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## Kévin Dubois

# Comparison of sea surface height measurements and calculations with the Delft3D-FM model and an analysis of forcing factors

## *Samanburður á mælingum á sjávarborði og líkanreikningum með Delft3D-FM og greining áhrifaþátta strandflóða*

*Kévin Dubois*, Angel Ruiz-Angulo, Halldór Björnsson, Sigurður Sigurðarson and G. Orri Gröndal*

## a. ABSTRACT

Floods regularly cause damage and disruption to activities in ports or other coastal areas. A recent noted 84 floods in the second half of the 20th century (Guðrún E. Jóhannssdóttir, 2017) but in an older summary it is stated that about 6 significant floods occur every decade (Páll Imsland and Þorleifur Einarsson, 1991). The frequency of those events and their possible increase under climate change suggest that it is important both to monitor the coastal sea level and to implement computational models to predict probable flooding.

Measurements of sea level have been carried out in several ports around Iceland. The measurements cover different lengths of time and are not overlapping everywhere. From those measurements, the data from seven ports have received particular attention, filling in some small gaps and also correcting the corresponding time shifts. For those stations, the revised data is currently available (Guðjón Scheving Tryggvason, 2016, 2017).

The Icelandic Meteorological Office has been working for some time on the installation of the coastal model Delft3D-FM (Deltares, 2020a, b) with the aim of being able to predict coastal floods. The numerical model solves the nonlinear shallow-water equations using finite volume elements in an unstructured mesh (about 150 m resolution along the coast). The model is forced by astronomical tidal forces, winds and pressure fields. The air pressure and winds that the model uses as input data come from the Harmonie forecasting system of the Icelandic Meteorological Office.

The model has already been used to simulate the water level for South-West of Iceland (cf. report March 2021) and compared with tide gauges measurements. The comparison was made both by calculating the tides in 6 stations for South-West of Iceland directly from the other tidal factors from the recent FES2014 system (Carrere et al. 2017) and using Delft3D-FM to calculate how the tidal wave reached the shore. The results of this comparison show that Delft3D-FM was better able to simulate the maximum sea level than FES2014, which demonstrates the importance of using a regional model to calculate tidal waves in detail. This comparison gives hopes that tides can be simulated elsewhere in the country, though comparison with the Reykjavík station is probably easier than with other stations as this station is the only IOC station in the country, and information from it stored in an international database such as those on which FES2014 is based.

## b. Introduction

The Icelandic coastline is slightly less than 5000 km, and most of it is vulnerable to sea-level rise and storm surges. Iceland lies in the path of persistent low-pressure systems and frequent wintertime cyclones. In the last century, there were about 6 (to 15) significant (to moderate) coastal flooding events per decade, especially on the South and West coasts of Iceland (Björnsson et al., 2018). Although individual events that have led to significant damage have been reported (e.g. Jóhannesdóttir, 2017; Viggósson et al., 2016; Eydísardóttir, 2015; Geirsdóttir et al., 2014; Sigurðarsson, 2004; Imsland & Einarsson, 1991), no peer reviewed study has examined coastal flooding in general at the coast of Iceland, neither for past nor projected flooding events.
Sea surface height along the coastline has not been well monitored, of about 18 measurement stations only Reykjavik is operated according to IOC standards (Sigurðarsson, 2018). Multiple analysis of ESL statistics from this station yield a 100 year flood of 1.1 to 1.2 m above average spring tide (Jónsson et al., 2017; Elíasson, 1996; Elíasson and Valdimarsson 1993), but statistics for other locations have with a few exceptions not been calculated due to lack of extended timeseries.

Thus, both monitoring and forecasting these events is relevant to the coastal communities. Hydrodynamic models with atmospheric forcing are useful to simulate storm surges, both for operational applications and risk assessments. The aim of this project is to improve knowledge of coastal floods in analyzing different storms and comparing them with the new Delft3D-FM coastal model from the Icelandic Meteorological Office (IMO). However, one shortcoming of the model should be mentioned, the model is not a wave model and it does not reproduce water level variations due to waves. This, as will be shown, can impact the model results.

## c. Methodology

At IMO, following the previous project with our pilot domain covering the South-West of Iceland (cf. report March 2021) we setup a model for the whole coastline of Iceland shown in Figure 1. We chose seven different time periods when notable storms happened in Iceland over different regions: November 1996, January 2000, December 2006, October 2008, December 2013, December 2015 and February 2016 (cf. table 1). The decision to use these time periods was also influenced by the fact that during these times, several different stations were available with data: Akranes, Reykjavík, Grindavík, Landeyjahöfn, Þorlákshöfn and Básasker

(Vestmannaeyjar), Sandgerði, Grundartangi, Ólafsvík, Patreksfjörður, Ísafjörður, Skagaströnd, Dalvík, Húsavík, Hornfjarðarós. Thus there was the opportunity to compare the model results against data from these stations.

Table 1 presents the main storms simulated for comparison. Sometimes, different storms happened within each simulation period. As the storm travels, some impacts can have been found elsewhere than the area here proposed which corresponds to the storm's lowest pressure. Strong winds are usually found travelling cyclonically around the storms' eye.

| **Storm** | **Dates** | **Area** | **Locations affected** | **Comments** |
|---|---|---|---|---|
| Nov. 1996 | 28th | South-East | Hornfjarðarós, Þorlákshöfn | Low pressure (963.3 mb) |
| Jan. 2000 | 10th | South-West and South | Grindavik, Vik | Flooding, very low pressure (954 mb) |
| Dec. 2006 | 10th | West and South | Grindavik, Ólafsvík | Very low pressure (931 mb) travelling from West to East of Iceland |
| Oct. 2008 | 9th | South-West | Grindavik, Akranes, Ólafsvík | Very low pressure (949.3 mb) |
| | 24th | North | | Very low pressure (937.5 mb) |
| Dec. 2013 | 18th | North-West | Landeyjahöfn, Vestmannaeyjar | Very low pressure (944.1 mb) |
| | 19th | East | Ísafjörður, Skagaströnd, Húsavík | Very low pressure (938.9 mb) |
| Dec. 2015 | 30th | South-East | Ísafjörður | Very low pressure (931 mb) travelling from South-East to North |
| Feb. 2016 | 16th | South-West | Akranes, Reykjavík, | Very low pressure (960 mb) |

| | | | | |
|---|---|---|---|---|
| | | | Grindavík, Landeyjahöfn, Þorlákshöfn, Vestmannaeyjar, Ísafjörður | |

**Table 1.** Time period chosen with associated noticeable storm.

We used the coastal model Delft3D-FM to simulate the flooding events. The numerical model is forced with hourly surface wind and pressure (IRCA reanalysis) throughout the domain and tidal constituents (FES2014) at the boundaries. The results are compared with the measurements from Vegagerðin's database. Two sets of simulations for each period were carried out to separate the contribution of each component: tide-only and the full forced simulation.

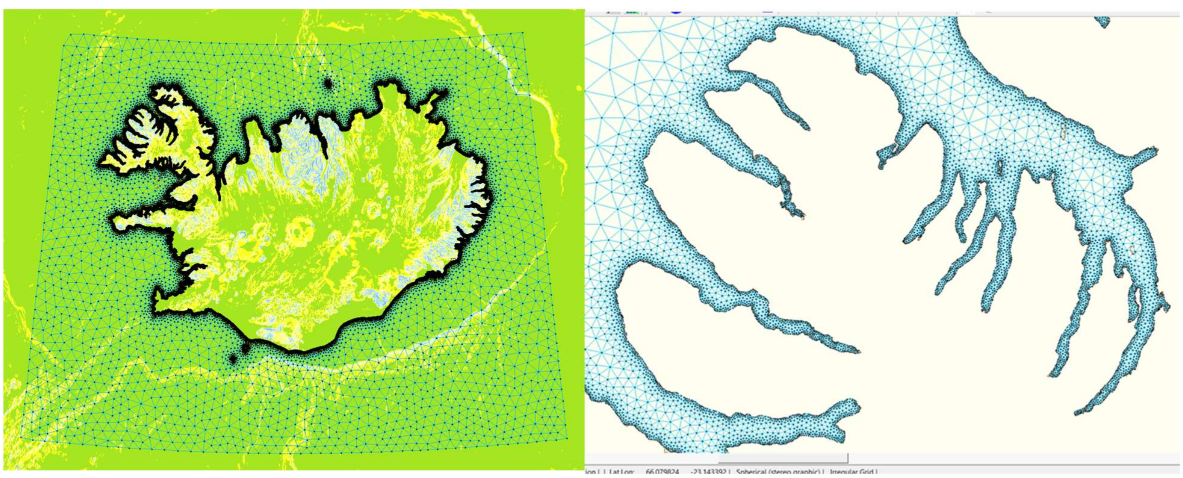

**Figure 1.** Map of the Icelandic full domain including the unstructured mesh showing higher resolution at the coast from pilot project. The stars represent the stations where the comparison was performed.

Finally, we compare the model outputs with the observed data at each station to assess the performance of the Delft3D-FM coastal model based on the same method as we used on the pilot project. More details on the model and grid are given in the appendix.

## d. Results and discussion

We have successfully performed seven different storm surge simulations for all Iceland. In the following (Figures 2 – 8), they are presented and shortly discussed. For each of the chosen storms, we compared the observations with the resulting simulations at the stations with available tide gauge data. For reasons discussed in more detail below, the high frequency variability in the observations is filtered out with a low-pass filter and the filtered results added to the figures.

The following figures the number of stations reported depends on how many locations were affected by the storm. As a consequence, some of the figure run over several pages, but all follow the same template for each station. Two plots for each station are presented, one plot with three panels and below it another consisting of four panels. In the first plot, the upper most panel shows the water level from observations (grey), the tidal model (dashed green) and the Delft3D-FM solution (blue). The middle panel shows the storm surge, resulting from subtracting the full signal from the tidal model, for the observations (grey) and the model full-forced with surface winds and pressure fields (blue). The bottom panel shows the residuals between the observations and the model. The period during the first three to five days of the simulations corresponds to the model spin-up time, and it is not used for further analysis as it has associated large errors for all stations. In the second plot, the upper most panel is the same one as the middle panel in the first plot showing us the storm surge both from observations and from the model. The second panel shows the pressure interpolated by the model at the station. The third panel shows us the easterly (u) in blue and northerly (v) in red wind components at the station. The fourth panel shows the wind magnitude.

**November 1996**

The results for **November 1996** are shown in Figure 2, where we compared at 6 stations showing a very good agreement at the different stations analyzed but with probable tide shift in Höfn. From the analysis, we performed 2 sets of simulations, which allowed us to get the surge signal. As the observations data are sometimes missing the filter data are set to zero value in some cases. On contrasting the observations and model results, we see that the model could reproduce especially well the water-level and surge signal for the stations in Patreksfjordur and Dalvik in the Westfjords and North of Iceland.

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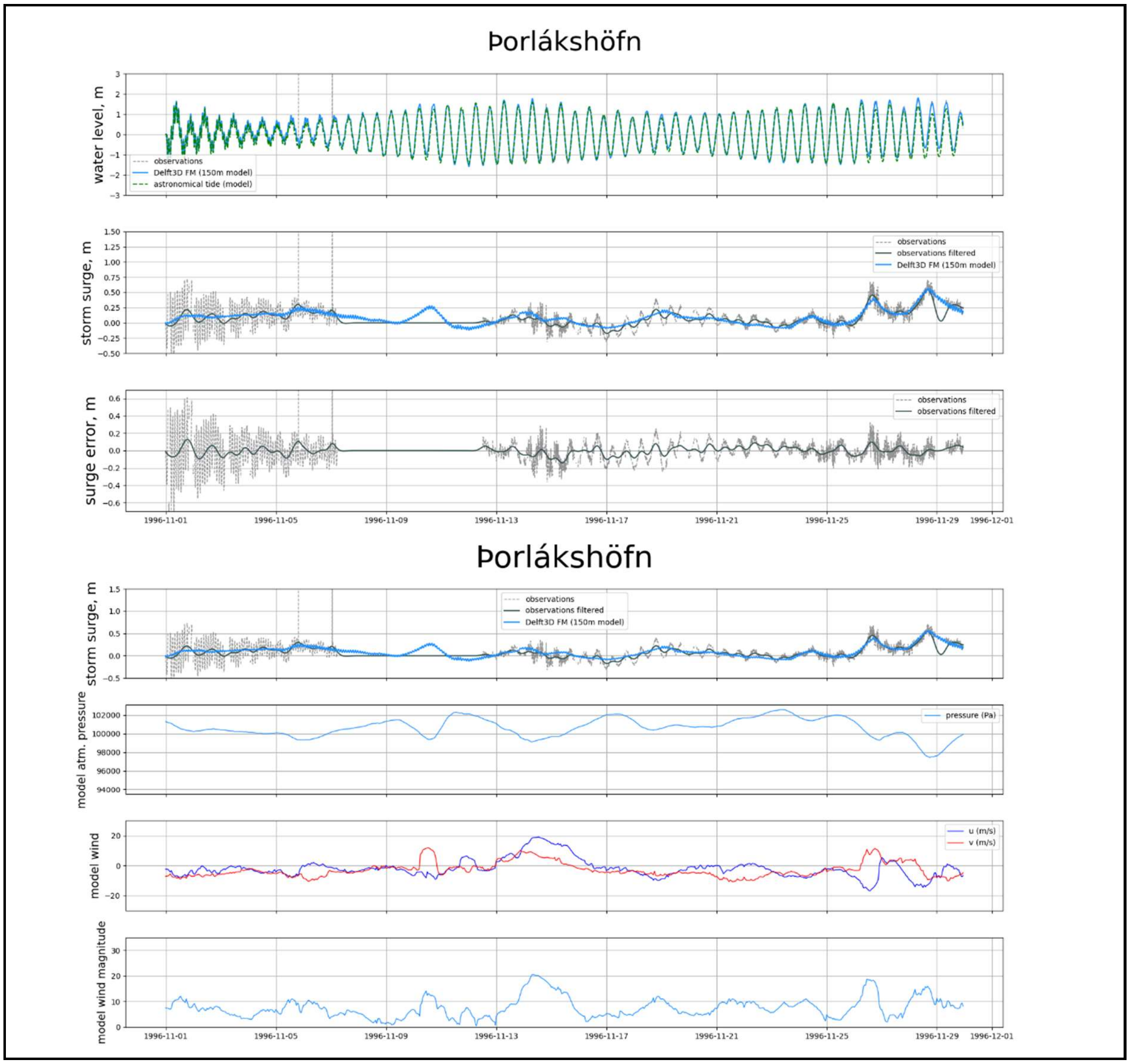

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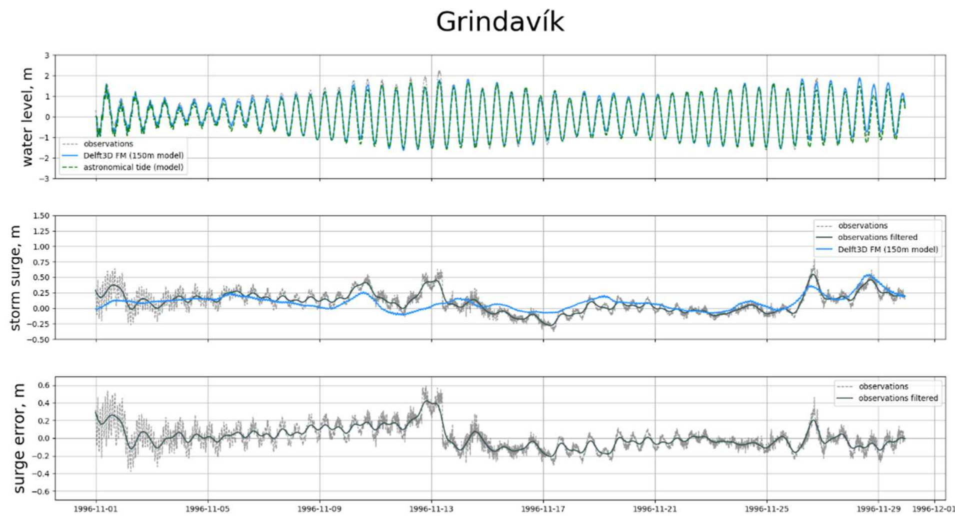


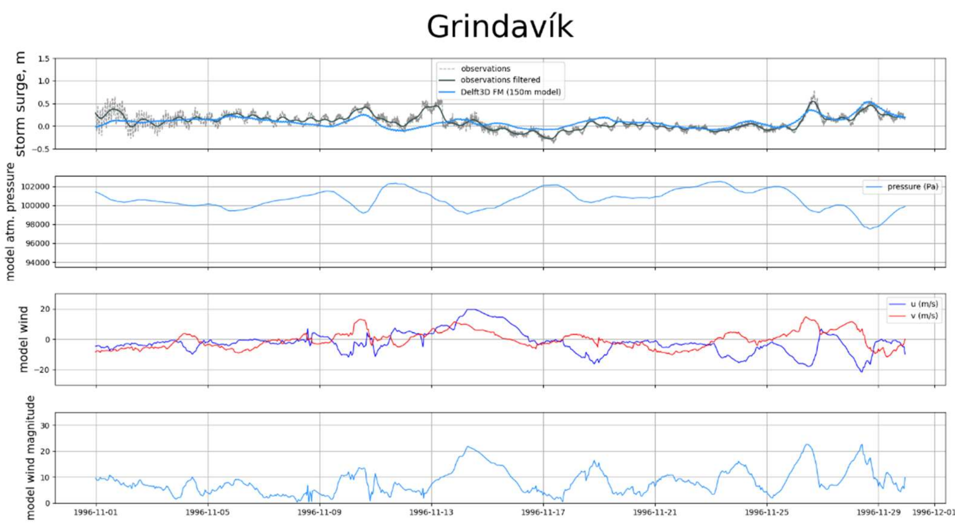

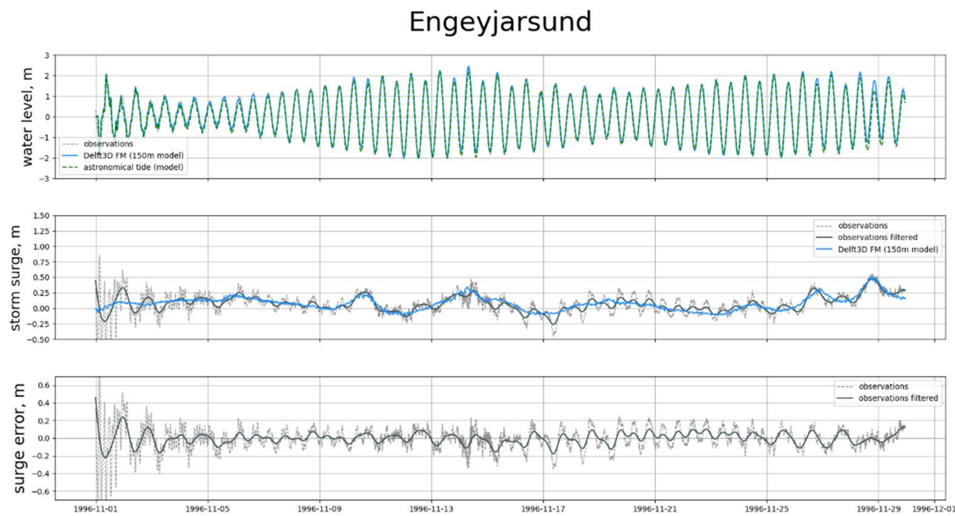
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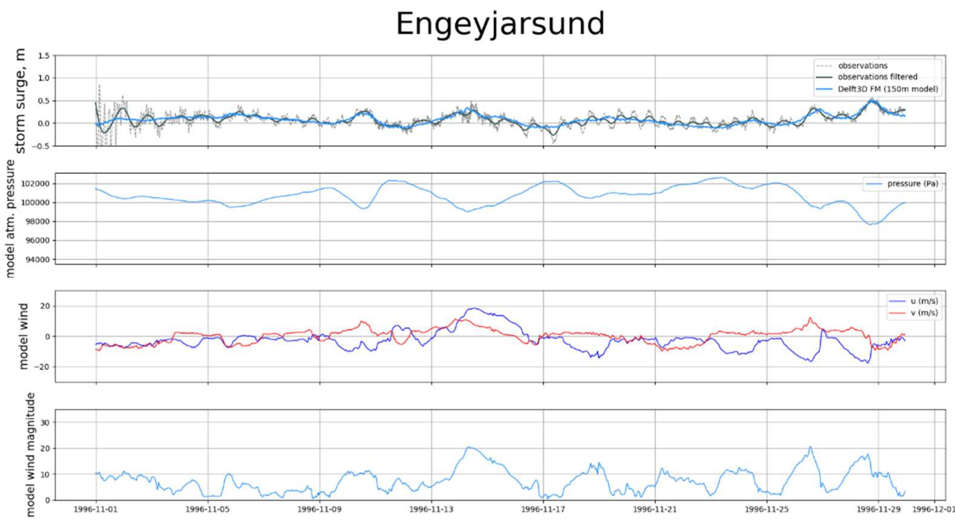
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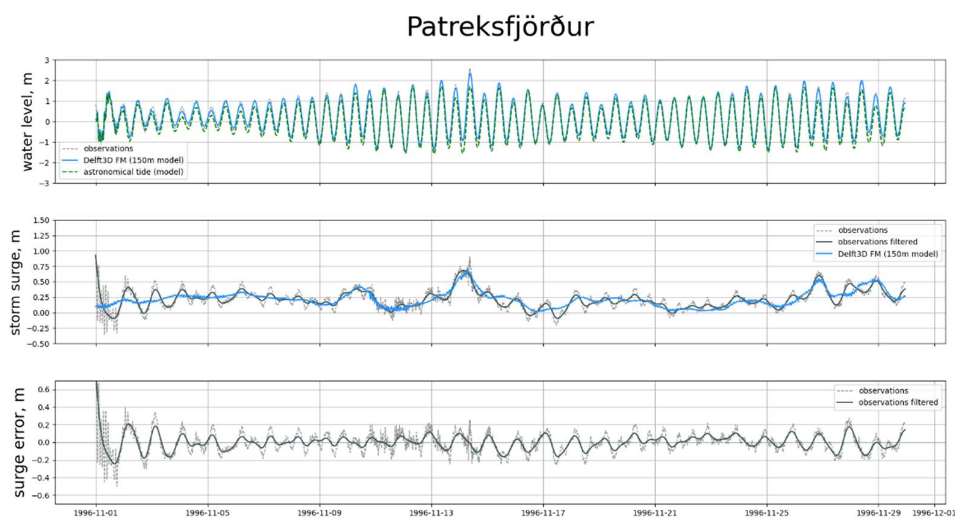
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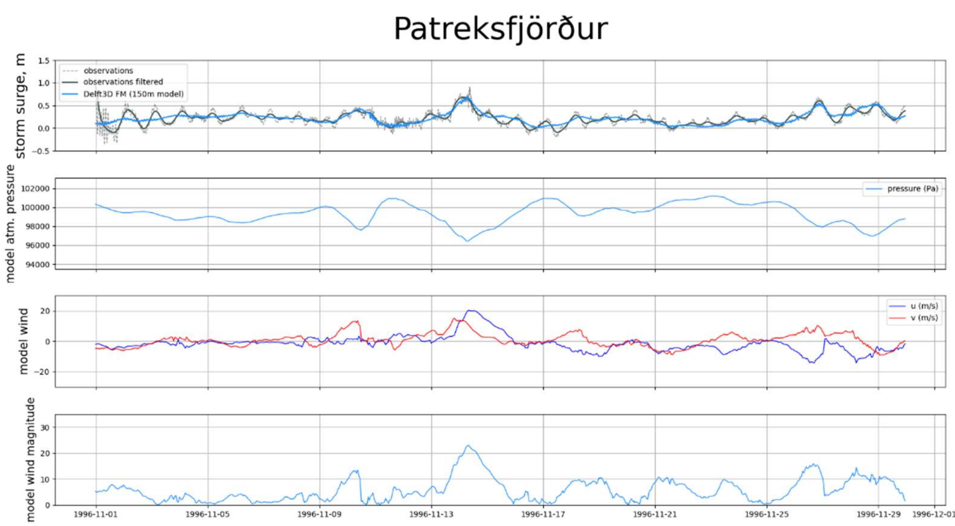
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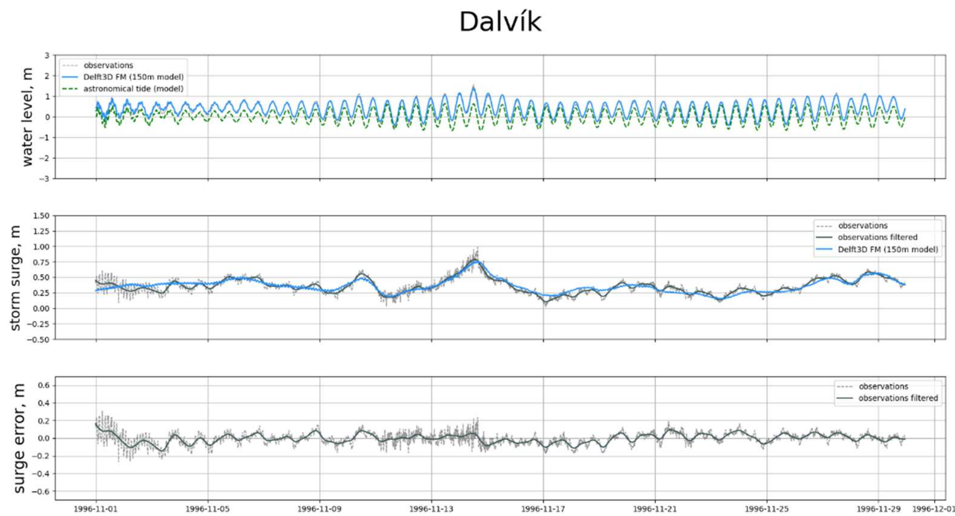
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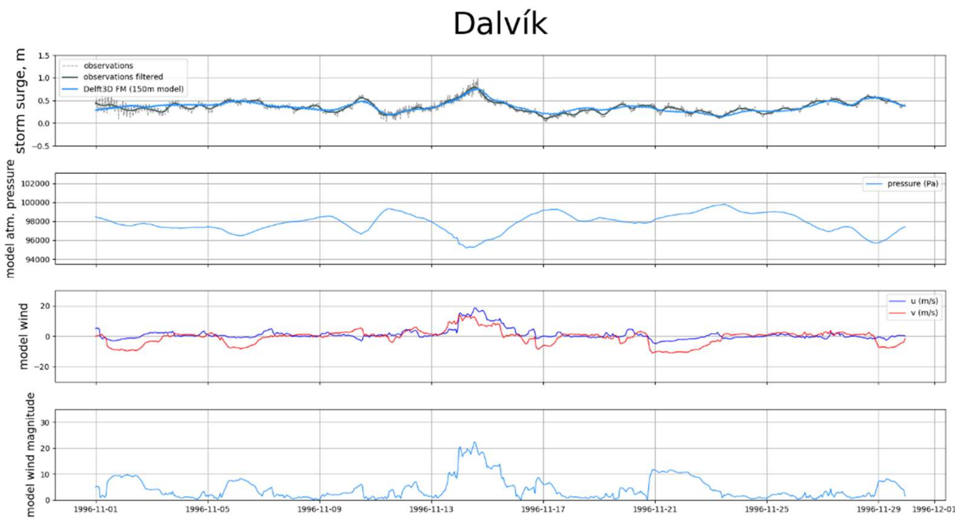
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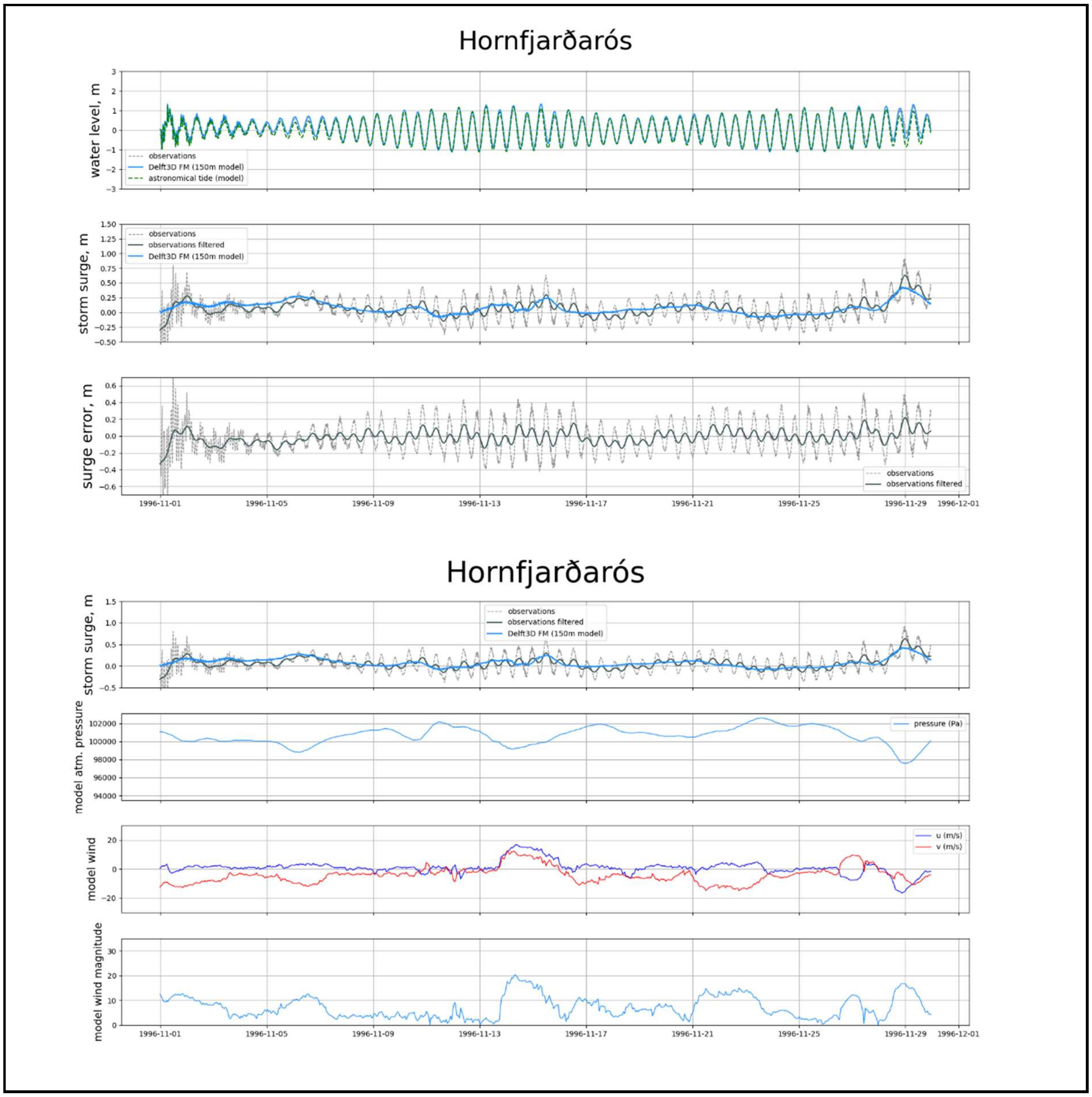
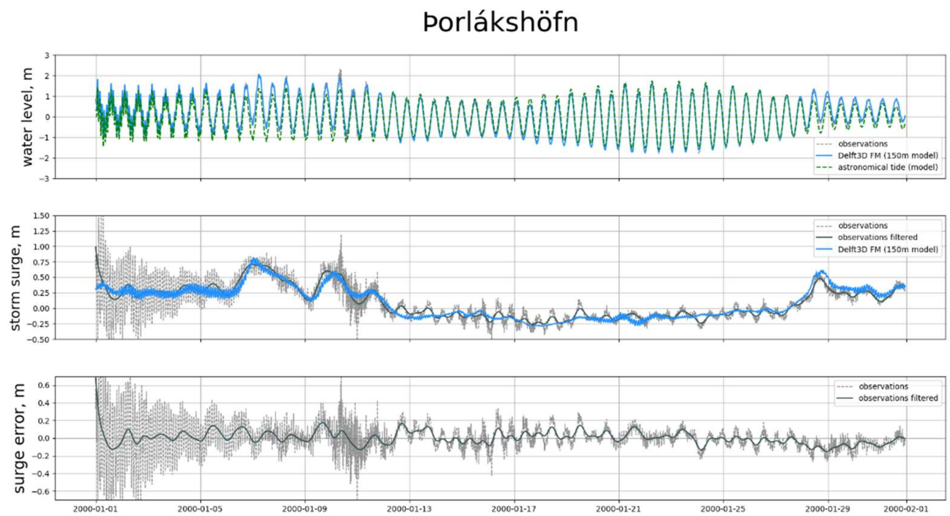



