ECOSTRESS Collection 2 Level 1 to 4 Tiled Products

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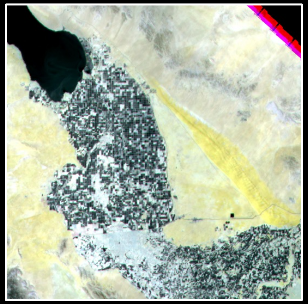
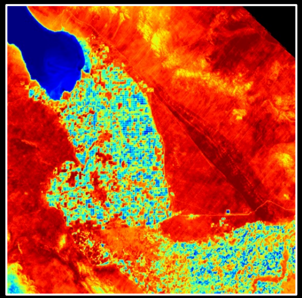
Jet Propulsion Laboratory
California Institute of Technology

L1CT_RAD



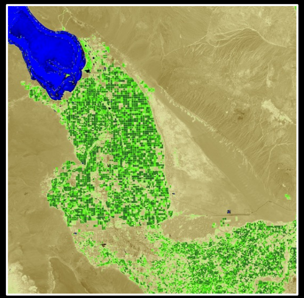
Radiance

L2T_LSTE



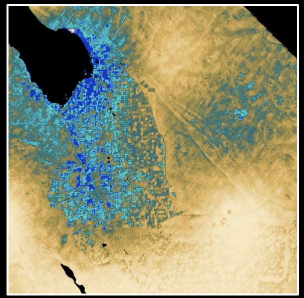
Surface Temperature

L2T_STARS



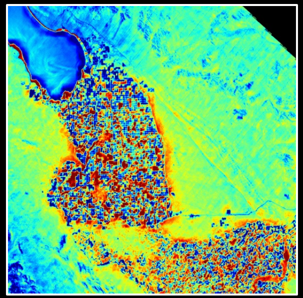
NDVI/Albedo

L3T_SM



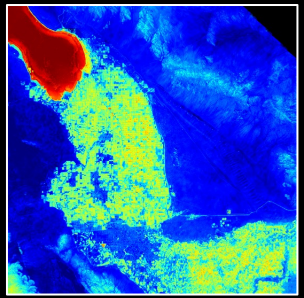
Soil Moisture

L3T_MET



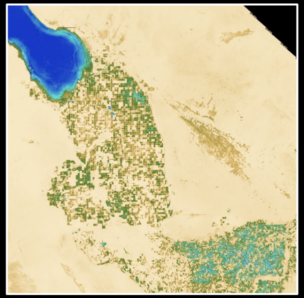
Meteorology

L3T_SEB



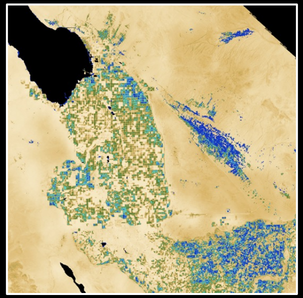
Surface Energy Balance

L3T_JET



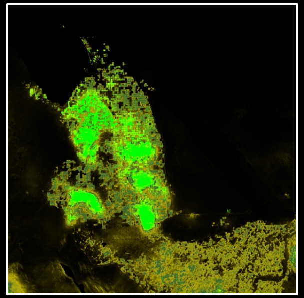
Evapotranspiration

L4T_ESI_PTJPL



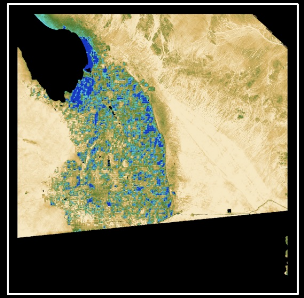
Evaporative Stress Index

L4T_WUE



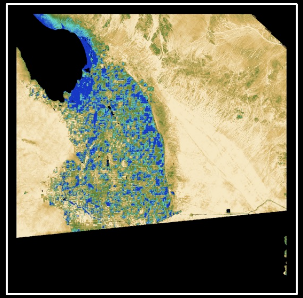
Water Use Efficiency

L3T_ET_ALEXI



DisALEXI Evapotranspiration

L4T_ESI_ALEXI

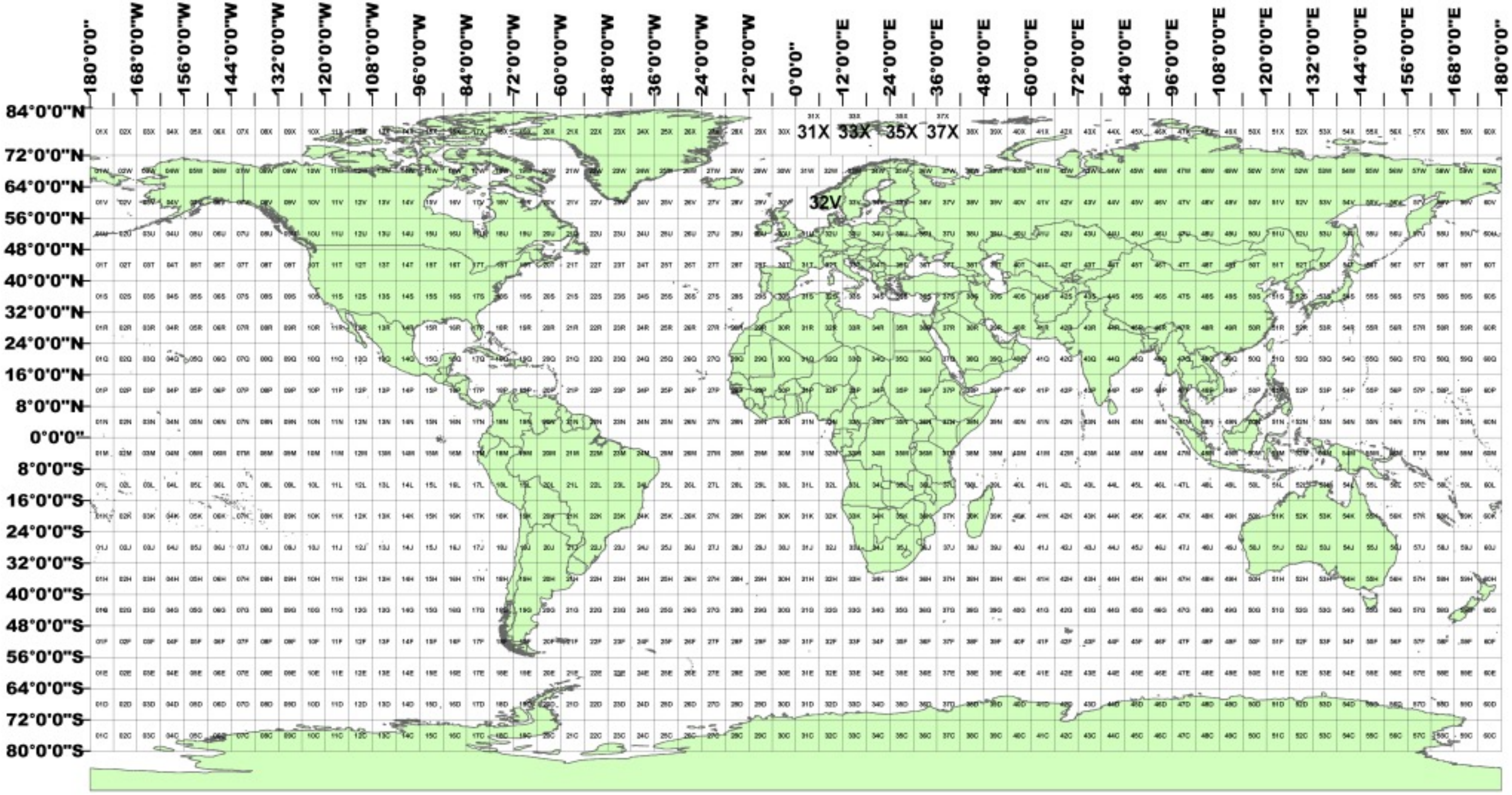


DisALEXI Evaporative Stress Index

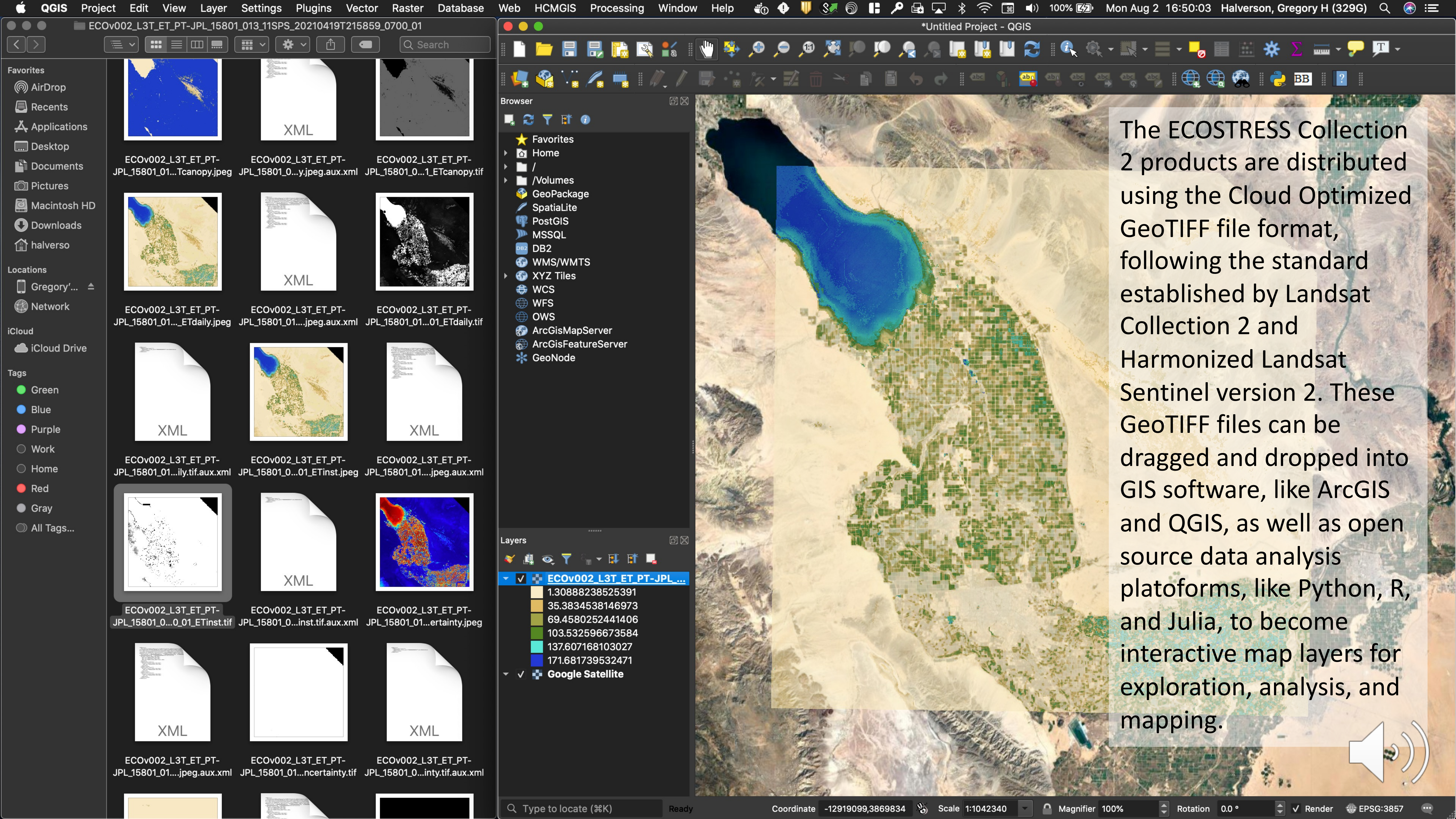
We have comprehensively revised the ECOSTRESS data products with improved algorithms and a new more accessible data format.

