Twelve years of MODIS BRDF/albedo and its intercomparison with GlobAlbedo, METEOSAT, MISR and FLUXNET

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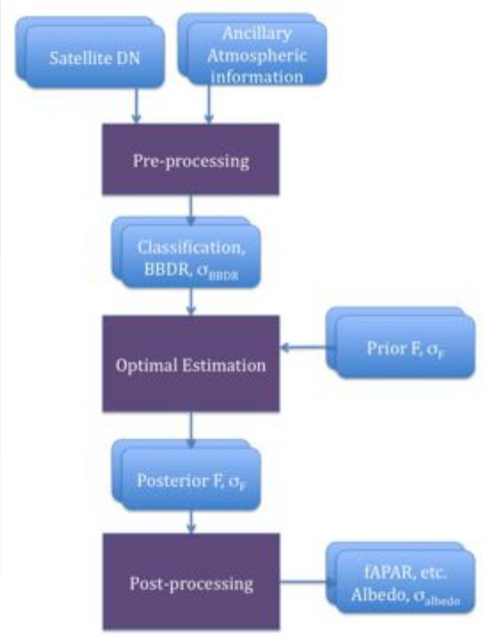
Overall Aims - GlobAlbedo

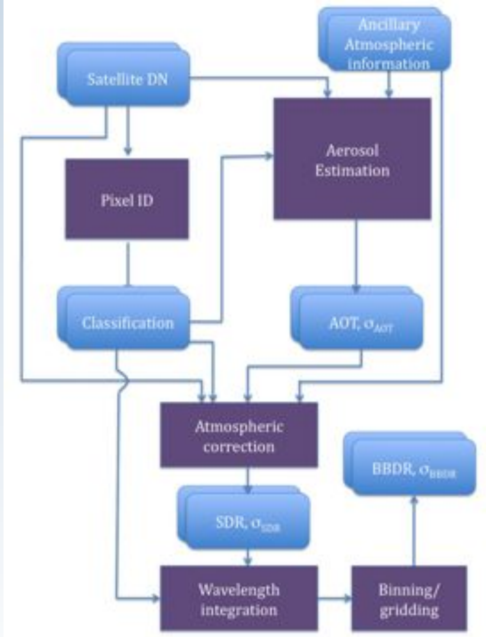
- Production of a 13 year record (1998-2011) of 1km Land Surface BroadBand Albedo (BBA) every 8 days and monthly from European space assets to provide an independent capability to generate this Essential Climate Variable
- Input data consists of level 1b (radiometrically calibrated, satellite projection) as well as MODIS MCD43A1,2 BRDF (3/2000-3/2012)
  - MERIS and AATSR (6/2002-12/2011)
  - VGT (24.3.98-31.1.03) and VGT2 (1.2.03-12/2011)
- An estimated uncertainty (variance-covariance matrix) is produced for each output pixel using an optimal estimation framework
- Validation of final albedo products as well as intermediate products (e.g. cloud masks, aerosol retrievals, narrow-to-broadband)
- GlobAlbedo products are freely available via wget/curl, http and an OGC-compliant webGIS

Product Processing and Validation

- Subset of GlobAlbedo products validated
- Focus on
  Pixel ID
  AOT
  SDR
  N-to-BB
  Albedo
- Validation performed by relevant producer with support from PI
- Russian Albedo validation performed by G. Schaapman-Strub



Overall GlobAlbedo processing chain



GlobAlbedo product flowchart

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BRDF TILE product (not currently distributed)

- 9 kernels [isotropic, geometric, volumetric] x [VIS, NIR, SW]
- 45 layers from 9 x 9 error variance/covariance matrix per pixel
- Pixel classification (land or water), Relative entropy (impact of priors), SZA
- Nsamples and Mdays used in BRDF retrieval from accumulator arrays
- 59 band product with each layer of 32-bit floating point arrays (324.09 MB)
- netCDF of ≈4.5 Tb (uncompressed) for a single processed year

Albedo TILE product (distributed)

- 6 albedos [DHR, BHR] x [VIS, NIR, SW]
- 6 standard errors for [DHR, BHR] for [VIS, NIR, BBA] derived from error variance/covariance matrix per pixel
- Pixel classification (water or land [snow or no-snow depending on Mdays]), Relative entropy (impact of priors), posteriori entropy
- Nsamples and Mdays used in BRDF retrieval from accumulator arrays
- 17-band product with each layer of 32-bit floating point arrays (93.37MB)
- netCDF of ≈1.5 Tb (uncompressed) for a single processed year

