CAM-Chem Chemical Forecasts

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Outline

- Science Objectives of CONTRAST
- CAM-Chem Description (using VSL Halogen version)
- Forecast Approach (3-Day, using GEOS5 met fields)
- Preliminary Model / Observation Comparisons

CONTRAST Science Objectives

Co-PIs: Elliot Atlas (U. Miami); Ross Salawitch (U. Md.); Laura Pan (NCAR)

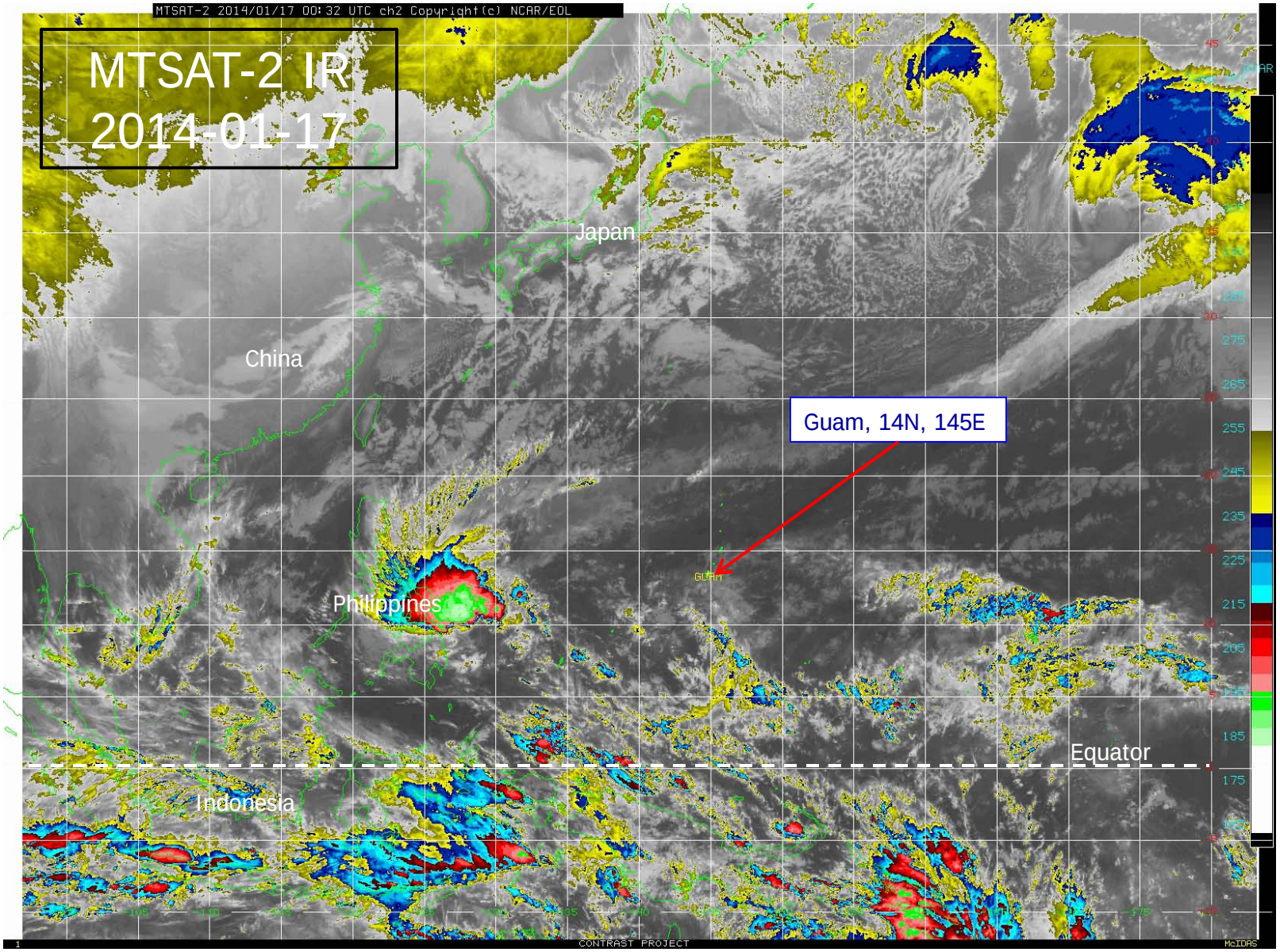
Location: Near Guam

Dates: January – February 2014

Major Objectives:

- Characterize the chemical composition and ozone photochemical budget at the level of convective outflow over the Western Pacific during the deep convective season.
- Evaluate the budget of organic and inorganic bromine and iodine in the TTL.
- Investigate transport pathways from the oceanic surface to the tropopause using the NCAR GV coordinated flights with British BAe-146 (CAST) and the NASA Global Hawk (ATTREX).

Weather Pattern (typical) Near Guam



CAM-Chem with VSL Chemistry

NCAR CESM CAM-CHEM

- Global Chemistry-Climate Model
- ~1.0° horizontal resolution
- Specified Dynamics Version (GEOS5)
- 56 vertical levels (surface to ~ 2 hPa)

Lamarque et al., *Geosci. Mod. Dev.*, 2012

Tropospheric Halogen Chemistry

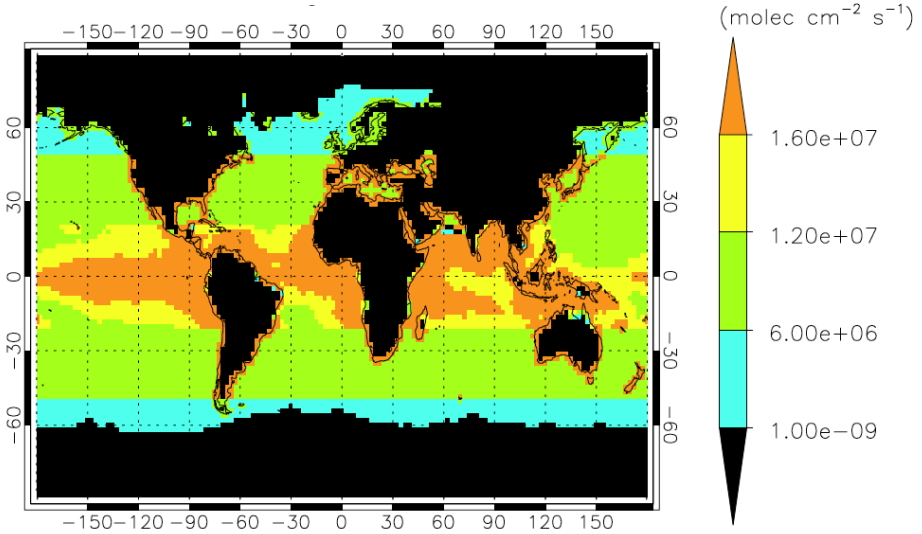
Halogenated sources from the ocean.

