Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

The assessment of minor tidal constituents in ocean models for optimising the ocean tidal correction

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The importance of minor tides

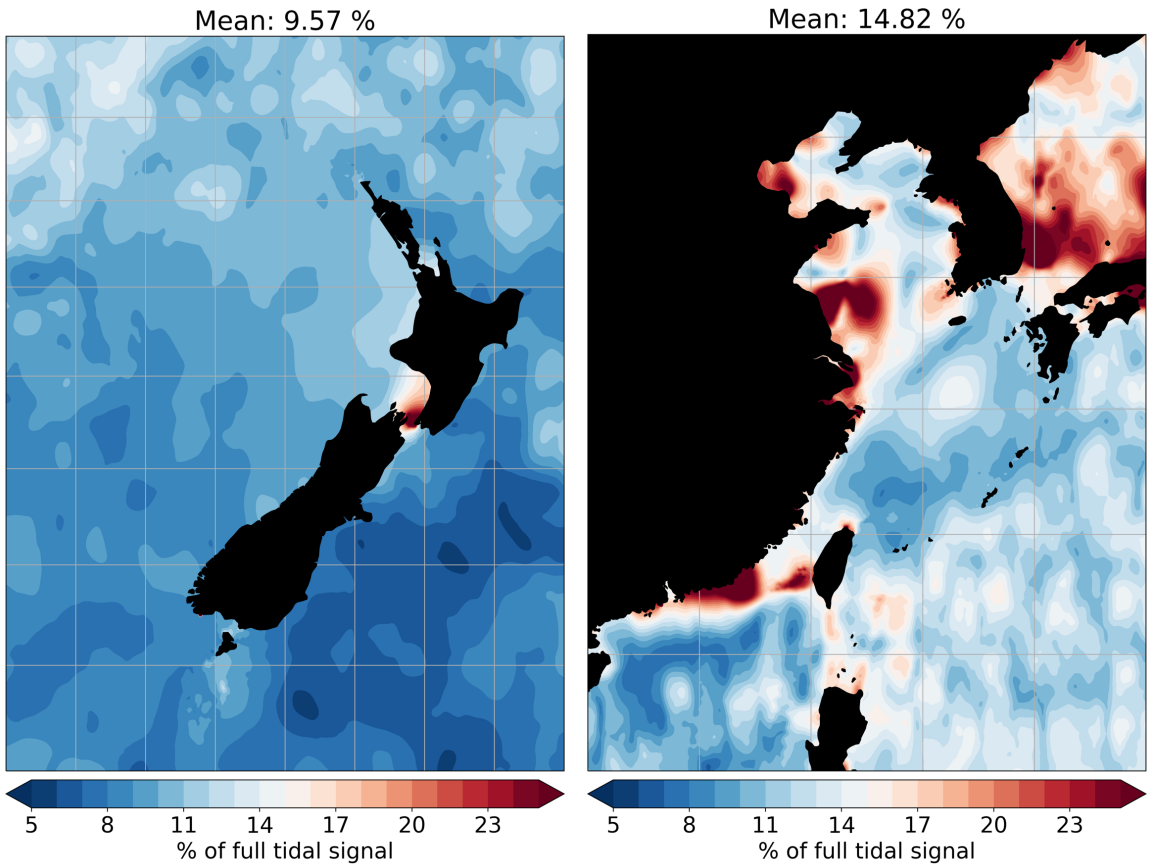


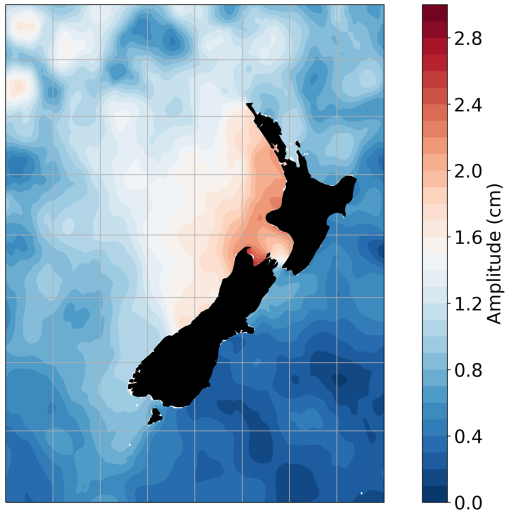
Figure. The percentage contribution of seventeen ‘minor’ tides from a regional EOT model relative to the full tidal signal comprising of 34 tidal constituents (including long-period and the major constituents) in (left) New Zealand and (right) the Yellow Sea + East China Sea.

