CEOS Land Product Validation (LPV) Soil Moisture Focus Group

Soil Moisture – Coming into the Spotlight of the International Science Community represented by GEO-CEOS-GCOS-GTOS-WCRP-GEWEX-etc

Tom Jackson & Wolfgang Wagner

with contributions & feedbacks from

Wouter Dorigo, Peter van Oevelen, Yann Kerr, Toshio Koiko, Richard de Jeu, Klaus Scipal, Han Dolman, Luca Brocca, Jean-Christoph Calvet and many more!

May 5, 2011

CEOS-LPV

- The value of satellite derived land products for science applications and research is dependent upon the known accuracy of the data (Validation).
- CEOS (Committee on Earth Observation Satellites), the space arm of the Group on Earth Observations (GEO), plays a key role in coordinating the land product validation process.
- The Land Product Validation (LPV) sub-group of the CEOS Working Group on Calibration and Validation (WGCV) is charged with addressing the challenges associated with the validation of global land products.

LPV

- Mission of the LPV sub-group
  - Foster and coordinate international validation activities for satellite-derived land products
  - Develop international validation protocols
  - Promote data sharing
  - Ensure that data and results are available to the user community.
- Product areas include seven ‘focus groups’ including soil moisture.
- *Current emphasis is on the independent and systematic evaluation of the GTOS (Global Terrestrial Observing System) terrestrial Essential Climate Variables (ECV) and long-term data records.*

CEOS LPV Soil Moisture Focus Group

- Chairs: W. Wagner and T. Jackson
- http://lpvs.gsfc.nasa.gov
- Objectives
  - Encourage cooperation for the establishment of a global in situ soil moisture network (ISMN).
  - Foster cooperation among soil moisture product teams.
  - Prepare guidelines for best practice data collection and validation.
- Key Accomplishment: Contributions to developing and launching the International Soil Moisture Network (ISMN).
- Near term issues
  - ECV (Standard of Practice)
  - Expand ISMN
  - …..

Development of Standards for Soil Moisture as an Essential Climate Variable

Global Terrestrial Observing System (GTOS)

(FAO, ICSU, UNEP, UNESCO, WMO)

GCOS, GTOS and TOPC

- GCOS = Global Climate Observing System
  - Joint undertaking of WMO, IOC, UNESCO, UNEP and ICSU
- GTOS = Global Terrestrial Observing System
  - Major component of GCOS
  - Joint undertaking of FAO, ICSU, UNEP and WMO
  - Chair: Riccardo Valentini
- TOPC = Terrestrial Observation Panel on Climate
  - One of the four GTOS Panels, co-sponsored by WCRP
  - Chair: Han Dolman
  - Wolfgang Wagner presented the progress on soil moisture at the 13th session of the TOPC on 10 -11 March 2011 at WMO in Geneva: Main discussion point: Need for Standardisation of Essential Climate Variables (ECVs)

Background: ECVs (1)

- Reliable assessment of global and regional environmental changes - both natural and human induced - *requires systematic, sustained observations*.
- The need for consistent and comprehensive global observations is particularly critical in case of *climate change*, due to the climate system affecting the environment and the society at all scales, from local to global.
- While such need exists in all three parts of the global system (atmosphere, oceans, land), it continues to be *least satisfied for the land component*.

Background: ECVs (2)

- Environmental parameters considered to be the most important for understanding, detecting, monitoring, and assessing the impact of climate change.
- For the terrestrial domain, the initial list consisted of 13 variables.
- Soil moisture was recognized as an emerging ECV in 2004 and added in 2009.
- ECVs considered for standardization so far, are
  - –Albedo
  - –Biomass
  - –FAPAR
  - –Fire disturbance
  - –Glaciers
  - –Ground water
  - –LAI
  - –Lake levels and reservoir storage
  - –Land cover
  - –Permafrost
  - –River discharge
  - –Snow cover
  - –Soil moisture
  - –Water use.

GCOS Progress on ECVs

- Identified the need for a mechanism for establishing standards, regulatory material and guidelines for terrestrial observing systems that will provide ECVs.
  - The term 'standard' is used for brevity to represent guidance materials, standards and reporting guidelines
- Identified essential climate variables for atmospheric, oceanic and terrestrial domains that are both currently feasible for global implementation and have high impact with respect to the UNFCCC and IPCC requirements.
  - Prioritization
- Assessed the status of the development of standards for each of the ECVs in the terrestrial domain.
- Defined a process for standard development.

