The ESA GlobAlbedo project

Jan-Peter Muller, Mullard Space Science Laboratory

Project Consortium: UCL, Brockman Consult, Swansea University, Freie Universität Berlin

Location: Washington DC, USA

Mullard Space Science Laboratory

advancing space science...

- located 35 miles from UCL main campus
- 15 miles from Gatwick airport
- members of department mainly focused on research and post-graduate supervision

Scientific Context

- Land surface-Atmosphere interactions important to climate prediction, especially related to Land Parameterisation Schemes for hydrology
- Albedo required for
  - Earth's surface energy balance
  - Parameterisation for Numerical Weather Prediction, climate monitoring and climate impact assessment
  - Modelling of soil and vegetation in land ecosystems
- Surface albedo includes both snow and ice-free as well as snow/ice surface cover
- Surface albedo plays a role in radiative forcing through changes in land cover providing a cooling effect and in the role of black Carbon (soot) to provide a new source of warming

Overall Aims

- Production of a 15 year record (1995-2010) of Land Surface Broadband Albedo (BBA) from European space assets to provide an independent capability to generate this Essential Climate Variable (ECV) to be continued into the future from 2013 with SENTINEL-3
- BBA will be produced at broadband (0.4-0.7µm, 0.7-3µm and 0.4-3µm) according to "white-sky/BHR" and "black-sky/DHR" formulations for snow-free (excluding permanent snow/ice) and including_snow on
  - an 8-day time-step with a rolling 16-day window length at 1km on a SIN equal area
  - A fixed monthly time-step on a Plate Carrée equal angle map projection at 30 arc-seconds, 0.05 degrees and 0.5 degrees
- Input data will consist of level 1b (radiometrically calibrated, satellite projection)
  - ATSR2 (6/1995-12/2008), MERIS and AATSR (6/2002-12/2010)
  - VEGETATION (24.3.98-31.1.03) and VEGETATION2 (1.2.03-present)

Overall Aims (2)

- With each BBA map, a set of bit masks and metadata will be supplied which will relate to the quality, data source and provenance of the data
- An estimated uncertainty (variance-covariance matrix) will be produced for each and every pixel which will be derived from end-to-end estimates radiance sensor inter-calibration (using CEOS-GEO QA4EO protocols) through aerosol correction through BBA
- User requirements specify that there is a need for NWP forecasters to have a
  - BBA>0.15; 10% and for
  - BBA<0.15; 0.015
- GlobAlbedo data products will be available via anonymous ftp, via http and via an OGC-compliant web-GIS service based on the CEOS-WGISS ICEDS
- Plan to collaborate with G. Leptoukh (NASA-GSFC) on inter-operability with GIOVANNI
- Subsetting of products will be built upon the CEOS Cal/Val portal, MERCI server developed by Brockmann Consult. Both GUI and programmable interface
- All code will be written in Java for platform independence using a cloud computing paradigm. All code will be made publicly available as part of the open source BEAM
- Products will be publicly available from 11/2011
- Crystal Schaaf, BU; Gabriela Schaepmann-Strub (U of Zurich) and Nigel Fox (NPL) are consultants

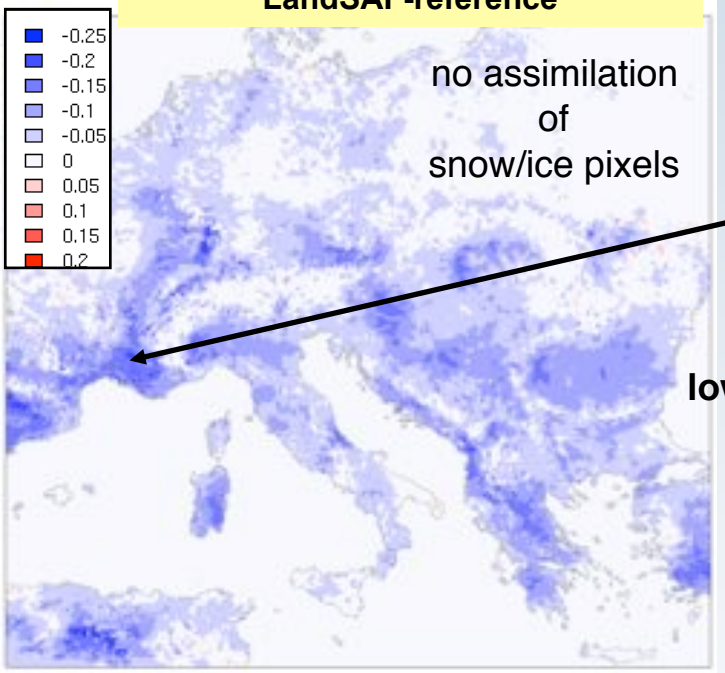
User inputs

- Users play a critical role in the development of baseline requirements and the assessment of whether these products are “fit for purpose”
- These users include:
  - Jean-Louis Roujean (Météo France)
  - Edouard Davin/Sonia Isabelle Seneviratne (ETH Zürich, CH)
  - Alexander Loew (MPI Hamburg, D)
  - Gunnar Myhre (CICERO, Norway)
  - Wolfgang Knorr (QUEST, UK)
  - Chris Taylor (CEH Wallingford, UK)
  - Samantha Pullen (UK Met Office/Hadley Climate Centre)
- All users have significant experience with MODIS albedo products

Use Case Example: APPLICATION FOR WEATHER FORECAST (J-L. Roujean, KO Meeting, 5/11/09)

Weather forcast model: ALADIN (~9.5km)
Two experiments: with ALADIN albedo and with Land SAF albedo analysis
Run every day at 00h: 20070201->20070731 (54h forcast)

Surface albedo 15022007 00UTC+12 LandSAF-reference

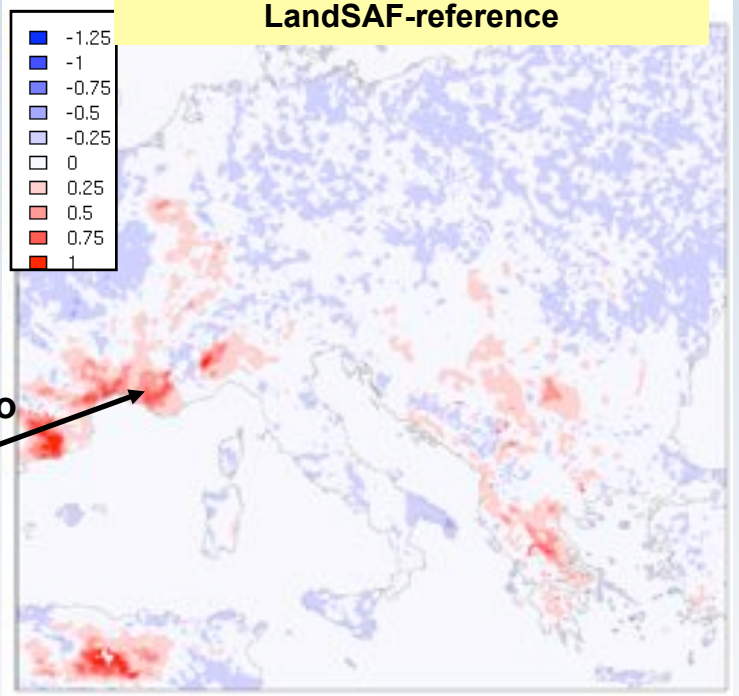


no assimilation of snow/ice pixels

Land SAF albedo is lower than ALADIN albedo

lower Land SAF albedo induced warmer atmospheric T2m

2m temperature 15022007 00UTC+12 LandSAF-reference



=> ALADIN model indicates a significant cold bias in winter, reduced thanks to sat. obs.

