Validation and Intercomparison of Global Leaf Area Index Satellite Products

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Fred Baret, INRA/EMMAH, Avignon
Jeff Morisette, USGS, Fort Collins, Co, (NASA'GSFC)
Jaime Nickeson, INNOVIM, Greenbelt, MD,USA
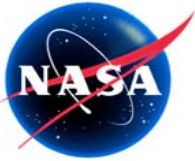Richard Fernandes, CCRS, Canada
Stephen Plummer, IGBP-ESA, , Italy
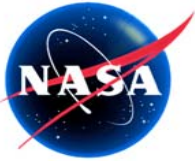Ranga Myneni, Boston University, USA
Greg Ederer, NASA's GSFC

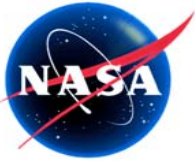*Garrigues et al., JGR, 2008*
Weiss et al., RSE, 2007

Outlines

1) Background

2) Direct validation and intercomparison methods

3) Intercomparison of 4 global LAI products : CYCLOPES v3.1, ECOCLIMAP, GLOBCARBON V1 and MODIS C4

4) Conclusions

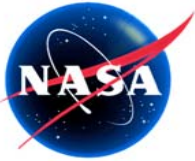5) Prospectives: potential of new earth observation systems

Background (1/2)
Leaf Area Index Product

✓ **Leaf Area Index**: Key surface characteristic for land surface models (cf. GCOS)

✓ **Definition**: half the total developed area of green leaves per unit ground horizontal surface area (Chen and Black, 1992)

✓ **Multiplicity of LAI satellite products** :

- MODIS (C4, C5)

- CYCLOPES (SPOT/VEGETATION)

- GLOBCARBON (VEGETATION, ATSR)

- CCRS (SPOT/VEGETATION)

- MSG/SEVIRI

Background (2/2)

✓ **Rationale**: Understanding the **uncertainty** of a given **LAI product** and **differences between products** is **critical for their proper use** (cf. QA4EO)

✓**LPV initiative** (Morisette et al., 2006)

- **Benefit of LPV infrastructure** to share data, methods, and results

- **Coordinated international effort**:
    - USA: Boston University, Oregon State University, the USDA Forest Service, and the EPA

    - Canada: CCRS and University of Alberta

    - Europe: ESA; INRA, Medias-France; the University of Milan-Bicocca, University of Helsinki; DLR; EOLAB and others.

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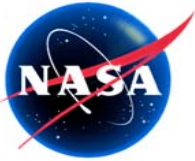
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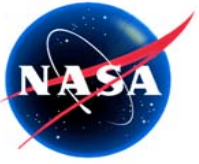
Methodological framework: Two approaches

1. **Direct validation**: quantify **the absolute uncertainty** of a given (LAI) product through **comparison with *in situ* measurements**

2. **Product intercomparison** (i.e. indirect validation): assess the **spatial and temporal consistency** between products

Direct Validation approach

LAI Field data

Transfer function

High resolution imagery (20-30m)
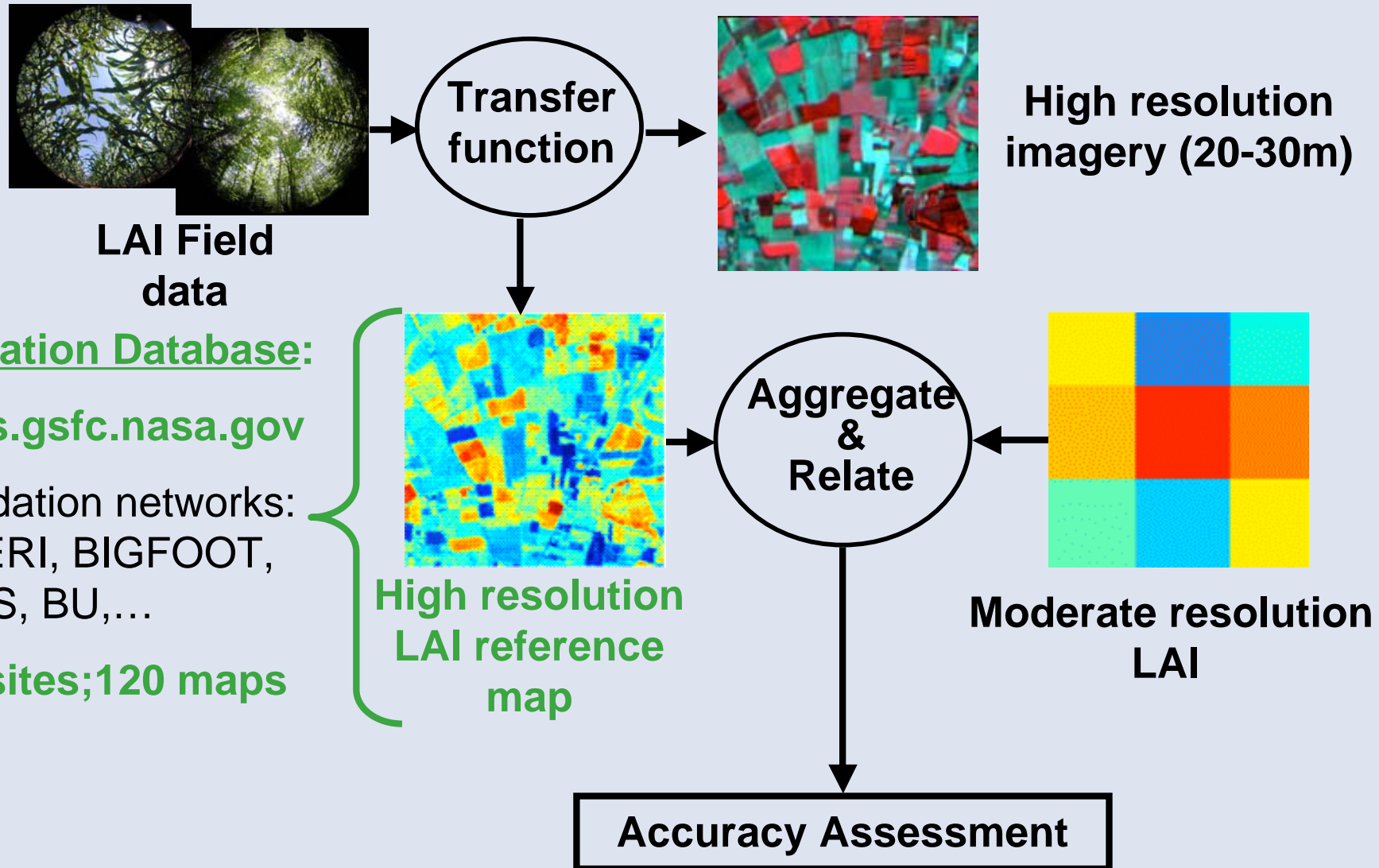
Validation Database:

- **lpvs.gsfc.nasa.gov**

- validation networks: VALERI, BIGFOOT, CCRS, BU,…

- **80 sites;120 maps**

High resolution LAI reference map

Aggregate & Relate

Moderate resolution LAI

Accuracy Assessment

Intercomparison approach
The BELMANIP Global Network of Sites
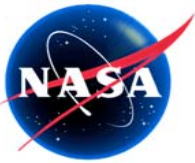
Baret, et al., 2006, IEEE TGARS special issue
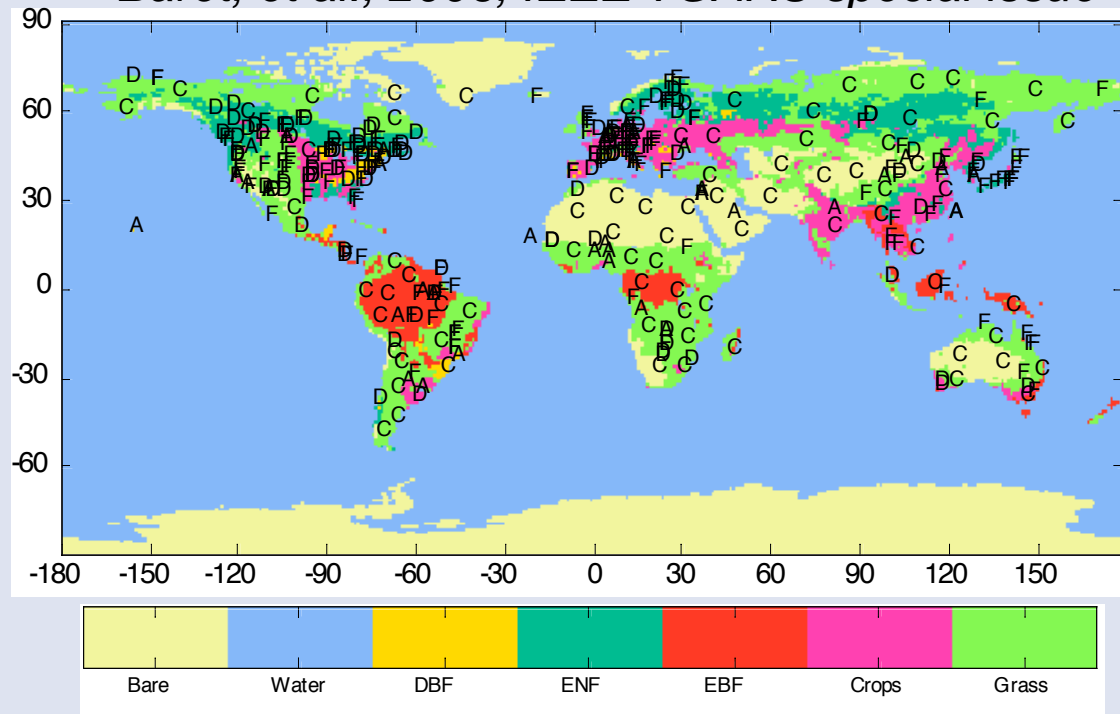
✓ **Designed to represent the global variability of land surface types**

