Remote Sensing Ecosystem Indicators

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Outline

- An overview of remote sensing
- Advantages/disadvantages and potential biases
- Accuracies
- Specific focus on Gulf of Maine
- 2 example data sets, timeseries and indicies
- Summary

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Overview and Background

Here: focus on satellite data. WHY?

Here: focus on ocean data WHY?

What is possible?

- Surface Temperature (SST)
  - NOAA, NASA MODIS (NOAA AVHRR data most mature)
- Ocean Color (optical properties $\Rightarrow$ turbidity, chlorophyll, ..)
  - NASA (especially SeaWiFS and MODIS)
- Surface Winds (velocity vector)
  - NASA (QuikSCAT)
- Dynamic Height (geostrophic current structure)
  - altimeters (problematic inside the Gulf of Maine and nearshore)
- Surface Roughness (waves, slicks)
- Salinity (coming soon)
  - but not likely to be useful near coast

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Advantages & Potential Biases

- continuous, repetitive orbits ⇒ time series
- federally funded platforms **(but not data processing & analysis)**
- systematic, continuous use of same sampling protocols
- synoptic coverage of very large areas, remote areas

All: have at-launch defined time/space resolution

All: measure surface properties **visible upper 2-15m**
infrared (SST) surface skin

All: require atmospheric correction **(for vis data > 90% of signal)**

Visible and IR: cannot penetrate clouds / fog

produce time series with gaps

possible errors at cloud edges / undetected clouds

biases towards certain seasons / weather patterns

Address these AMAP with time/space statistics

- take advantage of OVERSAMPLED DATA

- at expense of *unresolvable* time/space scales

SST and Ocean Color Specifics in Gulf of Maine

SST: 1km spatial resolution

atmospheric correction

day / night capability + 2 satellites = 4+ images / day

NOAA AVHRR data: since 1985 (21+ years of data)

31,000 images

Color: 1km spatial resolution ⇒ CHLOROPHYLL

atmospheric correction

daytime only, 1 image / day

(2 satellites, but combining data not so easy)

time series since Sept 1997

(9+ years SeaWiFS, 4+ years MODIS)

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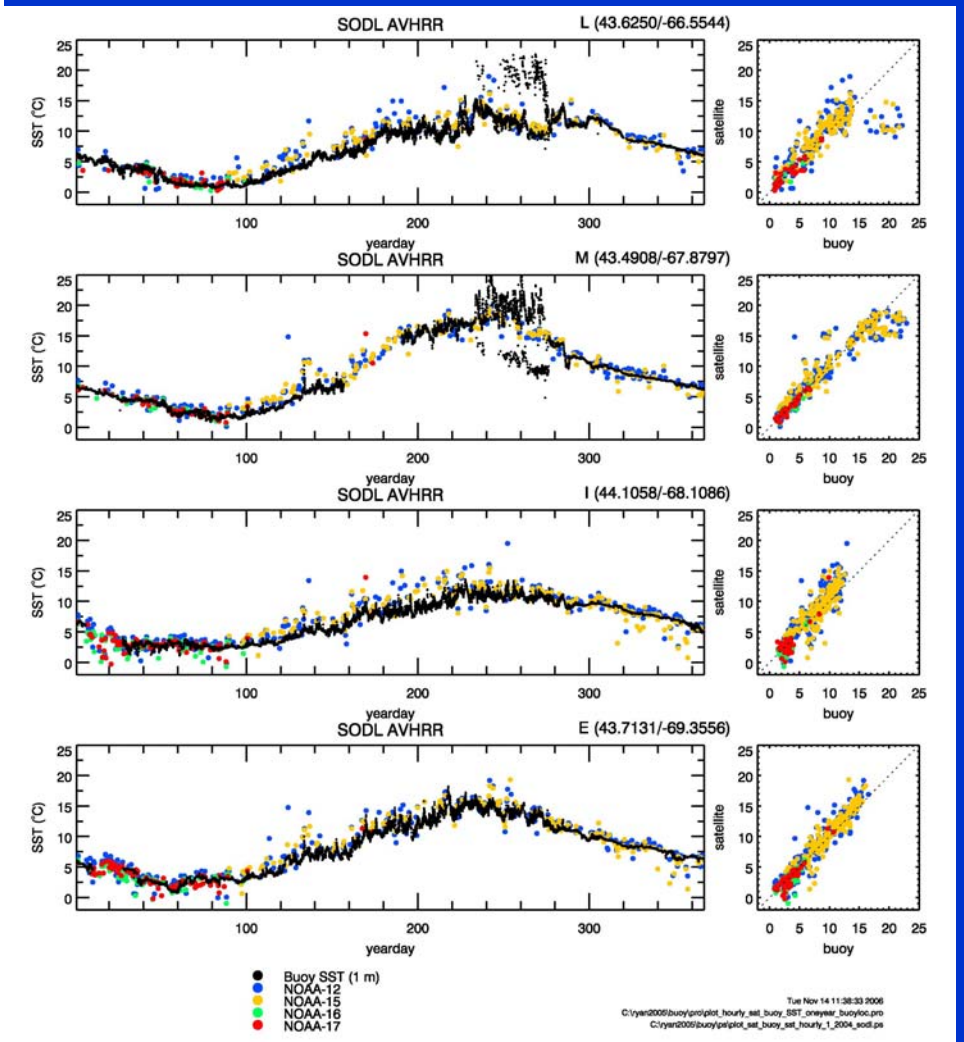
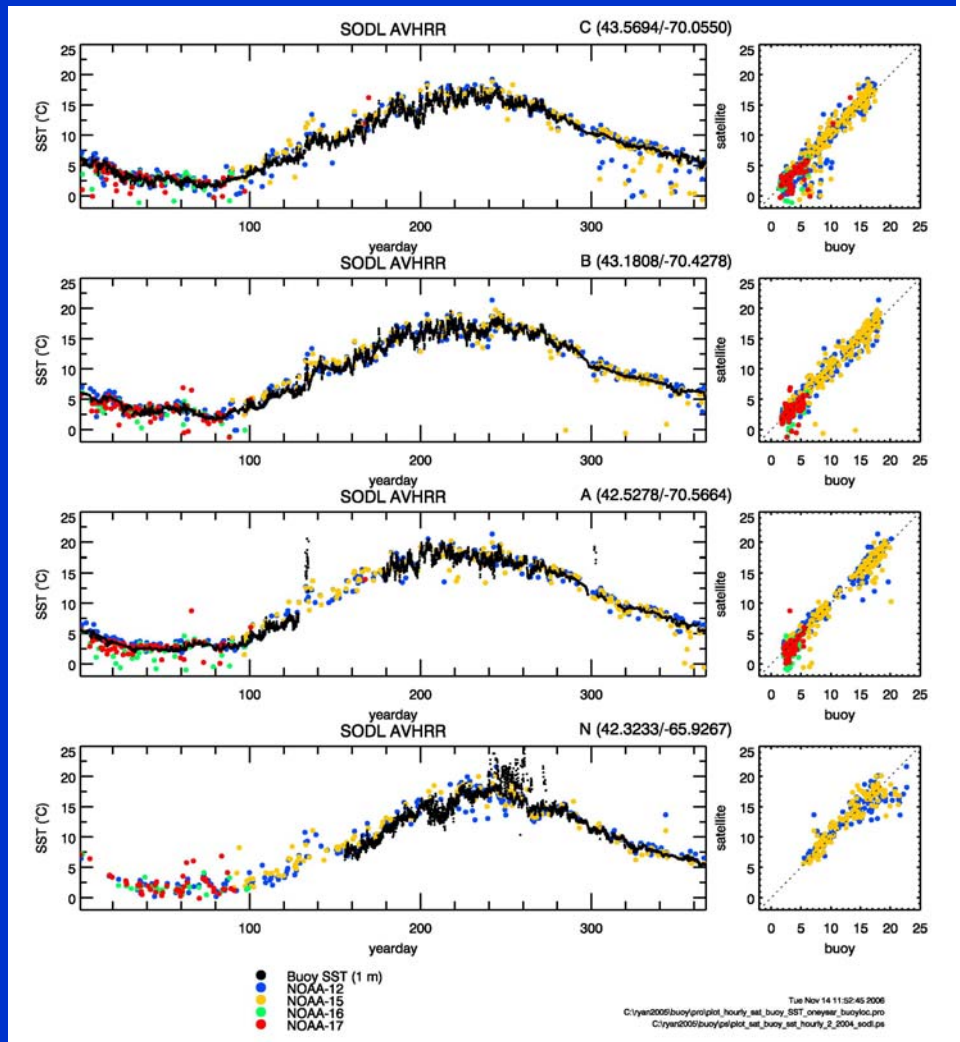
Accuracy

