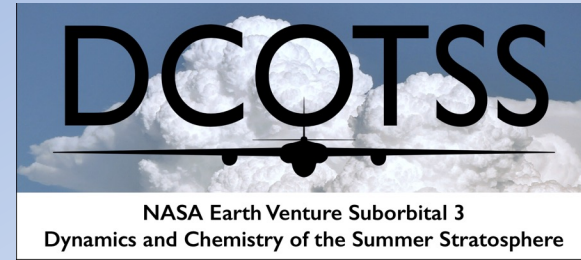


Dynamics and Chemistry of the Summer Stratosphere

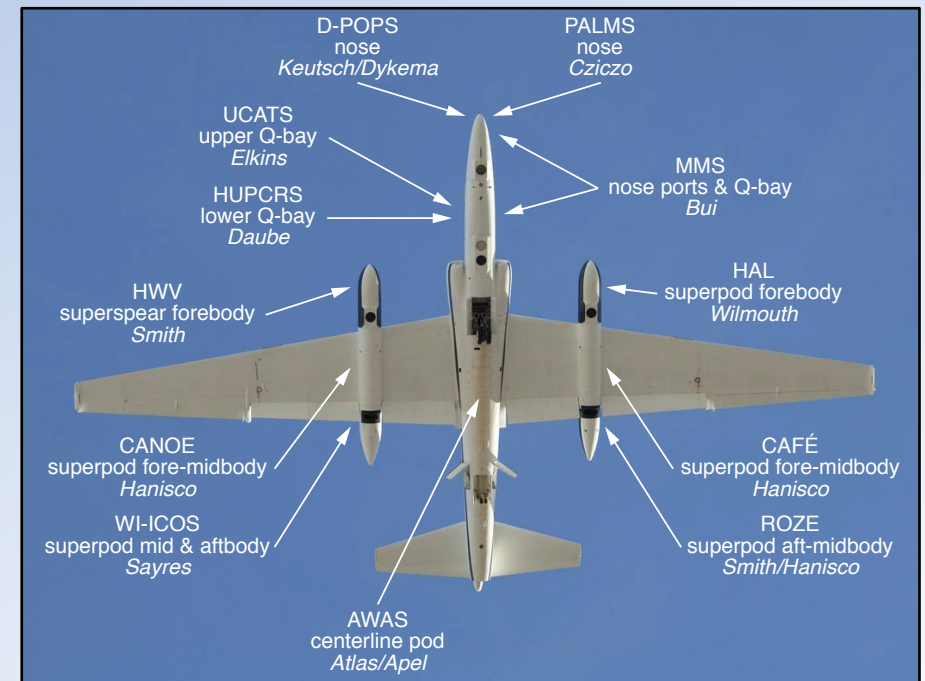
DCOTSS

Mission Overview, Data Access, and
Data Analysis

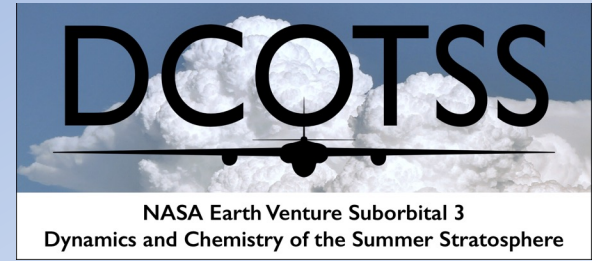
DCOTSS Mission



- The DCOTSS mission investigates the role of
 1. Tropopause-overshooting convection
 2. North American Monsoon Anticyclone (NAMA)in controlling summertime lower stratosphere composition
- Mission platform is the NASA ER-2
- Two multi-week deployments:
 - July-August 2021** (11 research flights)
 - May-July 2022** (14 research & transit flights)

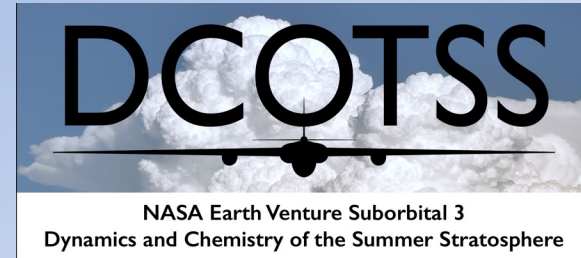


Data Obtained/Produced



1. ER-2 instrument (in-situ) data
2. Mission report data
3. Balloon observations of ozone and water vapor
4. ERA5 reanalysis & back trajectories along flight track
5. Radar and satellite observations of tropopause-overshooting convection
6. Chemistry model output along flight track
7. Convection-allowing model (CAM) output for select flights

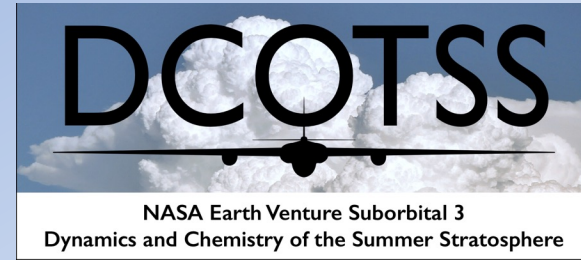
Aircraft (Instrument) Data



Instrument	Measurements
Advanced Whole Air Sampler (AWAS)	>20 constituents with varying lifetimes
Compact Airborne Formaldehyde Experiment (CAFE)	Formaldehyde
Compact Airborne Nitrogen diOxide Experiment (CANOE)	Nitrogen Dioxide
Harvard Halogens (HAL)	Chlorine Monoxide, Chlorine Nitrate
Rapid OZone Experiment (ROZE)	Ozone
Harvard University Picarro Cavity Ringdown Spectrometer (HUPCRS)	Carbon Monoxide, Carbon Dioxide, Methane
Harvard Water Vapor (HWV)	Water Vapor
Meteorological Measurement Systems (MMS)	Pressure, Temperature, Horizontal and Vertical Wind
Particle Analysis by Laser Mass Spectrometry (PALMS)	Aerosol Composition
DCOTSS Printed Optical Particle Spectrometer (DPOPS)	Aerosol Size Distribution
UAS Chromatograph for Atmospheric Trace Species (UCATS)	Ozone, Water Vapor, Nitrous Oxide, Sulfur Hexafluoride, CFC-11/12/113, Halon 1211/2402
Water Isotopologues – Integrated Cavity Output Spectrometer (WI-ICOS)	Water Vapor, Dueterated Water, Total Water (vapor + ice)

- 1 Hz: ROZE, HWV, MMS, UCATS Water Vapor, CAFE, CANOE, DPOPS, PALMS
- 0.5 Hz: UCATS Ozone
- 0.1 Hz: HUPCRS, WI-ICOS
- ~0.03 Hz: HAL
- ~0.01 Hz: UCATS
- Variable: AWAS

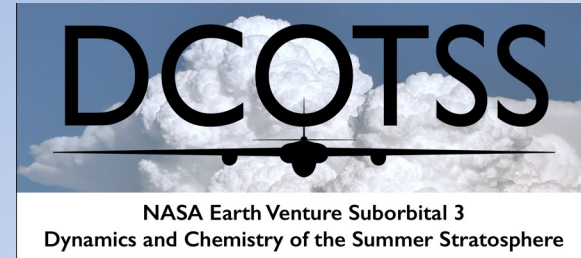
Aircraft Merge Files



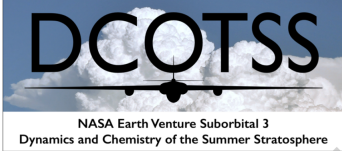
- In addition to the individual instrument files, merge files containing all airborne data and model output interpolated to the flight track are archived
- There are 3 types of merge files available:
 1. 1-Hz
 2. 0.1-Hz
 3. During AWAS samples
- For instruments with a sample rate coarser than the merge file resolution, non-sample times are filled with missing numbers
- For instruments with a sample rate finer than the merge file resolution, averages of the original data are assigned to each time

Report Data

- Short [typically 4-6 pages] mission scientist reports, summarizing the planning and completion of each flight
- Slides from in-field forecasting and flight planning discussions will also be archived



DCOTSS ER-2 Mission Scientist Flight Summary Report



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

Flight identifier: RF05
Science goals: Recent (0-1 day old) convective plume sampling
Start of flight (UTC): 2021-07-29 10:47Z
End of flight (UTC): 2021-07-29 18:25Z
ER-2 Pilot: Greg "Coach" Nelson
Mission Scientist: Rei Ueyama

Version	Report date and time (UTC)	Author
1	2021-07-30 19:00Z	Ueyama, Rei
2	2021-07-31 09:00Z	Keutsch, Frank

Instrument Performance:

Legend: ■ =Up ■ =Provisional ■ =Down ■ =No Report



Instrument	Status
AWAS	Up
CAFE	Up
CANOE	Up
HAL	Up
HUPCRS	Up
HWV	Up
MMS	Up
PALMS	Up
DROPS	Up
ROZE	Up
UCATS	Up
WPCOS	Up

Aircraft Performance: Good

Science Objectives:

The primary objective of DCOTSS research flight #5 (RF05) was to sample the outflow plume from recent (0-1 day) overshooting convection over Minnesota and Wisconsin. Strong overshooting convection over Minnesota started on 28 July and continued through the morning of RF05 (Fig. 1). During this time period, echo tops reached as high as ~60-64 kft, a few km above the tropopause. The convective system continued to move southeast on the morning of the flight (Fig. 2). A vertical sheet of overshooting material was expected to be over Indiana and Iowa, which was also projected to move southeastward. The challenge of RF05 was to sample

