Changes in Cloud Cover and Cloud Types over the Ocean from Surface Observations, 1954-2008

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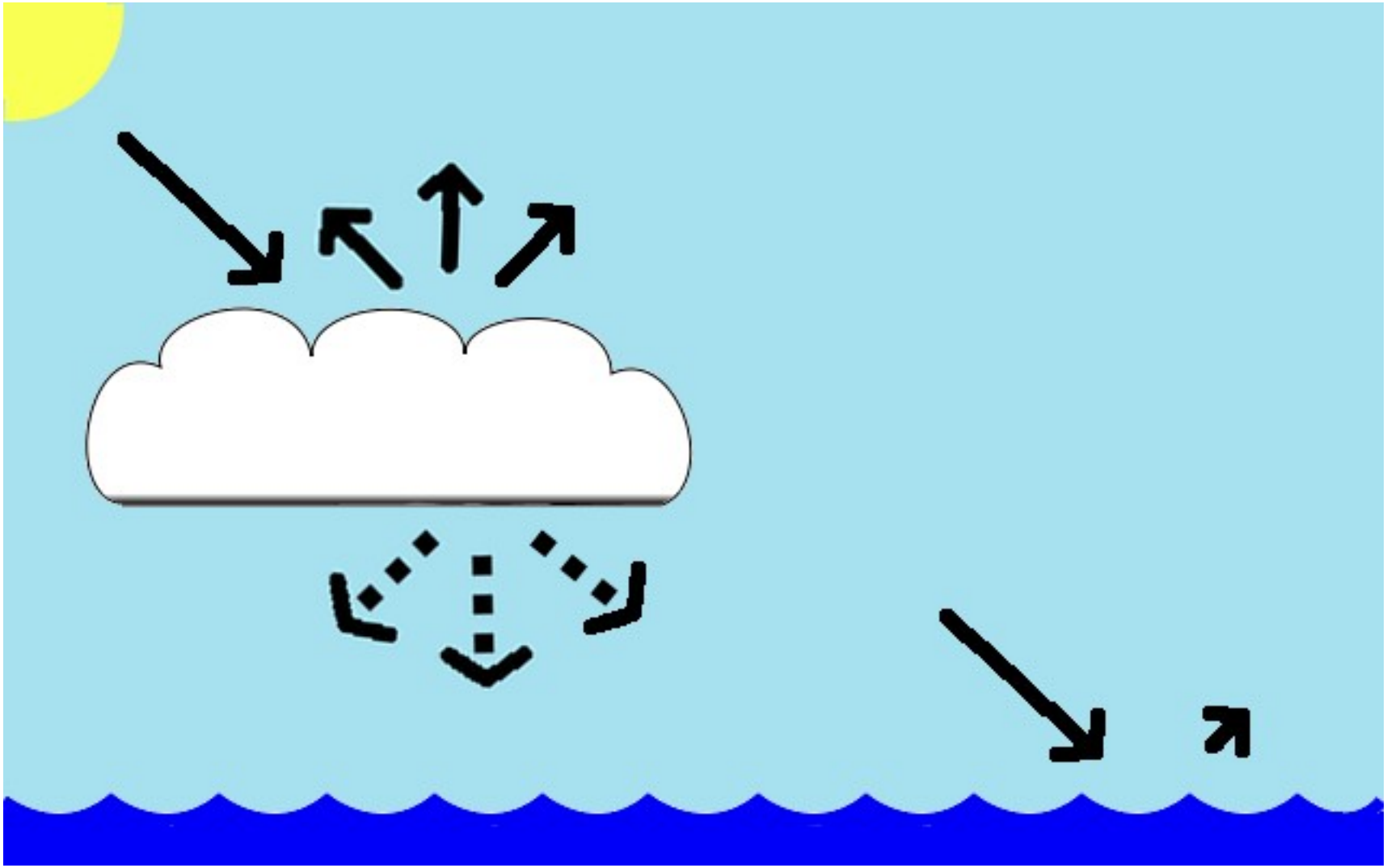
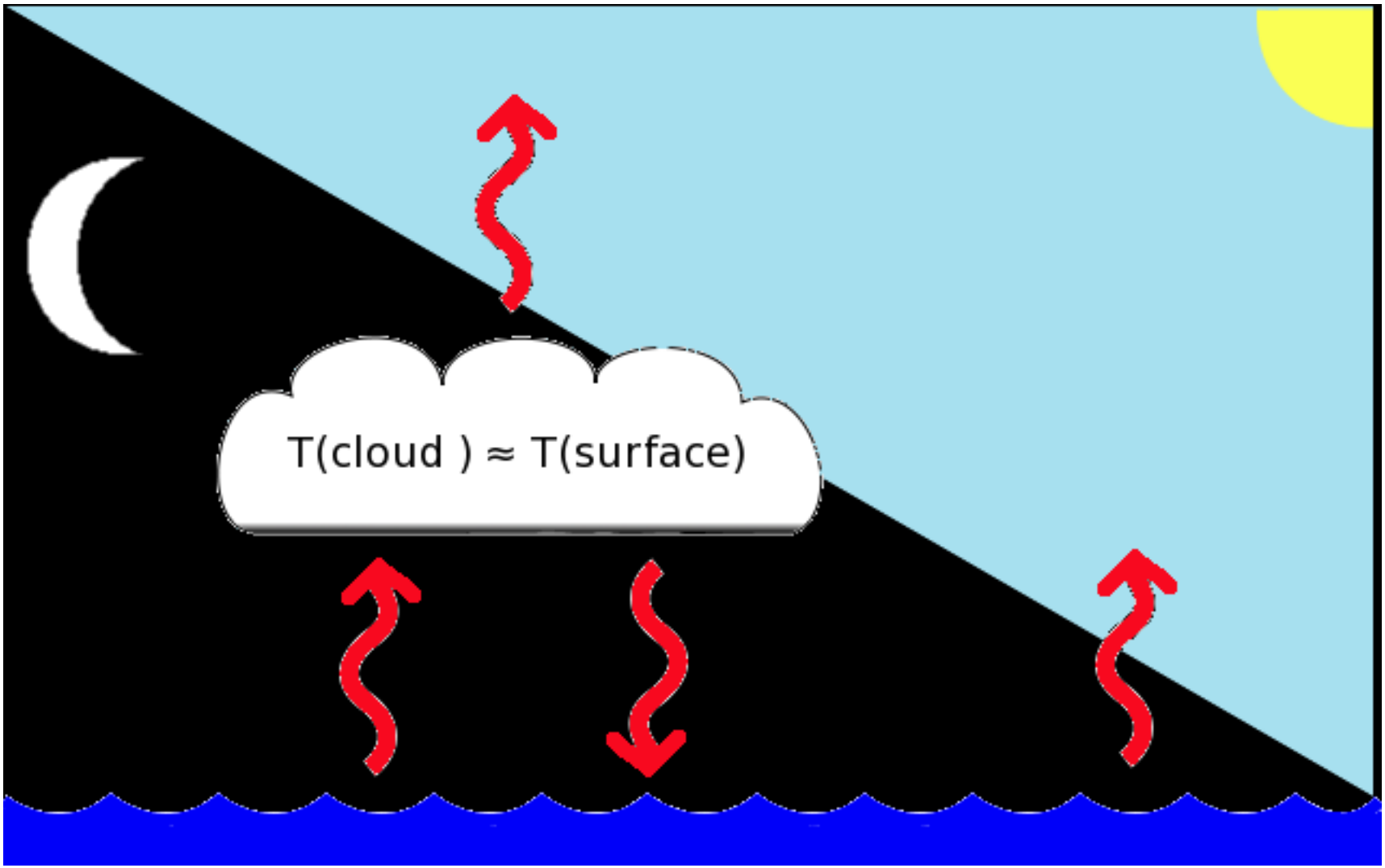
Clouds and the Environment

- Clouds can warm or cool the surface
- Depends upon:
  - Cloud type
  - Cloud height
  - Surface characteristics (albedo)
  - Time of day
- Surface feeds back on cloud characteristics

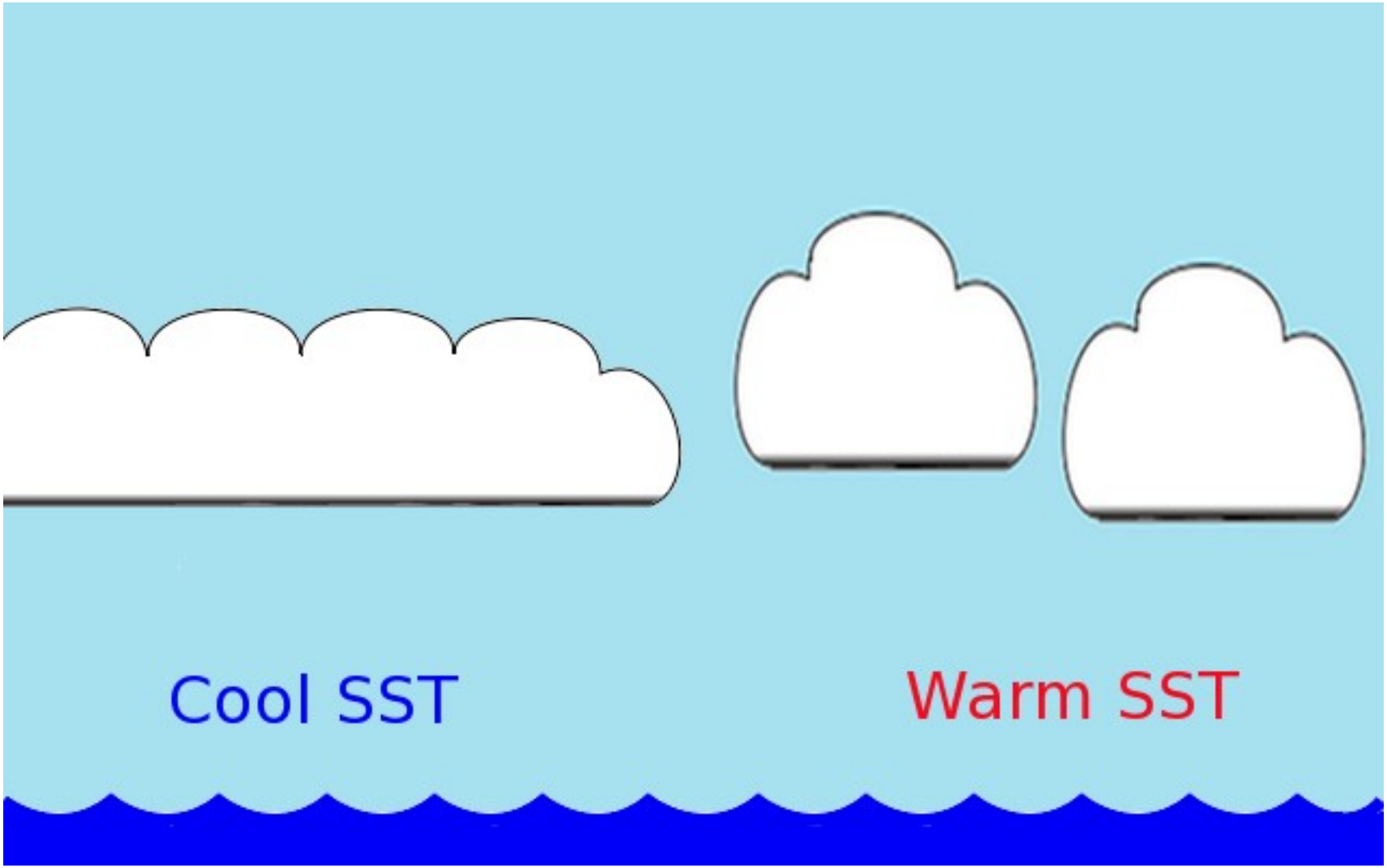
Clouds and Sunlight



Clouds and Infrared Radiation (IR)



Low Clouds and Sea Surface Temperature

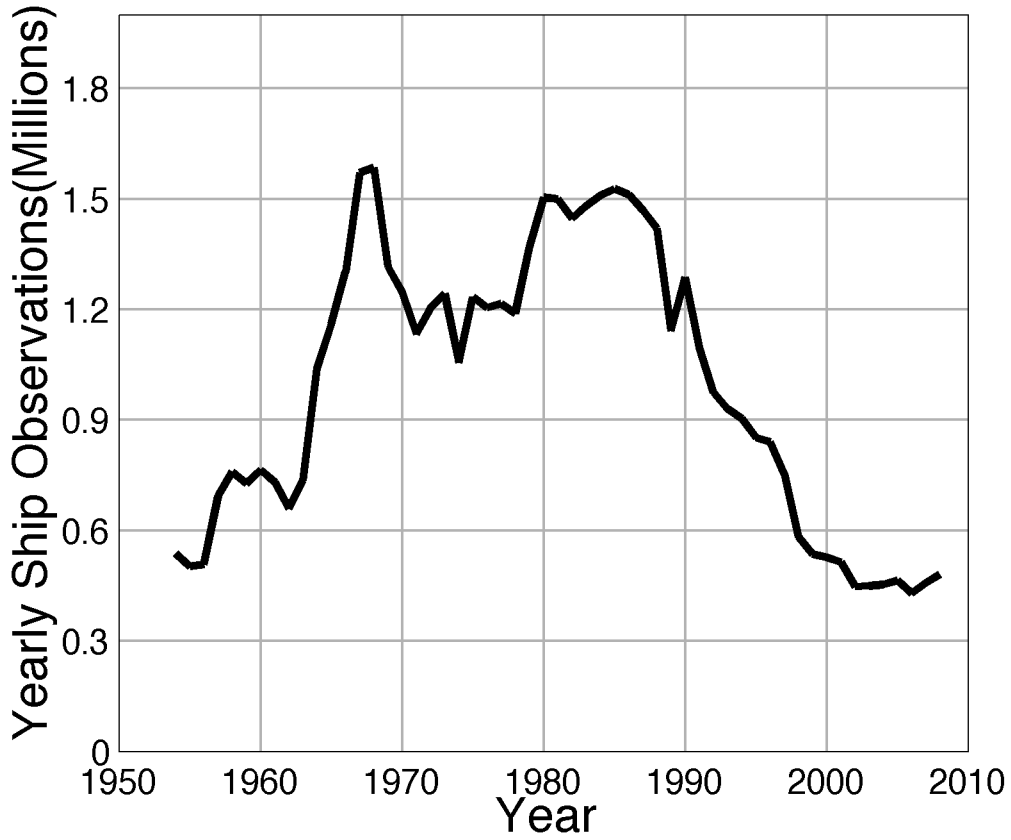


Cloud Data

- To better understand and relate cloud cover to atmospheric processes and changes we need:
  - Cloud types
  - Cloud levels (low vs. high)
  - Separate day vs. night cloud amounts
  - Long period of record
- Surface observations provide all of this information with the longest continuous period of record

