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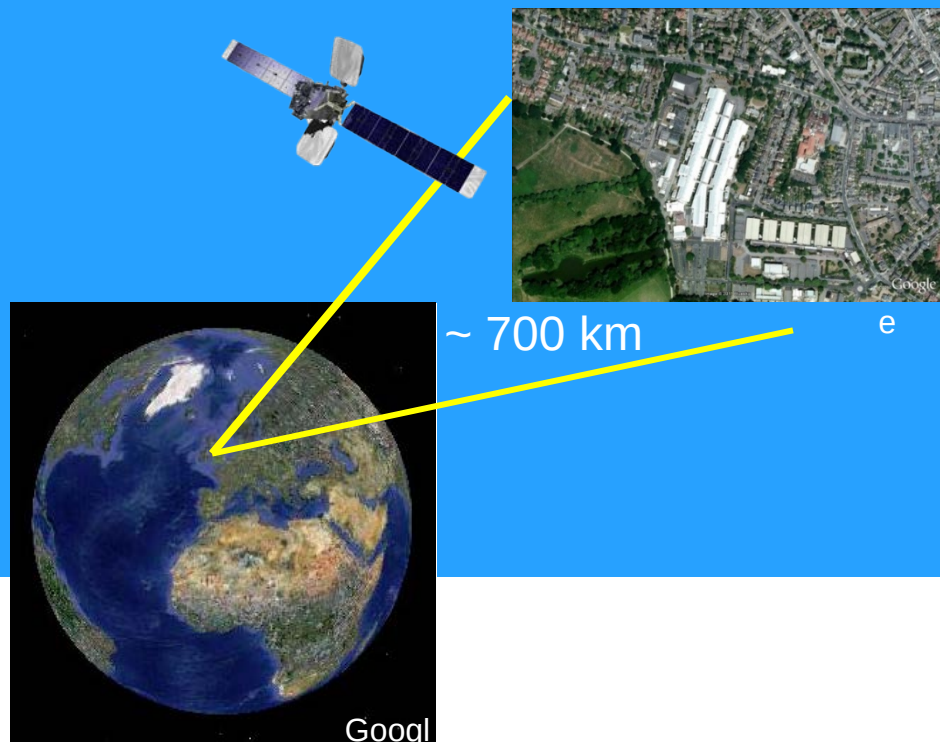
Earth Observation and Climate Measurement

Dr Nigel Fox
Head of Science
EO, Climate & Optical



International community

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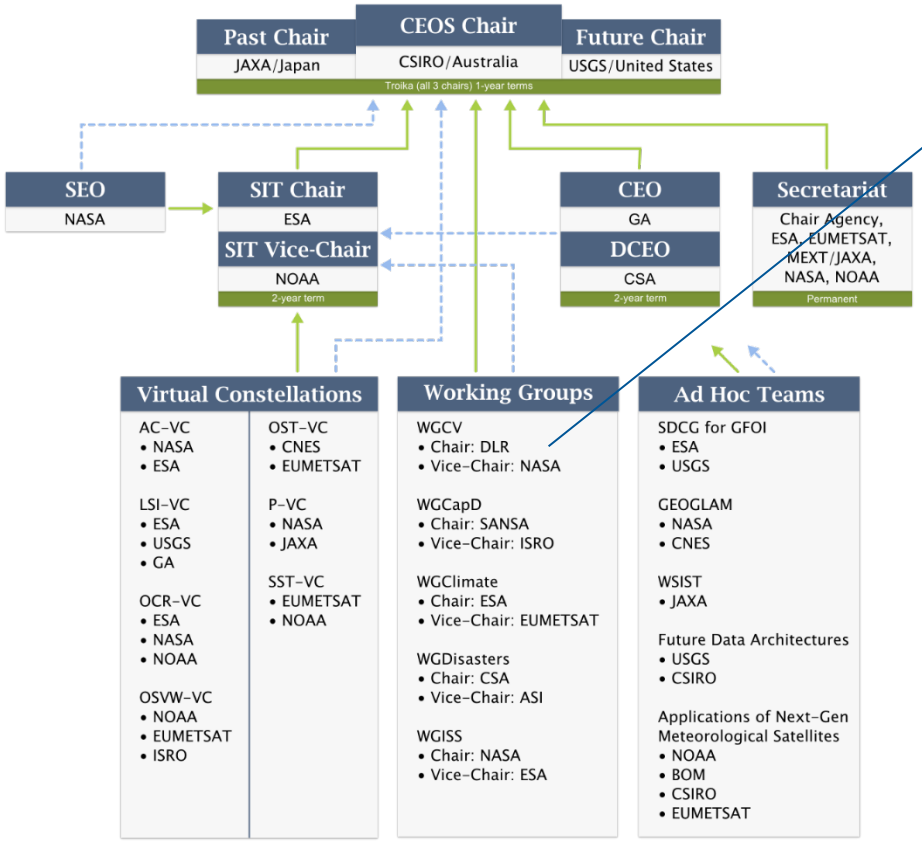
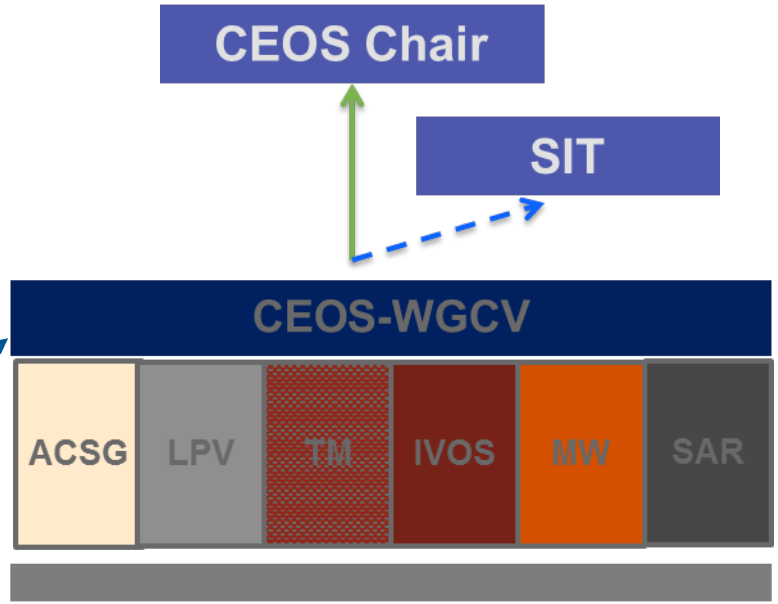
GEO GROUP ON EARTH OBSERVATIONS

103 member countries + 90 organisations

CEOS Committee on Earth Observation Satellites

31 member Agencies + 28 organisations





GSICS Global Space-based Inter-Calibration System

Operational (Meteorological space agencies)

Satellite Data Products:

Knowledge/information

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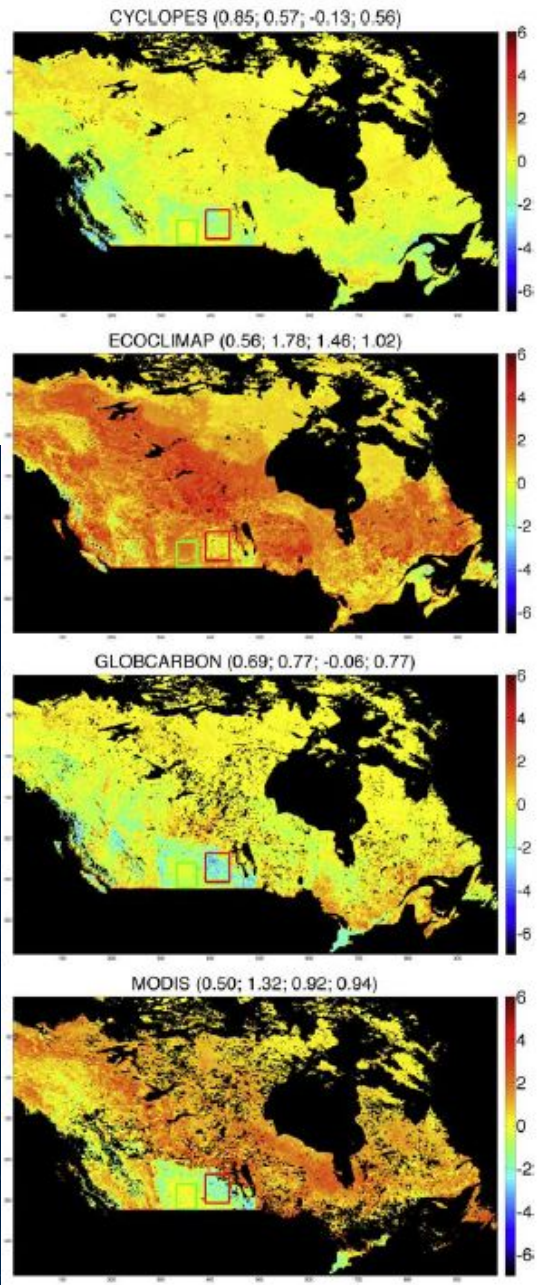
Desire

