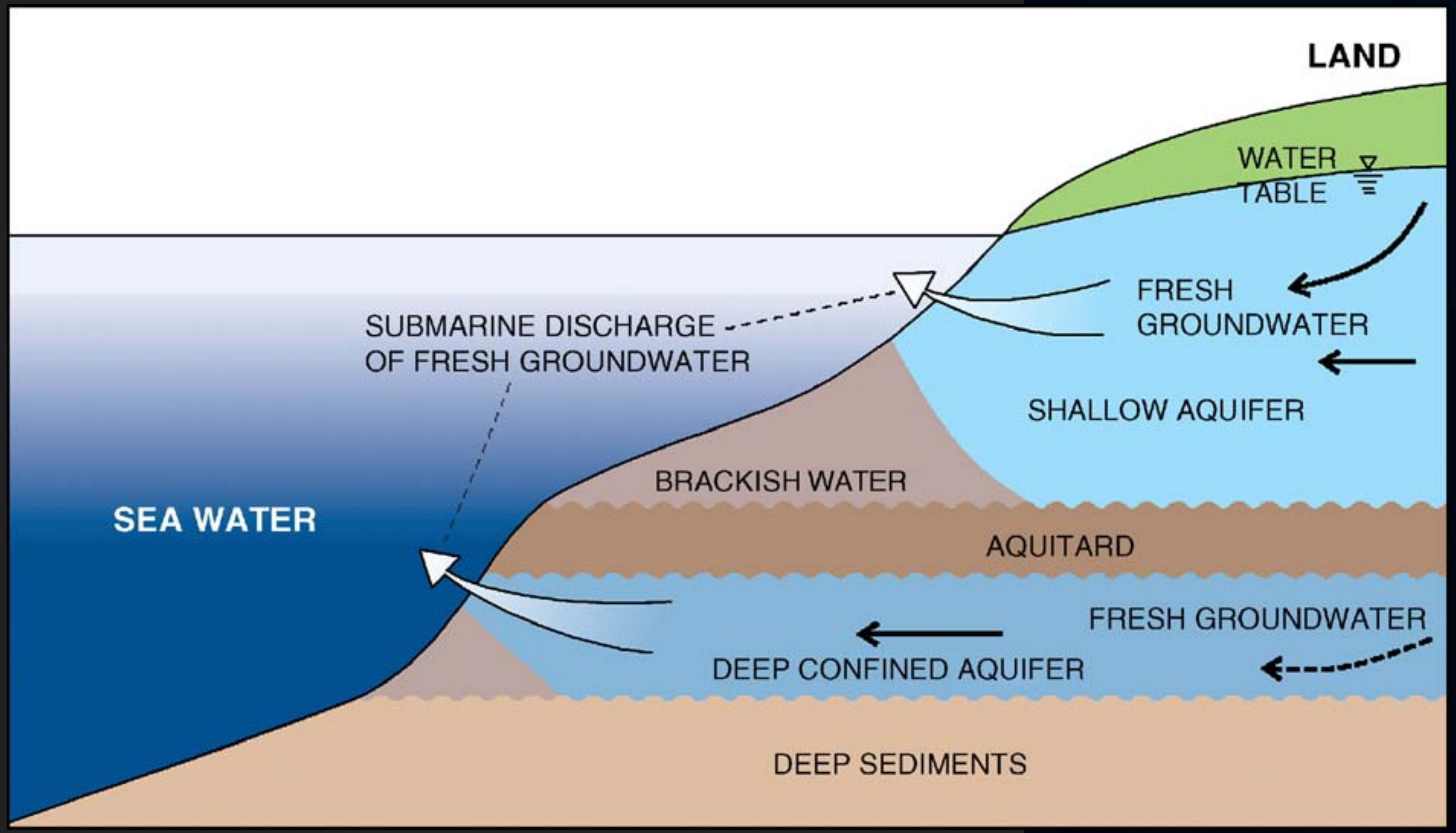
University of Pittsburgh
Department of Geology and Environmental Science

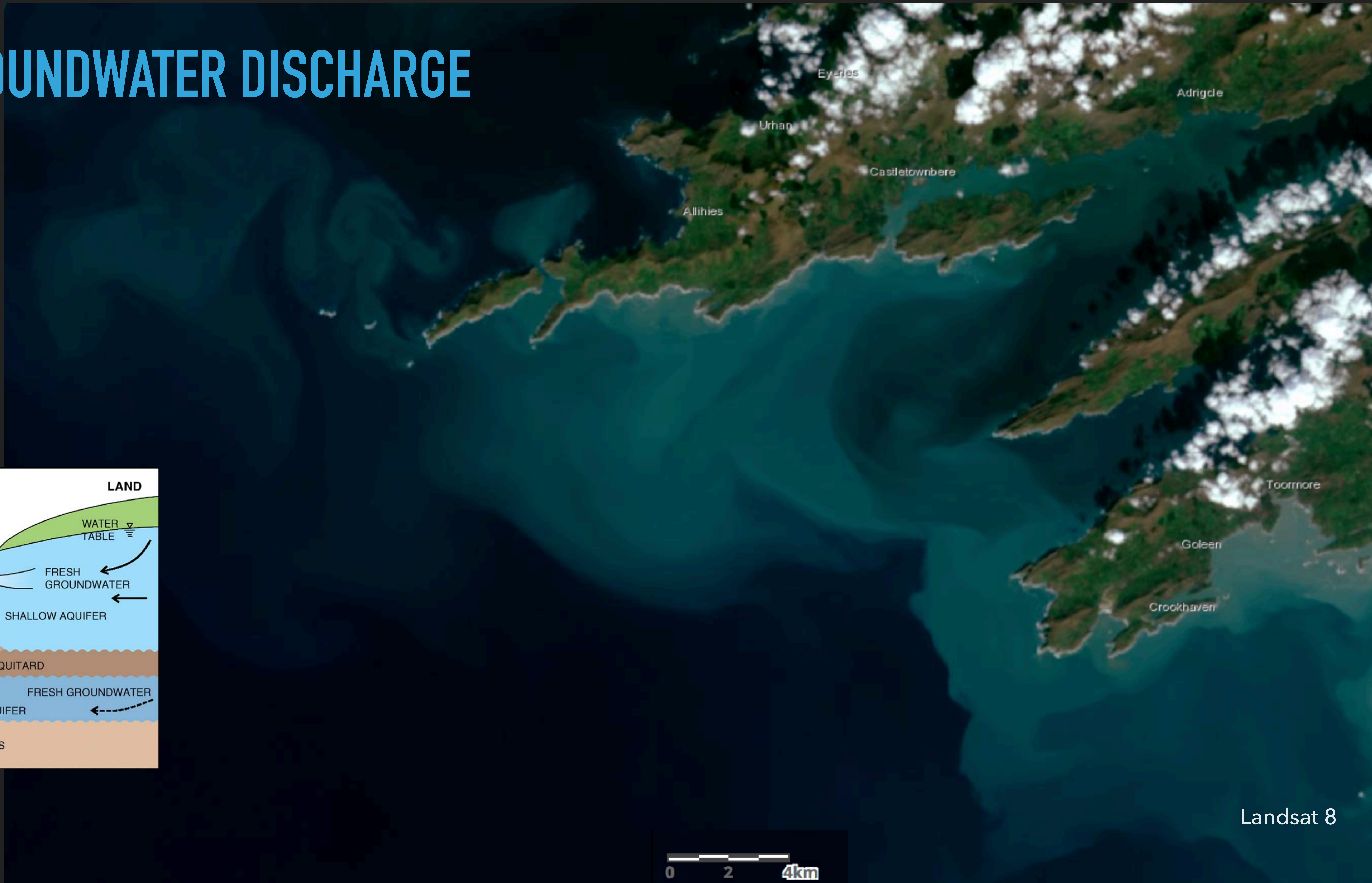
Júlio Caineta and Brian F. Thomas

EXPLORING LINKS BETWEEN SEA SURFACE TEMPERATURE AND COLOR IN COASTAL AREAS UNDER THE EFFECT OF SUBMARINE GROUNDWATER DISCHARGE

SUBMARINE GROUNDWATER DISCHARGE



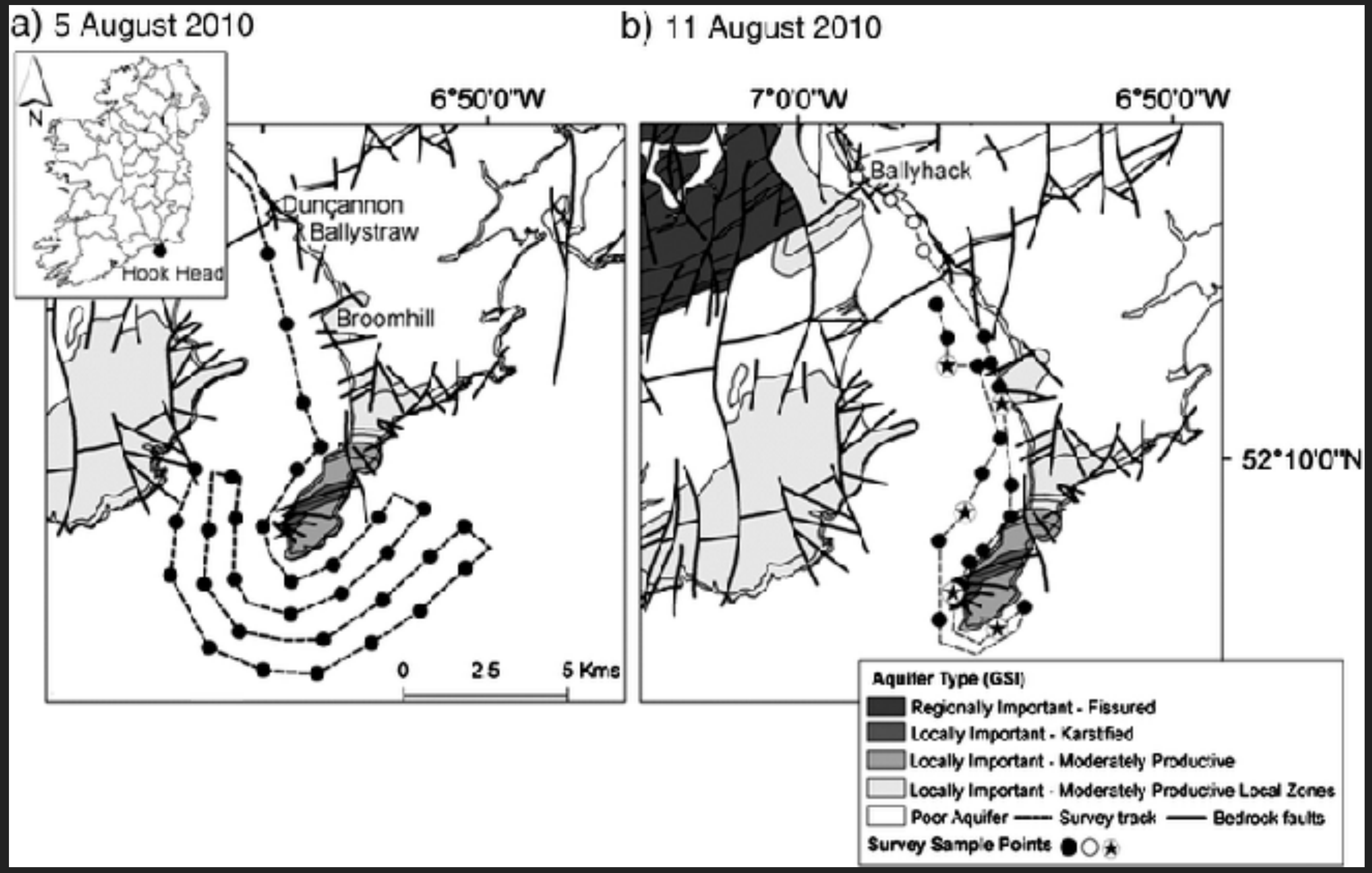
Adapted from Burnett et al., 2006

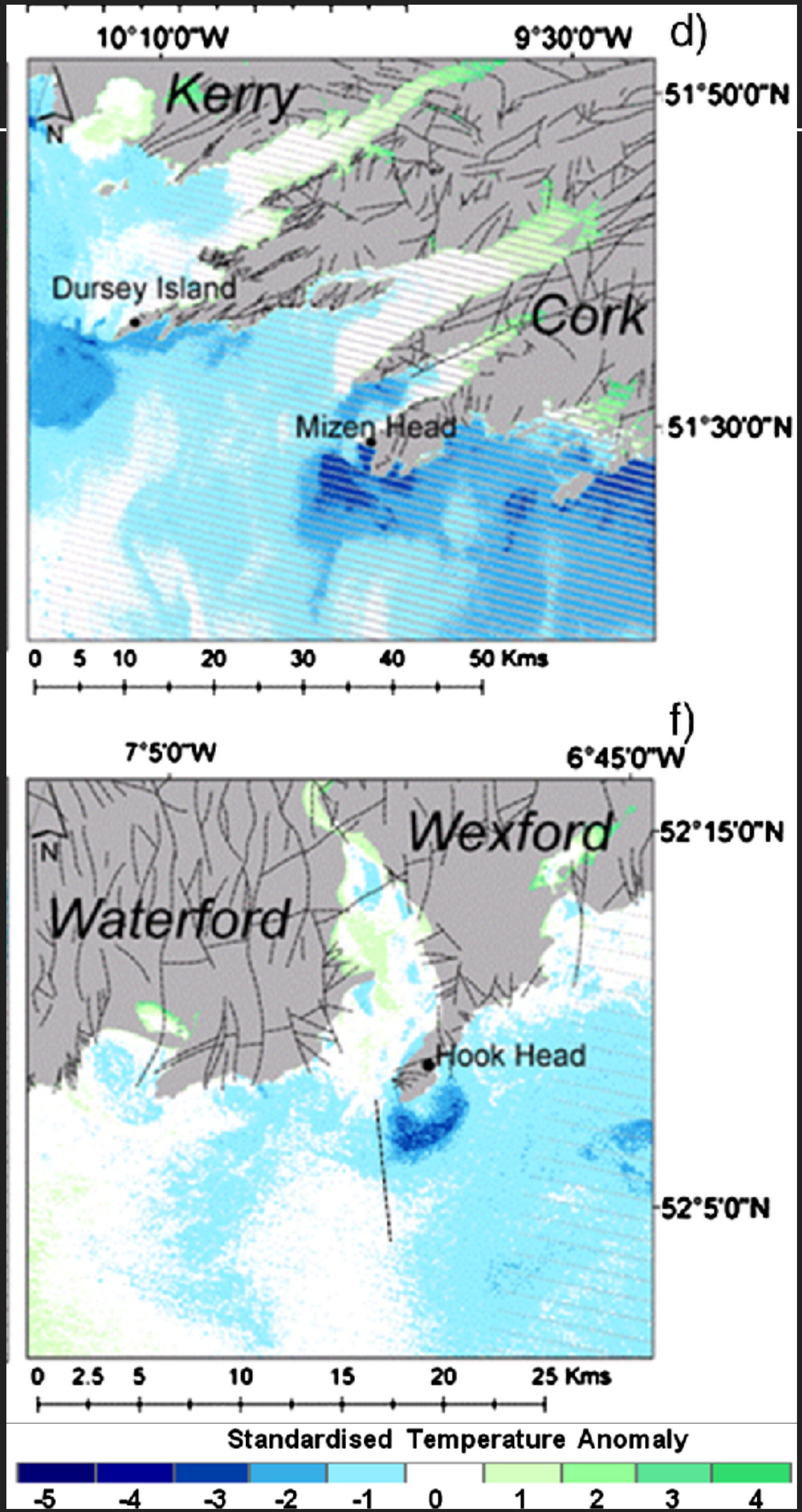


Landsat 8

SUBMARINE GROUNDWATER DISCHARGE

- Remote sensing approaches use TIR
- Move to field measurements to further assess SGD
- Can we go further with remote sensing data?

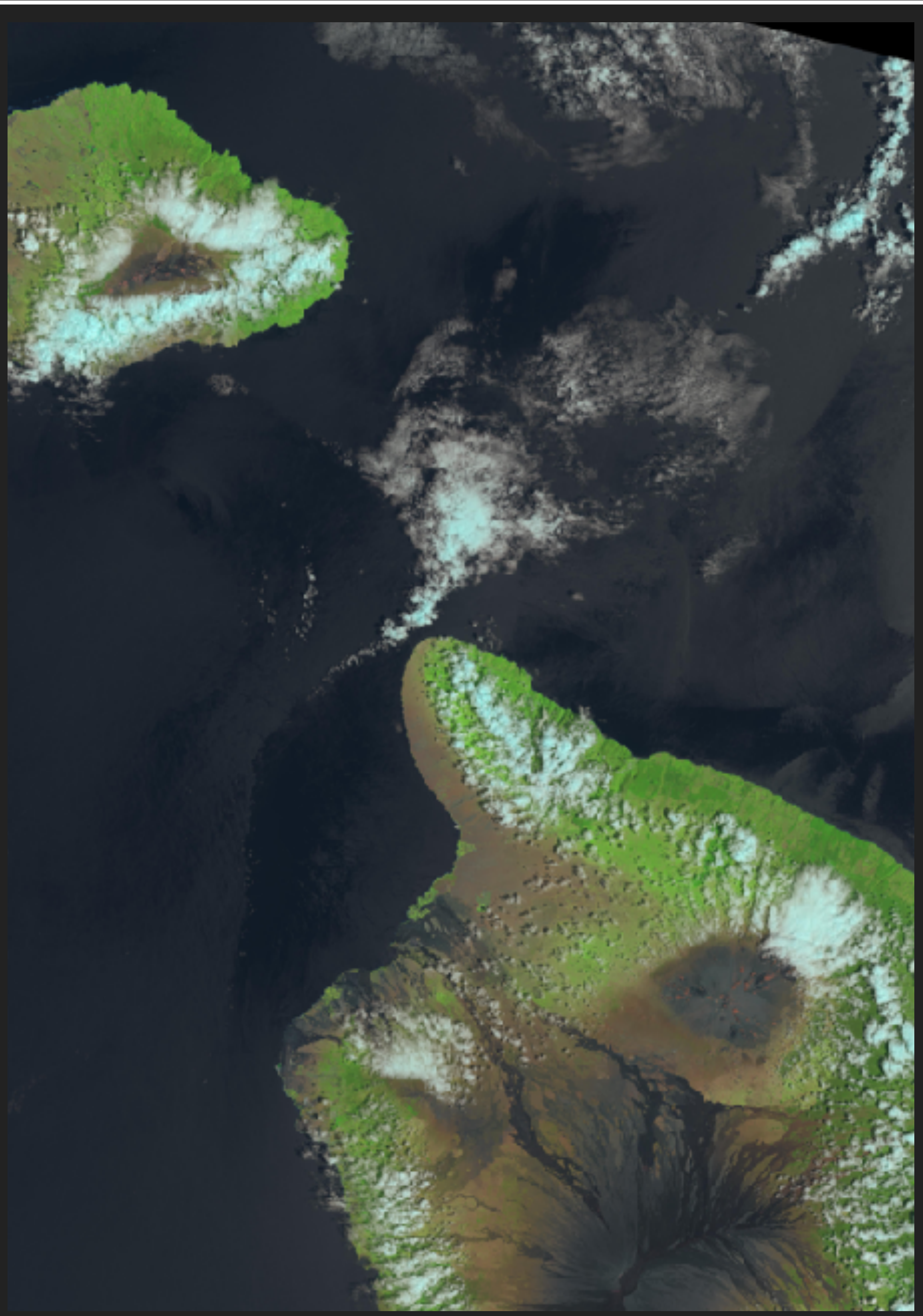




Adapted from Wilson and Rocha, 2012

IN THIS STUDY

- links to SST
- links to color
- TIR and VIS



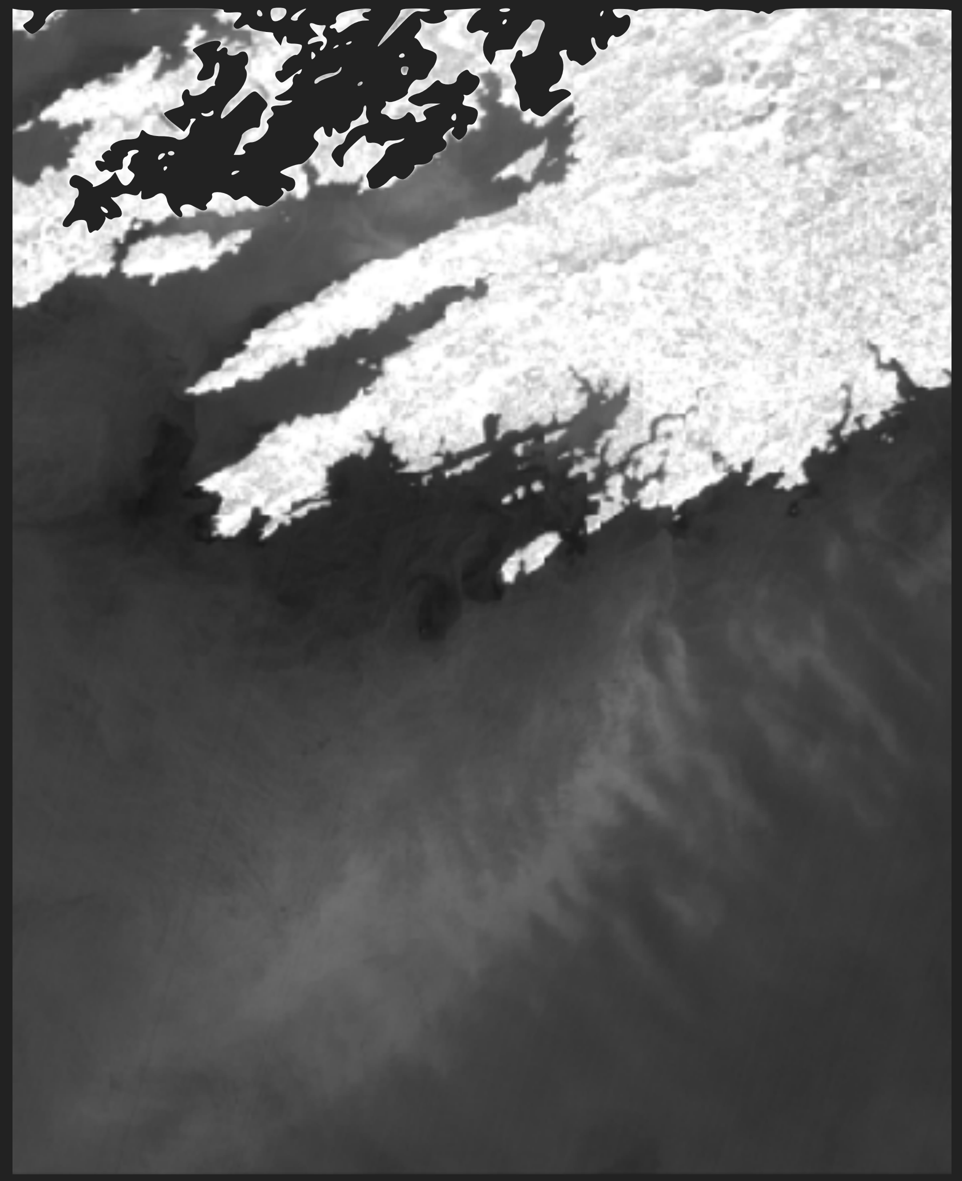
Visible (RGB)

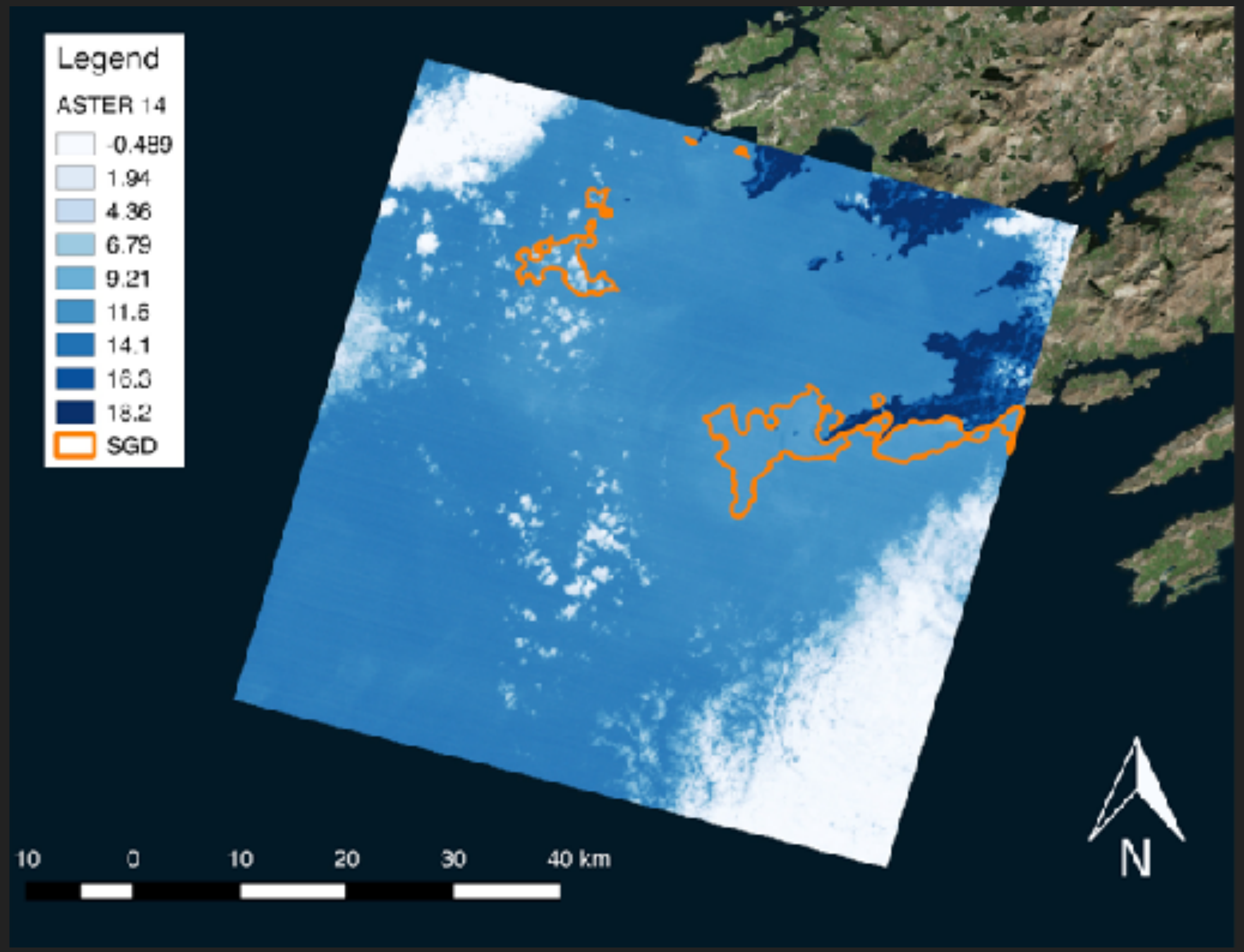
Thermal Infrared (TIR)

- Goal: better constrain locations of potential SGD occurrences
- Explore the links between SGD and changes in SST and OC through RS
- Map areas of PSGD and compare them with known locations

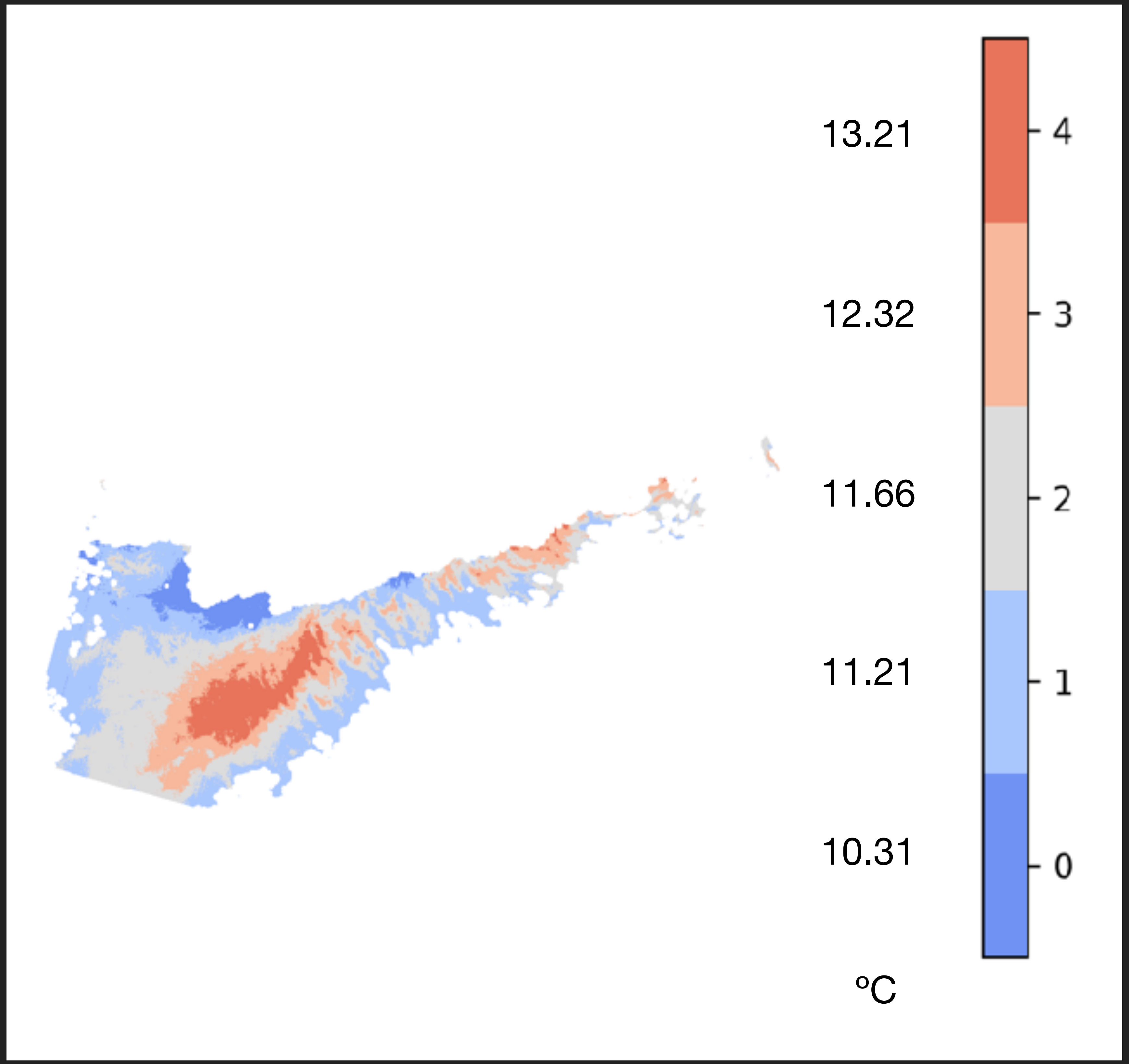
PRELIMINARY RESULTS

- Ocean Color vs Sea Surface Temperature
  - Experiments suggest that colder waters likely under the
    effect of SGD have different spectra (color)
  - Coldest and warmest waters have less color variability
  - Identified subset of colors per temperature interval
- Temperature anomalies
  - Automatic method
  - Pinpoint locations

