Minutes v1.0
LSI-VC-10 Teleconference #1: CARD4L and the Product Family Specifications

12 May 2021

Participants

Catalyst (PCI):	Wolfgang Lueck
CEO:	Marie-Claire Greening
CSA:	Paul Briand
DLR:	Martin Bachmann
ESA:	Ferran Gascon
EC/JRC:	Peter Strobl
GA:	Adam Lewis
IEEE:	Chris Durell, Brandon Russell
ISRO:	Manju Sarmu, Vinod Bothale, Keerthi, Radhika, Raghavender N, Santhi Sree, Anjani, Saritha PK
JAXA:	Takeo Tadono, Ake Rosenqvist, Yukio Haruyama
KARI:	Seok Weon Choi, Daehoon Yoo, Dong Han Lee, KW Jin
LSI-VC Sec:	Matt Steventon, Libby Rose, Stephen Ward
NASA:	Andy Mitchell, Chris Lynnes, Bradley Doorn, Ed Armstrong, Jim Irons
SEO:	Brian Killough
UK Catapult for UKSA:	Electra Panagoulia
USGS:	Steve Labahn, Chris Barnes, Steve Covington, Chris Barber

The presentation slides compiled for this meeting are here and also attached in Appendix A.

Introduction

Adam Lewis (GA, LSI-VC Co-Lead) and Steve Labahn (USGS, LSI-VC Co-Lead) welcomed everyone to the first of four teleconferences that make up the virtual LSI-VC-10 meeting. This call is focused on CARD4L and the Product Family Specifications (PFS). LSI-VC will consider endorsement of the new Aquatic Reflectance CARD4L PFS and then hear about updates to the Normalised Radar Backscatter and Polarimetric Radar PFS, as well as the status of some other in-development PFS. LSI-VC will then hear from participants on the latest plans of CEOS Agencies regarding CARD4L assessment and production.

Matt Steventon (LSI-VC Secretariat) presented an overview of the agenda and an update on CARD4L assessment progress on behalf of Medhavy Thankappan (GA). Matt acknowledged that the peer review process is progressing slower than planned and this was discussed at the last monthly LSI-VC teleconference:

- *At a minimum the CARD4L assessment process takes 12-14 weeks, but lately this has been in excess of 18 weeks turnaround. Need to explore options for accelerating the process, as a long turnaround presents problems for data providers (e.g., hinders any necessary adjustments to work flows / product development). Need to streamline, at least for the threshold level perhaps.*
- *The assessment workload for WGCV is high and perhaps unsustainable. It was suggested that for the threshold level assembling the peer review panel is perhaps not necessary. Instead, this might be handled by the single WGCV POC alone, through self-declaration and one-on-one discussions.*

Medhavy plans to use the opportunity of the WGCV-49 meeting (June 29 – July 2, 2021) to propose a more streamlined peer review process in an attempt to address the slow turnaround issues.

Discussion

- Brian Killough (SEO, NASA) agreed that the review process is a bit slow at present and supported the idea of a streamlined peer review process.
- Adam Lewis (GA) questioned why ESA's Sentinel-2 Surface Reflectance (SR) submission is being 'partially' assessed at the Threshold level. Matt noted that the submission is known to not currently meet one of the specification parameters and hence is being reviewed as Threshold minus this one parameter. Action is underway at ESA to address this missing information (DOI), after which the assessment will be rapidly re-assessed to confirm a full Threshold status. This process was agreed to accelerate the assessment by working in parallel. Adam suggested that this approach should not become common.
- Manju Sarmu (ISRO) agreed that the peer review process should be streamlined. Vinod Bothale (ISRO) followed up by saying good progress has been made by ISRO and their preliminary self-assessment is underway.
- Steve Labahn (USGS, LSI-VC Co-Lead) asked for clarification on the progress of the v5.0 SR and Surface Temperature (ST) assessments submitted by USGS in August 2020. Matt responded that there is one response pending from a panel member, and the decision will not wait until the WGCV-49 meeting. Steve reinforced his previous comments that the process needs to be streamlined to ensure that datasets remain up-to-date with future revisions of the PFS, which could happen annually.

Endorsement of the New Aquatic Reflectance CARD4L PFS

Chris Barnes (USGS) presented details of the new Aquatic Reflectance (AR) CARD4L PFS. The team is looking for endorsement of the PFS from LSI-VC-10.

Discussion

- Chris Barnes noted that the team tried to make sure the PFS was not a 'wishlist' from the aquatic community, and hence they would like to get feedback from the broader community to make sure the threshold level is achievable. To aid this process, USGS intends to perform an informal assessment of their own aquatic reflectance product to get an understanding of how achievable it is. Adam reinforced that the value of the PFS has to be questioned if it is not achievable. Steve Labahn noted that the discussion has highlighted some concerns that the teams have already had, and there are a few items in the PFS that might be hard to achieve.
- Ake Rosenqvist (JAXA) suggested that, when conducting the annual review, it is easier to move something from threshold to target, rather than the other way around. It is easier to relax the requirements. Steve Labahn commented that the team is uncertain as to which requirements are potentially set too high at the moment, and that further input from data providers is required. Ake reflected on his own experience when developing the radar PFS, noting that it wasn't until the PFS were released that data providers were able to comment on which specifications were difficult to reach. He also commented that the team should think about what is really necessary for the product (threshold), compared to what is good to have (target). Adam Lewis agreed with these points, noting that the LSI-VC has a leadership role in the field, and that the group should agree on the principles that Ake has discussed and to articulate them as guidance. Ake noted that a discussion on

"Inclusivity vs Scientific Rigour" is scheduled for teleconference #3, which might provide further discussion on this topic.

- Adam Lewis suggested that before the PFS is endorsed, it needs to be clear that it is achievable. Without knowing whether the PFS is achievable the team may be setting a research agenda, which is not the role of the LSI-VC. Threshold should be what is required by the user community, but also achievable.
- Chris Barnes asked whether it would be worth going back to the AR PFS group to ask if they can add some notes to new requirements, in order to provide evidence of the achievability. Steve Labahn suggested that we could ask for literature or other evidence to support the achievability of the requirements.
- Ake Rosenqvist suggested that before endorsement, the team could produce sample products that meet the requirements. This would confirm they are achievable and sensible.
- Ferran Gascon (ESA) asked about the status of the Landsat 8 provisional AR product and whether the compliance with these requirements has already been checked. Chris Barnes and Steve Labahn responded by saying they have yet to commence an assessment, but will do so in the next couple of weeks.
- Steve Labahn reinforced that the PFS needs to be broadly achievable, beyond one algorithm or data provider.
- Adam Lewis commented that the targets could be things the user community would like, and which may be achievable with technology developed soon, but are not achievable yet. The threshold would be what is achievable today that would make it more useful for a broad user community.
- Ferran Gascon reinforced the idea of creating a provisional product, such as the Landsat 8 product. He suggested that the provisional product should be checked against the threshold requirements before publication of the PFS. He also noted that ESA is still far from having a similar product.
- Steve Labahn questioned the expectation of provisional product development before the endorsement of a PFS. He noted that quite a bit of development work and a large team would be required for USGS to produce a provisional product before the PFS is endorsed.
- Manju Sarma (ISRO, NRSC) asked in chat: "*What kind of scientific feedback do you get from the community? How many really participate in the feedback? How do you motivate people to give feedback?*" Response from Steve Labahn: "*Great question, Manju sarma. The initial candidate list of science expert review panel members was generated from input from the CEOS members and from those who have been participating in LSI-VC. Then, that candidate list was engaged and asked for additional members in their communities (aquatic reflectance in this case) who were interested and willing to actively participate. Notably, it does initially draw from active CEOS participants, but the intent/desire is to be as inclusive as possible.*"
- Chris Barnes clarified that only evidence for the feasibility of new requirements (that is, not those inherited from the already endorsed SR PFS) would need to be provided.

LSI-VC-10-01	Chris Barnes to consult the team responsible for the Aquatic Reflectance PFS and work with them to gather evidence that the PFS as it is	**ASAP**

	currently written is achievable at the Threshold level. This work will be limited to fields that are unique to the Aquatic Reflectance PFS, not those that also appear in the Surface Reflectance PFS that was used as the basis. The idea of providing sample products to support the endorsement of the PFS will also be explored.	

DECISION 01	The Aquatic Reflectance PFS will be endorsed out of session (via email) following LSI-VC-10, to allow time to check that the PFS is achievable at the Threshold level and to consider the possibility of a sample product to accompany the endorsement.

PFS Updates: Normalised Radar Backscatter (NRB) and Polarimetric Radar (PR)

Ake Rosenqvist presented the CARD4L SAR and LiDAR update. Noting the still unresolved discussion around the geolocation accuracy requirement and the difficulty for longer wavelength SAR missions to meet the current specification, Ake asked whether endorsement of the planned updates to the NRB and PR PFS could take place out of session via email.

Discussion

- Regarding the geolocation accuracy specification set at 0.2 pixels, Adam Lewis noted that DE Africa's experience is that the data can be produced to 0.25 (potentially 0.2). Additionally, he noted that the data would have both vertical and horizontal uncertainties, and he questioned whether it would be best for the group to set the specification at 0.25. Ake Rosenqvist responded by noting that refraction is dependent on wavelength, so it is easier to meet the 0.2 requirement for X- and C-band missions. Due to the higher uncertainty associated with longer wavelengths, it is not possible for L-band missions to meet the 0.2 requirement, and P-band missions will never get close. A better geometric accuracy is desirable, however the mission specifications play a role in this and hence it is not always possible. This again leads to the discussion of inclusivity vs scientific rigour. With the specification set at 0.2, this excludes many missions.
- Paul Briand (CSA) referenced a CSA/NRCan study that investigated the relationship between DEM accuracy and geolocation accuracy. Ake noted that most data providers use publicly available 30m DEMs and not many providers outside Europe use a finer resolution. Ake asked Paul to share the results of their study.
- With an agreement to postpone the endorsement of the PFS updates, Ake will continue the study and discussions with the SAR PFS team, before presenting a proposed resolution to LSI-VC.
- Jim Irons (NASA) questioned what the LSI-VC would want to ask of the LiDAR Altimetry projects (IceSAT-2 and GEDI)? Ake Rosenqvist responded by noting that they will work with data providers to make sure the PFS are achievable and attractive for them to produce. Jim followed by noting that IceSAT-2 and GEDI meet the specifications already, and asked whether they would just need to

quantify the specifications for the community. Ake commented that the purpose of CARD4L is to provide measurement products that are not available from the mission in normal cases.

- Brian Killough (CEOS SEO, NASA) asked for Ake to share a draft of the LiDAR PFS. Ake agreed that he can share the very early draft that is based on the radar document.
- It was agreed that Ake Rosenqvist will share the list of LiDAR team member names with Jim Irons.

DECISION 02	The Normalised Radar Backscatter & Polarimetric Radar PFS annual revisions will be endorsed out of session (via email) following LSI-VC-10. The extra time will allow a conclusion to the study regarding ionospheric effects on SAR geolocation accuracy and the appropriate pixel value to place on the geometric accuracy fields.

LSI-VC-10-02	Paul Briand to share with Ake a study undertaken by CSA and NRCan on the relationship between DEM accuracy and geolocation accuracy.	**ASAP**
LSI-VC-10-03	Ake to share the current draft of the Lidar PFS.	**ASAP**
LSI-VC-10-04	Ake to share information regarding the CARD4L Lidar team and its membership with Jim Irons.	**COMPLETE**

Nighttime Lights Surface Radiance PFS

Brian Killough presented. The team plans to have the PFS ready for endorsement by LSI-VC-11. It was noted that NASA's Black Marble product is expected to meet all requirements of the PFS and should be sufficient to prove that the threshold requirements are suitable and achievable.

Agency Updates: Plans Regarding CARD4L Assessment and Production

KARI

Seok Weon Choi (KARI) presented KARI's study into the SR CARD4L alignment of Level-1 KOMPSAT-3/3A products. As KOMPSAT are high-resolution satellites, many requirements are challenging. The study yielded promising results for cloud/cloud shadow detection and atmospheric corrections. However, the geometric correction requirement (a sub-pixel accuracy of less than 0.5 pixels rRMSE) is almost impossible to meet for KOMPSAT's original resolution. Downsampling to about 5 m resolution could be a potential workaround.

Discussion:

- Ake Rosenqvist questioned whether KOMPSAT data is publicly available. Seok noted that it is currently only commercially available.

- Electra asked whether the LSI-VC has any experience with other data providers that have been struggling with the accuracy requirements for high-resolution datasets. Adam acknowledged that as spatial resolution increases, it will be harder for providers to meet this particular requirement, however the value is necessary to provide a certain confidence that pixels are consistent throughout time.
- Chris Durell (IEEE) asked whether something like a sub-pixel point source could help in meeting the requirements. Seok noted that despite having a very robust set of GCPs, the requirement will still be a challenge.
- Matt Steventon noted that flexibility for higher resolution sensors was something that was being considered for the annual review process of the SR PFS.
- Ake Rosenqvist noted the same issue has been raised in the SAR group. Downsampling or filtering data to meet CARD4L requirements has been discussed. There is potentially the need for a more flexible approach around accuracy requirements. It could involve attaching a recommendation for the user to filter the data if needed for long time series analysis.

JAXA

Takeo Tadono (JAXA) presented the ALOS-2 mission status and ALOS-4 mission development status. The JAXA PALSAR/JERS-1 annual global 25 m mosaics are being reprocessed to improve geometric accuracy, to use only single-year data (i.e., no gap-filling), in GeoTiff format, and to make them CARD4L NRB compliant. A new quad-pol PALSAR-2 mosaic is expected in Q4 2021. Reprocessing of the ALOS and ALOS-2 scene-based standard product archives by a JAXA supercomputer (JSS2/JSS3) is ongoing to bring those up to CARD4L status as well.

ESA

Ferran Gascon (ESA) presented on the VH-RODA 2021 workshop (particularly findings from the session on institutional and commercial ARD) and on Sentinel-2 CARD4L compliance. Sentinel-2 products are expected to be compliant with CARD4L requirements soon, after full activation of geometric refinement and inclusion of a DOI (Digital Object Identifier) in the metadata.

Ferran also presented on Sentinel-2 Collection 1, which will be generated by reprocessing the full Sentinel-2 archive for both Level-1C (TOA reflectance) and Level-2A (surface reflectance and cloud mask) products. The reprocessing campaign is foreseen to start during Q4 2021, with Collection 1 available to users by the second half of 2022. Collection 1 will feature several improvements on both Level-1C and Level-2A products. Collection 1 targets CARD4L compliance for Level-2A products (currently only DOI inclusion is missing).

On CEOS Work Plan Action **VC-19-05**, *Open-source library for surface reflectance product generation:* Sen2Llike software is available open-source at: https://github.com/senbox-org/sen2like Sen2Like pilot productions have been provided to several teams (Copernicus Services, Szantoi et al., Labahn et al., Roy et al., Schaaf et al.). Pilot productions are also available to LSI-VC members. Sen2Like is being compared with NASA HLS. Sen2Cor will also become available (open-source) on GitHub during Q3 2021. The new release of Sen2Cor will support both Sentinel-2 and Landsat.

Discussion:

- Regarding progress on Sentinel-1 ARD direct from ESA/EC, Ferran recalled the letter from LSI-VC to EC asking for a Sentinel-1 ARD (CARD4L) product. A timeline has yet to be defined for this product, as ESA is in the middle of a change in contracts for the ground segment to move to a more cloud-based architecture. By mid-2022, the ground segment would potentially be able to expand and add new products. A Sentinel-1 ARD product direct from ESA/EC will likely not be feasible before 2023.

LSI-VC-10-05	Matt to publish the interoperability terminology developed by LSI-VC & WGISS on the CEOS / LSI-VC / CEOS ARD website(s).	**ASAP**

ISRO

Radhika (ISRO, NRSC) presented the ongoing assessment of Resourcesat-2/2A CARD4L products. The current results and next steps are summarised on these slides. Potential areas of collaboration were also identified around atmospheric data handling (dealing with high variations in neighbouring AOD values and the lack of AOD data over the Himalayan region).

Discussion:

- Vinod Bothale (ISRO) reiterated ISRO's willingness to collaborate in this area.
- Steve Labhan asked whether each of the collaboration points listed above are necessary to complete the Threshold self-assessment, or are they just improvements to the product? Vinod responded that these are required to ensure the robustness of the ARD product.

NASA

Chris Lynnes (NASA) presented on some of the considerations NASA is making with regard to applying the CEOS ARD concept to its products. Considerations include the applicability to Level-2 and Level-3 products and the pros/cons of targeting each. Chris also presented some outcomes from the 25 November NASA Workshop where CARD4L was discussed. The conclusions of the workshop were to: try for 'quick wins' with Level-3/4 products; engage with CEOS on ARD for other disciplines; and, to apply a more nuanced approach for Level-1/2 products.

DLR

Martin Bachmann (DLR) presented EnMAP and its ground segment. He noted that CARD4L SR (V5.0) is suitable for hyperspectral data, and a self-assessment has been completed and submitted for peer review. Martin also presented some obstacles to achieving full Target conformity.

Discussion:

- Steven Covington (USGS) asked whether the team found any areas that were lacking in the specifications, when it comes to hyperspectral data sources. Are there some characteristics that aren't being captured in the metadata that would be warranted for these types of data? He also asked if the team will be providing nominal stray light information that might be referenced.
- Regarding stray light information, Martin noted that there are currently no plans to make the full stray light characterisation available. This is because users of the datasets have no feasible means of completing this processing step themselves, as they would need detailed knowledge of the instruments to make appropriate calibrations.

CSA

Paul Briand (CSA) gave a short summary of CSA's ARD plans. CSA has developed a toolbox for users to generate ARD products on-demand from Level-1C (orthorectified sigma nought). They are also developing an analysis platform and plan to include SAR and optical ARD products based on CARD4L specifications. CSA hopes to do a self-assessment for Radarsat next year. They are also transforming their ground segment, and are currently assessing SAR processing on the cloud, which will provide more flexibility.

LSI-VC-10-06	Paul to share details of the tool CSA is developing for users that will generate Radarsat ARD on demand.	**ASAP**

Other Updates

Steve Labhan gave an update on the commercial sector.

Maxar: There have been ongoing discussions with Maxar about their interest in CARD4L, which has revealed that a large portion of their user community works beyond the 'Level 2' products that CARD4L targets – with a greater focus on Level 5 and other RGB imagery products.