Processing: Innovations in Albedo retrieval

Prof. P. Lewis, UCL

Prior knowledge constraint

- Regularisation is form of prior knowledge constraint
  - Yesterday, likely to be same as today, with given tolerance
- MODIS backup algorithm, another example
  - Assume knowledge of BRDF shape
  - But sharp transition – not within optimal estimation framework
- Geiger et al. (2008) (MSG)
  - Weak (constant) prior to condition solution
- **GlobAlbedo:**
  - Dynamic (per 8-day time period), spatial prior
    - To condition solution in case of weak sampling
    - To 'gap fill'

$$\left[\sum_{i=0}^{N} K'^{T} C_{O\,i}^{-1} K' + C_{p}^{-1}\right] F_{t} = \left[\sum_{i=0}^{N} K'^{T} C_{O\,i}^{-1} R + C_{p}^{-1} K_{p}\right]$$

$$J_{p\,t} = \left(F_{t} - F_{p\,t}\right)^{T} C_{p\,t}^{-1} \left(F_{t} - F_{p\,t}\right)$$

Rationale

- Prior allows solution even when sampling weak (or non-existent)
  - Obviate need for backup algorithm
- Part of Optimal estimation framework
  - Can estimate uncertainty
  - Can estimate impact of new observations
    - Relative entropy
- Prior here is MODIS climatology (MCD43A1,2):
  - Based on 500m BRDFs
  - But need uncertainty
    - Conservative estimate

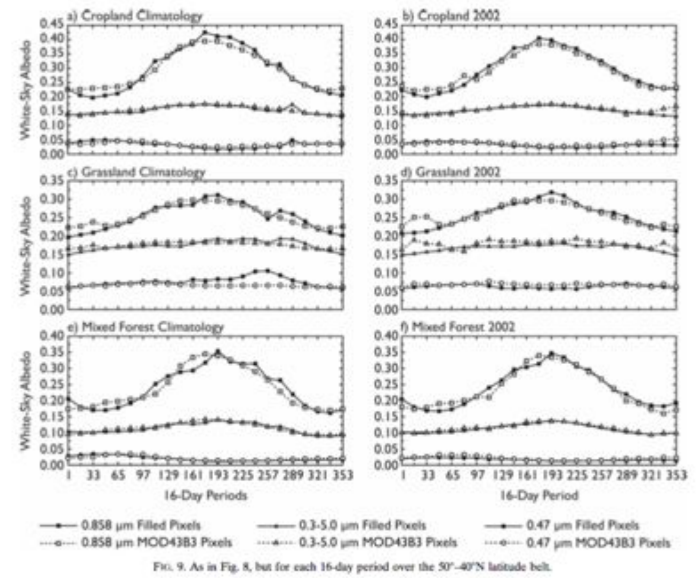


FIG. 9. As in Fig. 8, but for each 16-day period over the 50°–40°N latitude belt.

three ecosystem classes: (a), (b) cropland, (c), (d) grassland, and (e), (f) mixed forest from (left) the 5-yr aggregate climatology and (right) the 2002 single-year albedo data.

Priors and treatment of Snow

- Impact of snow significant
  - Develop 2 priors (snow/no snow)
  - Each associated with different inputs (snow/no snow)
- Snow can have strong forward scattering peak
  - Can claim kernels not appropriate
  - But no suitable replacement model available
    - Attempts e.g.:
      - Klein and Stroeve, 2002; Stroeve and Nolin, 2002; Liang et al., 2005
  - Separation of snow/no snow allows route for possible replacement of snow model

Generation of priors

- Input: MODIS Collection V005 BRDF-Albedo model parameters product
  - MCD43A1, MCD43A2 at 500m* (2000-2010)
- Same kernel models used
- Estimate climatology and uncertainty in parameters
  - Uncertainty to include actual variation: conservative
- Product has no uncertainty information, but 4 QA states
  - Apply weighting to QA states: *relative* uncertainty $W_{c0} = \frac{1}{\sigma_{QAc0,k}}$

Code	Meaning
0	best quality, full inversion (WoDs, RMSE majority good)
1	good quality, full inversion
2	Magnitude inversion (numobs >=7)
3	Magnitude inversion (numobs >=3&<7)
4	Fill value

