Winds Climate Continuity and CO_2 Surface Flux Mission

Ernesto Rodriguez
QuikSCAT Project Scientist
Jet Propulsion Laboratory
California Institute of Technology

Background

- After 10 years of operation, the QuikSCAT antenna stopped spinning in November, 2009
- The next US scatterometer, the Dual Frequency Scatterometer (DFS) (Decadal Review mission to NOAA), will not launch until 2017, at the earliest
- To mitigate the climate data record gap, NASA HQ tasked JPL to investigate the possibility of a low-cost QuikSCAT gap filler
  - Free flyer too expensive due to launch vehicle+bus costs
  - ISS deployment using existing flight parts mitigates cost concerns
- **Direction from M. Freilich**: find strong **science** rationale that fits within NASA goals. This is not an operational concept that meets NOAA needs.

Science Working Group

- M. Bourassa (FSU)
- P. Chang (NOAA)
- D. Long (BYU)
- L. Jones (FCU)
- E. Rodriguez (JPL)
- F. Wentz (RSS)
- Z. Jelenak (NOAA)
- We are looking at others to join us…

Payload Concept

- Use spare flight parts integrated into a novel instrument
  - Ku-band hardware from QuikSCAT
  - C-band hardware from SRTM
- Avoid antenna rotation to minimize cost
- Preliminary accommodation studies show that design fits comfortably in ISS JEM instrument module
- NASA JSC review of concept for accommodation and safety
- Instrument capabilities:
  - Dual frequency radar measurements
  - Wind estimation in a limited (~300 km swath) swath at ~47deg boresight with resolution <25 km
  - Ability to measure at incidence angles of other (EUMETSAT, ISRO, China) existing or projected scats

Mission Objectives

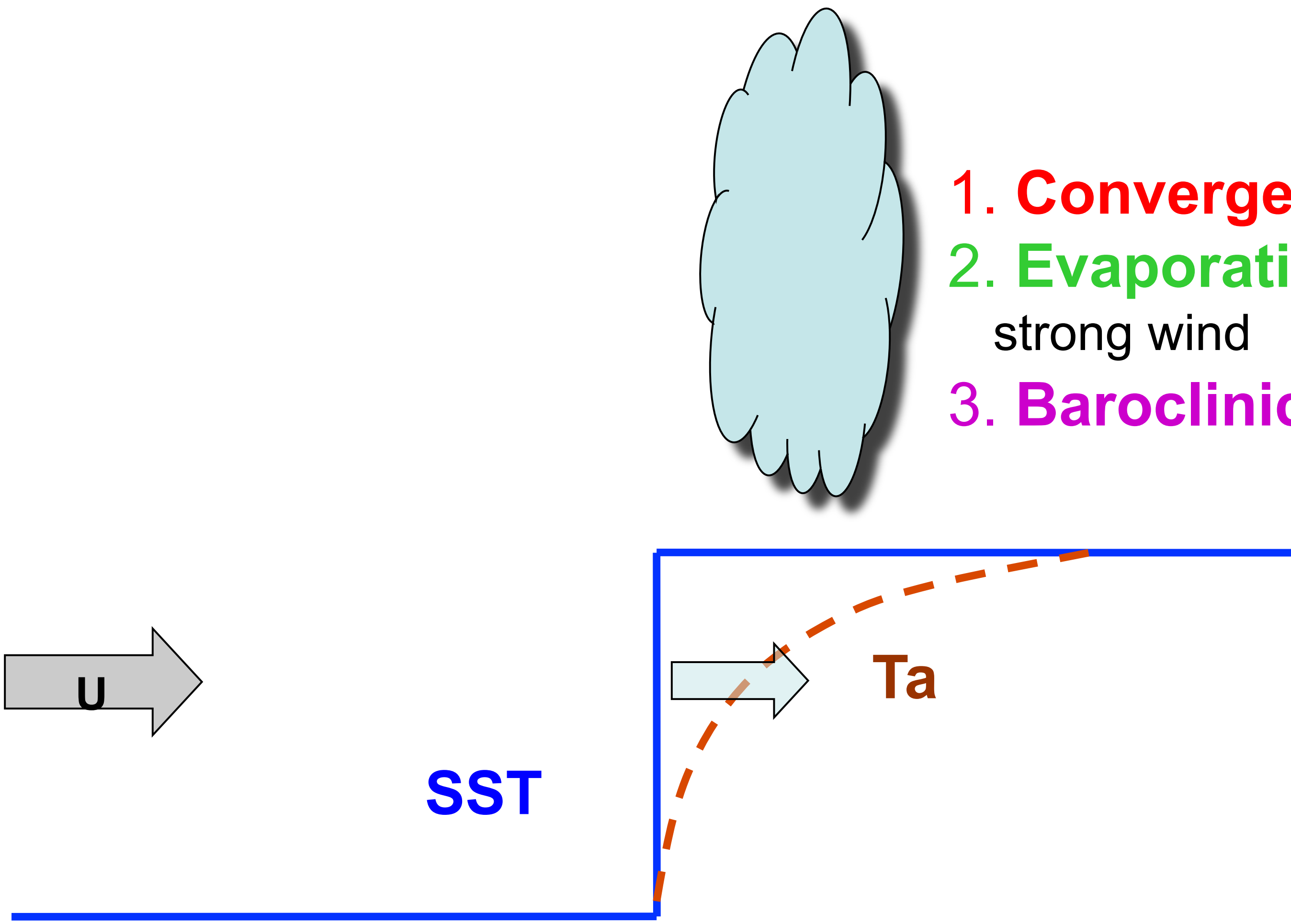
1. Provide cross-calibration of multiple radar scatterometer missions to insure the continuity and improve the quality of the ocean vector winds climate data set.
2. Provide a proof of concept demonstration of the ability to measure global CO_2 ocean/atmosphere vertical fluxes from space.
3. Provide data for DFS risk reduction and validation

