Measuring Sea Surface Temperature and Climate Variables from ATSR to SLSTR

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Outline

- **The Along Track Scanning Radiometers.**
- **Some of the ATSR Achievements**
- **Key technology advances from ATSR to SLSTR**
- **Summary**

Acknowledgements:

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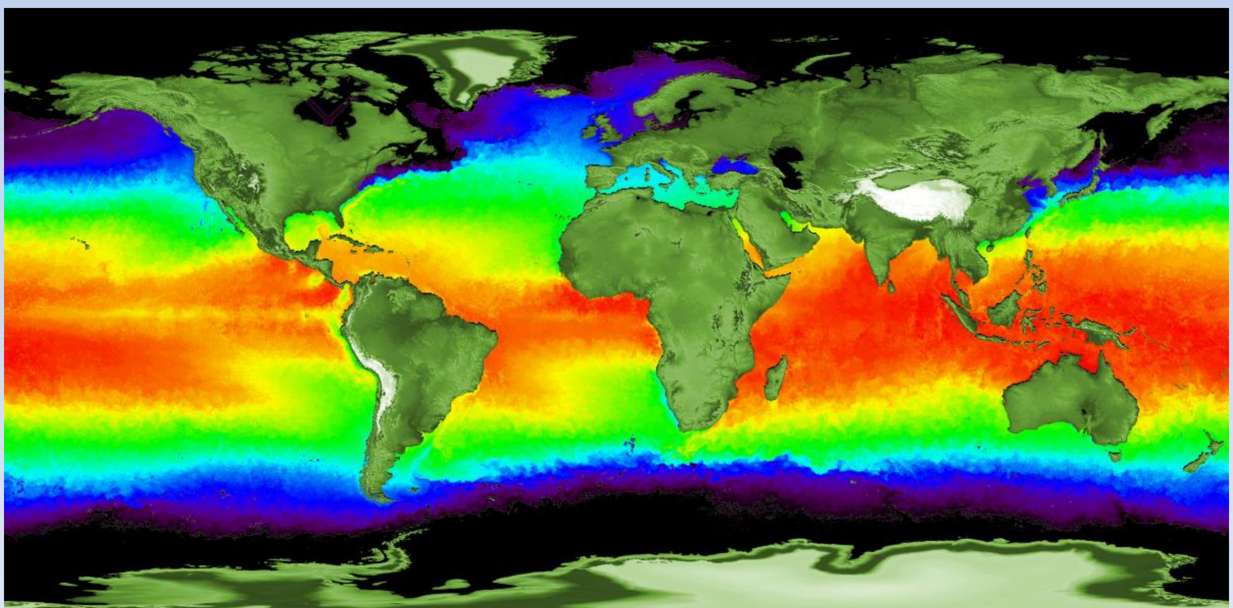
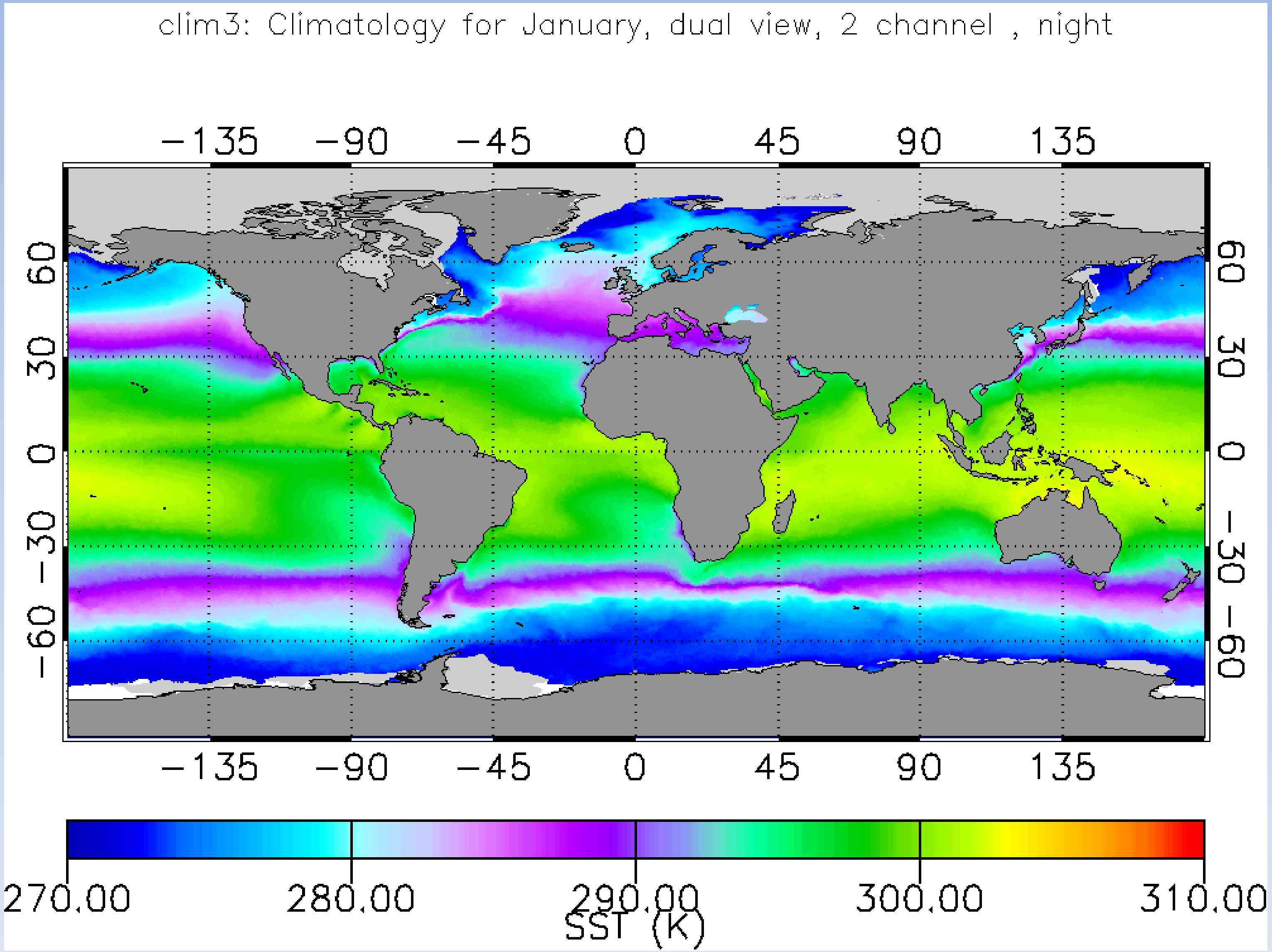
The ATSR Mission

- The Along Track Scanning Radiometer (ATSR) Mission
- Primary objective to measure Sea Surface Temperature (SST) with an accuracy of 0.3 K (1-sigma limit)
- Thermal and visible data for land studies (e.g. temperature, vegetation):
    - Secondary objective is to measure Land ST (LST) with an accuracy of 1.0 K at night and 2.5 K during the day (1-sigma limit)
- Provision of a long-term dataset for global climate change studies

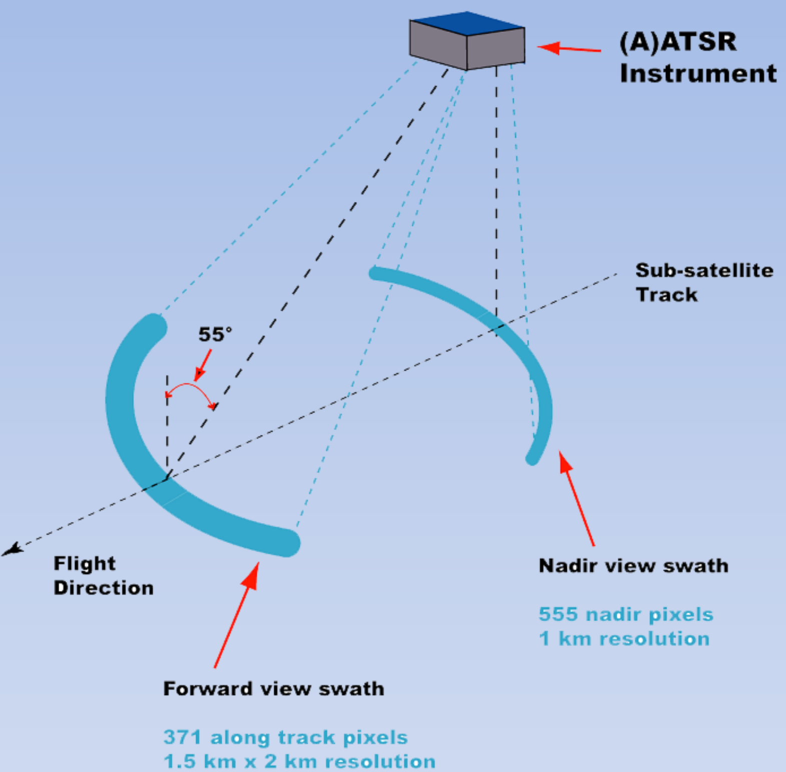


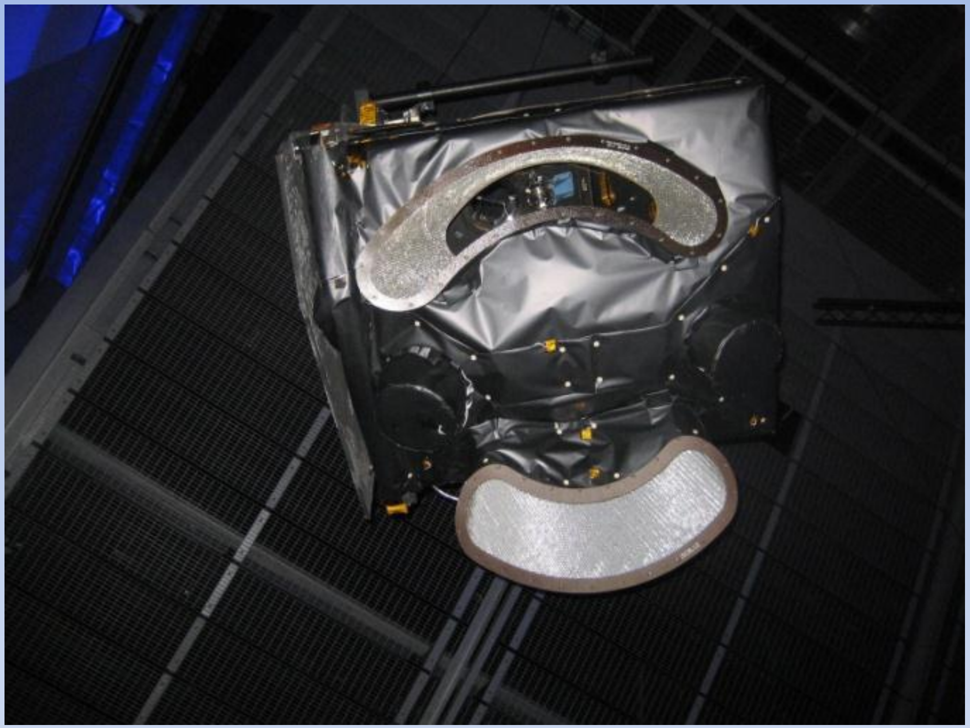
- ATSR-1 (ERS-1)
  09/1991 - 03/00
- ATSR-2 (ERS-2)
  04/95 - now
- AATSR (Envisat)
  03/02 – 04/12