** Thanks to Dave Obler and Robert Wolfe for supply of data on USB2 disks*

Generation of priors

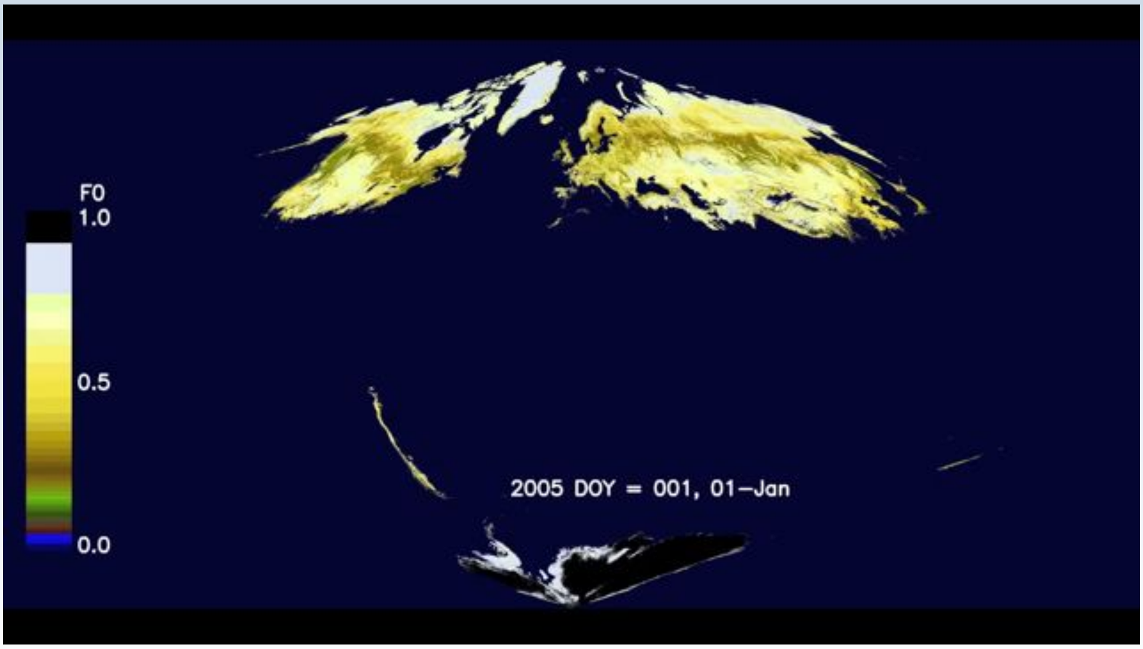
- Mean: $$\bar{f}_k(i,j) = \frac{1}{N_{(i,j)}} \sum_{c=0}^{c=3} \sum_{yQAc} W_{c0} f_{QAc,k}(i,j)$$ $$N_{(i,j)} = \sum_{c=0}^{c=3} \sum_{yQAc} W_{c0}$$
- Standard error (incl. small number bias correction):

$$\sigma_{1,2}^2 = \frac{\sum_{i=1}^{i=n} w_{QAi} \sum_{i=1}^{i=n} \left[w_{QAi} (x_{1,i} - \bar{x}_1)(x_{2,i} - \bar{x}_2) \right]}{\left(\sum_{i=1}^{i=n} w_{QAi} \right)^2 - \sum_{i=1}^{i=n} w_{QAi}^2}$$

$$s_{1,2}^2 = \sigma_{1,2}^2 \Big/ \sum_{i=1}^{i=n} w_{QAi}$$

- Examined temporal-weighting of priors:
  - Very similar to a weighting of climatology priors

MODIS Priors “With Snow” (every 8 days over 10 years)



