Space and time scales of sea surface salinity variability in the open ocean

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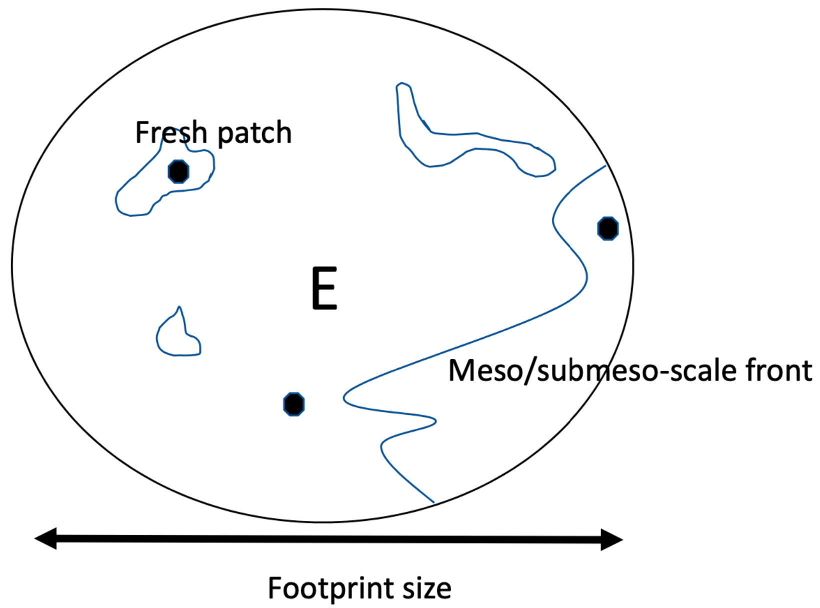
SSS Subfootprint variability (SFV)

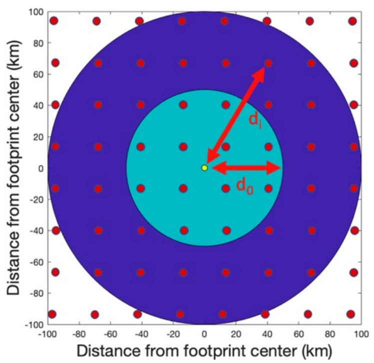
Bingham, 2019



We have been able to make estimates of SFV and associated representation error (RE) using various techniques

- Models
- Mooring data
- Intensely sampled field observations from the SPURS campaigns

- Bingham & Brodnitz (2021)
- Bingham et al. (2021)
- Bingham & Li (2020)
- Bingham (2019)
- D'Addezio et al. (2019)



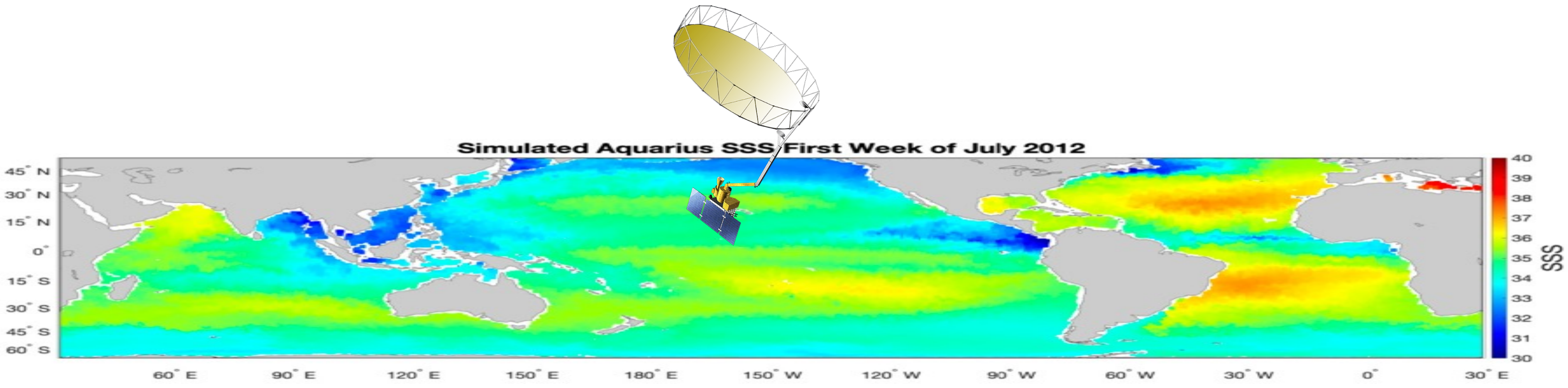
Bingham et al., 2021

SFV is the weighted standard deviation of salinity within the footprint of a satellite
RE is the difference between a footprint-averaged value of SSS and a point measurement from a float or mooring

The Simulated SSS data (Bingham et al., in review)

Start with the high-resolution (2 km) SSS dataset from the ECCO LLC-4320 simulation

Sampled as if SMOS, SMAP and Aquarius were flying over it, and Argo floats popped up into it



Subfootprint variability (SFV)

Bingham et al., 2021

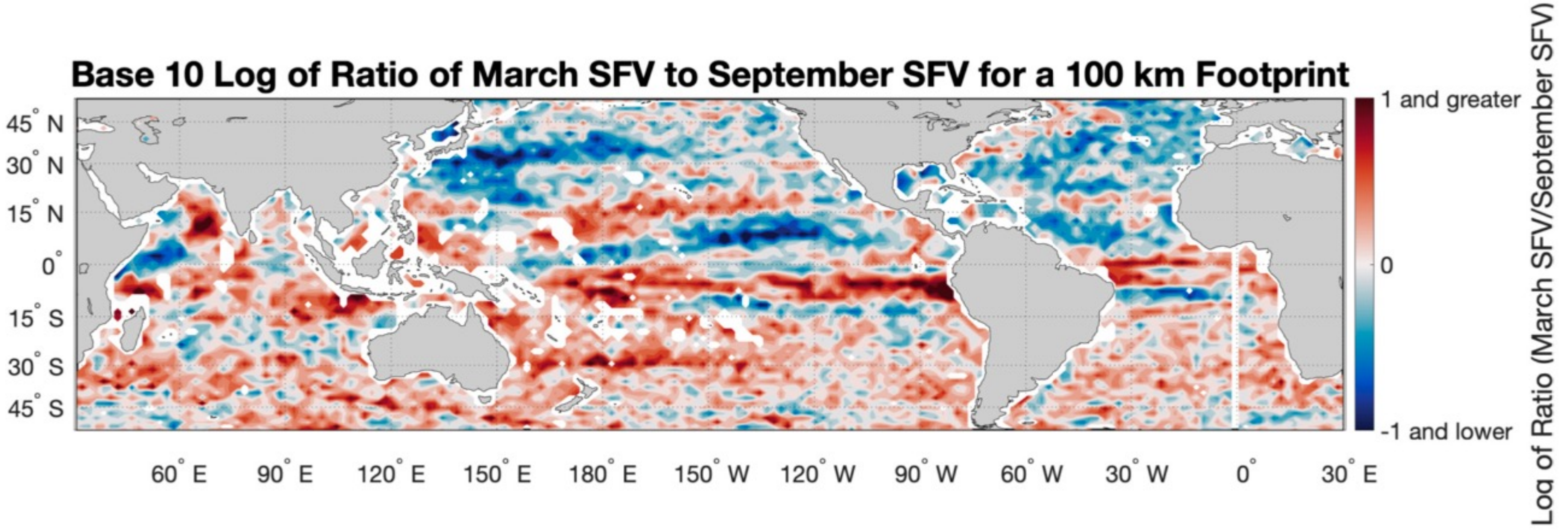


Figure 7. Log_{10} of the ratio of median SFV in March to the median SFV in September for a 100 km footprint. Color scale is on the right.

