INFLAME

In-situ Net Flux within the Atmosphere of the Earth Experiment

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CERES Science Team Meeting

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INFLAME Objective

- Measure the spectral dependence of radiative heating rates in the troposphere.
  - Flight demonstration goal is to measure net flux with sufficient stability to estimate radiative heating rates from the net flux divergence in 1 km layers of the troposphere with an accuracy of 10% at 5 km.
- Milestones:
  - Proposed: 11/2004
  - Funded: 11/2005
  - Calibration: 7/2009
  - Test flight: 1/5/2010

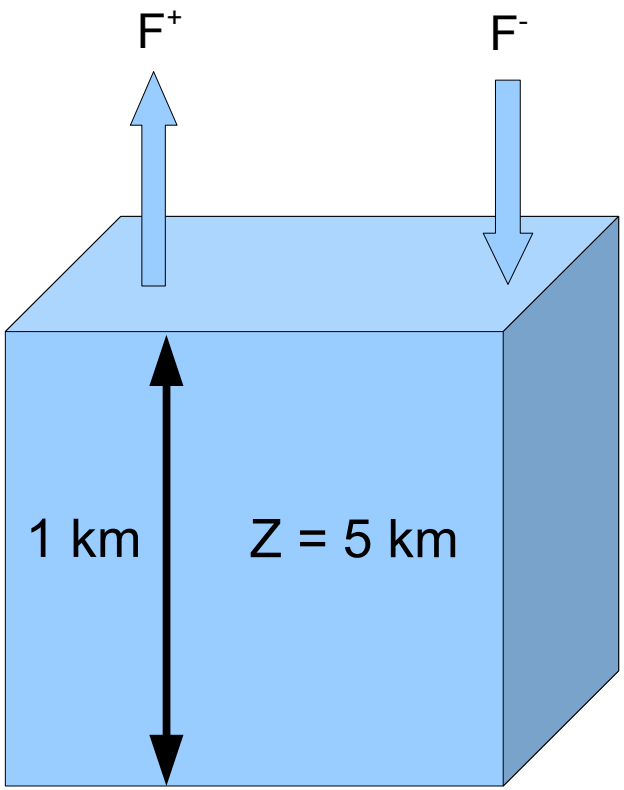
Measurement Overview

- **Consider a unit cube in the terrestrial atmosphere:**
  - Spectral flux is the energy per unit frequency interval flowing through one face (F^+ or F^-);
  - Net Flux is the difference in energy flowing through one face in opposite directions:

$$Fz = F^+ - F^-$$

  - Flux divergence is given by dFz/dz;
    - Assume dFx/dx and dFy/dy are small.
- **Radiative heating rate is estimated from the measured flux divergence:**

$$\frac{dT}{dt} = \frac{-1}{\rho c_p} \frac{dF_z}{dz}$$



Measurement Challenge

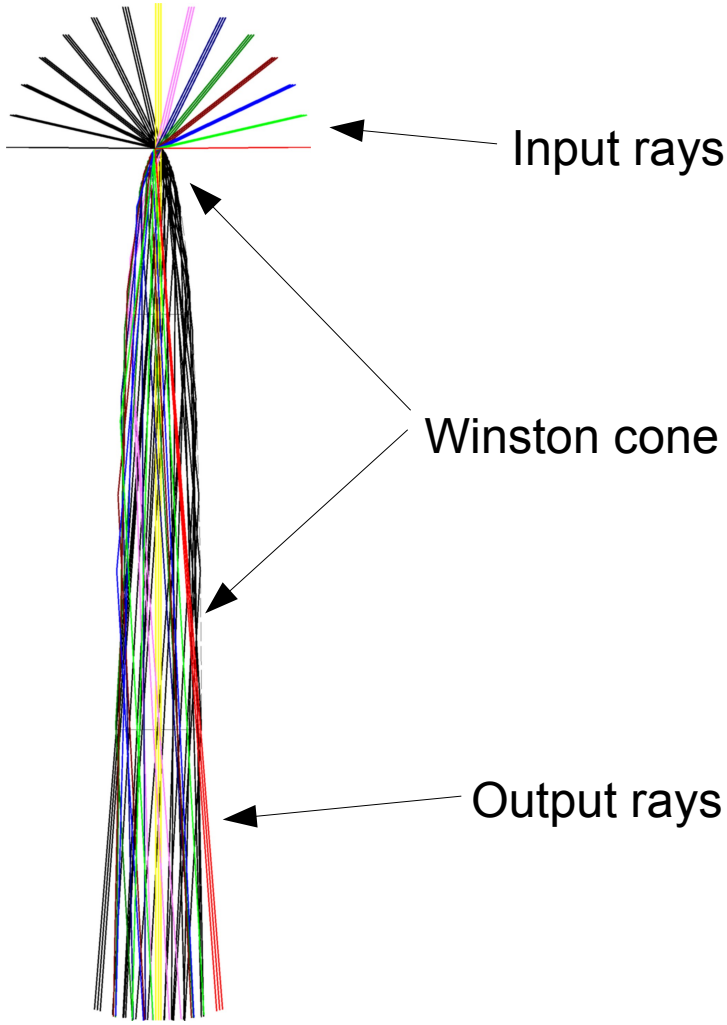
- What if we use uplooking and downlooking instruments to measure fluxes as functions of altitude, subtract to get net flux, and take the derivative to get flux divergence?
  - Need to measure small changes in the difference of large numbers:

	F+, W/m2	F-, W/m2	Fz, W/m2	dFz/dz, W/m2 km
Thermal IR	344	263	81	16.1
Solar	80	768	-688	-13.6

- Small systematic errors in measured F+ and F- can easily be as large as dFz/dz.

INFLAME Approach: F+ and F-

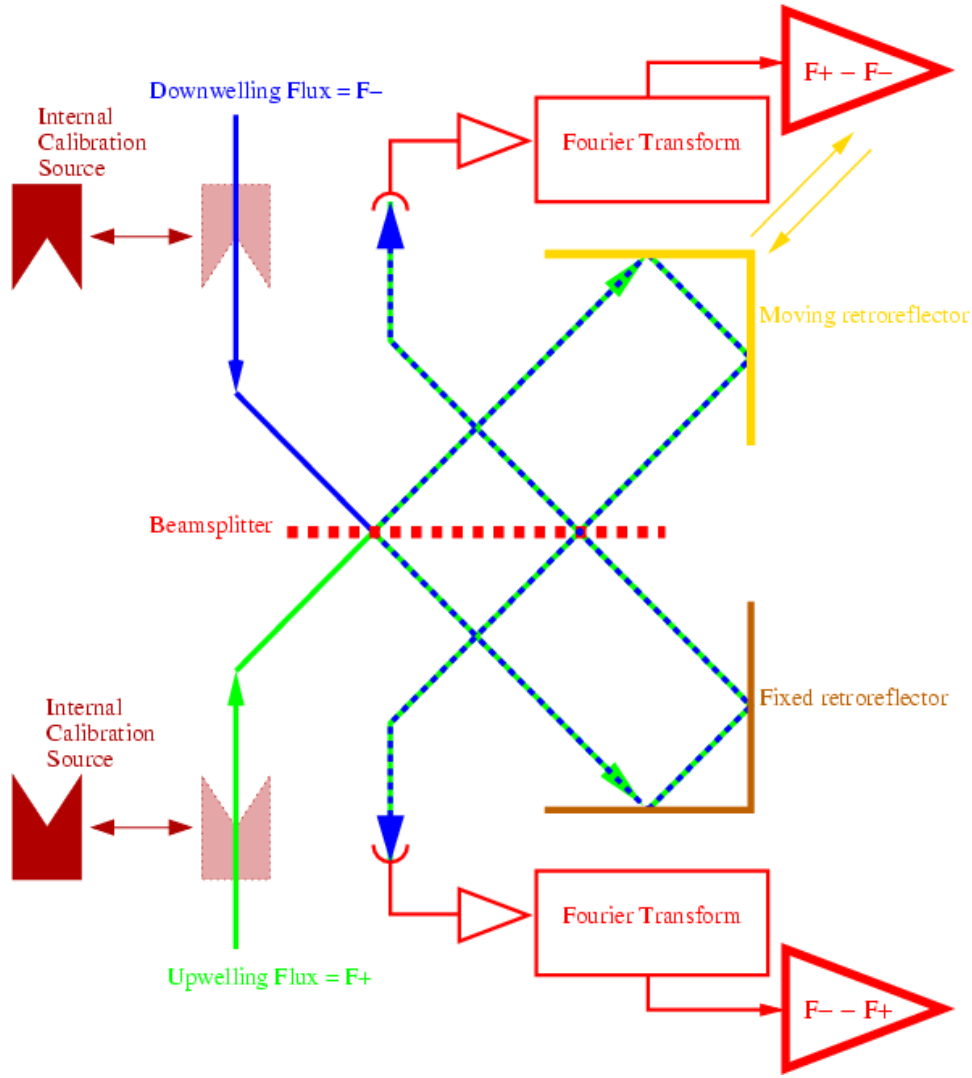
- Most instruments measure radiance, not flux.
- Measuring flux requires collecting light over a full hemisphere.
- We use a non-imaging Winston cone to collect radiation and collimate it into an f/6.8 beam.
  - Input aperture is 1mm diameter.
  - Output aperture is 13.6 mm diameter.



