On the spatial resolution of the future SWOT SSH measurements

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What’s the smallest spatial scale SWOT can resolve?

100km?

What’s the smallest spatial scale SWOT can resolve?

50km?

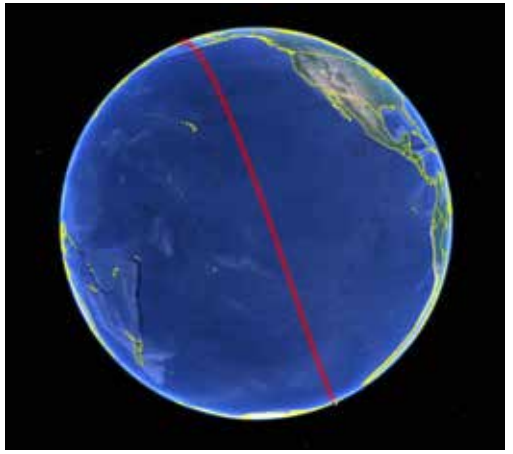
What’s the smallest spatial scale SWOT can resolve?

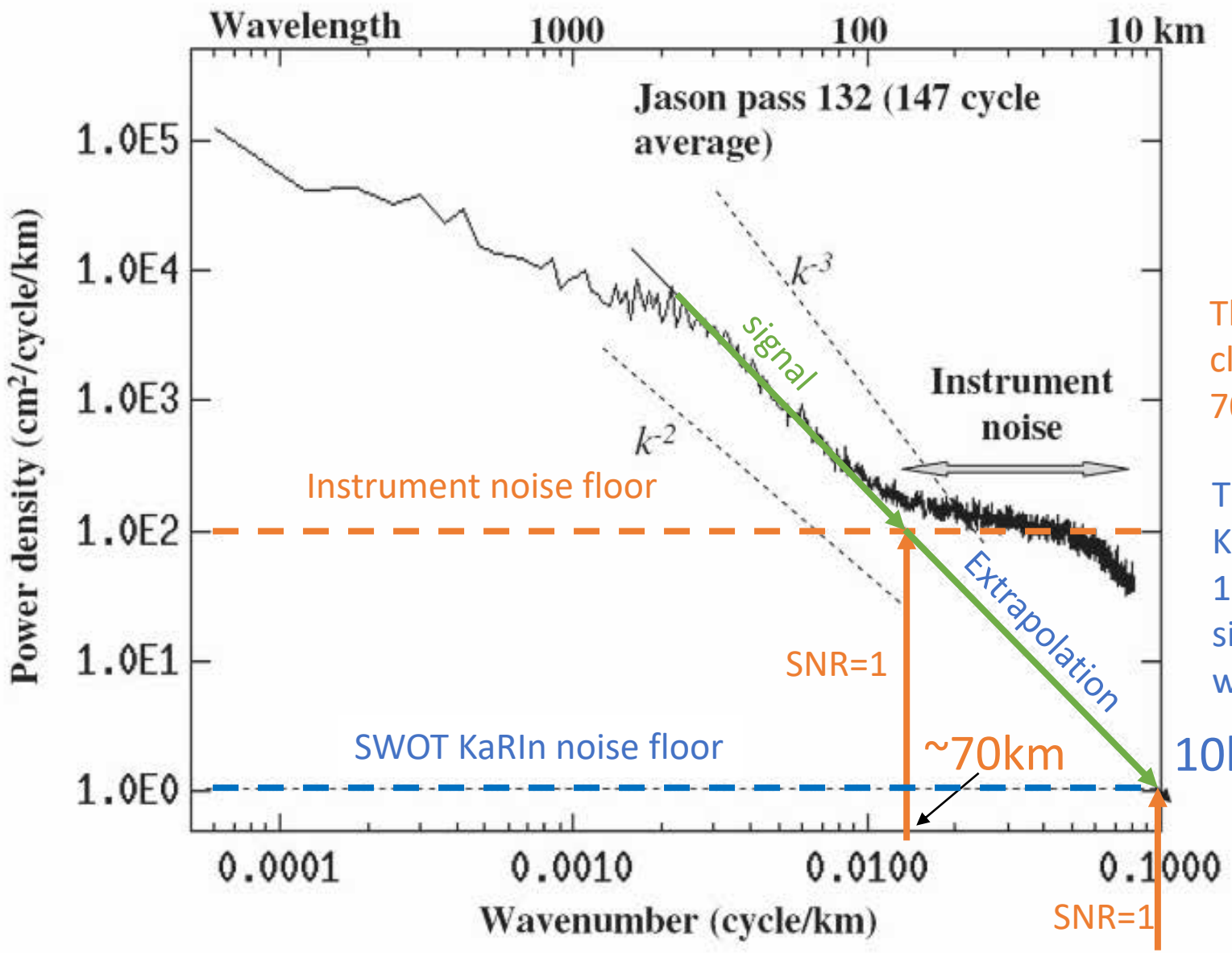
15km?

We do not know for sure without real data.

What about an informed guess?

Extrapolation from Nadir altimeter



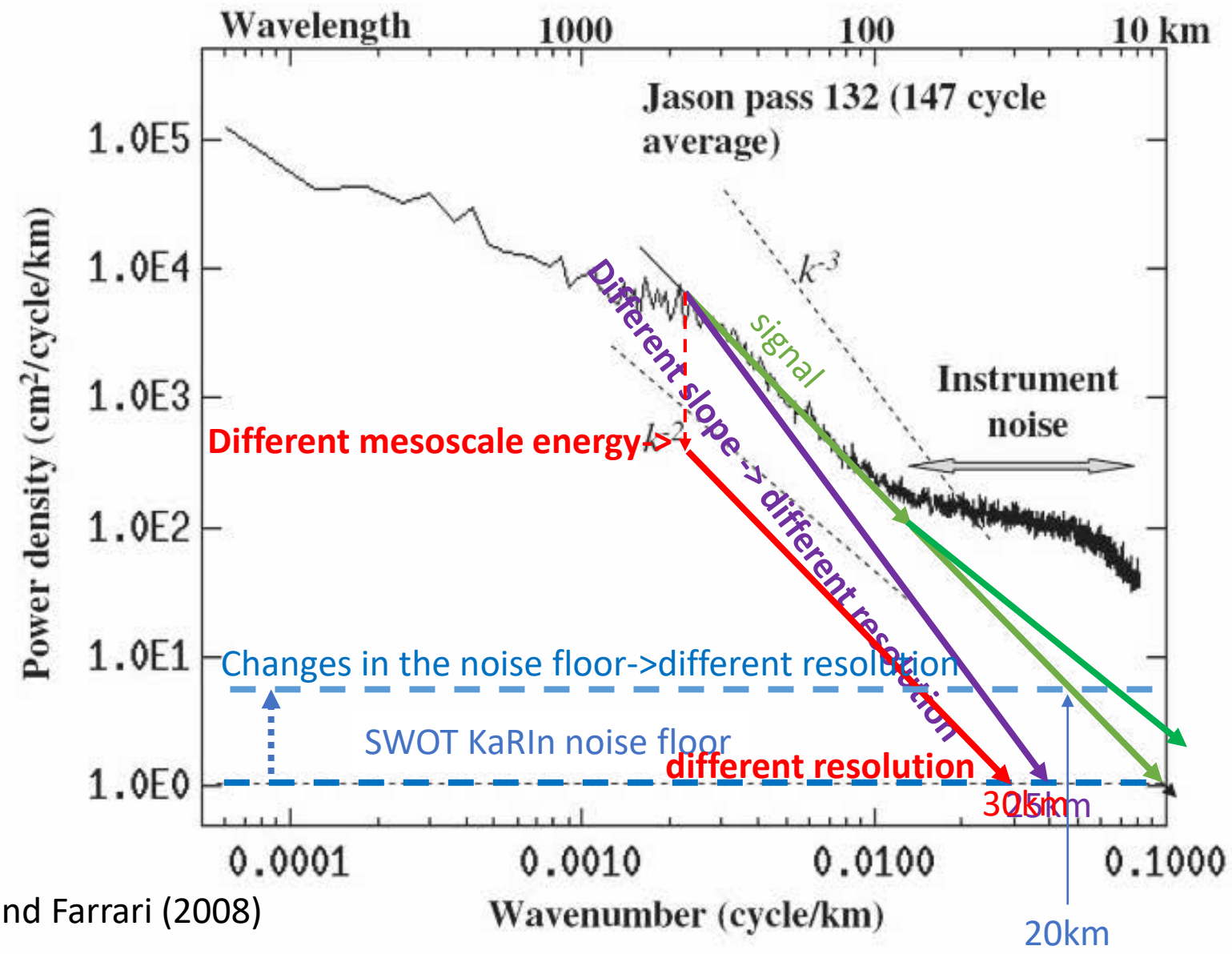


The resolution of the Jason-class nadir altimeter is about 70km. (Dufau et al., 2016)

The resolution of SWOT KaRin can be as small as 10km by extrapolating the signal from the long wavelength.

Fu and Farrari (2008)

Factors affecting the SWOT scale



Fu and Farrari (2008)

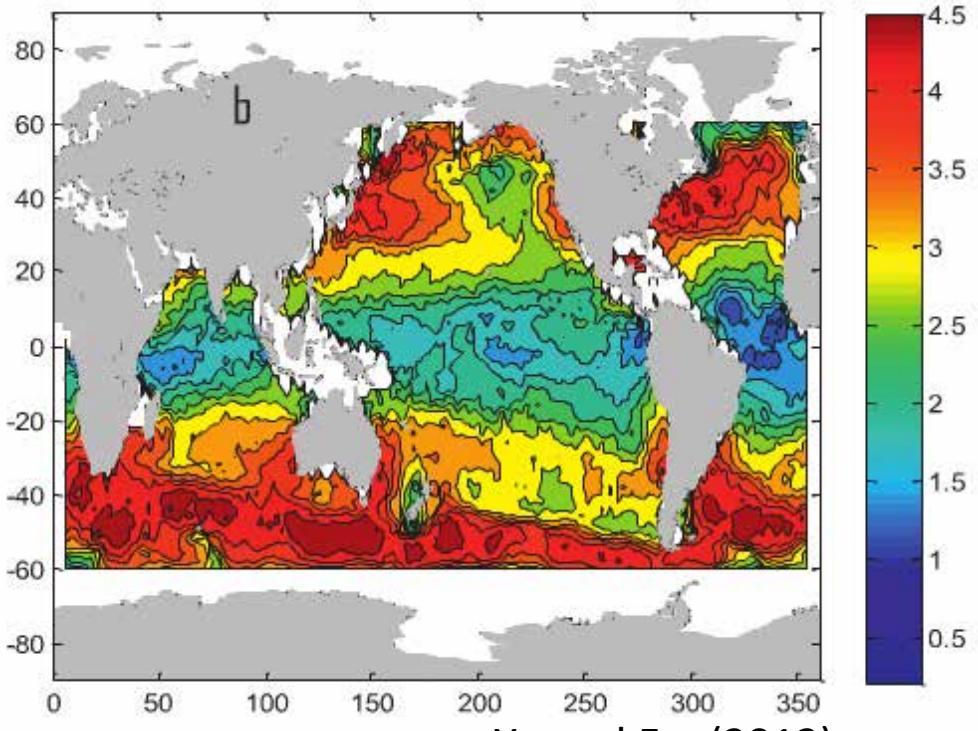
1. the spectral slope

2. the energy level at mesoscale (300-500km)