AVHRR SST vs **GOMOOS** buoy surface





Accuracy / Data Stability

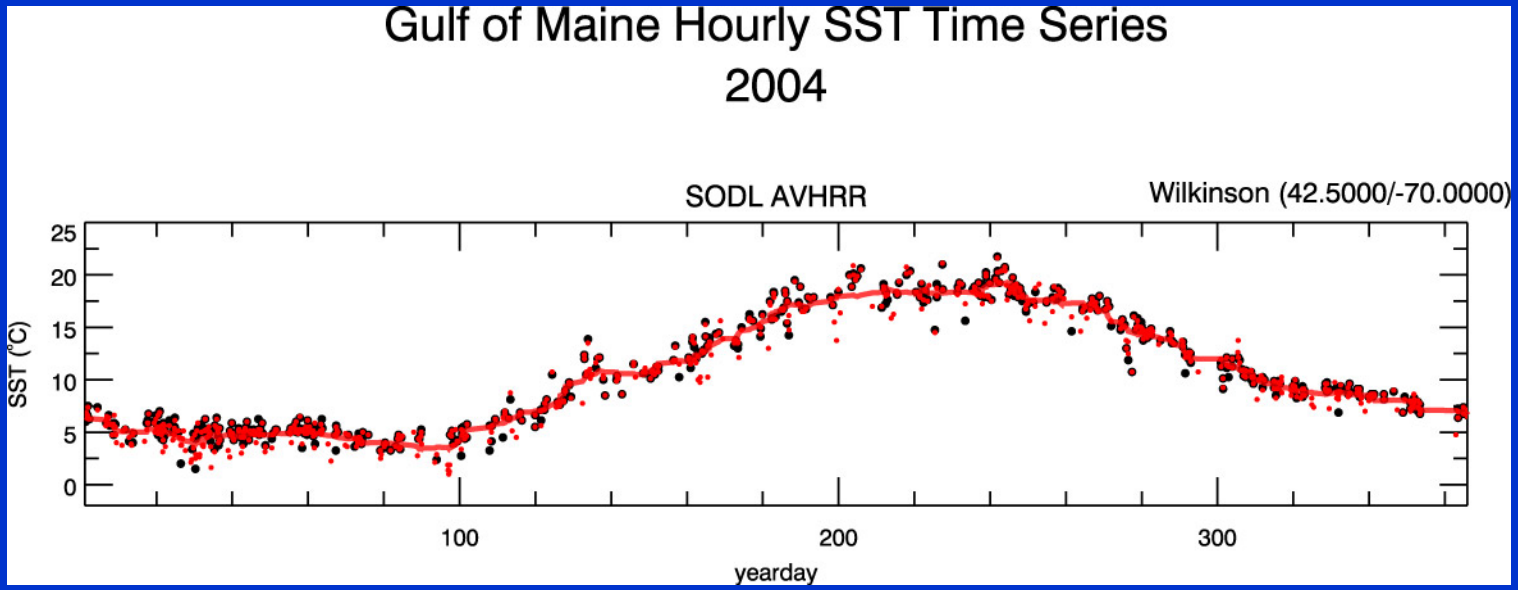
Reduce noise by time / space averaging

Example: Wilkinson Basin 2004

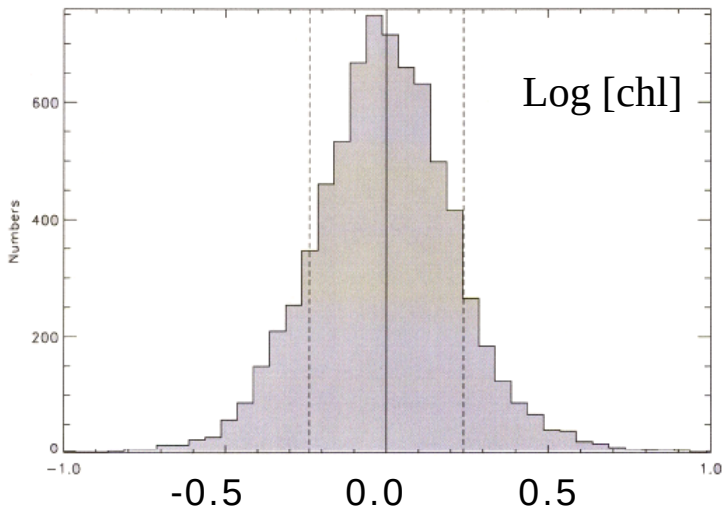
Black: single pixel sample

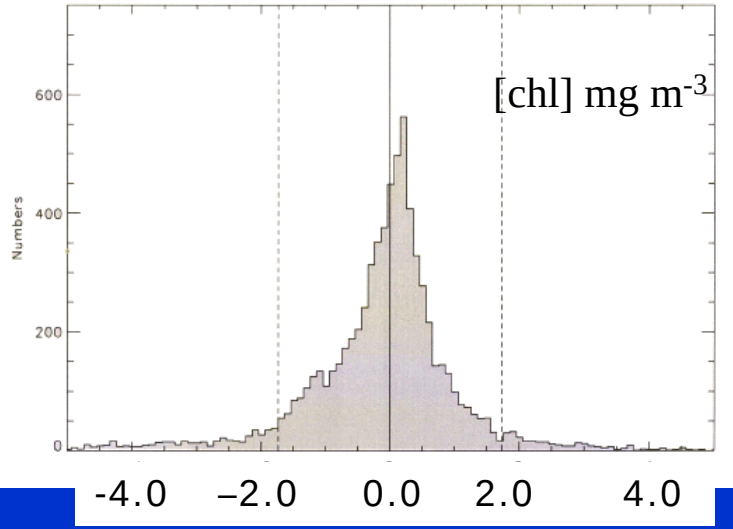
Red: space median

Red line: space median 5 day running mean



Accuracy





Δ = In situ - satellite

SeaWiFS CHLOROPHYLL

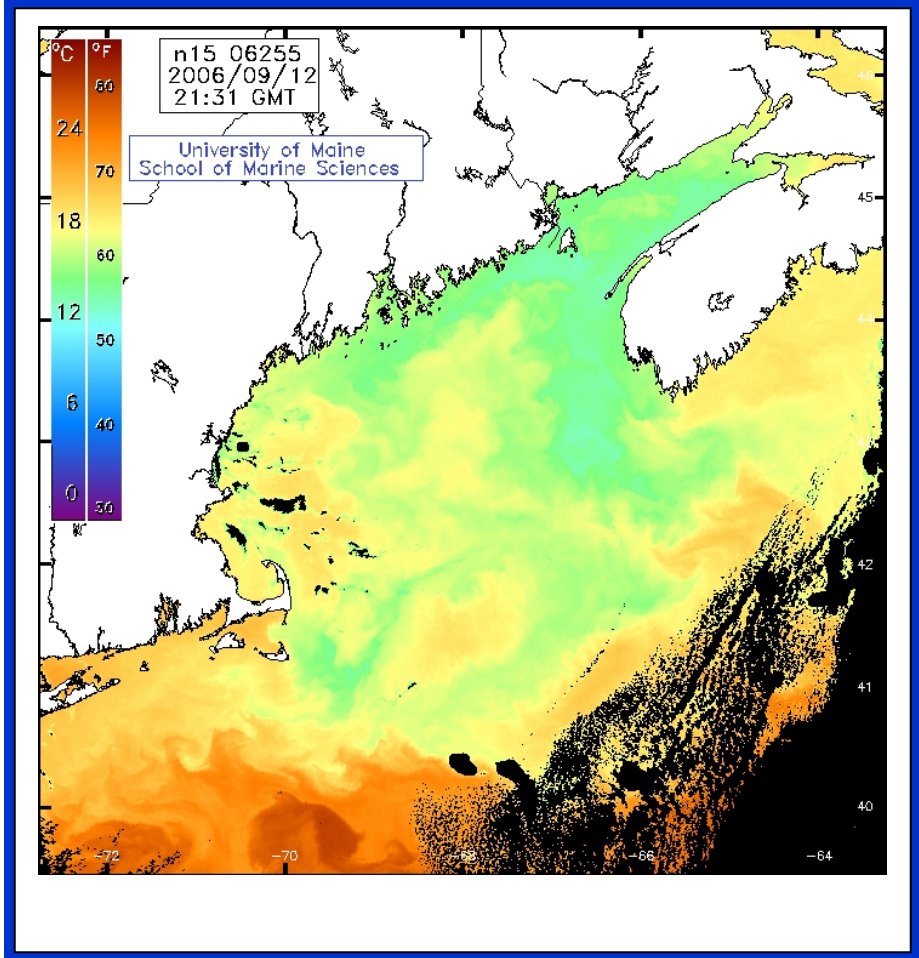
Vs ship chlorophyll (within hour of satellite overpass)

Δ = In situ - satellite

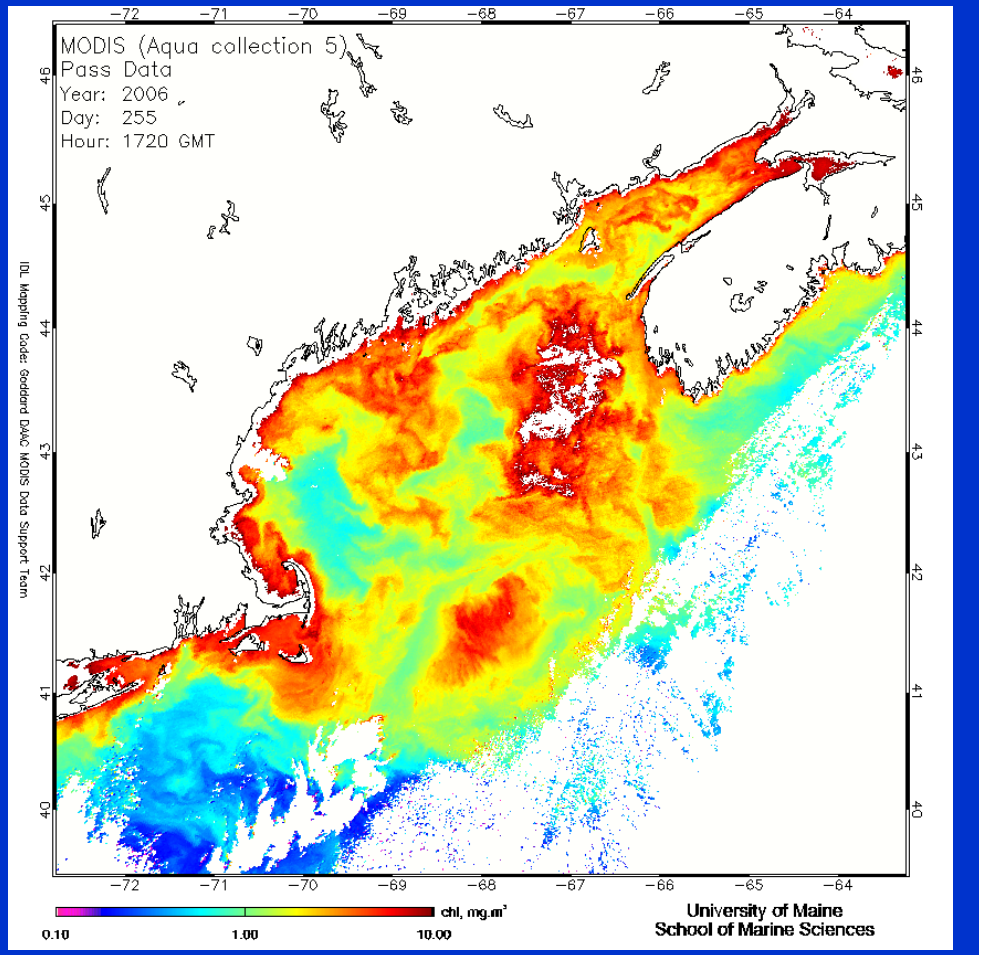
Summer (Maine – Nova Scotia ferry)