ATSR SST CLIMATOLOGY



The Advanced ATSR on ENVISAT

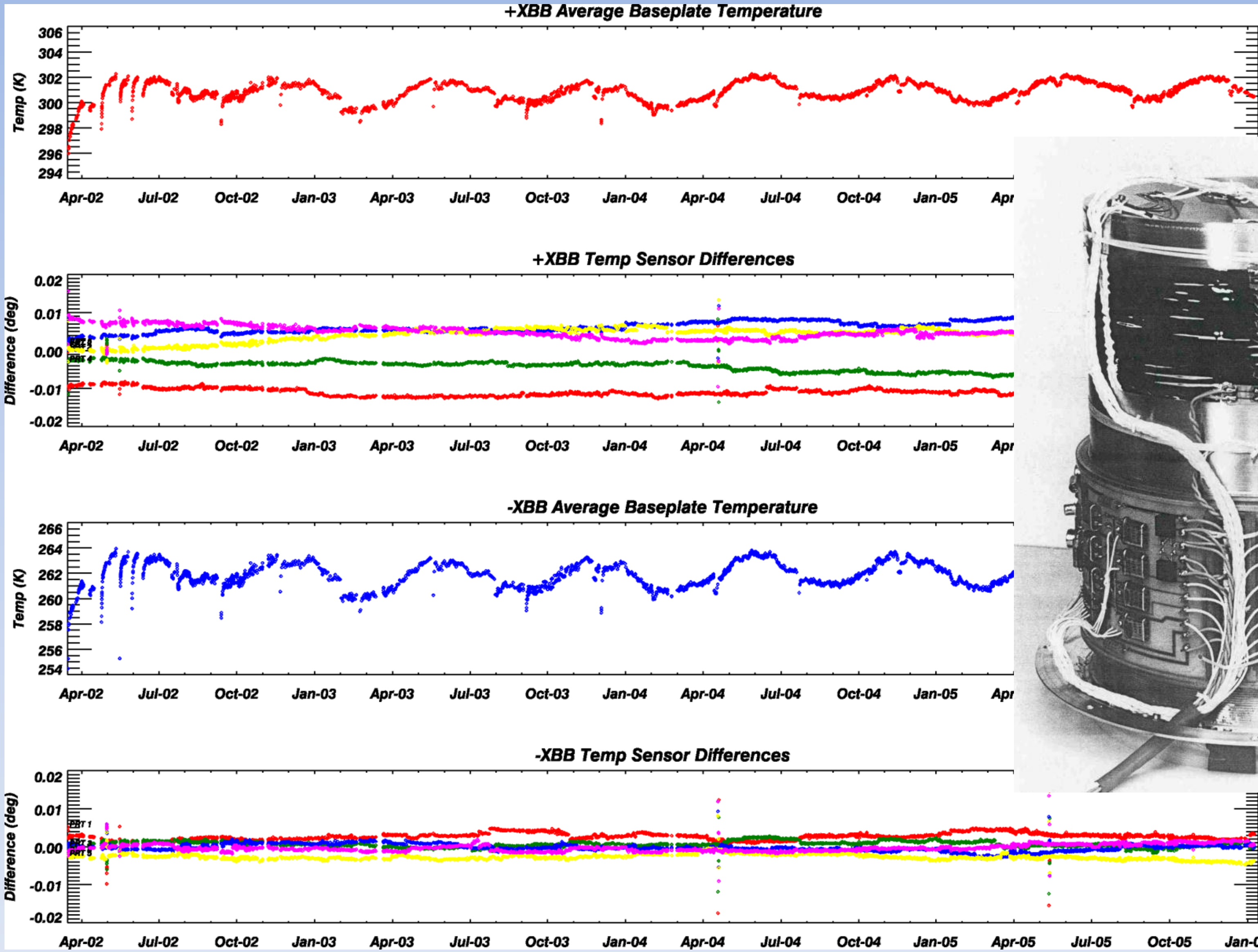


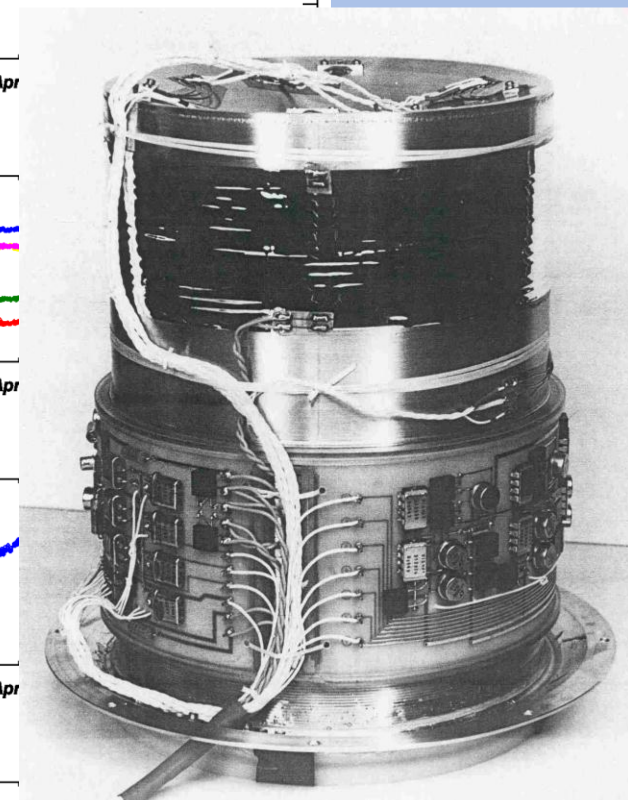


AATSR:

- Dual-view infra-red radiometer (atmosphere correction)
- Three thermal IR channels for surface temperature (ST): 12, 11 and 3.7 microns
- Intrinsic on board calibration: 2 accurate on-board black bodies for IR calibration
- 1 km resolution, 512 km swath width
- Excellent long-term performance in space

BB Temperature Sensor Stability



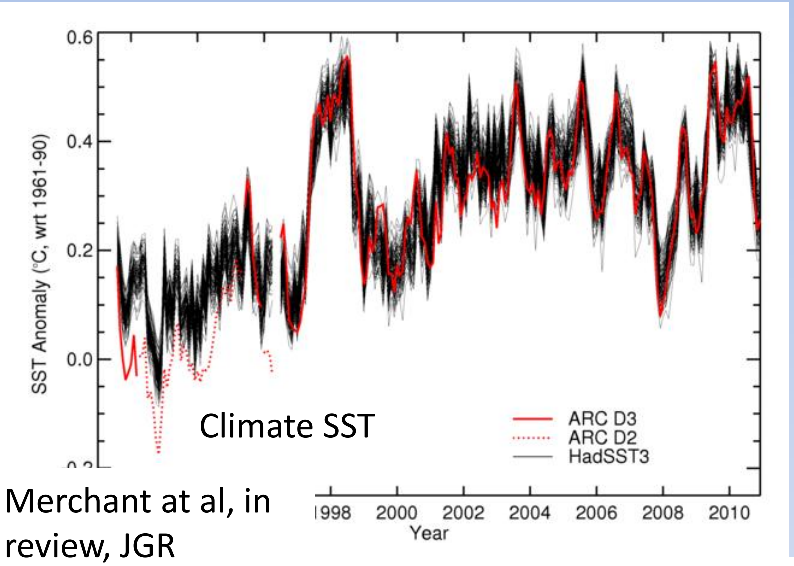


Some ATSR Achievements

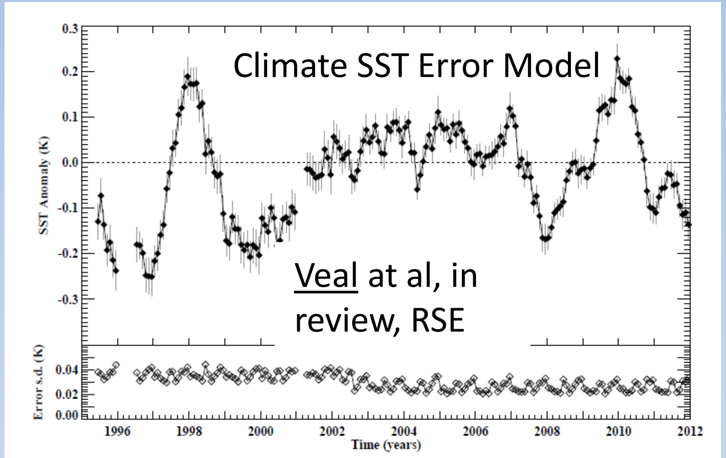
Climate T data sets (now in CCI)

Remote Sensing of Environment Special Issue

- Llewellyn-Jones and Remedios, RSE, 2012 (editors of Special Issue and introduction to issue
- Good et al, RSE 2012, ATSR Saharan dust index over oceans
- Emburey, Merchant and Corlett, RSE 2012, Preliminary ARC validation of ARC SST

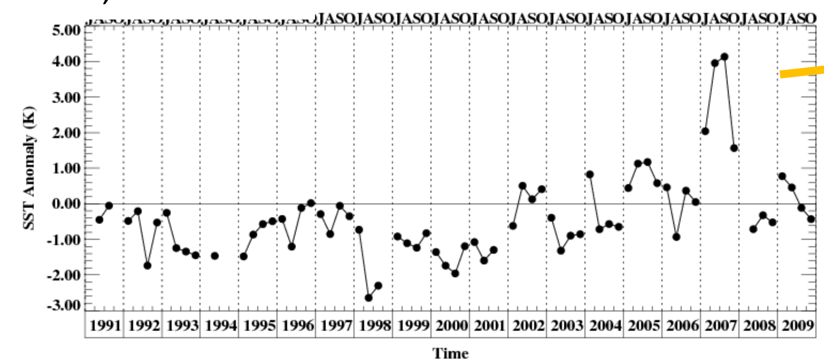


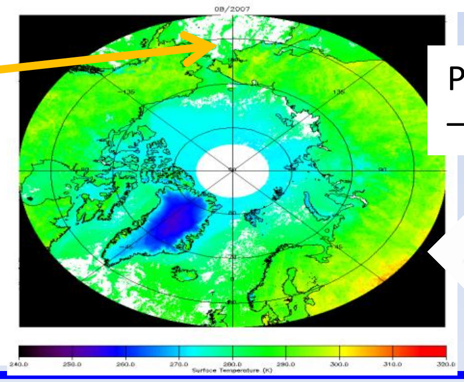
Merchant at al, in review, JGR

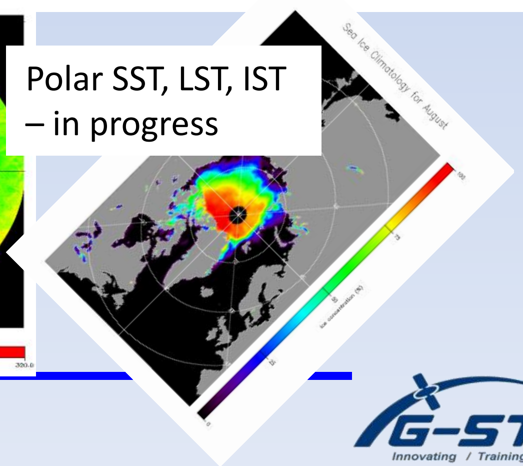


Veal at al, in review, RSE

Figure 10: Night-time dual-view 3-channel monthly mean global SST anomaly (to climatology for the base period January 1997 to December 201` Error bars indicate the estimated 1 sigma uncertainty.

