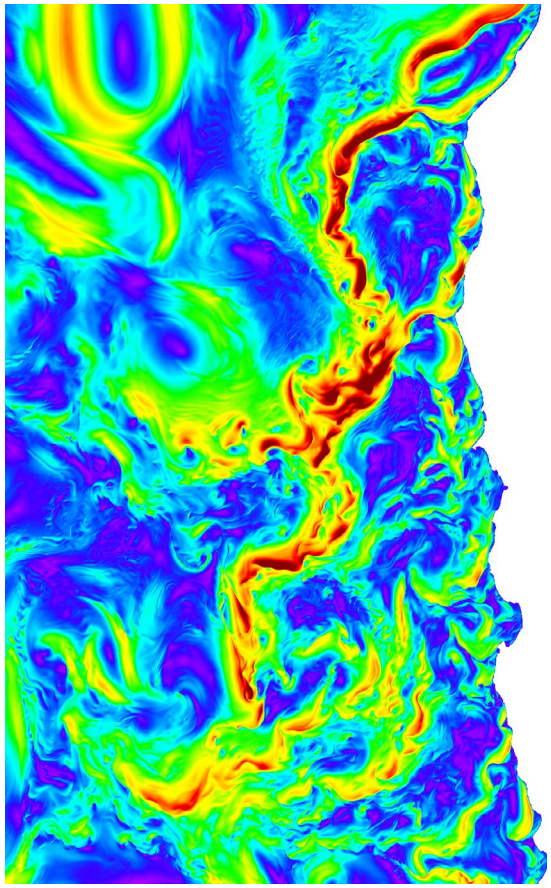
Future Prospects for Estimation of Surface Ocean Velocity and Vorticity from a Winds and Currents Mission (WaCM)

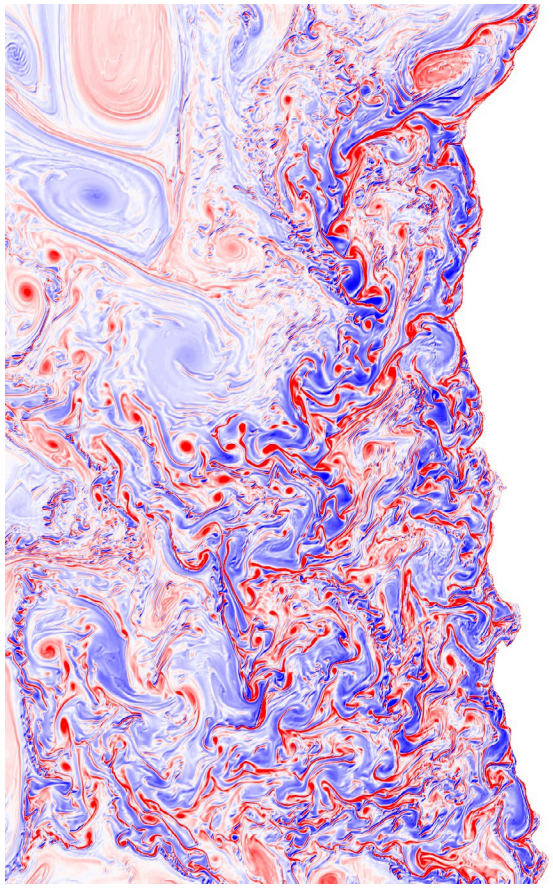
Dudley Chelton
Oregon State University

with contributions from

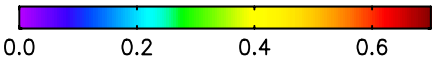
Michael Schlax, Roger Samelson, Tom Farrar,
Jeroen Molemaker and Jim McWilliams

Current Speed and Vorticity in the CCS: ROMS Model with 0.5 km x 0.5 km Grid Resolution

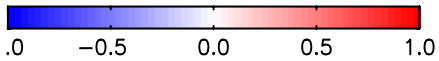




100 km

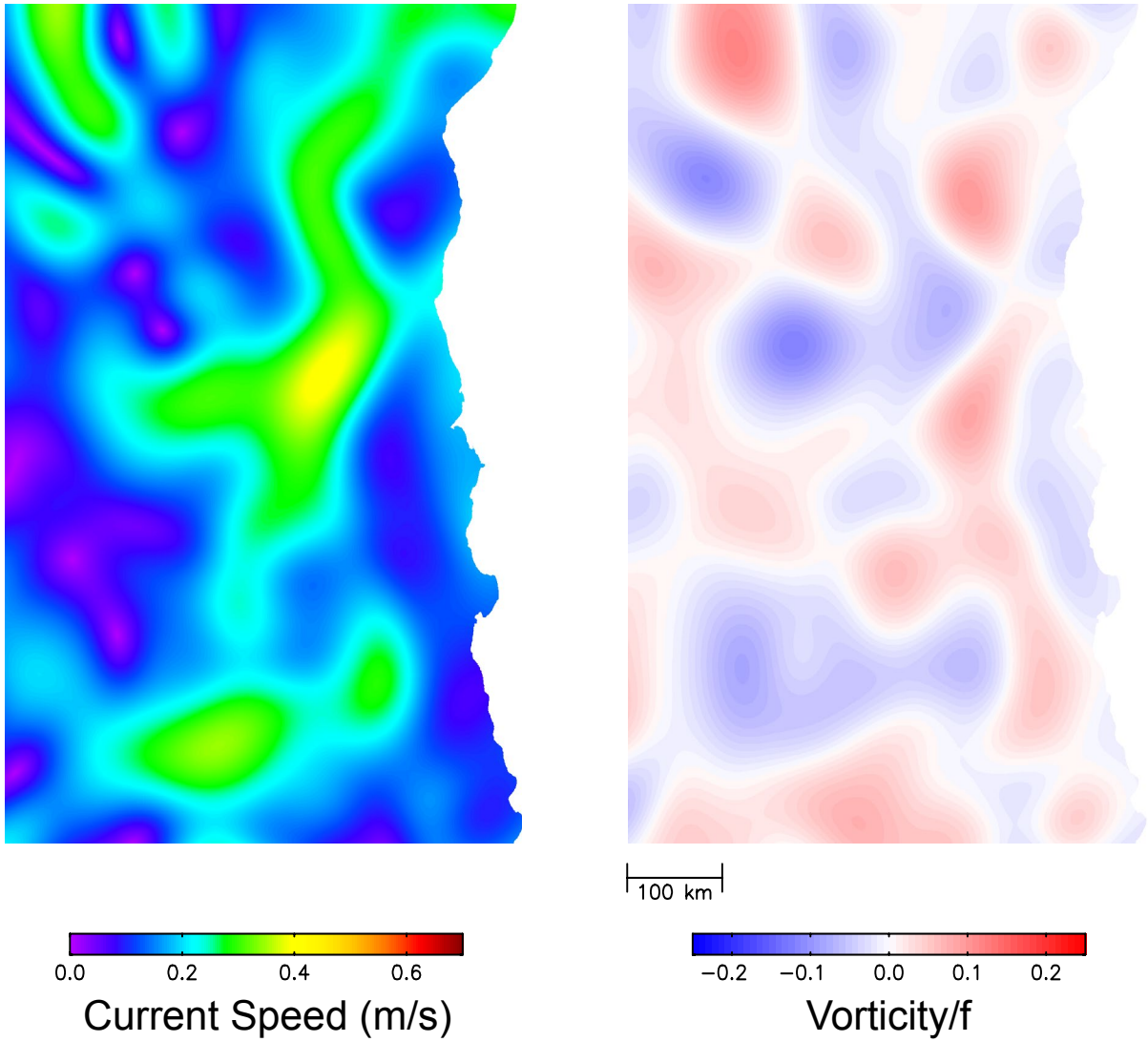


Current Speed (m/s)



Vorticity/f

Current Speed and Vorticity in the CCS: Present Capabilities from AVISO SSH Fields Geostrophic with 200 km x 1 month Smoothing



Future Satellite Instruments for Observations of Mesoscale to Submesoscale Variability

1. Surface Water and Ocean Topography Mission

   SWOT will observe SSH across a swath of width 120 km with a 20 km nadir gap, a footprint size of 1 km and a measurement error of 2.74 cm. The scheduled launch date is 2021.

