Proteus for CRYSTAL-FACE

C-F Science Team Meeting (30 Jan-1 Feb. 2002)

Sponsors: NASA & IPO

Investigators:

NASA (LaRC,GSFC,GISS)
U of Wisconsin-Madison
MIT
U of Colorado
U of Lille

C-F Performance:

Ceiling: 58,000 ft
Max Airspeed: 350 ktas
Endurance: 8 hrs
Operating Altitude:
100 to 58,000 ft

Payload:

NAST-I (mid-IR FTS)
NAST-M (μwave)
FIRSC (far-IR FTS)
RSP (SW-NIR pol.)
Air POLDER (Multi-spectral Vis. pol.)

Objectives

- **Science Measurement**
  - Cirrus cloud radiation
  - Cloud radiative properties (emittance, reflectance, transmittance, polarization)
  - Cloud phase, optical depth, and microphysical properties (particle size and shape) and geometrical properties (height and depth)
  - Atmospheric thermodynamic properties of the environment
    ol burden and vertical properties

    y sensed cloud parameters to model predictable variables (e.g.,

    ictable variables (e.g., temperature and water vapor) in order to

    ariables (e.g., temperature and water vapor) in order to build
    d parameterizations for use in weather and climate prediction
    dels

    els, and retrieval algorithms of existing research (e.g., EOS Terra
    and Aqua) and forthcoming experimental and operational remote
    ing systems (e.g., EO-3/IOMI and NPOESS)
    O-3/IOMI and NPOESS)

Measurement Capabilities

Spectral Measurement Range(0.4μm-0.5 cm)

Upwelling terrestrial & atmospheric radiance (IR, Far-IR, μ-wave)

Surface & atmosphere reflected solar radiance (Vis, near IR)

NAST-I (NPOESS Airborne Sounder Testbed-Interferometer)
IR Spectrum: 3.5 - 16 microns
NAST-M (NPOESS Airborne Sounder Testbed-Microwave)
μ-wave: 54, 118, 183, 425 GHz Bands
FIRSC (Far-Infrared Sensor for Cirrus)
Far-IR spectrum: 10-35 & 80-135 cm-1

Air-POLDER (POLarization and Directionality of the Earth's Reflectance)
visible/near infrared radiometer at several wavelengths and polarizations

RSP (Research Scanning Polarimeter)
Vis/NIR bands: 0.41 – 2.25 μm

PRODUCTS

Direct Products

- calibrated radiances (Vis, near IR, IR, Far-IR, & μ-wave)
- BRDFs and BPDFs

Derived Products

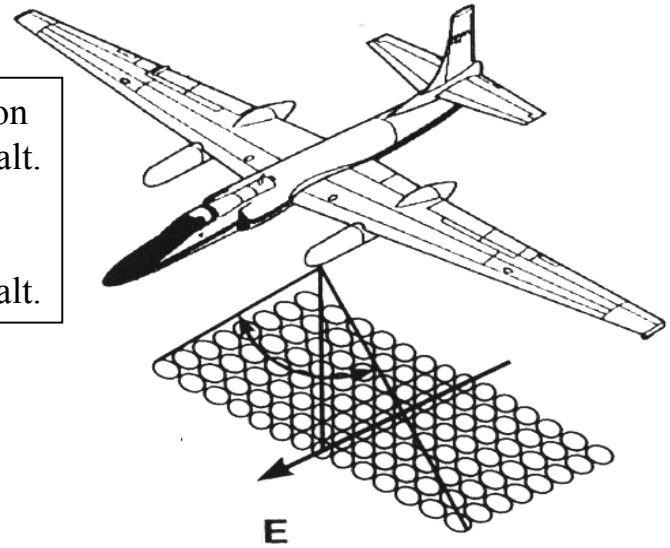
- atmospheric temperature & water vapor profiles
- surface temperature & emissivity
- cloud properties (altitude, temp, emiss, trans, reflec, pol, phase, IWP, particle size and shape)
- aerosol properties (geometric depth, Vis and IR optical depth)