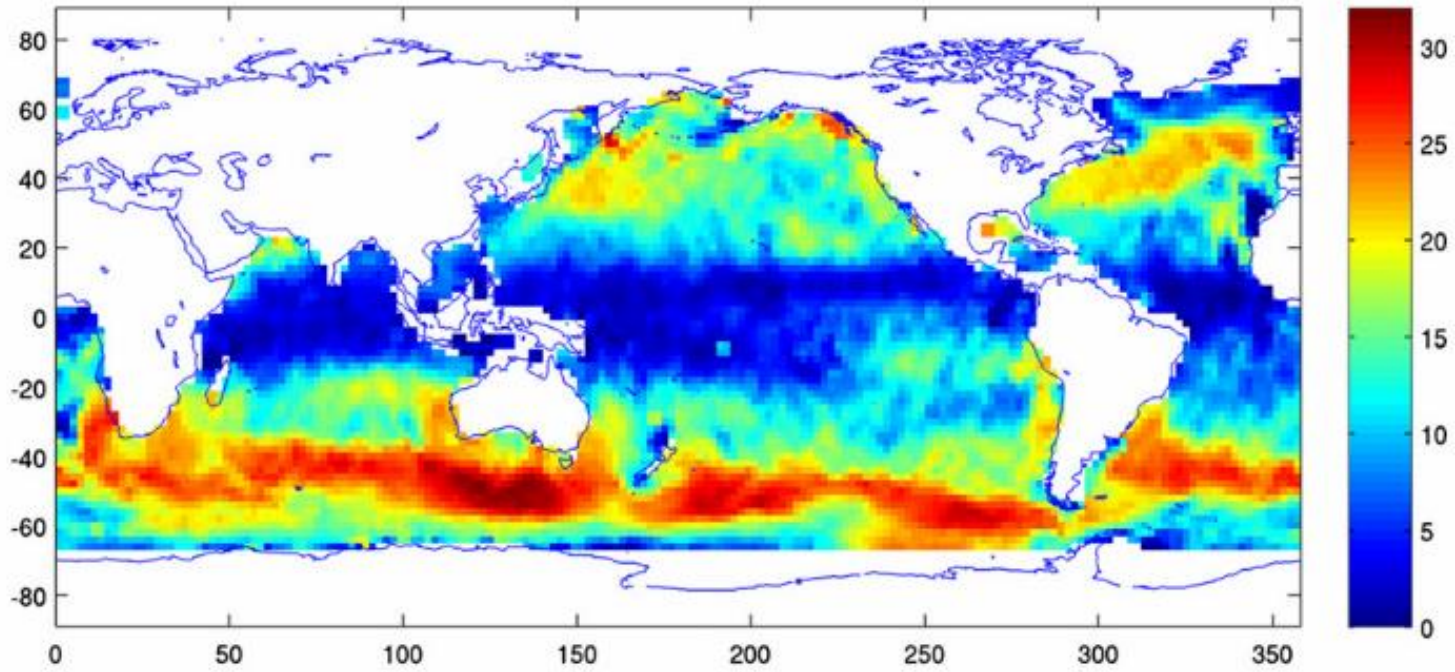
3. the noise floor (depends on the surface wave height)

4. Non-constant spectral slope (due to high frequency baroclinic waves)

Variations due to the ocean signal



Xu and Fu, (2012)



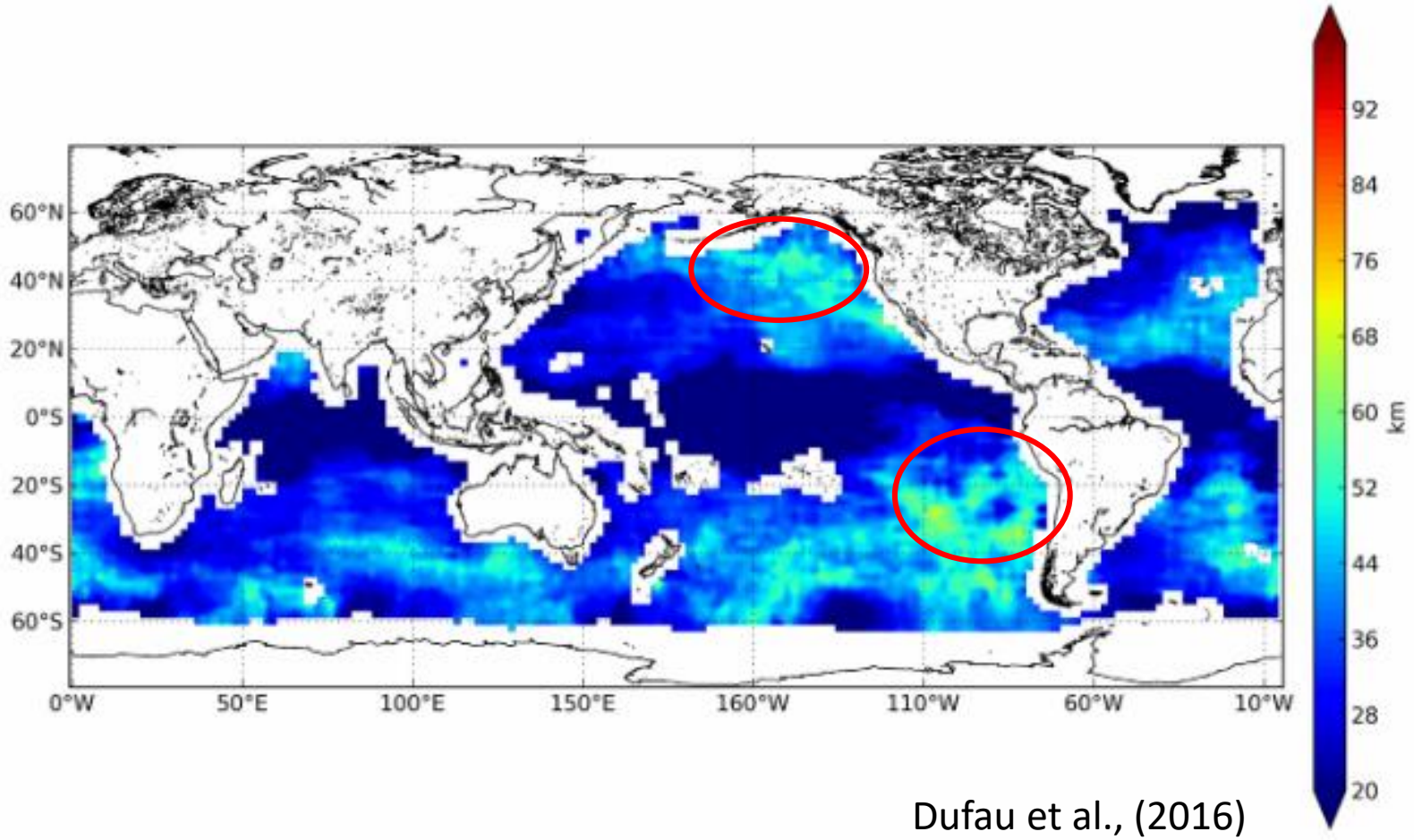
Fu and Ubelmann, 2014

The wavenumber spectra slope shows a large geographic variation.

SWOT scale is geographically dependent (with a uniform 2m significant wave height). Mid-latitude: ~15-25km; Southern Ocean: ~25-35km.

Variations due to significant wave height

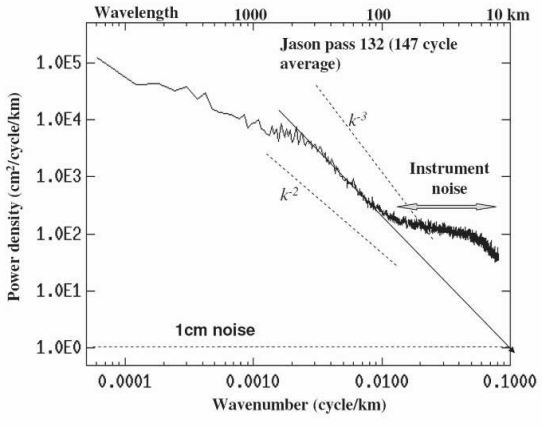
- Based on the mean SWH from March to October 2013.
- No seasonal variance was considered.



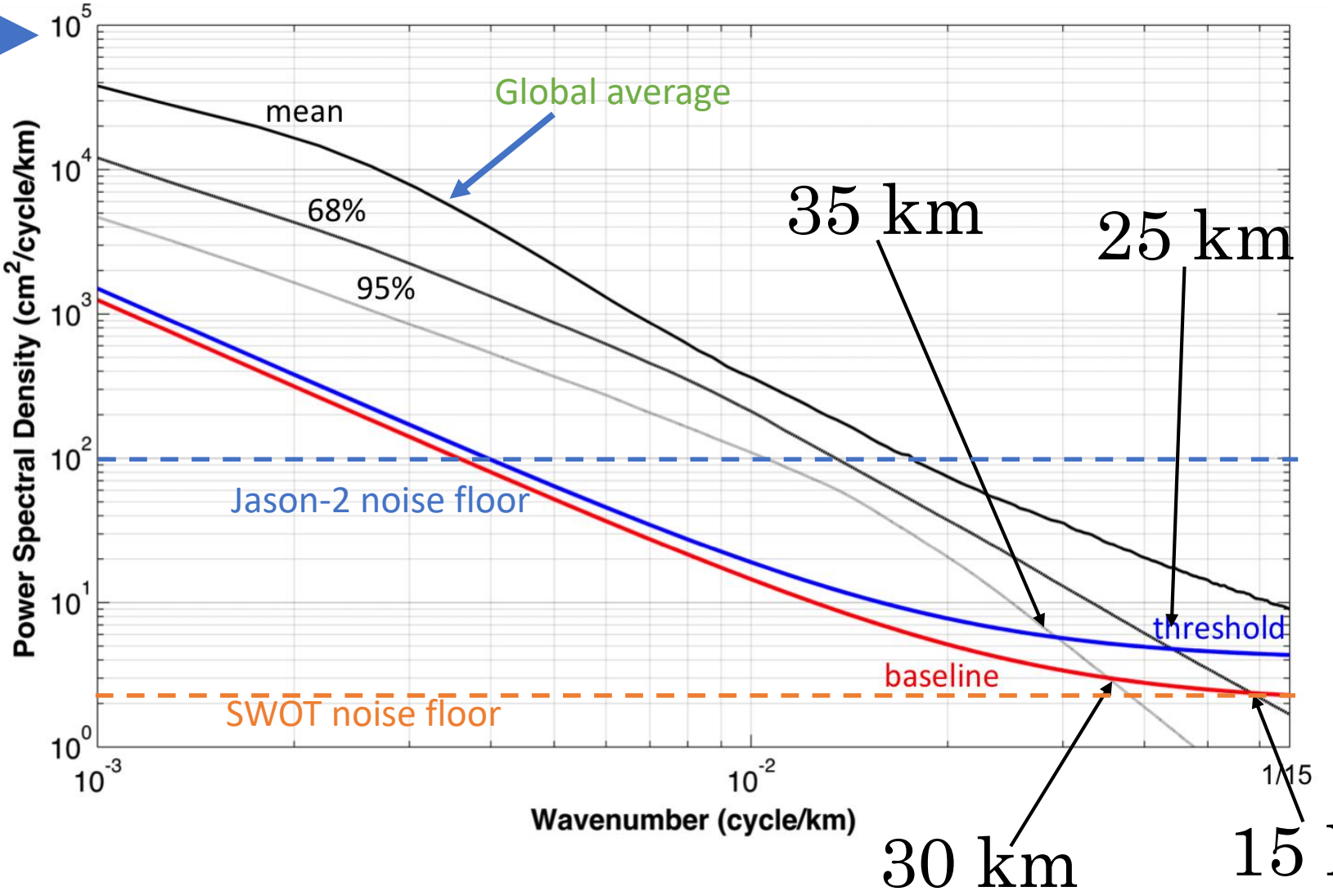
Dufau et al., (2016)

Figure 10. 1-D mesoscale resolution capability (in wavelength in km) estimated for the future SWOT mission, taking into account Jason2 estimated spectral slopes and mean SWH from March to October 2013.