GCOS Report

- For each ECV a brief summary was provided of:
  - Importance and urgency
  - Readiness and feasibility
  - Available documentation (to use in drafting the standards)
  - Existing expertise (specialized scientific/ technical groups, committees)

ECVs: Urgency and Importance

- How critical (in relative terms) is the need for a standard becoming available during the next 2-4 years?
- Are some standards, guides or similar documents in place which can serve in the interim?
- Are only few groups/ organizations involved who are already collaborating/ sharing methodologies (thus lessening the urgency for a standard)?

ECVs: Readiness and Feasibility

- Has the observation methodology developed sufficiently to enable definition of an international standard?
  - Does sufficient documentation exist upon which a Draft International Standard could be built?
- Are there candidate groups for providing technical expertise in the development of a standard?

ECVs: Prioritization

- Tier 1a = Tier 1 (High (H) – Medium (M) urgency, H-M readiness):
  - Biomass
  - Glaciers and Ice Caps
  - Land Cover
  - Permafrost
  - Soil Moisture
- Tier 1b = coincident with Tier 1a (provided resources are available):
  - Leaf Area Index
  - River Discharge
- Tier 2 (M-Low (L) urgency, H-M readiness):
  - Albedo
  - Fraction of Absorbed Photosynthetically Active Radiation
  - Snow Cover
- Tier 3 (L urgency or L readiness):
  - Fire Disturbance
  - Lake Levels and Reservoir Storage
  - Ground Water
  - Water Use

ECV Soil Moisture

- Importance and urgency
  - Soil moisture is a very important environmental variable for land- atmosphere interactions as well as for agricultural and other human activities. It varies greatly in space and time, thus its measurement presents a difficult challenge. In practice, only space- based measurements are potentially capable of providing the spatial and temporal resolution required for soil moisture information to be useful for the above purposes. However, available sensing technologies can only respond to surface moisture (not soil profile), and they need to be calibrated with surface measurements. Thus both site and landscape level soil moisture information is required, and in situ soil moisture determination is an essential element of the overall measurement strategy.
- Feasibility and readiness
  - While point soil moisture measurements are well established, the main challenge for this ECV is standardization in describing and reporting the distribution of near- surface soil moisture in support of satellite- based sensing strategies. Although methodology development in this respect has not progressed far enough to attempt standardization, a guide documenting possible approaches and their relative merits would be valuable for current and upcoming satellite missions.
- Available documentation
  - Various measurement methods have been developed over time and documented in the published literature. Studies have also been conducted regarding the various methodologies and the interpretation of the measurements (refer to SBSTA, 2009a). However, no international standards or protocols have been published that deal specifically with soil moisture measurements at site or landscape levels. In the context of soil moisture as ECV the main issue is estimation of areal distribution of surface soil moisture because satellite- based estimates refer to relatively large individual cells; a key issue is therefore upscaling of point measurements to represent larger areas.
- Lead group(s)
  - Standard preparation: This topic is not ready for definitive standardization. However, a guide document for upscaling options that would also address the issues with supporting measurements (e.g., sampling design) is highly desirable. Contributions to such an activity could come from international programs (e.g., GEWEX) and from projects associated with satellite soil moisture missions.
  - Technical input: International or national research programs contain the expertise needed for the preparation of such a guide.

Soil Moisture ECV

- Key issues for standardization:
  - How specific (in terms of the measurement methodology) should the standard be? Should only principles be defined, or should acceptable alternative measurement approaches also be included?
  - What are the measurements required per site (soil moisture and ancillary)?
  - What criteria for upscaling should be met and what are the possible approaches?
  - What other information is required for standardization (e.g., satellite images, terrain information), and how is this to be standardized?
  - How should the information be reported at both site and upscaled levels (reporting format and content, ancillary information, etc.)?
  - How should uncertainties be minimized and reported?
- Suggested action:
  - Organize an international workshop(s) to complete an ISO Workshop Agreement on the preparation and reporting of site- and landscape-level soil moisture information.