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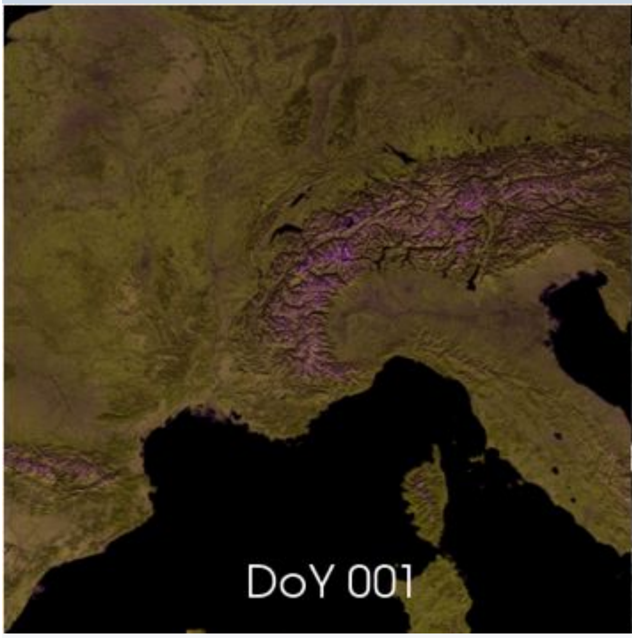
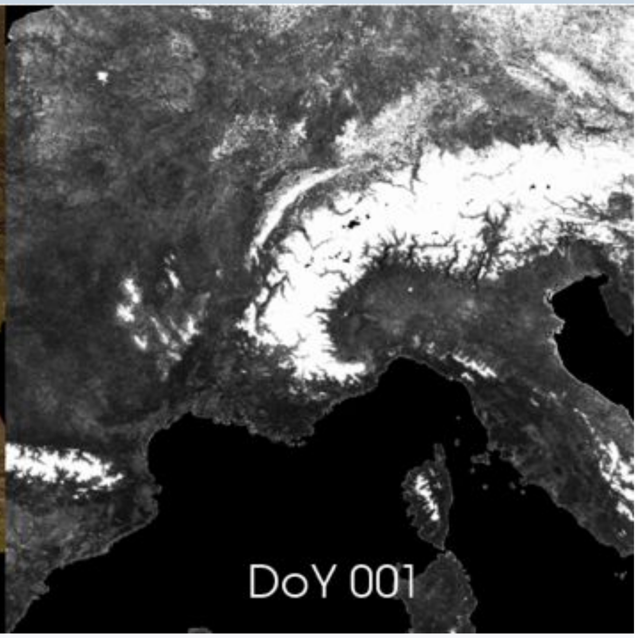
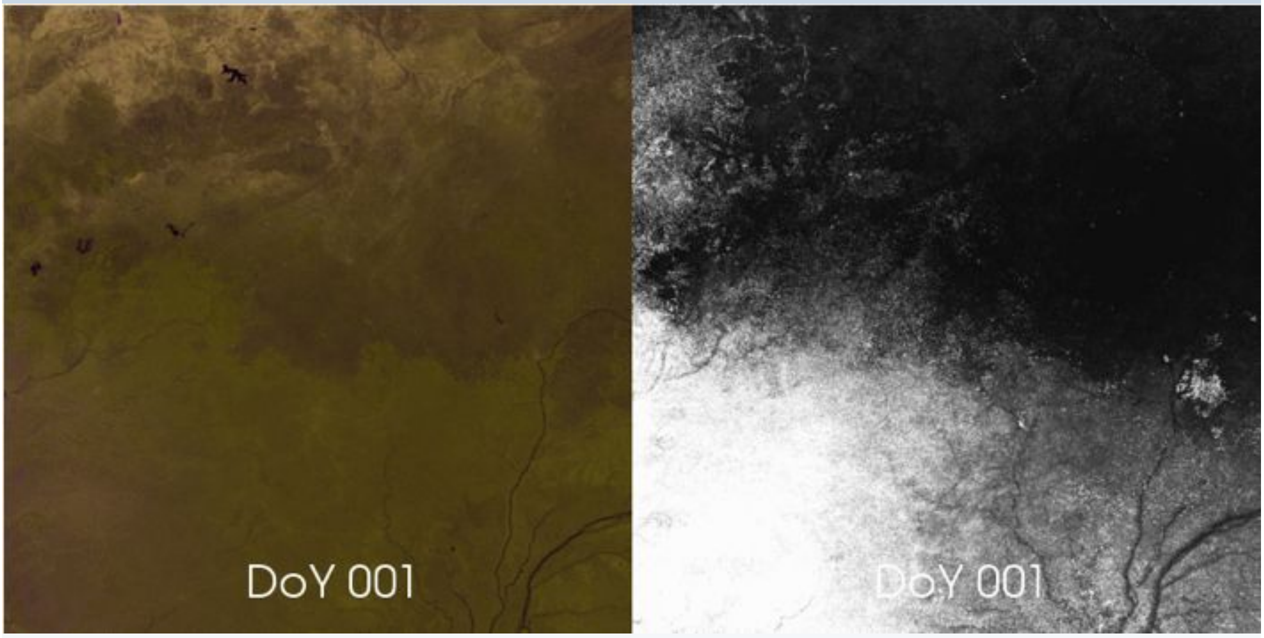
MODIS - Prior





MODIS-derived prior for tile h18v04 for 2005 – FCC SW f0, NIR f0, VIS f0 (RGB) and standard error model parameter f0 VIS, image scaled 0:0.25

MODIS - Prior



MODIS-derived prior for tile h19v08 for 2005 – FCC SW f0, NIR f0, VIS f0 (RGB) and standard error model parameter f0 VIS, image scaled 0:0.25

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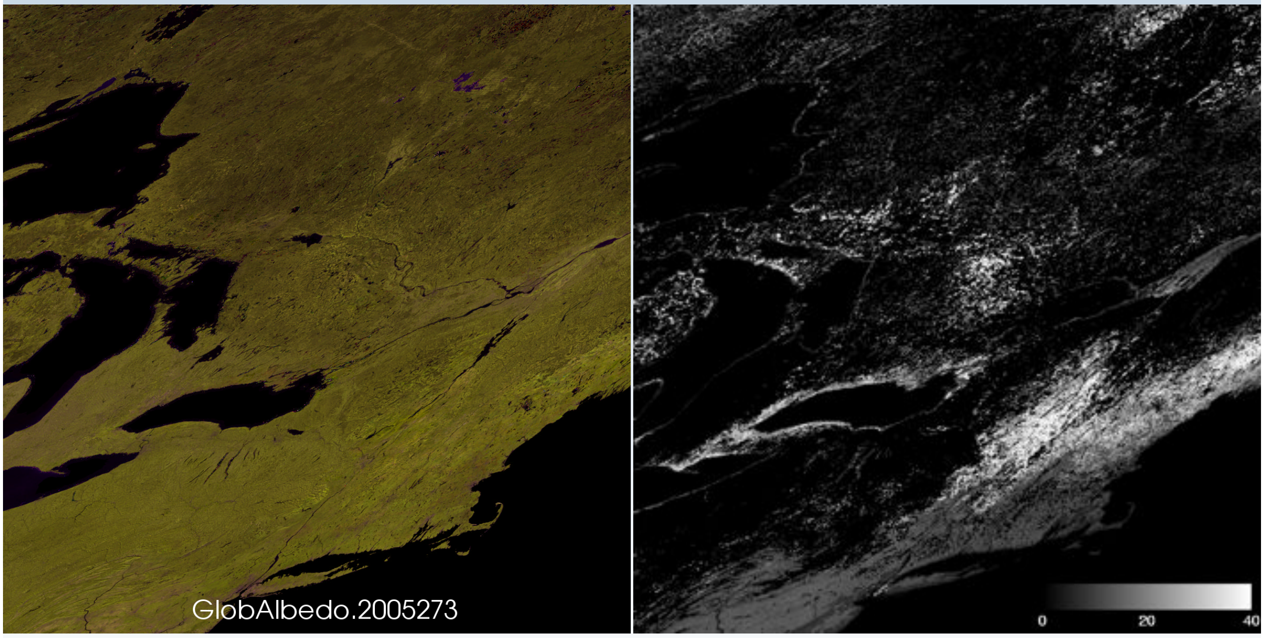
Relative Entropy - assessment of impact of MODIS on GlobAlbedo



