# Remote monitoring of giant kelp biomass and photosynthetic condition

## An evaluation of the potential for the Hyperspectral Infrared Imager (HyspIRI) mission

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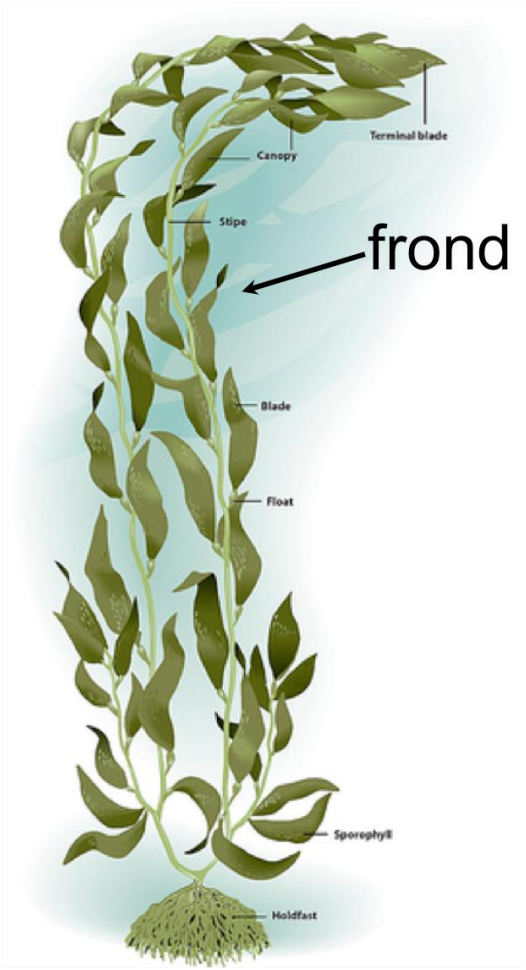
Photo: Stuart Halewood

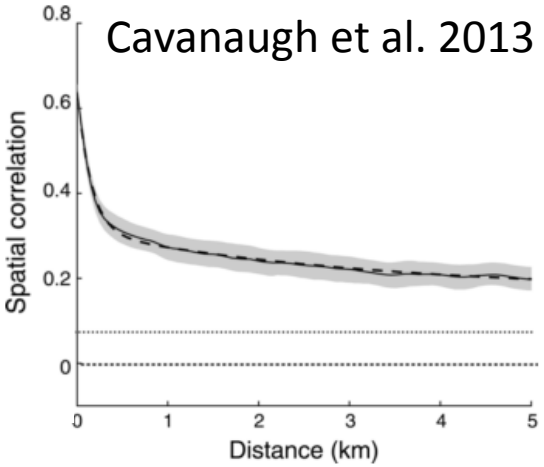
# Giant kelp is highly dynamic… and important

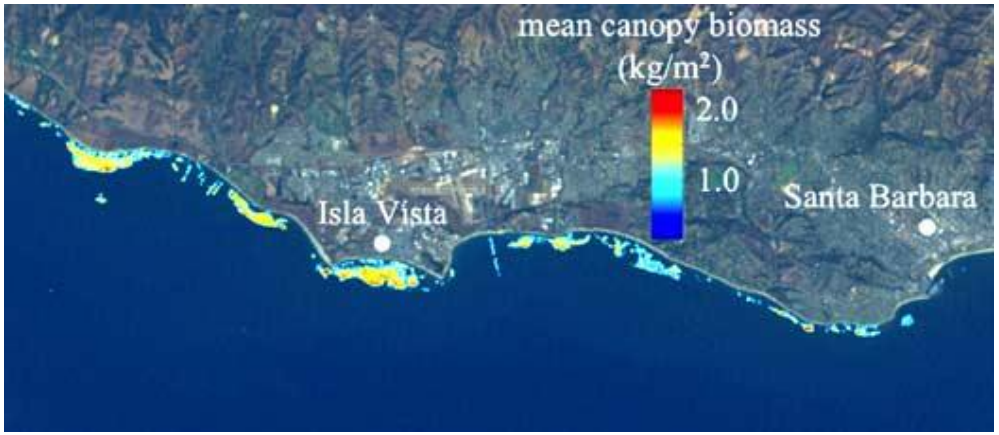




- Thallus lifespan: ~2.5 yr
- Frond lifespan: ~4 months
- Frond growth rate: 0.5 m $d^{-1}$
- Canopy amenable to remote sensing
- Food and habitat for important species

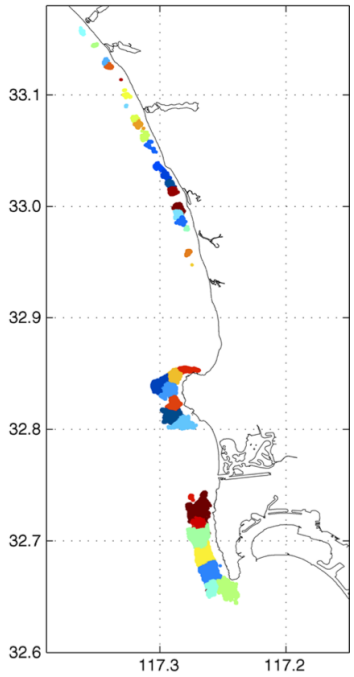
# Landsat 5 kelp canopy biomass timeseries

