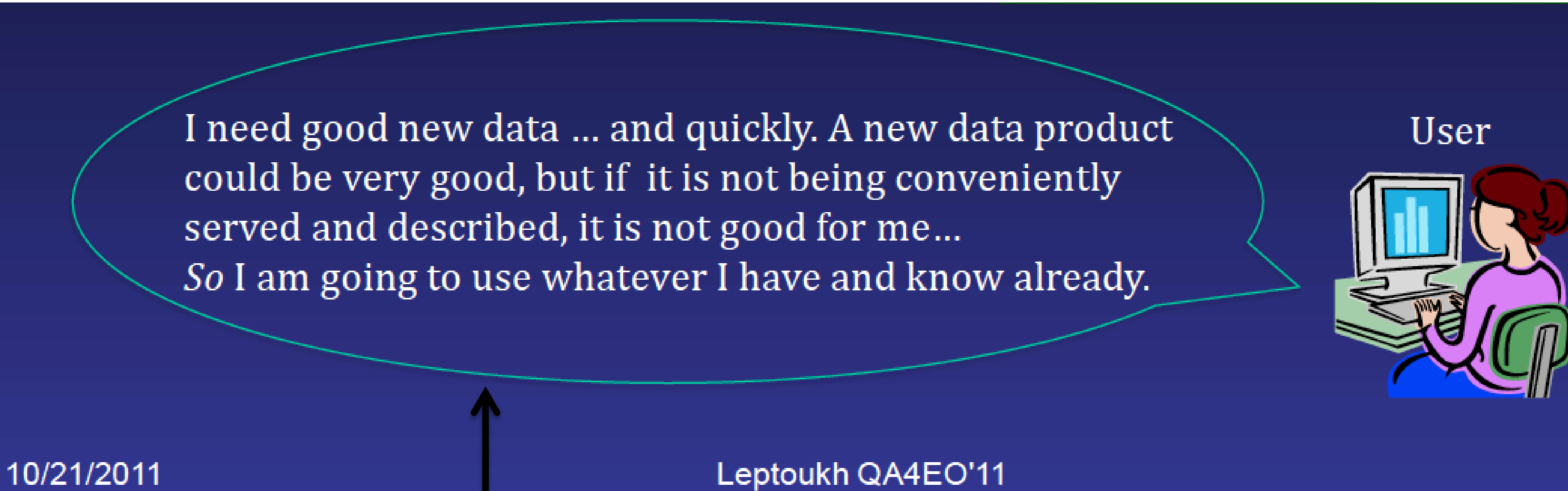
QA4ECV project (2014-2017)
Status: 29 September 2016

Folkert Boersma (KNMI) and Jan-Peter Muller (UCL)

FP7 QA4ECV project (2014-2017)

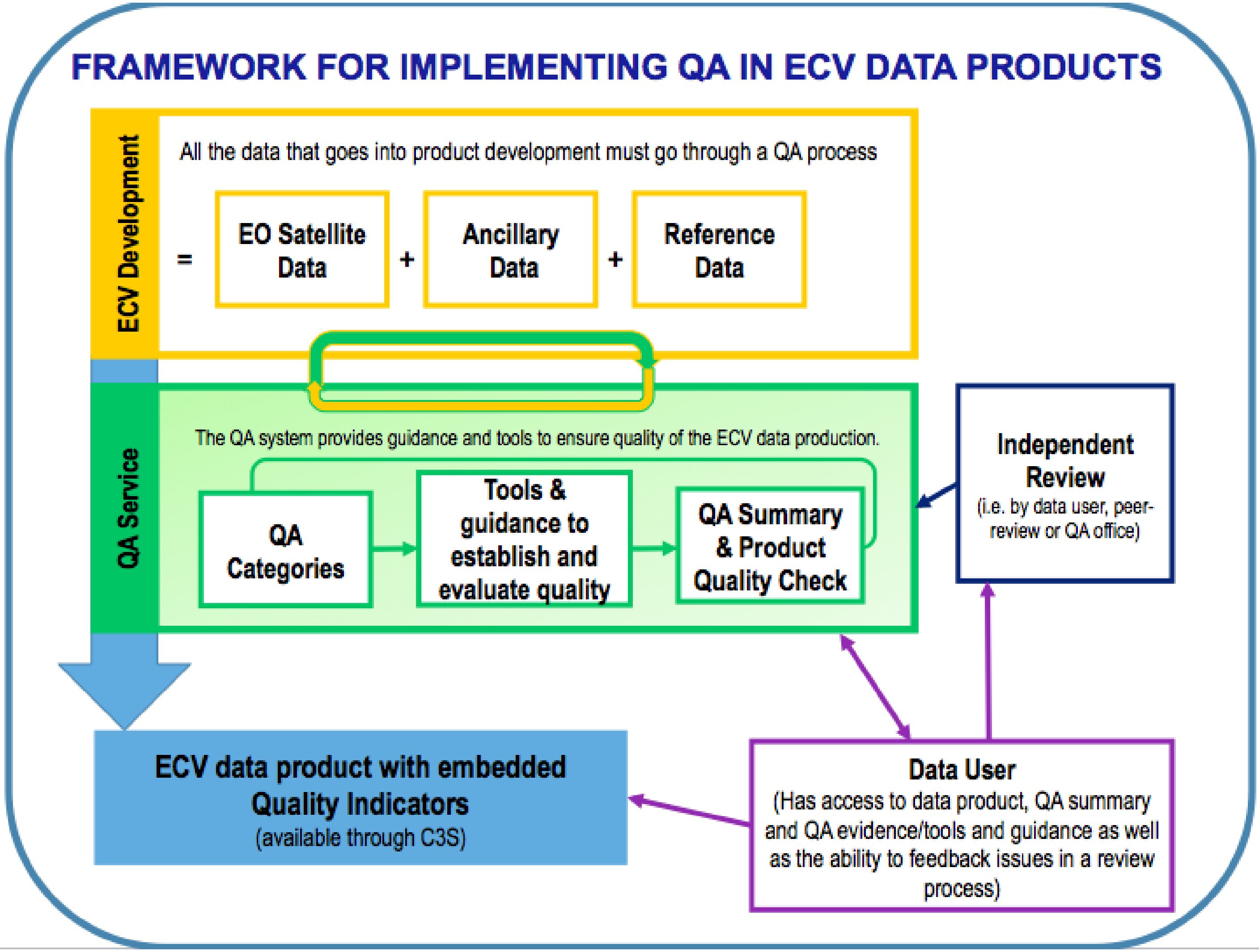


This is where QA4ECV comes in

www.qa4ecv.eu

Users need clear info on validity of EO/climate data sets,
Producers have unique records, but need to provide quality info

QA Framework



QA Service

What do we have?

- The tool that will enable the production, annotation and publishing of ECV product ***traceability chains***.

Which products/services still require development work?

- The QA Service being developed in QA4ECV is a ***prototype***. So the concepts and framework of tools, standards and templates will be compiled. They will go through consultation with product developers and product users – and be developed even further in the ECMWF Lot 2 contract that NPL has won.

QA Service

What are the further research needs?

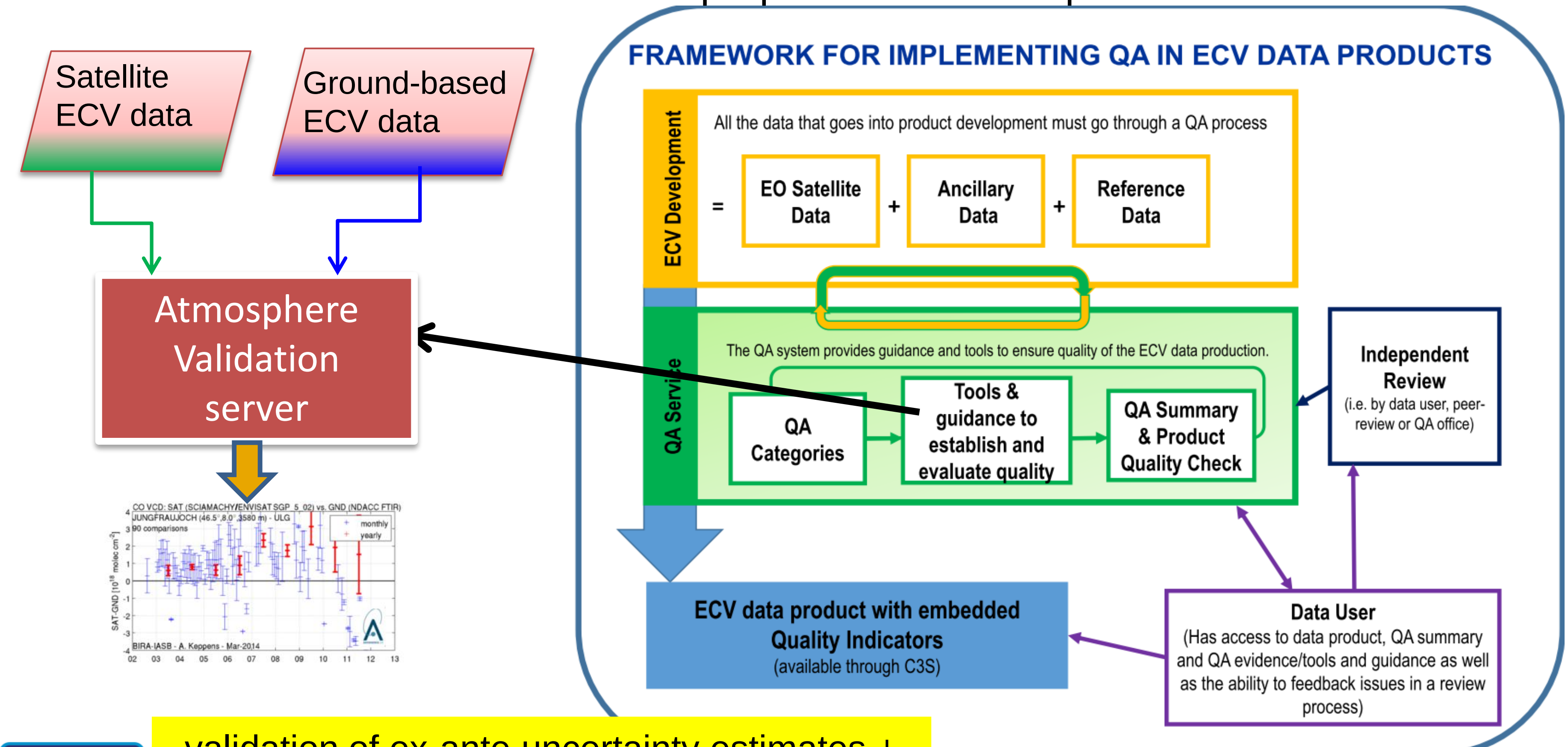
- Develop concepts and interaction with product developers as well as product users, in order to shape the look, feel and utility of the QA service categories and QA summary information.

QA4ECV tools: Atmosphere Validation Server

Objective: Develop pilot Quality Assurance framework for Essential Climate Variables

→ Producer can assure the quality of his/her data product

→ User can evaluate the fitness-for-purpose of the data product



validation of ex-ante uncertainty estimates + estimate of uncertainties in validation process

The atmospheric validation server

WP1 | WP3 | WP2 | WP4 | WP5

- Translating user requirements to validation requirements ← WP1 QA4ECV user survey+ GCOS requirements
- Formalization of validation requirements → Detailed Processing Model v1+v2

v1. July 2015

v2. June 2016

- For HCHO, NO2, CO
- Extensive feedback from experts
- Co-location settings, plots, scientific justification,…

We are here → Technical implementation → Web-based prototype QA/Validation service

