GCOM-W2 Water & Winds Mission

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With a lot of input from:
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And additional input from:

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Outline

- Instrumentation (short version)
  - A scatterometer by itself in not likely to be funded
  - Success depends on exciting science goals
- International Partners
- Paths to funding US component
- Science Objectives

Instruments to Meet Science

- An AMSR class radiometer with additional high frequency channels for cloud ice (AMSR3)
- Pencil beam scatterometers
  - Ku-band (10km nominal resolution)
  - Doppler Ka-band (5km nominal resolution for winds)
    - Ocean current measurements
      - Spatial resolution: <25 km
      - Temporal resolution: <10 days
      - Vector velocity accuracy: 5 cm/s – 10 cm/s
- Key innovations:
  - High resolution winds for coastal applications and calculation of small scale (3x scatterometer spacing) divergence and curl
  - Surface currents
- Many science application benefit by co-flying active/passive combination

Ongoing Studies

- JAXA, ISRO, and JPL have signed a letter of cooperation to jointly study the feasibility of a joint microwave radiometer/scatterometer mission
- Preliminary discussions have resulted in a nominal configuration including AMSR3, Ku scatterometer, Ka Doppler scatterometer
- A joint team developed a draft science and operations requirement document that will be available for community inputs
- If accepted by the agencies, the nominal launch date would be around 2020

ISRO/JAXA/JPL Partnership

- Indian Space Research Organization (ISRO)
  - Will provide Ku-band scatterometer
  - Possibly provide the launch vehicle
    - Hope to finalize late in June
  - Government interest is largely operational
- Japanese Aerospace Exploration Agency (JAXA)
  - Providing the AMSR3 instrument (radiometer)
  - Providing the satellite bus
- Jet Propulsion Laboratory
  - Providing Ka-band Doppler scatterometer

Paths to Funding US Component

- Short-term (for 2020 or 2021 launch)
  - NASA Earth Ventures (all dates below in fiscal year)
    - EV Instrument (to be released early in 2015; $90M cap)
    - EV Mission (to be released in Spring 2015; $150M cap)

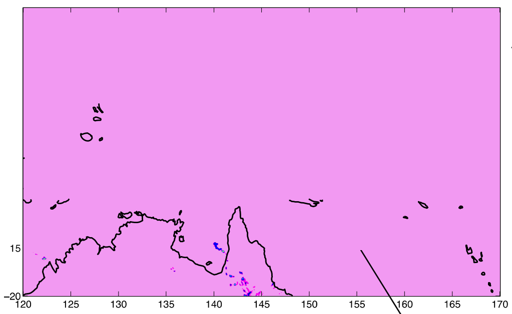
Mission	Mission Type	Release Date	Selection Date	Major Milestone
EVI-3	Instrument Only	Q2 FY2015	Q1 FY2016	Delivery NLT 2020
EVI-4	Instrument Only	Q4 FY2015	Q3 FY2016	Delivery NLT 2021
EVM-2	Full Orbital	Q3 FY2015	Q2 FY2016	Launch ~2021
EVI-5	Instrument Only	2017	2018	Delivery NLT 2023
EVS-3	Suborbital	2017	2018	N/A
EVI-6	Instrument Only	2019	2019	Delivery NLT 2024

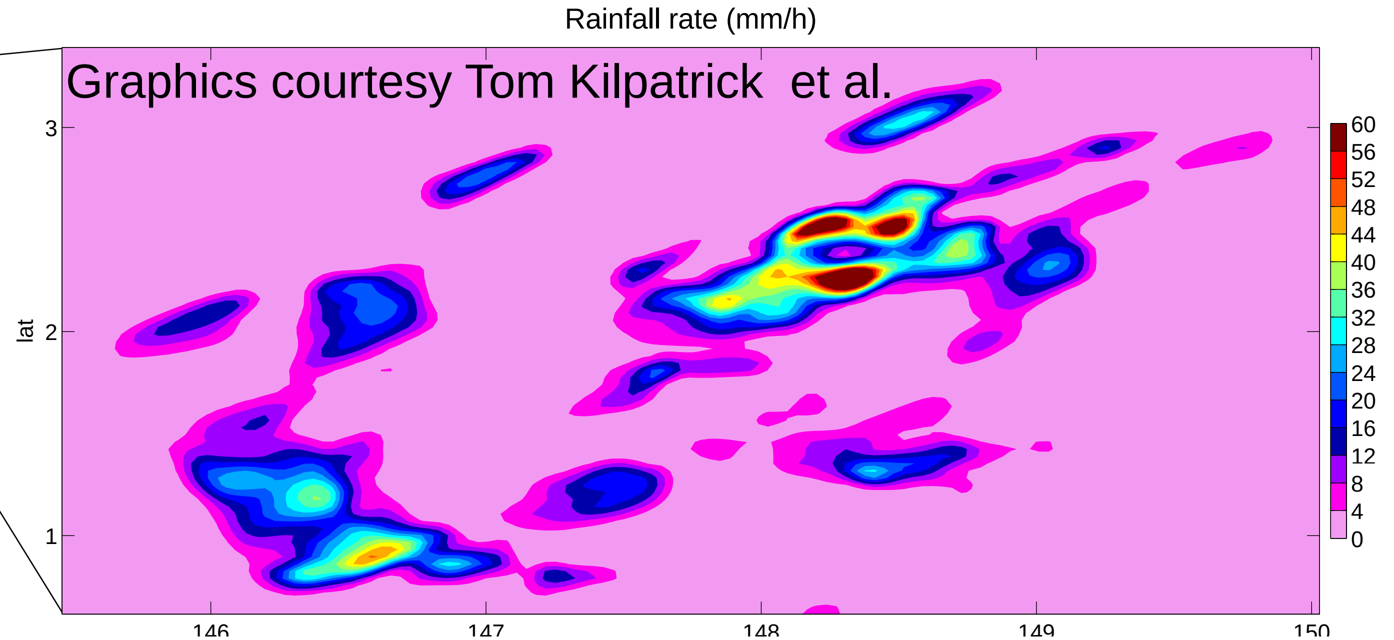
- Long-term – decadal survey (with more cloud & surface coupling)

Science Goals

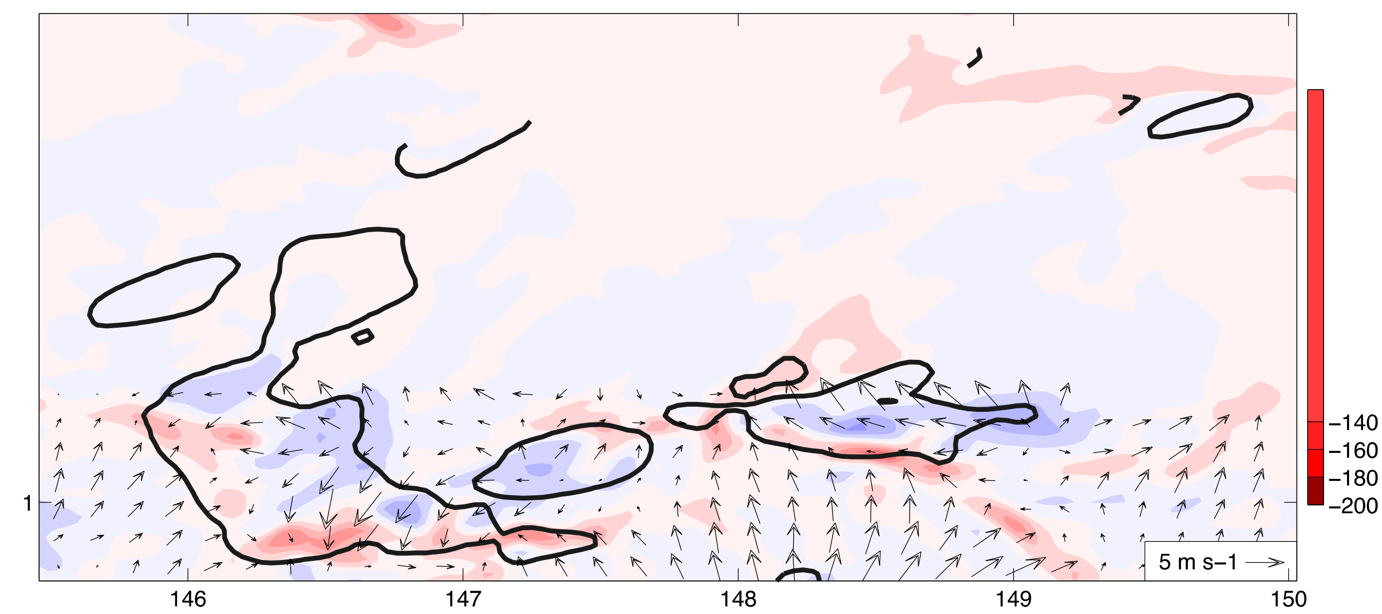
- GCOM-W2 was originally conceived of for examination of the water cycle
- We have goals related to
  - Water cycle
  - Energy budgets
  - Ocean forcing
  - Wind and SST coupling
  - Cloud and surface coupling
  - Continuity of climate data records
  - Ice motion
  - And a few others
  - A science and operational requirements document is available for those interested (email mbourassa@fsu.edu)

