



**NASA DIRECT READOUT
CONFERENCE (NDRC-9)**
THE 9TH INTERNATIONAL EOS/S-NPP
DIRECT READOUT CONFERENCE

Valladolid, Spain
June 21 – 24, 2016

PROCEEDINGS

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Introduction

The purpose of the NASA Direct Readout Conference (NDRC) was to provide a venue for awareness and exchange of remote sensing science research and corresponding real-time applications focused primarily on the use of Direct Readout (DR), or real-time Earth observations from NASA Earth Observing System (EOS) and Suomi NPP (S-NPP) instrument data, along with exposure to enabling technologies.

Toward this purpose we had plenaries and poster sessions, but also incorporated several workshops focused on specific real-time applications, algorithms, and systems. This was enhanced by vendor presence to provide keen insights into algorithm and system implementation onto operational systems, as well as commercial availability of such capabilities.

The NDRC attendees were able to:

- Exchange and share techniques and knowledge for the optimal use of real-time Earth observations
- See demonstrations and evaluations of Earth observations benefiting society
- Discover and discuss the latest EOS/S-NPP science algorithms for real-time applications
- Discuss approaches, methods and techniques to transition research Earth remote sensing algorithms to real-time applications algorithms that are able to generate information for decision support systems
- Better understand the differences between real-time algorithms and standard algorithms from various sources
- See and hear first-hand what technology tools are available to support real-time Earth observation product generation for decision support systems
- Better understand the breadth and scope of how the EOS and S-NPP instrument data can support real-time applications
- Better understand available near real-time data products and provisioning systems available from NASA, NOAA and international space agencies and science organizations

Conference Program

The conference program was divided into four parts: plenary sessions, poster sessions, workshops, and vendor exhibits. Abstract submissions for the plenary presentation, poster sessions and workshops addressed the following themes:

1) Applications for Societal Benefits

This theme is subset into 4 of the 9 areas defined by Global Earth Observation System of Systems (GEOSS) that are meaningful to DR users.

Agriculture: Supporting sustainable agriculture and combating desertification. Satellite observations effectively monitor the status, and consequences, of agricultural activities. Issues covered included: land use and land cover change; changes in the extent and severity of land

degradation and desertification; and real-time environmental mapping, using information services.

Disasters: Synoptic, low latency observations that are critical to support disaster mitigation and response activities, thereby reducing loss of life and property from natural and human-induced disasters. Presentations and workshops focused on:

- flood detection, mapping and modeling
- volcanic eruptions (including aviation safety)
- air quality, transport and health risks
- fire detection and mitigation

In addition to improved hazard detection and characterization, subject matter was presented that focused on forecasting, assessment and management, including timely dissemination of information via integrated systems, and enhanced products for hazard response.

Ecosystems: Improving the management and protection of terrestrial, coastal and marine resources: Near real-time observations for monitoring spatial extent and condition of natural resource stock levels in ecosystems such as forests, rangelands, coastal zones and oceans, as well as continuity of observations for monitoring ocean and canopy properties. Presentations and workshops were also given on methodologies and near real-time observations available to detect and predict changes in ecosystem condition as a result of human impacts and environmental conditions.

Weather: Improving access to real-time weather information, forecasting and warning. Workshops and posters focused on the application of near real-time data products and methods to fill critical spatial gaps in observations of wind and humidity profiles; precipitation over ocean areas; and improving the quality of nowcasts and short-term forecasts.

2) Science and Algorithms for Direct Readout

- Algorithm calibration, regional/global product validation and continuity from EOS to S-NPP
- Nowcasting and forecasting modeling using real-time EOS/S-NPP data

3) Direct Readout Technology Tools, Measurement and Data Processing Techniques

- Efficient image processing, scaling, and smoothing techniques
- Real-time data visualization tools
- Data dissemination via geostationary communication systems
- Near-real-time science data processing systems
- Operational and research processing software packages for DR applications

Participants were asked to consider the following avenues for discussion throughout the conference program:

- What kinds of applications are you interested in seeing developed?
- What types of data/algorithms are needed for your potential and/or existing application and information needs?
- Provide information on the actual or potential use of the presented algorithms/product/application in the context of your organization's needs.
- Are there particular challenges/shortcomings/unmet needs? Where can things be made better?
- Are there opportunities for collaboration with other attendees and workshop leads (regional applications, data sharing, etc.)?
- Discuss scenarios with the broader group to identify innovative ideas, potential improvements, etc.

Workshops

Workshops were organized around four disciplines:

- Crosscutting Science and Technology, chaired and organized by Patrick Coronado [NASA Goddard Space Flight Center (GSFC) DRL]
- Land, chaired and organized by Brad Quayle [USDA Forest Service RSAC], Chair of the International Land Direct Readout Coordinating Committee
- Oceans/Freshwater, chaired and organized by Jasmine Nahorniak [OSU], Chair of the International Direct Readout Ocean Steering Committee (IDROSC)
- Atmosphere, chaired and organized by Anders Soerensen ([EUMETSAT] and Allen Huang [U-W)/SSEC] [both from the International TOVS Working Group (ITWG)]

The workshop structure consisted of discipline specific subject matter of interest to the majority of attendees, and/or problem areas. The content was presented in an end-to-end context by invited subject matter experts.

Acknowledgements

The NASA Direct Readout Conference (NDRC-9) would not have been possible without the participation and support of numerous people. The NDRC-9 organizing committee would like to thank the event co-sponsors including NASA, the University of Valladolid Remote Sensing Laboratory (LATUV), the World Meteorological Organization (WMO) and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). These organizations were instrumental to the implementation of the conference and also provided support to make the event possible. The conference organizing committee would particularly like to thank LATUV for hosting the event, and LATUV and NASA for coordinating the conference logistics. Additionally, the organizing committee thanks the representatives of all the international space agencies, science organizations, vendors and other attendees who supported and participated in the conference and helped to make it a success.

Land Discipline Session Overview

The second day of the NDRC (Wednesday, June 22nd) was devoted to land discipline applications of direct readout/near real-time data. This portion of the NDRC agenda consisted primarily of workshops focusing on the current status of science processing algorithms, availability of near real-time data products and their relevance to land discipline decision support systems and applications. Selected presentations and workshops provided on other days of the NDRC were "cross-cutting" and had relevance to all three discipline areas represented at the NDRC - land, oceans/fresh water and atmosphere.

Of the 190 registrants to the NDRC, most, 143, identified themselves either as interested in or associated with land discipline applications that leverage near real-time remote sensing data.

Algorithm/Product Status and Improvements Highlights

The following highlights key points from NDRC land discipline workshops provided for selected science algorithms/data products.

Multi-angle Implementation of Atmospheric Correction (MAIAC)

- MAIAC (MCD19) is available as a Collection 6 algorithm/product that assesses land surface information for each grid cell based on a time series measurements from observations for the past 4-16 days.
- The algorithm derives several gridded MODIS daily land and atmosphere products, including a nadir BRDF-adjusted reflectance (NBRF) for all land and specific ocean bands at multiple spatial resolutions, more spatially explicit aerosol optical thickness (AOT) product at 1km over dark and bright surfaces, and snow cover characterization products at 1km.
- Coordination with several organizations to assess the applicability of MAIAC for improved monitoring is ongoing (aerosols and PM2.5 estimates from biomass burning, vegetation greenness anomalies associated with short-term climate variations, early detection of effects by forest pests/pathogens, impacts of overgrazing on rangeland health).
- Plans and initial activities between the MODIS/VIIRS science team and NASA Direct Readout Lab (NASA DRL) are ongoing to implement MAIAC in the direct readout environment for MODIS and VIIRS. The MODIS NBRF product will be provided at 250m resolution in the direct readout implementation of the MAIAC algorithm to be implemented into IPOPP.
- To ensure continuity and consistency with MODIS, MODIS land team is bringing VIIRS data to 1km resolution. However, the direct readout version of VIIRS MAIAC algorithm plans to leverage the higher resolution data provided by the Imagery bands.

Soil Moisture Active/Passive (SMAP) Mission Science and Applications Overview

- SMAP was designed to provide science data products every 2-3 days characterizing soil moisture measurements in the top layer and freeze-thaw state and modeled estimates of soil moisture in the root zone.
- Approximately 6 months after SMAP launch on January 31, 2015, the radar instrument stopped transmitting due to power supply issue and is no longer operable. SMAP radiometer is fine and continues to provide science data.
- The potential use of other sources of radar data (e.g. Sentinel 1) is being investigated to support generation of radar and radar/radiometer products. There may also be efforts in the future to attempt to restart the SMAP radar if potential risks to radiometer can be avoided.
- Enhanced processing techniques are being evaluated to improve the quality and spatial resolution (36km vs. 9km) of soil moisture products based on SMAP radiometer observations at the routine SMAP observation frequency. Results are comparable to 9km radar/radiometer products provided before radar failure.
- Experimental products based on SMAP radiometer Sentinel 1 A/B radar appear promising and can provide soil moisture measurements at spatial resolutions of 1km to 3km at 6-12 day temporal frequencies.
- In addition to their availability from NASA Distributed Active Archive Centers (DAACs) (<https://search.earthdata.nasa.gov>) in standard science data formats, SMAP data products are also available in user friendly data formats (KML, GeoTiff and ASCII) and can be accessed for viewing within the NASA WorldView application (<https://worldview.earthdata.nasa.gov>).
- SMAP was not designed with direct broadcast capabilities. However, the SMAP science team and NASA DRL are coordinating to port SMAP science algorithms to produce relatively low latency Level 1, 2, 3 and 4 data products from the SMAP mission data stream for distribution through the NASA Land, Atmosphere Near real-time Capability for EOS (LANCE) and/or other near real-time data dissemination portals. Upon approval by the SMAP science team, NASA DRL and SMAP science team will also coordinate to package and make the algorithms available to the global user community to produce higher level data products from Level 0 SMAP data.