INFLAME Approach: Fz

- Direct uplooking and downlooking apertures to the two inputs of a 4-port Fourier transform spectrometer (FTS);
- Scan FTS to produce complimentary interferograms at two outputs;
- Fourier transform interferograms to estimate the spectrum of the net flux

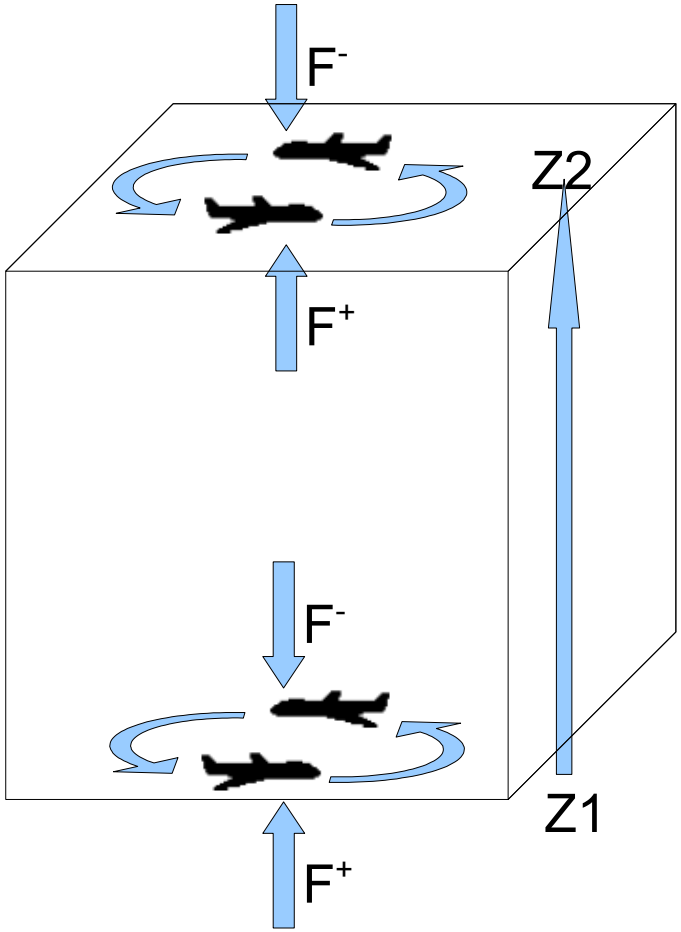
$$Fz = F+ - F-$$



INFLAME Approach: dFz/dz

- Measure the net vertical flux F(Z1) at the base of the cube (altitude Z1).
- Measure the net flux F(Z2) at the top of the cube (altitude Z2).
- The vertical flux divergence is estimated by:

  [F(Z2)-F(Z1)]/(Z2-Z1)



INFLAME Measurement Platform

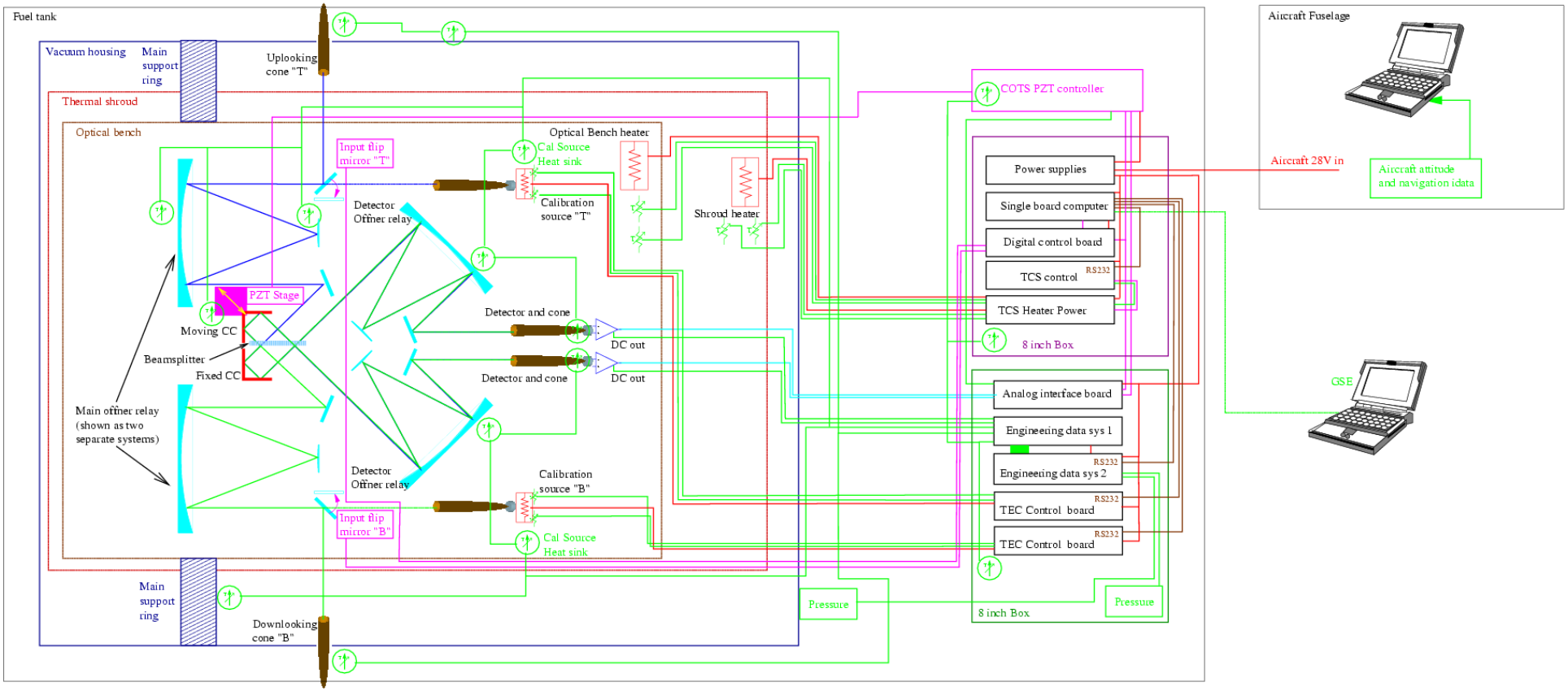
INFLAME mounted in wingtip fuel tanks

Instrument Overview

- We use two instruments to cover the required spectral range:
  - LW instrument covers thermal IR, 100 μm to 3 μm.
  - SW instrument covers solar, 3 μm to 0.3 μm.
- Main differences between LW and SW are the calibration sources, optical coatings, and detectors.

