Calibration Validation For Imaging Spectroscopy, Hyperspectral, Spectroradiometers

Cindy Ong

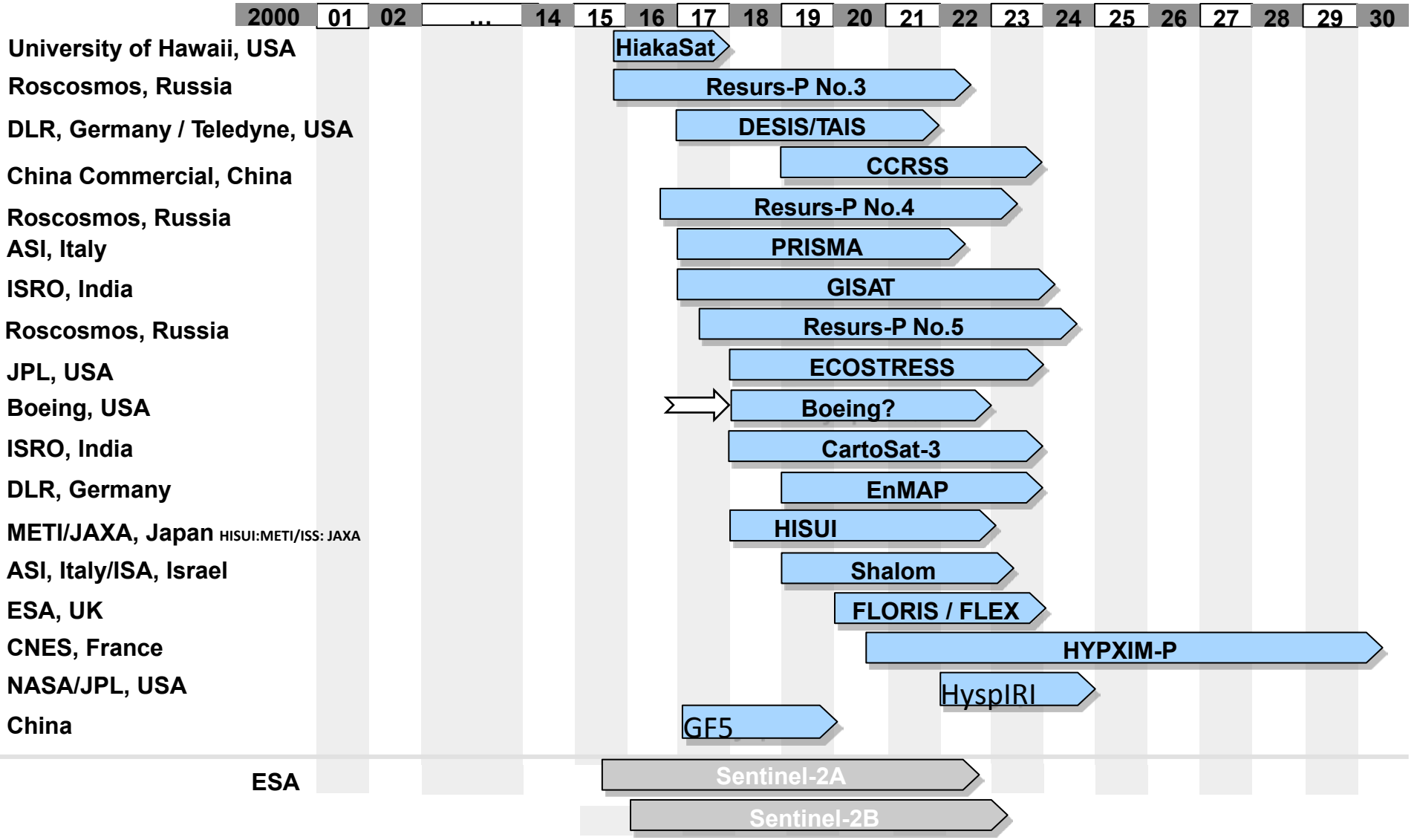
Main International Imaging Spectroscopy Community Of Practices