- Minor tides have long been included in the estimation of tidal corrections and play an important role in the prediction of sea level from satellite altimetry.
- In the two regions shown here, the 17 minor tides* make up 9.6% and 14.8% of the tidal signal obtained from a total of 34 constituents, respectively.
- Most empirical ocean tide models infer the minor tidal constituents using Admittance theory (Ray 2017), due to the difficulty of estimating these tidal signals and computational load.
- In this presentation, we discuss the accuracy of inferred tidal constituents compared to direct estimations from empirical and numerical model simulations.

* Minor tides used: R2, NI2, MS4, M4, LA2, MSF, EPS2, N4, MSQM, M3, MKS, MN4, MI2, J1, T2, L2 and MKS2

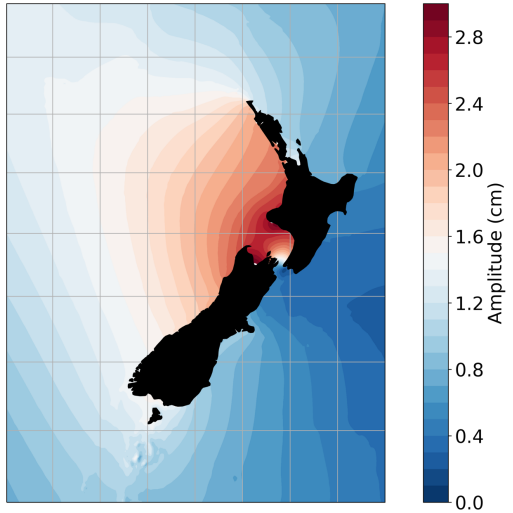
The approaches of minor tide estimation (showing J1 below)

- Empirical Model Estimation (EOT20, *Hart-Davis et al 2021a*)



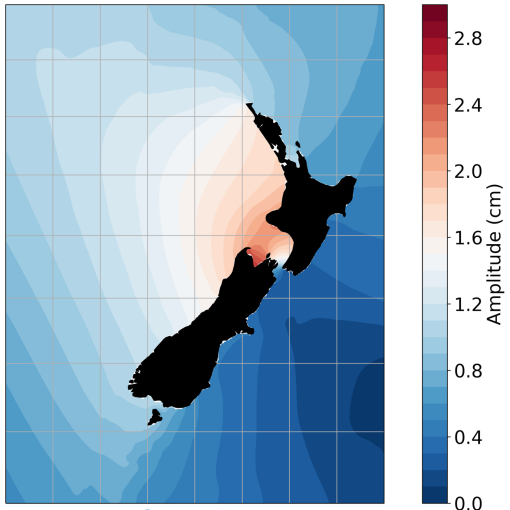
  - EOT20 is the latest in a series of empirical ocean tide (EOT) models derived using residual tidal analysis of multi-mission satellite altimetry at DGFI-TUM.
  - In this study, a regional version of EOT20 (henceforth known as EOT-R) is presented that contains an extended number of tidal constituents.

- TiME hydrodynamic model (TiME, *Sulzbach et al 2021*)



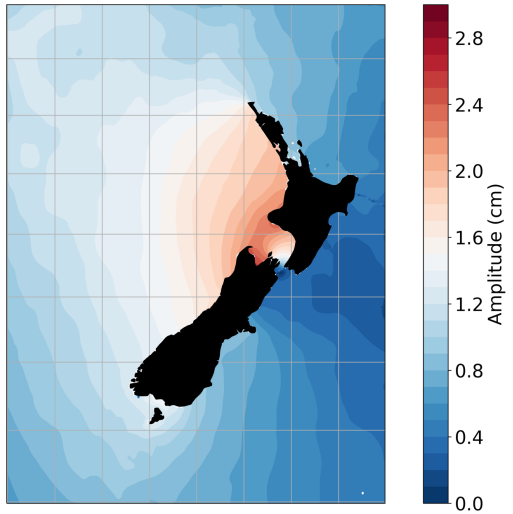
  - TiME is a numerical tide model that provides a vast number of minor tidal constituents that.
  - TiME solves the shallow water equations on a global 1/12-degree grid under consideration of dynamic effects, that are known to exert a critical influence on tidal oscillation systems.