✓ BELMANIP-2: **420 sites selected** from GLC-2000 global land cover map
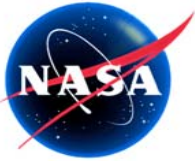
LAI intercomparison framework
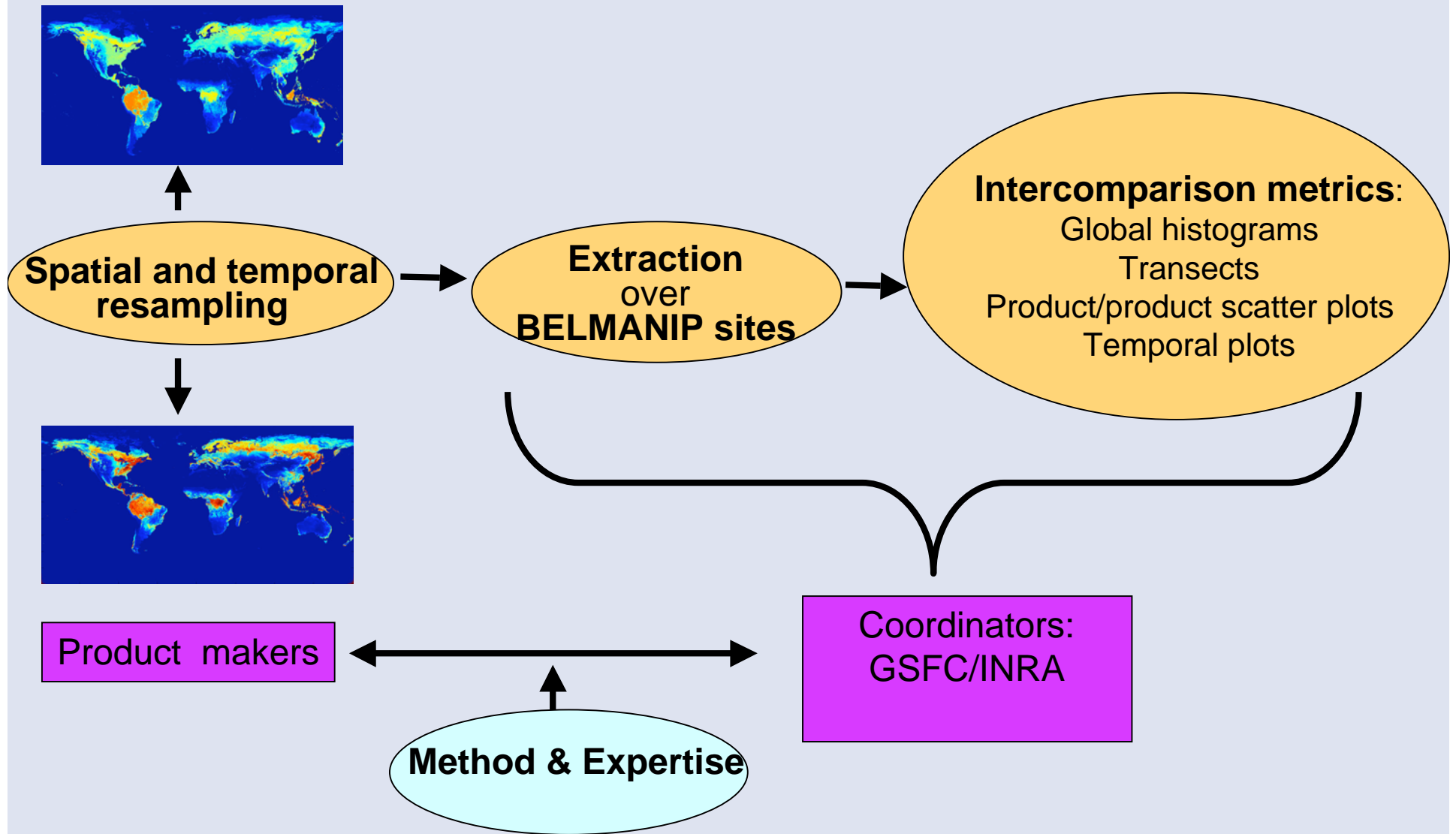
Outlines

1) Background

2) Direct validation and intercomparison methods

3) Intercomparison of 4 global LAI products : CYCLOPES v3.1, ECOCLIMAP, GLOBCARBON V1 and MODIS C4

4) Conclusions and Prospectives: potential of new earth observation systems

Investigated Products

Product	Sampling	Algorithm	Shoot clumping	Canopy clumping	Landscape clumping	Smoothing
CYCLOPES (V3.1) *Baret et al., 2007*	1/112° 10 days	Neural Network, RTM 1D	No	No	Yes	No
ECOCLIMAP *Masson et al., 2003*	1/120° 1 month	Empirical (based on NDVI variation)	Yes	Yes	No	No
GLOBCARBON (V1) *Deng, 2006*	1/11.2° 1 month	Model derived VI-LAI relationship	Yes	Yes	No	Yes
MODIS (C4) *Knyazikhin et al., 1998; Myneni et al., 2002*	1 km 8 days	Main: LUT, RTM 3D; Backup: LAI-NDVI empirical relationship	Yes	Yes	Partly	No

Intercomparison: at 1/11.2° and a monthly time step
Period: 2001-2003

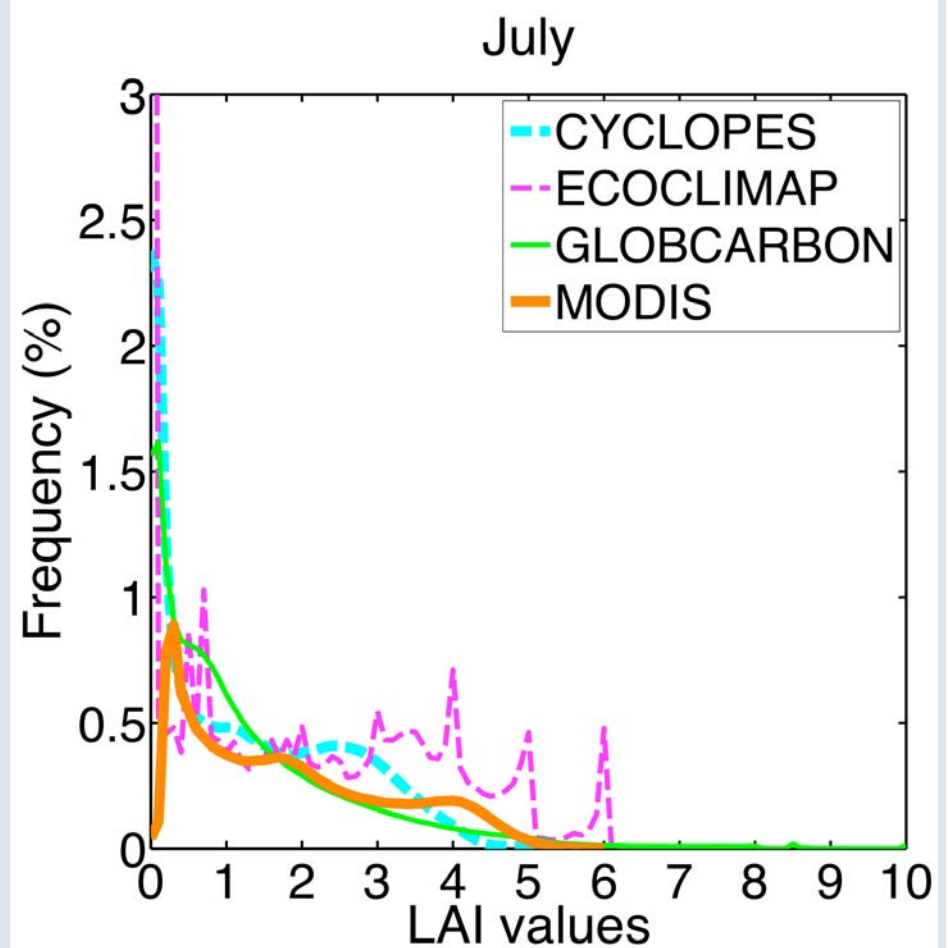11

Global maps (Aug 2002)

ECOCLIMAP

GLOBCARBON
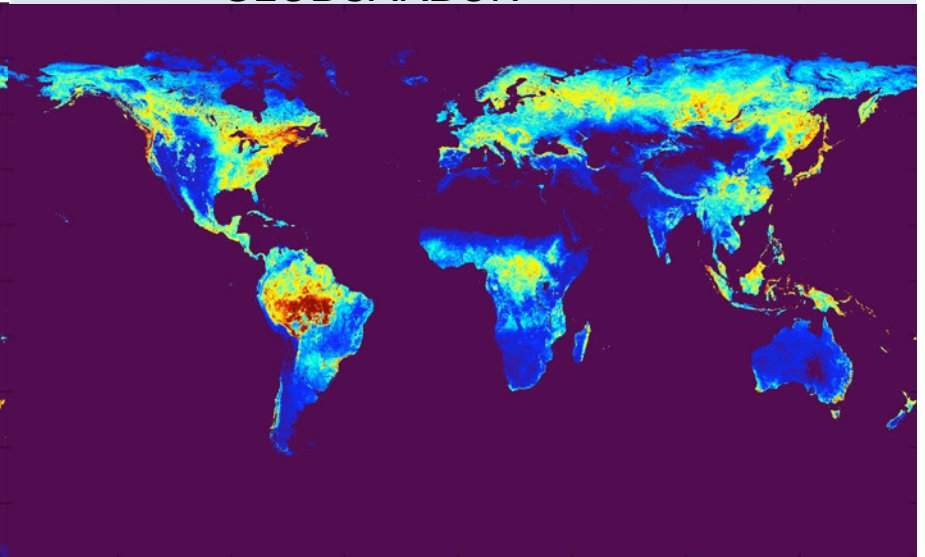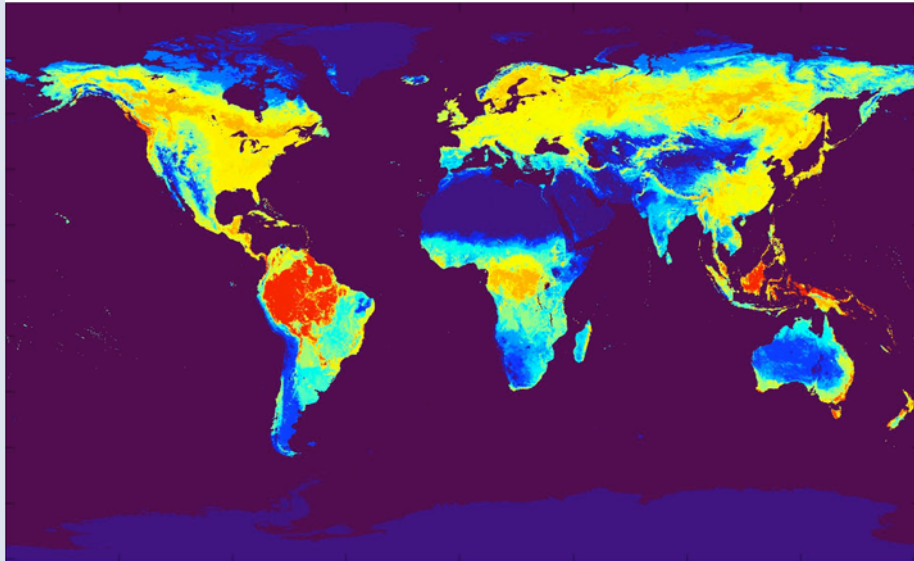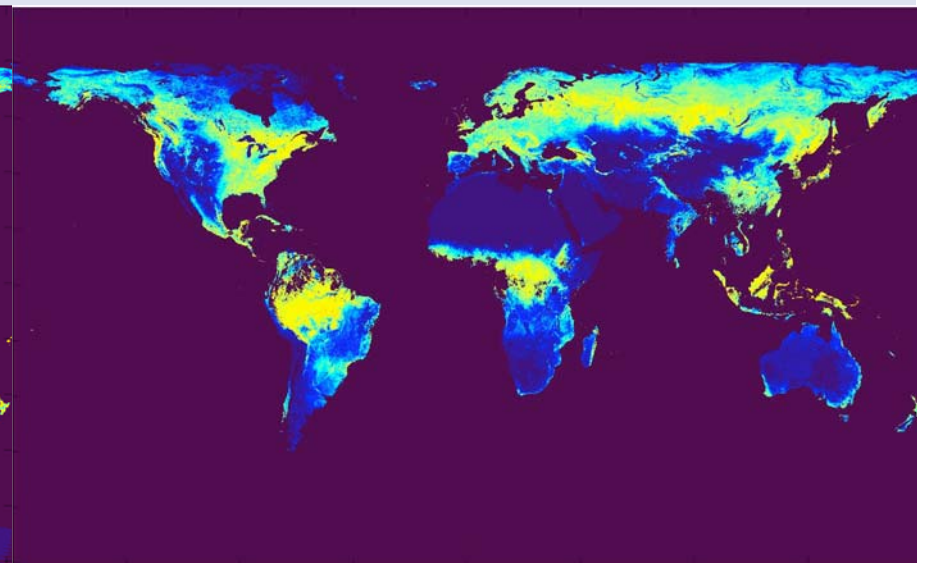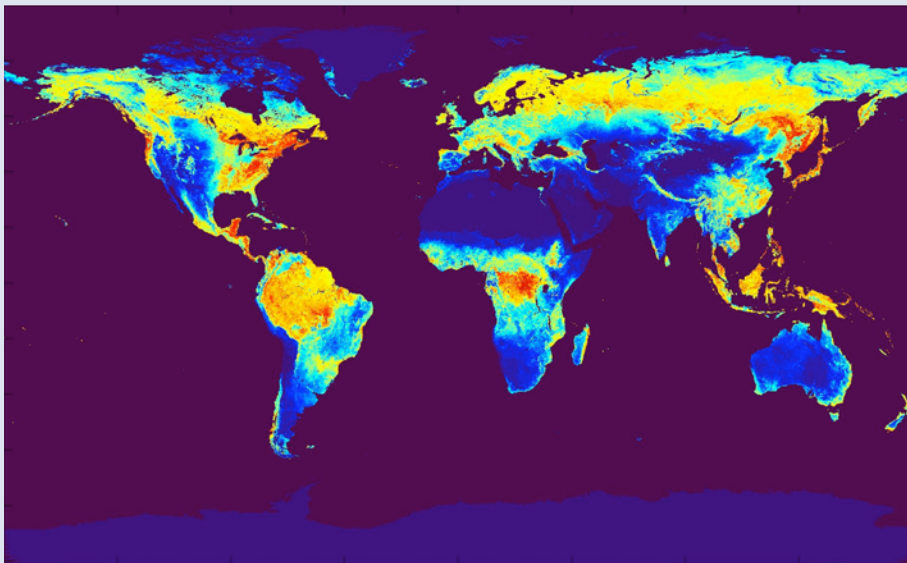
MODIS

