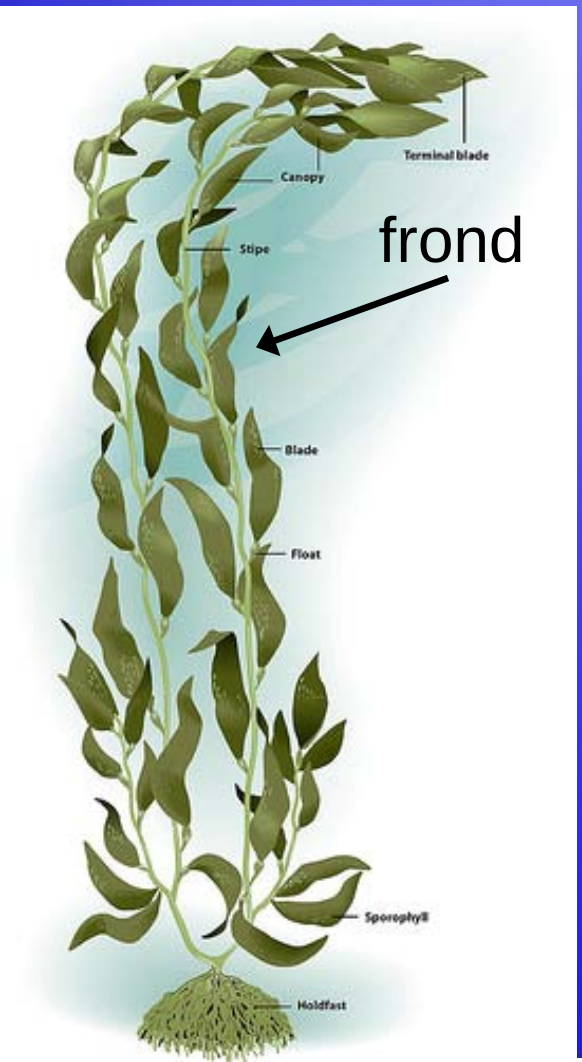
Giant Kelp Forests and their Responses to Climate Variability

Kyle Cavanaugh, Dave Siegel, Dan Reed
University of California Santa Barbara

Macrocystis pyrifera – Giant Kelp



- Plant life spans:

  ~ 2.5 years
- Frond life spans:

  ~ 4 months
- Frond growth can be 0.5 m/day

What controls kelp populations?

NUTRIENTS: "our most lasting effects result from very large scale, low-frequency episodic changes in nutrients" (Dayton et al. 1999)

PHYSICAL DISTURBANCE: Work in Southern and Central California found that wave driven disturbance explained more variability in biomass and production than nutrients or grazing (Reed et al. *in prep)*

Goal

- Characterize the controls of giant kelp dynamics across a wide range of spatial and temporal scales
  - by combining diver and satellite data

LANDSAT 5

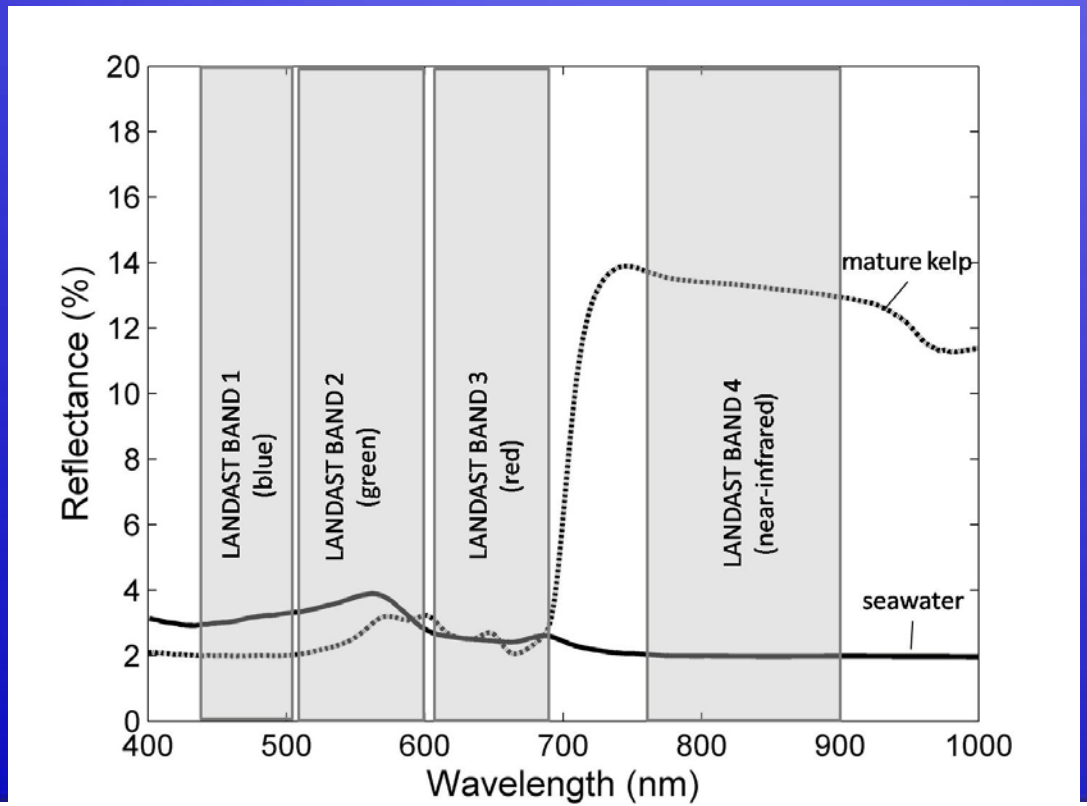
- 30 m resolution multispectral imagery
- Imagery available from 1984-present with a 16 day repeat cycle
  - Cloud free image available approx. every 1-2 months

Spatial scaling issues

- Last year Phil Dennison and Dick Zimmerman presented results examining feasibility of mapping kelp at 60 m resolution
- Good agreement in kelp fractions when scaling up
- Bias in area estimates increases (nonlinearly) when resolution decreases
  - Depends on shape of kelp beds

LANDSAT Spectral Unmixing

- Model every pixel as a linear combination of water and kelp endmembers



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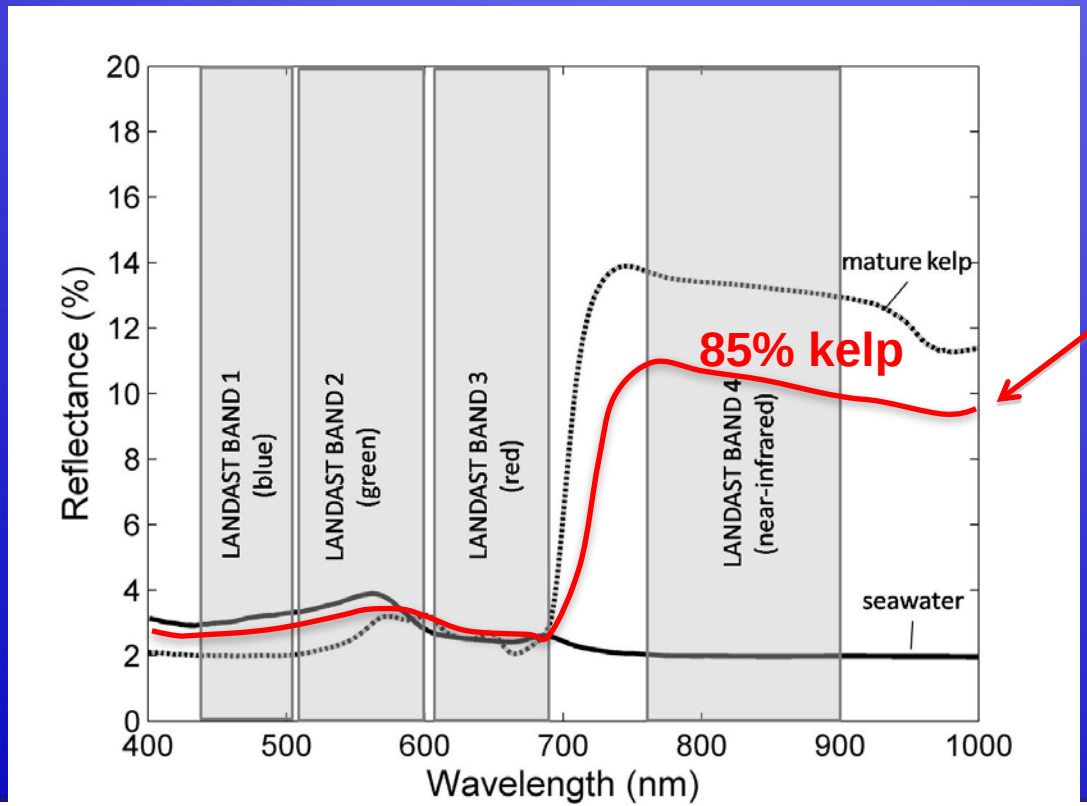

