A Study of Stratosphere-Troposphere Exchange Associated with Tropical Storms

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Abstract

We propose to fly *in situ* ozone and water vapor instruments on board the ER-2 during CAMEX-4 flights over severe tropical convection. The aim of these measurements is to examine stratosphere-troposphere exchange (STE) processes over hurricanes in the Atlantic. The purpose is to determine whether significant lofting of upper tropospheric air into the stratosphere occurs under such situations. Such transport affects the chemistry of the lower stratosphere. Concomitant transport of lower stratospheric air into the upper troposphere also occurs; this may impact tropical storm formation or evolution. Data will be analyzed to assess frequency and location of STE and its impact on the stratosphere and on tropical storm evolution.

CIRES

CAMEX-4 Science Team Meeting
March 13-15, 2002
New Orleans

Scientific Questions:

1) How is air transported from the troposphere to the stratosphere?

2) What role does convection play in dehydrating air to the low mixing ratios observed in the stratosphere?

3) Does transport of high PV stratospheric air into the upper troposphere affect tropical storm formation and/or evolution?

Measurements:

In situ ozone and total water on the ER-2

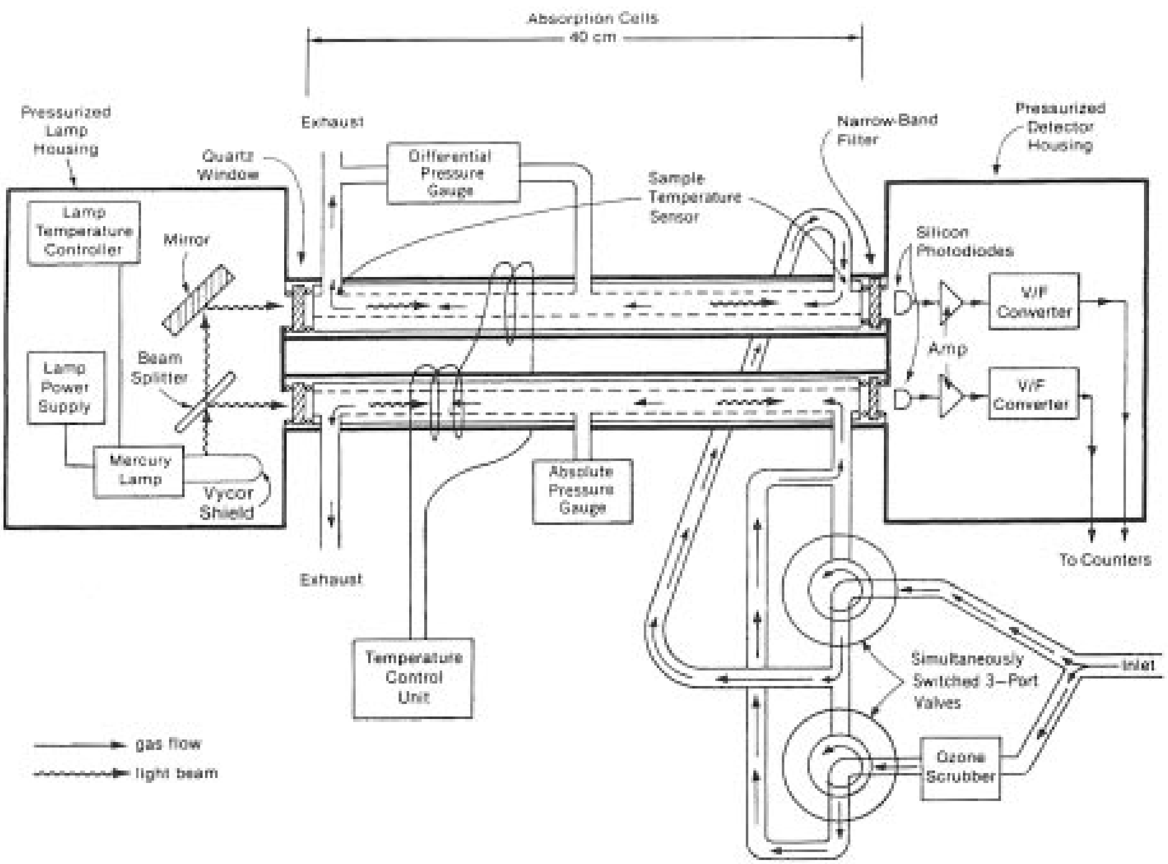
Instruments:

Dual-Beam UV Absorption Ozone Photometer

Lyman-α Total Water Hygrometer

NOAA Dual-Beam UV Absorption Ozone Photometer

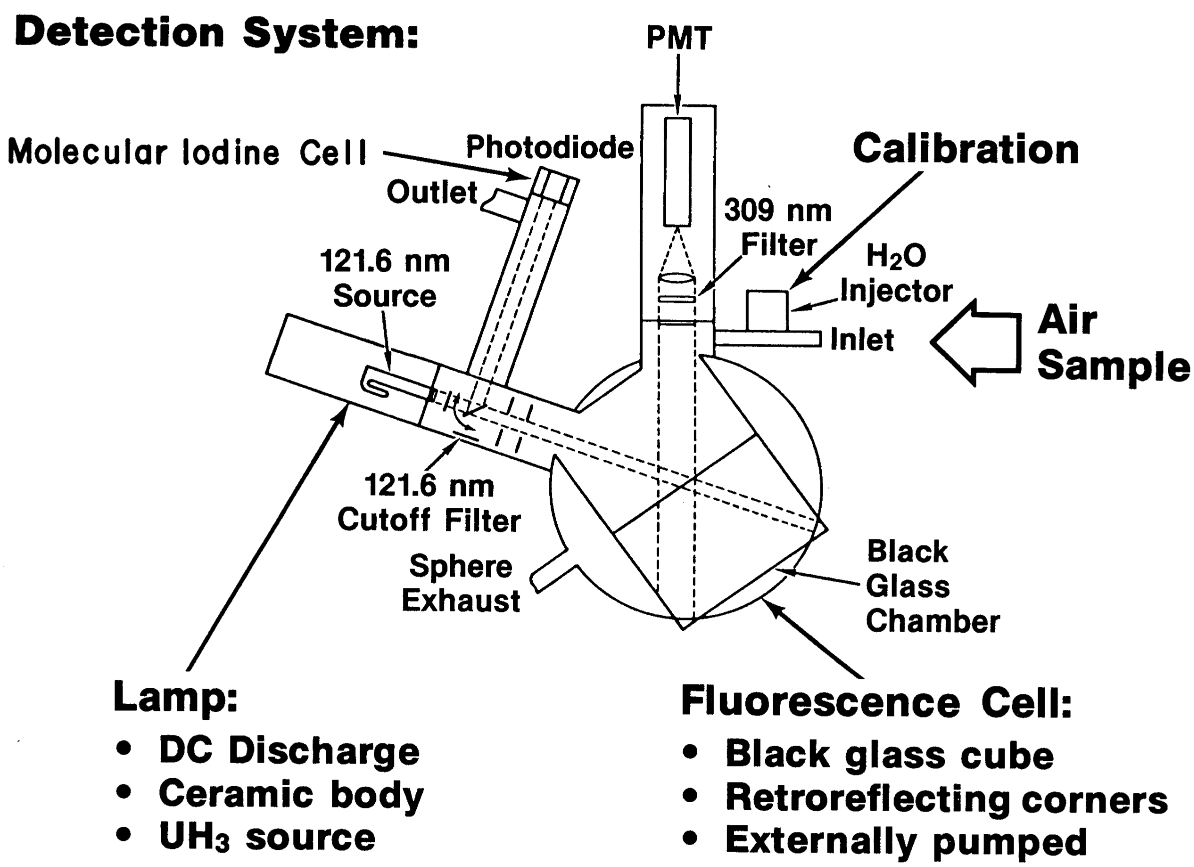
Ozone is measured using a photometer consisting of a mercury lamp, two sample chambers that can be periodically scrubbed of ozone, and two detectors that measure the 254-nm radiation transmitted through the chamber (*Proffitt et al.* [1983]). The ozone number density is calculated using the ozone absorption cross-section at 254 nm. At a one-second data collection rate, the minimum detectable concentration of ozone (one standard deviation) is 1.5 x 10^{10} molecules/cm^3 (0.6ppbv at STP).



Accuracy:	3% + precision
Precision:	1.5 x10^{10} molecules/cm^3
Weight:	24 kg
Data rate:	1 second

NOAA Lyman-α Total Water Hygrometer

Total water is as vapor with a Lyman-α hygrometer (Kelly et al. [1989]). Lyman-α light (121.6 nm) photodissociates water to produce an excited OH radical. The fluorescence from this radical at 309 nm is detected with a phototube and counting system. The Lyman-α radiation produced with a DC-discharge lamp is monitored with an iodine ionization cell that is sensitive from 115 nm to 135 nm. Calibration occurs in flight by injecting water vapor directly into the ambient sample flow.