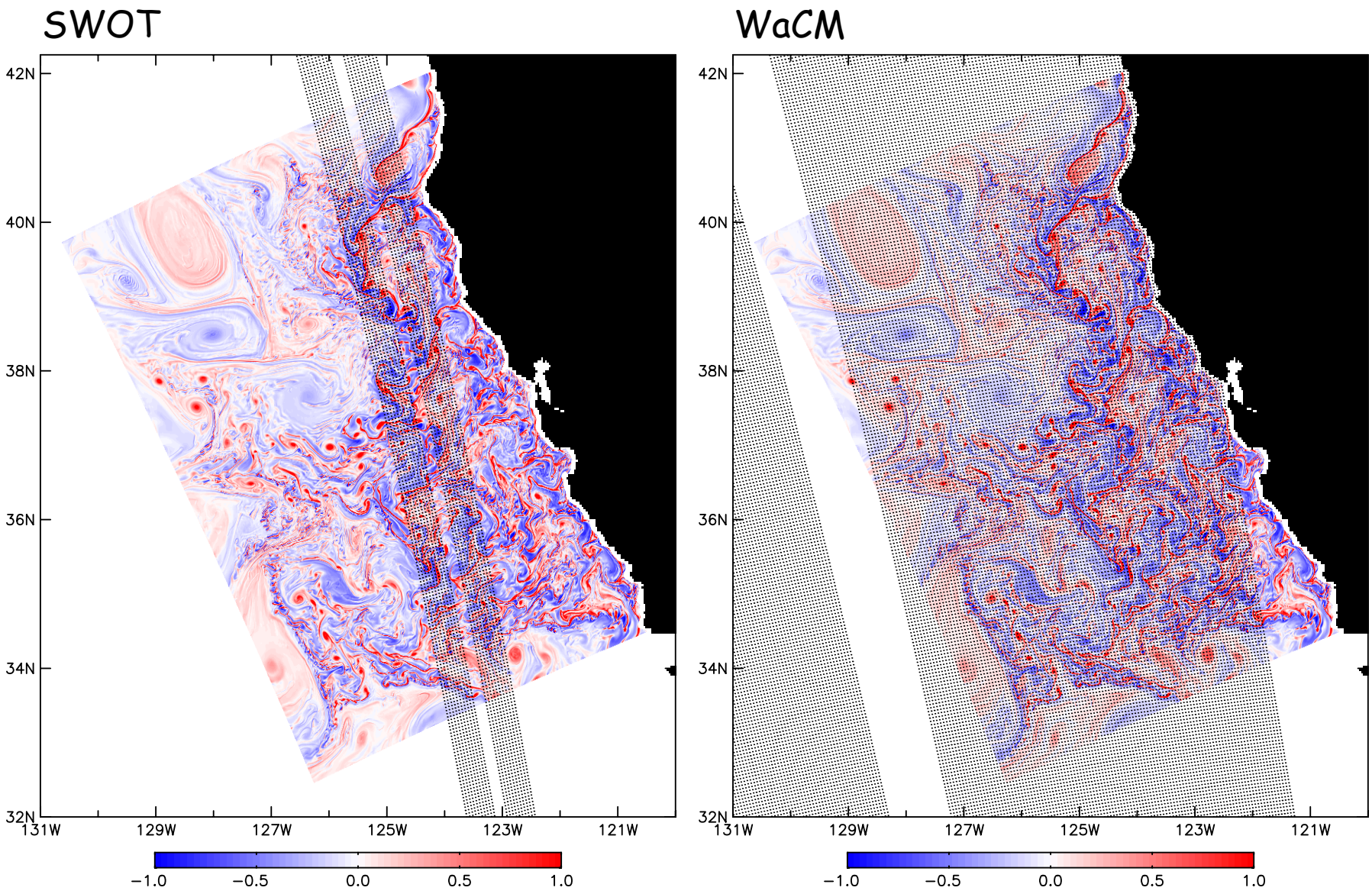
   This requires double differentiation to get geostrophic vorticity ζ_g.

2. Winds and Currents Mission Concept

   WaCM will observe surface winds and surface ocean velocity across a swath of width 1300 km with a 100 km nadir gap and a footprint size of 5 km. The baseline measurement errors are 0.5 m/s for surface currents. WaCM is under consideration for the Decadal Survey for Earth Science from Space. The earliest possible launch date is 2023.

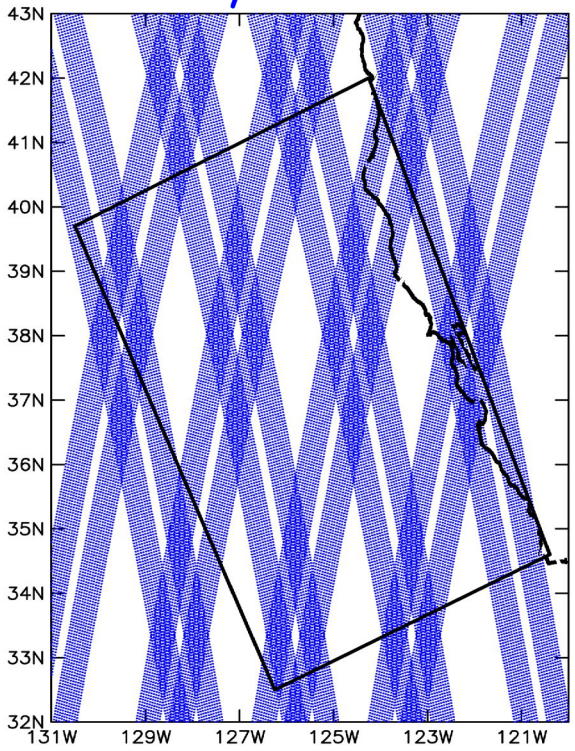
   This requires single differentiation to get vorticity ζ and is not subject to limitations of the geostrophic approximation.

SWOT versus WaCM Measurement Swaths

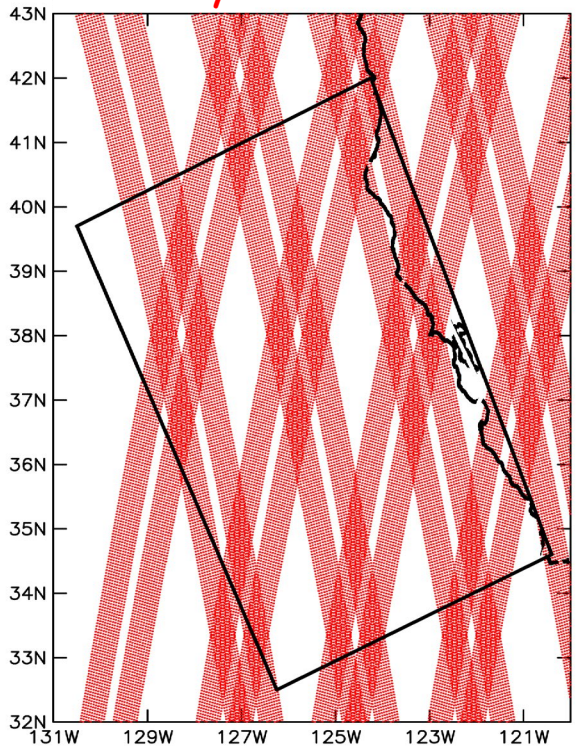


SWOT 4-Day and 14-Day Subcycles in the CCS Region during Each 21-Day Exact Repeat Period