**Figure 2.** Storm surge: observations and numerical model estimates for **November 1996.** Note the error in Höfn which is most likely due to a tide shift in the model.

**January 2000**

Similarly, the results for **January 2000** are shown in Figure 3, where we compared 7 stations. However, as we mentioned before, we can highlight a high peak in the observation dataset on the 10th of January 2000 in Grindavik which was not reproduced by the model suggesting that the discrepancy could be attributed to the wavefield, trapped waves or local resonant effects. Here, much higher resolution grid, and/or the inclusion of a wave model would be needed to study this further.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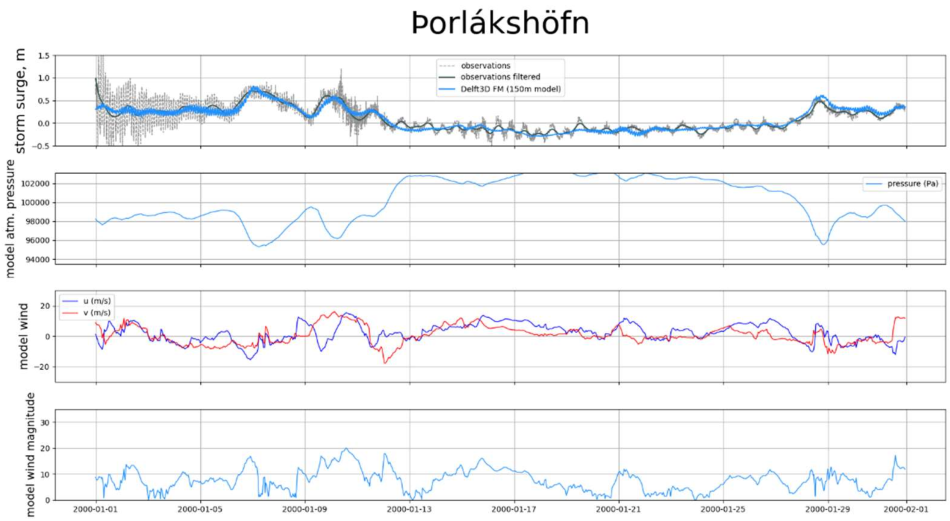
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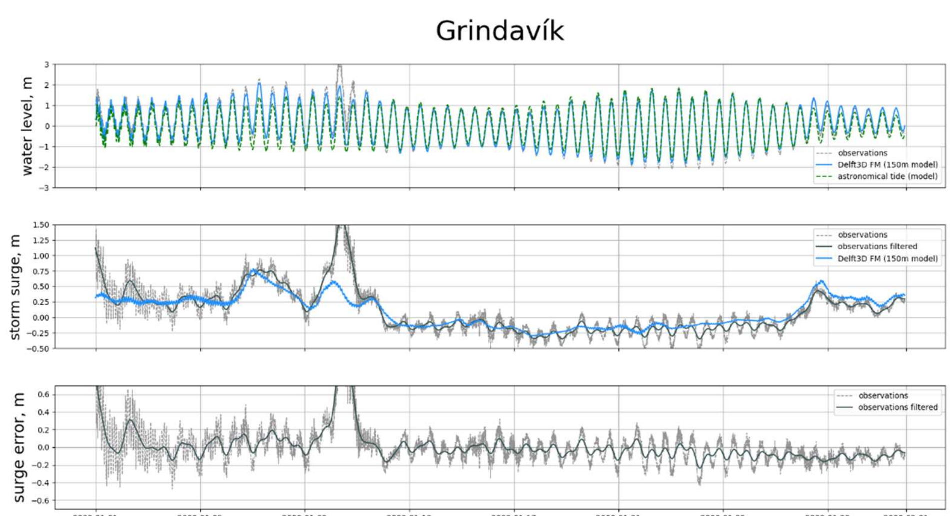
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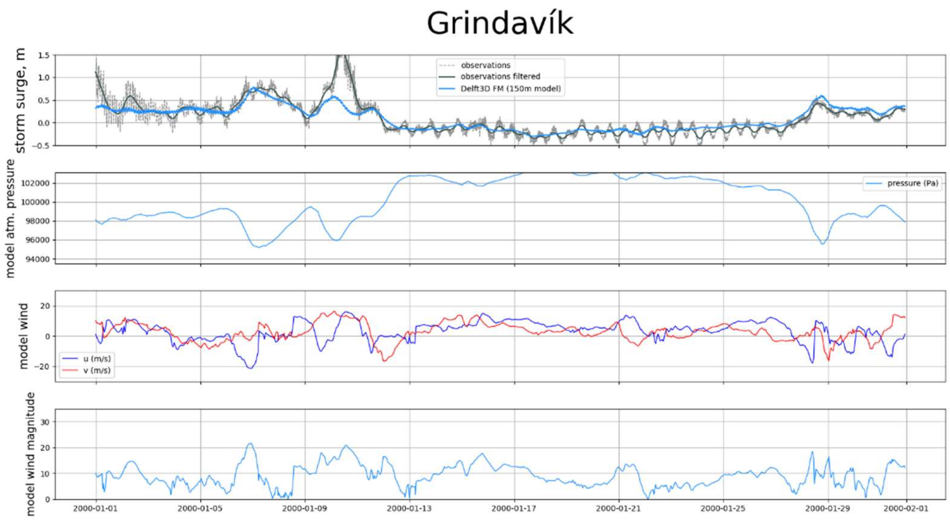
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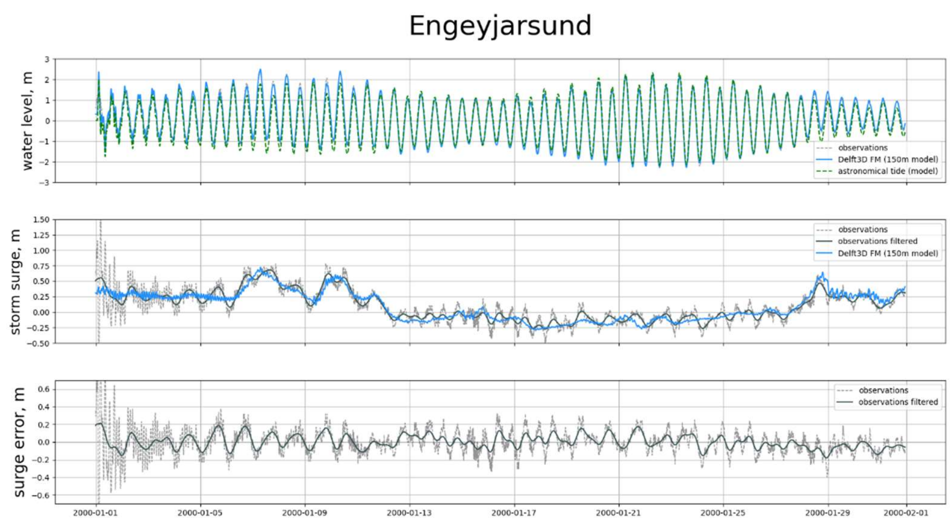
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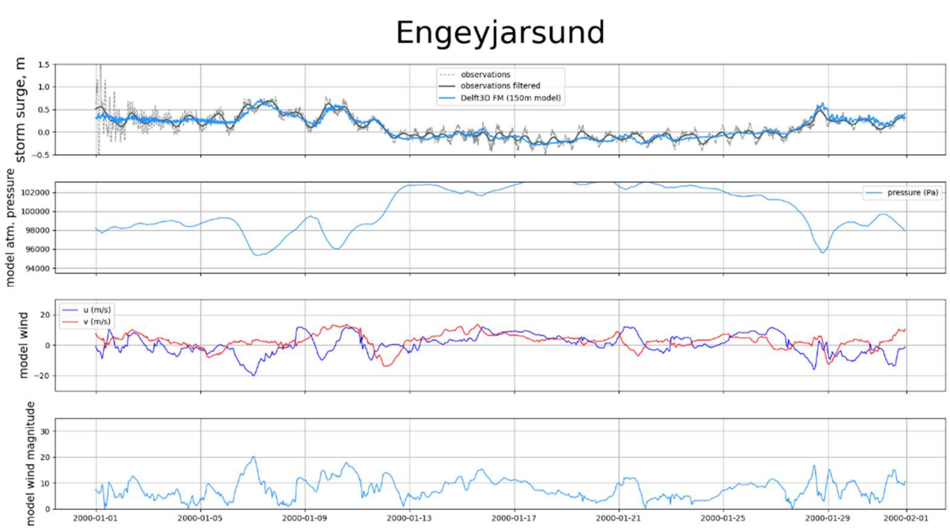
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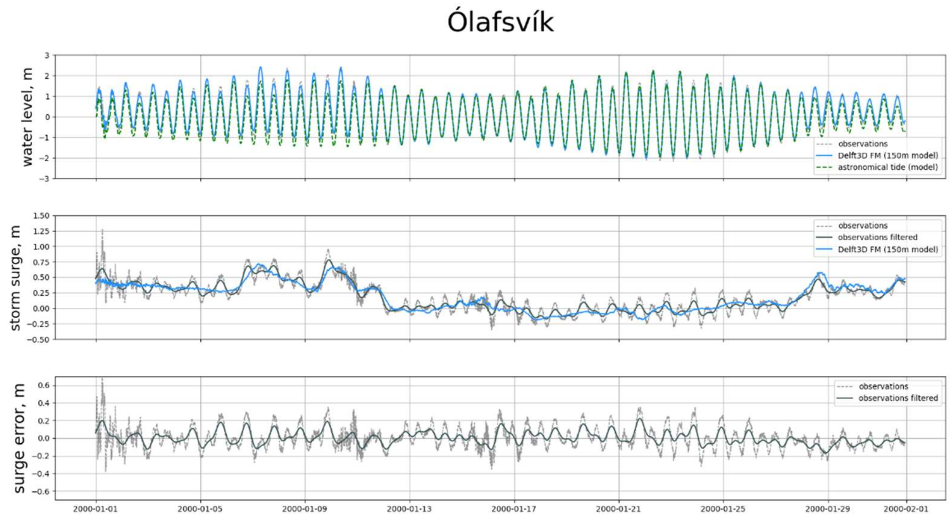


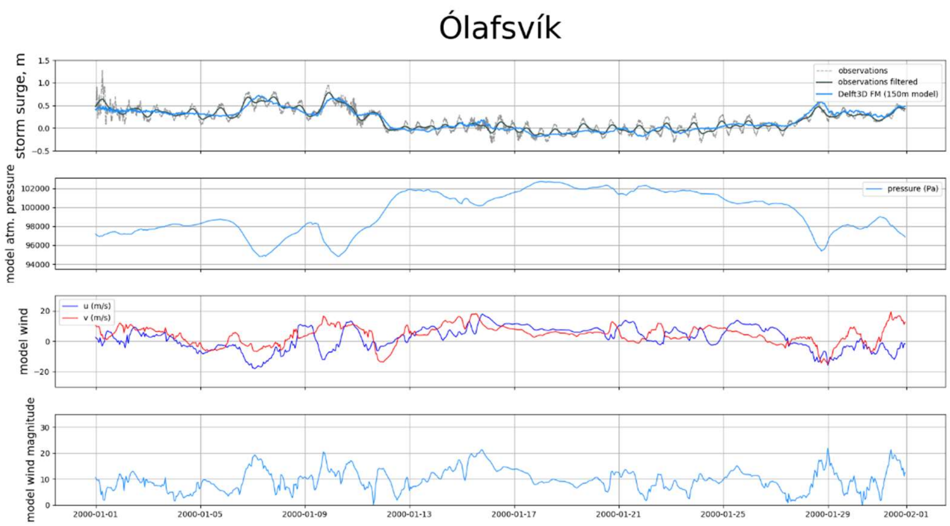


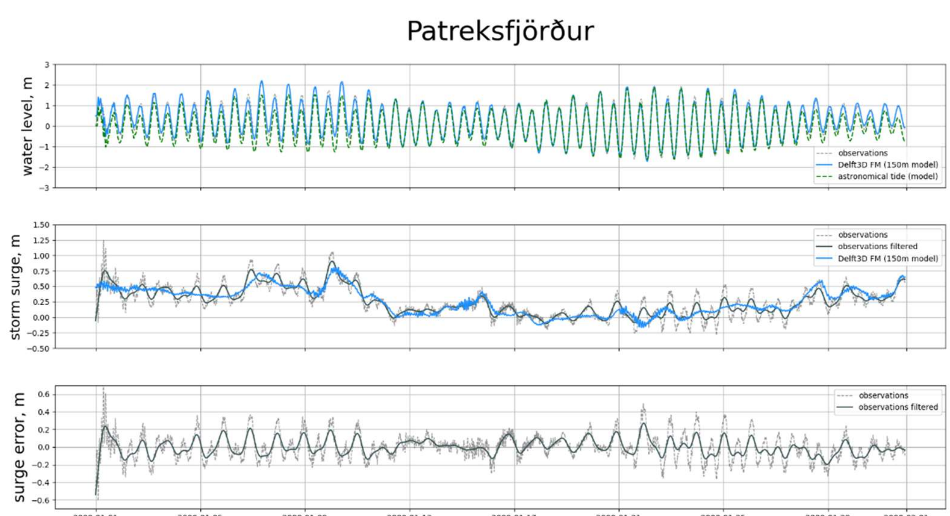

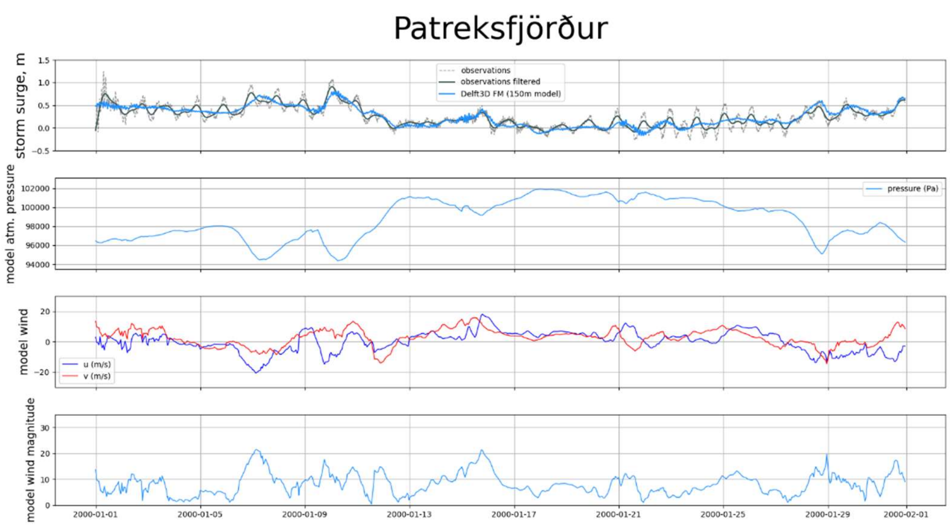
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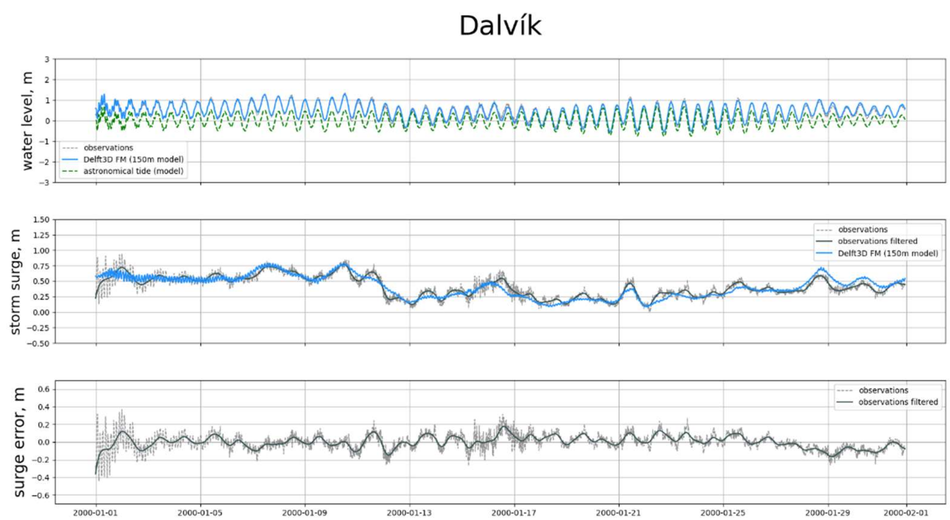
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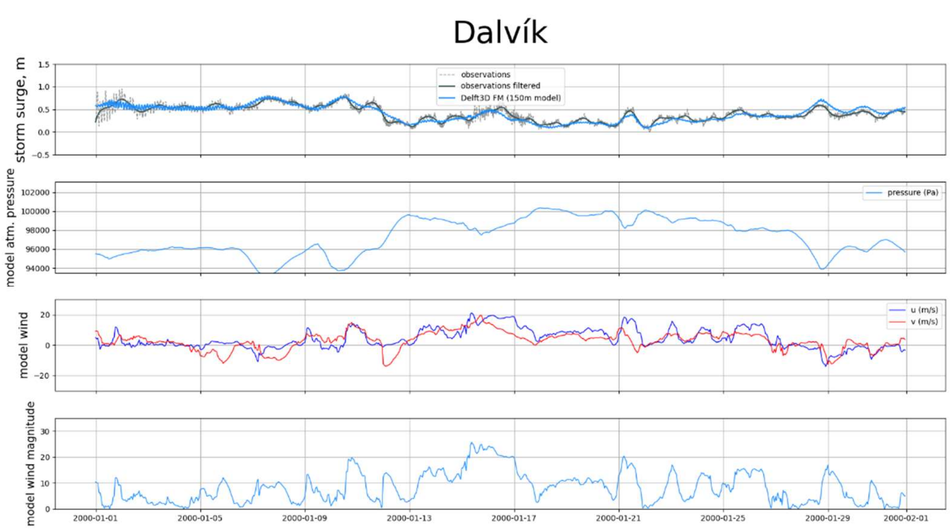
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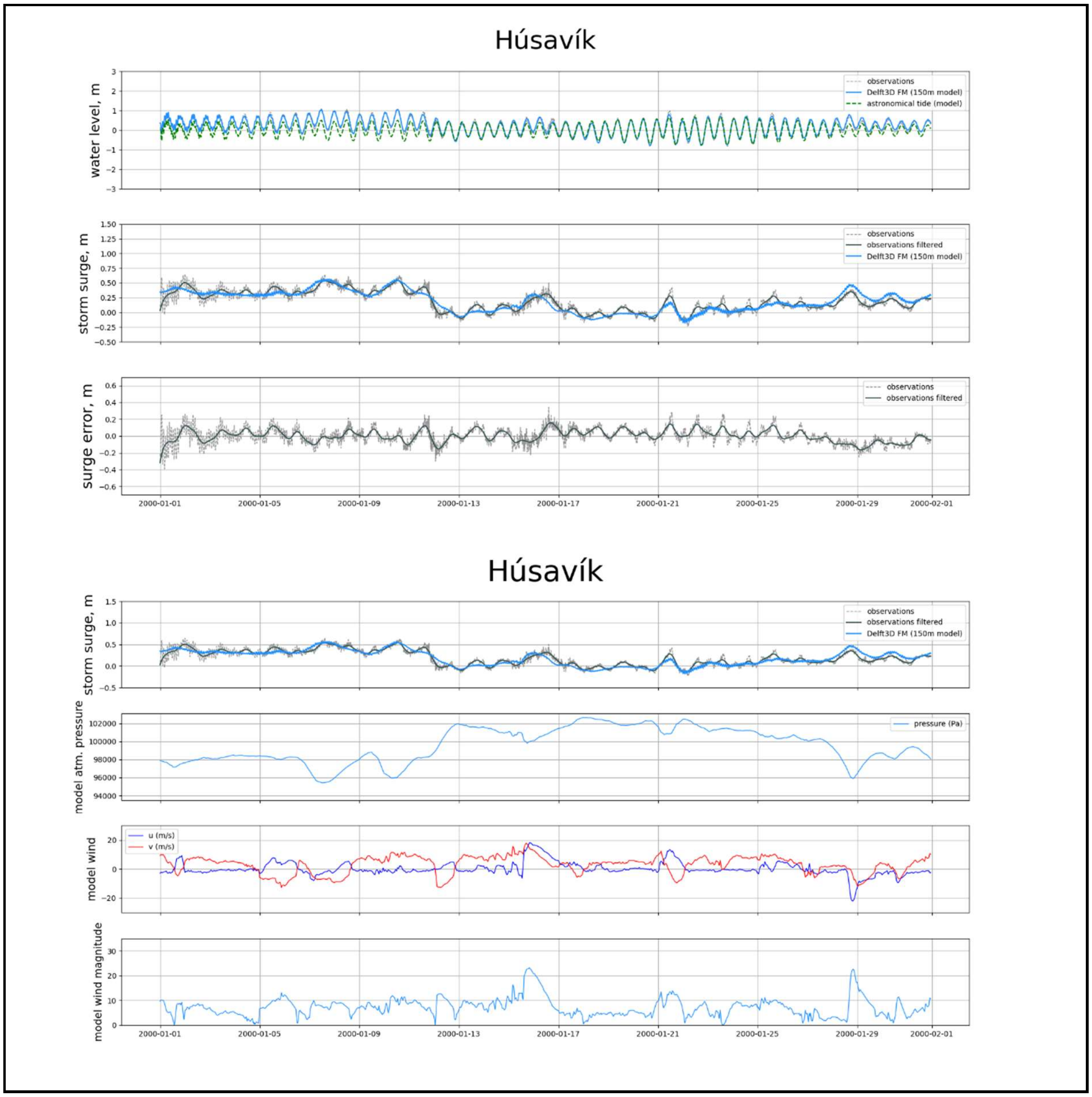
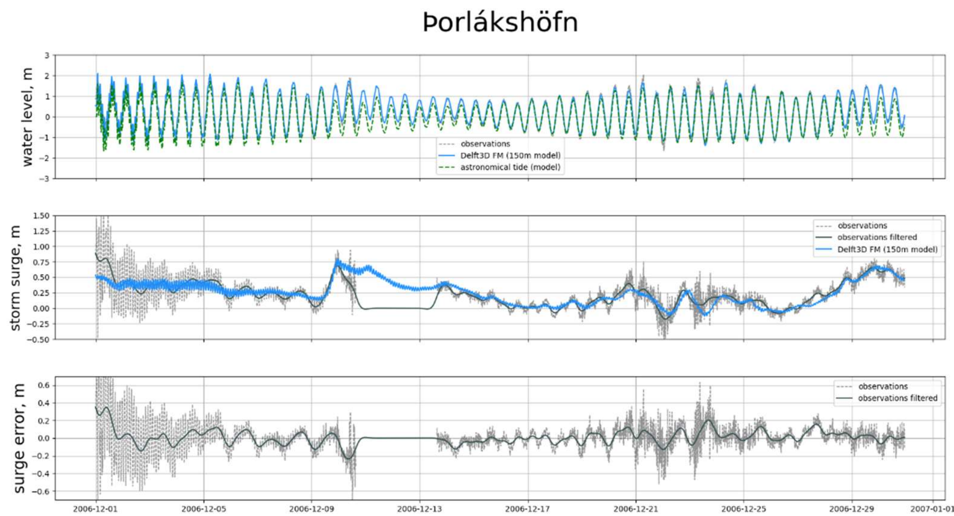



