Question & Answer Session

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Amber McCullum (amberjean.mccullum@nasa.gov), Juan Torres-Pérez (juan.l.torresperez@nasa.gov) or Zachary Bengtsson (bengtsson@baeri.org).

Question 1: Is it possible to measure nitrate concentration in the agricultural fields from hyper-spectral imagery?

Answer 1: While I don't think hyperspectral data can be used to measure nitrogen directly, it is very useful for measuring chlorophyll concentrations. Some research has used chlorophyll concentrations as a proxy for nitrogen concentrations in agricultural fields. Here is an excerpt from the abstract of one study that used this method:

"Our results showed that hyper-spectral reflectance in the 807.6 nm region had the highest significant correlation with cotton leaf chlorophyll. Cotton leaf chlorophyll corre-lated significantly with soil nitrate-nitrogen and cotton yield. Because leaf chlorophyll is an indicator of nitrogen deficiency, our results suggest that hyperspectral reflectance may be used as a tool to help farmers determine nitrogen deficiency, which may subsequently lead to increased crop productivity and reduced environmental pollution."
https://www.researchgate.net/publication/234024893_Relationship_Between_Hyperspectral_Reflectance_Soil_Nitrate-Nitrogen_Cotton_Leaf_Chlorophyll_and_Cotton_Yield_A_Step_Toward_Precision_Agriculture

Here is another paper that monitored soil nitrogen with ground-based data and hyperspectral data in agricultural fields:
https://www.researchgate.net/publication/312415409_Monitoring_Soil_Nitrate_Nitrogen_Based_on_Hyperspectral_Data_in_the_Apple_Orchards

Question 2: What does the asterisk on ECOSTRESS mean?

Answer 2: ECOSTRESS was not designed specifically to be a hyperspectral sensor. We mention it here because: while the optical portion of the sensor is multi-spectral, the thermal data and mission deployment will be used to benefit future hyperspectral missions as well.

Question 3: Can the hyperspectral data be used for crop monitoring and crop type classification, if yes please explain how?
Answer 3: Yes! We will cover this more extensively during our first case study example in session 2, so please join us for that explanation next week. This is a prominent application. The data was used to differentiate the peaks and wavelength ranges in the crop types.

Question 4: Are hyperspectral data available via Google Earth Engine?
Answer 4: A limited amount of hyperspectral data is available through GEE. This data is exclusively from EO-1 Hyperion at a limited spatial coverage. However, you can access hyperspectral data from NASA and USGS portals to add it to GEE as an asset and still work with it using GEE tools. GEE developers are constantly updating their data archives, so it's always a good idea to check back frequently to see what new datasets are made available directly in GEE.

Question 5: One constraint on multi-spec bands are the atmospheric windows where signal can or can't get through. The curves shown for hyperspec seem to ignore these windows. Is hyperspec also subject to these constraints?
Answer 5: Yes, hyperspectral data are also subject to the constraints of the atmospheric windows. Here is a nice explanation of atmospheric windows: https://gisgeography.com/atmospheric-window/. For visible and IR wavelength the windows are there.

Question 6: Is HICO data available for India and is it available to researchers?
Answer 6: HICO data is available for certain coastal areas in India. HICO data is readily available through the NASA OceanColor Web online data access platform. Make sure to attend our session 3 training where we will be going over how to access this data in our demonstration!

Question 7: How are clouds removed in hyperspectral images?

Answer 7: Clouds present an issue in hyperspectral imagery in the same manner as with (optical) multispectral imagery. There are techniques such as cloud masking that can be used to remove the pixels with clouds. We recommend using a threshold of 20% cloud cover.

Question 8: What did you use to make the HICO visualization with the RGB slider? That could be really useful as a teaching tool.
Answer 8: This animation was made by a team at NASA Goddard. Here is the link if you'd like to get more information and/or use this in your teaching:
https://oceancolor.gsfc.nasa.gov/gallery/feature/H2013229192426.html

Question 9: Are the rays emitted by different remote sensing satellites harmful for delicate coral reefs during the scan?
Answer 9: No. Remember most of these sensors, particularly the hyperspectral ones, are passive sensors. This means they do not emit any "ray". Passive sensors ONLY receive the reflected signal from the targets, land- or ocean-based.

Question 10: Does ECOSTRESS have information for South America?
Answer 10: There are a few locations of ECOSTRESS data in South America as it is on the ISS. Here is a map that identifies locations for ECOSTRESS data:
https://ecostress.jpl.nasa.gov/observations

Question 11: ECOSTRESS is hyperspectral or thermal? Is it affected by cloud cover?
Answer 11: It has multi-spectral optical data and thermal data. The optical data are still affected by cloud cover. Here is the technical website for ECOSTRESS that outlines the bands:
https://ecostress.jpl.nasa.gov/instrument

Question 12: Can ECOSTRESS measure soil moisture?
Answer 12: ECOSTRESS is primarily used for measuring Evapotranspiration (ET), not soil moisture. The SMAP mission has soil moisture data.