Ocean Vector Winds Climate Data Record

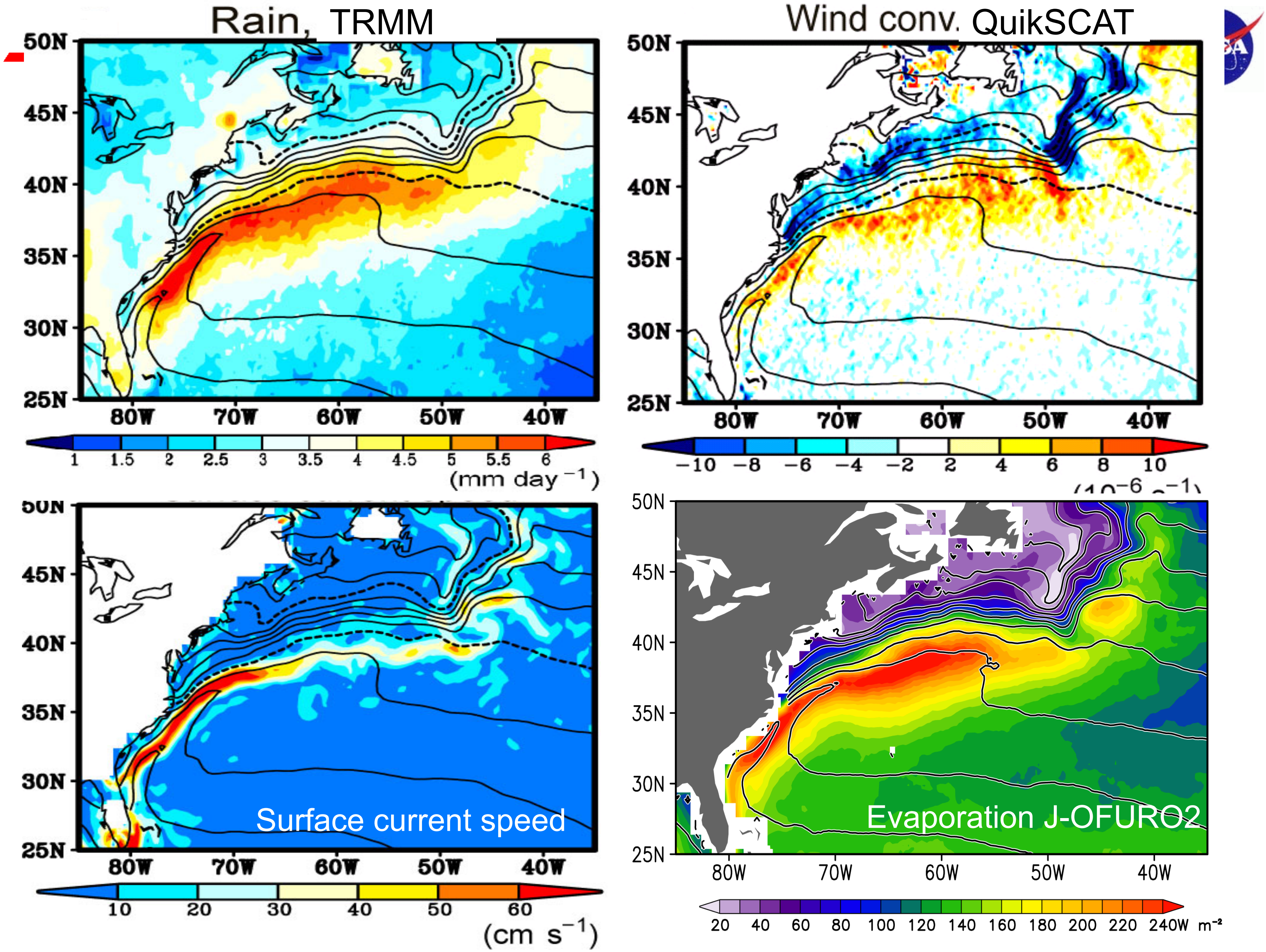
- Ocean vector winds and wind stress are an essential data record for understanding global climate change:
  - Wind stress drives ocean circulation, the primary means of global heat transport and storage
  - Winds are key determinants for fluxes between the ocean and atmosphere
    - Gas fluxes (CO_2 and other green house gases)
    - Latent heat transport (evaporation)
    - Momentum and energy fluxes
- The flux of CO_2 into the ocean and its trend over time are key unknowns in global warming models
- Climate data record consistency over multiple decades and instruments
- Scatt superior for measuring long term trends in winds since it is more stable- self calibrating

