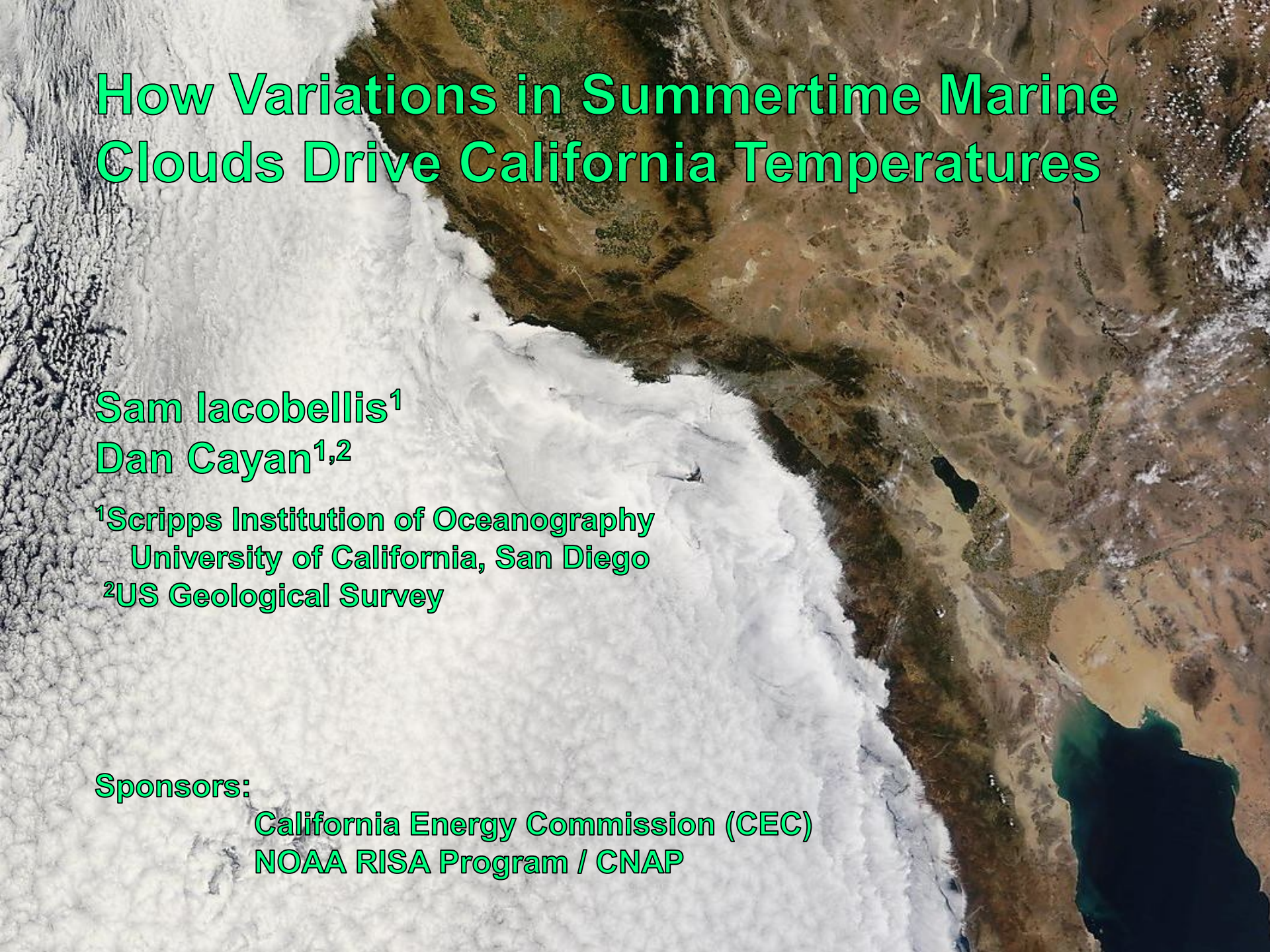
How Variations in Summertime Marine Clouds Drive California Temperatures



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Sponsors:

California Energy Commission (CEC)
NOAA RISA Program / CNAP

Data Sources

A) Albedo (dominated by cloud albedo)

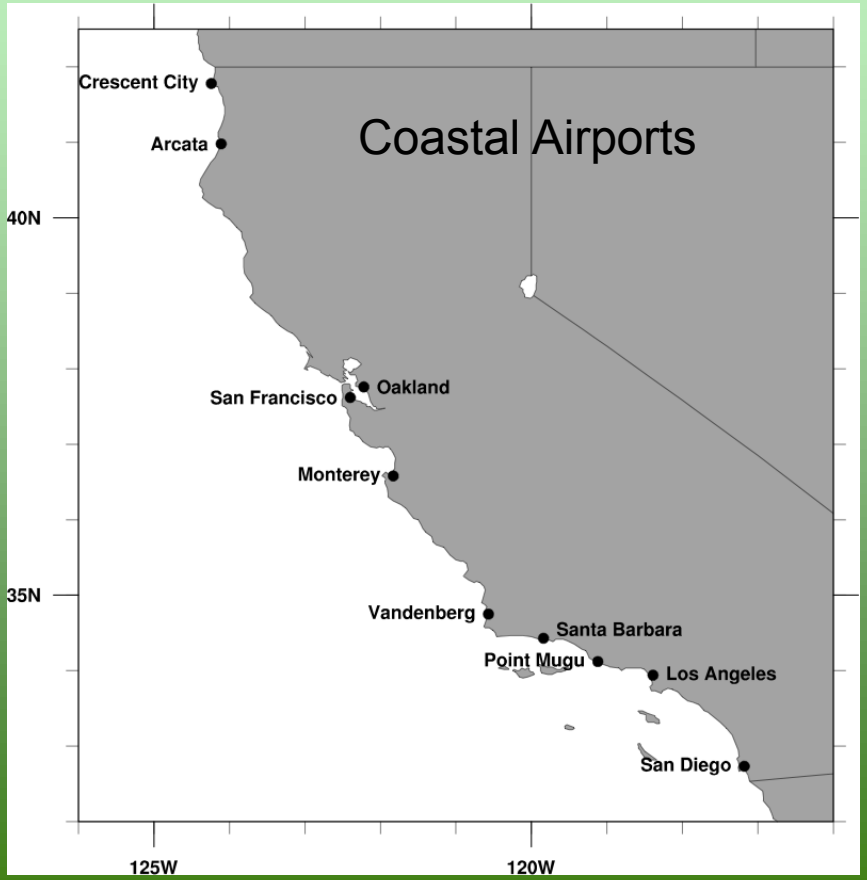
- GOES Imagery, 1km resolution; 30 min temporal; 1996-2011, E NPac/W US