f_0 SW,NIR,VIS (RGB)

Relative Entropy

Final Products

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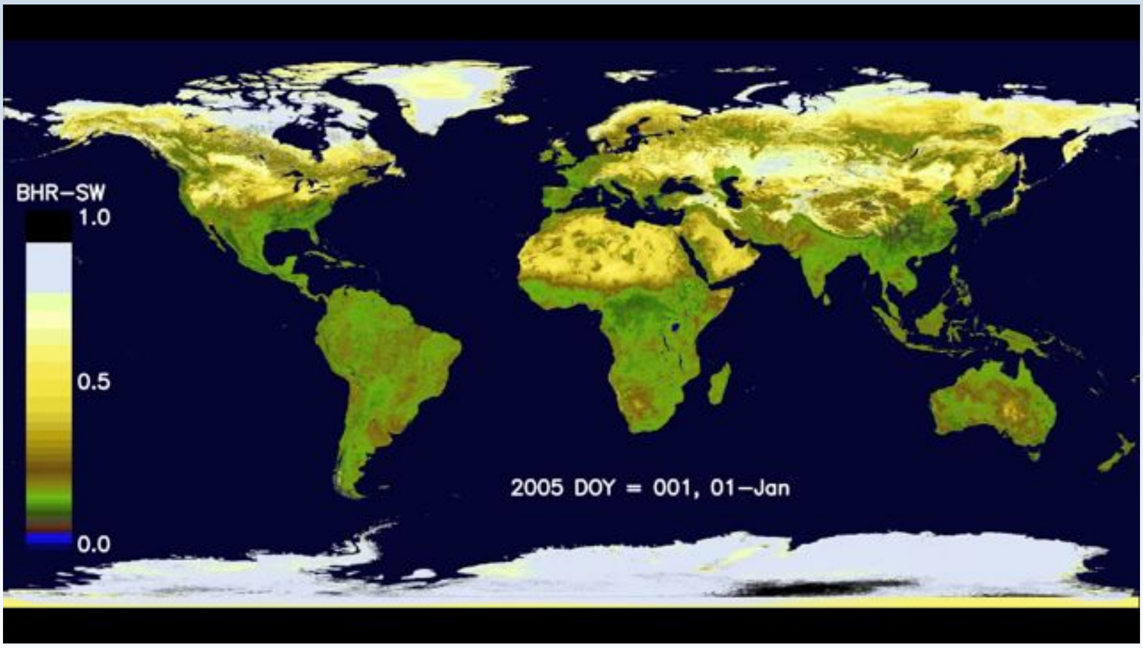
GlobAlbedo 8-daily BHR (using MSA CLUT)



