Sea Surface Height Slope Computation: A proposal to remove the slope product requirement

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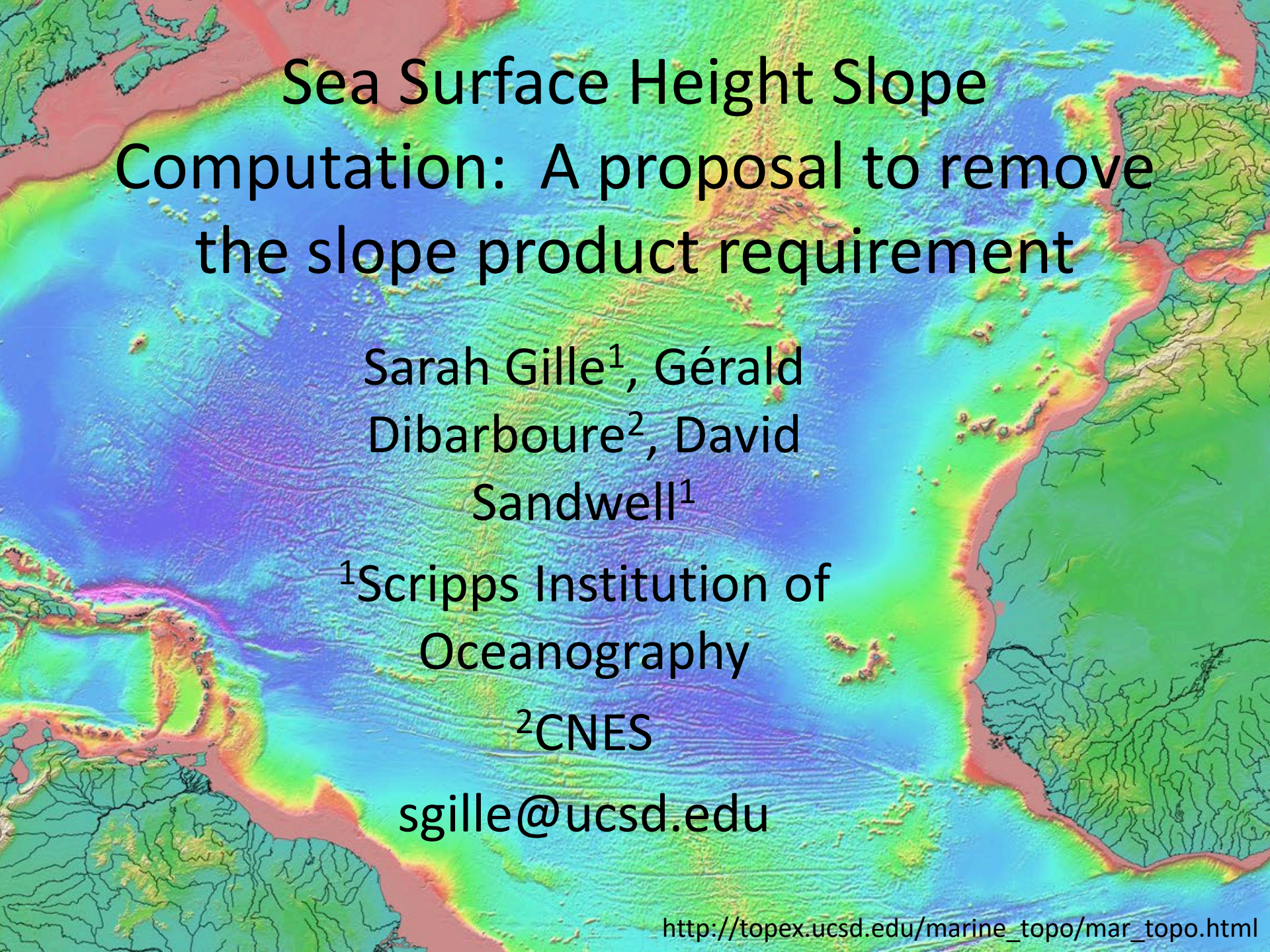
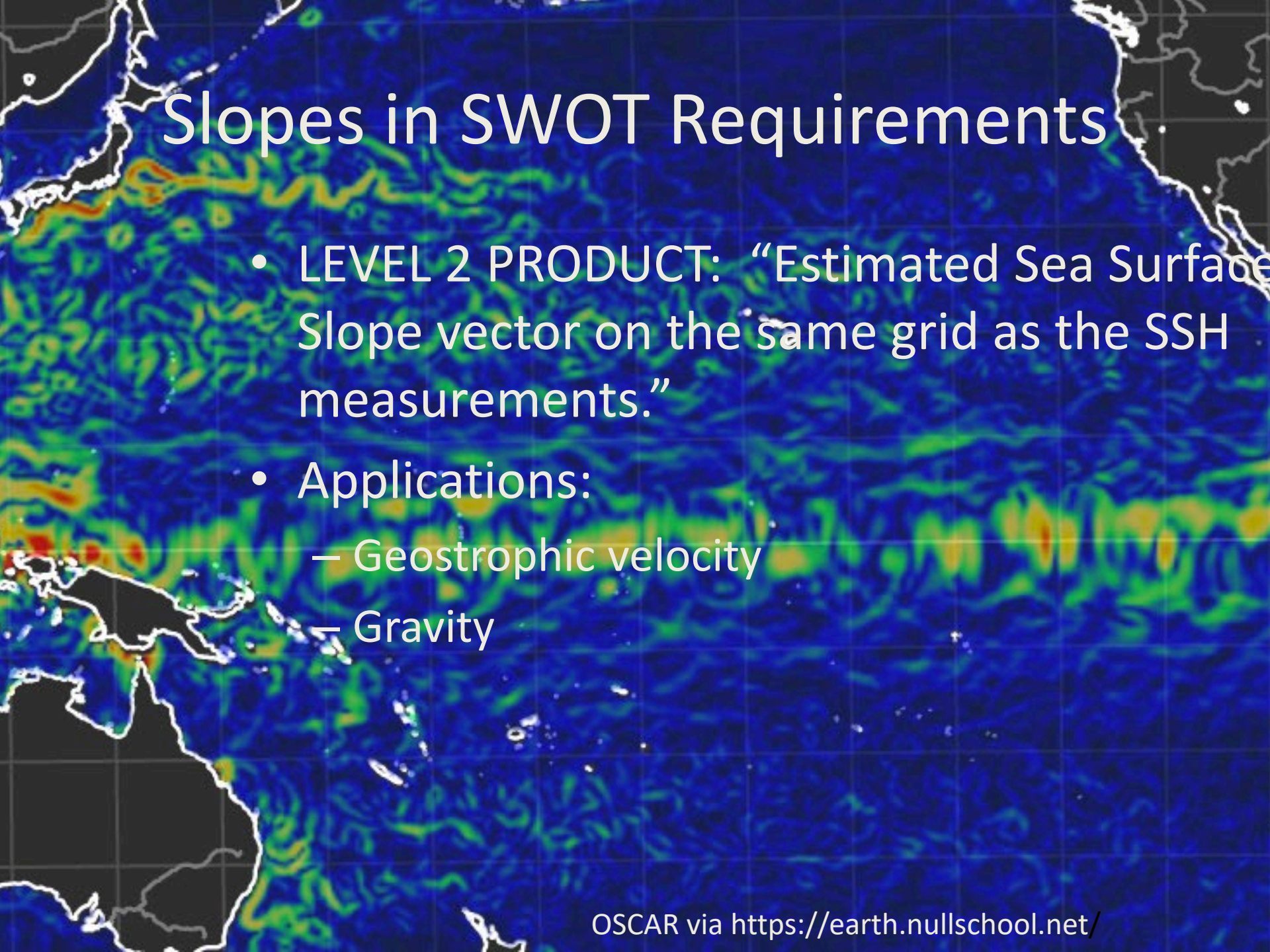