Surface Observed Cloud Climatology

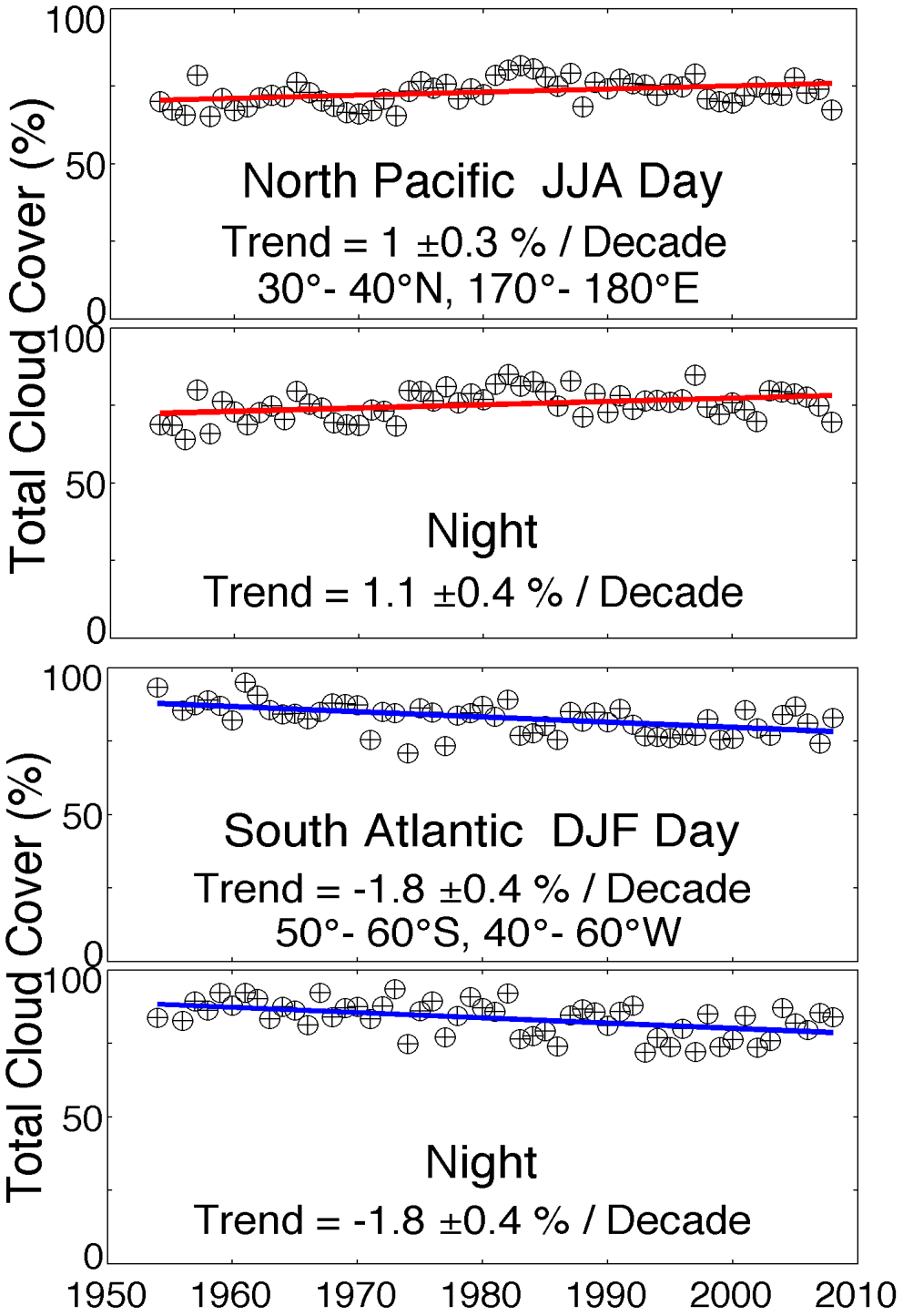
- Ocean data spans 1954-2008
  - Based on data from ICOADS
  - Data from ships (and drifting stations on sea ice)



- Land data spans 1971-1996 (update to 2009 forthcoming)
  - From fixed weather stations on land
  - Using new source after 1996 (ISH, from NCDC)

Day & Night Observations

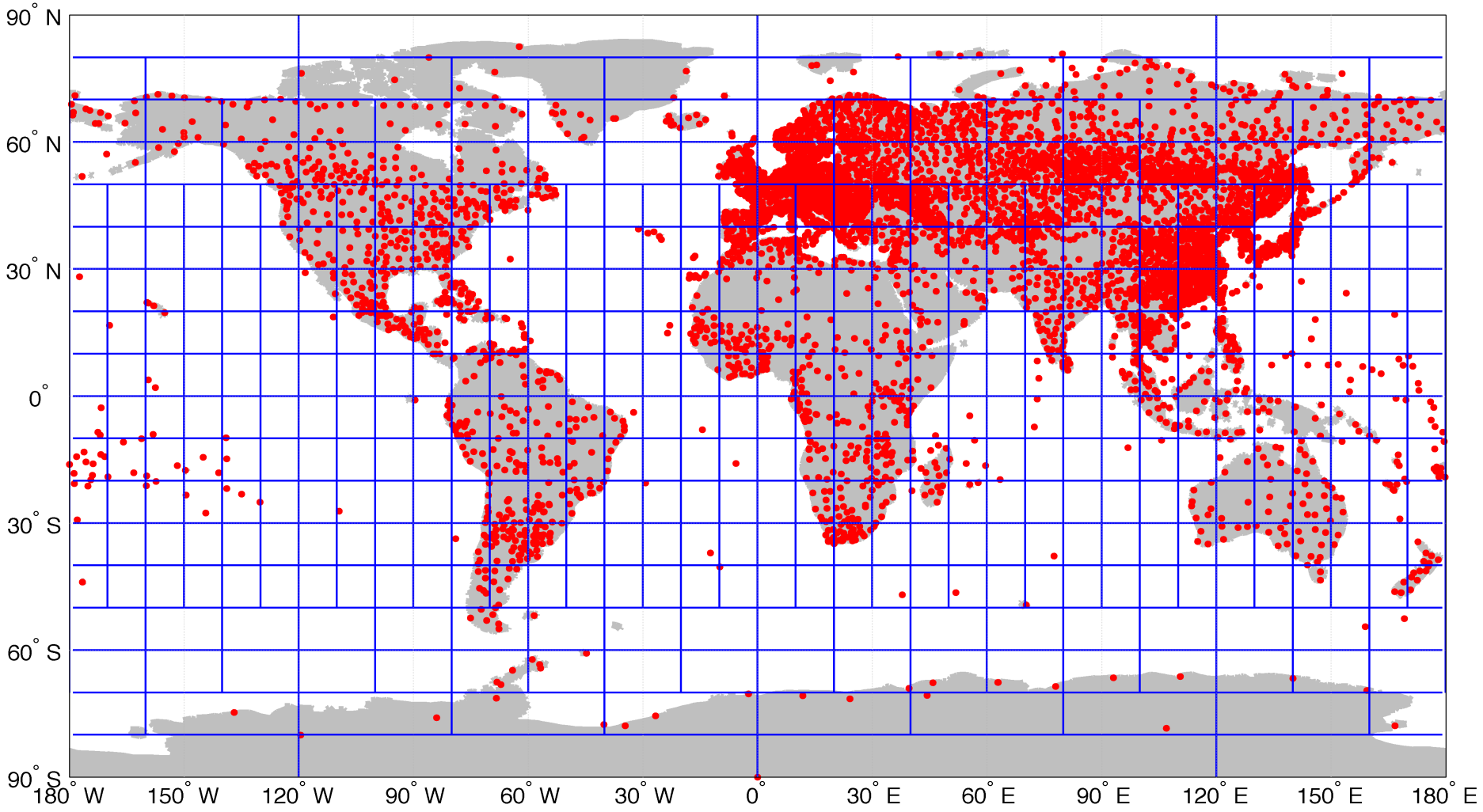
- We select only observations made under specified conditions
- Night trends and variations are similar to day
- For this study, only daytime observations are used



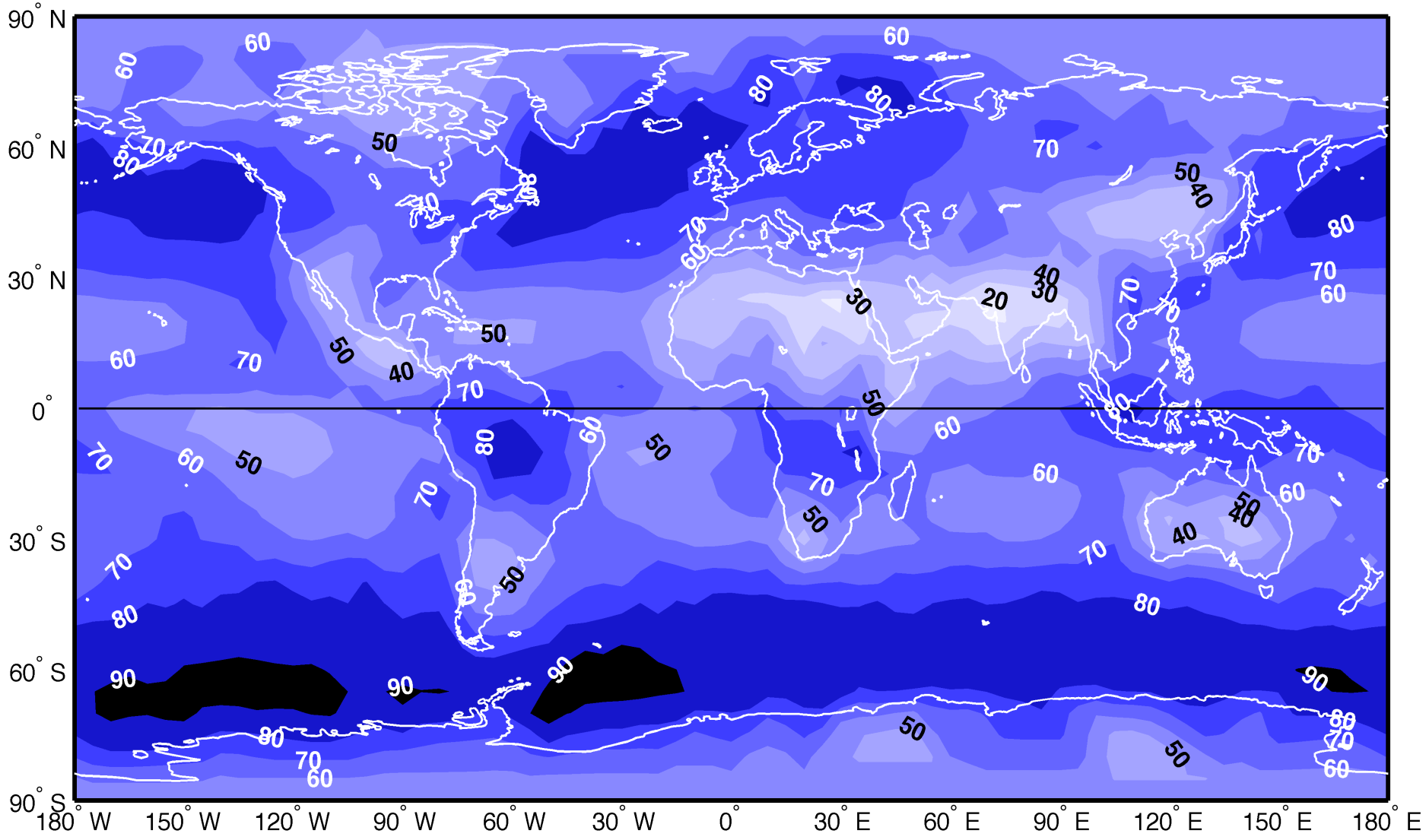
Surface Observed Cloud Climatology

- Total of 9 cloud groups plus total cloud cover and clear-sky frequency
  - Low level clouds:
    - Stratocumulus, Stratus, Fog, Cumulus, Cumulonimbus
  - Mid level clouds:
    - Altostratus, Altocumulus, Nimbostratus
  - High cloud (cirriform)
- Cloud Amount as well as Frequency of Occurrence
- Though synoptic observations allow for 27 cloud types (9 at each level), reporting differences between nationalities requires averaging sub-types into this structure.