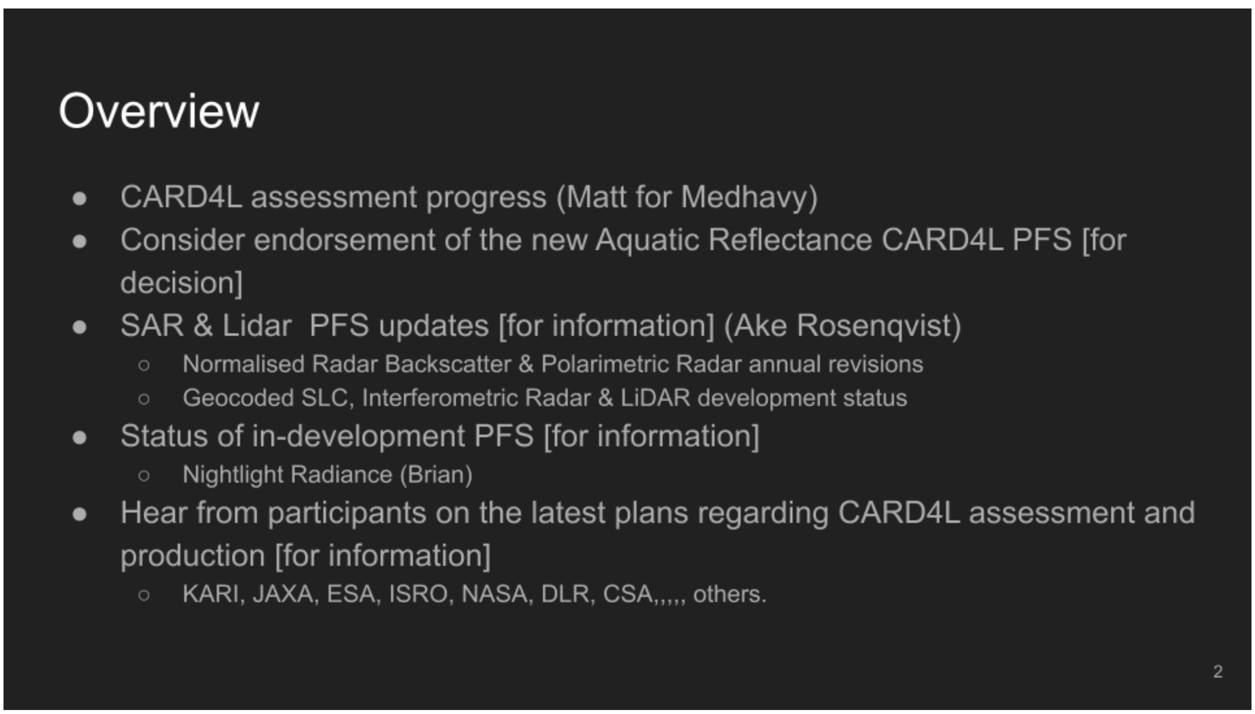
Planet: A Planet-USGS meeting was held recently. LSI-VC has participated in the past ARD conferences organised by Planet and intends to continue this engagement. A planning committee for ARD21 has been formed. The plan is to hold the meeting face-to-face. The target date is the last week of October (week before the CEOS Plenary). Location is TBD, but potentially on the west coast of the U.S. or perhaps Denver or Boulder in Colorado.

Closing

Steve Labahn (USGS, LSI-VC Co-Lead) thanked everyone for their attendance and very valuable contributions to the discussion. He noted that the next LSI-VC-10 call will focus on LSI-GEOGLAM and LSI-Forests & Biomass.

LSI-VC-10 Teleconference #2: LSI-GEOGLAM and LSI-Forests & Biomass will be held May 17, 16:00 – 19:00 US East / May 18, 06:00 – 09:00 Australia East.

Appendix A: Meeting Presentation Slides



CARD4L Assessment Progress

- v5.0 USGS SR and ST assessments are nearing completion, awaiting response from a panel member
- ESA Sentinel-2 SR submission (at Threshold level) has now been received. A quick turnaround assessment is planned, as no review panel is being assembled for this partial assessment.
- Element 84 Sentinel-2 SR: further questions have been sent back to Element 84. The assessment is for threshold and partial target.
- The DLR EnMap review (simulated products provided) is underway.
- INPE and KARI are planning to initiate self-assessments / peer reviews

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Aquatic Reflectance PFS

Christopher Barnes
CEOS LSI-VC, USGS/KBR

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Aquatic Reflectance PFS

- Coordinated by: *Andreia Siqueira (GA)* & *Chris Barnes (USGS/KBR)*
- Development began in March 2020 with endorsement targeted for LSI-VC-10
- Applies to data collected by multispectral and hyperspectral sensors operating in the VIS/NIR/SWIR wavelengths over coastal and inland water bodies
- Using the Surface Reflectance PFS as a baseline, GEO-Aquawatch, Water-ForCE and subject matter experts around the world met virtually to review/modify and/or generate new Threshold and Target requirements
  - Technical Lead: *Arnold Dekker (SatDek)*

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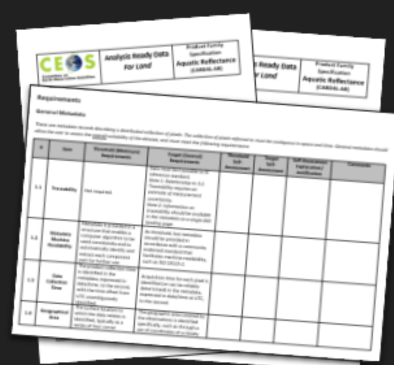
Aquatic Reflectance PFS

- Requirements summary of changes:
  - General Metadata (17/17)
  - ***No requirement changes***
  - Per-Pixel Metadata (13/20)
  - *1 requirement modified*
    - Sea/Lake/River Ice Mask
  - *10 new requirements identified*
    - Adjacency Effects
    - Altitude (ASL)
    - Bidirectional Reflectance Distribution Function
    - Deep/Shallow Water
    - Floating Vegetation/Surface Scum Mask
    - Optically Deep or Optically Shallow Assessment
    - Sky Glint Mask
    - Sun Glint
    - Turbid Water Flag
    - Whitecap/Foam Mask



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Aquatic Reflectance PFS

- Requirements summary of changes continued:
  - ***Radiometric and Atmospheric Corrections*** (6/15)
  - *1 requirement modified*
    - Atmospheric Reflectance Correction
  - *10 new requirements identified*
    - Adjacency Effects Correction
    - Bidirectional Reflectance Distribution Function
    - Floating Vegetation/Surface Scum Correction
    - Other Trace Gaseous Absorption Corrections
    - Sky Glint Correction
    - Sun Glint Correction
    - Surface Reflected Vegetation Spectral Correction
    - Turbid Water Correction
    - Whitecap and Foam Correction
  - ***Geometric Corrections*** (1/1)
  - ***No requirement changes***
- ~80% of the Aquatic Reflectance PFS requirements correspond with Surface Reflectance PFS requirements

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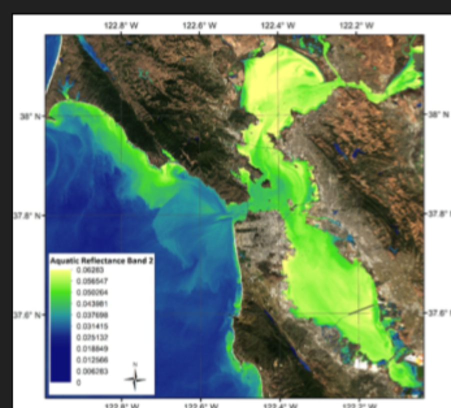
Aquatic Reflectance PFS

- Next steps:
  - Seeking Aquatic Reflectance PFS Version 1.0 review and endorsement at LSI-VC-10
  - Make Version 1.0 available from the CARD4L website to solicit community feedback
  - USGS intends to conduct an informal self-assessment evaluation against its Landsat 8 Provisional Aquatic Reflectance Product



Landsat 8 Provisional Aquatic Reflectance Product. OLI Band 2 (Blue band) San Francisco Bay, CA.

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Radar and Lidar PFS

Ake Rosenqvist
JAXA/soloEO

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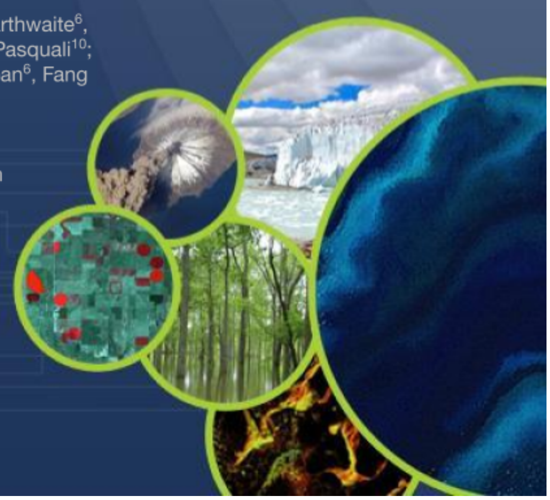
Committee on Earth Observation Satellites

CARD4L SAR & LiDAR update for LSI-VC-10

Ake Rosenqvist[1,2]

On behalf of:
Bruce Chapman[3], Danilo Dadamia[4]; Francois Charbonneau[5], Matt Garthwaite[6], Marco Lavalle[3], Franz Meyer[7], Nuno Miranda[8], Katrin Molch[9] , Paolo Pasquali[10]; Andreia Siqueira[6]; David Small[11], Takeo Tadono[2], Medhavy Thankappan[6], Fang Yuan[6], Howard Zebker[12], Zheng-Shu Zhou[13]

1 – solo Earth Observation; 2 – JAXA; 3 – NASA JPL; 4 – CONAE; 5 – NRCan; 6 – Geoscience Australia; 7 – ASF; 8 – ESA; 9 – European Commission (DG DEFIS); 10 – sarmap; 11 – Univ of Zürich; 12 – Stanford Univ; 13 – CSIRO



LSI-VC-10 #1, 12 May, 2021


CARD4L SAR & LiDAR
Current status
Completed 2019 & 2020, Annual rev. 2021
• Normalised Radar Backscatter (NRB)
• Polarimetric Radar (POL)
Under development:
• Geocoded SLC (GSLC)
• Interferometric Radar (INSAR)
New under consideration:
• Multi-mission NRB
To be revived:
• Lidar Terrain & Canopy Height
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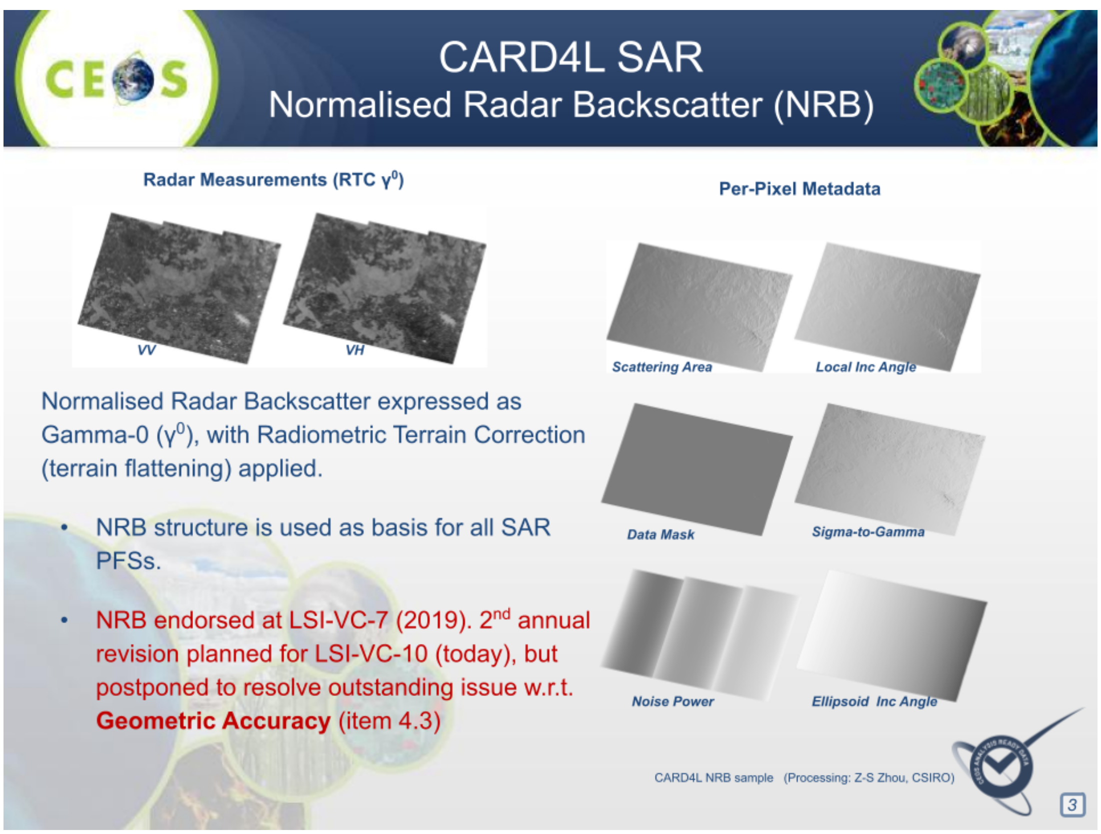
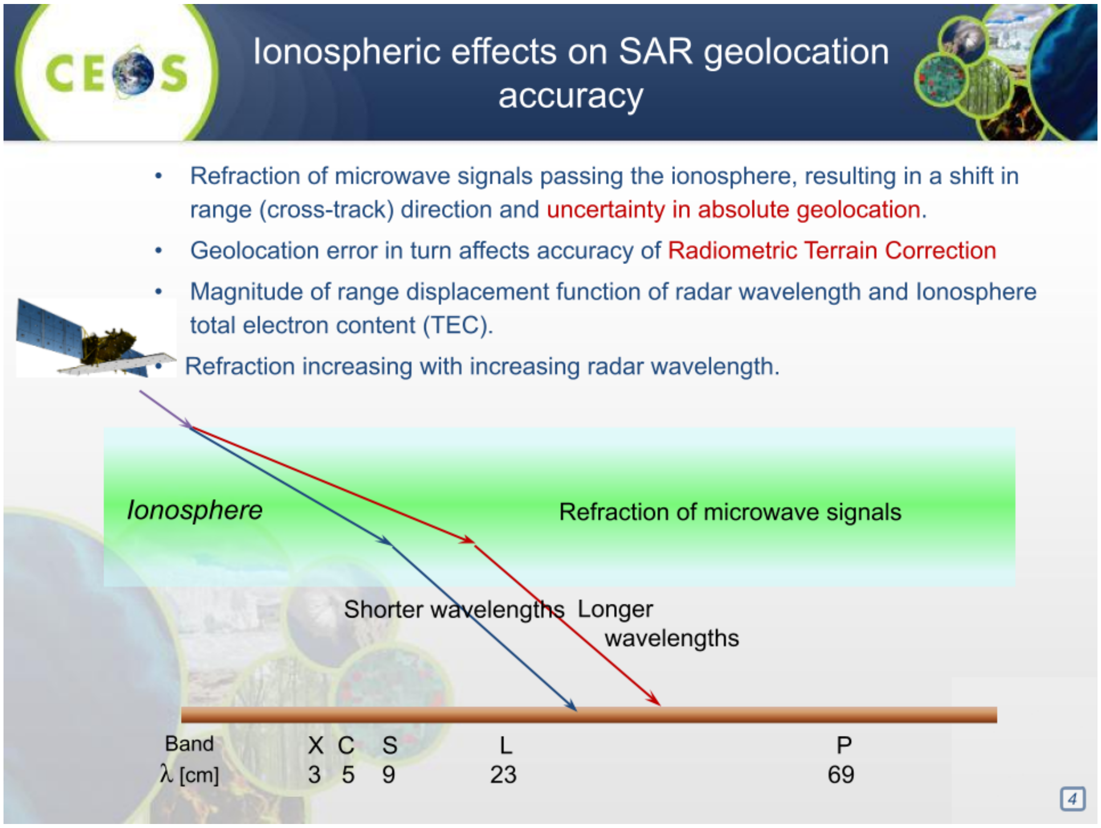

CARD4L SAR
Normalised Radar Backscatter (NRB)
Radar Measurements (RTC γ0)
VV
VH
Per-Pixel Metadata
Scattering Area
Local Inc Angle
Data Mask
Sigma-to-Gamma
Noise Power
Ellipsoid Inc Angle
Normalised Radar Backscatter expressed as Gamma-0 (γ0), with Radiometric Terrain Correction (terrain flattening) applied.
• NRB structure is used as basis for all SAR PFSs.
• NRB endorsed at LSI-VC-7 (2019). 2nd annual revision planned for LSI-VC-10 (today), but postponed to resolve outstanding issue w.r.t. Geometric Accuracy (item 4.3)
CARD4L NRB sample (Processing: Z-S Zhou, CSIRO)
3


