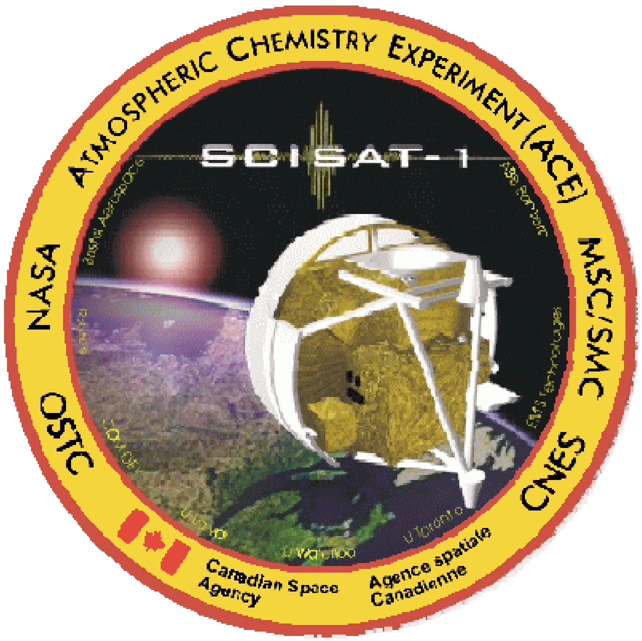
Canadian Space Agency
Agence spatiale canadienne

Update on Canadian missions, activities and mission concepts of relevance to SPARC and IGAC

Thomas Piekutowski

WCRP SPARC Scientific Steering Group
Kyoto, 26-30 October 2009

SCISAT – ACE: Instruments



Launched August 2003

Routine operations since February 2004

- Infrared Fourier Transform Spectrometer (FTS) operating between 2 and 13 microns with a resolution of 0.02 cm^{-1}
- 2-channel visible/near infrared Imagers, operating at 0.525 and 1.02 microns (cf., SAGE II)
- Suntracker keeps the instruments pointed at the sun’s radiometric center.
- UV / Visible spectrometer (MAESTRO) 0.285 to 1.03 microns, resolution ~1-2 nm
- Startracker

SCISAT – ACE: Measurements

Profiles of 18 molecules were derived after launch. Profiles of over 34 molecules are derived now.

The extremely high signal-to-noise permits retrieval of weak spectra.

Baseline species (version 2.2):

H_2O, O_3, N_2O, CO, CH_4, NO, NO_2, HNO_3, HF, HCl, N_2O_5, $ClONO_2$, CCl_2F_2, CCl_3F, as well as pressure and temperature from CO_2 lines

Other routine species:

COF_2, CHF_2Cl, CF_4, CH_3Cl, C_2H_6, SF_6, OCS, HCN

Research species:

CCl_4, HOCl, H_2O_2, HO_2NO_2, CCl_2FCClF_2, CH_3CClF_2, ClO, C_2H_2, CH_3OH, HCOOH, N_2 and additional isotopologues

OSIRIS

Optical Spectrograph and InfraRed Imaging System

on the Odin spacecraft

routine operations since 2001

Limb radiance profiles of scattered sunlight from 270 nm to 810 nm.

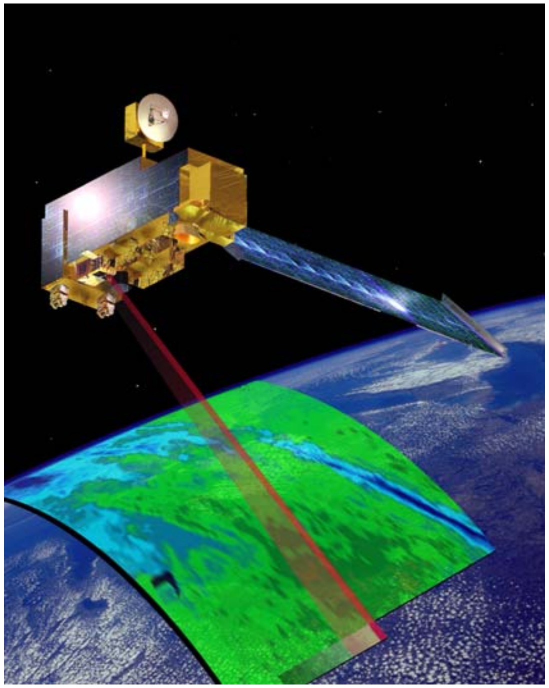
The profiles, which are constrained to the sunlit section of the orbit, have a height resolution varying between 1 and 2 km.