WCRP, GEWEX and WOAP

- WCRP = World Climate Research Programme
- GEWEX = Global Energy and Water Cycle Experiment
  - A core project of WCRP
- WOAP = WCRP Observations and Assimilation Panel
  - A unifying theme within WCRP
- WOAP held a “Workshop on Evaluation of Satellite-Related Global Climate Datasets” at ESA, Frascati, Italy, April 17-19, 2011.
  - http://www.congrex.nl/11C06/
  - Workshop goal: Assessment of selected ECV
  - Terrestrial ECVs: Soil moisture, snow, fAPAR/LAI
  - Soil moisture writing team: Yann Kerr, Toshio Koiko, Richard de Jeu, and Wolfgang Wagner
    - 5 Recommendations

Recommendations

1. Strengthen International Cooperation
2. Define Interfaces in the ECV Production (Satellite)
3. Inter-calibration and Reprocessing
4. Launch First International Assessment
5. Bundle Documentation Efforts

What Can We Do?

- Identify variables and reach a consensus:
  - 0-5 cm
  - 0-100 cm, root-zone. Profile?
  - Units of measurement
- Recommend a procedure for standardizing any instrument based measurement set to these variables.
  - Gravimetric sampling of the 0-5 cm and the “other” depth.
  - Review issues associated with alternative sensors.
- Adapt the SMAP up-scaling activity to address the ECV standards.

Discussion Points

- Should the International Soil Moisture Working Group (ISMWG) be the lead in compiling all necessary documentation in one “soil moisture master document“?
- Should an international assessment be conducted now (with data from 2010)?
- Any comments on the Soil Moisture Standardization Process initiated by GCOS?
- Where and when shall the next “ISMWG workshop“ be held?
  - Suggestion: 21-22 April 2012, weekend before EGU 2012 in Vienna
- For comments and contributions please send an e-mail to
  - Wolfgang Wagner (ww@ipf.tuwien.ac.at)
  - Tom Jackson (Tom.Jackson@ARS.USDA.GOV)

Backup

Recommendation 1: Strengthen International Cooperation

- Level 2 algorithm development has so far been taken care by the individual satellite teams in a rather separate fashion
- CEOS space agencies are highly recommended to lead periodical data set assessment, re-processing and inter-sensor calibration in cooperation with the science community
- The establishment of a CEOS Soil Moisture Satellite Constellation may be considered to foster cooperation between NASA, ESA, JAXA, EUMETSAT and other agencies with an interest in the subject.
- The cooperation with GEWEX, GEOSS task team and wide communities shall actively be sought.
  - International Soil Moisture Working Group lead by Peter van Oevelen (GEWEX) and Tom Jackson (USDA)
  - CEOS Land Product Validation Team on Soil Moisture lead by Wolfgang Wagner (TU Wien) and Tom Jackson (USDA).

Recommendation 2: Define Interfaces in the ECV Production

- The establishment of a long-term ECV soil moisture data record requires the integration of data from several space agencies.
- It is recommended that space agencies continue to be responsible for their Level 1 and Level 2 products, sharing the data (both Level 1 and Level 2) freely for any effort directed to producing long-term data records.
- The main tasks of an ECV processing centre would thus be to
  - collect Level 2 soil moisture data directly from the space agencies or any other organisation capable of maintaining Level 2 processing capabilities for a significant period
  - characterise the spatio-temporal errors of the individual data sets
  - mask the data where necessary
  - bring them to a common reference
  - merge them
- NOTE: Users usually want to know the soil moisture content in the soil profile (root zone). Correspondingly, Level 3 and Level 4 data sets may become the ECV soil moisture data sets that are of highest interest to the climate research community

Recommendation 3: Inter-calibration and Reprocessing

- Currently there are not sufficient reprocessing capabilities for dealing in a timely manner with Level 1 and Level 2 updates
- Level 1 inter-calibration is often not well enough known
- The strengthening of inter-calibration and reprocessing capabilities is highly recommended
  - Complete reprocessing of the ERS-1 and ERS-2 scatterometer Level 1 data
  - Determine ERS-ASCAT Level 1 inter-calibration biases
  - Provide enhanced capacities for SMOS Level 1 and Level 2 reprocessing
  - Inter-calibrate AMSR-E and Windsat Level 1 data
  - Ensure consistency of AMSR-2 calibration with respect to AMSR-E
  - etc.