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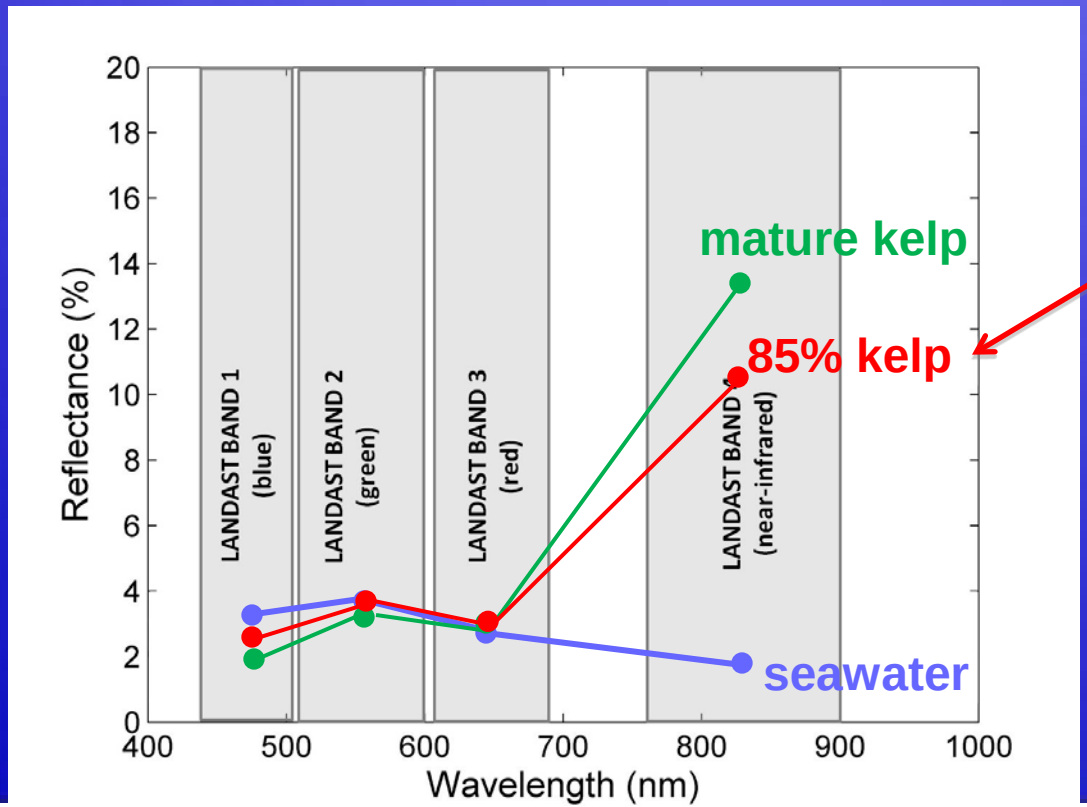
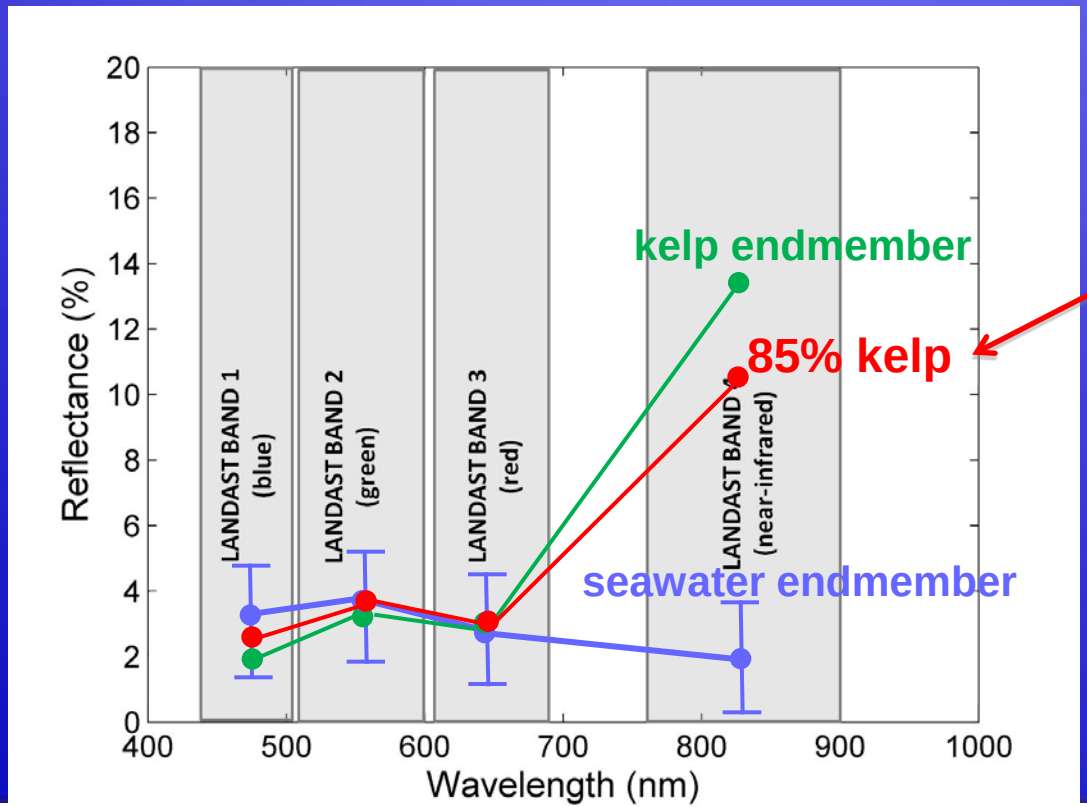
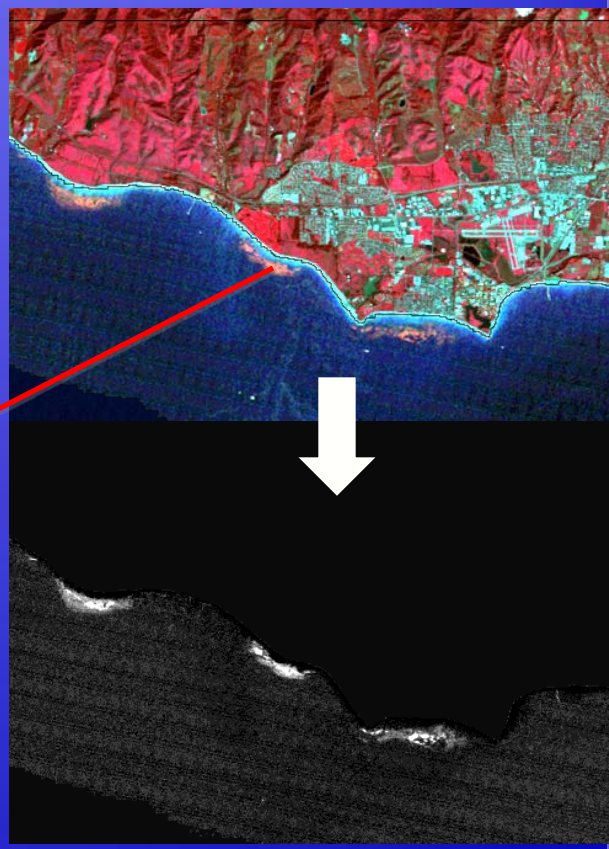


Endmember selection

- Single kelp spectra chosen from multitemporal spectral library (using EAR; Dennison and Roberts, 2003)
- Multiple water endmembers to account for water variability (sediment, glint, phytoplankton, etc.)





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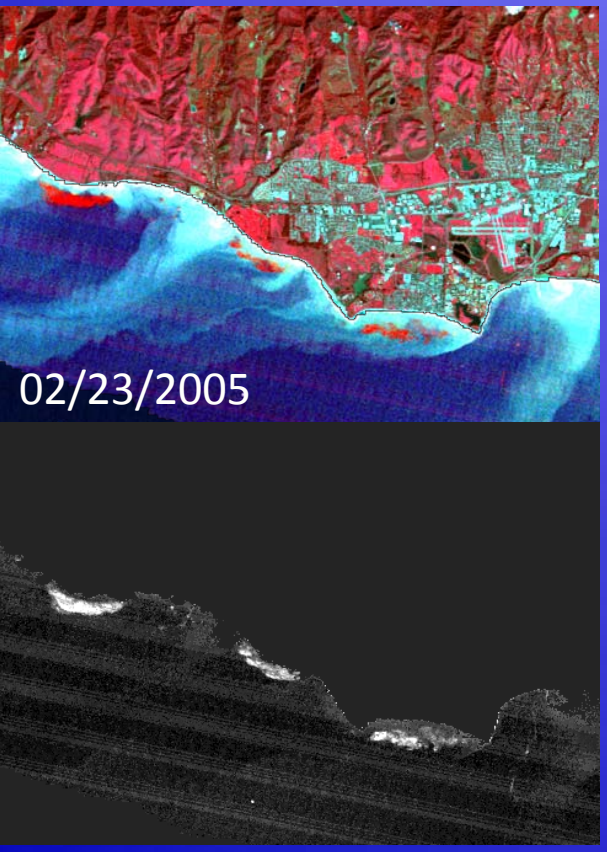
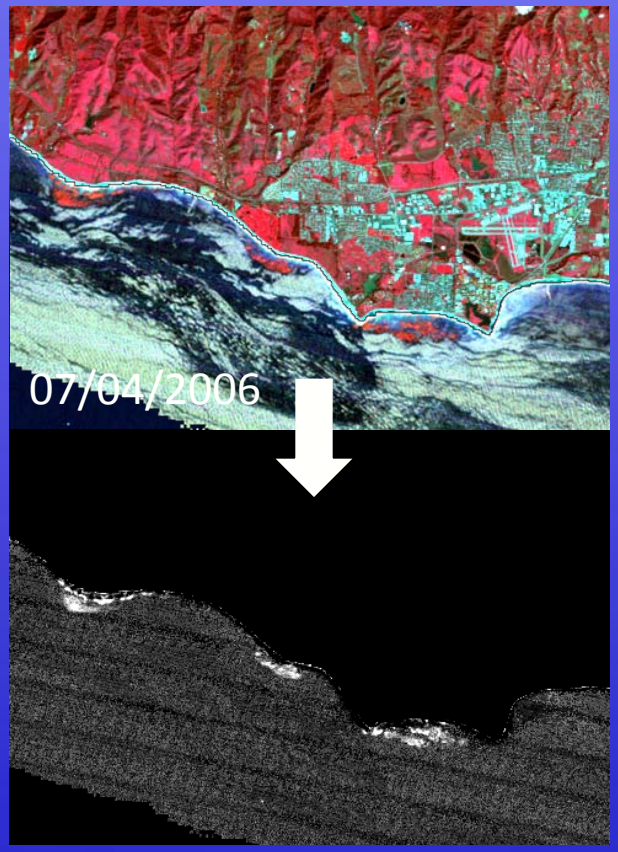
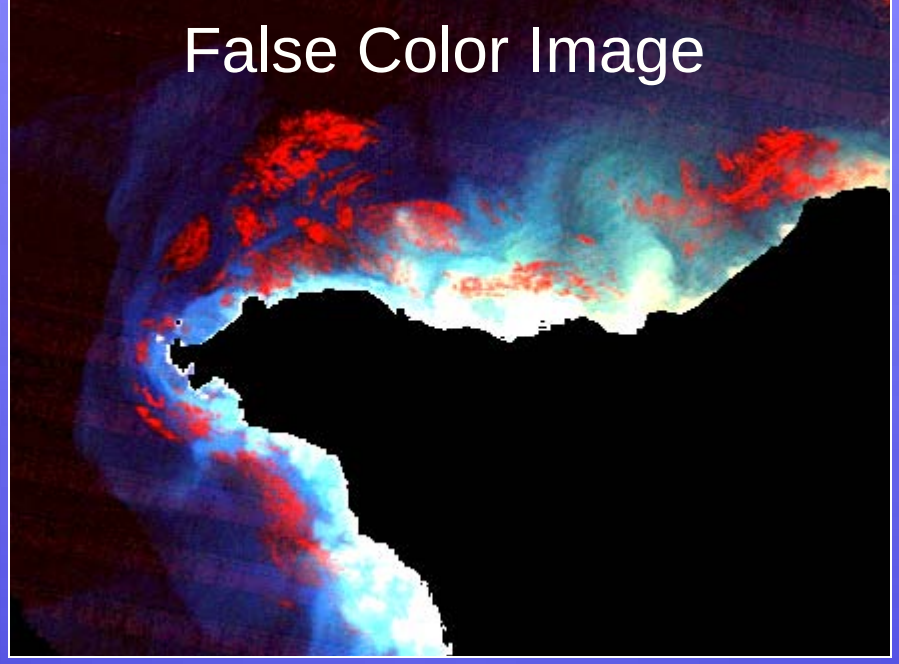
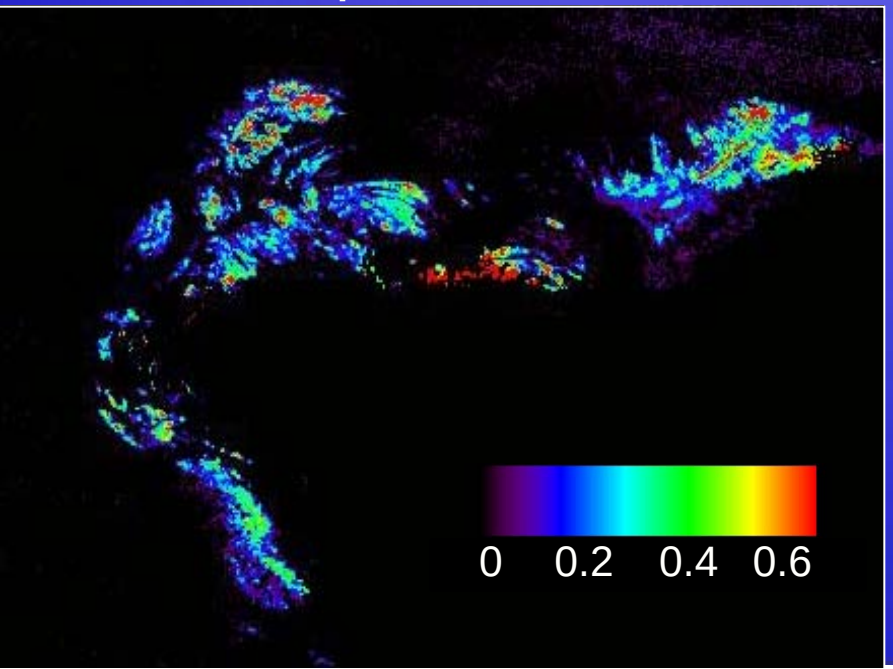




