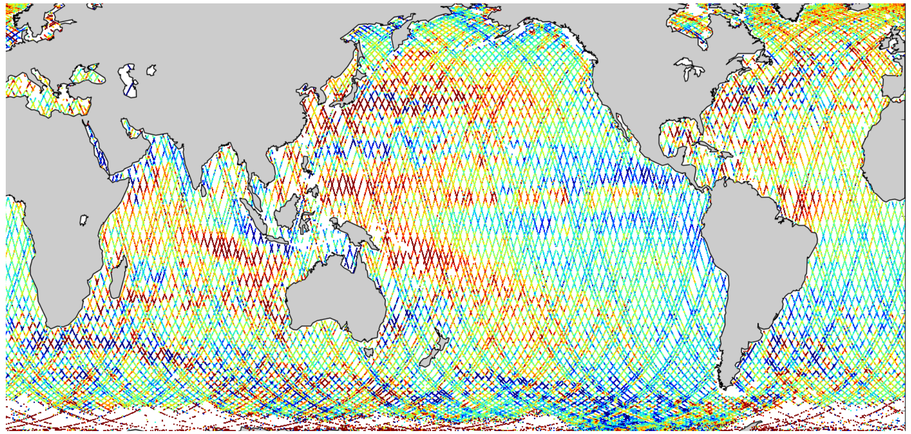
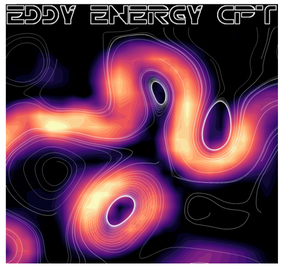
scale aware eddy kinetic energy from along-track sea surface height measurements

CESM-OMWG / CPT 4 February 2021





CPT: observations group
Jacob Steinberg
w/ Sylvia Cole, Kyla Drushka, Ryan Abernathey

Outline

- how are along-track measurements made & why we prefer them

- what do we do with these measurements?
    1. spatial filtering and eddy kinetic energy (EKE) as a function of scale
    2. spatial filtering python library
    3. 1D tracks → 2D maps

- science: using this tool we explore spatial and temporal patterns of EKE

** Relationship / relevance to the CPT **

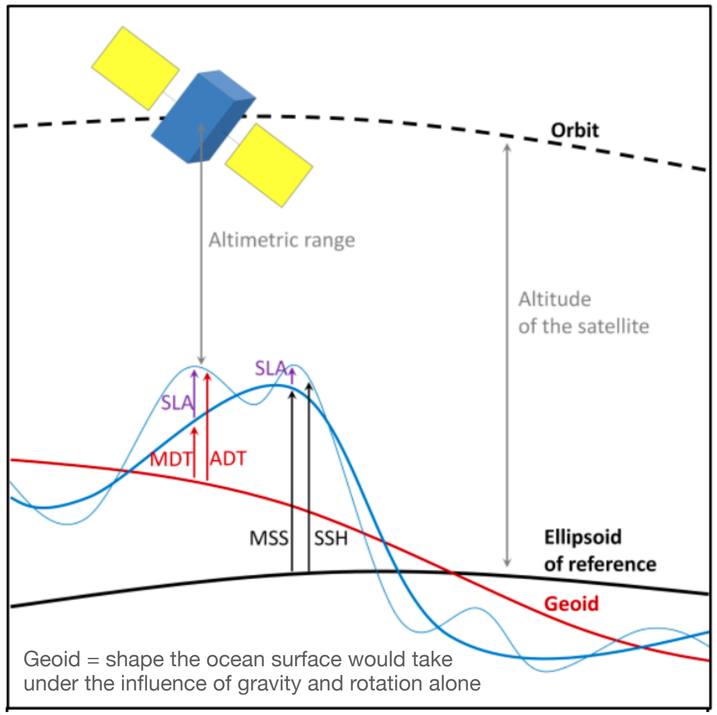
with this analysis we hope to allow comparison between scale-aware observational estimates of EKE with model estimates of EKE across a variety of resolutions

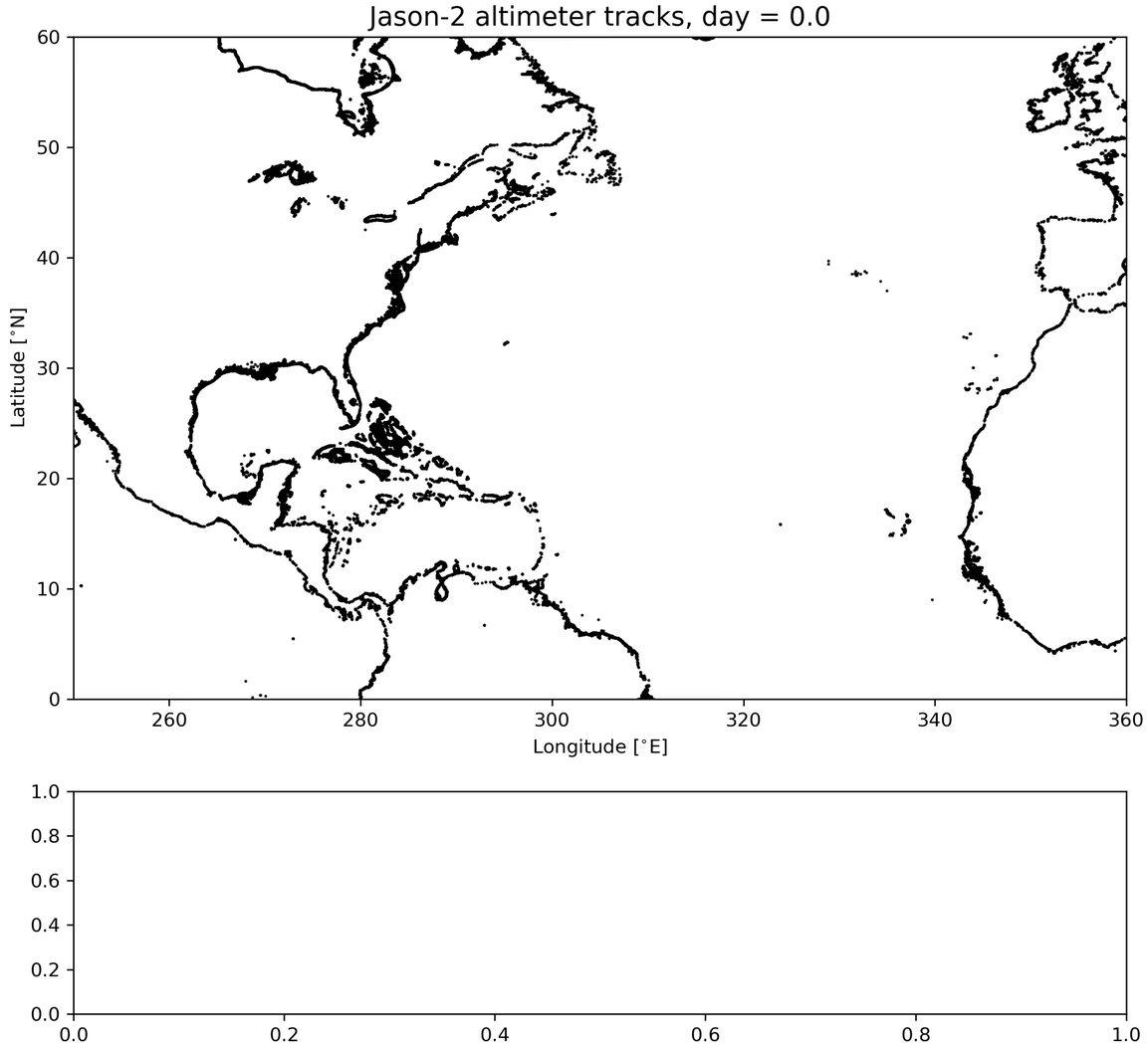
Along-track absolute dynamic topography, ADT

- temporal resolution: track repeat time = 10 days
- horizontal resolution = 7 km

* measurements are initially filtered to account for instrument noise *

Expectation:
- effective resolution is ~ 50 km
- we can adequately resolve mesoscale eddy energy





