Overview of Recent Earth Observation Programmes

What has kept the division busy for the last 25-30 years!

Dr Chris Mutlow
Head of Earth Observation and Atmospheric Science Division
RAL Space
Science and Technology Facilities Council

Thanks to Jacqui Russell, John Bradford, Georgina Miles, Alison Waterfall, Brian Kerridge, Richard Holdaway, and too many others to mention!

Science & Technology Facilities Council

Introduction

or why are you guys @ STFC RAL Space anyway???

Some History for those too young to know it already!

- In 1979 SERC inherited the Appleton and Rutherford Laboratory's roles in Earth Observation
- From 1979 until 1995 → **SERC** funded the development of EO Instrumentation
  - **NERC** funded the data exploitation
- 1995 → **SERC** funding for EO Instrumentation moved to **NERC's** responsibility
  - SERC started ATSR-2, HIRDLS, EOS MLS before the transfer so they go too!
  - SERC EO Team @ RAL left behind as part of newly formed **CCLRC; *but team still working on the above and other activities in support of NERC***
- 2007 → **CCCLRC** merges with **PPARC** to form **STFC**
- April 2011 **→ NERC's** funding for EO Instrumentation moved to **UK Space Agency** Responsibility

How is RAL Space involved in EO Projects?

Typical ways RAL Space get involved to support UK Scientists and Industry…..

- User requirements gathering and sensor/data set requirements specification
- System architect and PI/Co-I roles
- Development of key technologies
- Sensor build
- Calibration and validation
- Scientific algorithm development
- Ground segment and software development
- Mission management
- Data management, distribution and curation

Foundations in late 1970's – Nimbus 7

Work on Nimbus series lays the foundations for UK and RAL Space involvement in many future missions …

- RAL Space involvement with **two** sensors
  - *Stratospheric and Mesospheric Sounder* (SAMS): Oxford leading, Reading and BAe
  - *Limb Infrared Monitor of the Stratosphere* (LIMS)
- Launched in October 1978
- Laid the foundations for future sensors
  - ISAMS, HIRDLS, MLS, Premier etc.

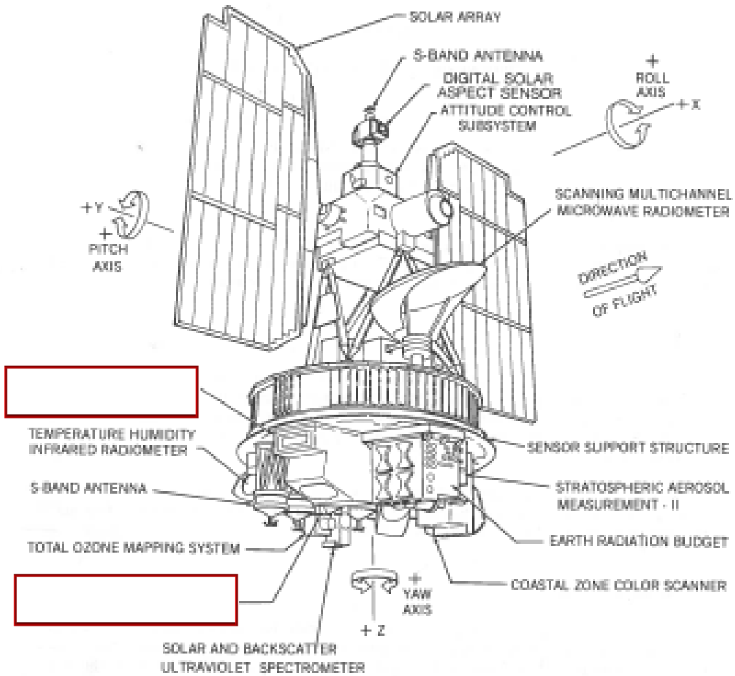


Figure 1-1. Nimbus 7 Observatory

Stratospheric and Mesospheric Sounder (SAMS)

- Observed infrared emission from the limb of the atmosphere
- Employed seven pressure-modulated cells and six detectors
- Aim was to determine temperature and vertical concentrations of H_2O, N_2O, CH_4, CO, and NO in the stratosphere and mesosphere.
- Very successful lead to development of ISAMS for UARS and space coolers!

Brian Kerridge and Chris Mutlow each gained their D Phil….!

After - **Satellite-Borne Measurements of the Composition of the Middle Atmosphere**, F. W. Taylor, A. Dudhia and J. G. Anderson, *Phil. Trans. R. Soc. Lond*. A 1987 323, 567-

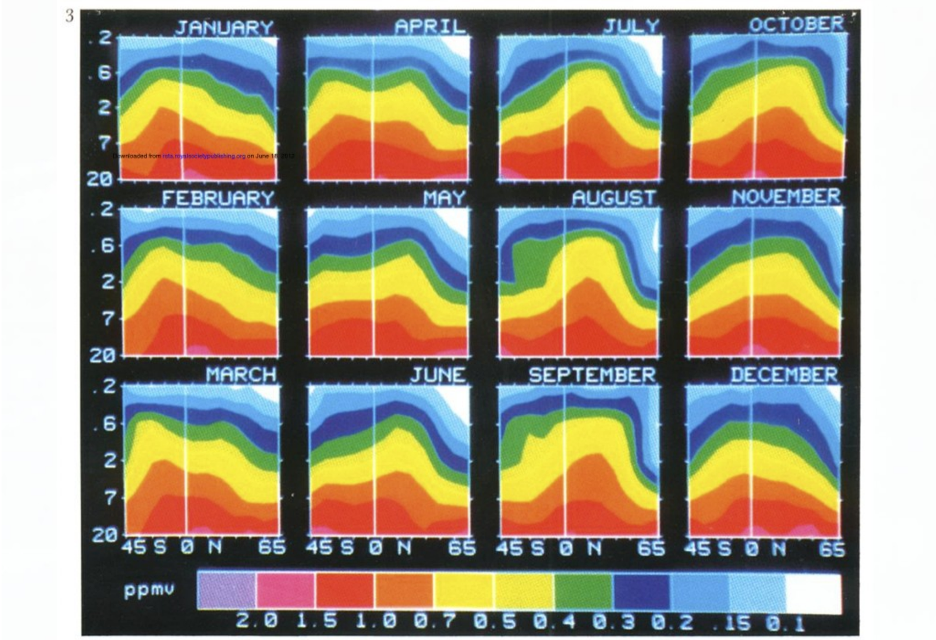


FIGURE 3. Monthly mean abundances of methane in parts per million by volume as measured by SAMS. The ordinate is logarithmic pressure from 20 to 0.2 mbar (approximately 20–60 km), and the abscissa is latitude. The data are zonal averages in 10° latitude bins for the three years 1979–81.