Cavanaugh et al. 2013

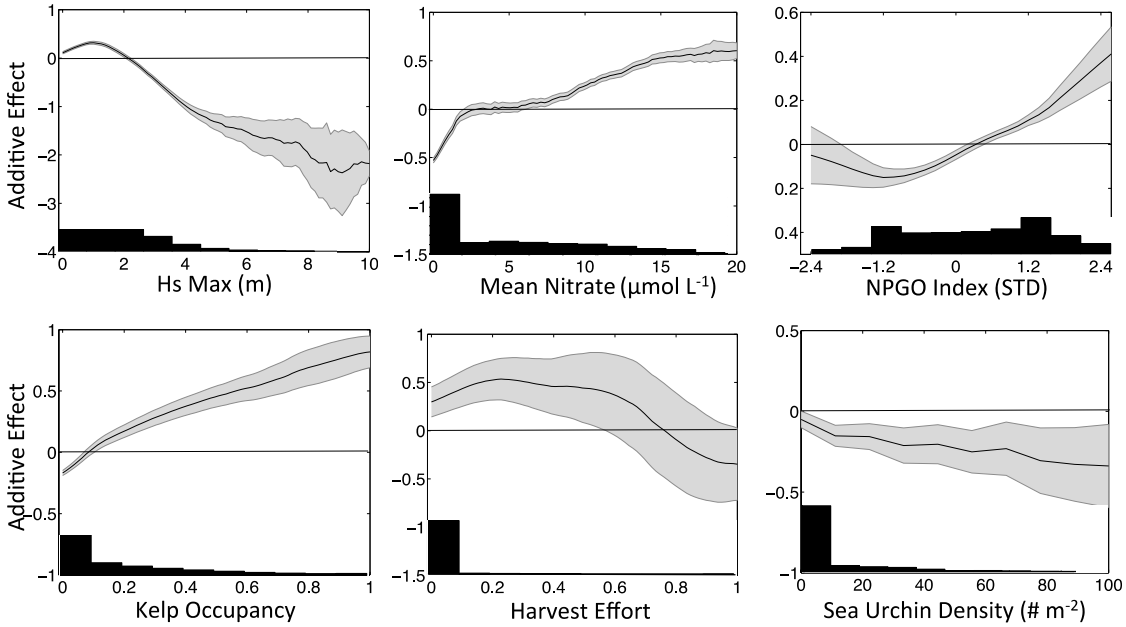



Cavanaugh et al. 2011



Cavanaugh et al. 2014



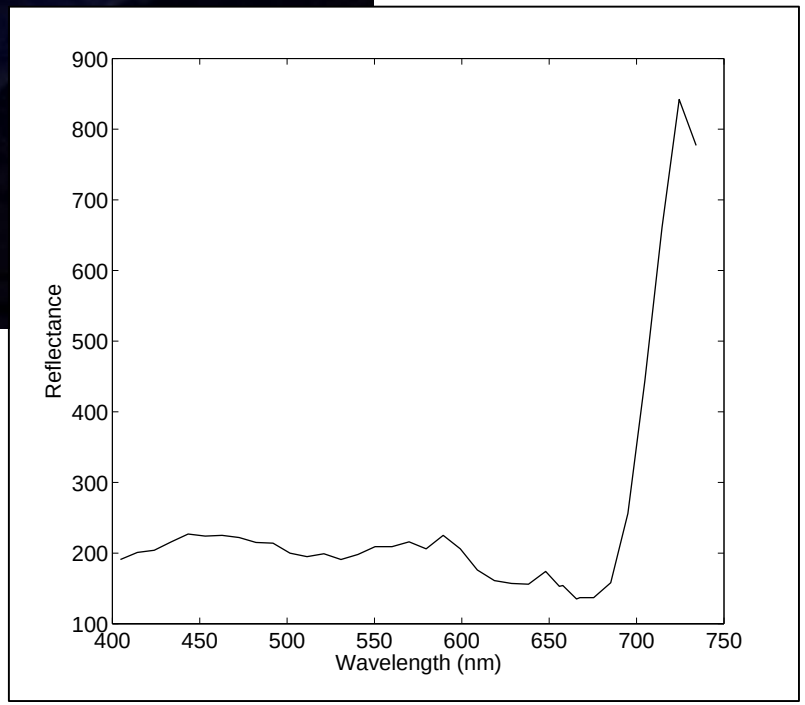

Bell et al. *in prep*

# Pigment dynamics are unknown

- Affect photosynthetic rates and net primary production
- Alter energy flows and change interaction strengths between kelp forest species
- Deterioration of fronds hinders ability to provide biogenic structure and withstand disturbance
- Likely to vary over time and space

# HyspIRI Preparatory Airborne Campaign

AVIRIS
Santa Barbara Box
4/11/2013
L2 Reflectance

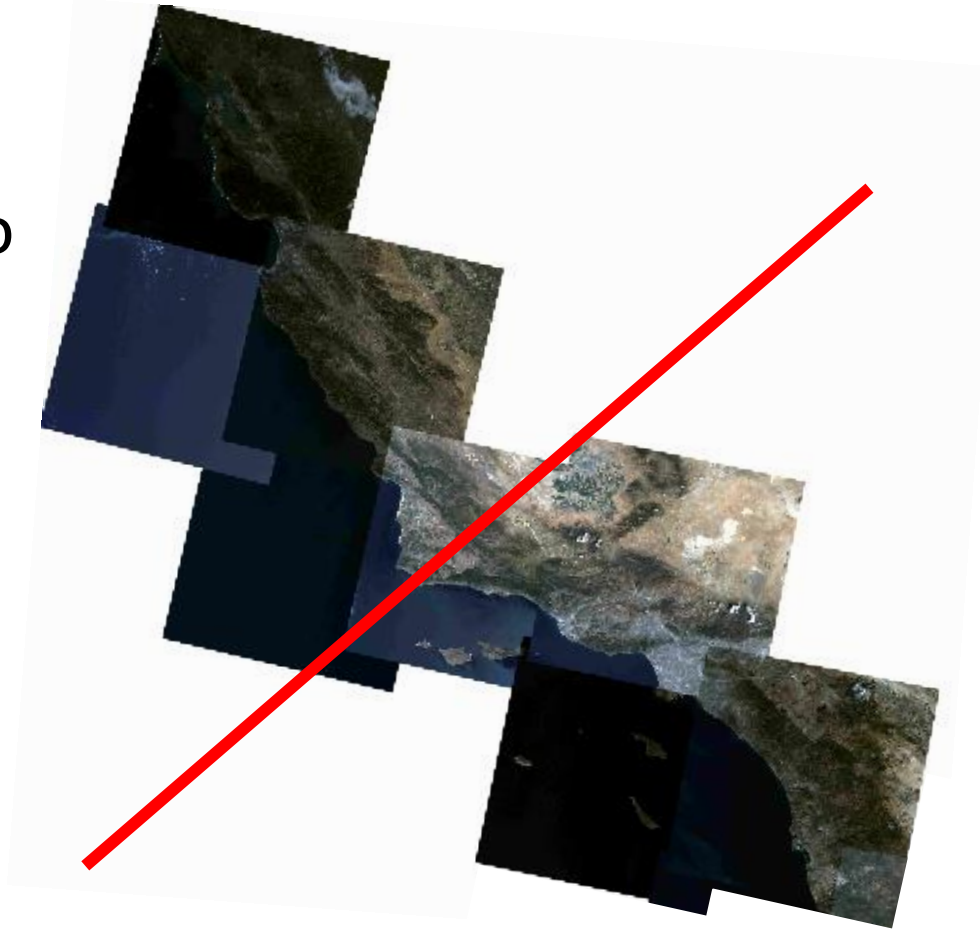


# Questions

- Will the 19-day revisit time of HyspIRI adequately capture giant kelp forest biomass and pigment state dynamics?
- Will the spectral resolution of HyspIRI allow for the assessment of pigment state of the giant kelp canopy?
- What new questions will HyspIRI allow researchers to answer concerning the ecological role of this globally distributed ecosystem engineer?

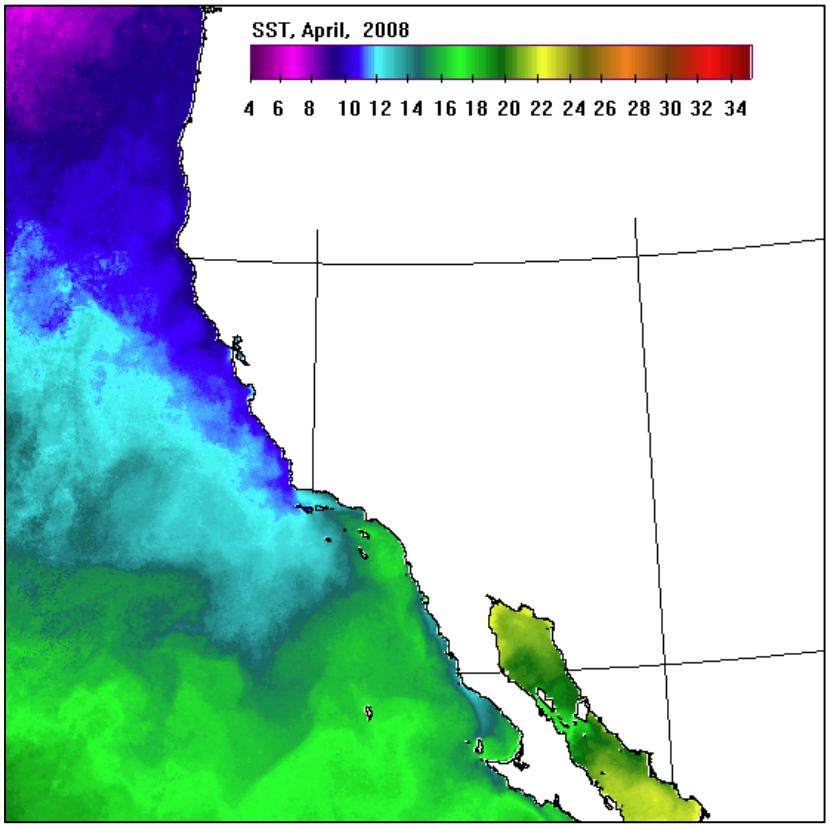
# Landsat kelp biomass timeseries

- 1984 – 2011
- San Francisco to US/Mexico border
- 8 scenes
  - 175 – 240 images each
- Wavelet analysis

