CEOS Land Product Validation Update
(and other housekeeping items...)

Miguel Román, Pierre Guillevic, Jaime Nickeson, Zhuosen Wang
with contributions from the CEOS-LPV Focus Area Leads

MODIS/VIIRS Science Team Meeting: June 6-10, 2016
CEOS > WGCV > LPV

**CEOS** - Committee on Earth Observation Satellites
- 31 CEOS Members (e.g. space agencies, research centers)
- 24 Associate Members (e.g., UNEP, WMO, GCOS)

CEOS coordinates civil space-based EO to benefit society

The **Working Group on Calibration and Validation** (WGCV) is one of 5 CEOS working groups.

**Land Product Validation (LPV)** is one of 6 WGCV subgroups

Current LPV Officers:

- **Chair**: Miguel Román, NASA GFSC
- **Vice-Chair**: Fernando Camacho, EOLAB/U. of Valencia
- **Secretariat**: Jaime Nickeson, SSAI/NASA GSFC
- **Protocol Dev.**: Pierre Guillevic, UMD/NASA GSFC
- **LPCS Liaison**: Zhuosen Wang, ESSIC/ NASA GSFC

+ 11 Focus Areas with ~2 co-leads each
# LPV Focus Areas and Co-leaders

<table>
<thead>
<tr>
<th>Focus Area</th>
<th>Co-leader 1</th>
<th>Co-leader 2</th>
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<tr>
<td>Snow Cover*, Sea Ice</td>
<td>Thomas Nagler (ENVEO, Austria)</td>
<td>Tao Che (Chinese Academy of Sciences)</td>
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<tr>
<td>Surface Radiation</td>
<td>Crystal Schaaf (U Mass Boston)</td>
<td>Alessio Lattanzio (EUMETSAT)</td>
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<tr>
<td>(Reflectance, BRDF, Albedo*)</td>
<td></td>
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<tr>
<td>Land Cover * and Land Use Change</td>
<td>Pontus Olofsson (Boston University)</td>
<td>Martin Herold (Wageningen University, NL)</td>
</tr>
<tr>
<td>Biomass*</td>
<td>Vacant</td>
<td>Vacant</td>
</tr>
<tr>
<td>FAPAR*</td>
<td>Arturo Sanchez (University of Alberta)</td>
<td>Nadine Gobron (JRC, IT)</td>
</tr>
<tr>
<td>Leaf Area Index*</td>
<td>Oliver Sonnentag (University of Montreal)</td>
<td>Stephen Plummer (Harwell, UK)</td>
</tr>
<tr>
<td>Fire*</td>
<td>Luigi Boschetti (University of Idaho)</td>
<td>Kevin Tansey (University of Leicester, UK)</td>
</tr>
<tr>
<td>(Active Fire, Burned Area)</td>
<td></td>
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<tr>
<td>Land Surface Temperature*</td>
<td>Simon Hook (NASA JPL)</td>
<td>Jose Sobrino (University of Valencia, SP)</td>
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<tr>
<td>(LST and Emissivity)</td>
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<tr>
<td>Soil Moisture*</td>
<td>Tom Jackson (USDA ARS)</td>
<td>Wolfgang Wagner (Vienna Univ of Technology, AT)</td>
</tr>
<tr>
<td>Land Surface Phenology</td>
<td>Matt Jones (Oregon State University)</td>
<td>Jadu Dash U Southhampton</td>
</tr>
<tr>
<td>Vegetation Index</td>
<td>Tomoaki Miura and Marco Vargas</td>
<td>Vacant</td>
</tr>
<tr>
<td></td>
<td>(University of Hawaii / NOAA/STAR)</td>
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LPV’s Core Mission

To integrate across LPV Focus Areas, CEOS Space Agencies, and the Land Discipline & Instrument Teams.
Status for: BRDF/Albedo (MCD43)

General Accuracy Statement
Validation at stage 3 has been achieved for the surface reflectance product (MCD43). The accuracy of the high quality 500m MODIS operational albedo is well less than 5% albedo at the majority of the validation sites studied thus far, and even those albedo values with low quality flags have been found to be primarily within 10% of the field data. Data for solar zenith angles greater than 70 degrees should be considered suspect.

While the daily algorithm has been shown to capture rapid changes well, such as snow melt and greenup, the values associated with rapid change may be flagged with lower quality flags and the algorithm can lag abrupt reactions in the field data.