Validation - Albedo Prototype products

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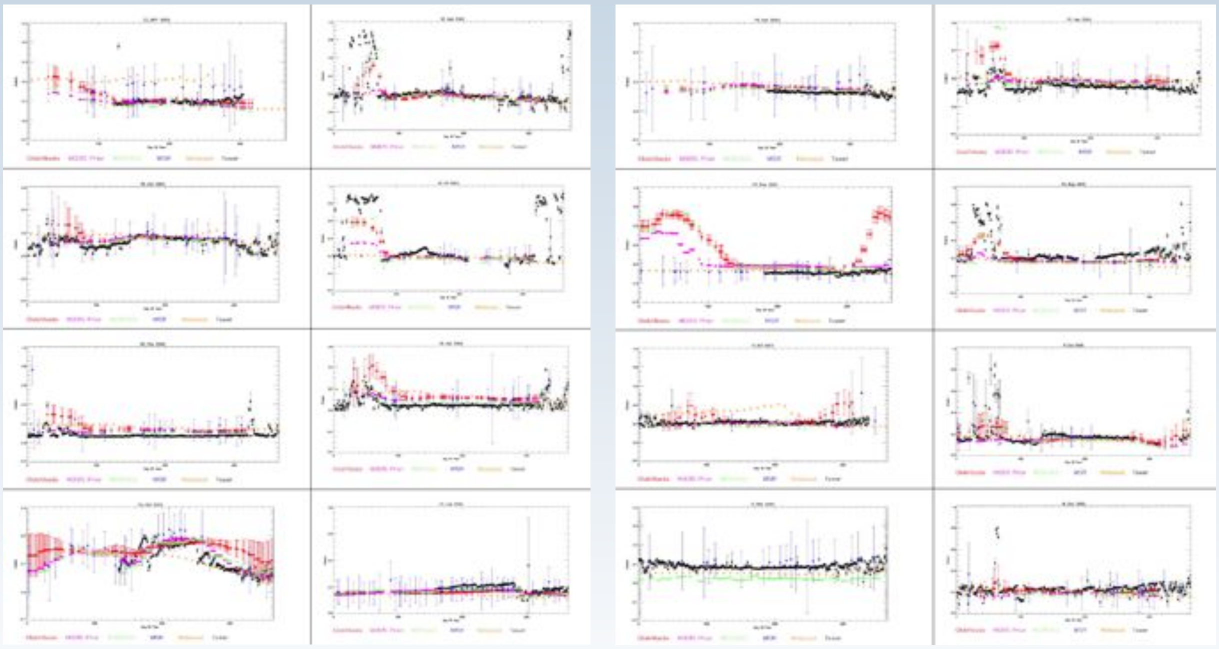
Albedo validation

- Focusing on 3 aspects
  - Intercomparison of Blue-Sky Albedo with tower albedometer measurements for representative sites which are homogeneous at 1-3km scale (Roman et al., 2009), Based mainly on FLUXNET 53 sites (Cescatti et al., RSE2012)
  - Assessment of BroadBand Albedo (VIS, NIR, SW) at the global scale on monthly time-steps with MISR and MODIS
  - Assessment of GlobAlbedo with METEOSAT (MSA)
- Tower albedometer data obtained from A. Cescatti from the La Thuile FLUXNET database with assistance from C. Schaaf of U. of Mass., Boston
- These data were processed to obtain averages over 11-13h Local Time using VEGETATION-derived AOD, Cloud Fraction and Snow cover
- Focus initially on Europe with coverage from METEOSAT

N.B. This work uses tower albedometer data acquired by the FLUXNET community and in particular by the following networks: AmeriFlux (U.S. Department of Energy, Biological and Environmental Research, Terrestrial Carbon Program (DE-FG02-04ER63917 and DE-FG02-04ER63911)), AfriFlux, AsiaFlux, CarboAfrica, CarboEuropeIP, CarboItaly, CarboMont, ChinaFlux, Fluxnet-Canada (supported by CFCAS, NSERC, BIOCAP, Environment Canada, and NRCan), GreenGrass, KoFlux, LBA, NECC, OzFlux, TCOS-Siberia, USCCC.

European FLUXNET/BSRN test sites (19 FLUXNET, 1 BSRN)

MODIS cf GlobAlbedo cf MISR cf METEOSAT cf FLUXNET



GlobAlbedo (±1sigma) MODIS Priors MC43A3 MISR (±1sigma) METEOSAT Tower

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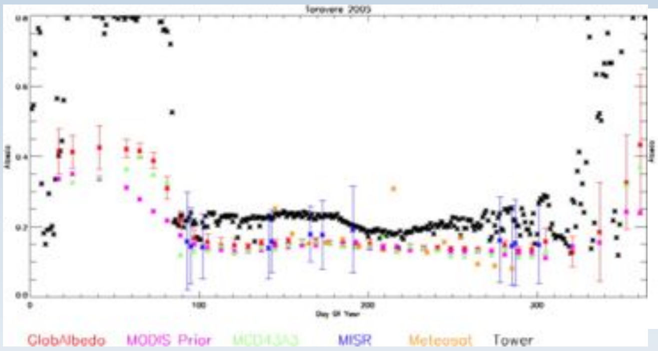
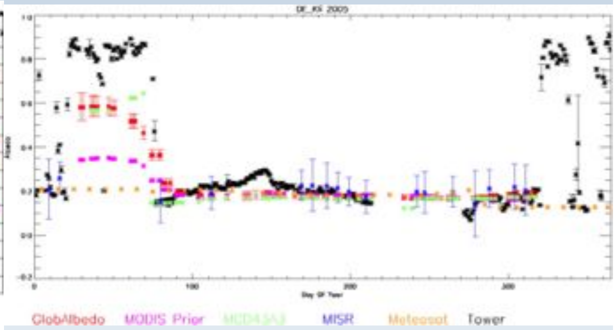
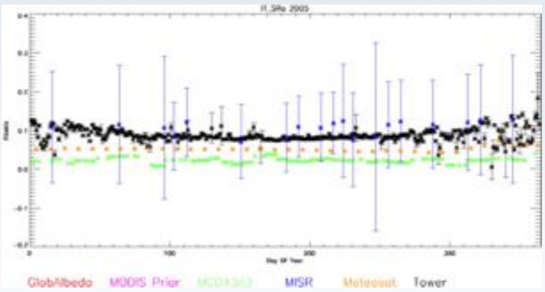
Intercomparison – some lessons learnt



