

Ocean tidal loading models assessment using 28 months of gravimetric tidal records in Dublin, Ireland

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2) *Ordnance Survey Ireland, Dublin, Republic of Ireland*



General information

- Project title: **Absolute Gravity Network Ireland (AGN Ireland)**
- Goal: Establish a **modern gravity control** based on absolute gravity measurement techniques across the whole island of Ireland
- Cooperation:
 - **Institute of Geodesy and Cartography**, Centre of Geodesy and Geodynamics, Warsaw, Poland
 - **Ordnance Survey Ireland**, Dublin, Republic of Ireland
 - **Ordnance Survey of Northern Ireland**, Land and Property Services, Belfast, Northern Ireland

Beginning of cooperation: June 2018



Absolute Gravity Network

The design of the network includes

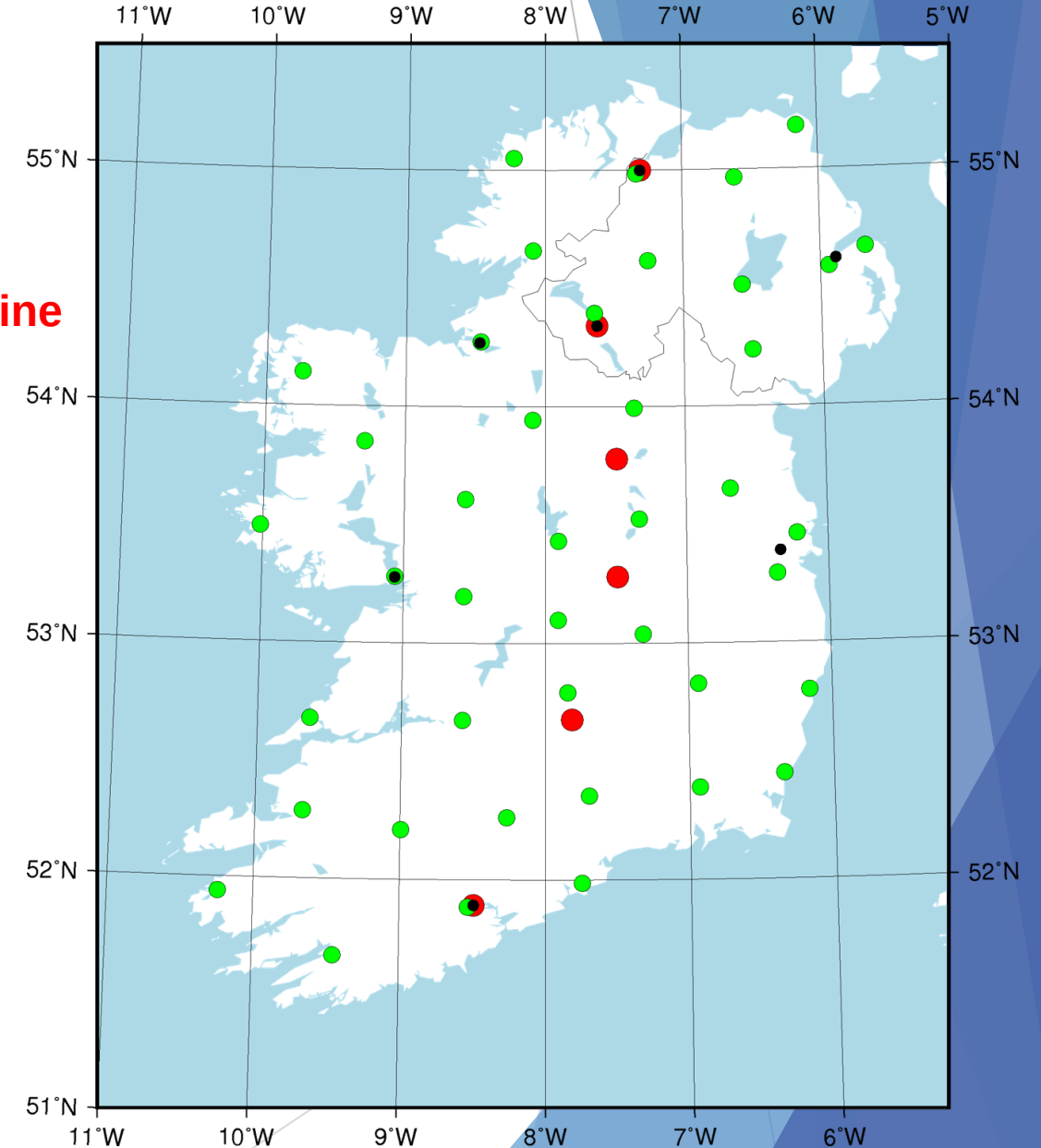
- **51 - field stations** of gravity control (*outdoors*)
- **6 - stations of the gravimetric calibration baseline** (*indoors*)

With additional surveys on:

- **7 - IGSN71** stations

Important remark (*for all stations*):

- **precise position and orthometric height determination**



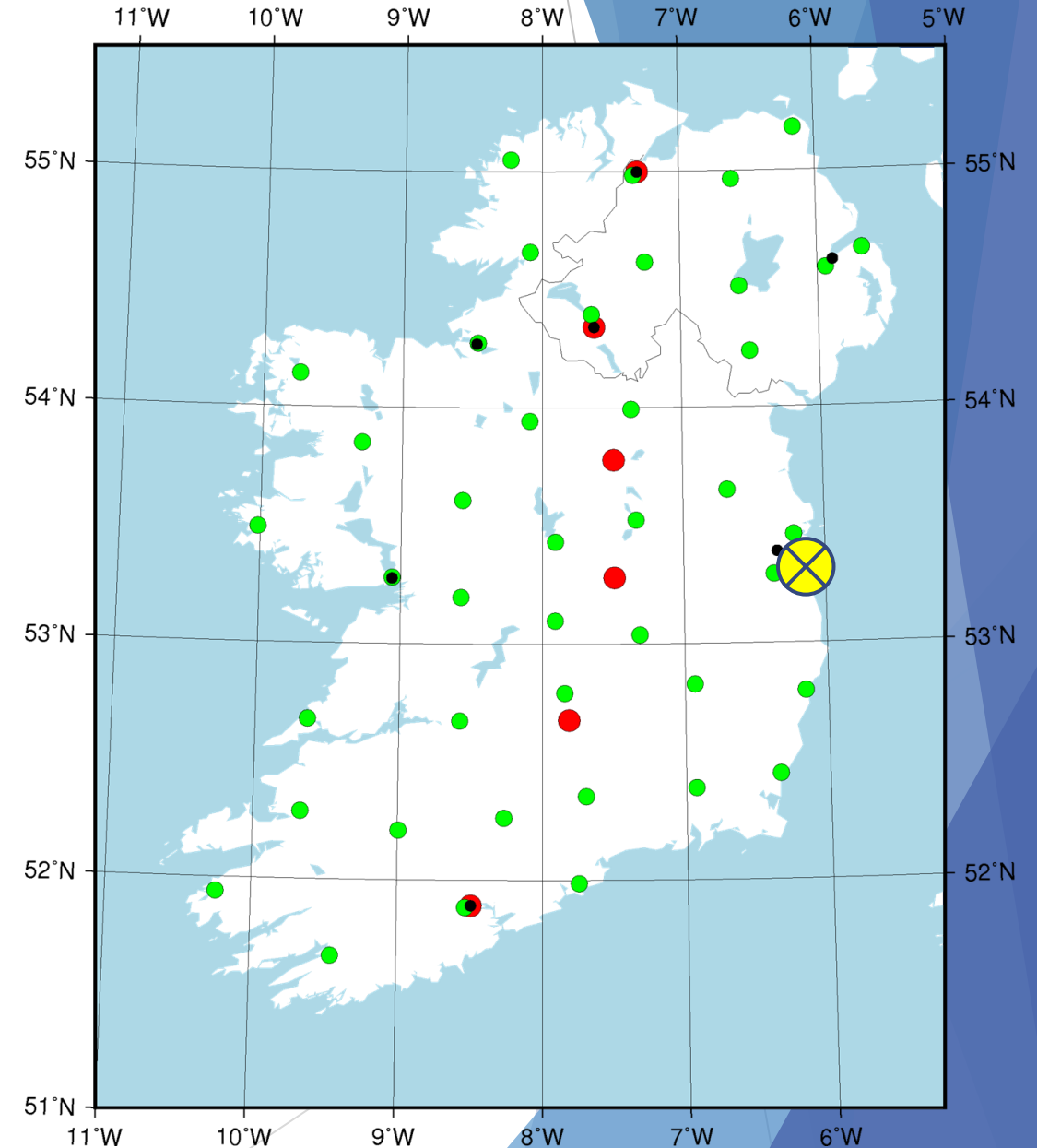
OS4.1 Tides in the past, present and future, EGU2021, April 19-30, on-line



Absolute Gravity Network

Additionally at OSi Headquarters (*Phoenix Park, Dublin*)

- Core site (⊗) for **repeated surveys with A10 gravimeter** (*start/finish each campaign*)
- Tidal gravity station (⊗) (*LaCoste&Romberg G-1084 gravimeter*) for **long term gravity monitoring** – evaluation of the Ocean Tidal Loading



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Methodology

- **Absolute gravity values** will be obtained primarily with **absolute gravity measurement techniques**
- Gravity value determined with the use of a **field absolute gravimeter (A10 sn 020)**
- **Vertical gravity gradient** will be determined at **each station** to reduce the gravity value to the benchmark level
- Expected **total uncertainty** of gravity determination at the benchmark level is $<100 \text{ nm/s}^2$ (1σ)
- Metrological control: **instrumental calibrations, absolute gravimeter comparisons**
- Re-processing: **IGRS standards 2021** including body tides (Tamura), barometric correction, polar motion and **ocean tidal loading (most suitable)**



