EU-FP7 QA4ECV: a 35 year ECV of albedos, fapar & LAI and their uncertainties

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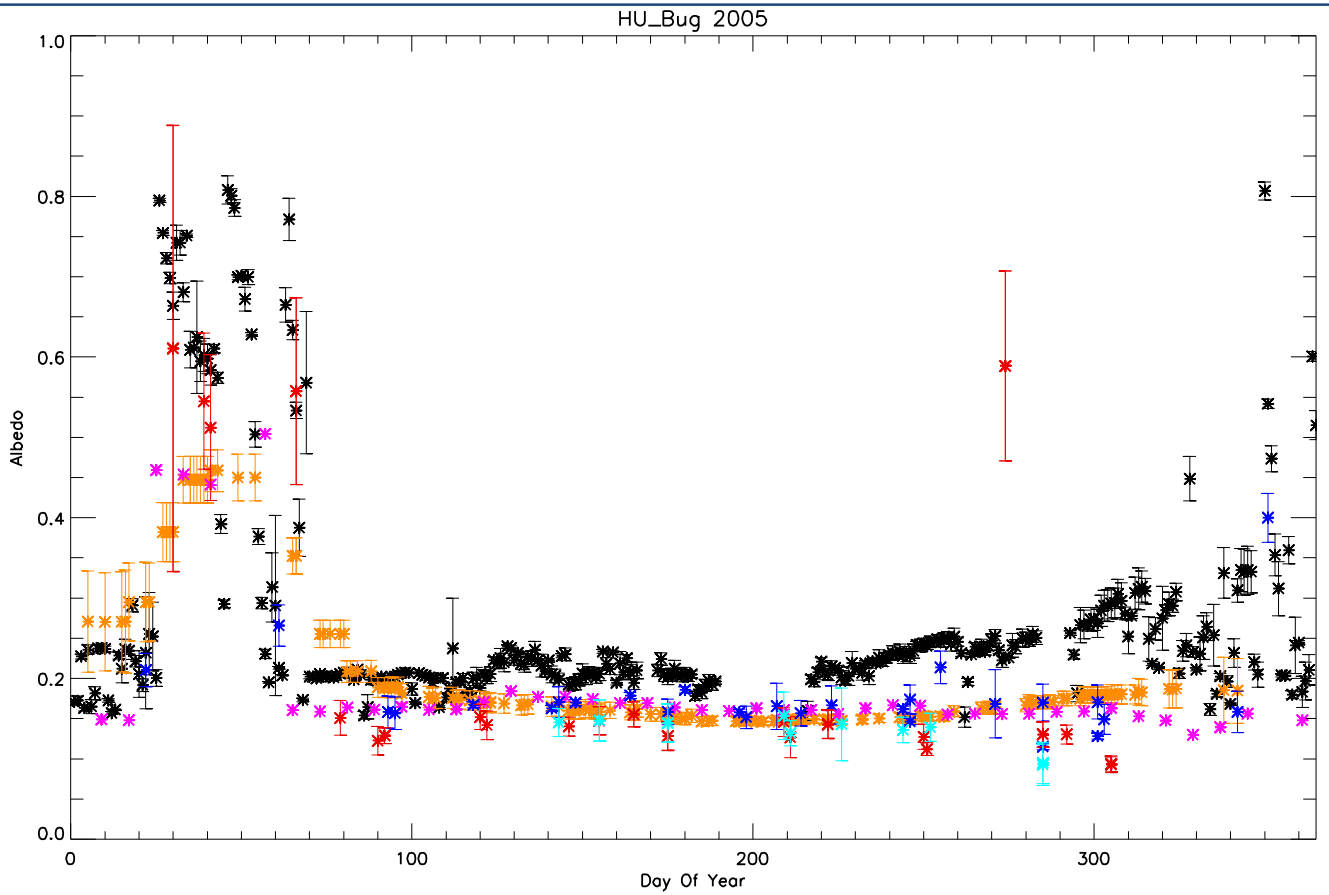
For land: data providers often use different instruments and different algorithms to produce the same parameter

Case: Albedo for a single location



GlobAlbedo MCD43C3 MISR MSA_M05 MSA_M07 Tower

N.B. All EO albedos agree with each other BUT disagree with tower measurements. This is unusual but not uncommon

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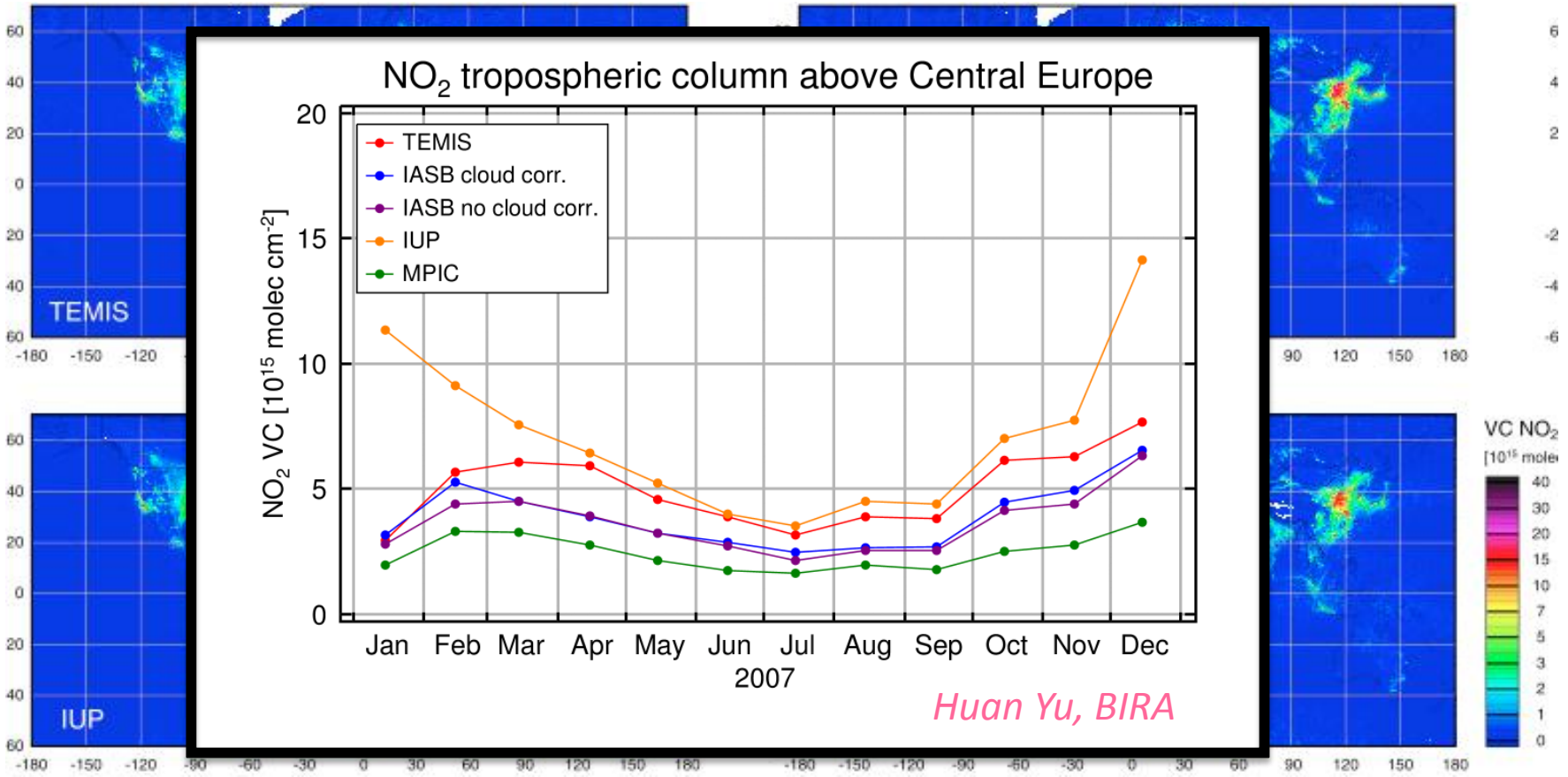
For Atmosphere