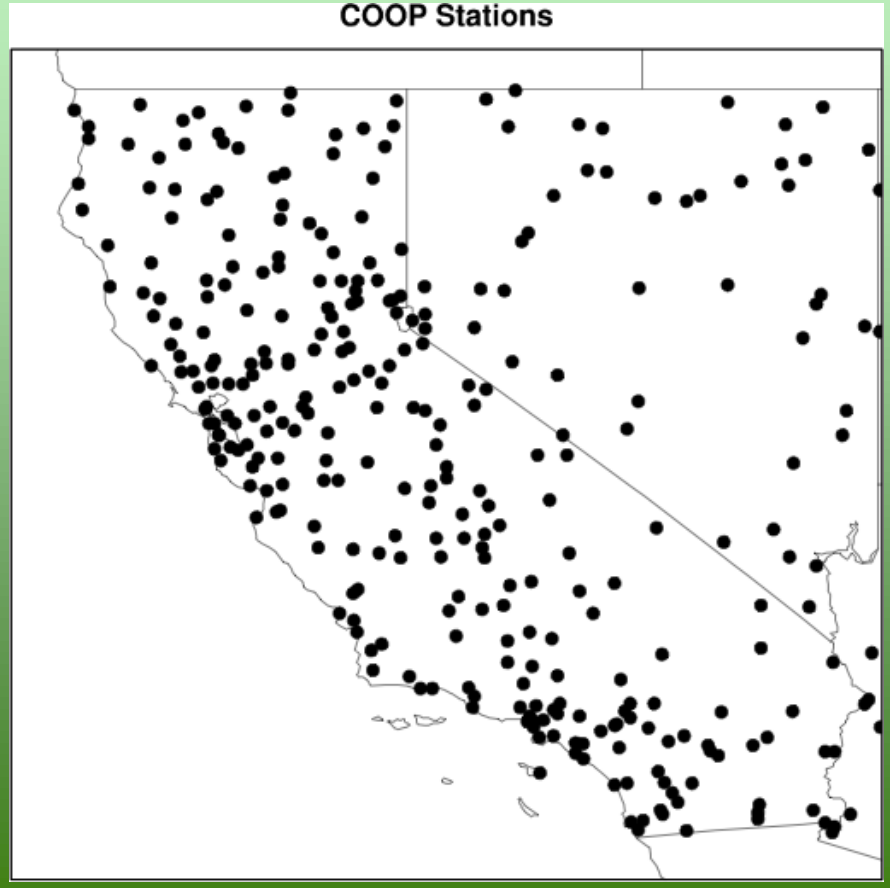
B) Surface-based Cloud Observations at Coastal Airports

- NCDC Integrated Surface Data Set (hourly; ~1950-2011)

C) Surface Daytime Temperatures

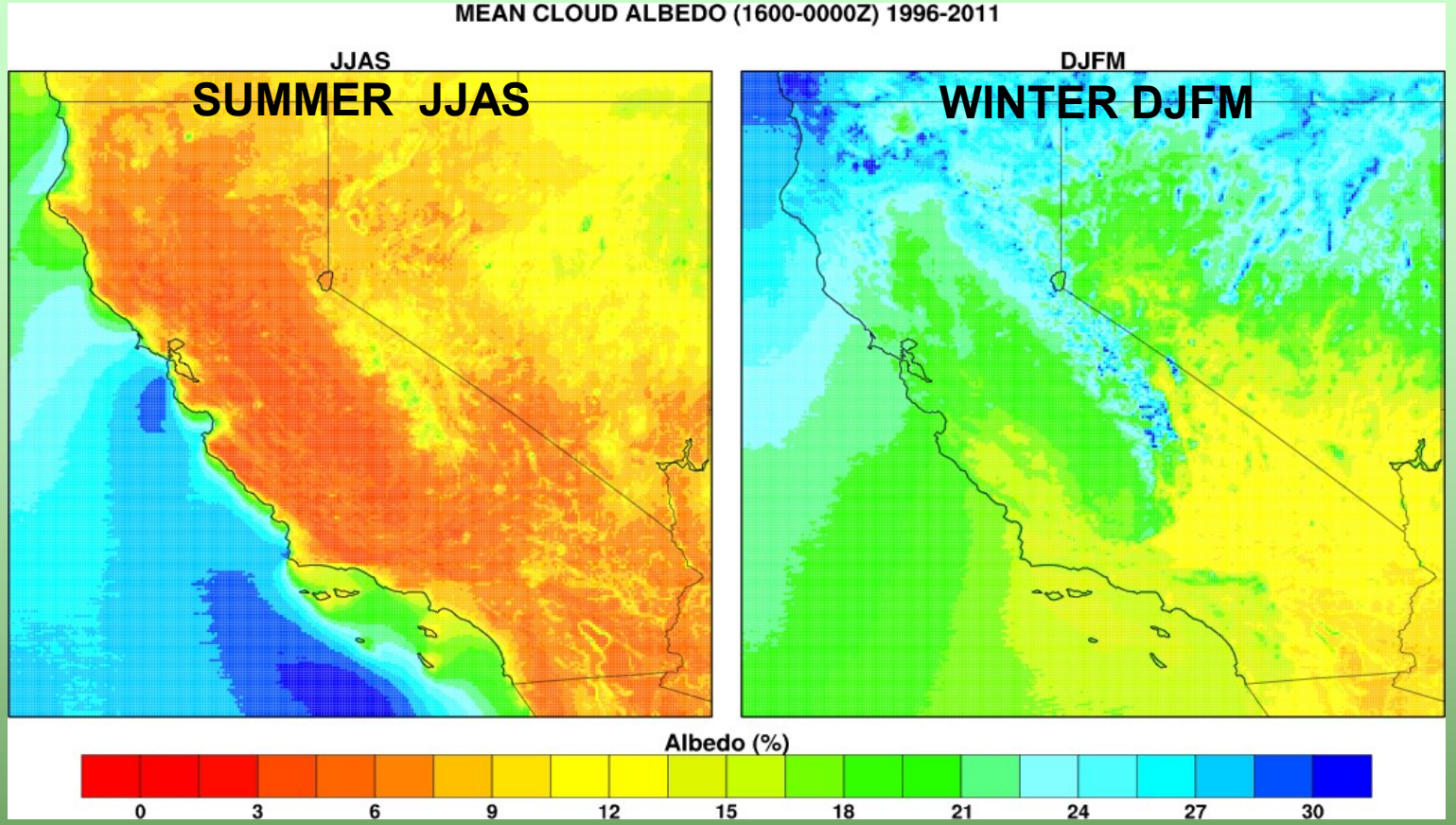
- Cooperative Observer Network (daily; ~1950-2011)





Summer and Winter Mean Cloud Albedo (1996-2011)