Balloon Data Collection/Creation Process

- Instruments:

- **EN-SCI Electrochemical Concentration Cell (ECC)**

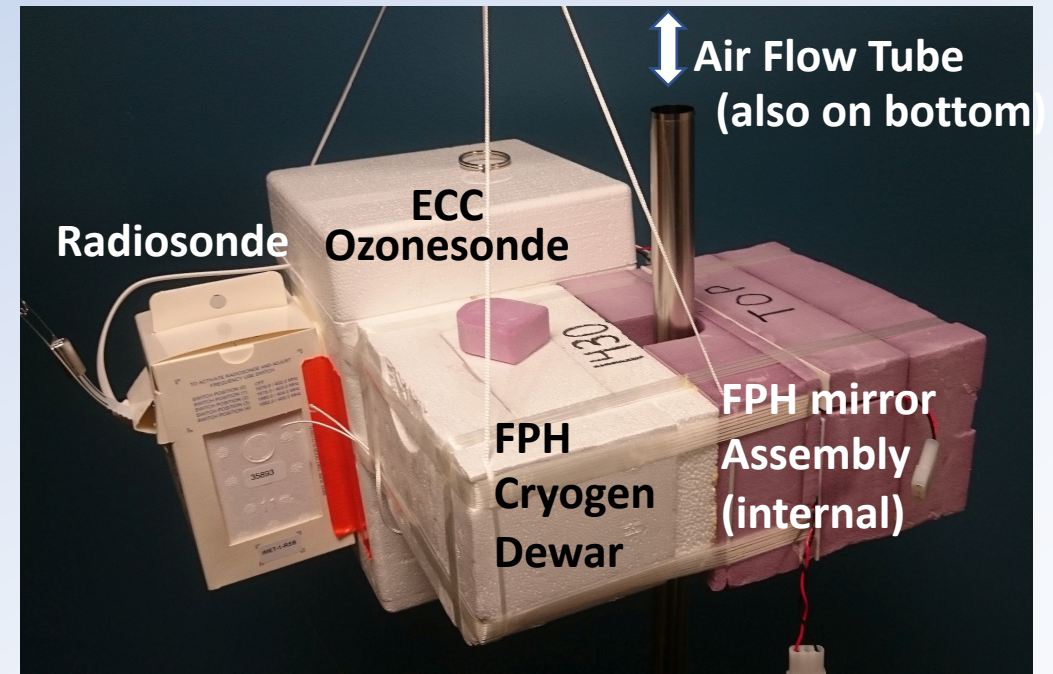
- O_3 partial pressure (P_{O_3})

- **Internet Radiosonde (RS)**

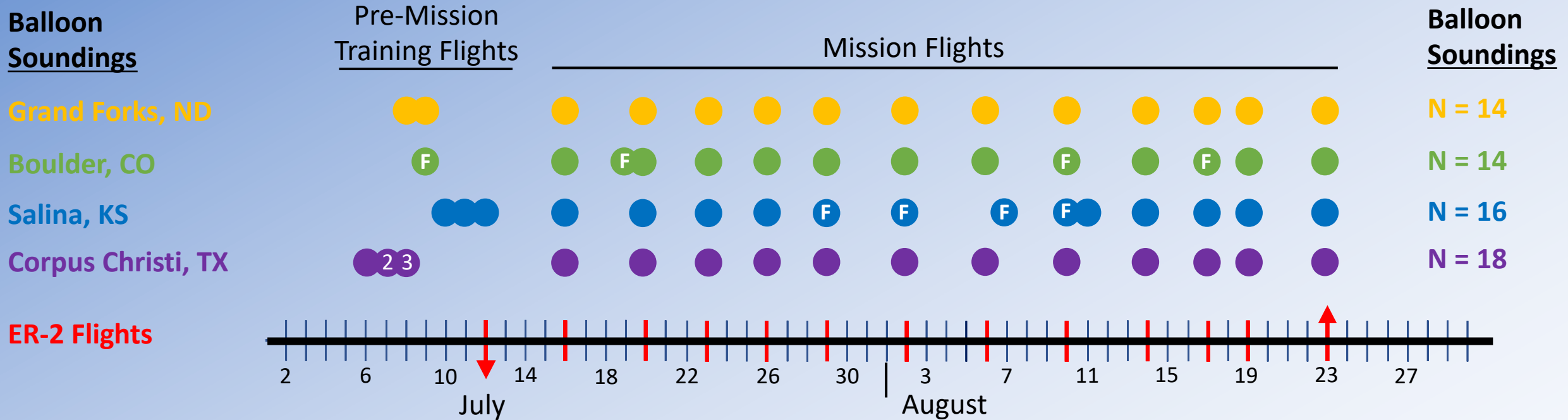
- T, P, RH, GPS 3D location (Lat, Lon, Geom. Altitude)

- **NOAA Frost Point Hygrometer (FPH)**

- H_2O partial pressure (via frost point temperature)



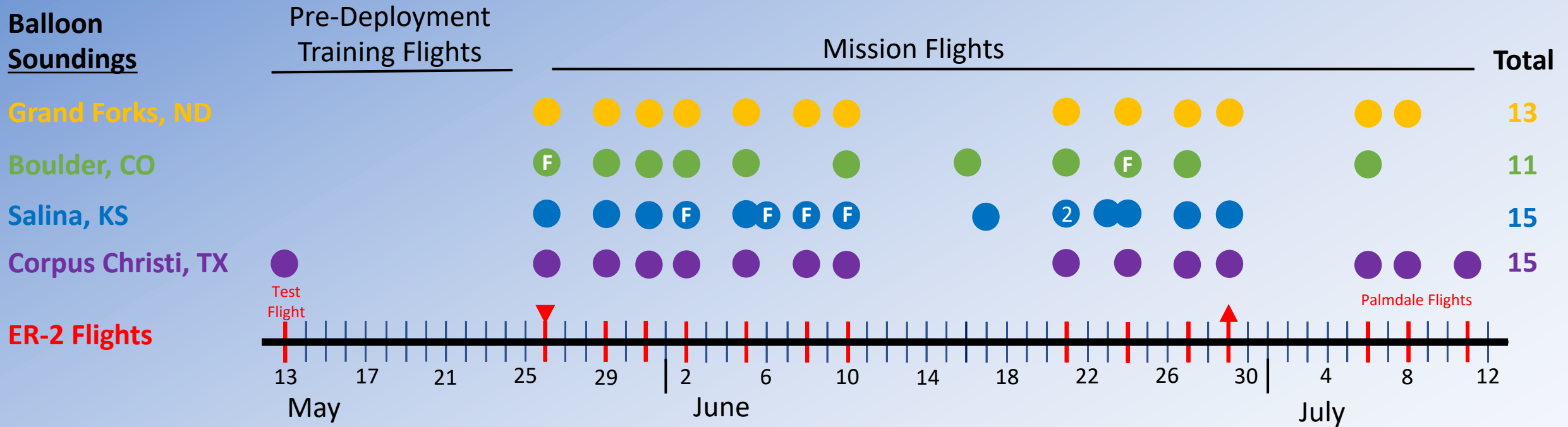
Timeline of Soundings and Flights *Deployment #1 (2021)*



8 soundings marked with "F" included a NOAA Frost Point Hygrometer.

Each of the 12 ER-2 flights from Salina were accompanied by a coordinated balloon sounding at all 4 sites

Timeline of Soundings and Flights *Deployment #2 (2022)*



6 soundings marked with "F" included a NOAA Frost Point Hygrometer.

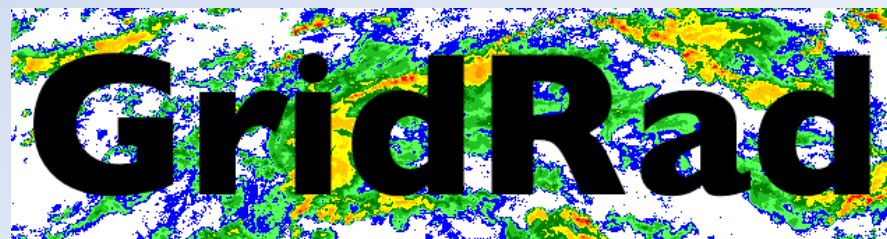
Nine of the 11 ER-2 flights from Salina were accompanied by a coordinated balloon sounding at all 4 sites

ERA5 Reanalysis & Back Trajectories

- Hourly ERA5 variables interpolated to the ER-2 flight paths
 - Winds: u , v , ω
 - Other: T , Z , SH , RH , PV
 - Tropopauses: lapse-rate tropopause p & Z
- Backward trajectories from the ER-2 flight paths using ERA5 winds and diabatic heating rates
 - Two versions: isentropic and diabatic, 3x3x3 particle cluster at each initial longitude, latitude, and potential temperature (λ , ϕ , θ) and $\lambda \pm 0.25^\circ$, $\phi \pm 0.25^\circ$, and $\theta \pm 3K$
 - Integrated backward 10 days, with positions saved every hour
 - T , Z , PV , and tropopauses from ERA5 interpolated to trajectory paths

