Heat and Desiccation Risk Prediction in Intertidal Shellfisheries

David S Wethey, Nicolás Weidberg
Sarah Woodin, Thomas Hilbish,
University of South Carolina
wethey@biol.sc.edu

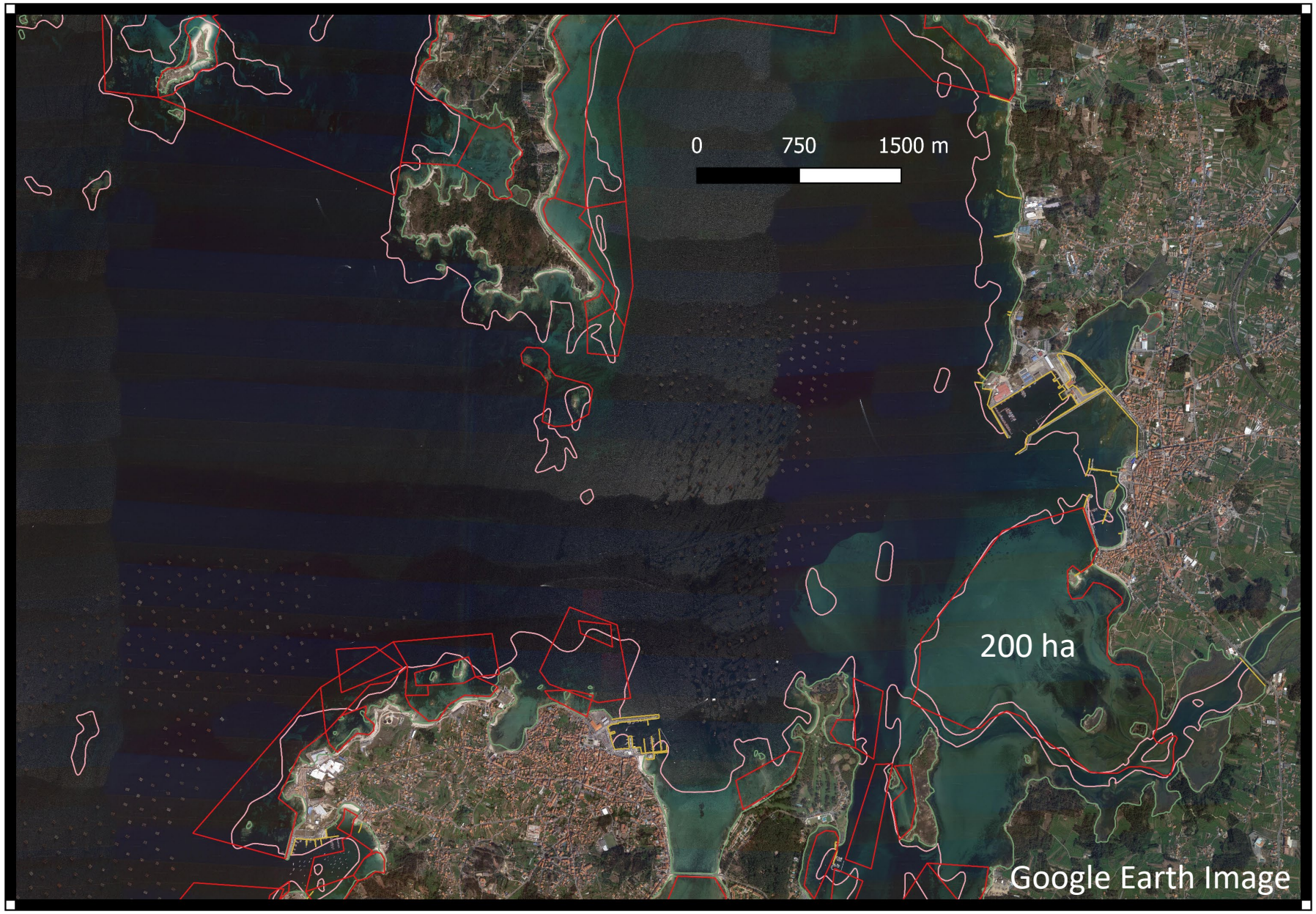
80NSSC20K0074

We are studying thermal stress in Intertidal Shellfish beds in Galicia, NW Spain

Delineated Beds outlined in Red
Low Tide Line in Pink
High Tide Line in Green & Yellow

The 200 hectare intertidal bed is where we have a collaborative project with the University of Vigo and the Cofradía de Mariscadoras de Cambados.

Intertidal clam beds harvested exclusively by women on foot.



Clams suffer mass mortality after heat waves.