Cloud and Surface Wind Coupling

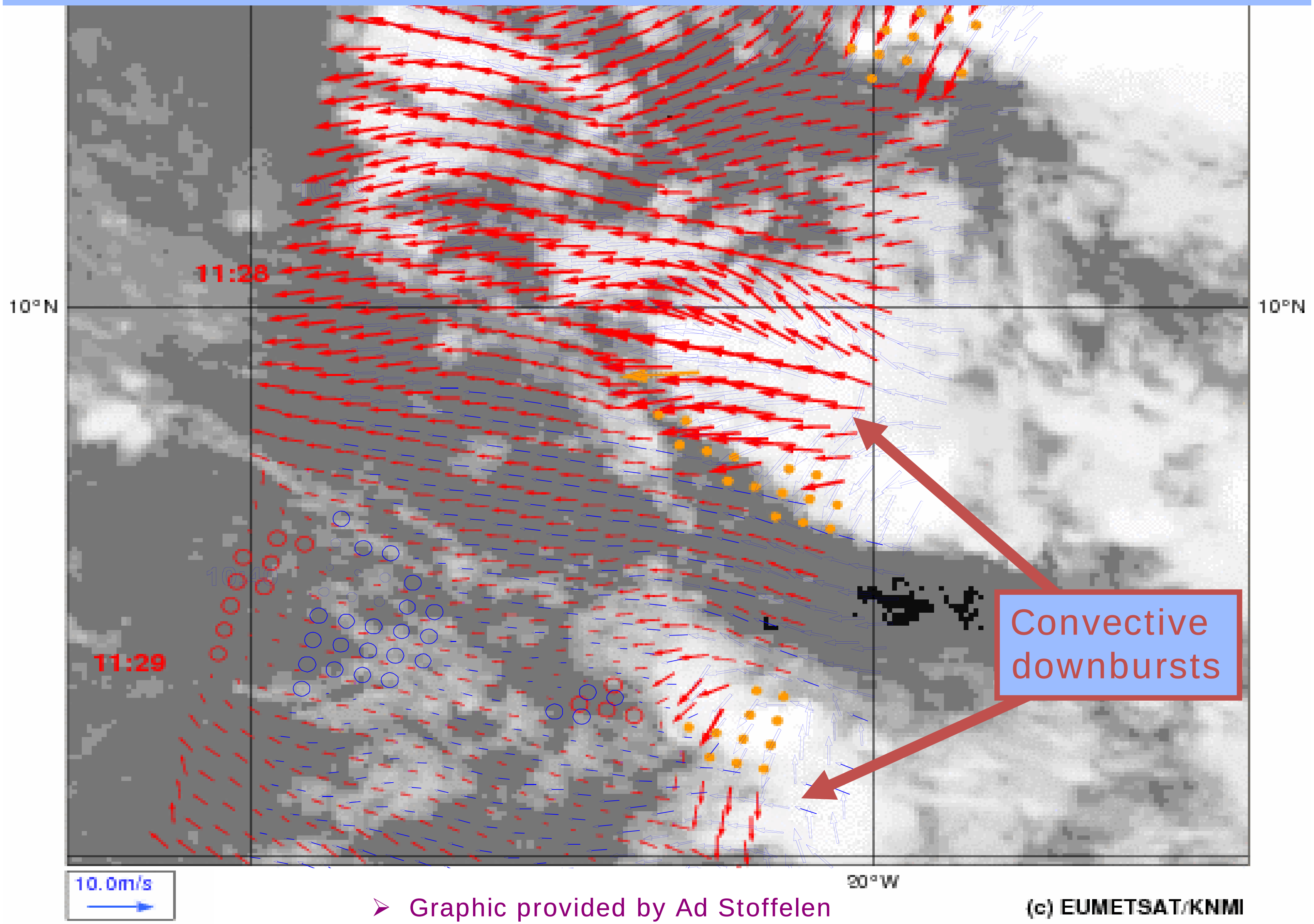




- Snapshots of rainfall rate from NICAM 3.5 km “MJO” run.
- Top: snapshot of rainfall rate indicates mesoscale convective systems.
- Bottom: Heavy rainfall (black contour) associated with surface wind *divergence* (blue), presumably related to cold pool dynamics.



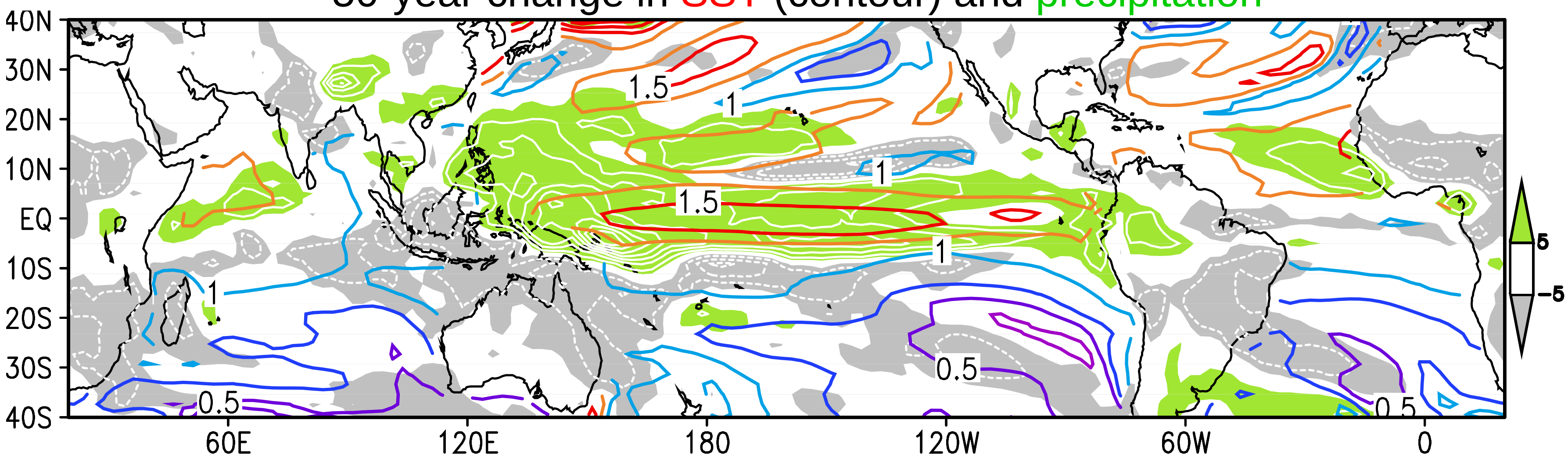
ASCAT-A and ASCAT-B come together



- Graphic provided by Ad Stoffelen

Link in Long-Term Changes in SST and Precipitation

50-year change in SST (contour) and precipitation

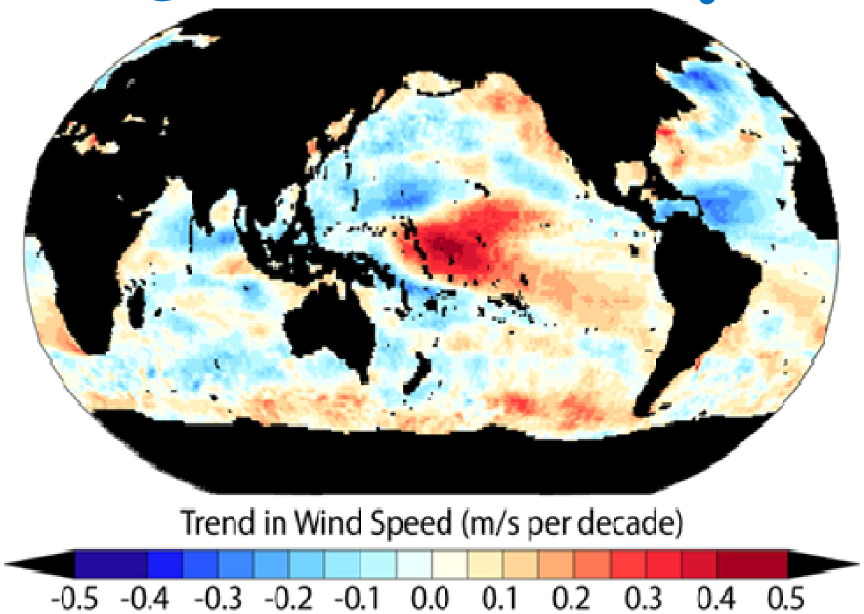


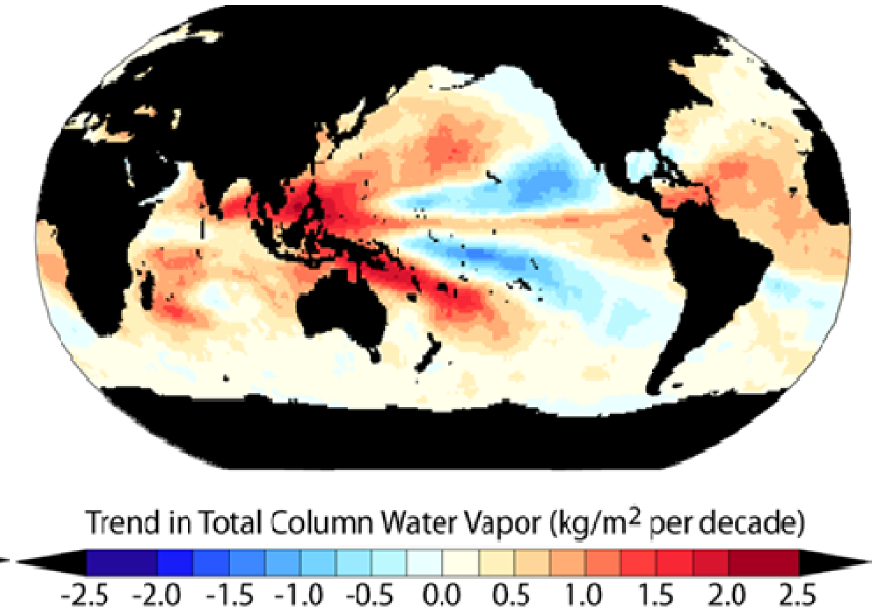
SST warming pattern determines rainfall change