- Many sensors
- Similar products
- Observations on demand' (nano-sats)
- Trustable for decades

Challenges

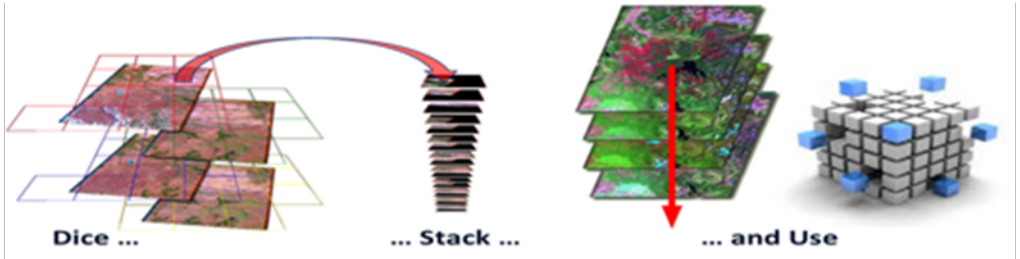
- Different algorithms
- Limited validation data
- Data similar but different
- Scene/pixel dependent Uc
- Lack of standardisation



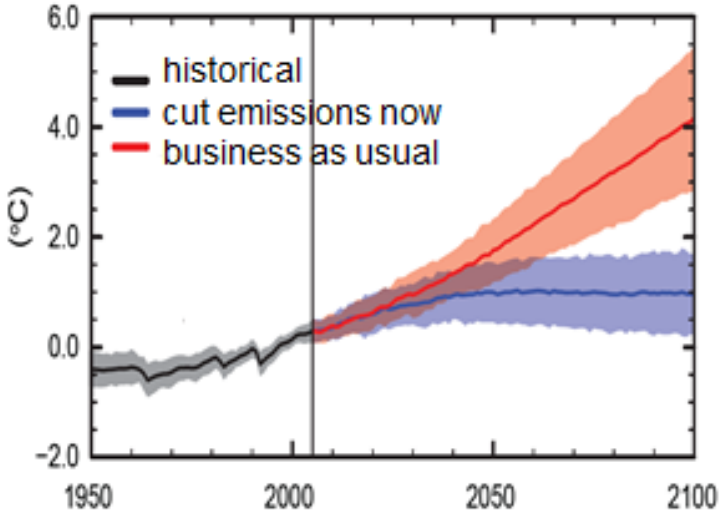
Current challenges

- Unabated climate change could cost up to 20% of GDP (Stern Review, 2006)
- With current data quality, wide variations in climate model forecasts cannot be reduced for many decades
- There are wide economic, political and social implications for 'getting it right'

Thus improving confidence in climate data to inform science, government and policy is our main focus but also supporting applications for agriculture/pollution etc



'Data cube' of 'Analysis Ready Data' requires robust analytics and provenance/QA from all data streams increasingly from 'on- demand' capacity from nano-sats



Earth observation at NPL

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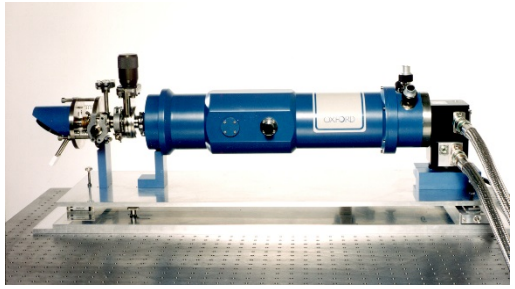
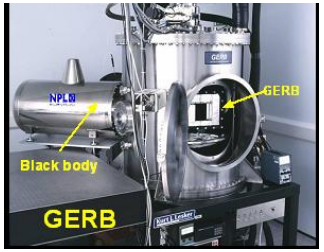
Satellite data quality

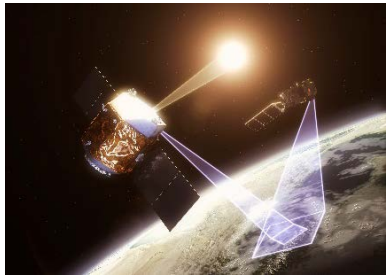
Pre-flight





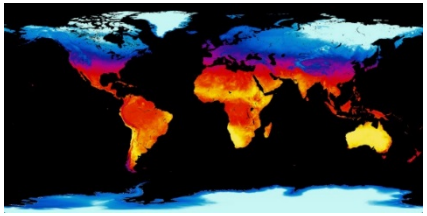
Instrument calibration and quality assurance
Current sensors under Cal Sentinel 2, 3, 4, EarthCARE, MTG

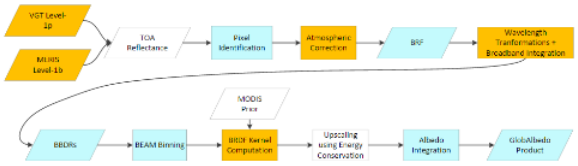
In-flight



Establishing test-sites, field-work validation & leading a world-first satellite calibration system, TRUTHS