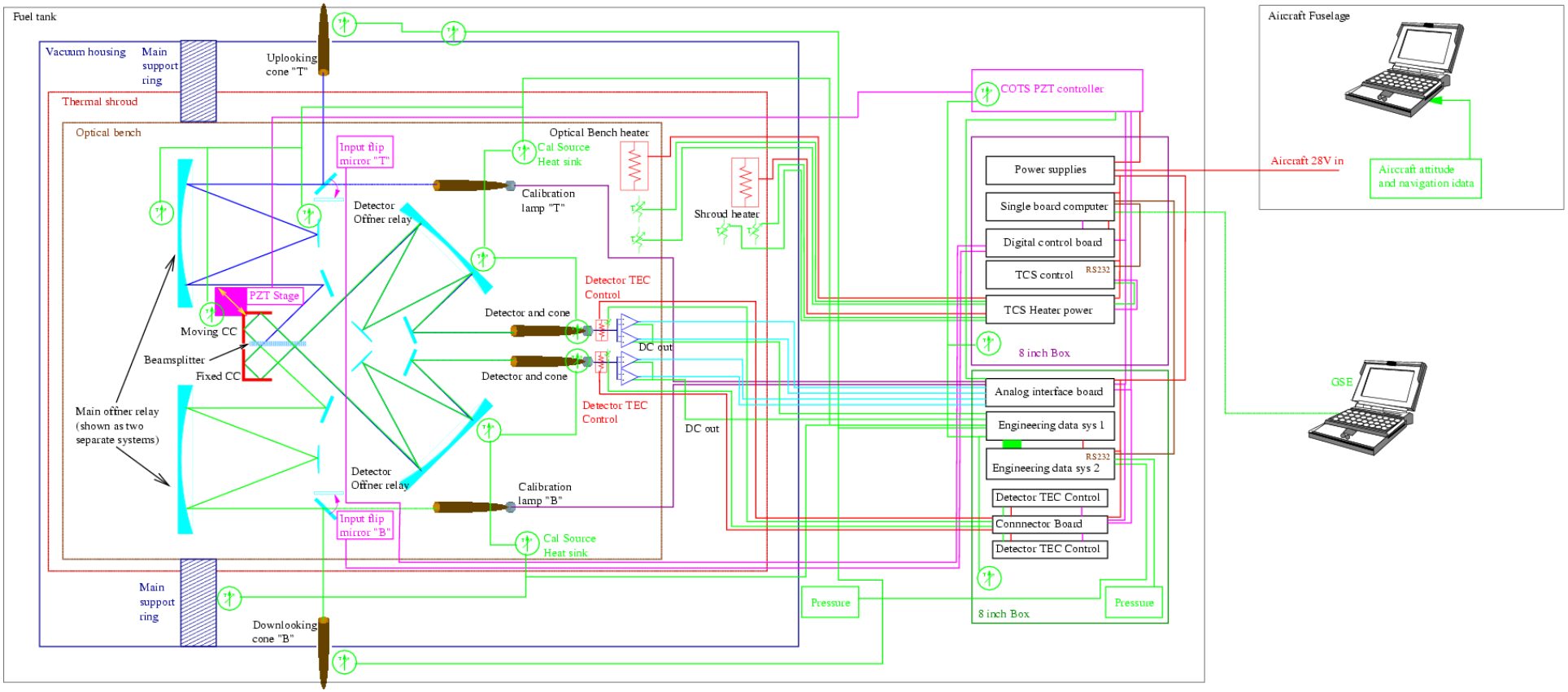
INFLAME Block Diagram: LW

LW Instrument Block Diagram

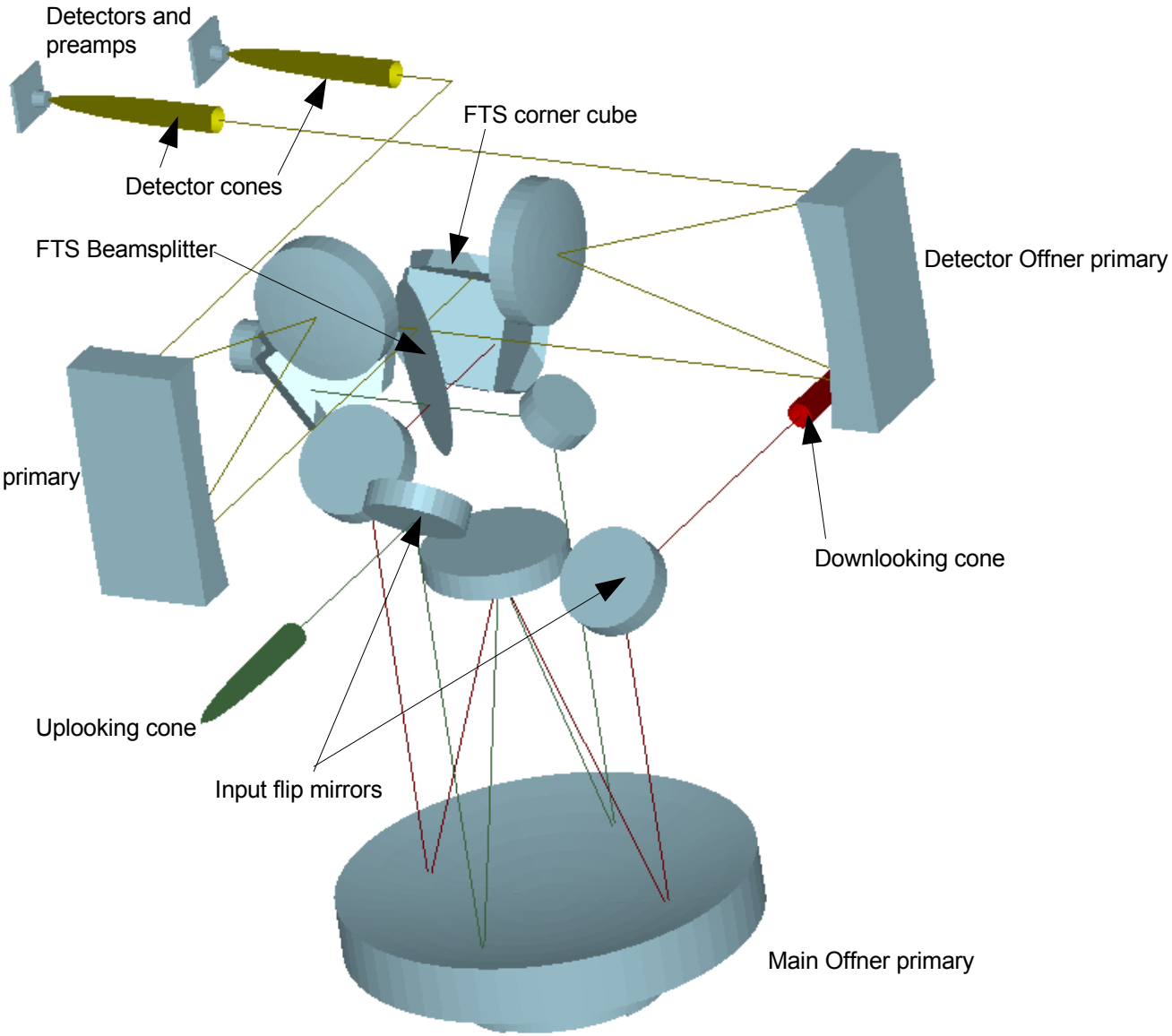


INFLAME Block Diagram: SW

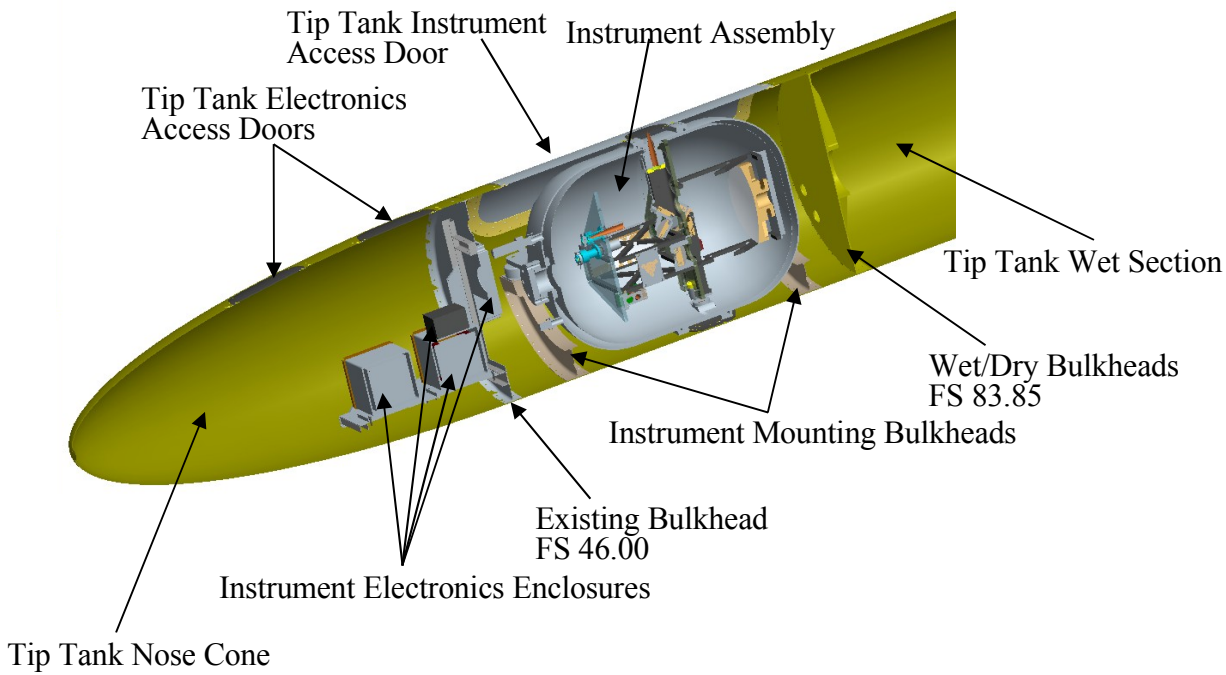
SW Instrument Block Diagram



