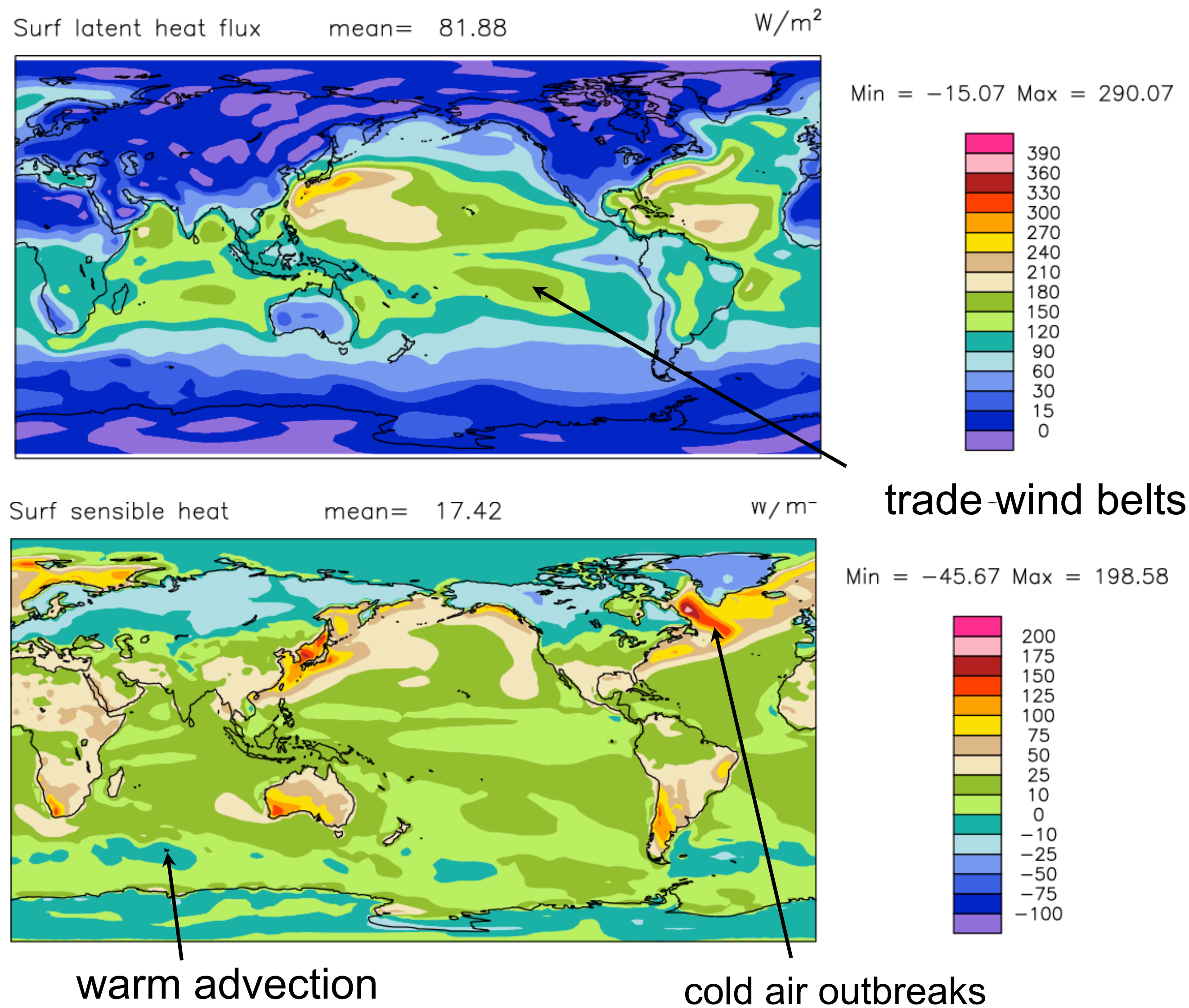
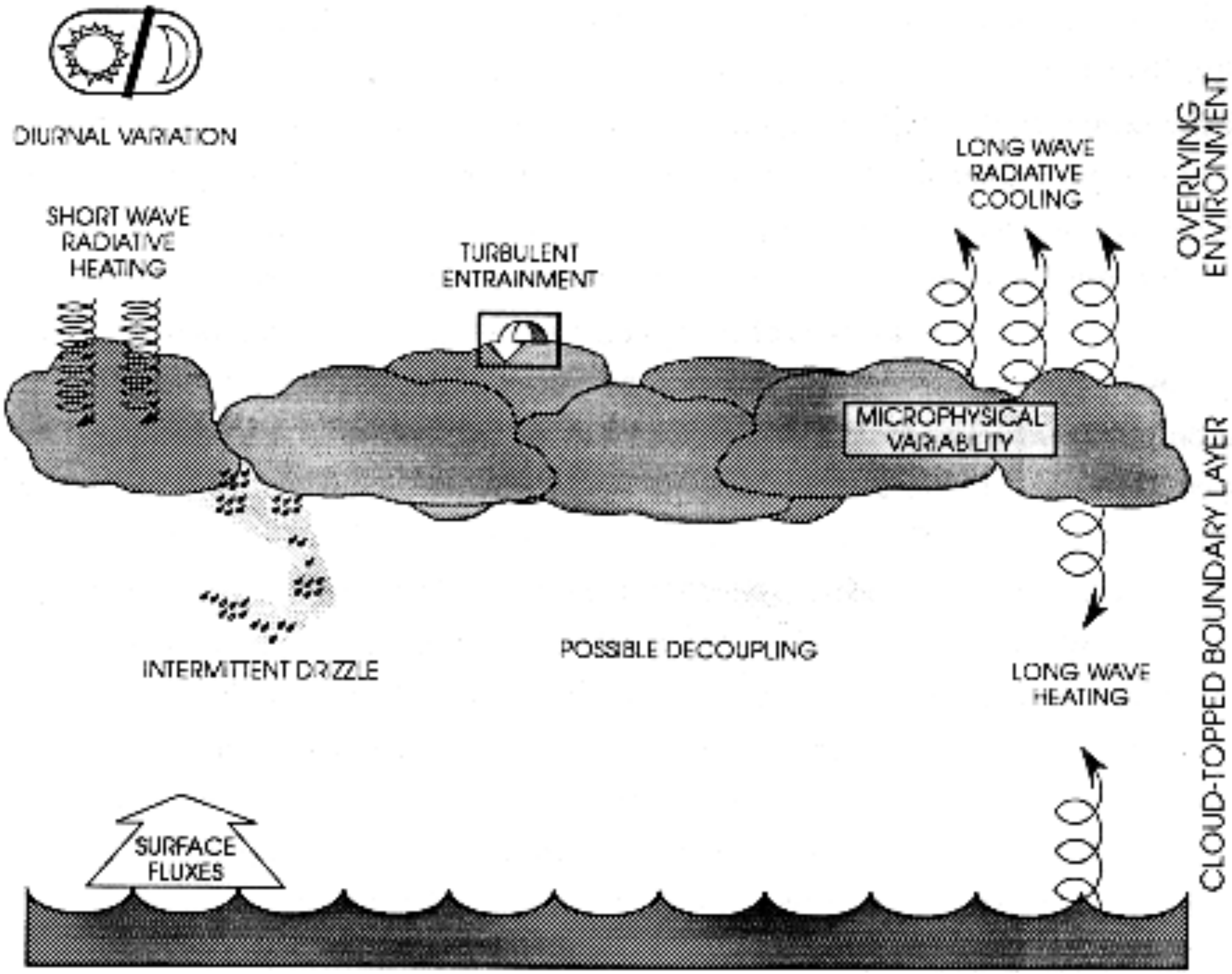
ERA40 surface fluxes (DJF)



