# Second SRIX Workshop: Minutes

**Date:** 23/11/23 - 24/11/23

**Location:** ESA ESRIN, Frascati, Italy and Online

## Actions

| ID | Activity | Responsibility of |
|---|---|---|
| 1.1 | Write Introduction | CEOS (Philipe and Fabrizo) |
| 1.2 | Write Section 2 | Raquel De Los Reyes |
| 1.3 | Write Section 3 | Raquel De Los Reyes |
| 1.4 | Write Section 4 | CSIRO? (At the request of Medhavy) |
| 1.5 | Write Section 5 | Ben Brede |
| 1.6 | Write Section 6 | Raquel De Los Reyes |
| 1.7 | Write Supporting Measurements Section | Margaret Kalacska with the assistance of Magdalena Smigaj |
| 1.8 | Write Instrument Types Section | Magdalena Smigaj |
| 1.9 | Write Trade Offs Section | Agreed this would encompass all sections - TBD |
| 1.10 | Write Flight Design Section | Juan Pablo Arroyo Mora and Margaret Kalacska |
| 1.11 | Write Processing Chain Section | TBD |
| 1.12 | Write Definitions Section | Community effort - create google doc to allow collaboration |
| 1.13 | Write Satellite Requirements Section | Raquel De Los Reyes |
| 1.14 | Write Field Target Section | TBD |
| 1.15 | Write Importance and Needs Section | All Participants |
| 2.1 | Provide Contact Details of Participating Authors | All Participating Authors |
| 2.2 | Provide Ideas regarding more ideas for papers | All Participants |

## Attendance

| Name | Organisation | ESRIN/Online |
|---|---|---|
| Niall Origo | National Physical Laboratory | ESRIN |
| Harry Morris | National Physical Laboratory | ESRIN |
| Chloe Randall | National Physical Laboratory | ESRIN |
| Ben Brede | GFZ | ESRIN |
| Valentina Boccia | ESA | ESRIN |
| Ray Soffer | NRC ARSL | ESRIN |
| Noelle Cremer | SERCO | ESRIN |
| Magdelena Smigaj | WUR | ESRIN |
| Medhavy Thankappen | Geoscience Australia | ESRIN |
| Raquel de los Reyes | DLR | ESRIN |
| Morven Sinclair | National Physical Laboratory | Online |
| Rasma Ormane | National Physical Laboratory | Online |
| Matthew Scholes | National Physical Laboratory | Online |
| Jorge Sanchez | EOLab | Online |
| Daniele Latini | GEO-K | Online |
| Honkavaara Eija | NLS | Online |
| Marcos Jimenez | INTA | Online |
| Leonardo De Laurentiis | ESA | Online |
| Ernesto Lopez-Baeza | University of Valencia | Online |
| Gabriele Brizzi | Serco | Online |
| Ricardo Diaz-Delgado | EBD-CSIC | Online |
| Maximilian Brell | GFZ | Online |
| Avi Pertiwi | DLR | Online |
| Margaret Kalacska | McGill University | Online |
| Lanconelli Christian | JRC-ISPRA-EXT | Online |
| Dries Raymaekers | VITO | Online |
| Nina Raqueno | RIT | Online |
| Bringfried Pflug | DLR | Online |
| Britta Themann | RHE Group Luxembourg | Online |
| Else Swinnen | VITO | Online |
| Fabrizo Niro | CEOS | Online |
| Fernando Camacho | EOLAB | Online |
| Juan Pablo Arroyo-Mora | NRC | Online |
| Ian Lau | CSIRO | Online |
| Jinlong Fang | National Satellite Meteorological Centre | Online |

| | | |
|---|---|---|
| Kosal Kuhn | Université de Montréal | Online |
| Nuria Cartez | Grumets Research Group | Online |
| Jadu Dash | University of Southampton | Online |

## Agenda

**Day 1:** 23/11/23, **Location:** Room E, Building 2, ESA, ESRIN, Teams Link

| **Time** (all times CET) | **Topic** | **Speaker** |
|---|---|---|
| 14:00 | Start and Welcome | Valentina Boccia (ESA) |
| 14:10 | Recap: What is SRIX4Veg | Niall Origo (NPL) |
| 14:30 | International Basis for SRIX4Veg | Valentina Boccia (ESA) |
| 14:40 | CEOS Perspective | Fabrizio Niro (CEOS) |
| 15:00 | SRIX4Veg Team Perspectives | All Participants |
| 16:00 | Coffee Break | |
| 16:20 | Scientific Results from SRIX4Veg | Niall Origo (NPL) |
| 16:40 | Lessons Learned from SRIX4Veg | Harry Morris (NPL) |
| 16:50 | Outcomes of SRIX4Veg | Niall Origo (NPL) |
| 17:10 | Feedback from the Community | All Participants |
| 18:20 | Meeting Close | |

**Day 2:** 24/11/23, **Location:** Room E, Building 2, ESA, ESRIN, Teams Link

| **Time** | **Topic** | **Speaker** |
|---|---|---|
| 09:00 | Start and Welcome | |
| 09:10 | SRIX4Veg2: Australia | Ian Lau (CSIRO) |
| 09:30 | Presenting the Protocol Template, Proposed Time and Proposed Scope | Niall Origo (NPL) |
| 09:50 | Proposed Formulation (Round Table) | All Participants |
| 10:50 | Coffee Break | |
| 11:00 | Group Photo | |
| 11:10 | Protocol Formulation Continued | All Participants |
| 13:30 | Meeting Close | |

# Key

**Q:** question

**A:** answer

**N:** note

**(*name*):** speaker or to who the note/question is addressed to

## Recap: What is SRIX4Veg

**Speaker:** Niall Origo (NPL)

- A brief overview of what are Fiducial Reference Measurements (FRM), what are their qualities, and why do we want to use them for validating vegetation.
- FRM SR contain interesting and useful information which can be used for various applications, they are spectrally and angularly dynamic which allow for biophysical parameters to be derived.
- As imaging spectrometers become lighter and cheaper meaning they can be put on UAVs, there is increased interest in their application. Surface reflectance validation can become a key application for such instruments. Considering it is such a new field, there aren't many established standards, hence the need to assess the variability across different users and methods.
- That's where the Surface Reflectance Intercomparison Exercise for Vegetation (SRIX4Veg) comes into play. The field campaigns of this exercise have two parts: SRIX4Veg-1 occurred on 18.07.2022 in Barrax, Spain. There were 2 experiments:
    - **Experiment 1:** participants had to provide information about their experiment plan (instrument, set-up, data collection and processing), and then perform this data collection based on provided theoretical satellite overpass.
    - **Experiment 2**: the participants collected data according to a predefined draft protocol.
- The instruments used were as standardised as possible; targets and the traceability for reflectance panels was provided. This exercise wasn't validating specific satellite overpass. There was no comparison of the ground based estimates versus the UAV estimates.
- The next stages include Workshop-2 (23.11.2023 - 24.11.2023), research papers, and most importantly a community agreed good practice protocol, containing all the key information and lessons learned.