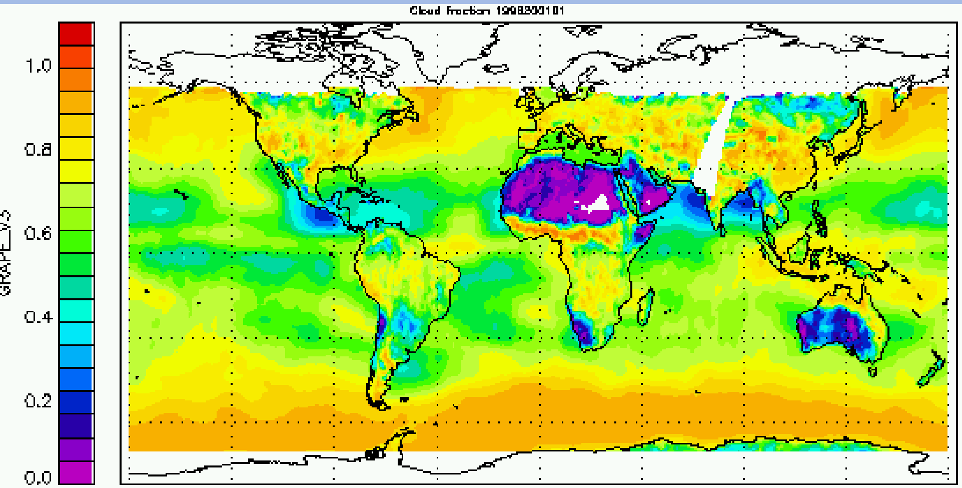




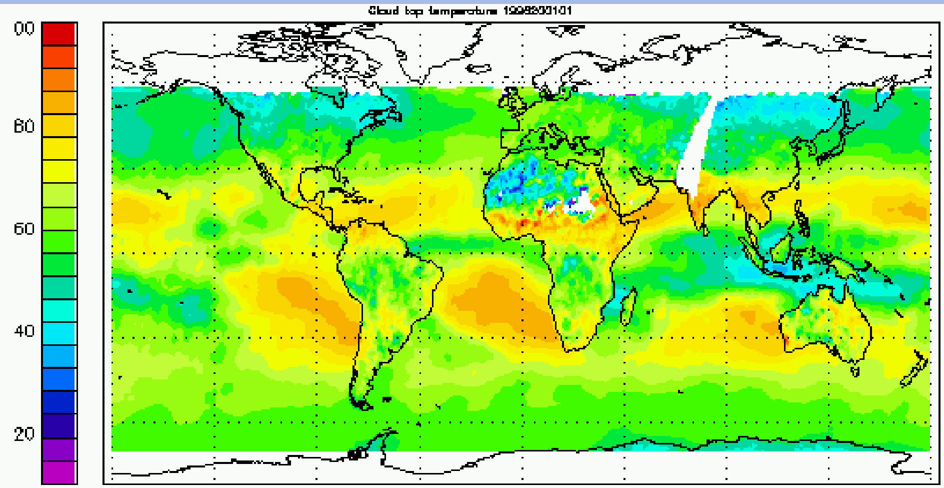


Polar SST, LST, IST – in progress

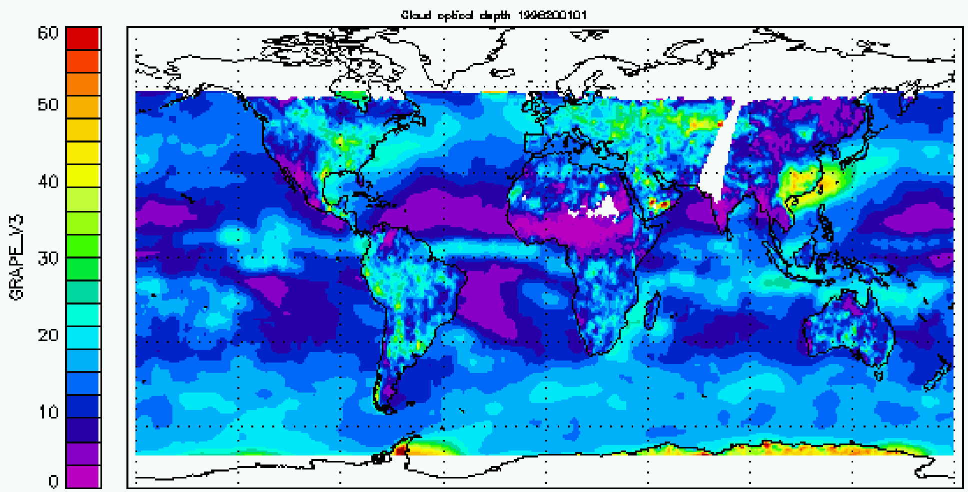
ATSR-2 clouds (now in CCI)



Cloud fraction 1996-2001



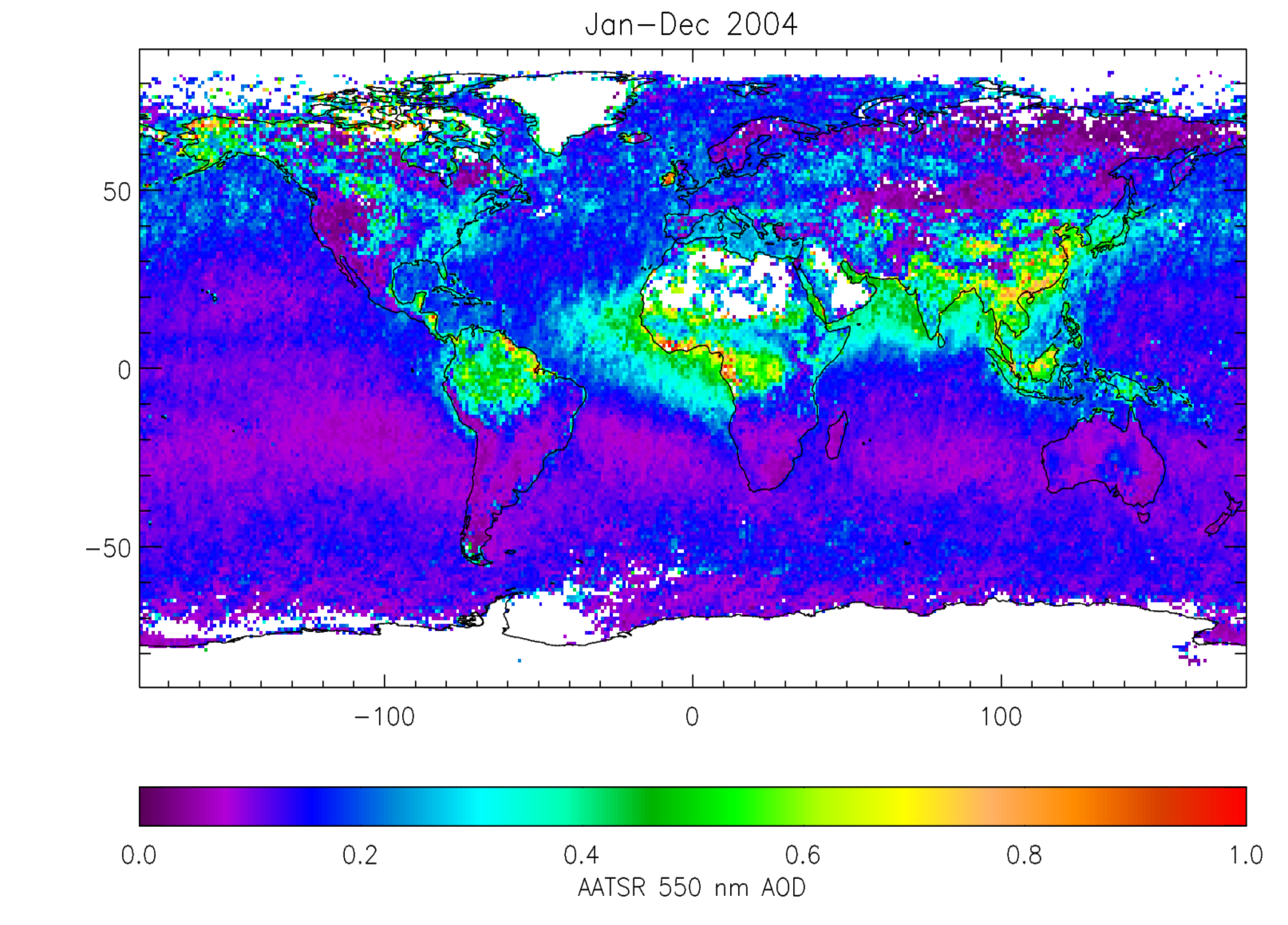
Cloud top temperature 1996-2001



Cloud optical depth 1996-2001

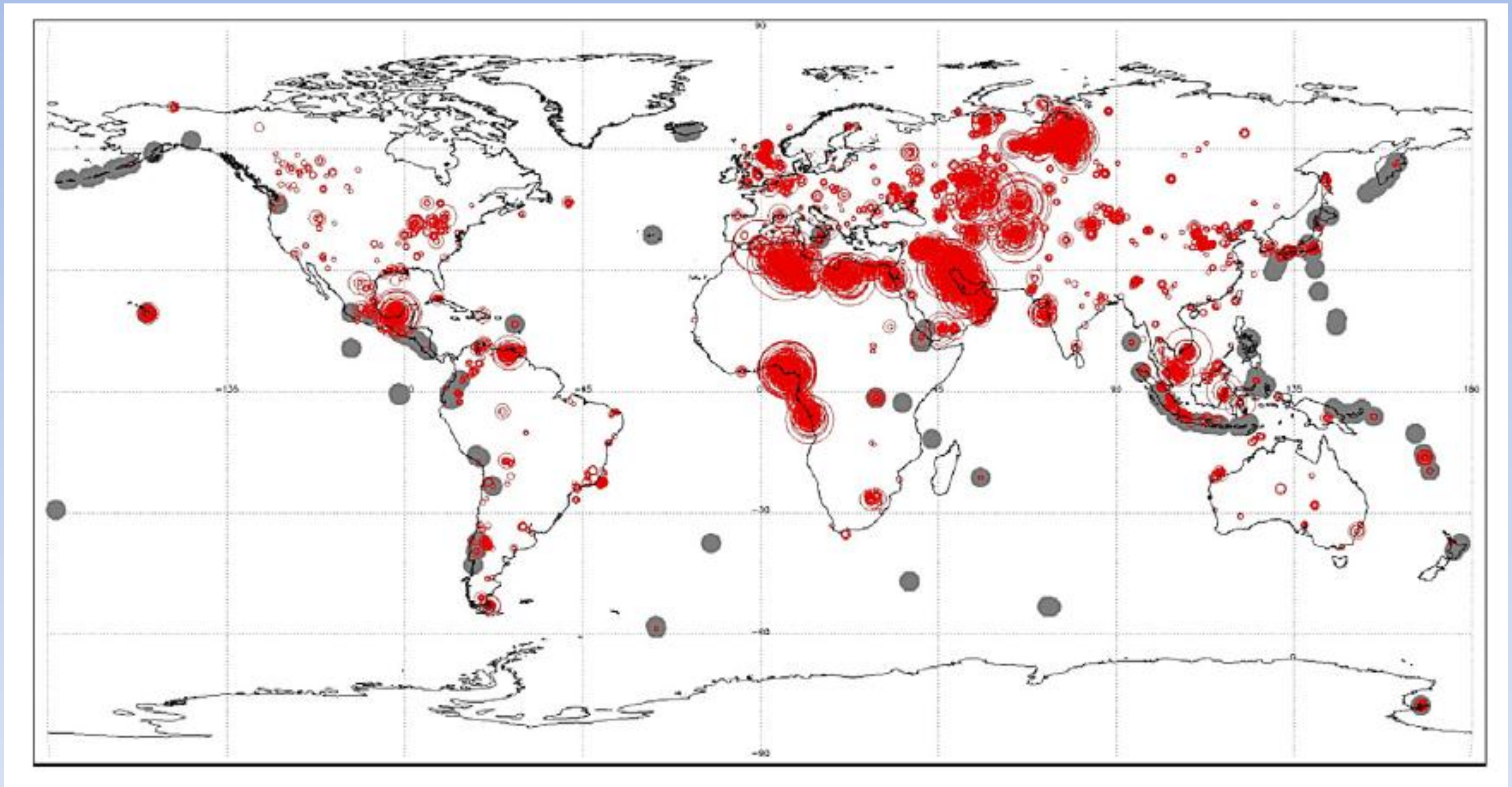
Global cloud data
Poulsen et al, 2010

ATSR aerosols (now in CCI)