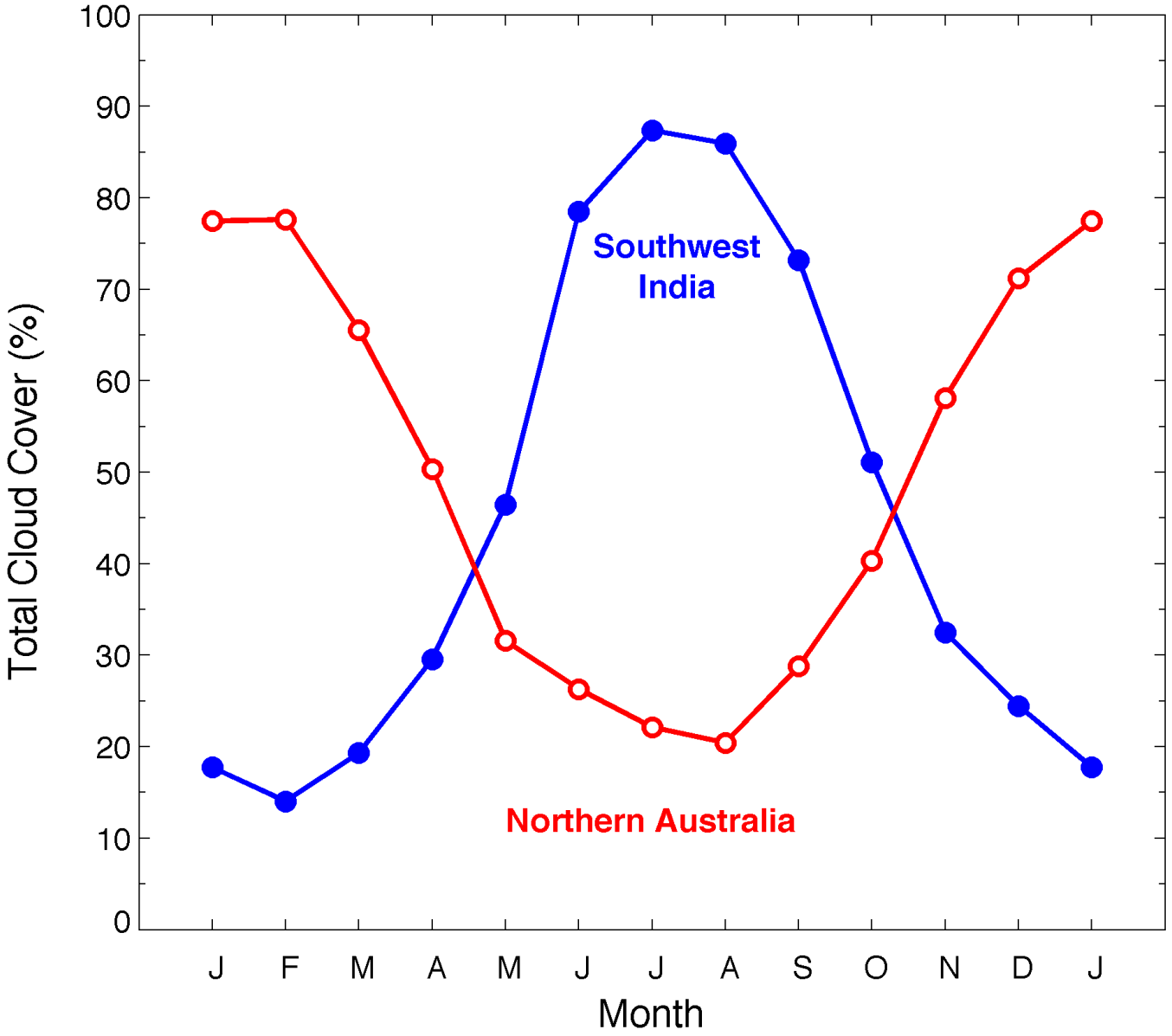
Data Available at Weather Stations or on a Grid



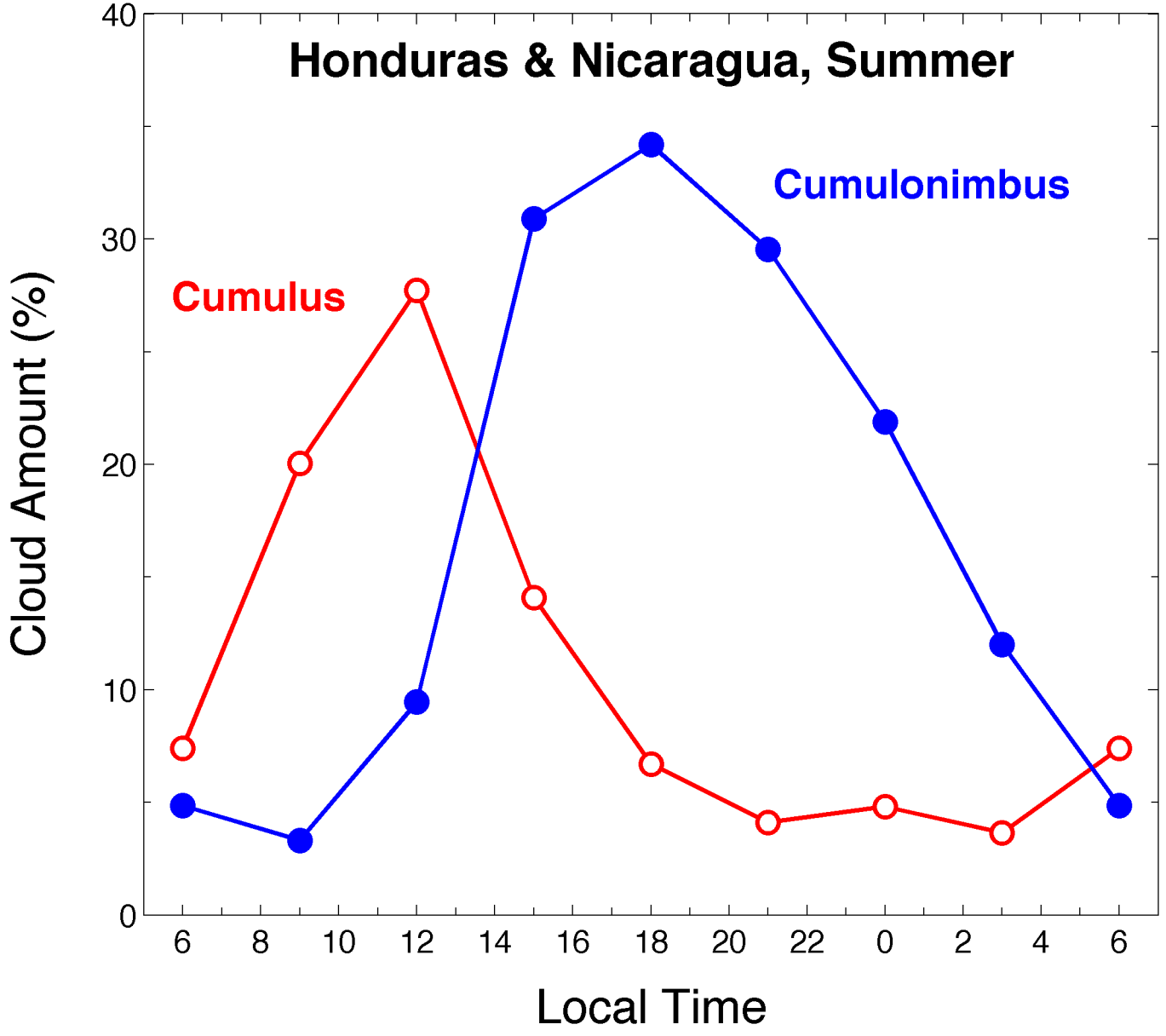
Data Products: Monthly & Seasonal Averages



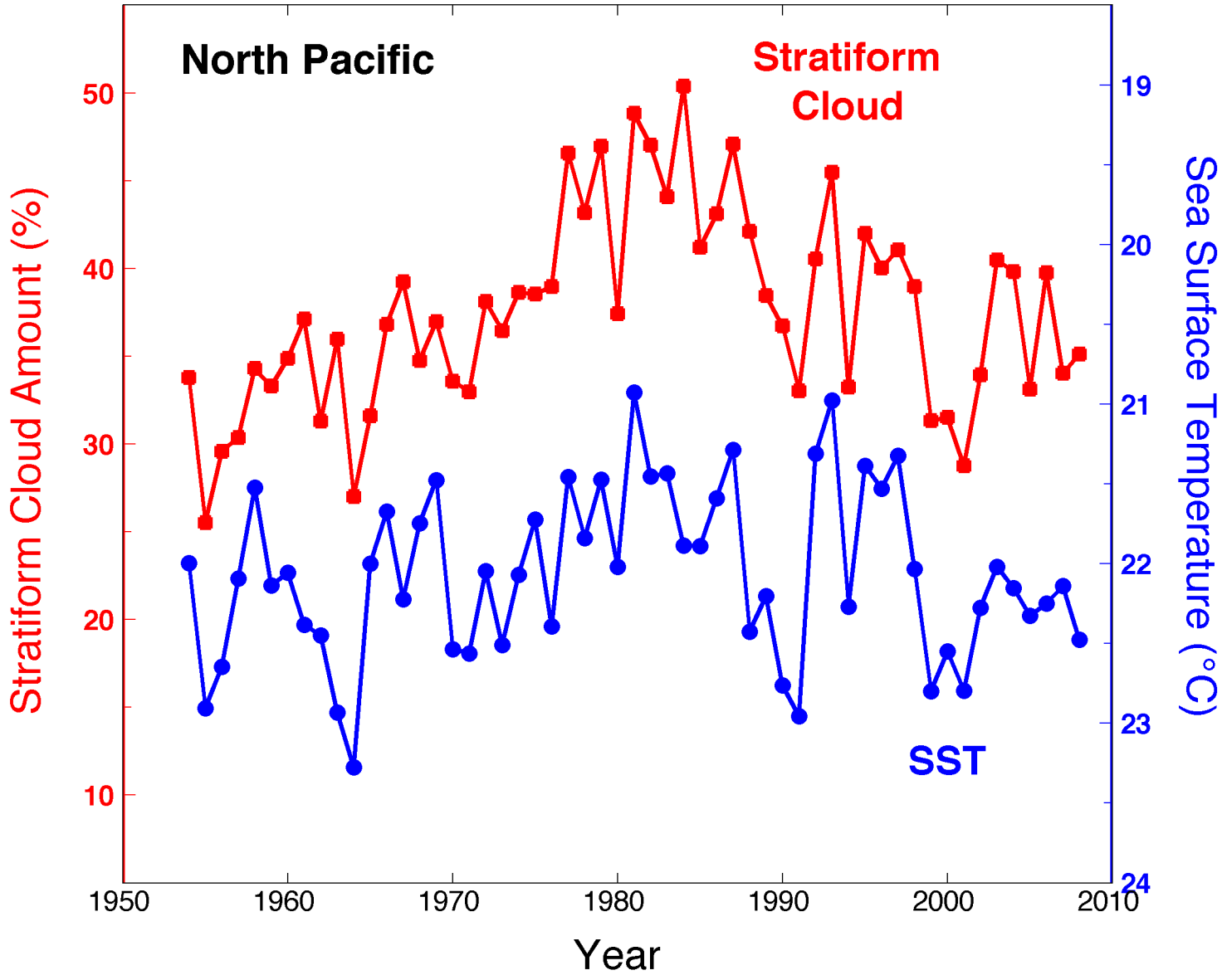
Data Products: Monthly & Seasonal Averages