Current status

2018.08-09. – 1st gravity survey trip to Ireland (~2900 km in Ireland)

2019.08-09. – 2nd gravity survey trip to Ireland (~3600 km in Ireland)



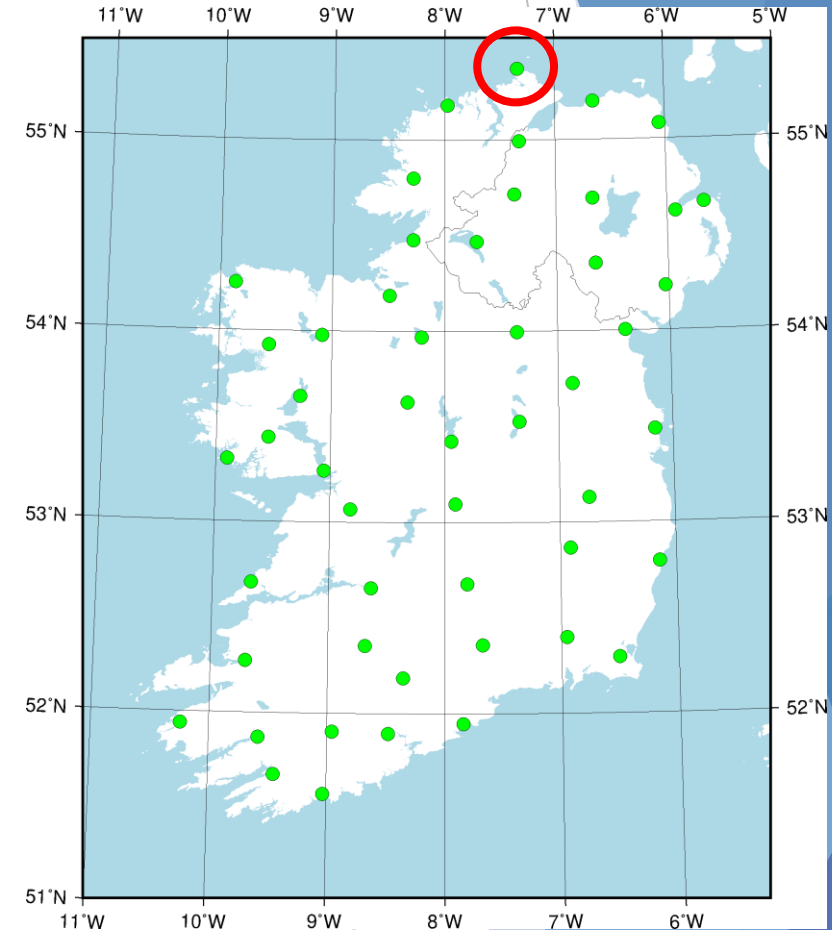
>90% of all survey have been completed

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Special consideration

Ocean Tidal Loading in Ireland

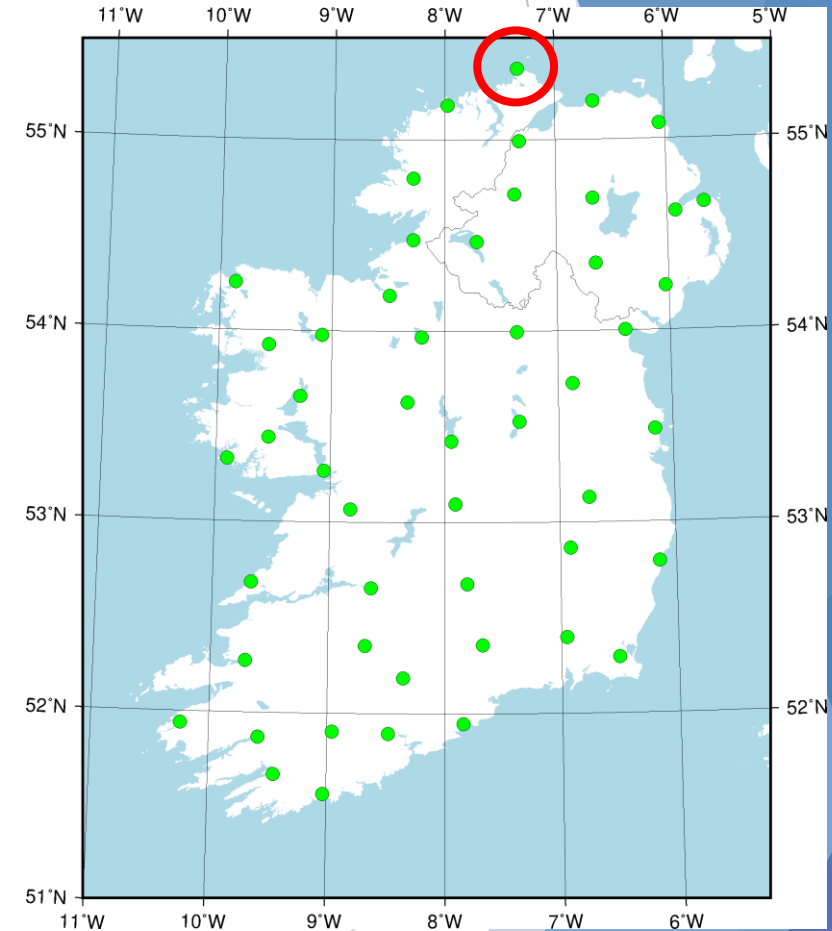
Malin Head example:



Special consideration

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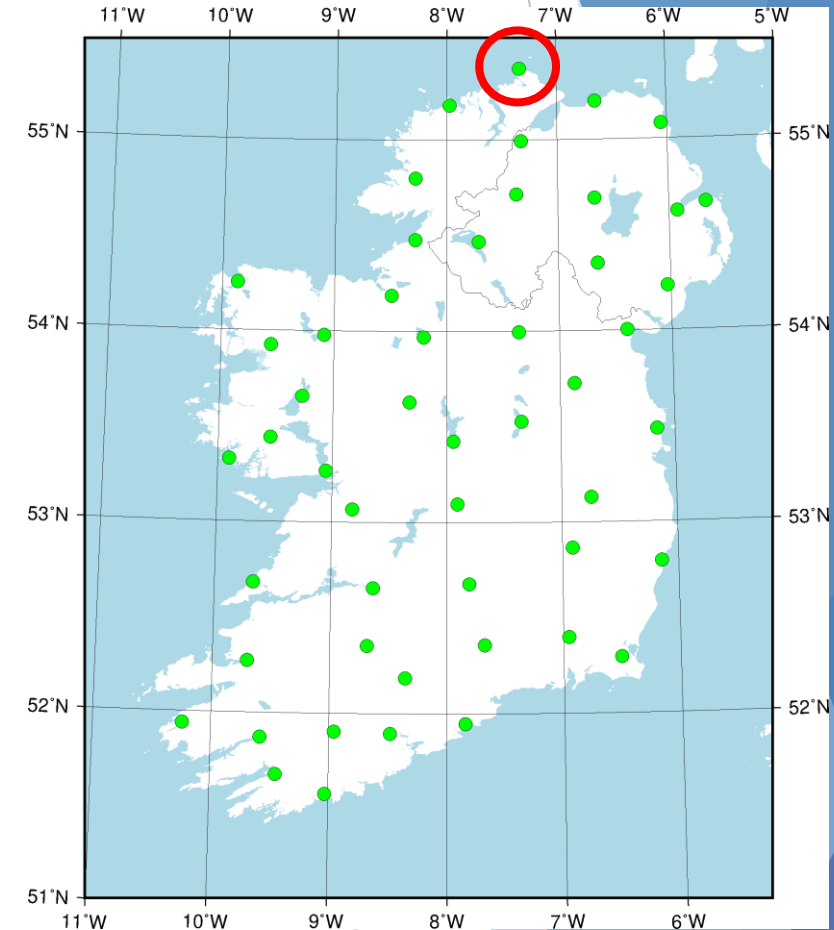
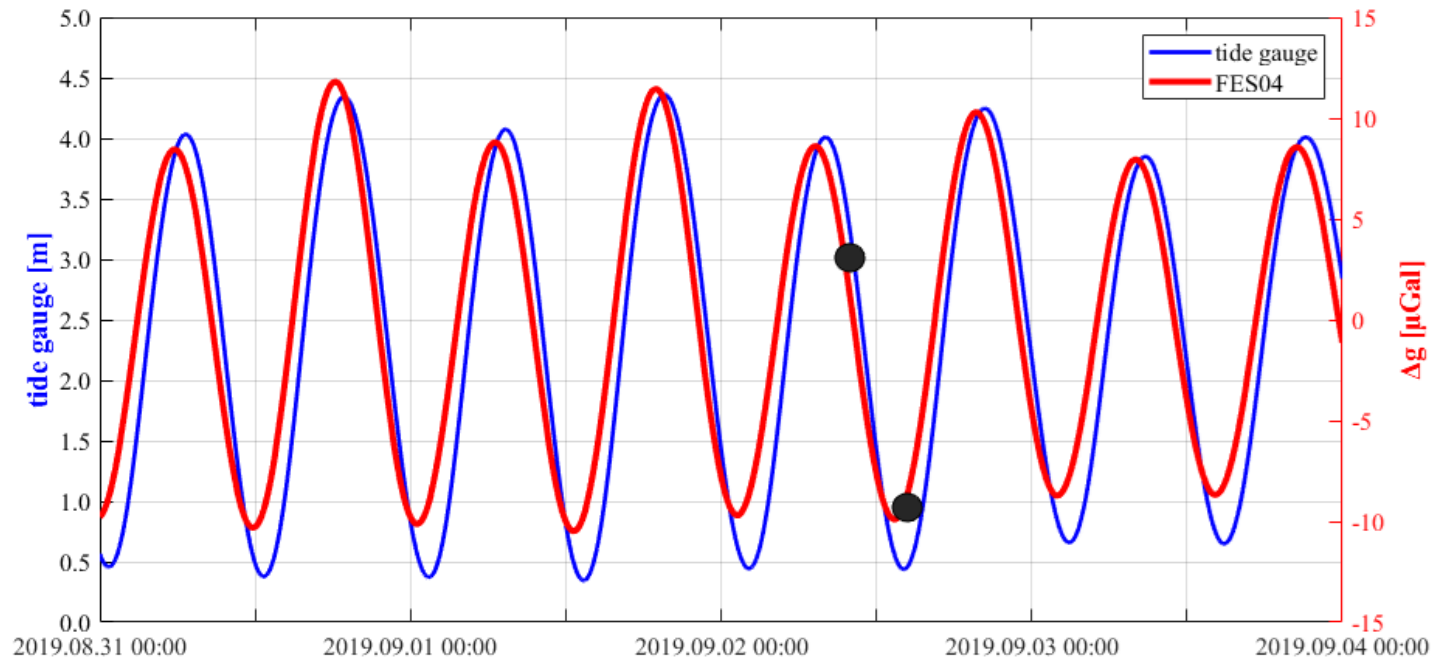


