CO_2 Flux Dynamics in the Gulf of Mexico

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Outline

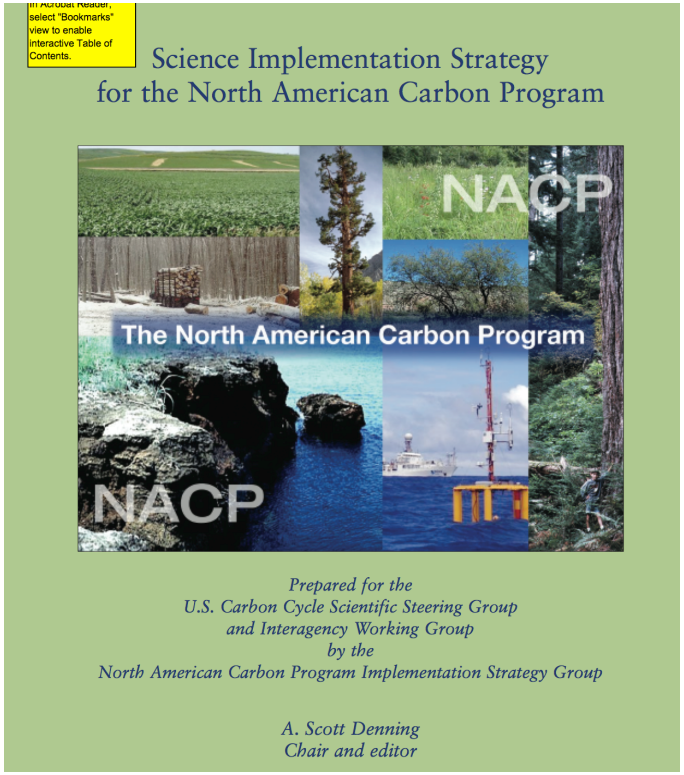
- Overall motivation
- Calculation of air-sea CO_2 flux
- Previous work
- Approach to create flux maps
- Remote sensing and modeling products
- Means of extrapolation/interpolation
  - *Determining ΔpCO_2 fields*
  - *Determining gas transfer velocities*
- Recommendations

North American Carbon Program Science Implementation Plan

1. "The ocean component will define the net effect of the marine system on the CO_2 concentration of the air exchanging with continental air masses."

2. "Critical for the NACP goals are the Tier 2 observations that, together with local time-series and satellite remote sensing, will be used to generate regional to basin scale CO_2 flux maps."

3. "Some studies have suggested that the "continental shelf pump" could be responsible for as much a 1 Pg C sink annually on a global basis. A coordinated large-scale coastal carbon exchange program is necessary to address the goals of the NACP. "



QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

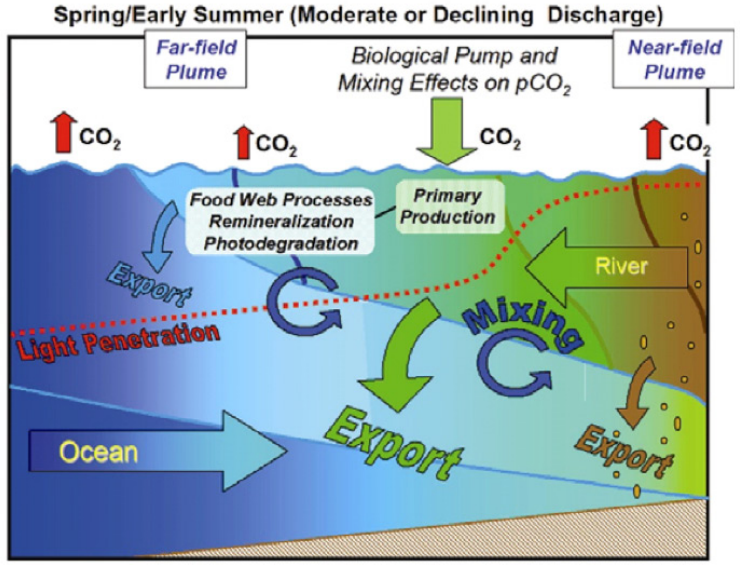
Gulf of Mexico- Objectives

Determine air-sea CO_2 fluxes in the GOM

(Global coastal flux estimates range from -1 to +0.2 Pg C/yr)

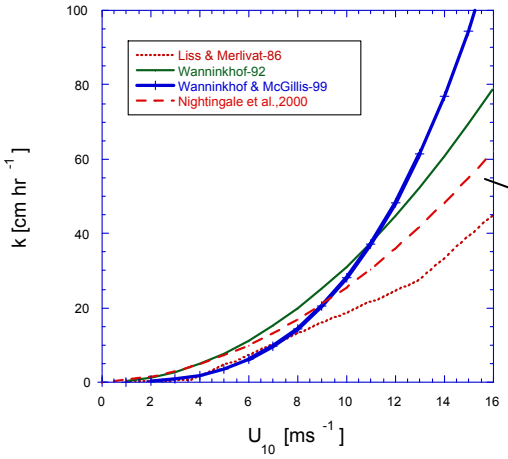
Elucidate the processes that control the pCO_2 levels

(Determine the large scale effects of continental/riverine input)



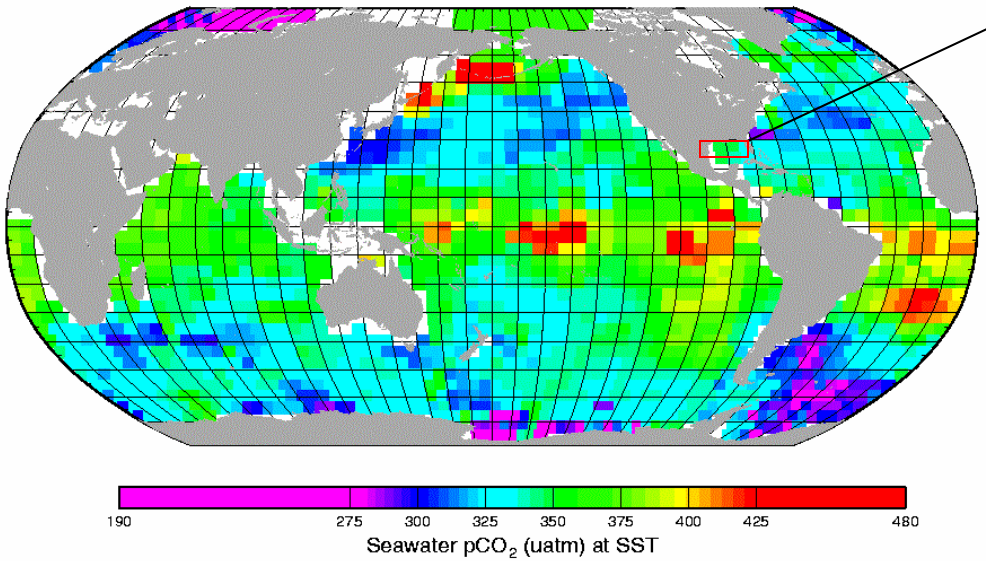
Lohrenz

Determination of Air-Sea CO_2 Fluxes in the Gulf of Mexico



$$F = (k\ s\ \Delta pCO_2)_{av}$$

(B) Climatological pCO_2 in Surface Water for February 1995

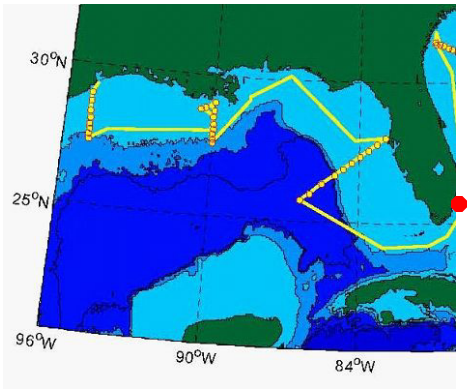


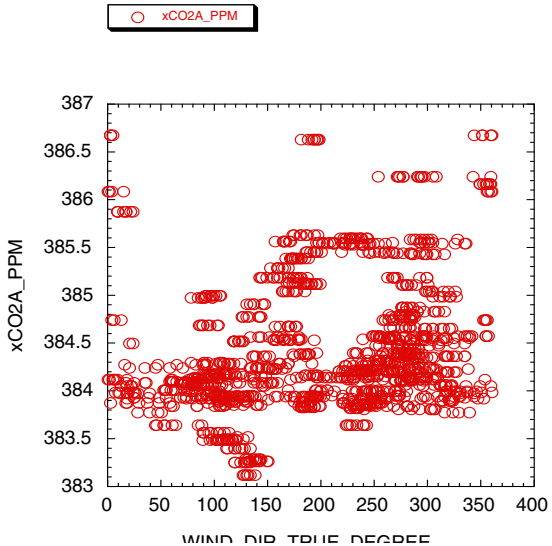
???? Pg C yr^{-1}

Measurement

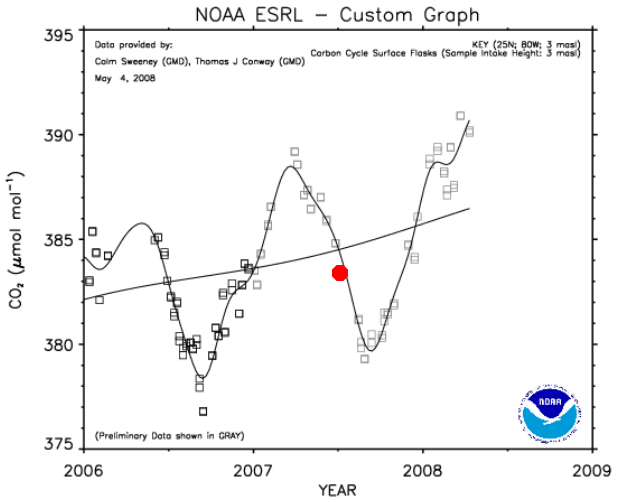
The net effect of the marine system on the CO_2 concentration of the air exchanging with continental air masses