- Data-assimilative hydrodynamic model (FES2014, *Lyard et al 2021*)



  - The FES2014 model is an ocean tide model that produces global atlases of 34 tidal constituents.
  - FES2014 is considered a valuable model for satellite altimetry corrections and, therefore, provides suitable reference for the results presented below.

- Linear admittance approach (from EOT20 tide model)



  - Using linear admittance, eight additional tidal constituents were inferred from the EOT20, henceforth referred to as EOT-I.
  - These constituents are:

    2N2, ϵ2, MSF, T2,
    J1, L2, μ2 and v2.

Difficulties in direct estimations of minor tides

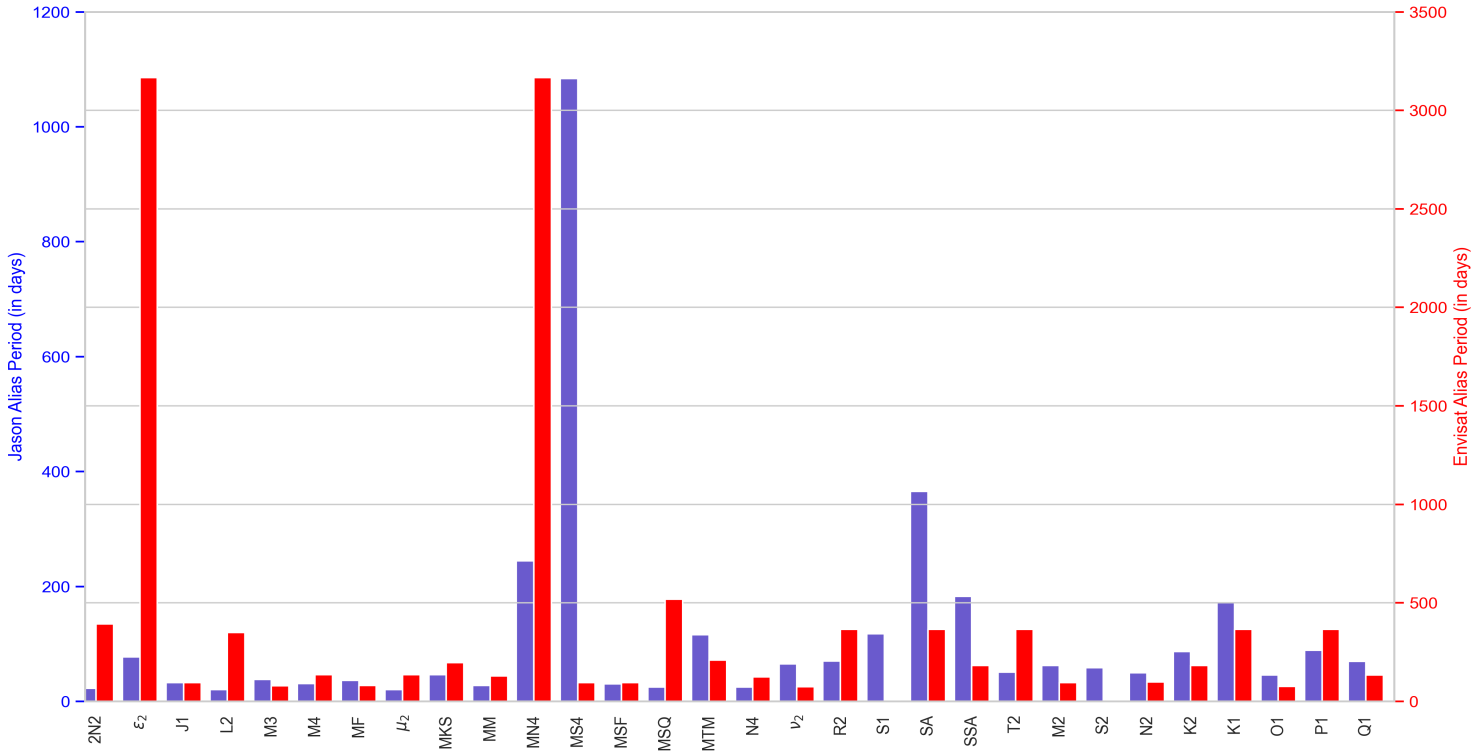


Figure. Aliasing periods of tides base on the orbits of the Jason and Envisat missions for the major and minor tides.

- The tidal aliasing periods of certain tidal constituents allow for the determination of certain tides from along-track satellite altimetry (Figure).
- The small signals of these tides, also make the difficult to estimate from satellite altimetry observations.
- A common theory to determine these tides, is linear admittance theory which is the relation of the tidal height with respect to the amplitude of the corresponding tide generating potential for a specific tidal wave.
- Numerical models also provide value here as they are not impacted by signal-to-noise ratios and aliasing periods and, therefore, can be used to directly estimate these tides

Tide Gauge Evaluation

- The TICON dataset (Piccioni et al 2019) was used to evaluate the estimations of certain eight minor tidal constituents in three different regions (New Zealand; Australia and Yellow Sea + East China Sea). For each tide gauge, the root-mean-square (RMS) is calculated.
- On average, the inferred estimations out performed the direct empirical estimations for three constituents (T2, 2N2 and MSF). For the remaining tides, the empirical estimations outperform the inferred estimations.
- The TiME estimations on average provide better estimations for the MSF and J1 tides compared to EOT-I.
- Based on this and the aliasing period, we recommend the direct estimation of the J1, L2, μ2 and v2 and, therefore, 2N2, ϵ2, MSF and T2 can be inferred using linear admittance.

