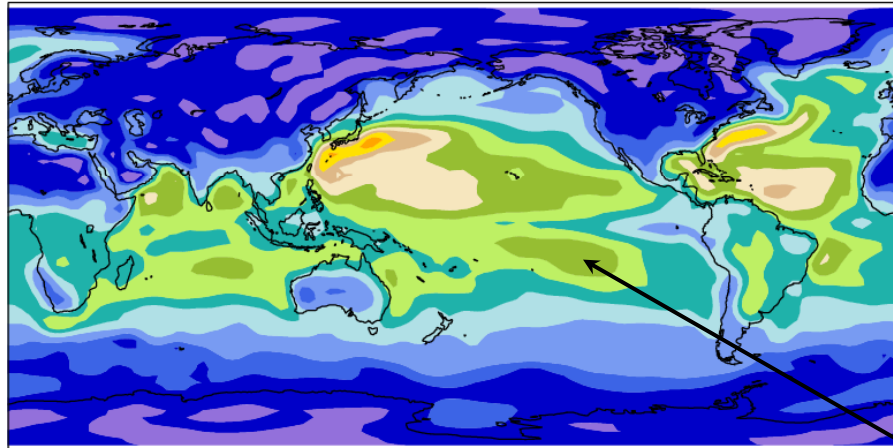
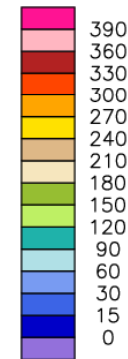


Surface fluxes (DJF)

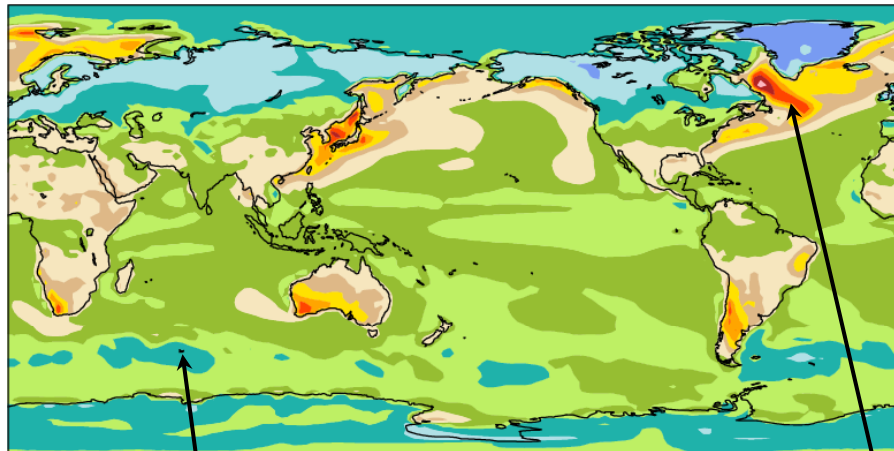
Surf latent heat flux mean= 81.88 W/m²



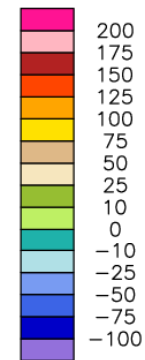
Min = -15.07 Max = 290.07



Surf sensible heat mean= 17.42 w/m²



Min = -45.67 Max = 198.58



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)



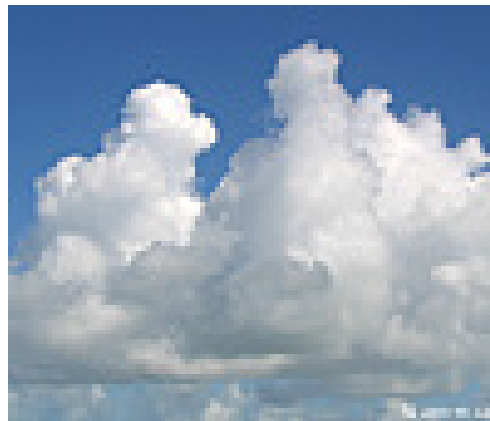
Stratocumulus (Sc)



Cu under Sc



Cumulus (Cu)