There are a lot of ECOSTRESS questions, I suggest you check out our lightning session on ECOSTRESS here: https://appliedsciences.nasa.gov/join-mission/training/english/new-sensor-highlight-ecostress

Question 13: What kind of research is done with HICO?
Answer 13: HICO was designed for coastal ecosystems applications. Its data has been used for coral reef analyses as well as other shallow-water coastal ecosystems. As it was installed in the ISS, the data acquisition was mostly on a user-based needs and there was a process to solicit data acquisition. This is why the coverage of HICO was limited to particular coral reef regions.

Question 14: The large number and continuous spectral bands in a hyperspectral system caused redundant spectral information between neighboring bands. How to decide which bands are more relevant for a particular application?
Answer 14: This is a great question! Because the bands are so closely spaced together, there can be high correlation among bands. We will discuss this at the end of the session. There are many techniques for identification of correlation among the bands. Therefore, there are some more advanced techniques, such as Principal Component Analysis (PCA) that can be used to identify the correlation among spectrally similar bands in order to choose the best bands for your study area. Due to the high spectral resolution, there can be quite a lot of noise in the data (signal to noise ratio), so the Minimum Noise Fraction (MNF) technique can be used to reduce the level of noise in the data. If you had 2 highly correlated bands, you may have to decide which is giving you more information for your application.

Question 15: Could Hyperspectral used to determine bathymetry?
Answer 15: Hyperspectral data can be used to analyze bathymetry in shallow water and is frequently used to map the bottom of coastal ecosystems. Here's a paper that used airborne-based hyperspectral data from the Compact Airborne Spectrographic Imager (CASI-2) for estimating bathymetry in Moreton Bay in Australia.
Brando et al (2009): https://doi.org/10.1016/j.rse.2008.12.003 Please stay tuned for session 3 where we will focus on coastal applications of hyperspectral data. It is limited though due to the interactions with water.

Question 16: If hyperspectral data is so granular and valuable, why are missions not operating at scale? Are the costs too high?
Answer 16: The costs are high, the datasets are very large, and the data are more difficult to process and analyze than multispectral data. While there are not many global missions

currently, you will notice that we highlighted some upcoming missions like PACE and SBG. They will be global.

Question 17: Is [PRISMA data] freely available somewhere? If yes, where could I find it?
Answer 17: PRISMA data were recently made available and can be accessed through a data order. Information about accessing data can be found on the Italian Space Agency's website.

Here is a article about the release of PRISMA data https://sbg.jpl.nasa.gov/news-events/prisma-data-are-now-available-for-access
Here is the PRISMA website: http://www.prisma-i.it/index.php/en/

Question 18: PACE is 5m spatial resolution?
Answer 18: No. The Ocean Color Instrument (OCI) in PACE will have a 5nm spectral resolution and a 1KM spatial resolution at nadir. Other sensors within PACE will have different spectral and spatial resolutions.
Here you can find the details on PACE: https://directory.eoportal.org/web/eoportal/satellite-missions/p/pace-mission#:~:text=%2D%20The%20PACE%20satellite%2C%20as%20envisioned,NIR%20to%20the%20shortwave%20infrared.
Here's another PACE site: https://pace.gsfc.nasa.gov/

Question 19: What is the maximum limit (and how) of the number of bands in hyperspectral. Actually, is there a limit? If yes, what does it depend on?
Answer 19: The number of bands depends on how closely spaced the bands are and the wavelength range that the data cover. Also, as we mentioned earlier, the bands that are close together can also be highly correlated. I have not seen more than about 220 bands.

Question 20: In Himalayan mountain vegetated cover areas, can we differentiate sedimentary rocks through Hyperspectral imagery?
Answer 20: The data are optical, so they will only gather information from the top of the canopy, so the area would need to be bare to differentiate the rocks.

Question 21: Which data are/will be freely available?

Answer 21: A variety of hyperspectral data are available through online platforms. HICO, CORAL, AVIRIS, EO-1 Hyperion, and more are all available online. Data from these sensors in particular are available through NASA OceanColor Web, NASA EarthData, USGS EarthExplorer, and other data access platforms you may be familiar with. Make sure to attend the following sessions of this training series, as we will be going over online data access to hyperspectral imagery.