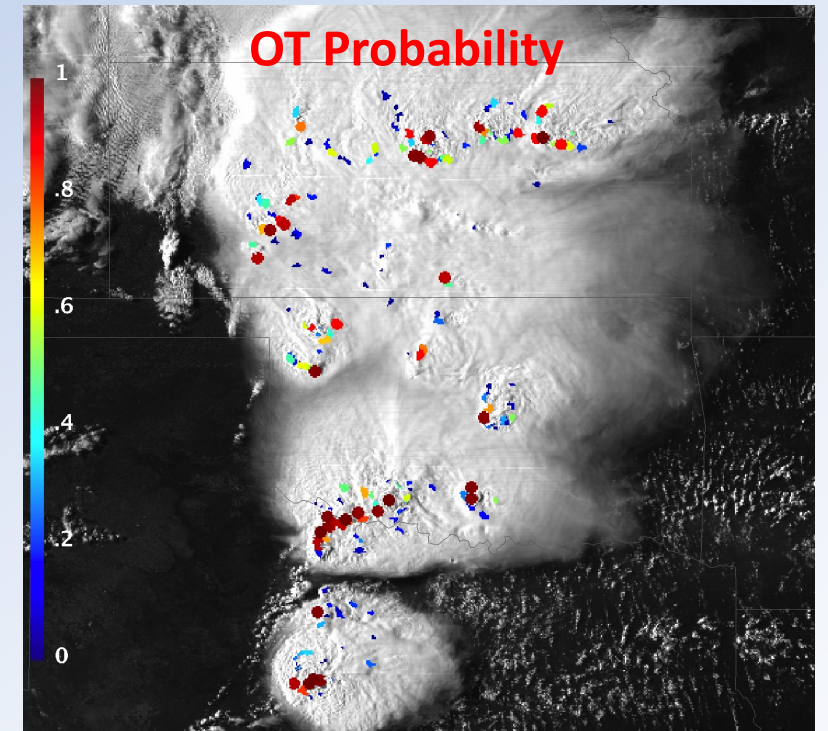
Radar & Satellite Observations

- Radar data are made for a CONUS-wide domain using the GridRad (see <http://gridrad.org>) space and time-weighted binning procedure for NEXRAD WSR-88D volumes
 - Grid resolution: $\sim 2\text{-km} \times \sim 2\text{-km} \times 0.5\text{-}1\text{ km}$ (horiz. x vert.)
 - Frequency: 10 minutes
 - Products: i) 10-min volumes of radar reflectivity and radial velocity spectrum width, ii) overshoot identifications (echo top relative to ERA5 tropopause), and iii) overshoot trajectories (5-day forward and isentropic, driven by ERA5)



Radar & Satellite Observations

- Geostationary (GOES-16 & -17) satellite data are processed over the CONUS and surrounding areas ($12\text{-}52^\circ\text{N}$, $65\text{-}135^\circ\text{W}$) by the NASA Langley group
 - Grid spacing: ~ 2 km per pixel
 - Frequency: 10 minutes
 - Products: i) 10-min visible and IR imagery, GLM lightning products, cloud top heights and overshooting top probabilities, and related environmental information, and ii) overshoot trajectories (5-day forward and isentropic, driven by ERA5)



Chemistry Model Output

1. Photochemical steady state box model results along flight track

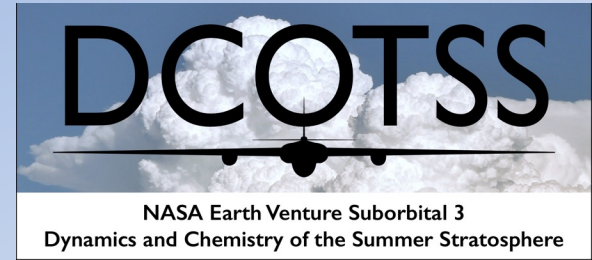
Key outputs:

- Photolysis rates (J values) at 10-second time resolution
- Mixing ratios of radical and reservoir species of active nitrogen (NO, NO₂, NO₃, N₂O₅, HNO₂, HNO₃, HNO₄), hydrogen (OH, HO₂, H₂O₂), chlorine (Cl, ClO, OClO, Cl₂, ClNO₂, ClNO₃, HOCl, HCl) and bromine (Br, BrO, Br₂, BrCl, HOBr, HBr, OBrO) at 1-min time resolution

Convection Allowing Model Output

- Convection-allowing model simulations will be conducted for select flights (those extensively sampling overshoot material) and other experiments
- DCOTSS flights chosen will range from weakly forced convection (difficult to reproduce) to strongly forced convection
- Simulations will be run for up to 48 hours and include passive tracers
- Anticipated models to be used:
 1. The Weather Research and Forecasting (WRF) model – real events
 2. Cloud Model 1 (CM1) – idealized experiments