- Emissions following Chl-a over tropics
- Catalytic release from sea-salt
- Do NOT have polar emission processes

Chemical Processes

- Photochemistry (Cl, Br, and I)
- Dry / wet deposition
- 9 Additional vsl Organic species included.
- 160 species, 427 reactions

$CHBr_3$ Flux in CAM-Chem

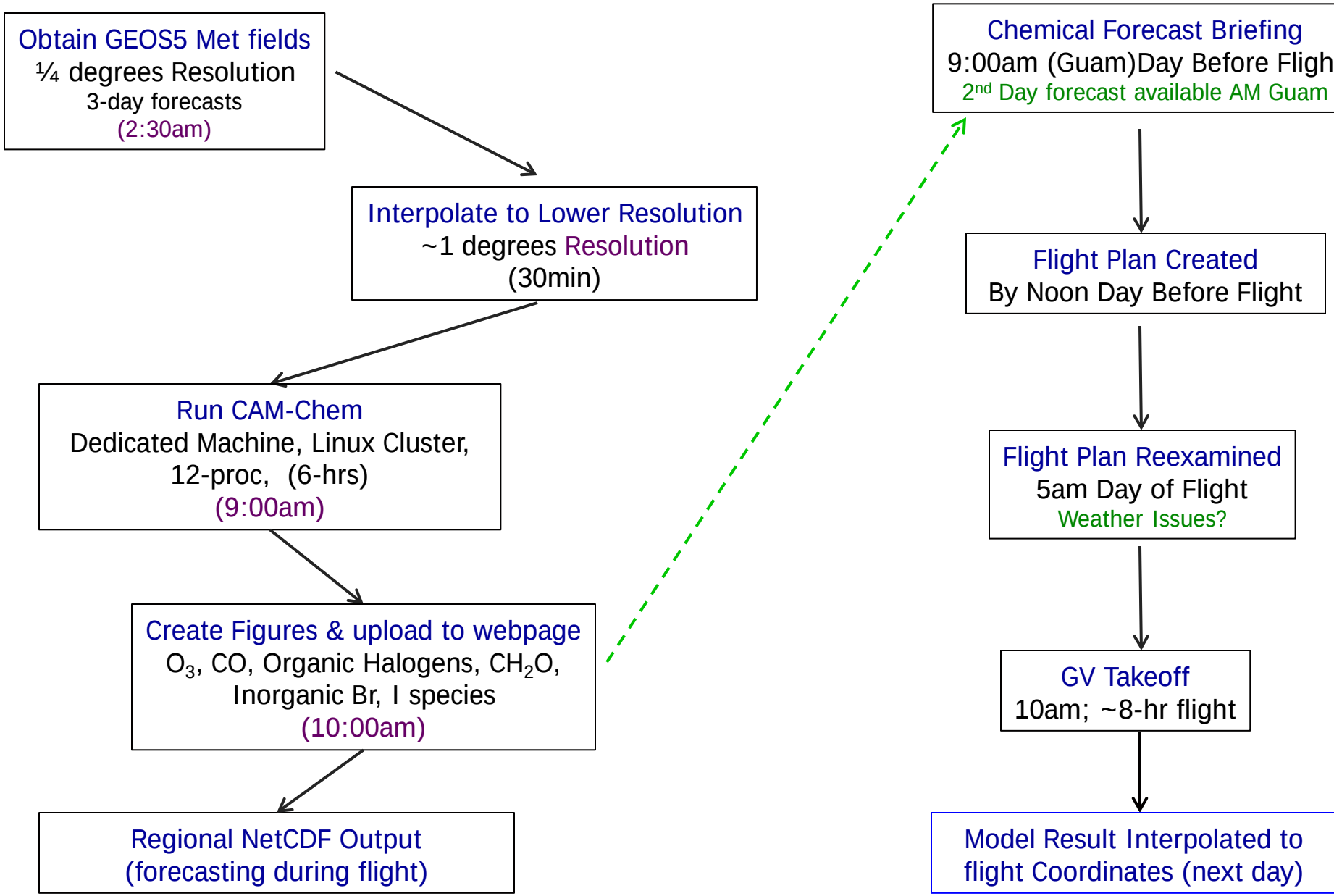


Source gas	Global annual flux (Gg yr^{-1})		Lifetime (this study)
	This study	Literature	
$CHBr_3$	533	400[a], 595[b], 448[d]	17 days
CH_2Br_2	67.3	113[c], 62[d]	130 days
CH_2BrCl	10.0	6.8[c]	145 days
$CHBr_2Cl$	19.7	23[c]	56 days
$CHBrCl_2$	22.6	16[c]	46 days
CH_3Br*	climatology	131[c]	1.6 yr[g]
CH_3I**	303	304[e]	5 days
CH_2ICl	234	236[f]	8 h
CH_2IBr	87.3	87[f]	2.5 h
CH_2I_2	116	116[f]	7 min

Total Bromine: 632 Gg Br yr^{-1}
Total Iodine: 600 Gg I yr^{-1}

Ordoñez et al., ACP, 2012; Saiz-Lopez et al., ACP, 2012.

