

Solar Forcing Effects of Shallow Cumuli at ACRF SGP Site

David Mills

University of South Carolina

GCEP End-of-Summer Workshop

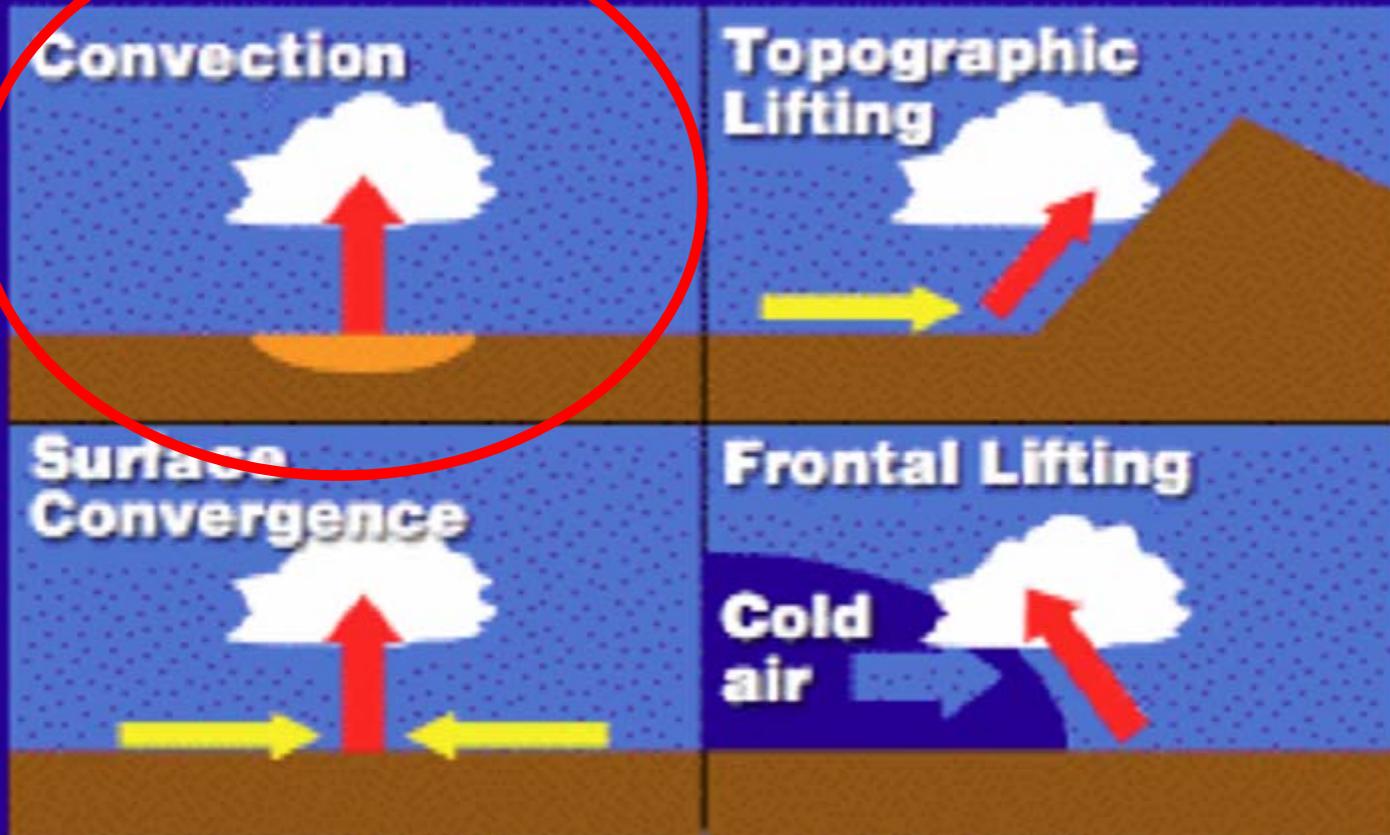
Pacific Northwest National Laboratory

Cumulus Cloud Development

- ▶ Shallow Cumulus are clouds primarily with flat bottoms and round tops formed by:
 - Moisture
 - Lifting Mechanism
 - Cloud Condensation Nuclei

- ▶ Shallow Cumulus occur over a large portion of continental and tropical regions.