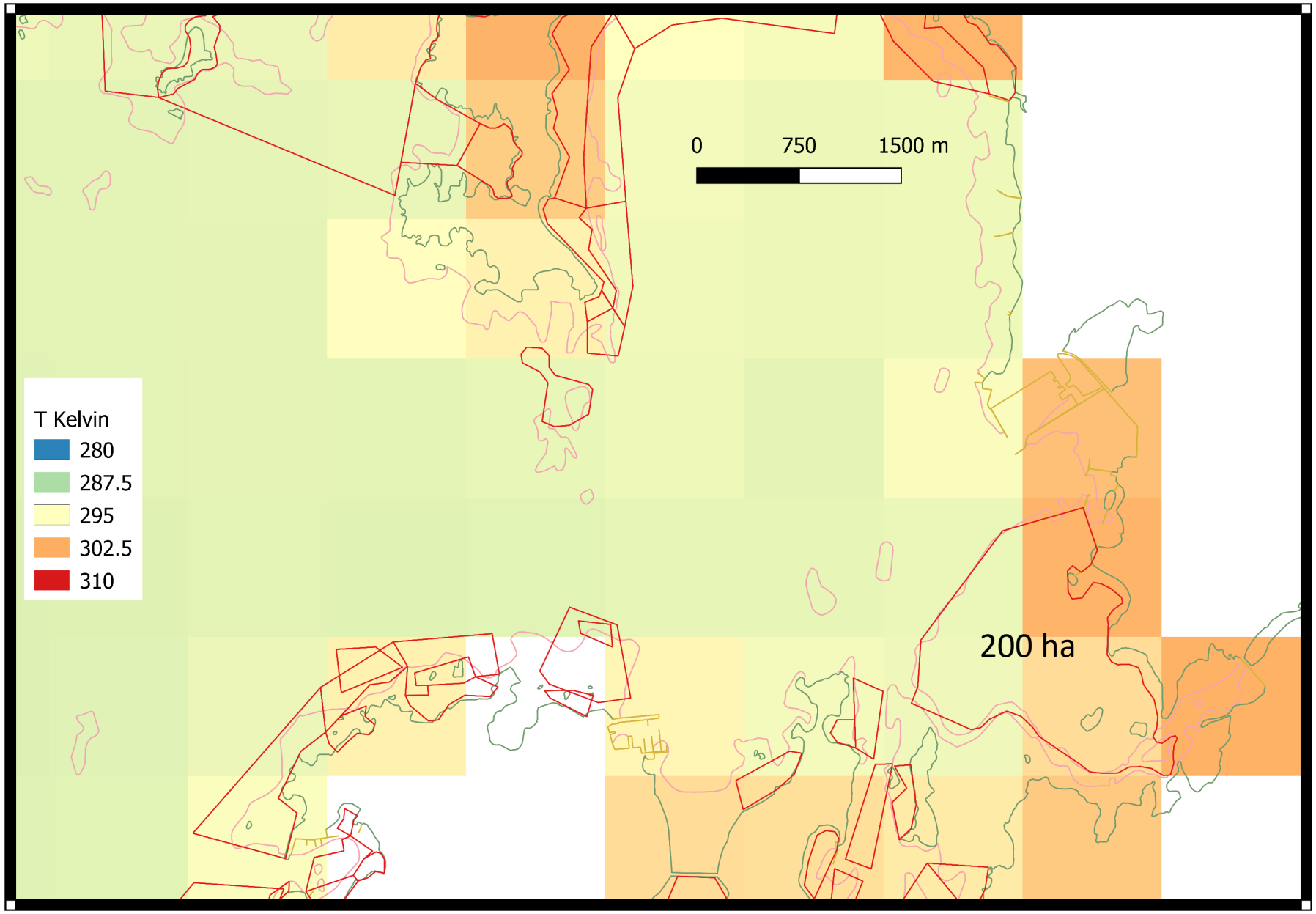
Intertidal Shellfish beds in Galicia, NW Spain – **VIIRS L2 SST Image**

Aug 22, 2020 13:10 UTC
Low Tide : 0.49 m at 11:02 UTC

750m pixels

Serious land contamination

Can’t resolve patterns within shellfish beds



Intertidal Shellfish beds in Galicia, NW Spain – **ECOSTRESS SST-LST Image**

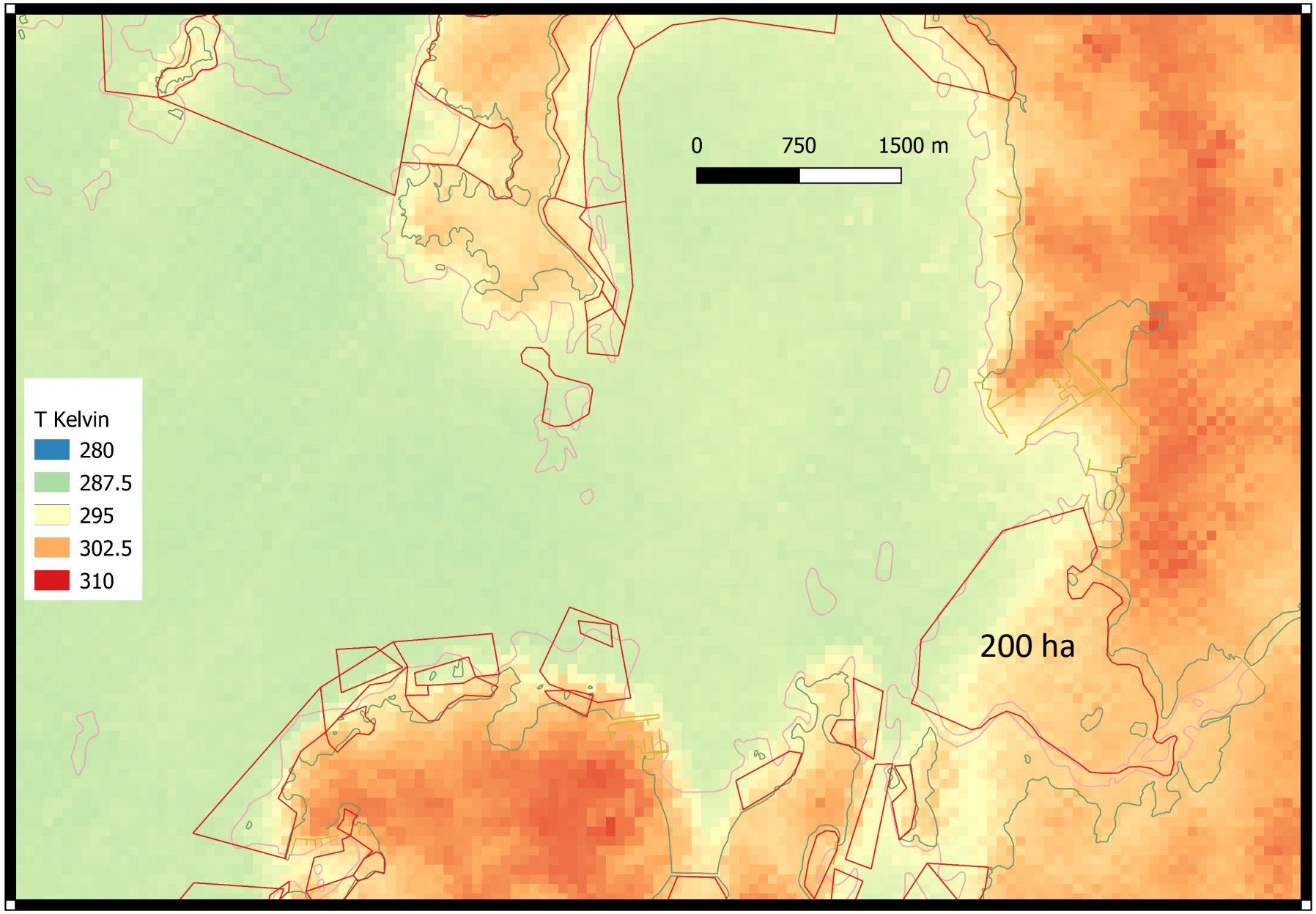
Aug 22, 2020 13:01 UTC
Low Tide: 0.49 m at 11:02 UTC

No contamination by land pixels.