Accuracy:	10%
Precision:	5%
Data rate:	1 second
Weight:	29 kg

Data files for both the ozone and water instrument have been submitted to the CAMEX-4 data archive.

Ozone data is complete for all flights.

Water data is complete for all but 3 flights. Flights with missing water data include:

1) Gabrielle flight (lost ~30% of the data due to a flash card failure)
2) Humberto flight on Sept. 24 (lost ~40% of the data due to a stuck calibration valve)
3) Transit flight to Dryden (calibration valve unstuck midway in flight, have data for ~50% of the flight)

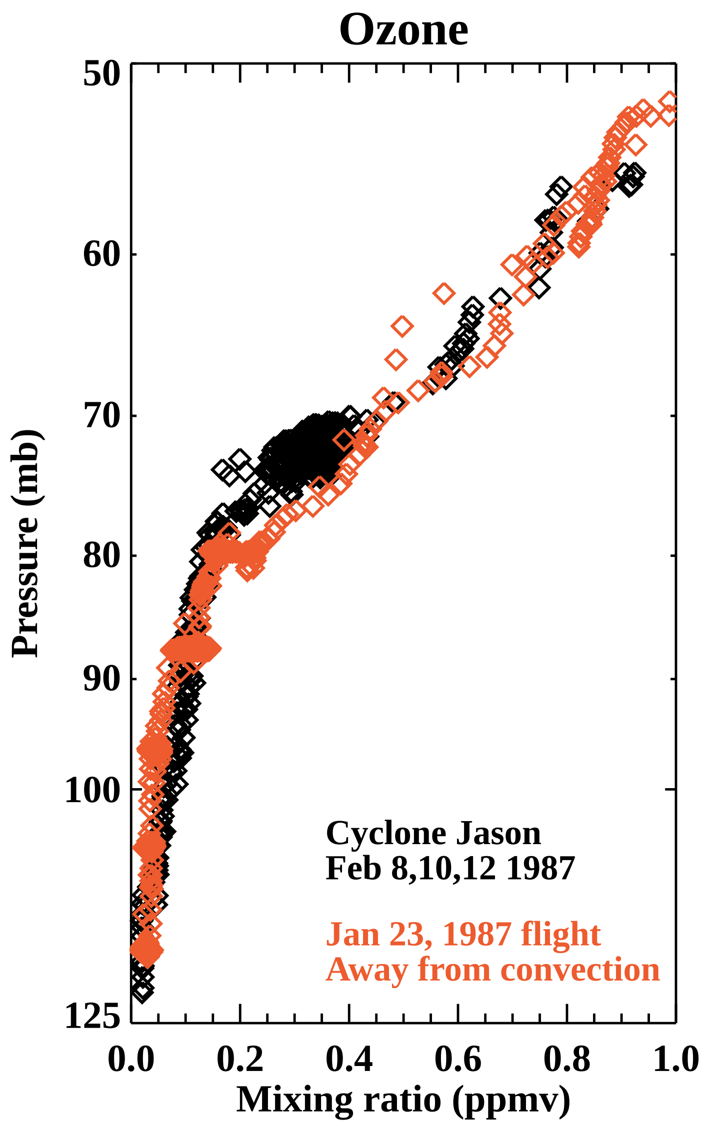
All files are in ASCII, and consist of two columns, UT seconds in flight and mixing ratio.

Prior to the CAMEX-4 flights, we have NOAA O_3 and H_2O data from 3 storms.

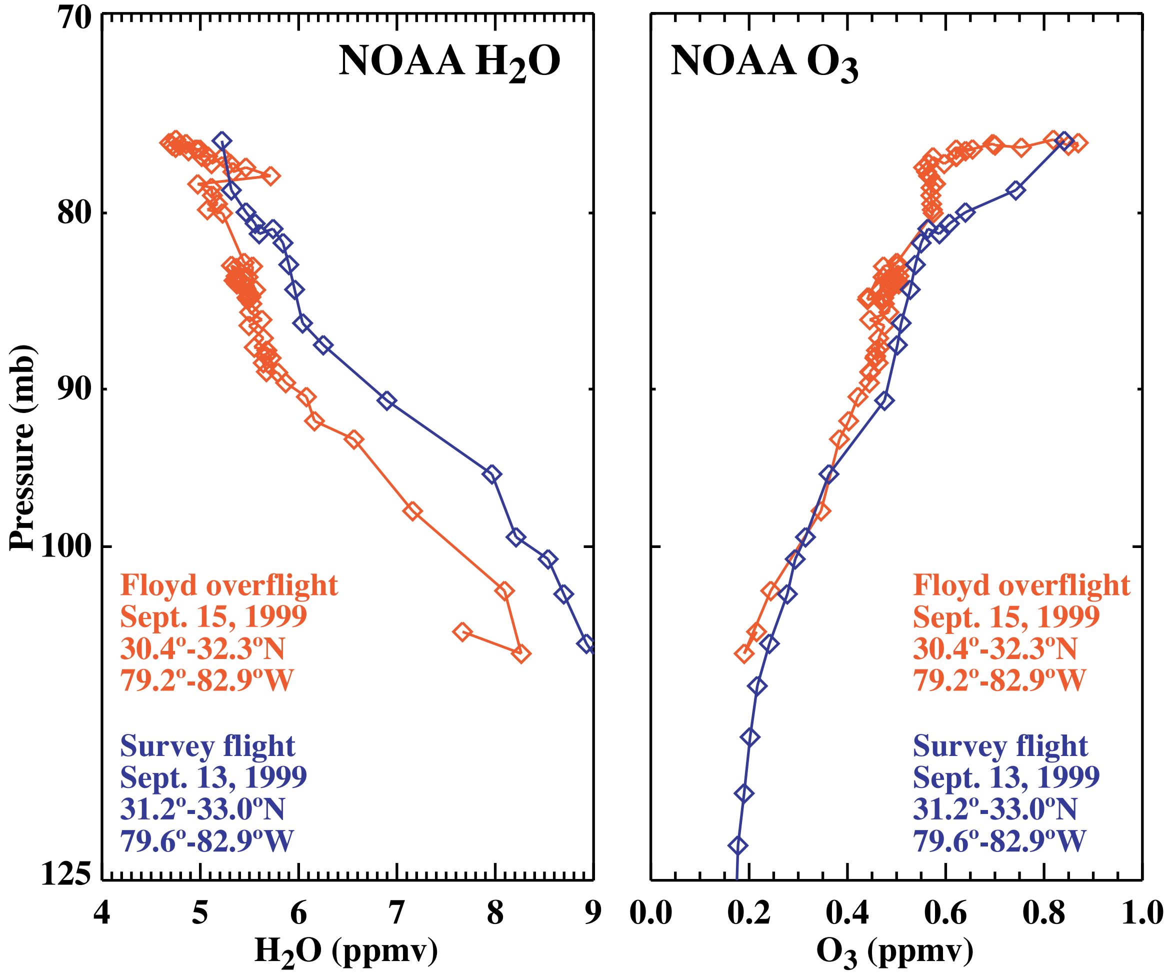
1) 1987, STEP-Darwin, ER-2 flew over Cyclone Jason.

2) 1994, ASHOE/MAESA, ER-2 flew near Typhoon Usha.

3) 1999, ACCENT, WB-57F flew over Hurricane Floyd.



