Remote Sensing Analysis of Cyclone Energy Uptake

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Outline

GOALS

Theory

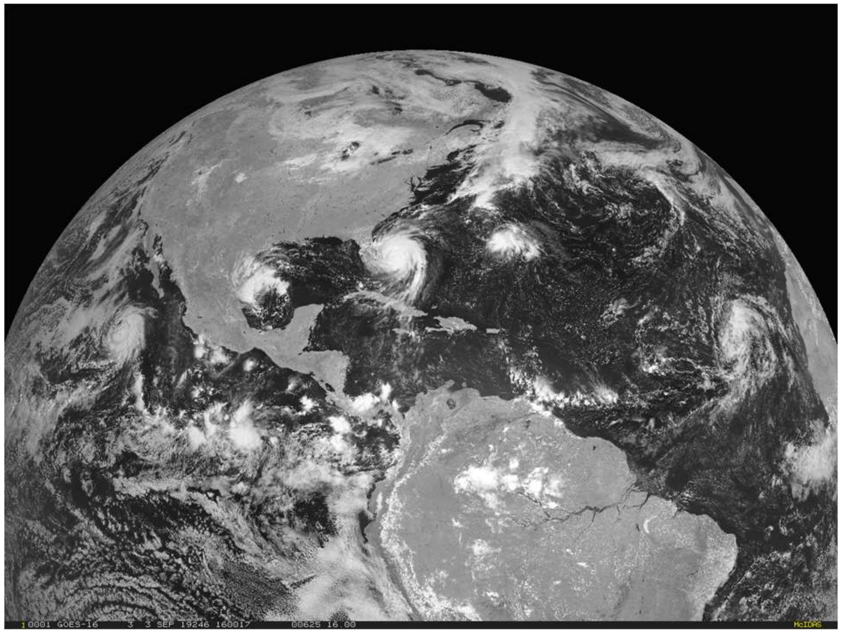
Methods

Results

Conclusions

Goal

- Determine correlation between hurricane intensity and energy uptake through analysis of sea surface temperature (SST) differentials



Hurricane trajectory visualization

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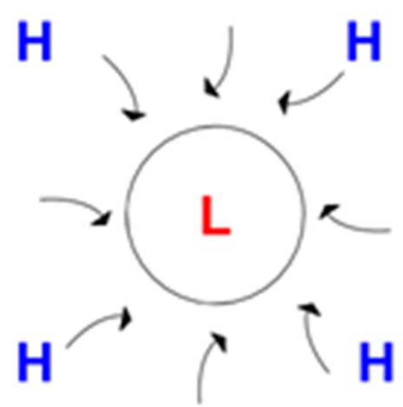
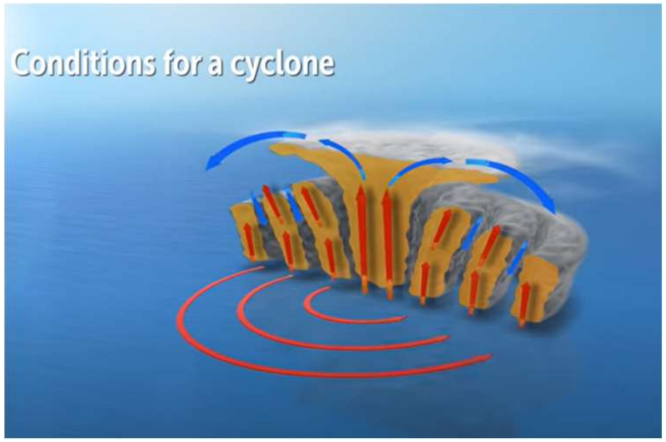
Theory – Hurricane Structure & Dynamics

- Center of low pressure forms over warm seas, resultant winds deflected via Coriolis effect
- Central, moist air heated by seas, rises and cools adiabatically, condensing vapor & releasing energy into upper atmosphere
- Negative pressure differential draws in adjacent air, subsequently gets heated, rises, then cools



Coriolis effect induces rotation about a center of low pressure



Hurricane cross section: warm air rises then cools & releases energy, falls back down

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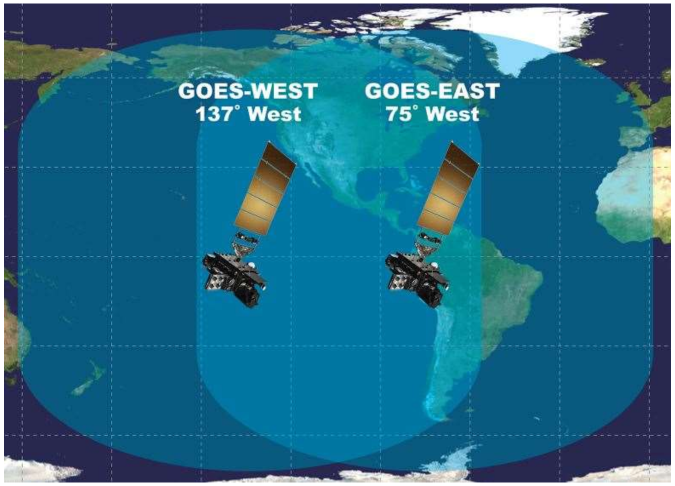
Theory – GOES 16 ABI

- Satellite: GOES 16 - Geostationary Operational Environmental Satellite
  - Stationed at longitude 75.2^{o}W in geostationary orbit
- Instrument: Advanced Baseline Imager (ABI)
  - 16 bands, λ = (0.47 – 13.28 μm)
  - Spatial res. = (.5 – 2 km)
  - Temporal res. = (30 sec – 30 min)