[Cedilnik, Carrer, Roujean and Mahfouf, "Analysis of satellite derived surface albedo for numerical weather prediction", **to be submitted**]

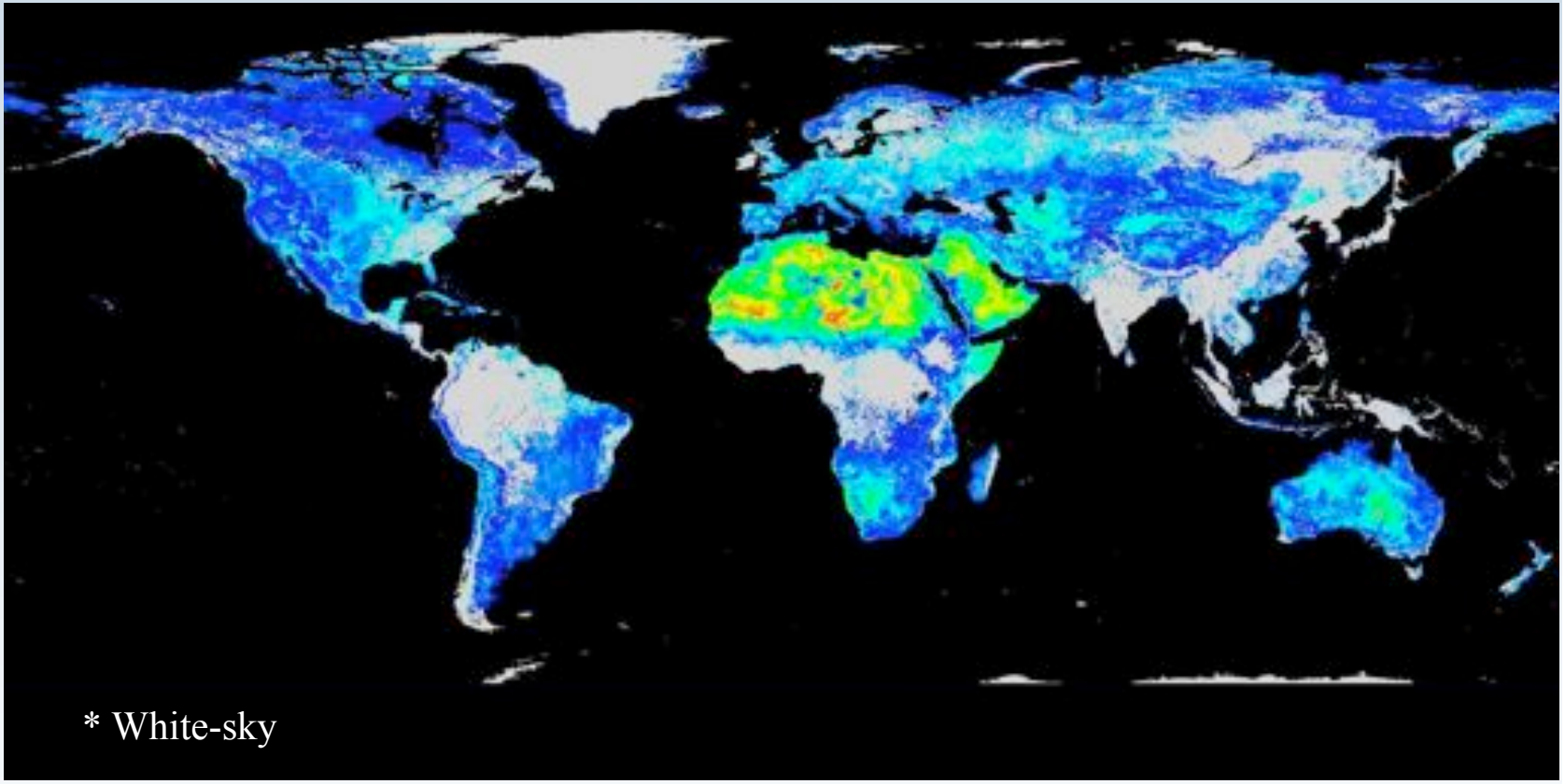
How will these objectives be achieved?

- UCL-MSSL will provide overall project leadership (management and scientific)
- Swansea University (SU), Pete North, to provide ATBDs and processing for SDR/SBRDFs from level 1-b input data for ATSR2, AATSR, VEGETATION (SPOT-4) and VEGETATION2 (SPOT-5)
- Freie Universität Berlin (FUB), Jürgen Fischer, to provide ATBDs and processing for SDR/SBRDFs from level 1-b input data for MERIS
- UCL-Geog, P. Lewis to provide ATBDs for SDR-to-BBA retrieval and gap-filling
- A common optimal estimation system will be developed by SU for atmospheric correction so that error estimates can be provided on a per SDR pixel basis
- Code for a distributed processing facility will be provided by Brockmann consult including production quality code (Java) to run on linux clusters based on ATBDs provided by UCL, SU and FUB
- UCL-MSSL to process from spectral SDRs to Broadband SDRs to BBA as well as provide archiving, visualisation, ordering, web-GIS and distribution facility
- A validation system will be established by Brockmann Consult at UCL-MSSL based on the MERCI system to allow initially the GlobAlbedo project team and their consultants and users access to both SDR/SBRDFs and BBA

Legacy - ESA MERIS AlbedoMap

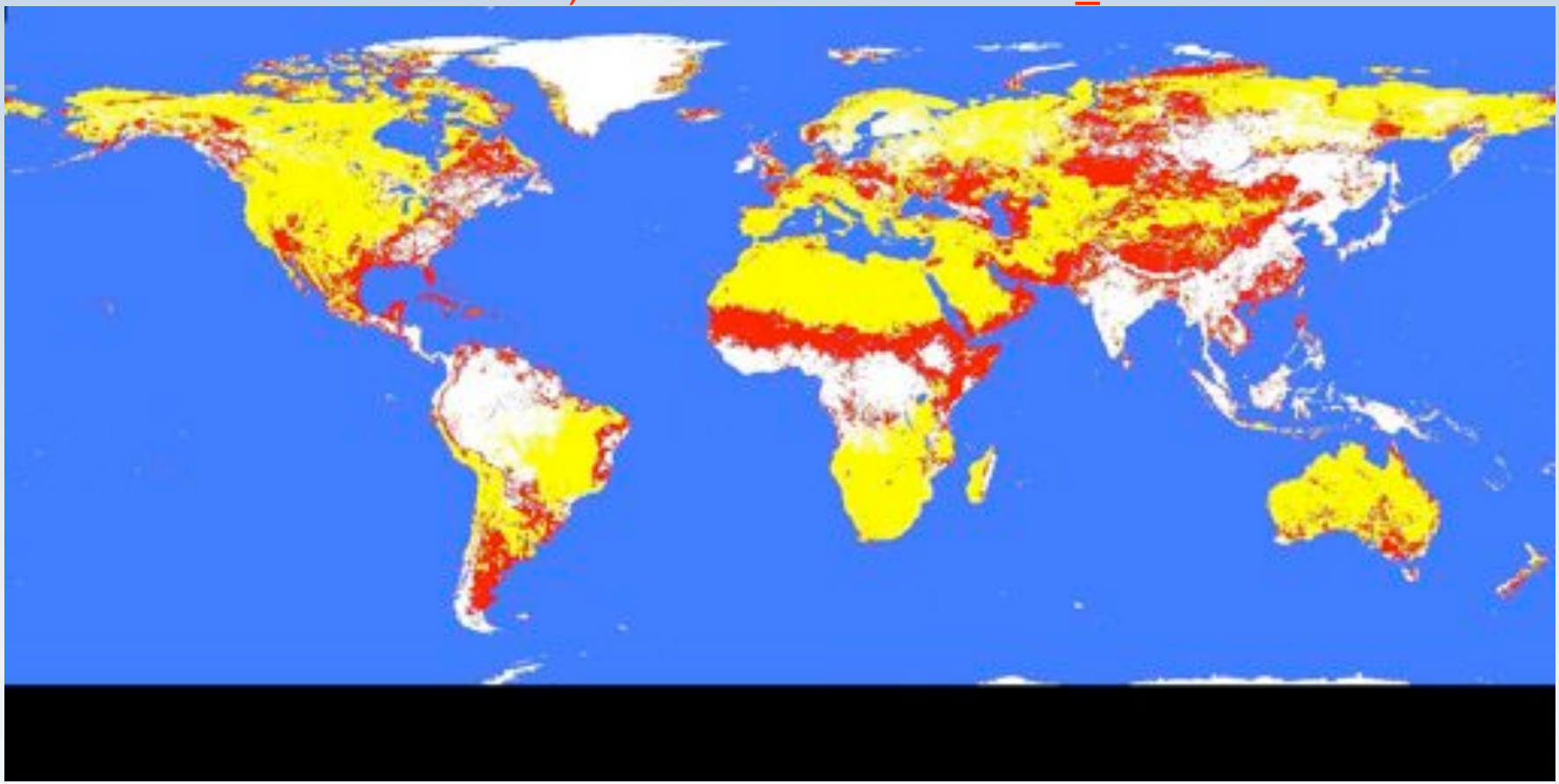
2002-2007 16-day albedo products for MERIS spectral bands based on MODIS collection 4 BRDFs