Application of Real-Time Satellite Precipitation Estimates

- Relatively precise precipitation estimates are important for several operational information needs including calibration/validation of numerical weather models, responding to extreme weather events, reservoir/river flow management, etc.
- Terrestrial-based precipitation gauges and radar systems (e.g. NEXRAD) are limited, particularly on a global scale, limiting comprehensive coverage.
- Global Precipitation Measurement (GPM) Mission, initiated in 2014, is a constellation consisting of the GPM Core Observatory and partner satellites from several international space agencies that measure precipitation.

- GPM is a follow on effort to the Tropical Rainfall Measuring Mission (TRMM) which provided rainfall estimates of the tropical zone of the planet from 1997 to 2015.
- GPM objective is to provide precipitation estimates at 2-3 hour intervals at a spatial resolution of 5km over 90% of the planet (between 65° north and south). Data latency is approximately 6 hours.
- Precipitation estimates derived by GPM are based on radar, radiometer, radar/radiometer and multi-satellite algorithms which are integrated with precipitation gauge data to minimize biases in satellite estimates.
- Synergies of GPM precipitation data with direct readout data include data fusion and provision of key geophysical parameters. For example, NASA is currently working to couple GPM and SMAP data products to support flood management information needs.

MODIS/VIIRS/Landsat Active Fire Data

- MODIS 1km Active Fire Product
 - Collection 6 improvements to the MOD14/MYD14 algorithm include processing over water pixels to identify gas flares; improved detection performance (fewer false alarms in tropical areas due to confusion with deforestation and lower omission errors with large fires); identifying more fires than C5 version of algorithm based on global validation results.
 - Global Terra/Aqua MODIS monthly active fire detection product (MCD14ML) classifies detected activity into 4 fire types – fire detection over land, static non-volcanic source, volcano and fire detection over water.
- VIIRS-AF 750m Active Fire Product
 - VIIRS-AF algorithm/product extends MODIS active fire data product continuity.
 - Algorithm is based on the MODIS Collection 6 algorithm and provides the same fire characterization attributes (detection confidence, fire radiative power).
- VIIRS 375m Active Fire Product
 - VIIRS 375m algorithm/product also extends MODIS active fire data product continuity and provides improved detection of small fires.
 - Algorithm leverages VIIRS Imagery Bands; MIR band (I4) is susceptible to saturation and folding.
 - Current version of the algorithm provides fire detections only, but latest version, based on a hybrid of the 750m and 375m product, will include fire radiative power estimates by leveraging coincident 750m data.
 - I4 band is also susceptible to noise over water and the South Atlantic Anomaly, but this has been corrected in the hybrid algorithm.
 - Global persistent thermal anomaly locations have been identified and validated with high resolution imagery to verify sources and are available as a dataset.

- The relatively spatially explicit and high temporal frequency 375m active fire detection data are being used in new fire behavior modeling applications.
- Landsat 8 30m Active Fire Product
 - Mid-infrared band is not available on Landsat to conduct traditional fire detection approach. The algorithm leverages reflectance data (near infrared and short-wave infrared ratio/differencing approach) to detect fire activity.
 - Provides much more spatially refined product than MODIS or VIIRS, but at a much more infrequent temporal resolution.
 - Algorithm can be extended to similar class sensors (e.g. Sentinel 2A/2B) and increase temporal observation frequency – every 1-2 days.
 - Latency of Landsat and Sentinel 2 data currently limits the use of this product for supporting near real-time applications.
- Sources of Global Active Fire Data
 - VIIRS Active Fire Team (<http://viirsfire.geog.umd.edu>)
 - VIIRS 750m and 375m products available.
 - NASA LANCE (<https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data>).
 - VIIRS 375m and MODIS 1km products available.
 - VIIRS 750m products are not provided due to the refined spatial resolution and small fire detection capability provided by the 375m product.

Burned Area Mapping and Monitoring Algorithms

- MODIS Burned Area Product
 - The current version of the MODIS direct broadcast burn area algorithm/product (MCD64A1) is implemented in the International Polar Orbiter Processing Package (IPOP) and is based on Collection 5.1.
 - The algorithm/product maps burned areas at monthly intervals by MODIS 10°x10° tiles at 500m resolution. Date of burning for each pixel is identified to the nearest day.
 - Collection 6 version of MCD64A1 is being validated and anticipated for release in late 2016.
 - MCD64A1 has a distinctively different approach to mapping burned areas compared to the original MODIS burn area product (MCD45A1) which will be discontinued in 2016. MCD64A1 uses a supervised classification approach applied to vegetation index time series data compiled from daily reflectance data, leverages contemporaneous active fire data and is more tolerant to noise and performs better under cloudy conditions.
 - Validation of Collection 6 version of MCD64A1 is being conducted using Landsat 8 data as per the Committee on Earth Observation Satellites (CEOS) burned area validation protocol. Results indicate a global increase in burned area vs. Collection 5, less temporal uncertainty in classified date

of burning, and some improvements in cropland burning due to harvest timing. Some improvement in results are traced to enhancements in input MODIS products (e.g. MOD09 reflectance).

- VIIRS Burned Area Product
 - The VIIRS product (VNP64A1) will adapt the MCD61A1 code to produce a 500m, tile-based product in HDF5 format that is consistent with the MODIS product.
 - VIIRS 750m bands corresponding to the MODIS bands used in MCD64A1 are used in the algorithm and oversampled to 500m for spatial consistency. VIIRS product will be validated with the same Landsat 8 reference data used for MODIS Collection 6.
 - It is anticipated the VIIRS production code will be finished and provided to the Science Investigator-led Processing System (SIPS) in early 2017.
- Future of Direct Broadcast Burned Area Product
 - MODIS/VIIRS Collection 6 code is more demanding making it challenging for its adaptability in direct readout processing environments.
 - There is preference to now develop a true real-time direct readout burned area algorithm/product. The strategy for such an algorithm/product would provide daily product updates, refine the product as additional days of observations are acquired, sacrifice the discrimination of the smallest burns to accommodate near real-time needs, leverage spatially refined active fire data more heavily (e.g. VIIRS 375m active fire product) and leverage burned/unburned probabilities compiled from MCD64 data record. Additionally, given that VIIRS will be providing observations for the next two decades, the focus of this algorithm/product will be for that instrument and also integrate NBRF reflectance data from MAIAC.

Decision Support Applications Dependent on NRT Observations/Data

The following highlights key points from workshops during the land discipline session focusing on decision support applications with dependencies on near real-time observations and derivative data, and other relevant presentations during other sessions of the NDRC. Please refer to the referenced presentations for specific information and details.

Advanced Fire Information System (AFIS)

- AFIS is a wildfire information monitoring and visualization application framework with a global scope developed by the South African Council for Scientific and Industrial Research (CSIR). The application supports integration of any source of data, including near real-time satellite-based active fire detection data and terrestrial-based camera observations and other sources of in-situ information.
- Key ancillary geospatial data/information can also be integrated (i.e. weather observations, fire danger/risk, model outputs and historical fire locations/extent) to provide context and enhance decision-making.

- AFIS interfaces include multiple facets to meet specific user needs, including fusion/integration of geospatial data, SMS/email notifications of fire activity within a defined area of interest, tools to select and manage information to facilitate situational awareness, statistical/reporting information of burned area relative to land cover and area of interest, analytics for satellite data to generate information products, integration of crowd sourced reports.
- AFIS online web viewer for the continental U.S. and South Africa are available at <http://usa.afis.co.za> and <http://southernafrica.afis.co.za>, respectively.
- Android and iOS versions of AFISMobile are also available (<http://www.afis.co.za/mobile>). More than 6,000 users have downloaded as of June 2016.

Monitoring Flood Events with NASA's Near Real-time Flood Mapping Products

- The NASA Near Real-Time Global Flood Mapping discriminates areas of flooding based on automated analysis of near real-time MODIS reflectance data and provides derivative data and mapping and visualization products (<http://oas.gsfc.nasa.gov/floodmap>). Data/products are typically available approximately 6 hours after last daily Aqua MODIS observation.
- Daily NASA LANCE MODIS MOD09 surface reflectance data products covering 223 MODIS tiles are used for processing inputs.
- Daily Terra and Aqua MODIS MOD09 data are compiled as daily composites in standard MODIS tiles, sharpened to 250m resolution and analyzed to detect water. The MODIS cloud mask (MOD35) and cloud (MOD06) products are used to identify and exclude clouds and shadows from the processing/analysis.
- Daily water detection results are verified and re-verified using iterative analysis of composited detection results from the subsequent two days resulting in three possible near real-time products based on recent observations (single day product from observations for the current day, two day composite product from observations for the current day and yesterday, or three day composite product from observations for the current day and the two previous days). In good observation conditions (relatively cloud-free), one or two day results are reliable. In persistent cloudiness, three day results can reduce the likelihood of false positives.
- Validation of flood products is based on ability to correctly detect visibly obvious water and if there are observable differences between flood waters and normal/permanent water levels.
- Validation efforts are conducted using previous flood events throughout the world in various biophysical settings that offer high quality MODIS and Landsat imagery during normal and flooded conditions.
- Classification results can be impeded by waters occluded under forest canopy and confusion in detection results from terrain/cloud shadows and barren/volcanic rock. The latter is being addressed by filtering with land cover data through the development and implementation of terrain shadow modeling and geometric

projection of cloud shadows. A refined static reference water layer is in development that identifies ephemeral water extent and can be used to discriminate seasonal flooding.

