Evaluation of MODIS, VIIRS and Landsat albedos at BSRN sites: Development of CEOS/WGCV/LPV albedo ECV protocols

Crystal Schaaf, Zhuosen Wang, Yan Liu, Angela Erb,
Jihyun Kim, Xiaoyuan Yang, Qingsong Sun, Miguel Román

University of Massachusetts Boston

NASA/GSFC

Boston University

And the numerous colleagues who contribute to the development and validation of satellite derived products

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http://www.wmo.int/pages/prog/gcos/Publications/gcos-154.pdf

ECV Albedo (Page 70)

Some albedo measurements (analogous to blue sky values) are acquired *in situ*, for instance, with pyranometers that integrate the incoming radiation reaching the sensor from an entire hemisphere. The coupling of two such instruments back-to-back to measure simultaneously the irradiance from the sky and the reflectance from the surface is the concept of so-called 'albedometers'. Those are deployed to WMO standards on stationary towers as part of the BSRN. Primarily broadband instruments have been deployed although a limited number of spectral measurements do now exist. The footprint characterized by these sensors is driven by the height of the tower above the surface; therefore the applicability of these measurements to satellite derived quantities is governed by the height of the *in situ* instrument above the top of canopy and representativeness of this footprint to the usually larger remotely sensed footprint. While the BSRN tower sites currently provide some of the highest-quality measurements available for radiation at the surface, they are spatially limited and the network needs to be expanded and adequately supported to achieve better representative global coverage.

Immediate action, partnerships and international coordination (Page 74)

Financial support is required to permit intercomparisons and benchmarking of albedo-type products on a continuing basis, including for field campaigns and partial contributions to established networks, such as BSRN and AERONET;

THIS LANGUAGE HAS BEEN RETAINED IN THE CURRENT VERSION UNDER REVISION (I PROVIDED COMMENTS TO THE TEMPLATE IN MAY 2014)

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	• Changes in albedo can be used to assess the extent of burnt areas
Contributing observing networks, systems or approaches	From IP-10 *Please update* **Contributing Network(s)** / **Status** / **Contributing Satellite Data** / **Status** CEOS WGCV; MODLAND; Atmospheric Radiation Measurement sites; / No designated reference network. / Multi-angular sensors. Geostationary Polar orbiters. GCMPs applied to measurements. / Use of operational meteorological satellites (SCOPE-CM Pilot Project) and moderate-resolution optical polar-orbiters. Continuation of multi-angular missions required
Links and references to observational methods and standards	*This could, for example, be to WMO Manuals and Guides, or to the proposed EOV specifications of observation deployment and maintenance for the ocean ECVs. This need not include generally applicable guidance such as the GCOS Climate Monitoring Principles and Dataset Guidelines. If material is judged to be in need of updating (as has been indicated for the GTOS Terrestrial ECV Reports) this should be noted.*
Requirements for spatial and temporal scale, accuracy/uncertainty and stability	*This could be done by reference (to OSCAR database if entry is up-to-date, to proposed EOV specifications, to entries in Satellite Supplement reproduced below), but should otherwise be discussed more explicitly. Any distinctions between requirements for observations and for data products should be noted.*
Arrangements for observational monitoring	*List what, if anything, is in place or needed for routinely checking functioning of observing system.*
Changes in observation	*List recent and planned future changes to observing networks, systems and methods. Discuss perceived threats.*
Observational performance	*Should build on immediately preceding entries, and give quantitative information on performance: spatial and temporal coverage, accuracy and stability (i.e. quality as well as quantity), where possible. Provision of graphs or tables (or pointers to where the underlying data can be found) is needed here (or under item*

Crystal Schaaf May 18, 2014
We have repeatedly stated that BSRN is the gold standard of albedo measurements and should be the designated network.

Crystal Schaaf
Fluxnet towers as well.

Crystal Schaaf
The standards laid out by BSRN in (McArthur, 2005; WMO, 2008) continue to be the best references – CEOS/WGCV/LPV is preparing a best practices document for using tower albedo and aircraft multiangle data to evaluate satellite albedo estimates.

- Schaaf, C.B., J. Cihlar, A. Belward, E. Dutton, and M. Verstraete, Albedo and Reflectance Anisotropy, ECV-T8: GTOS Assessment of the status of the development of standards for the Terrestrial Essential Climate Variables, ed., R. Sessa, FAO, Rome, May 2009.

McArthur, L.J.B., BS RN Operations Manual V2.1, WCRP 121, WMO/TD-No. 1274, April 2005, www.wmo.ch/pages/prog/wcrp/PG_Reports_WCRPS eries.html, *www.bsrn.awi.de/fileadmin/user_upload/Home/Publications/McArthur.pdf*.

WMO. 2008: World Meteorological Organization Commission for Instruments and Methods of Observation (WMO/CIMO) Guide to Meteorological Instruments and Methods of Observation. Preliminary seventh edition. Report WMO-No. 8, Geneva, Switzerland. *www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/Draft-7-edition.html*, *www.wmo.ch/pages/prog/www/IMOP/publications/WMO-8-Guide-contents.html*.

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Satellite Albedo Products

- Committee on Earth Observation Satellite (CEOS) Working Group on Cal/Val (WGCV) Land Product Validation (LPV) http://lpvs.gsfc.nasa.gov/
  - LPV leads: Gabriela Schaepman (University of Zurich), Miguel Román (NASA/GSFC)
- Subgroup on Albedo http://lpvs.gsfc.nasa.gov/srad_home.html
  - Subgroup leads: Crystal Schaaf (University of Massachusetts Boston); Xavier Ceamanos (Météo-France)
  - Encourage satellite product intercomparisons
    - Occasional workshops and special sessions
  - Develop LPV Evaluation Protocol (Zhuosen Wang)
- Assessments with *in situ* data
  - BSRN (gold standard)
  - Flux towers (Fluxnet)
  - LTER, NEON (US), TERN (Australia)
- Airborne campaigns
  - NASA CAR, NEON AOP, NASA GLiHT etc.

Satellite Albedo Product Accuracy/Uncertainty (Generally 5-10%)

- MODIS Global (5%-10%)
  - Cescatti et al., 2012, Román et al., 2009; 2011; 2013, Wang et al., 2012; 2014
- VIIRS global
  - Justice, Román et al., 2013
- MISR global
  - Pinty et. al., 2010; Taberner et al., 2010
- GLOBAlbedo global
  - Muller et al., 2012
- CERES global surface
  - Rutan et al., 2009
- POLDER-3/Parasol global
  - Maignan et al., 2004, Hautecoeur and Roujean, 2004
- LSA-SAF MSG/SEVIRI Regional
  - Carrer et al., 2010
- Geoland-2 g local (SPOT/VGT)
  - Camacho et al., 2012
- SCOPE-CM fusion of GEO albedos
  - Lattanzio et al., 2013
- GLASS (global)
  - Liang and Liu, 2012
- Landsat
  - Shuai et al., 2011; Román et al., 2013

