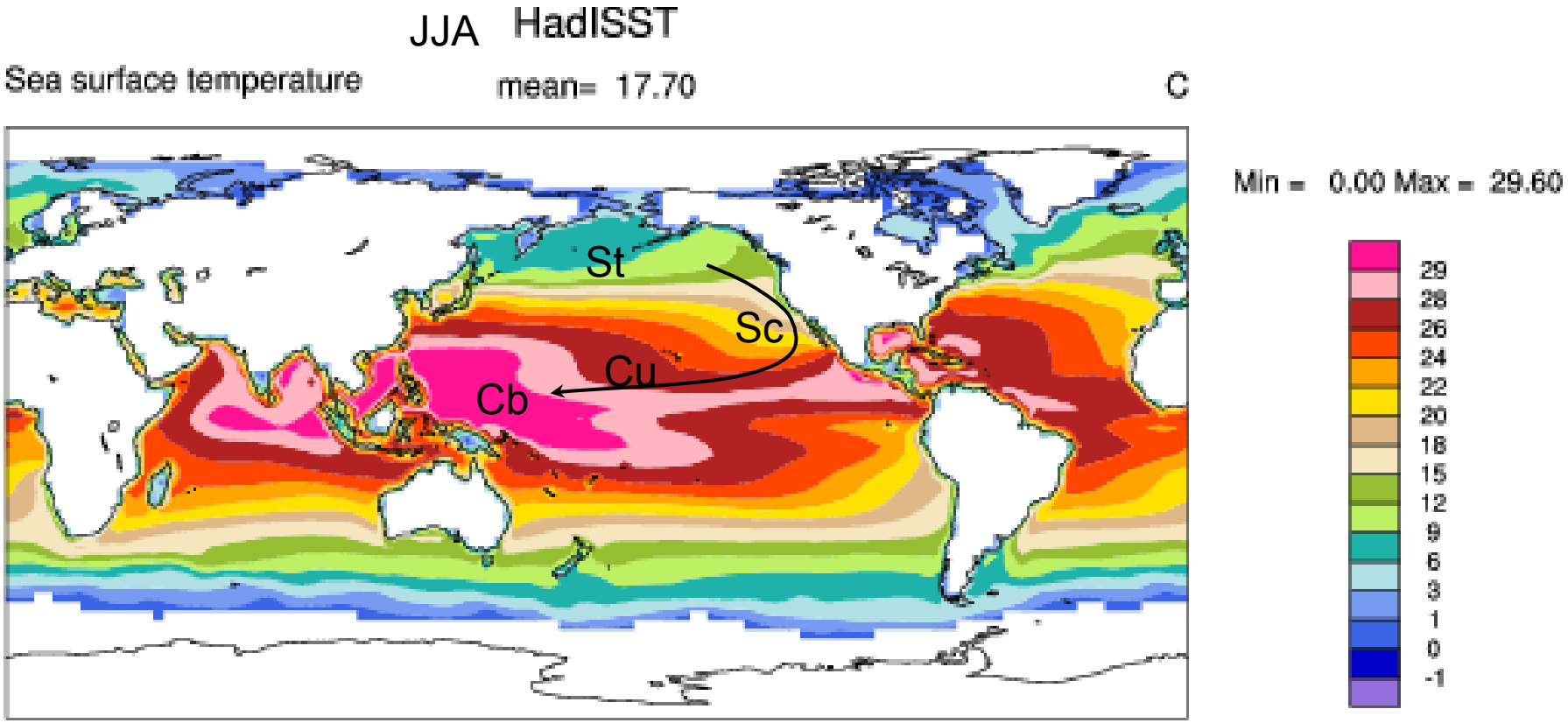
MBL Lecture 1, Slide 2

ARM Image Library


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.