SWOT science requirement



1. The ocean signal is based on the Jason-2 altimeter averaged globally.
2. The KaRIn noise is based on a fixed 2-meter significant wave height, which can vary seasonally and geographically.
3. Our objective: a closer look at the distribution of the SWOT resolution both in space and in time considering a varying SWH-induced noise.

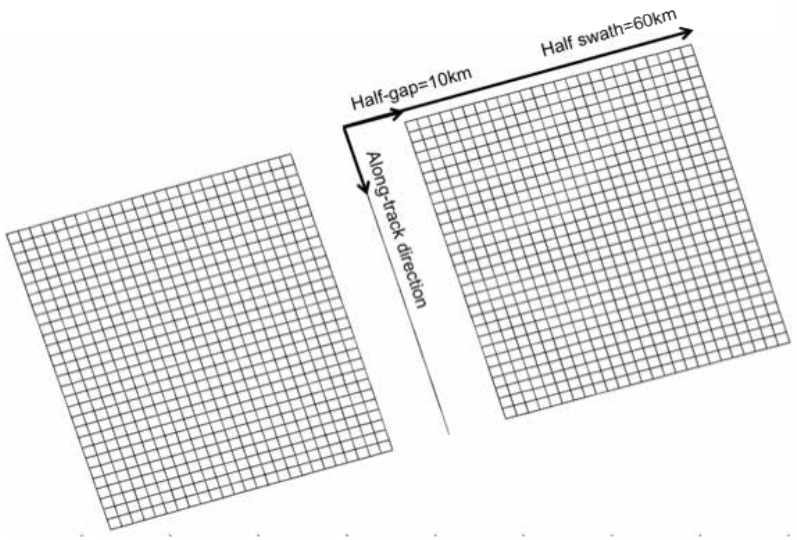


Rodríguez, E., 2016

A closer look at the distribution of the SWOT resolution

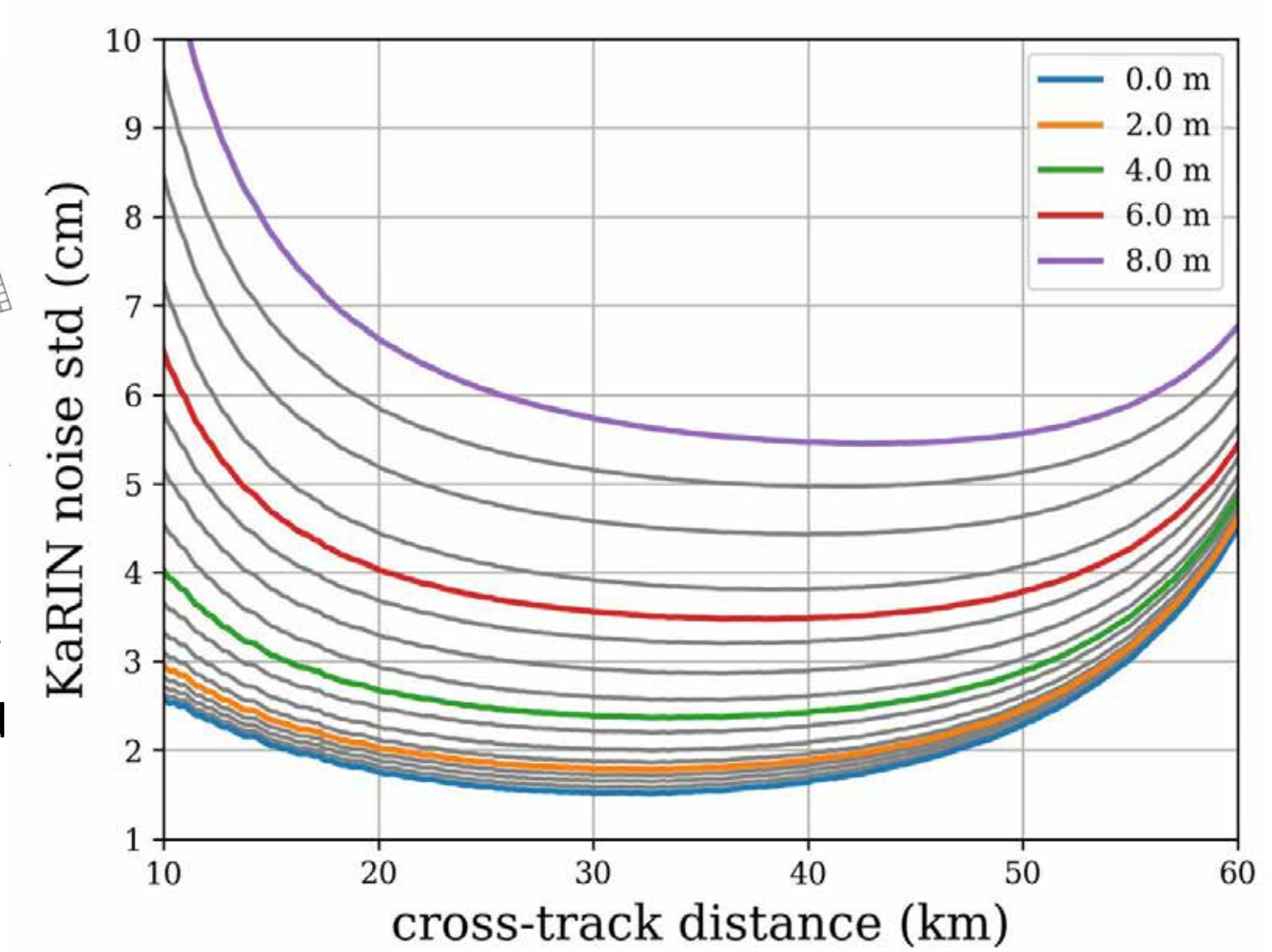
1. KaRIn noise (season, longitude, latitude)
   - KaRIn noise is a function of significant wave height.. Altimetry product will be used.
2. SSH (season, longitude, latitude)
   - Use a global simulation

KaRIn noise as a function of cross-track distance and SWH



Gaultier et al., (2015)

The RMS of the random KaRIn noise as a function of the cross-track distance and significant wave height (SWH).