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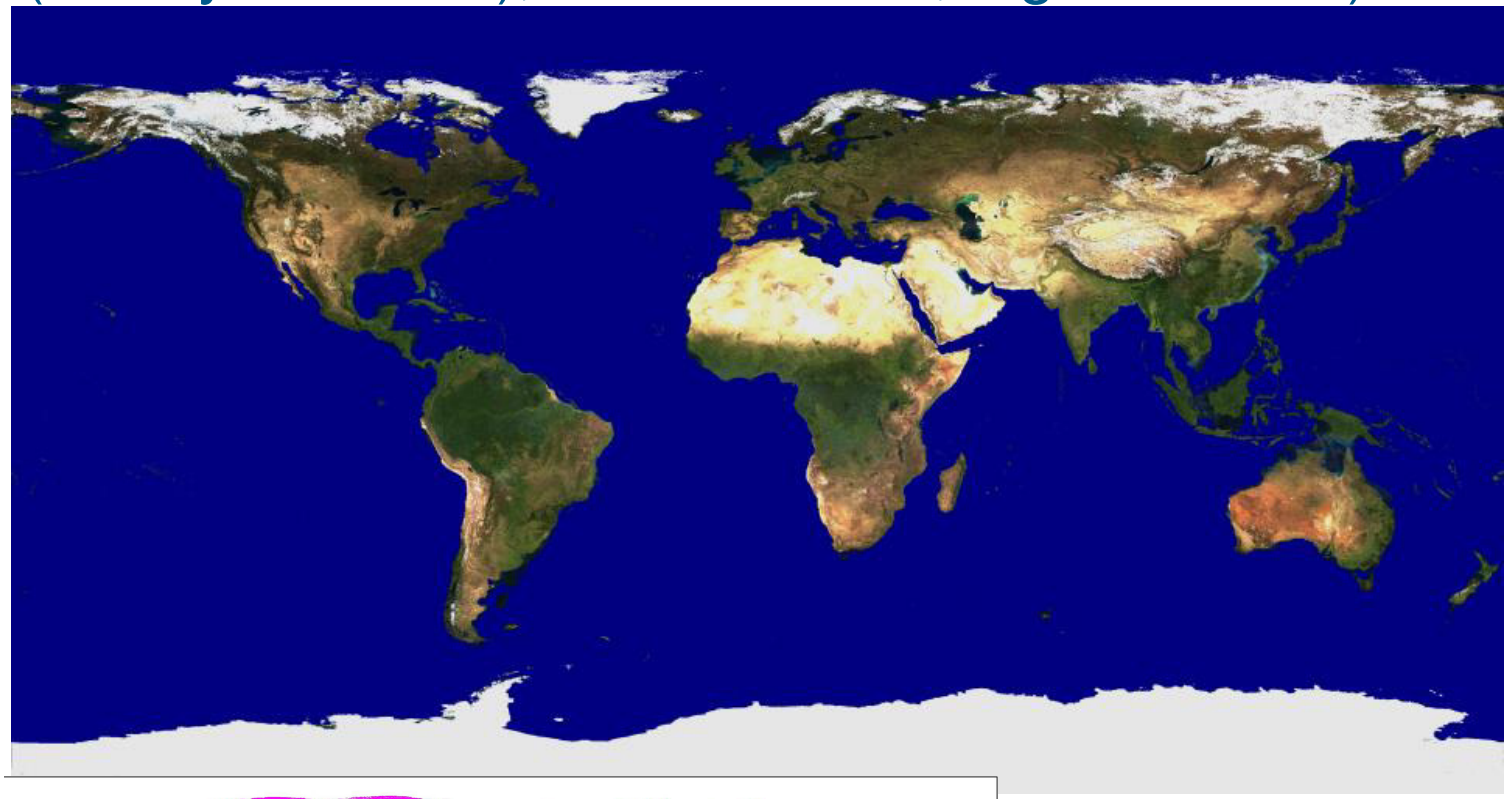
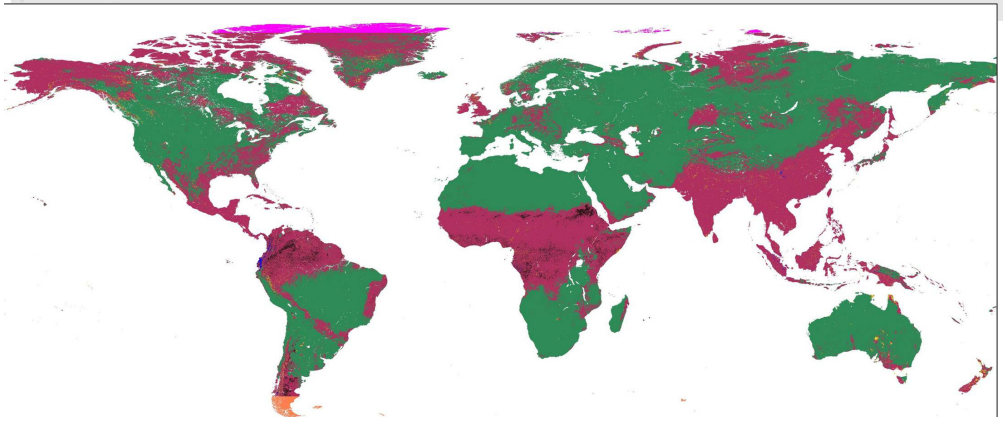
Areas of difficulty for validation of satellite products (high terrain, ephemeral snow, snow variations, ice (mostly not done), coastal areas, high latitudes)





MODIS Day 193, 289 2010
Gapfilled, snow added

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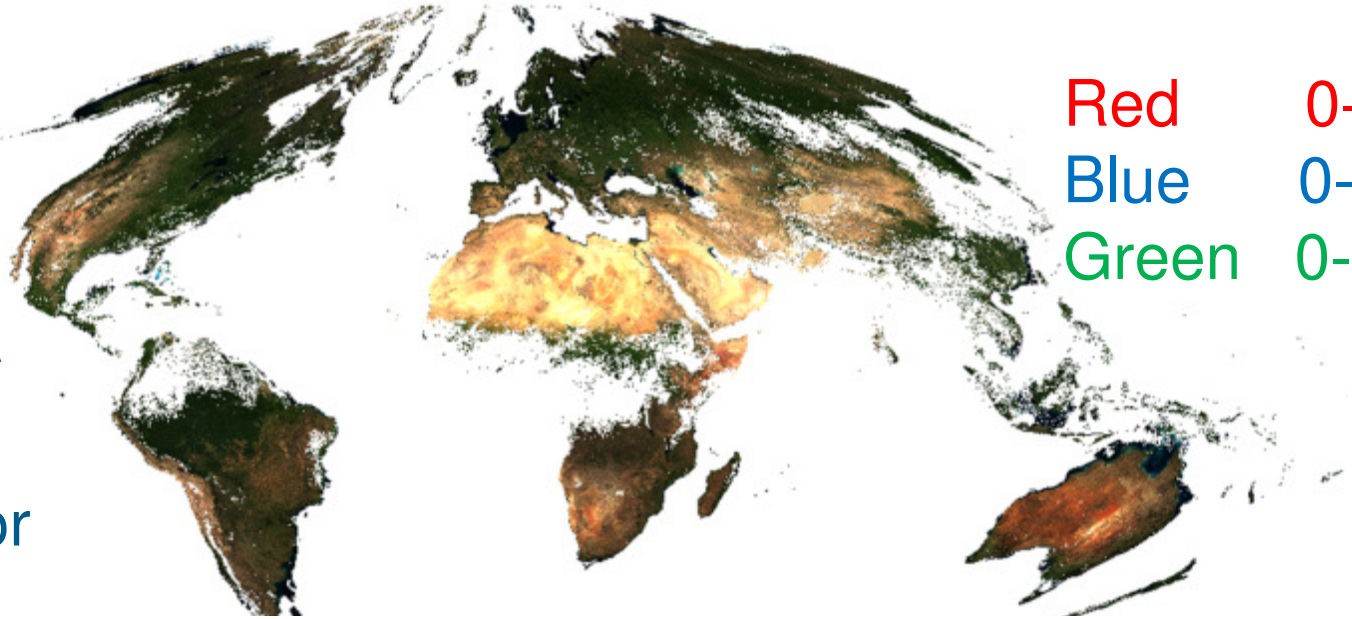
Validation Protocol for Moderate Resolution Satellite Albedo Products (Zhuosen Wang (NASA/GSFC) POSTER P26)

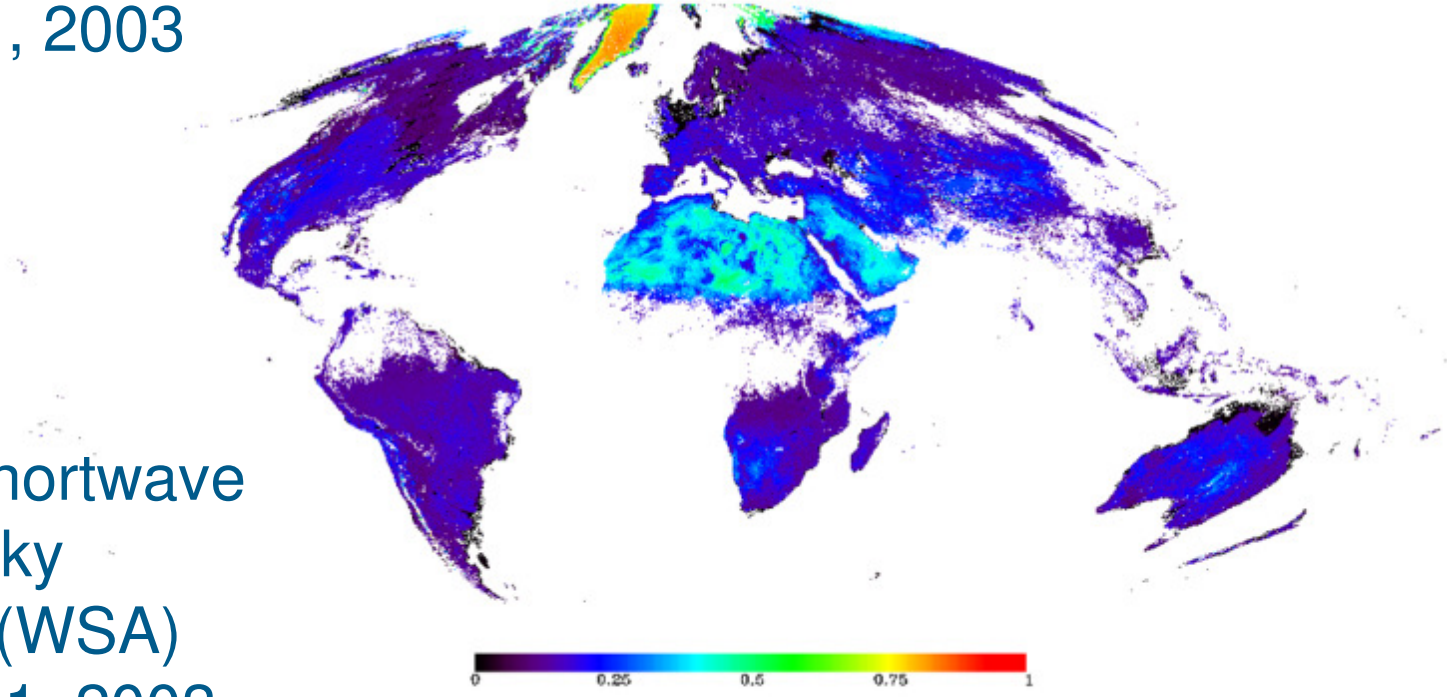
- First use higher resolution satellite (or airborne) imagery to evaluate the spatial representativeness of a site with respect to moderate resolution satellite pixels/FOVs.
- If a site is not spatially representative for albedo product validation, this does not in ANY WAY imply that the site is not ideal for radiation or flux studies etc. – only that the surrounding landscape is sufficiently varied that the tower albedo footprint does not adequately capture the larger satellite pixel/FOV
- After ascertaining that the site is spatially representative, then AOD can be used to generate satellite derived blue sky albedos and comparisons can be made with the tower albedo values.

