Empirical mapping of incoherent internal tides

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An Approach to Empirical Mapping of Incoherent Internal Tides With Altimetry Data

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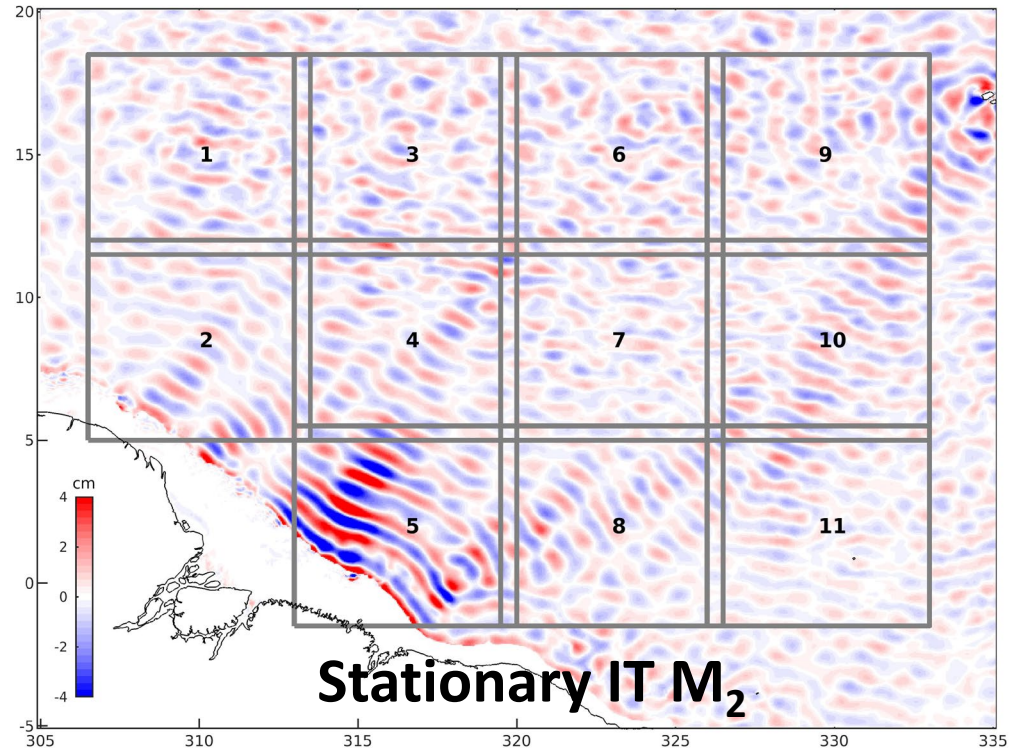
Goal: empirical estimate of time-variable IT as a correction to SWOT data

Approach: fit time-variable IT using a small number of basis functions

- → **Time dependence from tidal frequency**
- → **Spatial structure derived from a numerical model (e.g., HYCOM)**

Use HYCOM model run for one year (2016) off Brazil in an area with strong incoherent IT (IIT) *(thanks to Jay Shriver)*



Stationary IT M_2

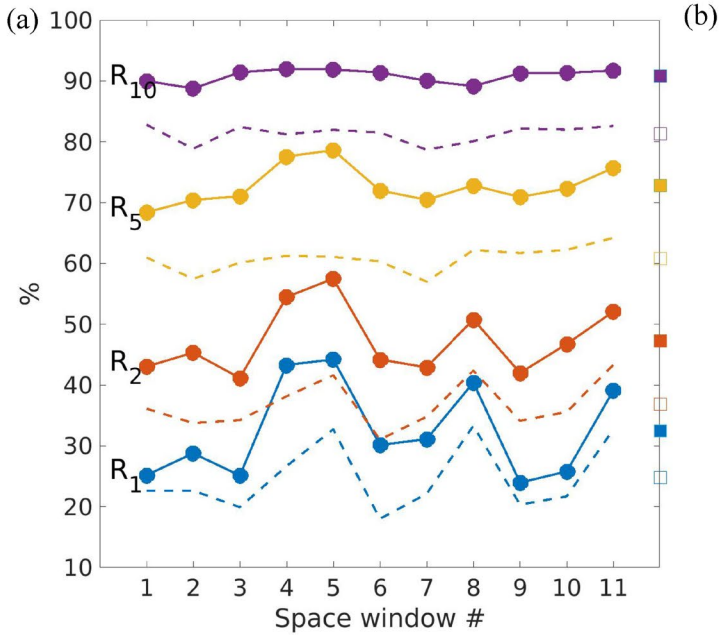
Start with Steric SSH, estimate of stationary IT removed