Cloud albedo; surface albedo influence has been processed out



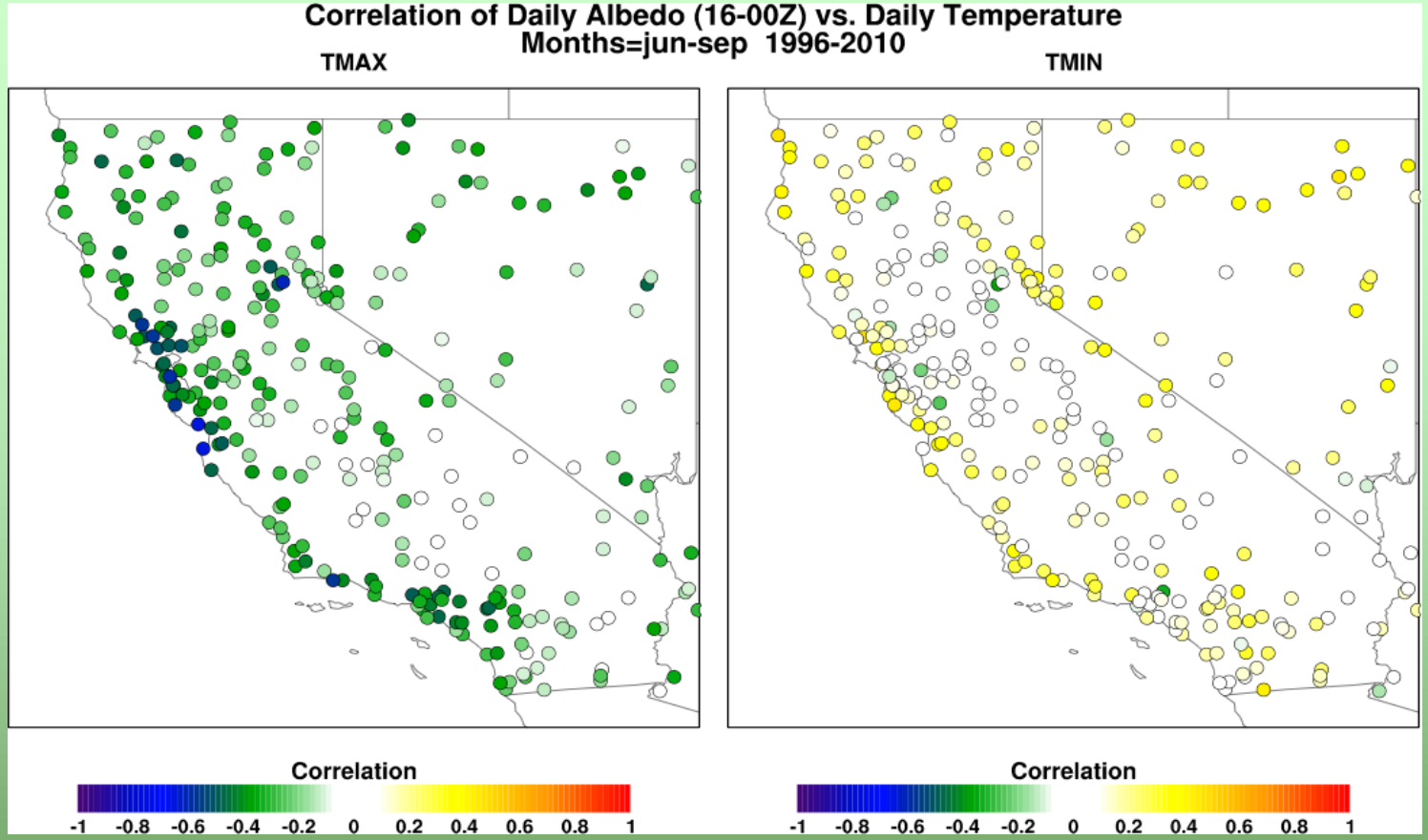
In contrast to winter,

Summer albedo reveals distinct contrast in cloudiness along coast

=> Indicates the strong influence of Marine Stratus Clouds

Cloud Albedo vs. Summer Daily Max and Min Surface Temp

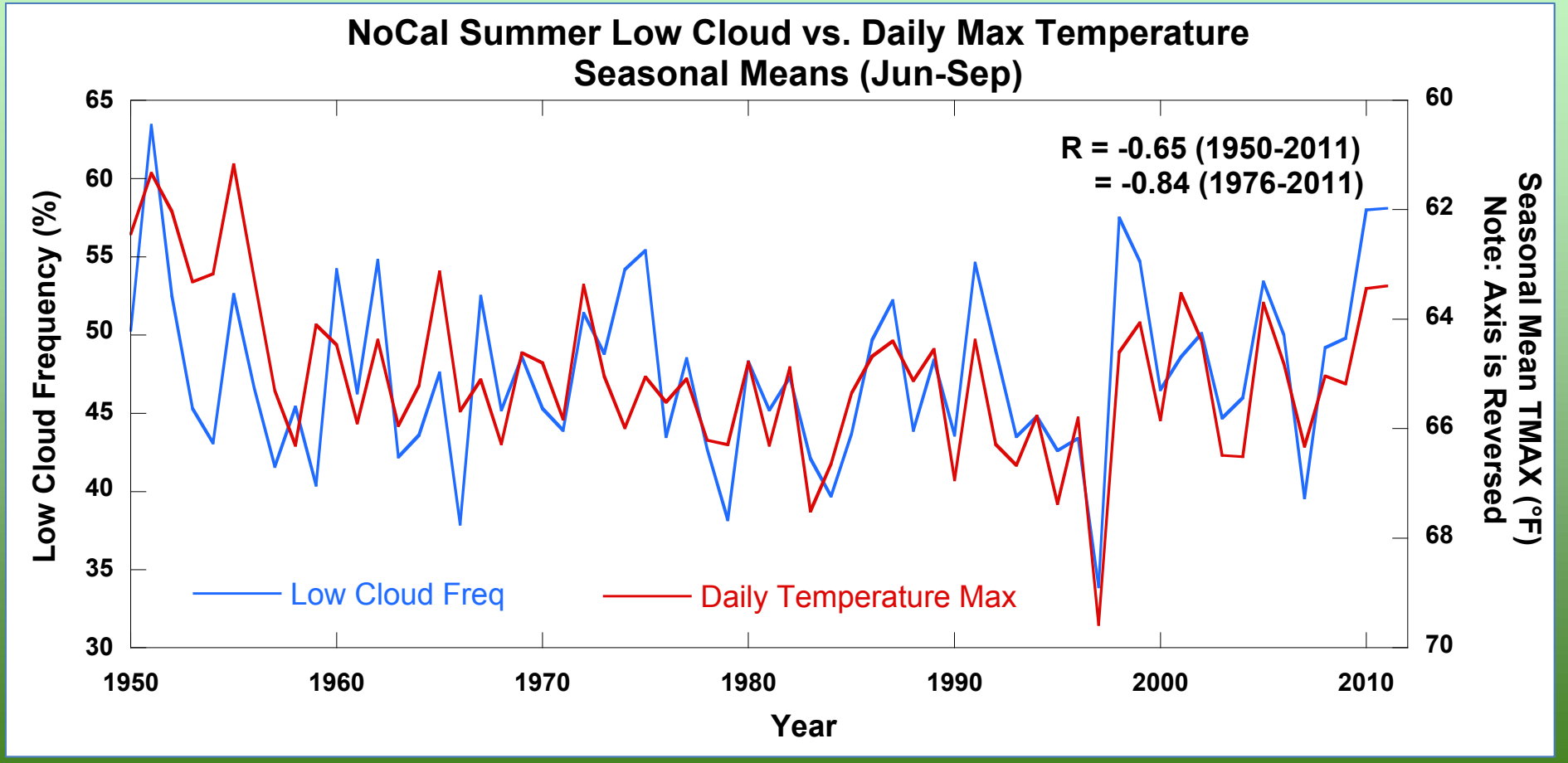
local correlations from daily COOP station records