Ship data courtesy of Barney Balch, Bigelow

Examples: individual images on specific days



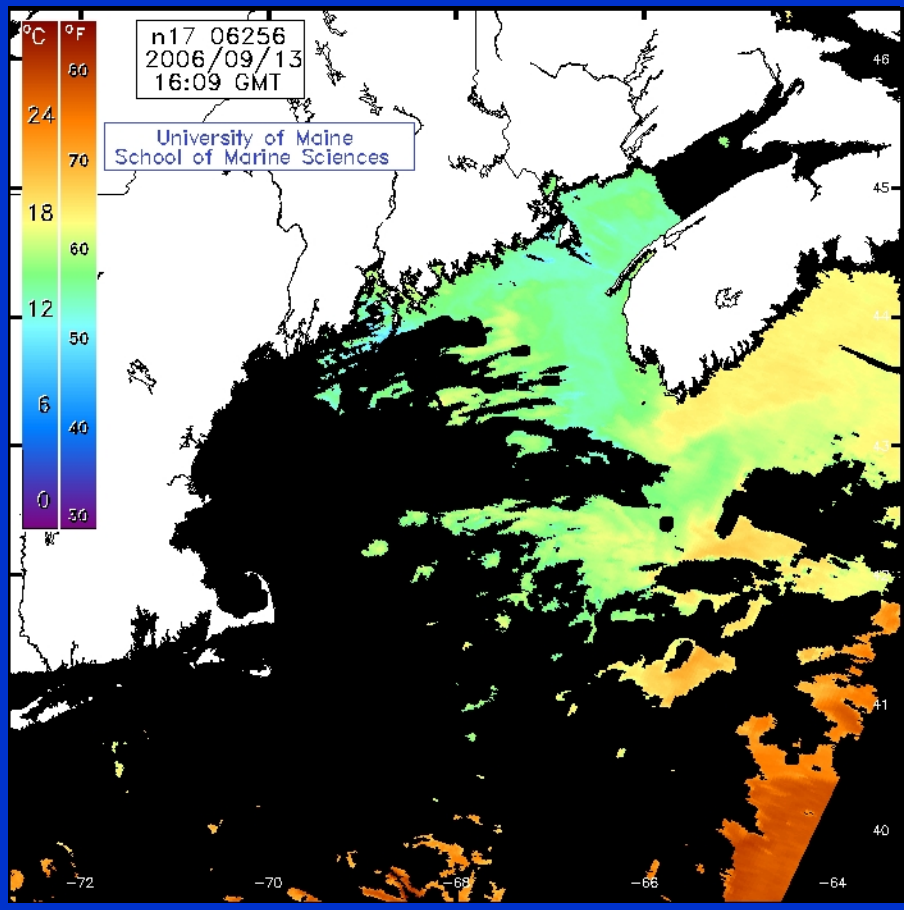
SST (°C)



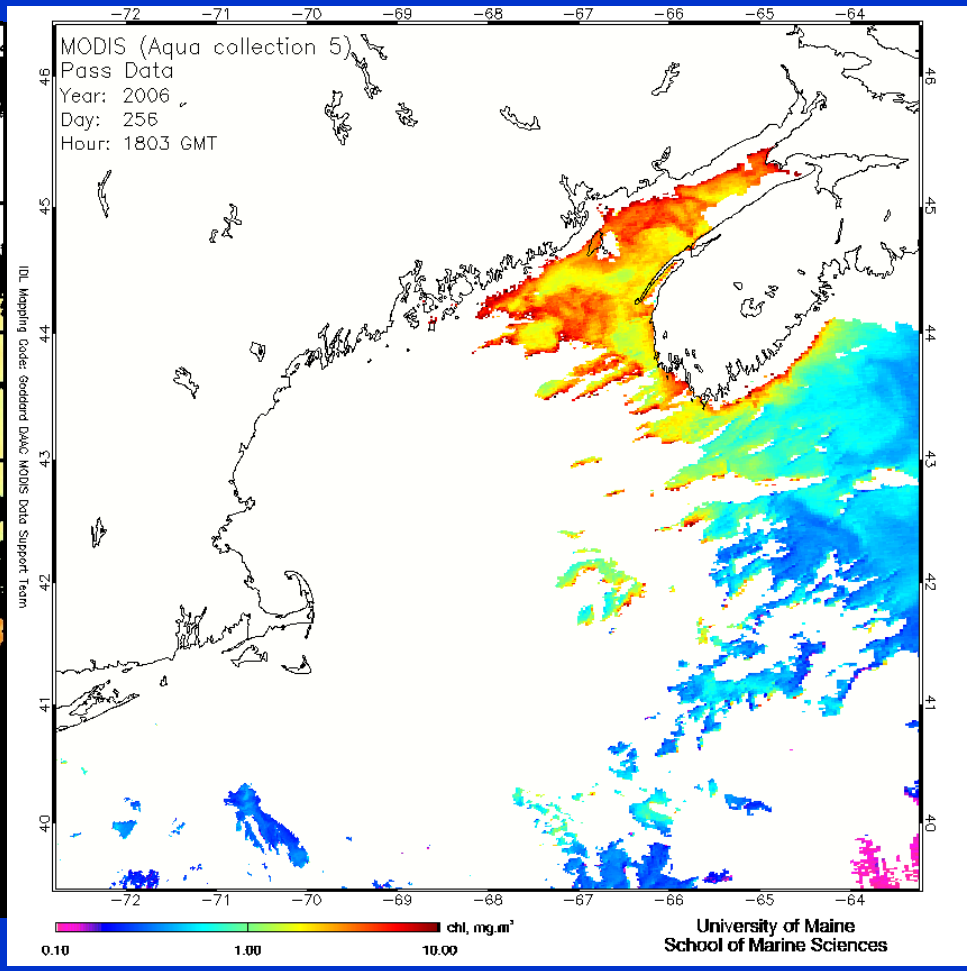
Chlorophyll (mg m^{-3})

12 September 2006

Examples: individual images on specific days



SST (°C)

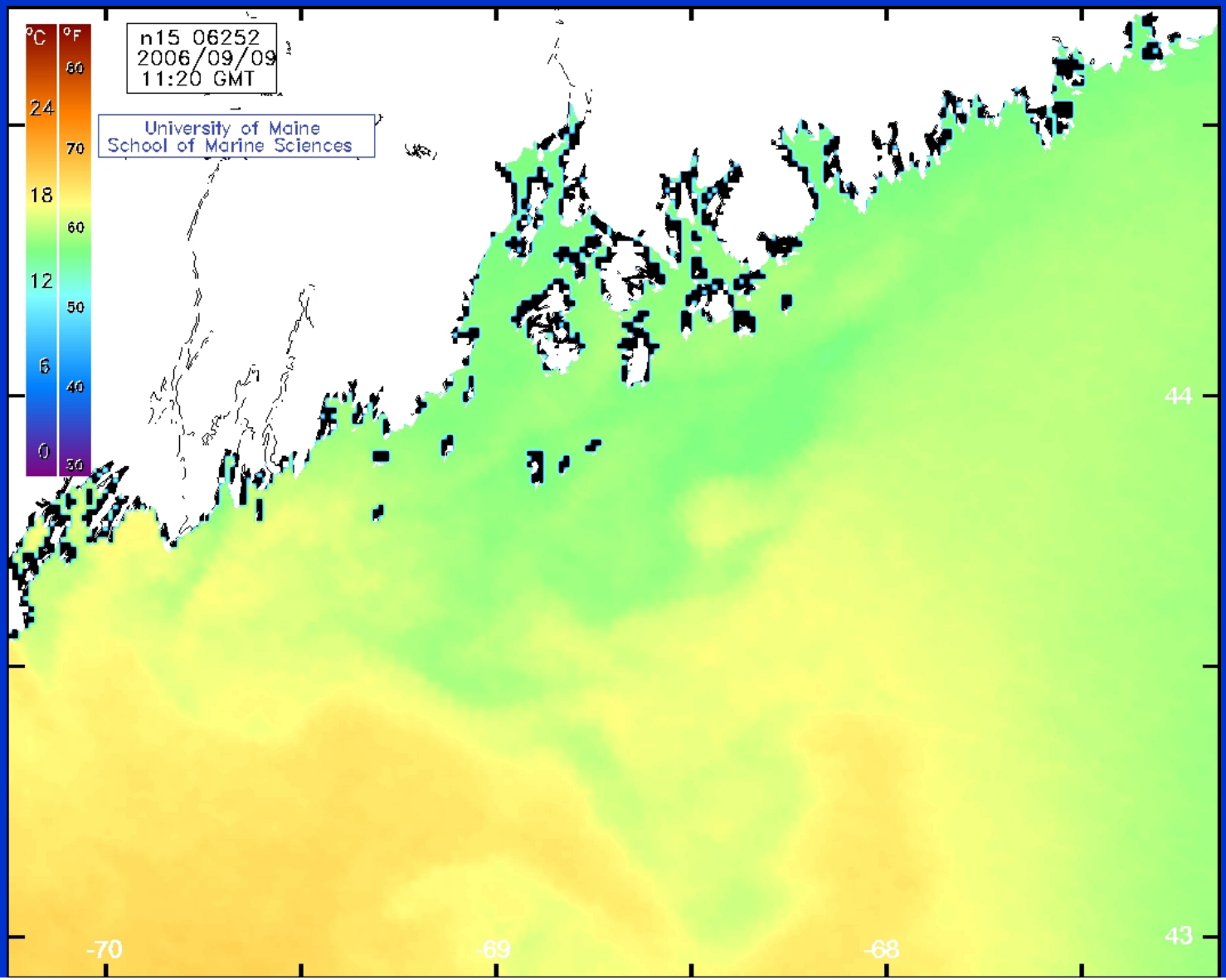


Chlorophyll (mg m^{-3})