Primary data products: O_3, NO_2 and aerosols

Science products: BrO, NO_3, mesospheric OH and H_2O

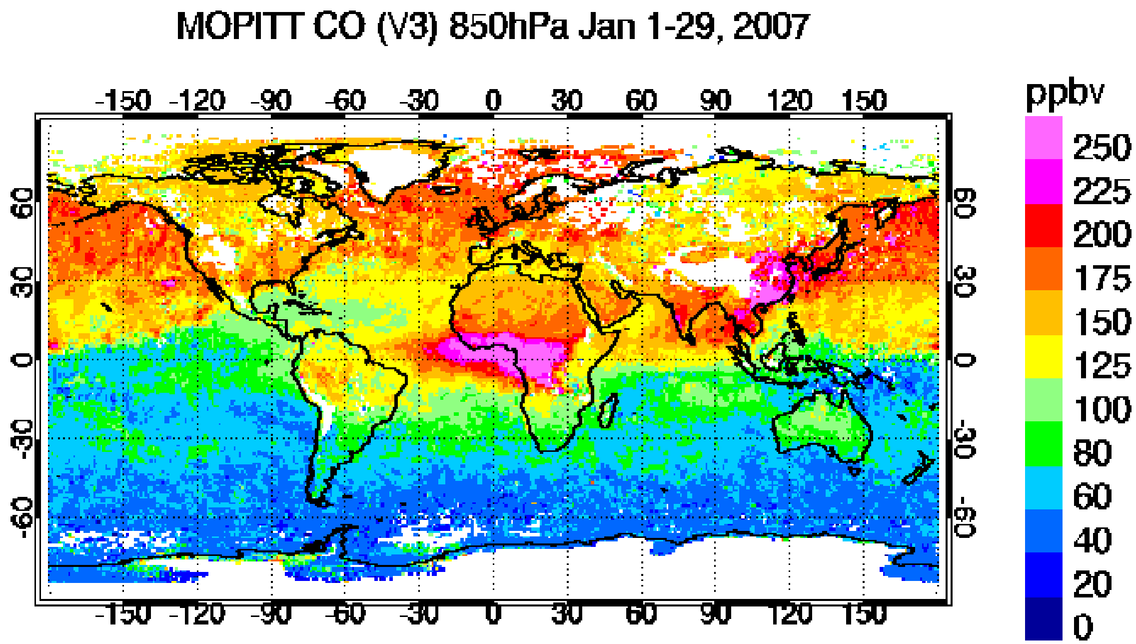
Validation shows OSIRIS ozone agreement with ACE-FTS and SAGE II better than 3% over the altitude range 18 km to 53 km. The OSIRIS observations can be used to extend the SAGE instruments data sets.

MOPITT



Measurement Of Pollution In The Troposphere, on NASA's Terra satellite, since 1999

More than 80 science papers providing a wealth of data on global pollutant monitoring and transport



Gridded at 1x1deg from MOP02-200701??-L2V5.*.hdf (apriori fraction < 50%)

Science Operations Centres

CSA supports the science operations of ACE-FTS, MAESTRO, OSIRIS and MOPITT through contracts to the Universities of Waterloo, Toronto and Saskatchewan. These contracts support:

- Instrument monitoring and operations
- Data processing and data product generation
- Algorithm development and re-analysis
- Data validation
- Data distribution and archiving

Validation and Modeling Activities

CSA has supported intensive ACE validation campaigns at PEARL each polar sunrise period since 2004. The Polar Environment Atmospheric Research Laboratory (PEARL) is a thoroughly instrumented facility at Eureka, Nunavut (80N, 86W) managed by CANDAC (Canadian Network for the Detection of Atmospheric Change) http://www.candac.ca/