Data providers use same instrument but different algorithms

Case: **NO_2**



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Introduction and motivation

User perspective:

I need good new data … and quickly. A new data product could be very good, but if it is not being conveniently served and described, it is not good for me…
So I am going to use whatever I have and know already.

User

10/21/2011 Leptoukh QA4EO'11

This is where QA4ECV comes in

Mission statement QA4ECV

- QA4ECV will show how trustable assessments of satellite data quality can facilitate users in judging fitness-for-purpose of the ECV Climate Data Record.

- QA4ECV will provide quality assured long-term Climate Data Records of several ECVs relevant for policy and climate change assessments.

ESA CCI Aerosol Cloud CMUG Fire GHG Glaciers Ice Sheets Land Cover Ocean Colour Ozone Sea Ice Sea Level S

CCI

ESA Climate Change Initiative

Wed, 2010-09-01 11:03
Climate change is arguably the greatest challenge facing mankind in the twenty-first century. Its importance has been recognised in re reports from the IPCC and from UNFCCC, and the overwhelming economic consequences are set out in the Stern Report.

GCOS Essential Climate Variables

The 50 GCOS Essential Climate Variables (ECVs) (2010) are required to support the work of the UNFCCC and the IPCC. All ECVs are technically and economically feasible for systematic observation. It is these variables for which international exchange is required for both current and historical observations. Additional variables required for research purposes are not included in this table. It is emphasized that the ordering within the table is simply for convenience and is not an indicator of relative priority.

Domain	GCOS Essential Climate Variables
Atmospheric (over land, sea and ice)	**Surface:**[1] Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget.
	Upper-air:[2] Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance)

Why QA4ECV is necessary

Users need clear info on validity of EO/climate data sets

Unique records available, but need info on strength/weakness

Need objective system

Need guidance

web portal

Quality Assurance System

- Provides traceable quality info on EO/climate data
- Tied to international standards
- QA tools to support user community in tracing quality
- Multi-decadal records for atmosphere/terrestrial ECVs

Maturity	Software readiness	Validation
1	Under development	…
2	Minor changes	…
3	…	Continuous cross-checking

There is a need for quality-assured long-term climate data records

Detailed objectives of QA4ECV

1. Rigorous QA methodologies for satellite ECV products
   - QA framework applicable to many ECVs
   - SW tools for 'do-it-yourself' QA
   - SI standards as in QA4EO (through NPL)

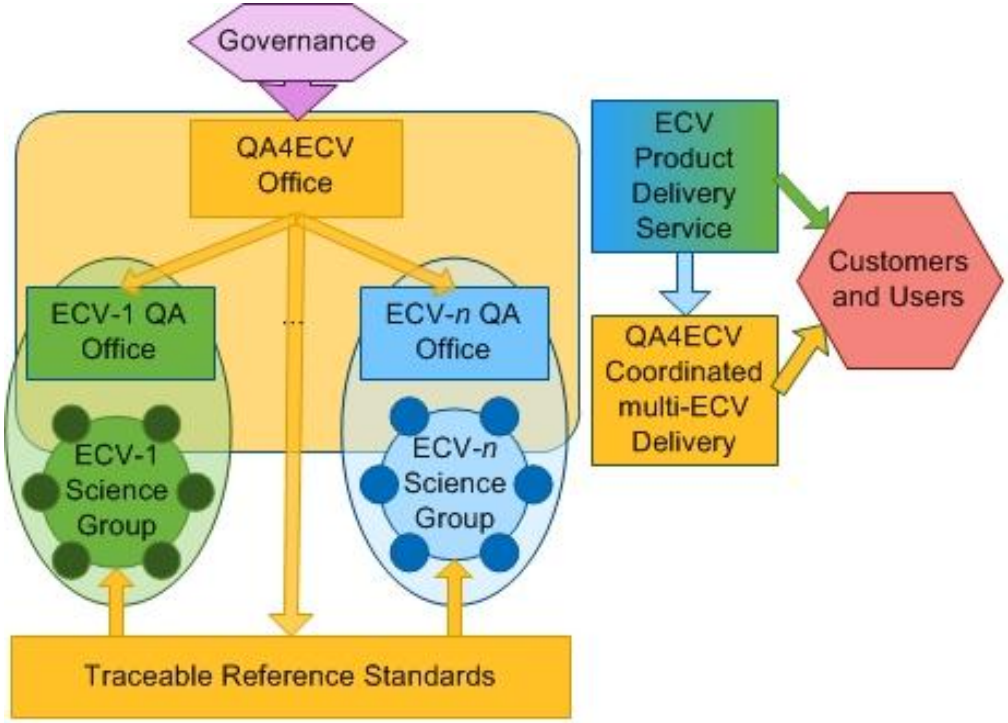
2. Multi-decadal satellite-derived global ECV records
   - 3 Terrestrial and 3 Atmospheric ECVs w/ global coverage
   - Not yet covered by ESA or EUMETSAT activities; 20-30 yr

3. Traceable QA applied to ECV retrievals and products
   - QA4ECV approach applied to independent reference data, ECV retrievals, and final products

4. Information on quality and fit-for-purpose nature of datasets
   - QA Office to audit ECV records against GCOS, WMO crit.
   - Assess impact of ECV records for applications

How will QA4ECV reach its objectives?