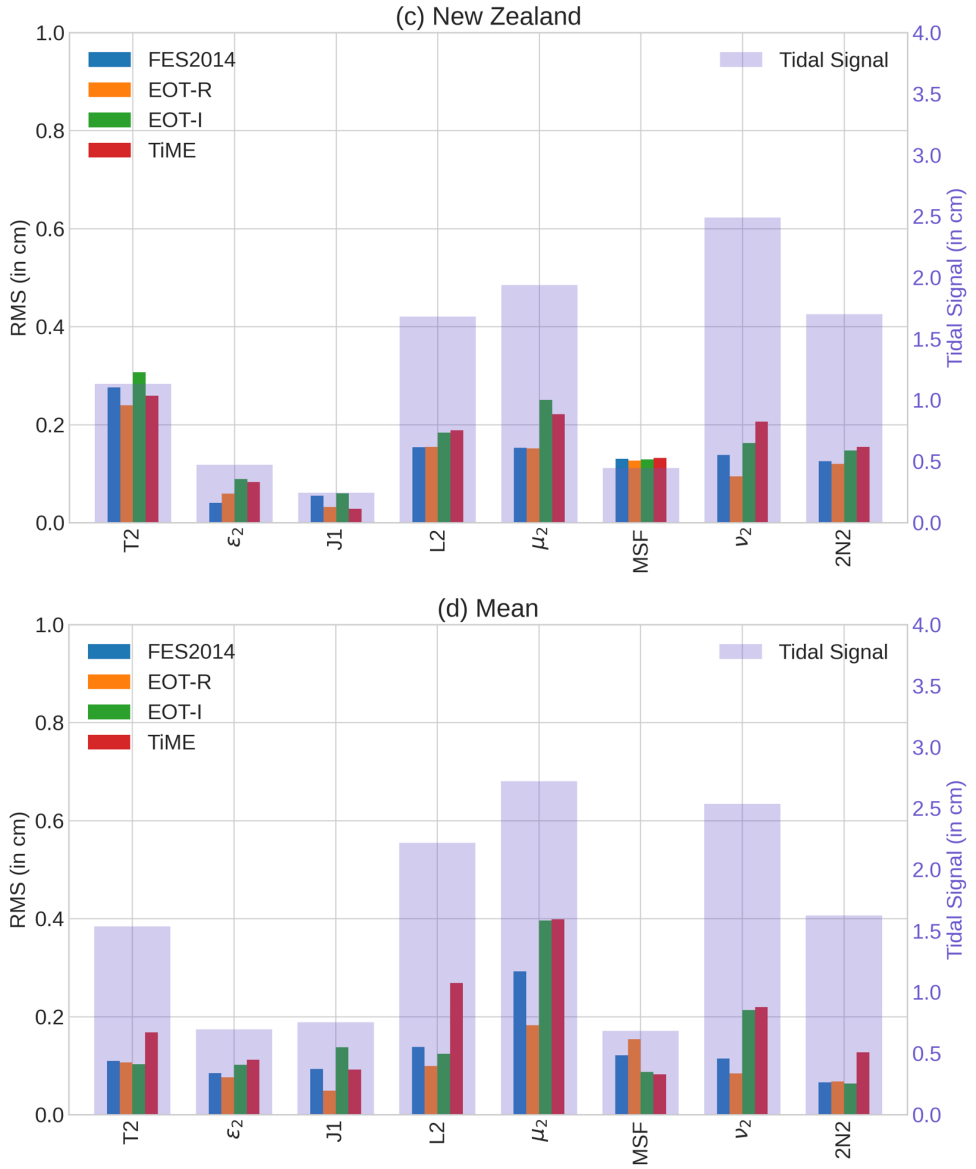