Example MERIS broadband albedo* product: DoY 193 (16-day time period : 12-27.7.03): Shortwave



N.B. Grey areas have missing data due to cloud cover

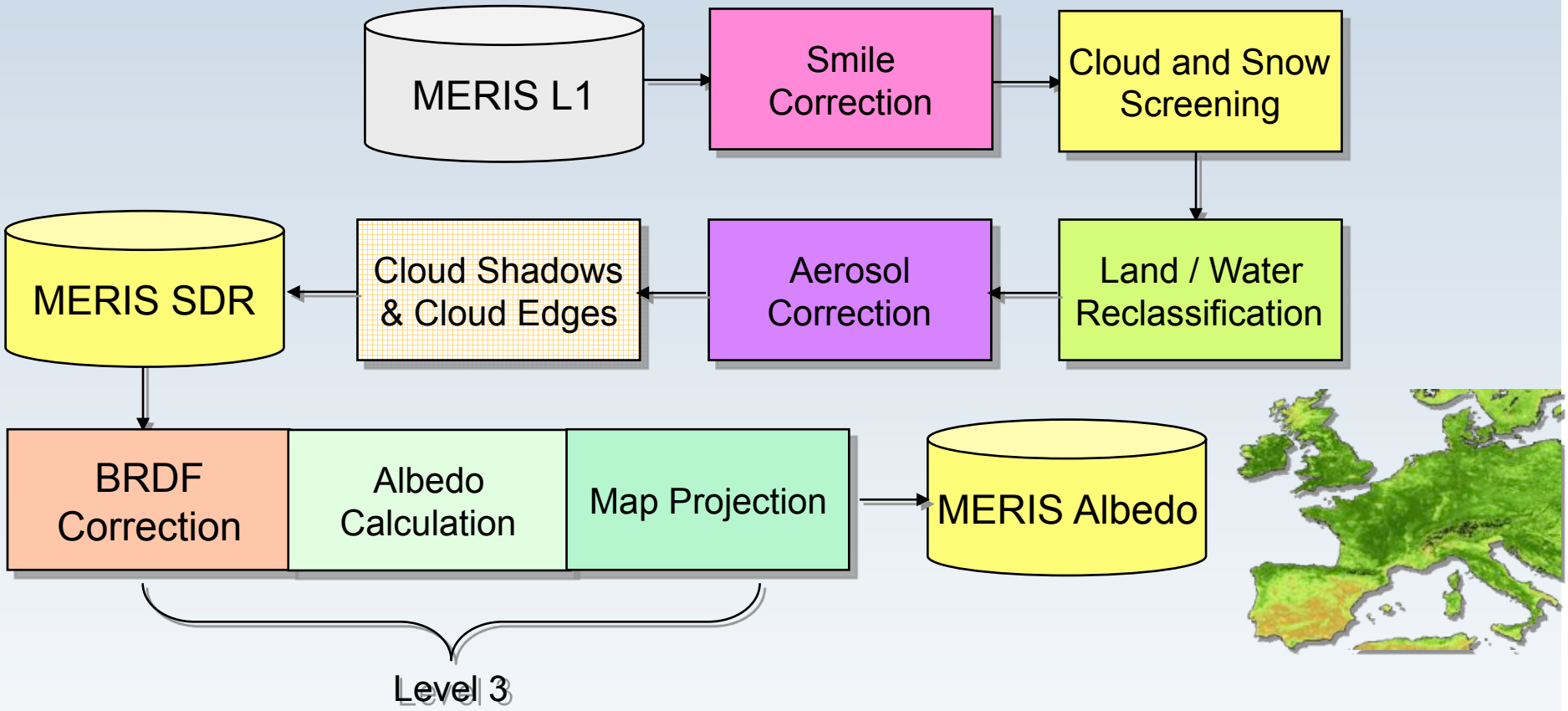
Example MERIS albedo bit-mask product: DoY 193 (16-day time period : 12-27.7.03): Source MOD43C2 BRDF_QA



Key. Yellow=Full Inversion, Red=Magnitude inversion, White=NO retrieval, Black=NO sun

N.B. Large areas of missing data due to cloud cover

MERIS AlbedoMap Processing Overview: heritage for GlobAlbedo

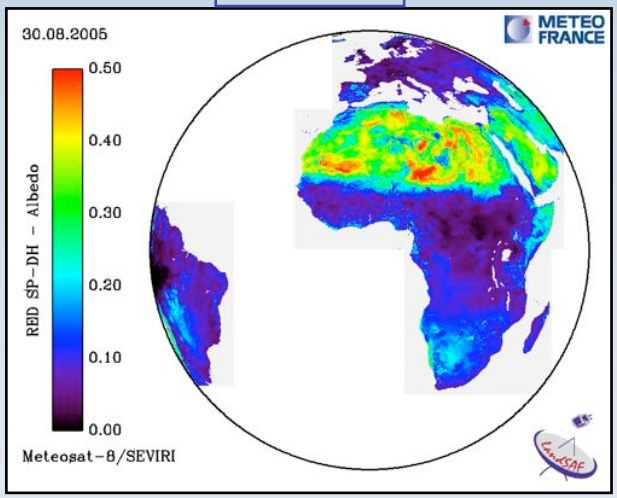


Validation approach

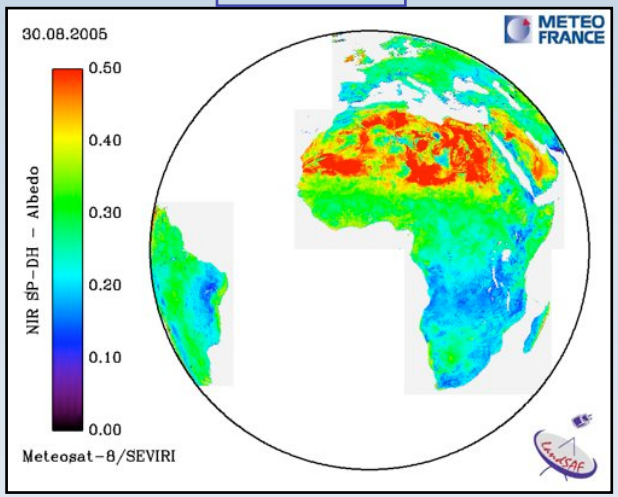
- SDRs will be compared for a few validation sites to ensure that inter-calibration has been performed correctly in collaboration with end users and "friends of GlobAlbedo". Will employ CEOS QA4EO process which will be documented with advice from CEOS-IVOS at NPL
- Three-point difference statistics will be produced for 16-day products using
  - GlobAlbedo
  - MODIS
  - MISR (to-be-computed from L2AS) 16-day products
  - METEOSAT daily products
- Monthly composites to be used for intercomparisons with
  - MISR 0.5º "true monthly" level-3 product
  - PARASOL monthly products
- Intercomparison with in situ data albedometer measurements from SURFRAD and BSRN (collaboration with Boston University, BU) and from field measurements (University of Zurich, UZ)
- Inter-comparisons with airborne measurements, where available in collaboration with BU