- Higher albedo => cooler daytime, warmer nighttime temps
- During day, strongest correlations along coast
- Albedo-Temp linkage appears entire California coast

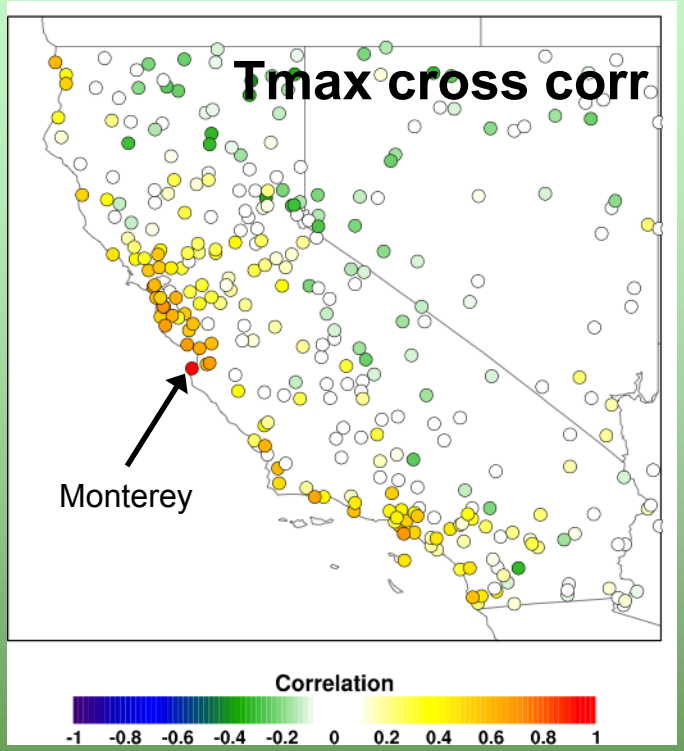
seasonal means show same relationship---

Daily Coastal Tmax varies Inversely as Cloud Freq.

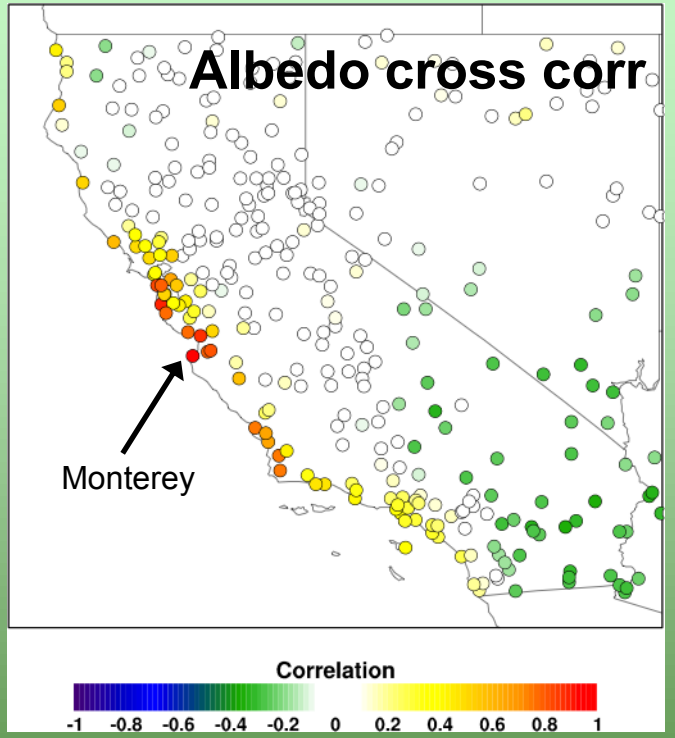


Daily anoms of Tmax and Albedo both exhibit broad spatial coherence along coast during summer (JJAS)

Cross Correlation of Seasonal Mean Daytime Temperature to Monterey 1950-2011



Cross Correlation of Monthly Mean Cloud Albedo to Monterey 1996-2011



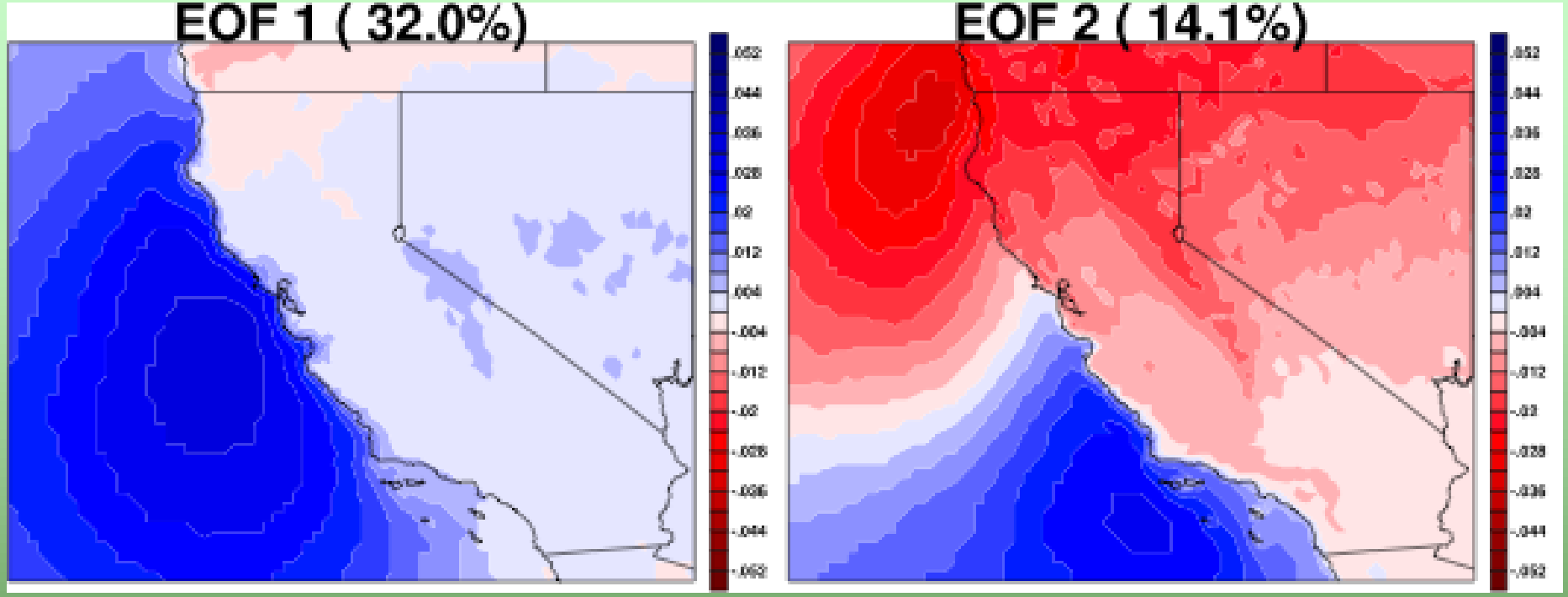
If summer is *cool* in Monterey, likely cool elsewhere along CA coastline