CMAM, the Canadian Middle Atmosphere Model,and its Data Assimilation System has been developed with the support of CSA research grants. CMAM, a version of Environment Canada's GCM, was used to perform ensembles of transient simulations addressing the policy-relevant question of the link between ozone recovery and climate change. These simulations will provide key Canadian contributions to the 2010 WMO/UNEP Ozone Assessment and the 2012 IPCC Climate Change Assessment Report. http://www.atmosp.physics.utoronto.ca/C-SPARC/

CSA also contributes to support of the SPARC International Project Office at the University of Toronto.

Committee on Earth Observation Satellites

CEOS
Committee on Earth Observation Satellites

CSA participates in the CEOS:

- Atmospheric Composition Constellation pilot project
- Working Group on Calibration and Validation – Atmospheric Composition Sub-Group

SCIENCE OBJECTIVES

Ozone Chemistry:
Human-made emissions have a major impact on the chemistry of the atmosphere. Changes in the ozone layer and the ozone hole will occur as climate changes (increasing greenhouse gases cool the stratosphere). In addition, the stratospheric circulation is predicted to accelerate, increasing the amount of stratospheric ozone transported into the troposphere and altering the distribution of trace gases in the stratosphere and upper troposphere. The primary goal of the CASS mission will be to continue the measurement record of stratospheric and upper tropospheric composition, particularly stratospheric ozone, halogen species, and aerosols.

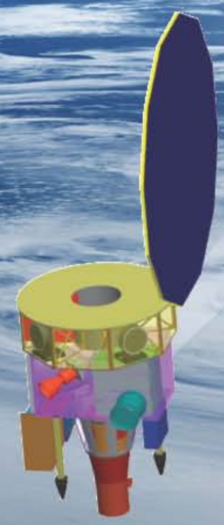
Climate Change:
Stratospheric aerosols—which are greatly increased during volcanic eruptions—also play a major factor in short-term climate change. CASS will monitor stratospheric aerosol levels allowing models to better predict cooling associated with volcanic events.

Proposed Schedule:

2009–12	Design/Build ACE-FTS II; Refurbish SAGE-III
2013	Integrate/Test ACE-FTS II, SAGE III on spacecraft
2014	Launch CASS, start atmospheric observations
2014–18	Prime CASS mission

The CASS Mission Concept

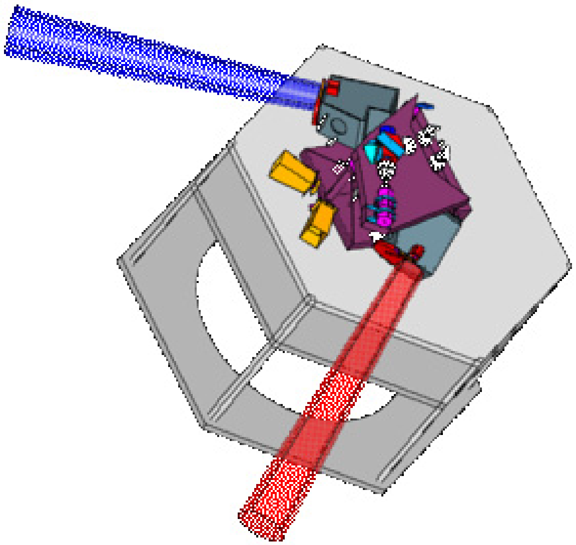
Chemical and
Aerosol
Sounding
Satellite



Understanding Ozone and Climate Change

SWIFT

Stratospheric Wind Interferometer For Transport studies (SWIFT) is an instrument designed to measure stratospheric winds and ozone concentration to improve our knowledge of the dynamics of the stratosphere, and the global distribution and transport of ozone. An alternate instrument approach will be evaluated to reduce technical risks and cost.