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)

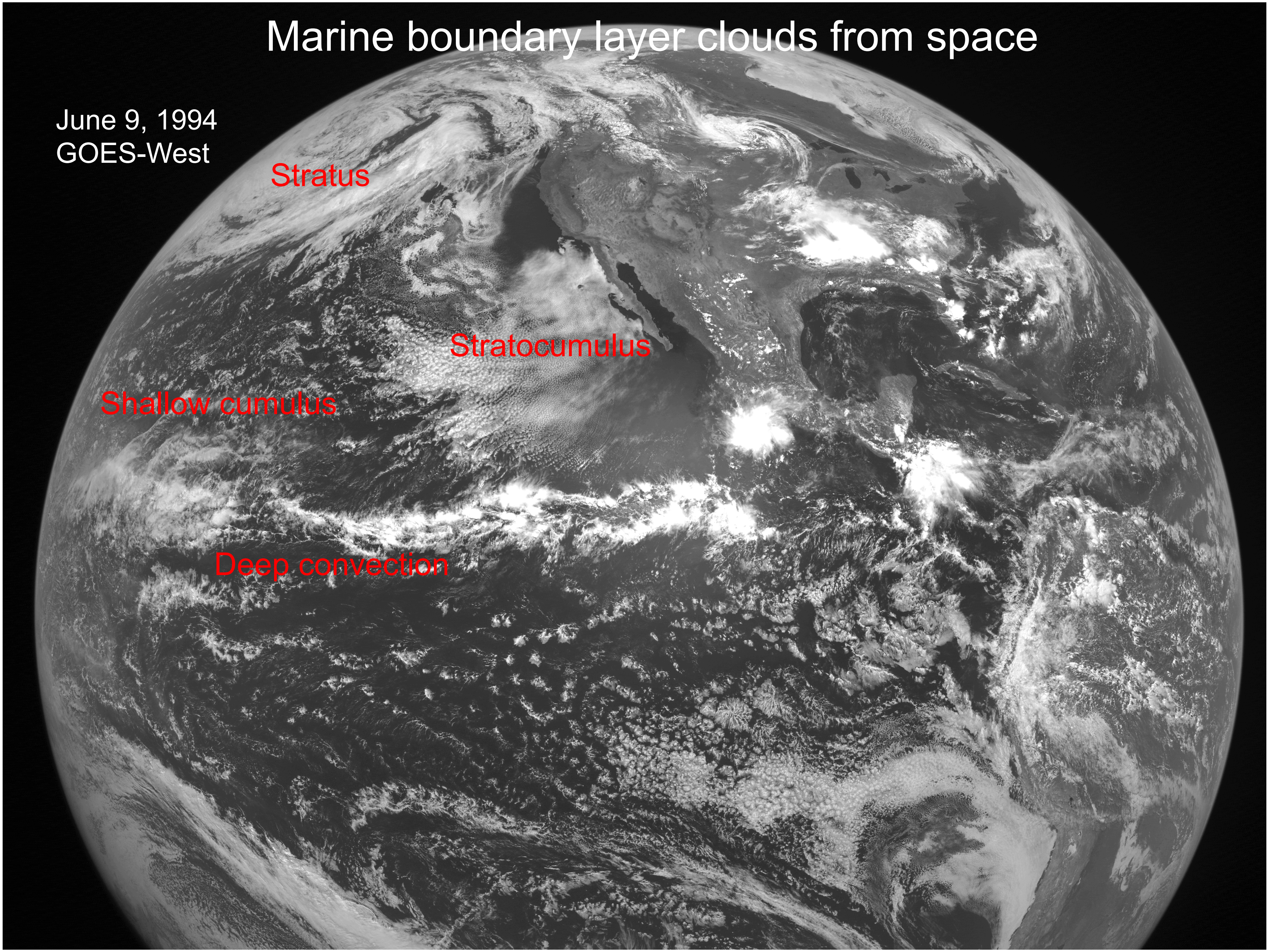
Stratocumulus (Sc)

Cu under Sc

Cumulus (Cu)