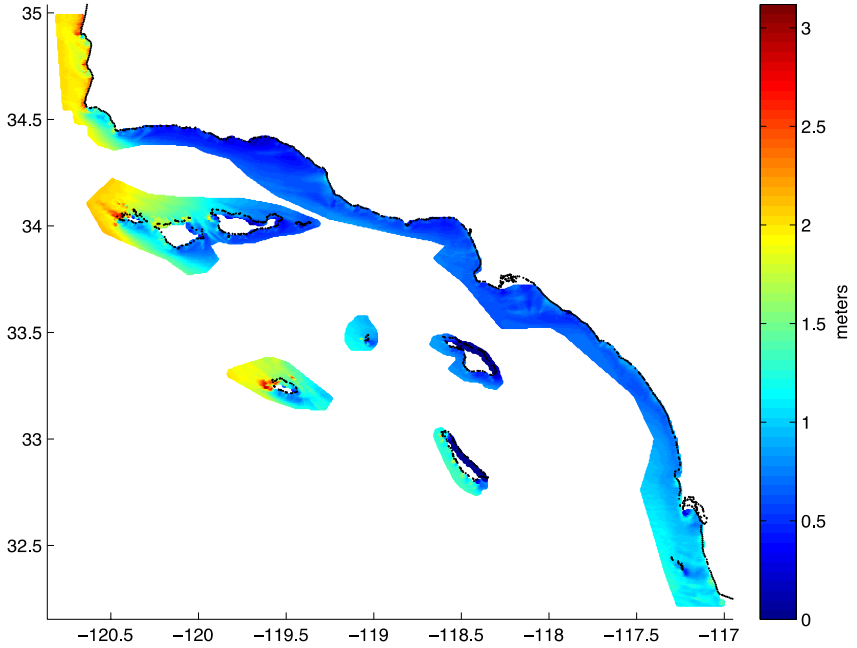


# Environmental conditions along the CA coastline are variable

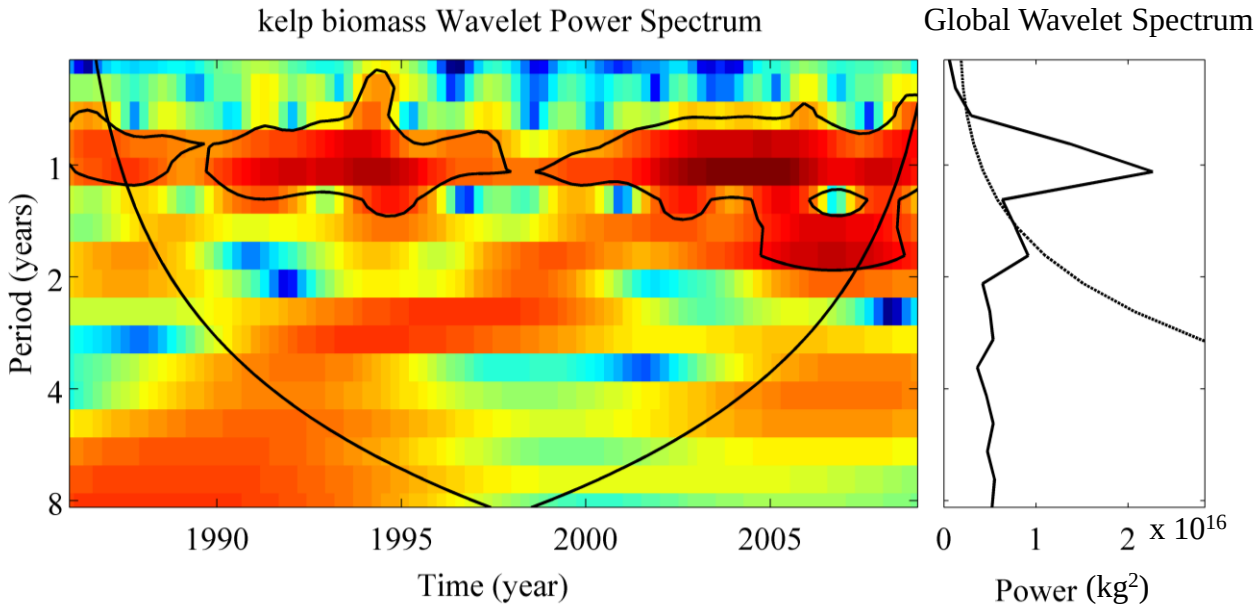
Sea Surface Temperature

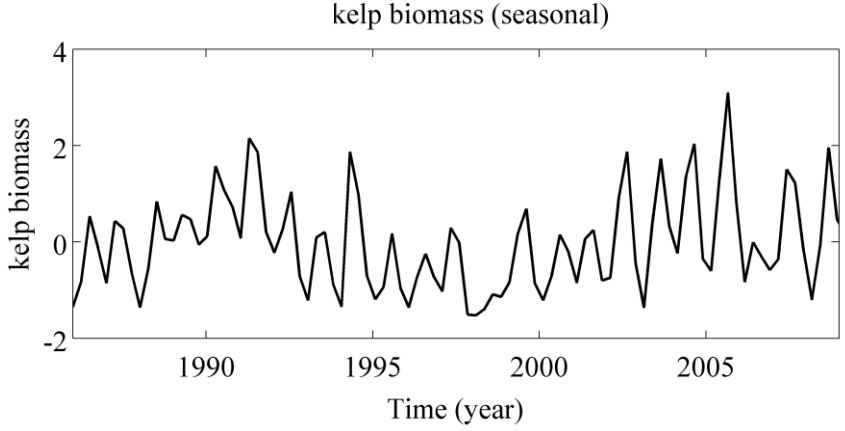


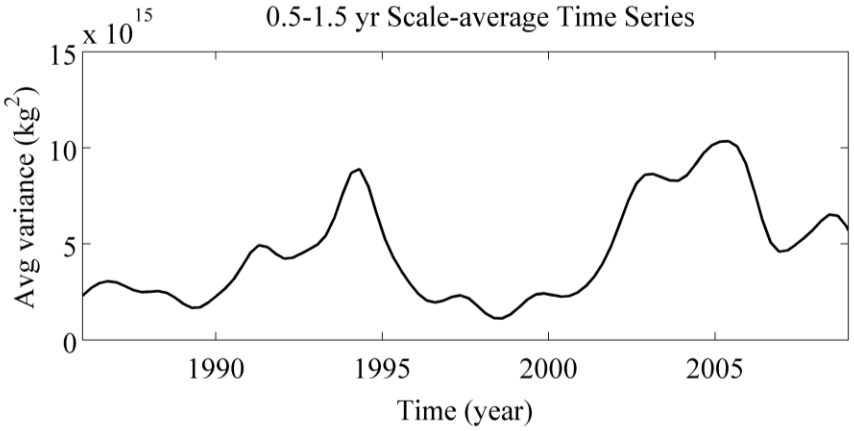