- European Association of Remote Sensing Laboratories (EARSeL) Special Interest Group Imaging Spectroscopy since 1998. Chair: Andreas Mueller, co-chair: Matthias Knuebuehler (http://atcor.dlr.de/SIG-IS.htm);
- IEEE Geoscience Remote Sensing Society (GRSS) Geoscience Spaceborne Imaging Spectroscopy (GSIS) / International Spaceborne Imaging Spectroscopy (ISIS) Technical Committee since 2007. Chair: Andreas Mueller, co-chair: Cindy Ong, Uta Heiden (http://www.grss-ieee.org/community/technical-committees/international-spaceborne-imaging-spectroscopy/);

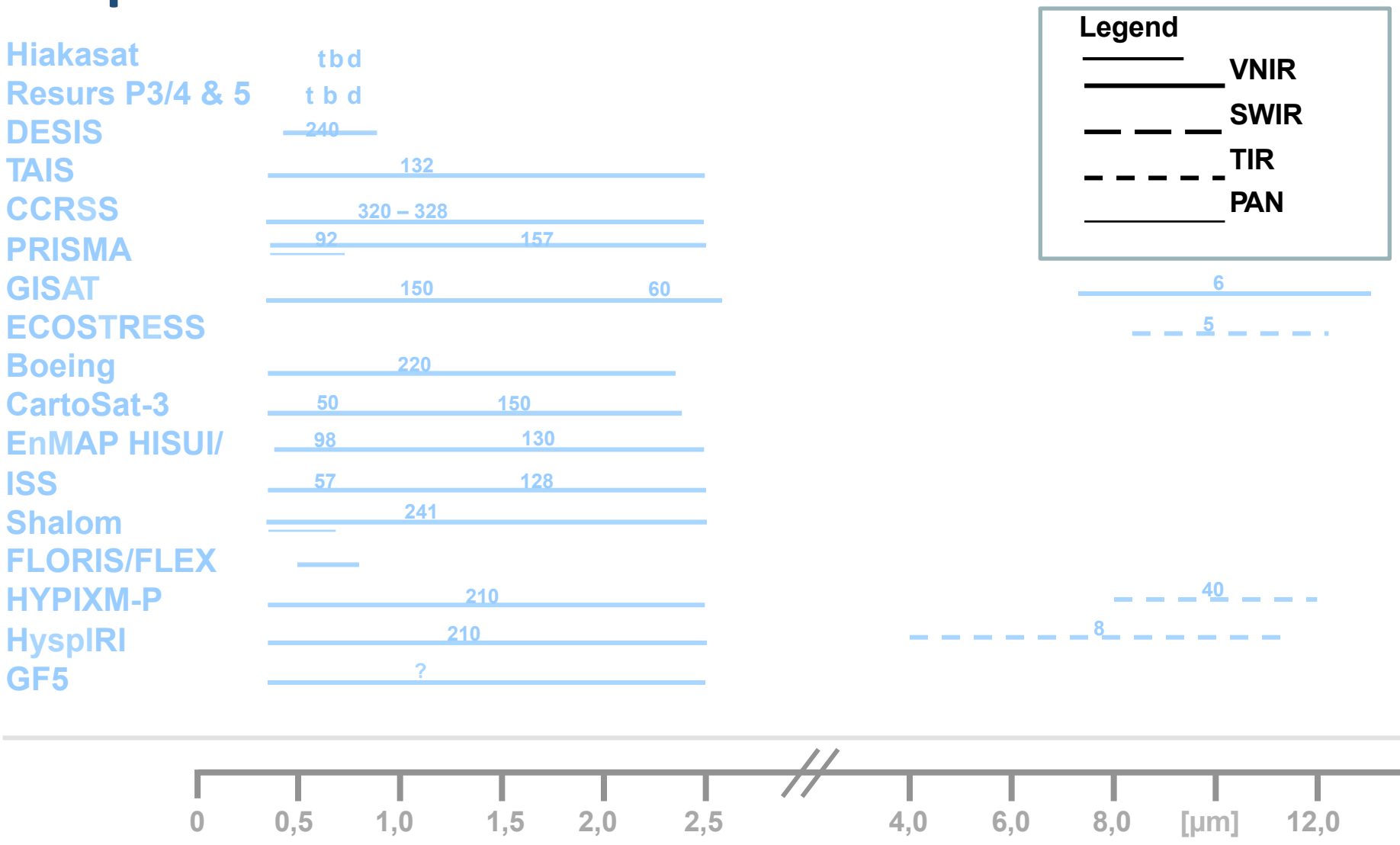
GSIS's Motivation For Calibration And Validation Activity