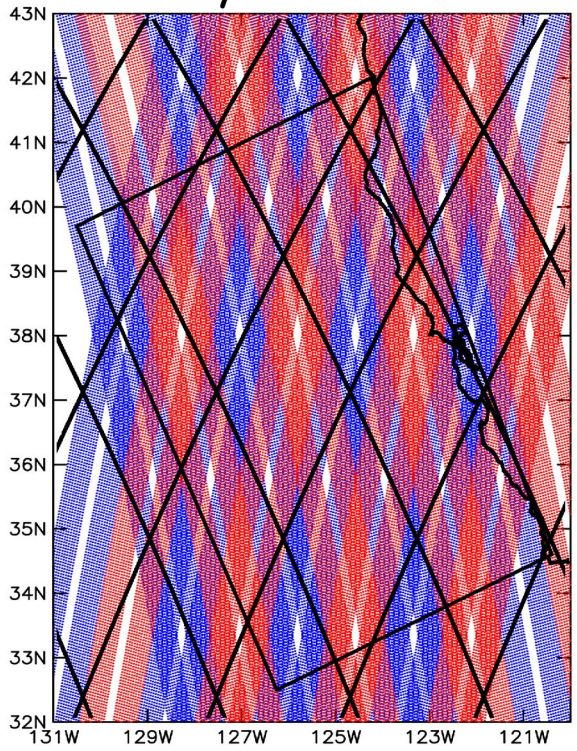
Days 3.5-7.0



Days 13.5-17.0



Days 3.5-17.0

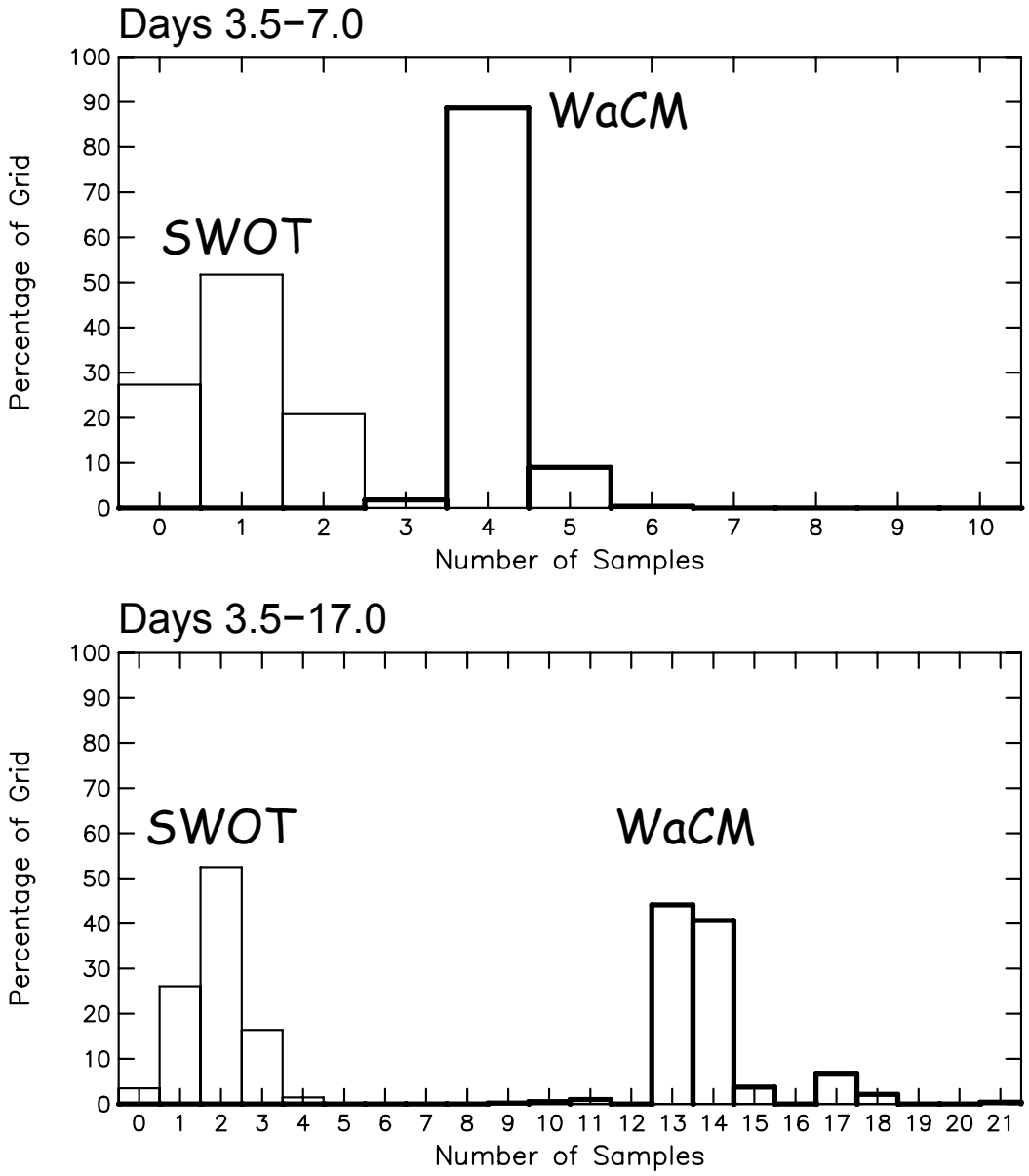


Black lines are TOPEX and Jason-1 & 2 ground tracks

The SWOT sampling pattern over the CCS consists of:

1. A coarse set of intersecting swaths over a 4-day period.
2. A 6.5-day gap with no coverage.
3. Another coarse set of intersecting swaths over a 4-day period that is offset longitudinally from the first 4-day subcycle.
4. Another 6.5-day gap with no coverage.

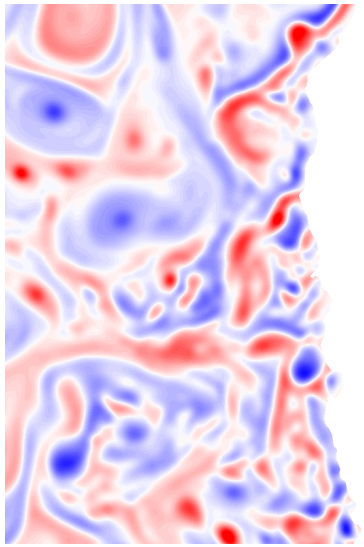
4-Day and 14-Day Sampling by WaCM and SWOT



WaCM 4-Day Average Vorticity/f with Filter Cutoff Wavelength 50 km

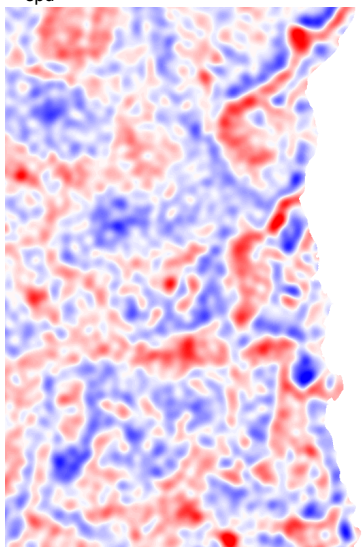
Error Free

a)



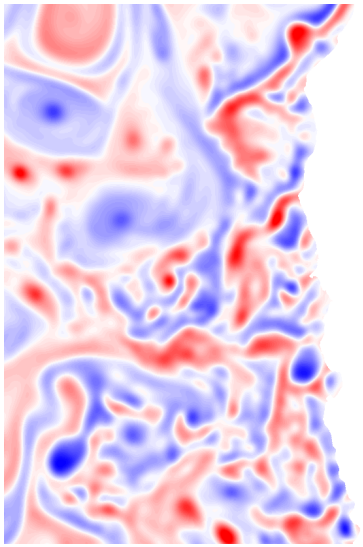
σ_{spd} = 0.5 m/s

b)



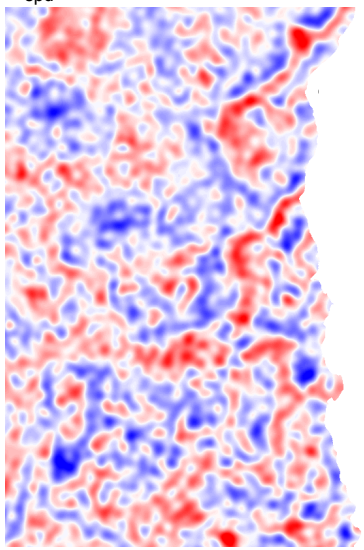
Error Free, Sampled

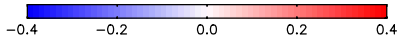
c)



σ_{spd} = 0.5 m/s, Sampled

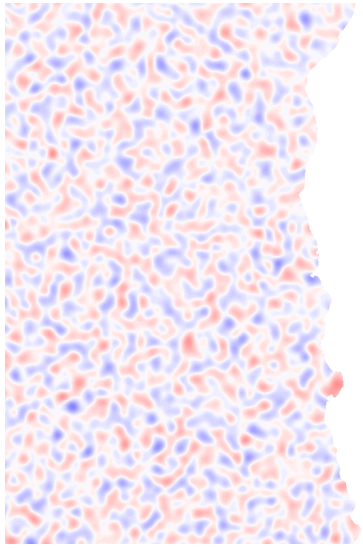
d)



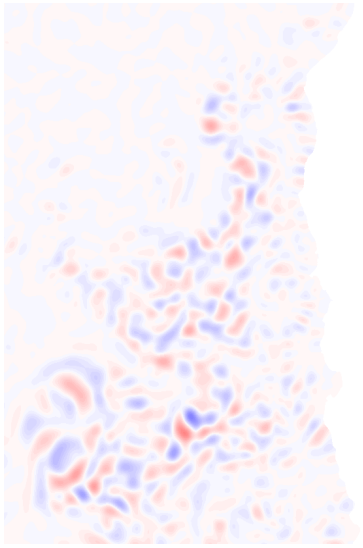


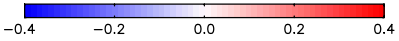
Differences from top left panel

e)

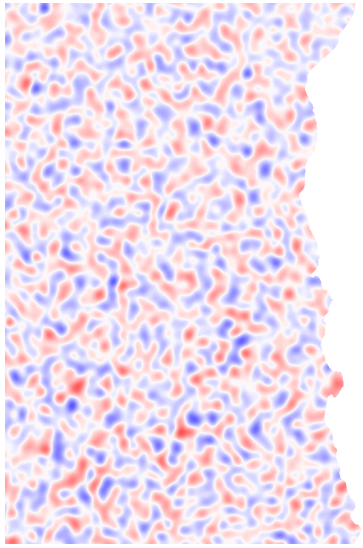


f)