March SFV / September SFV using a high-resolution model (ECCO LLC-4320)

SFV has a seasonal cycle, and tends to be largest in the fall, especially in the Atlantic basin

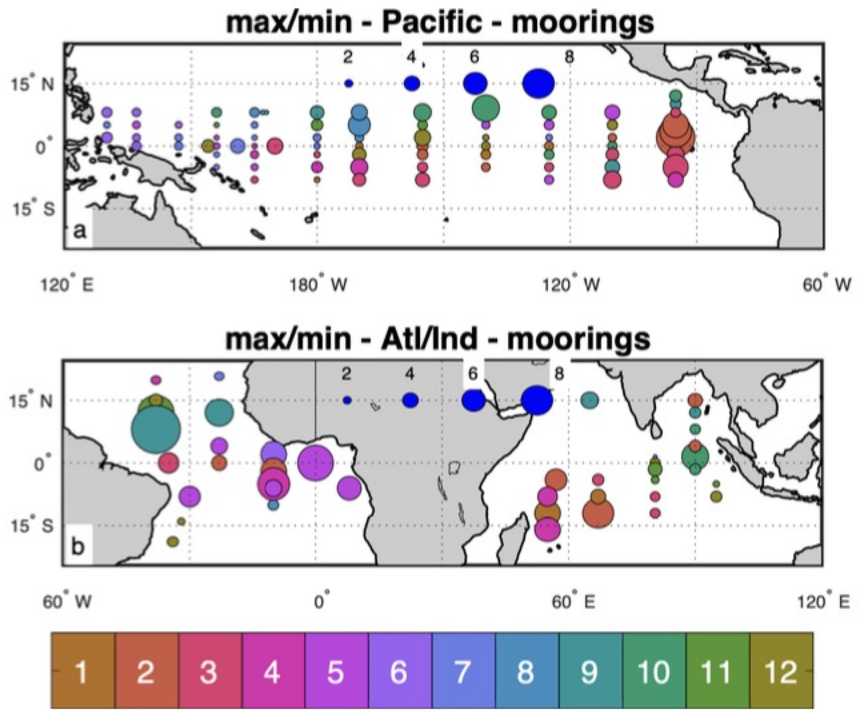
This is opposite to the observed seasonality in surface flow variance (Rocha et al. 2016)

Short-term variability (STV)

Bingham & Brodnitz, 2021

STV is the variance at short (~7 day) time scales measured at one location

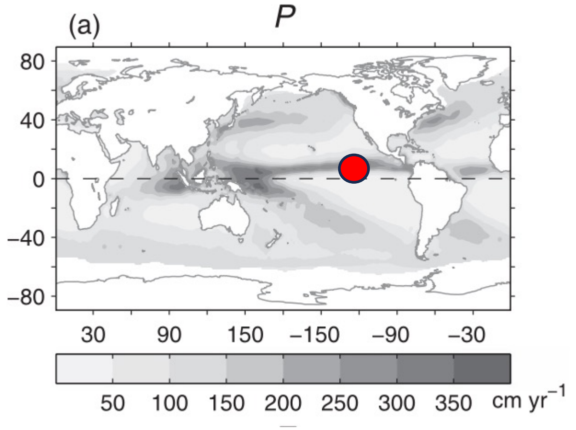
Ratio of maximum to minimum monthly STV, colored by month of maximum, using the Global Tropical Moored Buoy Array

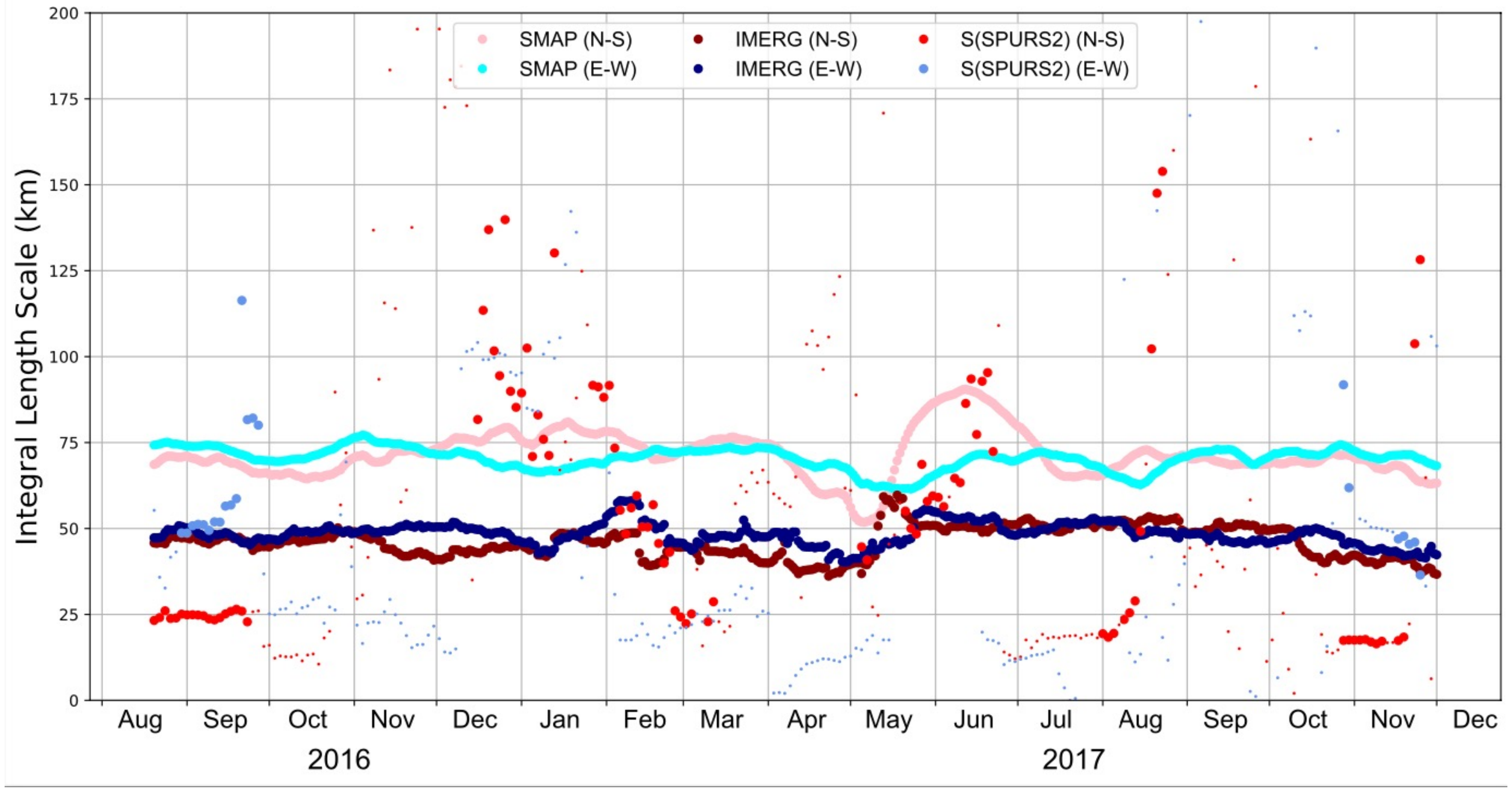


Integral length scales in the SPURS-2 region from in situ and satellite data

Length scales computed from in situ data are highly variable, especially in the meridional direction