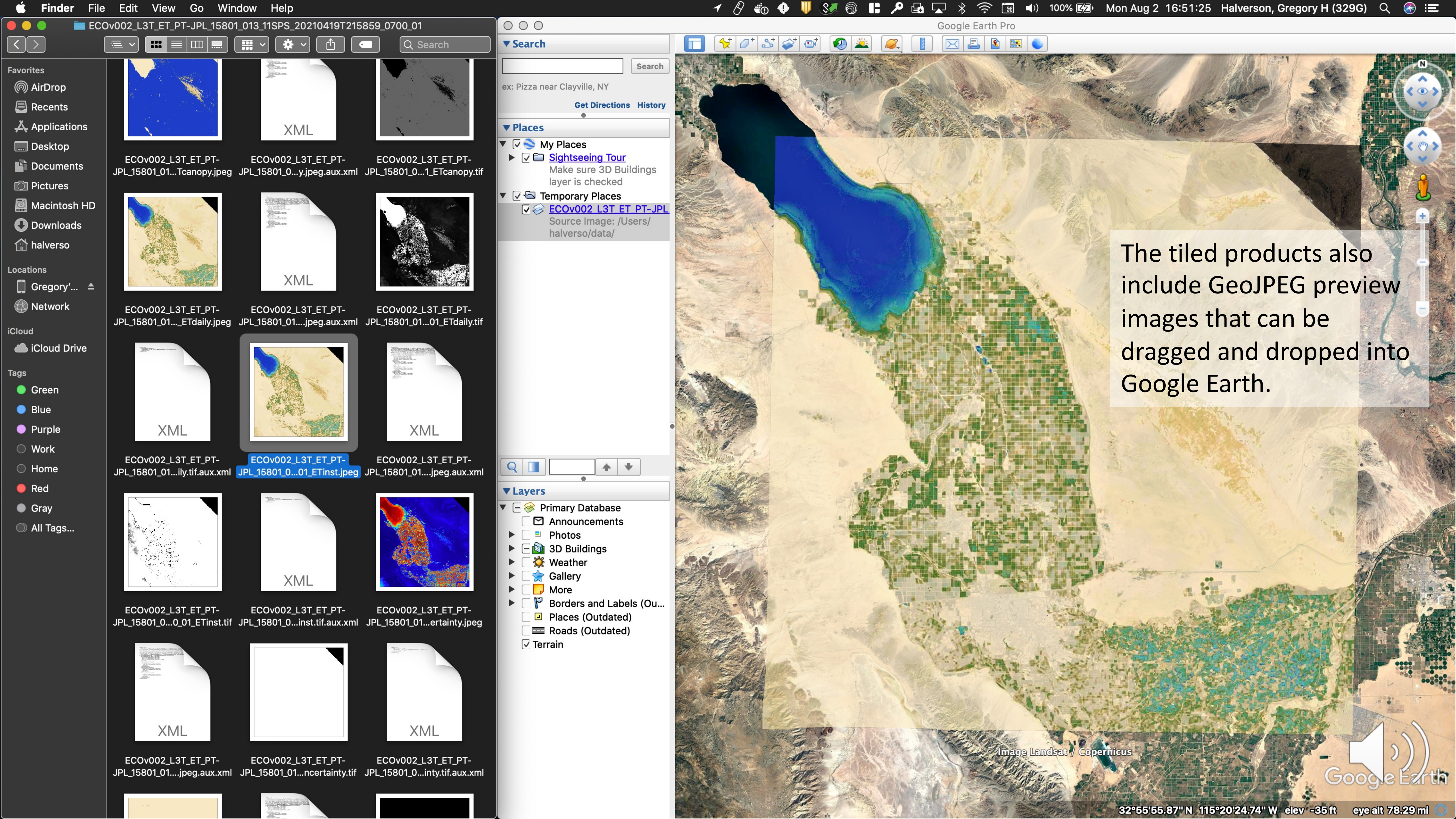
These products will contain additional key data layers required for modeling surface energy balance, including NDVI, albedo, soil moisture, air temperature, humidity, and net radiation.

The Collection 2 products use the Sentinel tile grid, following Harmonized Landsat Sentinel. This tile grid is a modification of the Military Grid Reference System, with each tile covering 100 km by 100 km with an additional 4.9 km overlapping edge (109.8 km x 109.8 km total). The Collection 2 products use a 70 m grid in local UTM projection for each tile.



https://hls.gsfc.nasa.gov/products-description/tiling-system/


The ECOSTRESS Collection 2 products are distributed using the Cloud Optimized GeoTIFF file format, following the standard established by Landsat Collection 2 and Harmonized Landsat Sentinel version 2. These GeoTIFF files can be dragged and dropped into GIS software, like ArcGIS and QGIS, as well as open source data analysis platoforms, like Python, R, and Julia, to become interactive map layers for exploration, analysis, and mapping.
*Untitled Project - QGIS
Browser
Layers
ECOv002_L3T_ET_PT-JPL_...
1.30888238525391
35.3834538146973
69.4580252441406
103.532596673584
137.607168103027
171.681739532471
Google Satellite
Coordinate -12919099,3869834
Scale 1:1042340
Magnifier 100%
Rotation 0.0 °
EPSG:3857


The tiled products also include GeoJPEG preview images that can be dragged and dropped into Google Earth.
ECOv002_L3T_ET_PT-JPL_15801_013_11SPS_20210419T215859_0700_01
Google Earth Pro
Search
Places
My Places
Sightseeing Tour
Make sure 3D Buildings layer is checked
Temporary Places
ECOv002_L3T_ET_PT-JPL
Source Image: /Users/halverso/data/
Layers
Primary Database
Announcements
Photos
3D Buildings
Weather
Gallery
More
Borders and Labels (Ou...
Places (Outdated)
Roads (Outdated)
Terrain
ECOv002_L3T_ET_PT-JPL_15801_01...Tcanopy.jpeg
ECOv002_L3T_ET_PT-JPL_15801_0...y.jpeg.aux.xml
ECOv002_L3T_ET_PT-JPL_15801_0...1_ETcanopy.tif
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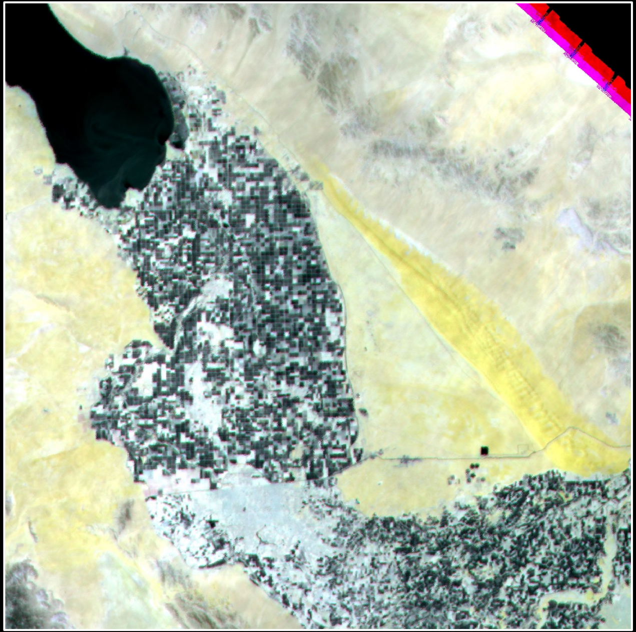
ECOv002_L3T_ET_PT-JPL_15801_01...ertainty.jpeg
ECOv002_L3T_ET_PT-JPL_15801_01....jpeg.aux.xml
ECOv002_L3T_ET_PT-JPL_15801_01...ncertainty.tif
ECOv002_L3T_ET_PT-JPL_15801_0...inty.tif.aux.xml
32°55'55.87" N 115°20'24.74" W elev -35 ft eye alt 78.29 mi

L1CT_RAD

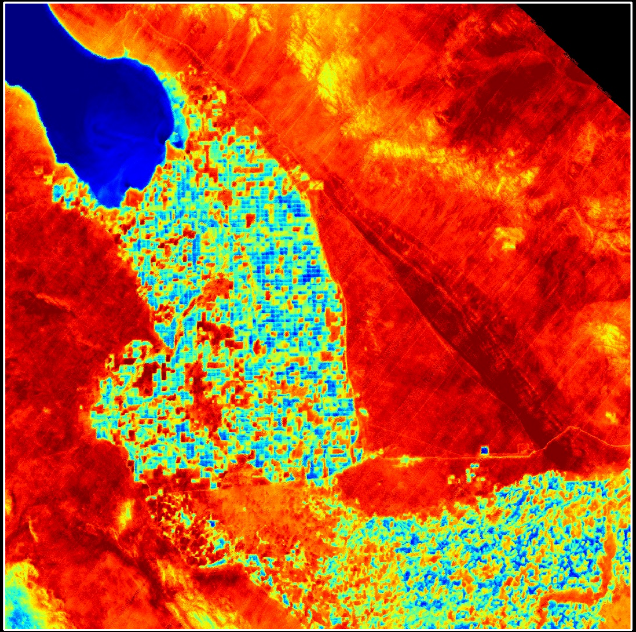


Name	Type	Units
radiance_1	float32	W m^{-2} sr^{-1} μm^{-1}
radiance_2		
radiance_3		
radiance_4		
radiance_5		
data_quality_1	uint16	quality flag
data_quality_2		
data_quality_3		
data_quality_4		
data_quality_5		
cloud	uint8	mask
water		

The L1CG RAD, L2G LSTE, and L2G CLOUD gridded products are processed as a group by ingesting and resampling the L1B RAD, L2 LSTE, and L2 CLOUD swath products and resampling them by nearest neighbor to a globally snapped 0.0006° grid. The L2 LSTE product is resampled and repackaged as the L2G LSTE product. The L2 CLOUD product is resampled and repackaged as the L2G CLOUD product. The L1B RAD product is resampled and repackaged as the L1CG RAD product, and it contains the cloud mask from L2G CLOUD as a quality layer. The L1CT RAD tiled products are subset from the L1CG RAD product and resampled to the 70 m UTM grid in each tile. The L2T LSTE product follows the same tiling procedure, resampled from the L2G LSTE product.

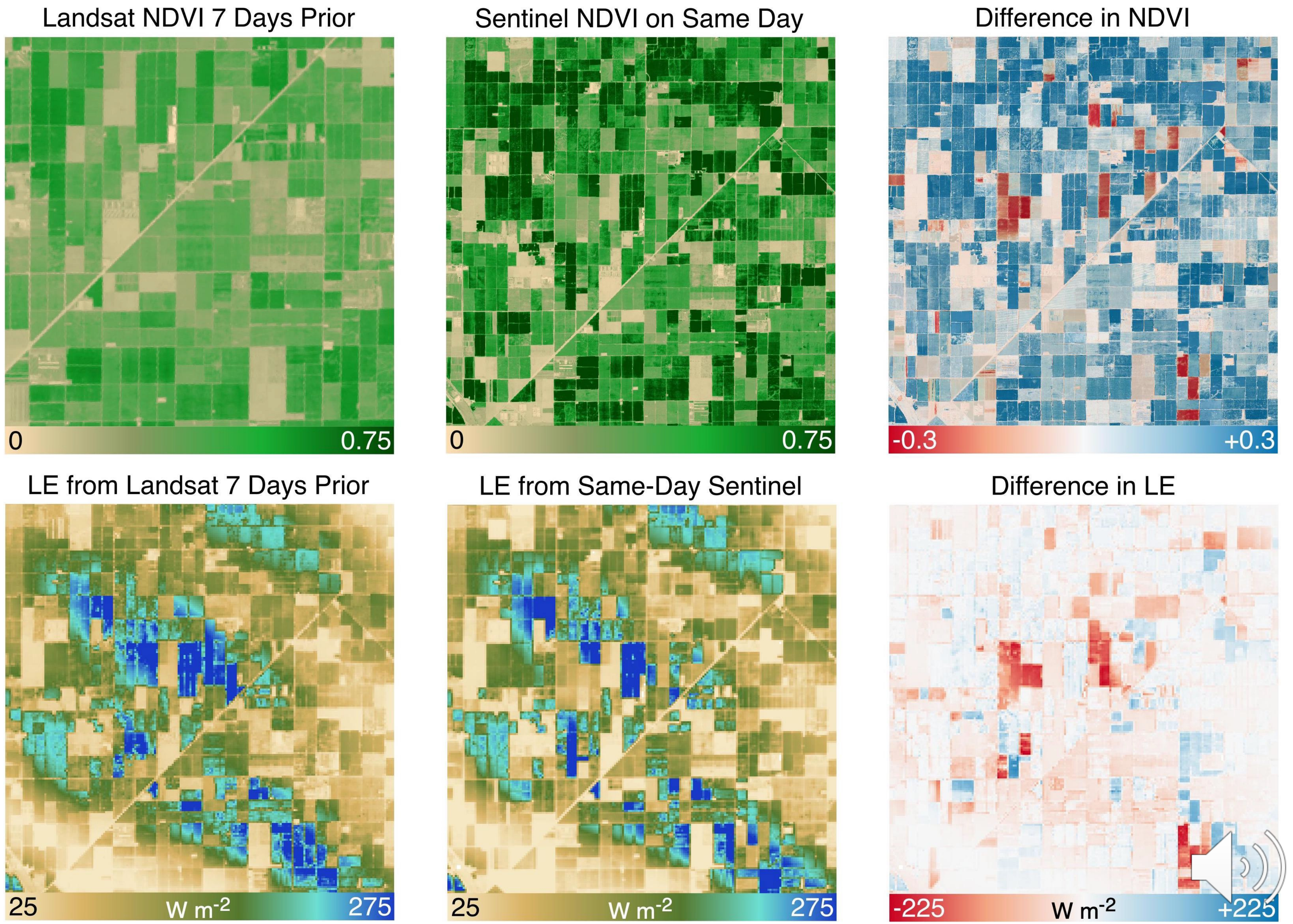
The L2G LSTE and L2T LSTE surface temperature (ST) products distribute ECOSTRESS bottom-of-atmosphere ST in Kelvin as the land-surface temperature (LST) layer, though valid estimates of both land and water surface temperatures are provided. The uncertainty of the ST estimate is provided as LST_err, and the broadband emissivity associated with this temperature is given as EmisWB. The low-level QC flag from the L2 LSTE product is resampled here. Please refer to the L2 LSTE user guide for interpretation of this quality flag. The view zenith angle of the observation is given in degrees as view_zenith. And the elevation in meters of the surface observed is included as height, taken from the SRTM.