121 ECOSTRESS pixels per VIIRS pixel and 196 pixels per MODIS pixel. 425 pixels within the 200 hectare shellfish bed.

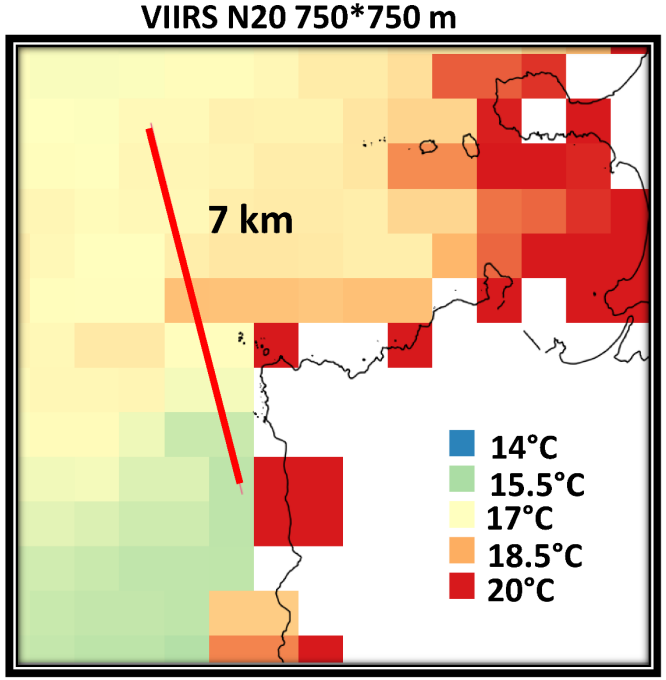
Temperature gradients from high to low tide marks well resolved: 8° C difference between high and low tide marks.

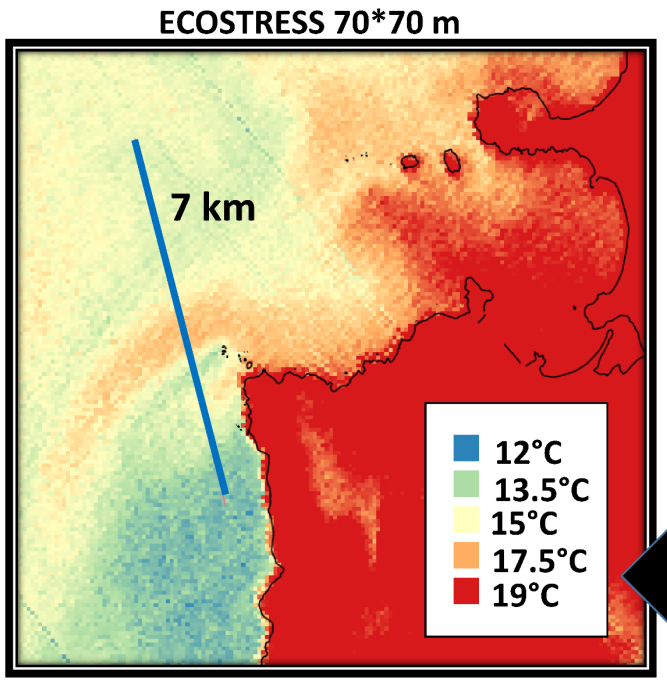
Low tide water line at 1.25 m well resolved

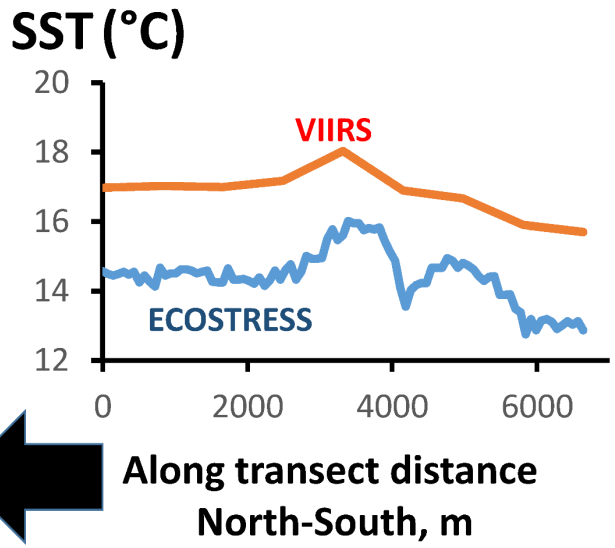


Clams suffer mass mortality during heat waves

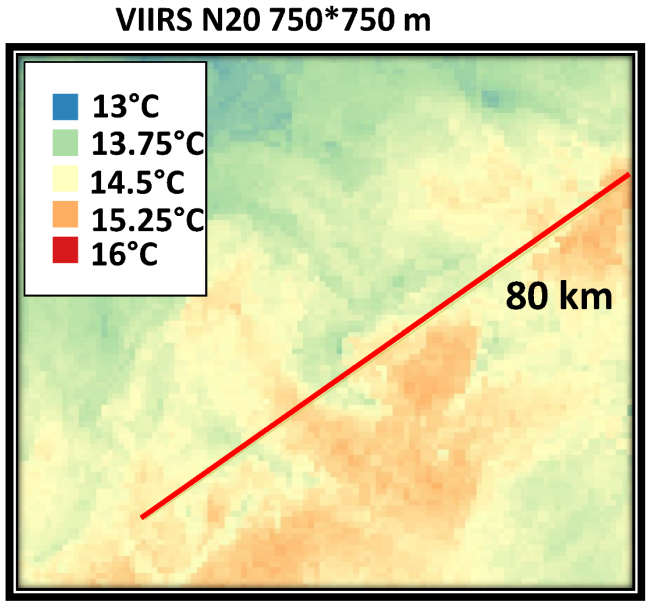
NW Spain: Upwelling shadow front (07/24/20)