GOES Positions
Credit: NOAA NESDIS

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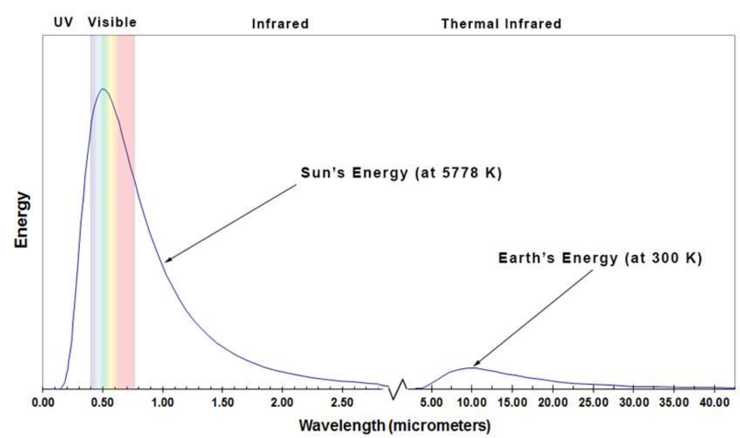
Theory – Energy Determination

- Convert digital optical information (number of photons striking detector) to thermal information (sea surface temperature)
- Planck Function: $T = \frac{\frac{1284.9}{\ln\left(\frac{8483.1}{SR}\right)+1} - 1}{.9991}$ (constants for B14)



Blackbody curves of Sun and Earth
Credit: Humboldt State University

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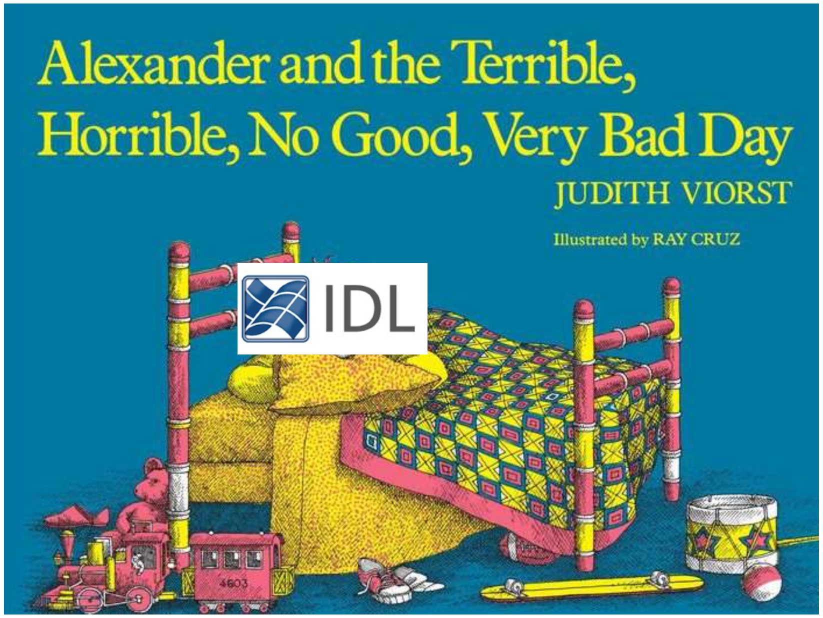
Methods

- Programmatically process GOES-16 imagery from 2018, 2019, 2020 hurricane seasons in MATLAB
- Determine energy uptake via SST differences, compare to reported hurricane intensity



IDL in a nutshell

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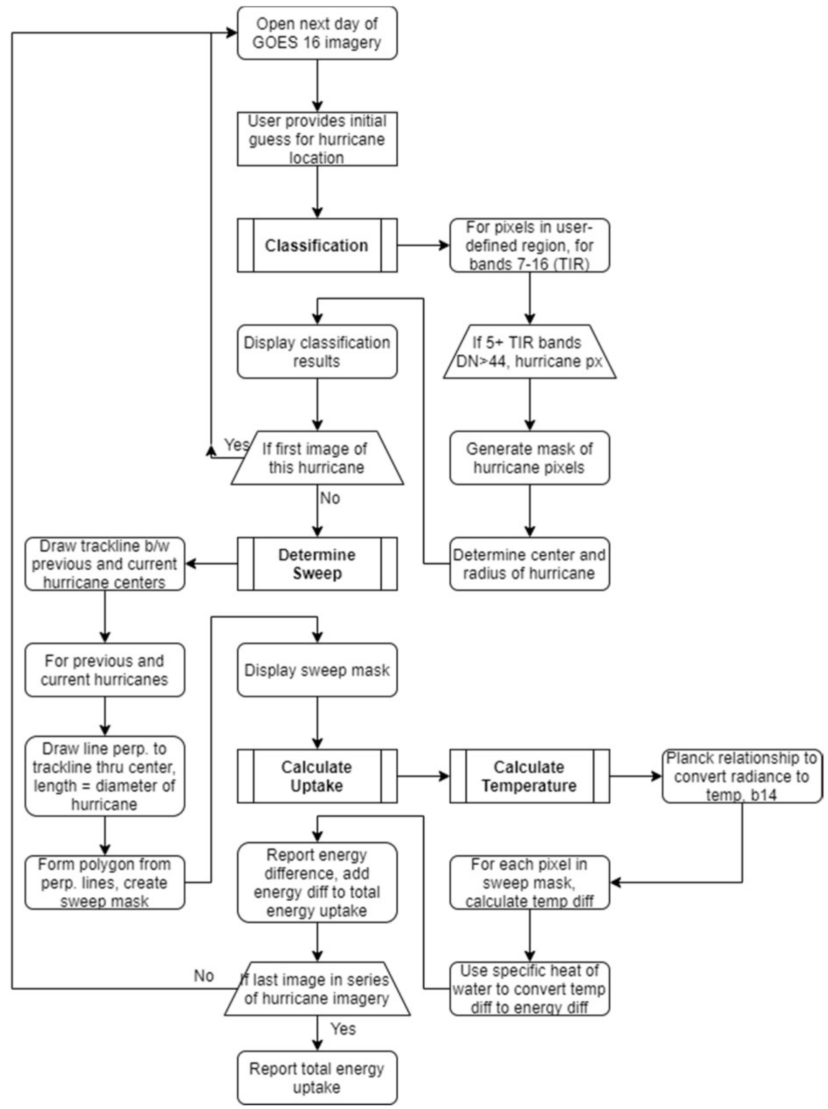
Methods – Script Outline