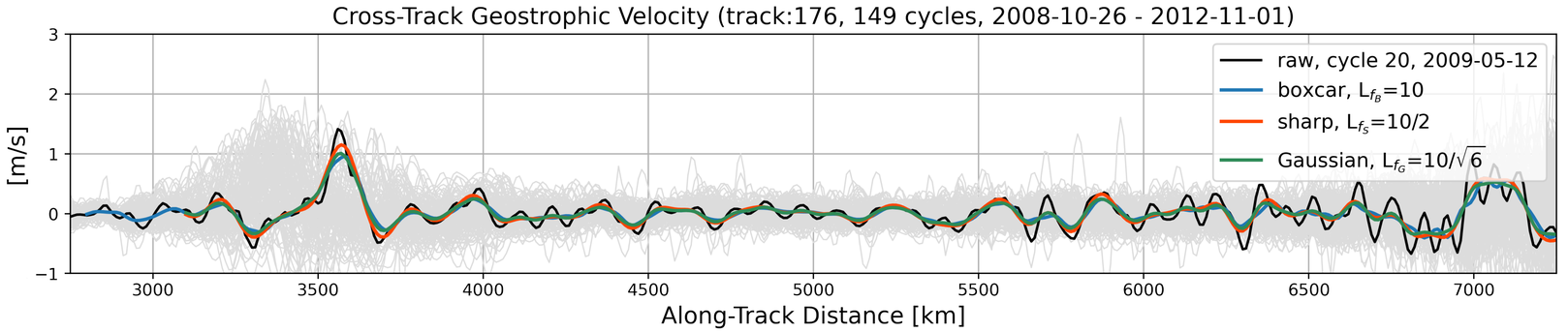
* sample from a decades long record *

processing and defining KE, MKE, EKE

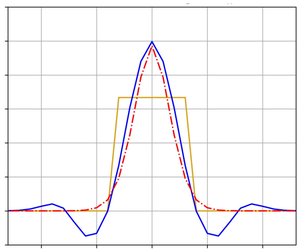
Kinetic Energy (KE):
along-track gradients of ADT

$$u_g = \frac{g}{f}\frac{d\eta}{dx}$$

ignoring the sign
(Arbic et al. 2012)

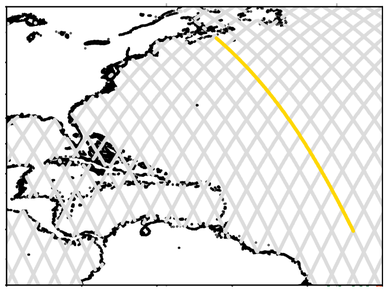


Filters are designed to match their cutoff wavelengths



filter kernels
- boxcar
- Gaussian
- 'sharp'/taper

Jason-2 subset track location



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$$MKE = \langle u \rangle_L^2$$
$$EKE = \langle u^2 \rangle - \langle u \rangle_L^2$$

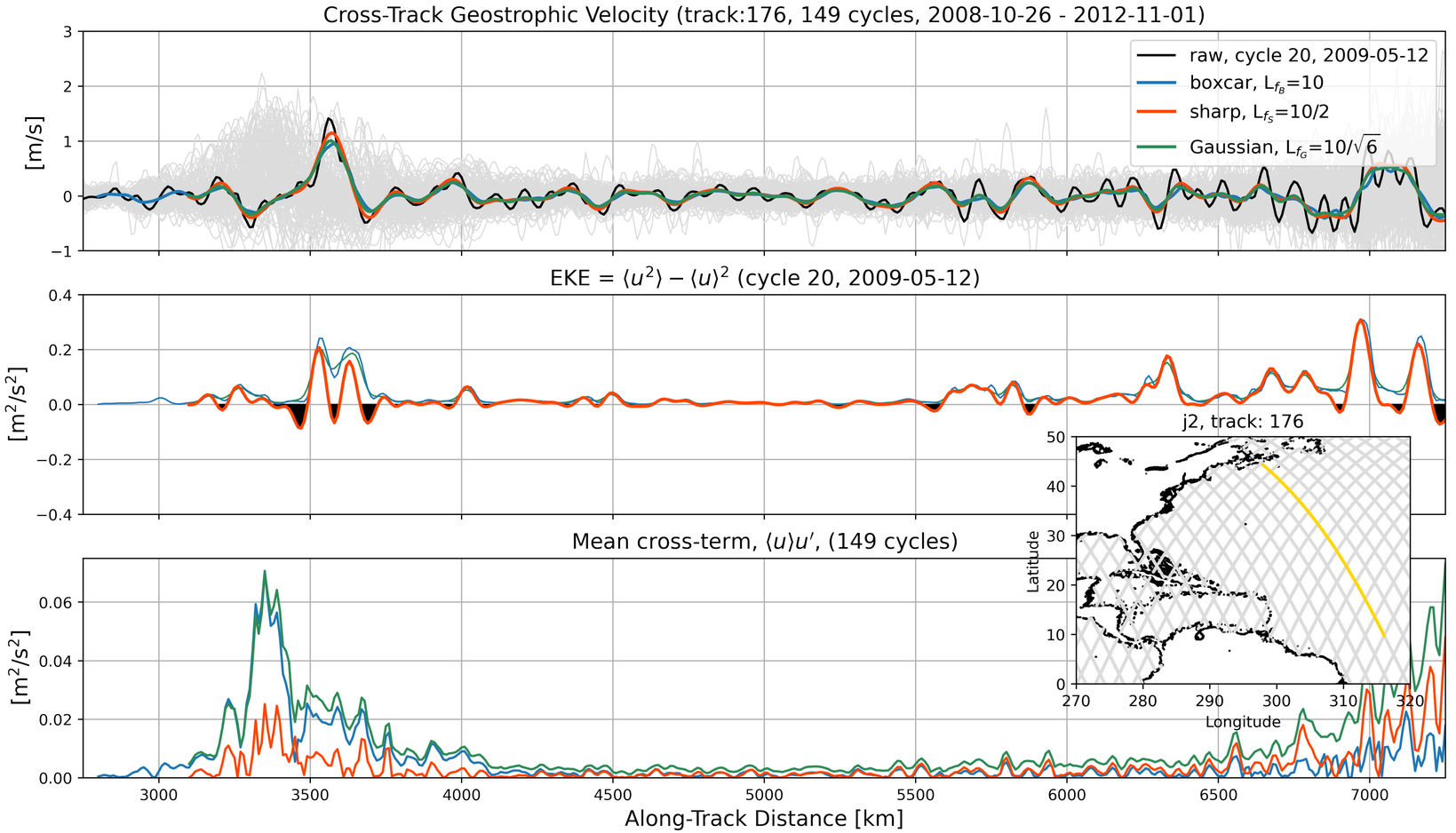
$\langle\rangle$ = spatial filter

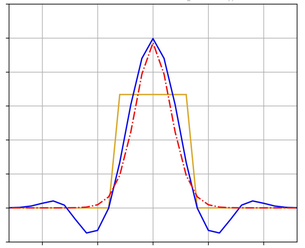
‘sharpness’ quantified (as a check)

