

Session A



Part 1 Question & Answer Session A

Please type your questions in the Question Box. We will try our best to answer all your questions. If we don't, feel free to email Savannah Cooley (savannah.cooley@nasa.gov). This document will be shared to the training webpage within one week.

- 1. Something I've always been a bit confused about is what we mean when we talk about light 'absorbed.' Where does it go?**
 - a. Light that is not transmitted or reflected is absorbed by the material and converted into thermal energy. The object gets hotter as light is absorbed, but the light's energy doesn't go away. I.e., Light that is "absorbed" occurs when the electromagnetic energy is transferred directly into the atoms or molecules of the material it hits.

- 2. Which satellite platform, collection, and spectral bands are being used for deriving LST measurements? Are these LST values sourced directly from a standard product (e.g., MODIS, Landsat) or derived through a custom retrieval methodology?**
 - a. There are several NASA instruments with thermal infrared bands that currently produce LST products from thermal infrared measurements. E.g. the 3 MODIS thermal bands (29, 31, 32) or the 2 Landsat 8 and 9 thermal bands (10, 11). They use different algorithms that are customized for the particular sensors but they all provide the same land surface temperature (and emissivity) product.

- 3. Is the ECOSTRESS data currently accessible?**
 - a. Yes. ECOSTRESS data can be accessed in several ways:
 - i. LPDAAC - To learn the fundamental steps for discovering and opening ECOSTRESS data products, you can utilize the recommended [LPDAAC tutorials](#)
 - ii. [NASA Earthdata - "ECOSTRESS" Search](#)
 - iii. [LP DAAC subsetting tool - AppEEARS](#). Click on: "point samples" or "area samples"
 - iv. Google Earth Engine (featured in Part 2)



4. How are Land Surface Temperature (LST) products validated?

- a. Satellite-based Land Surface Temperature (LST) products are validated using **ground-based thermal radiometers** that measure surface-leaving radiance at the exact moment of a satellite overpass. This recorded radiance is mathematically converted into a kinetic surface temperature and directly compared against the satellite's retrieved pixel value to calculate accuracy and bias.
 - i. Ex: Lake Tahoe site. Water bodies are highly reliable because their emissivity is quite stable and known a priori, isolating atmospheric correction accuracy
 - ii. <https://calval.jpl.nasa.gov/>
- b. High resolution airborne campaigns (HyTES) pixels can be used in conjunction with ECOSTRESS data if an overpass of both occurs at the same time.

5. I understand since thermal remote sensing relies on naturally emitted weak thermal radiation, the sensors have a coarser resolution to capture thermal energy effectively. Is NASA or ESA working towards making thermal imagery sensor resolution even higher than the existing ones? What level of resolution is achievable in the near future (since UHI and local heat hotspot studies require much higher resolution)?

- a. Yes, both NASA and ESA are actively pushing toward finer-resolution thermal observations. The next generation of agency missions will deliver roughly 50–60 m TIR data with daily-to-3-day revisits.
- b. Longer wavelengths (thermal infrared) require larger optical detector elements to collect enough photons, and cryocooling adds mass, power, and cost etc. This has historically kept TIR satellites at 60–100 m (ASTER, ECOSTRESS) vs. 10–30 m for VNIR sensors.
- c. The ESA mission LSTM provides resolution to 50m. To increase the resolution means incurring a significant cost.

6. Which kind of emissivity retrieval algorithm will the new missions use?

- a. Most of these missions are designed to support multi-band Temperature-Emissivity Separation (TES) retrievals, rather than relying on Split-Window assumptions



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- b. LSTM and other missions are also exploring newer Optimal Estimation techniques that rely on historical ‘first guess’ emissivities to constrain the retrieval problem and provide better uncertainties in the estimated values.

- 7. How do ECOSTRESS datasets differ from LANDSAT datasets already available from USGS?**
 - a. Each sensor has different characteristics: spatial resolution, temporal resolution. See slide 36 of the presentation for a comprehensive table of different instruments, their spatial resolution, TIR bands, temporal resolution, etc.