Atmospheric Processes of Climate and its Changes (APOCC) RFP-2007

We solicited innovative ideas for missions that:

- Will lead to new scientific understanding of atmospheric processes that regulate Earth's climate and thereby lead to reduced uncertainty in climate forecasts;
- Address questions of particular importance for northern latitudes or that otherwise benefit Canadians;
- Build on Canada’s considerable experience and capacity in atmospheric science;
- Complement and are synergistic with planned international satellite missions.

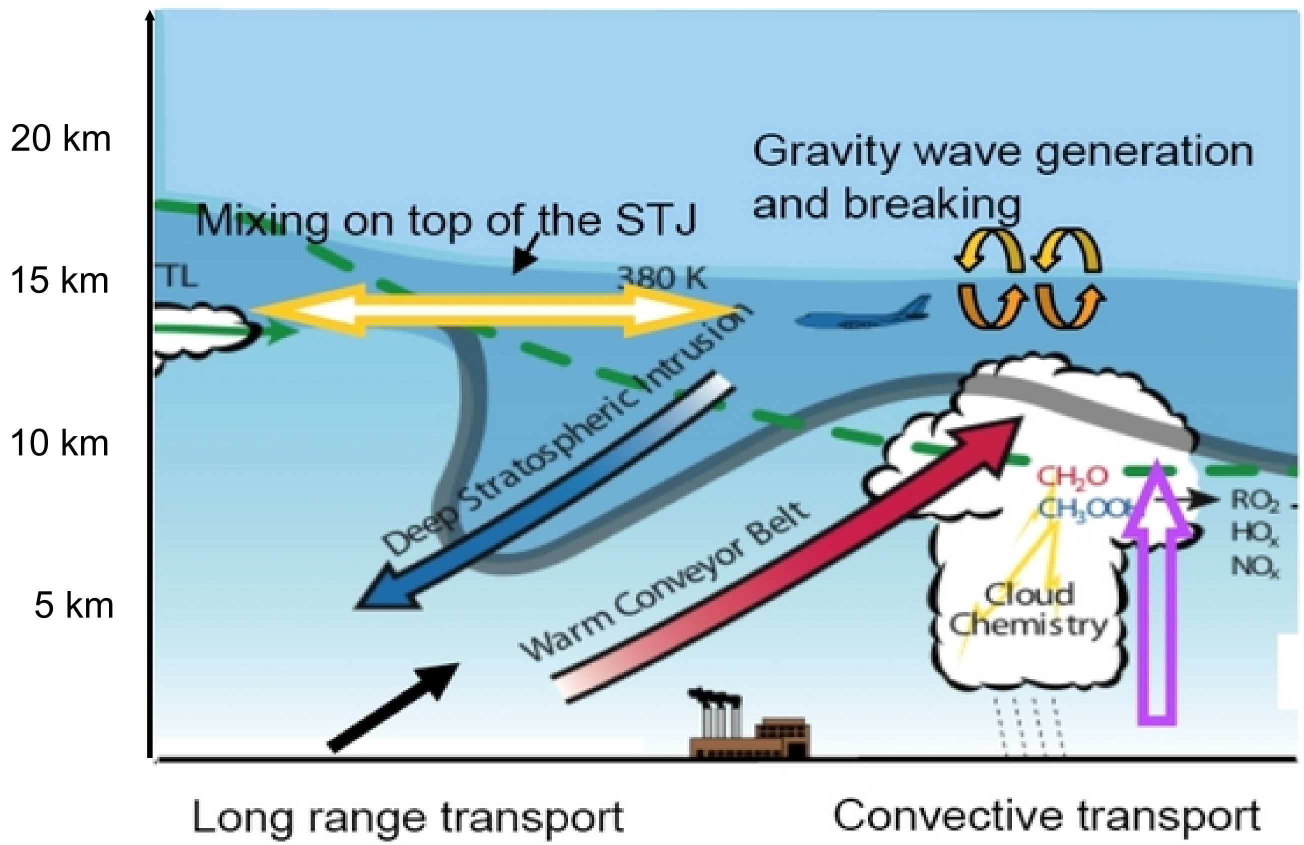
S T E P

O_3

NO_2

N_2O

HNO_3



H_2O

T

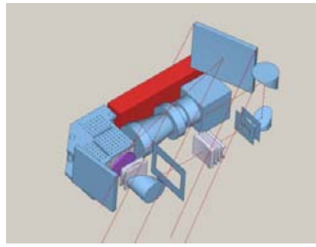
CO

ClO

Stratosphere Troposphere Exchange Processes

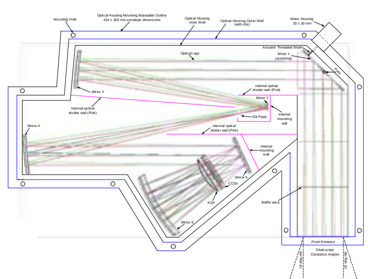
STEP: Three Instruments

Spatial Heterodyne Observations of Water



SHOW

Canadian Atmospheric Tomography System