Data Products: Diurnal Cycle – Every 3 Hours

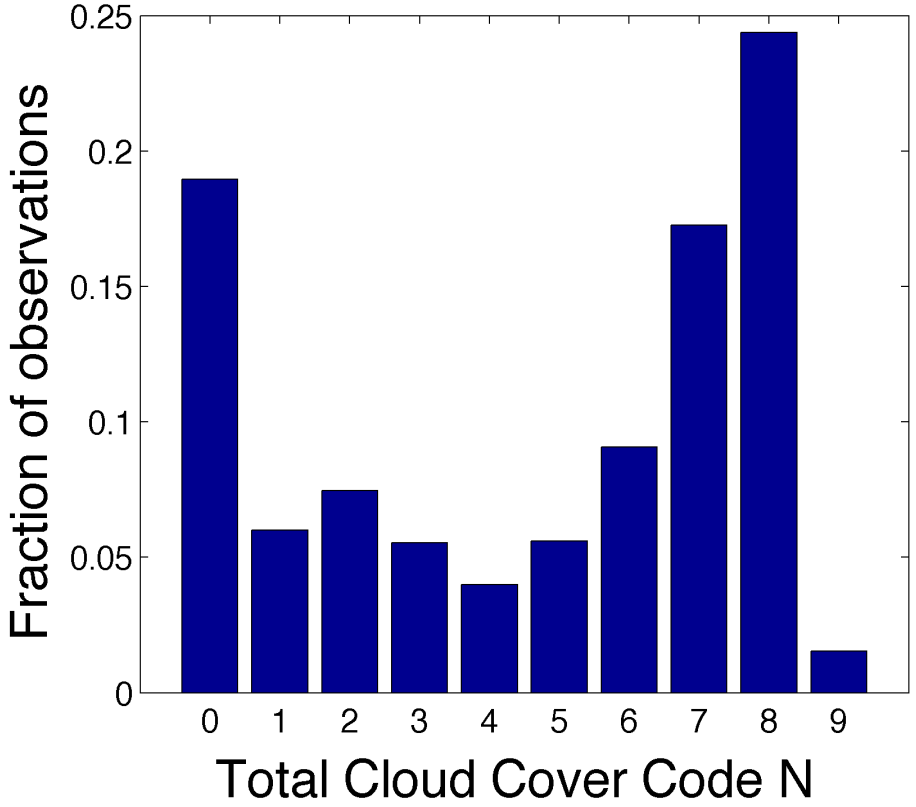


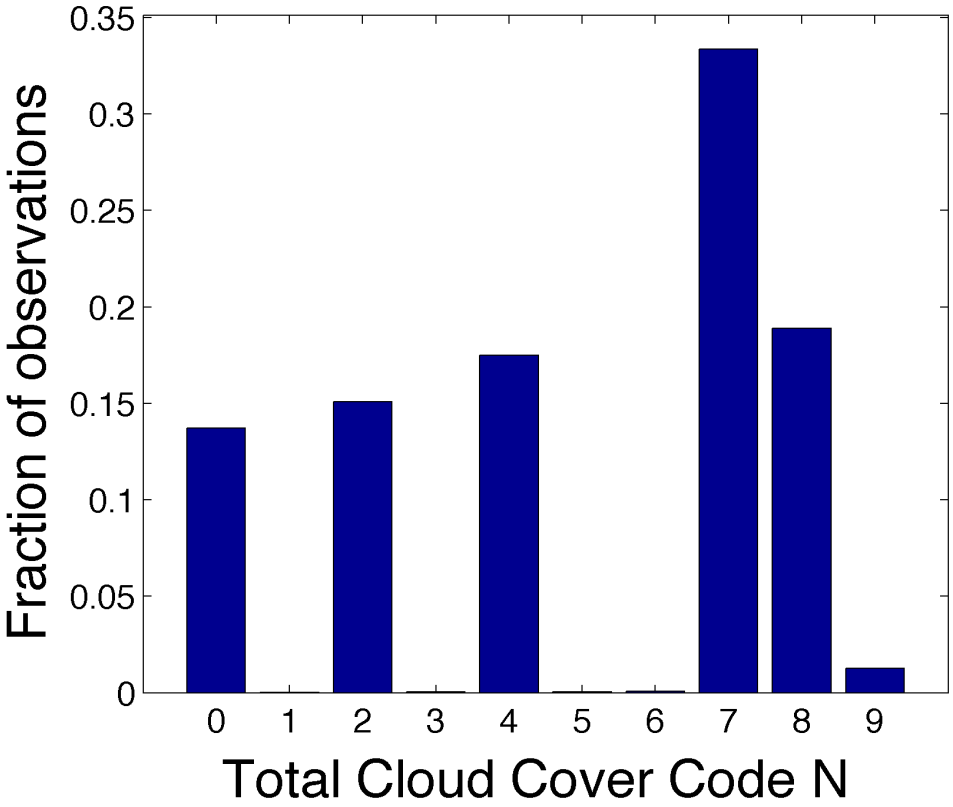
Data Products: Year-Year Variations



Quality Control & Averaging (Land Stations)

- Stations are evaluated first by analyzing relative frequency of reported cloud amounts





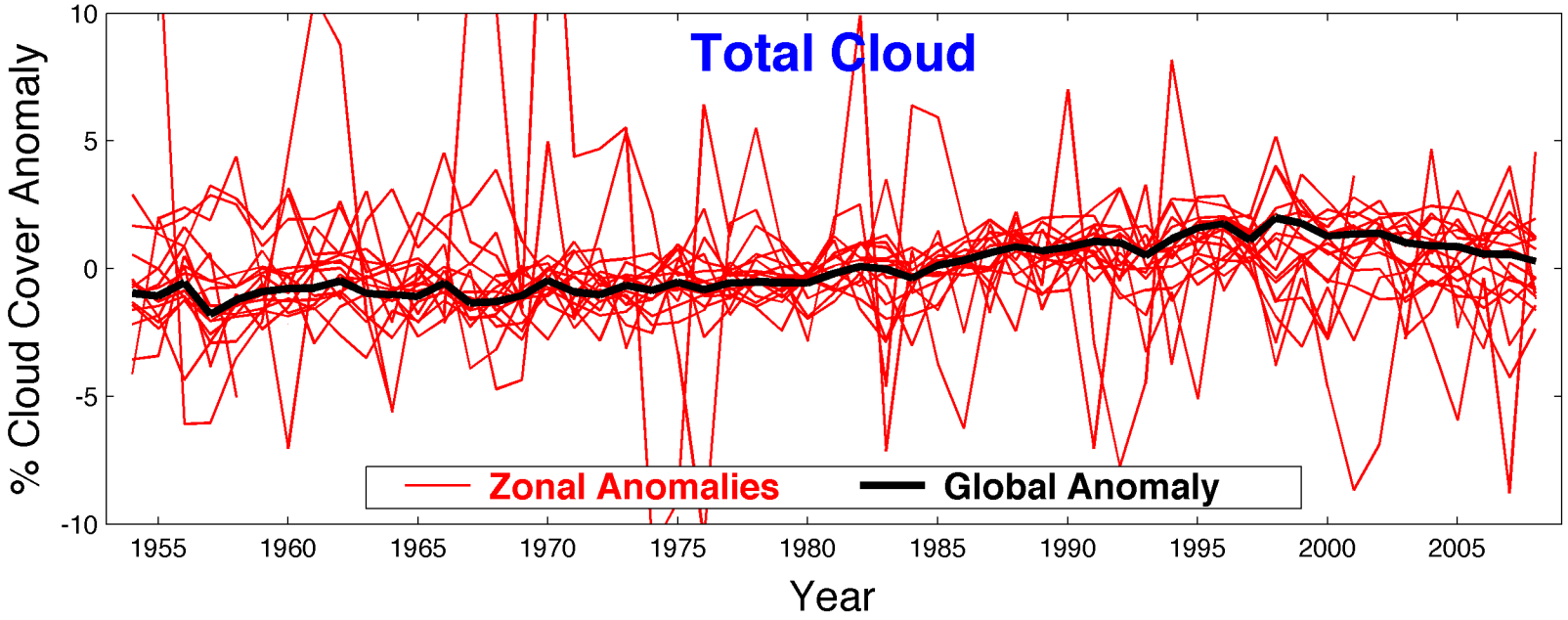
- Good frequency count
- Done by human observer in the synoptic code

- Bad count
- Likely an automated observer (ASOS)

Quality Control & Averaging

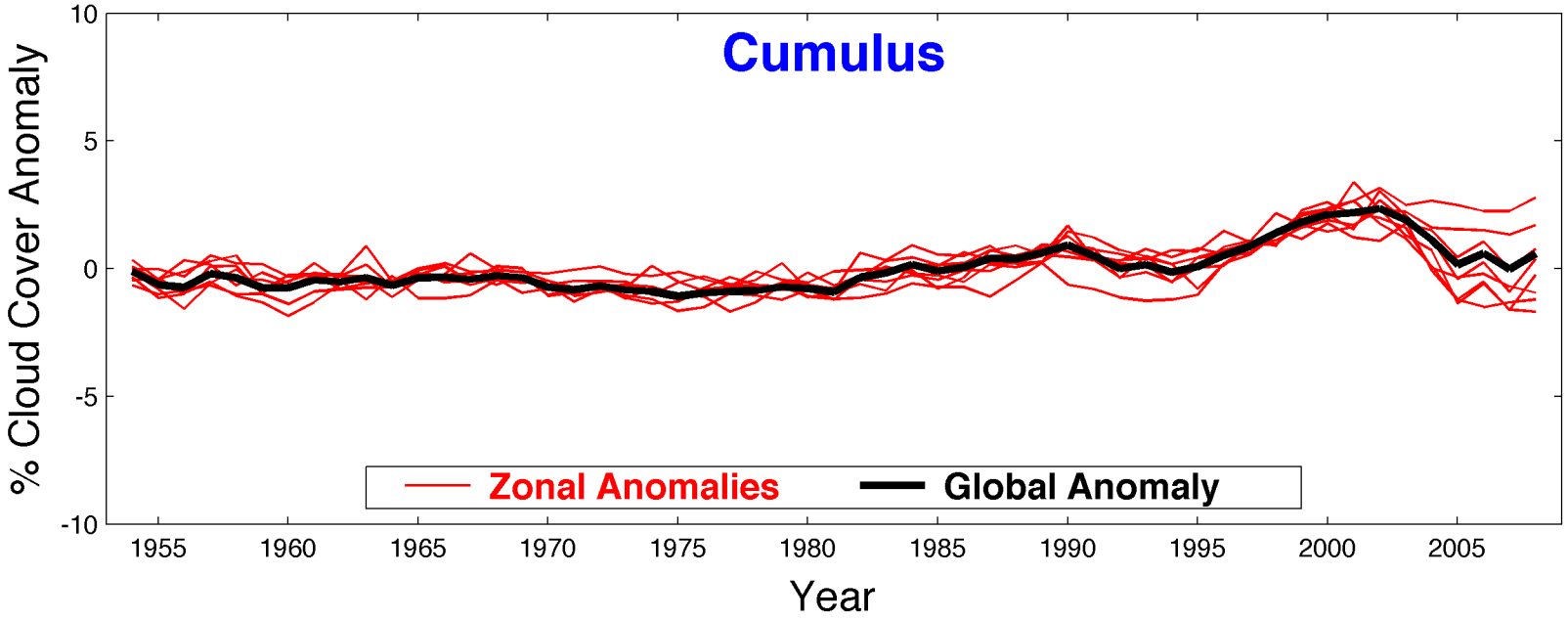
- Good ship reports are averaged within 10° lat/lon grid boxes
  - Average cloud amounts are formed per season, per box with a minimum of 25 observations per season
- Global average time series calculated using seasonal anomalies
  - Individual boxes require 30 years in record, each decade (1954-2008) represented by 3 or more years – to contribute to global averaging
  - Seasonal box values averaged based on relative box size & ocean area
  - Eliminates most bias due to unequal # of observations between boxes, different box size/ocean area

Global & Zonal Time Series



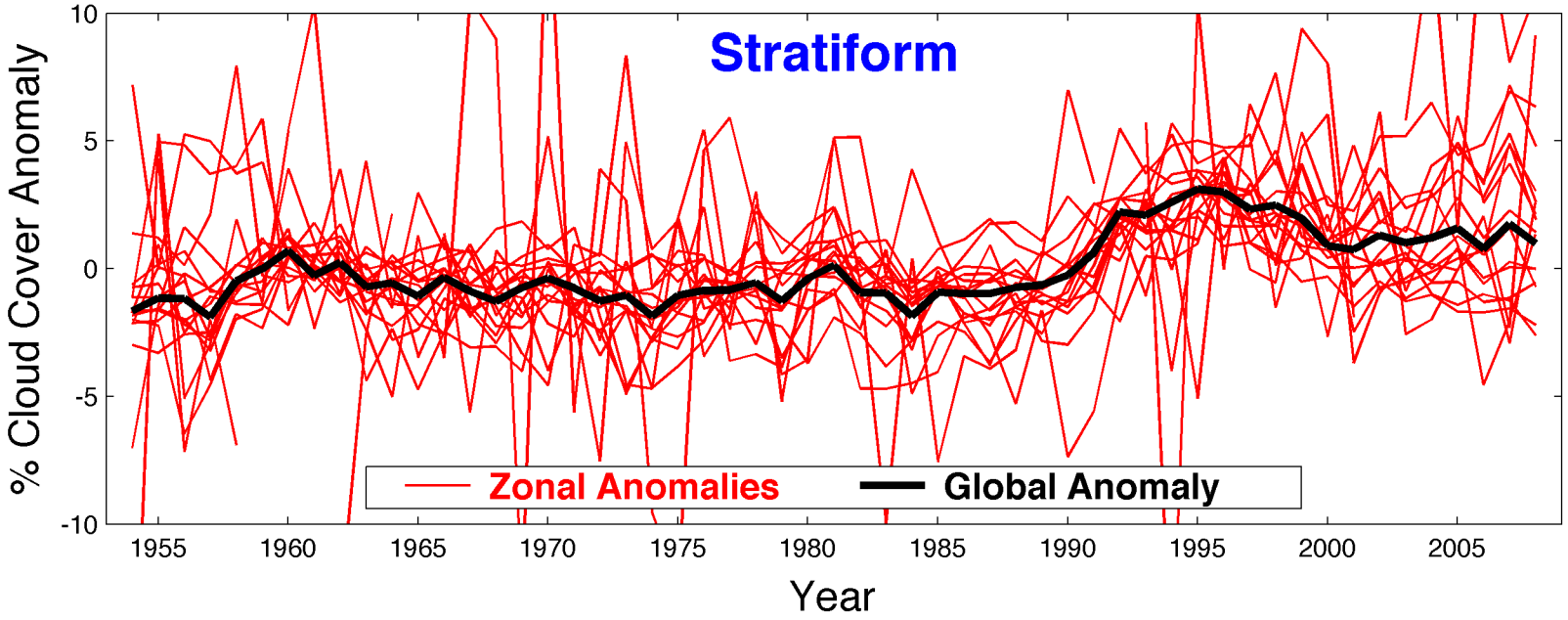
- After quality control and averaging, global time series are computed
  - Long-period variation, coherent between latitude bands (zones) seen in time series
  - Variation is seen for most cloud types