Lifting Mechanisms



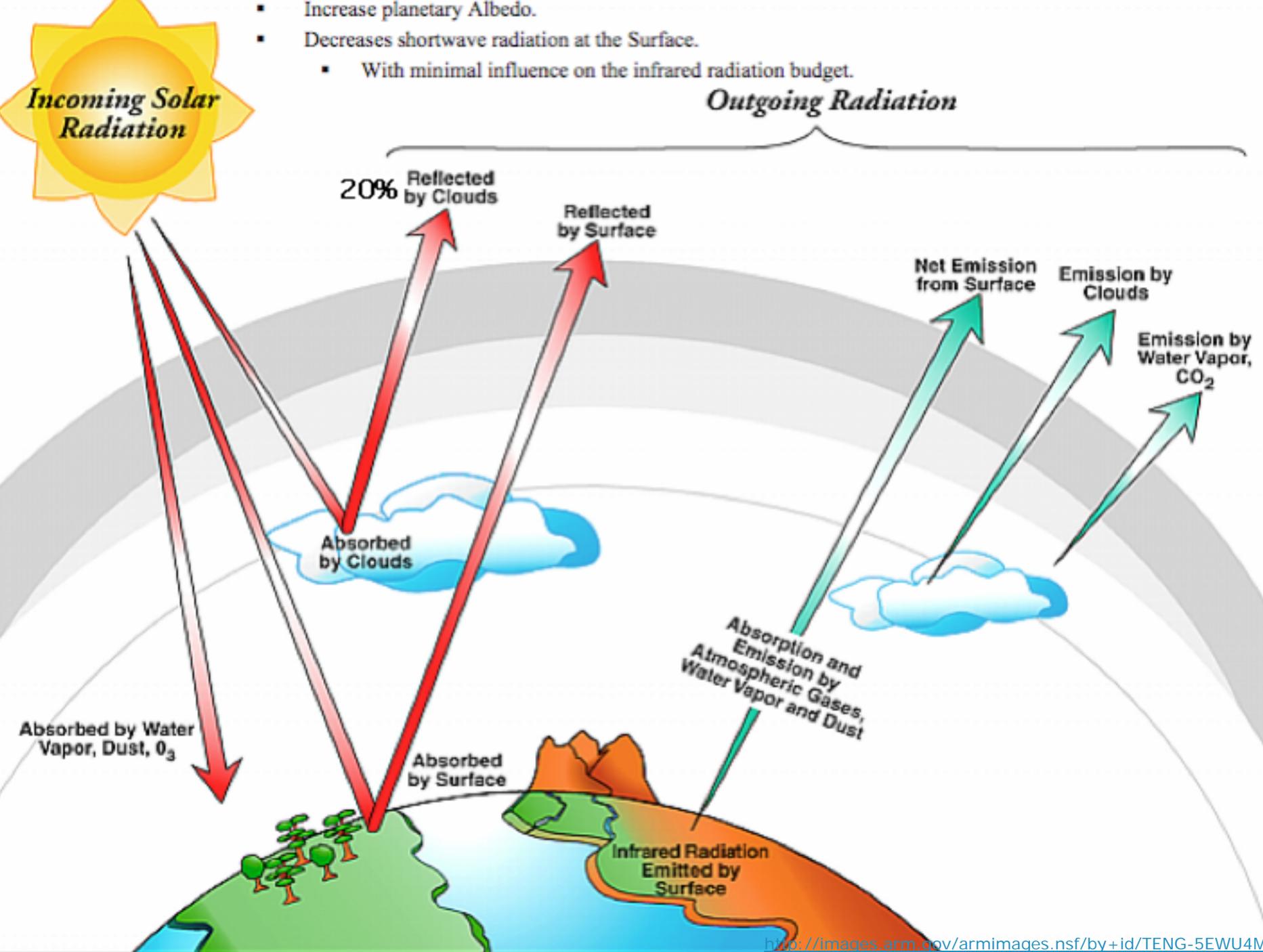
Shallow Cumulus Clouds

- ▶ These clouds are smaller than the grid spacing used in most numerical models of the atmosphere
- ▶ Because of their sub-grid sizes, their radiative effects in climate models have large uncertainties