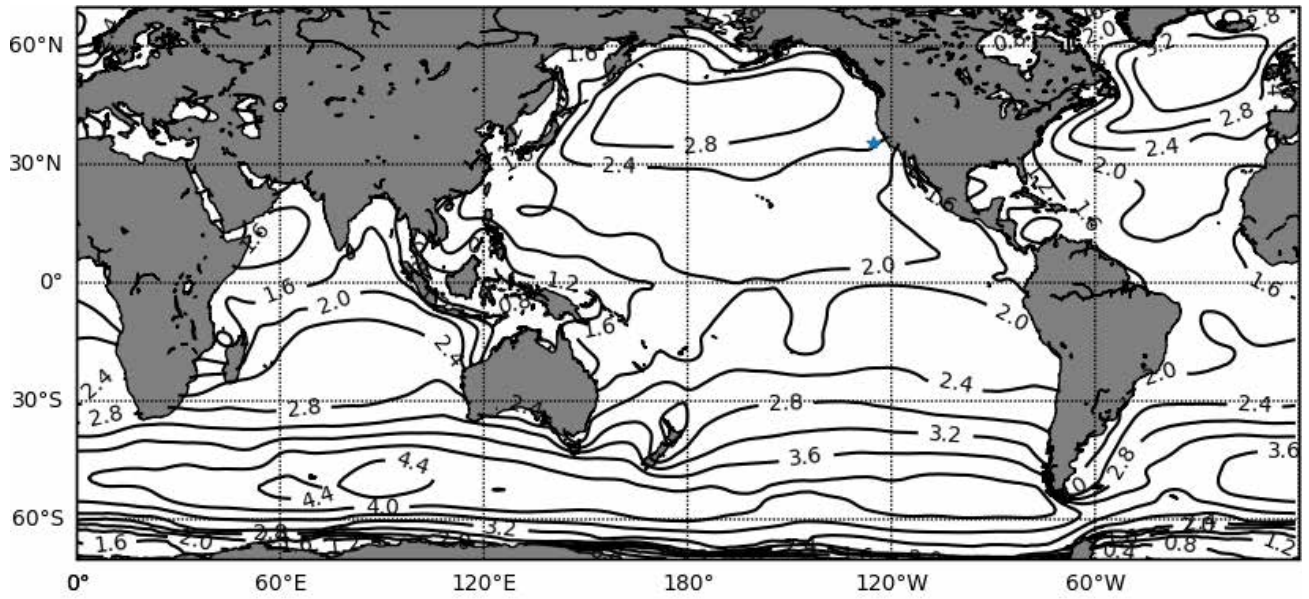
Esteban-Fernandez, 2017

SWH has seasonal and geographical dependence

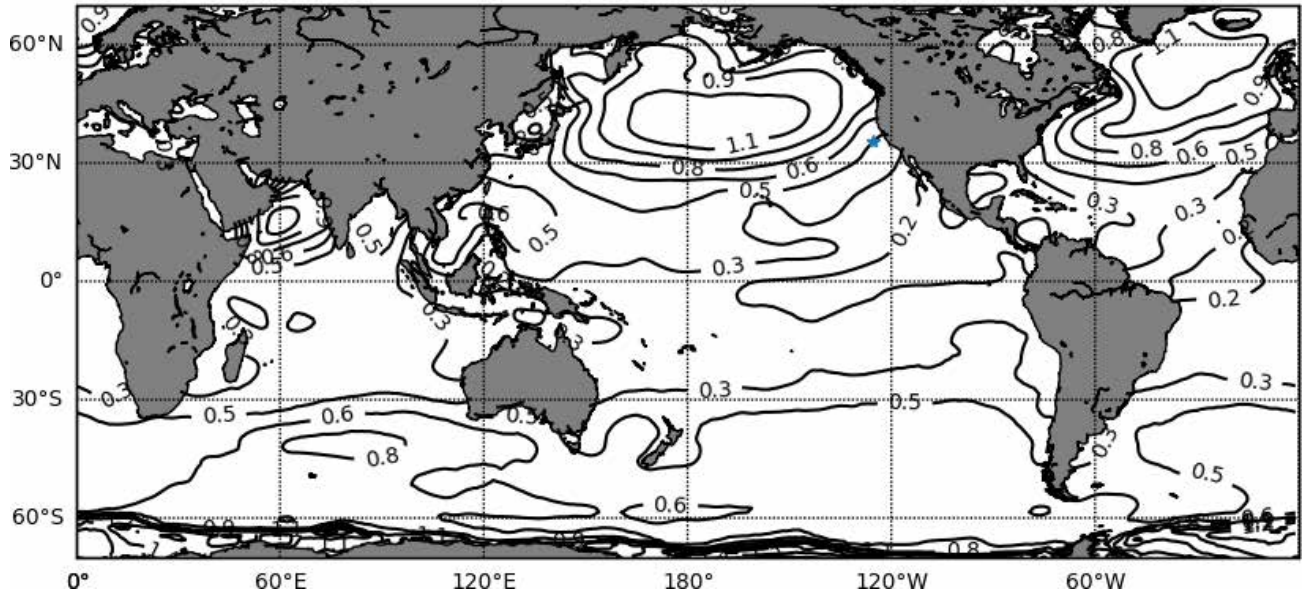
1. Large SWH in the high latitudes especially in the Southern Ocean (>3.6m).

2. Large seasonality in the Northern hemisphere 30-60°N.

Annual mean

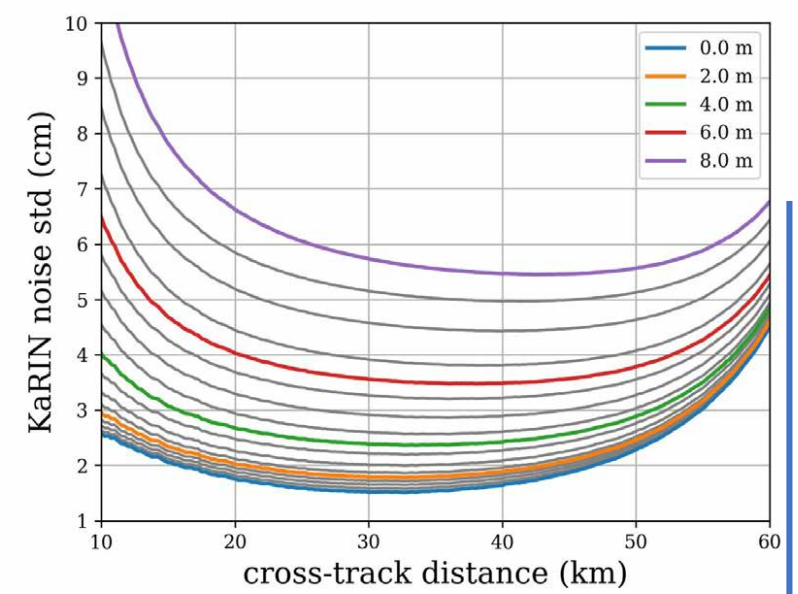


Seasonal variation



Data from Queffeulou (2004)

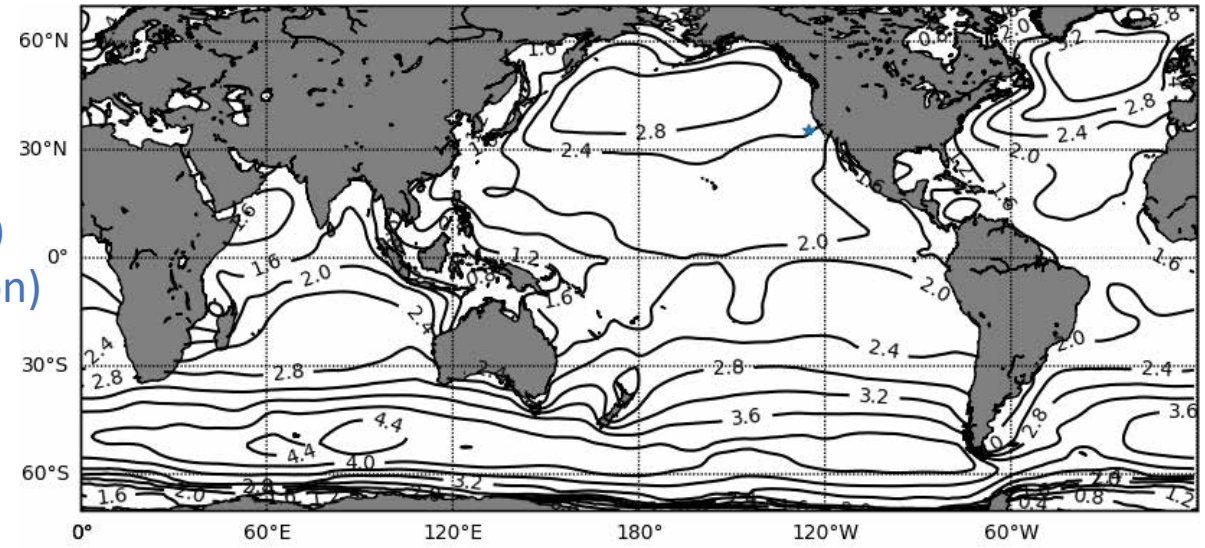
Convert SWH to the power spectra density of the KaRIn noise



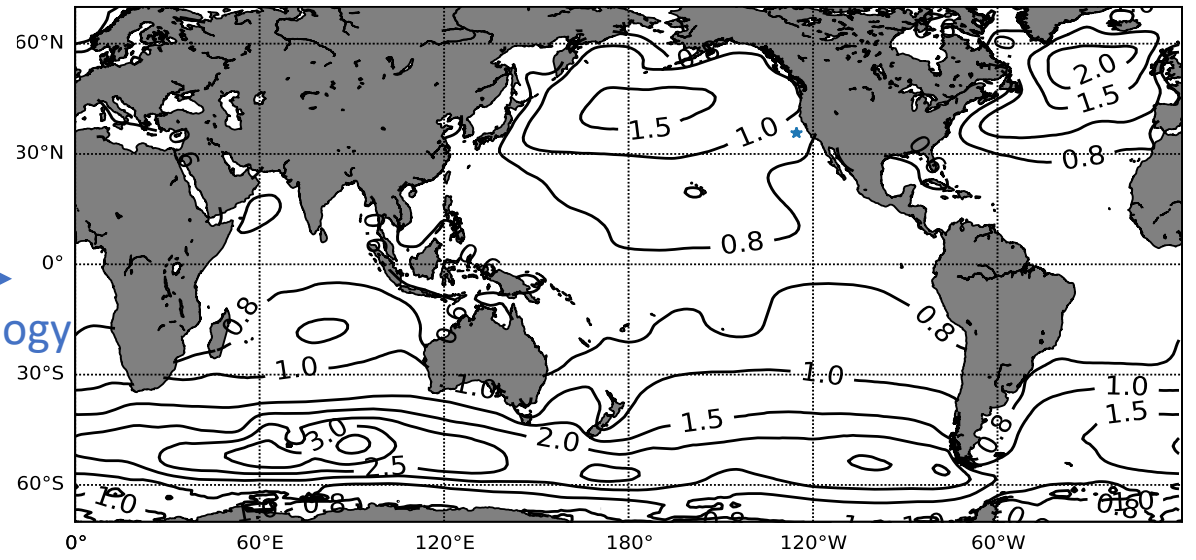
Averaged cross-track

KaRIn noise
$(cm^2/cpkm)$
(season, lat, lon)

Substitute SWH climatology



with SWH climatology

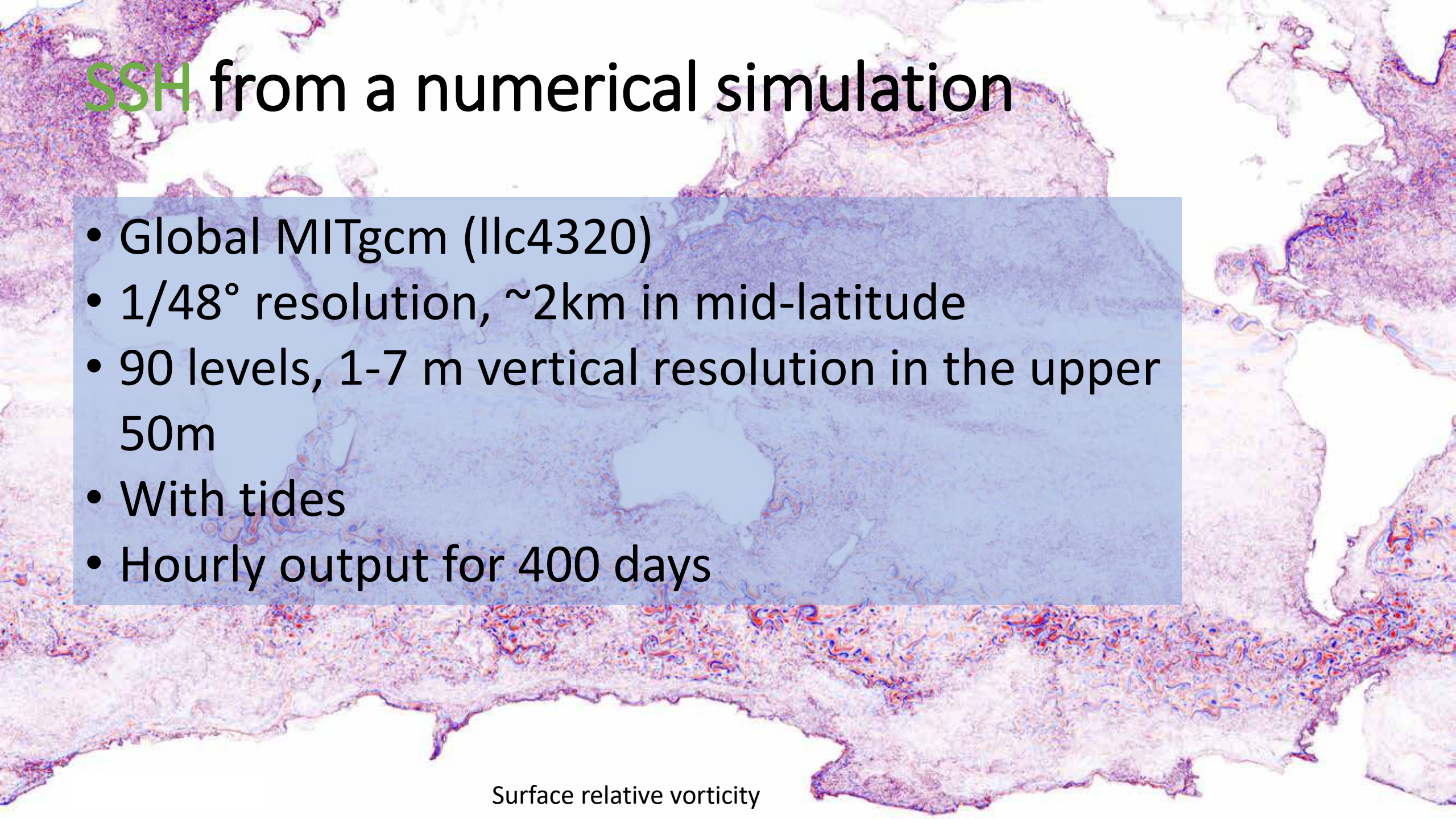


A closer look at the distribution of the SWOT resolution

1. KaRIn noise (season, longitude, latitude)
   - KaRIn noise is a function of SWH and cross-swath position
2. SSH (season, longitude, latitude)
   - Use a global simulation