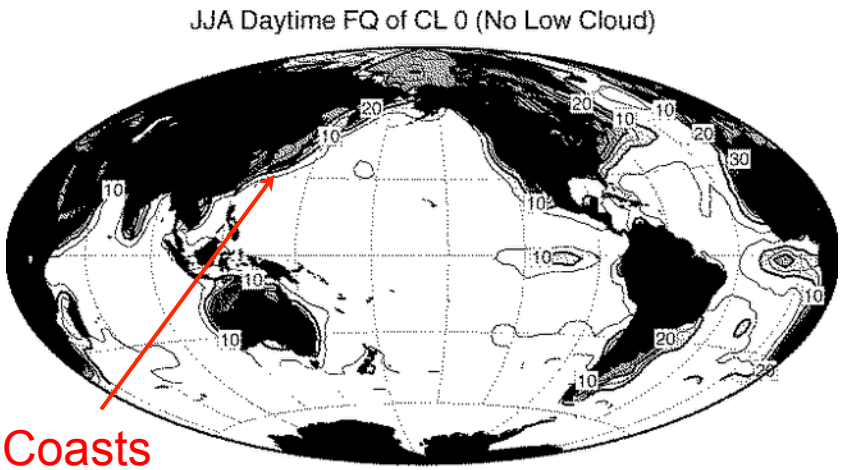


Warren surface cloud climatology

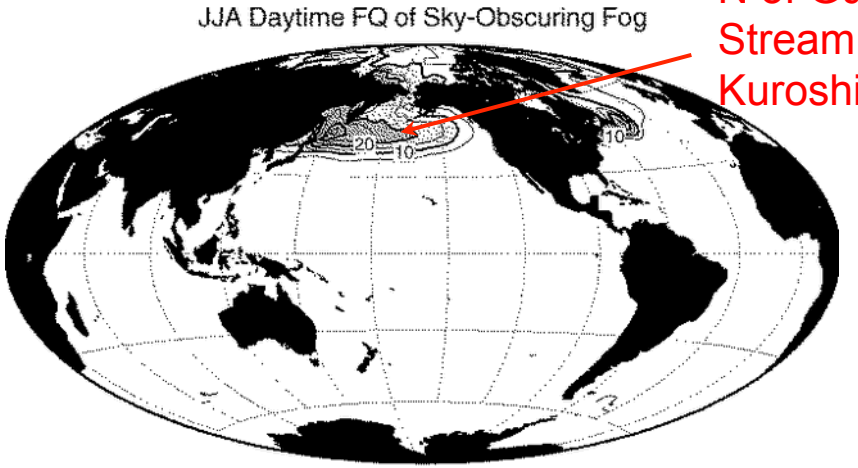
- http://www.atmos.washington.edu/CloudMap
- 45 years of routine ship observations