Thomas et al, ACP, 2010

ATSR gas flares

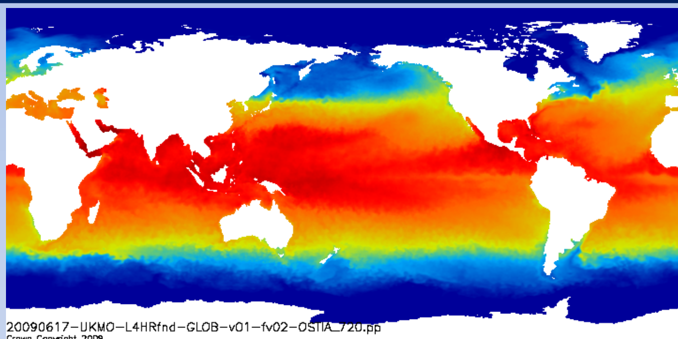


Casadio et al; ALGO3 persistent hot spot sites (1991–2009) RSE 2012

Average night-time SST for May (2003-2008)

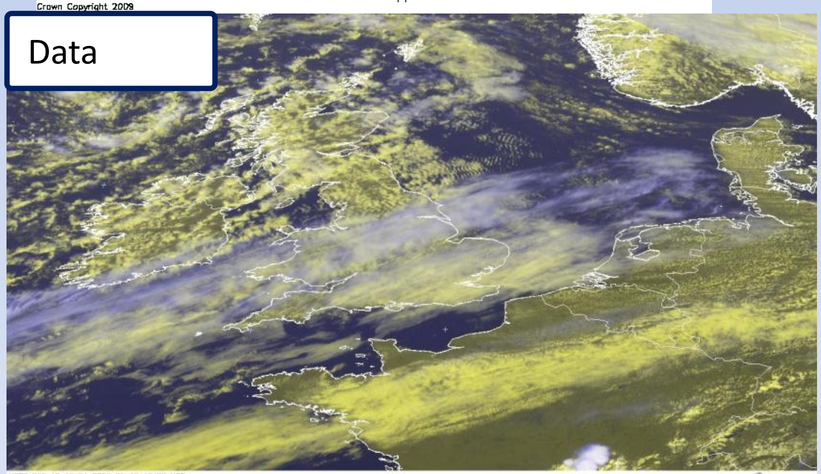
The business of weather forecasting: the Met Office, using AATSR SST

Met Office Ostia SST Analysis: Innovative data fusion. Stark... and Corlett, 2008



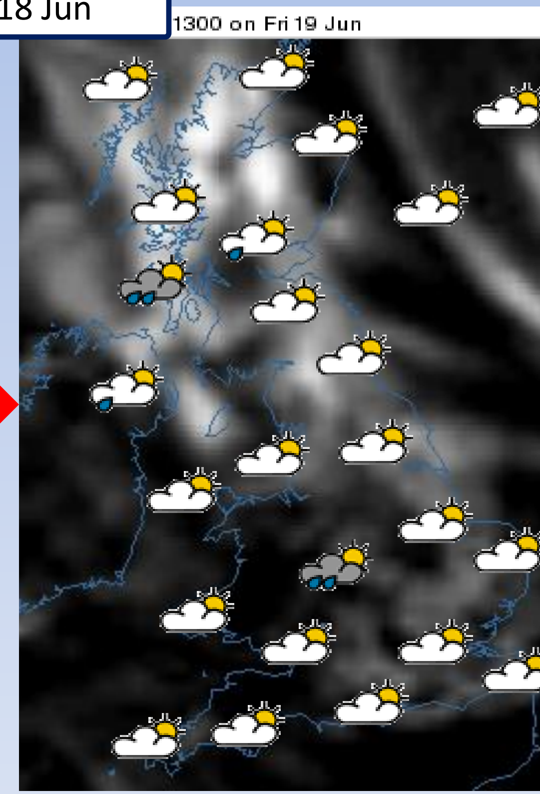
System Development

Data



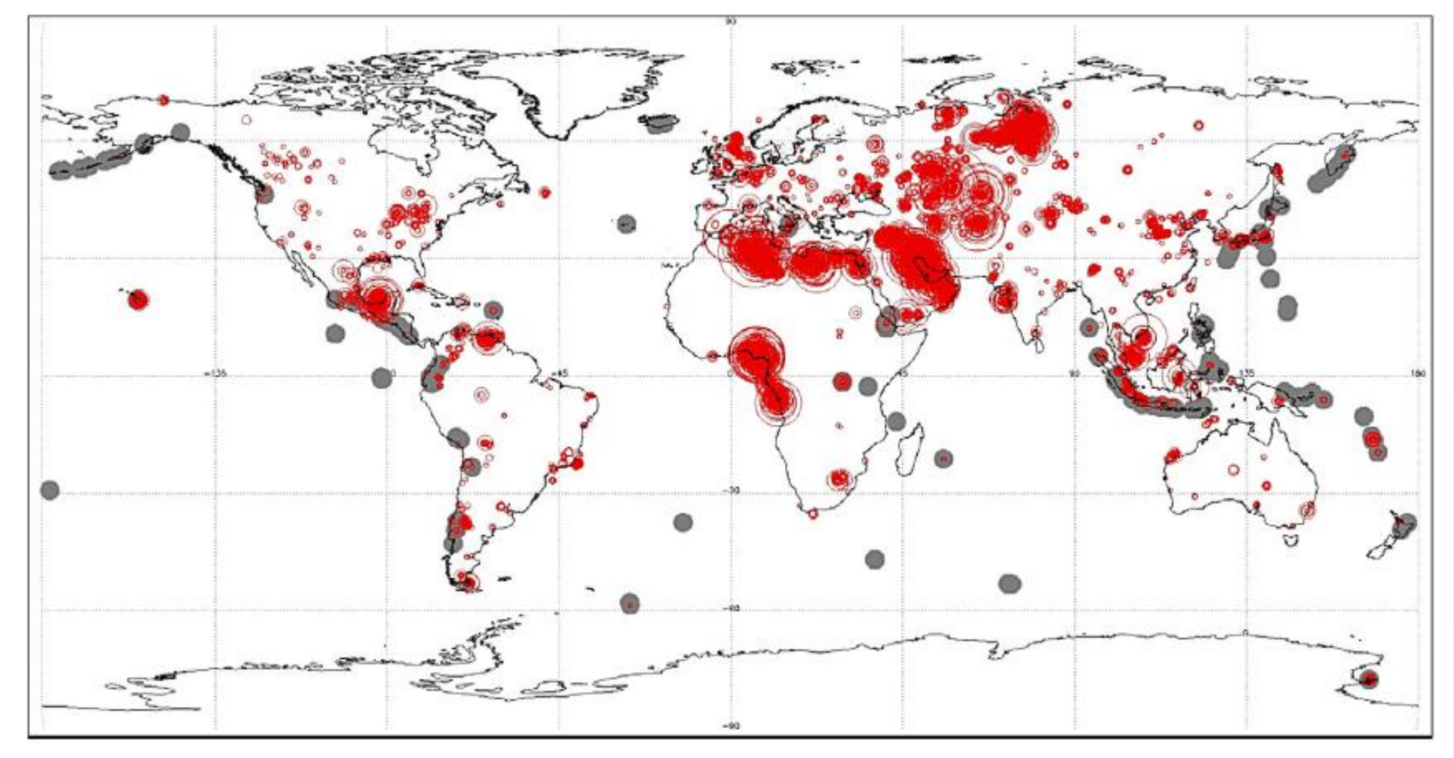
Met Office Forecast Model

Met Office Forecast: 18 Jun



The “Big Picture”

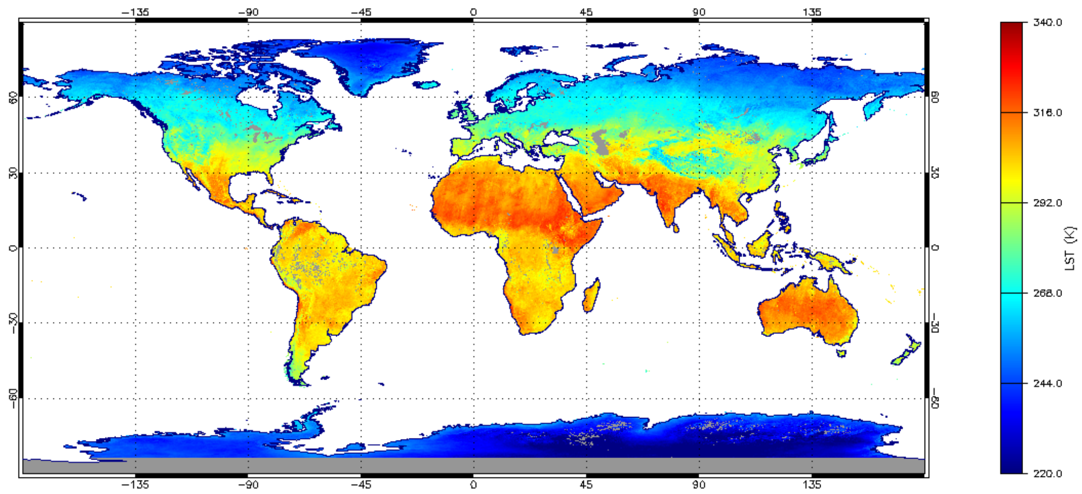
- Climate change time series: SST, aerosols, clouds, fires; LST
- Impact of SST on weather forecasting
- Impacts: SST, LST, fires, gas flares, surface reflectance