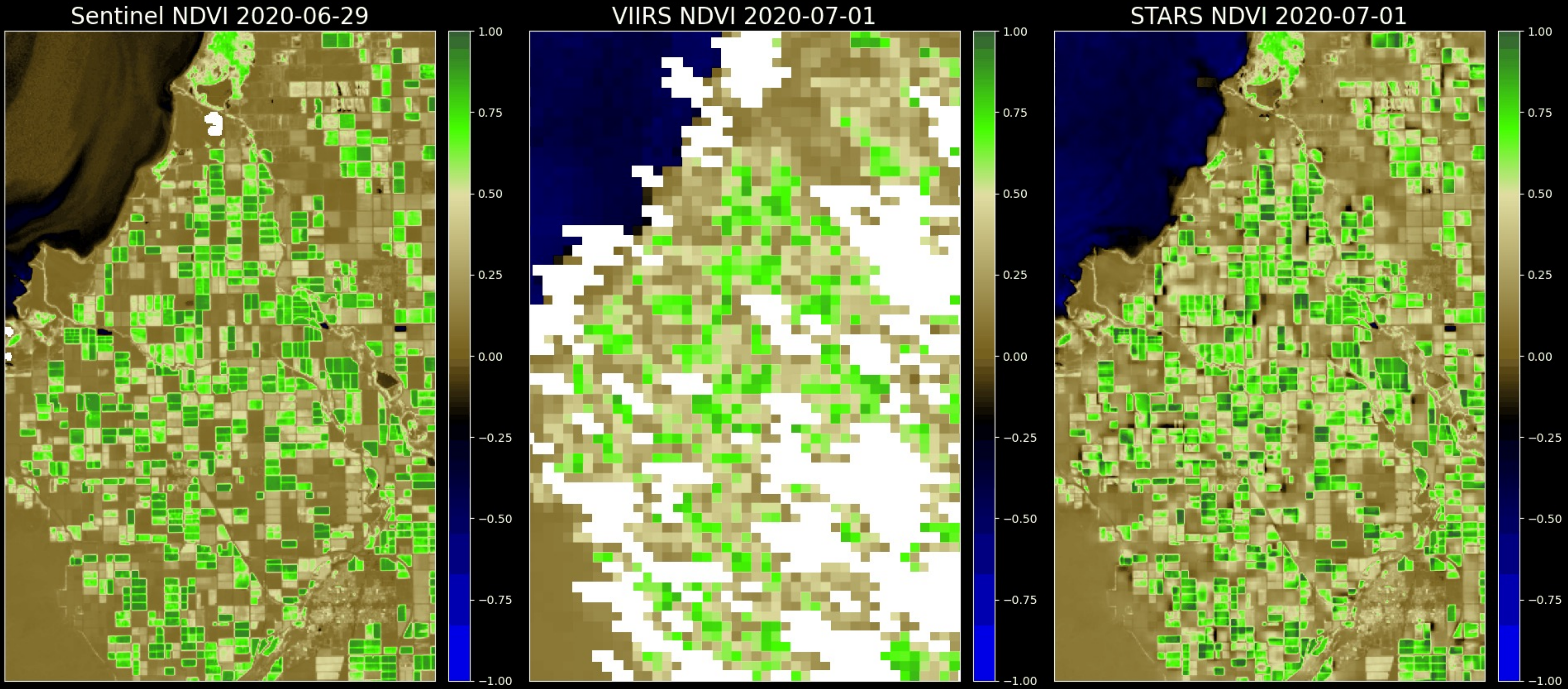
L2T_LSTE



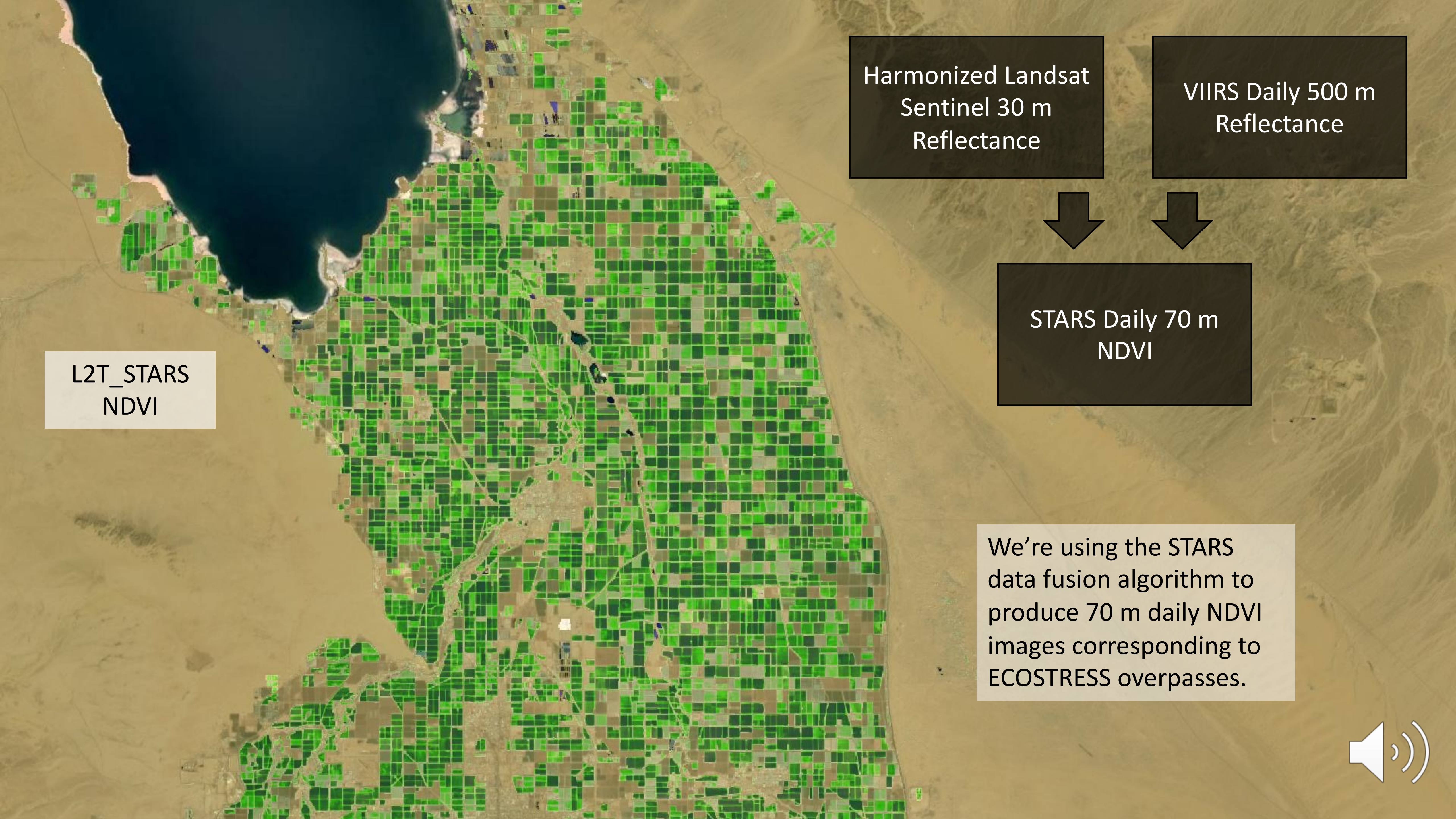
Name	Type	Units
LST	float32	Kelvin
LST_err		Kelvin
EmisWB		unitless: 0 to 1
height		meters
view_zenith		degrees
QC	uint16	quality flag
cloud	uint8	mask
water		mask

A major challenge in using a thermal sensor to estimate evapotranspiration is co-incident high-resolution NDVI and albedo. These land surface properties are highly sensitive to abrupt changes, such as harvest and fires, so any temporal lag in these inputs can result in large errors in evapotranspiration output.

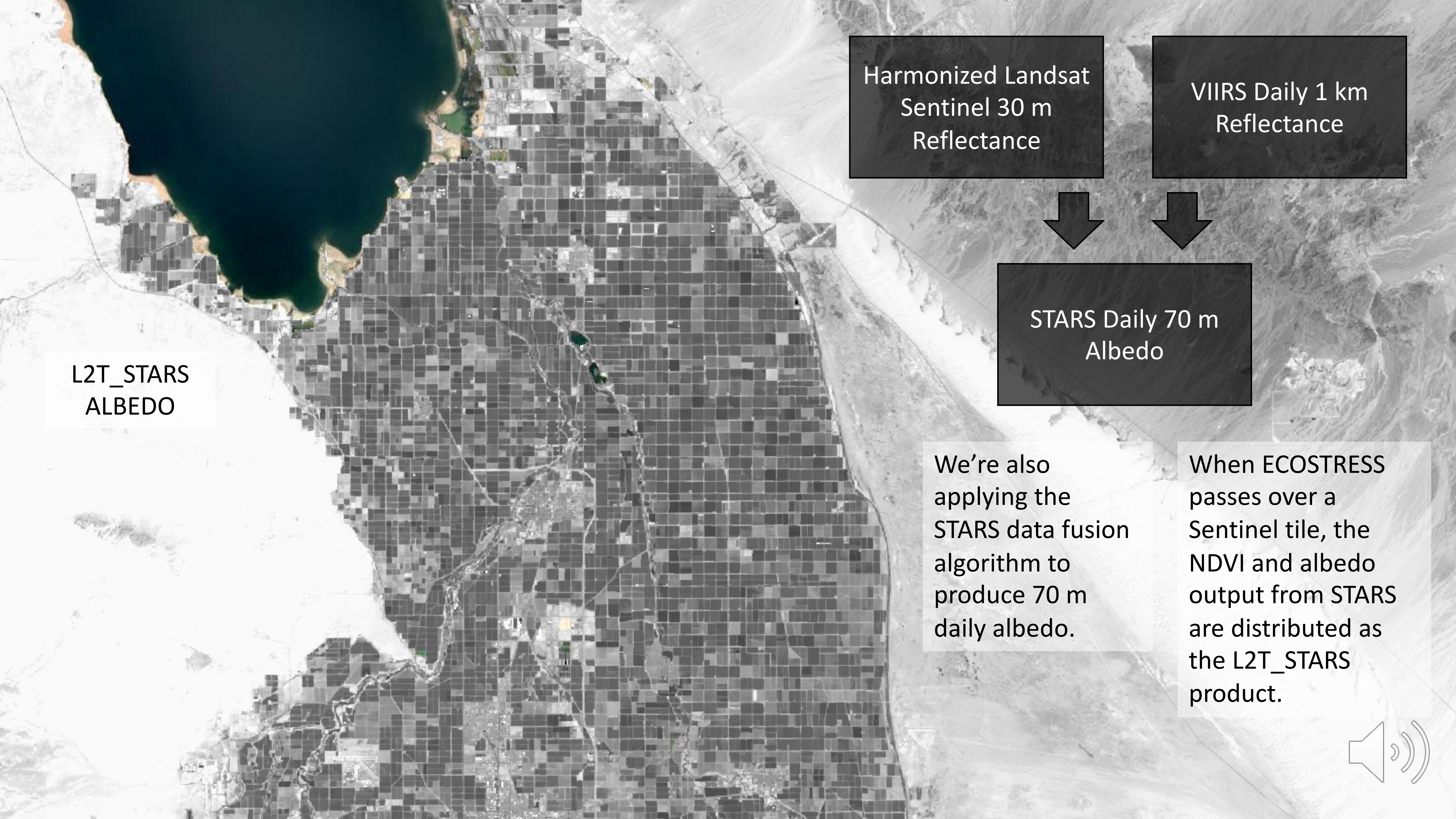




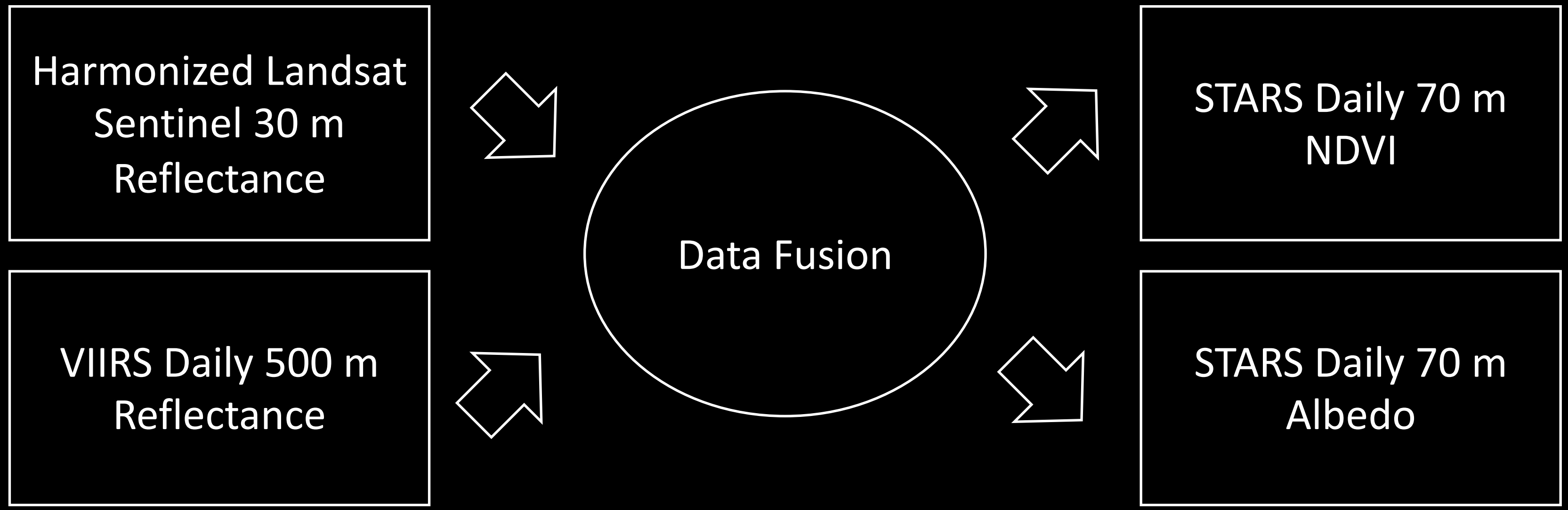
To mitigate this problem, we have developed a new data fusion technique called STARS that allows us to combine the 30 spatial resolution of Harmonized Landsat Sentinel with the daily temporal resolution of VIIRS to generate 70 m daily products.