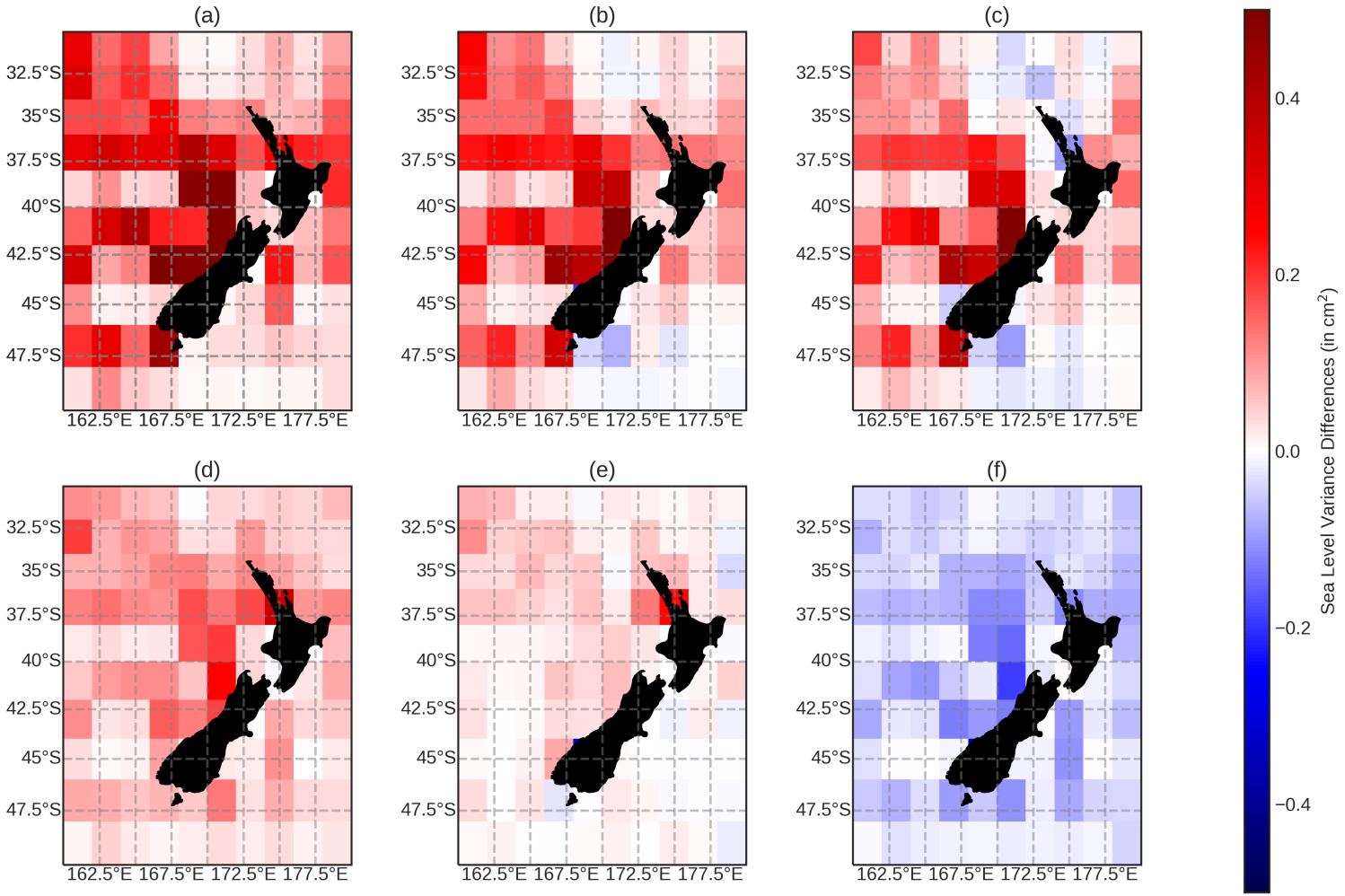