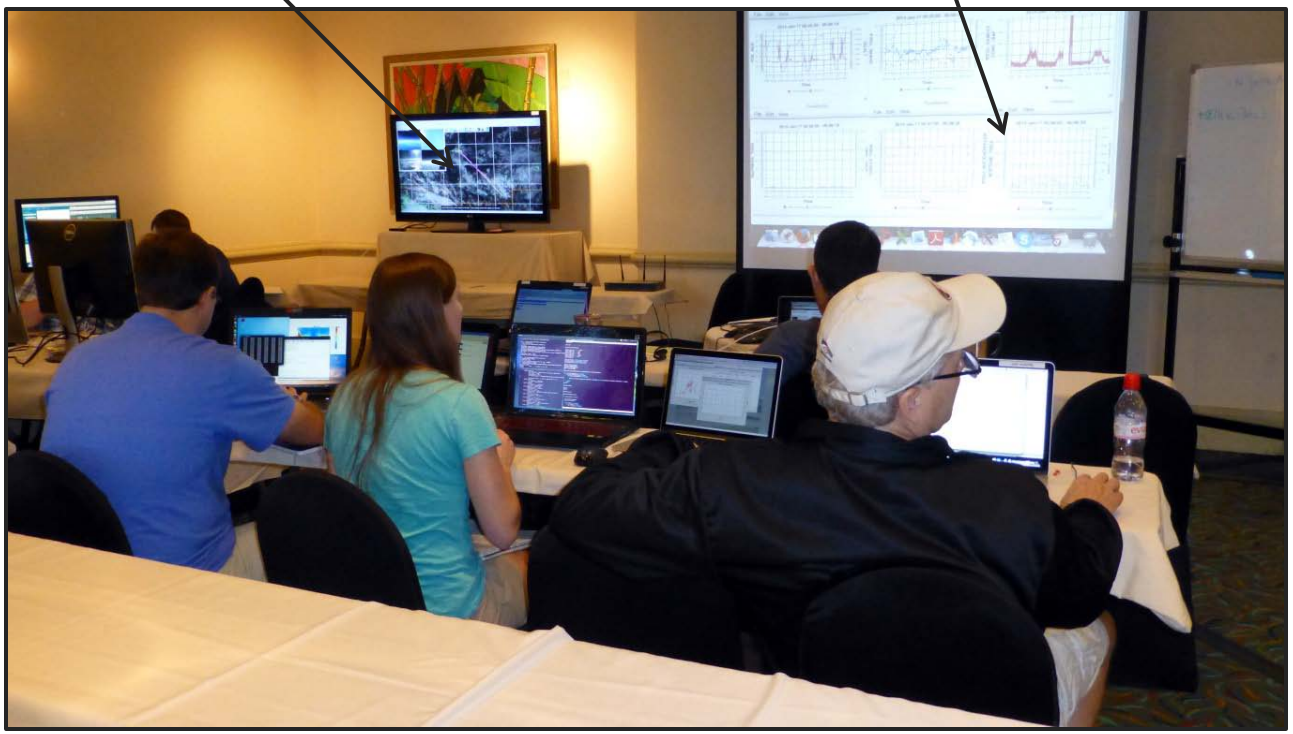
Automated Chemical Forecasts



Operational Center

Aircraft Location and Cameras Displayed

Monitoring Instruments during flight
Aeros software



Operational Room scientist connected to scientist on GV via “ichat”

Photo taken by Ross Salawitch

Next: Example Forecasts and Comparison to Obs.

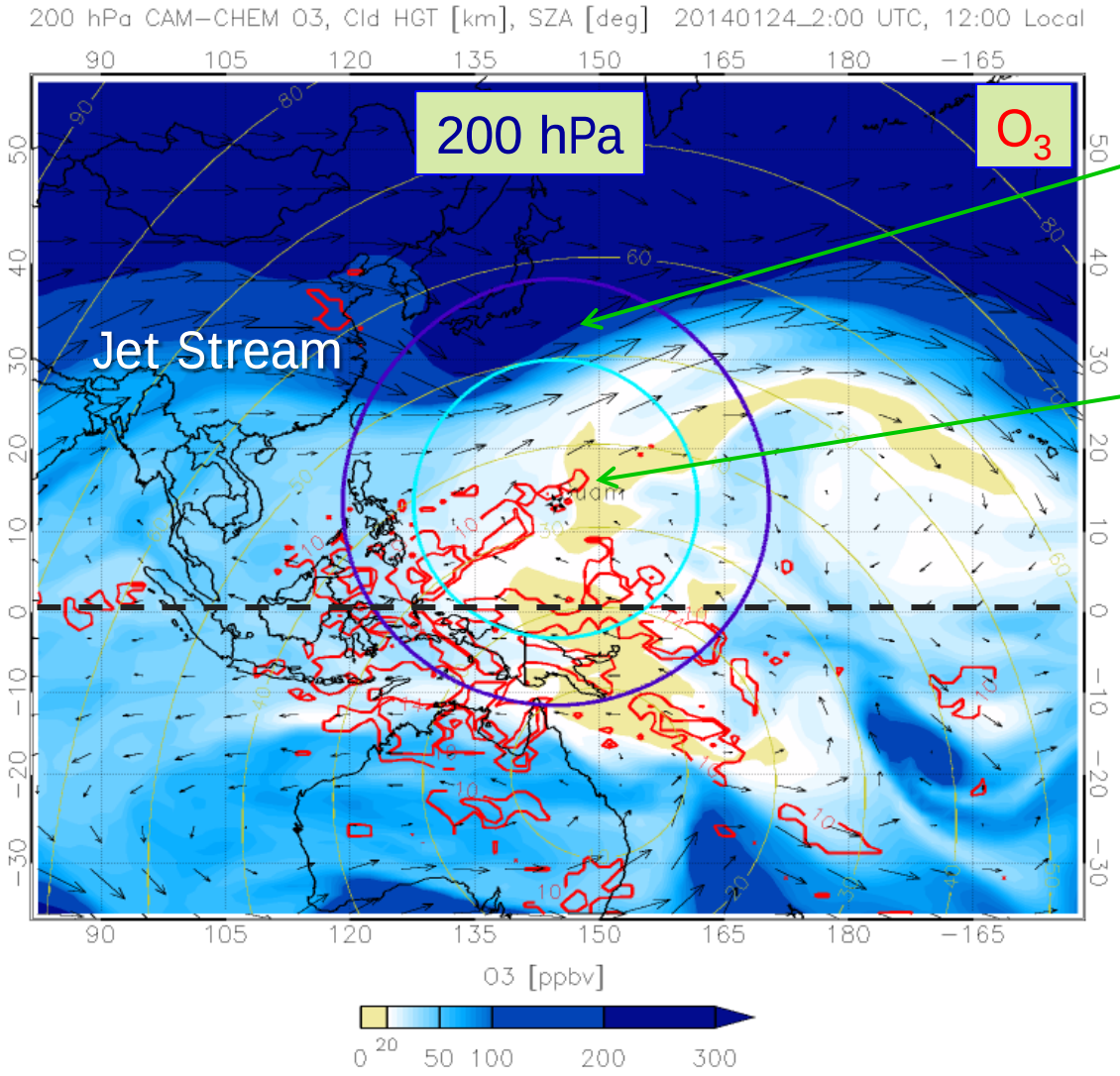
Will show two Research Fights (RFs)...