GOMECC cruise July 2007





Direction	xCO_{2air}	sd	# point
0-90° (N-E)	384.3	0.6	20
90-180° (E-S)	384.2	0.6	50
180-270°(S-W)	384.5	0.7	52
270-360°(W-N)	384.6	0.7	48



XCO_2 higher than KEY station

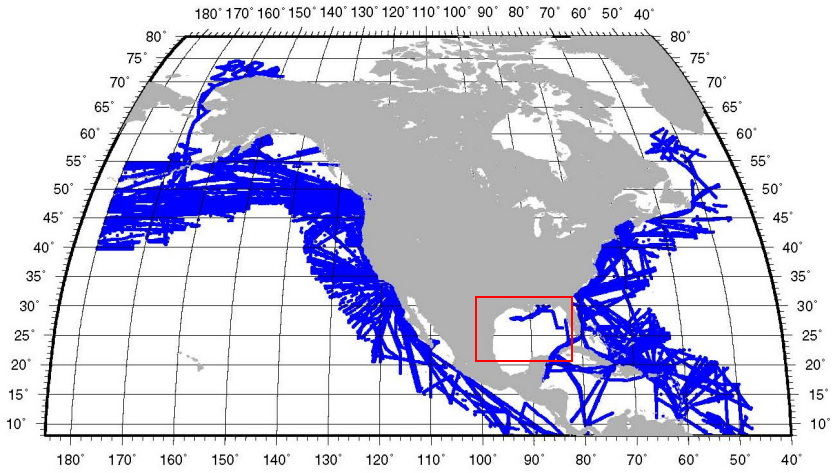
Subtle differences in XCO_2 with wind direction, if any

Need a dedicated effort/augmentation for air measurements

http://www.esrl.noaa.gov/gmd/

Estimates of Air-Sea CO_2 Fluxes in the Gulf of Mexico

Very little CO_2 data



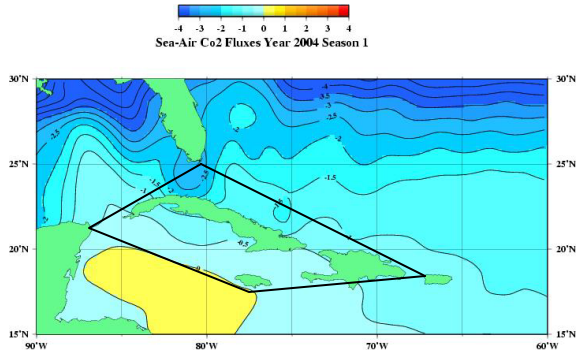
"Although observations are limited, it appears that these waters are a CO_2 source and the coastal waters have similar pCO_2 and SST as the offshore waters." *(Chavez, Takahashi, et al., 2007 SOCCR report)*

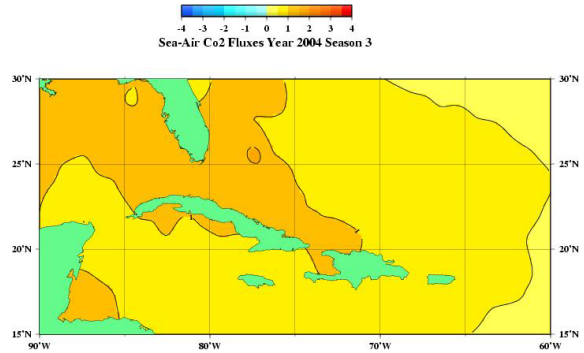
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Previous work

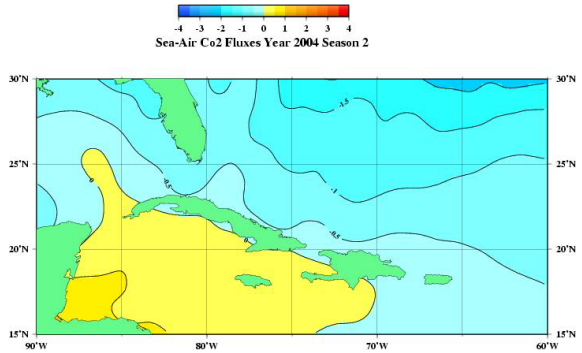
Regional Patterns of Seasonal Fluxes in the Caribbean

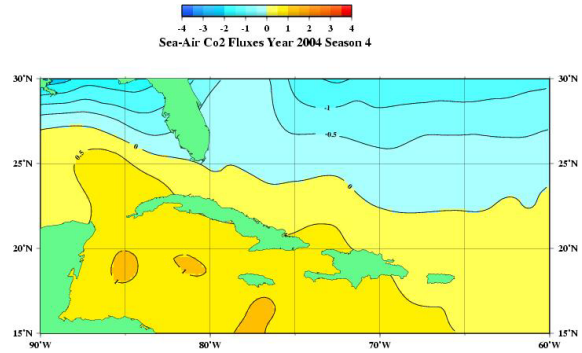
2004 Explorer of the Seas





$\Delta pCO_2 = f(SST, position)$





Based on algorithms on SST and data, at Southern edge of GOM,

the region is a CO_2 sink

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TIFF (LZW) decompressor
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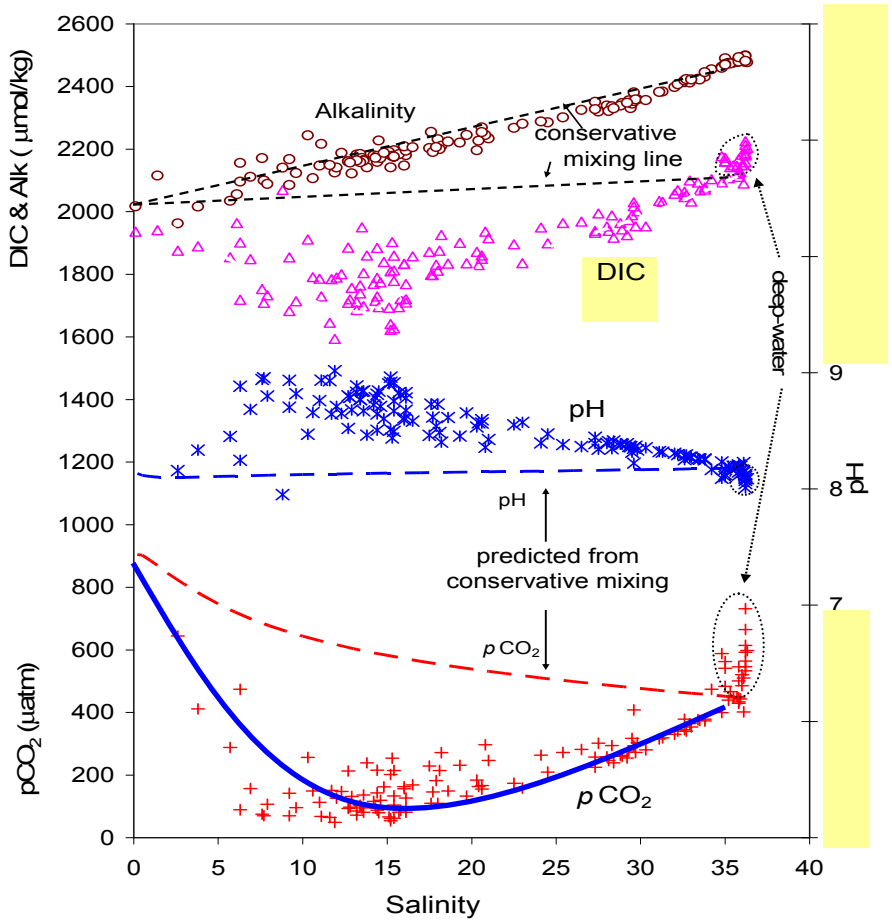
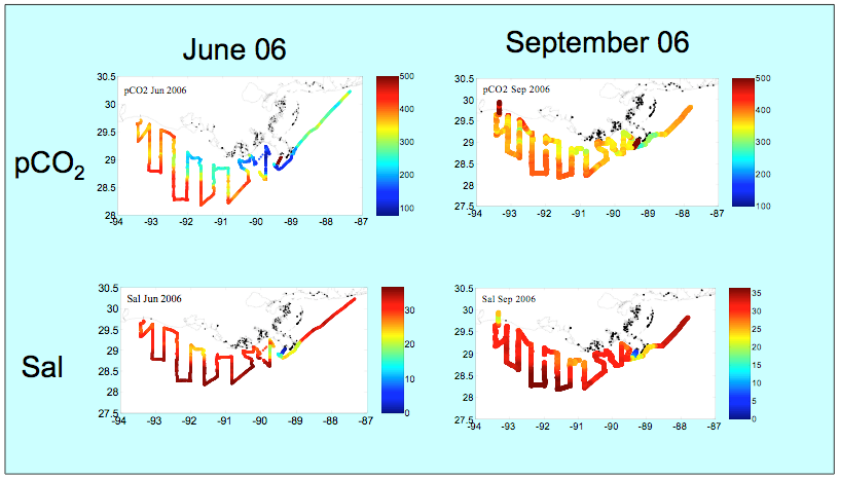
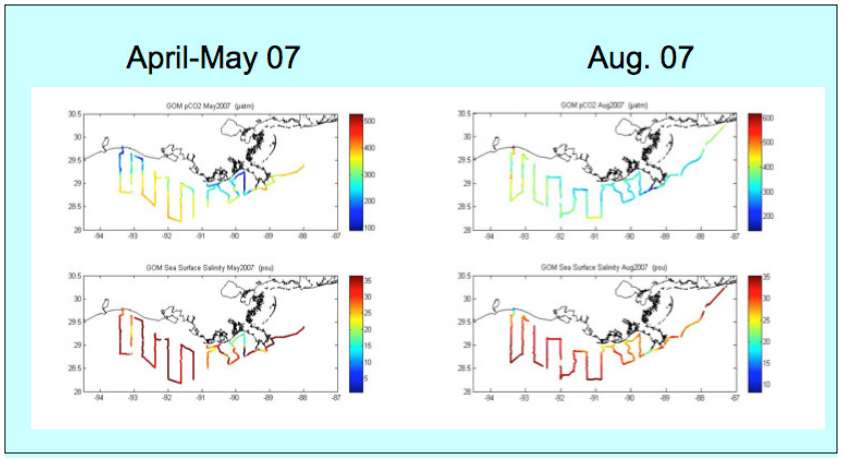
Previous Work