Cumulonimbus



Marine boundary layer clouds from space

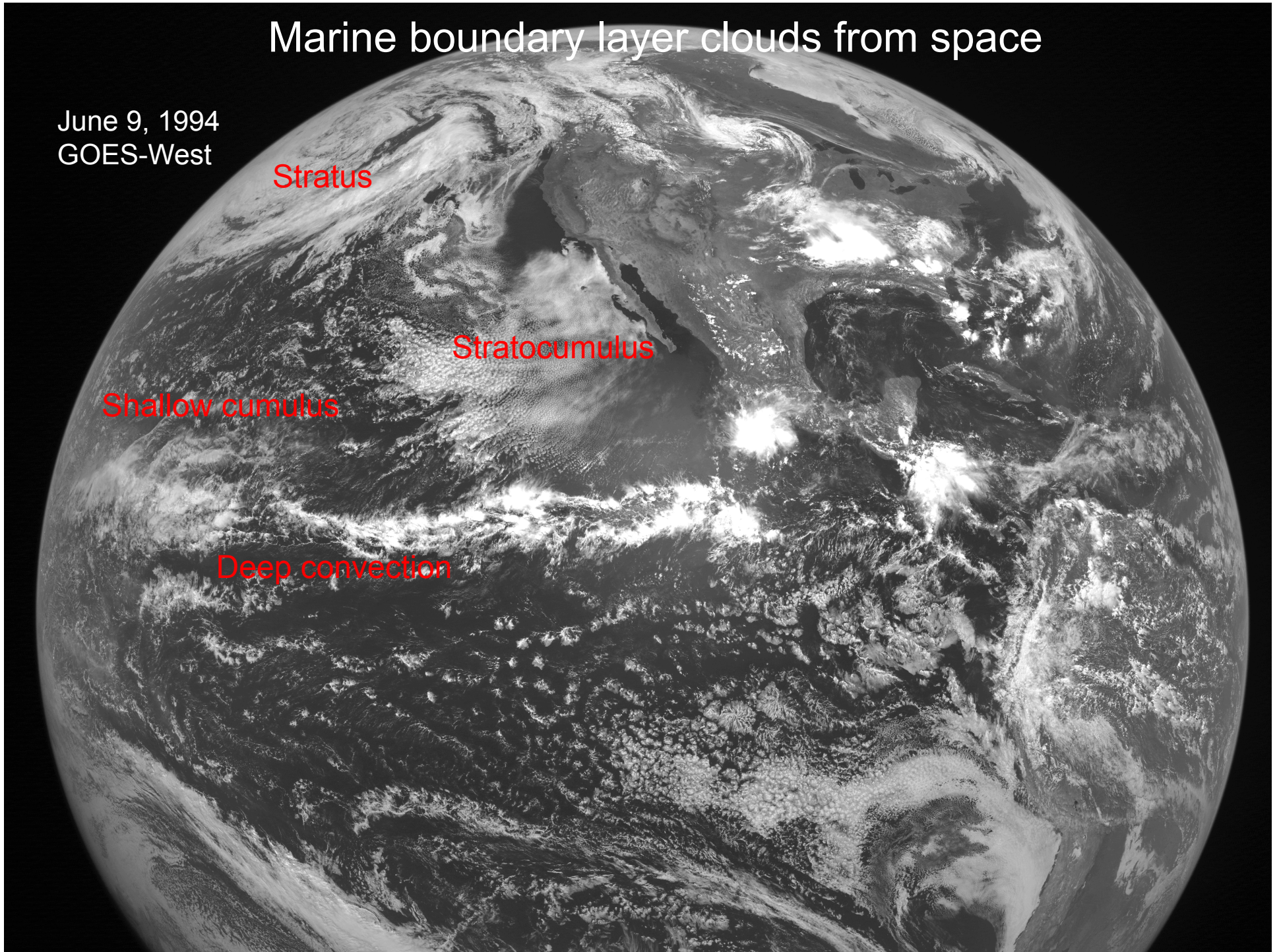
June 9, 1994
GOES-West

Stratus

Stratocumulus

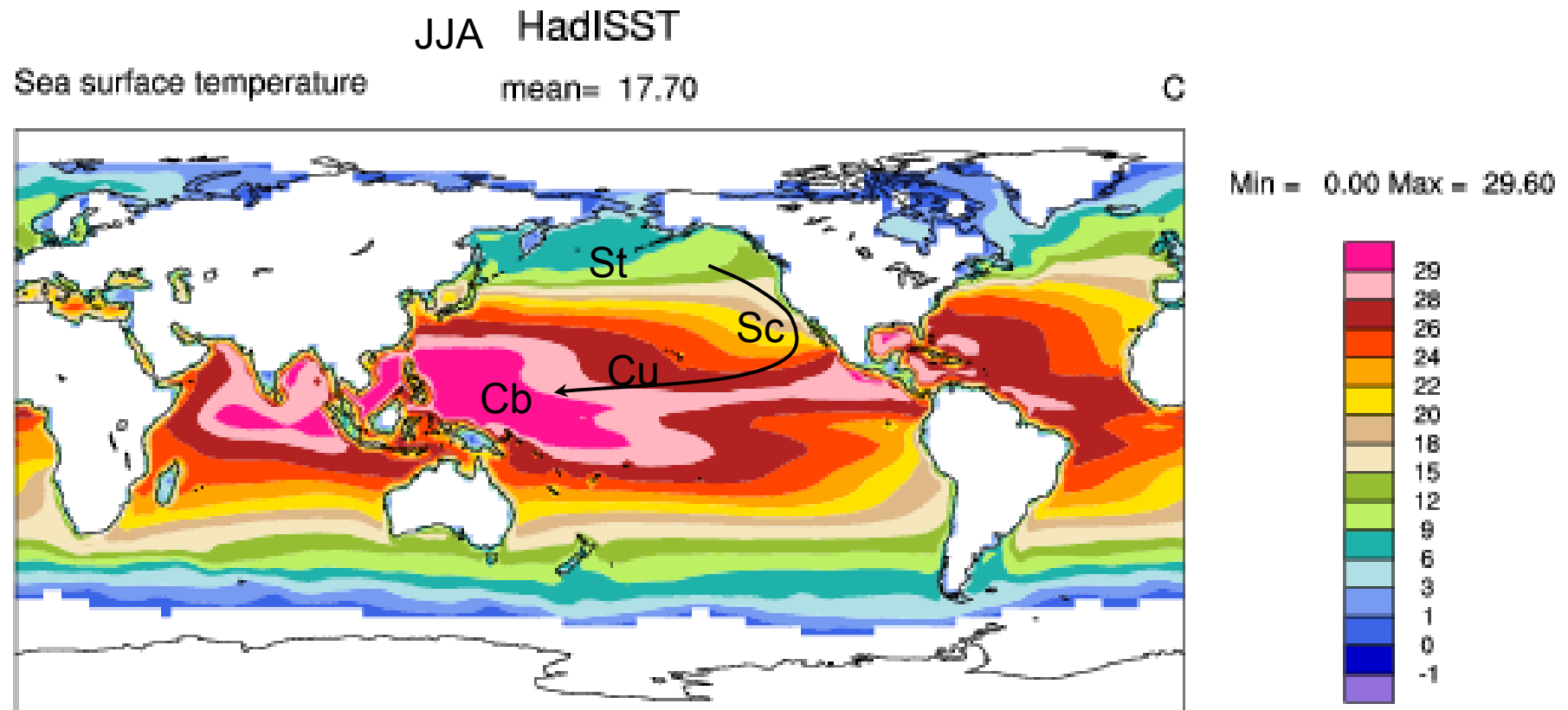
Shallow cumulus

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.



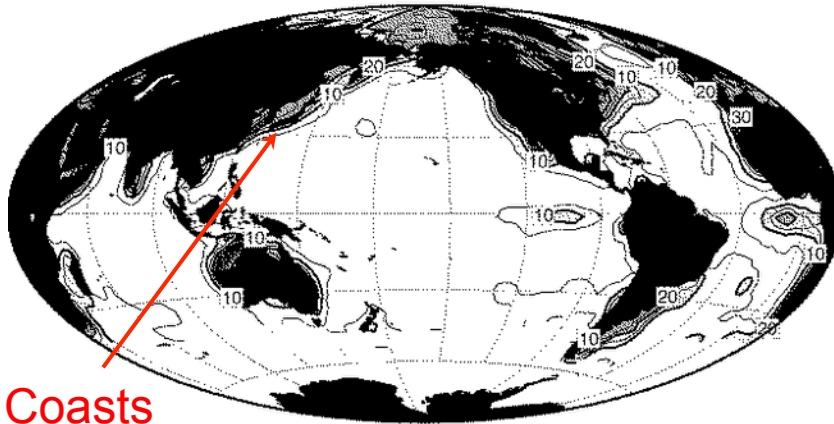
Warren surface cloud climatology

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

advection from warm land to cold SST

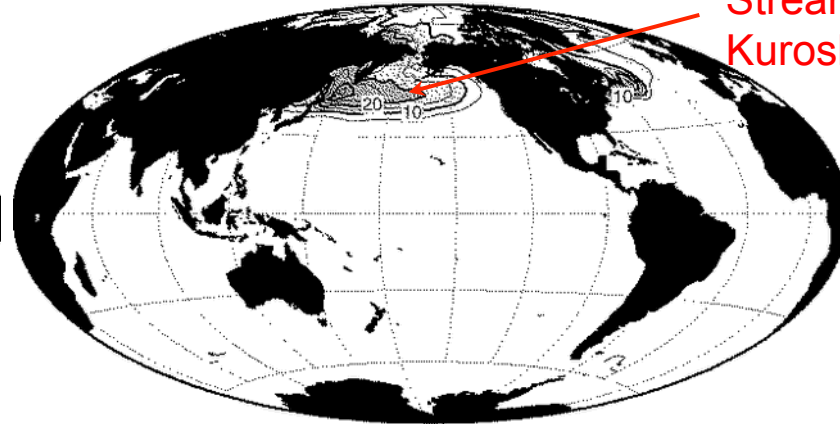
advection from warm to much colder SST

JJA Daytime FQ of CL 0 (No Low Cloud)