December 2016
In progress

https://github.com/stcorp/harp

HARP tools

WP5 Validation of HCHO, NO2, CO ← Web-based prototype QA/Validation service

WP5 Validation of HCHO, NO2, CO ← WP4 Satellite data

Partially generated & and available
http://www.qa4ecv.eu/ecv/

WP5 Validation of HCHO, NO2, CO ← WP3 Reference data

Partially ready & and available

WP5 Validation of HCHO, NO2, CO → QA on algorithms / QA on data products

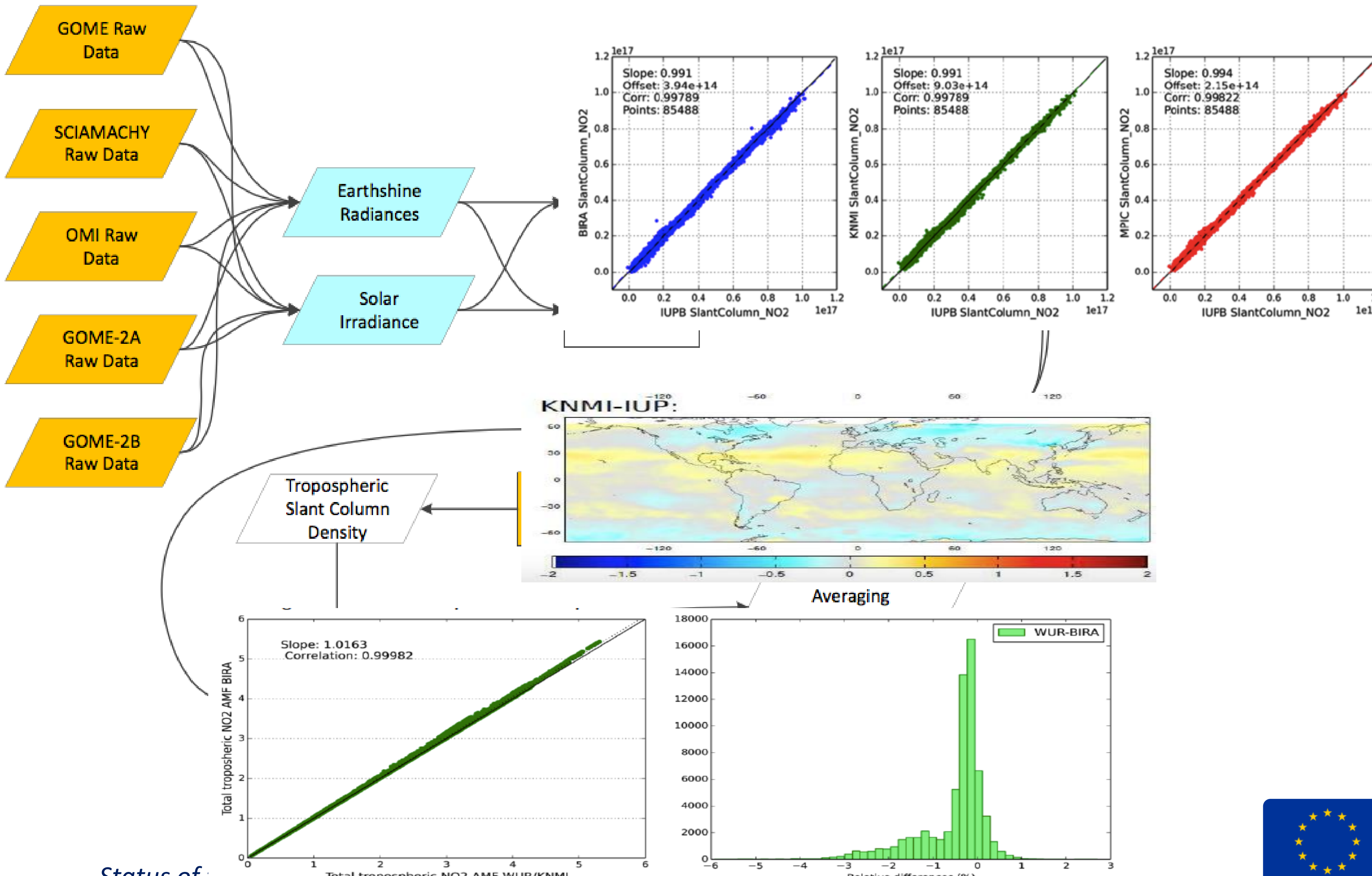
December 2016
June 2017

- In QA4ECV the pre-operational Atmosphere ECV Validation Server will be demonstrated with HCHO, NO_2 and CO satellite and reference data.

FUTURE WORK IN COPERNICUS CONTEXT

- Upscaling needed to fully operational mode
- Upgrade needed for handling near-real-time data
- Extension to other ECVs: Tailor generic validation server with specific settings (ad hoc co-location criteria, user-defined output…)
- Incorporate research results (GAIA-CLIM WP3, Fiduceo)

Atmosphere ECV precursor development



Atmosphere ECV precursors

What do we have?

- NO_2, HCHO, and CO in production and made available (v1.0)
- Includes full uncertainty propagation and breakdown

Which products/services still require development work?

- Need to write PSD for all ECV precursors
- Harmonization with ESA CCI data format?

What are the further research needs?

- Integrate ECV dataset with S5P TROPOMI (launch 2017)
- Test and validate product and uncertainties
- aerosol corrections, BRDF-research, high-resolution a priori
- Ready for ESA CCI and ECV+ lot from C3S

Quality Assurance for Essential Climate Variables

NEWS PROJECT INFO PUBLICATIONS QA SYSTEM ECV DATA FORUMS CONTACT

FP7-SPACE-2013-1
Project No 607405

Headlines

- QA4ECV at RSPSoc / CEOI Conference
- Outline of a Framework for a QA Service in Support of C3S

Introduction

Quality-assured satellite data are of central interest to the QA4ECV project. Satellites have revolutionised the Earth's observation system of climate change and air quality over the past three decades, providing continuous data covering the entire Earth. However, many users of these data are not conscious of the quality of these satellite data. Because of this, the European Union expressed in its 2013 6th FP7 Space Research Call a need for reliable, traceable, and understandable quality

Quality Assurance for Essential Climate Variables

NEWS PROJECT INFO PUBLICATIONS QA SYSTEM ECV DATA FORUMS CONTACT

FP7-SPACE-2013-1
Project No 607405

Essential Climate Variables

LAND	ATMOSPHERE
Albedo	CO
LAI	HCHO
FAPAR	NO_2

QA4ECV provides long-term data records for 3 Land Essential Climate Variables (ECVs) and 3 Atmosphere ECV precursors. Click on the ECV of your interest to access the data, to find a graphical representation of how these data have been retrieved (Traceability Chain), and to access a FAQ Forum.

ECV DATA

- ECVs Glossary
- CO Product
- FAPAR Product
- GlobAlbedo - Broadband Albedo Product
- LAI and FAPAR
- HCHO Product

QA4ECV NO_2 ECV precursor

A joint product by: KNMI, BIRA-IASB, University of Bremen, MPI-C, and Wageningen University

NO_2 Data

Regional Tropospheric NO_2 columns from OMI

<-- previous day
<-- previous month
next day -->
next month -->

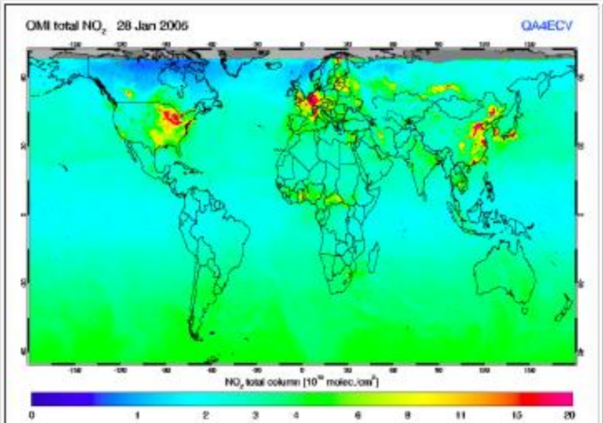
NO2 of 28 January 2005

NO_2 observations for:

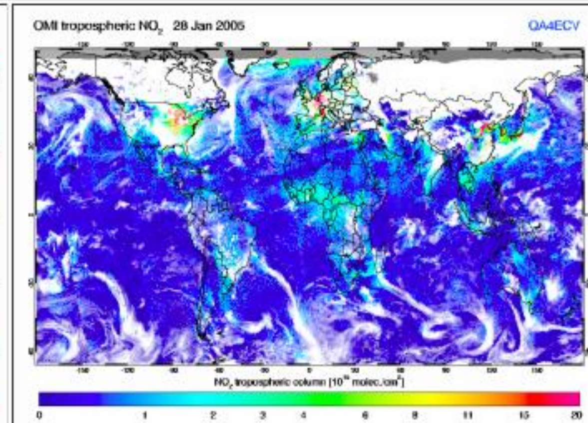
Region: World
Year: 2005
Month: January
Day: 28