Question 22: SBG: When do you see it launched; Thermal bands, what would be the spatial resolution?
Answer 22: That has yet to be decided, I'd suggest becoming involved with the SBG Applications community, there is an event in February. For the thermal bands the range will be somewhere between 300 to 12oo nanometers with more than 5 bands, and a revisit time of 1 to 70 days. The mission is still in the development phase.

Question 23: You have said that Hyperspectral Remote sensor captures more than the three visible bands (RGB) as compared to the three RGB for Multispectral. Can you elaborate more on this?
Answer 23: Please refer to the presentation provided.

Question 24: Have any of the initiatives had experience with observation of plastic waste and plastic litter in water and on the surface of the soil?
Answer 24: There has been some work on this (plastic in the ocean). ARSET's 2020 Coastal training covered this a bit (marine debris). Using field specs to id plastic or debris in coastal areas as a baseline to develop a spectral library.
https://pubs.acs.org/doi/10.1021/acs.est.8b02855

Question 25: Why does the hyperspectral data come with medium/coarse spatial resolution? While I was mapping urban land use/land cover classification using (EO-1) Hyperion for my class project, it was very difficult to identify land use classes with 30 m pixel size. With this pixel size, how will you be able to map vegetation or urban features accurately unless you want to map something for a broader scale?
Answer 25: Mission design results in tradeoffs in the various resolutions (temporal, spatial, etc.) Supplementing With different data can aid in these applications. Commercial data is an option (however, there is a cost). Drone data acquisition is an option.

Question 26: To my knowledge ENVI is one powerful image processing for hyperspectral data, but it is not free. What are free but powerful image processing softwares for hyperspectral data?
Answer 26: Software like NASA SeaDAS and QGIS are great free options to work with hyperspectral data. We will show QGIS in Part 2 of this series. SeaDAS (in Part 3) can be used for completing atmospheric correction and applying algorithms to imagery. However, these platforms do not have standard operating procedures for working with a lot of hyperspectral sensors.

Question 27: Atmospheric correction must be applied even if it is Level 2 data?
Answer 27: Level 2 data are atmospherically corrected to obtain surface reflectance. This data has typically gone through the necessary pre-processing steps to start analyzing data. Hyper is typically available in L1.

Question 28: Can master's students be a part of PACE, SBG, and GLIMR?
Answer 28: We encourage anyone interested to get involved with upcoming hyperspectral missions. Each of these missions has working groups and applications teams interested in user input and involving scientists at all stages of their education. Here are some links to help you get involved:
https://pace.oceansciences.org/app_involved.htm
https://sbg.jpl.nasa.gov/groups

Question 29: Considering the limitations in accessing Hyperspectral data, what factors should one consider in order to access Hyperspectral data for a particular study area (e.g., an area located in Malawi, Southern Africa)?
Answer 29: The first step in data access for hyperspectral data is making sure your study area falls within the limited spatial extent of hyperspectral missions. You can filter data based on spatial extent in most NASA and USGS data portals. We will go over data search filtering in the next two sessions. We will demo this in Earth Explorer in Part 2.

Question 30: I'm actually curious about Airborne AVIRIS data applications in the atmospheric sector. Can you guys please cover that more elaborately and also can you please help me to learn more by providing some information through where I can learn about it?

Answer 30: AVIRIS has been used for air quality and wildfire smoke assessment applications. Using hyperspectral data for these applications can allow for better differentiation between airborne pollutants and can capture pollutants that may be missed with the limited spectral resolution of multispectral imagers.
ARSET's Health and Air Quality trainings and an upcoming Wildfires training may touch upon this.

Question 31: Is the precursor SBG data freely available?
Answer 31: I would suggest using AVIRIS data as precursor data for SBG.
For accessing AVIRIS data use the AVRISI data portal here:
https://aviris.jpl.nasa.gov/dataportal/

You can also get more information on the HyspIRI work here. This did not move forward as a full mission: https://hyspiri.jpl.nasa.gov/airborne

Question 32: Is denoising applied to L2 or L1 data? Otherwise, are toolboxes or python routines available somewhere?
Answer 32: Depending on the sensor of interest, some of the denoising (along with a series of other corrections for image artifacts) takes place during radiometric corrections, so this would have been done in the level 1 processing step. Many data need to be further processed by the user to deal with noise after this as well.