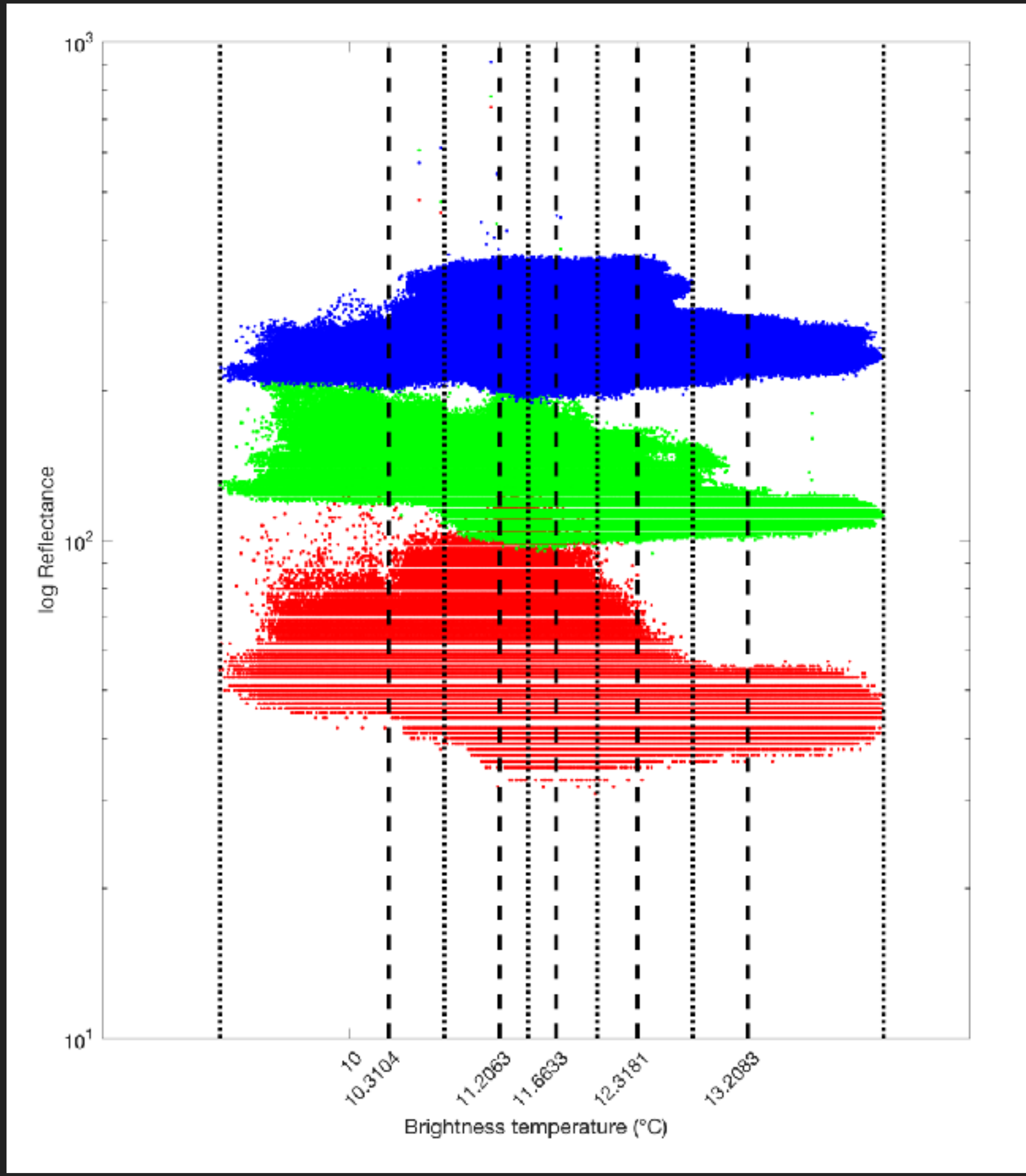




TEMPERATURE VS VISIBLE SPECTRA



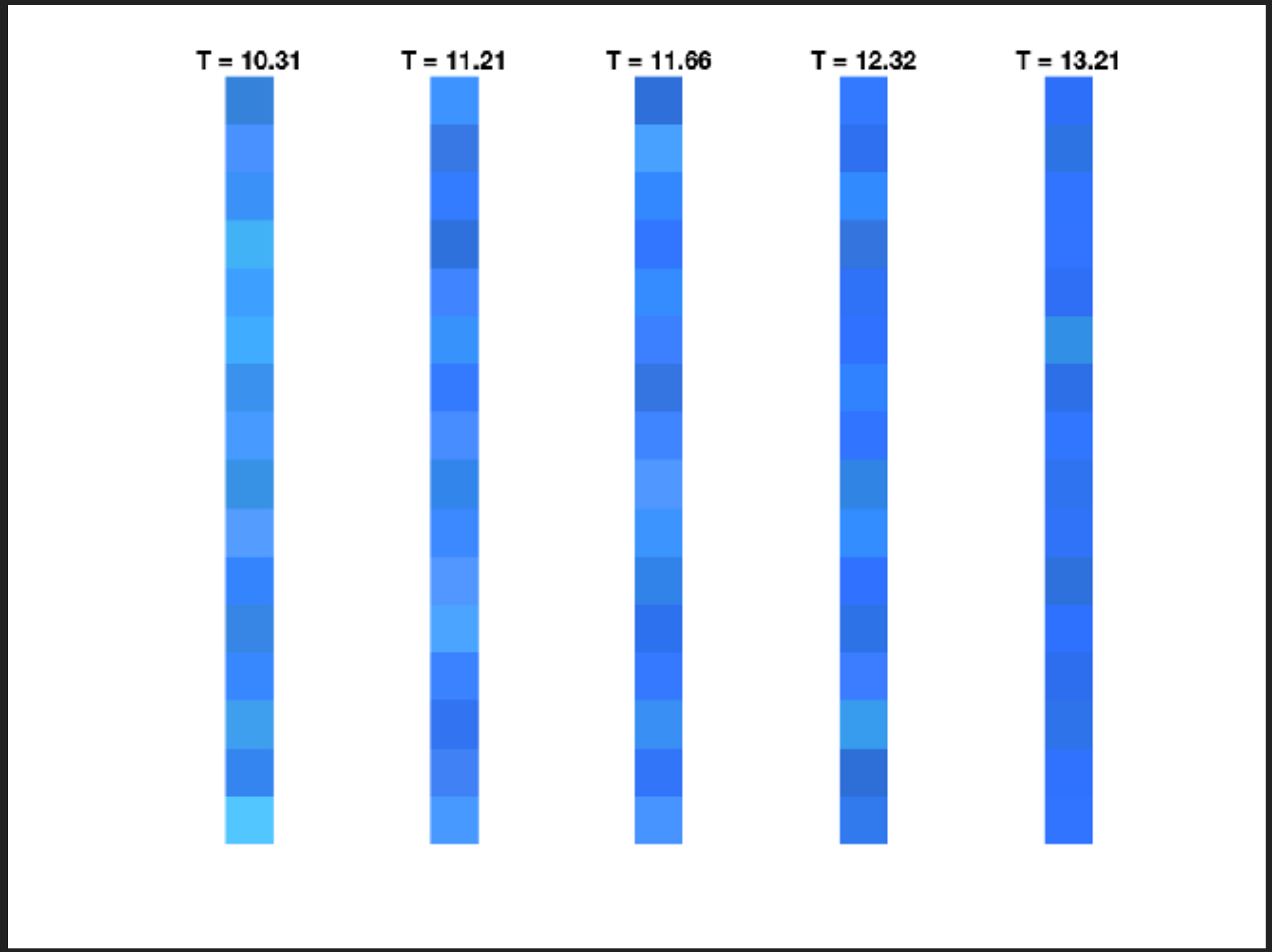
5 TIR ranges

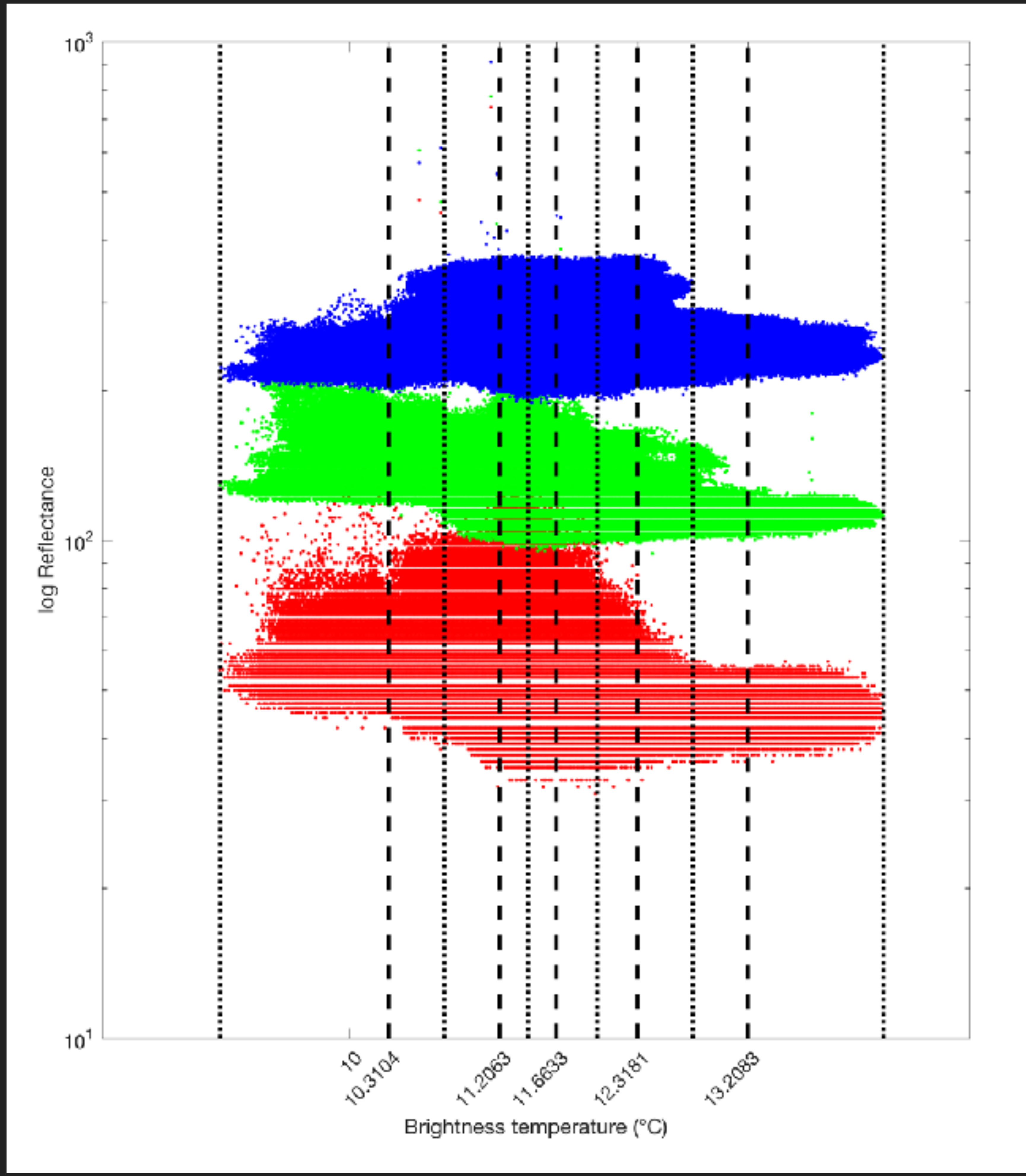


5 TIR ranges

TEMPERATURE VS VISIBLE SPECTRA

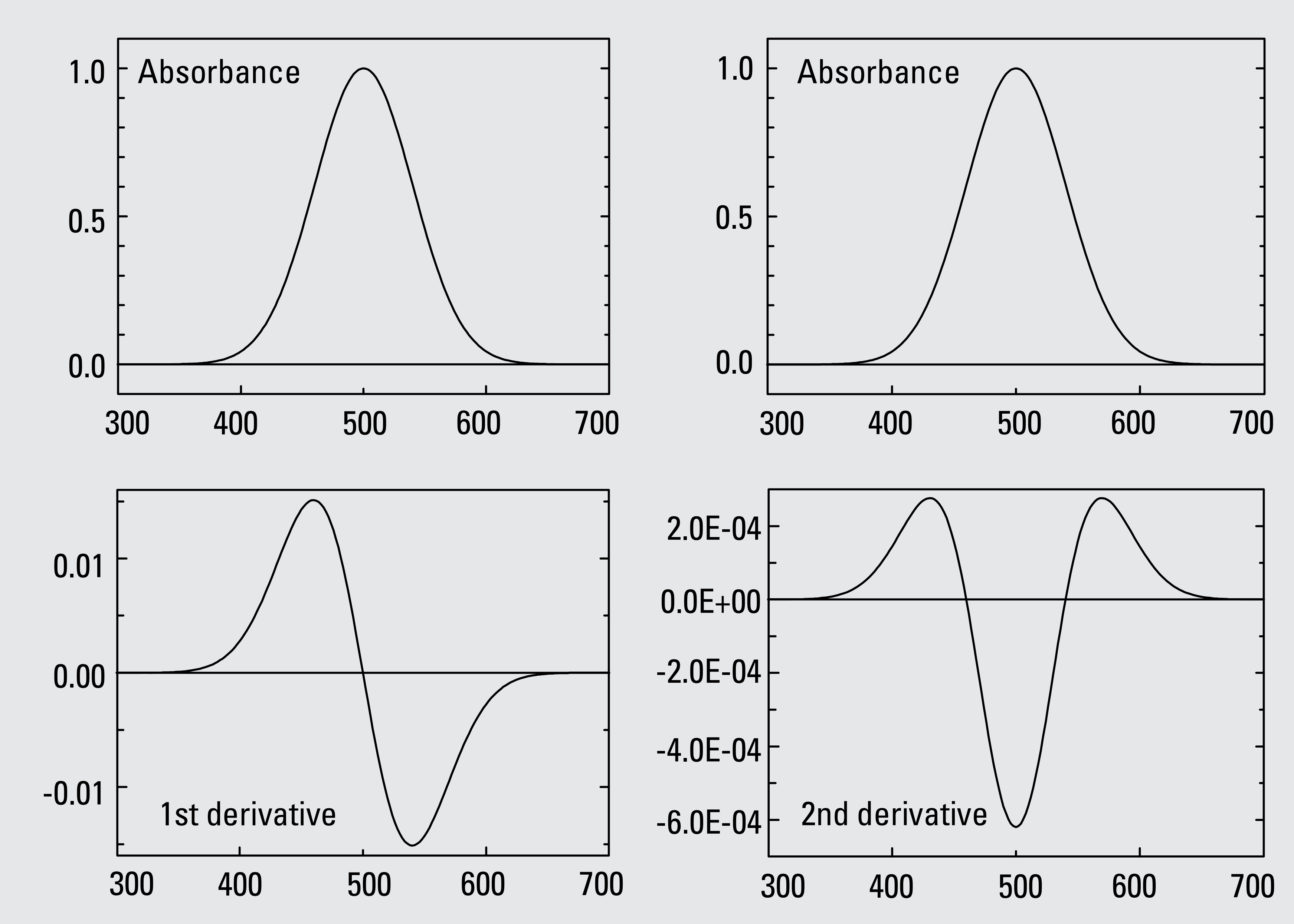
- What colors are in each TIR range?
  - Quantize to 16 colors





5 TIR ranges

DERIVATIVE SPECTROSCOPY



Adapted from Owen, 1995

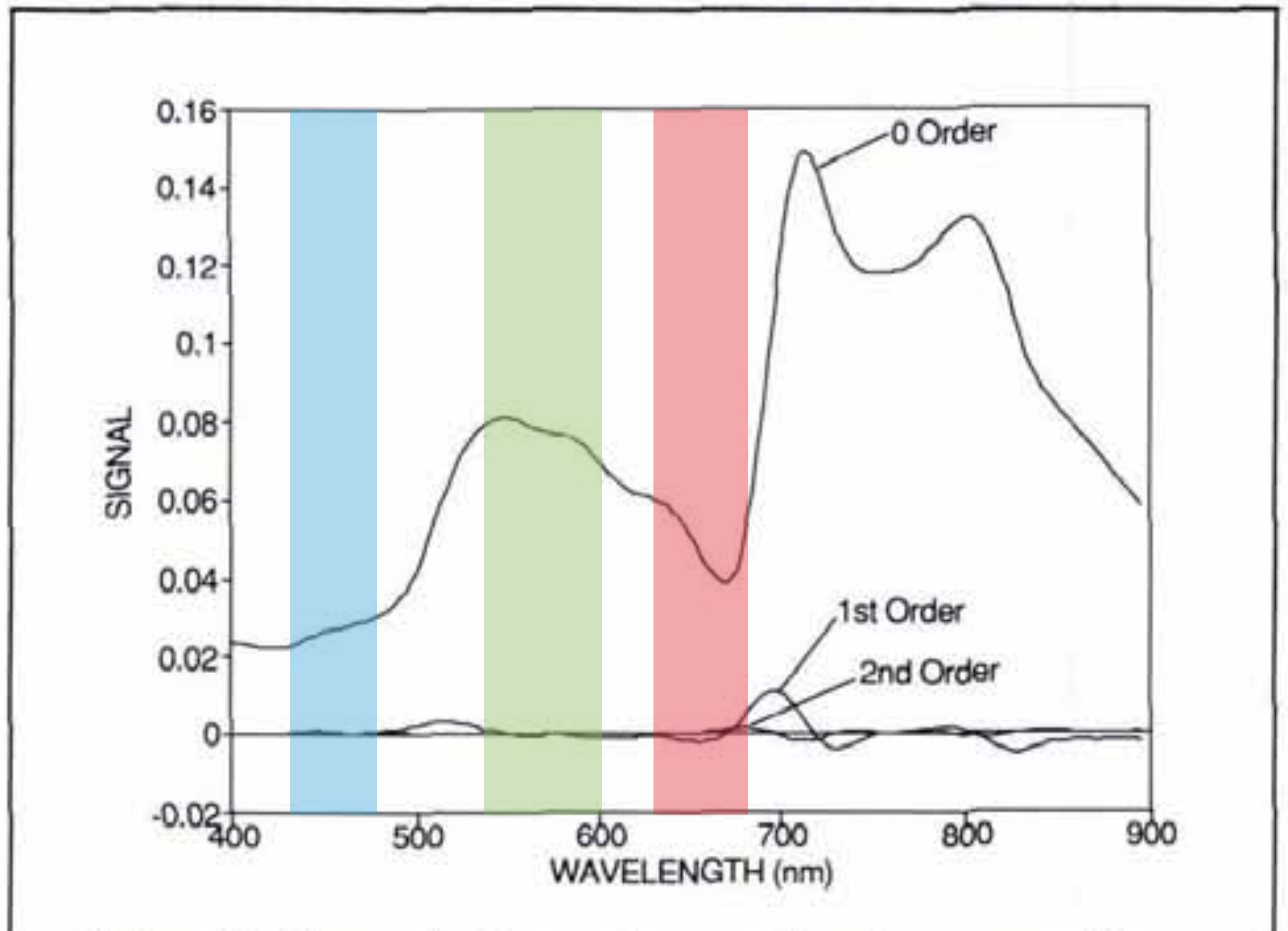
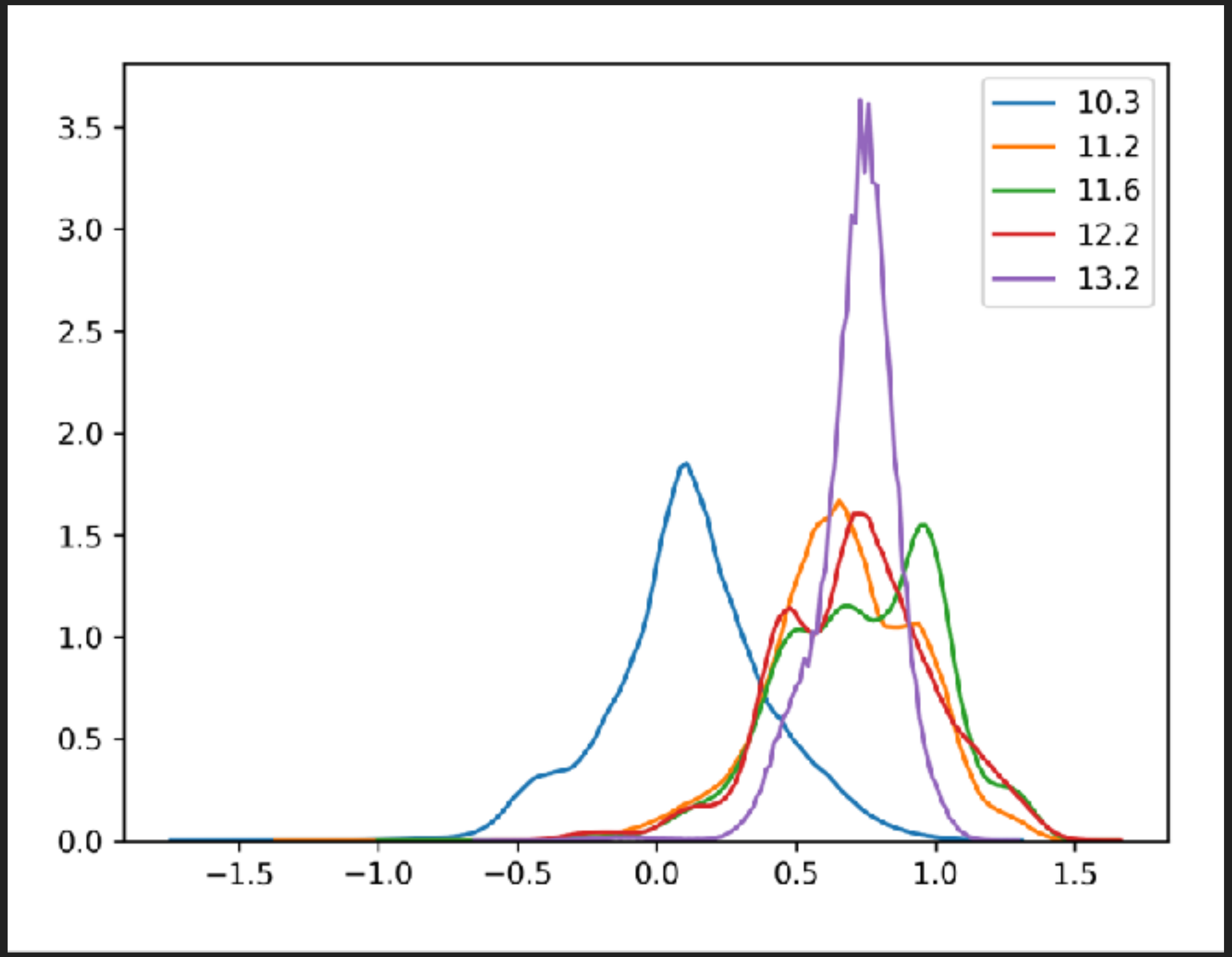


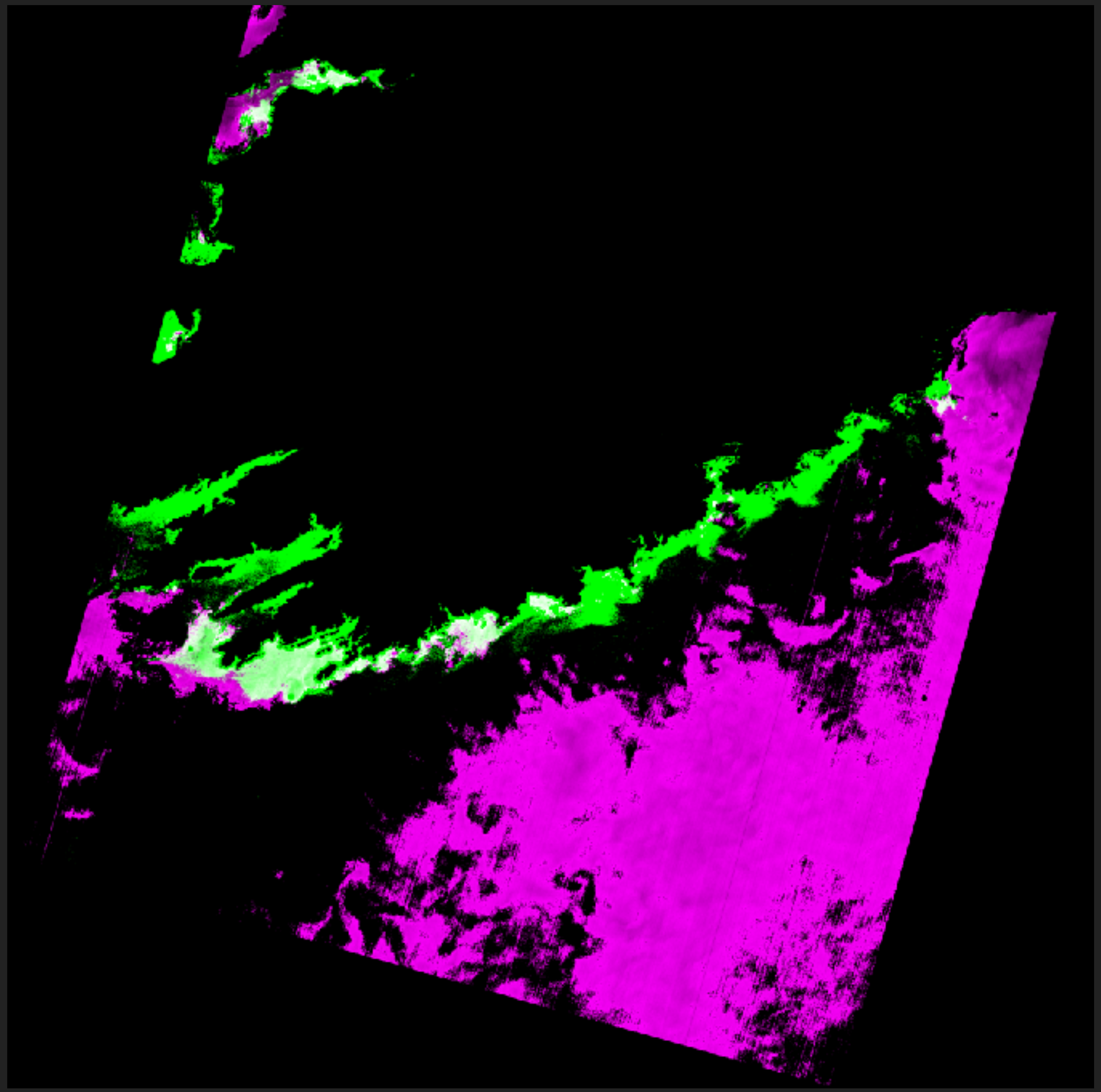
Figure 3. Zero-, first-, and second-order curves for water with suspended sediments and algal chlorophyll.

Adapted from Goodin et al., 1993

DERIVATIVE SPECTROSCOPY



PDF of 2nd derivative per cluster

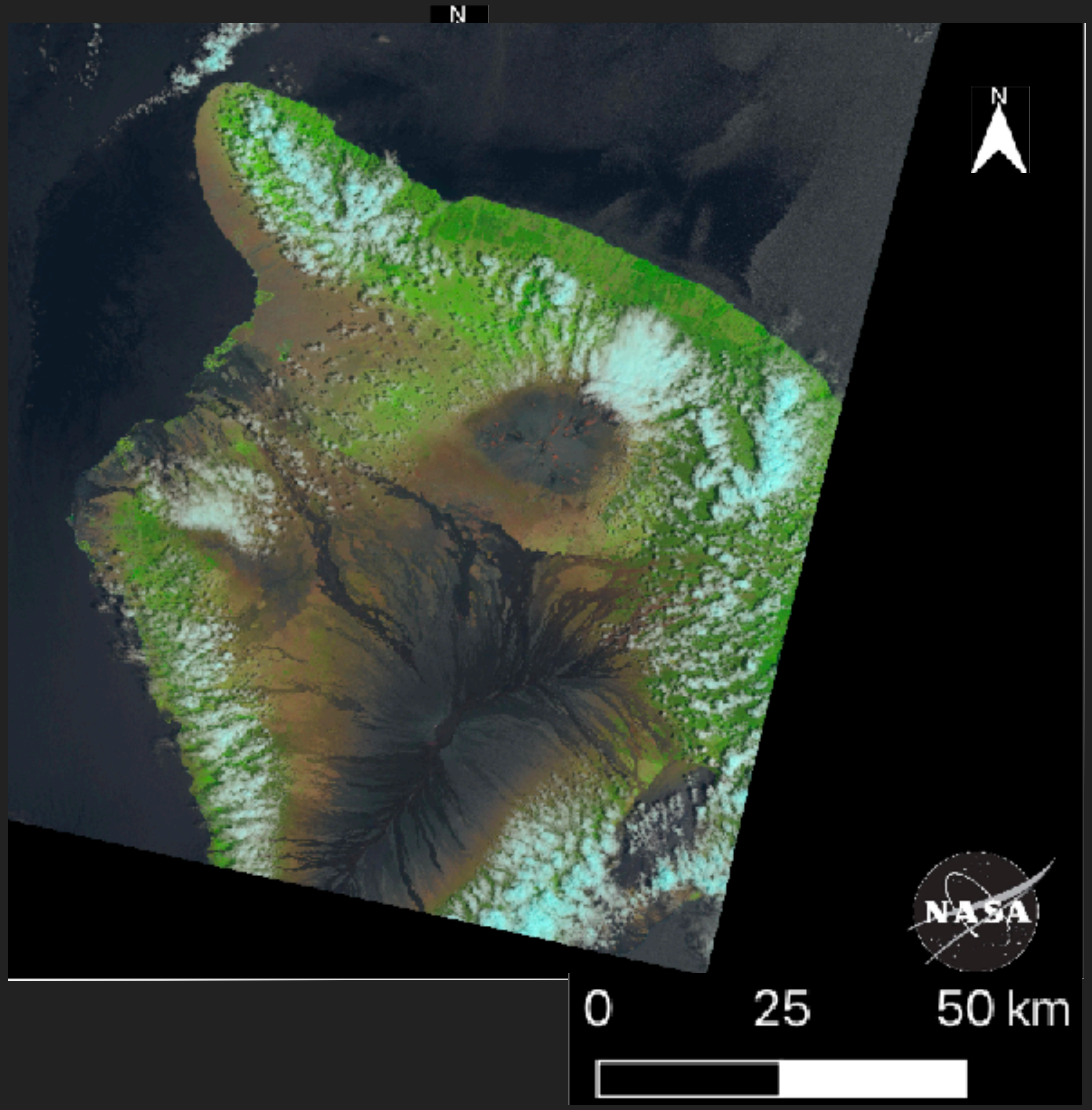


Green: Change of signal in the 2nd derivative
Purple: temperature lower than the mean
White: both conditions

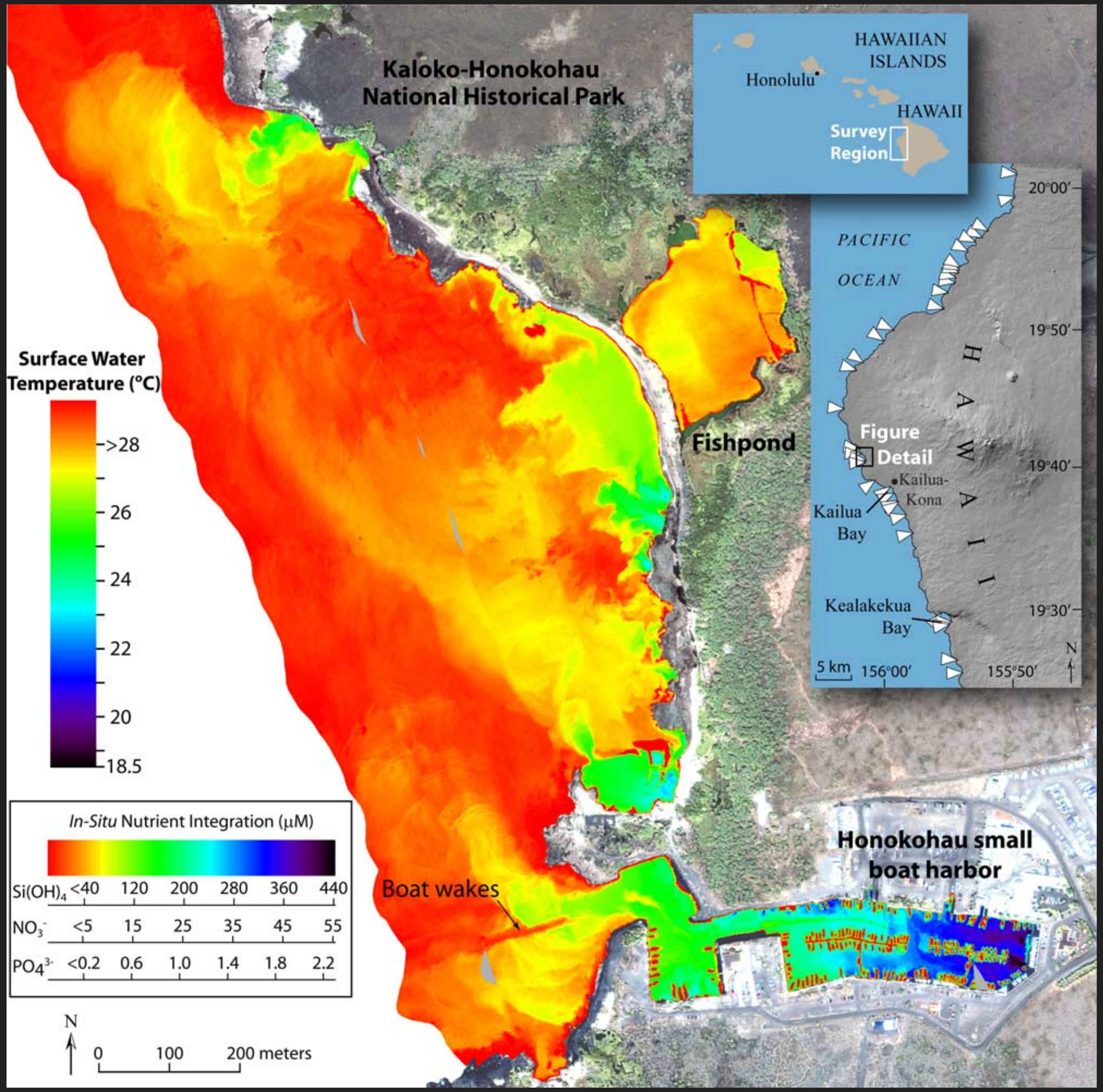
CHALLENGES AND LIMITATIONS

- Limitations
  - Experiment with other locations and seasons
  - Refine clustering steps, further analyze descriptors
  - Focus on coastal areas, where SGD is more likely to occur
  - Limited matching with the expected (lab) spectrum
- Possible solutions
  - more bands/coverage over the red-edge