- 8. How can we validate the TIR RS-derived LST data if we don't have In-situ data??**
 - a. We could compare the LST results to another sensor passing over at the same time, that has been validated by past in situ matchups. E.g. we could look for ECOSTRESS-Landsat matchups and indirectly validate Landsat LST from previously validated ECOSTRESS measurements.

- 9. In Part 2, we are going to learn to downscale native 70m ECOSTRESS LST data to 10m using a Random Forest model. For a neighborhood-level (LSOA) urban heat vulnerability analysis in London, do you recommend using the 10m downscaled product, or is it safer to stick to the native 70m resolution to avoid introducing model artifacts when aggregating to neighborhood polygons?**
 - a. I would analyze both and observe differences in details that you can see. E.g. at 10m you can see temperatures of individual streets and rooftops which can not be discriminated at 70m. The RF model will disaggregate the coarser 70m into finer components, but maintains radiometric normalization, meaning if you sum up the 10m components you will still get to the same 70m temperature you started with.

- 10. How can we select the appropriate remote sensing data for our LST-based studies (considering the trade-off between temporal and spatial resolution within complex heterogenous urban cities)?**
 - a. That depends on whether you want high spatial vs high temporal resolution. There is a trade-off; you can't have both. ECOSTRESS



provides 3-5 day repeat at 70m, while MODIS provides a daily repeat but at 1km resolution.

11. Can land surface temperature be used on a small scale to see underground structures (for example, due to the difference in temperature between normal soil and soil that has stone/marble under it near the surface)?

- a. If the substrate results in a different temperature at the surface then yes we will see that, but not necessarily know why.
- b. For example, if there is a thicker slab of concrete and asphalt on a road, you would be able to see it in an analysis.

12. Could you repeat the example you mentioned regarding the extent which incorrect emissivity values can affect the resulting LST value?

- a. Yes. Split-window errors will occur in systematic fashion any time that emissivity is incorrectly assigned – leading to systematic biases. The Mauna Loa Caldera example here provides a clear illustration. Basaltic lava flows have strongly variable and spectrally complex emissivity in the 8–12 μm range, dropping below 0.90 in some channels. The 10% emissivity difference shown in the graph arises in the 11 micron channel when comparing the standard Level 2 MODIS split window approach to the Temperature Emissivity Separation (TES) Algorithm retrieval from the same MODIS input. The split-window algorithm (MOD11), retrieves a temperature of 310 K- approximately 12–14 K cooler than ASTER TES (322 K) and MOD21 TES (324 K), both of which explicitly retrieve emissivity. This is not a subtle calibration issue: it's a physically meaningful error driven entirely by the wrong emissivity assumption. The key rule of thumb shown here is that a 1.5% emissivity error propagates to roughly 1 K of LST error.
- b. This means that over rocky, sandy, and geologically diverse surfaces, split-window errors can reach 3-10 K. For applications such as urban heat island analysis and ecosystem thermal stress — where 1–2 K differences are scientifically meaningful.

13. How well does the ECOSTRESS Temperature Emissivity Separation algorithm perform over highly heterogeneous, complex urban materials?



- a. Good question. In theory it will be more accurate than e.g. a split-window approach that assumes some given emissivity based on land cover classification as an example, because TES physically separates the LST and emissivity components. However TES relies on an 'emissivity calibration curve' to solve the T/E separation and there are very few urban lab spectra used in that calibration curve, meaning some man-made materials like some metals may not be captured accurately by the calibration curve.

Algorithm Theoretical Basis Document (ATBD):

https://ecostress.jpl.nasa.gov/downloads/atbd/ECOSTRESS_L2_ATBD_LSTE_2018-03-08.pdf

14. Is there a straightforward way to determine the smallest temperature change that can be detected across an urban environment with known emissivity?

- a. The floor is set by the sensor's equivalent delta temperature. It is also dependent on the accuracy of the measurement itself. On average, you want 1 degree or less of variance (in Kelvin).