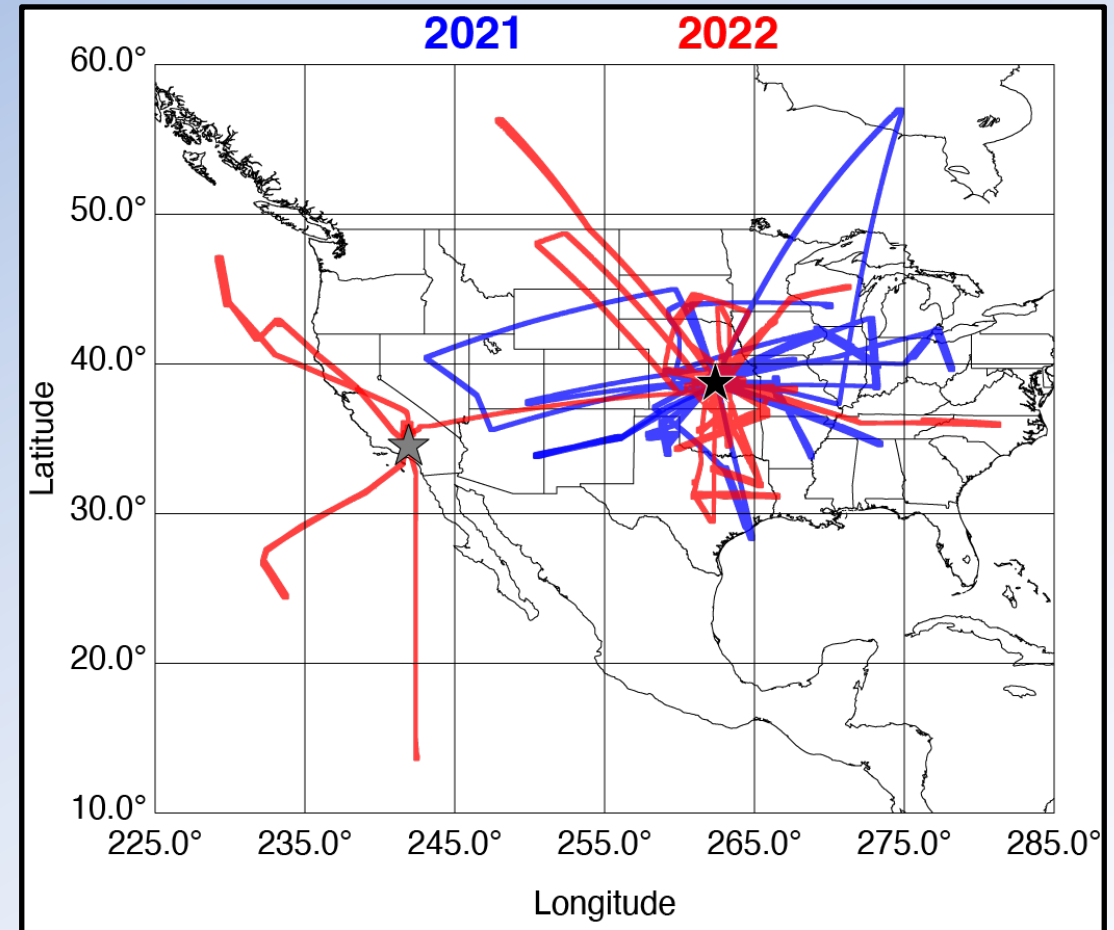
Data Archive



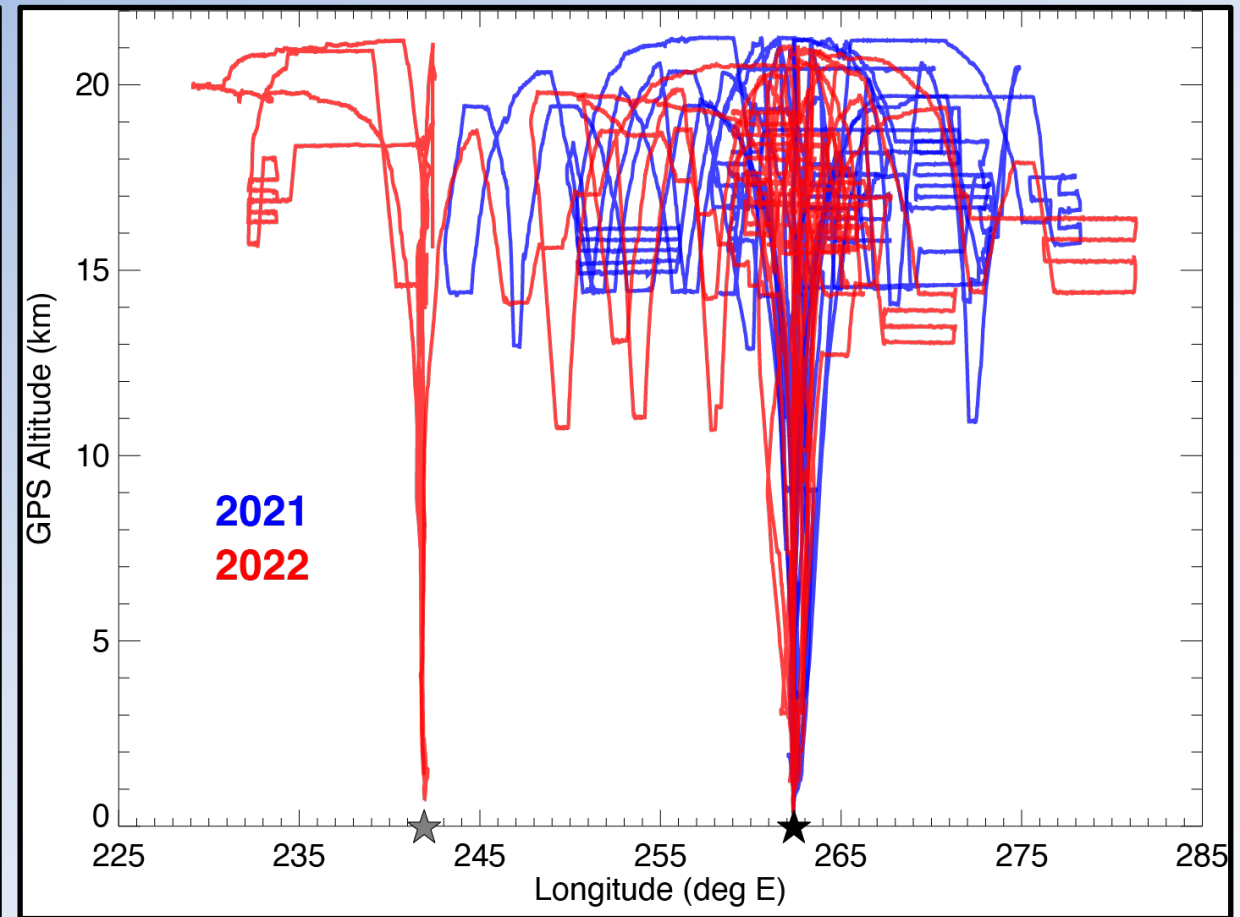
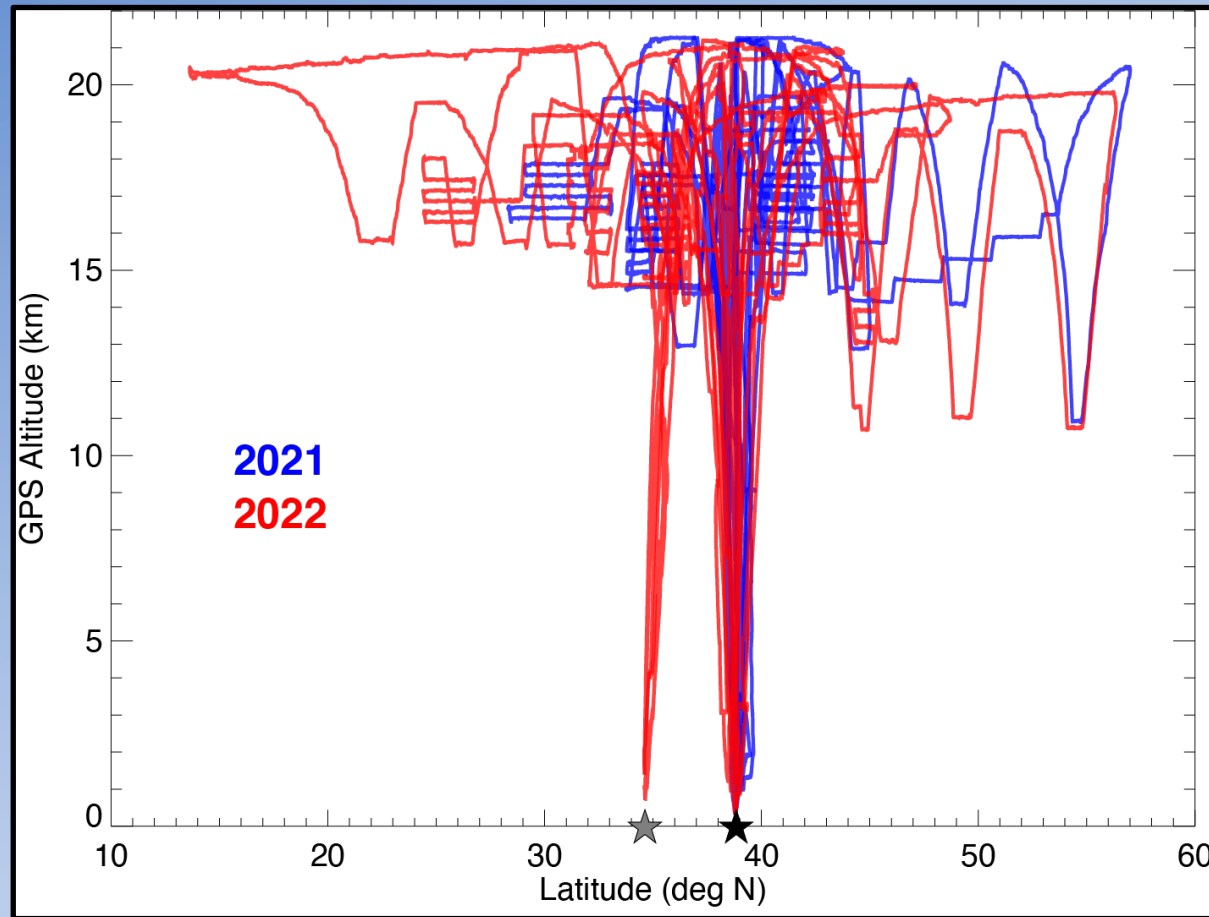
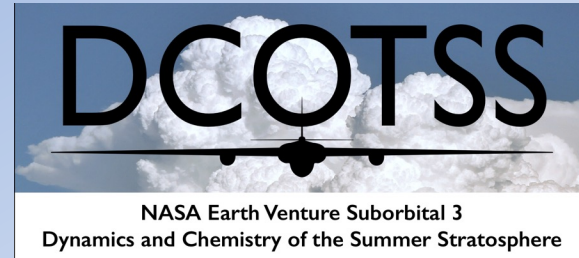
- The public DCOTSS archive is hosted at NASA's Atmospheric Science Data Center (ASDC):
<https://asdc.larc.nasa.gov/project/DCOTSS>
- Direct access to each data collection:
 - https://doi.org/10.5067/ASDC/DCOTSS-Aircraft-Data_1
 - https://doi.org/10.5067/ASDC/DCOTSS-Balloon-Data_1
 - https://doi.org/10.5067/ASDC/DCOTSS-Radar-Satellite-Data_1
 - https://doi.org/10.5067/ASDC/DCOTSS-Model-Output_1
 - https://doi.org/10.5067/ASDC/DCOTSS-Reports_1

2021 & 2022 Deployment Overview

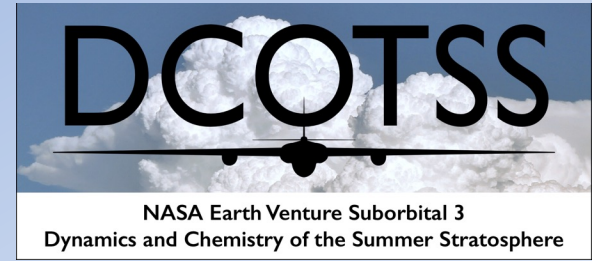
- DCOTSS was primarily based out of Salina, Kansas
- In 2022, DCOTSS also conducted research sampling on transit flights to/from Palmdale, CA
- 2021 Accomplishments: 11 research flights from Salina
- 2022 Accomplishments: 2 transit flights, 9 research flights from Salina, 3 research flights from Palmdale