CYCLOPES

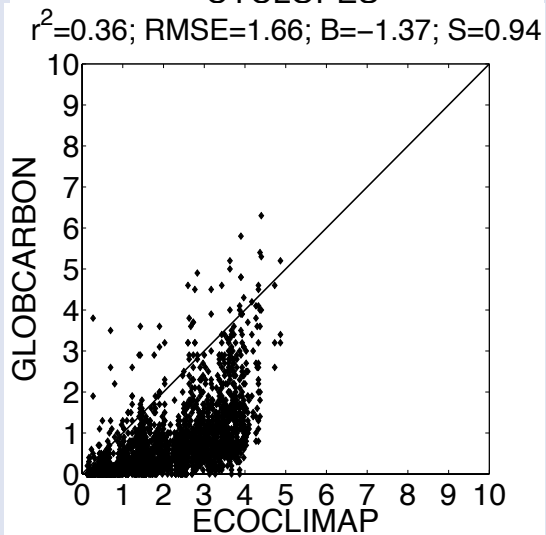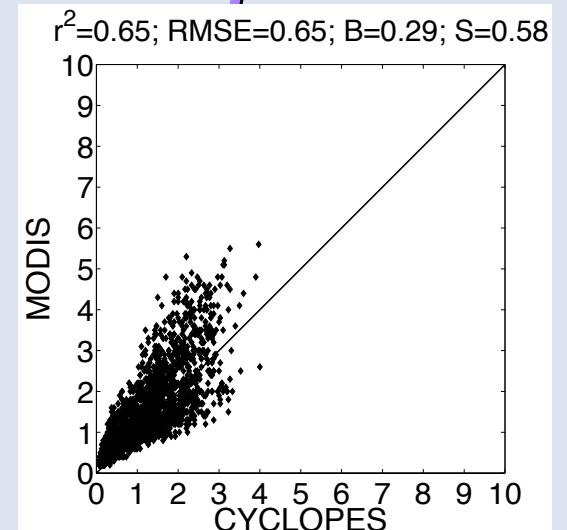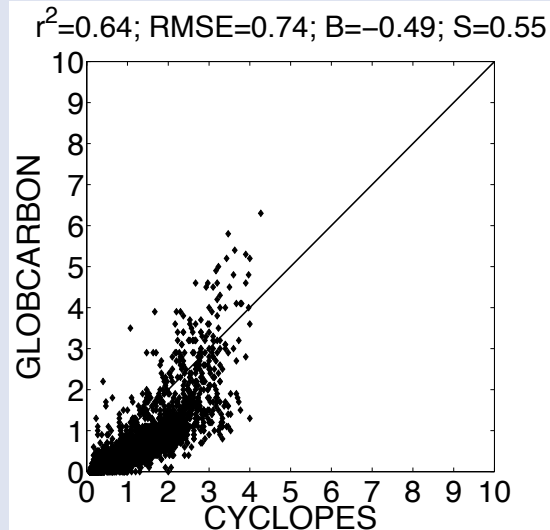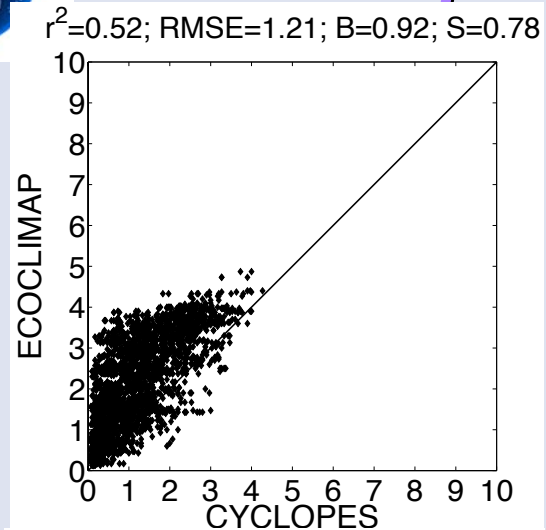# *Global LAI value distributions*
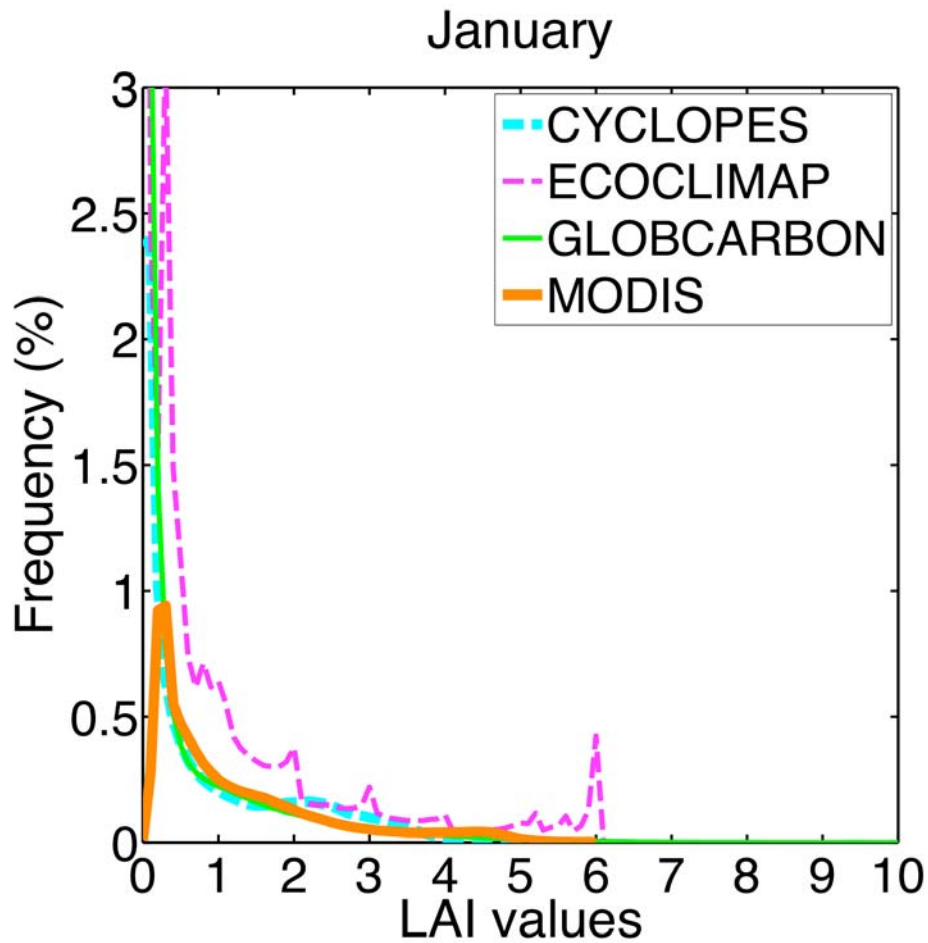
- ➢ **Important differences between the LAI value distributions in July**
- ➢ **Erratic and unrealistic LAI distribution for ECOCLIMAP**
- ➢ **Too low frequency of low LAI values for MODIS**
- ➢ **Early saturation for CYCLOPES (max LAI~ 4)**
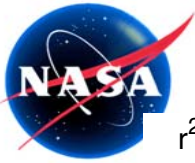
Scatterplots over the BELMANIP crop sites

r^2=0.52; RMSE=1.21; B=0.92; S=0.78

r^2=0.64; RMSE=0.74; B=−0.49; S=0.55

r^2=0.65; RMSE=0.65; B=0.29; S=0.58

r^2=0.36; RMSE=1.66; B=−1.37; S=0.94

r^2=0.31; RMSE=1.20; B=−0.69; S=0.98

r^2=0.62; RMSE=0.98; B=0.76; S=0.62
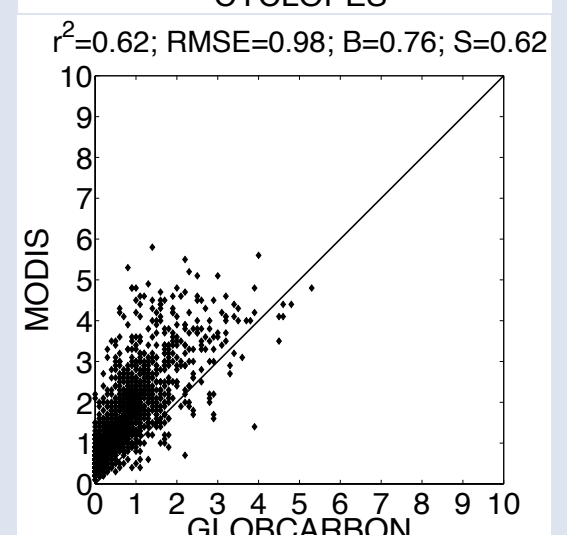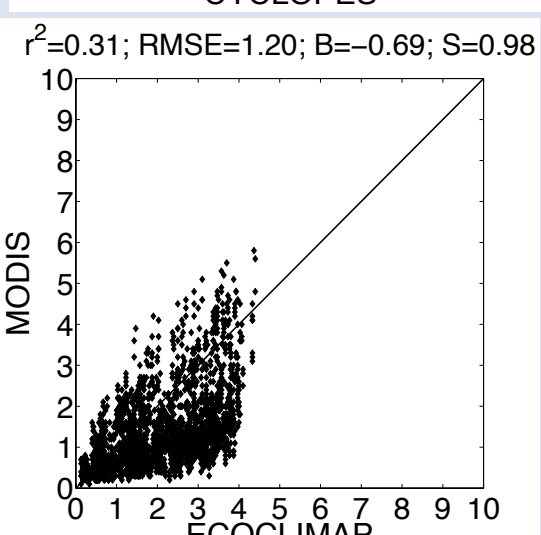
✓ **General overestimation of ECOCLIMAP for all vegetation types**
✓ **MODIS >CYCLOPES >GLOBCARBON**: canopy modelling differences or/and surface reflectance bias between MODIS and CYCLOPES (Verger et al.,2008)