submit

Main page tropospheric NO2

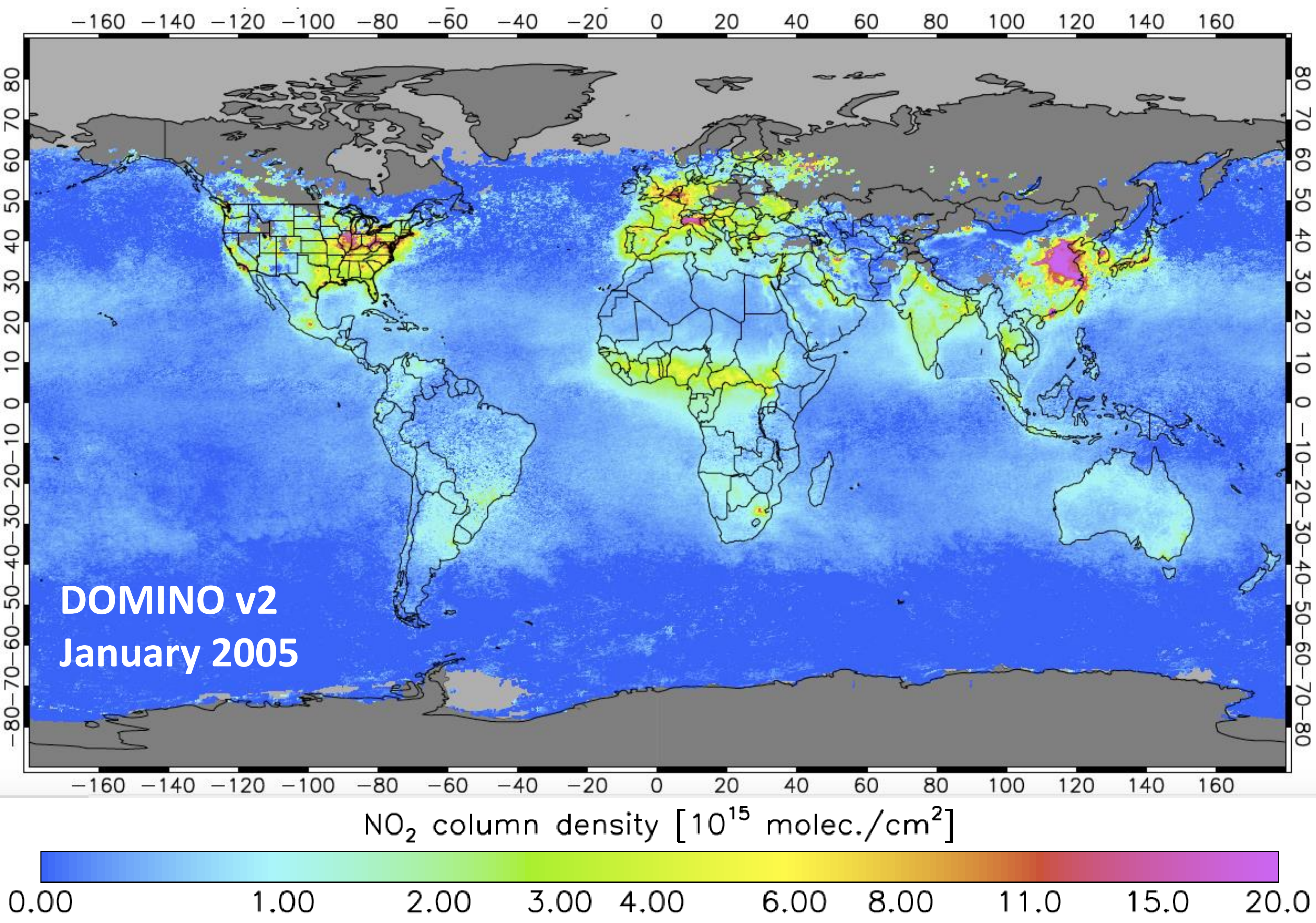


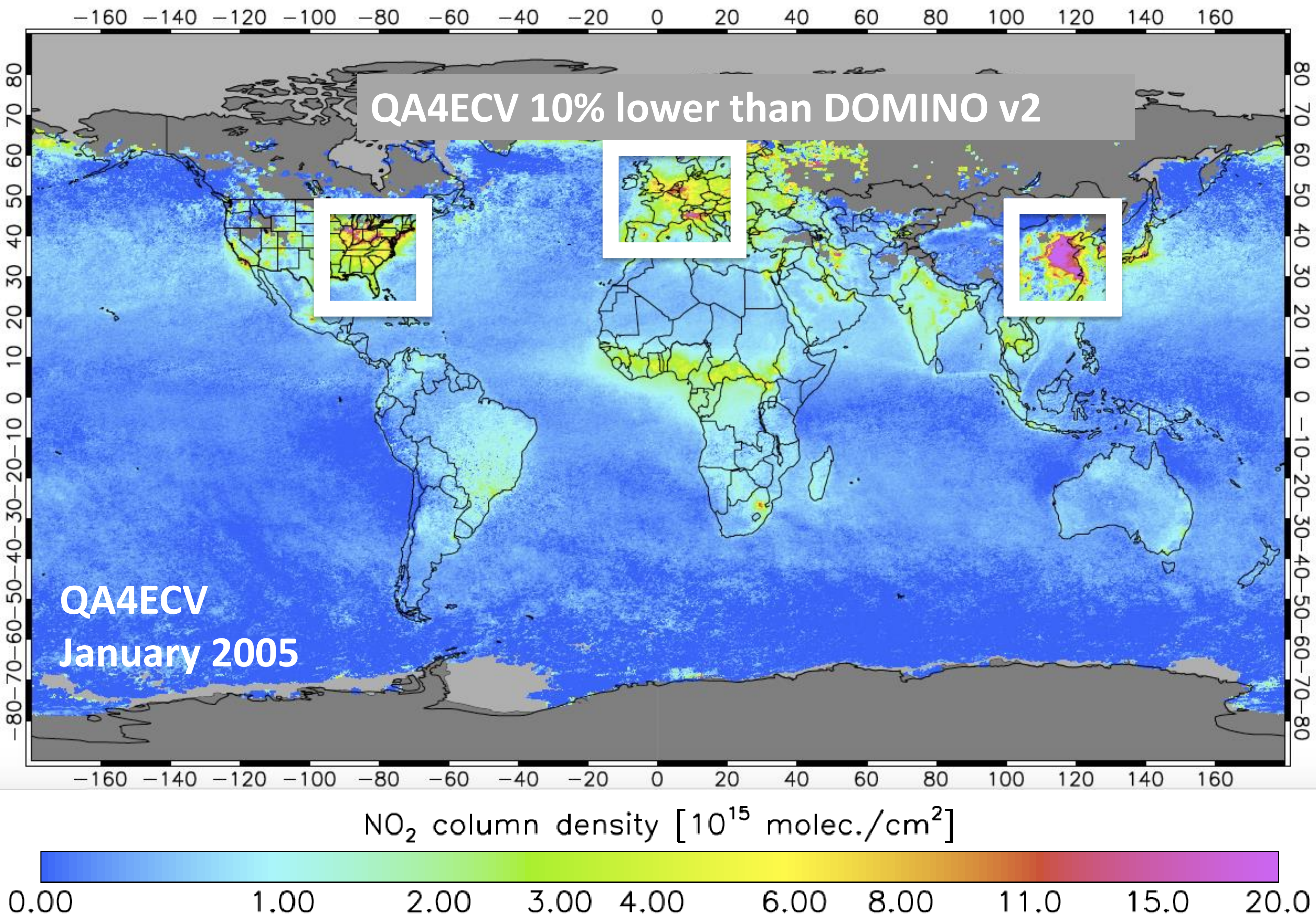
Total column



Tropospheric column

NO2 data file

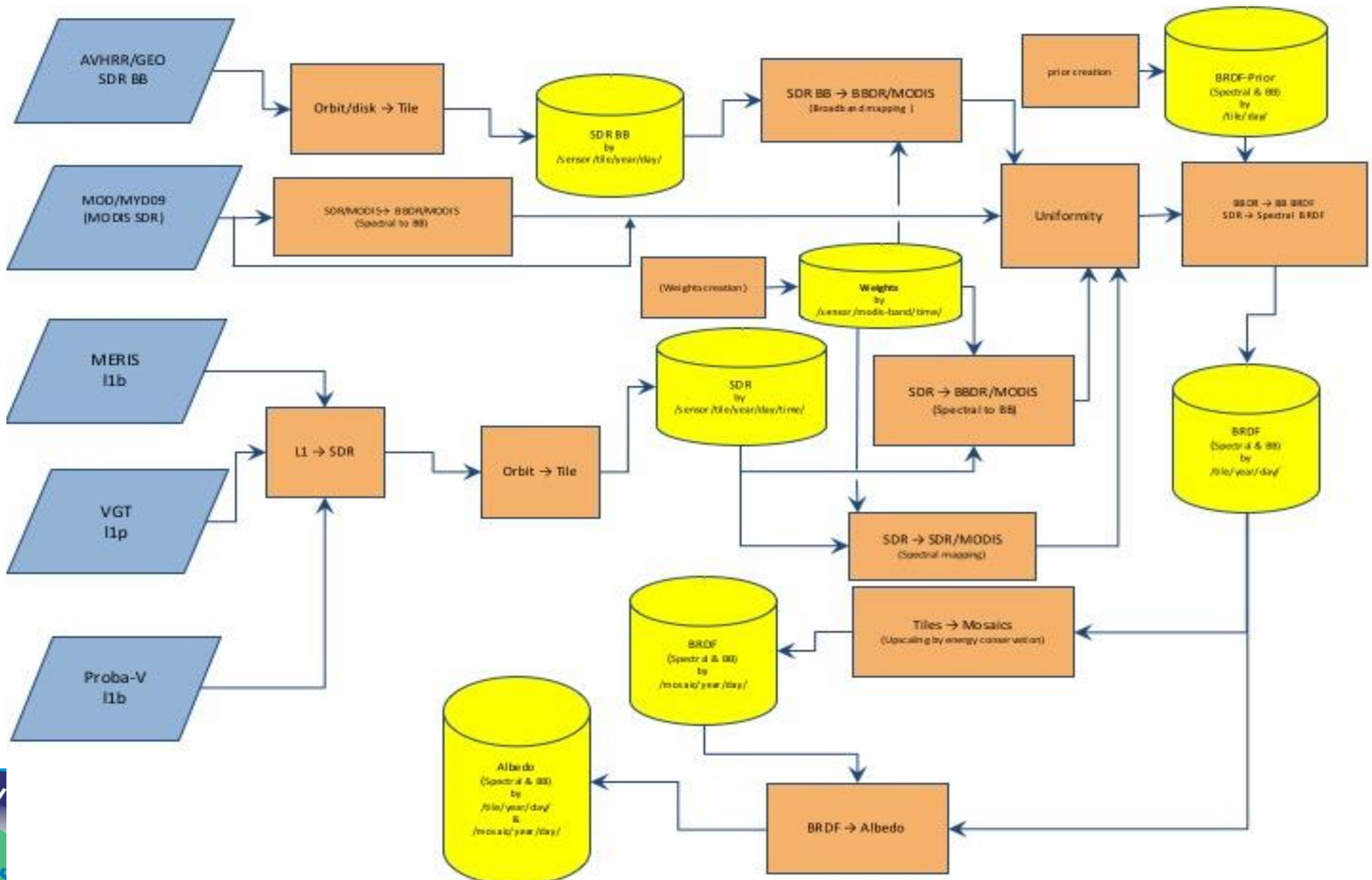

DOMINO v2
January 2005
−160 −140 −120 −100 −80 −60 −40 −20 0 20 40 60 80 100 120 140 160
NO2 column density [10^15 molec./cm^2]
0.00 1.00 2.00 3.00 4.00 6.00 8.00 11.0 15.0 20.0


QA4ECV 10% lower than DOMINO v2
QA4ECV
January 2005
−160 −140 −120 −100 −80 −60 −40 −20 0 20 40 60 80 100 120 140 160
80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80
NO_2 column density [10^{15} molec./cm^2]
0.00 1.00 2.00 3.00 4.00 6.00 8.00 11.0 15.0 20.0

Land ECVs (all have per pixel var-covar uncertainties)

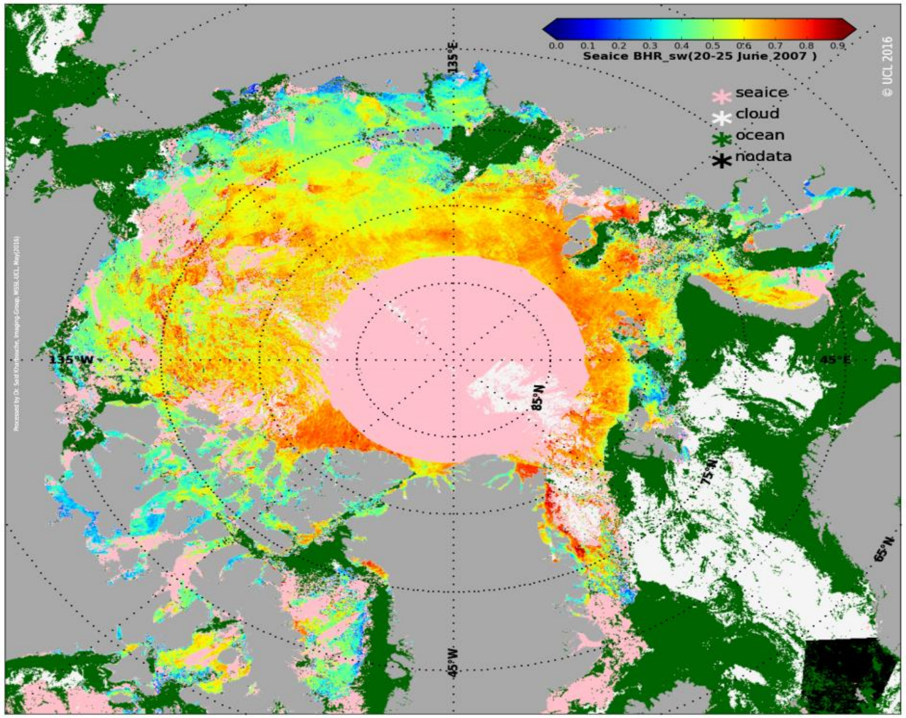
- **Albedo** (1 or 5km, spectral, daily, monthly) is in production on UK CEMS for
  - MVIRI (METEOSAT First Generation+MSG-HRVIS) + AVHRR (1981-2014)
  - MODIS Collection 6 Prior (daily, 1km, 10 spectral bands, 2000-2016)
  - European + NASA data fusion (daily, 1km, 10 spectral bands, 1998-2016)
- **LAI/Fapar using TIP** : in production, albedo datasets (1981-2014; 1998-2016)
- **FAPAR** based on AVHRR (5km, 10-daily): in production (1981-2014)
- Data will initially be evaluated by land partner tasked with their quantitative evaluation (A. Loew, LMU)
- **Website for Data Access** under development but data will only be distributed once it has been assigned a DOI for each dataset and all the documentation is completed
- All products have uncertainties, traceability chain and validation
- Upscaling studies from field-scale through airborne scale to EO satellite
- Validation of ALGORITHMS using realistic scene simulation

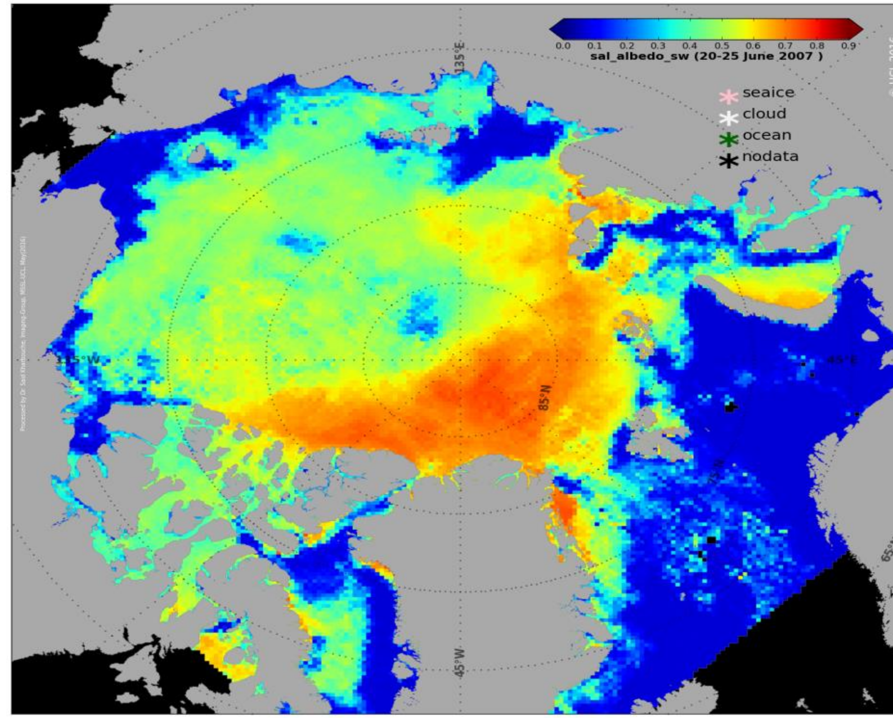
Albedo Processing Chain

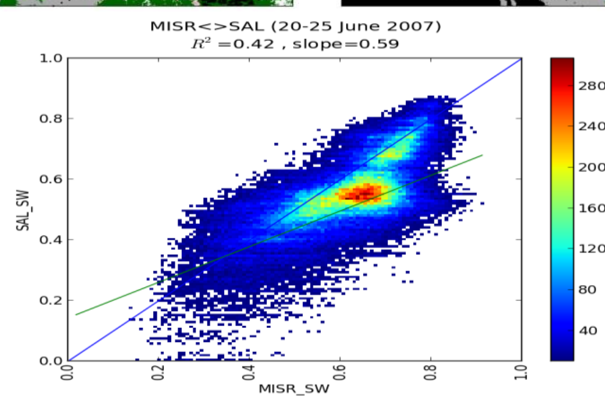


Sea-Ice comparison of MISR+MODIS vs CLARA-SAL :20-25 June 2007

Daily, weekly, monthly 1km maps of INSTANTANEOUS spectral BRF/albedo of sea-ice from 2000-2016. No coverage from VGT, Proba-V

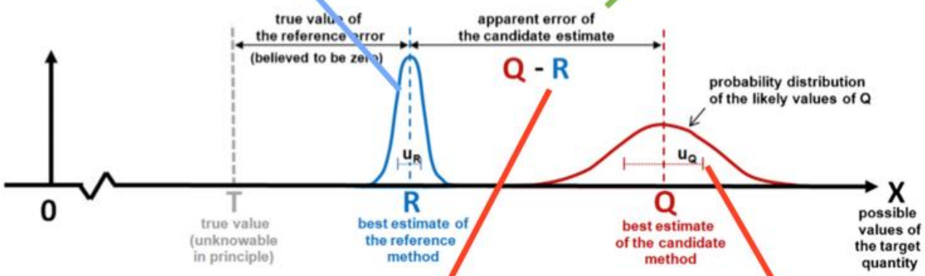






Field measurement uncertainty

The apparent error between satellite-based and in-situ measurements are also a result of the uncertainty of both: but how can we quantify the contributions separately?



Validate satellite-based products, space ECVs vs ground-based values

Test conformity with GCOS requirements

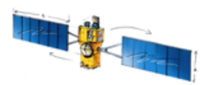
Two Uncertainties:

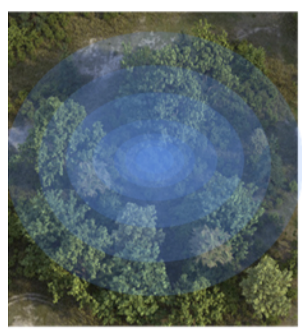
1. Field measurements
2. Retrieval Algorithm

QA4ECV WP3 Land : How to assess the uncertainties from ?