CATS

Stratosphere Troposphere Exchange And climate Monitor Radiometer

STEAMR

Species	Range/ Vertical Resolution / Horizontal Sampling
O_3 (VMR)	7-40 km / 1.5 km / 50 km
O_3 (cm^{-3})	10-50 km / 200 m / 50 km
NO_2 (cm^{-3})	10-40 km / 200 m / 50 km
H_2O (VMR)	7-40 km / 1.5 km / 50 km
H_2O (cm^{-3})	10–40 km / 1.0 km / 7 km
Sulphate Aerosols	Tropopause-35 km / 200 m / 50 km
BrO	TBD
UTLS Aerosols	UTLS/ 200 m/ 50 km
CO (VMR)	8 – 28 km / 1.5 km / 50 km
N_2O (VMR)	8 – 40 km / 1.5 km / 50 km
HNO_3 (VMR)	8 – 35 km / 1.5 km / 50 km
CLO (VMR)	12 – 40 km / 1.5 km / 50 km
Temperature (K)	6 – 40 km / 1.5 km / 50 km

Mission for Climate and Air Pollution: MCAP

Science objective:

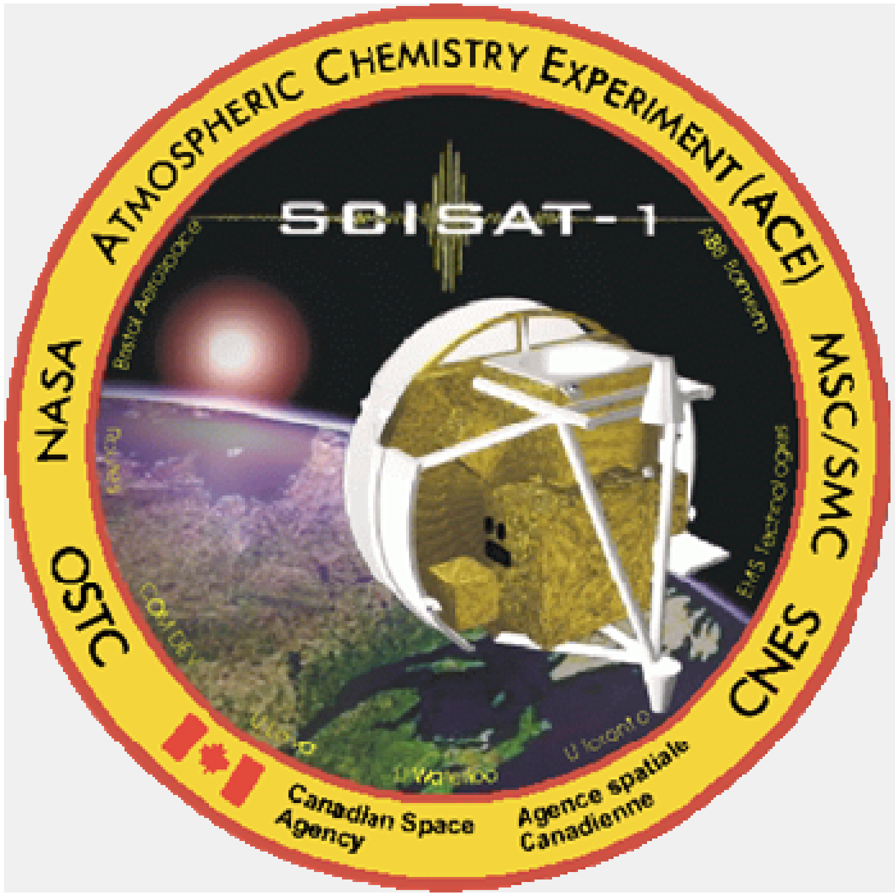
- To determine the linkages between climate change effects and air quality through integration of measurements of composition and aerosols.