advection from warm land to cold SST

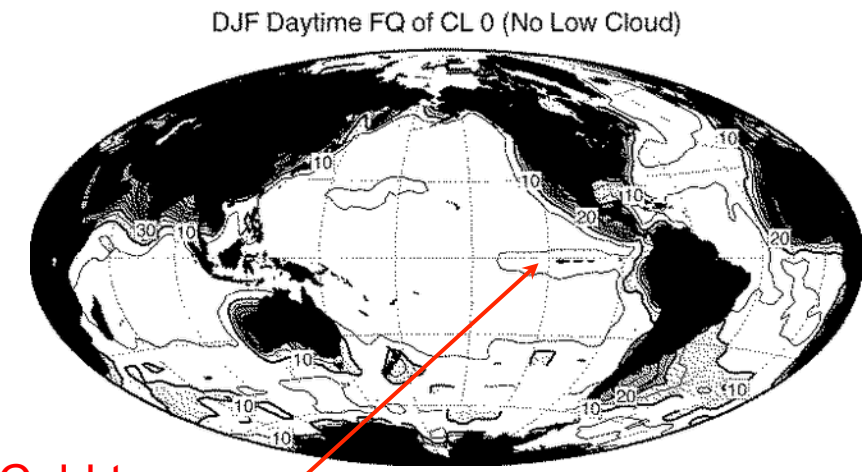
advection from warm to much colder SST



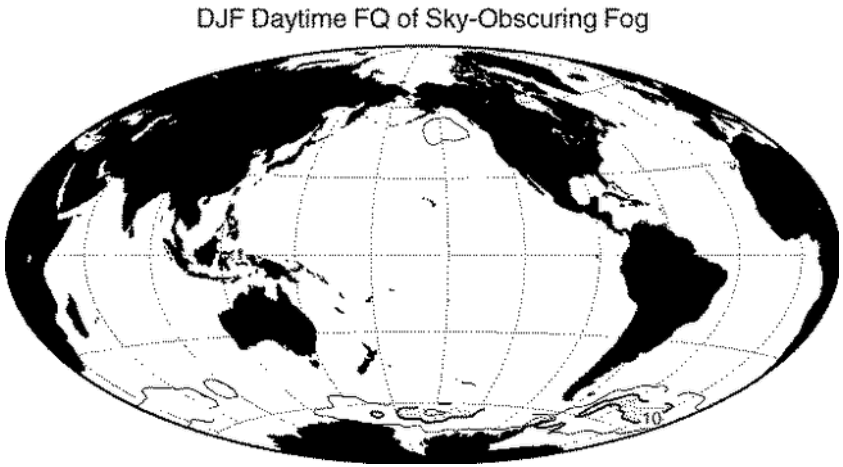
Coasts



N of Gulf Stream, Kuroshio



Cold tongue

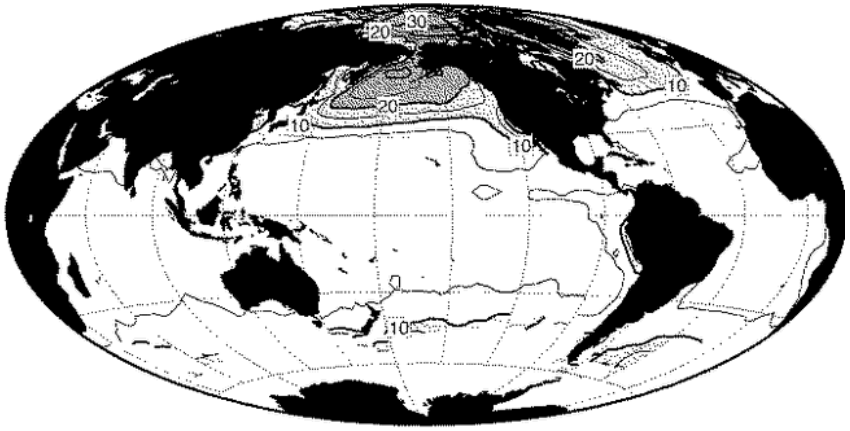


Norris et al. (1998, *J Climate*)

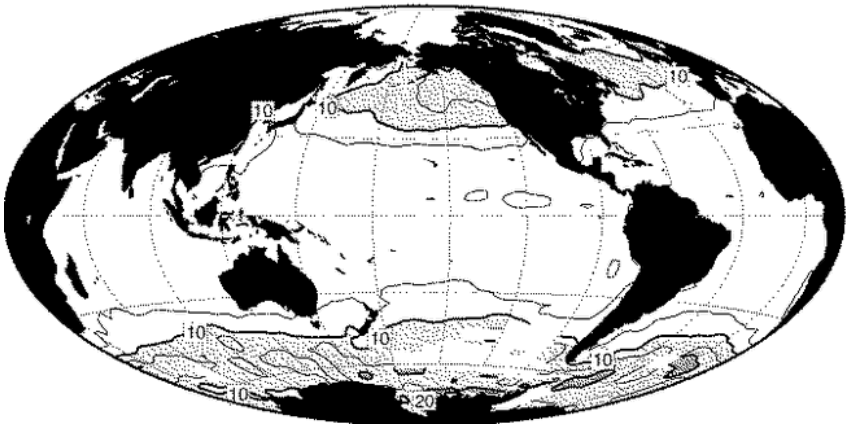
Cold-ocean MBL cloud types

Weak air-sea temperature differences

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

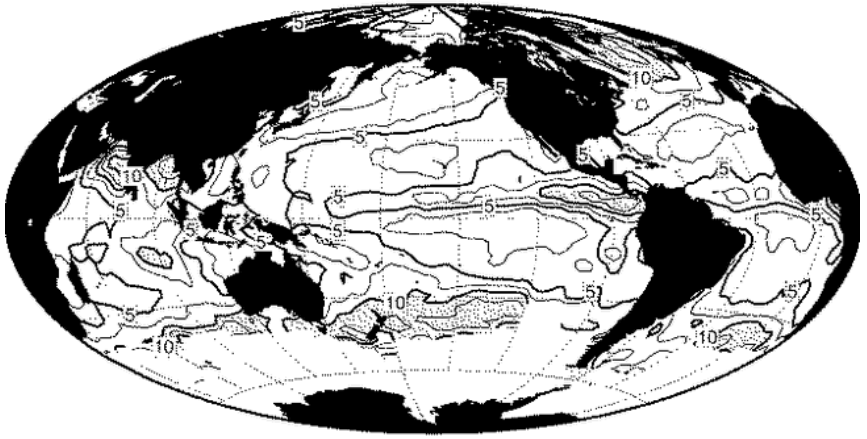


DJF Daytime FQ of CL 6 (Fair-Weather Stratus)