- **Imminent launches of spaceborne imaging spectroscopy sensors**
  - **at least 2 sensors are in the final stages of developments and will be launched in the next 3 years, 5 projected in the next 5 years;**
- **Calibration and validation is an important underpinning need for imaging spectroscopy mission especially post-launch to track sensor performance, and, throughout the life of the mission;**
- **Some sensors may have little or no on-board calibration;**
- **Calibration and validation is a generic requirement shared amongst all sensor providers where GSIS could make fruitful contributions to enable collaborative efforts;**
- **The need for multi-temporal work and wall-to-wall coverage is inevitable**
  - **This cannot be done with a single sensor in the foreseeable future: multi-senso "fusion" is inevitable. Calibration, cross-calibration is the lynch pin to enable this;**

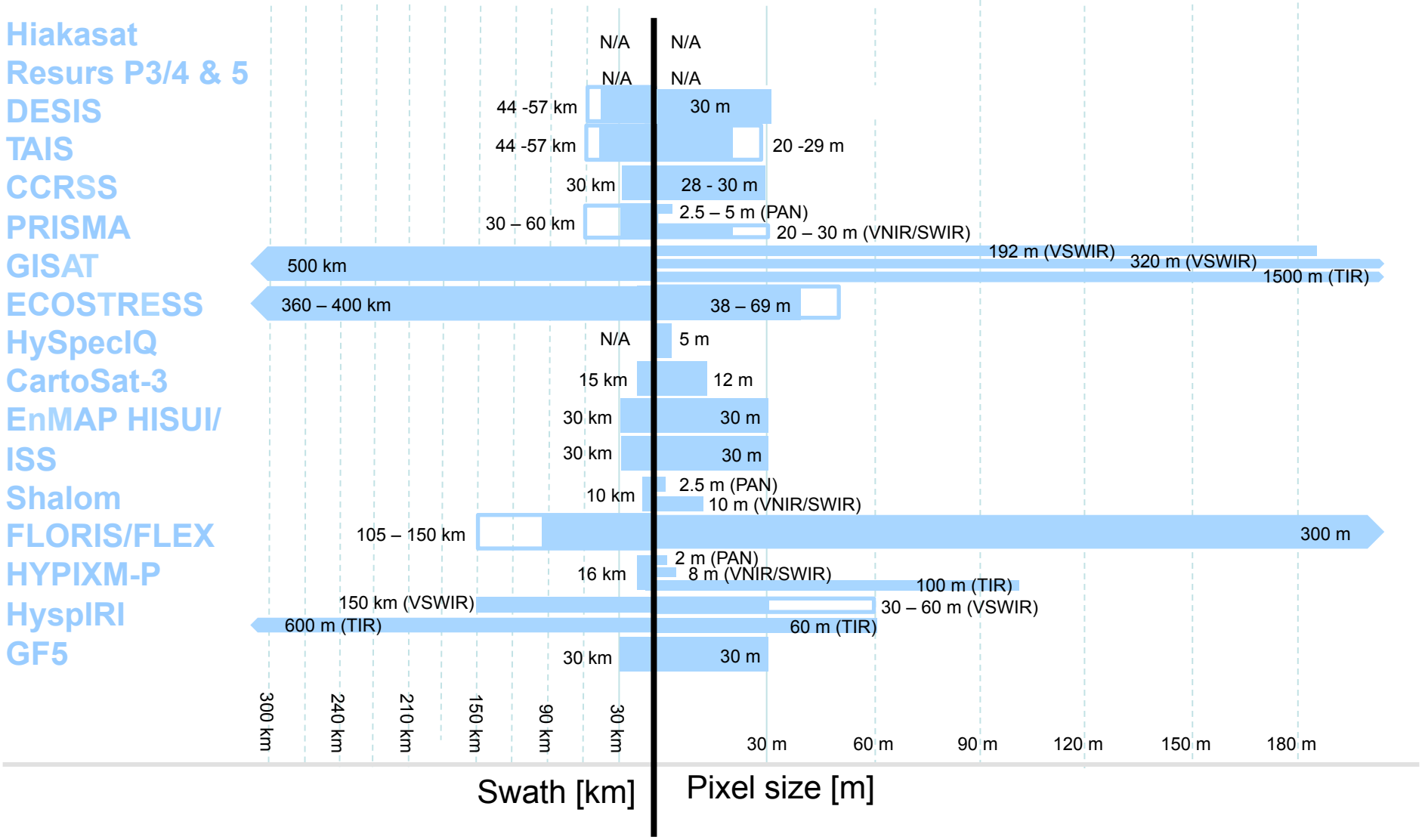
Future spaceborne imaging spectroscopy EO missions – launch and life time