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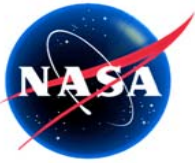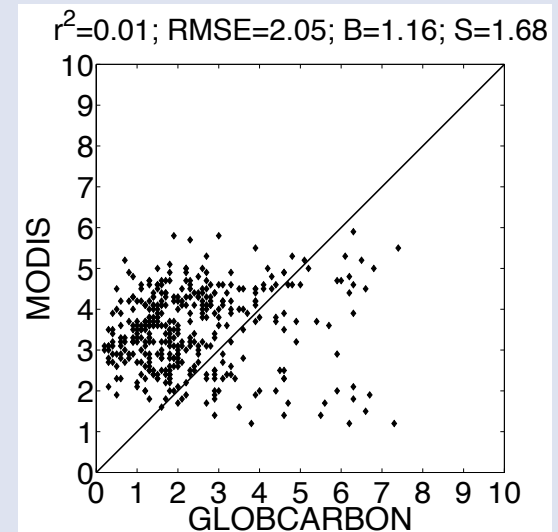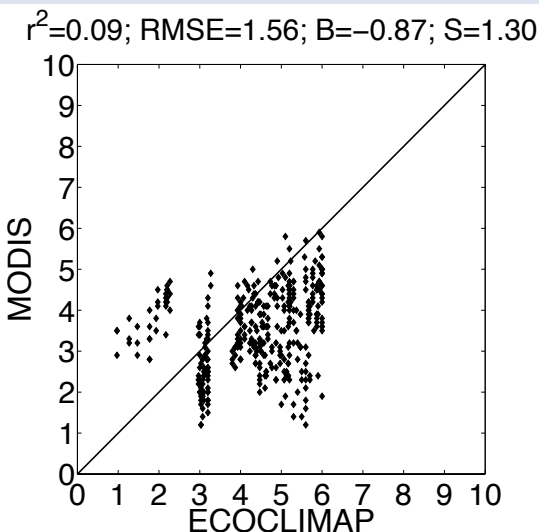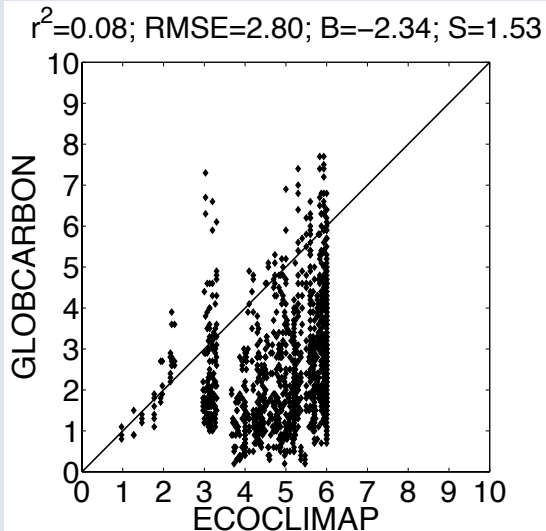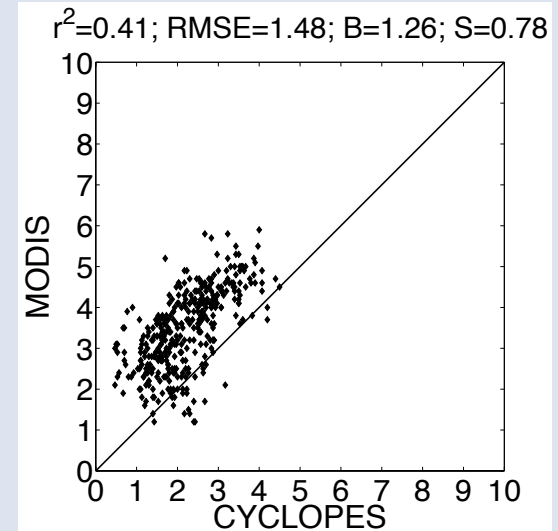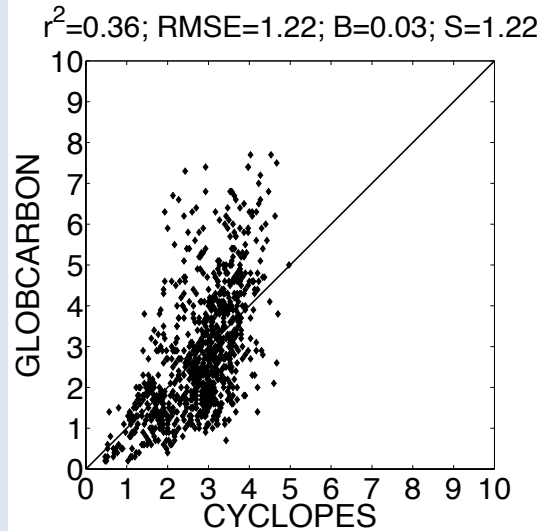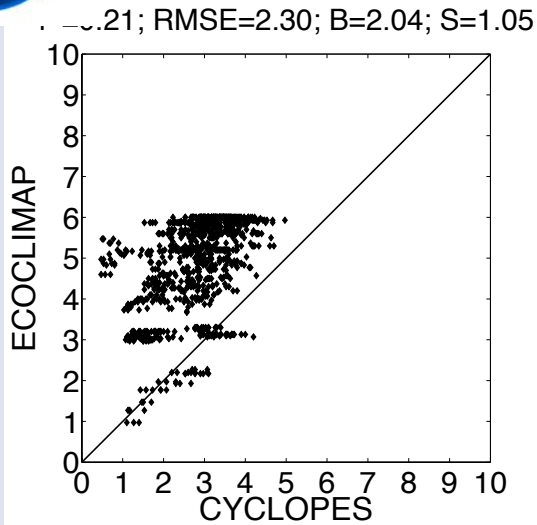
Scatterplots over Evergreen Needleaf Forest sites
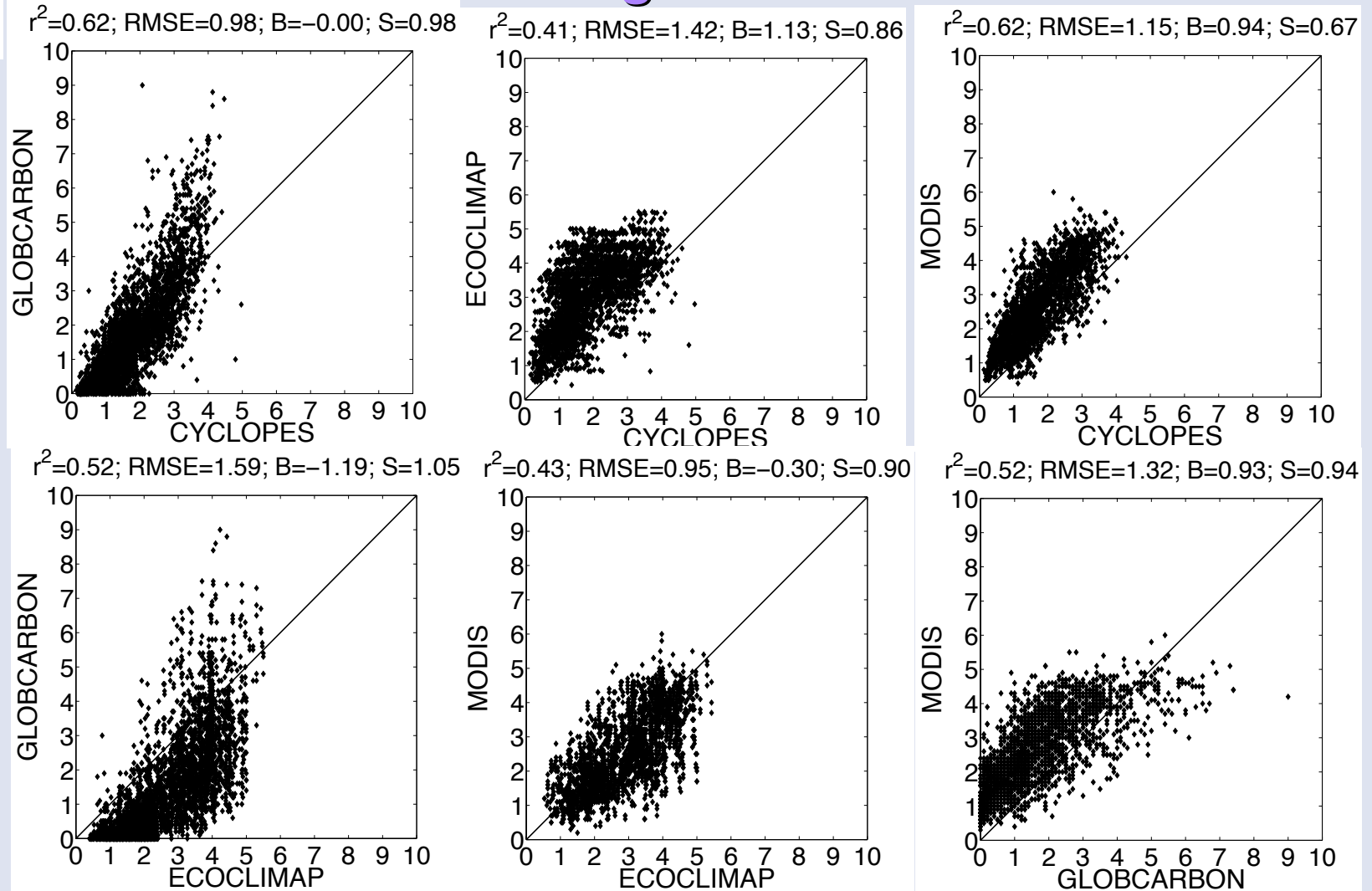
- ✓ **Large discrepancies over forests**, due to differences in canopy structure modelling
- ✓ **Over forests, MODIS provides much larger LAI than the other products**
- ✓ **Too low values for CYCLOPES** (maximum of 4)
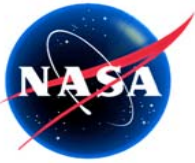- ✓ For all products, **unrealistic LAI<1 for closed canopy ENF**
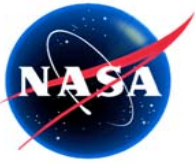
Scatterplots over the evergreen broadleaf forest