Riverine effects on pCO_2

High nutrient input causes pCO_2 drawdown







Cia and Lohrenz pers. com.

QuickTime™ and a
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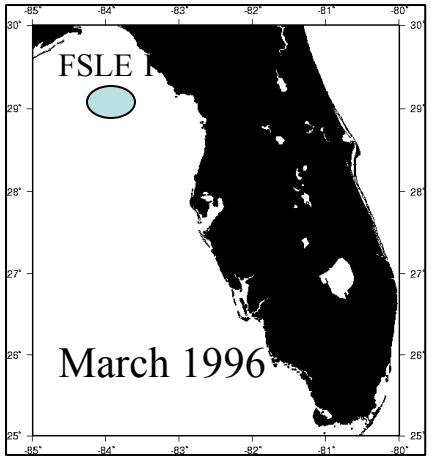
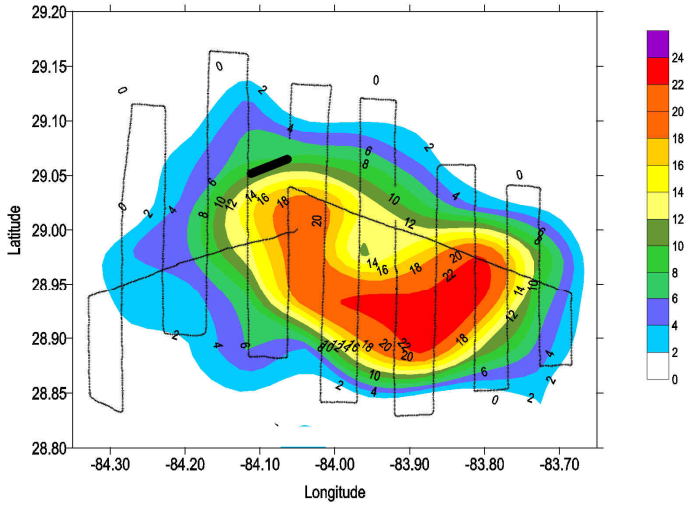
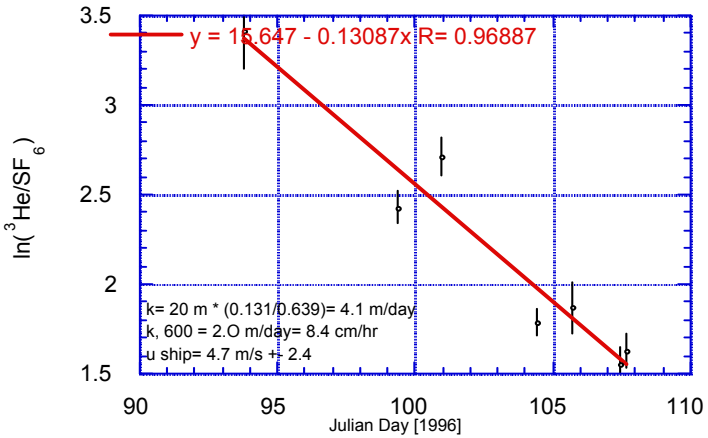
Previous Work

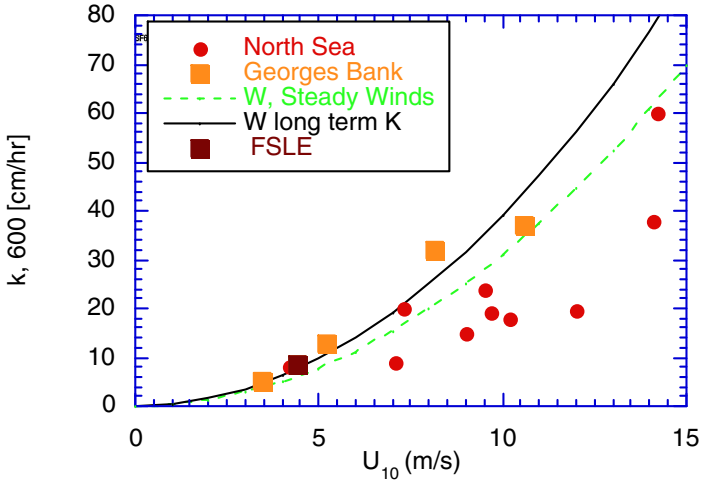
Gas Transfer Velocity Estimates

Gas transfer estimates is on the high side of the gas exchange-wind speed envelope









Wanninkhof et al. 2007

Previous Work

Creation of Flux Maps in the Gulf of Mexico

* Obtain data from ships and other platforms (moorings, small boats)
* Create regional algorithms with biogeochemical and physical parameters that are measured at higher frequency and with regional coverage
* Use high data coverage to create flux maps that captures spatial and temporal variability

(High frequency) products available:

Q-Scat Wind: for gas transfer

Reynolds SST: for pCO_{2w} (tied to ship SST)

Location: different biogeochemical provinces (SOM)