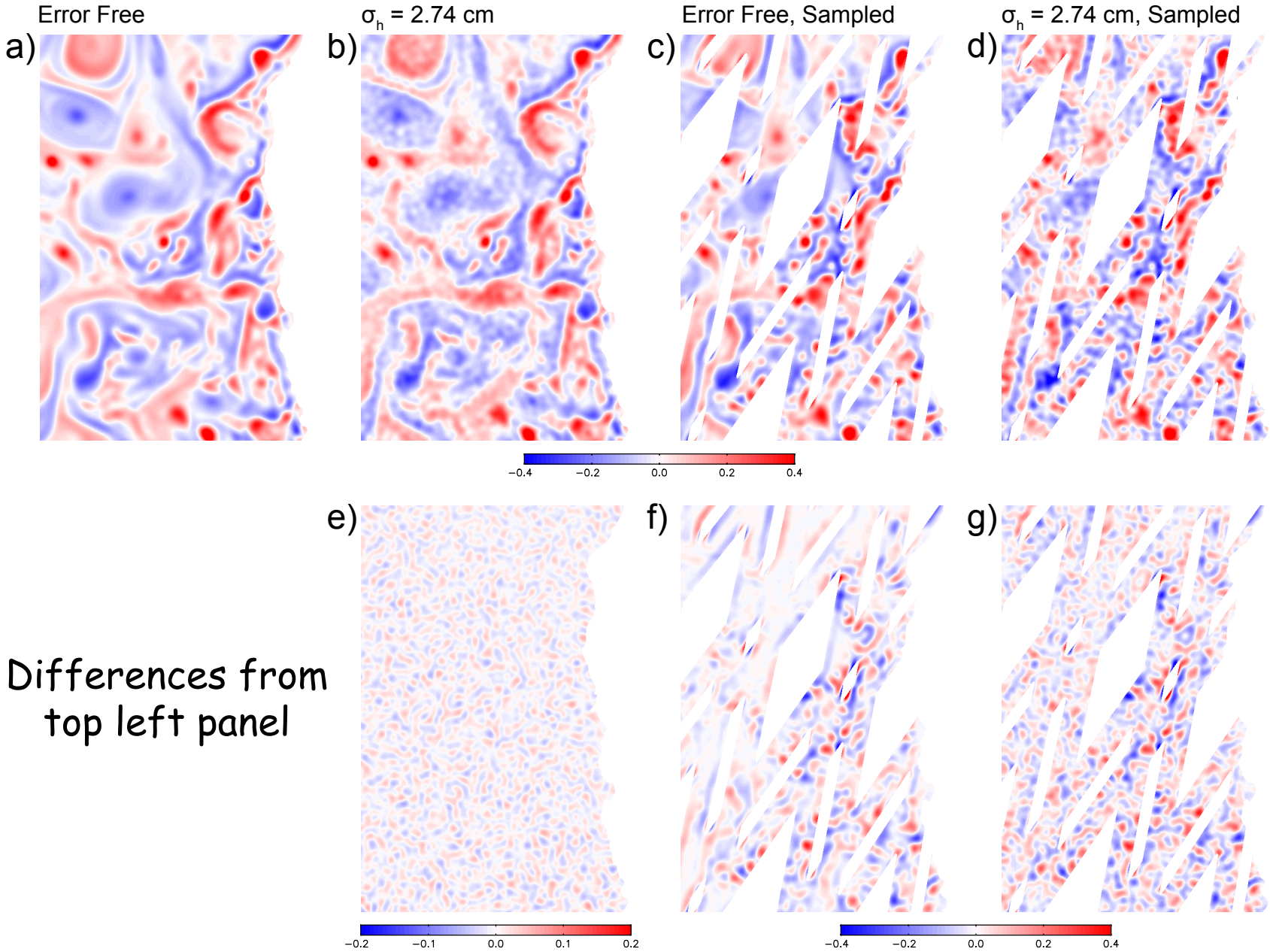




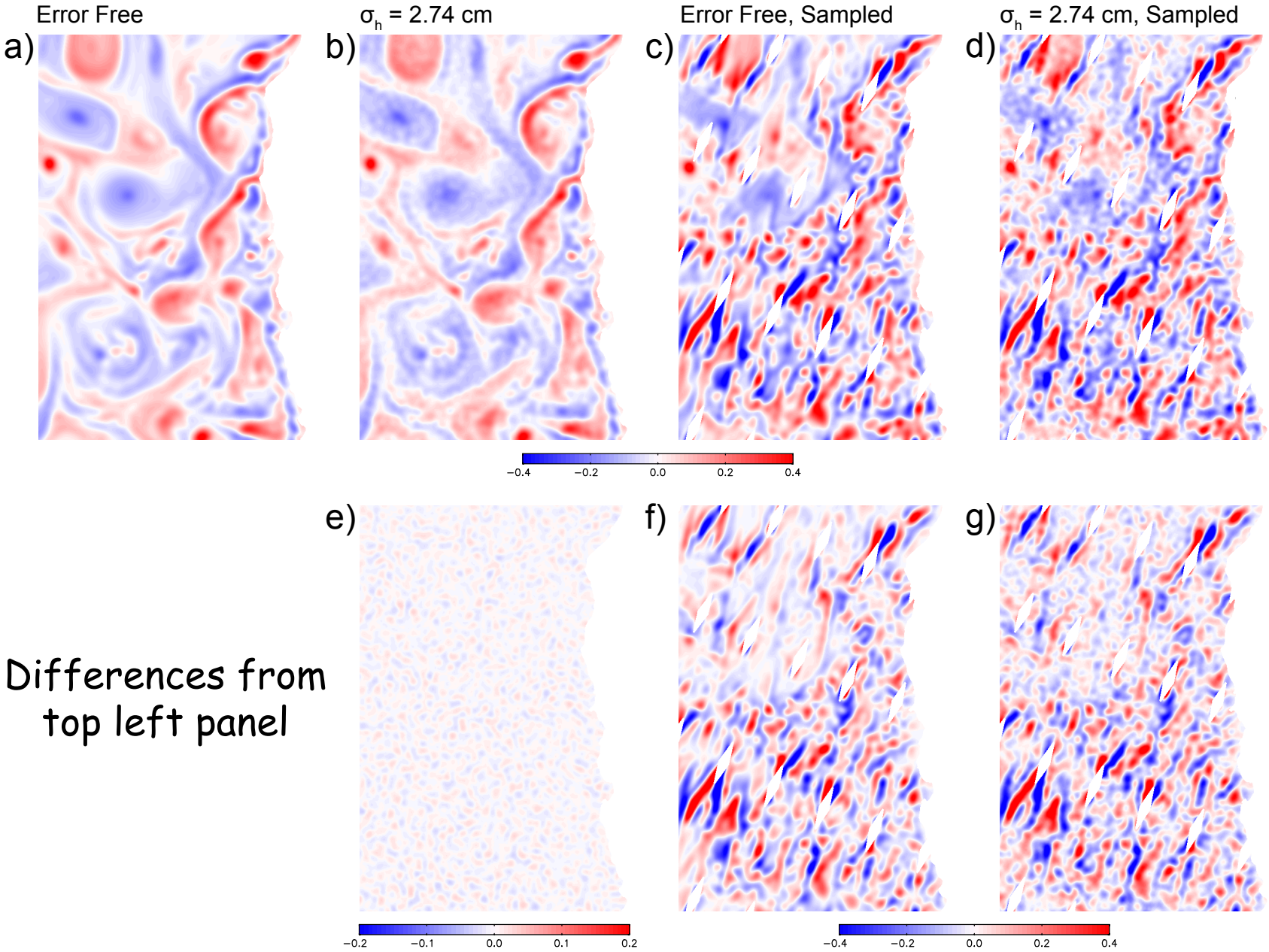
g)



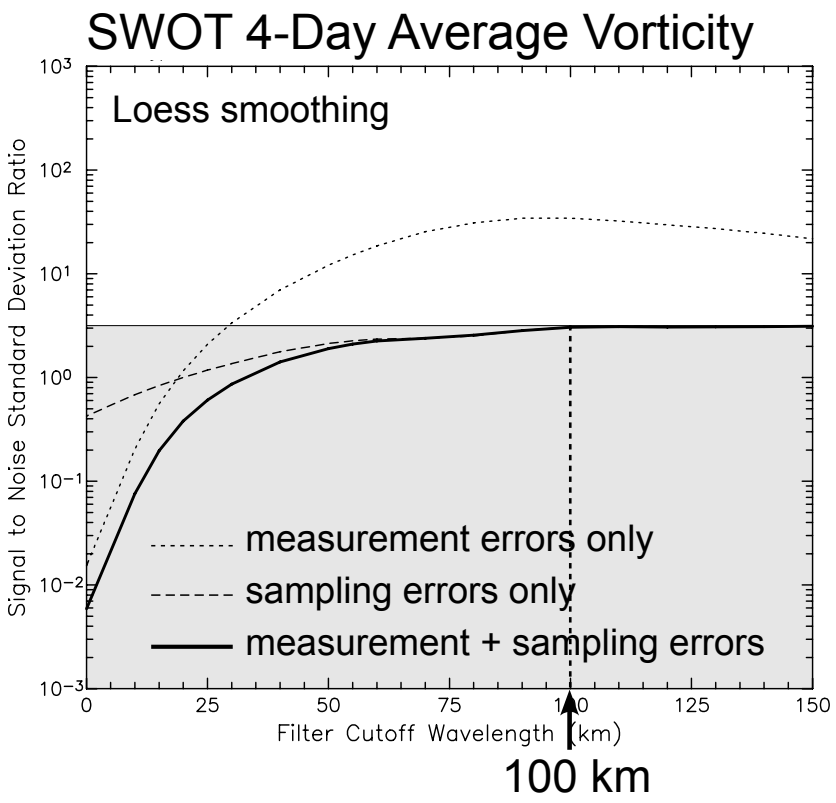
SWOT 4-Day Average Vorticity/f with Filter Cutoff Wavelength 50 km