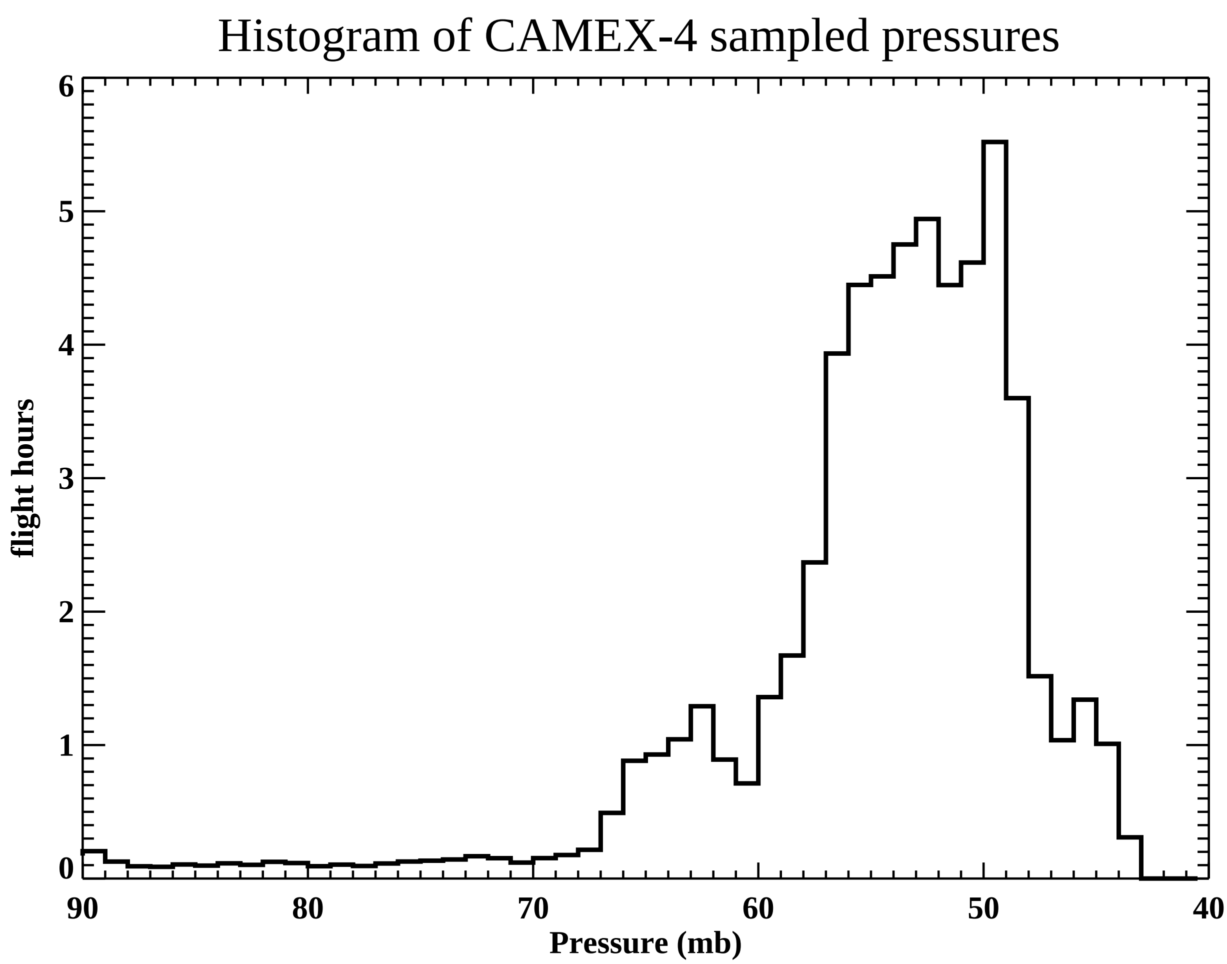
This shows low O_3 in the 70-80 hPa layer above Jason, likely due to upward transport of tropospheric air. Larger values of ozone in the 90-100 hPa layer may be due to downward transport of stratospheric air.



Hurricane Floyd overflight profile (red diamonds) compared with a vertical profile in the same area taken 2 days earlier (blue diamonds). Measurements were taken from the NASA WB-57F during the second deployment of the ACCENT experiment in September 1999. Points plotted (volume mixing ratio versus pressure) are 1 minute averages.

This shows possible dehydration over the storm, and lofting of O_3 poor air ~80 hPa over Hurricane Floyd.

Key point: Based on these previous flights, the signal we were interested in sampling appears to be between the tropopause and 70 hPa. In particular, we wanted level flight legs over the tropical storms between 100 and 70 hPa, or 55-65 kft.