Product status updated: November 2015
Product version: Collection 5/6

Supporting Studies:
Title: Evaluation of MODIS albedo product (MCD43A) over grassland, agriculture and forest surface types during dormant and snow-covered periods
View Summary Results From This Document

Title: Re-evaluation of MODIS MCD43 Greenland albedo accuracy and trends
Author: Stroeve, J., J.E. Box, Z. Wang, C. Schaaf, A. Barrett
View Summary Results From This Document

MODIS Maintenance PIs: Need to keep your val status pages updated!!
MODIS/VIIRS Subsets FTP Access Page

Used by multiple teams (VIIRS ST, VCST, LPDAAC, ORNL, NOAA/STAR)
Land Product Quality Assessment
Golden Tile Time Series

Approach:
Summary statistics for \((10^\circ \times 10^\circ)\) SIN golden tiles.

Early VIIRS (solid lines) vs. Aqua MODIS C6 (dashed-dot lines) **Vegetation Index** (left), **LST** (center), and **Surface Reflectance** (right). 6-month trending shown for observations from savanna class (tile h20v11).
Discipline Teams

Instrument Teams

CEOS Member Agencies and Affiliates

http://ceos.org/about-ceos/agencies/
The LPV Validation Framework

Lead Agency: NASA

Lead Agencies: Various

Lead Agency: ESA

Lead Agency: USGS/NOAA
CEOS-LPV 5-Year Roadmap

<2016  2017  2018  2019  >2020

- Operational Validation Framework: Land Product Characterization System (Lead Agencies: USGS/NOAA)
- Albedo, Burned Area, & LST Protocols
- Phenology, ET, & Soil Moisture Protocols (Lead Agency: NASA)
- CEOS Carbon Actions 7/8 (NASA CMS Program)
- Biomass Protocol (Lead Agencies: NASA/ESA)
- snowpex
- ECV protocols and procedures for Snow ECV (Lead Agency: ESA)
- WGCV Atmospheric Correction Intercomparison Exercise (Lead Agency: ESA)
- Atmospheric Correction and VI Protocols (Lead Agencies: ESA/NOAA)

Field Campaigns and IOPs

New Missions
- SMAP
- ICESat-2
- ECOSTRESS
- GEDI
- NLSAR

Sustained Missions
- sentinel-2A/b
- sentinel-3A
- sentinel-3B
- Landsat 9
- JPSS-1
- JPSS-2

Vision

All missions support validation & validation is on-going
Uncertainty information determined through standard practices & protocols
Algorithms are iteratively improved based on validation results

Operational Validation Framework: Land Product Characterization System

Albedo, Burned Area, & LST Protocols

Phenology, ET, & Soil Moisture Protocols (Lead Agency: NASA)

CEOS Carbon Actions 7/8 (NASA CMS Program)

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snowpex

ECV protocols and procedures for Snow ECV (Lead Agency: ESA)

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Fiducial Reference Data Sets: Key Players

Long-Term Agro-ecosystem Research Sites and Farm Resource Regions

NASA POCs (Pierre Guillevic, Brad Doorn, Chris Justice)
Full List of Organizations: http://www.ars.usda.gov/SP2UserFiles/Program/211/LTAR%20Collaborators%20alphabetical%20FINAL.pdf
Fiducial Reference Data Sets
NASA small-UAS Partnerships: GSFC, ARC and BlackSwift Technologies LLC

Two Instrument Systems
Soil Moisture (w/ L-Band Radiometer - SBIR)

MultiAngle, MultiSpectral Imagers (Román, et al - IRAD)

Two Types of s-UAS
Tempest (Established Platform)

SuperSwift (New, GeoScience Tailored Platform)

Electric s-UAS (both):
Max Wt. ~15 lbs
P/L Wt. ~5 lbs
Endurance~1 Hr
MALIBU (Multi Angle Imaging Bidirectional Reflectance Distribution Function sUAS)

- **MALIBU** is a pathfinder concept funded through NASA’s Internal Research and Development Program (IRAD) to develop a multi-angle remote sensing technique using small Unmanned Aircraft Systems (sUAS).

- The instrument package includes two multispectral imagers, oriented at two different viewing angles, to capture key surface radiation and biophysical parameters.

- GSFC instrument system is packaged in a Black Swift Technologies LLC *Tempest* aircraft (seen deployed here).
The MALIBU instrument design includes two Tetracam optical units matching the optical Land channels of key Land sensors such as Landsat-8 OLI, Sentinel-2 MSI, Terra/Aqua MODIS, Terra MISR, and Suomi-NPP/JPSS VIIRS.
Six types of drone concepts ‘crazier’ than MALIBU...