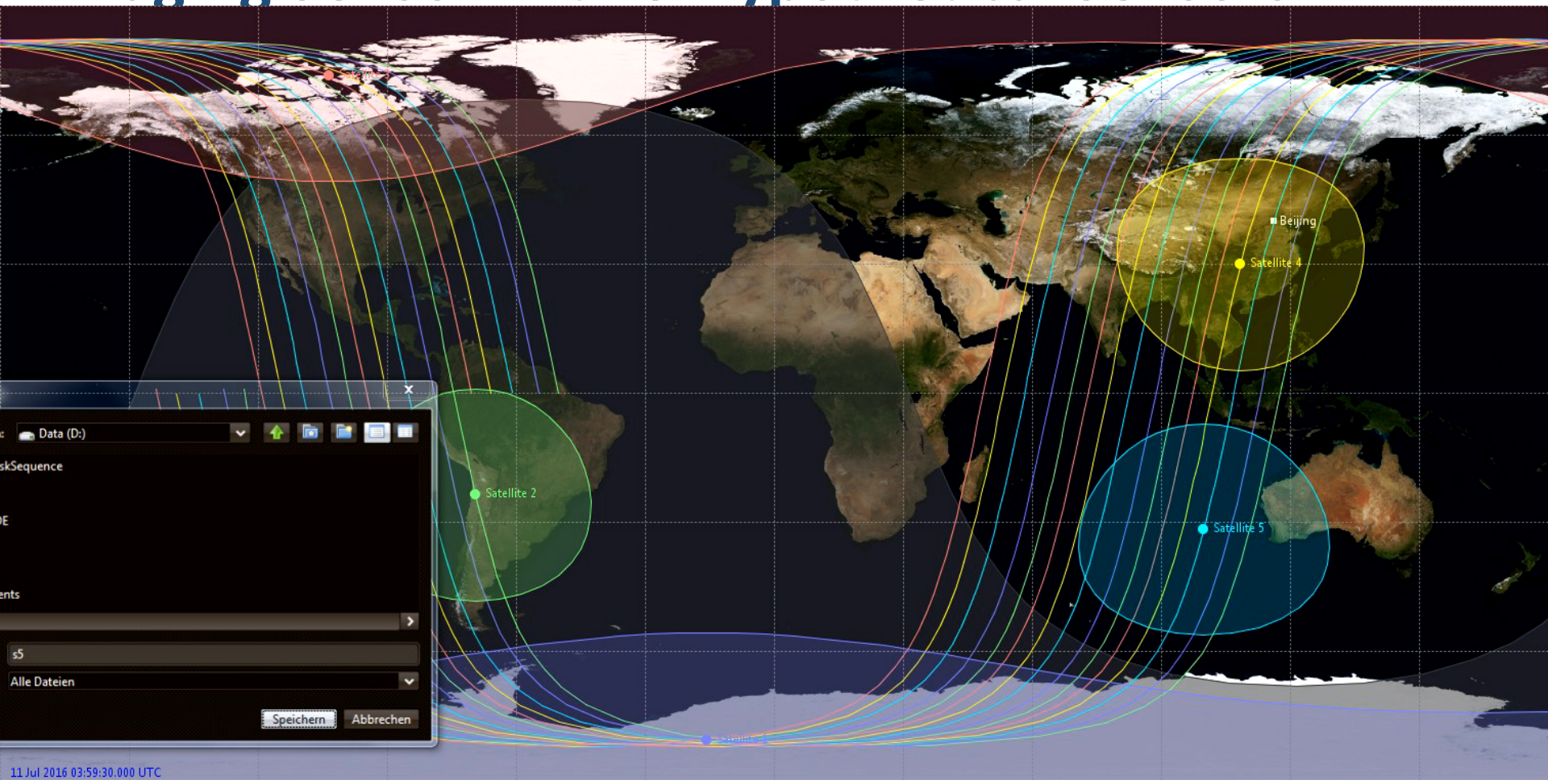
Spaceborne imaging spectroscopy future missions – Spectral characteristics