Products & Exploitation



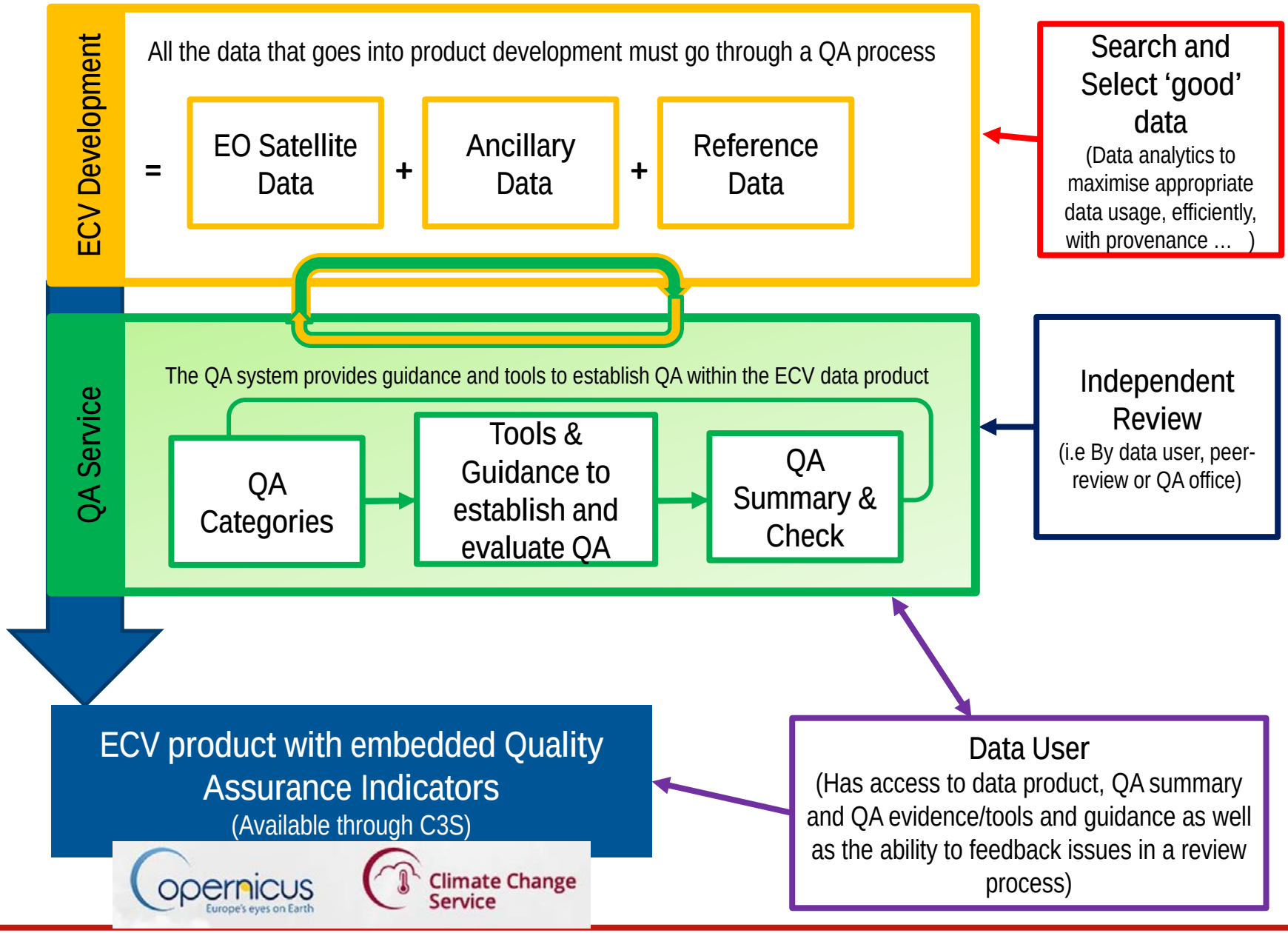


Improving climate services & models to support UK policy

Essential Climate Variables (ECV)

The Global Climate Observing System (GCOS) of UN has defined 50 ECVs that must be observed accurately over the long term to support climate modelling (~2/3 have an optical related measurand)

FRAMEWORK FOR IMPLEMENTING QA IN ECV DATA PRODUCTS



Traceability Diagrams

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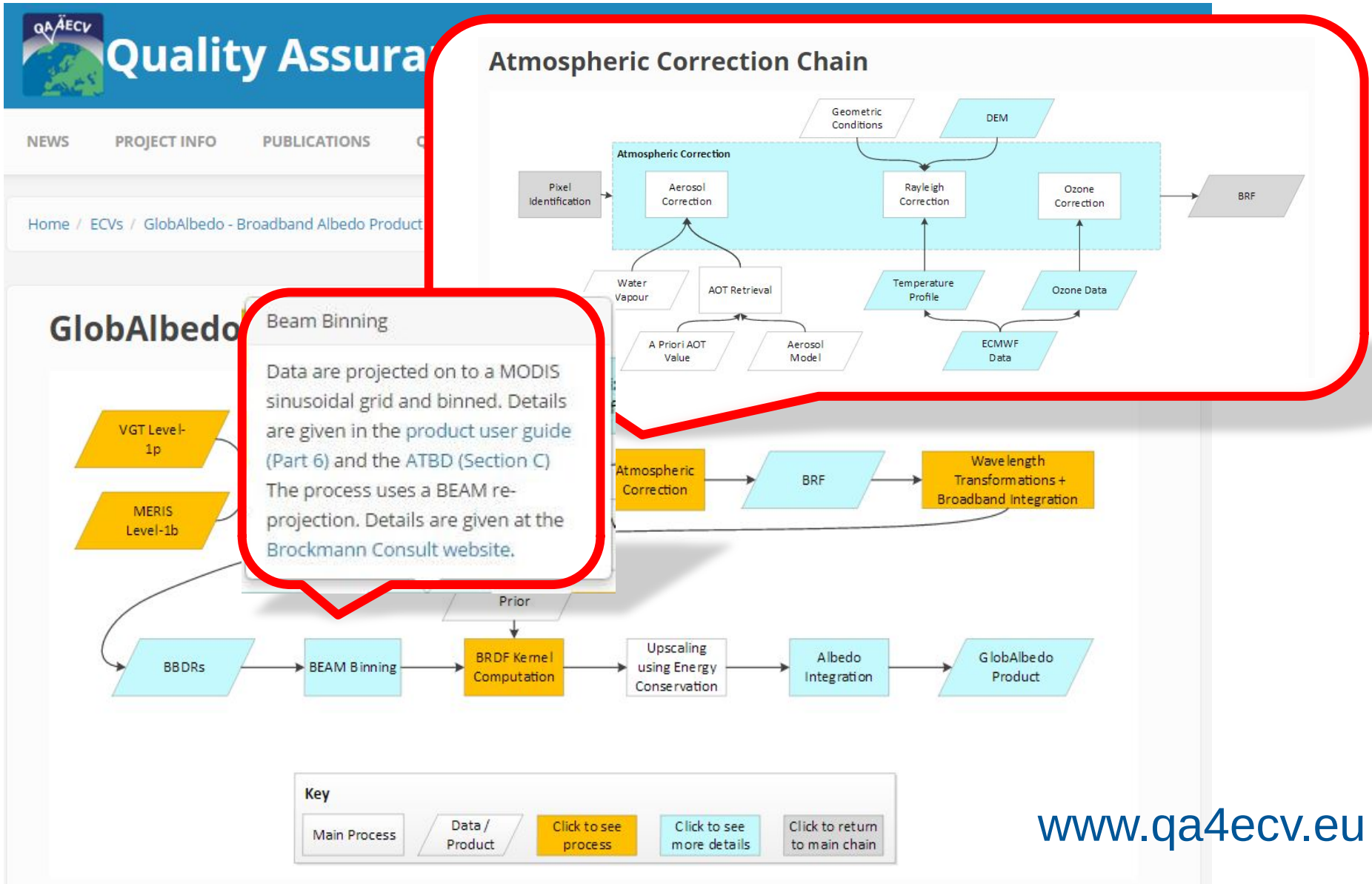

www.qa4ecv.eu

RADCALNET: network of characterised autonomous instrumented test-sites (reflectance) (initially 4: US, Fr, China, + ESA (Namibia)

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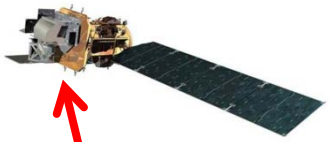
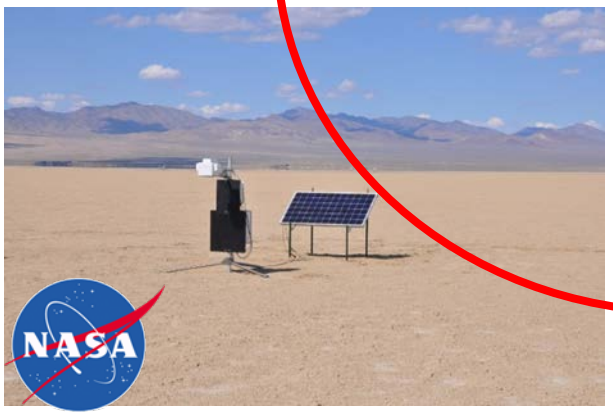