2021 & 2022 Deployment Overview



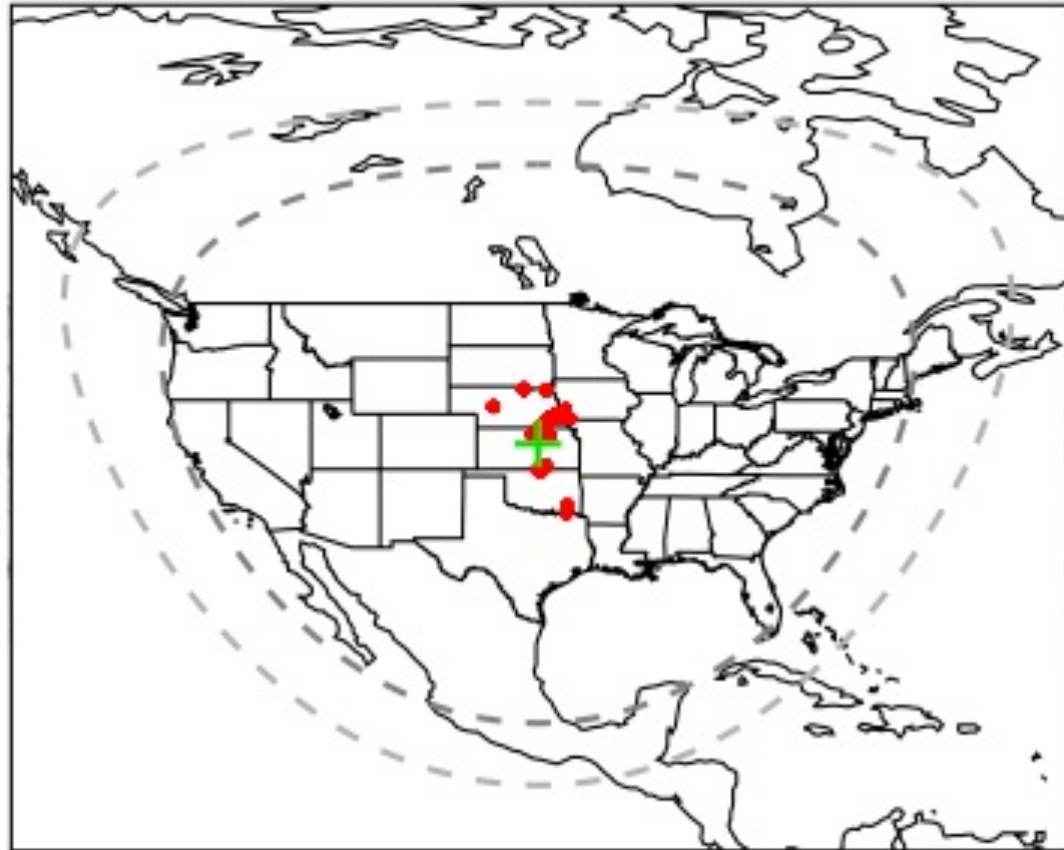
DCOTSS Flight Strategy



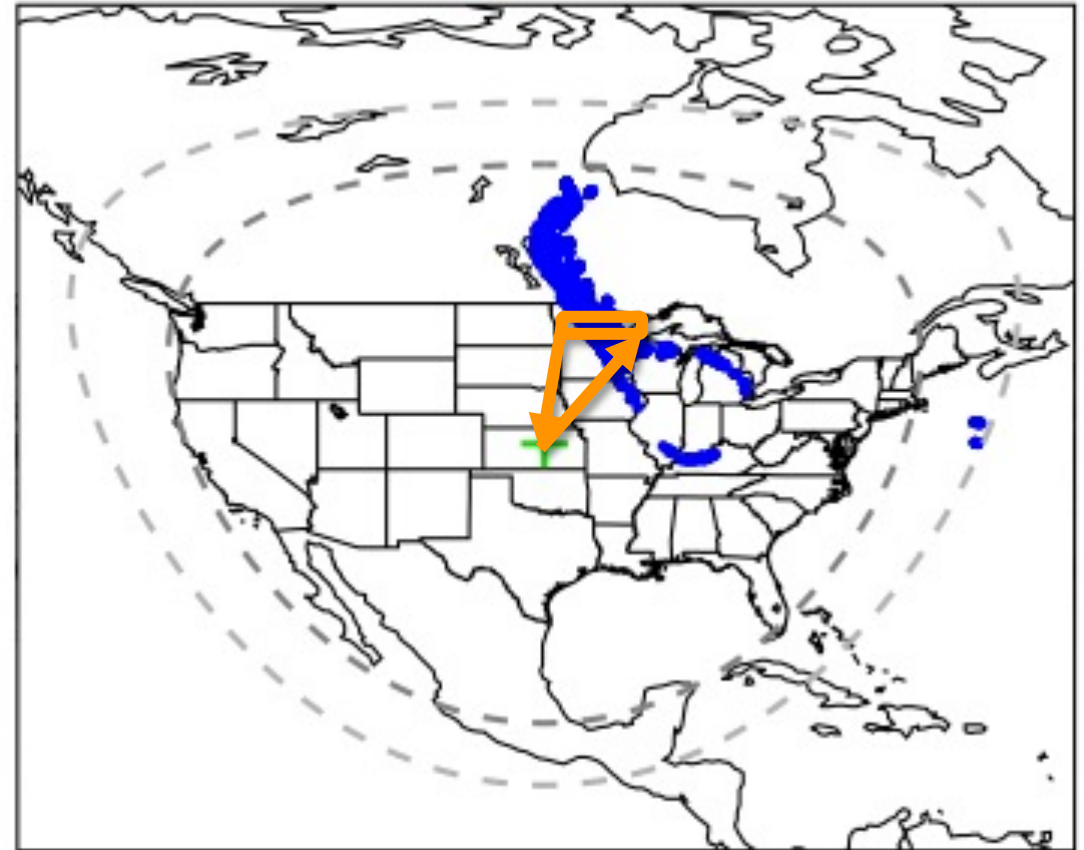
- Targeting overshoot air was a 3-step process:
 1. Near-real-time radar + satellite overshoot identification
 2. Trajectory forecasts of overshoot plume positions, driven by NCEP GFS winds
 3. Flight planning to sample overshoot air perpendicular to prevailing flow, with level legs at altitudes near the tropopause up to the highest altitude expected