Global & Zonal Time Series



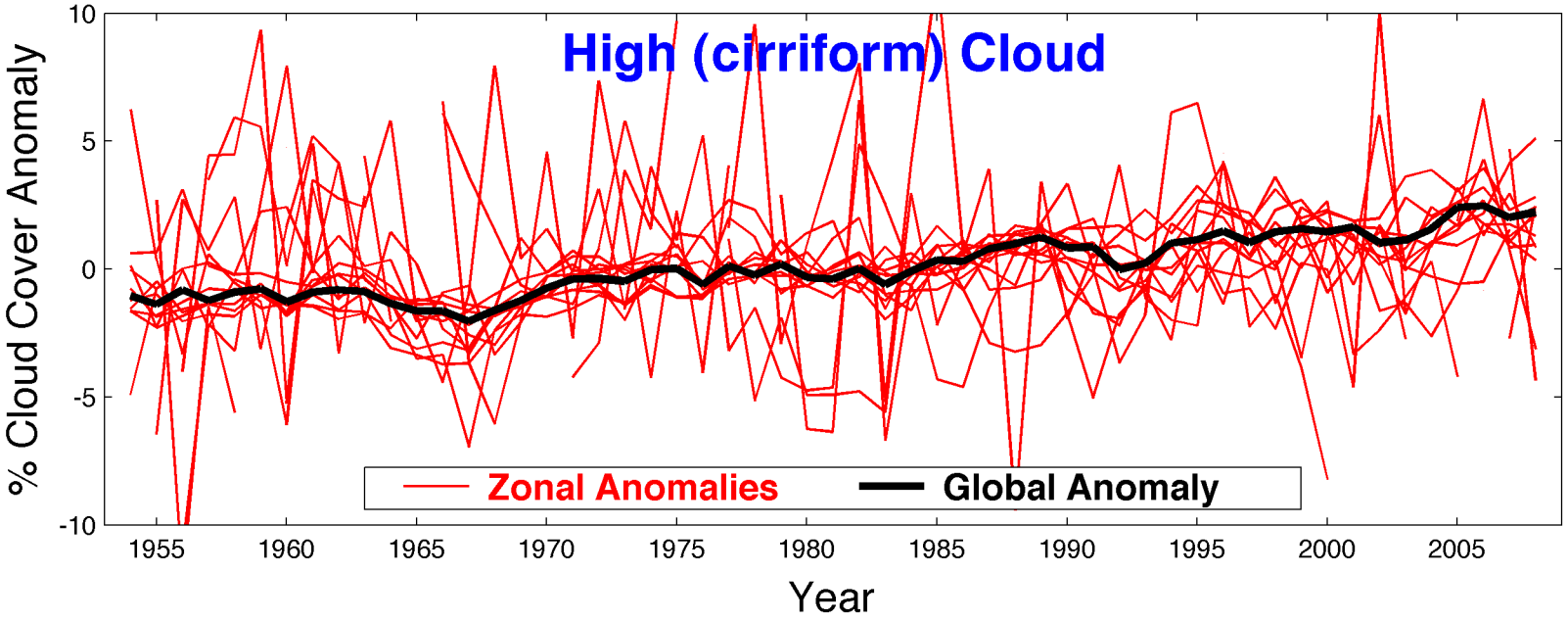
- No trade-off between types is seen
- No proxy data shows agreeing variation (that we have found)

Global & Zonal Time Series



- Possible explanation 1:
  - Variations in fraction of ships from different countries
  - Testing was done by Joel Norris
    - Attempted to simulate changes in nationalities over time
    - Did not produce the same variations

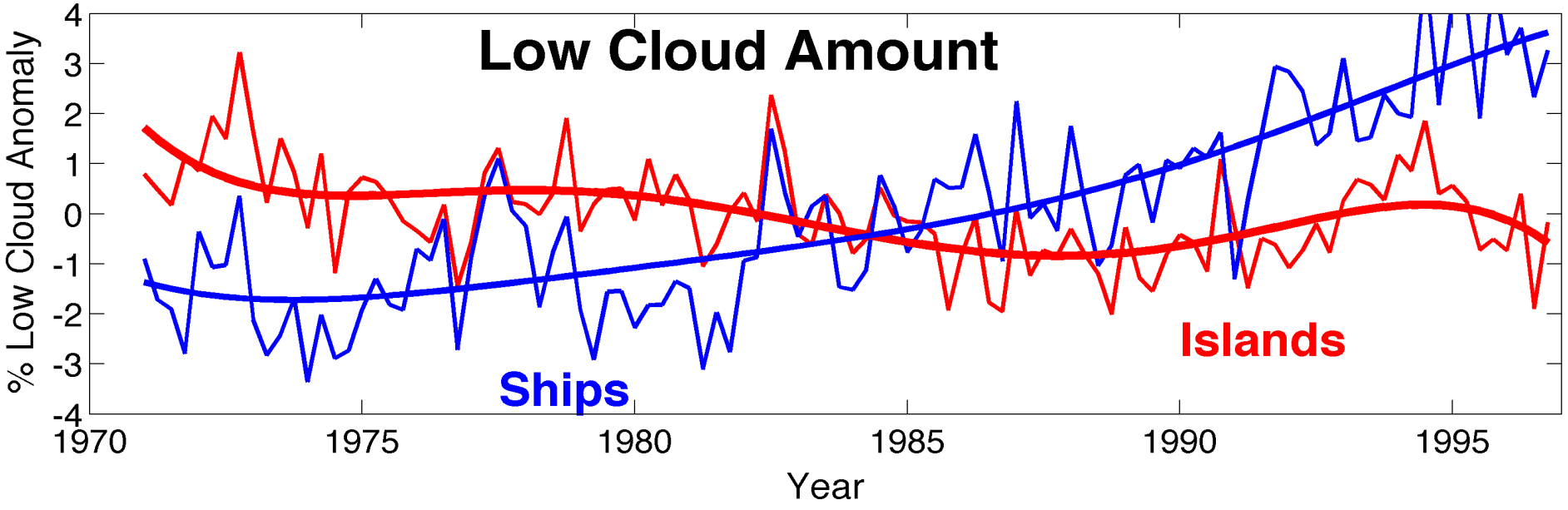
Global & Zonal Time Series



- Possible explanation 2:
  - Subtle changes in observing procedure over time
  - No changes have been documented

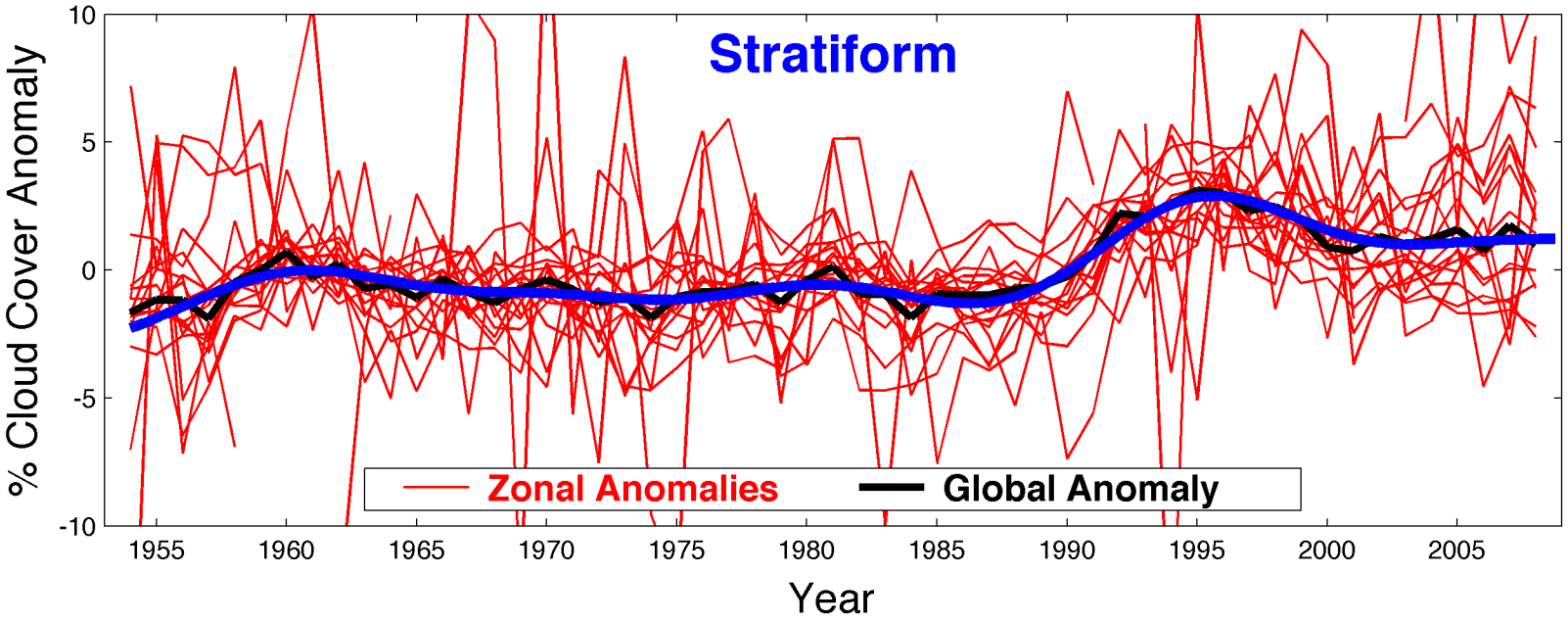
Global & Zonal Time Series

- Long-term variations from ship observations have been compared to those taken on islands in the central Pacific Ocean
  - Little agreement is seen on the long-term scale, while agreement IS seen at shorter time scales (year-year)
- Therefore, these variations are assumed to be spurious, must be removed



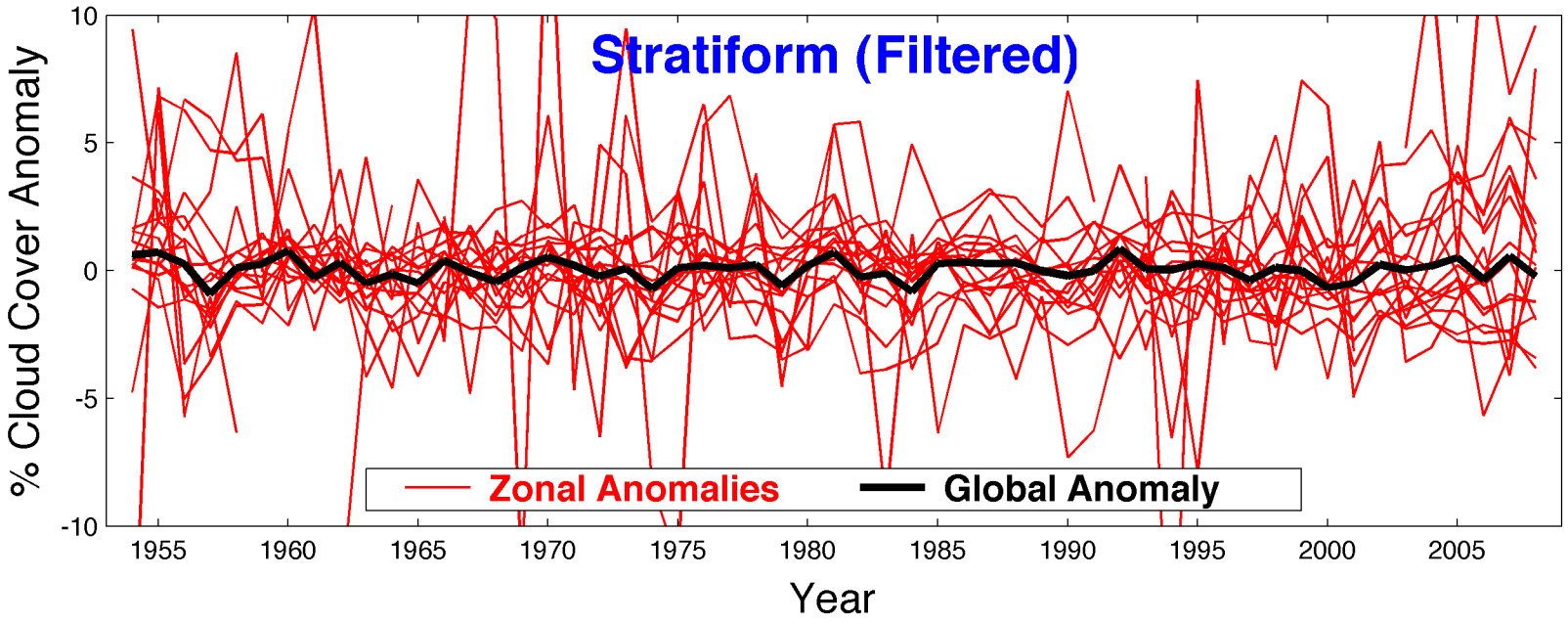
Removing Spurious Variation

- Long-term, global variation is approximated using a low-pass filter (blue curve)