esa

+

Namibia established & operated by NPL with CNES

SI Traceability for network to satellites

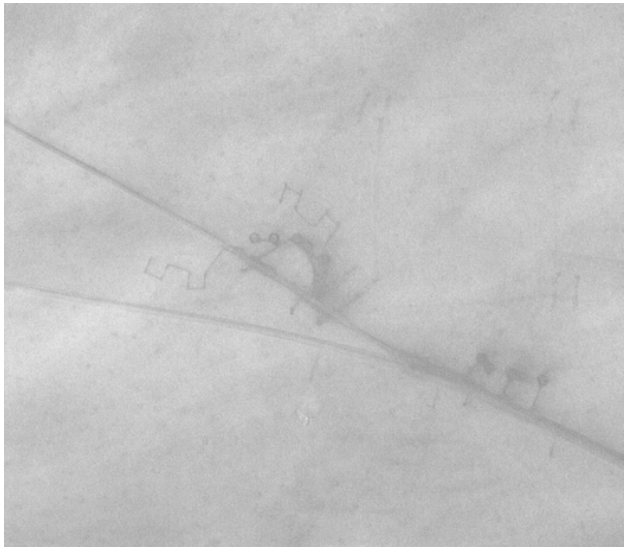
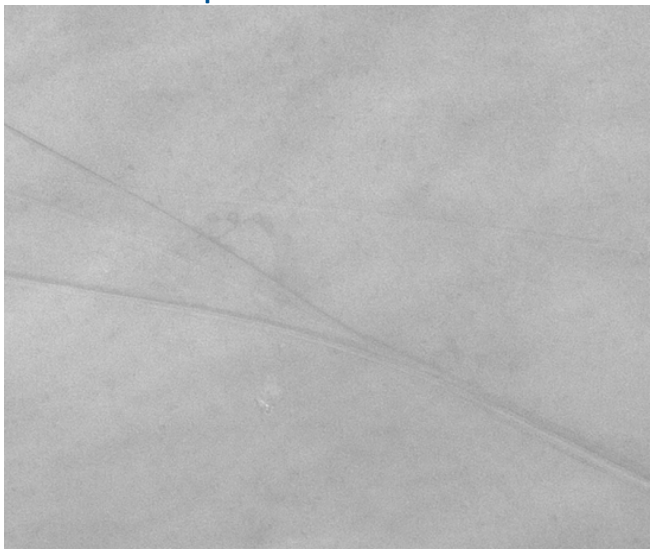


NASA

cnes

Impact of the characterization campaign

Monitoring using PLEIADES 70cm resolution imagery

Before	Right After	Now
Sept 9th 2015	Dec. 18th 2015	April 27th 2016
		
	Footprints Impact: ~6%	Footprints Impact: ~2%

Limited impact and fading away…

Characterisation to enable SI traceability has its challenges!

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- Reflectance measured over large areas in short time as illumination source (sun) angle moves
- (Laboratory instruments/concepts need to be adapted to the field
- Suffer Extremes of temperature/environment
- Atmosphere well-characterised & no clouds
- Uncertainty (for climate) factor 5 to 10 too high

Multi-angular reflectance

"Ghost-Busters"

Good Exercise

Also the oceans

"Colour" ↑

&

Temperature

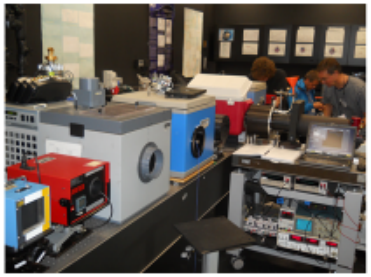
←

A surprise for the "locals"

COMPARISONS

BB comparison (June 2016)

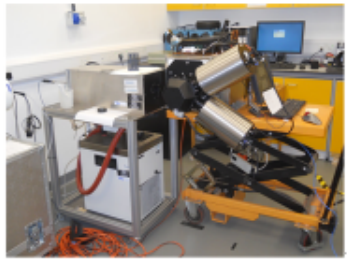
1. Miami University - USA
2. ONERA - France
3. University of Valencia- Spain
4. University of Southampton - UK
5. Qing Dao -China
6. RAL - UK
7. CSIRO - Australia
8. KIT- Germany



273 K to 323 K (0 to 50 °C)

Radiometer comparison

1. Miami University (USA)
2. ONERA (France)
3. University of Valencia (Spain)
4. University of Southampton (UK)
5. Qing Dao (China) -1
6. Qing Dao (China) -2
7. RAL (UK)
8. CSIRO (Australia)
9. KIT (Germany)
10. DMI (Denmark)
11. GOTA (Canary Islands
12. JPL NASA (USA)
13. Ian Barton (Australia)

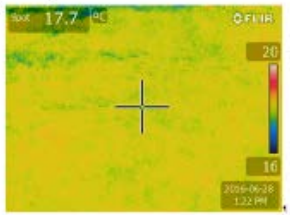


MAERI (UofM) viewing NPL ammonia Heat pipe

240 K to 318 K

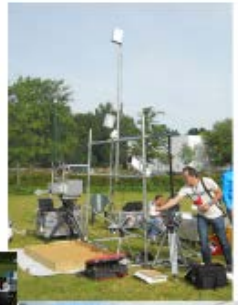
WST comparison @Reservoir near NPL and Heathrow airport July 2016

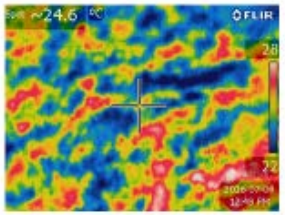
1. University of Valencia (Spain)
2. University of Southampton (UK)
3. Qing Dao (China) -1
4. Qing Dao (China) -2
5. RAL (UK)
6. CSIRO (Australia)
7. KIT (Germany)
8. DMI (Denmark)
9. GOTA (Canary Islands)
10. JPL NASA (USA)



LST (Sun & Cloud) @ NPL sports field and carpark

1. University of Valencia (Spain)
2. KIT (Germany)
3. JPL NASA (USA)
4. ONERA (France)





Emissivity

Enabling ‘user generated’ per pixel Uc images

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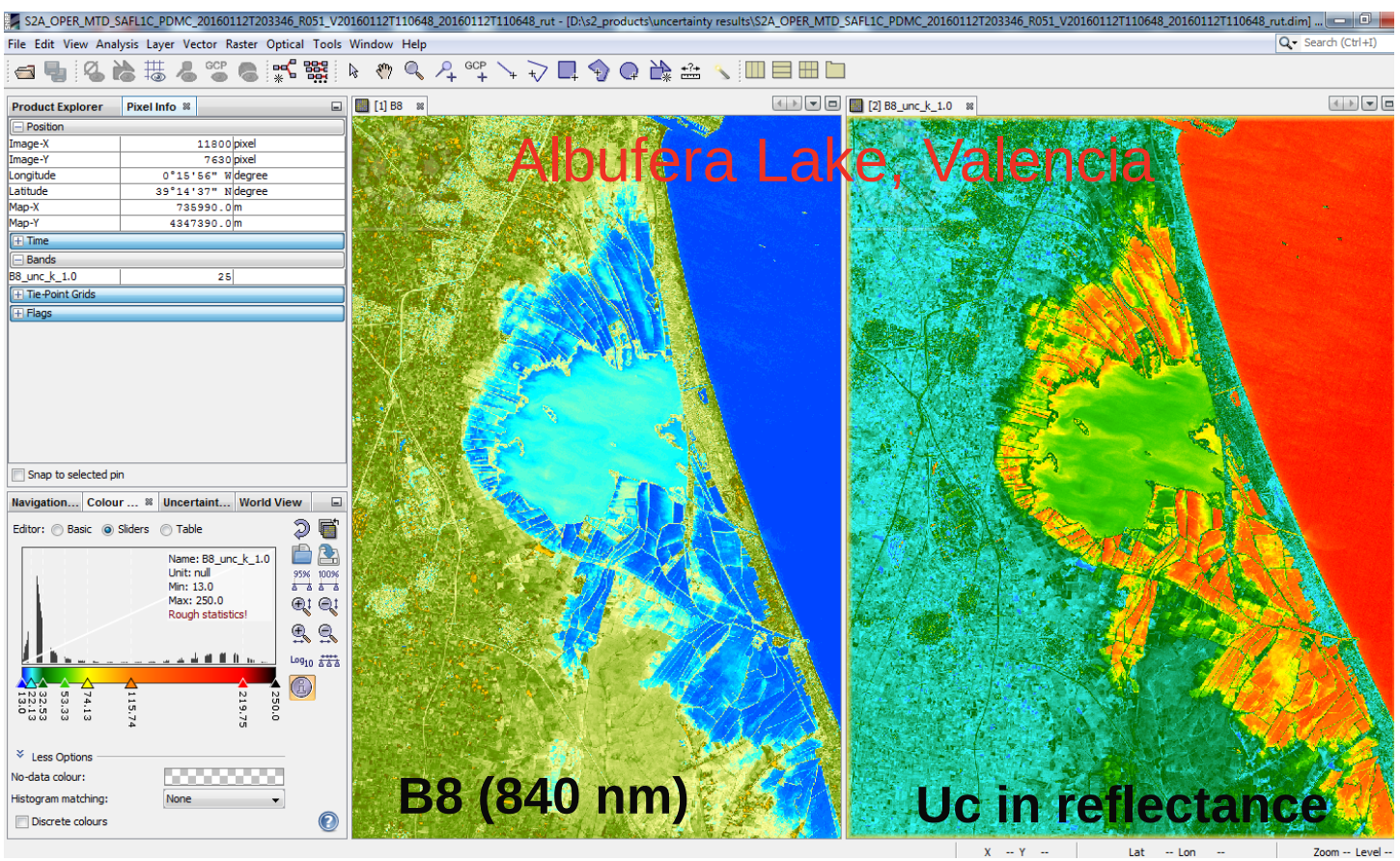