13 September 2006
(the next day!)

Spatial resolution

1km for these ocean data



Time series development

⇒ temporal averages

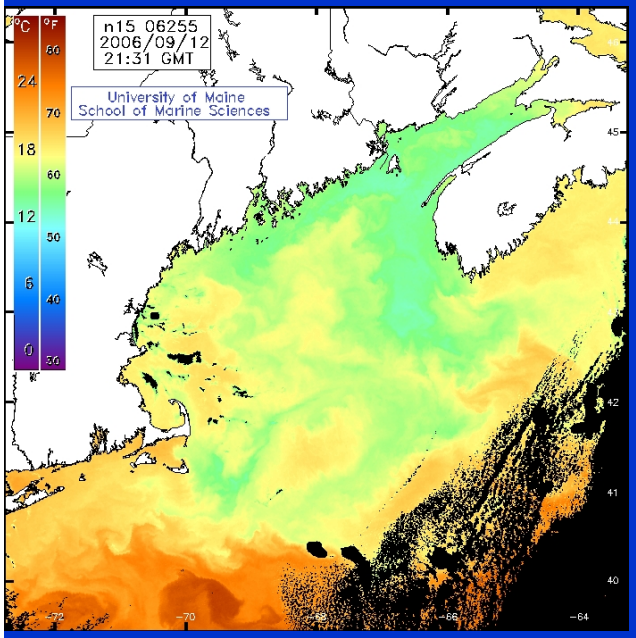
- actually *composites*

- loss of daily details

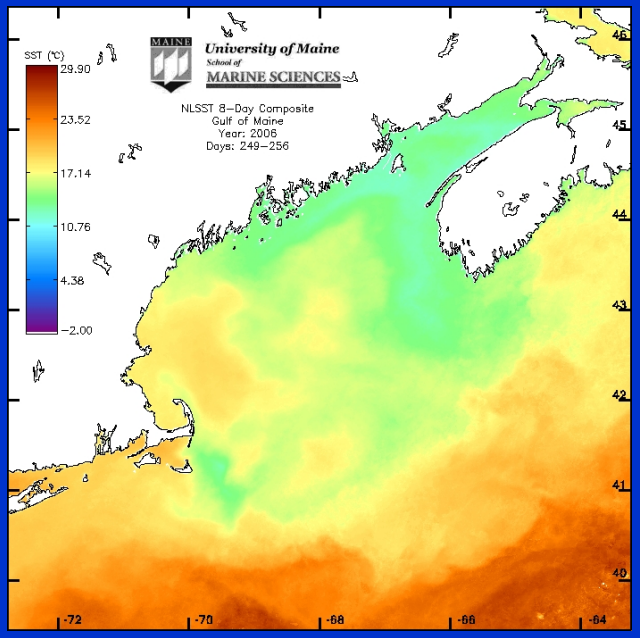
- decrease gaps due to cloud cover