- Goal: To sample the lowermost stratospheric poleward of the Jet Stream (RF06).

- Goal: Survey flight to sample low ozone region SE of Guam (RF03).

Stratospheric Intrusion Forecast.

Goal: To sample the lowermost stratospheric air poleward of the Jet Stream.



O_3 between ~200 ppb North of Guam.

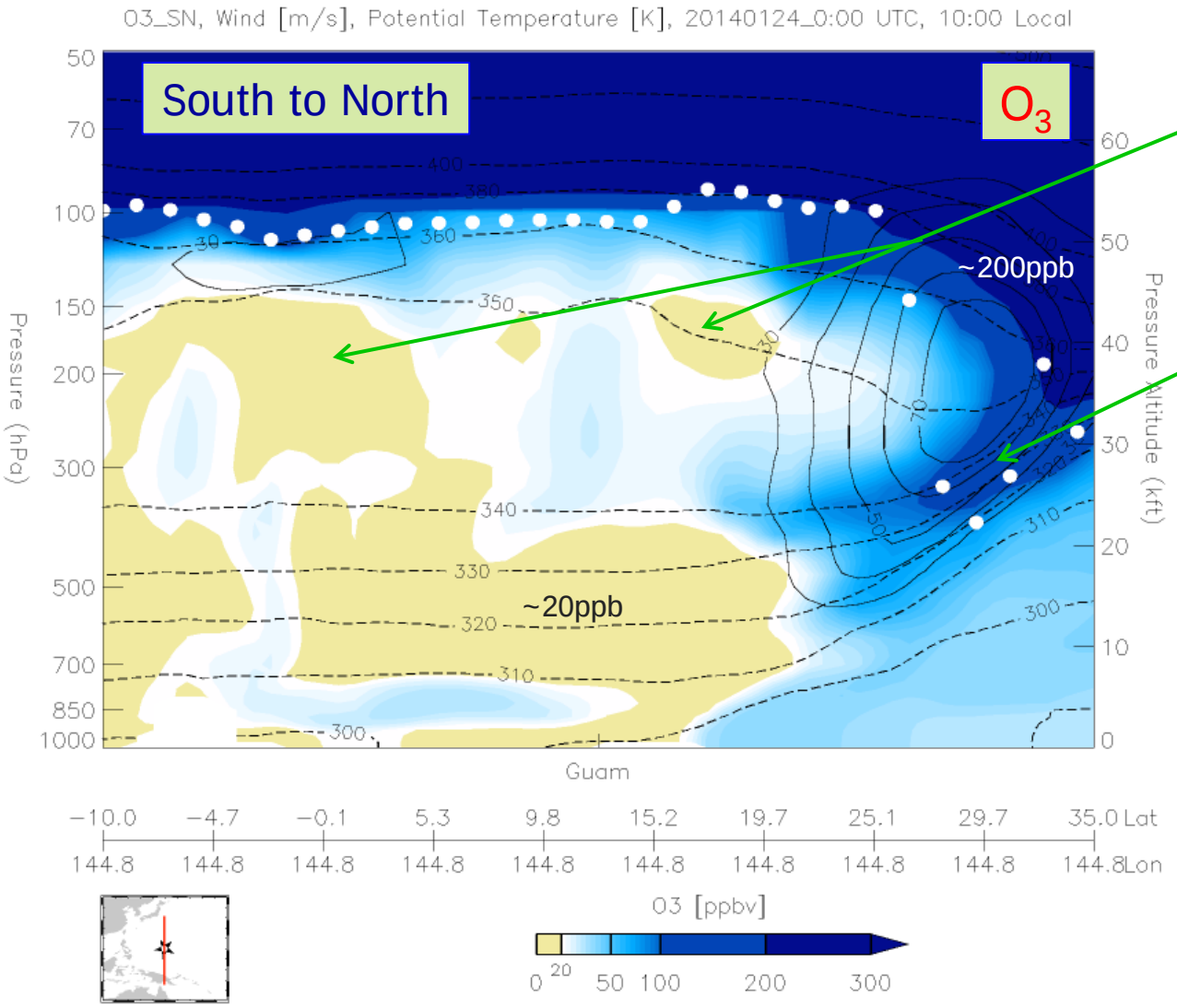
O_3 ~20 ppb near Guam. Influenced by convection.

Red contours are cloud top height (near convection).

Black dashed line designates the Equator.

Stratospheric Intrusion Forecast.

Goal: To sample the lowermost stratospheric air poleward of the Jet Stream.



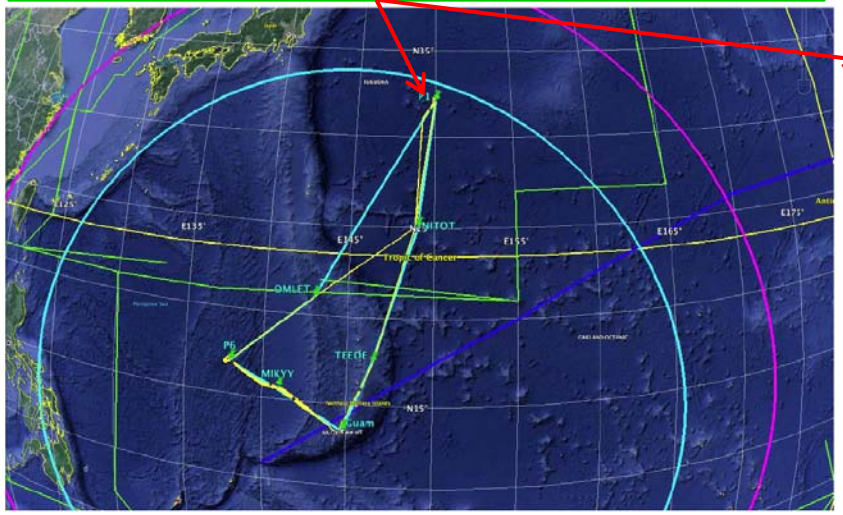
Recently convected air low in ozone (~20ppb).

Stratospheric intrusion ~30N.