Step 1: Develop a Quality Assurance System



Governance: EU (through EEA?), principles QA4EO, links to CEOS, WMO, ESA, etc

QA4ECV Office: Metrological traceability, through National Metrology Institute. QA process management. Harmonisation/Support Multi-ECV. Audit of Auditors. 'Certification'

ECV-specific QA Offices: Independent verification by technical expert of QA activities of Science Group and/or independent QA for that ECV.

ECV-science group: Delivers quality assured ECV record through ECV-specific product delivery and climate coordinated delivery service, to users.

Potential framework for QA4ECV Service Provision.

- Users obtain a one-stop-shop for all QA info
- The QA4ECV Office provides independent verification of ECV QA
- Traceability to SI & community reference standards through metrology institute
- Support the retrieval groups with QA tools, software and uncertainty analysis

How will QA4ECV reach its objectives?

Step 2: Generate multi-decadal ECV records

Land ECVs

- Spectral albedo, LAI & FAPAR
- Surface and vegetation state
- Indicators for land use change, biosphere activity
- Measured since 1980s
- Evaluate carbon cycle & water cycle in climate models

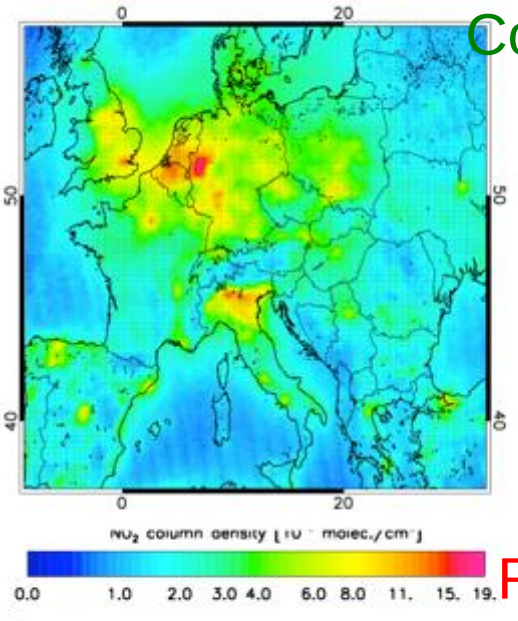
Atmosphere ECVs

- NO_2, HCHO & CO
- Air pollutants
- Drive ozone and aerosol formation
- Measured since 1995/2000
- Evaluate atm. chemistry modules in climate models
- Provide info on effectiveness of policies, trends in fires etc.

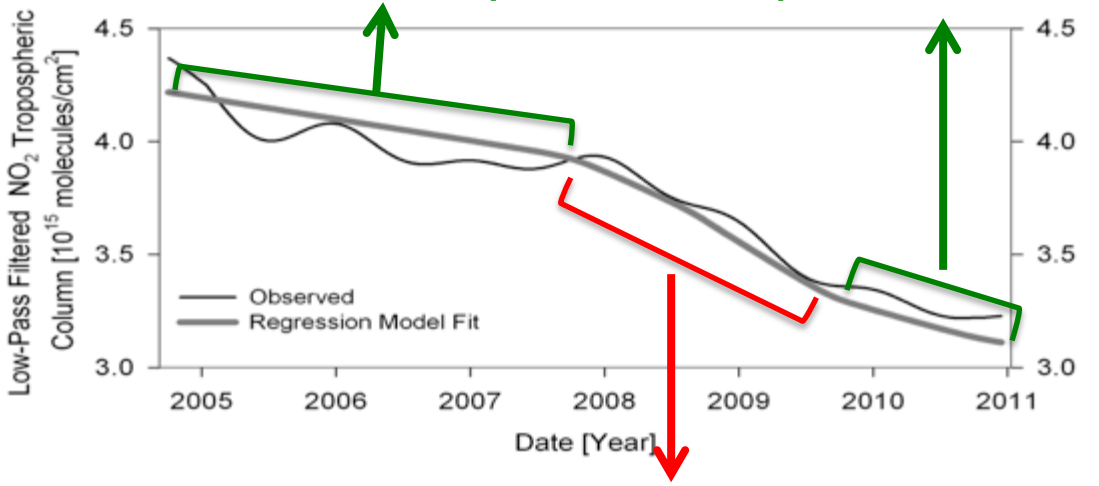
ECV sets do exist to some extent, but they are not necessarily coherent and not quality assured.