1. Ground-based measurements: calibration,
2. Space ECVs products:

space sensor → data → retrieval algorithm → space product (σ_{prod})





HOW TO FIND THE TRUE VALUES?

space / 'reference' 1:1

reference product ($\sigma_{ref} \approx 1\%$)

in-situ / 'reference' 1:1

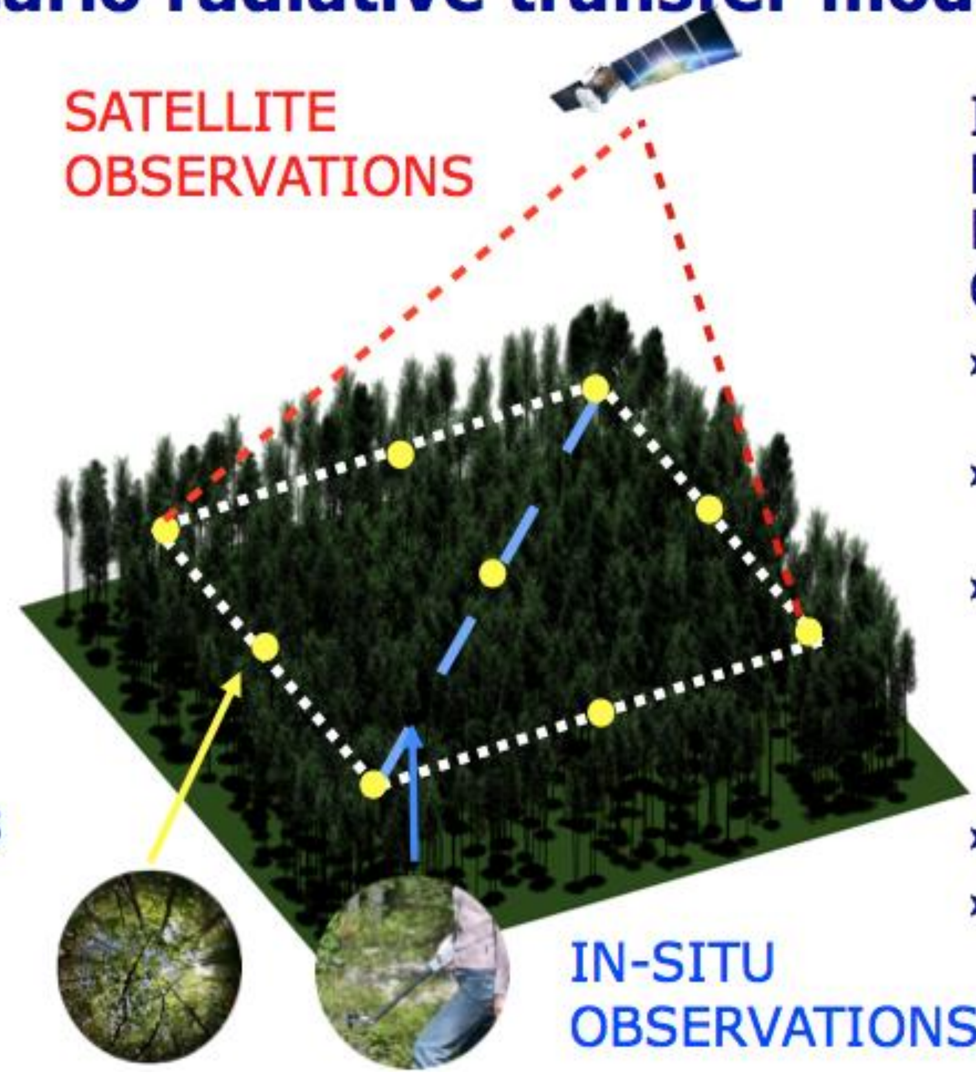
in situ sensor → data ($\sigma_{data} \approx 1\%$) → retrieval algorithm → in situ product (σ_{prod})

3D Monte Carlo radiative transfer models

Physically-based 3D complexity

Can place sensors above (satellites) or within (in-situ) the canopy

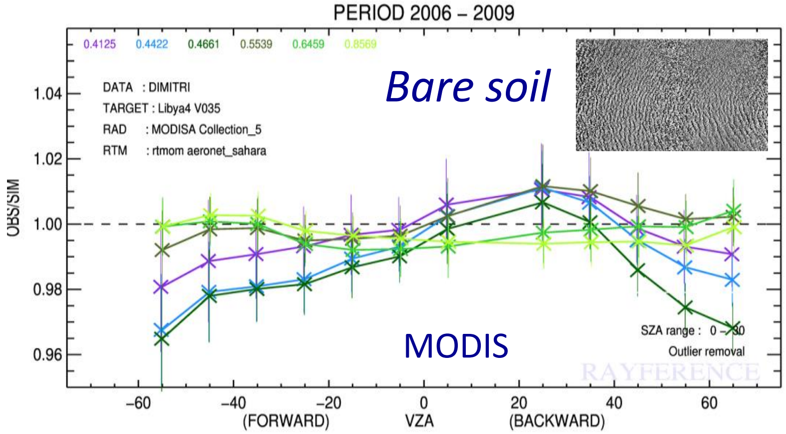
Validated against in-situ measurements and other 3D MCRT models (RAMI, ROMC)



IN 3D MODELLING WE KNOW OR CAN COMPUTE:

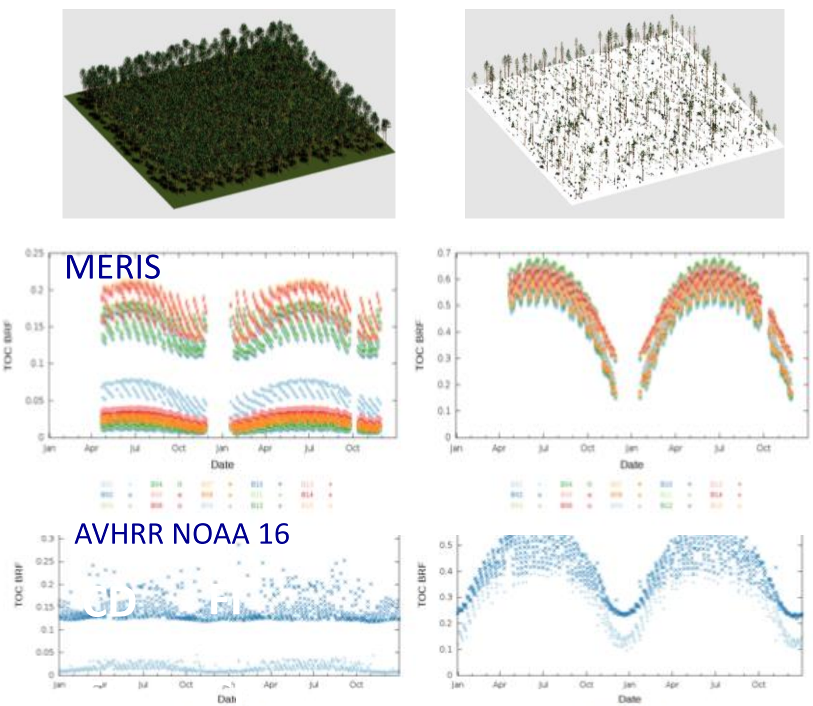
- The true values of LAI, FAPAR, Albedo
- The angular pattern of incident radiation
- The number, size, shape, orientation and reflectance properties of every scatterer
- Canopy architecture
- Spectro-directional properties

Space BRF TOA (TOC) Simulations



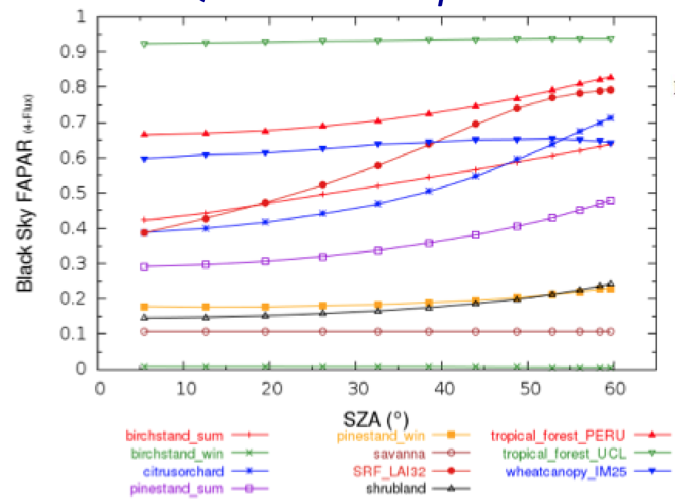
Example of nadir looking Raytran surface BRF simulation over Libya-4 over the 100km×100km ROI acquired with a 250m pixel resolution CCD camera.

