On the spectral slope discontinuity in SSH spectra

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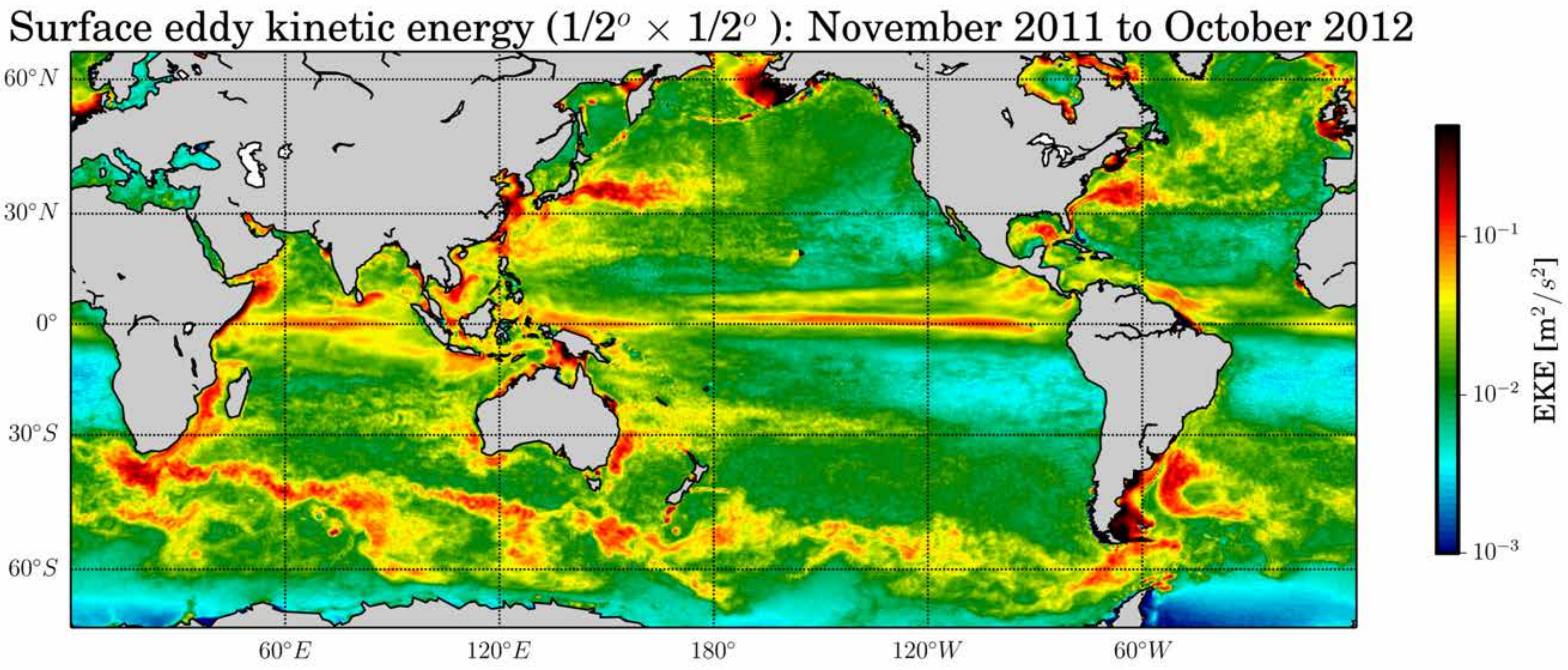
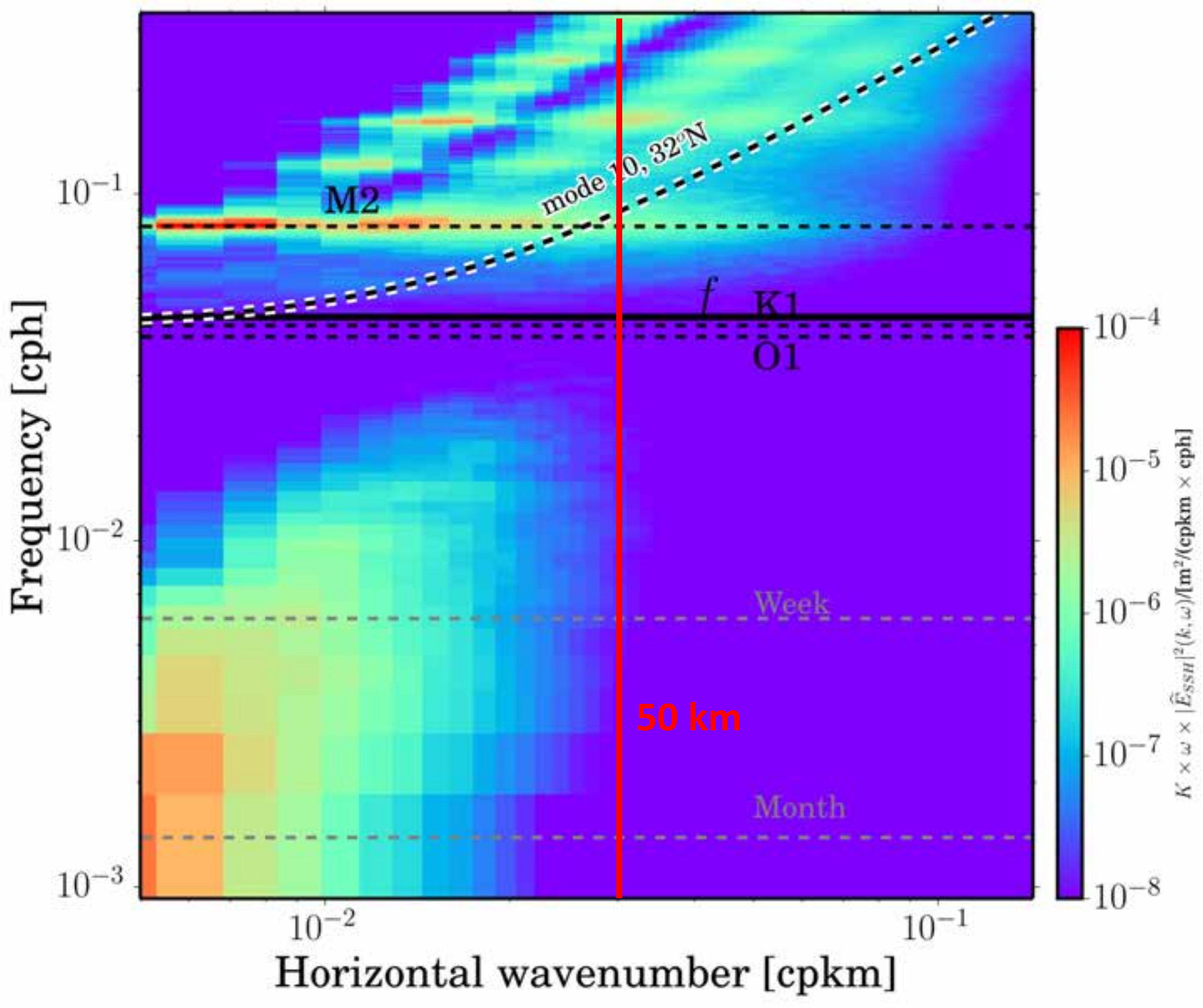
CL#18-3173