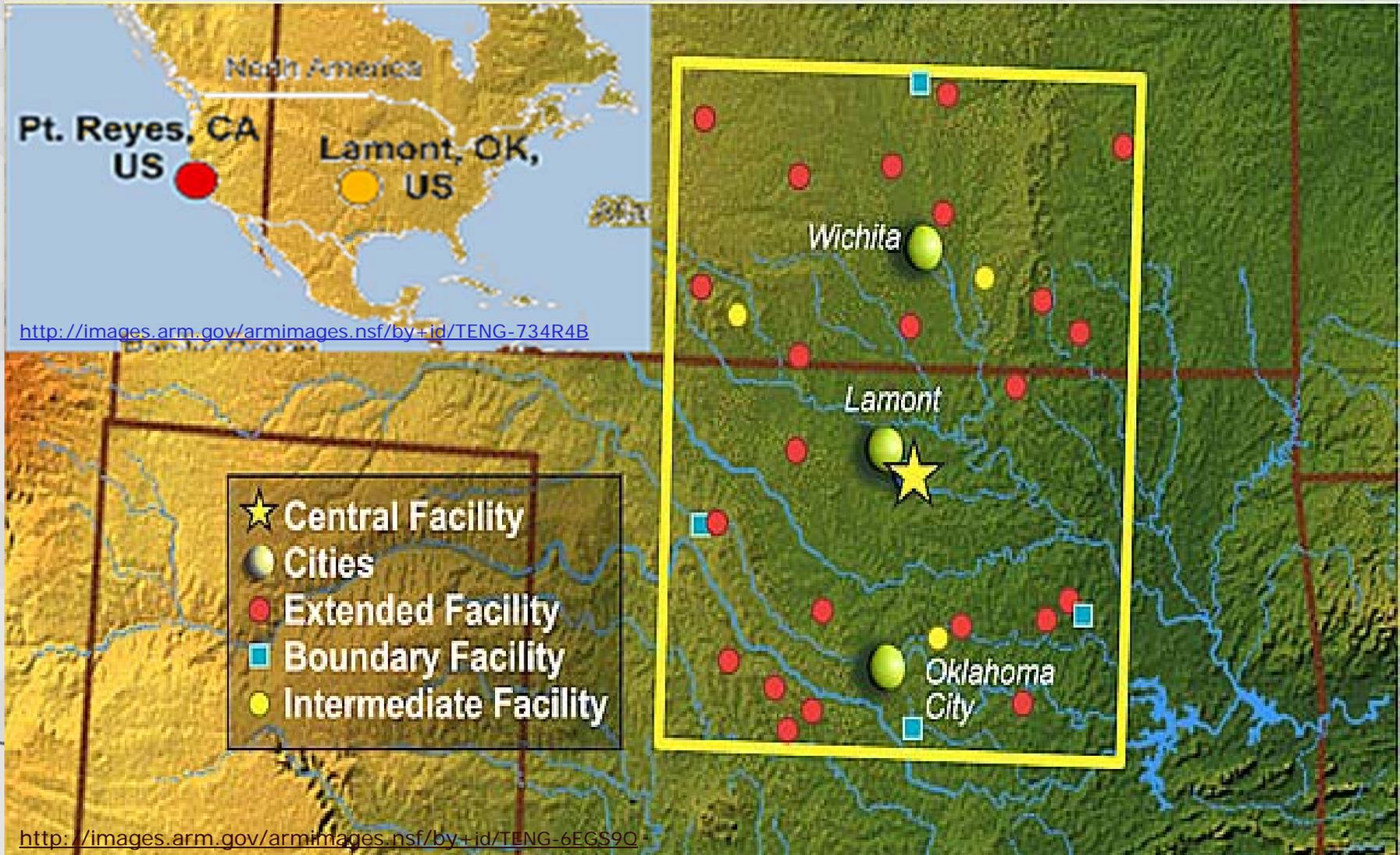
- Increase planetary Albedo.
- Decreases shortwave radiation at the Surface.
 - With minimal influence on the infrared radiation budget.