Question 33: How do you get first derivative band images from hyperspectral reflectance band images (0 to 288 bands) using ENVI software?
Answer 33: It looks like you might need to use the spectral angle mapper in ENVI. This is not something I have done before, but this website has some nice information and tutorials from ENVI: https://www.l3harrisgeospatial.com/docs/whole-pixel_hyperspectral_analysis_tutorial.html

Question 34: Does EO-1 imagery have a QA band?
Answer 34: There is a calibration file available for Hyperion data, but I am not sure if there is a specific QA band. You can find more information here:

https://www.usgs.gov/centers/eros/science/usgs-eros-archive-earth-observing-one-eo-1-differences-hyperion-data-sets?qt-science_center_objects=0#qt-science_center_objects

Question 35: Is CORAL available for the Atlantic region?
Answer 35: No. Unfortunately, the CORAL mission was only flown in the Pacific. There is some data for the Florida Keys, but it is very limited and might not be available yet.

Question 36: In a coastal environment, can we use Hyperspectral data for sediment and coastal plantation classification applications both on the same sensor?
Answer 36: Please stay tuned for session 3 where we will cover coastal/ocean applications. One case study we present is the use of hyperspectral data for mangroves.

Question 37: Experience with airborne acquisitions is showing problems with coregistration between VNIR and SWIR data, actually acquired by two different sensors. How is this handled with Hyperion or other sensors when pixels are not perfectly collocated?
Answer 37: With satellite systems, co-registration is often not as much of an issue as with airborne systems. This is because the satellite systems are operating along a specific orbit. Here is a paper that discusses co-registration of Hyperion images: https://www.researchgate.net/publication/264079753_A_Study_on_Automatic_Coregistration_and_Band_Selection_of_Hyperion_Hyperspectral_Images_for_Change_Detection

Question 38: Based on previous experience, are there suggestions on which wavelengths to choose (in order to reduce data size) depending on the purpose of the analysis?
Answer 38: We will cover this a bit more in sessions 2 and 3, but this is very dependent on your specific application and the reflectance properties of what you are interested in studying. The wavelengths that are most beneficial will be different even within specific vegetation types. But yes, it is useful to determine which bands provide the most useful information to reduce the number of bands you need to analyze.

Question 39: Question on the PACE mission: could you please give some details on OCI? Field of view, global observation or only ocean/coast? The SWIR spectral range has 7 bands? What is the general instrument concept for the VNIR range? Prism, grating, filters...
Answer 39: Details on PACE architecture can be found here: https://directory.eoportal.org/web/eoportal/satellite-missions/p/pace-

mission#:~:text=%2D%20The%20PACE%20satellite%2C%20as%20envisioned,NIR%20to%20the%20shortwave%20infrared. We will cover the OCI in session 3 in more detail.

Question 40: Thank you for this comprehensive overview of hyperspectral imaging! In some future course, will ARSET consider a training on UAV-Hyperspectral imaging (in person maybe?)
Answer 40: Thanks for this suggestion. We are always looking for ideas for future trainings from our participants. We will take this into consideration.

Question 41: What is the difference between atomic and molecular reflectance in the context of remote sensing?
Answer 41: Optical remote sensing measures the reflected energy from a target. There is some molecular scattering that occurs in the atmosphere, such as Rayleigh scattering. Check out the book: *Spectroscopy and Remote Sensing* for more detailed information on this. Here is a nice presentation about this as well:
http://www.edc.uri.edu/nrs/classes/nrs409509/RS/Lectures/409509EMR.pdf

Question 42: Is it possible to distinguish species of vegetation with hyperspectral data?
Answer 42: Yes! We will cover this extensively in sessions 2 and 3.

Question 43: Since hyperspectral data has such a high number of narrow spectral bands, can you share briefly on some considerations on using supervised or unsupervised classification methods for land cover mapping? I am asking because I feel it would be harder to use unsupervised classification for hyperspectral data (but I could be wrong)!
Answer 43: We will provide an example of the use of hyperspectral data for land cover classification in session 2. But yes, you are correct in assuming that it will likely be more difficult for the computer to differentiate between the most useful bands for creating separate classes within an unsupervised approach. I could imagine the associated errors being larger. But there are techniques, such as machine learning that can improve this approach. You could use a form of PCA analysis to choose a few important bands prior to running an unsupervised classification as well. I usually prefer a supervised approach with ground-based data.
Here is some additional information:

- https://ieeexplore.ieee.org/document/1027101

- https://towardsdatascience.com/land-cover-classification-of-hyperspectral-imagery-using-deep-neural-networks-2e36d629a40e

Question 44: Where can we find the methodologies, formulas and values for the correction (Radiance and Reflectance) of Hyperion images?
Answer 44: Here is a good website for some useful tutorials in ENVI:
https://www.l3harrisgeospatial.com/docs/whole-pixel_hyperspectral_analysis_tutorial.html
You can also further familiarize yourself with the specifications of available hyperion data products in the EO-1 user manual here:
https://lta.cr.usgs.gov/DD/EO1.html#process_level

Question 45: As you mentioned, one of the main limitations of hyperspectral remote sensing is the relatively complicated and resource-demanding atmospheric correction algorithms. How do you at NASA (or maybe other agencies) plan to deliver the future data? Because if the atmospheric correction will be on the user end, then this limitation will not be removed. Maybe it will be used only at universities but not in the industry. Thank you.
Answer 45: I think this will be decided on a case-by-case basis for each new instrument. I am not part of the development team, but I would suggest becoming involved with the PACE and SBG mission development meetings.