MODIS Daily
Albedo
BRDF NBAR
V006 MCD43A



Red 0-0.3
Blue 0-0.3
Green 0-0.3

V006 True color
NBAR
DOY 201, 2003



V006 Shortwave
White Sky
Albedo (WSA)
DOY 201, 2003

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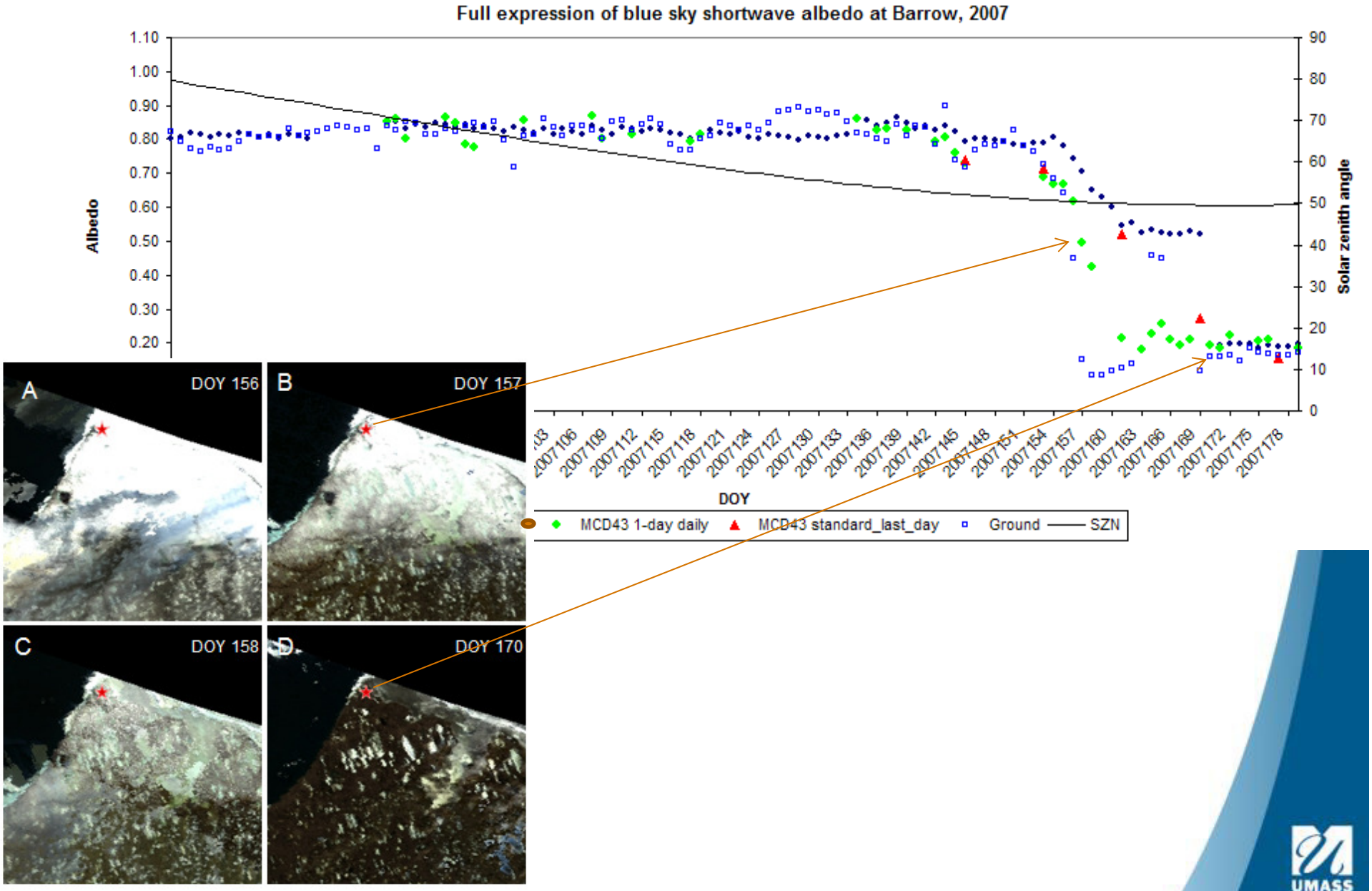
MODIS Daily BRDF/Albedo Barrow



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Suomi NPP VIIRS vs MODIS Daily V006

Suomi NPP VIIRS

MODIS V006

True color BSA of tile H12V04 of New England and southeastern Canada, Sept 2013

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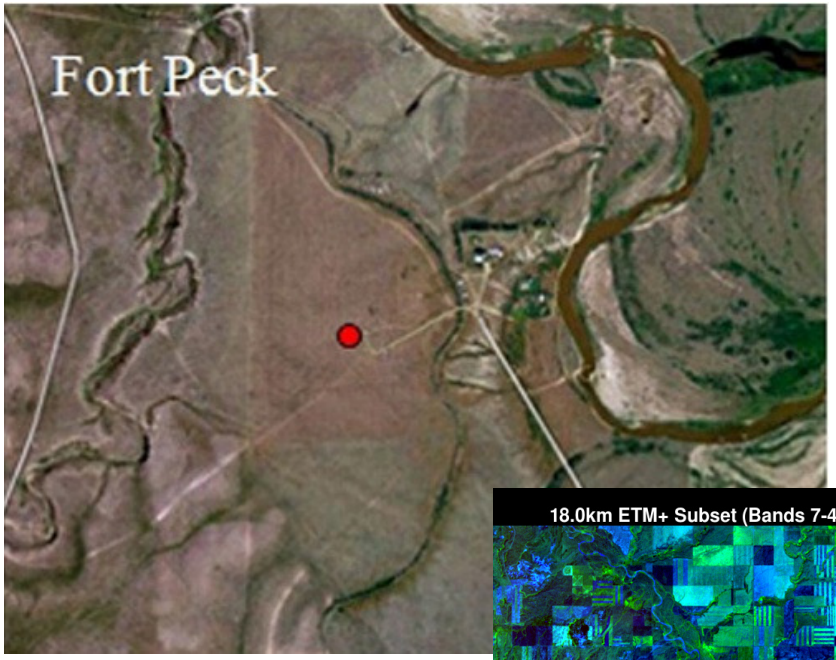
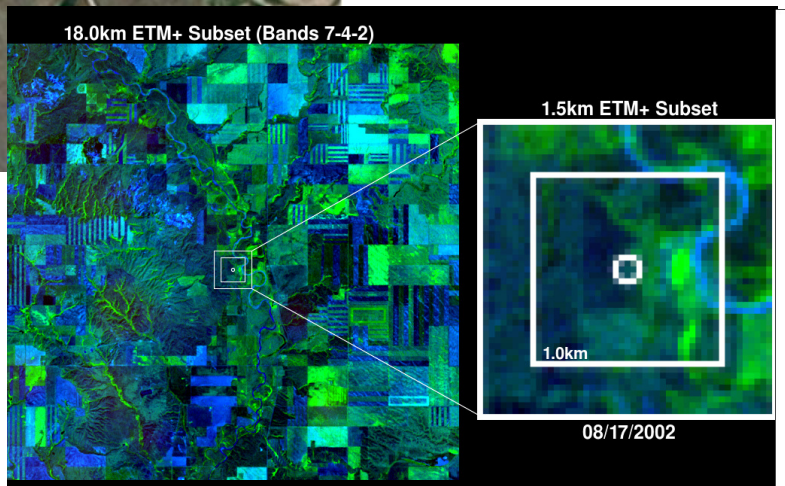
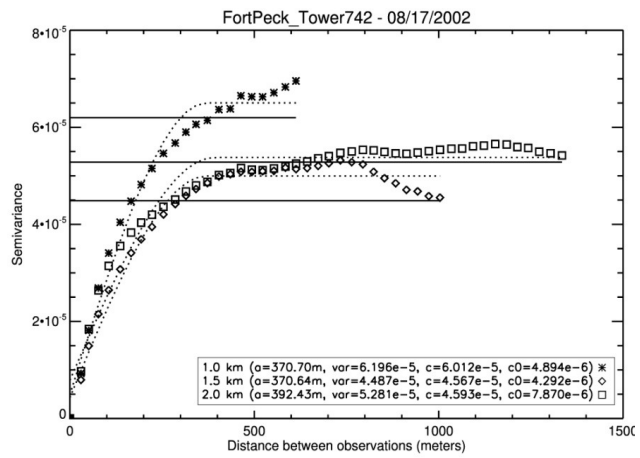
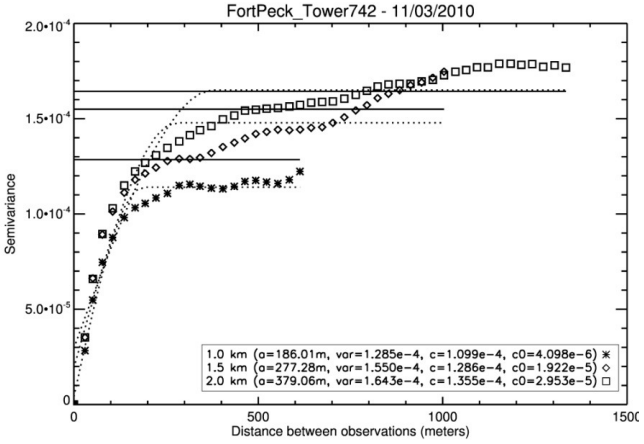
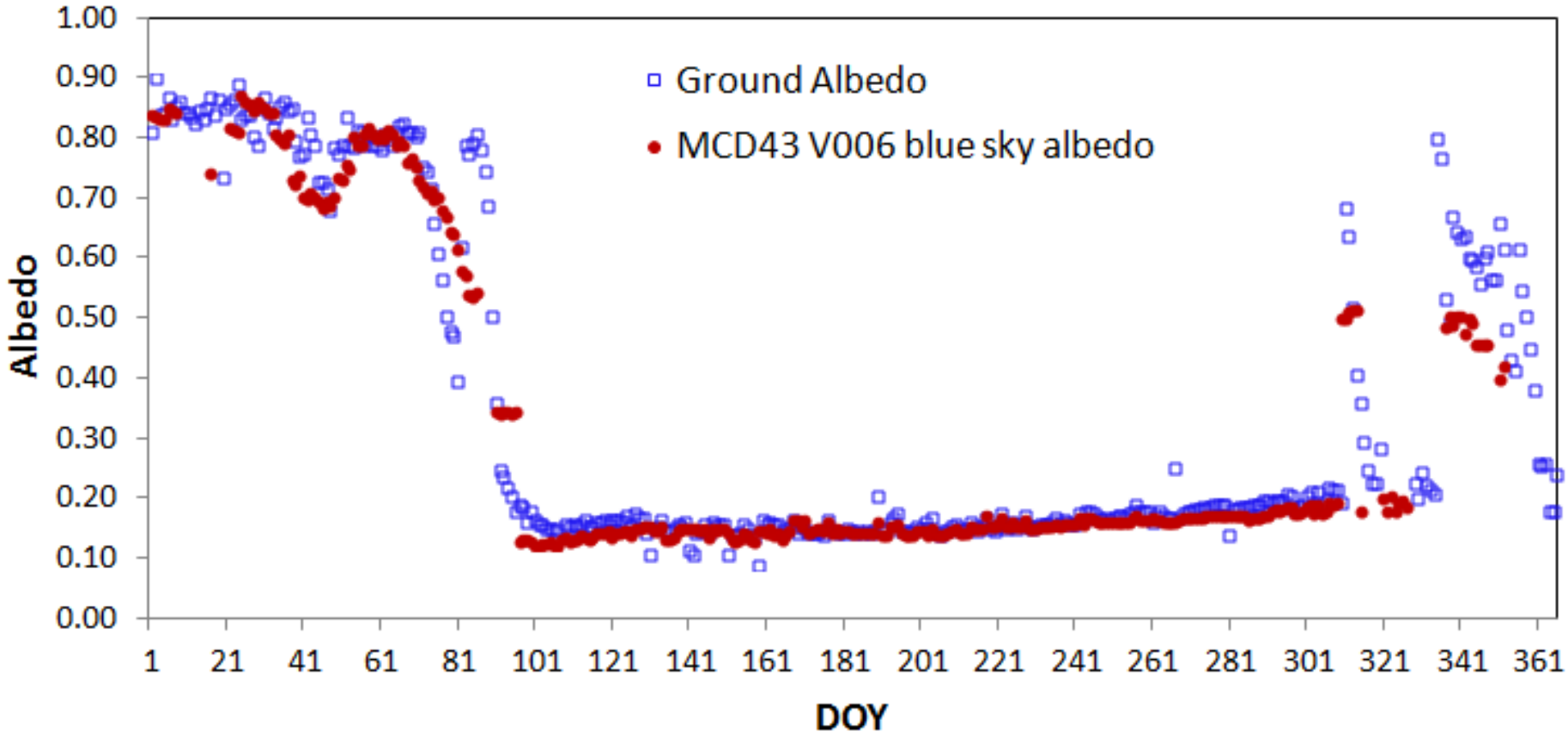
Fort Peck MT