- The leads of this application at NASA Goddard Space Flight Center (GSFC) are currently investigating the possibility of NASA LANCE adopting the daily flood mapping data processing and product generations. They are also investigating the integration of radar observation data from Sentinel 1 (cloud penetration) and reflectance data from Landsat and VIIRS. Suggestions were also made and discussed at the NDRC regarding the feasibility of integrating MAIAC derivatives into the flood mapping procedure (i.e. cloud mask, dynamic land/water/snow mask, etc.).
- Potential synergies to consider with integration of flood mapping approach at direct readout facilities include institutional knowledge to evaluate seasonal water layers and derived flood products, relatively lower latencies (may reduce availability times by several hours), regional customizations/optimizations for water detection algorithm to improve accuracy.

Integration of Satellite Remotely Sensed Data in Operational Crop Assessment Decision Support Systems

- The US Department of Agriculture (USDA) International Production Assessment Division (IPAD) collects and analyzes global crop production and status to compile monthly agricultural supply and demand reports (<http://www.usda.gov/oce/commodity/wasde>).
- Satellite remote sensing observations in the context of ancillary data/information are critical for developing reliable forecasts on a global scale on harvested area, yield, and production. The MODIS Global Agricultural Monitoring (GLAM) Production System (<http://glam1.gsfc.nasa.gov>) developed by NASA in conjunction with the USDA provides MODIS global NDVI and surface reflectance data from 2002 to present. Ancillary data/information products essential to crop monitoring and also extracted from satellite observations include precipitation (TRMM and GPM), soil moisture (Soil Moisture and Ocean Salinity [SMOS] and SMAP) and evapotranspiration (MODIS and Landsat).
- USDA decision support applications integrate GLAM data to query, visualize, stratify and extract by land cover/crop types, geopolitical units and crop reporting districts to support reporting requirements and to conduct within season time series analyses to assess forecasted crop yields. Derived information is used to assess the current seasons forecast yield to previous year's data.

Land Discipline Observations and Recommendations

The following summarizes observations of relevance to the land discipline identified during the NDRC and recommendations.

Advocate for Near Real-Time Capabilities on Future Satellite Systems

Representatives from the direct readout user community need to have a voice to promote

the availability of direct broadcast capabilities on future moderate resolution observation assets operated by NASA, NOAA and international space agencies.

If direct broadcast capabilities for planned missions are not feasible, at a minimum, space agencies must provide low latency access to higher level products derived from mission data streams, such as NASA LANCE. For example, although direct broadcast capabilities are not available onboard, near real-time data products from Sentinel 3A/3B sensors will be provided in 3 hours or less via European Space Agency (ESA) Data Hubs.

Increase Collaboration to Utilize New and Evolving International Missions

There is a need to assess and monitor new and evolving satellite missions that may be utilized for near real-time applications by all disciplines and support continuity in observations. Ongoing communication with space agencies (JAXA, ESA, ISRO, etc.) is necessary to coordinate and identify pathways to access and leverage products from these missions via direct broadcast or low latency data streams.

Current examples include 1) the ESA Sentinel 3 constellation with the first of two missions launched in February 2016 and a second mission to be launched in early 2017; and, 2) the JAXA Global Change Observation Mission – Climate (GCOM-C1) to be launched in late 2016. The Ocean and Land Color Instrument (OLCI) and Sea and Land Surface Temperature Radiometer (SLSTR) onboard the Sentinel 3A/3B platforms and the Second-Generation Global Imager (SGLI) on GCOM-C1 can augment the capabilities provided by NASA/NOAA assets to provide near real-time observations and derivative products for land, ocean and atmosphere variables (ocean color, ocean and land surface temperature, chlorophyll concentration, active fire detection and characterization, vegetation condition, cloud properties, etc.).

Increase Coordination between the NASA Direct Readout Laboratory and NASA/NOAA Missions

The NASA DRL has coordinated with EOS science teams over the past 16+ years to develop and implement science processing algorithms/products in the direct readout processing environment. Their technical capability and institutional knowledge should continue to be leveraged to enhance the capability of Suomi-National Polar Orbiting Partnership (S-NPP) and Joint Polar Satellite System (JPSS) missions, other NASA or NOAA missions, and relevant international missions to provide low latency data products to meet the needs of end users and decision support systems.

Continued NASA DRL coordination with current and future missions will support the flexible implementation of science sanctioned algorithms into the direct readout processing environment and maintain continuity of science products with future missions. Recent and current relevant examples of the benefits of this coordination include 1) NASA DRL collaboration with the MODIS science team to develop and implement the VIIRS versions of the current version of MODIS science algorithms to maintain the continuity of the science data record for near real-time applications; and 2) ongoing NASA DRL coordination with the SMAP science team port SMAP algorithms into a near real-time environment and support the availability of higher level SMAP data products at relatively low latencies through NASA LANCE. The latter of these examples also demonstrates

how direct readout technologies can be leveraged to improve quality and expand the availability of products in near real-time data dissemination portals.

Additionally, data post-processing, extraction and enhancement technologies developed and maintained by NASA DRL can be extended to support more mission data products. This will enable end users to access and more effectively leverage science data products in user-friendly formats that can be ingested into decision support system frameworks.

Continuity of MODIS/VIIRS Observations

Since 2002, continuity of morning and afternoon MODIS observations have been provided by Terra and Aqua missions. Barring an unforeseen failure, it is anticipated that Terra's orbit will be maintained until 2021 when its equatorial overpass time and orbit altitude will begin to degrade. The VIIRS instruments are identified to provide continuity from observations and data products established by legacy EOS MODIS instruments.

The JPSS-1/VIIRS mission is scheduled for launch in March 2017 followed by JPSS-2/VIIRS in 2021. JPSS-1 will not be in a morning orbit. It will be in an afternoon ascending orbit 8 days out of phase to S-NPP/VIIRS and at a similar overpass time. This situation jeopardizes the ability of near real-time decision support applications to provide multiple, temporally dispersed observations on a daily basis and also presents the possibility of a potential long term continuity gap in calibrated morning observations and science data products (i.e. legacy Advanced Very High Resolution Radiometer [AVHRR] sensors on METOP platforms do not have inter-mission calibration requirements and do not afford the robust spectral and spatial observations provided by MODIS and VIIRS).

Integration of Social Media into Near Real-Time Decision Support Systems

Decision support systems for monitoring hazards, ecosystems, human health, etc. can benefit from instantaneous feedback mechanisms afforded by social media. Systems that integrate social media feedback channels can leverage "crowd sourcing" to corroborate observations and forecasts compiled from based near real-time remote sensing data. Integration of qualitative information "from the ground" reported via messaging (tweets, postings, etc.) and documented through other mediums (e.g. photos, videos, etc.) provide context and increase the value of quantitative data and products provided in near real-time decision support systems, particularly for rapidly evolving events.

Foster Ongoing Communications in the Near Real-Time Community

In the context of rapidly changing technologies and capabilities, face to face meetings held every 2-3 years are too infrequent for near real-time application practitioners and end users to stay current. Additionally, due to various constraints, these forums cannot be attended by all interested persons.

As an outcome of NDRC, it is recommended that NASA and NDRC discipline leads collaborate to foster opportunities for continued communication activities between conference events to support the exchange of technologies and ideas among the global near real-time application, decision support and end user community. This can be provided in the form of ad-hoc or regularly scheduled virtual workshops focused on mission updates, development of new and/or refined algorithms, calibration/validation

activities, new and/or evolving decision support systems, etc.

Oceans/Freshwater Discipline Overview

The third day of the conference (Thursday, June 23rd) was devoted to ocean and freshwater discipline topics in addition to a few cross-cutting topics. The topics covered included: VIIRS Day/Night Band (DNB) applications, the Sentinel 3 mission, SeaDAS software, fisheries applications, NOAA VIIRS ocean color products, and monitoring for ecosystems and human health.

Of the 190 registrants, 50 expressed an interest during registration in the ocean/freshwater discipline.

Points for Further Consideration

In summary, the following points were raised during the conference for further consideration.

1. Future Sensors: Desired Characteristics

Direct broadcast

Direct broadcast capabilities are under consideration for future Sentinel missions and PACE; the direct readout community needs to be at the table to help inform the decisions.

Geostationary sensors

Data at high spatial resolution and at least daily temporal resolution are desired.

High spatial resolution

This is required to resolve events in small lakes and tributaries.

Timeliness

This can help capture an event before it progresses (for example, some organisms multiply by the hour).

2. VIIRS Day-Night Band (DNB): Recommendations for Future Work

Enhanced study

The VIIRS DNB is performing above spec; this should be widely advertised and more attention paid to potential DNB applications.

Improved corrections

Improved corrections for lunar illumination, stray light, twilight, nighttime geolocation, terrain, lunar BRDF, cloud effects, and aurora effects are needed.

Validation

More *in situ* validation is necessary for the DNB products.

3. Satellite Data: Ease-of-Discovery, Ease-of-Use, and Documentation

Citizen scientists

Satellite products need to be easily discoverable, useable, and understood by citizen scientists.

