CONTRASTING LIDAR RETRIEVED CIRRUS OPTICAL PROPERTIES WITH IN-SITU AND ASSOCIATED CRF: *RETHINC FIELD CAMPAIGN HOUSTON, TX - AUG 2017*

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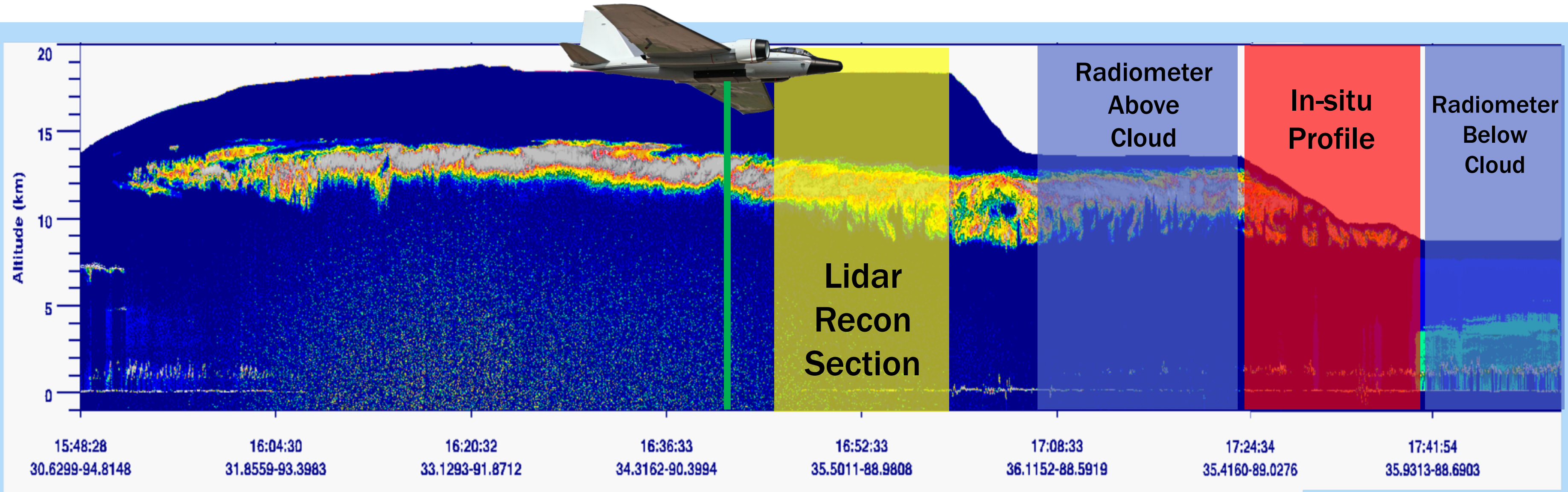
July 12th