Figure. The RMS of the models relative to the tide gauges as well as tidal signal of the 8 tidal constituents evaluated obtained from TICON.

Regional improvements of sea level estimates based on constituent estimation



- The minor tides of the different solutions were combined with the major tides of EOT20, to create a tidal correction for the Jason-2 satellite altimeter.
- From this, the SLA was estimated following the same approach, simply with different ocean tidal corrections. Following this, the gridded variances were compared for each model, with a reduction in variance being the desired result.
- The results showed, that the direct estimation of tides (EOT-R) provides a more suitable correction than inferring the tides. However, when using the recommendations from the tide gauge analysis, the results were further improved.

Figure. The sea-level variance differences between the scenarios presented for the Jason-2 altimeter in the New Zealand region. (a) minTiME–EOT-R; (b) minTiME–EOT-I; (c) minTiME–minFES; (d) minFES–EOT-R; (e) minFES–EOT-I; and (f) EOT-R–EOT-I.

Regional improvements of sea level estimates based on constituent estimation

- By taking the recommendations from the tide gauge analysis, EOT-H (hybrid) was created to be compared to EOT-R. This allows for maintenance of the higher accuracy tidal estimations, but also utilises admittance theory to infer tides where satellite altimetry struggles to do so.

- The variance differences remain very low and never exceeds 0.1 cm^2, with the average difference being 0.002 cm^2 in favour of EOT-H. This demonstrates that the recommendations of this study are suitable for use in the tidal correction for satellite altimetry.