Requested documentation

Documentation describing the differences between the various NOAA and NASA VIIRS ocean products (and data formats) would be very helpful for end-users.

Standard data format

It was suggested that adopting a standard format for the satellite products would increase usage and enhance collaboration.

VIIRS Day-Night Band (DNB)

Major objectives of DNB products are to develop recommendations for more effective energy usage, reduce energy poverty, and increase energy accessibility.

The DNB is currently being used for: detection of unreported fishing activities from vessel lights (Asanuma), detecting bioluminescence, detecting lights from industrial processes (e.g. fracking), classifying land use in cities, monitoring seasonal variation in light usage (esp. holidays), mapping energy patterns, mapping culture from space, mapping "energy poverty", and mapping disaster power outages ("NASA Scientists can measure the EKG of a City" – Smithsonian Magazine). While the DNB can also detect fires, it is not the optimum source for that information (rather the AF product should be used). Issues that need to be tackled to improve DNB products include: lunar illumination, stray light, twilight, nighttime geolocation, terrain correction, lunar BRDF correction, aurora effects, and validation. The DNB is performing well above spec. The capabilities of the DNB should be widely advertised to ensure that the scientific community is poised to utilize the data to their full potential.

Sentinel-3

Sentinel-3A was launched Feb 16, 2016. It includes the OLCI (Ocean and Land Color Instrument) that provides estimates of products including SST, HABs, mean sea level, LST, fires, and aerosols with a revisit time of 2 days. The OLCI has more bands and higher spatial resolution than MERIS. There is no direct broadcast capability, however the goal is to provide L2 products within 3 hours of collection. Sentinel-3B is expected to be launched in late 2017. Sentinel-3B also does not have a DB antenna, but can download partial dumps to improve timeliness. However, this requires the use of 5-6 meter antennas. It is recommended that the direct readout community take part in these discussions.

Fisheries

Principle aspects of fisheries are: 1) harvesting, 2) stock assessment, and 3) management and conservation. NRT ocean color data are needed for: optimizing harvesting, optimizing assessment surveys, detecting and monitoring harmful algal blooms, and dynamic ocean management (making forecasts). Currently fisheries products utilize 8-day and monthly data, not direct readout data. Monthly composites have the advantage of looking better (fewer cloud gaps) than daily data. It is difficult to sell the utility of daily satellite data to managers. Fisheries wish list:

- Geostationary data (daily coverage) – to improve spatial coverage (cloud-free areas) on shorter timescales

- A common time-step for various products to simplify temporal composites
- Better spatial resolution for sea surface height (SSH) and salinity
- Coastal SSH products
- Frontal products
- Free access to SSH data

Monitoring for Ecosystems and Human Health

Decision makers need information the day of the event. The data need to be easily accessible, understandable by the end user, and trusted. Warnings are based on probabilities and short-term predictions.

Requirements:

- High spatial resolution - Need to be able to resolve small lakes
- Timeliness - Organisms multiply by the hour

Algorithms

VIIRS ocean algorithms

Confusion was expressed regarding the differing VIIRS chlorophyll products available from NASA and NOAA; several different algorithms are in use. Documentation describing why the different flavors exist, what their differences are, and which should be used in which situation would be helpful.

VIIRS data format

The VIIRS data products differ in file format depending on whether they originated from NASA or NOAA. To increase the utility of the data and enhance collaboration, it was suggested that a standard data format be adopted. Based on this feedback from the community, the NASA DRL Team is evaluating approaches for establishing seamless interoperability between the NASA VIIRS L1 and operational NOAA VIIRS data. One possible solution is a converter to transform VIIRS L1 output to the VIIRS SDR format.

SeaDAS algorithm submissions

Some conference attendees were unaware that algorithms can be submitted to the NASA Ocean Biology Processing Group for possible inclusion in SeaDAS. It was recommended that this option be more widely advertised.

Conclusion

In summary, three key topics became major foci during the oceans/freshwater discipline discussions. These included: (1) the necessary characteristics required for future sensors to address critical issues; (2) the unexpected high quality and results from the VIIRS day-night-band and its products; and (3) the importance of data discovery, ease-of-use, and documentation. This overview provides specific recommendations from the oceans and freshwater communities on each of these topics. Note that on the surface these issues are cross-cutting. It is recommended that each of these topics be considered for further evaluation and action by the broader scientific community to the benefit of all disciplines.

Atmosphere Discipline Overview

The fourth day of the conference (Friday, June 24) was devoted to atmosphere topics in addition to a few cross-cutting topics.

Of the 190 registrants, 50 expressed an interest during registration in the Atmosphere discipline.

Points for Further Consideration

In summary, the following points were raised during the conference for further consideration.

1. Data Product Formats

Participants expressed concern over the emerging situation where two product formats and two processing packages would be available for VIIRS, that is: the processing package and format being used operationally by NOAA for their NRT dissemination and the CLASS archive; and the newly-developed processing package and format developed for NASA science applications. Both processing packages will be made available to the DB community. Specific concerns included:

- Any format change has an impact on the user side, and the impact comes with a cost in the short term. There must be very good arguments for changing format to justify the short-term costs.
- Two different formats for the same product suite may act as an obstacle to cooperation, splitting an otherwise potentially united user community in two.
- Potential collaborators would need to address format differences before they can share science.
- Depending on the processing package I use, my products would differ from those available at the NOAA CLASS archive.

2. Direct Broadcast Capability on Sentinel Satellites

Sentinel-3 satellites do not have Direct Broadcast capability. Sentinel-3B has already been built; it does have the capability for multiple downlinks of stored data per orbit, but reception would require a larger antenna (e.g., 5 or 6m). It is hoped that the Direct Broadcast capability may be reinstated on future Sentinel satellites.

3. FY-3 Downlink

The Chinese FY-3 Polar Orbiting Meteorological Satellites are now part of the EARS network, with FY-3C being the latest in this family of satellites. The Direct Broadcast in X-band from the FY-3 satellites makes use of either Right Hand Circular Polarized (RHCP) or Left Hand Circular Polarized (LHCP), with FY-3D foreseen to use RHCP and FY-3E foreseen to use LHCP. As many DB reception stations, including the EARS network, currently are limited to the reception of RHCP, EUMETSAT is seeking clarification on the matter of RHCP/LHCP through CGMS. If the China Meteorological Administration (CMA) maintains the foreseen

usage RHCP/LHCP, then EUMETSAT will upgrade the antenna feeds at the core European stations to support both RHCP and LHCP. Alternatively, if CMA would standardize on RHCP, the EARS antennas and many other existing antennas would be compatible with the FY-3 polarisation as is.

4. Limb Sounders

Most of the instruments we fly are mappers, but we sometimes need profilers. For that you need Limb sounders. There is a timeline gap in this type of instrument.

5. Measuring CO from Space

There is a need for measuring CO from space. A recent decision was made where a CO instrument was decided against.

6. Risk of Flying Product

Suggested new decision support product: "risk of flying." For example, with volcanic emission, how much volcanic ash would be too much, and how would you create a statistical product? Who interprets risk? Now just trying to figure out what impacts flying, e.g., ash, SO₂, and at what concentrations, etc.

7. Microwave Imager

Propose microwave imager on upcoming satellite(s).

8. IMAPP

Funding needed to continue IMAPP development beyond 2017.

Presentation/Workshop Summaries

Summaries of NDRC presentations and workshops based on submitted abstracts and supporting information are provided below. Complete Presentation and Workshop slides are available via the DRL Web Portal:

<https://directreadout.sci.gsfc.nasa.gov/?id=dspContent&cid=244>

Tuesday, June 21, 2016 – Crosscutting Science and Technology

LATUV Presentation - Jose Luis Casanova (LATUV)

The aim of this presentation is to show how a laboratory without external support could take advantages by using readout data and carry out interesting and fruitful projects, providing useful products for the society.

In 1991, we bought our first National Oceanic and Atmospheric Administration (NOAA) receiver from the University of Bradford, UK. It was a very cheap receiver because at the beginning it was moved by hand since it had not a motor driving the horn. Looking for an operational application of this receiver, we found a problem to be solved: forest fires are one of the most destructive environmental problems in the Mediterranean countries. At that time, any help was welcomed by the forest fire services and we provided them with a forest fire risk and fast forest fire detection system, both of them based on earth observation. That was the first step on a long way on the field of forest fires.

After the first contract, we participated in some European projects on this topic funded by the European Space Agency (ESA), and others funded by Local, Regional and National Governments. In addition to that, we spread our field of activities but always looking for operational projects to be able to provide useful services. We did not forget our academic activities, participating in Conferences, Symposia and publishing numerous papers which gave us more than 20 PhD degrees, but never forgetting our main idea: to be useful to our society by means of direct and operational services.

Fishing, crop forecasting, insurances, forest monitoring, weather forecast, and flooding are some of the issues we were dealing with. Moderate Resolution Imaging Spectroradiometer (MODIS), Suomi NPP, Feng Yun, MetOp and MSG receivers have replaced our early NOAA receiver, and we maintain a large archive of daily images.

As a result, the Laboratory of the University of Valladolid (LATUV) has accomplished more than 200 projects and contracts over the last 25 years, published around 300 papers and communications, prepared a lot of young students currently working in large companies or having their own company, etc. And all of these successes have been possible thanks to the direct readout data. Finally, we encourage everyone to take advantage of the broadcasting services in the confidence that thanks to them you can generate enormous services to society.