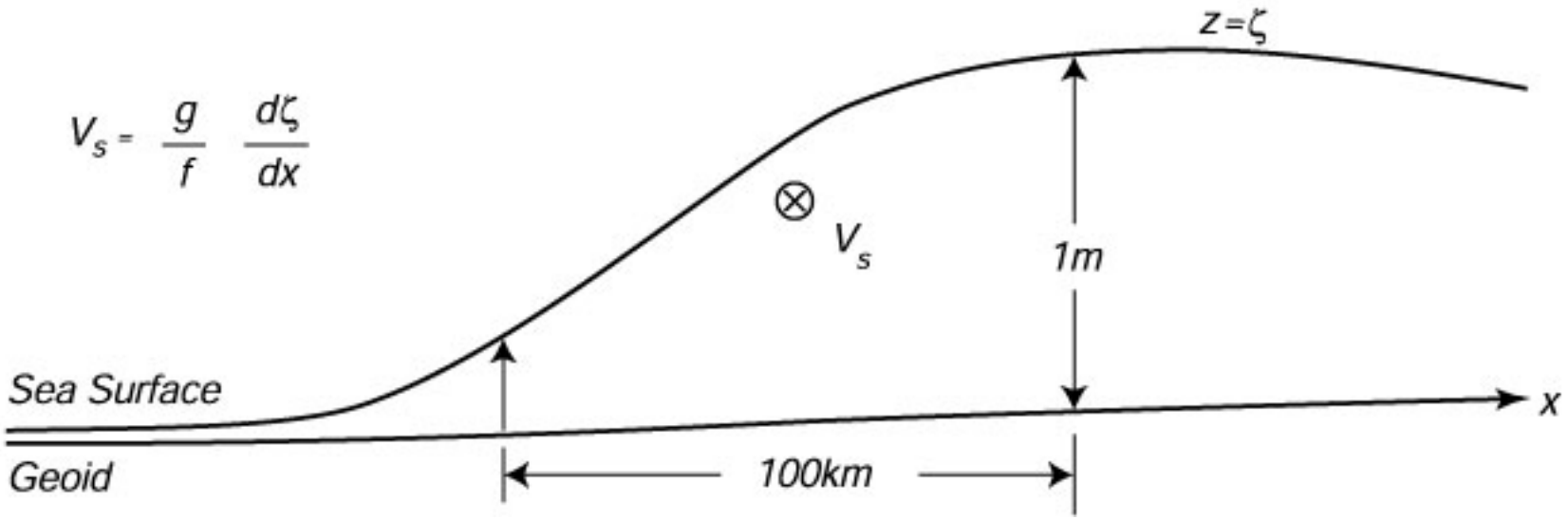
Slopes in SWOT Requirements

- LEVEL 2 PRODUCT: "Estimated Sea Surface Slope vector on the same grid as the SSH measurements."
- Applications:
  - Geostrophic velocity
  - Gravity



OSCAR via https://earth.nullschool.net/

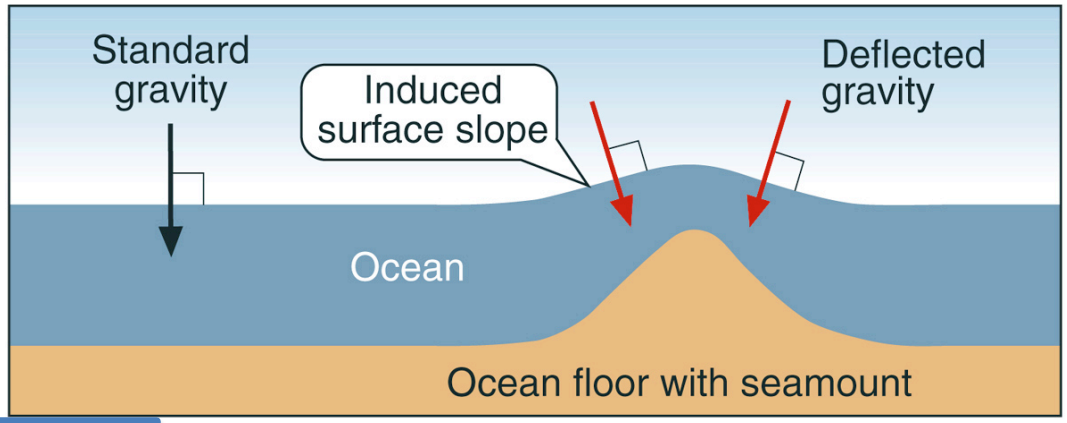
Geostrophic velocity



- Geostrophic velocity depends on slope.
- Can we produce a slope product that will minimize slope errors at small scales and have better quantified uncertainties?

http://oceanworld.tamu.edu/resources/ocng_textbook/chapter10/chapter10_03.htm

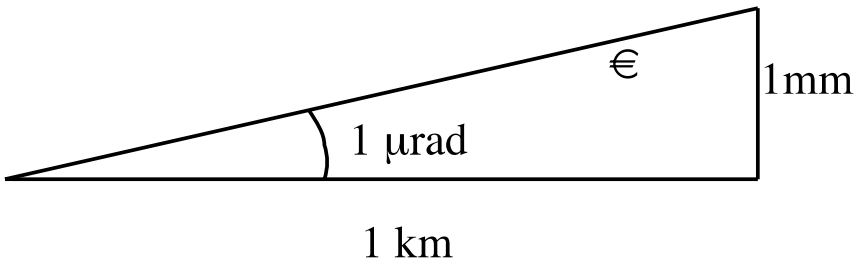
Slope is used for estimating gravity and bathymetry