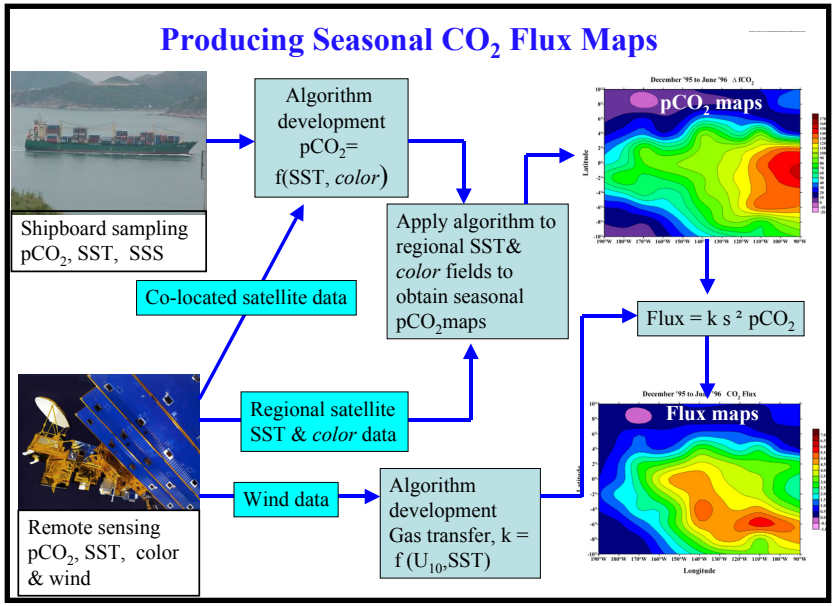
Chlorophyll: productivity

Mixed layer depth: entrainment

Salinity: delineation of provinces

Sea surface height: entrainment

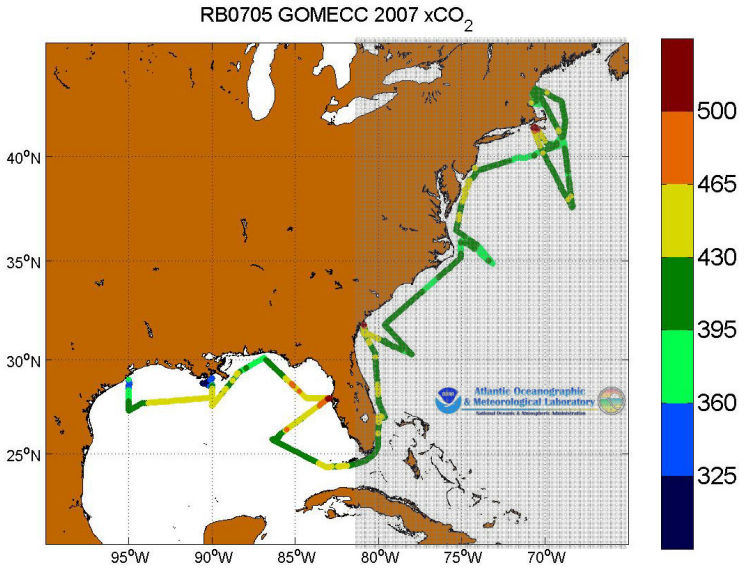
QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

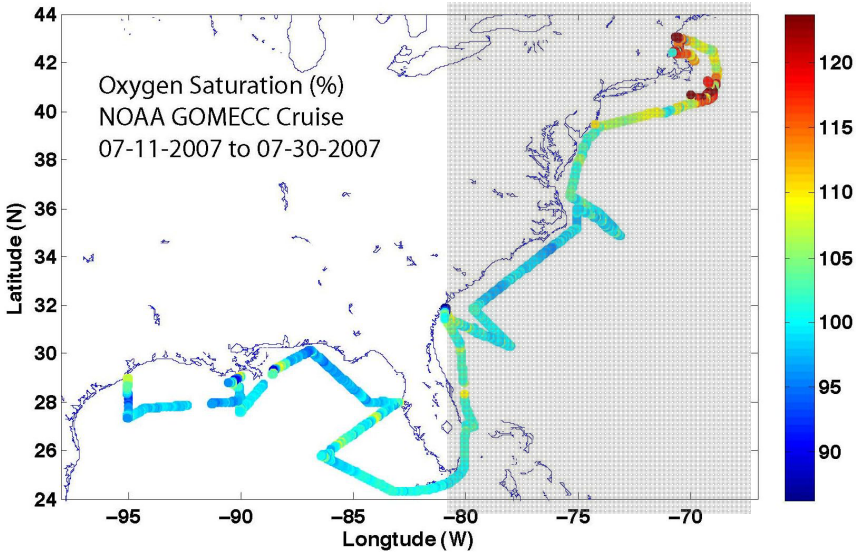


Approach

Determination of pCO_2 fields

1. pCO_2 data - GOMECC cruise- July 2007





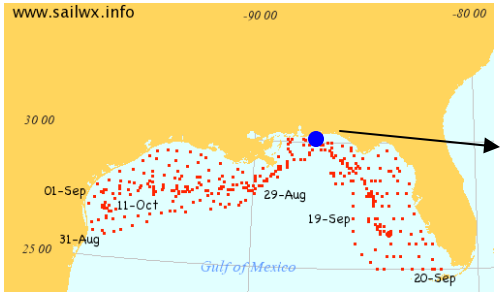
Langdon and Salisbury

Anti-correlation pCO_2 and O_2 supersaturation near the coast

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

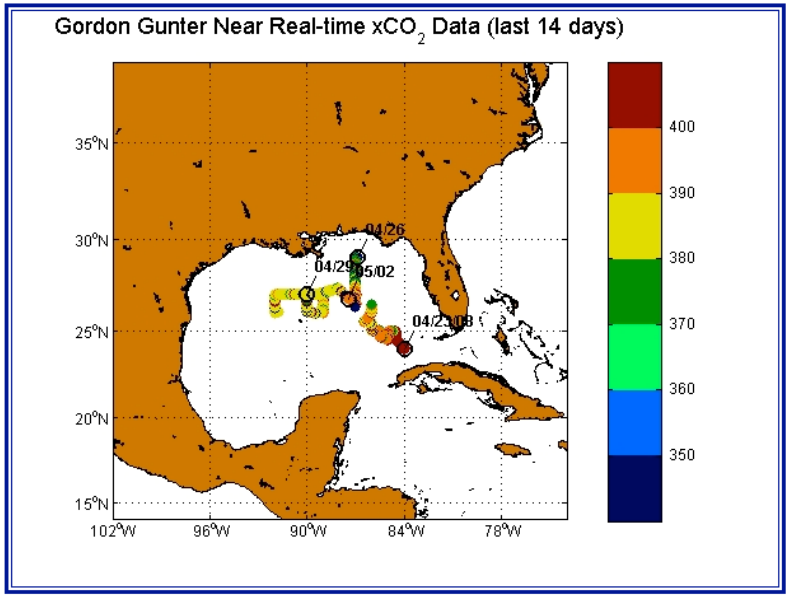
Determination of pCO_2 fields

2. Underway data NOAA fisheries ship *Gordon Gunter*



pCO_2 mooring
Sabine&Lohenz

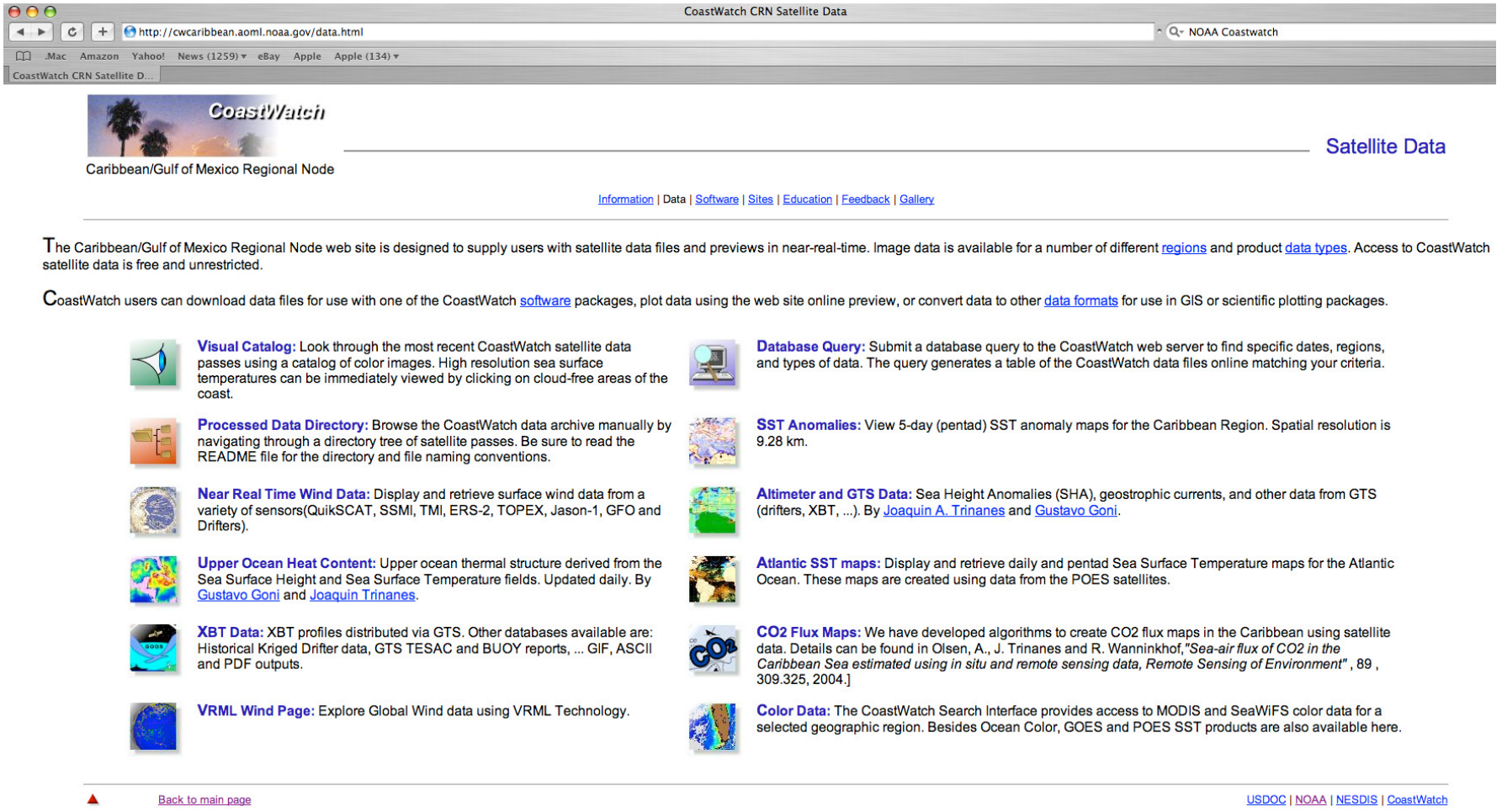
R/V Gordon Gunter cruise track showing color coded xCO2 data. This display is updated every morning.