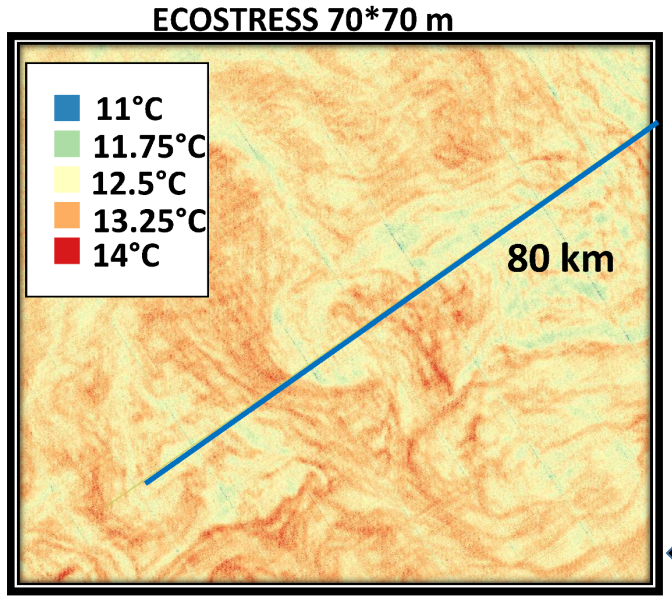


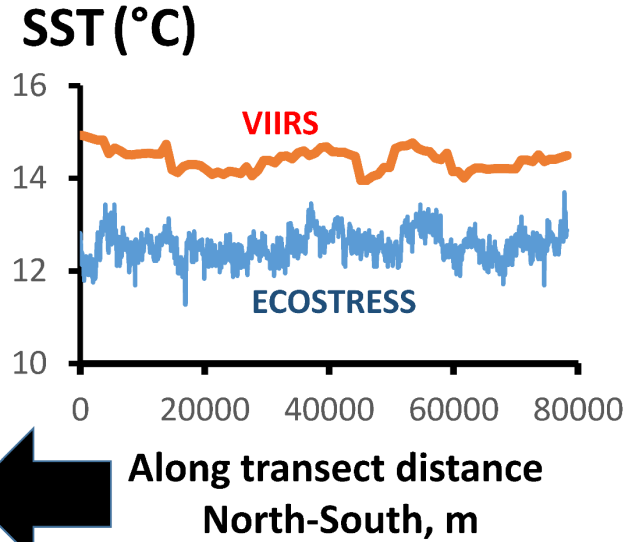




NW Spain: Upwelling filaments and internal waves (03/28/21)







Upwelling Features

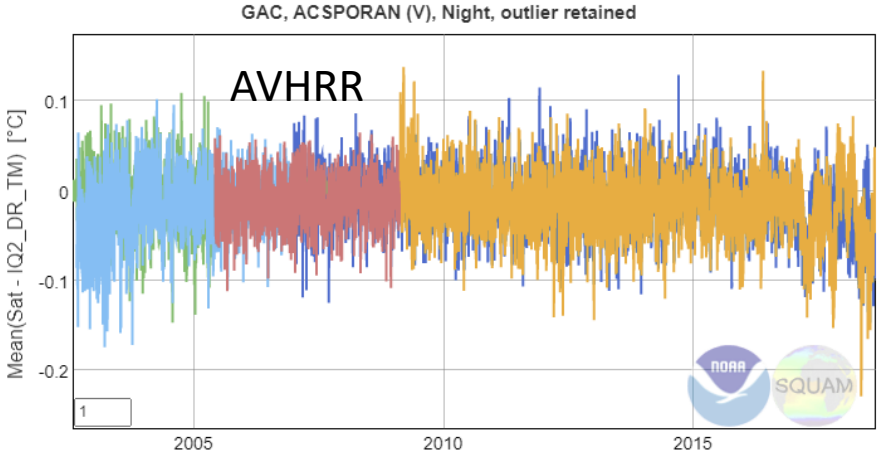
- Fronts and filaments resolved by ECOSTRESS that are not detected by VIIRS.
- Gradients much better characterized by ECOSTRESS than VIIRS.
- ECOSTRESS 1-2 K Cold Bias.

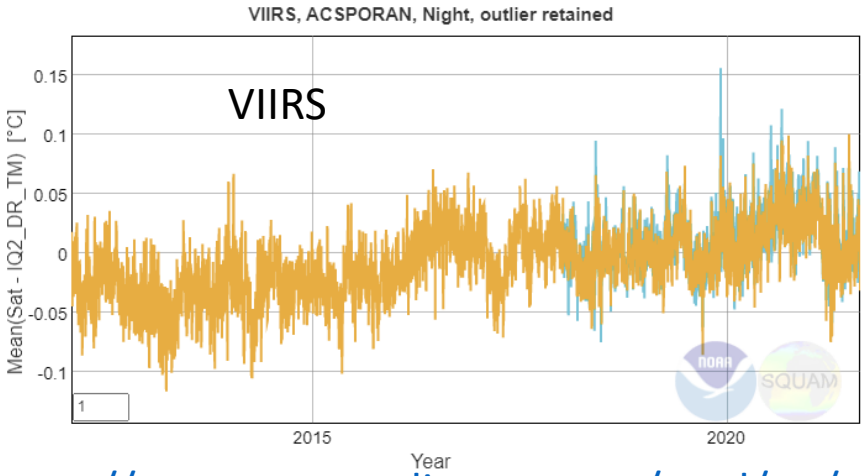
Context -- Why LST/SST Accuracy is Important