If summer is *cloudy* in Monterey, likely cloudy elsewhere along CA coastline

Primary Daily Cloud Anomaly Patterns – broad coherence

as shown by leading EOFs

EOFs Constructed from Daily Mean Cloud Albedo (Jun-Sep 1996-2011)

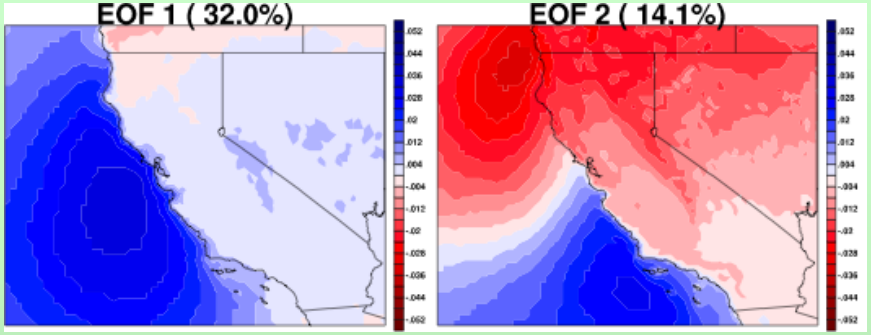


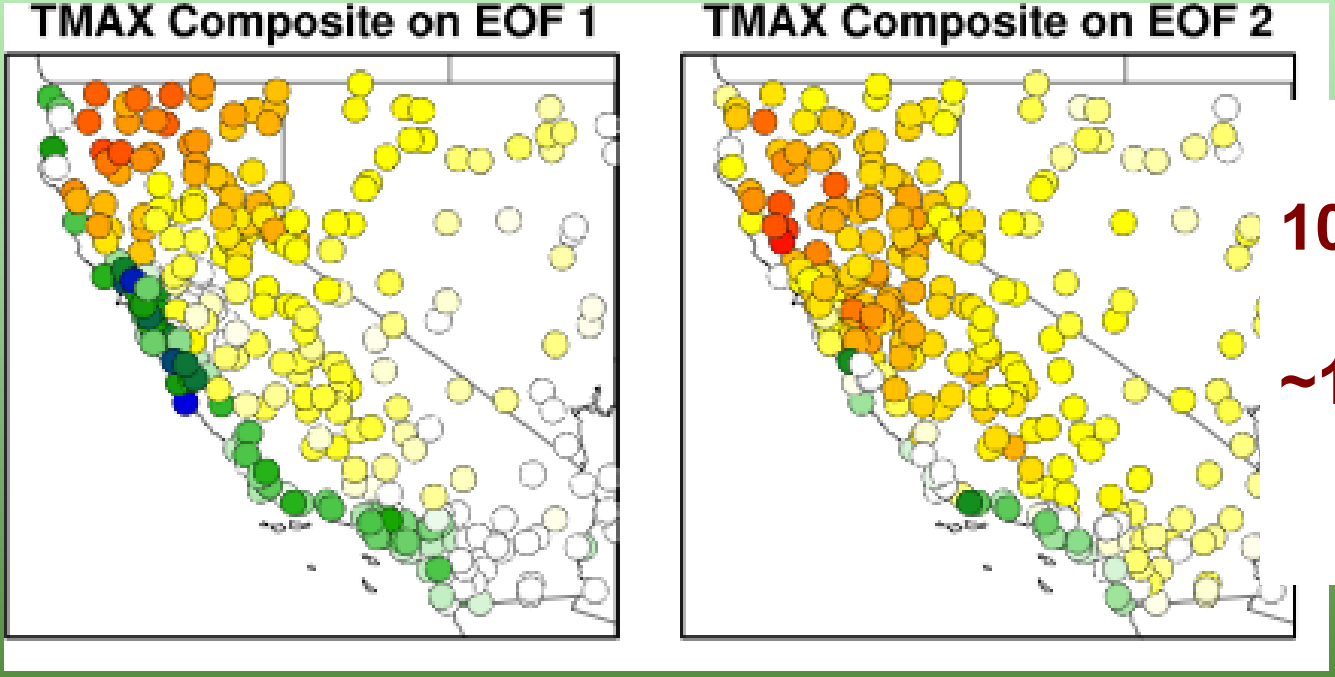
dominated by extensive ocean-based marine stratus

exhibits coherent anomalies that extend from North to South and vary oppositely North to South

Composite Daily Maximum Temperature on "Strong" EOF days

Strong Day when PC > 90th Percentile



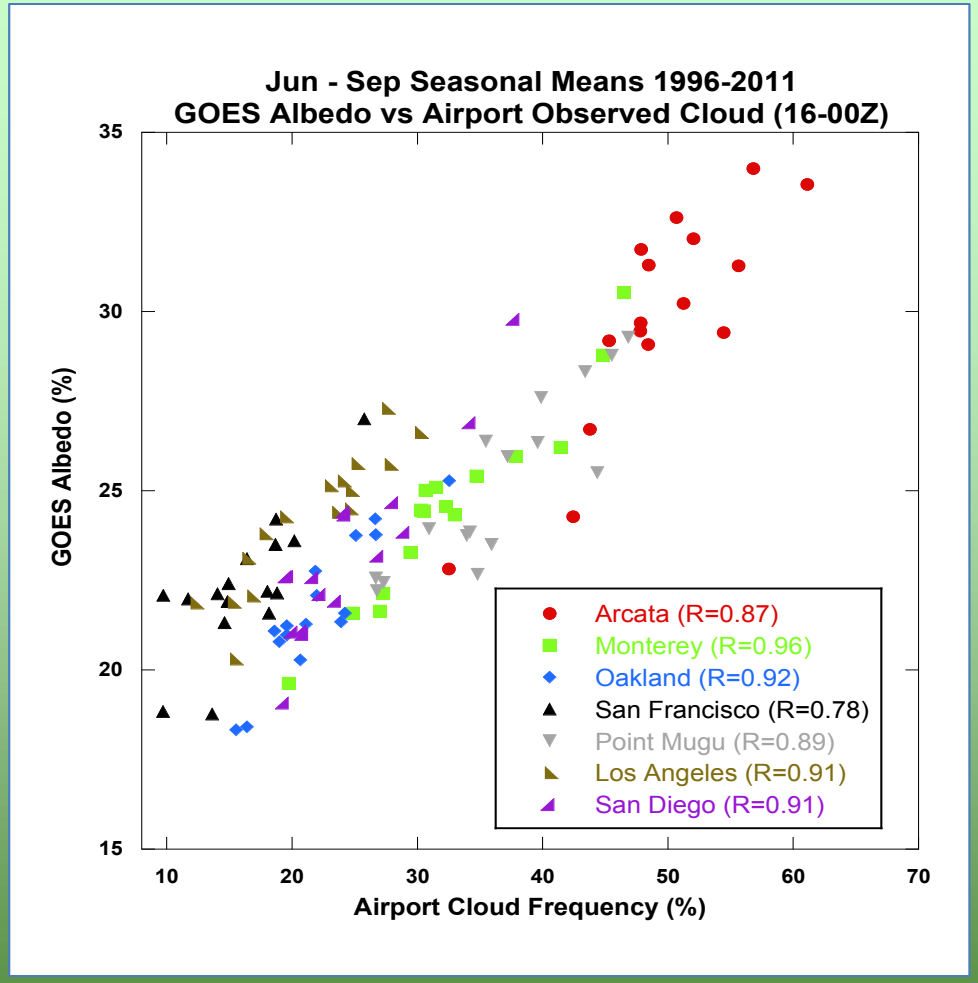


10% albedo change corresponds to ~1° C Tmax change along coast

from regression analysis

Airport Cloud Observations allow Expanded Time Record

Coastal Airport Cloud Frequency vs. GOES Albedo (JJAS Seasonal Means):