- Package Delivery
- IED Detection
- Hurricane Drone
- Food Delivery
- Wildfire Drone
- Pollinating Drone
NASA Flight Readiness Review Approval
COA-Gov’t

National Aeronautics and Space Administration

Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia 23337-5099

Reply to Attn. of: Code 830 / AFSRB Chairman

TO: 840/PM, Tempest UAS

FROM: 830/Chairman, Airworthiness and Flight Safety Review Board (AFSRB)

SUBJECT: Flight Release for the Tempest UAS

REF: (a) FRR Meeting Minutes. March 25, 2016.
(b) UAS FOM, March 2016
(c) Tempest UAS Pilot Operating Handbook (Flight Manual)

1. In accordance with the recommendations of the AFSRB in Reference (a), the Tempest UAS is certified for flight under the sUAS Provisions of the UAS FOM, Reference (b). All flights shall be flown in accordance with the Tempest UAS pilot operating handbook, Reference (c), UAS FOM and NPR7900.3, Reference (d). In the event of conflicting guidance, the more restrictive policy shall be used.
December 11, 2015

Exemption No. 13967
Regulatory Docket No. FAA–2015–1684

Mr. Jack Elston
Black Swift Technologies
2100 Central Avenue
Boulder, CO 80301

Dear Mr. Elston:

This letter is to inform you that we have granted your request for exemption. It transmits our decision, explains its basis, and gives you the conditions and limitations of the exemption, including the date it ends.

This document is concerned with operations of UAS in Canada for commercial use weighing less than 25 kg (55 lbs). More specifically, this document is concerned with operations of UAS that do NOT require a Special Flight Operations Certificate (SFOC). To operate a UAS that is exempt from an SFOC, this falls into 2 categories, sub 2 kg and 2 kg to 25 kg. The requirements and operational limitations for each class are listed below in the following two sections. The infographic outlining these rules is attached in the Appendix. However, the detailed requirements listed in the following two sections are taken from the more detailed Advisory Circular (AC) No. 600-004 2. Note that Transport Canada can issue a fine of up to $25,000 to a company not following these rules.

The operator must have the following 4 things in their possession, ready to show to any Transport Canada representative:

| Copy of UAS Exemption (i.e., this document with all provisions in the previous section followed) |
| Proof of Liability insurance                                                                 |
| Contact Information                                                                       |
| Aircraft System Limitations (i.e. manuals)                                                 |
Pawnee NGL flight area

40°45'41.04"N (40.7614)
104°38'48.141"W (-104.646706)
2NM radius

DENVER TERMINAL AREA

Pilots are encouraged to use the Denver Terminal Area Chart for flights at or below 6000 feet.

Examples of Class B Airspace:
- Ceiling in hundreds of feet
- Floor in hundreds of feet

Hazard Area

Maximum Area

GODDARD SPACE FLIGHT CENTER
NASA-FAA Approved MALIBU Sites

Meeting COA-Gov’t and FAA Section 333 requirements

MODIS/VIIRS Team Member Discount! ~ $350/flight hour
International Programs concerned with Terrestrial Earth Observations

GEO / GEOSS
Group on Earth Observations / Global Earth Observation System of Systems
URL: http://www.earthobservations.org/
Forum: http://www.earthobservations.org/project.jsp.html

UNFCCC
United Nations Framework Convention on Climate Change

SBSTA
Specialized Body for Scientific and Technological Advancement

GCOS
Global Climate Observation System
URL: http://www.wmo.int/pages/prog/aco/gcos.php
Forum: http://www.earthobservations.org/forum.jsp.html

GOOS
Global Ocean Observation System
URL: http://www.wmo.int/pages/prog/aco/goos.php
Forum: http://www.earthobservations.org/forum.jsp.html

TOPC
Terrestrial Observation Panel for Climate
URL: http://www.wmo.int/pages/prog/aco/topc.php?name=TOPC

AOPC
Atmospheric Observation Panel for Climate

OOPC
Ocean Observation Panel for Climate

CEOSS
Committee on Earth Observation Satellites
URL: http://www.ceos.org/

WG-HSS
Working Group on Information Systems and Services

WG-CV
Working Group on Calibration and Validation

WG-C
WG-Edu
WG-V
Virtual Constellations

SAR
Synthetic Aperture Radar

TMPS
Terrain Mapping

ACOS
Atmospheric Chemistry

IVOS
Infrared Visible Optical Sensors

MSO
Microwave Sensors

LPV
Land Product Validation

Land Cover
LAI & FPAR
Fire
Surface Radiation
Land Surface Temperature
Soil Moisture
Vegetation Index & Phenology
Snow Ice
Biomass

www.ceos.org
CEOS Carbon Activity: History and Background


- 42 Actions identified in the report for specific response – first discussed at SIT Technical Workshop in September 2013

- April 2014: Proposed establishment of a study team to take forward the Actions and also identify formal CEOS mechanism to manage Actions.
LPV Biomass Focus Area Goals:

Validation protocols focusing on core site selection, field sampling using Terrestrial and Airborne LIDAR Systems, and spatial representativeness and uncertainty quantification of in situ measurements.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>RIEGL VZ400</th>
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<tbody>
<tr>
<td>Time-of-flight</td>
<td>Time-of-flight</td>
</tr>
<tr>
<td>Recorded Data</td>
<td>Multiple discrete return Waveform</td>
</tr>
<tr>
<td>Scan Configuration</td>
<td>30-130 zenith 0-360 azimuth</td>
</tr>
<tr>
<td>Wavelengths</td>
<td>1550 nm</td>
</tr>
<tr>
<td>Angular Resolution</td>
<td>0.04-0.03 mrad zenith 0.04-0.73 mrad azimuth</td>
</tr>
<tr>
<td>Beam Divergence</td>
<td>0.35 mrad</td>
</tr>
<tr>
<td>Laser Class</td>
<td>1</td>
</tr>
<tr>
<td>Pulse Rate</td>
<td>100 kHz 300 kHz</td>
</tr>
<tr>
<td>Weight</td>
<td>9.6 kg</td>
</tr>
<tr>
<td>Max. Range</td>
<td>200 m 120 m</td>
</tr>
</tbody>
</table>

Practicality Optimizations:
- 3.4 kg
- 33 second scan
- IP68 waterproof
- Wireless operation

Capability Optimizations:
- 0.04 mrad max resolution
- 200 m max range
- Multiple return / waveform
TOPC-18 Panel & Experts

TOPC/USA Delegation

Miguel Román (CEOS/NASA)  Sassan Saatchi (JPL)  Tom Painter (JPL)  Jeff Key (NOAA)
GCOS Land Surface Temperature (LST) Status

LST to become ECV!!
(Just in time for inclusion in the new GCOS-IP due for UNFCCC COP 22.)

• Process *took years* since initial inquires. LPV LST & Emissivity focus area leads first made a strong case for inclusion and pushed the case forward.

• Key players (Hook, Sobrino, Hulley, Guillevic, Warren, Remedios) iterated on variable definitions, requirements for satellite/reference/climate, and completed a Draft IP section: *Not easy!*

• Proposal presented by the CEOS-LPV Chair (Román) and endorsed by the TOPC-18 Panel in April, 2017.
GCOS follows a 3 phase approach driven by users

2015 Status Report started the 3rd assessment cycle with a new Implementation Plan due in 2016 for UNFCCC COP 22

Factors that helped ‘seal the deal’ for LST at TOPC-18:
-- Community Consensus

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Land Surface Temperature and Emissivity Product Validation

Simon Hook, NASA Jet Propulsion Laboratory, USA
Jose Becerro, University of Valencia, Spain

Focus Area on Land Surface Temperature and Emissivity Product Validation

Land Surface Temperature Definition

Land surface temperature (LST) is defined as the temperature derived from a radiative energy balance of a surface and provides the best approximation to the surface skin thermodynamic temperature based on a measure of radiance (Norman and Becker, 1995). LST is also called (directional) radiometric temperature or skin temperature.

Units: The unit of LST is Kelvin (K). Degree Celsius (°C) is also commonly used.

Land Surface Emissivity Definition

The emissivity of an isothermal, homogeneous emitter is defined as the ratio of the actual emitted radiance to the radiance emitted from a black body at the same thermodynamic temperature (Norman and Becker 1995).

Units: Dimensionless.


Highest Validation Stage Currently Reached for Satellite-Derived Land Surface Temperature and Emissivity Products

Validation stage 1 (LPV validation stage hierarchy) - The highest LPV validation stage reached for satellite-derived land surface temperature and emissivity products. For reaching validation stage 3 and higher, an increased number of global validation sites, covering all surface types, with extended temporal coverage, as well as intercomparison of different LST products are needed.

Land Surface Temperature Validation Methods

Four different methods have been widely used to validate and determine the uncertainties in LST products derived from satellite measurements (Schneider et al., 2012; Guilleux et al., 2014).
Current focus of TOPC is to identify measurable terrestrial key variables that control the physical, biological and chemical processes affecting climate and are indicators of climate change.

**Biological/Ecological (6)**
- Land cover and Land Use Change
- FAPAR
- Leaf area index
- Above ground biomass
- Soil carbon
- Fire disturbance

**Hydrological (5)**
- River discharge
- Water use
- Ground water
- Lakes
- Soil moisture

**Cryospheric (4)**
- Snow cover
- Glaciers and ice caps
- Ice sheets and ice shelves
- Permafrost

**Surface Properties (4)**
- Albedo
- Land surface temperature
- Energy fluxes
- Anthropogenic greenhouse gases

New, Revised, and Proposed

11 ECVs are directly linked to MODIS/VIIRS Land Products
http://lpvs.gsfc.nasa.gov