6-week cruise track Sept-Oct 2007

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Remotely Sensed Data / Assimilation models



NOAA Coastwatch Caribbean/Gulf of Mexico Regional Node:
http://cwcaribbean.aoml.noaa.gov/data.html

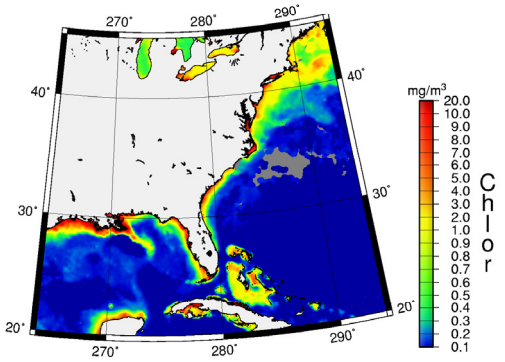
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Data products

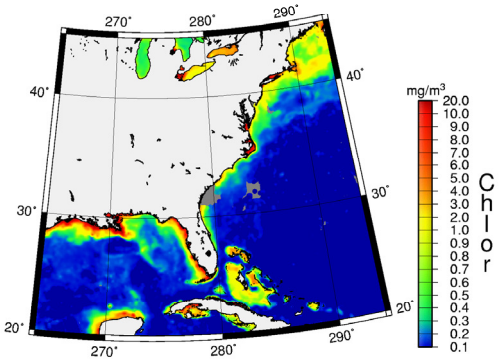
Remotely Sensed Data / Assimilation models

Color:

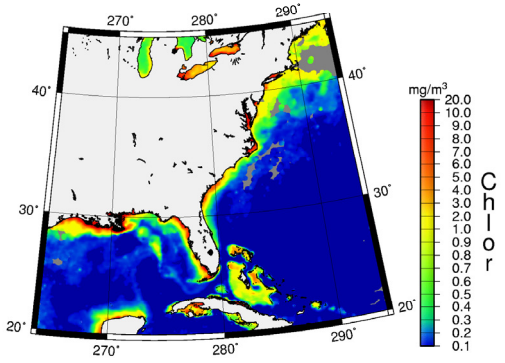
JD 190-194, 2007



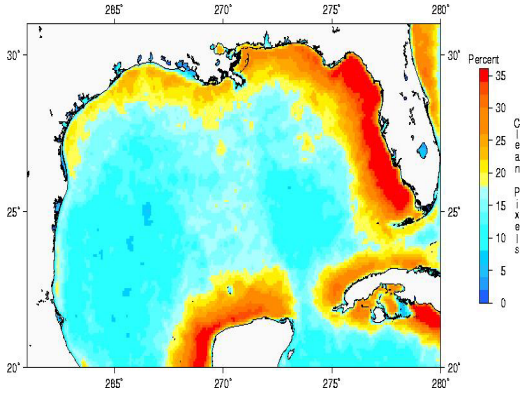
JD 215-219, 2007



JD 200-204, 2007



% clean pixels MODIS GOM

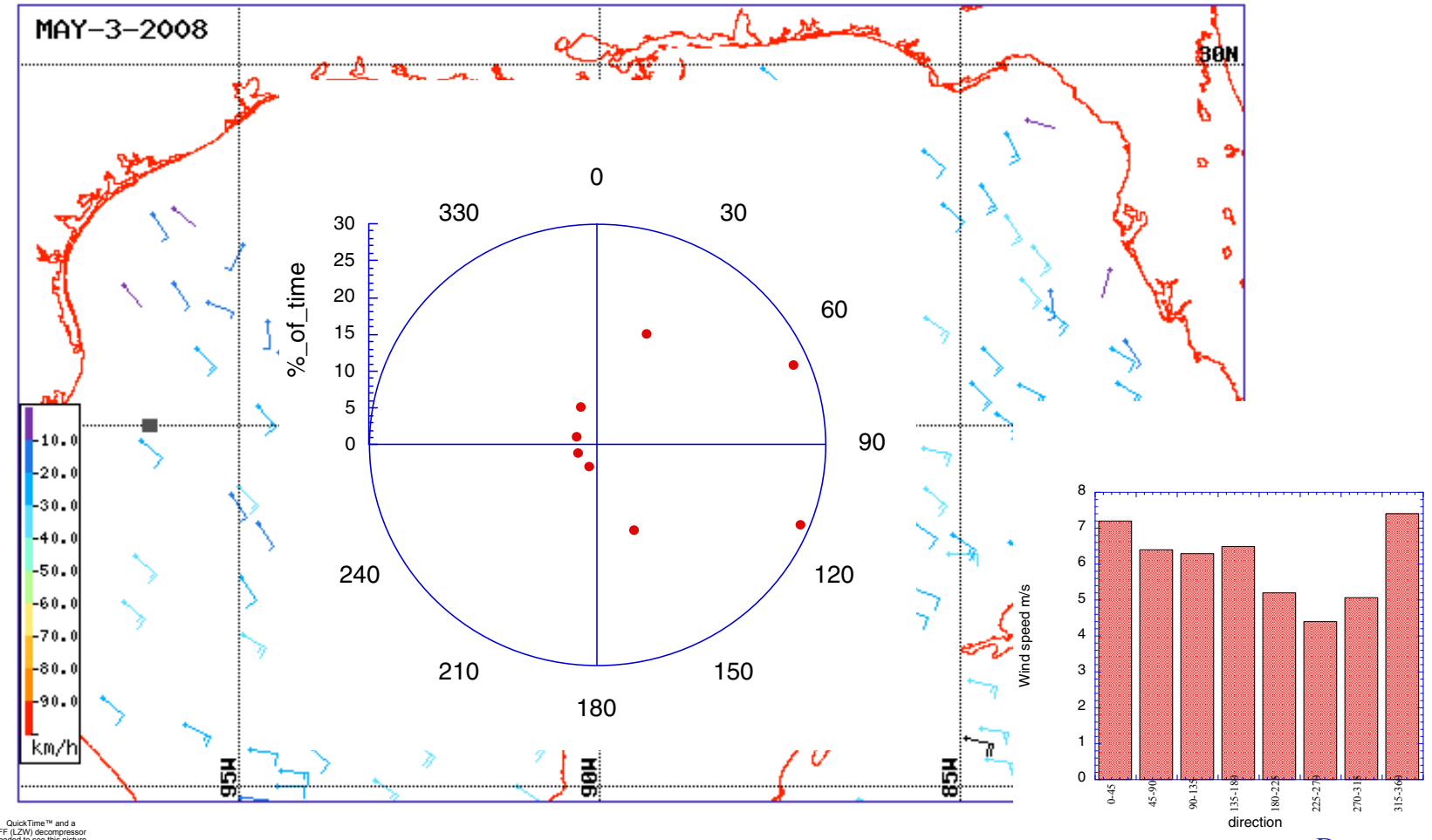


QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Data products

Wind:

QuickScat - 25 km resolution 2 passes/day



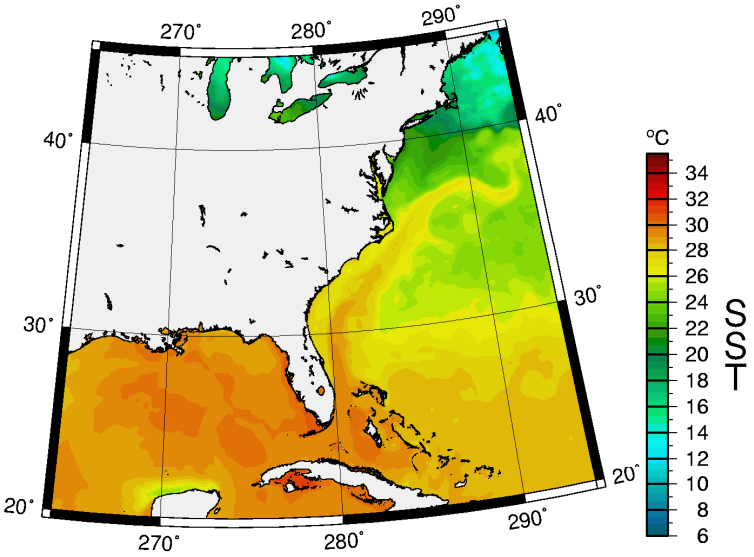
QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