DCOTSS Flight Strategy

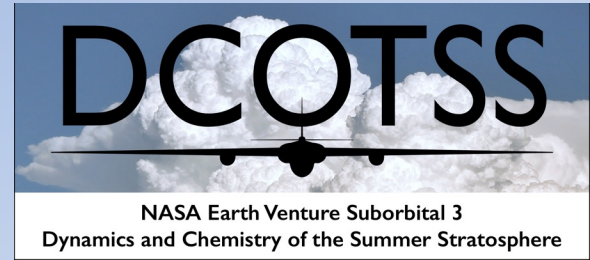
Overshoot Locations



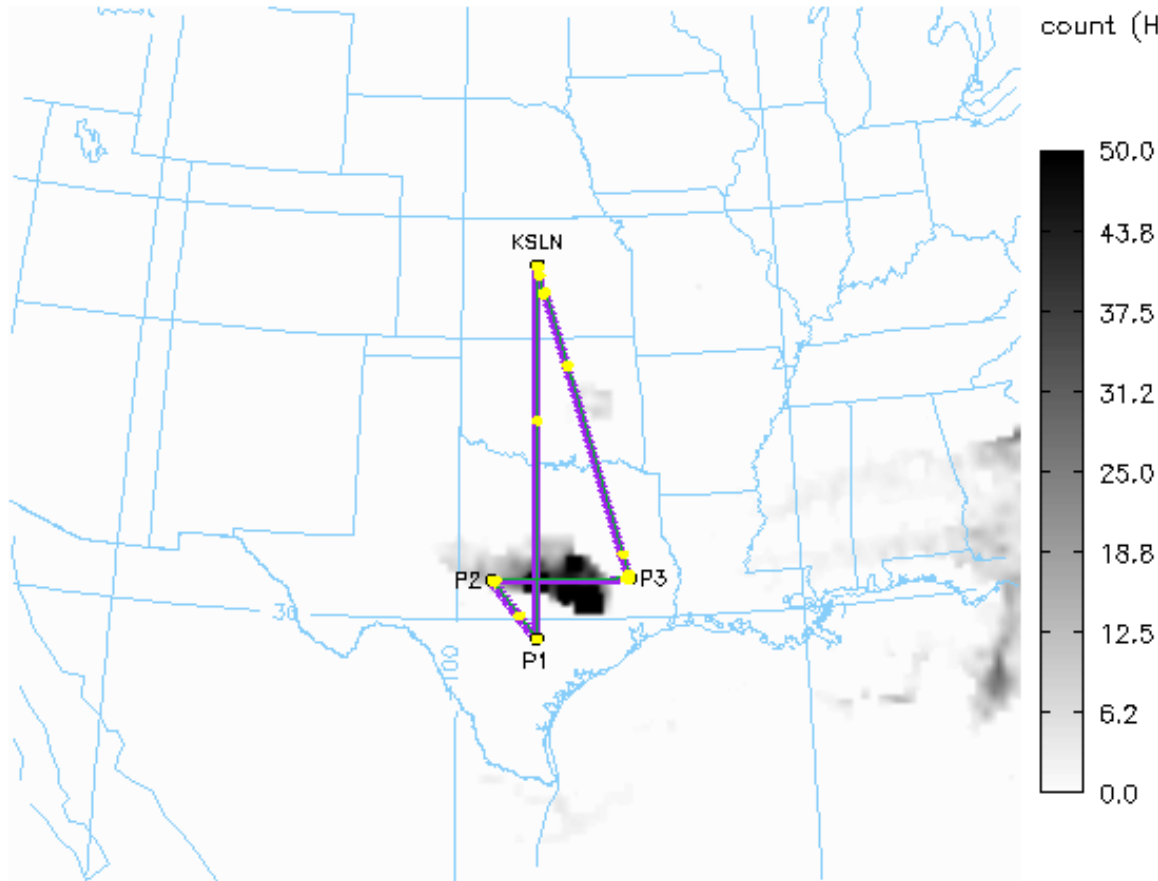
1-Day Forecast



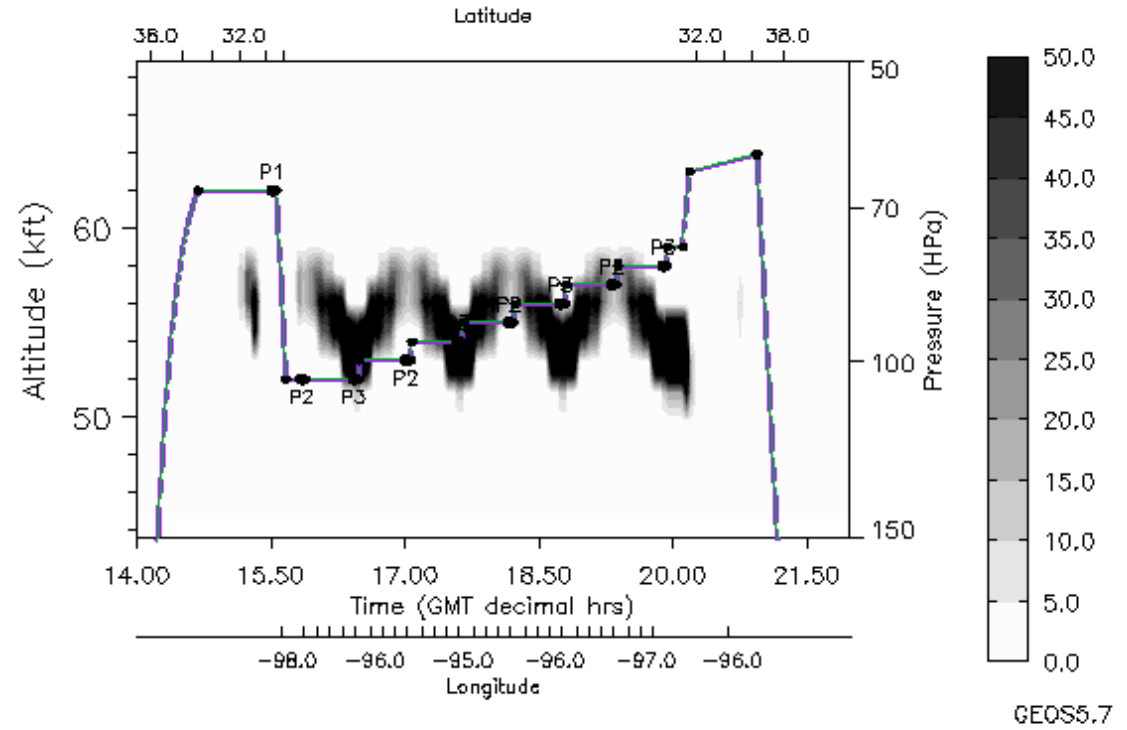
Example DCOTSS Forecast & Flight Plan



2022-06-10T19:00 UTC (12-hr fcst) at 85.0 HPa
count (Hours)



2022-06-10T19:00 UTC (12-hr fcst)
count (Hours)



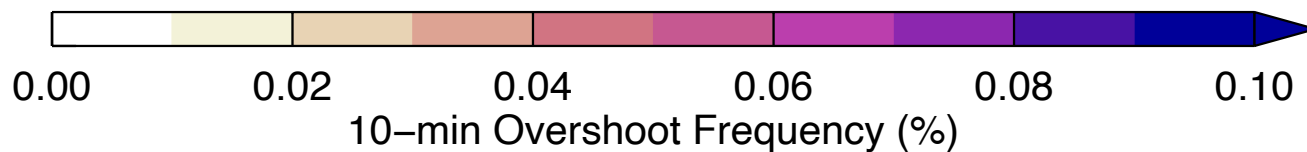
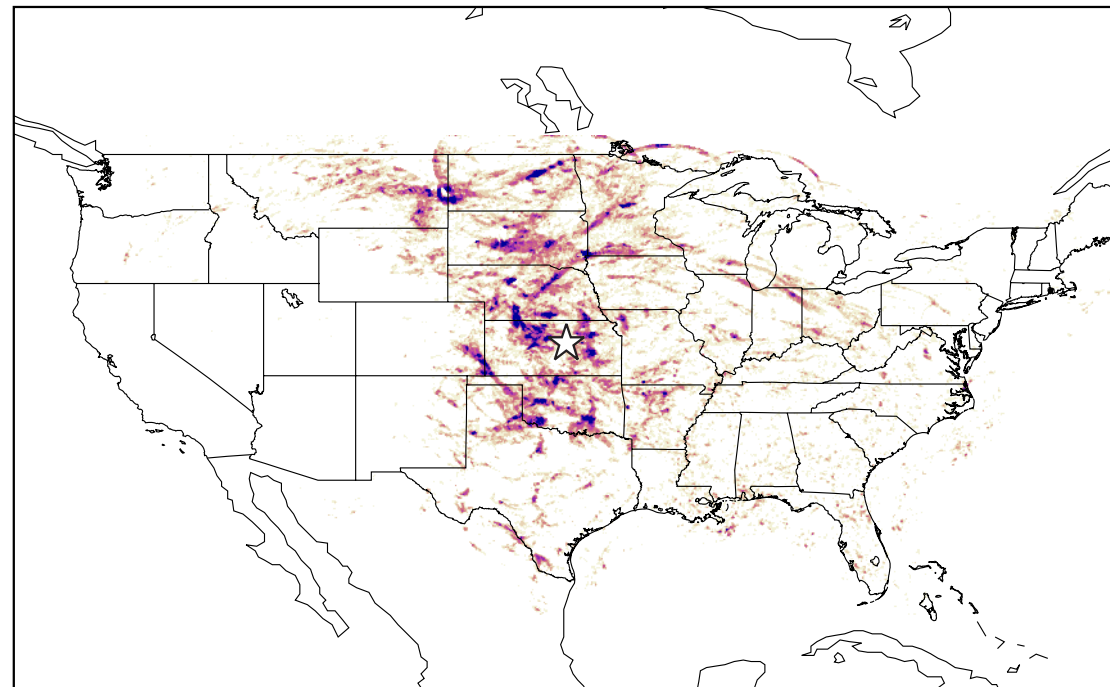
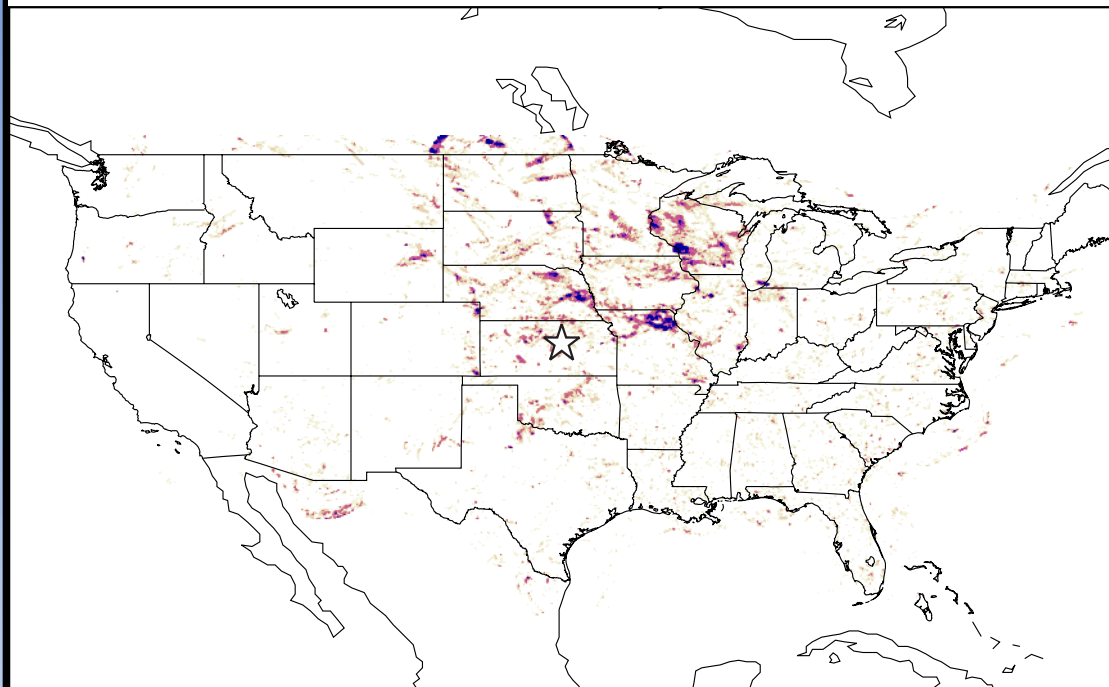
ER2 806: dcotss_RF17_2022-06-10_NAS4BD6 v. v3

ER2 806: dcotss_RF17_2022-06-10_NAS4BD6 v. v3

DCOTSS Overshoot Summary (Radar)