Limb Infrared Monitor of the Stratosphere (LIMS)

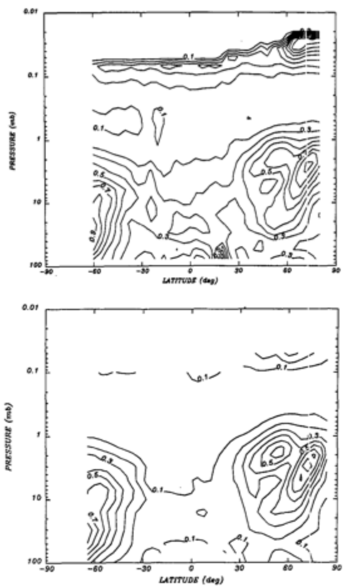


FIG. 14. As in Fig. 13, except for ozone. Contour interval is 0.1 ppmv.

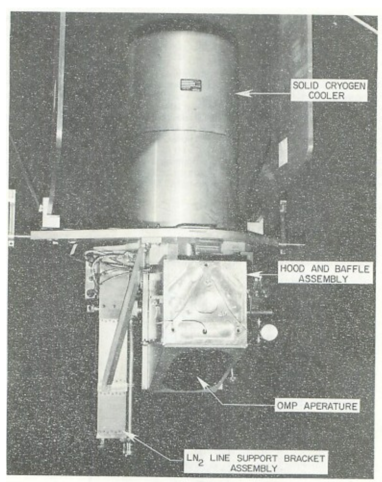


Figure 4-6. LIMS Proto-Flight Model Instrumentation Installed on Mounting Yoke

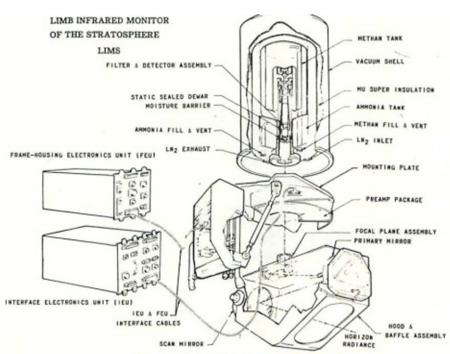


Figure 4-5. LIMS Instrument Configuration

- The objective was to obtain vertical profiles in the lower to middle stratosphere of:
  - Temperature
  - Concentration of O_3, H_20, NO_2, and HNO_3
  - H_20 down to the stratopause,
  - temperature and ozone up to the lower mesosphere
- LIMS had a solid cryogen so only lasted 7 months

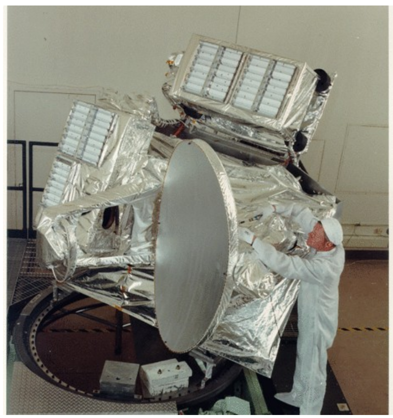
Practical demonstration of why space coolers needed to be invented quickly….!

Upper Atmosphere Research Satellite (UARS)

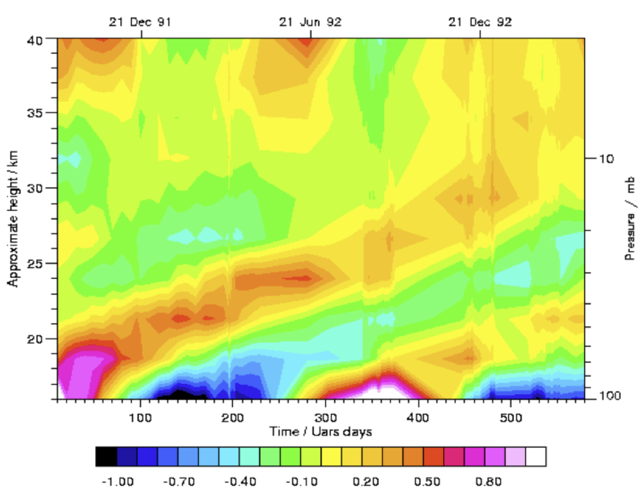
*RAL Space involvement in **three** sensors….*

- Improved Stratospheric and Mesospheric Sounder (ISAMS)
  - Covered in Fred Taylor's Talk
- Microwave Limb Sounder (MLS)
- Halogen Occultation Experiment (HALOE)
- Launched in 1991

Microwave Limb Sounder (MLS)



Tropical "tape recorder" signal in MLS H2O data
adapted from Mote et al. *J. Geophys. Res.*, vol. 101, 3989-4006 [1996]