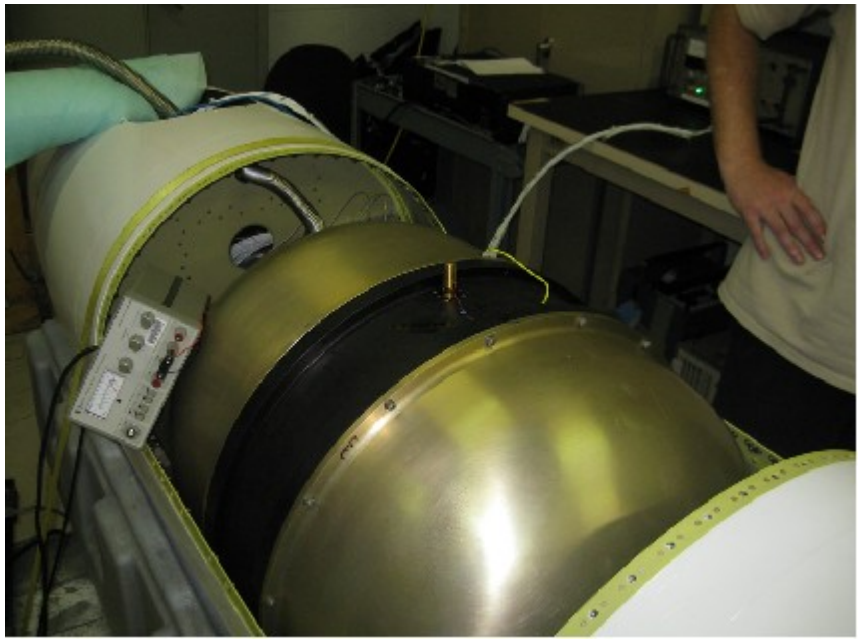
Optical Layout

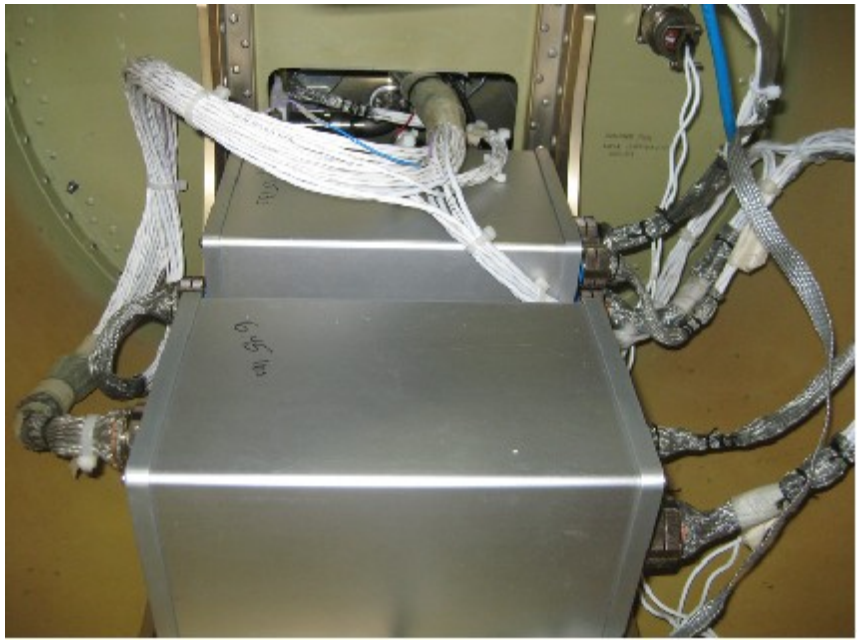


Fuel Tank Integration



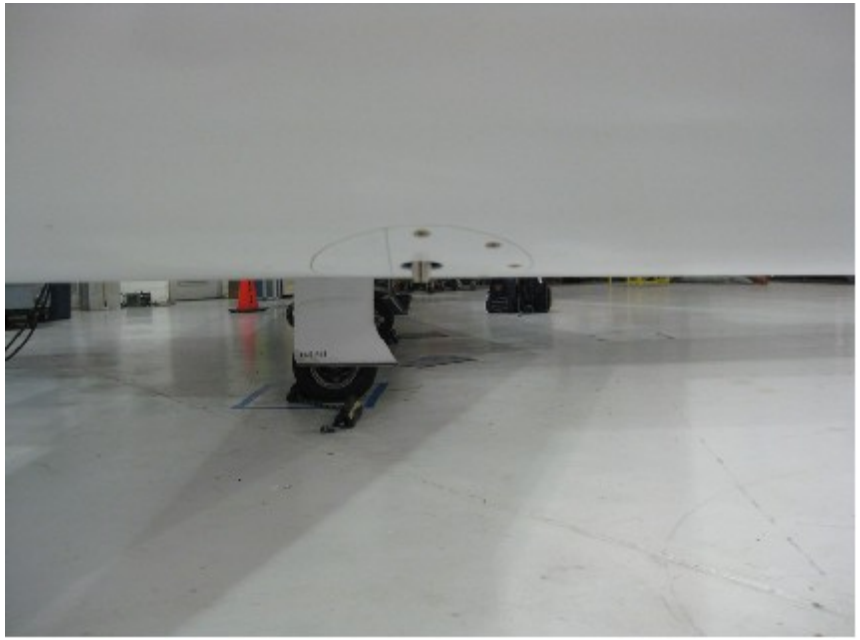
LW Compatibility: 7/29/2009





LW Flight Install: 1/4/2010