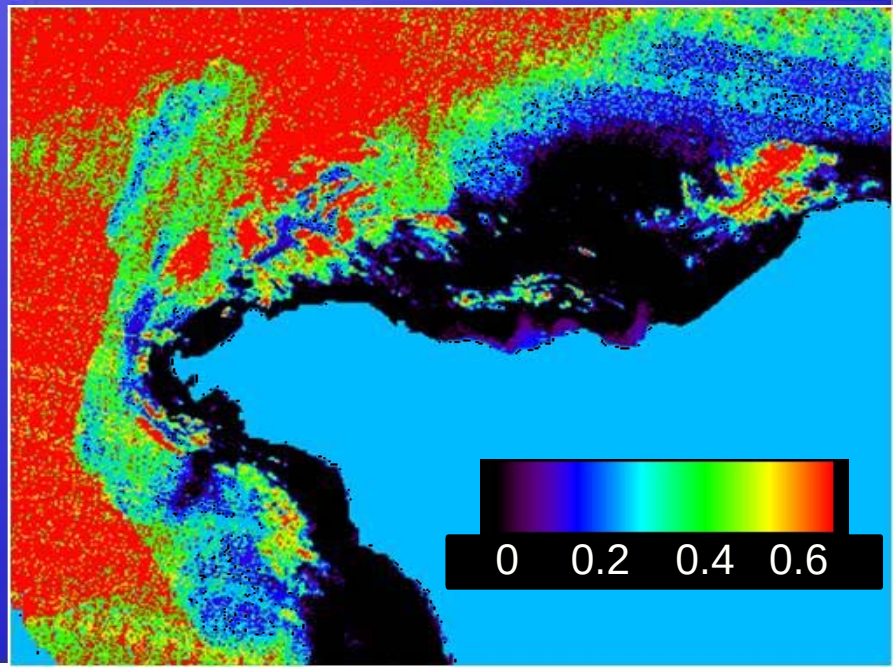
False Color Image



Kelp Fraction

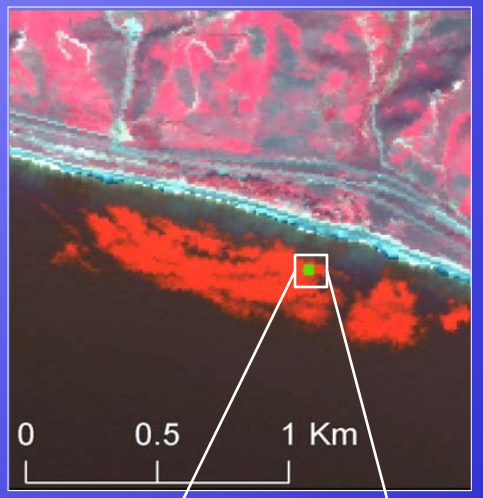


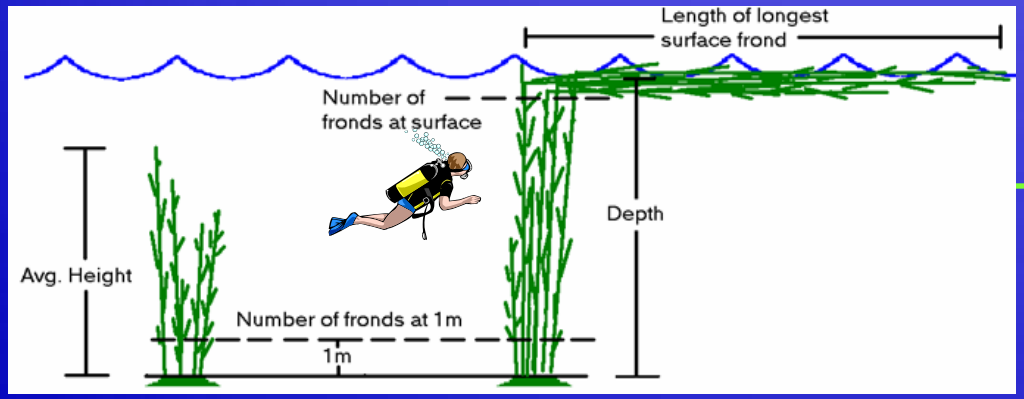
NDVI

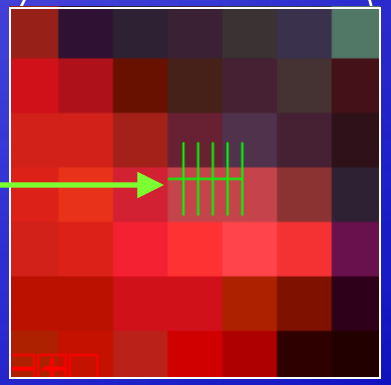


SBC-LTER Diver Surveys

- Turn fractions into canopy biomass
- Monthly non-destructive allometric biomass surveys from 2002-present