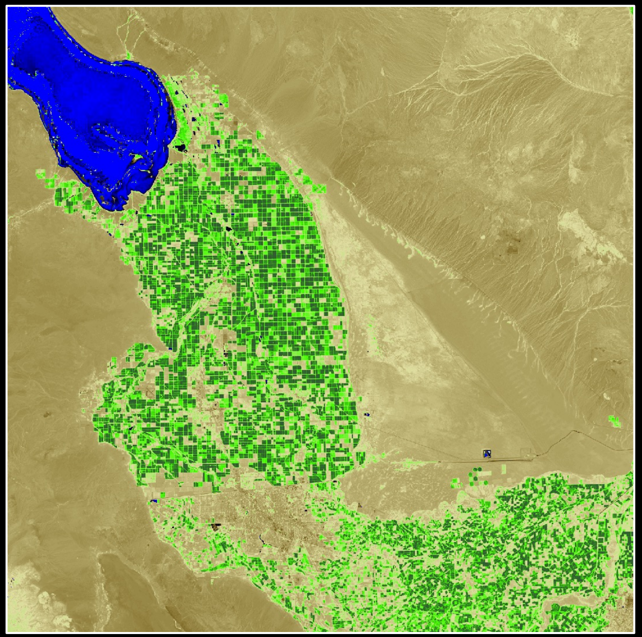


We're using the STARS data fusion algorithm to produce 70 m daily NDVI images corresponding to ECOSTRESS overpasses.


L2T_STARS
ALBEDO
Harmonized Landsat Sentinel 30 m Reflectance
VIIRS Daily 1 km Reflectance
STARS Daily 70 m Albedo
We're also applying the STARS data fusion algorithm to produce 70 m daily albedo.
When ECOSTRESS passes over a Sentinel tile, the NDVI and albedo output from STARS are distributed as the L2T_STARS product.

L2T_STARS





Name	Type	Units
NDVI	float32	index: -1 to 1
NDVI-UQ		
albedo	float32	proportion: 0 to 1
albedo-UQ		

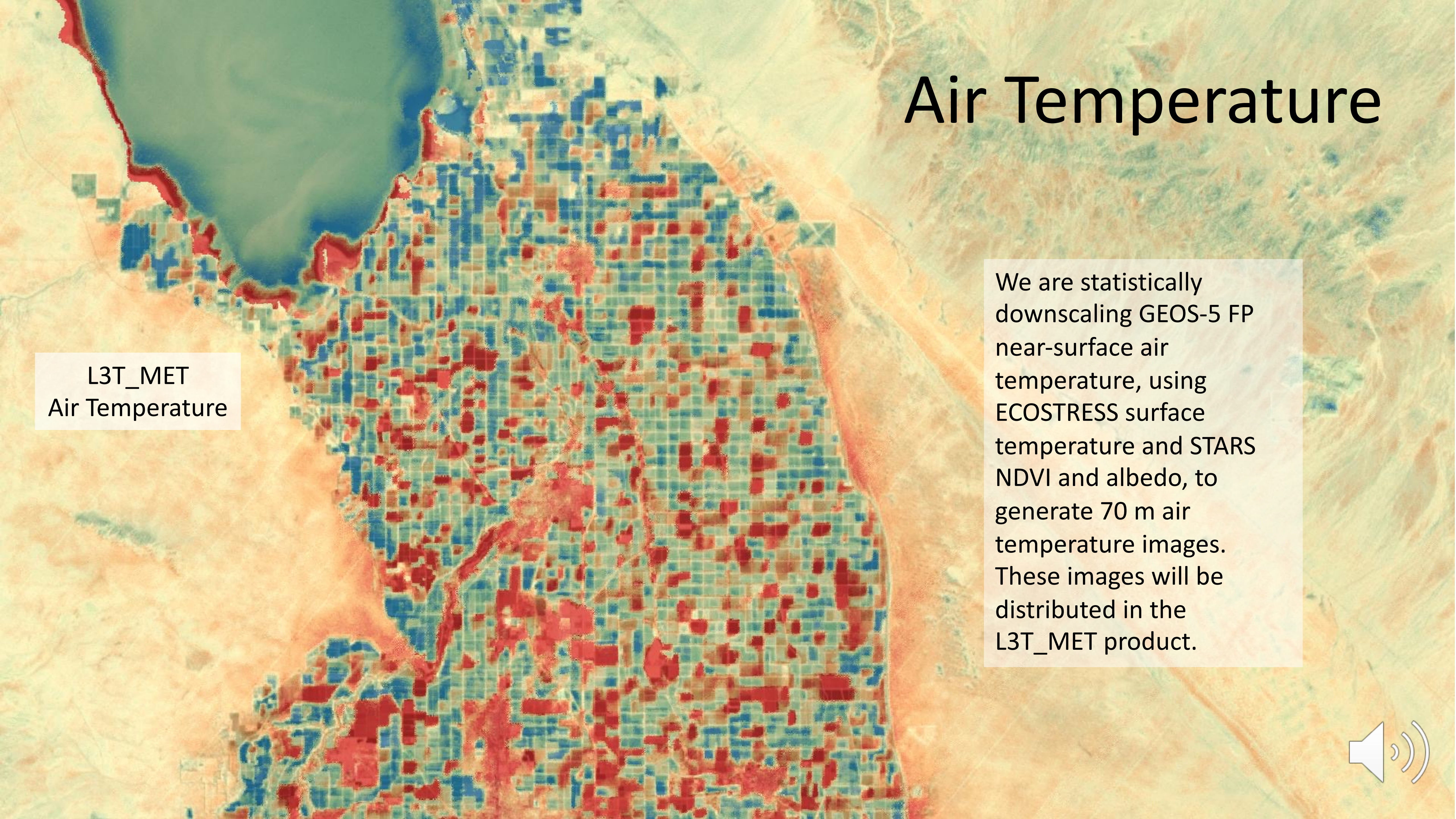
The Spatial Timeseries for Automated high-Resolution multi-Sensor data fusion (STARS) algorithm is used to generate a best estimate of Normalized Difference Vegetation Index (NDVI) and albedo on the day of each ECOSTRESS overpass. We use an initial version of the STARS algorithm developed through ROSES to fuse temporally sparse but fine spatial resolution images from the Harmonized Landsat Sentinel (HLS) 2.0 product with daily temporal resolution but coarse spatial resolution images from the Suomi NPP Visible Infrared Imaging Radiometer Suite (VIIRS) VNP09GA product.

Each STARS tile run loads the prior covariances recorded from the most recent tile run and advances the model each day with fine updates from HLS and coarse updates from VIIRS up to the day of the target ECOSTRESS overpass. The daily coarse updates are generated as a 16-day aggregate of VNP09GA using the VNP43 algorithm for BRDF correction.

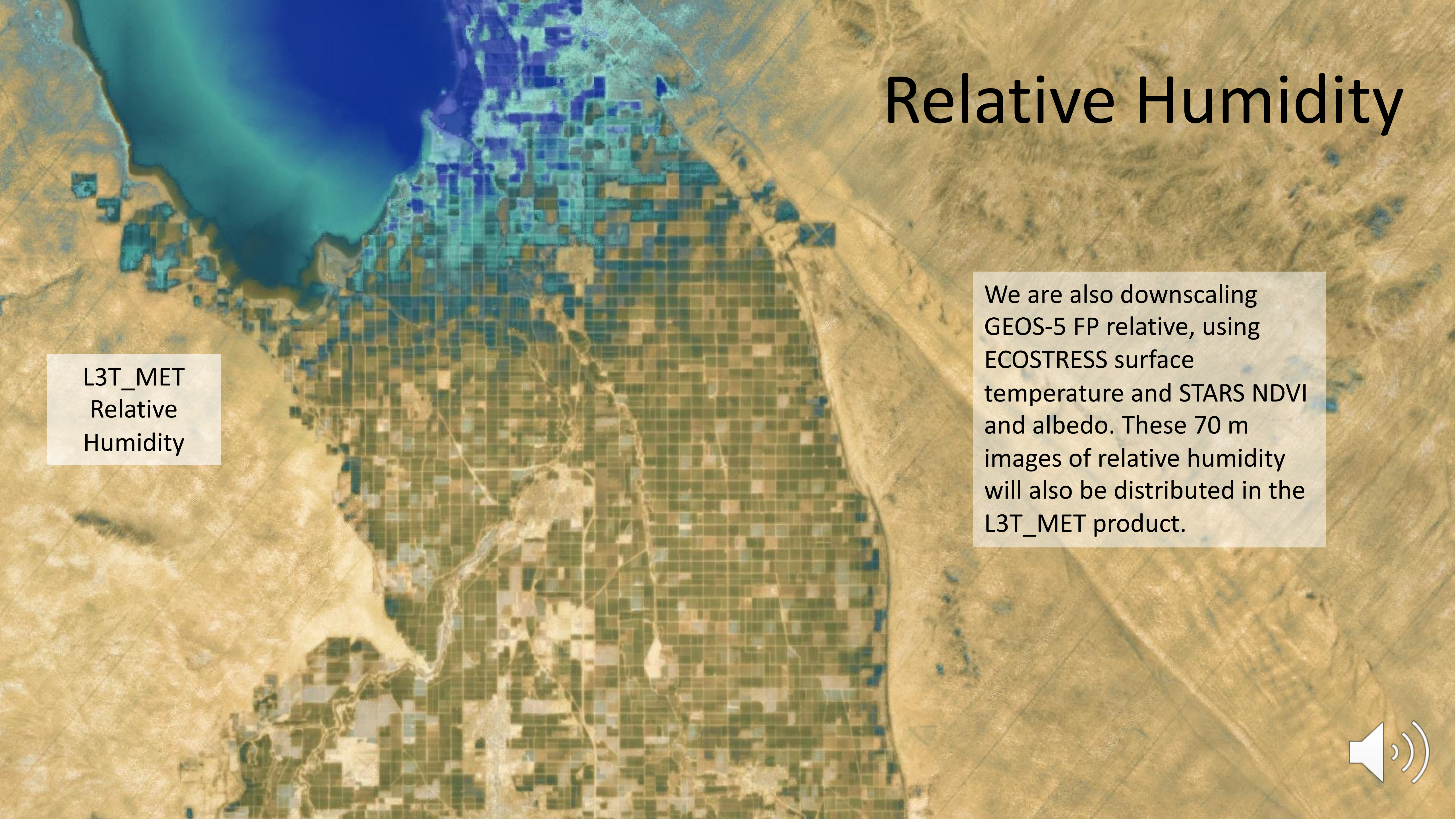
Please refer to Maggie’s talk for more about the STARS algorithm.

Air Temperature

We are statistically downscaling GEOS-5 FP near-surface air temperature, using ECOSTRESS surface temperature and STARS NDVI and albedo, to generate 70 m air temperature images. These images will be distributed in the L3T_MET product.