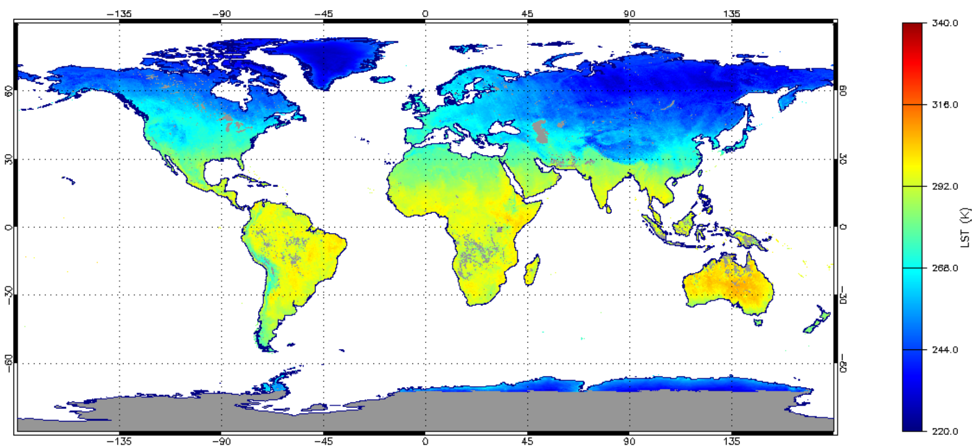
Key technology advances from AATSR to SLSTR on Sentinel-3

Sea and Land Surface Temperature Radiometer

Land Surface Temperature



Day



Night

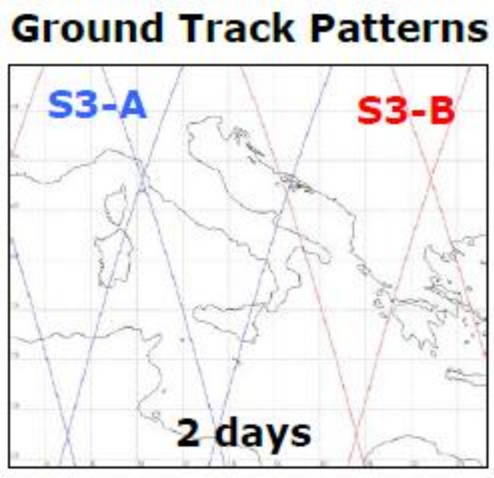
SLSTR characteristics

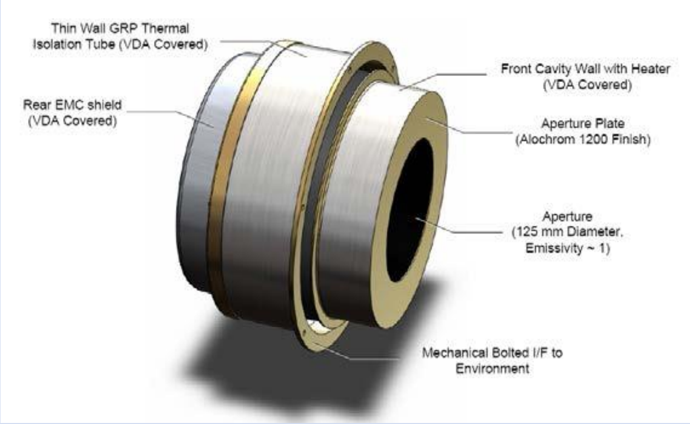
- Equivalent baseline performance to AATSR (ATSR-4!)
- Recognition of LST (land) as being important in addition to SST (sea)
- Backwards oblique view + double scanner
- Wider swath (improved re-visit)
- Extra SWIR (cloud) channels
- Improved fire channels
- Visible channels at 0.5 km resolution
- Launch April 2014

Coppo et al, J. Mod. Opt, 2010
Donlon et al, RSE, 2012

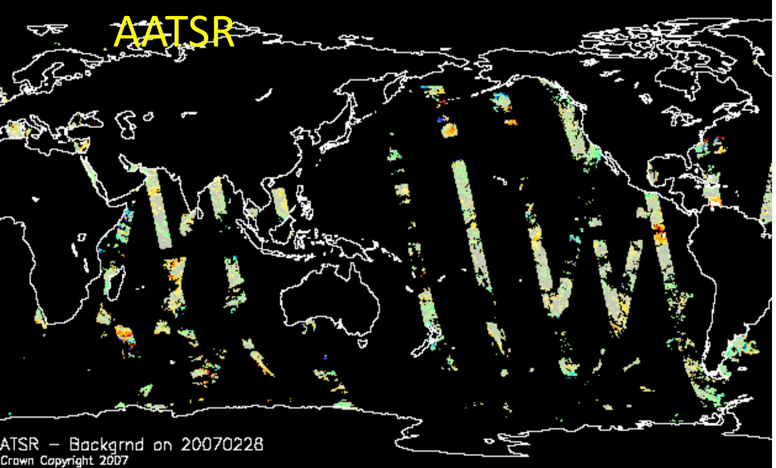
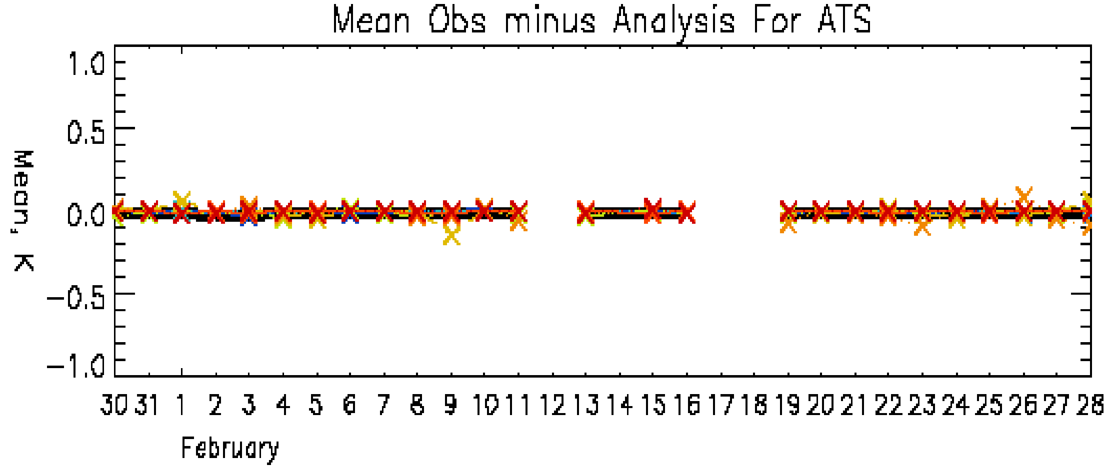
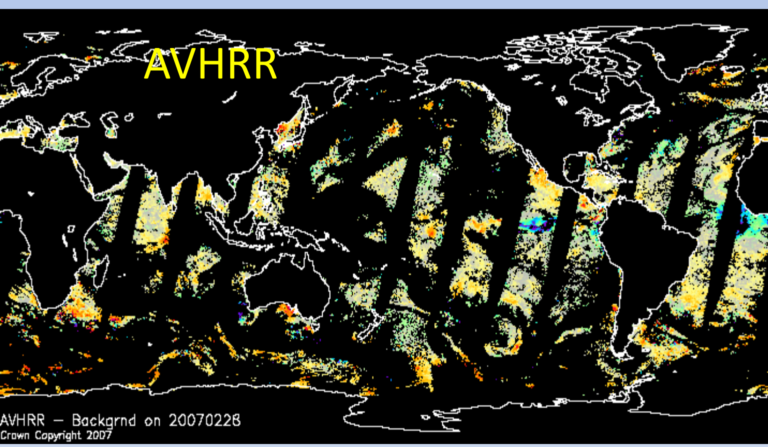
Improved Sampling

- Improve the sampling but maintain dual view
- Use two satellites
- Wider swath (1420 km, nadir) but Instrument design change (double scanner)
- Flip mirror leads to different optical paths nadir vs oblique
- Challenges
  1. Maintain the radiometric calibration
  2. Maintain the thermal stability





8 PRT sensors + 32 Thermistors
T° non-uniformity < 0.02 K
T° Abs. Accuracy 0.07 K
T° error BOL <0.02 K
T° stability < 0.3 mK/s


AATSR
ATSR – Backgrnd on 20070228
Crown Copyright 2007

Mean Obs minus Analysis For ATS
1.0
0.5
0.0
−0.5
−1.0
Mean, K
30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
February

AVHRR
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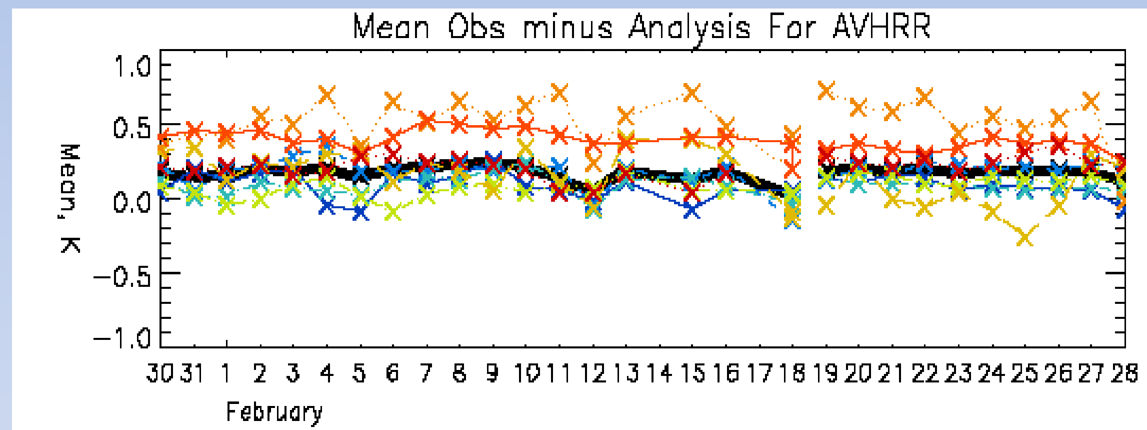
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Mean, K
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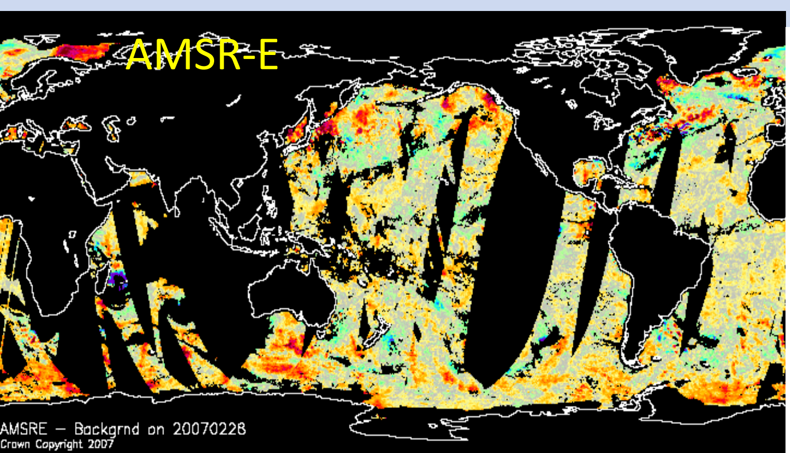
February