Policy control with OMI NO_2 measurements

2005

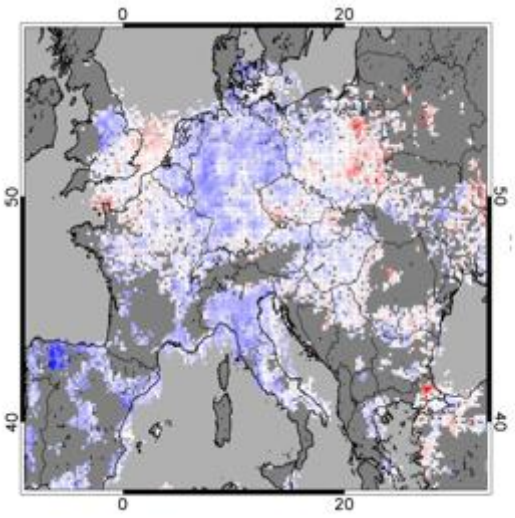


Continuous reduction (2004-2010): -2% to -5%

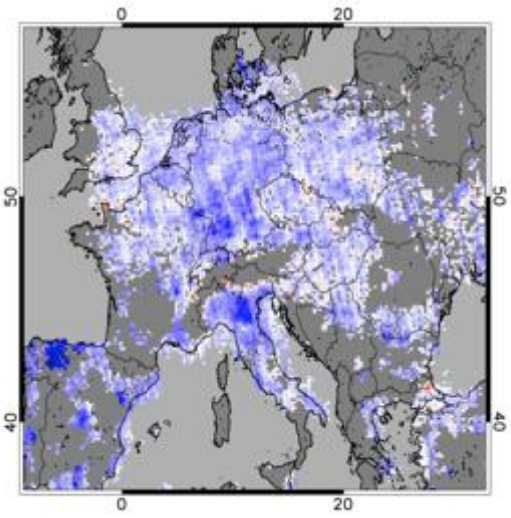


Recession Change (2008-2009): -15% to -30%

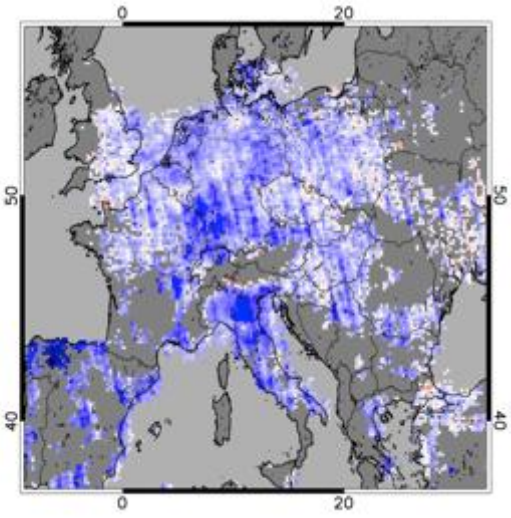
2008/2005



2009/2005



2010/2005



Castellanos and Boersma, Sci. Rep., 2012

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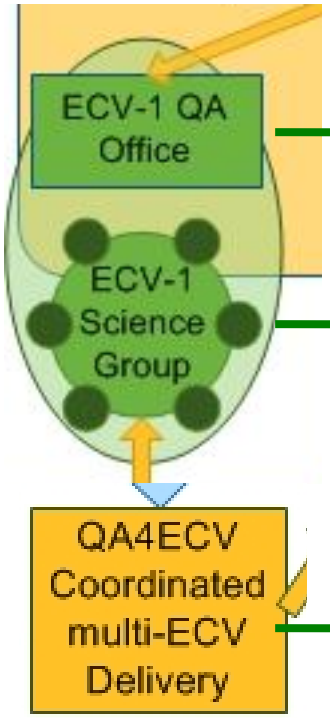
How will QA4ECV reach its objectives?

Step 3: Apply the QA System to ECVs



QA of independent reference data themselves

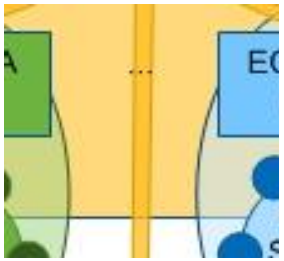
QA of the ECV retrieval algorithm (steps)

QA of complete ECV record & test against GCOS criteria

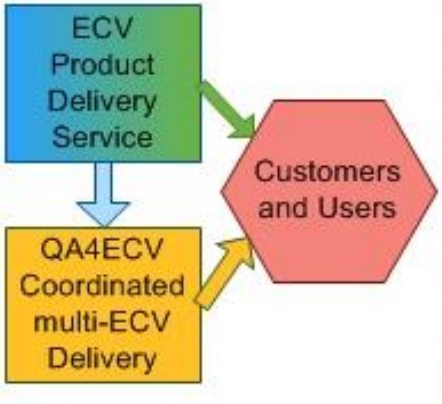
How will QA4ECV reach its objectives?

Step 4: Interact with the users

From the beginning … by involving users and suppliers in the design of the QA4ECV Office / workshops



Throughout the project… by interaction with users on the functionalities (‘do it yourself’ QA) and its applicability across (other) ECVs



To the end …

QA reports on on the ECV data records (green)

QA reports on retrieval algorithms (yellow)

Fit-for-purpose reports

Contribution of QA4ECV to GMES Climate Service

FP7-SPACE-2013-1: *"…contribute toward the (pre-) operational capacities … of GMES, by augmenting the number of currently available quality-assured long term ECV records and by providing methodologies suitable for reliable assessments of the climate quality of ECV products."*

- A clear tested blueprint for an implementable pre-operational Quality Assurance (QA) service to underpin future European-wide multi-ECV Climate Services.
- A fully automated validation system enabling independent stakeholder assessment of QA of Atmosphere ECV products from different producers.
- A set of tools for the production, auditing and use of quality information for ECV records

The ECVs to be generated

1. Spectral albedo — Radiation budgets, AOT, LAI, FAPAR
2. LAI — Radiation budgets, CO_2, soil moisture
3. FAPAR — Radiation budgets, CO_2, soil moisture

2010 Implementation Plan for GCOS:

… parties are called to 'develop and implement coordinated and complementary strategies for long-term measurements of … ozone and precursor species' (NO_2, SO_2, HCHO, and CO) 'Development of long-term datasets based on the currently available measurements from the past 15 to 20 years' (GCOS-154, section 3.1.11, page 42).