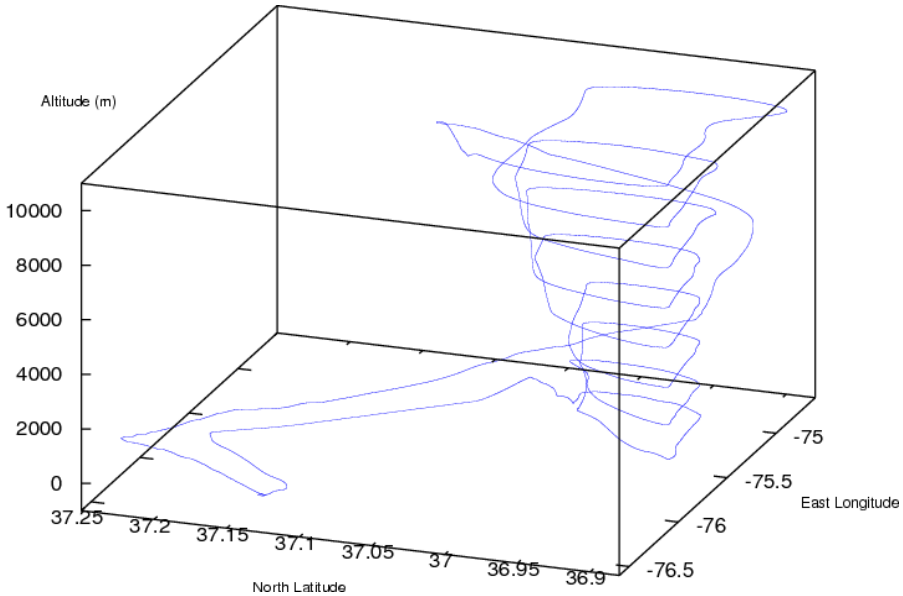
SW Flight Install: 1/4/2010

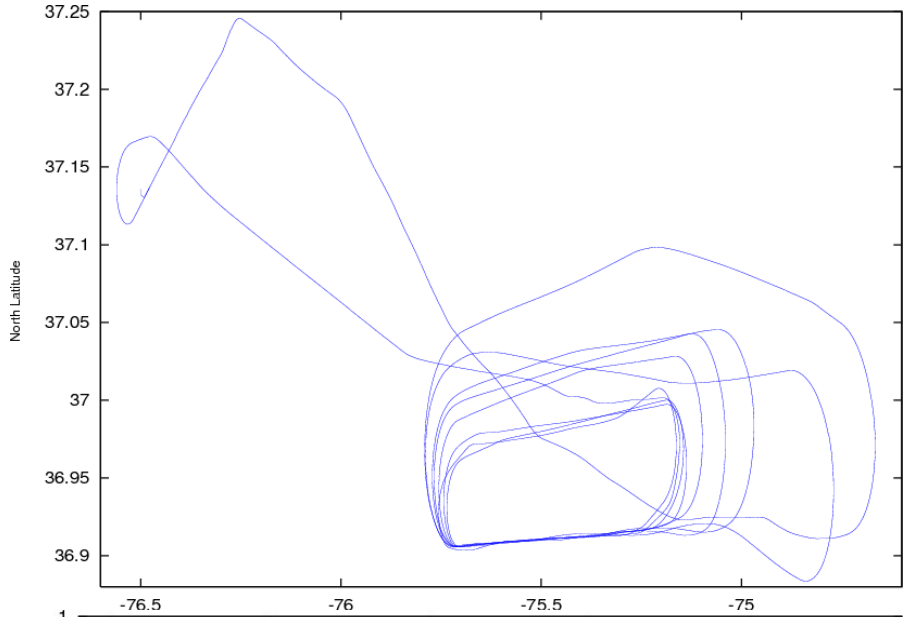


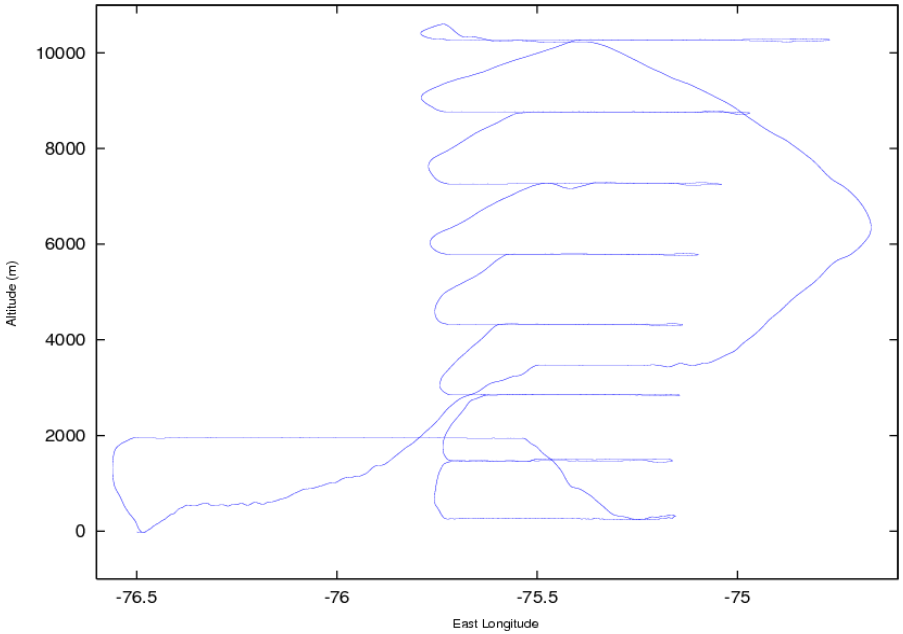
Flight Prep and Takeoff: 1/5/2010

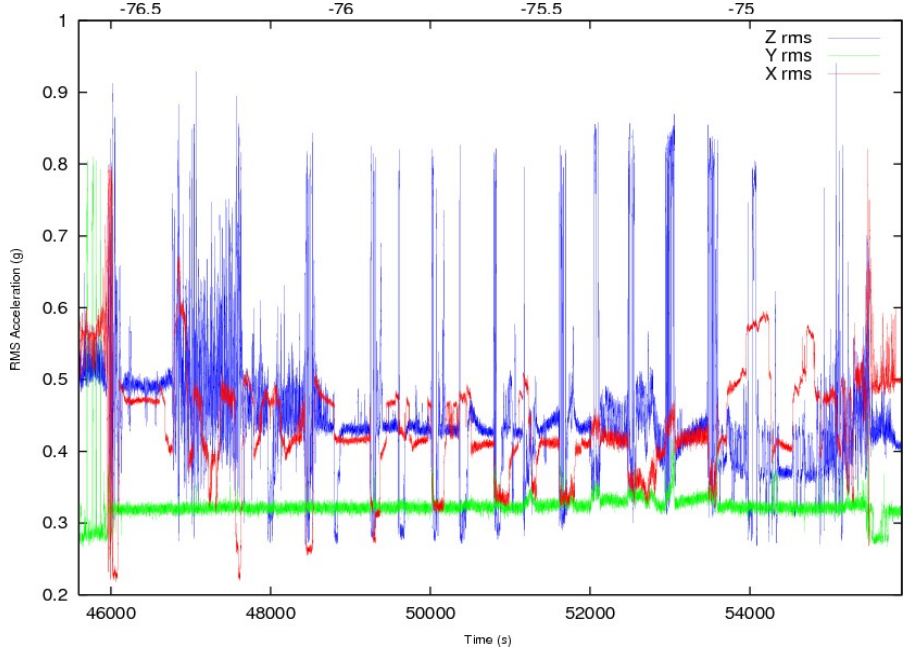