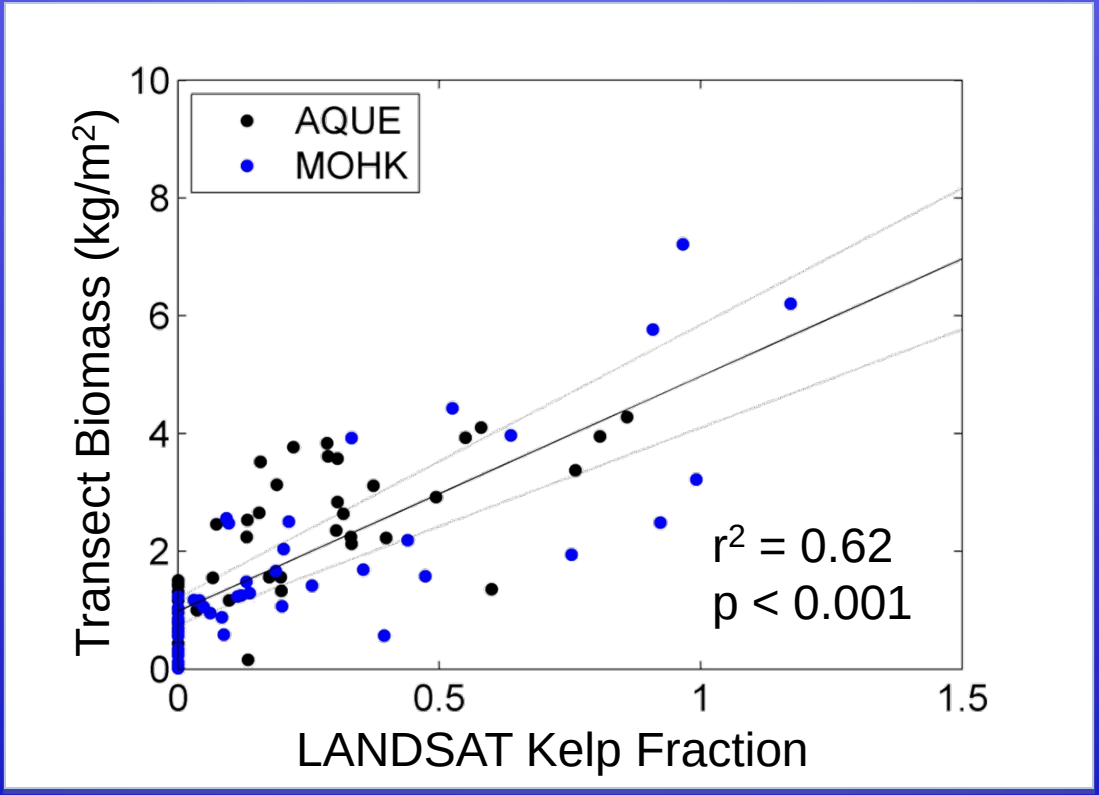






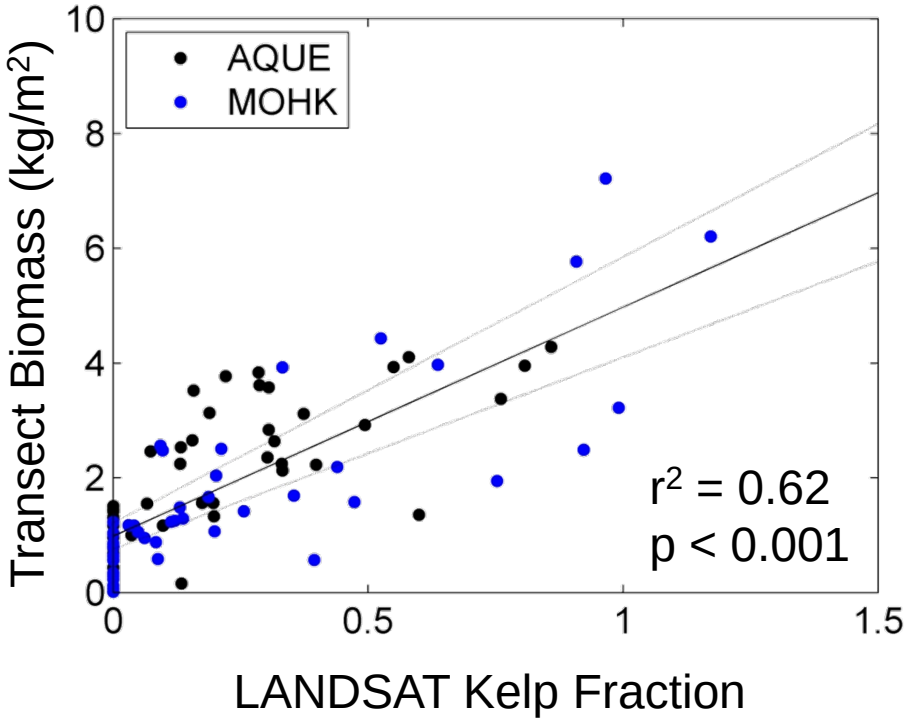
Biomass from LANDSAT

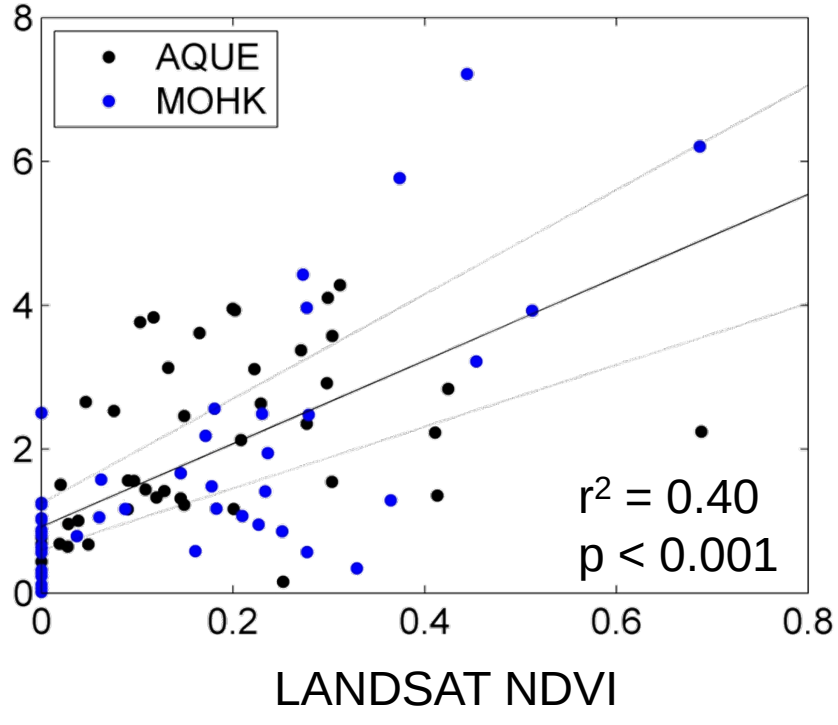
Strong relationship between kelp fraction and diver measured canopy biomass



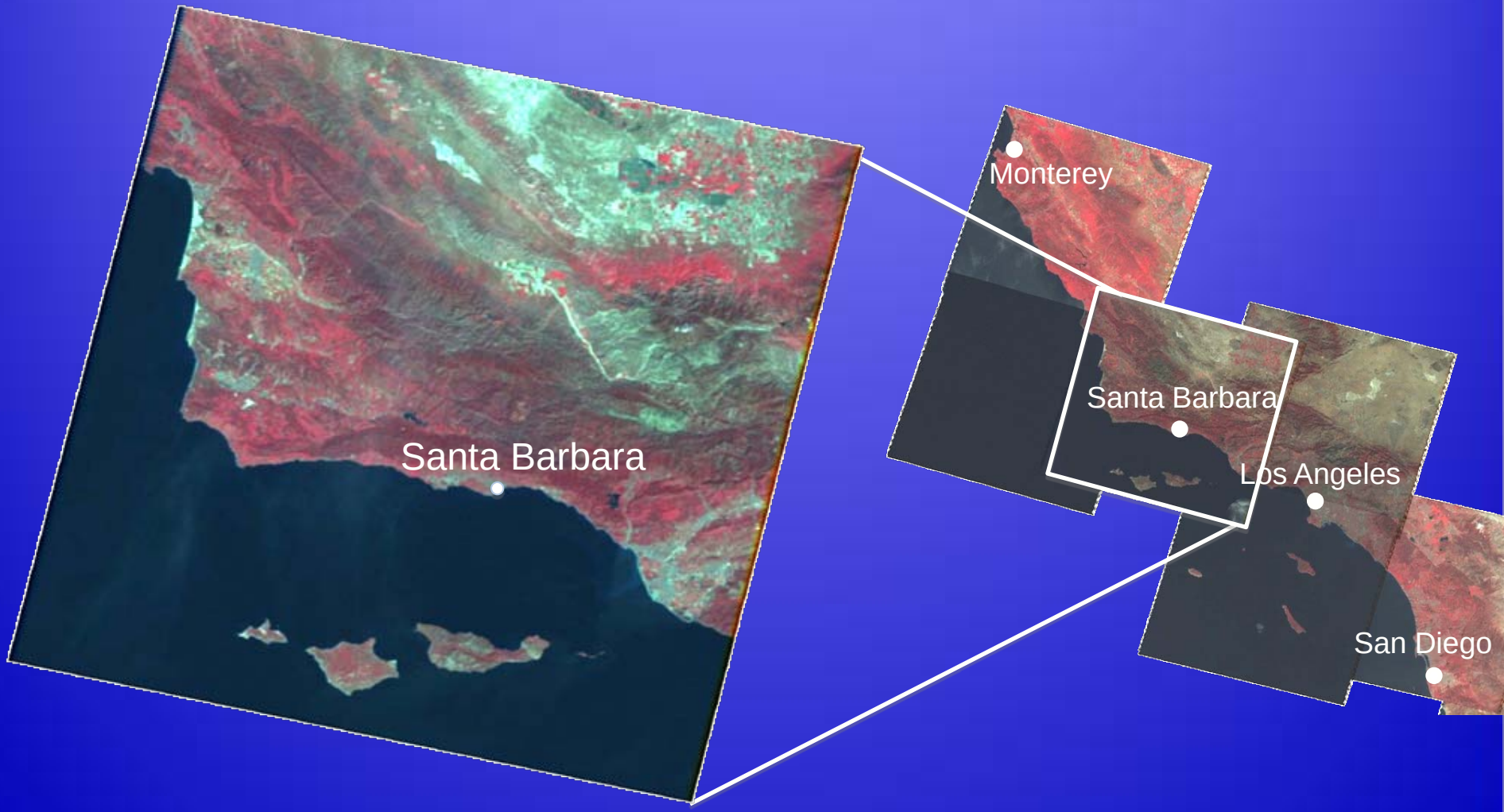
Biomass from LANDSAT

Canopy biomass is better correlated to kelp fraction than NDVI





Temporal kelp dynamics in the Santa Barbara Channel (1984-2009)