Fort Peck


18.0km ETM+ Subset (Bands 7-4-2)
1.5km ETM+ Subset
1.0km
08/17/2002
18.0km TM Subset (Bands 7-4-2)
1.5km TM Subset
1.0km
11/03/2010


FortPeck_Tower742 - 08/17/2002
Semivariance
Distance between observations (meters)
1.0 km (a=370.70m, vor=6.196e-5, c=6.012e-5, c0=4.894e-6)
1.5 km (a=370.64m, vor=4.487e-5, c=4.567e-5, c0=4.292e-6)
2.0 km (a=392.43m, vor=5.281e-5, c=4.593e-5, c0=7.870e-6)


FortPeck_Tower742 - 11/03/2010
Semivariance
Distance between observations (meters)
1.0 km (a=186.01m, vor=1.285e-4, c=1.099e-4, c0=4.098e-6)
1.5 km (a=277.28m, vor=1.550e-4, c=1.286e-4, c0=1.922e-5)
2.0 km (a=379.06m, vor=1.643e-4, c=1.355e-4, c0=2.953e-5)



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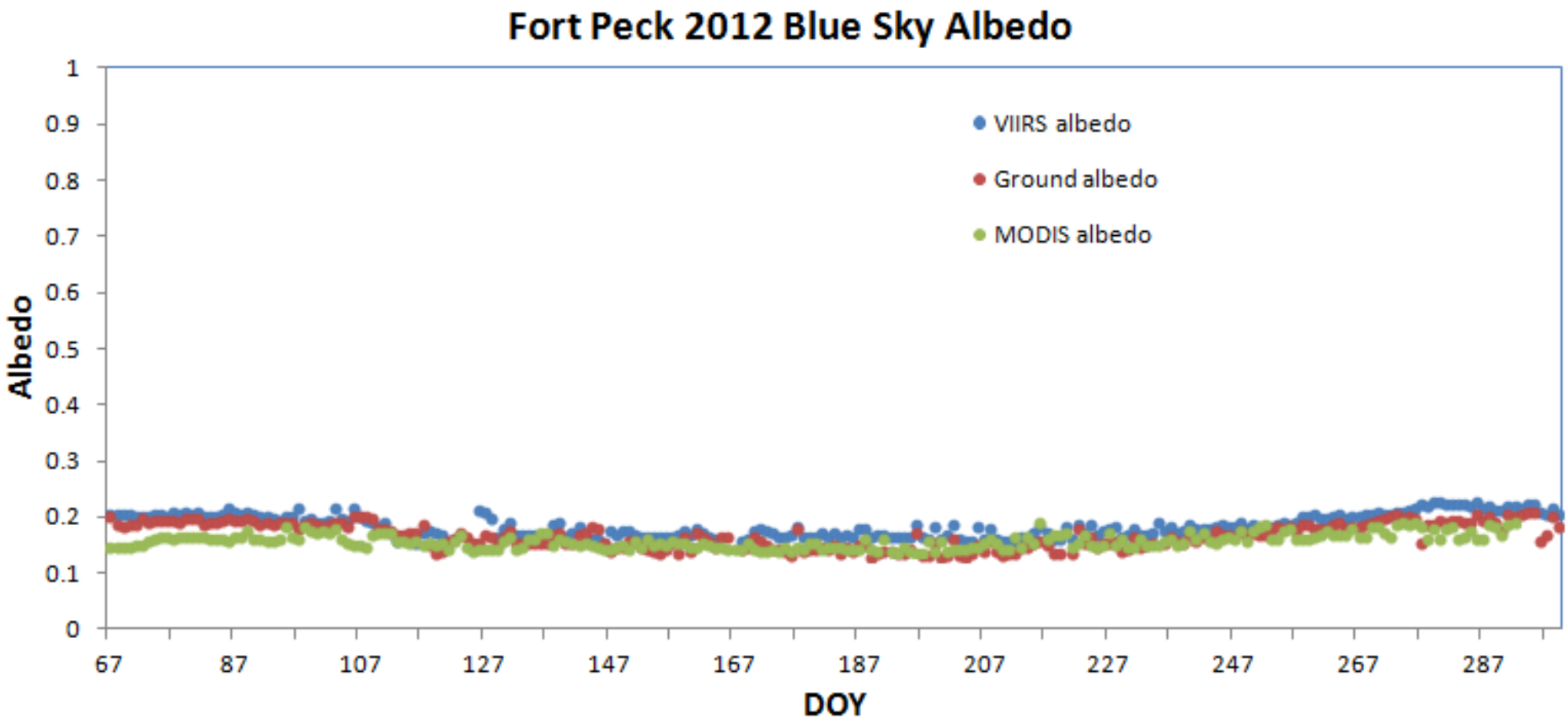