IF $u' = u - \langle u \rangle$

$$KE = \langle u \rangle^2 + u'^2 + \langle u \rangle u'$$

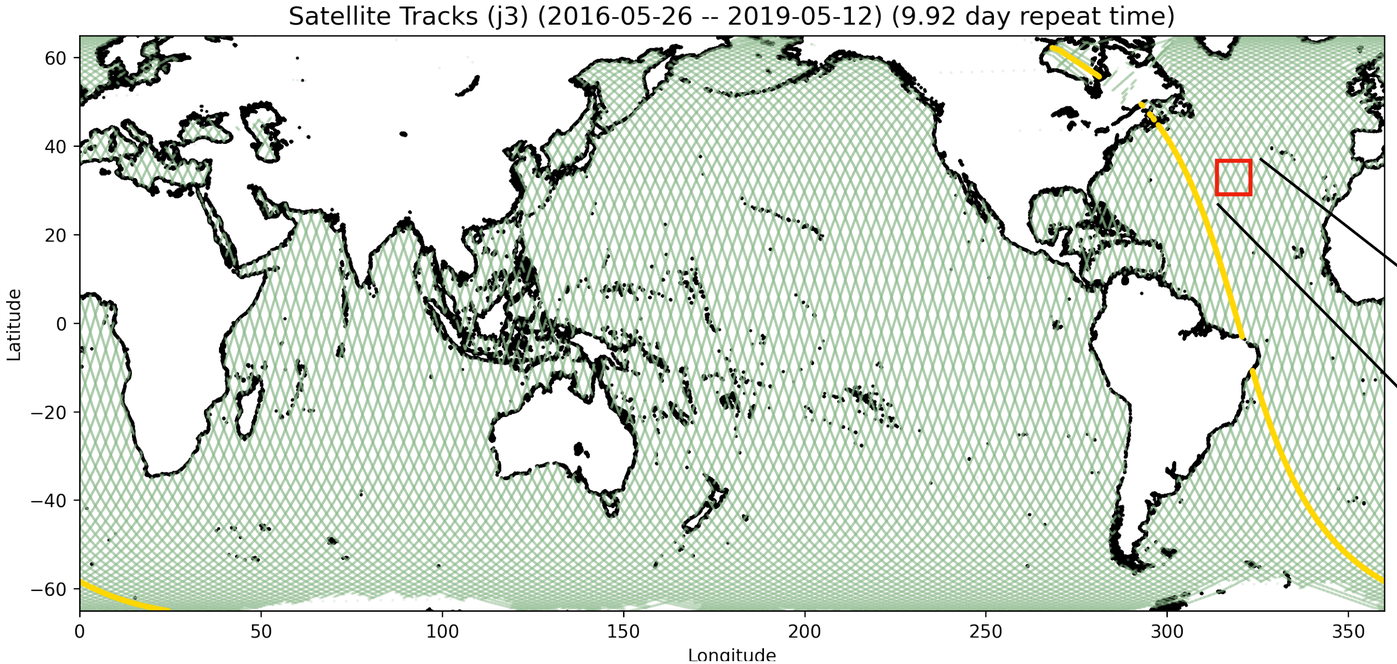
want to minimize this last term

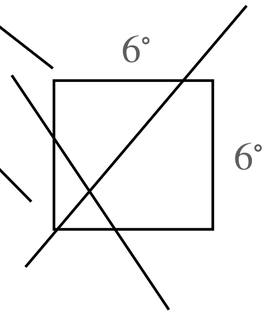




filter kernels
- boxcar
- Gaussian
- ‘sharp’ / taper

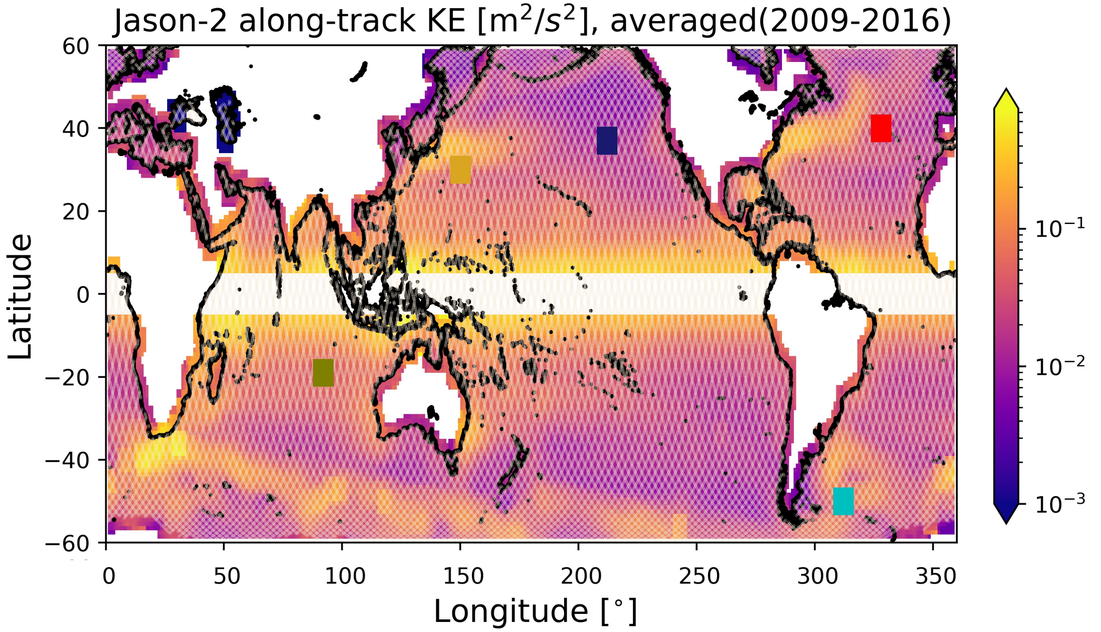
1D tracks to 2D global maps





moving bin-average
- permits regional comparisons

* note select locations for later *



review

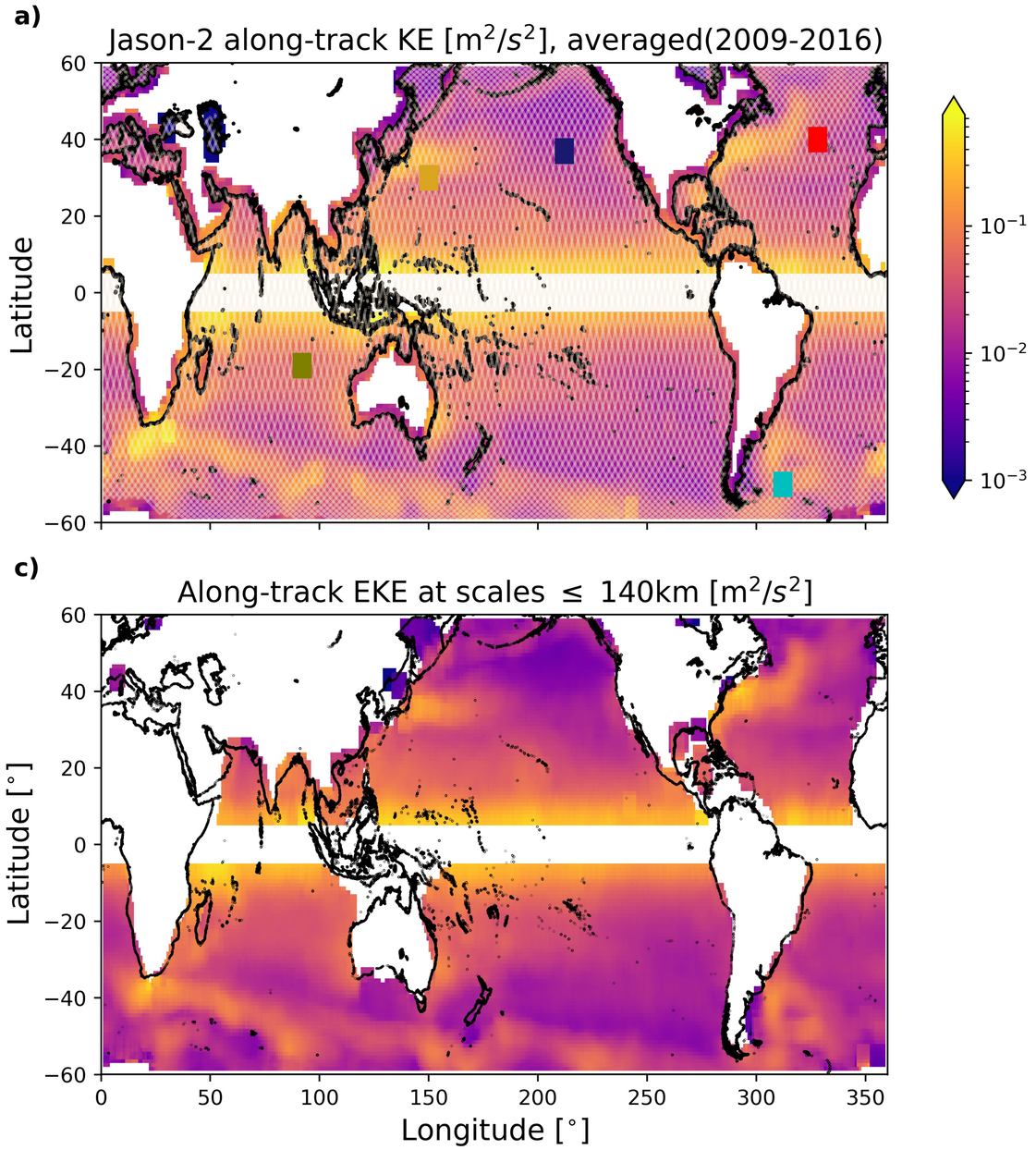
<u>generalized utility of this tool</u>

- filter cross-track geostrophic velocity (or sea level anomaly) using a filter of your choice
  - filter kernel: boxcar, Gaussian, ‘sharp’
  - filter method: fixed scale [km], fixed degree [°], L_{d_1}