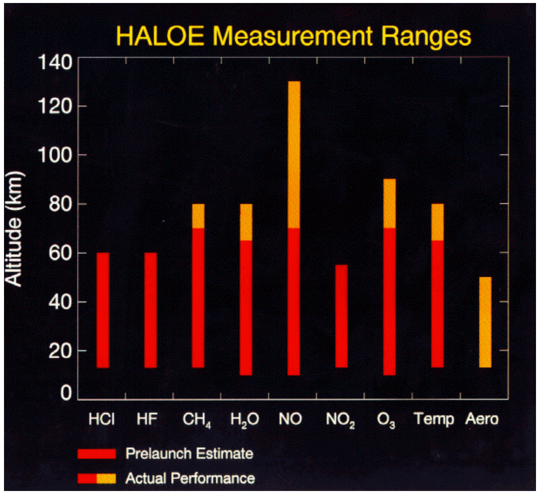


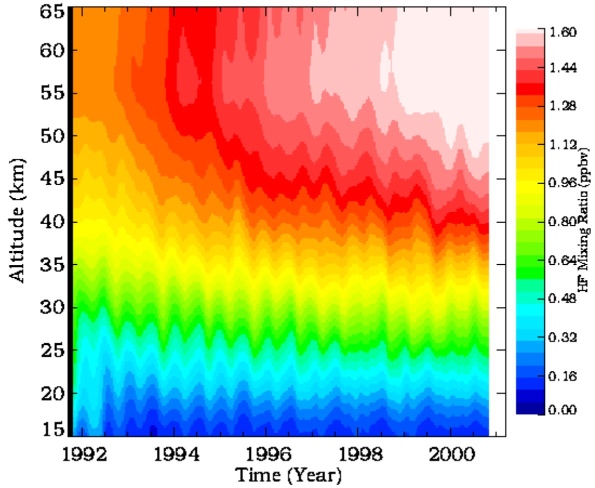
- MLS detected microwave thermal emissions from Earth's limb to create vertical profiles of atmospheric gases, temperature, pressure and cloud ice.
- Three radiometer channels:
  - 63 GHz to measure temperature and pressure.
  - 183 GHz to measure water vapor and ozone.
  - 205 GHz to measure ClO, ozone, sulfur dioxide, nitric acid and water vapor.
- RAL Space worked with Herriot-Watt and Edinburgh to supply the 183GHz H_2O channel

HALogen Occultation Experiment (HALOE)

- HALOE used solar occultation
  - tracking the sun during unrise or sunset.
  - The scan will measure the amount of solar energy absorbed by gases in the atmosphere.
- It measured vertical profiles of O_3, HCl, HF, CH_4, H_2O, NO, NO_2, temperature, aerosol extinction, aerosol composition and size distribution versus atmospheric pressure at the Earth's limb.

RAL Space had a Co-I role and undertakes the data archiving for UK Scientists…

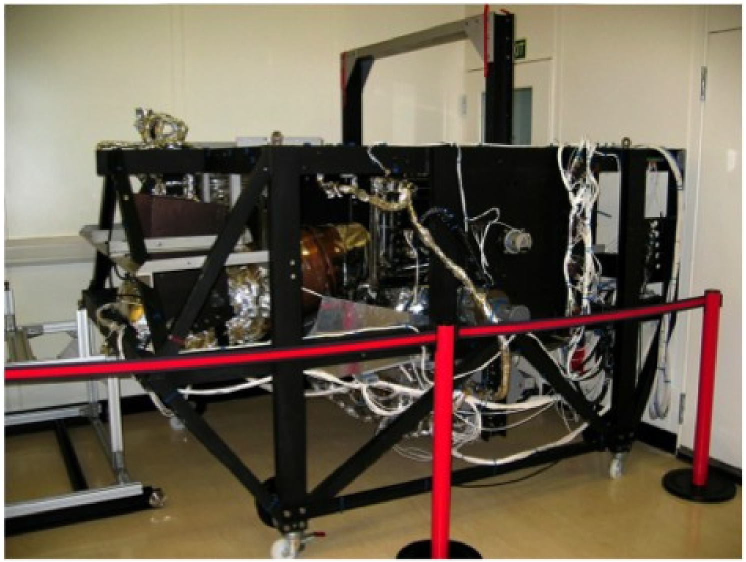




Contributions to other microwave sensors

Important contributions to operational instrument suite and upcoming science missions!

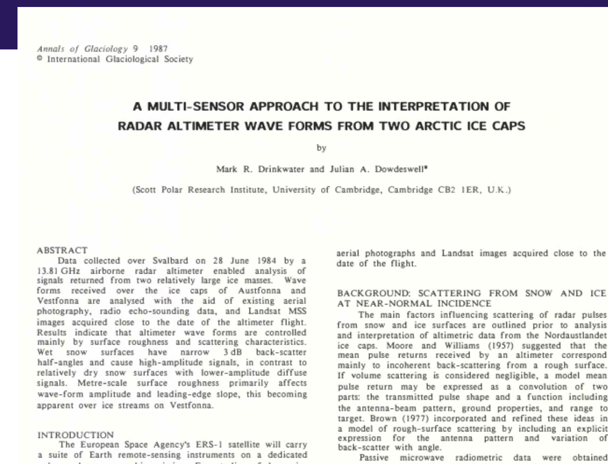
- Advanced Microwave Sounder Unit-B (AMSU-B) carried by NOAA-15, 16, and 17
  - Components for 150GHz Channel
- Microwave Humidity Sounder (MHS) flying onNOAA-18 and ESA MetOP
  - Radiometric testing
- Humidity Sounder for Brazil
  - Mixer components for 150 and 183GHz channels
- *New mm-wave technology developments for MARCHALS and Premier*



Radiometric calibration rig for the Microwave Humidity Sounder (MHS) @ RAL Space Centre for Calibration of Satellite Instrumentation (UKCCSI)

Altimetry and Transponders

- John Powell's Group at RAL developed corner reflectors and transponders for altimeter calibration
- They were used for various altimeter calibrations in airborne campaigns and for ESA Missions
  - See publication in Annals of Glaciology
  - ULMO Systems our first spin-out??
- They increased the accuracy of space altimeter measurements from ERS-1 etc.
- Recently deployed in support of Cryosat-2



Annals of Glaciology 9 1987

A MULTI-SENSOR APPROACH TO THE INTERPRETATION OF RADAR ALTIMETER WAVE FORMS FROM TWO ARCTIC ICE CAPS

by

Mark R. Drinkwater and Julian A. Dowdeswell*

(Scott Polar Research Institute, University of Cambridge, Cambridge CB2 1ER, U.K.)