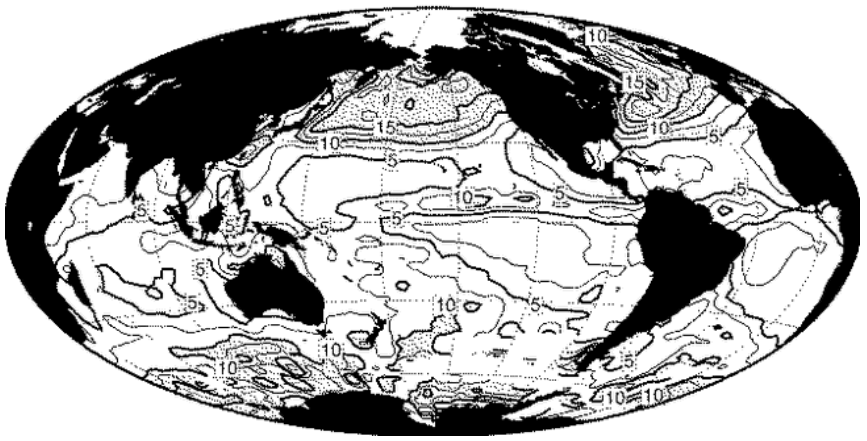


Deep storm systems

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



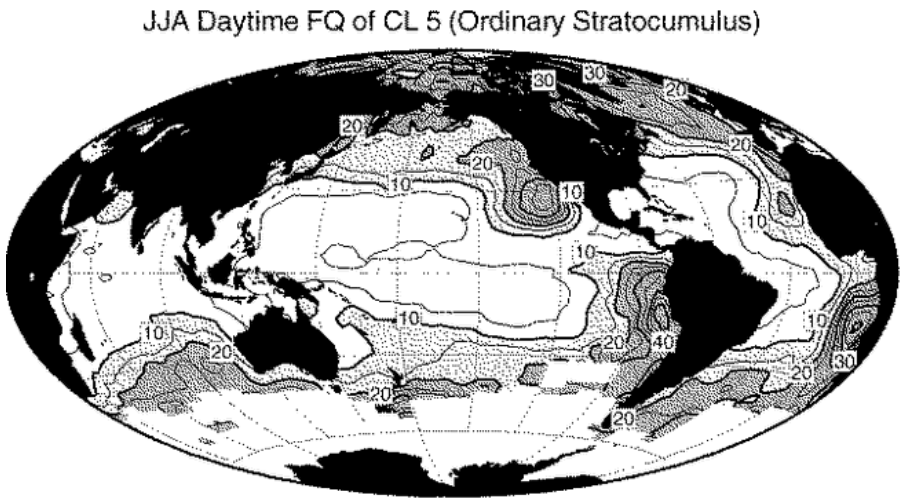
DJF Daytime FQ of CL 7 (Bad-Weather Stratus)

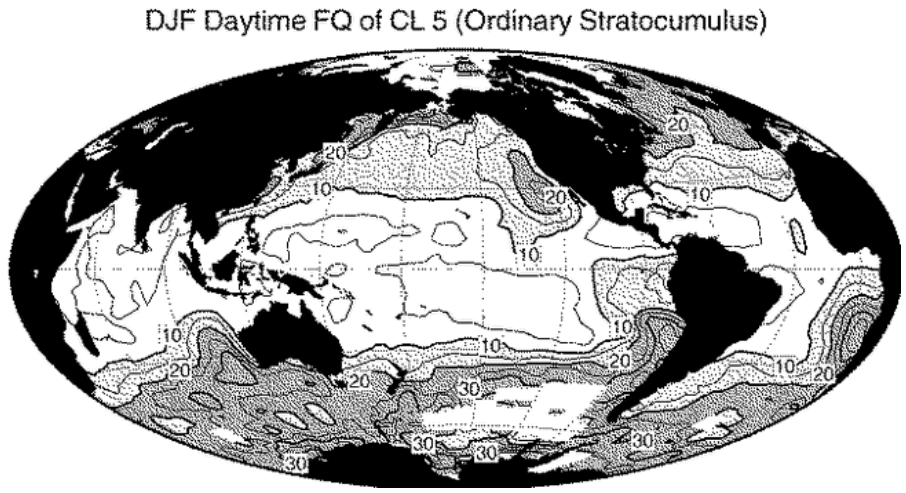


Norris et al. (1998, *J Climate*)