CASE STUDY

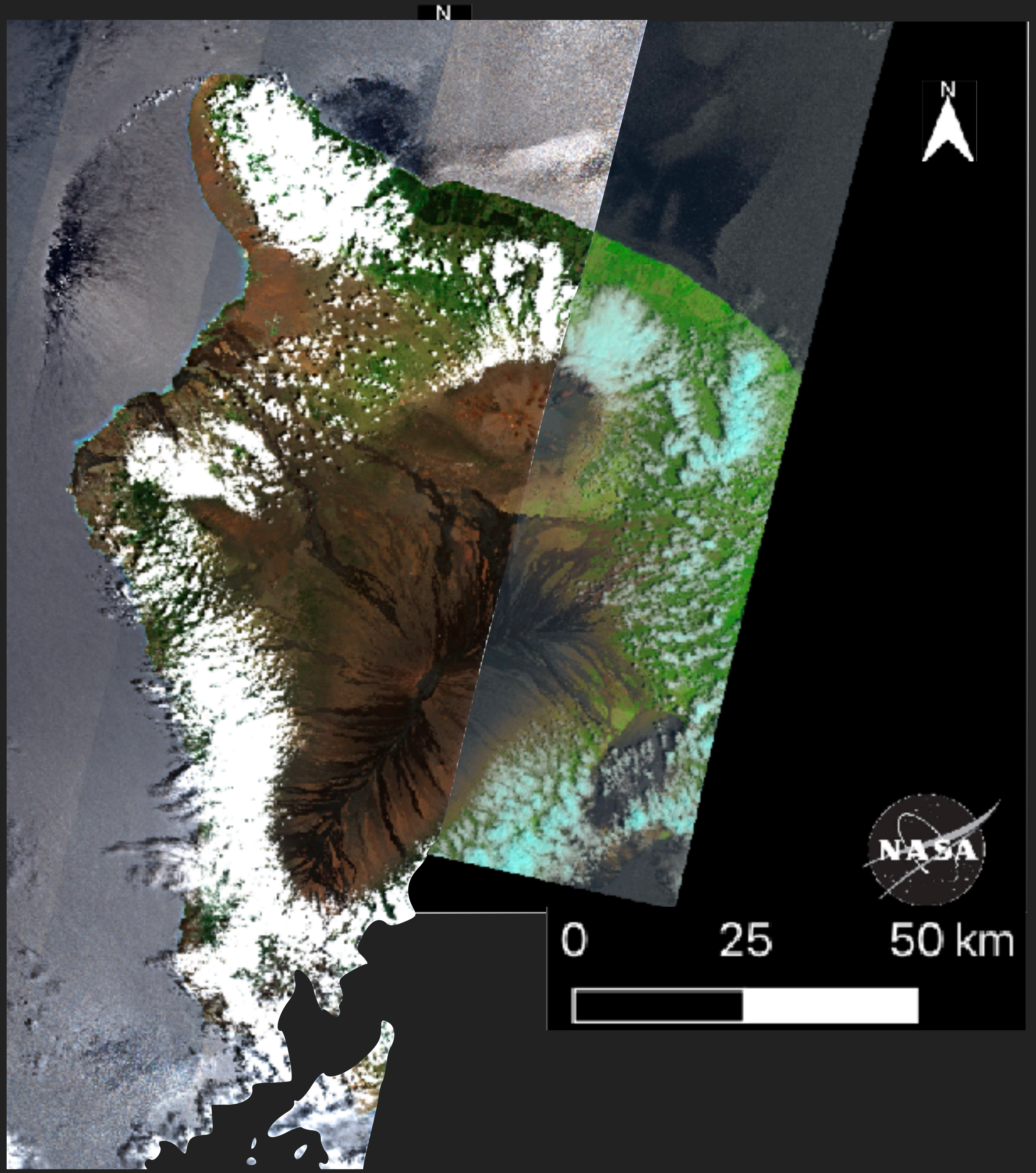


Landsat 8 2019-04-06 20:42:41 UTC



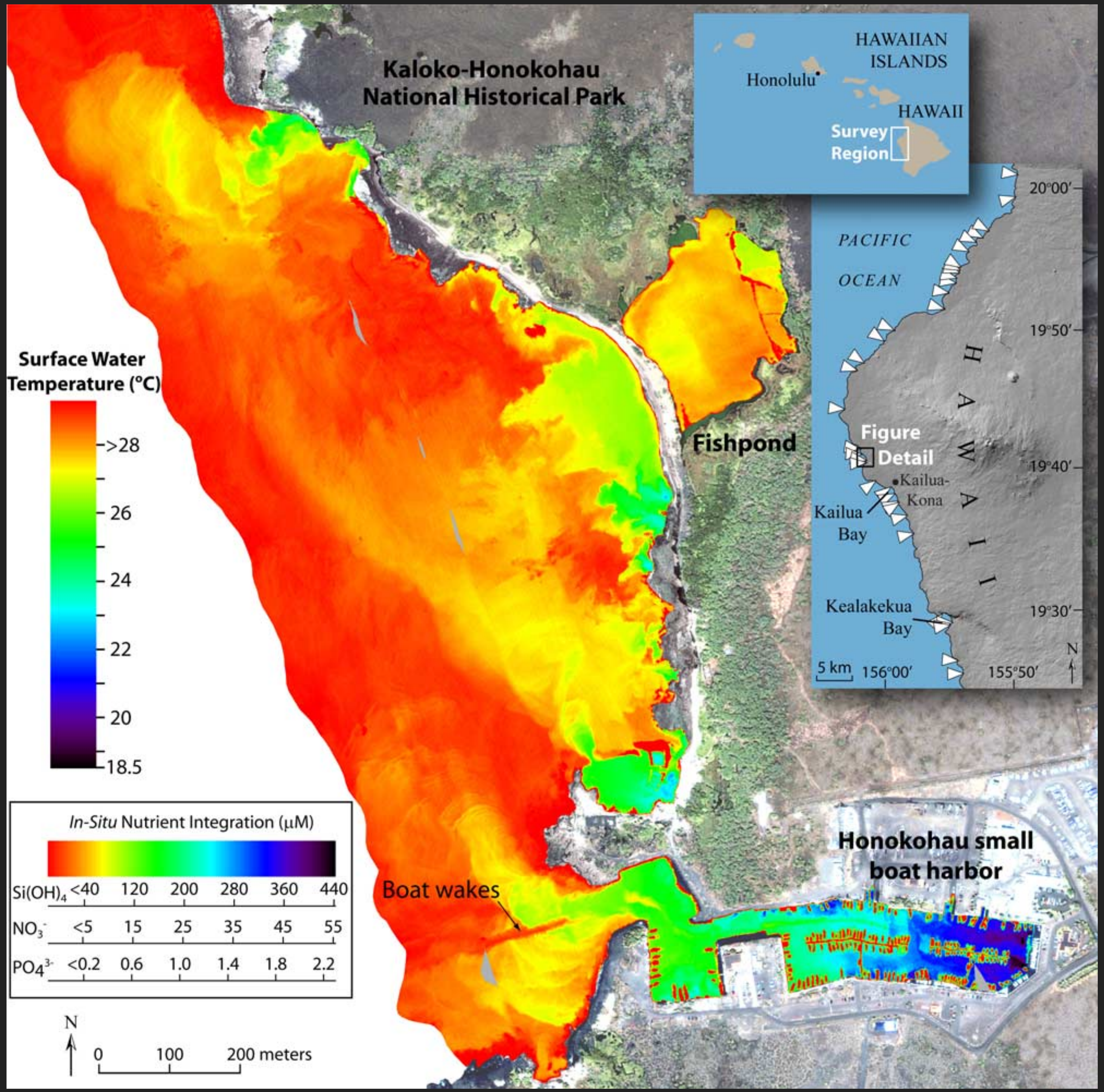
Adapted from Johnson et al., 2008

CASE STUDY



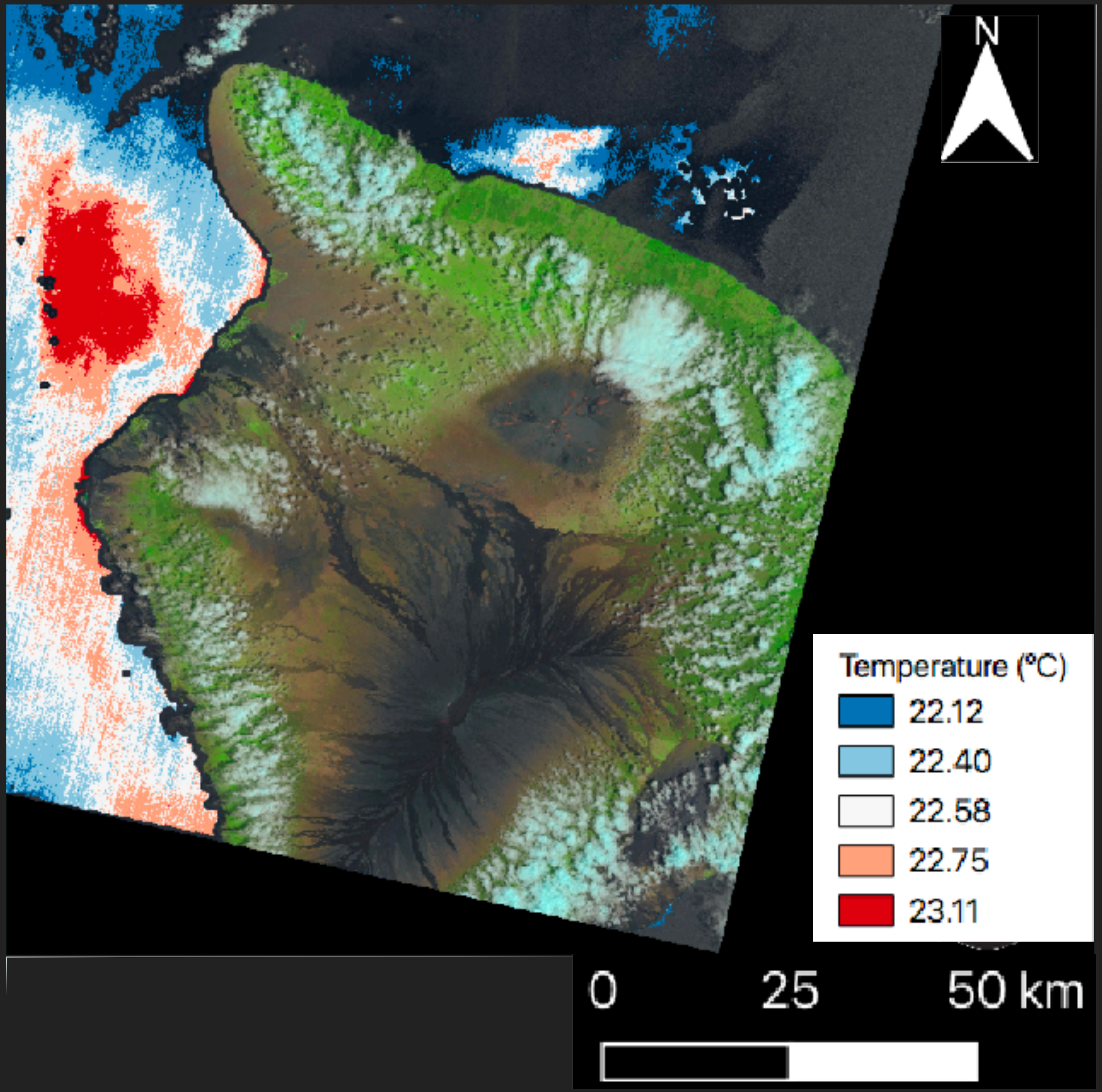
Landsat 8 2019-04-06 20:42:41 UTC

Sentinel-2A 2019-04-06 21:05:51 UTC

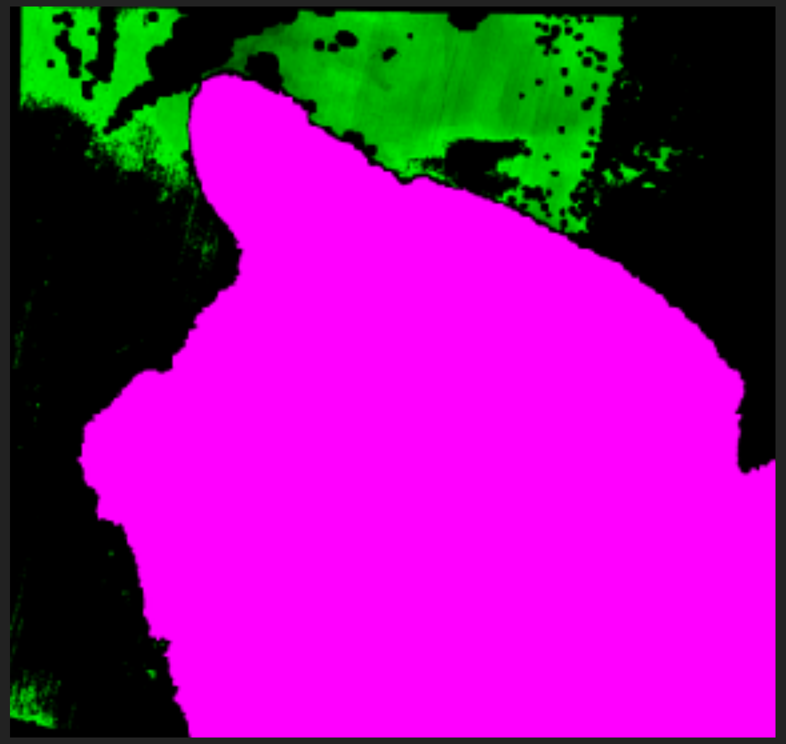


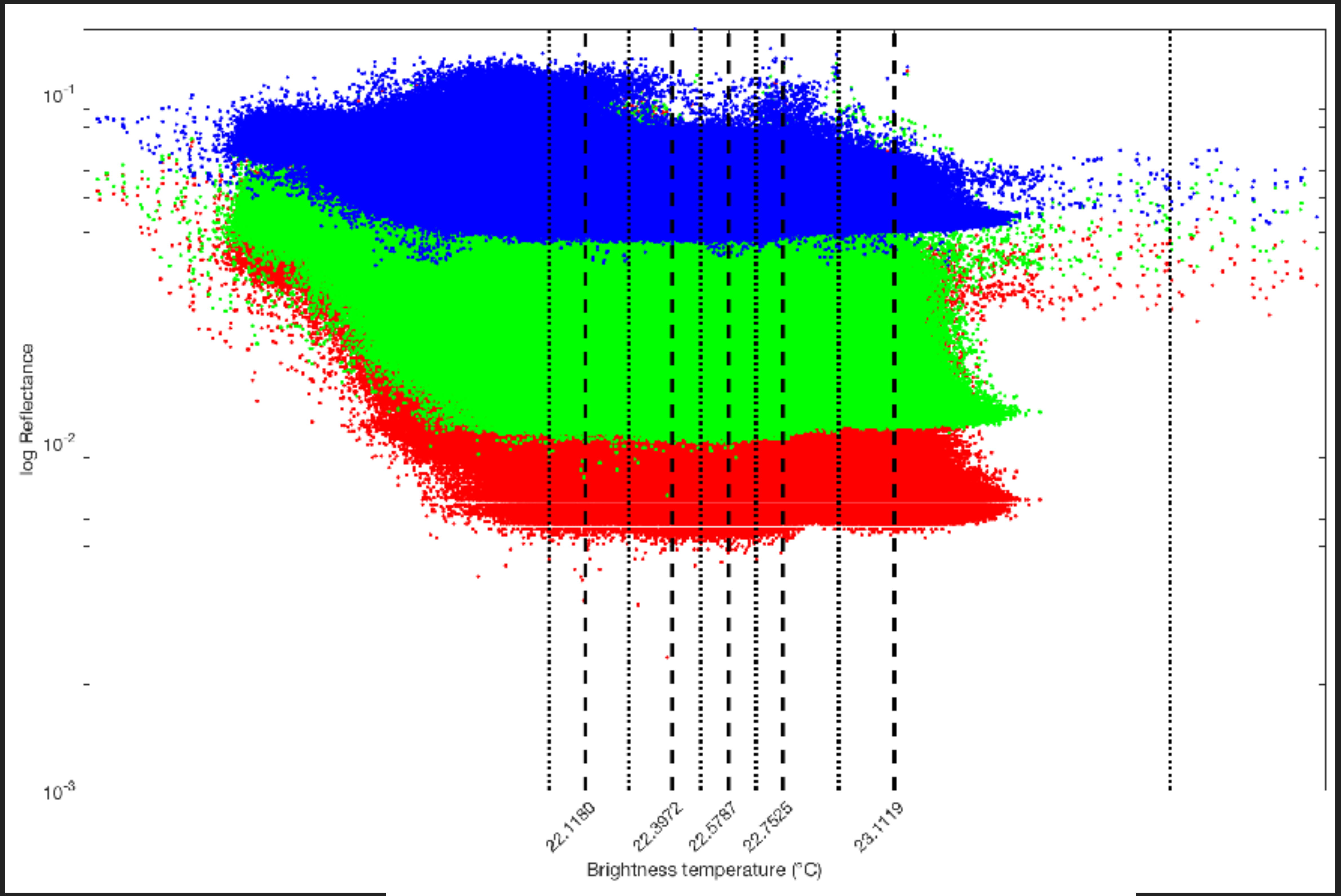
Adapted from Johnson et al., 2008

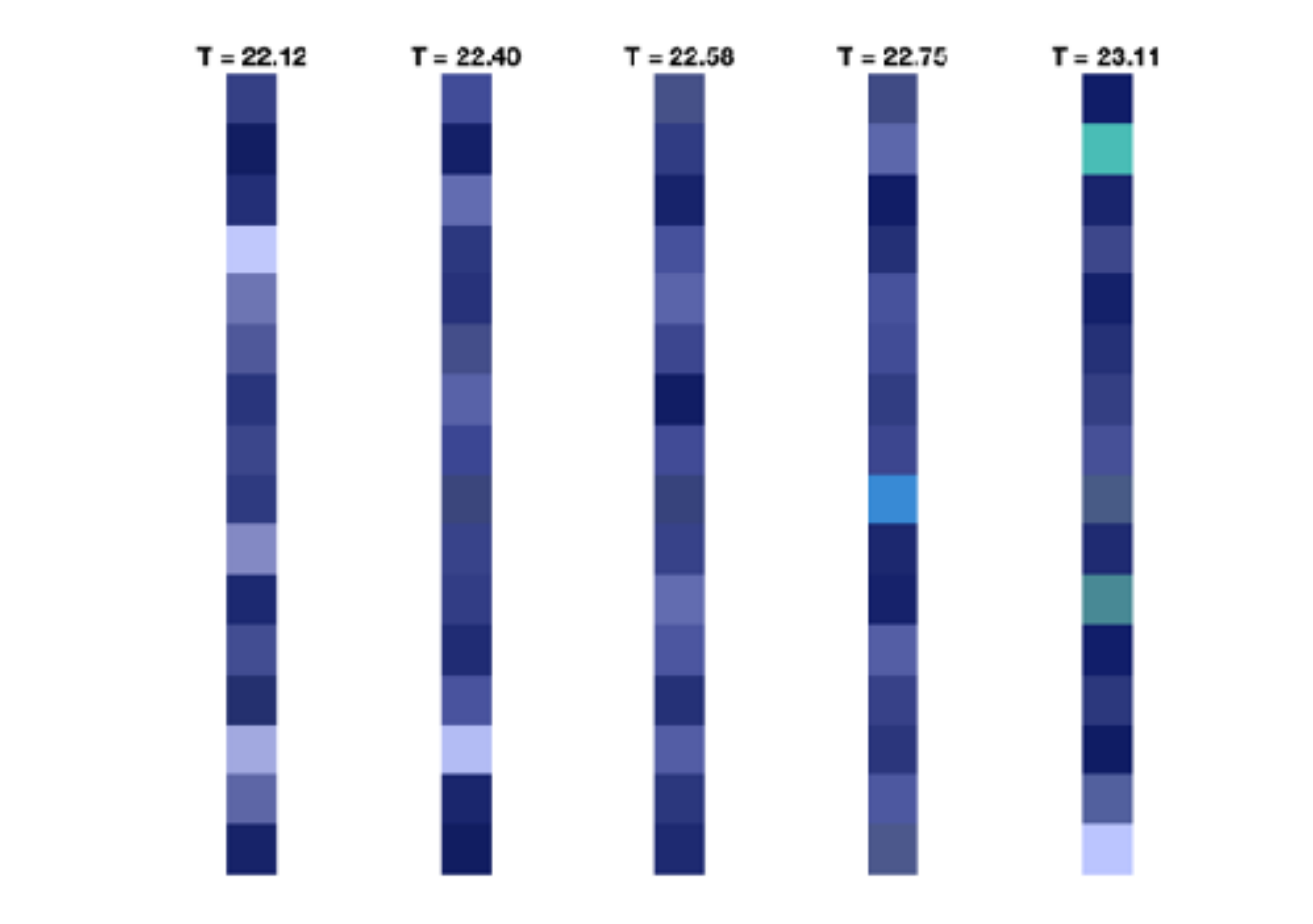
TEMPERATURE VS VISIBLE SPECTRA



Temperature below average







DERIVATIVE SPECTROSCOPY — LANDSAT 8 VS SENTINEL 2

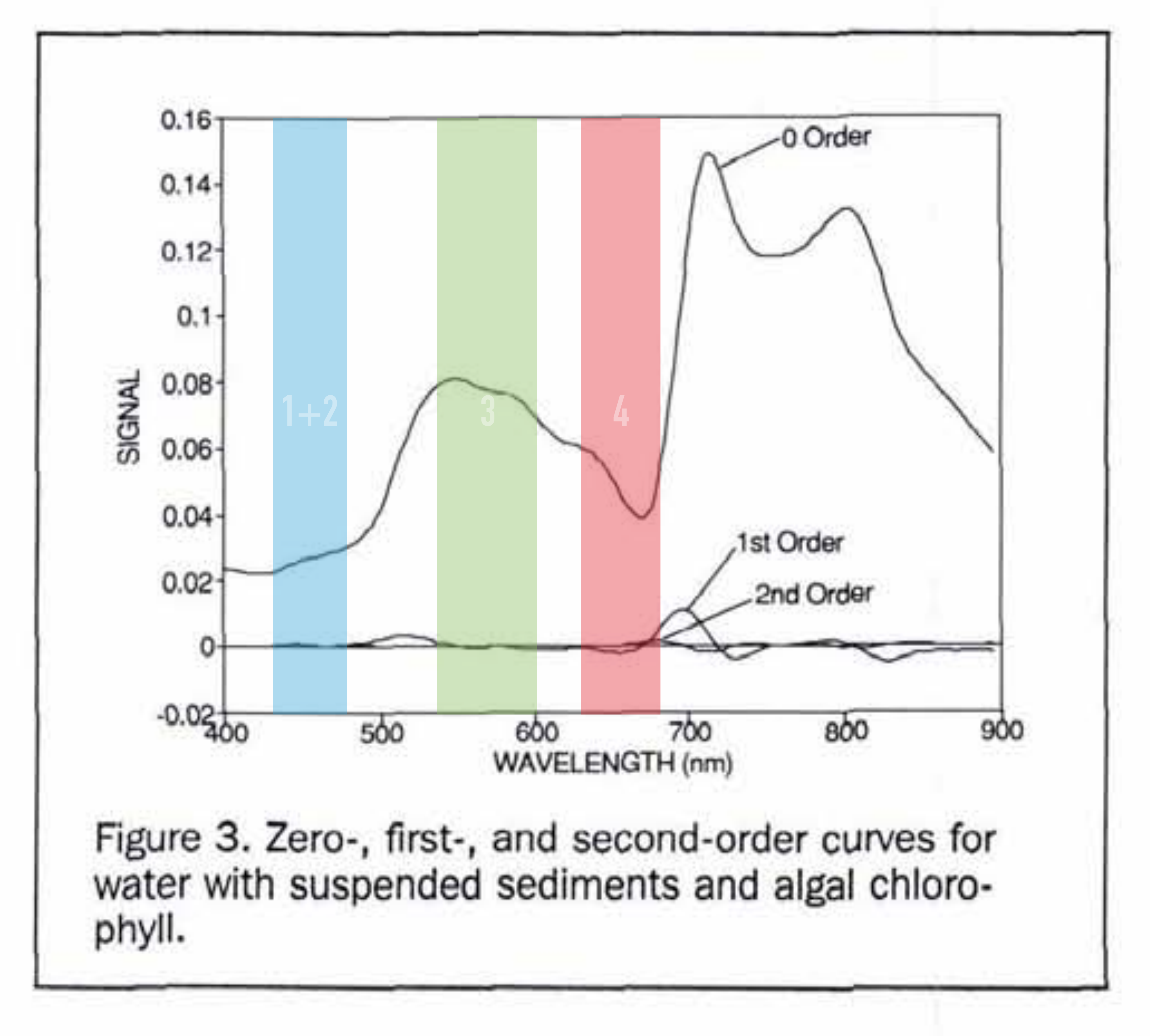


Figure 3. Zero-, first-, and second-order curves for water with suspended sediments and algal chlorophyll.

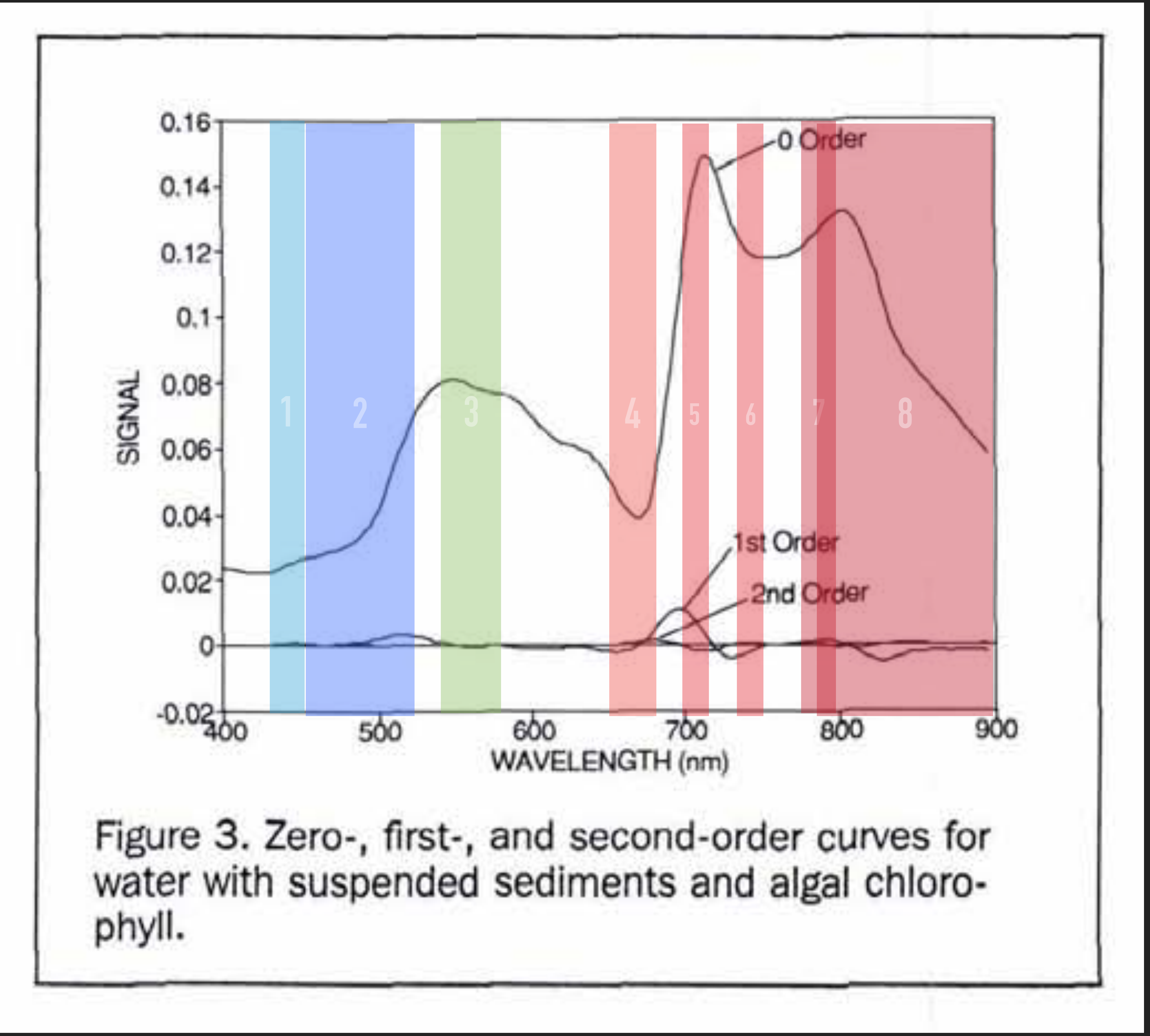
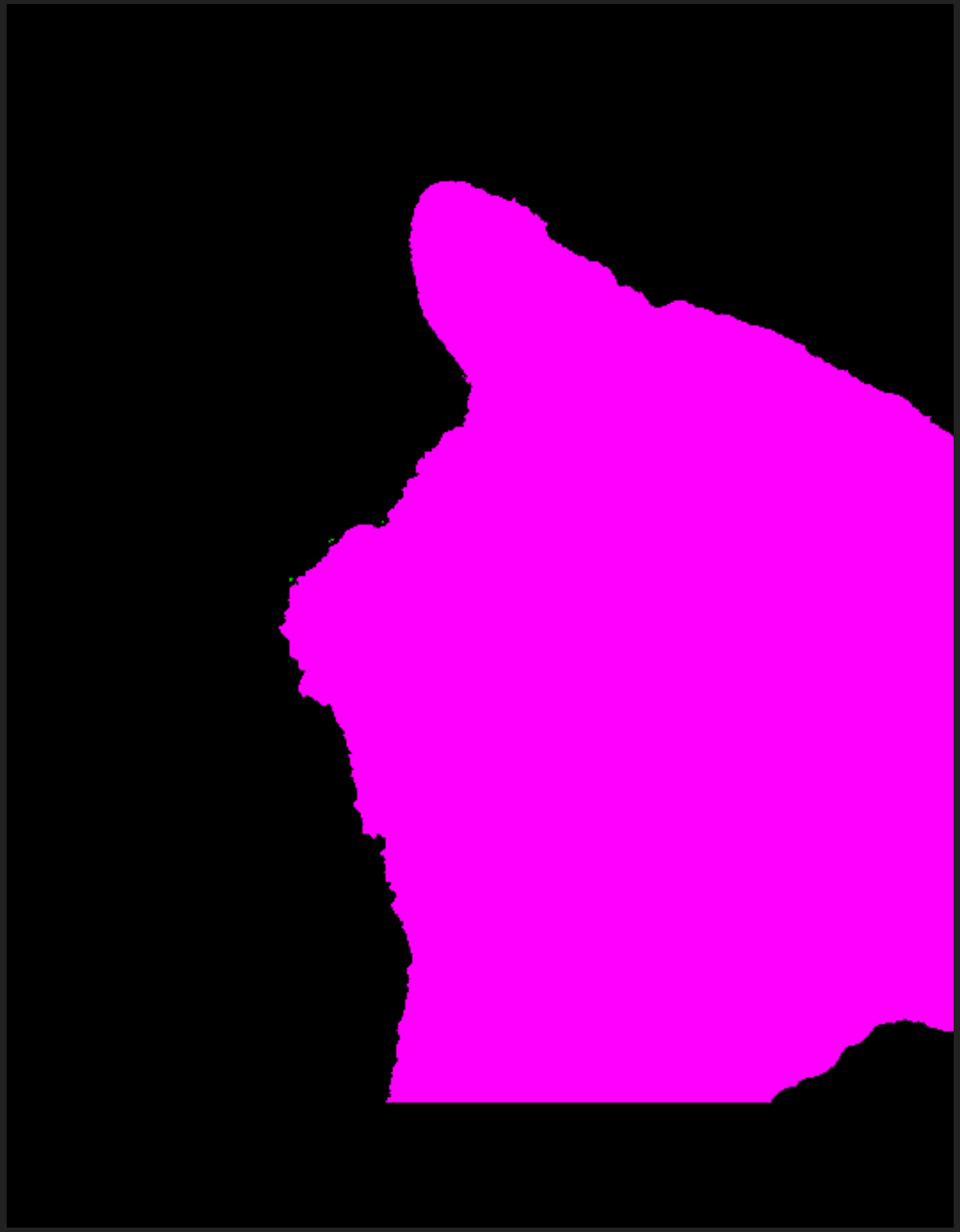