NAST-I

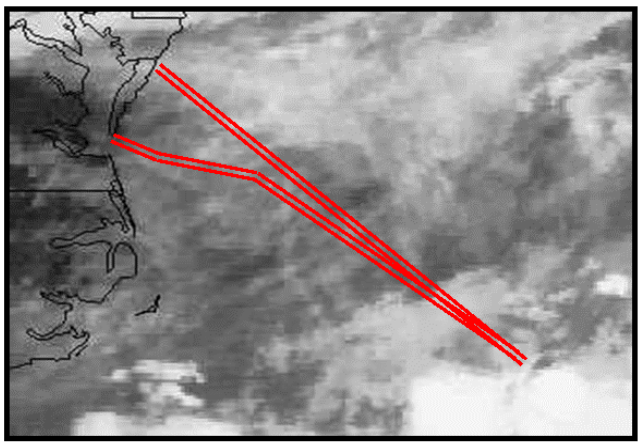
- **instrument characteristics**
  - infrared Michelson interferometer (9000 spectral channels) 3.5 – 16 microns @ 0.25 cm^{-1}
- **aircraft accommodation**
  - aft region of underbelly NAST pod
- **radiative measurement capability**
  - calibrated radiances with 0.5 K absolute accuracy, 0.1 K precision

Spatial Resolution
130m/km flight alt.

Swath Width
2 km /km flight alt.

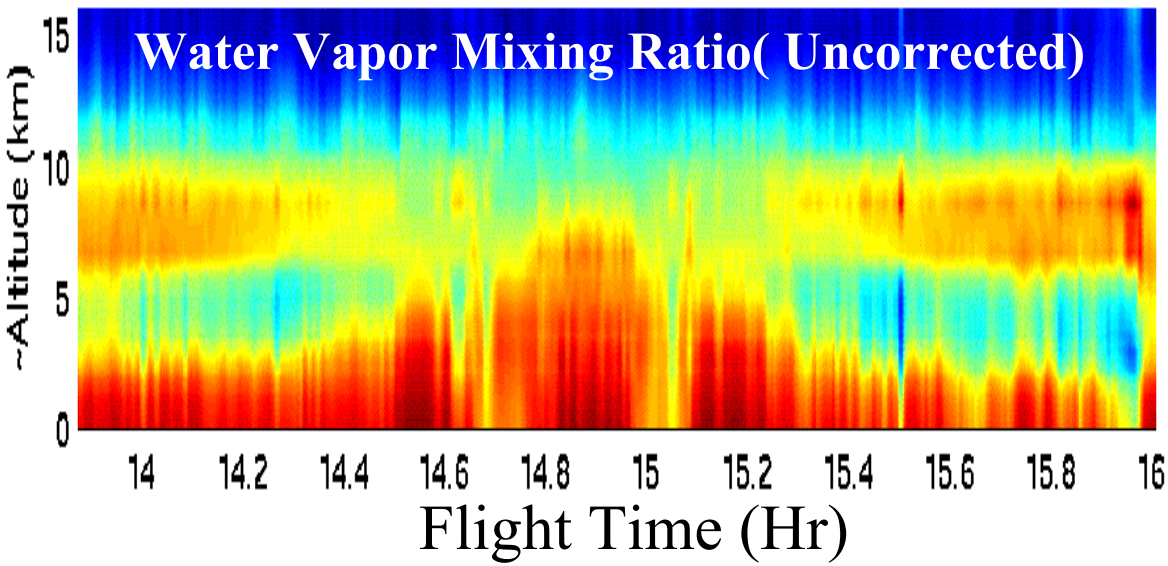


Proteus Flight Track (July 12, 2001)



GOES IR (1515 GMT)