**Summary:** In order to develop community agreed guidelines for retrieving and validating surface reflectance, the SRIX4Veg exercise was created. In its first stages, a field work campaign was completed in Spain (2022), where participants from various organisations collected data in two stages. First they followed an individually designed and submitted experiment plan and then repeated the same measurements following draft guidelines developed by the organisers based on the observations and feedback from the first stage.

## International Basis for SRIX4VEG: An ESA Perspective

**Speaker:** Valentina Boccia (ESA)

- The number of Earth Observation (EO) niches is rapidly increasing, which requires a large number of satellites that provide similar yet different information, which in itself is a challenge. In addition, not all of the data is taken advantage of, so we need to find ways to harness its full potential.

- Calibration and validation activities are crucial, so by coming together and agreeing on the best practises and finding ways to fix existing inconsistencies will allow us to enhance the interoperability of current and future ESA satellites.

- ESA has three ranges of satellites: science, Copernicus, and meteorology, in addition to third party missions. A long term vision is the harmonisation of all these systems. The ESA validation system consists of FRMs, monitoring tools, inter comparison of other satellites, and validation with Level 3 data.

- SRIX4Veg is a mechanism to advance on an international level, generate community-agreed protocols and procedures for surface reflectance validation using UAVs, based on rigorous traceability and uncertainty estimates.

**Summary:** ESA controls a large number of satellites with various applications. There is a lot of potential data to be recovered from these systems, all of which require calibration and validation. Through the SRIX4Veg exercise a best practices protocol can be developed, to advance on an international scale and validate the surface reflectance using UAVs.

## CEOS Perspective

**Speaker:** Fabrizio Niro (CEOS)

- Proliferation of satellite EO missions providing hyperspectral resolutions.

- Mission is to ensure long term confidence, accuracy, quality of satellite based EO data and products.

- Our vision is a system of systems, ensure quality indicators, traceability and uncertainty.

- Outcomes for CEOS:

    - Terminology and references (e.g. vocabulary, reference Solar Spectrum, reference Lunar models)

    - FRM and supersites (e.g. super characterised sites following well established protocols useful for satellite land products, FRM assessment framework)

    - Inter-comparison exercise (e.g. ACIX (atmospheric), CMIX (cloud), DEMIX (orthorectification process), BRIX (biomass), SRIX4Veg (surface reflectance of vegetation)

    - Protocols (e.g. The Land Product Validation (LPV))
    - Networks (e.g. RADCalNet, SARCalNet, TIRCalNet)
    - Database and tools (e.g. Cal/Val portal provides a repository of documents, tools, datasets)

- **Q** (Leonardo De Laurentiis): *Is the matrix in the publication?*

  **A**: Yes, in the WGCV documents, to see how this can be improved/applied, there is still ongoing research.

- **Q**: *Will the presentations be available?*

  **A**: Yes

- **Q**: *Is SRIX4Veg mainly for "good practice"?*

  **A:** There are loads of applications to surface reflectance, this is only for validating products. There will be recommendations, treatment of the general area, but primary focus is on validating surface reflectance.

**Summary:** The mission is to ensure long term confidence, accuracy, and quality of satellite based EO data and products. Our vision is a system of systems, ensuring quality indicators, traceability and uncertainty. The desired outcomes include: terminology/references, FRM/supersites, Intercomparison exercise, protocols, networks, and database/tools.

## SRIX4VEG Team Perspective

**Speaker:** Multiple (specified below)

- Daniele Latini (GEO-K)
    - UAV system: MS camera, 9 bands, compliant with VIS and NIR of Sentinel-2.
    - Dataset elaboration: co registration, geometric correction, radial correction, and radiometric calibration.
    - Exp. 1: Common protocol, Calibration from tarp, View angle filtered, Orthorectification and orthomosaic.
    - Exp. 2: GEO-K Acquisition Protocol, final dataset had 56 images, 3 cm resolution, 10 min flight time. Objective is to model BRDF using Neural Network (NN) trained with UAV-based observations.
    - Feedback: overall positive, for the proposed approach after Exp. 1. A possible step up for improving the accuracy of the geolocation data. Orthorectification and orthomosaic processing may corrupt the reflectance information. Use of RTK Drones.
- Chloe Randall (NPL)
    - NPL is the national metrology institute of the UK.