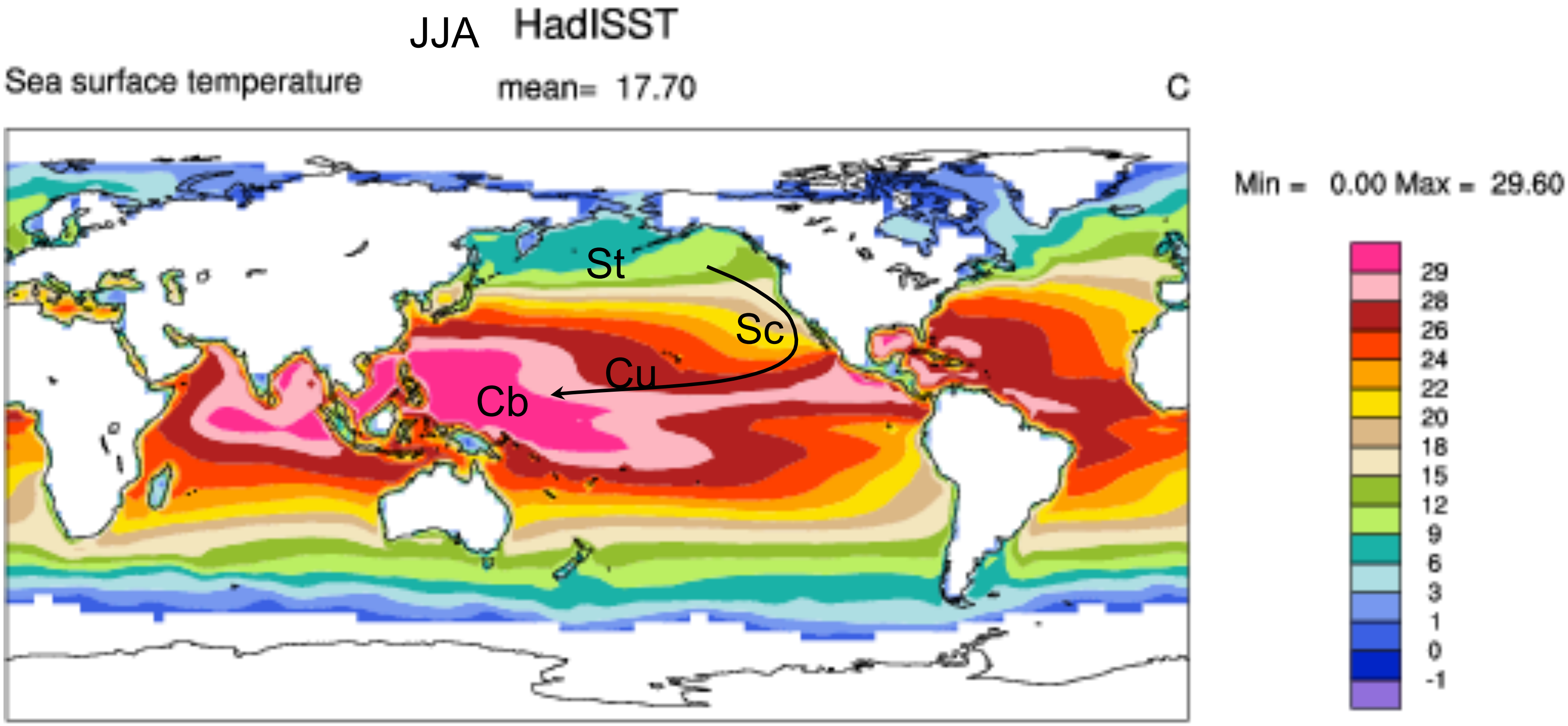
Cumulonimbus

ARM Image Library

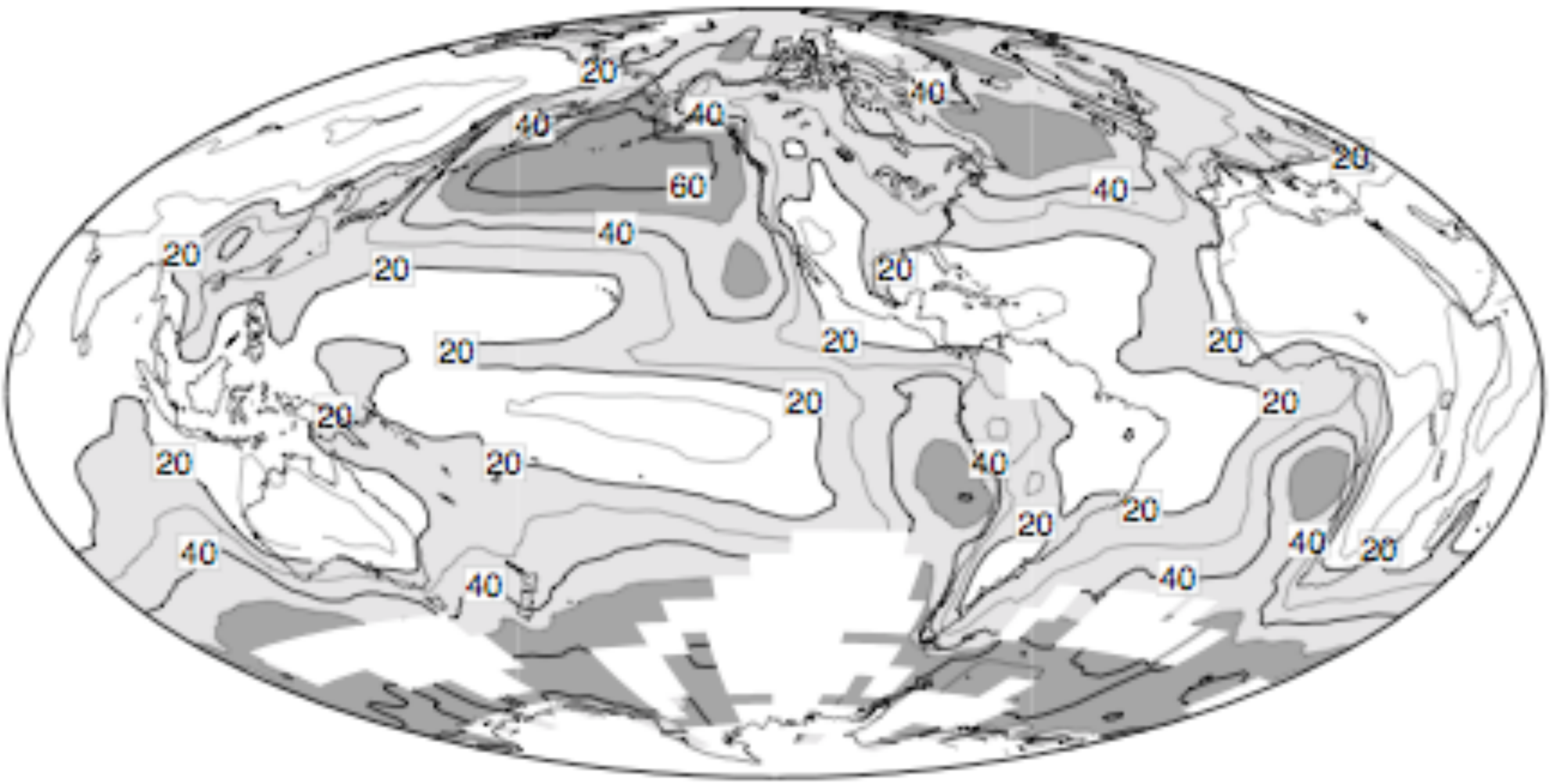

Marine boundary layer clouds from space
June 9, 1994
GOES-West
Stratus
Stratocumulus
Shallow cumulus
Deep convection

Observations over the oceans

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



Annual Stratus Cloud Amount

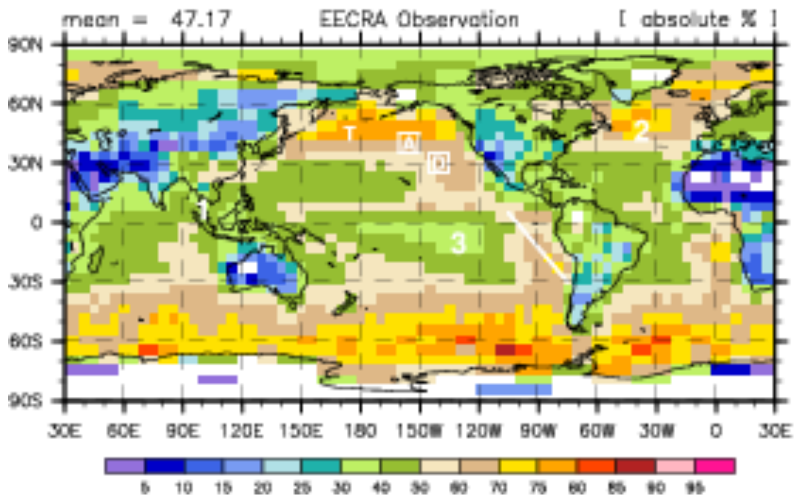


Klein and Hartmann (1993), from surface observations

‘stratus’ = stratus + stratocumulus + fog

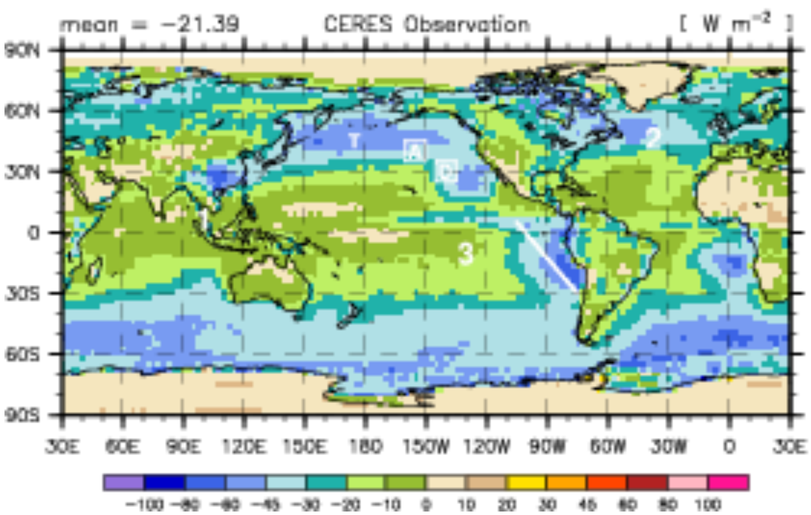
Boundary-layer cloud amount and cloud radiative effect

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.