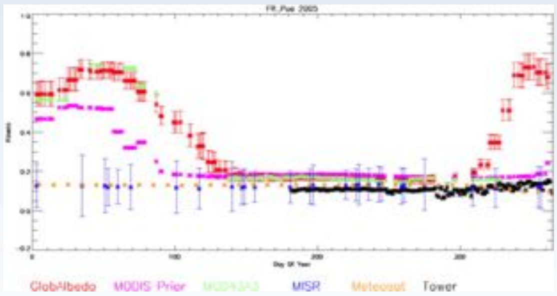
EO < 50% FLUXNET during snow and 20% otherwise



MODIS priors <50% during snow



Why is MCD43 so low cf MSA, MISR & tower?



Why do MSA & MISR indicate no snow?

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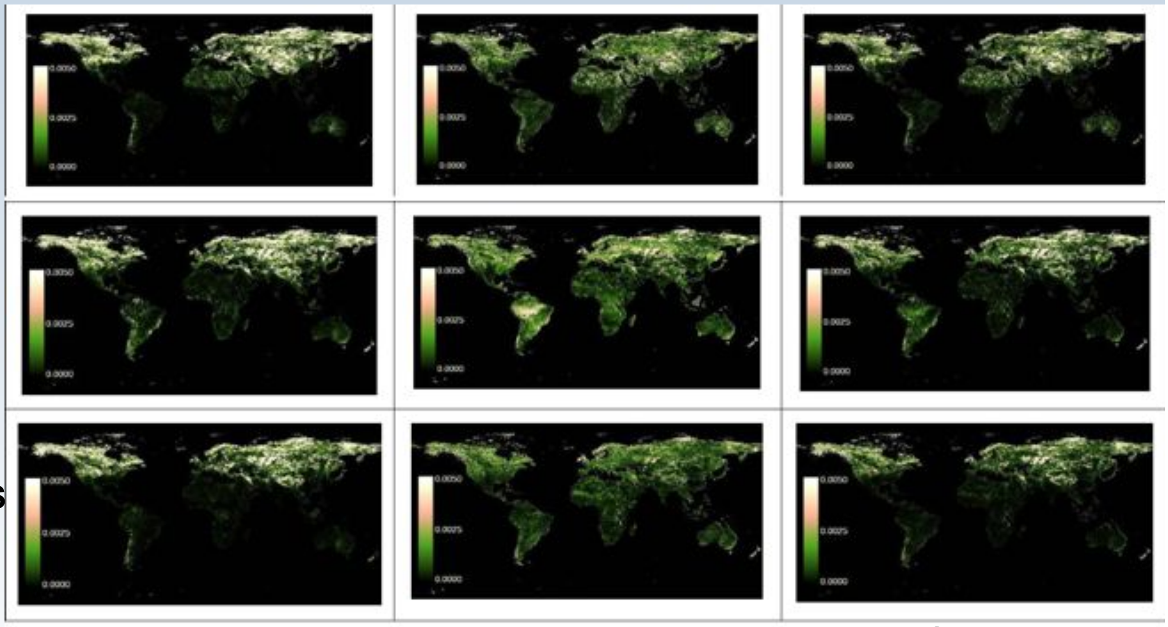
Global 0.5º BHR albedo triple collocation variance