Policy objective:

- To provide insight into the developing issues of atmospheric change in order to monitor the effectiveness of policy enactment and to provide predictive capability for future generations.

Component Measured	**Technique**	**Instrument Type**	**Instrument Designation**
CO_2 CH_4	Solar absorption – surface reflection – nadir	Fourier Transform Spectrometer	MCAP-FTS
CO	Thermal Emission - nadir	Correlation spectrometer (thermal and solar)	MCAP-CR
NO_2 , O_3 , HCHO, SO_2, BrO, glyoxal	Solar absorption – surface reflection - nadir	Solar Reflection Spectrometer	MCAP-SRS
Aerosols & clouds	Solar absorption/reflection	Visible imager with multi-angle capability	MCAP-MAI
Clouds	Thermal Emission	Infrared Imager	MCAP-II

SOAR - Solar Occultation for Atmospheric Research

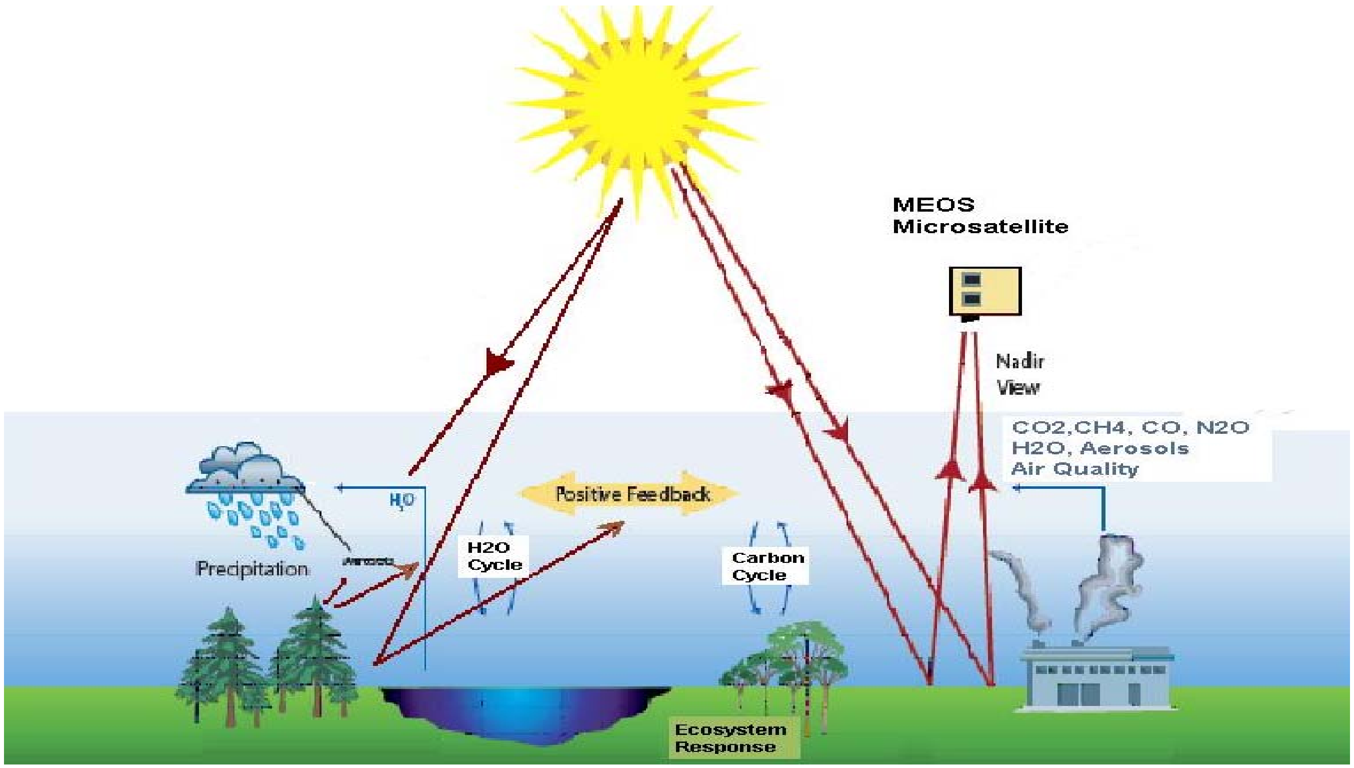


Similar to SCISAT-ACE

with advanced capabilities

Vertical profiles of atmospheric gases and aerosols

MEOS: Miniature Earth Observer Satellite



1500-1700 nm F-P Spectrometer: CO_2, CH_4

2200-2400 nm F-P Spectrometer: CO, CO_2, N_2O, H_2O

300 to 500 nm Imaging Spectrometer: O_3, NO_2, SO_2, H_2CO, $C_2H_2O_2$, BrO

O2 A-band F-P Imaging Spectrometer

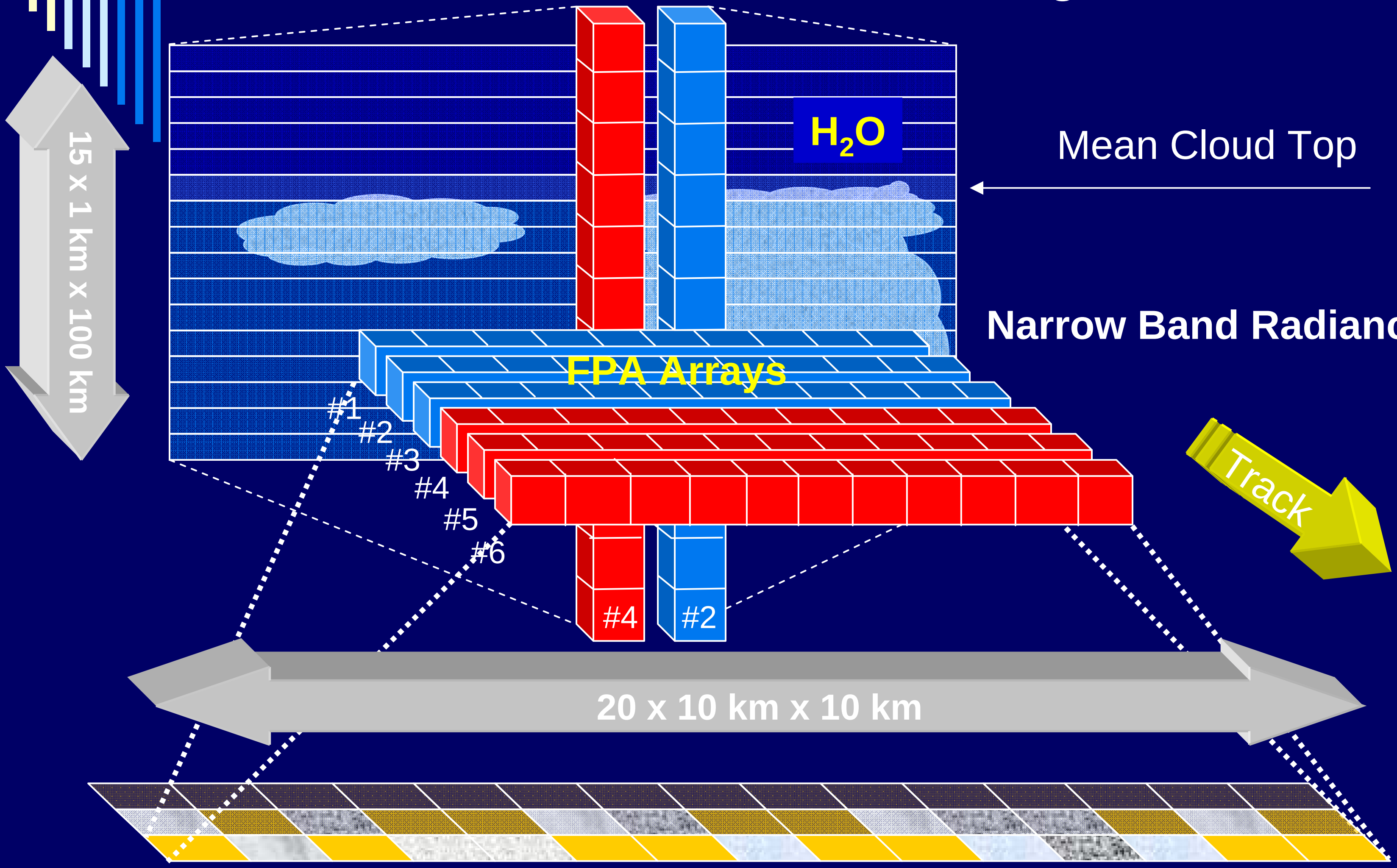
CMOS VIS Imager

TICFIRE (Thin Ice Clouds in a Far IR Experiment)
Primary Science Objectives

- Monitor the formation of cold-dry anomalies in Polar Regions and near the tropopause.
- Improve measurements of low water-vapour concentration (< 2 mm columnar) where cold regions are most sensitive.