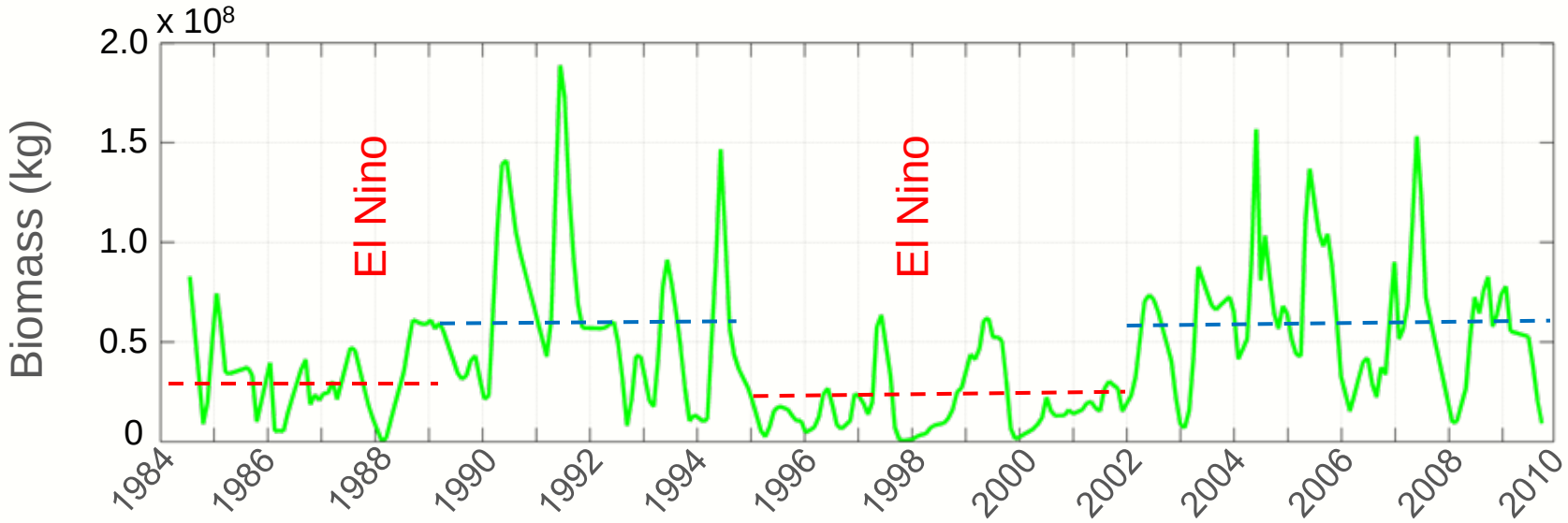


Temporal kelp dynamics in the Santa Barbara Channel (1984-2009)

- Regional mean: 41500 metric tons of kelp canopy

  Equals mass of ~400 blue whales

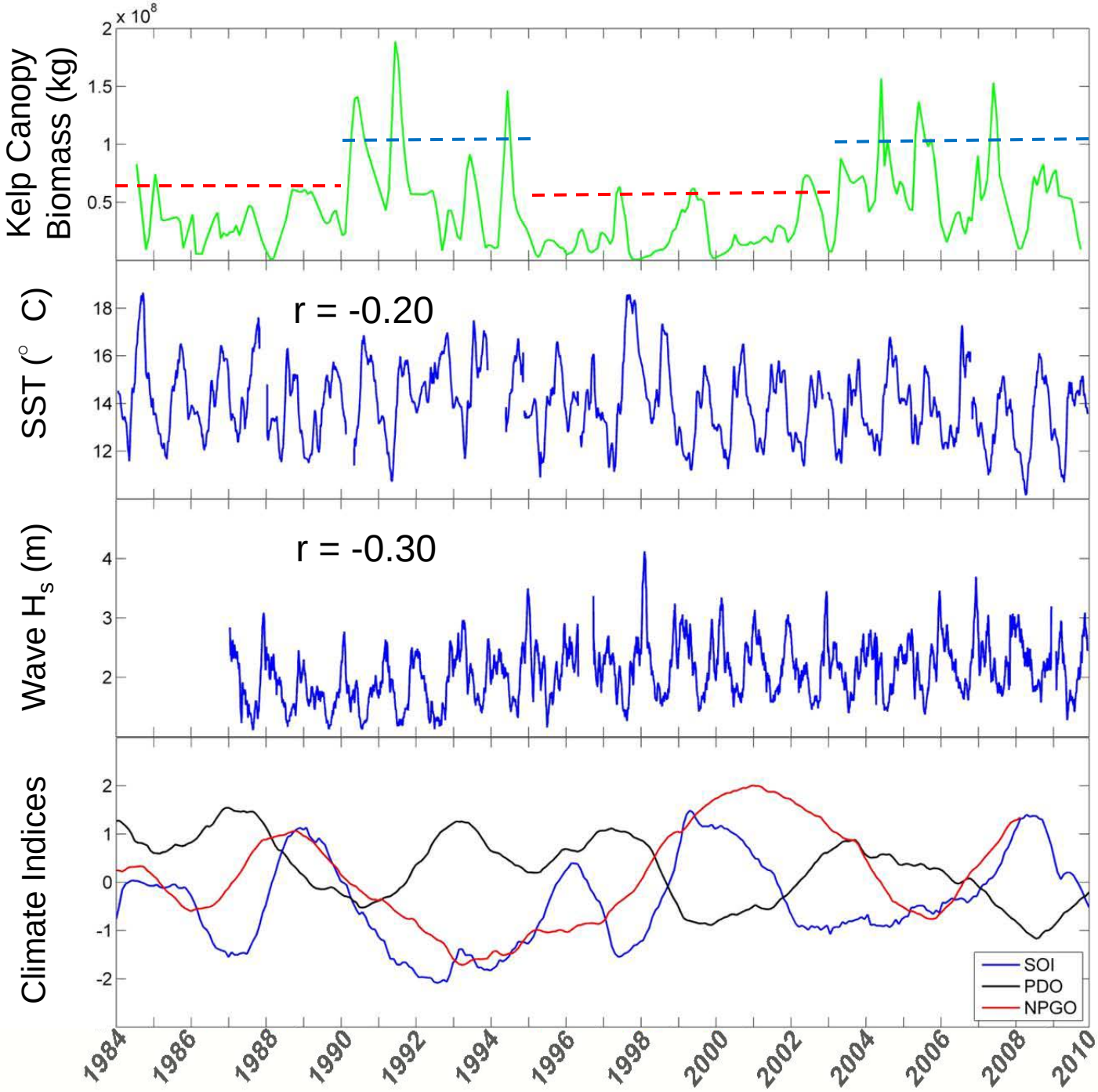
- Low in winter, high in summer/fall
- Seasonal cycle superimposed on a 5-7 year cycle



Physical Data

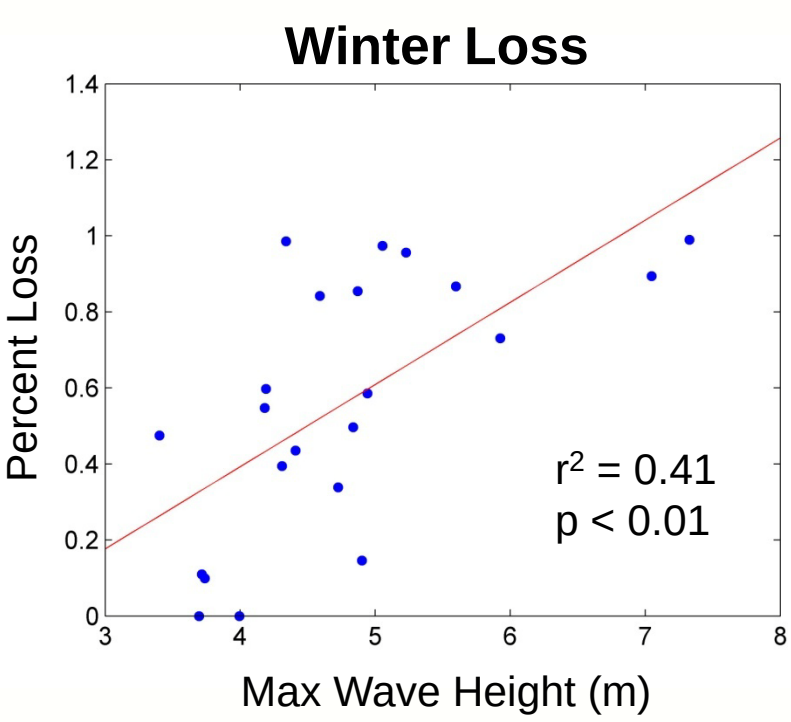
- Significant wave height from Harvest buoy (1987-2009)
- Sea surface temperature (SST) from Pt. Arguello buoy (1984-2009)

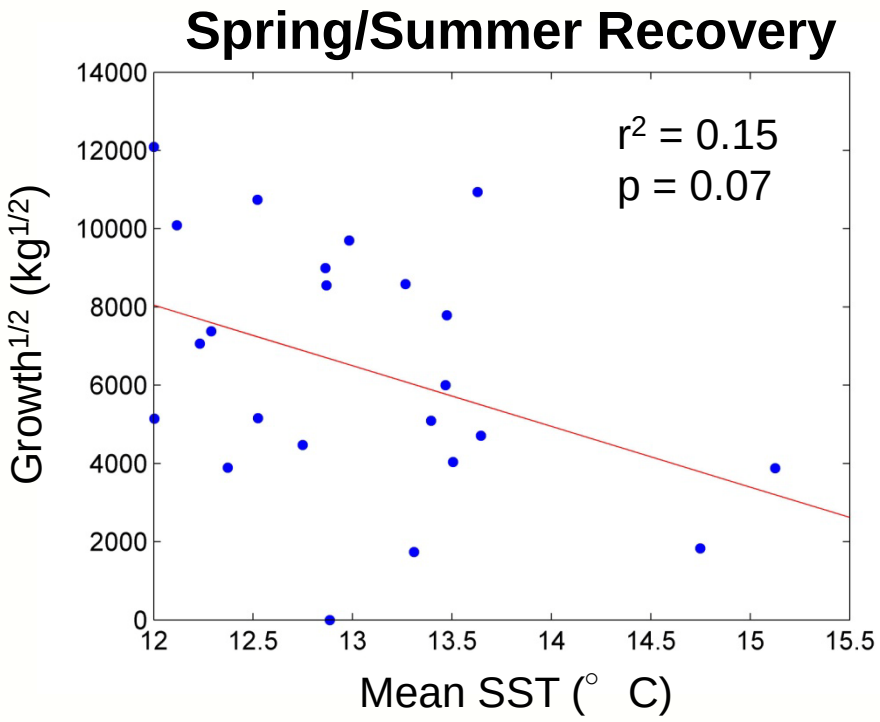
SST is a good proxy for nutrients


Kelp Canopy Biomass (kg)
x 10^8
2
1.5
1
0.5
SST (° C)
r = -0.20
18
16
14
12
Wave H_s (m)
r = -0.30
4
3
2
Climate Indices
2
1
0
-1
-2
SOI
PDO
NPGO
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