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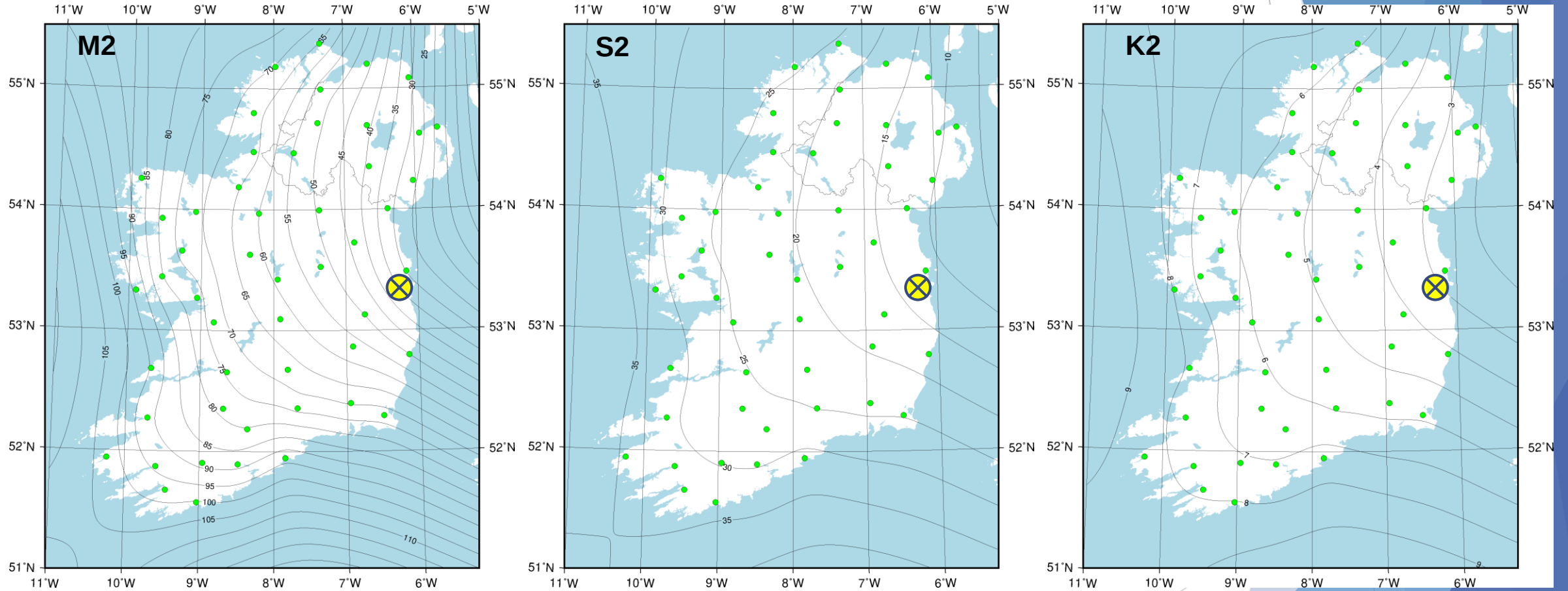
Tide gauge vs. FES04 (**-2.6 m** and **-120 nm/s²** within 4.5 hours)



Special consideration

Ocean Tidal Loading in Ireland

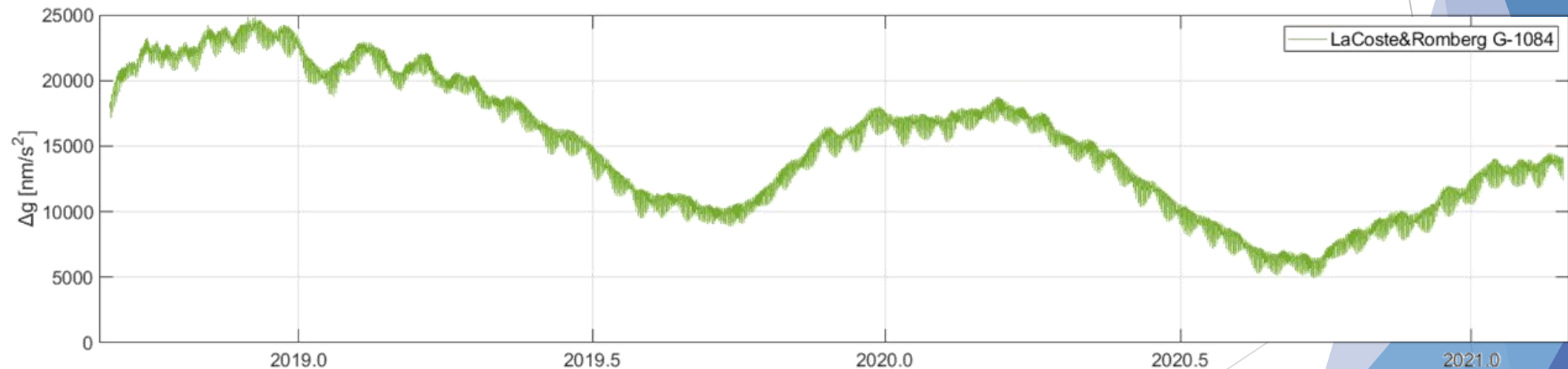
Amplitudes for selected tidal waves (FES04 – most commonly used) in $[\text{nm}/\text{s}^2]$



Tidal data analysis

2018.09.03 – 2021.02.24 (~905 days) – Tidal record setup at OSi headquarters (*Phoneix Park, Dublin*)

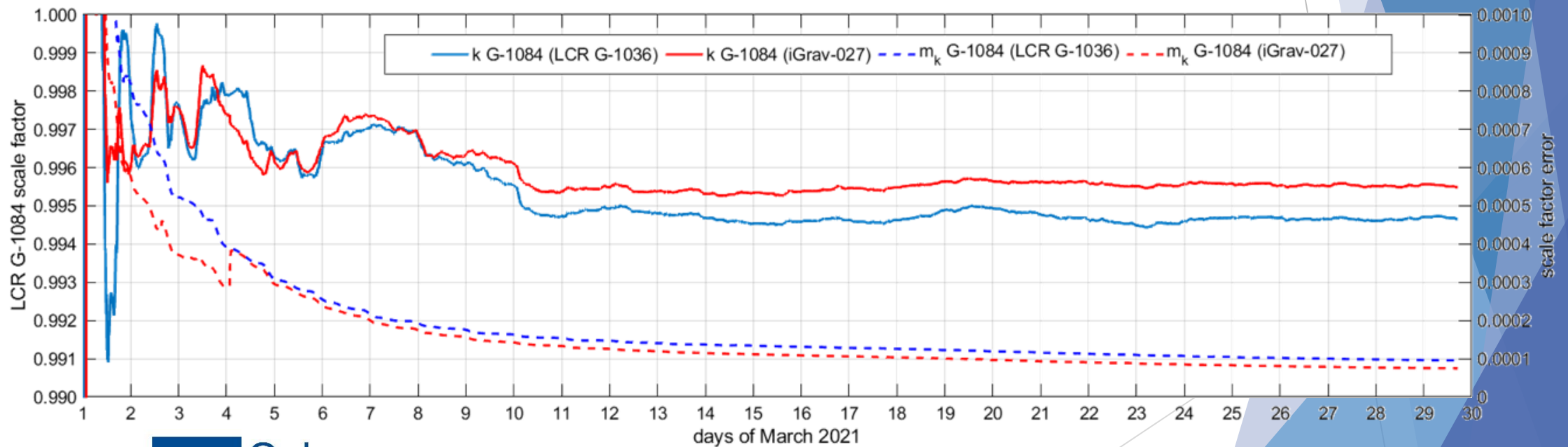
- LaCoste&Romberg model G-1084 (*LRFB-300 feedback*) + Raspberry Pi for data recording
- Sampling rate: ~2Hz, data completeness : >99.9% (*905 days*)
- Goal is to **evaluate the available OTL models** for Ireland with actual tidal records and select the most suitable one (effect is 10× times larger than in central Europe)
- Recorded tidal signal (resampled to 1 hour):



Tidal data analysis

Scale factor determination

- 2021.03 – after return of the LCR gravimeter to Borowa Góra Observatory from Dublin
- Simultaneous records together with LCR G-1036 and iGrav-027 gravimeters (~28 days) with well determined scale factors
- Least squares adjustment of high pass filtered data (0.6 cpd)