Significant Wave Height



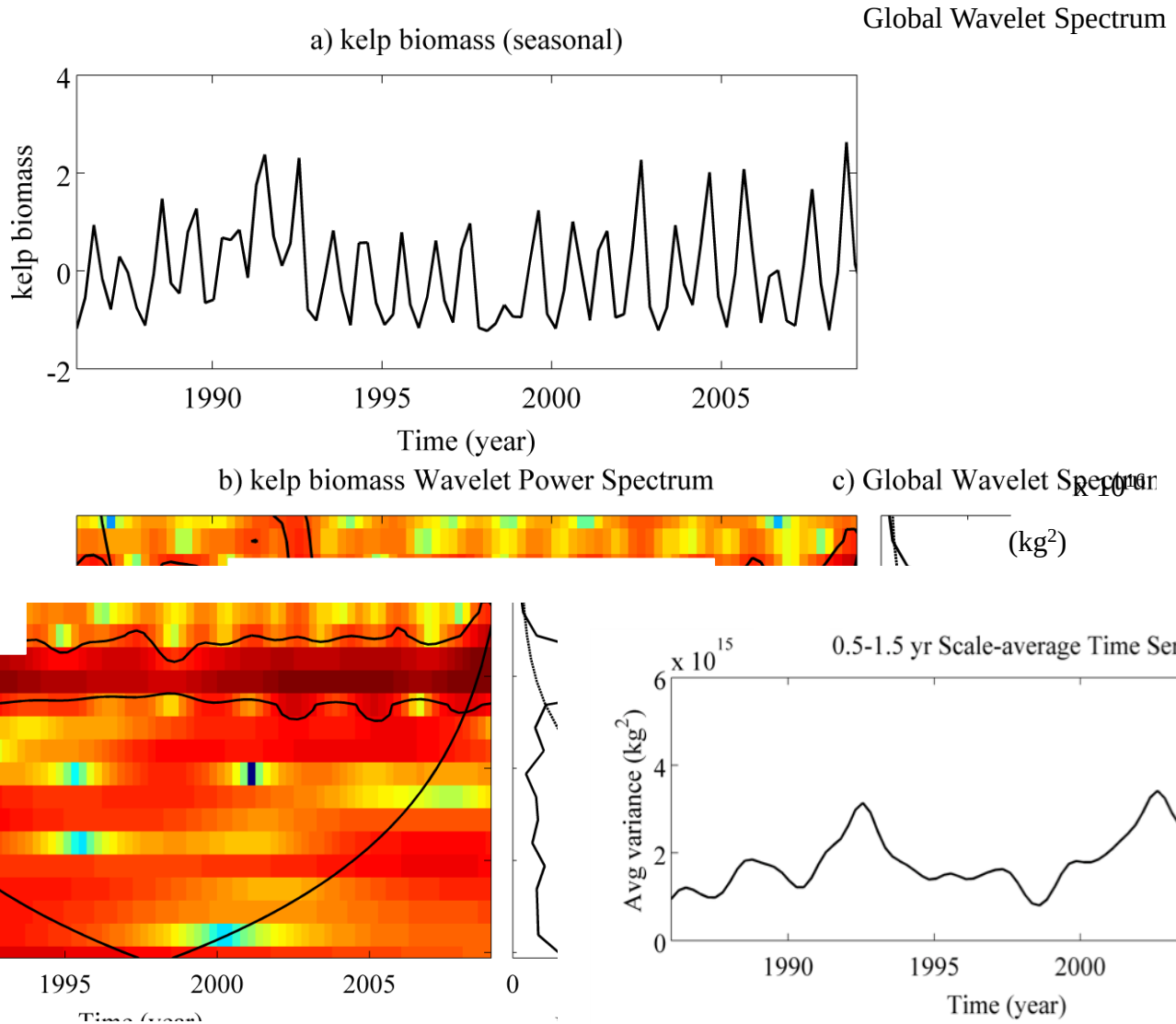
# Kelp biomass patterns in CA a mix of seasonal and interannual flucuations



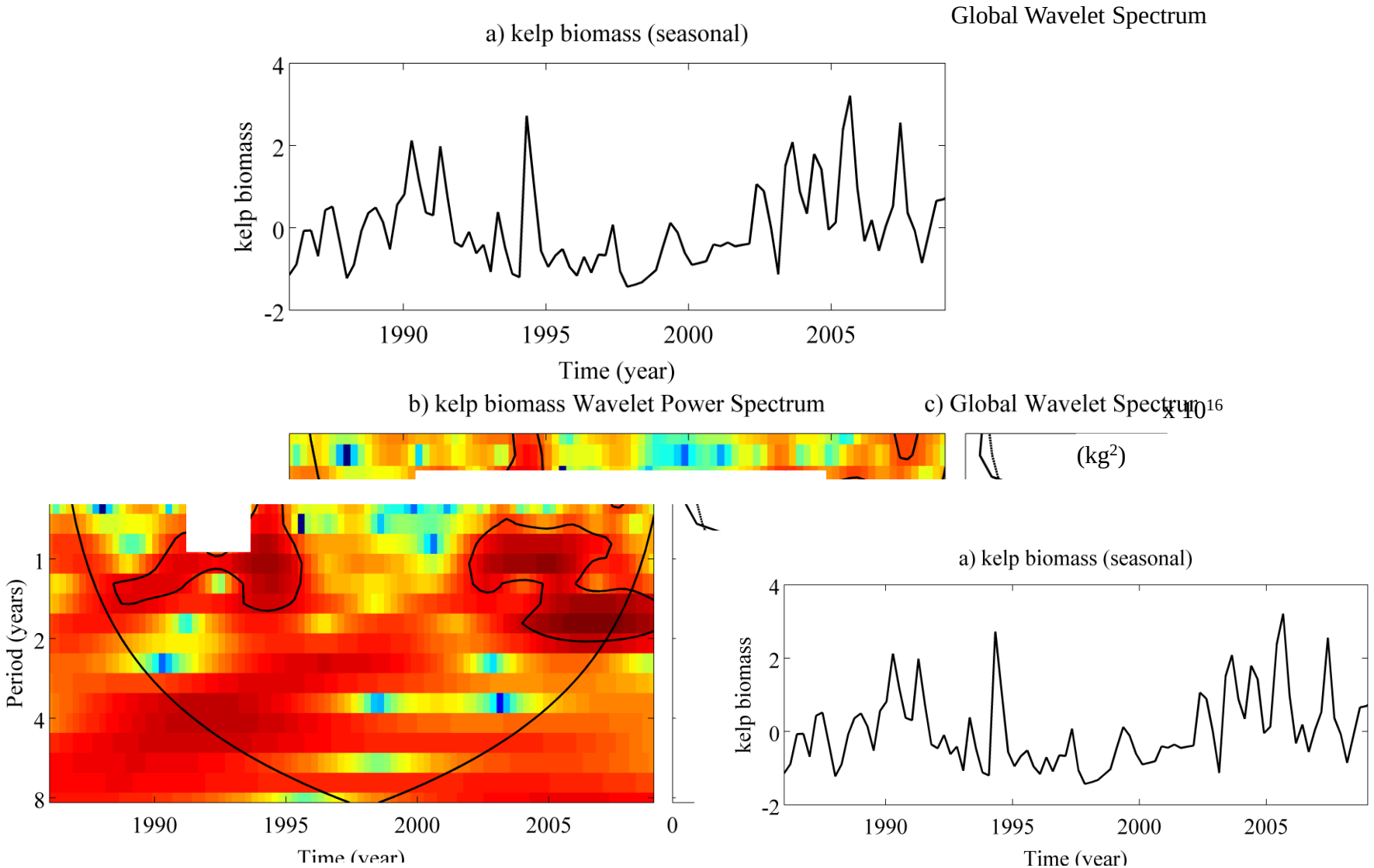



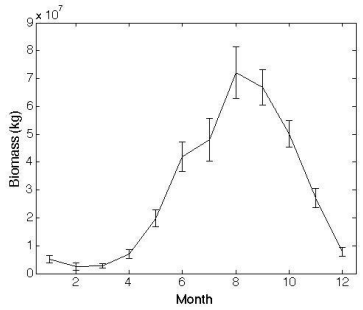
# Central CA dominated by 1-year periodicity