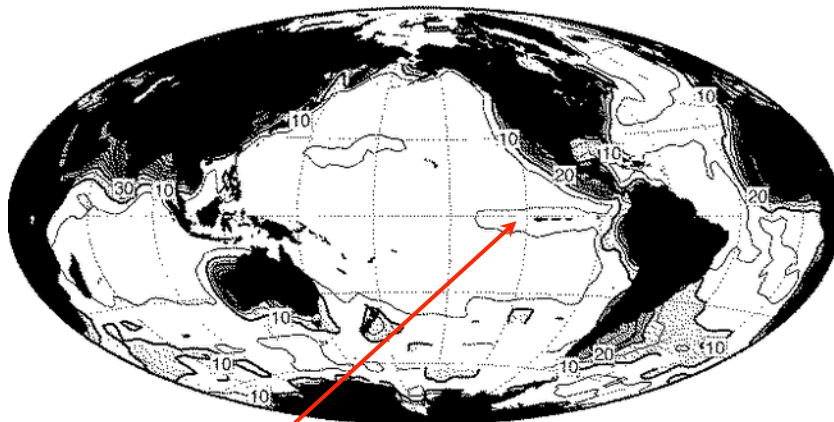
Coasts

JJA Daytime FQ of Sky-Obscuring Fog



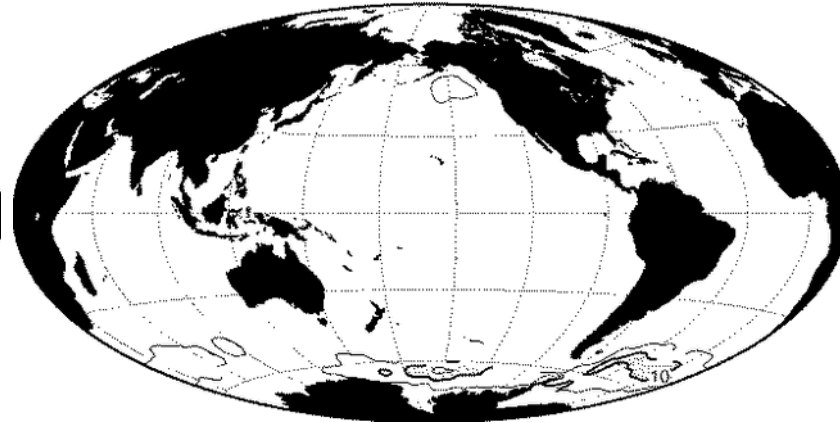
N of Gulf Stream, Kuroshio

DJF Daytime FQ of CL 0 (No Low Cloud)