**Figure 3**. Storm surge: observations and numerical model estimates for **January 2000.**

**December 2006**

The third set shown in Figure 4 corresponds to the storm in December 2006 comparing 7 stations. Despite the missing observation data, we can see a similar phenomenon in Grindavik as the one discussed above for January 2000 with two high peaks in the water level. We also highlight issues with the simulation of water level in Patreksfjordur, although here model-observation discrepancy may also be affected by issues with the atmospheric data. Other than that, the model reproduces well the water level and storm surge at each station.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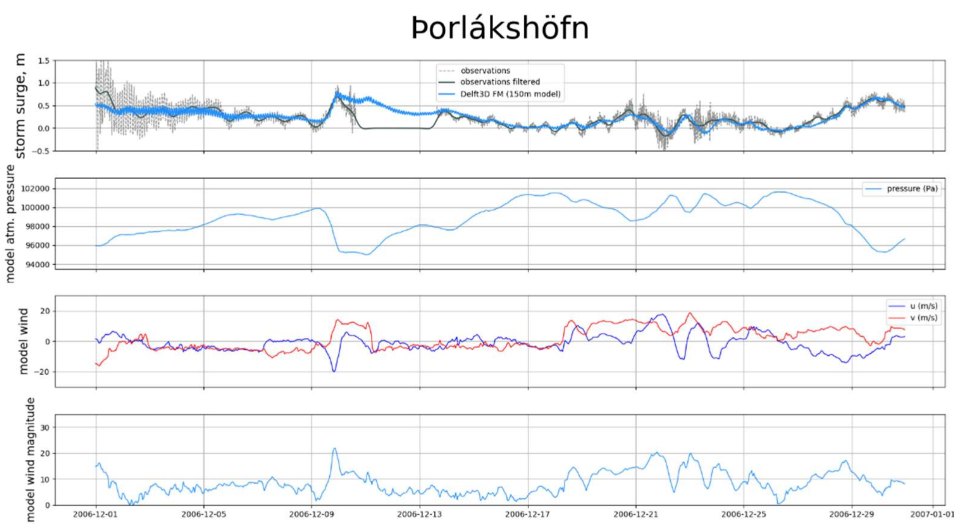
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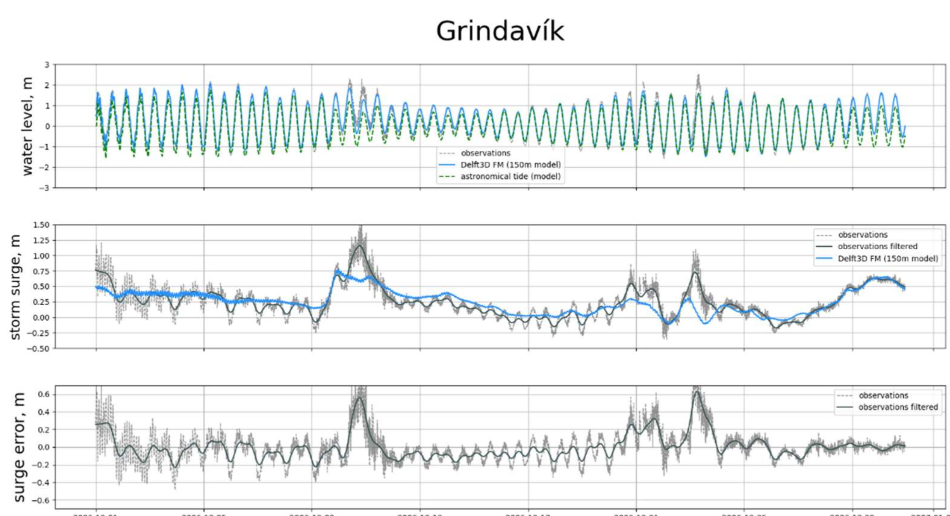
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surge error, m
observations
observations filtered
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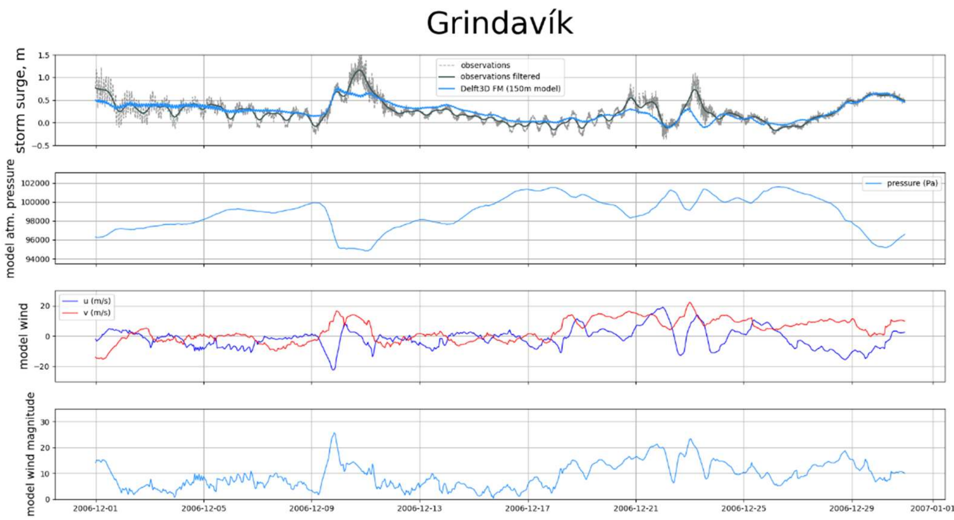
2007-01-01


Grindavík
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observations
observations filtered
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model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
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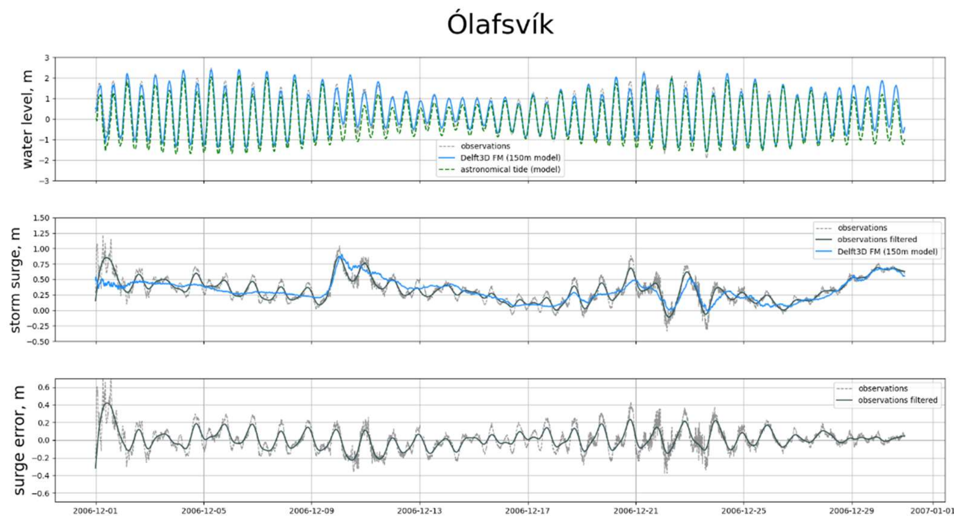
Ólafsvík
water level, m
observations
Delft3D FM (150m model)
astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
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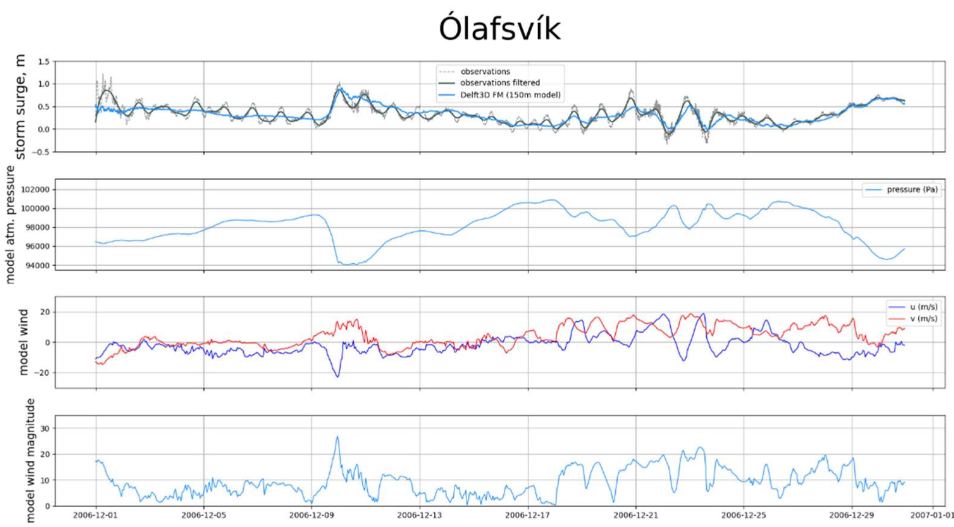
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observations
observations filtered
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model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
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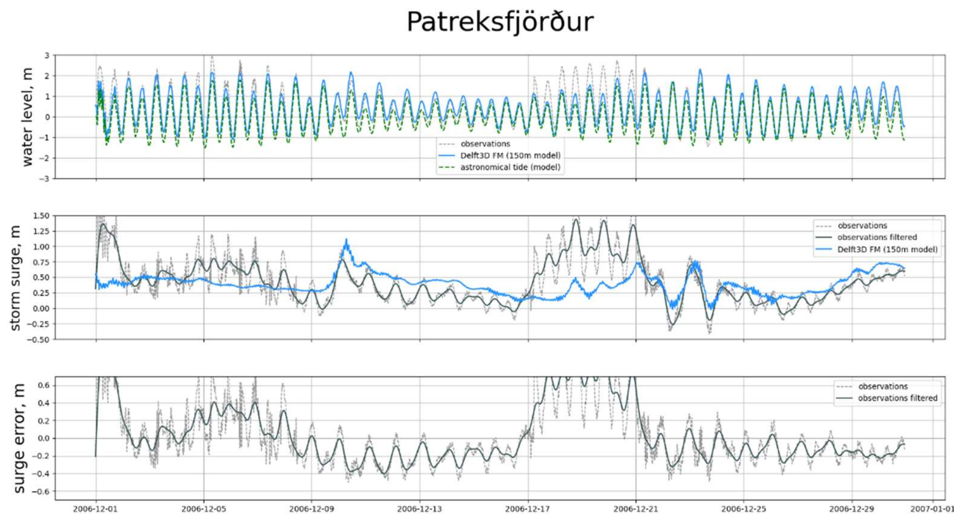
2007-01-01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astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
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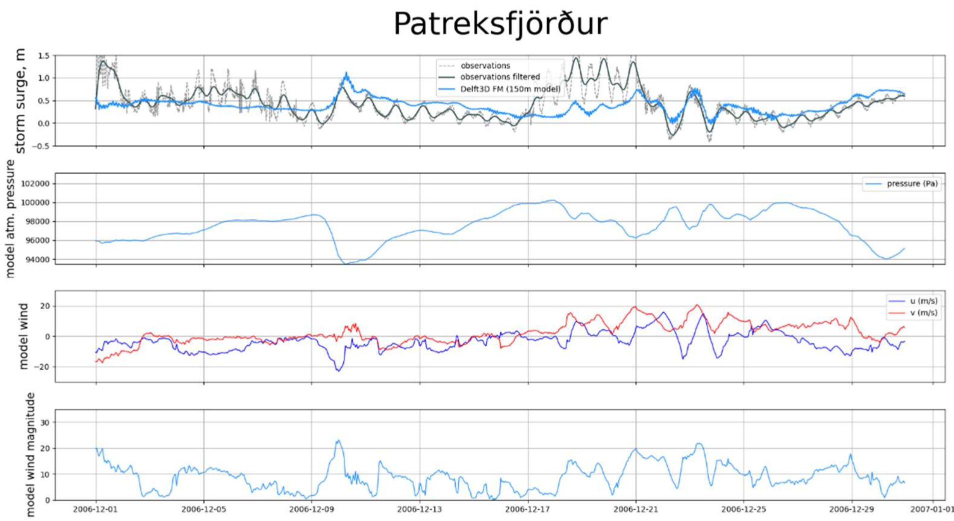
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observations
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model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
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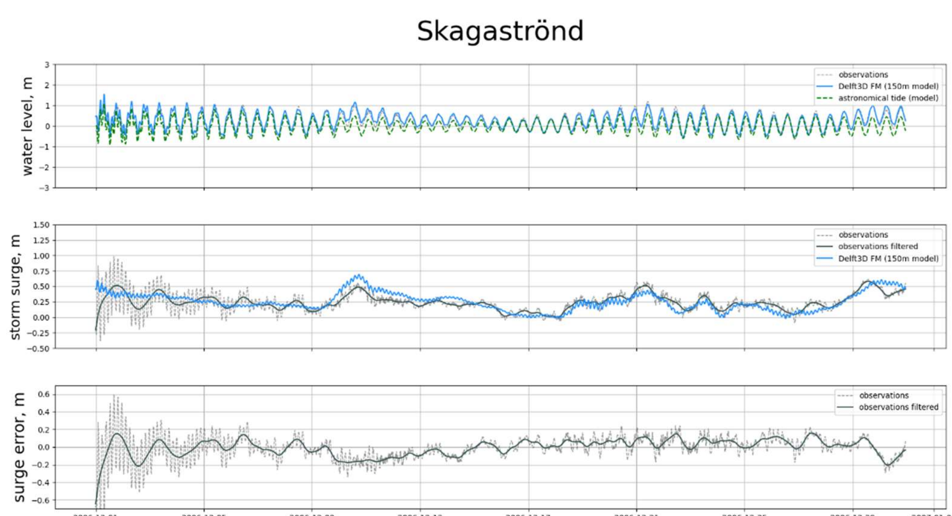
2007-01-01


Skagaströnd
water level, m
observations
Delft3D FM (150m model)
astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
2006-12-01
2006-12-05
2006-12-09
2006-12-13
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2006-12-25
2006-12-29
2007-01-01

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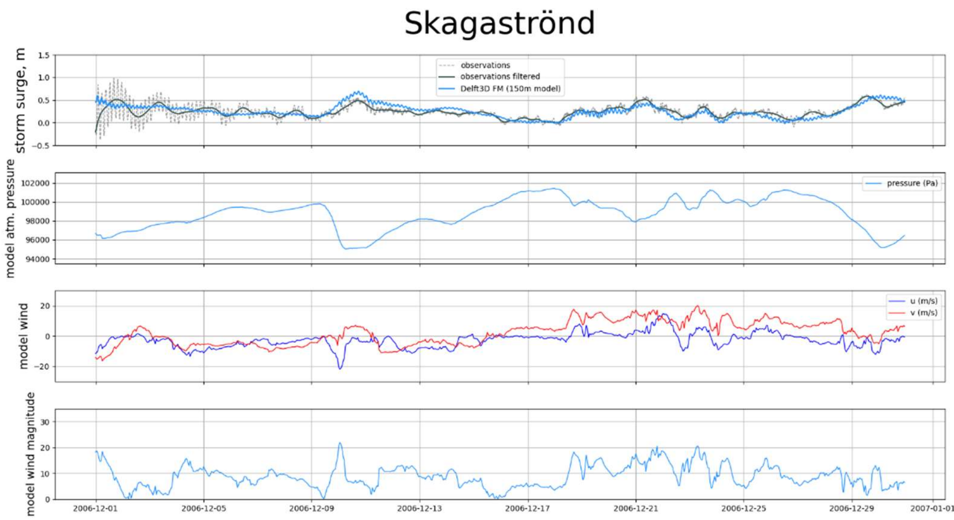


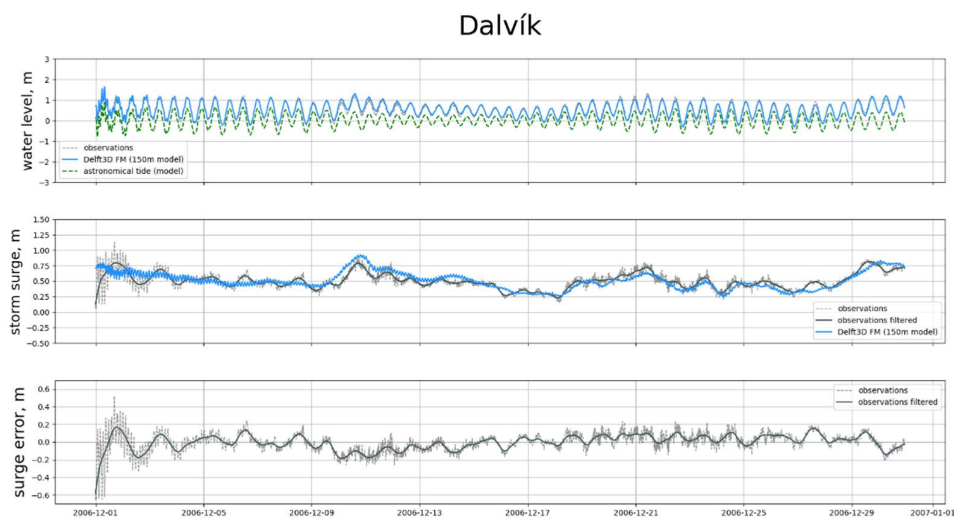


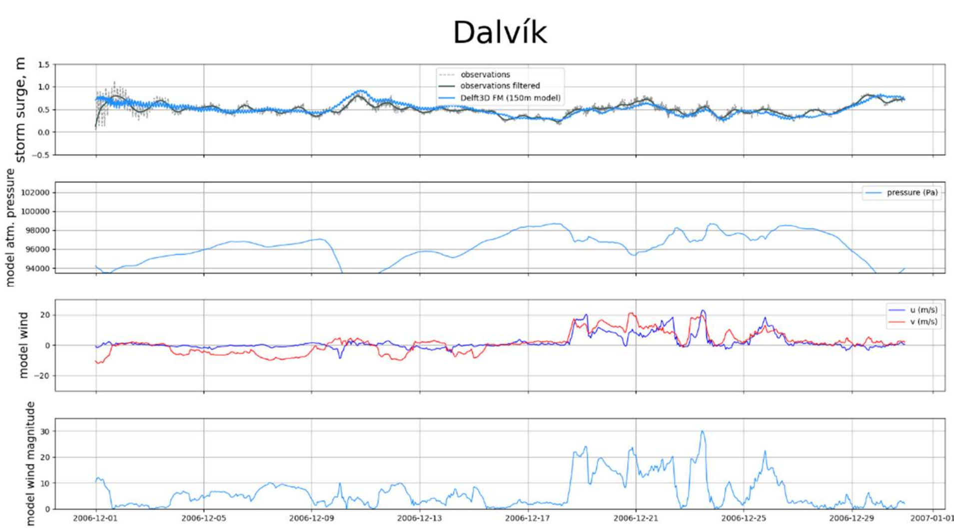

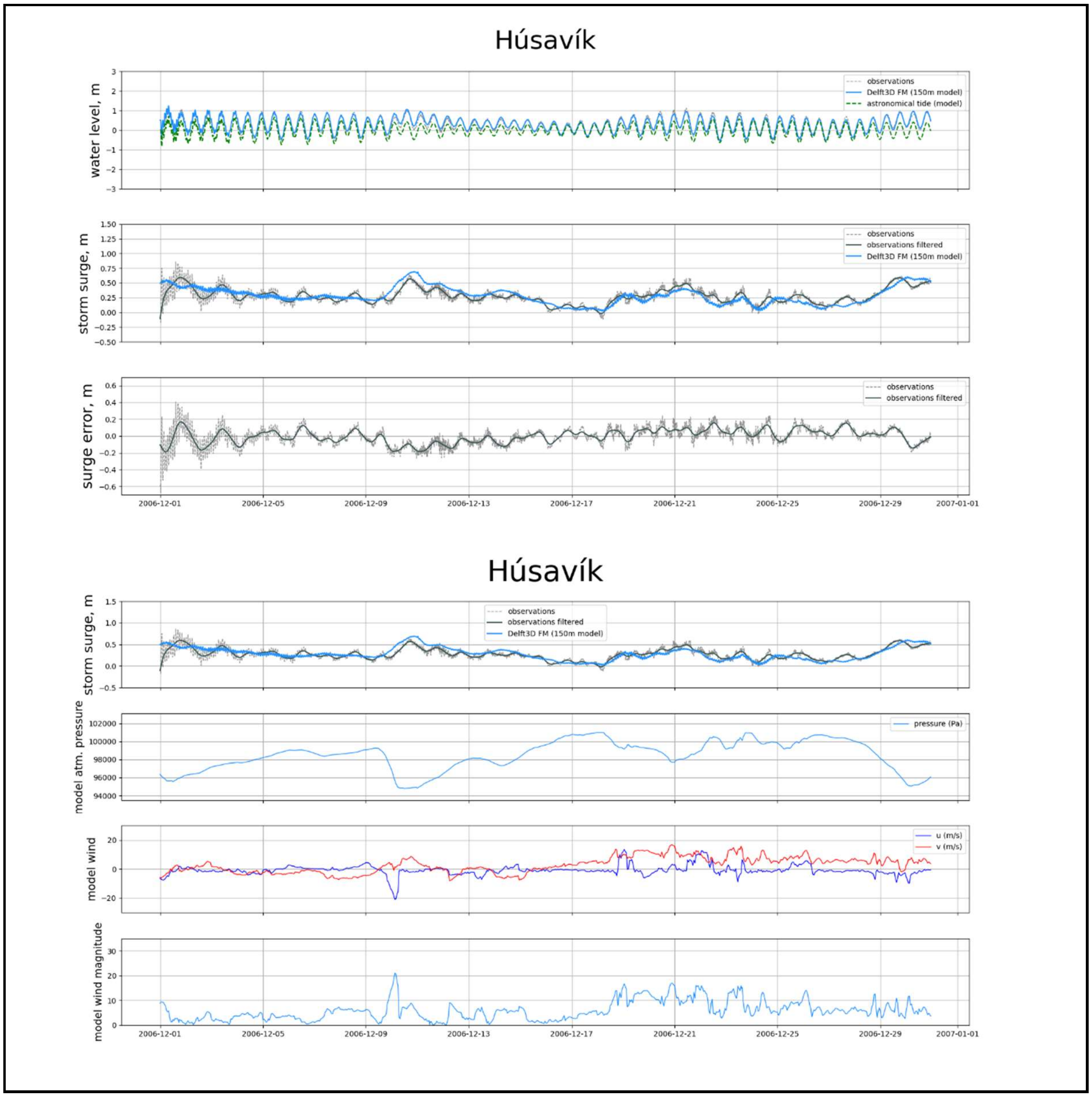


**Figure 4.** Storm surge: observations and numerical model estimates for **December 2006.**

**October 2008**

The fourth set shown in the Figure 5 corresponds to the storm in October 2008 comparing 8 stations. We can see that, as previously, some measurements are missing data as in þorlakshöfn where it becomes impossible to make a meaningful model-observations comparison. We can also highlight, here again, the high peak of water level in Grindavik which the model cannot reproduce properly as explained above for January 2000.