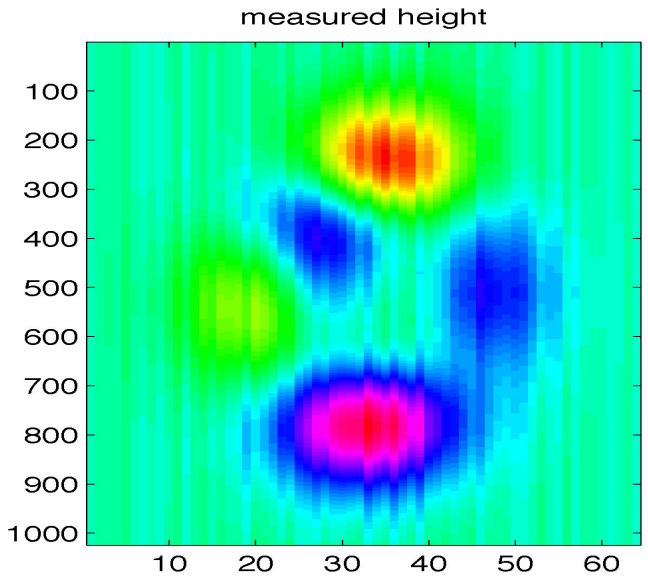
Fourier transform of Laplace's equation

$$\Delta g(k) = \frac{ig_o}{|\mathbf{k}|}\left(k_x \eta(\mathbf{k}) + k_y \xi(\mathbf{k})\right)$$

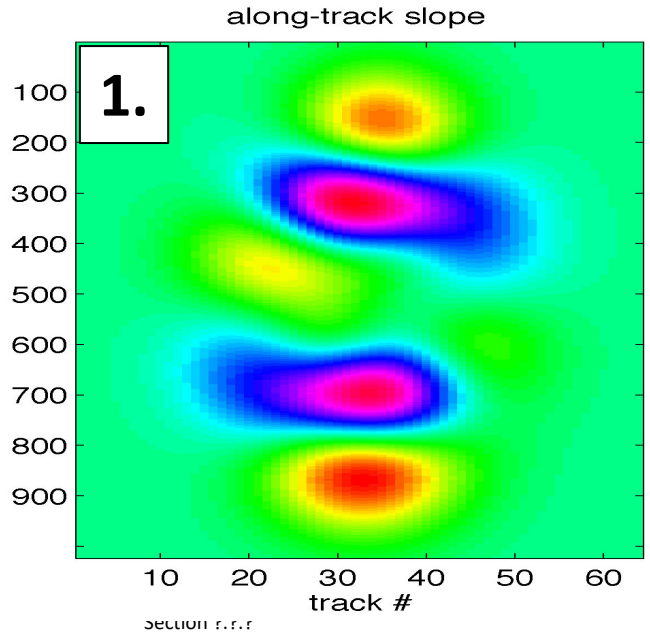
1 μrad of slope error ⇔ 1 mGal gravity error

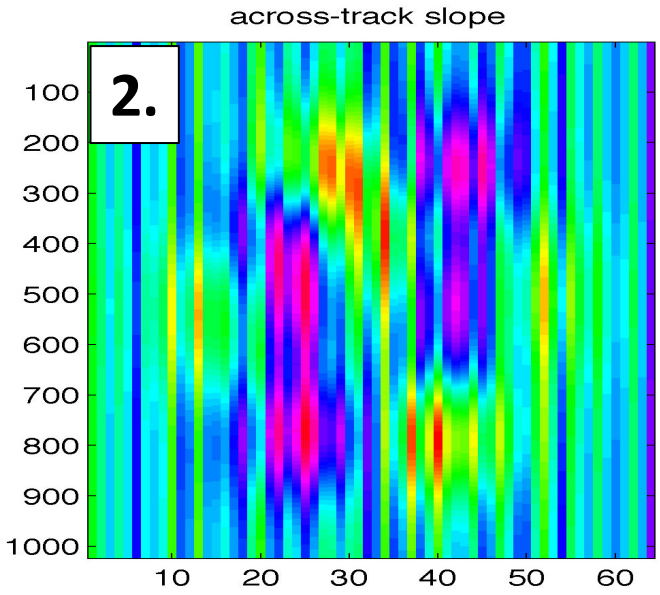


Two ways to construct a slope grid from profiles:



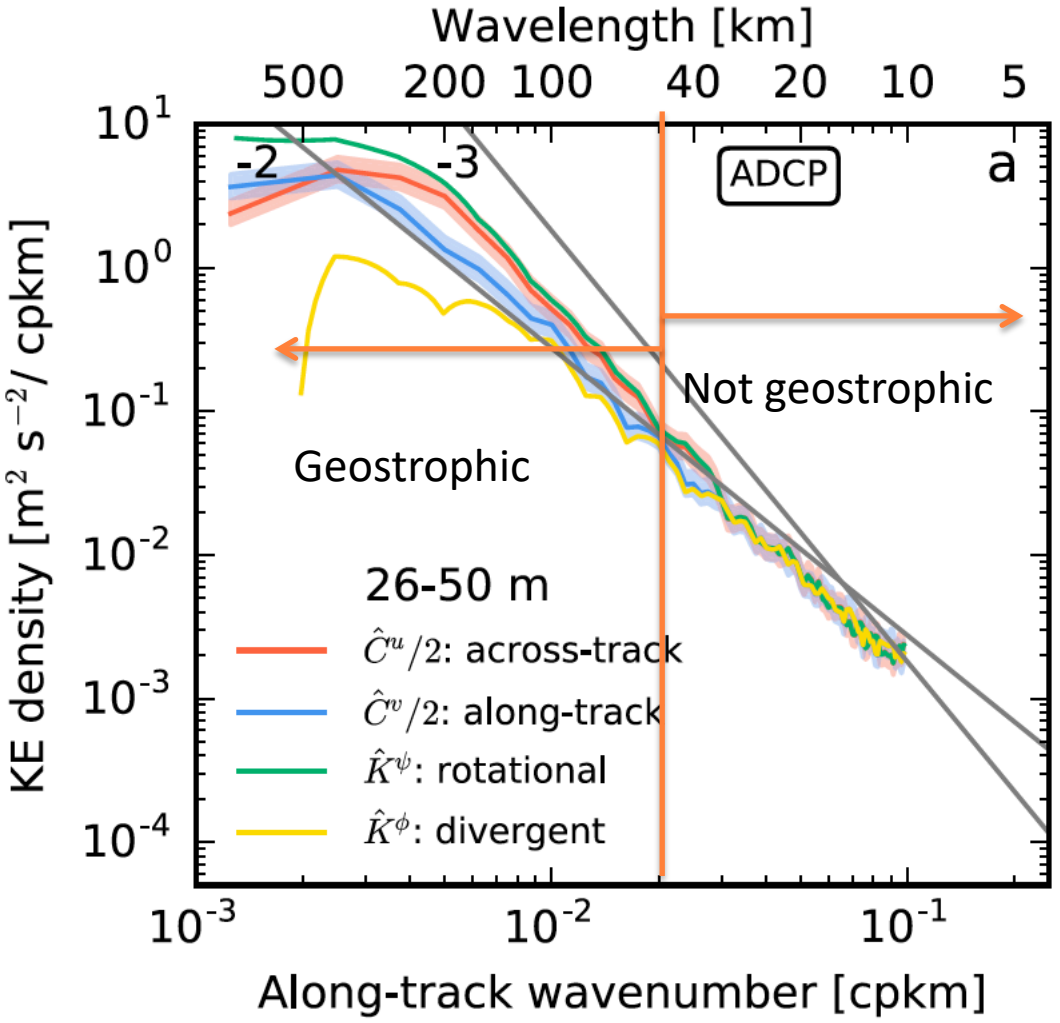
1. **Take along-track derivative** and combine ascending and descending slopes to form *x* and *y* slope grids.
2. Construct height grid and take *x* and *y* derivatives. This results in high cross-track noise.





Challenges: 1. High-wavenumber motions not in geostrophic balance

- Rotational (~geostrophic) dominates for scales longer than 50 km
- Rotational and divergent comparable for shorter length scales.