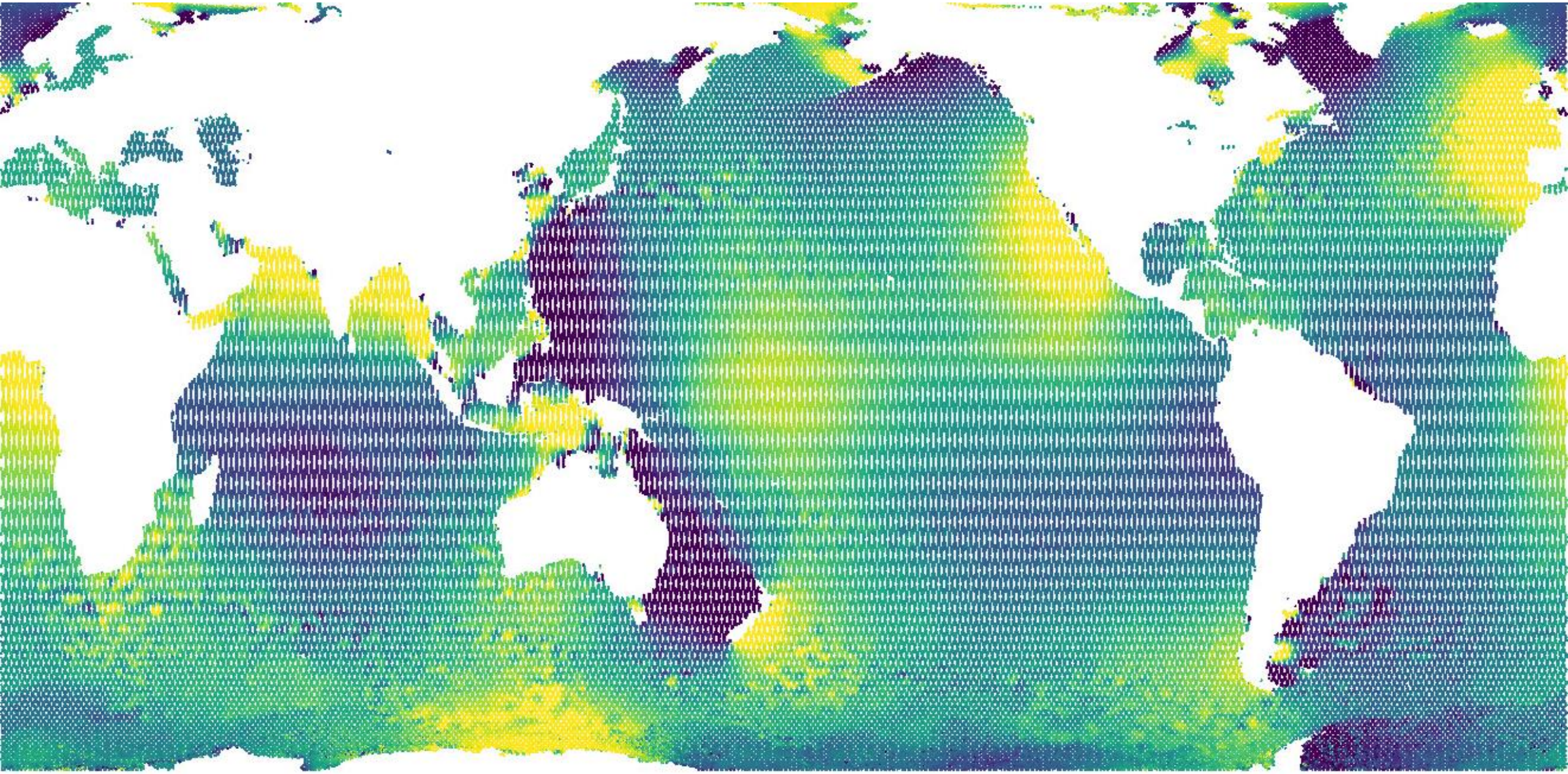
SSH from a numerical simulation

- Global MITgcm (llc4320)
- 1/48° resolution, ~2km in mid-latitude
- 90 levels, 1-7 m vertical resolution in the upper 50m
- With tides
- Hourly output for 400 days

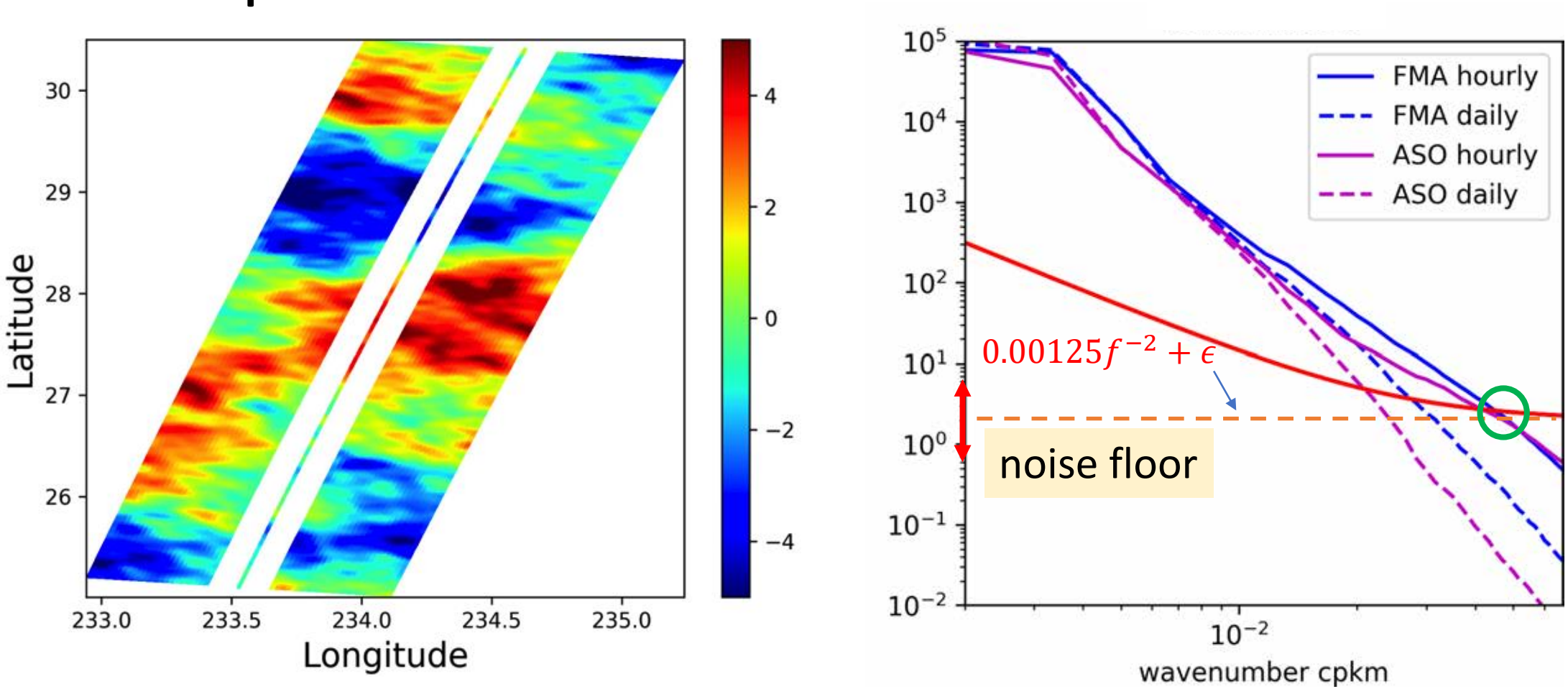


Surface relative vorticity

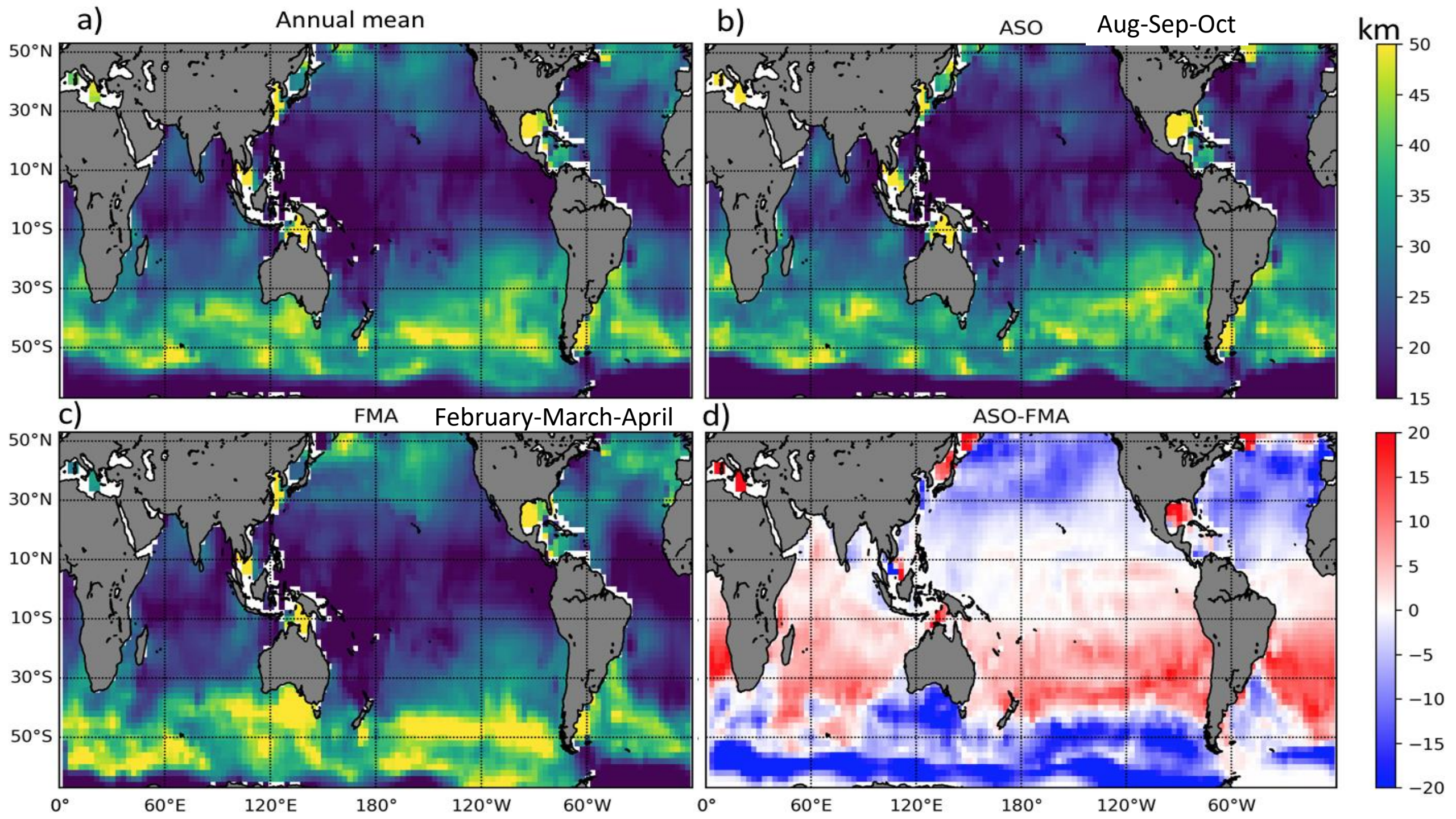
Interpolate the model SSH onto SWOT swaths (only the Nadir tracks are shown in this figure)