ABSTRACT

Data collected over Svalbard on 28 June 1984 by a 13.81 GHz airborne radar altimeter enabled analysis of signals returned from two relatively large ice masses. Wave forms received over the ice caps of Austfonna and Vestfonna are analysed with the aid of existing aerial photography, radio echo-sounding data, and Landsat MSS images acquired close to the date of the altimeter flight. Results indicate that altimeter wave forms are controlled mainly by surface roughness and scattering characteristics. Wet snow surfaces have narrow 3 dB back-scatter half-angles and cause high-amplitude signals, in contrast to relatively dry snow surfaces with lower-amplitude diffuse signals. Metre-scale surface roughness primarily affects wave-form amplitude and leading-edge slope, this becoming apparent over ice streams on Vestfonna.

INTRODUCTION

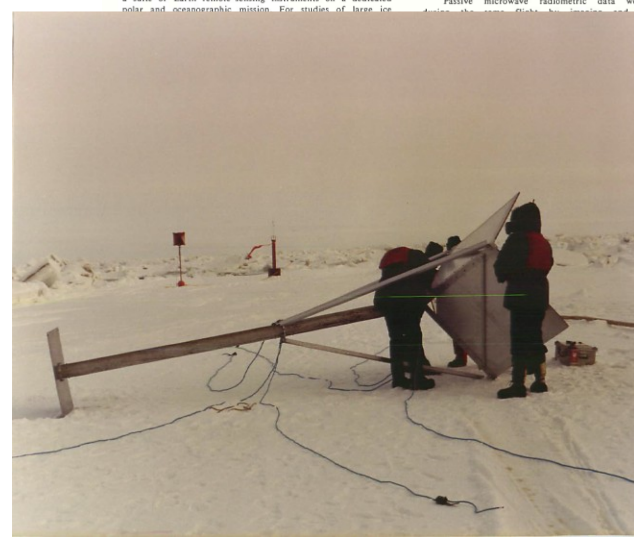
The European Space Agency's ERS-1 satellite will carry a suite of Earth remote-sensing instruments on a dedicated polar and oceanographic mission. For studies of large ice

aerial photographs and Landsat images acquired close to the date of the flight.

BACKGROUND: SCATTERING FROM SNOW AND ICE AT NEAR-NORMAL INCIDENCE

The main factors influencing scattering of radar pulses from snow and ice surfaces are outlined prior to analysis and interpretation of altimetric data from the Nordaustlandet ice caps. Moore and Williams (1957) suggested that the mean pulse returns received by an altimeter correspond mainly to incoherent back-scattering from a rough surface. If volume scattering is considered negligible, a model mean pulse return may be expressed as a convolution of two parts: the transmitted pulse shape and a function including the antenna-beam pattern, ground properties, and range to target. Brown (1977) incorporated and refined these ideas in a model of rough-surface scattering by including an explicit expression for the antenna pattern and variation of back-scatter with angle.

Passive microwave radiometric data were obtained



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RAL Space involvement with current satellite data sets

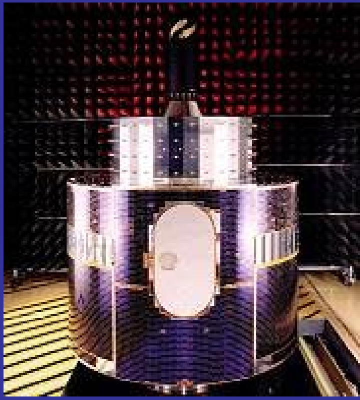
Geophysical retrievals from...

- (A)ATSR → SST, clouds and aerosols
- AVHRR → clouds and aerosols
- GOME and GOME-2 → ozone etc.
- MODIS → clouds, aerosols, surface reflectance
- SERVIRI → clouds and aerosols
- IASI → ozone, methane, etc…
- SCIAMACHY
- MIPAS
- Mission advisory groups for EUMETSAT post-EPS, S5P, Premier

(A)ATSR Data being used to validate …

- Other satellite sea surface temperature (SST) data sets
- Visible data sets from:
  - AVHRR
  - MODIS
  - MERIS

Geostationary Earth Radiation Budget project



Funding

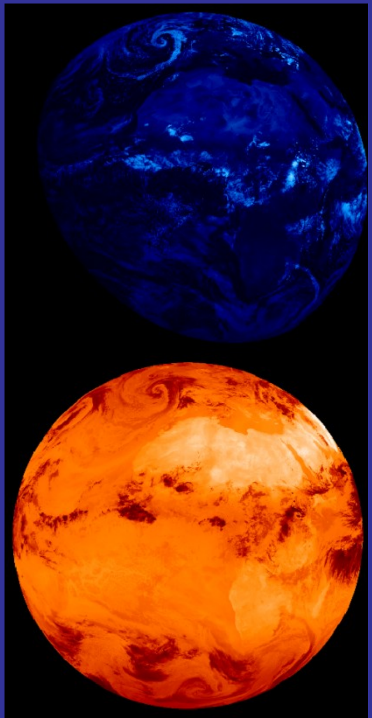
GERB 1 funded by UK (NERC funding), Belgium & Italy.
Build & operation of GERBs 2, 3 & 4 funded by EUMETSAT

Science Team

Imperial (PI John Harries), LU, Met Office, ESSC, RMIB, GKSS, U Valencia, GKSS,

Instrument Team

RAL (optical and electronic design and instrument build), AMOS (Belgium), Officini Galileo (Italy), Imperial College (calibration), Leicester University (detectors), AEA technology, NPL