15th AMS Cloud & Radiation Conference

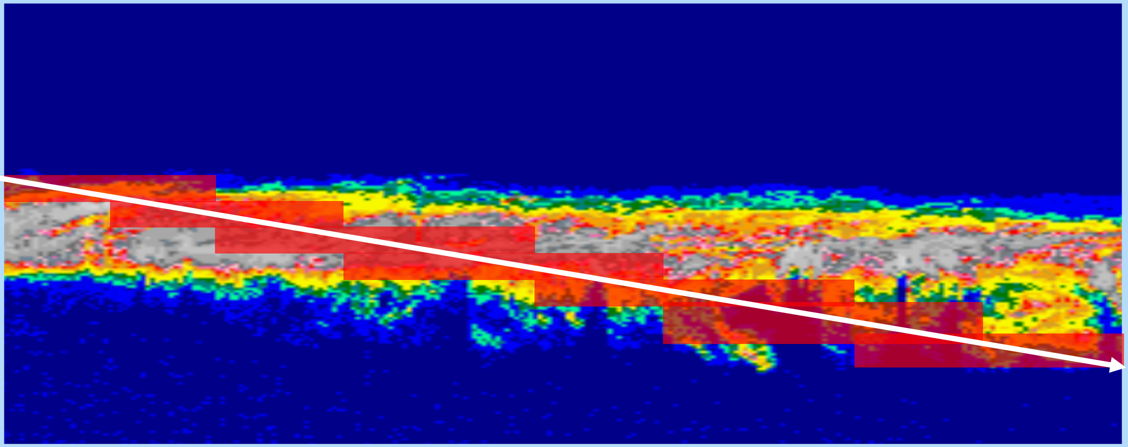
RETHINC FIELD CAMPAIGN

- Radiative Effects of Thin Cirrus
- More accurately quantify cirrus radiative effects
  - Synoptic vs. Convectively developed Cirrus
- NRL sponsored campaign
  - Ellington Field Houston, TX.
  - NASA JSC WB-57 aircraft (~60k feet)
- 3 year campaign
  - 2 Years Houston, TX (*2017 & 2018*)
  - Last year Fairbanks, AK (*2019*)
- SPEC inc. (*Boulder, CO*)
  - Crystal habit
    - (Large variation with formation mechanism)
  - Effective Crystal size
  - Size distribution
  - Ice water content
  - Derived extinction coefficient
- Radiometer Array (*NRL*)
  - Direct irradiance measurements above and below cirrus cloud layer
- Cloud Physics Lidar (*GSFC*)
  - Cloud height & thickness
  - Parameterized microphysical & optical properties

RETHINC FLIGHT PATTERNS



- Compare lidar derived microphysical & optical properties to in-situ profile
- Average lidar segment in step function
- Analyzed 4 of 6 flights from campaign



CPL MICROPHYSICAL & OPTICAL PROPERTIES

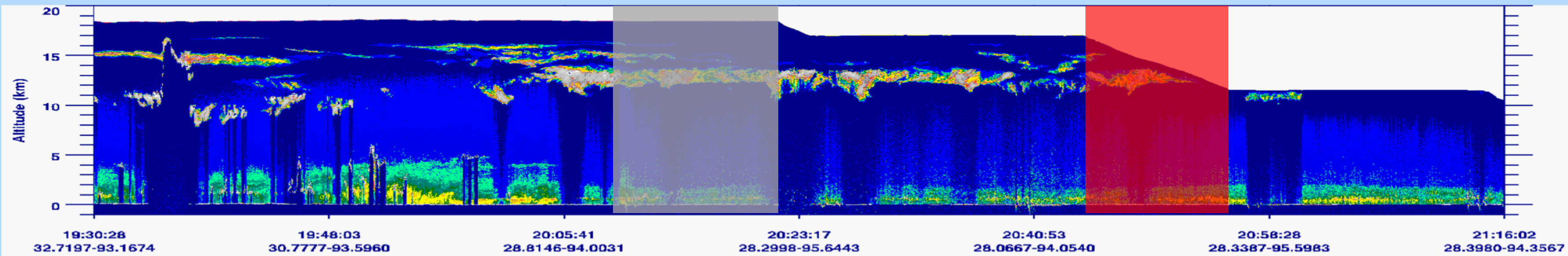
Extinction Coefficient

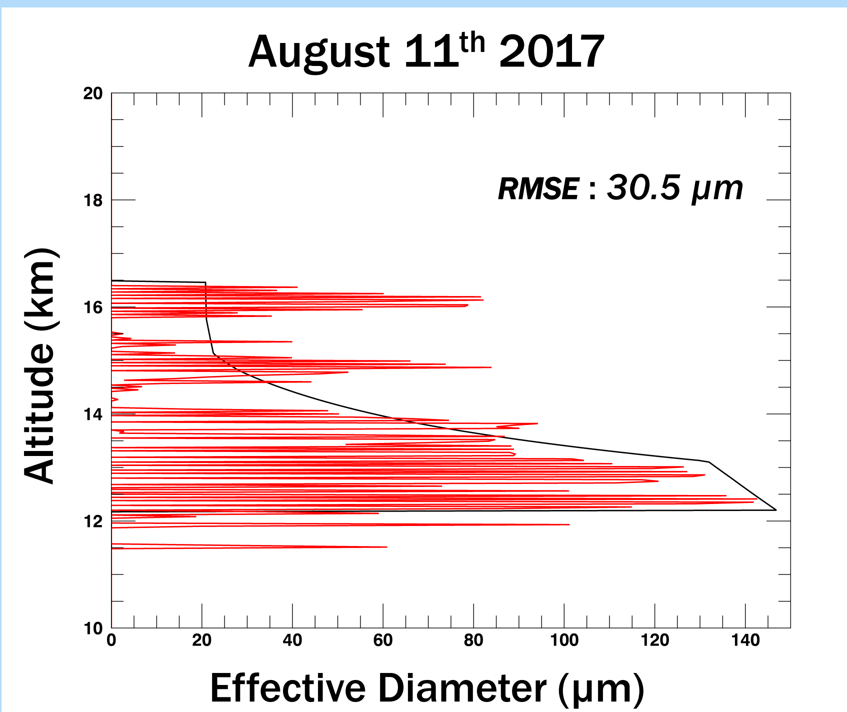
- Lidar Ratio (Extinction/Backscatter)
  - Klett Method (Klett 1981; 1985)
- LR assumed vertically constant through layer
  - Can be directly calculated (constrained)
    - Transmission loss method
  - Use of look up table