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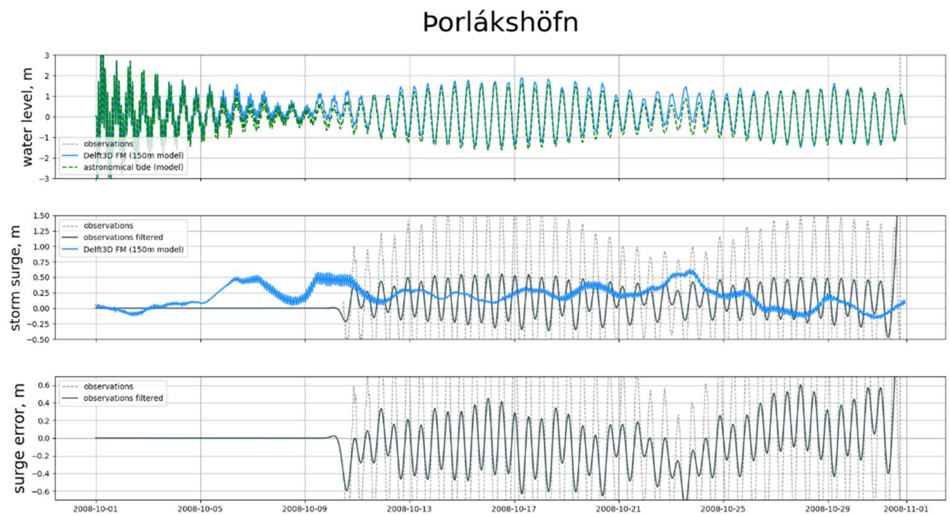


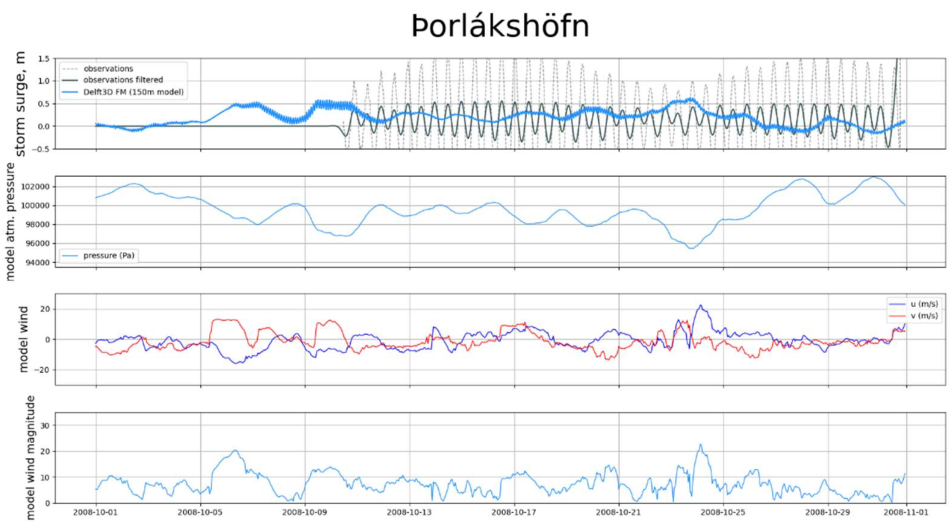


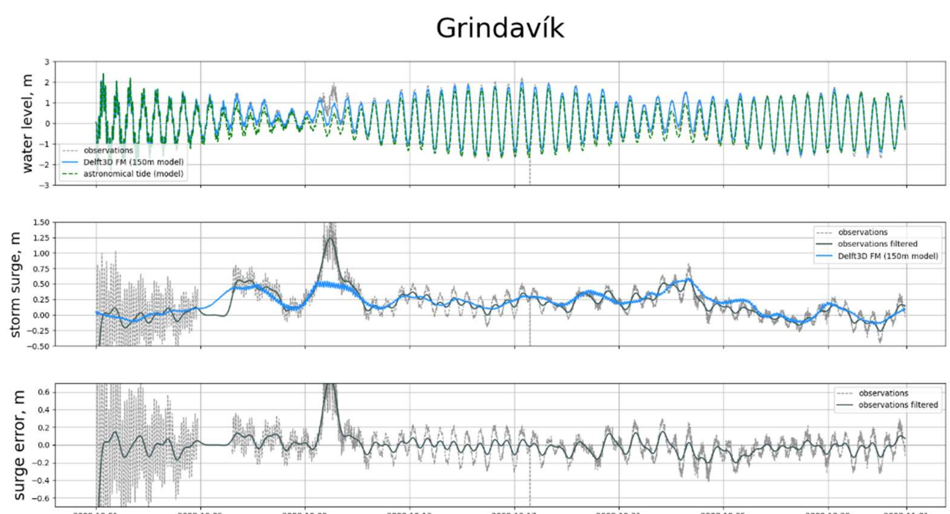

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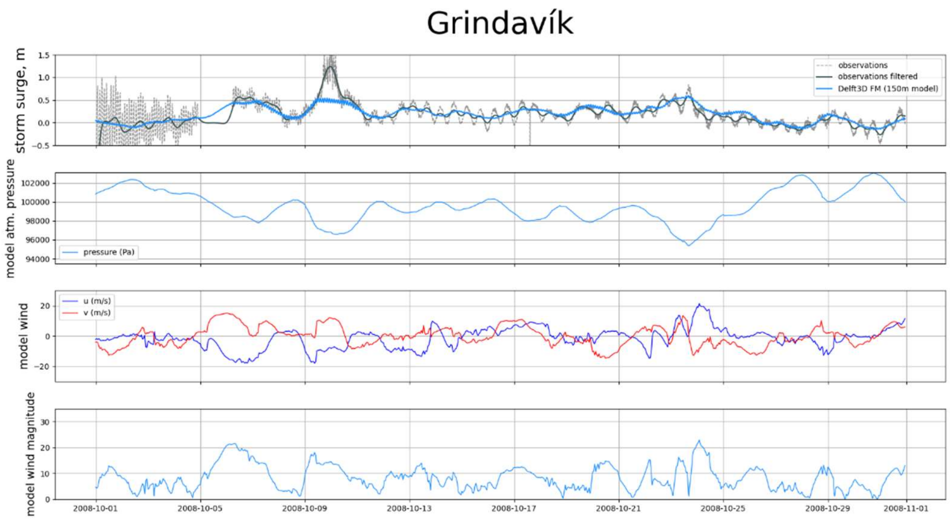


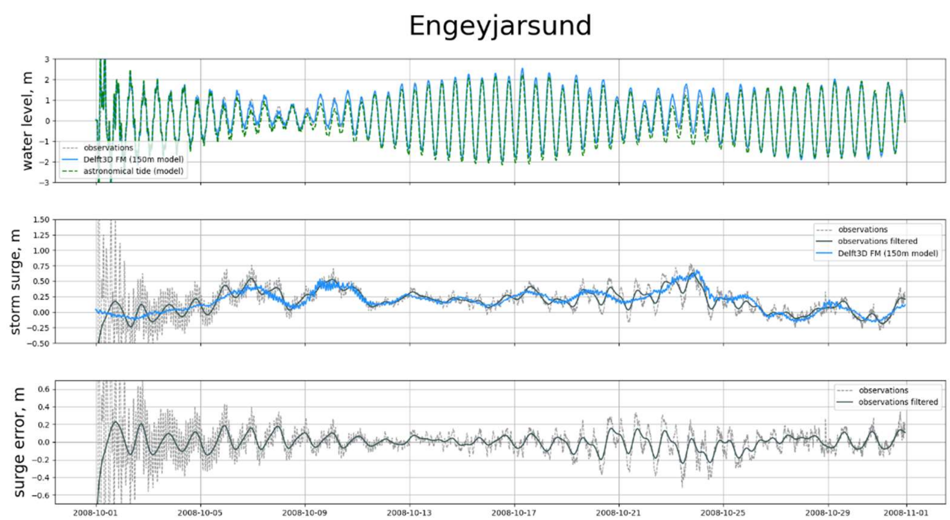


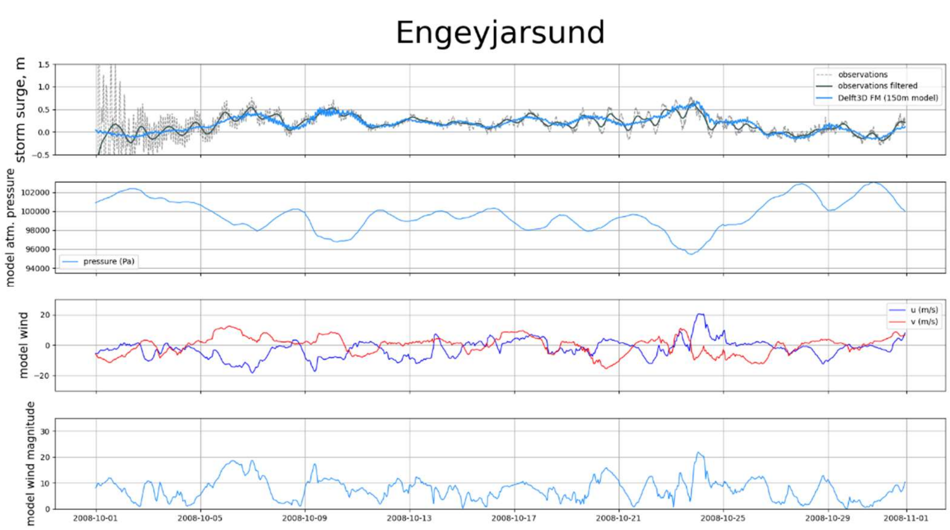

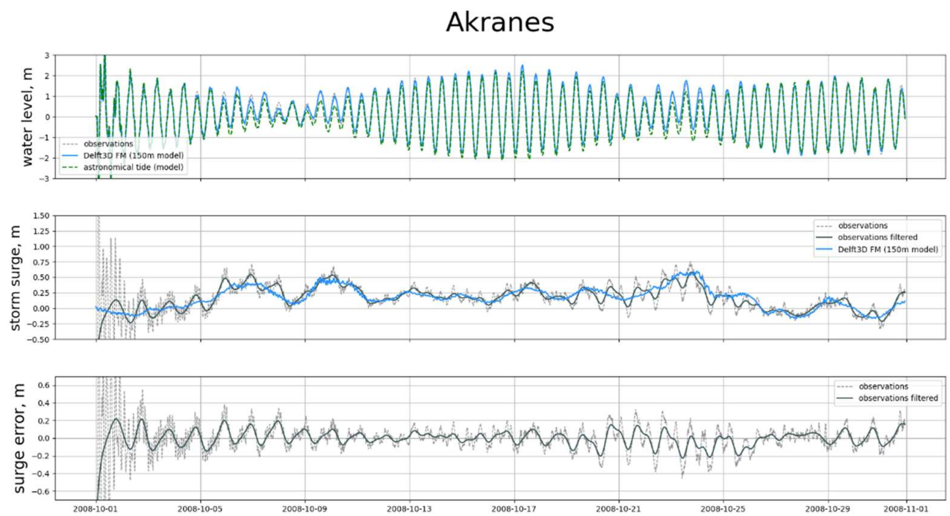
Akranes
water level, m
observations
Delft3D FM (150m model)
astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
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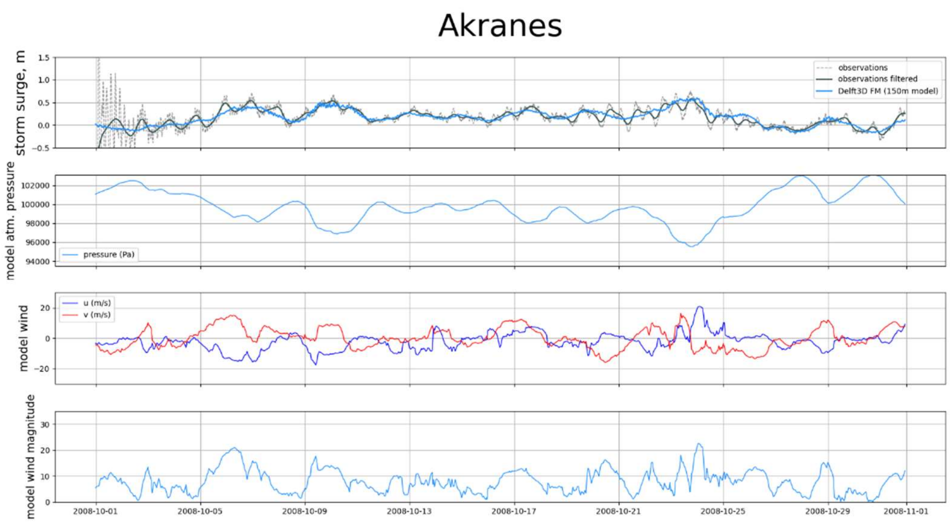
2008-10-05
2008-10-09
2008-10-13
2008-10-17
2008-10-21
2008-10-25
2008-10-29
2008-11-01


Akranes
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
2008-10-01
2008-10-05
2008-10-09
2008-10-13
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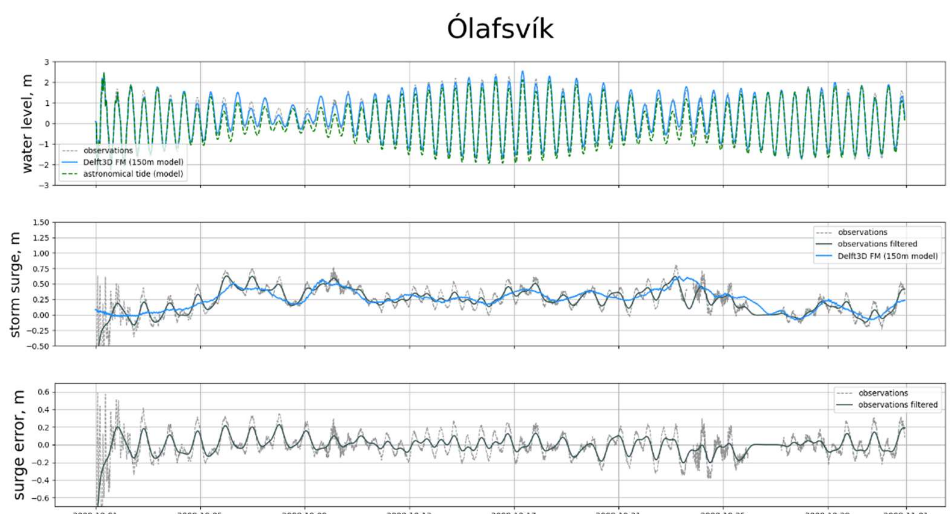
2008-11-01


Ólafsvík
water level, m
observations
Delft3D FM (150m model)
astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
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2008-10-05
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2008-10-13
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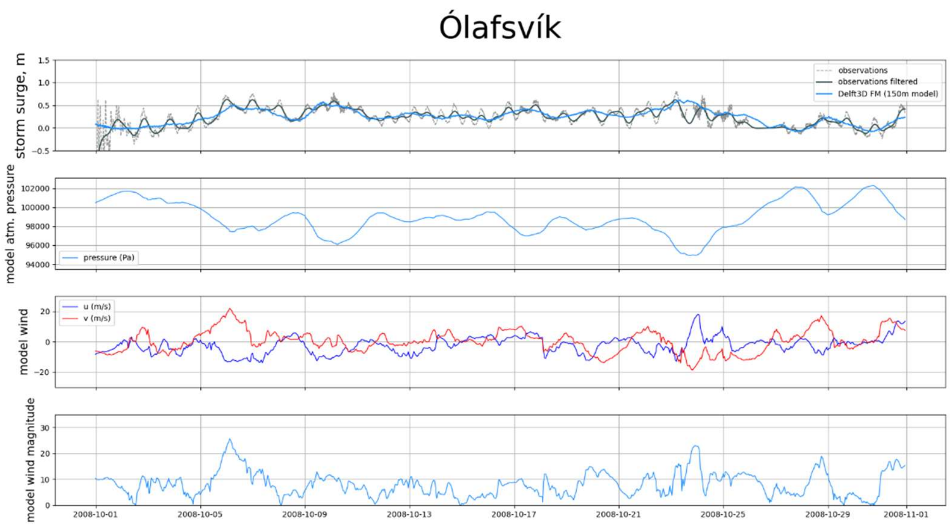
2008-11-01


Ólafsvík
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
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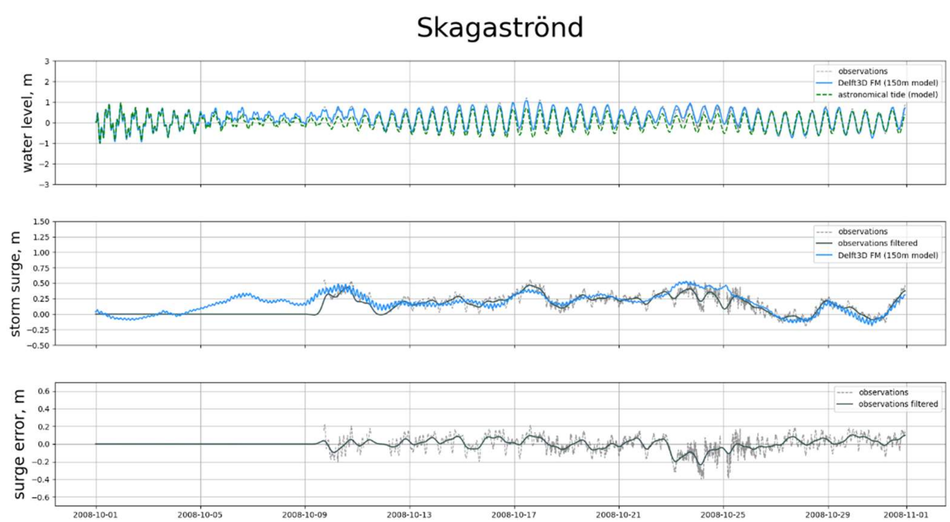
2008-11-01


Skagaströnd
water level, m
observations
Delft3D FM (150m model)
astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
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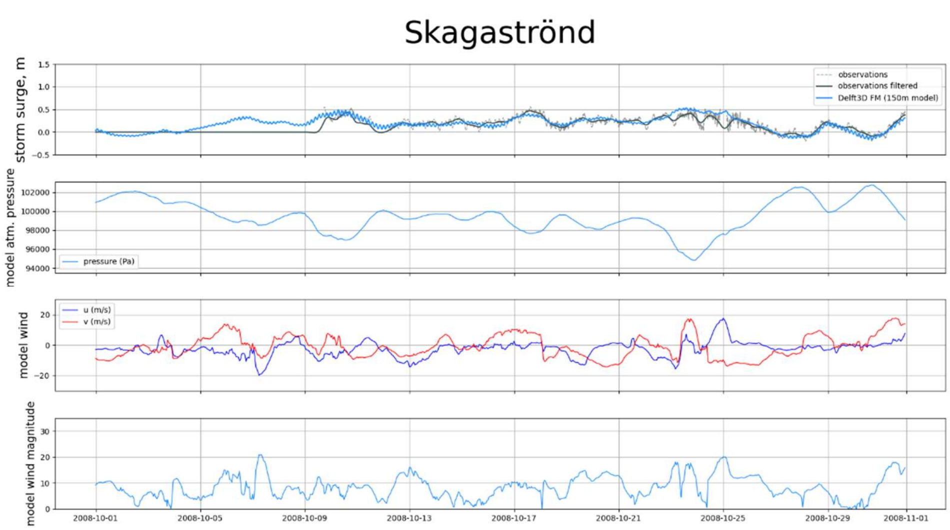
2008-11-01


Skagaströnd
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
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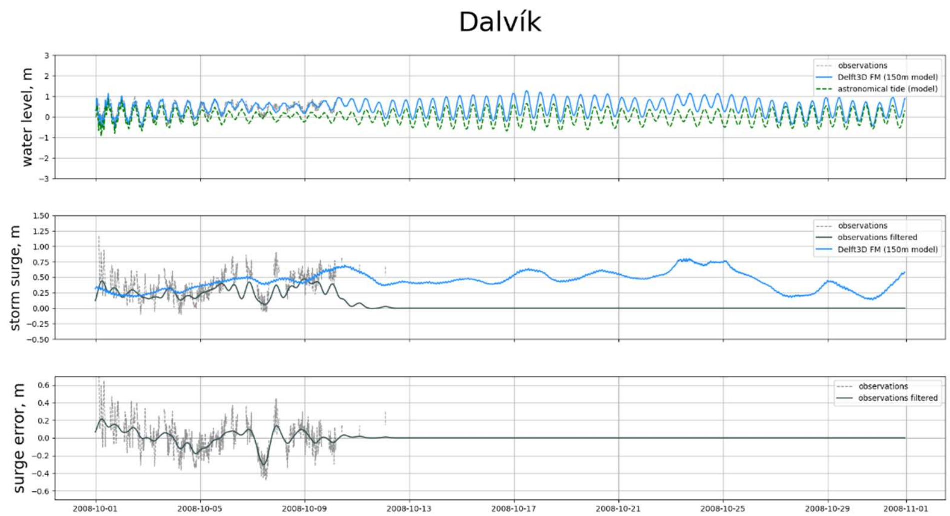
2008-11-01


Dalvík
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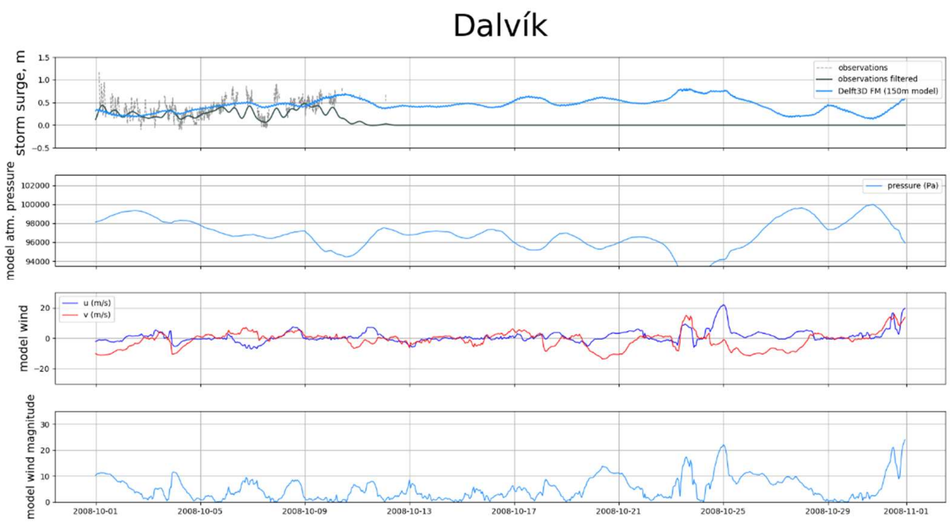
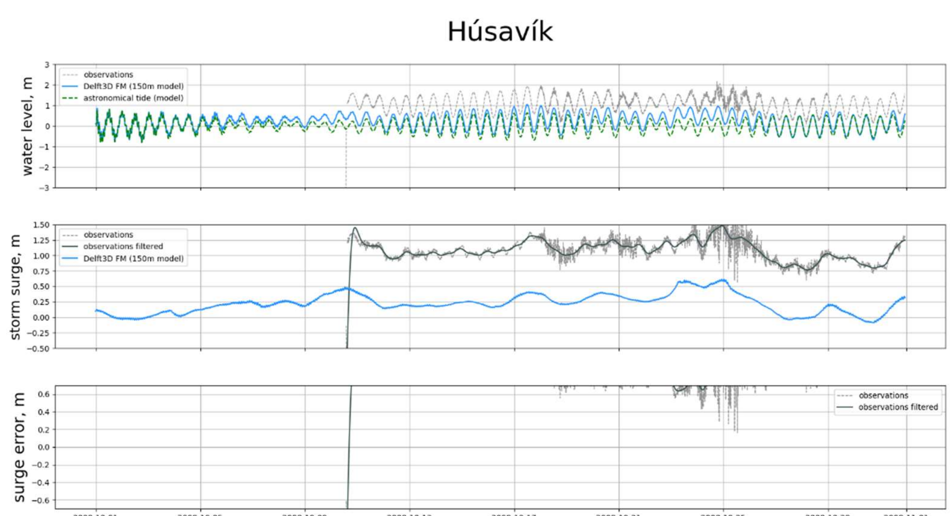
storm surge, m
surge error, m
observations
Delft3D FM (150m model)
astronomical tide (model)
observations filtered