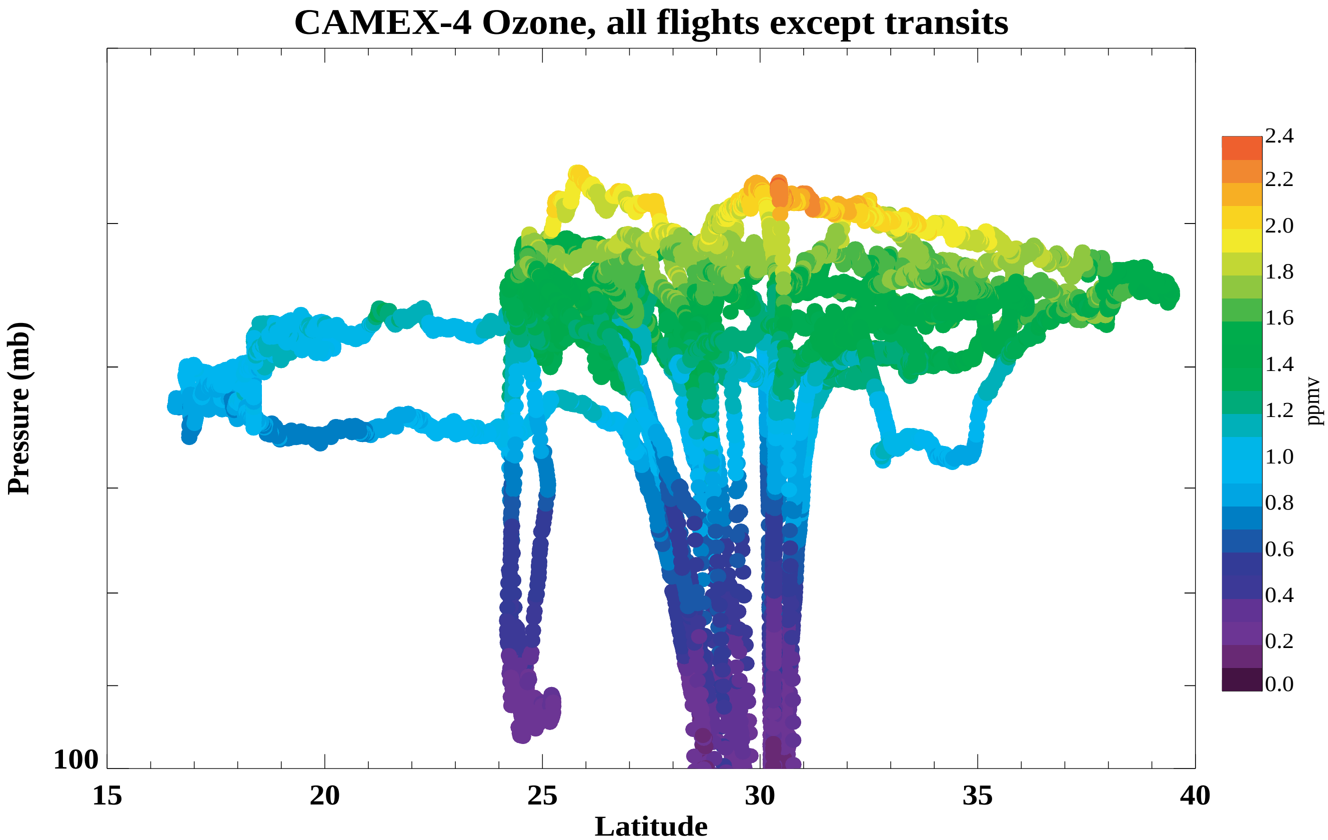


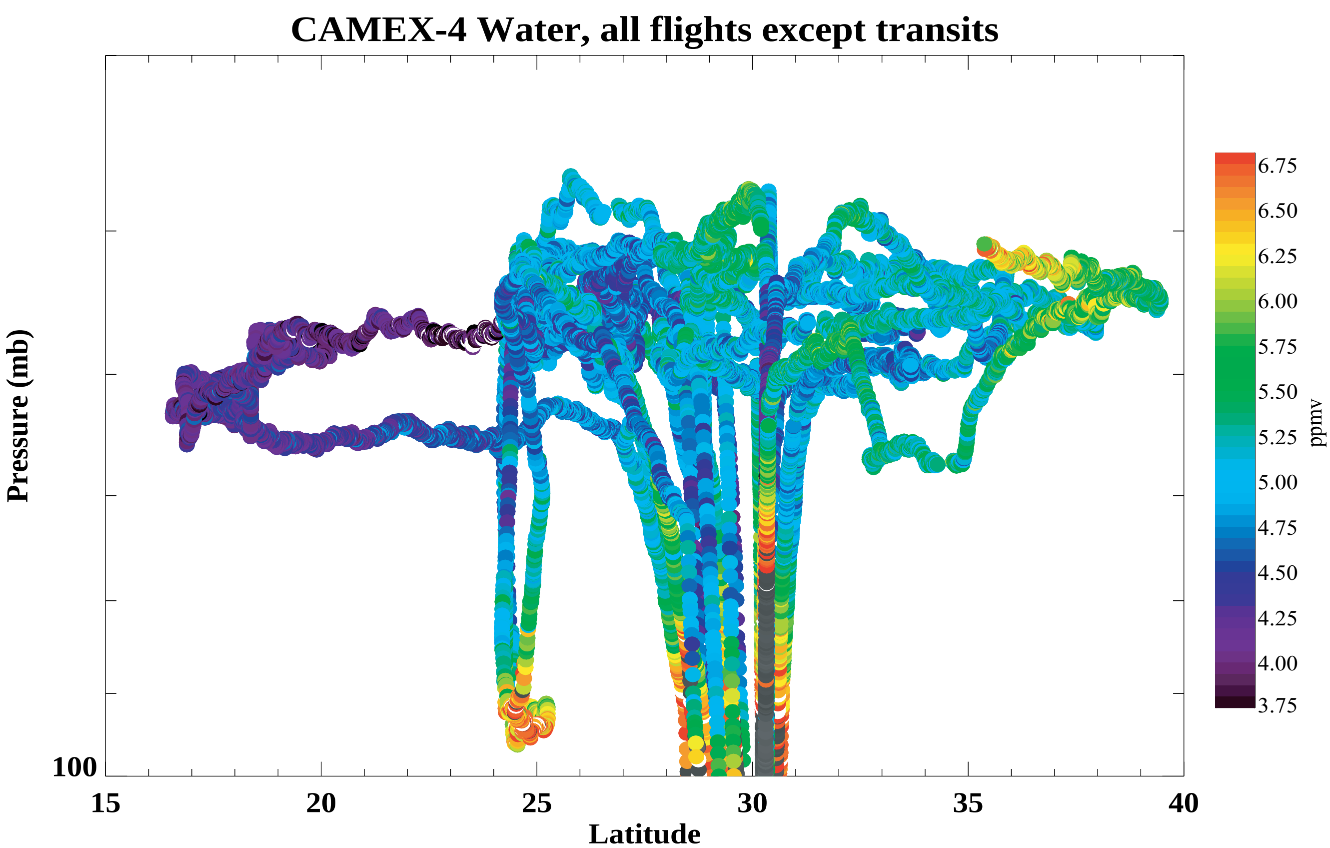
Since we clearly didn't get flights at the levels of interest for our proposed study, we are now assessing what we can do with the in situ data collected.

Initially, we're looking for evidence of gravity wave propagation above the tropical storms. This will involve collaboration with Joan Alexander (at CORA) and M. J. Mahoney (at JPL) using the MTP data once it is in final form.

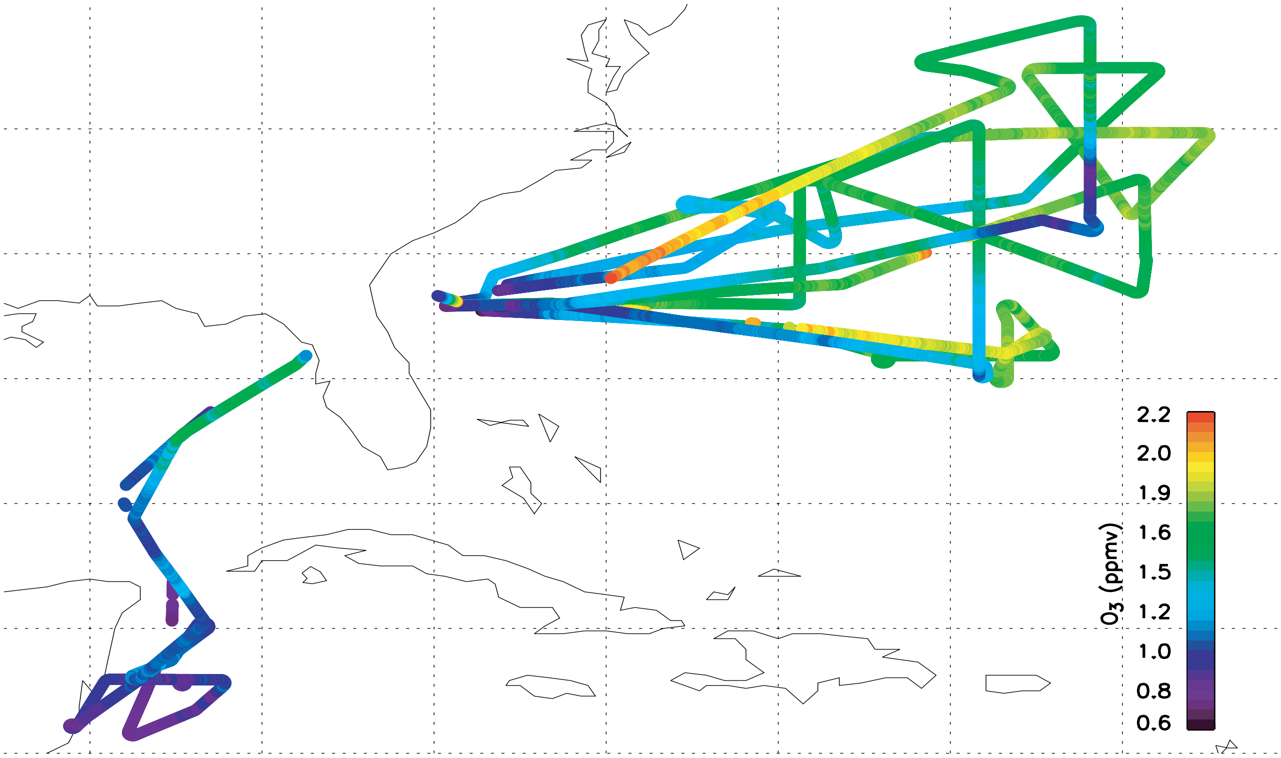
We are also trying to simulate the storms sampled with MM5 runs to look at mixing processes and gravity wave propagation above the tropopause. (Eric Ray, AL)