- define and compute MKE and EKE for **any** and **all** filter scales
  - a partitioning of energy into two reservoirs
- define and map to latitude/longitude grid

// data are accessed on Pangeo, where pre-processing is consistent for all users

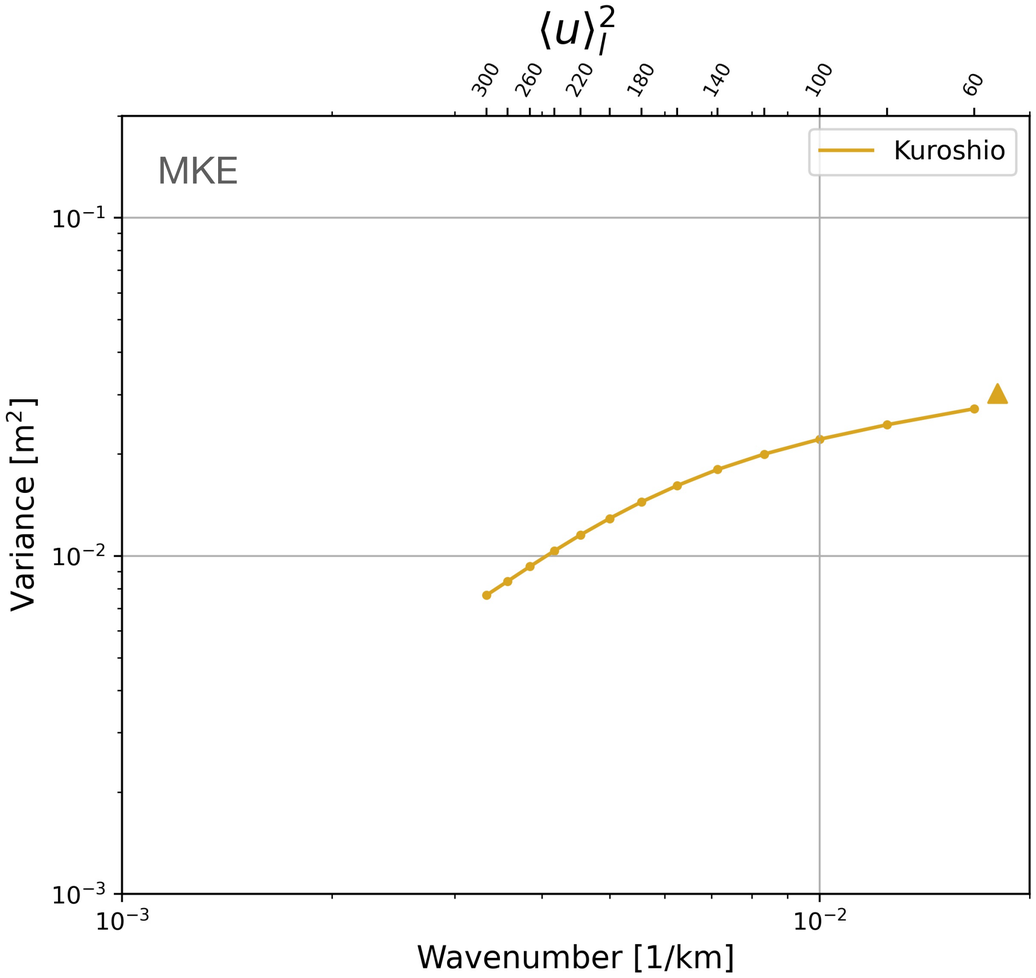
PANGEO

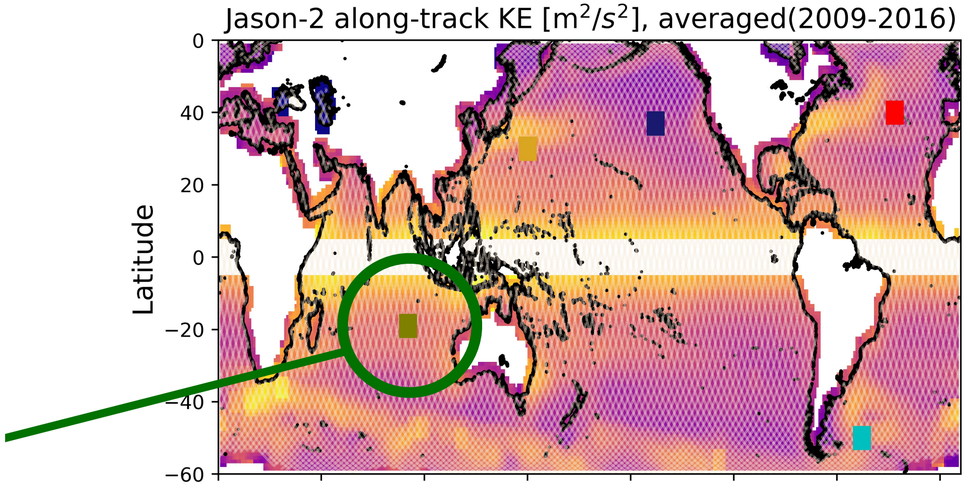


what if we filter to across a range of scales?