AMSR-E
AMSRE – Backgrnd on 20070228
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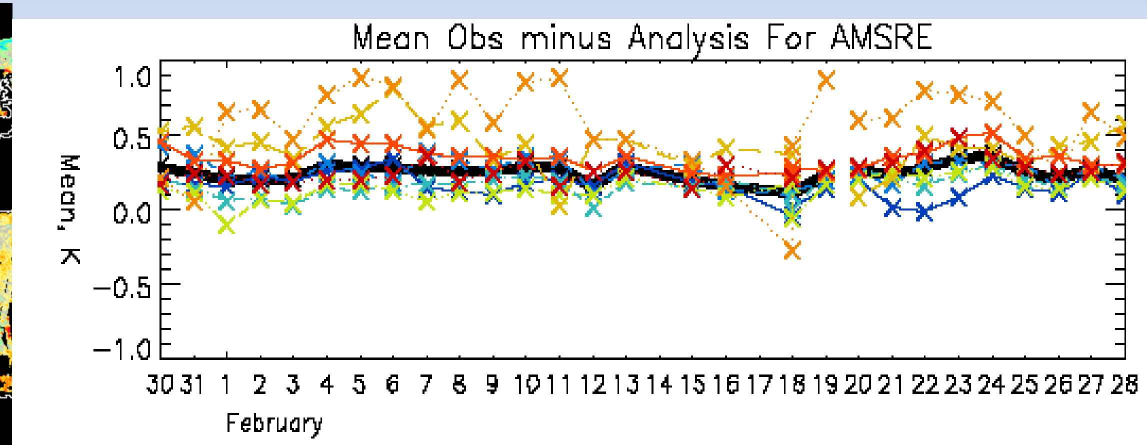
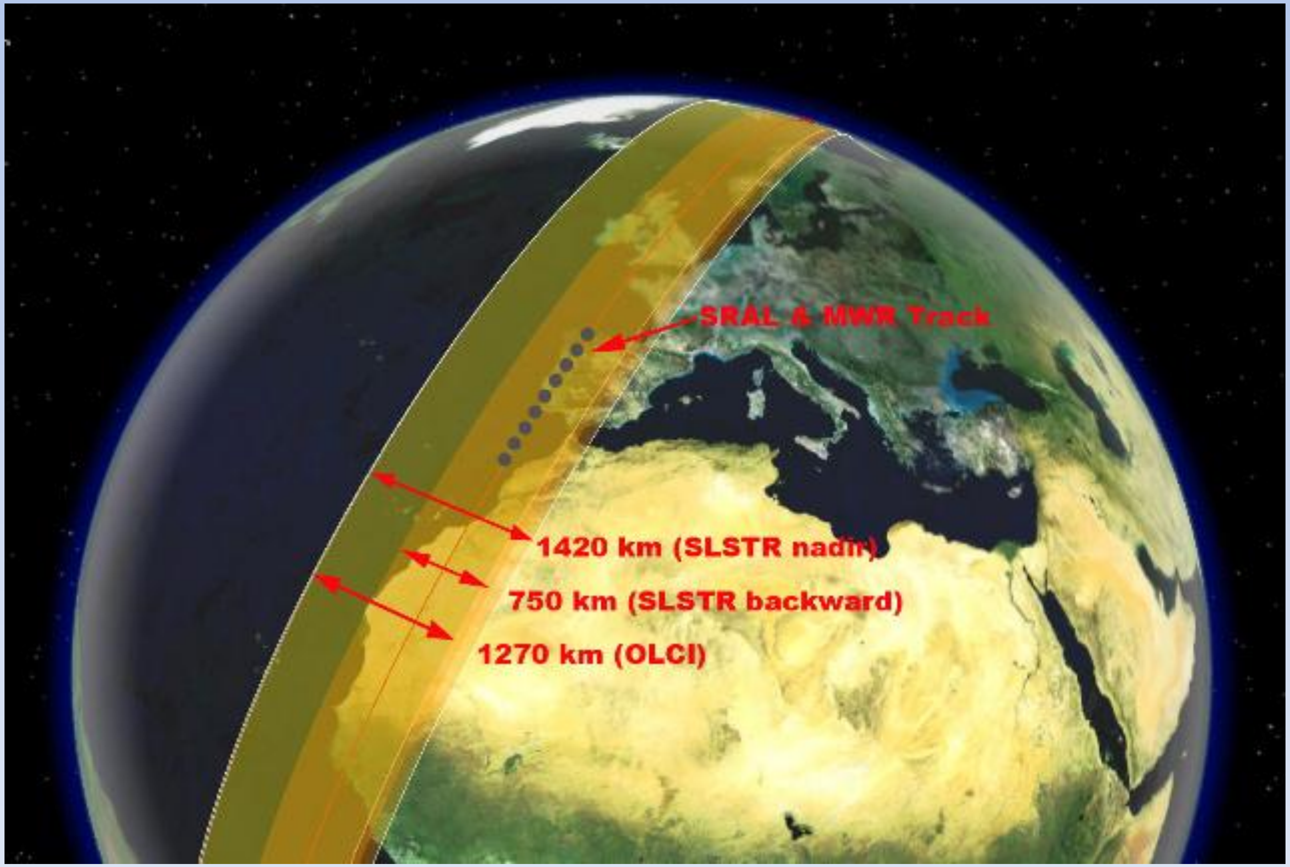

Mean Obs minus Analysis For AMSRE
1.0
0.5
0.0
−0.5
−1.0
Mean, K
30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
February

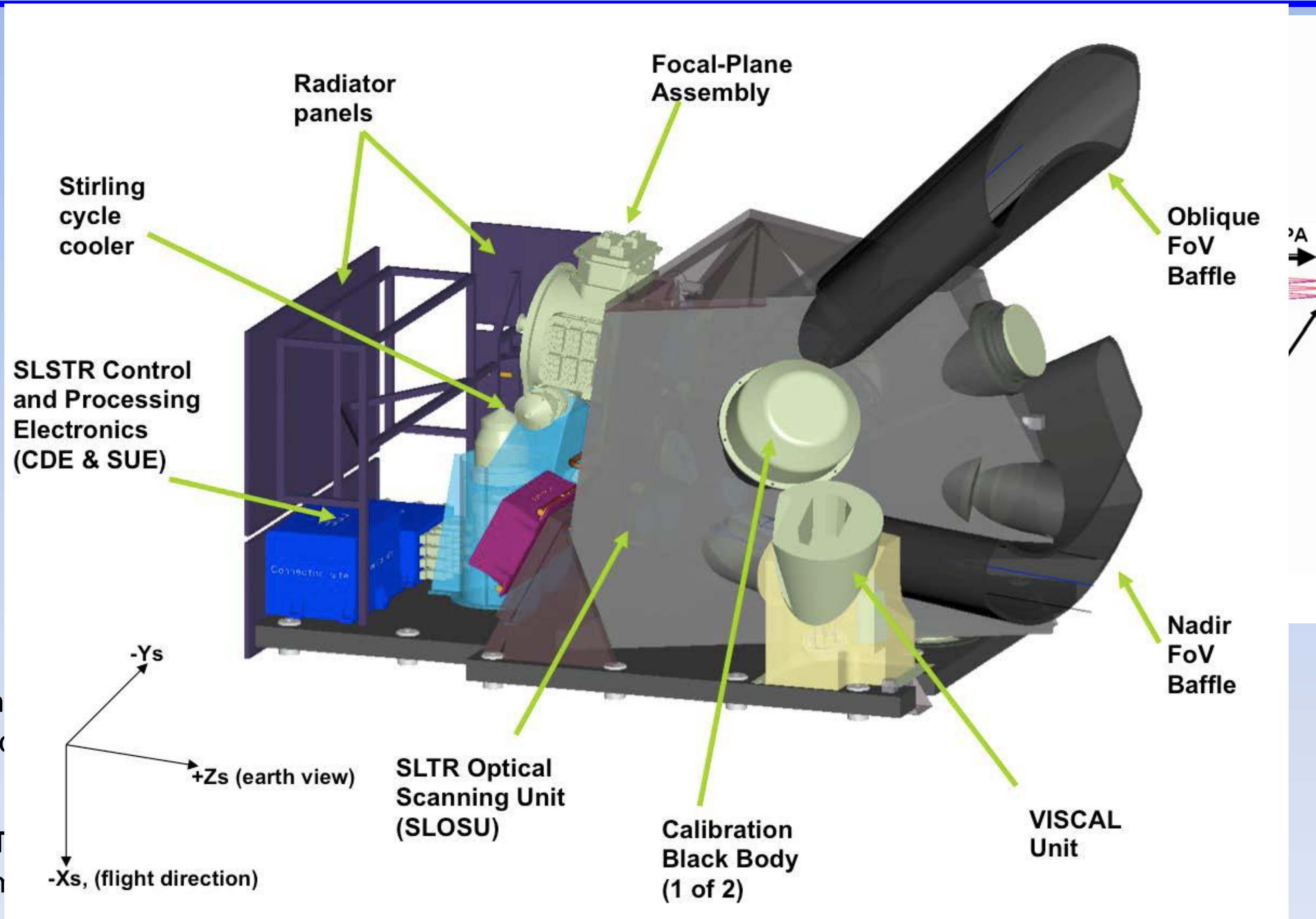
SLSTR: wide swath

- One S-3 gives revisit time of 1.5 to 1.9 days
- Two S-3 gives revisit time of 0.8 to 0.9 days

(but clouds!)



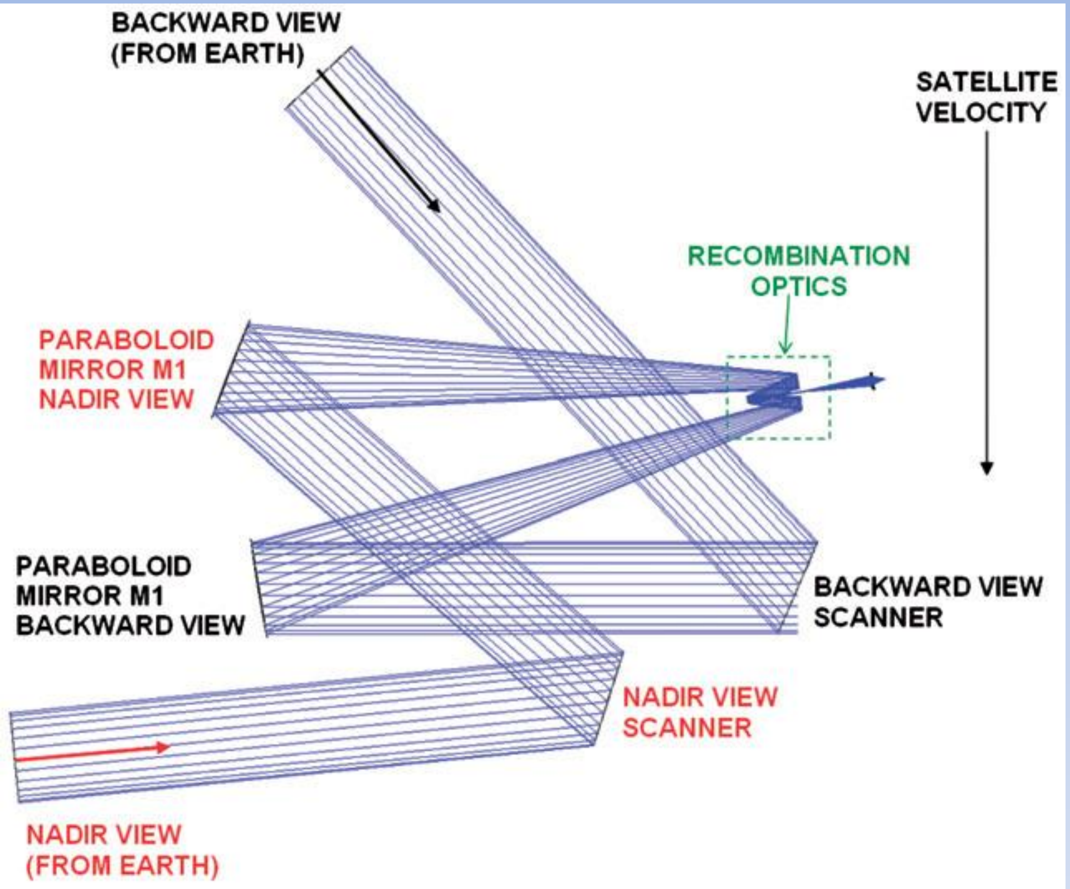
SLSTR schematic

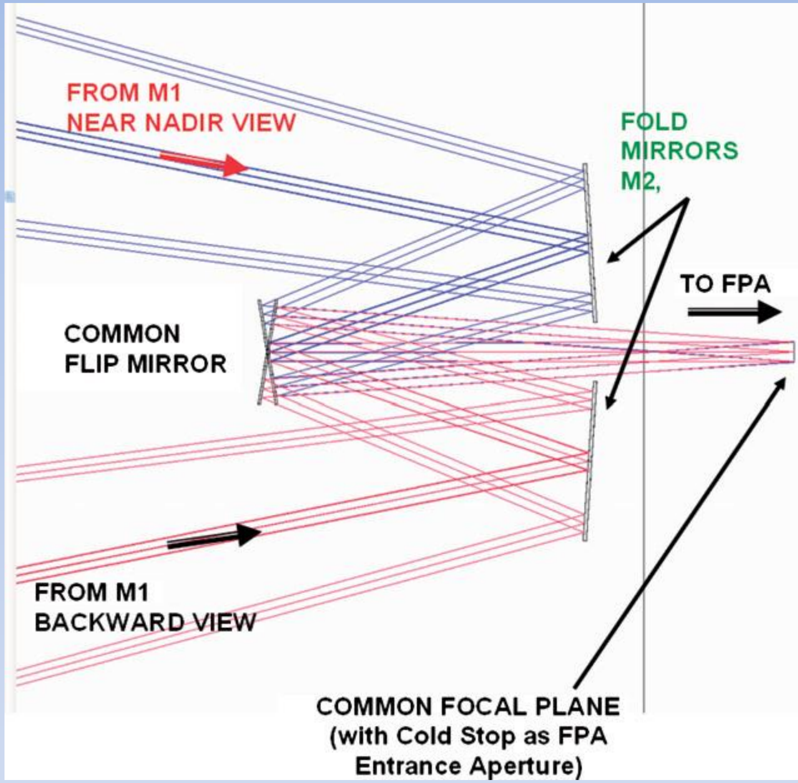


ε viewin
polarised

BT
en

SLSTR double scanner

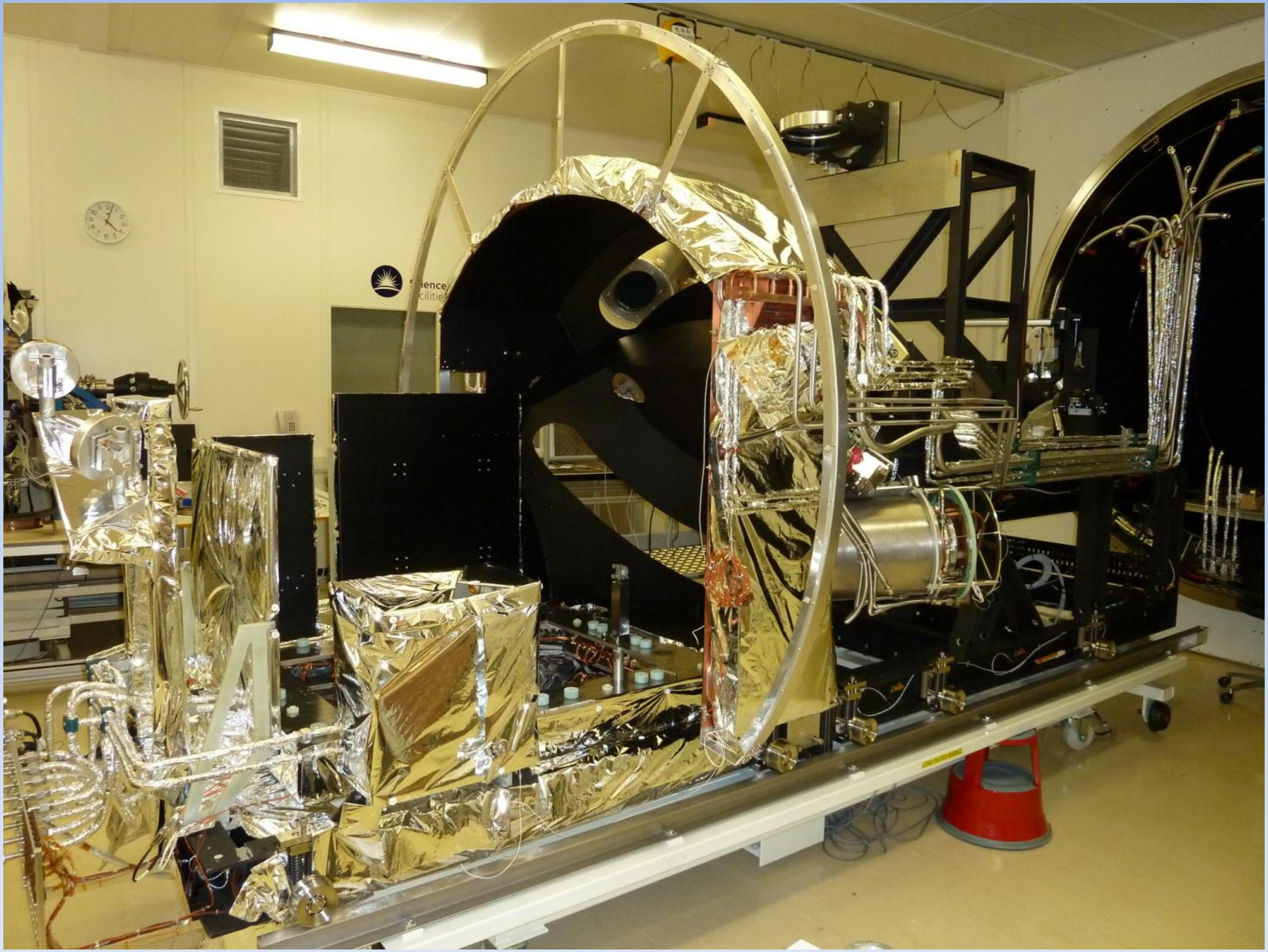




University of Leicester

SLSTR Calibration Facility (RAL)

EOS



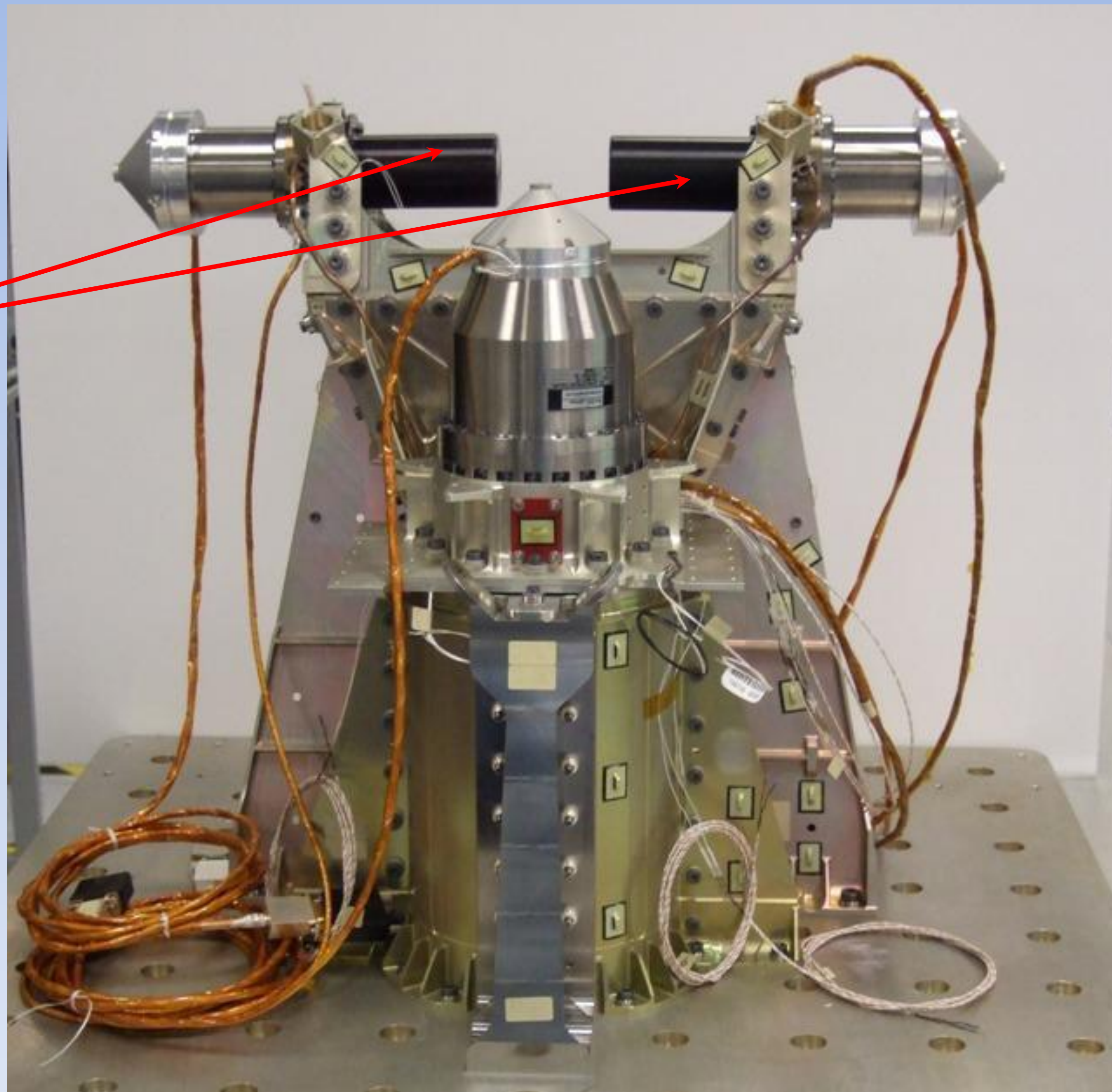
AATSR

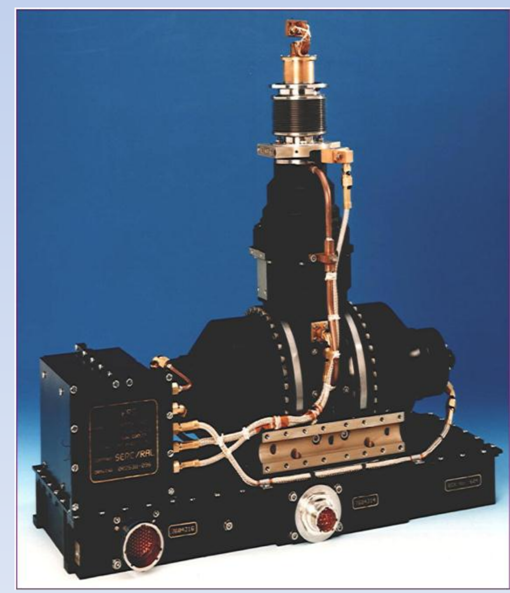
ENVISAT

G-STEP Innovating / Training / Collaborating

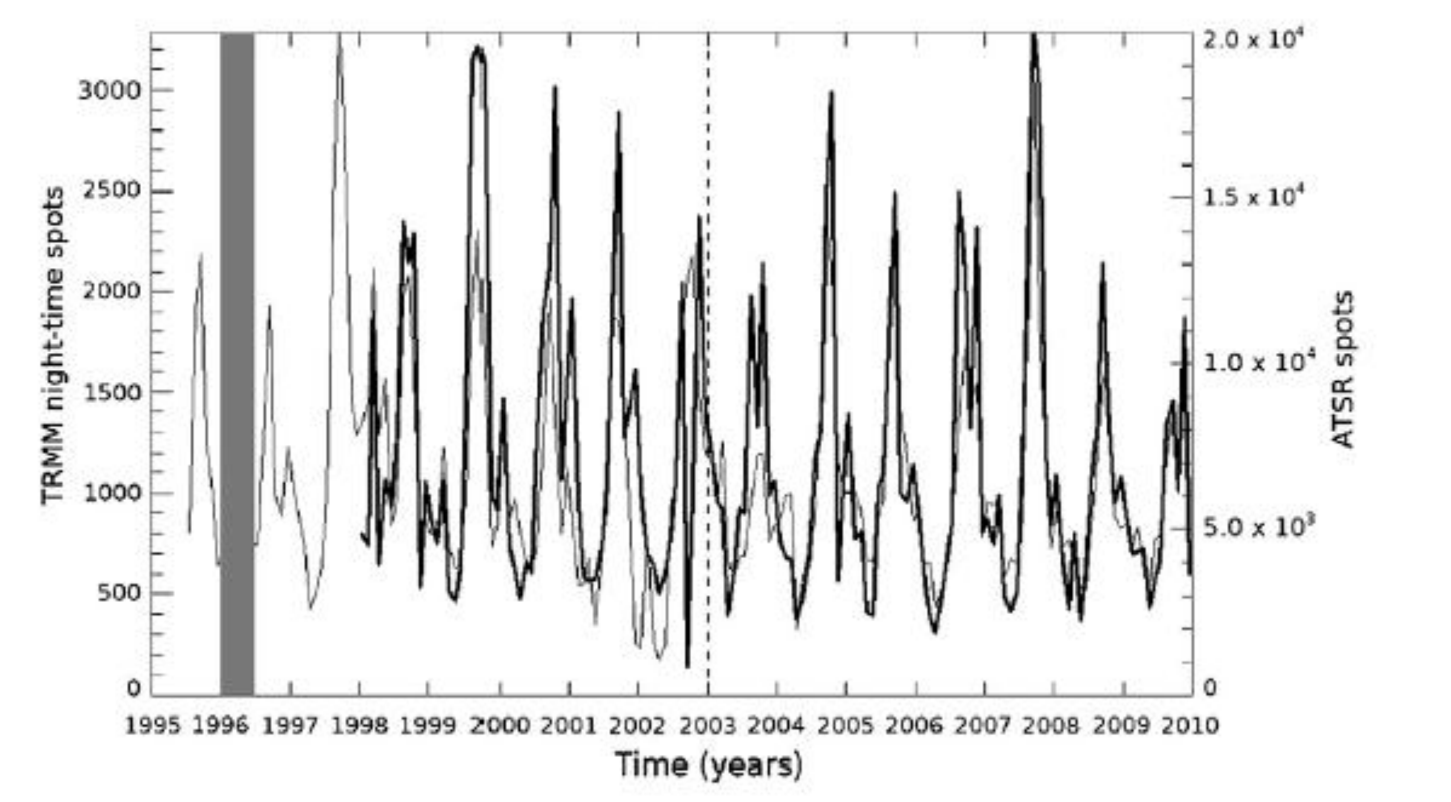
SLSTR Coolers (Astrium)

Cold fingers (50-80 K single stage Stirling cycle coolers





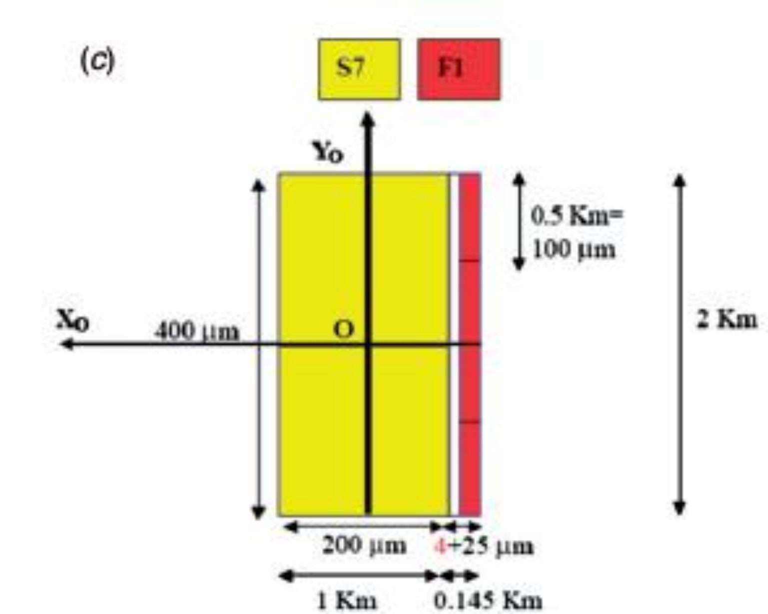
ATSR fires



Monthly night-time ATSR and TRMM-VIRS fire counts (spots) vs. time. Left ordinate axis refers to TRMM-VIRS (black), right ordinate axis refers to ATSR (grey). Casadio et al, RSE, 2012

Fire channels

- "Remove" saturation limit for fire detection day and night
- Use two adapted fire channels with wide dynamic range
  - S7 (F1 = 3.74 μm) with additional narrow pixel column.
  - S8 (F2 = 10.85 μm) with different low gain signal chain
- Include also other channels such as S6 (2.25 μm) in the day
- Fire radiative power (FRP) as well as fire counts (Wooster et al, RSE, 2012)



Synergy: SLSTR and OLCI

- Complete overlap with OLCI (SLSTR nadir view offset from orbit track)
- One common VIS channel (865 nm) used for co-location.
- Synergy level 1c product. Synergy aerosols over land.

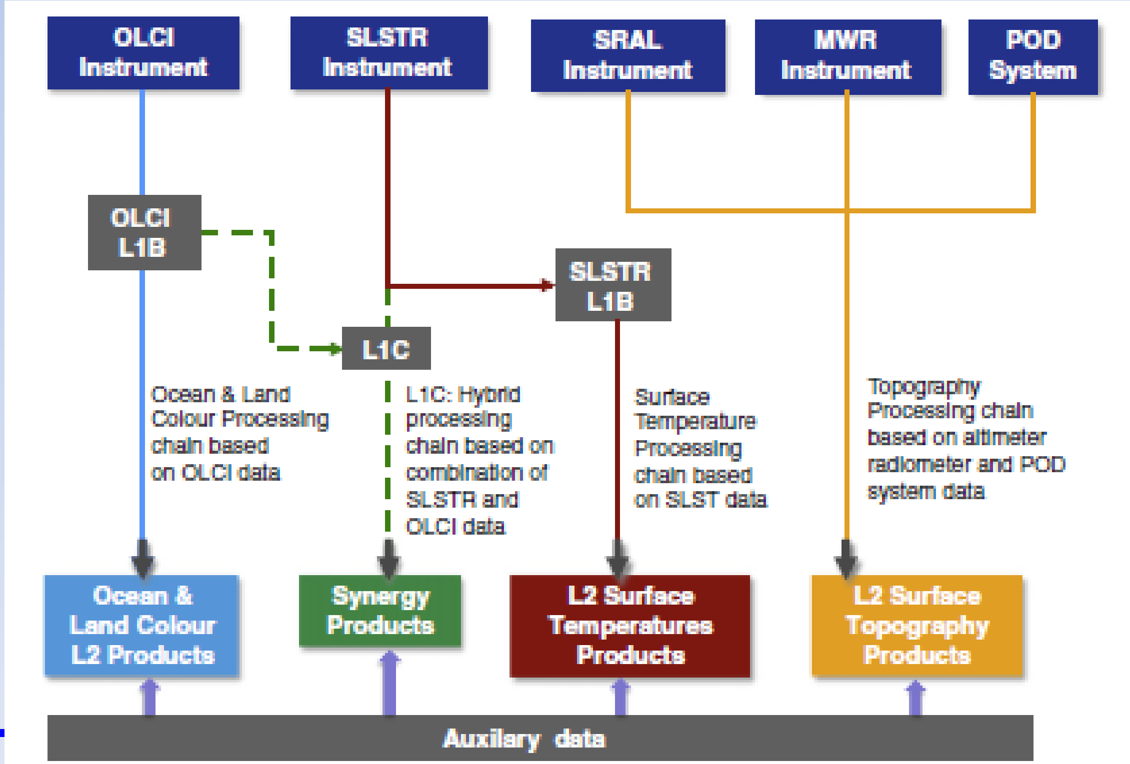


Fig. 12. A schematic overview of Sentinel-3 generic data processing chains.

UK Data Processing

Sentinel-3 operational processing will provide a good stream of data: SST, LST, (synergy) aerosols over land

However:

1. For science (e.g. climate model evaluation), UK scientists will need to improve data quality.
2. For science, we will need further products, e.g. fire, consistent aerosols over ocean/land, clouds. UK scientists lead these efforts
3. The data volumes are very large.

   SLSTR L1 = 230 Tbytes/yr; Synergy L1 = 280 Tbytes/yr

   SLSTR L2 (marine) = 30 Tbytes/yr; SLSTR(land) = 14 Tbytes/yr
4. Need co-ordinated UK data provision and ground segment with academic/industry involvement (CEMS+)

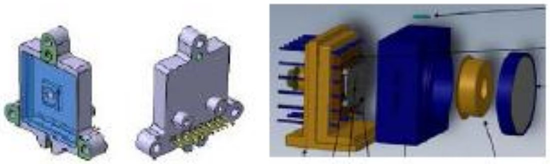
Summary

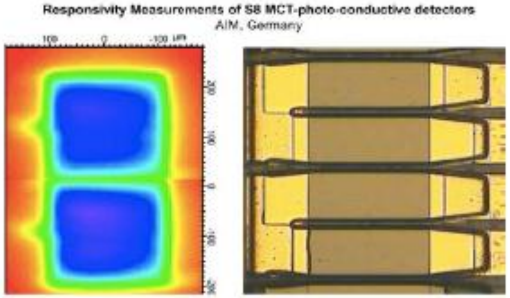
- The ATSR missions have been a great success.
- SLSTR (ATSR-4) is a new step change in the ATSR missions.
- There will be challenges with the launch of the SLSTR instrument: complexity; radiometric calibration; data processing
- UK has strong leadership in ensuring climate quality data sets which will be needed for science and for policy.
- A data gap exists between AATSR and SLSTR.......

SLSTR Detectors

SLSTR Detectors

- S1-S3 (VIS): Si Photo Voltaic
- S4-S6 (SWIR): MgCdTe Photo Conductive
- S7 (MWIR): MgCdTe Photo Conductive
- S8-S9 (TIR): MgCdTe Photo Conductive
- F1 (MWIR): Implemented as additional wafers on S7 detector
- F2 (TIR): Implemented on S8 using additional gain setting





- **The use of detector arrays is a major change from AATSR single element detectors**
- **This is required because of the scanning design**