4. NO_2 — O_3 (T+S), AOT, AAI, albedo
5. HCHO — O_3 (T), AOT, AAI, surface T, albedo, LAI
6. CO — O_3 (T), AOT, AAI, surface T

QA4ECV Aims – Global Land surface products

- Produce 35 years (1982-2016) of Land Surface Spectral & BroadBand BRDF/Albedo, fapar, LAI every day at 1, 5, 25km & monthly 0.05º & 0.5º from European & US space assets to generate Essential Climate Variables. Quality Assurance at each pixel using optimal estimation.
- Input data level 1b (radiometrically calibrated, satellite projection) with a priori climatology derived from MODIS C5 BRDF (3/2000-3/2014)
  - GEO (SCOPE-CM :1982-2016) & AVHRR (LTDR :1982-2016)
  - VEGETATION (3/1998-12/2013) & PROBA-V (9/2013-12/2016)
  - MERIS (6/2002-4/12) & ATSR2 6/95-3/00, AATSR 6/02-4/12
  - Level 2 only: MODIS C6 (3/2000-12/2016), MISR (3/2000-12/2016)
- Validation of final albedo products & intermediate products (e.g. sensor-to-sensor, cloud masks, aerosol AOD, narrow-to-broadband)
- 726Tb of CEMS space (NERC Big Data) - all products to be freely available via wget/curl, http, WPS and display browse & animations

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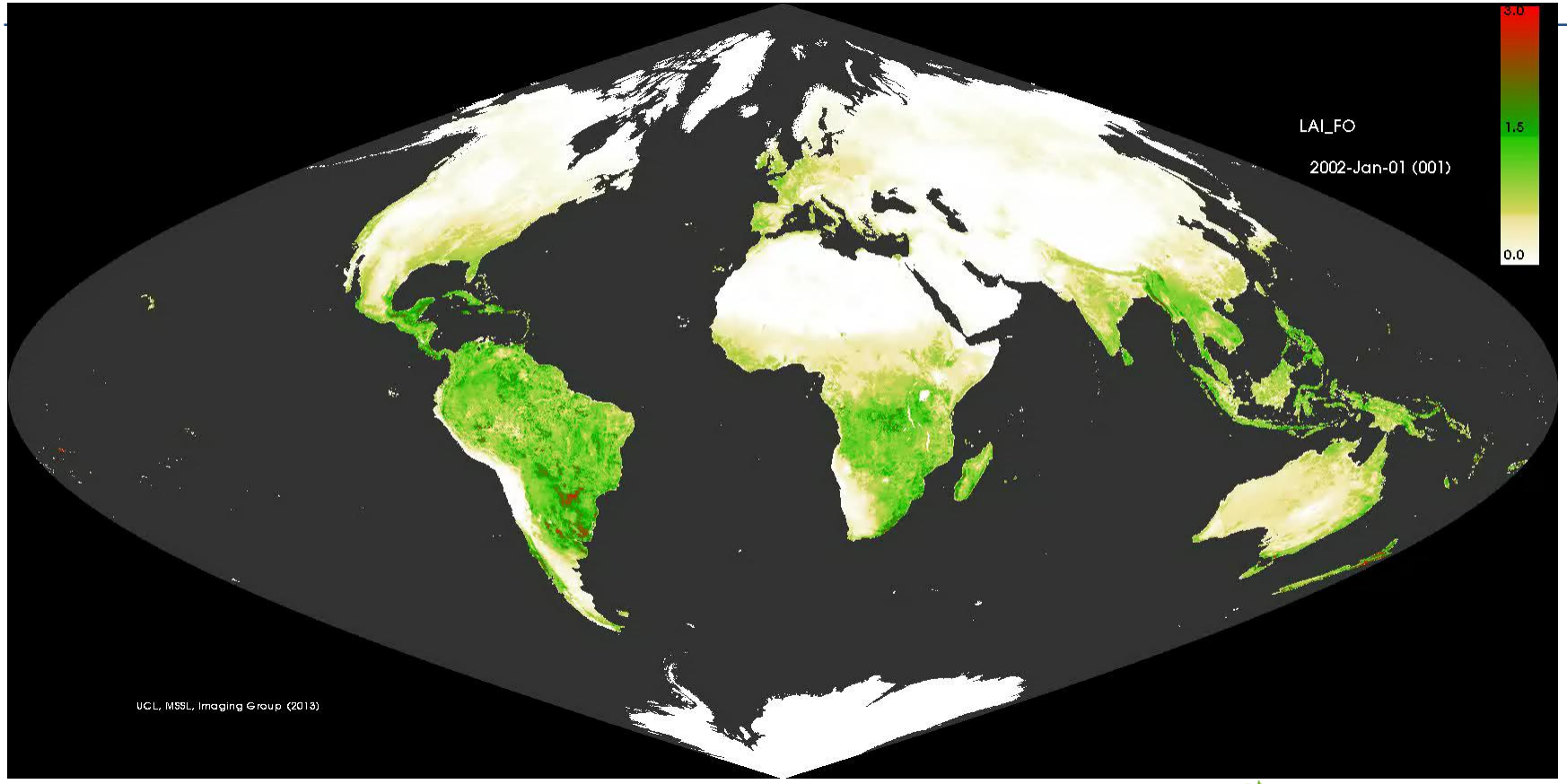
Prior Art - Example LAI derived from GlobAlbedo using TIP*