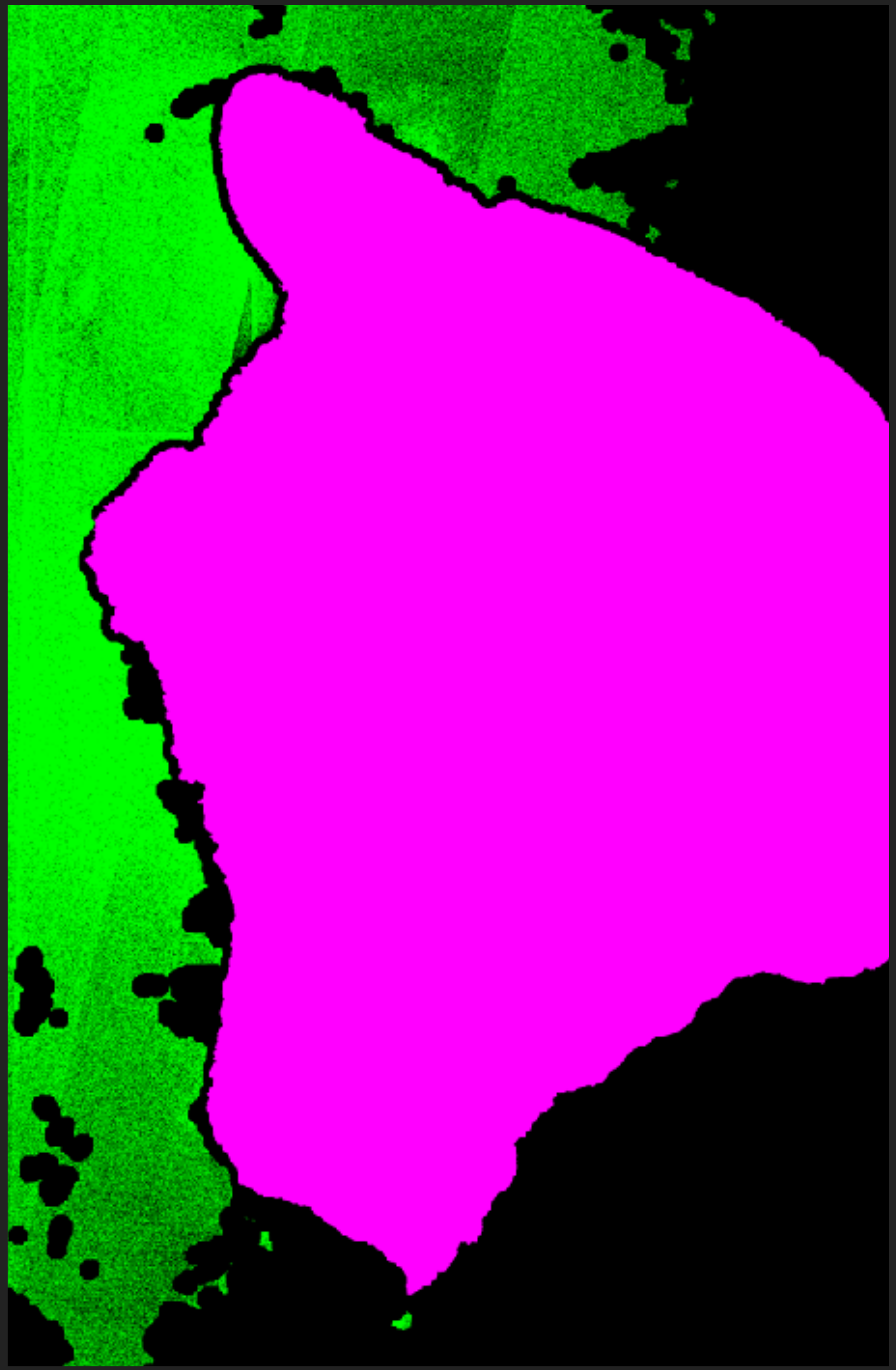
Figure 3. Zero-, first-, and second-order curves for water with suspended sediments and algal chlorophyll.

Adapted from Goodin et al., 1993

DERIVATIVE SPECTROSCOPY — LANDSAT 8 VS SENTINEL 2



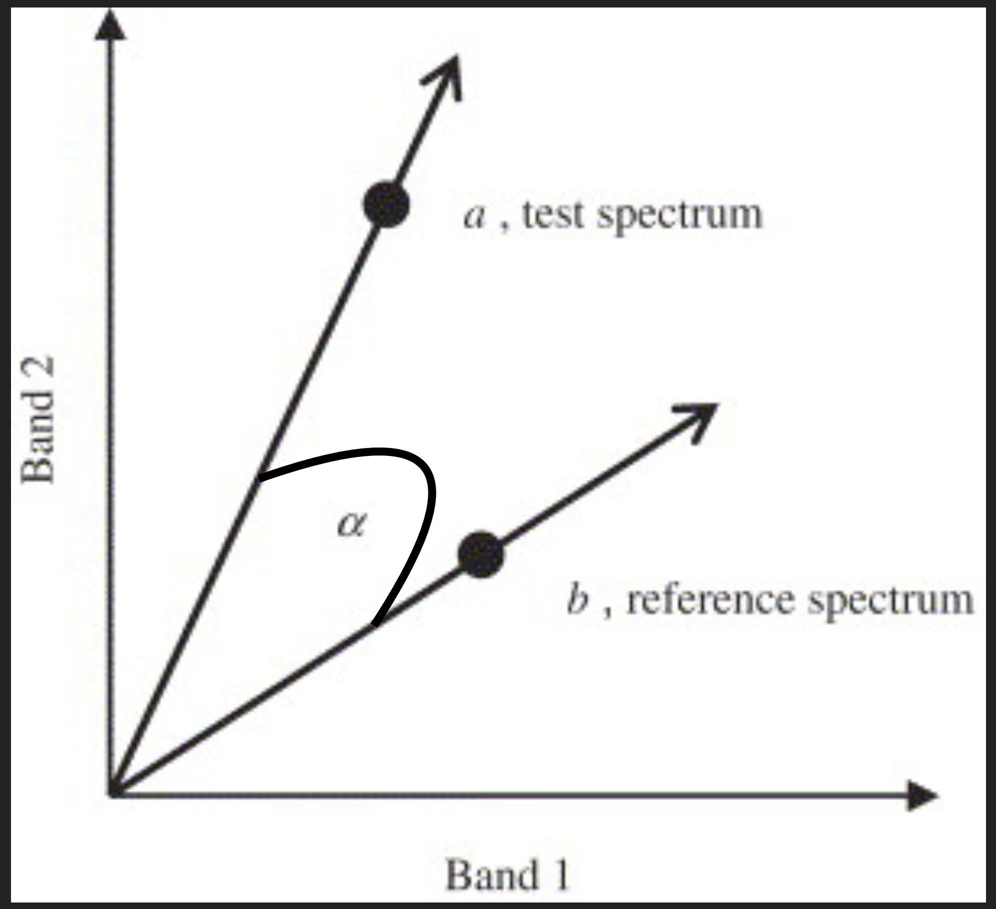
Landsat 8 (3–4)



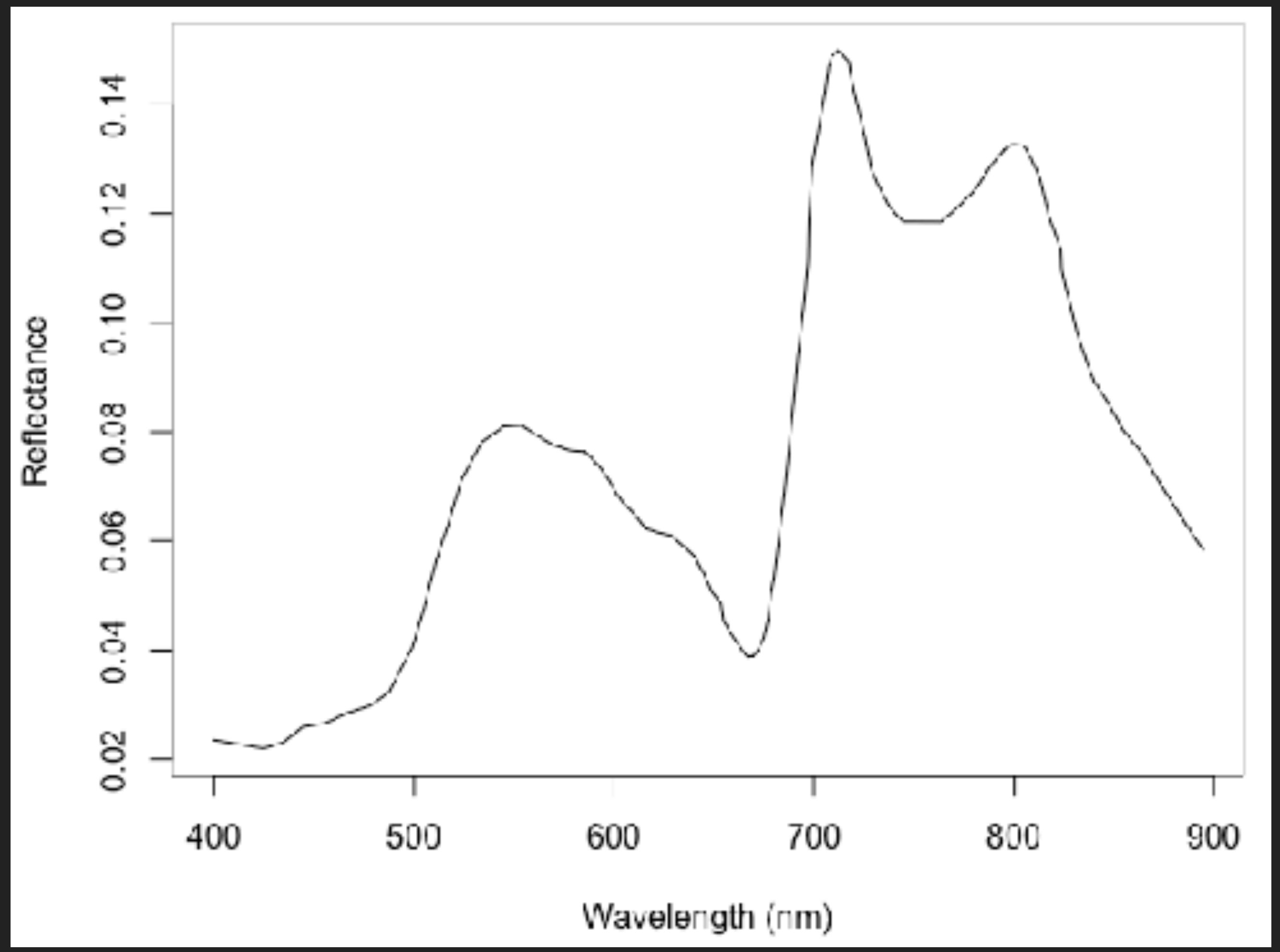
Sentinel 2 (3–4)

Sentinel 2 (4–5)

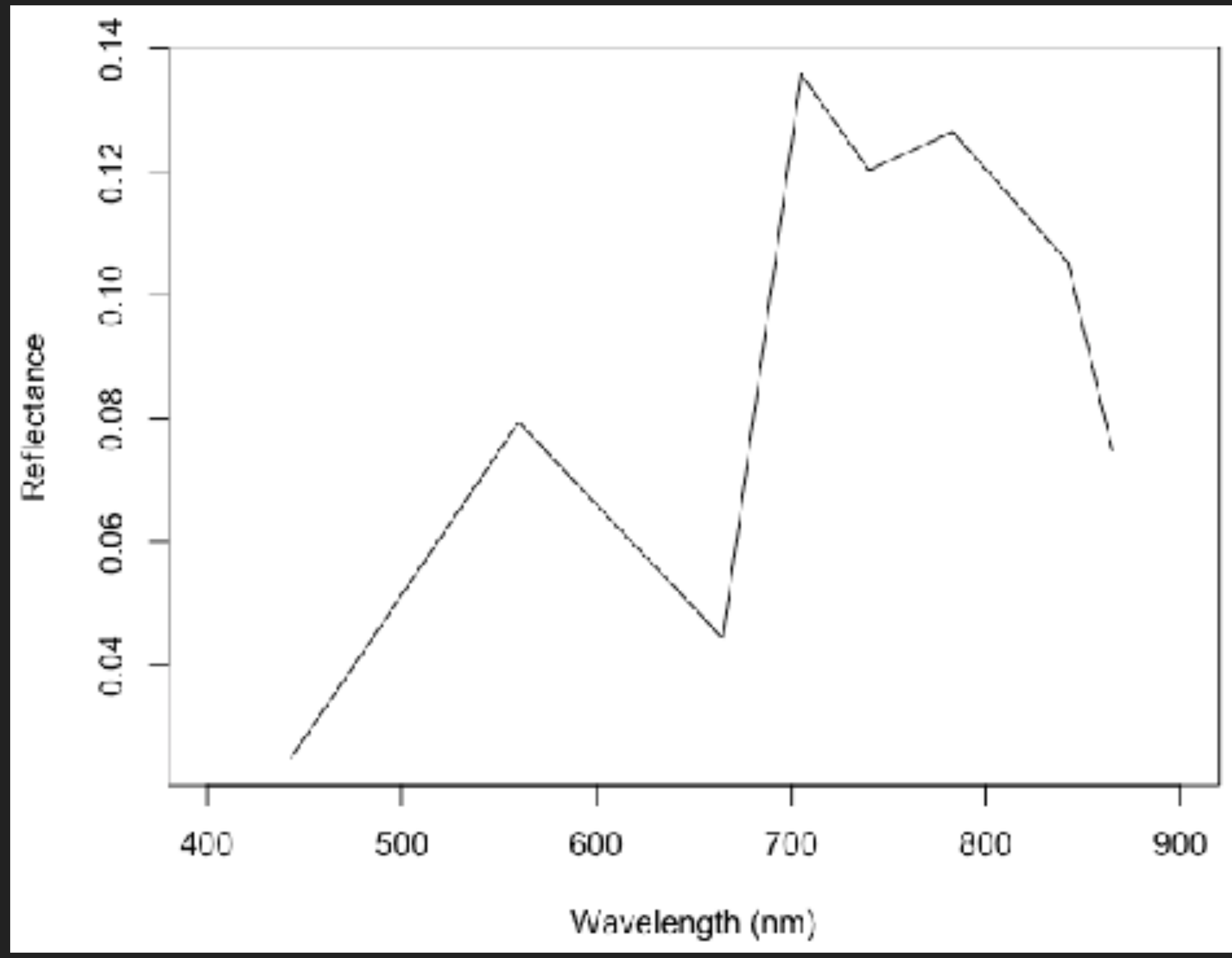
SPECTRAL ANGLE MAPPER



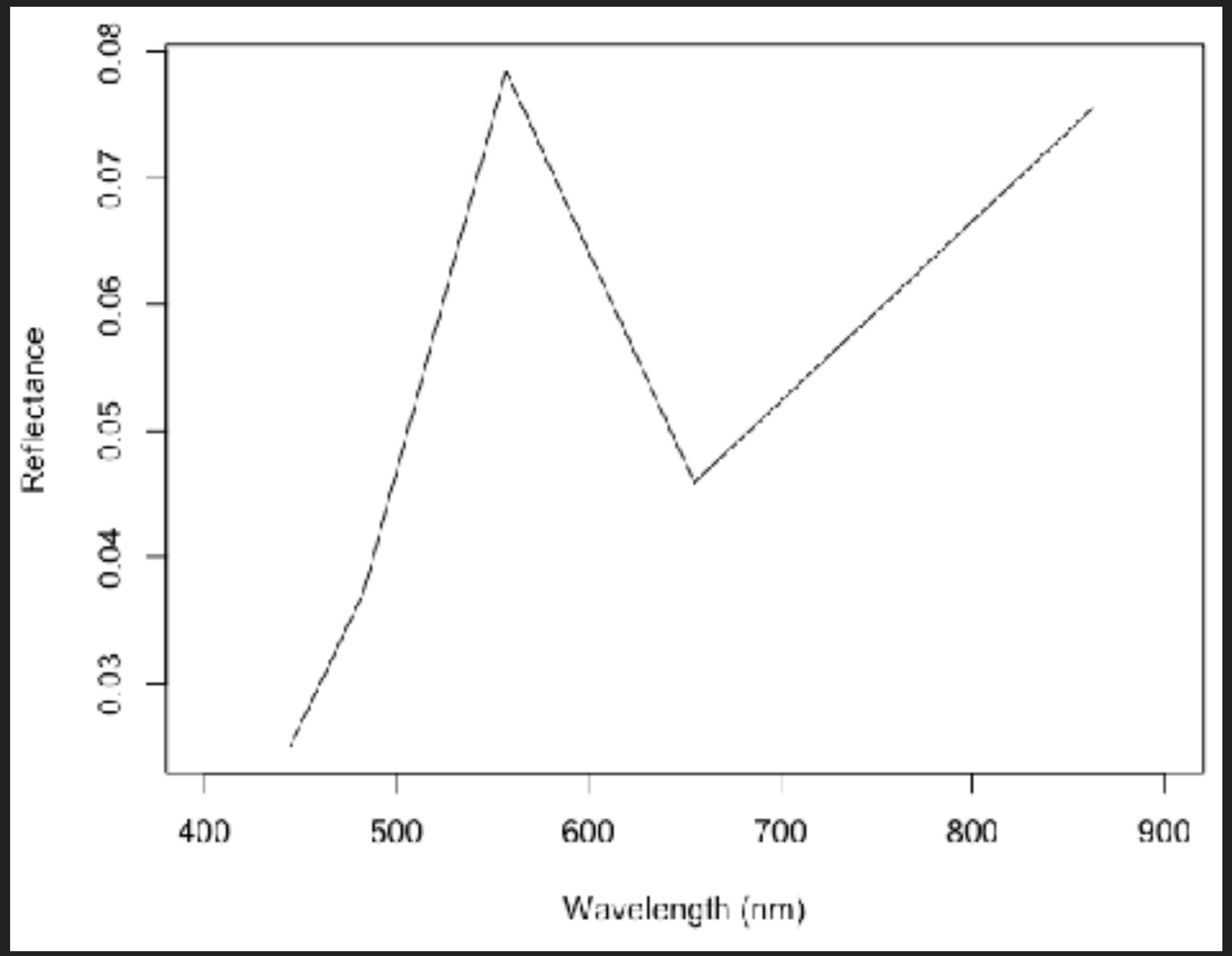
Adapted from Park et al.. 2007



Adapted from Goodin et al., 1993



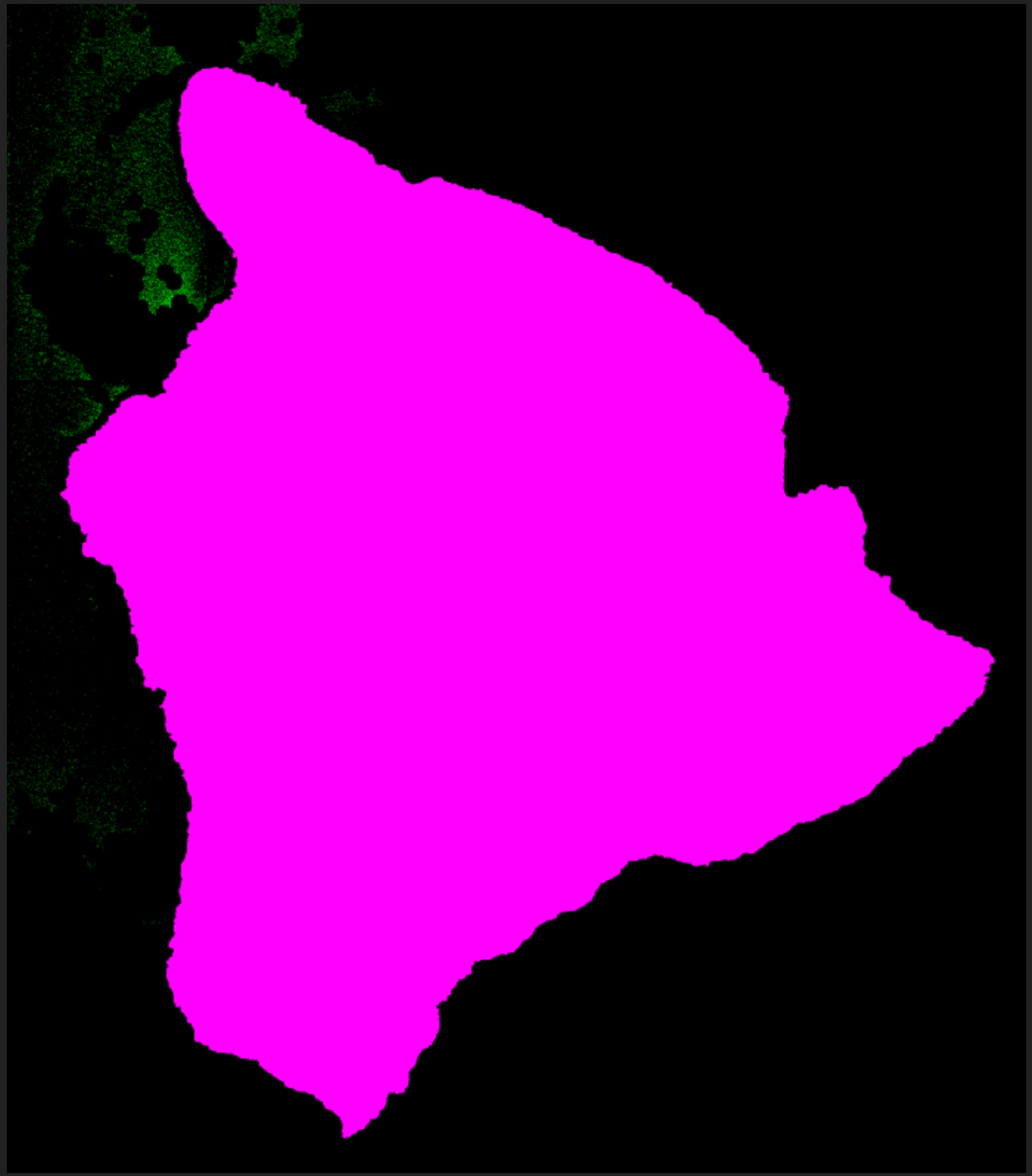
Resampled to Sentinel 2 (8 bands)



Resampled to Landsat 8 (5 bands)

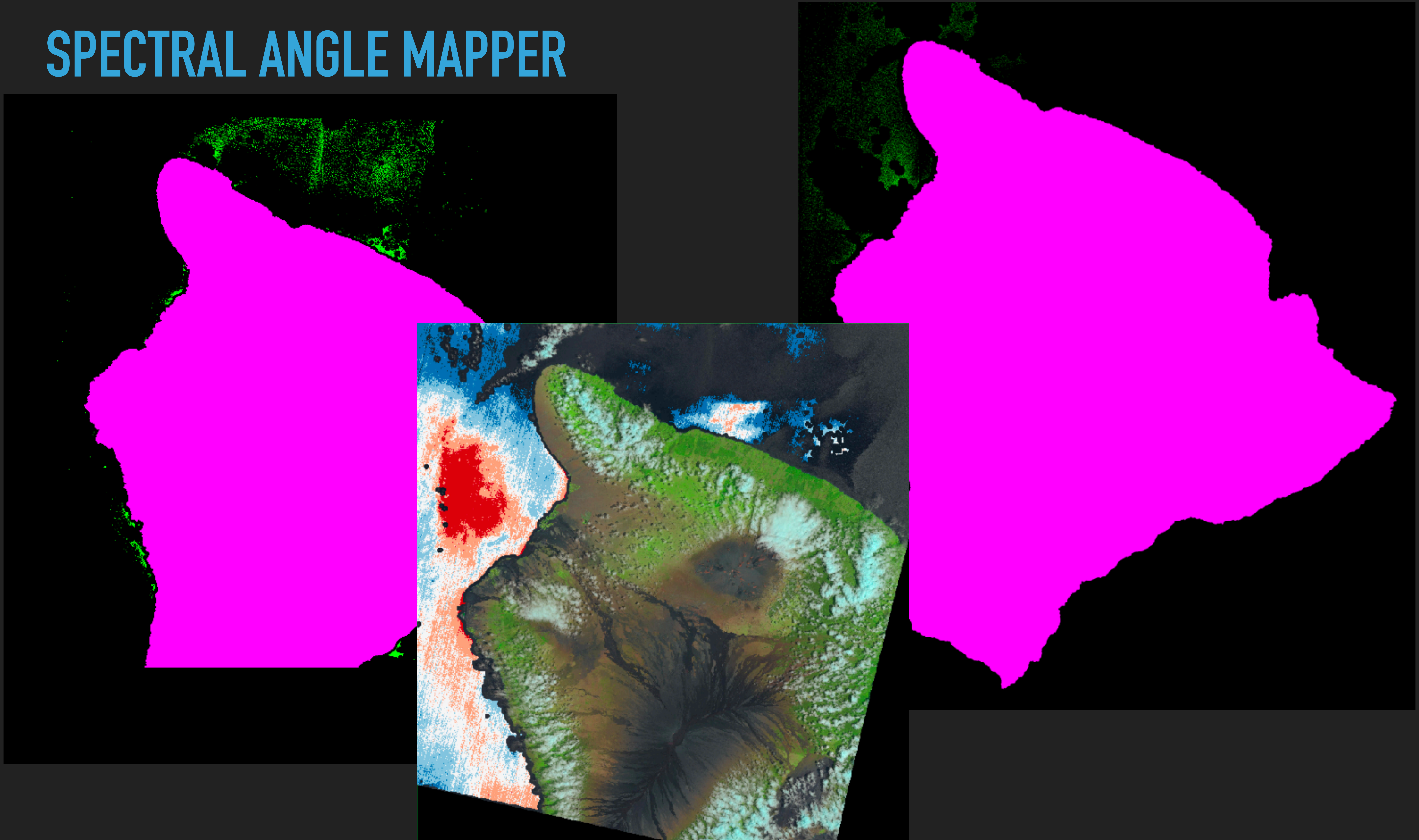
SPECTRAL ANGLE MAPPER

Landsat 8
Lowest 5% SAM

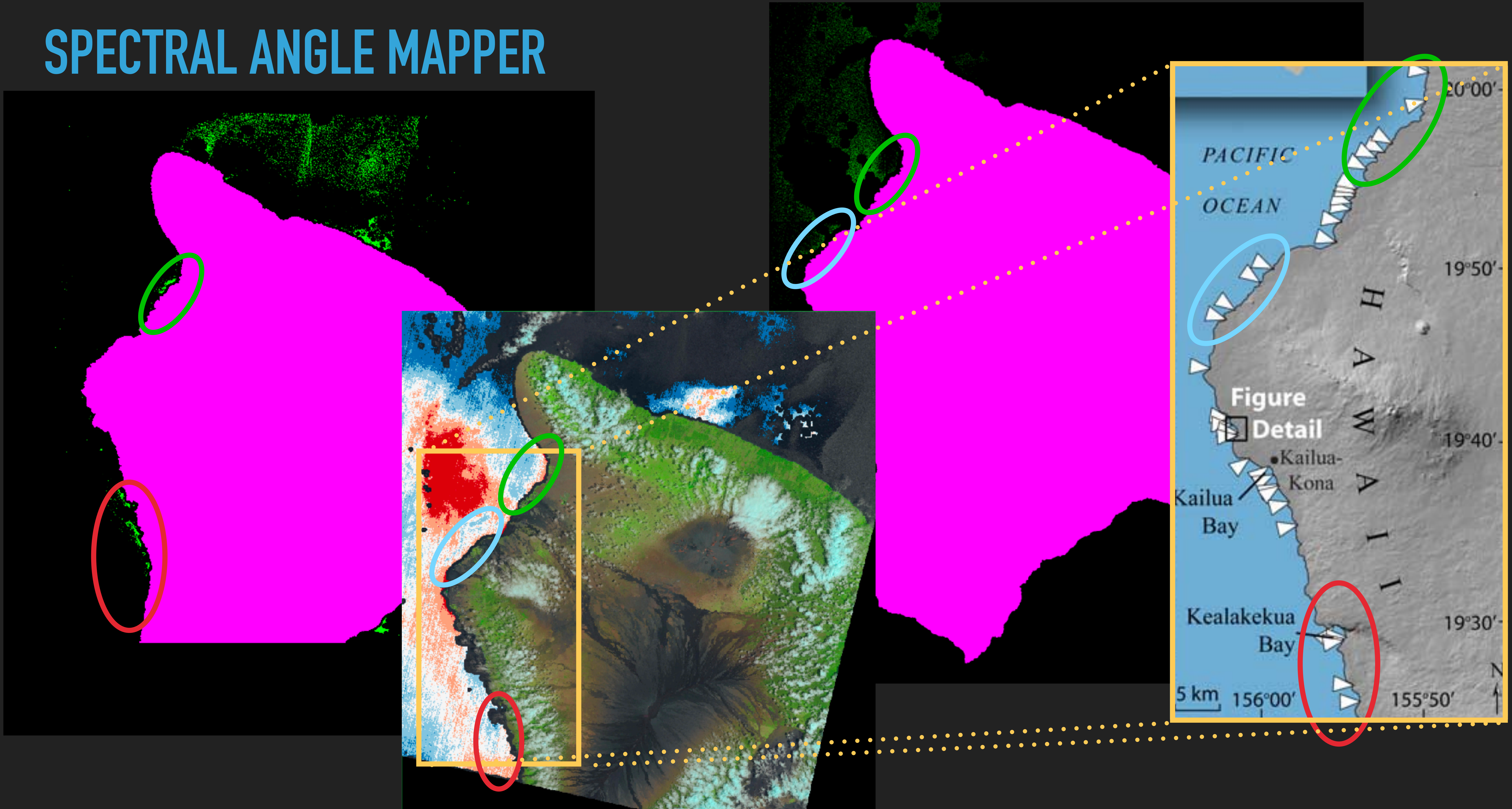


Sentinel 2
Lowest 5% SAM

SPECTRAL ANGLE MAPPER



SPECTRAL ANGLE MAPPER



MAIN FINDINGS

- Ocean Color vs Sea Surface Temperature
  - More bands / spectra coverage may help to improve certainty
  - Time-coinciding TIR imagery is beneficial
  - Cold plumes may not be the coldest in the scene, but they are still colder than surrounding waters
  - Angular distance more robust than change of signal of the derivative