Harmonic analysis in

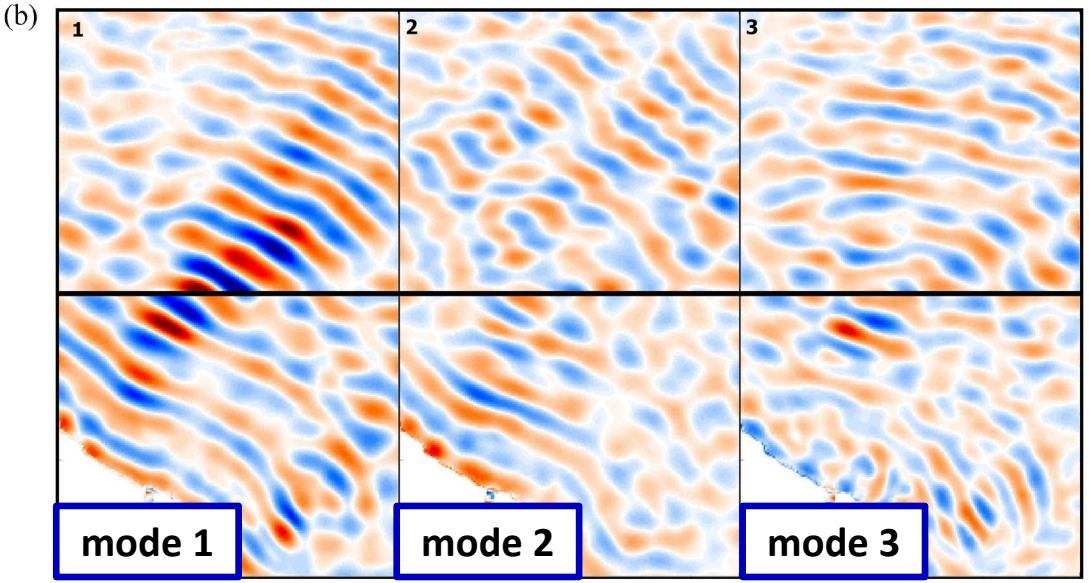
- **10°×10° spatial patches**
- **14-day time windows**

→ Time-resolved estimates of M_2 IT with low frequency resolution

Use principal Components Analysis (PCA) of the sequence of windowed HA estimates to define dominant spatial modes of non-stationary M2 internal tide:



Fraction of variance explained by 1, 2, 5, 10 modes (M_2 solid, S_2 dashed)



Real parts of first three modes for patches 5, 4

Reminder: spatial basis functions (from PCA of complex HC) are complex, and describe a periodic signal

PCA model for non-stationary IT in time window j

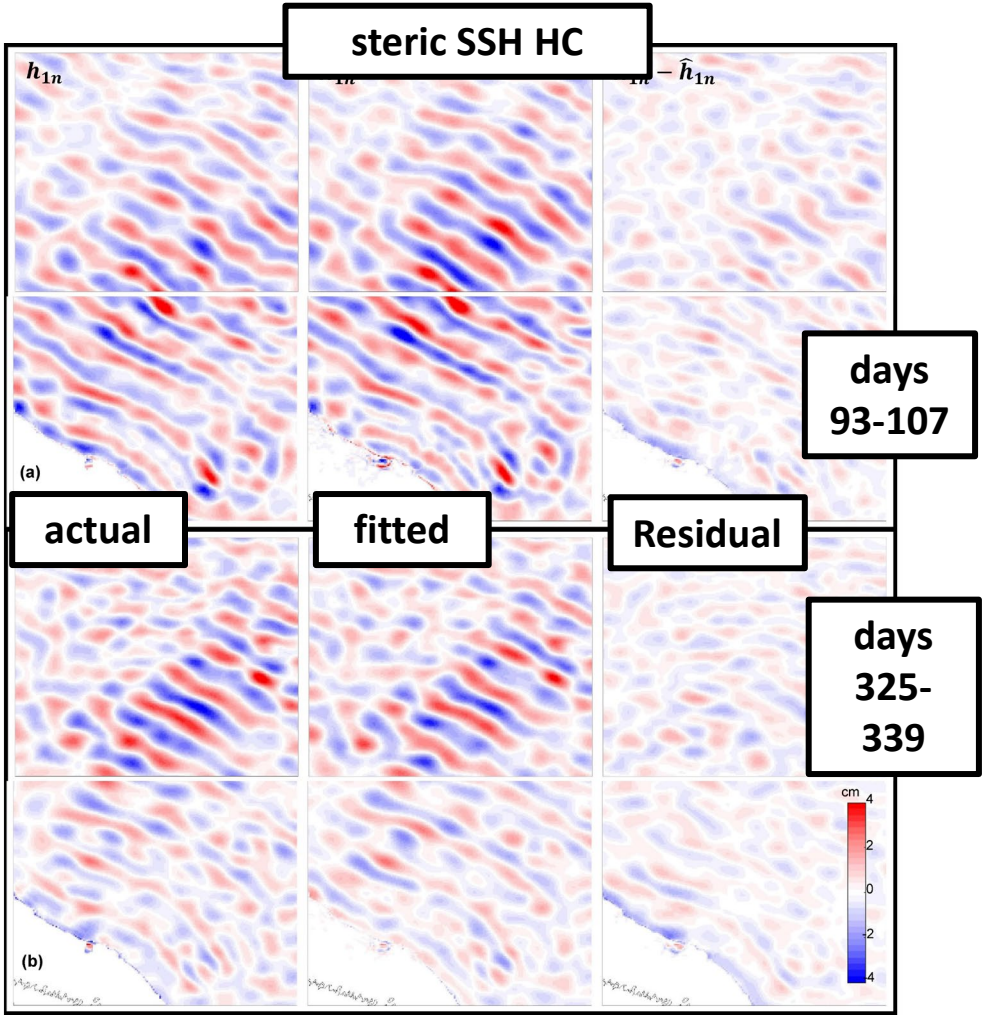
$$H_j(\mathbf{x},t) = \mathrm{Re}\left[\sum_{l=1}^{L} c_{lj} U_l(\mathbf{x}) e^{j\omega t}\right]$$