Summary of data collected

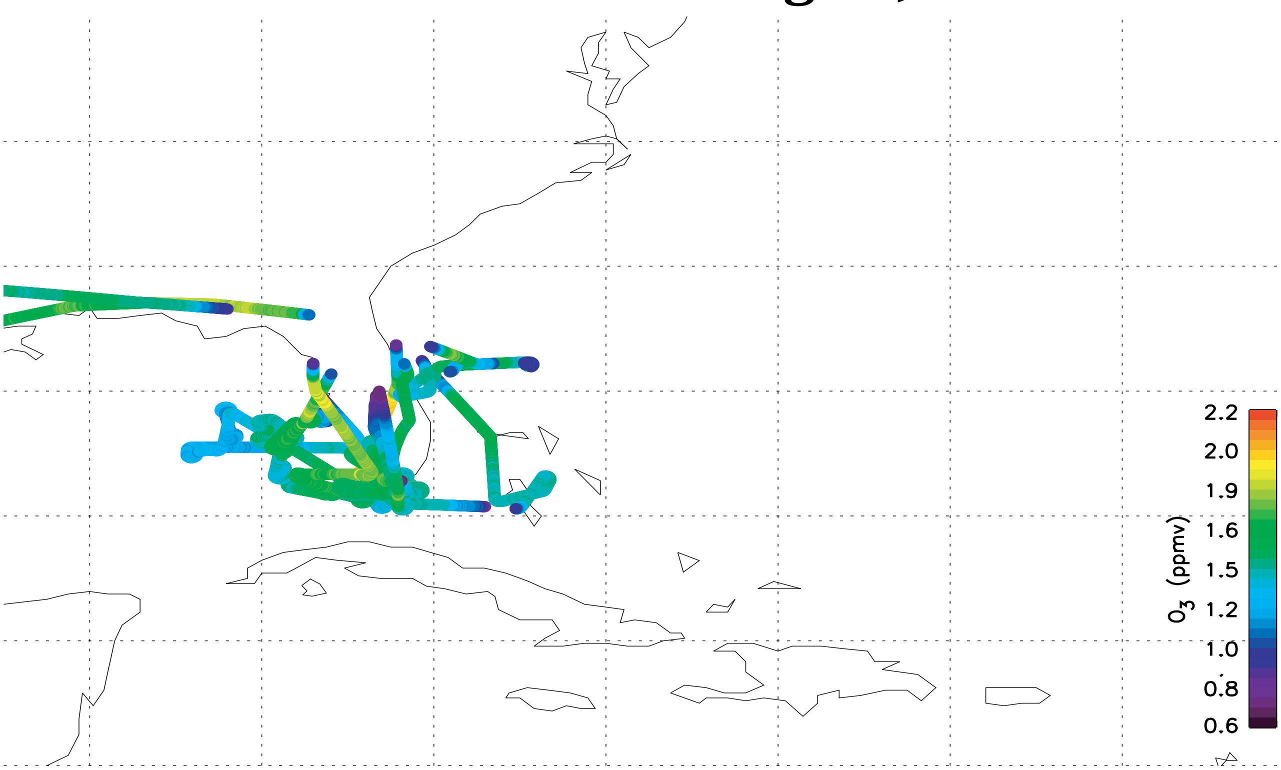




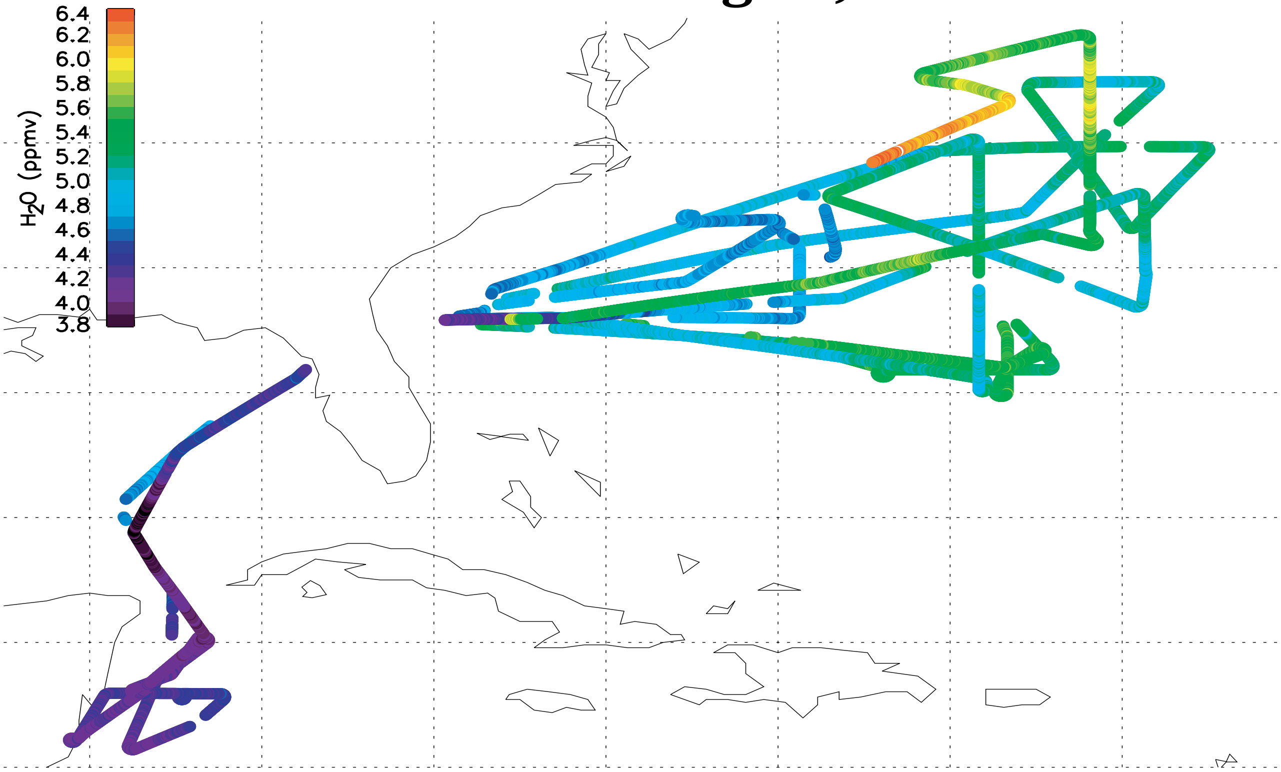
CAMEX-4 storm flights, 45-65 mb



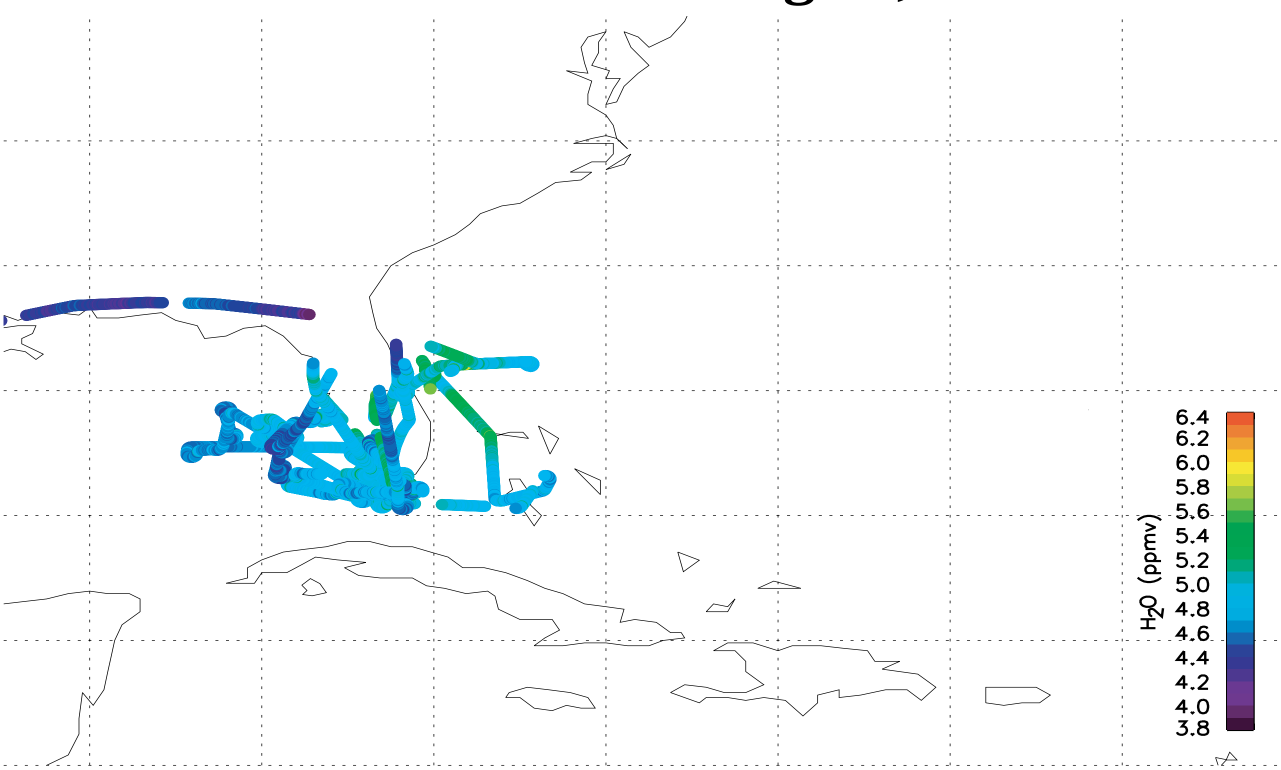
CAMEX-4 non-storm flights, 45-65 mb



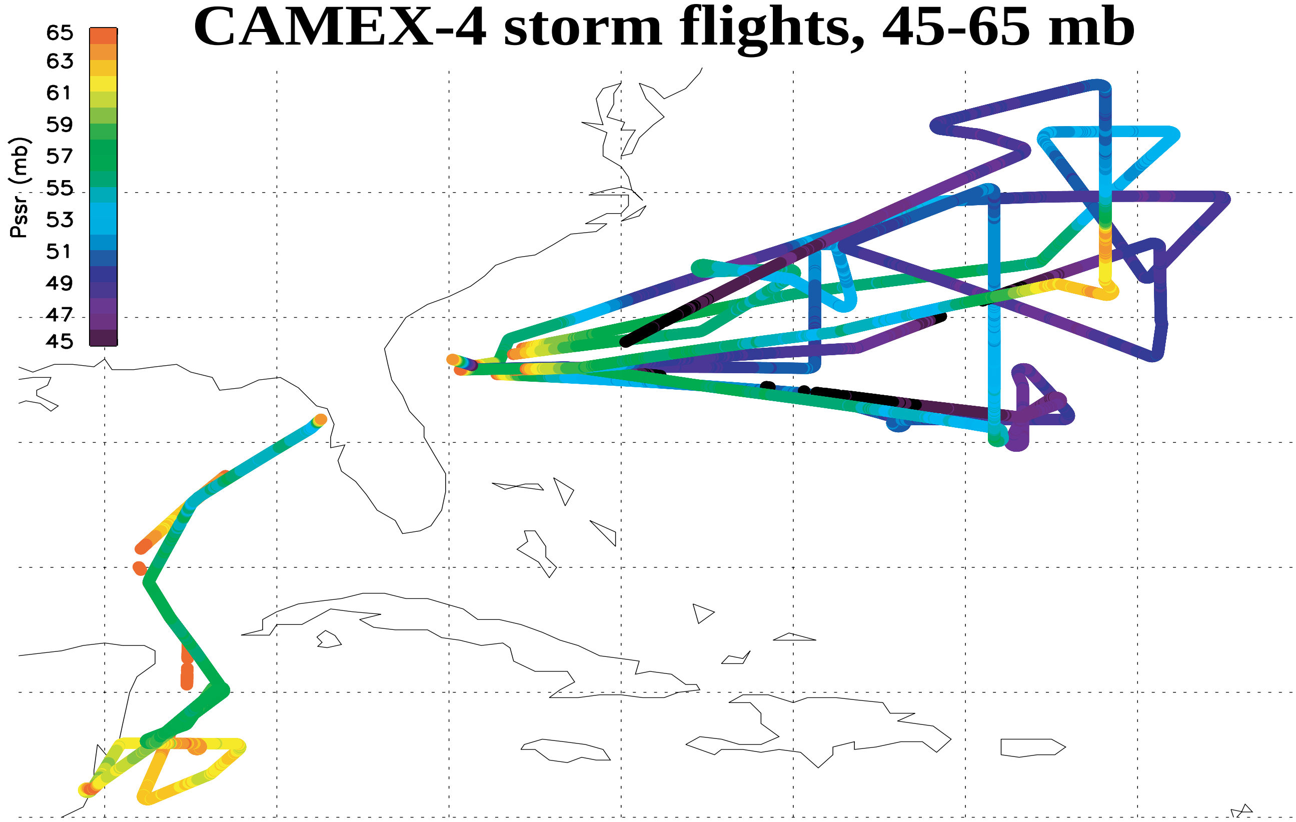
CAMEX-4 storm flights, 45-65 mb



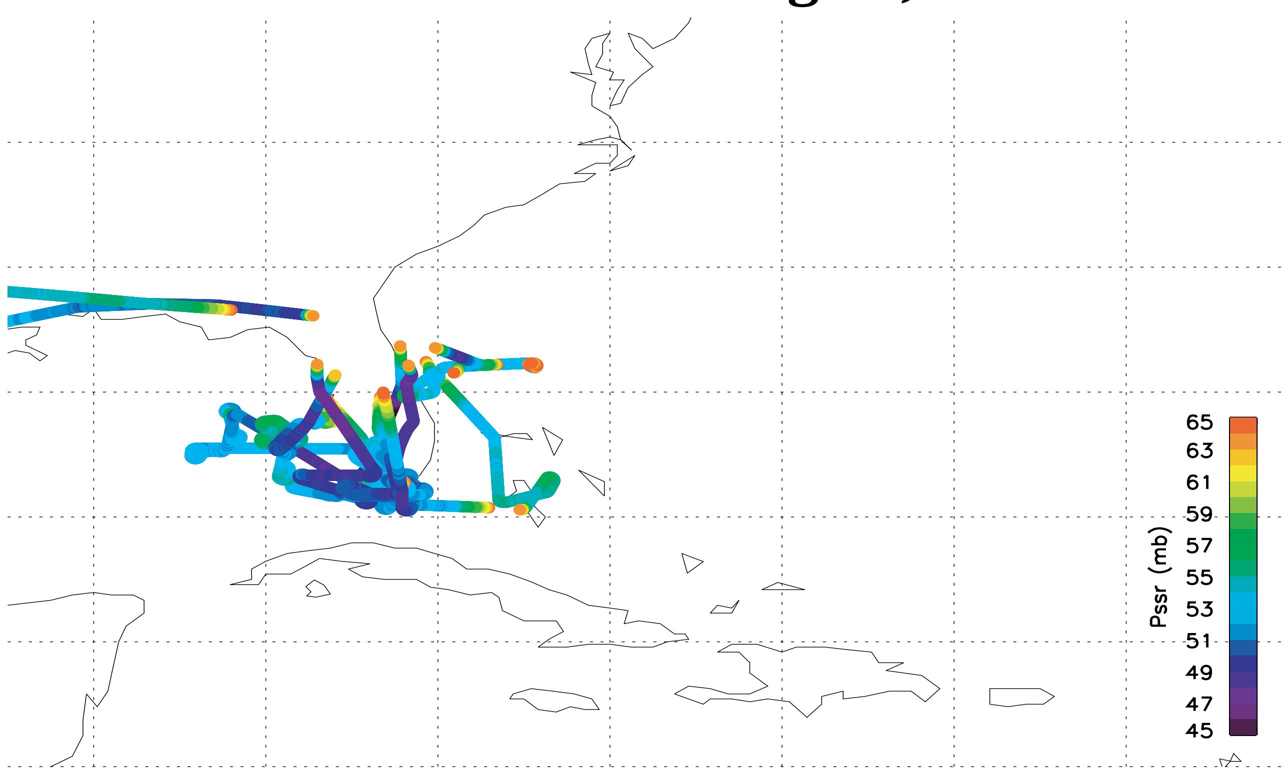
CAMEX-4 non-storm flights, 45-65 mb

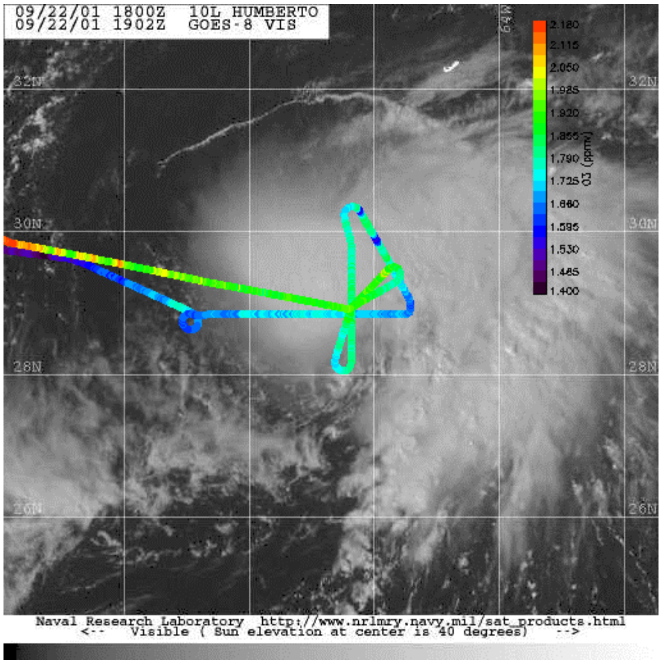


CAMEX-4 storm flights, 45-65 mb



CAMEX-4 non-storm flights, 45-65 mb




09/22/01 1800Z 10L HUMBERTO
09/22/01 1902Z GOES-8 VIS
64W
32N
30N
28N
26N
2.180
2.115
2.050
1.985
1.920
1.855
1.790
1.725
1.660
1.595
1.530
1.465
1.400
O3 (ppmv)
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
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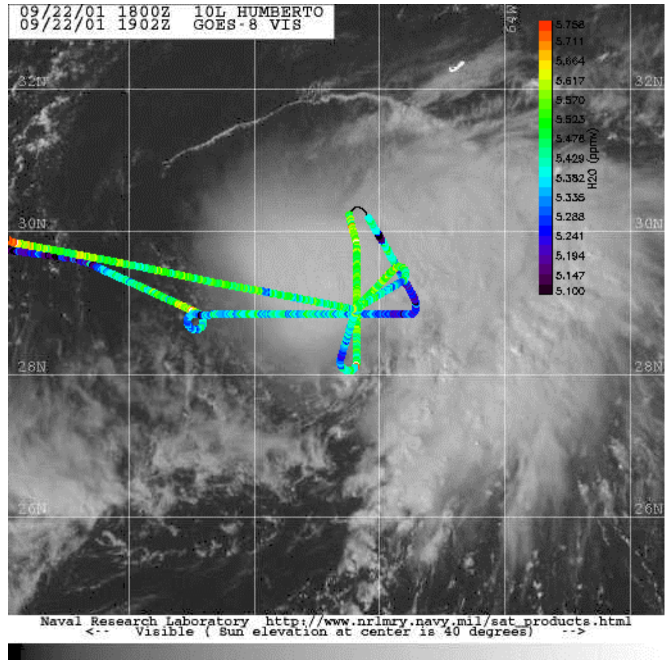
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09/22/01 1902Z GOES-8 VIS
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32N
30N
28N
26N