Spaceborne imaging spectroscopy future missions – Spatial characteristics

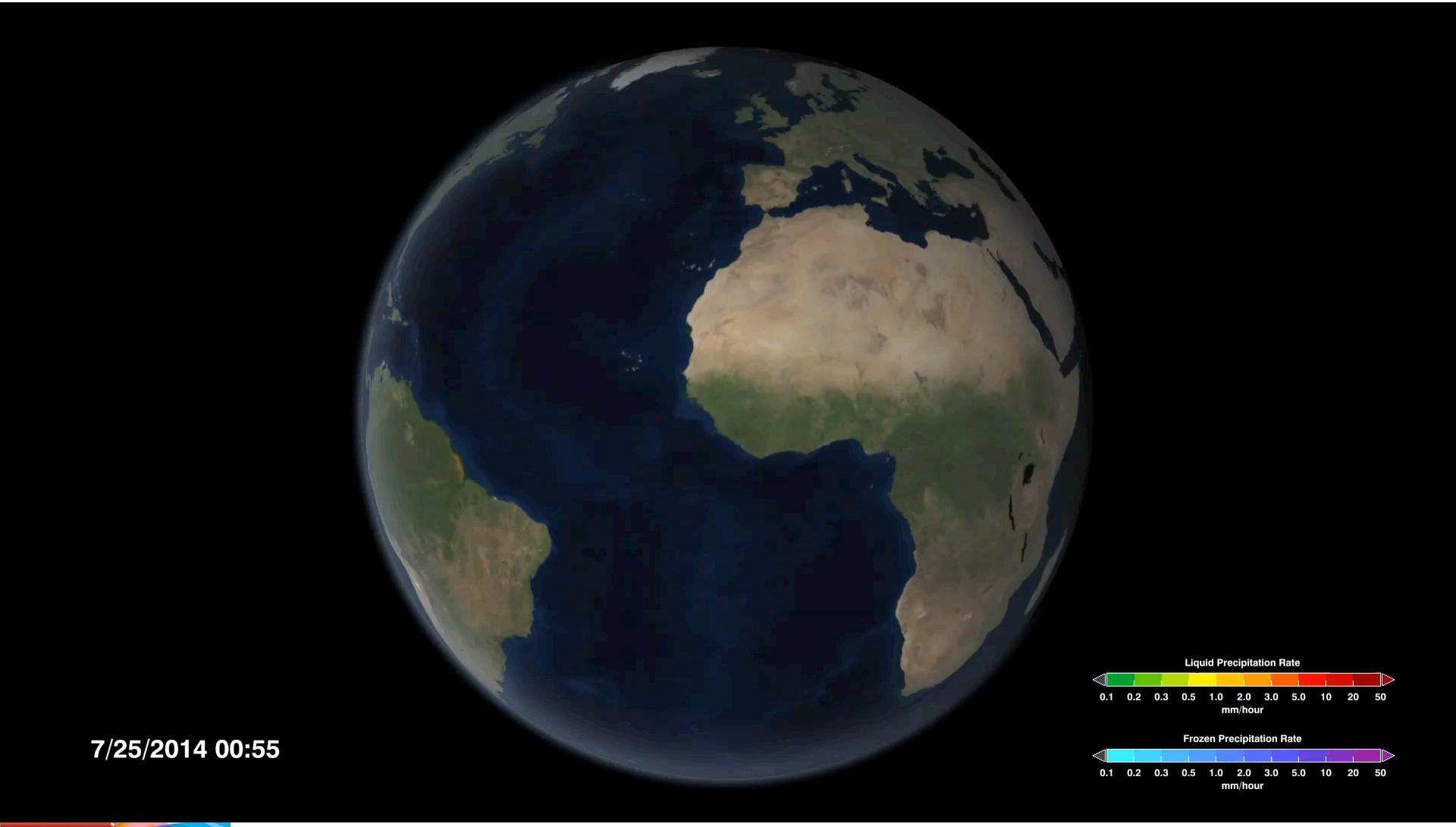


Hypothetical Virtual Constellation Of Spaceborne Imaging Sensor with 5 Hypothetical Sensors