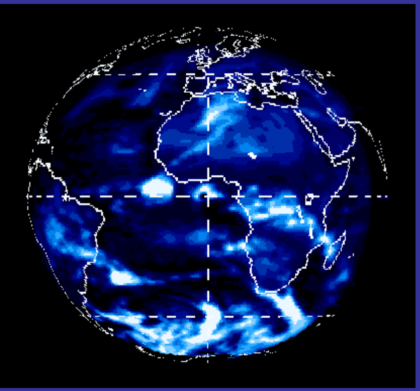
Ground Segment

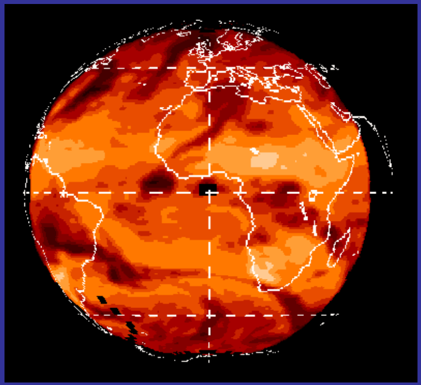
RAL (Primary data processing), RMIB (products), Imperial (operations)

GERB observations and products

Level 2 15 minute flux products

Reflected Solar flux   Emitted Thermal flux





Instrument ops at Imperial: monitors instrument health, plans operations and prepares commands for EUMETSAT

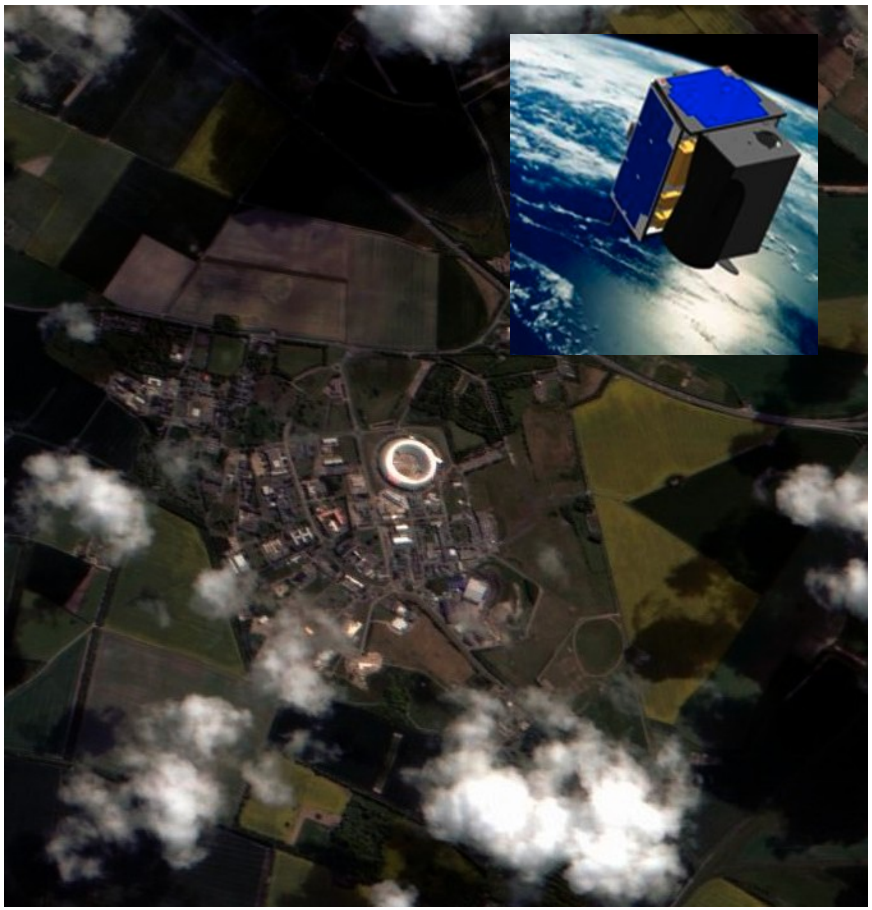
RAL level 1.5 processing: Raw data is received at EUMETSAT and transmitted to RAL for processing to level 1.5 (calibrated geolocated, filtered radiances)

RMIB level 2 processing: Level 1.5 is transmitted to RMIB and processed to level 2 unfiltered radiance and flux products, using SEVIRI data for scene identification

GERB level 1.5 filtered radiances, products at RAL from the raw data

GERB flux products are available from the BADC for the period April 2004 to present