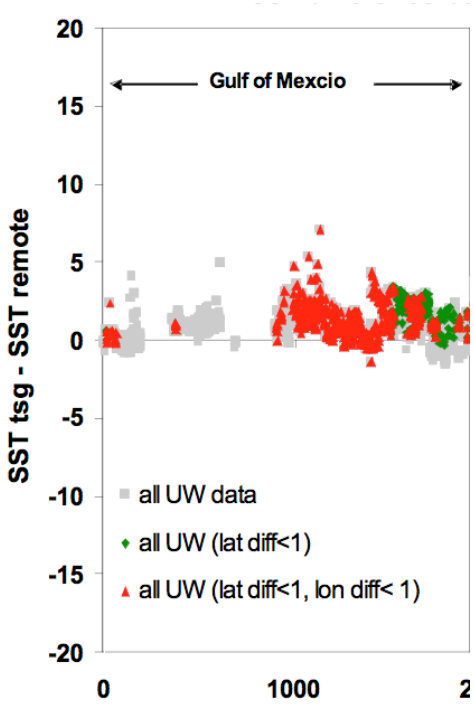
Data products

SST-

Issues: skin temperature, near surface gradients, haze

Causing a cold bias





QuickTime™ and a
TIFF (LZW) decompressor
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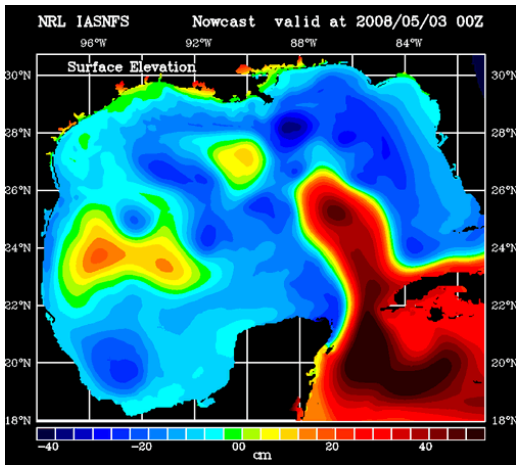
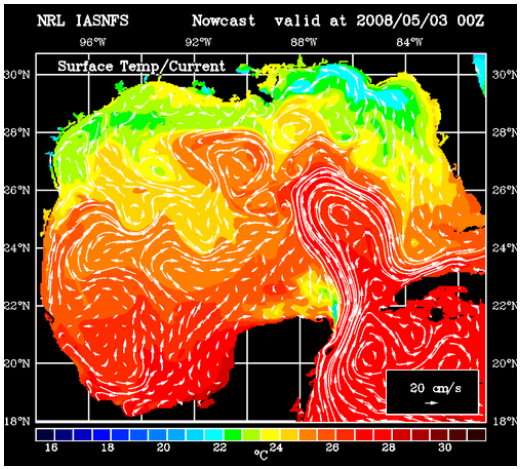
Data products

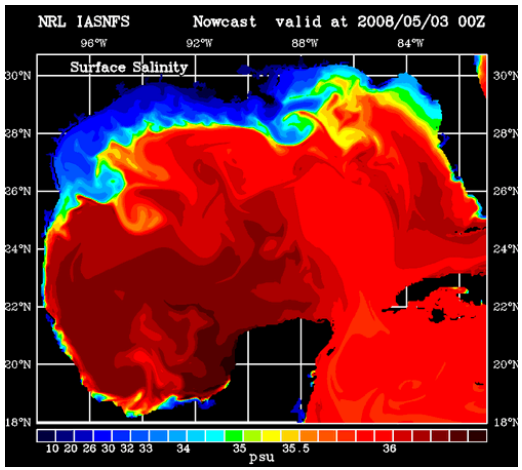
Data Assimilation models

IASNFS

Experimental Real-Time Intra-Americas Sea Ocean Nowcast/Forecast System







http://www7320.nrlssc.navy.mil/IASNFS_WWW/IASNFS_intro.html

A potential powerful tool for regional interpolation/extrapolation

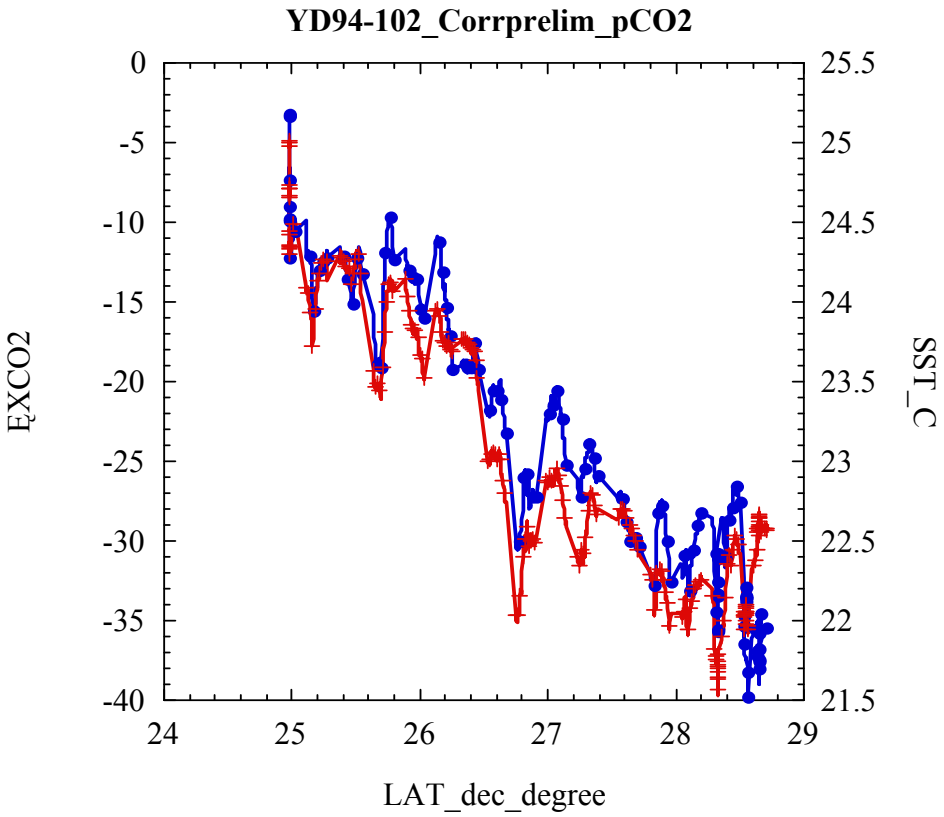
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