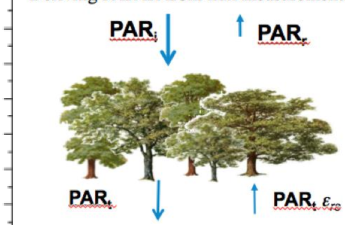
Pinestand summer and winter



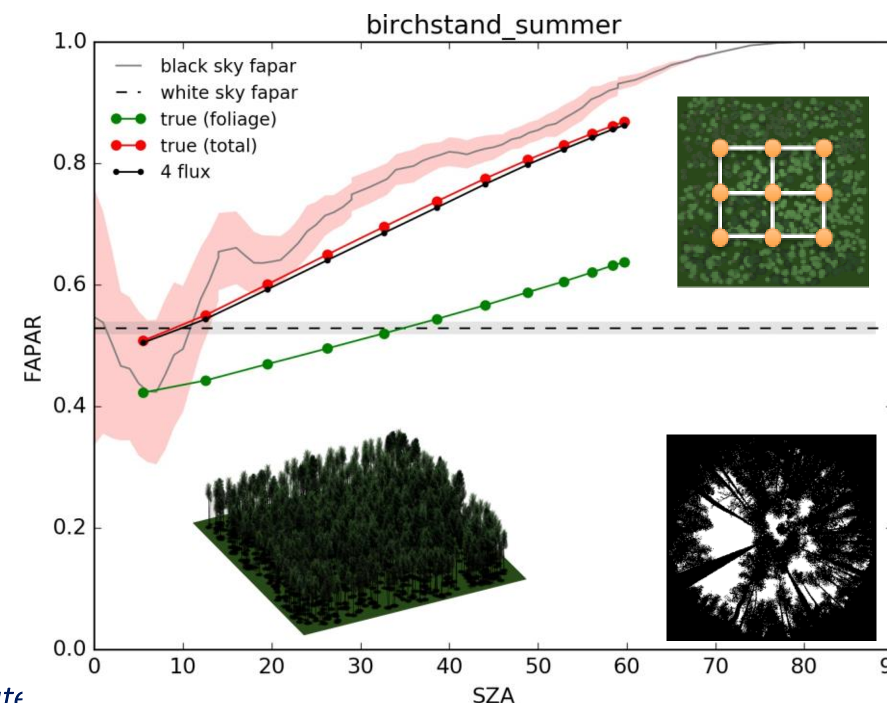
In-situ Simulations

All QA4ECV canopies





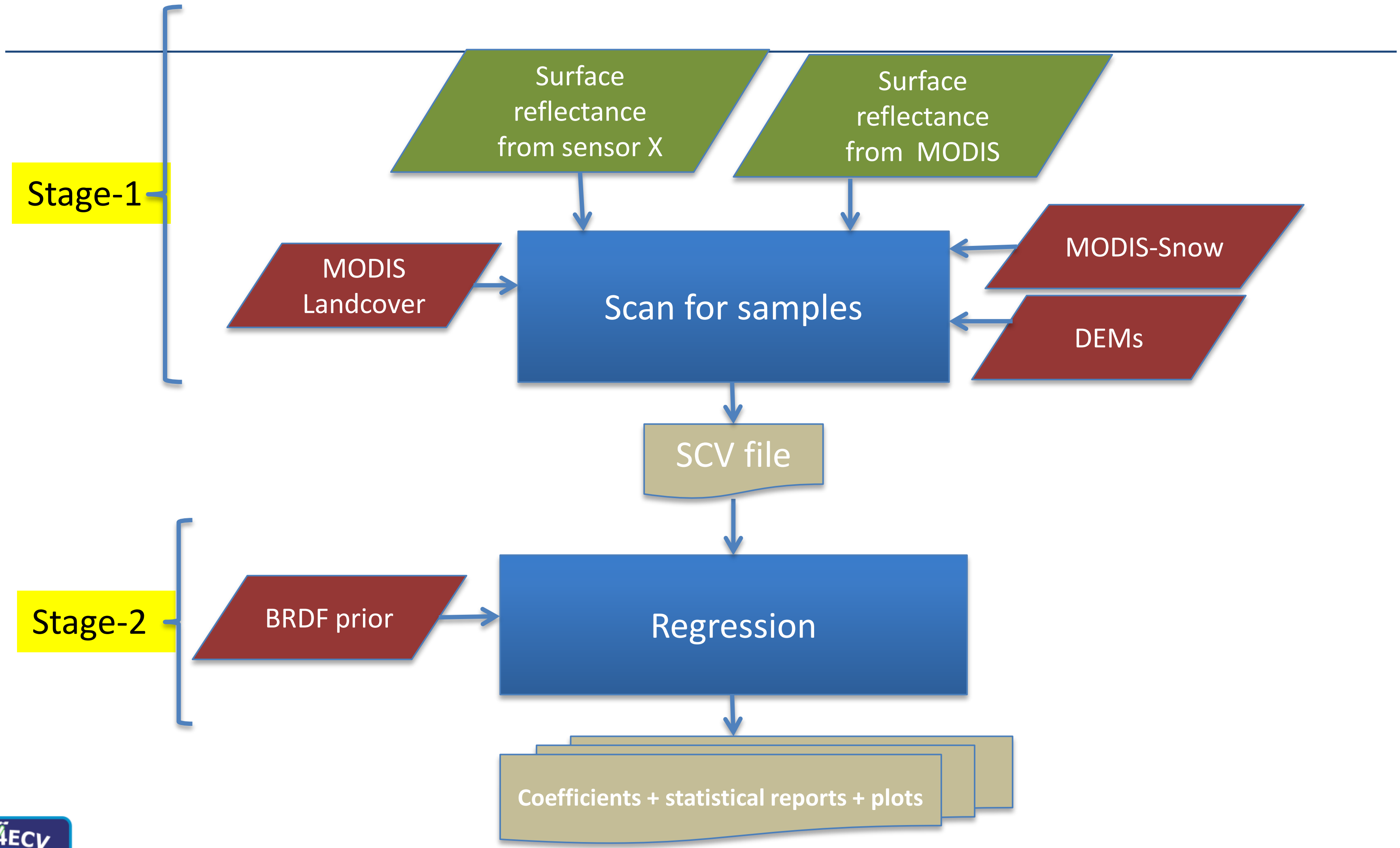
All in-situ methods



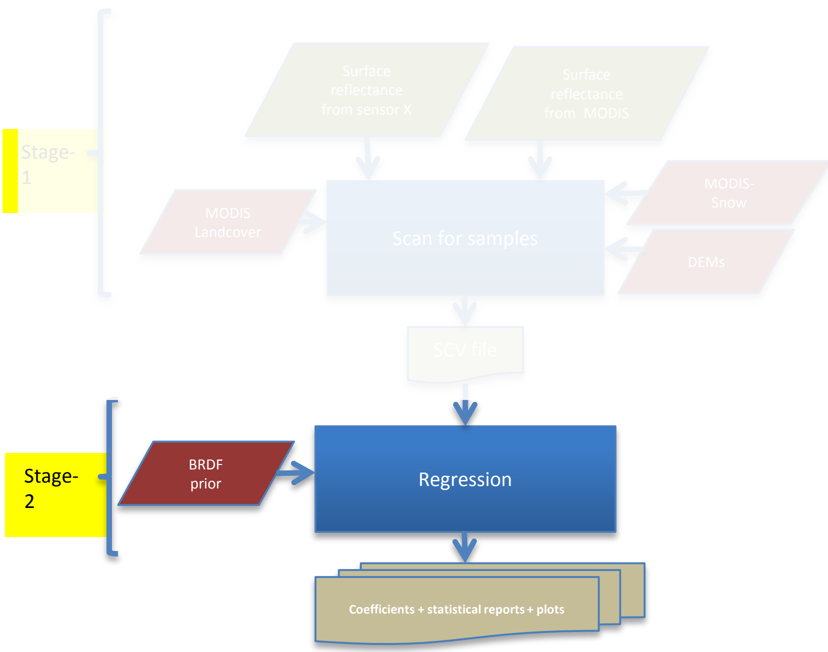
Progress : Development of harmonised retrieval for surface BRDF/albedo

- Complete and test implementation of MODIS spectral mapping scheme as proposed by UCL:
  - Implementation of mapping MERIS SDR (15 bands) → MODIS SDR (7 bands) completed.
  - Implementation of spectral SDR (7 MODIS bands) to spectral BRDF and albedo completed.
  - Implementation has been tested in local environment. Migration to CEMS is currently underway.
- Compare/verify BRFs derived from this with MOD09 BRFs for selected tiles:
  - A first SDR cross-check with corresponding MOD09GA products looks reasonable. A systematic comparison/verification is in preparation.
- Generate broadband BRDF/albedo from Proba-V (2014-present) for selected tiles using spectral mapping scheme to VGT wavelengths:
  - BRDF/albedo generation (daily and 8-day) completed for 2014 for ALL tiles. Products available on CEMS.
- Generate daily 1km, 10 spectral band MODIS Collection 6 “prior” for optimal estimation
  - Most tiles generated

Spectral Mapping (Overview)



Initial Results: (MERIS/MODIS-like vs MODIS)



band_1

band_2

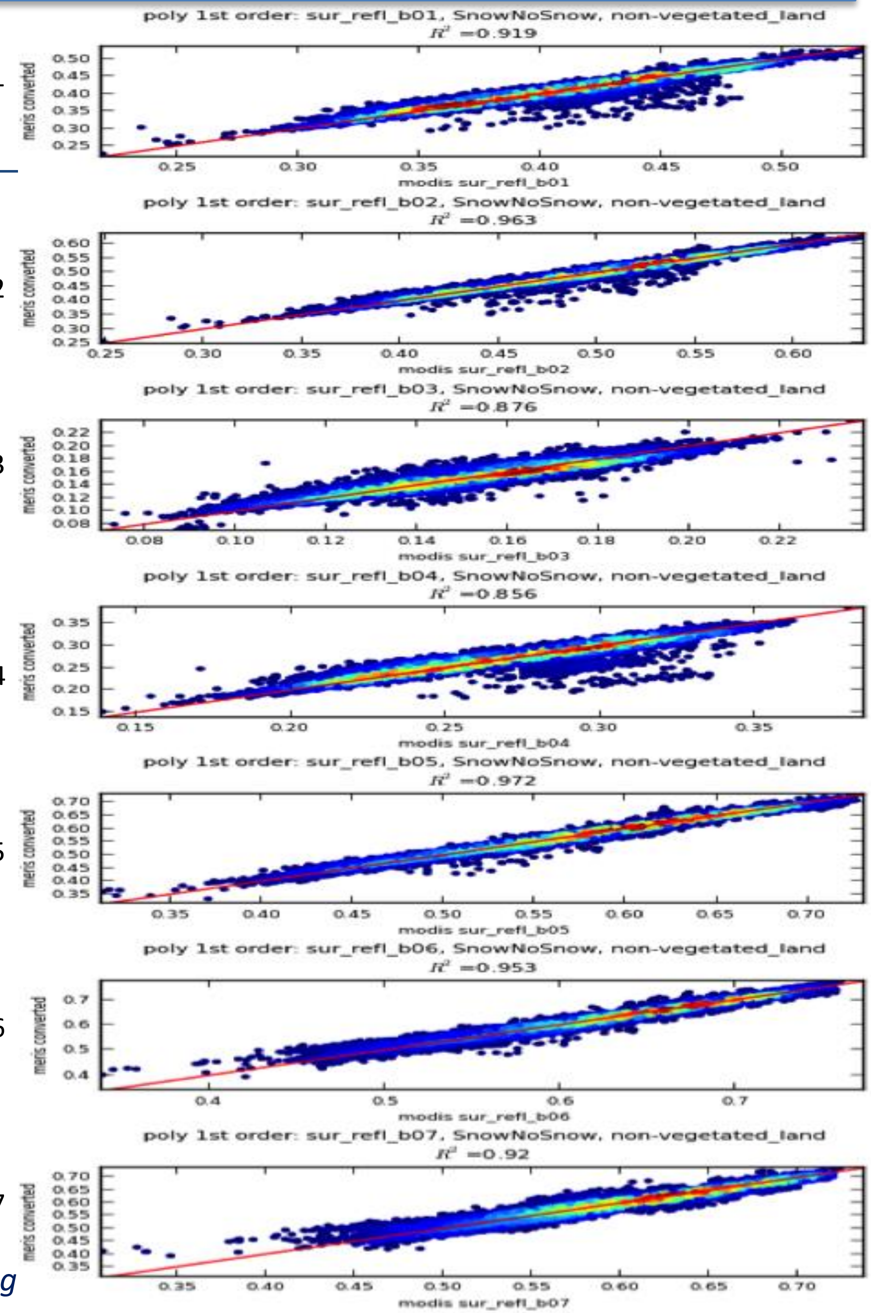
band_3

Band_4

band_5

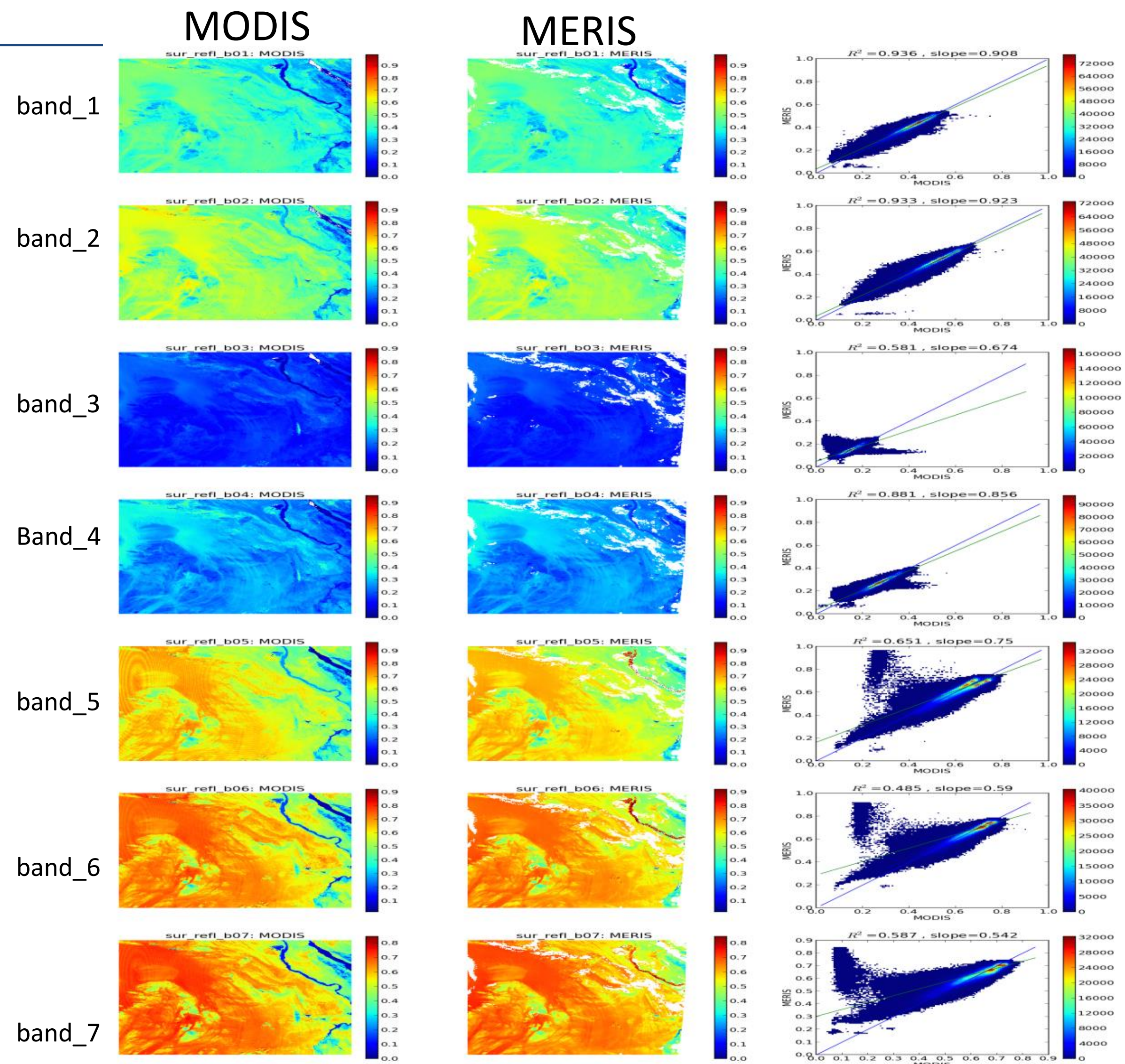
band_6

band_7



Initial Results: (MERIS/MODIS-like vs MODIS)

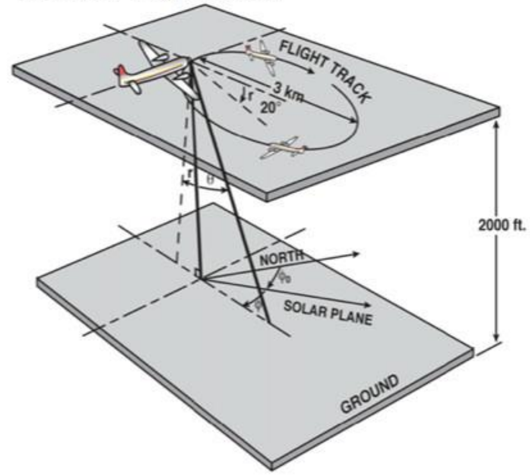
Tile: h20v06 (Egypt)
Date_Modis: 11 Aug 2011
Date_Meris: 08 Aug 2011
Gap in angles: <5deg