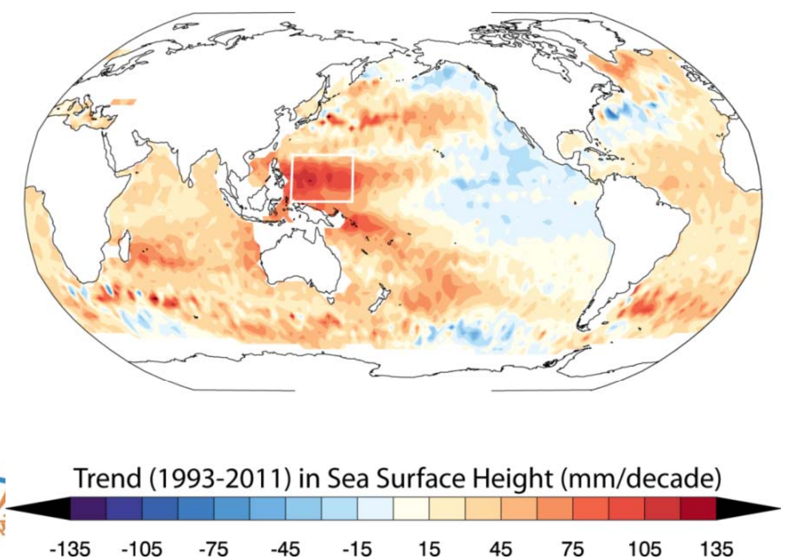
- Xie and others argues that changes in SST patterns have substantial impacts on changes in the water cycle
- Wentz, Yu and others have found that the change in surface evaporation is highly influenced by changes in surface winds
- Liu, Hilburn and others have shown links between winds and moisture transport

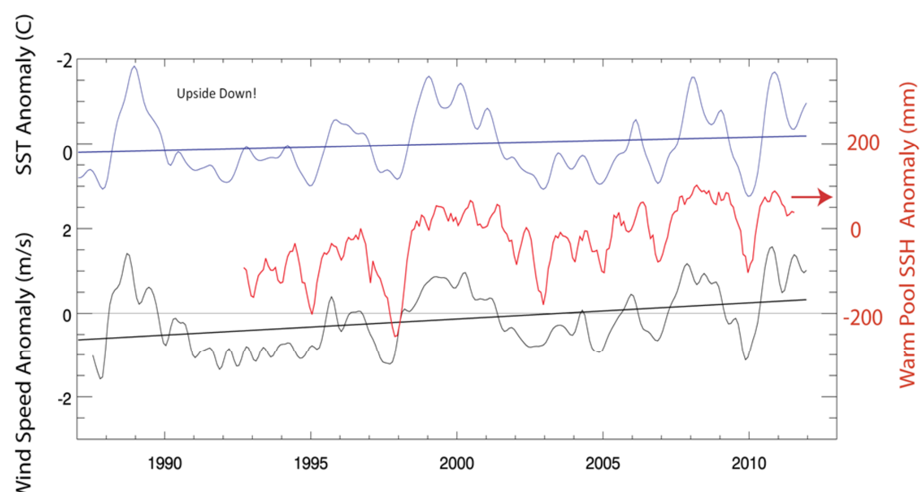
Graphic courtesy Shang-Ping Xie

Climate Record
Quarter-Century Trends from Satellites







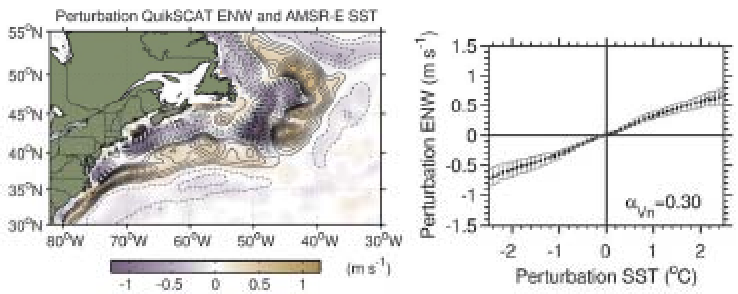


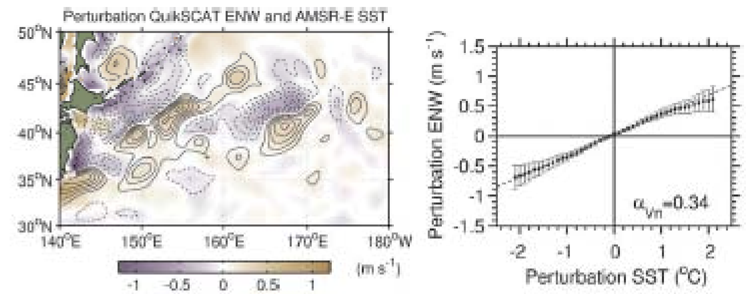
Graphic courtesy Frank Wentz

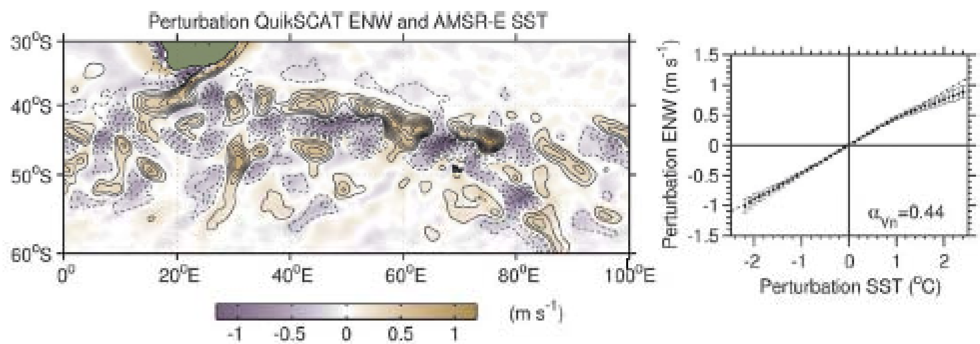
Coupling Between SST and Winds

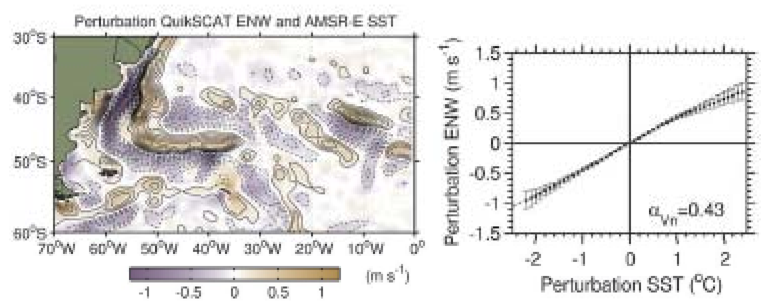
The Coupling Between SST and Wind Speed in 4 Frontal Regions

(Gulf Stream, Kuroshio Extension, Agulhas Return Current and Brazil-Malvinas Current)





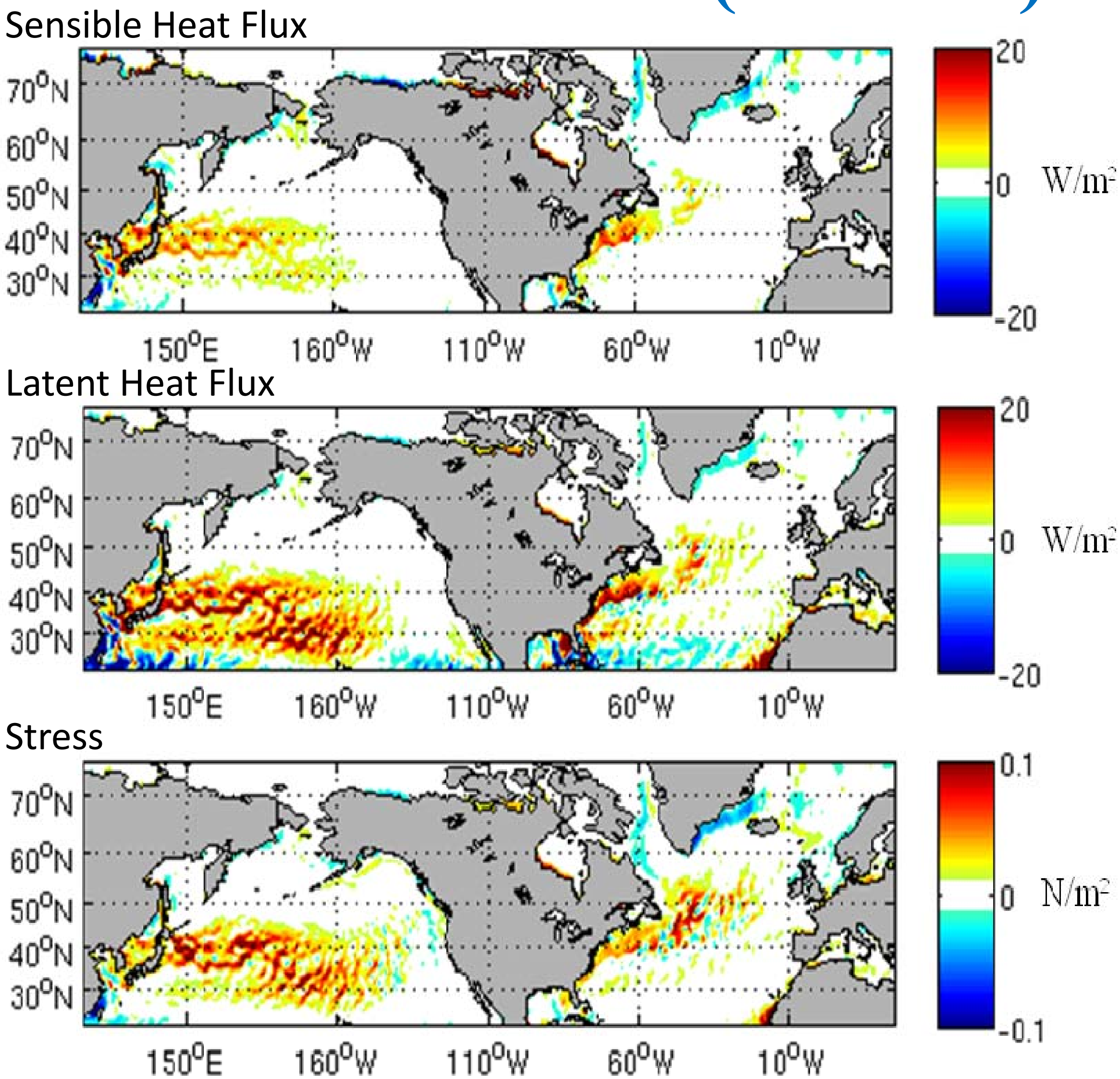




June 2002 - May 2009
Averages

From O'Neill et al. (2012, J. Clim.)