Relative Humidity

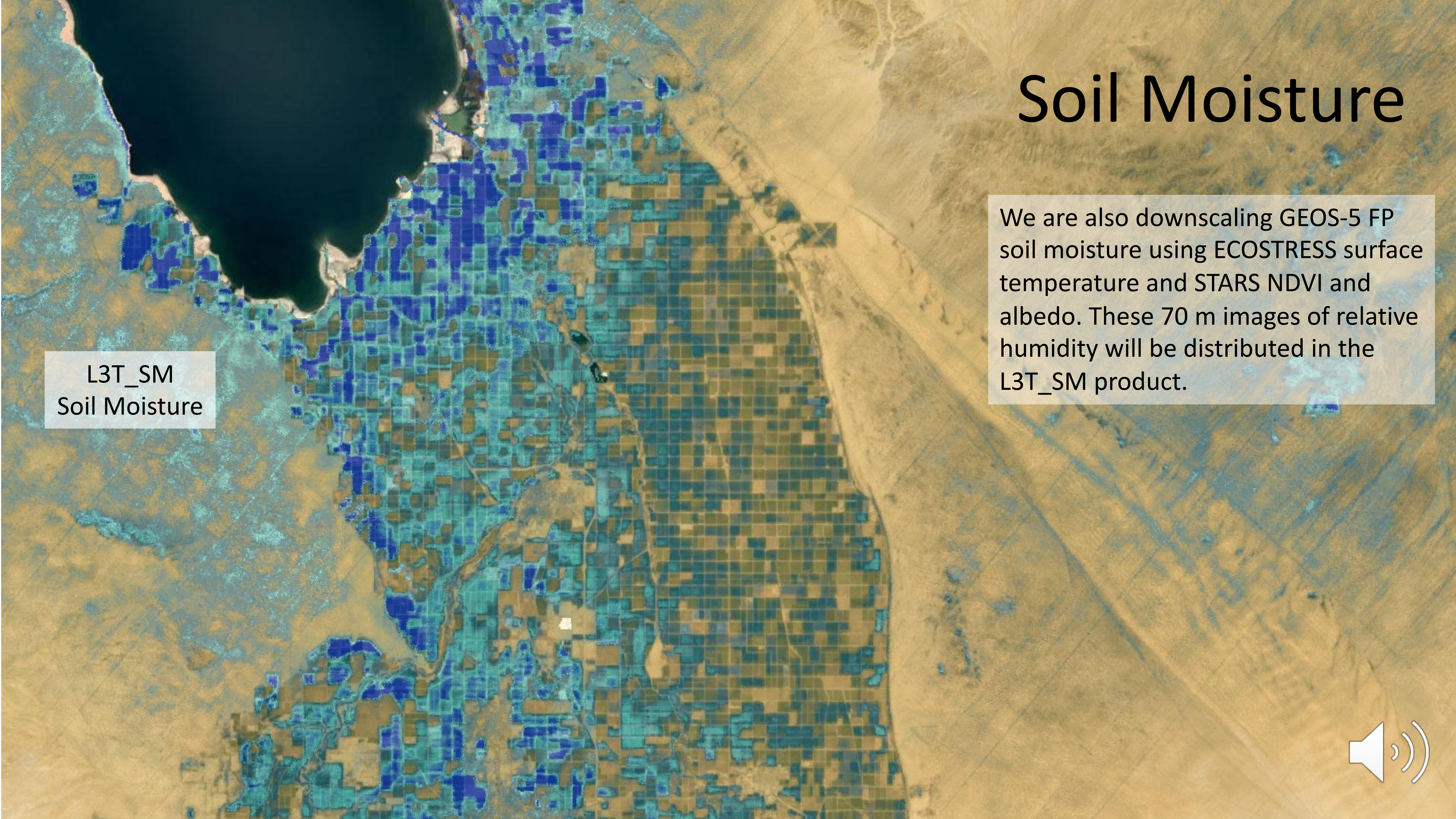


L3T_MET
Relative
Humidity

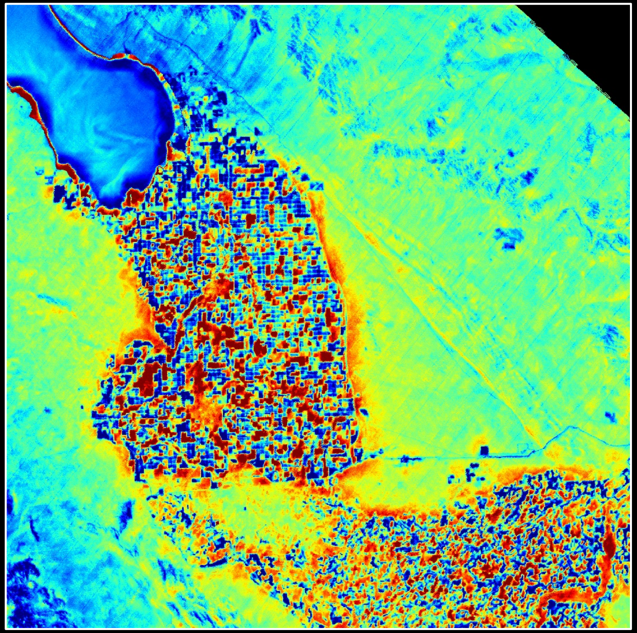
We are also downscaling GEOS-5 FP relative, using ECOSTRESS surface temperature and STARS NDVI and albedo. These 70 m images of relative humidity will also be distributed in the L3T_MET product.

Soil Moisture

We are also downscaling GEOS-5 FP soil moisture using ECOSTRESS surface temperature and STARS NDVI and albedo. These 70 m images of relative humidity will be distributed in the L3T_SM product.



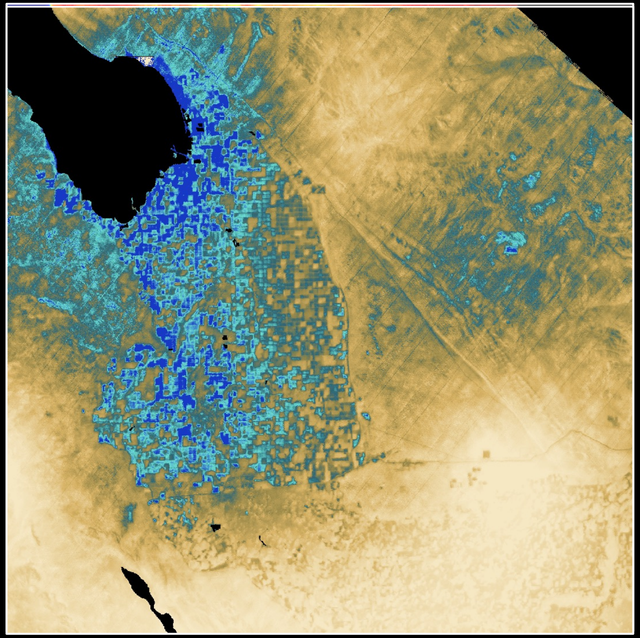
L3T_MET



Name	Type	Units
Ta	float32	Celsius
RH		proportion: 0 to 1
cloud	uint8	mask
water		

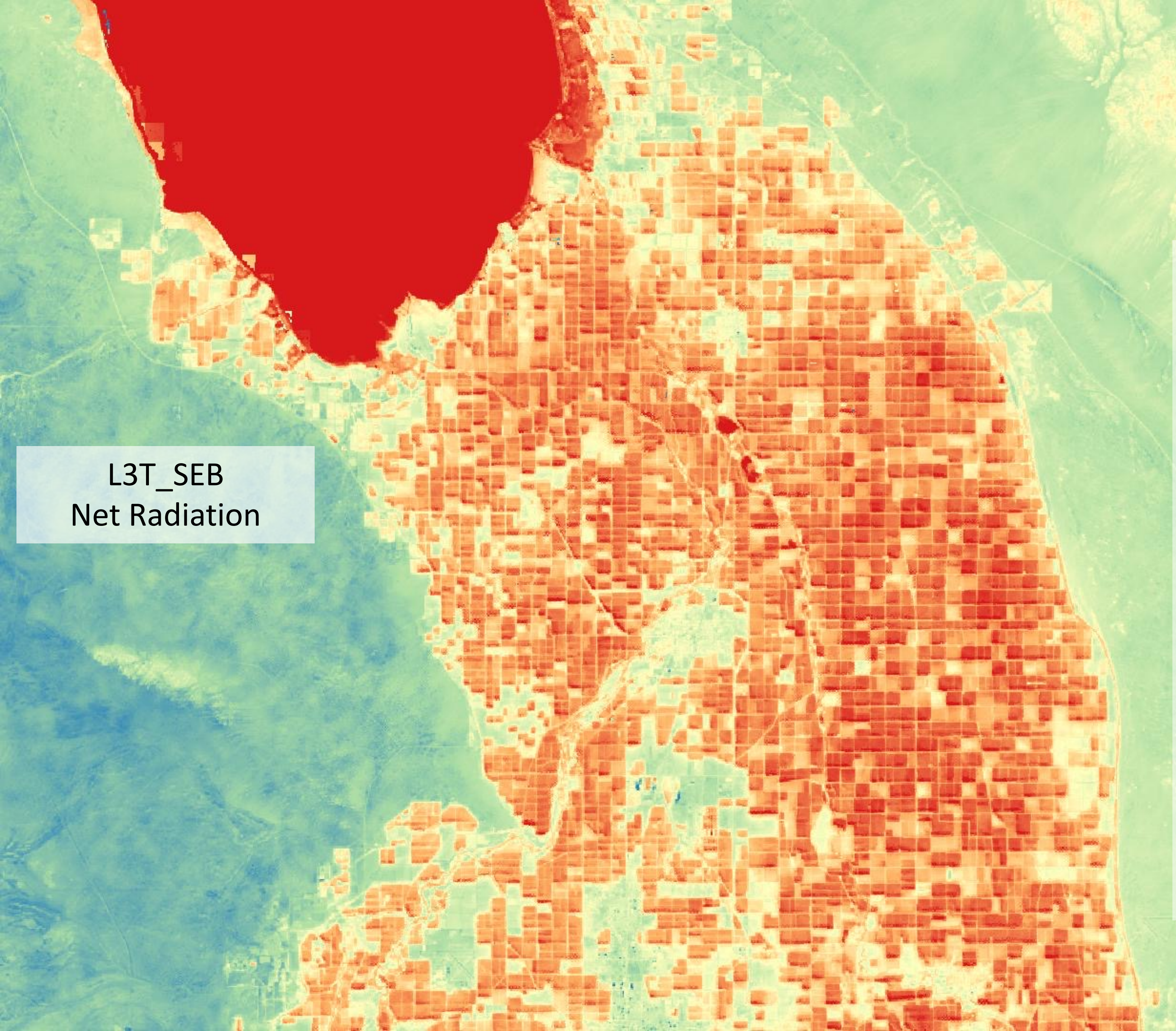
Coarse resolution near-surface air temperature (Ta) and relative humidity (RH) are taken from the GEOS-5 FP tavg1_2d_slv_Nx product. Ta and RH are down-scaled using a linear regression between up-sampled ST, NDVI, and albedo as predictor variables to Ta or RH from GEOS-5 FP as a response variable, within each Sentinel tile. These regression coefficients are then applied to the 70 m ST, NDVI, and albedo, and this first-pass estimate is then bias-corrected to the coarse image from GEOS-5 FP. This same down-scaling procedure is applied to soil moisture (SM) from the GEOS-5 FP tavg1_2d_lnd_Nx product. Areas of cloud are filled in with bi-cubically resampled GEOS-5 FP.

L3T_SM



Name	Type	Units
SM	float32	proportion: 0 to 1
cloud	uint8	mask
water		

Net Radiation

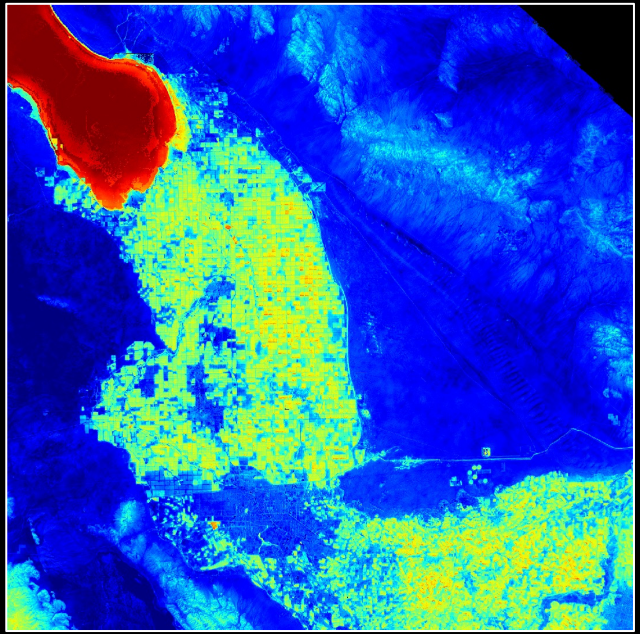


We would like to cultivate a community of end-user surface energy balance modeling and enable downstream processing of additional evapotranspiration models. We invite you to consider the ECOSTRESS Collection 2 products as inputs to your evapotranspiration algorithm. In addition to the land surface properties, near-surface meteorology and soil moisture that we are distributing as products, we will also distribute instantaneous net radiation in the L3T_SEB product.