In situ values are very different from satellite-measured



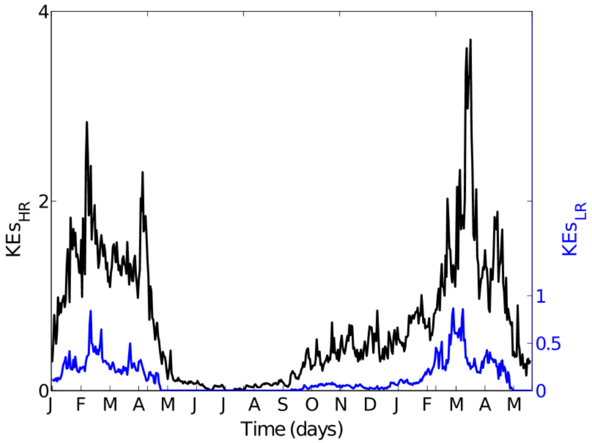


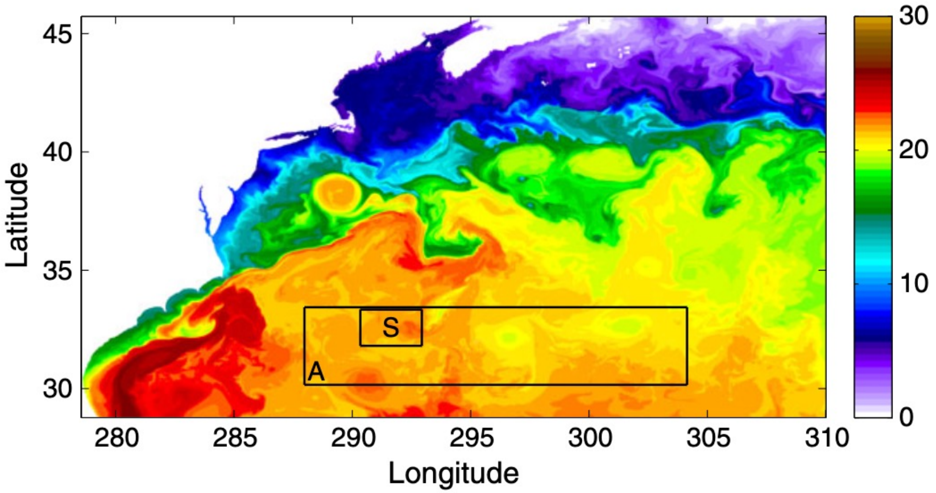
Chi et al., 2023, accepted

For surface flow…

- Mixed-layer instability scaling (Fox-Kemper et al., 2008) suggests that short spatial scale variability at the surface should be largest in winter and early spring when the mixed-layer is deepest
- Verified in limited regions (e.g. Mensa et al., 2013; Rocha et al., 2016; Sasaki et al., 2014)

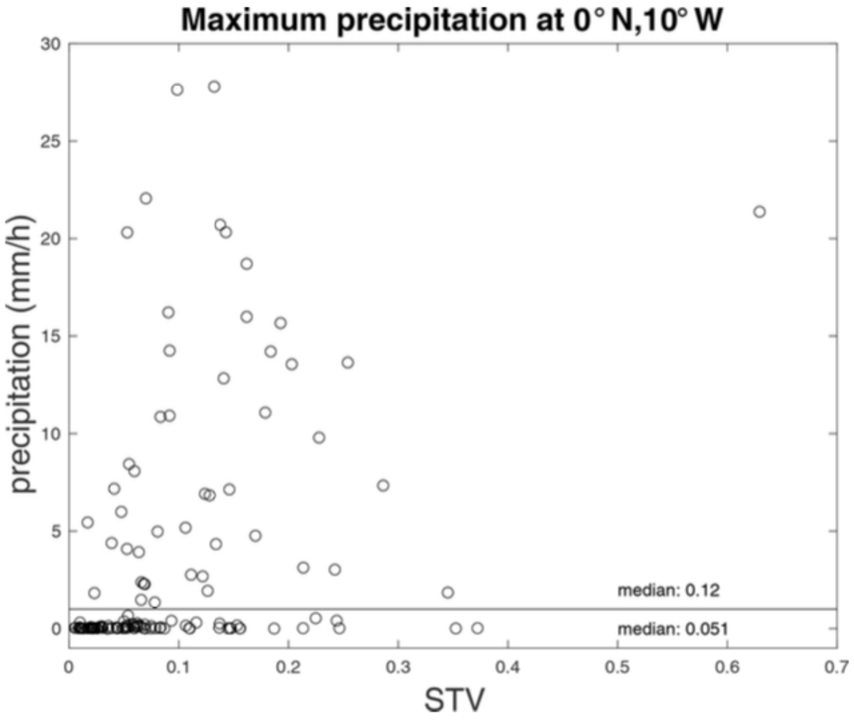
Integrated submesoscale KE within box S
Blue (black) – low (high) resolution
(Mensa et al., 2013)





Short spatial scale variability in SSS

- What generates it?
- What is its seasonality?
- How important is it to ocean dynamics relative to temperature?
- Relationship to rainfall?



Precipitation vs. short-term (~7-day) variability at one tropical mooring

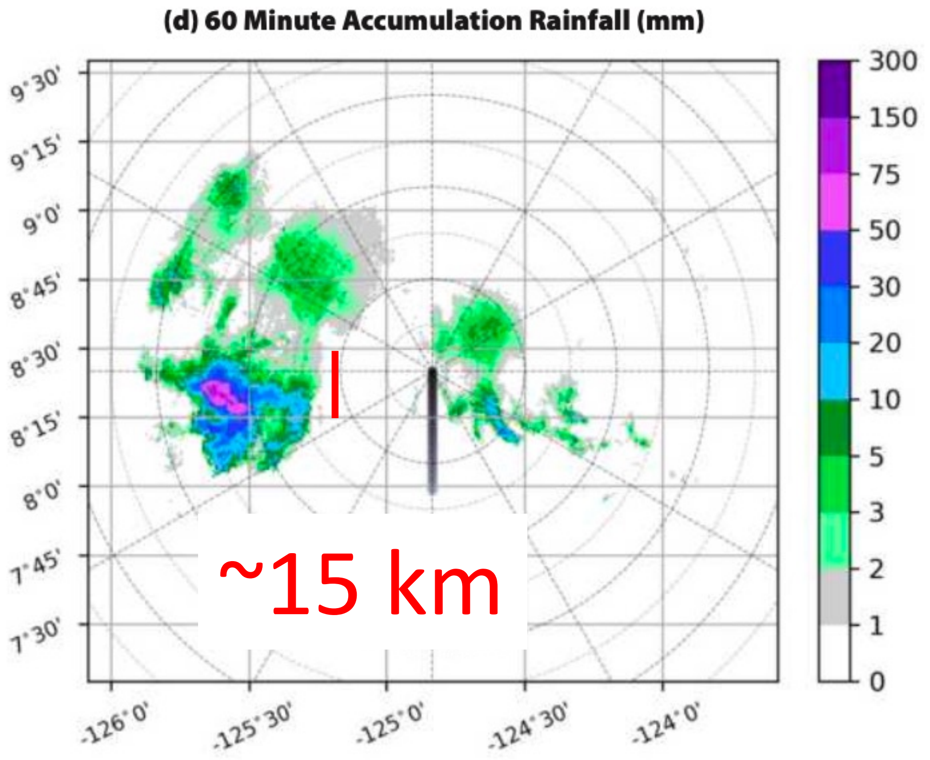
STV is larger during periods when there is rainfall

