Empirical relationship between GOES optical depth and ARM SGP radar-lidar cloud thickness for Deep Convective Clouds

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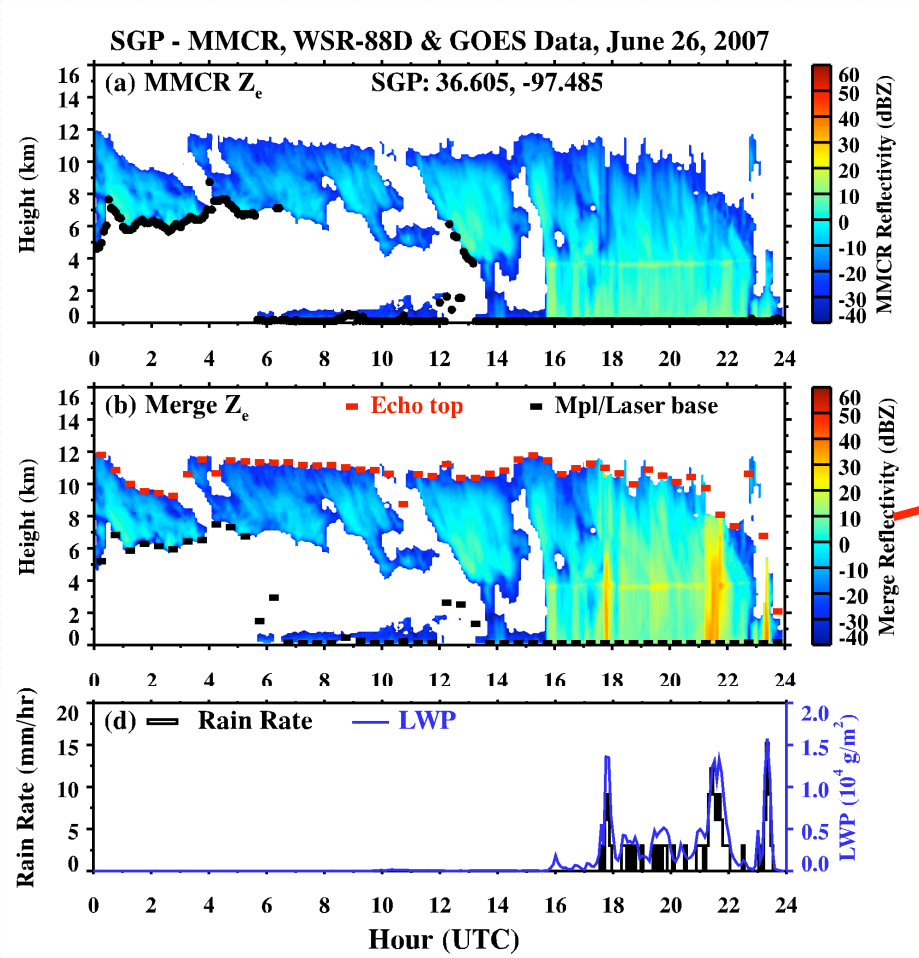
Estimate Cloud Thickness

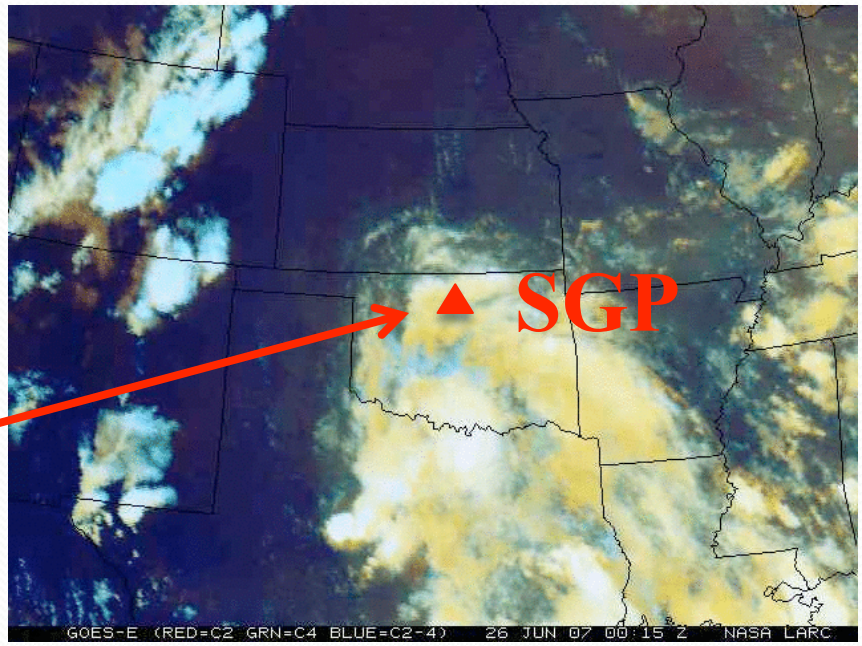
- **Use GOES retrieved optical depth to estimate cloud physical thickness**
- **Focus on *optically thick clouds* (i.e. deep convective clouds)**
- **Cases selected from 10-years ARM SGP MMCR and WSR-88D combined reflectivity data (Feng. et al. 2009)**
- **GOES results retrieved from Pat Minnis group**