Cold tongue

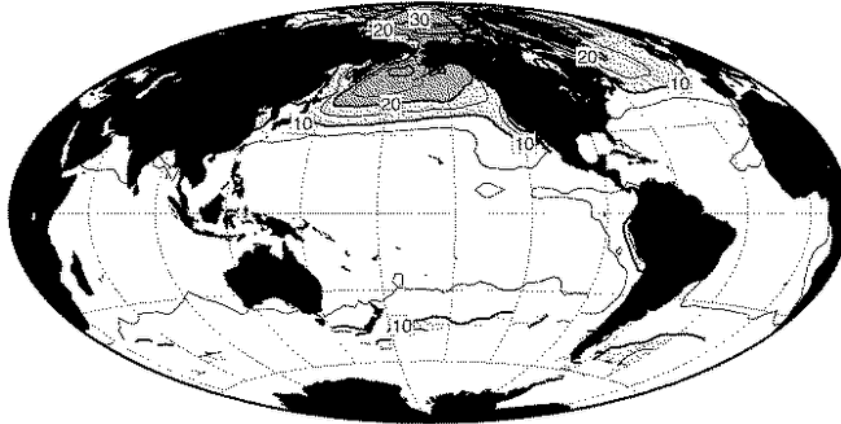
DJF Daytime FQ of Sky-Obscuring Fog



Cold-ocean MBL cloud types

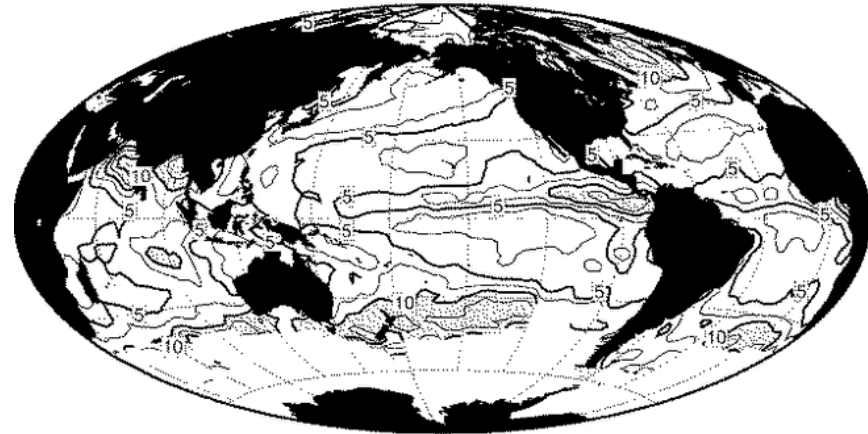
Weak air-sea
temperature differences

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

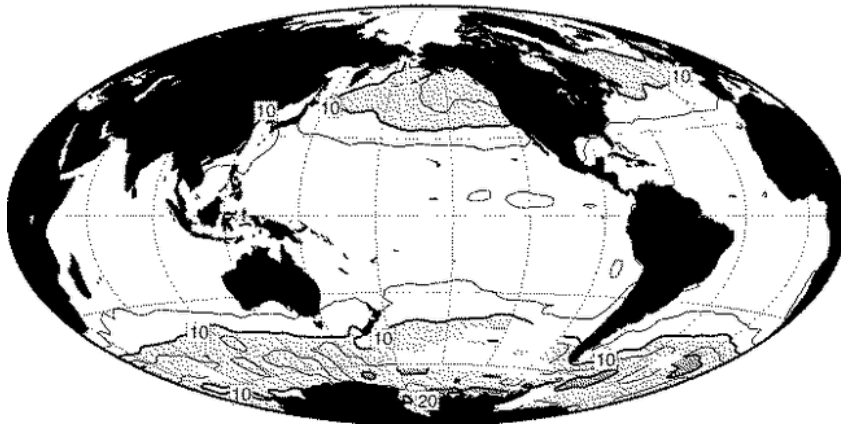


Deep storm systems

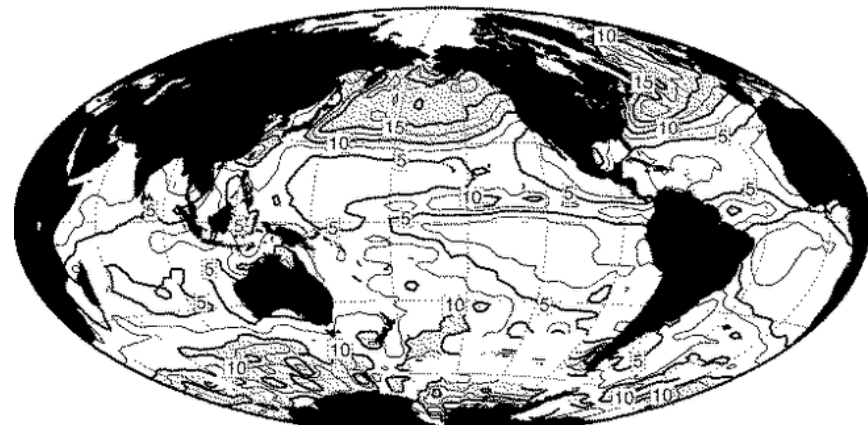
JJA Daytime FQ of CL 7 (Bad-Weather Stratus)