The Earth Observation Activities at INTA - Eduardo de Miguel LLanes (INTA)

The National Institute of Aerospace Technology (INTA) is a Public Research Institution focused on aerospace research and technology; it is part of the Spanish Ministry of

Defense. Its goals include research, development and the definition and management of large programs, mainly (but not exclusively) within the field of aerospace technology. This diversity of goals hosts a diversity of activities in the field of Earth Observation, with a few of them relevant for Near Real Time applications. The activities reviewed in this presentation are:

- Airborne remote sensing, which is currently based in hyperspectral imagers (Airborne Hyperspectral Scanner [AHS] and Compact Airborne Spectrographic Imager (CASI)) and where INTA offers a full service from flight planning to delivery of level 2 products
- Specific programs at the Canarias Space Center (CEC-Maspalomas), including CREPAD, E-PAC, SPOT DRS, and EARS
- The ground segment for the Spanish missions Paz and Ingenio
- Developing software for image processing, mission simulators and ground segment prototypes

Other Earth Observation activities at INTA include defense programs, atmospheric research (with ground-based, airborne, balloon or satellite instrumentation) and the development of an airborne Synthetic Aperture Radar (SAR). Engineering tasks for Earth Observing payloads are also performed at INTA, chiefly the SEOSAT-Ingenio AIV, and the development and operation of the Apis camera onboard the OPTOS cubesat.

These activities are scattered through different departments and units, with the INTA web site (www.inta.es) the best way to address a specific activity.

Two activities relevant for the Near Real-time (NRT) community might serve as sample of INTA capacities:

- INTA is a partner of the EUMETSAT/EARS service. In this service, data from EUMETSAT and NOAA polar-orbiting satellites are relayed to the EUMETSAT center in Darmstadt with a timeliness suited to the needs of European operational short-range regional weather prediction models (<15 min). The INTA EARS service made the first transmissions in October 2002, relying only NOAA-ATOVS sounder data. In 2005 this service started to include AVHRR data from NOAA satellites. In 2006, after the launch of the first METOP, the service was extended to ATOVS, AVHRR and ASCAT from METOP. In 2012 it started Suomi-NPP and FY3A and FY3B satellites acquisitions to support new regional services like EARS-VIIRS.
- INTA SEOCFI tool is a software suite for direct georeferencing of remote sensing images from orbital data and a sensor model. It is based on ESA's Earth Observation Mission CFI SW (EO-CFI), a set of C libraries with functions for solving orbital and satellite pointing problems. The tool includes auxiliary routines for orbit propagation, attitude computations, TM processing and others. SEOCFI is intended for mission performance analysis and for alternative processing methods at user side; for example those demanded by near real time applications.

EOS and SNPP/JPSS-1 Mission and Instrument Update - Patrick Coronado (NASA)

EOS Direct Broadcast/Direct Readout operations are considered an important part of the world-wide EOS Ground System. All EOS missions are older but continue to operate well and provide great science data: Terra (16+ years), Aqua (14+ years), and Aura (12+ years). EOS missions are projected to last for many more years (estimates are approximately another 6 to 9 years). Both Terra MODIS and Aqua MODIS and their on-board calibrators continue to operate and function normally. Dedicated effort by the MODIS Characterization Support Team (MCST) and Science Data Support Team (SDST), and support from science algorithm developers, remain critical to MODIS instrument calibration/data product quality. Challenging issues identified for both MODIS instrument calibration will be investigated and addressed for future improvements of data processing/reprocessing.

SNPP Visible Infrared Imaging Radiometer Suite (VIIRS) on-orbit performance (4.5 years) has become very stable. Effort from the VIIRS Characterization Support Team (VCST) is vital in support of Science Investigator-led Processing System (SIPS) for producing the improved and consistent VIIRS data products. Multiple and major instrument calibration activities in the coming year will be more challenging for both MCST and VCST.

NASA Science Roadmap - Tsengdar Lee (NASA)

This presentation included an on-orbit constellation overview; a review of upcoming launches and mission development; Venture Class status, plans and schedule; and plans for sustained land imaging. NASA's Earth Science Division (ESD) has four major thrusts: Research, Flight, Applied Sciences, and Technology. Applied Sciences includes wildfires and disasters applications. A breakdown of the ESD FY15 budget was presented, showing that 58% was devoted to disciplinary and interdisciplinary sciences. Status of current missions and upcoming missions was reviewed, with emphasis on the In-Space Validation of Earth Science Technologies (InVEST), an on-orbit technology validation and risk reduction program for small instruments and instrument systems that could not otherwise be fully tested on the ground or airborne systems. Venture-Class missions complement the systematic missions, and provide flexibility to accommodate scientific advances and new implementation approaches. Future missions will include more small satellites, providing opportunities for the Direct Readout community to leverage these missions, including developing strategies for collecting data from multiple satellites to create data products. Sustained land imaging, including future Landsat satellites, has been budgeted through 2035.

NASA Direct Readout Laboratory (DRL) - Patrick Coronado (NASA)

NASA, as a science research organization, has developed space-borne remote sensing instruments and corresponding science algorithms to measure and quantify geophysical parameters for use in understanding and quantifying climate change. Many of these algorithms developed by the Science Investigator-led Processing System (SIPS), are applicable for real-time regional applications. In support of these real-time and near-real-time applications the DRL, acting as the implementation arm of the NASA DR program, has been bridging the gap between NASA science and end-user applications, thereby

developing support technologies and porting science algorithms to function in a DR environment for application users. Through the use of near-real-time data obtained from internet-based data centers and from the DB systems on the EOS and SNPP satellites, real-time environmental data are made available on a continuous basis world-wide for ready data processing given the following three elements necessary to render useful products by the general application user: instrument specific algorithms with data processing tools to handle a live data stream; data product formatting or data transport tools; and product distribution mechanisms for decision support systems enabling the use of space-borne remote sensing data for real-time applications. The NASA DR model has identified key technology categories that the DR end-user would have to contend with in order to be compliant with a multi-satellite, multi-instrument environment. These categories include: real-time system processing tools (i.e., the International Polar-Orbiting Processing Package [IPOP]), Consultative Committee for Space Data Systems (CCSDS) packet re-assembly and standard data reformatting tools (i.e., Real-Time Software Telemetry Processing System [RT-STPS] and Hierarchical Data Format (HDF) to GeoTIFF Converter [H2G]), instrument-specific calibration and geo-registration algorithms, a Science Processing Algorithm (SPA) wrapping schema for standard system integration and sustainment, and real-time data distribution mechanisms such as Simulcast. NASA has addressed these in the form of specific technologies that are generic in nature and can be integrated into existing or developing DR systems.

Global Observations and Role of Near Real-Time/Direct Readout in NASA Disaster Response Activities - Miguel Roman (NASA)

The NASA Applied Sciences Disasters Program promotes the use of Earth observations to improve the prediction of, preparation for, response to, and recovery from natural and technological disasters. By sponsoring application science, the Program advances the readiness of results to enable disaster management practices, advance damage reduction, and build resilience. The Program targets a spectrum of disasters, including floods, earthquakes, volcanoes, and landslides as well as combined hazards and cascading impacts. The geospatial intelligence and tools on local, regional, and global scales support a community of disaster stakeholders. This is achieved by facilitating timely access to reliable, relevant data and data products, focusing on the utility of information, maps, and models, and ensuring delivery in useable and understandable formats for incident response, emergency management, and recovery teams. The Disasters Program creates partnerships where applied research is necessary for developing and deploying next-generation technology, as well as airborne and satellite assets, while stimulating research and analysis to better understand and describe hazards.

Our research program continually advances new science and low latency observations for situational awareness. New flood and inundation models provide guidance on the extent and depth of water impacts, whether from extreme rain and flash floods, to seasonal storms and hurricanes. Novel earthquake models and maps describe the magnitude and extent of the geophysical impact, as well as aftershock likelihood and the threat of tsunamis. Mapping hotspots for volcano gaseous emissions and ash plumes, oil spills and debris, as well as the extent of dispersion and flows, are also targets of the

program. From utilizing the newest Synthetic Aperture Radar (SAR) satellites for mapping earthquake, flood, and typhoon damage, to repurposing global positioning technologies for infrastructure and coastal monitoring, as well as acquiring visible light and day/night images of disaster zones, our team develops unique capabilities to assess impacts and inform actionable decisions.

When disasters occur, our researchers become providers and distributors of images, data, and damage assessments. The Disasters team and network of partners and volunteers assist with hazard assessment, evaluation of severity, and identification of impacts near vulnerable infrastructure, crops, and lifelines, and—especially in remote areas where observations are sparse—provides guidance for action. From the perennial eruptions of Alaska’s Mount Pavlof, to the 2015 earthquake and landslide disaster in Nepal, our program mobilizes scientists and collaborators to ready new methods of detecting, evaluating, and predicting disasters and their social, cultural, and economic consequences with the goal of reducing risk and strengthening resilience.

NASA Global Near Real-time Environment (LANCE) - Karen Michael (NASA)/Diane Davies (NASA)

NASA’s Land, Atmosphere Near real-time Capability for EOS (LANCE) (<https://earthdata.nasa.gov/lance>) supports application users interested in monitoring a wide variety of natural and man-made phenomena. Global Near Real-time (NRT) data and imagery from the AIRS, AMSR2, MISR, MLS, MODIS, OMI and VIIRS instruments are available much quicker than routine processing allows. Most data products are available within 3 hours from satellite observation. NRT imagery are generally available 3-5 hours after observation. This presentation describes LANCE; its origins, structure and governance as well as providing an overview of products and how these can be accessed. Some Direct Readout stations use LANCE data as a backup in the event of problems downloading data in near-real time. Over the last two years LANCE has seen an increase in the number of users that view and download LANCE NRT products through Worldview (<https://worldview.earthdata.nasa.gov/>). Global NRT imagery can be interactively viewed through Worldview and the underlying Global Imagery Browse Services (GIBS) (<https://earthdata.nasa.gov/about/science-system-description/eosdis-components/global-imagery-browse-services-gibs>).