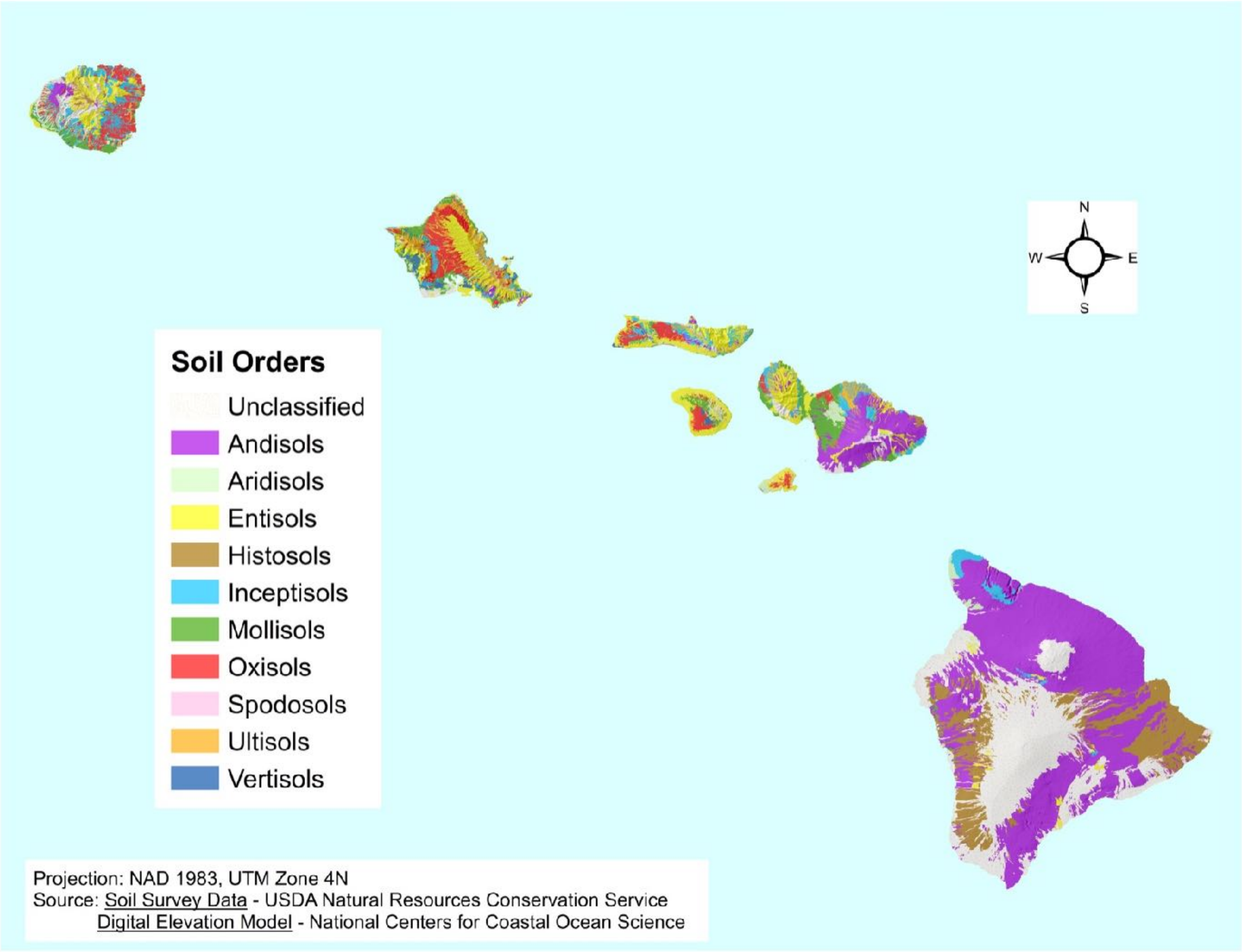
LIMITATIONS / NEXT STEPS

- Missing other areas of potential SGD
- There are limited close joint-overpasses between L8 and S2
- Just one target spectrum particular to a limited and controlled area
  - Experiment with other spectra

- Tackle areas where upwelling events are common
  - Integrate currents and wind data
- Quantitative validation and uncertainty quantification
  - Use existing ground truth data

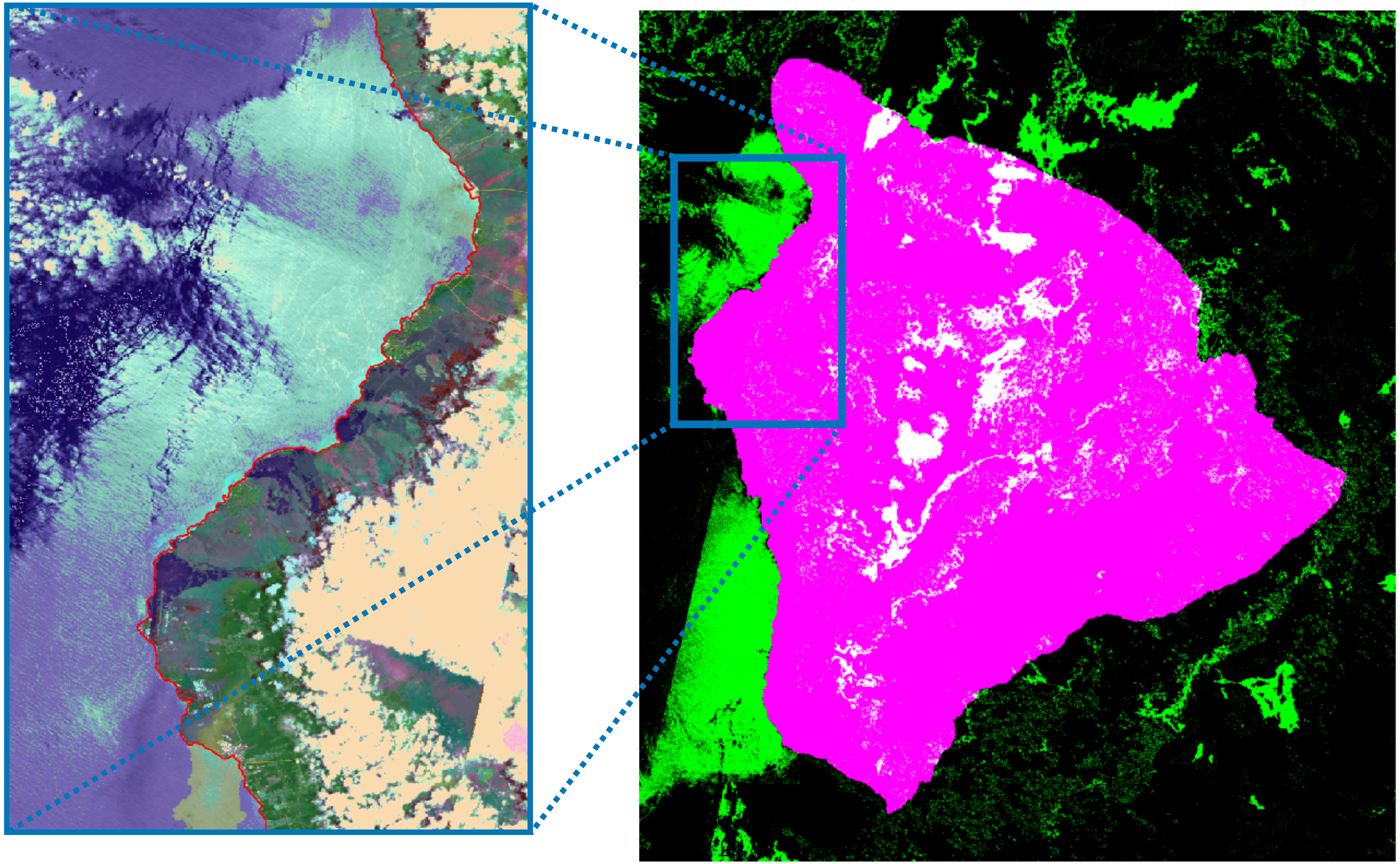
Thank you, comments are appreciated!

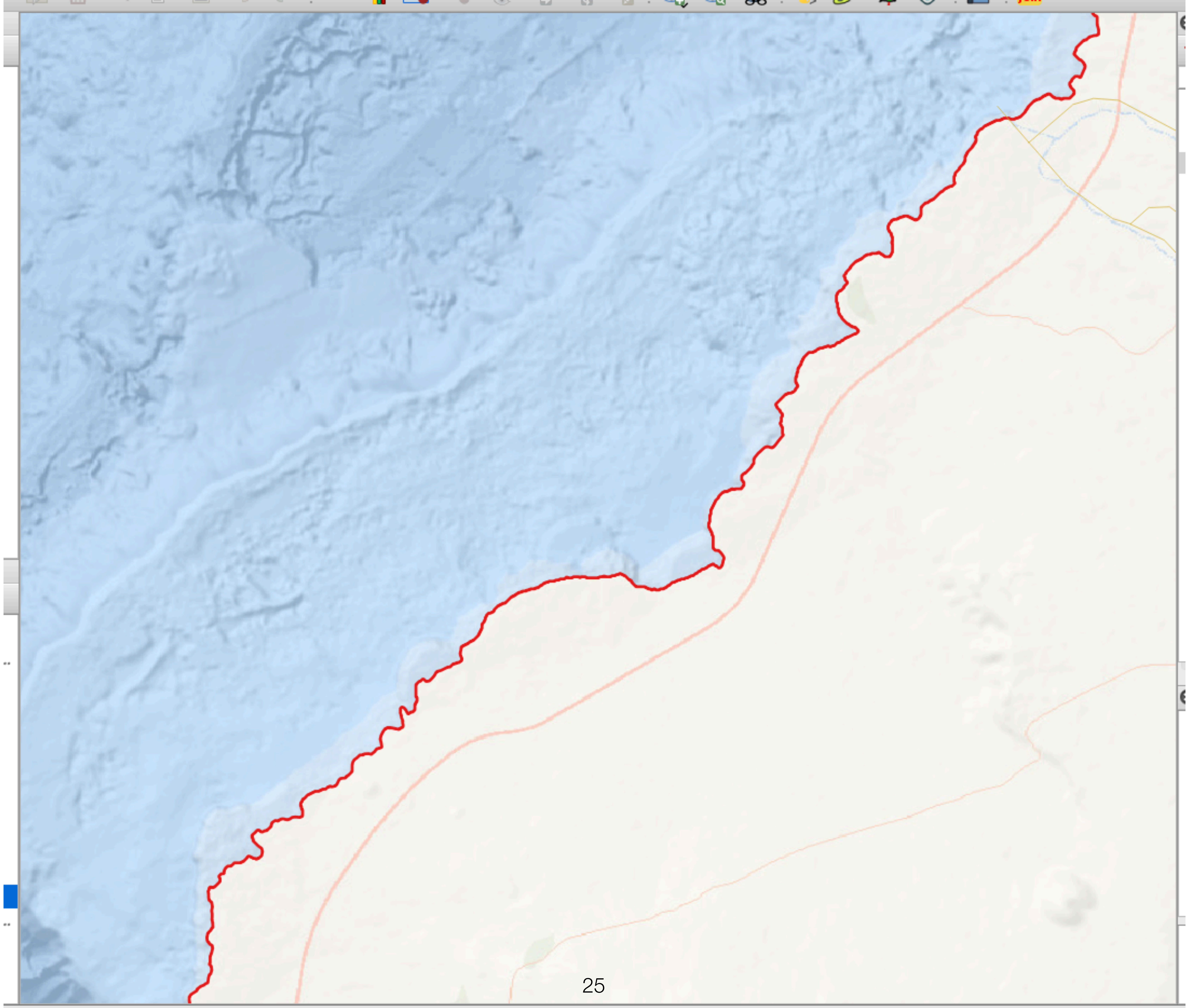
julio.caineta@pitt.edu

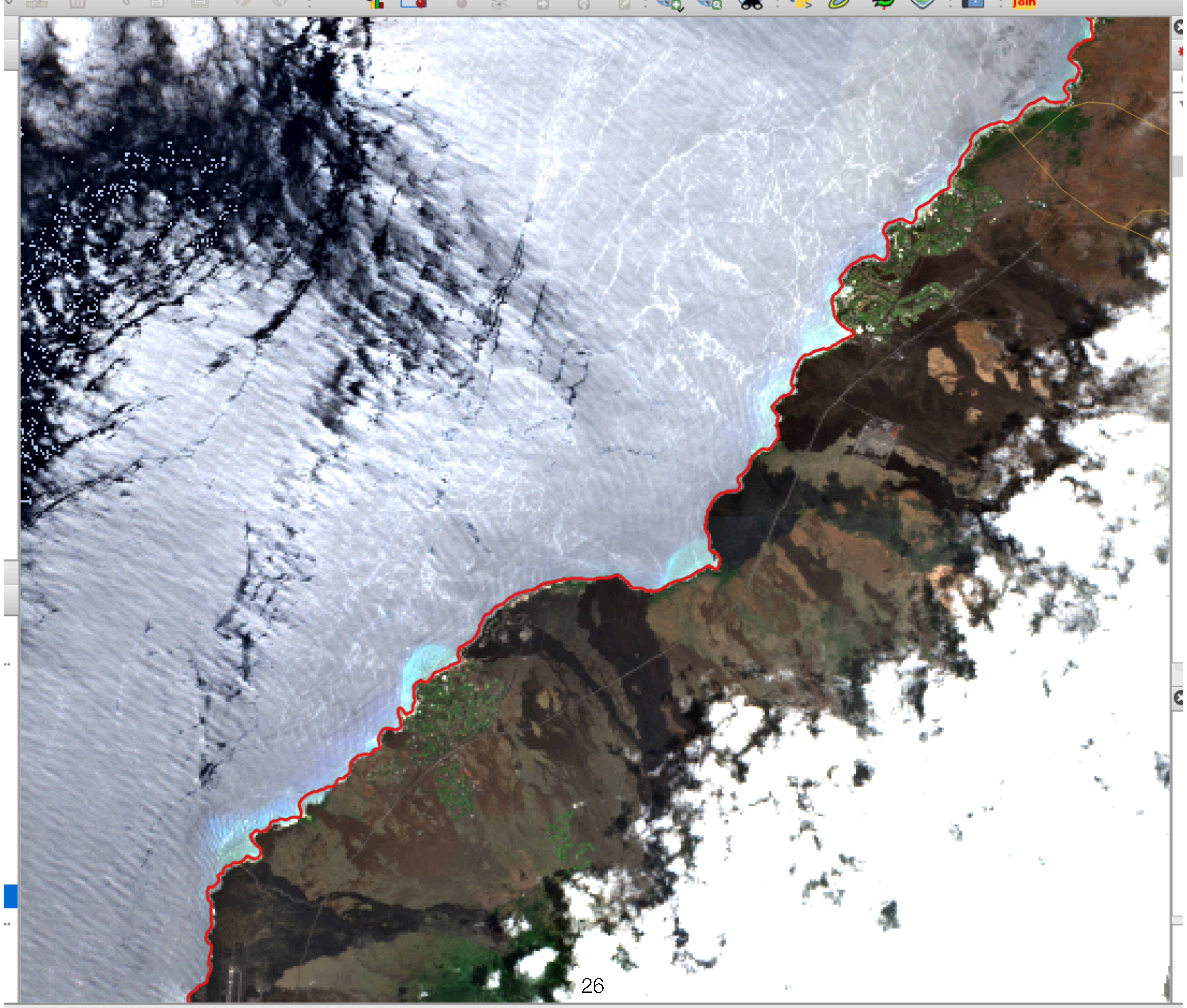


N
W
E
S
Soil Orders
Unclassified
Andisols
Aridisols
Entisols
Histosols
Inceptisols
Mollisols
Oxisols
Spodosols
Ultisols
Vertisols
Projection: NAD 1983, UTM Zone 4N
Source: Soil Survey Data - USDA Natural Resources Conservation Service
Digital Elevation Model - National Centers for Coastal Ocean Science

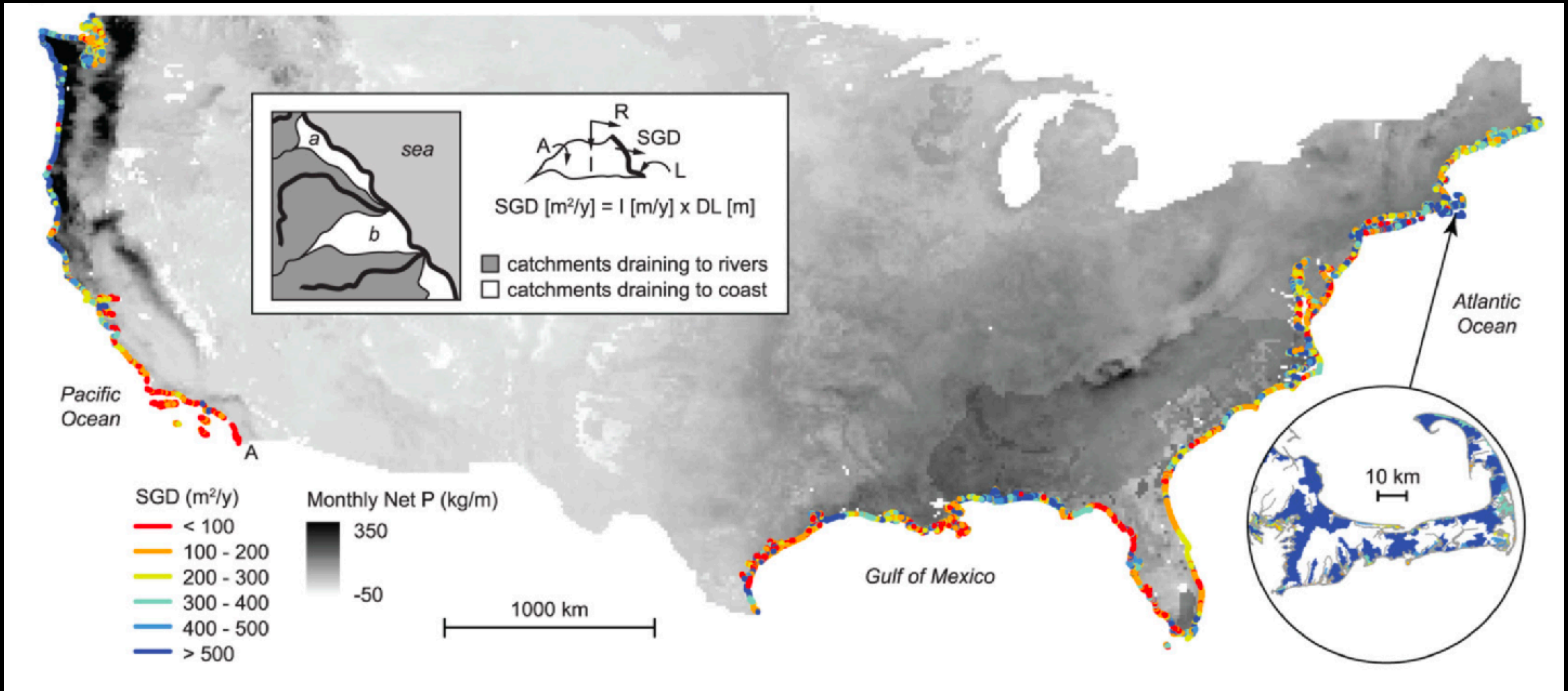
“Colored” bays were being masked as belonging to areas with medium probability clouds (green px on the figure in the right). Left figure: true color image overlayed with classification (light green is medium prob cloud; blue is water)