Deep Convective Cloud

SGP MMCR+WSR-88D



GOES RGB Image



Data Filter

- GOES pixel level optical depth averaged within 10-km radius, centered at SGP site
- MMCR cloud thickness averaged ±10 min at GOES scan time
- Liquid cloud identified by GOES are not used
- Cirrus (z_{base} > 6 km) are not used
- Multi-layer cloud with maximum single layer thickness < 5 km are not used
- Thin clouds (thickness < 2 km) are not considered

Data Filter (continued')

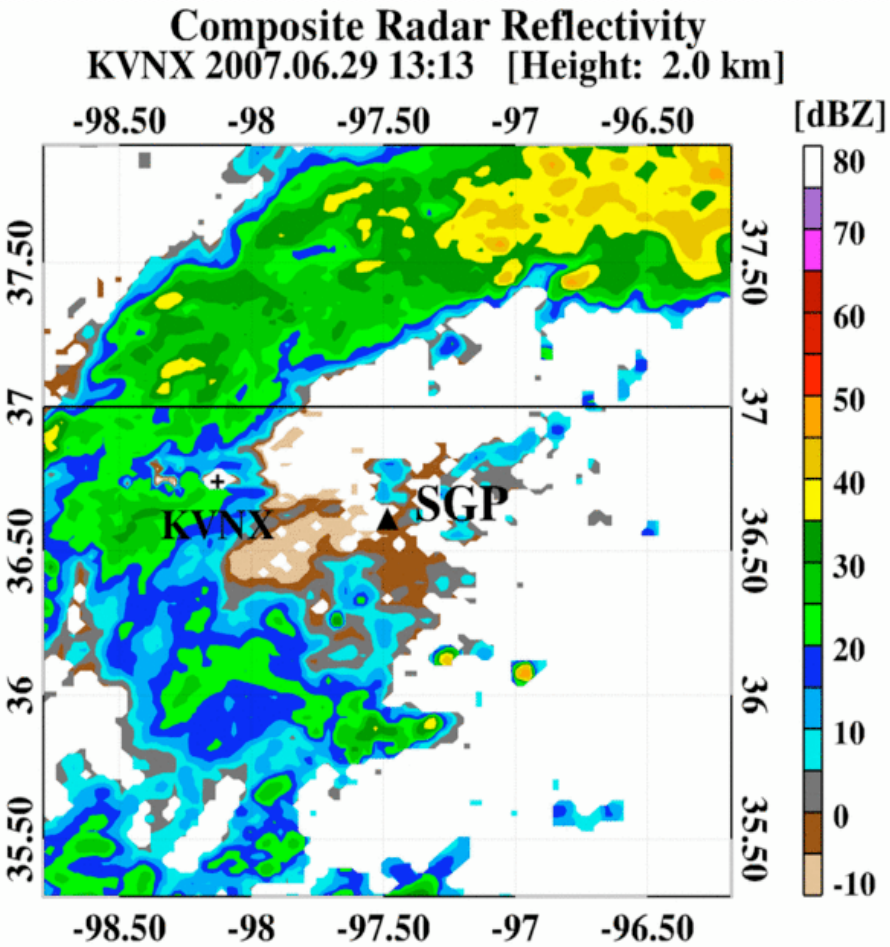
- **GOES data separated to daytime (VISST) and nighttime (SIST) retrieved optical depth**
- **Cloud cover > 95% in 10-km radius**
- **Cloud homogeneity (*U*) is used to constrain the comparison:**