GA

MISR

MODIS



Visible *NIR* *SW*

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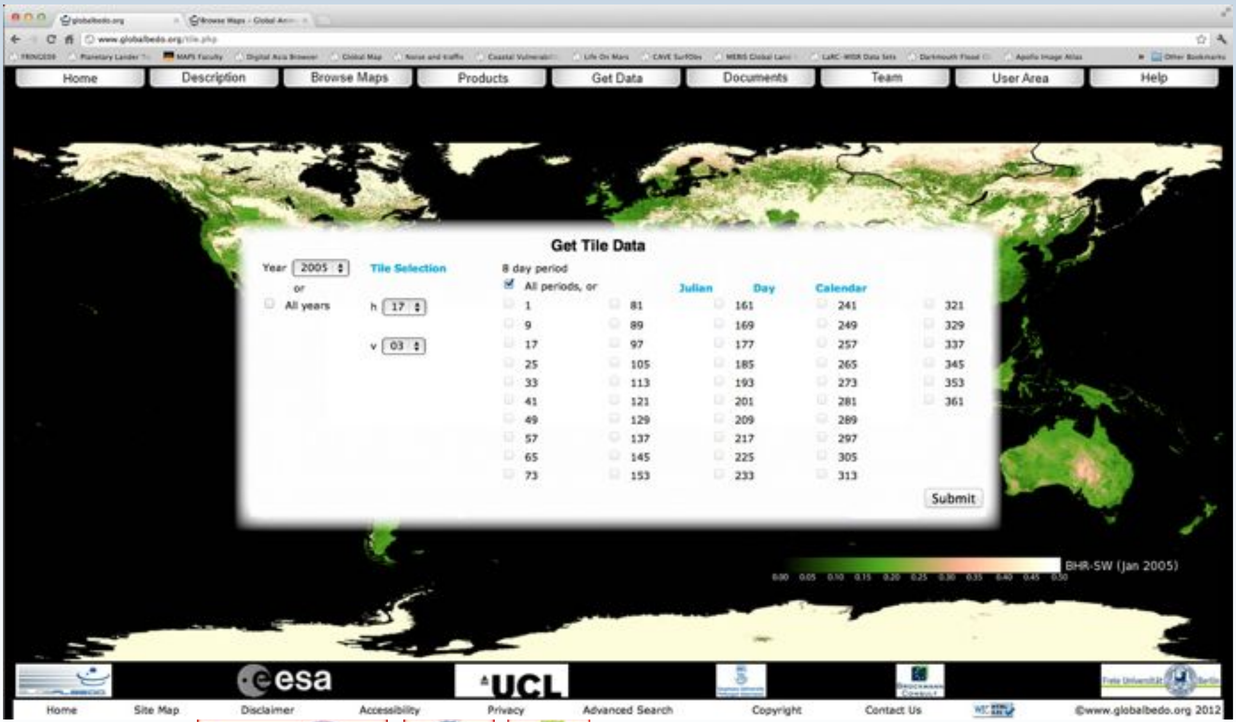
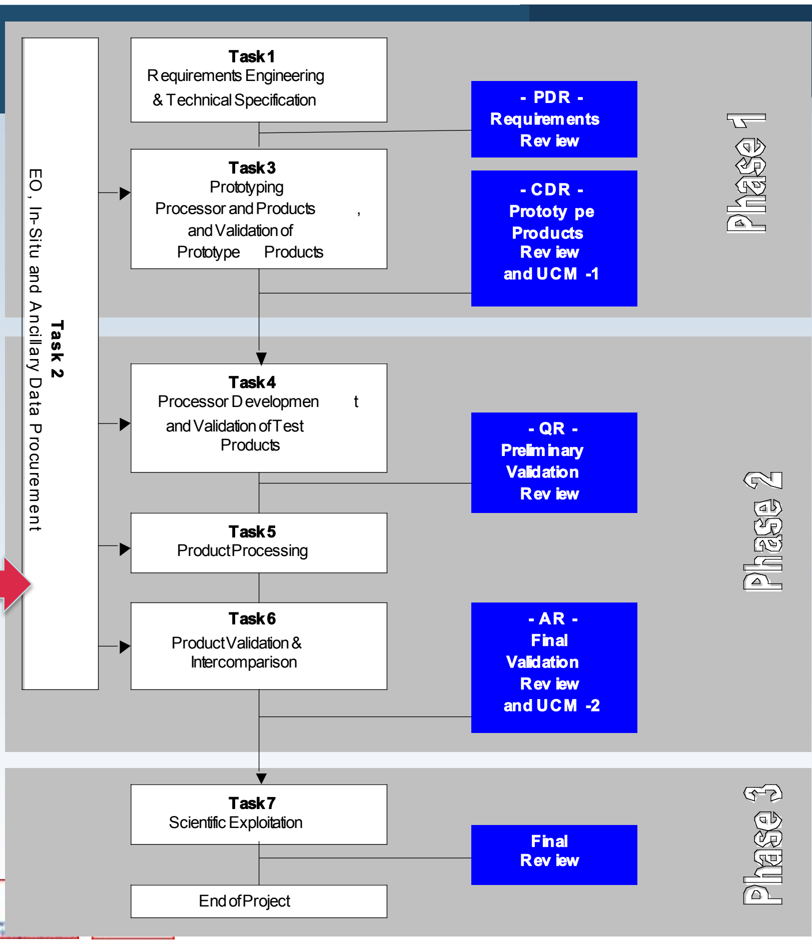
How do you browse and get hold of the data?



What next?

- MODIS prior to be extended forward (3/10-3/12)
- 13 year processing due to be completed by 11/12
- Validation datasets are established from FLUXNET and BELMANIP for global sites for entire time period
- Inter-comparisons with MISR, MCD43, METEOSAT Land-SAF continue
- ECMWF, Météo-France, MPI Hamburg, UK Met Office testing impact of uncertainties on NWP forecasts



What next? Global spectral BRDF at MODIS wavelengths at 10km interpolated to 1nm from MODIS priors & VGT/MERIS