- https://pace.gsfc.nasa.gov/
- https://sbg.jpl.nasa.gov/

Some available hyperspectral products are also already available in Level 2 atmospherically corrected format. For example, HICO data products are available in both Level 1 radiance and Level 2 surface reflectance formats.

Question 46: Is there a tradeoff between spectral and spatial resolution?
Answer 46: Yes, there is always a tradeoff between spectral, spatial, and temporal resolution in the instrument design.

Question 47: Why are you talking about multi-angle "polarimeters" when you are referring to the next PACE? As far as I know, polarimetrics has its main applications in radar imagery, how it is applied in hyperspectral imagery?
Answer 47: While imaging polarimetry is a primary feature that must be considered with radar data, it can also be used in passive optical imagery. Here is a feature collection that discusses the benefits of this within mission design:
https://www.osapublishing.org/ao/abstract.cfm?uri=ao-45-22-5453

Question 48: Is there a map that can show the regions of hyperspectral data available? We work in the Amazon, specifically in the Ecuadorian part.
Answer 48: This is specific to the sensor of interest? Each data type generally has their own information about where data are located. Another option would be to use the search options of a data portal to identify your region of interest and then find which data are available in that area. You can use EarthExplorer, which we will demo in session 2 here:
https://earthexplorer.usgs.gov/

Question 49: Hyperspectral data available in the web site for developing countries?
Answer 49: It depends on the sensor. They are located in many different locations. Many of the hyperspectral sensors were designed to target specific locations, so you will need to search for your area depending on the sensor you are using. Most online data portals allow you to filter search results to a specific study area. We will go over some of these online data sources in the following 2 sessions. We will demonstrate how to search and download these data.

Question 50: What innovative governance, exceptional ideas and applications, based on earth observation, biodiversity, global sustainability, that address global, societal and commercial challenges, during and after COVID-19?
Answer 50: That is a major question that is beyond the scope of this training. However, in regards to remote sensing training, there are many initiatives that have gone online to reach participants during the pandemic. There are many trainings offered on the ARSET website related to different application areas, such as land management, health and air quality, water resources, and disasters.

NASA Applied Sciences Program has some resources related to COVID-19 as well:

- https://appliedsciences.nasa.gov/our-impact/story/nasa-covid-19-dashboards-give-view-viruss-effects-above
- https://appliedsciences.nasa.gov/our-impact/story/rapid-response-applied-sciences-research-covid-19s-environmental-connections
- https://earthdata.nasa.gov/covid19/

Question 51: Can a possible application also be for waste management to identify different types of waste materials?
Answer 51: Hyperspectral imagery is useful in the identification and mapping of mine waste and sewage effluent. The high spectral resolution of hyperspectral imagery provides the opportunity to differentiate between waste accumulated in the ocean and a variety of surface properties. Depending on the types of waste you are interested in identifying, hyperspectral data can be used to create spectral profiles used to classify waste. Here is an example of mine waste evaluation from AVIRIS:
https://aviris.jpl.nasa.gov/proceedings/workshops/00_docs/Hauff_web.pdf

Question 52: Is the VIIRS sensor a hyperspectral sensor?
Answer 52: No. VIIRS only has about 5 bands in the visible and several more in the infrared region. Here you can find details on VIIRS including the band wavelengths:
https://lpdaac.usgs.gov/data/get-started-data/collection-overview/missions/s-npp-nasa-viirs-overview/

Question 53: I'm not sure what was meant by the 160-1200 nm for the ECOSTRESS bands. Could you clarify?
Answer 53: This is the wavelength range where the ECOSTRESS sensor collects data. Here is more information about the ECOSTRESS instrument:
https://ecostress.jpl.nasa.gov/instrument

Question 54: Are ECOSTRESS and Hyperon covering only the USA or all the world's countries? These sensors (ECOSTRESS, Hyperion, HICO) are open and free or commercial?
Answer 54: Hyperion data exists for a variety of locations throughout the world but are limited in spatial extent, however, what is available, these data are open. This also applies to ECOSTRESS data. The sensors we focus on in these trainings, including ECOSTRESS,

Hyperion, and HICO, are not commercial and data is free and accessible through a variety of online platforms like EarthExplorer, GloVis, NASA Earthdata, and NASA OceanColor Web. In the next two Parts, we will be demonstrating online data access and data search filtering options.