Small Scale (<600km) Changes in Fluxes



- Modeled changes in fluxes due to changes in wind speed caused by SST gradients
- Monthly average for December
- Small scale changes are large compared to accuracy requirements
- This spatial variability is currently not in reanalyses
- This spatial variability should be considered in evaluating the observing system

Graphic courtesy of John Steffen

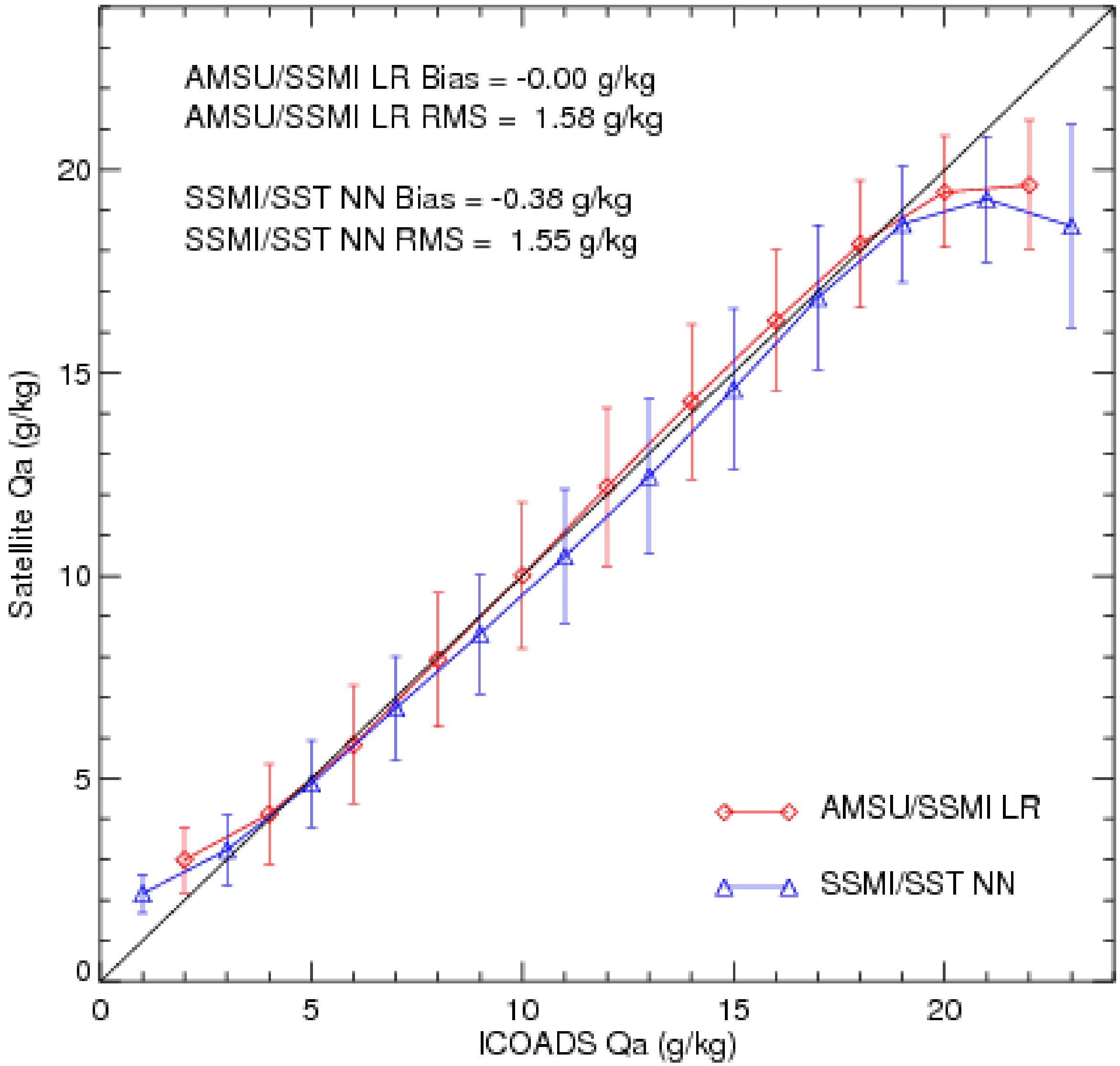
Surface Turbulent Fluxes

- Sensible and latent heat fluxes contribute to the energy budget
  - Latent heat is proportional to evaporation
- These turbulent fluxes are determined from bulk flux parameterizations, which are functions of
  - Wind speed
  - Surface current
  - Sea surface temperature
  - Near surface (e.g., 10m) air temperature
  - Near surface (e.g., 10m) humidity
  - Surface pressure (weak dependence)
  - Sea state

Surface Turbulent Fluxes

- Sensible and latent heat fluxes contribute to the energy budget
  - Latent heat is proportional to evaporation
- These turbulent fluxes are determined from bulk flux parameterizations, which are functions of
  - Wind speed relative to the surface (scatterometer)
  - ~~Surface current~~
  - Sea surface temperature (AMSR3)
  - Near surface (e.g., 10m) air temperature (AMSR3 + Scat)
  - Near surface (e.g., 10m) humidity (AMSR3 + Scat)
  - ~~Surface pressure (weak dependence)~~
  - ~~Sea state~~
- Retrievals for air temperature and humidity have greatly improved in recent years.

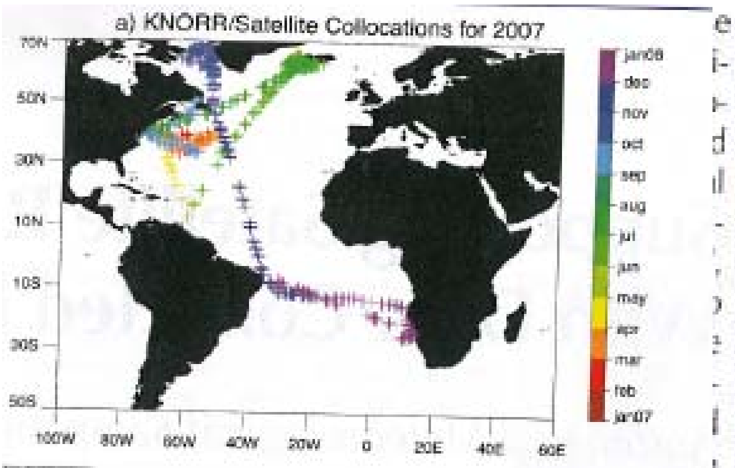
Comparison of Two Retrieval Techniques



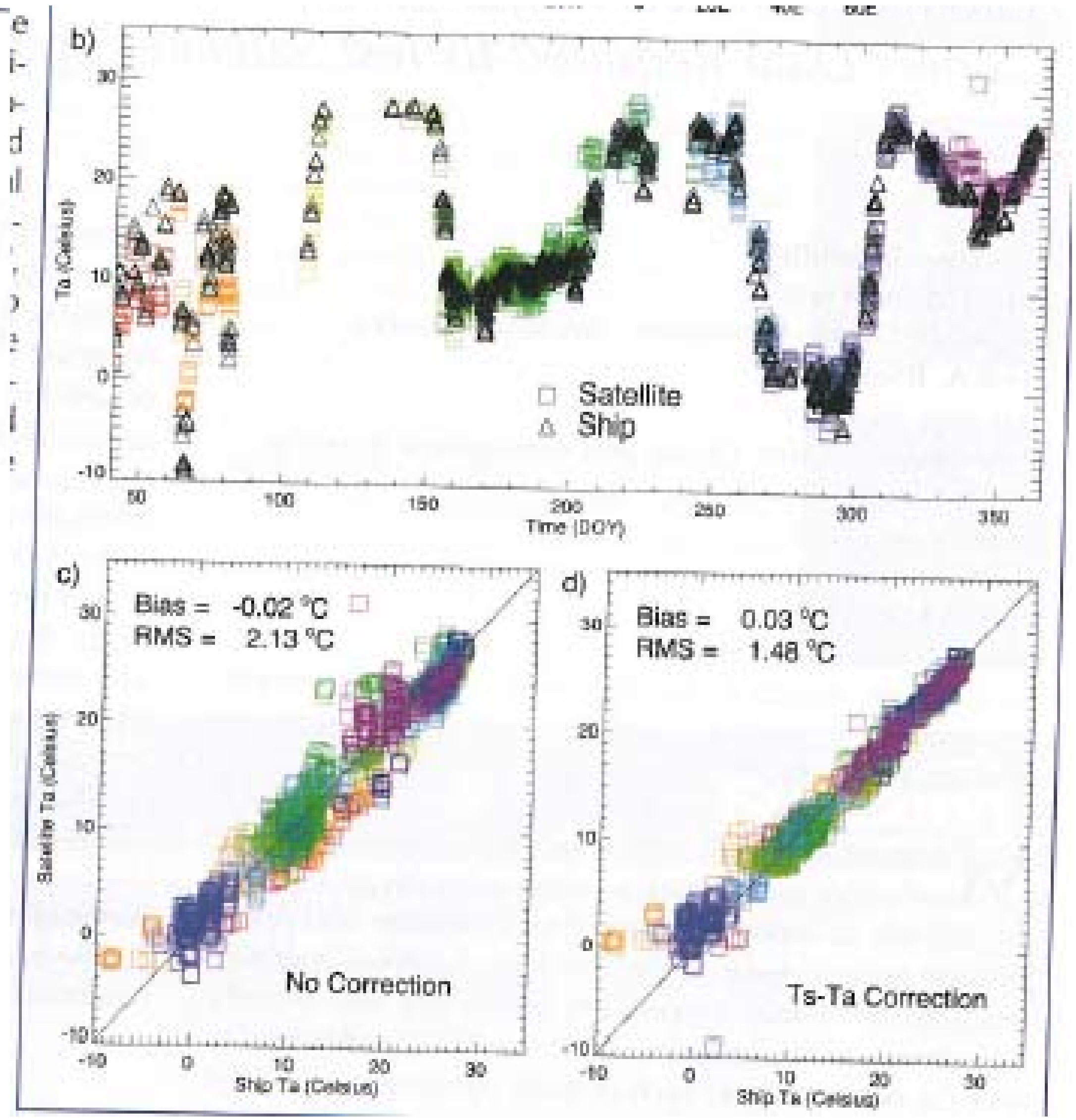
- Blue – Roberts et al. (SeaFlux)
- Red – Jackson and Wick
- Need more data to improve extremes