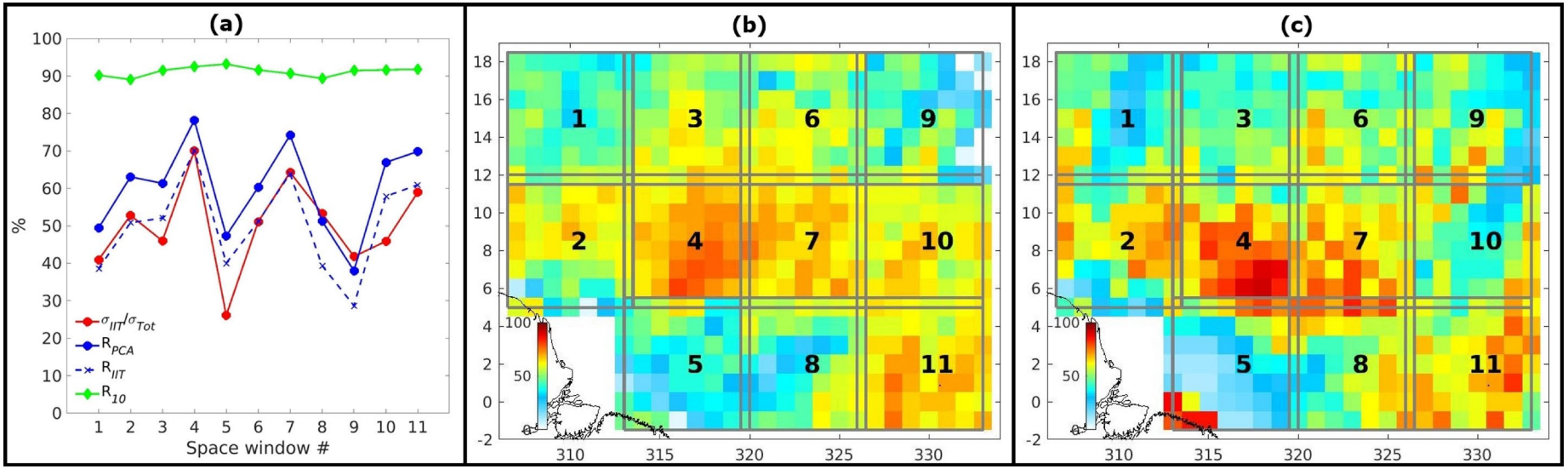
ω = nominal M2 frequency

$L=10$ spatio-temporal basis functions

Complex coefficients vary with time window – fit to available data in each space/time window

- simulate SWOT data using HYCOM SSH (steric and non-steric), using simulator to add noise
- Filter along track to remove long wavelength signal, subtract stationary IT estimate
- Fit this synthetic data in each space/time window using 10 spatio-temporal basis functions (for M_2 only)