NAST-I Log10[VMR (g/kg)] Vertical Cross Section



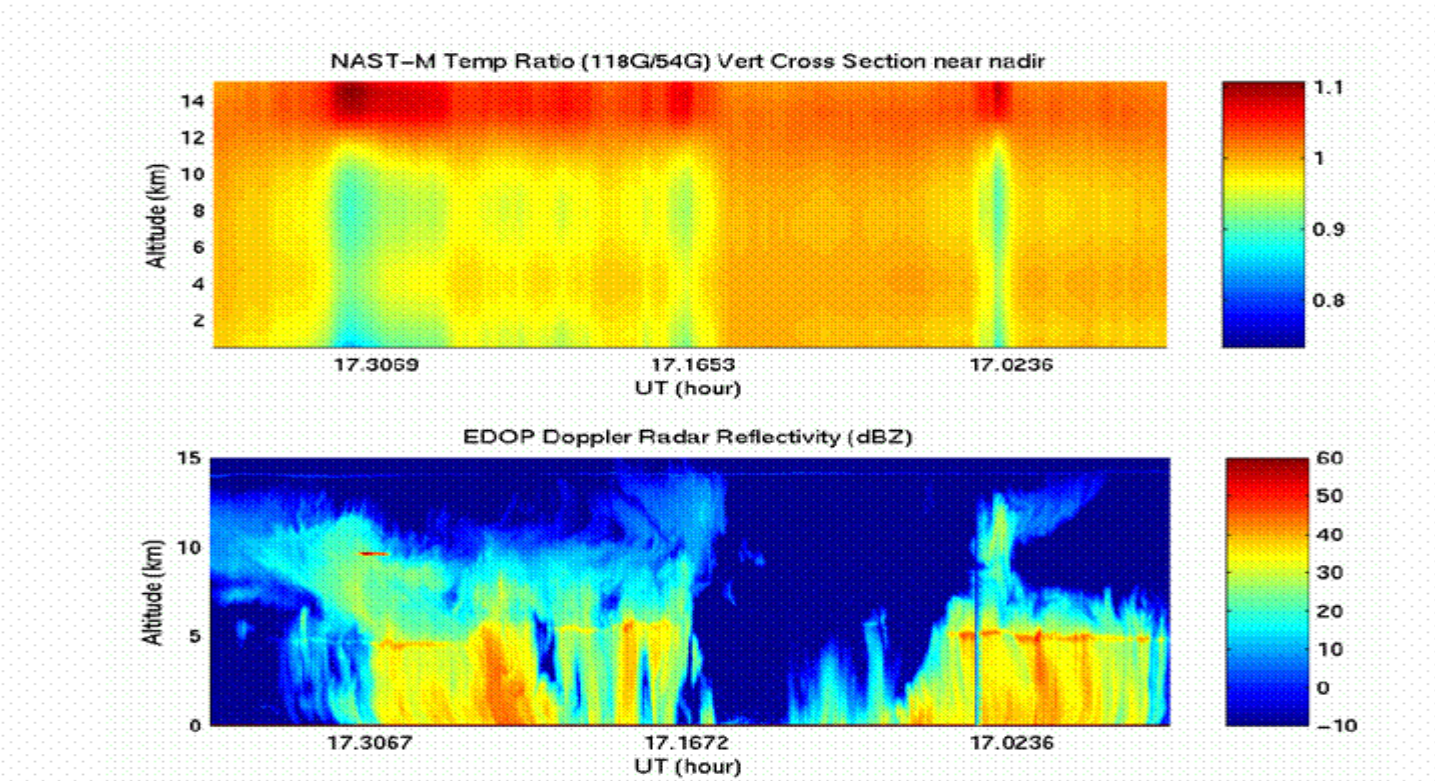
Investigators: Smith (LaRC), Larar (LaRC), Zhou (LaRC), Revercomb (UW), Antonelli (UW), Baum (LaRC @ UW)

NAST-M

Specifications:

Spectral Bands	Channels	Range(GHz)	DTrmsK	DTrms(5-km)	WF Altitude
Oxygen Band	8	50.3-56.02	0.19-0.23	0.07-0.08	Surface to 100 mb
Oxygen Line	7	118.75±0.45-3.5	0.19-0.61	0.07-0.22	Surface to 80 mb
Water Line	7	166, 183.3±1-10	0.25-0.6	0.09-0.22	Surface to 200 mb
Oxygen Line	7	424.76±0.28-3.25	0.34-1.0	0.12-0.35	600 mb to 60 mb

Nadir Ground Resolution: 130m/km km; scans, –58 to +78 degrees from nadir



Investigators: Staelin (MIT), Rosenkranz (MIT), Tsou (LaRC)

NAST C-F Tasks and Deliverables

Field deploy the NAST-I and NAST-M instruments aboard the Proteus

*Provide preliminary measurement **performance summaries** within 24 hours of science flights*

*Provide **quick-look measurement** data summary **products** for select mission target scenes during in-field phase*

Provide NAST calibrated radiances and retrieved geophysical parameters

*Provide spatially & temporarily geolocated, calibrated **NAST-I infrared radiances** within 6 months after completion of field phase*

*Provide spatially & temporarily geolocated, calibrated **NAST-M microwave brightness temperatures** within 6 months after completion of field phase*