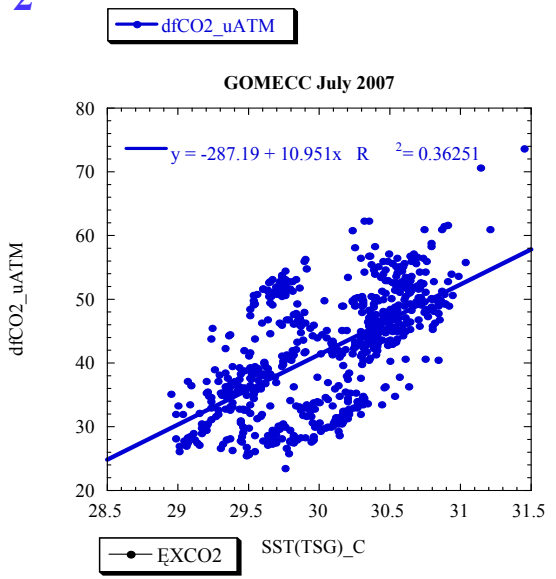
Data products

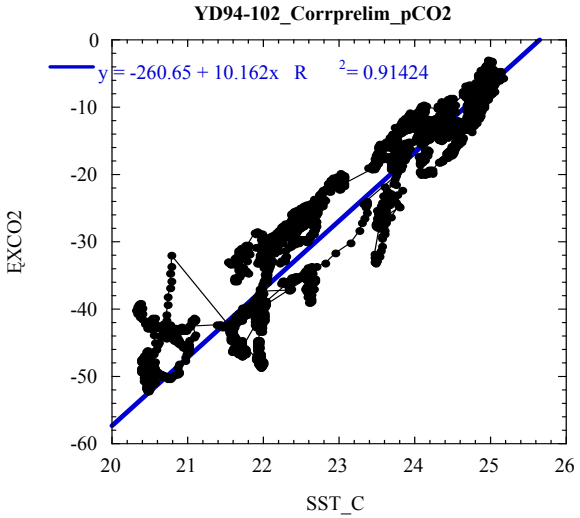
Algorithms for pCO_2

For > 80 % of GOM pCO_2 is strongly correlated with SST

Gordon Gunter 2008







QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

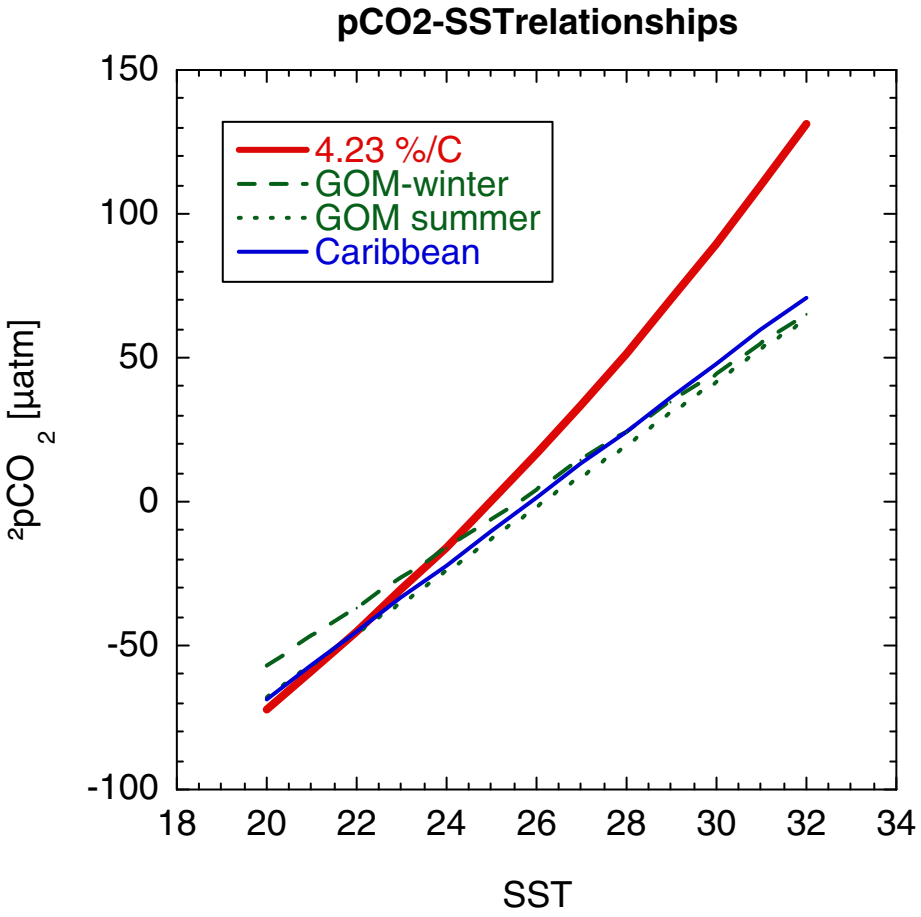
Interpolation

Algorithms for pCO_2

Similar relationship as for Caribbean Sea 2003-2005:

$\Delta fCO_2 = 11.63\ SST + 0.77\ Lat - 0.42\ Long - 361$

$\Delta fCO_2 = 11.63\ SST - 301$



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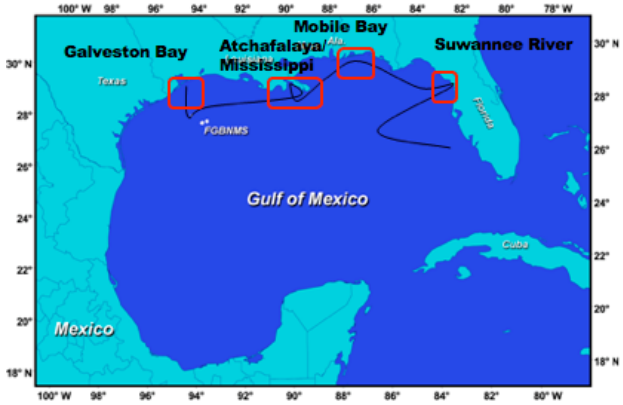
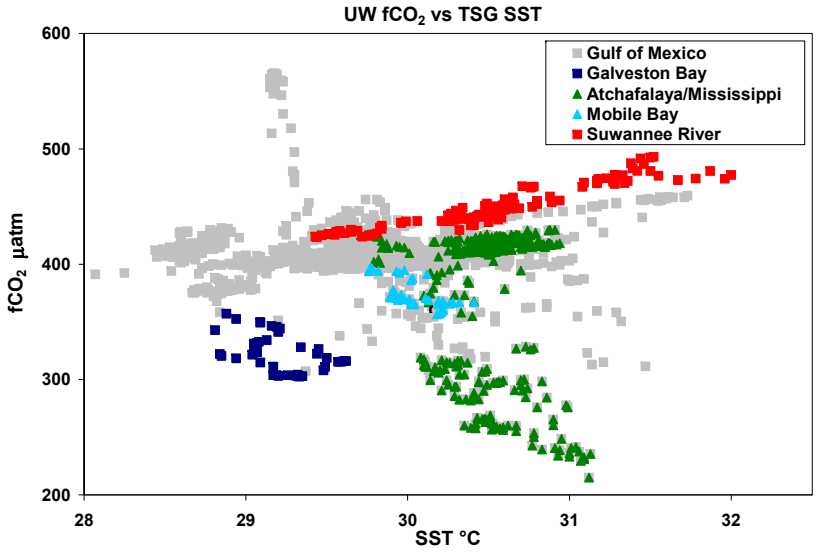
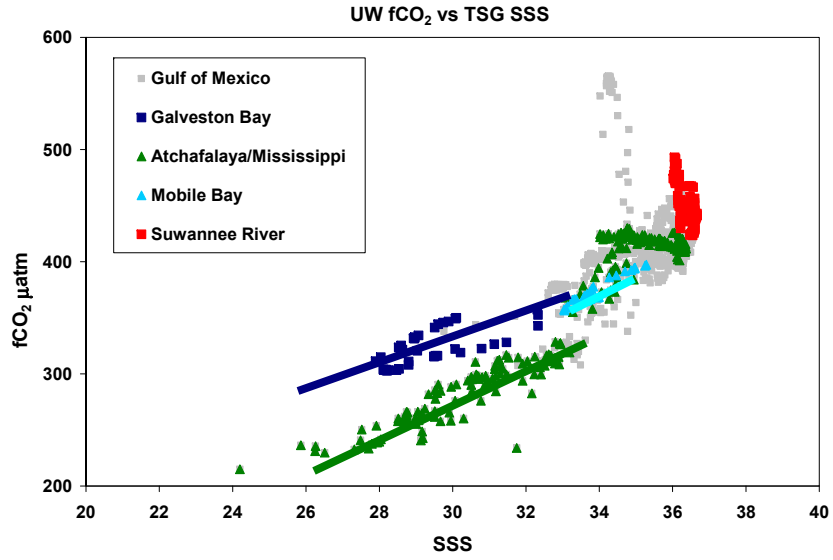
Interpolation

Algorithms for pCO_2

Now for the remaining 20 % ????







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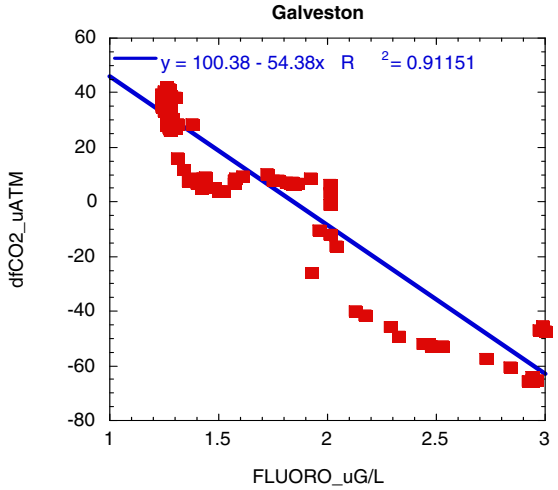
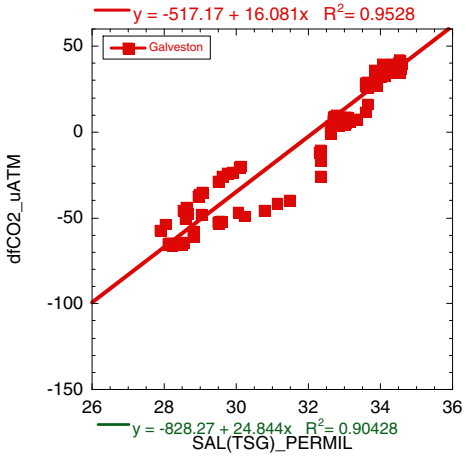
TIFF (LZW) decompressor
are needed to see this picture.