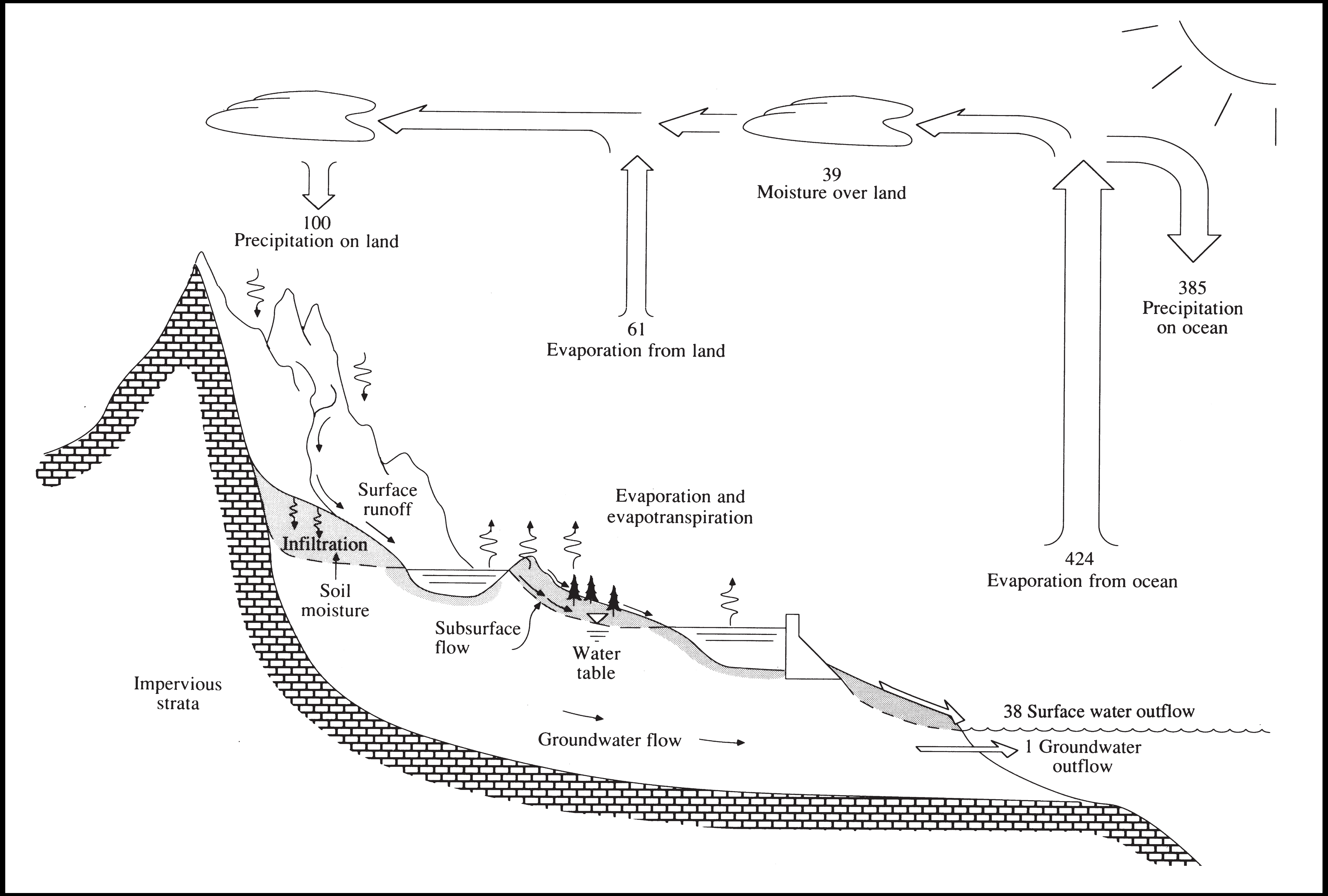




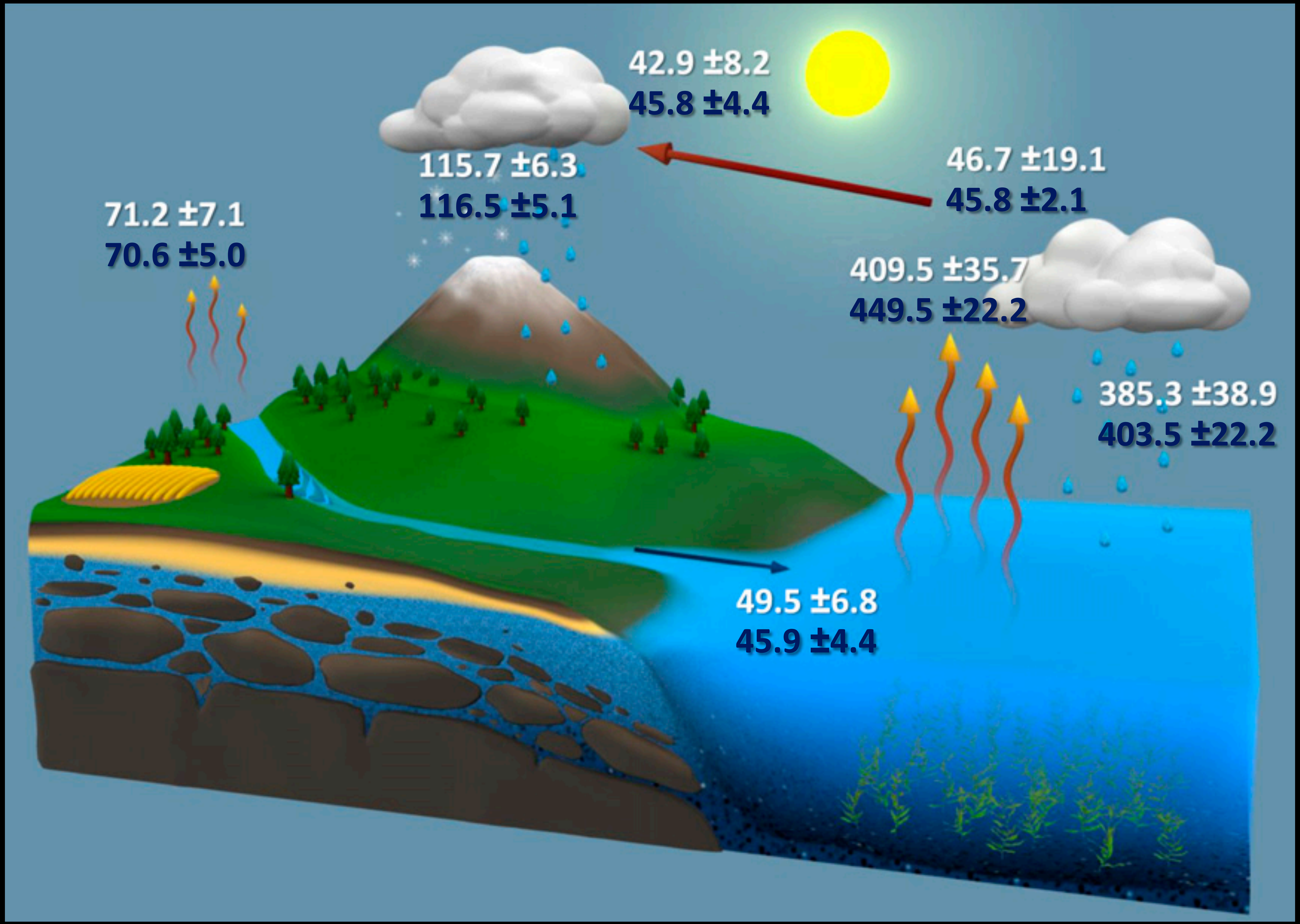
Review



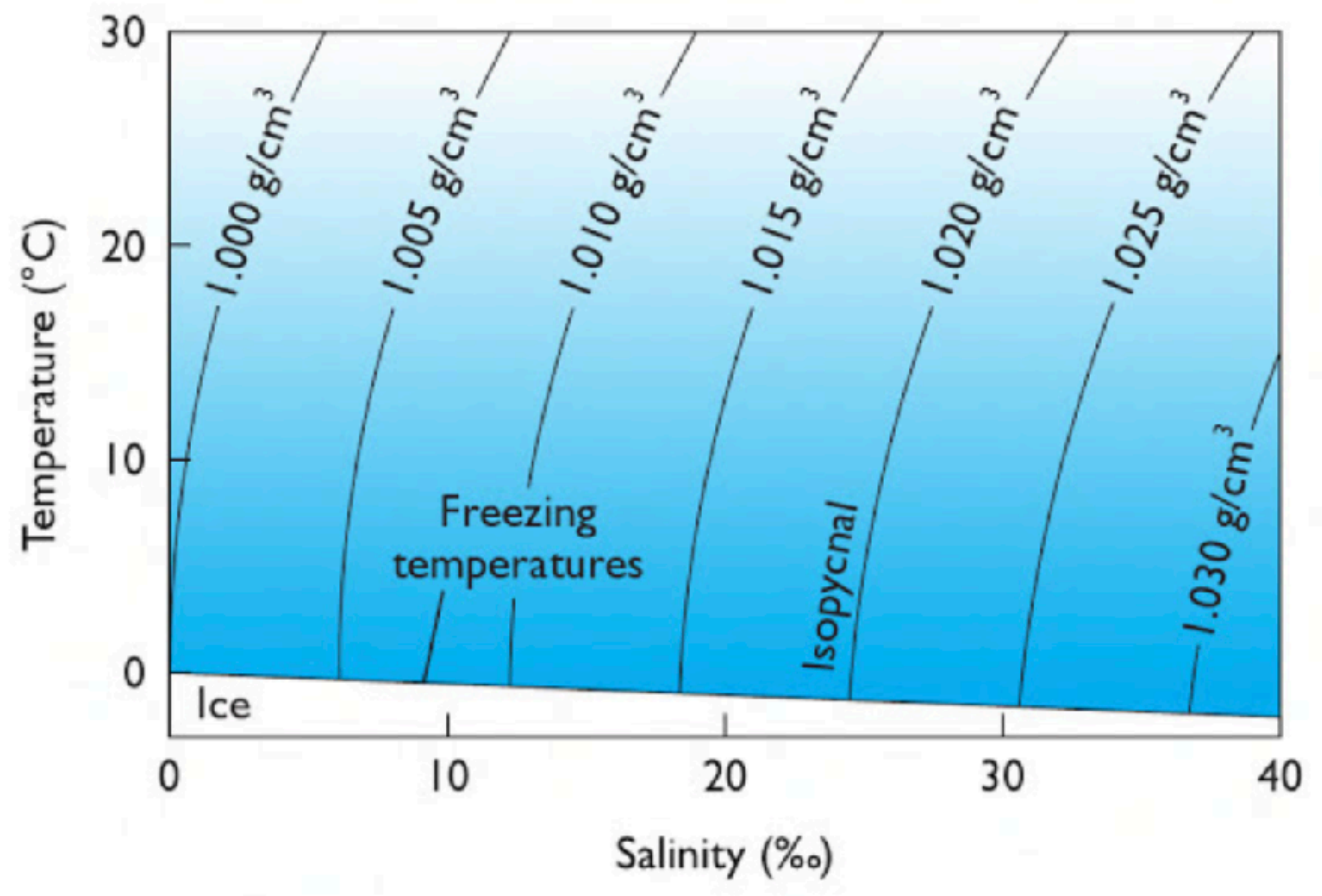
Sawyer et al., 2016



Chow et al., 1988

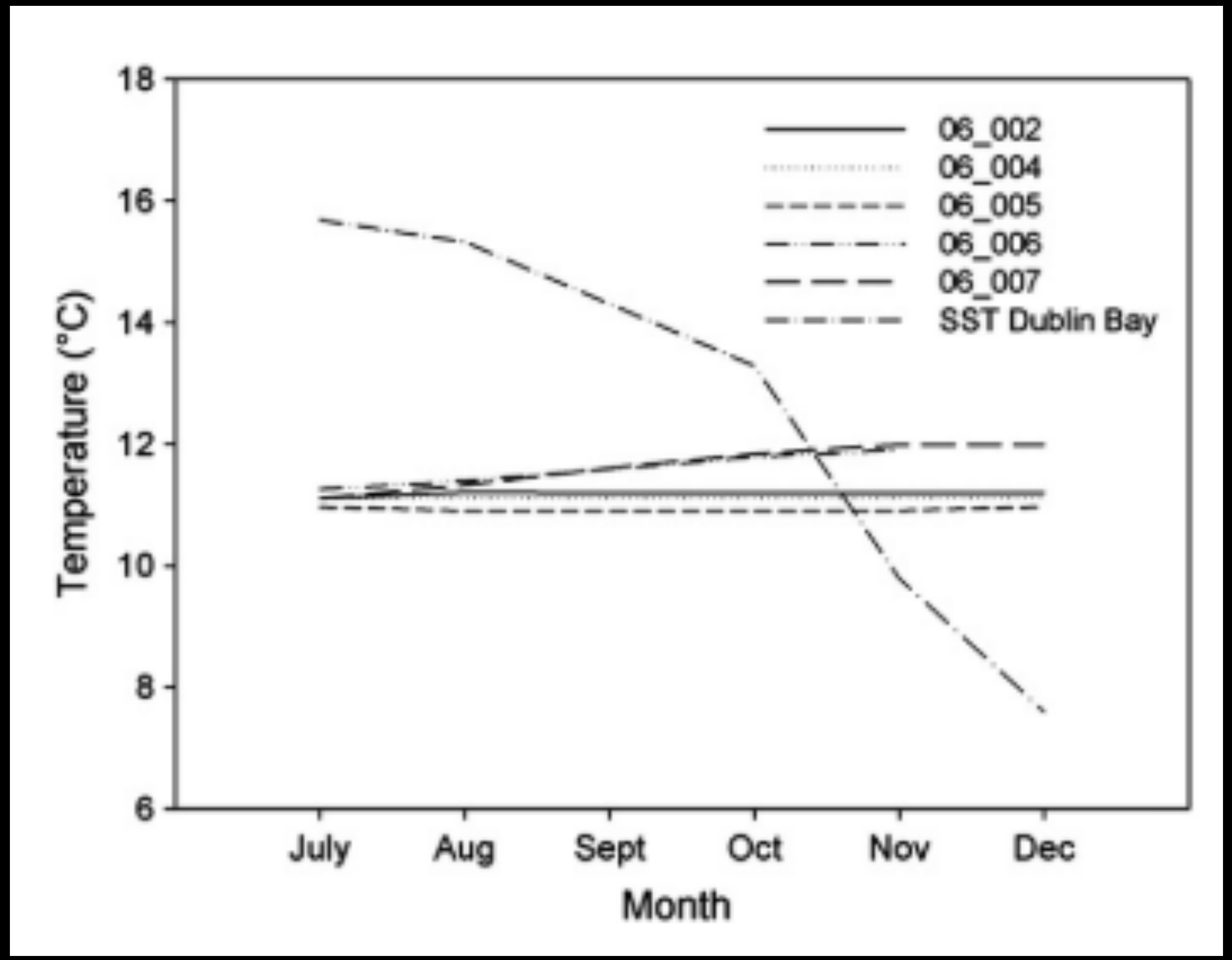


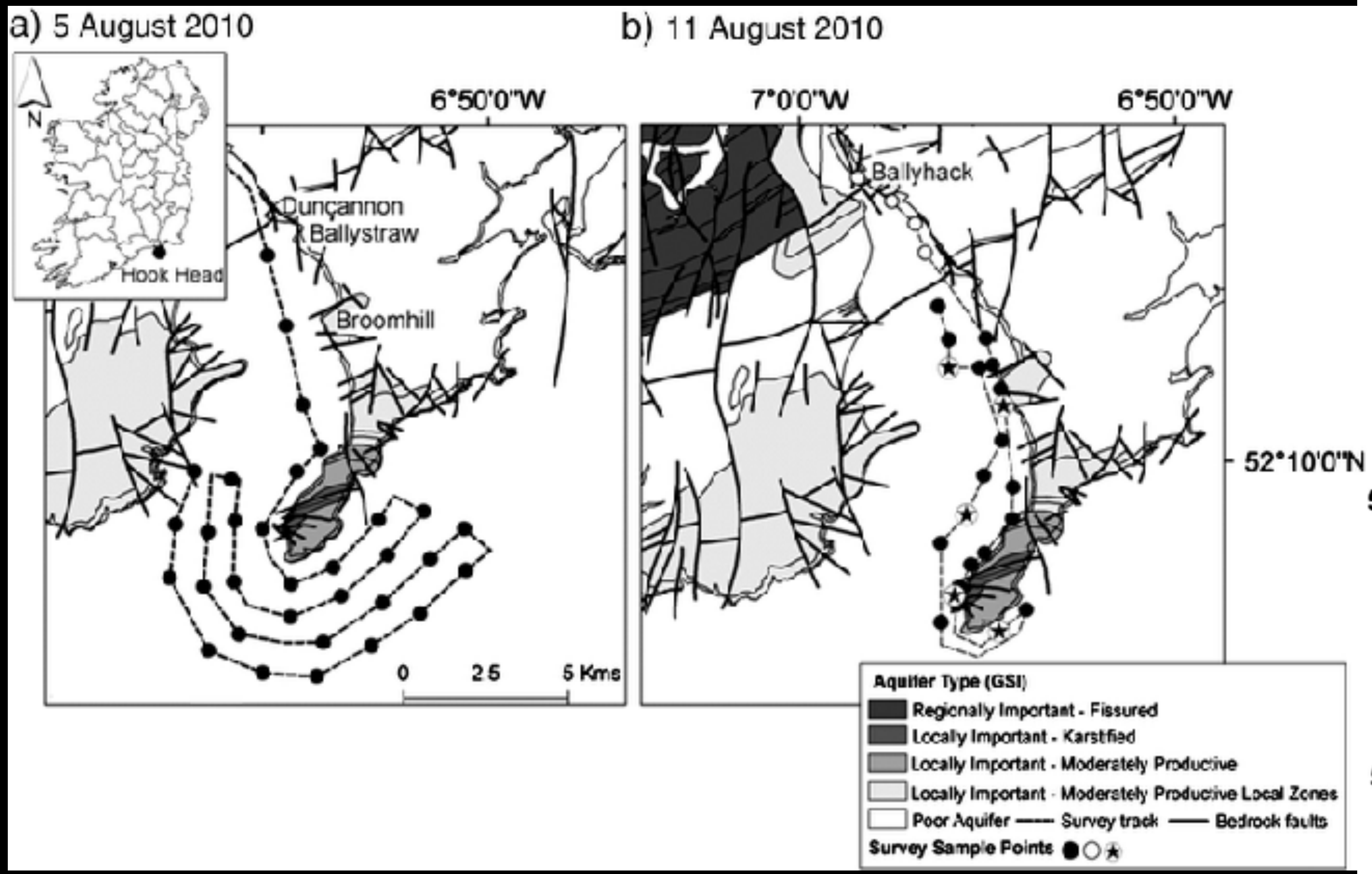
Rodell et al., 2015

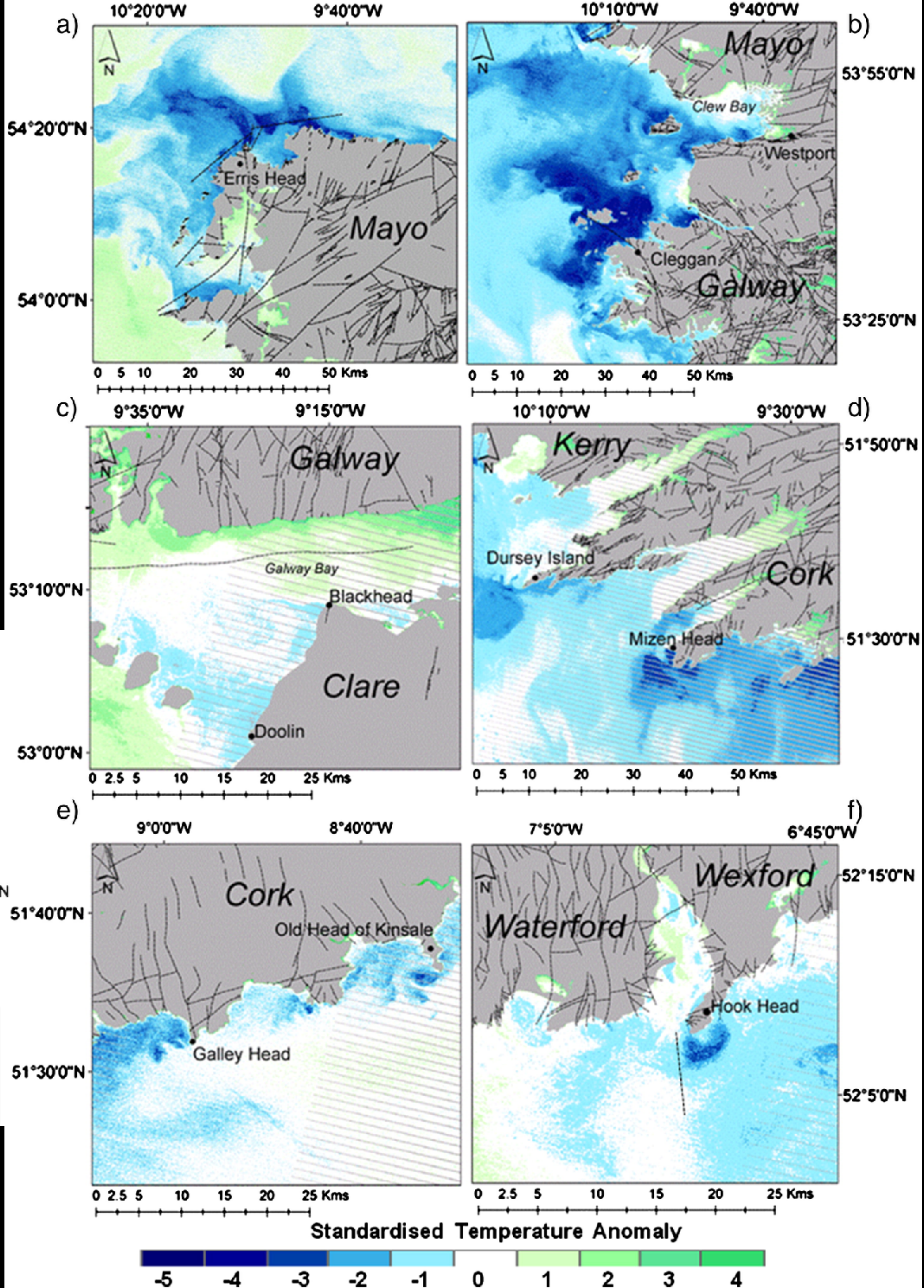


(a) SEAWATER DENSITY

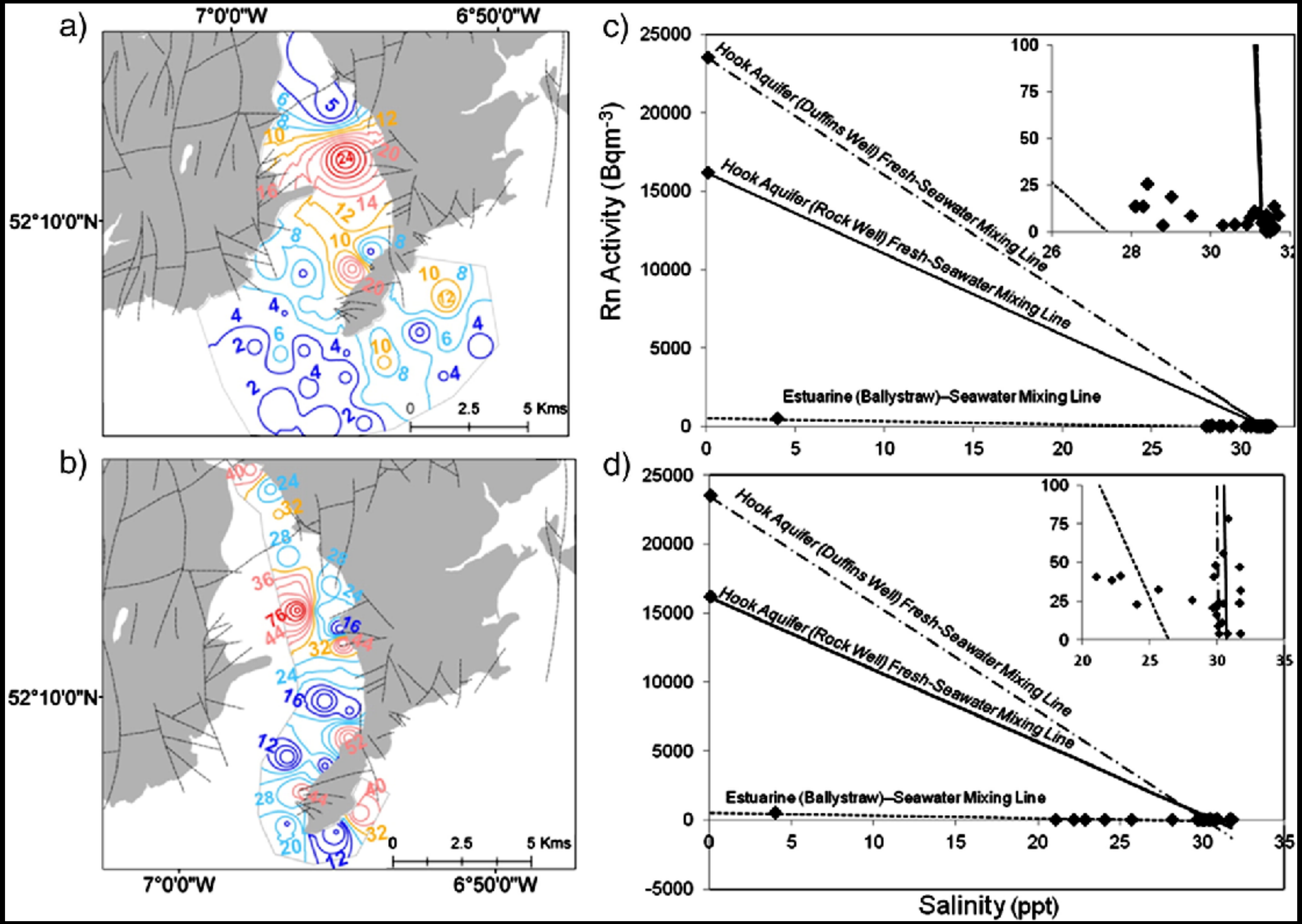
Pinet, 2011



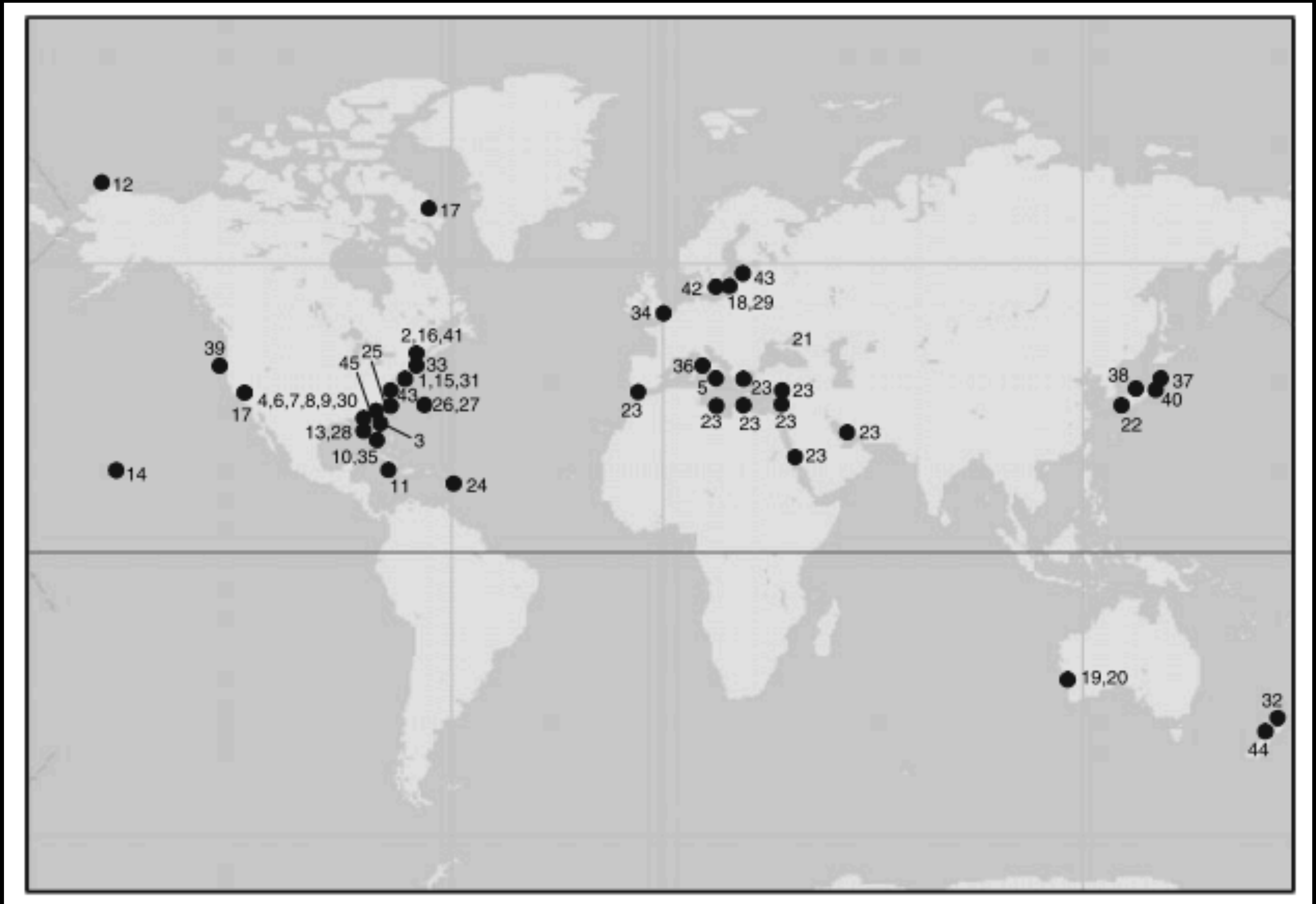




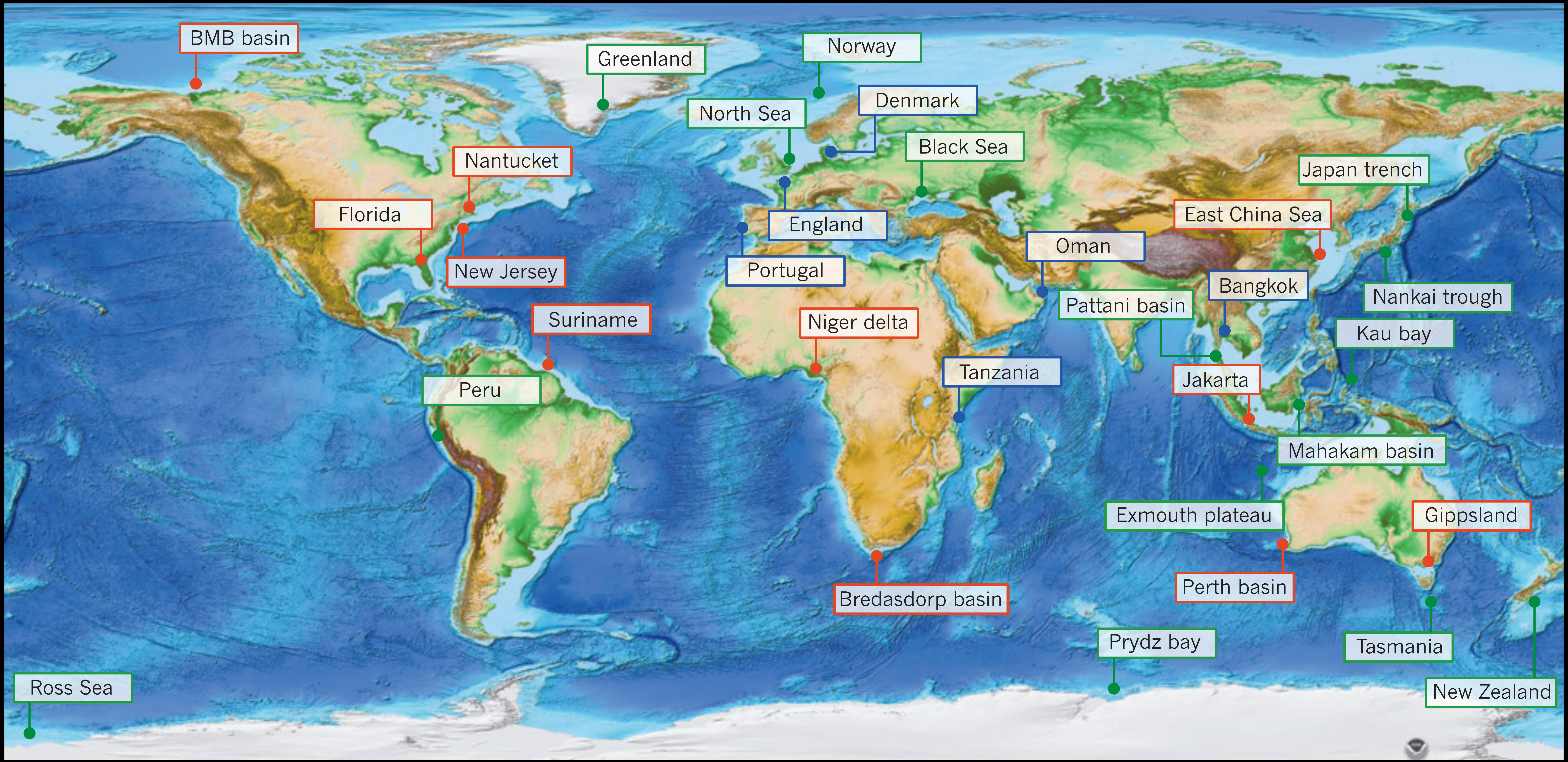
Wilson & Rocha, 2012



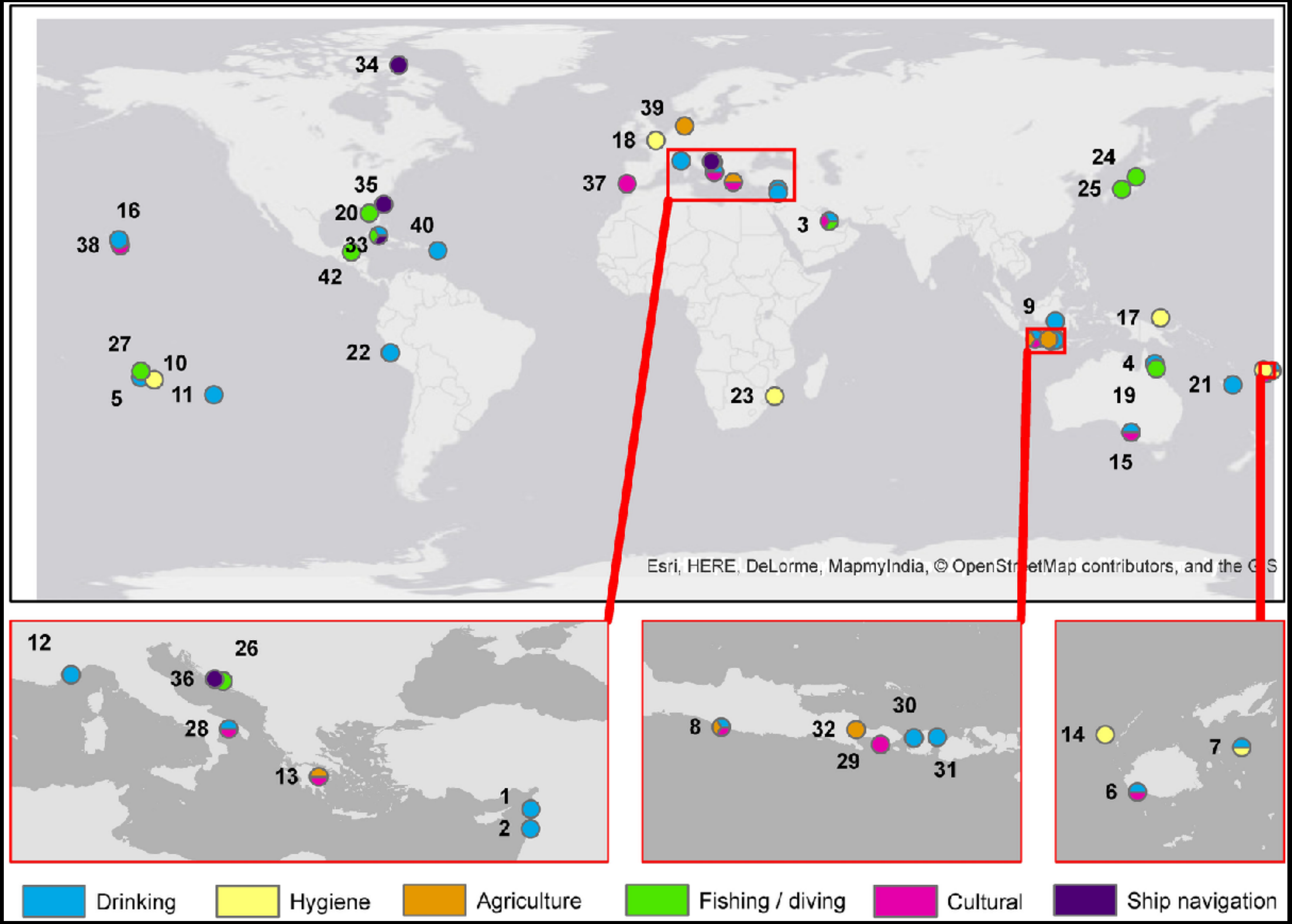
Wilson & Rocha, 2012



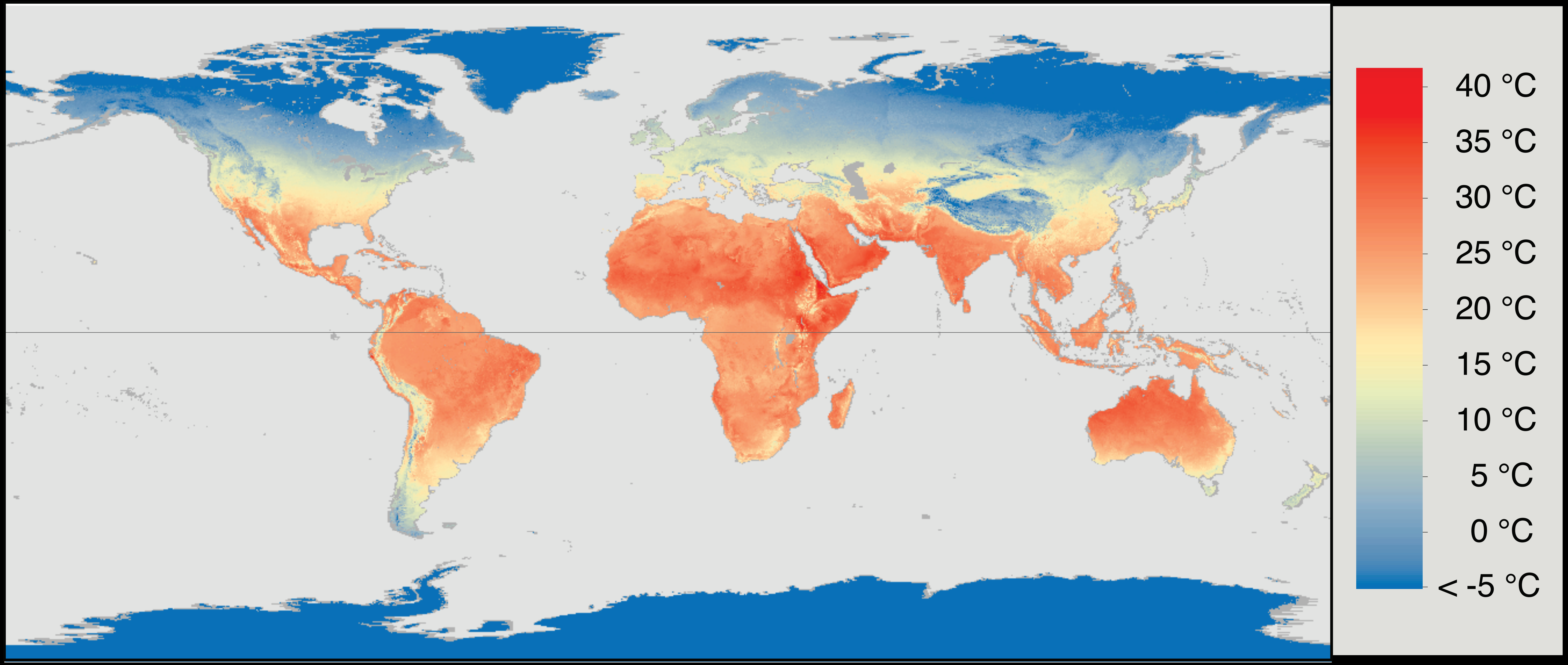
Taniguchi et al., 2002



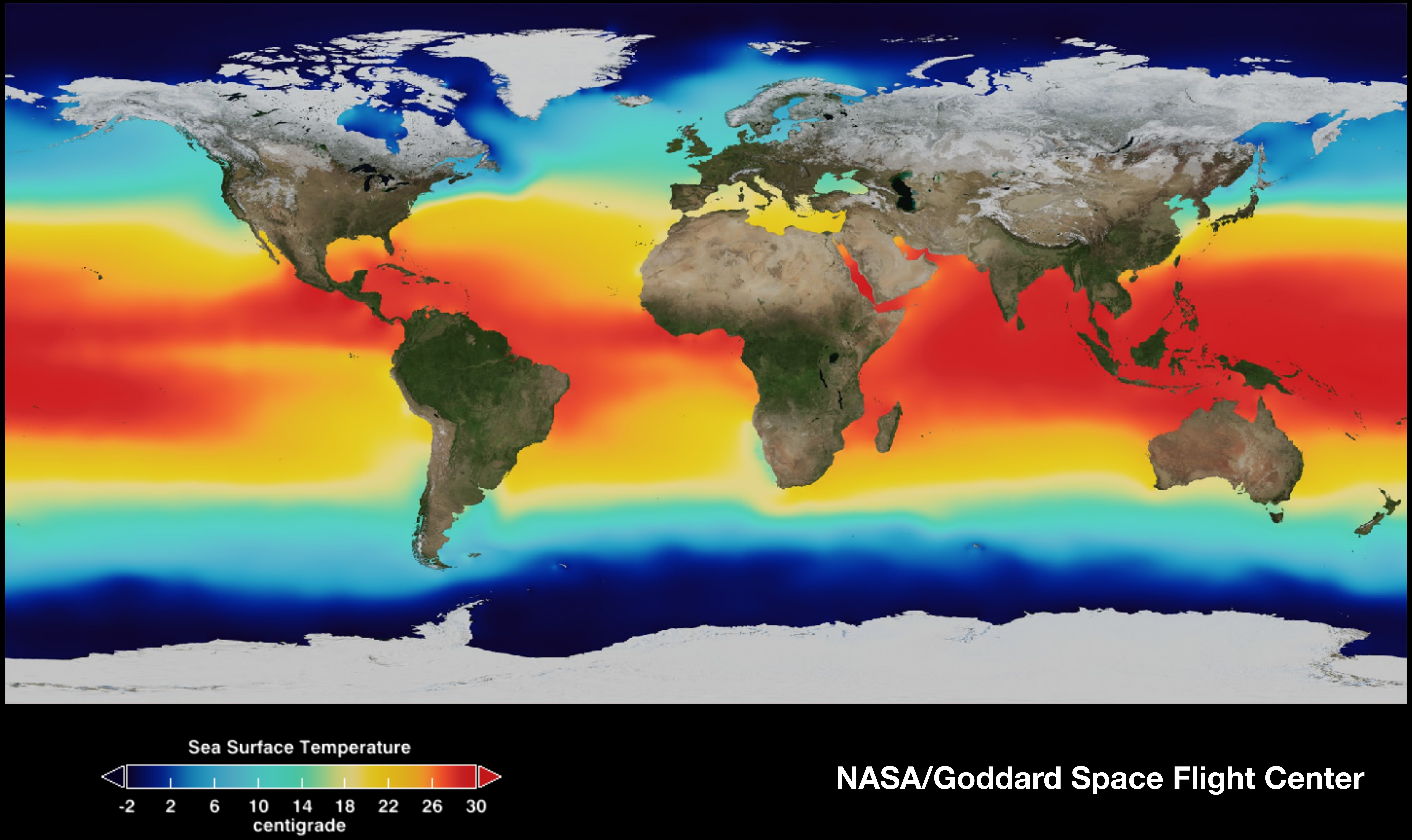
Post et al., 2013



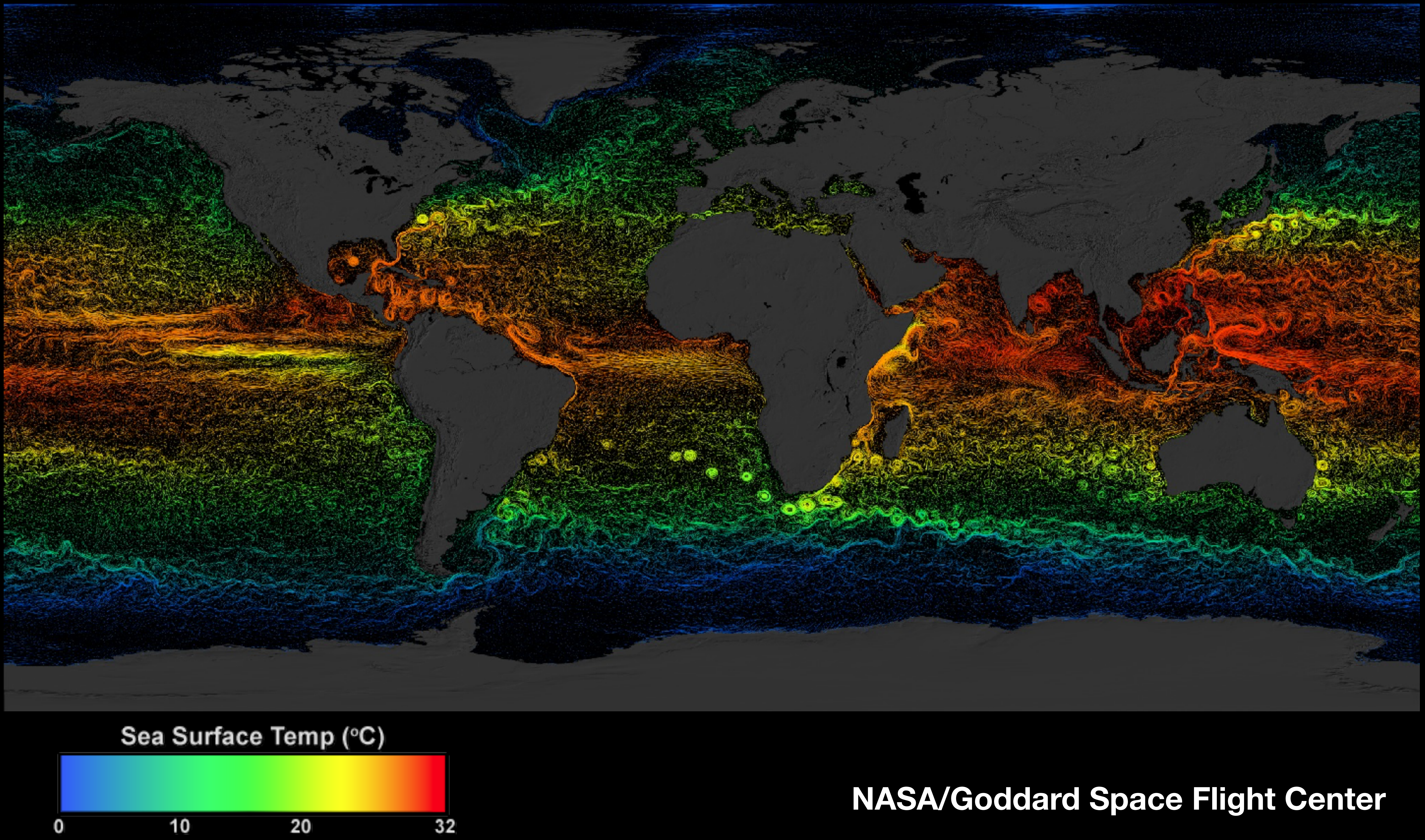
Moosdorf & Oehler, 2017



Benz et al., 2017