Operational SST Accuracy is High

Bias vs in-situ Drifters

Bias typically < 0.1 K

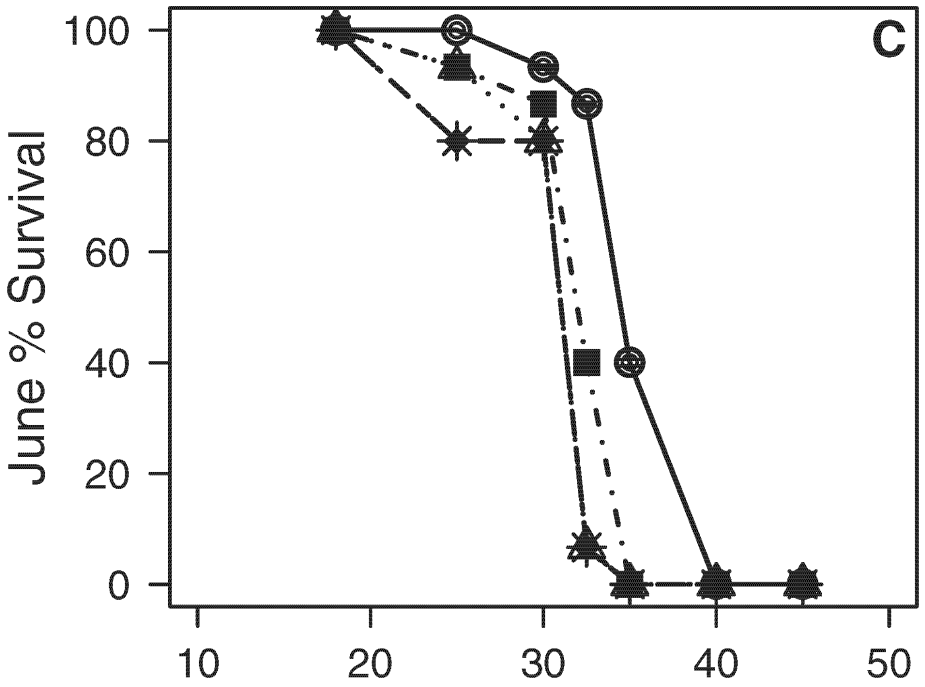




https://www.star.nesdis.noaa.gov/socd/sst/squam/

Small Temperature Differences Matter

Mussel survival drops from 80% to 7% between 30 C and 32.5 C



Jones et al. 2009, Biol Bull 217:73-85

ECOSTRESS Calibration/Validation vs Ocean In-situ Observations

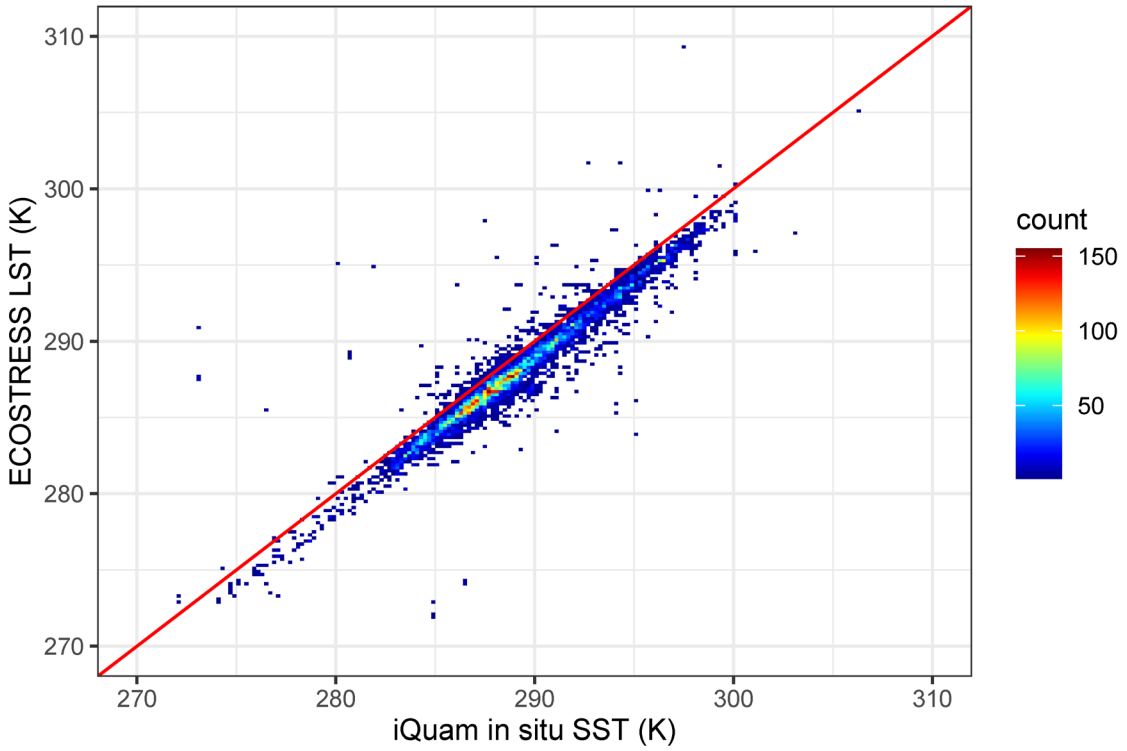
- Infrared emissivity of ocean more spatially uniform than land
  - Can validate both temperature and emissivity
  - Independent error estimation
- Specific heat of water higher than most terrestrial materials
  - Diurnal temperature variation is smaller than on land
- More in-situ observations available than on land
  - 7900 platforms, 2.2 million QC'd observations/month in NOAA iQuam
  - Large number of collocations to ECOSTRESS per month
- Triple collocations to in-situ and geostationary observations
  - Available for all ECOSTRESS observations
  - Geostationary cloud algorithms tuned for ocean observations

Calibration of ECOSTRESS Temperatures with *in situ* and Satellite Observations

- ECOSTRESS
  - Radiances, LST, Emissivities, Cloud Mask
- *In situ*
  - NOAA iQuam *in situ* SST Quality Monitor (used to verify all NOAA satellite SST products)
  - Used quality 5 data only within 30 min and 100 meters of cloud-free ECOSTRESS pixel
- Geostationary satellite match-up to iQuam / ECOSTRESS observations
  - NOAA 16, NOAA 17, Himawari-8, MSG-1, MSG-4 from https://podaac.jpl.nasa.gov
  - Pixel size 2 km, processed by NOAA Operational SST algorithm/ ESA cloud algorithm
  - Used cloud-free pixels within 30 min and 1.5 km of each matched ECOSTRESS and iQuam observation
- Polar satellite whole scene match-up to ECOSTRESS pixels
  - VIIRS instrument on NOAA N-20 and SUOMI-NPP satellites from https://podaac.jpl.nasa.gov
  - Pixel size 750 m, processed by NOAA Operational SST algorithm
  - Used cloud-free VIIRS pixels within 90 min and 375m of ECOSTRESS pixels