Tidal data analysis

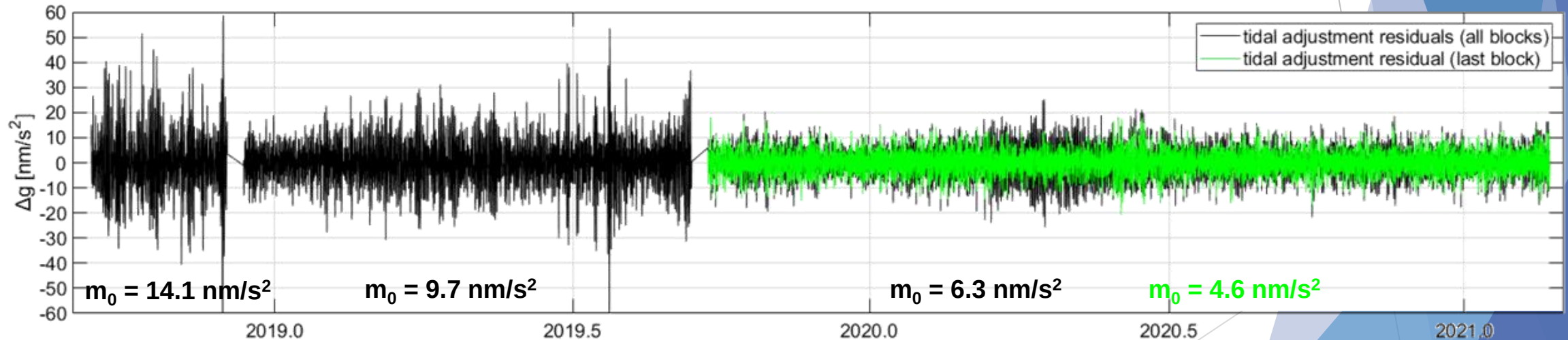
Scale factor determination

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- Simultaneous records together with LCR G-1036 and iGrav-027 gravimeters (~28 days) with well determined scale factors
- Least squares adjustment of high pass filtered data (0.6 cpd)
 - From LCR G-1036: 0.99465 ± 0.00010
 - From iGrav-027: 0.99549 ± 0.00008
 - Mean: **0.99512 ± 0.00009** (used in tidal analysis)



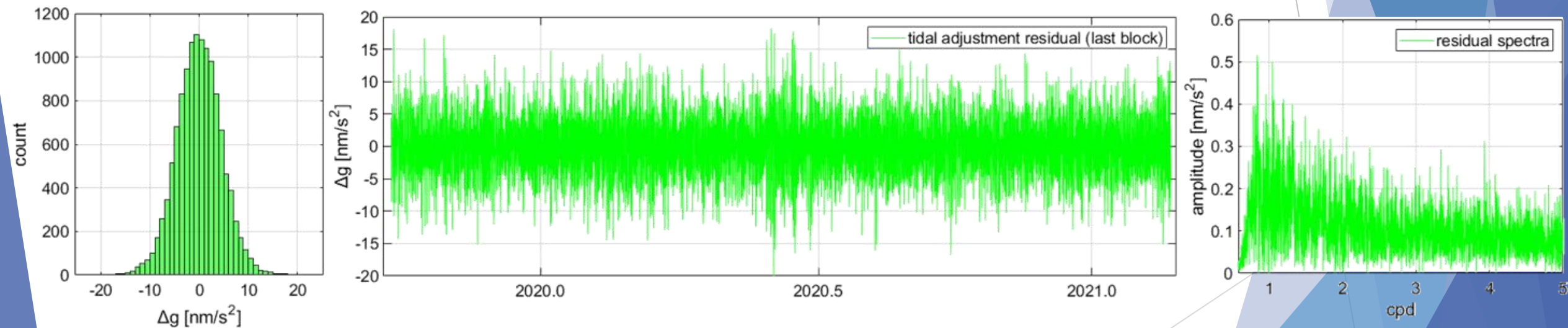
Tidal data analysis

- Resampling to 1 minute, data preparation (TSoft)
- Resampling to 1 hour and tidal adjustment (et34-x-v80-gnusim)
- Time series divided into 3 blocks – consistent with gravimeter **setup adjustment/correction**
- $m_0 = 8.5 \text{ nm/s}^2$ (all blocks – 905 days) – below expectation
- $m_0 = 4.6 \text{ nm/s}^2$ (last block – 516 days) – within expectation – used for further analysis
- Tidal adjustment residuals:



Tidal data analysis

- Tidal adjustment results for last block (et34-x-v80-gnusim)
- HP filter used: n1h1h008.nlf
- Adjusted tides: wave group selection 0.75-2.0 years – according to publication in BIM 150
- Barometric regression coefficient: $-4.1860 \pm 0.0349 \text{ nm/s}^2/\text{hPa}$
- $m_0 = 4.55 \text{ nm/s}^2$



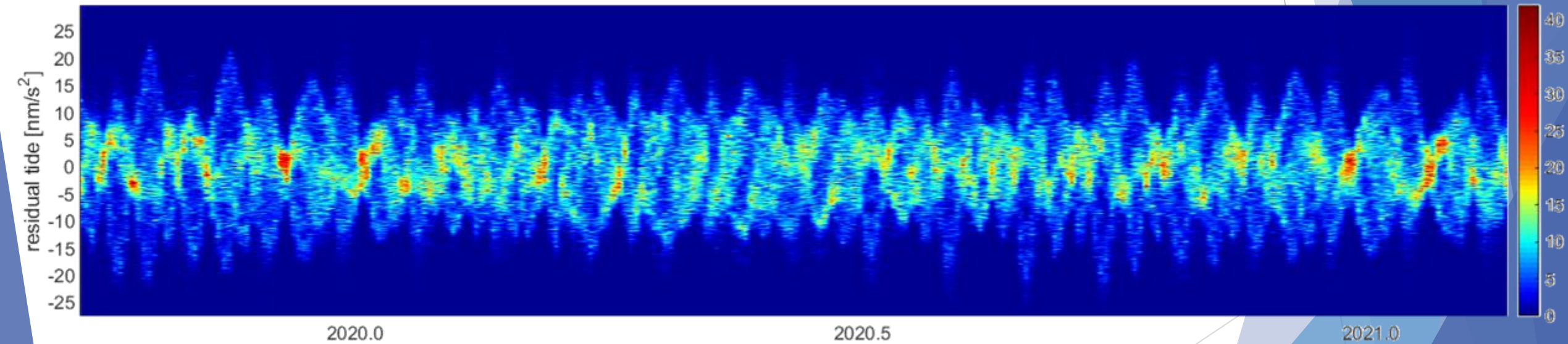
Tidal data analysis

- Combine **adjusted tides (A)** with theoretical **body tides (Tamura)** used in absolute gravity surveys and a variety of **ocean tidal loading models (OTL)**
- OTL models obtained from Chalmers Loading Provider – M.S. Bos and H.-G. Scherneck (<http://holt.oso.chalmers.se/loading/>)
 - All available models except Schwiderski (large discrepancies)
 - In total 29 OTL models were used for analysis (stacked on the plot below) – developed in Tsoft
 - All models are only used for 0.58 cpd and higher frequencies (Q1, O1, P1, K1, N2, M2, S2, K2)
- Analysis of **residual tides (R)**: $R = A - T - OTL$
 - Amplitudes, phases determinations
 - Residual tide statistics