Bingham & Brodnitz (2021)

Evaporation is a large-scale and steady process

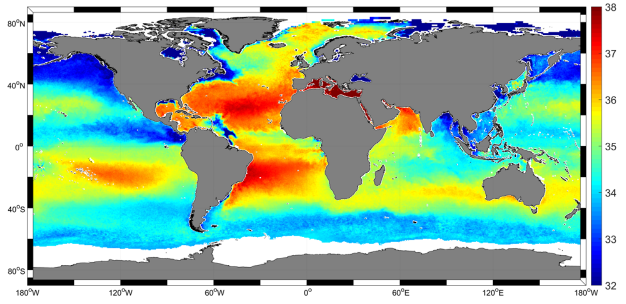
Yu, 2011

- Rainfall is a small-scale and intermittent process

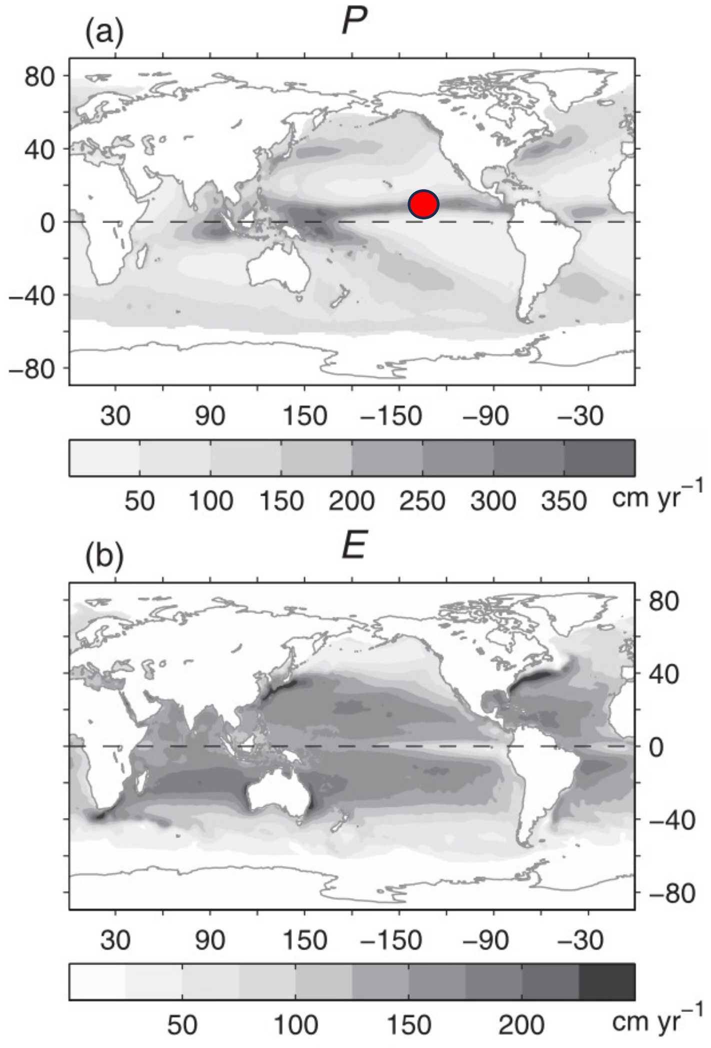


Rainfall accumulation from ship-based radar in the tropical Pacific

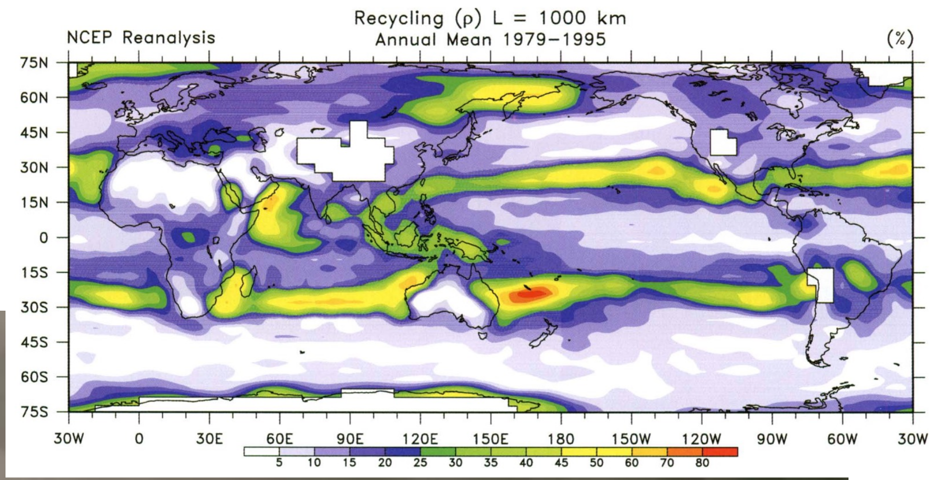
Rutledge et al. 2019



Esa.int



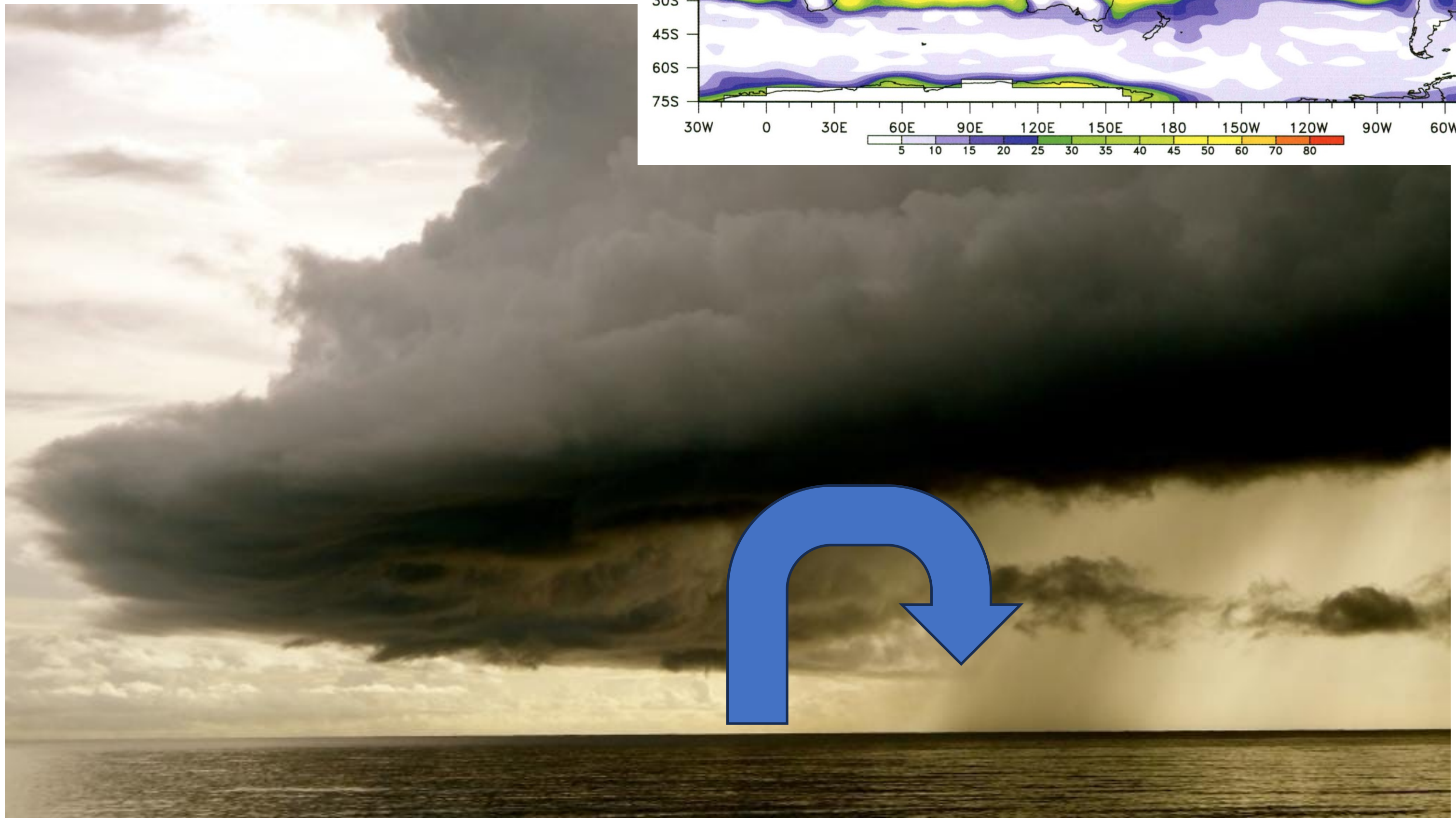
Moisture recycling (Trenberth, 2003)