Langley Research Center

Flight Track and Accelerometer

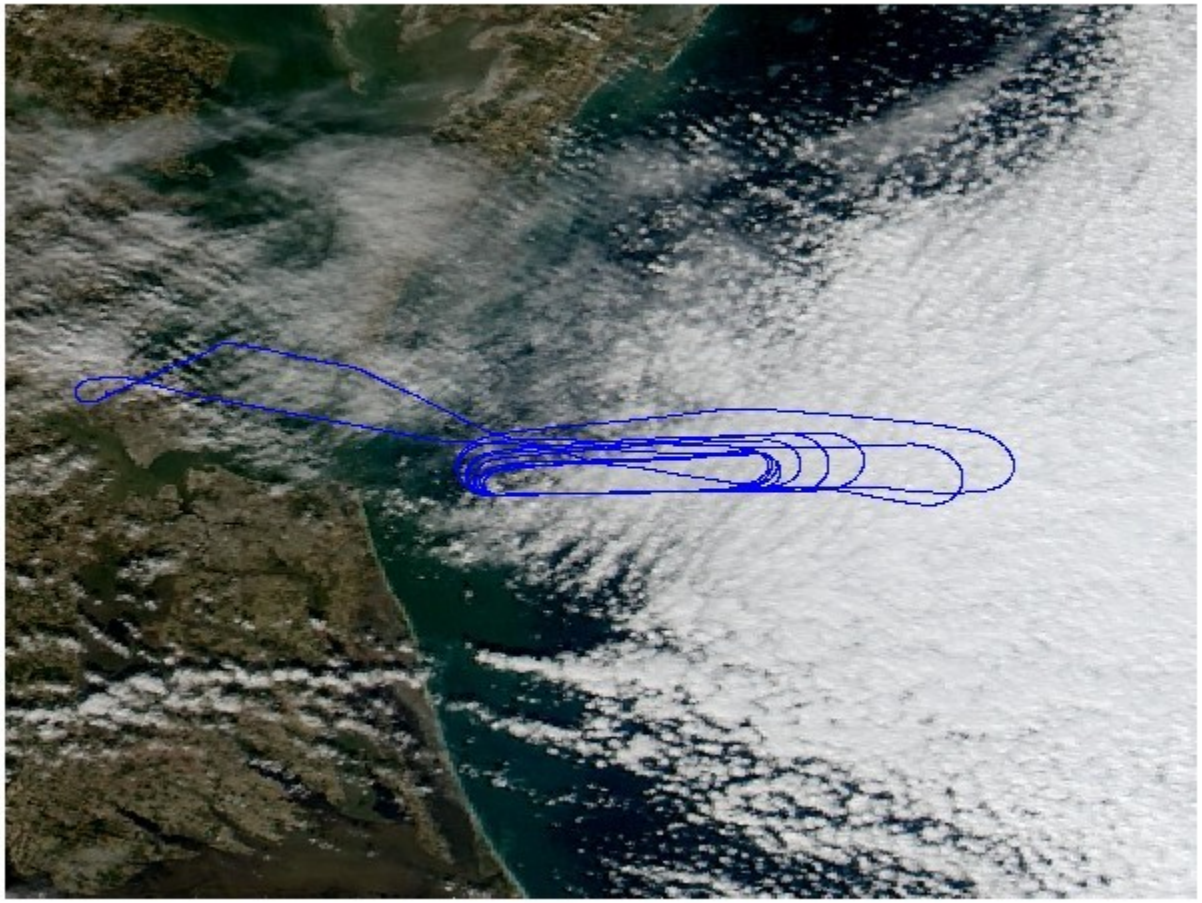




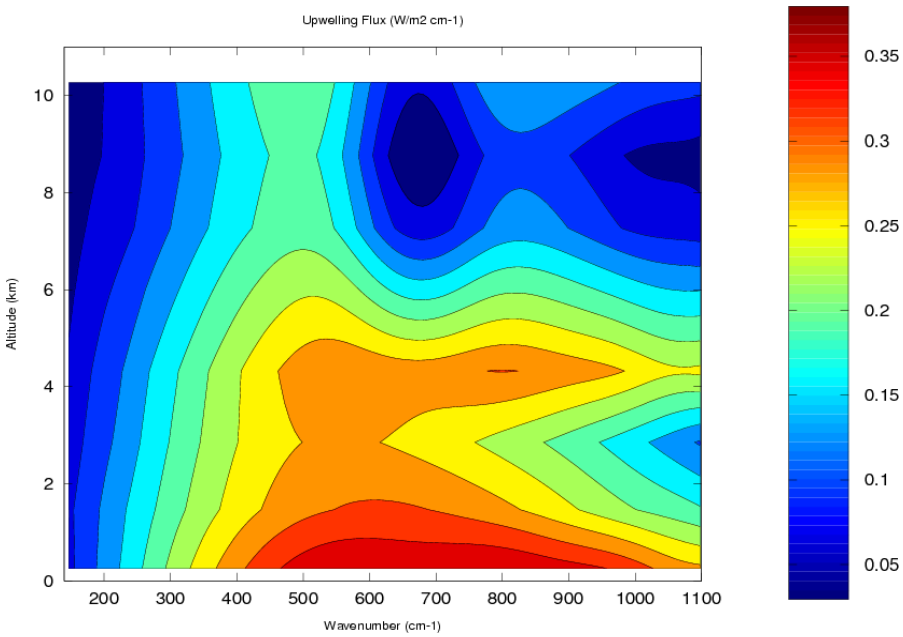


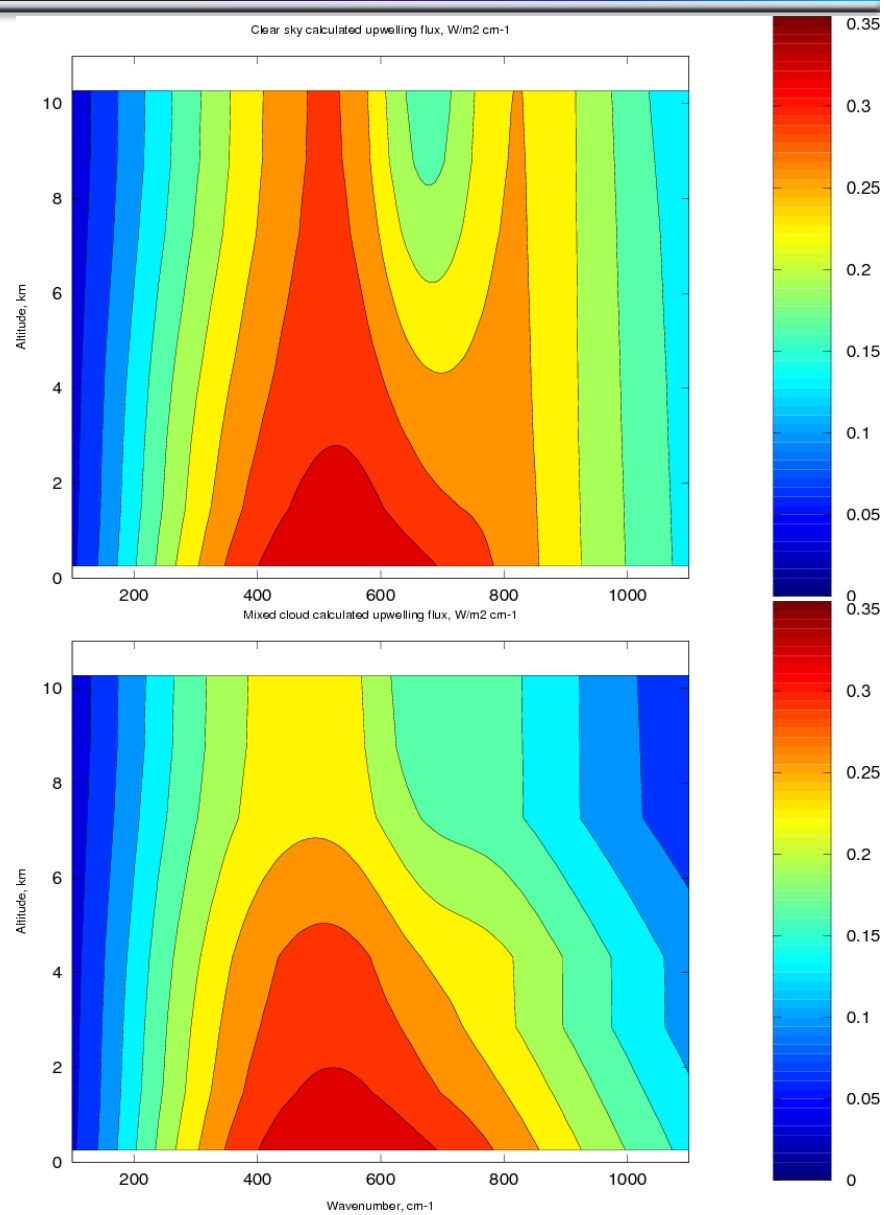


MODIS Visible Imagery



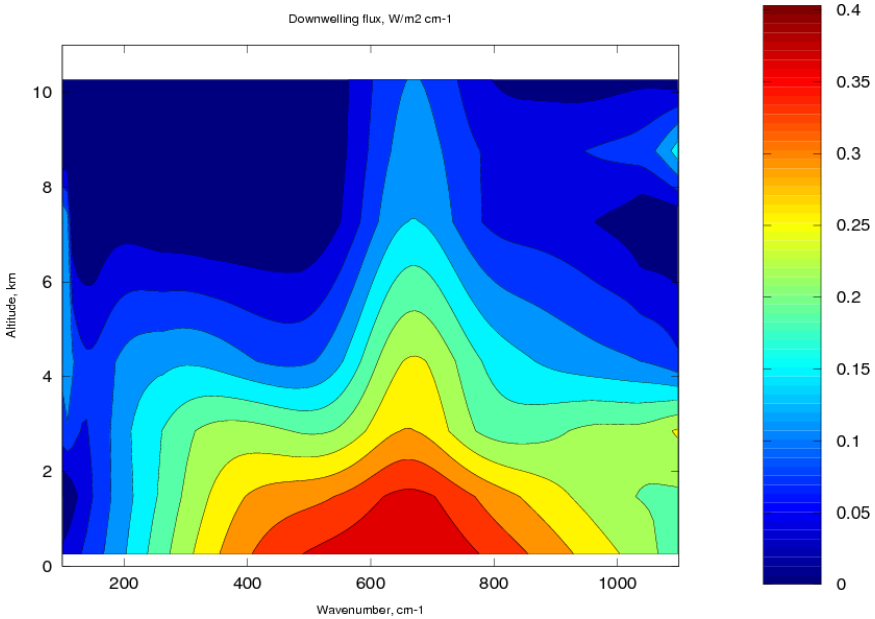