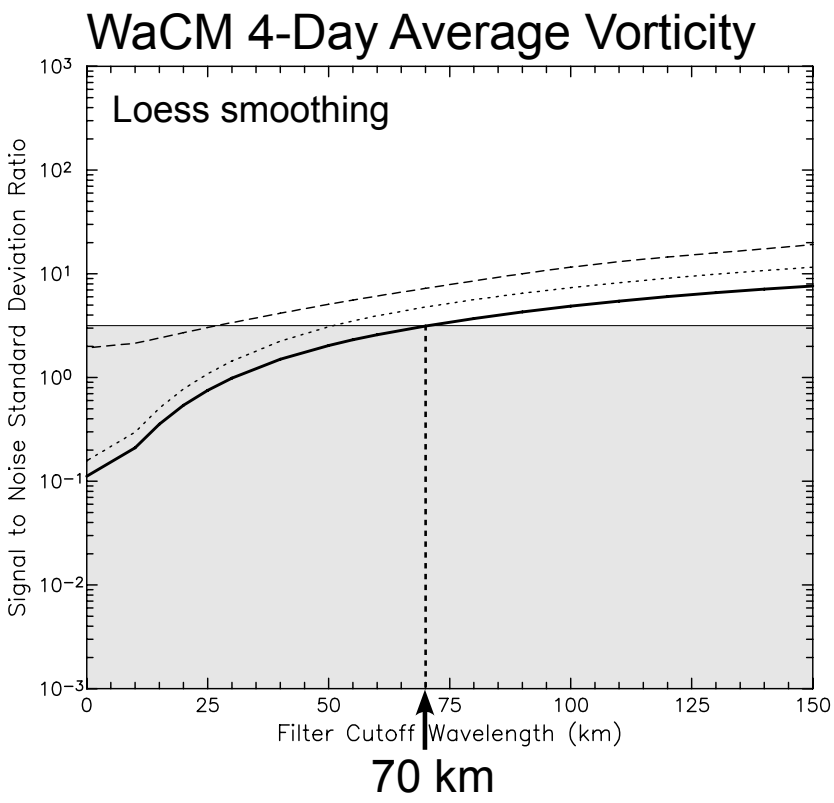


SWOT 14-Day Average Vorticity/f with Filter Cutoff Wavelength 50 km



Signal-to-Noise Standard Deviation Ratio



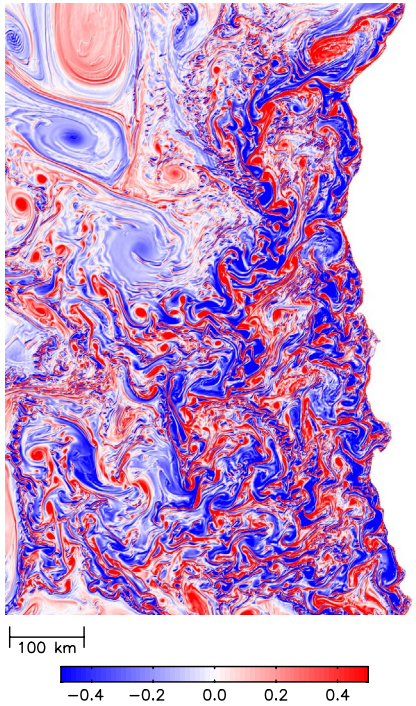


The resolution of SWOT estimates of geostrophic velocity is limited by sampling errors rather than measurement errors.

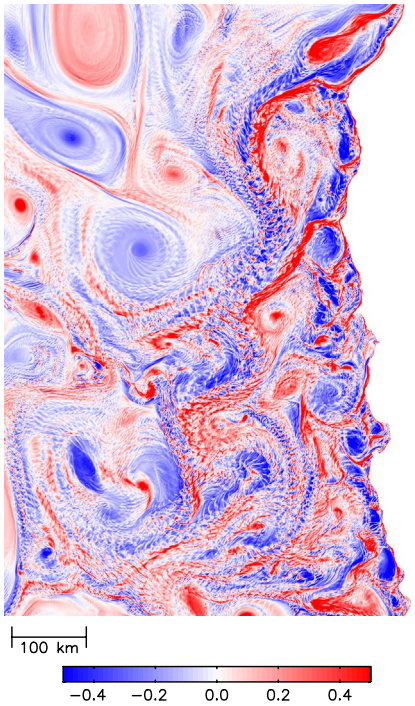
In contrast, the resolution of WaCM estimates of velocity is limited primarily by measurement errors rather than sampling errors.

Vorticity/f

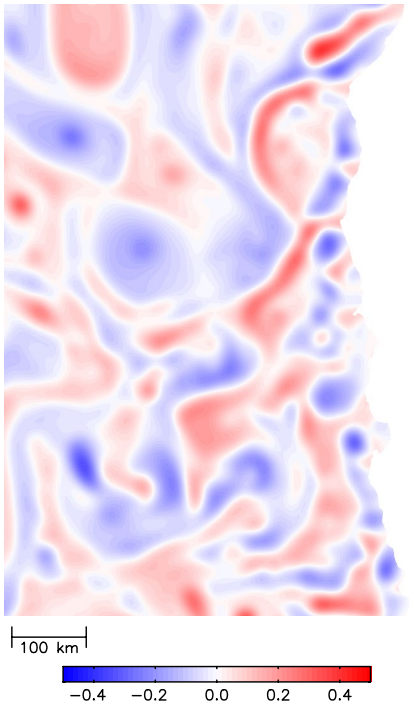
Snapshot
No Smoothing



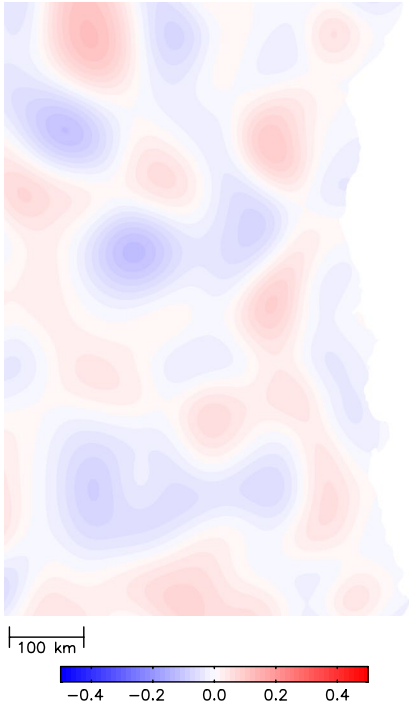
4-Day Average
No Smothing



Baseline Design
4-Day Average
with Filter Cutoff
Wavelength 70 km



Present Capability
30-Day Average
with Filter Cutoff
Wavelength 200 km



The Uniqueness of the WaCM Doppler Scatterometer Mission

Whereas conventional scatterometry measures the wind forcing and altimetry measures the ocean response, Doppler scatterometry measures both the wind forcing and the ocean response from a single instrument.

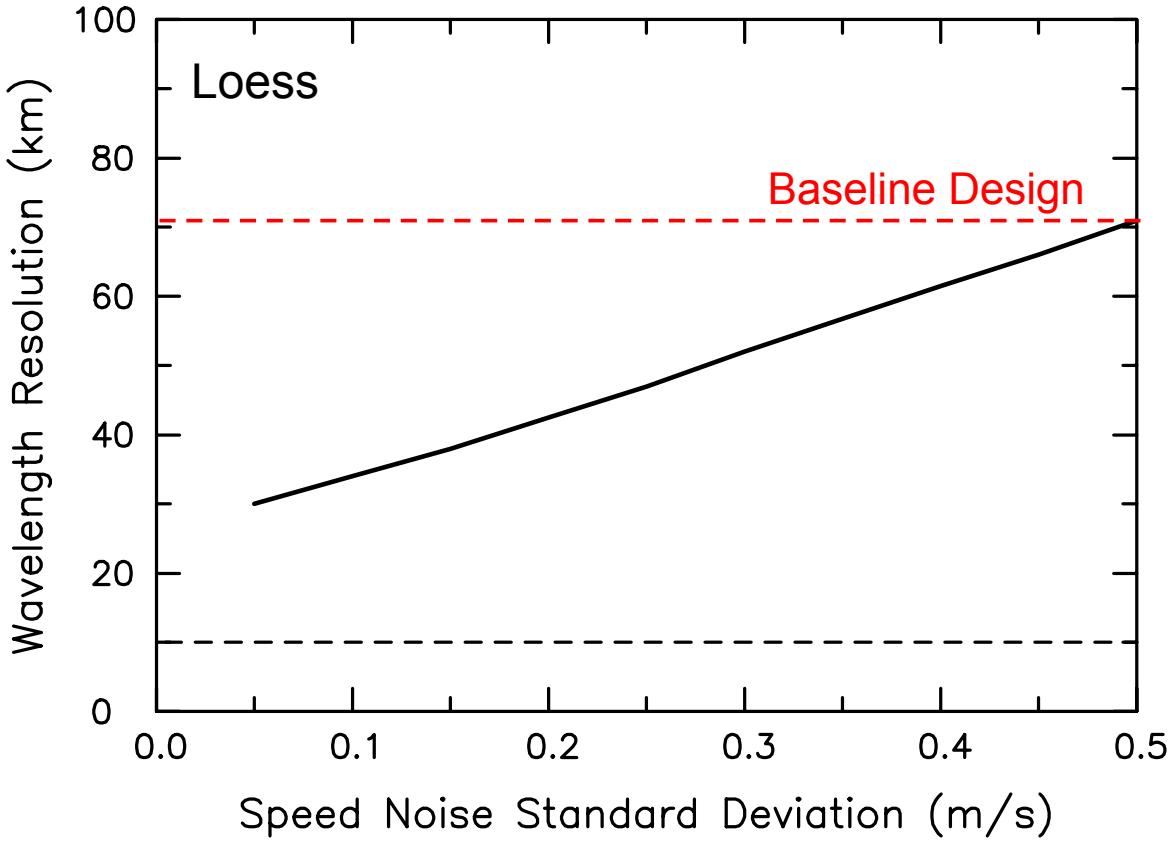
Furthermore, WaCM measurements of surface velocity are not limited by the geostrophic approximation.