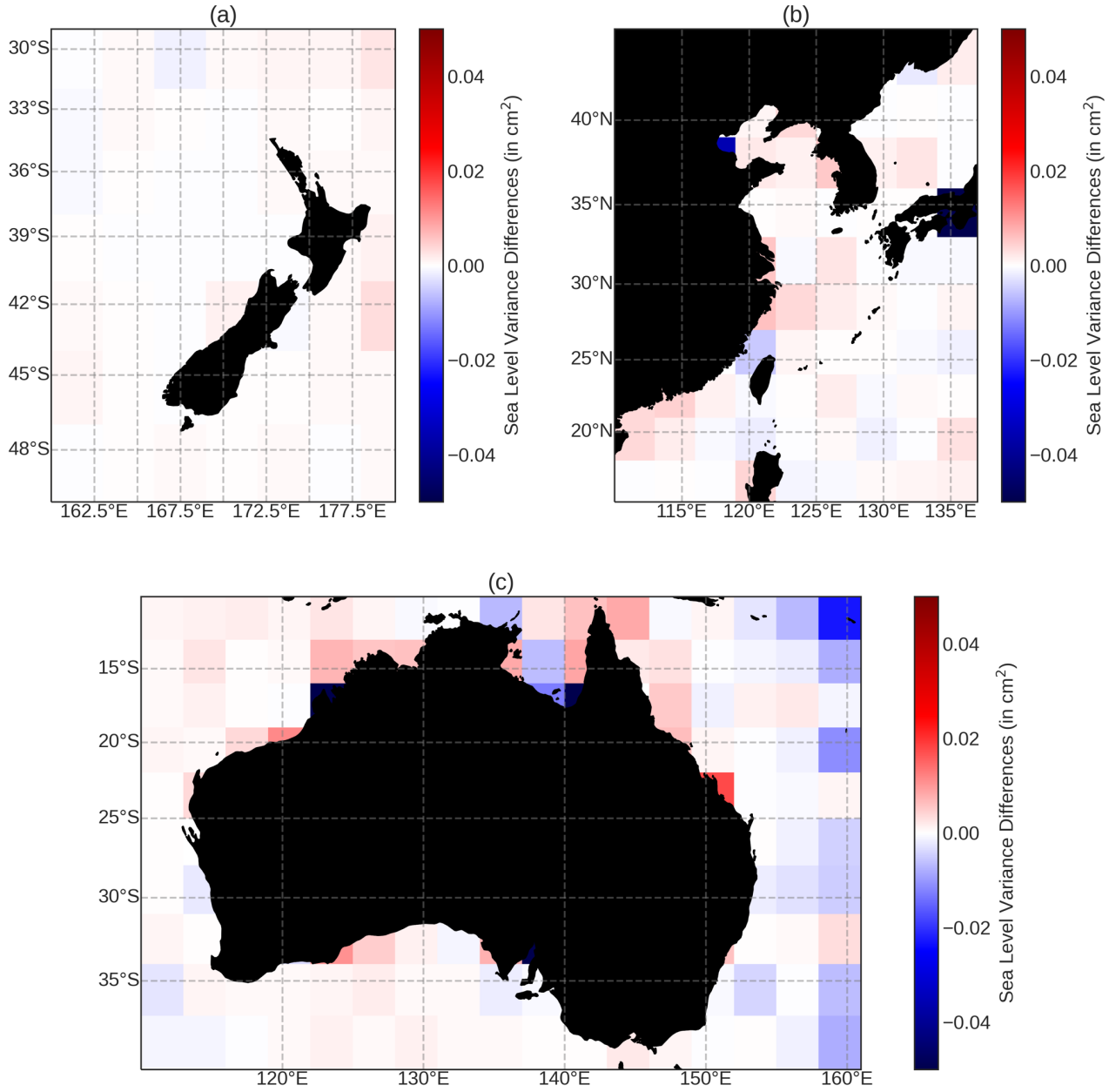


Figure. The sea-level variance differences between EOT-R and EOT-H for (a) New Zealand, (b) the Yellow Sea and (c) Australia. When the regions are coloured red, EOT-R shows a reduction in SLA variance, while the opposite is the case in blue regions.

Take home messages

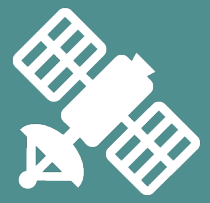
Development

Here, the comparison between methods of estimating minor constituents is presented and compared to in-situ tide gauge data (obtained from TICON) and using gridded satellite altimetry (obtained from OpenADB).

In-situ Validation

The tide gauge analysis provided insight into the accuracy of particular methods. Insights into which tides to should be inferred (2N2, ϵ_2, MSF and T2) and directly estimated (J1, L2, μ_2 and ν_2) was determined.

Gridded Variance Analysis



The results of the variance analysis, showed that the recommendations of the tide gauge analysis did provide the best results. However, encouraging signs were also seen in the combination of different tide models

Future Work

Further investigations are taking place to produce a hybrid of constituents from different models to improve the overall estimation of tides. The impact of 3rd-degree tides (Sulzbach et al 2022) on tidal estimations is also being investigated.

ANY QUESTIONS?

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For more information:
https://doi.org/10.3390/rs13163310

or

Key References

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