Large inconsistencies between all the products (saturation of the radiometric signal, residual atmospheric and cloud contamination, uncertainty in canopy structure models)
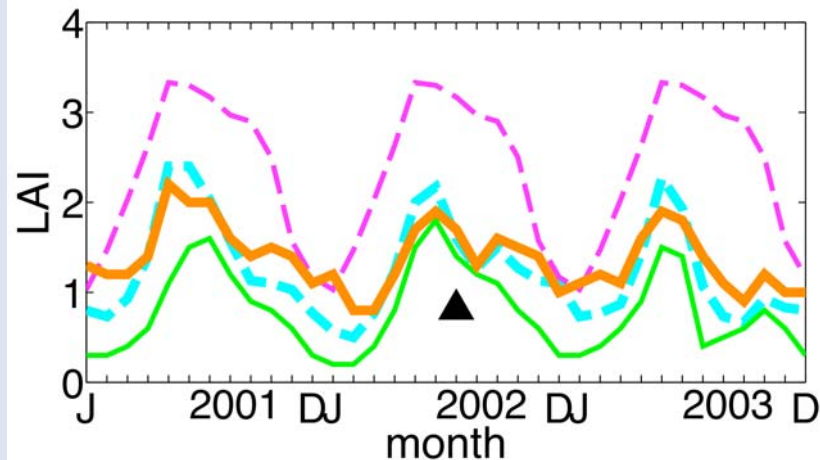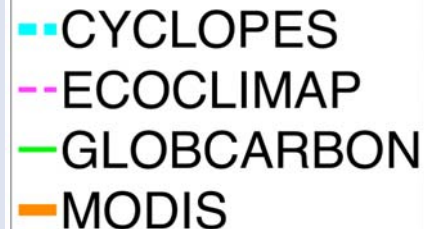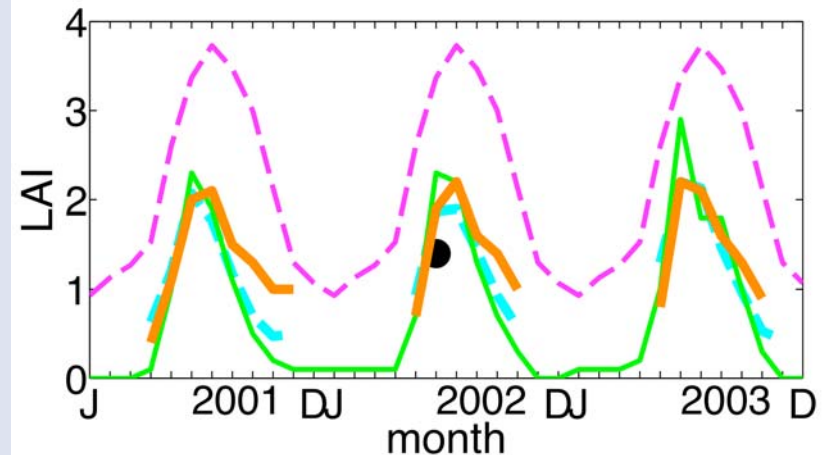
Temporal consistency (1/2)

Grassland

Larzac, France, Lat=43.94, Lon=3.12

Cropland

Walnut Creek, USA, Lat=41.96, Lon=−111.61

Legend:
- **- - CYCLOPES**
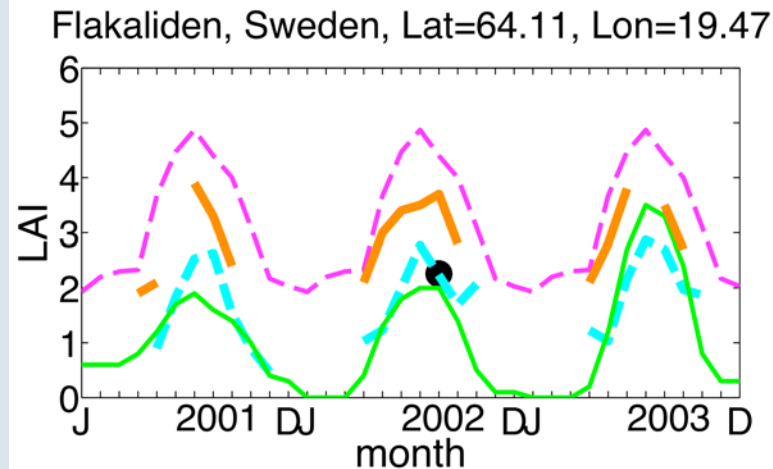- **- - ECOCLIMAP**
- **— GLOBCARBON**
- **— MODIS**

■ **Ground data**

✓ **Consistent and realistic temporal profiles** over croplands and grasslands
✓ All the products capture **interannual variations**, except ECOCLIMAP
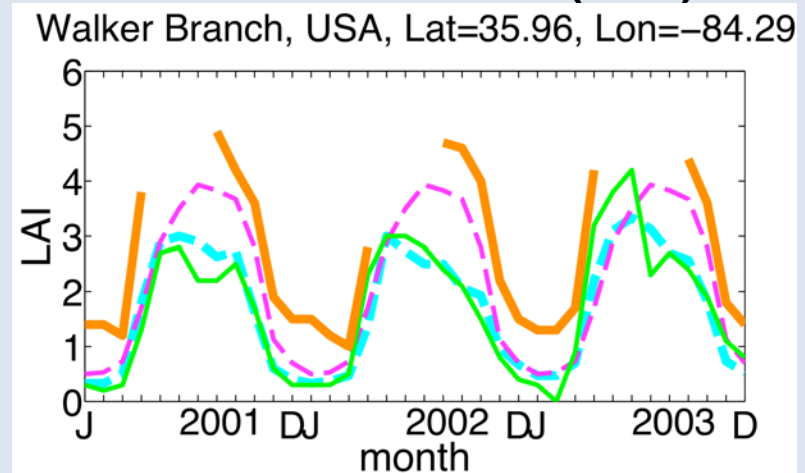✓ **Best agreement** is achieved by **MODIS and CYCLOPES**
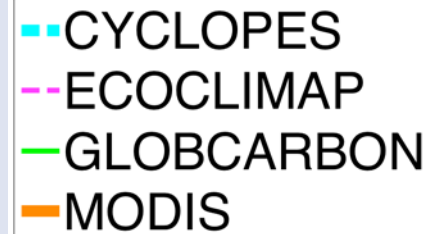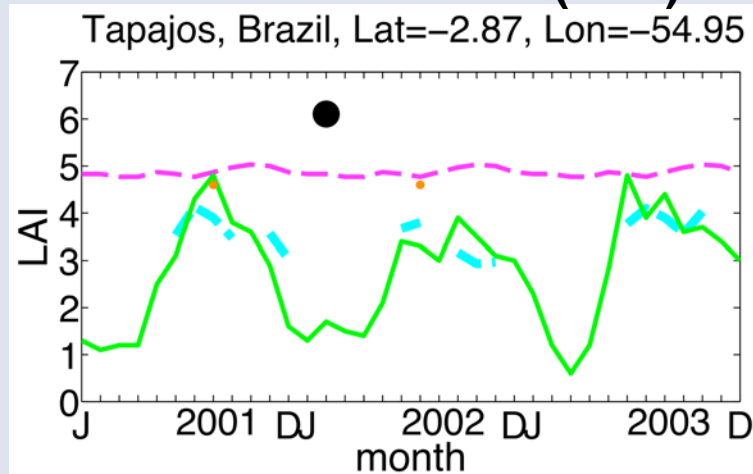
17
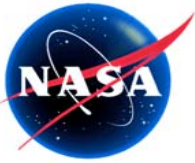
Temporal consistency (2/2)

Ever. Needle. For (ENF)

Flakaliden, Sweden, Lat=64.11, Lon=19.47

Decid. Broad. For (DBF)

Walker Branch, USA, Lat=35.96, Lon=−84.29

Ever. Broad. For (EBF)