- Identify Thin Ice Cloud TIC-1 (non-precipitating) and TIC-2 (precipitating), and cloud top altitude.

#1 : 7.9 – 9.5 µm
#2 : 10 – 12 µm
#3 : 12 – 14 µm
#4 : 16 – 18.5 µm
#5 : 22.5 – 27.5 µm
#6 : 30 – 50 µm

TICFIRE Nadir-Limb Views along Track



Low [H_2O] column, TIC-1/2 type, Light PCP initiation

[H_2O] prof, crystal size (2-30µm), COD, T_{sfc}

IWC, crystal shape, ice / liquid phase

APOCC Way Forward

- Six studies began in 2008: finish summer - autumn 2009.
- Concepts will be examined at a CSA workshop 1-3 Dec.'09. Presentations and discussion will address science merit, synergy with other science and operational EO satellites, science and technical readiness, suborbital development activities, cost and partnerships.
- The dialogue begun here with the Canadian EO science community and with partner agencies and organizations will continue for several months. It will contribute to CSA planning for technology development, suborbital science, instrument contributions to international space missions, and Canadian science satellites in the coming decade.
- It is anticipated that CSA will pursue several instrument and satellite opportunities, in different cost categories, that derive from the APOCC mission concepts.

Atmospheric to Earth System Science

- Workshop on developing collaborative research activities involving the use of space-based EO, between the Canadian Atmospheric Science community and other sectors of the Canadian Earth System Science community.
- The morning session will focus on long-term goals and observation needs to address high priority science questions in surface-atmosphere interactions in the domains of climate and air quality. Speakers will identify opportunities for collaboration in use of ground, airborne and space-based measurements and in modeling.
- The afternoon session will focus on near-term collaborative research opportunities with regards to validation and use of data from recent and future satellites of interest to the CSA (e.g., GOSAT, Aquarius/SAC-D, ESA's Sentinels and Earth Explorers, SMAP).

Cost Effectiveness Drives Investment Choices

1. Make good use of available data.
2. Instrument+Validation+Operation contributions to enable partnership missions when well suited to Canadian interests and capabilities.
3. Lead missions when required.

Summary

The Canadian atmospheric science community has a long-standing interest and expertise in atmospheric composition and dynamics.

The CSA invests in spaceborne atmospheric remote sensing, in production & validation of high quality data, and in interactive chemistry-climate modeling.

The CSA is likely to continue investing in atmospheric science missions that help us to understand ozone recovery, air quality and the processes linking these with climate.

The CSA places great value in partnerships:

- with Canadian scientists, government departments and industries;
- with international organizations;
- with other space agencies.