Dalvík
storm surge, m
model atm. pressure
model wind
model wind magnitude
observations
observations filtered
Delft3D FM (150m model)
pressure (Pa)
u (m/s)
v (m/s)


Húsavík
water level, m
storm surge, m
surge error, m
observations
Delft3D FM (150m model)
astronomical tide (model)
observations filtered

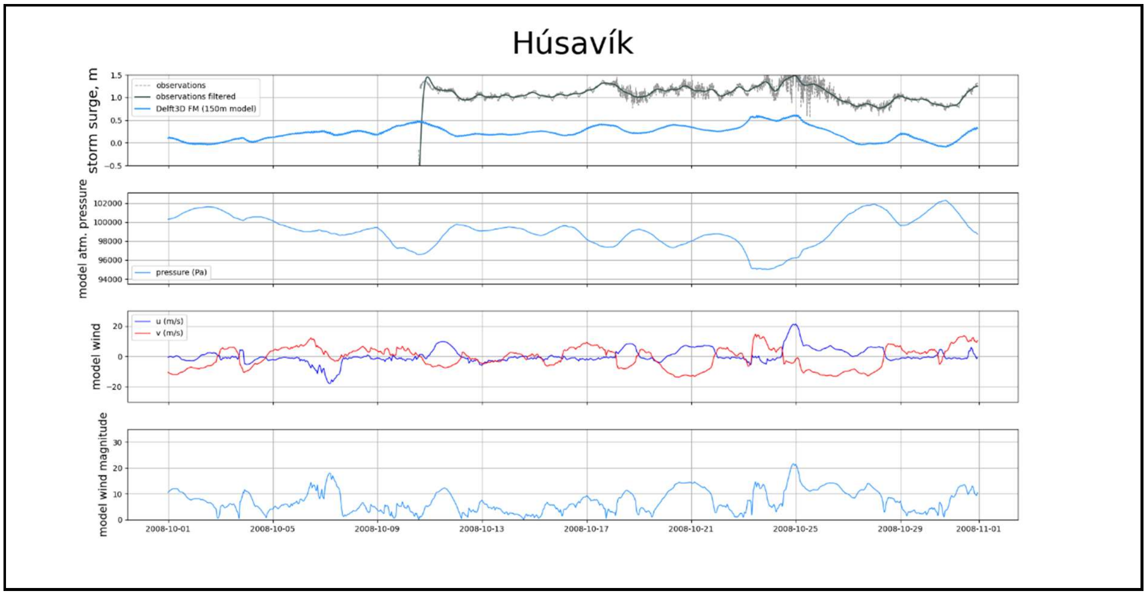



**Figure 5.** Storm surge: observations and numerical model estimates for **October 2008.**

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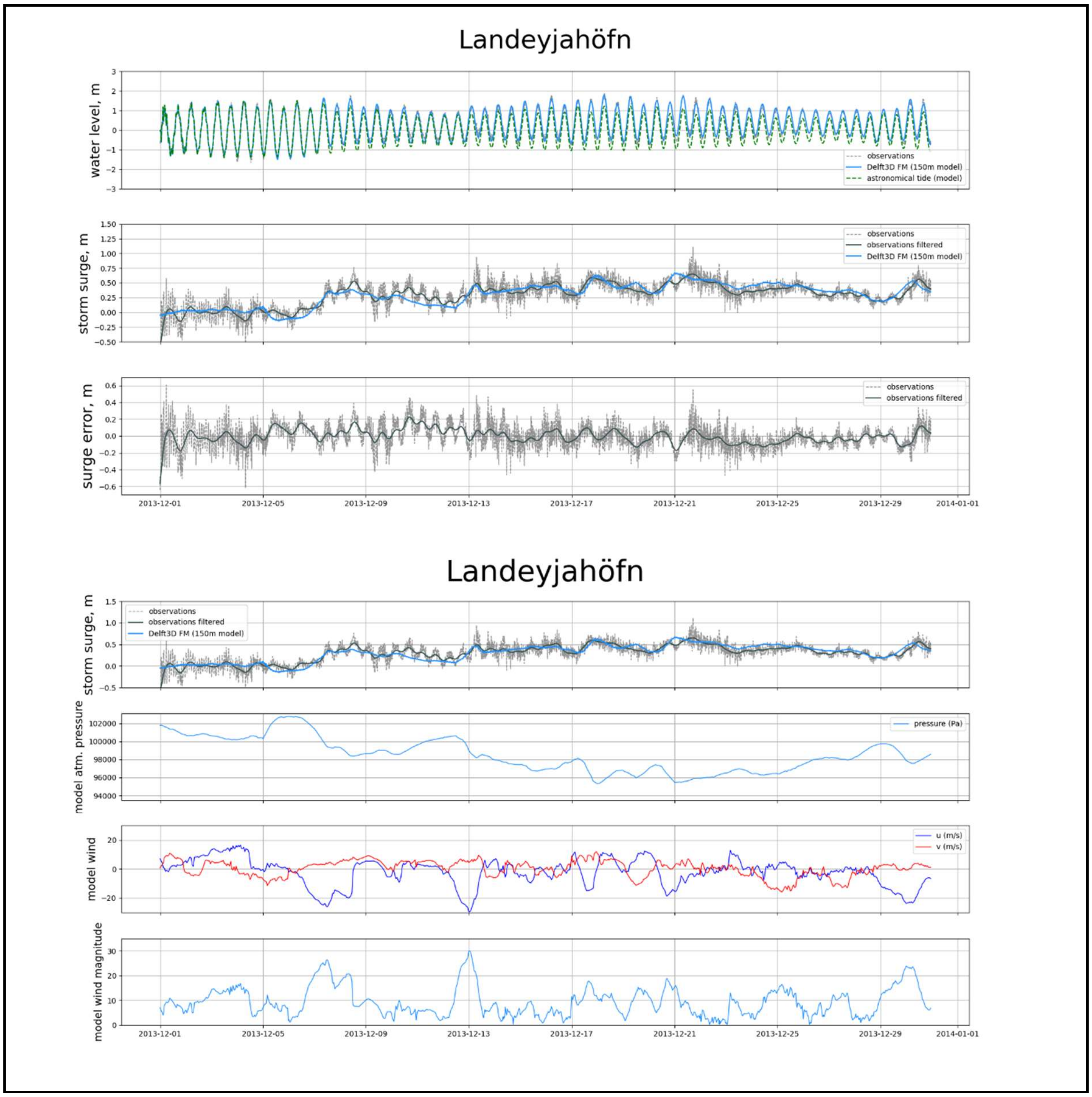
**December 2013**

The fifth set shown in the Figure 5 corresponds to the storm in December 2013 comparing 11 stations. We can see that, as previously, some measurements are missing data and have most likely errors as in Akranes too which makes it more difficult to analyze. However, we can see that for the other stations, the model is, here again, reproducing well the water level and storm surges.



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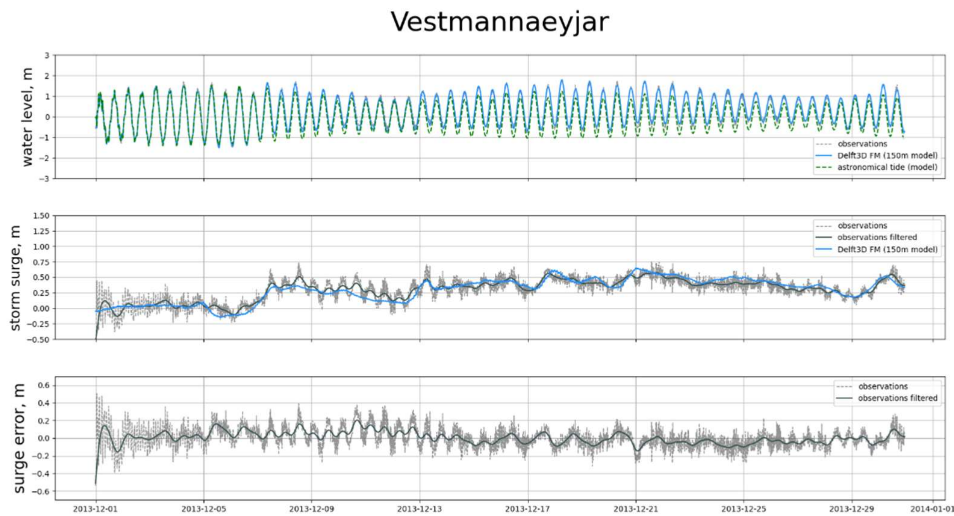
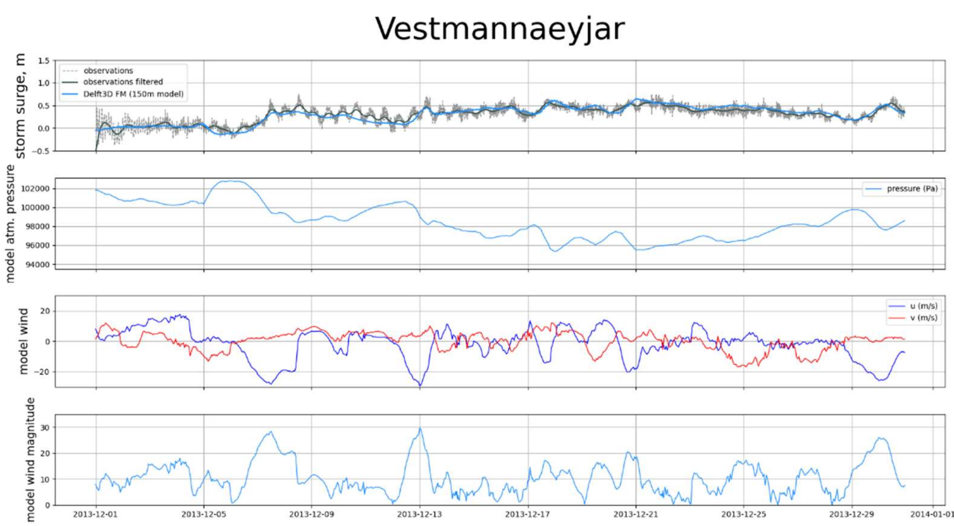
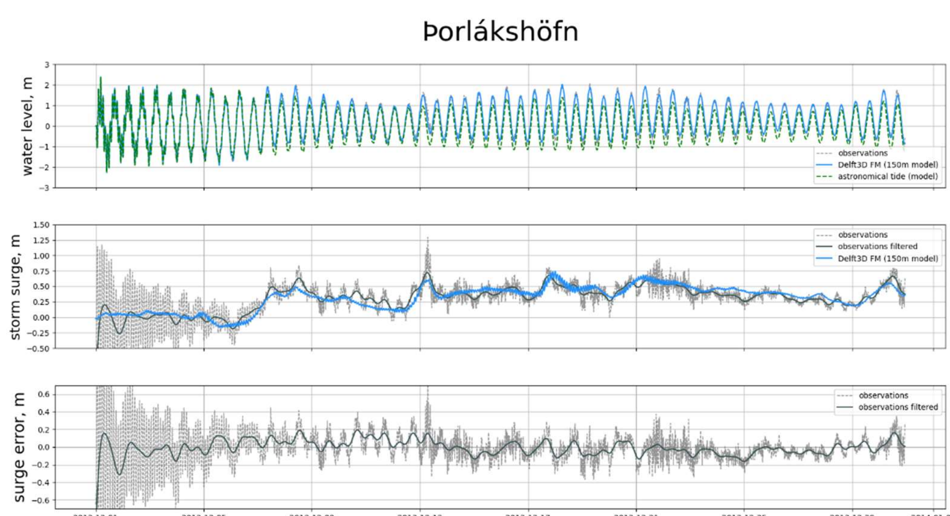
Veðurstofa Íslands



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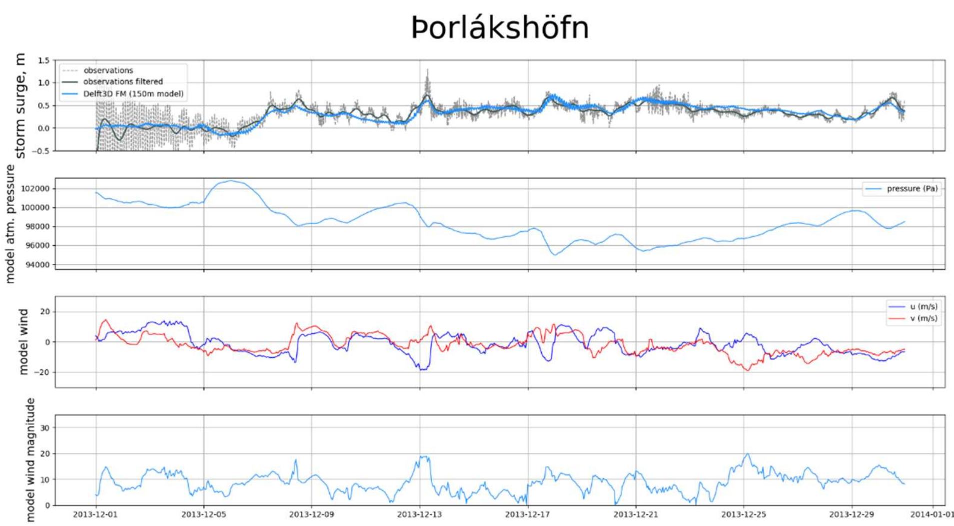


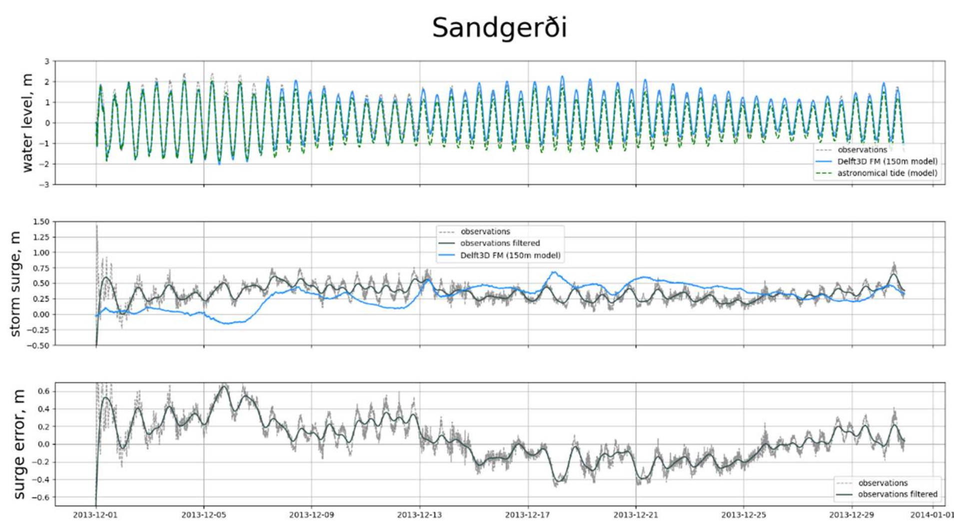


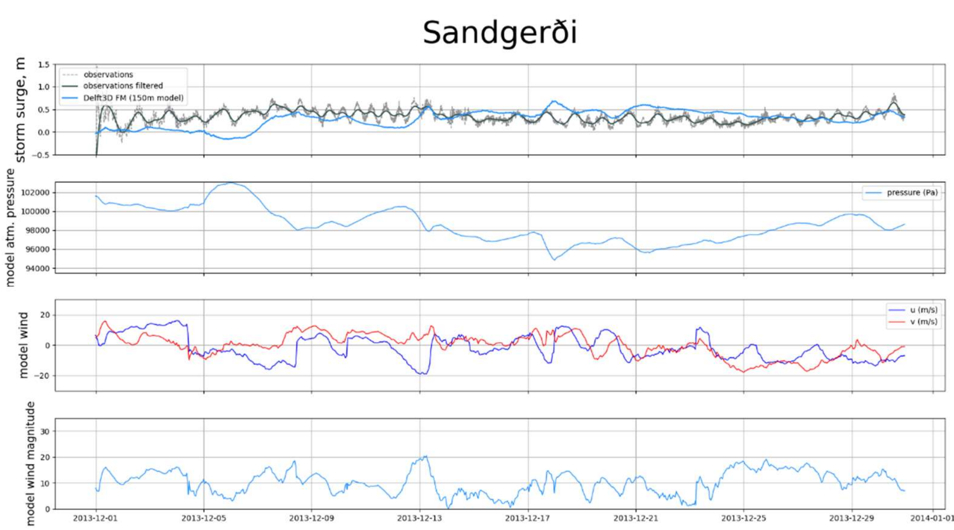

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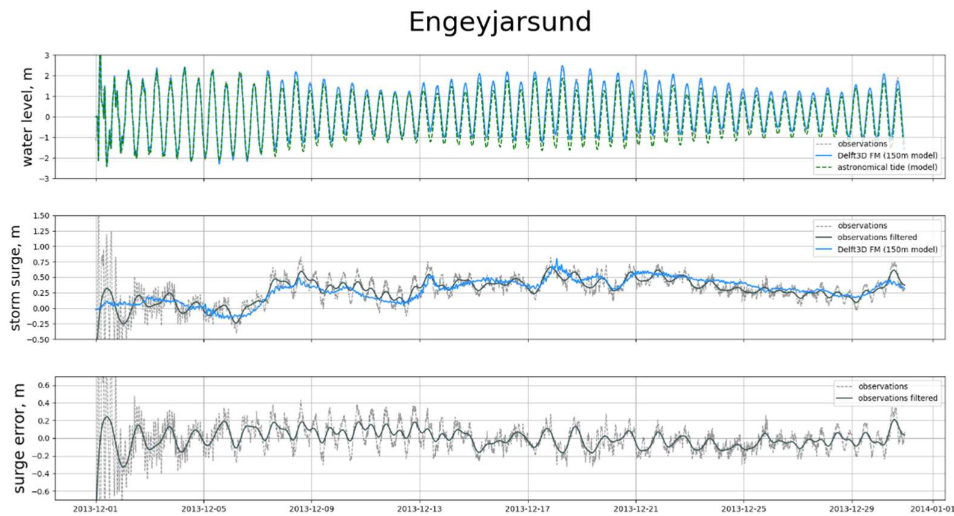


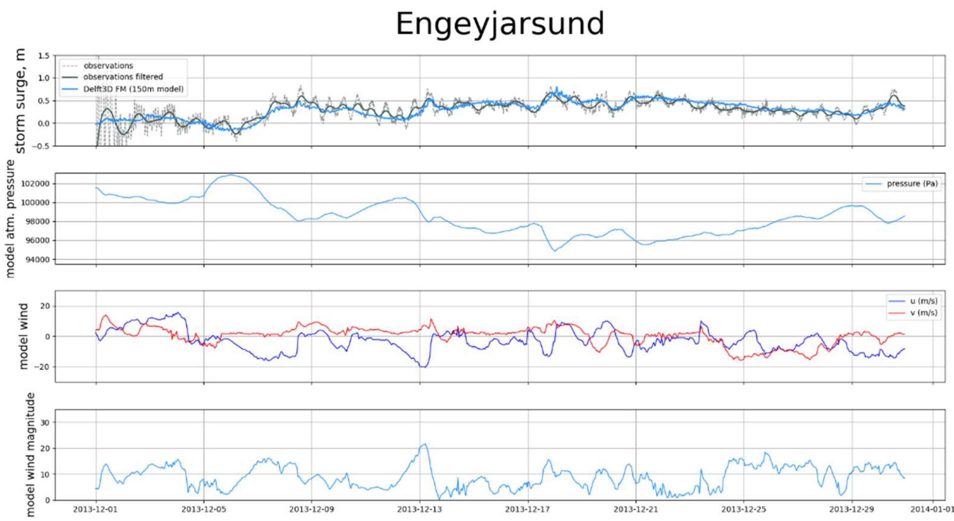


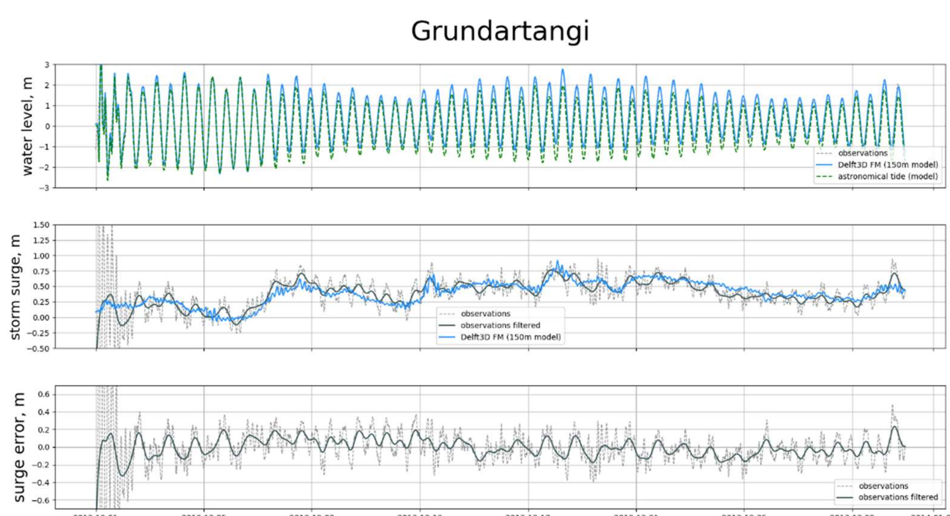

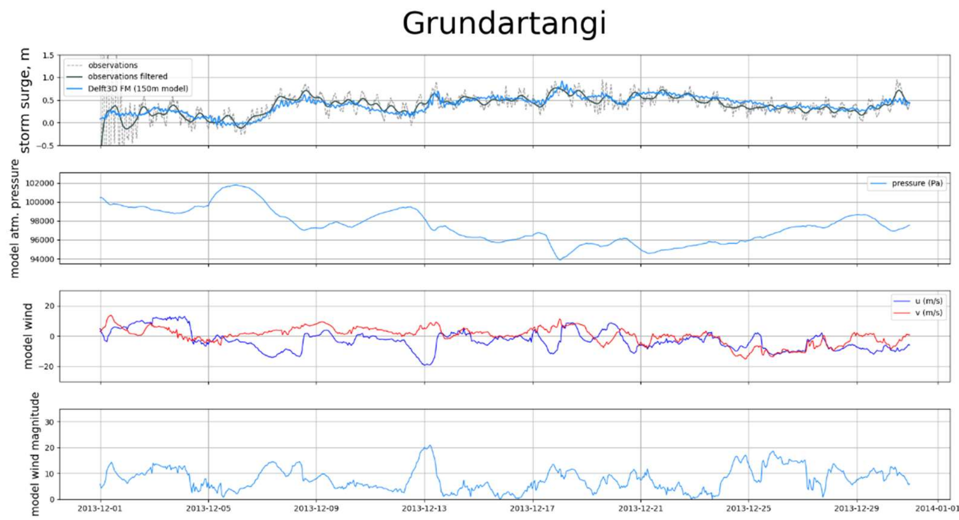
Grundartangi
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observations
observations filtered
Delft3D FM (150m model)
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pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
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2013-12-05
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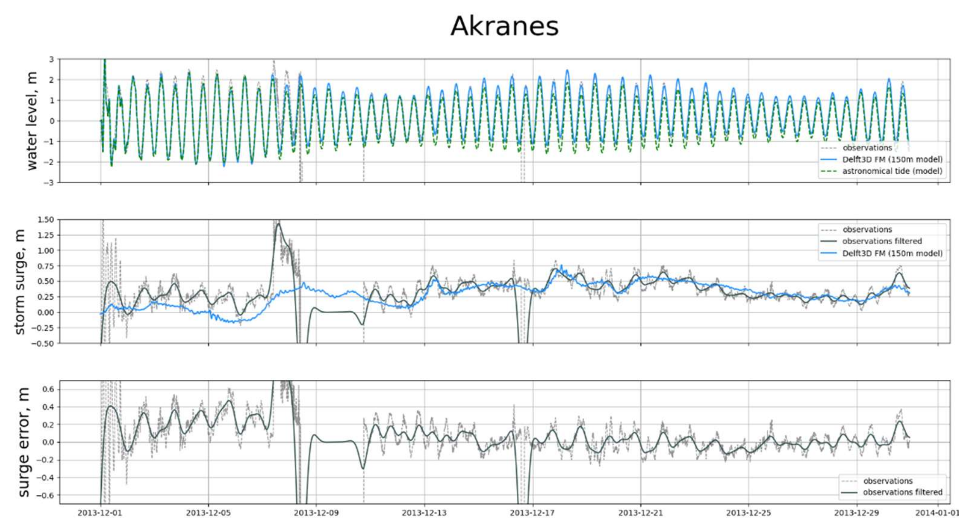
2014-01-01