Tapajos, Brazil, Lat=−2.87, Lon=−54.95

- -CYCLOPES
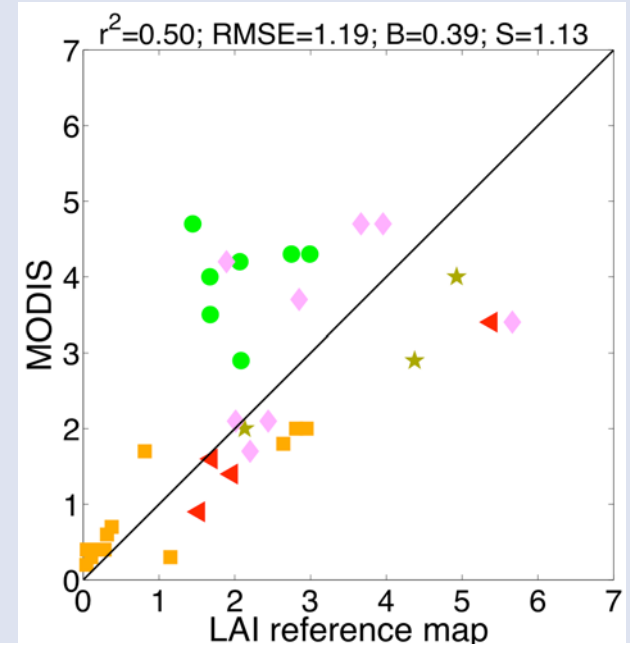**- -ECOCLIMAP**
—GLOBCARBON
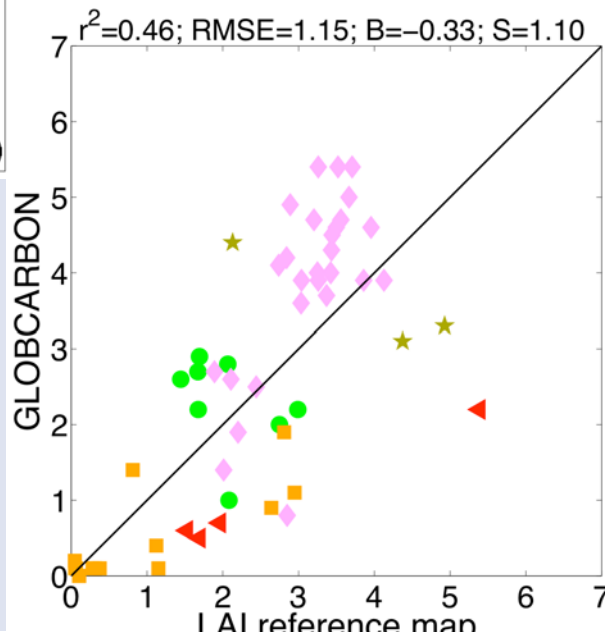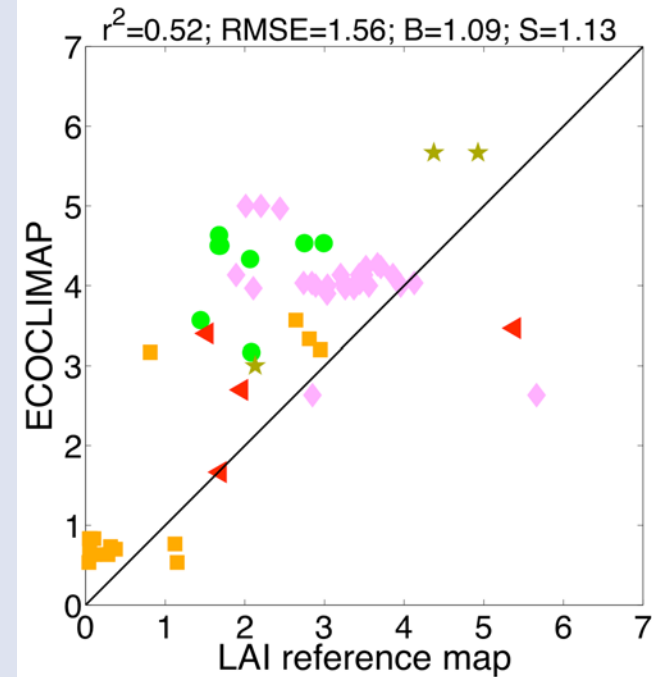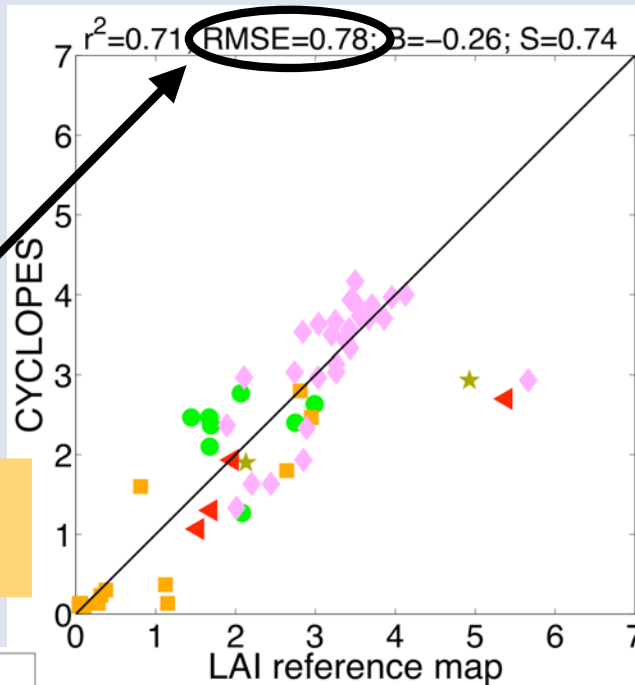**—MODIS**

■ Ground data

- ✓ **Poor temporal continuity** of **CYCLOPES and MODIS** over Northern Latitude sites
- ✓ Over **DBF**: overestimation of MODIS in winter and failure in summer
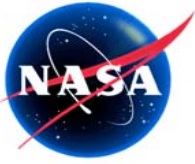- ✓ **Large temporal inconsistencies** and poor temporal continuity over **EBF**

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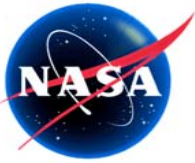# *Direct validation: Product versus LAI reference Maps*

Best agreement for CYCLOPES

Summary of the product performances

Criteria	CYCLOPES	ECOCLIMAP	GLOBCARBON	MODIS
Global distribution	+	-	+	+
Spatial consistency	+	-	-	+
Spatiotemporal continuity (no gaps)	-	+	+	-
Temporal consistency	+	-	-	+
High LAI	-	+	+	+
Low LAI	+	+	+	-
Comparison to in-situ data	+	-	-	-

Conclusions & Pending issues

➢ **Validation data**:
  - need to **improve measurement accuracy**
  - need to **quantify their uncertainty**
  - need to better characterize the **seasonal and global variability** of LAI

➢ **Current work**:
  - exercise **refined** at **3km spatial sampling**
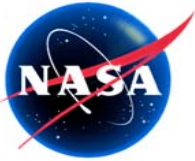 - including **new version of products** (MODIS Collection 5)

➢ **Typical methodological framework for other products** (cf. OLIVE system)

➢ **A critical exercise:**
  - part of the cal/val process as defined by WGCV and QA4EO
  - required for a **consistent integration of multiple satellite products** in climatic data records
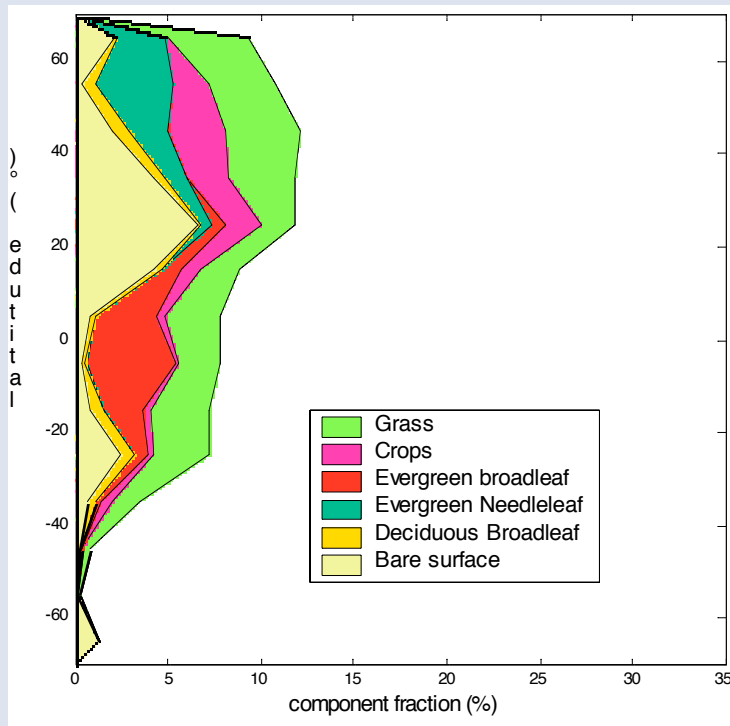
➢ **Need to be properly updated and** <u>**supported**</u> **by space agencies**
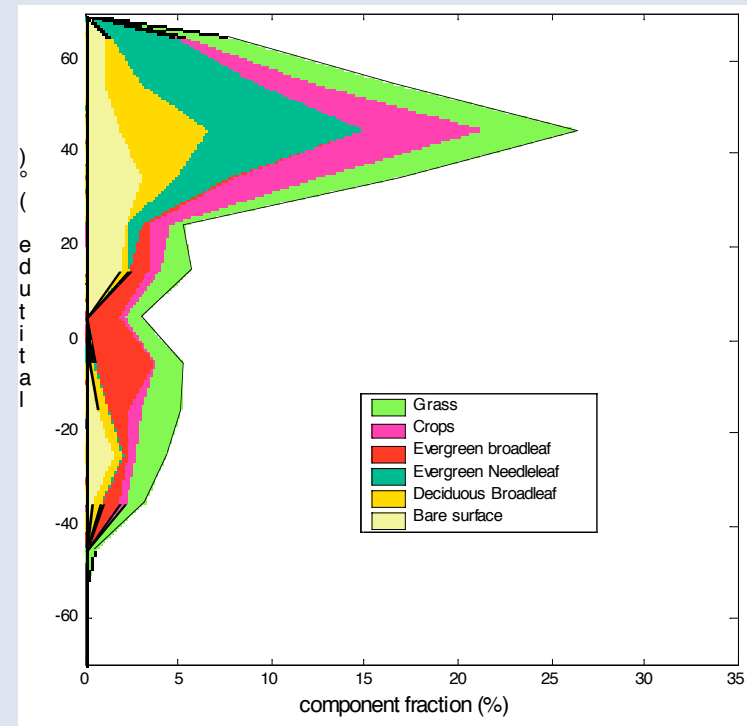
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ADDITIONAL SLIDES

Approach (2/5)
The BELMANIP Global Network of sites

ECOCLIMAP global classification (Masson et al, 2003)

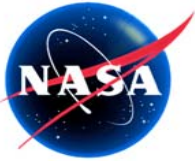

Global surface type distribution   BELMANIP surface type distribution

(Baret et al., 2006)

➡ 76 sites were added to FLUXNET, AERONET and Direct Validation sites to better sample latitude, longitude and surface types (grass, bare surface, evergreen broadleaf forest)

Approach (4/5)
LAI reference Map Database

• Direct validation conducted at BELMANIP sites at LAI reference maps have been generated

• Using the LPV infrastructure to bring together LAI maps from several projects and groups:

- •North America: BIGFOOT, Boston University, EPA, CCRS, University of Alberta, USDA (SMEX02), NACP , CEOS/LPV …

- •Europe: VALERI (INRA, France), CARBOEUROPE (Milan University, Italy), BIOTA/GLOWA-AFRICAN projects (DLR), MSG validation sites (Valencia University, Spain),