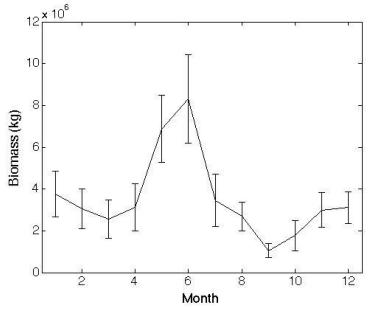


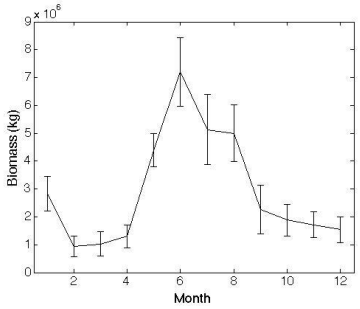
# Southern CA periodicity highly variable

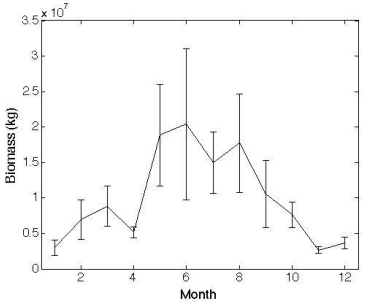


# There is spatial variability in the seasonal cycles of kelp biomass

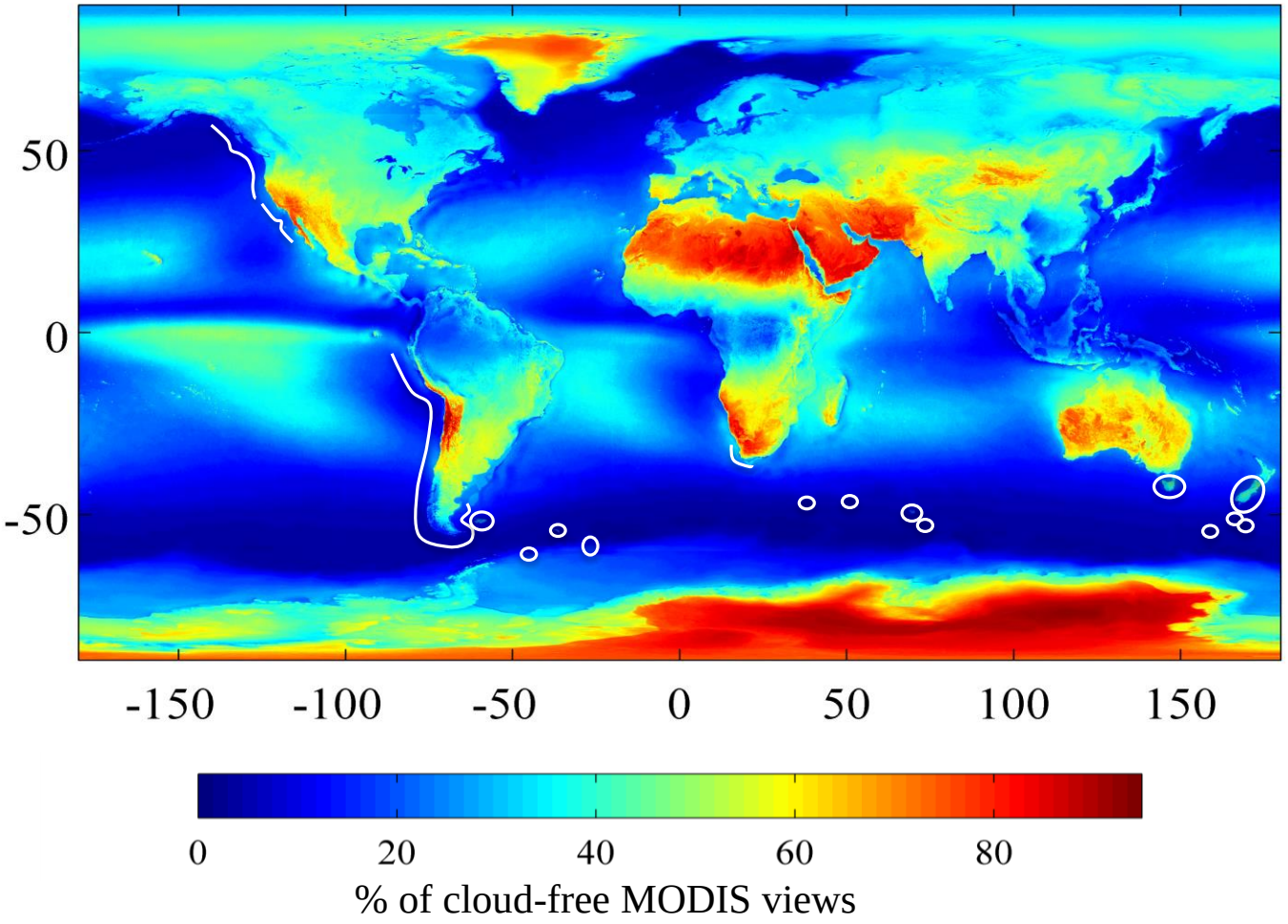


# Will HyspIRI provide seasonal coverage of giant kelp globally?

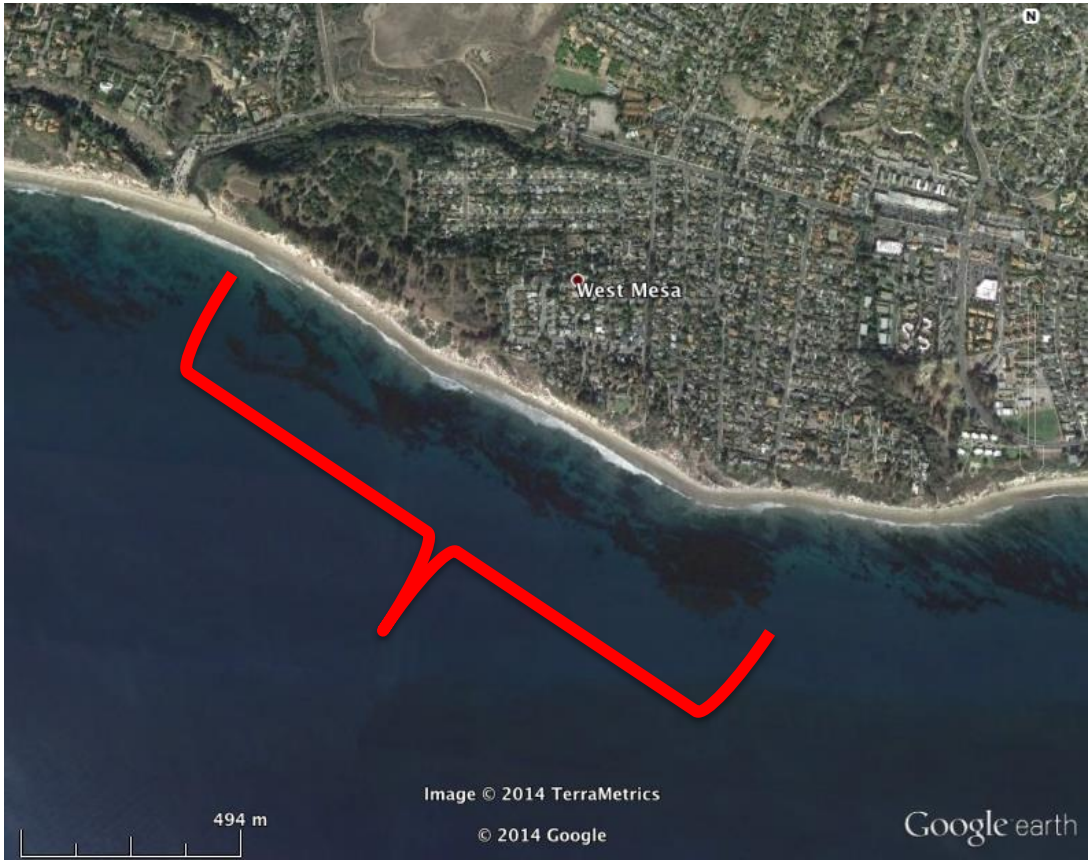



Data kindly provided by Michael Mercury

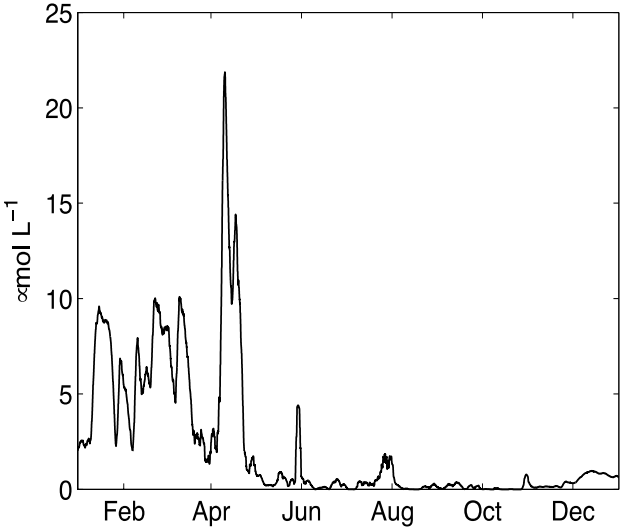
# HyspIRI will provide at least one seasonal cloud-free image in the vast majority of giant kelp's range

| | Region | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **NW North America** | **SW North America** | **South America** | **Falkland Islands** | **South Africa** | **Tasmania** | **New Zealand** | **Sub-Antarctic Islands** |
| **HyspIRI only** | | | | | | | | |
| Jan-Mar | 1.0 (0.2) | 2.0 (0.5) | 1.0 (0.6) | 1.1 (0.2) | 2.5 (0.8) | 1.5 (0.4) | 1.4 (0.4) | 0.6 (0.3) |