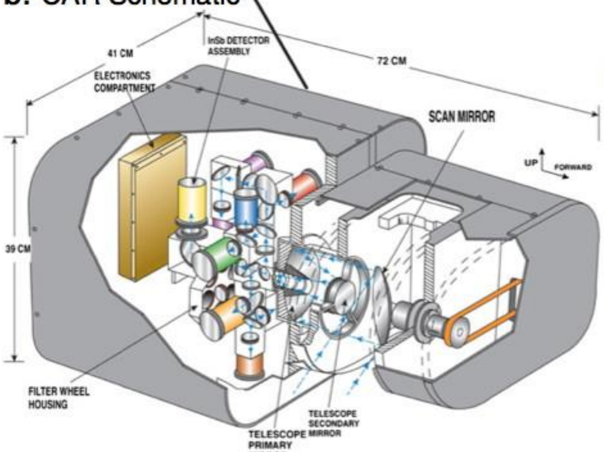
NASA CAR (Cloud Absorption Radiometer) : an excellent source for BRF

a. Jetstream-31 Aircraft

c. BRDF Flight Track



b. CAR Schematic

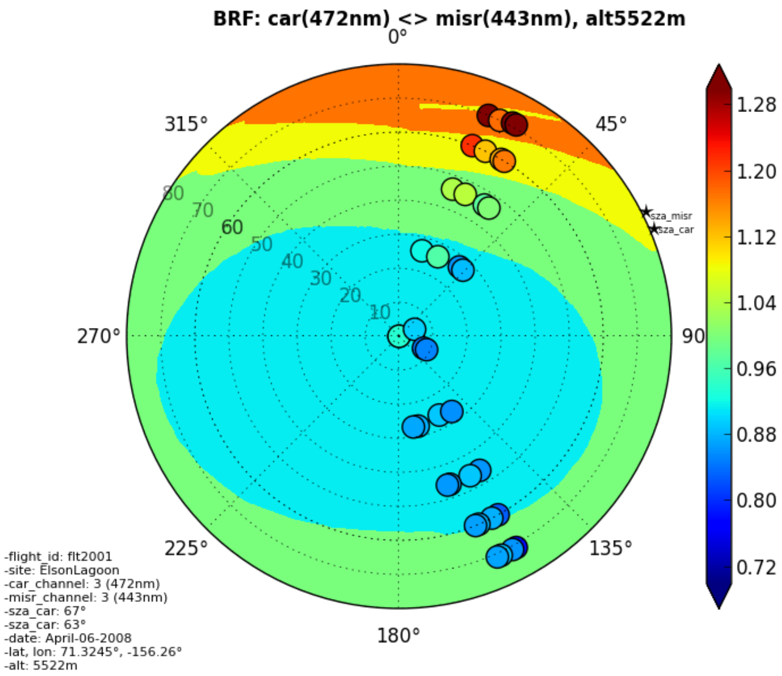


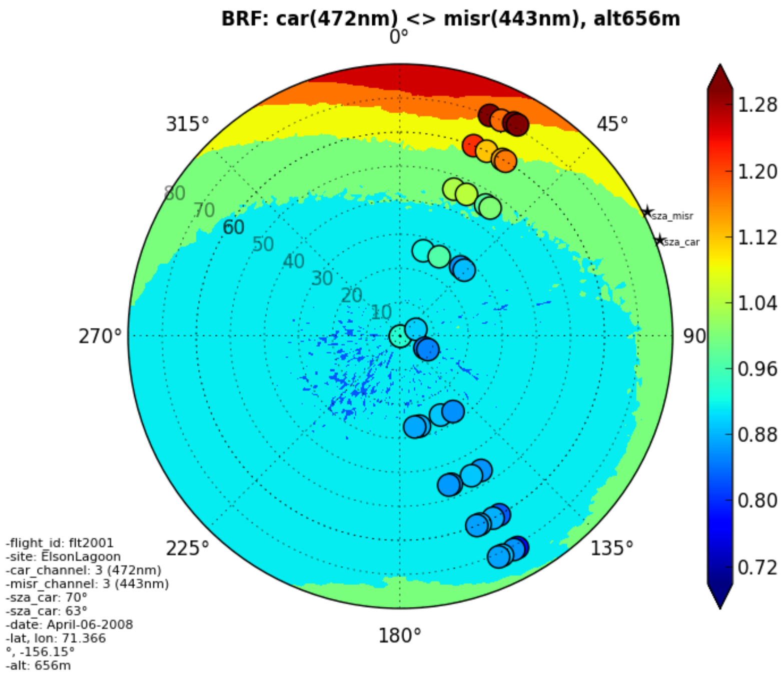
d. Cloud Absorption Radiometer (CAR) Parameters

Angular scan range	190°
Instantaneous field of view	17.5 mrad (1°)
Pixels per scan line	382
Scan rate	1.67 scan lines per second (100 rpm)
Spectral channels (μm; bandwidth (FWHM))	14 [a] (8 continuously sampled and last six in filter wheel): 0.340(0.009), 0.381(0.006), 0.472(0.021), 0.682(0.022), 0.870(0.022), 1.036(0.022), 1.219(0.022), 1.273(0.023), 1.556(0.032), 1.656(0.045), 1.737(0.040), 2.103(0.044), 2.205(0.042), 2.302(0.043)

Gatebe, C. K., et al. (2010). *ACP*, *10*(6), 2777.

MISR cf CAR at 2 different altitudes





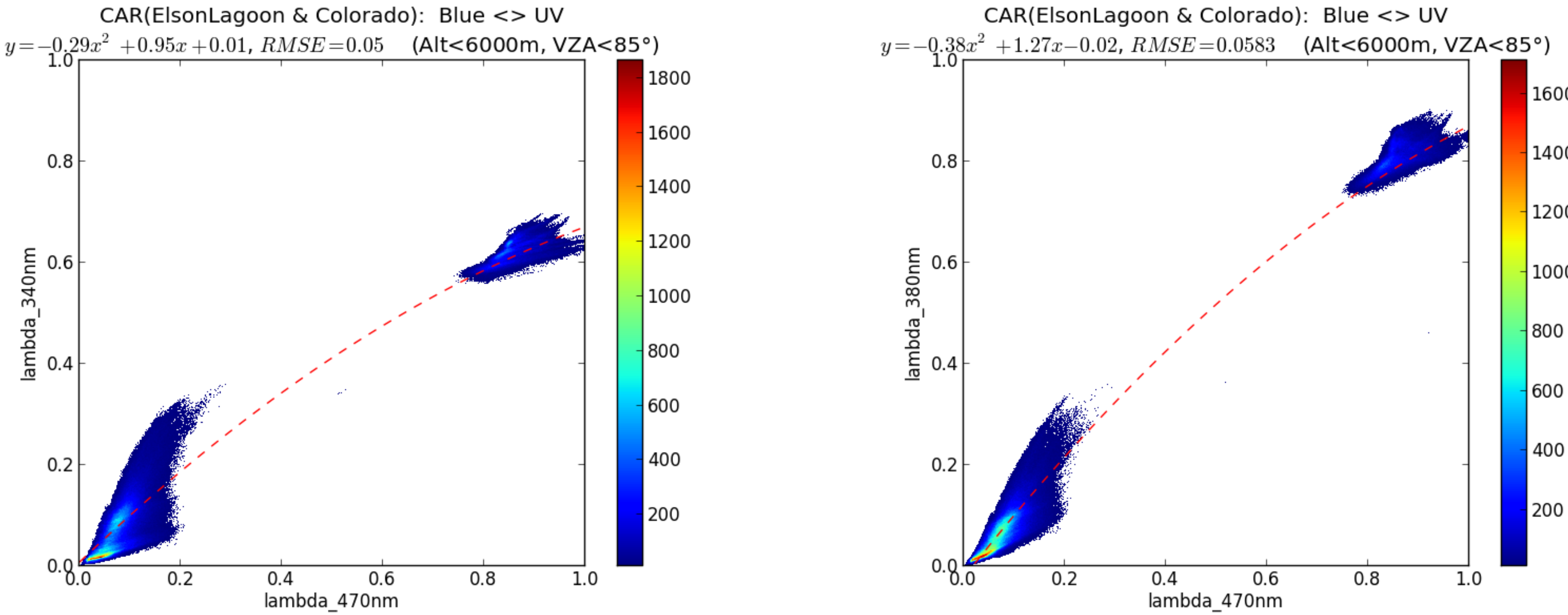
IFoV≈100m

IFoV≈10m

Kharbouche, Muller, Gatebe (ISRSE 2015)

"BLUE" MODIS (470nm) to → UV (340nm)

NASA CAR data employed to map MODIS blue channel images to UV (for NO2)



Daily MODIS climatology from 16 years of daily 10-spectral bands

Progress : Production of Multi-decadal ECVs

BROCKMANN CONSULT GMBH

- Complete entire time series for METEOSAT region for all years:
  - MVIRI BRF disks --> 200x200 BBDR tiles completed for 1982-2006. Products available on CEMS.
  - SEVIRI BRF disks --> 200x200 BBDR tiles completed for 2006-2009. Products available on CEMS.
  - Meteosat MVIRI 200x200 BBDR tiles --> BRDF/albedo 8-day tiles completed for 1982-1993. Products available on CEMS.
- Complete VGT/Proba-V for period 1998-2014 using GlobAlbedo modified processor:
  - Proba-V daily and 8-day albedo processed for 2014. Products available on CEMS.
  - VGT: L1b → SDR tiles completed for 04/1999 - 05/2014. Products available on CEMS.
- Complete all GEO/AVHRR years for areas of overlap, AVHRR only elsewhere:
  - AVHRR BRF global --> 200x200 BBDR tiles completed for 2005. Products available on CEMS.
  - AVHRR BRF input data for other years is currently being transferred to CEMS.
  - Awaiting SCOPE-CM contribution from NOAA & JMA for other GEO areas

QA4ECV

EUMETSAT Contributions to QA4ECV

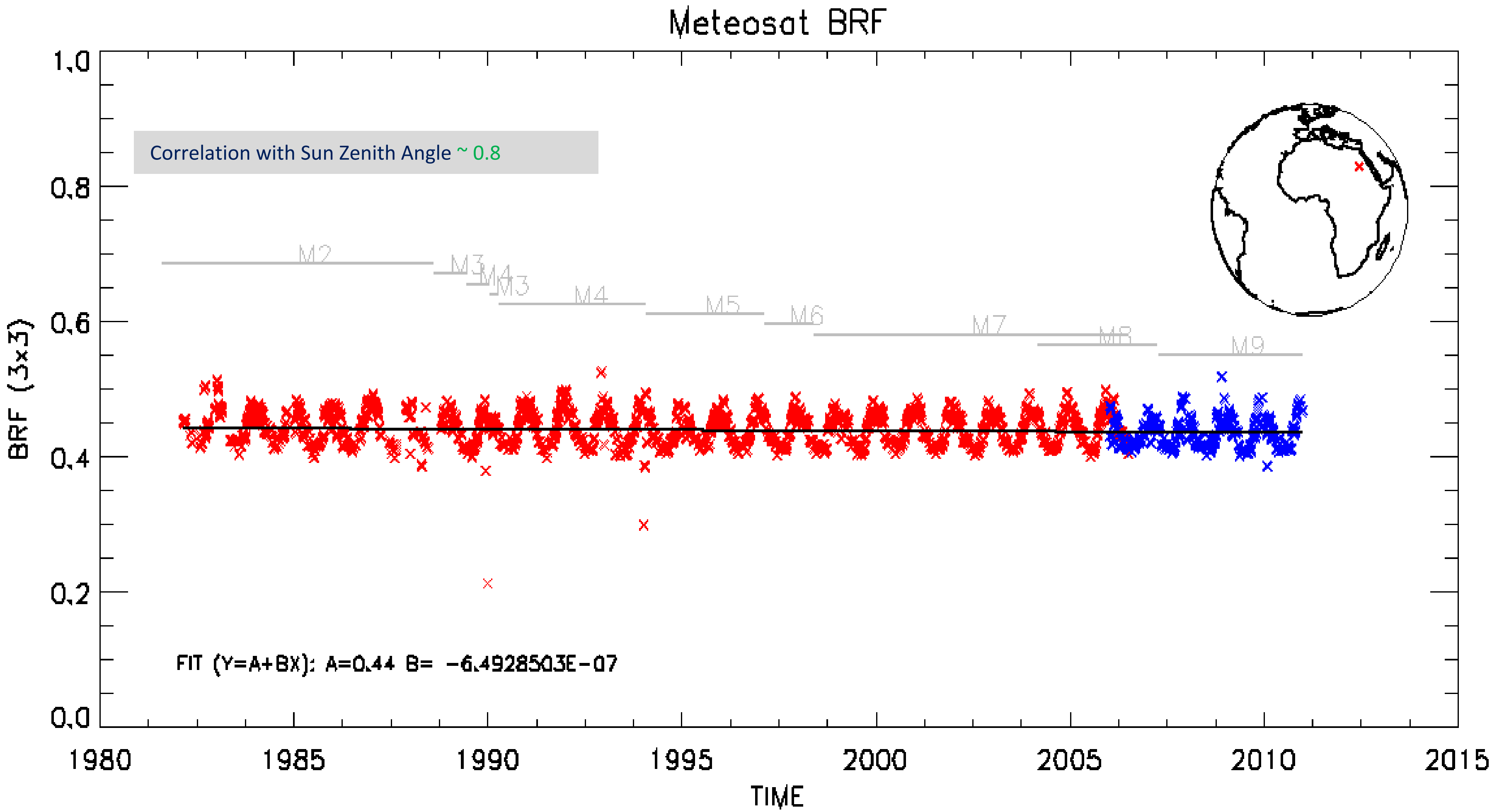
- **Albedo cloud removal:** a two-steps method for removing clouds has been developed (Lattanzio, A., Fell, F., Bennartz, R., Trigo, I. F., and Schulz, J.: Quality assessment and improvement of the EUMETSAT Meteosat Surface Albedo Climate Data Record, Atmos. Meas. Tech., 8, 4561-4571, doi:10.5194/amt-8-4561-2015, 2015.)

- **BRF uncertainties estimation:** a mathematical solution for the estimation of spectral and shortwave (0.3-3.0 µm) uncertainty of BRF has been derived and applied.

- **Processing of MSG HRVIS:** a new sensor (SEVIRI) and two new satellite (MET08 and MET09) have been processed. The band processed is HRVIS because spectrally very similar to First Generation Meteosat. This allows for a more homogenous data record.