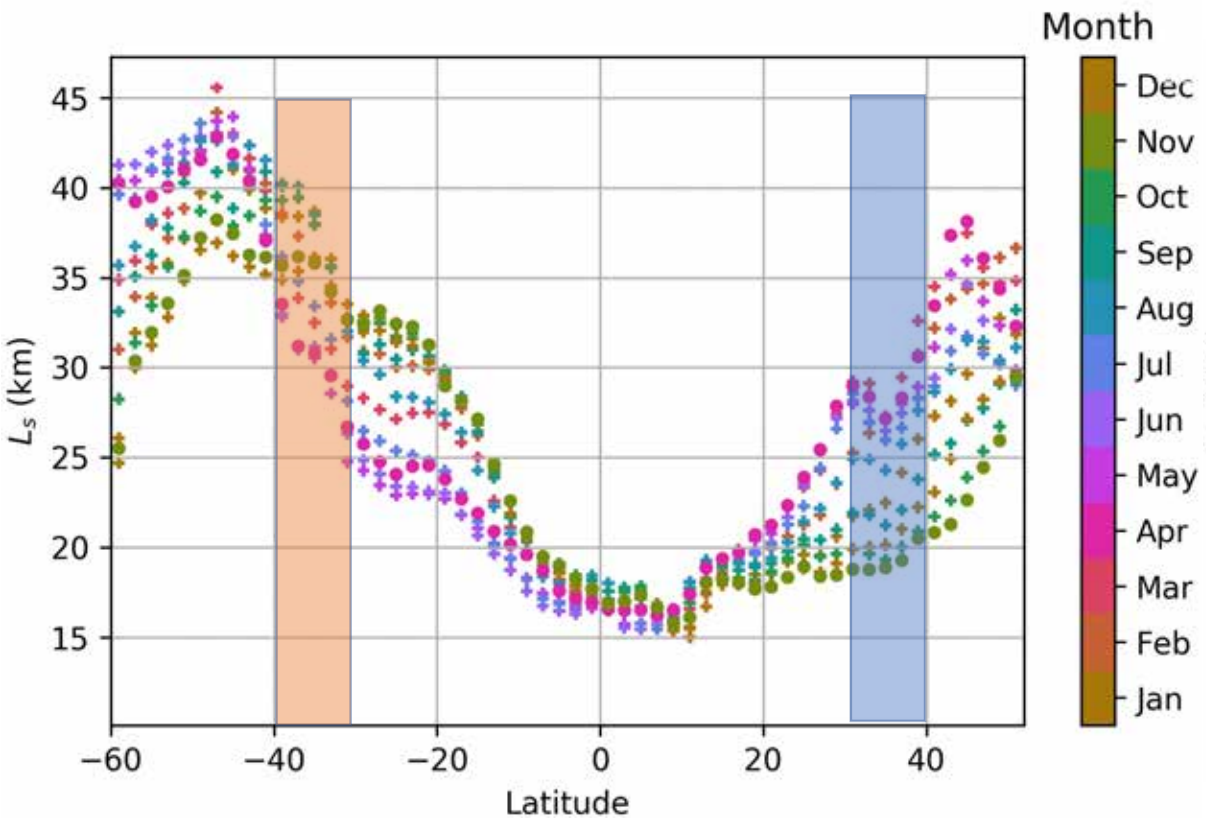
An example



1. Divide the whole swath into segments for the wavenumber spectrum calculation (left panel)
2. The spectrum slope changes seasonally and is non-uniform for different wavenumber range (right panel, blue and purple solid lines)
3. The non-uniform spectrum slope is due to high frequency baroclinic waves (right panel, compare solid and dash lines of the same color

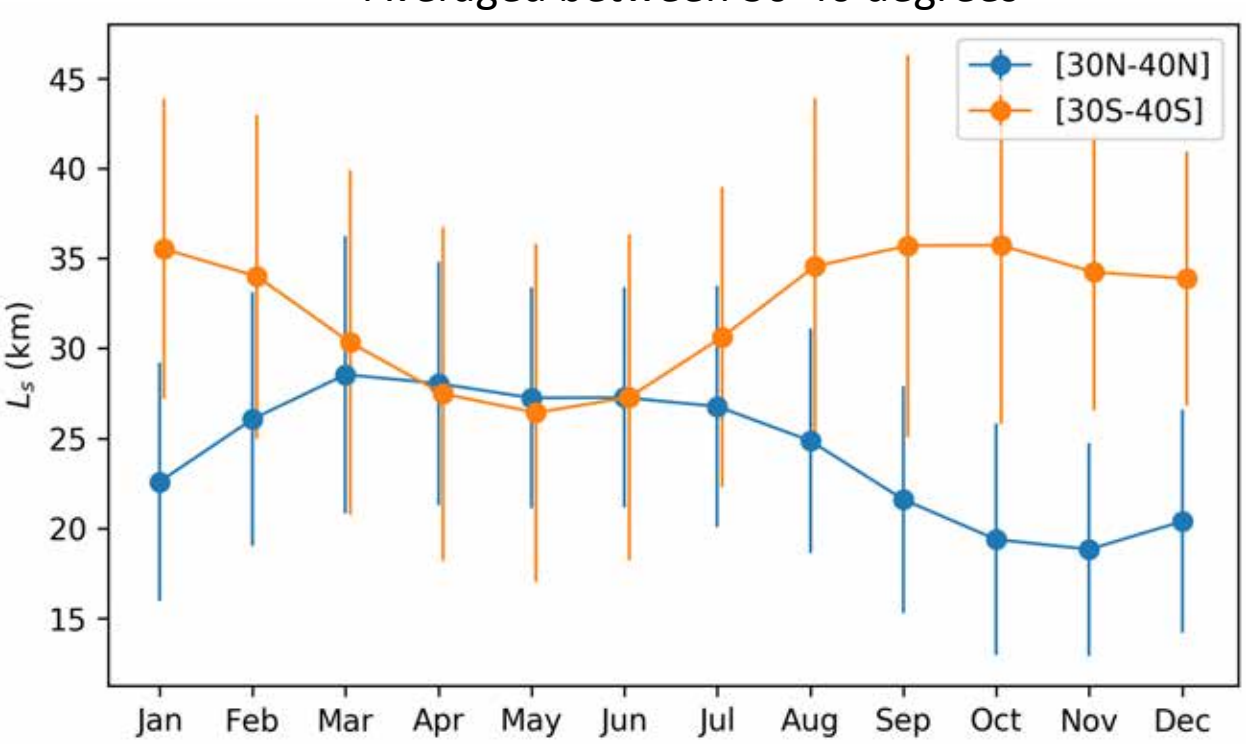

a)
Annual mean
b)
ASO
Aug-Sep-Oct
km
50
45
40
35
30
25
20
15
c)
FMA
February-March-April
d)
ASO-FMA
20
15
10
5
0
−5
−10
−15
−20
50°N
30°N
10°N
10°S
30°S
50°S
0°
60°E
120°E
180°
120°W
60°W

Latitudinal and seasonal variations



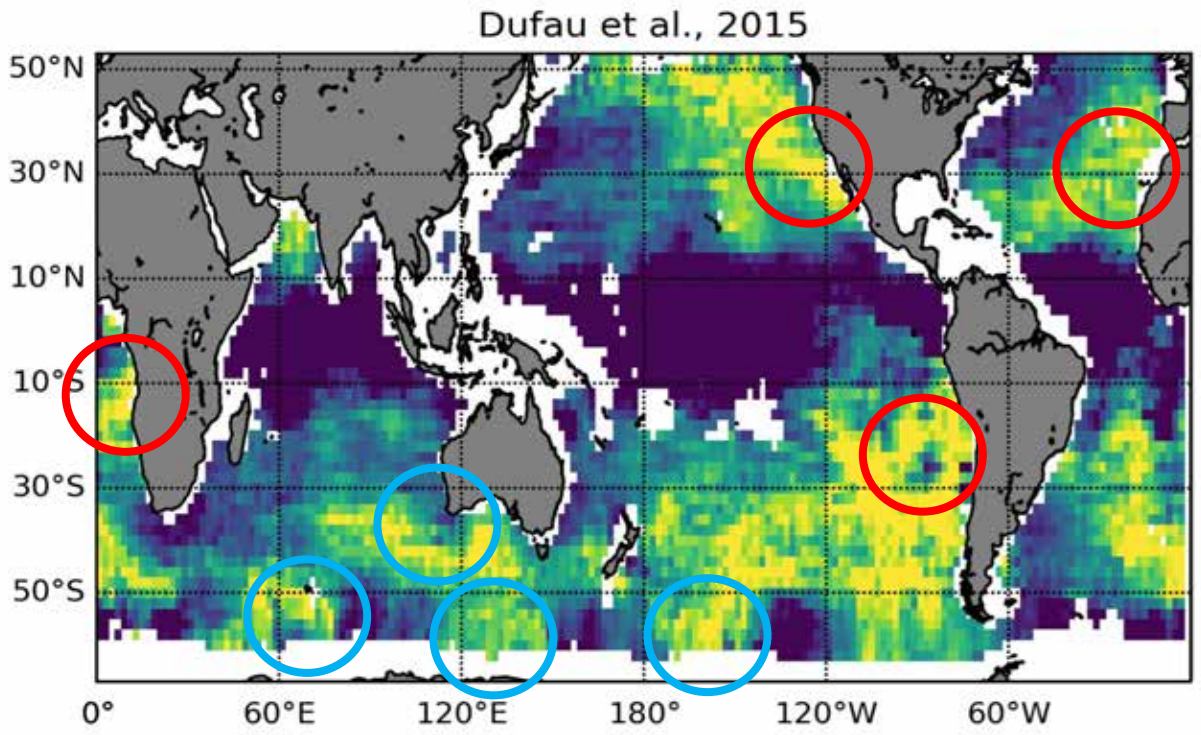
- From low to high latitudes: 15km-40km.
- Seasonal variation: ~10km in mid-high latitudes

