



Highlights of 2003 CLEX-Based Research (14 Oct 2001 CLEX-9 Case Study)

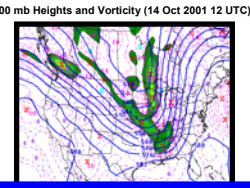
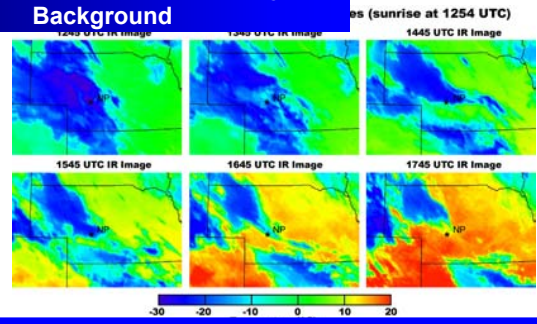
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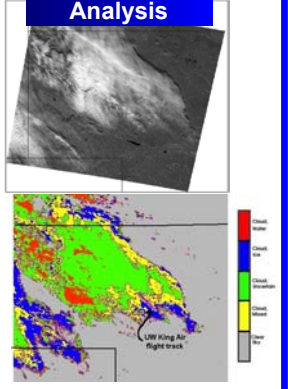
14 Oct 2001 CLEX-9 Case Study

The 14 Oct 2001 CLEX-9 day was composed of two Wyoming King Air missions. The first lasted from 1215 to 1610 UTC and focused on an extensive mid-level cloud deck over Western NE. The second mission, which lasted from 1711 to 1833 UTC, sampled a mid-level cloud beneath a 1740 UTC MODIS overpass NE of North Platte, Nebraska.

Background

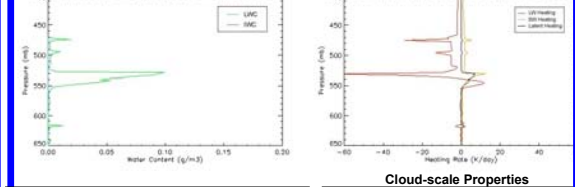


MODIS Analysis



1740 UTC MODIS overpass of 250m visible (.67 μm) and cloud phase products. Note wave-like patterns (NW to SE orientation) in the visible image.

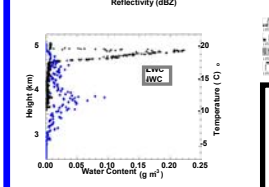
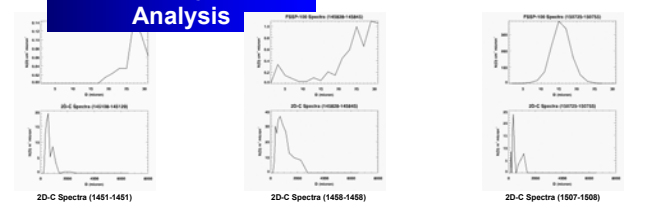
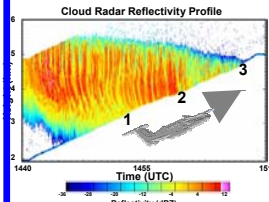
Bulk Microphysics and Radiative Transfer Analysis



Cloud-averaged profiles of LWC and IWC are shown above. Though no IWC content is shown above, significant ice was observed during aircraft transects near cloud base. The heating rate profiles (above right) indicate a moderate net heating (+12 K day⁻¹) just above cloud base and a strong net cooling (-50 K day⁻¹) just below cloud top. This cloud was thin enough to experience solar heating throughout the cloud layer. The maximum solar heating rate at cloud top is similar in magnitude to the longwave heating at cloud base.

- Cloud-scale Properties**
- Cloud base: 4643 m MSL
 - Cloud depth: 458 m
 - average LWC: 0.038 g m⁻³
 - average IWC: 0
 - Liquid effective radius: 10.9 microns
 - Ice effective radius: 0
 - Visible optical depth: 5.4
 - Cloud base temp: -19 C
 - Cloud top temp: -22 C
 - Subsidence term: 2.07×10^{-08} (kg kg⁻¹ s⁻¹)
 - Entrainment term: -1.52×10^{-08} (kg kg⁻¹ s⁻¹)
 - Radiation term: 1.92×10^{-10} (kg kg⁻¹ s⁻¹)
 - Precipitation term: 0
- (Cloud sampling times: 1215 to 1610 UTC)

Microphysical Analysis



The vertical profile of LWC (black diamonds) and IWC (blue diamonds) during the 14 October 2001 straight-line ascent from 1440 to 1510 UTC.