LLC4320 simulation

MITgcm 1/48°: EKE



IGWs dominance at higher wavenumbers in summertime



Frequency-wavenumber spectra of SSH: Kuroshio Extension in summertime

- **SSH mostly explained by BMs at scales larger than 50 km**
- **SSH mostly explained by IGWs at scales smaller than 50 km**

Loss of geostrophic balance

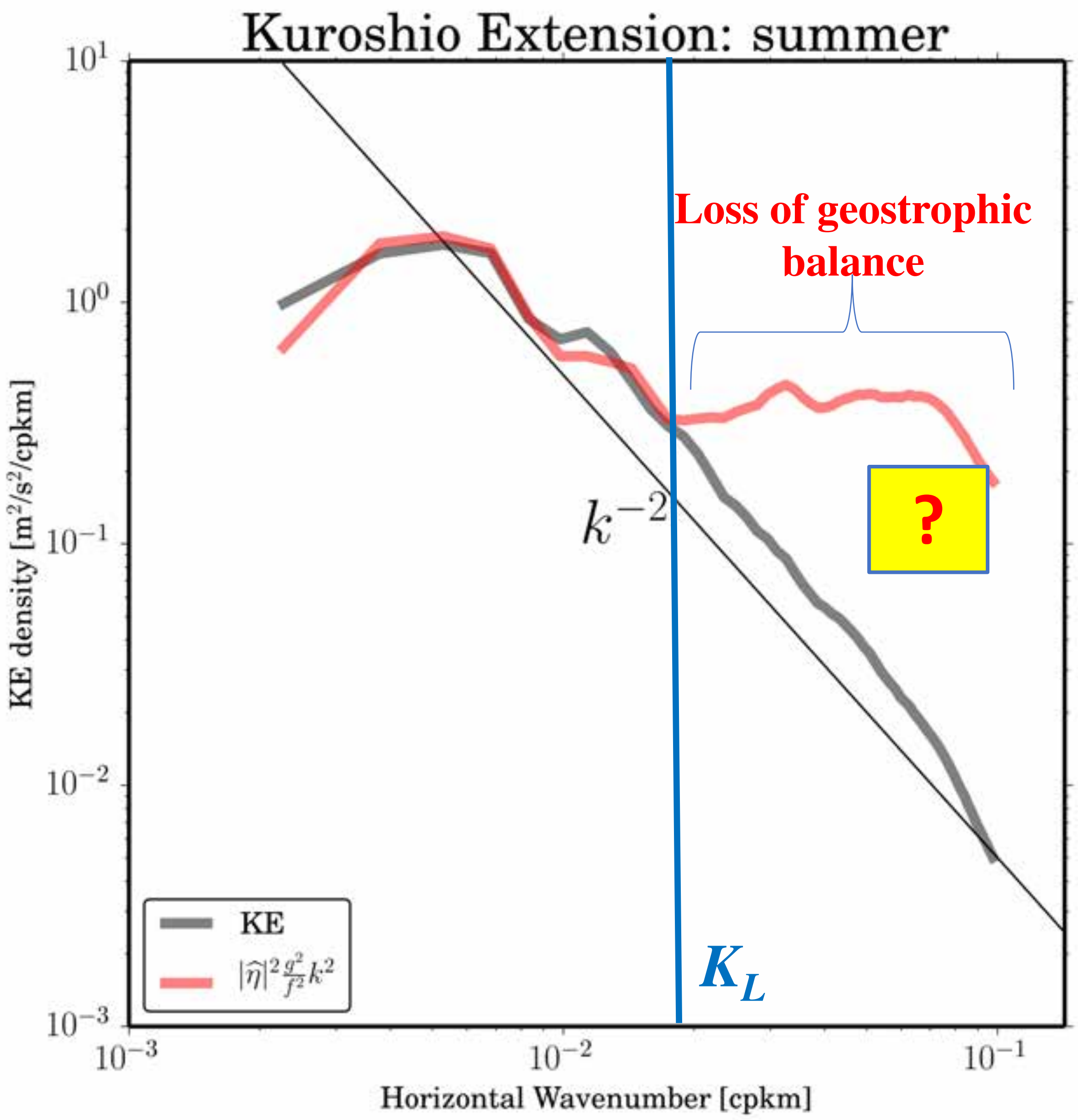
- **Geostrophic KE highlights the spectral slope discontinuity**

$$\widehat{KE} = |\hat{\eta}|^2 \frac{g^2}{f^2} k^2$$

K_L is the transition scale (Qiu et al. 2018)