    - Instruments: Headwall with DJI, ground instruments: ASD spectrometer, Trimble base station, Tarpaulin Solar Light Company microtops.
    - Image Characterisation: uniformity correction within the flight, non-conformity demonstrated.
    - Satellite validation with UAV: convert to ref orthorectification VZA filtering pixel matchup spectral response convolution.
    - VZA filtering: additional uncertainties from BRDF due to changes in VZA.
    - UAV satellite validation: importance of conformity testing highlighted.
- Magdalena Smigaj (WUR)
    - WUR Headwall system: VNIR hyperspectral system deployed on DJI M300 platform (sensitive to strong winds, long flight time ~30 min)
    - SRIX4Veg acquisition overview: decided to fly 50 m AGL, flightime overlap of 50%, 10 min of flight time, 3 cm spatial resolution. Empirical line method (ELM) for radiometric correction based on field spectral measurements of deployed field targets. Flightline co-alignment (within 10 cm in XY direction) and mosaicking. An issue is uncertainty in absolute positioning (no GCPs).
- NERC (Niall Origo NPL substituted)
    - Hyperspectral Imager (Headwall Co-Aligned VNIR-SWIR Imager with LIDAR attachment). Grey reference panel. Flightlines aligned with 8.62 degrees from North, 80 m distance to object as ALT.
    - Discussed NERC laboratory facilities for hyperspectral imager characterisation, spectral and radiometric calibration.
    - Developed uncertainty budget.
    - There is an aim of standardisation of the calibration and uncertainty budgeting, for better intercomparison.
- Raymond J. Soffer (NRC ARSL)
    - Since 2015 implemented and tested a model for validation of satellite products.
    - Collected Sky Irradiance Measurements for 3 days. Upscaling validation process: laboratory, field spectroscopy, RPAS Hyperspectral, Airborne Hyperspectral, and Spaceborne Hyperspectral
    - Collected 7 flights of data, put various panels on the ground. Cross Calibration is usually done in the laboratory, also they do uniformity characterisation of field panels. Using field spectrometer in the laboratory a 9x9 grid is created of the target, which gives uniformity plots of the panel. Processed using standard Hyspex software. Current sources of uncertainties: Hyspex (std), ASD (NPL std), BCRF (lab std). Had some saturation issues for 40% of the panels and tarps.

- **Best practises**: need to track trends in absolute reflectance of reference panel over time, provide baseline info necessary for uncertainty budget, methodology can be implemented for modest cost with limited laboratory equipment. RPAS Data Acquisition: standardise the resulting imagery, different hyperspectral imagers have different optimal settings.

- Benjamin Brede (GFZ)
  - GFZ: EnMAP mission and sensor parameters
  - In Barrax Cubert FireflEYE 185 System, FOV: 13 degrees. Flight design (Exp 1. based on SRIX4Veg protocol) and (Exp 2. cross-lines). Custom workflow was developed from scratch (for data processing): geometry and radiometry.
  - Points of concern: Foreoptics (limited observations of interest, only 44% of images contain the VAA/VZA of interest) and Vignetting (normalised average of DNs of all images taken in-flight: ripple pattern, clear non-uniform response).
  - Evaluation of hyperspectral snapshot: (pro) Wide FOV possible, No DSM needed, Light weight (con) market for snapshot cameras focuses on inspection/classification problems and laboratory/indoor use.
  - Recommendations: Geometry (GCPs necessary, SfM relies on panchromatic bands), radiometry (system characterisation). Current activities/outlook are new sensor (Hyspex Mjolnir VS-620), New platform (2x Acecore NOA), Prepare flight operations in specific category >25 kg.

- **Q**: *The flight altitude and speed – were they given or could choose?*

A: It was as standardised as possible, but not everyone fully supported it. The requests were: relationship between overlap and the height. Then it depended on the field of view of the instrument/system.

**Q**: *Does having different platforms have an effect on the wind influence?*

A: Yes, should be accounted for in upcoming campaigns.

**Q**: *(For Daniele Latini): Collecting data at different angles was really good for geolocations. What did you use for georeferencing: what approach was used – motion software packages with limited control on angle/pixels or did you use direction referring approach?* We used software Metashape (Agisoft Metashape). Also collected some points for better accuracy. Difficult to do it, because the test site was very uniform and difficult to find a point on site for reference. We construct some procedure to collect reference data, but in the end we got good georeferencing accuracy.

**N:** *(Juan Pablo Arroyo-Mora for Daniel Latnini)*: No valid reports on corruption. Juan Pablo Arroyo-Mora says they have publications for understanding these issues and how to fix them.

**N:** *(Juan Pablo Arroyo-Mora)* Need to improve the uncertainty analysis, corrections, errors, and characterisations – NPL has a high responsibility to teach and implement the correct methods for developing traceability in all stages of data collection and processing.

**Summary:** All the instruments and settings used by the participants are listed under each presenter. In addition some have listed the various obstacles faced during the exercise, feedback as well as future outlook and recommendations.

## Scientific Results of SRIX4VEG

**Speaker:** Niall Origo

- Supporting data (IMU/GPS and DEM) collected before the campaign. A separate flight was conducted before the campaign with just the LiDAR sensor collecting data to produce a height map of the surrounding area for use in orthorectification.

- Data processing first involved the reflectance. Some spectra in the longer wavelengths had large uncertainties. Processing involved the individual scans. For each sequence of measurements reflectance was calculated and interpolated for the middle timestep (before and after the sequence). Two sequences of the reflectance targets before and after each user, so those are also interpolated.

- Some of the reflectance spectra were impacted by poor user alignment (e.g. off the panel). Spectra that fell outside of 2 standard deviations were removed Account for changes in illumination conditions. After removing the outliers, the uncertainty was significantly reduced.

- Some caveats on the comparison: it is preliminary in status (not all data is available yet), some of the data wasn't useable, so the criteria had to be expanded. Longer time difference in between pairs to get a certain number of matchups.

- Analysis: looked at the pairwise difference. Names were kept anonymous.
- Band-based assessment: there is a clear preference for Experiment 1 producing lower differences across almost all bands. Niall expected larger differences for lower reflectance bands due to noise, but in real life there was a clear preference to Exp. 1. The number of samples was reduced due to lack of full pairs, but statistically speaking there were a few outliers which skewed the average in Exp. 2. Differences w.r.t. the SZA as you approach the higher end, the ceiling of difference increases.
- Conclusion: the results indicate the need for a protocol, minimum difference was quite high and reduction in the mean/median reaches up to 25%

- **Q**: *Why is not symmetric data processing (reflectance) plots?*

  **A**: The flights didn't start/finish at the same time across the days.

- **Q (Ben):** *Is High SZA error due to larger changes in movement?*

  **A:** Potentially but cannot say this statistically yet. There was a further discussion regarding the cause of this error associated with high SZA, but since there is not enough data from this campaign a clear conclusion cannot be made.

- **Q**: *What is the meaning of the mean in these results?*

  **A:** For each band it is the mean across all pairs

- **Q:** *Is this data going to be made available?*

**A:** One outcome will be a paper and data availability will be discussed here.

**Summary:** There is a clear preference for Experiment 1 producing lower differences across almost all bands. We expected larger differences for lower reflectance bands due to noise, but in real life there was a clear preference to using a standard protocol. The number of samples was reduced due to lack of full pairs, but statistically speaking there were a few outliers which skewed the average in Experiment 2. Differences w.r.t. the SZA as you approach the higher end, the ceiling of difference increases. The results indicate the need for a protocol, minimum difference was quite high and reduction in the mean/median reaches up to 25%.