To what extent does the atmosphere add salinity/density variance to the upper ocean through the recycling of moisture?

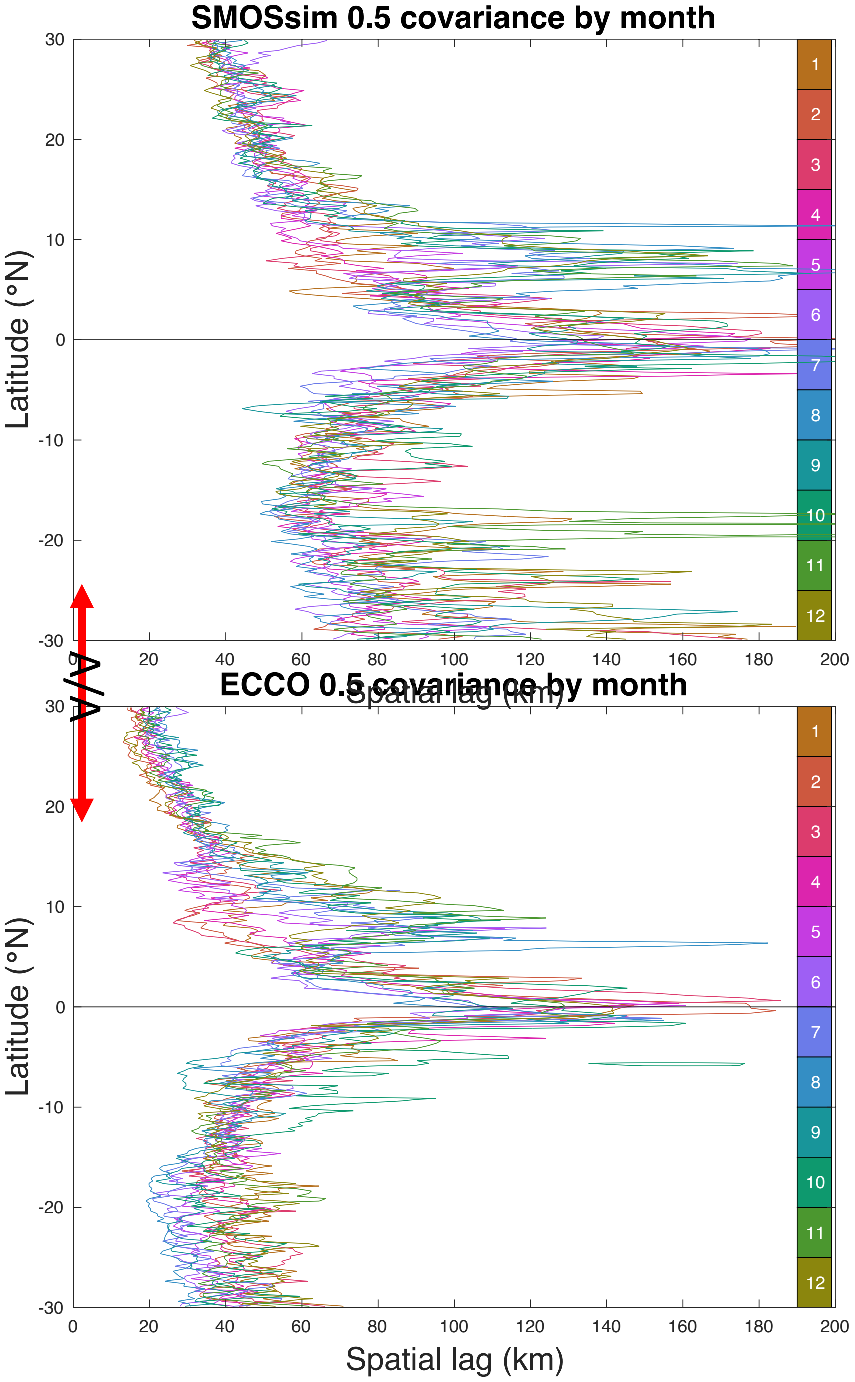
What impact does the added salinity variance have on upper-ocean processes?

Can salinity variance be used to diagnose rainfall?



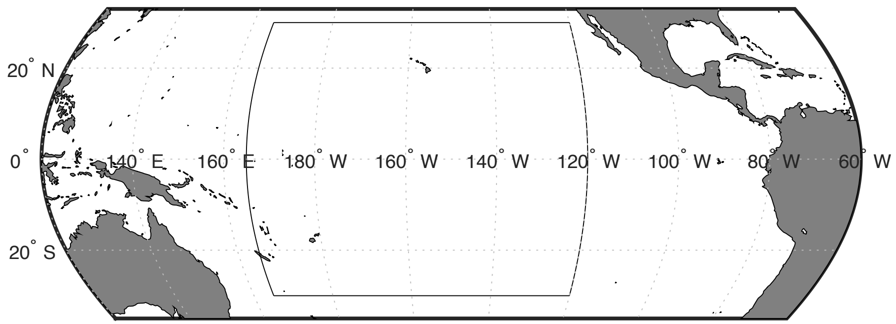
https://amiduedson.medium.com/3-types-of-rainfall-fcfadcaadbef

Comparing zonal covariance between unfiltered (2 km) ECCO data and simulated SMOS