- Here is a map that identifies locations for ECOSTRESS data: https://ecostress.jpl.nasa.gov/observations
- For Hyperion, you can search for locations on the Earth Explorer website: https://earthexplorer.usgs.gov/
- For HICO you can search for data locations on the OceanColor website: https://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=hico

Question 55: Why is the spatial resolution of hyperspectral satellites moderate (30m)? Is it because the light reaching the sensor has to be split into so many narrow bands?
Answer 55: There is always a tradeoff between spectral, spatial, and temporal resolution in the instrument design. Mission design results in tradeoffs in the various resolutions (temporal, spatial, etc.) Supplementing with different data can aid in these applications. Commercial data is an option (however, there is a cost). Drone data acquisition is an option. Hyperspectral having 220+ bands results in large datasets and leads to limitations.

Question 56: On these Hyperspectral missions (slide 31), what is the typical revisit time of these sensors?
Answer 56: These are all specific to the individual sensor. They range from about 5 day to 30-day revisit times.
Here is a paper that outlines some of these temporal resolutions of the upcoming or current missions, make sure to download PDF to see tables which display specifications of each sensor: https://www.mdpi.com/2072-4292/10/2/157

Question 57: I'm curious about the size of the airborne instruments. I assume that they're large, based on the aircraft cited. Is anyone working on miniaturizing hyperspectral sensors for use in smaller aircraft?
Answer 57: Indeed, most of the airborne sensors mentioned on the webinar are big and heavy. This is why a platform such as a Twin Otter or bigger is needed to fly them. There are private companies that have developed hyperspectral cameras that can be flown in drones

and are mostly for land-based applications, like agriculture to increase yield. Also, these might not have the signal to noise ratio necessary for appropriate classification of land or ocean ecosystems.

Question 58: Is there a summary map of hyper spectral data coverage worldwide?
Answer 58: There is no comprehensive summary map of hyperspectral data coverage worldwide. Data coverage is typically displayed on the online platform where data for each sensor are available. You can use the websites linked in question 6 to explore availability of data.

Question 59: How can we know the reflectance of different minerals from hyperspectral data? Are there any reports or data related to that and can you please provide information about that (link or report or article)?
Answer 59: Similar to the land cover classification you might be familiar with, you can use the spectral profiles of exposed minerals on the Earth's surface to identify different minerals. We will look into this in Part 2 of this series.
Check out this special issue on hyperspectral mineral mapping:
https://www.mdpi.com/journal/minerals/special_issues/mineral_mapping#published

Question 60: Are the limitations low Signal to Noise Ratio (SNR) or high SNR ratio? High SNR is good right? Low is bad right?
Answer 60: We look to reduce the noise. You want to have a ratio where the signal is much higher than the noise. There are techniques to do so. That is beyond the scope of this training but if there is enough interest, possibly we can design a future training to address this.

Question 61: Are there ground-based hyperspectral databases that are used to classify space-based hyperspectral data?
Answer 61: Handheld specs can be used to create spectral libraries. These can be compared to satellite data. Many researchers prefer to collect in situ at the same time of a satellite overpass to assist with ground-based verification usually within one hour of the satellite overpass to account for atmospheric changes, and if for the ocean, for water column variations.

Question 62: Any estimate for when SBG might launch?
Answer 62: At the earliest, SBG will be launched in the mid-to-late 2020s. In Early February 2021 there will be a community-based webinar on the development of SBG.
Here's the SBG website: https://sbg.jpl.nasa.gov/
The 4th NASA Surface Biology & Geology Community Webinar is February 18th at 1pm Eastern Time. The link to register for the SBG Community webinar is https://forms.gle/jerYj1i4AvWmD6fq6

Question 63: What are the tradeoffs? Is there a tradeoff between spectral resolution and spatial or temporal resolution?
Answer 63: See previous answer. Collection, storage, the sensor itself leads to these tradeoffs.

Question 64: And are there reference space-based hyperspectral data? For example, a healthy pine tree looks like X in hyperspectral, a dying pine tree looks like Y in hyperspectral.
Answer 64: The USGS Spectral Library has a variety of surface reflectance measurements for vegetation, soils, minerals, etc. Take a look here: https://www.usgs.gov/labs/spec-lab/capabilities/spectral-library
For coastal or ocean systems you might get ground-based data at: SeaBASS: https://seabass.gsfc.nasa.gov/search#bio
Collecting your own in situ measurements in your region of interest is a best practice.