Conclusions

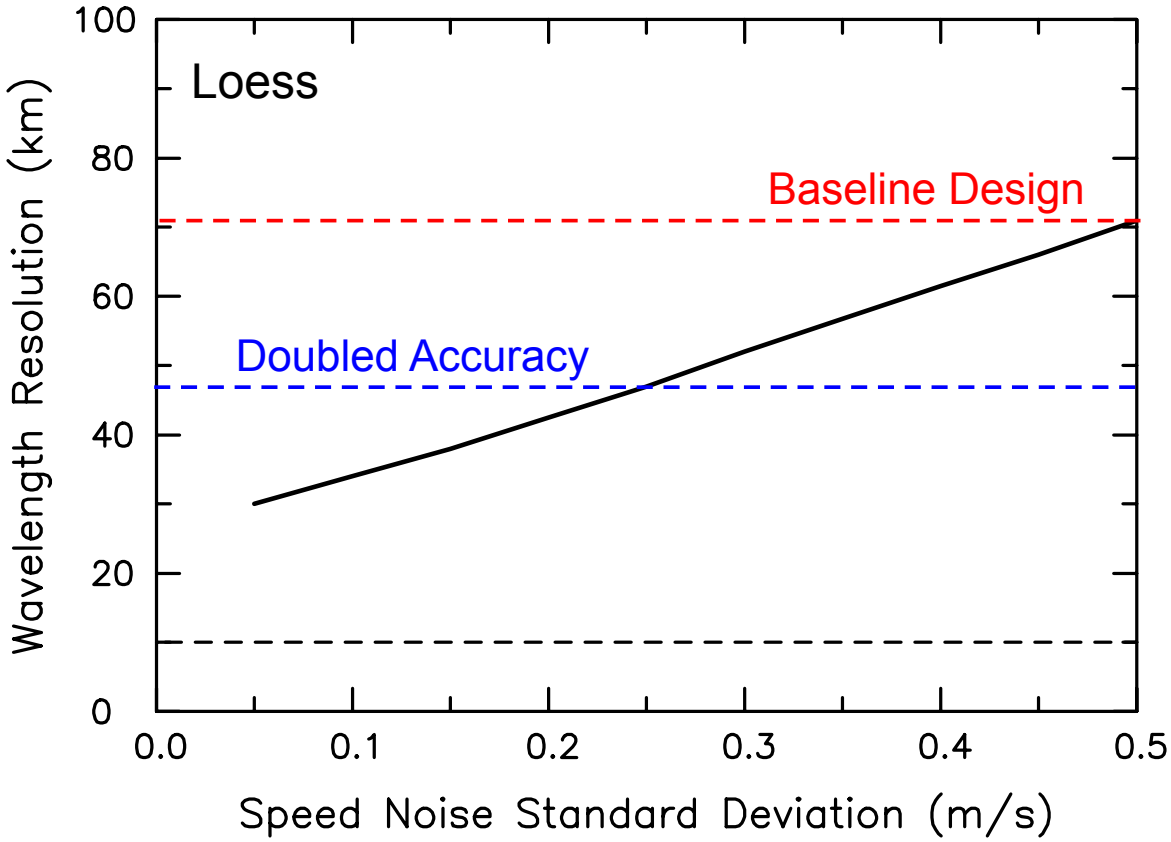
- The effects of measurement and sampling errors are very different for WaCM and SWOT:
  - SWOT is most limited by sampling errors because of its very narrow swath and the rapid evolution of submesoscale variability.
  - WaCM is limited primarily by measurement errors.
- With a noise of 0.5 m/s, WaCM would provide 4-day average maps of current velocity and vorticity with resolutions of ~50 km and ~70 km, respectively, corresponding to radius scales of ~10 km and 15 km.
  - This is far superior to what will be achieved from SWOT.
  - This would also significantly improve the resolution capability of about 200 km and 30-day averages from presently available satellite data.

Extra Figures

Dependence of Wavelength Resolution Capability on WaCM Measurement Noise for Estimates of 4-Day Averaged Vorticity

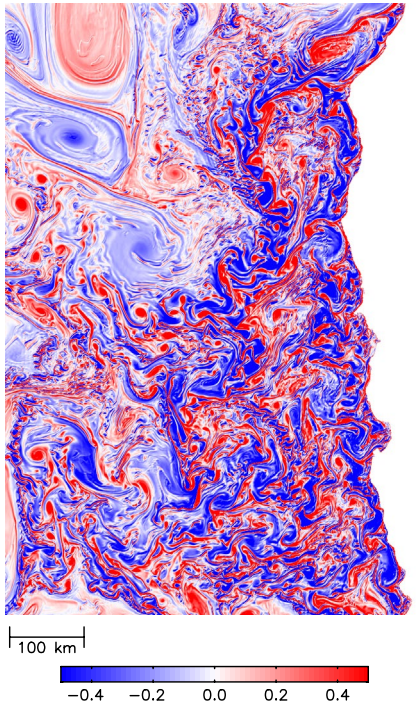


Dependence of Wavelength Resolution Capability on WaCM Measurement Noise for Estimates of 4-Day Averaged Vorticity

