Far-Infrared Spectroscopy of the Troposphere
- FIRST -

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CERES Science Team Meeting
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- Space Dynamics Laboratory
- Harvard Smithsonian Center for Astrophysics
- Raytheon Vision Systems
- ITT
- DRS Technologies
- JPL
- NIST
- U. Wisconsin
- Imperial College
- Numerous members of scientific community
Overarching Objectives

• To improve understanding Earth’s climate and climate change through a combination of new observations and innovative data analysis

• Work focuses on:
  – “Far-Infrared” part of the spectrum 15 - 100 μm
    • FIRST; INFLAME; CORSAIR; FIDTAP
  – Solar spectrum via measurement of atmospheric heating rates
    • INFLAME

• Approach:
  – Develop new technology where needed (IIP, ATI, ACT)
  – Exploit existing data sets as applicable (EOS, IIP)
  – Generate new data sets to fill voids in knowledge (CLARREO)

Demonstrate accurate, stable instruments & related technology for space based on well-defined science measurement objectives
Overview

Since 2001 six projects have been funded by NASA:

• **IIP’s**
  – FIRST (IIP 2001)
  – INFLAME (IIP 2004)
  – CORSAIR (IIP 2007)

• **Advanced Technology Initiative (ATI)**
  – FIDTAP (2006-2008)

• **Campaigns (NASA Radiation Sciences Program)**
  – FORGE/RHUBC
    • Wisconsin 2007
    • Atacama Desert, Chile, 2009

• **Data analysis (EOS Science Team Re-Competition)**
  – CERES/AIRS analysis and Far-IR residuals
Where we are now

- **FIRST instrument**
  - Demonstrated beamsplitter, FTS, focal plane technologies for far-IR
  - Participating in science campaign (FORGE/RHUBC)
  - Successful comparison against AERI; AIRS
  - Unique testbed available for evaluating new detectors, blackbodies, etc.

- **INFLAME instruments**
  - Entering build and calibration phase - flight demo in January 2009

- **FIDTAP**
  - Successfully demonstrates new far-IR detectors April 2008

- **CORSAIR selected**

- **CERES/AIRS far-IR studies well underway**
**Instrument Incubator Program - IIP**

**Far-Infrared Spectroscopy of the Troposphere - FIRST**

**Description and Objectives**

Measure the Far-Infrared spectrum of the Atmosphere and Earth (10 to 100 μm)

Far-IR observations are the key to understanding the greenhouse effect and the radiative feedbacks associated with increased anthropogenic forcings.

Far-IR key to understanding cirrus effects, etc.

**Approach**

- Simulate space environ.

- Develop
  - High-throughput Michelson FTS
  - Broad-bandpass beamsplitter
  - Advanced detector system

**Partners**

Utah State Univ. – Interferometer
Harvard SAO – Beamsplitters
19-member science advisory team

**Status**

6/2005 – Successful flight demo/balloon flight
9/2006 – Second flight for CALIPSO validation
3/2007 – Ground calibration vs. AERI at UW
4/-10/2009 - RHUBC/FORGE campaign Chile
10/2010 - CORSAIR detector evaluation @ LaRC

Journal articles forthcoming
FIRST Radiances June 2005 and September 2006
- Clear Sky -

FIRST Measured Radiances

June 7 2005 14:25 UT
June 7 2005 14:25 LT
September 18 2006 14:03 LT

Radiance (W m^{-2} sr^{-1} (cm^{-1})^{-1})

Wavenumber (cm^{-1})
Cause of Far-IR Radiance Differences
2006 - 2005

Lower troposphere much cooler

Mid-troposphere much drier
FIRST & AIRS Radiance comparison

FIRST, 9/18/2006
FIRST, 6/7/2005
AIRS, 9/18/2006
AIRS, 6/7/2005
FIRST 820 cm\(^{-1}\) Brightness Temperature
250 m MODIS Visible Imagery

June 7, 2005

September 18, 2006;
Note clouds in image
Comparison of FIRST Cloudy and Clear Spectra
September 2006

Far-Infrared

Mid-Infrared
FIRST at University of Wisconsin
March 2007

- FIRST port
- AERI port
- Detector dewar
- Zenith port
- Spectrometer
- Electronics
AERI - FIRST Detail

03/22/2007 FIRST-AERI Comparison

Radiance (W/m² sr cm⁻¹)

Wavenumber (cm⁻¹)

FIRST
AERI
AERI & FIRST Comparison

Overcast

Clear, cold, and dry

FIRST, 3/22/2007
UW AERI, 3/22/2007
UW AERI, 3/23/2007
RHUBC/FORGE

- August to October 2009
- Chajnantor, Chile
- ARM Mobile Facility; FIRST; other instruments
- Radiosondes launched during daily observing periods
- Science
  - Spectroscopy of far-IR
  - Radiative cooling
  - Cirrus forcing
  - Extensive cross-calibration against AERI-ER
  - Extensive evaluation against LBL codes
RHUBC/FORGE
Ground-based, Uplooking, Low H₂O

Tropical Atmosphere

Surface Radiance (Tropical)
IWP = 4.25 cm

4 km Radiance (Tropical)
IWP = 0.10 cm
View from Chajnantor, Chile site for RHUBC/FORGE
H = 17,500 feet; p = 500 mb; H₂O < 0.4 mm
Major Technology Elements

• Passively Cooled Detectors (Raytheon Vision Systems)
  – Antenna Coupled Terahertz Devices
  – Potential for 100 to 1000 times more sensitive (D*) than pyroelectric

• SI Traceable Blackbodies in Far-IR (SDL; NIST)
  – Flight prototype blackbody w/ well-characterized emissivity
  – On-orbit emissivity monitor in far-IR

• Broad Bandpass Beamsplitters (ITT)
  – Cover 5 to 50 μm region in 1 beamsplitter
  – Potentially enables 1 instrument to cover CLARREO range

• Detector evaluation to take place in FIRST @ Langley in Year 3
  – LaRC; JPL; Raytheon
Langley Projects and Relation to CLARREO

Sensor Technology and Science

**FIRST**
- Far-IR FTS, beamsplitter
- Calibration
- Focal plane design

**INFLAME**
- Highly stable FTS design

**CORSAIR**
- High sensitivity, uncooled det’s.
- Calibrated, SI traceable BB’s in far-IR
- Efficient, broad bandpass beamsplitter

**FIDTAP**
- Sensitive, broadband, cryogenic, far-IR detectors

**RHUBC/FORGE**
- Cross-calibration
- Cirrus radiative forcing
- Radiative cooling
- Spectroscopy

**CERES/AIRS**
- Assess far-IR/TOA radiation balance