Outgoing Radiation



ACRF SGP Site

(ARM Climate Research Facility, Souther Great Plains site)



ARSCL VAP

(Actively Remote Sensed Clouds Location, Value-added Product)

► Compilation of various measurement instruments:

- Microwave Radiometer
- Millimeter-Wavelength Cloud Radar
- Vaisala Ceilometer
- Micropulse Lidar

► Used to provide the best estimate of:

- Cloud Base Height
- Cloud Top Height
- Cloud Thickness

Total Sky Imager (TSI)

- ▶ Provides a visual of Hemispheric sky conditions during daylight hours.



Cloud Identification

Our criteria for Identification of shallow cumulus clouds:

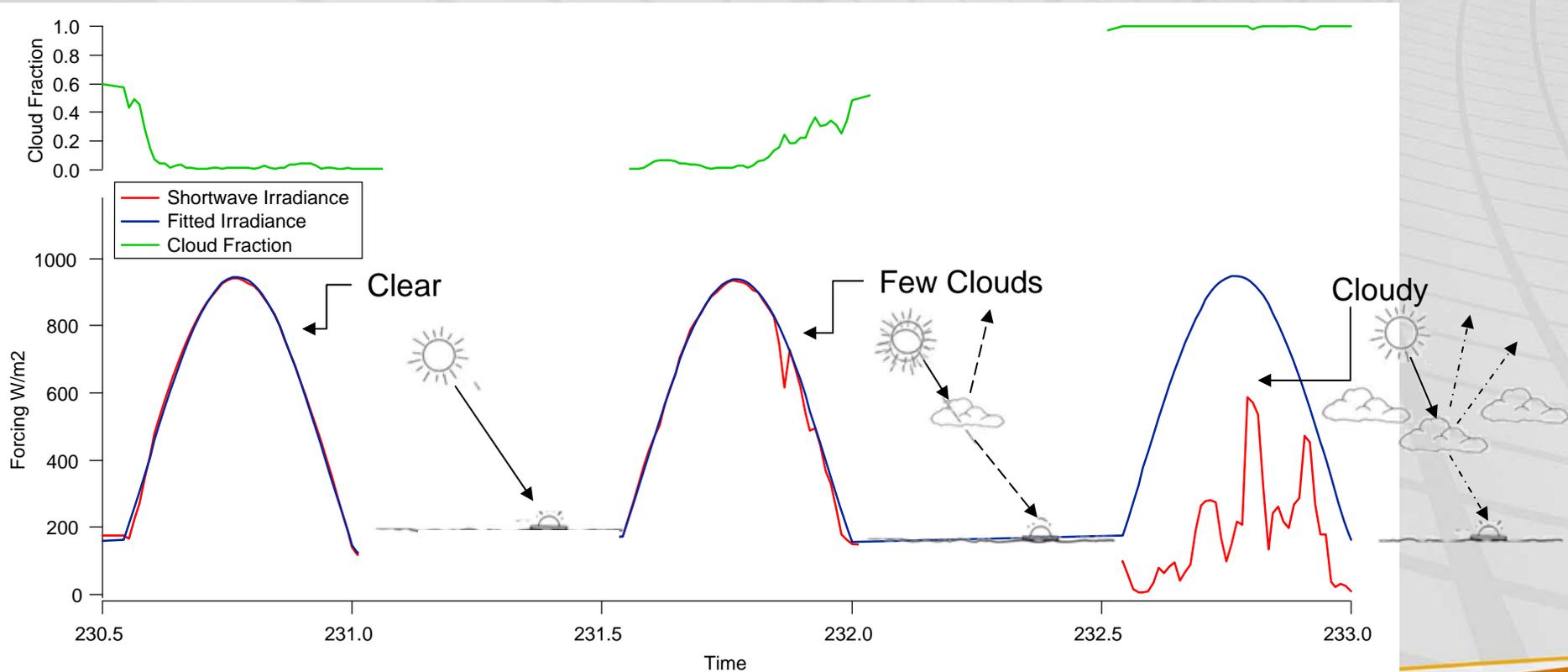
- Cloud Base Height between 0.3 - 3 km
- Cloud Top Height between 1.5 - 3 km
- Cloud Thickness ~1 km
- Verify using Total Sky Imager