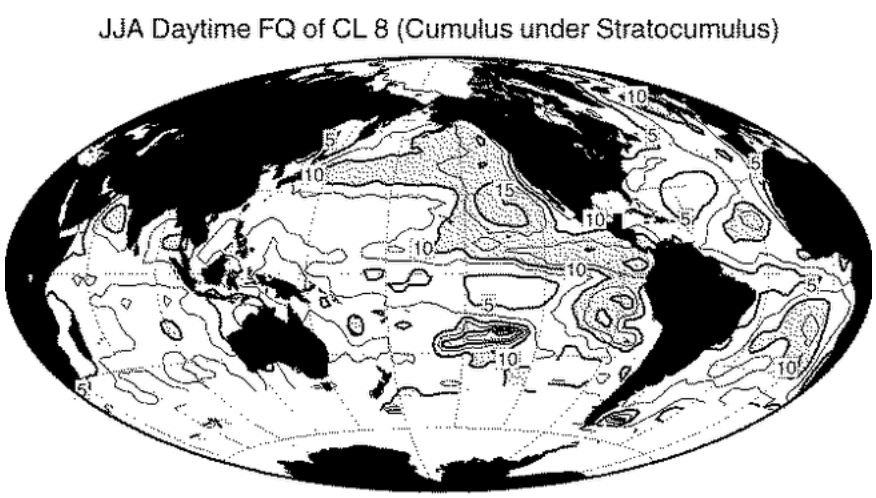
Cool-ocean MBL cloud types

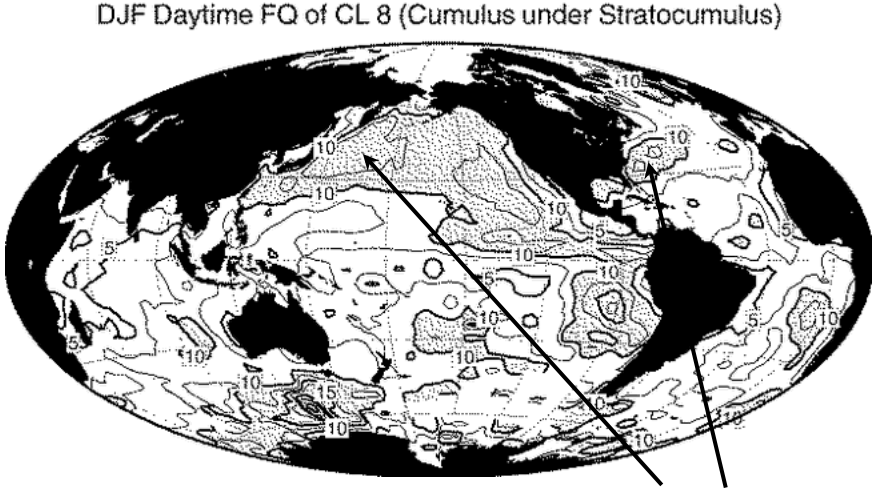
Cold advection, cool SST





Cold advection, medium SST

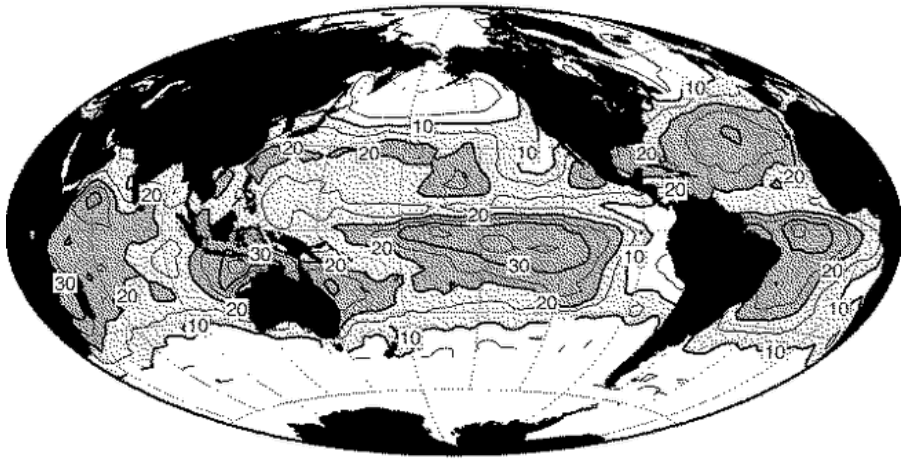




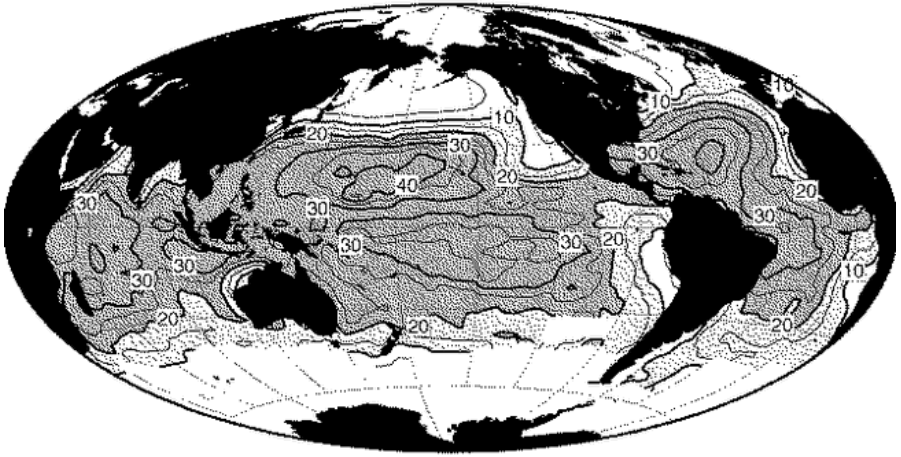
Cold air outbreaks

Cumulus-topped MBLs

JJA Daytime FQ of CL 1 (Small Cumulus)