$$U = \tau_\sigma / \overline{\tau}$$

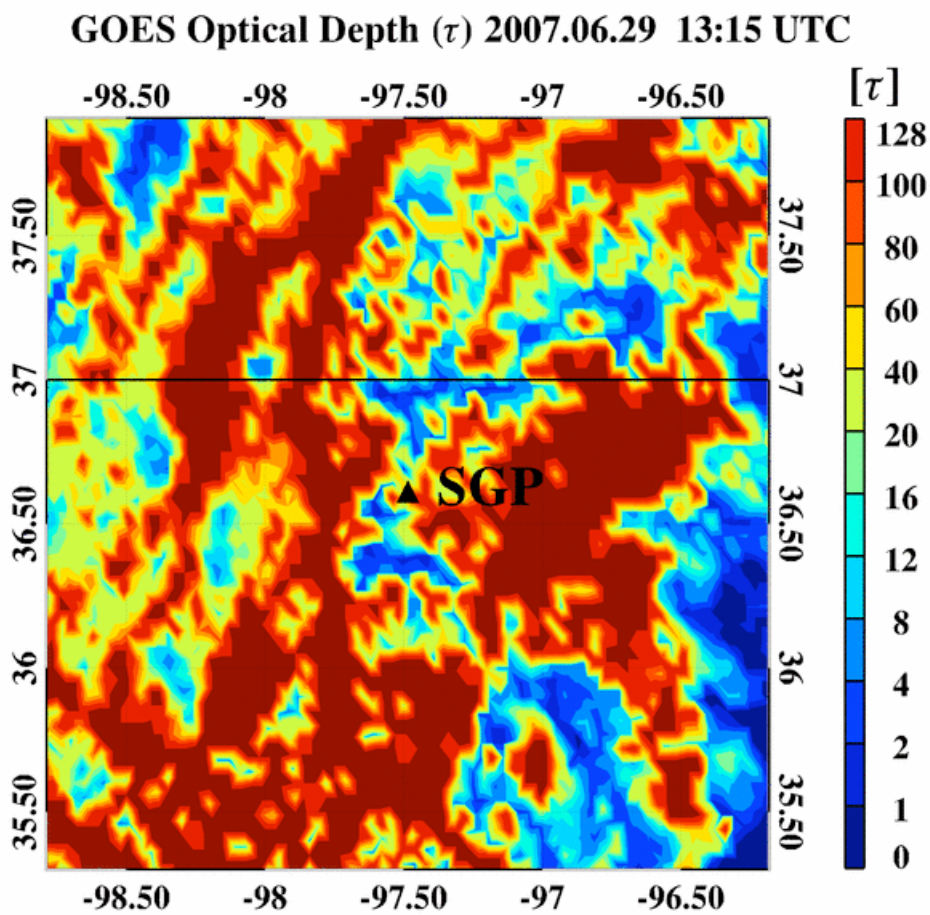
- ***U* < 0.15 is considered very uniform cloud, on the other hand, *U* > 0.5 is not**

Sample Case (Daytime)