## Lessons Learnt from SRIX4VEG

**Speaker:** Harry Morris

- Focus on the practical elements of the campaign, relevant for planning the second phase
- Successes:
    - Importance of local contact and facilities. Very hot conditions, limited space and tables, a lot of kit. Need for rest time and shades.
    - Shipping the equipment, local universities helped get on top of the schedule.
    - Training, reaffirm the message and prepare for the next day, view the site beforehand, test the systems which need resolving before the strict flying schedule.
    - Coordinate message groups due to limited time and space, making sure everyone is there on time, batteries don't overheat from waiting etc.
    - Auxiliary measurements required many people.
    - Grateful for extra targets to better understand the environment conditions.
    - Bringing additional/extra equipment.
- Challenges:
    - Heat, +40 degrees, a lot of the equipment especially drones have the threshold of 40 degrees so had to put them in the shade.
    - Farm trucks went through and added dust which impacted the measurements and the schedule.
    - Data processing, a lot of storage required (~5 TB).
    - Logistics: for 2$^{nd}$ phase in particular, having a separate coordinating team to ensure everything is going smoothly.
- **Q/N (Ray)**: Missing a note on safety, a lot of heavy equipment. Need to have strict safety protocols to operate for individual participants. Should be addressed and indicated in the best practises.

- **A (Niall)**: It was hard to control what everyone was doing and there was a degree of expectation that individual H&S protocols would be sufficient.

- **Q/N (Margaret)**: There is an internationally accepted concept "international safety manual", which could be included as highly recommended in the protocol. Operations manager has an authority about what Is allowed and can happen, so by deciding on such role they could then oversee all the groups generally.

- **N (Juan Pablo)**: Safety is the first priority, so there should be only one page of the health and safety protocols and then adjust the science according to.

- **A (Niall)**: The first day was a trial day and was great to learn what worked and what did not – remembering this was a unique setup involving a large number of teams to coordinate. This aspect was fixed by the start of the experiments. It is my feeling that H&S should be a small part of the protocol and should revert institutional/aviation authority guidelines.

**Summary:** Successes identified were the importance of local contact and facilities, training, coordination across the group, auxiliary measurements, brought extra equipment. Some challenges included heat, farm trucks, data processing, and logistics.

## Outcomes of SRIX4VEG

**Speaker:** Niall Origo

- The main outcome is the protocol document, internationally agreed by the community as the good practice at the current time to meet the challenge.

- Protocol template document has been created, first edition has to be submitted for review mid Q1.

- Expected to have a journal paper featuring these results, intention is not to compare participants but to demonstrate a need for a protocol and have the opportunity to recommend the next steps. Request for contact details for all participants involved in SRIX4Veg to be given to NPL as currently on have main institute contact.

- There is a lot of data/information collected. So a lot of potential for other papers and collaboration opportunities.

**24.11.2023**

**Recap of the outcomes.**

- **Q**: *Is there any group that knows that they have preliminary results that are not updated or there are parts missing?*

- **A:** We are waiting on results from one team and another set needs to be updated. We got some data quite late, so we need time to assess whether it's up to standards. In parallel to protocol writing, we will get up to speed with each individual team to make sure data is best quality.

**Summary:** The main outcome is the protocol document, in addition to journal papers featuring these results (anonymous) and potentially other papers considering how much data has been gathered.

## Feedback from the Community

**Speaker:** All

**Protocol document**: Proposed document structure has been reviewed by the SRIX4Veg working group (including ESA, USGS, CSIRO and NPL). It follows the form of general protocol structures from available examples on the CEOS LPV website (Albedo, Biomass, LAI).

- Questions to consider: Are there any missing sections? Any unnecessary sections?

- **N (Juan)**: at first look seems comprehensive and a good start, it's not possible to cover absolutely everything, but cover to the best of our abilities.

- **N (Ben)**: mention something explicitly about geometry, definitions and requirements.

- **N**: Not sure about the scope of the document. Summarise the relationship between the satellite pixel as it seems and as it reflects on the ground.

  **A (Niall)**: With high resolution, we can distribute our sampling appropriately.

- **N**: Section 4 mentions ground based measurements, even though the protocol is mainly for UAV data. How far are we willing to go? Briefly mention other collection methods as relevant topics, but in terms of specific details it should be avoided in this document.

- **N**: Good practises for instrument: will we talk about platform integration? Must decide how far do we want to take it. Feels wrong to recommend a specific way, but should mention limitations and thresholds. Warning on the impact of gimbling/not gimbling has on the data, reference valid papers and the additional uncertainties. Indicate platforms/certain solutions more applicable in different weather conditions and when does each make sense. We don't have to specify, but make sure that the quality of the data depends on the specific circumstances.

- **N (Juan Pablo):** The more information on the data we provide to the user, the more can be obtained from it. How do we provide not only the protocol "best practises" but self-evaluate all the different systems we use from previous experiences. Have a matrix where we can provide users with the data with a complimentary document, where we provide metadata to the users.

- **N**: requirements for other projects should include uncertainties and precisions. Will depend on formulation. Have to make sure the requirements might be too strict and might require tiering of them. If there is a campaign that is more complex and has different surfaces, the function will be different. Correcting for these things will be very complex to include in the protocol.

- **N**: Homogeneous. If we have a 3D surface, so how does the sunlight project through those pixels etc. So adds more things to worry about in homogeneous surfaces.

  **A (Niall)**: We have sensors that can provide us with loads of data, I recommend we get rid of some data to reduce it to the surface. This won't produce the "prettiest" images, but it's more reasonable, that should be included in the protocol.

**N**: If we are going to a field with non-homogeneous surface. We should specify higher/lower than 1 % to ensure that data is the best even in the best conditions. Otherwise we need to suggest the best areas. We should suggest 5 % (the S2 mission requirement) as the mathematical requirement to validate a satellite mission (it is unclear what uncertainty was being discussed).