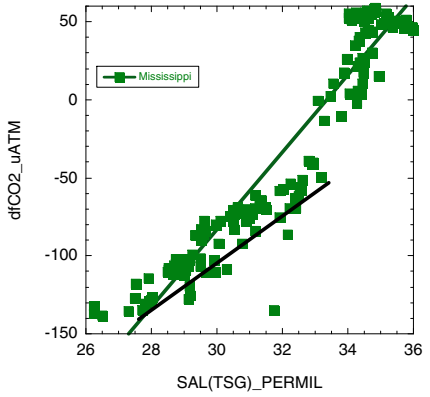
Interpolation

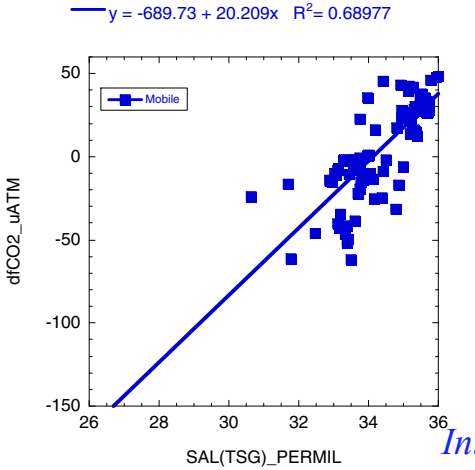
Algorithms for pCO_2

"Near-shore": GOMECC
Correlations with salinity and color









See: Joe Salisbury, UNH
Steve Lohrenz, USM

QuickTime™ and a
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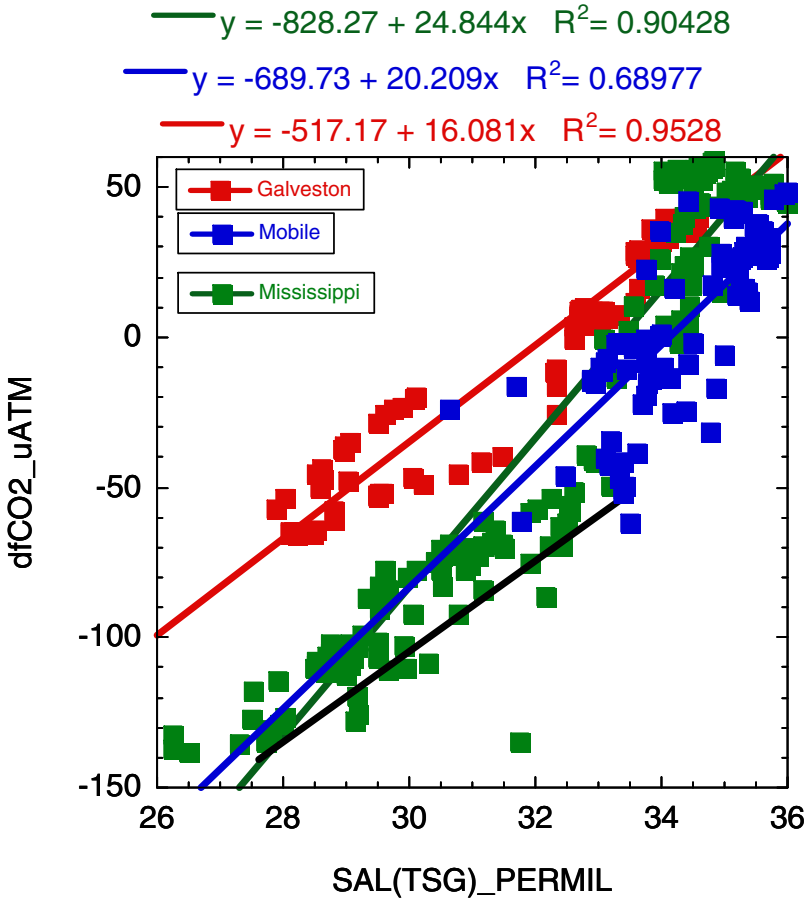
Interpolation

Algorithms for pCO_2



QuickTime™ and a
TIFF (LZW) decompressor
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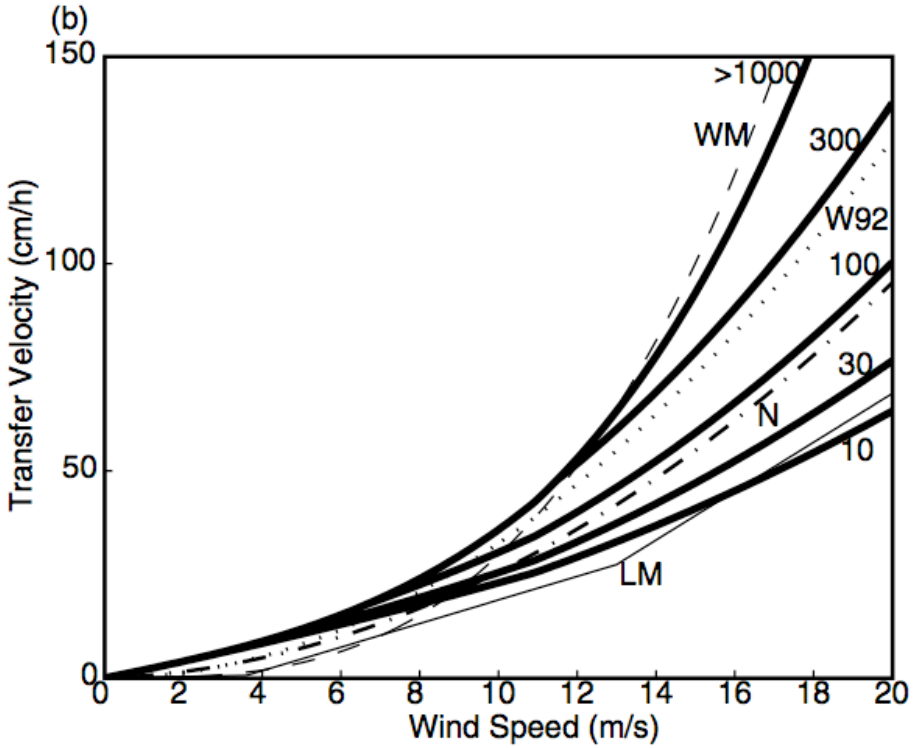
Interpolation

Gas Transfer Velocities

GOM- Fetch, low winds, chemical enhancement, surfactants?



Woolf, Tellus 2005

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

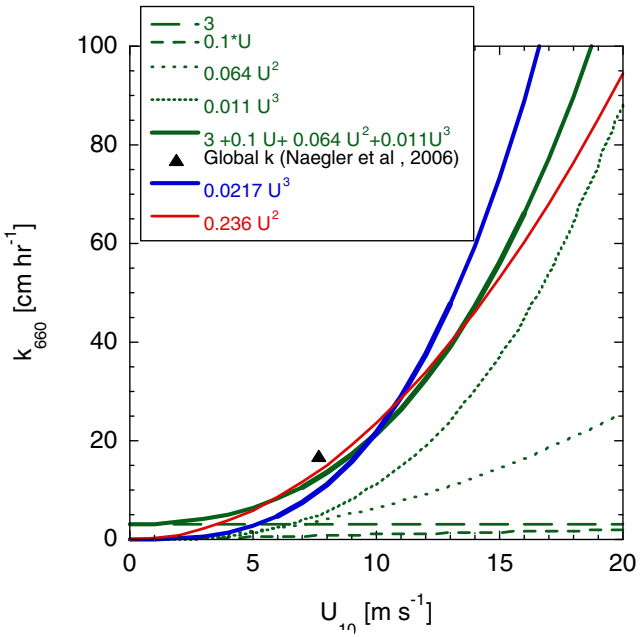
Gas Transfer Velocities

An inclusive parameterization of gas exchange with wind

Wanninkhof, Asher, Sweeney, Ho, McGillis, Annual reviews, submitted

$k = a + b\,U + C\,U^2 + d\,U^3$

Constant:	Chem enhancement, non-wind induced turbulence
Linear:	Transfer across solid boundary
Quadratic:	Wind stress
Cubic:	Dissipation, bubbles



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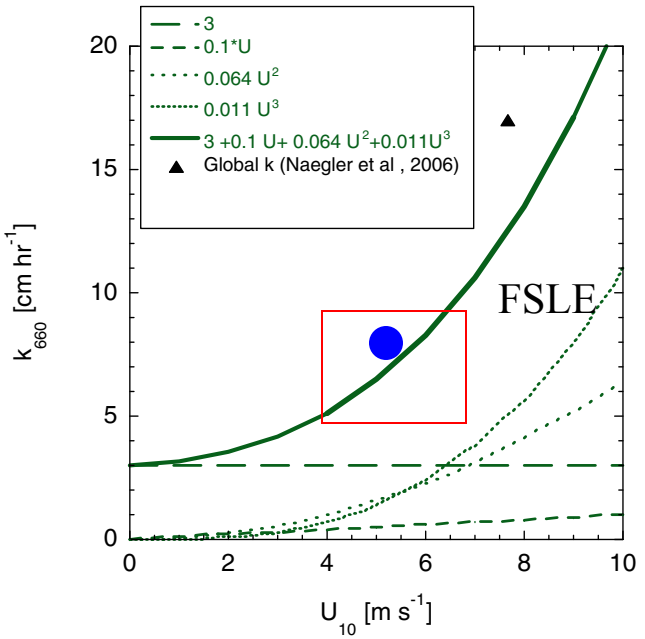

k vs u

Recommendations

To constrain air-sea fluxes in GOM and its effect on North America:

- Provide support for surface water pCO_2 observing system (ship and mooring)
- Develop robust algorithms in regions affected by riverine input (Use color!)
- Perform process study for direct measurement CO_2 fluxes (year-long study on platform)
- Establish robust air sampling program