| Apr-Jun | 1.3 (0.3) | 2.0 (0.5) | 1.1 (0.4) | 1.1 (0.3) | 2.1 (0.6) | 1.4 (0.4) | 1.4 (0.4) | 0.7 (0.3) |
| Jul-Sep | 1.5 (0.6) | 2.3 (0.7) | 1.1 (0.3) | 1.0 (0.2) | 2.1 (0.6) | 1.3 (0.4) | 1.4 (0.4) | 0.9 (0.4) |
| Oct-Dec | 1.0 (0.2) | 2.2 (0.6) | 0.9 (0.5) | 1.1 (0.2) | 2.2 (0.7) | 1.3 (0.3) | 1.2 (0.3) | 0.6 (0.2) |
| **HyspIRI & Landsat 8** | | | | | | | | |
| Jan-Mar | 2.2 (0.4) | 4.4 (1.0) | 2.1 (1.3) | 2.5 (0.5) | 5.4 (1.8) | 3.2 (0.8) | 3.0 (0.9) | 1.3 (0.7) |
| Apr-Jun | 2.9 (0.6) | 4.3 (1.2) | 2.4 (0.8) | 2.3 (0.6) | 4.6 (1.3) | 3.0 (0.8) | 3.0 (0.9) | 1.6 (0.7) |
| Jul-Sep | 3.4 (1.4) | 4.9 (1.6) | 2.4 (0.7) | 2.2 (0.5) | 4.6 (1.4) | 2.9 (0.8) | 3.0 (0.8) | 1.9 (0.9) |
| Oct-Dec | 2.1 (0.5) | 4.8 (1.3) | 1.9 (1.0) | 2.5 (0.5) | 4.8 (1.6) | 2.8 (0.7) | 2.6 (0.6) | 1.3 (0.5) |

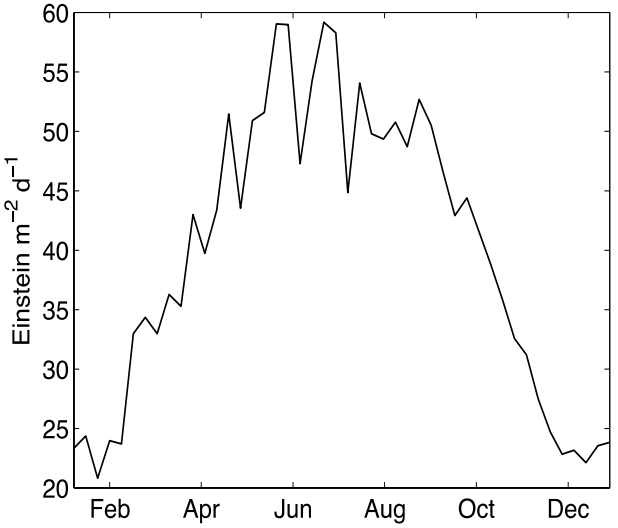
# Nutrient and light conditions vary seasonally at Mohawk reef