Completed fapar & LAI for 2002-2011 inc. uncertainties

* Pinty et al. (2007) J. Geophys. Res.-Atmos. 112 (D10), D10116

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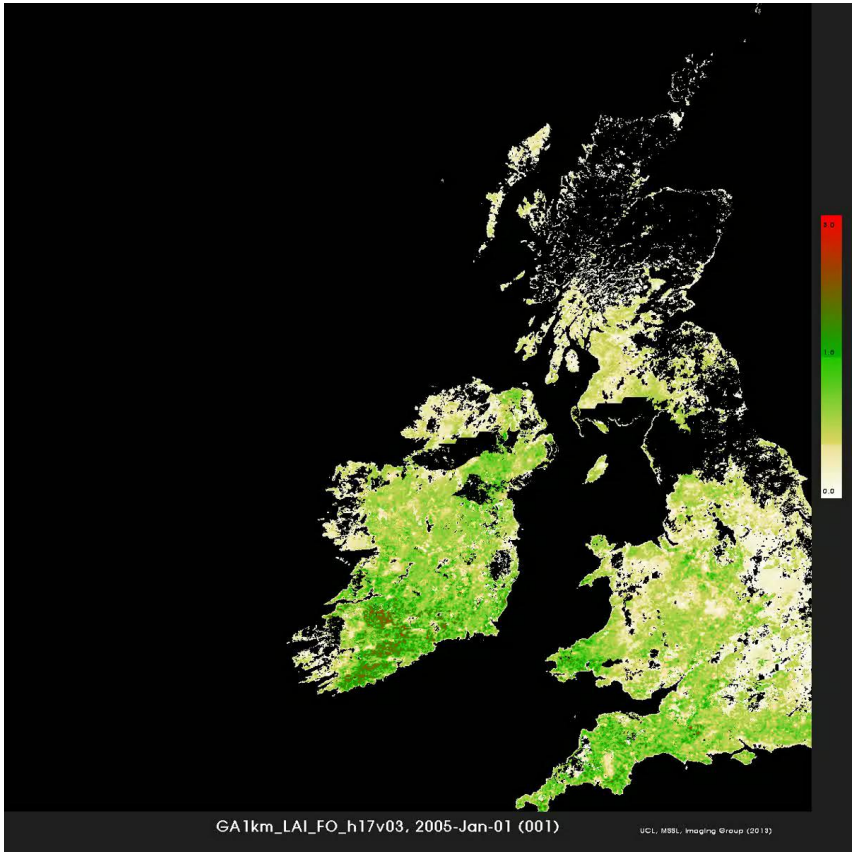
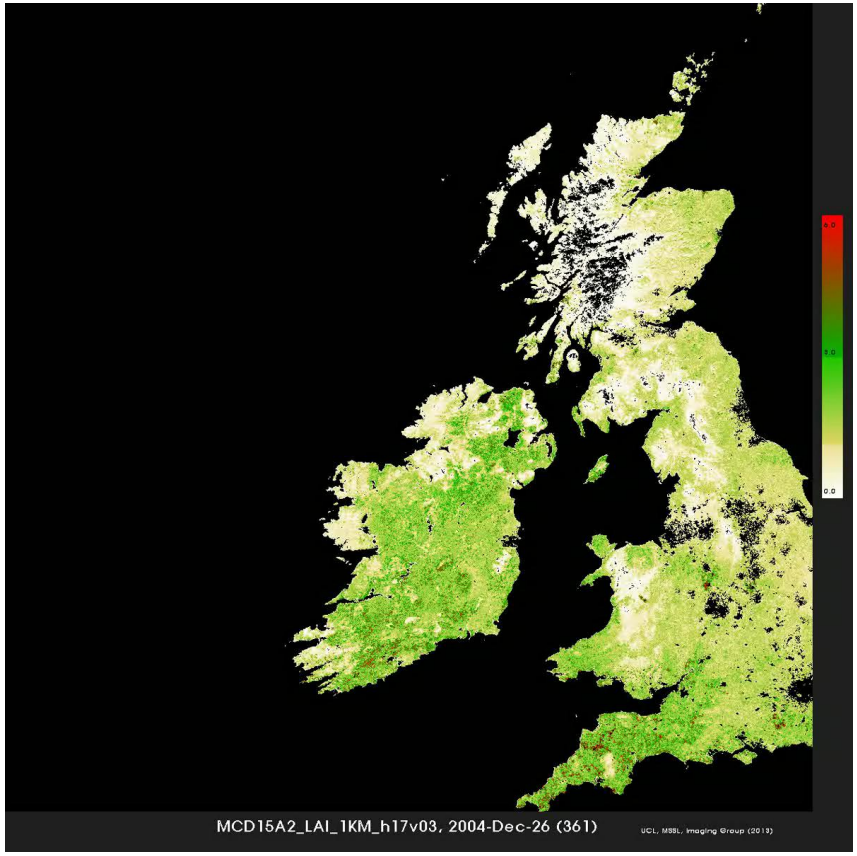
WACMOS - ET
Support to science element

QA4ECV

Intercomparison of LAI derived from GlobAlbedo vs MODIS





GlobAlbedo

MODIS

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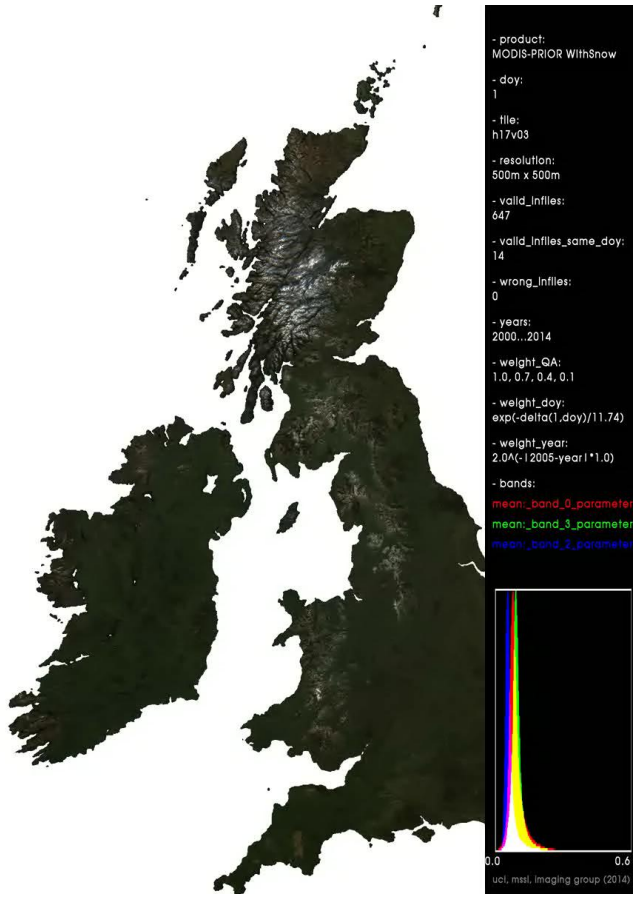
Re-processed MODIS Prior using all spectral and 3 broadbands

- Processed on CEMS in 3 days(81 times faster than on 8-core blade)
- Completed all 326 tiles at 500m for 14 years of MODIS data
- Once Collection 6 daily products available, will re-process to obtain daily prior