SEVIRI Spectral albedo products

0.6 μm

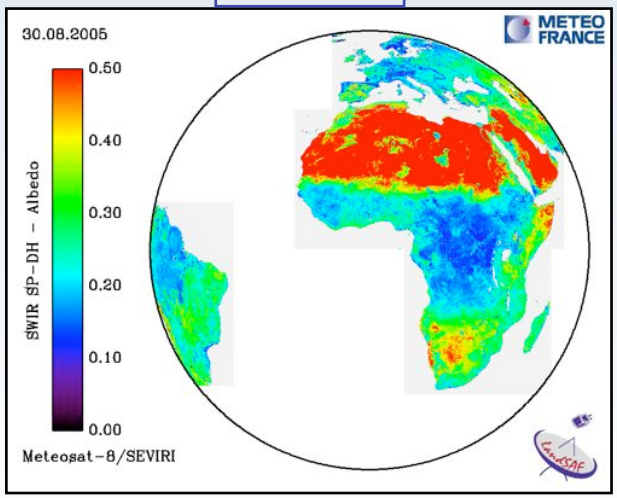


0.8 μm



August 30, 2005

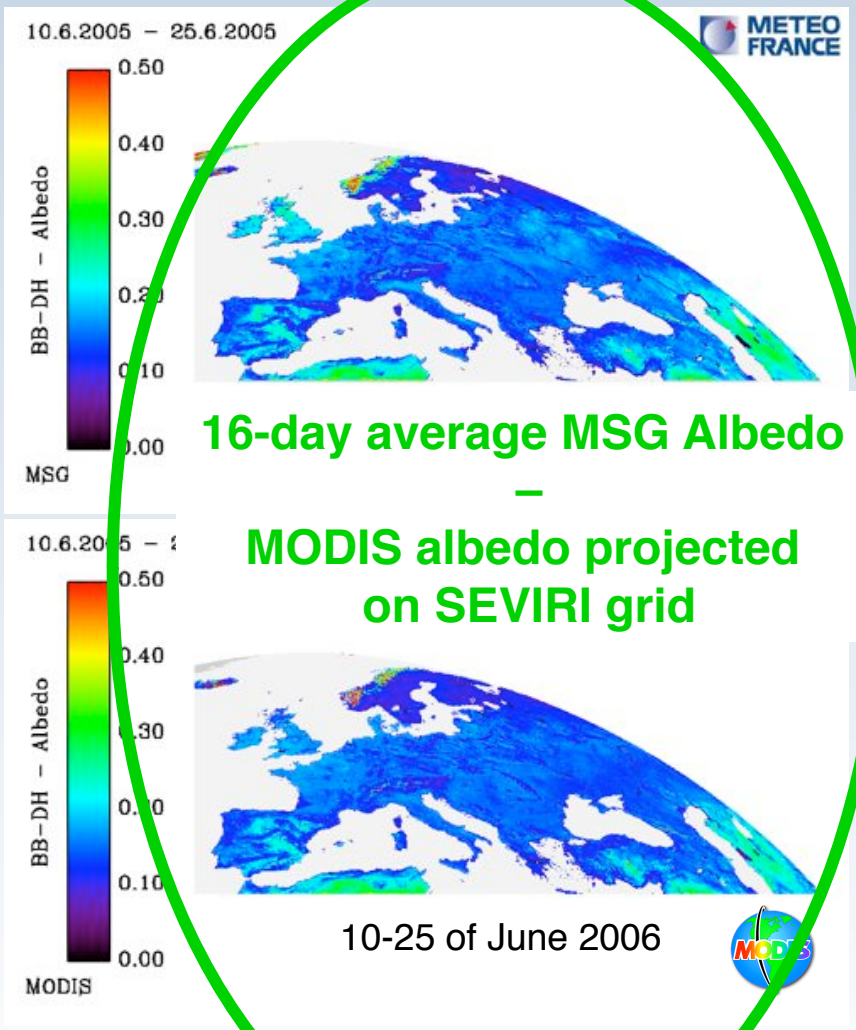
1.6 μm



- **Spatial Resolution: 3km at the Sub-Satellite Point**
- **Projection: native MSG/SEVIRI Projection**
- **Products: Spectral & BB for DHR (noon) & BHR**
- **Production Frequency: Daily**
- **Effective Temporal Resolution: 5 Days**
- **Format: HDF5**
- **Timeliness: 3 hours**
- **Dissemination: EUMETCast, project website**

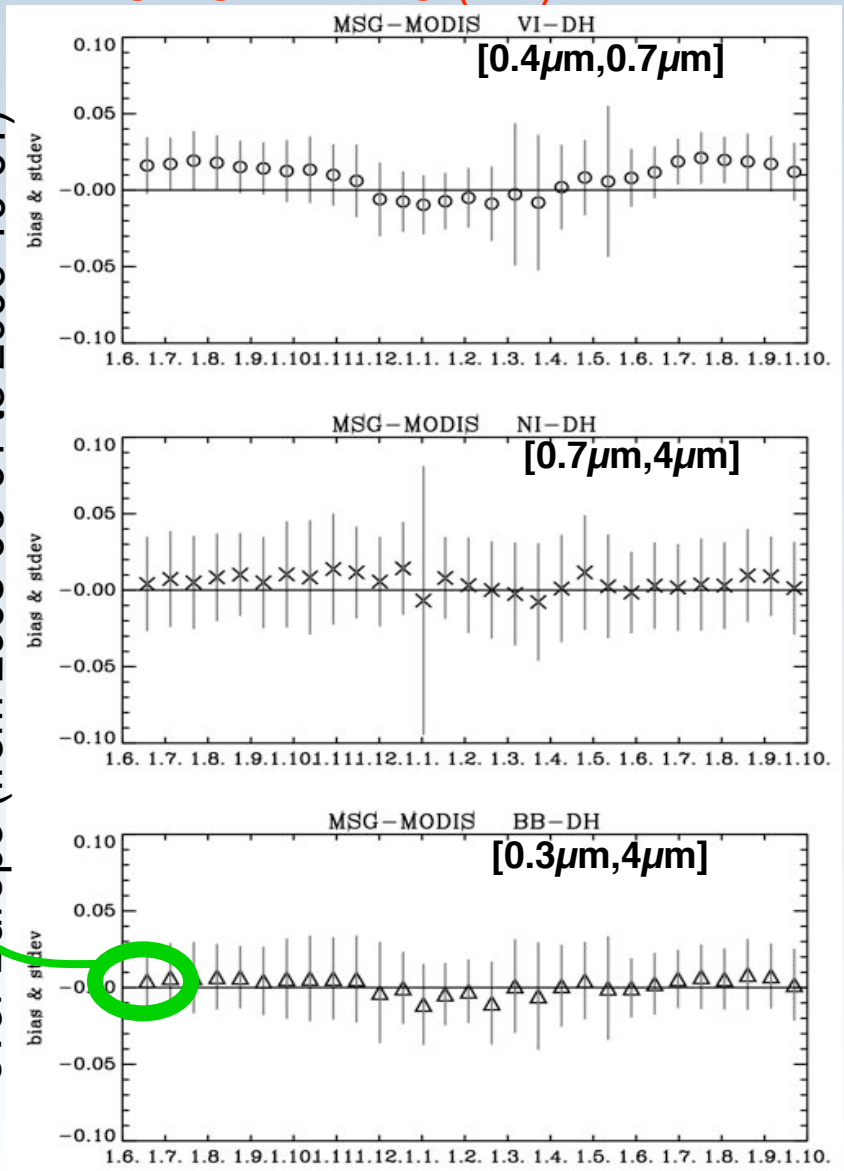
Courtesy of J-L Roujean

COMPARISON WITH MODIS ALBEDO (1/2)