Bourassa, M. A., S. Gille, D. L. Jackson, B. J. Roberts, and G. A. Wick, 2010, TOS

Evaluation of Satellite Retrievals of 10m Ta and Qa



- Comparison to research vessel observations from SAMOS



Smith, S. R., M. A. Bourassa, and D. L. Jackson, 2012

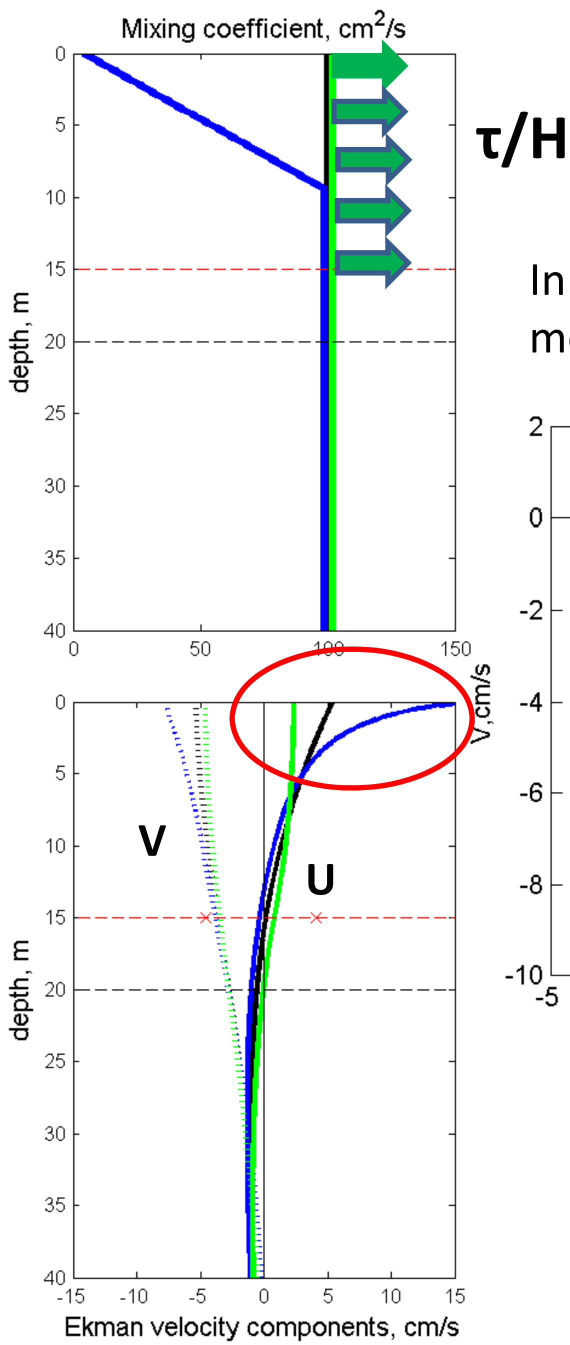
Consequences of Changes in Surface Heat Fluxes

- Changes in oceanographic circulation
- Storms over western boundary currents have a tilt
  - Induces a vertical circulation that helps pump moisture into the free atmosphere
  - How do these changes in fluxes impact flux into free atmosphere and down stream climate?
  - How important is the cloud coupling with surface winds and fluxes?

Importance of satellite measurement of surface currents

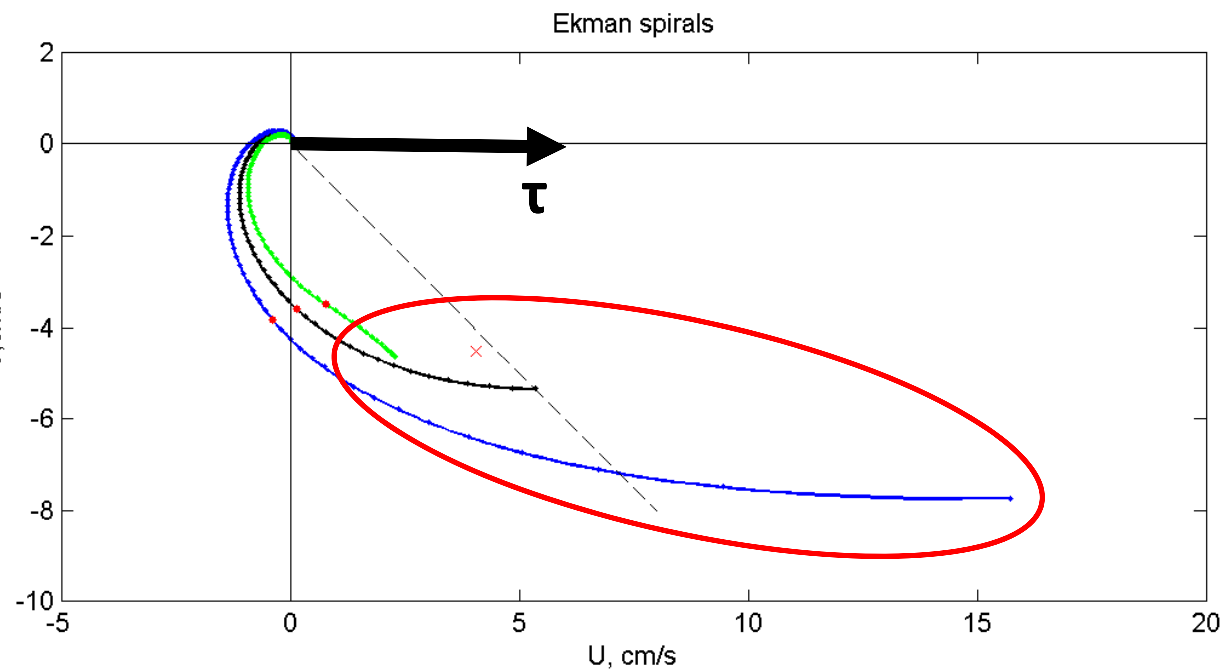
- Satellite measurement would provide the first global map and periodic monitoring of surface current
- Surface currents are difficult to derive theoretically because they are sensitive to details of the mixed-layer model. Satellite measurements will help to improve models of vertical momentum exchange in the upper ocean.
- Ocean is largely driven by wind. While wind stress $\boldsymbol{\tau}$ is momentum air-sea flux, knowing collocated $\boldsymbol{\tau}$ and surface velocity $\mathbf{V}$ also allows computation of kinetic energy flux (or wind work on the ocean): $A = \rho \cdot \boldsymbol{\tau} \cdot \mathbf{V}$
- Improved spatial resolution allows to move observations closer to the coast, where:
  - Fast western and eastern ocean boundary currents play important roles in basin-wide balances
  - Wind stress curl, induced by wind interaction with eastern ocean boundaries and with islands, generates beta-plumes, extending westward across entire oceans.

Slide courtesy Nikolai Maximenko



2. Surface currents are difficult to derive theoretically because they are sensitive to details of the mixed-layer model. Satellite measurements will help to improve models of vertical momentum exchange in the upper ocean.

In figures: difference between solutions of three simple Ekman models is largest at the sea surface



2. Also need to add Stokes drift and near surface turbulence (see work of Weber and Jenkins among others)

Slide courtesy Nikolai Maximenko

Conclusion

- There are tremendous opportunities with a the combination of a scatterometer and a radiometer.
- For an Earth Ventures proposal to be successful we need to build a strong science case.
  - Your input is welcome
  - We will focus on no more than three topics
    - Coupled surface and boundary-layer processes impacting energy and water cycle?
    - Arctic circulation?
    - Coastal winds and??
    - And hidden in there, the climate record
  - Other topics will be listed with a short description and linked to the three main topics

Backup

Overview of AMSR Instrument

- Deployable main reflector system with 2.0m diameter (1.6m for AMSR-E).
- Frequency channel set is identical to that of AMSR-E except 7.3GHz channel for RFI mitigation.
- Two-point external calibration with improved HTS (hot-load).
- Add a redundant momentum wheel to increase reliability.