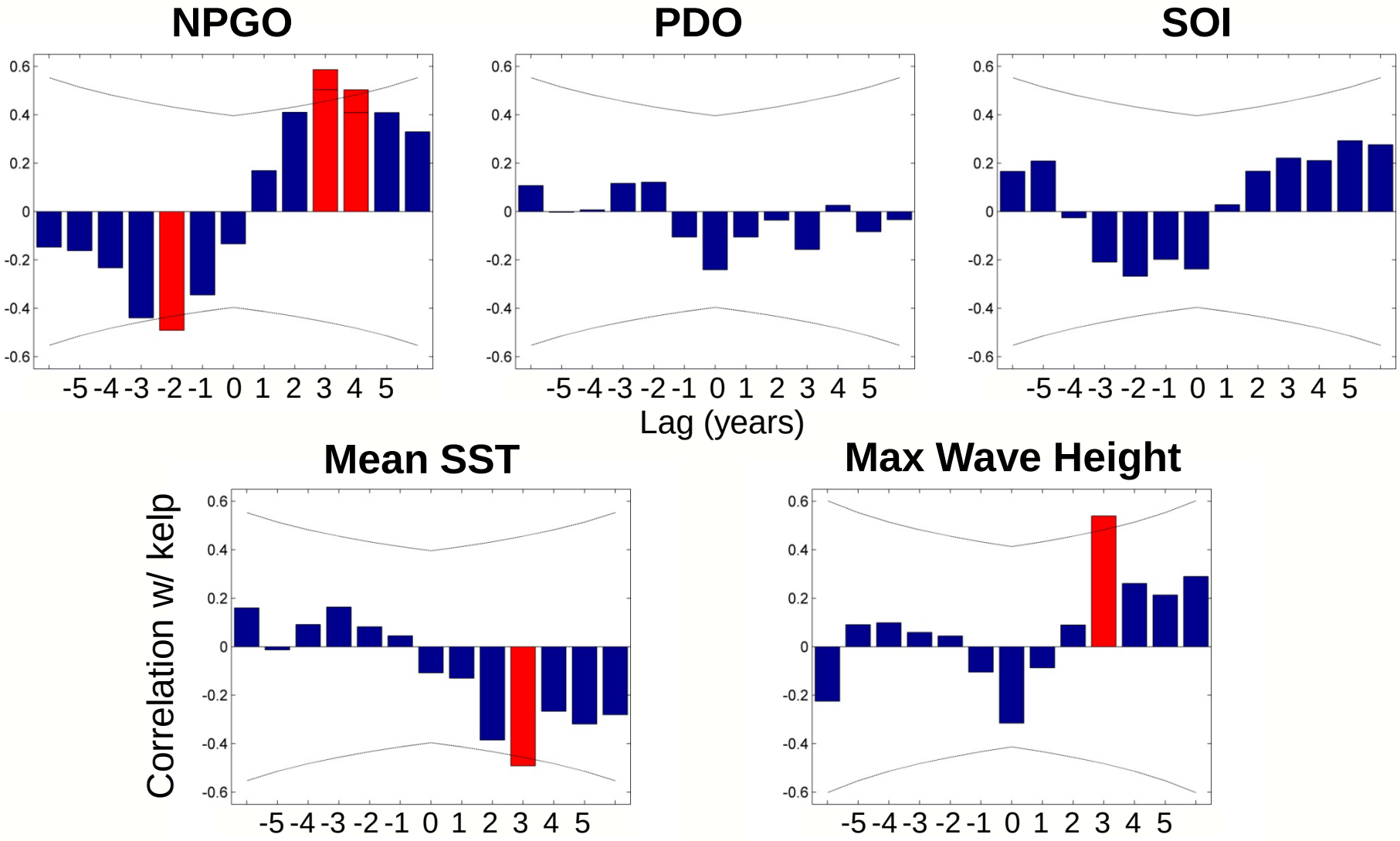
Seasonal Forcings

- Wave induced mortality is direct and immediate
- Effect of SST/nutrients is delayed and complicated by other factors