See Oscar's talk, for observational evidence

- **KE spectra do not display any discontinuity**



Kinetic energy of IGWs

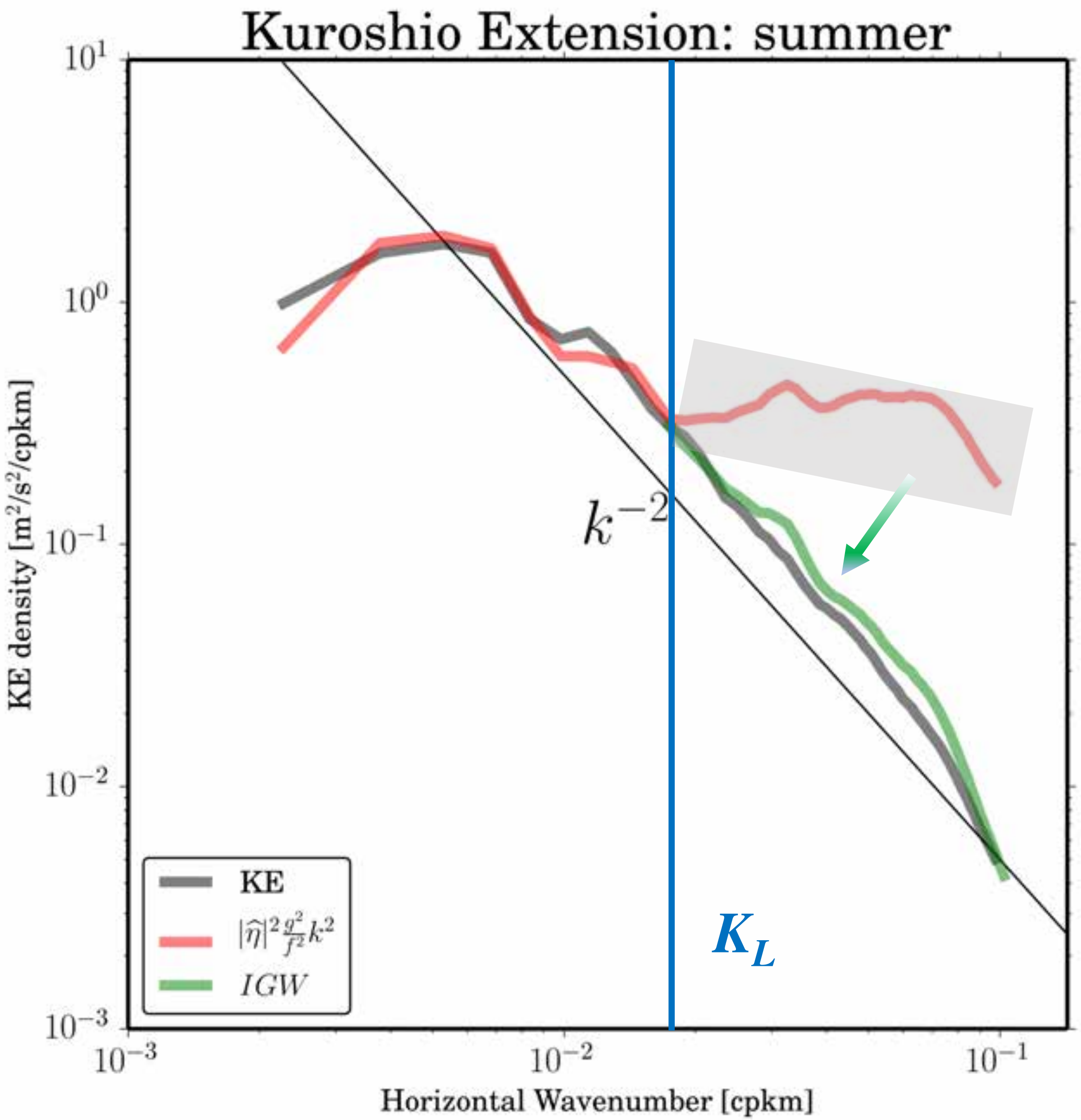
- **Linear shallow water approximation is used to recover the continuity of the spectral slope**

$$\widehat{KE}_{\mathrm{igw}} = |\hat{\eta}|^2 g^2 k^2 \frac{(\omega^2 + f^2)}{(\omega^2 - f^2)^2} = |\hat{\eta}|^2 \frac{g^2}{f^2}\left(2 + Rd^2 k^2\right)/\left(Rd^4 k^2\right)$$