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



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



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

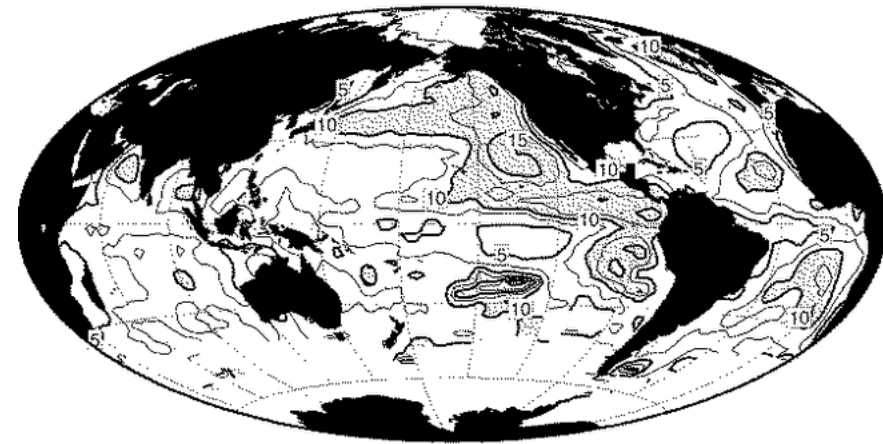
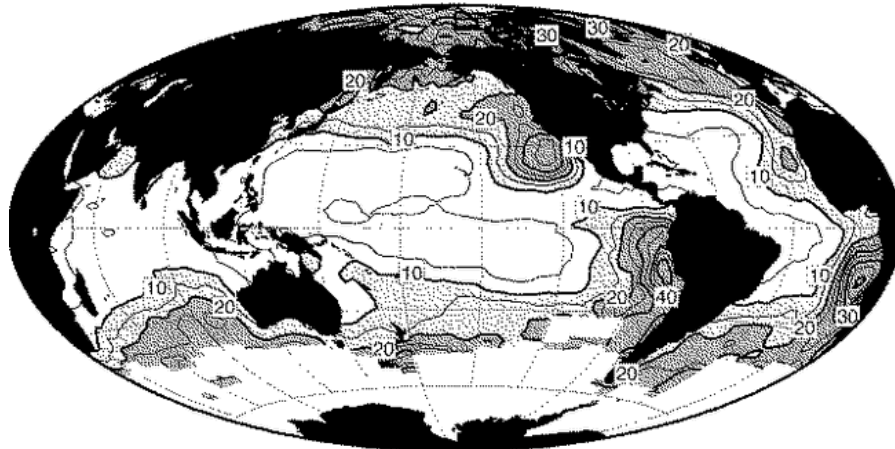
Cool-ocean MBL cloud types

Cold advection, cool SST

Cold advection, medium SST

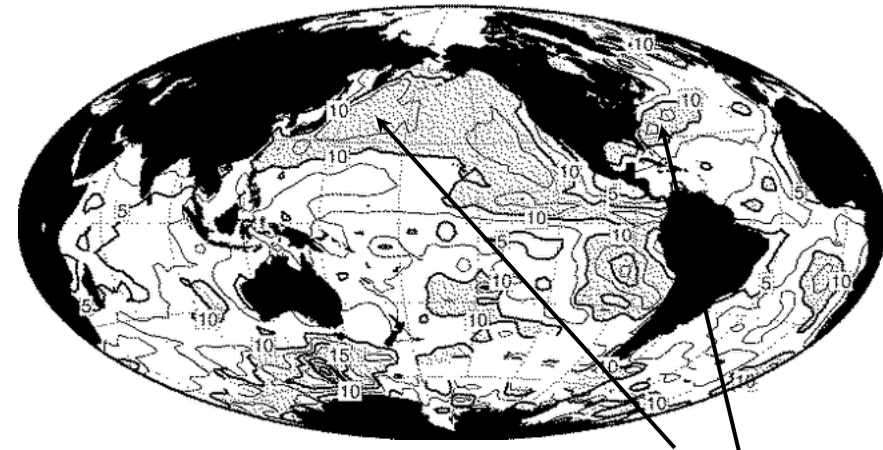
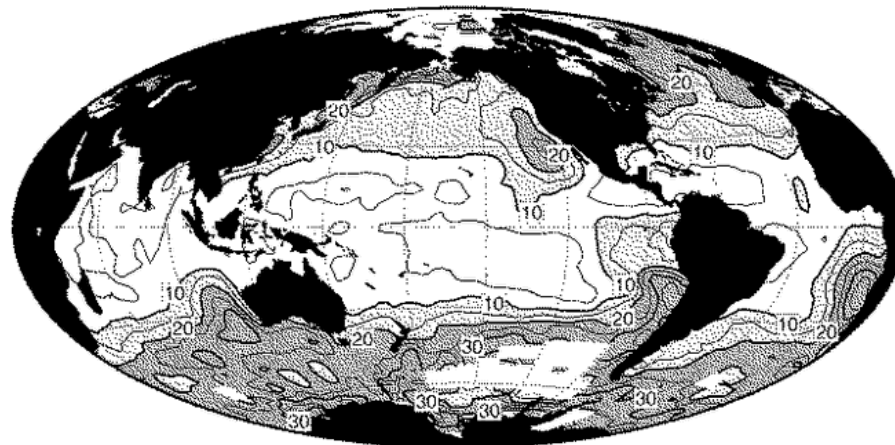
JJA Daytime FQ of CL 5 (Ordinary Stratocumulus)