Question 65: As we make the bandwidth narrower to increase spectral resolution, how much does the SNR decrease (i.e., how much does the high noise level increase relative to the signal)?
Answer 65: This depends on how narrow the bands are spaced. The more narrow, the more ratio may be an issue. Each sensor's design will also affect this.

Question 66: What about Inverse Minimum Noise Fraction, can we use its output directly for processing?
Answer 66: Minimum Noise Fraction (MNF) technique can be used to reduce the level of noise in the data. If you had 2 highly correlated bands, you may have to decide which is giving you more information for your application.

Question 67: I noticed that in some of the hyperspectral missions, only a few bands are monitored (e.g., 6 bands instead of +128). You mentioned that Principal Component Analysis (PCA) is used for figuring out which wavelengths to keep. Is that how you selected the bands to be monitored in these lower spectral resolution cases?
Answer 67: PCA works by determining how closely wavelength bands are to each other. For example, NIR has the highest reflectance in that range for healthy vegetation. This is an iterative process. Find your range(s) of interest, then narrow your search from there.

Question 68: For the CORAL sensor do you know how the biophysical parameters you mentioned are linked or compared to spectral data?
Answer 68: The team focused on primary production as the main biophysical parameter. We will cover more about the CORAL mission on Session 3 of this series. More information can also be found here. https://coral.jpl.nasa.gov/

Question 69: In several regions, the clouds are covering the region almost the whole year, so is this an obstacle to get proper images to make analysis. Can hyperspectral data handle this better than multispectral data?
Answer 69: Yes! Clouds are an issue with hyperspectral data as they are with multi-spectral data. No, hyperspectral data does not handle this any better. Radar (SAR) data may supplement as cloud cover will not be an issue.

Question 70: Can any of the data sets be used for identifying different types of plastic waste within the coastal regions and the seas/oceans?
Answer 70: Yes. There has been some work on this (plastic in the ocean). ARSET's 2020 Coastal training covered this a bit (marine debris). Using field specs to id plastic or debris in coastal areas as a baseline to develop a spectral library.
https://pubs.acs.org/doi/10.1021/acs.est.8b02855
Another recent paper on marine debris is: Acuña-Ruz et al (2018):
https://www.sciencedirect.com/science/article/pii/S0034425718303730

Question 71: For ECOSTRESS, you mentioned a thermal radiometer has a resolution/band with less than VIS and NIR? How does this work at the sensor level? Are there two sensors?
Answer 71: Information on the ECOSTRESS architecture and design can be found at:
https://ecostress.jpl.nasa.gov/instrument

Question 72: Looking beyond COVID-19, has hyperspectral imagery been used for pandemic risk surveillance?
Answer 72: I'm not aware of the use of hyperspectral imagery for pandemic risk surveillance. However, there are various health applications of hyperspectral data. These studies are typically completed for vectors of disease that share a close relationship with their environment (like mosquitoes and standing water; or ticks and land cover type/vegetation density), essentially using remotely sensed environmental data as a proxy for the presence of disease risk.

Question 73: Can we use Hyperspectral data to monitor changes in coastline? How can we do that if we can?
Answer 73: Yes! We will cover coastal and ocean applications in session 3 of this training. Here is an article related to HICO with some additional resources: https://www.nasa.gov/mission_pages/station/research/news/HREP_HICO_Legacy

Question 74: Why are there bad bands in Hyperion's data and how they can be identified?
Answer 74: Some bands of Hyperion are more heavily influenced by atmospheric properties, like water vapor, and thus have a higher signal to noise ratio. Therefore, oftentimes these bands are removed for analysis. Here is a reference paper for more information: https://www.researchgate.net/publication/317218952_Comparison_of_efficient_techniques_of_hyper-spectral_image_preprocessing_for_mineralogy_and_vegetation_studies

Question 75: Is there a catalog of band combinations that you can use to classify specific minerals, vegetation, etc. in your scene?
Answer 75: The USGS Spectral Library has a variety of surface reflectance measurements for vegetation, soils, minerals, etc. Take a look here: https://www.usgs.gov/labs/spec-lab/capabilities/spectral-library

Question 76: Do you have hyperspectral signatures libraries available and open?
Answer 76: The USGS Spectral Library has a variety of surface reflectance measurements for vegetation, soils, minerals, etc. Take a look here: https://www.usgs.gov/labs/spec-lab/capabilities/spectral-library

Here is one for agriculture: https://catalog.data.gov/dataset/global-hyperspectral-imaging-spectral-library-of-agricultural-crops-for-conterminous-unite