Video courtesy Andreas Mueller, DLR

Seamless Global Precipitation Measurement From 12 Different Sensors



ISIS TC
International Spaceborne Imaging Spectroscopy Technical Committee

Video courtesy NASA's Scientific Visualization Studio
More information: svs.gsfc.nasa.gov/goto?4283

Calibration And Validation Workshop, National Environment Research Council Field Spectroscopy Facility, University Of Edinburgh

- **Purpose & Objectives**
  - Gather a core group of domain experts to establish a good practice framework for radiometric and spectral calibration and validation in support of spaceborne imaging spectroscopy missions;
  - Hosted by (NERC) Field Spectroscopy Facility (FSF) at the University of Edinburgh: take advantage of FSF's expertise in calibration and validation of imaging spectroscopy sensors to demonstrate good practices in the FSF's associated laboratory facility;

GSIS TC
Geoscience Spaceborne Imaging Spectroscopy Technical Committee

Terms Of Reference

- Review existing, if necessary provide new definition, and consolidate of terminology related to the calibration and validation of imaging spectroscopy sensors;
- Review existing, if necessary provide new definition, and consolidate of data/metadata standards related to the calibration and validation of imaging spectroscopy sensors;
- Review of current best practice protocols for vicarious calibration (including the use of the moon) and related laboratory calibration, instrumentation requirements and site selection criteria, and document gaps or extensions required specifically for imaging spectroscopy missions. Recommend a good practice protocol/method building on previous work;

Findings: Terminology, Standards, Metadata Standards

- **Considerable work conducted by EUFAR "Standards and Protocols" (N7SP) Networking Activity;**
  - Leveraging and building on this work is important;
  - Metadata standards, terminology, quality layers well established and tools are well developed. These are potentially readily adopted but some modifications may be required;
  - Establish a controlled vocabulary which may be useful, for example, for data level definitions. NB. upcoming ISO standard on level definitions;

Tools developed by EUFAR

- Tools/toolboxes (http://www.eufar.net/tools/)
  - EUFAR Metadata Creator (EMC): produce metadata (conform to INSPIRE standards) to facilitate data storage and searches for airborne scientific campaigns;
  - EUFAR General Airborne Data Processing Software (EGADS) Python-based toolbox for processing airborne atmospheric data. It provides a framework for researchers to apply expert-contributed algorithms to data files, and acts as a platform for data inter comparison;
  - EUFAR Flight Finder (EFF): geospatial-temporal search interface to locate EUFAR data within the EUFAR data archive to facilitate the location and identification of EUFAR flights and to link to the appropriate data files in the archive;
  - Airborne Science Mission Metadata Creator (ASMM): create a standard set of mission reports, aiding in classification and searches of data sets based on flight phenomena, mission parameters or other criteria;
  - SWAMP: Hands-on lesson and data for vegetation studies with pktools (SWAMP);
  - Hyperspectral Soil Mapper (HYSOMA): provide experts and non-expert users with a suite of tools that can be used for soil applications (distribution under the idl-virtual machine);
  - TETRAD: Hands-on lesson for airborne measurements in atmospheric science: focus on turbulence and clouds;
  - HYLIGHT: Airborne Laser Scanning and Hyperspectral Imaging Data tools

Findings: Field Metadata

- There are a number of spectral database systems that are potentially well developed systems such as Specchio or ECOSIS;
- There is still little agreement on metadata requirements (related to field spectral data, eg. Specchio & ECOSIS differ) although there are attempts - Jiminez, et. al. 2014 (based on ISO and OGC) and Rasaiah, et. al, 2015;
- Quality and completeness measures currently not available, consideration merited;
- Consider mechanism for linking field spectra with associated with spaceborne cal/val data;