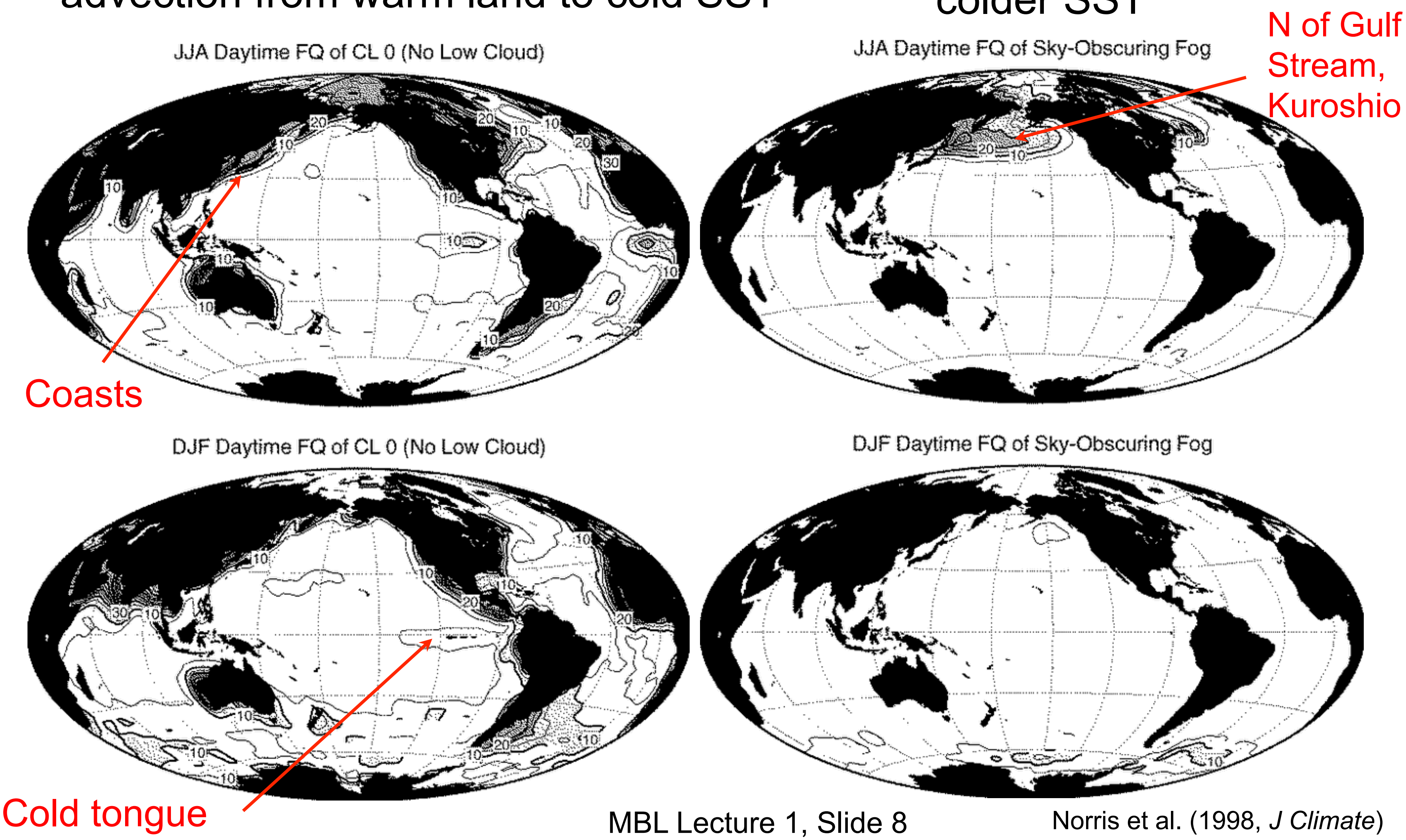
- Marine boundary-layer cloud is the most radiatively important cloud type for the current climate.

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



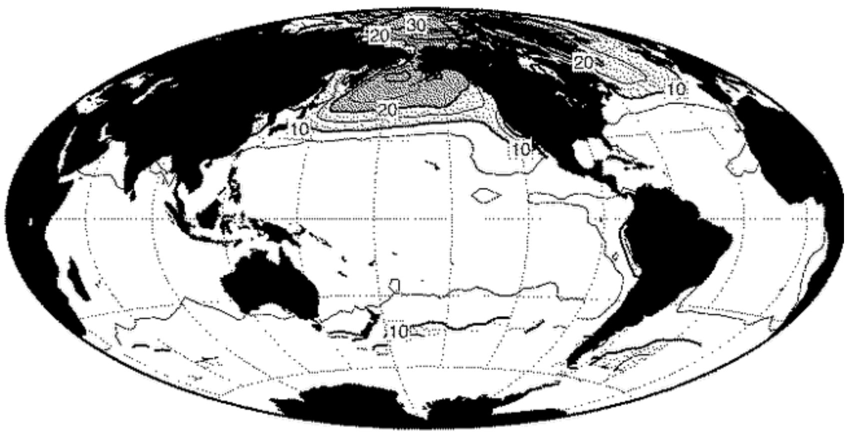
Norris et al. (1998, *J Climate*)

Cold-ocean MBL cloud types

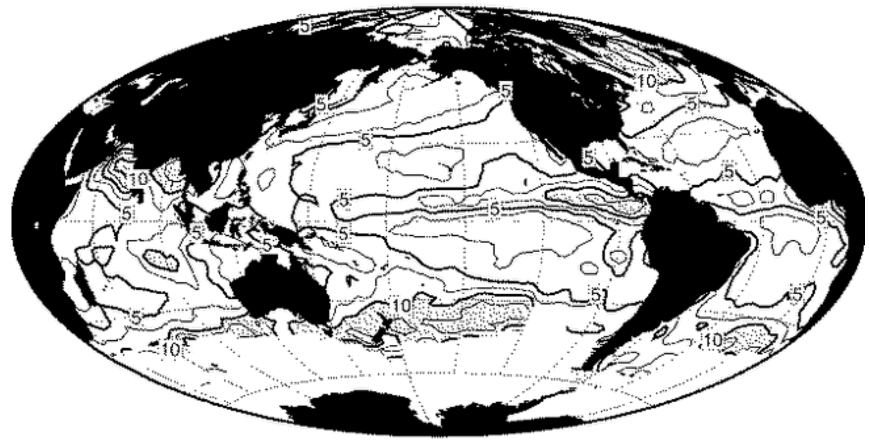
Weak air-sea temperature differences

Deep storm systems

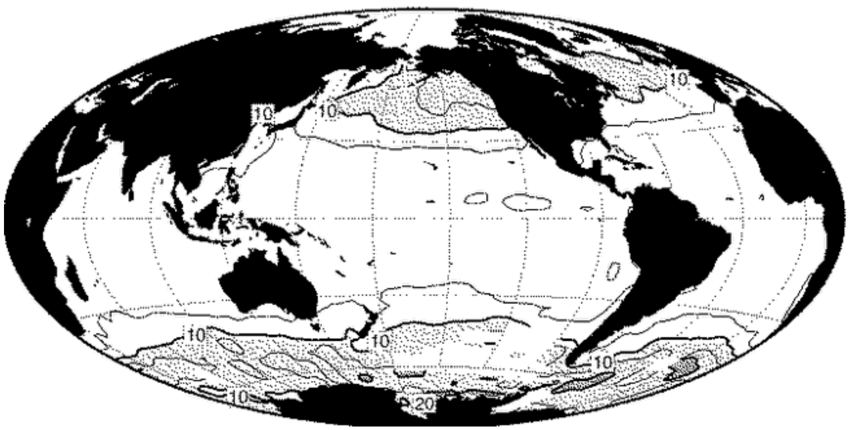
JJA Daytime FQ of CL 6 (Fair-Weather Stratus)