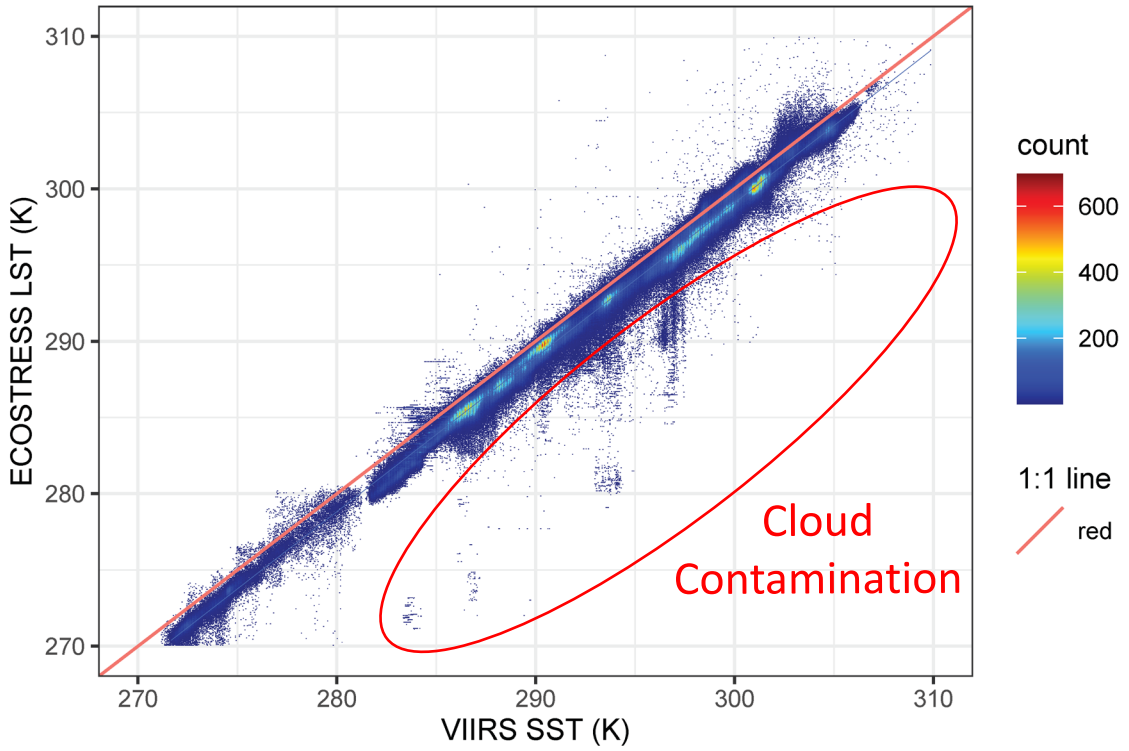
Clear-sky ECOSTRESS vs NOAA-iQuam in-situ

Bias = -1.05 , sd= 0.88, r^2 = 0.94, n=19,443



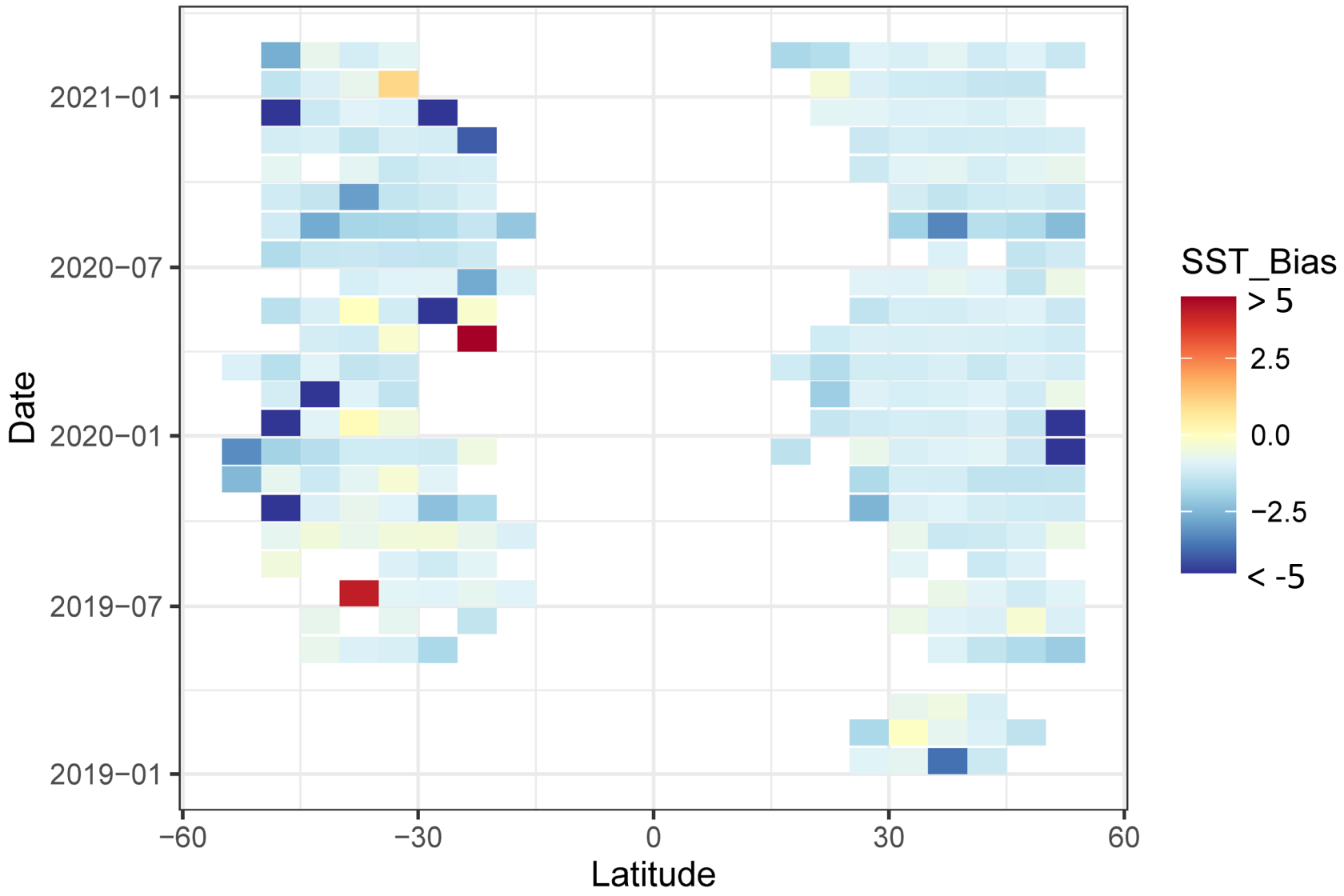
Clear-sky ECOSTRESS vs NOAA-VIIRS

Bias = -1.02 , sd= 0.67, r^2 = 0.99, n=2,282,368



ECOSTRESS SST Bias vs Date and Latitude

ECOSTRESS ocean pixels at clear sky geostationary pixel coordinates (N=19,443)