Findings: Laboratory Calibration

- Radiometric
  - Protocols for calibration of field spectrometers and airborne instruments available from FSF, combined FSF & CSIRO, UofA as template to work from.
  - Learn from experiences on uncertainty/error analysis from CEOS WGCV community;
- Spectral/wavelength calibration
  - Wavelength calibration verification using spectral emission lamps, absorption filters including Mylar & acetate sheets, atmospheric features, and NIST Atomic Specta Database;
  - Wavelength uncertainty required – gap is tool box track peaks, troughs, system FWHM (resolution), spectral sampling interval (bandwidth), etc.;
  - Traceability - mostly not applicable;
  - Routine QA testing of all field systems recommended;

Findings: Vicarious Calibration

- **Leverage from large body of knowledge in CEOS WGCV;**
  - RadCalNet will be an important resource for imaging spectroscopy missions;
  - Imaging spectroscopy community need to gain a better understanding of error budget;
  - Imaging spectroscopy community is in a position to contribute efforts to build knowledge on **spectral calibration**;
- **EUFAR refers to and draws upon CEOS WGCV resources, FSF and others;**
  - Airborne acquisition necessitate reactive, single campaign based approach sometimes requiring the deployment of artificial targets or larger tolerances for site characteristics and sometimes compromises for environmental conditions. Spaceborne missions affords the luxury of using “ideal” targets and waiting for “ideal” conditions;

Uncertainties/Error

- Reported work is mainly from EnMAP and DESIS team;
  - Quite a large effort on radiometric as well as spectral uncertainty estimation;
- Airborne developed at EUFAR;
  - RSL, DLR, NERC, ONERA…..

Reflectance-Based, Imaging Spectrometer Error Budget Training Course

- 15-17 July 2016, Chinese Academy of Sciences Olympic Campus
- Led by Dr Kurtis Thome (NASA Goddard), Mr Chris MacLellan (University of Edinburgh), Dr Cindy Ong (CSIRO), Dr Martin Bachmann (DLR)
- The goal of the training activity is to:
  - Teach the basic procedures and methods of the reflectance-based calibration method for use with imaging spectrometry, and,
  - Describe how those concepts translate into an error budget, both for understanding the repeatability, as well as the absolute uncertainty.

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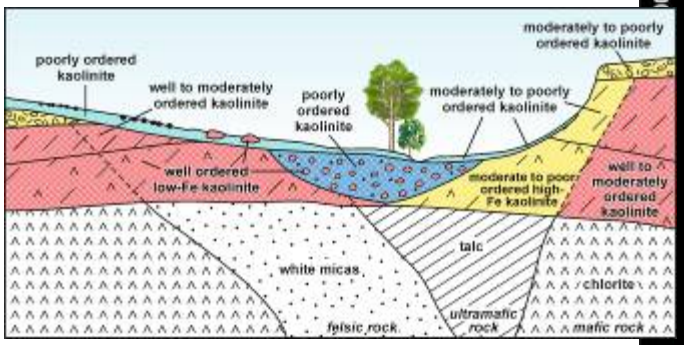
Kalgoorlie – surface mineral mapping regolith cover

kaolin disorder

- Cudahy *et al*. MERIWA (2005)