*Provide spatially & temporarily geolocated **NAST geophysical parameter retrievals**, using both infrared and microwave data where advantageous, for appropriate mission target scenes, after 6 months of post-field phase*

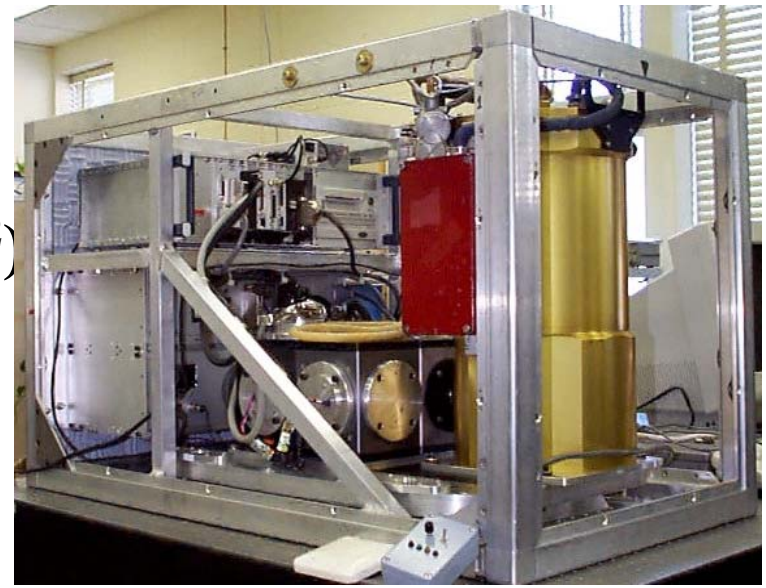
Perform radiometric and science product validation inter-comparisons with time and space coincident aircraft (e.g. ER-2 & WB-57), ground-truth, and satellite-based (e.g. Terra, Aqua) measurements

Results from select inter-comparisons will be summarized and made available to the CRYSTAL-FACE project office via web page postings

Proteus NAST Payload Configuration

Far-Infrared Sensor for Cirrus (FIRSC)

- **Fourier Transform Spectrometer:**
  - **Channel 1: 10-47 cm^{-1} (300-1400 GHz; 200-1000 μm); Channel 2: 80-135 cm^{-1} (75-125μm)**
  - Detectors: 1) Bolometer @ 0.3 K; 2) Ge:Ga photoconductor @ 4 K
  - **Spectral resolution: ≥0.1 cm^{-1}**
  - FTS scan time: ≤4 seconds
  - **NEΔT: 1.0 K at 30 cm^{-1} ($\propto 1/\nu^2$)**
  - Field of view: 0.03 radians
  - Aperture: 5.4 cm diameter
  - Instrument mass: 140 kg
  - Power: 400 Watts