- Classification
- Sweep Determination
- Temperature Calculation
- Energy Uptake Calculation



Script flowchart

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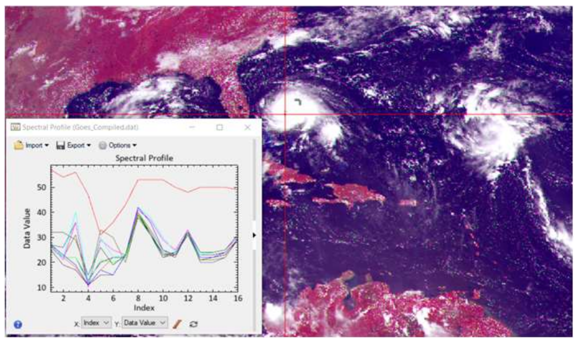
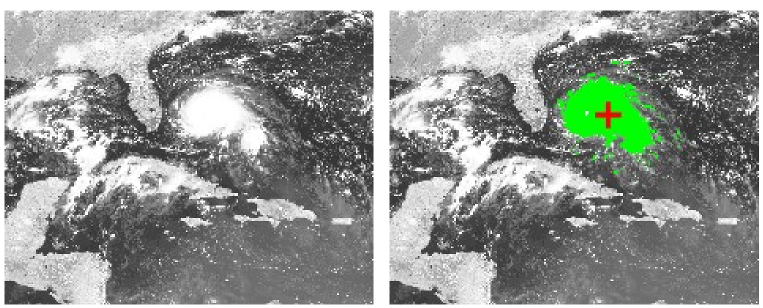
Methods – Classification

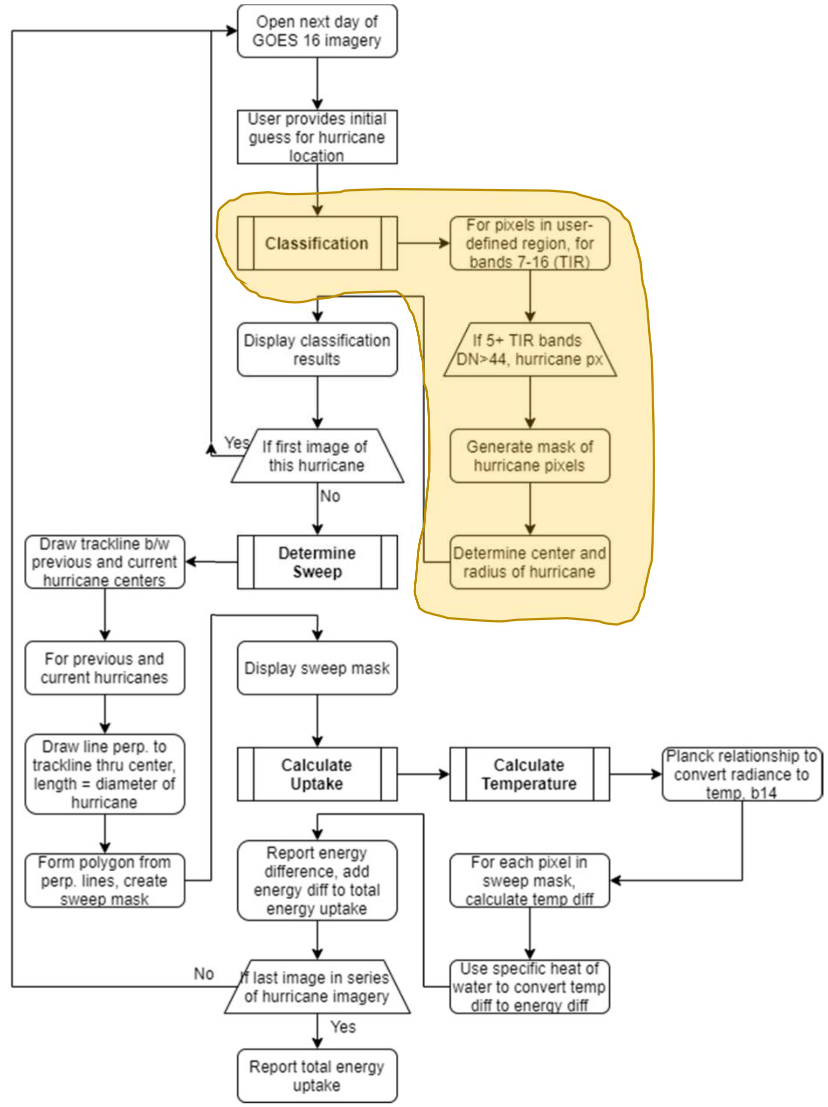
- Binary Encoding:
  - For each pixel, if X% of bands are above DN=Y, count that px