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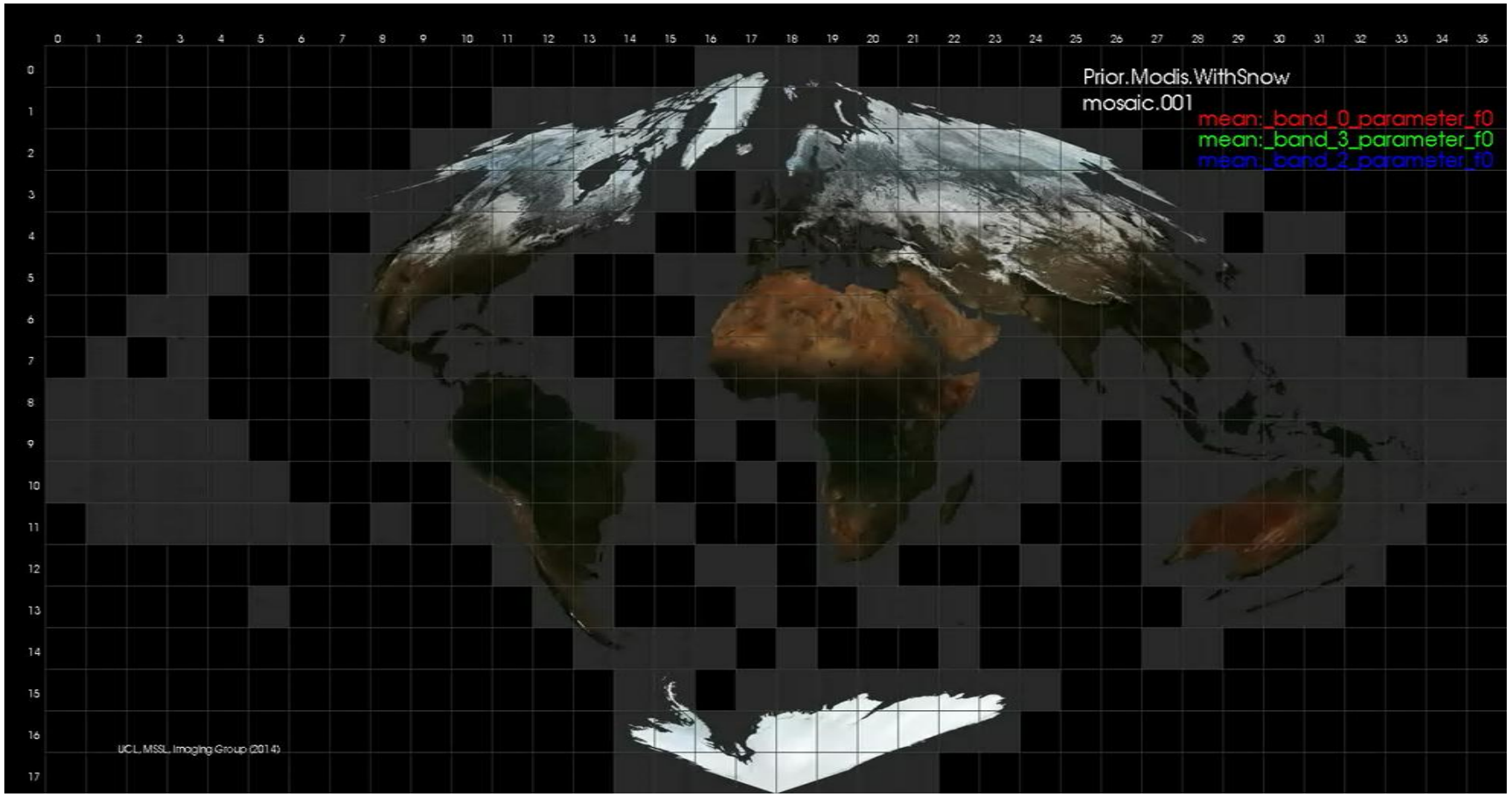
Global MODIS Prior in False Colour



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Example uses of CEMS-JASMIN for global land surface products

- **Objective 1:** Re-project BRDF files from SIN-coordinates to lat/lon using an Energy Conservation method
  - **Challenge:** the projected SIN-Tiles into lat/lon results for non-rectangular shapes, with different SIN tiles
  - **Solution:** SIN and Lat,Lon Cells are represented by geometry polygons rather than simple points and then the process is based on ratios of common area rather than on simple distance
    - **Challenge**: huge number of polygons to be spatiality indexed and processed. **This process requires massive RAM and usually takes a very long time!**
    - **Solution**: Use Cloud-computing system on CEMS-JASMIN (~100 times faster than 224-core in house linux cluster!)
- **Objective 2:** Create specific albedo products for computation of 8-daily LAI/fAPAR between 2002 and 2011 at 3 different resolutions: 1km, 5km and 25km
  - **Challenge:** Upscale big data BRDF (50TB) from 1km to 5km and 25km using energy conservation method, and then create separate Albedo-Snow_only and Albedo-Snow_Free products: **This process is extremely time consuming!**
  - **Solution**: Cloud-computing system in CEMS-JASMIN (~100 times faster than 224-core in house linux cluster)