- • Others : ?
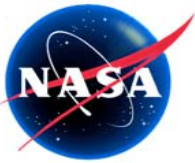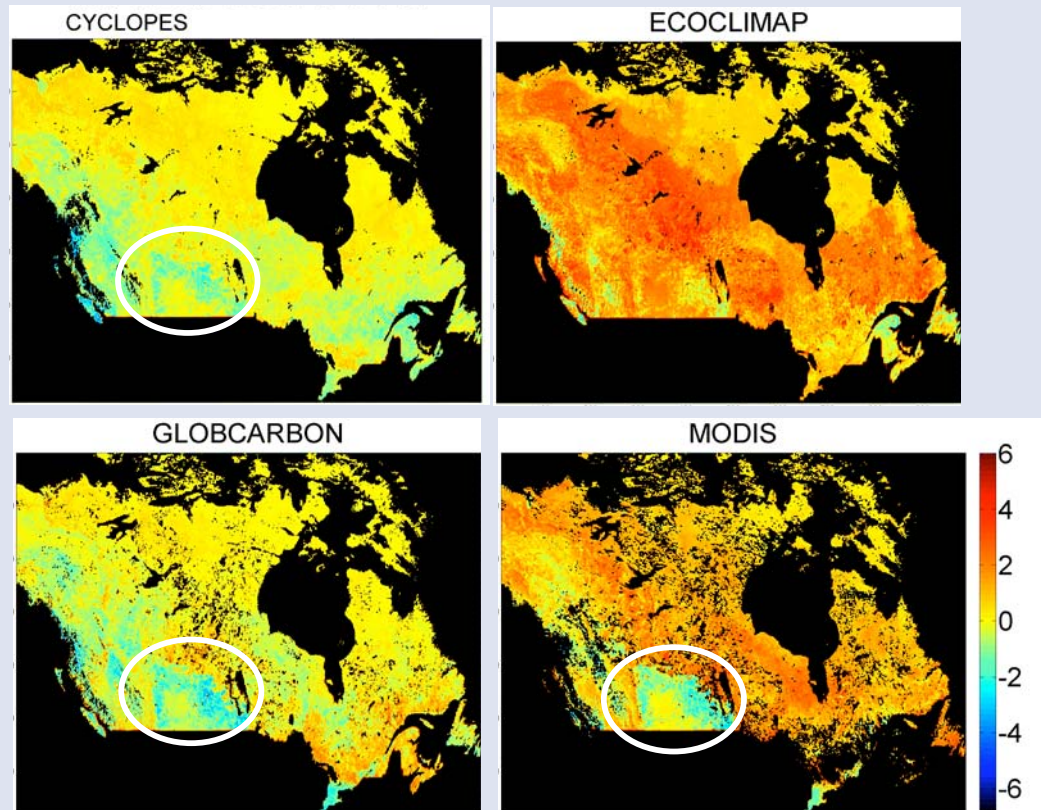
40 sites and 80 LAI HR maps available so far.
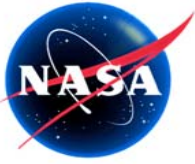
Transect over Africa (25° est)
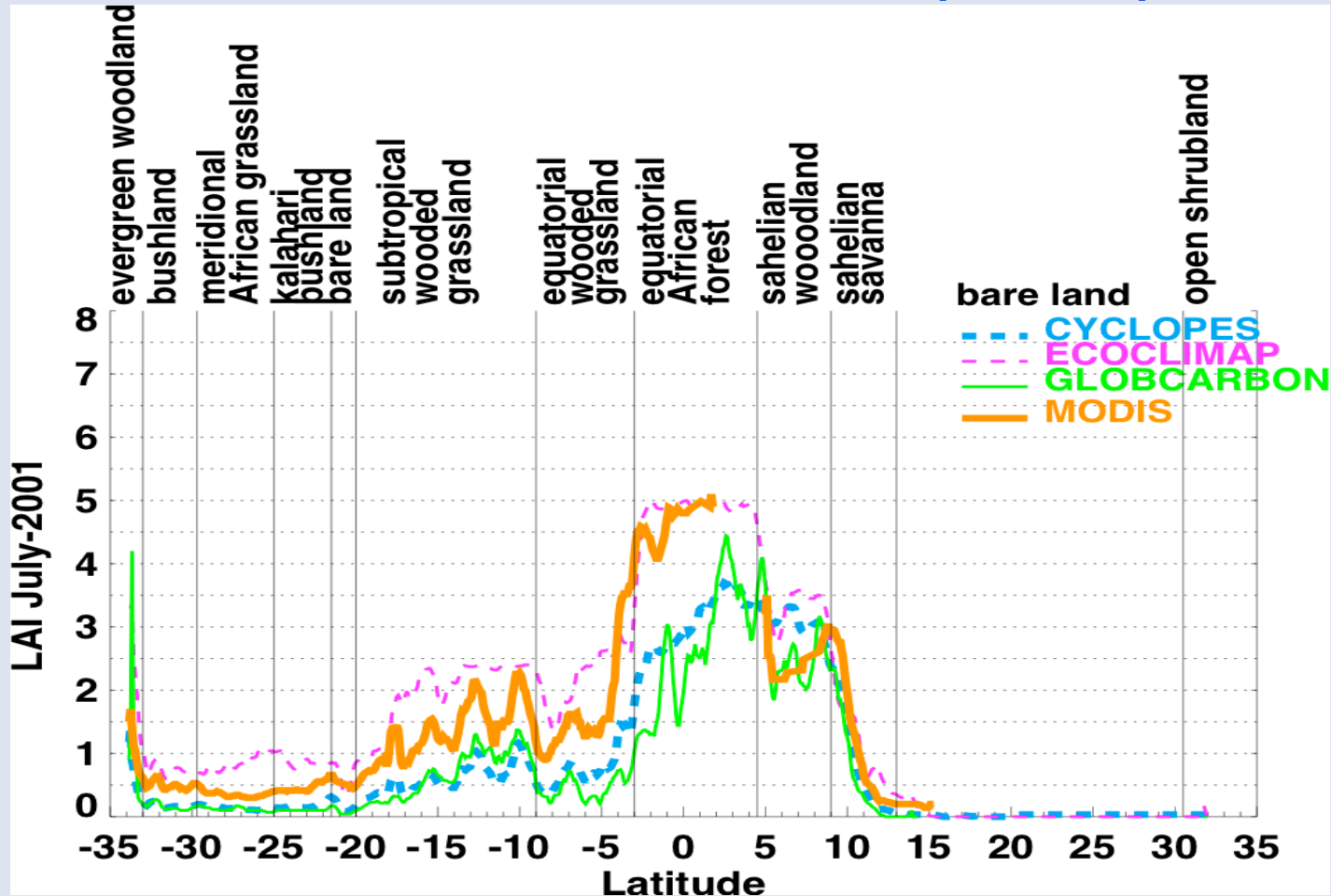
- **Best spatial continuity** for ECOCLIMAP and GLOBCARBON
- **Two groups of products**:
  – GLOBCARBON and CYCLOPES : good agreement over grassland
  – ECOCLIMAP and MODIS: higher and more reaslistic values over Equatorial forest
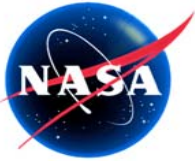
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Regional consistency
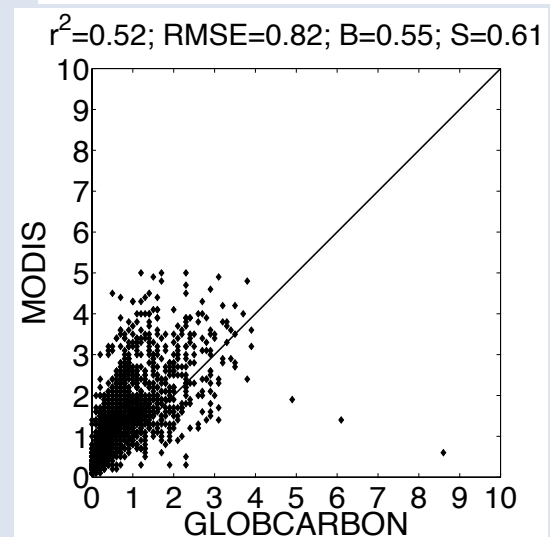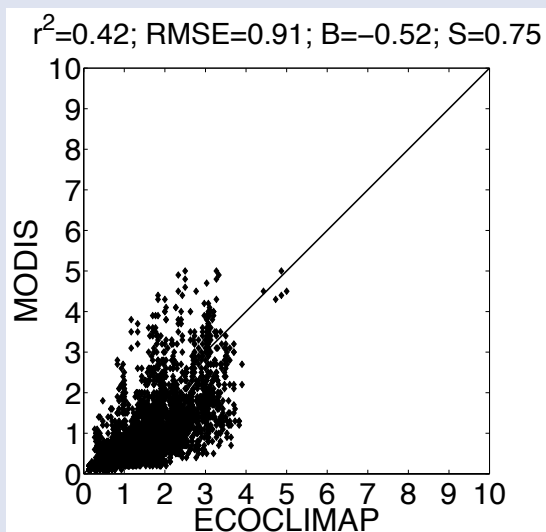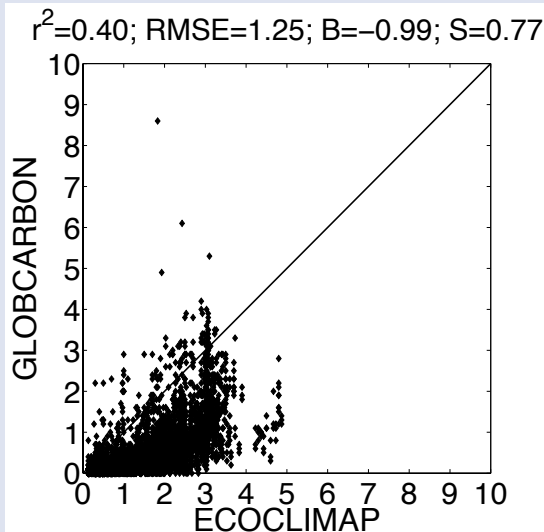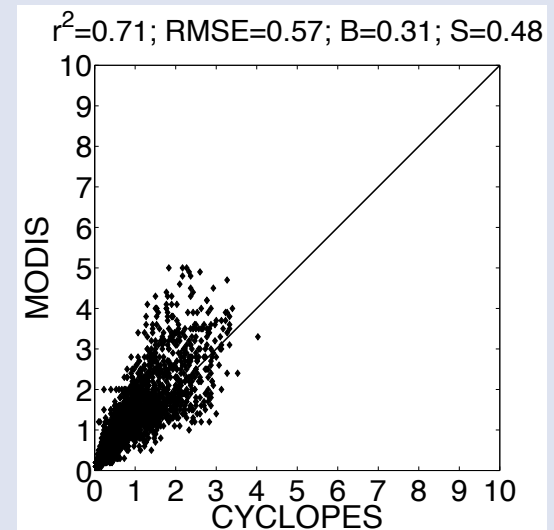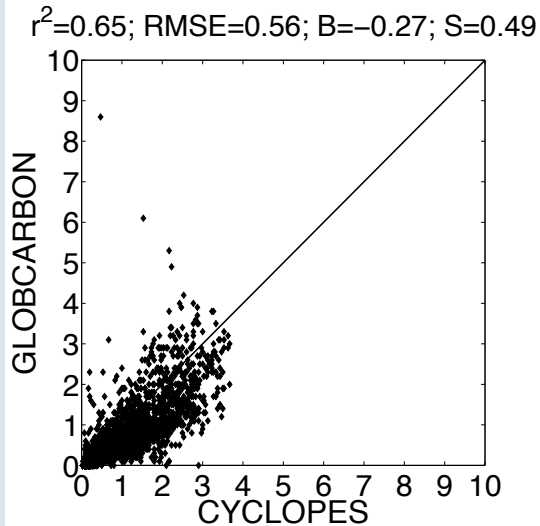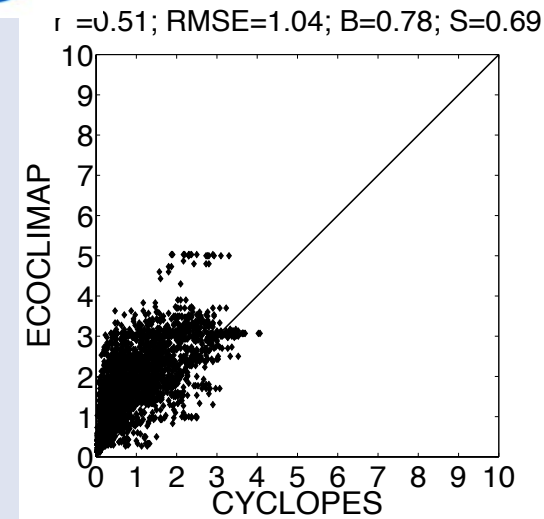# Comparison with CCRS map over Canada