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Geostatistical Tables

Growing Season

Rank	ID	Name	Surface Type	Rcv	Rse	Rsv	Rst	STscore
1	E13	S. Great Plains	Grass	0.003	0.014	0.384	-0.190	4.843
2	PSU	Rock Spring	Cultivated	0.043	0.387	0.119	-0.245	1.912
3	FPE	Fort Peck	Grass	-0.085	0.718	-0.055	-0.137	1.235
4	GCR	Goodwin Creek	Grass	-0.051	0.663	-0.391	0.322	1.089
5	BOS	Boulder (TM)	Grass	-0.020	0.803	0.480	-0.403	0.906
6	SXF	Sioux Falls	Grass	0.147	0.999	1.285	-0.271	0.638
7	BON	Bondville	Grass/Agriculture	0.144	0.733	1.584	0.512	0.676

Comparatively **more** representative sites

Comparatively **less** representative sites

Senescence

Rank	ID	Name	Surface Type	Rcv	Rse	Rsv	Rst	STscore
1	E13	S. Great Plains	Grass	0.323	0.024	1.342	-0.355	1.435
2	PSU	Rock Spring	Cultivated	0.258	0.505	0.466	-0.218	1.221
3	FPE	Fort Peck	Grass	-0.090	0.705	0.050	-0.229	1.207
4	SXF	Sioux Falls	Grass	0.097	0.726	-0.102	0.187	1.170
5	GCR	Goodwin Creek	Grass	-0.061	0.681	-0.363	0.232	1.112
6	BOS	Boulder (TM)	Grass	-0.108	0.787	0.510	-0.459	0.873
7	BON	Bondville	Grass/Agriculture	0.222	0.538	1.880	0.606	0.694

Rank	ID	Name	Surface Type	Date	Rcv	Rse	Rsv	Rst	STscore
1	BOU	Boulder (Tall tower)	Grass	12/09/2002	0.223	0.000	0.221	0.142	5.119
2	BAR	Barrow	Tundra	05/24/2002	0.074	0.022	0.297	-0.175	4.895
4	DRA	Desert Rock	Desert	09/21/2002	0.176	0.792	0.523	-0.187	0.920

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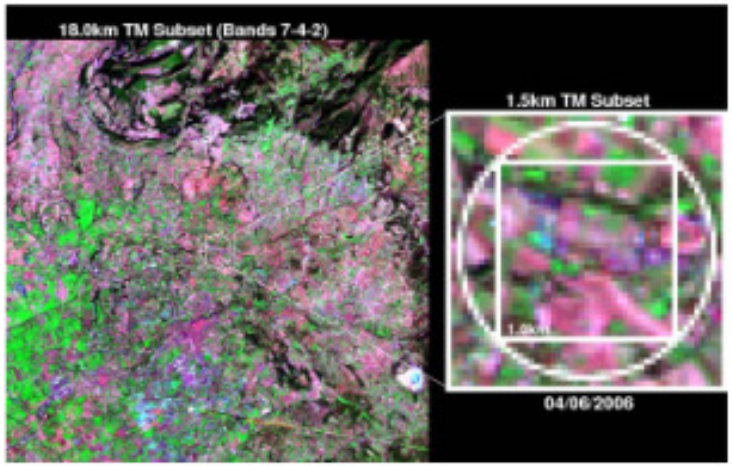
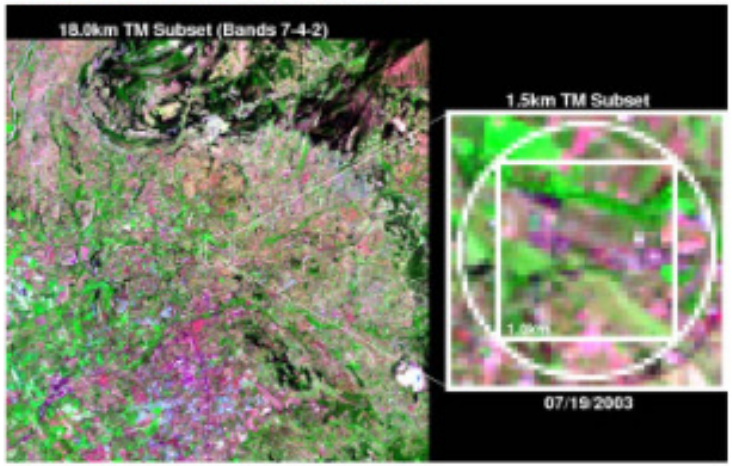
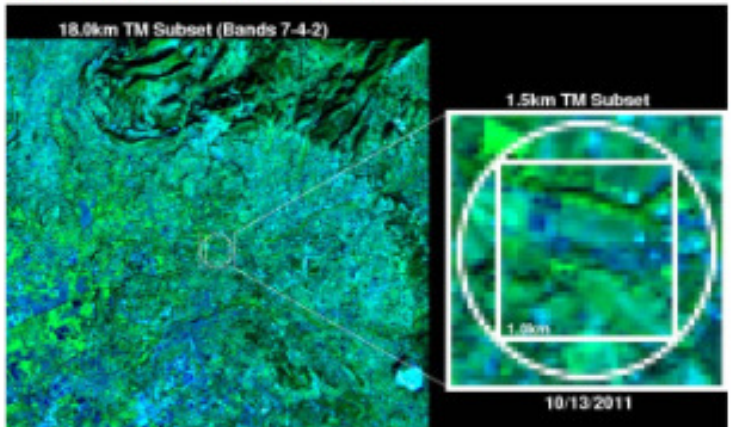
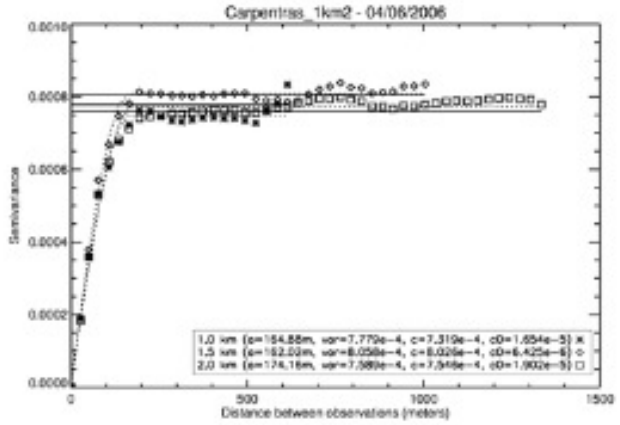
Recent Stations						
Cabauw	CAB	The Netherlands	51.9711	4.9267	Agricultural	Representative
Carpentras	CAR	France	44.083	5.059	Agricultural	Representative
Gobabeb	GOB	Namib Desert, Namibia	-23.5614	15.042	Arid	Less representative except at lowest resolutions
Payerne	PAY	Switzerland	46.815	6.944	Agricultural	Less representative except at larger resolutions
Toravere	TOR	Estonia	58.254	26.462	Agricultural	Less representative tower too short