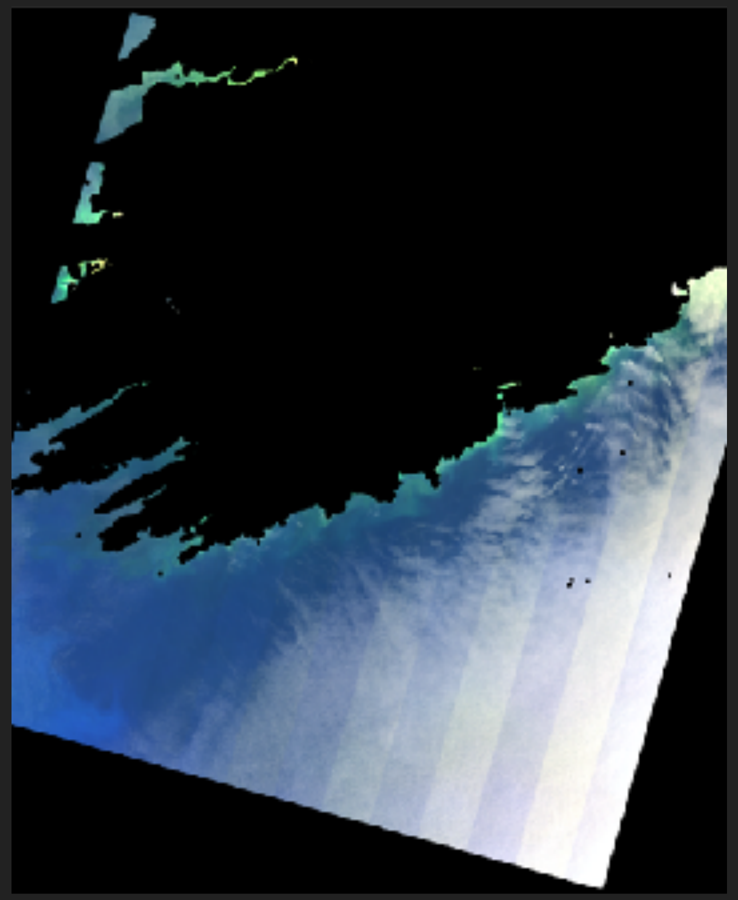


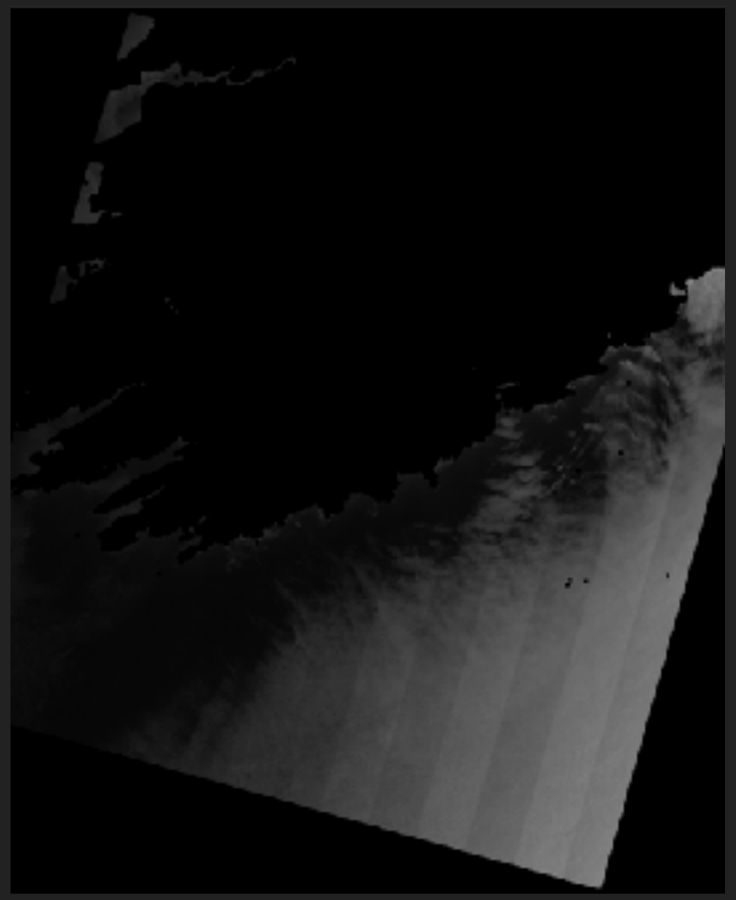
NASA/Goddard Space Flight Center

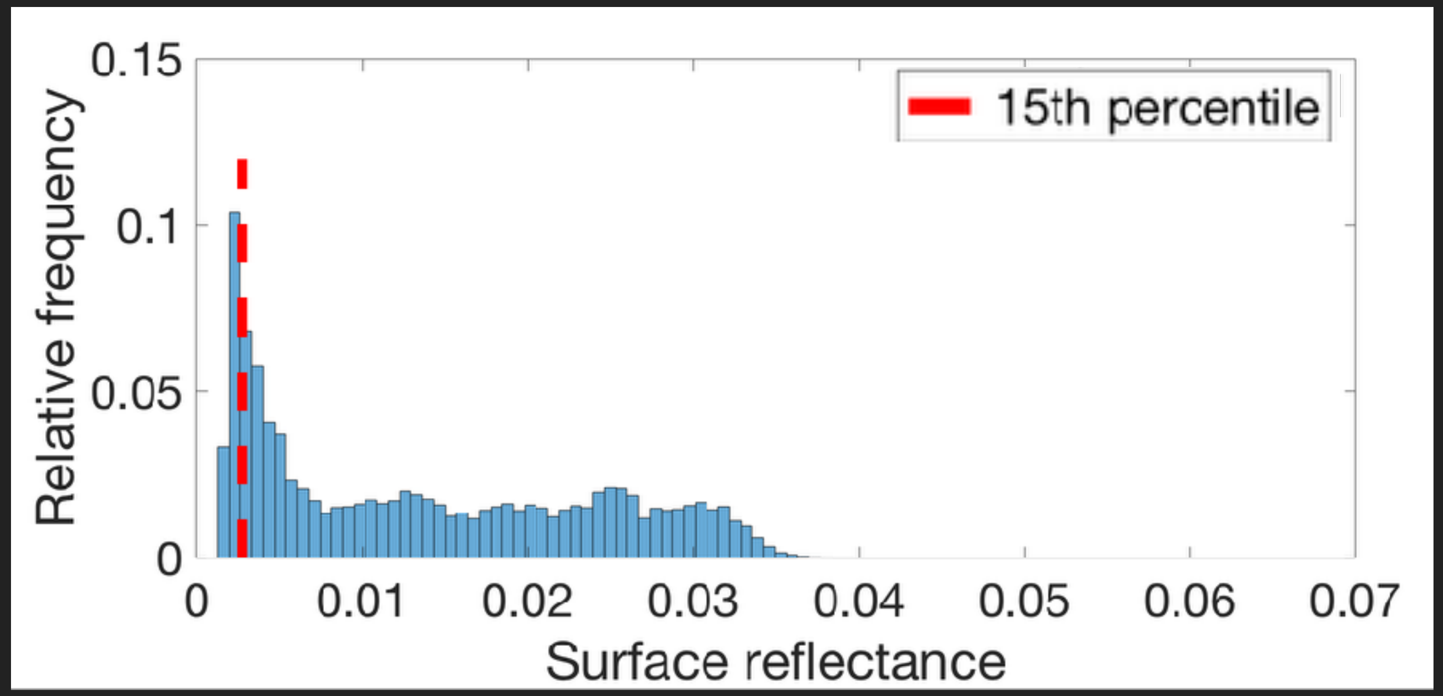


NASA/Goddard Space Flight Center


Water mask


Bands 431 (RGuB) masked


Band 5 (NIR)

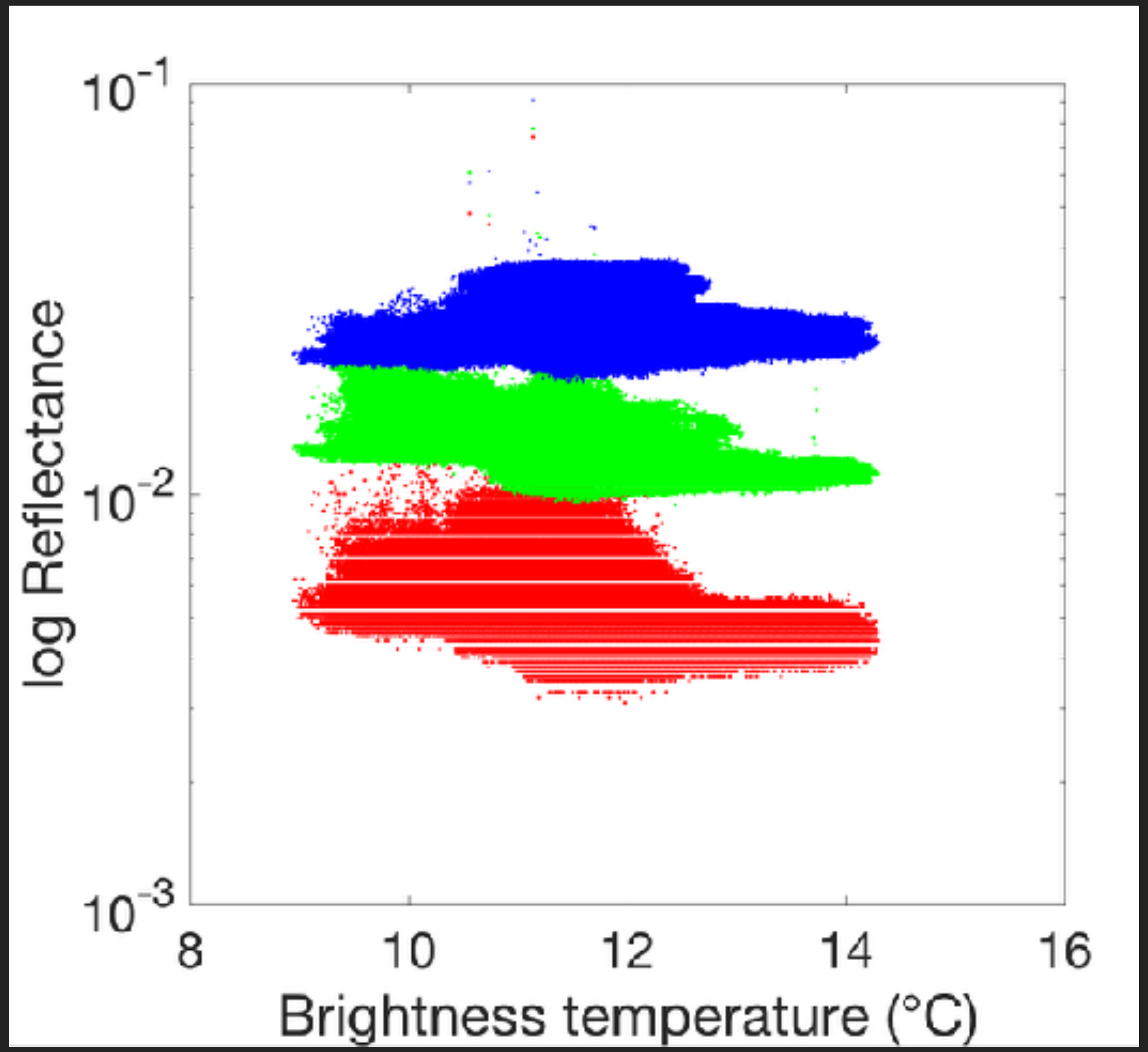


NIR Mask

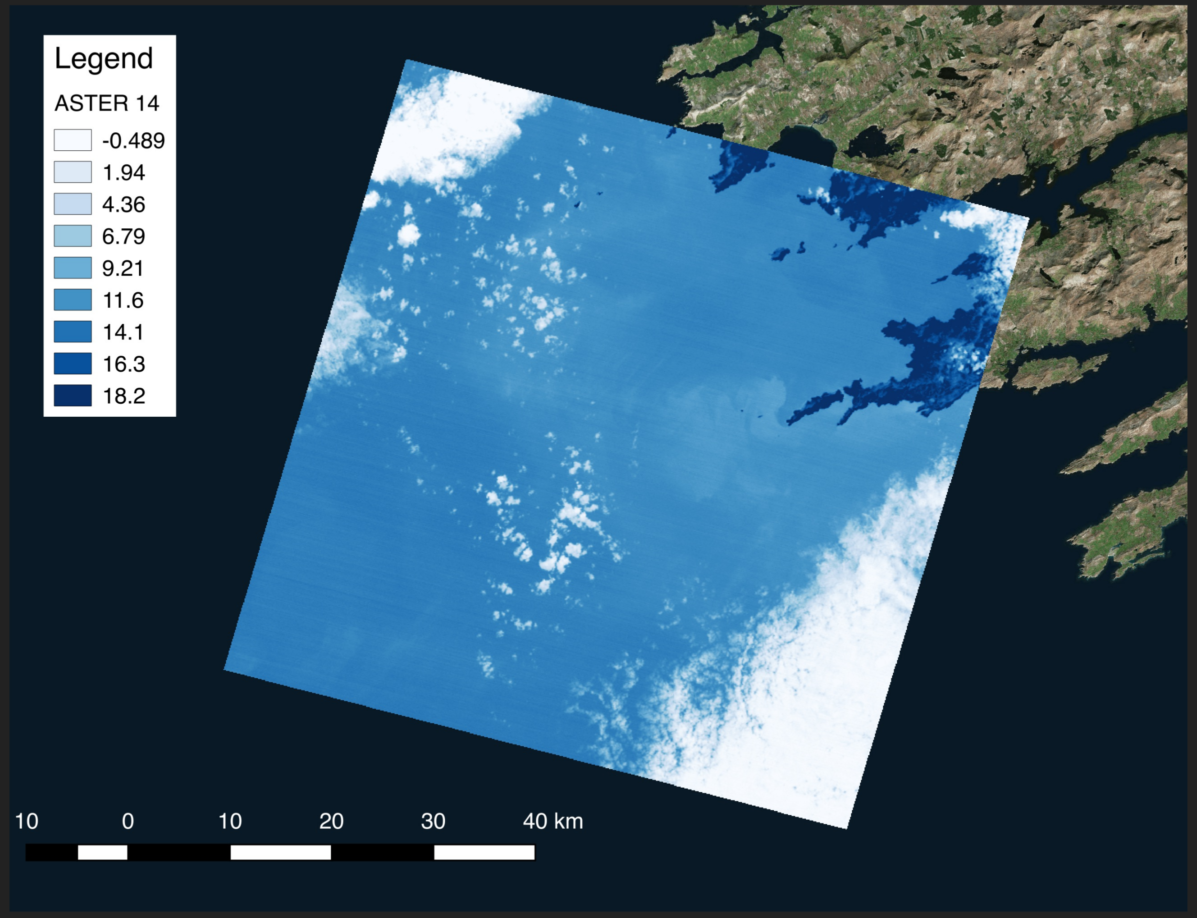

Band 5 mask


Band 5 mask closing

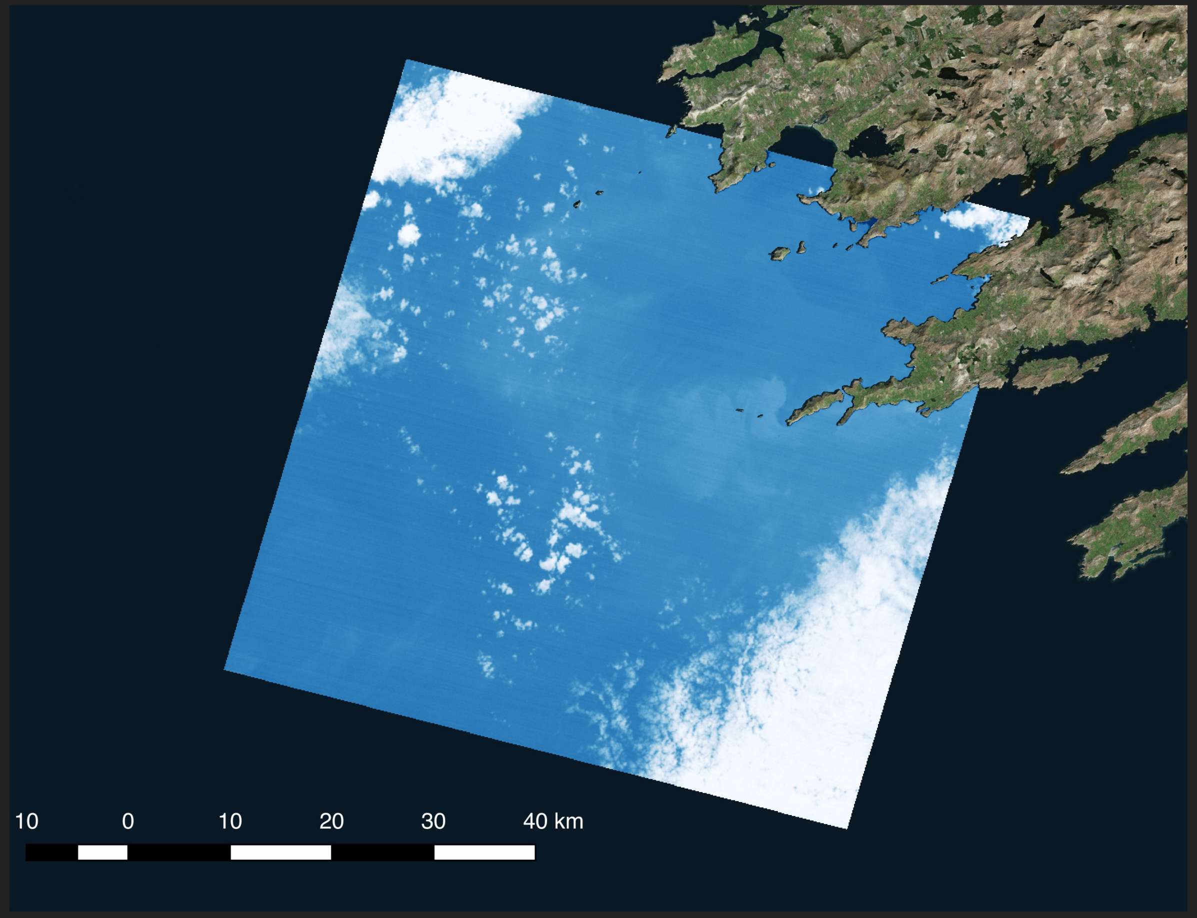

Bands 431 (R G uB) NIR masked



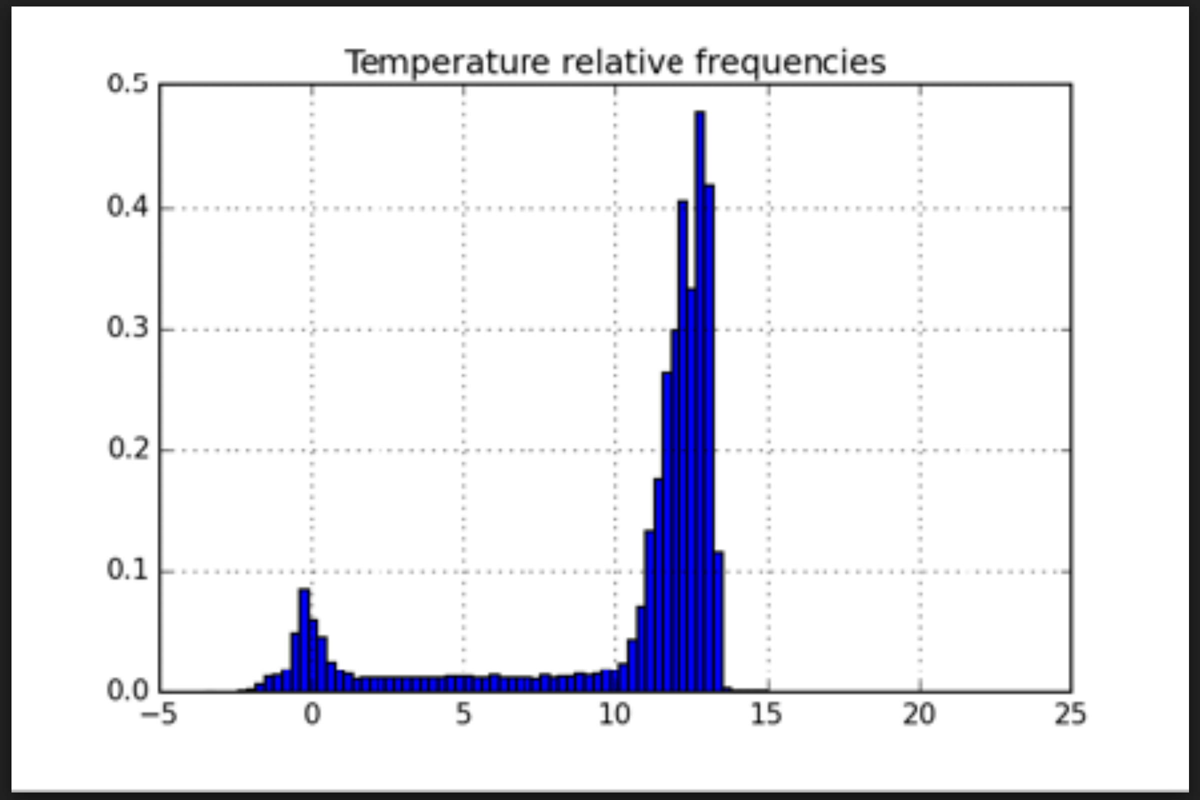
METHODS & RESULTS



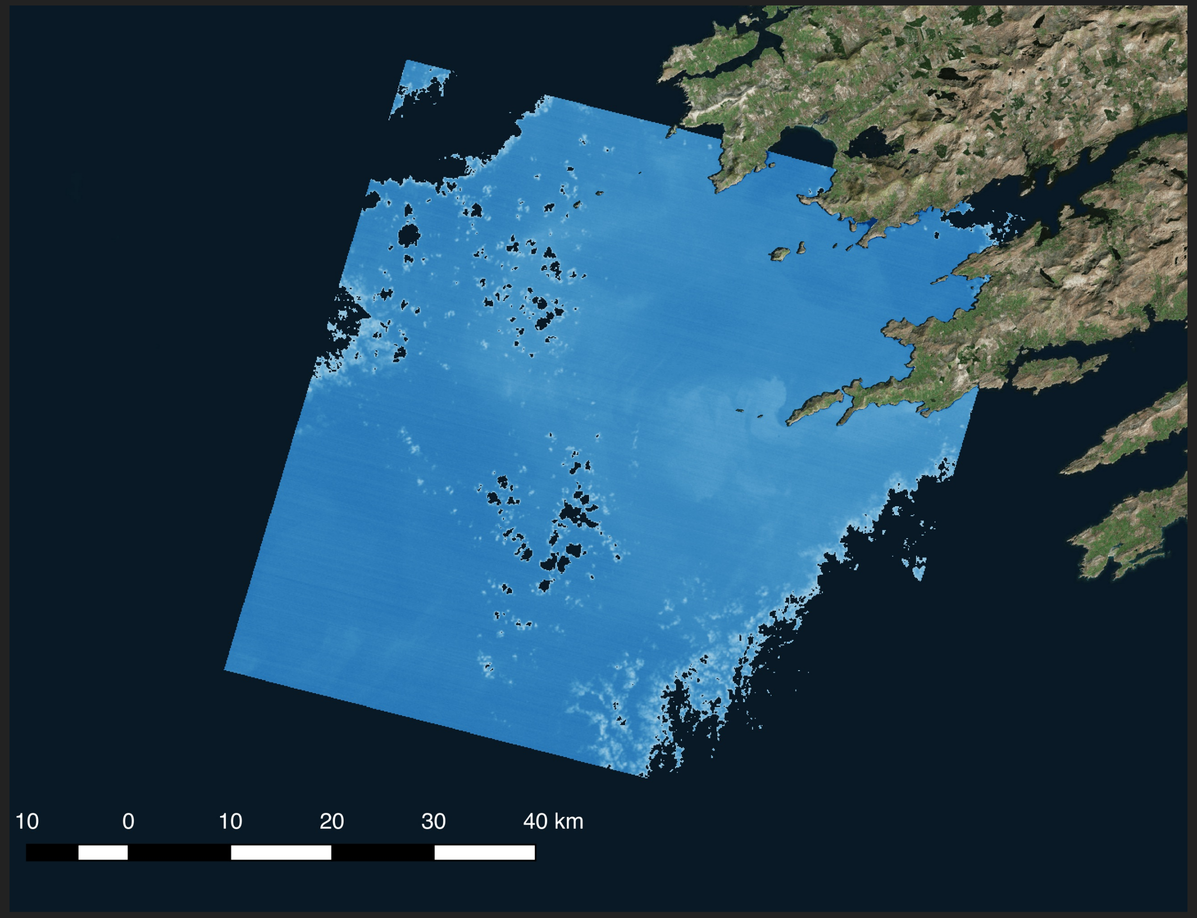
ASTER L1T Band 14
(10.95 - 11.65 µm) to °C



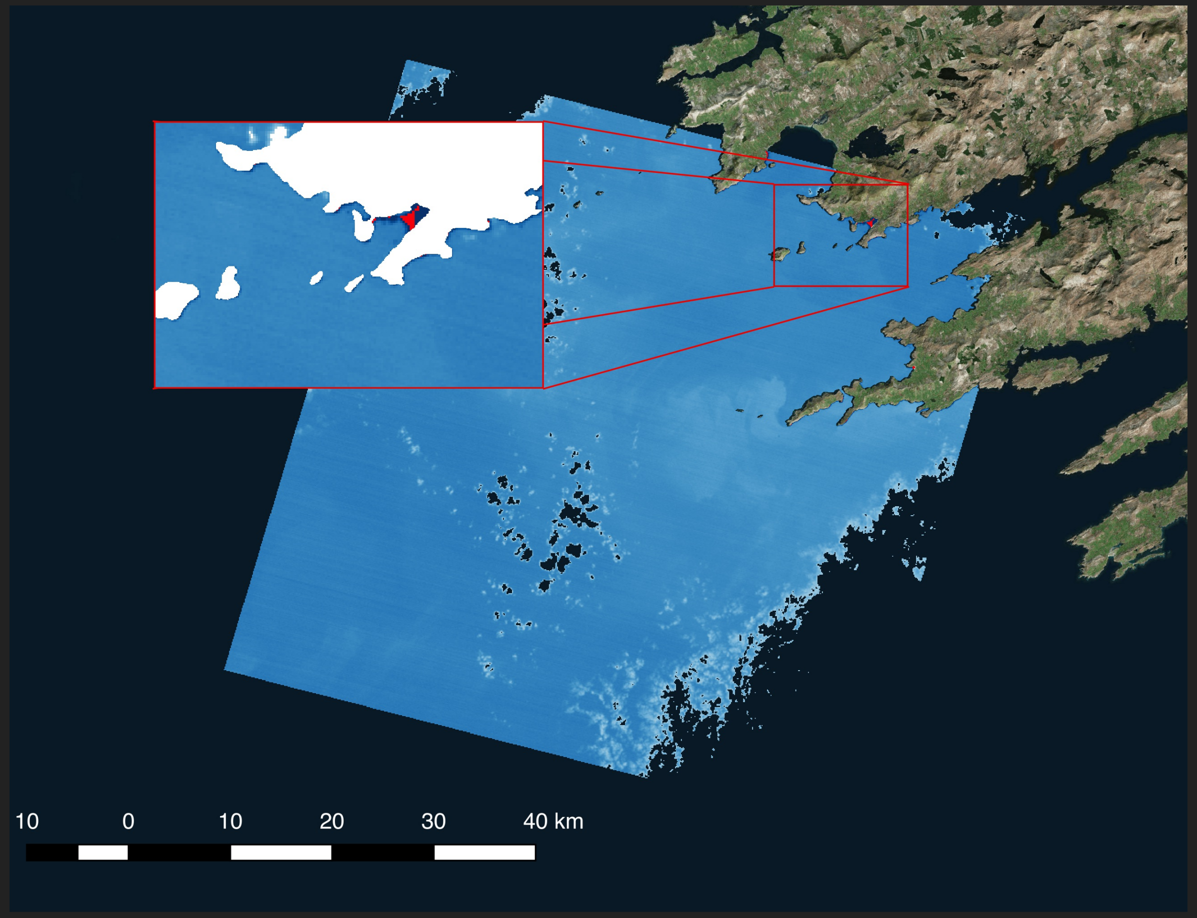
Mask land



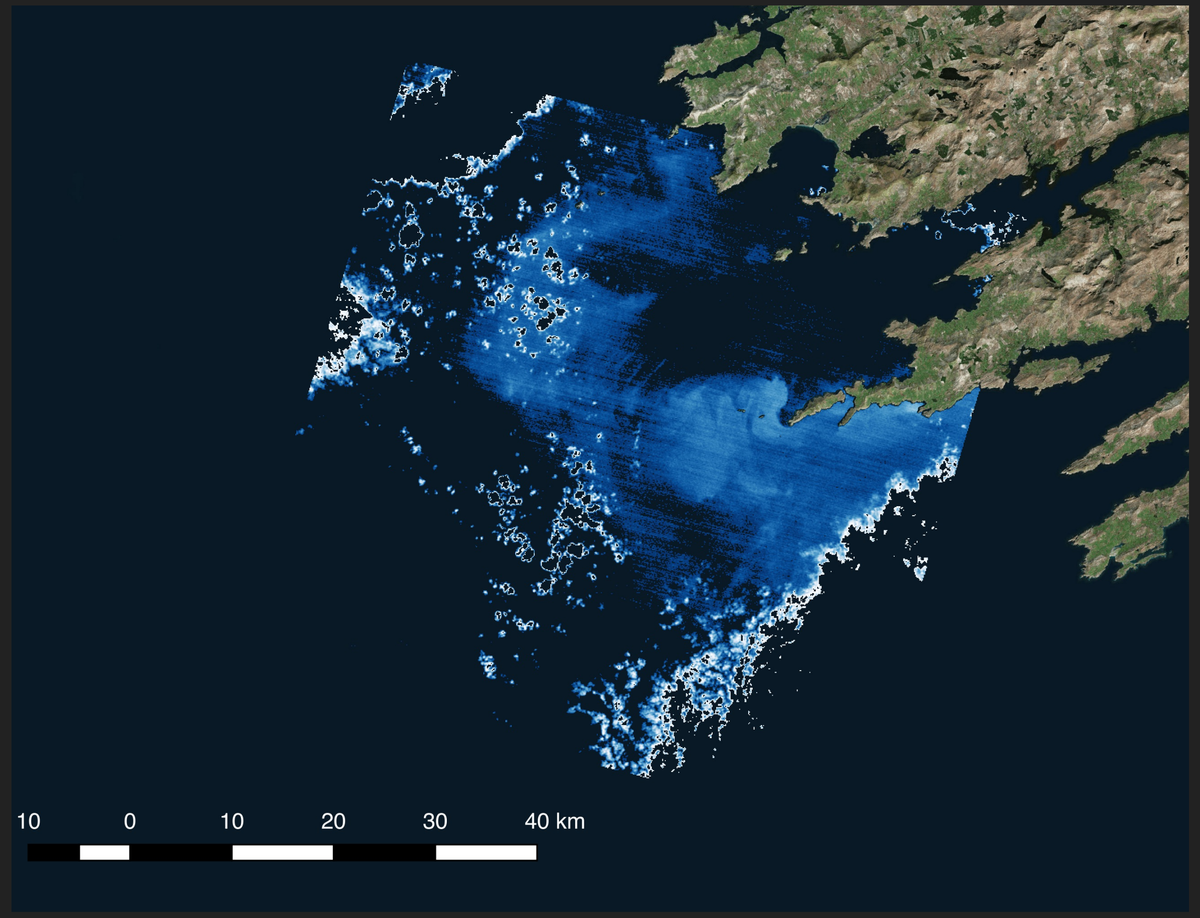
Temperature histogram



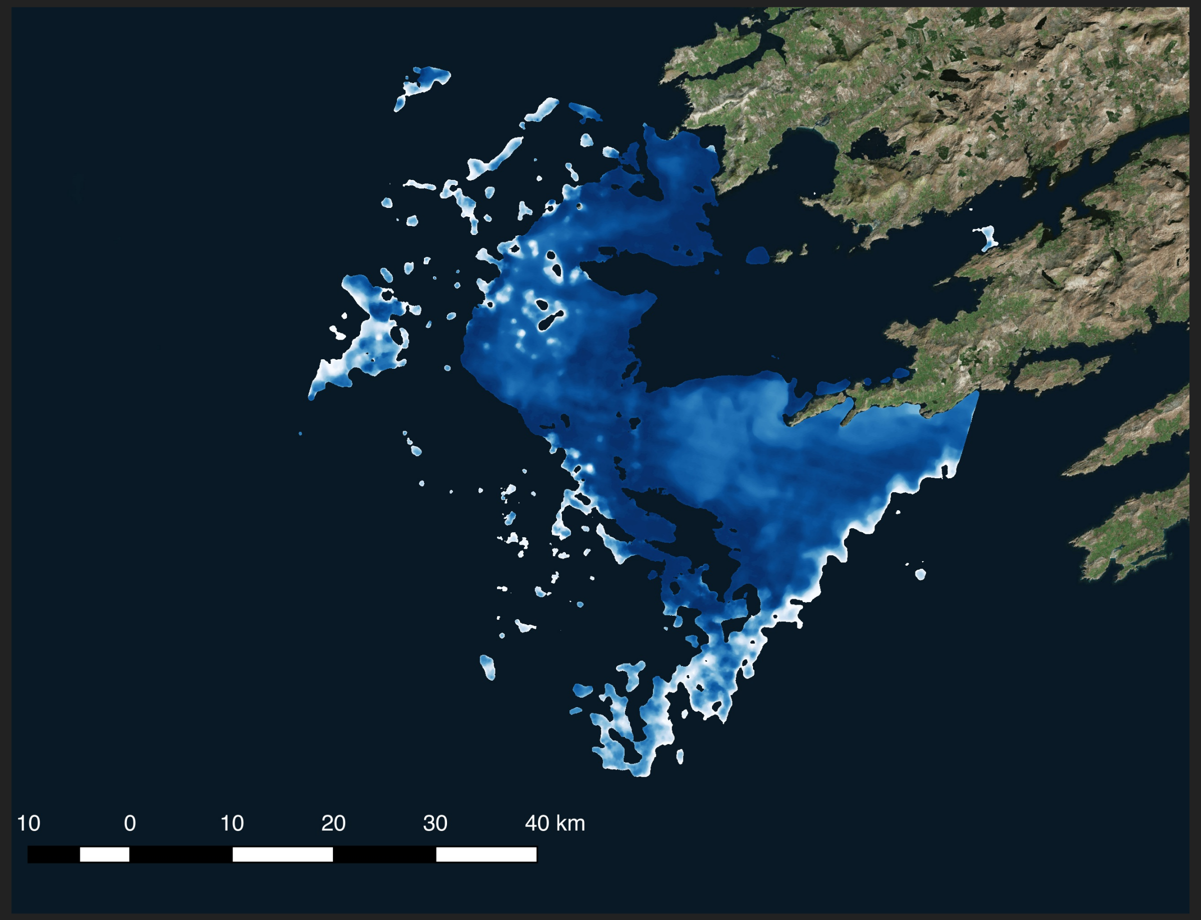
Mask clouds
$T > \overline{T} - \sigma_T$