Averaged between 30-40 degrees

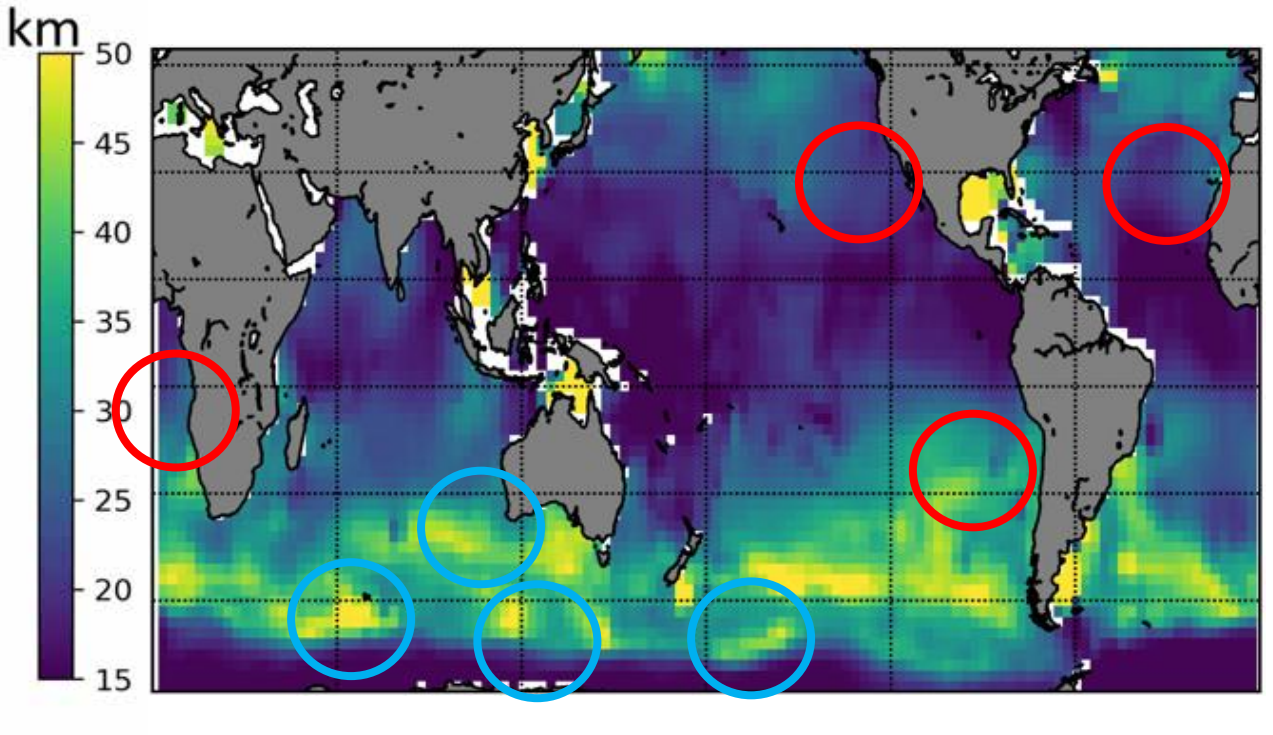


- Clear seasonal variation
- Inter-hemispheric antiphase
- different peak time for different latitudes

Compare with Nadir altimeter results



Altimeter extrapolation Dufau et al., (2016)



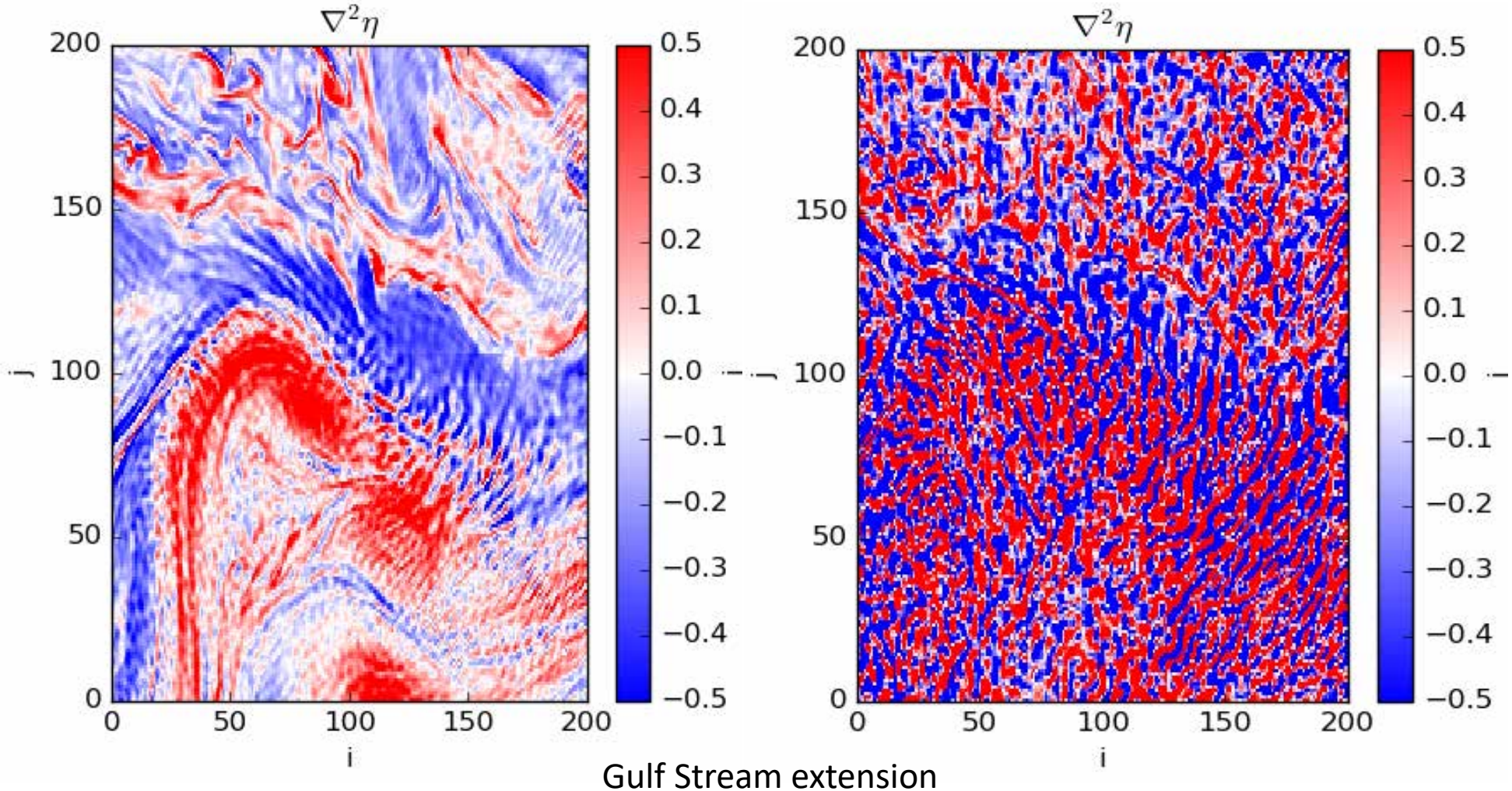
Model results

1. Two results are largely consistent.
2. Except for regions with energetic high-frequency internal gravity waves

Observability of high frequency internal gravity waves
It's a challenge and an opportunity.