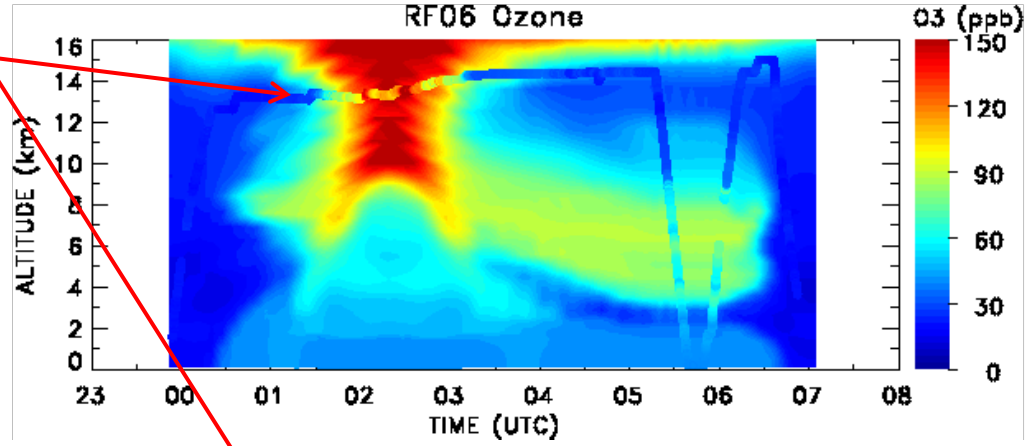
Black lines are zonal wind contours.

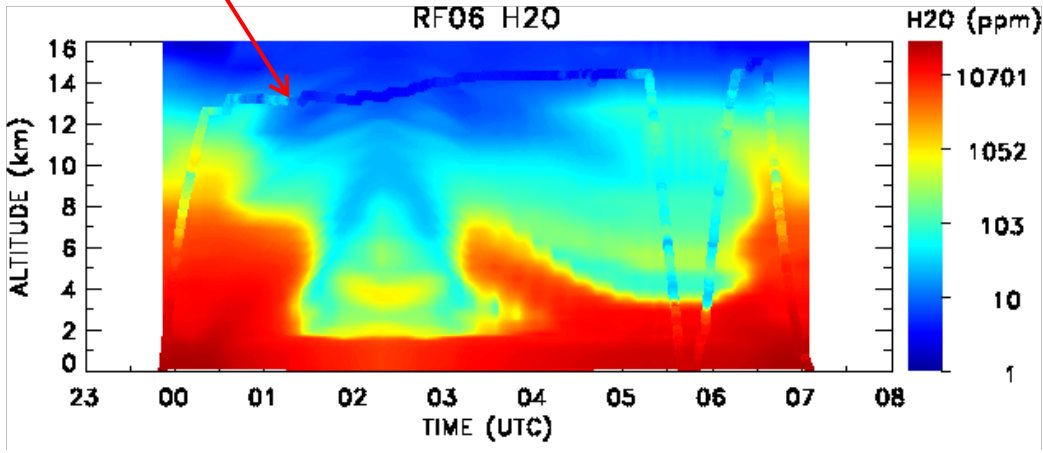
Capturing Stratospheric Intrusion (RF06)

Sampled Stratospheric air at ~32.5N, 150E



RF06 flight plan (cyan) and flight track (yellow). The front that produced the weather and acted as the air mass boundary in the region is shown by the blue line. The deep profile (spiral descent and enroute ascent) was carried out near P6. The FIR boundaries are marked by the green lines.





- Model overestimates O_3 during aircraft spiral later in the flight (4-8km region).

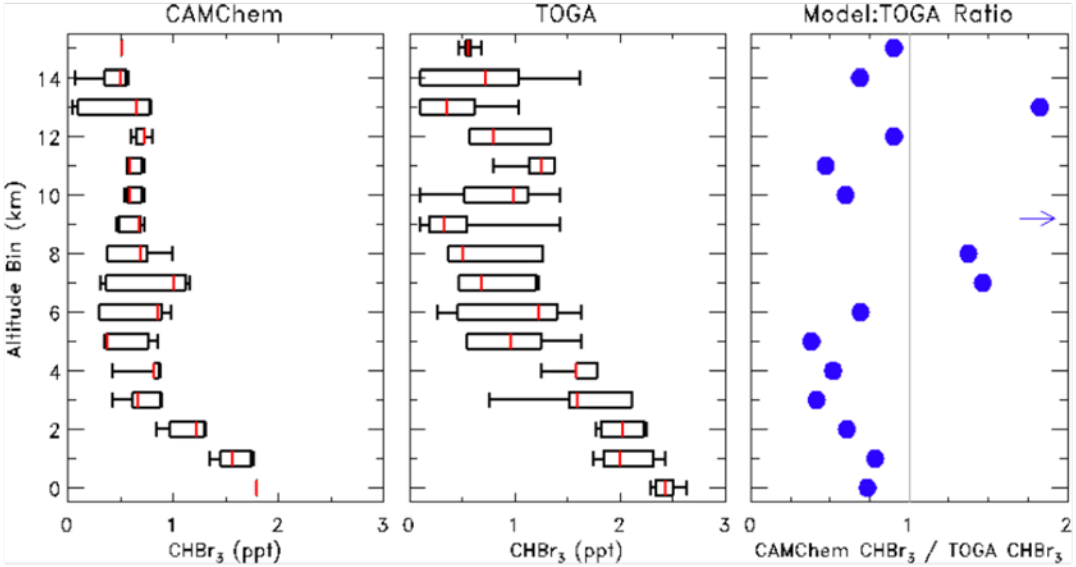
Summary:

- These are preliminary results, observations are plotted on flight track.
- Model does a reasonable job of capturing gradients in O_3 and H_2O for this flight. This is not true for all RF (see next few slides).
- The model overestimates O_3 and underestimates H_2O during the stratospheric intrusion.

Figure created by J. Nicely, T. Canty, R. Salawitch.

Organic Halogens: Bromoform (RF06)

Trace Organic Gas Analyzer, using a fast GC-MS technique (TOGA), Apel, Riemer, Hornbrook, NCAR.



TOGA will measure multiple halocarbon, hydrocarbons, oxygenates, and N & S compounds. We will also have the AWAS which will measure many of the same species.