TOPSAT

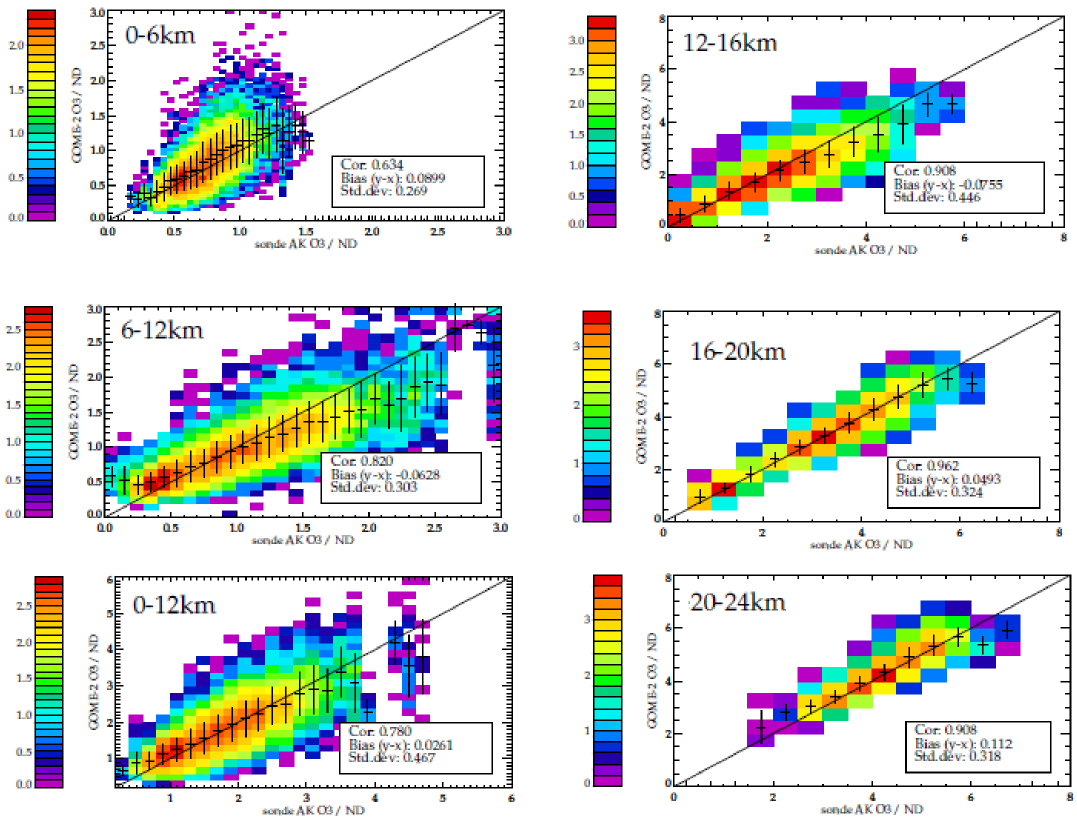


TopSat was conceived, designed and built in the UK…

- RAL Space developed its state-of-the-art lightweight camera.
  - It records images with 2.5m pixels from 600km orbit height.
  - It is very compact and light
- It can carried onboard a microsatellite
  - Providing a very low cost solution with high performance.
- TOPSAT was jointly funded by BNSC and the Ministry of Defense

Example of GOME-2 Ozone

RAL Space contribution to ESA Ozone ECV Project….



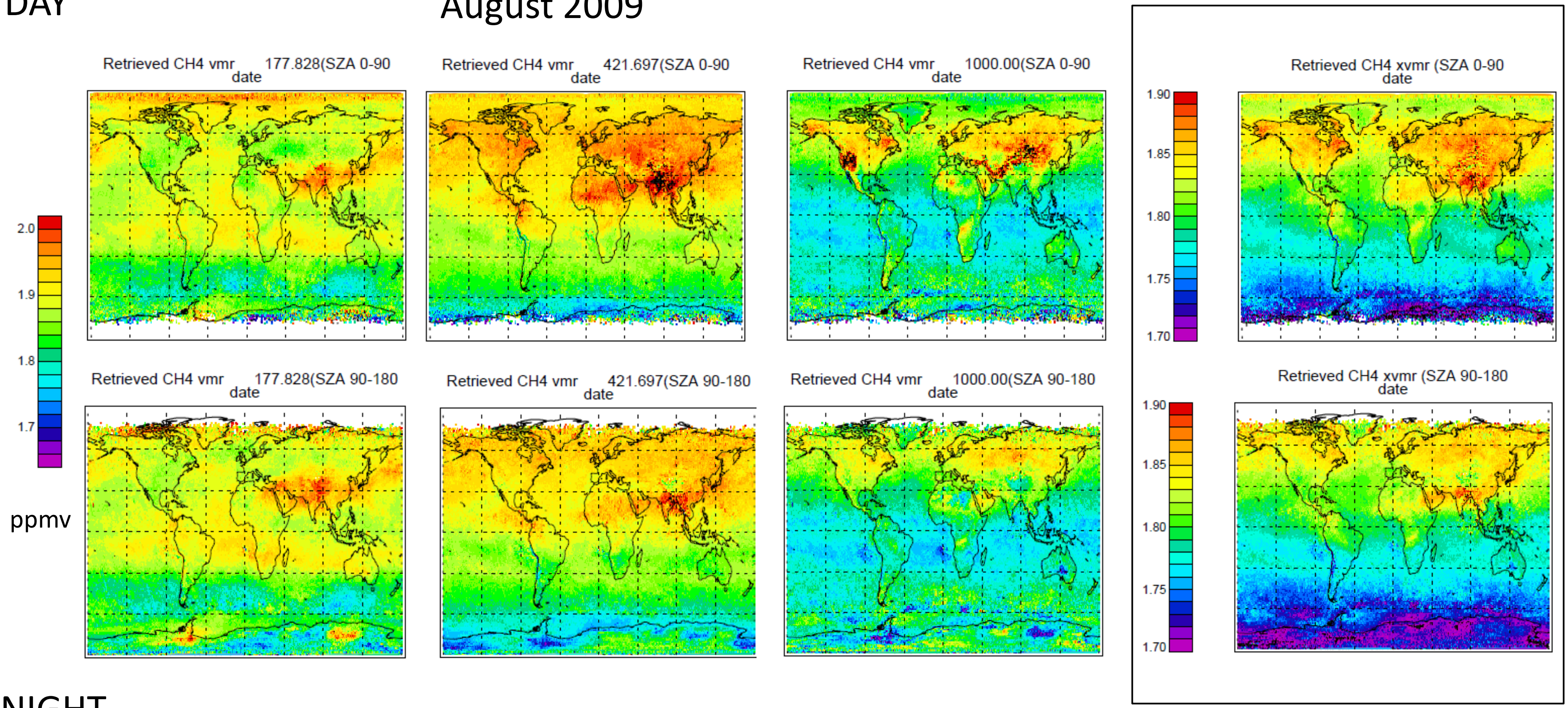
GOME-2 O_3 against sondes in troposphere and stratosphere