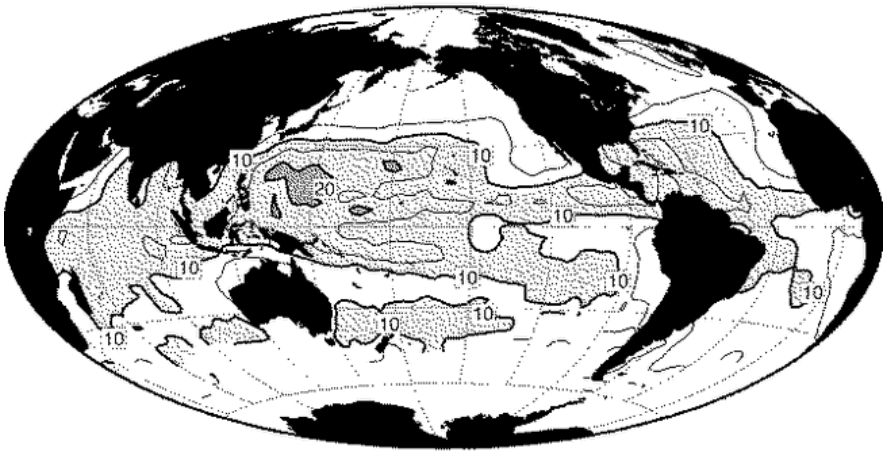


JJA Daytime FQ of CL 2 (Moderate and Large Cumulus)

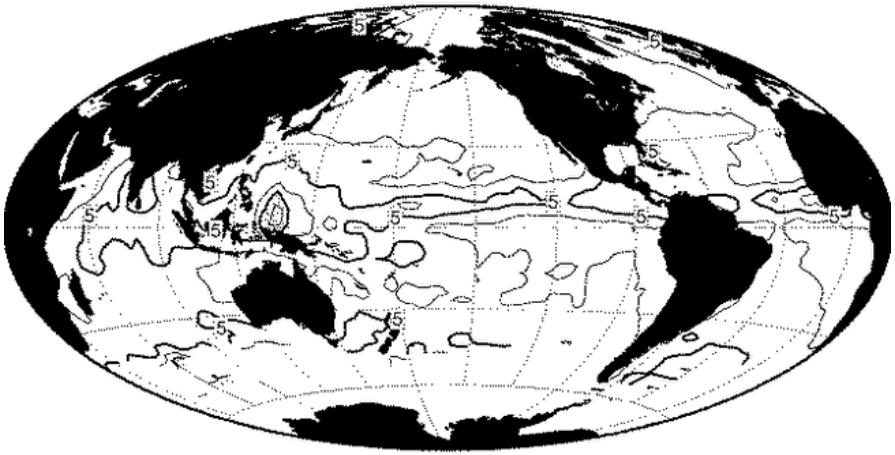


Norris et al. (1998, *J Climate*)

JJA Daytime FQ of CL 3 (Cumulonimbus without Anvil)



JJA Daytime FQ of CL 9 (Cumulonimbus with Anvil)



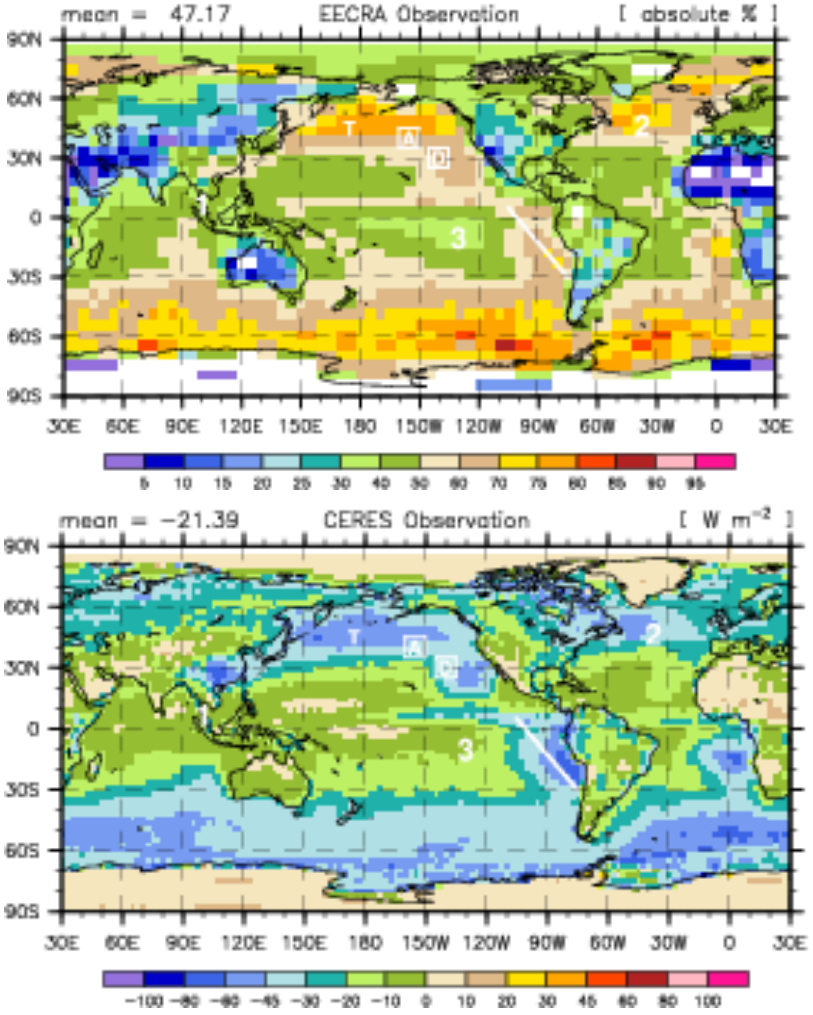
Over warm oceans, Cu-topped MBLs > 70% of time.