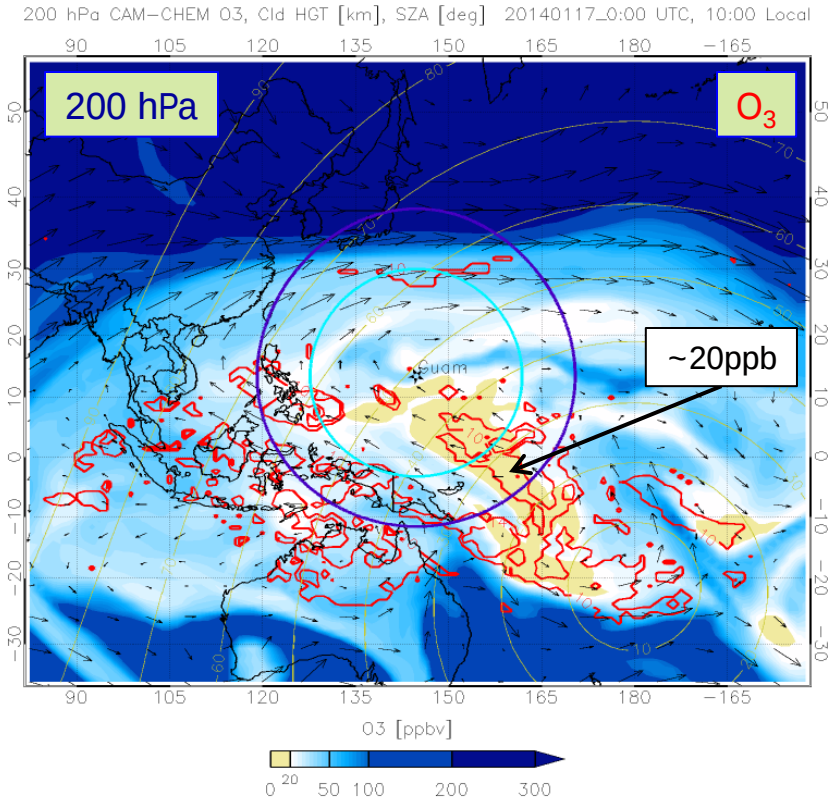
Inorganics halogens will be measured by CIMS (in situ) and AMAX-DOAS (remote).

Summary:

- These are preliminary results.
- Surface abundance is >2ppt in observations. Slightly less in model.
- Both model and observations have significant reduction in Bromoform ($CHBr_3$) in the TTL. This is consistent with photolysis degradation.
- Post mission analysis will focus on examining the budget of both the organic and inorganic halogens from the surface to the TTL.

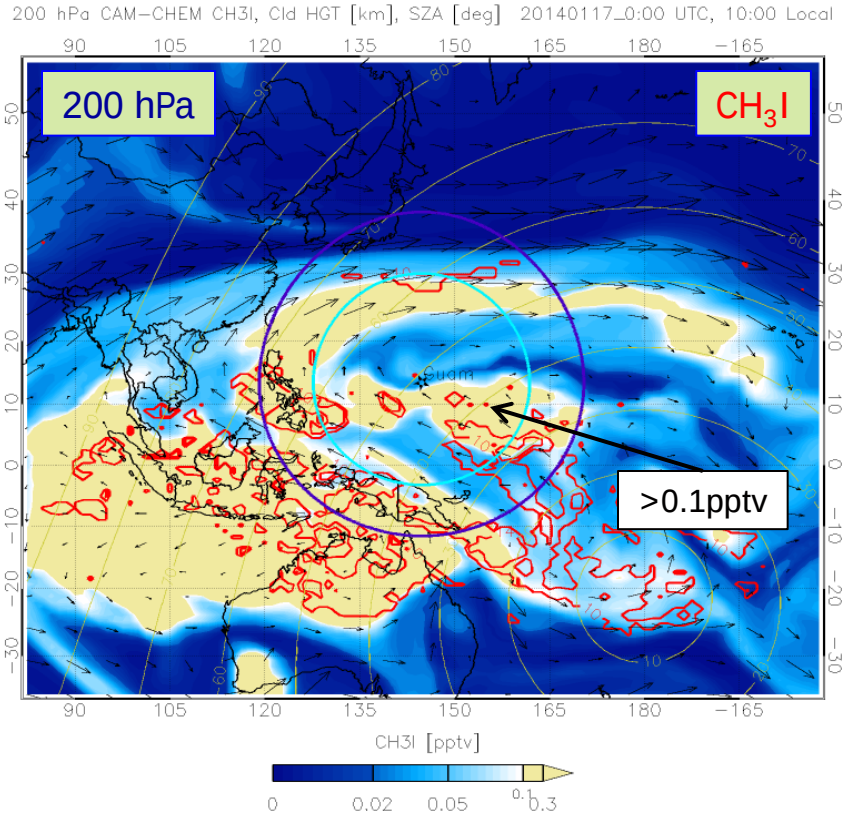
Figure created by J. Nicely, T. Canty, R. Salawitch.

Southern Survey Flight (Forecast)



Good opportunity to sample low O_3 in recently convected air masses.

Weather pattern for this flight shown in fourth slide.