Example of Methane Retrievals from IASI

Monthly mean data on retrieval levels

DAY

August 2009



ppmv

NIGHT

178 hPa

422 hPa

1000 hPa

Column averaged mixing ratio

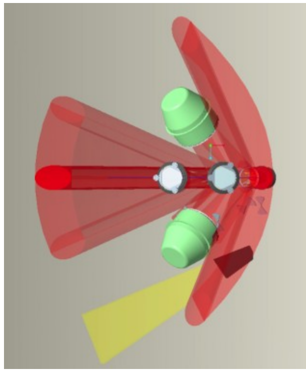
Sea and Land Surface Radiometer (SLSTR) for GMES Sentinel 3

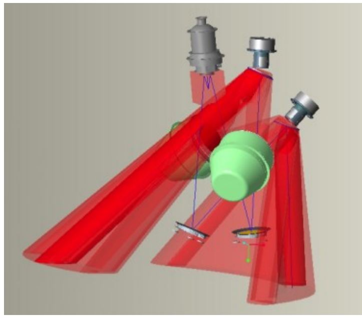
SLSTR is the follow-on to the very successful Along Track Scanning Radiometer (ATSR) series…..

- SLSTR's objectives include that of maintaining sea surface temperature data continuity after Envisat
  - *Launch by 2014 on the GMES Sentinel 3 satellite primed by Thales, Cannes*
- Much of the design is firmly based on the heritage of previous, proven (A)ATSR designs
- SLSTR has some completely new design features:
  - additional channels, higher spatial resolution in some channels, and a wider swath

The SLSTR consortium is led by Selex-Galileo in Florence, and includes RAL Space and Jena Optronik as a major partners

RAL Space have a prominent role in the design, development, and calibration of SLSTR and its algorithms…..

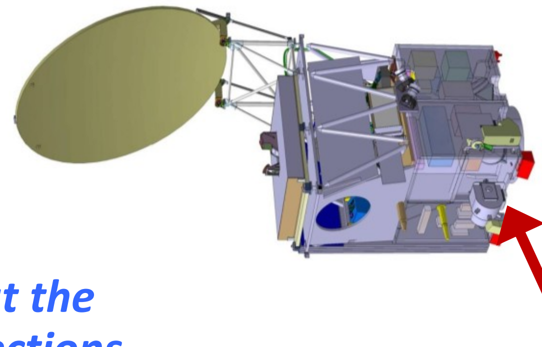




Broad-Band Radiometer (BBR) for ESA EarthCare

One of the Core Missions in ESA's Earth Explorer Programme aimed at clouds and climate…

- Satellite Prime → Astrium GmbH
- Broad-Band Radiometer Prime → SEA
  - Supported by RAL Space, SciSys, and Sula



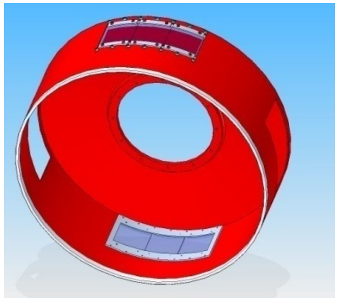
BBR's role is to study the radiance at the top of the atmosphere, in three directions for cloud and climate studies.

Broad-**B**and **R**adiometer

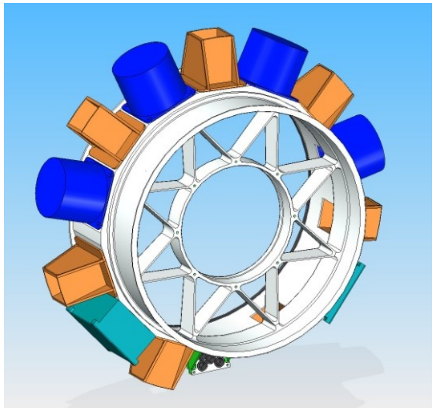
(SEA, **RAL**, Sula, SciSys)

Broad-Band Radiometer (2)

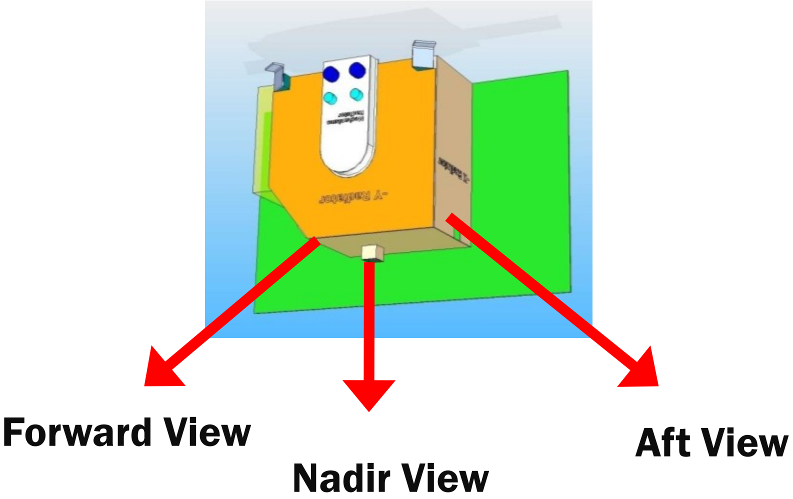
- Contains 3 fixed telescopes viewing forward, nadir and aft
  - Each view has a linear array of broadband 2.5-50µm detectors
- Telescope views are 'chopped' between:
  - Earth scenes
  - hot and cold black-body calibration sources
- *RAL Space responsible for:*
  - optical, thermal,
  - mechanical and system design,
  - design and manufacture of the telescope assembly,
  - AIV of the complete instrument