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5.664
5.617
5.570
5.523
5.476
5.429
5.382
5.336
5.288
5.241
5.194
5.147
5.100
H2O (ppmv)
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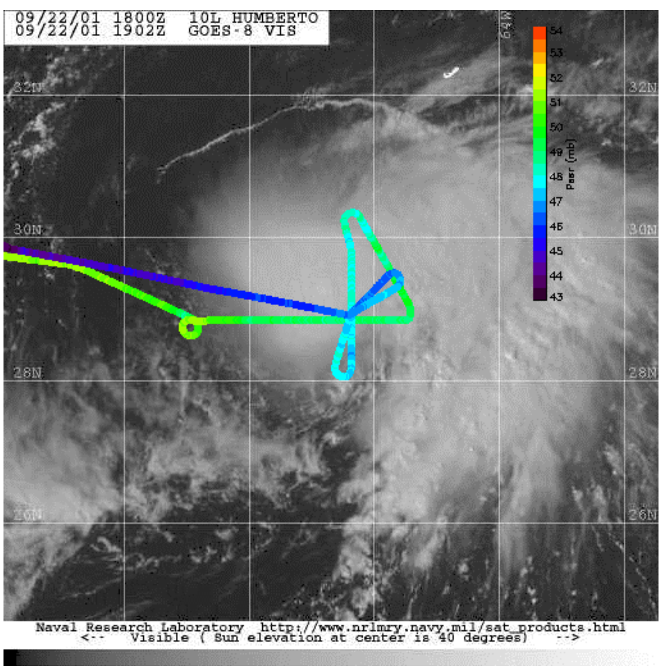
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09/22/01 1902Z GOES-8 VIS
64W
32N
30N
28N
26N
54
53
52
51
50
49
48
47
46
45
44
43
Pser (mb)
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
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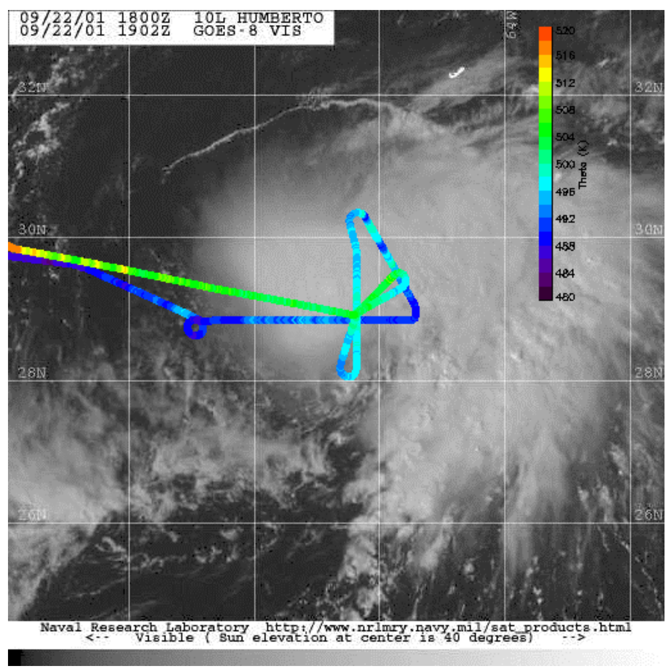
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09/22/01 1902Z GOES-8 VIS
64W
32N
30N
28N
26N
520
516
512
508
504
500
496
492
488
484
480
Theta (K)
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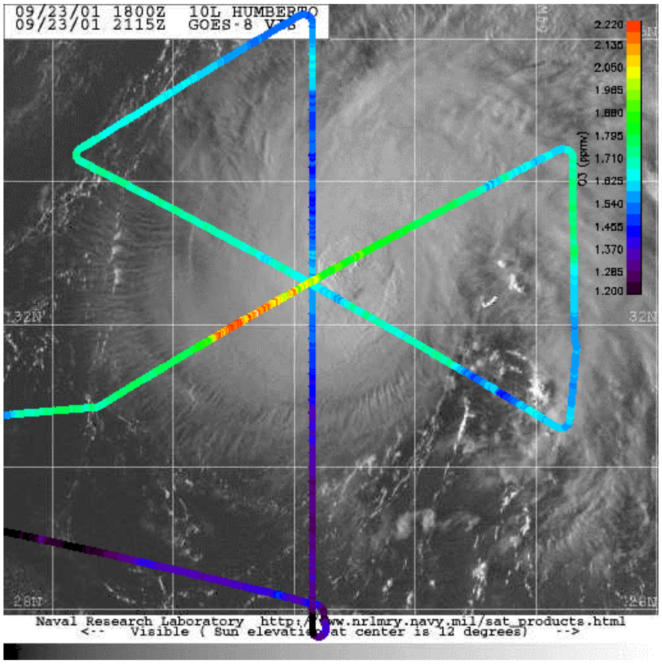
09/23/01 1800Z 10L HUMBERTO
09/23/01 2115Z GOES-8 VIS
O3 (ppmv)
2.220
2.135
2.050
1.965
1.880
1.795
1.710
1.625
1.540
1.455
1.370
1.285
1.200
32N
32N
28N
28N
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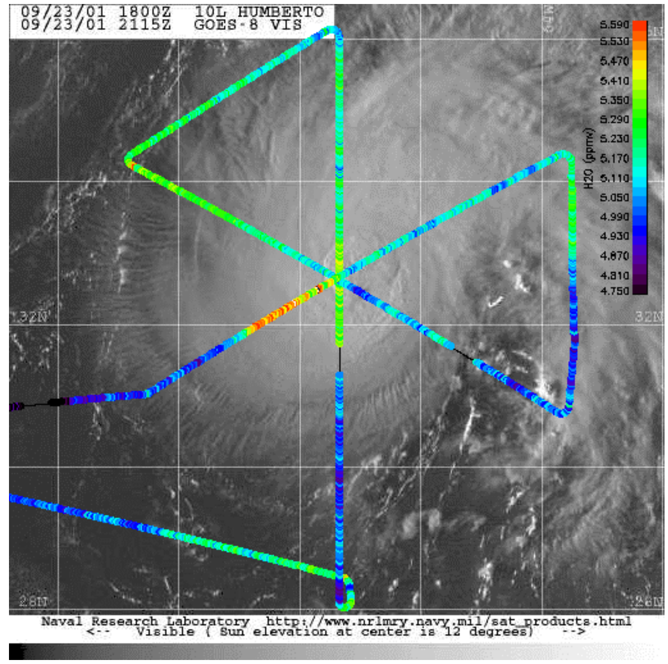