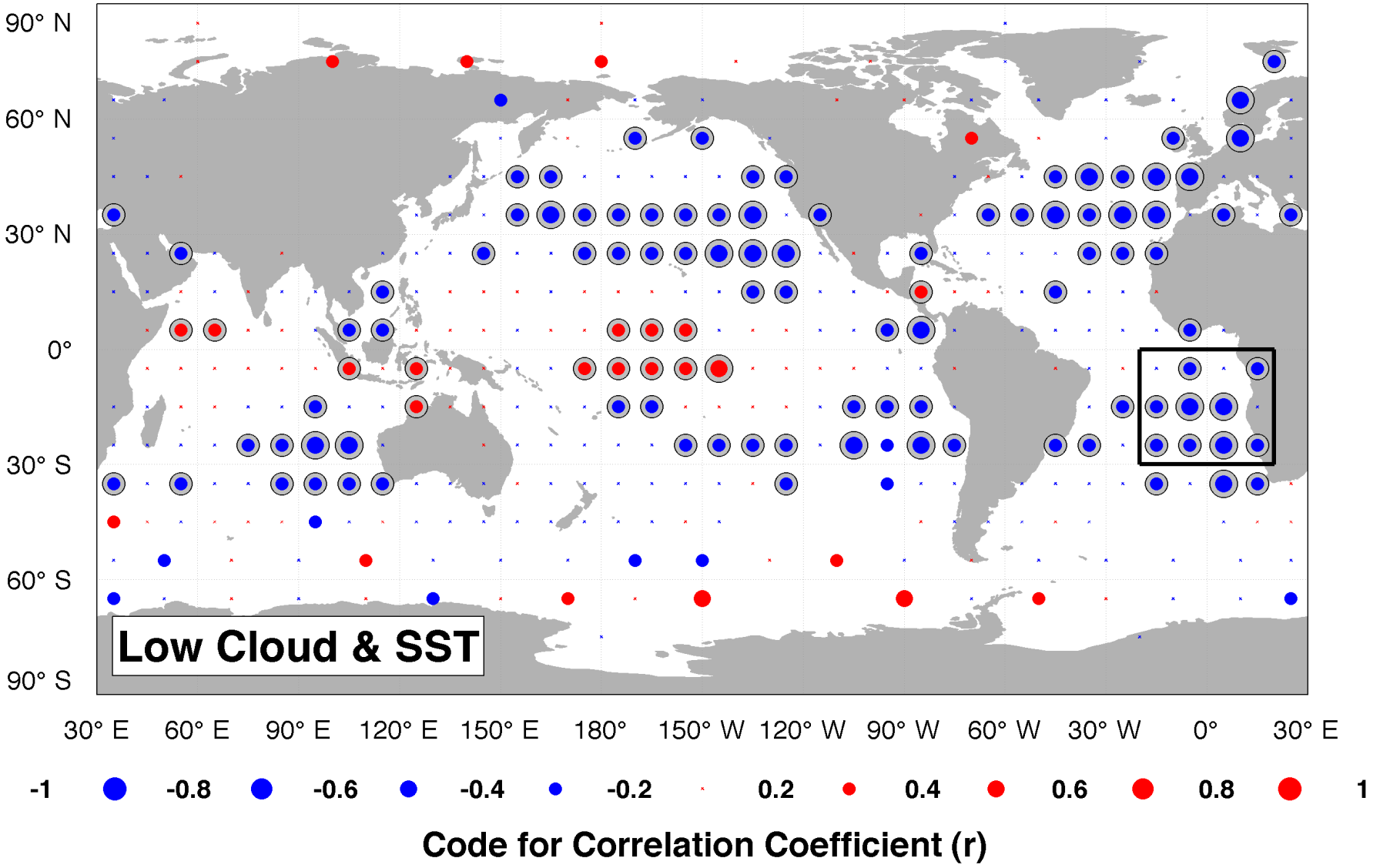
Removing Spurious Variation

- In each box, filtered time series is scaled to mean cloud amount then subtracted
- Assumes no global trend, so our focus is on regional variation



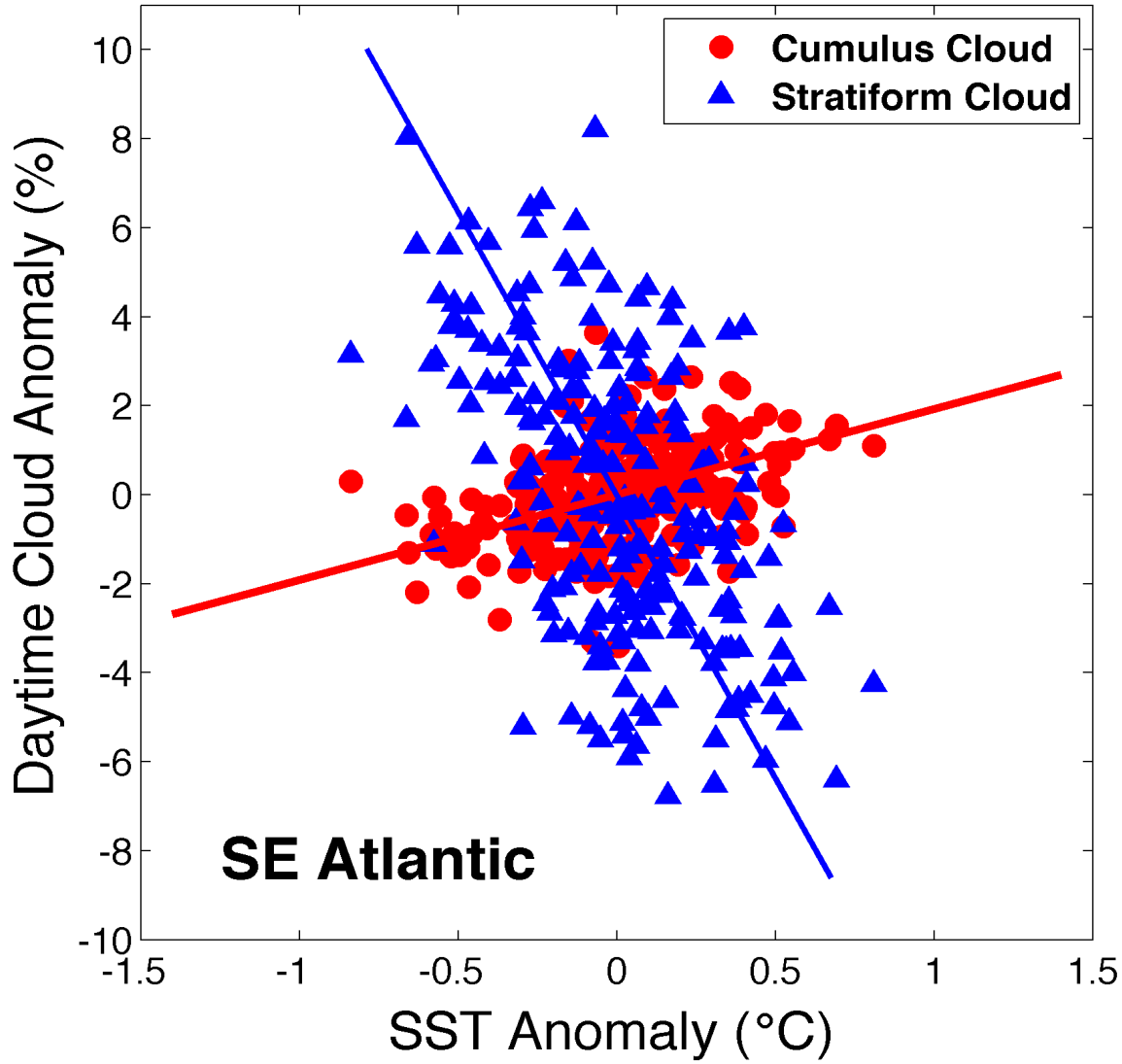
Correlation of Low Cloud Cover with SST

- SST and cloud time series filtered locally (in each box)



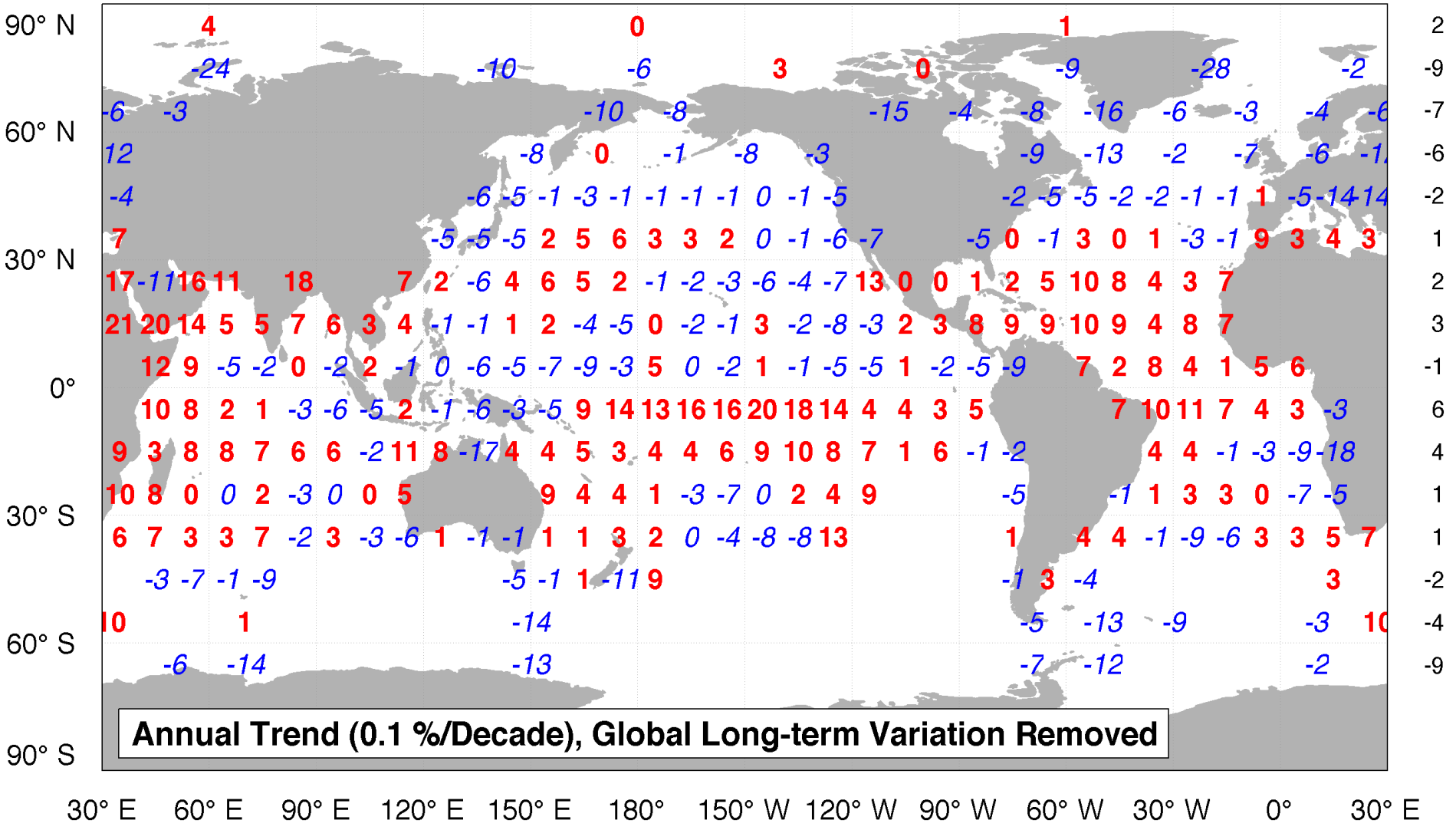
Correlation of Low Cloud Cover with SST

- Low clouds break up as SST warms
  - Stratiform clouds become patchy
  - Cumulus clouds prevail
  - Warming SST reduces overlying low clouds
  - Positive feedback
- Low cloud changes?