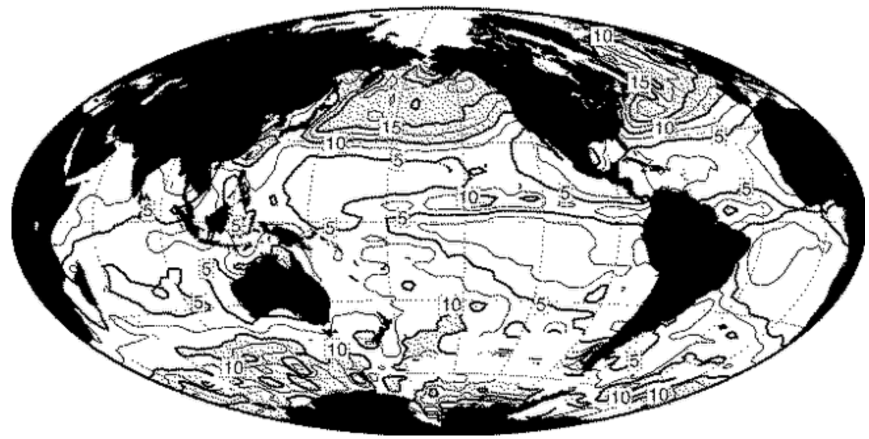
JJA Daytime FQ of CL 7 (Bad-Weather Stratus)



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



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



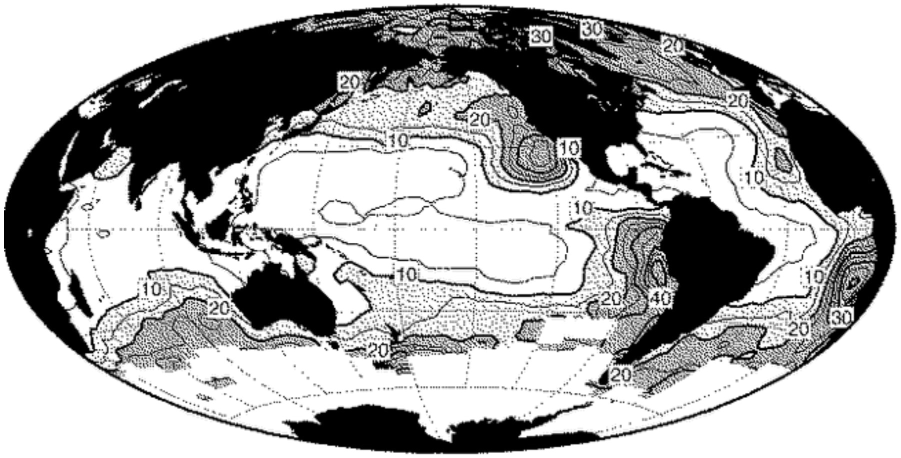
Norris et al. (1998, *J Climate*)

Cool-ocean MBL cloud types

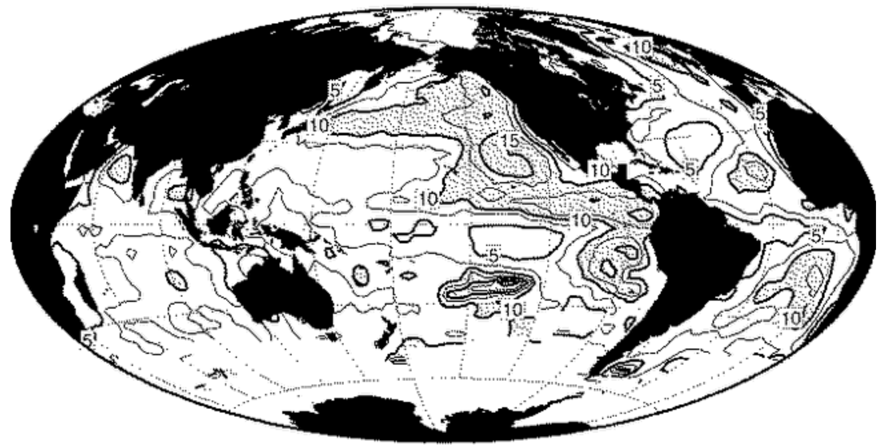
Cold advection, cool SST

Cold advection, medium SST

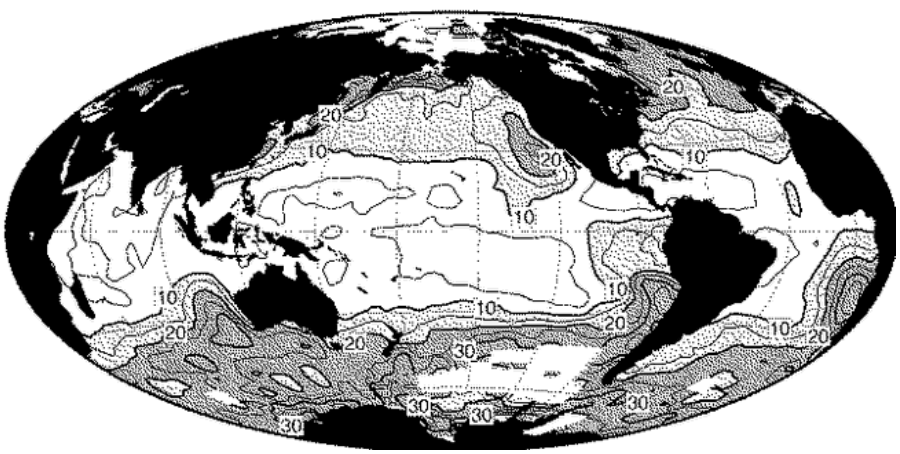
JJA Daytime FQ of CL 5 (Ordinary Stratocumulus)



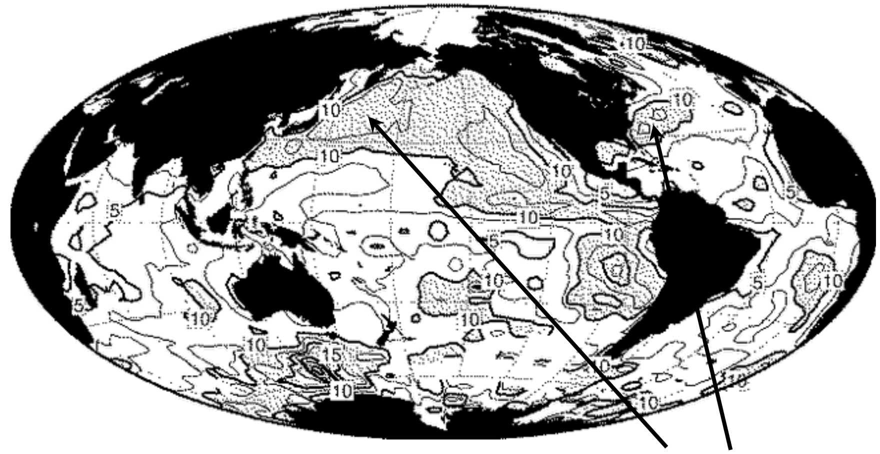
JJA Daytime FQ of CL 8 (Cumulus under Stratocumulus)