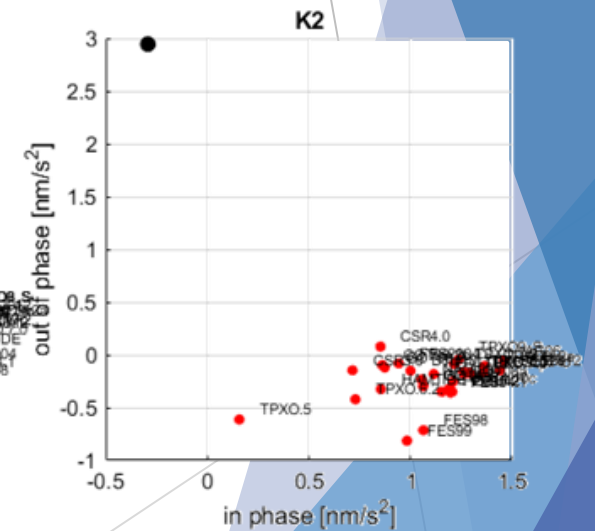
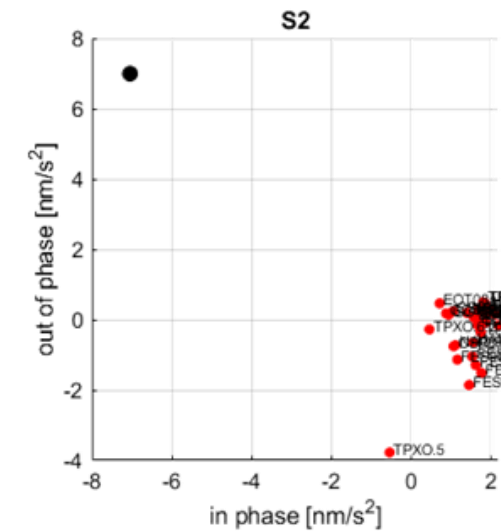
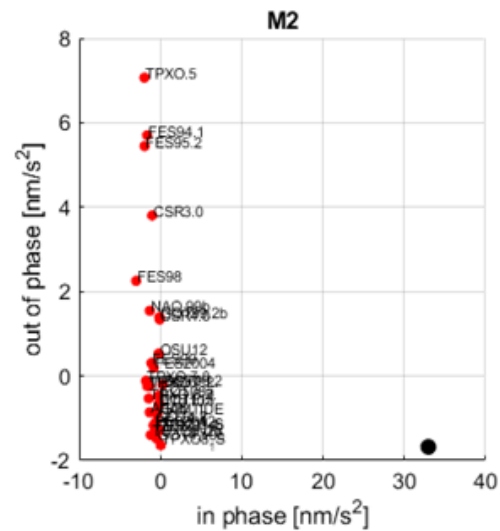
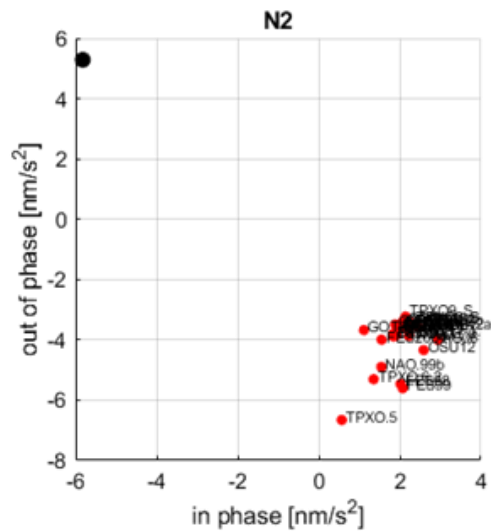
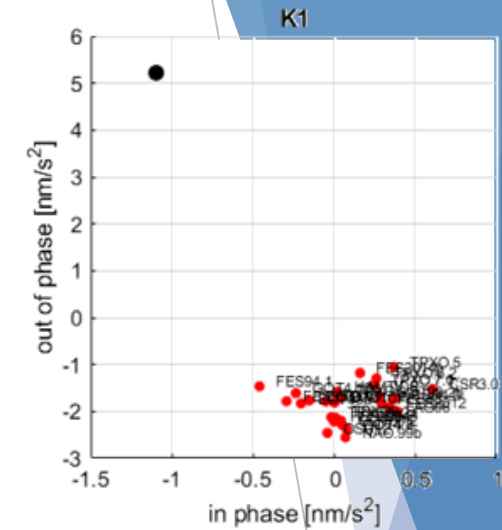
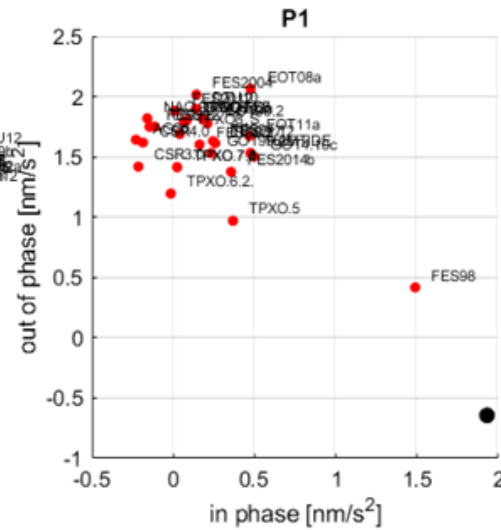
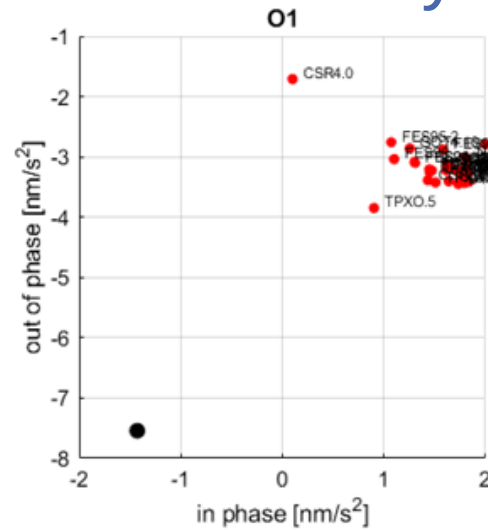
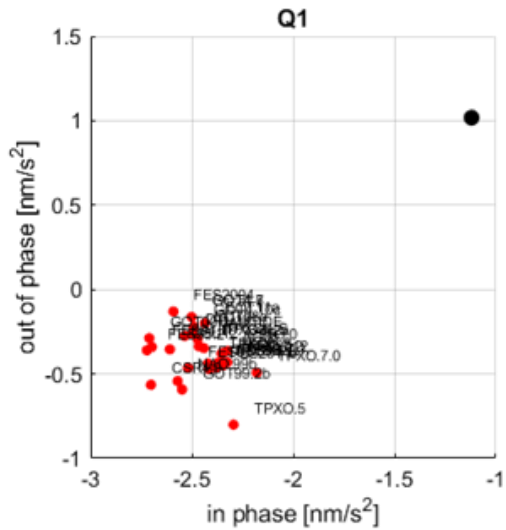


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 - Stacked residual tides for all OTL models



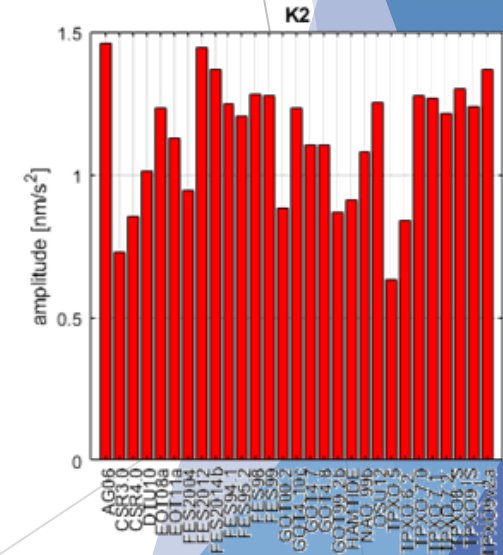
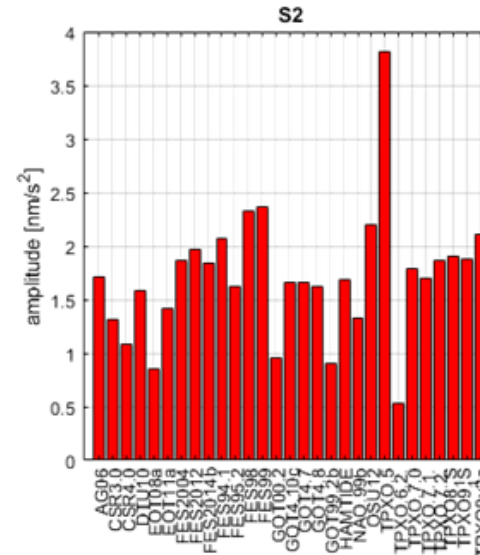
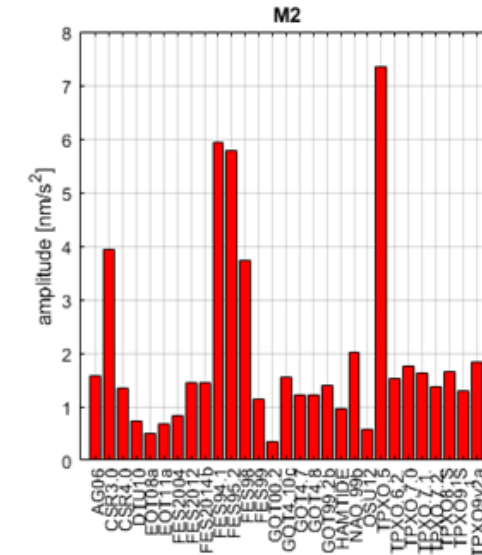
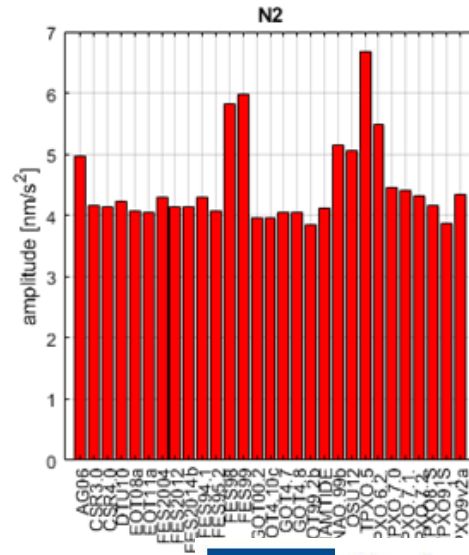
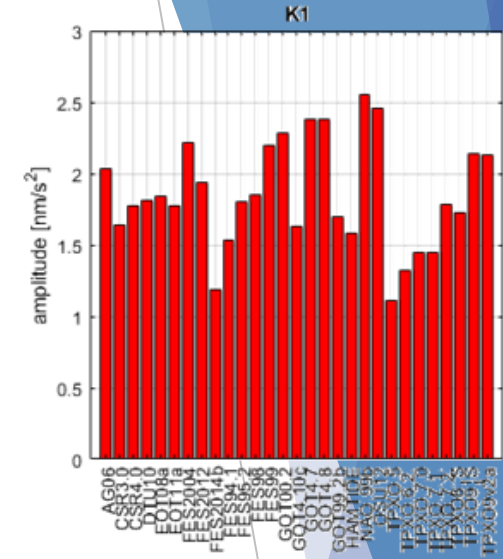
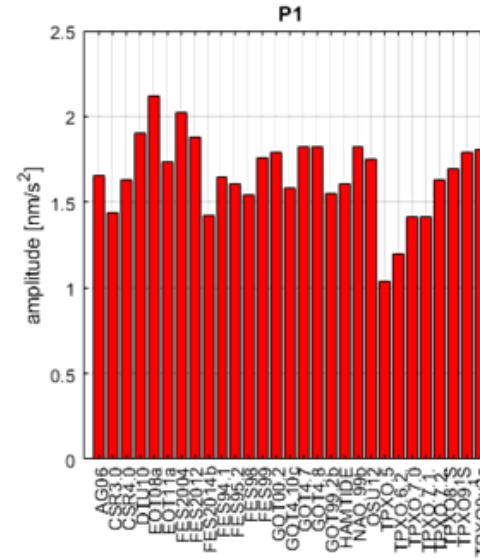
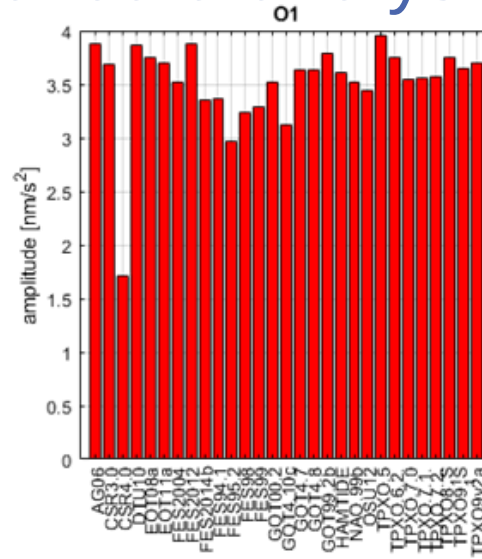
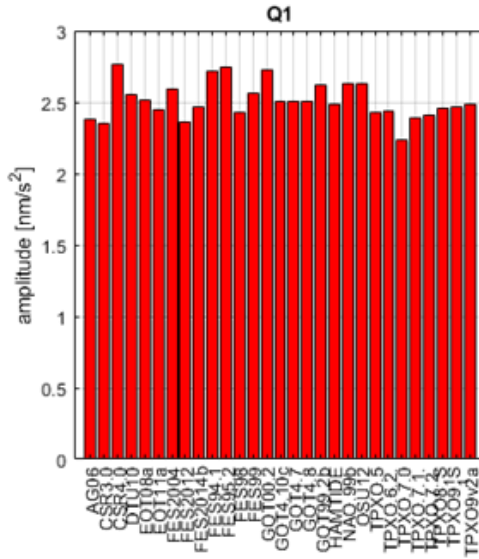
Tidal data analysis