Akranes
water level, m
observations
Delft3D FM (150m model)
astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
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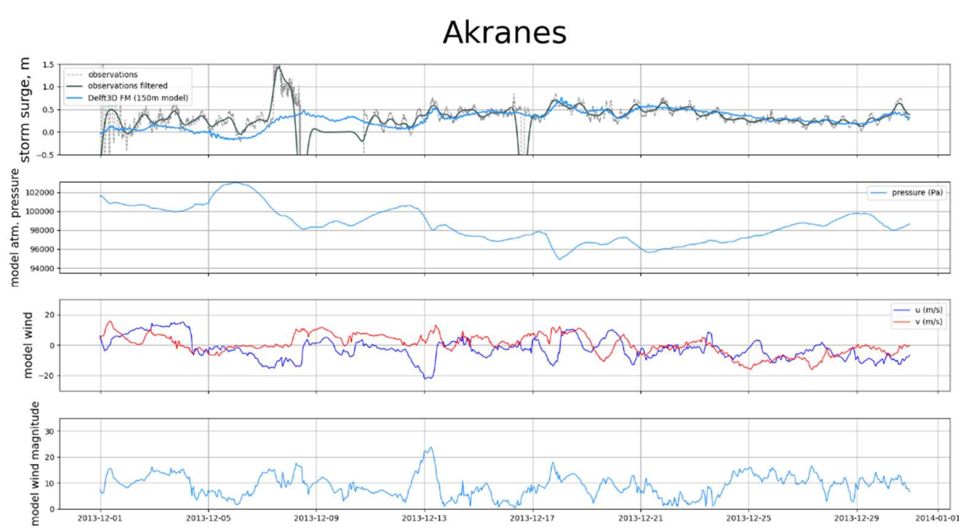
2014-01-01


Akranes
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
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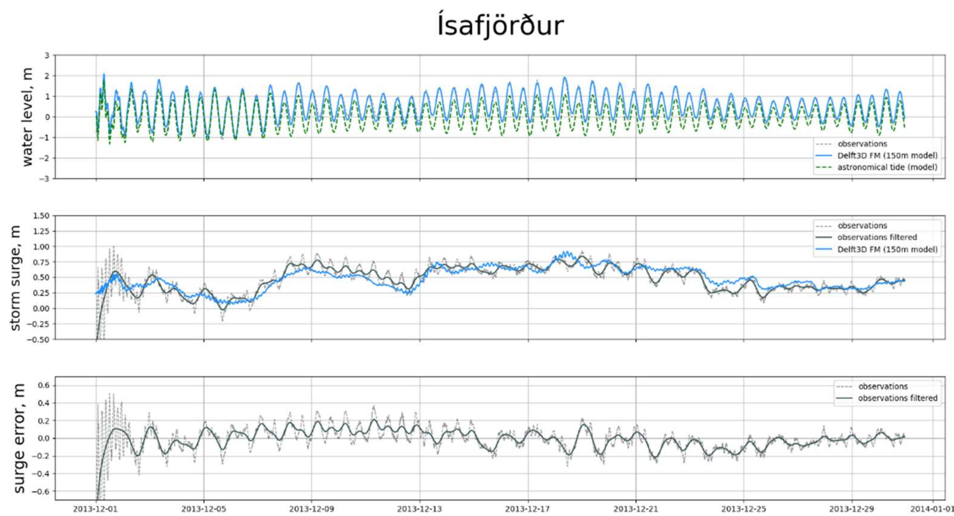
2014-01-01


Ísafjörður
water level, m
observations
Delft3D FM (150m model)
astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
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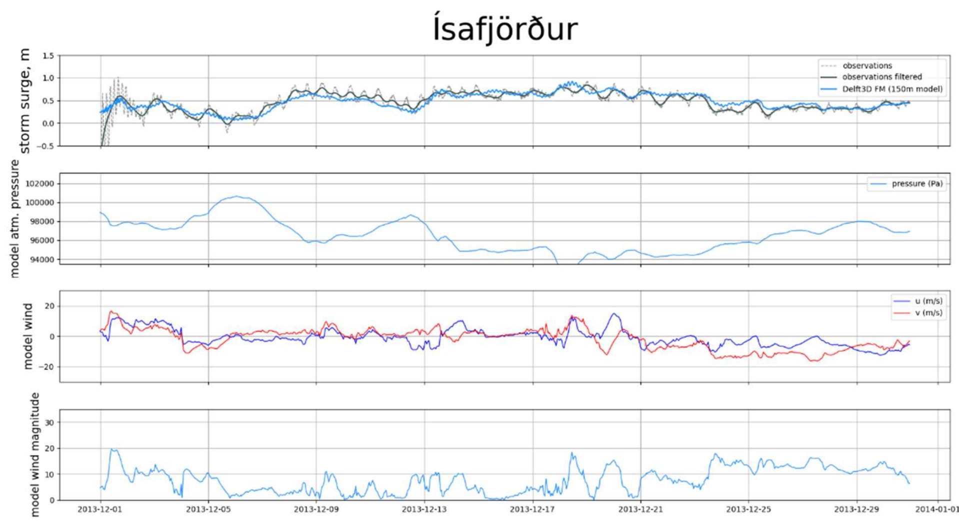
2014-01-01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storm surge, m
observations
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Delft3D FM (150m model)
model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
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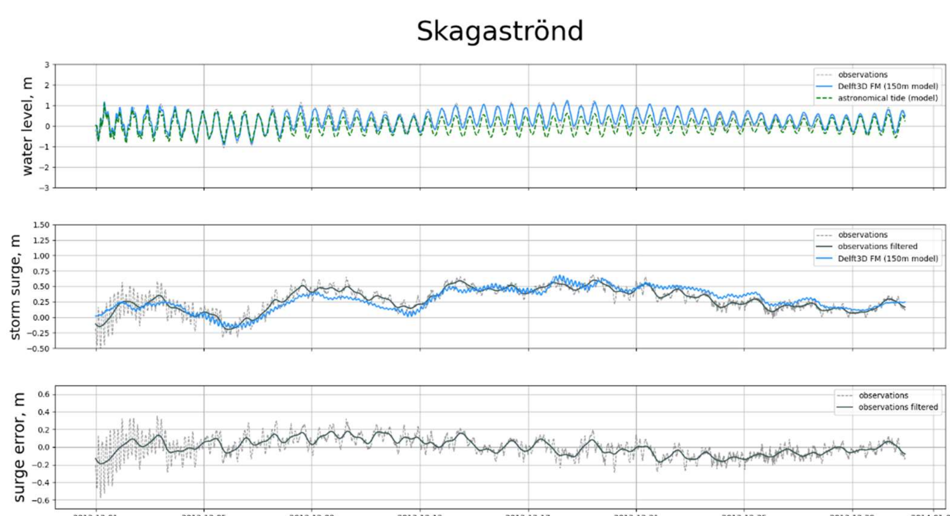
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astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
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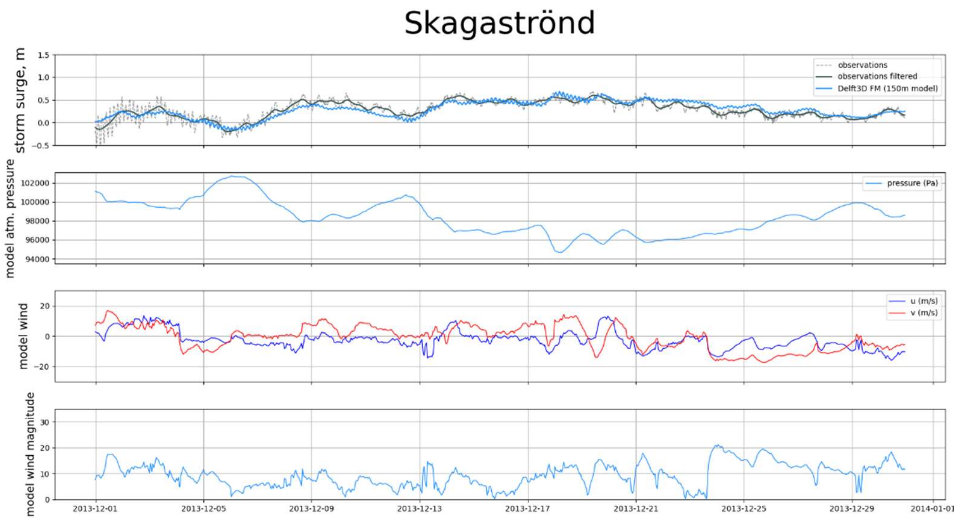
2014-01-01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observations
observations filtered
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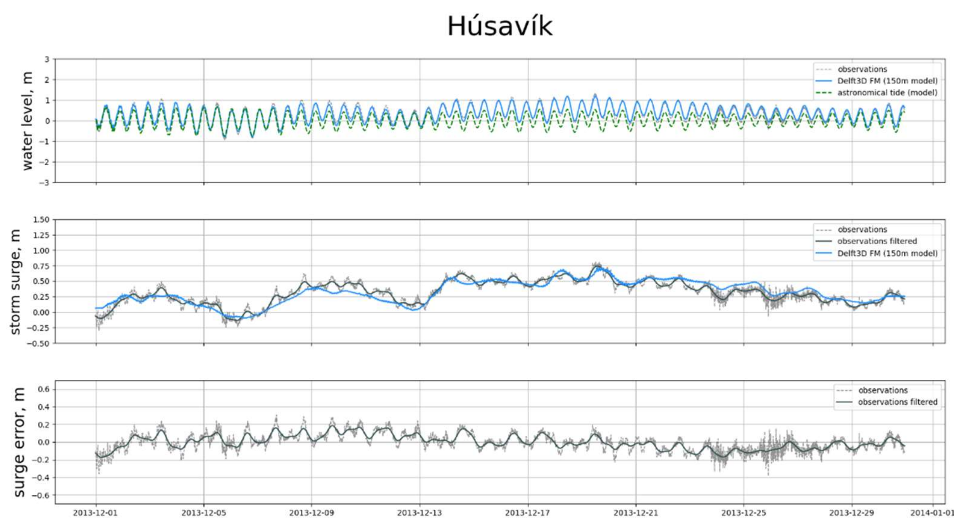
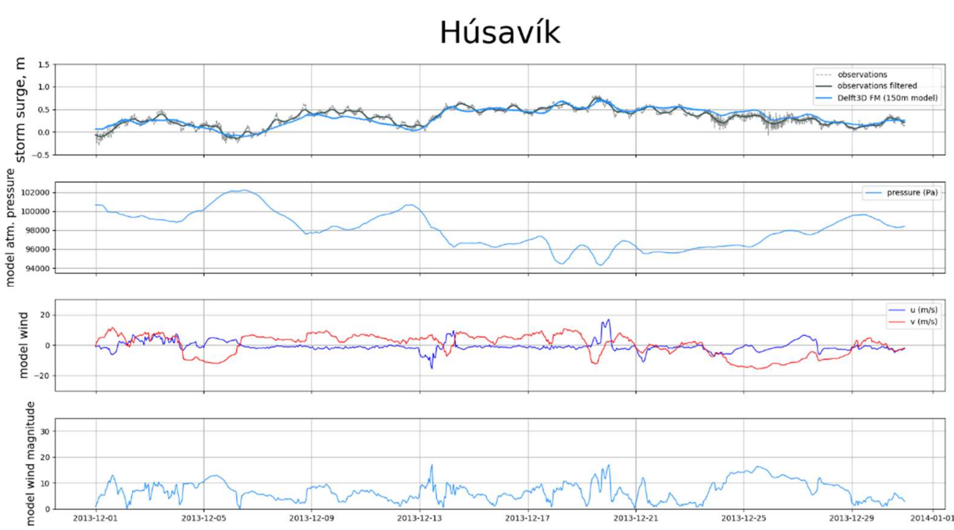
pressure (Pa)
model atm. pressure
u (m/s)
v (m/s)
model wind
model wind magnitude


Húsavík
observations
Delft3D FM (150m model)
astronomical tide (model)
water level, m
observations
observations filtered
Delft3D FM (150m model)
storm surge, m
observations
observations filtered
surge error, m


Húsavík
observations
observations filtered
Delft3D FM (150m model)
storm surge, m
pressure (Pa)
model atm. pressure
u (m/s)
v (m/s)
model wind
model wind magnitude

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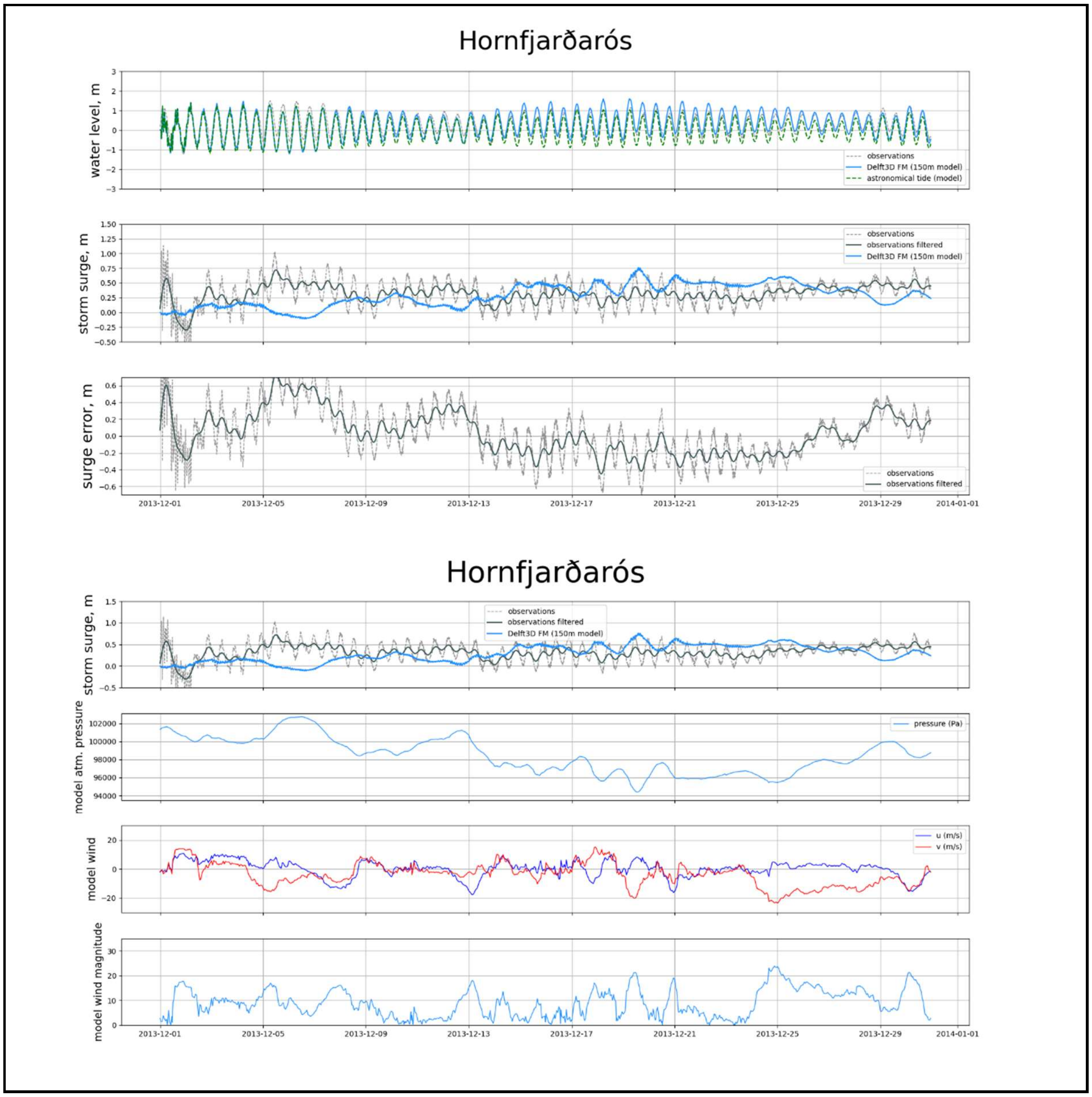



**Figure 6.** Storm surge: observations and numerical model estimates for **December 2013.**

**December 2015**

The sixth set shown in the Figure 6 corresponds to the storm in December 2015 comparing the only station available of Isafjörður. We can see that the model is reproducing really well the water level in the Westfjords with an error of more or less 20 centimeters error.

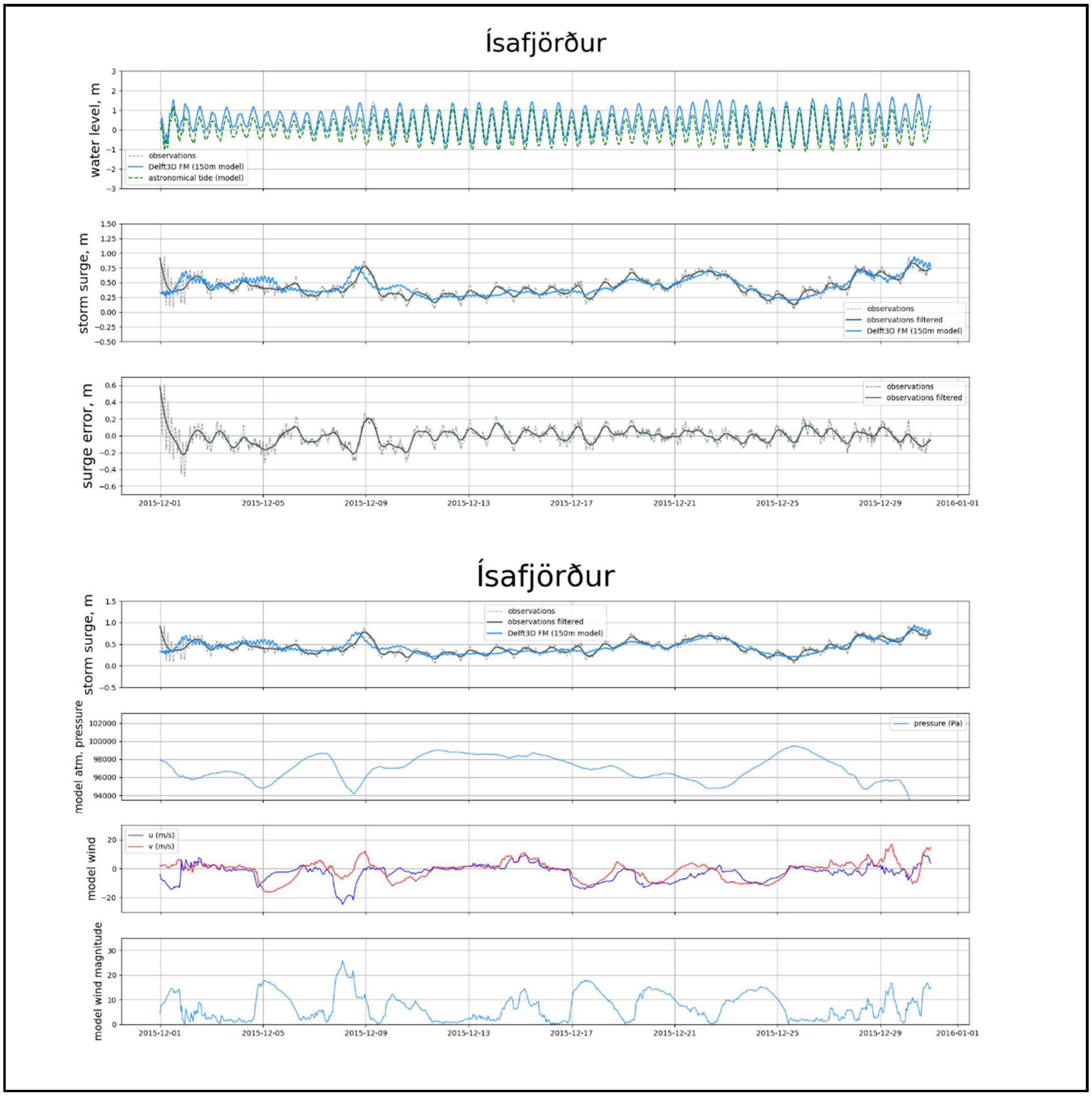
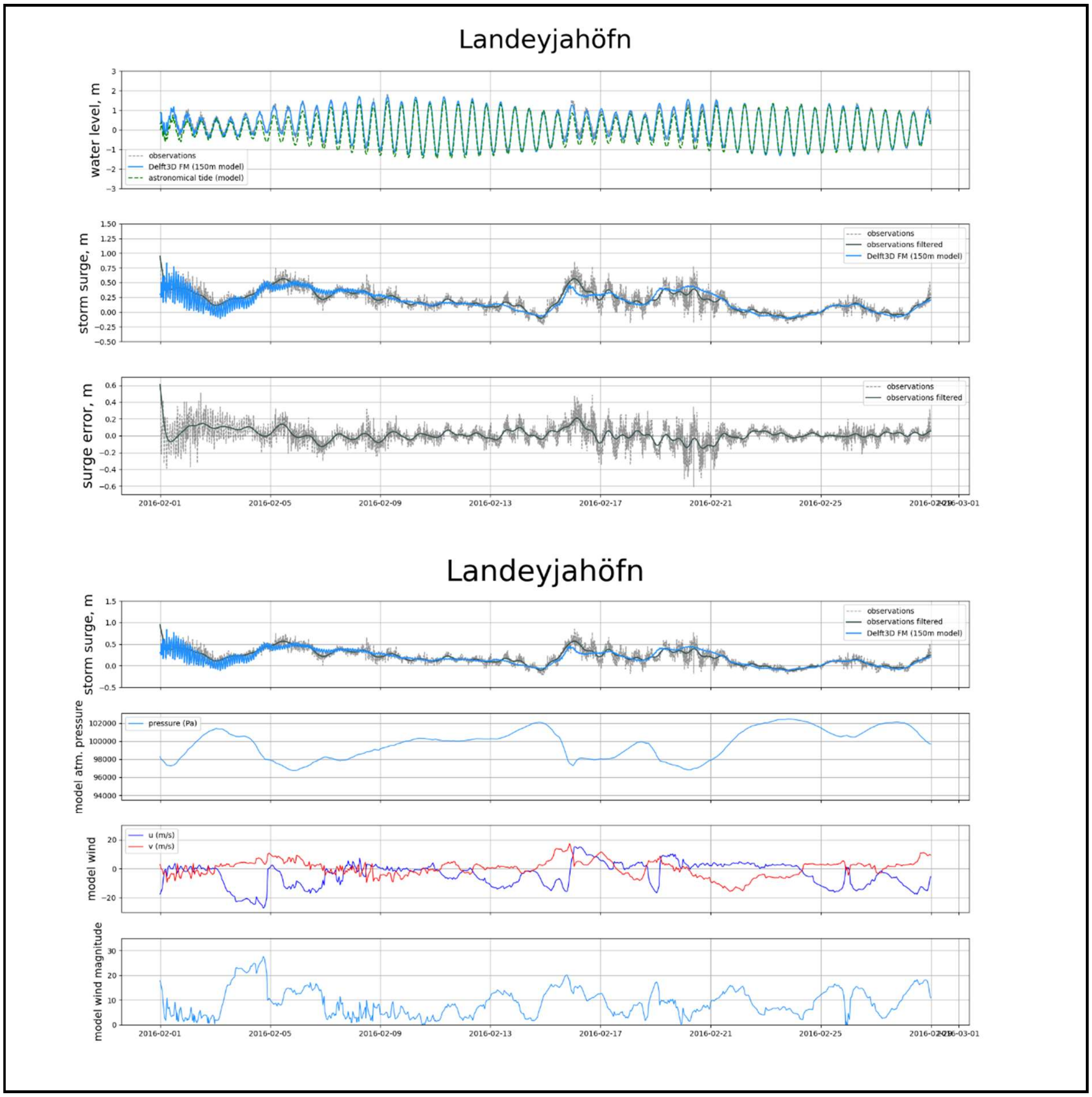



**Figure 7.** Storm surge: observations and numerical model estimates for **December 2015**

**February 2016**

The last set shown in the Figure 8 corresponds to the storm in February 2016 comparing 8 stations. We can see that, as for our pilot project with a smaller domain and a different mesh, the model using a new mesh and bigger domain is reproducing the water level and storm surges as well in the South-West of Iceland. We can also highlight as shown on the previous figure that the model looks to work well in the Westfjords as shown with the Isafjörður's station. However, as explained before, the station of Höfn has a most likely tide shift within the model. This could be explained by the location of the station with, at that time, where the tide gauge has been measuring the water level.