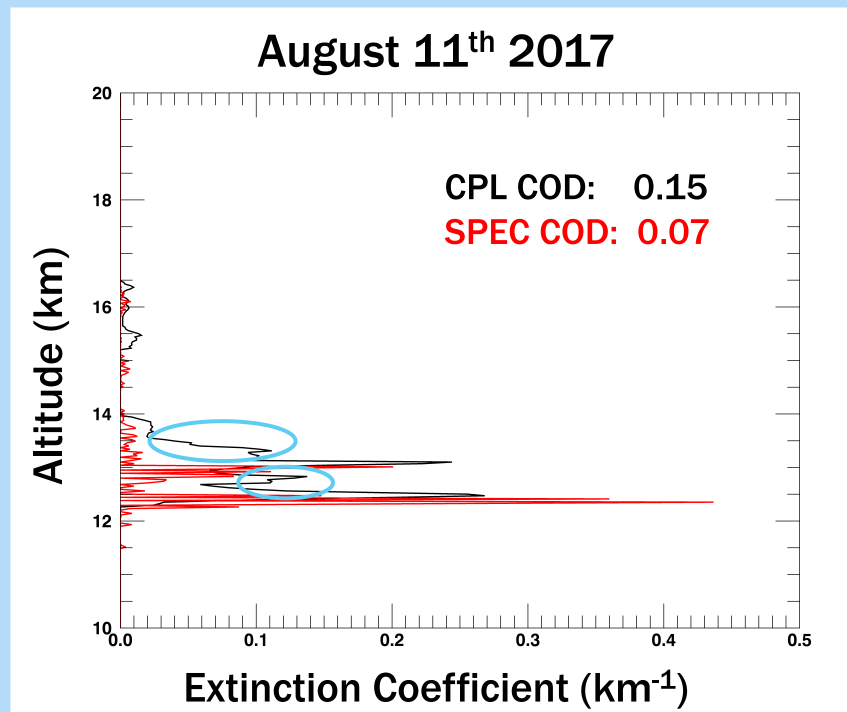
Ice Water Content & Particle Effective Diameter

- Heymsfield *et al.* 2014
  - CATS (*ISS*)
  - CALIPSO (*A-Train*)
- Effective diameter function of temperature profile
- IWC function of extinction and effective diameter

CPL & SPEC PROFILE COMPARISONS







IWC AND EXTINCTION

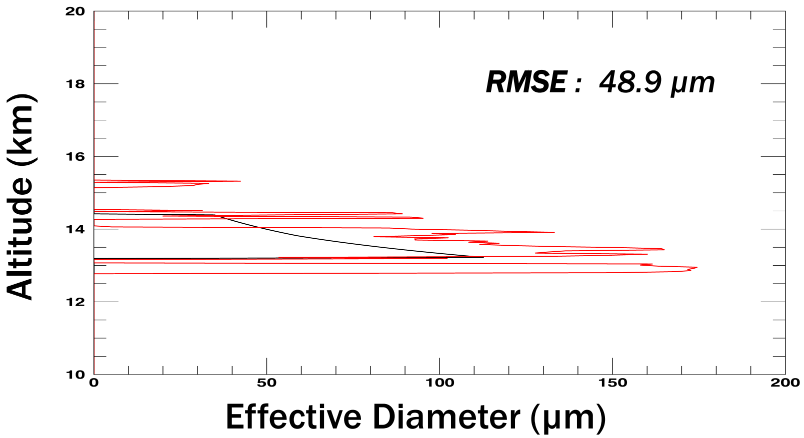
Date	Extinction (km^{-1}) Mean & Std Dev		IWC ($g\ m^{-3}$) Mean & Std Dev	
	CPL	SPEC	CPL	SPEC
July 27th	0.22 +/- 0.10	0.20 +/- 0.21	0.0093 +/- 0.0047	0.0044 +/- 0.0051
Aug 06th * *Thick Anvil*	0.23 +/- 0.12	0.92 +/- 1.29	0.011 +/- 0.0064	0.025 +/- 0.035
Aug 10th	0.29 +/- 0.16	0.033 +/- 0.033	0.0095 +/- 0.0057	0.00050 +/- 0.00054
Aug 11th	0.050 +/- 0.062	0.027 +/- 0.072	0.0016 +/- 0.0021	0.00055 +/- 0.0015