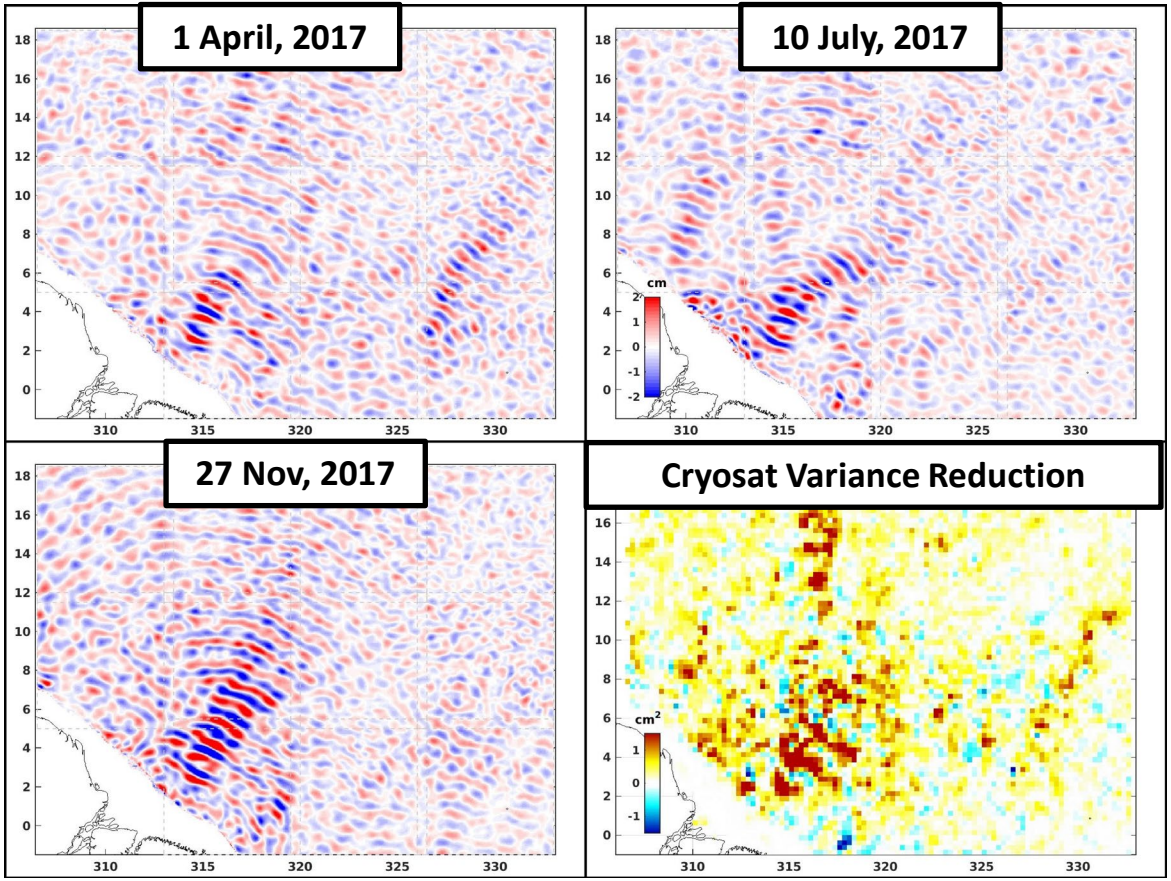
~ 50-70% of IIT signal is fit, more in areas with strong IIT

R_{PCA}
fraction of M_2 band non-stationary signal fit by model

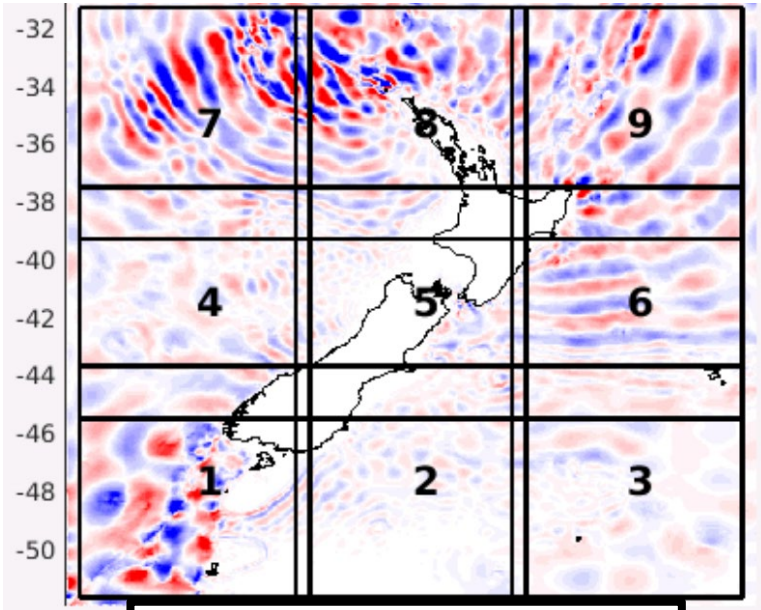
$\sigma_{IIT}/\sigma_{Total}$
fraction of M_2 band signal that is non-stationary