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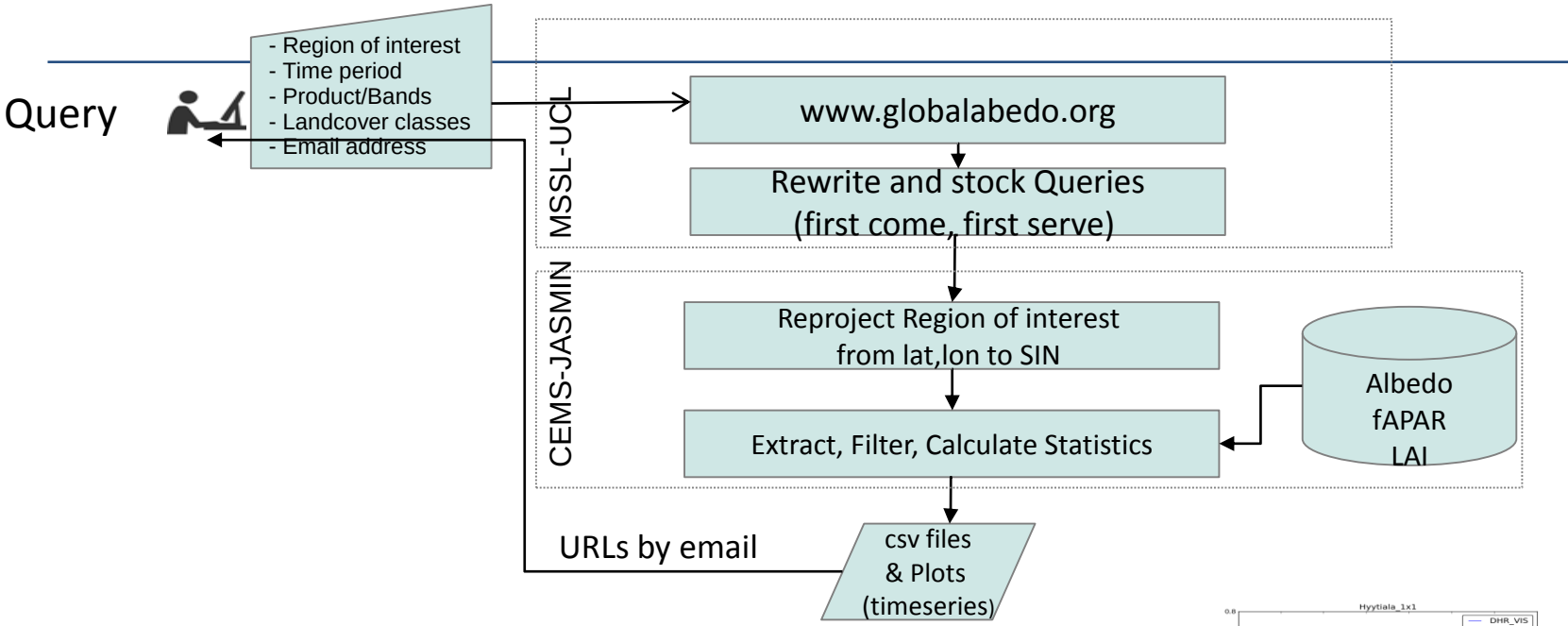
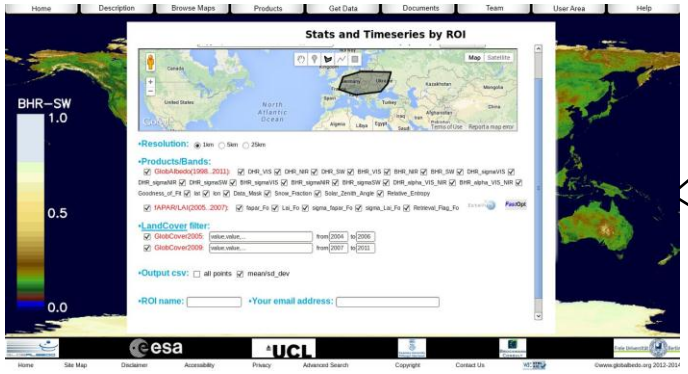
Example use of CEMS-JASMIN(2) for near-line subsetting

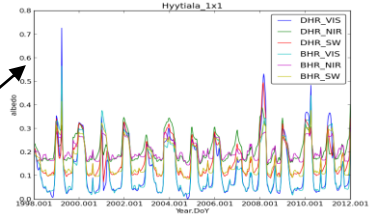


On-line statistics (Albedo, LAI/fAPAR, filtered by landcover) by Region of Interest: point, line or polygon.

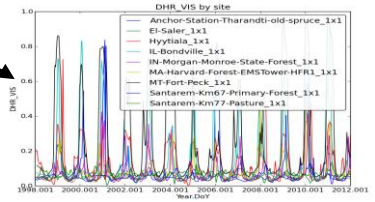
Being integrated into Microsoft-Azure



Stat by band



Stat by site



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Where are we now and where do we go next?

- All GlobAlbedo BBDRs and BRDFs copied onto CEMS after 2nd re-processing
- All MODIS Collection 5 (MOD09 & MYD09) BRFs downloaded (25 Mbytes/day) to CEMS. Will download Collection 6 when available (from Oct 2014)
- All MISR (MISR2AS) BRFs downloaded. All AVHRR LTDRs available
- MERIS & ATSR2 & AATSR level-1b already available. VEGETATION level-1b about to be copied onto CEMS
- GEO data from METEOESAT is being processed for a test year into BRFs. Testing software for ingestion into data fusion
- GEO data from GOES & GMS is being processed into BRFs
- FastOpt processed 10 years of GlobAlbedo data into fapar & LAI
- All previous products available through GlobAlbedo.org website
- Systematic processing of 35 years starts in July 2015
- Monte Carlo ray-tracing being employed to derive simulated "validation test datasets"

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Anticipated users of QA4ECV products

Data users from Land community

- Researchers
- Authorities (forest management, urban planning)
- Policy makers (assessment of trends, history)

Data users from Atmosphere community

- Researchers
- Authorities (Public health, climate)
- Policy makers (trends, chemistry-climate feedbacks)

QA system users (ECV developers and users)

WP1 provides formal links with other ECV projects, within the EUMETSAT SAF Network and ESA CCI to ensure that the system developed in QA4ECV has wider applicability.

Anticipated users of QA4ECV products

Our own project

- Interface between albedo and atmosphere retrievals
- Climate modellers to assess fitness-for-purpose of Land ECVs for climate research and modelling
- Chemistry-climate modellers to assess fitness-for-purpose of Atmosphere ECVs for AQ, chemistry-climate, and trends

- MACC-II & GIO Global Land
- S5P and new geostationary sensors (TEMPO, S4, GEMS)

QA4ECV users

Obtain data through:

- Project website - www.qa4ecv.eu

Needs/requirements have been identified

- from the start of the project; user survey, set-up helpdesk

QA4ECV obtains user needs through

- Maintain active dialogue with users and key projects to ensure dissemination and use of QA system
- Coordinated outreach with other 4 other FP7 Space projects

Feedback will be organized through

- Helpdesk
- Links to relevant projects (ESA CCI, EUMETSAT SAF)
- Within our project (fitness-for-purpose WP)

Expected impacts

…contribute toward the (pre-) operational capacities in the climate change context of GMES, by augmenting the number of currently available quality-assured long term ECV records and by providing methodologies suitable for reliable assessments of the climate quality of ECV products.

1. Concept service to underpin European-wide ECV services
2. Validation system (QA independent ref., retrieval & product)
3. Tools for ‘do-it-yourself’ QA
4. Quality assured multi-decadal records Land & Atmosphere

…substantially support (in combination with climate model predictions) climate change impact and adaptation action assessments, policy development and policy monitoring for global, European and national users.

1. Interaction with policy makers and users at start and throughout the project
2. Ingestion of Land ECV records in (climate) models will add to European Clearing House Mechanism