$$\omega^2 = f^2\left(1 + Rd^2 k^2\right)$$

Rd **is the third baroclinic Rossby radius of deformation**

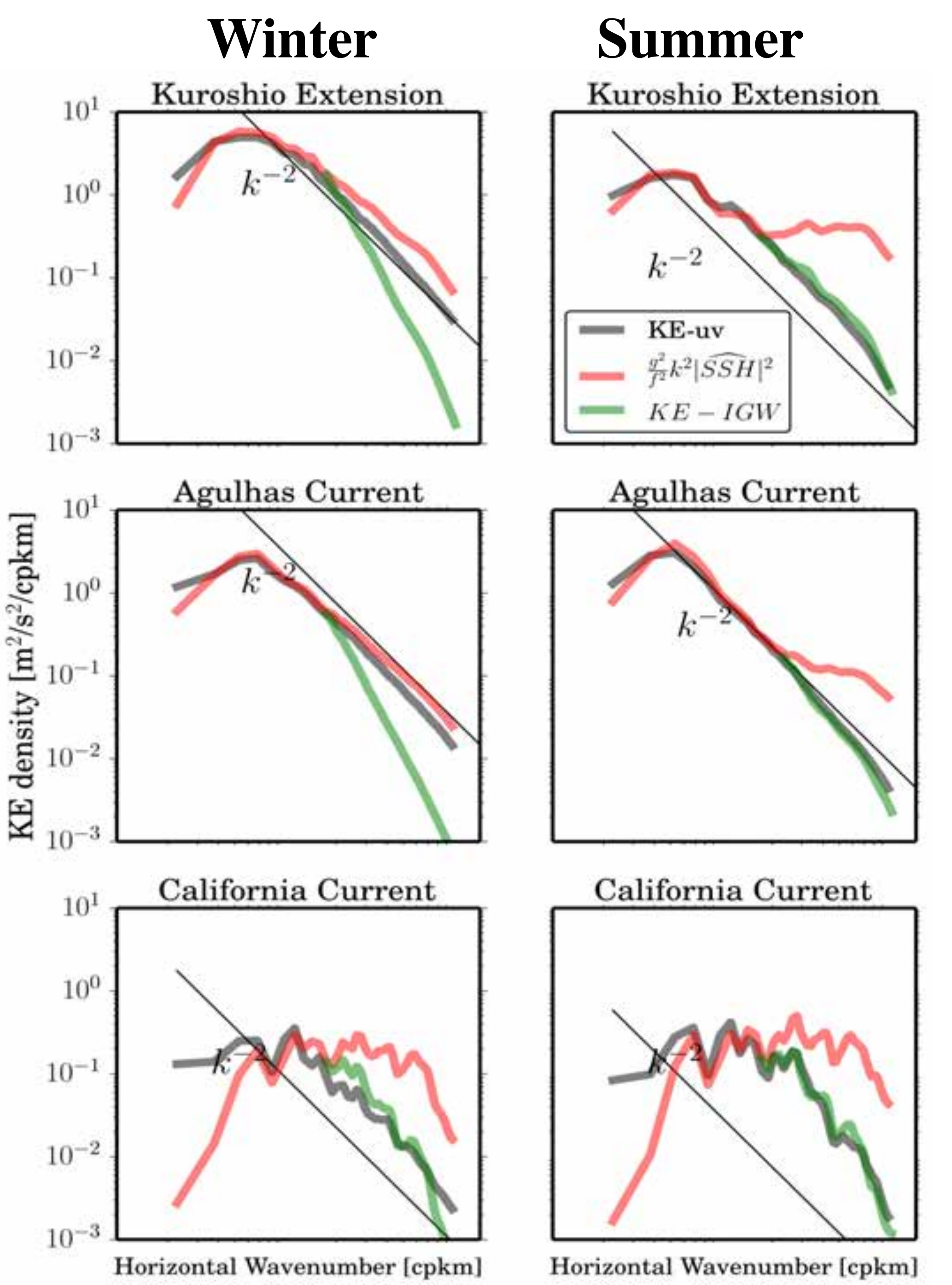
$\widehat{KE}_{\mathrm{igw}}$ **is the kinetic energy of IGWs**



Spectral slope discontinuity: geographical and seasonal dependence

The methodology works in those high-EKE regions only in summer

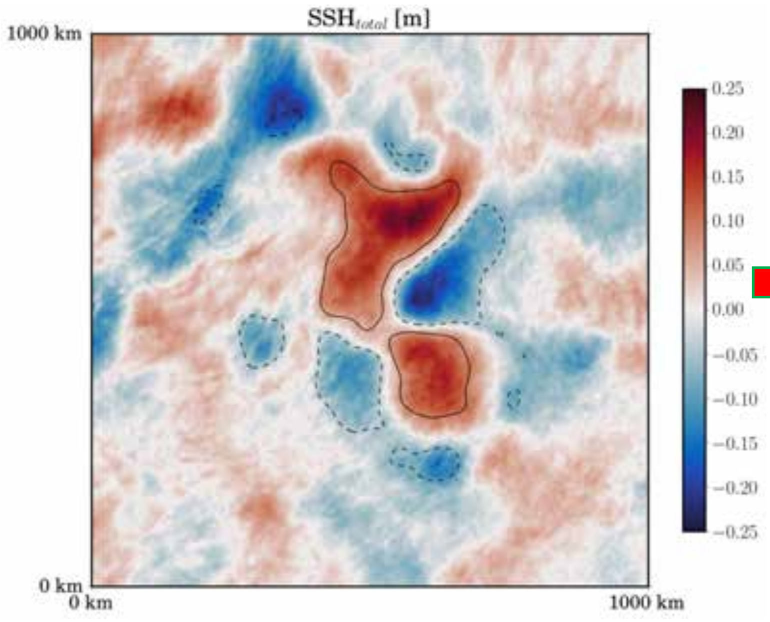
The methodology works in those low-EKE regions, either in winter or summer!