Hurricane/cloud pixel spectrum vs sea & land



Example classification results



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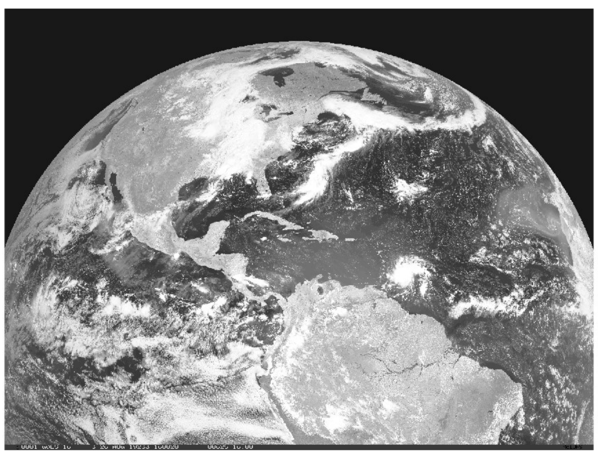
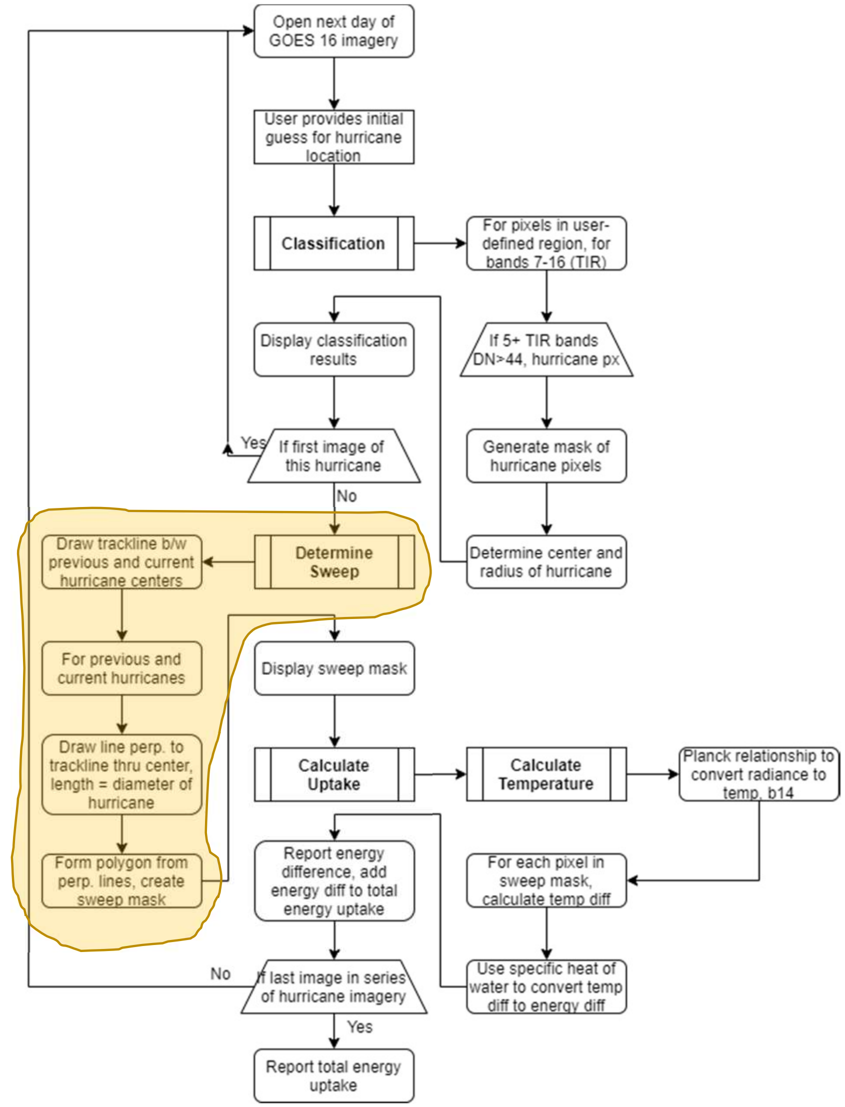
Methods – Sweep

- Classify two consecutive hurricane images
- Draw polygon between two hurricane masks
- Within polygon, invert mask to define swept region



Example sweep determination



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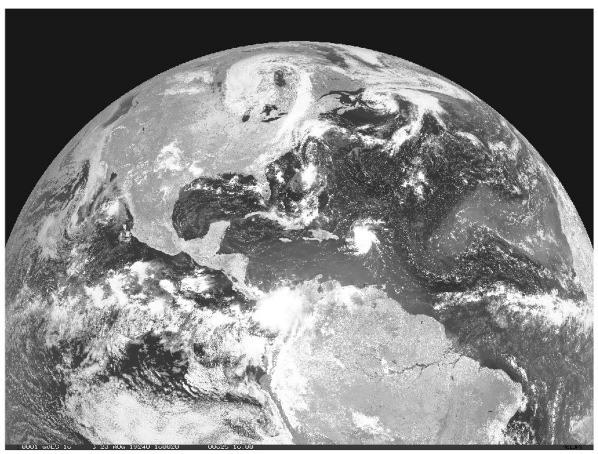

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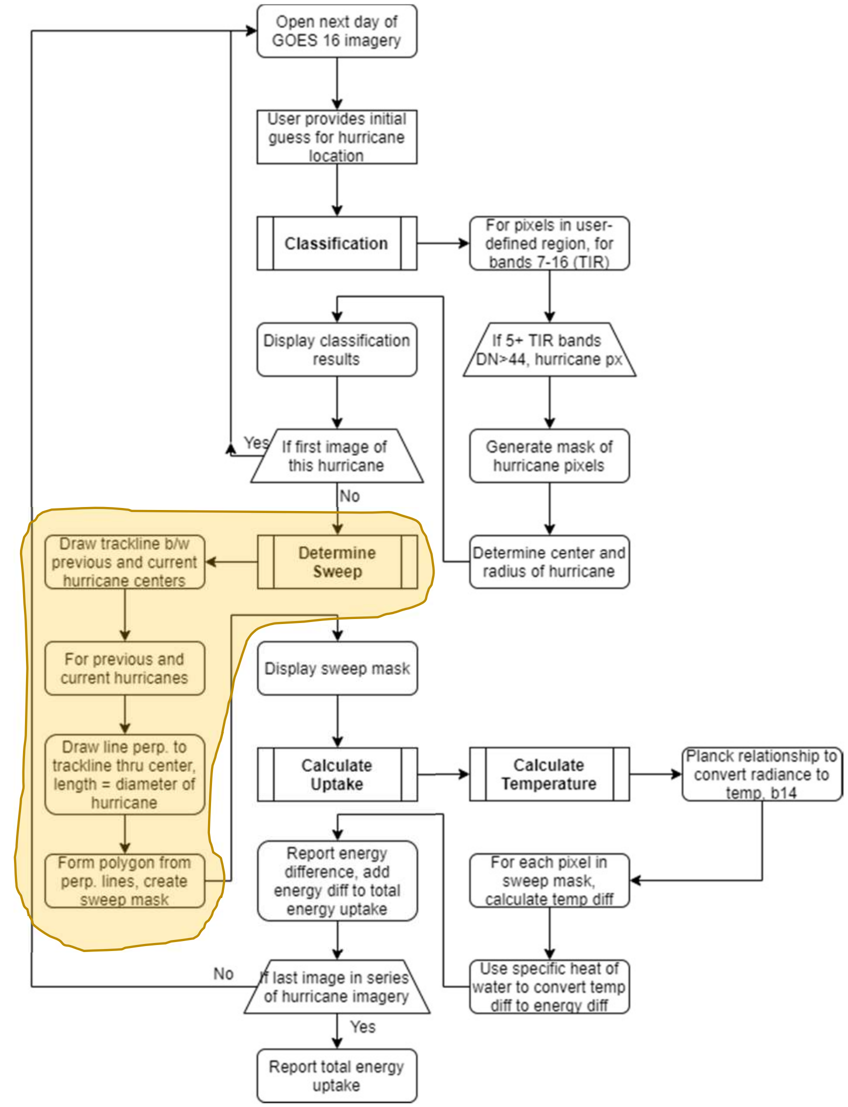