60-300 km at 20 km intervals

At one location and for two filter types





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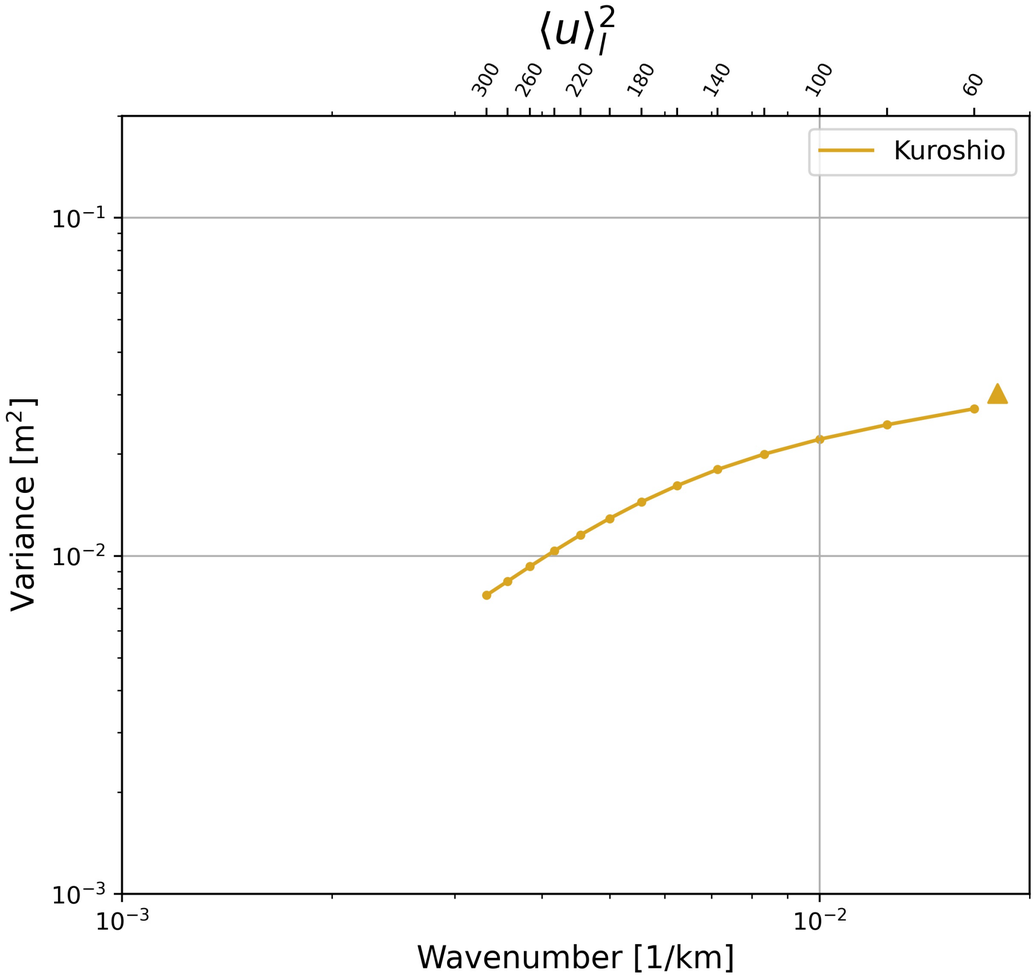
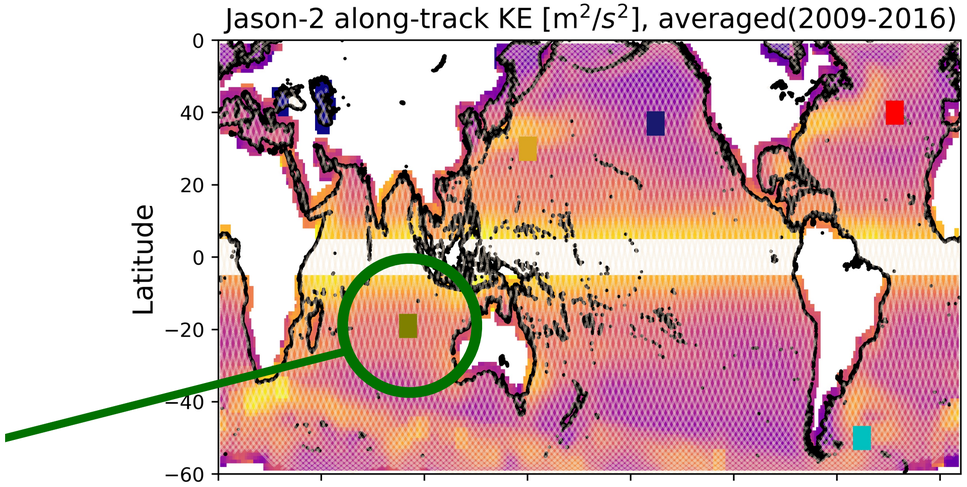
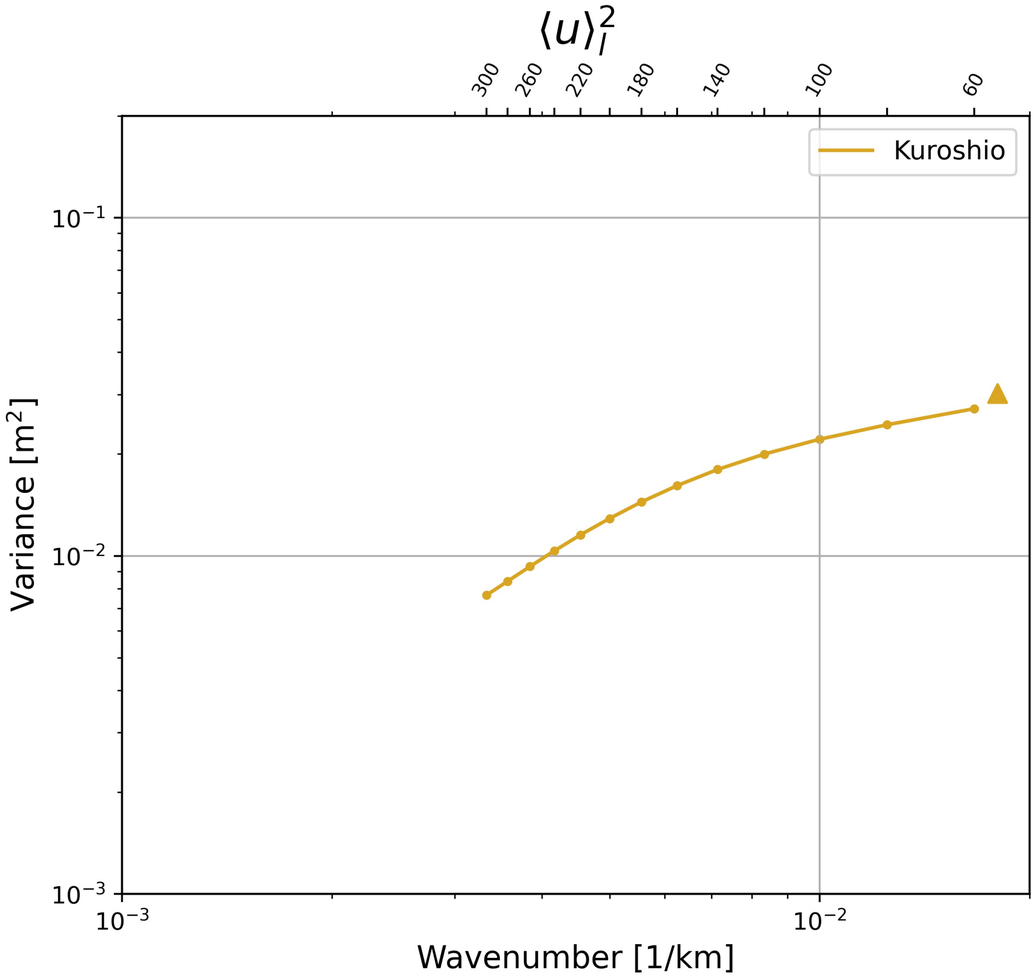


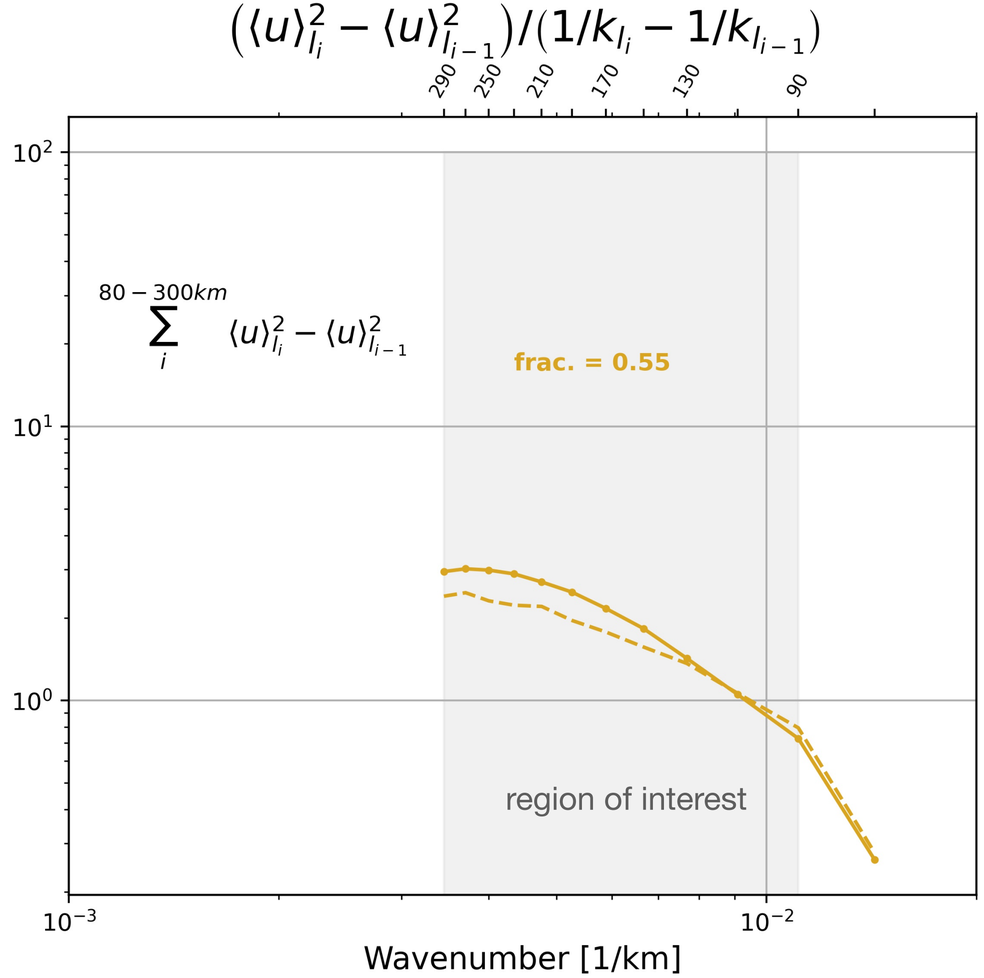


difference adjacent MKE estimates to determine energy within wavenumber bands

what if we filter to across a range of scales?