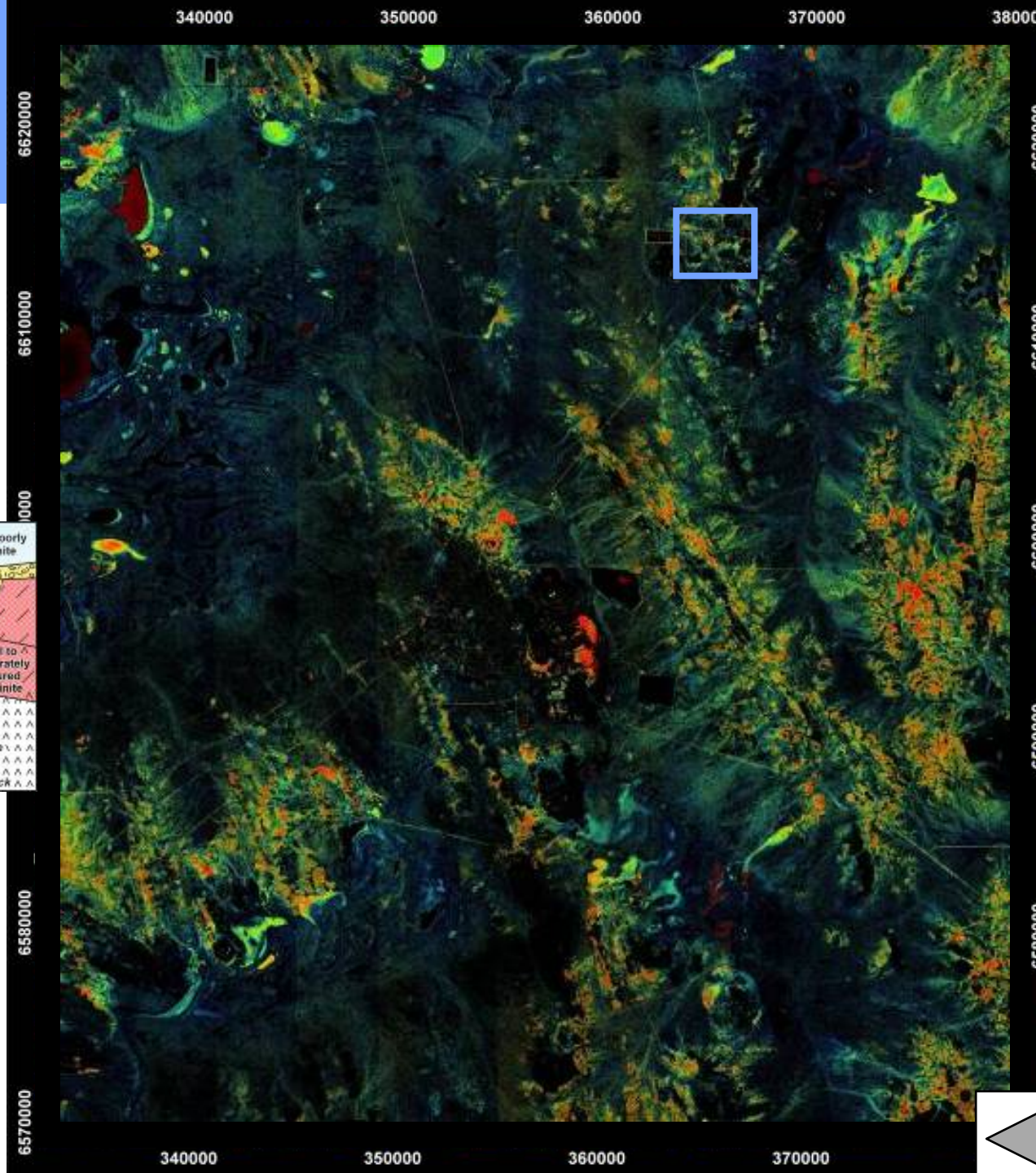
1.9 — 2.2

poorly ordered kaolin — well ordered kaolin



Depositional

Erosional



Guidebook On Calibration And Validation Of Earth Surface Observing Spaceborne Imaging Spectrometers

- Authors list established (28 authors in different fields of expertise)
- Structure and chapter of the guidebook developed
- First draft handed out with timetable
- Meeting planned during IGARSS for further coordination and detailing structure and content

Future Calibration And Validation Initiatives

- **Use training course to collate information for web-based training;**
  - Initially, training will be recorded and the videos made available as a resource on the GSIS web page. There are plans to develop this further into a web-based training based on standards and protocols where possible;
- **Planning for the next stages of cal/val initiative**
  - Put learnings from the cal val training in Beijing to the test and also demonstrate protocols for laboratory calibration at the Optical Labs at the University of Arizona and an endorsed RadCalNet site at Railroad Valley, potentially in conjunction with acquisition of a newly launched spaceborne imaging spectroscopy sensor;
  - Attendees to write reports to be submitted for competition with best report awarded a prize presented at the Valencia IGARSS and a presentation to be made at the GSIS invited session;