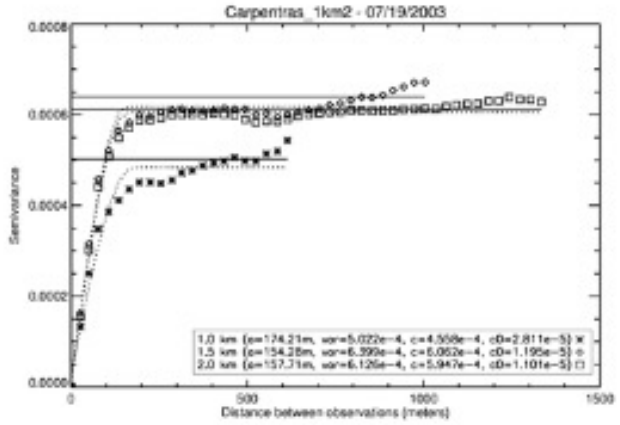
Carpentras, France

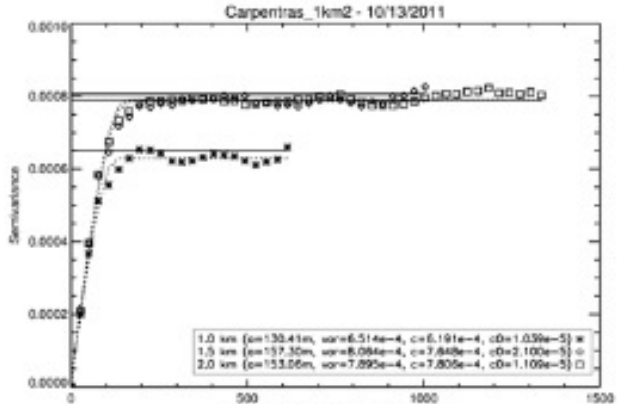




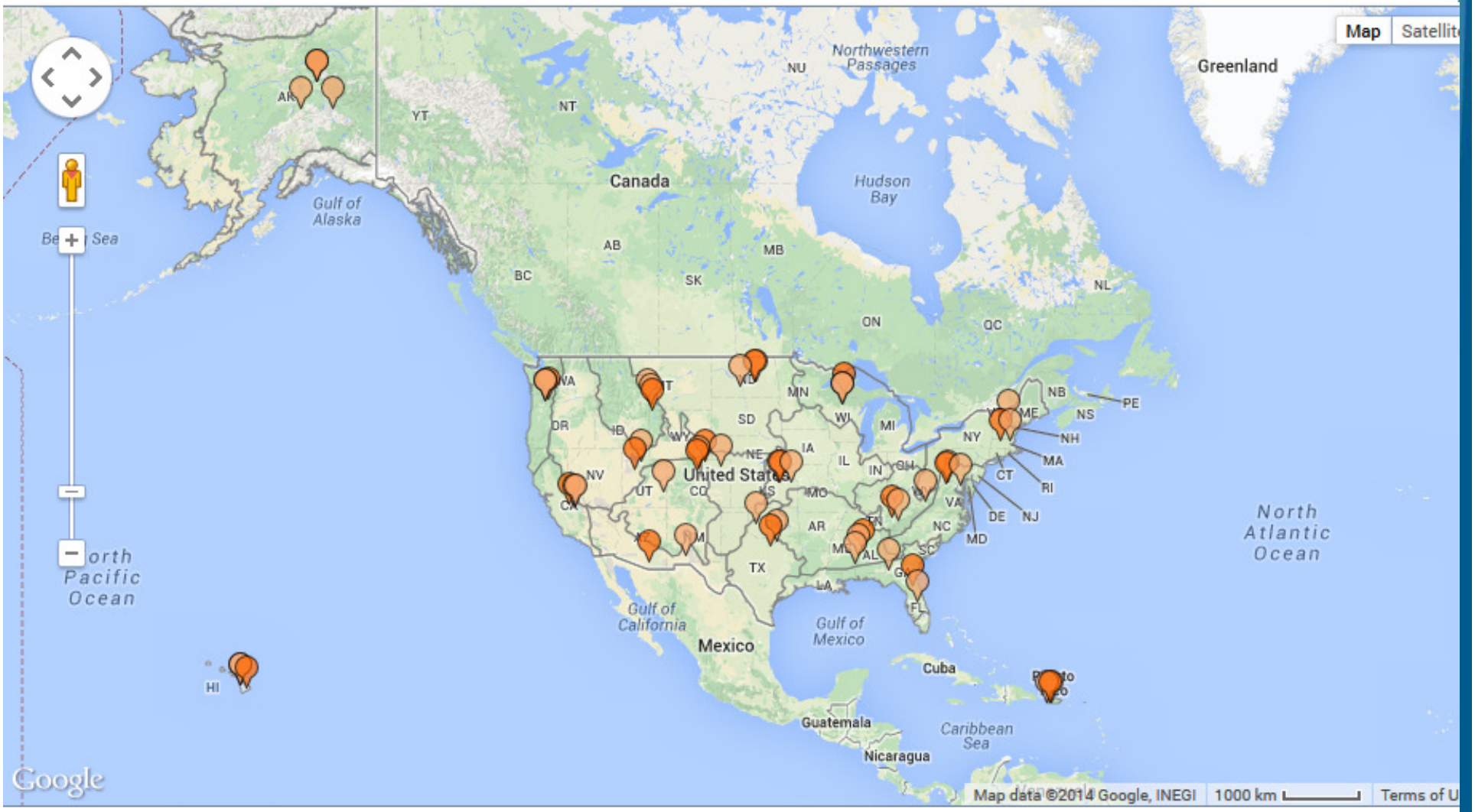








National Ecological Observatory Network (NEON)



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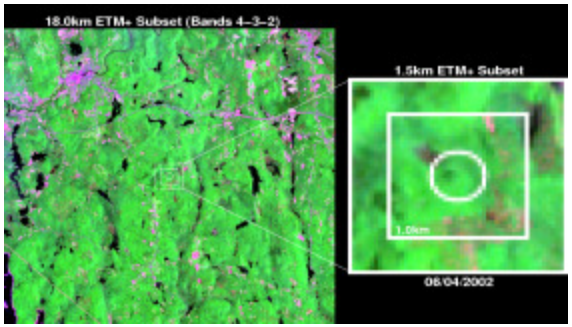
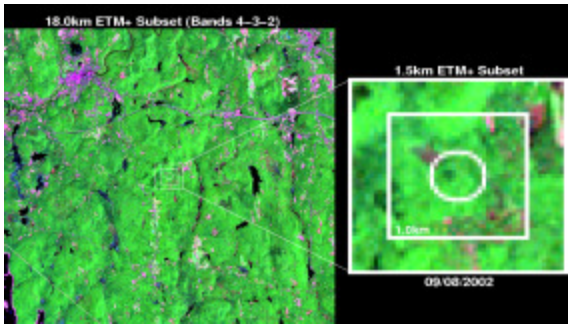
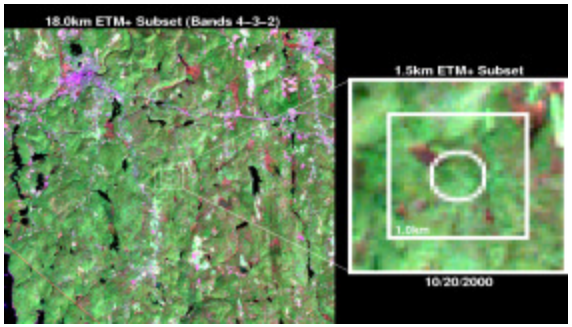
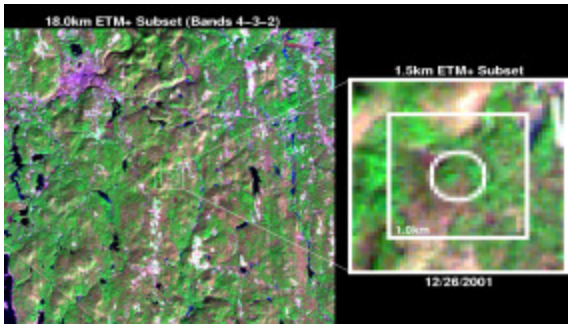
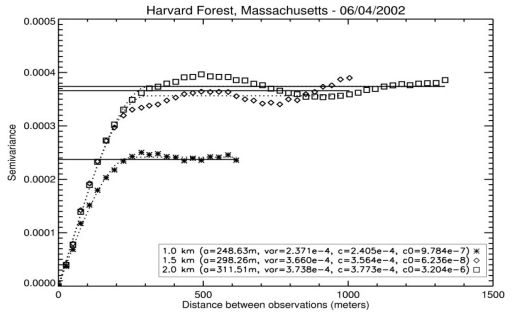
Spatial Representativeness Harvard Forest

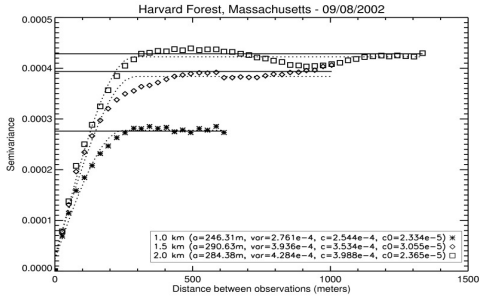


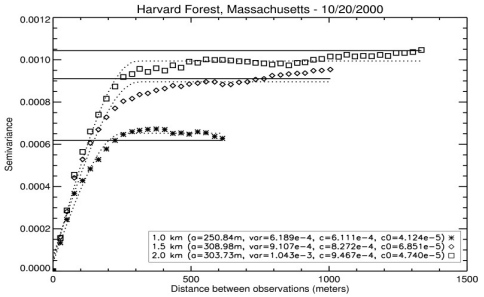


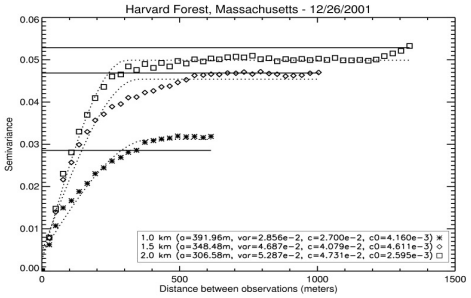












1. Photosynthetically Active Radiation Measurements in a profile on our towers and in our soil array
2. Cimel SunPhotometer (Aerosol Measurements) on top of most of our towers
3. SPN1 Sunshine Pyranometer on top of all our towers
4. CMP22 Direct & Diffuse Pyranometer on top of ~33% of our towers
5. NR01 Four Component Net Radiometer on top of every tower and in our soil array (for longwave)
6. Phenology Cameras on every tower

(Jeff Taylor, NEON)