Ionospheric effects on SAR geolocation accuracy
Refraction of microwave signals passing the ionosphere, resulting in a shift in range (cross-track) direction and uncertainty in absolute geolocation.
Geolocation error in turn affects accuracy of Radiometric Terrain Correction
Magnitude of range displacement function of radar wavelength and Ionosphere total electron content (TEC).
Refraction increasing with increasing radar wavelength.
Ionosphere
Refraction of microwave signals
Shorter wavelengths
Longer wavelengths
Band X C S L P
λ [cm] 3 5 9 23 69
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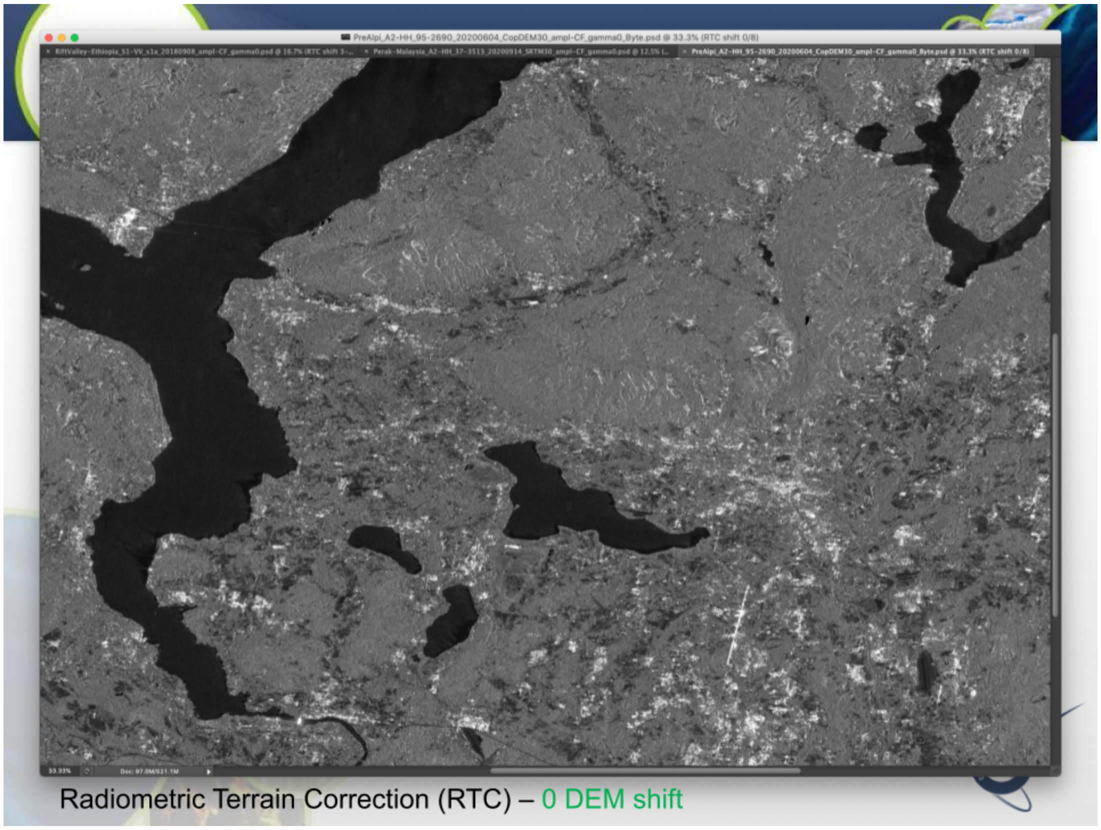
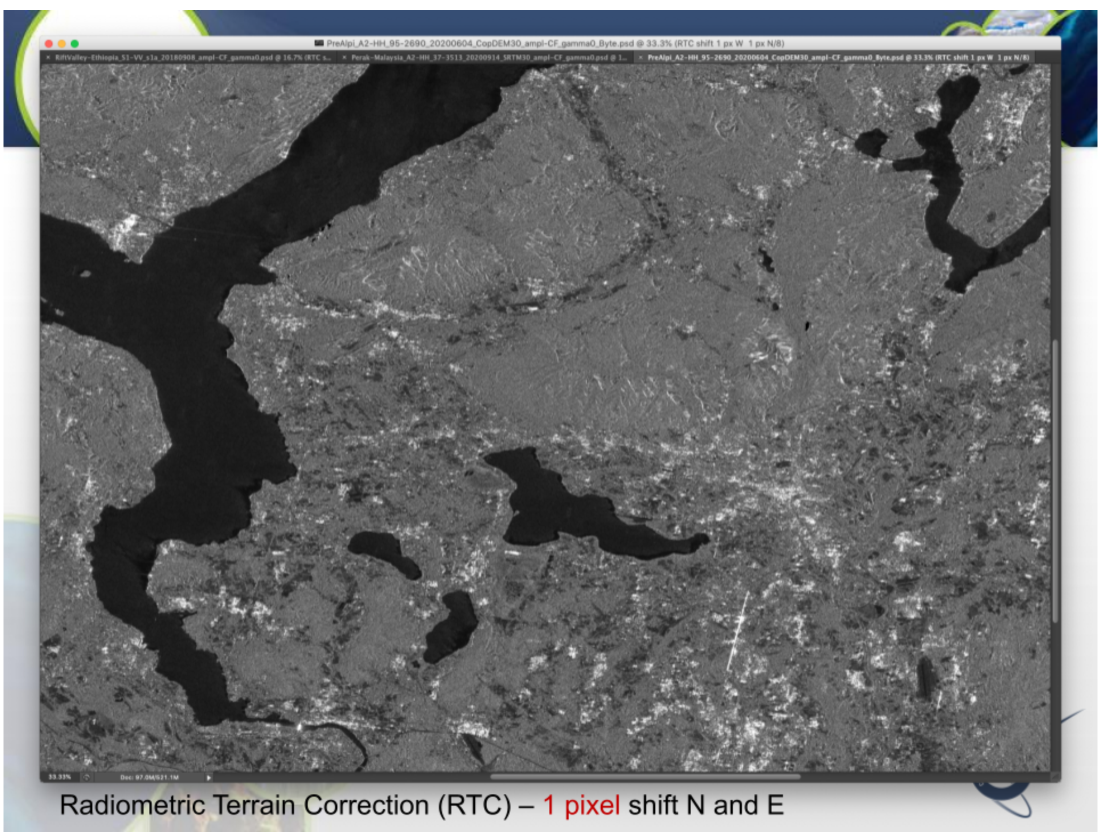
Geometric Terrain Correction (GTC) – 0 DEM shift


Radiometric Terrain Correction (RTC) – 0 DEM shift

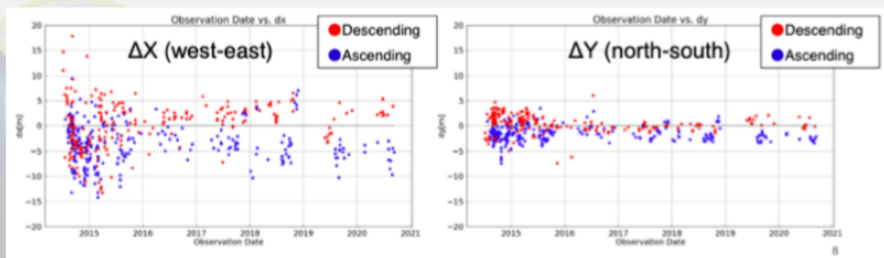

Radiometric Terrain Correction (RTC) – 1 pixel shift N and E


Radiometric Terrain Correction (RTC) – 2 pixels shift N and E


Radiometric Terrain Correction (RTC) – 3 pixels shift N and E

Ionospheric effects on SAR geolocation accuracy

- Study initiated by CARD4L SAR team to assess impact
- Assessing a range of CEOS mission data
  - ALOS/ALOS-2, Sentinel-1, Radarsat-1/2, RCM, NovaSAR.
  - (SAOCOM, TSX, CSK, if available)
- Over a range of geographical areas with different topography and land cover
- Aim to complete study in June.
- Question: Can endorsement be foreseen between LSI-VC meetings, or will it have to wait until LSI-VC-11 (Sept?)



Example: PALSAR-2 geometric uncertainty. Note EW (range) > NS (azimuth)

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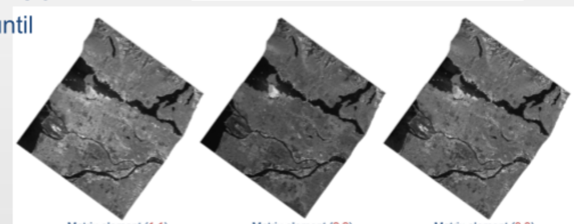
CARD4L SAR
Polarimetric Radar (POL)

- PFS development led by NRCan, CSIRO & JPL
- CARD4L POL covers two product types:
  - Polarimetric Decomposition
  - Polarimetric Covariance Matrix
- POL structure mirrors that of the NRB, with the exception of the measurement data (□)
- Endorsed at LSI-VC-9 (2020). Annual revision planned for LSI-VC-10, but postponed until NRB Geometric Accuracy requirement agreed upon.

Decomposition image
(Yamaguchi decomp., Quad-pol)



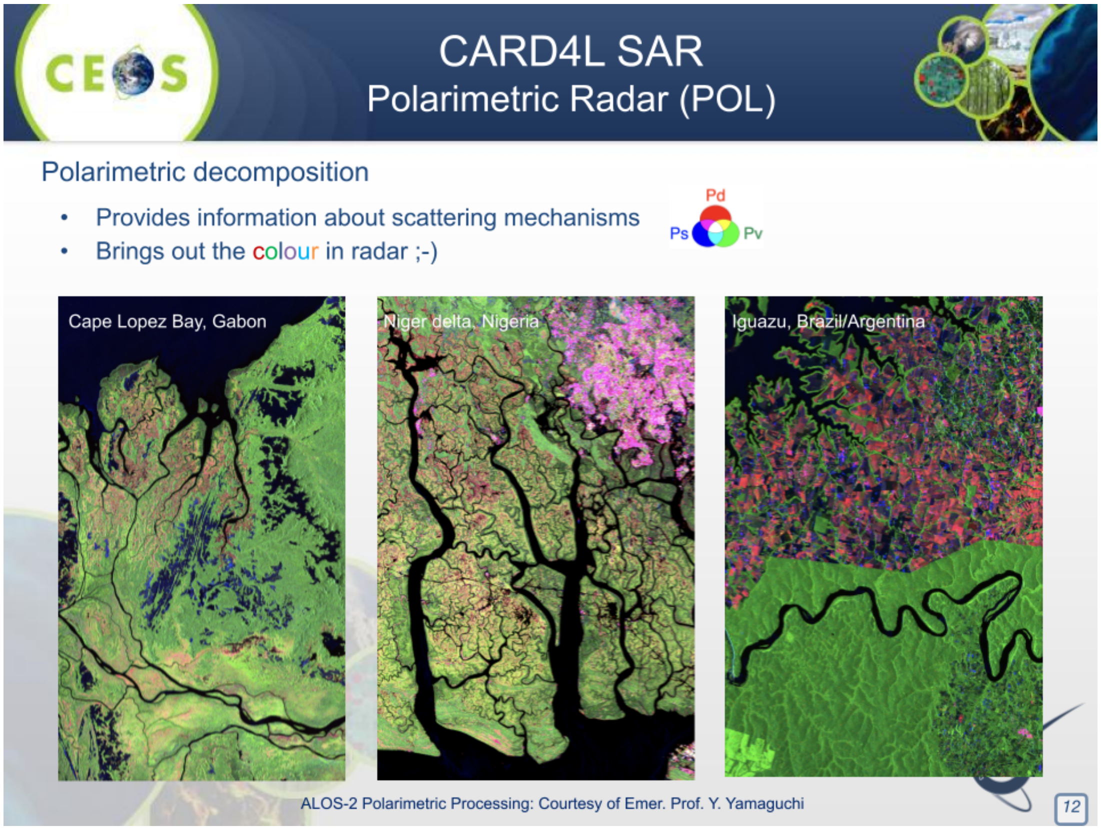
Matrix element (1,1) REAL HH intensity

Matrix element (2,2) REAL HV intensity

Matrix element (3,3) REAL VV intensity

Matrix elements (1,2) (1,3) & (2,3) COMPLEX (Re + Im): Polarimetric phase

RADARSAT-2 (MDA)
Processing: F. Charbonneau (NRCan)


CARD4L SAR
Polarimetric Radar (POL)
Polarimetric decomposition
• Provides information about scattering mechanisms
• Brings out the colour in radar ;-)
Pd
Ps
Pv
Cape Lopez Bay, Gabon
Niger delta, Nigeria
Iguazu, Brazil/Argentina
ALOS-2 Polarimetric Processing: Courtesy of Emer. Prof. Y. Yamaguchi
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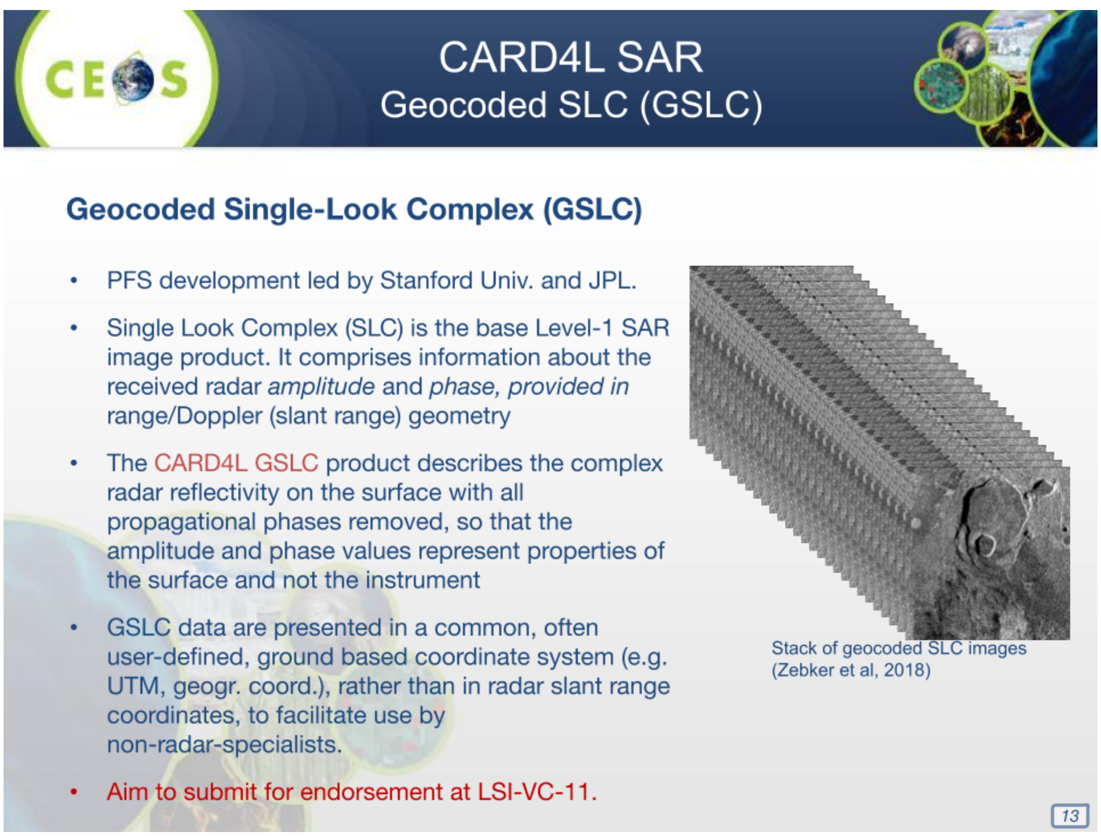
CARD4L SAR
Geocoded SLC (GSLC)
Geocoded Single-Look Complex (GSLC)
• PFS development led by Stanford Univ. and JPL.
• Single Look Complex (SLC) is the base Level-1 SAR image product. It comprises information about the received radar amplitude and phase, provided in range/Doppler (slant range) geometry
• The CARD4L GSLC product describes the complex radar reflectivity on the surface with all propagational phases removed, so that the amplitude and phase values represent properties of the surface and not the instrument
• GSLC data are presented in a common, often user-defined, ground based coordinate system (e.g. UTM, geogr. coord.), rather than in radar slant range coordinates, to facilitate use by non-radar-specialists.
• Aim to submit for endorsement at LSI-VC-11.
Stack of geocoded SLC images
(Zebker et al, 2018)
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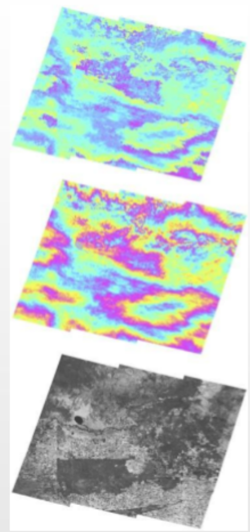
CARD4L SAR
Interferometric Radar (INSAR)

Interferometric Radar (INSAR)

- PFS development led by Geoscience Australia
- A suite of three products generated by InSAR processing of two images captured of the same geographic area at different times:
    - **Wrapped interferogram**: Image of differential phase signals between two SLC images
    - **Unwrapped interferogram**: Image of differential phase signals where the wrapped fringes are summed ("unwrapped") to give a continuous phase signal across the image
    - **Interferometric coherence**: Image of phase coherence between the two images.
- Aim to submit for endorsement at LSI-VC-12



Sentinel 1 interferometric products
(Geoscience Australia team)

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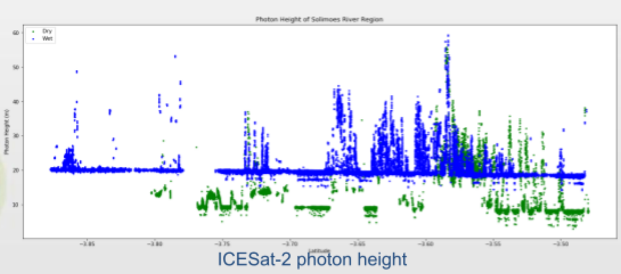
CARD4L LiDAR
Terrain and Canopy Top Height

LiDAR – measurements of vegetation canopy structure and height. GEDI and ICESat-2 launched in 2018 + MOLI targeted for 2024. Proposal to develop CARD4L for LiDAR well received by mission teams.

New CARD4L subgroup on LiDAR launched in 2019

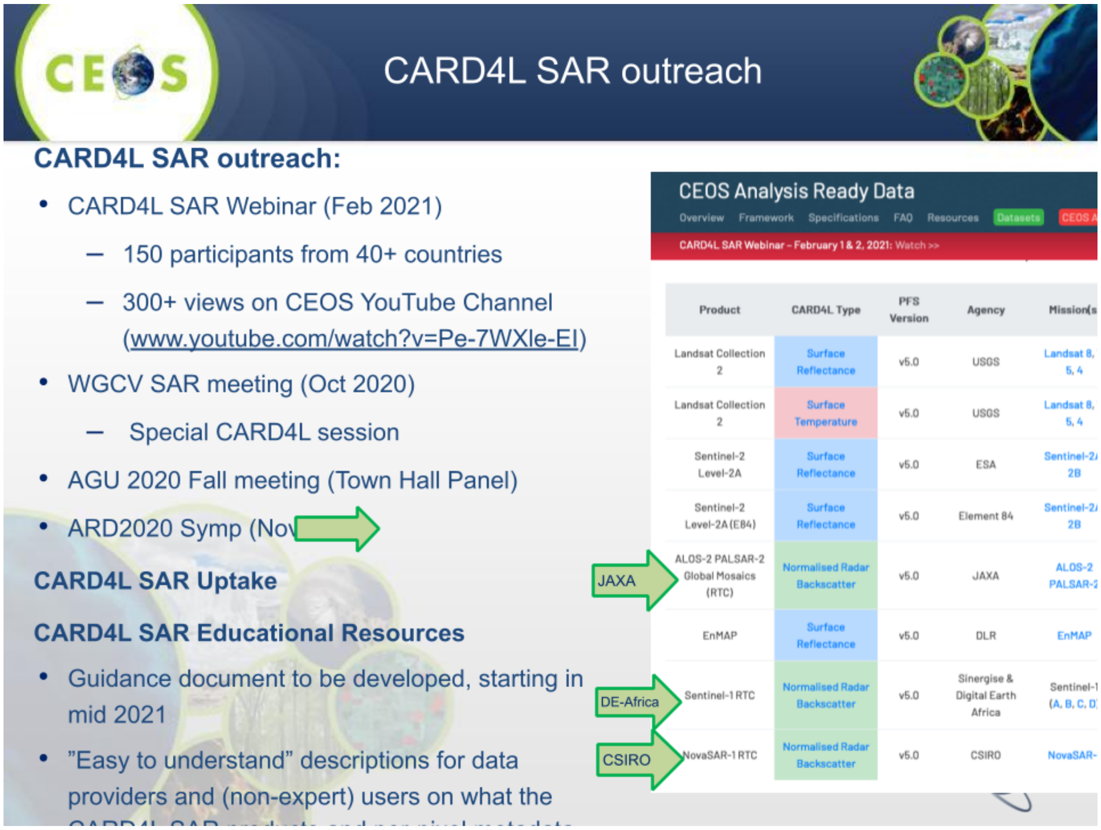
- Group members representing 3 spaceborne LiDAR missions + science users
- Target PFS: Terrain & Canopy Top Height

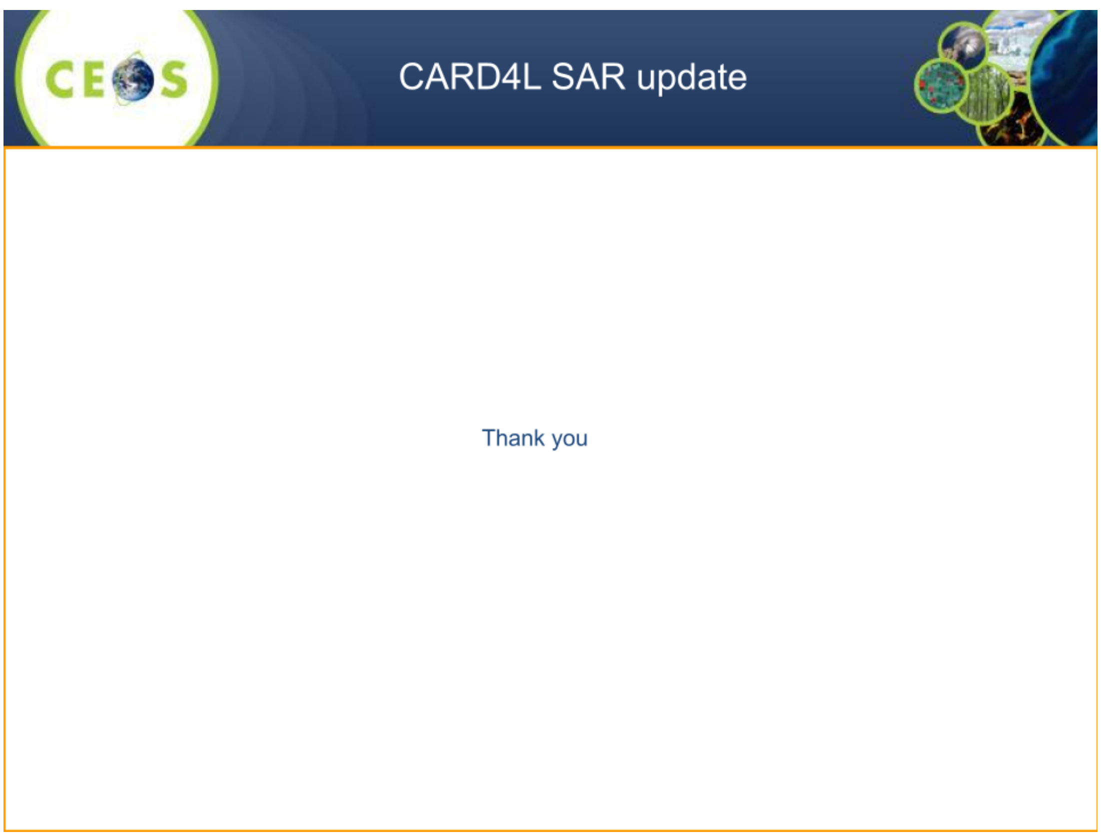
- Progress in 2020 slow ...
- Attempt to revive activity in 2021, depending on interest from LiDAR mission group and users.