**A (Niall)**: We shouldn't validate mixed pixels? We don't know the uncertainty in these surfaces. Is the surface the driving factor or the protocol/methodology?

**N**: We need to come up with something for a homogeneous pixel, before jumping into a surface with more complexity.

**A (Niall)**: If you want to go to these levels of uncertainty, you must consider these. The angular component has a big role in vegetation, you could have a vegetation surface but the angular component is still very big. By considering all needed factors for heterogenous surface, we can go to homogenous surfaces.

**N:** The problem is in the validation requirements. I will pick the site and then check the requirements.

**A (Niall)**: How do you partition these things? Down to the instruments or down to the factors? Typically in comparison, there is uncertainty on each instrument (satellite and drone) and then comparison uncertainty, which are outside the radiometry of the instruments.

**N**: Where are they going with the data? If I want to look at glaciers, it doesn't care if you want 2 % uncertainty, the instrument isn't right. Different needs depending on the application, might have different validation needs and application. What will they do with the reflectance?

- **N (Max)**: Scale problem. Biggest benefit for drone based measurement, the measurement can be scale independent, meaning we don't have to care about mixed pixels. This could only be done if we think from the satellite perspective, which is important for vegetation, more heterogeneity. With drone flying low there is a lot of shadowing, balancing of the observation geometries is not so easy, so should be said for generating this validation data. From my point I'd say to try to think from pre-processing and application to filter the observation geometry to make it a bit more scale independent, making uncertainty propagation more powerful. For a rough surface (e.g. forest canopy) and observation of 20 degree for the instrument you should be able to scale the measurement geometry and spatial scale. Possible with e.g. point clouds. Every pixel is a point load pixel with a coordinate, so you can figure out the points which would be best followed or weighted to the comparison measurement on the ground. Generate a reference measurement as the satellite sees it from above. This has the added benefit of not suffering from pixel loss and duplication, see which area is measured with a lower uncertainty and can weight them and get rid of all the regular calibration and validation problems.

  **N:** Problem in finding homogeneous sites.

  **A (Niall)**: Drones give the opportunity to assign uncertainty for heterogeneous sites.

- **N (Jadu/Max)**: Will see the 1 m heterogeneity in the drones. With satellite we can't consider that heterogeneous, but with the drone you can. So must be homogeneous for the satellites. To really align it with object from a satellite point of view, that should be respected by the protocol for the end user it is possible to filter the oversampling so it is comparable to the satellite. We want to get rid of the problem by measuring more heterogeneous sites.

**A (Niall)**: the issues around the movement of the platform become small when dealing with these areas, so we don't really have to worry about the ones that go outside, and filter by the view angle, so will have enough data just won't look too nice.

- **N:** Need to find a way to represent the results properly despite the number of points. Protocol should discuss the representative radiometry and not just "a pretty picture" for a presentation.

- **N**: How many people have the ability to pull up the VZA?

**A (Niall)**: Goes back to manufacturer relationship, when you have the field of view so can do the basic one need a communication with the manufacturer. Need to go through the process to get the specific data from some instruments, which are not provided as default in some cases.

- **N**: relation between GPS time and the tick of the instrument is an issue. Hopefully in the future manufacturers will give this information or provide software which will allow for it. How much of this we reference in the protocol?

**A (Niall)**: What if people can't match up to the platform? Just assume it's perfect, which will lead to average correctness (not for all systems, just a proposition). Should not refer to specific manufacturers by name.

- **N (Jada)**: Agree, one of the key point would be to consider how do we QC individual point clouds? do we agree on a set of metrics? Also, we need a clear understanding of what is the requirement from different satellite SR products?

**Useful Resources/Contacts:**

- Contribution and co-authorship from all participants
    - Please provide contacts - **action**
- Potential for more papers regarding this
    - Please share ideas - **action**

**Summary:** The main topics of this discussion boiled down to: Health and Safety, Scope/Magnitude, separate the intercomparison side from the general guidance, requirements: site uncertainty and how that relates to UAV flight time, trade-offs: image quality versus radiometric purity, more Lidar format of results, each measurement is a point rather than pixel.

**Meeting close for 23/11/2023**

## 24/11/2023

## SRIX4VEG Australia

**Speaker:** Ian Lau (CSIRO)

- There is a large community of UAV users in Australia and one objective is to bring them together and showcase Australia's EO capabilities.
- Need for standardising UAV data within the field.
- Information on the site:
    - Site is in Calperum - a supersite with infrastructure including a flux tower and other instruments.
    - A long history of collecting data.
    - In March it is the lowest rainfall and moderate temperatures . It's a wooded area with vegetation.
- Plan:
    - Insurance, regulation and field equipment etc is being prepared.
    - 5 local teams (+1 observer).
    - 11-15 March 2024.
- Ground and airborne instrumentation on slides with team details.

**Q:** Same set up as last time (i.e. two experiments)?

**A:** Common flight plan is going to happen, but individual flight plan is time dependent.

**Q:** What is the difference between SRIX4Veg 1 and 2?

**A:** SRIX4Veg 2 will use a site that is over a natural environment rather than a cropland.

**Q:** Are you going to validate other variables other than surface reflectance?

**A:** Will not have enough people to take more measurements so this is unlikely.

**N (Ian):** Has tasked a satellite to fly overhead so this will add to data.

## Presenting the Protocol Template, Proposed Timescale and Proposed Scope

**Speaker:** Niall Origo (NPL)

- Recap of the goals of SRIX4Veg:
    - Highlights the difference between this and FRM4Veg.
    - Main focus is HS systems with potential to expand for specific MS if required.
    - All other information is covered in yesterday's notes (deadlines etc).
- Goal for discussion is start assigning tasks to specific teams so that work can begin. Set out specific actions based off todays and yesterday's discussions.

**Q:** Is there any data missing from campaign 1? Incomplete analysis?

**A:** Yes there is data that has not been sent but Niall is aware and is in contact with them. Some data also arrived late in the day so not much analysis has been completed.