LW Upwelling Flux

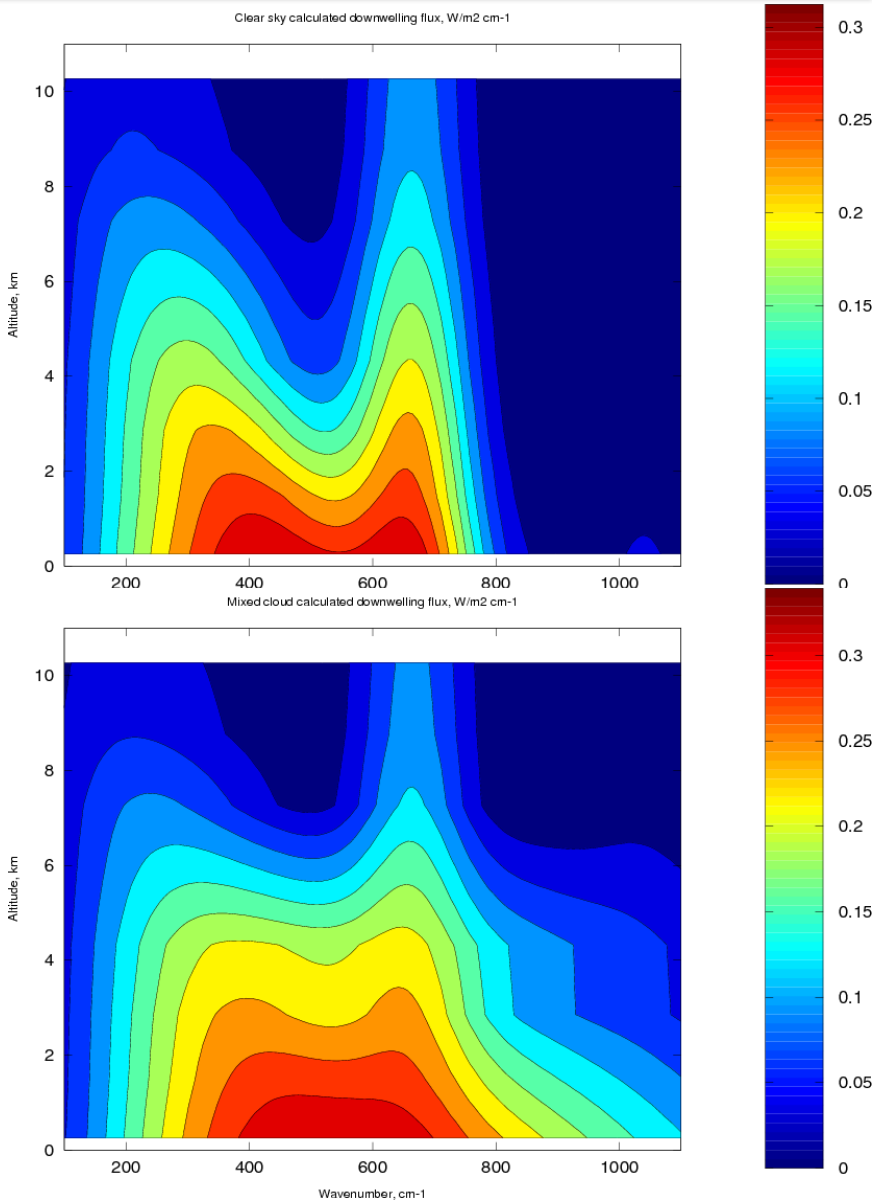




Measured (left) and calculated clear (right top) and cloudy (right bottom) upwelling flux for 1/5/2010 flight. Clouds were included at 1-1.5 km and 5.5-6 km.