CCRS product considered as a regional reference over Canada

- – 1km, 10-days resolution
- – VI-LAI empirical relationships
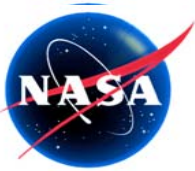- – Shoot & canopy clumping

Global products have difficulties to capture specific spatial patterns that are better depicted by regional algorithms
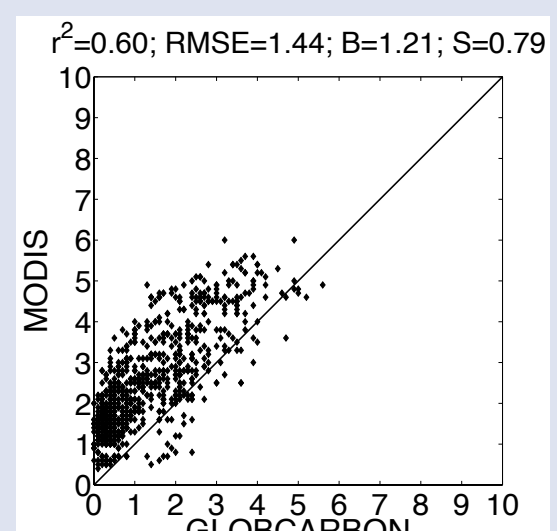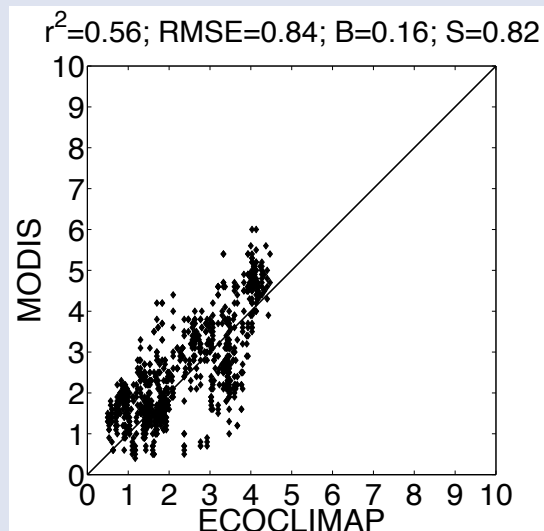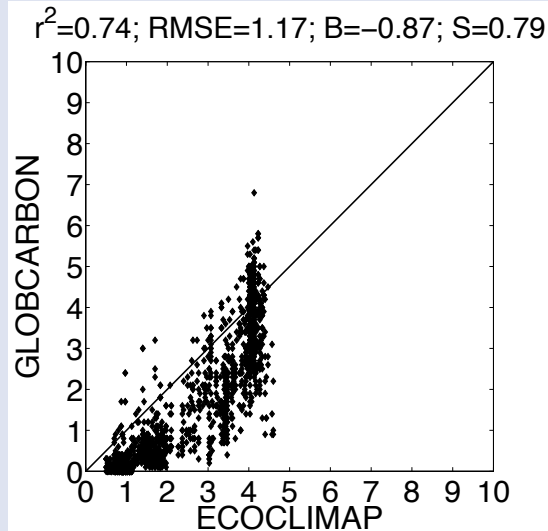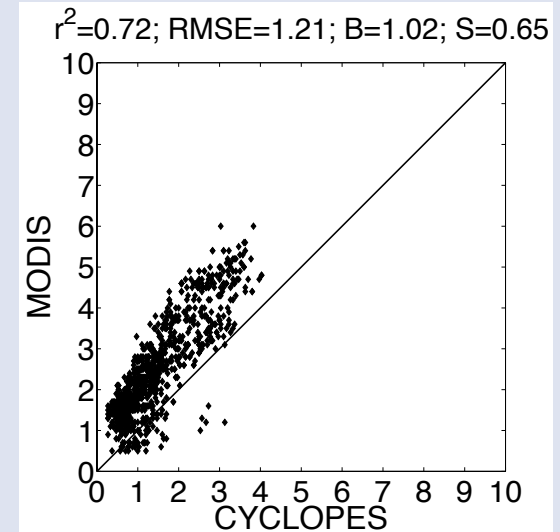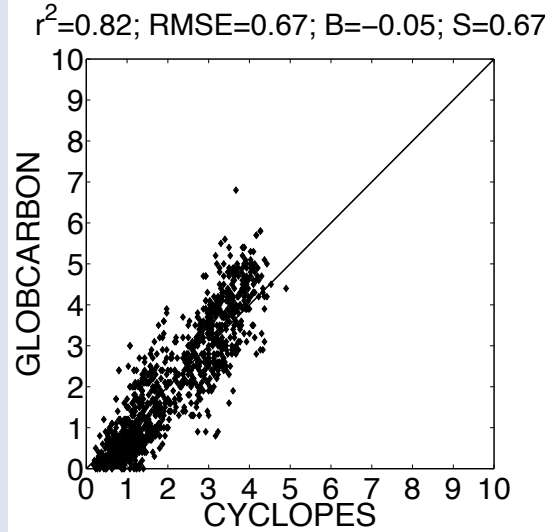
Scatter plot over the BELMANIP sites-Grasslands

- large bias between ECOCLIMAP and others for all land covers
- Good agreement between CYCLOPES, MODIS and GLOBCARBON
- MODIS >CYCLOPES >GLOBCARBON

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Scatter plot over the BELMANIP sites-DBF

r^2=0.70; RMSE=1.03; B=0.77; S=0.69

r^2=0.82; RMSE=0.67; B=−0.05; S=0.67

r^2=0.72; RMSE=1.21; B=1.02; S=0.65

r^2=0.74; RMSE=1.17; B=−0.87; S=0.79

r^2=0.56; RMSE=0.84; B=0.16; S=0.82

r^2=0.60; RMSE=1.44; B=1.21; S=0.79
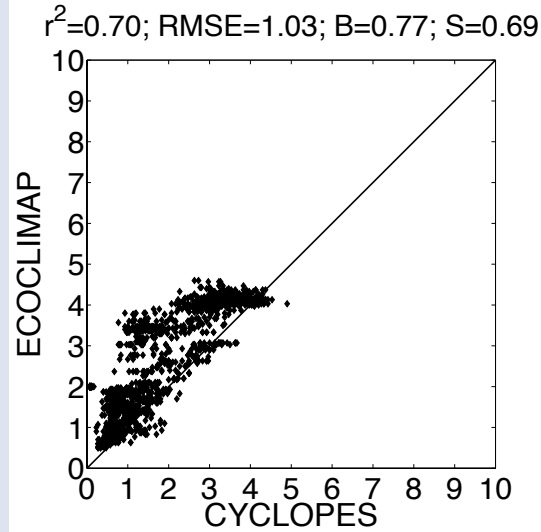
-Good agreement between GLOBCARBON and CYCLOPES

Temporal consistency

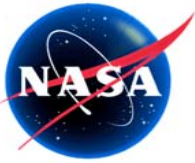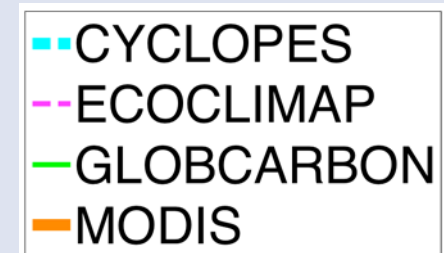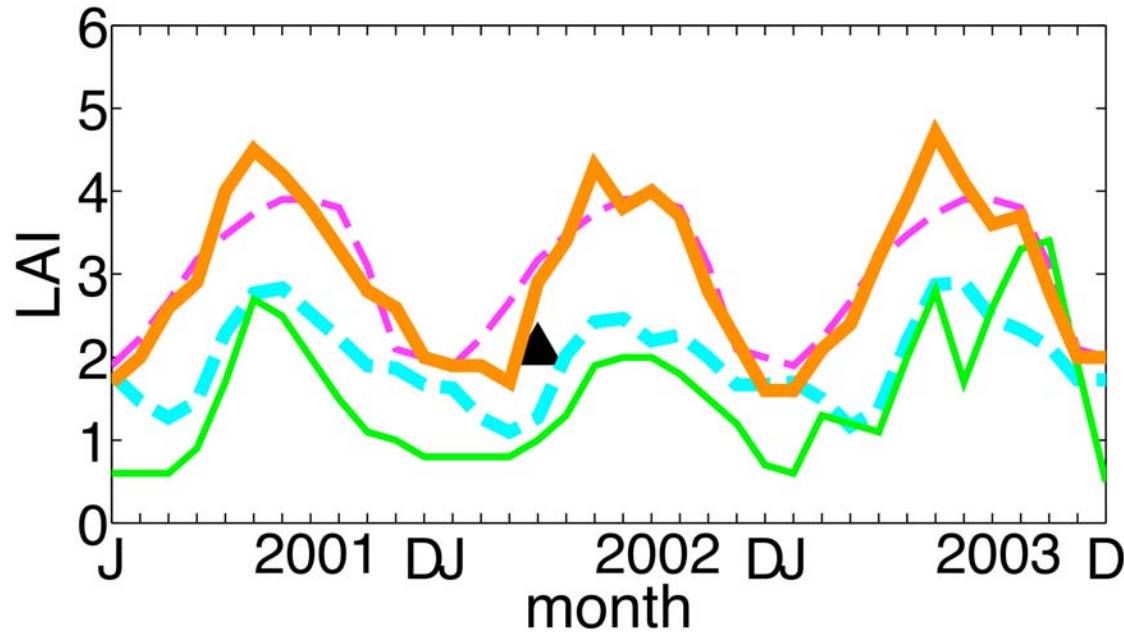**Ever. Needle. For**

Nezer, France, Lat=44.57, Lon=−1.05

Legend:
- CYCLOPES
- ECOCLIMAP
- GLOBCARBON
- MODIS

■ **Ground data**
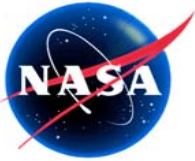
Summary or product performances

Criteria	CYCLOPES	ECOCLIMAP	GLOBCARBON	MODIS
LAI distribution	Max too low over EF	Too much round values	Max too high at 10km resolution	Too few low values
Continuity	Gaps	**No gaps**	Gaps in spite of gap filling process	Gaps
Spatial consistency	**OK**	No intra-class variations	Shaky profiles	**OK**
Temporal consistency	Good seasonal trends Good inter-annual variability	Good seasonal trend No inter-annual variability	Good seasonal trend Spurious variations over forests	Too high values in winter and over sparse vegetation Good inter-annual variability
Comparison to in-situ data	Closest to HR maps	Largest differences with HR maps		Overestimation over forests