- Eliminated days with:
 - Clouds caused by large scale circulation (Cirrus)
 - Agricultural burning
 - Precipitating clouds
 - Cumulus clouds transitioning to Stratocumulus

Shortwave Flux Analysis Value Added Product

- ▶ The **Shortwave Flux Analysis** Value Added Product uses methods provided by Charles Long and Thomas Ackerman (2000) which uses various methods and tests to measure and predict the shortwave irradiance.
- ▶ This analysis provides an empirical fit, to estimate the **clear sky irradiance** based on clear conditions near the day of interest.
- ▶ The hemispheric **Cloud Fraction** (CF) defines the percentage of the sky covered with clouds.

Shortwave Flux Analysis Value added Product



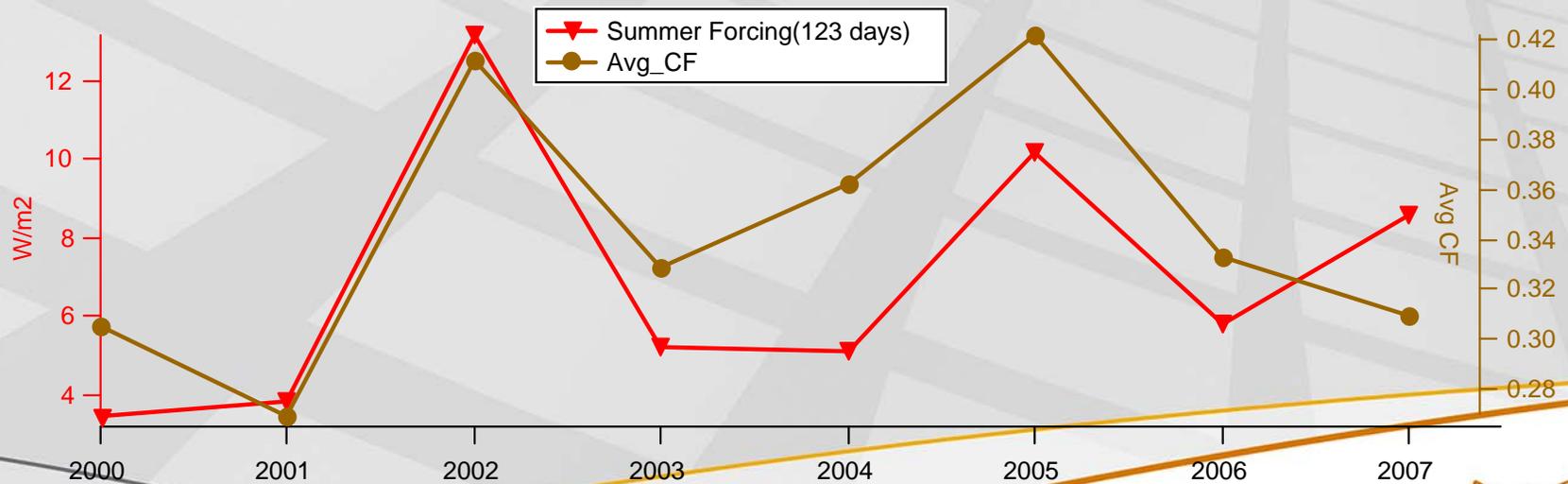
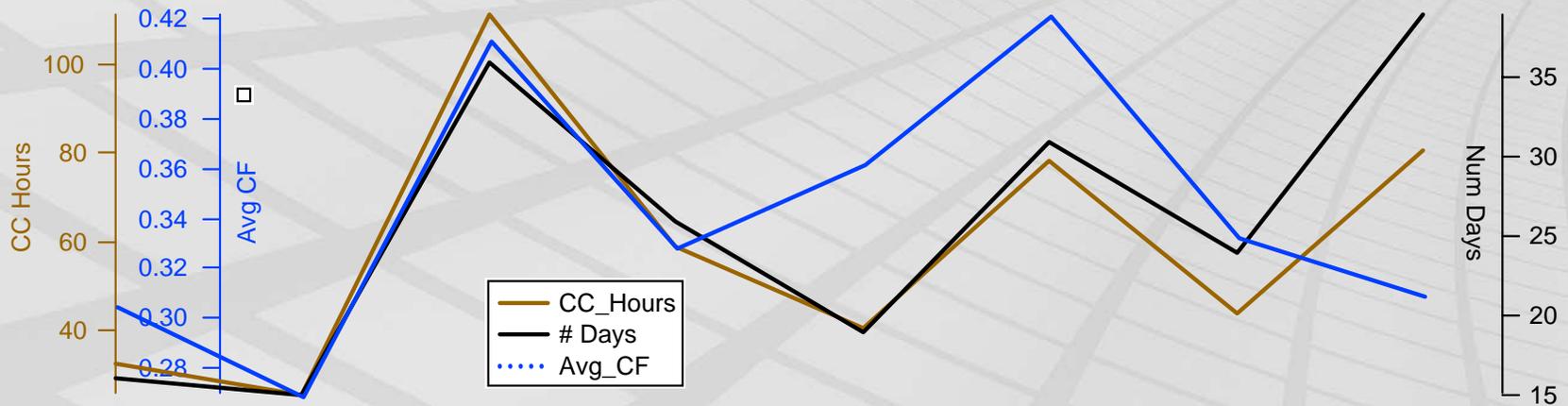
Analysis