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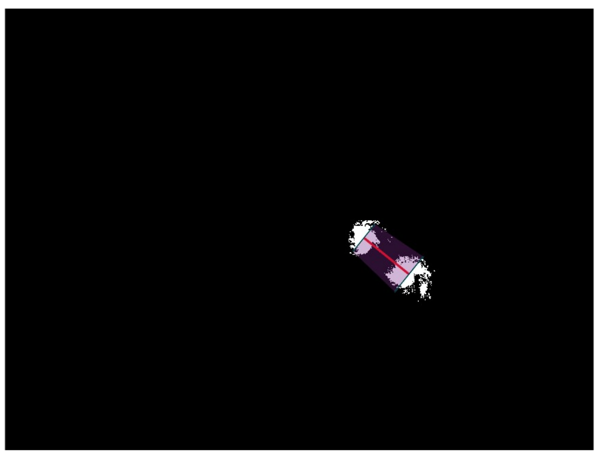

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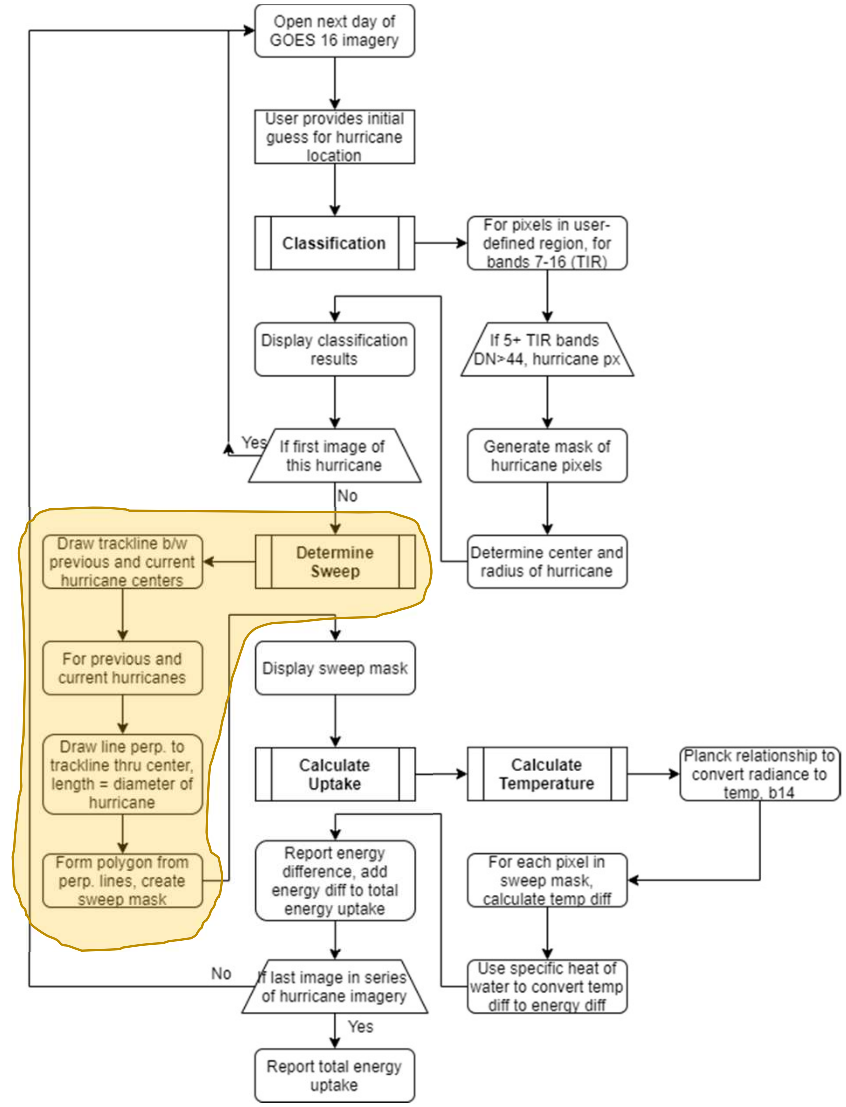