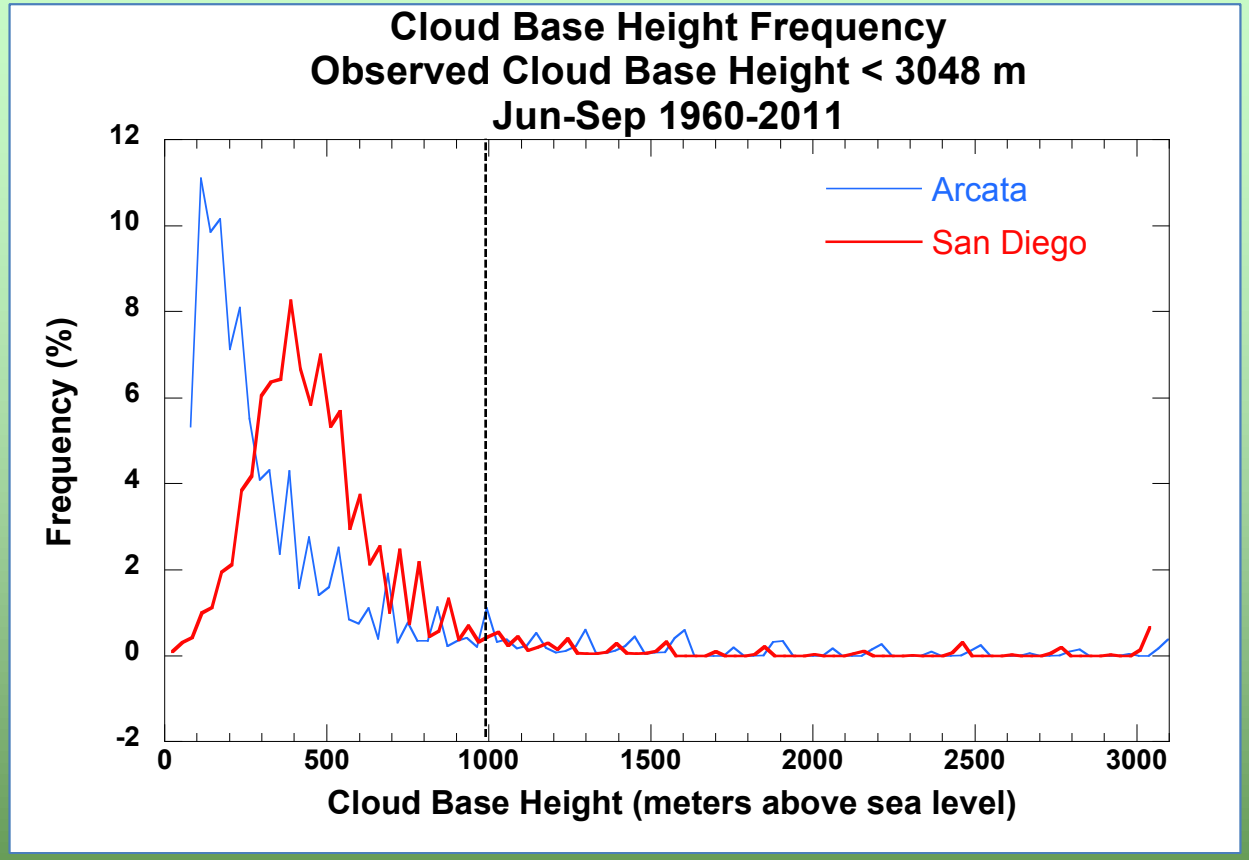
Strong correlations between satellite and surface measurements

coastal cloud record can be extended back to 1950

but, low cloud definition is very important---

Cloud Base Height Used to Distinguish Marine Stratus

Frequency Distribution of Cloud Base Height at Arcata and San Diego (JJAS)



Here, use base height of 1000m as threshold for stratus

different results may obtain w different base height threshold

Define *Low Cloud Index* for Northern and Southern California
Similar to Fog Index of Johnstone and Dawson (2009)

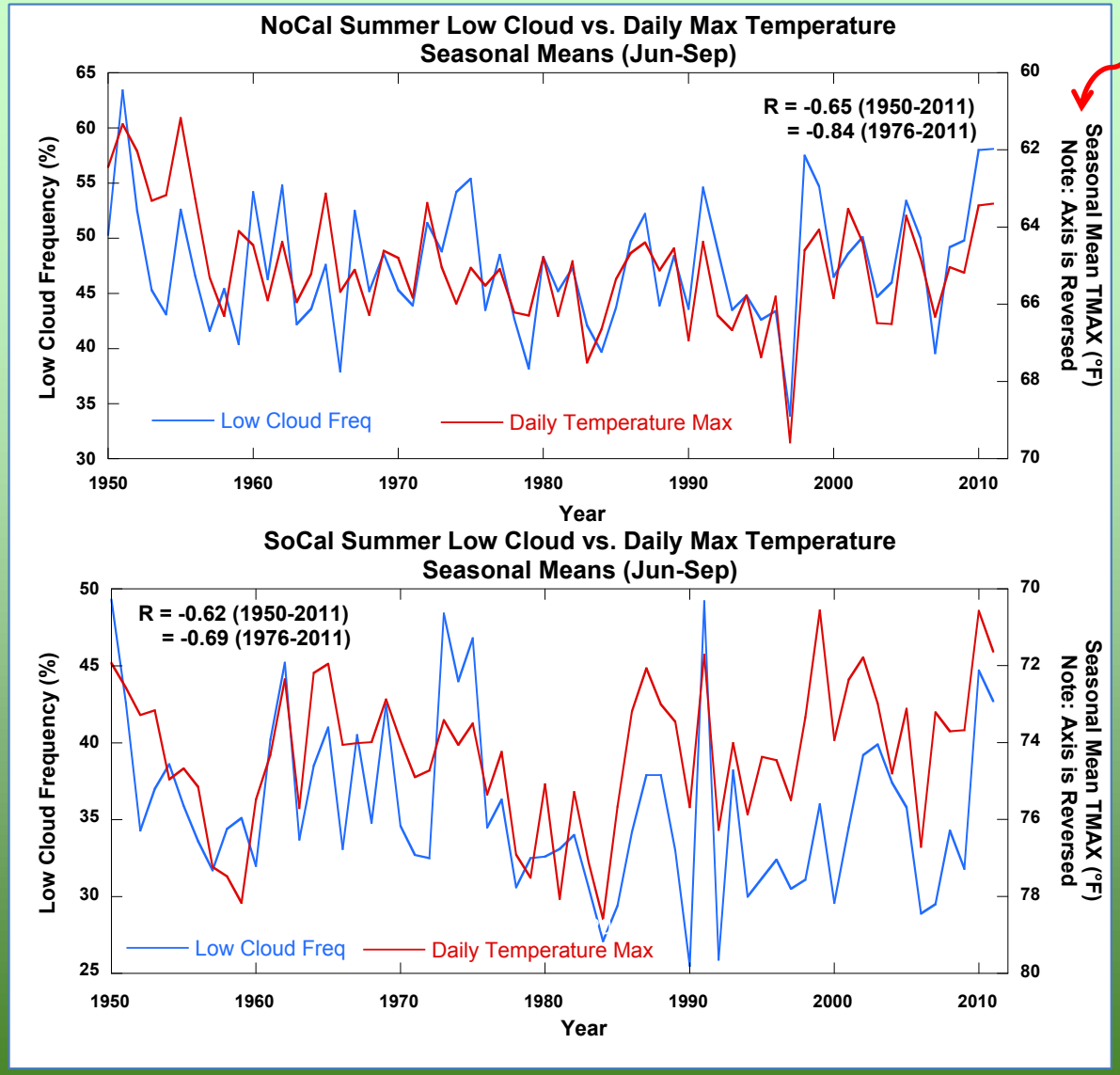
Northern California: Arcata and Monterey
Southern California: Los Angeles and San Diego