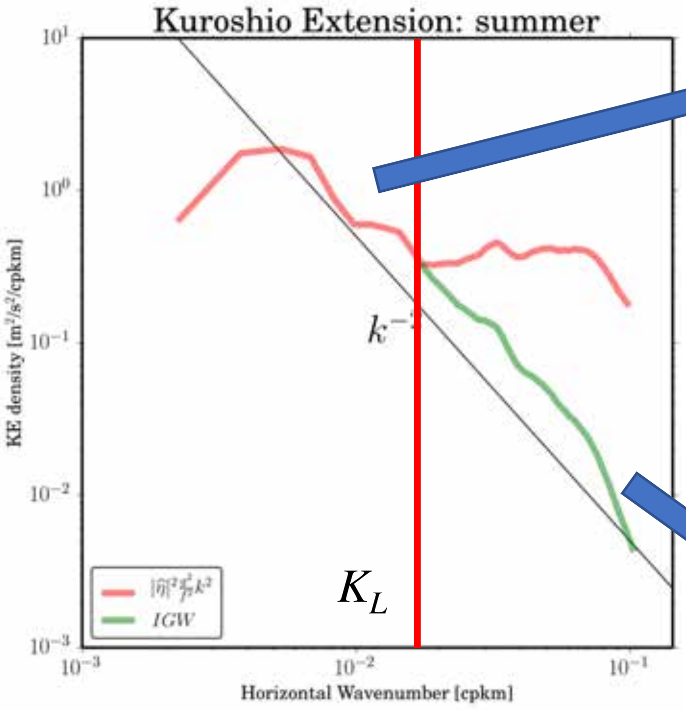
How to exploit the SWOT wide-swath

Wide-swath produces $\eta(x, y)$ and therefore $\hat{\eta}(k, l)$

Physical space



Spectral space

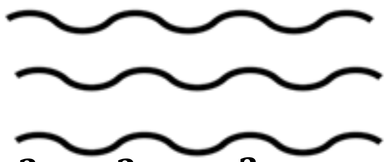


Physical space

Geostrophic balanced motions: $\hat{\eta}_{geo}(k, l)$

$k^2 + l^2 < K_L^2$

Internal gravity waves: $\hat{\eta}_{igw}(k, l)$



$k^2 + l^2 > K_L^2$

Reconstructing the velocity field: Balanced motions + internal gravity waves

Geostrophic balanced motions:

$$\hat{\eta}_{geo}(k,l) \ \ at \ \ k^2 + l^2 < K_L^2$$

$$\hat{u}(k,l) = \frac{igl}{f}\hat{\eta}_{geo}(k,l)$$

$$\hat{v}(k,l) = -\frac{igk}{f}\hat{\eta}_{geo}(k,l)$$

Internal gravity waves using shallow water equations:

$$\hat{\eta}_{igw}(k,l) \ \ at \ \ k^2 + l^2 > K_L^2$$

$$\hat{u}(k,l) = \mathrm{g}\hat{\eta}_{igw}(k,l)\frac{[\omega k + ilf]}{(\omega^2 - f^2)}$$

$$\hat{v}(k,l) = \mathrm{g}\hat{\eta}_{igw}(k,l)\frac{[\omega l - ikf]}{(\omega^2 - f^2)}$$

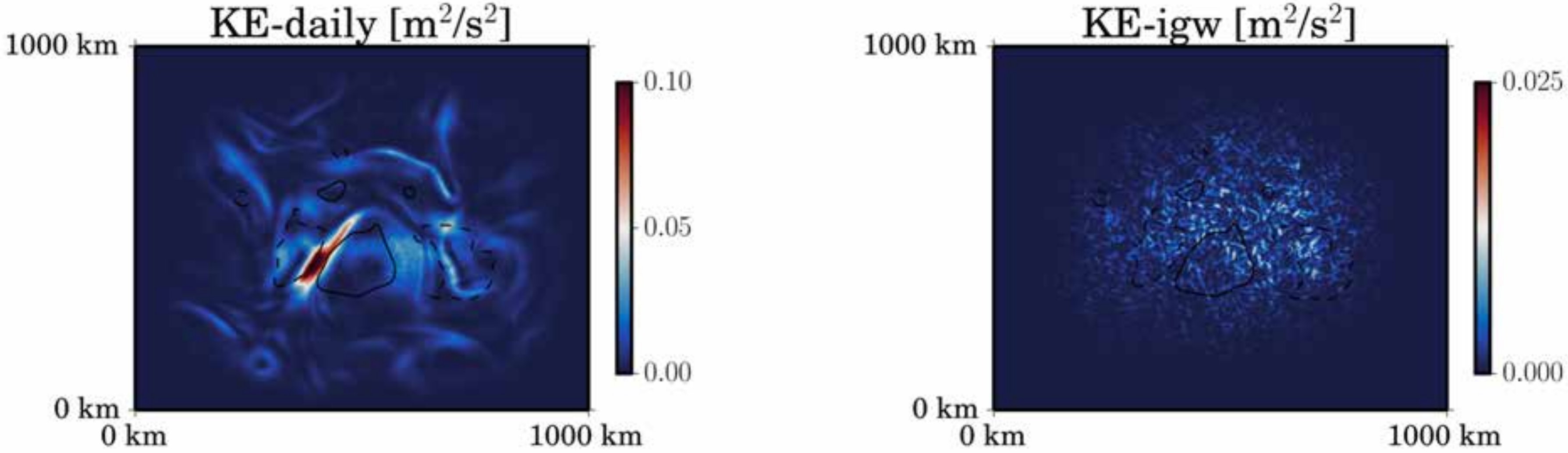
$$\omega^2 = f^2(1 + {Rd_{3rd}}^2 K^2)$$