Chopper Drum

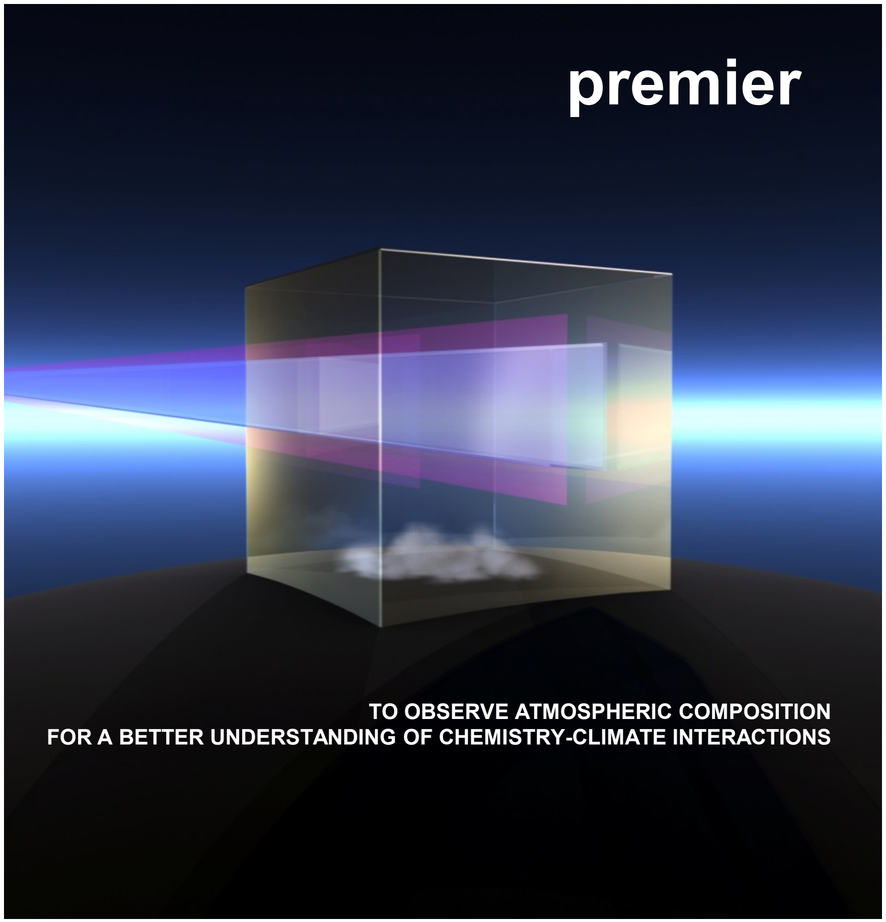


Calibration Drum



Premier

One of the three ESA Earth Explorer 7 Candidate Missions



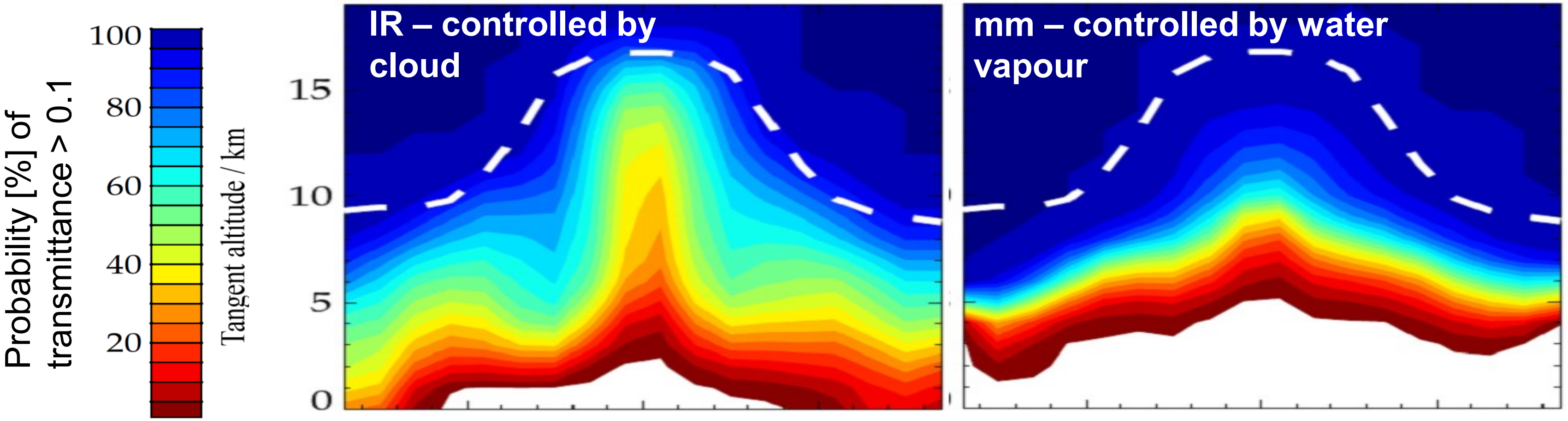
- To explore processes controlling global atmospheric composition in the mid/upper troposphere and lower stratosphere; region of particular sensitivity for surface climate.
  - *by resolving 3-D structures of trace gases, thin cirrus and temperature in this region on finer scales than previously accessible from space*
- To explore links with surface emissions and pollution
  - *by exploiting synergies with nadir-sounders on MetOp/SG*
- **Scientific Objectives**
  - A. Impact of UTLS variability and the general circulation on surface climate
  - B. Trace gas exchange between the troposphere and stratosphere
  - C. Impact of convection, pyro-convection and their outflow on UTLS composition
  - D. Processes linking the composition of UTLS and the lower troposphere
- In addition, to advance operational applications for satellite composition data and contribute to global, height-resolved monitoring

Complementarity of IR and mm-wave limb sounders

- **Target trace gases:**
  IR: CH_4; organic compounds; nitrogen oxides
  mm-wave: CO; HCN & CH_3CN (biomass burning indicators);

- **Sensitivity to cirrus particle size:**
  IR: $R_e < 100\mu$
  mm-wave: $R_e > 100\mu m$

→ *Different penetration depths into troposphere for H_2O, O_3, HNO_3 & HCN*



Thank you for you attention!