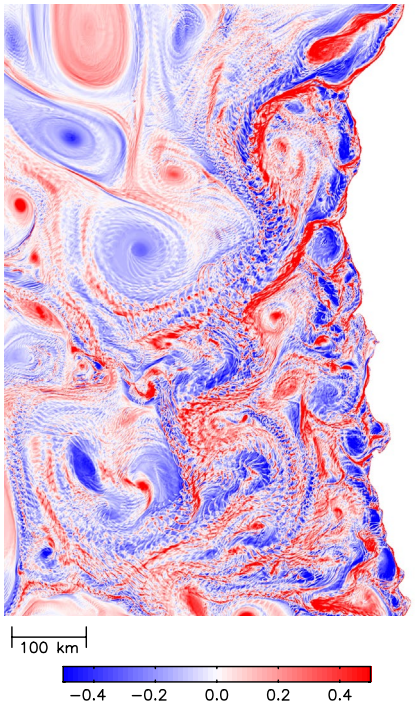


Vorticity/f

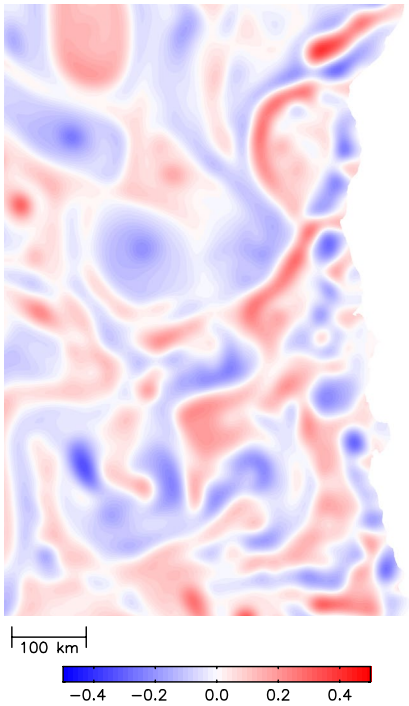
Snapshot
No Smoothing



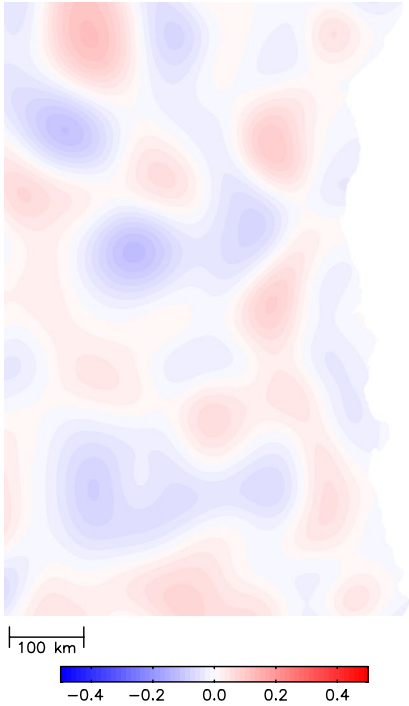
4-Day Average
No Smothing



Baseline Design
4-Day Average
with Filter Cutoff
Wavelength 70 km

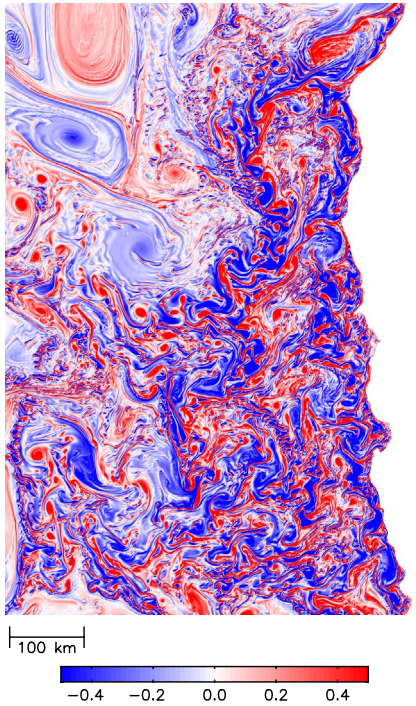


Present Capability
30-Day Average
with Filter Cutoff
Wavelength 200 km

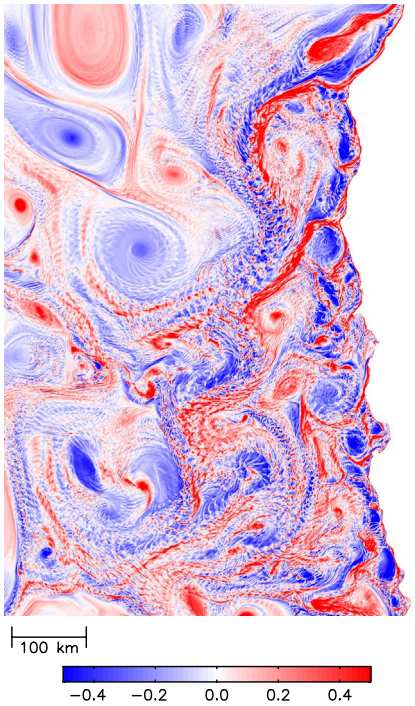


Vorticity/f

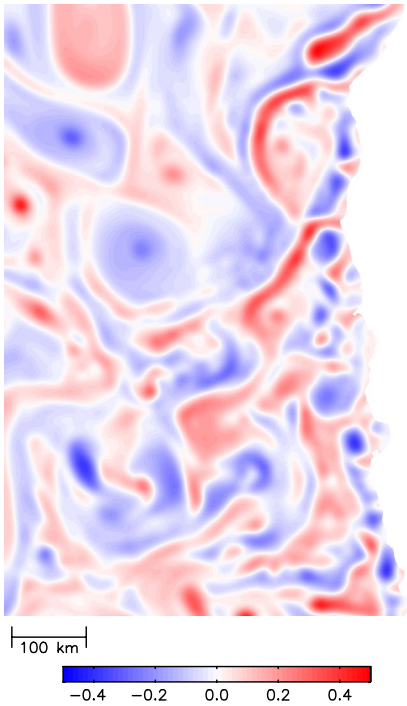
Snapshot
No Smoothing



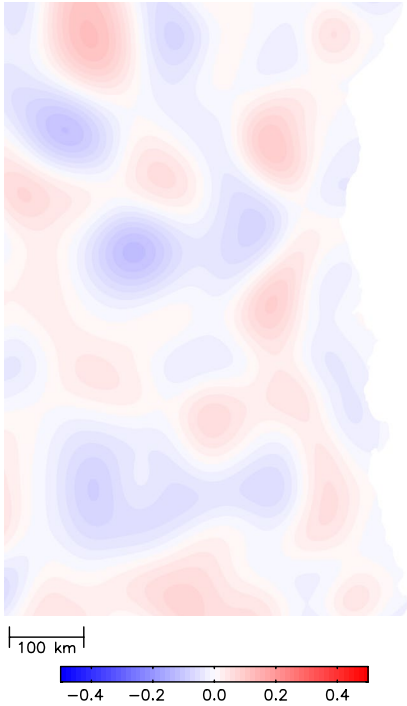
4-Day Average
No Smothing



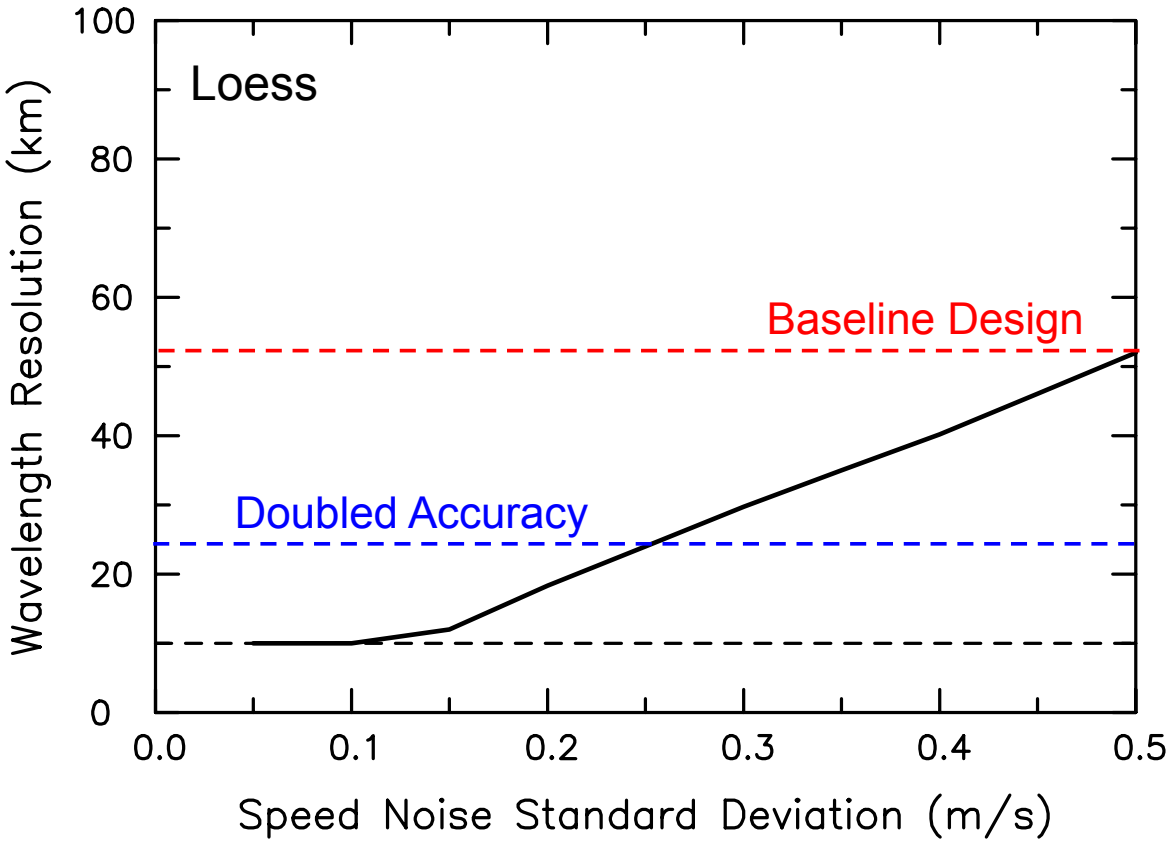
Doubled Accuracy
4-Day Average
with Filter Cutoff
Wavelength 50 km



Present Capability
30-Day Average
with Filter Cutoff
Wavelength 200 km

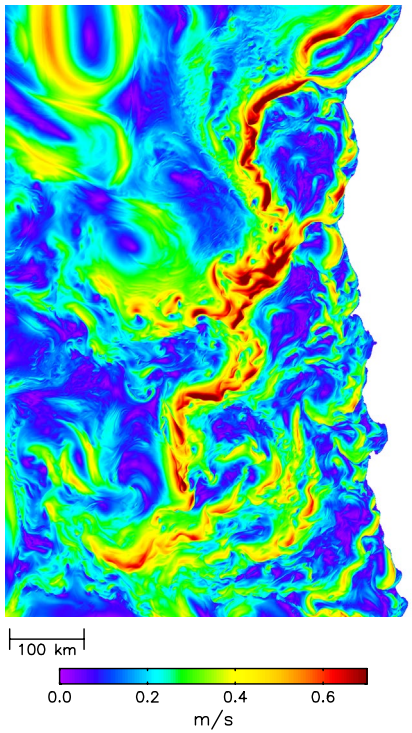


Dependence of Wavelength Resolution Capability on WaCM Measurement Noise for Estimates of 4-Day Averaged Speed