JJA Daytime FQ of CL 8 (Cumulus under Stratocumulus)



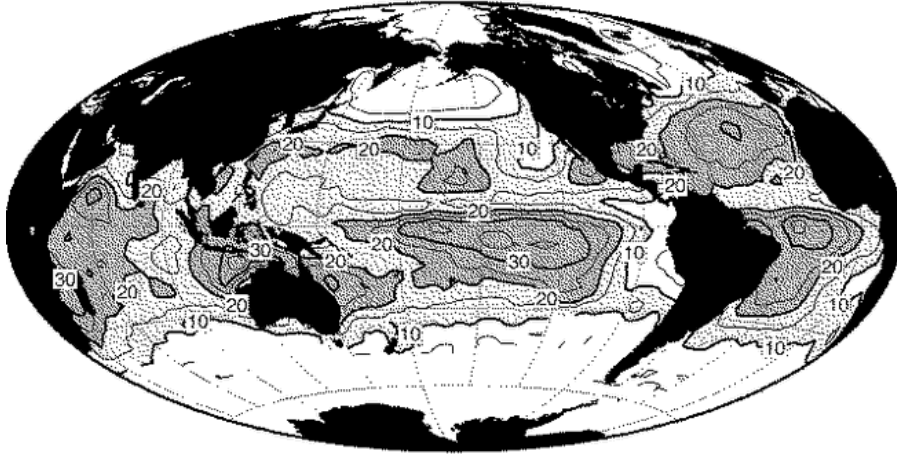
DJF Daytime FQ of CL 5 (Ordinary Stratocumulus)

DJF Daytime FQ of CL 8 (Cumulus under Stratocumulus)

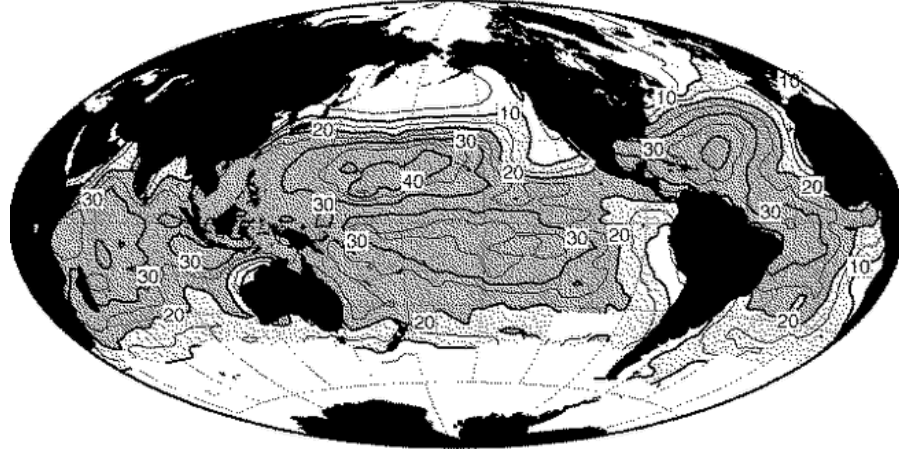


Cumulus-topped MBLs

JJA Daytime FQ of CL 1 (Small Cumulus)

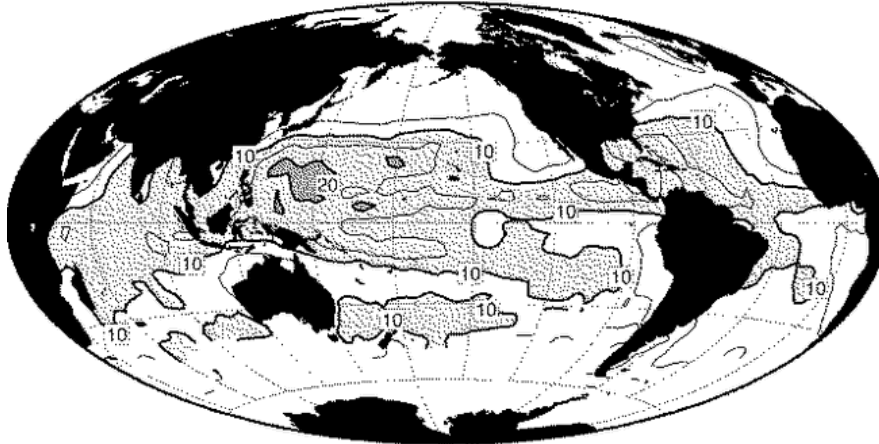


JJA Daytime FQ of CL 2 (Moderate and Large Cumulus)