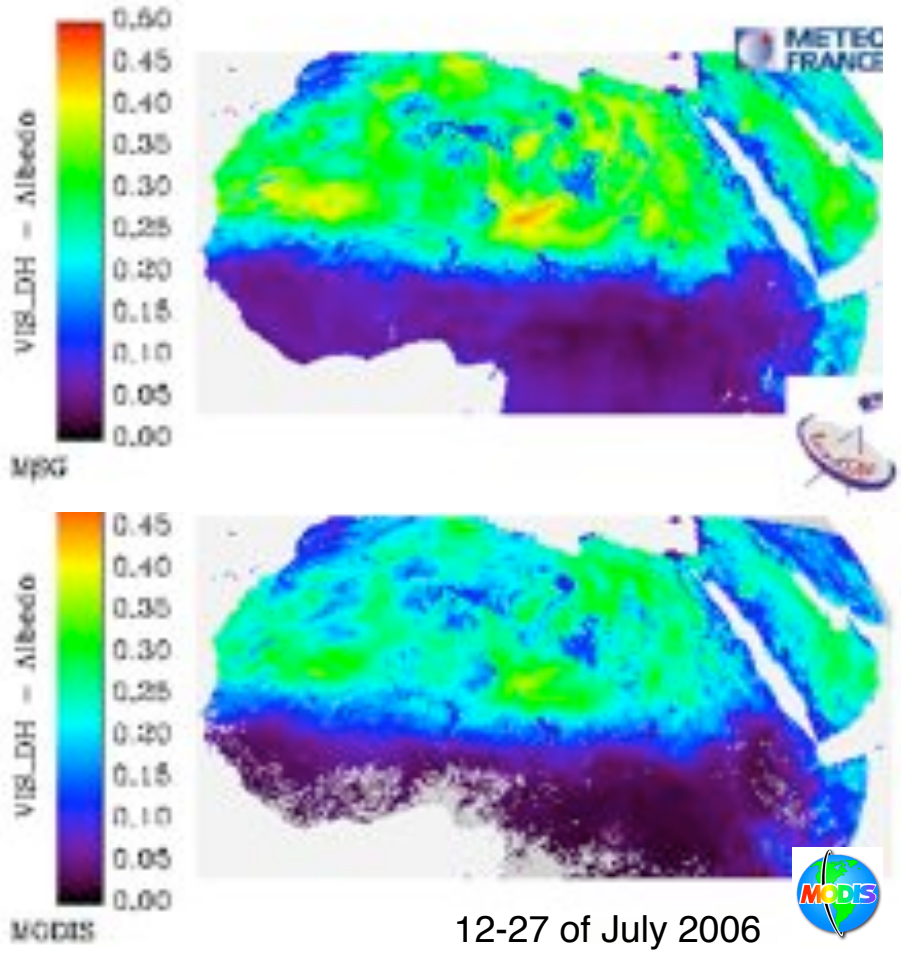


Courtesy of J-L Roujean

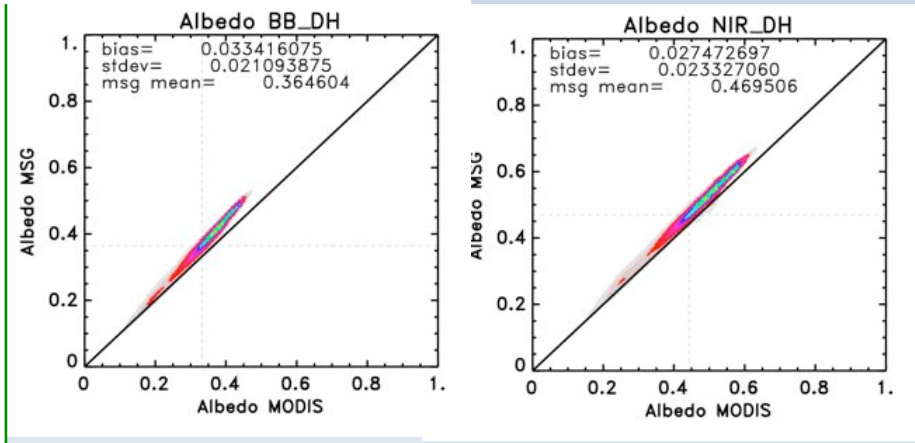
over Europe (from 2005-06-01 to 2006-10-01)

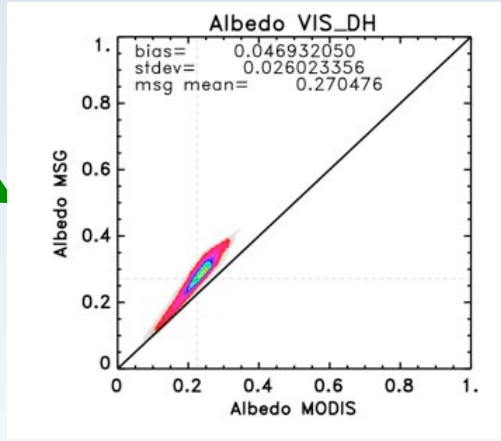


COMPARISON WITH MODIS ALBEDO (2/2)

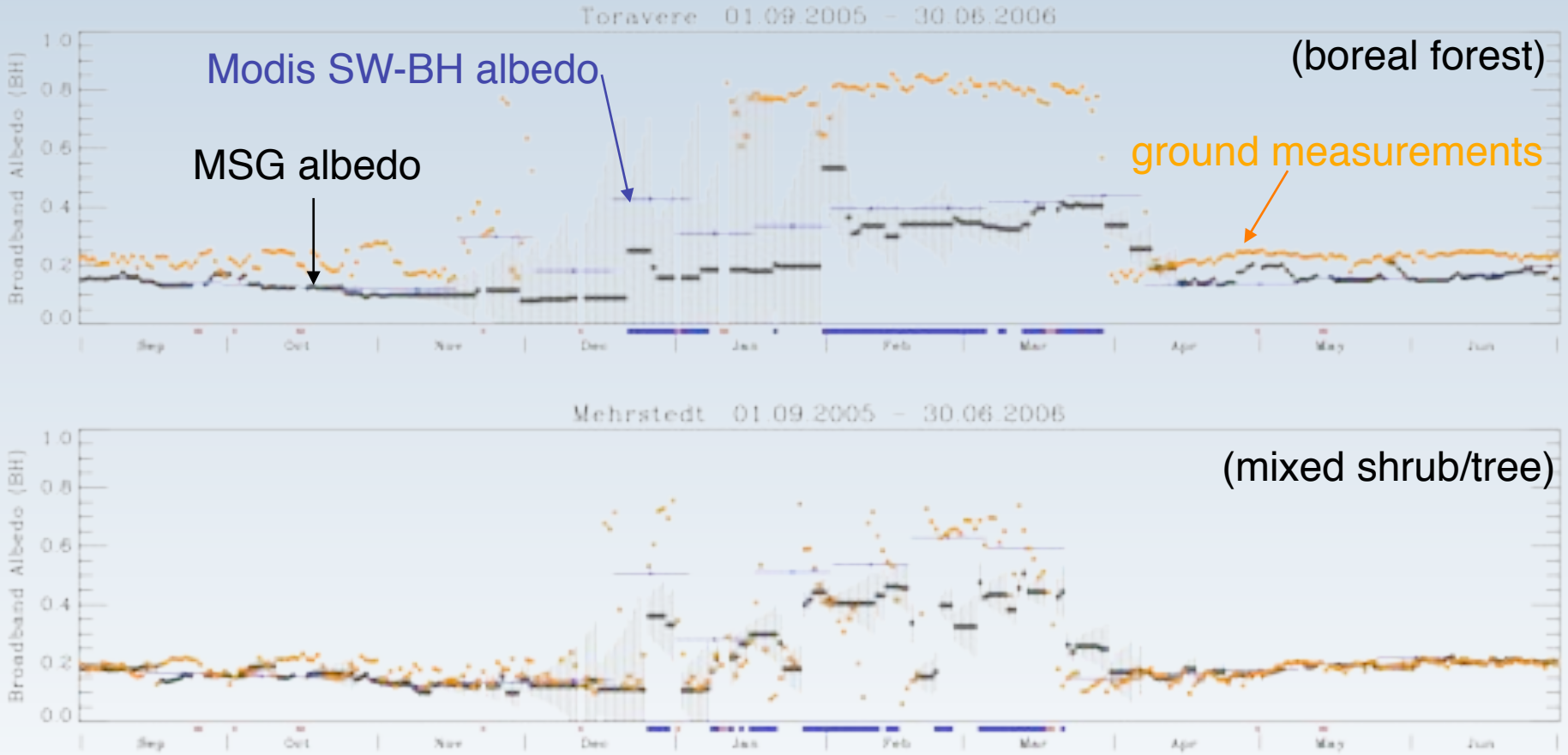


12-27 of July 2006





ALBEDO TIME SERIES (snowfall episodes)



Courtesy of J-L Roujean

BBA retrieval and gap-filling

P. Lewis, UCL Geography

BBDR-BB model parameters

- Fit 'observations' of broad band directional reflectance to BRF model
  - Include constraints
- Linear kernel driven model

$$R_{\Lambda}\left(\Omega_v,\Omega_s\right) = f_{iso,\Lambda} + f_{vol,\Lambda}K_{vol}\left(\Omega_v,\Omega_s\right) + f_{geo,\Lambda}K_{geo}\left(\Omega_v,\Omega_s\right)$$