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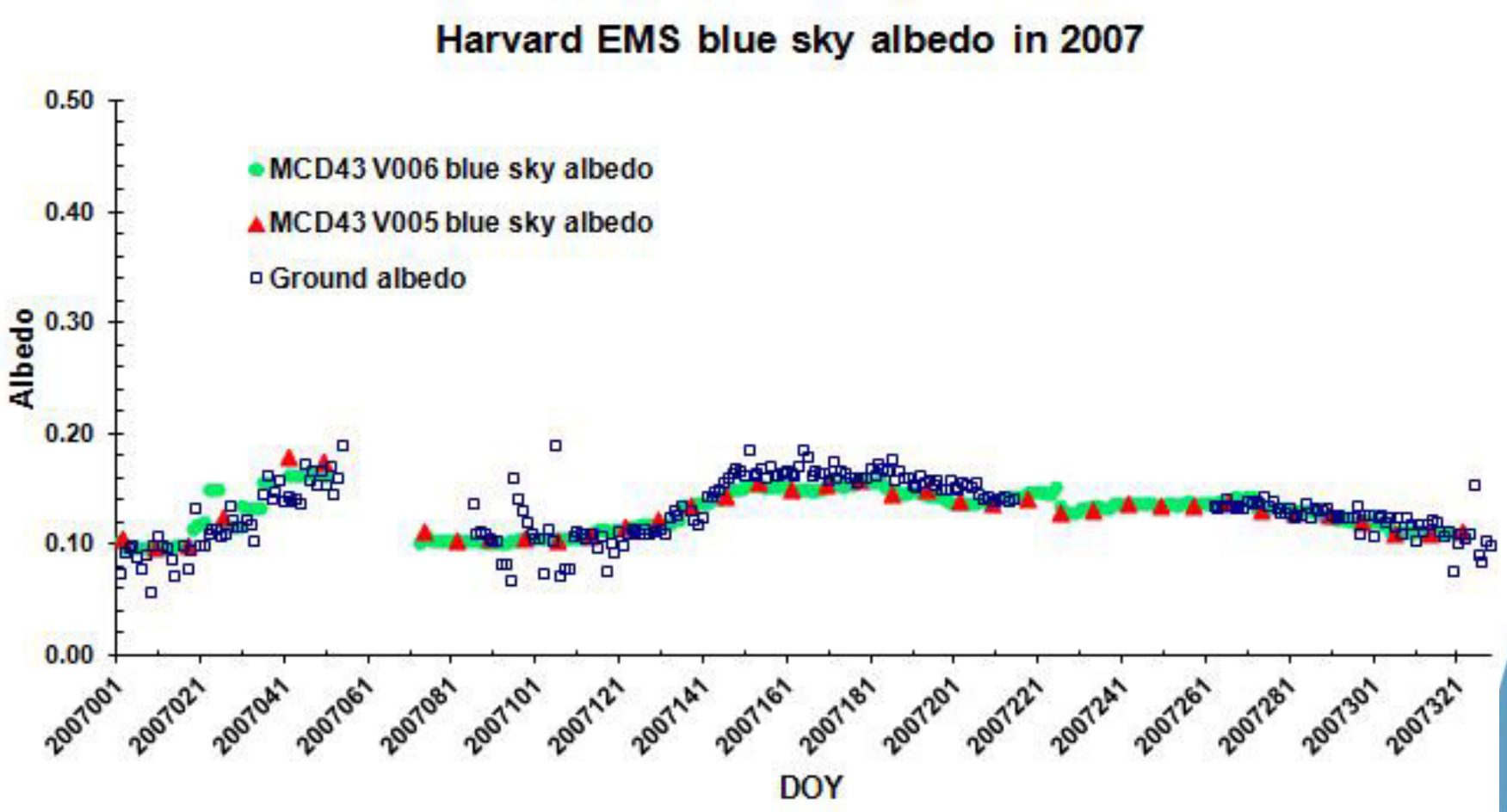
Satellite Products NEED Forested Sites



Harvard is an Ameriflux and LTER site as well as NEON

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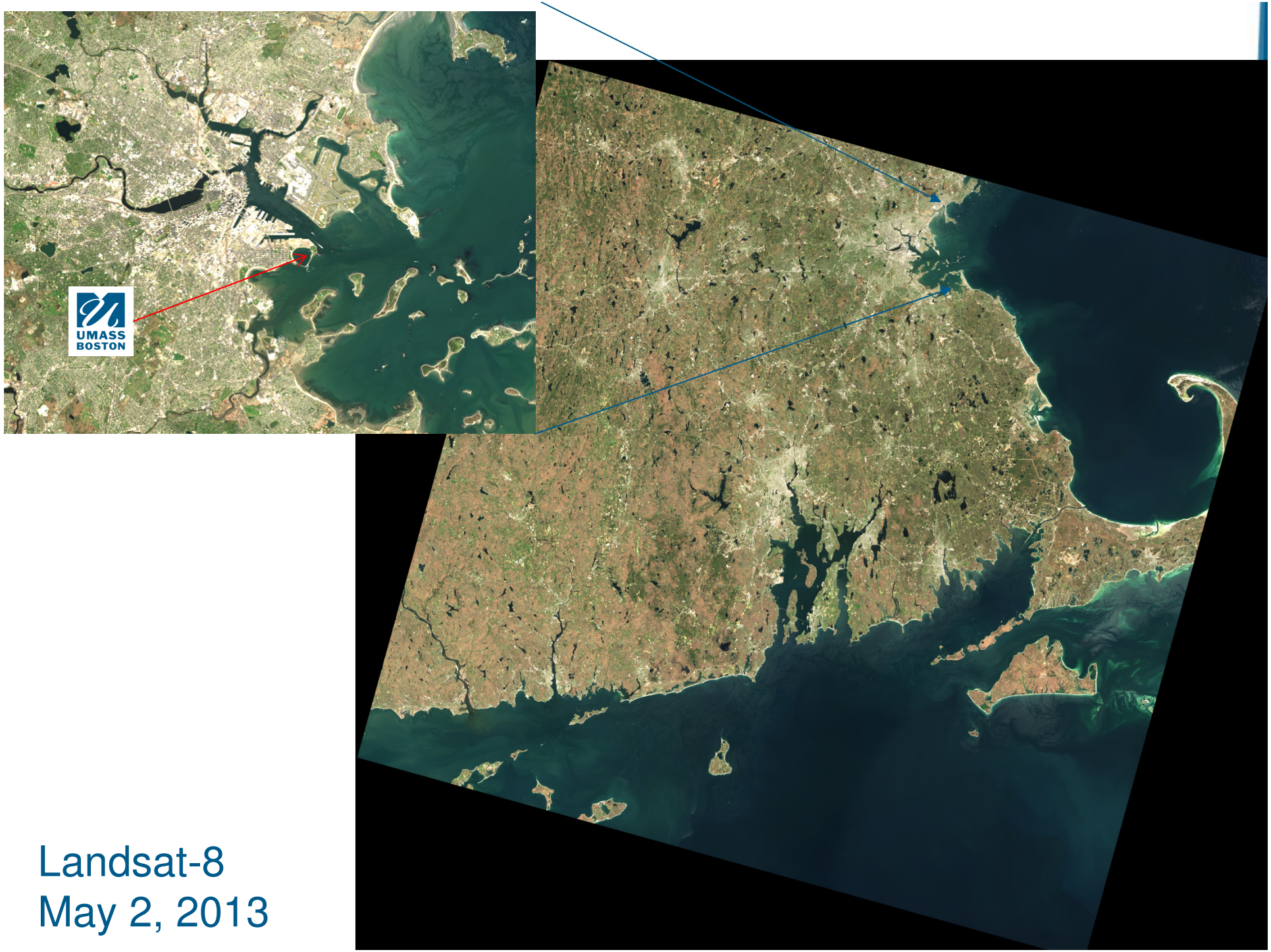
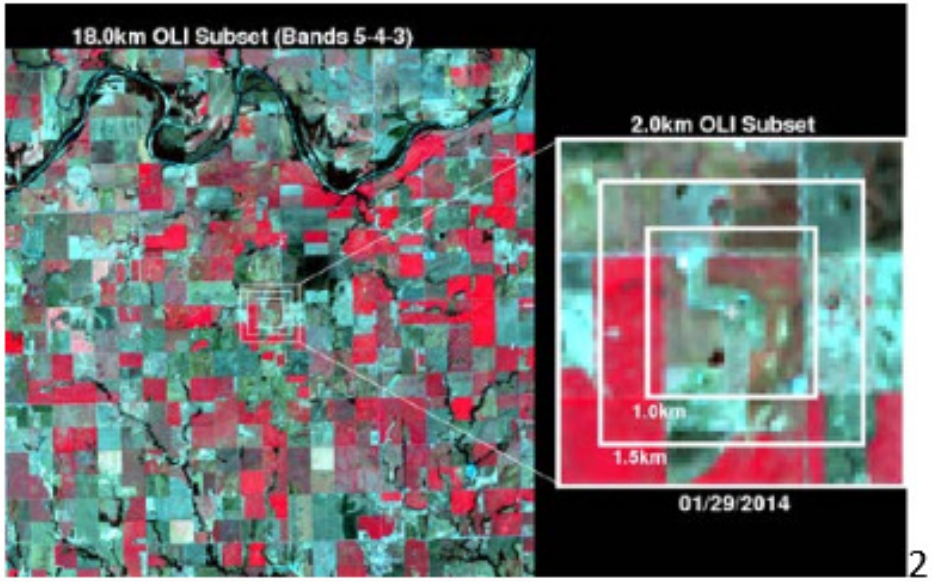
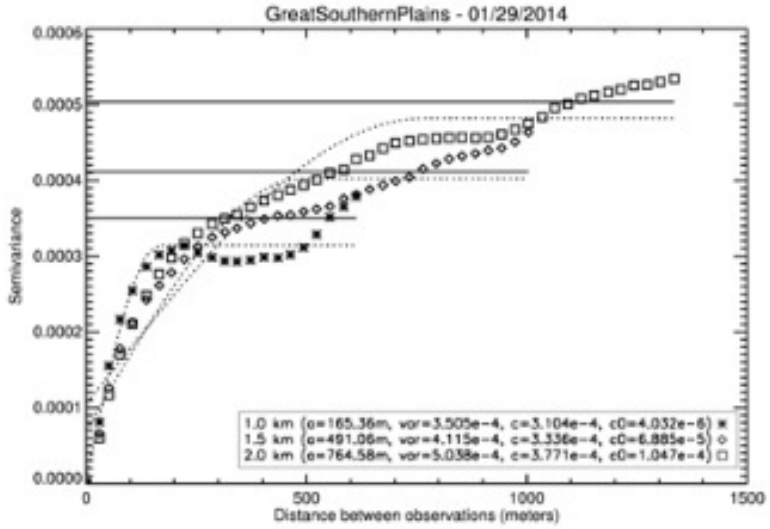
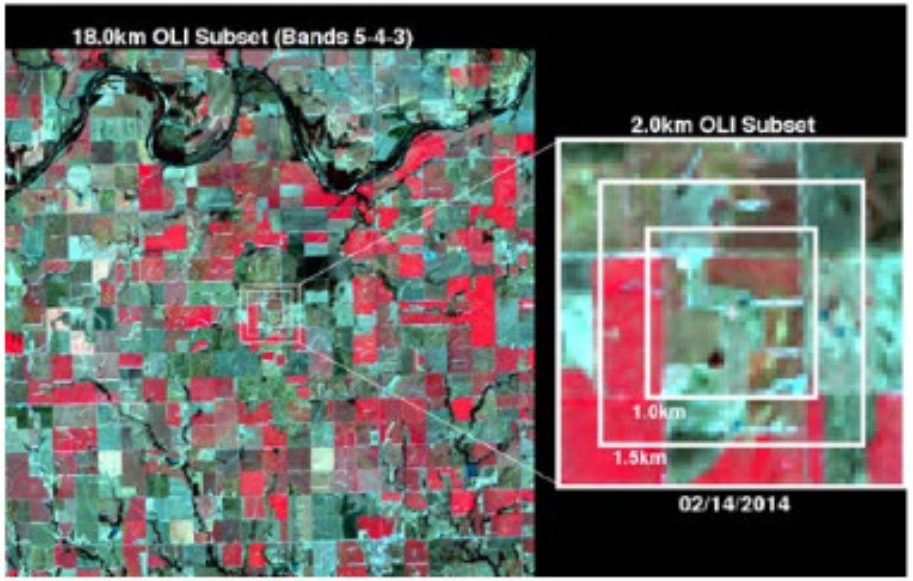