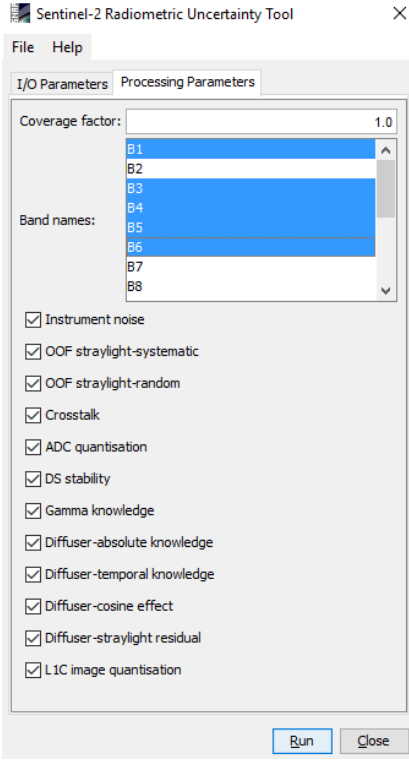

Sentinel 2 constellation will produce 1.8 TBytes a day (scene ~1.4GB), adding Uc info would double size (increasing storage and transfer time)

NPL developed software tool to allow scene dependent Uc image to be created by, and at the user terminal after data download

Virtual Truth

Metrology for Earth Observation and Climate

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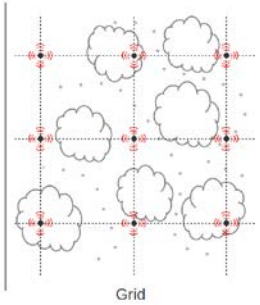
- Establishing ECV traceability through modelling, reference measurements and test-site characterisations

Instrument characterisation in lab and field conditions

Testing and evaluation of sampling schemes
(Temporal, Spatial)



3D Radiative Transfer model
- Simulate a virtual validation site (algorithm quantification)
- Simulate real-world test site

Comparison of in situ with satellite data with full traceability and known uncertainties

Traceability and Validation of Bio-physical products

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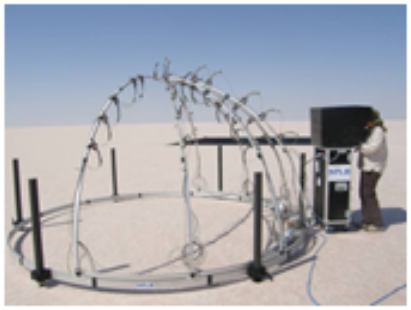
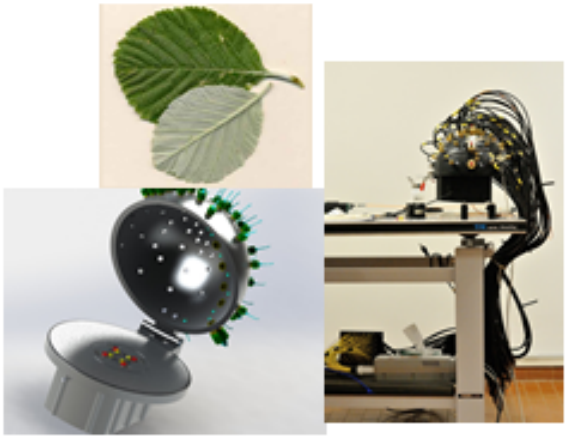
Metrology for Earth Observation and Climate

Field Gonio-meter for spectral reflectance (BRF) of individual leafs

(JRC, INRIM, NPL)