**GridRad Overshoot Summary for 2021
(July 5 – Aug 23)**

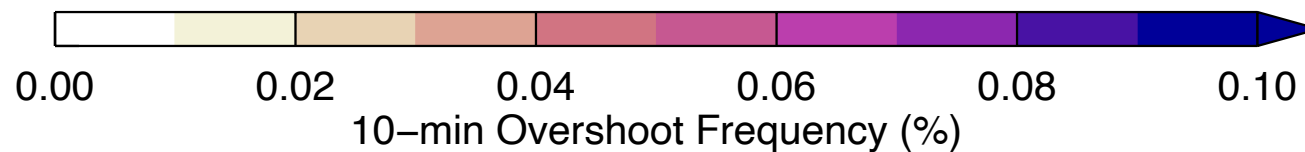
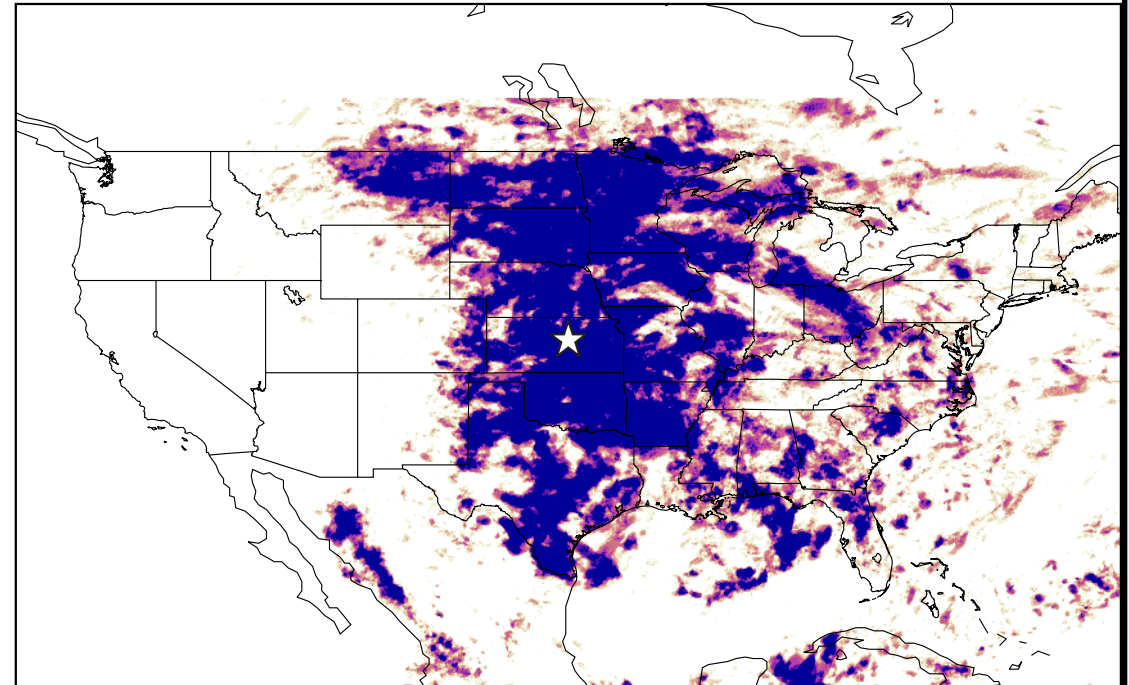
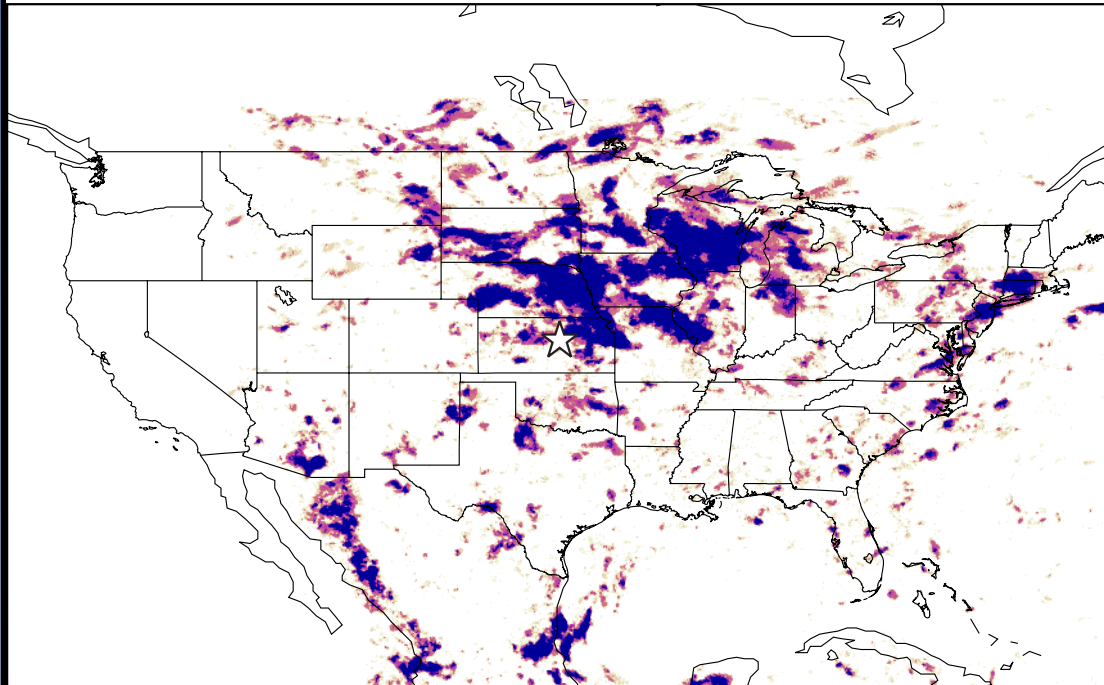
**GridRad Overshoot Summary for 2022
(May 12 – July 12)**



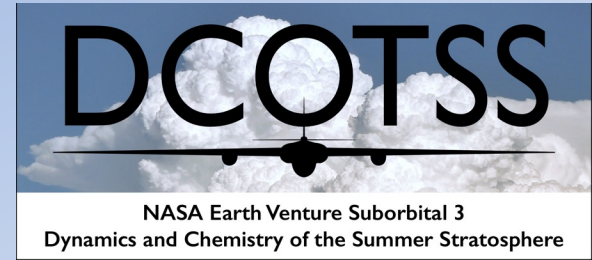
DCOTSS Overshoot Summary (Satellite)

**GOES Overshoot Summary for 2021
(July 5 – Aug 23)**

**GOES Overshoot Summary for 2022
(May 12 – July 12)**



2021 Prelim Deployment Summary

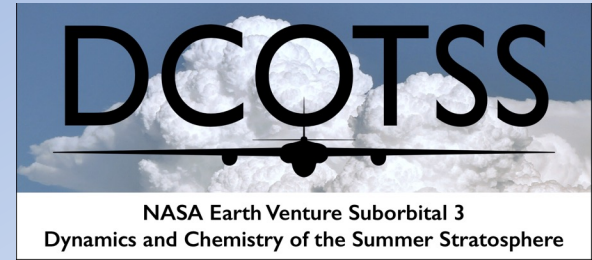


Flight Name	Date	Recent Convection	Aged Convection	Active Convection	PyroCb	Stratospheric Background
RF01	16 July 2021				?	X
RF02	20 July 2021				?	X
RF03	23 July 2021	X	X			X
RF04	26 July 2021	X				X
RF05	29 July 2021	X				X
RF06	02 Aug 2021	X	X		X	X
RF07	06 Aug 2021					X
RF08	10 Aug 2021	X	X			X
RF09	14 Aug 2021		X			X
RF10	17 Aug 2021	X	X			X
RF11	19 Aug 2021	X	X			X

Recent Convection = overshoot material age < 36 hr
Aged Convection = overshoot material age > 36 hr

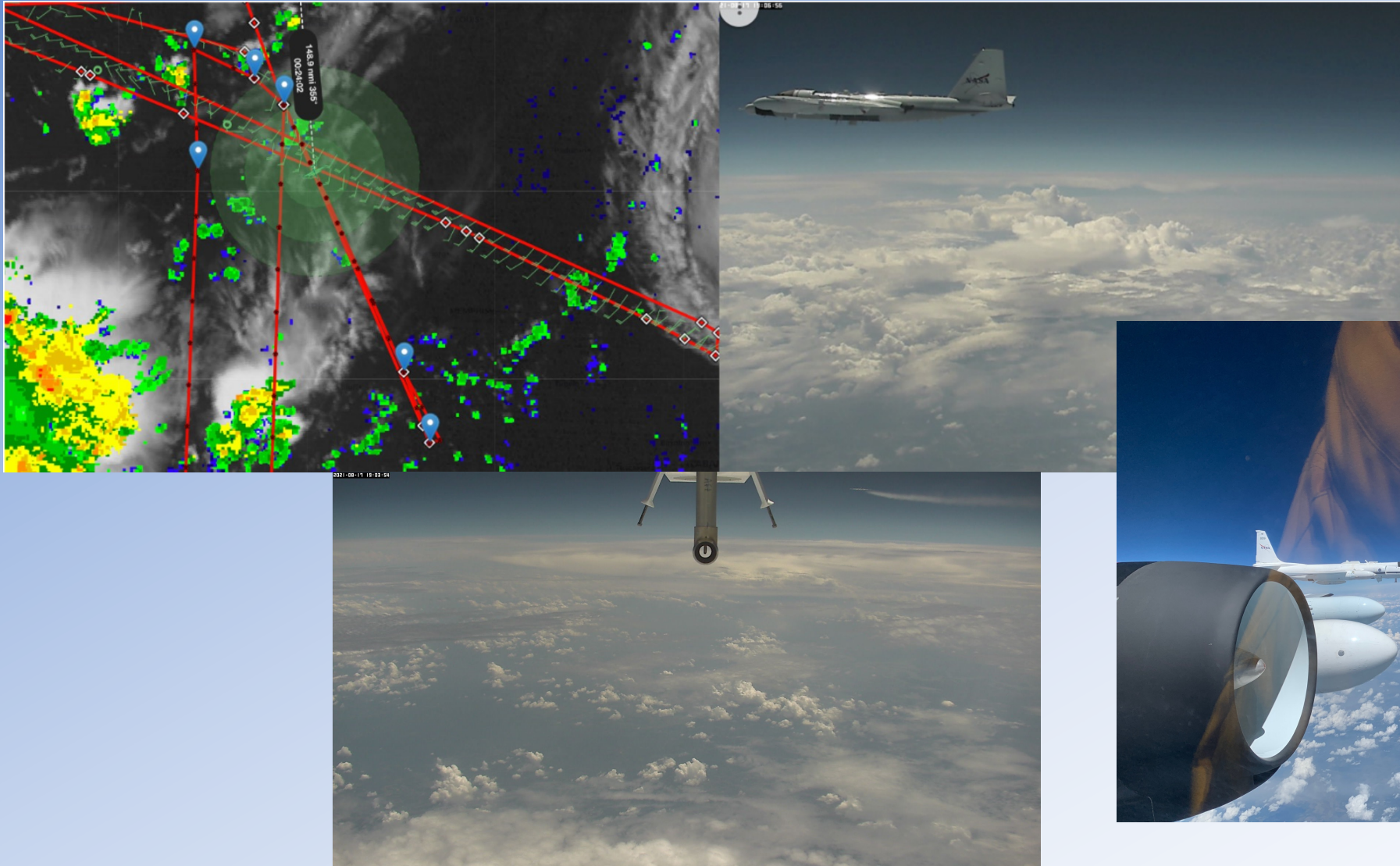
Active Convection = overshooting during sample
PyroCb = sourced by fire-generated convection