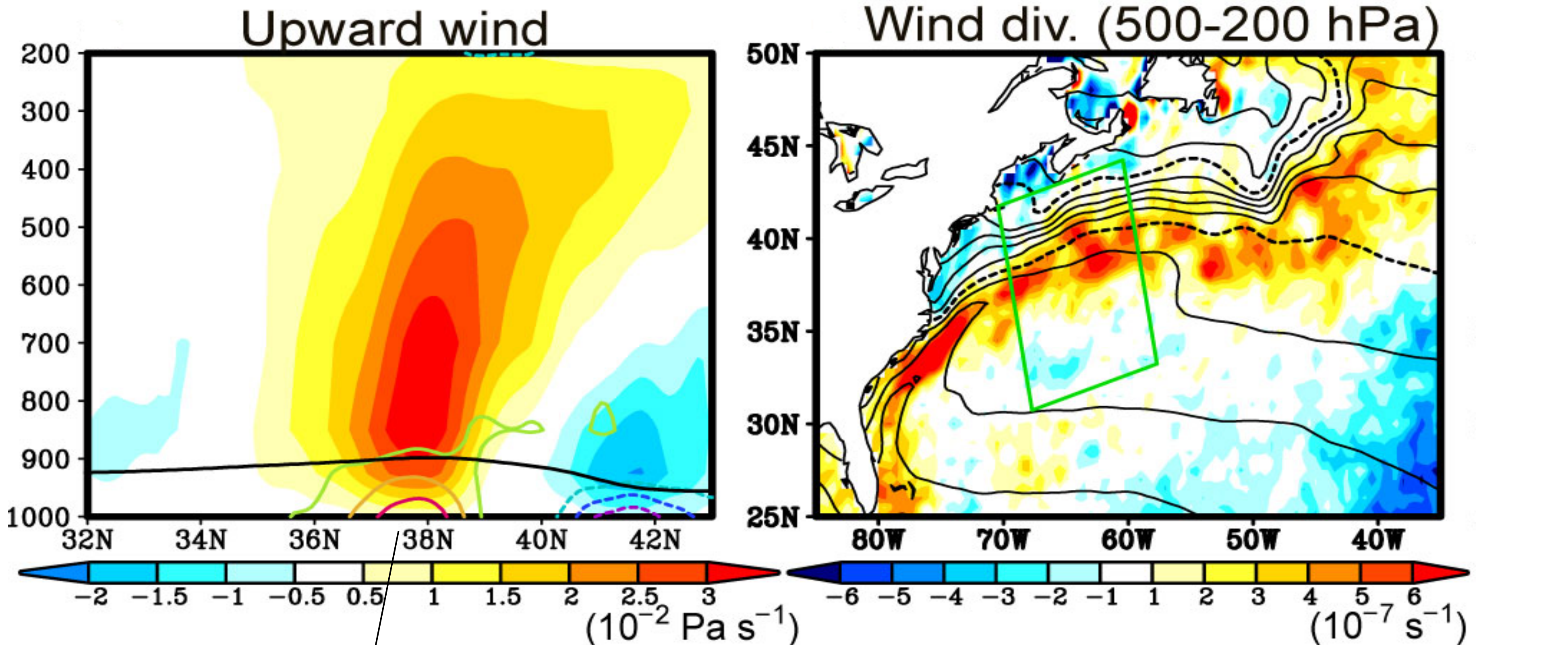
Issues in Extending the OVW Climate Data Record