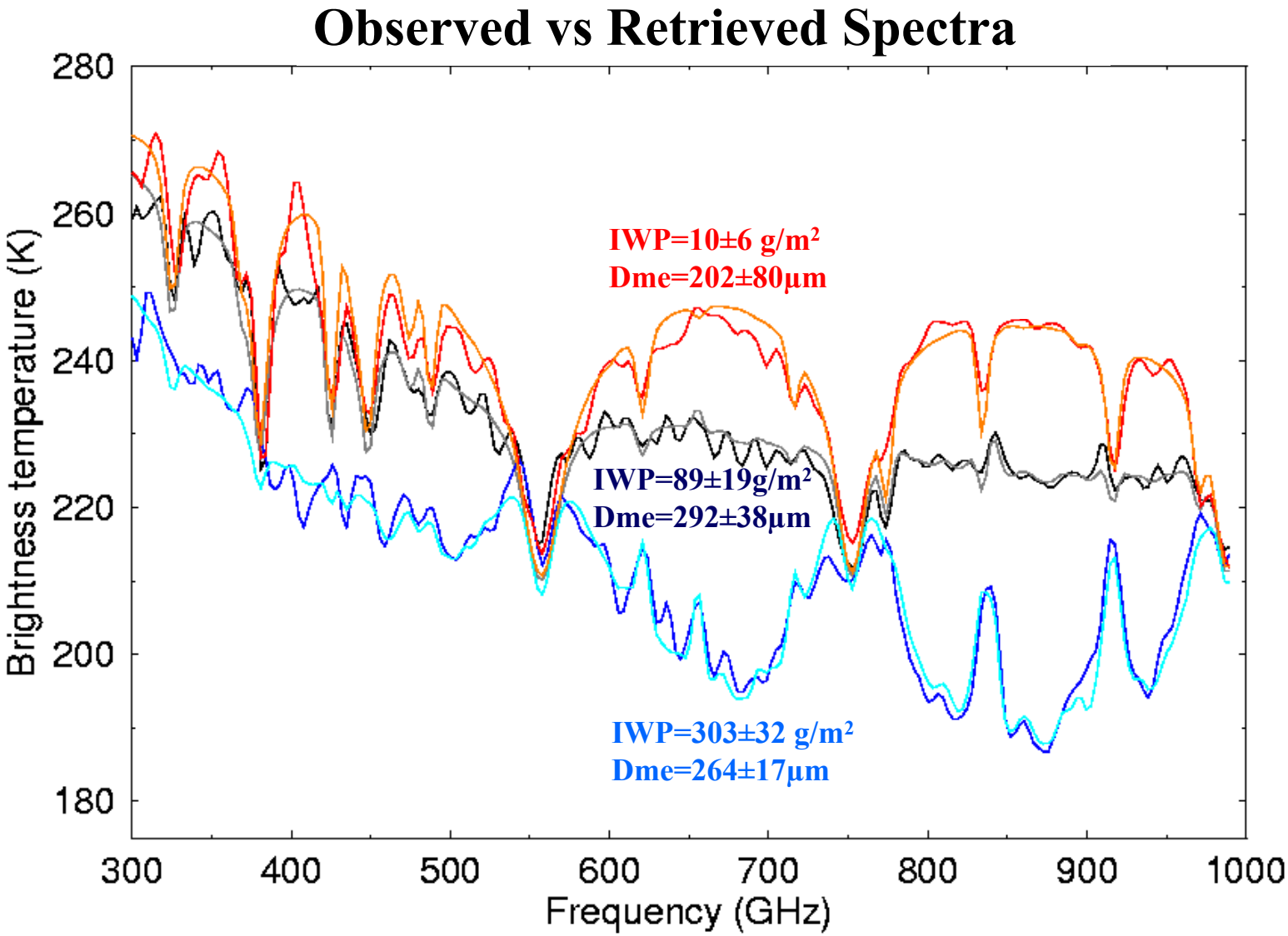
- **Nadir viewing from Proteus aircraft main pod**

Instrument PI: Mike Vanek (LaRC) Science PI: Frank Evans

FIRSC Science

- FIRSC measures nadir submillimeter radiance spectrum.
- Existing algorithm will be used during experiment to retrieve cirrus ice water path (IWP) and median mass equivalent sphere diameter (Dme).
  Sensitivity: IWP >10 g/m^2 D_{me}>50 μm
- Objectives: Demonstrate and validate submillimeter cirrus retrievals
- Provide IWP and Dme retrievals for satellite retrieval and cloud model evaluation.
- Flight track preferred: as high as possible, coordinated with ER-2