Consistent ~1 K cold bias
No obvious seasonality of Bias

Southern Hemisphere
- Fewer observations
- Mean bias more negative

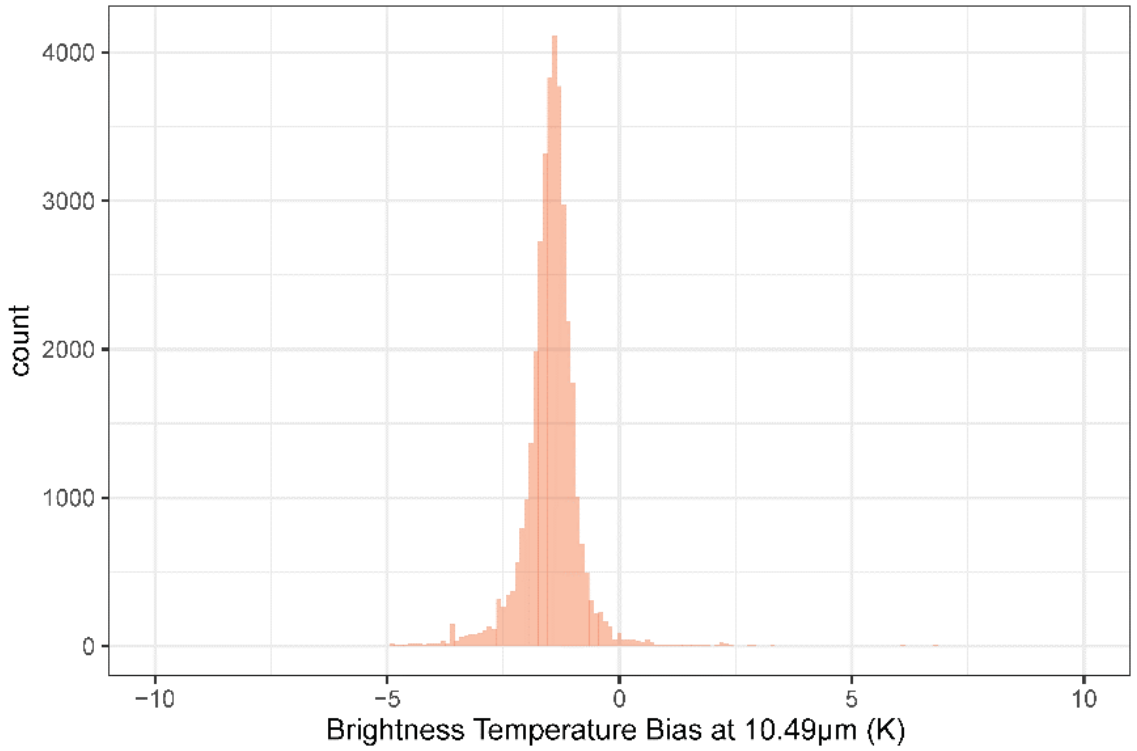
Northern Hemisphere
- More observations
- Mean bias less negative

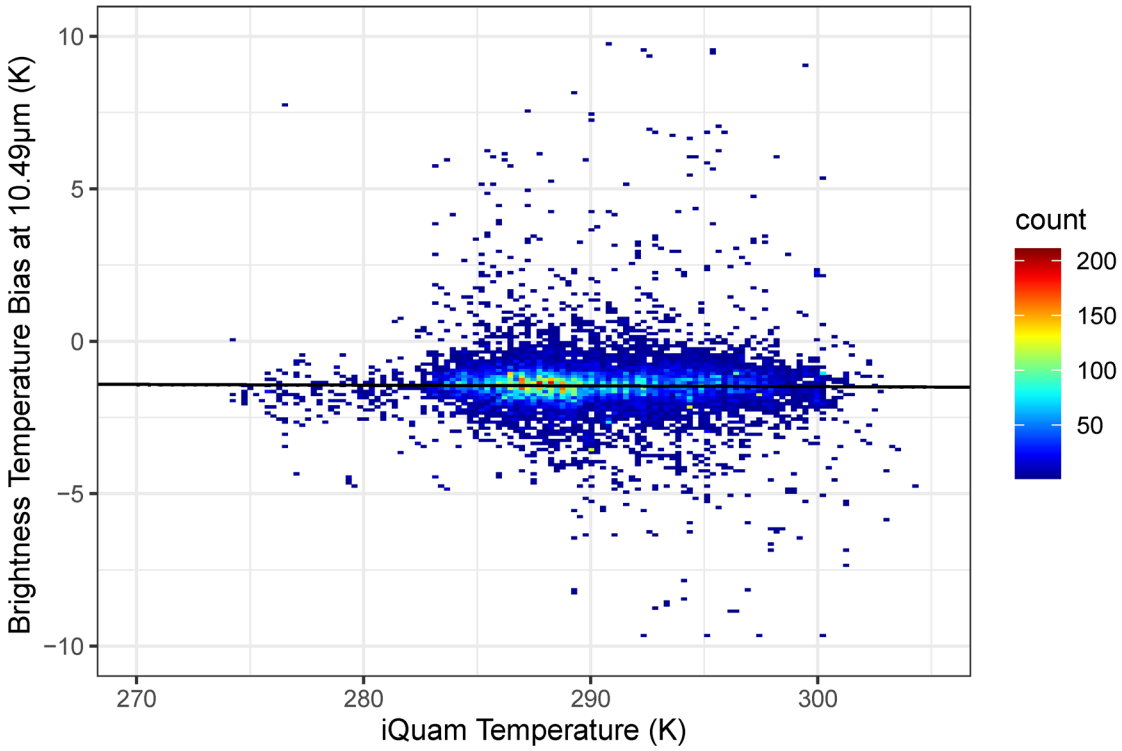
Origins of the Surface Temperature Bias

ECOSTRESS ocean pixels at Clear-sky Geostationary pixel coordinates

RTTOV 12 Radiance Transfer Model / ECMWF ERA-5 hourly 0.25° weather reanalysis data