NASA VIIRS Level-1 - Fred Patt (NASA)

The NASA VIIRS Level-1 Algorithm/Software Working Group (L1ASWG) was formed to develop software and data product formats to support NASA's climate data research requirements. The first release of the software was completed in October 2015 and is operational at all three VIIRS Science Investigator-led Processing System (SIPS). The software has a number of features that also support Direct Readout data processing, and public release of the software is planned.

Volcanic Detection/Air Quality Using OMI and OMPS - Seppo Hassinen (FMI)

Direct Readout products are especially suitable for monitoring of fast evolving hazards, like volcanic eruptions, as well as for other situations when decisions are needed reasonably soon. This talk focused on monitoring of volcanic emissions of ash and SO₂

from an aviation security point of view, as well as give a practical air quality example.

EUMETSAT Operational Hyperspectral Level-2 Products - from Global to Regional Services - Thomas August (EUMETSAT)

The IASI Level 2 (L2) processing chain operated in the EUMETSAT'S Central Facility provides essential geophysical parameters, which are distributed in Near-Real Time (NRT) to the Users via EUMETCast and the GTS. They include vertical profiles of temperature and humidity (T,q), related cloud information, surface emissivity and temperature, and Atmospheric Composition (AC) parameters: carbon monoxide, ozone and several other trace gases.

The version 6 (v6), released in September 2014 (August et al, EUMETSAT Conference 2014), includes a number of algorithm innovations like the synergetic use of collocated microwave measurements from AMSU and MHS enabling sounding in cloudy situations, an advanced all-sky retrieval methodology referred to as PWLR for piece-wise linear regression (Hultberg et August, NASA Sounding Science meeting 2014, ITSC-20 2015) which is used as first-guess to an optimal estimation (OE) and the reconfiguration of the OE with an original channel selection, taking full advantage of principal components analyses (Hultberg et August, ITSC-18).

As a result, the IASI L2 v6 offers unprecedented temperature and humidity sounding capabilities at the IASI footprint resolution in terms of precision and useful yield. This presentation included the performances of the atmospheric and surface products, as assessed during long-term monitoring and validation studies and cooperations. The high quality and yield of the new IASI L2 products is showing potential for different applications and in particular for regional applications where timeliness is critical. Also presented were the plans and status of deploying the IASI L2 processing in a direct broadcast framework to meet the more demanding nowcasting timeliness requirements.

BlueMarble - Vanu Dasgupta (NASA)

The potential of regionally-produced near real-time EOS and SNPP science data products is often not fully realized from the standard research data products. This is due to a lack of available tools that can unlock the unique features that may be derived from these standard products. BlueMarble is an evolving tool that bridges the gap between science data products and end-user applications. It empowers end users by giving them a tool to unlock these unique features, thereby enhancing their user experience as well as extending the utility of their decision-support systems. Within the design of BlueMarble there is special attention given to ease of use and utility of value-added products. BlueMarble features a combination of core utilities (generation of Geographic Information System [GIS] compatible Geotiffs, user-defined projections and resolutions, subsetting and mosaicing, vector overlays, automated data selection based on swath/Region-of-interest overlap determination); specialized algorithms to deal with sensor-specific characteristics or artifacts (e.g., sharpening of moderate resolution bands, dealing with dropouts and bowtie-related issues, addressing interpolation requirements, addressing data quality issues, etc.); and application specific utilities (e.g., overlays of fires or aerosols on background imagery). This workshop included examples of extended

application-specific multi-mission/multi-sensor data products that BlueMarble produces. Also discussed were BlueMarble's capabilities, ease of use, and extensibility.

Wednesday, June 22, 2016 – Real-time Land Science Applications

WORKSHOP: Multi-angle Implementation of Atmospheric Correction (MAIAC) - Alexei Lyapustin (NASA)

MAIAC is a new algorithm that uses time series analysis and processing of groups of pixels for advanced cloud detection and retrieval of aerosol and surface bidirectional reflectance properties. Recent studies showed that MAIAC significantly improves the accuracy of atmospheric correction over northern latitudes and tropics, including the Amazon region, as compared to the standard MODIS surface reflectance products. This discussion provided an overview of MAIAC processing and products with several application examples.

WORKSHOP: SMAP - Vanessa Escobar (NASA)

This workshop included discussion of mission status, post launch applications, and the use of data products by Early Adopters and the Soil Moisture Active Passive (SMAP) mission user community. Now in Phase E of the mission life, SMAP plans to gather lessons learned from its community and get a better understanding of the impact SMAP has in areas of applications. To that effort, Early Adopter case studies are being conducted in weather, agriculture, flood, drought, health and national security to help quantify the value of SMAP data.

WORKSHOP: Applications of Real-time Satellite Precipitation Estimates - Francisco Tapiador (UCLM)

The Global Precipitation Measurement (GPM) mission constellation provides products which are suitable for the near real-time monitoring of extreme hydrometeorological events. This workshop reviewed the applicability of the GPM estimates of precipitation in the land realm.

WORKSHOP: Active Fire - Louis Giglio (NASA ST)/Wilfrid Schroeder (NASA ST)

This workshop covered the latest MODIS Collection 6 and VIIRS active fire algorithms. It also described the MODIS Collection 6 algorithm changes that targeted outstanding commission and omission errors, highlighting improved fire detection performance metrics relative to the Collection 5 algorithm. Two VIIRS active fire products were demonstrated, namely (i) the baseline 750m resolution data set using an adapted MODIS Collection 6 algorithm and (ii) the new 375m product providing higher resolution fire detection data. The workshop also described select regional/global fire mapping and emissions/air quality applications serving the broader user community.

WORKSHOP: Burned Area Mapping and Monitoring Algorithms - Louis Giglio (NASA ST)/Wilfrid Schroeder (NASA ST)

This workshop covered the status of the Collection-6 MODIS burned area product, to be generated using the MCD64A1 burned area mapping algorithm, as well as the progress made in adapting the mapping approach to the VIIRS instrument. A potential path for

developing a true, NRT burned area mapping algorithm optimized for direct broadcast applications was also discussed.

Advanced Fire Information System (AFIS) - Philip Frost (CSIR)

AFIS is a web-based and mobile application for mapping, visualization and monitoring of global active fires, as well as burned areas in NRT from satellite and ground based sensors. Fire danger and weather forecast model output integration/fusion facilitate decision support as well as crowd sourcing through an innovative mobile app linked to an online dashboard.

WORKSHOP: Monitoring Flood Events with NASA's Near Real-time Flood Mapping Products - Dan Slayback (NASA)

NASA Goddard Space Flight Center's Global Flood Mapping project generates near real-time flood and surface water maps from the MODIS and Landsat instruments. These products are freely available, and are also often incorporated into maps customized for the specific event by the Dartmouth Flood Observatory. This workshop described the strengths and limitations of these products, along with the ability to examine the product archive to place current events in context.

WORKSHOP: USDA World Agricultural/Food Security Monitoring - Dath Mita (USDA)

The primary mission of the USDA's IPAD is to collect, analyze, and disseminate global crop production information in a timely and cost-effective manner with scientific backing. This includes monitoring country-specific crop conditions and natural events that cause both biotic and abiotic stresses on crops, such that crop yield, harvested area, and production forecasts of world's main grains, oilseeds, and fiber are updated on a monthly basis. The resulting reports are delivered to the USDA's World Agricultural Outlook Board (WAOB) to be published in The World Agricultural Supply and Demand Estimates (WASDE). The USDA IPAD uses a convergence of evidence approach to generate world crop intelligence, and satellite remote sensing data is one of the most important data sources. It is a challenging task to generate reliable crop forecasts on a global scale on harvested area, yield, and production, but remotely sensed data platform allows us to explore the data and extract useful information. This presentation demonstrated the conceptual and operational approaches of transforming data into value-added intelligence key for data-driven and knowledge-based decision making. The various data sources and customized database and portals that run in the background of IPAD's decision support systems e.g., Crop Explorer, were presented.

The presentation then provided an overview Of IPAD's operational use of GIMMS MODIS Global Agricultural Monitoring Production System and Other Decision Support Systems. The GIMMS MODIS Global Agricultural Monitoring system (GIMMS MODIS GLAM, <http://glam1.gsfc.nasa.gov/>) was developed and provided by the NASA/GSFC/GIMMS group for the USDA/FAS/IPAD Global Agricultural Monitoring project. The GIMMS MODIS GLAM provides consistent and well-organized long-term data, from 2002 to current. The data are easy to query, visualize, and download at multiple spatial scales. The extraction of MODIS-NDVI (250-meter) Time Series cropland data for yield analysis

is discussed based on a case study of wheat cultivation in East China plain, Henan province. The basic protocols of extracting and displaying data and conducting quantitative analysis of observed NDVI values were presented and discussed. We employed a quantitative analysis, a stepwise regression model that involves calculating the area under the NDVI curve to be used as in-season crop condition variables in the regression model to make inference on yield and production during the growing season. Further, the presentation also provided an understanding of how each of the life-cycle stages of wheat plant relates to productivity and how NDVI values are quantitatively used as a "guide" in determining in-season productivity trend(s) and the critical time period(s) for yield. Four wheat growth stages, winter hardening and vernalization, spring growth-development, yield formation and senescing and physiological maturity were discussed in the model.