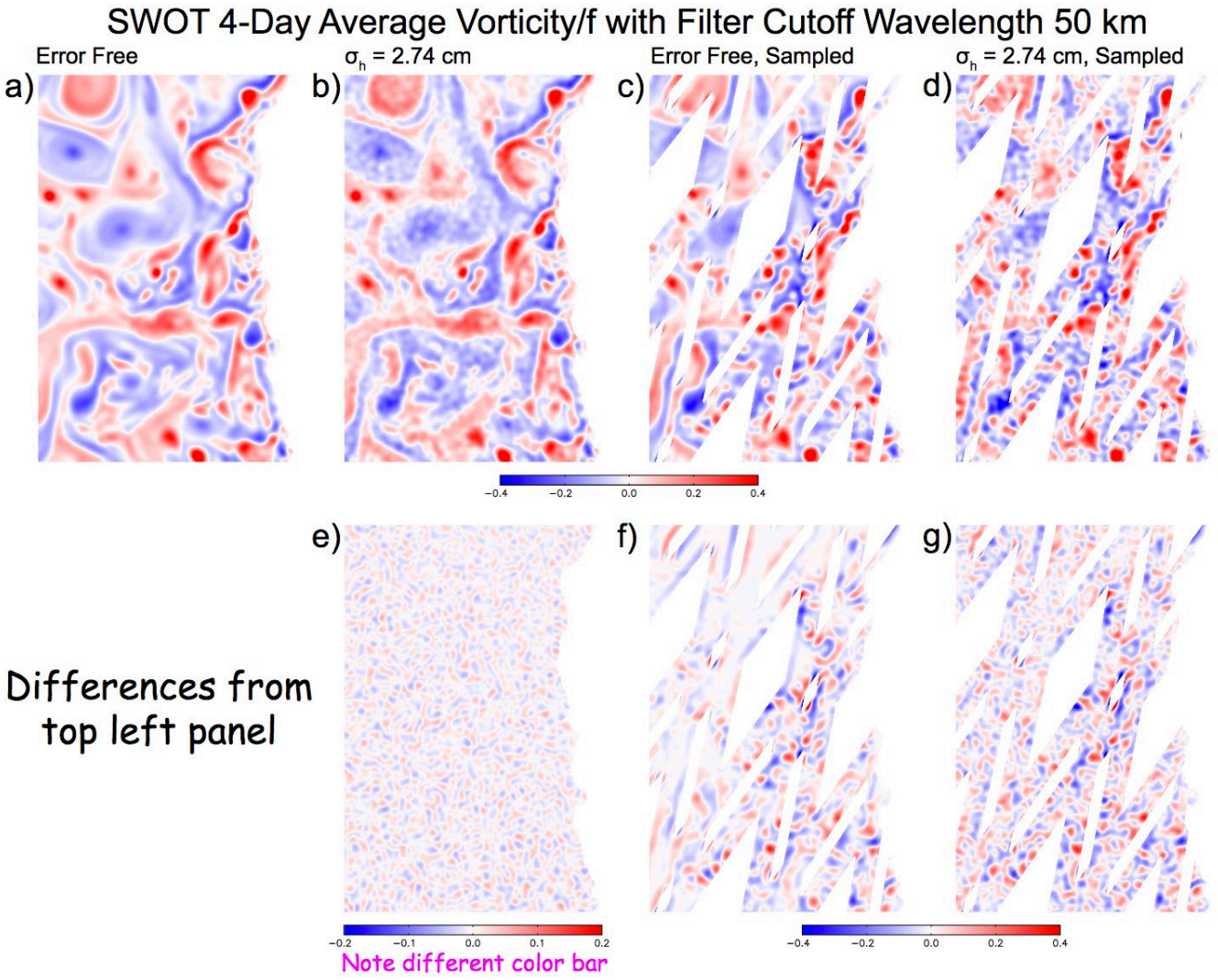


Rocha et al, JPO, 2016: Drake Passage

See also Callies and Ferrari, 2013; Bühler et al, 2014

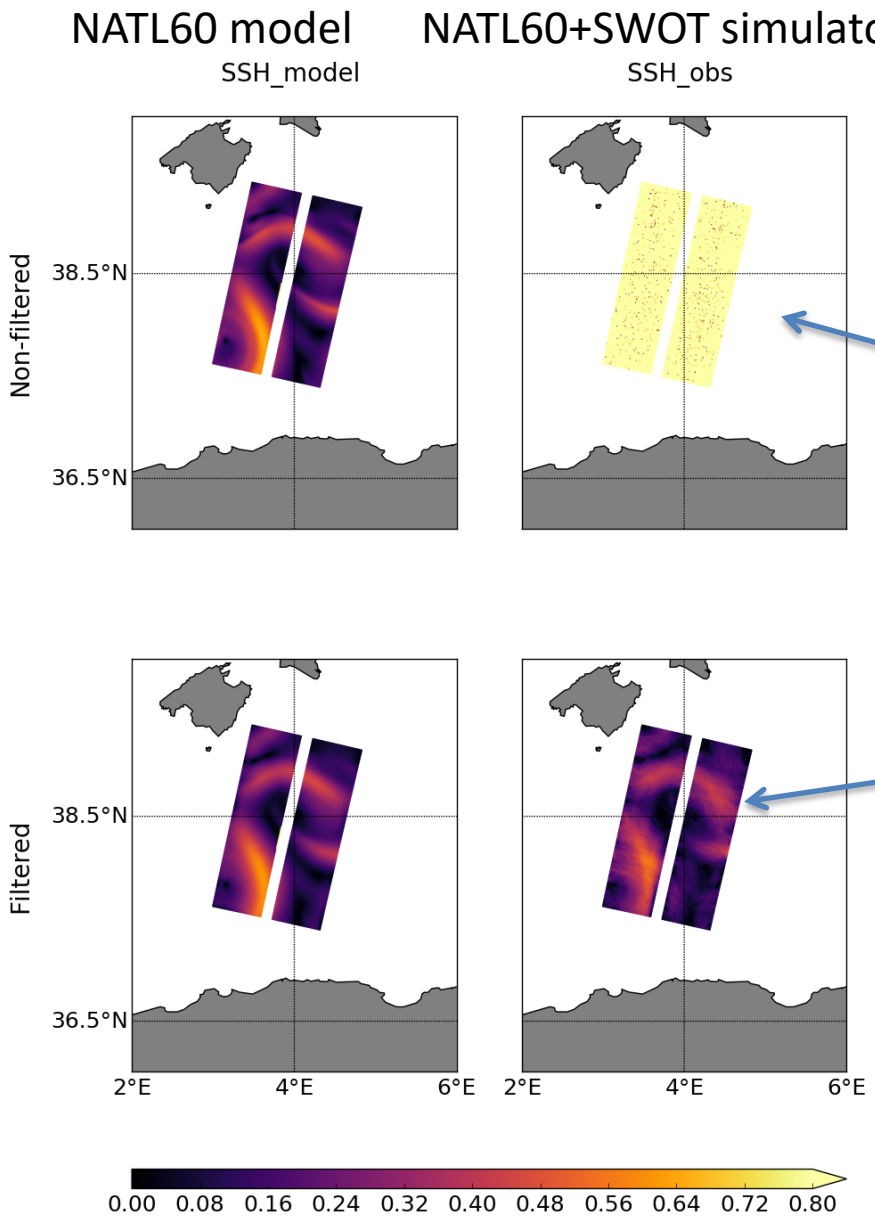
Challenges: 2. Noise dominates at small scales