- increase statistical stability

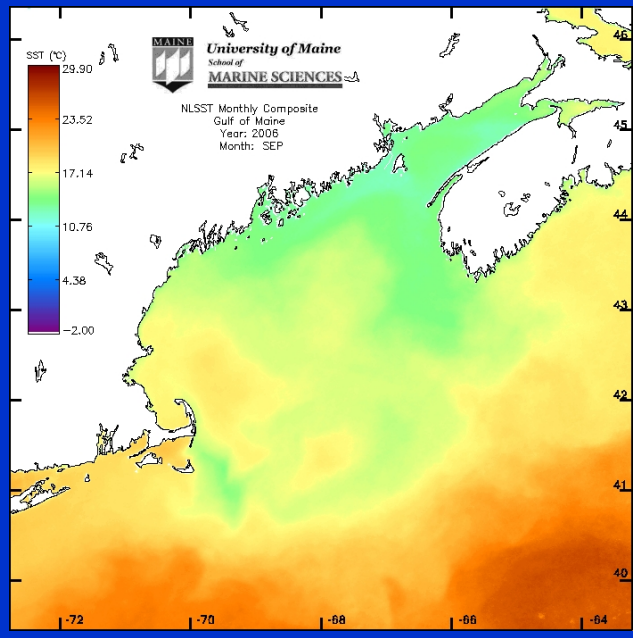
single scene



8-day

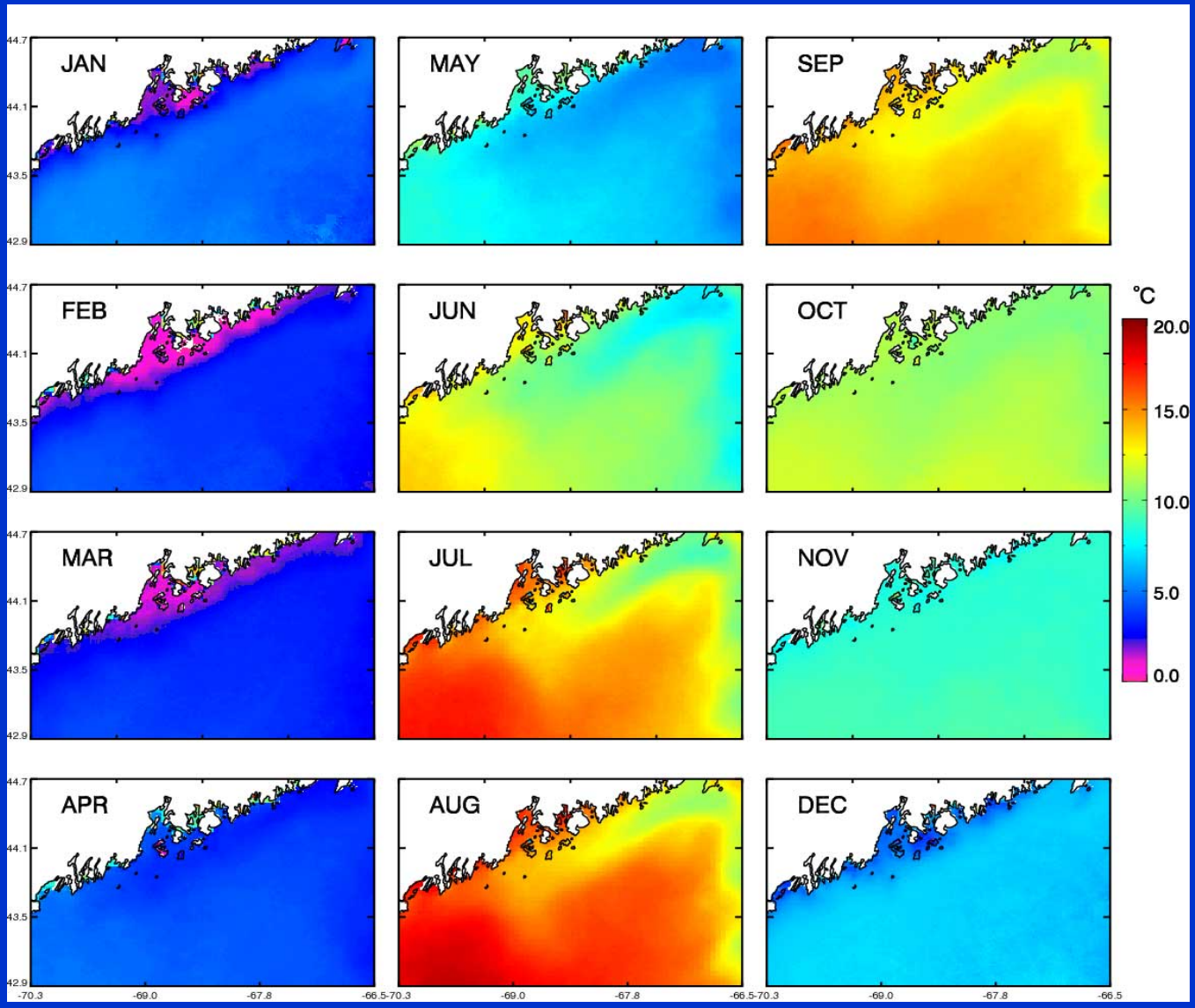


month



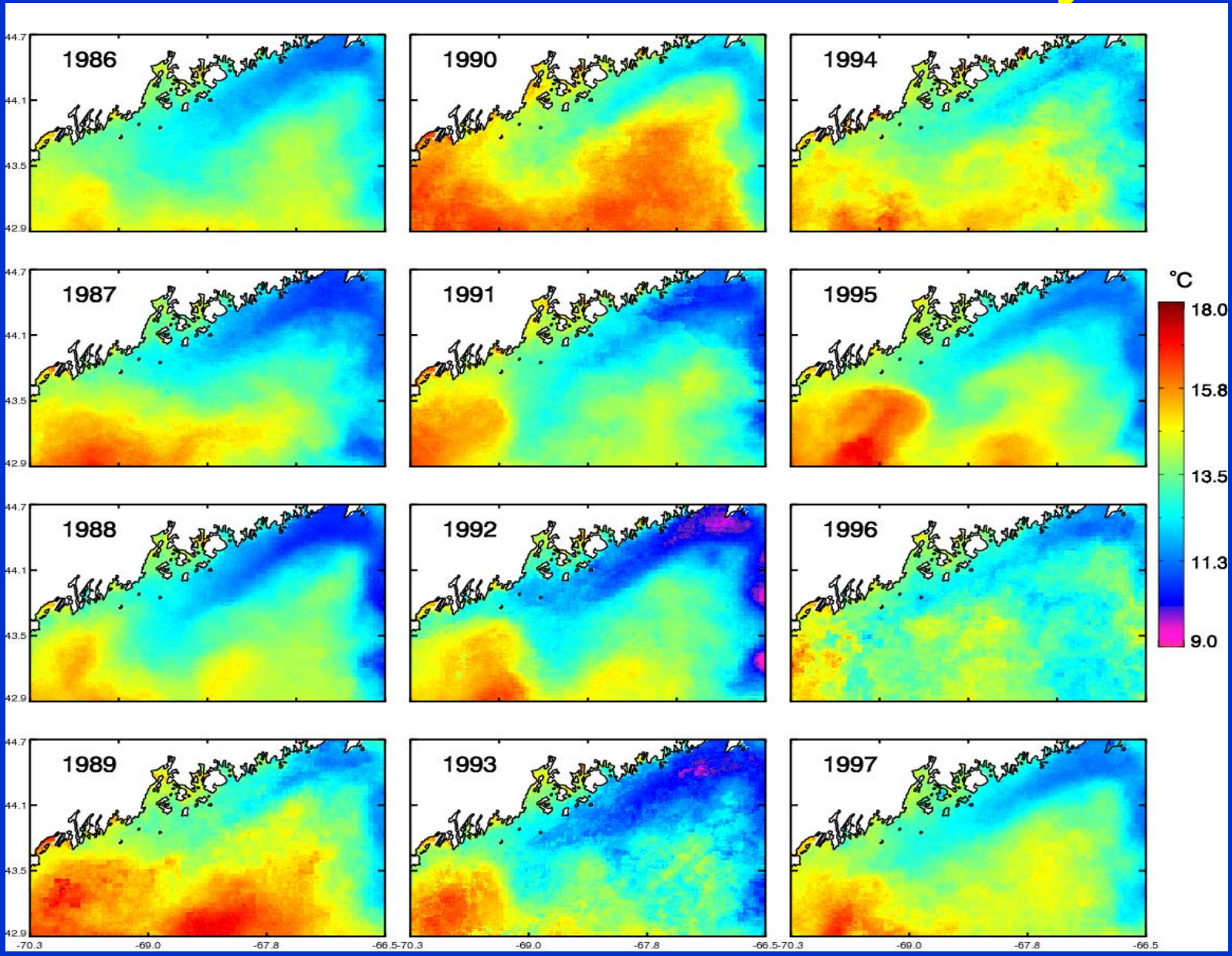
Sept 2006

Seasonal Cycles

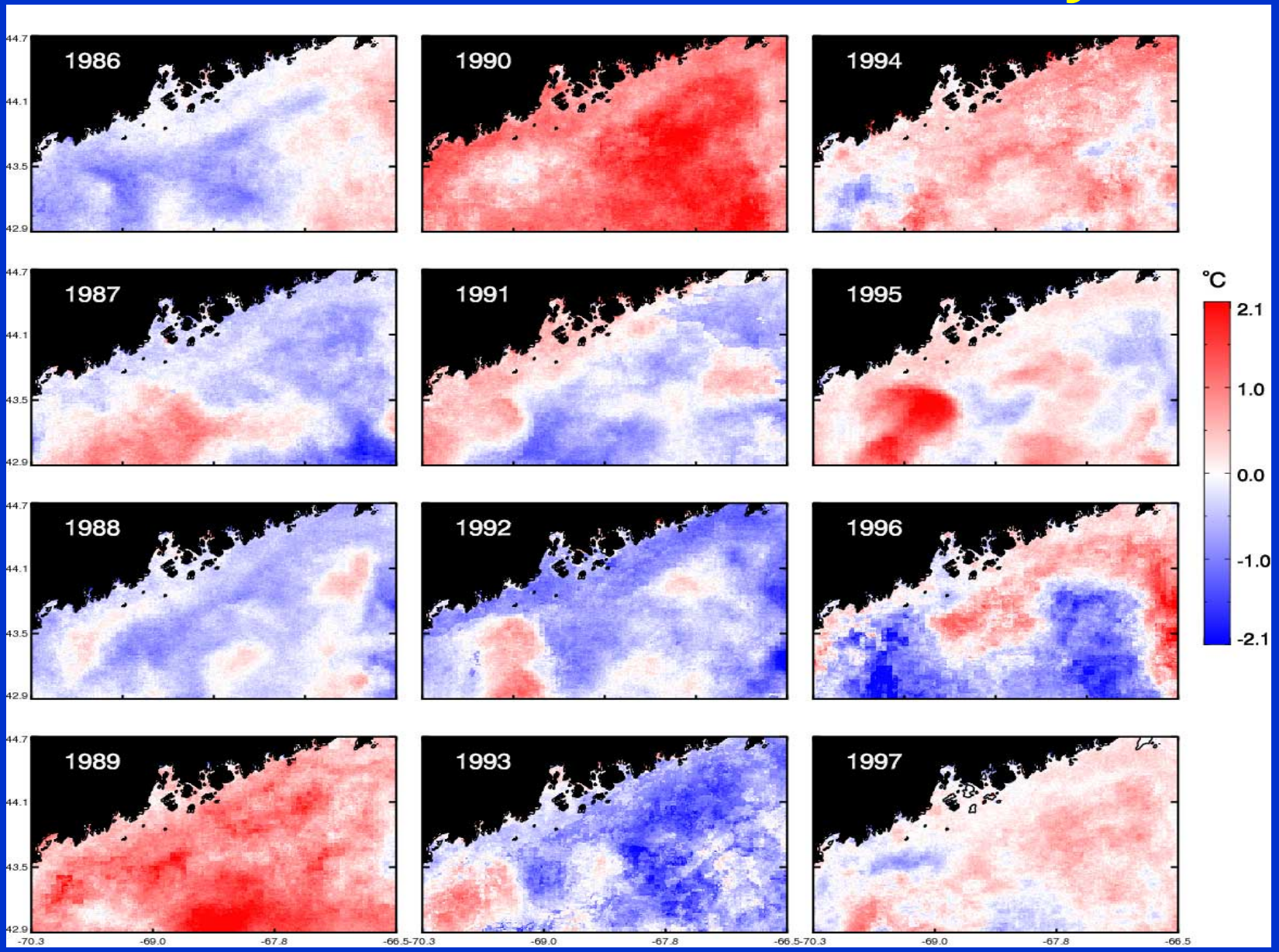


Monthly Climatology (here, 15 years)