- QuikSCAT (1999-2009) started the OVW climate data record
- Multiple scatterometers are, or will be, available that have the potential for extending the OVW CDR
  - ASCAT (EUMETSAT), OSCAT (ISRO), HY-2 & CFOSCAT (China), DFS (NOAA)
- These scatterometers are in sun-synchronous polar orbits that preclude significant coincident data overlap
- Each scatterometer estimates winds using a model function tuned to the instrument (and which may hide instrument biases)
- Experience with QuikSCAT and ASCAT shows that significant differences related to sampling at different times of day or problems in cross-calibration may present a significant problem for establishing a consistent global OVW climatology
- Traditional calibration targets (e.g., the Amazon) are known to exhibit significant diurnal and secular variability
- Retrospective analysis



1. **Convergence**
2. **Evaporation**: large (Ts-Ta) & strong wind
3. **Baroclinicity**

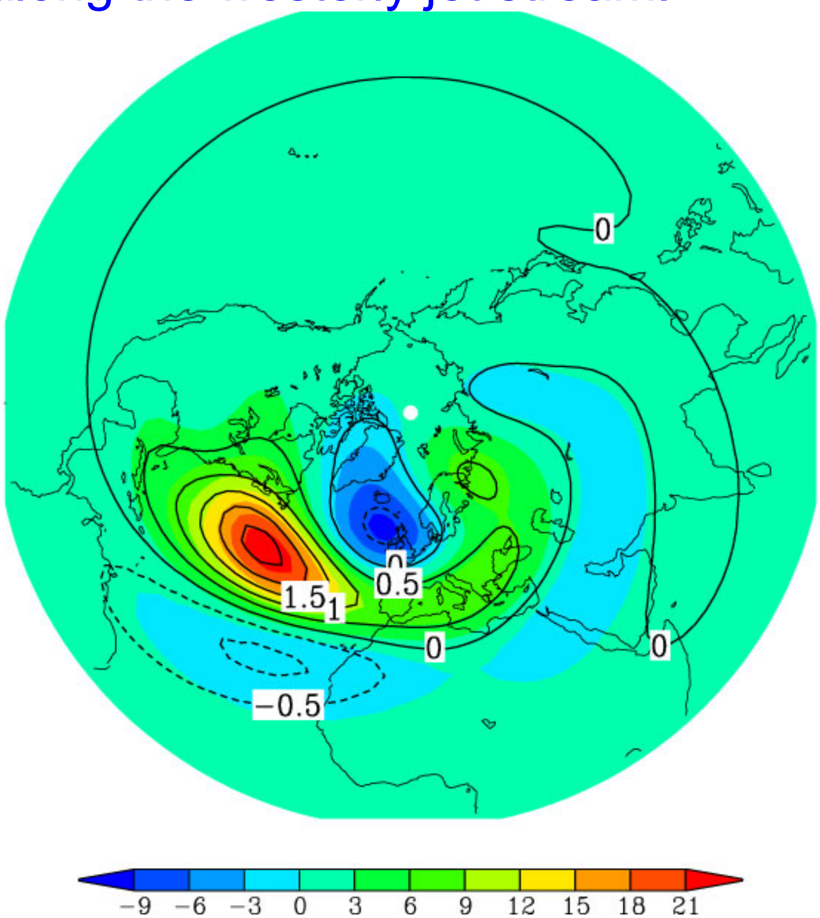

Rain, TRMM
50N 45N 40N 35N 30N 25N
80W 70W 60W 50W 40W
1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6
(mm day^{-1})
Wind conv. QuikSCAT
50N 45N 40N 35N 30N 25N
80W 70W 60W 50W 40W
−10 −8 −6 −4 −2 2 4 6 8 10
Surface current speed
50N 45N 40N 35N 30N 25N
80W 70W 60W 50W 40W
10 20 30 40 50 60
(cm s^{-1})
Evaporation J-OFURO2
50N 45N 40N 35N 30N 25N
80W 70W 60W 50W 40W
20 40 60 80 100 120 140 160 180 200 220 240 W m^{-2}



Colored contour: wind convergence.
Black contour: boundary layer height.

Minobe, S., A. Kuwano-Yoshida, N. Komori, S.-P. Xie, and R.J. Small, 2008: Influence of the Gulf Stream on the troposphere. *Nature*, **452**, 206-209.