09/23/01 1800Z 10L HUMBERTO
09/23/01 2115Z GOES-8 VIS
H2O (ppmv)
5.590
5.530
5.470
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5.350
5.290
5.230
5.170
5.110
5.050
4.990
4.930
4.870
4.810
4.750
32N
28N
28N
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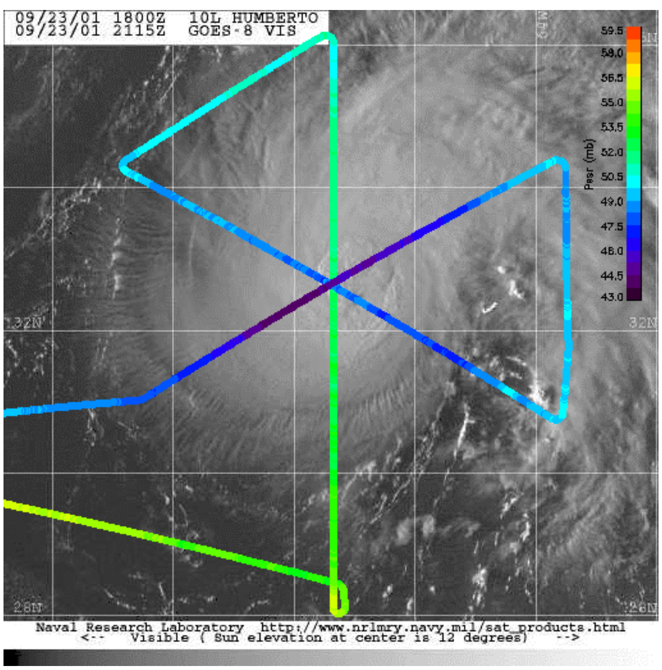
09/23/01 1800Z 10L HUMBERTO
09/23/01 2115Z GOES-8 VIS
Pesr (mb)
59.5
58.0
56.5
55.0
53.5
52.0
50.5
49.0
47.5
46.0
44.5
43.0
32N
32N
28N
28N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
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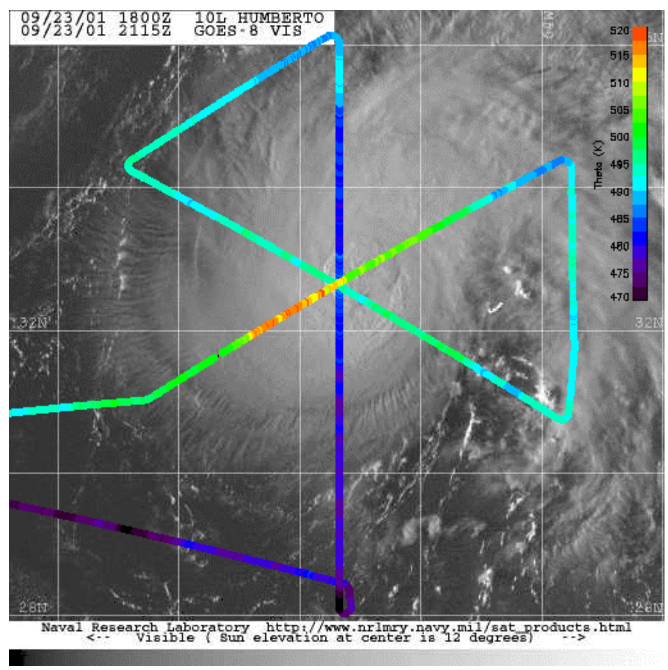
09/23/01 1800Z 10L HUMBERTO
09/23/01 2115Z GOES-8 VIS
Theta (K)
520
515
510
505
500
495
490
485
480
475
470
32N
28N
28N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
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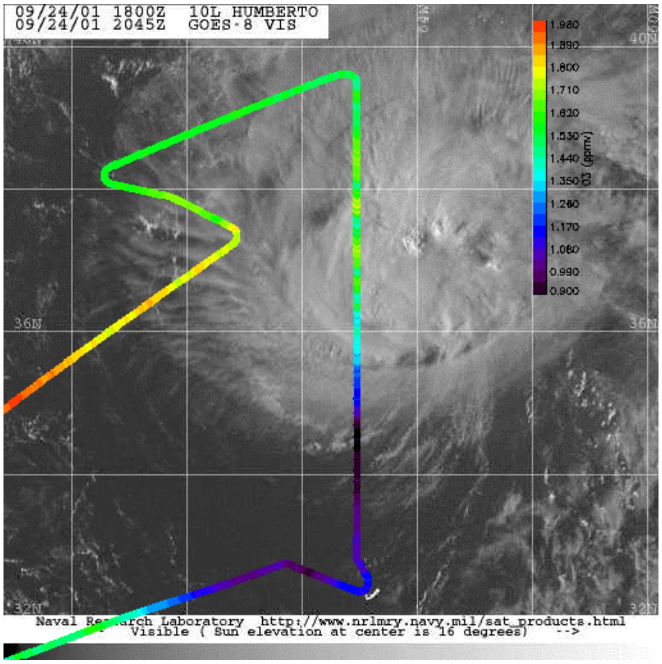
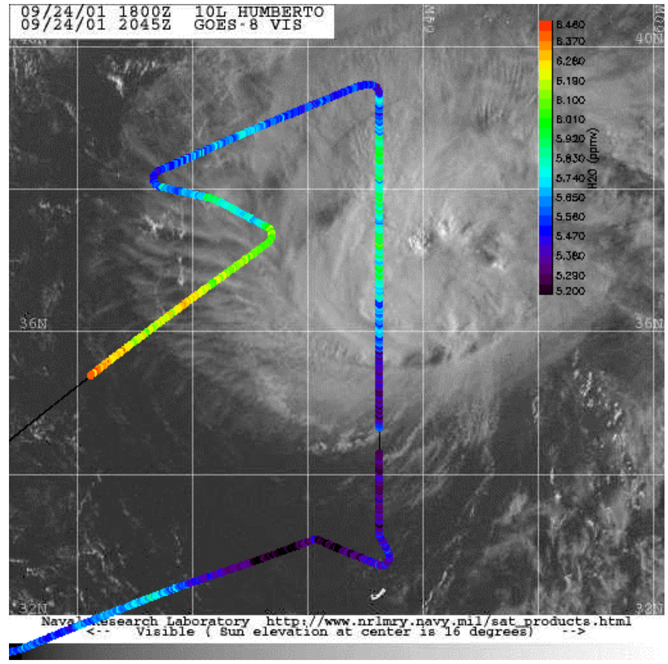
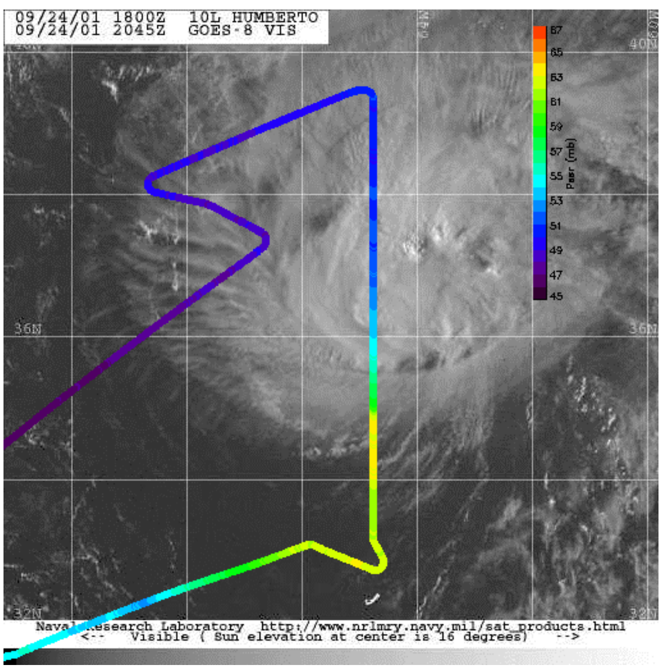