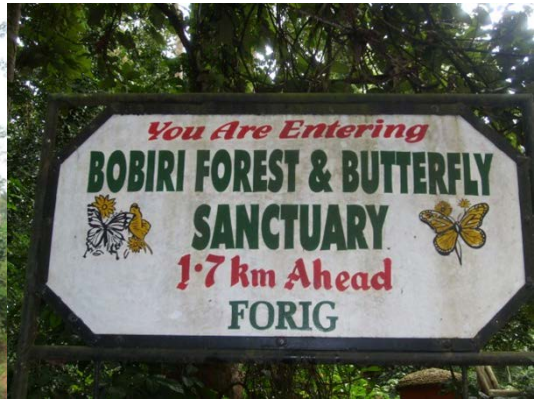


GRASS ~ 2 m diameter



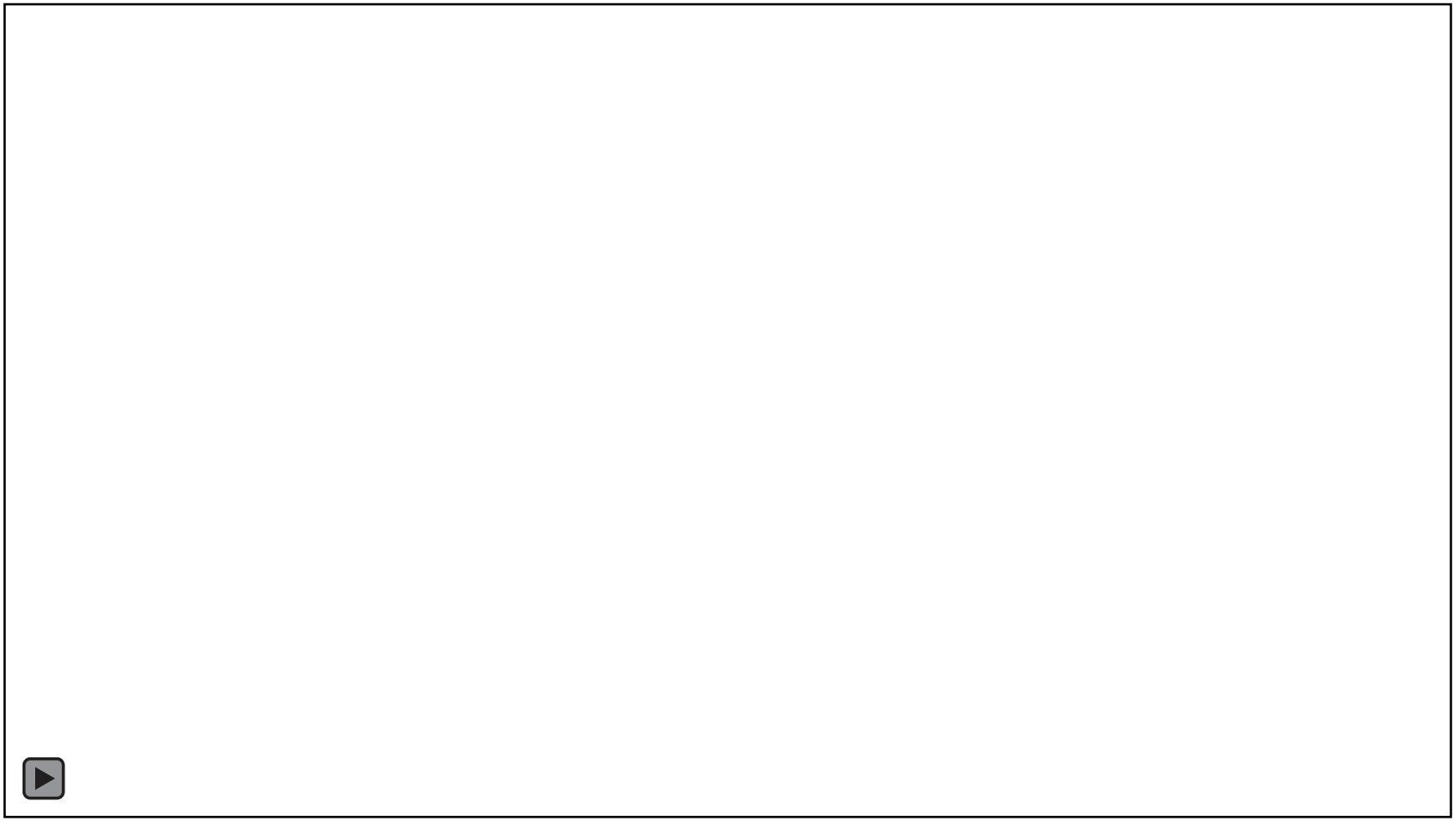
To ~ 20 cm diameter

NPL Management Ltd - Commercial



Data collection to build ‘point cloud’

National Physical Laboratory



Build virtual forest

- What is minimum data set ?
- Ground monitoring sensors?
- Scaling ?
- Validation and Uc evaluation

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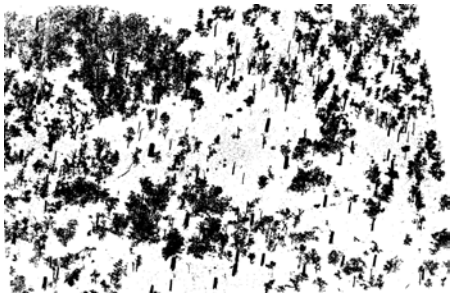
6 ha pointcloud

↳ Tree identification

↳ Model woody skeleton

↳ Add foliage

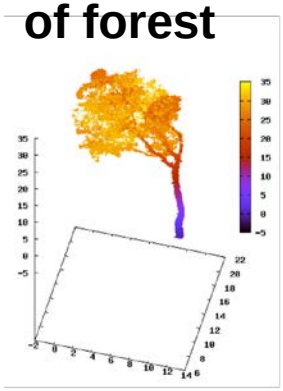


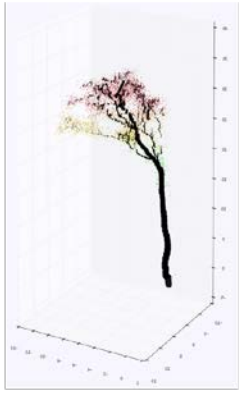
Point cloud of forest

Cleaned up forest

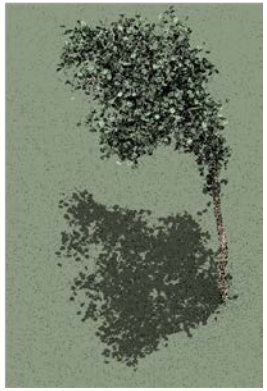
Build trunk

Add branches





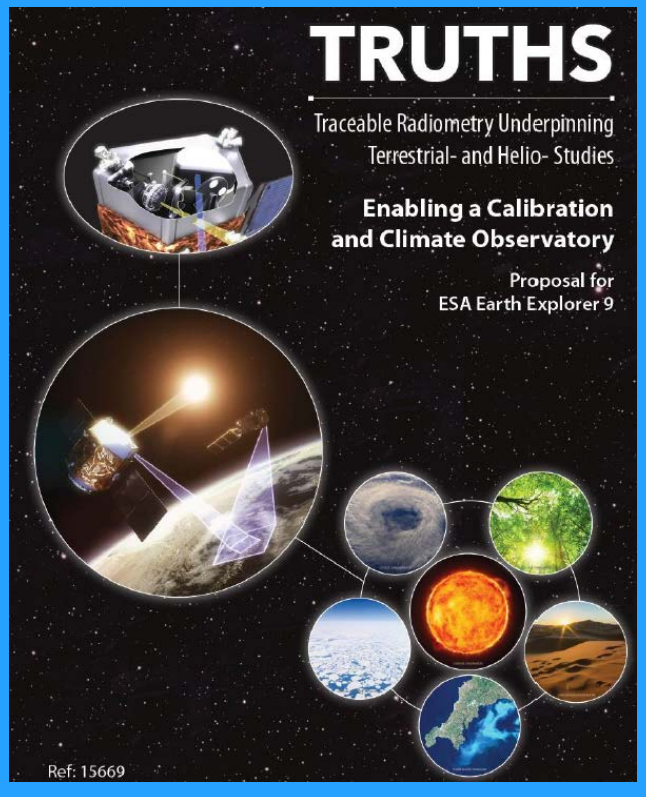
Add leaves

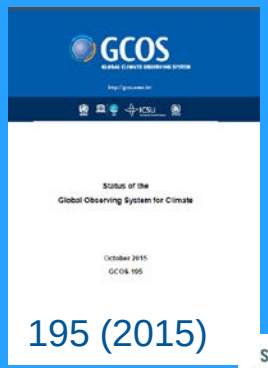


Simulate in RT code

- Different forest types ?
- Time consuming and data hungry processing
- Representativeness ?
- Global scale!!

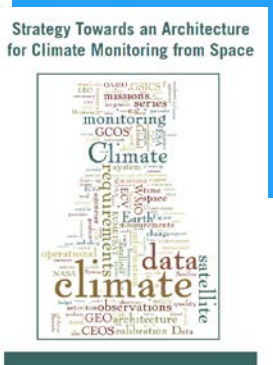
TRUTHS (Traceable Radiometry Underpinning Terrestrial and Helio-Studies): Enabling a calibration & climate observatory (a proposal to ESA EE9)





195 (2015)

"TRUTHS has important potential contributions to make both directly through well-calibrated measurements and indirectly through facilitating inter-calibration of the data from other platforms" **GCOS 2015**



CEOS/CGMS/WMO (2013)

"….a dedicated mission flying an SI traceable calibration reference standard would be an important element of a future architecture (see CLARREO and TRUTHS)."

TRUTHS

Establishing a 'fiducial' reference data set of TOA level 1 data for climate and calibration

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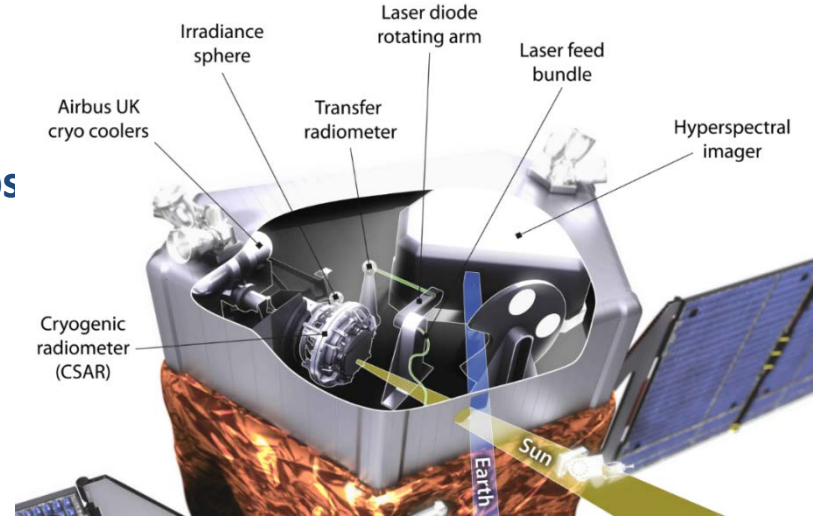
- A satellite proposed with a wide UK partnership led by NPL to provide 10 times more accurate climate data (a Snapshot of climate state from which to monitor change) and upgrade the performance of the world's EO satellites
  - A space climate and calibration observatory, NMI in space
- Benefits include:
  - Informing policy on the best adaptation strategies
  - Facilitating growth in climate services extracting value from 'Big Data' quantifying long term risk e.g. insurance
  - Secondary products agriculture, resources …
- Based on heritage components: submitted to ESA also looking for national and bi-lateral partnerships also possibilities on ISS
- Economic business case in development