15. Would LST be T_{kin} or T_{rad} ?

Refer to slides 15-25 of the training. The summary is as follows:

Kinetic temperature (T_{kin}): True physical temperature;

Brightness temperature (T_B): Temperature blackbody would need for observed radiance;

Radiometric temperature (T_{rad}): TB integrated across all wavelengths

Kinetic temperature (T_{kin}) is what we can think of as the "ground truth" - the actual thermal state of the surface determined by molecular motion. But satellite sensors don't measure this directly.

Instead, they measure radiance and convert it to brightness temperature (T_B) by inverting Planck's Law. Brightness temperature is defined as the temperature a perfect blackbody would have to be to emit the radiance we observe. What we call the Radiometric temperature (T_{rad}) integrates Brightness temperature across all wavelengths (via the Stefan-Boltzmann constant). T_{rad} can be related directly back to kinetic temperature with the equation on slide 25:



$$T_{rad} = \epsilon^{1/4} \times T_{kin}$$

Since $\epsilon < 1$ for all real surfaces, $T_{rad} < T_{kin}$. The drier and sandier the surface, the larger the gap between them.

16. Is there a way to distinguish between land surface temperature and the temperature of the air near the land surface?

- a. Yes, by direct measurements, e.g. using a radiometer to measure the surface temperature and a temperature probe to measure the air temperature. At the Lake Tahoe site, there are instruments that pick up these measurements.

17. Given the known uncertainties in retrieving near-surface temperature, humidity, and radiative fluxes from satellite data – especially due to surface emissivity, selective gas absorption, and cloud–radiation interactions – what approaches are NASA missions exploring to better capture the combined human-relevant exposure burden in dense urban environments?

- a. The general direction is towards actionable products. For the scope of this training series, our primary focus is on land surface temperature. We will look into this further. There is active research being done in this field, but NASA has no direct mission looking into the human-relevant exposure burden.

18. Could you please explain the physics behind the difference between Split-Window and TES?

- a. The TES algorithm uses three or more thermal channels to assume emissivity and assumes no prior background.

19. Will we need QGIS, GEE, or R/R Studio for Part 2?

- a. Yes, to follow along with the demos, participants will need QGIS, GEE, and R/R Studio for Part 2.

20. Given that diseases such as Ebola, Hantavirus Andes, Covid-19 and Nipah are strongly influenced by near-surface temperature, humidity, aerosol load and air-quality interactions, what steps are NASA missions taking to improve retrieval of these human-relevant, ground-level exposure



parameters — especially where uncertainties in emissivity, selective gas absorption and cloud–radiation interactions limit current satellite products?

- a. Refer to our previous air quality trainings and join us for our upcoming training regarding Aerosols and PM2.5.

21. Is ECOSTRESS data available globally? How do we access this data?

- a. ECOSTRESS has near-global coverage. The ECOSTRESS instrument is aboard the International Space Station (ISS) and collects data between 52° N and 52° S latitudes. See Q3 for ECOSTRESS data access.

22. I have used the thermal bands to calculate LST derived from Landsat imagery. How are they different in terms of MODIS Terra/Aqua?

- a. The primary difference lies in the classic remote sensing trade-off between spatial and temporal resolution. Landsat instruments offer fine spatial resolution (100 m native pixels resampled to 30 m) but have a sparse 16-day repeat cycle. Conversely, MODIS (Terra/Aqua) provides daily global coverage, but at a much coarser spatial footprint of 1000 m per pixel.
- b. Their spectral configurations dictate the types of algorithms used. While historical Landsat missions (1-7) relied on a single thermal band, later Landsat 8 & 9 (2 TIR bands) and MODIS (16 TIR bands) feature multiple dedicated thermal channels, enabling multi-band approaches like the Split-Window (MOD11) or the more advanced Temperature-Emissivity Separation (MOD21) algorithms to calculate land surface temperature dynamically.