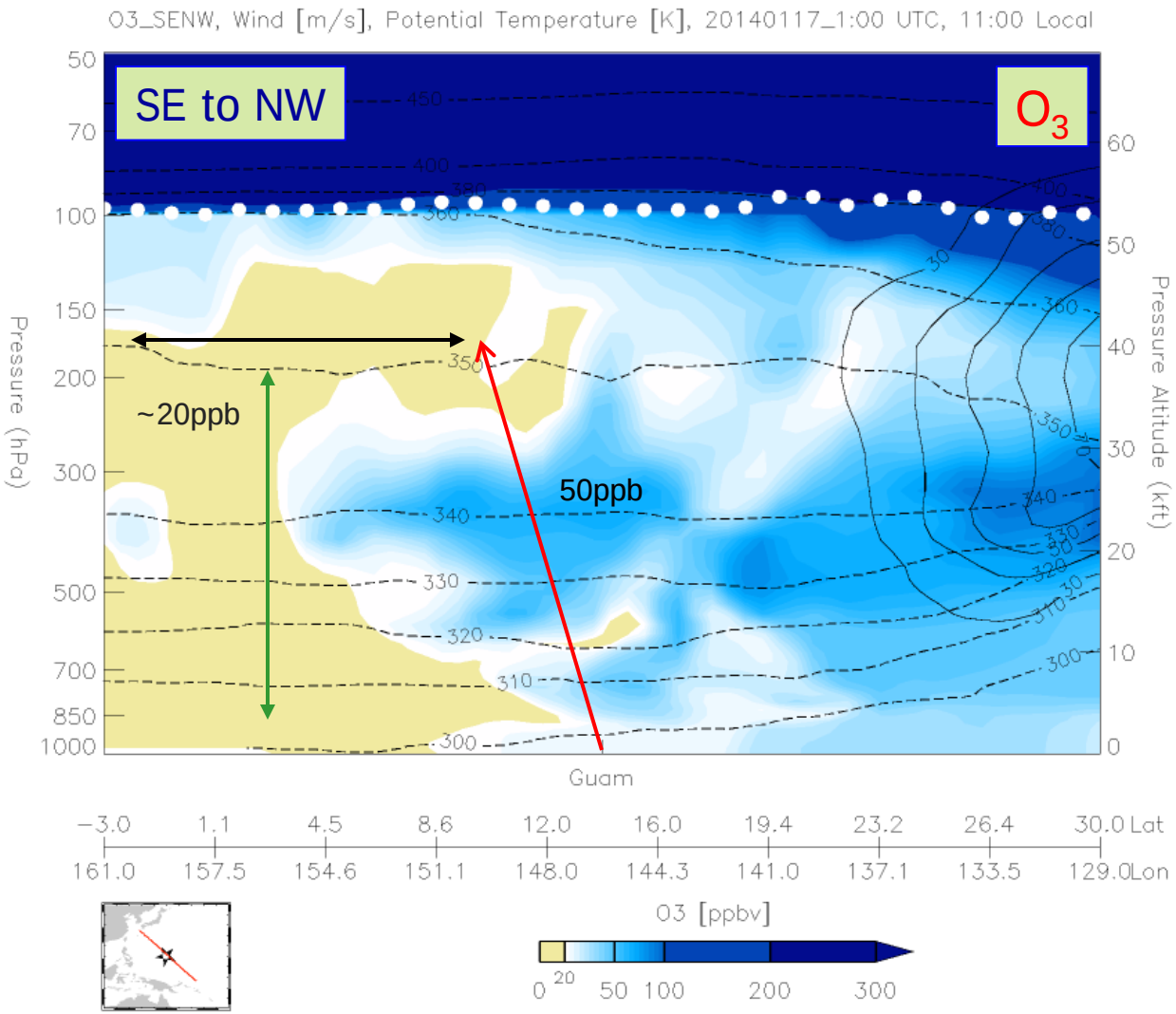


Large convective region SE, S, and SW of Guam (red circles are cloud top height, 10km, 14km).

CH_3I (higher) and O_3 (lower) in region where air has been recently convected.

Planned research flight to examine SE trajectory.

Southern Survey Flight (Forecast).

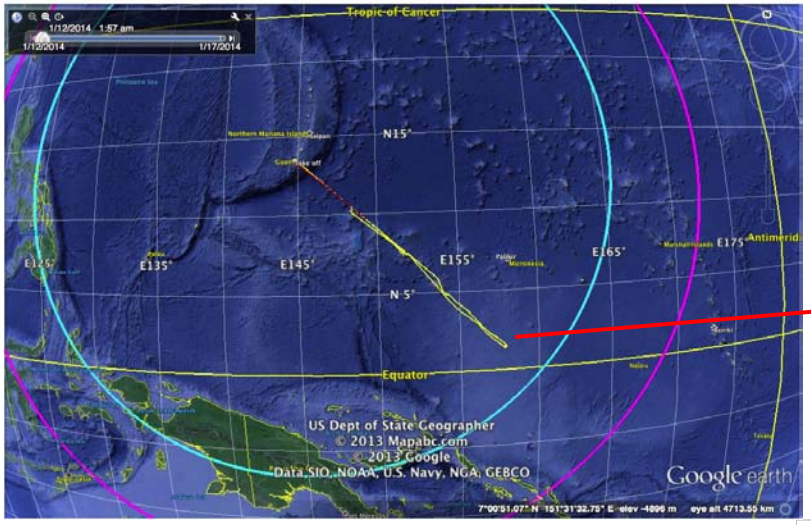


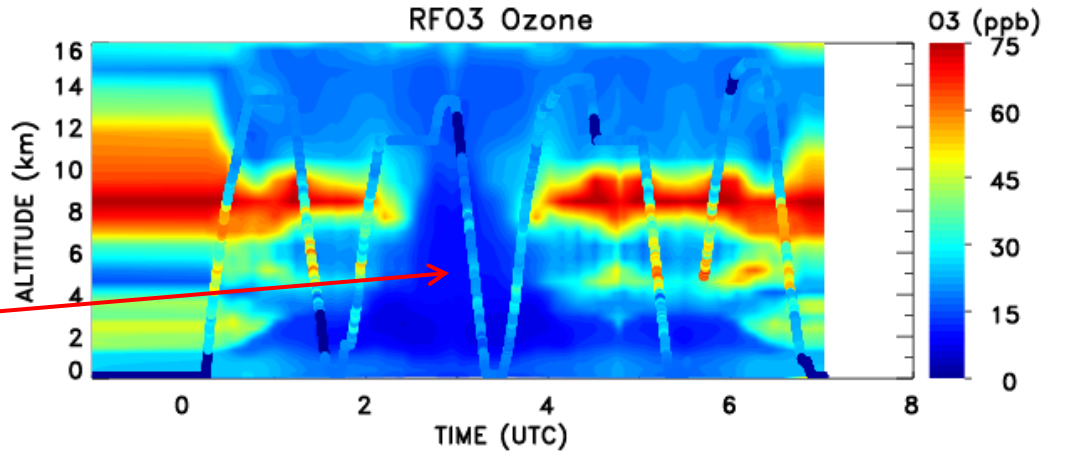
Forecasts shows ozone gradient SE of Guam (red line).