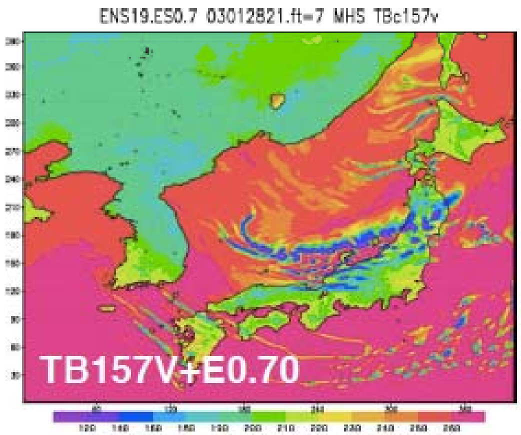
GCOM-W1/AMSR2 characteristics	
Scan and rate	Conical scan at 40 rpm
Antenna	Offset parabola with 2.0m dia.
Swath width	1450km (effective 1600km)
Incidence angle	Nominal 55 degrees
Digitization	12bits
Dynamic range	2.7-340K
Polarization	Vertical and horizontal

AMSR2 Channel Set				
Center Freq. [GHz]	Band width [MHz]	Pol.	Beam width [deg] (Ground res. [km])	Sampling interval [km]
6.925/ 7.3	350	V and H	1.8 (35 x 62)	10
10.65	100		1.2 (24 x 42)	
18.7	200		0.65 (14 x 22)	
23.8	400		0.75 (15 x 26)	
36.5	1000		0.35 (7 x 12)	
89.0	3000		0.15 (3 x 5)	5

Courtesy K. Imaoka, JAXA

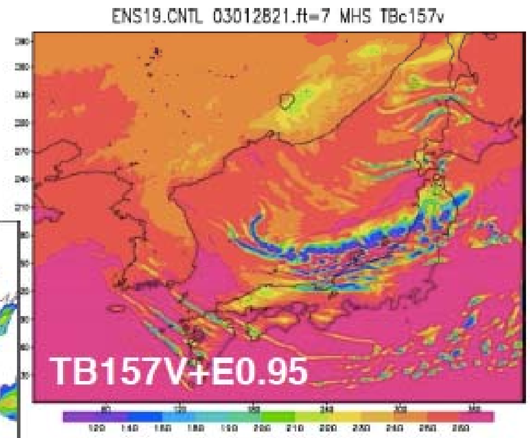
Potential AMSR Enhancements

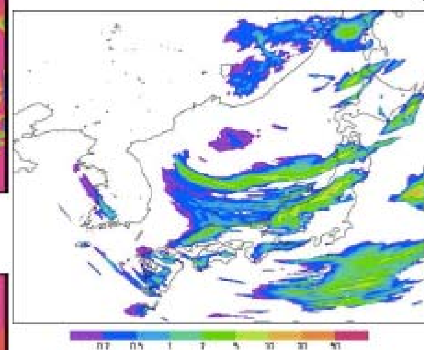
Examples of Tb simulations:
TB(157V & 190V) for ε_s=0.7 & 0.95



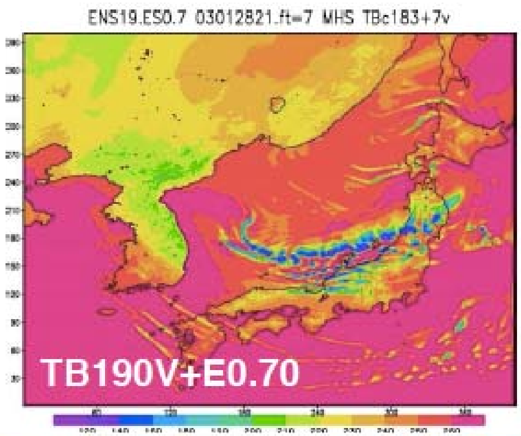
T_B157V

Sensitive for ε_s at window region



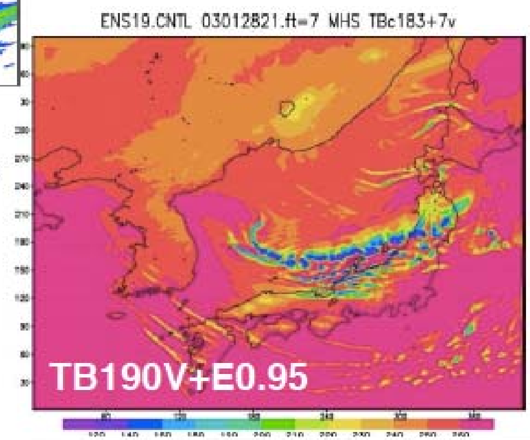


Tb computation based on CRM Ensemble Simulations for Upper Cold Low



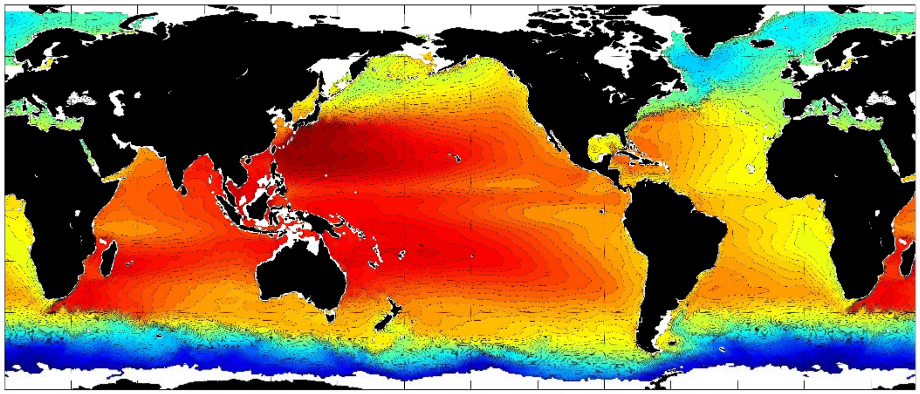
T_B190V

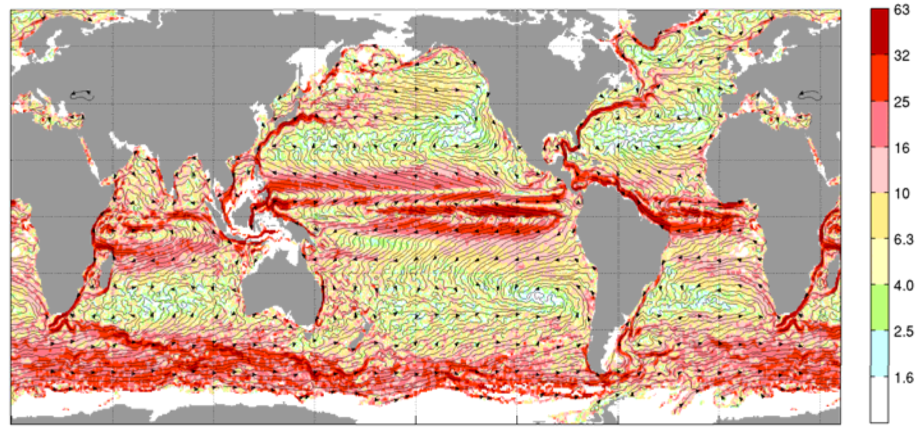
Insensitive for ε_s at absorption band

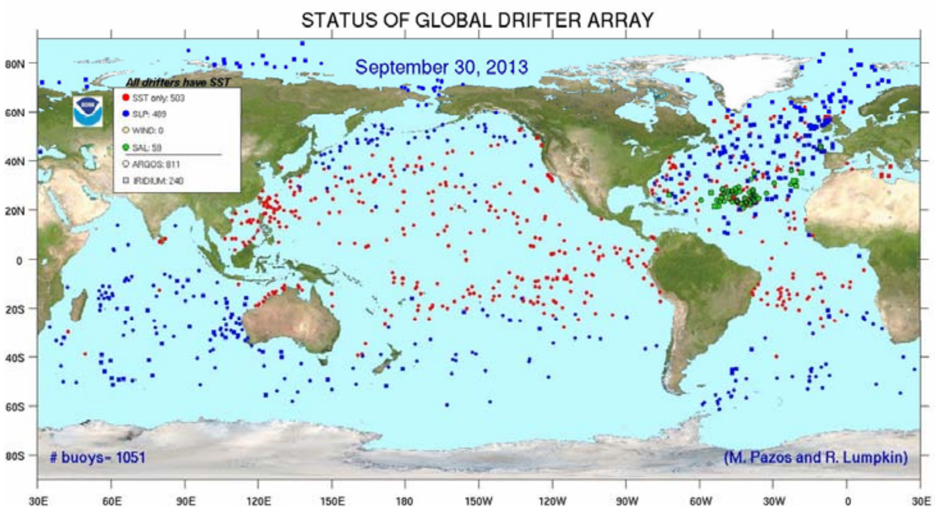


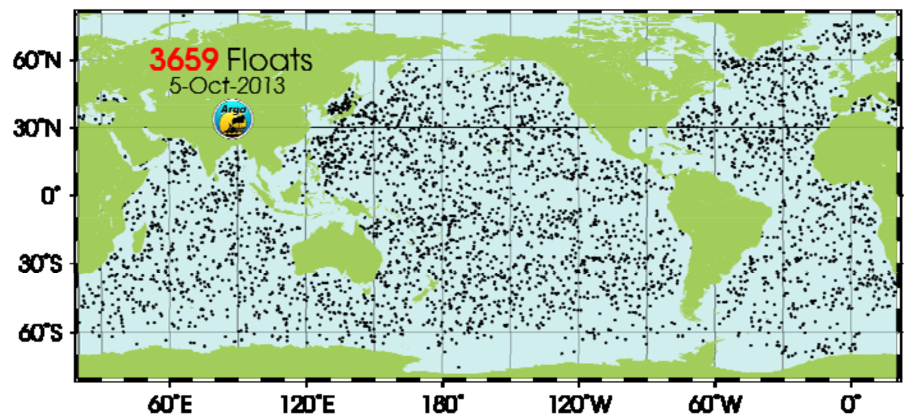
Provided by Dr. Kazumasa Aonashi of MRI/JMA.