## Protocol Formulation

**Speaker:** All Participants

**Rough Notes:** *(Available in the unedited version of this document)*

**Formal Notes:**

**Session 1**

- **N (Niall):** Provided a summary of yesterday's discussion:
    - Highlighted the need for health and safety and it was decided that this can go in the appendix.
    - The purpose of the protocol will not be surface reflectance data collection in general, but with a focus on validation.
    - Specific requirements for site uncertainty in relation UAV sampling and flight design.
    - Trade-off for image quality and radiometric purity was discussed with a focus on radiometric purity prioritised.
    - Data should be dealt with as a point cloud, moving away from orthorectification.
    - Focus for today could be what sections are missing and what can be added?
- **N (Juan):** There are still cases within literature when ASDs are used inappropriately (too close to the surface) with a suggestion that this campaign/protocol can be used to verify the use of ASDs
    - The idea is that UAVs cannot be used in isolation so can the scope of the protocol be widened to other instruments used in the campaign?

        - Currently there is an item in considerations where this discussion could go, regarding other instrumentation.

    - The question to the floor is that there is already guidelines present; does this need more information in our protocol?

    - Belief that in the CalVal community is that instruments are used incorrectly but this is not implemented in the wider field.

    - **N (Niall)**: Protocol should include the effect of not using best practices; additionally, what kind of uncertainties will these practices introduce (no use of tripod etc). This also applies to the processing of the data. Suggest alternative and suggestive measurements e.g. measure the panel at all areas to obtain uniformity.

    - **N (Ben):** Related this issue to the discussion yesterday regarding how uncertainties may be introduced if methods are not as refined as possible.

        - i.e. if there are non-perfect conditions, what uncertainties can be applied, this could be ASD error or lack of SI calibration.

    - Should we repeat or add information about ground measurements when there are dedicated communities towards this? (potential for confusing the message when there is existing literature).

    - **Conclusion:** This was not resolved as the conversation drifted but worth consideration.

- **N (misc):** There was a push for specific minimum requirements for validation and then add uncertainties for other parameters.

    - There is capacity to always improve and no campaign will be the same.

    - But there still needs to be a minimum requirement.

    - Returned to this later.

- **Q (Ben):** How do we deal with quality vs quantity in the protocol?

- **A (Niall)**: We are working within a narrow region with low battery time, so unless batteries improve, we won't look at big areas. Therefore, we will always need some ground measurements, e.g. a spectrometer sampling ground measurements. Regarding quality and quantity, the quality in this case is the uncertainty, so in most cases if we specify the uncertainty expectations it's fine. We should be clear that uncertainty is involved in all steps of this protocol. Intro section mentions the role of CEOS WGCV, so we might need a section to expand on this and mention what documentation is needed before you consider starting a campaign.

- **Q:** What can be considered a validation exercise?

- **A:** FRM paper was published recently regarding this topic.

    - Documentation is now available to specify what an FRM is which emphasises this point.

    - In intro maybe there should be a discussion of this paper and the points it makes and outline what documentations should be understood before implementation.
    - For next campaign these papers recommendations should be implemented.

- **Q** Can we implement the protocol that will be produced following this discussion at SRIX2?
- **A:** Yes.
- **Q:** Regarding the of scope chapter 5.
    - There is currently no protocol in surface reflectance, although there is documentation regarding albedo. SR should be tackled in this protocol.
    - Suggestion for chapter 6 to focus on scaling approach.
    - Global validation is something that is needed which will involve other metrics (hypernets etc).
- **A (Fabrizo):** SRIX can have basic background information on surface reflectance data collection and global scaling; however, focus on should remain specifically on UAV validation of satellite data.
    - There are other projects that can deal with the other issues.
- **N:** Only rotar platforms were used in the campaign, should we limit the protocol to this?
- **A (Juan)**: Yes. The technology is evolving, there are characteristics which make it more difficult for data acquisition. The good news is that rotocopters are a good option achieving 5x5 pixels for validation can charge batteries in 15 min. It has been tested and we are able to select 2 areas for 2.5 hectares which is large and for each area we have 500,000 spectra. There is one octocopter in Germany that can fly for 1h but costs 80k.
    - Flight time should be considered due to limitations in battery time.
    - No one used fixed wing which will increase flight time.
    - What would be the effect of larger pixels due to this methodology?
    - No one knows of any fixed wing HS.
    - There are many logistical challenges with this platform as characteristics of fixed wing make it unsuitable in many cases for CalVal e.g. hard landings with delicate instruments.
    - Rotar copters are very well suited (these can be recharged within 15 minutes in some cases).
- **N**: There was a concern that the general protocol (regulation and safety etc) is being stretched in industry and that there is a responsibility for the group to hold itself to a high standard.

- **N (Ray):** A discussion around the stability of calibration panels. Some groups calibrate these carefully in laboratory conditions regularly, meanwhile others do not have easy access to these facilities. The discussion focussed on what the protocol should be with calibration in the laboratory and the field.
    - Back and forth discussing the trade-offs of further calibration, especially in relation to flight time, cost logistics.
        - i.e. It is not easy to use this much equipment in the field and this should not be underestimated.
        - In an ideal world there would be many large panels, but this is not realistic.
    - If you have a misalignment, you're going to see that your compensation is not lined up properly with the data. If it's the matter of being misaligned going to have a down/up spike up, you can get a w/m shaped spikes. There are ways to evaluate that, and the impact might be big, but that's a manufacturer issue.
    - Regular calibration of panels in laboratory was encouraged to ensure sensor stability.
    - Discussion moved to the role of the manufacturer in this process - i.e. sending instruments back to them for calibration, raising the issue of cost.

  **N (Juan)**: instruments are expensive, is the manufacturer providing you with characterisation? We need the traceability. Then we can move forward and demand this from the manufacturers who refuse to do it as it is expensive.

  **N**: In the calibration section, recommendations should be raised, as well as where more research is required. Must demonstrate methods and instruments that work both in the laboratory and in the field.

  **N (Niall)**: Recognise that this is a young field and we can't know everything, we still require more research.

  **N (Jada):** In terms of calibrating this is all about us telling the community how to do it e.g. how to calibrate spectrometer in the laboratory, so we want the same procedure in the field. So this is more like a guide.

- **N (Margaret)**: Having those kinds of recommendation e.g. minimum set of characteristics, which should help with narrowing down which manufacturers to use. We can't assume that it'll be possible with all of them. Some instruments are just not there yet. This can help understand users what their currently available choices are.