Months: June – September

Assume all clouds with cloud base < 1000 meters are marine stratus

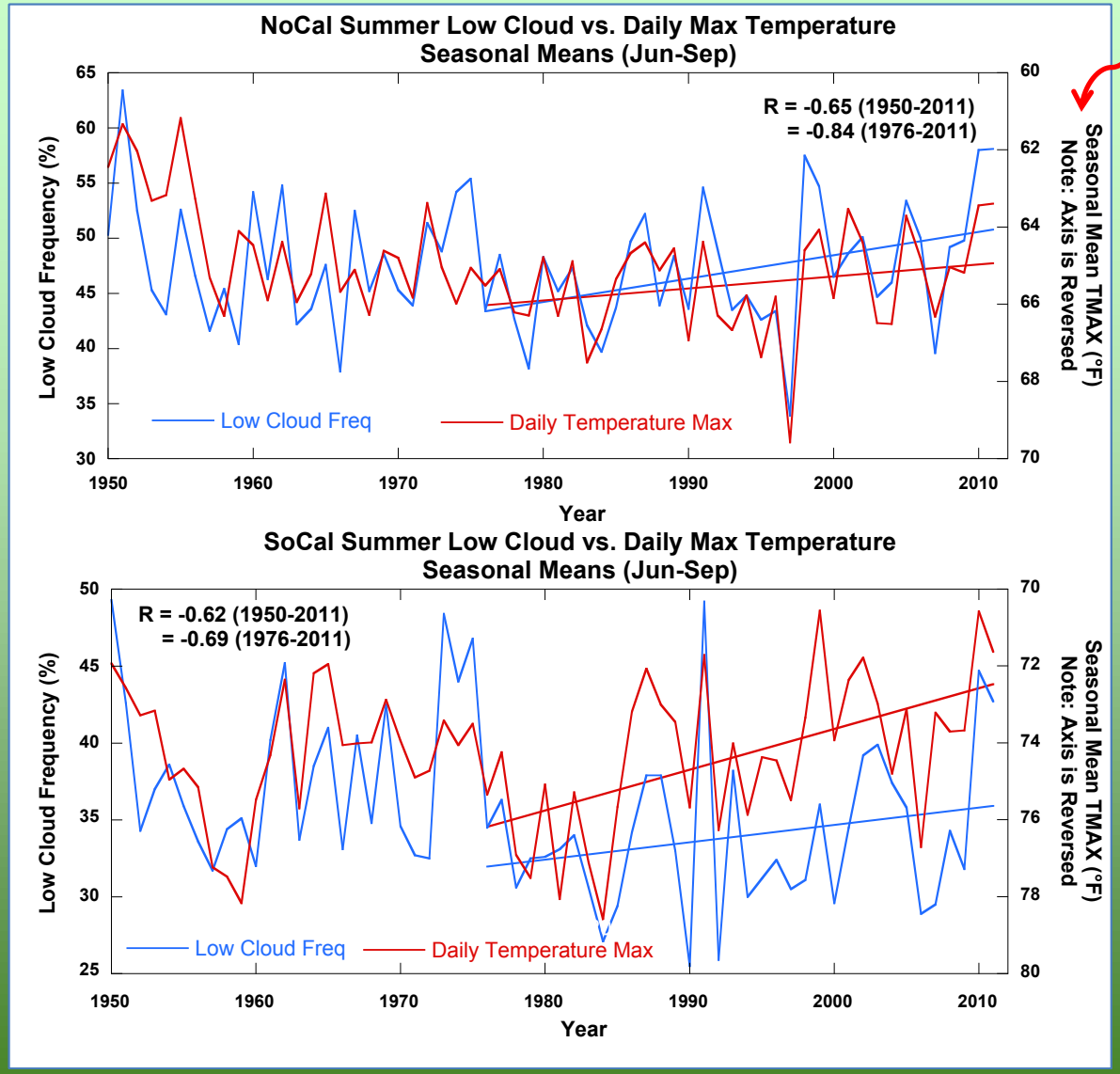
Seasonal Mean (JJAS) Low Cloud and Daytime Temperature

NOTE: TEMP AXIS IS REVERSED!!!



Strong Correlation between Low Cloud and Daytime Temps on seasonal scale

Seasonal Mean (JJAS) Low Cloud and Daytime Temperature



NOTE: TEMP AXIS IS REVERSED!!!

Lebassi et al (2009) found daytime temperatures along California coast decreasing since 1970s.

THIS STUDY:

Since mid-1970s along coast

- Decreasing daytime temperatures
- Increasing Albedo/cloud

SUMMARY

- In summer, coastal cloud anomalies along California are driven by varying marine stratus patterns,
having a reach over large parts of eastern N Pacific .

- Strong correlation between stratus cloud albedo and Tmax (to lessor extent to Tmin) on daily and seasonal time scales. Linkage is particularly strong at coastal sites.
SST not does not provide comparable Tmax skill as albedo (not shown).

- Temperature response probably strongly controlled by radiative effects from clouds, but other mechanisms (e.g., advection) are likely at play.