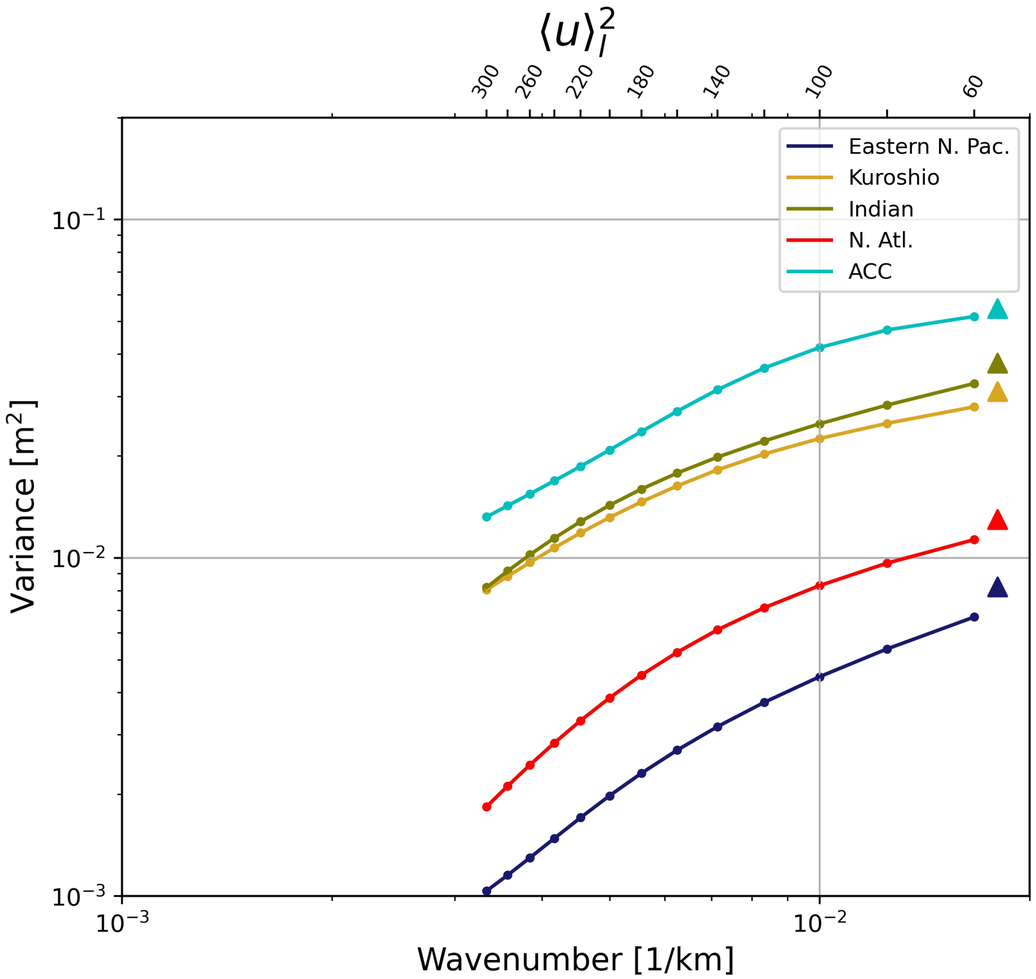
At one location and for two filter types

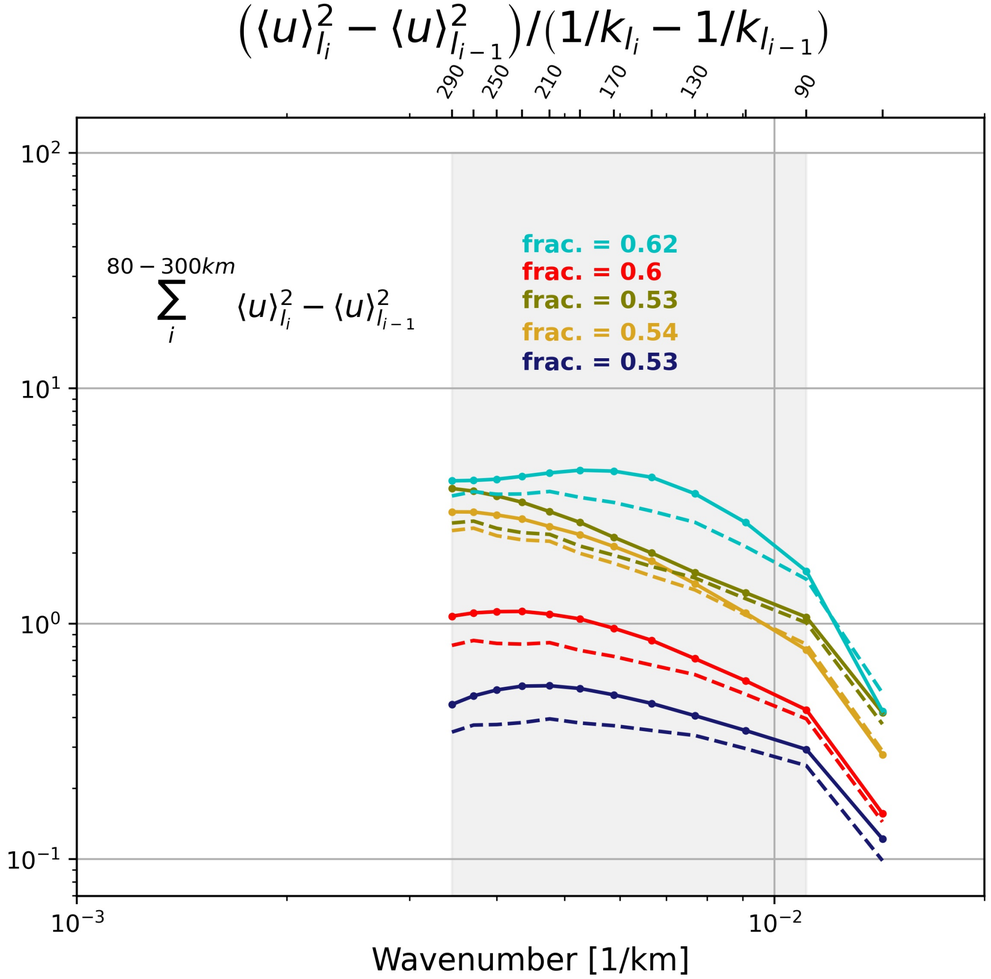




what if we filter to across a range of scales?

At five locations and for two filter types



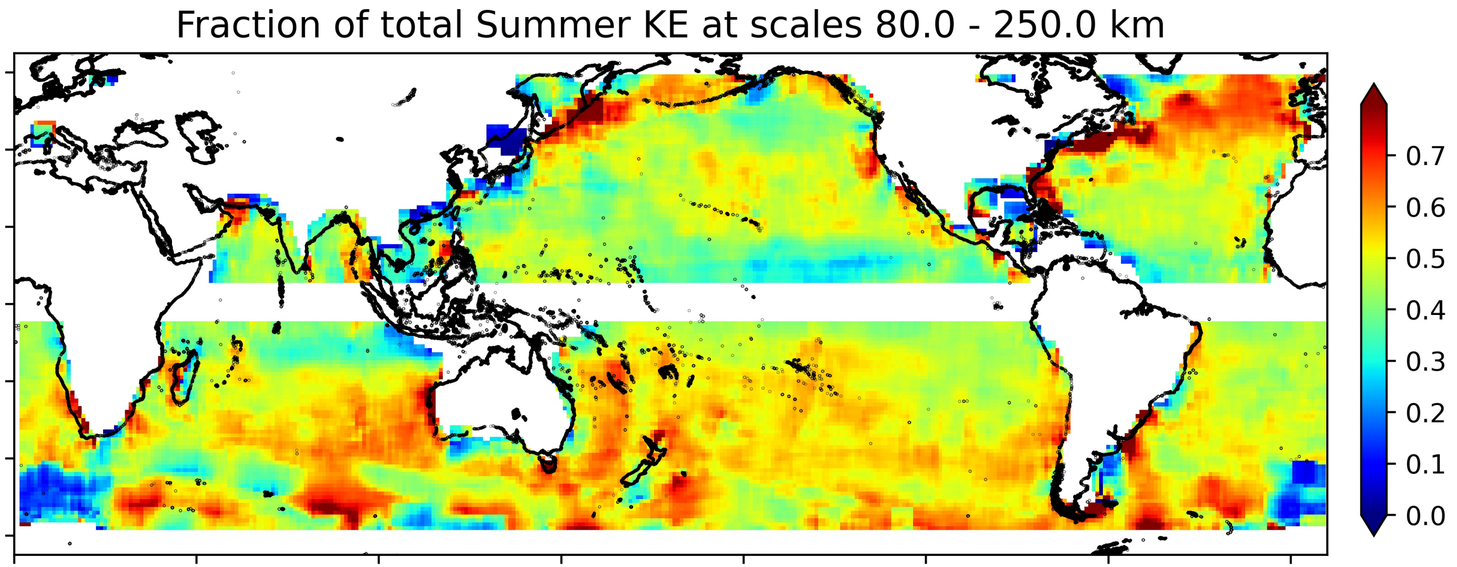


what if we filter to across a range of scales?