- To obtain estimates of parameters

$$\left\{f_{iso}(\Lambda), f_{vol}(\Lambda), f_{geo}(\Lambda)\right\}$$

- For Λ = VIS, NIR, SW

Model parameter estimation

- Minimise discrepancy

$$e^2 = \sum_i \left(\rho_i - \hat{\rho}_i\right)^T C_{obs,i}^{-1} \left(\rho_i - \hat{\rho}_i\right) + \sum_i \left(\delta_n p_i\right)^T C_{smooth,i}^{-1} \left(\delta_n p_i\right) + \sum_i \left(p_i - \hat{p}_i\right)^T C_{prior,i}^{-1} \left(p_i - \hat{p}_i\right)$$

$$Observations: \sum_i \left(\rho_i - \hat{\rho}_i\right)^T C_{obs,i}^{-1} \left(\rho_i - \hat{\rho}_i\right)$$

$$smoothness: \sum_i \left(\delta_n p_i\right)^T C_{smooth,i}^{-1} \left(\delta_n p_i\right)$$

$$priors: \sum_i \left(p_i - \hat{p}_i\right)^T C_{prior,i}^{-1} \left(p_i - \hat{p}_i\right)$$

Gap filling

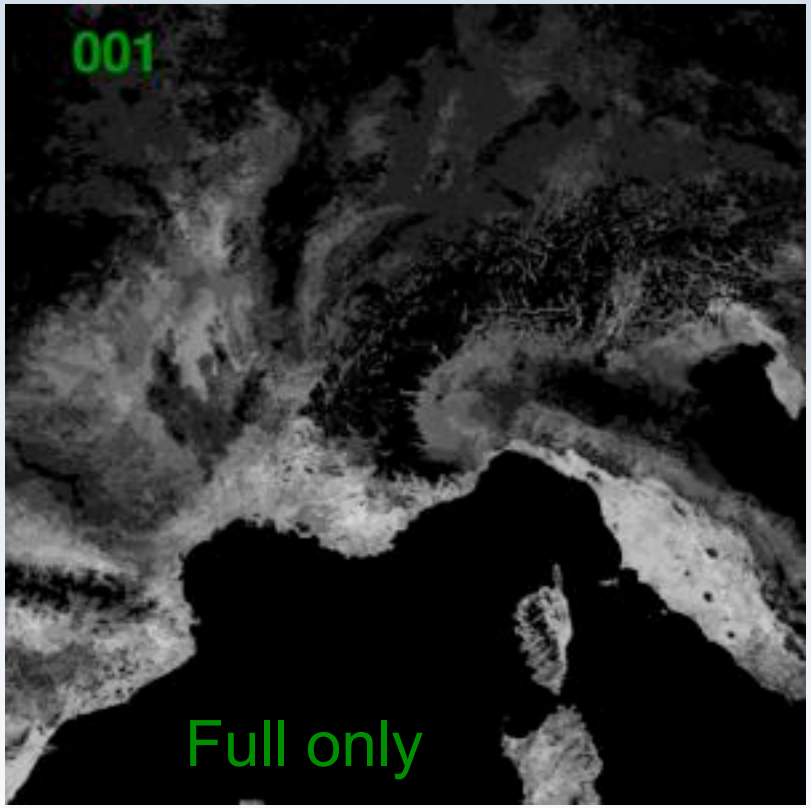
- **Use of prior obviates need for gap filling**
  - Provided have 'full' specification of prior
    - i.e. no gaps
  - And good estimate of uncertainty of prior
  - Possible that some sites never seen by MODIS?
    - Certainly some … e.g. Arctic in winter
      - … but can't produce albedo for this …
- **Temporal smoothness also reduces need for gap filling**
  - Uncertainty simply increases when there are gaps
  - Use double exponential (Laplace fn) in time
    - After Roujean et al.
    - Instead of 'full' smoothness constraint/Kalman filter
  - Issue: definition of decay constant?

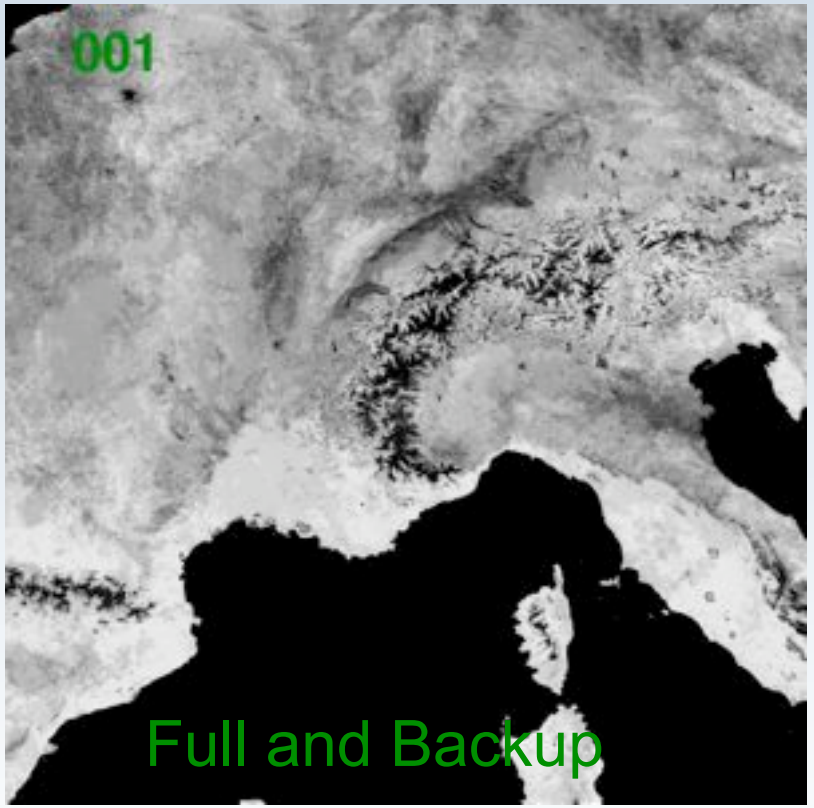
Background albedo

- **Most reliable current estimates for priors**
  - MODIS albedo: 2000-2010
  - Characteristics:
    - Global 500m, gridded
    - Every 8 days (16 day window)
    - Snow flags
    - 'full' retrievals
      - RTLiSpR inversion
    - 'backup' retrievals
      - 'magnitude inversion'
- Issues
  - How to combine full and backup retrievals?
  - How to define temporal weighting?

Number of samples

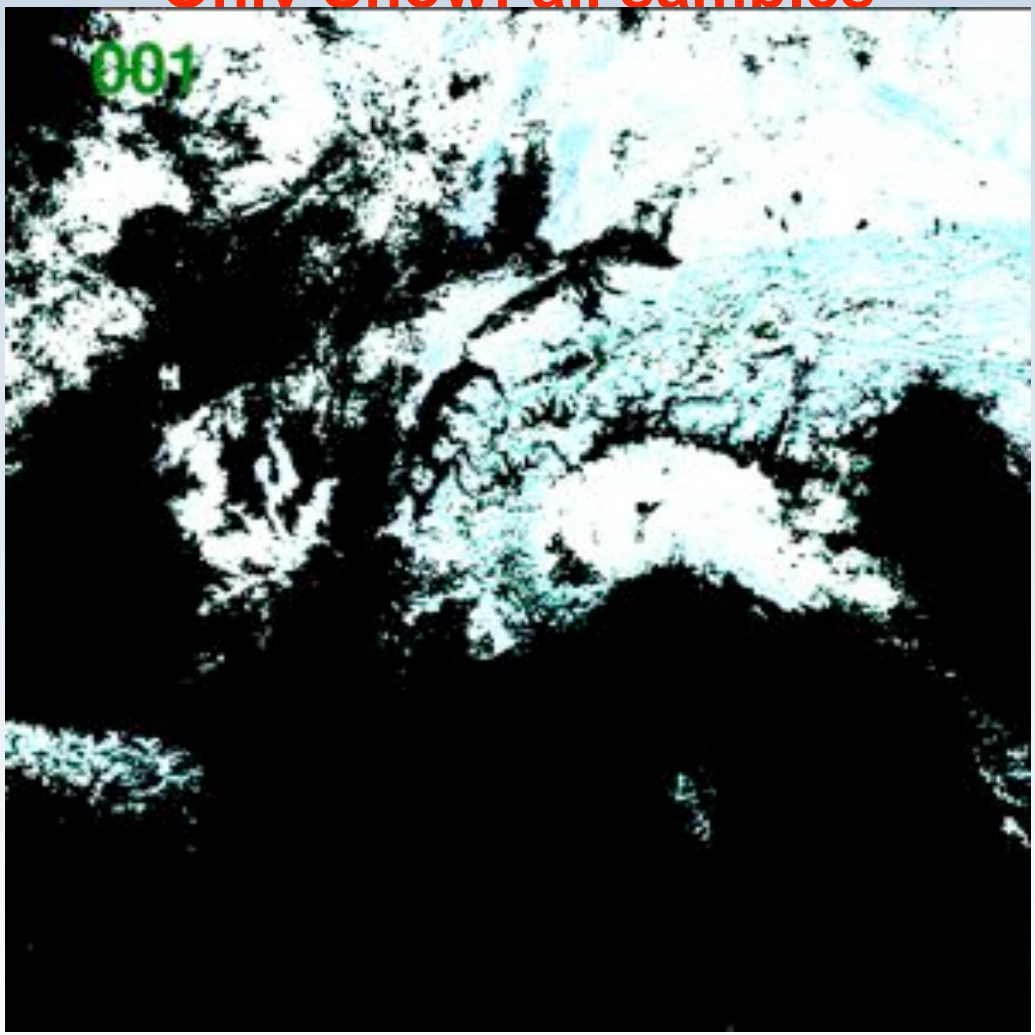
- Over 10 year period, no. of samples will vary
  - May be zero for full inversion in places