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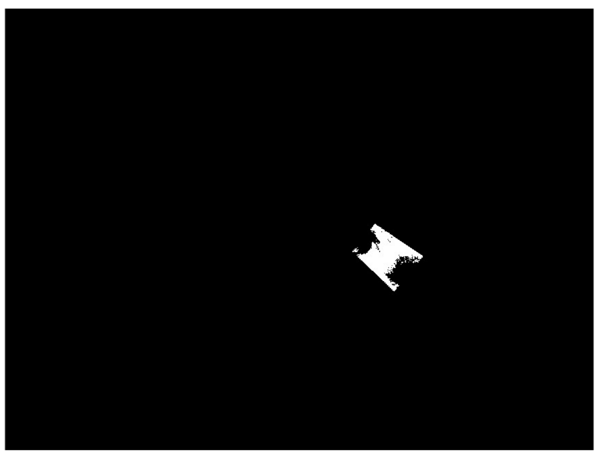
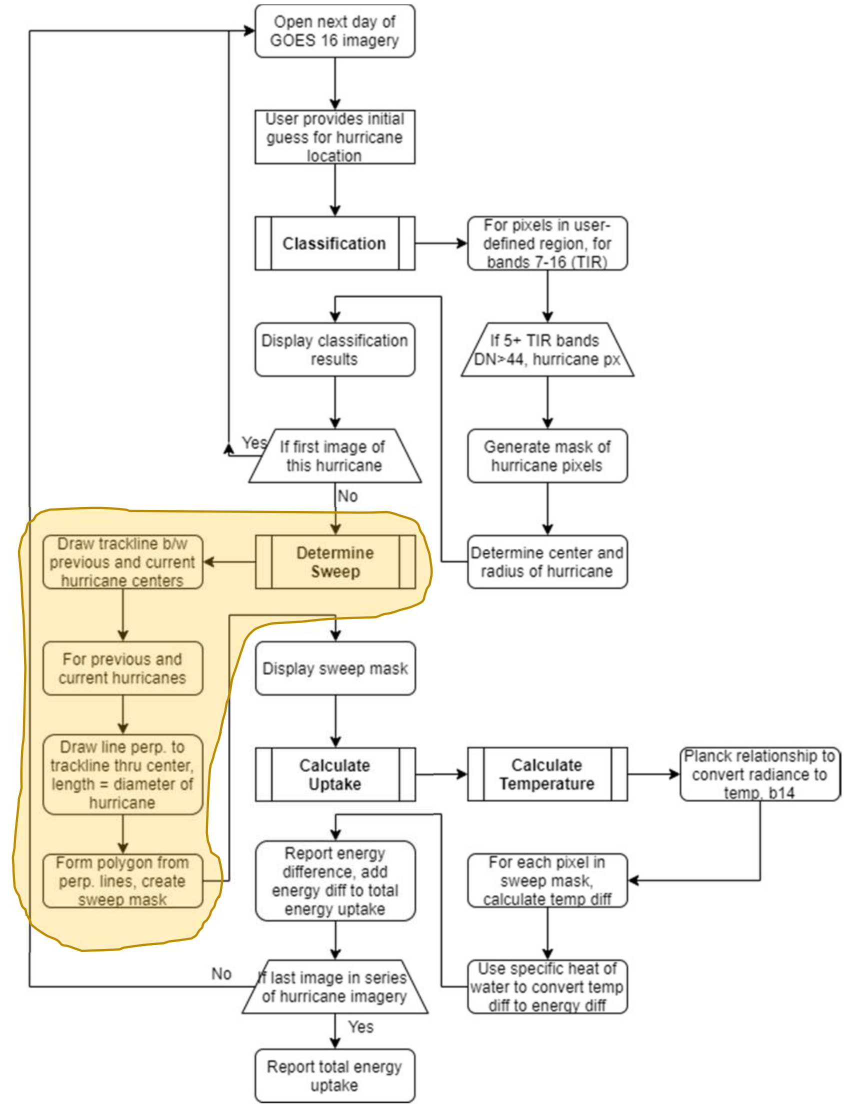


Example sweep determination



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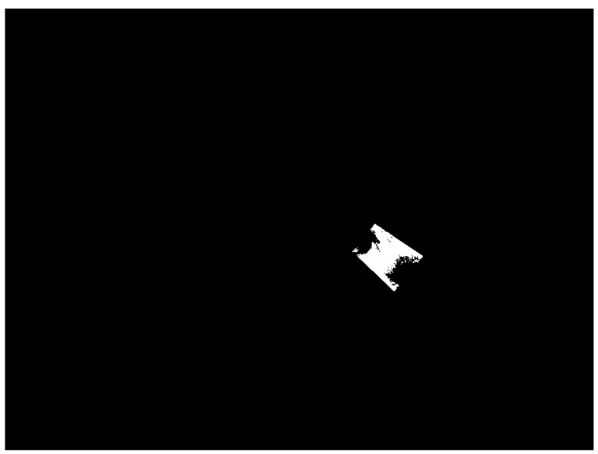