Simulated SMOS L3 zonal covariance – 0.5 contour

ECCO zonal covariance – 0.5 contour



Random thoughts…

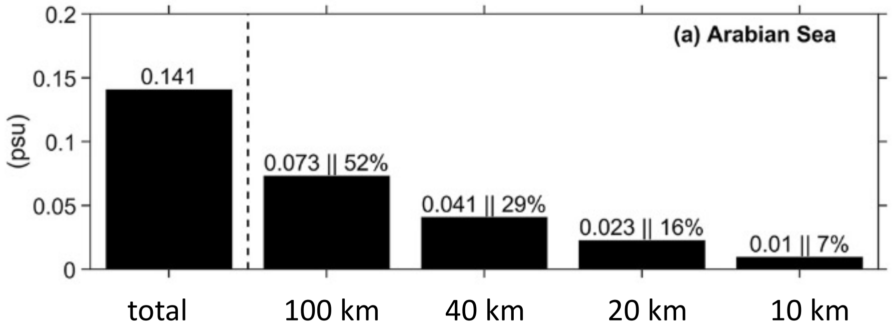
- Atmosphere and ocean are connected at short spatial scales through the input of SSS variance and recycling of moisture
- Rainfall is a small-scale, patchy and intermittent process, and its impact on upper-ocean circulation is not well-understood
- Large portions of the SSS spatial spectrum are unsampled with current technology, especially in mid- and high-latitudes
- Observed SSS spatial scales are limited by the sampling
- Can short spatial scale variability be used as a proxy for rainfall?
- Rainfall may be more effective at generating SSS spatial variance than submesoscale stirring
- The connection between large-scale SSS distribution and small-scale processes is not well-understood, especially in the tropics

Extra slides

Subfootprint variability (SFV)

Median SFV for different footprint sizes using NCOM. Grid spacing 1 km, effective resolution ~10 km

D'Addezio et al., 2019



Percent of variance as a function of spatial scale for the Arabian Sea

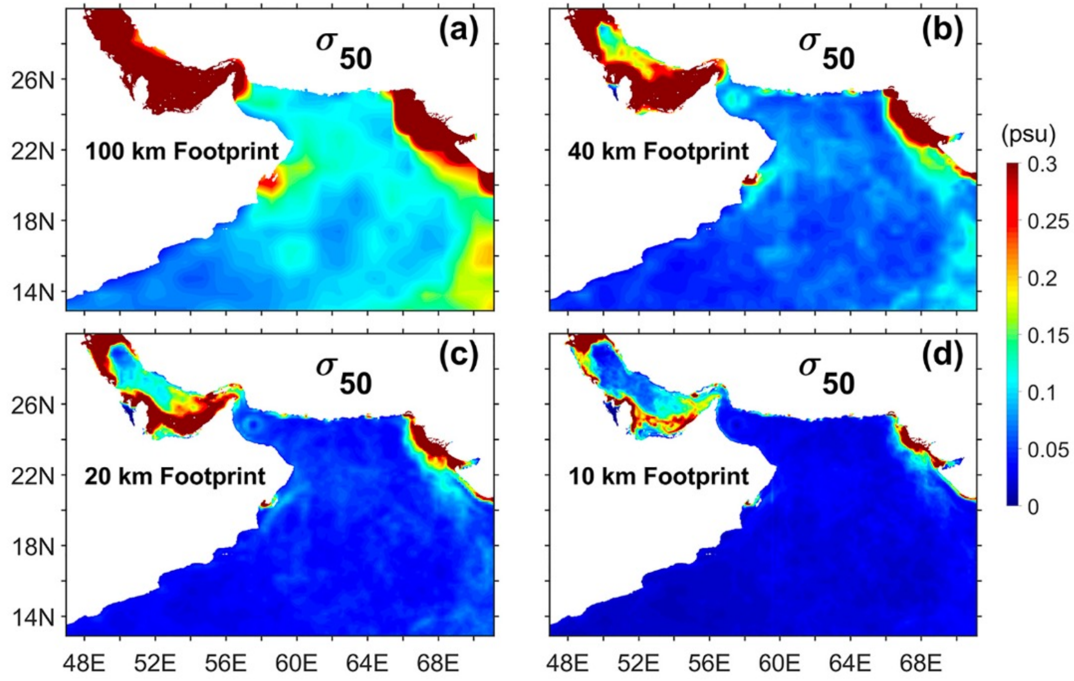
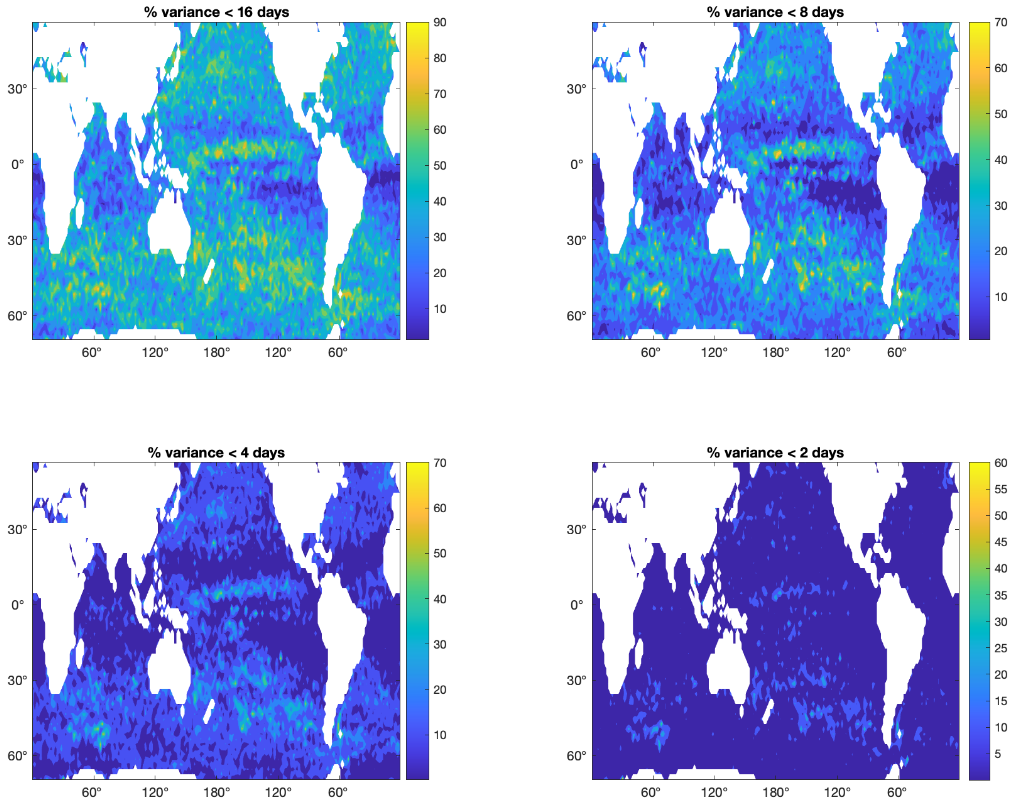
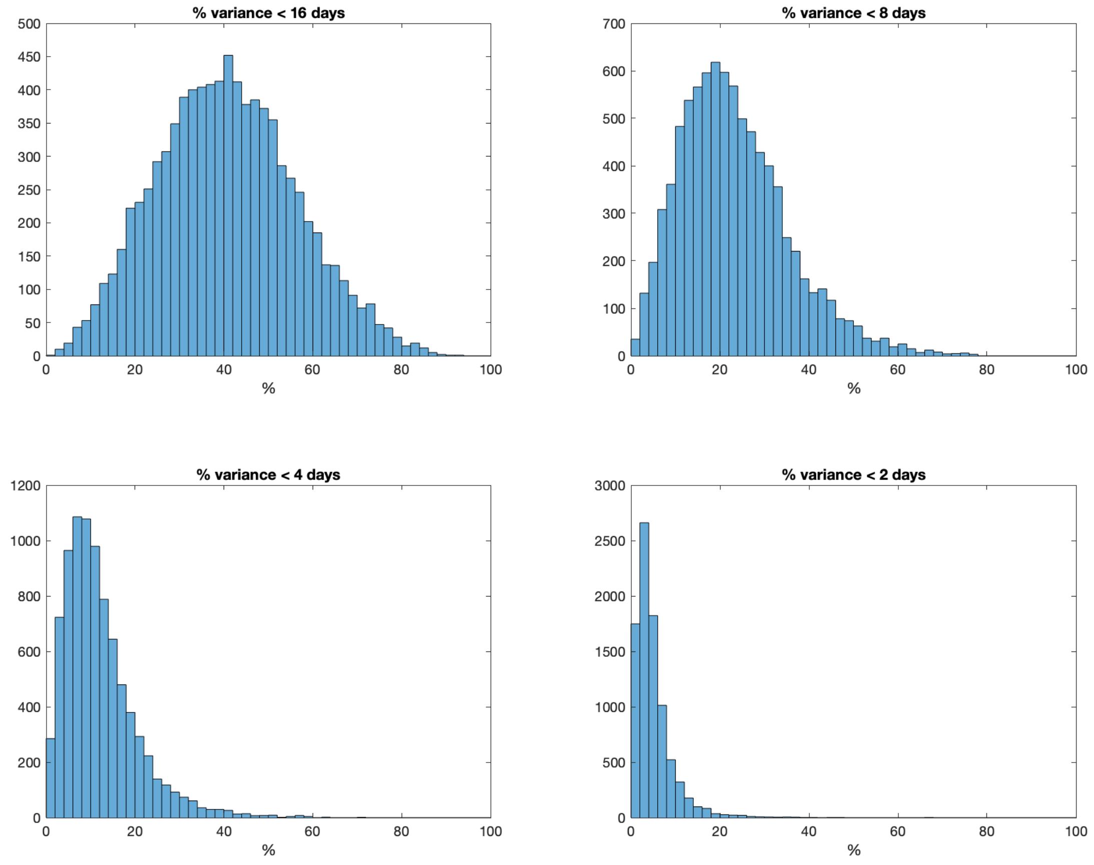