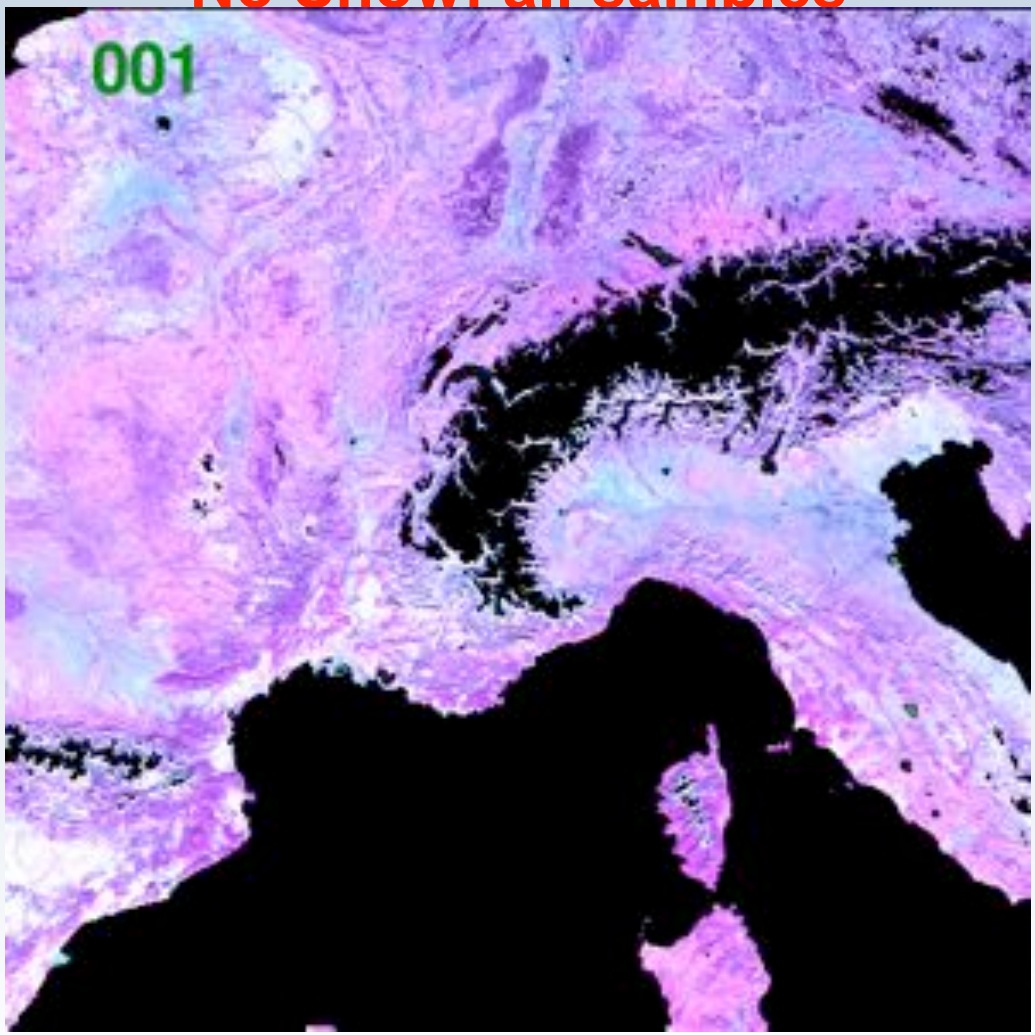


Scaled
0-10

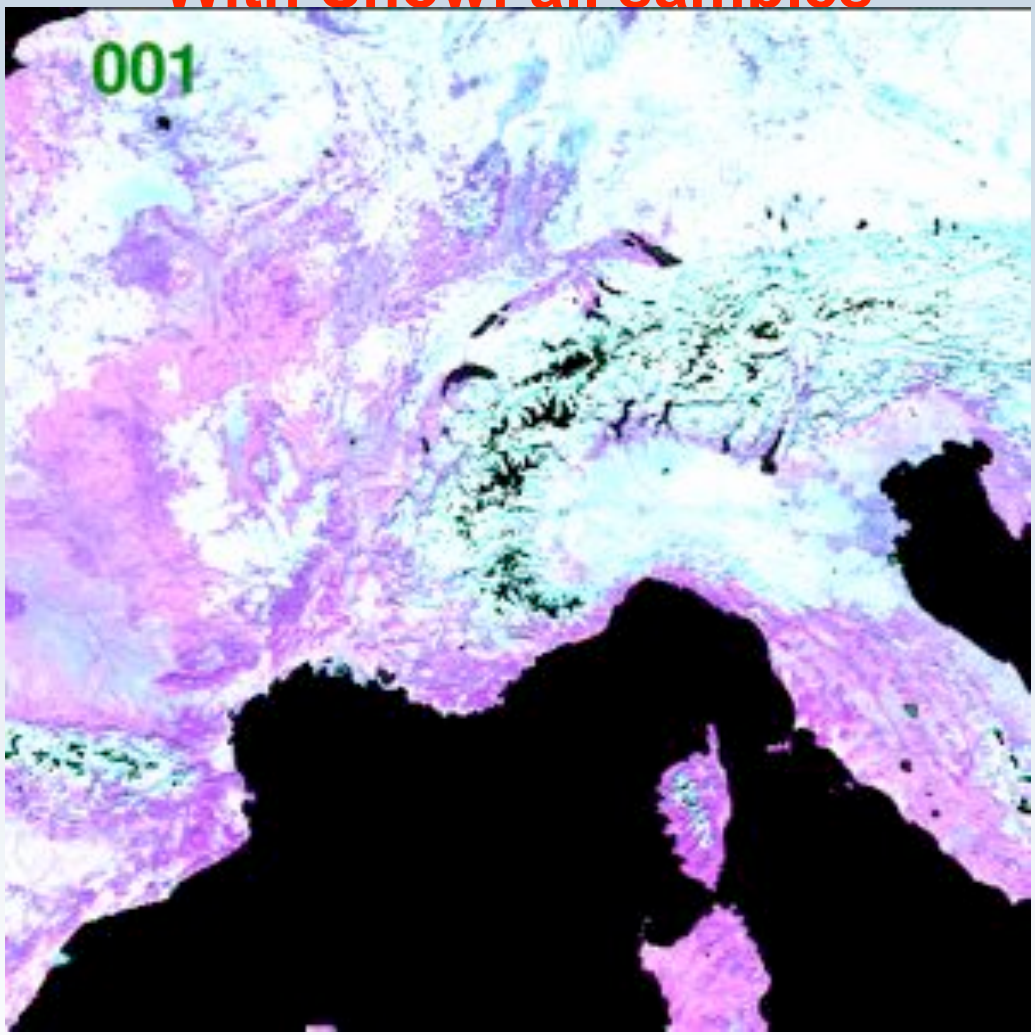
Only Snow: all samples



No Snow: all samples

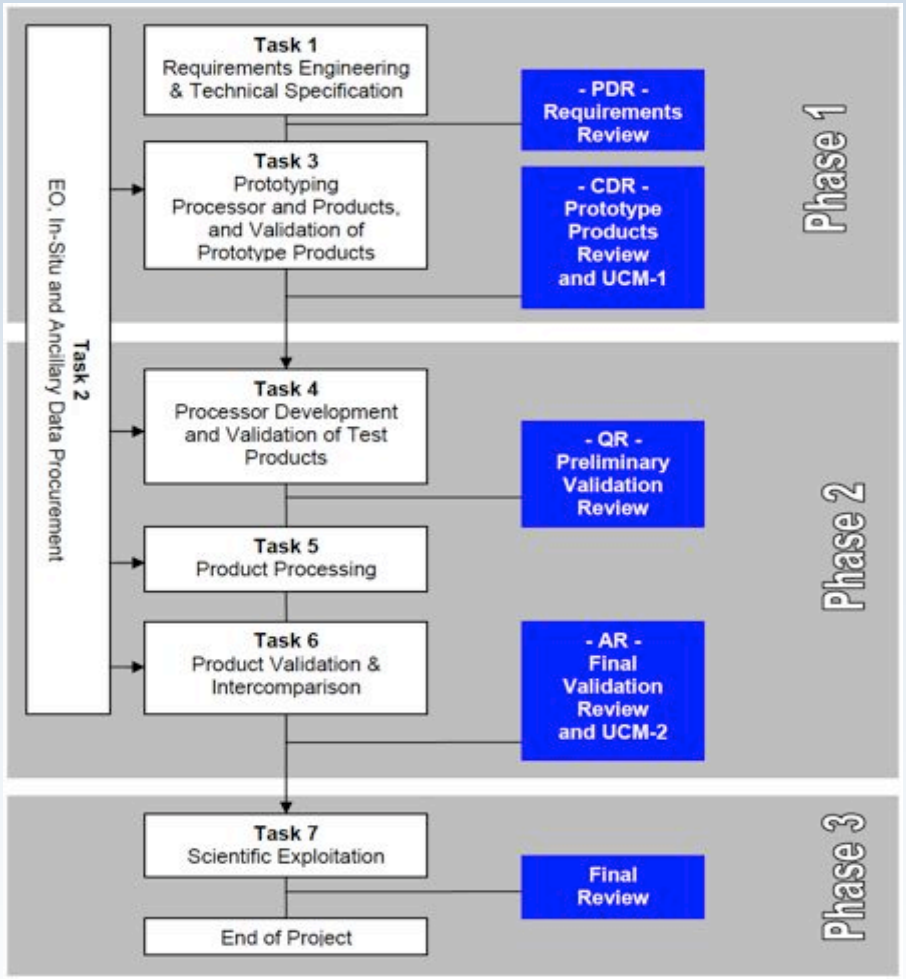


With Snow: all samples



GlobAlbedo Work Logic

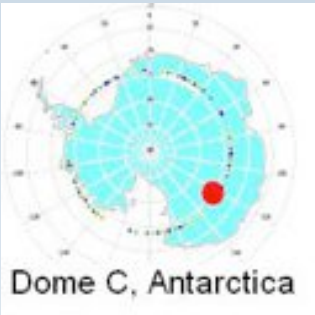
Start: 11/5/09



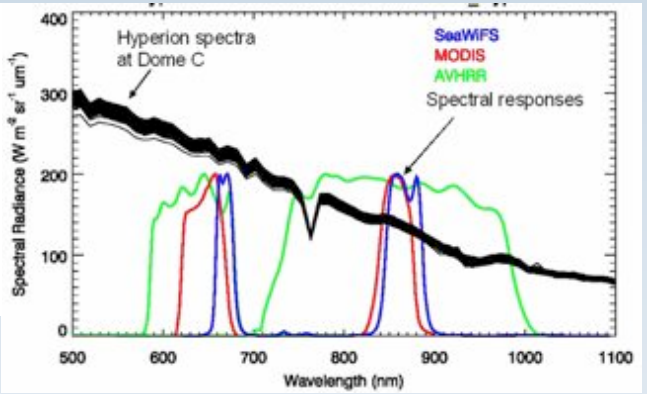
End: 11/5/12

Sensor inter-calibration using QA4EO

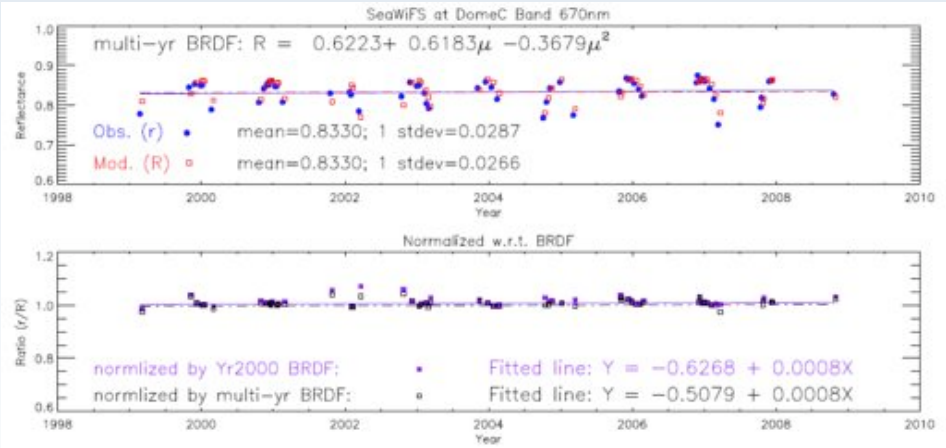
- The production of BroadBand Albedo (BBA) requires calibration of individual spectral reflectance values and its transformation from narrowband to broadband
- Usually this is performed using radiative transfer simulations
- Dome-C (available from Dec-Jan each year) can be used for Simultaneous Nadir Observations (SNO) between satellites with similar spectral bands (e.g. ATSR2 cf AATSR, VGT1 cf VGT2)
- Hyperspectral ToA radiances can also be used to transform narrow-to-broadband
- Link via NPL consultant to ESA/NOAA sponsored CEOS intercalibration exercises and QA4EO using DOME-C



Cao, CEOS-30



Comparison of Hyperion EO-1 spectra with SeaWiFS.MODIS & AVHRR spectral responsivities



SeaWiFS SDR and Nadir-corrected BRDF

Scientific Exploitation

J-P. Muller, UCL-MSSL

Scientific Exploitation: Overview

- Four different collaborators invited to participate on the following general topics:
  - assessment of the effects of surface albedo change (including land cover change, biomass burning, variations in snow cover, etc.) on radiative forcing of climate, either between natural or pre-industrial versus current conditions, or over the time pan of the GlobAlbedo data set,
  - DGVM or GCM model assimilation and/or verification, for the purposes of investigating the effects of improved description of the surface energy balance, or of the vegetation phenology,
  - Development and testing of albedo parameterisations

Scientific Exploitation

- CICERO (Gunnar Myhre, N) for an assessment of the effects of surface albedo change on radiative forcing of climate (in association with J-P Muller, UCL-MSSL)
- QUEST (Wolfgang Knorr, UK) for an investigation of the effects of an improved description of the surface energy balance (in association with P Lewis, UCL-Geo)
- MPI Hamburg (Alexander Loeuw, D) in association with J. Fischer (FUB) for
  - Assessment of the impact of the new albedo data set on the radiative forcing and energy budget within ECHAM/JSBACH at the global scale
  - Identify regions with large albedo changes and assess the feedback of land surface albedo dynamics on climate model simulations in those regions
- CEH (Chris Taylor, UK) in ssociation with P. North (SU) for
  - Comparison of existing GCM albedo with new GlobAlbedo values
  - Estimation of PFT and background albedo for GCM parameterisation
  - Evaluation of impacts of revised albedos on GCM forecasts