23. Can you suggest which products to utilize to combine AOD data with LST?

- a. To combine Aerosol Optical Depth (AOD) with Land Surface Temperature (LST) effectively, the MODIS suite on the Terra and Aqua satellites is an excellent starting point. Because both measurements are captured simultaneously by the same sensor, you avoid spatial and temporal co-registration errors. You can pair the standard MODIS LST products (such as MOD11A1 or the TES-based MOD21A1) with the MODIS Level 2 or Level 3 Aerosol products (MOD04_L2 or the high-resolution 1 km MAIAC product, MCD19A2).
- b. For higher spatial resolution urban studies, you can also combine Landsat-derived LST products with AOD records extracted from the



European Space Agency's Sentinel-5P or Sentinel-3 platforms, though you will need to carefully account for time-of-day overpass differences between the satellites.

24. ECOSTRESS visits the Earth's surface at different times. How do we compare ET measurements? How near to real-time are the datasets?

- a. Because ECOSTRESS flies on the International Space Station, its non-sun-synchronous orbit allows it to sample the diurnal cycle, picking up ground conditions at varying times of day. To compare Evapotranspiration (ET) measurements across scenes with different overpass times, scientists normalize the instantaneous data using scaling models. These frameworks scale the "snapshot" observation up to a daily total by leveraging continuous environmental variables, such as reference ET or solar radiation data from local weather models
- b. Regarding data latency, standard ECOSTRESS data products are usually processed and available via AppEEARS within a few days of acquisition. This latency depends largely on how quickly external ancillary atmospheric data can be ingested to complete the essential atmospheric corrections

25. What is the finest resolution [smallest pixel] available for thermal remote sensing data? How long is the available record?

- a. In the realm of freely accessible spaceborne data, ECOSTRESS currently leads the pack with a native spatial resolution of 38×69 m. Looking forward, the upcoming TRISHNA and LSTM missions aim to operationalize global footprints around 50–60 m. For ultra-fine details, airborne instruments like NASA JPL's HyTES offer resolution between 1–30 m, though these are limited to targeted flight campaigns
- b. The global spaceborne thermal record dates back significantly. MODIS and ASTER have provided steady multispectral thermal archives since 1999–2000, while the Landsat series offers a multi-decade archive of single-channel thermal data extending back to the launch of Landsat 4 in 1982

26. Passive daytime radiative cooling paint has high albedo in addition to high thermal emissivity through the heat atmospheric window. Can this cooling be measured by remote sensing?



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- a. Yes, this macro-cooling signature can be detected by thermal remote sensing instruments. Because these specialized paints reject solar heat while efficiently radiating thermal energy directly out to space through the 8–14 μm atmospheric window, their true physical (kinetic) temperature drops substantially below surrounding surfaces
- b. However, measuring this from space depends on pixel scale. If a single cool-roof installation is small relative to a satellite's spatial footprint (like an ECOSTRESS 70 m pixel), its unique thermal signal will be diluted by sub-pixel mixing with the hotter asphalt or concrete around it. This is why the 10 m downscaling machine-learning workflow we cover in Part 2 is valuable for urban materials tracking

27. I find the multiple time a day feature of ECOSTRESS a very cool thing. However, how do we manage the fact that we may have less density of information per time point, especially where clouds are problematic?

- a. Cloud data gaps can be a major hurdle in thermal remote sensing. To manage this drop in temporal density, researchers often rely on seasonal compositing techniques. Instead of examining a single day, data points are grouped into multi-month windows (e.g., June–August) to construct a localized, aggregate diurnal curve. Gaps can also be managed using data fusion workflows, where the spatial precision of ECOSTRESS is blended with highly frequent - but spatially coarse- thermal data from geostationary weather satellites (like GOES)

28. How do we validate older Land Surface Temperature (LST) products without ground-based data?

- a. If historical ground-based radiometer assets are unavailable, scientists can utilize inter-satellite cross-validation. If an older sensor has overlapping operational years with a newer, well-validated instrument, we can identify Simultaneous Nadir Overpasses (SNOs)—instances where both sensors view the exact same surface at the same moment—to directly benchmark the historic sensor's measurements.
- b. Alternatively, stable pseudo-invariant targets such as uniform desert dunes or deep, large inland water bodies (like Lake Tahoe) can be used. Because the emissivity properties of deep water are physically stable and well-known, scientists can model historic radiance expectations to isolate and verify the sensor's long-term performance