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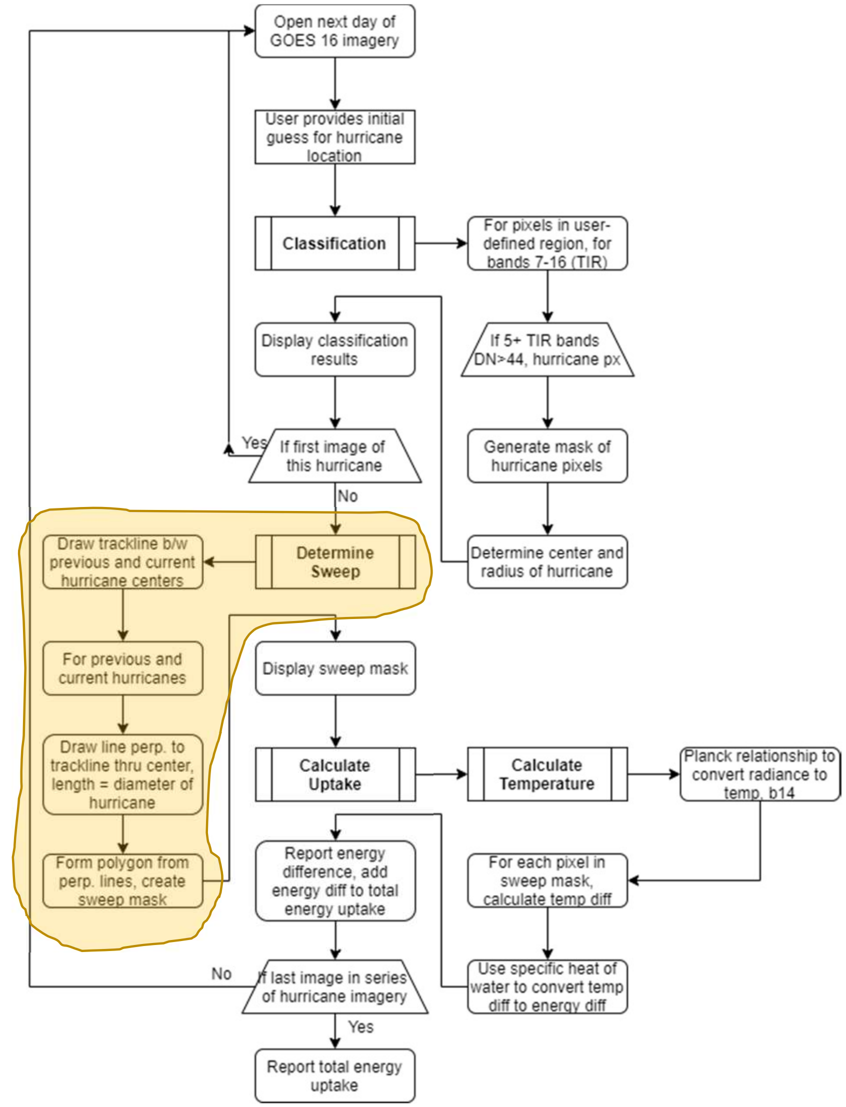

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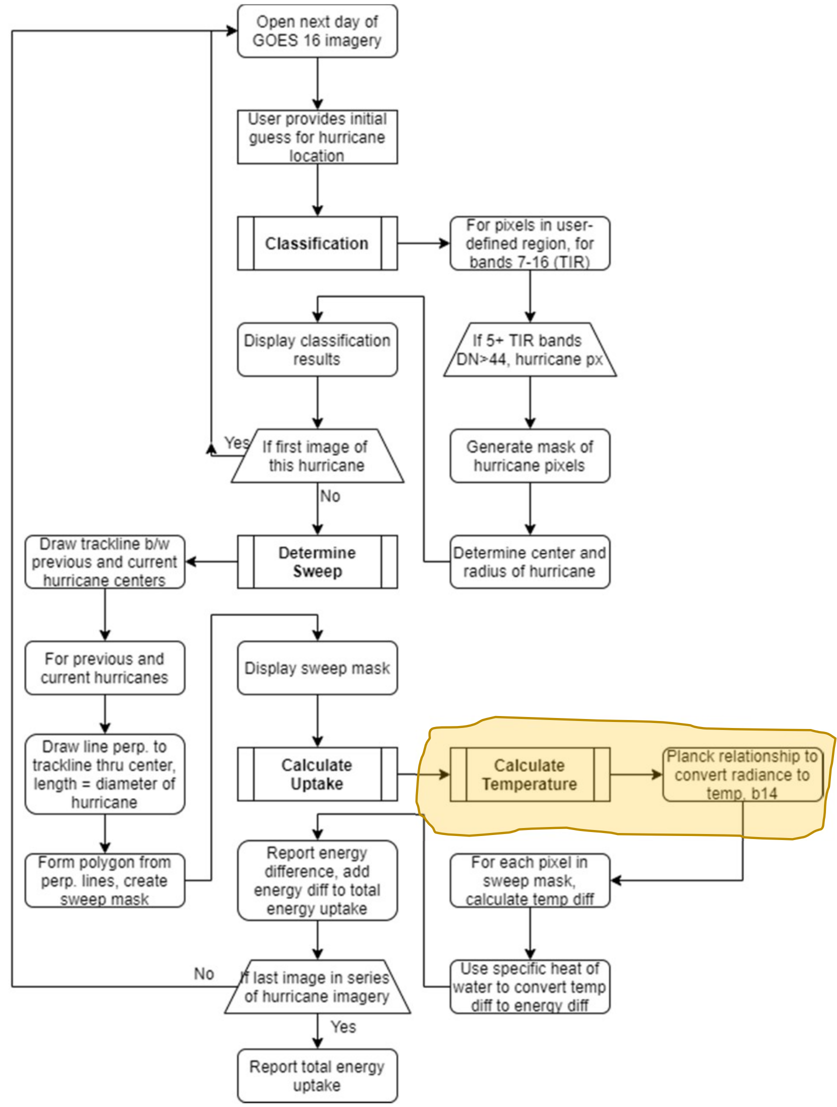
Methods – Temperature

- Thermal IR bands DN to Temp
  - Undo compression: DN → SR
  - Planck: SR → T

Digital Compression: $SR = a * DN + b$

Planck Function: $T = \dfrac{\dfrac{1284.9}{\ln\left(\dfrac{8483.1}{SR}\right)+1} - 1}{.9991}$ (B14)

- Note: Compression constants a and b unavailable. Temp differences & therefore energy uptake in arbitrary units.