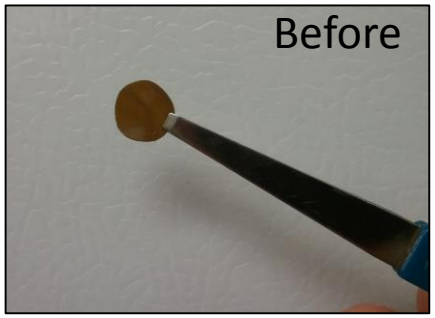

Nitrate 2013

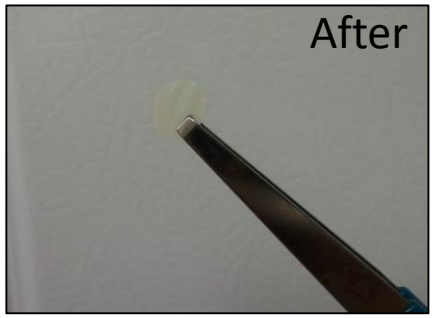


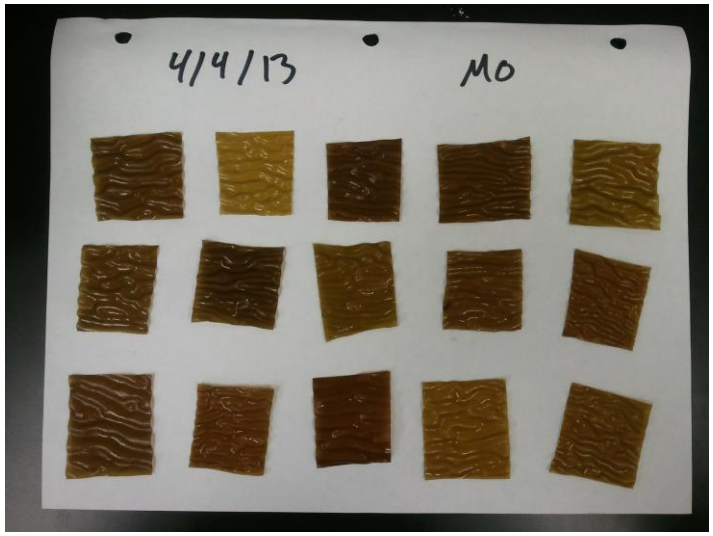

PAR 2013



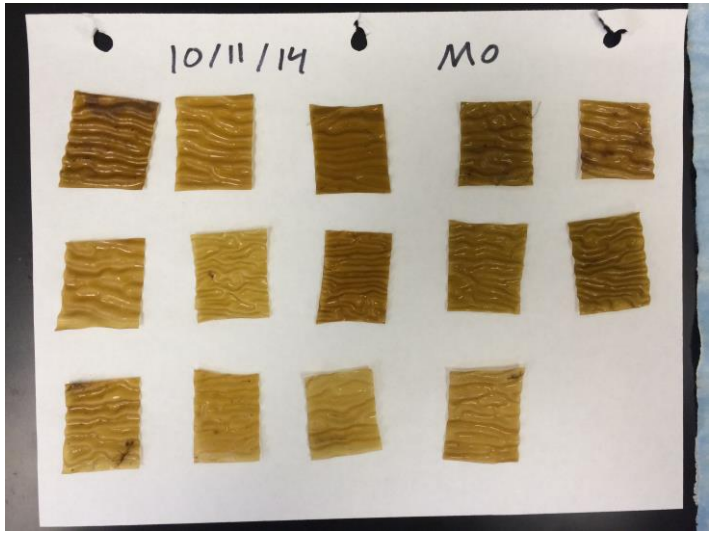
# Kelp pigments vary in space and time

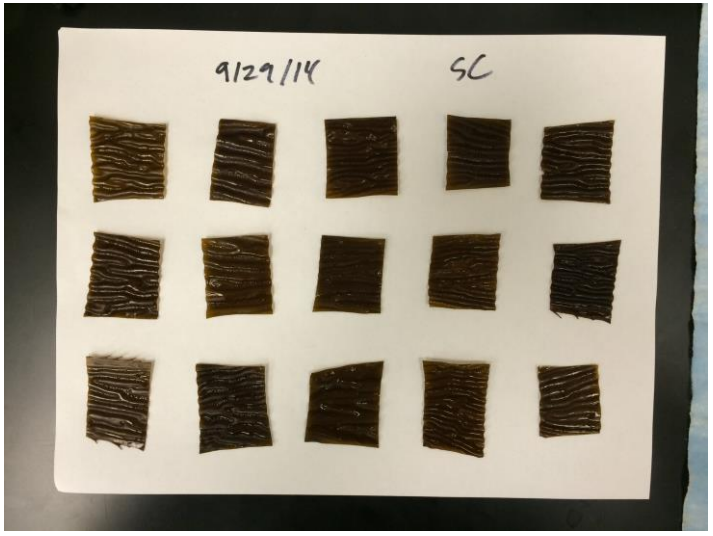


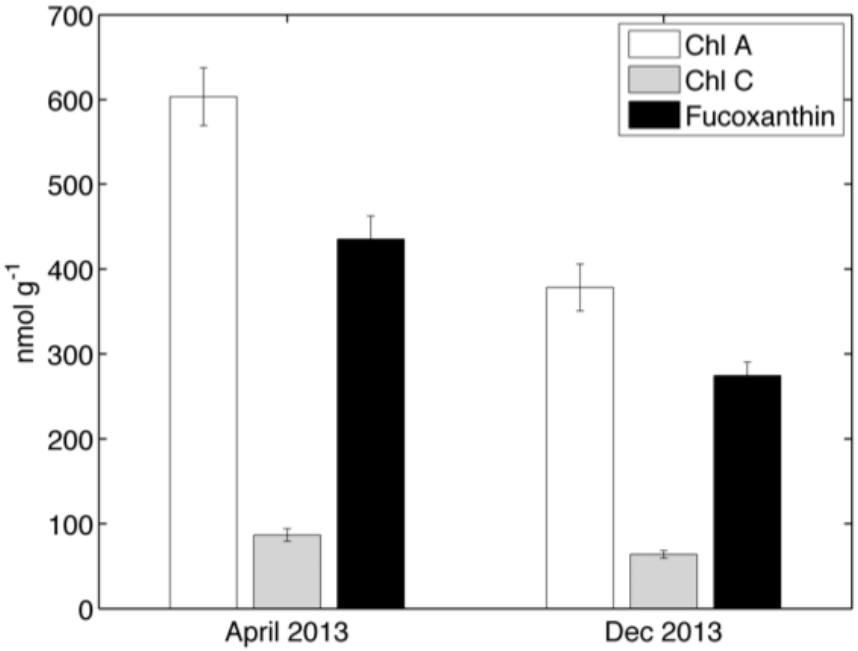




- Chl *a*, Chl *c*, fucoxanthin
  - Apr & Dec 2013
  - Seely et al. 1972
- Reflectance and transmittance
  - Both at 1nm (350 – 800nm)