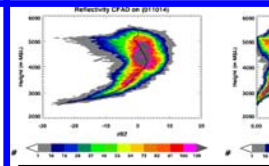
King Air below the generating cells (point 1). 2D-C is beginning to show increases in IWC, while LWC remains near 0. This is also apparent in the spectra from FSSP and 2D-C. FSSP concentration ≤ 1 , and 2D-C showing wider size distribution and higher values (max $\approx 35 \mu\text{m}^3$).

King Air entering the generating cells (point 2). 2D-C IWC at a Maximum in this region, while LWC remains near 0. FSSP concentration still ≤ 1 . 2D-C now showing wider size distribution and higher values (max $\approx 35 \mu\text{m}^3$).

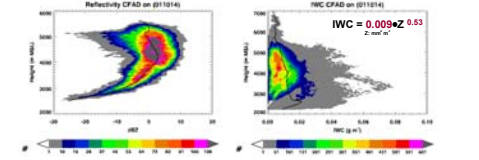
KA approaching cloud top (point 3). 2D-C IWC has fallen back off in this region, while LWC shows peak values of 0.22 g m^{-3} . FSSP concentration at a maximum ($> 300 \text{ cm}^{-3}$). 2D-C back to narrow size distribution and lower values (max $\approx 24 \mu\text{m}^3$).

The top of the cloud (point 3) appears to be the source region for ice production, with 2D-C imagery showing populations of small sector plates and small spherical particles, many of which are likely super cooled cloud droplets. Temperature $\approx -23 \text{ }^\circ\text{C}$.

Radar Analysis

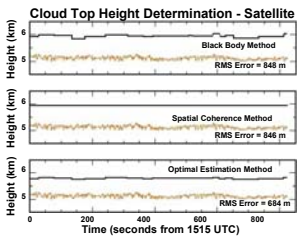
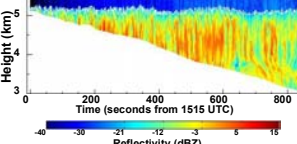


Contoured Frequency by Altitude Diagram (CFAD) of WCR reflectivity and WCR-derived IWC from 14 October 2001 (straight-line ascent from 1440-1510 UTC). Ice Water Content-Reflectivity (IWC-Z) Relationship derived from 2D-C probe particle size distribution data assuming Mitchell et al. (1990) "all-snow" mass-dimensional relationship.



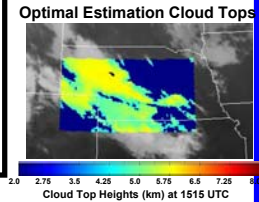
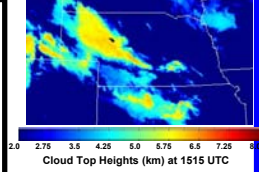
Contoured Frequency by Altitude Diagram (CFAD) of WCR reflectivity and WCR-derived IWC from 14 October 2001 (entire case).

Cloud Top Height Estimations

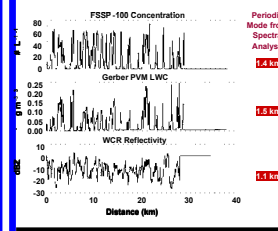


Three single channel (10.7 μm) methods of determining cloud top heights are explored here. Upper left plot depicts a vertical cross section of 95 GHz radar reflectivity with cloud top heights shown in white and are used as "truth" in this study. The three methods investigated here include:
Black Body Method (Invert Planck function, convert to height with local sounding)
Spatial Coherence Method (Based on work by Coakley and Bretherton, 1982. This method is well suited for single layered homogenous clouds)
Optimal Estimation Method (Use a sounding for a priori cloud layer height and then iterate using radiance and spatial coherence until height converges. This method worked best on this case and can easily be transitioned to any operational center)

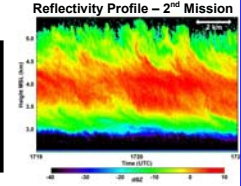
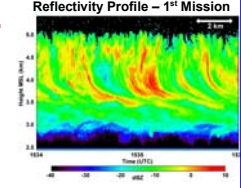
Black Body Cloud Tops



Spectral Analysis



The 95 GHz cloud radar reveals detailed structure of generating cells, with significant horizontal variability in cloud properties. Spectral Analysis reveals cellular structure with primary horizontal mode of 1-1.5 km evident in FSSP, Gerber and radar data.



Significant questions yet to be addressed

- mixed phase clouds?
- What sustains the supercooled liquid water region observed near cloud top?
- Why do some clouds dissipate after sunrise while others continue through the morning hours? How does the introduction of shortwave radiation impact the cloud lifecycle?
- Furthermore, there are no cloud models that successfully simulate observed mid-level cloud structures.
- Can we identify a cloud dissipation index (CDI) that can be applied to mid-level mixed phase clouds?
- Do oceanic or tropical mid-level mixed-phase clouds differ significantly from their mid-latitude brethren?