29. Can we have some training on the atmospheric correction of thermal data using RT code like MODTRAN or RTTOV?

- a. We appreciate this feedback. Atmospheric correction is indeed a core challenge of isolating clear surface features from atmospheric attenuation. While standard NASA data products handle this automatically using rigorous radiative transfer codes behind the scenes (ECOSTRESS L2 processing uses RTTOV), learning to run packages like MODTRAN or RTTOV independently is an excellent topic for an advanced technical workshop. We will pass this recommendation along to the ARSET planning team for future curriculum development

30. Re. Question 4, is there also validation over urban areas?

- a. Validation is vastly more complex than validating over water bodies or open deserts. Because urban environments are a chaotic jigsaw puzzle of materials (asphalt, concrete, shingles, grass) nested within short distances, ground radiometers have a tough time representing what a coarse satellite pixel actually "sees."
- b. Urban validation would need to rely heavily on nested data scales. This could involve deploying networks of distributed surface sensors and combining them with high-resolution airborne sensor campaigns, like HyTES. By flying over a city at the exact moment a satellite passes overhead, the airborne thermal pixels can characterize sub-pixel heterogeneity and map the structural accuracy of urban satellite LST products.

31. In dense urban areas, how should we interpret LST when buildings dominate the landscape? Is it mainly capturing rooftop materials, street-level surfaces, or a mixture of both, and how should we think about its relationship to near-surface air temperature?

- a. At standard satellite resolutions, an urban pixel is inherently a composite mixture of everything in the sensor's line of sight: rooftops, road surfaces, wall structures, and vehicle metal. Because spaceborne sensors look primarily from a nadir (top-down) perspective, rooftops and wide pavements dominate the signal, whereas narrow street canyons may be partially obscured by building geometry



35. What is the correct way to do atmospheric correction for the ECOSTRESS LST data?

- a. For the vast majority of researchers and applications, the recommended approach is to leverage NASA's pre-calculated, standard Level 2 LST data product (ECO2LSTE). This product has already been atmospherically corrected via the Temperature-Emissivity Separation (TES) algorithm, utilizing global data assimilation systems (GEOS / MERRA-2) to accurately model and remove atmospheric noise. Your primary responsibility as an analyst is to inspect and apply the embedded Quality Control (QC) bit flags to remove cloud edges or poor-quality pixels before performing your spatial analysis.

36. How can we check that the downscaling has worked if we do not have information on the ground?

- a. When checking downscaled models without ground-truth stations, researchers rely on radiometric preservation tests and cross-resolution validation. First, you verify that the downscaled output preserves the original total energy; if you aggregate your fine-resolution 10 m downscaled pixels back up to the native 70 m grid size, the averaged temperature should perfectly match the native, unmodified satellite measurement.
- b. Second, you can perform a scale-climbing validation check. You systematically blur your native data to a much coarser resolution (e.g., degrading 70 m data to 500 m), apply your downscaling machine learning model to that blurred set, and compare the predicted output back against your original, untouched 70 m scene to calculate your true spatial modeling error.

37. How do we cross-calibrate thermal sensors with different bands like ECOSTRESS and TIRS in their SNO pass?

- a. Cross-calibrating mismatched sensors during a Simultaneous Nadir Overpass (SNO) requires compensating for differences in their Spectral Response Functions (SRFs). Because ECOSTRESS and Landsat TIRS sample slightly different widths of the thermal window, they will record different radiance values even when staring at the exact same temperature block.



surface energy heading up toward the satellite while adding its own upwelling thermal path radiance into the detected radiance signal.