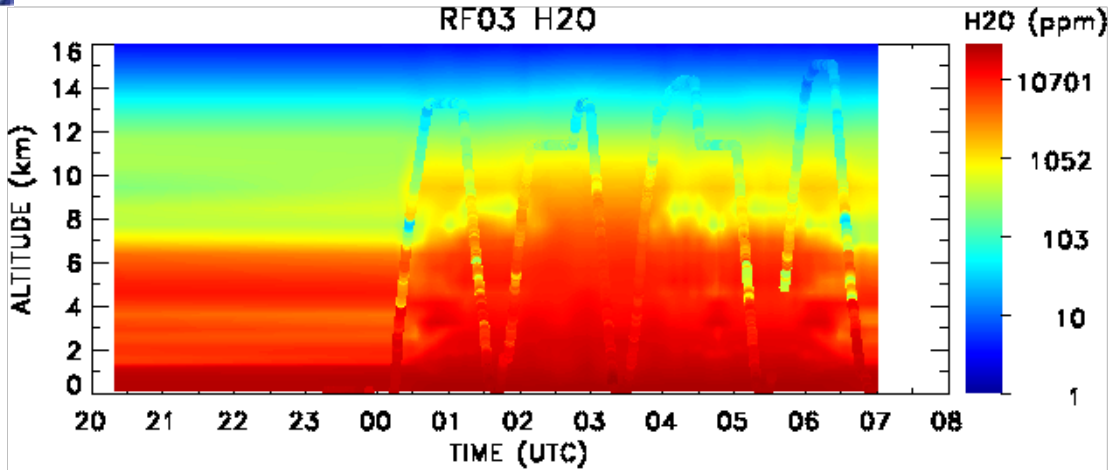
Low O_3 values at GV cruise altitude (~200hPa) (Black line)

Low ozone from surface to UT starting at 5N (green line).

Southern Survey Flight (RF03)







Summary:

- SE trajectory from Guam (to ~2N, 158E). Eight profiles obtained during flight.
- Model did captured the low ozone (~20ppb) near Equator (red arrow).
- However, the model did not adequately capture the vertical structure of O_3 and H_2O North of ~5-degrees latitude

Southern Survey Flight (RF03)

Br/BrO:

These are preliminary results.

Controlling factors that increase the Br to BrO ratio...

- Rate of reaction:

$Br + O_3 => BrO + O_2$

Rate proportional to T, O_3

Higher Br/BrO for T< ~200K (positive activation energy) and low O_3 ~50ppb

- Rapid photolysis of BrO:

$BrO + h\nu => Br + O$

- Low abundance of Formaldehyde

$CH_2O + Br => BrO + CH_2$

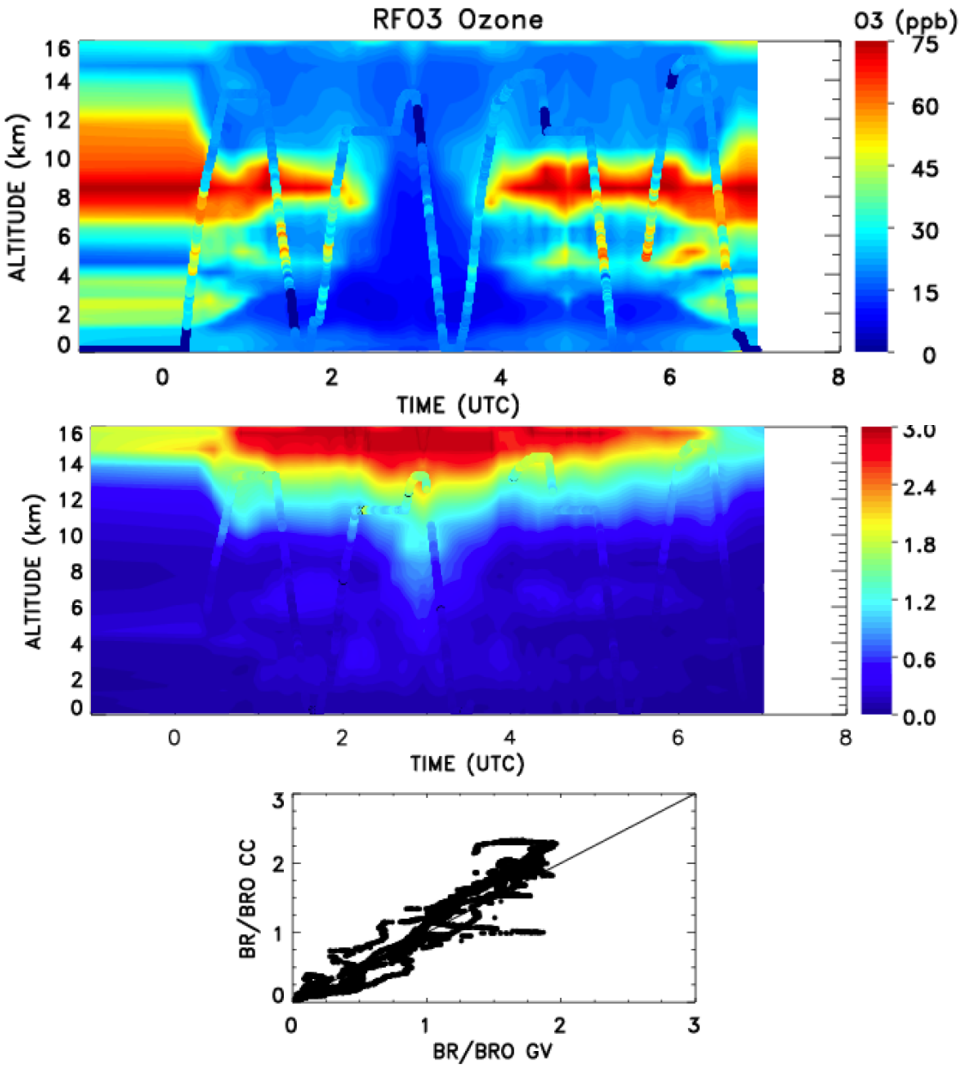


Figure 10. Top: curtain plot (CAM Chem Br/BrO ratio sampled along flight track) and snake (ratio inferred GV measurements of J BrO, O_3, and HCHO) Bottom: scatter plot of CAM Chem (CC) Br/BrO versus GV Br/BrO.

Figure created by J. Nicely, T. Canty, R. Salawitch.

Summary

- CAM-Chem has (is) being used for chemical forecast for the CONTRAST mission. There are currently 10 RFs. A large team of scientists have contributed to this "forecasting" effort.

- Preliminary results show that CAM-Chem "generally" represents the observed distributions of O_3, Organic Halogens, H_2O vapor, and the derived Br/BrO in the Western Pacific region.

- However, depending on the research flight, the model has difficulty representing "specific" details along the flight track regarding magnitude and gradients of select species. This can be due to multiple factors (e.g., horizontal and vertical resolution, parameterized convection, surface emissions, SD nudging factors, forecast meteorology, missing chemical processes, etc...).

Thank you for your attention!

Photo taken from GV by Pavel Romashkin (near Guam)