Phasor plots – observed OTL (black dot), residual tide (red dots)

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Tidal data analysis



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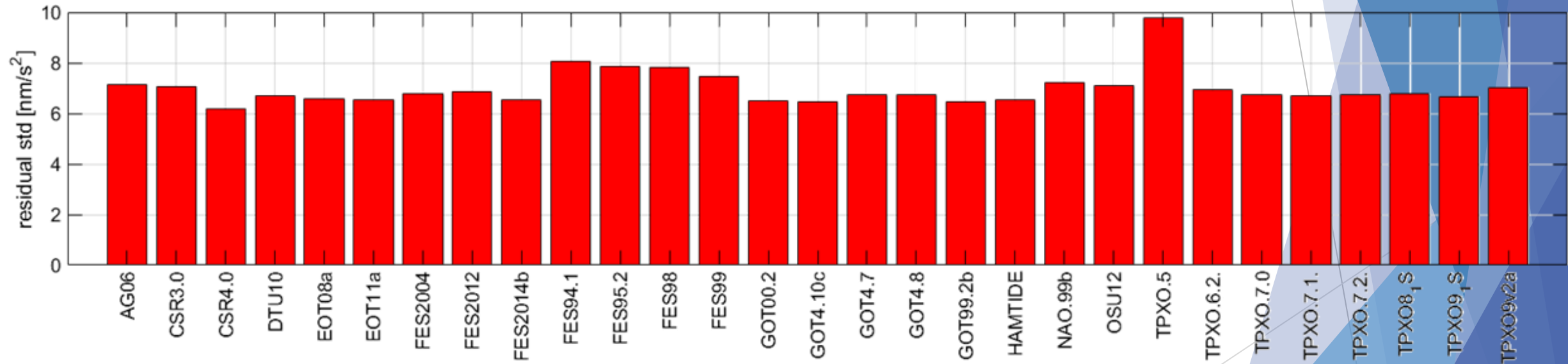
National Mapping Agency

Residual tide amplitudes

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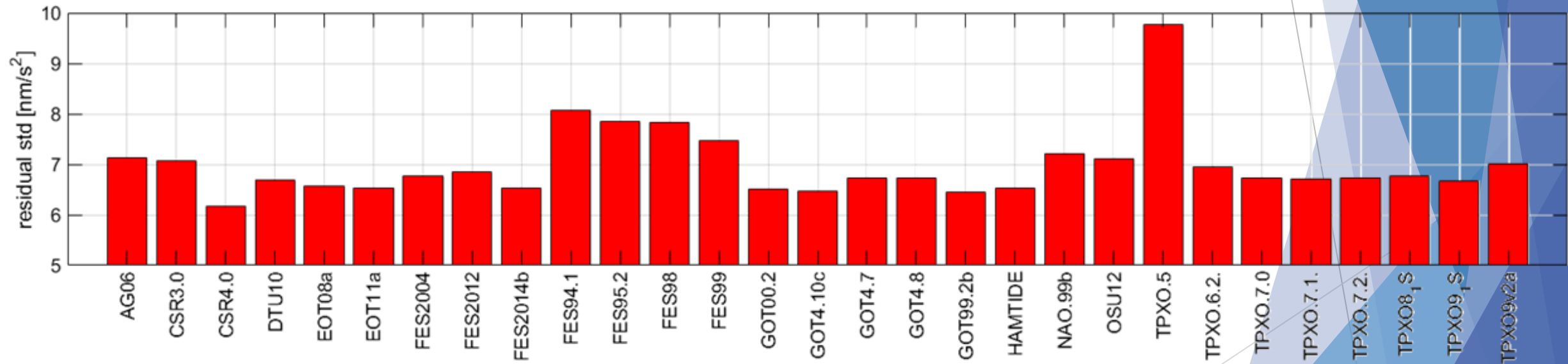
Tidal data analysis

- Difficult to pin point one model that is „best” for all tidal constituents
- Practical approach is to select the smallest residual tide signal
- **Standard deviations** of the residual tide signals for each model:



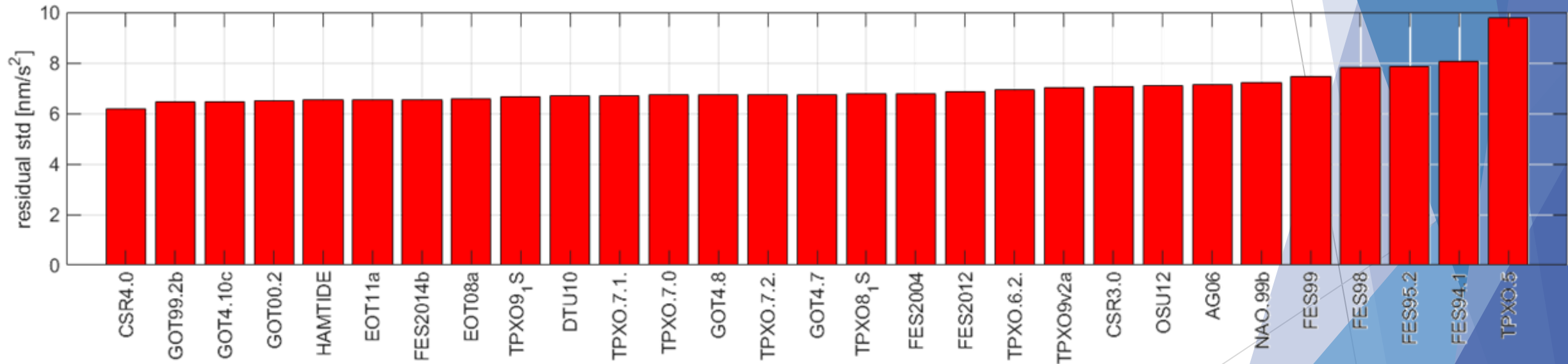
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- **Standard deviations** of the residual tide singnals for each model (scale change):