- b. If these atmospheric fluctuations are not isolated and corrected, the sensor will report an inaccurate at-sensor radiance value (L_{sat}), causing a miscalculation of the final land surface temperature. This dynamic interaction highlights why accurate, real-time atmospheric modeling is mandatory for reliable data products.
- 41. Would a day/night algorithm be more accurate over man-made materials as this does not rely on this empirically derived relationship in the TES algorithm?**
- a. It is possible that in specific urban scenarios, a day/night operational algorithm could outperform the TES algorithm. The TES algorithm depends heavily on an empirical relationship (the MMD curve) to balance its mathematical equation. A day/night algorithm could bypass this empirical curve constraint by observing the exact same pixel twice over a short window, using the core change in temperature between day and night to solve the radiative transfer equation. However, this would require perfect pixel co-registration and assumes the surface structure or moisture balance didn't change drastically between the satellite passes
- 42. Is there a way to distinguish between land surface temperature and the temperature of the air near the land surface using satellite data?**
- a. See Q16
- 43. How can we combine data from GRACE/GRACE-FO, CERES, and MODIS/ECOSTRESS in a single Earth-atmosphere-ocean system model to estimate changes in water mass and radiative balance, given that the data are noisy, the errors are correlated, and the processes in the climate system are nonlinear?**
- a. This question is outside the scope of this training.
- 44. We have collection 2 level 2 tier 1 product of various landsat mission in 30m resampled as a surface temperature, it uses single channel algorithm, how it different from the algorithms you mentioned. and if water surface temperature is the concern, how can I proceed. suppose it is a long term study to see how thermal regime of river changes?**



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- a. The Single-Channel algorithm relies on a single thermal band and depends entirely on external atmospheric models to estimate and subtract atmospheric noise. This differs from Split-Window (2 bands) or TES (3+ bands) methods, which leverage internal mathematical differences between adjacent channels to clear out atmospheric interference dynamically.
- b. If your primary objective is tracking water surface temperatures in a river, Landsat's Collection 2 product is highly reliable. Because water has a stable and universally known thermal emissivity profile (~ 0.99), the single-channel algorithm avoids its biggest mathematical hurdle- emissivity uncertainty. For a long-term river study, you can confidently utilize this data, provided you apply quality masks to clear out clouds and eliminate sub-pixel mixing artifacts along narrow riverbanks.

45. For ECOSTRESS and evapotranspiration, is it possible to separate the contributions from soil and vegetation?

- a. Yes, the ECOSTRESS PT-JPL model decomposes total evapotranspiration (ET) into three distinct flux components using physical and biophysical constraints driven by surface temperature and vegetation indices. The ECOSTRESS PT-JPL algorithm allows for the separation of soil evaporation, transpiration and canopy interception- each of these components can be accessed and downloaded individually on AppEEARS.

Session B



Part 1 Question & Answer Session B

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 Savannah Cooley (savannah.cooley@nasa.gov). This document will be shared to the training webpage within one week.

- 1. How is NASA's Civil Space Technology program currently evaluating decentralized, AI-driven sub-pixel reconstruction from international independent developers to mitigate cloud cover gaps in equatorial regions?**
 - a. To our knowledge there is no NASA program that is structured as you describe and carrying out such evaluations. If there's a specific initiative we haven't encountered, we would welcome a pointer afterward. But the underlying challenge you're identifying - persistent cloud cover in equatorial regions limiting useful thermal observations- is an important issue, and there's substantial NASA-supported work approaching it from several directions.
 - b. Operational compositing and quality filtering is the most established approach and is what we'll work through in Part 2 with ECOSTRESS. The workflow combines: applying the L2 quality flags to remove cloud-contaminated and low-confidence pixels, applying the dedicated cloud mask, and then building multi-day composites (median, percentile, or weighted) that fill gaps in any single overpass with neighboring clear-sky observations. For tropical and equatorial regions, multi-week to multi-month composites are often necessary to achieve usable coverage. The diurnal sampling of ECOSTRESS helps here too - by visiting the same location at different times of day, ECOSTRESS may catch a clear window that a fixed sun-synchronous sensor would always miss.
 - c. Multi-sensor fusion is another approach. It involves combining TIR observations from multiple platforms (Landsat, ASTER, MODIS, ECOSTRESS, VIIRS) to increase the probability of clear observation at any given location and date. There's also growing use of microwave LST retrievals (AMSR-2, SMAP-derived land surface temperature), which can see through clouds at the cost of much coarser spatial resolution - useful as a cloud-gap backstop and for fusion with TIR.