09/24/01 1800Z 10L HUMBERTO
09/24/01 2045Z GOES-8 VIS
40N
36N
32N
1.980
1.890
1.800
1.710
1.620
1.530
1.440
1.350
1.260
1.170
1.080
0.990
0.900
O3 (ppmv)
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
Visible (Sun elevation at center is 16 degrees) -->


09/24/01 1800Z 10L HUMBERTO
09/24/01 2045Z GOES-8 VIS
40N
36N
32N
6.460
6.370
6.280
6.190
6.100
6.010
5.920
5.830
5.740
5.650
5.560
5.470
5.380
5.290
5.200
H2O (ppmv)
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Visible (Sun elevation at center is 16 degrees) -->


09/24/01 1800Z 10L HUMBERTO
09/24/01 2045Z GOES-8 VIS
40N
36N
32N
67
65
63
61
59
57
55
53
51
49
47
45
Pair (mb)
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
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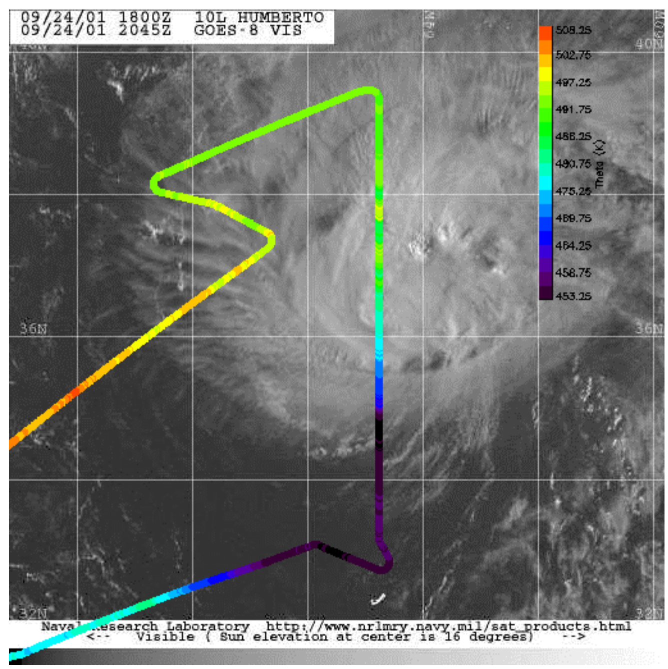
09/24/01 1800Z 10L HUMBERTO
09/24/01 2045Z GOES-8 VIS
40N
36N
32N
508.25
502.75
497.25
491.75
486.25
480.75
475.25
469.75
464.25
458.75
453.25
Theta (K)
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Visible (Sun elevation at center is 16 degrees) -->

What next?

1) Try to characterize storm and non-storm vertical profiles of ozone and water vapor.

2) Look for evidence of wave propagation up to ER-2 altitudes in both MTP and ozone data.

3) Attempt to model STE and lowermost stratosphere mixing processes above the storms sampled during CAMEX-4.

4) Acquire the high resolution TOMS data and look for total ozone signatures (a la *Rodgers et al.* [1990] and *Stout and Rodgers* [1992]).

5) Attempt to get an ozone instrument on the NOAA G4 for next hurricane season. (One is currently flying on the G4 this winter.)