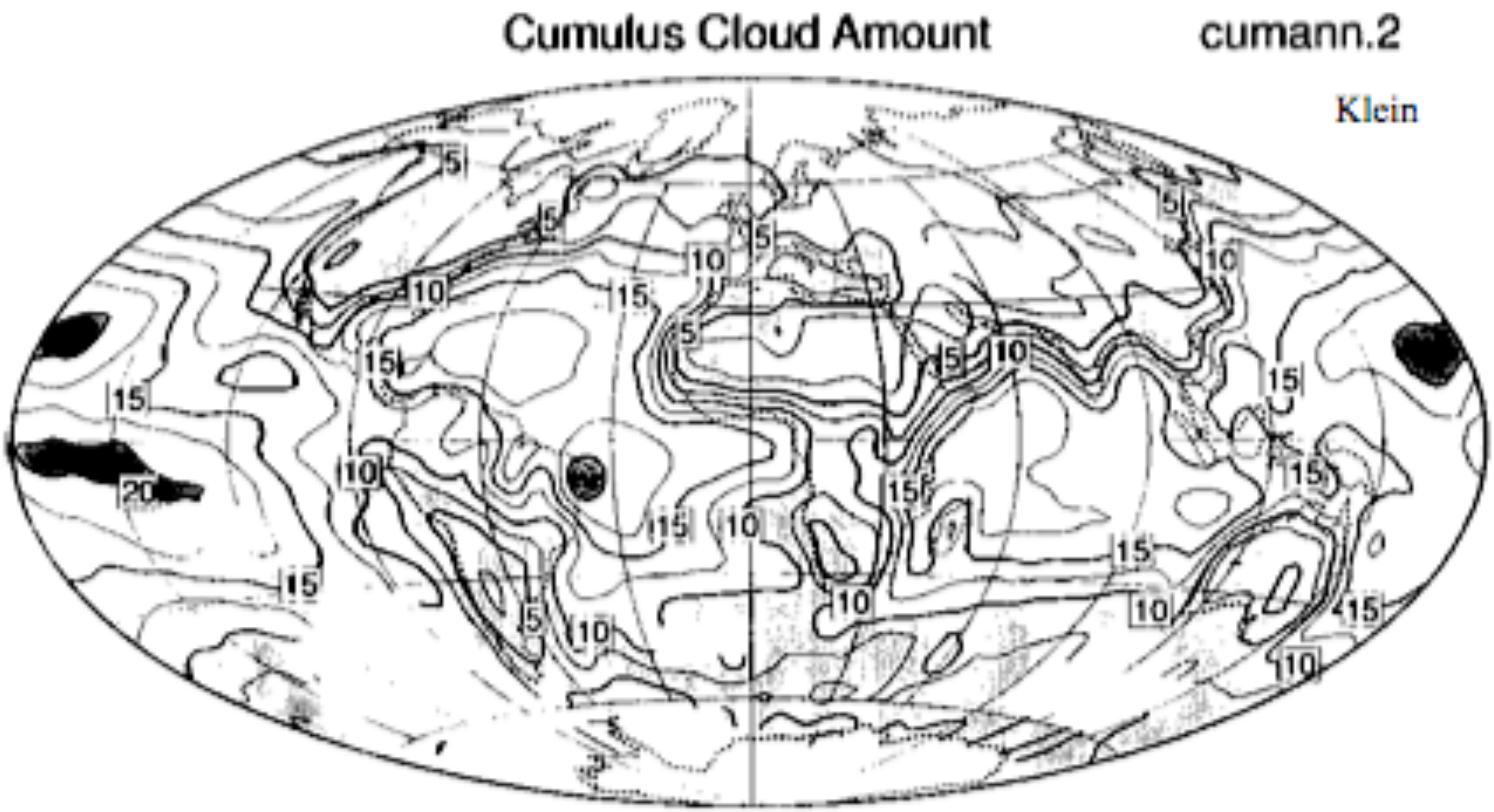
DJF Daytime FQ of CL 5 (Ordinary Stratocumulus)



DJF Daytime FQ of CL 8 (Cumulus under Stratocumulus)



Cold air outbreaks


Cumulus Cloud Amount
cumann.2
Klein
5
5
5
5
10
10
10
15
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15
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15
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15
20
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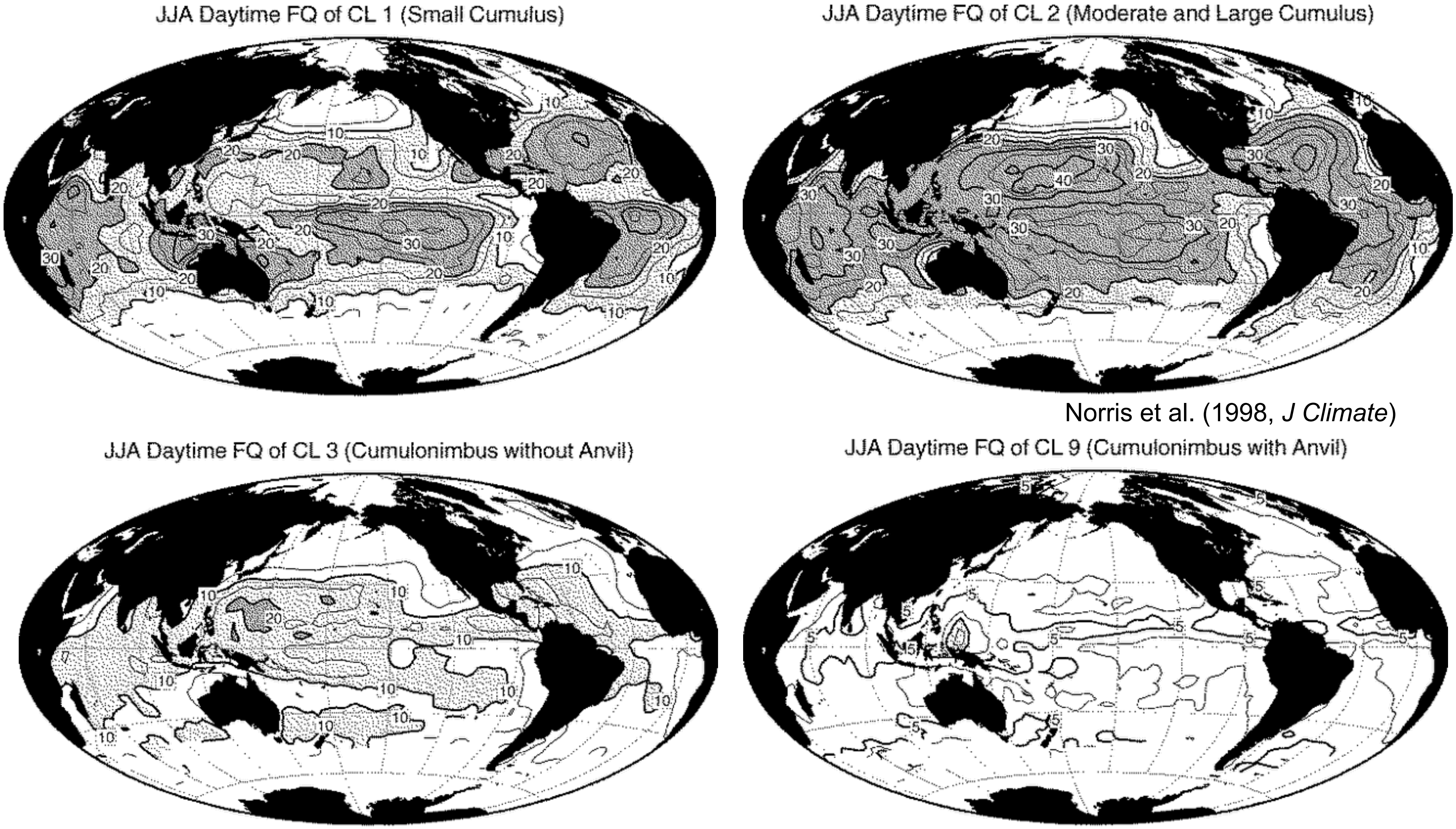
15
5
5
10