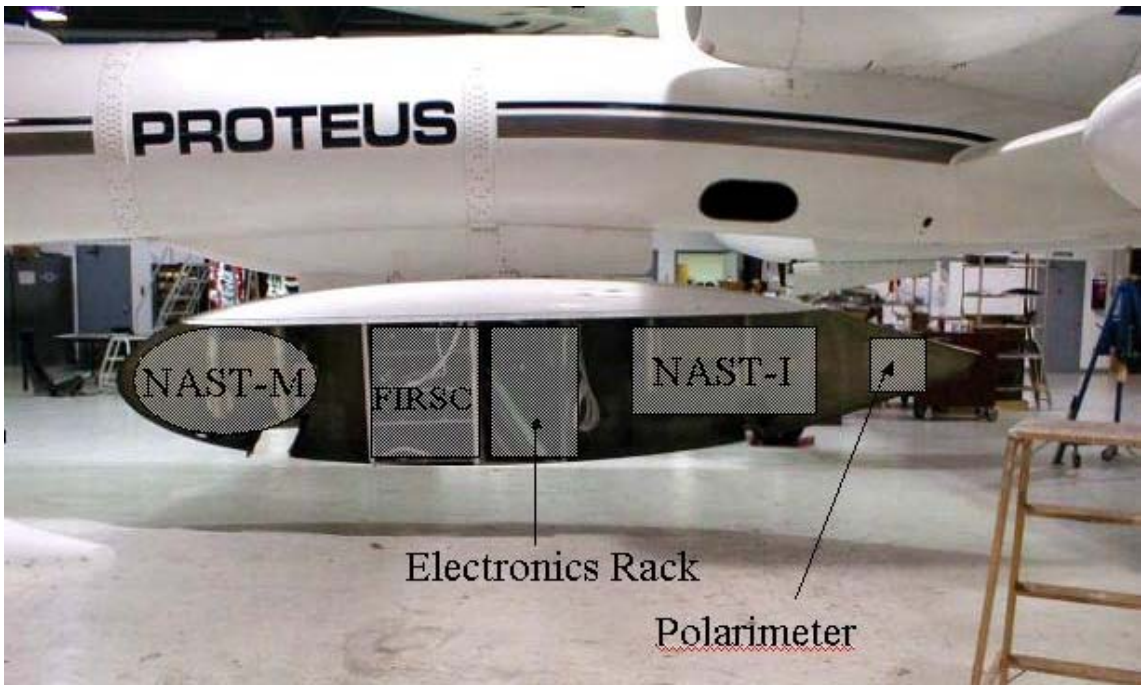
FIRSC (T_b Decrease from Ice Scattering)



Proteus NAST Payload Configuration

Research Scanning Polarimeter (RSP)

- The Research Scanning Polarimeter measures I, Q and U simultaneously in 9 spectral bands at 0.41, 0.47, 0.555, 0.67, 0.865, 0.96, 1.59, 1.88 and 2.25 μm.
- The uncertainty in measurements of the degree of linear polarization is 0.2% (0.1% precision) and the uncertainty in the radiometric measurements based on previous lamp and reflectance based calibrations is 5%.
- 14-bit dynamic range with SNR of 1000 for a Lambertian equivalent reflectivity of 0.1.



- RSP observations can cover an angular range of +/-60° about nadir. The actual viewing angle range is still to be determined, depending on the distance of the RSP from the observation port in the Proteus skin and the port size.

PI: Brian Cairns (GISS)

Objectives

- **Science Measurement**
  - Cloud phase
  - Cloud optical depth
  - Cloud particle size
  - Cloud shape
  - and when cirrus are not present, or are very thin, aerosol burden and a detailed microphysical model of the aerosol.

- **Research:**
  - to determine how well cirrus cloud habit can be determined from multiangle polarimetric measurements. Existing results from POLDER and the analysis of Coffeen's measurements by Liou demonstrate sensitivity to particle shape, but have never been verified against *in situ* measurements.

- **Science data processing** is straightforward and science data can be made available during the field campaign. Analysis will take place in the months following the C-F field campaign and will use GOM calculations to provide cirrus single scattering properties and vector doubling/adding multiple scattering calculations as the basis for the retrieval of cirrus cloud properties from RSP science data.

POLDER Characteristics and Observation Principle

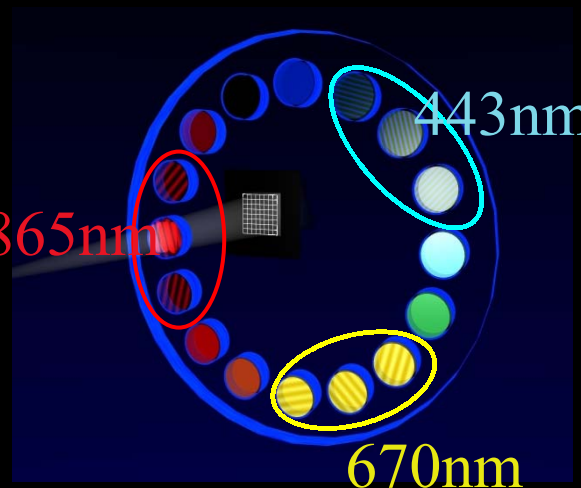
Wide field of view :

±43° along track

±51° cross track

CCD Matrix: 242 x 274 detectors

Filters wheel with up to 9 spectral bands in VIS/NIR and 3 polarized channels



POLDER wide FOV and CCD matrix allow for :

- Instantaneous observation of the scene within FOV
- Multi-angle measurements of total and polarized radiances (3 bands)