Recommendation 4: Launch First International Assessment

- No internationally coordinated assessment has so far been carried out
- Start with an assessment for the year 2010
  - Only global, freely available, well documented data sets shall be considered
  - 3-4 Sensors, 6-8 products
- The assessment itself should be done by an independent third party (i.e. not one of the data producers) using data provided by the “official source” and re gridded to the same fixed grid (possibly by the funded “evaluator”)
- Point-wide validation
  - Comparison with in-situ measurements (10-20 sites) and modelled surface soil moisture data
- Global comparisons
  - Inter-comparisons
  - Triple collocation
  - R-metrics
  - Error propagation (voluntary contribution by producers)

Recommendation 5: Bundle Documentation Efforts

- Being a rather new ECV there is yet limited documentation
- Many groups – many reports
- Suggestion: Write one „Soil Moisture Master Document“ that can meet most reporting needs
- Lead agent?
  - GEWEX International Soil Moisture Working Group (ISMWG)
- This was already discussed and perceived as a good way forward by a group of soil moisture researchers at the EUMETSAT/ESA Scatterometer Science Conference held in Darmstadt, Germany, April 11-13, 2011
  - Chris Rüdiger, Wouter Dorigo, Mehrez Zribi, Jean-Christoph Calvet, Patricia de Rosnay, Luca Brocca, Clara Draper, Klaus Scipal, Wolfgang Wagner

Background (3)

- Validation activities need to be coordinated in order to reach consensus from the international community, ensure a traceable and transparent process.
- Key responsibilities of each focus area include
  - Informing and involving the respective community members on LPV sub-group activities and meetings
  - Organizing topical workshops
  - Expanding LPV involvement in situ networks and collaboration globally
  - Leading satellite-derived land product inter-comparison activities
  - Leading the development of “best practice” land product validation protocols for products within their domain.

LPV Sub-Group Reference

- ASSESSING SATELLITE-DERIVED LAND PRODUCT QUALITY FOR EARTH SYSTEM SCIENCE APPLICATIONS: RESULTS FROM THE CEOS LPV SUB-GROUP, Joanne Nightingale, Gabriela Schaepman-Strub, Jaime Nickeson, Fred Baret, LPV Focus Area leads. ESA-iLEAPS-EGU Joint Conference on Earth Observation for Land-Atmosphere Interaction Science, 2010.

Standardization Process

- The preparation of international standards is fundamentally a consensus- building process.
- For the resulting ECV standards to be applicable at national and sub-national levels as well as internationally this process requires the identification, evaluation of options, and resolution of various technical and practical issues.

ECV Standardization

- In developing a plan for standardizing individual ECVs, a key challenge will be to identify the specific issues a standard must address.
- Given that the goal of this process is to track the evolution and impacts of climate change in the terrestrial domain, the most important questions concern the extent/ coverage, characteristics/ quality, consistency (including compatibility), and availability/ accessibility of the observations (and information on these attributes) for individual ECVs.

ECVs: In Situ and Satellite Observables

- Although the issue of standardization initially arose in the context of in situ observations, many terrestrial ECVs require use of satellite data.
- Ideally, the ECV standards should encompass both in situ and satellite data.
- However, a good portion of the satellite-based techniques is at an experimental stage, variously focusing on product validation, algorithm development, or sensor development.

Standardization Guidance

- The desired number of deliverables from each ECV standardization project and the scope of each are also an important consideration.
- ISO experience has shown that the preparation and approval of a complex, comprehensive standard is more difficult and lengthier than of several simpler standards addressing components of the problem.
- …better to get some specific things done that can be agreed on instead of getting involved in long process that attempts to address everything?

Soil Moisture ECV

ECV	In Situ Observations			Role of Satellite Data	Source of In Situ Observations
	Specific Observation Type Needed	Spatial Dimension	Exactly Co-Located		
Soil Moisture	Profile moisture distribution	Point	No	None	National monitoring programs/ Science programs
	Landscape moisture distribution	Areal distribution		Primary (under develop-ment)	

- When data are collected by NMP or SP the procedures are most likely to differ between countries/programs.