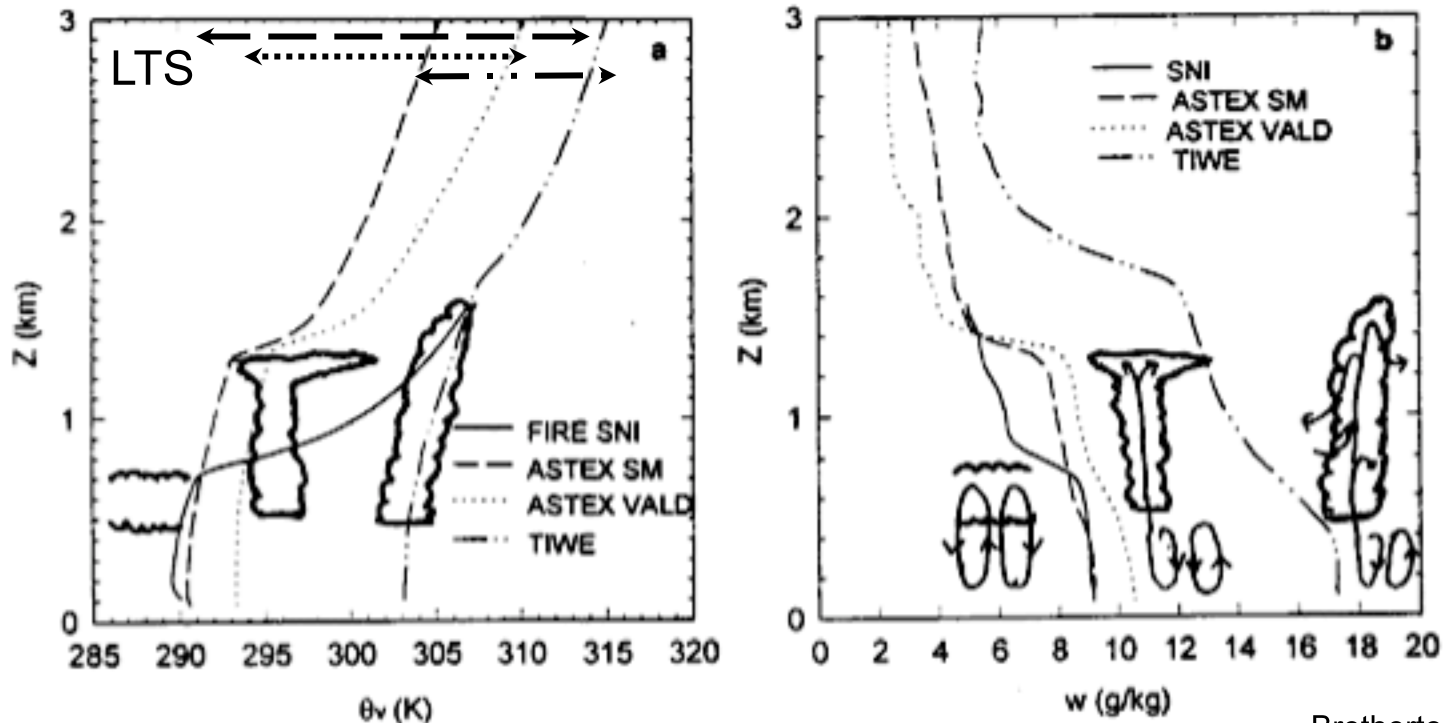
Cumulus-topped MBLs



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

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.

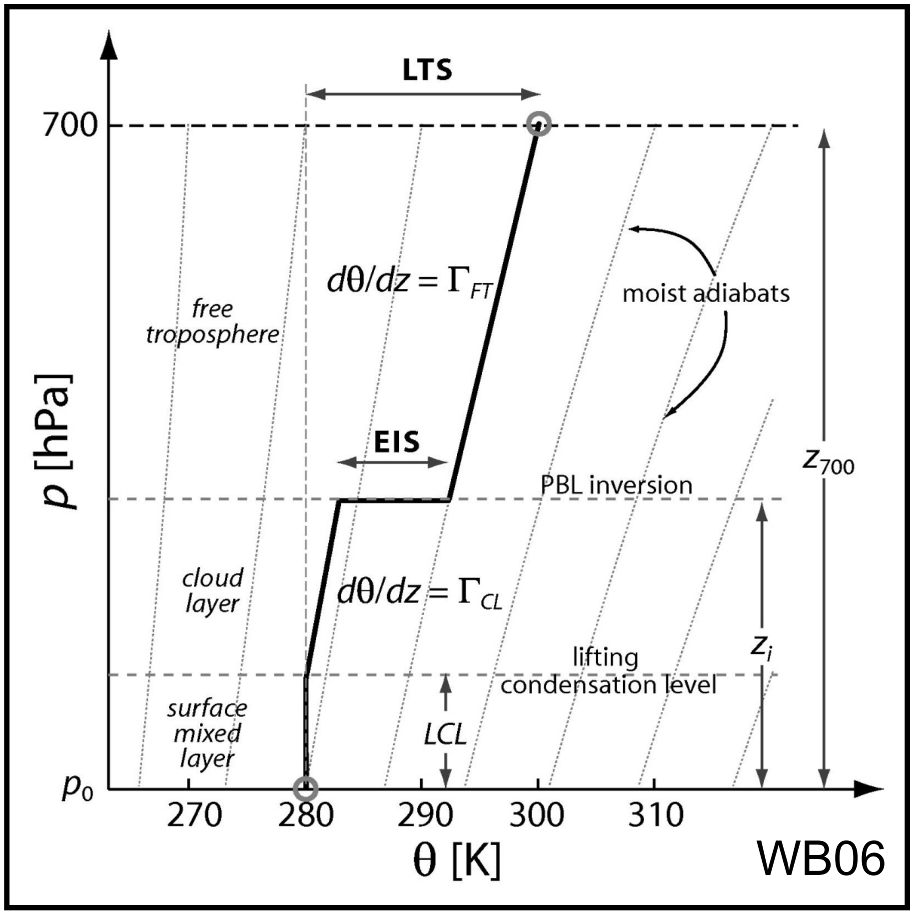
Measures of lower-tropospheric stratification

Lower tropospheric stability (Klein&Hartmann 1993)

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

Estimated Inversion Strength (Wood&Breth 2006)