- ▶ Data was collected from the Summers (May-August) of 2000 - 2007
- ▶ Cloud forcing was computed for each 15-minute Interval
 - Computed by subtracting net clear sky empirical fit from the actual recorded shortwave irradiance.

$$\left(I_{\downarrow, Obs} - I_{\uparrow, Obs} \right) - \left(I_{\downarrow, Fit} - I_{\uparrow, Fit} \right)$$

- Integrated forcing over the daylight period and analyzed by summer, month, and period.
- Computed arithmetic mean for each period to compare to previous studies containing all clouds.

Impact of Cloud Cover and Duration



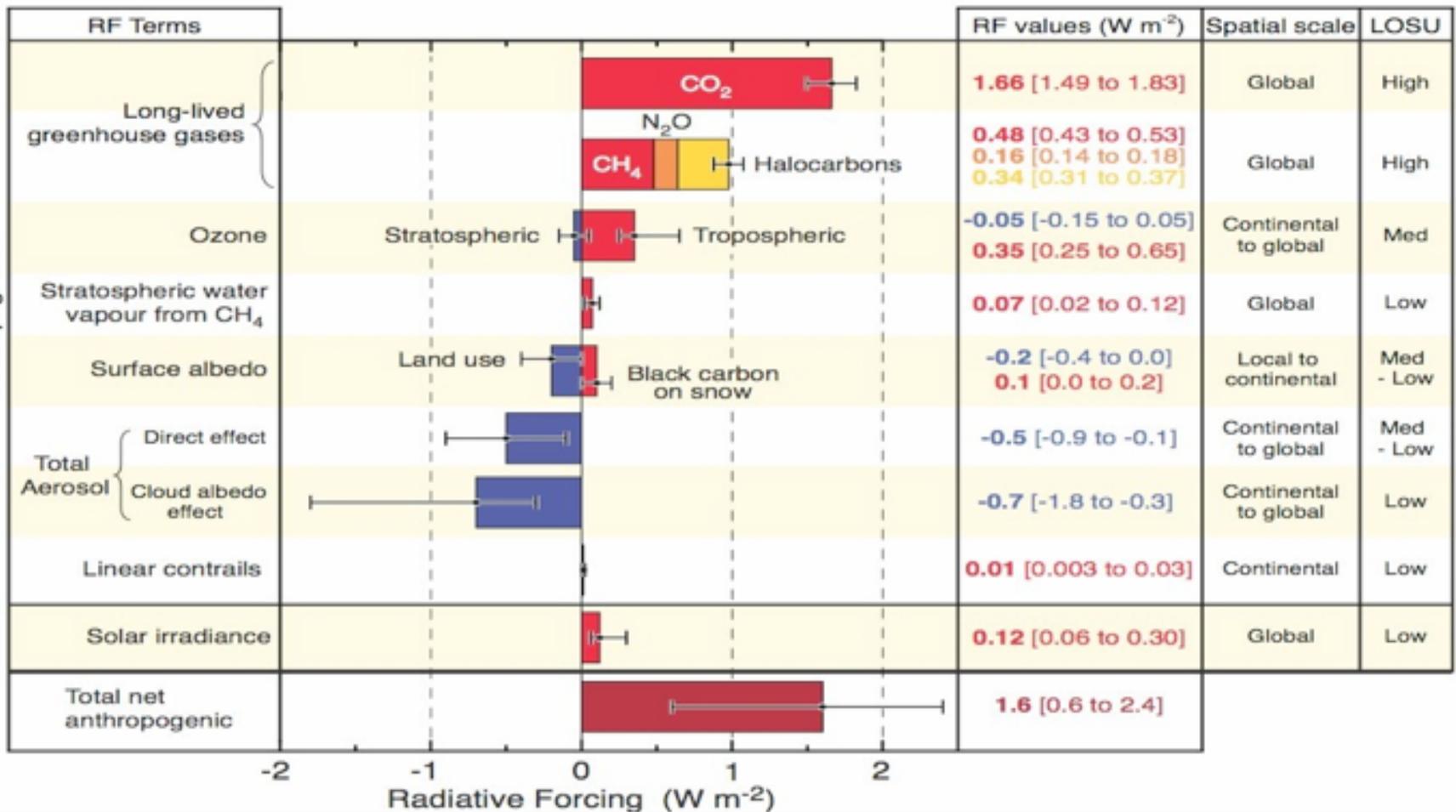
Results

- ▶ There were 206 days with Shallow Cumulus out of the 8 summers (984 days).
- ▶ The summer shortwave forcing effect of Shallow Cumulus for the 8 summers was -6 W m^{-2} .
- ▶ The extrapolated annual shortwave forcing effect of Shallow Cumulus for the entire 8 year period was -2 W m^{-2} .
 - Assumed there were no shallow cumulus outside of the summers.

Results

- ▶ The -2 W m^{-2} forcing is larger than the forcing associated with various greenhouse gases reported by the IPCC.

Radiative Forcing Components



Summary

- ▶ The effects of the Shallow Cumulus are very significant in accurately modeling climate. The SGP site is representative of many continental regions as well as Tropical regions.
- ▶ □ The extrapolated annual shortwave forcing of shallow cumulus for the entire 8 year period (2922 days) was -2 W m^{-2} . This value is comparable to, and larger than most of the forcing associated with various greenhouse gases as reported by the IPCC (IPCC 2007), which are $1-2 \text{ W m}^{-2}$.

Thanks

- ▶ Pacific Northwest National Lab
 - Larry K. Berg
 - Evgueni Kassianov
 - William Shaw
- ▶ Department of Energy
- ▶ Global Change Education Program
 - Jeff Gaffney
 - Nancy Marley
 - Milton Constantin

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.