- Concluded that in the context of this specific protocol a section (subsection) should include:
    - A "troubleshooting" technique to spot miscalibration and misalignment etc.
    - A requirement for calibration and stability - stating this specifically with an intention to push manufacturers to improve their calibration efforts (note this was raised again later to push for more parameters to be made available by manufacturers. For example, provide some form of traceability).

    - In similar protocols there was a knowledge gap and activities section, and a similar section should be included.
    - This extended into pushing for documentation with toolboxes and more data parameters.
    - Information on laboratory and field calibration in the protocol.
- Points that were not clarified:
    - Should the UAVs be calibrated before and after each flight? Expensive.
    - What does CEOS recommend to do in the laboratory for calibration (should this be in the protocol?) If it is not known then put in gaps section.
    - Discussion around what can be used as a cheaper calibration panels. An example of a cheap material with reflectance of 1% was raised.
        - Performed well but limited testing so far.
    - There should be a push into what exact parameters are needed to conduct a validation. This was raised multiple times however a concise outcome was not outlined.
- **N:** It is important to note that CalVal is not possible with all instruments.
    - This should be outlined in protocol such that it is known.
    - Minimum set of requirements needed for calibration and validation - again this was often pushed but no parameters seemed to be set.
- A push to state what is not known and beyond our capabilities to push for more research.
- **Q (Niall):** Are we considering the validation of hyperspectral satellite data in this protocol?
    - **N (Juan Pablo)**: Our group is working on that: developing a new CalVal system for hyperspectral data. Challenge is the instrument, panel gives a lot of information about your own system. It's important to use our current systems, we need systems with good endurance. We have the technology, just need to get there after research.
    - **N:** Discussion around the use of RadCalNet which has 3-10nm resolution giving smooth edges. There are challenges with this, however it is possible with uncertainty trade off.
    - **N (Max)**: Validating hyperspectral missions is possible with hyperspectral UAV instruments but there are challenges. E.g. some stations do not cover the full spectrum of sampling in comparison to upcoming missions.
    - **N:** This is not the end of SRIX; there may be a SRIX 3 where this can be included in more detail.

    - **N (Niall):** The idea is not to have a section on HS but it is a need so it should be considered when answering points that are less relevant for MS but should be highlighted if HS is considered.

- **A (Niall)**: It'll be difficult, but it's needed so we should at the very least introduce it.
- **N (Ray)**: Issue of scale has not yet been raised: in our experiment 1 data we had saturation issues, once saturated the pixels become compromised.
    - Related to leaf angle.
    - Can be dealt with gain but that is complex.
    - This is not an issue when flying higher with a coarser resolution.
    - Can we make the pixels so that the saturation is not an issue without introducing SNR with gain; i.e. coarser pixels.
    - **Q:** Was this specific to veg?
    - **A (Ray):** This issue happened with backscattering not forward which is main issue with veg, therefore may also be present with other surfaces.
    - **N (Margaret):** SRIX data is not only data where this is an issue, seen this with 2 other examples across different sensors.
    - This is a broader concern that should be considered .
        - What about water on the surface with rain?
    - **N (Juan):** Recommends doing a preliminary flight can be really useful to define params that will help with calibration - helps with specular reflectance issues.
    - Spectral saturation can be filtered out - but it is losing data which will affect the effect of data to validate satellite band.
    - No specific conclusion to this point but subsection to be included regarding saturation and SNR issue.
- Previous discussion may effect what surfaces are appropriate, should we rule out some?
    - **N (Juan)**: Can't discriminate ecosystems. More complex ones, might be worth doing preliminary data acquisition. Which sensors need to be programmed under flight plan to get something comparable.
    - Protocol should remain as the beauty of UAV is it can measure challenging areas we should not remove this.
    - Example raised with peatland that is very different but still critical.
    - Conclusion to be site agnostic.
- **N (Juan):** Word of caution to SRIX2 - do not underestimate the utility of preliminary flight.

    - **N (Niall):** Potential for the testing day to be used for this.

- **N (Max):** It is not known what data structure is required to compare with satellite.
    - Can have low uncertainty but it may not be comparable (example due to spectral signatures that are not seen by satellite).
    - Do we have a recommended data structure?
    - Preparation of data to make it comparable to satellite pixel is needed - i.e. know what you are looking for?
    - Are we outlining the upscaling process and how this will affect the data structure required.
    - We should specify how to change the data set into something comparable to the satellite pixel; however the user should know what they are comparing (resampled data etc).

**SESSION 2**

- **N (Niall):** General format - Discussion on the format and content of protocol, saving the final half hour for participants to commit to writing/organising specific sections.
- **Q (for Ian):** For the next SRIX campaign, will it follow the same format as Spain?
- **A (Ian):** The main focus will be to implement the protocol created from this workshop to see if it is appropriate for use, with unseen parties participating. If there is time to conduct individual flight plans we can try this as well
- **N (Niall):** We should discuss the following:
    - Battery time and flight duration (overlap, height, speed).
    - Atmospheric properties - what dataset is informing the calibration etc?
    - Field Targets - size, number, reflectance levels (NRC).
- Began with field targets:
    - **N (Ray)**: Recommend 3$^{rd}$ or 4$^{th}$ panel. It's an additional cost, to buy and maintain. Maybe should recommend a minimum. We concluded that 50% was too much, 40% panel might not be needed as we don't do that normally and that's expensive.
    - **N (Niall)**: we want to have general rules, as this is vegetation and its dark, so 50%+ for a desert example would be good.
    - **N (Margaret)**: Ray provide more details, as you have looked at this closer. The challenge with panels is the cost due to their quality. We came across a material for lowest end: disposable, it has so far at 1% reflectance been good for low cost and buying multiple.

- **N (Ray):** Margaret found in Japan velvet material, which stretched over substrate, produced 1% black target, and only cost 100$ for 2 meters by 2 meters. It performed very well. Still need testing. Having said that we want a 5% value, so wouldn't want to go only with one.

- **N (Niall):** How many pixels do we want? What is the uniformity of your detector? What is the minimum amount?

- **N (Ray):** want 4x4 or 5x5 pixels plus boundary area, as we don't want to use the edges in the average and std values. It can't be moving too fast either, as cant know if the pixels get contaminated. Therefore, you need a bigger panel.