Stratus cloud amount and net cloud radiative effect

Stratus cloud amount (%)

correlated with…

Net CRE [W m^{-2}]

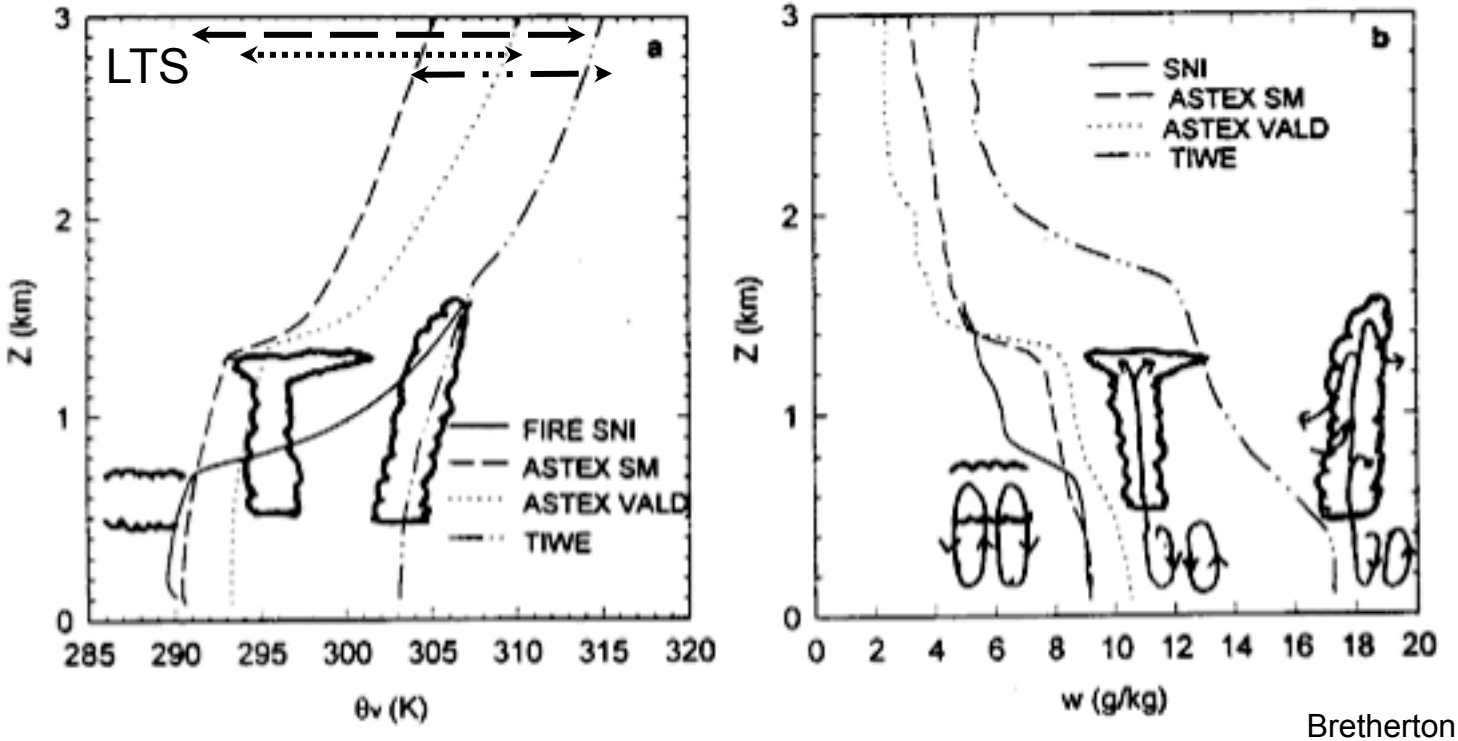


CRE = change in net (shortwave+longwave) radiation into TOA due to clouds.