- Vorticity needs an extra derivative
- Amplifies noise



Chelton, 2017 IOVWST

Addressing the Challenges: Optimal Filters



Intensity of geostrophic velocity (m/s) (i.e. "geostrophic speed")

Spurious velocities due to high frequency noise (primarily from KaRIn, with other contributors)

Filter, minimizing cost function.

Gomez Navarro and Cosme, in prep. See splinter session presentation by Emmanuel Cosme.

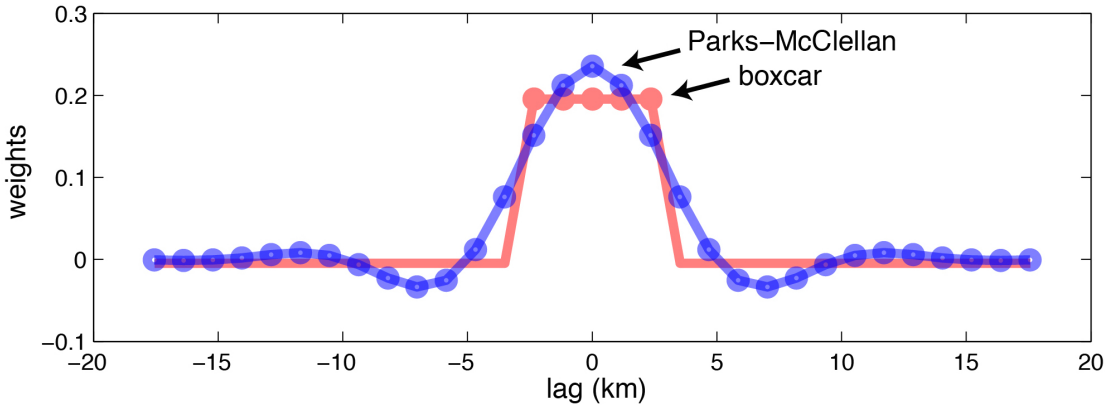
Challenges for gravity: Optimizing derivative filter for profiles