    - Note that roll and yaw will effect this number and if they are extreme we need more pixels.

- **Q (Niall):** At what height are these measured at, I'm assuming the same as data acquisition

- **A (Ray):** No they can be at any height - causing debate.

    - Some argument to say the atmosphere can be well modelled, and that the change could be negligible (small fraction of uncertainty).

    - It is believed that Ray can confirm this with his data.

    - Opinion is that the calibration panel should be measured completely, multiple overpasses.

    - There can be issues with BRDF.

    - Beware that there is only 15 minutes of flight time and that this step could get long.

    - Uniformity correction can be done in lab.

    - Lab calibration removes flight time.

    - Can you take off from reference panel? Measure with altitude as UAV takes off.

    - **N (Juan)** 50cmx50cm JP (good to 120m) if the sensor is stable.

        - Worry that these methods of calibration are not appreciating the logistics of flying and its challenges.

        - Offered to write small section on HS (1page) and future prospectives.

    - Separate consideration for calibration and data acquisition. Can it be determined that different heights for these steps is acceptable?

    - Is there any data on how the panel changes with time outside?

        - No, but changes were within noise for multiple years.

- **N (Niall)**: Processing chain: what data to produce to make the quantity same as satellite. Need to have generic form included. Then, how much detail do we include for each techniques and topics, their uncertainties etc.? I imagine an instructional style, where we say things about known targets, certain things are highly recommended, depending on which parts of field are you looking at? Relating the instructions to AGB style.
    - Discussion around finding VZA, some introduce this data directly, others (Headwall) do not.
        - Processing with GPS and ticker was explained for Headwall.
        - Does conversion method for headwall introduce uncertainty (depends on the surface, as Lambertian surfaces are ok).
        - Frame based cameras tend not to have IMUs.
    - Highlight the data structure and quality with rough guideline of pre-processing so do not go into too much detail of the processing.
        - Start with what information is needed at the end.
        - Every field and satellite pair will require different data structures and quality.
    - **N:** With respect to UAV data, we have Level 1 product and certain steps apply to these. How can you do the error propagation if you don't have the 0 product/ raw data? Unless you trust the manufacturer to do the error propagation properly.
        - The importance of temporal alignment with the IMU is highlighted.
    - **N**: If you have a misalignment, you see the results in the Geo corrected imagery, which characteristics can be explained by this misalignment.
    - **N (Max)**: essential to have the elevation model with the point cloud of this side. Which has a lot of pre-processing steps. In the end we should define the steps and requirements, which can be aligned with the minimum requirements between the alignment between the GPS and timestamps. Give a brief overview for the pre-processing in the guidelines. Pre-processing should come from a high level perspective

- **N (Niall):** Validation metrics and recording the results. There is lots of reference material regarding this, do we consider the situations where this content is not available? This might be quite broad.
    - There is lots of reference materials for this (NPL and GUM etc).
    - **N (Fabrizio)**: In FRM assessment framework there is a specific section to provide guidance on transformations from FRM to satellite, this chapter should provide the information.

- Are we moving away from orthorectification?

    - If point cloud is being used then the spatial accuracy of both systems need to align so that they can be matched.
    - But this depends on what resolution is required from satellite, this problem is not relevant for high resolution. (i.e. if there is a large uncertainty in satellite position, a small mismatch in LiDAR positioning will not make a significant difference.
    - What about dealing with the soil which is not seen by satellite.
        - For this we would need effective coalignment so this raises the issue again and should be in the focus on the guidelines. Structural information cannot be considered separate from spectral.
        - The impact of this effect is challenged and debated.
    - If you filter the VZA to align with the satellite then this can help, however if there is a wind effect with leaf movement this will not be picked up by satellite but it will by UAV.
        - Can we find the uncertainty due to leaf movement in wind as field sites are typically windy?
    - Reminder for the protocol to outline what can be controlled, and how to assign uncertainty or method of dealing with this for uncontrollable factors (wind etc).

- **N (Niall):** Irradiance methods are useful but not a mature science yet, this should be discussed in the protocol but the main method should still be reference panels.
- **Q:** Can we introduce a validation target in addition to a calibration target?
- **A (Niall):** Yes
- GPS reference points:
    - At the very least, reference one visible point with an associated uncertainty so that the accuracy of the data can be determined geometrically.
- **Q:** Has the viewing angle content been agreed to be included as a section in the protocol?
- **A (Niall):** Yes.
- Processing:
    - Should we outline a typical process (describe what people normally do), even if its orthorectification etc and then highlight the differences in this protocol?
    - Agree to start with the end product (highlight the requirements at the end of each section).
    - Try to be inclusive of all methods.
- Minimum positioning requirements: have co alignment and involve all the pre-processing steps.

- **Q:** Writing style focused on vegetation?
- **A (Fabrizo):** Aim was to make it sensor and site agnostic but do we have the knowledge and data on this? No we do not, keep it to veg. Mention what the community is and where their expertise lie, it may not cover other land use types (water, peatland etc).

## Protocol Section Allocation

This was discussed here and can be found in the action table at the beginning of the document.

Meeting close (Niall)

**Summary**

The meeting discussed the role of ground measurements and fixed wing platforms in the protocol. Additionally, the scope of the protocol was limited to validation protocol rather than standard data acquisition, however, hyperspectral data should be considered. Concern was raised over the stability of calibration panels and how this can be measured in laboratory and field. The group decided that this would be a good opportunity to push manufacturers on the availability of data and capabilities of their products through means of recommendation within the protocol. There was discussion around what sites are acceptable for validation, but the group is dedicated to making this a site agnostic protocol (within the scope of vegetation, no water and peatland etc). It was recommended that a preflight should be conducted so that the land can be understood before completing validation. The issue surrounding size and quantity of calibration panels was raised with suggestions of a validation panel in addition to a calibration panel recommended. The content of the processing chain was outlined, i.e. moving away from orthorectification. The analysis of standard uncertainty should not be specifically described in the protocol but instead the reader should be directed to current materials. Finally, the actions for writing the protocol were outlined.

**Useful Resources:** https://elib.dlr.de/106545/1/Spie_Proceeding.pdf