Interannual Variability

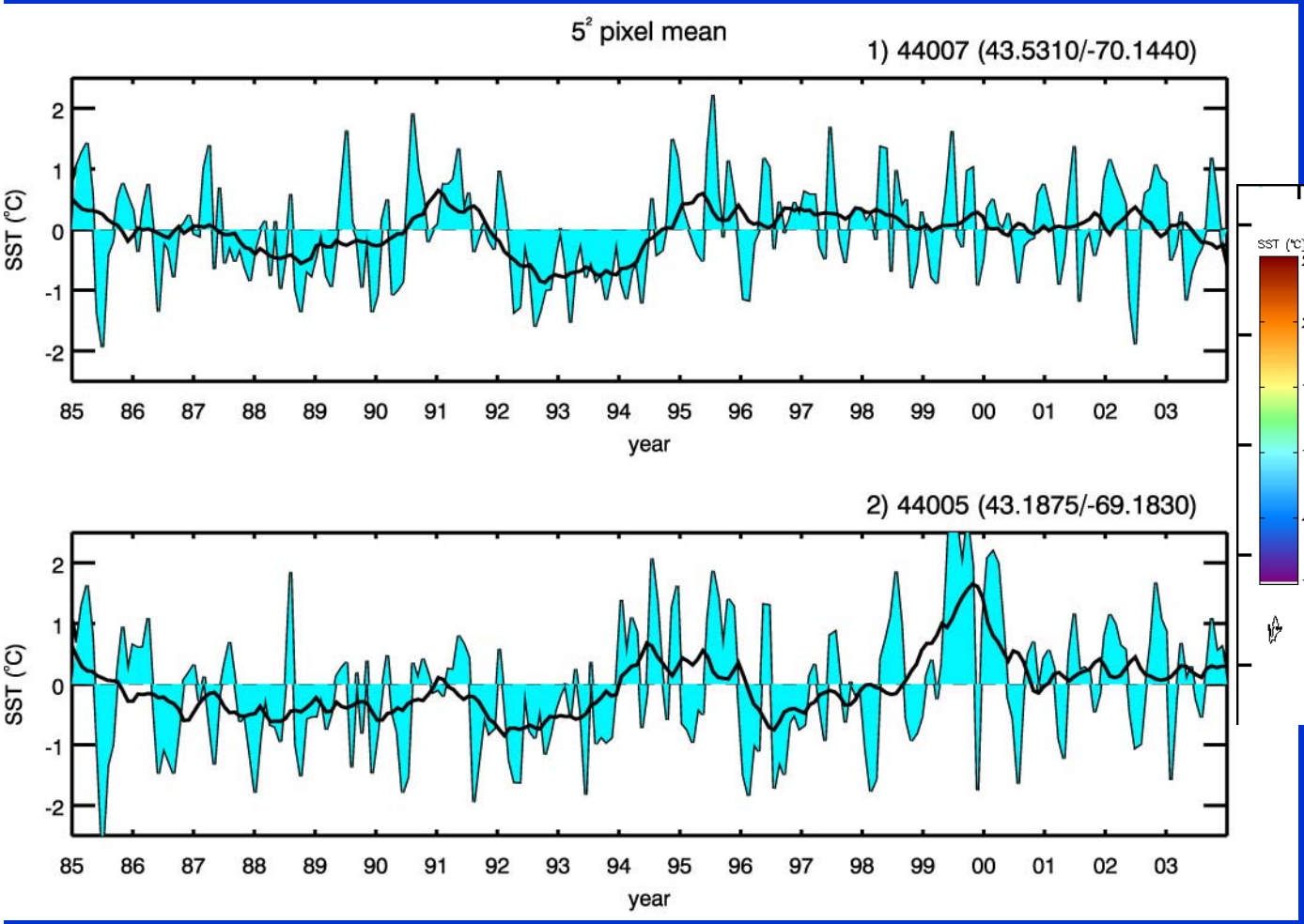


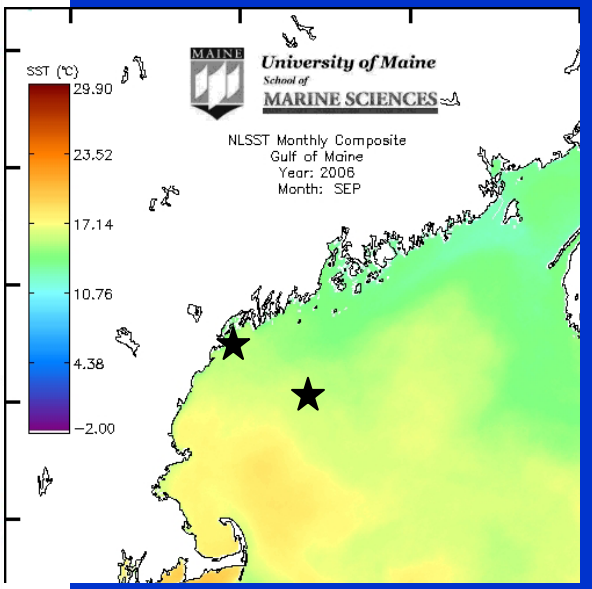
Interannual Variability



Interannual Variability

SST Time series @ specific locations





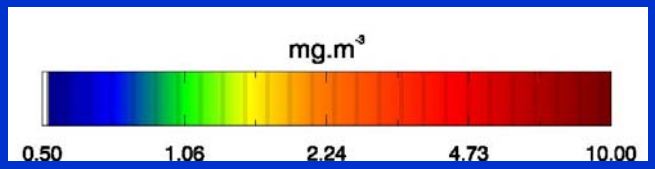
Blue shade: monthly anomalies

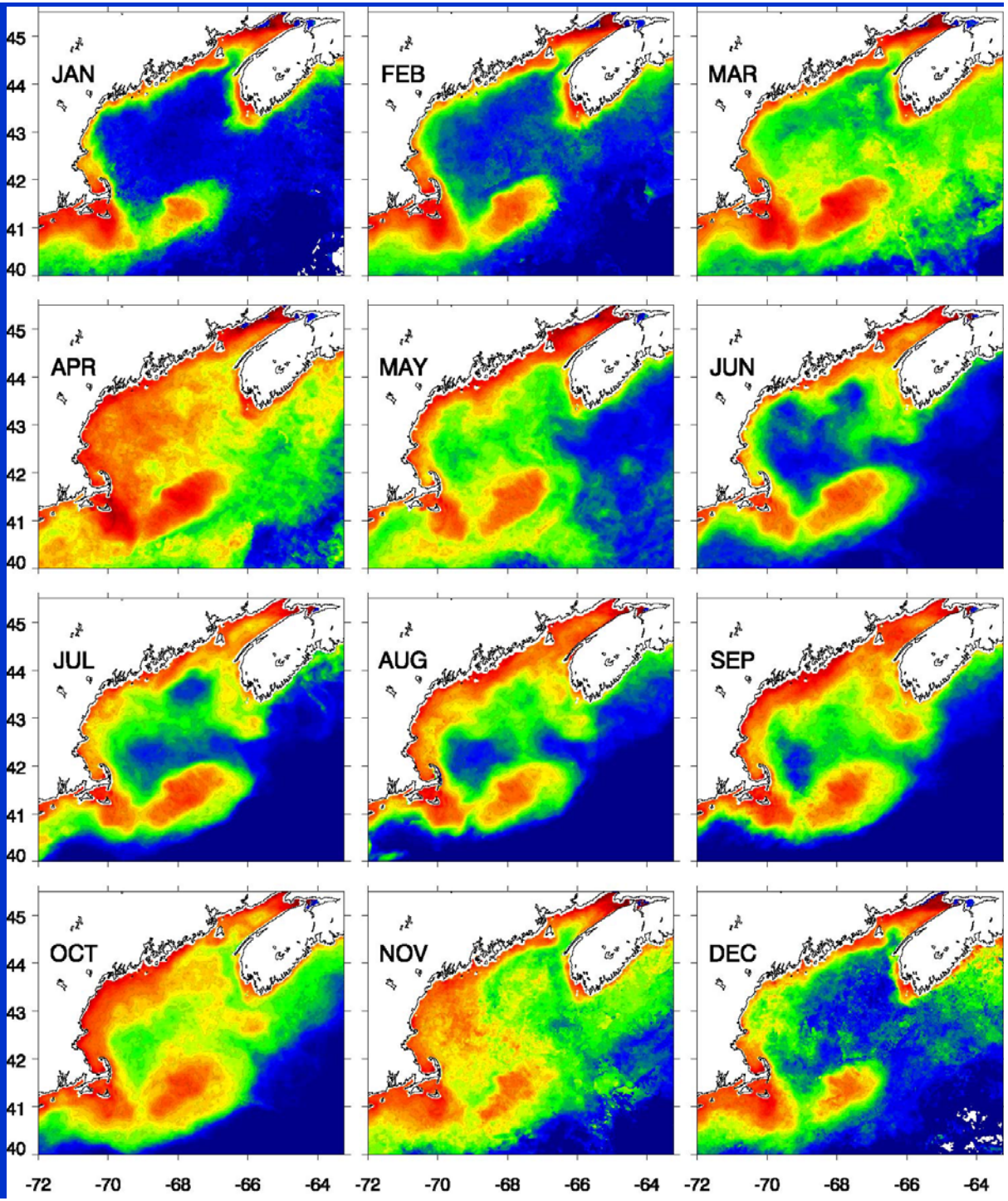
Black line: 12 month running mean

Chlorophyll Climatology (8 years)