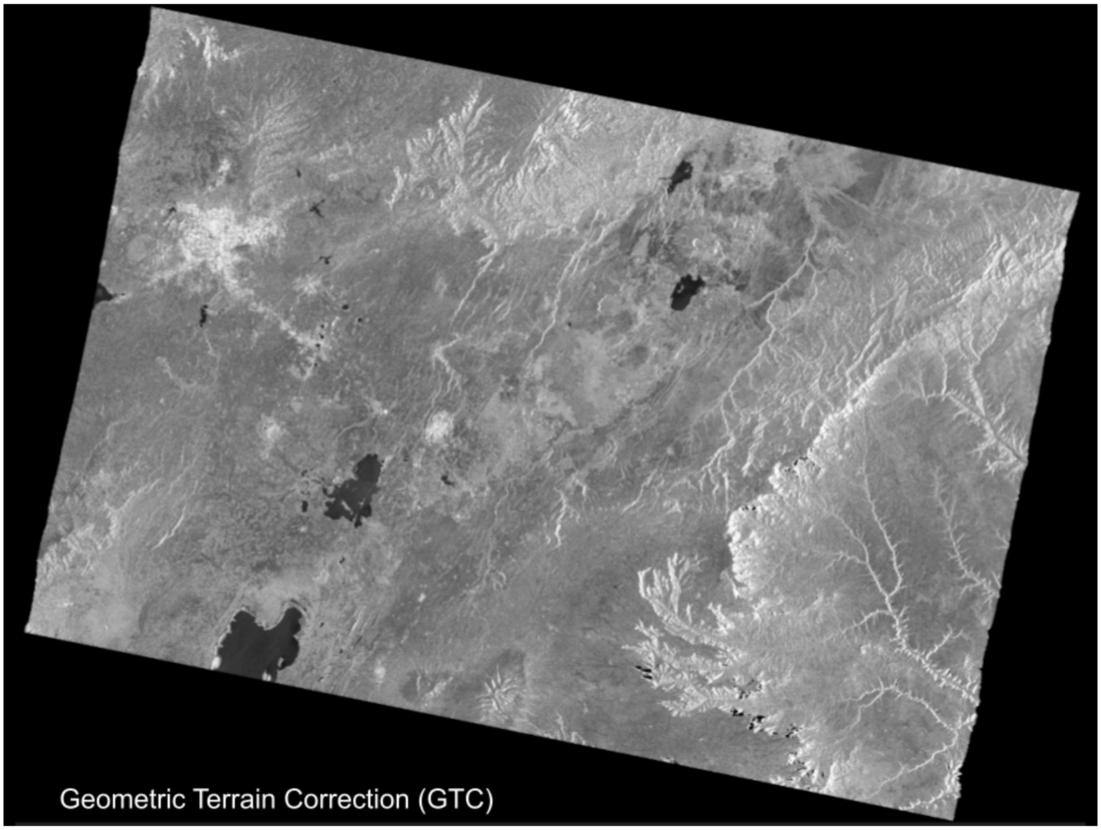


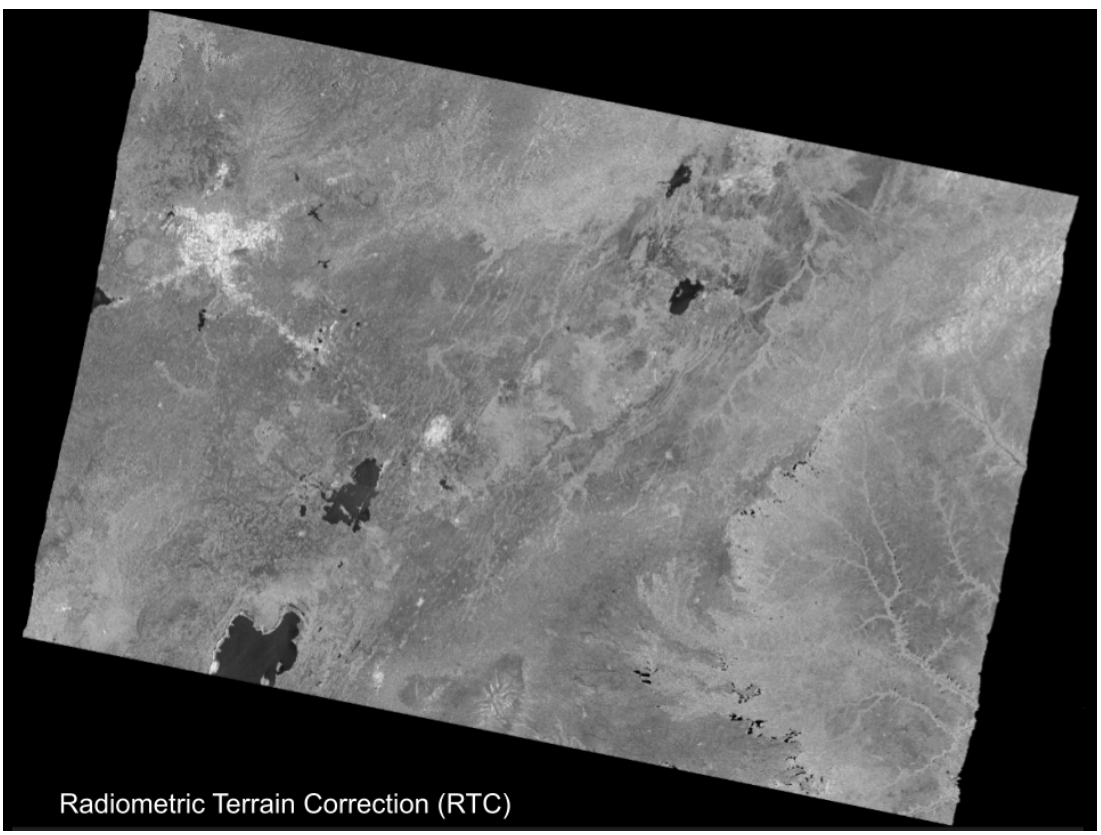
ICESat-2 photon height
(Amazon river transects at dry and wet season)

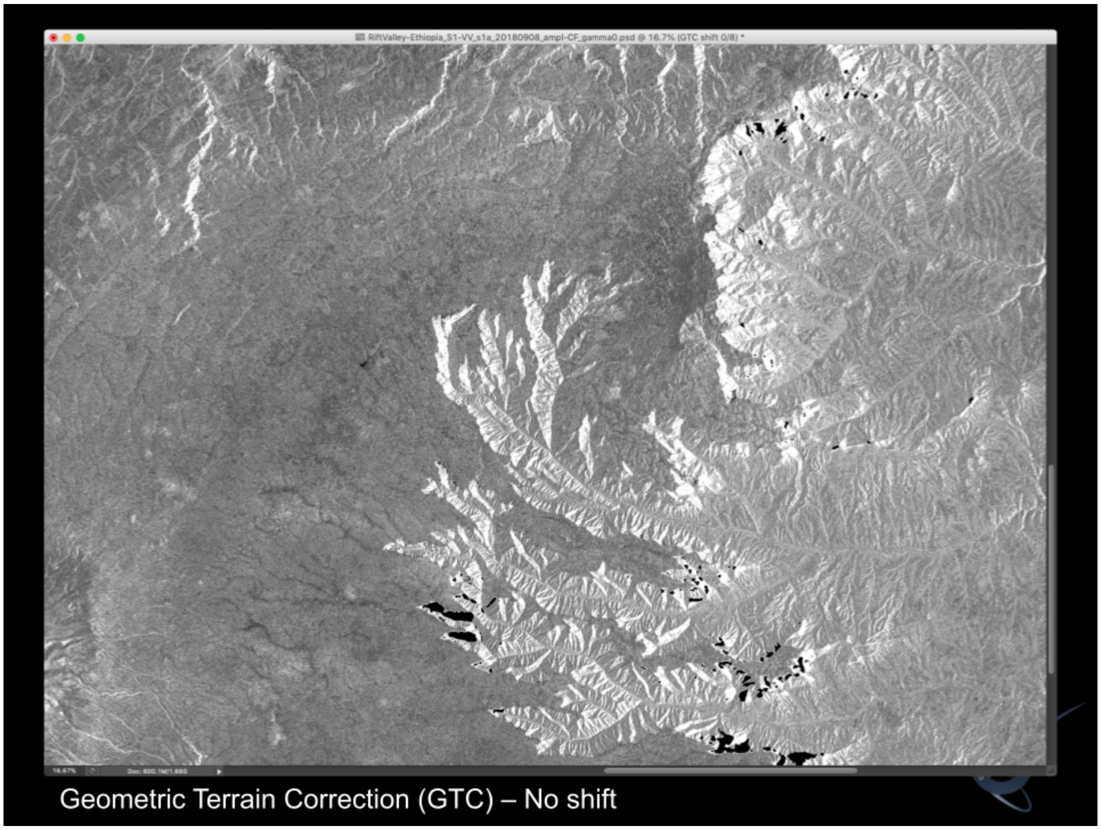
15

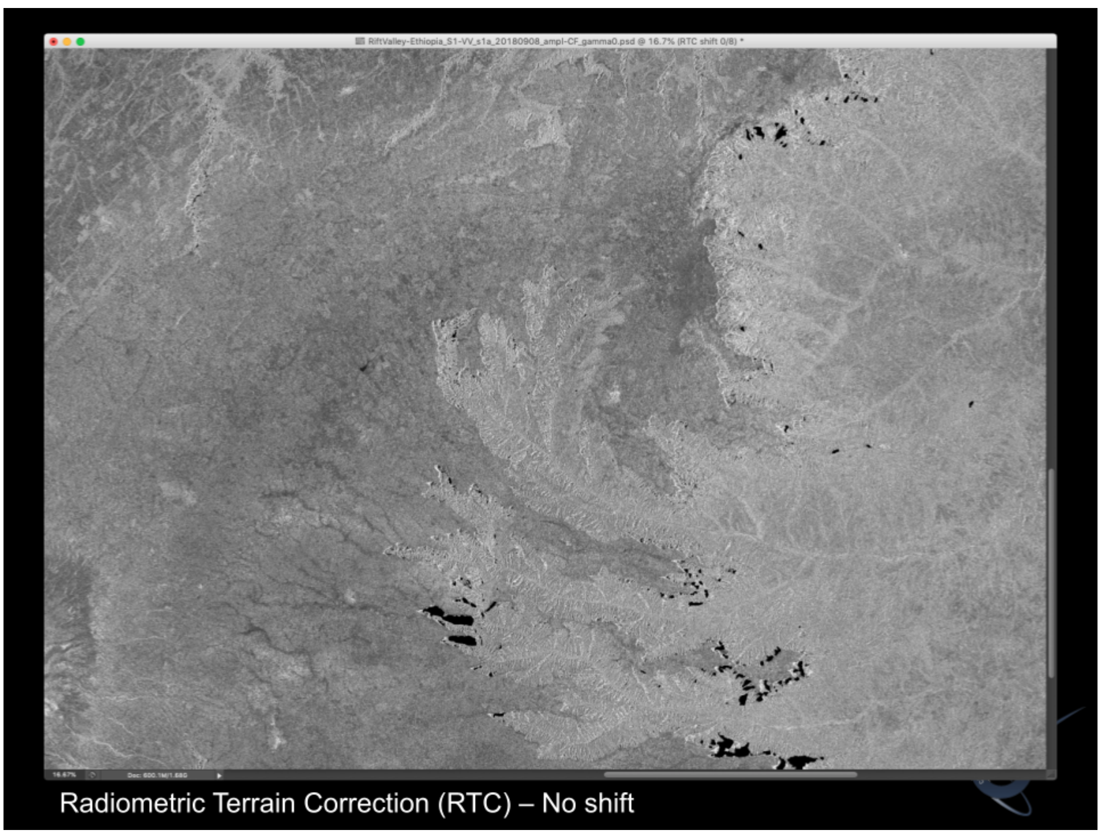

CARD4L SAR outreach
CARD4L SAR outreach:
• CARD4L SAR Webinar (Feb 2021)
– 150 participants from 40+ countries
– 300+ views on CEOS YouTube Channel (www.youtube.com/watch?v=Pe-7WXle-EI)
• WGCV SAR meeting (Oct 2020)
– Special CARD4L session
• AGU 2020 Fall meeting (Town Hall Panel)
• ARD2020 Symp (Nov
CARD4L SAR Uptake
CARD4L SAR Educational Resources
• Guidance document to be developed, starting in mid 2021
• "Easy to understand" descriptions for data providers and (non-expert) users on what the
CEOS Analysis Ready Data
Overview Framework Specifications FAQ Resources Datasets
CARD4L SAR Webinar – February 1 & 2, 2021: Watch >>
Product | CARD4L Type | PFS Version | Agency
Landsat Collection 2 | Surface Reflectance | v5.0 | USGS
Landsat Collection 2 | Surface Temperature | v5.0 | USGS
Sentinel-2 Level-2A | Surface Reflectance | v5.0 | ESA
Sentinel-2 Level-2A (E84) | Surface Reflectance | v5.0 | Element 84
ALOS-2 PALSAR-2 Global Mosaics (RTC) | Normalised Radar Backscatter | v5.0 | JAXA
EnMAP | Surface Reflectance | v5.0 | DLR
Sentinel-1 RTC | Normalised Radar Backscatter | v5.0 | Sinergise & Digital Earth Africa
NovaSAR-1 RTC | Normalised Radar Backscatter | v5.0 | CSIRO
JAXA
DE-Africa
CSIRO

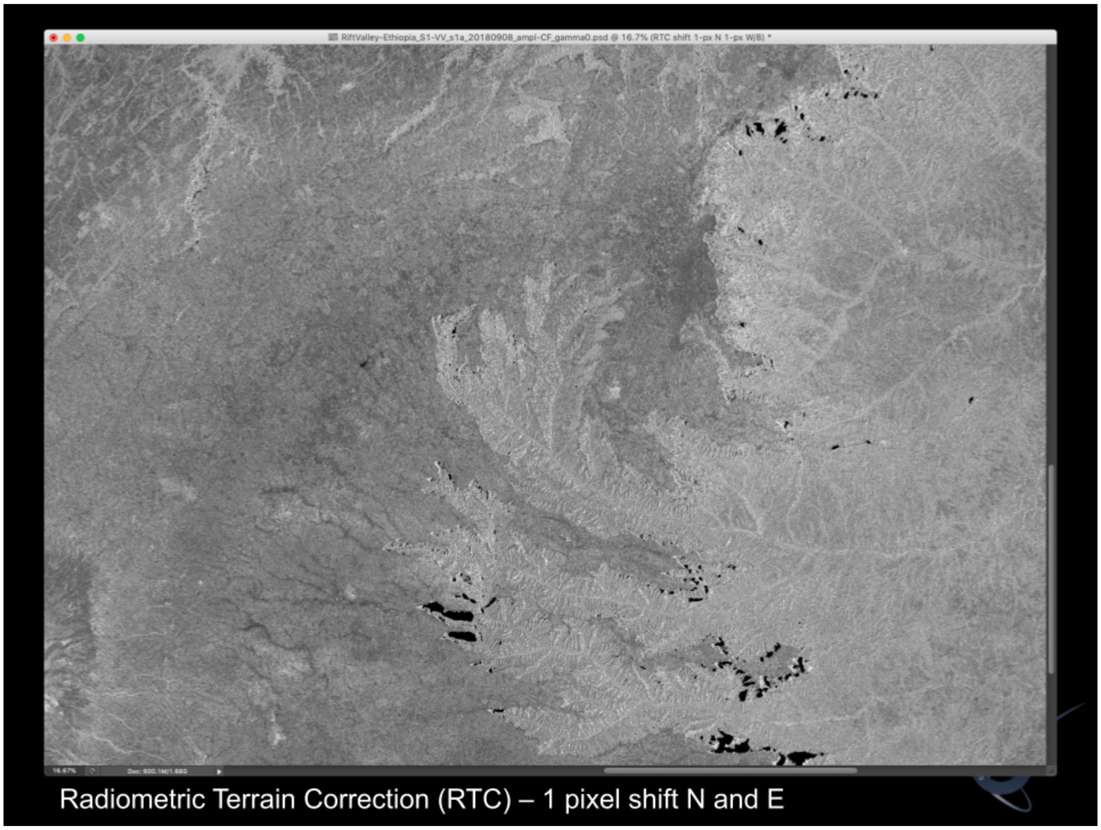

CARD4L SAR update
Thank you


Geometric Terrain Correction (GTC)


Radiometric Terrain Correction (RTC)


Geometric Terrain Correction (GTC) – No shift


Radiometric Terrain Correction (RTC) – No shift


Radiometric Terrain Correction (RTC) – 1 pixel shift N and E


Radiometric Terrain Correction (RTC) – 3 pixels shift N and E

Nighttime Lights Surface Radiance PFS

Brian Killough
CEOS SEO, NASA

10

Summary of PFS Plans

- Coordinated by Brian Killough (CEOS SEO, NASA) with detailed support from Miguel Roman (NASA, USRA) and Zhousen Wang (NASA GSFC).
- Development began in Oct 2020 with endorsement planned for LSI-VC-11 (later 2021).
- Working with a team of ~20 people (NASA, NOAA, CEOS) to develop the PFS.
- Applies to data collected by nighttime light sensors operating in the VIS/NIR wavelengths. Resolutions are in the order of 10m to 1km.
- Uses the surface reflectance PFS as a baseline with several modifications and additions.

