2021 Open Data Workshop
(December 7th)

DCOTSS
NASA Earth Venture Suborbital 3
Dynamics and Chemistry of the Summer Stratosphere

ERA5 Reanalysis Variables and TRAJ3D Back Trajectories

ERA5 and TRAJ3D

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Special thanks to Kai-Wei Chang

Three products based on ERA5 reanalyses

1. **Hourly ERA5 global tropopause analyses**
2. **ERA5 variables interpolated to the ER-2 flight paths**
3. **TRAJ3D back trajectories from the ER-2 flight paths using ERA5 winds and diabatic heating rates**

ERA5 reanalysis products from ECMWF

- **Pressure coordinate files**: global, 0.75° × 0.75° horizontal, unevenly spaced in p, 1 h in time
  - Used for tropopause analysis and interpolation of selected variables to ER-2 aircraft positions (flight paths)
- **Isentropic coordinate files**: global, 0.75° × 0.75° horizontal, unevenly spaced in θ, 1 h in time
  - Used to provide velocity for isentropic and diabatic back trajectories initialized at ER-2 aircraft positions
- Hersbach et al., 2020, *QJRMS*, https://doi.org/10.1002/qj.3803

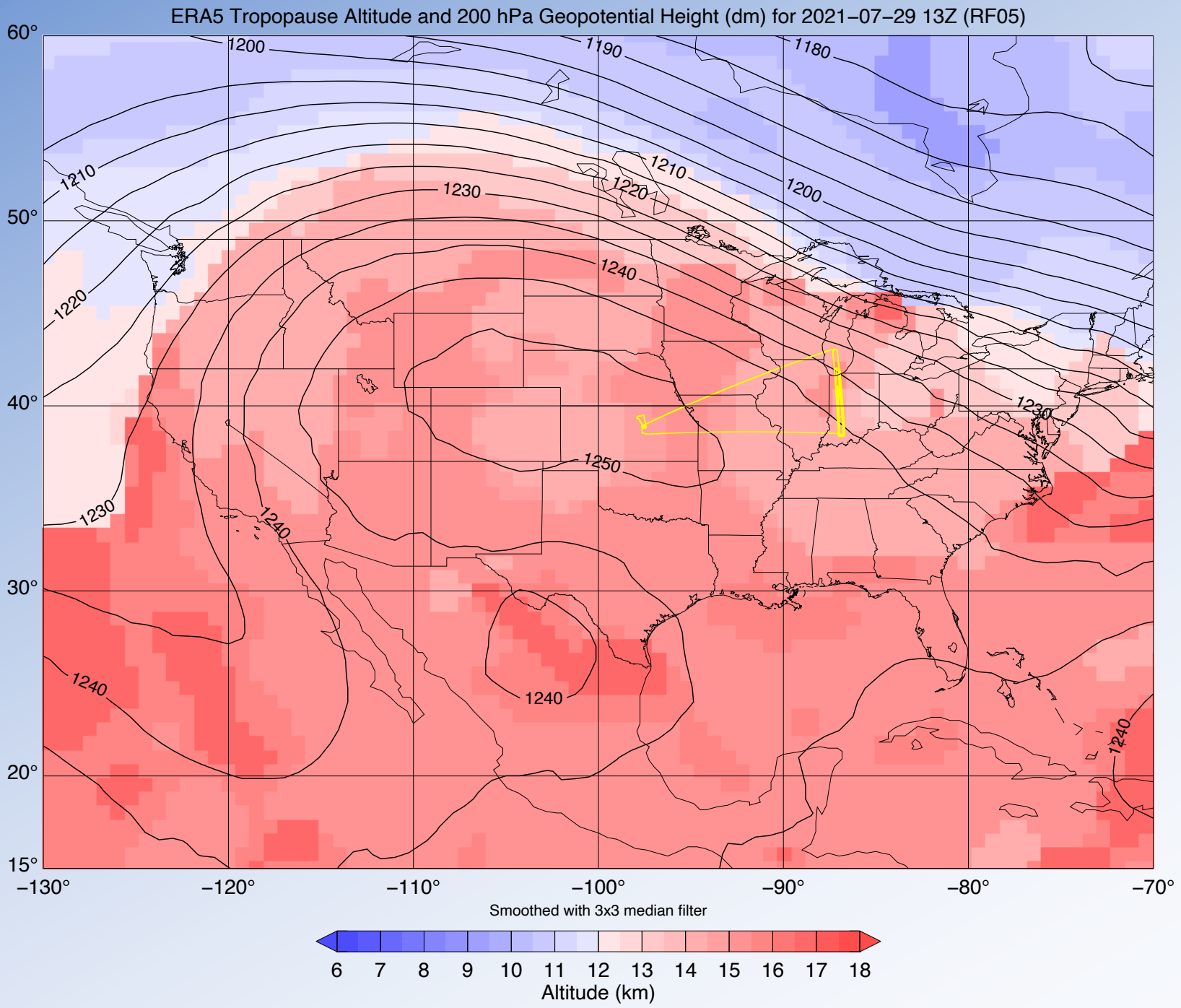
ER-2 position and state variables

- Longitude, latitude, and altitude from ER-2 NAV GPS
- Pressure, temperature, and potential temperature from Meteorological Measurement System (MMS)
- 1-second data