2021 Prelim Deployment Summary

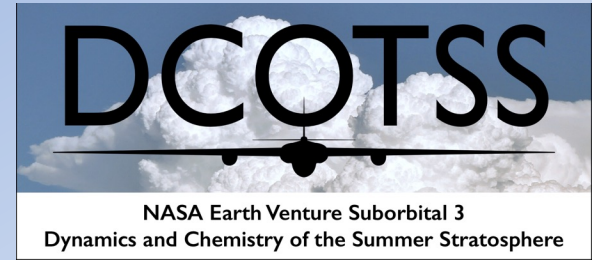


Flight Name	Date	Flight Notes
RF01	16 July 2021	Northbound survey flight across the jet; possible PyroCb plume in Canada
RF02	20 July 2021	Survey flight to center of North American Monsoon Anticyclone (NAMA)
RF03	23 July 2021	Survey west side of NAMA; recent convection in AZ; aged convection from NV to SD
RF04	26 July 2021	Intense sampling over TX panhandle of outflow from recent overshooting event in OK
RF05	29 July 2021	Intense sampling of outflow from recent convection in MN and WI; sunrise obs. of Cl species
RF06	02 Aug 2021	Intense sampling over TX of 1–3-day aged outflow from Great Plains; possible smoke over KS
RF07	06 Aug 2021	High-altitude sunset chlorine chemistry (E-W at 44°N); NAMA/tropopause break survey
RF08	10 Aug 2021	Recent convection in northern IL
RF09	14 Aug 2021	Aged convective outflow from KS storms sampled over OH
RF10	17 Aug 2021	Aged convective outflow over southeast US; possible near-tropopause outflow from TS Fred; coordinated flight with WB-57
RF11	19 Aug 2021	Aged outflow from Sierra Madre and recent outflow from TX, sampled over NM

RF10 Coordination with WB-57

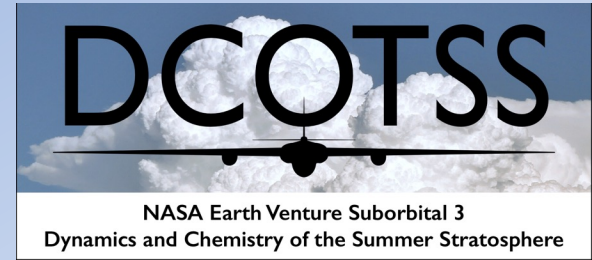


2022 Prelim Deployment Summary



Flight Name	Date	Recent Convection	Aged Convection	Active Convection	PyroCb	Stratospheric Background
TR03	26 May 2022		X			X
RF12	29 May 2022	X				X
RF13	31 May 2022			X		X
RF14	02 June 2022		X			X
RF15	05 June 2022					X
RF16	08 June 2022	X		X		X
RF17	10 June 2022	X				X
RF18	21 June 2022		X		X	X
RF19	24 June 2022	X		X		X
RF20	27 June 2022		X			X
TR04	29 June 2022					X
RF21	06 July 2022					X
RF22	08 July 2022					X
RF23	11 July 2022		X			X

2022 Prelim Deployment Summary

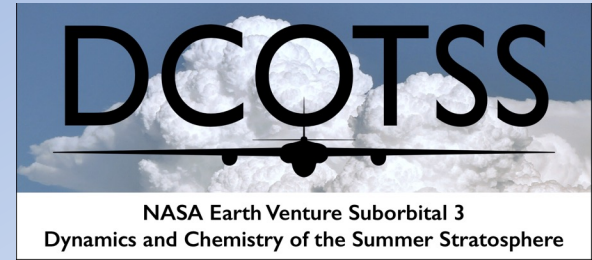


Flight Name	Date	Flight Notes
TR03	26 May 2022	Transit from CA to KS; high altitude sample; sample deep trough; sample aged convection
RF12	29 May 2022	Sample recent outflow over WI
RF13	31 May 2022	Active convection outflow in OK (from an above-anvil cirrus plume producing severe storm)
RF14	02 June 2022	2-day aged outflow from 31 May event sampled over TN & NC
RF15	05 June 2022	Northward survey flight and deep profiles
RF16	08 June 2022	Recent and active convection over OK (~4 hr sampling within overshoot material)
RF17	10 June 2022	Recent, deep (up to ~18.5 km) outflow over TX
RF18	21 June 2022	Northwest survey flight across the jet
RF19	24 June 2022	Recent high-alt (~19.25 km) outflow from tornadic storm in KS; active convection in NE & SD
RF20	27 June 2022	Recent convection over AR sampled over TX
TR04	29 June 2022	Large-scale survey flight across the jet to the NWUS and into NAMA interior from KS to CA
RF21	06 July 2022	Southern survey and attempted sample of Hunga-Tonga aerosol layer
RF22	08 July 2022	Sunrise chemistry with high ozone over NE Pacific Ocean
RF23	11 July 2022	2–3-day aged Sierra Madre outflow over Pacific Ocean

Incredible Views



Preliminary DCOTSS Scorecard



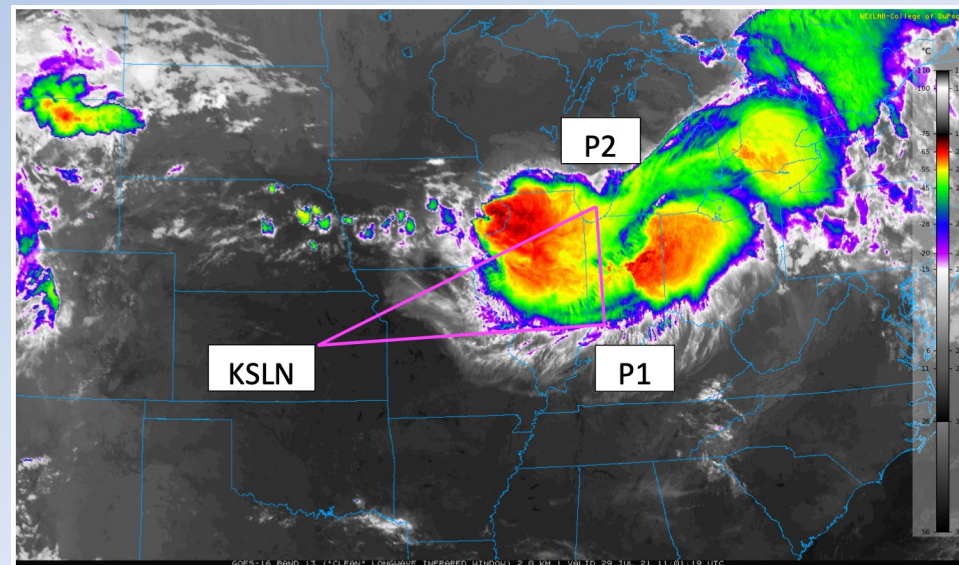
	No. Flights (total = 25)
Recent Convection	≥ 11
Aged Convection	≥ 11
Active Convection	3
Any Convection	≥ 18
PyroCb	≥ 2
Stratospheric Background	25

Data Download Demo

Data Analysis Demo

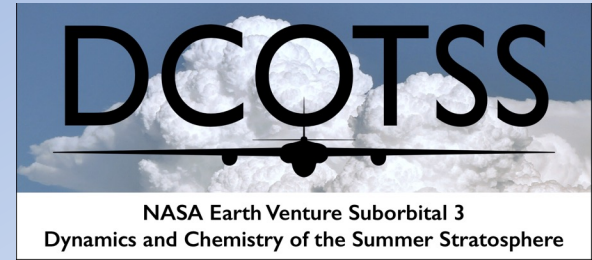
Analysis Demo – 29 July 2021

- Simple python-based analysis of a few in situ measurements during the 29 July 2021 flight
- Flight objective: intensively sample outflow from recent overshooting storms in Minnesota and Wisconsin
- Plan (from mission report):

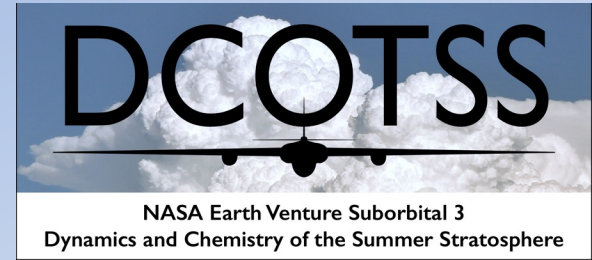


Analysis Demo – 29 July 2021

- Python code and still images available at:
<https://github.com/CameronHomeyer/DCOTSS>
- Demo break...



Current Archival Summary



Data Type	2021	2022
Aircraft data	Available	Expected by Feb 2023
Mission Reports	Available	Available
Balloon Observations	Available	Expected by Feb 2023
ERA5 Flight Trajectories	In Process	Expected by April 2023
Radar/Satellite	Available	Available
Overshoot Trajectories	Available	Expected by Jan 2023
Chemistry Model Output	TBD	TBD
CAM output	TBD	TBD

Open Discussion