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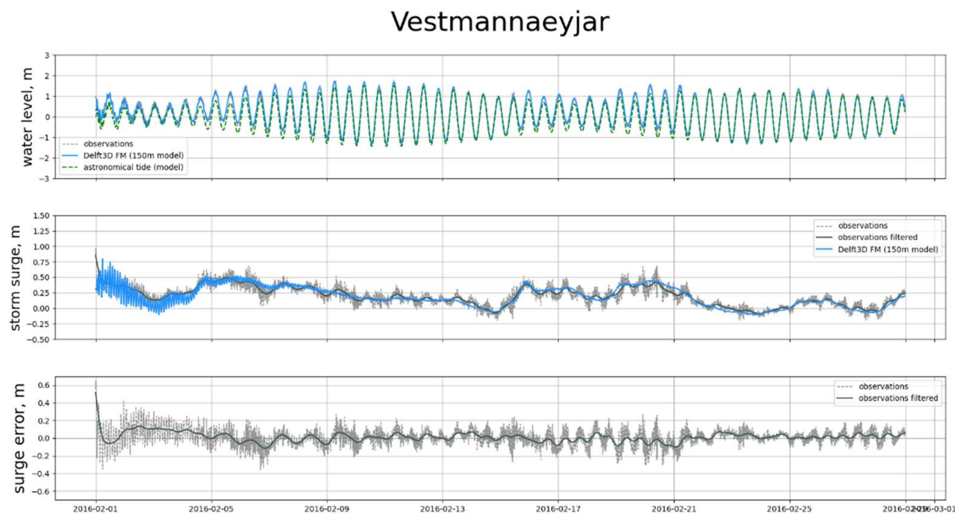
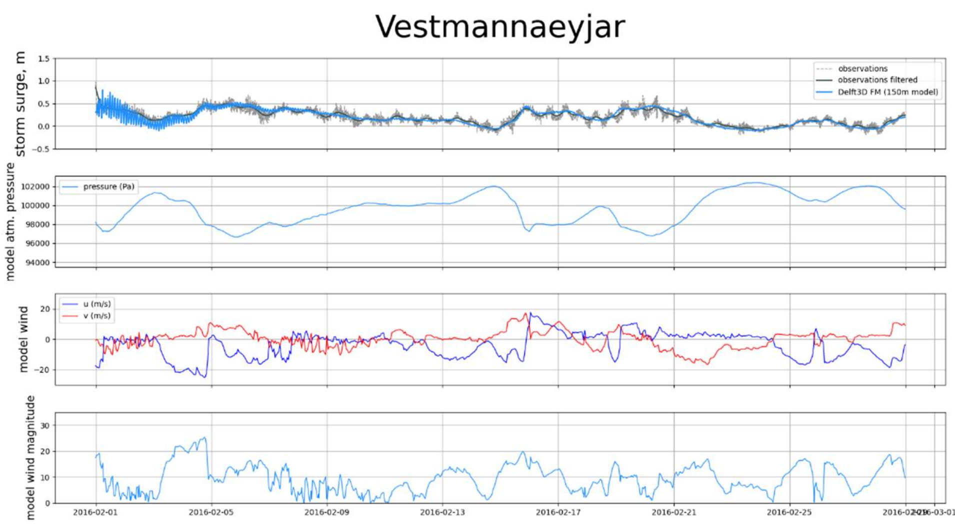
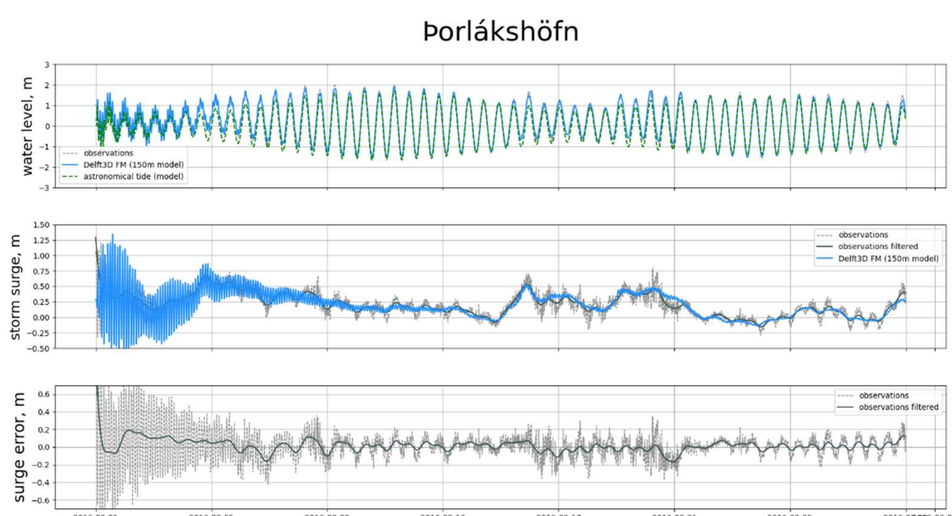
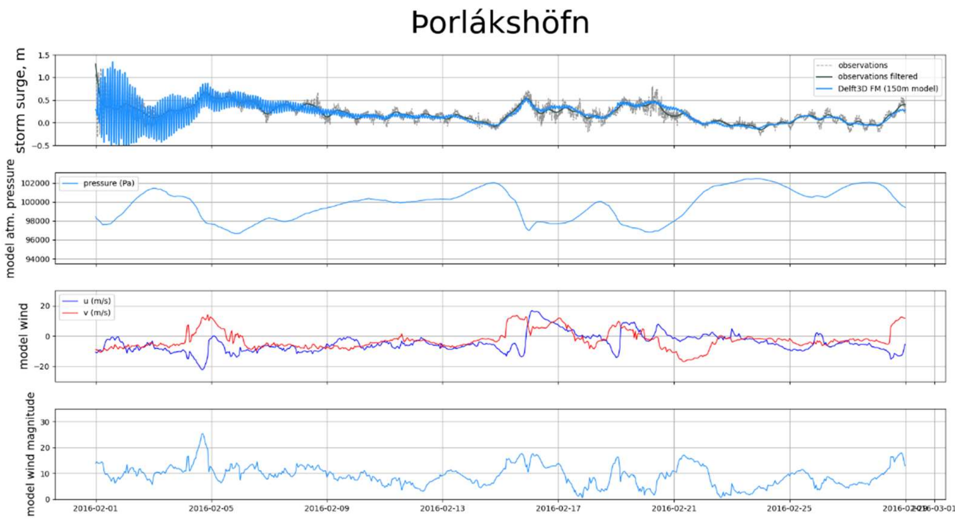
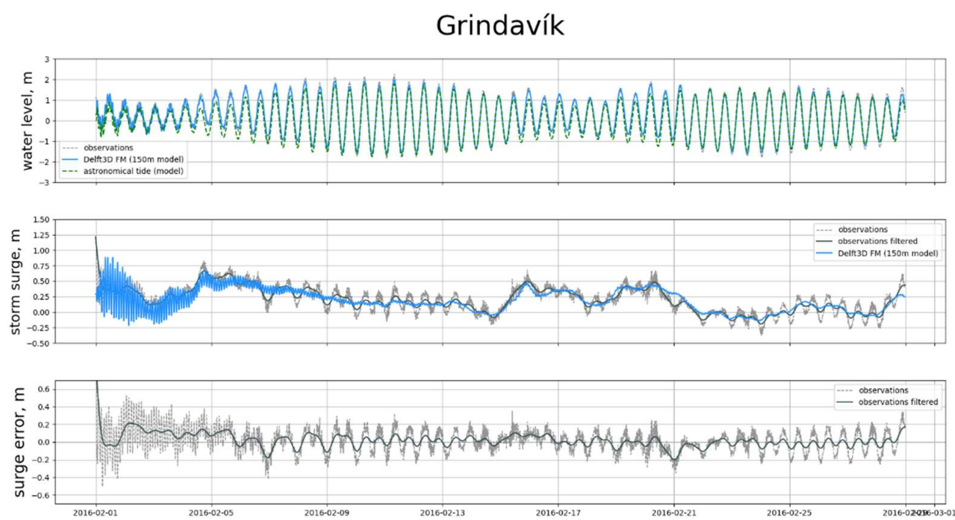
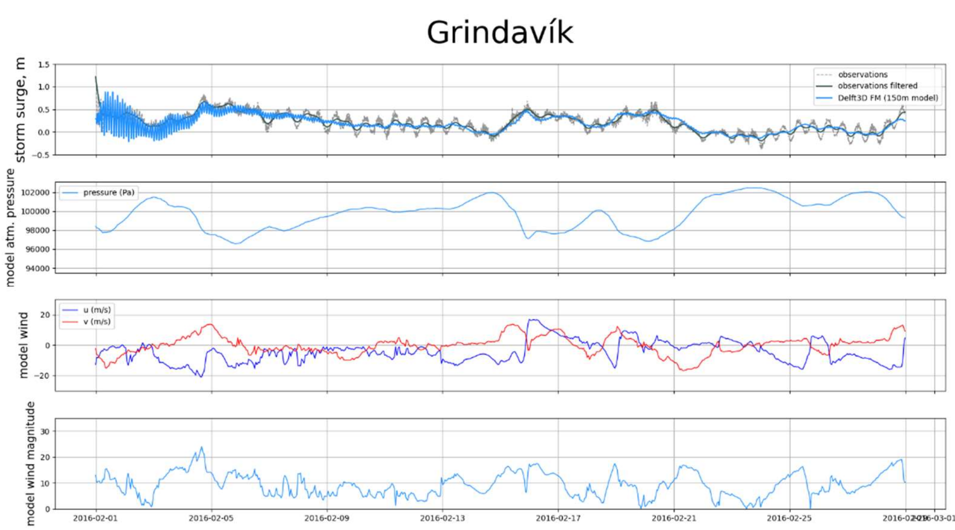


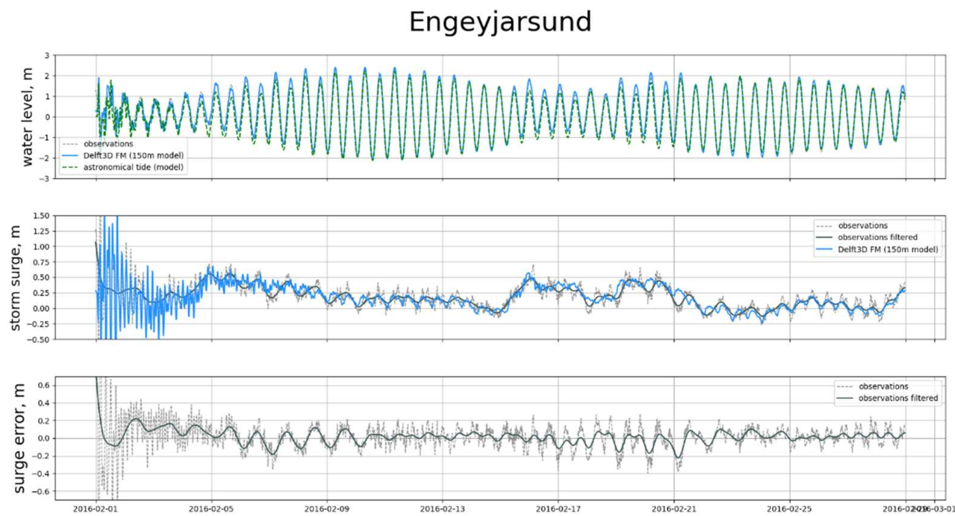



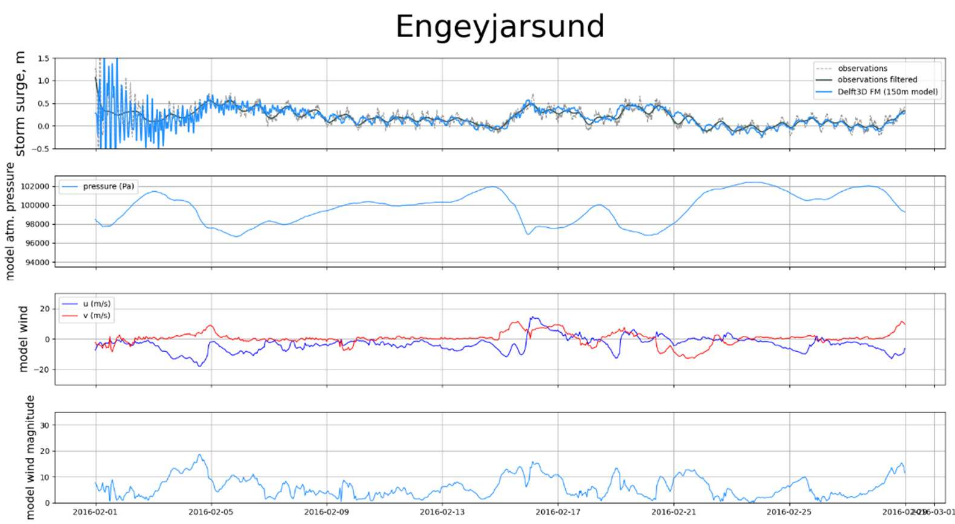



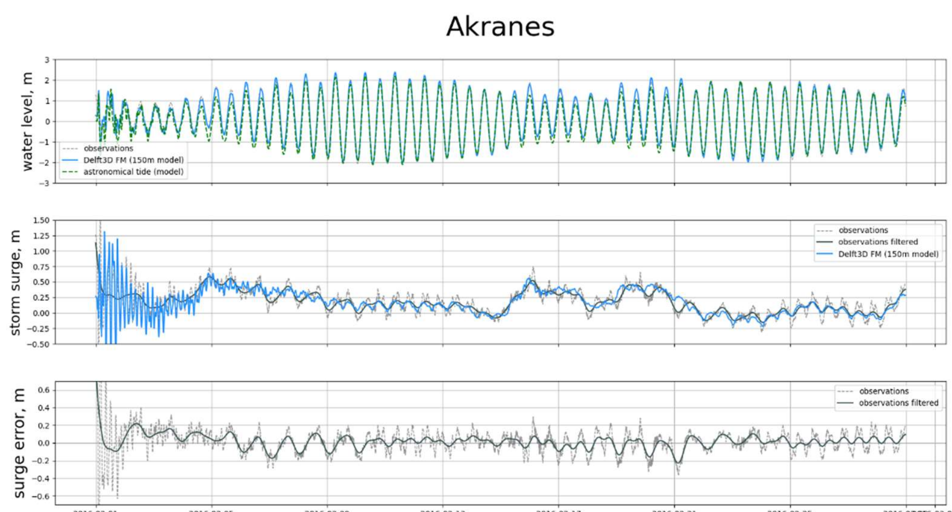

Þorlákshöfn
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
2016-02-01
2016-02-05
2016-02-09
2016-02-13
2016-02-17
2016-02-21
2016-02-25


Grindavík
water level, m
observations
Delft3D FM (150m model)
astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
2016-02-01
2016-02-05
2016-02-09
2016-02-13
2016-02-17
2016-02-21
2016-02-25


Grindavík
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
2016-02-01
2016-02-05
2016-02-09
2016-02-13
2016-02-17
2016-02-21
2016-02-25


Engeyjarsund
water level, m
observations
Delft3D FM (150m model)
astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
2016-02-01
2016-02-05
2016-02-09
2016-02-13
2016-02-17
2016-02-21
2016-02-25
2016-03-01


Engeyjarsund
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
model atm. pressure
pressure (Pa)
model wind
u (m/s)
v (m/s)
model wind magnitude
2016-02-01
2016-02-05
2016-02-09
2016-02-13
2016-02-17
2016-02-21
2016-02-25
2016-03-01


Akranes
water level, m
observations
Delft3D FM (150m model)
astronomical tide (model)
storm surge, m
observations
observations filtered
Delft3D FM (150m model)
surge error, m
observations
observations filtered
2016-02-01
2016-02-05
2016-02-09
2016-02-13
2016-02-17
2016-02-21
2016-02-25
2016-03-01

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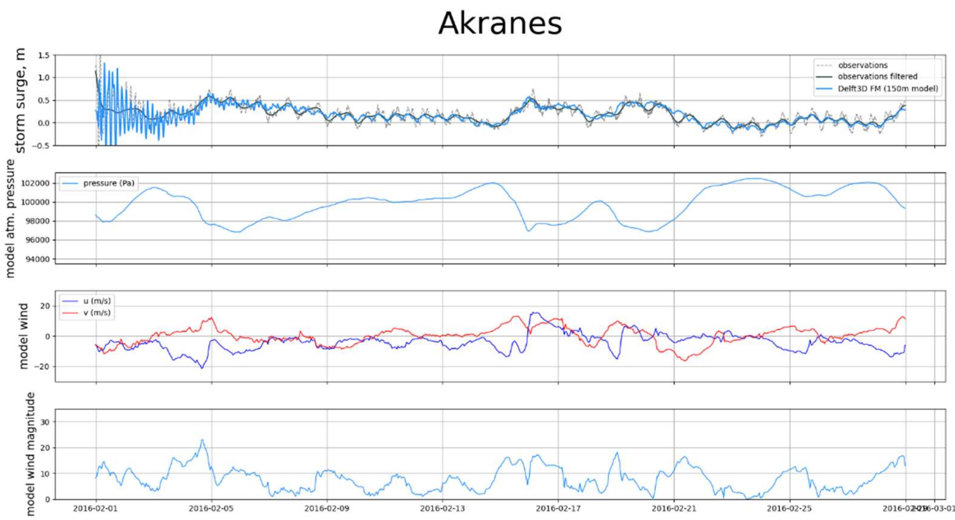


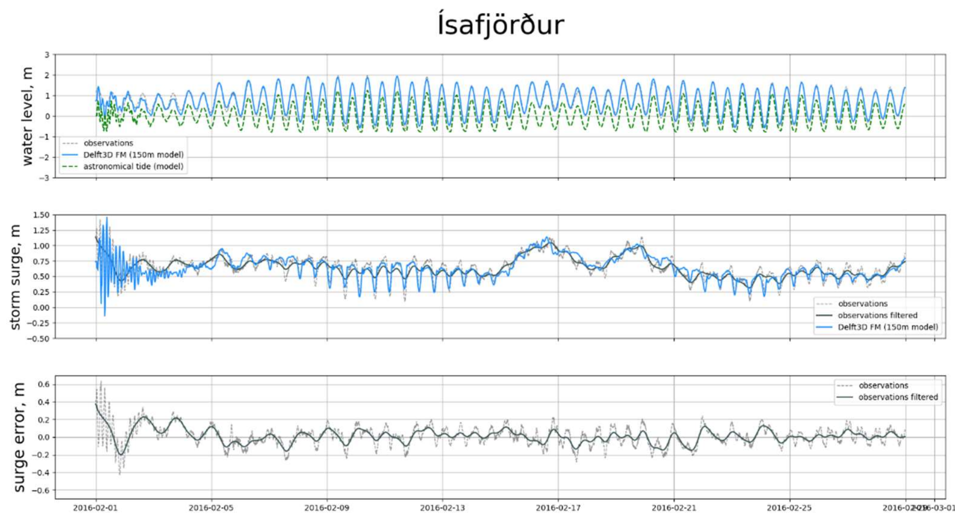


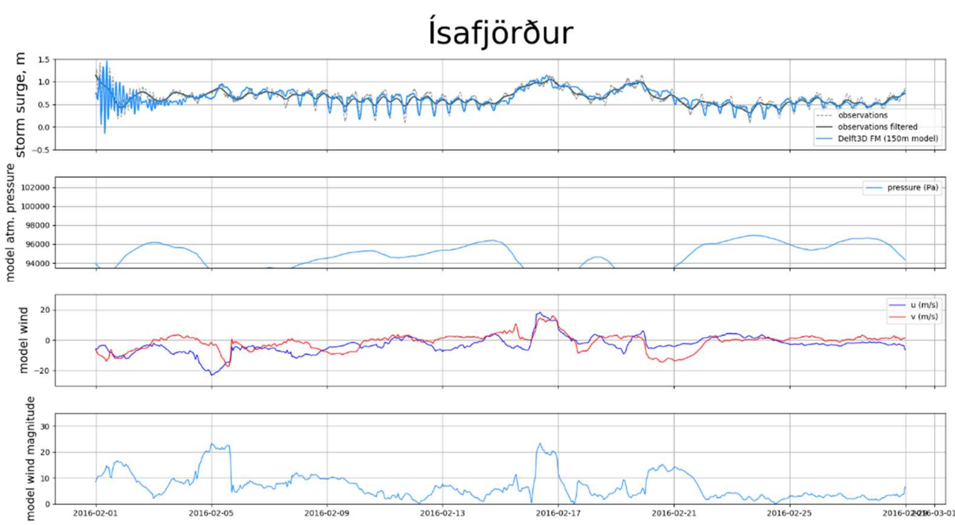

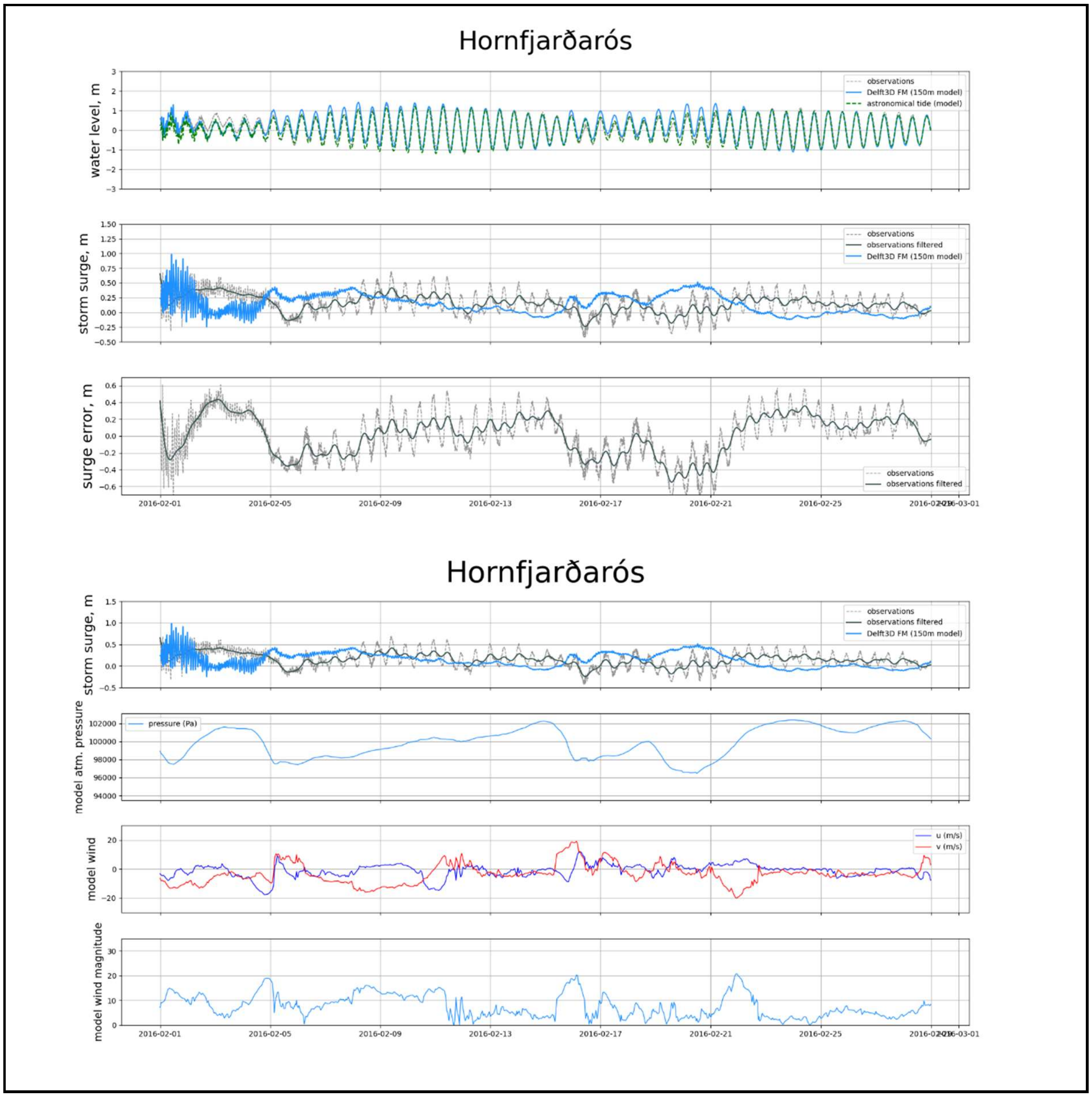


**Figure 8.** Storm surge: observations and numerical model estimates for **February 2016**

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From the figures 2 to 8, we clearly observe that the numerical model cannot reproduce the high frequency variability recorded in the measurements. This variability is mostly associated with waves and wave effects are not included in the model. The model is forced with atmospheric inputs with hourly resolution and its inability to generate higher frequency variability leads to an automatic filtering of the high frequencies and a mismatch with observations at that frequency scale. By filtering the observations with a Butterworth low-pass filter that eliminates the higher frequencies (see appendix for details), it becomes clear that the low frequency part of the signal is well reproduced by the model.

The overall storm surge estimates are satisfactory, we estimate an error between the model and the observations of around 20 centimeters once the model is past the spin up time. The model gives a good approximation of the sea level height during both calm and stormy weather all around Iceland.

Nevertheless, there are some events for the specific station of Grindavik where the model did not perform as well as we would like. In these cases, extremely high water levels were measured, up to a 2 meters storm surge water level without the model reproducing more than modest increase in sea level. As the model performed relatively well for the same period in Reykjavik and during all the other simulations, we do believe that other factors, such as the wave setup was dominant in this case. However, to verify this, a wave model would need to be added to the modelling.

We also can highlight the mismatch between the model and observations data in Höfn. As mentioned before, this looks like a tide shift between the model and the observation data. It could also come from the place where the tide gauge is recording and the one setup within the model as we did not have the exact position of the tide-gauge at this location. Further research on this should be done to assess the present error.

In the appendices, we highlight the good correlation (calculated without spin-up time) between the observations and the model with a coefficient of determination r-squared above 97% depending on the quality of the observation data and the storms and stations chosen.

We could also regret the lack of observations data especially in the East of Iceland which could not permit us to get a good overview of how well the model is performing in this specific area.

## e. Conclusion

We have successfully performed storm surge simulations for all Iceland during 7 storm events in the following periods: November 1996, January 2000, December 2006, October 2008, December 2013, December 2015 and February 2016. The results from the model are compared with the observations at available stations showing a relatively good agreement. The numerical model cannot reproduce the high variability observed in the measurements as it is lacking the higher frequency forcing effects due to wave setup, a component that can be significant for some stations. From the analysis, we performed 2 sets of simulations, which allowed us to get the surge component result of the atmospheric conditions. From this analysis we also decided to compare the surge with the atmospheric forcing where we could see a good agreement between the pressure and the surge. As highlighted in the pilot study, it looks like the inverse barometer effect is the main driver of the surge around Iceland but that we cannot neglect completely the wind neither. The spin up time response is very similar for all stations and it is about 3 to 5 days. Past this spin up time, simulations' errors of around 20 centimeters subsist. This error includes most of the time the lack of a surface wave component but can also worsen during high surface waves time-period. As the overall storm surge estimates are satisfactory the main result of this study shows that the Delft3D-FM model can be used to simulate storm surges in Iceland.

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## g. ACKNOWLEDGEMENTS

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**Comparison of observations and simulations**

This section is for the storm surge data analysis only. The performance of the model is explored by comparing the low pass filtered observations with the model outputs. Among the limitations of the model are the forcing frequency, which occurs every one hour and this limits the response periods below 1 hr. The following scatter plots show the points from the middle panels of the figures above from the first plot only after the spin up process but including the post storm period as well. The observations are in the X-axis and the model outputs on the Y-axis.