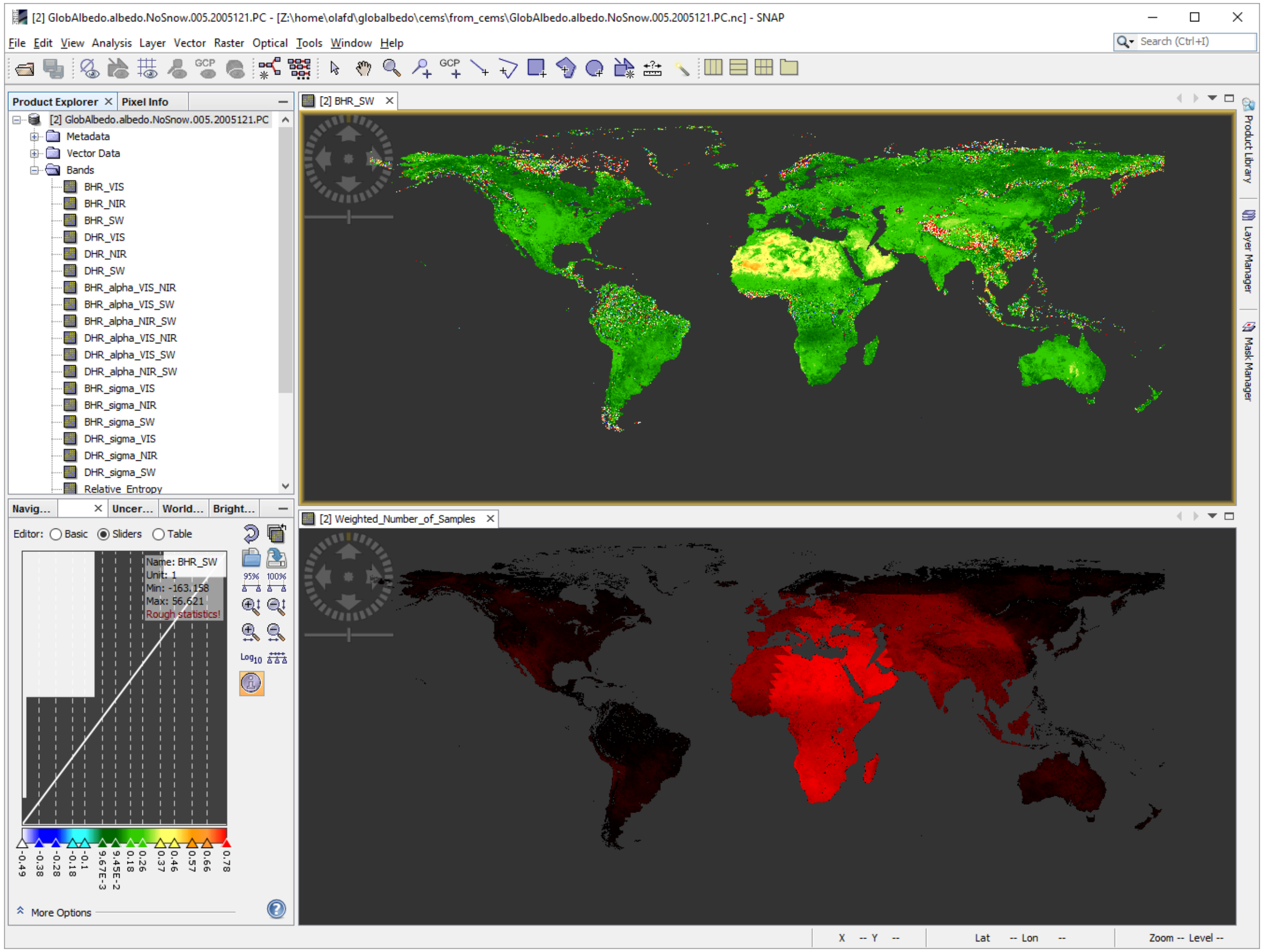
- **GEO-BRF Data Record with uncertainties**: a 28 years long daily data record enclosing 7 satellites has been produced. The dataset includes both spectral and shortwave BRF with corresponding per-pixel estimated uncertainty.

Shortwave BRF Time series retrieved from METEOSAT



Shortwave (0.3-3.0 µm) BRF retrieval time series on Libya desert from 1982 to 2010 derived using MVIRI instrument onboard Meteosat first (M2-M7) and SEVIRI instrument on board second (M8-M9) generation.

First GEO+AVHRR data fusion results



BHR-SW

Nsamples

FAPAR and LAI from BHRs & full cov. matrix: TIP 5D

TIP (two-stream inversion package):

- inversion of radiative transfer in the vegetation canopy-soil system
- based on two-stream model (Pinty et al., 2006)
- Bayesian approach, giving posterior uncertainties
- retrieval of effective LAI and FAPAR (Voßbeck et al., 2010)
- first and second derivatives from automatic differentiation (TAF, FastOpt)

TIP-5D:

- In QA4ECV, TIP is extended to use full covariance matrix of BHRs

=> rigorous uncertainty propagation based on covariances <=

Possible developments:

- narrow band (spectral) inputs
- multi-spectral input BHRs

Optimisation:
find 2-stream parameters matching BHR VIS and BHR NIR

At Optimum:
- optimal LAI
- simulated VIS-absorption in canopy is FAPAR

Error Propagation:
- use 2nd derivative at optimum to determine posterior covariances

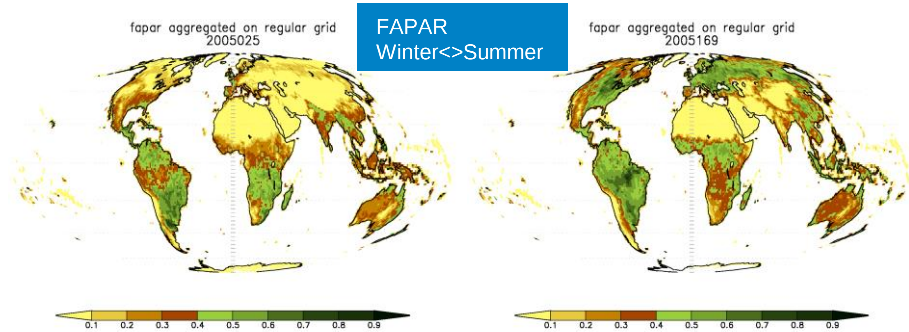
From Covariances:
uncertainties on LAI and FAPAR

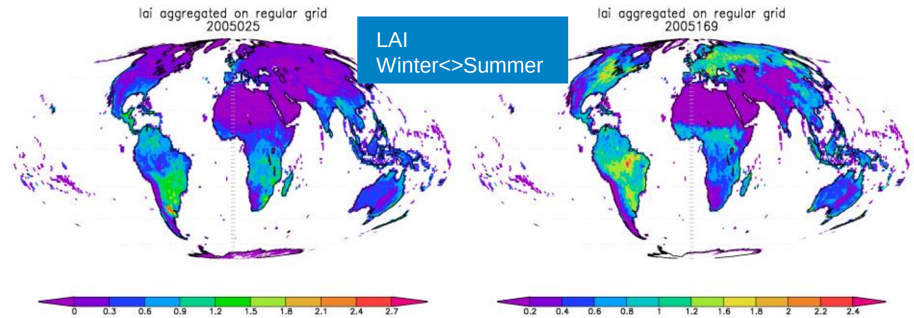
TIP-Tables:
inversions are tabulated over **observation space** for performance.

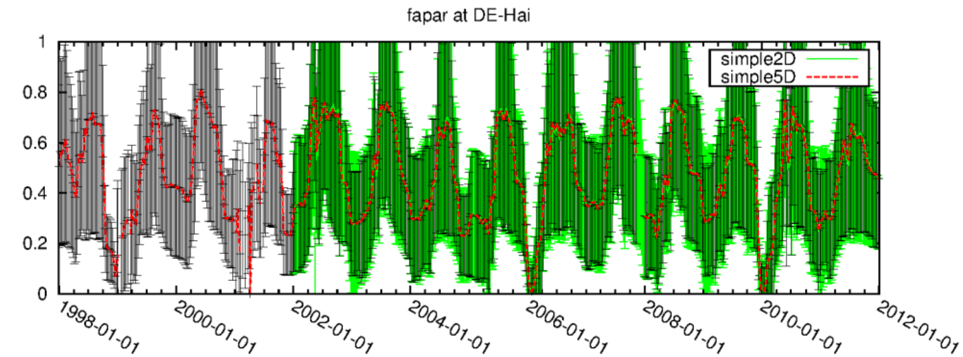
TIP5D: an ECV retrieval algorithm for FAPAR & LAI in QA4ECV

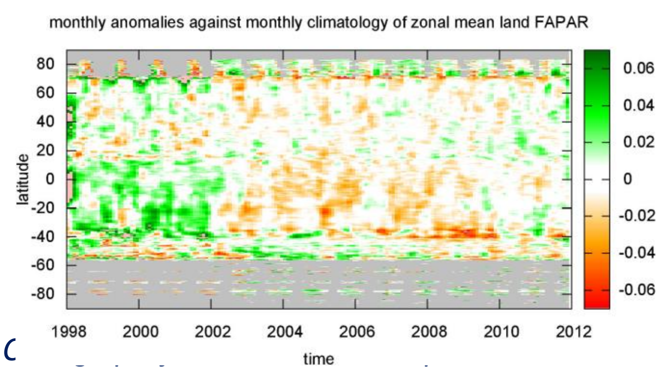
Simon Blessing, Ralf Giering
FastOpt

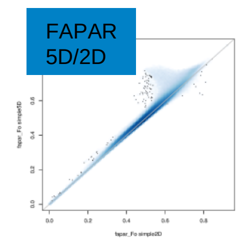
- documented and reviewed procedure
- per pixel uncertainty from propagation of full BHR covariance information
- output is NetCDF-4 with CF conventions
- GlobalAlbedo BHRs 1998-2011 reprocessed with TIP-5D
- compared to 2D product, 5D fapar and LAI have a slightly reduced uncertainty
- ready to process global 1982-2016 AVHRR+GEO VIS+NIR BHR
- processing of daily 1km resolution BHRs expected to take ~10 days on CEMS for whole period
- highly scalable processing with adjustable time and memory requirements per job (admin's dream)











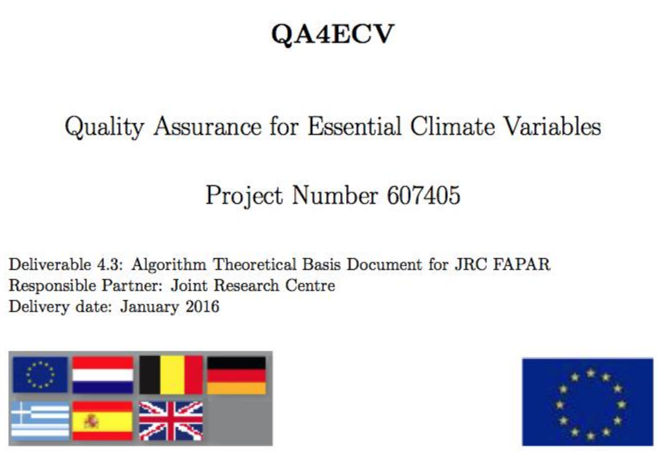
JRC FAPAR

Operational constraints: Fast computations and applying to ***each single acquisition image*** (generic algorithm)

Scientific constraints: Take into account **sensors spectral properties &**geometries of illumination and view: angular (atmospheric), and underneath/below vegetation soil effects

Continuity of ESA MERIS/OLCI products

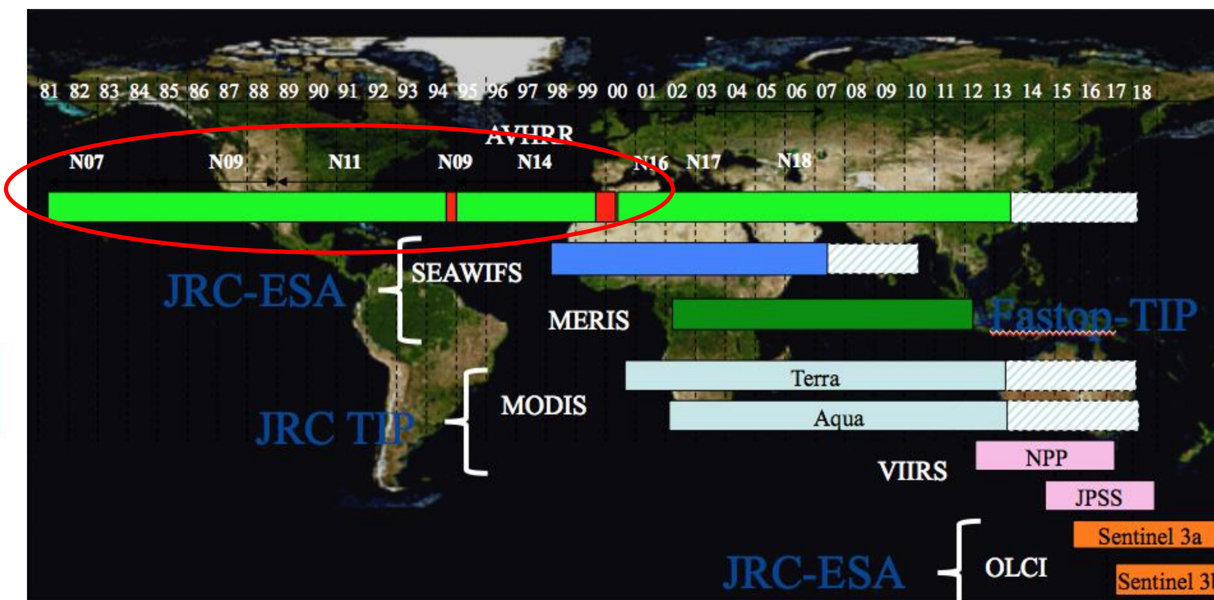
- **Instantaneous 'Green' FAPAR**
- Rectified values over both vegetated and soil surfaces.