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- d. AI/ML research for cloud detection and analysis is an active area of research. NASA's Earth Science Technology Office (ESTO) funds AI algorithm development. The broader research community is publishing actively on deep learning approaches - these are mostly at research-to-pre-operational stages rather than embedded in standard data products yet.

Also, NASA's open data and open code policies, the Earth Information System platform, and numerous NASA competitions and challenges do create pathways for external developers - including international researchers - to contribute algorithms. So while I can't confirm the specific program you mentioned, NASA is generally moving toward more open and collaborative algorithm development.

2. What about using split window in urban areas, (mainly impervious surfaces with scarce vegetation)?

- a. Impervious-dominated urban areas with scarce vegetation are exactly the case when Split-Window retrievals have some of the largest errors. The algorithm relies on a constant land-cover-based emissivity with a lookup table for "urban developed." but most pure impervious surfaces - including asphalt, concrete, brick, metal roofing - have lower or more variable emissivity than that. The result is a systematic cold bias typically in the 2–5 K range over heavily built-up cores, and substantially larger errors over metallic surfaces.
- b. For UHI work where impervious surfaces dominate, TES-based products are the right tool: ECOSTRESS L2 LST, MOD21 (Aqua and Terra), ASTER, and the forthcoming TRISHNA, LSTM, and EAGLE-TIR products. This is precisely the use case TES was designed to handle, and it's why we'll be working with ECOSTRESS rather than a Split-Window product in Part 2.
- c. Spectral contrast is also lost. Many urban materials (concrete, asphalt, certain ceramics) have meaningful spectral emissivity structure in the 8–10 μm range. With only two thermal bands, Split-Window cannot resolve this — it implicitly treats the two bands as having the same emissivity, which isn't true for many built materials.
- d. Land cover map currency. Cities change. The lookup tables underlying Split-Window typically reference land cover products that may be several years out of date. New construction, repaving, and demolition aren't



reflected, so even where the lookup approach is conceptually appropriate, the underlying classification may be wrong.

3. What emissivity input is better for split window LST retrieval method in urban areas?

- a. See Q2 response for discussing the advantages of TES over split-window emissivity retrievals.

4. How are cloud-contaminated pixels handled in ECOSTRESS products?

- a. In version 1 of ECOSTRESS data, the cloud mask was more conservative and feedback from users led to the development of a more flexible cloud masking product that can be applied at the user's discretion. We will go into more detail during Part 2 of this training series.

5. Can I get ECO2LSTE version 2 data for Ghana?

- a. Yes. ECOSTRESS has near global coverage due to its placement on the International Space Station (ISS). It is available in Ghana and other parts of West Africa.
- b. ECOSTRESS data can be accessed in several ways:
 - i. LPDAAC - To learn the fundamental steps for discovering and opening ECOSTRESS data products, you can utilize the recommended [LPDAAC tutorials](#)
 - ii. [NASA Earthdata - "ECOSTRESS" Search](#)
 - iii. [LP DAAC subsetting tool - AppEEARS](#). Click on: "point samples" or "area samples"
 - iv. Google Earth Engine (featured in Part 2)

6. Can machine learning improve TES-based emissivity retrieval accuracy?

- a. This is an active area of research, but we cannot state any current efforts based on prior knowledge. While the Temperature-Emissivity Separation (TES) algorithm relies on a fixed, empirical calibration curve to balance its equations, researchers could replace or augment this step with machine learning models. Specifically, researchers could use neural networks and random forests to ingest auxiliary variables- such as antecedent rainfall, season, and multi-spectral optical reflectances - to predict a more accurate "first guess" emissivity constraint. This could be especially helpful over highly heterogeneous urban surfaces and changing soil



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moisture boundaries where standard empirical curves struggle to capture real-world conditions.

