Thunderstorm Generation of Cirrus From an ER-2 Radar Perspective

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Collaborations
Starr et al., McGill, Mace, Z. Wang,
J. Wang, A. Heymsfield, F. Evans,..
Objectives

• Document vertical and horizontal wind structure at upper levels of thunderstorm generated anvil cirrus using EDOP and CRS.
• Examine the role of wind shear on thunderstorm cirrus generation.
• Relate the EDOP and CRS-based IWC, fallspeeds, particle size, etc. to the overall structure of the thunderstorm-generated cirrus.
• Cases: 23 July, 28 July, 29 July, 7 July, 19 July, 9 July
EDOP and CRS  Reflectivity

edop_020723_2004-2025

CRS_020723_2004-2025
Time Sequence of Passes on 23 July
Southwest to Northeast
ER-2 Doppler Radar (EDOP)

- Precipitation radar located in nose of NASA ER-2 high-altitude aircraft emulates satellite view
- Coherent Doppler operation at X-band (9.6 GHz) frequency
- Dual-fixed antennas for nadir and forward views along aircraft track
- Forward beam provides dual polarization capability for microphysical characterization of precipitation (liquid, snow, hail)

**Key Parameters:**
- Gate Spacing (vertical res.) 37.5 m
- Max. Unambiguous Range 35 km
- Nyquist Velocity 34 ms⁻¹
- Along-track sampling 100 m
- Footprint at surface (nadir) 1.1 km
- 4 Receivers: Nadir, Nadir Surface, Forward Co-Pol, Forward Cross-Pol

Minimum detectable signal ~ -20 dBZₑ at 4.4 kHz PRF, 0.5 s average, 10 km range.
EDOP and CRS Vertical Air Motions

\[ v_d = v_f - w_a - V_{ac} \]

- \( v_d \) = measured Doppler velocity
- \( V_{ac} \) = aircraft motion
- \( v_f \) = hydrometeor fallspeed
- \( w_a \) = air vertical motion

- **Doppler velocities** very accurate (0.1 ms\(^{-1}\)) except near cloud edges and very high-shear regions.
- **Aircraft motion** correction from very good (few tenths ms\(^{-1}\)) to much worse (1.0 ms\(^{-1}\)) in ER-2 - level gravity wave regions.
- **Vertical velocity** estimate depends on fallspeed estimate accuracy.
EDOP-Derived Winds

Vert velocity

Along-track wind

S = 2x10^-3 s^-1

Peak wind
18 ms^-1 @13 km
Cells in Different Stages of Development

Along-track wind

Refl

Vert vel

collapsing new cell

Trop
EDOP 23 July 2003   2004-2025 UTC

Along-track wind

Fallspeed

Trop

>20 ms⁻¹
Decaying Towers and Cirrus Generation

020723_1939-1954  CRS Refl  EDOP Vect

020723_2004-2025  CRS Refl  EDOP Vect
Complex Cirrus Layers Near Thunderstorms

fspd ~ 0.5 ms$^{-1}$
IWC Comparison-Single Frequency

020723_2004-2025

EDOP IWC

CRS IWC

Atten. & mie scatt.
Particle Sizing in Cirrus Trail

Layer-averaged reflectivity
9.6 GHz, 94 GHz

Significant Mie scattering at 7-8 km altitude indicates location of largest particles.
Summary and Future Work

• Continue on 23 July case but also examine other cases with respect to shear effects on radar-observed convective structure and cirrus.
• Provide observational inputs for cirrus modeling studies (Starr, ..).
• Continue with CRS & EDOP calibration, data quality, data distribution.
• Work toward well-validated algorithms for IWC, fallspeeds, and particle sizes using EDOP, CRS, and CPL that can be applied to all C-F data for process studies. [collaboration, CloudSat].
• CRS upgrades for improved sensitivity.
Sounding and Winds
23 July 2003

MOB 7/23/2002 1523 UTC

ALL 7/23/02 Soundings
Along and Cross Track Winds