EFFECTIVE DIAMETER COMPARISON

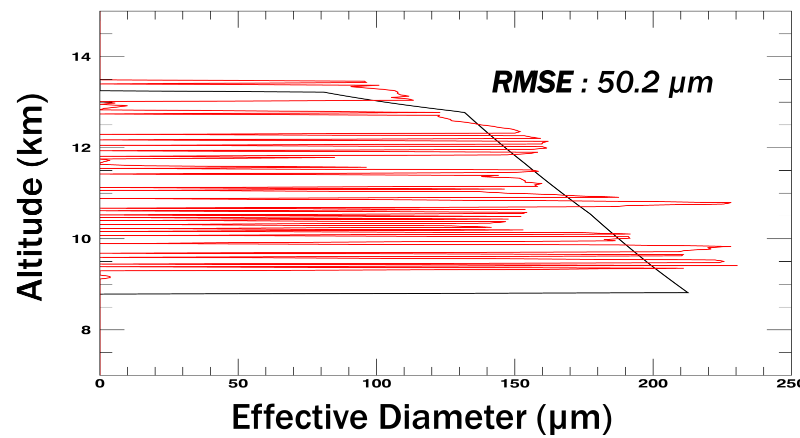
Date	CPL Mean D_{eff}	SPEC Mean D_{eff}	D_{eff} RMSE
July 27th	65.0 µm +/- 23.1	114.9 µm +/- 41.2	48.9 µm
Aug 06th *	163.4 µm +/- 32.3	141.0 µm +/- 54.6	50.2 µm
Aug 10th	102.3 µm +/- 48.0	100.6 µm +/- 19.2	28.0 µm
Aug 11th	65.0 µm +/- 47.7	64.7 µm +/- 40.2	30.5 µm