Monthly Seasonal Variability

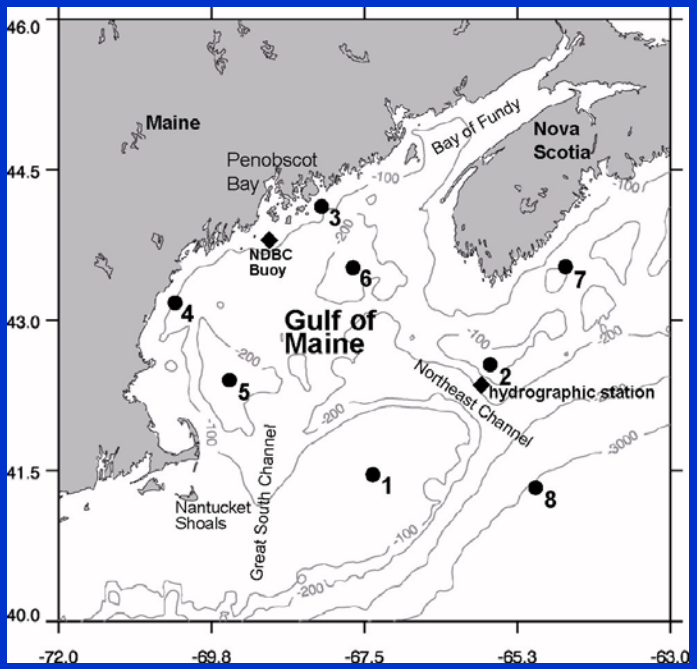
the annual cycle

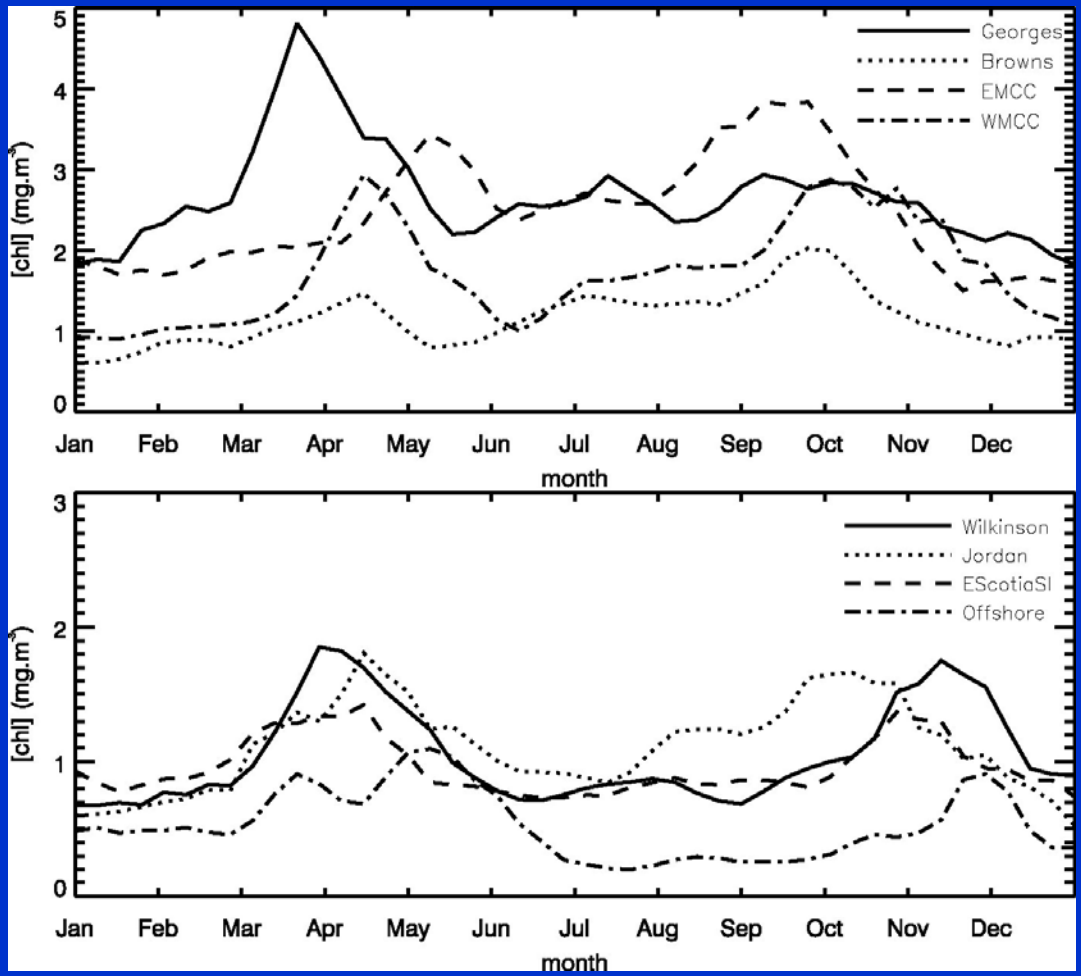




Chlorophyll

Climatological Seasonal Cycles: 8 locations

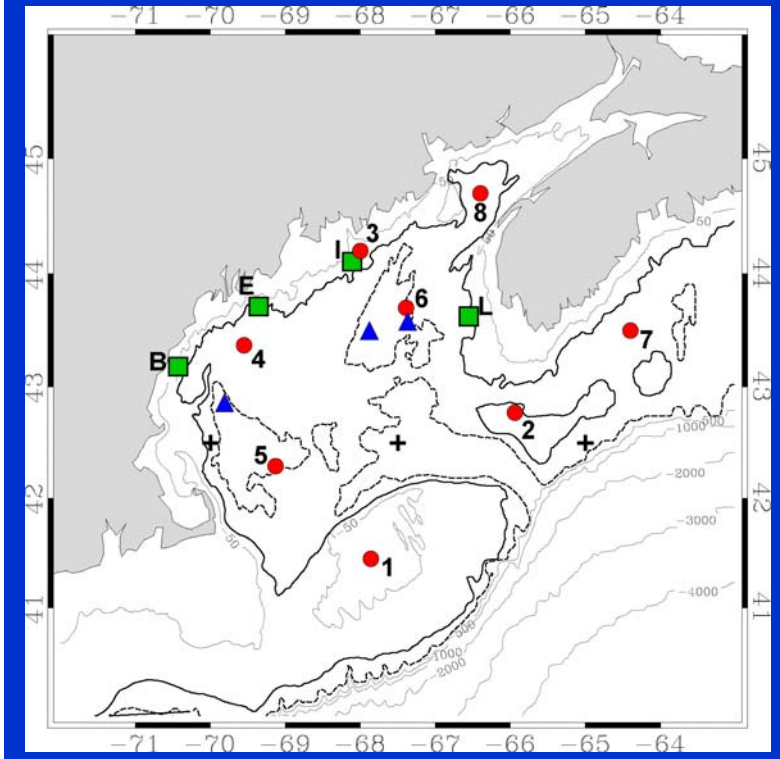


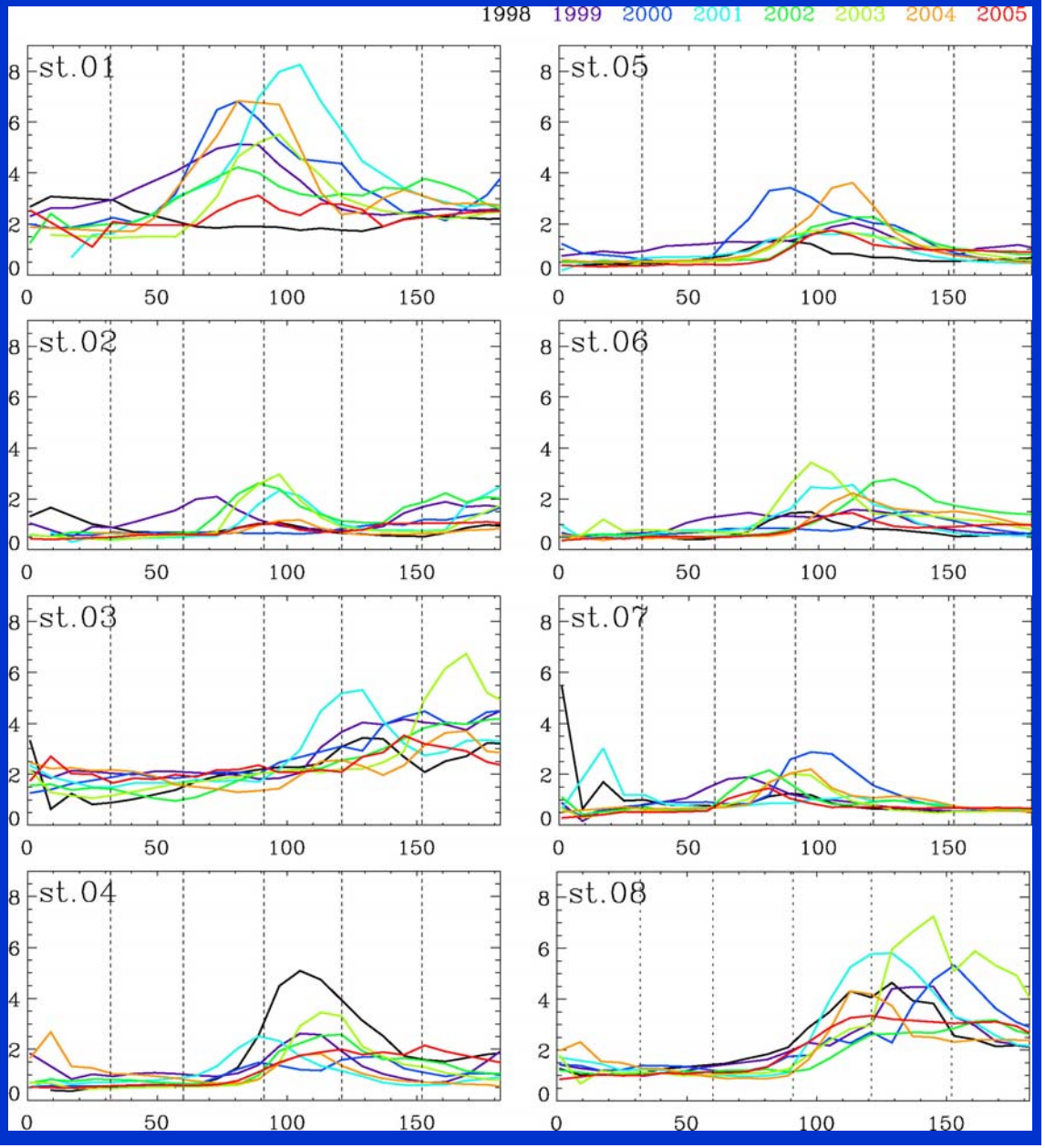


Point: strong spatial heterogeneity (timing and magnitude)

Chlorophyll Interannual Variability

here... SPRING (days 1-180)

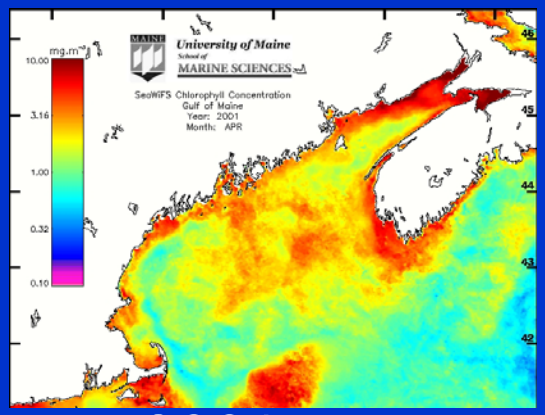




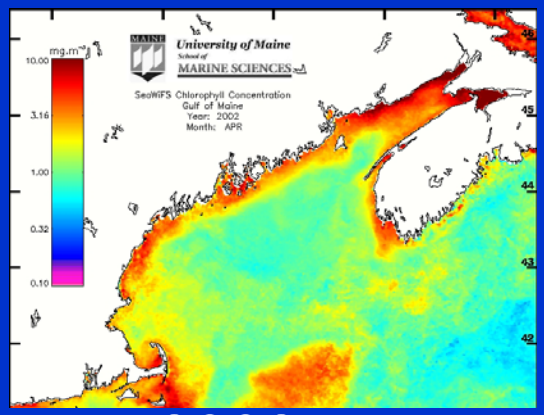
Point: strong interannual differences

Chlorophyll Interannual Variability

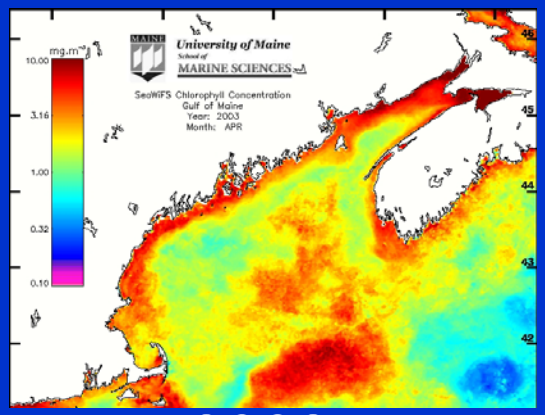
Spring Bloom (April)