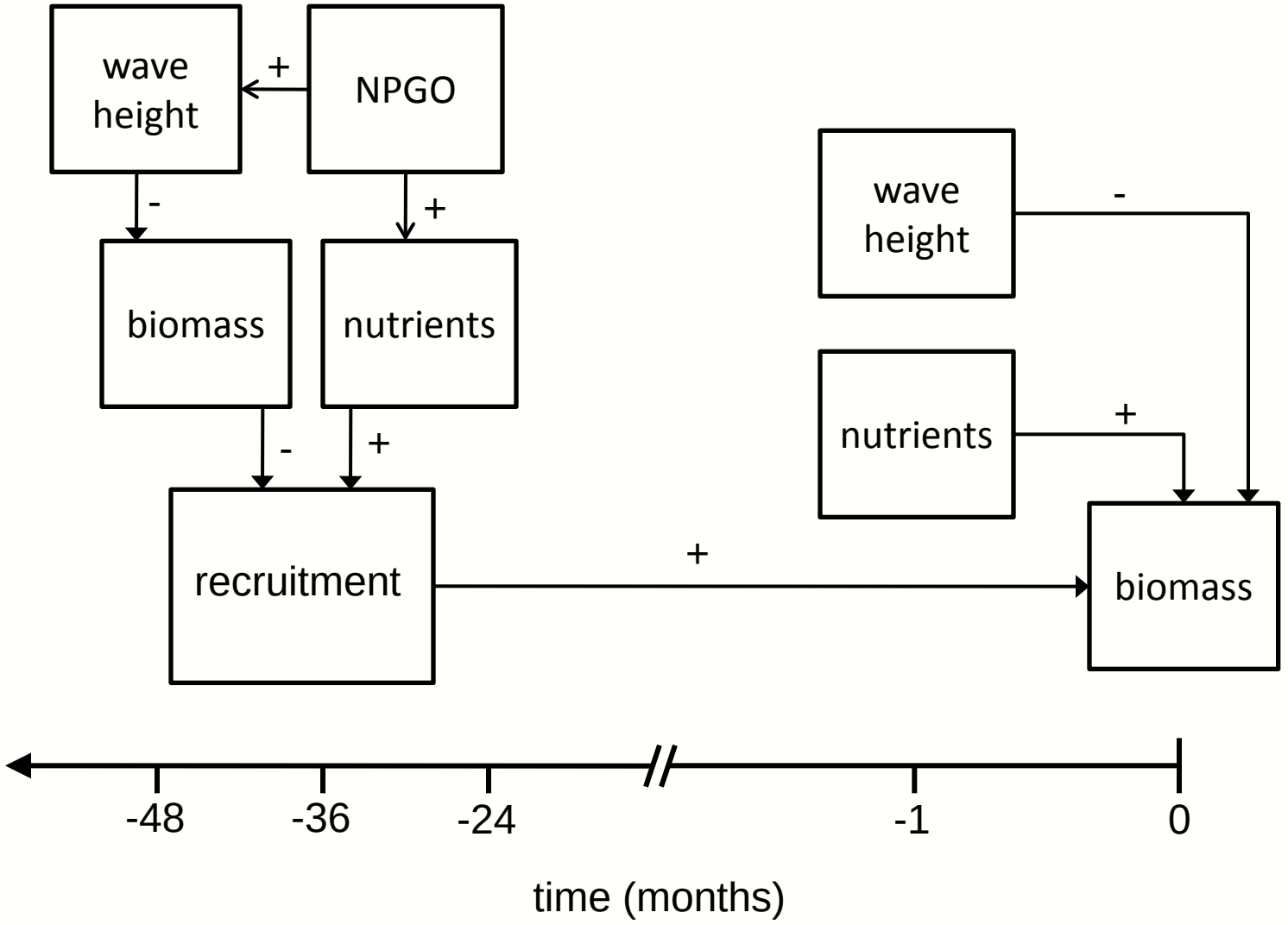




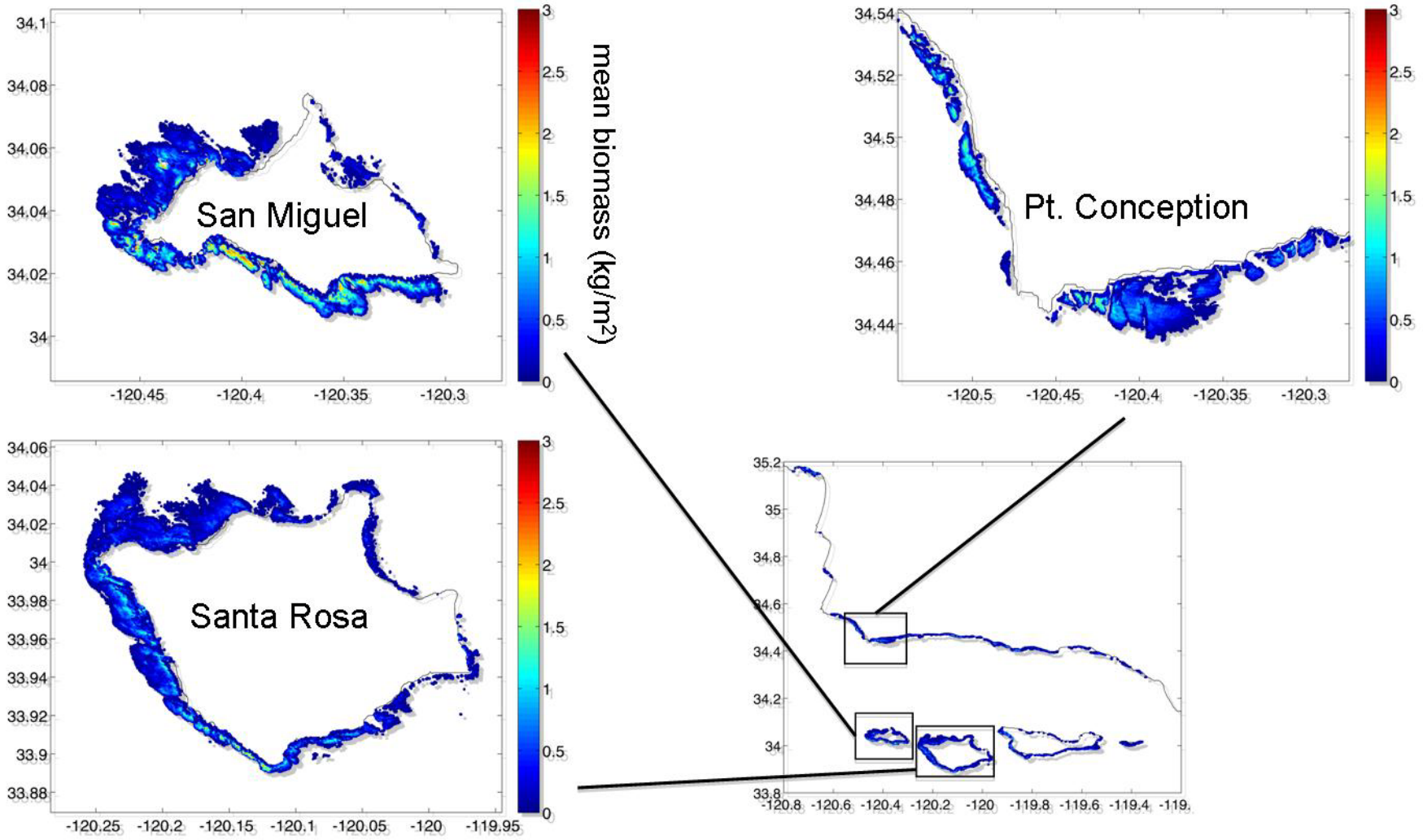
Inter-annual Forcings



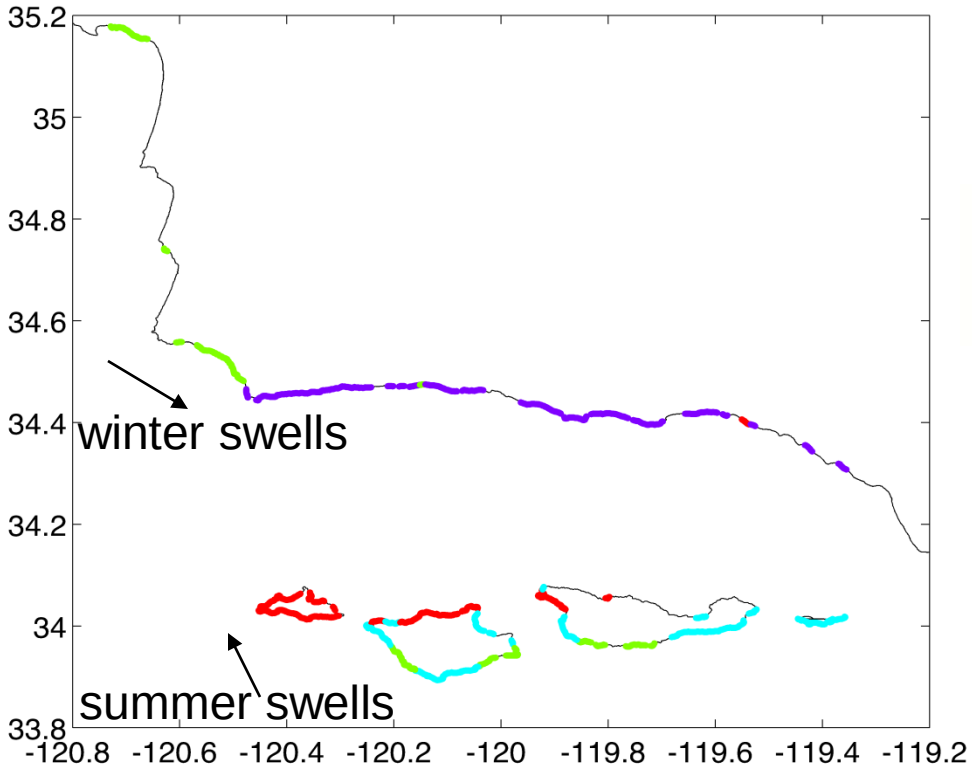
Kelp population controls

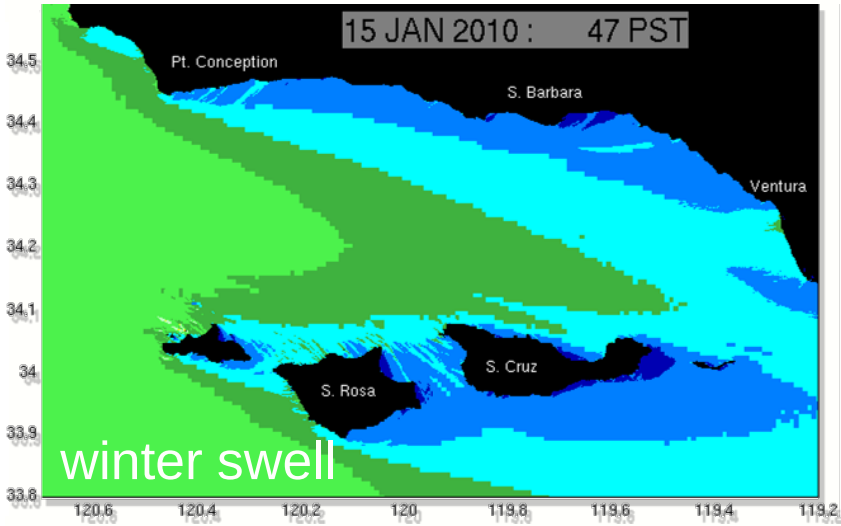


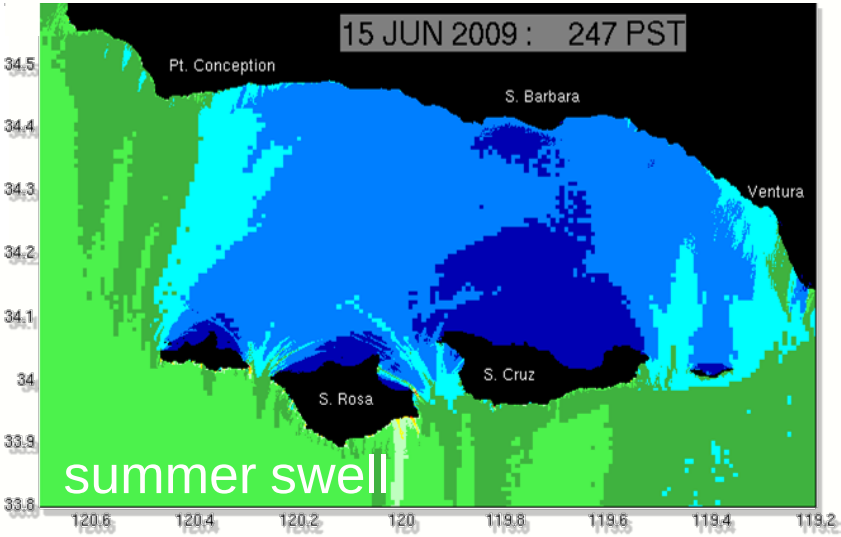
Spatial kelp dynamics in the Santa Barbara Channel (1984-2009)



Cluster Analysis







Correlation with physical variables

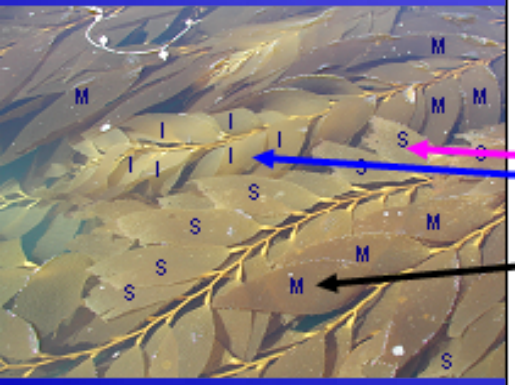
	kelp biomass			
sst	-0.05	**-0.32**	-0.05	**-0.26**
waves	**-0.52**	-0.13	**-0.32**	-0.15

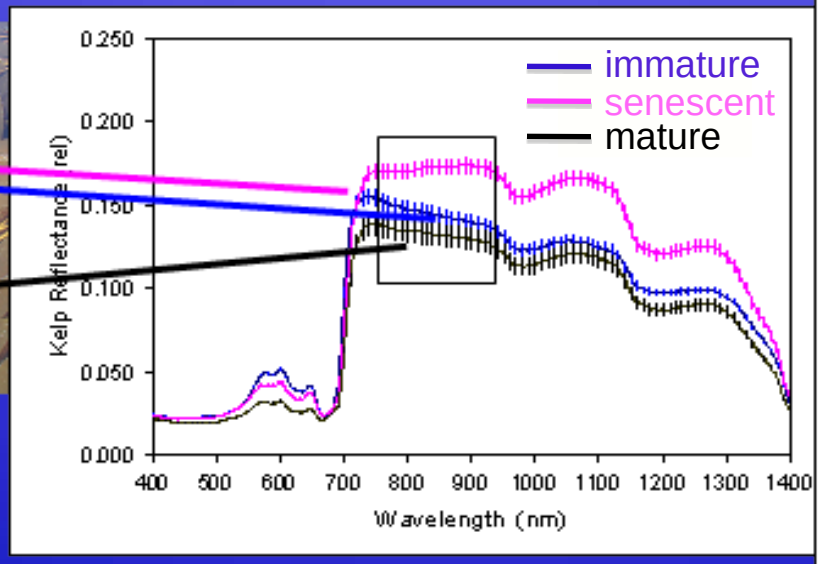
Summary

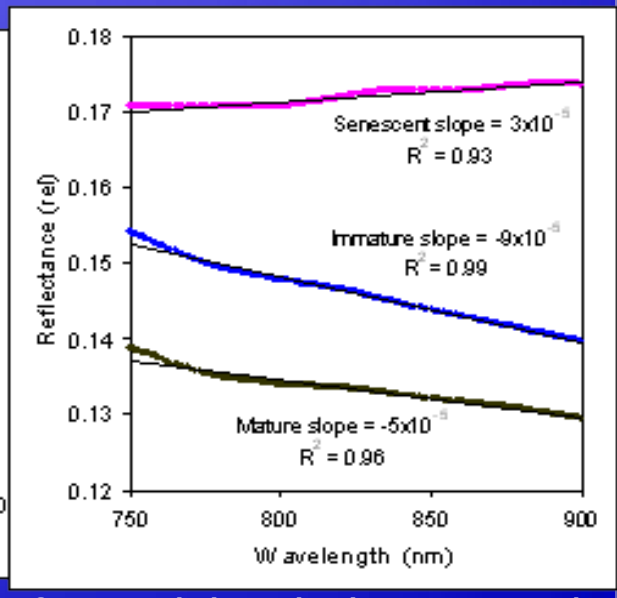
- We have created a time series of giant kelp biomass in the Santa Barbara Channel between 1984-2010 with unprecedented spatial and temporal resolution from LANDSAT imagery
- Region-wide monthly kelp dynamics are negatively correlated with max wave height, annual kelp biomass lags SST, waves and the NPGO by 3 years
- Sub-regional dynamics cluster along wave exposure gradients