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Summary of PFS Plans

- There have been a number of revisions by team members. The current version (0.4) is nearing completion.
- ~ 80% of the Nighttime Light Surface Radiance PFS requirements correspond to the Surface Reflectance PFS requirements.
  - **Per-Pixel Metadata** - replaced solar with lunar (radiance and viewing angles) and , added brightness temperature and solar zenith angle.
  - **Atmospheric Corrections** - removed aerosol, water vapor and ozone corrections. Added general atmospheric scattering, lunar radiance corrections and stray light corrections.
- Several important paper references have also been added to the document.

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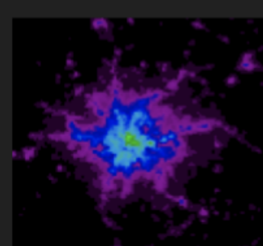
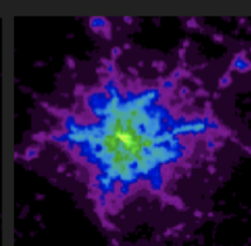
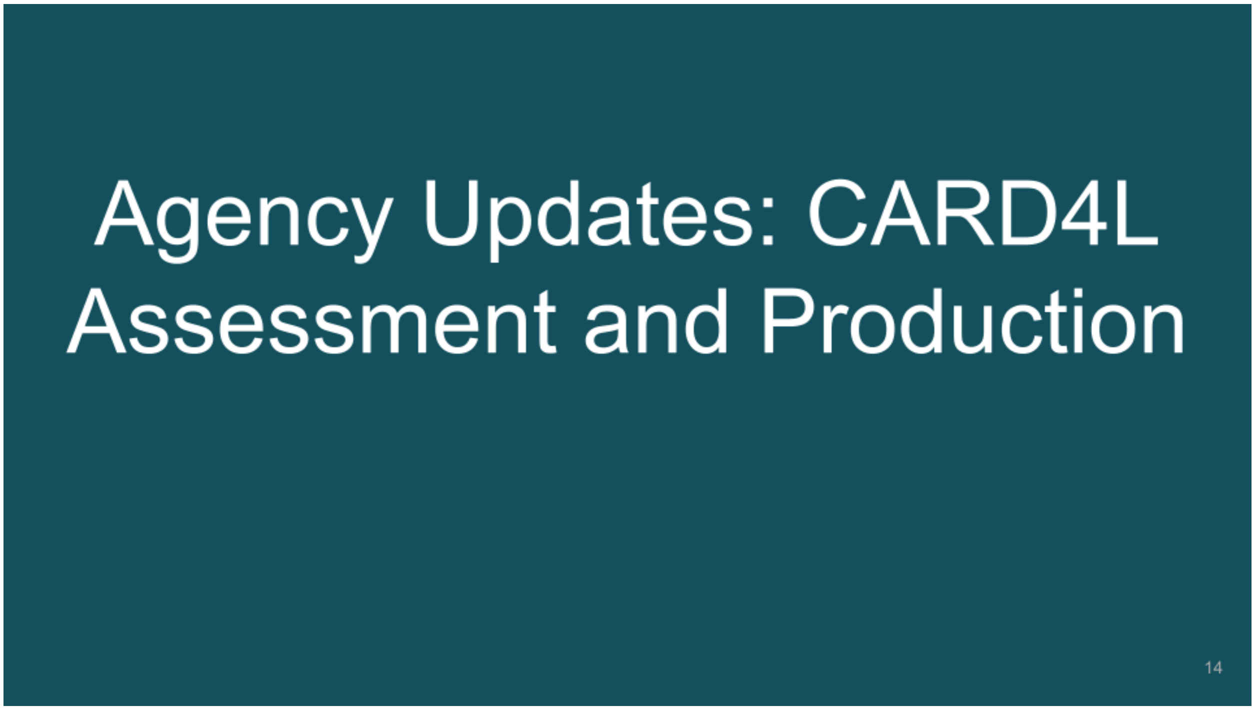
Next Steps

- Seeking Nighttime Light Surface Radiance PFS version 1.0 review and endorsement at LSI-VC-11.
- Make version 1.0 available from the CARD4L website to solicit community feedback.
- Identify a specific dataset example (e.g. NASA's Black Marble) to conduct a self-assessment against the PFS and later consider full CARD4L review and approval.





13


Agency Updates: CARD4L Assessment and Production
14


KARI
15

Experiments for achieving CARD4L

- **Current K3/K3A data does not meet CARD4L PFS even Threshold requirement.**
- **Technical challenges to CARD4L specifications for current K3/K3A data**
  - Per-pixel metadata
    - **Pixel-level cloud/cloud shadow detections**
  - Surface reflectance measurements
    - **Atmospheric corrections**
  - Geometric Correction
    - **Sub-pixel accuracy : less than 0.5 Pixel rRMSE**
- **We performed experiments to see if CARD4L on K3/K3A is feasible**
  - Experiments about three major technical components above

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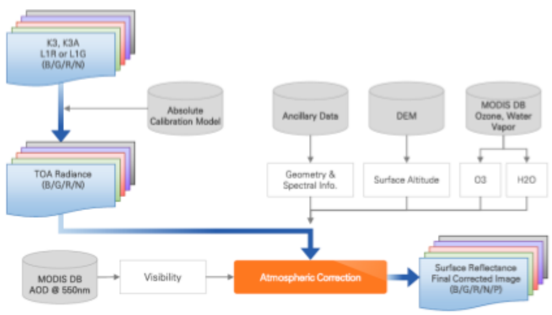
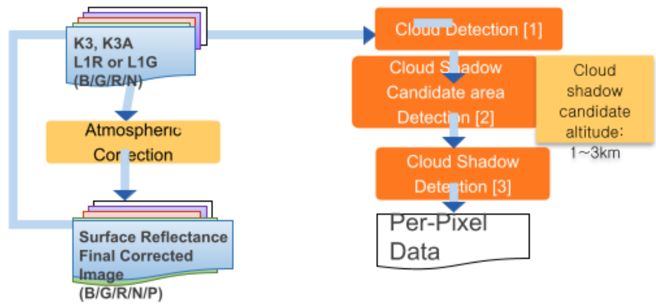
Flow Chart

Atmospheric Corrections



Cloud Detection



[1] Qing Zhang and Chunxiz Xizo, Cloud Detection of RGB Color Aerial Photographs by progressive Refinement Scheme, IEEE, November 2014
[2] Victor J.D. Tsai, A Comparative Study on Shadow Compensation of Color Aerial Images in Invariant Color Models, IEEE, June 2006
[3] Tianxing Wang and 3 others, Effect of Solar-Cloud-Satellite Geometry on Land Surface Shortwave Radiation Derived from Remotely Sensed Data, RemoteSens, July 2017

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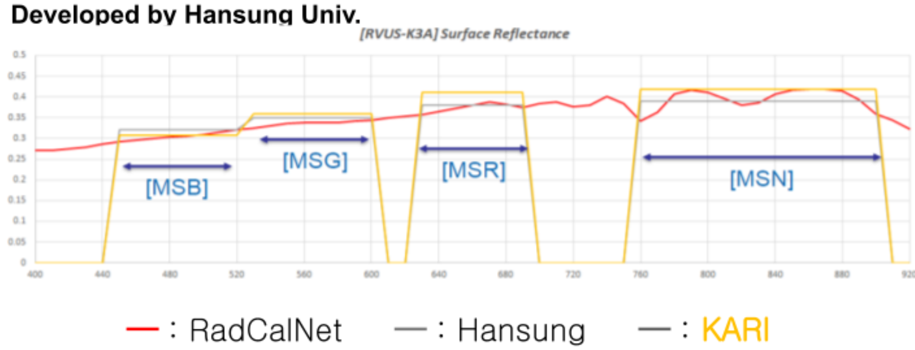
Atmospheric Corrections

- **Verifications**
  - Reference: RadCalNet Data on Railroad Valley Playa (USA)
    - **Provided by CEOS**
    - **Providing surface reflectance, AOT @ 550nm, Water vapor, Ozone, etc.**
  - Data for cross-check: Surface reflectance using AERONET + OTB tool
    - **Developed by Hansung Univ.**

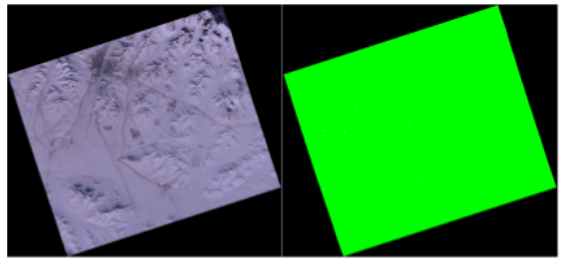


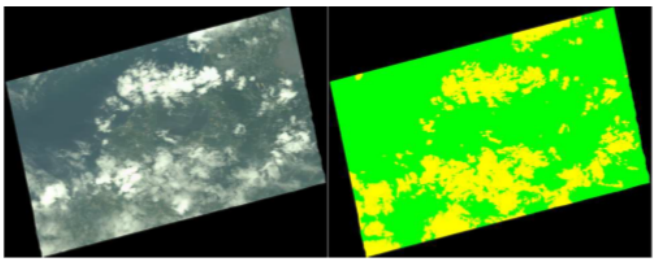
Cloud Detection

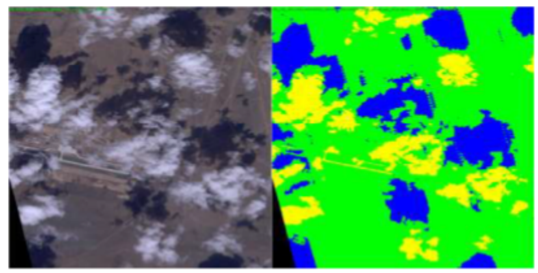
- **Results**

(black)	Un-filled Region
(yellow)	Cloud
(blue)	Cloud Shadow
(green)	Filled Region with No-Class

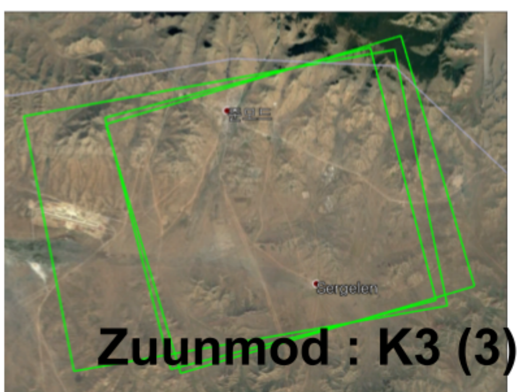
- Black : Un-filled region
- Green : No class region
- Yellow : Cloud
- Blue : Cloud Shadow

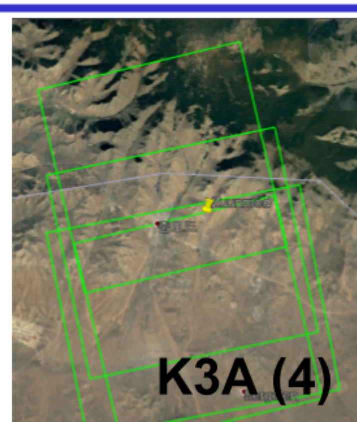




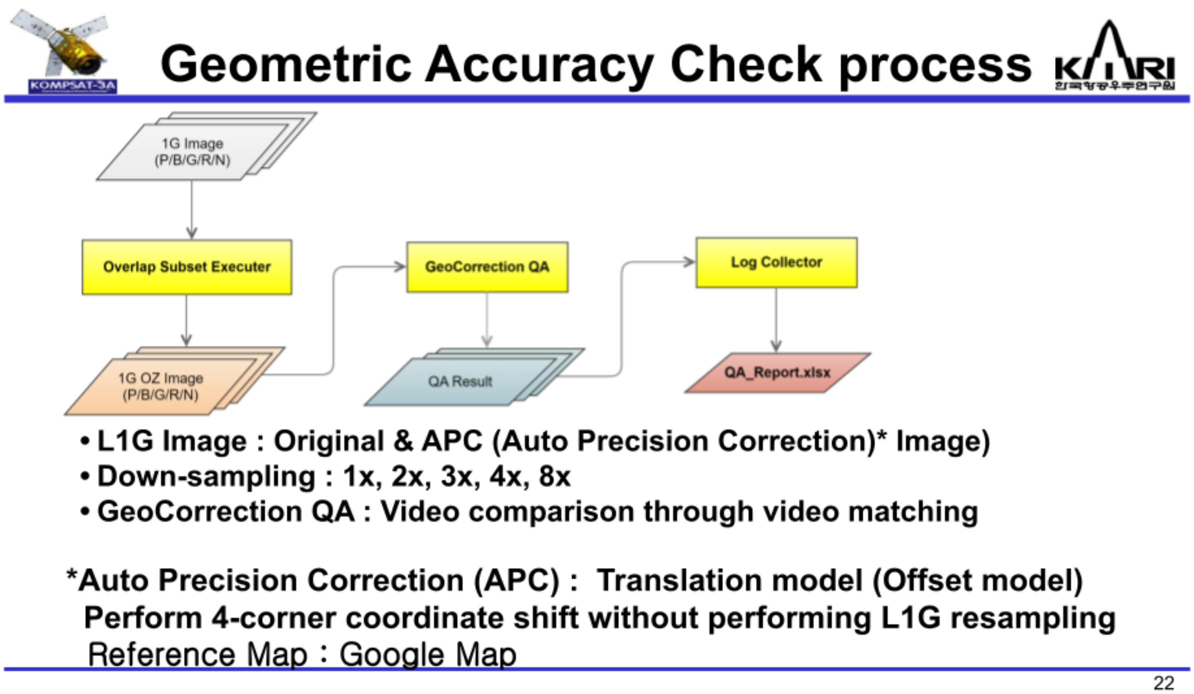


Geometric Accuracy Check for ARD





Product Folder	Satellite	Product Level	OrbitAtt Type	Orbit Direction	Band Name	Roll (deg)	Pitch (deg)	Yaw (deg)	Min.(m)	Max.(m)	Avg.(m)	Latitude (deg)	Longitude (deg)
K3_20170918055952_28479_08141357_L1G	KOMPSAT-3	L1G	PODPAD	ASCENDING	B	-29.36	-0.15	-2.23	1309.31	1669.40	1466.00	47.72	106.83
K3_20170920053857_28508_08141357_L1G	KOMPSAT-3	L1G	PODPAD	ASCENDING	B	-0.65	-0.17	-2.56	1329.38	1935.93	1469.10	47.72	106.88
K3_20171130052713_29545_08141357_L1G	KOMPSAT-3	L1G	PODPAD	ASCENDING	B	16.21	-0.16	-2.39	1486.21	1857.57	1750.94	47.73	106.89
K3A_20170411055901_11293_00085085_L1G	KOMPSAT-3A	L1G	PODPAD	ASCENDING	B	17.07	0.87	2.25	1348.09	1994.83	1607.53	47.75	106.88
K3A_20170709060050_12638_00067274_L1G	KOMPSAT-3A	L1G	PODPAD	ASCENDING	B	23.80	1.07	2.02	1329.45	1804.57	1466.68	47.71	106.88
K3A_20170910054945_13590_00098945_L1G	KOMPSAT-3A	L1G	PODPAD	ASCENDING	B	6.64	0.46	2.44	1428.30	1603.53	1506.51	47.74	106.95
K3A_20170919054739_13726_00075366_L1G	KOMPSAT-3A	L1G	PODPAD	ASCENDING	B	2.82	0.30	2.48	1342.26	1707.42	1459.33	47.65	106.98


Geometric Accuracy Check process
KOMPSAT-3A
KARI
1G Image (P/B/G/R/N)
Overlap Subset Executer
1G OZ Image (P/B/G/R/N)
GeoCorrection QA
QA Result
Log Collector
QA_Report.xlsx
• L1G Image : Original & APC (Auto Precision Correction)* Image)
• Down-sampling : 1x, 2x, 3x, 4x, 8x
• GeoCorrection QA : Video comparison through video matching
*Auto Precision Correction (APC) : Translation model (Offset model)
Perform 4-corner coordinate shift without performing L1G resampling
Reference Map : Google Map
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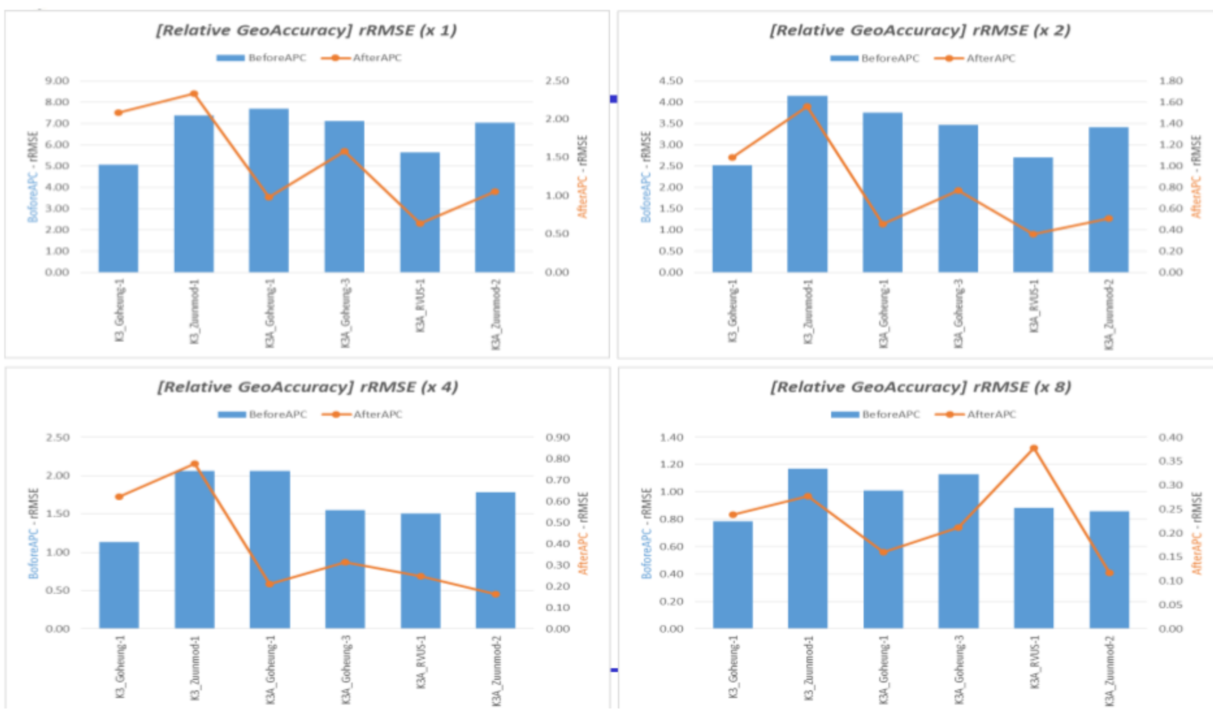
[Relative GeoAccuracy] rRMSE (x 1)
[Relative GeoAccuracy] rRMSE (x 2)
[Relative GeoAccuracy] rRMSE (x 4)
[Relative GeoAccuracy] rRMSE (x 8)
BeforeAPC
AfterAPC
AfterAPC - rRMSE
K3_Goheung-1
K3_Zuunmod-1
K3A_Goheung-1
K3A_Goheung-3
K3A_RVUS-1
K3A_Zuunmod-2

Conclusion

- We assessed compliance of K-3/3A (KOMPSAT-3/3A) level 1 products with CARD4L-SR PFS. Since the K-3/3A is high-resolution satellite, many requirements are still challenging.
- To investigate whether CARD4L on K3/K3A is feasible, we performed experimental tests on cloud/cloud shadow detection and atmospheric corrections and geometric correction requirements.
- We obtained promising results to comply CARD4L requirements for cloud/cloud shadow detection and atmospheric corrections. However, Geometric Correction requirement (Sub-pixel accuracy : less than 0.5 Pixel rRMSE) is almost impossible to meet for K3 / K3A original resolution.
  - Down sampling image (about 5 m resolution) for K3 /K3A show the possibility to meet the CARD4L requirements.