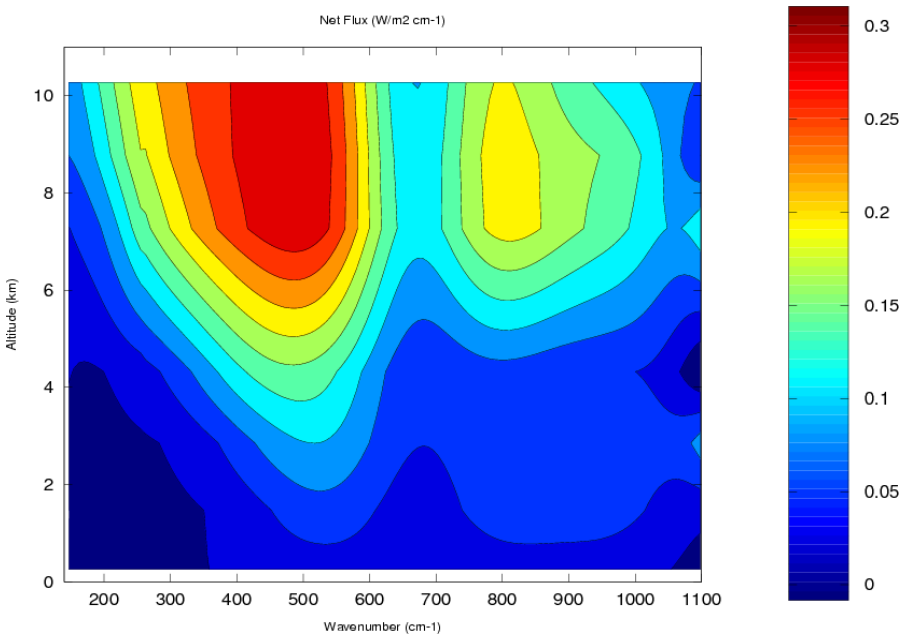
LW Downwelling Flux

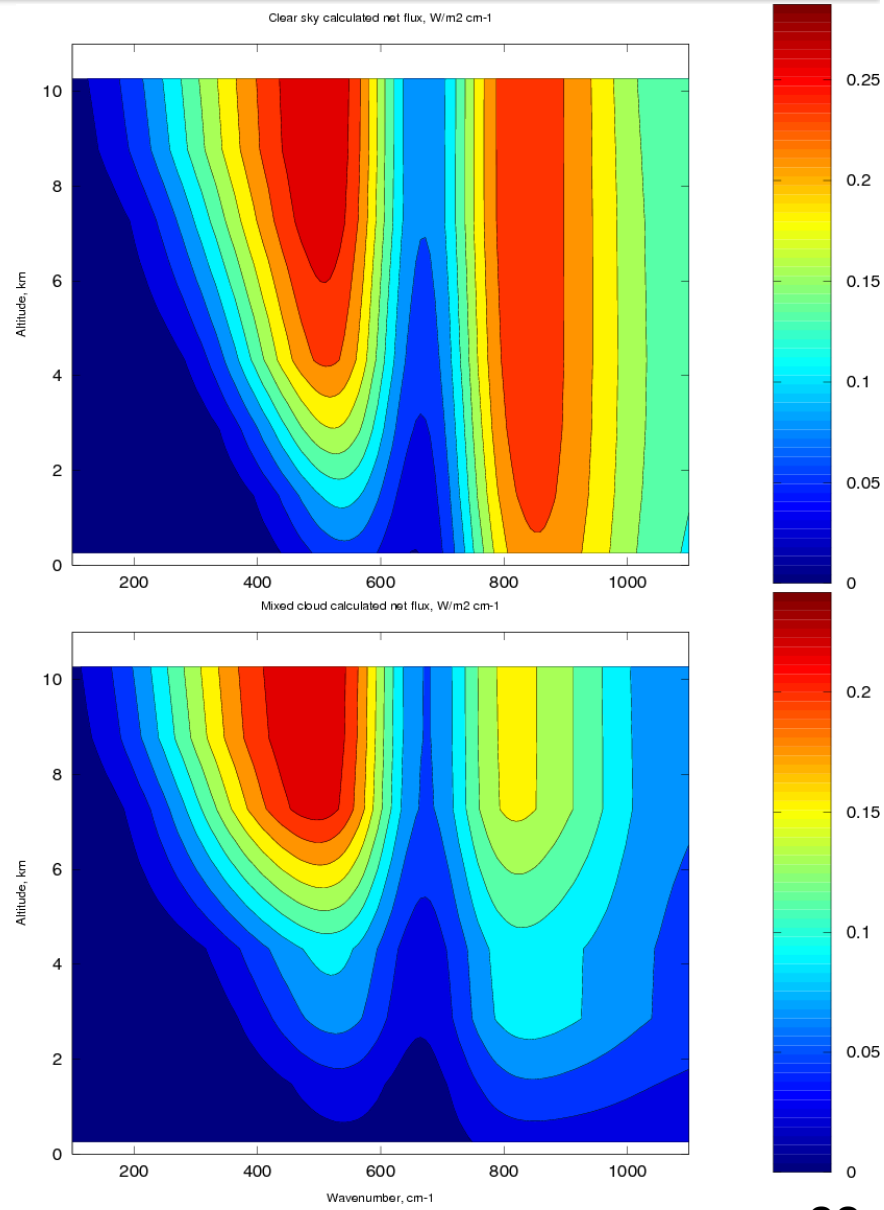




Measured (left) and calculated clear (right top) and cloudy (right bottom) downwelling flux for 1/5/2010 flight. Clouds were included at 1-1.5 km and 5.5-6 km.

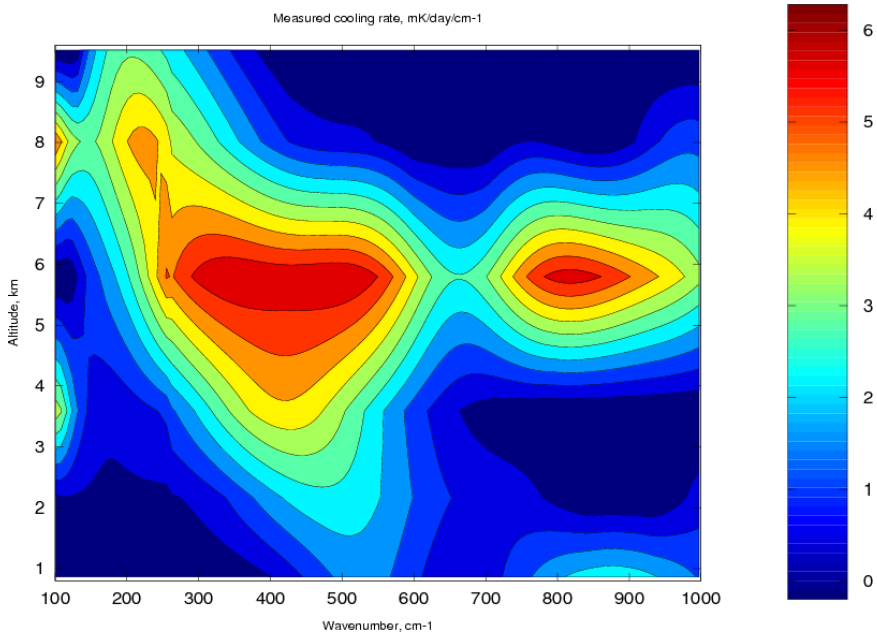
LW Net Flux

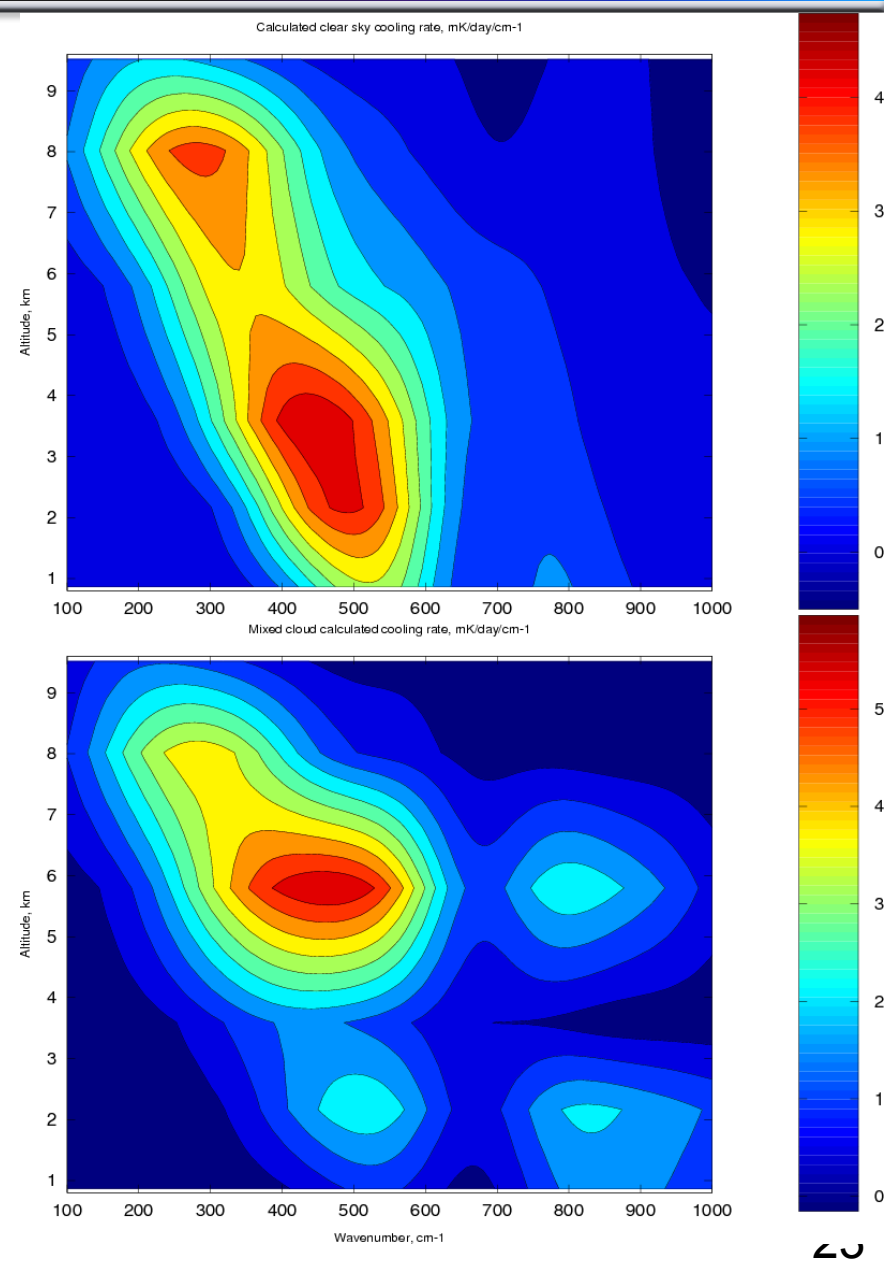




Measured (left) and calculated clear (right top) and cloudy (right bottom) net flux for 1/5/2010 flight. Clouds were included at 1-1.5 km and 5.5-6 km.

Derived LW Cooling Rates





Measured (left) and calculated clear (right top) and cloudy (right bottom) cooling rates for 1/5/2010 flight. Clouds were included at 1-1.5 km and 5.5-6 km.

INFLAME Flight Results

Summary

- IR FTS (LW): 3-100 μm in lab; 10-100 useful during flight.
  - Analysis is ongoing.
- UV-NIR FTS (SW) 0.6-1.1 and 1.4-3 μm in lab; no useful flight spectra obtained.
  - Commercial controller failed due to excessive drift with temperature before takeoff.
  - Sensitivity lower than expected, possibly due to shear; further lab investigation is required.