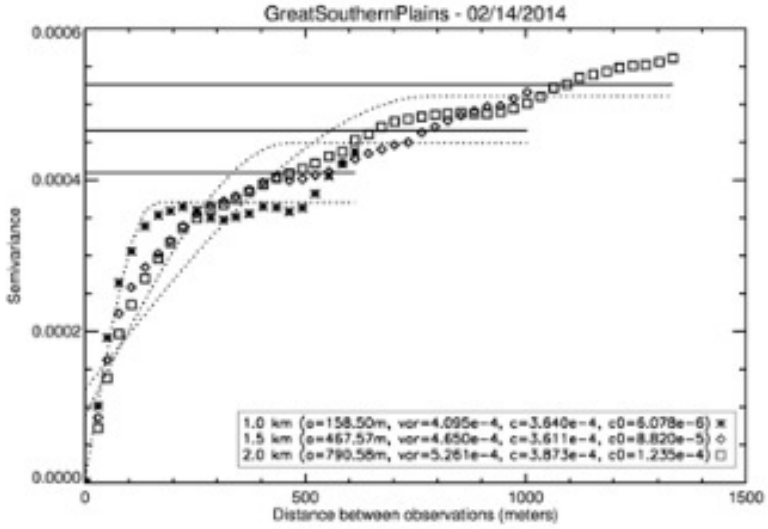
Landsat-8
May 2, 2013

Landsat 8

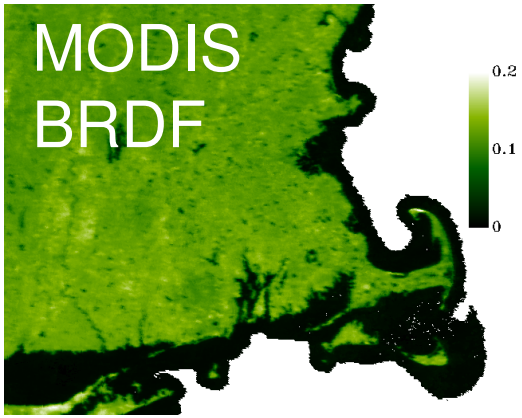

18.0km OLI Subset (Bands 5-4-3)
2.0km OLI Subset
1.0km
1.5km
01/29/2014

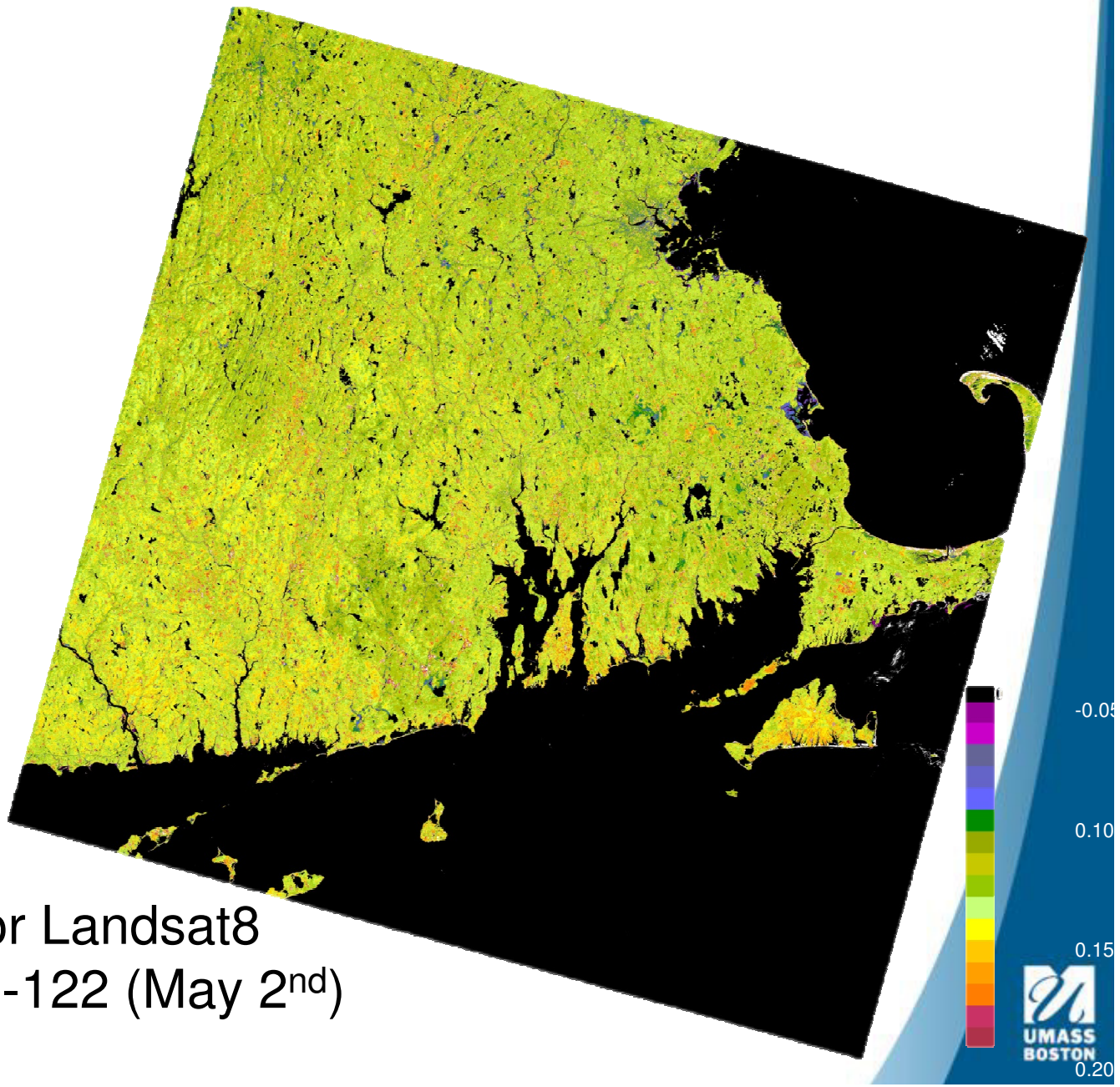

GreatSouthernPlains - 01/29/2014
Semivariance
Distance between observations (meters)
1.0 km (a=165.36m, vor=3.505e-4, c=3.104e-4, c0=4.032e-6)
1.5 km (a=491.06m, vor=4.115e-4, c=3.336e-4, c0=6.885e-5)
2.0 km (a=764.58m, vor=5.038e-4, c=3.771e-4, c0=1.047e-4)


18.0km OLI Subset (Bands 5-4-3)
2.0km OLI Subset
1.0km
1.5km
02/14/2014


GreatSouthernPlains - 02/14/2014
Semivariance
Distance between observations (meters)
1.0 km (a=158.50m, vor=4.095e-4, c=3.640e-4, c0=6.078e-6)
1.5 km (a=467.57m, vor=4.650e-4, c=3.611e-4, c0=8.820e-5)
2.0 km (a=790.58m, vor=5.261e-4, c=3.873e-4, c0=1.235e-4)

Landsat Albedo-Need Higher Resolution Imagery





White Sky Albedo for Landsat8
p12r31 on day 2013-122 (May 2nd)