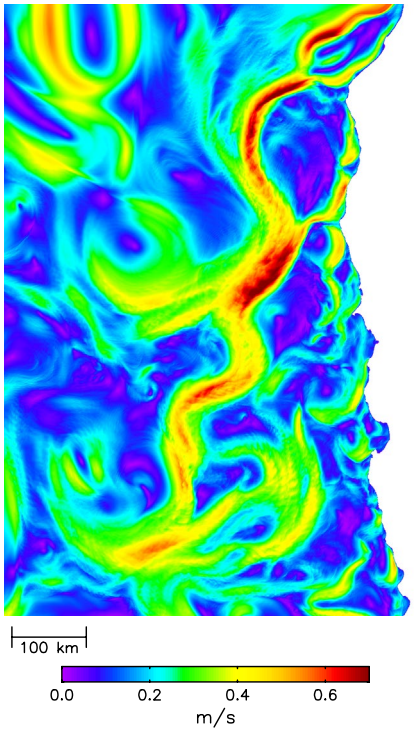


Current Speed

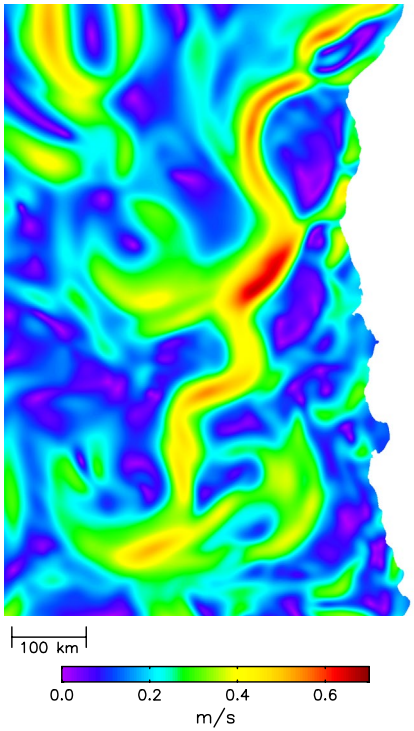
Snapshot
No Smoothing



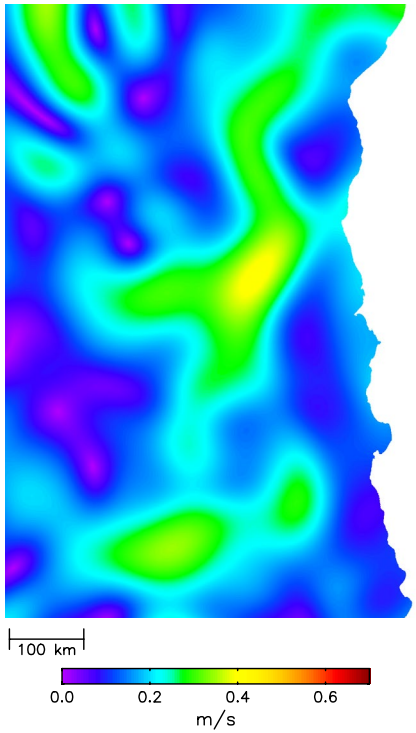
4-Day Average
No Smothing



Baseline Design
4-Day Average
with Filter Cutoff
Wavelength 50 km

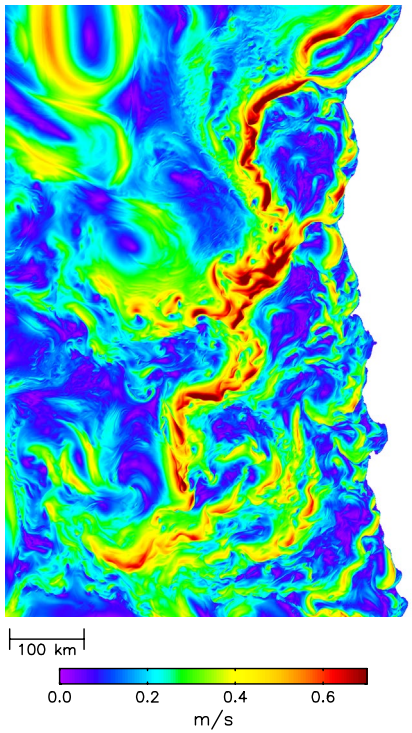


Present Capability
30-Day Average
with Filter Cutoff
Wavelength 200 km

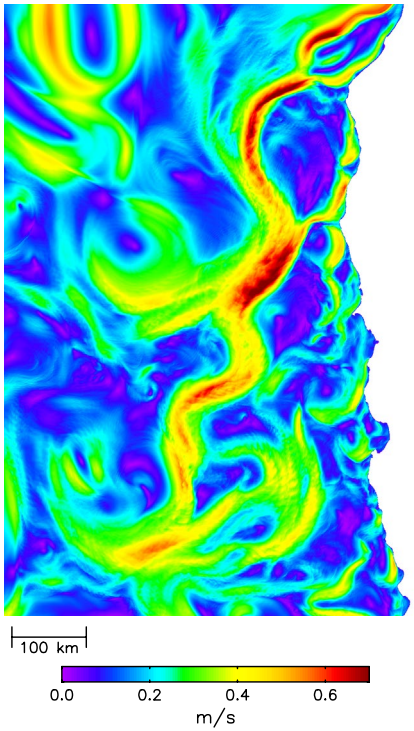


Current Speed

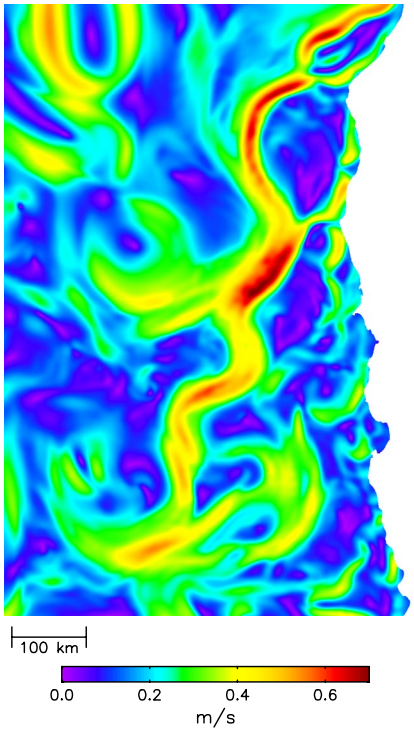
Snapshot
No Smoothing



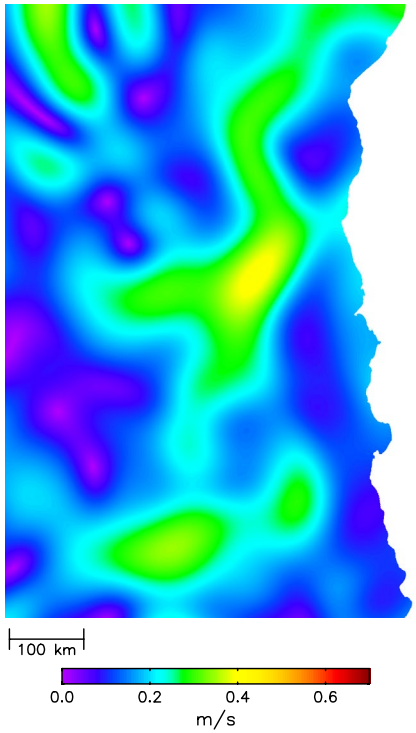
4-Day Average
No Smothing



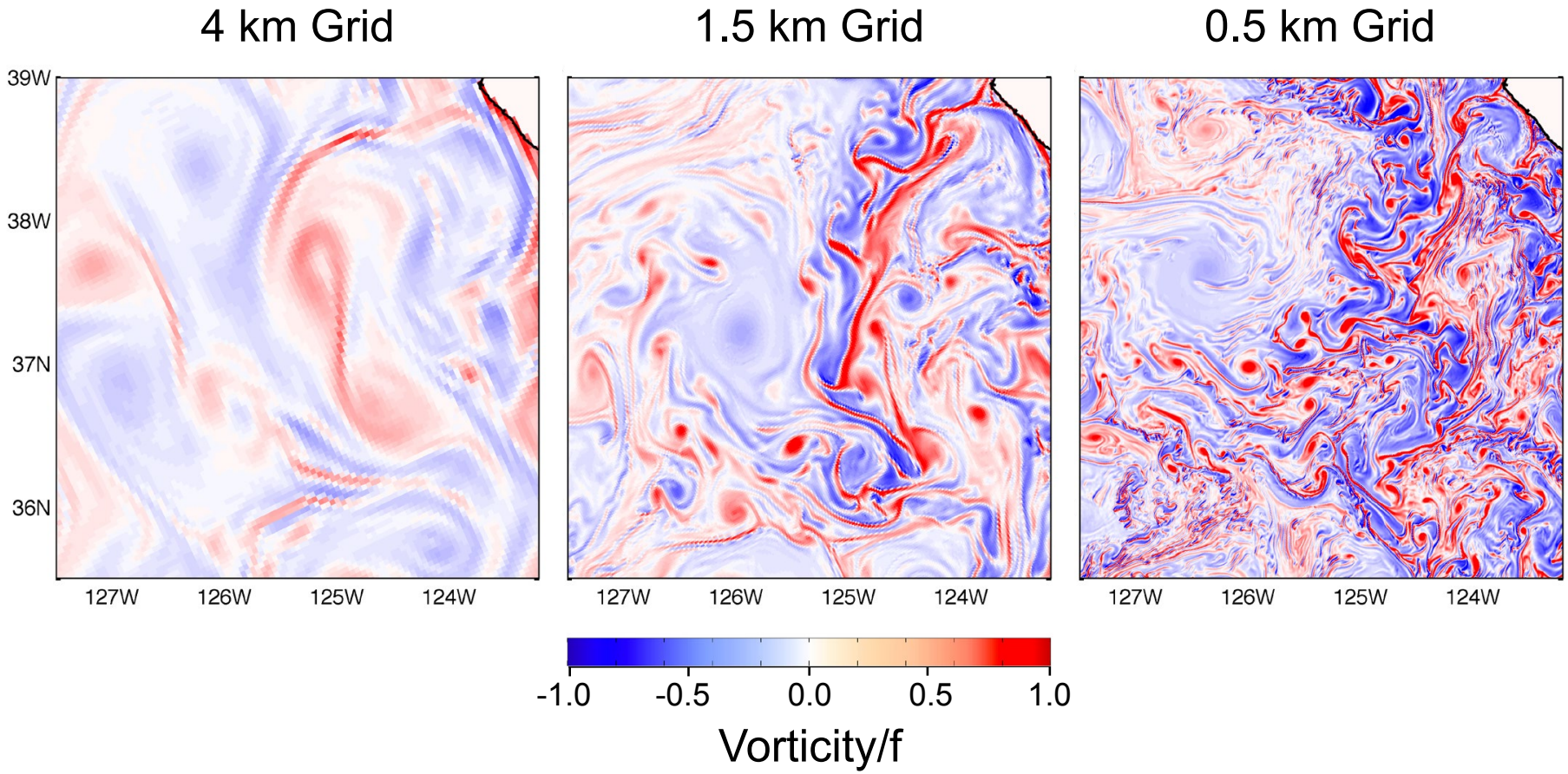
Doubled Accuracy
4-Day Average
with Filter Cutoff
Wavelength 25 km



Present Capability
30-Day Average
with Filter Cutoff
Wavelength 200 km



The Importance of Model Grid Resolution for Simulating Submesoscale Variability



The rapid evolution of submesoscale variability poses major sampling challenges to satellite observations, especially SWOT because of its narrow swath width.

31-Day Animation of ζ/f from ROMS Model of the CCS
(repeated 4 times)