Inverse FFT

Reconstructing the 2D velocity field in the physical space: amplitude and phase

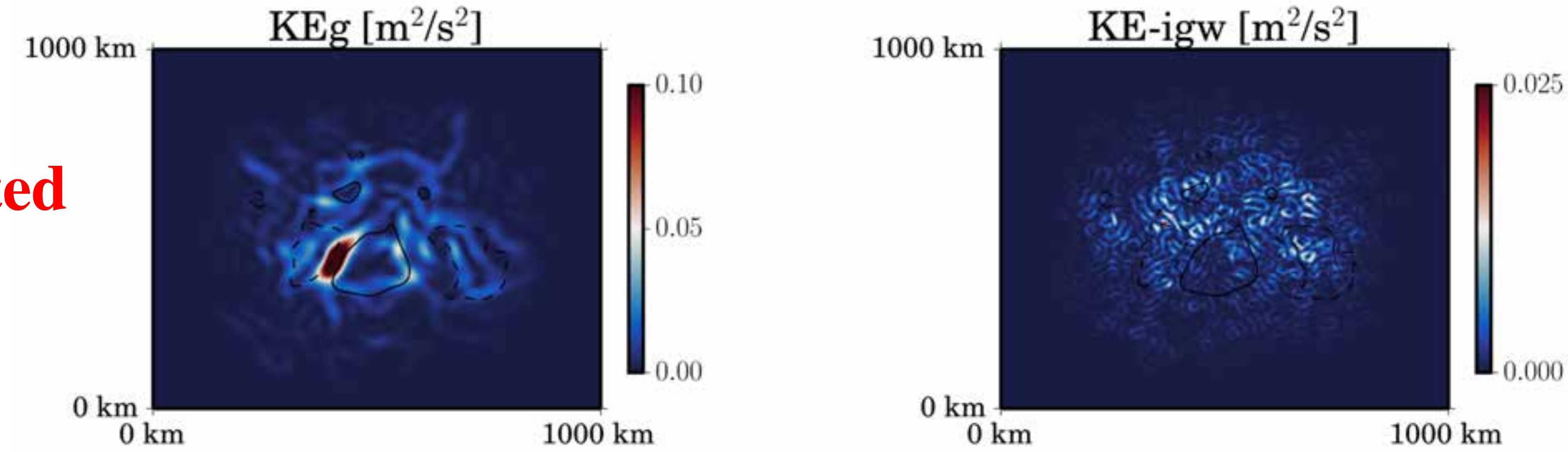
Comparison between true KE and KE reconstructed