WSR-88D Reflectivity

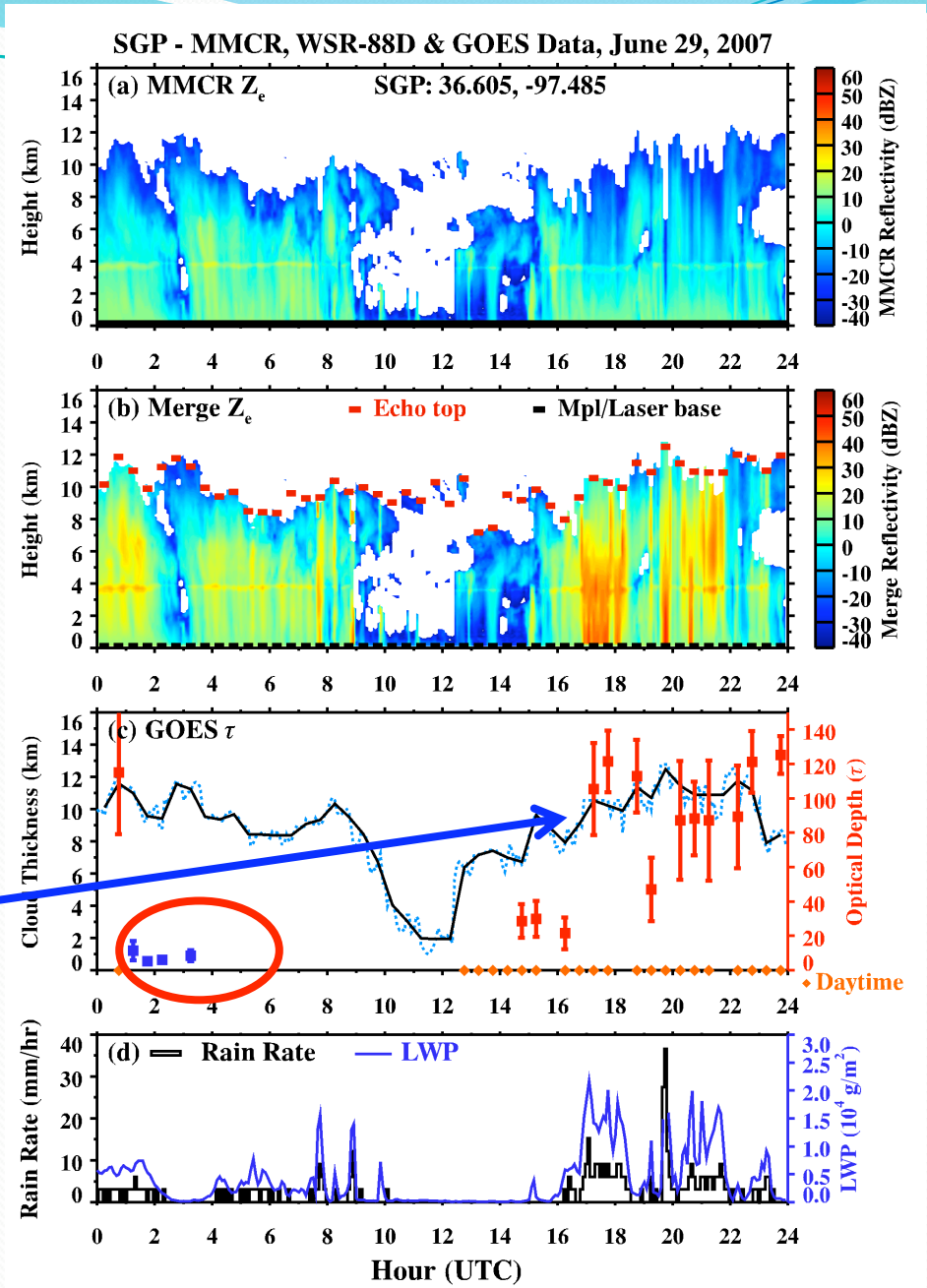


GOES Optical Depth

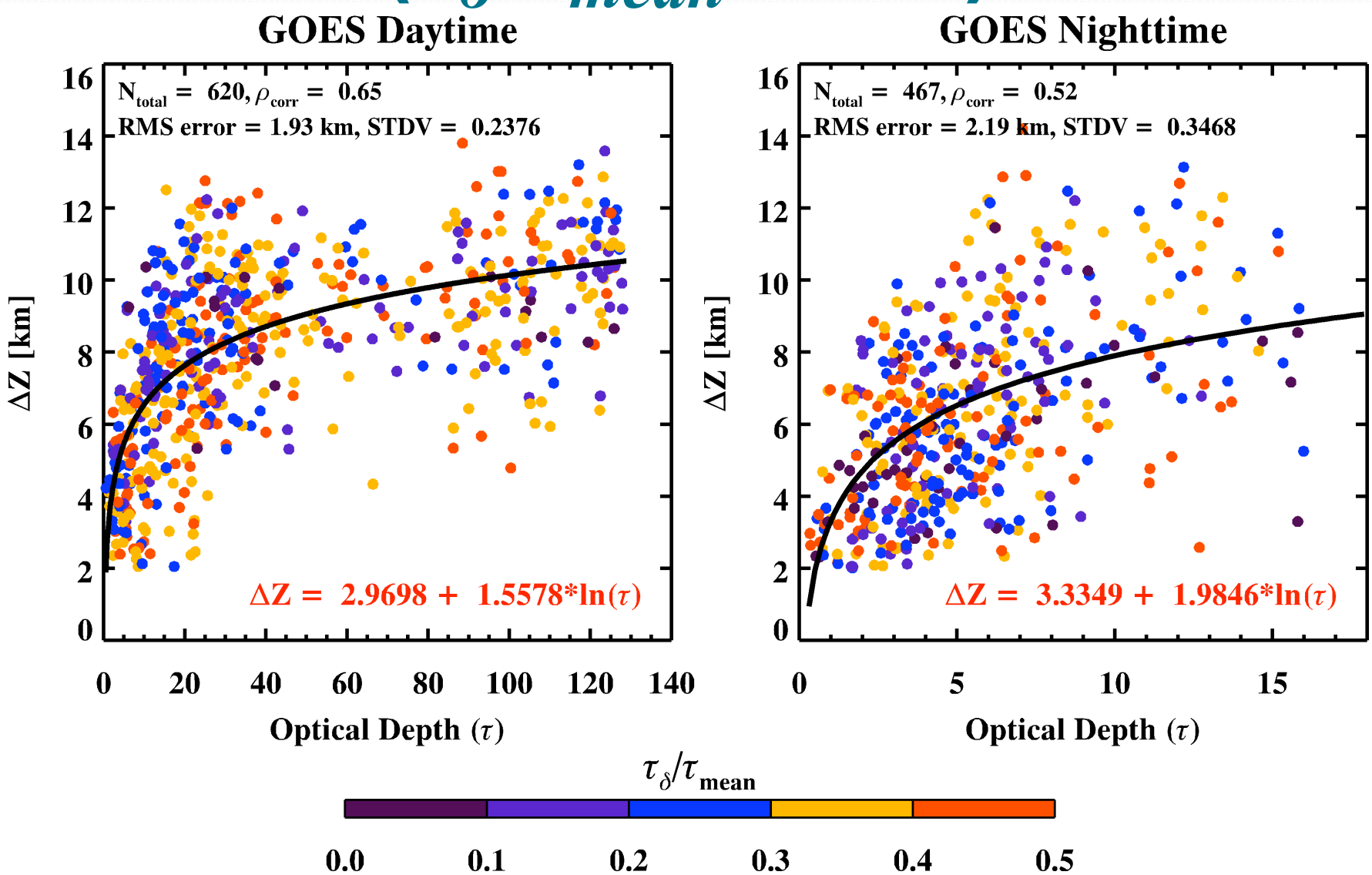


SGP Data

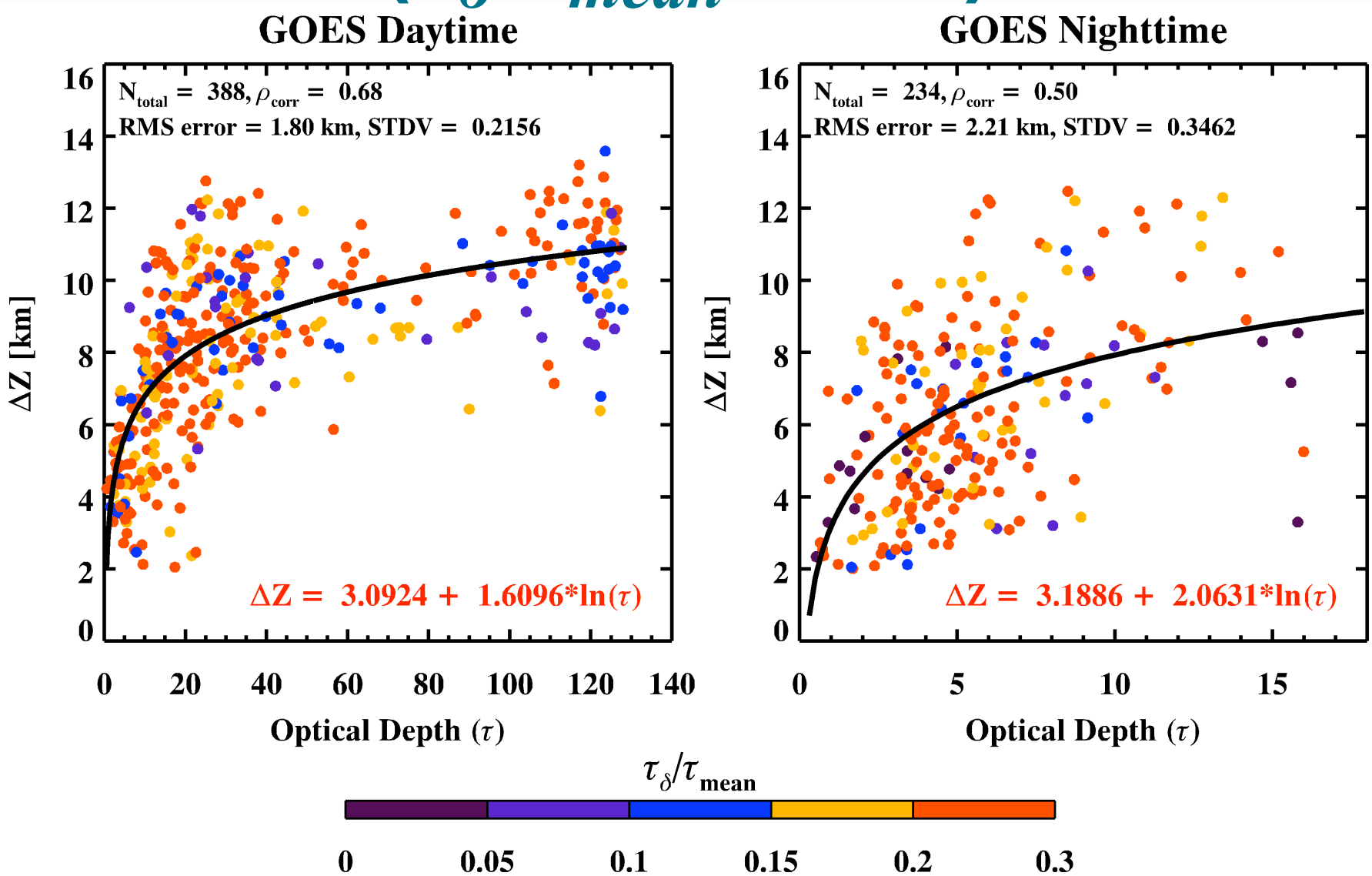
- Daytime optical depth is an order of magnitude larger than nighttime
- τ generally increases with physical thickness
- But significant variations shows DCC very dynamic
  - Cloud gaps (~19.5UTC)
  - Large τ_σ
- Data shown here all have $\tau_\sigma/\tau_{mean} < 0.5$



Result ($\tau_\sigma/\tau_{mean} < 0.5$)



Result ($\tau_\sigma/\tau_{mean} < 0.3$)



Z_{thick} Empirical Fit

- **For $\tau_\sigma/\tau_{mean} < 0.5$, the function fits are**
- **Daytime ($N = 620$)**

$$\Delta Z = 2.9698 + 1.5578 \cdot \ln(\tau)$$

  - **RMS error = 1.93 km, correlation coefficient = 0.65**

- **Nighttime ($N = 467$)**

$$\Delta Z = 3.3349 + 1.9846 \cdot \ln(\tau)$$

  - **RMS error = 2.19 km, correlation coefficient = 0.52**

Z_{thick} Empirical Fit

- **For $\tau_\sigma/\tau_{mean} < 0.3$, the function fits are**
- **Daytime ($N = 388$)**

$$\Delta Z = 3.0924 + 2.0631 \cdot \ln(\tau)$$

  - **RMS error = 1.80 km, correlation coefficient = 0.68**

- **Nighttime ($N = 234$)**

$$\Delta Z = 3.1866 + 2.0631 \cdot \ln(\tau)$$

  - **RMS error = 2.21 km, correlation coefficient = 0.50**