LIDAR VS. SPEC
CRYSTAL EFFECTIVE DIAMETER

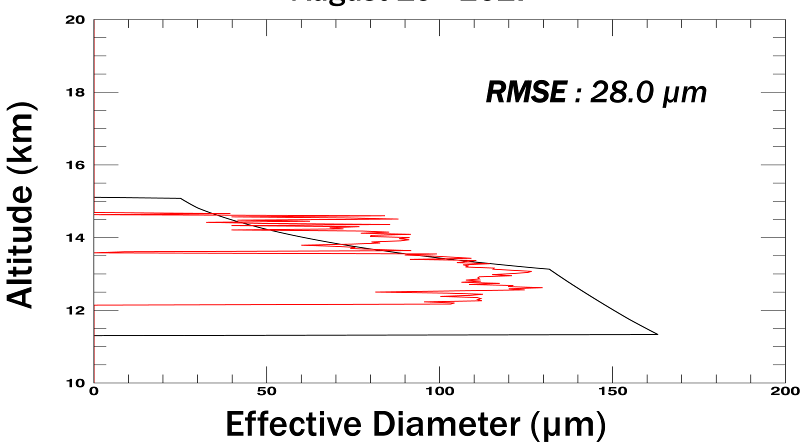
July 27th 2017



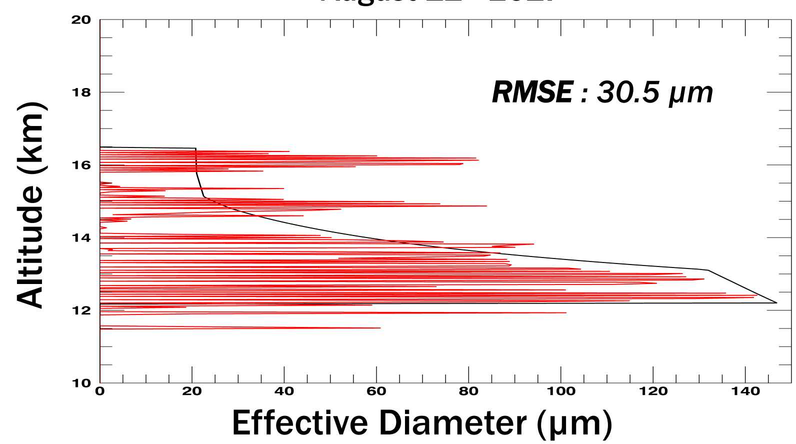
August 6th 2017



August 10th 2017



August 11th 2017



RADIATIVE FORCING SIMULATIONS

- LibRadtran Model (Mayer and Kylling, 2005)
- Thermodynamic profile each flight period
  - GEOS-5
  - Pressure, Altitude, Temperature, Water Vapor, Ozone

- Surface Albedo: 0.2
- Zenith Angle: 24° (Average over all flight periods)
- Ice Optical Properties: Ping Yang *et al. 2013*
  - Scattering properties & asymmetry parameter

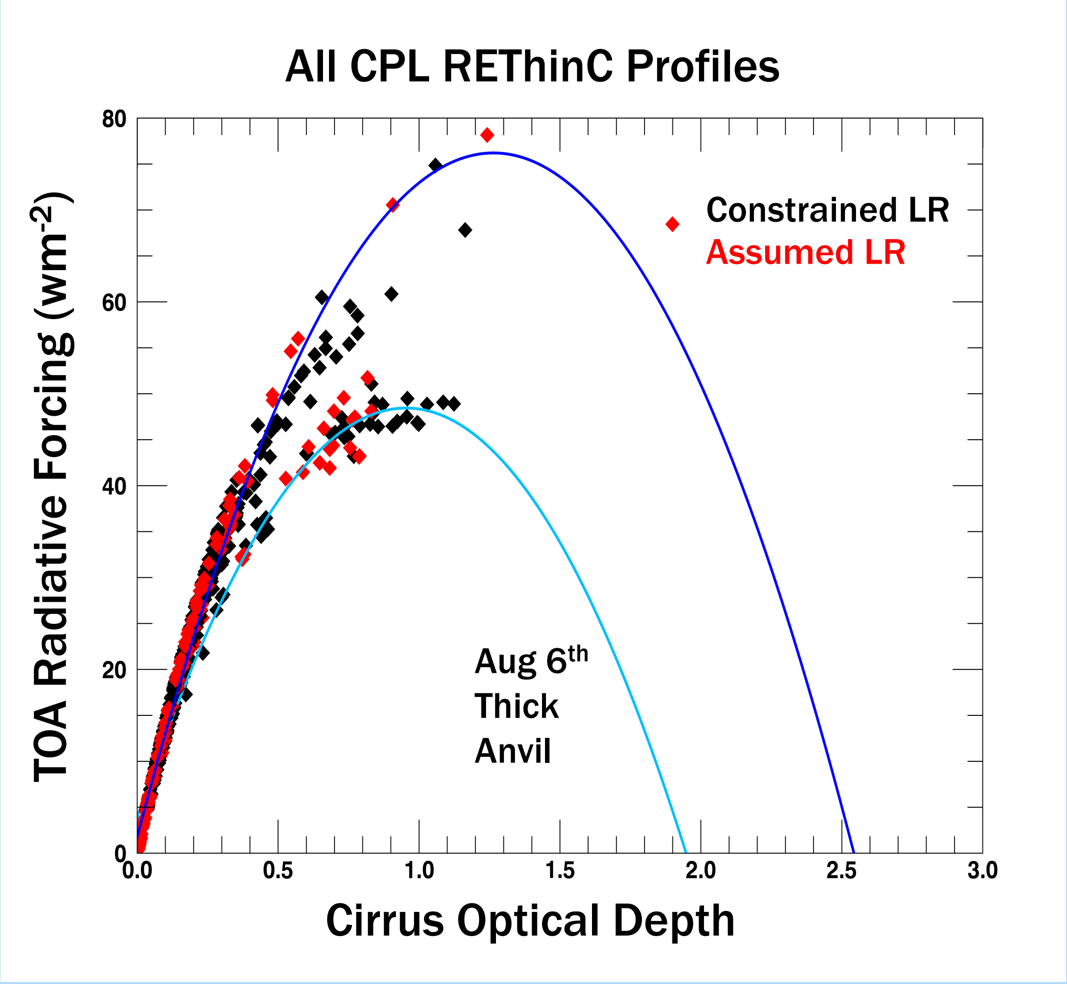
- Lidar prescribed COD input instead of extinction parameterized by model
- Cirrus layer defined by IWC and effective diameter