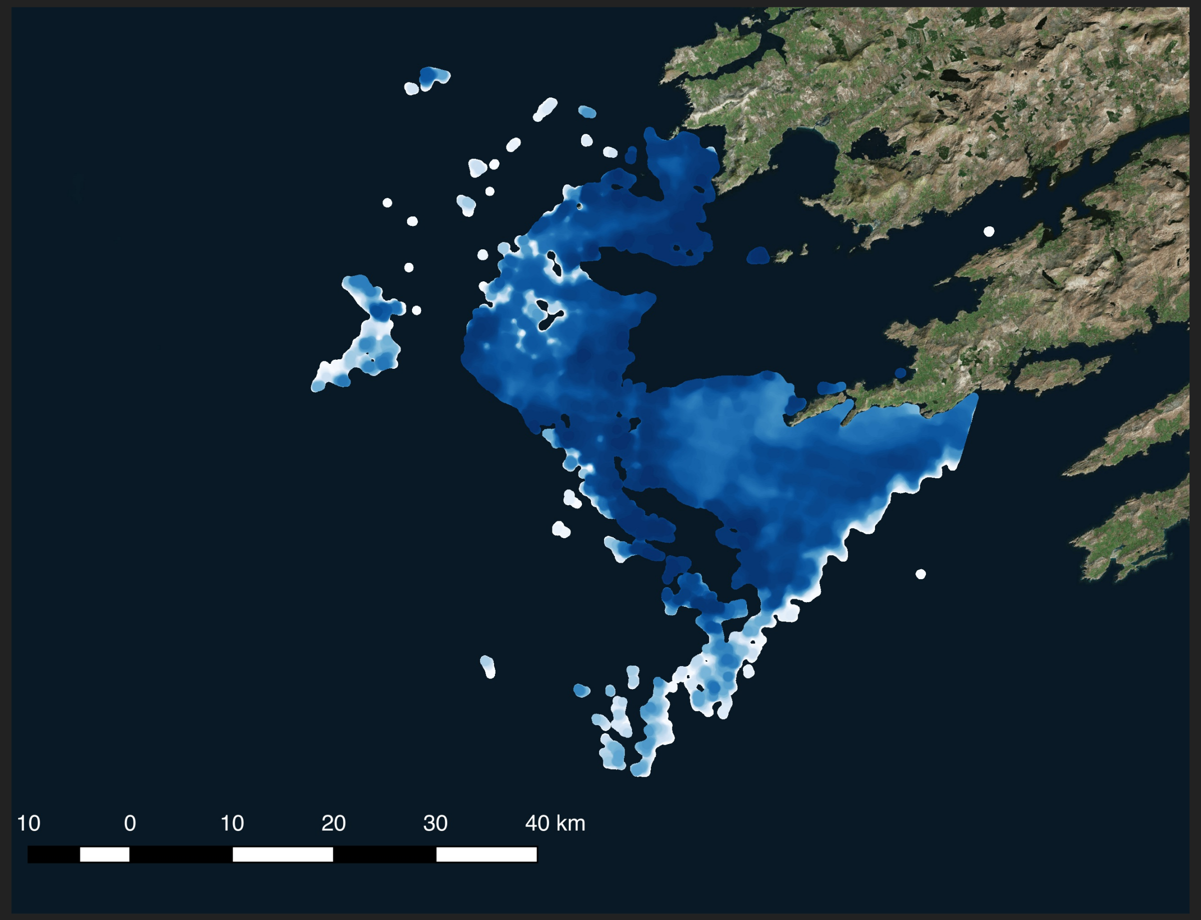
Mask hotspots
$T < \overline{T} + 2\sigma_T$



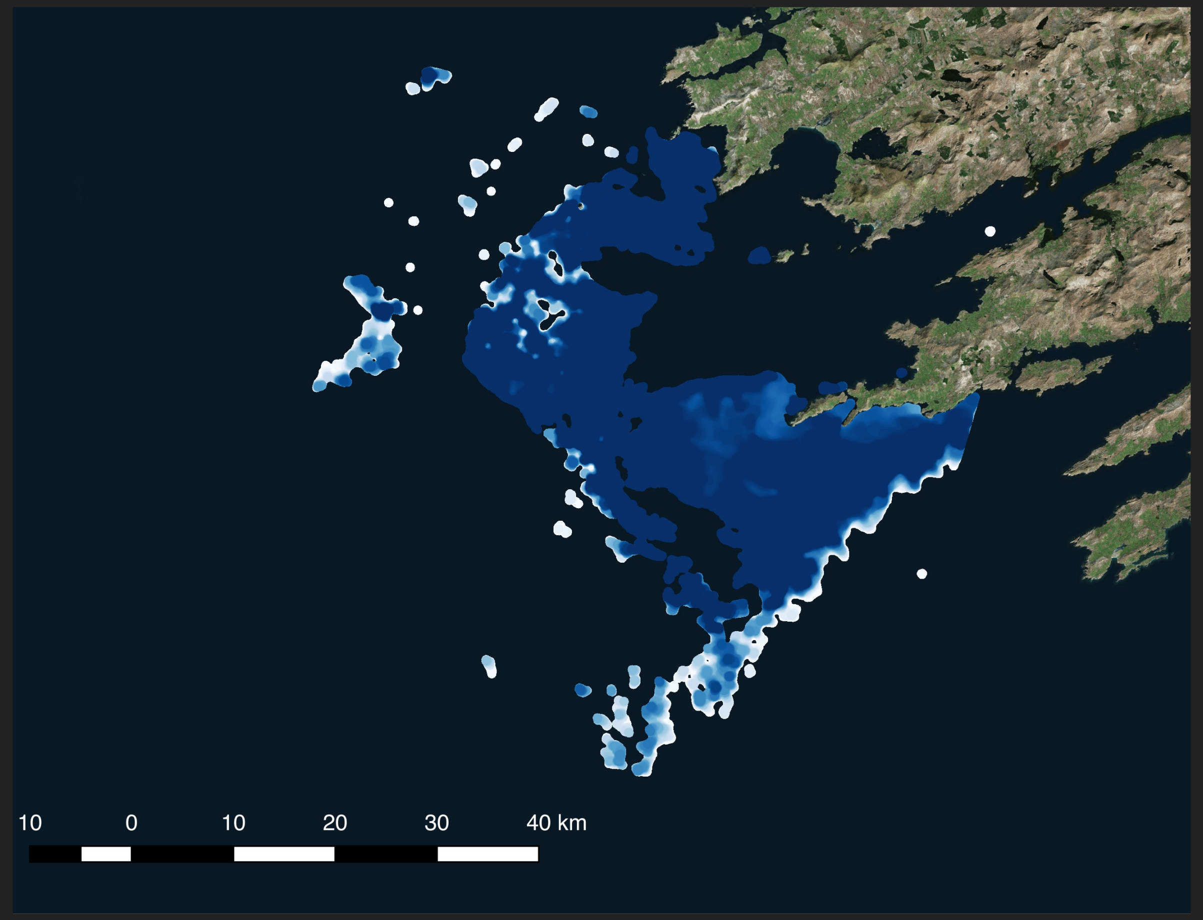
Mask average
$T < \overline{T}$



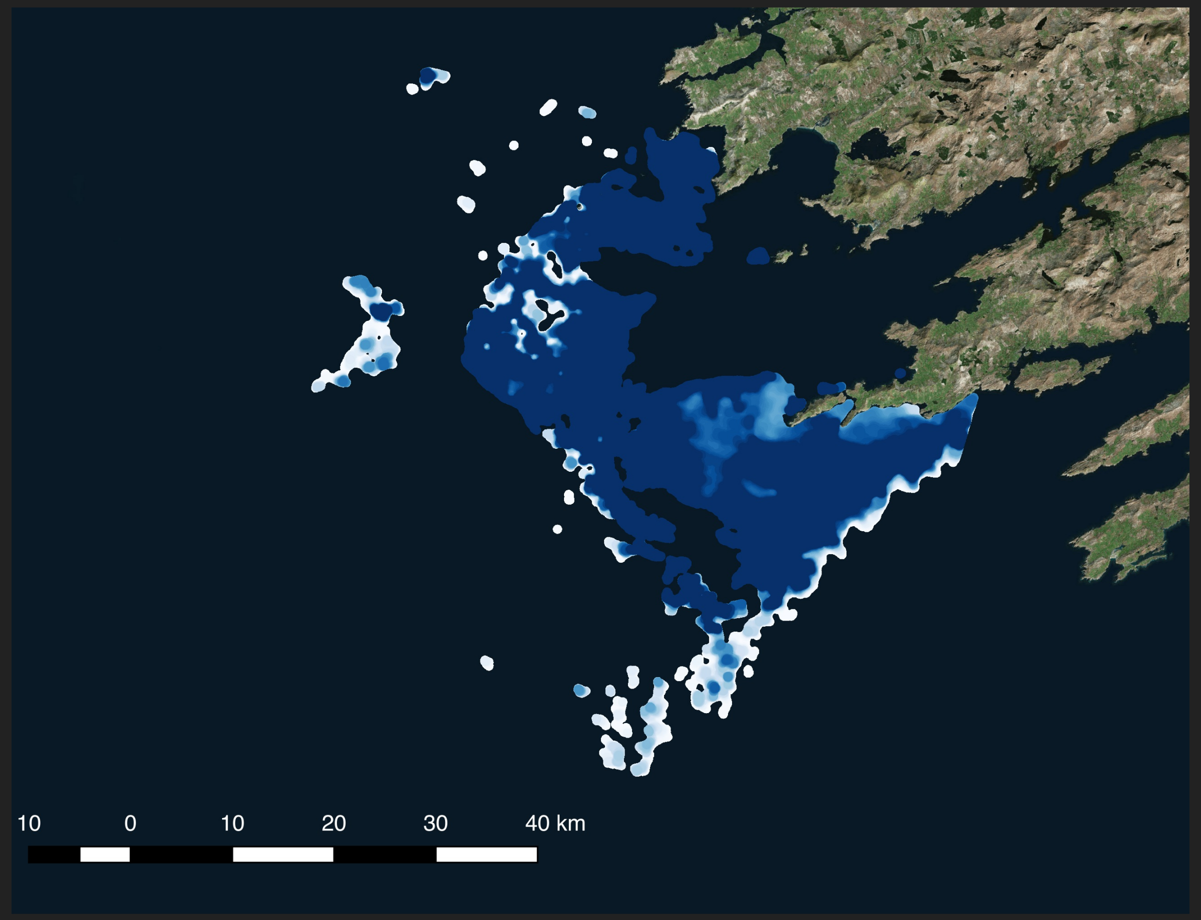
Median filter



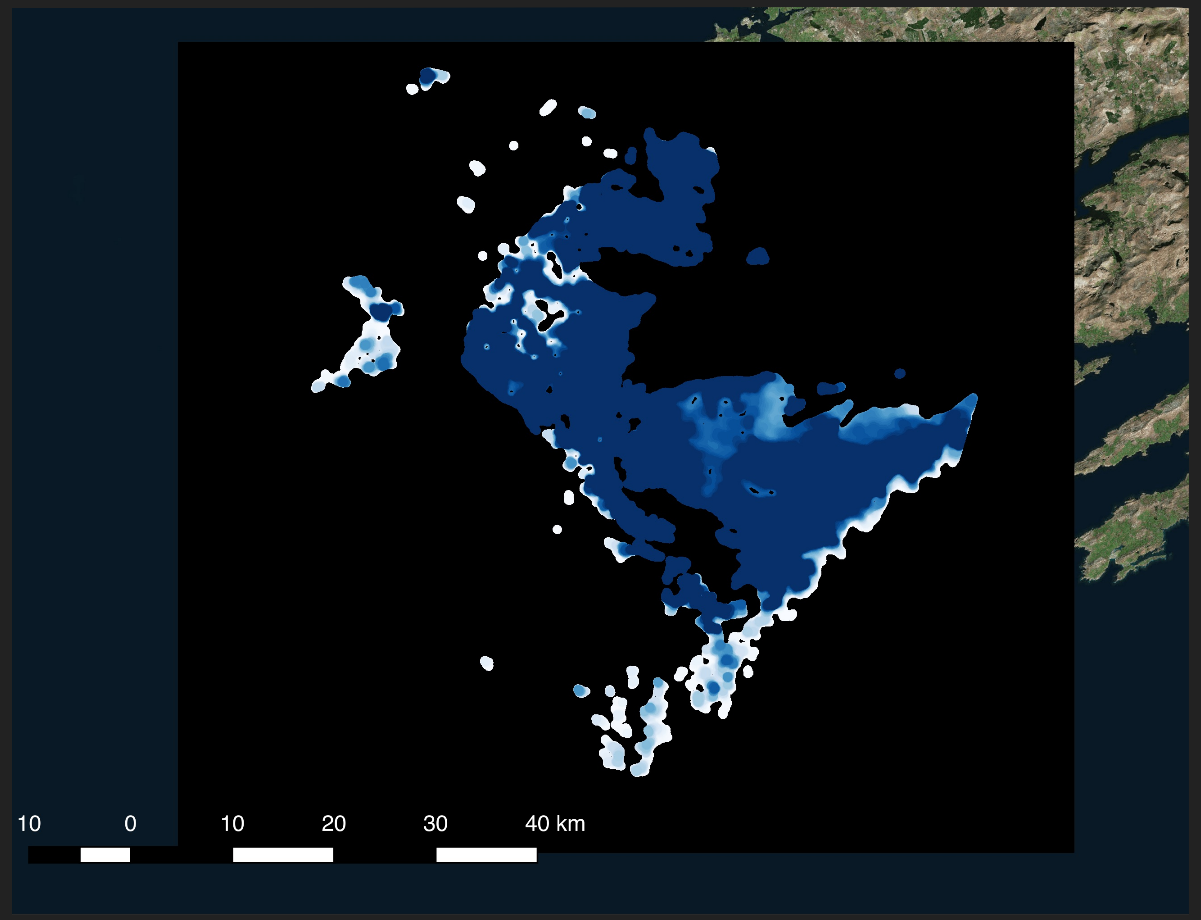
Morphological opening



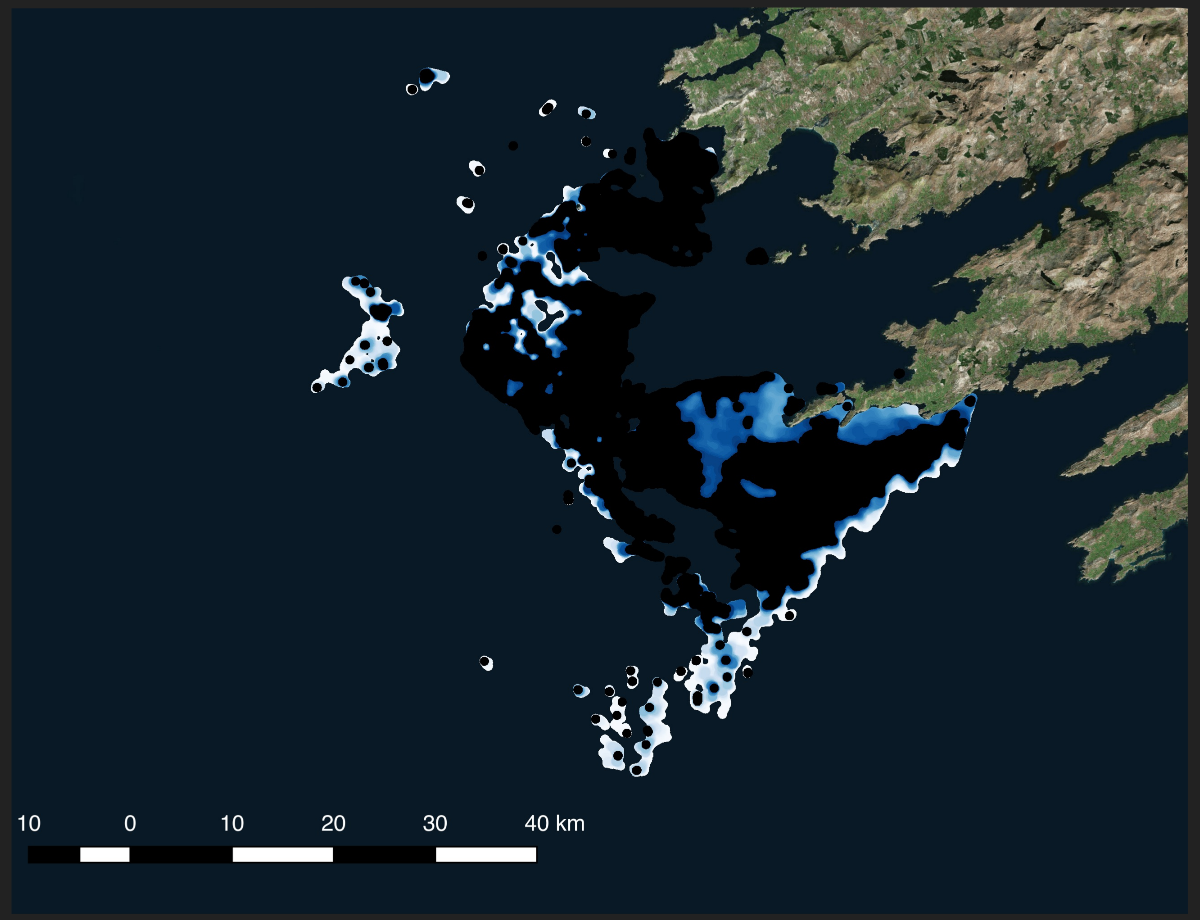
Histogram stretch
Rescale intensity



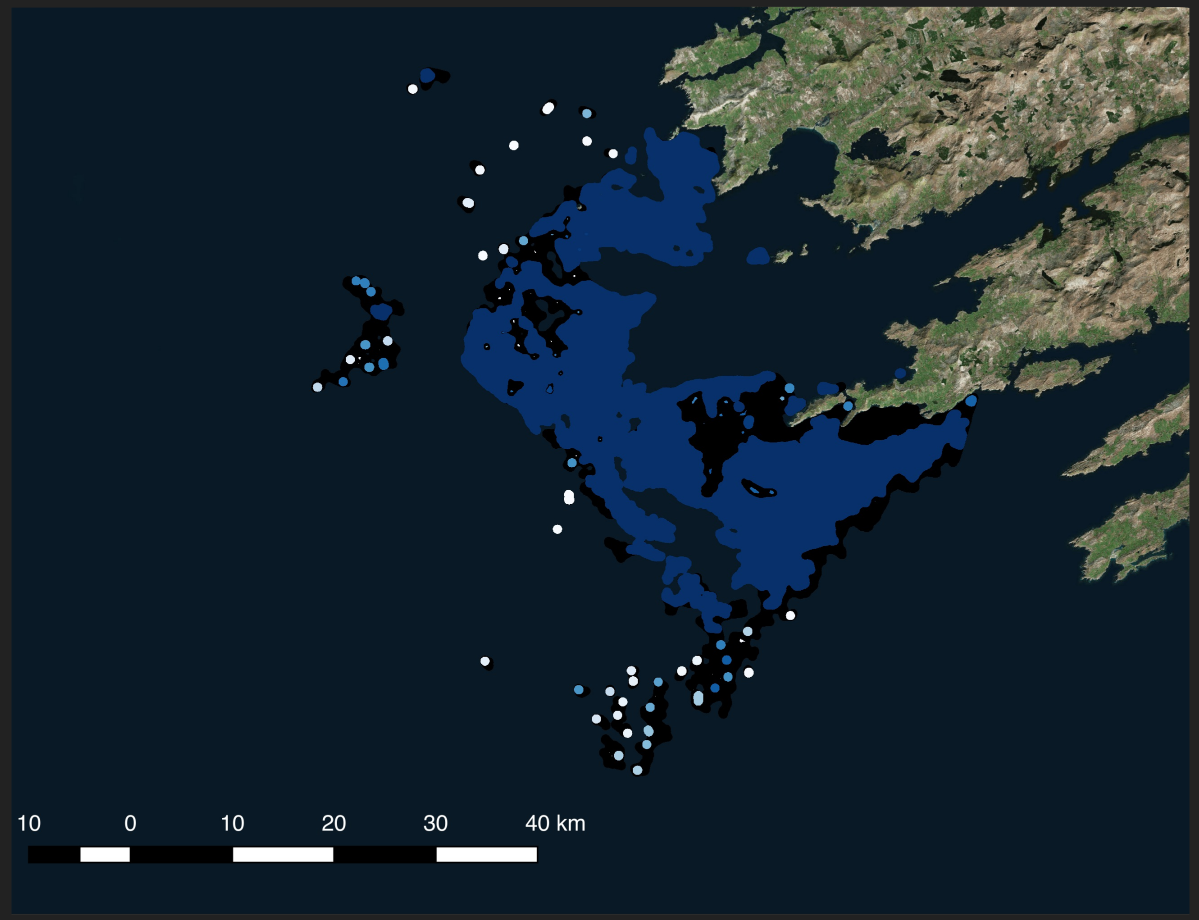
Histogram stretch
Gamma adjustment



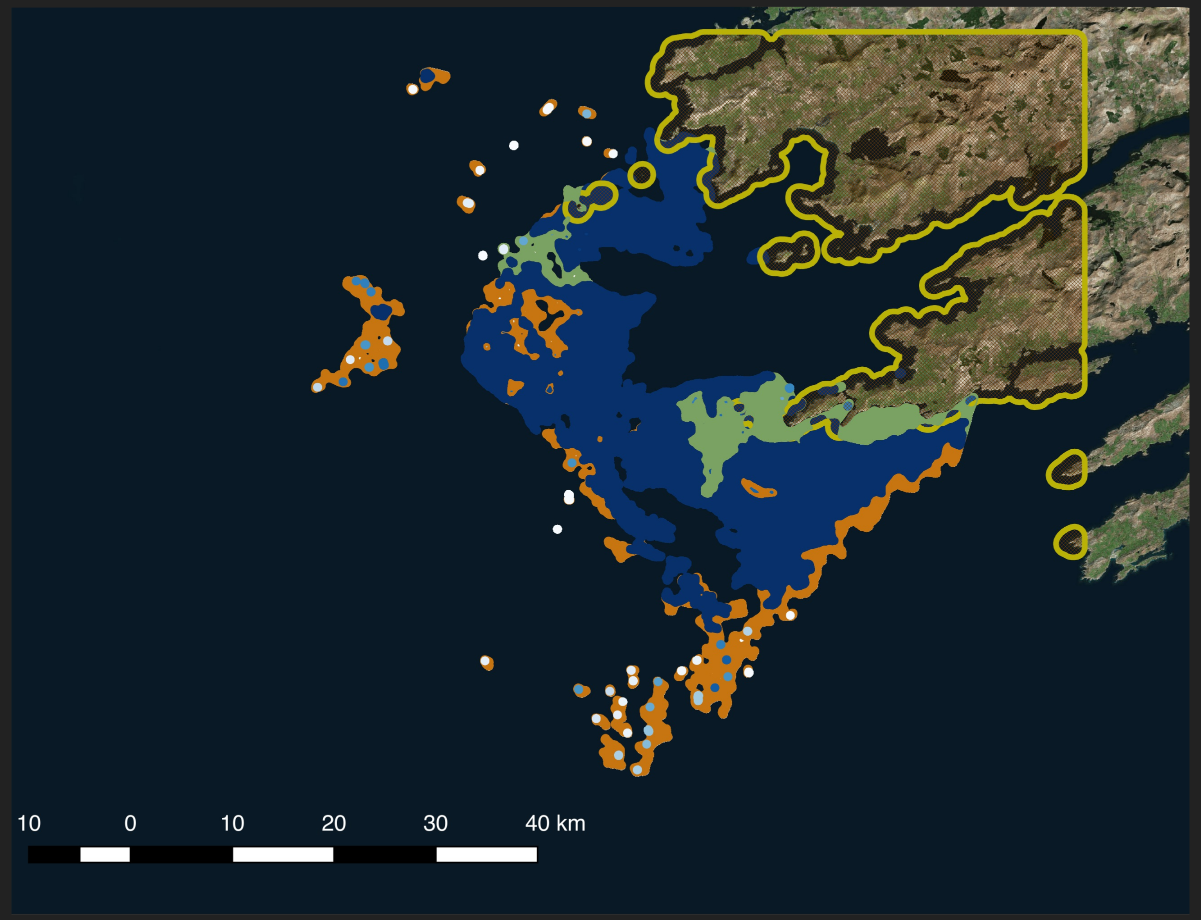
Mask extrema
Local minima



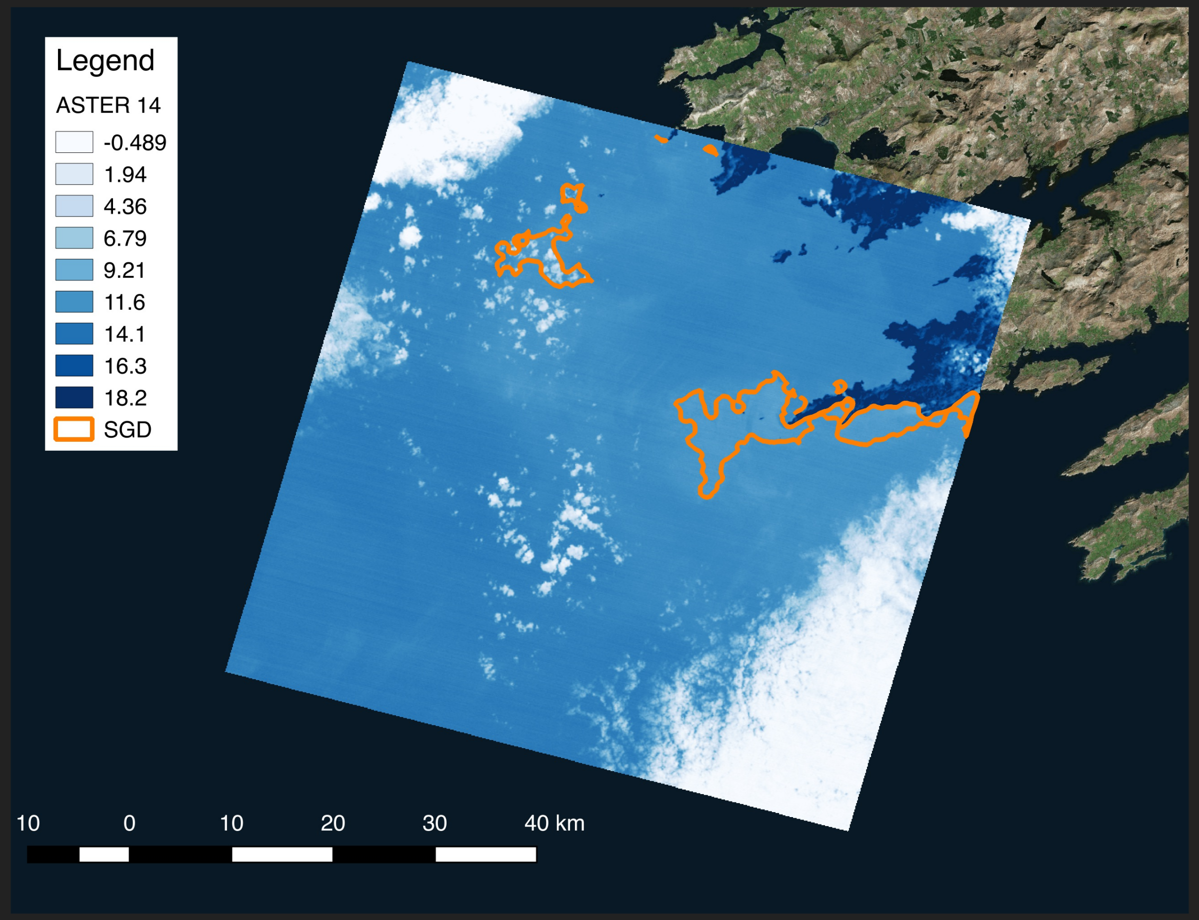
Mask extrema
Local maxima



Mask extrema
NOT(Local maxima OR Local minima)



Select close to coast
1 km buffer



SGD plumes
automatically detected

PROS

- Automatic method
- Pinpoint locations

CONS

- May not work everywhere (untested)
- Assumptions may need fine tuning