Thursday, June 23, 2016 – Real-time Oceans/Fresh Water Remote Sensing

Possibility of Day-Night-Band of VIIRS to Detect Fishing Activities - Ichio Asanuma (TUIS)

The possibility of the VIIRS Day-Night-Band (DNB) to detect fishing activities was presented. Light distributions detected by DNB were studied with the vessel locations provided by the Automatic Identification System (AIS), which reports the locations of vessels greater than 300 tons, and the lights from fishing boats. The threshold to detect the lights from the surface background lights, while the Moon and illuminated clouds present, was discussed with the brightness temperature data of M12.

WORKSHOP: Suomi-NPP VIIRS Nighttime Environmental Products for Land Science and Disaster Response Applications - Miguel Roman (NASA)

A new generation of satellite instruments, pioneered by the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB), now offers global measurements of nocturnal visible and near-infrared light that are suitable for Earth science and climate studies. These novel low-light measurements open doors to a wealth of new and expanded interdisciplinary research topics, ranging from urban sustainability, improved weather forecasting, and enhanced climate data records. This talk covered the following core applications areas: fundamental questions and challenges surrounding quantitative nighttime remote sensing; novel capabilities, applications, and algorithms involving VIIRS DNB measurements of interest to the research and operational communities; and temporal studies of night light for change detection.

Sentinel-3 Mission Overview – Susanne Mecklenburg (ESA)

This presentation provided an overview and current status update of the Copernicus Sentinel-3 Mission. The Sentinel missions are a new family of satellites designed to meet the operational needs of the European Space Agency (ESA) Copernicus program. The Sentinel-3A mission was launched by ESA on February 16, 2016. It will be joined by the Sentinel-3B mission scheduled for launch in early 2017. The Sentinel-3 mission carries four instruments. Optical imaging payloads on both platforms include the Ocean and Land Color Instrument (OLCI) and the Sea and Land Surface Temperature Radiometer (SLSTR) to assess ocean color and land surface/vegetation conditions. The topography

mission payload consists of the Synthetic Aperture Radar Altimeter (SRAL) and the MicroWave Radiometer (MWR) used to support the measurement of sea surface and land ice topography. Near real-time Level 2 ocean, land and atmosphere data products from Sentinel-3 will be available from ESA less than 3 hours post-acquisition. Calibration and validation of Sentinel-3 data products is ongoing.

WORKSHOP: SeaDAS 7 for Ocean Data Users - Fred Patt (NASA)

The SeaWiFS Data Analysis System (SeaDAS) is a comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data. While originally developed to support the SeaWiFS mission, it now supports most US and international ocean color missions. The primary focus of SeaDAS is ocean color data, but it is applicable to many satellite-based earth science data analyses. SeaDAS 7 represents the most significant overhaul of SeaDAS in decades. This workshop described the features and functionalities of SeaDAS.

WORKSHOP: Fisheries - Cara Wilson (NOAA)

As a field "fisheries" encompasses not just commercially important fish stocks, but all Living Marine Resources (LRMs), including threatened and endangered species of fish, as well as marine mammals and invertebrates. There are three distinct aspects of fisheries: harvesting, assessment and conservation. This workshop covered all three aspects of fisheries, and discussed how near-real time satellite data are used in these applications.

VIIRS Ocean Color Products from Global Open Oceans and Coastal/Inland Turbid Waters - Menghua Wang (NOAA)

The Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting Partnership (SNPP), which has 22 spectral bands similar to the Moderate Resolution Imaging Spectroradiometer (MODIS), is a multi-disciplinary sensor providing observations for the Earth's atmosphere, land, and ocean properties. This presentation provided some extensive evaluations and assessments of VIIRS ocean color data products, including normalized water-leaving radiance spectra $nL_w(\lambda)$ at VIIRS five spectral bands, chlorophyll-a concentration, and diffuse attenuation coefficient at 490 nm $K_d(490)$ (and at the Photosynthetically Available Radiation [PAR], K_dPAR), over global open oceans and particularly turbid coastal and inland waters. Specifically, VIIRS ocean color products derived from the NOAA Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing system, which is the NOAA official data processing system, were evaluated and compared with those from in-situ measurements, as well as ocean color data derived from Aqua MODIS. Specifically, this presentation showed evaluation results using the Near-infrared (NIR)-based, Shortwave Infrared (SWIR)-based, and NIR-SWIR combined ocean color data processing approaches. Furthermore, to meet requirements from all users, we propose to routinely produce two ocean color data streams, i.e., the NRT data and delayed science quality data. The NRT ocean color data stream has the advantage of quick data turnaround with data latency approximately 12-24 hours, while the science quality data stream has high consistency (with the mission-long data reprocessing) and accuracy of ocean color products. The implementation details for the two data streams were discussed. In addition, we have significantly improved on-orbit

sensor calibration by combining the lunar calibration into the current solar calibration method, showing that it is now necessary to have both solar and lunar calibrations for VIIRS. With the improved data processing algorithms and sensor calibrations, VIIRS mission-long ocean color data were successfully reprocessed in May 2016. Our results show that VIIRS is capable of providing high-quality global ocean color products in support of science research and operational applications.

WORKSHOP: Monitoring for Ecosystem and Human Health - Erin Urquhart (EPA)

This workshop focused on creating an interoperable network for applied and operational use of Direct Readout technology in coastal and inland waters. Topics included potential for mobile application dissemination, oil spill monitoring, inland and coastal Harmful Algal Blooms (HABs), exposure risk applications for municipal drinking and recreational systems, and citizen science. The objective was identifying existing resources, gaps, and next steps toward building networks for water quality.

Friday, June 24, 2016 - Real-time Atmosphere Science Applications

Status and Future Atmosphere Near Real-Time Applications - Allen Huang (UW)/Anders Soerensen (EUMETSAT)/Carlos Cabanas (EUMETSAT)

This presentation provided a summary overview of the current and future atmosphere near real-time applications, including meteorological satellites, instruments and products and their application. The presentation was divided into sections covering the developments in the US, Europe, Russia and China respectively. Starting from the current missions, it provided an outlook to planned future missions and applications.

Atmospheric Composition - Christian Retscher (EUMETSAT)

This presentation highlighted general aspects of atmospheric composition and provided an overview on related main application areas, the role of satellite-based remote sensing in monitoring and forecasting atmospheric composition, and related measurement techniques. Specifically the presentation focused on application areas for stratospheric ozone and air quality monitoring, but further discussed aspects of biomass burning, fire emissions, and volcanic eruptions as well as monitoring greenhouse gases. It concluded with a discussion on EUMETSAT missions relevant to atmospheric composition and provided an outlook on the potential data use for Direct Readout.

EUMETSAT EARS Network – Overview and the New VIIRS Day Night Band Service - Anders Soerensen (EUMETSAT)

EUMETSAT is an intergovernmental organization that supplies weather and climate-related satellite data, images and products to the National Meteorological Services of the organization's Member and Cooperating States in Europe, as well as other users worldwide.

The services provided by EUMETSAT help to enhance and safeguard the daily lives of European citizens. They aid meteorologists in identifying and monitoring the development of potentially dangerous weather situations and in issuing timely forecasts and warnings to emergency services and local authorities, helping to mitigate the effects

of severe weather and protecting human life and property.

EUMETSAT is known as the operator of Meteosat geostationary and Metop polar orbiting satellites and as the provider of global data from these satellites. During the last decade, however, it has also developed systems to provide additional meteorological and oceanographic satellite data to users in its Member States and beyond. These include provision of high timeliness regional data by the EUMETSAT Advanced Retransmission Service (EARS).

The EARS regional data services deliver products from polar orbiting meteorological satellites with a timeliness of 15 to 30 minutes from sensing, through the local processing, collection and redistribution of sounding and imagery data acquired directly from the satellites at a network of Direct Readout stations. This short latency, combined with more frequent observations available from multiple satellites, make products usable for Now-casting (NWC) and Numerical Weather Prediction (NWP) applications over Europe.

EARS reduces errors in NWP models, bringing great benefits to citizens, decision-makers and the weather sensitive sectors of the economy of EUMETSAT's member states. It also adds value in predicting rapidly developing high impact weather up to a few hours ahead (e.g., for air traffic management, sea-ice level navigability, road traffic, and high wind events).

EARS has provided timely polar satellite data from the EUMETSAT Metop and National Oceanic and Atmospheric Administration (NOAA) satellites, comprising eight separate data services: EARS-ASCAT, EARS-ATOVS, EARS-AVHRR, EARS-IASI, EARS-NWC, EARS-ATMS, EARS-CrIS and EARS-VIIRS. A major achievement in 2015 was the integration of the Chinese Meteorological Administration (CMA) FY-3C satellite into the EARS system, which is now providing a new regional vertical atmospheric sounding service (EARS-VASS) from data acquired from the early morning polar orbits at Lannion, Athens, Svalbard, Kangerlussuaq and Maspalomas stations. EUMETSAT is currently preparing the establishment of a sounding service and an imager service based on Direct Broadcast data provided by the FY-3D satellite; launch is foreseen for November 2016.