L3T_SEB

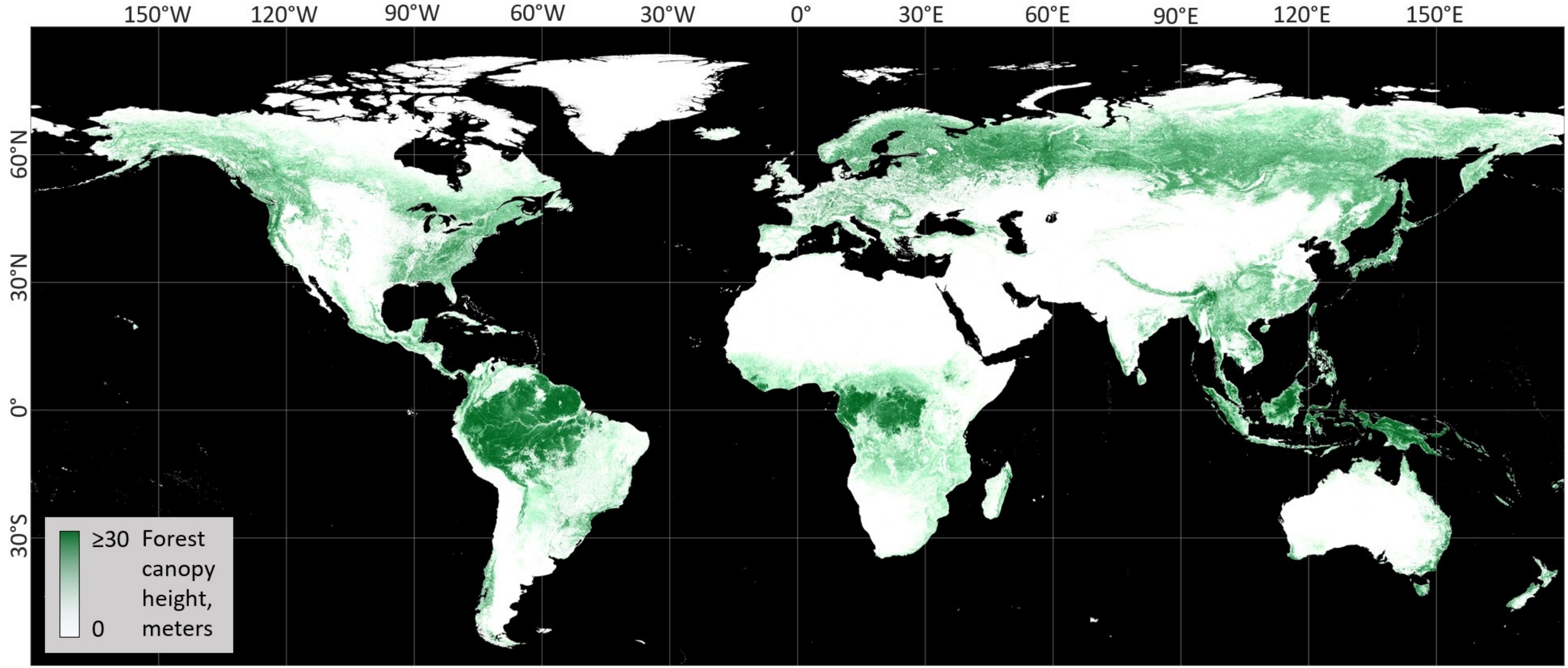
The JET surface energy balance workflow begins with an artificial neural network (ANN) implementation of the Forest Light Environmental Simulator (FLiES) radiative transfer algorithm, following the workflow established by Dr. Hideki Kobayashi and Dr. Youngryel Ryu. GEOS-5 FP provides sub-daily Cloud Optical Thickness (COT) in the tavg1_2d_rad_Nx product and Aerosol Optical Thickness (AOT) from tavg3_2d_aer_Nx. Together with STARS albedo, these variables are run through the ANN implementation of FLiES to estimate incoming shortwave radiation (Rg), bias-corrected to Rg from the GEOS-5 FP tavg1_2d_rad_Nx product.

The Breathing Earth System Simulator (BESS) algorithm, contributed by Dr. Youngryel Ryu, iteratively calculates net radiation (Rn), ET, and Gross Primary Production (GPP) estimates. The BESS Rn is used as the Rn input to the remaining ET models and is recorded in the L3T SEB product.

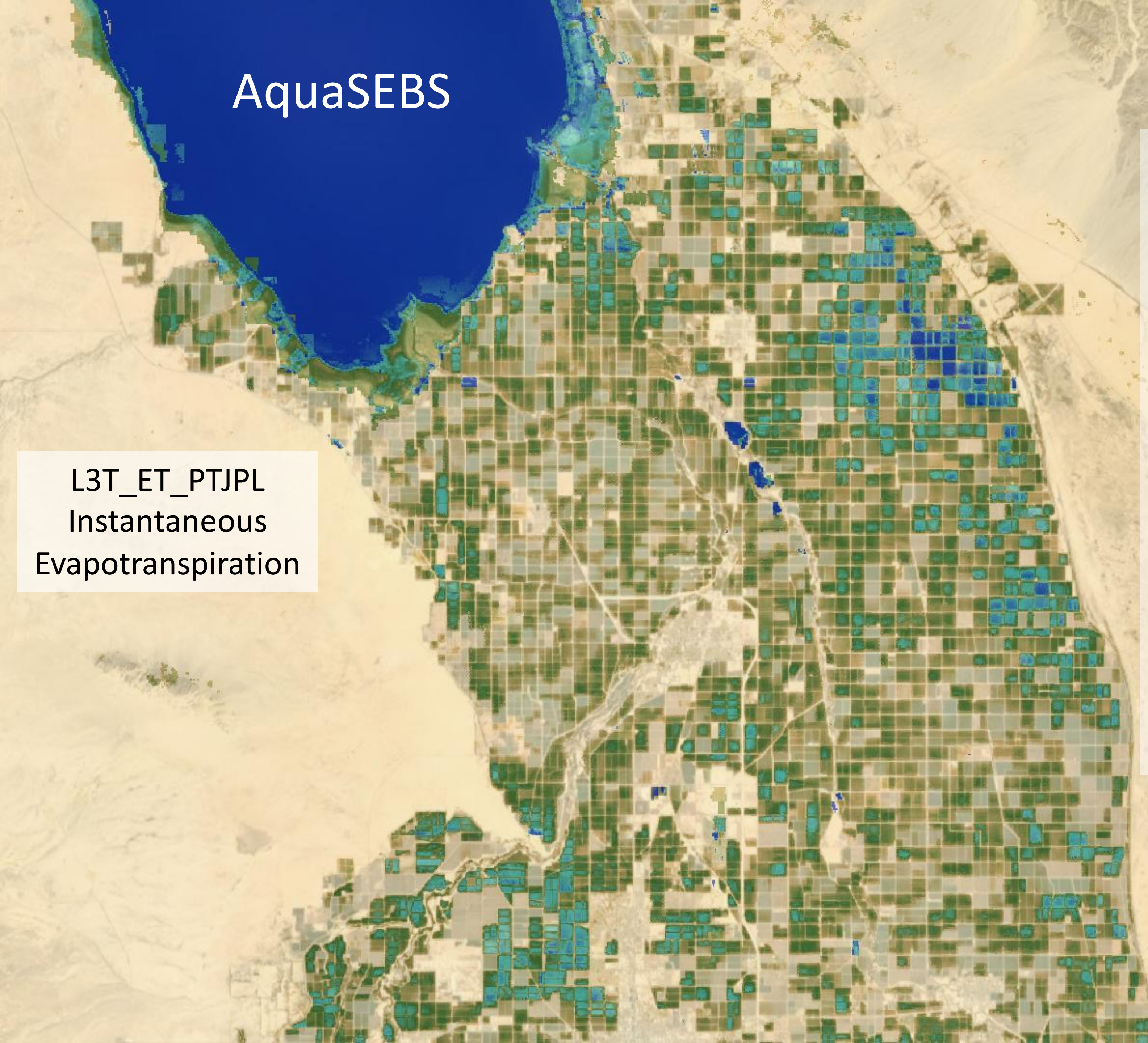


Name	Type	Units
Rg	float32	W m^2
Rn		
cloud	uint8	mask
water		

The global 30 m map of canopy height produced by the GEDI mission facilitates improved estimates of evapotranspiration and gross primary production.



Global Land Analysis and Discovery https://glad.umd.edu/dataset/gedi



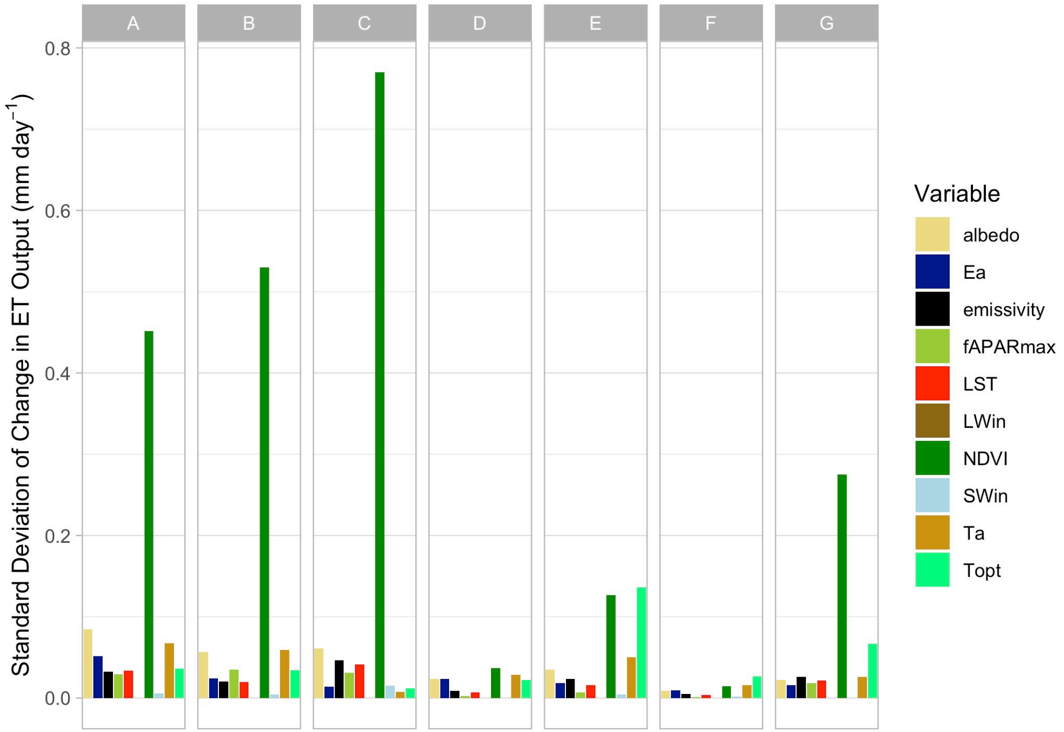
PT-JPL-SM

ECOSTRESS Collection 2 includes Adam Purdy's PT-JPL-SM model of evapotranspiration, also developed in coordination with SMP, which ingests soil moisture and canopy height to produce a more robust ET product than the PT-JPL model used in Collection 1. We are now also processing water surface evaporation using the AquaSEBS model of water heat flux, as demonstrated in OpenET. These enhanced estimates of instantaneous and daily evapotranspiration will be distributed in the L3T_ET_PTJPL, and normalized indices of Evaporative Stress Index will be distributed in the L3T_ESI_PTJPL product.

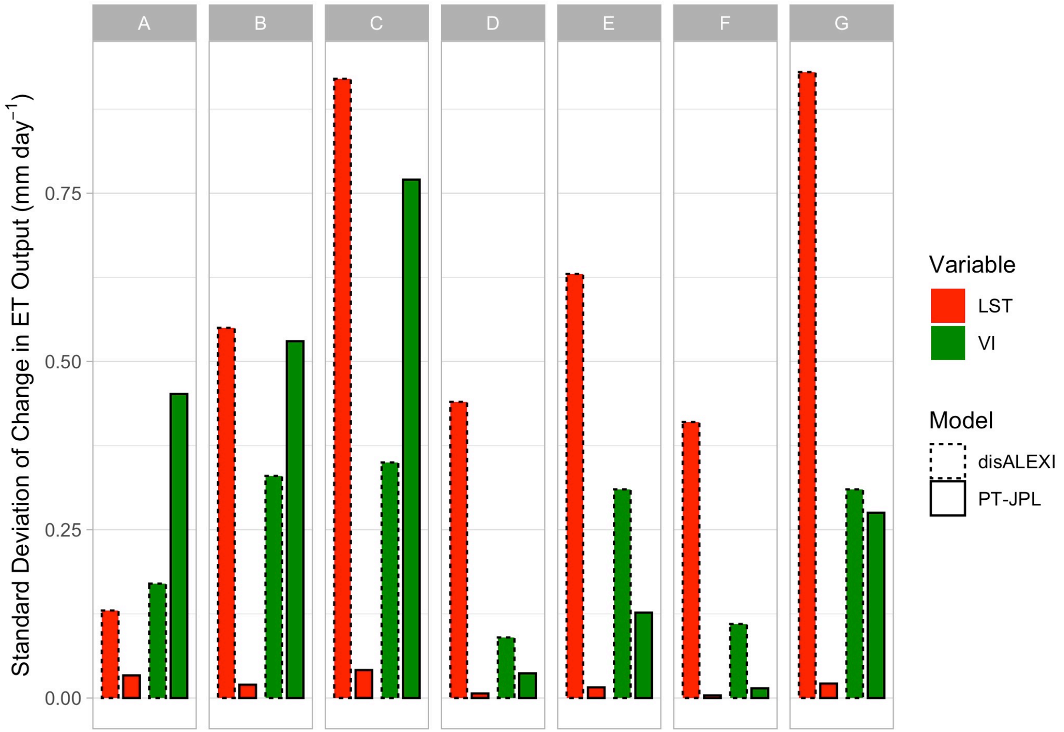
Purdy, A.J., Fisher, J.B., Goulden, M.L., Colliander, A., Halverson, G., Tu, K., Famiglietti,J.S., (2018), [SMAP soil moisture improves global evapotranspiration.] Remote Sensing of Environment 219: 1-14 https://doi.org/10.1016/j.rse.2018.09.023

Abdelrady, A.; Timmermans, J.; Vekerdy, Z.; Salama, M.S. Surface Energy Balance of Fresh and Saline Waters: AquaSEBS. *Remote Sens.* **2016**, *8*, 583. https://doi.org/10.3390/rs8070583

The advantage to using PT-JPL for ECOSTRESS evapotranspiration is its ability to distinguish transpiration from other forms of evaporation, but this comes at the cost of increased sensitivity to vegetation index. This sensitivity has prompted us to explore alternative models of evapotranspiration, including the Surface Temperature Initiated Closure (STIC) model.