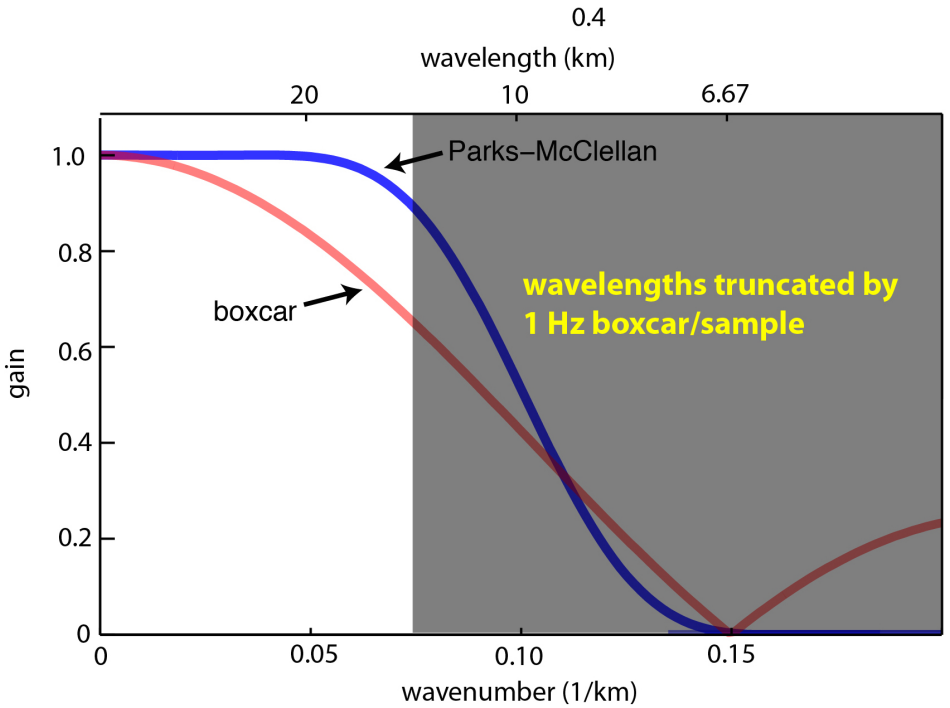
Standard 1 Hz sampling is suboptimal for gravity recovery.

Noise at wavelengths shorter than the Nyquist (13 km) is folde back into the main lobe.

Gravity amplitude is reduced by 0.6 at Nyquist.

Need careful filter design and at least 4 Hz sampling (1.7 km) to recover 13 km wavelengths.



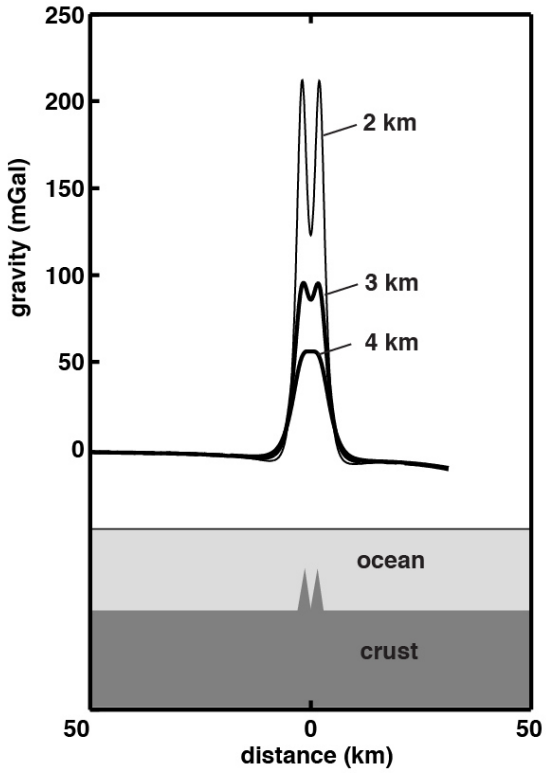


What is the shortest wavelength gravity signal expected for SWOT?

$$g(k,z) = g(k,0)\, e^{-2\pi kz}$$

gravity at altitude = gravity at seafloor x upward continuation

	$\lambda=1/k$	z	gain
shallow margin	2 km	1 km	0.043
deep ocean	8 km	4 km	0.043
GOCE altitude	8 km	200 km	10^{-68}



slope at 2 km wavelength: 250-m sampling (boxcar) or 500-m sampling for a “better” low-pass filter/decimation

Proposal: Remove the requirement to provide slopes in data files

- Remove the requirement to provide slopes in data files
- In research mode, continue to explore options to best use sea surface height gradients for oceanographic and geophysical applications, as a user-defined calculation
  - better stencils
  - characterization of noise and noise correlation
  - compute along-track and cross-track slope from swath data? Suppress cross-track derivative at swath boundaries?

Notes

Why slopes?

- a. Why are slopes intrinsically interesting and why were they in the original specifications? The value of computing geostrophic velocity and higher derivatives? The possibility of correlated error and the potential benefit of minimizing the impacts of correlated error.
  b. The challenges in dealing with high wavenumber slopes:
  --break down of balanced motions (Callies; Rocha; etc.)
  --noise (Chelton slides)
  c. Geophysics perspective....
  d. Proposal: remove slopes from requirements
  Moving forward: continue to explore options that will allow for good sea surface height gradients for oceanographic and geophysical applications (e.g. better stencils; characterization of noise and noise correlation) but allow this to happen in research mode as a user-defined calculation.