how one might use this tool

Filter bands = 60-300 km at 10 km intervals

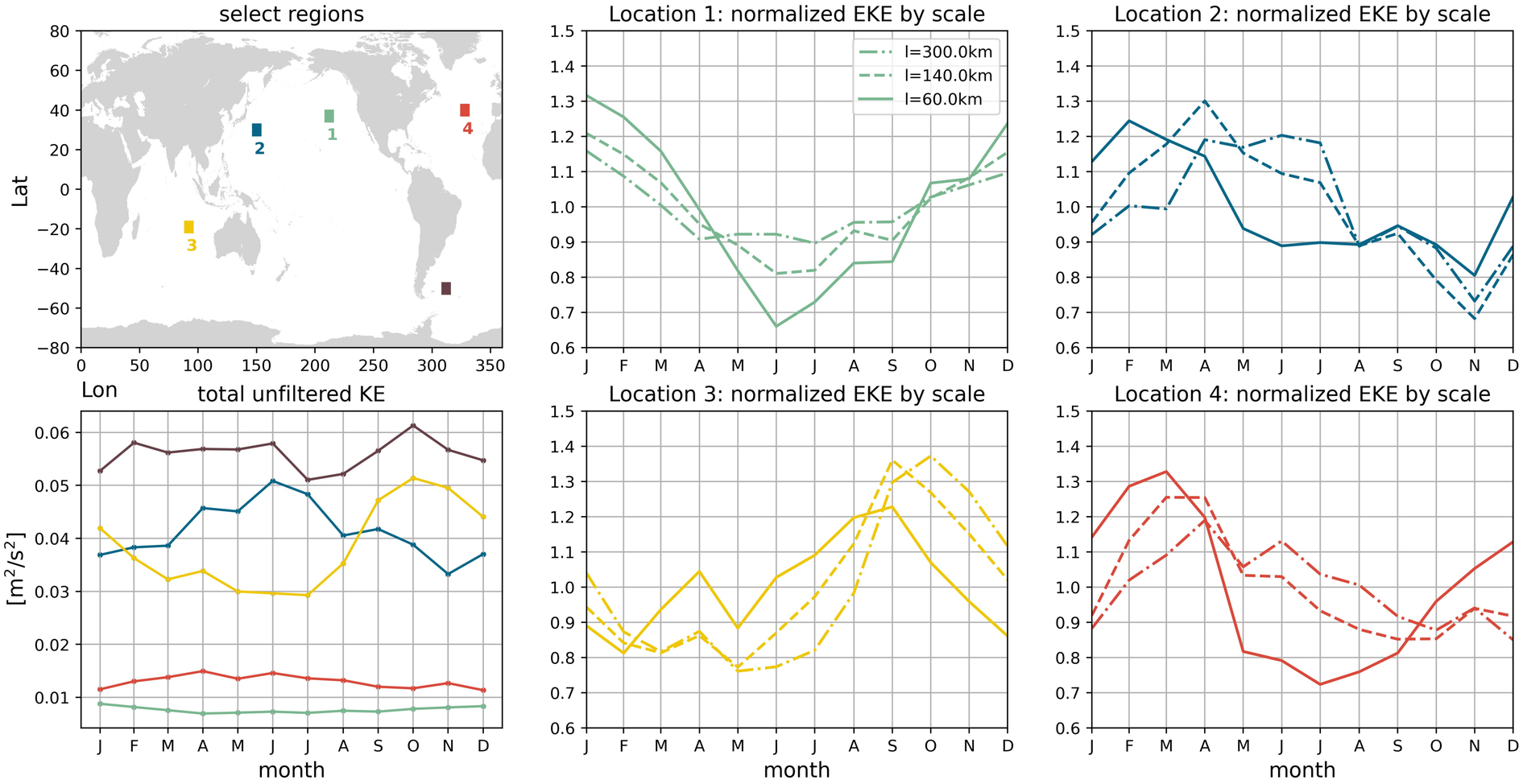
- energy within bands



- most energetic band…

- rate of decrease in variance across bands …

stepping back to consider details of four sites (after making 2D maps)
* 7 year dataset *