Standard deviation of changes in PT-JPL ET output using target input variable perturbations and all other variables held fixed.



Comparison of PT-JPL and disALEXI-JPL standard deviation of changes in ET output using surface temperature (LST) and vegetation index (VI) variable perturbations from the and all other variables held fixed.

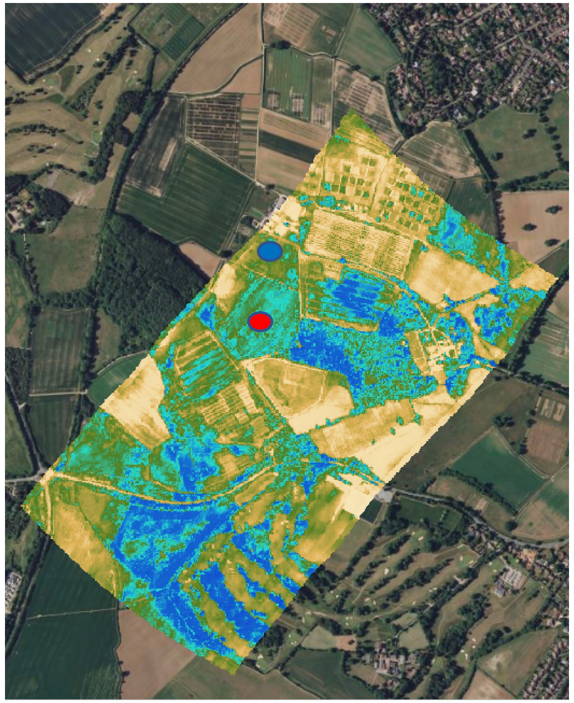
Halverson et al., *Statistical Uncertainty Quantification and Sensitivity Analysis for the ECOSTRESS PT-JPL Evapotranspiration Algorithm*, in preparation

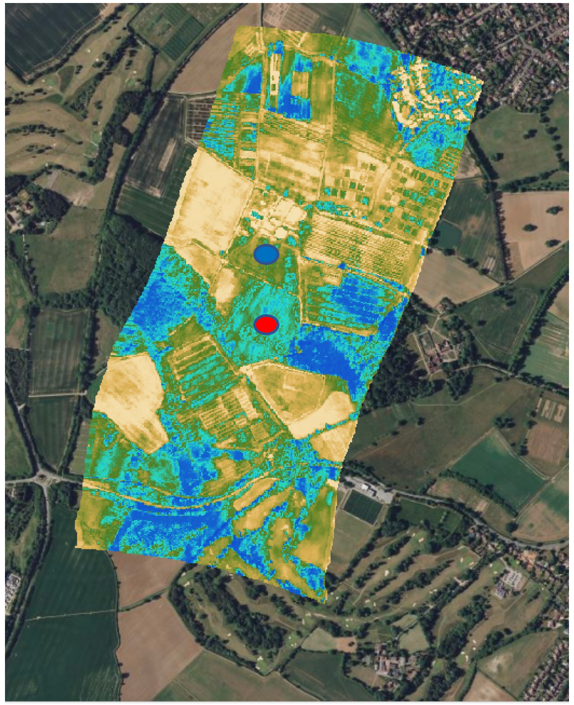
JPL Evapotranspiration Ensemble (JET)

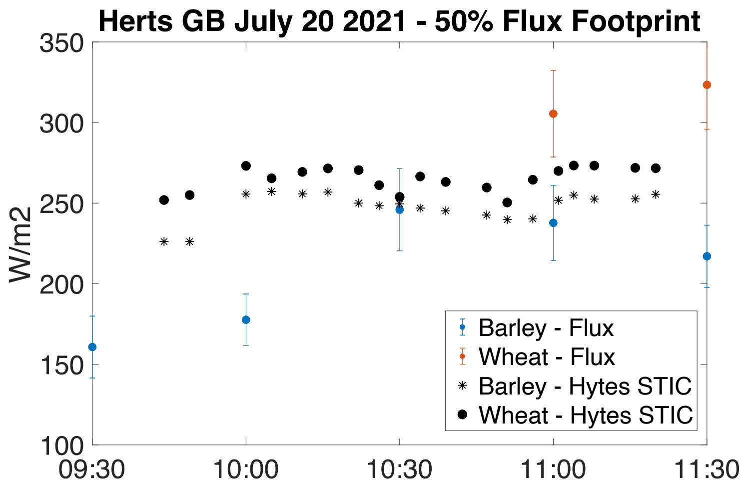
Collection 2 is expanding the PT-JPL ET product into the JPL Evapotranspiration Ensemble (JET) product, with multiple ET estimates including PT-JPL-SM, MOD16, adapted from the MODIS ET product, and BESS adapted from our GPP algorithm. This will allow the user to better interpret the uncertainty in the range of estimates between models. We are also including a surface temperature sensitive algorithm called STIC.

Surface Temperature Initiated Closure (STIC)

The JET product includes an ECOSTRESS implementation of the Surface Temperature Initiated Closure (STIC) model of evapotranspiration. The STIC model takes surface temperature into account directly in Penman-Monteith, improving sensitivity of evapotranspiration to surface temperature. We hope that STIC can complement PT-JPL-SM as a thermally sensitive evapotranspiration estimate that can help us reveal the diurnal cycle of thermal plant stress. Madeleine has been working with Kaniska Mallick, experimenting with processing the STIC model using HyTES surface temperature as a proxy for ECOSTRESS, SBG, TRISHNA, and LSTM, and comparing this initial output to eddy covariance data.







Barley Flux Tower
Wheat Flux Tower

Pascolini-Campbell, M. et al.

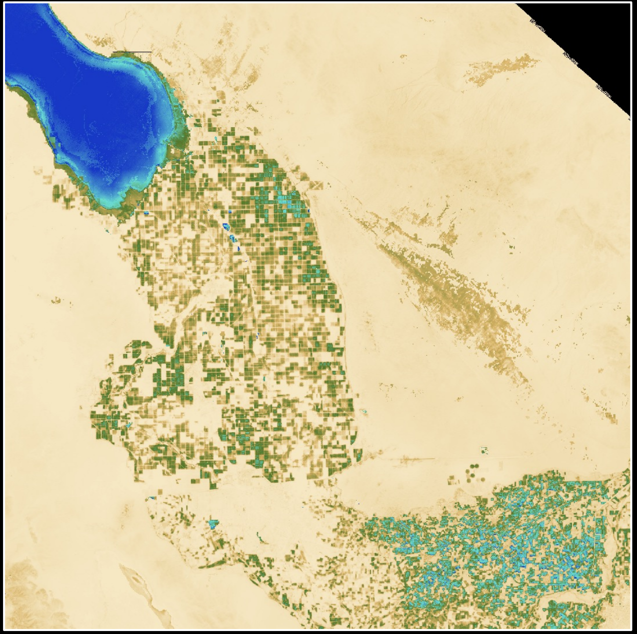
K. Mallick *et al*., "Surface Temperature Initiated Closure (STIC) for surface energy balance fluxes" in *Remote Sensing of Environment*

L3T_JET

The PT-JPL-SM model, developed by Dr. Adam Purdy and Dr. Joshua Fisher was designed as a SM-sensitive evapotranspiration product for the Soil Moisture Active-Passive (SMAP) mission, and then reimplemented as an ET model in the ECOSTRESS ensemble, using the downscaled soil moisture from the L3T SM product. Similar to the PT-JPL model used in ECOSTRESS Collection 1, The PT-JPL-SM model estimates instantaneous canopy transpiration, leaf surface evaporation, and soil moisture evaporation using the Priestley-Taylor formula with a set of constraints. The total instantaneous ET estimate combining these three partitions is recorded in the L3T JET product as PTJPLSMinst. The proportion of instantaneous canopy transpiration is recorded as PTJPLSMcanopy, leaf surface evaporation as PTJPLSMinterception, and soil moisture as PTJPLSMsoil.

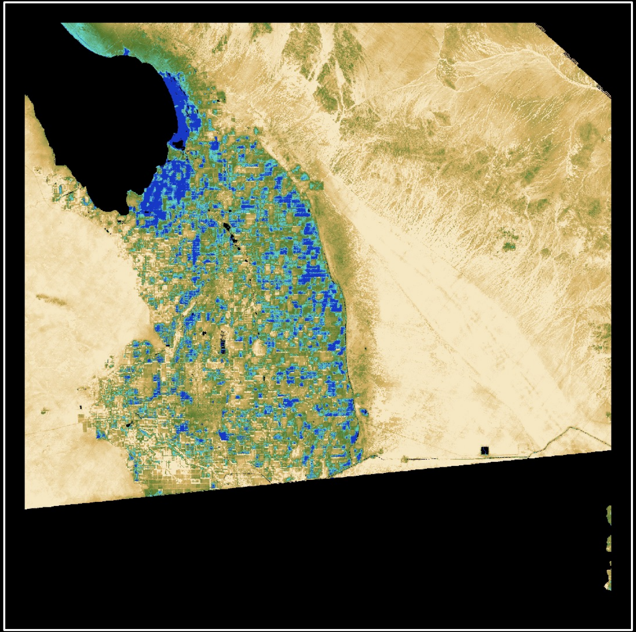
The Surface Temperature Initiated Closure (STIC) model, contributed by Dr. Kaniska Mallick, was designed as an ST-sensitive ET model, adopted by ECOSTRESS for improved diurnal estimates of ET. The STIC instantaneous ET is recorded in the L3T JET product as STICinst.
The MOD16 algorithm was designed as the ET product for the Moderate Resolution Imaging Spectroradiometer (MODIS). MOD16 uses a similar approach to PT-JPL and PT-JPL-SM to independently estimate vegetation and soil components of instantaneous ET, but using the Penman-Monteith formula instead of Priestley-Taylor. It is provided here as an additional estimate in the L3T JET product, MOD16inst.

The ET estimate from BESS is recorded in the L3T JET product as BESSinst. The median of PTJPLSMinst, STICinst, MOD16inst, and BESSinst is upscaled to a daily ET estimate in millimeters per day and recorded in the L3T JET product as ETdaily. The standard deviation between these multiple estimates of ET is considered the uncertainty for the ECOSTRESS evapotranspiration product, as ETinstUncertainty.



Name	Type	Units
ETdaily	float32	W m^{-2}
ETinstUncertainty		
PTJPLSMinst		
STICinst		
MOD16inst		
BESSinst		
PTJPLSMcanopy	uint8	percent: 0 to 100
PTJPLSMinterception		
PTJPLSMsoil		
cloud	uint8	mask
water		