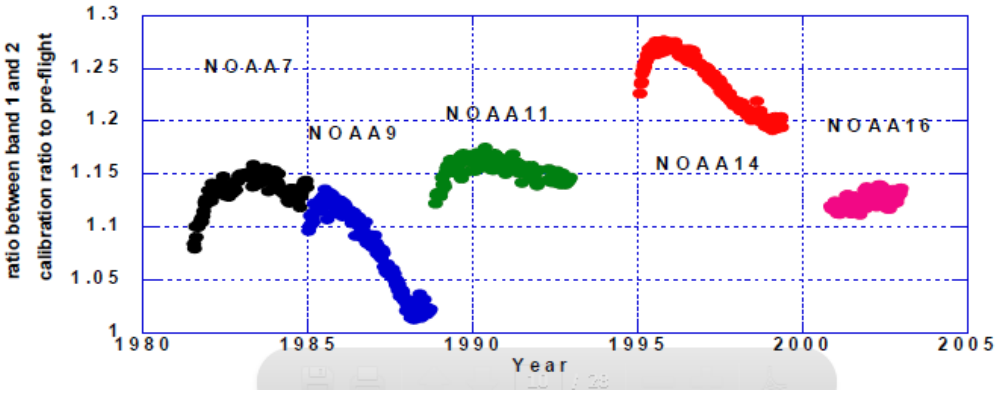


Imperial College London
UK SPACE AGENCY
EMRP European Metrology Research Programme Programme of EURAMET
University of Reading
SURREY SATELLITE TECHNOLOGY LTD
RAL Space
Met Office
Metrology for Earth Observation and Climate
UCL
CEOI-ST
TELESPAZIO VEGA UNITED KINGDOM
AIRBUS DEFENCE & SPACE

What does TRUTHS measure?

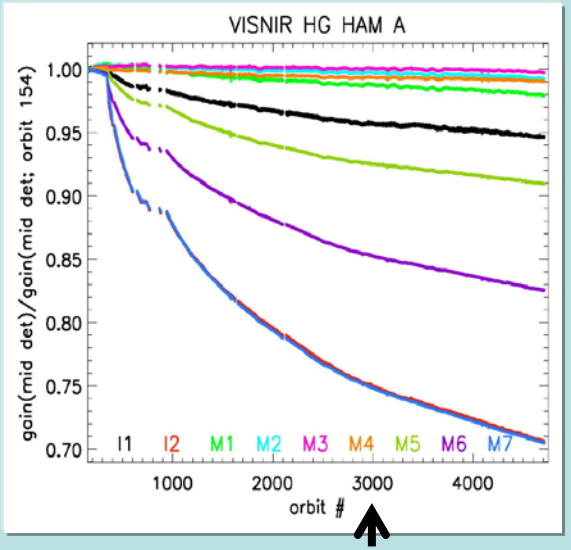
- Incoming Total Solar Irradiance - 0.01%
- Incoming spectral Solar irradiance (300 – 2400 nm) - 0.3%
- Earth reflected solar spectral radiance (320 – 2400 nm) - 0.3%
  - Globally @ 50 m spatial resolution & 5 nm spectral
  - Can be convolved to address many ECVs and applications

In addition to climate:



'greening' of the deserts – nominally a measure of Vegetation should be linear in desert

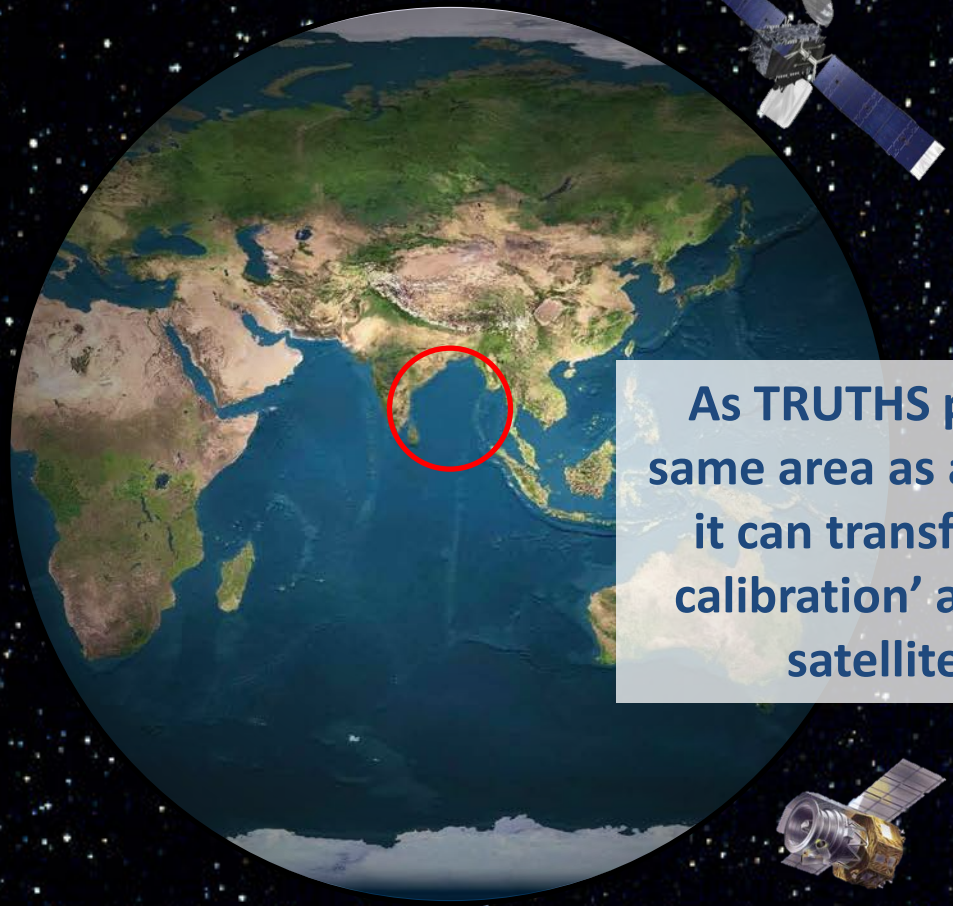
VIIRS (Blonski (NOAA))



~6 Months

All optical sensors drift from pre-flight calibration

TRUTHS upgrades the Earth observing system for climate



As TRUTHS passes over the same area as another satellite, it can transfer its ‘absolute calibration’ and upgrade the satellites accuracy

Training Course: Uncertainty analysis 'GUM for EO'