Based on daily average

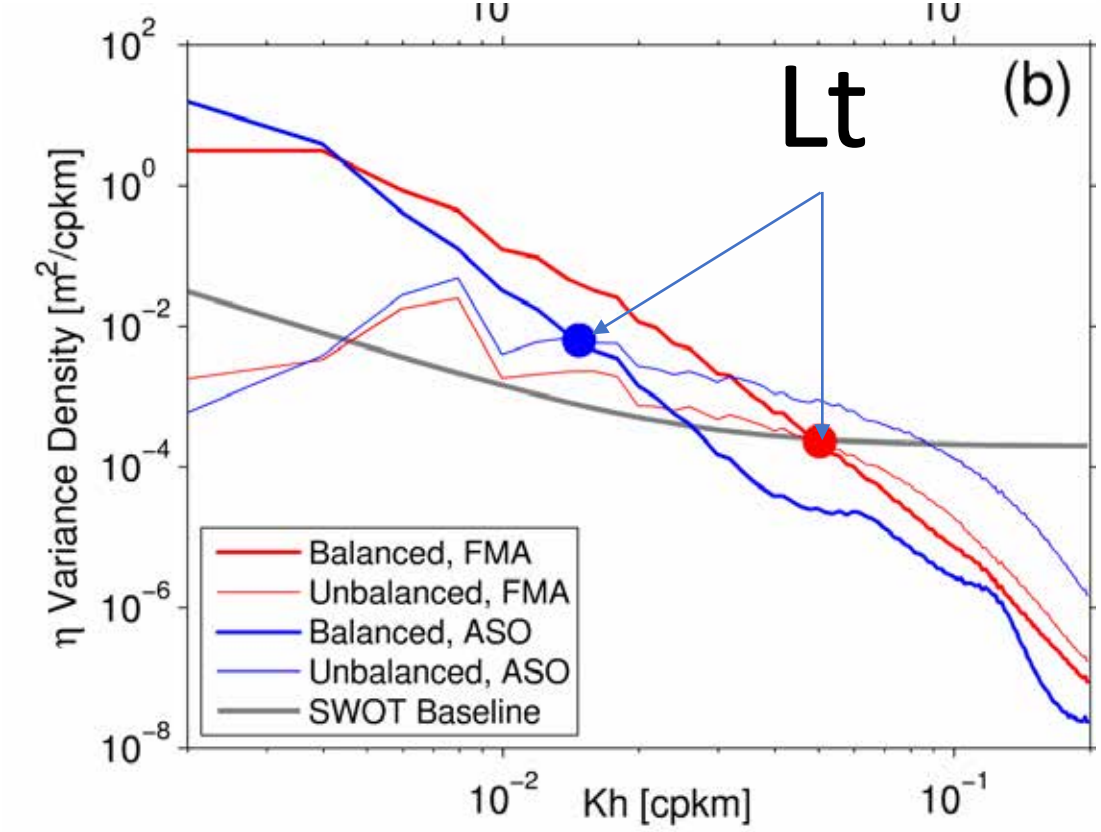
Based on snapshot

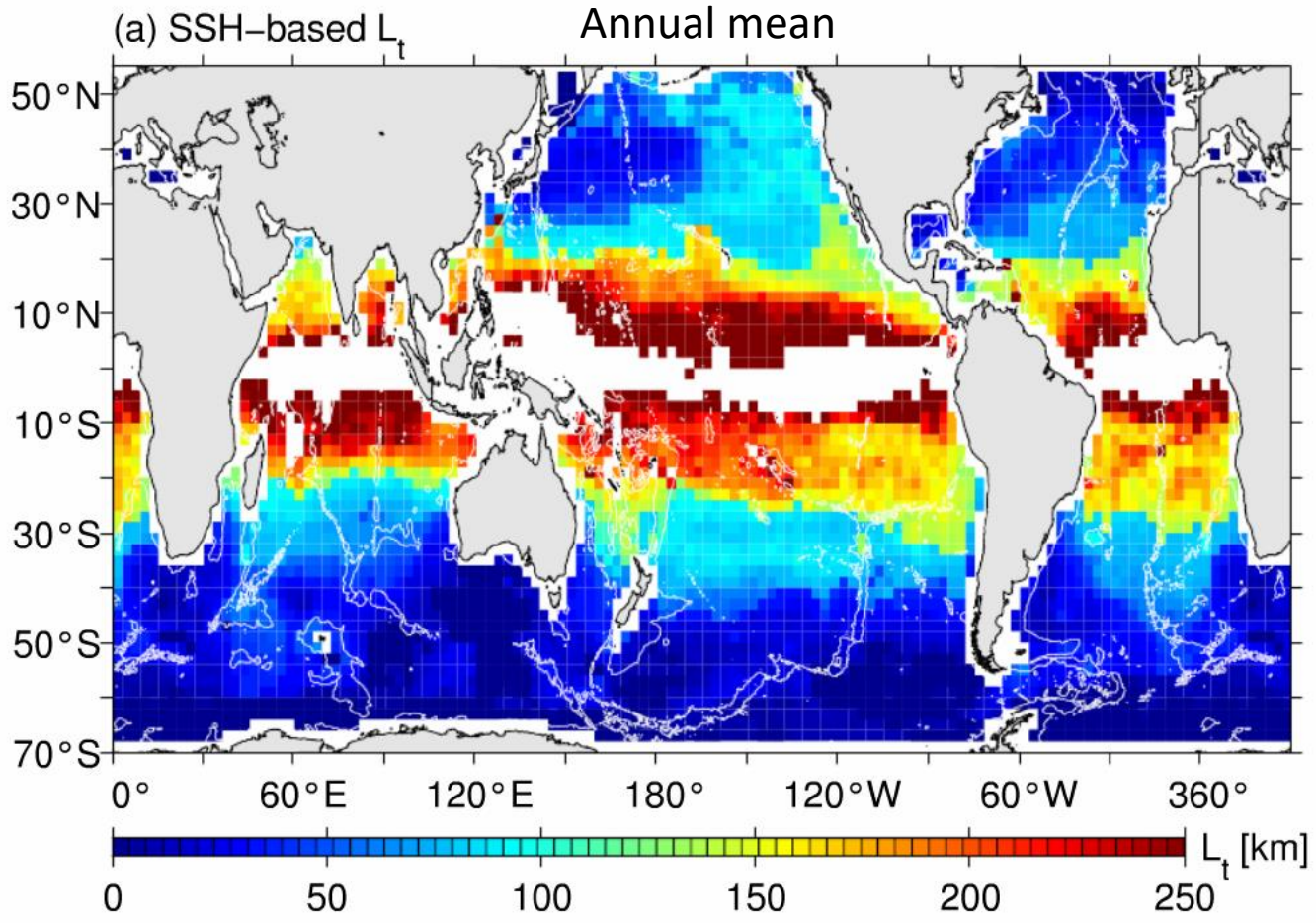


Gulf Stream extension

The transition scale from balanced to unbalanced dynamics is defined as Lt.

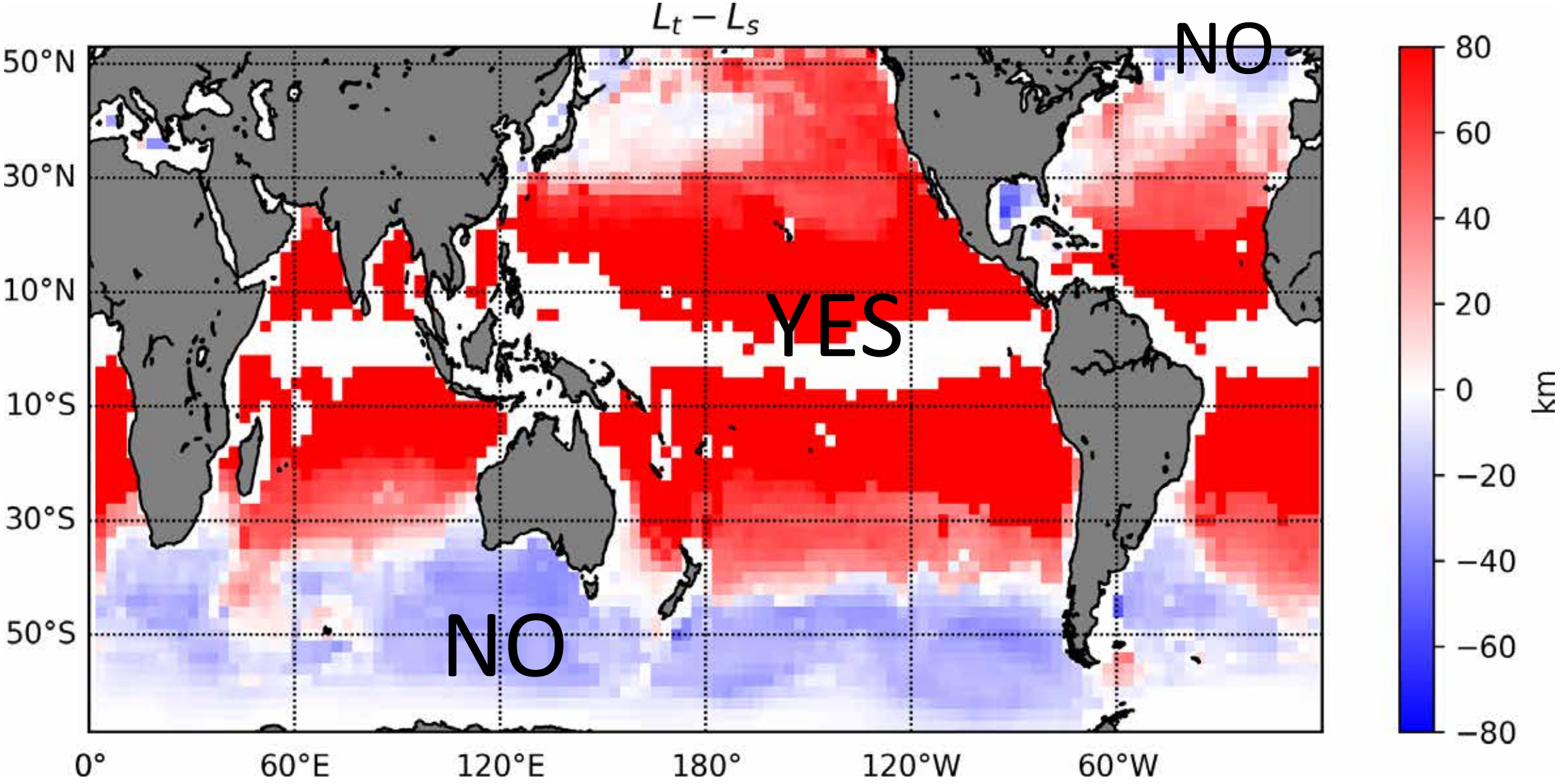
Where and when does SWOT resolve Lt?



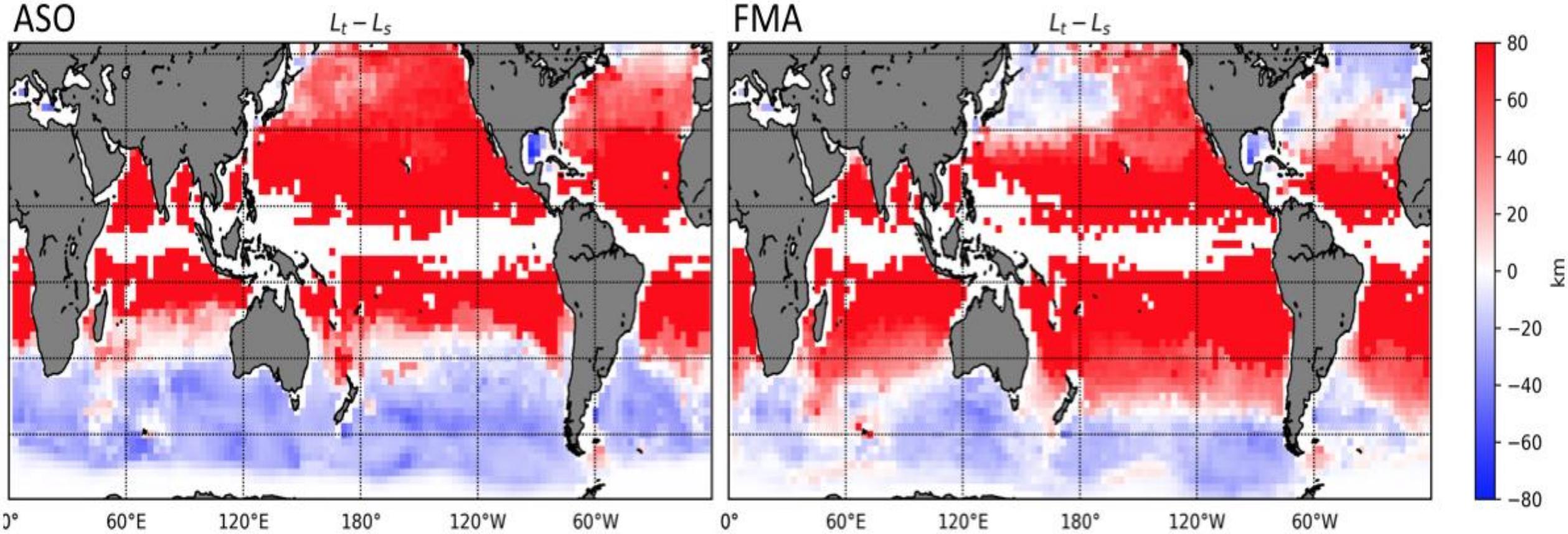


Qiu et al., (2018)

Can SWOT resolve the transition scale Lt?



The observability of waves also depends on the season.



Summary

- SWOT will resolve the SSH with a spatial scale increasing from ≤15km in the tropics to ~30-50km in the high latitudes with larger values in the Southern Ocean. Seasonal variability is small in low latitudes and large (~10 km) in mid and high latitudes.
- Internal gravity waves/tides will be observed by SWOT in the majority of the world oceans except for the Southern Ocean and the North Atlantic high latitudes. How to distinguish waves versus eddies from SWOT snapshots will be a major challenge in using SWOT data.
- We have not considered the SWOT resolution of eddies (balanced) and waves (unbalanced) separately.
- The results are based on a numerical simulation. Consider them as a guideline, not mission promise.