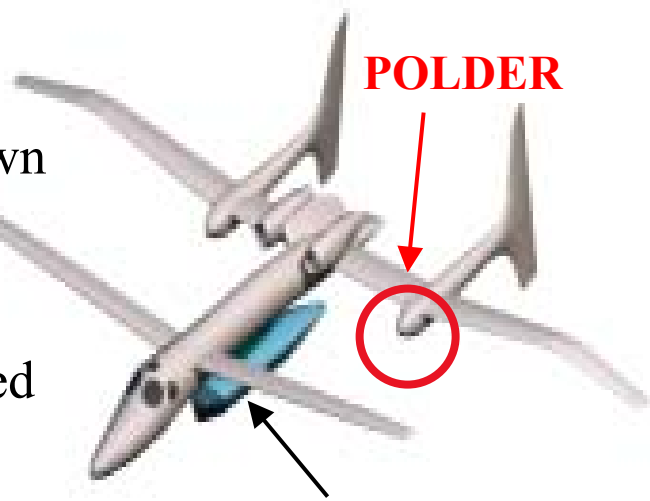
PI: Jerome Reidi (GSFC)

Main interest and Objectives

- Analysis of tropical cirrus clouds BRDF and BPDF
- Remote sensing of cirrus optical and microphysical properties - Focus on use of multi-angle and polarization measurements
- Preparation for A-TRAIN mission that includes Parasol (POLDER on micro-satellite) - Flight in formation with ER2 highly desirable

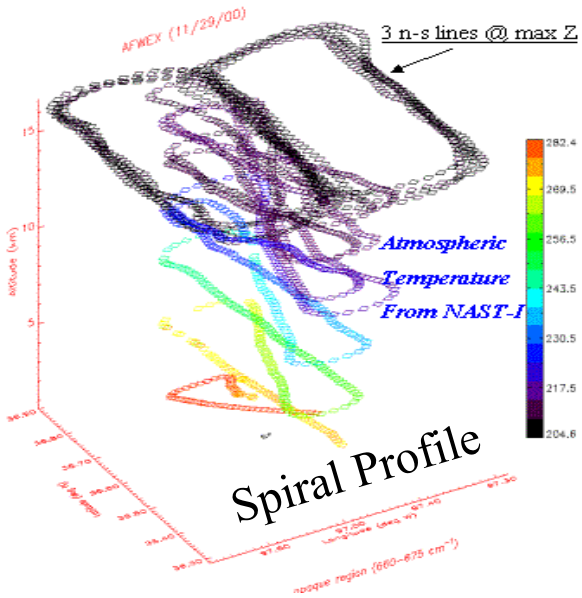
Integration and operations requirements

- Location : front of PROTEUS boom tail
- Requirement : the lens must be in open air (for incident polarization measurement), must look down and have +/- 60° (120° total) free field of view
- Main challenge : timing for integration and development of the new acquisition system required for operation in automated mode and high altitude non pressurized location



Preferred Flight Profiles*

- **NAST**
  - Max Altitude Across and Along Cirrus Anvil
  - Map Clear Sky Environment
  - Vertical profile through Cirrus Layer



- **FIRSC**
  - Max Altitude Across and Along Cirrus Anvil

- **RSP**
  - In the principal plane when the sun elevation is low enough that this significantly enhances the observable scattering angle range (e.g. sun elevation less than 60°).
  - Upwind and downwind to enhance matching of multi-angle views of the same piece of cirrus

- **POLDER**
  - Max Altitude

* Coordinate with ER-2 and WB-57 Flight Tracks

Proteus Science Measurement Summary

Instrument			Cloud Properties To Be Retrieved									
	δλ	º	Ph	Sh	D_e	IWP	τ	Ht	δZ	T	Q	A
NAST-I	3.5-16 µm	±45	X		X	X	X	X	X	X	X	X
NAST-M	700-5000 µm	+78 -58			X		X	X		X	X	
FIRSC	75-1000 µm	±0			X	X	X	X				
RSP	0.4-2.25 µm	±60	X	X			X					X
POLDER	0.4-0.9 µm	±43 ±50	X	X			X					X

δλ (spectral range), º (scan angle), Ph (phase), Sh (shape),
D_e (diameter), IWP (ice water path), τ (optical depth), Ht (height)
δZ (thickness), T (temperature profile), Q (moisture profile), A (aerosol)