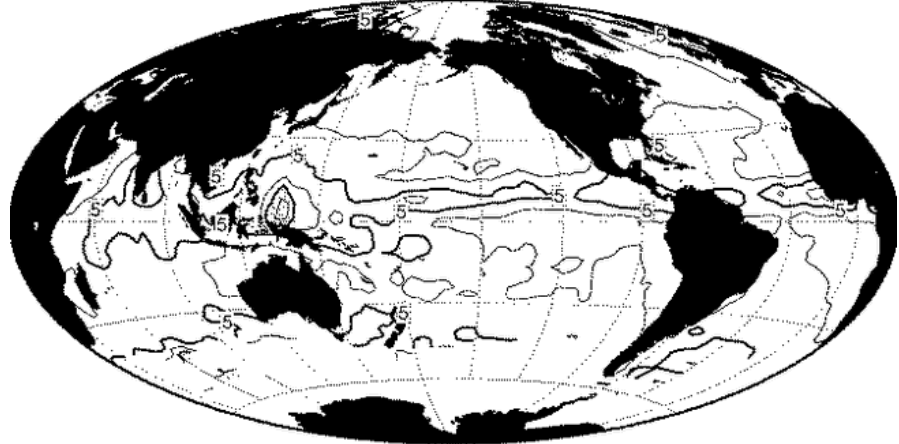


Norris et al. (1998, *J Climate*)

JJA Daytime FQ of CL 3 (Cumulonimbus without Anvil)



JJA Daytime FQ of CL 9 (Cumulonimbus with Anvil)



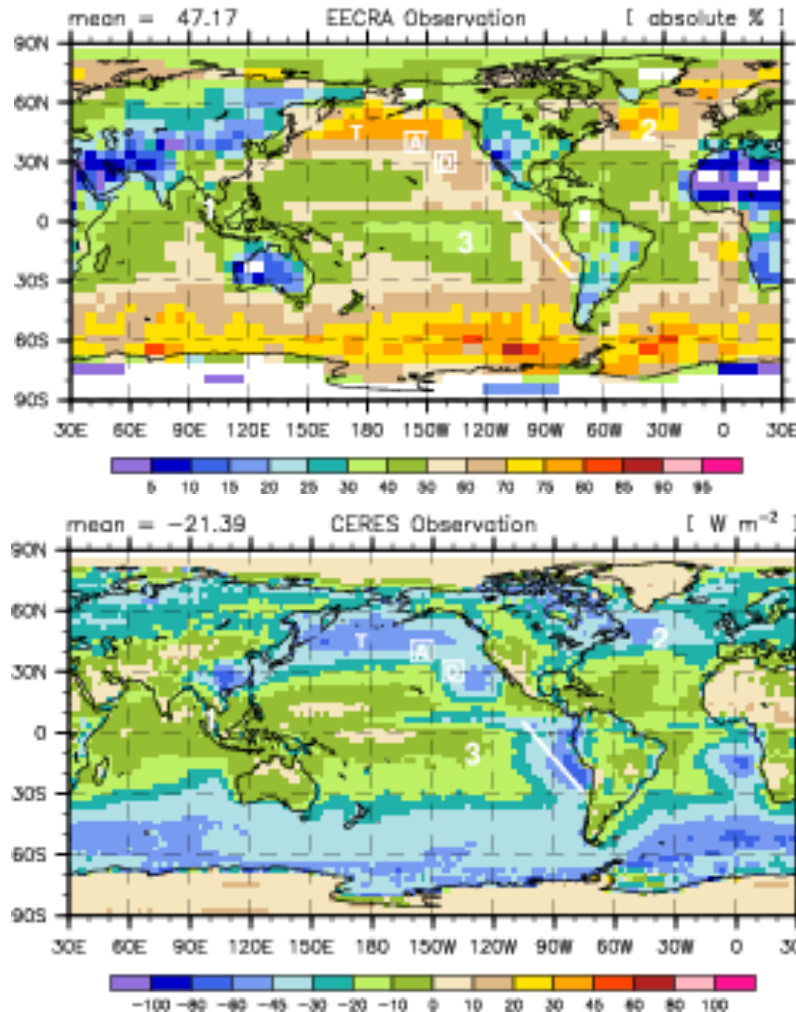
Over warm oceans, Cu-topped MBLs > 70% of time.

Stratus cloud amount and net cloud radiative effect

Stratus cloud amount (%)

correlated with...