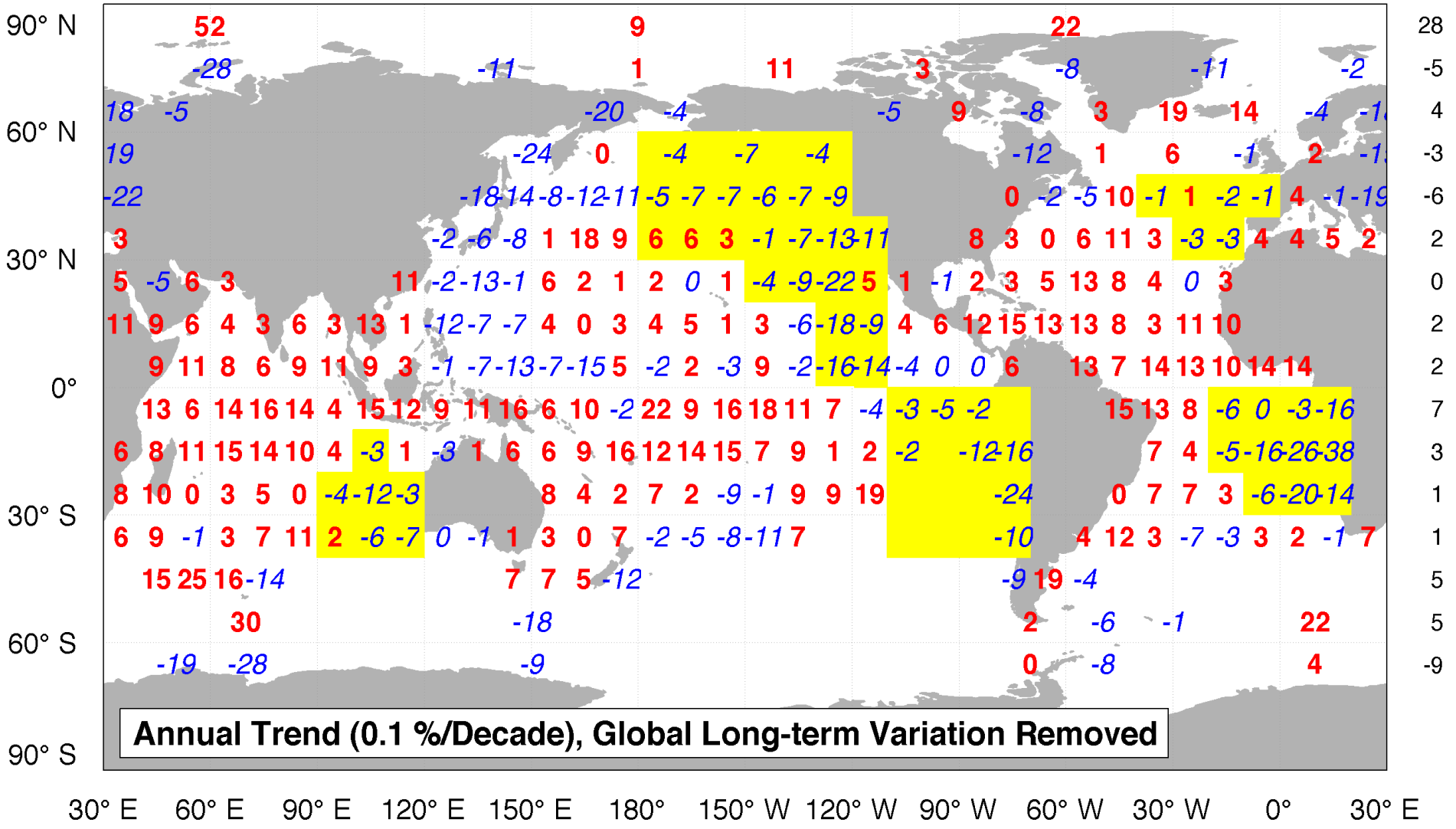
Linear Trends in Total Cloud Cover

- Trends are generally small (Less than 2% / Decade)



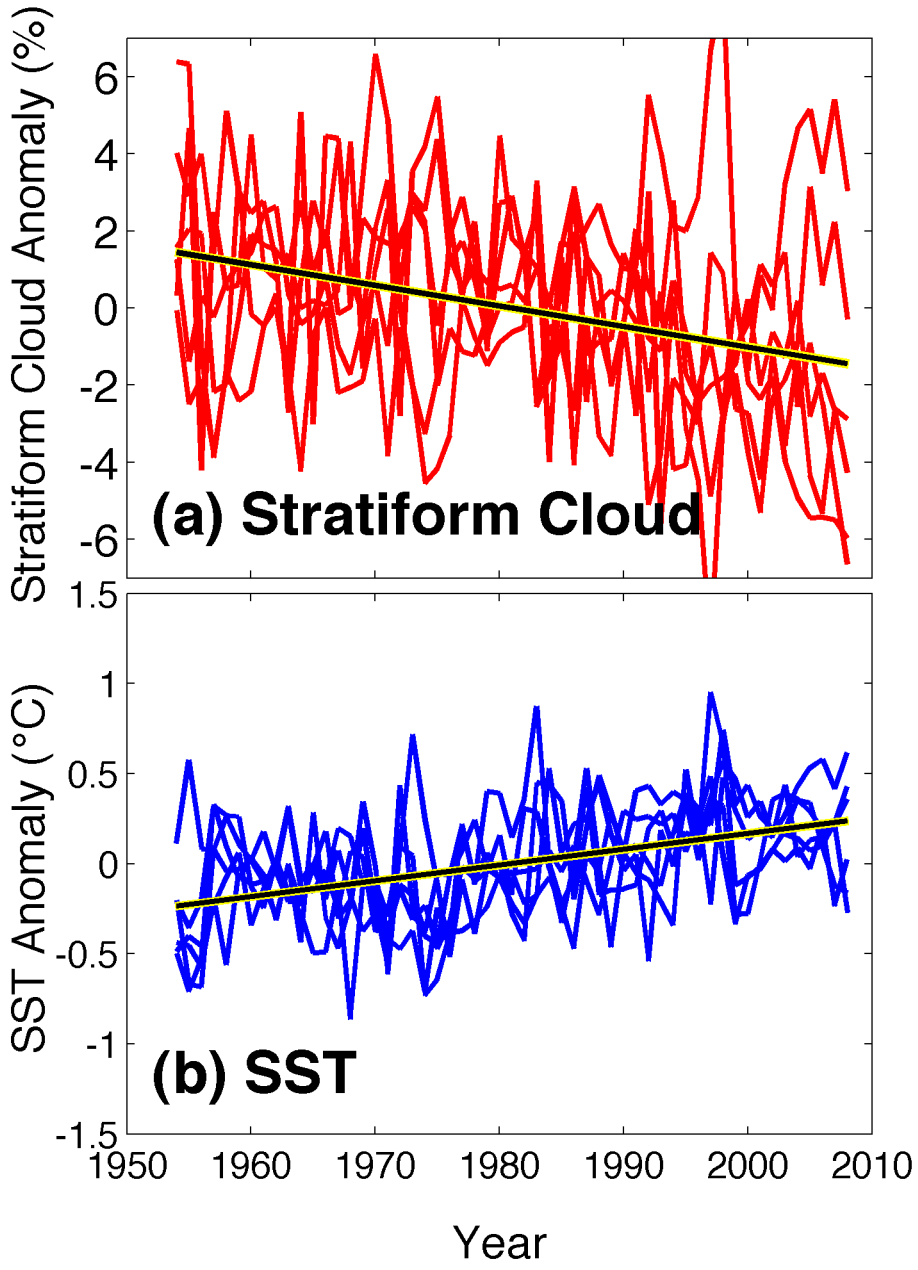
Linear Trends in Stratiform Cloud Cover

- Stratiform cloud cover shows a noteworthy pattern



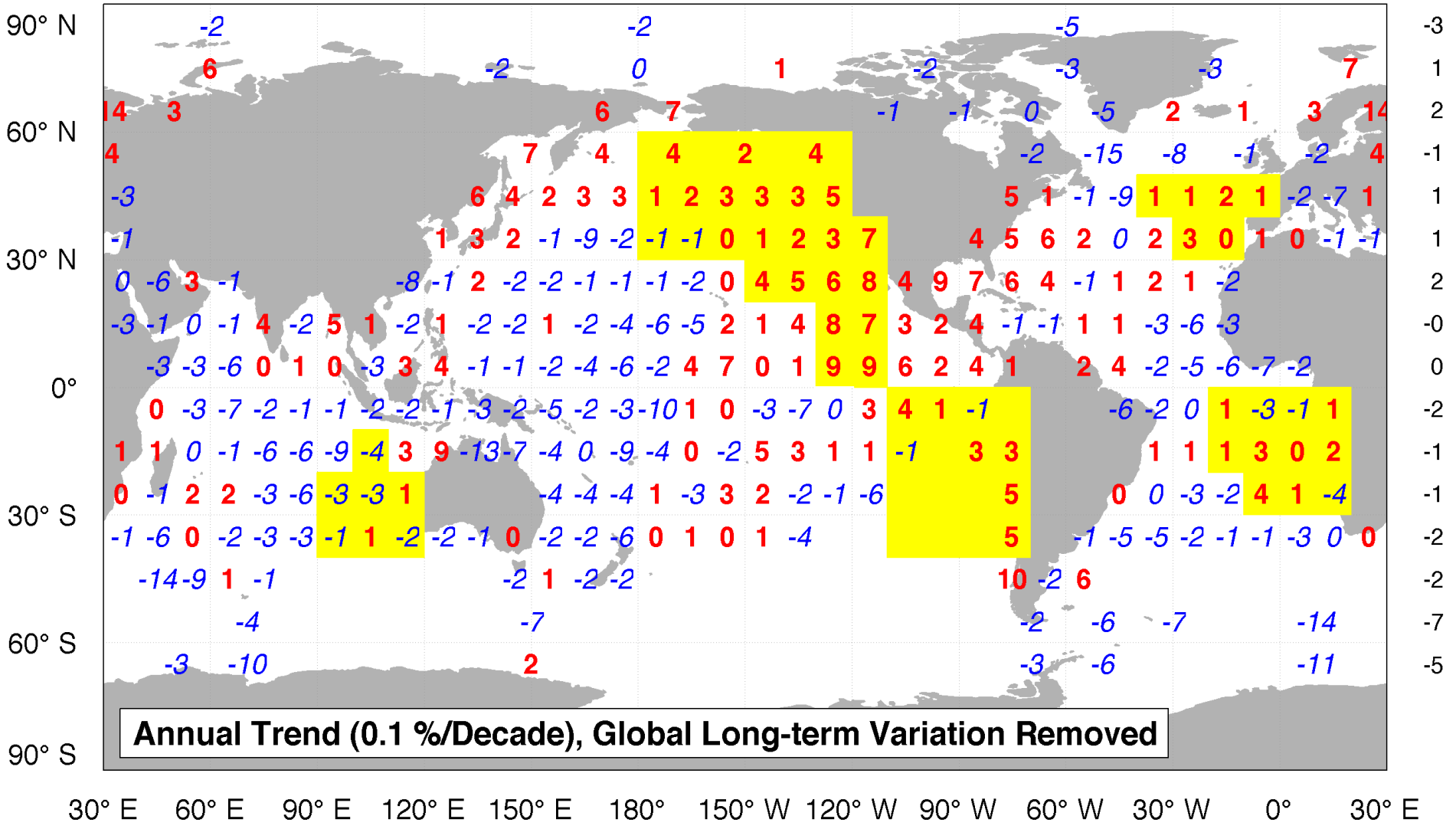
Linear Trends in Cloud Cover

- In regions where Stratiform clouds and SST correlate, stratiform clouds are decreasing
- SST is seen to be increasing in the same areas
- Evidence of a positive feedback to warming sea surface
- Expect an increase in Cumulus clouds



Linear Trends in Cumulus Cloud Cover

- Corresponding increases in Cu are seen, but small



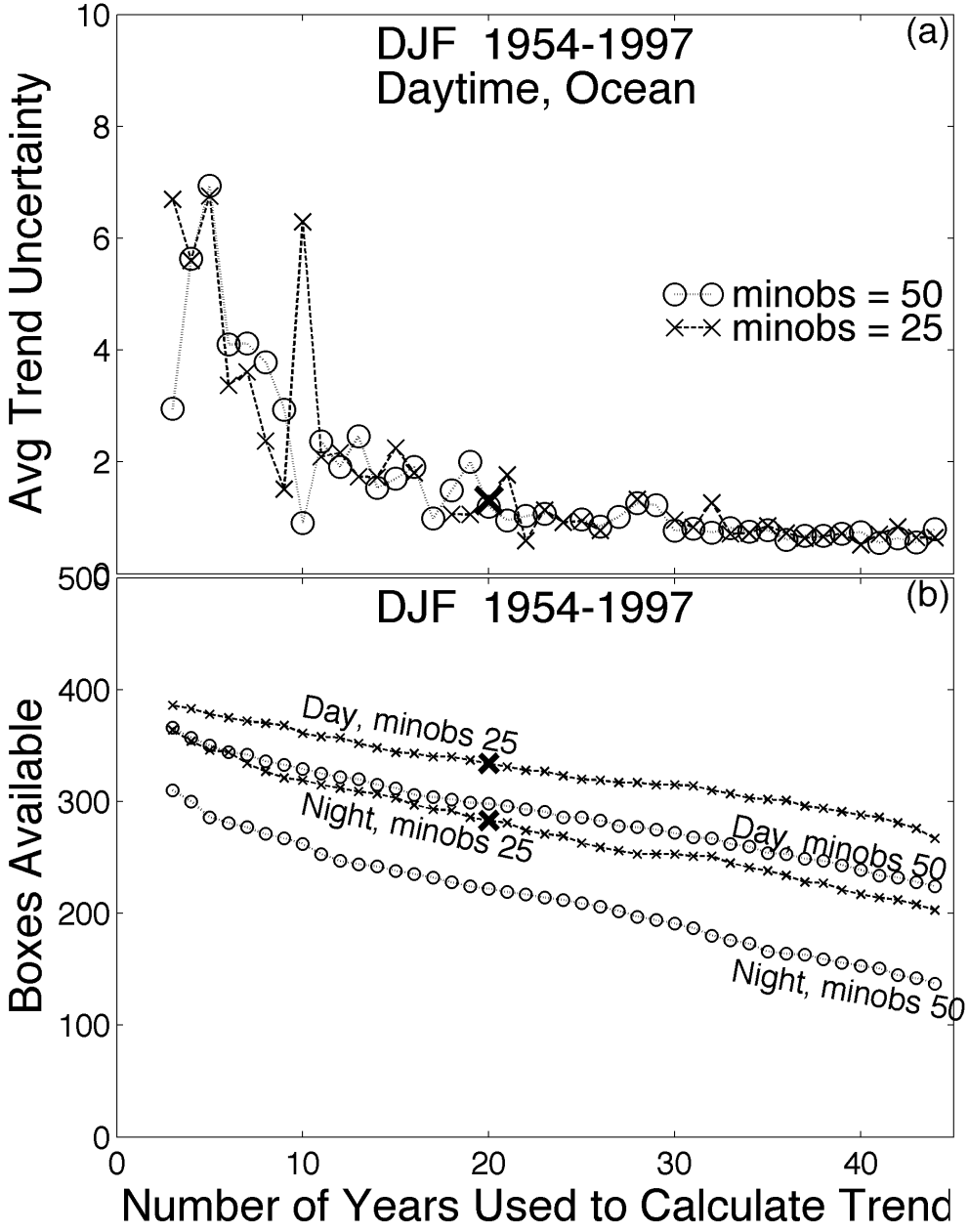
Conclusions

- A cloud climatology from surface observations is available over land and ocean areas
  - Land – 1971-1996 (being updated through 2009)
  - Ocean – 1954-2008
- Mysterious long-term variation is seen in the ocean data
  - We have not seen other 'proxy' data that substantiates the validity of this variation, so it is assumed to be spurious
  - The source of the variation remains unknown
  - Variation can be removed using a low-pass filter