SIMULATED
TOA RADIATIVE FORCING

Date	CPL Average Profile: Estimated TOA Radiative Forcing	SPEC In-Situ Profile: Estimated TOA Radiative Forcing
July 27th	73.4 $W\ m^{-2}$	15.0 $W\ m^{-2}$
August 6th *	41.9 $W\ m^{-2}$	-14.3 $W\ m^{-2}$
August 10th	65.2 $W\ m^{-2}$	3.10 $W\ m^{-2}$
August 11th	17.4 $W\ m^{-2}$	3.30 $W\ m^{-2}$

- Large variability in retrieved cloud optical depth and ice water content (~60%)
- Sampling discontinuities
  - Varying horizontal and vertical resolutions
- Temporal variability in cloud layer
  - SPEC in-situ flight profile ~20-40 minutes after CPL overpass

TOA CIRRUS RADIATIVE FORCING

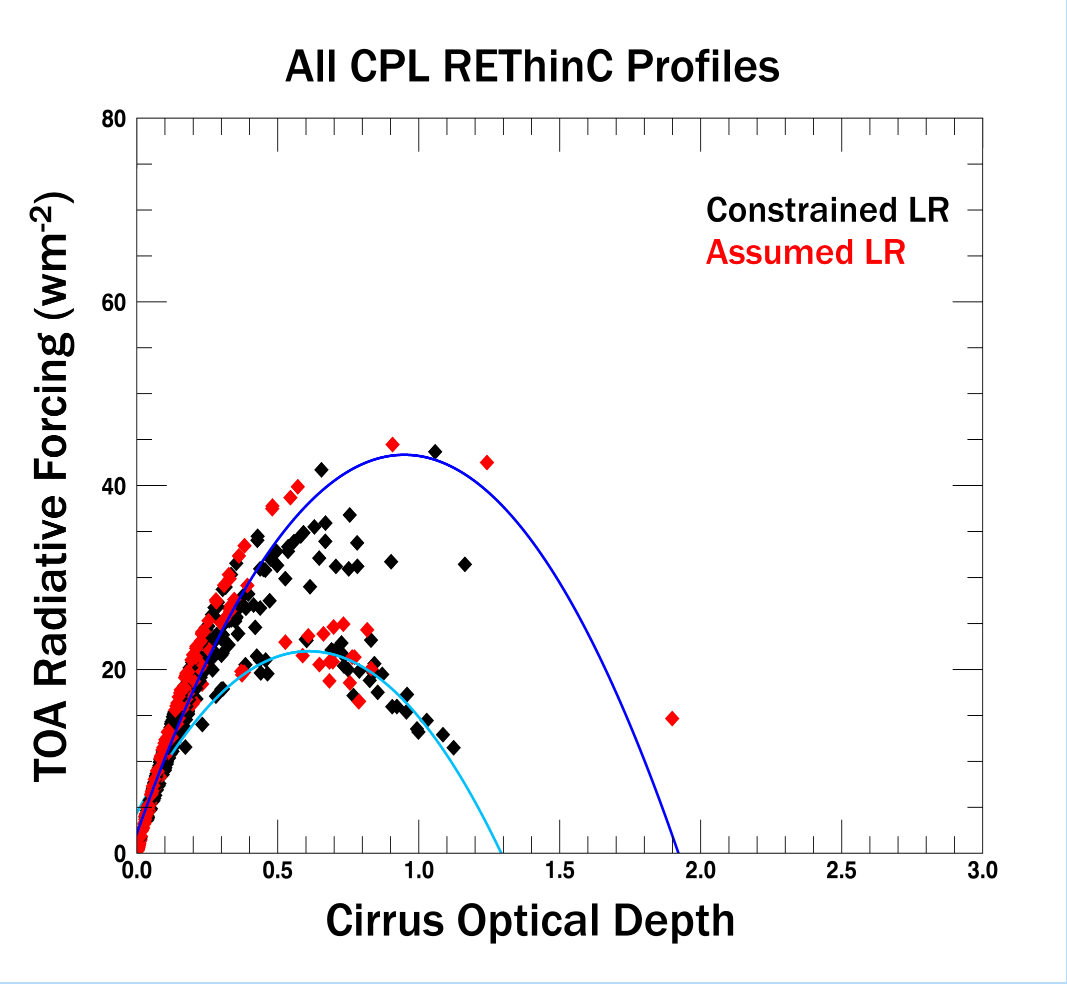


Crystal Habit: Bullet Rosette
(common synoptic cirrus)

Mean Lidar Ratios (sr)

Date	Mean LR
July 27th	20.6
Aug 6th *	23.7
Aug 10th	21.1
Aug 11th	25.4

FUTURE WORK



Crystal Habit: Aggregate of Columns