Fig. 6. Arabian Sea σ_{50} (psu) for footprint sizes (a) 100 km, (b) 40 km, (c) 20 km, and (d) 10 km.

Percent variance by time scale

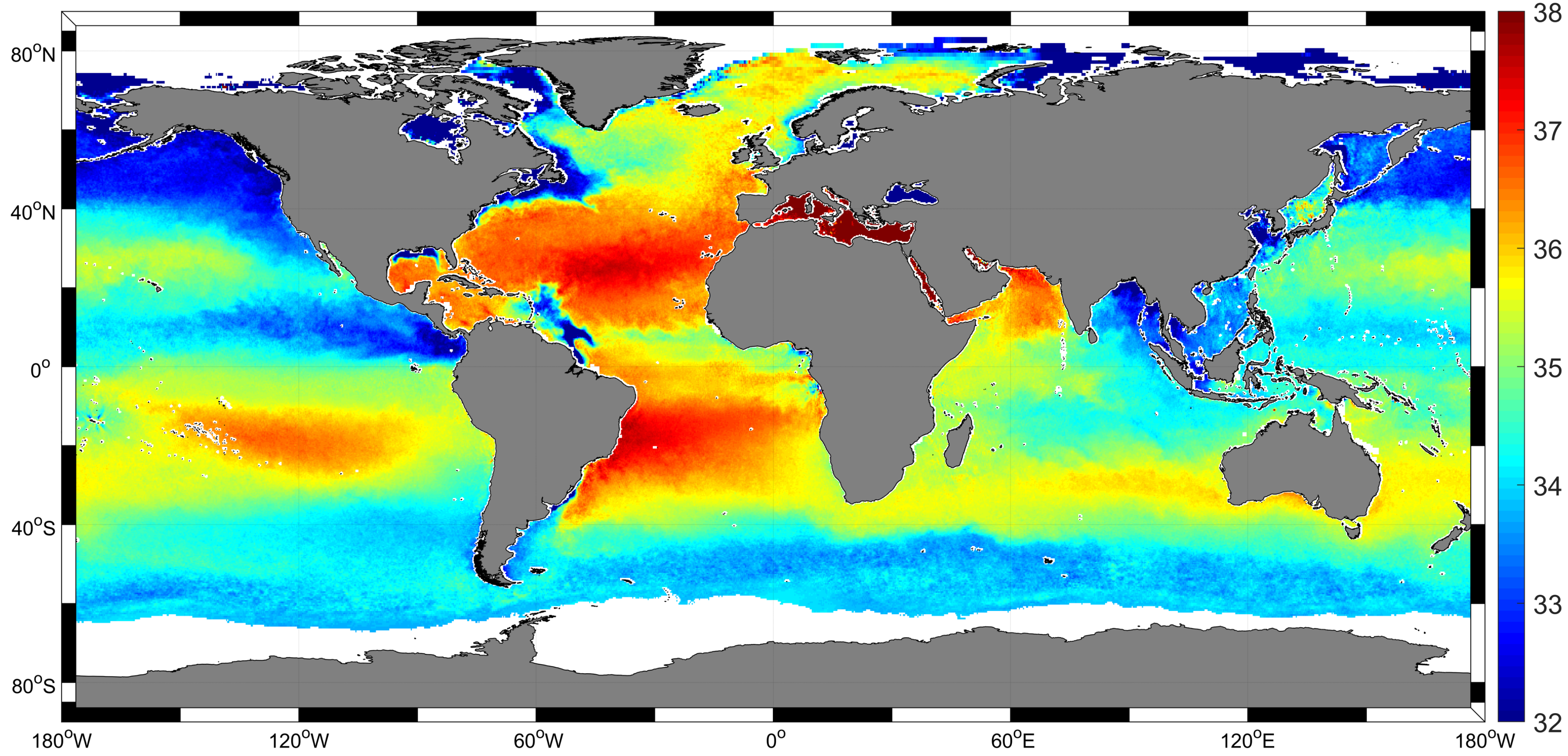


Percent of variance with time scale < the given value (e.g. 16 days)