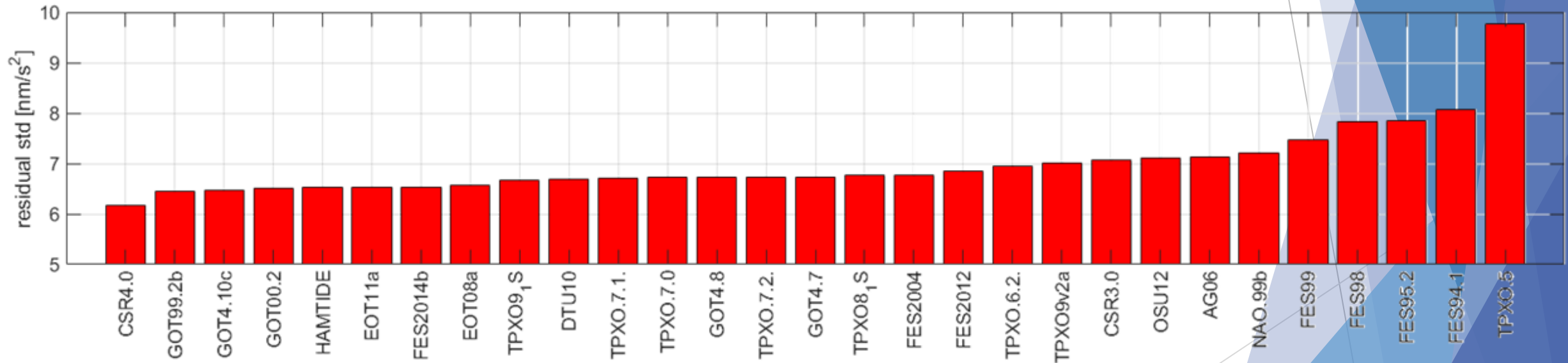
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- Difficult to pin point one model that is „best” for all tidal constituents
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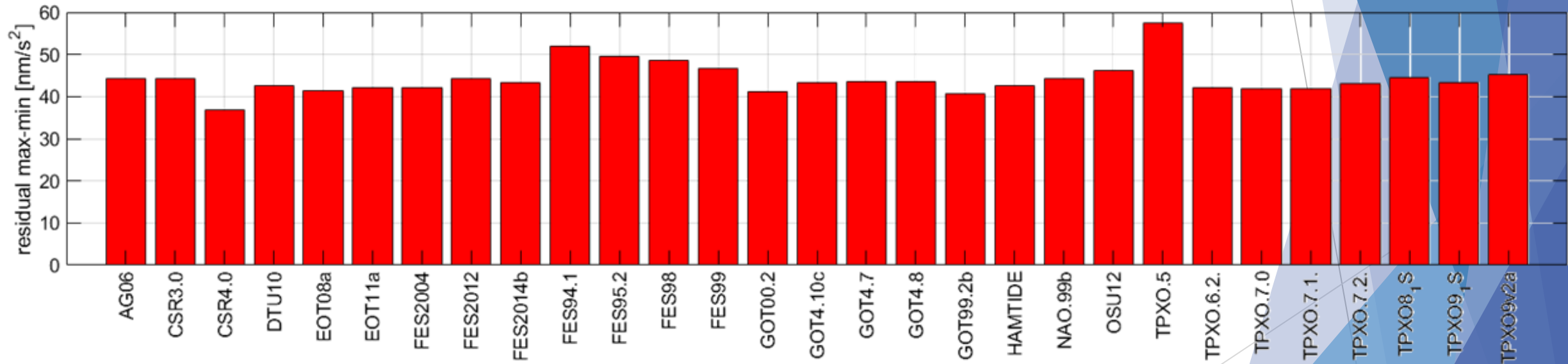
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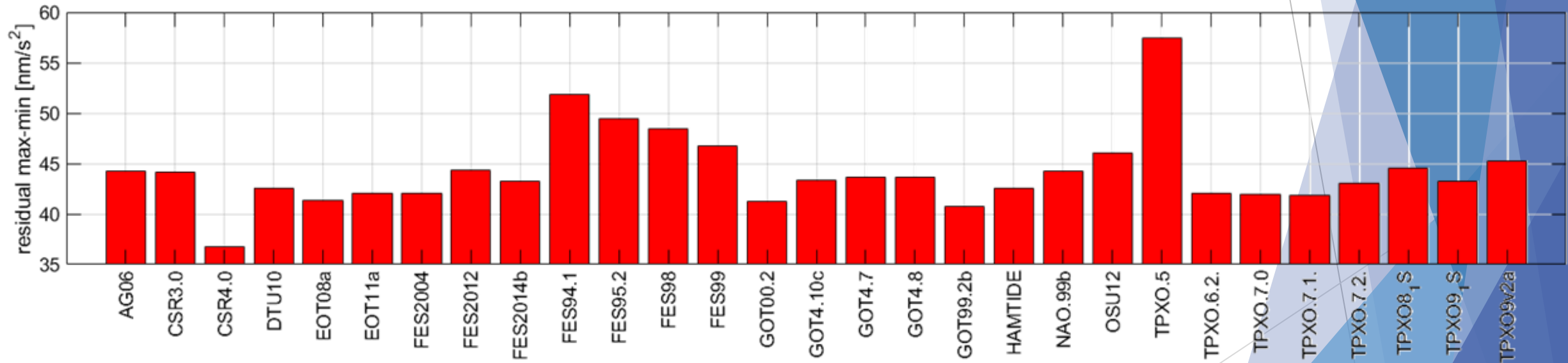
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- **Maximum minus minimum** of the residual tide signals for each model:



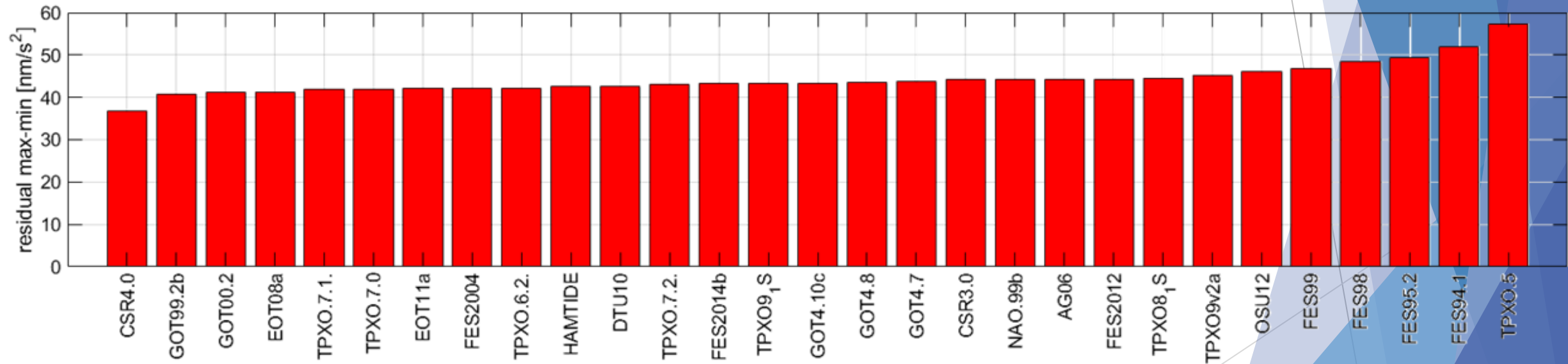
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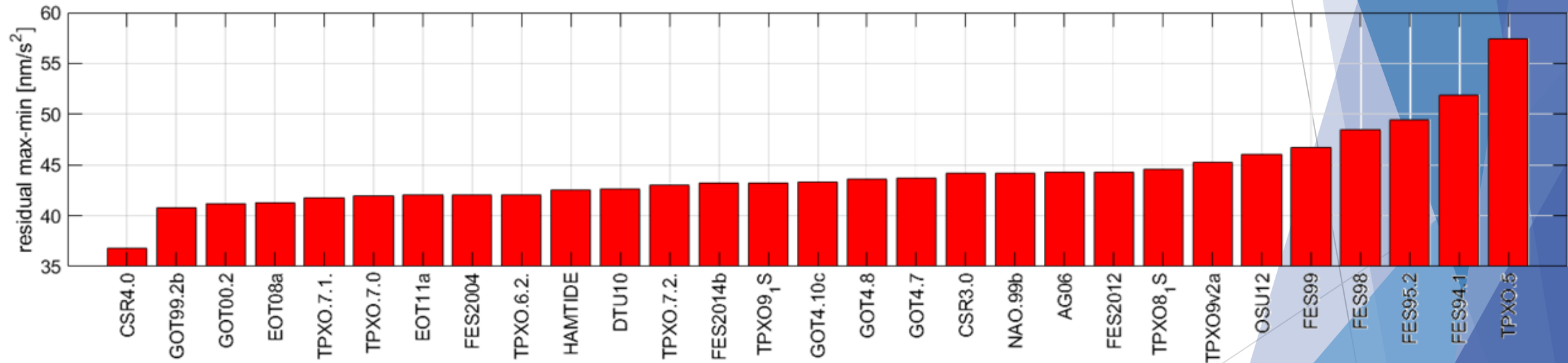
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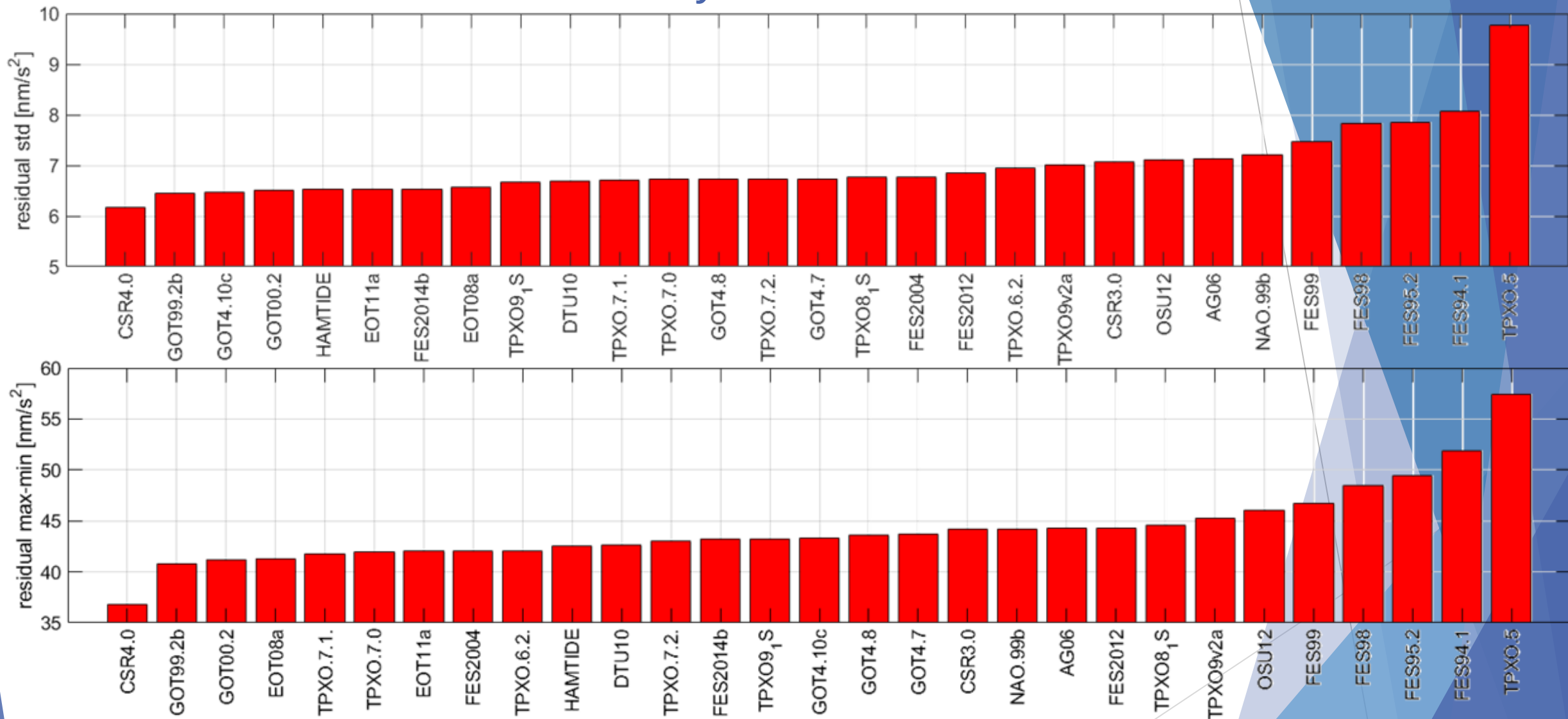