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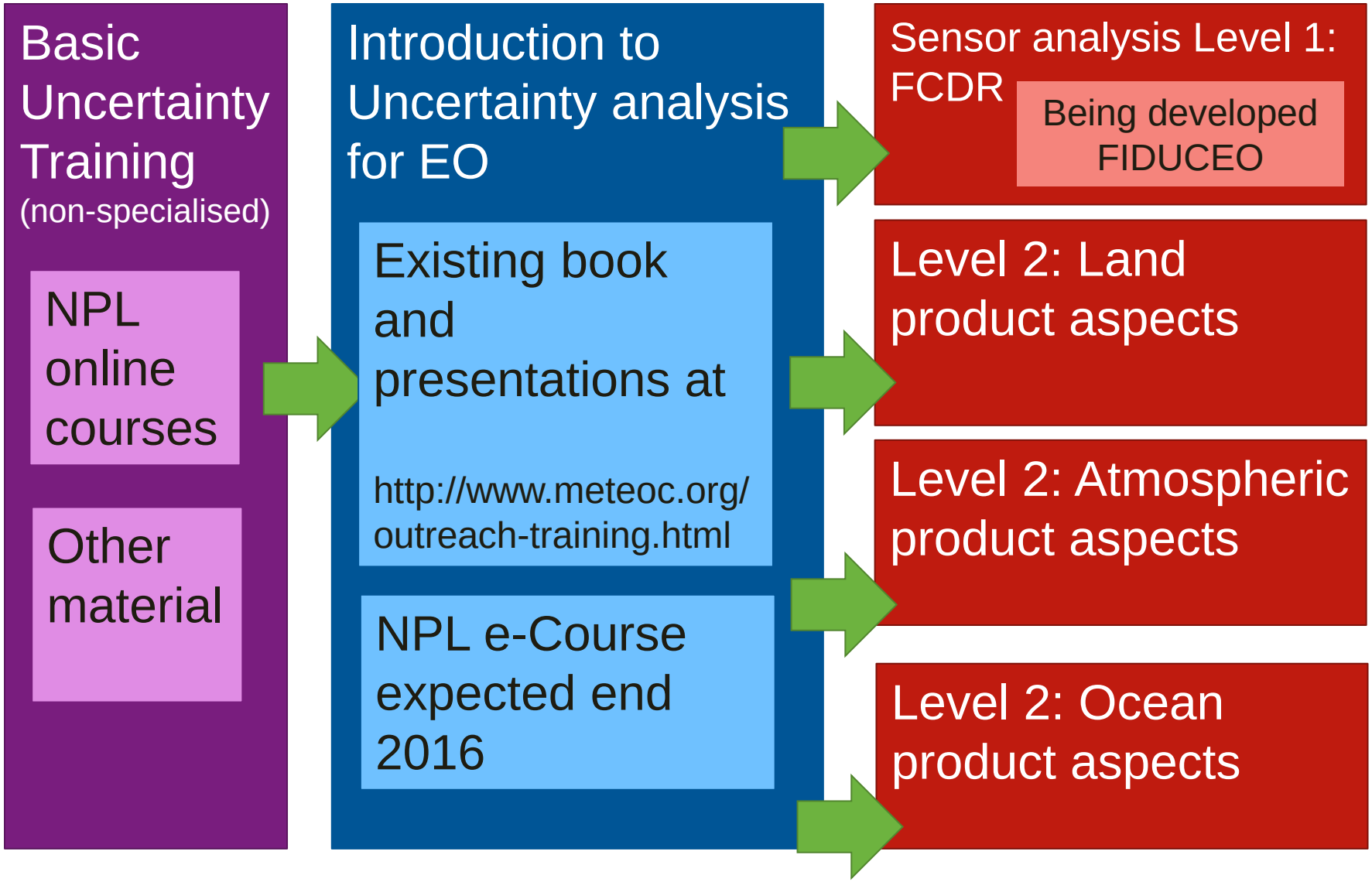


MetEOC-2 (Started Sep 2014) Coordinator N Fox (NPL)

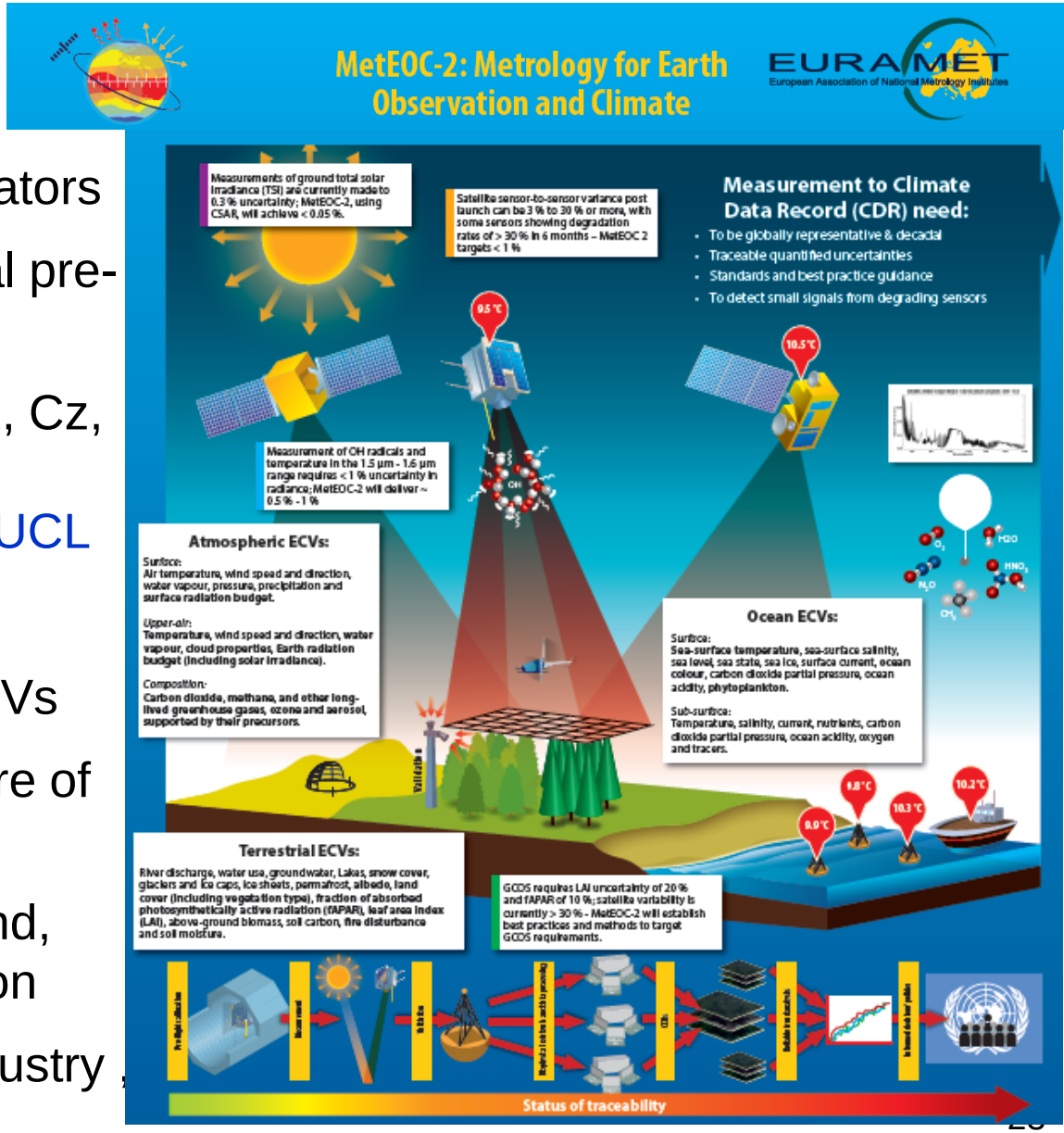
www.emceoc.org (MetEOC-3 proposal in preparation)

NPL National Physical Laboratory

~ 40 man years of effort
- aligned to WMO, CEOS, GEO, ESA, etc ~15 collaborators

MetEOC 1: resolved most critical pre-flight Cal needs of EO sector

- NMIs from, UK, F, D, Fi, I, NL, Cz, Sp, CH
  + RAL, DLR, FGI, BUW, Ujul. UCL
- Concentrates on Post-launch
- End to End Traceability & ECVs
- Seek to establish virtual centre of excellence
- Addresses ~15 ECVs in Land, Atmosphere, Ocean, Radiation
- Stakeholder support from industry, academia, international orgs



In summary

- **NPL supports a range of work to improve the data that goes into climate models, from instrument design to the end-user product**
  - **How to ascribe Uc (QA info) to a product**
  - **Means to assign scene dependent Uc per pixel for a CDR**
- **TRUTHS provides a comprehensive benchmark for the Fundamental Climate Data Record (FCDR) in the solar reflective domain provides benefits along the entire C3S supply chain, CCI and other EO applications including upgrade of sensor performance particularly valuable for new nano-sats and a flagship for Metrology**
- **New metrology new skill sets ranging from Geographers to Mathematicians & the need to educate on SI and Uc analysis in general**

As we increase the accuracy in climate data, we reduce risk and increase the effectiveness of policies and adaptation strategies