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JAXA

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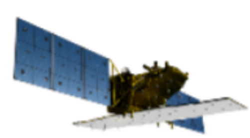
JAXA mission and CARD4L product development update

Takeo Tadono, JAXA EORC
Ake Rosenqvist, soloEO/JAXA

LSI-VC-10 #1 – May 12, 2021

ALOS-2 mission status

- ALOS-2 payload performance nominal – No geometric, radiometric or polarimetric anomalies have been observed
- ALOS-2 in extended mission phase since May 2019
- Observation duty cycle reduced to 30% (from 50%) to conserve mission resources
    - Observations in Fine Beam Stripmap mode limited to one single global coverage per year (target)
    - Observations in 50 m ScanSAR mode proceed without reduction. Regional observations every 3 cycles (42-day repeat, 9 obs/year). Focus on pan-tropics and crustal deformation areas.

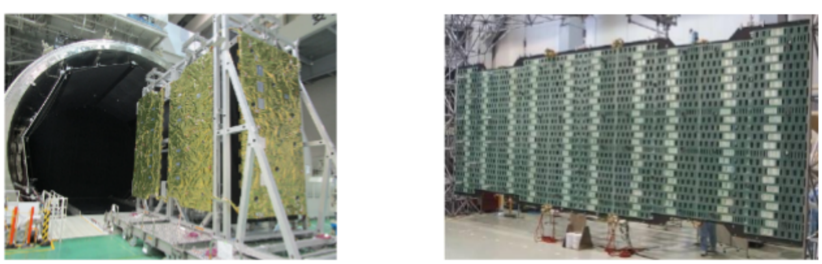


JAXA ALOS-4 mission development status 28

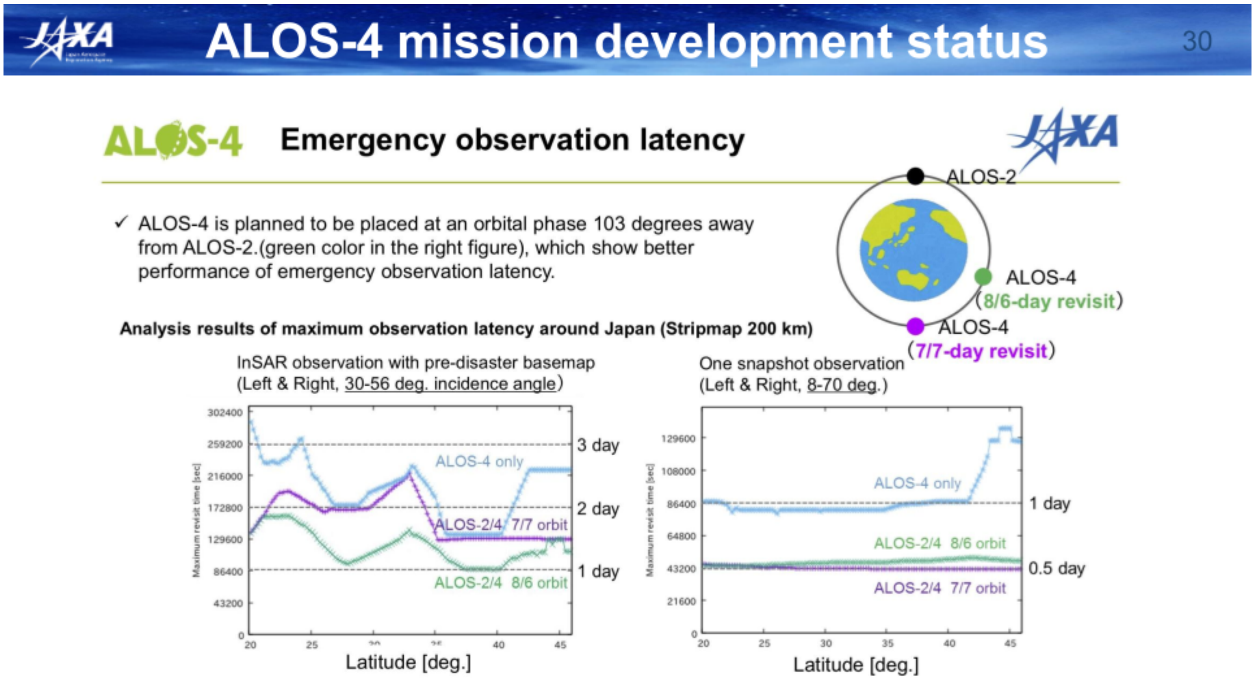
- ALOS-4 PALSAR-3 to provide continuation and enhanced performance of ALOS-2 PALSAR-2. Key improvements include wider swath and observation capacity in both dual- and full polarimetric modes.
- Currently in Phase D – Proto-Flight Model (PFM) manufacturing and tests
- Launch shifted – now foreseen within JFY 2022 (2022/04-2023/03)
- Operations to commence 6 months after launch (3 mo check-out, 3 mo Cal/Val)
- Global observation strategy under development
- Joint operations with ALOS-2 planned until ALOS-2 EOL

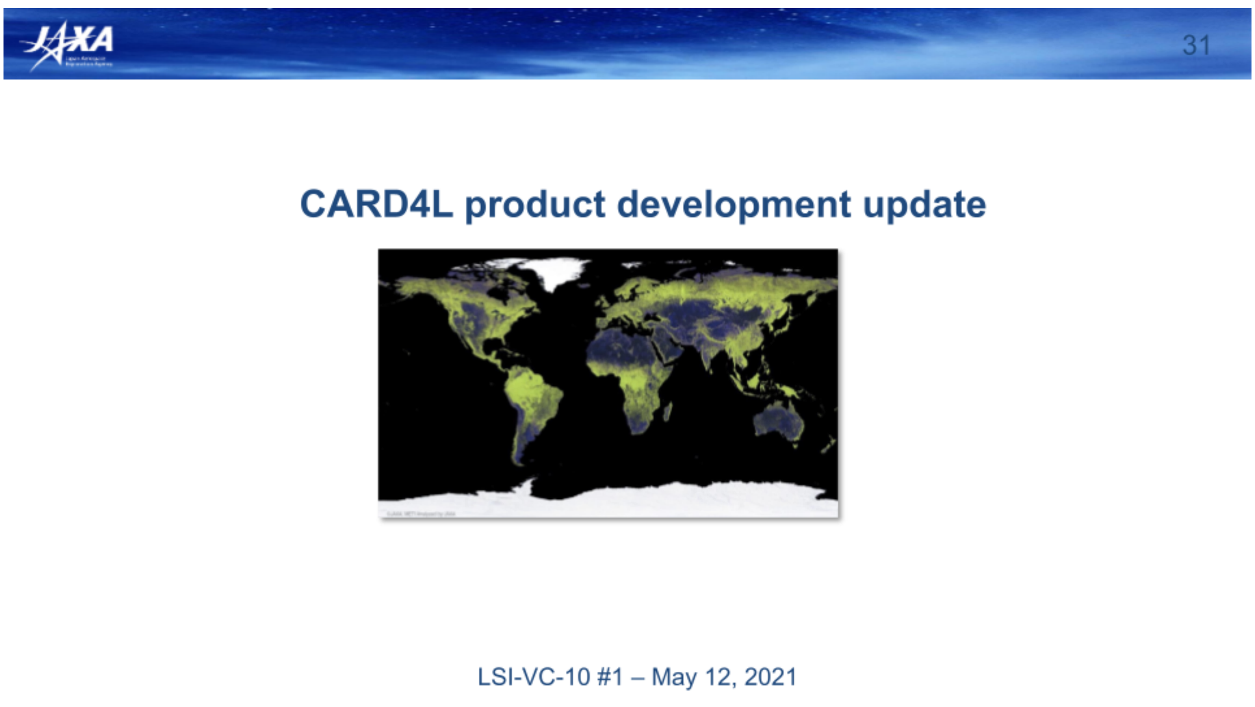
JAXA ALOS-4 mission development status 29

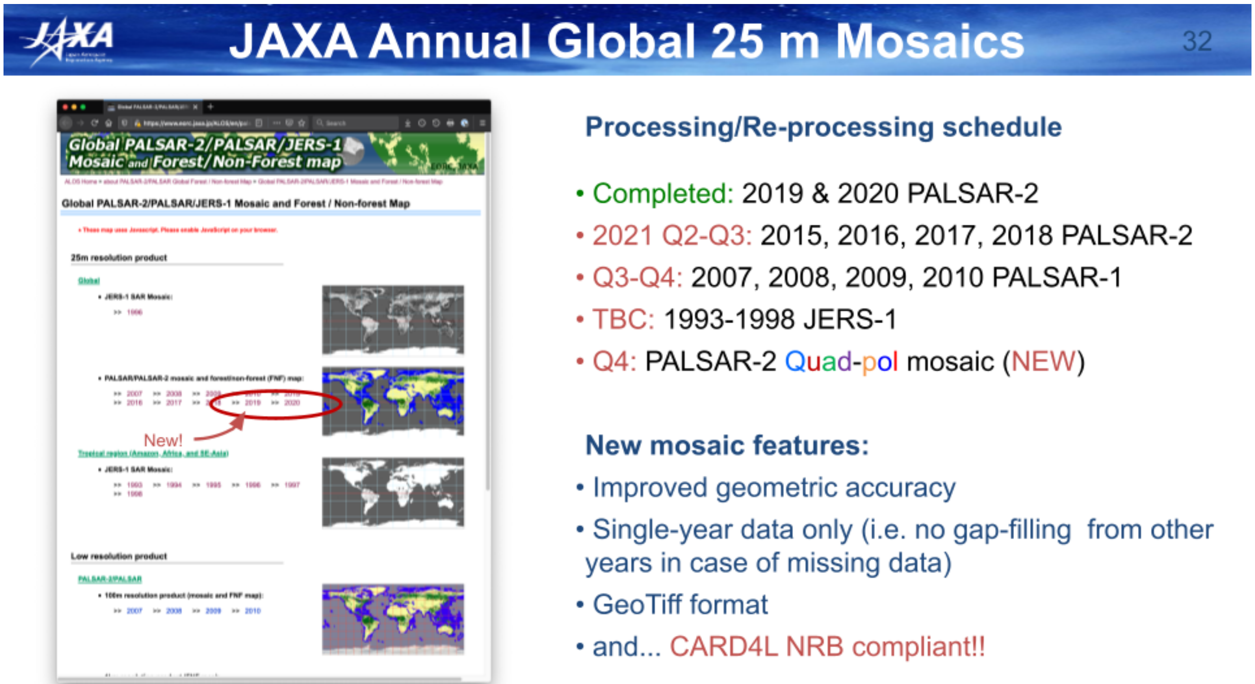
- ALOS-4 PALSAR-3 to provide continuation and enhanced performance of ALOS-2 PALSAR-2. Key improvements include wider swath and observation capacity in both dual- and full polarimetric modes.
- Currently in Phase D – Proto-Flight Model (PFM) manufacturing and tests
- Launch planned within JFY 2022 (2022/04-2023/03)
- Operations to commence 6 months after launch (3 mo check-out, 3 mo Cal/Val)
- Joint operations with ALOS-2 foreseen

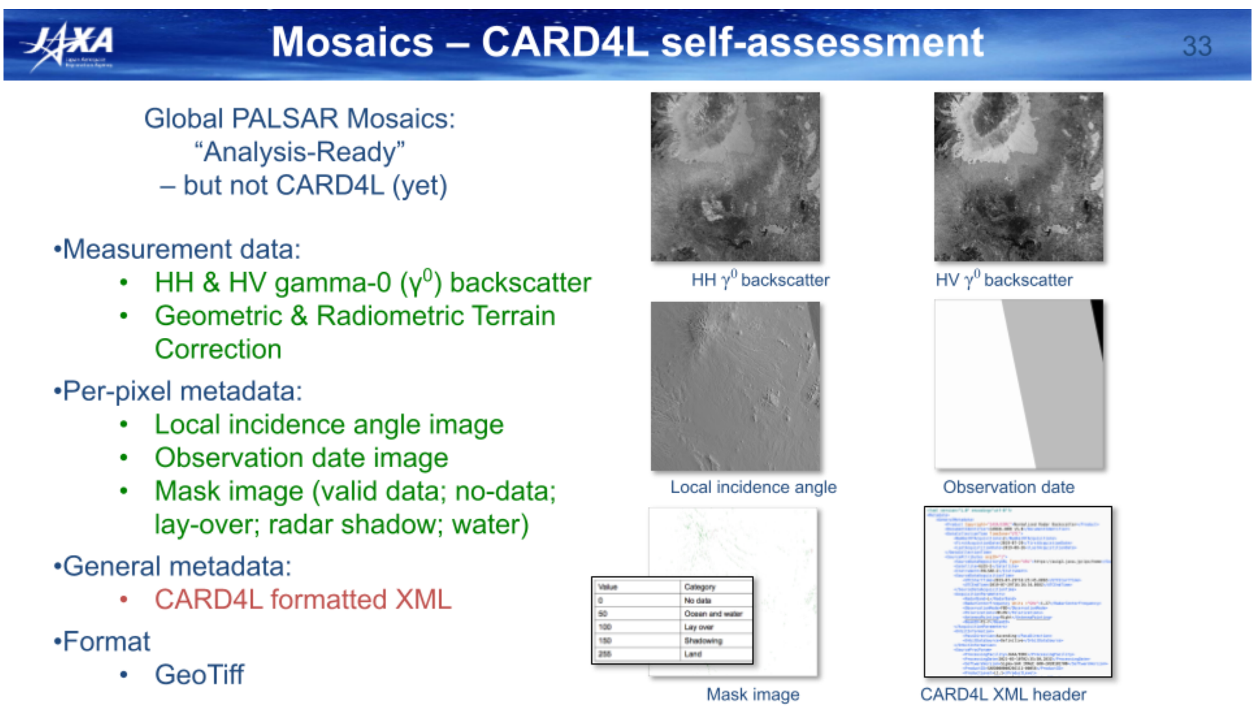


PALSAR-3 antenna PFS tests


ALOS-4 mission development status
30
ALOS-4 Emergency observation latency
JAXA
✓ ALOS-4 is planned to be placed at an orbital phase 103 degrees away from ALOS-2.(green color in the right figure), which show better performance of emergency observation latency.
ALOS-2
ALOS-4 (8/6-day revisit)
ALOS-4 (7/7-day revisit)
Analysis results of maximum observation latency around Japan (Stripmap 200 km)
InSAR observation with pre-disaster basemap (Left & Right, 30-56 deg. incidence angle)
One snapshot observation (Left & Right, 8-70 deg.)
3 day
2 day
1 day
ALOS-4 only
ALOS-2/4 7/7 orbit
ALOS-2/4 8/6 orbit
1 day
0.5 day
Latitude [deg.]
Latitude [deg.]


31
CARD4L product development update
LSI-VC-10 #1 – May 12, 2021


JAXA Annual Global 25 m Mosaics
32
Global PALSAR-2/PALSAR/JERS-1 Mosaic and Forest/Non-Forest map
Global PALSAR-2/PALSAR/JERS-1 Mosaic and Forest / Non-forest Map
25m resolution product
Low resolution product
New!
Processing/Re-processing schedule
• Completed: 2019 & 2020 PALSAR-2
• 2021 Q2-Q3: 2015, 2016, 2017, 2018 PALSAR-2
• Q3-Q4: 2007, 2008, 2009, 2010 PALSAR-1
• TBC: 1993-1998 JERS-1
• Q4: PALSAR-2 Quad-pol mosaic (NEW)
New mosaic features:
• Improved geometric accuracy
• Single-year data only (i.e. no gap-filling from other years in case of missing data)
• GeoTiff format
• and... CARD4L NRB compliant!!


Mosaics – CARD4L self-assessment
33
Global PALSAR Mosaics:
“Analysis-Ready”
– but not CARD4L (yet)
•Measurement data:
• HH & HV gamma-0 (γ0) backscatter
• Geometric & Radiometric Terrain Correction
•Per-pixel metadata:
• Local incidence angle image
• Observation date image
• Mask image (valid data; no-data; lay-over; radar shadow; water)
•General metadata:
• CARD4L formatted XML
•Format
• GeoTiff
HH γ0 backscatter
HV γ0 backscatter
Local incidence angle
Observation date
Value
Category
0
No data
50
Ocean and water
100
Lay over
150
Shadowing
255
Land
Mask image
CARD4L XML header

Mosaics – CARD4L self-assessment

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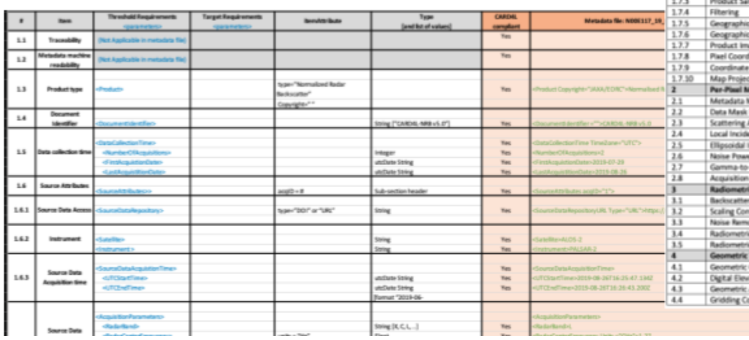
CARD4L NRB v5.0 :

- Self-assessment completed
- Target compliance with v5.0 except two items:
  - Scattering Area (per-pixel metadata)
  - Geometric Accuracy
- Awaiting update to NRB. Outstanding issues foreseen to be resolved.