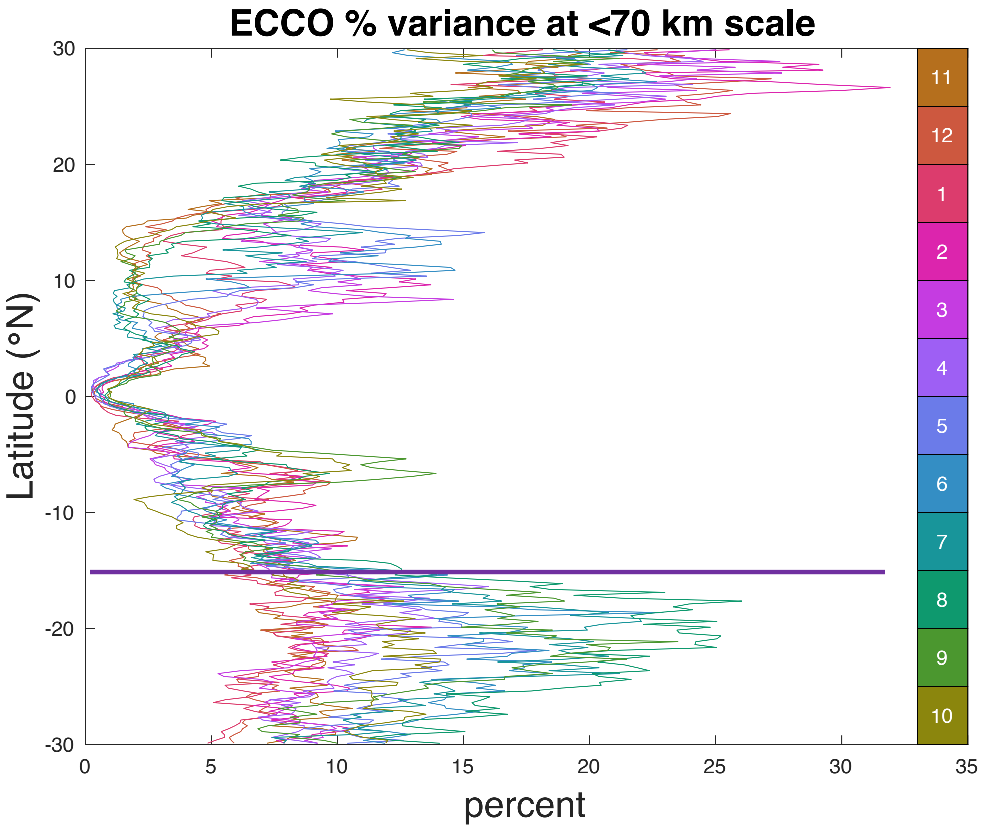


These are histograms of the data presented at left

Mean SSS


80°N
40°N
0°
40°S
80°S
180°W
120°W
60°W
0°
60°E
120°E
180°W
38
37
36
35
34
33
32

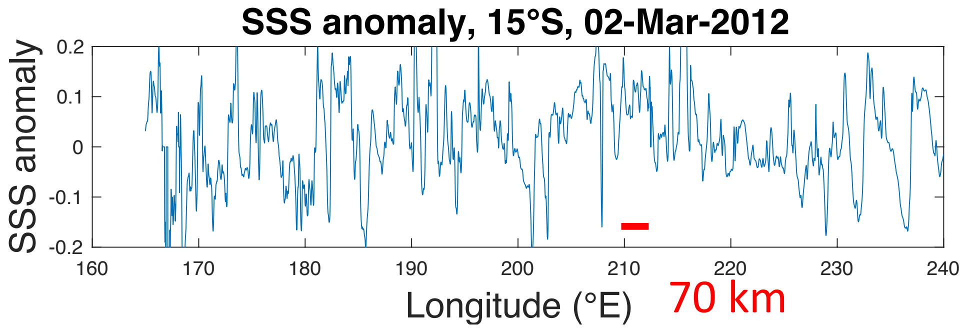
Percent zonal variance at scales <70 km

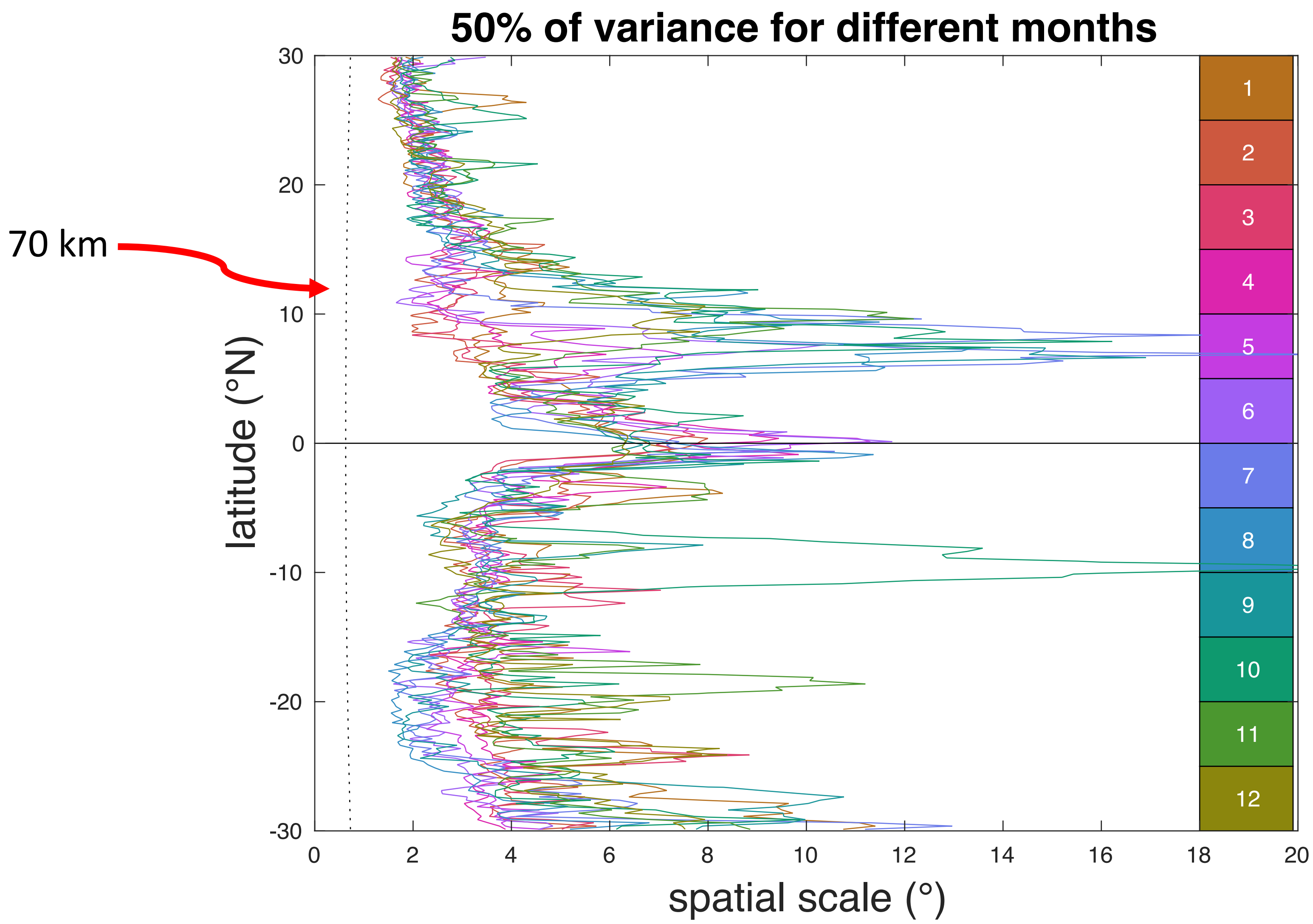


Monthly mean removed

Different colors are different months – key at right

In mid-latitudes, percentages are 5-25%




50% of variance for different months
70 km
latitude (°N)
spatial scale (°)
30
20
10
0
-10
-20
-30
0
2
4
6
8
10
12
14
16
18
20
1
2
3
4
5
6
7
8
9
10
11
12