Net CRE [W m^{-2}]

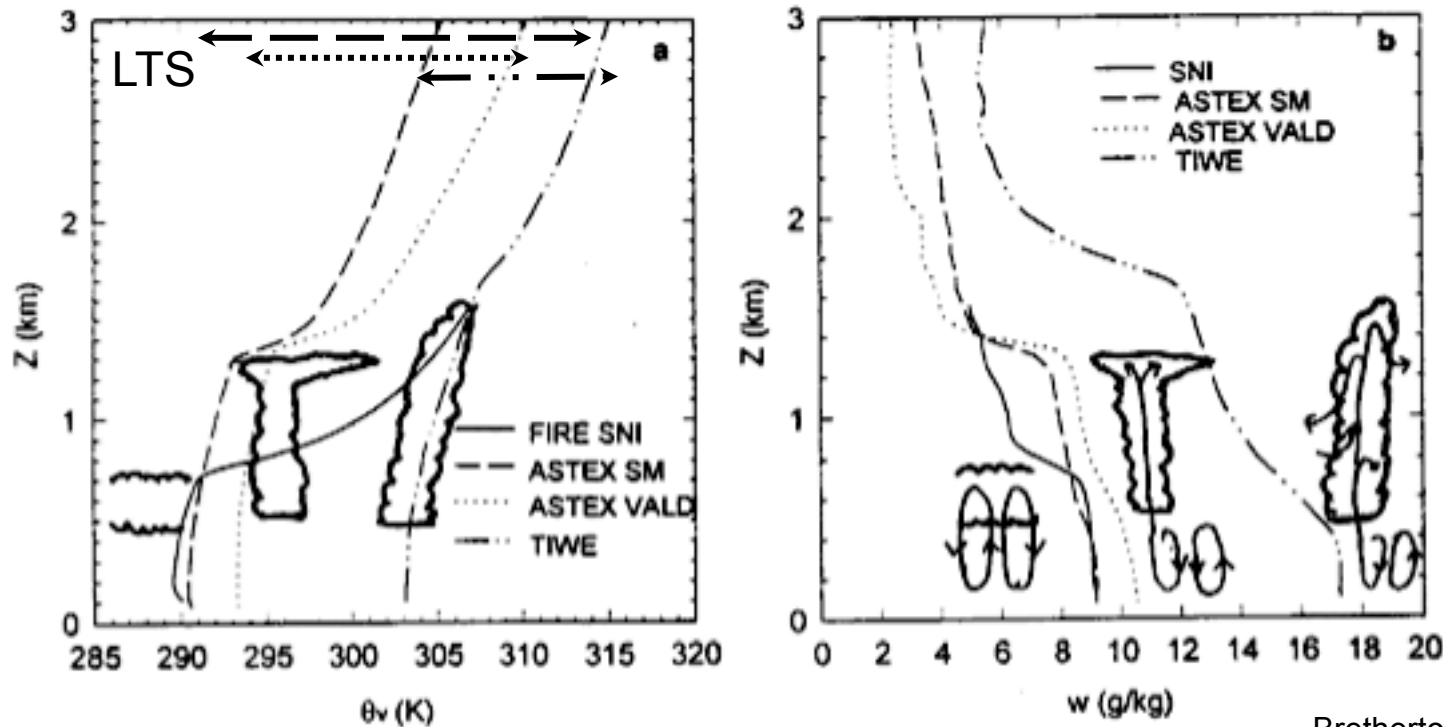


CRE = change in net (shortwave+longwave) radiation into TOA due to clouds.

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

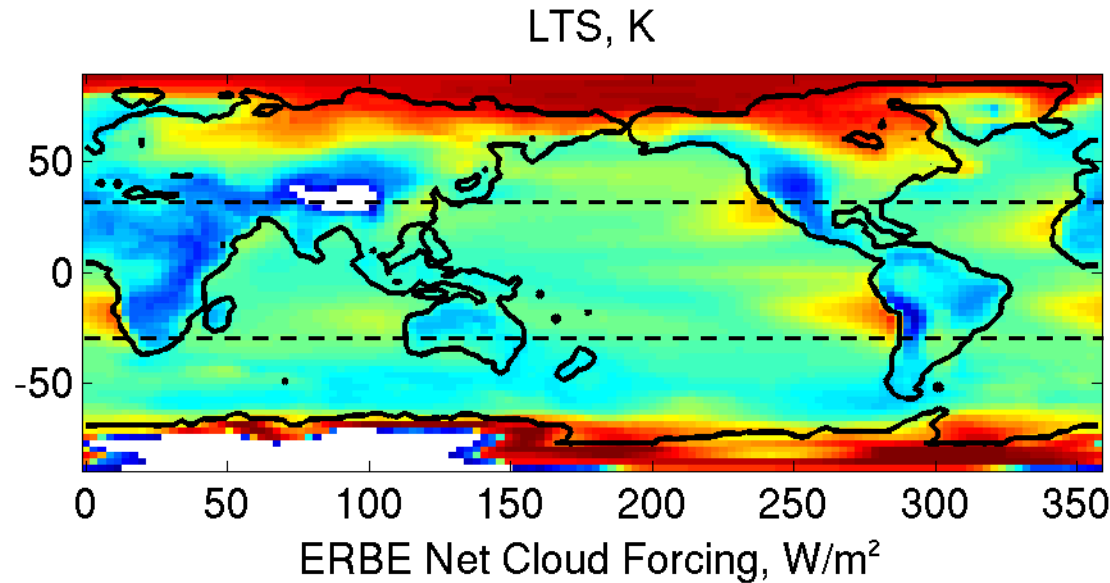


Bretherton 1997,
after Albrecht et al. 1995

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) = $\theta_v(700 \text{ hPa}) - \theta_v(1000 \text{ hPa})$

Lower tropospheric stability $LTS = \overline{W}_{700} - SST$



30
25
20
15
10
5
0

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