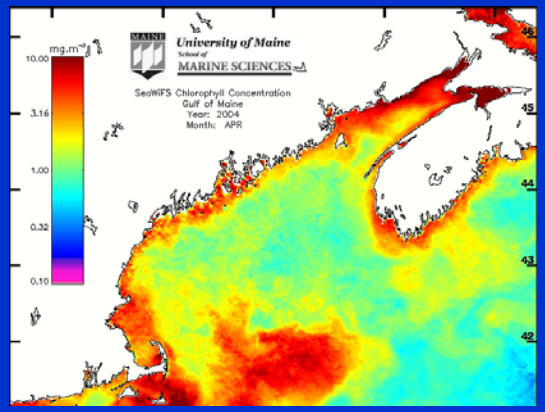
2001



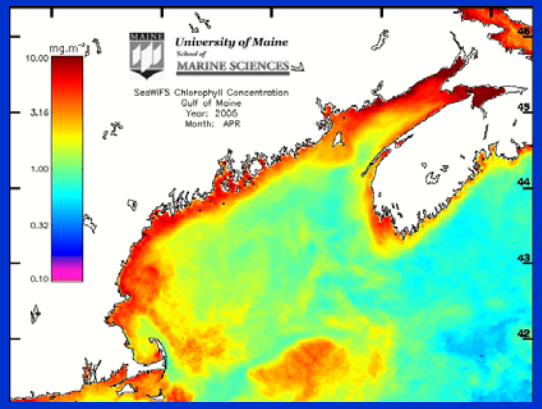
2002



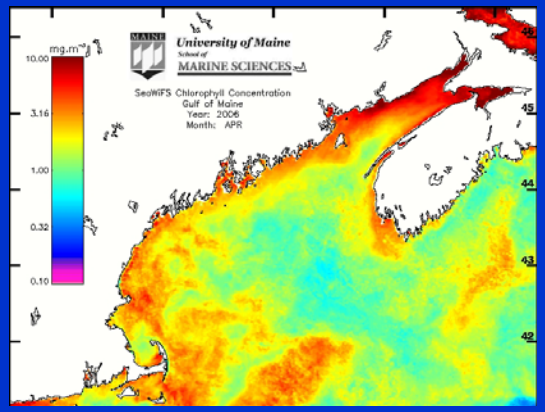
2003



2004



2005



2006

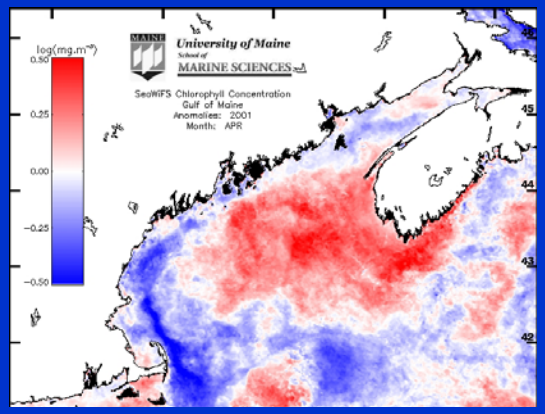
Points: - strong interannual variability

- heterogeneous space patterns

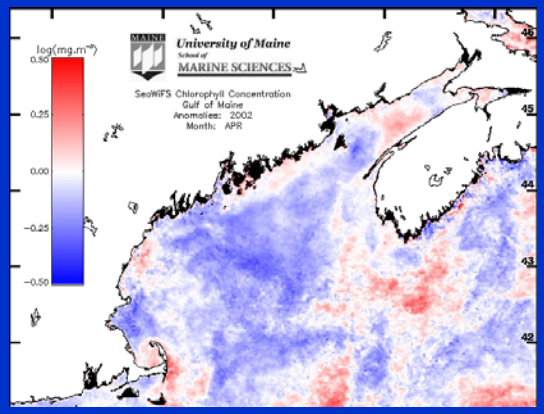
Chlorophyll Interannual Variability

Spring Bloom (April)

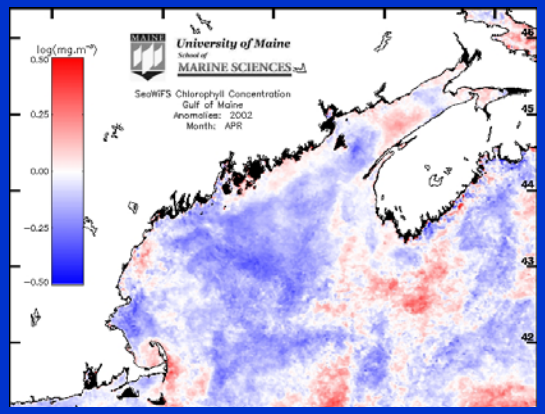
Anomalies (from 9 year mean): + RED, - Blue



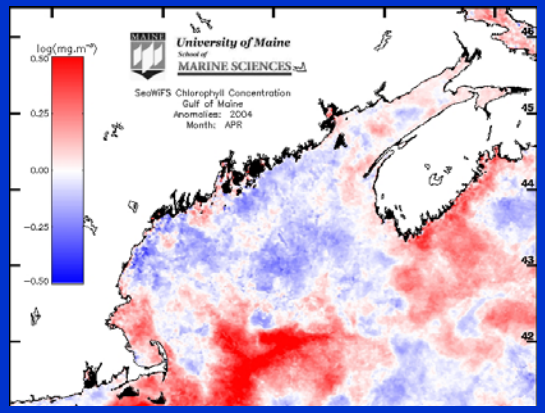
2001



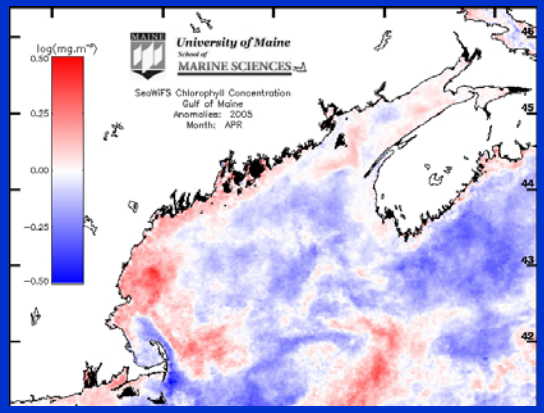
2002



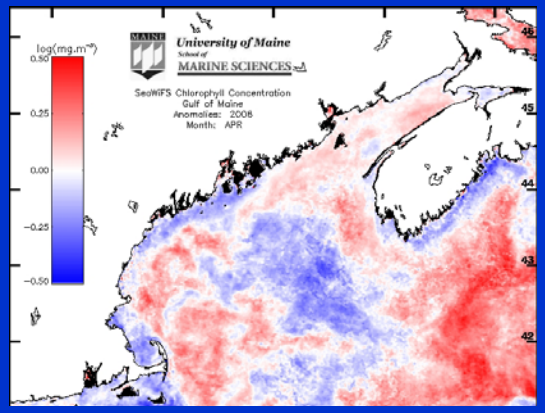
2003



2004



2005

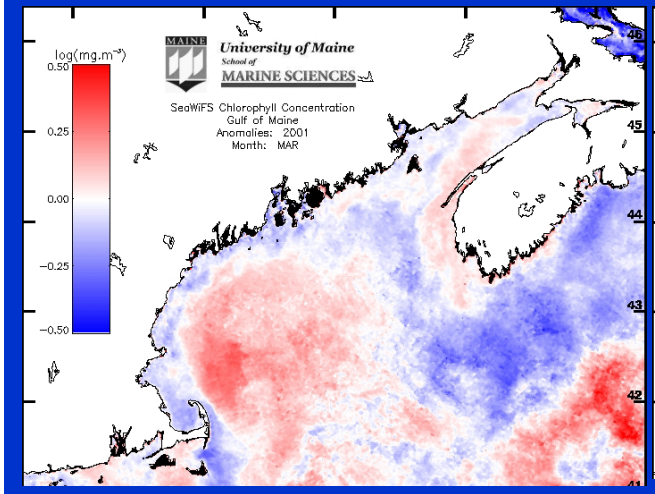


2006

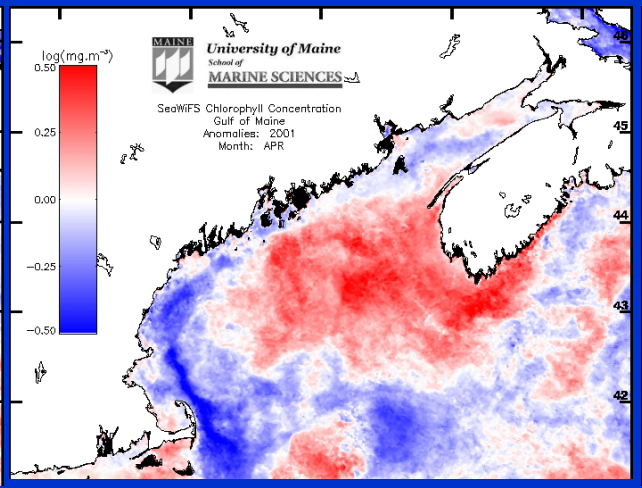
Chlorophyll Interannual Variability

Spring Bloom (April)

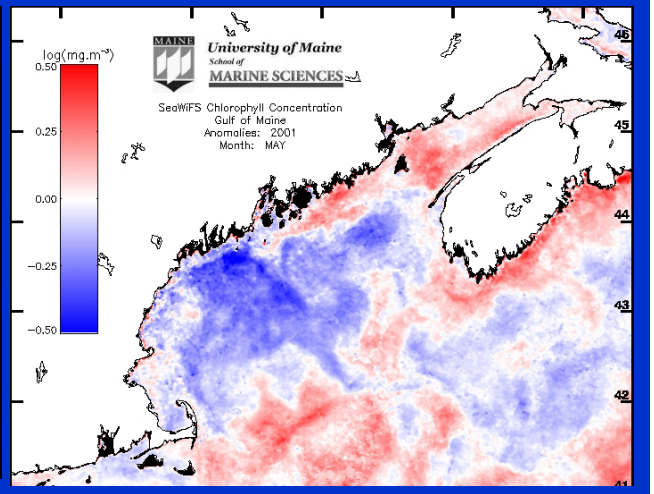
Anomalies (from 9 year mean): + RED, - Blue



March



April
2001



May

Point: temporal persistence of anomalies < month

Summary: **Oceanographic Remote Sensing Data**

Ocean ecosystem indicators [relationships to other ecosystem parameters]

Effective time series and anomalies

Messages so far:

- live within statistical accuracy ranges
- deal with data gaps due to clouds

improve both with statistics (make use of very large volumes of data)

- research area

  - limits “effective” minimum temporal resolution to ~ weekly

- interannual variability in the Gulf of Maine

  - seasonal cycle dominates BUT strong interannual variability
  - strong regionality [rarely the same anomaly (or sign) at one time]
  - anomalies temporally variable over monthly time scales

These images and more @ **www.seasurface.umaine.edu**

Thank You

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