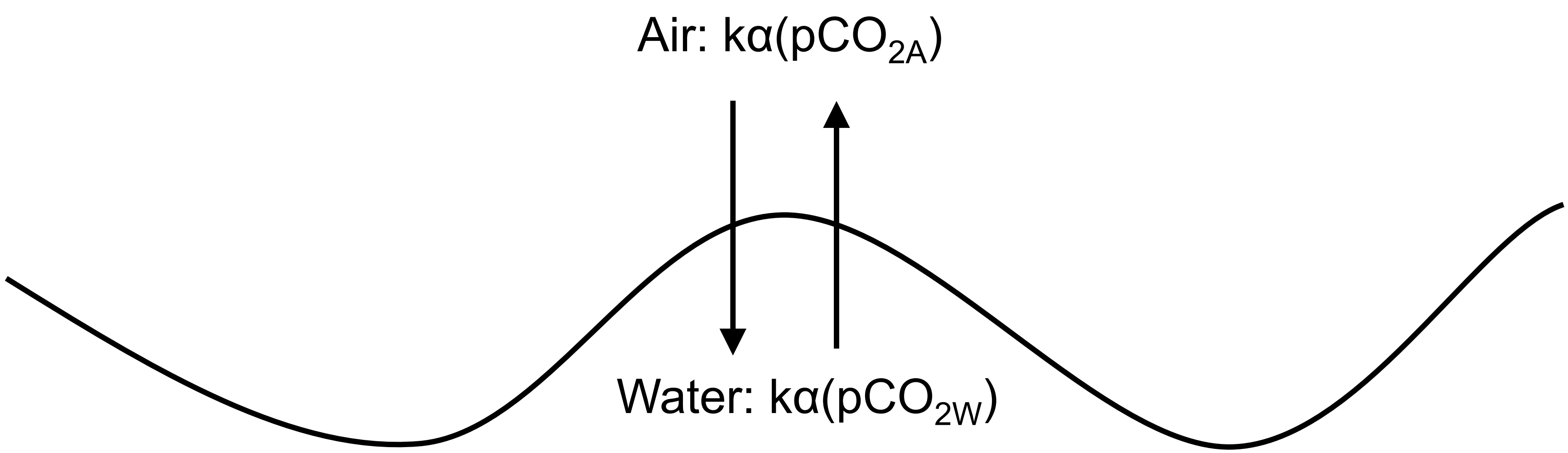
Gulf Stream-induced upward motion penetrates into the upper troposphere, forcing planetary waves that propagate along the westerly jet stream.



Upper tropospheric response to Gulf-Stream heating: Geopotential height at 250 hPa

Minobe, S., A. Kuwano-Yoshida, N. Komori, S.-P. Xie, and R.J. Small, 2008: Influence of the Gulf Stream on the troposphere. *Nature*, **452**, 206-209.

Gas Vertical Flux Estimation



Net air-sea flux: $F = k\alpha\Delta(pCO_2)$

Transfer velocity: k = F(**wind**, bubbles, surfactants, wave slope)

CO_2 Vertical Flux Measurements

- The rate and regional distribution of absorption of CO_2 by the ocean is the key uncertainty in predicting future atmospheric CO_2 concentrations and global warming
- CO_2 flux variability is dominated by temporal variability atmospheric variables: pCO_{2A} and wind stress. Ocean variability is much slower and depends on factors that can be monitored by other means (e.g., SST).
- In order to estimate instantaneous fluxes, it is required that pCO_{2A} and wind stress be measured simultaneously
  – OCO measurements are insufficient since there is no coincident wind measurement and wind temporal and spatial variability is not properly captured by models
  – Surface pCO2 vs integrated CO2 from OCO

CO_2 Flux Measurement Concept

- Need to monitor seasonal variability and do not want to be biased by the diurnal cycle
  - Implies non-sun synchronous orbit
- Wind stress measurements require a Ku or C scatterometer with sufficient azimuth variability to enable wind estimation
  - Dual frequency useful for mitigating rain contamination and improving stress accuracy
- pCO_2 measurements to be met with a pulsed lidar system
- Swath requirement: large enough to get seasonal global coverage in a non-repeat orbit (e.g., ISS orbit) (~100km - 300km)
- Orbit inclination: desire full ocean coverage. ISS orbit sufficient for sampling key regions, but misses Southern Ocean. The initial instrument would be a proof of concept instrument.
- Spatial resolution: <25 km
- Minimum mission duration: 1 year to capture the seasonal cycle. Desire 5-10 years to capture climate trends.