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



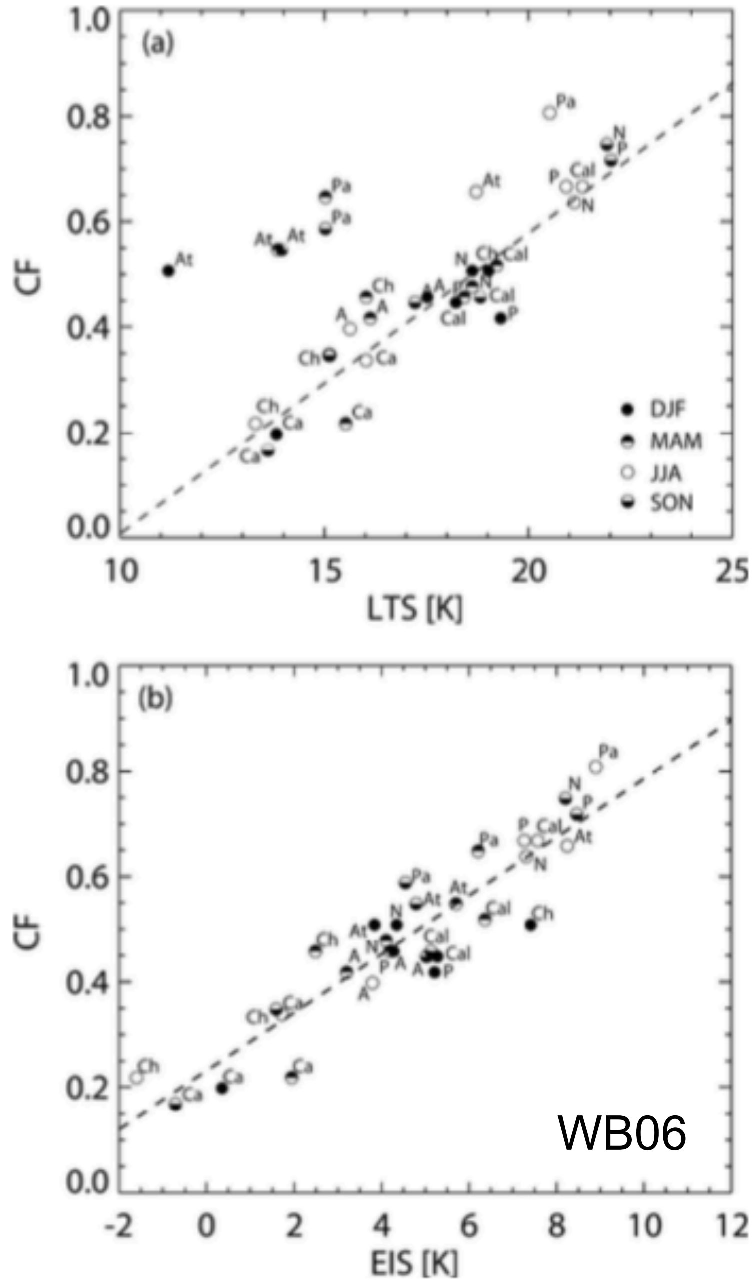
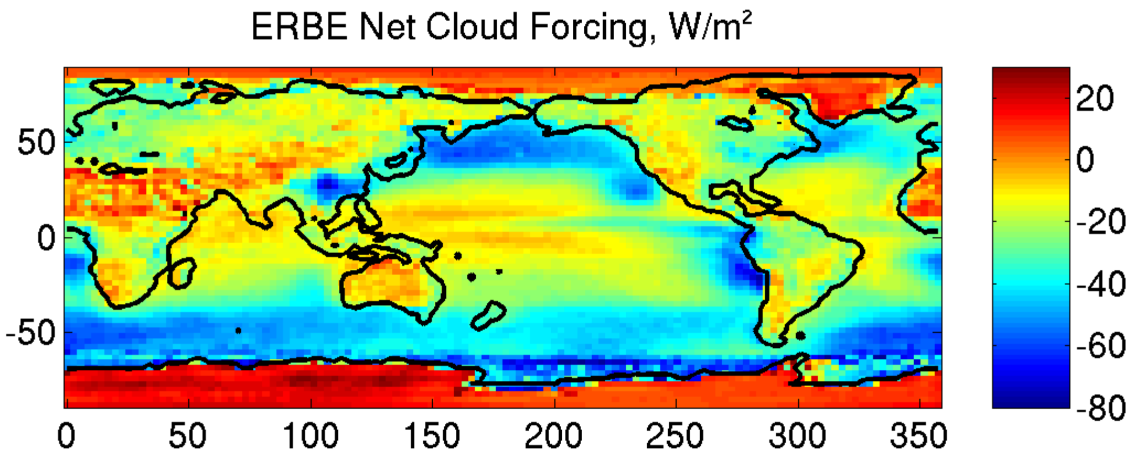
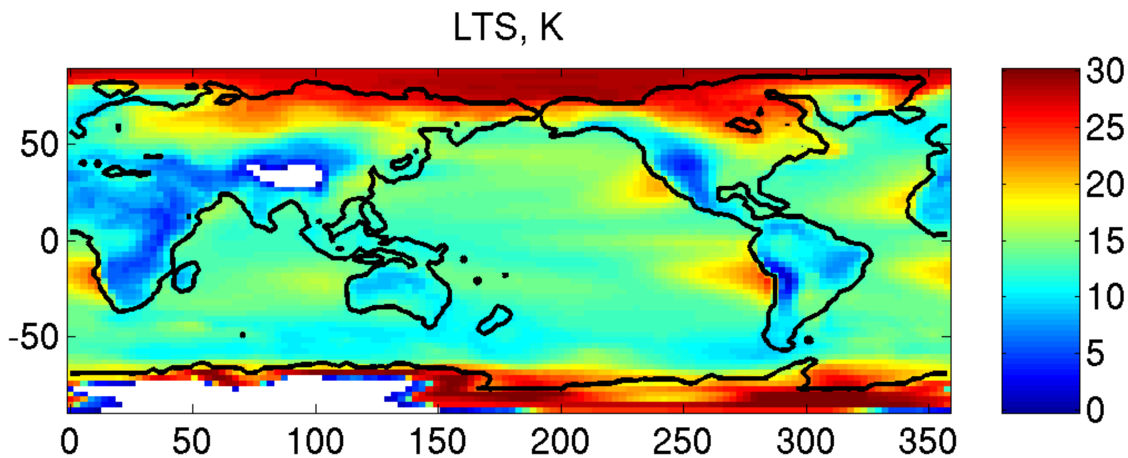
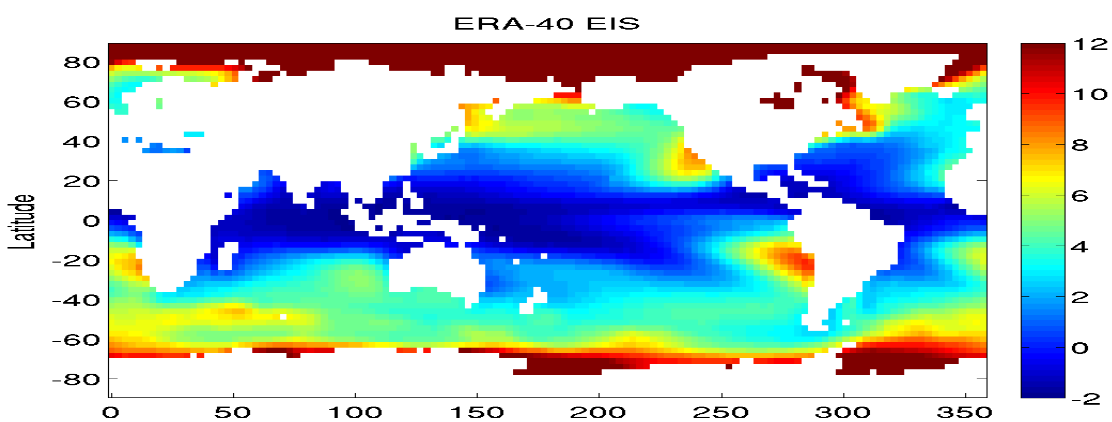


FIG. 6. Relationship between (a) LTS and low cloud amount, and (b) EIS and low cloud amount, for seasonal means at the locations described in Table 1. All seasons/regions where LTS > 10 K are plotted.







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

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

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.