QA4ECV

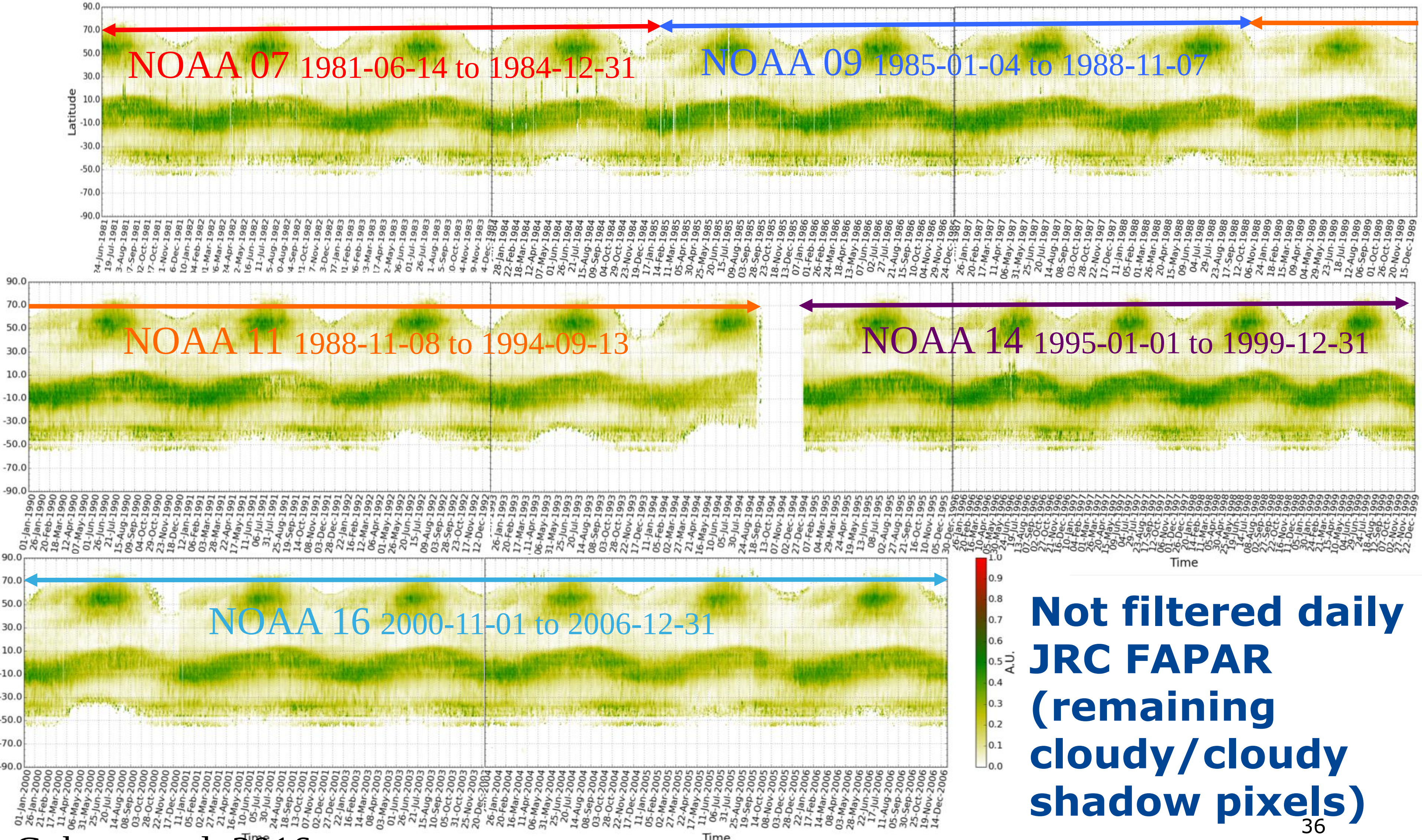
Quality Assurance for Essential Climate Variables

Project Number 607405

Deliverable 4.3: Algorithm Theoretical Basis Document for JRC FAPAR
Responsible Partner: Joint Research Centre
Delivery date: January 2016



Gobron, 2016



Not filtered daily JRC FAPAR (remaining cloudy/cloudy shadow pixels)

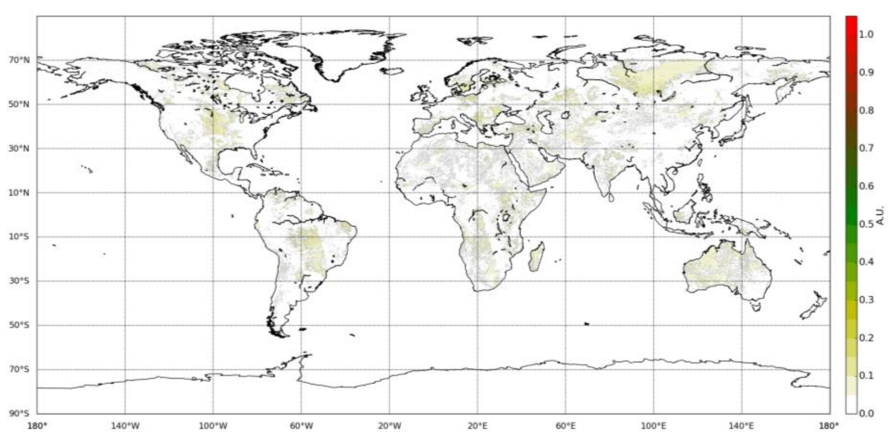
Gobron et al. 2016

Daily Uncertainties

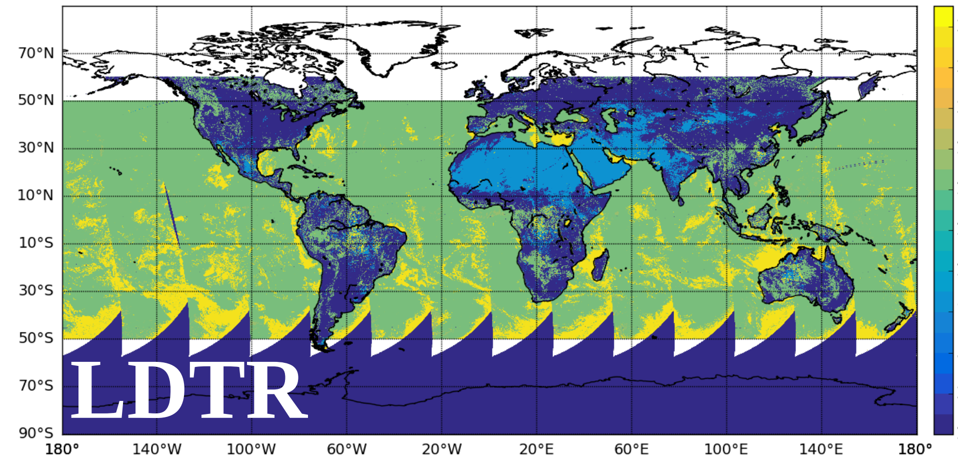
$$\sigma^2_{FAPAR} = \left(\frac{\partial g_0}{\partial x}\right)^2 \sigma_x^2 + \left(\frac{\partial g_0}{\partial y}\right)^2 \sigma_y^2 + 2\frac{\partial g_0}{\partial x}\frac{\partial g_0}{\partial y}\sigma_{xy}$$

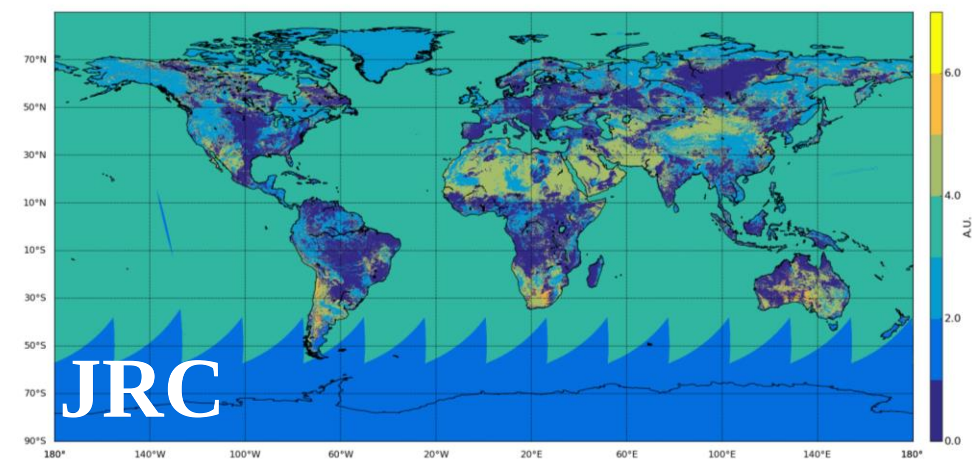
where σ_x^2 and σ_y^2 are the standard deviation error of the rectified channels in Band 1 and Band 2, respectively.

$$\sigma^2_{\rho^*_\lambda} = 2. \times (0.05 \times \rho_\lambda + 0.005)$$

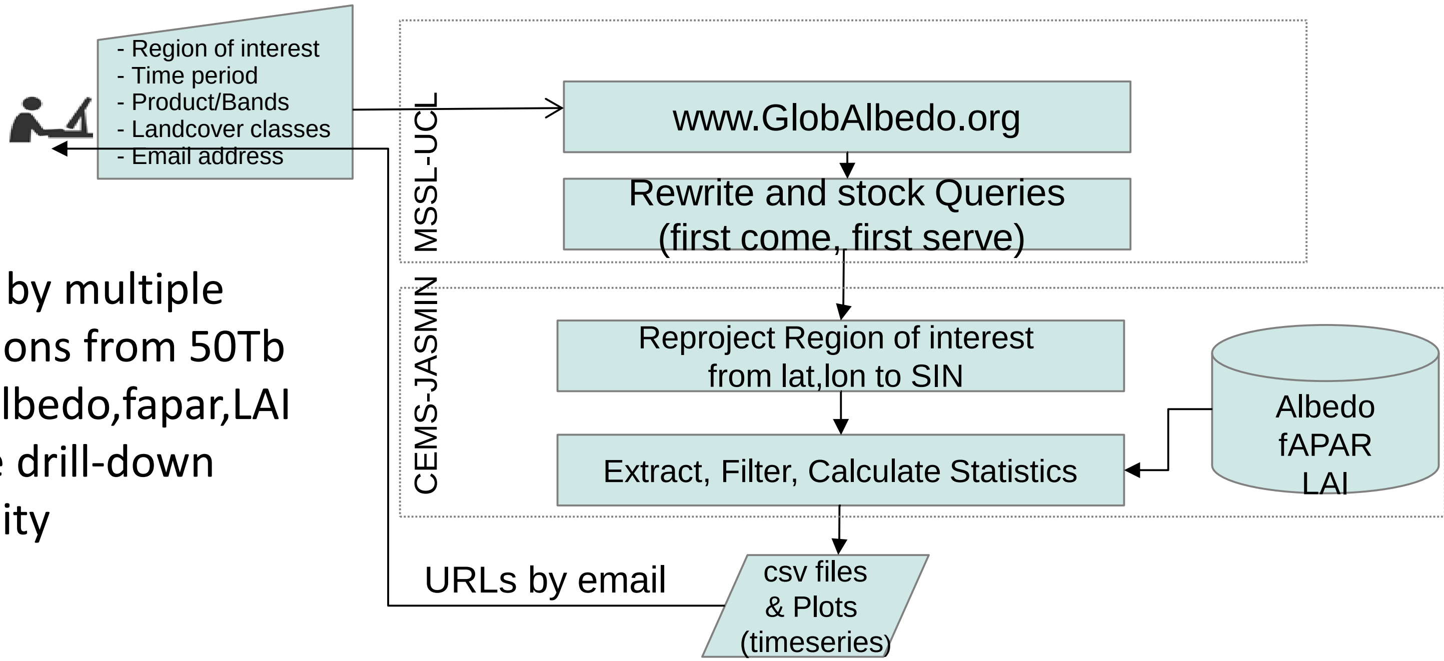


FLAGs





Prototype of CEMS-JASMIN for near-line subsetting of albedo, fapar, LAI datasets for roll-out in QA4ECV

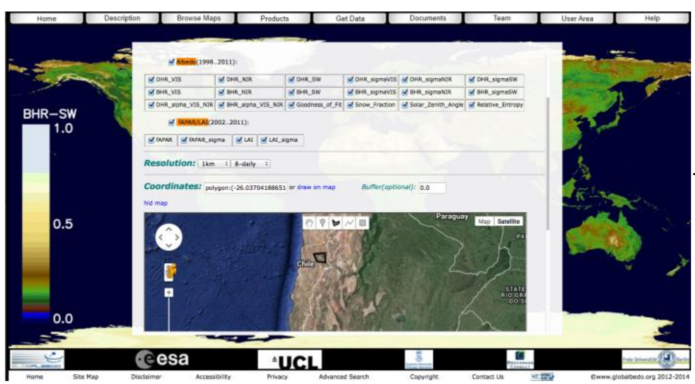


Subset by multiple Conditions from 50Tb input albedo,fapar,LAI

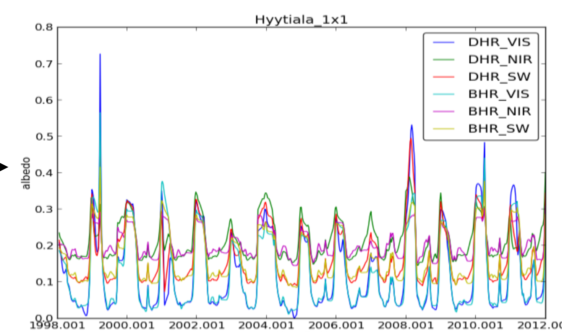
Unique drill-down capability

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

Tested on **Microsoft-Azure**



Stats by band



FUTURE WORK IN COPERNICUS CONTEXT

- Interfacing to Atmospheric products via improved surface spectral BRFs at the absorption wavelengths
- Upgrade needed for handling near-real-time data (Sentinel-2,3)
- New algorithm validation framework can be extended to new sites (e.g. topography)
- Inter-operability with other ECVs stored at CEMS
- Incorporate research results (Fiduceo)