Surface currents are not well measured





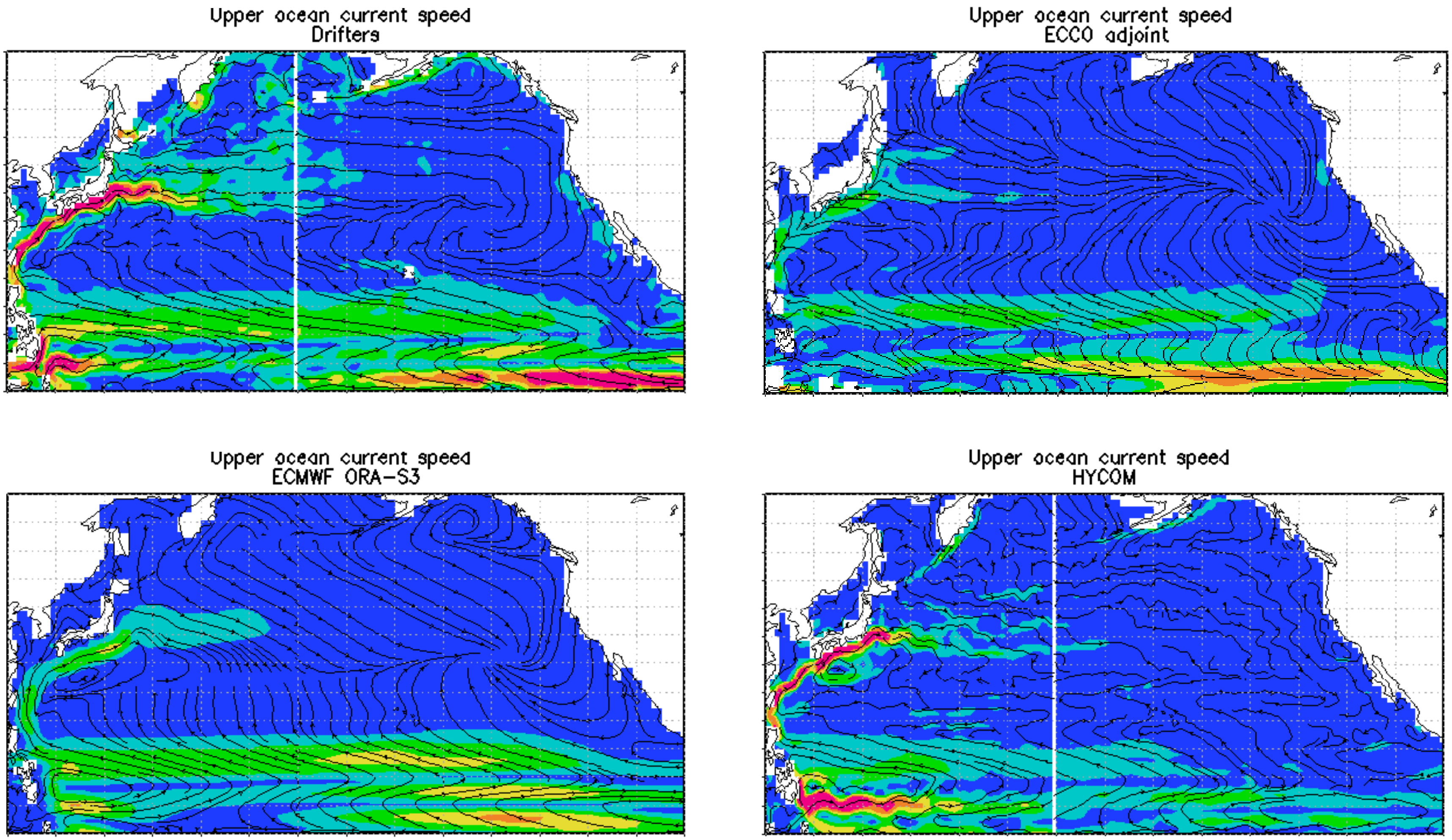




1,051 active drifters (approx. 1 drifter per 4x4 degree bin; probably 30-50% are undrogued)

3659 active Argo floats
(3659 / 10 days * 10 hours ≈ 152 continuous sites)

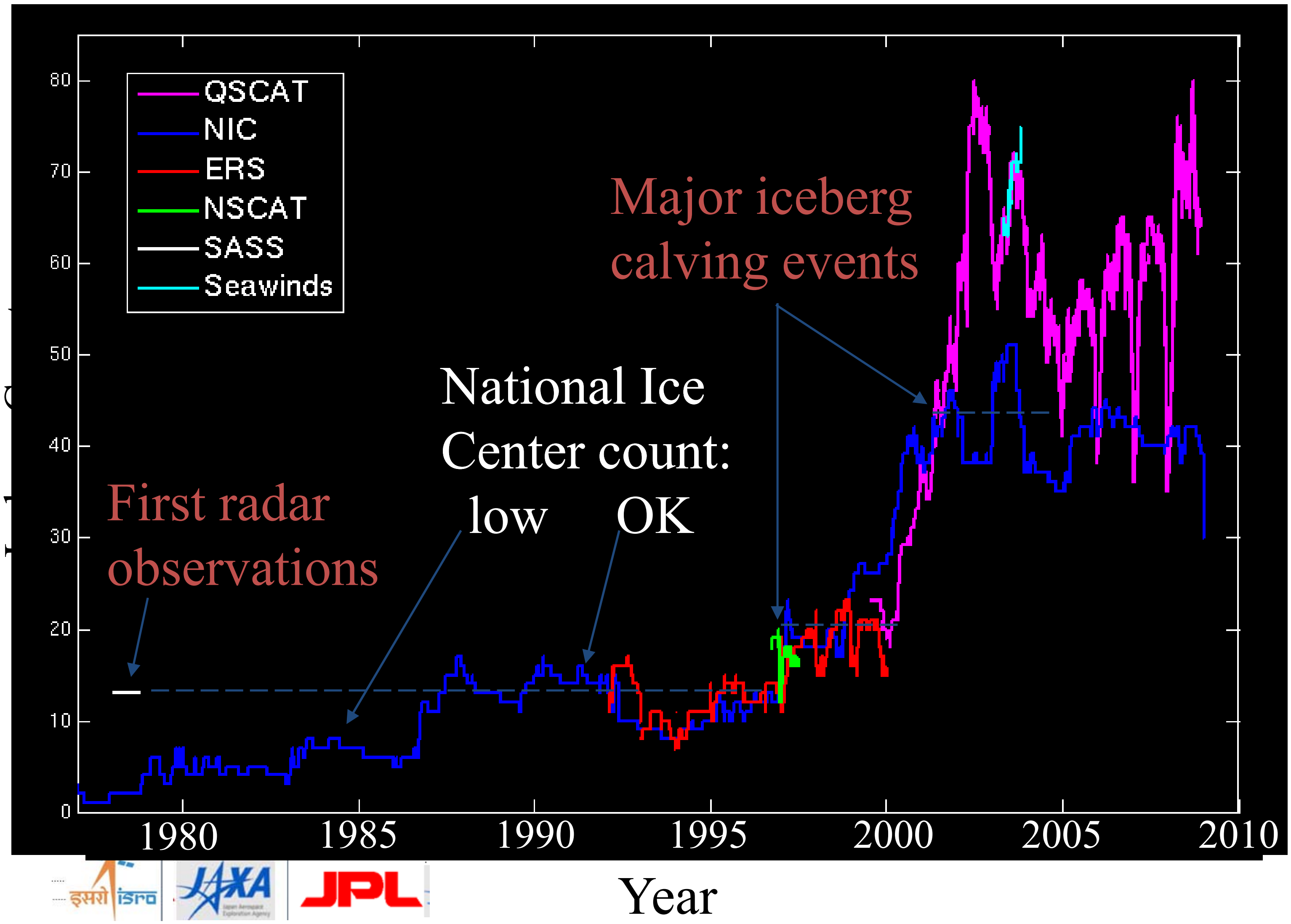
Surface currents are not well modeled



Why even most reputable models do not care about discrepancy with observations?

(Jim Potemra, 5th Int. Marine Debris Conference, 2011)

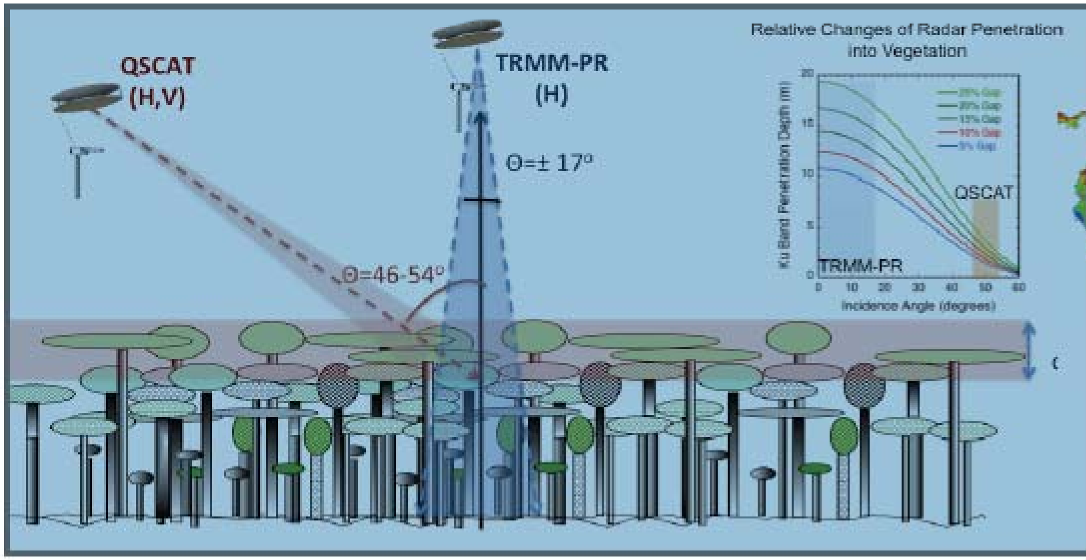
Icebergs Increasing?