Used same basis functions to fit nadir altimeter data (Jason 2/3, SARAL A/B, Sentinel 3A/3B from 2016-17)

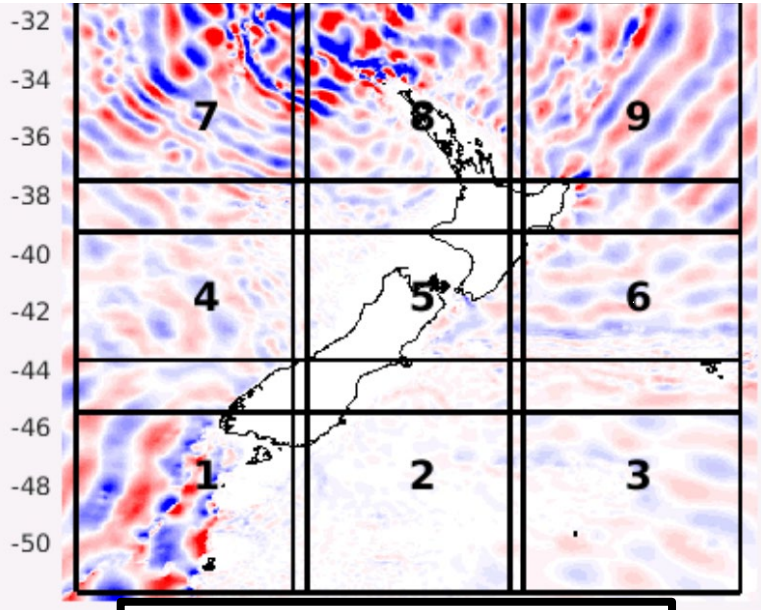
Cryosat variance reductions in 0.25 x 0.25 degree bins suggests some skill as a correction for IIT



Current efforts: different area, using different models to generate basis functions, synthetic data



MOANA regional model (ROMS) -- ~20 year run



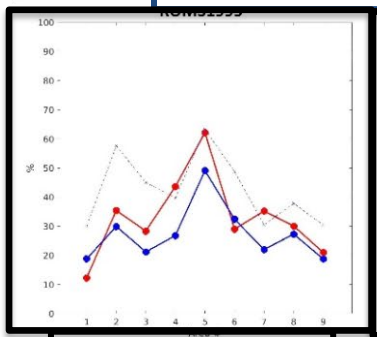
global model (HYCOM)

Stationary M2 internal tide, estimated from 2014 outputs for both

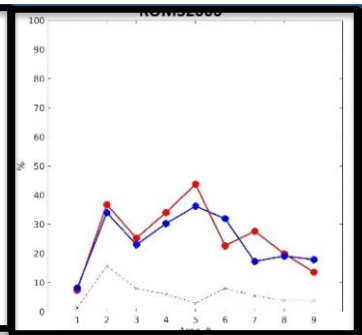
Initial results here: not so promising!

- Basis functions from PCA of HCs computed for 20 day windows, 10 (1994-2004) years of ROMS outputs
- Fit synthetic SWOT data – showing statistics for individual years
- 2014 ROMS run is a different model configuration (more vertical levels, less diffusive tracer transports)

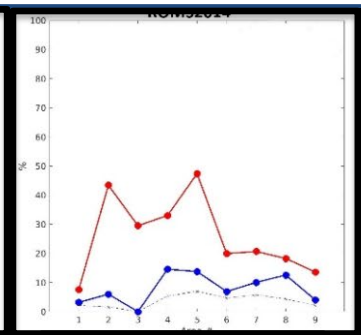
R_{PCA}: fraction of M_2 band non-stationary signal fit by model



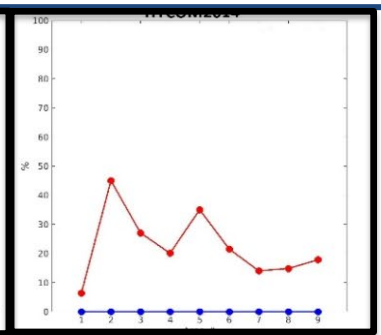
ROMS 1995



ROMS 2000



ROMS 2014



HYCOM 2014