(more common convective cirrus)

- Analyze CRF dependency on crystal habit
  - To be provided by SPEC upon complete data delivery
- Compare with radiometer measurements from REThinC flights
  - Also to be ready later this summer

CONCLUSIONS

- CPL averaged profile of extinction and ice water content did not agree well with the in-situ
  - Sampling discontinuities
  - Temporal variability/evolution of cirrus layer
    - In-situ fight profile ~20–40 minutes after CPL overpass
  - Large variability in estimated TOA cloud radiative forcing
- CPL parameterized effective diameter agreed moderately well with the in-situ
  - Less horizontal variability
- CRF vs. COD values follow a parabolic trajectory more dependent on layer microphysical properties (habit) than lidar ratio

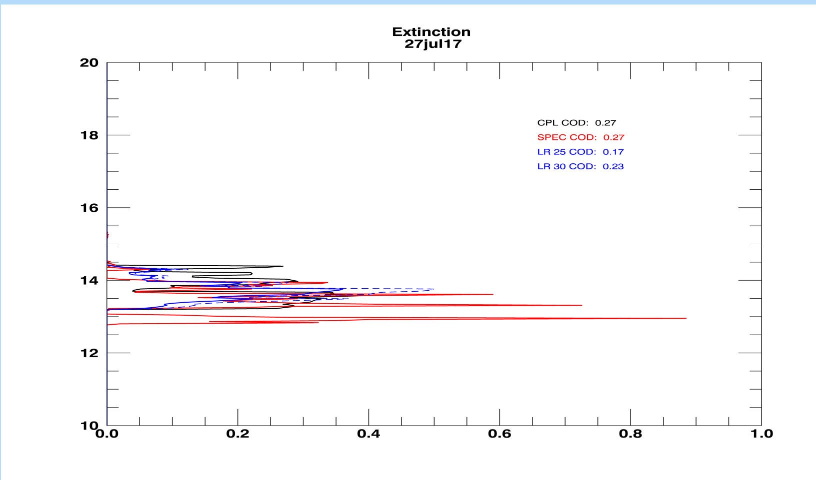
QUESTIONS?