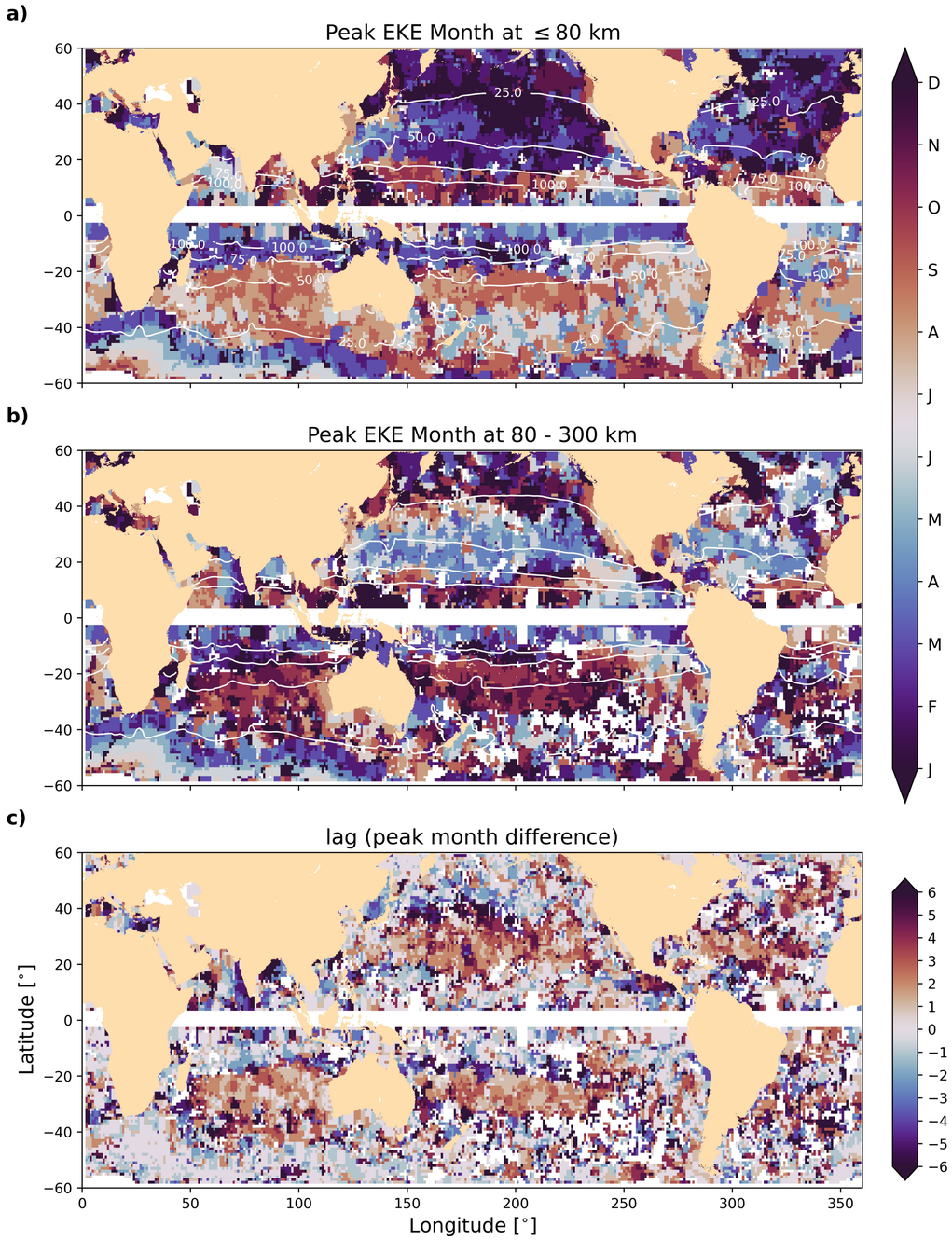


Month at which EKE is a maximum

small scales
< 80 km

medium scales
80 - 250 km

Lag
RED = larger scale energy peak precedes small scale energy peak

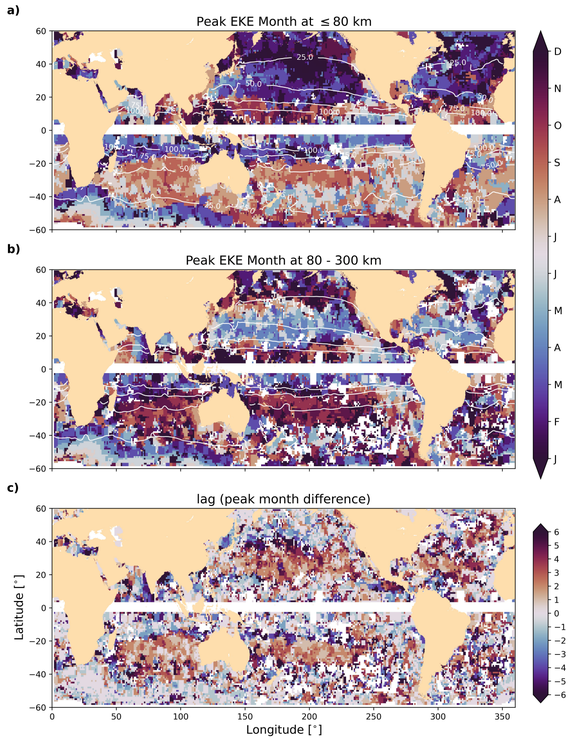


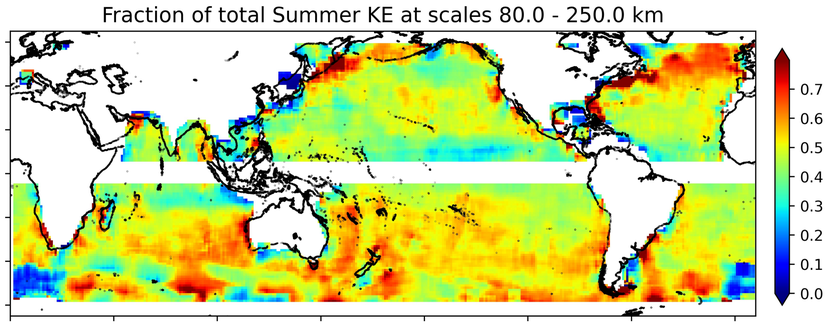
Grey regions (not land) are those at which maximal seasonal change is > 25% of mean EKE

Conclusions:

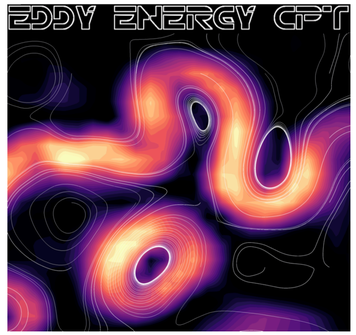
- we have developed a tool capable of filtering KE in a scale aware manner
  - designed for community use and comparison to model mesoscale eddy energy (resolved and unresolved)
  - variable filter type and filter framework

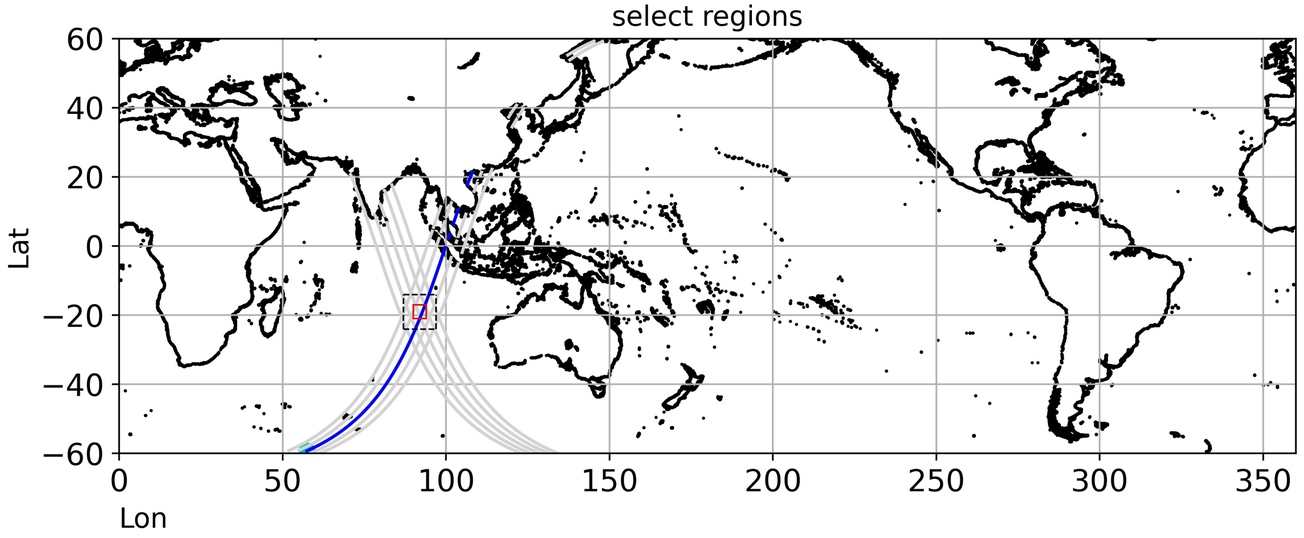
- using this tool :
  - We can show geographic patterns in the partitioning of energy across scales
  - We see a seasonal cycle in EKE that reveals locations where small scale EKE is maximum before medium-large scale EKE is maximum (evidence of the inverse cascade associated with geostrophic turbulence).



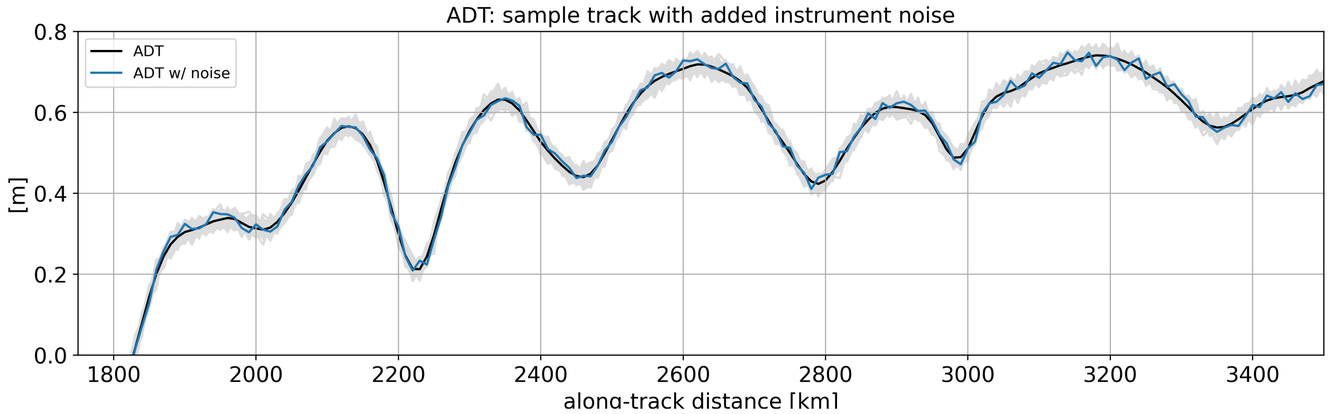


…we can and plan to use this filtering tool on in-situ 1d observations (Oleander)





Take select tracks and for each cycle:
- add random error w/ 1.1 cm rms (200 times)



Take gradient, estimate velocity, filter, calculate MKE & EKE