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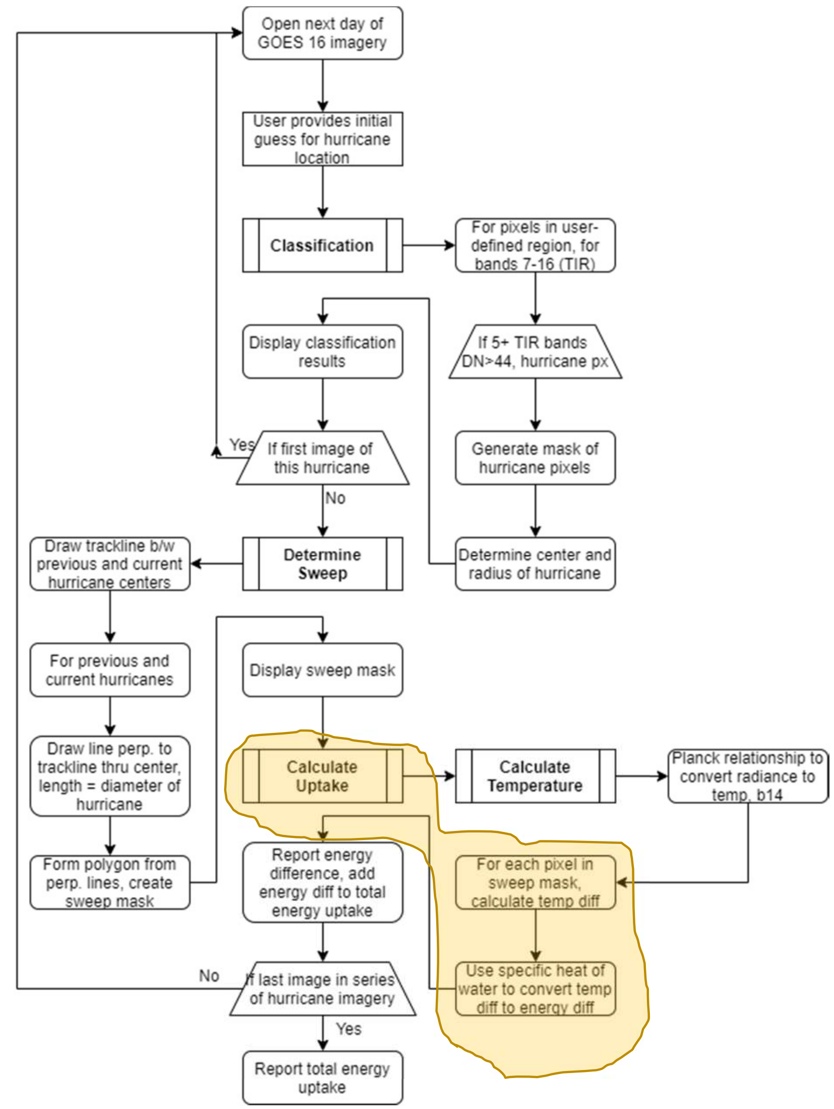
Methods – Uptake

- Calculate temperature difference between consecutive iterations in sweep mask
- Calculate area of sweep mask, assume 1m deep – convert volume to mass
- Specific heat of seawater:
  - C = 4100 J/kgK

Energy: $E = mc\Delta T$



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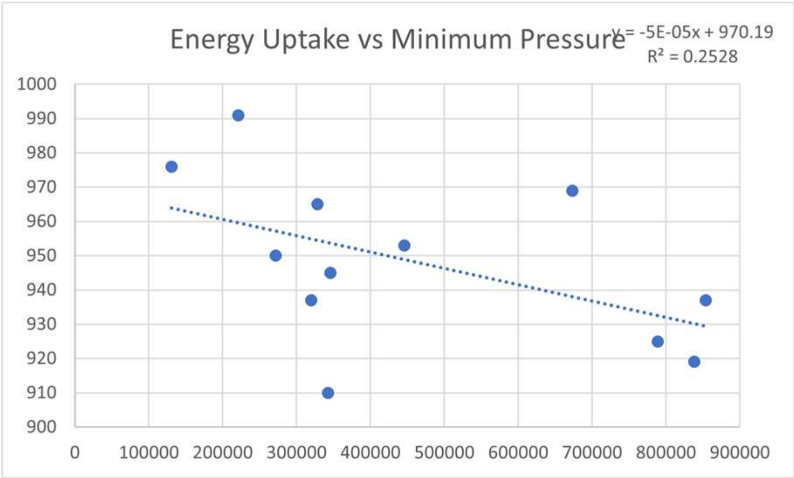
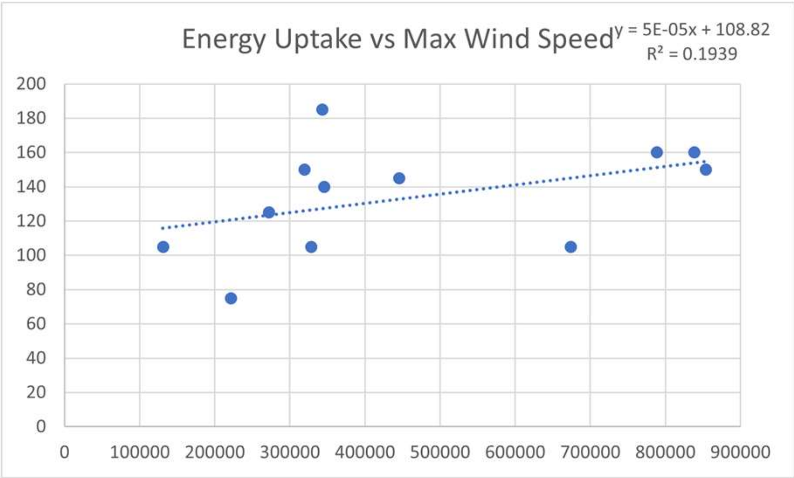
Results

- Correlation between energy uptake and reported intensities weak to nonexistent





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Conclusions

- Possible contributions to weak correlation:
  - Temperature algorithm only accounts for temp of top 10μm of sea, hurricanes extract heat from much deeper
  - Energies varied significantly between iterations (up to ~4 O.O.M), ROIs (up to ~2 O.O.M) – AKA Signal-to-Noise too low
  - Difficult to discern between system clouds and others
  - Script doesn’t handle stationary systems well

Questions?