EUMETSAT EARS Network – the New FY-3-based Service - Carlos Cabanas (EUMETSAT)

EARS has provided timely polar satellite data from the EUMETSAT Metop and National Oceanic and Atmospheric Administration (NOAA) satellites, comprising eight separate data services: EARS-ASCAT, EARS-ATOVS, EARS-AVHRR, EARS-IASI, EARS-NWC, EARS-ATMS, EARS-CrIS and EARS-VIIRS. A major achievement in 2015 was the integration of the Chinese Meteorological Administration (CMA) FY-3C satellite into the EARS system, which is now providing a new regional vertical atmospheric sounding service (EARS-VASS) from data acquired from the early morning polar orbits at Lannion, Athens, Svalbard, Kangerlussuaq and Maspalomas stations. EUMETSAT is currently preparing the establishment of a sounding service and an imager service based on direct broadcast data provided by the FY-3D satellite, which launch is foreseen for November 2016.

WORKSHOP: Nowcasting - PPS Algorithms and Products - Adam Dybbroe (SMHI)

The EUMETSAT Polar Platform System (PPS) is a software package developed in the frame of the Satellite Application Facility for Nowcasting and Very Short Range Forecasting (NWCSAF) providing algorithms and infrastructure for generating cloud and precipitation products from VIIRS and AVHRR data. PPS takes as input VIIRS Sensor Data Record (SDR) data (e.g., as provided by CSPP) and AVHRR data as provided by AAPP. The PPS outputs cloud mask, cloud type, Cloud Top Temperature and Height (CTTH), precipitation (using AVHRR and AMSU/MHS, and only on NOAA/Metop platforms), and cloud microphysical properties. The cloud microphysical properties are the Cloud Phase and Liquid Water Path (official validated products), as well as the auxiliary parameters Ice Water Path, Effective Radius and Optical Thickness. This workshop included a brief description of the science behind the PPS algorithms, familiarized participants with PPS products and how to interpret them, and provided examples of how they can be used in Nowcasting. It concluded with a demonstration of how PPS can be run in a real-time environment.

WORKSHOP: Direct Broadcast Data in NWP - William Bell (UK Met Office)

This workshop covered the use of DB data in regional and global Numerical Weather Prediction (NWP) focusing initially, as an example, on the use of such data in the Met Office assimilation systems. The Met Office currently use DB radiance data from MHS, ATMS, IASI, CrIS and AIRS in their regional NWP system, and both global and locally received data in their global NWP system. This workshop summarized the benefits of various data types for global and regional NWP, and demonstrated how the timeliness constraints imposed by regional NWP drive the need for DB data. In conclusion the workshop considered some of the challenges in using satellite data in regional NWP.

Transition from EOS to SNPP (IMAPP and Next Steps) - Allen Huang (UW)

The International MODIS/AIRS Processing Package (IMAPP) continues to support the EOS Direct Readout community with Terra MODIS and Aqua MODIS/AIRS products and applications software. The Community Satellite Processing Package (CSPP) continues to support the polar-orbiting satellite Direct Readout community with a wide range of software and products supporting Suomi NPP, Metop, NOAA, EOS, and FY-3 satellites. NOAA uses CSPP in its operations, especially for the Alaska and Pacific Region due to latency and bandwidth concerns. CSPP provides sounder data with improved latency to NWP centers. CSPP will include most NOAA enterprise algorithms, where latency is important. CSPP is being prepared for NOAA-20 (JPSS-1) support in early 2017. The next International TOVS Working Group (ITWG) Direct Broadcast workshop is scheduled for March 2017 in Argentina.

WORKSHOP: IMAPP Training Workshop – From Theory to Applications - Kathy Strabala (UW)

The International MODIS/AIRS Processing Package (IMAPP) DB training workshops strive to promote the use of Aqua and Terra DB data for the enhancement of environmental forecasting and decision making. The courses focus on the use of locally acquired data and products from organizations who manage X-band antennas around the

world. The 3-5 day courses include morning overviews of the Aqua and Terra satellite instruments and products, allowing the students to become familiar with the data and theory behind the standard land, ocean and atmosphere science products available through IMAPP, and the strengths and weaknesses of each one. Each afternoon consists of lab exercises where students explore local data sets and applications described in the morning sessions. The final day of the workshop consists of student presentations describing a local investigation on a topic of their choice. In summary, these are hands-on, practical courses focused on teaching the student environmental decision making skills based on remote sensing data. To date, 12 workshops have been taught on 6 continents including students from more than 60 countries, working in coordination with IGARSS, GEOSS, and the WMO.

WORKSHOP: Community Software Tools - Martin Raspaud (SMHI)/David Hoesle (UW)

The Pytroll project comprises almost 20 free and open source python modules to read, analyze, process and write weather satellite data. Users and developers from all around the world are contributing to make Pytroll the go-to python framework for weather satellite imager data. The workshop began by presenting the different Pytroll modules, covering data reading, combining, remapping, and decorating among other things. This was followed by real-world examples (read actual python code examples) on how to perform different weather satellite related tasks, using polar orbiting imager data. Finally, the workshop demonstrated how to batch-process data, as well as how Pytroll is used for stable 24/7 operations at the Swedish Meteorological and Hydrological Institute (SMHI), using message queues for low-latency real-time processing of weather satellite data.

Polar2Grid is an all-in-one precompiled software package that makes it easy to create high quality images from satellite data files with a simple command line interface. Development of Polar2Grid started over 4 years ago to help direct broadcast users with a script for converting VIIRS SDRs in to AWIPS-compatible NetCDF files. Since then, Polar2Grid has grown into an entire python package supporting more than 7 satellite data formats, including Terra and Aqua MODIS HDF4, and more than 4 output data formats while still being usable from a single command line call. Creating 24-bit atmospherically corrected true color imagery involves executing a simple bash shell script and pointing it to the input data files. Recently, the Polar2Grid project has started contributing to and using the open source software created by the PyTroll group. This collaboration will give software developers easy access to all of the features of Polar2Grid in an easy to use set of python libraries, while Polar2Grid will still provide the simplified command line interface to which users are accustomed.

Posters

Poster files are available via the DRL Web Portal:

<https://directreadout.sci.gsfc.nasa.gov/?id=dspContent&cid=244>

The following posters were displayed at the NDRC-9:

- Water-Stress Monitoring of Oak Savanna Woodlands Using Satellite Thermal Data – Maria P. Gonzalez-Dugo (IFAPA)
- Aqua and Terra Direct Broadcast Data in Support of Operational Environmental Forecasters – Kathleen Strabala (UW)
- Comparing Copernicus Emergency Management Service-Mapping with Landsat-based Map from NBR High-level Data Product for Quasi Real-Time Assessing Wildfires Damage – Carmen Quintano (University of Valladolid)
- Recent Developments in Receiving, Processing and Utilizing NRT Meteorological Polar-orbiting Data – Katerina Melnik (ScanEx)
- Polar2Grid: Reprojecting Satellite Data Made Easy – David Hoesle (UW)
- Satellite activities, facilities and Capabilities at NSDC, Finland – Timo Ryyppö (FMI)
- Pytroll: A Python Framework for Weather Satellite Data – Martin Raspaud (SMHI)
- SatPy: A Python Library for Weather Satellite Imagery – David Hoesle (UW)
- MDEO System for Environmental Monitoring in Morocco – Chaker El Amrani (Abdelmalek Essaadi University)
- BlueMarble: A Tool for Bridging Science to Applications – Swarvanu Dasgupta (NASA)
- The Hydrological Cycle of the Amazon Basin: Climatic Impact of Deforestation – Juan Gregorio Rejas (INTA)
- A Warning Malaria Index for Tanzania Based on EO and Weather Modeling – José Luis Casanova (University of Valladolid)
- Comparison of SMAP-Derived Soil Moisture Products for Near Real-Time Root-Zone Soil Moisture Estimation – Nilda Sánchez (University of Salamanca)
- Retrieving and Broadcasting Near-Real Time Biophysical Parameters from MODIS And SEVIRI Receiving Stations at the Global Change Unit of the University of Valencia – J.A. Sobrino (University of Valencia)
- Timely Information for Frost Impact Mitigation from MODIS Aqua and WRF NWP Forecasts – Maungu Oware (RCMRD)
- A Satellite-based Water Quality Information Service for Lake Victoria – James Mumina (RCMRD)

- Daily Assessment of Geometric Errors with Advanced Himawari-8 Imager (AHI) In 2015 – Wataru Takeuchi (University of Tokyo)
- The IMAA Satellite Direct Readout Station: Twenty Years of Research Activity – Teodosio Lacava (CNR-IMAA)
- Ground and MODIS GPP 8-d Products: Inter-comparison Results on the Upper Spanish Plateau (Spain) – Maria Luisa Sanchez (University of Valladolid)
- Efficient Prediction of Total Ozone in Column Based on SVR algorithms, Suomi NPP Data and Numerical Models – Julia Sanz (University of Valladolid)
- Monitoring Estuarine Salt Crusts Using Hyperspectral Data (River Odiel, SW Spain) – Jorge Buzzi Marcos (IGME)
- Global View: A Testbed Environment for Near Real-time Quality Monitoring and Algorithm Development – Kelvin Brentzel (NASA)
- The University of Oviedo's MODIS Reception Antenna: Real-Time Weather Products – Carmen Recondo González
- MODIS Reception Antenna at the University of Oviedo (Spain): Online Free Products and Services Related to Forest Fires – Carmen Recondo González
- Large Scale Monitoring of Short-term Topsoil Organic Carbon Variations Using Sensor MODIS – Carmen Recondo González