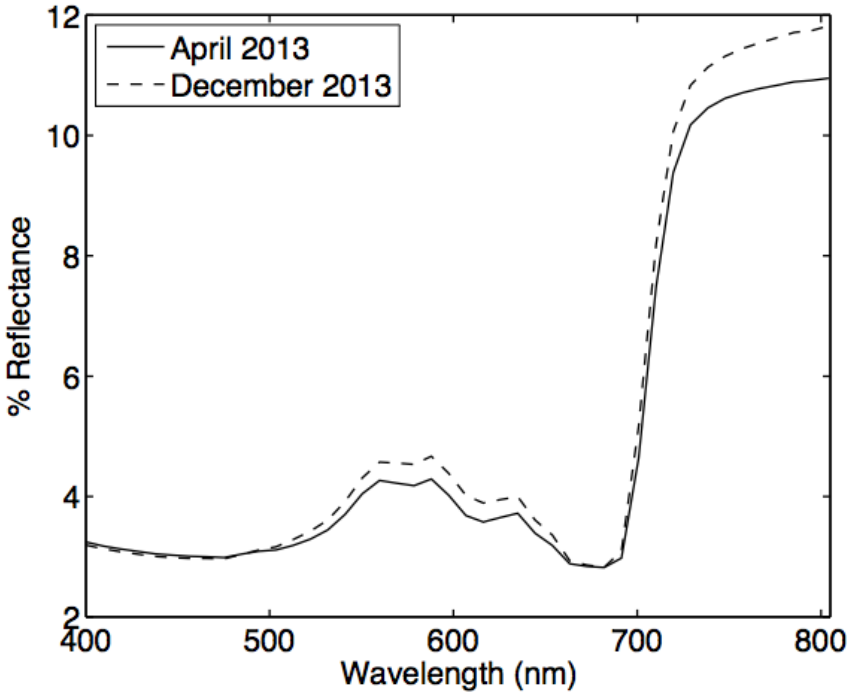


# Pigments and reflectance change seasonally at Mohawk

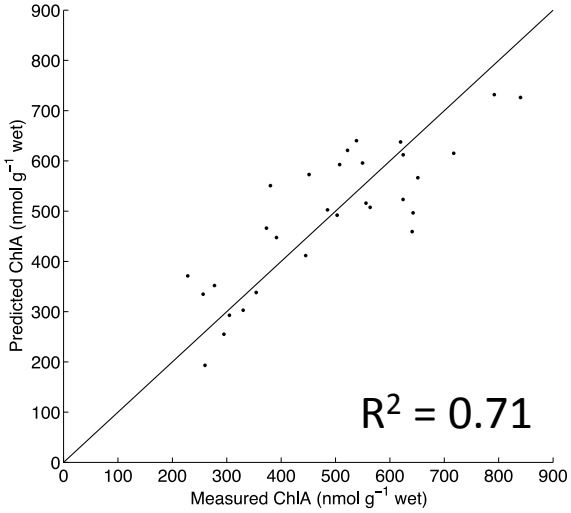



AVIRIS degraded lab spectra

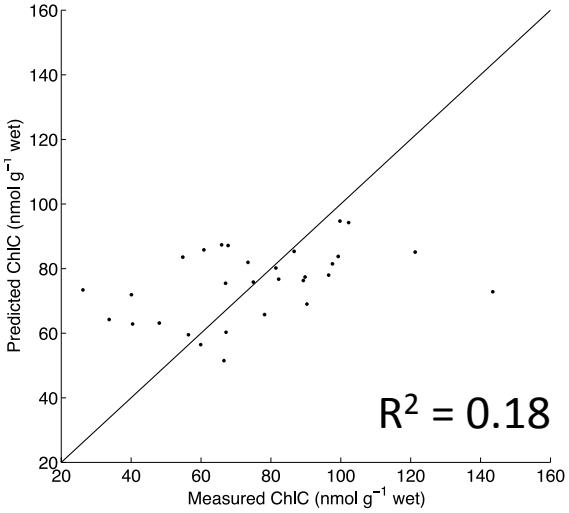


# AVIRIS reflectance should be able to evaluate ChlA and fucoxanthin

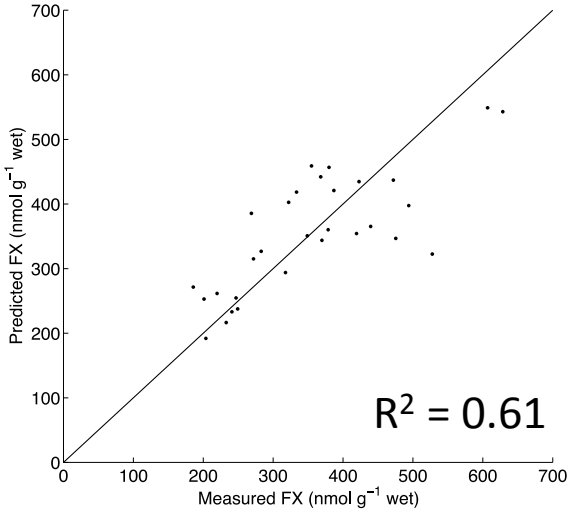
ChlA




ChlC

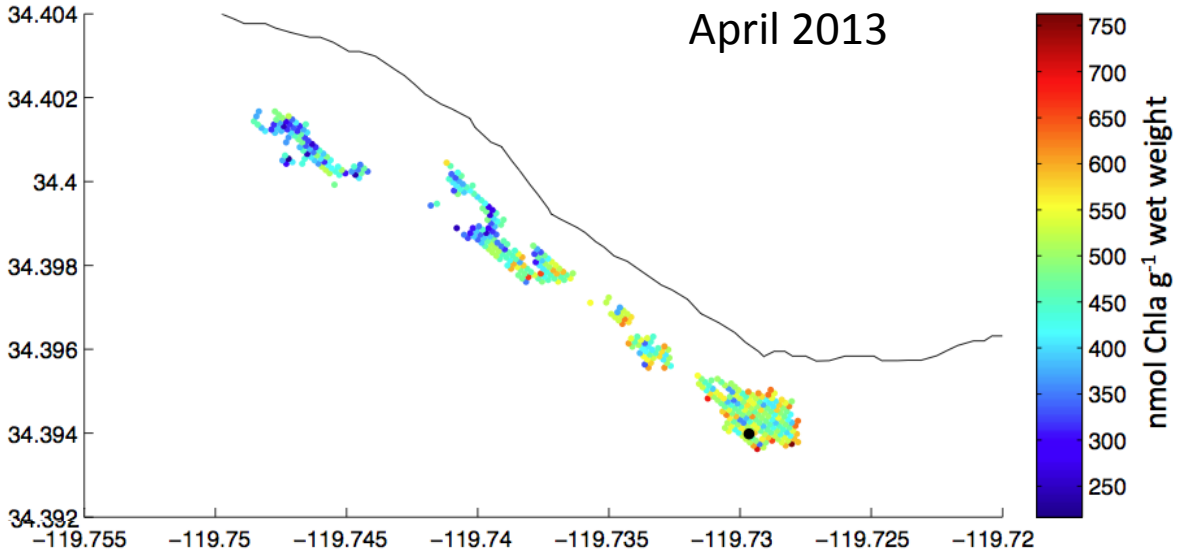


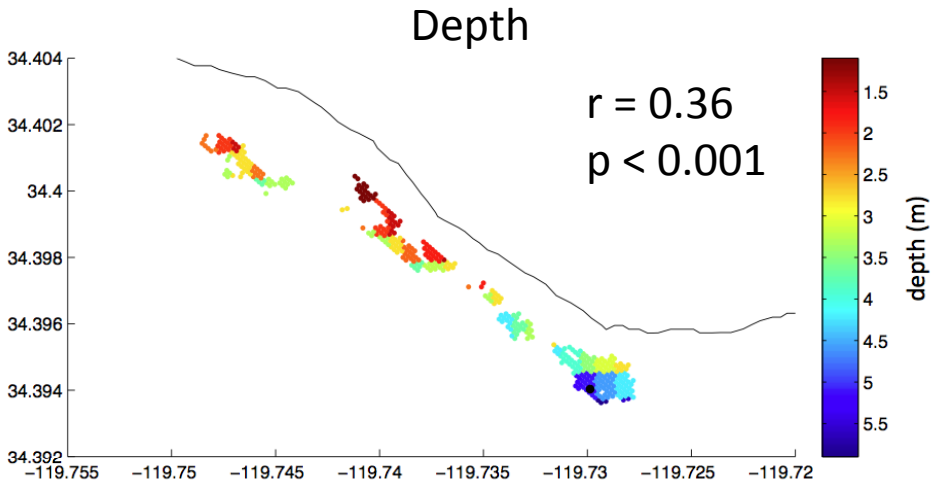

FX

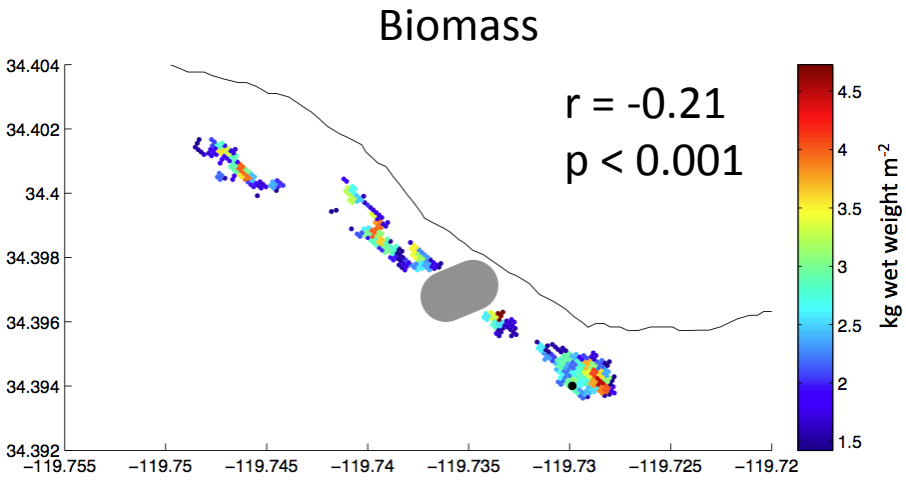



- First derivative of pseudo absorbance δ(Log 1/R)
- Leave-one-out cross validation

# Mohawk reef canopy pigment varies in space



# Future directions

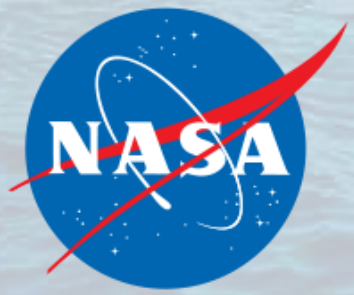
- Examine kelp/frond age dynamics
  - Probability of frond mortality is dependent on frond age (Rodriguez et al. 2013)
  - Age can be linked to pigment concentrations
- Improve biomass estimates
  - Frond senescence drives biomass dynamics in some areas
- Test abundance/fitness peaks in range
  - Test biogeographic theories
  - ID environmental drivers of range limits

# Take aways…

- HyspIRI should provide adequate temporal resolution to measure seasonal giant kelp dynamics – except sub-Antarctic islands
- The spectral resolution will be sufficient for estimating ChlA and fucoxanthin
- There are many interesting ecological questions that this new information can help answer

# Acknowledgements


- Michael Mercury
- Dan Reed
- Norm Nelson
- Clint Nelson
- Shannon Herrer




# Thank You!

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Photo: Kenneth Kopp