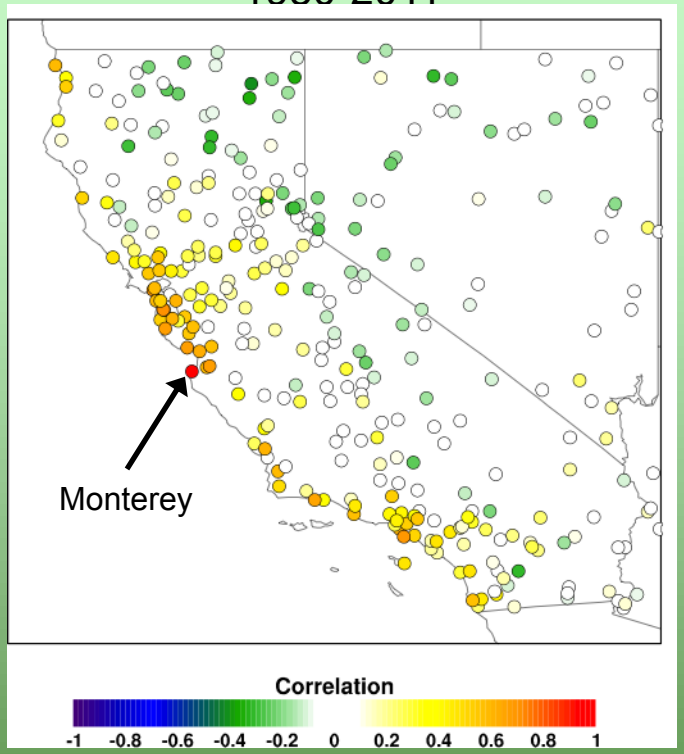
- Consistent trends since mid-1970s but not clear if these are result of natural variation (PDO, ENSO) or climate change.

- Impacts are wide ranging—e.g., energy, health, ecosystems

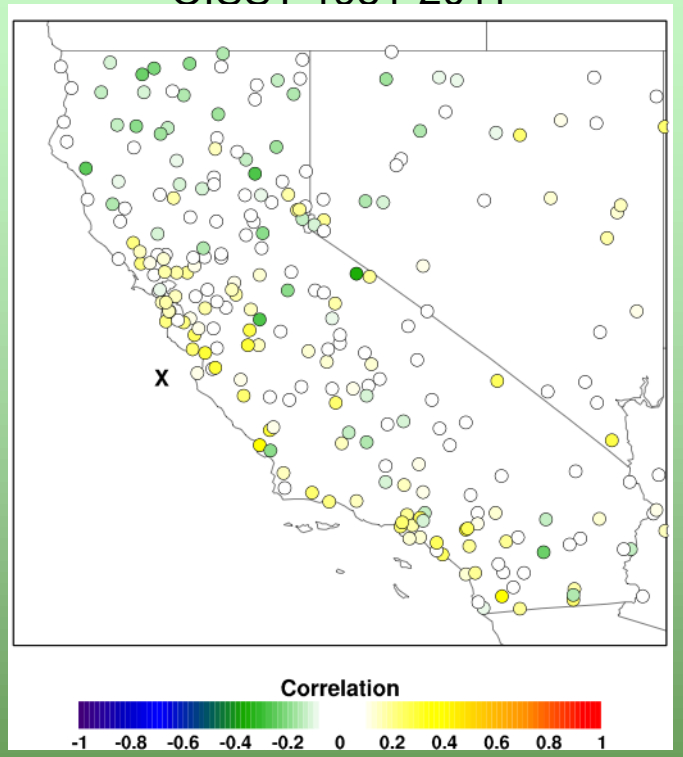
ARE TEMPERATURES RESPONDING TO SST?

I'd leave this one out—can state it in summary

Cross Correlation of Seasonal Mean Daytime Temperature to Monterey 1950-2011

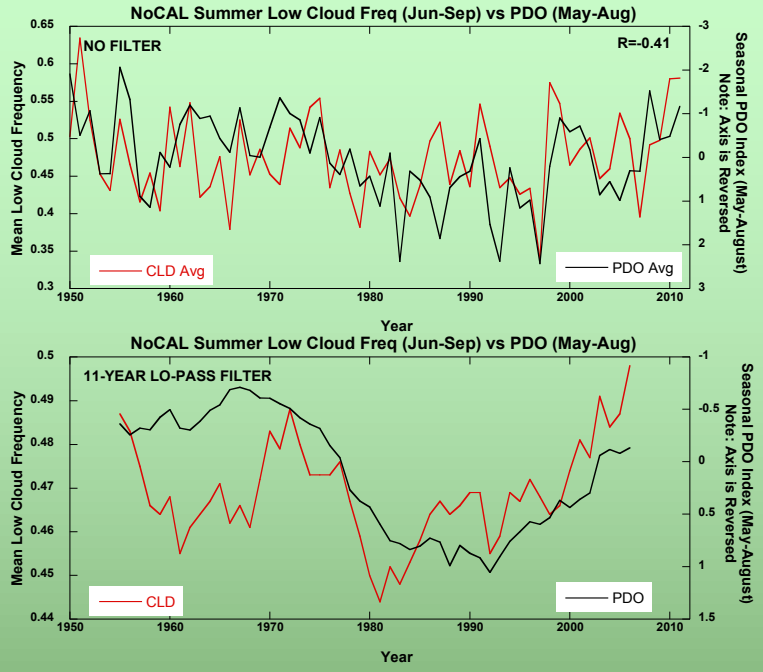


Correlation of Seasonal Mean Daytime Temperature to Monterey SST OISST 1981-2011

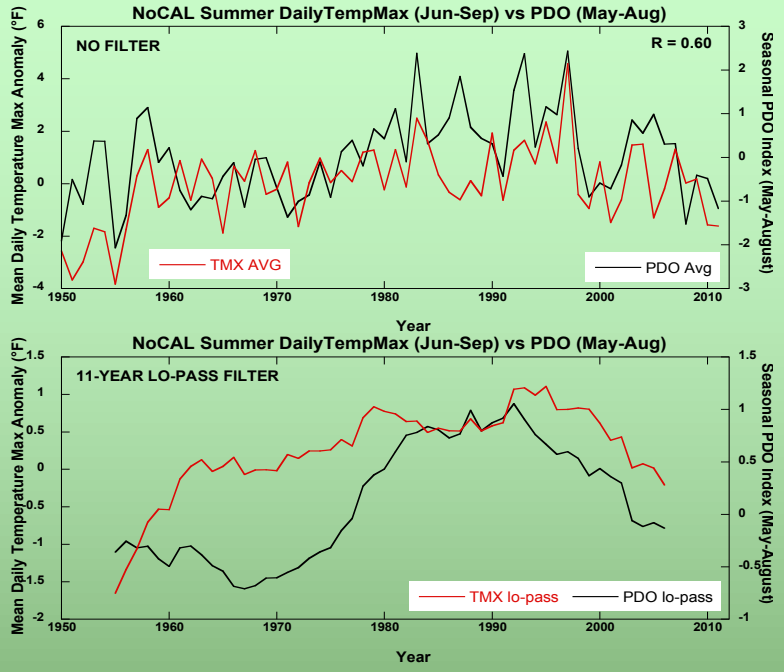


SST not as strongly associated with seasonal Tmax as is seasonal cloud albedo]

NOCAL LOW CLD FREQ VS. PDO



NOCAL DAILY TEMP MAX VS. PDO



also, higher cloud heights during warm PDO periods