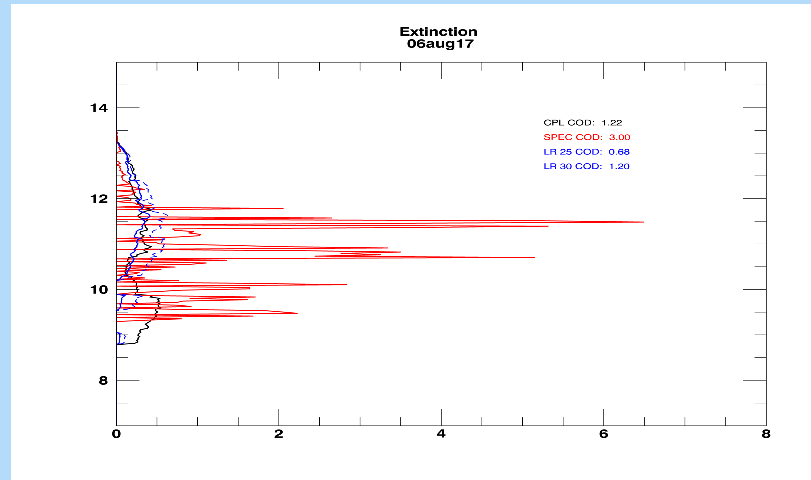
BACK UP SLIDES

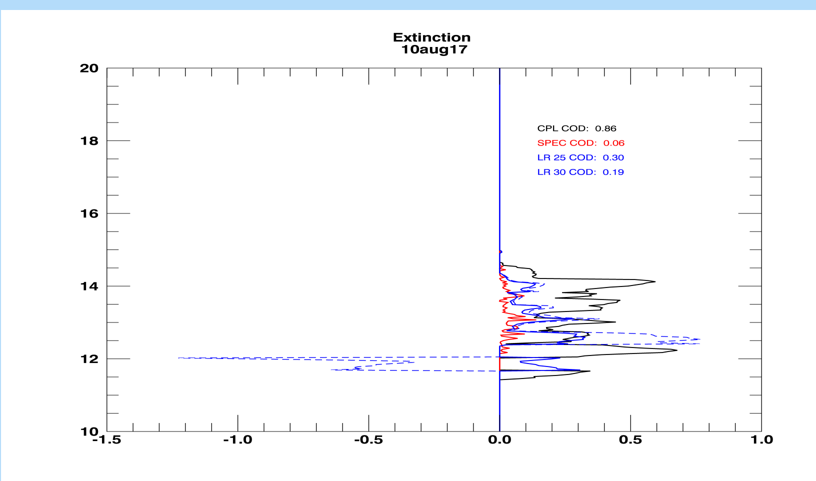
CPL & SPEC PROFILE COMPARISONS

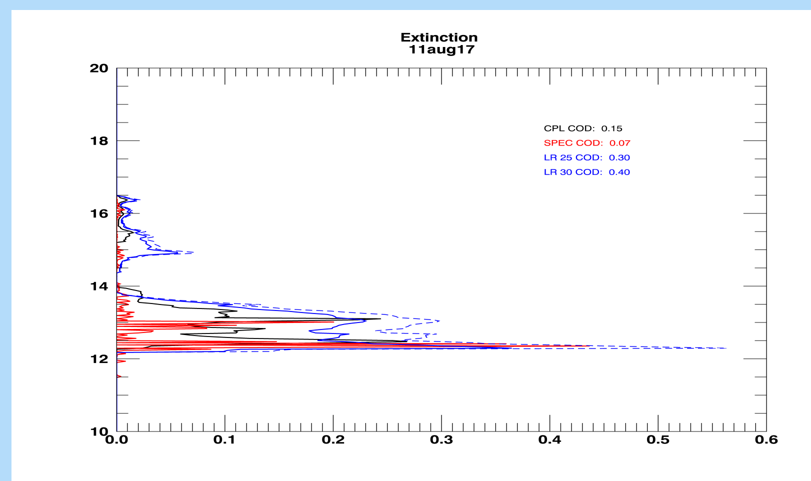
Date	Cloud Optical Depth		Ice Water Path (g m^{-2})	
	CPL	SPEC	CPL	SPEC
July 27th	0.27	0.27	11.11	5.83
Aug 06th *	1.22	3.00	57.03	81.52
Aug 10th	0.86	0.31	27.66	4.84
Aug 11th	0.15	0.07	4.81	1.31
Mean % Difference	*66.8 %*		*61.4 %*	

LIDAR VS. SPEC EXTINCTION COEFFICIENT









ELASTIC BACKSCATTER LIDAR EQUATION

- Substitute lidar ratio in for extinction

$$[\beta_A(r)+\beta_M(r)]\exp\{-2\int[\alpha_A(r)+\alpha_M(r)]dr\} = ATB$$

$$[\beta_A(r)+\beta_M(r)]\exp\{-2\int[S_A(r)\beta_A(r)+\alpha_M(r)]dr\} = ATB$$

- Then solve for β_A assuming a constant value of S_A
- You can then solve for extinction

$$\alpha_A(r) = S_A(r)\beta_A(r)$$

  - This technique is often referred to as the Klett method