ERA5 tropopause analyses

- Hourly global analyses on 0.75° × 0.75° grid
- Lapse-rate tropopause altitude Z_{trop} computed by linearly interpolating T to regular 250 m geopotential height grid at each horizontal grid point and applying WMO algorithm
  - Minimum altitude 5 km; maximum altitude 20 km
- Primary tropopause is identified everywhere; secondary tropopause, if present
- Pressure and temperature interpolated to Z_{trop}

Tropopause analysis for 2021-07-29 13Z (RF05)



ERA5 tropopause file structure

- NetCDF files; 1 file per hourly ERA5 analysis
- Coordinate variables: longitude and latitude from ERA5 grid; tropopause index (zero-based)
- Dependent variables (2-D): Z_trop, p_trop, T_trop
- File name: DCOTSS-ERA5-tropopause_YYYYMMDD_<version>.nc
- Typical file size: ~625 kB

ERA5 Reanalysis Variables along the ER-2 Flight Path

- ERA5 variables interpolated to the ER-2 flight path
  - $u, v, w, T, Z, SH, RH, PV, p_{trop}, Z_{trop}$
- 4-D linear space-time interpolation to instantaneous ER-2 position

ERA5 flight path file structure

- NetCDF files; 1 file per flight; 1 time dimension
- ER-2 variables: TIME_START, TIME_STOP, LONGITUDE_ER2, LATITUDE_ER2, GPS_ALTITUDE_ER2, P_MMS
- ERA5 variables: u_ERA5, v_ERA5, w_ERA5, T_ERA5, Z_ERA5, SH_ERA5, RH_ERA5, pv_ERA5, p_trop_ERA5, Z_trop_ERA5
- File name: DCOTSS-ERA5-track_ER2_YYYYMMDD_<version>.nc
- Typical file size: ~3 to 4 MB
- Included in merged files

Back Trajectories from the ER-2 Flight Path

- Separate isentropic and diabatic 10-day back trajectories TRAJ3D trajectory model and ERA5 winds. Initial conditions are the 1 s positions along the ER-2 flight path.
- 3×3×3 cluster of particles at each initial longitude, latitude, and potential temperature (λ, ϕ, θ) and λ ± 0.25°, ϕ ± 0.25°, and θ ± 3K. Time step 0.25 h.
- Particle positions saved at hourly synoptic times and at the initial and final times (if not exactly on the hour)
- Horizontal velocity (u, v) from hourly isentropic analyses, vertical velocity ($\dot{\theta}$) from 3-hourly diabatic heating rates

Back trajectory file structure

- NetCDF files; 1 file per initial condition, zipped by synoptic hour (up to 3600 files); 1 particle dimension, 1 time dimension
- Position: longitude, latitude, and altitude (θ) as a function of time for each particle
- ERA5 variables interpolated to trajectories: T_ERA5, Z_ERA5, pv_ERA5, Z_trop_ERA5, theta_trop_ERA5
- Typical file size: 188 kB

Data Limitations & Considerations

- Tropopause
  - Vertical resolution is ~0.5 to 1 km, discretized on 0.25 km grid
  - Limited vertical resolution of ERA5 analysis can lead to missing the primary tropopause. Data are noisy near the tropopause break.
- Back trajectories
  - Numerical (truncation) error is very small
  - Primary error sources are winds and initial conditions
  - Use 3×3×3 grid of particles to evaluate uncertainty, particularly errors in the initial vertical position

Tentative Archival Timeline

- ERA5 data are final
  - Tropopause analysis is final
- ER-2 data are still preliminary (as of 2021-12-07)
  - ERA5 variables along the flight path and back-trajectories will be available 1 to 2 weeks after the ER-2 data are final

Upcoming Conference Presentations

- **AGU Fall Meeting:** Chang et al., *Convective Forcing of the North American Monsoon Anticyclone at Intraseasonal and Interannual Time Scales*, Session A15N (Poster)
- **AMS Annual Meeting:** Chang et al., *Transport and Confinement of Plumes from Tropopause-overshooting Convection Over the Continental United States During the Warm Season*, Session 5.1 (Oral)