True



Amplitude and phase

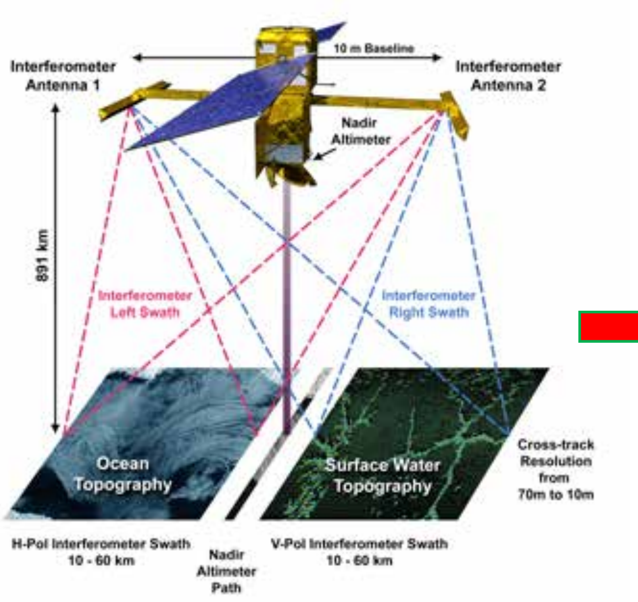
Reconstructed



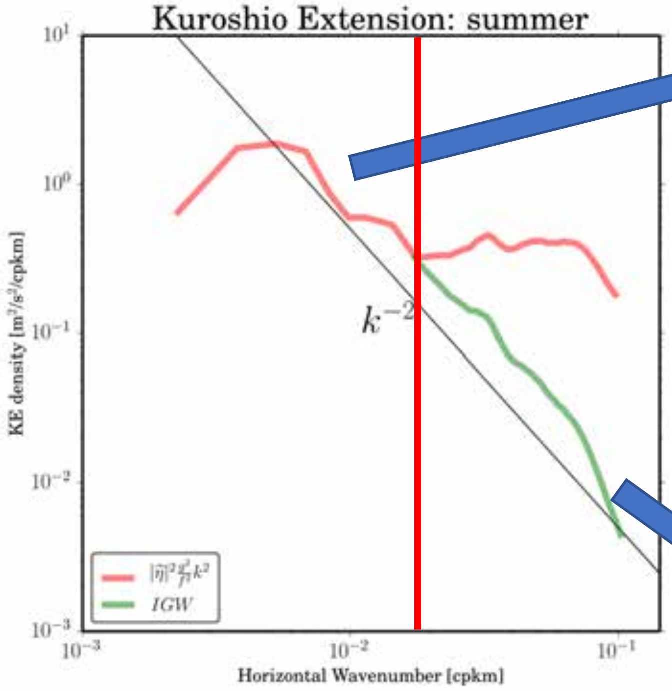
Amplitude and phase

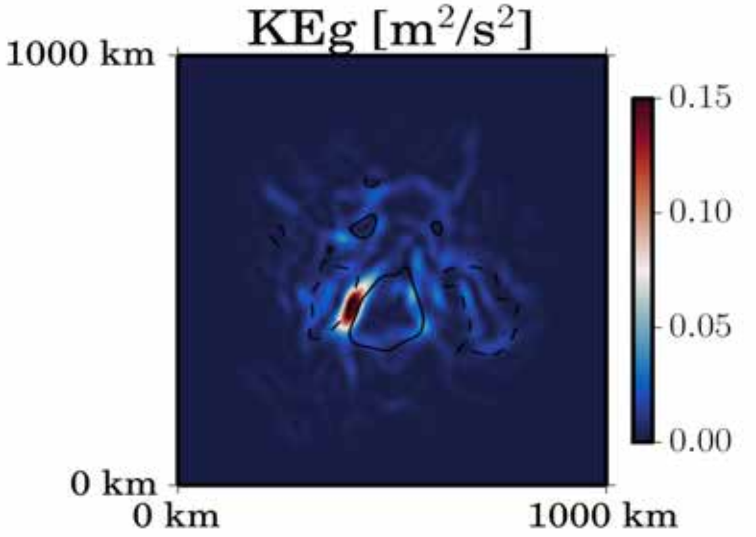
Future applications of the SWOT wide-swath

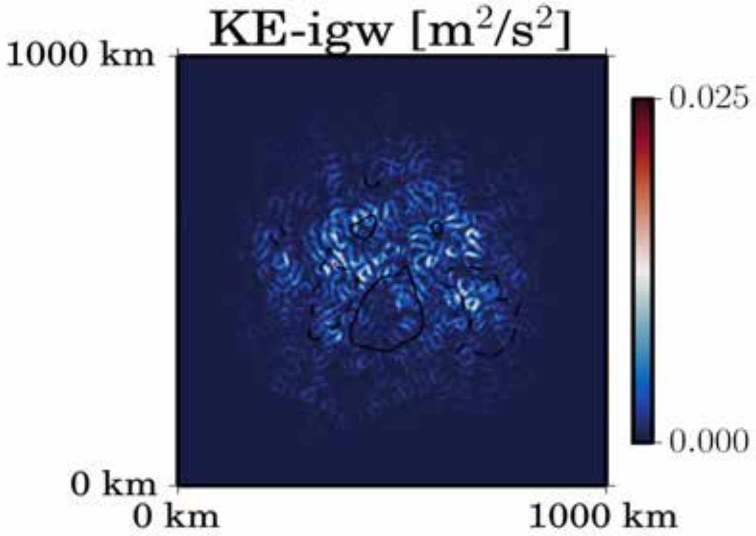
SWOT observations



Spectral analysis







Such spectral slope discontinuity for SSH, + the wide-swath property of SWOT, can be exploited to diagnose BMs and IGWs !

Conclusions

- **The reconstructions from SSH(x, y) over geostrophic balanced motions and IGW is a work in progress**

- **We would to extend the Kuroshio example to other oceanic regions, in particular the California Current**