10.49 µm Brightness Temperature Bias vs RTTOV mean = -1.34 K, sd= 1.89 K





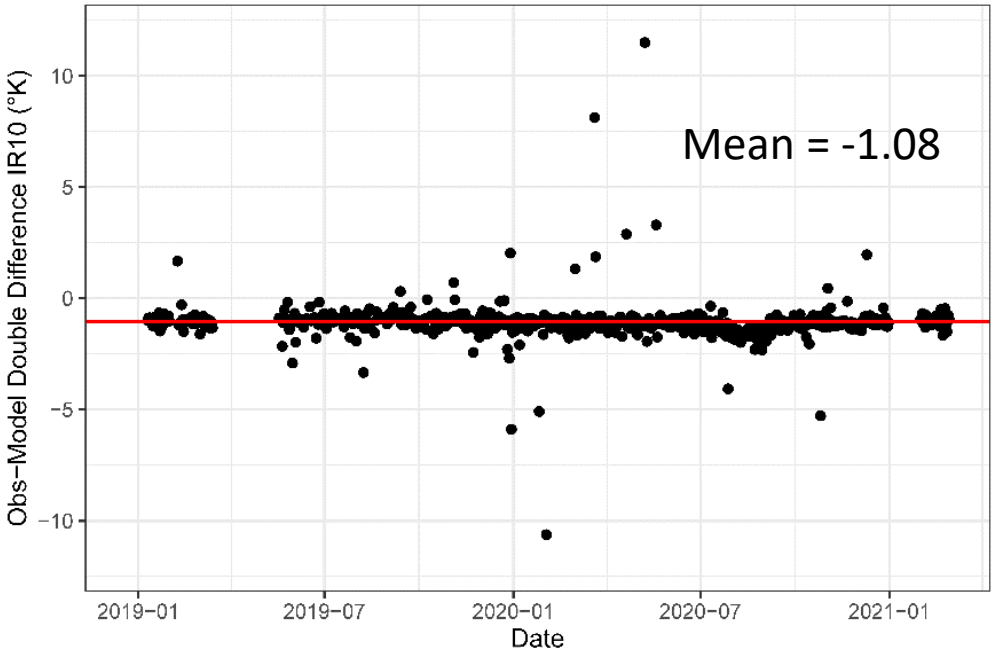
Model-Observation Double Differences

ECOSTRESS BT Bias – ABI Geostationary BT Bias

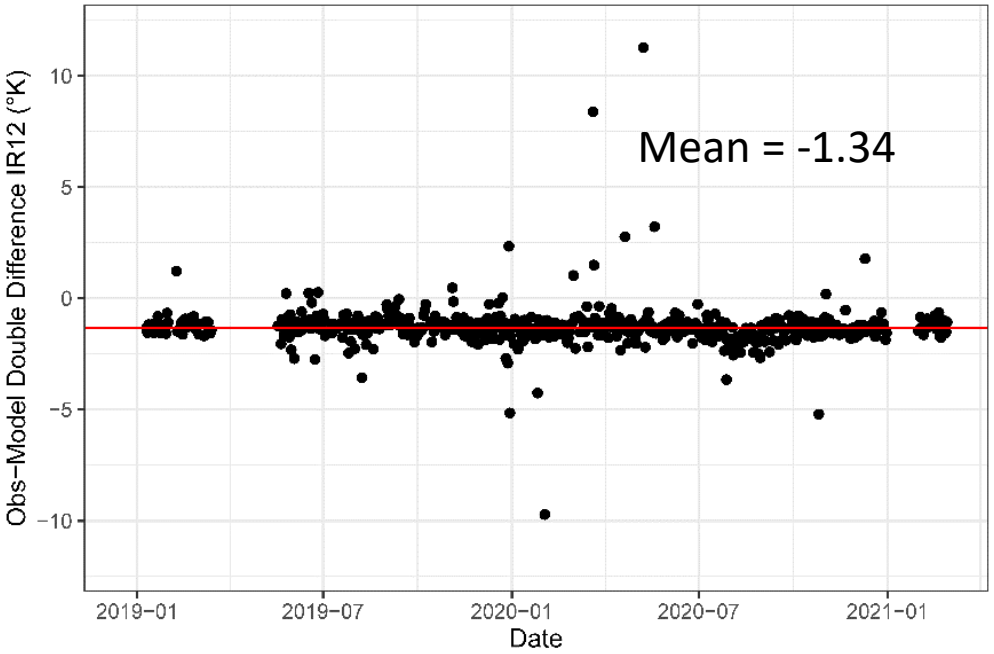
Model = RTTOV 12 Radiance Transfer Model

$DD_{SAT\text{-}REF}$ = ECO[Obs - RTTOV)] – ABI[Obs - RTTOV]

Double Difference BT 10.49µm



Double Difference BT 12.09µm



No change in Model-Observation bias during ECOSTRESS operations

ECOSTRESS BTs Cold Bias

Sea surface temperatures from ECOSTRESS are attracting a great deal of interest from the Group for High Resolution SST and ocean modelers.

- They would like to see a standard L2 GHRSST product (PODAAC standard files).
- We have repackaged L1 GEO, L2 LST and L2 Cloud data into GHRSST format netcdf for our collaboration with Australia Bureau of Meteorology.
- Split-Window regression algorithms are alternatives to TES for specific L2 SST product
  - Emissivity of ocean surface is very tightly constrained so it is not necessary to use a temperature-emissivity separation method.
  - If Brightness Temperature biases can be removed, can use radiance transfer models like RTTOV to generate the regression coefficients (Merchant et al. 2008, RSE)
  - If Brightness Temperature biases can't be removed, regression coefficients can be established from drifter & buoy data and validation can be done with sea-going radiometer data, or vice versa (Petrenko et al. 2014, JGR)
- We are evaluating split-window SST algorithms, using ECOSTRESS BT, and view zenith angles.
- Best algorithms are of the form
  - $SST = a_0 + a_1 BT_{10.49} + a_2(BT_{10.49} - BT_{12.09}) + a_3(BT_{10.49} - BT_{12.09})(\sec(VZA)-1.0)$
  - R^2 in excess of 0.95, RMSE < 0.7 K

- ECOSTRESS SST spatial resolution is 10× greater than VIIRS, and the sensor is temporally stable.
- It has a shorter return interval than Landsat, so it can resolve patterns relative to tides.
- The ECOSTRESS L2 Surface Temperature product has a 1°K cold bias, and the brightness temperatures have a similar cold bias relative to RTTOV radiance transfer models and geostationary satellite sensors.
- Bias correction of ECOSTRESS data yields a ultra-high resolution product with broad applications in biological and physical oceanography, especially in the coastal zone where land contamination of SST is a serious problem.
  - SST around complex headlands, fjords and islands
  - SST at spatial scale of sessile organism populations and aquaculture operations
  - Intertidal temperature gradients during low tide when thermal risks are highest