Moving forward (on to hyperspectral imagery)

- Spectral unmixing will be much more accurate
- Allows us to get at age structure, senescence, species differentiation
- Potential to combine LDCM & HyspIRI

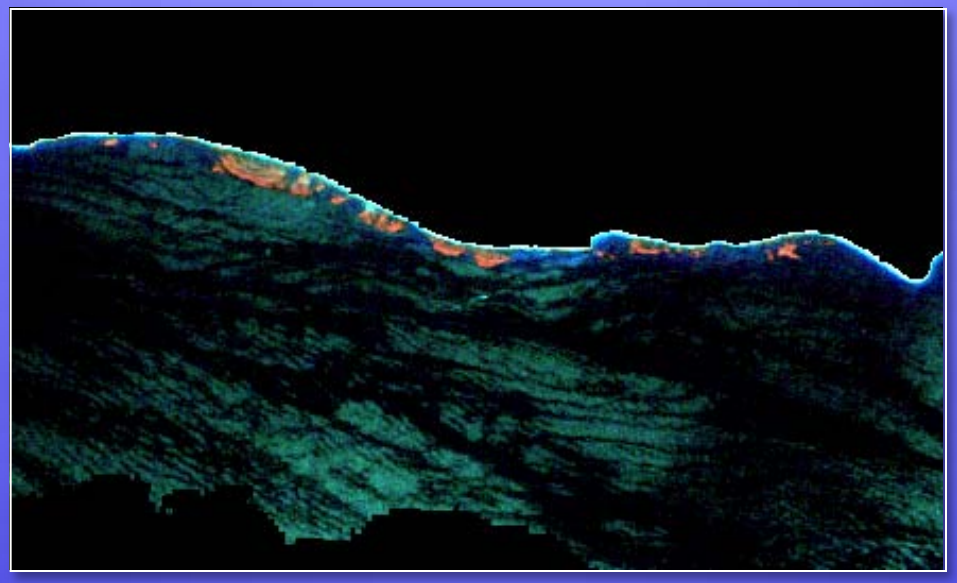






(data from Richard Zimmerman)

Thank You!!



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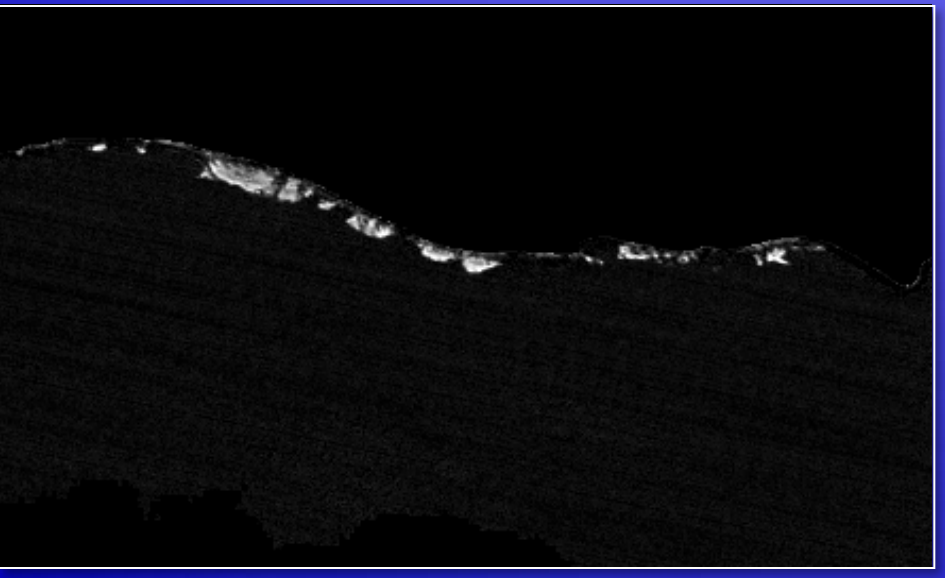
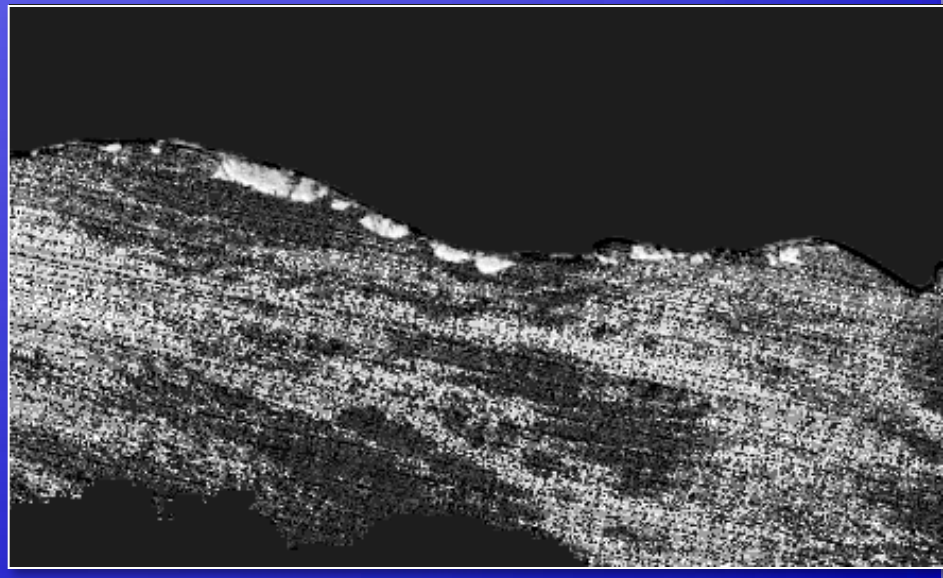
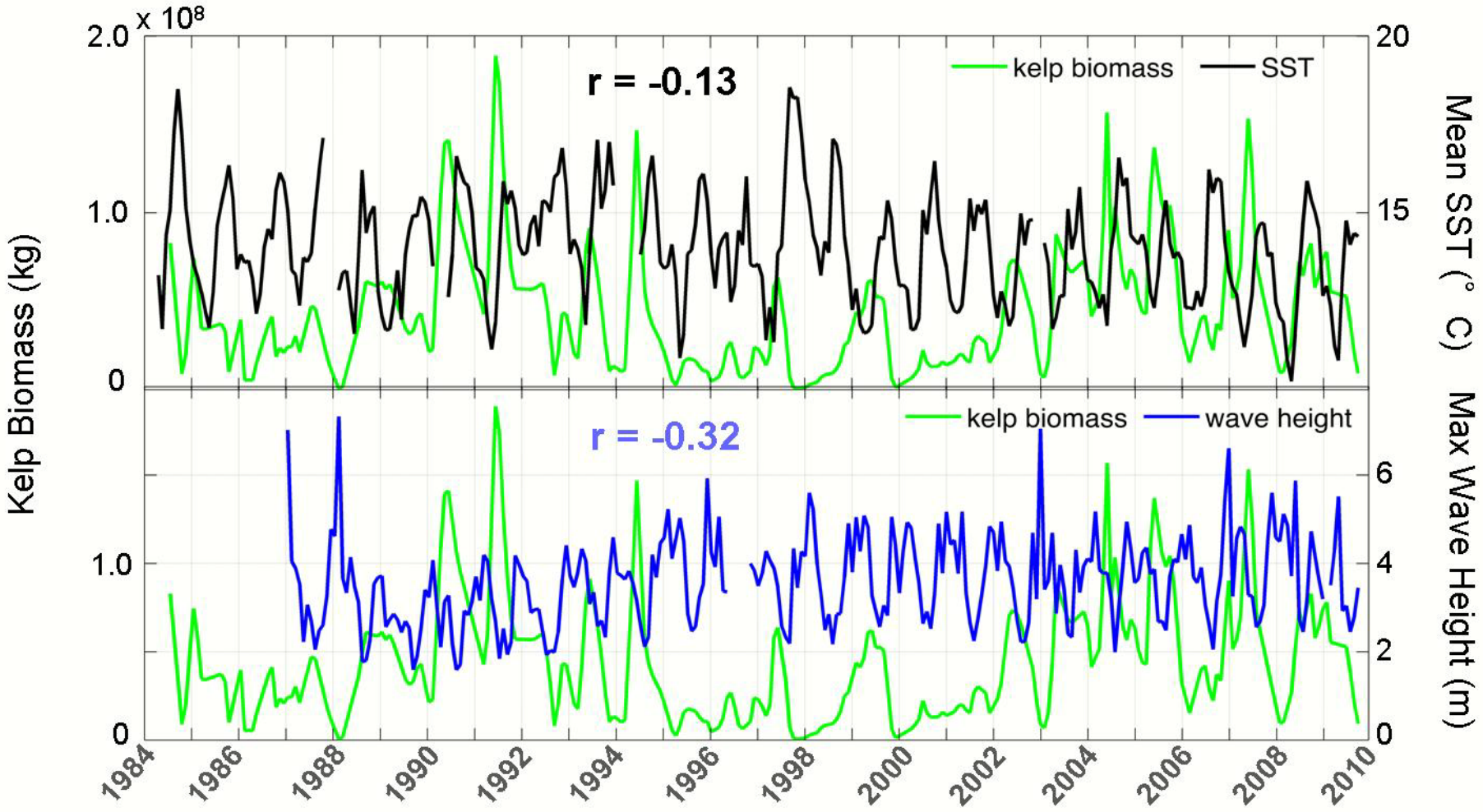


NDVI



Seasonal Forcings