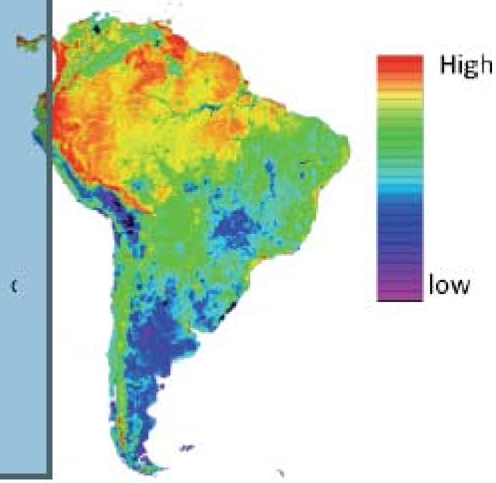


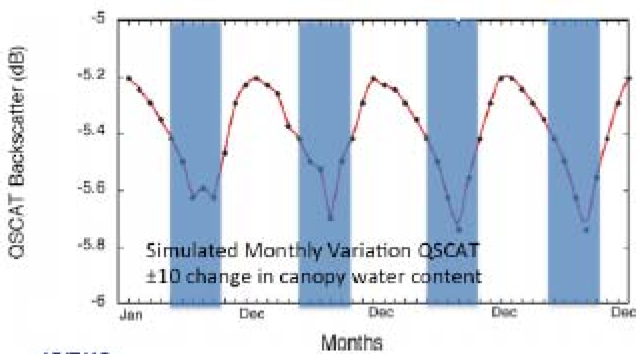
Much of the apparent NIC increase is an artifact of better iceberg tracking technology

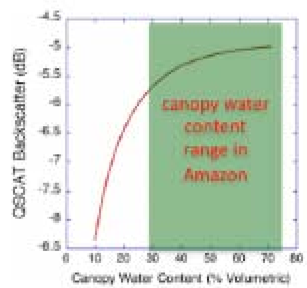
Recent calvings of Ross and Ronne Ice shelves are within the range of expected variation

QSCAT Sensitivity to Canopy Water Content









$$\sigma_p^0 = \gamma_p \left[\frac{1-\exp(-\alpha_p W_c \sec\theta)}{\sqrt{W_c}} \right]$$

W_c = canopy water content

γ_p and α_p : forest type calibration paramete

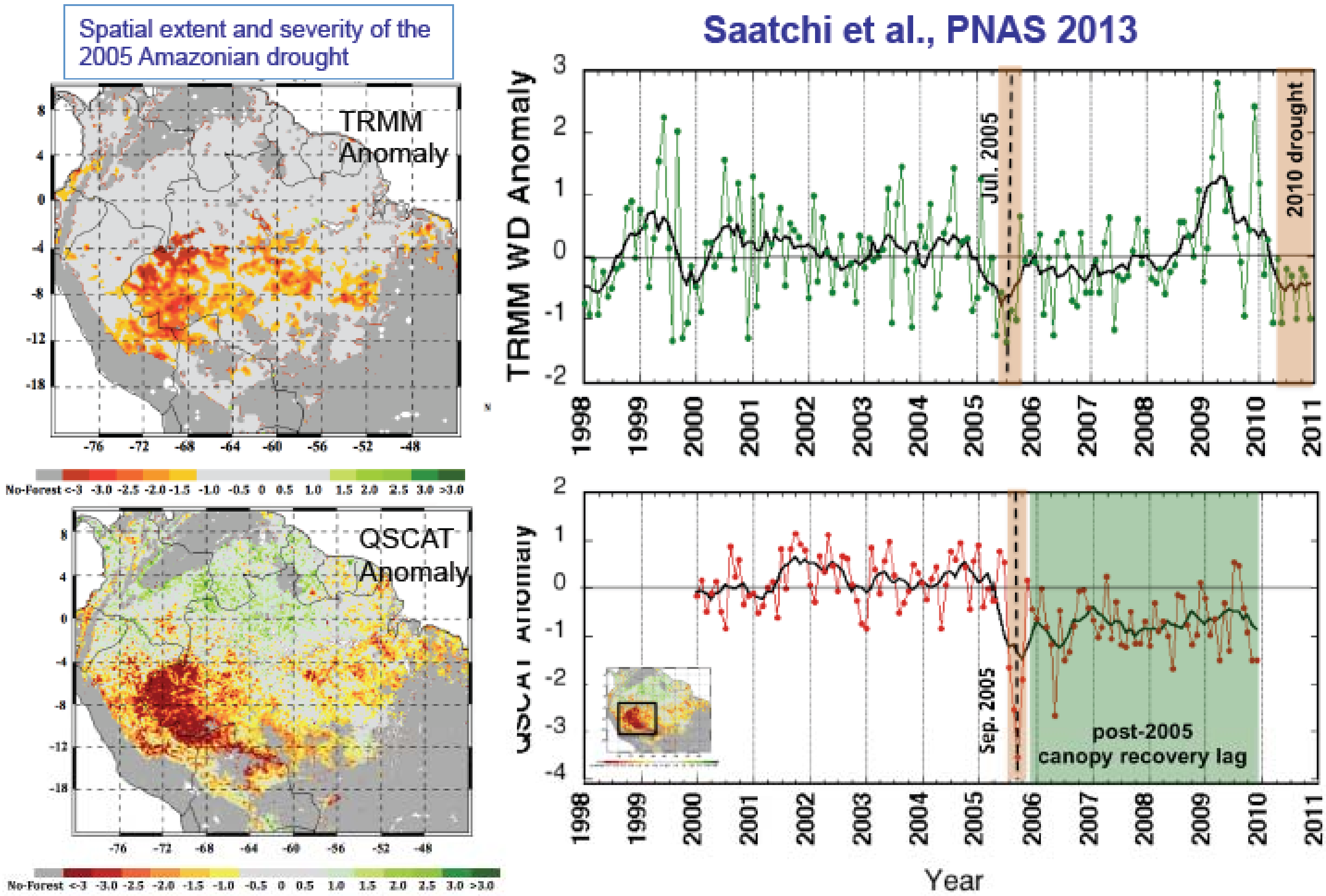
p : polarization (H,V)

d_c : canopy penetration depth

- Nadir pointing instruments have much greater penetration of canopy
- QSCAT-like scanning pencil beam is more sensitive to upper layer of vegatation

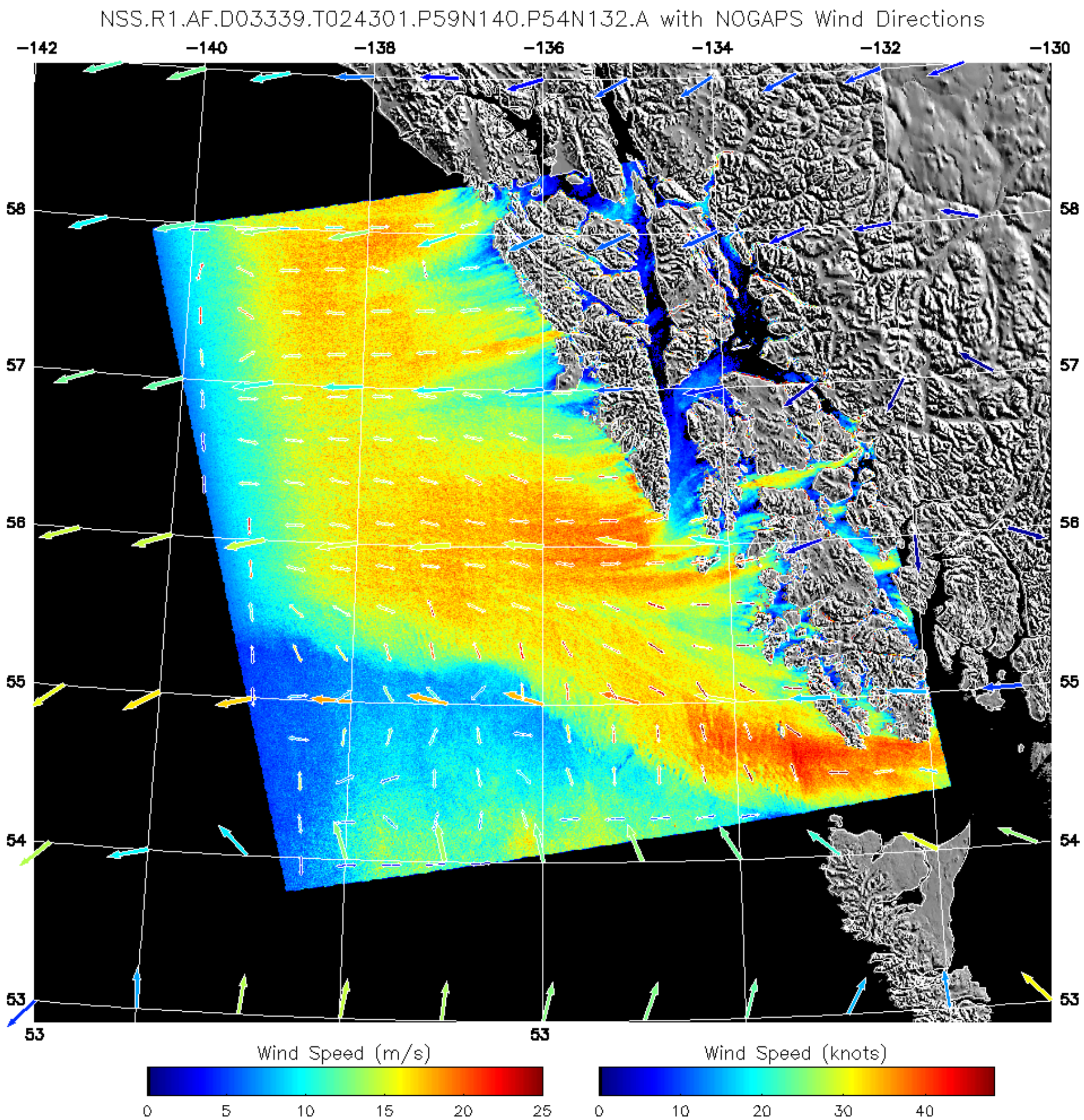
Graphic courtesy S. Saatchi

Persistent Effects of Severe Drought on Amazonian Forest Canopy



Graphic courtesy S. Saatchi

Mesoscale Features in Near Coast



- **SAR Wind Image**
- **Baranof Island**
- **Radarsat-1**
- NOGAPS wind direction
- 05 Dec 2003
- 04:43 UTC
- Slide courtesy of Bill Pichel