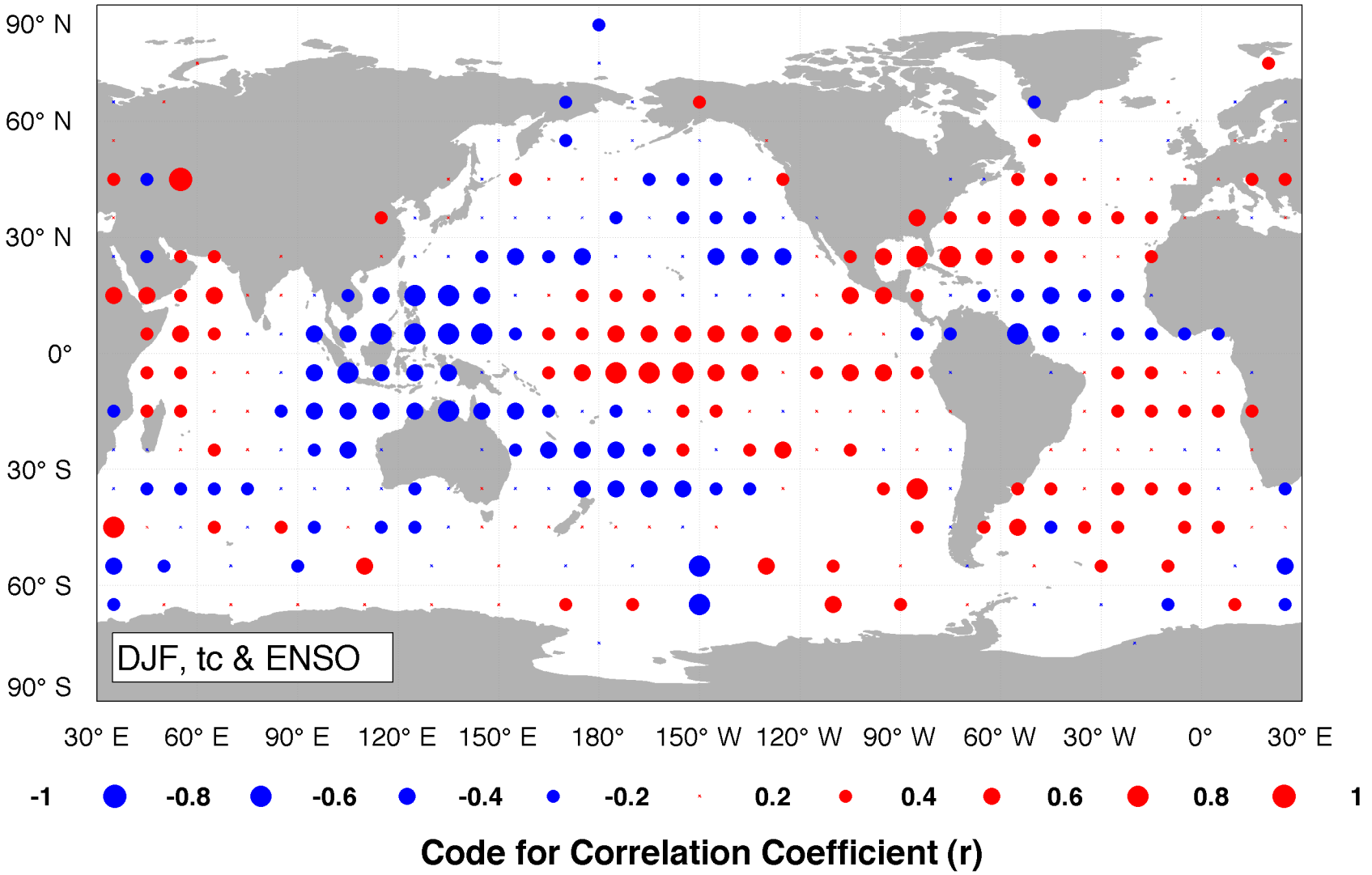
Conclusions

- After long-term variation is removed, cloud cover correlates well with SST
  - Especially low stratiform clouds in eastern subtropical ocean basins (regions of strong inversions and persistent stratus cloud)
- In these same regions, filtered time series of stratiform clouds shows a declining trend
  - An increase in SST is also observed
  - Compensating trends in Cumulus are smaller

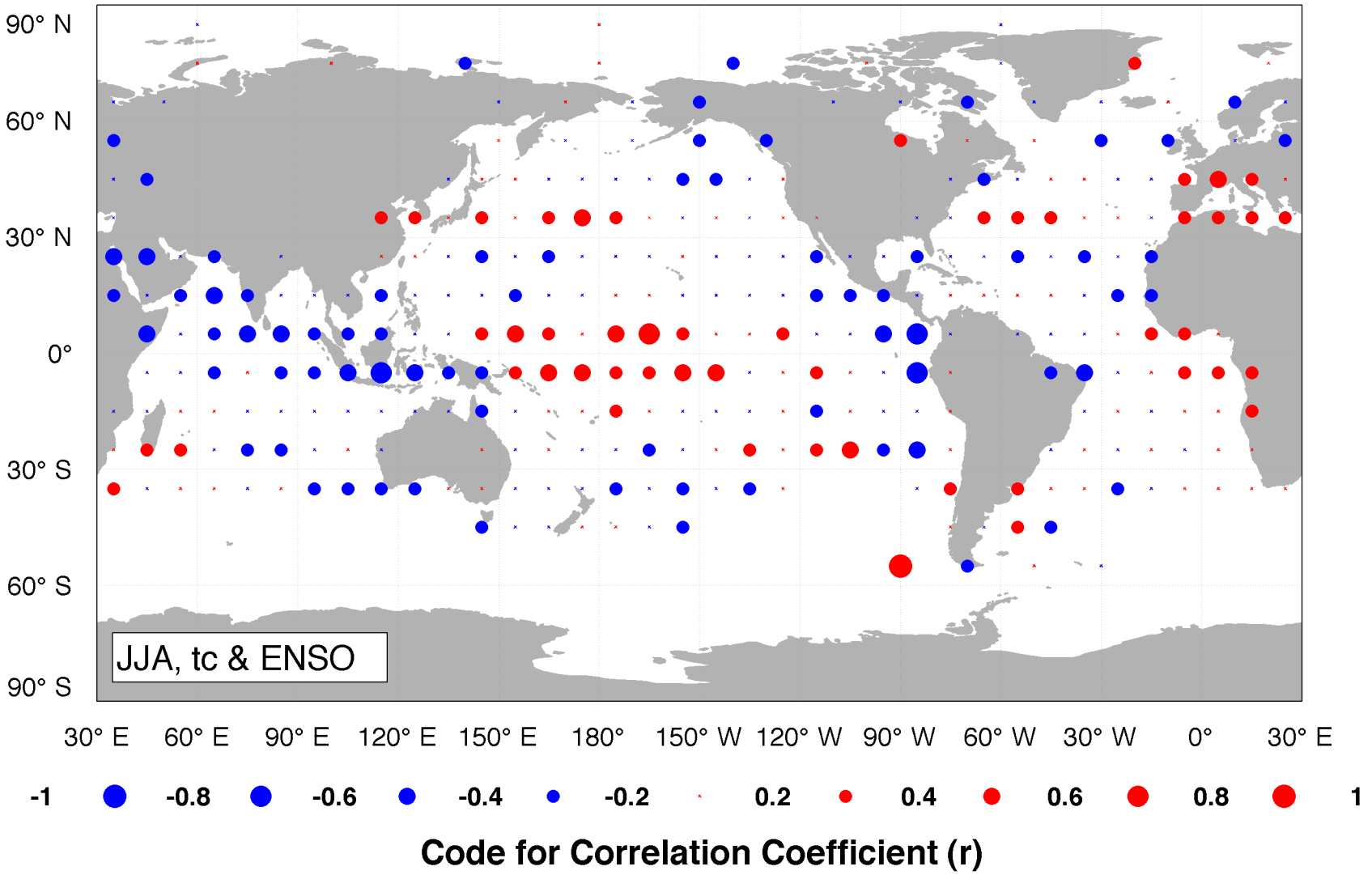
Extra Slides 1 – Criteria for Choosing Minobs



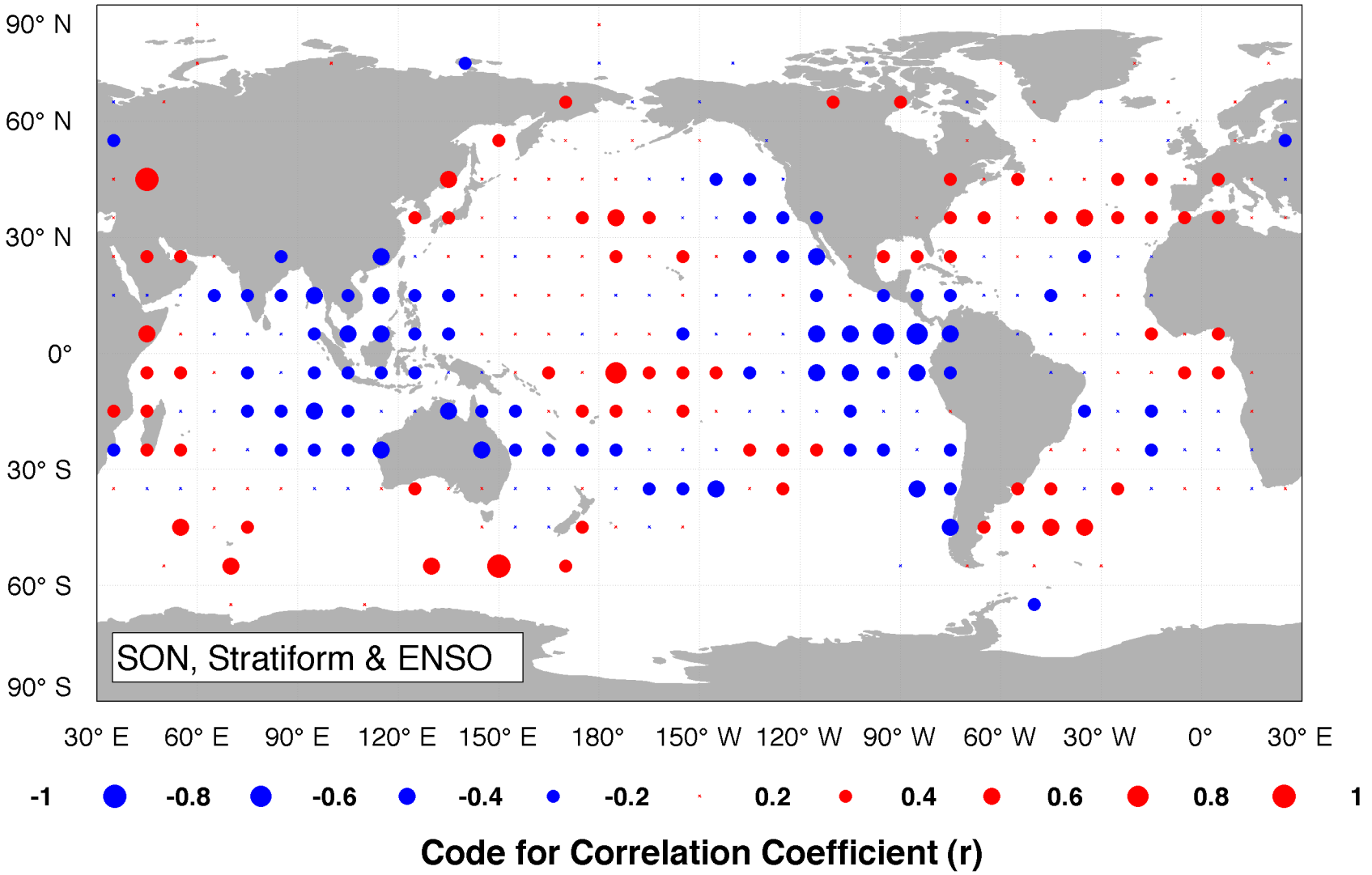
Extra 2 – Total Cloud Cover & ENSO - DJF



Extra 3 – Total Cloud Cover & ENSO - JJA



Extra 4 – Stratiform Clouds & ENSO - SON



Extra 5 – Cumulus Clouds & ENSO - SON