		Threshold	Target
1	**General Metadata**		
1.1	Traceability	YES	
1.2	Metadata Machine Readability	YES	
1.3	Product Type	YES	
1.4	Document Identifier	YES	
1.5	Data Collection Time	YES	
1.6	**Source Data Attributes**		
1.6.1	Source Data Access	YES	
1.6.2	Instrument	YES	
1.6.3	Source Data Acquisition Time	YES	
1.6.4	Source Data Acquisition Parameters	YES	
1.6.5	Source Data Orbit Information	YES	
1.6.6	Source Data Processing Information	YES	
1.6.7	Source Data Image Attributes	YES	
1.6.8	Sensor Calibration	YES	
1.6.9	Performance Indicators	YES	
1.6.10	Source Data Polarimetric Calibration Matrices		Not required
1.6.11	Mean Faraday Rotation Angle		Not required
1.6.12	Ionosphere Indicator		Not required
1.7	**Product Attributes**		
1.7.1	Product Data Access	YES	
1.7.2	Ancillary Data		Not required
1.7.3	Product Sample Spacing	YES	
1.7.4	Filtering	YES	
1.7.5	Geographical Bounding Box	YES	
1.7.6	Geographic Image Extent	YES	
1.7.7	Product Image Size	YES	
1.7.8	Pixel Coordinate Convention	YES	
1.7.9	Coordinate Reference System	YES	
1.7.10	Map Projection	YES	
2	**Per-Pixel Metadata**		
2.1	Metadata Machine Readability	Not applicable	
2.2	Data Mask Image	YES	
2.3	Scattering Area Image		NO
2.4	Local Incident Angle Image	YES	
2.5	Ellipsoidal Incident Angle Image		Not required
2.6	Noise Power Image		Not required
2.7	Gamma-to-Sigma Ratio Image		Not required
2.8	Acquisition Date Image	YES	
3	**Radiometric Terrain Corrected Measurements**		
3.1	Backscatter Measurements	YES	
3.2	Scaling Conversion	YES	
3.3	Noise Removal	YES	
3.4	Radiometric Terrain Correction Algorithms	YES	
3.5	Radiometric Accuracy		Not required
4	**Geometric Terrain Corrections**		
4.1	Geometric Correction Algorithms		Not required
4.2	Digital Elevation Model	YES	
4.3	Geometric Accuracy		NO
4.4	Gridding Convention	YES	

Standard products – CARD4L NRB target

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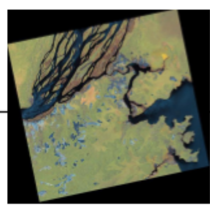
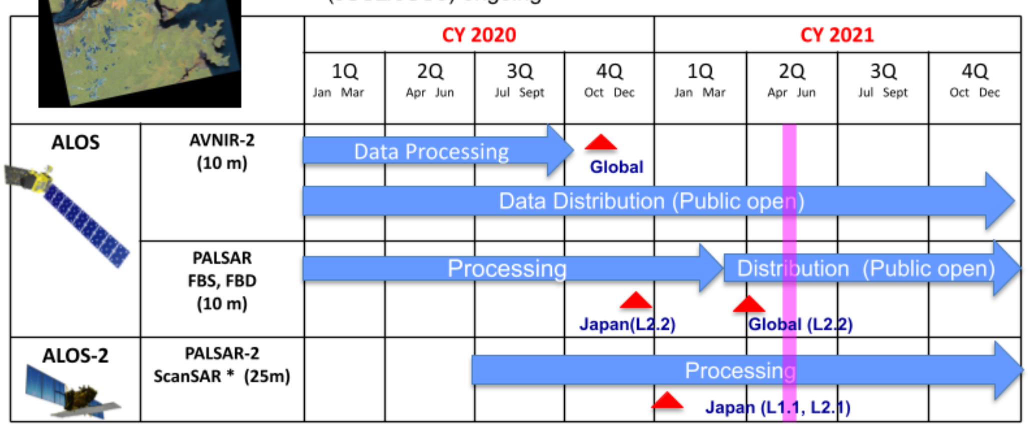


Scene-based standard products:
Reprocessing of ALOS and ALOS-2 archives by JAXA Super Computer (JSS2/JSS3) ongoing



* Production of ALOS-2 ScanSAR L2.2 (RTC) to start before the end of 2021. Software tool for conversion to CARD4L NRB product level to be provided

Thank you

ESA

Day 1: Tuesday 20 April 2021

13:00 – 14:00		**Introduction**	
13:00 – 13:10		Welcome	Toni Tolker-Nielsen (ESA)
13:10 – 13:25		Introduction, Objectives	Philippe Goryl (ESA)
13:25 – 14:00		Update on: • ESA EDAP project • NASA Commercial Smallsat Data Acquisition (CSDA) Program • JACIE coordination	Henri Laur (ESA) Kevin Murphy (NASA) Jon Christopherson (KBR) / Greg Stensaas (USGS)
14:00 – 18:00		**Institutional / Commercial ARD**	**Chair: Ferran Gascon (ESA)/ Steven Hosford (CNES)**
14:00 – 14:30	1A1	CARD4L development and status	Andreia Siqueira (Geoscience Australia)
14:30 - 15:00	1A2	ARD beyond land. CEOS perspective.	Edward M. Armstrong (JPL)
15:00 – 15:30	1A3	SAR: ARD from New Space perspective: • ICEYE • e-GEOS	Shay Strong (ICEYE) / Axel Oddone (e-GEOS)
15:30 - 16:00	1A4	Optical Sensor: ARD from New Space perspective: • Indigo Agriculture • Planet • Maxar	Ignacio Zuleta (Indigo Agriculture) Rasmus Houborg (Planet) Fabio Pacifici (Maxar)
16:00 - 16:30	1A5	CARD4L concrete examples: Sentinel-2/LANDSAT and Sentinel-1	Ferran Gascon (ESA) / Steve Labahn (USGS) / David Small (University of Zurich)
16:30 – 16:40		**Coffee Break**	
16:40 – 18:00	**1A6**	**Discussion**	**ALL**
18:00		**End of Day 1**	

VH-RODA / Session on Institutional & Commercial ARD

Definition of Analysis Ready Data (ARD)

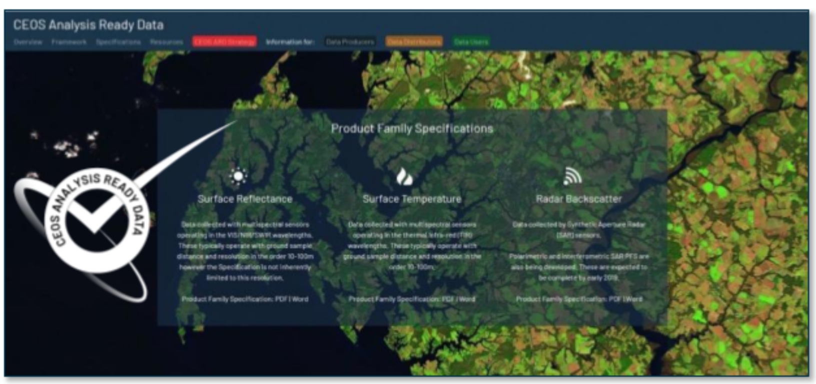
- ✔ Institutional sector well advanced with:
  - ✔ CARD4L specifications defined for 5 product families,
  - ✔ additional CARD4L specifications in the pipeline,
  - ✔ CEOS-endorsed terminology and
  - ✔ interest in developing CEOS ARD specifications for non-land applications.
- ✔ Commercial sector brought additional concepts/thoughts like:
  - ✔ ARS (Analysis Ready Services), going beyond the notion of product that limits the range of downstream applications, or
  - ✔ the need to move towards product Levels 4 and 5.

Commercial space involvement

- ✔ General consensus that sensor agnostic, standardised and easy-to-use products are interesting for non-expert users.
- ✔ Commercial sector is showing some support to CEOS-lead CARD4L initiative (2 commercial products under certification: Sinergise Sentinel-1 and Element 84 Sentinel-2).
- ✔ Need to reinforce CEOS-led initiatives to promote ARD in general and CARD4L in particular (e.g. in venues like ARD workshop, JACIE, VH-RODA) to foster adoption of CARD4L by the commercial sector.
- ✔ Need to reinforce the promotion of the benefits brought by existing and future CARD4L products in the general effort towards facilitating missions inter-operability + advantage of being first movers.

S2 Analysis Ready Data (ARD) – Level-2A

- ✔ Process initiated to certify Sentinel-2 Level-2A products.
- ✔ Sentinel-2 products expected to be compliant CARD4L requirements soon, after full activation of geometric refinement and inclusion of a DOI (Digital Object Identifier) in the metadata.



Sentinel-2 Towards CARD4L compliance

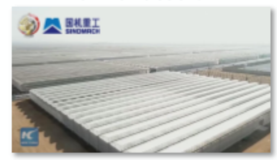
Improvement of geometric performances since 30 March 2021:

- ✔ Absolute geolocation accuracy from 11m improved to **8 m** (CE95).
- ✔ Multi-temporal co-registration accuracy from 12m improved to **5 m** (CE95).

Not Refined Geometry

Refined Geometry

Greenhouses in Egypt's former desert



Copyright: New China TV

Copyright: contains modified Copernicus Sentinel data (2020), processed with Sentinel Hub EO Browser

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Towards Sentinel-2 Collection 1

- ➔Collection 1 will be generated reprocessing full S2 archive for both Level-1C (TOA reflectance) and Level-2A (surface reflectance and cloud mask) products.
- ➔Reprocessing campaign foreseen to start during Q4 2021.
- ➔Collection 1 available to users by second half 2022.
- ➔Collection 1 will feature several improvements on both Level-1C and Level-2A products.
- ➔Collection 1 targets CARD4L compliance for Level-2A products (currently only DOI inclusion is missing).

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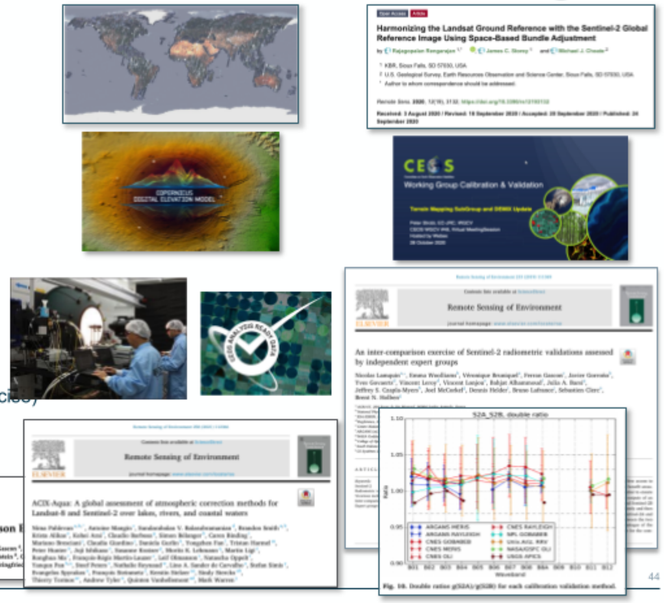
S2 - Landsat Interoperability

- ✔ **Geometry :**
  - ✔ S2 GRI (Global Reference Image)
  - ✔ Copernicus DEM (Digital Elevation Model)
  - ✔ DEMIX (DEMs Intercomparison eXercise)
  - ✔ DGGS (Discrete Global Grid System)
- ✔ **Top-Of-Atmosphere Radiometry :**
  - ✔ Sensor inter-comparison using an integrating sphere
  - ✔ S2 “inspired” by Landsat-8 bands
  - ✔ Absolute radiometry inter-comparison
- ✔ **Surface Reflectance and Cloud Mask:**
  - ✔ ACIX (Atmospheric Correction Intercomparison eXercise)
  - ✔ CMIX (Cloud Mask Intercomparison eXercise)
  - ✔ CARD4L [http://ceos.org/ard]
- ✔ **Harmonised and Fused Products**
  - ✔ Sen2Like



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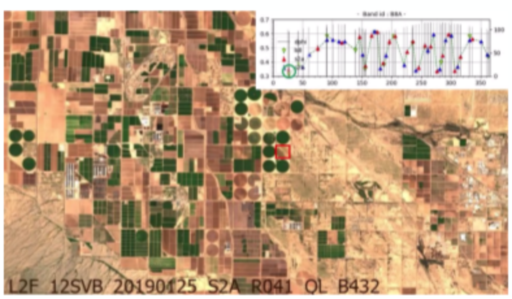
VC-19-05: Open-source library for surface reflectance product generation



- ✔ Sen2Like software available in open-source at: https://github.com/senbox-org/sen2like
- ✔ Sen2Like pilot productions provided to several teams (Copernicus Services, Szantoi et al., Labahn et al., Roy et al., Schaaf et al.).
- ✔ Pilot productions also available to LSI-VC members.
- ✔ Sen2Like being compared with NASA HLS.

- ✔ Sen2Cor will become also available also in open-source on GitHub during Q3 2021.
- ✔ Sen2Cor new release in open-source will support both Sentinel-2 and Landsat.

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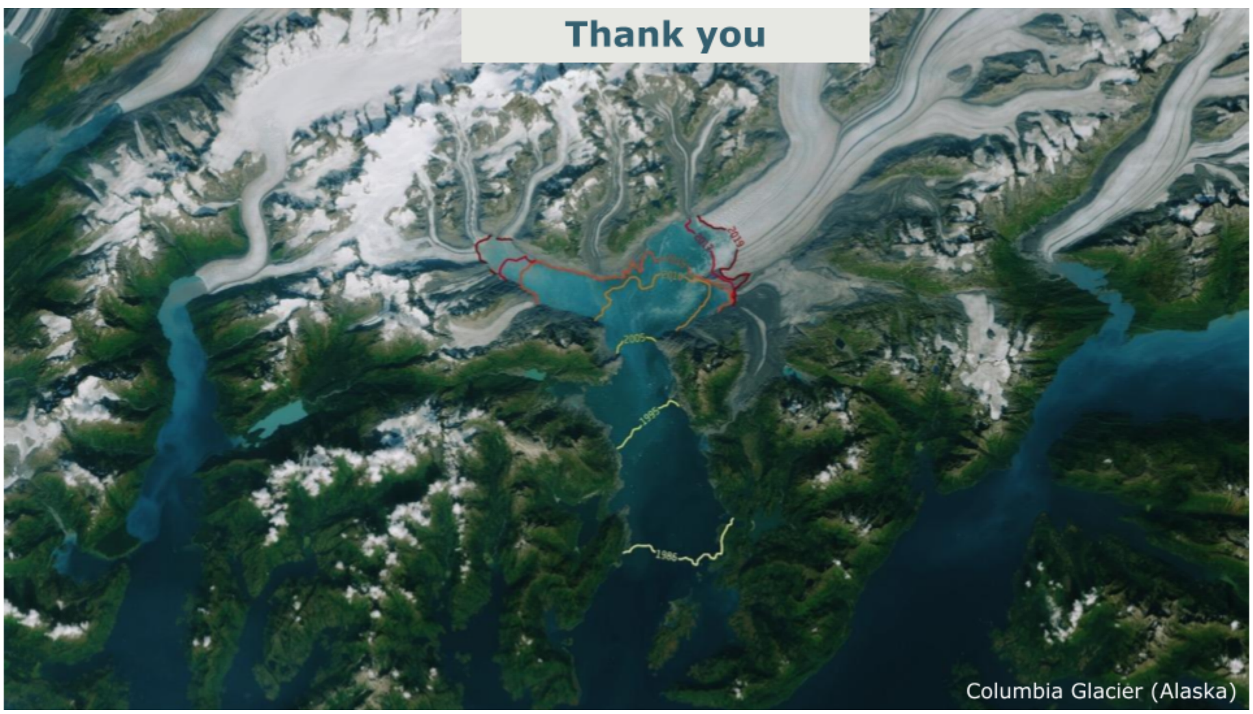
Landsat + Sentinel-2 in Google Earth Timelapse

Google statement:

"As far as we know, Timelapse in Google Earth is the largest video on the planet, of our planet. And creating it required out-of-this-world collaboration. ***This work was possible because of the U.S. government and European Union's commitments to open and accessible data****. Not to mention their herculean efforts to launch rockets, rovers, satellites and astronauts into space in the spirit of knowledge and exploration. Timelapse in Google Earth simply wouldn't have been possible without NASA and USGS Landsat program, the world's first (and longest-running) civilian Earth observation program, and the* ***European Union's Copernicus program with its Sentinel satellites****."*

https://blog.google/products/earth/timelapse-in-google-earth/



ISRO

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CARD4L and Product family specification(PFS):

Assessment and Production: RS2/2A Products-NRSC/ISRO

LSI-VC-10 : 12 May 2021

T. Radhika, NRSC, ISRO

Objective

- Design an approach to generate Analysis Ready Data (ARD) set using IRS sensors data.
- Currently we propose to generate ARD sets from Resourcesat-2 series (RS2/RS2A)

ARD (Surface Reflectance Family) product includes temporal sets in compliance with CARD4L product family specs..

- Top of Atmosphere (TA) reflectance (reflectance calculated "at sensor," not atmospherically corrected)
- Surface Reflectance (SR) (atmospherically corrected)
- Pixel Quality Assessment (QA) (common and sensor specific quality bands included)
- General meta data
- Quality meta data

From relevant/similar sensors

Resourcesat-2/ 2A:

The Resourcesat-2(RS-2) satellite was launched by the Indian Space Research Organization (ISRO) on April-2011, followed by Resourcesat-2A(RS-2A) on Dec-2016, to ensure systematic and repetitive coverage of the earth's surface to provide data for integrated land and water resource management.