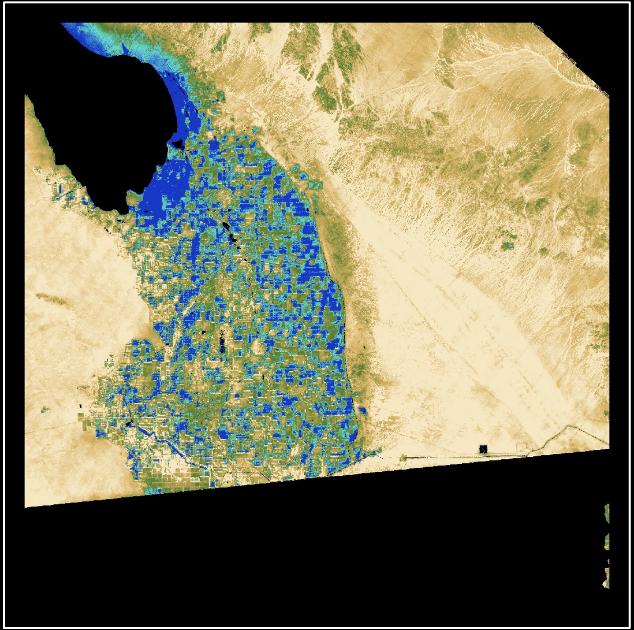
L4T_ET_ALEXI



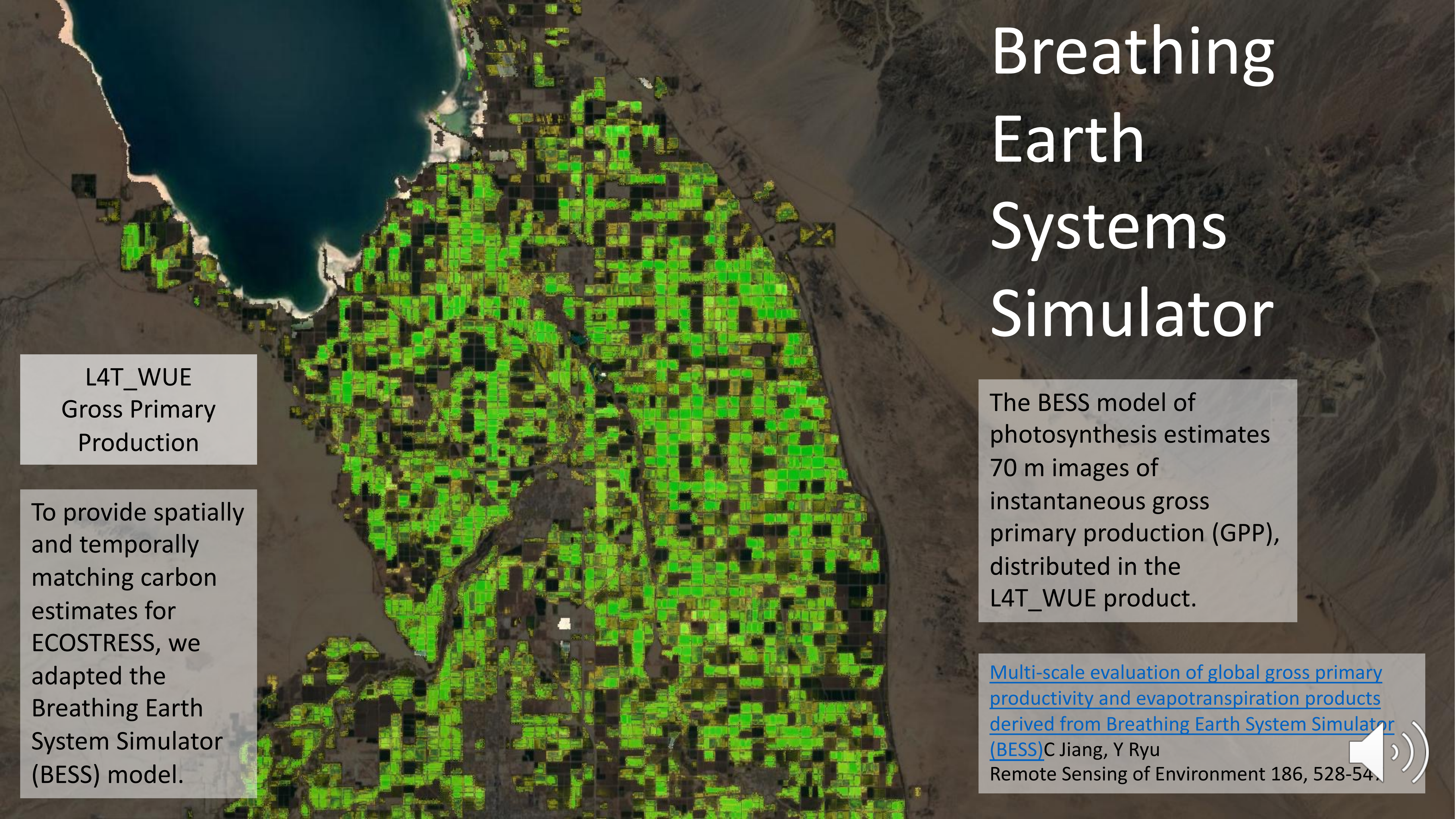
Name	Type	Units
ETdaily	float32	mm/day
ETdailyUncertainty	float32	mm/day

In addition to the ensemble product containing PT-JPL-SM, STIC, MOD16, and BESS estimates of ET, there is a separate ET product for DisALEXI-JPL. This product is run independently because it limited to processing within the United States and is prone to unavailable input data. Contributed by Martha Anderson of the United States Department of Agriculture (USDA), DisALEXI-JPL takes an iterative approach to mapping of fine spatial resolution ET based on surface temperature. DisALEXI-JPL ingests the coarse resolution ET images produces by the Atmospheric Land Exchange Interface (ALEXI) model and downscales them using ECOSTRESS ST by running the Two-Source Energy Balance (TSEB) ET model using the ST image from ECOSTRESS, NDVI and albedo from STARS, and meteorology from Climate Forecast System Reanalysis (CSFR). The fine spatial resolution ET output from each TSEB run is compared to the coarse resolution image from ALEXI, and an adjustment is applied to the air temperature input before running TSEB again. This spatial disaggregation approach to ET estimation produces daily ET images that are sensitive to ECOSTRESS ST, but this product does not contain an instantaneous estimate of ET for diurnal analysis. Daily ET in millimeters per day with uncertainty is written to the L3T ET ALEXI product, and ESI with uncertainty is written to the L4T ESI ALEXI product.

L4T_ESI_ALEXI



Name	Type	Units
ESIdaily	float32	ratio: 0 to 1
ESIdailyUncertainty	float32	ratio: 0 to 1



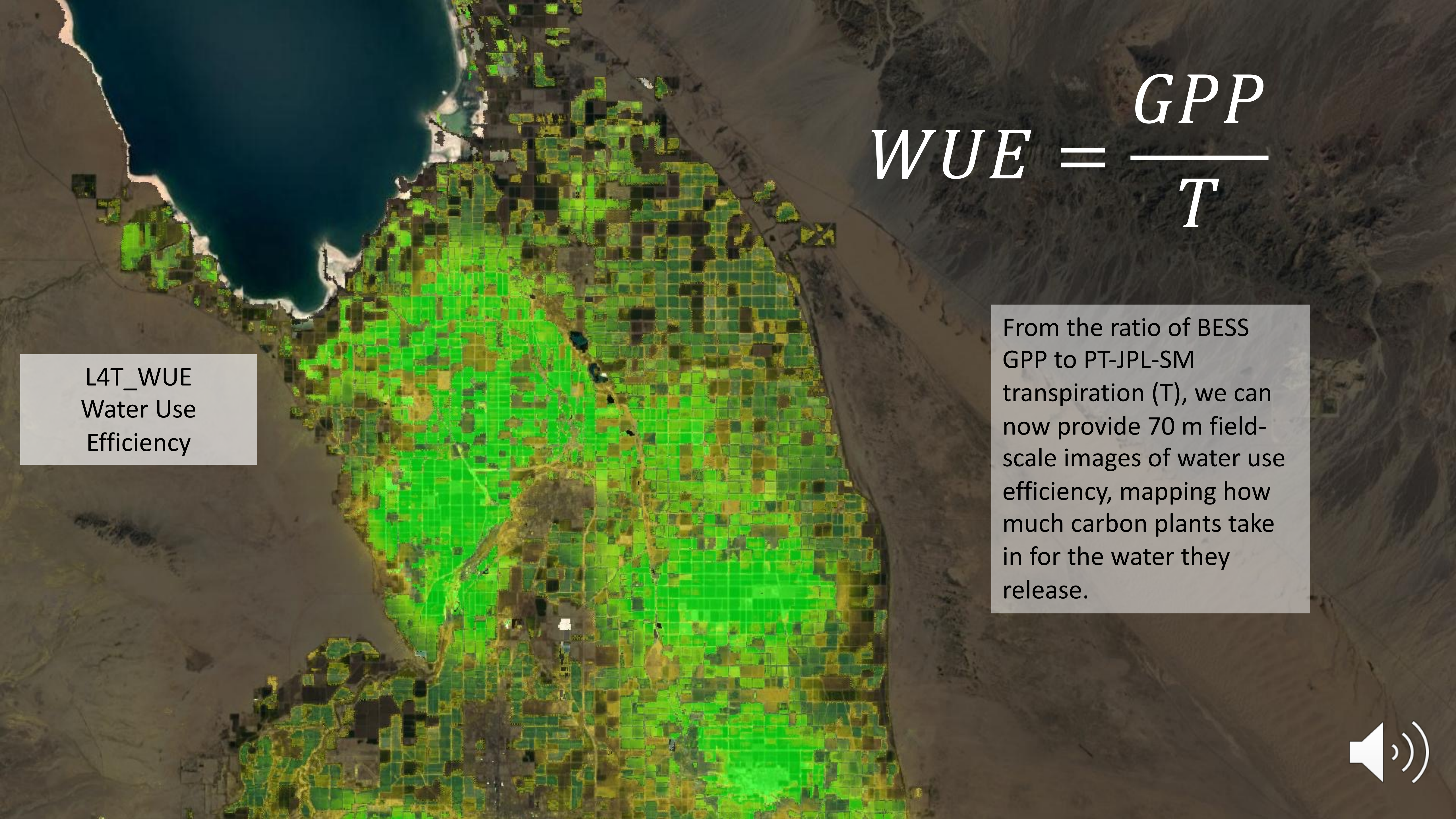
Breathing Earth Systems Simulator

L4T_WUE
Gross Primary Production

To provide spatially and temporally matching carbon estimates for ECOSTRESS, we adapted the Breathing Earth System Simulator (BESS) model.

The BESS model of photosynthesis estimates 70 m images of instantaneous gross primary production (GPP), distributed in the L4T_WUE product.

[Multi-scale evaluation of global gross primary productivity and evapotranspiration products derived from Breathing Earth System Simulator (BESS)]C Jiang, Y Ryu
Remote Sensing of Environment 186, 528-54

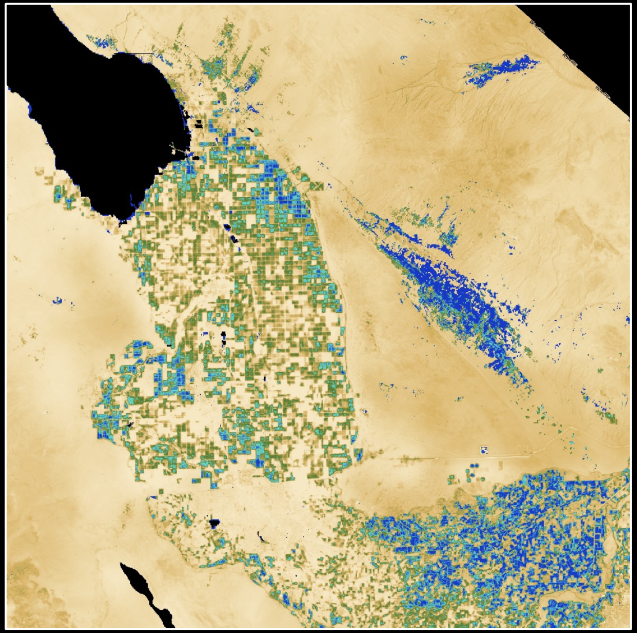


$$WUE = \frac{GPP}{T}$$

L4T_WUE
Water Use
Efficiency

From the ratio of BESS GPP to PT-JPL-SM transpiration (T), we can now provide 70 m field-scale images of water use efficiency, mapping how much carbon plants take in for the water they release.

L4T_ESI

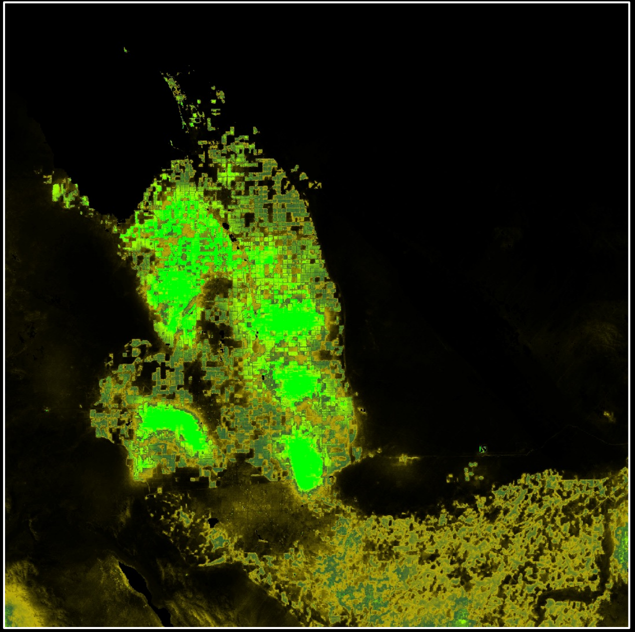


Name	Type	Units
ESI	float32	ratio: 0 to 1
PET	float32	W m^{-2}
cloud	uint8	mask
water	uint8	mask

The PT-JPL-SM model generates estimates of both actual and potential instantaneous ET. The potential evapotranspiration (PET) estimate represents the maximum expected ET if there were no water stress to plants on the ground. The ratio of the actual ET estimate to the PET estimate forms an index representing the water stress of plants, with zero being fully stressed with no observable ET and one being non-stressed with ET reaching PET. These ESI and PET estimates are distributed in the L4T ESI product.

The BESS GPP estimate represents the amount of carbon that plants are taking in. The transpiration component of PT-JPL-SM represents the amount of water that plants are releasing. The BESS GPP is divided by the PT-JPL-SM transpiration to estimate water use efficiency (WUE), the ratio of grams of carbon that plants take in to kilograms of water that plants release. These WUE and GPP estimates are distributed in the L4T ESI product.

L4T_WUE



Name	Type	Units
WUE	float32	g C kg^{-1} H_2O
GPP	float32	μmol m^{-2} s^{-1}
cloud	uint8	mask
water	uint8	mask

The development of these improved algorithms and implementation of these tiled data products demonstrates a feasible and cloud-enabled work-flow for the future SBG suite of surface energy balance products, coordinated with TRISHNA and LSTM.

These tiled products facilitate new opportunities for near-real time monitoring of high-resolution temperature and plant stress and allow greater ease of use for data analysis and science.

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- Martha Anderson (United States Department of Agriculture)
  - DisALEXI-JPL development
- Youngryel Ryu (Seoul National University)
  - BESS carbon model development
- Maggie Johnson
  - STARS data fusion model development
- Andreas Colliander
  - Soil moisture downscaling method development
- Madeleine Pascolini-Campbell
  - STIC evapotranspiration model development
- Kerry Cawse-Nicholson
  - DisALEXI-JPL evapotranspiration model development
- Christine Lee
  - Early User Community

ECOSTRESS Collection 2 Level 1 to 4 Tiled Products

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