Question 77: About the future of hyperspectral sensors, what will happen when the planet has a lot of cloud cover and pollution? Will the sensors still be useful?
Answer 77: Hyperspectral data are limited by cloud cover and some pollution. There are atmospheric correction techniques that can account for some things like water vapor, but clouds and smoke need to be considered when using these optical sensors. Radar data (SAR) can be used to penetrate clouds and smoke, so that is an alternative for cloudy regions. ARSET has many SAR trainings available, including one on forest monitoring from last year. https://appliedsciences.nasa.gov/join-mission/training/english/forest-mapping-and-monitoring-sar-data

Question 78: Are HICO datasets available for all locations? I'm unable to download HICO data from the NASA ocean color archive over the period of 2013 in the Red Sea region.
Answer 78: HICO data was collected based on the research team requests. Therefore, data might not be available for specific sites and for particular years. This might be the case.

Question 79: What are the open data sources covering Central Africa?
Answer 79: Data availability will depend on the sensor of interest. Here are a few resources you could use to check on the availability of data in Central Africa:

- Here is a map that identifies locations for ECOSTRESS data: https://ecostress.jpl.nasa.gov/observations
- For Hyperion, you can search for locations on the Earth Explorer website: https://earthexplorer.usgs.gov/
- For HICO you can search for data locations on the OceanColor website: https://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=hico

Question 80: Has hyperspectral data been used for soil classification?
Answer 80: I believe this has been done, but not extensively. Hyperspectral data can be used for monitoring soil properties, such as nitrogen. Here are a few resources:

- https://ieeexplore.ieee.org/document/7456607
- https://www.tandfonline.com/doi/abs/10.1080/03650340.2017.1359416

Question 81: How are hyperspectral data classified if there are no ground truth data available?
Answer 81: Unsupervised classification can be used when there are no ground-based data. This involves a computer algorithm that iteratively identifies different land cover types, and then is modified and improved by the user. This can be more difficult with hyperspectral data than multispectral data since there is often high correlation among spectrally similar bands. Therefore, you may need to remove some bands prior to classification. We have a previous ARSET training on land cover classification techniques here: https://appliedsciences.nasa.gov/join-mission/training/english/land-cover-classification-satellite-imagery

Question 82: What Atmospheric Correction Algorithms are recommended to use for Hyperspectral Data?
Answer 82: Many hyperspectral data products are created for easy processing in ENVI. FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes) in ENVI is a typical method of hyperspectral atmospheric correction. Other options include ACORN (Atmospheric Correction Now) and ATREM (Atmospheric Removal Program). We will briefly discuss these options in session 2.

Question 83: Has there been any research into whether hyperspectral data could be used as a proxy for ground geochemistry acquired via soil sampling? For example, might copper-rich soil reflect different wavelengths than non-copper-rich soil?
Answer 83: Yes, this has been done, but not extensively to my knowledge. We will cover one example next week on the use of hyperspectral data for mapping volcanic mineral deposits, where ground-based data were also collected. Here is a link to the paper we will cover next week: https://www.sciencedirect.com/science/article/pii/S0034425703001925

Question 84: Aren't there fewer photons to be captured in a narrower band detector than a broader band detector?
Answer 84: Because hyperspectral imagery is detecting energy at narrow band ranges this leads to the issue of signal to noise ratios and the interference of the reflectance properties due to things like water vapor in the atmosphere. So this is an important limitation of hyperspectral data.

Question 85: How sensitive is this information to cloud presence? And are there cloud free mosaics available for example in Google Earth Engine?
Answer 85: Hyperspectral information is sensitive to cloud cover, similar to multispectral imagery. Google Earth Engine has a limited amount of EO-1 Hyperion data available. However, data swaths are not contiguous, so mosaics are not available. There are options to filter data for cloud cover in EarthExplorer and other data acquisition platforms. Earth Engine developers are always adding data to their collections, so keep an eye out for new hyperspectral additions. You can even request that they make hyperspectral data available in GEE.

Question 86: Can any dataset be used for underground (topsoil surface to .05-meter depth) microorganism community and types?
Answer 86: Optical hyperspectral data are not ground penetrating. They just measure surface reflectance. However, there are SAR sensors that can penetrate the ground and can be used for monitoring things like soil moisture in agricultural fields. I am not sure if any microorganisms can be identified, unless they have associated dielectric properties. ARSET has other trainings on the use of SAR data for various applications.

Question 87: Can we use hyperspectral data for crop type discrimination?
Answer 87: Yes! We will review a case-study example of this in session 2, so stay tuned!