	AWiFS	LISS-3	LISS-4
No of Bands	4	4	3
Spectral Band2 (μ)	0.52 – 0.59 (green)	0.52 – 0.59 (green)	0.52 – 0.59 (green)
Spectral Band3 (μ)	0.62 – 0.68 (red)	1.55 – 1.70 (SWIR)	1.55 – 1.70 (SWIR)
Spectral Band4 (μ)	0.77 – 0.86 (NIR)	0.77 – 0.86 (NIR)	0.77 – 0.86 (NIR)
Spectral Band5 (μ)	1.55 – 1.70 (SWIR)	1.55 – 1.70 (SWIR)	-
Resolution (m)	56	24	5.8
Swath (km)	740	140	70
Revisit period (days)	5	24	5

Status of RS2/2A Data products :CARD4L framework

- Expertise in realizing Ortho- Surface reflectance(SR) products
- Thorough Validation carried out with Insitu measurements - varied reflectance features , ISRO-CAL sites and with OLI
- RS-2/2A SR product is in good agreement with OLI with R2 > 95 % for R2A and R2 ~ 90 % for R2
- Geometric Accuracy : better than a pixel (CE90)
- QA band with cloud and cloud shadow
- Variation of SR values is more on Aquatic features

PFS assessment

1. General Metadata
1.1 Traceability
1.2 Metadata Machine Readability
1.3 Data Collection Time
1.4 Geographical Area
1.5 Coordinate Reference System
1.6 Map Projection
1.7 Geometric Correction Methods
1.8 Geometric Accuracy of the Data
1.9 Instrument
1.10 Spectral Bands
1.11 Sensor Calibration
1.12 Radiometric Accuracy
1.13 Algorithms
1.14 Auxiliary Data
1.15 Processing Chain Provenance
1.16 Data Access
1.17 Overall Data Quality

Threshold : 9/10, Target 7/17

4. Geometric Corrections
4.1 Geometric Correction

Threshold : 0/1, Target 0/1

2. Per-Pixel Metadata
2.1 Metadata Machine Readability
2.2 No Data
2.3 Incomplete Testing
2.4 Saturation
2.5 Cloud
2.6 Cloud Shadow
2.7 Land/Water Mask
2.8 Snow/Ice Mask
2.9 Terrain Shadow Mask
2.10 Terrain Occlusion
2.11 Solar and Viewing Geometry
2.12 Terrain Illumination Correction
2.13 Aerosol Optical Depth Parameters

Threshold : 5/7, Target 5/11

3. Radiometric and Atmospheric Corrections
3.1 Measurement
3.2 Measurement Uncertainty
3.3 Measurement Normalisation
3.4 Directional Atmospheric Scattering
3.5 Water Vapour Corrections
3.6 Ozone Corrections

Threshold : 4/4, Target 4/6

Analysis Ready Satellite Data at NASA

Christopher Lynnes

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Analysis Ready Satellite Data

Chris Lynnes*, NASA

*U.S. Govt. Civil Servant

1

CARD4L* Definition

...satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets.

Analysis type unspecified, except...

...time series analysis emphasized

*CARD4L = CEOS Analysis Ready Data for Land

2

Analysis Ready Data (ARD) Benefits

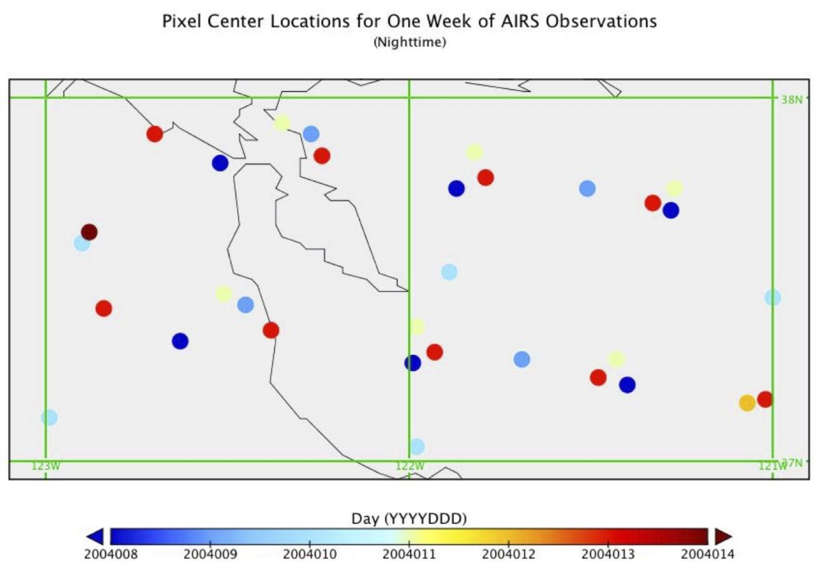
- ARD requires:
  - Important metadata
  - Easy to use spatial characteristics
  - Corrections for confounding factors (e.g., atmospheric)
- ARD promises to make time series analyses easier
- Especially useful for:
  - Applications

3

Can Level 2 Data Be Analysis-Ready?

4

L2 Time Series Analysis is...hard

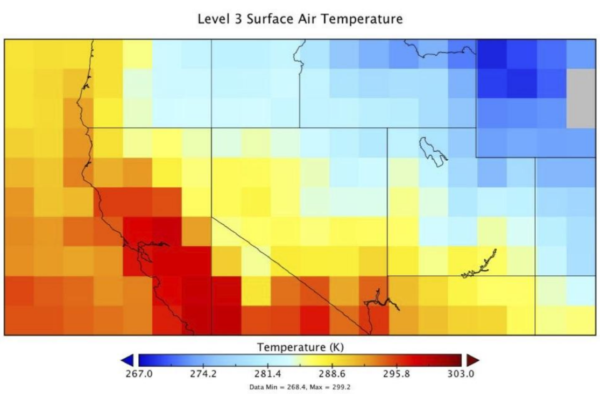


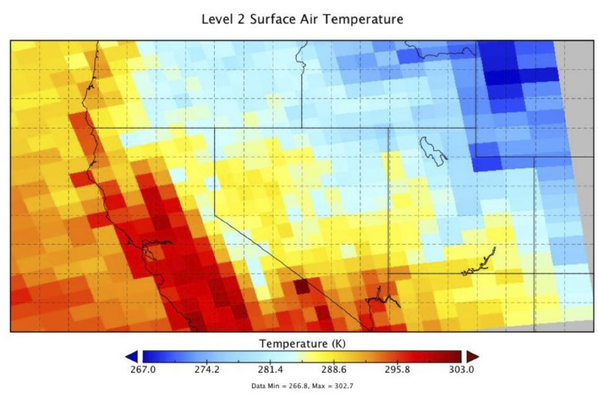
5

Aggregation to Level 3 (L3) gridded data regularizes geolocation, but...

6

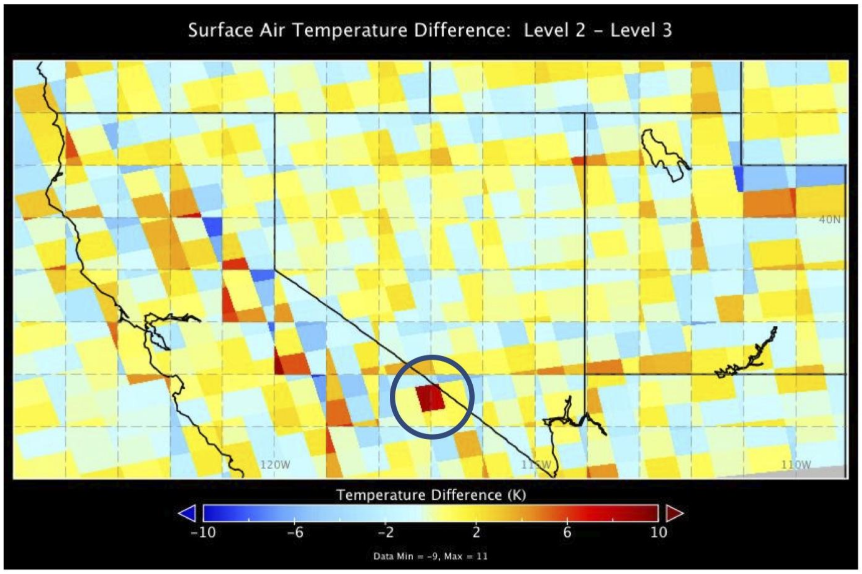
...at the cost of spatial resolution...





7

...and suppresses extreme values



8

Caveats of Level 3 Data

1. Spatial resolution degradation
2. Suppression of extreme values
3. Systematic bias over time in heterogeneous pixels
4. Day boundary artifacts
5. Difficulty of assigning numerical uncertainty to pixels
6. "Beating" of fast moving phenomena (e.g. dust storms) in long-duration aggregates (e.g., MISR monthly)
7. Irretrievable information loss when reprojecting from original L3 projection
8. Difficulty of assigning pixel level quality

9

NASA Workshop 11/25/2020

1. Try for quick wins with Level 3 / Level 4 data
2. Engage with CEOS w.r.t. ARD in other disciplines
3. Apply a more nuanced approach with L1/L2...

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Making L1/L2 data analysis-ready

1. Make L1 and L2 data easier to analyse
   a. Tooling
   b. Modifications to data organization
   c. Capacity Building: examples and tutorials
2. Support on-the-fly gridded ARD from L1 and L2 data
   a. Defer resampling as long as possible to limit information loss
   b. Quantify information loss

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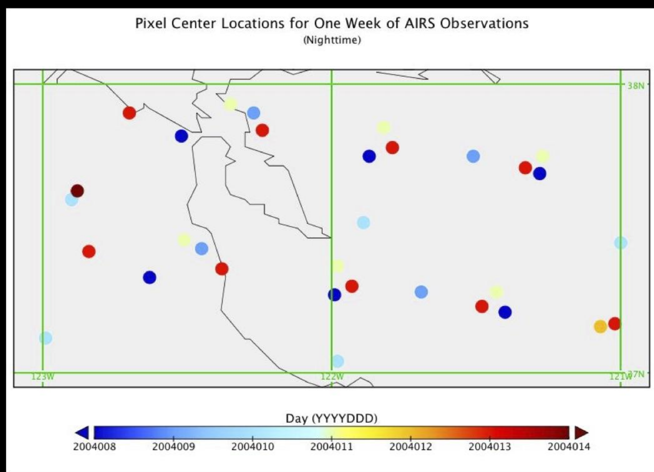
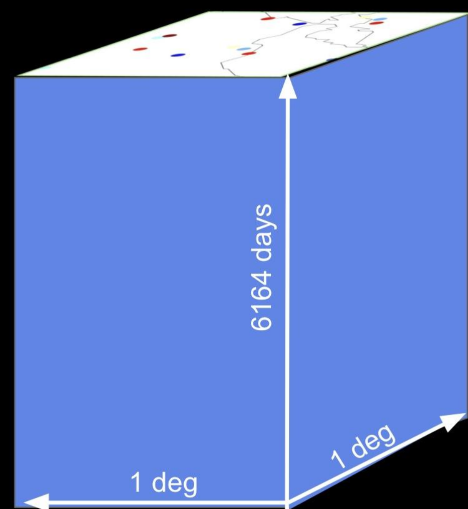
L2G Time Stacks





DLR: EnMAP
ARD / CARD4L Metadata

Martin Bachmann et al., DLR
for the EnMAP Ground Segment

EnMAP
Hyperspectral Imager

Federal Ministry for Economic Affairs and Energy

EnMAP
ARD / CARD4L Metadata

Martin Bachmann et al., DLR
for the EnMAP Ground Segment

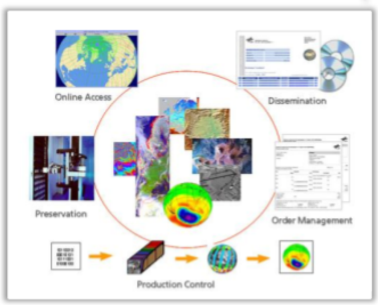
GFZ Helmholtz-Zentrum Potsdam DLR OHB System

Supported by the DLR Space Administration with funds of the German Federal Ministry of Economic Affairs and Energy on the basis of a decision by the German Bundestag (50 EE 0850).

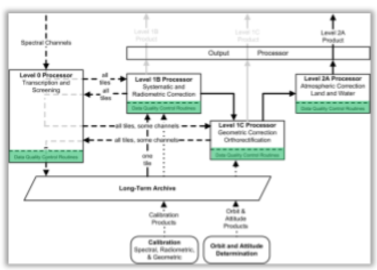
EnMAP
Hyperspectral Imager

Overview

- DLR's multi-mission infrastructure „DIMS"
  - Incl. TerraSAR-X, ENVISAT and others
  - GEOSERVICE: ISO19115 & INSPIRE
  - Current topics: ARD-complient hosting of S-1 & S-2 archives



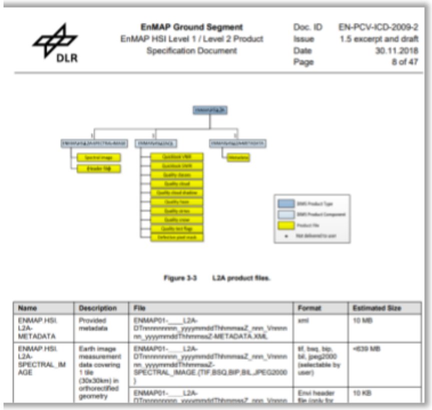
- EnMAP – German Hyperspectral Mission
  - COPERNICUS contributing mission
  - Launch: Q1 2022
  - Processing up to L2A (ortho-rectified BOA reflectance)
  - L2A: tiled products, 218 bands
  - Processing similar to DESIS @ ISS
  - Complete sample products available: https://www.enmap.org/data_tools/testdata/



EnMAP – Product Specifications & Metadata

- Archived product: L0+ incl. metadata up to L2A
- L1B, L1C, L2A (land & water) user product generation on demand
- L2A product: Datacube + Quicklooks + 8 QualityLayers + XML Metadata

CARD4L-SR (V.5.0) is suitable for hyperspectral data



@ L0, L1B, L1C, L2A:

Layers:
- Quicklooks (VNIR, SWIR)
- Classification
- Cloud
- Cloud shadow
- Haze
- Cirrus
- Snow
- QC flags (sat., strip., quality)
- Defective Pixel Mask

Metadata:
- Data Quality
- Geo. accuracy (matching)
- Atm. conditions
- …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Ground Segment 3

DLR

Obstacles reg. full „target“ conformity

- Auxiliary information (esp. reference image, DEM + derivates) partially commercial
- Traceability of instrument lab. calibration would require industry commitment / likely change of contracts
- Parts of the geo/spec/rad calibration information is provided within metadata (RPCs, spectral smile)…
- … other parameters (esp. straylight) too exhaustive to be provided
- In-orbit radiometric performance will be documented within publications, uncertainty budget @ L2A in development

Summary Self-Assessment Table

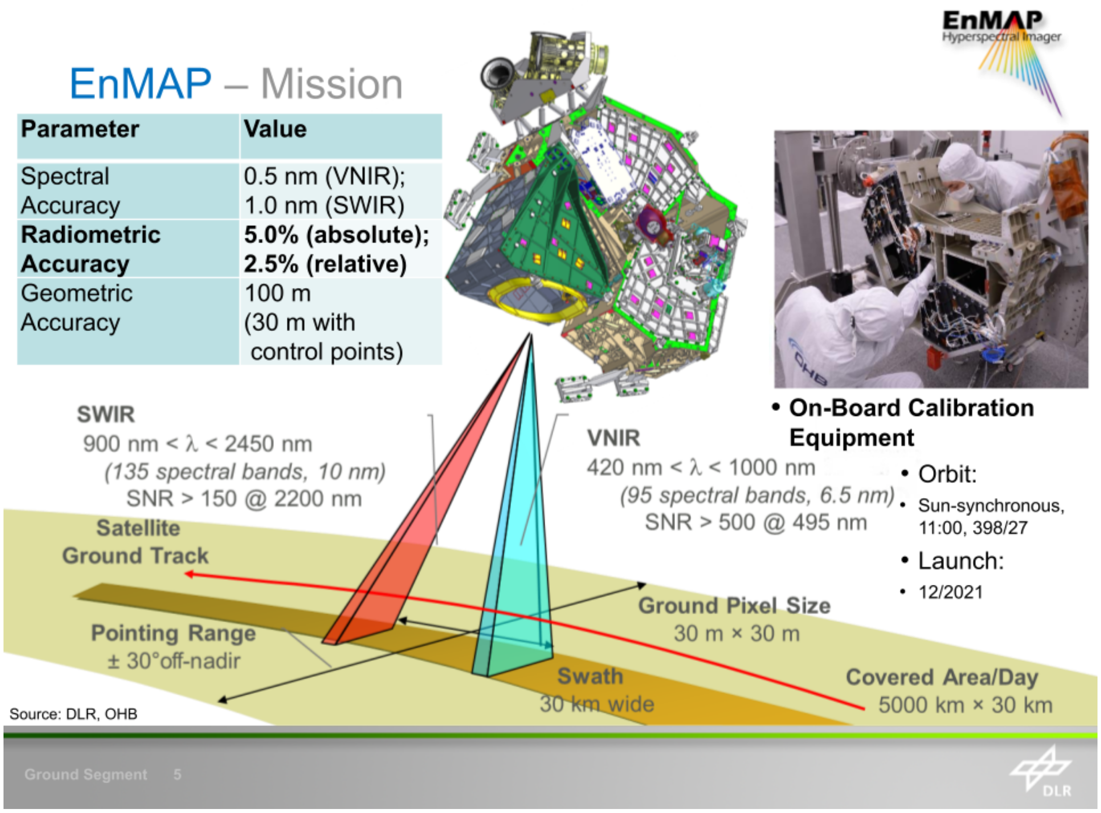
	Threshold	Target
1. General Metadata		
1.1 Traceability	n.a.	no
1.2 Metadata Machine Readability	ok	ok
1.3 Data Collection Time	ok	no
1.4 Geographical Area	ok	ok
1.5 Coordinate Reference System	ok	ok
1.6 Map Projection	ok	ok
1.7 Geometric Correction Methods	n.a.	ok
1.8 Geometric Accuracy of the Data	n.a.	ok
1.9 Instrument	ok	ok
1.10 Spectral Bands	ok	ok
1.11 Sensor Calibration	n.a.	no
1.12 Radiometric Accuracy	n.a.	no
1.13 Algorithms	ok	partially
1.14 Auxiliary Data	ok	no
1.15 Processing Chain Provenance	n.a.	no
1.16 Data Access	ok	ok
1.17 Overall Data Quality	n.a.	ok
2. Per-Pixel Metadata		
2.1 Metadata Machine Readability	ok	ok
2.2 No Data	ok	ok
2.3 Incomplete Testing	ok	ok
2.4 Saturation	ok	partially
2.5 Cloud	ok	ok
2.6 Cloud Shadow	ok	ok
2.7 Land/Water Mask	n.a.	ok
2.8 Snow/Ice Mask	n.a.	ok
2.9 Terrain Shadow Mask	n.a.	no
2.10 Terrain Occlusion	n.a.	no
2.11 Solar and Viewing Geometry	ok	no
2.12 Terrain Illumination Correction	n.a.	no
2.13 Aerosol Optical Depth Parameters	n.a.	tbd
3. Radiometric and Atmospheric Corrections		
3.1 Measurement	ok	no
3.2 Measurement Uncertainty	n.a.	partially
3.3 Measurement Normalisation	n.a.	no
3.4 Directional Atmospheric Scattering	ok	ok
3.5 Water Vapour Corrections	ok	ok
3.6 Ozone Corrections	n.a.	ok
4. Geometric Corrections		
4.1 Geometric Correction	ok	ok

Ground Segment 4

DLR

EnMAP – Mission

Parameter	Value
Spectral Accuracy	0.5 nm (VNIR); 1.0 nm (SWIR)
Radiometric Accuracy	**5.0% (absolute); 2.5% (relative)**
Geometric Accuracy	100 m (30 m with control points)



- **On-Board Calibration Equipment**
- Orbit:
  - Sun-synchronous, 11:00, 398/27
- Launch:
  - 12/2021

Wrap-up

LSI-VC Leads