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

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

Subtropical PBL soundings

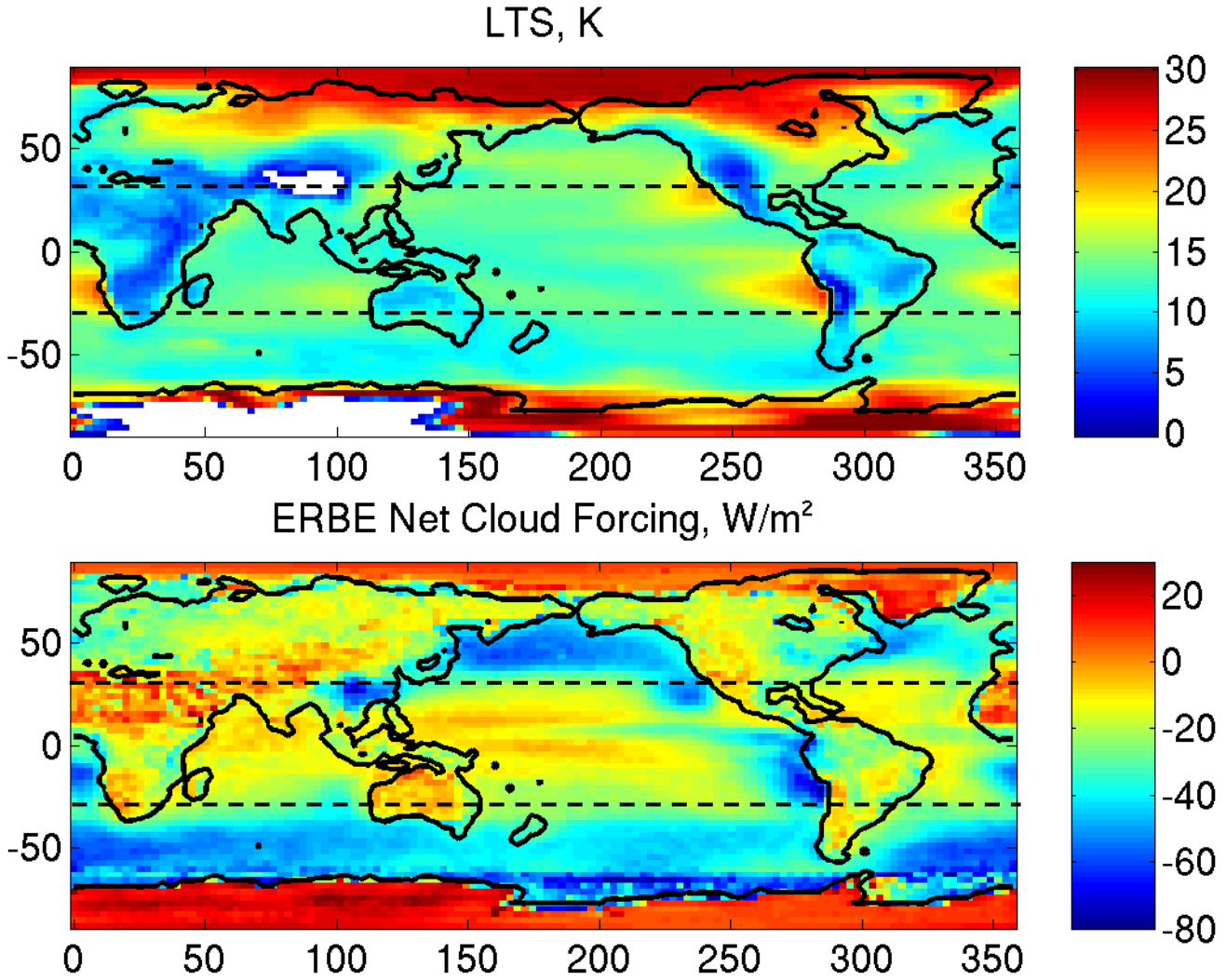


Bretherton 1997,
after Albrecht et al. 1995

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 (LTS) = θ(700 hPa)-θ(1000 hPa)

Lower tropospheric stability LTS = θ_{700} - SST



Geographically and seasonally correlated with subtropical marine stratus cloud cover and net CRE (Klein & Hartmann 1993)