- 7. How well can the ECOSTRESS data be scaled to land cover maps derived from Sentinel or NAIP imagery?**
 - a. This combination (ECOSTRESS and Sentinel-2_) is the basis for the downscale workflow for the demonstration in Part 2 of this training series. Sentinel is available at 10 m resolution and can help with interpretation.

- 8. How is NASA's Civil Space Technology program currently evaluating decentralized, AI-driven sub-pixel reconstruction from international independent developers to mitigate cloud cover gaps in equatorial regions?**
 - a. Refer to Q1.

- 9. Which programming skills are most commonly used in NASA thermal remote sensing workflows – Python, R, or Google Earth Engine? What are some good beginner research projects using ECOSTRESS data?**
 - a. All three are used for Thermal RS workflows. Python is the predominant programming language, but R is also used as well. Google Earth Engine has account limitations, but is used as well. GEE is also good for working with large areas and large amounts of data. In Part 2, R Studio and Google Earth Engine will be demonstrated.

- 10. Which satellite thermal datasets provide the best balance of spatial and temporal resolution for mapping Urban Heat Islands in arid regions like Morocco, where hot surrounding soils often mask the urban heat signature?**
 - a. Referring to slide 36 in the presentation, there is a table that shows the thermal bands and what they work best with. In regards to arid regions, having higher spatial resolution can be a benefit and ECOSTRESS data could be best for this area. If you need daily data, MODIS data can best for this at the cost of spatial resolution. Using more thermal bands can help with emissivity.

- 11. What are some beginner-friendly project ideas using ECOSTRESS LST data for urban heat analysis?**



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- a. A case study that will be highlighted in Part 2 will cover a heat wave in Los Angeles, California. Stay tuned!
- b. For beginner research projects using ECOSTRESS data, some other entry-level concepts include:
 - i. Micro-climate corridors: mapping the cooling footprint of urban parks into surrounding residential blocks during a summer day.
 - ii. Diurnal material characterization: tracking how quickly industrial commercial rooftops heat up in the morning versus cooling down after sunset compared to surrounding vegetation.
 - iii. Agricultural water stress: Combining ECOSTRESS LST and Evapotranspiration (ET) products across a single irrigation zone to identify drought vulnerabilities

12. How can uncertainty in emissivity and atmospheric correction be incorporated into machine learning models used for thermal image analysis?

- a. Refer to Q6.

13. How accurate are satellite thermal datasets compared with meteorological stations for mapping Urban Heat Islands?

- a. It is vital to recognize that satellite thermal sensors and meteorological stations measure two completely different physical properties. Satellites measure Land Surface Temperature (LST)—the physical skin temperature of the top layer of the ground. Meteorological stations, conversely, measure ambient air temperature inside a shaded shelter typically 2 meters above the ground.
- b. Because air and surface materials absorb and shed heat at vastly different rates, their values diverge sharply. On a clear summer afternoon, a dark parking lot's LST can easily reach 60°C, while a nearby weather station reads an ambient air temperature of 35°C. Because of this structural difference, weather stations cannot be used to directly validate satellite LST measurements. Instead, satellite data is validated using ground-based thermal radiometers that point directly at uniform surfaces to capture true skin radiance at the exact moment of the satellite overpass.



14. Do you have any suggestions for how students can get involved in research work or contribute to ongoing studies in this area? How can we prepare to contribute to research in this field?

- a. Trainings such as this one are a step in the right direction! Networking with people in the field and thinking about how this can work best for you and your community can also get you thinking about how to apply this data into your workflow.
- b. We highly encourage exploring NASA's [EarthRISE Developers Academy](#), which pairs students with professional mentors to work on 10-week rapid feasibility projects applying remote sensing data to real-world community issues. Additionally, visiting the open-source code repositories for major missions on GitHub and participating in data hackathons (such as the annual NASA Space Apps Challenge) provide practical, highly visible ways to engage with the professional remote sensing community.

15. Aside from Ground Thermal Radiometers, do you use soil temperatures from Mesonet Networks?

- a. To our knowledge, data from soil temperature probes are not used for satellite-based LST validation.