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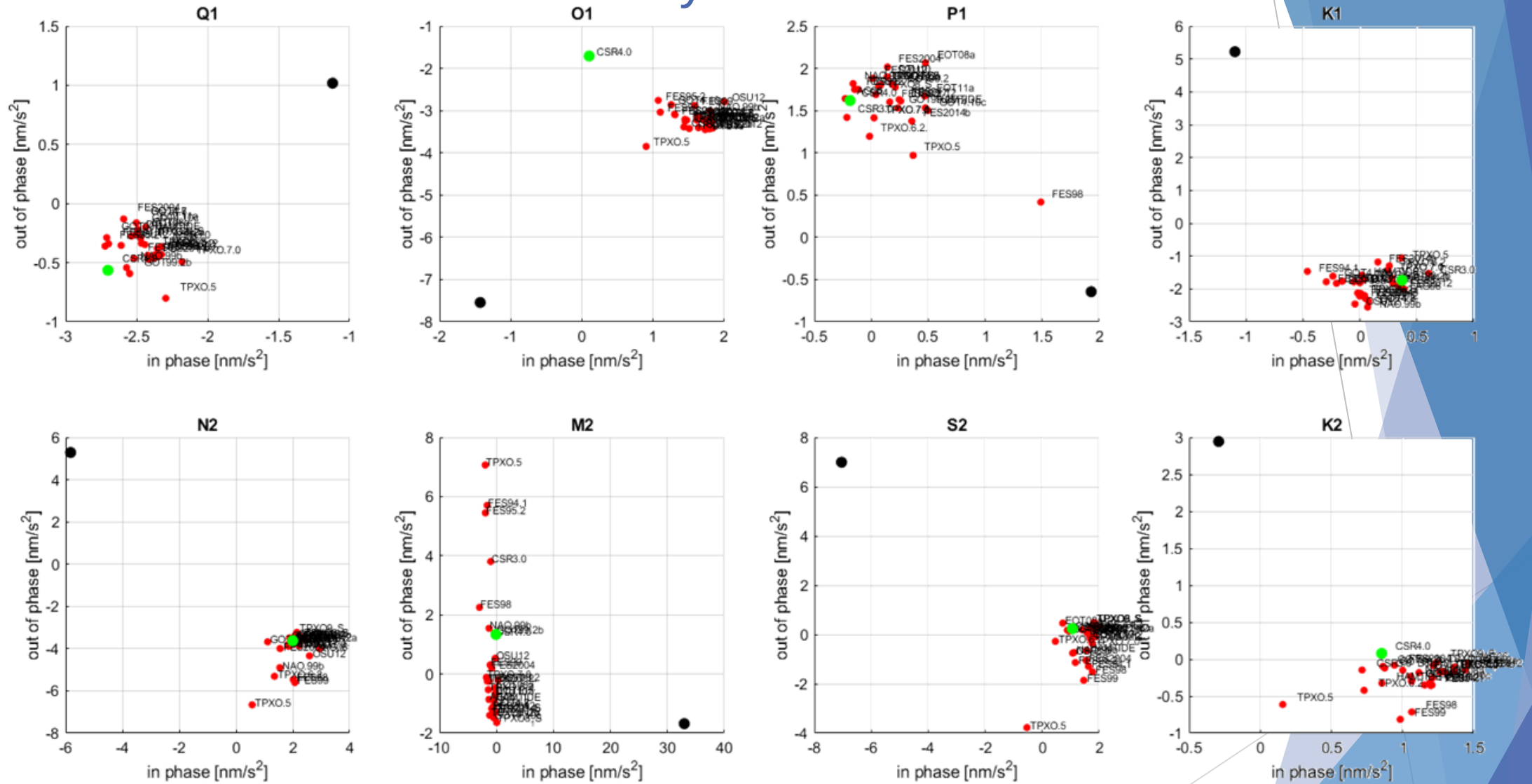
Tidal data analysis



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Tidal data analysis



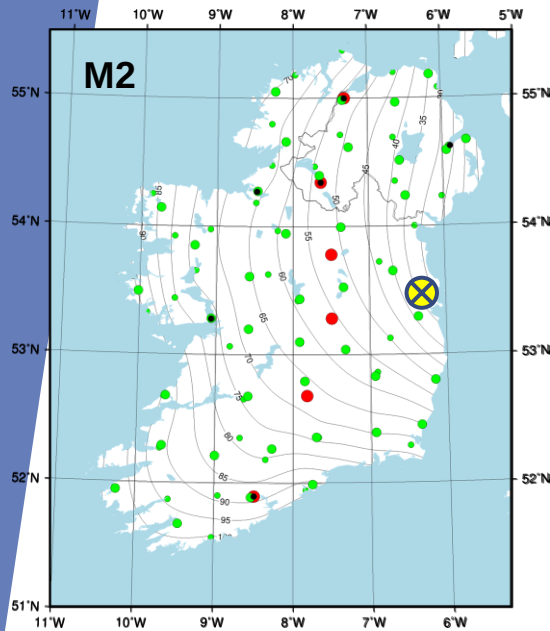
Conclusions

- LCR model G gravimeter is proven to still be a usefull tool for OTL analysis in a remote location
- Tidal analysis produced a satisfactory **4.6 nm/s²** adjustment error
- **Phasor plots** analysis does not indicate a clear „best” model to use, different models show improvement for diferent tidal constituents
- Statistics of residual tides allow a more direct indication of the most efficient residual tide signal
- **CSR 4.0** OTL model proved to provide the **smallest variations** and **standard deviation**, hence should be considered as most suitable to be used for correcting absolute gravity surveys within the framework of the AGN Ireland project



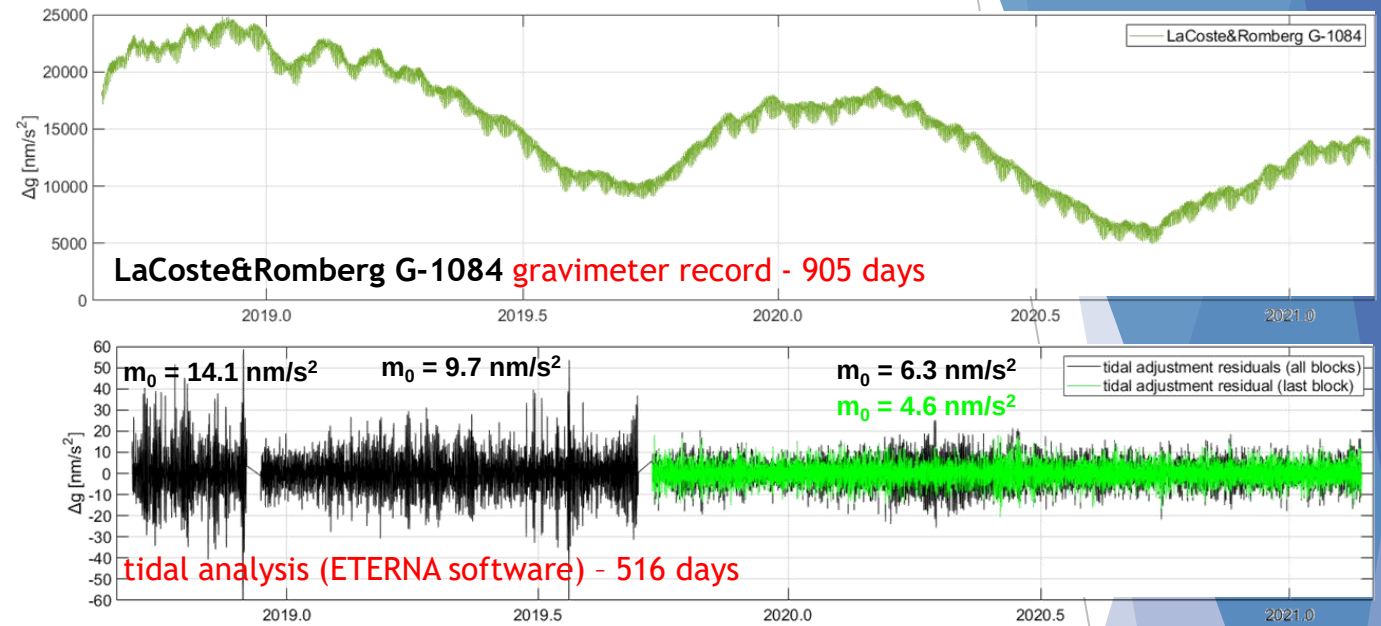
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Absolute Gravity Network Ireland

- absolute gravity measurement (A10 type)
- total uncertainty $<100 \text{ nm/s}^2$ (1σ)
- Re-processing: **IGRS standards 2021** including body tides (Tamura), barometric correction, polar motion and **ocean tidal loading (most suitable)**
- **Chalmers ocean loading provider (OTL models source)**



Residual tide assesment (29 models)

Residual Tide = **adjusted tide** – body tide model – OTL model

Residual tide standard deviation:

