GV flight scenarios for START08 and PreHIPPO – Draft V3

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Summary

Science objectives: The goal of the START08 experiment is to investigate the influence of multi scale dynamics on the chemical and microphysical distribution of the extratropical upper troposphere and lower statosphere (ExUTLS). In this region a number of transport processes are known to be important, including Rossby wave breaking, tropopause folding, gravity wave breaking and turbulence, and convective transport. The impact of these processes on the chemical composition and cloud formation will be investigated using meteorological, microphysical, and chemical tracer measurements.

The goals of START08 flights are (1) to obtain tracer distributions and tracer relationships across the tropopause for a range of thermal and dynamical conditions, (2) to diagnose PV ozone relationship and mixing characteristics inside stratospheric and tropospheric intrusions, (3) to characterized the composition and photochemical age spectrum of the airmass under the influence of tropospheric to stratospheric intrusion above the jet, (4) to find signatures of gravity wave generations by jet and front, (5) to examine the cirrus cloud layers near the extratropical tropopause, (6) to explore flight strategies of sampling convective transport.

The goal of the PreHIPPO flights is to measure cross sections, from the boundary layer to the tropopause, of chemical species for a large range of latitudinal and source/sink regions. This is a pre-study of the global survey of atmospheric trace gases related to the Carbon Cycle. JeffCo based flights to go as North/South as possible will be conducted. Two flights of overnight landing in the Arctic region are planned.

Flight resources: The total allocated flight resources are 150 GV hours, 88 for START objectives and 62 for HIPPO objectives. The flights will be planned with emphasis of either START or HIPPO science but optimize the synergy when possible. Considering 7-8 hours as the nominal flight duration for each flight, there will be 11-12 flights with START emphasis. 6 flights are planned with HIPPO emphasis, including two Arctic survey flights. Considering the experiment to be conducted in roughly 6 weeks, there will be roughly 3 flights per week.

Flight Scenarios: Five START flight scenarios and 3 HIPPO flight scenarios, with variance, are described in this document. The flight scenarios presented are conceptual and the specific flight plans will be made based on meteorology of the flight day.

START flights:

S1. Extratropical Tropopause and transition layer (ExTP/ExTL) Survey (plan to have 3 flights, once each month)

S2. Stratospheric intrusion (tropopause fold) (plan to have 3 flights, April-May)

S3. Tropospheric intrusion (poleward into lowermost stratosphere) (plan to have 3 flights, April to May, the type of events are known to have higher occurrence frequency in April than May)

S4. Convective transport (plan to have 1 or two short flights in June)

S5. Gravity wave (plan to have 1 flight, conditions more likely in April)

HIPPO flights:

H1. Northern Survey (8 hr flights, plan to have two flights, one in each phase of the mission)
H2. Southern Survey (8 hr flights, plan to have two flights, one in each phase of the mission)
H3. Arctic CH_4 source flight (overnight) (two 15 hr flights one in each phase of the mission)

(Additional Note: a GV - DC-8 comparison flight is in planning. Details TBD)

Flight scenarios: START08

Flight Scenario S1. ExTP or ExTL survey

Science questions: Are there chemical discontinuities in the ExUTLS? If yes, where are they located? Is there a chemical transition layer between the troposphere and stratosphere that is distinct from both the troposphere and stratosphere? How are the properties of the transition layer related to the lifetime or large-scale gradients of the trace species measured? How is the depth of the chemical transition layer related to the thermal structure of the tropopause and the dynamical processes occurring? How does depth of the mixing/transition layer depend/relate to the thermal structure and the vorticity in the UTLS? How does the mixing influence the microphysical processes in the transition region and the condition of cirrus formation? What is the relation between the mixing the tropopause inversion layer? How are the condisitons of cirrus cloud formation related the UT synoptic scale dynamics?

Observational objectives: Cross tropopause profiling at selected locations to cover a wide range of latitudes and dynamical and thermal conditions. The targeted conditions are: cyclonic/anticyclonic contrast, the subtropical/polar jet contrast, region of merging/double jets, a range of upper level flow patterns (e.g. 200 hPa relative vorticity), region of large separation of thermal and dynamical tropopause/ ozone pause. Region of likely cirrus clouds and sustained contrails. Also cover different month seasonal evolution

Forecast needs: Tropopause pressure and altitude, existence of secondary tropopause, wind fields and identification of jets, upper level vorticities, PV cross sections, theta lapse rate. Conditions for cloud information and contrails. This flight type can be flown for just about any day, so it may be reserved for days when the synoptic scale meteorology is less ideal for other flight patterns.

Flight strategy: Take off to the level of subtropical jet core, cross the jet core, profiling the anticyclonic side of the jet. Cruise poleward and profile on the cyclonic side of the subtropical jet. Cruise poleward to sample the horizontal gradient across the polar jet core and profiling on each side of the jet core.

Note: profile across the tropopause can be extended to boundary layer at selected locations to help HIPPO objectives.

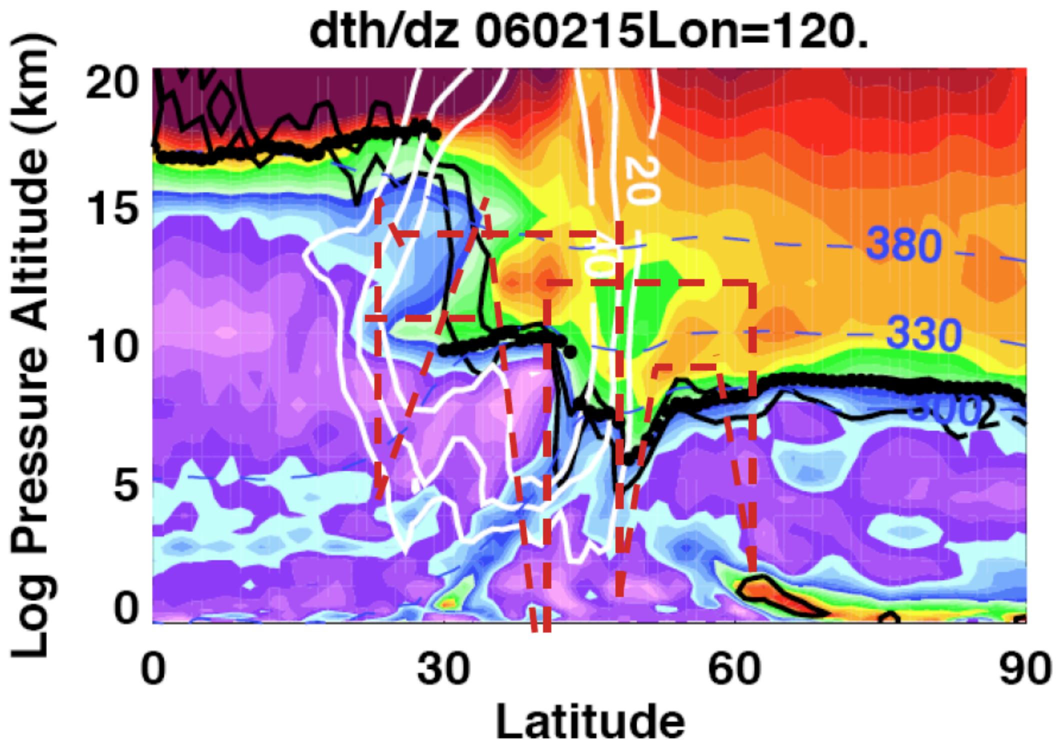


Figure 1. Conceptual drawing for flight S1. Color image shows the static stability (in terms of potential temperature lapse rate), purple tropospheric (1-5 K/km), red stratospheric (16-20 K/km), blue is near stratospheric (6-10 K/km), and green near tropospheric (11-15 K/km). Also shown are wind field (white contours), PV (2 and 4 pvu contours, black), the thermal tropopause (black dots), and isentropes (blue dash lines). The red dash line indicate a possible flight scenario.

Flight Scenario S2: Stratospheric Intrusion

Science Questions: Are the ozone values in the fold significantly higher in the spring compared to the December 2005 measurements? What is the ozone-PV relationship in the fold? Is the relationship evolving as a part of wave cycle? How mixed is the air mass in the fold, across the jet core? What are the values of tracers with different lifetimes? Under these conditions, what are the relationships among the thermal tropopause, PV based tropopause, and the ozone pause? What is the fate of the air mass in the fold? Do the deep intrusions enhance the boundary layer ozone?

Observational objectives: target deep intrusions and region of cut-off low, potentially at different phase of the cycle, map gradient and identify mixing signature by tracer correlations.

Forecast needs: Region of deep intrusions based on jet, tropopause height, cross sections of all potential locations, satellite maps in near real time for UTLS ozone distribution and total columns for high ozone locations.

Flight strategy: Using wind field, ozone, and water vapor to locate the intrusion; map horizontal gradients at multiple levels, and vertical gradients on both side of the jet core

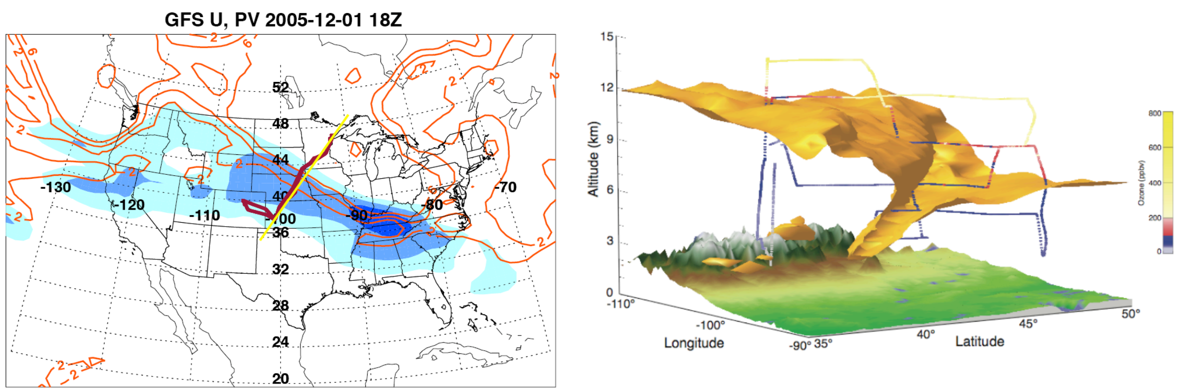


Figure 2. Example taken from START05 flight 1, December 2005 [Pan et al., 2007]

Flight Scenario S3: Tropospheric Intrusion

Science Questions: What is the chemical composition and photochemical age of the air mass in the low stability/low ozone layer? Where is the air mass in tracer-tracer space? Is the layer associated with cirrus occurrence? What dynamical processes control the occurrence? Where are the transport origin and the fate of the air mass? How mixed is the layer?

Observational objectives: map out the chemical composition and the gradient along the latitudinal extent of the intrusion, at the center of the layer, profiling to sample the vertical structure near the jet and in the mid point of the intrusion and near the end of the intrusion.

Forecast needs: Spatial extent of the multiple tropopause occurrence, Pressure/altitude of the primary and secondary tropopause, level of the static stability minimum in the region between first and second tropopause, jet positions, strength, map of PV and static stability or theta lapse rate at several levels, including the level of minimum theta lapse rate, high-resolution PV. Due to the aircraft ceiling, careful analysis of the altitude structure over the region is important. A-train track.

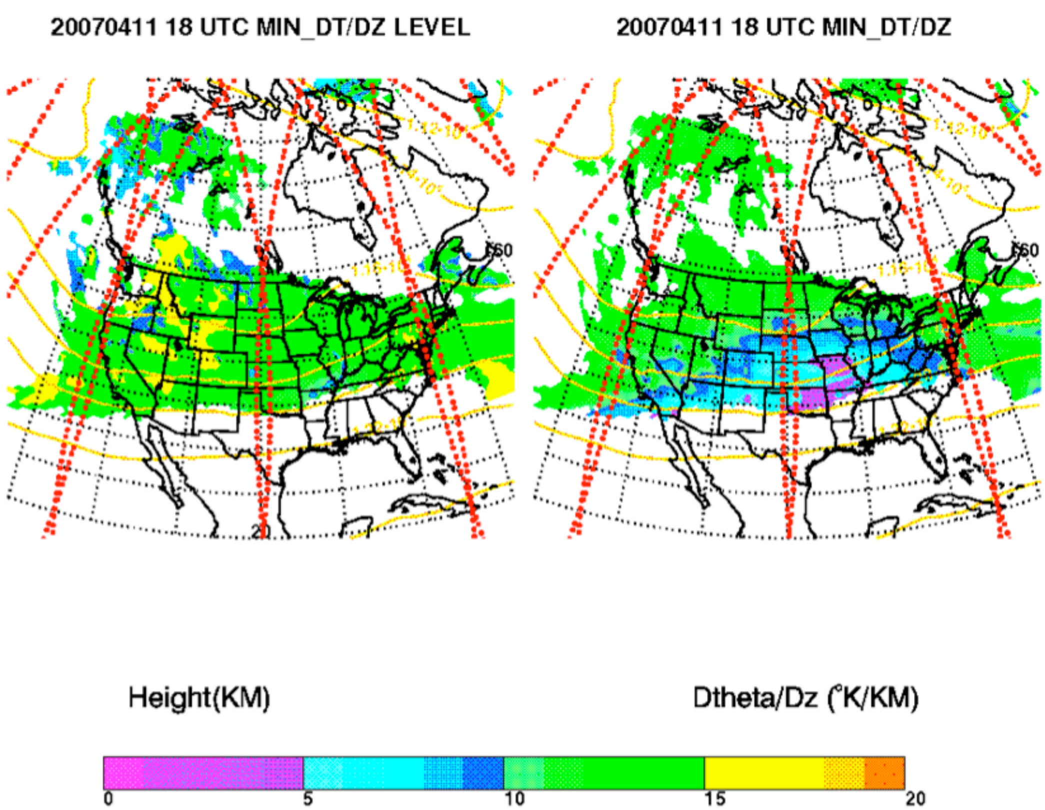


Figure 3. Both maps show the distribution of low stability layer between the primary and the secondary tropopauses. The left panel shows the altitude of minimum, the right panel shows the theta lapse rate at minimum.

Flight strategy: Take off to the jet core, first sample the equator side of the jet core. Identify the minimum level of the low stability air. Follow the level poleward to cover the whole range based on the forecast and if the flight duration limit allows. Profile down at the high latitude end of the intrusion. Profiling to the maximum altitude, optimally reach the secondary tropopause, before landing.

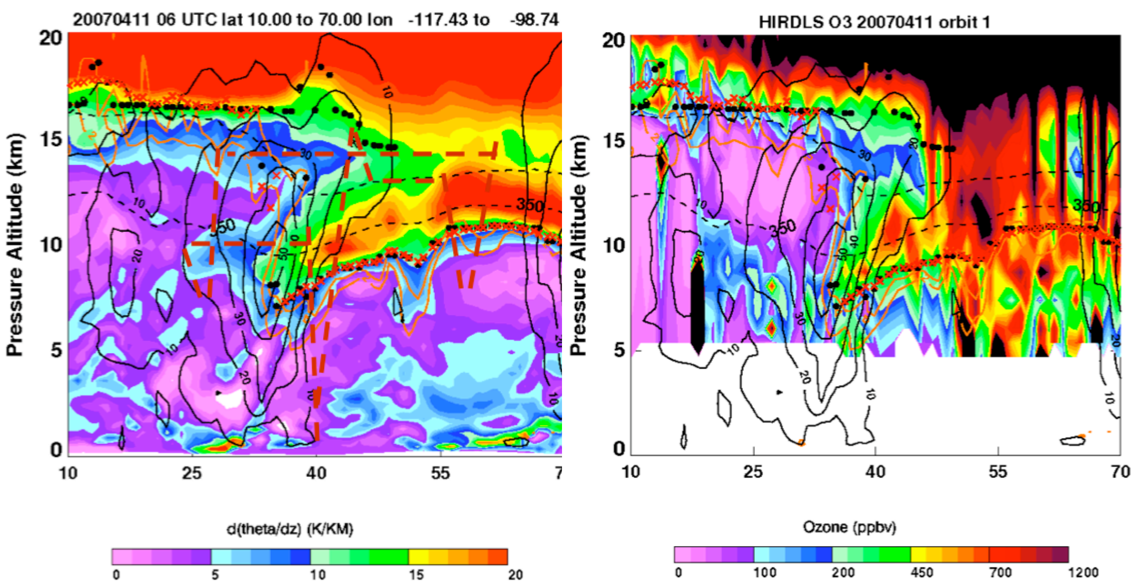


Figure 4. Flight scenario for Type S3. Left: color image is GFS based theta lapse rate. Wind field, PV and thermal tropopause, including secondary tropopause are shown. Right: HIRDLS ozone cross section. Post flight reference.

Flight Scenario S4: Convective transport

V1 – active isolated storm (this type of flight may not be pursued but may be considered by future HEFT missions)

Science Questions: The science goals are limited–the flight is principally designed to understand the capability of the GV aircraft in probing active thunderstorms/deep convection in preparation for setting details of aircraft flight scenarios for the upcoming DC3 program. The present flight will provide some information on the transport of chemical tracers (e.g., CO, CO_2, whole air sampler constituents, etc.) to and some of the microphysical properties within the downwind anvil region. For example, the flight will determine the fraction of nearer-surface constituents within the anvil and the temporal changes over the lifetime of the storm. The flight will also provide a reasonable estimate of the amount of NO produced by the lightning activity.

Observational objectives: exercise the forecast capability to locate this type of storm preferably not too far from JeffCO and in a region where ATC will not limit the flight tracks.

Forecast/nowcast needs: convective forecast to identify probable areas for genesis of isolated convection; nowcasting to direct the aircraft to the actual locations of convection. Need access to the NLDN cloud-to-ground lightning flash count data.

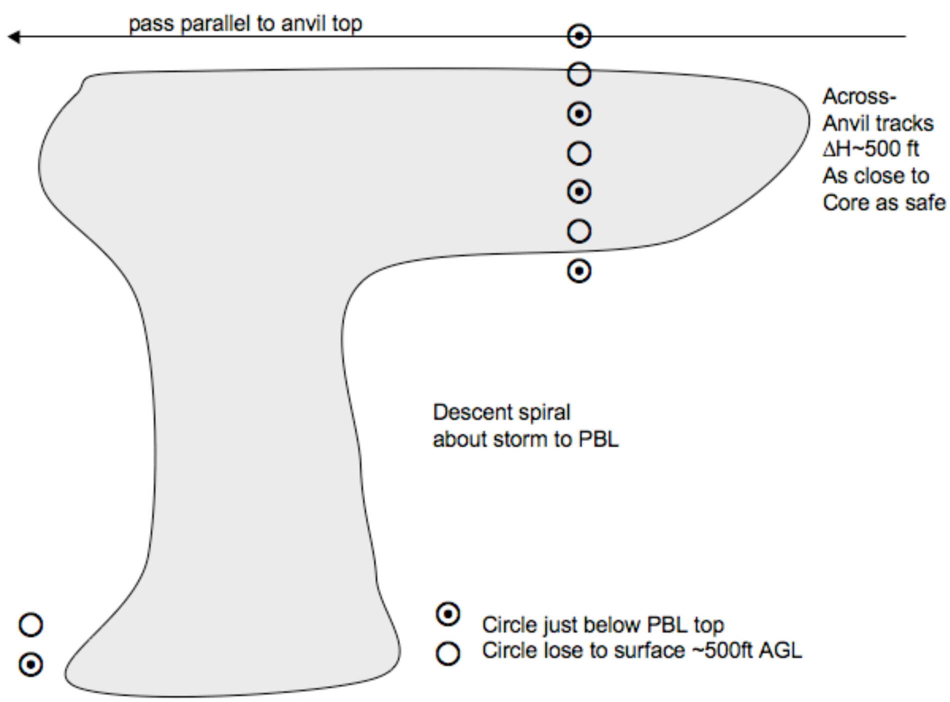


Figure 6: Schematic of the flight track for an isolated storm study. The pattern would be repeated as many times as allowed by fuel considerations.

V2, Collapsed isolated storm or storm complex

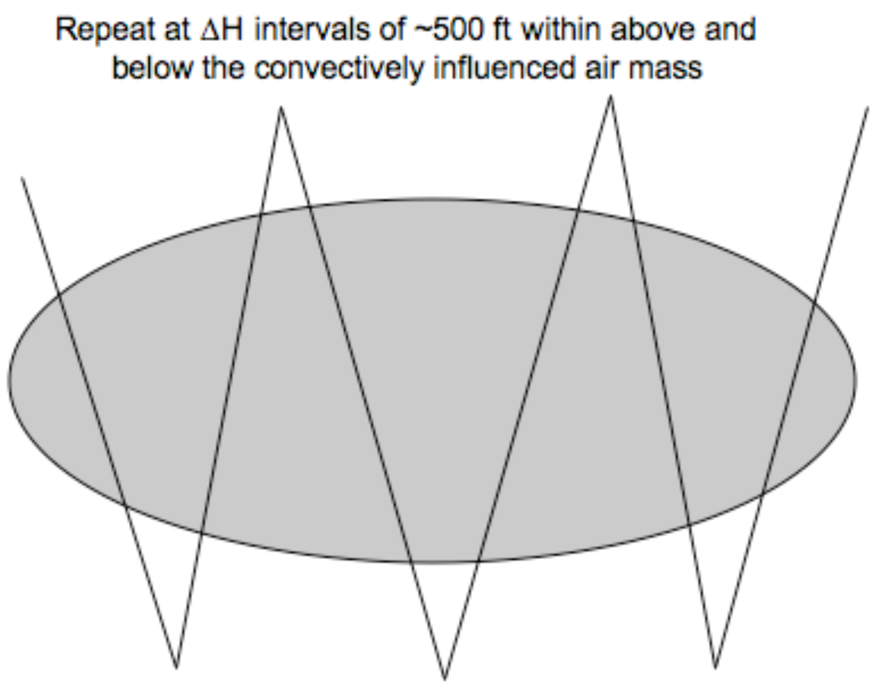
Science Questions: similar to the previous one but also test ability to track, find, and sample the convectively influenced air mass post storm collapse. Provide OMI satellite validation.

Observational objectives: similar to the previous one.

Forecast/nowcast needs: convective forecast to identify probable areas for genesis of isolated convection; nowcasting to direct the aircraft to the actual locations of convective outflow remnants within a few hours of storm collapse.

Flight strategy: as in Fig. 7 or similar at different levels within the region of where the anvil outflow is transported. Need to have early-in-the day storm (~noon time) so that probing of the air mass is done in daylight. If possible, correlate timing with OMI instrument overpass.

Figure 7. Top view of a collapsed storm and flight track:.



Flight Scenario S5: Gravity wave (GW)

Science Questions: How significant is the jet/front as the source for GW? Can the current state of art model predict the GW from jet/front?

Forecast needs: mesoscale model forecasts to identify regions of likely gravity-wave generation.

Flight strategy: Assuming we will have 5-hour flight time and HIPAER travels at 800km/h, we start from the level of maximum wind (~8-10km) along the jet core to the exit region for 1 hour, ascend to maximum altitude (~13km) and take the same track back to above the jet core, take a 45 degree angle to the right of jet exit, sample 1.5 hour, then descend to the level of jet core (8-10km), take the same track back to the jet core. Sample cross jet circulation if more time available, shorten the second back-forth flight distance if time constrained.

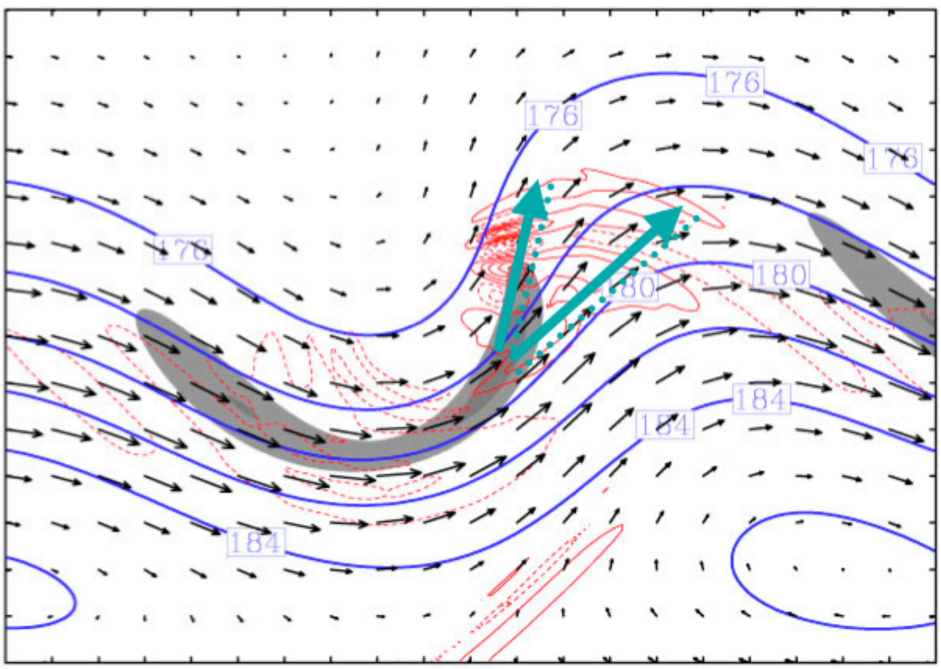


Figure 8: The 13-km pressure (thick blue line, every 2 hPa), horizontal divergence (thin red line; solid, positive; dashed, negative; every 5x10-6 s-1) and wind vectors (maximum of 25 m s-1) simulated from the triple-nested mesoscale model MM5 with horizontal (vertical) resolutions of 10 km (360 m). The wind speed at 8 km (near the maximum jet strength level) greater than 45m s-1 is shaded in grey (every 5 m s-1). Tick mark distance is 300 km.

HIPPO flights

H1: Northern survey leg. Fly North from Boulder as far as possible, with vertical profiles from cruise to 500 ft (or a missed approach at a rural airport) every 150 to 200 km. On the return leg go for maximum altitude over Jeffco.

H1-A-variant: To optimize START synergy, initiate the vertical profiles in the stratosphere and go for maximum altitude at the Northern end of the flight, with the plane directed to where it could reach the highest PV on that ascent.

H1-B-variant: To exercise payload re-start capabilities (a HIPPO requirement), go North and land (e.g. at Edmonton. Use the opportunity to reach higher latitudes than would otherwise be possible. This flight would require successful completion of H1 or H1-A-variant.

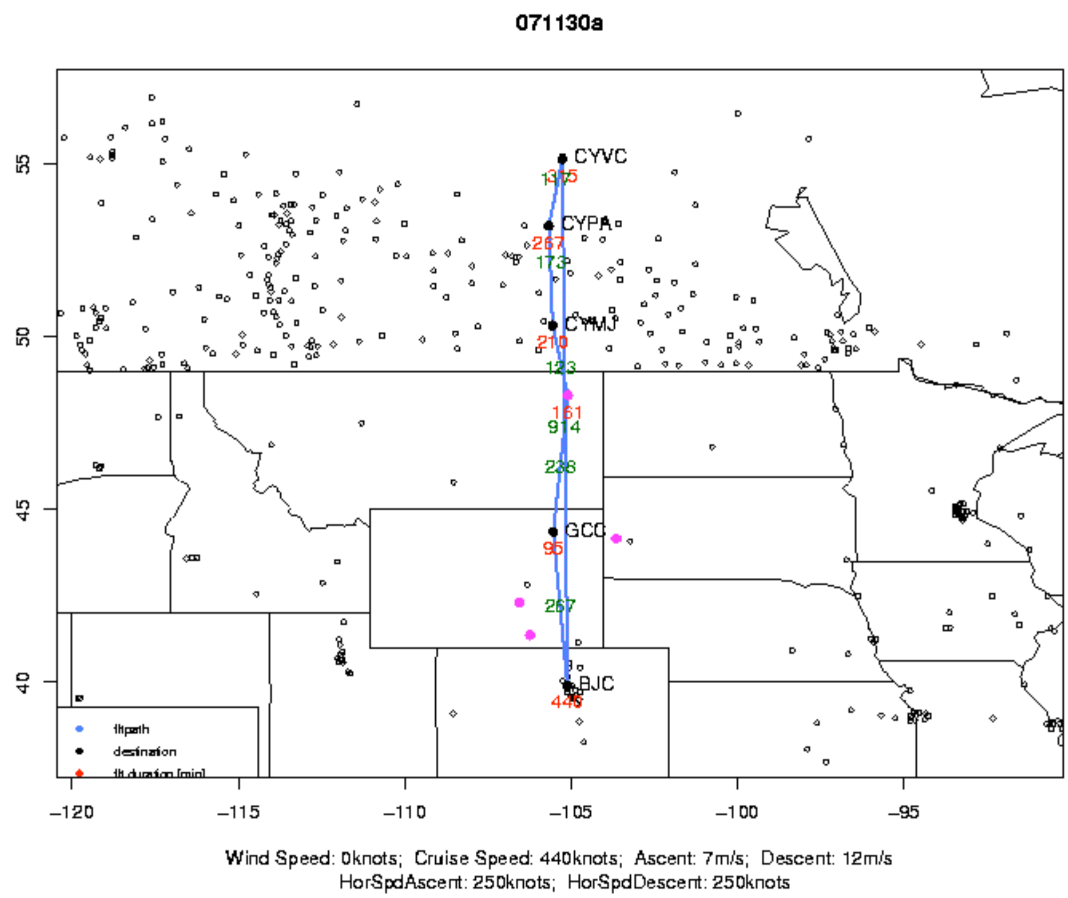


Figure 9. PreHIPPO Northern survey.

H2: Fly to San Diego and land to refuel. Fly as far south as possible from San Diego before returning to Boulder. Vertical profiles are obtained every 150-200 km, from the upper troposphere to 500 ft.

H2-A-Variant: Fly SE to the Gulf of Mexico, refueling at Houston/Ellington (EFD). Fly as far South as possible (if overflight permission is obtained from Mexico) or SE (if no overflight permission), then return to Jeffco.

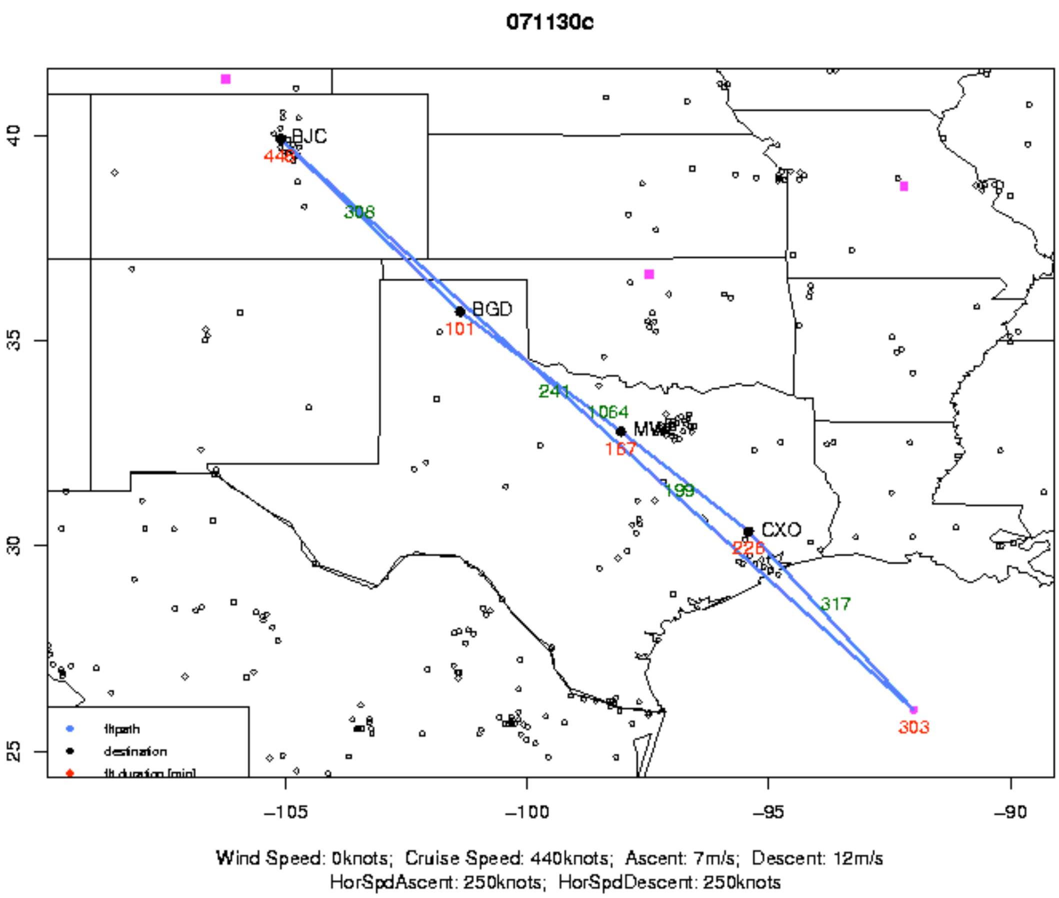


Figure 10. PreHIPPO southern survey.

H3. Arctic overnight flight.

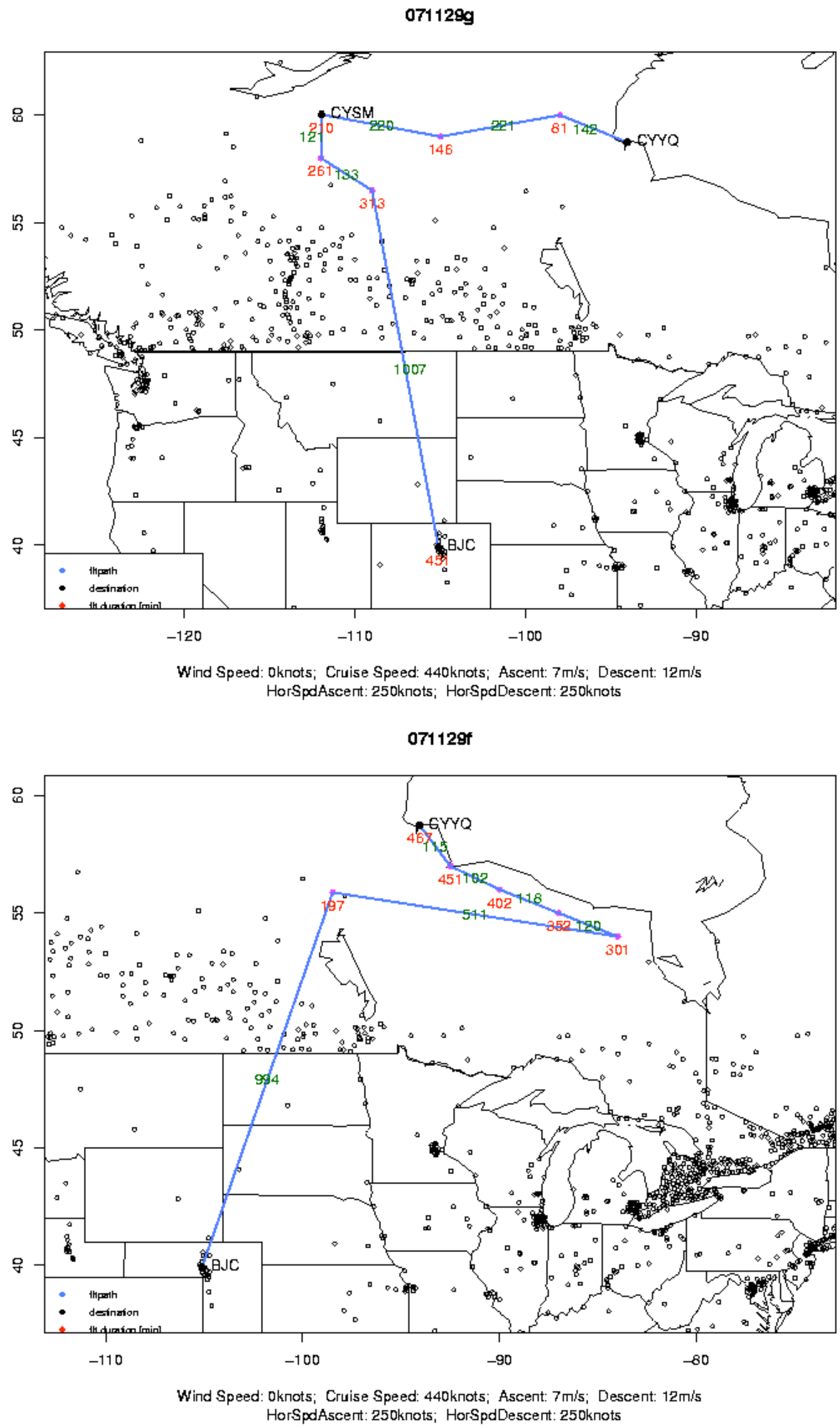


Figure 11 a, b.