We present 7 sets of plots corresponding to the 3 different storms selected for this study. The performance of the model is satisfactory for most stations. We observe that for Grindavík the model often underestimates for a relatively short period of time the storm surge opening several possibilities to explain this as we described in the text above. Some stations for some storms also do not look a good accuracy (Patreksfjordur, Dec. 2006 ; þorlakshöfn-Dalvik-Husavik, Oct. 2008 ; Akranes, Höfn, Dec. 2013 ; Höfn, Feb 2016) where missing data and most likely errors in the observation dataset were found.

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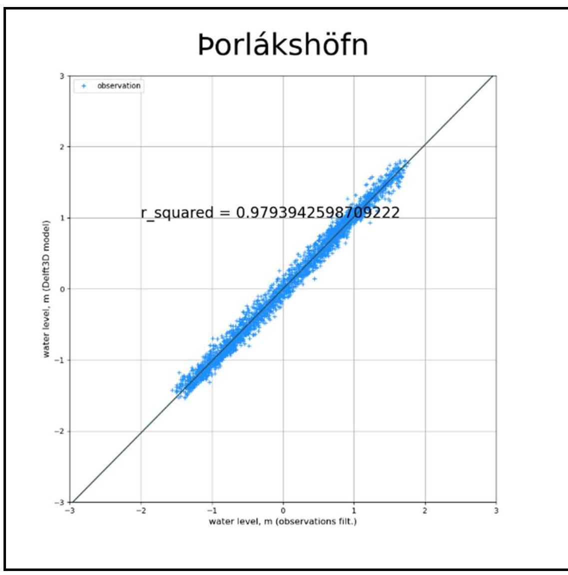


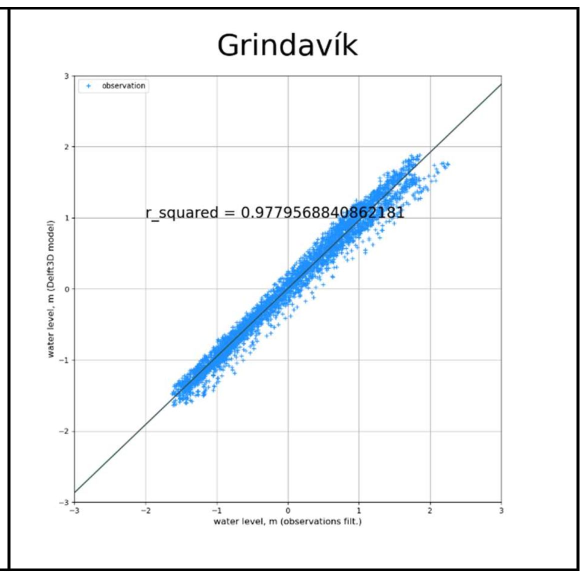

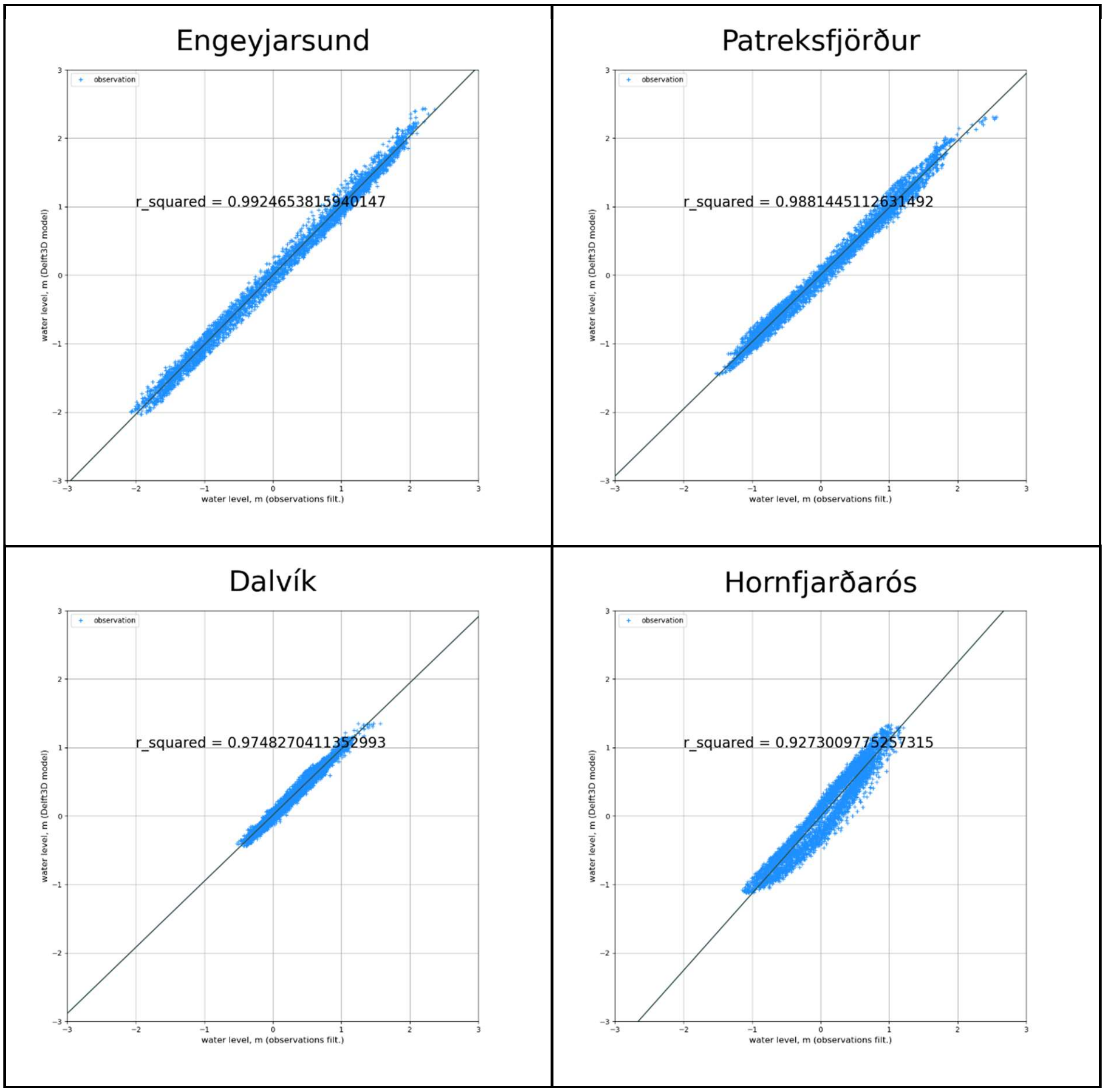


**S1**. Scattered plots for the comparison of observations (x-axis) and numerical model estimates (y-axis) for November 1996.

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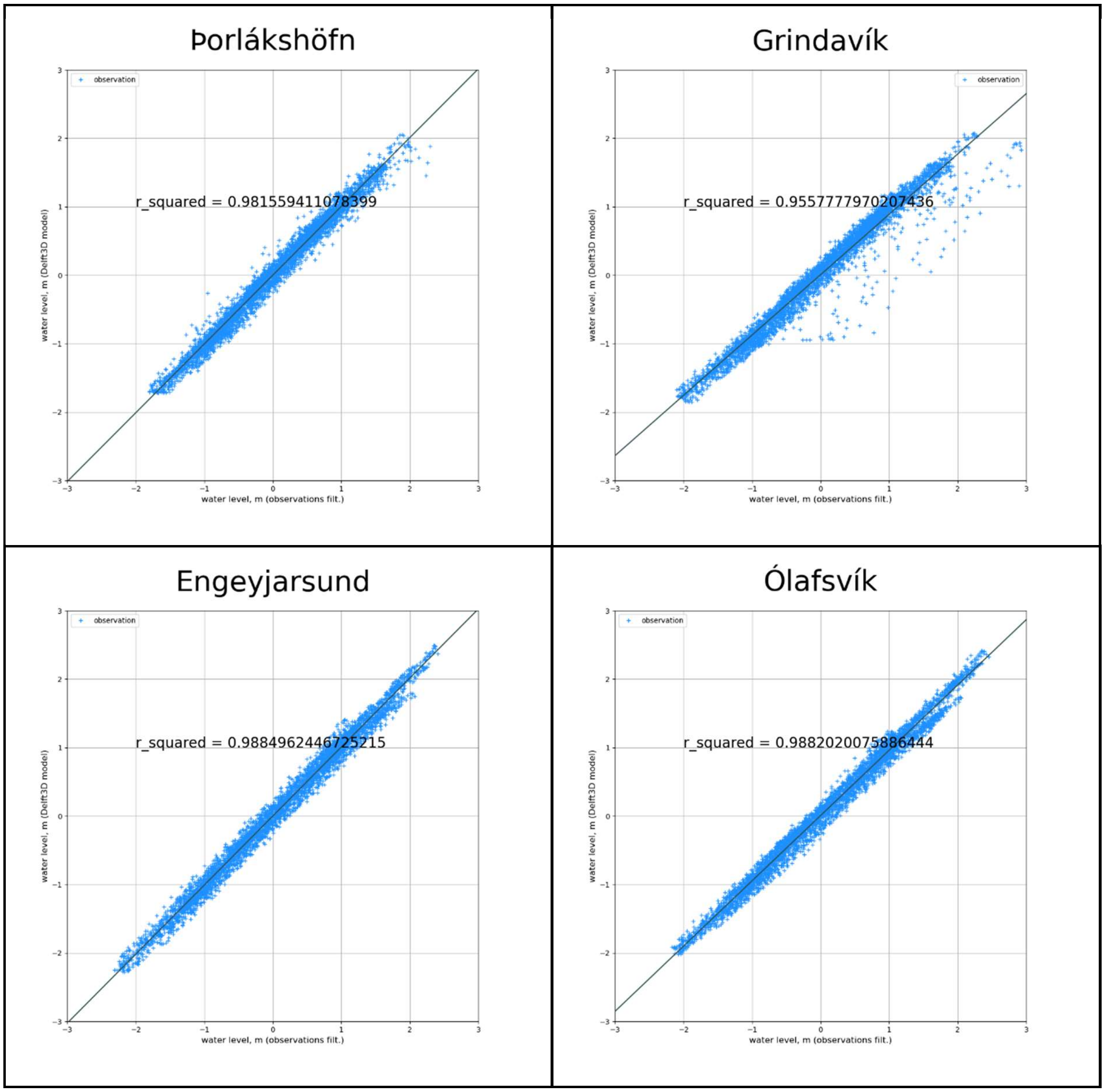
## January 2000



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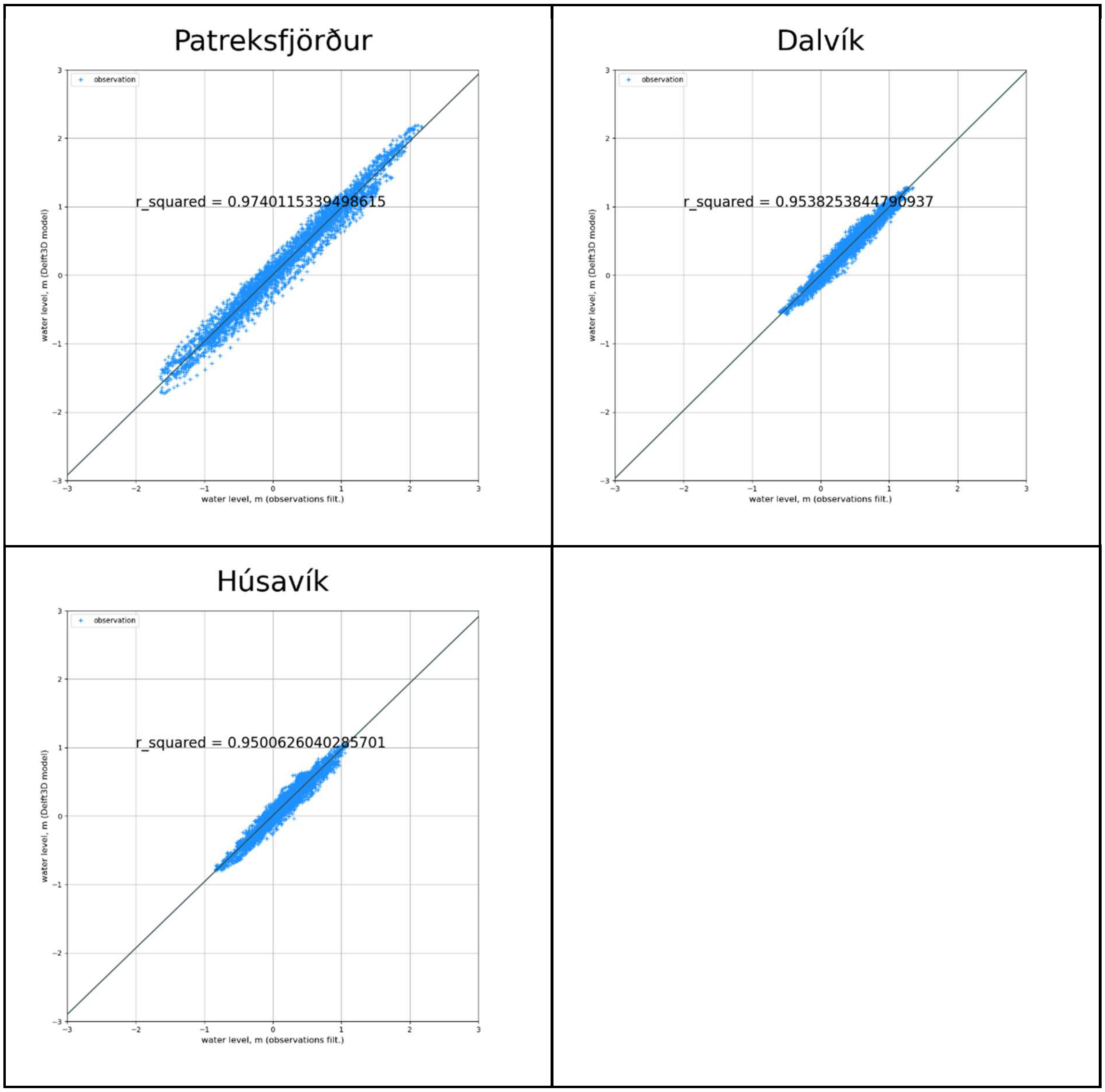


**S2**. Scattered plots for the comparison of observations (x-axis) and numerical model estimates (y-axis) for January 2000.

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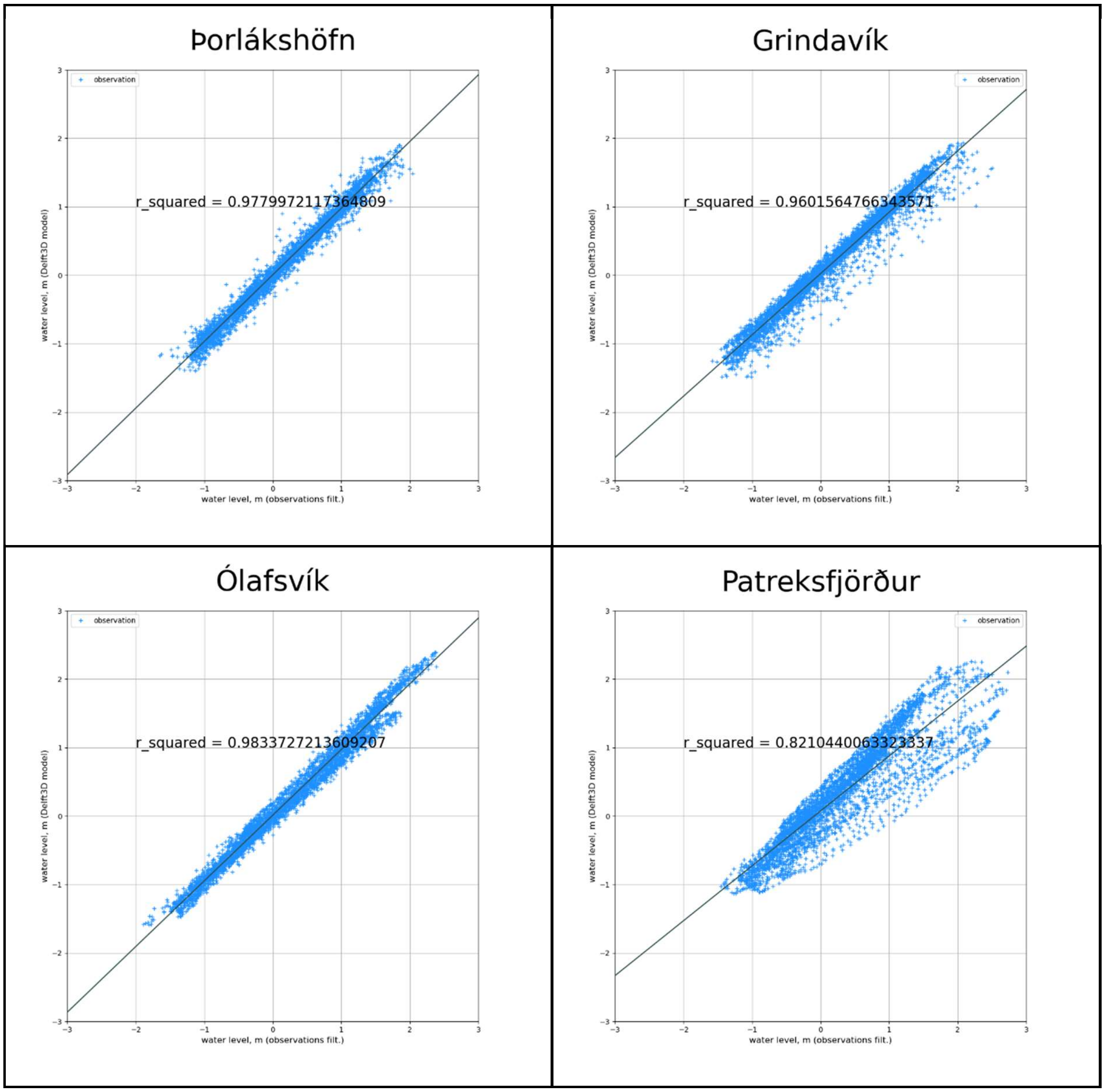
**December 2006**



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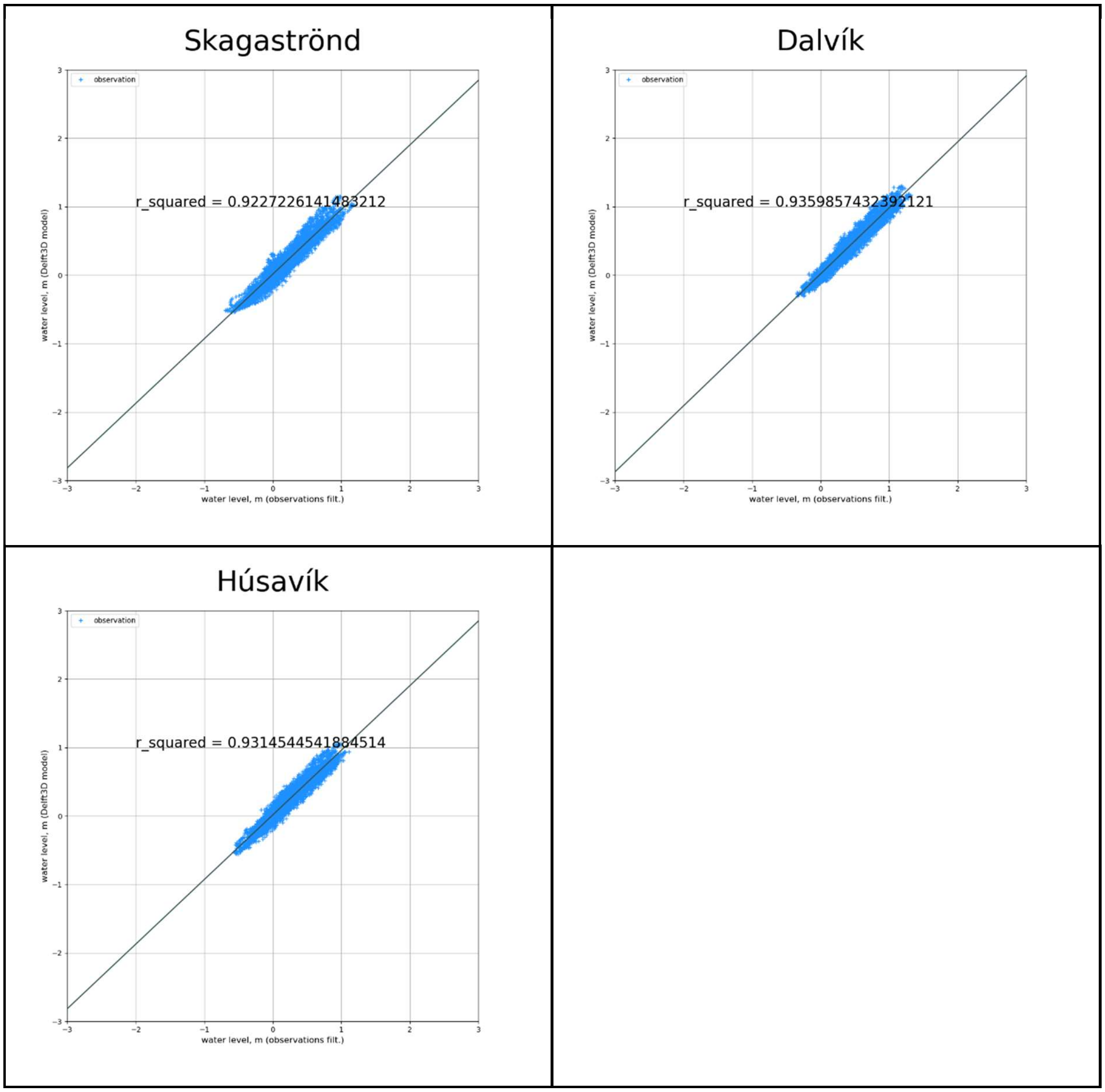
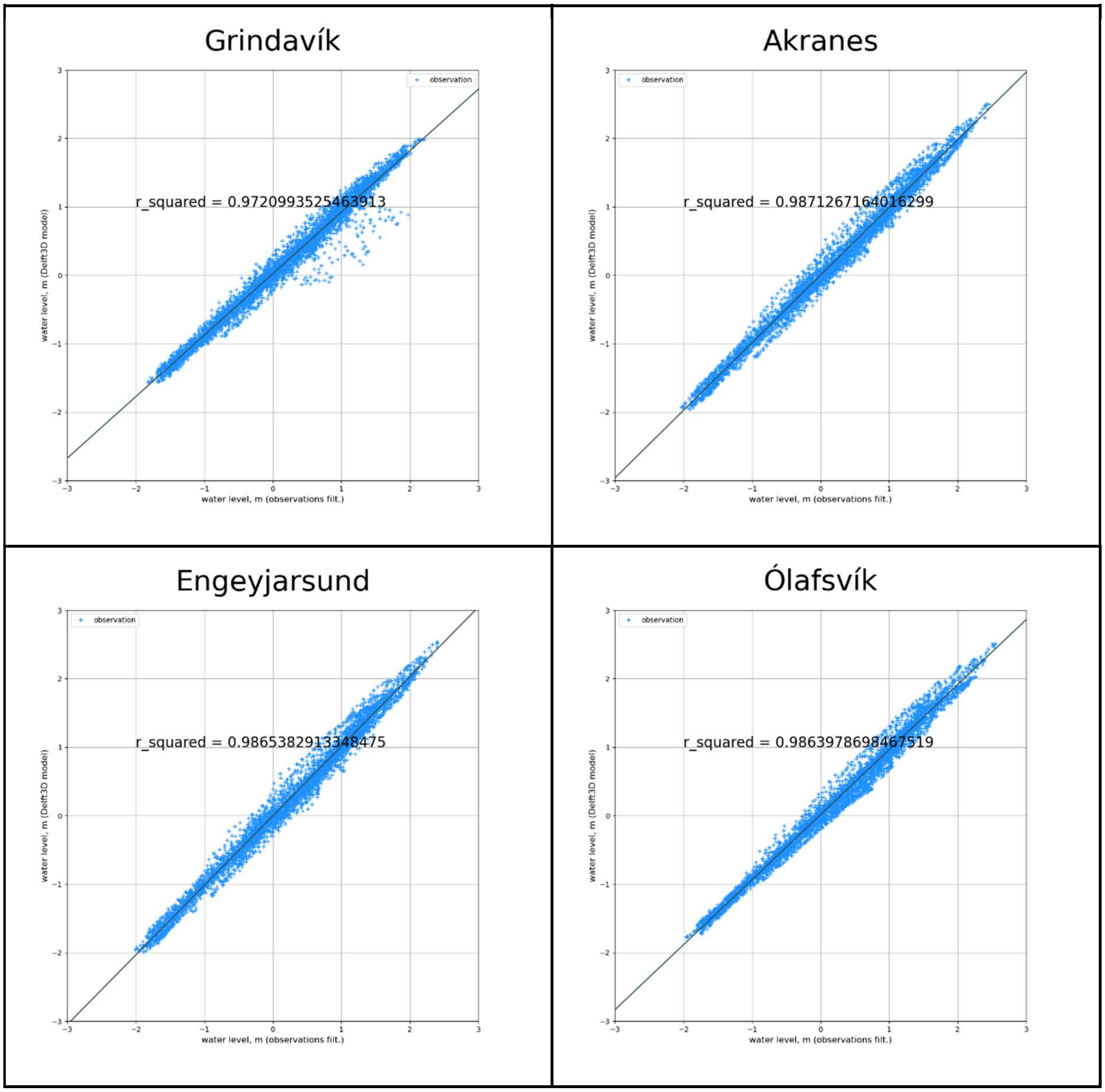
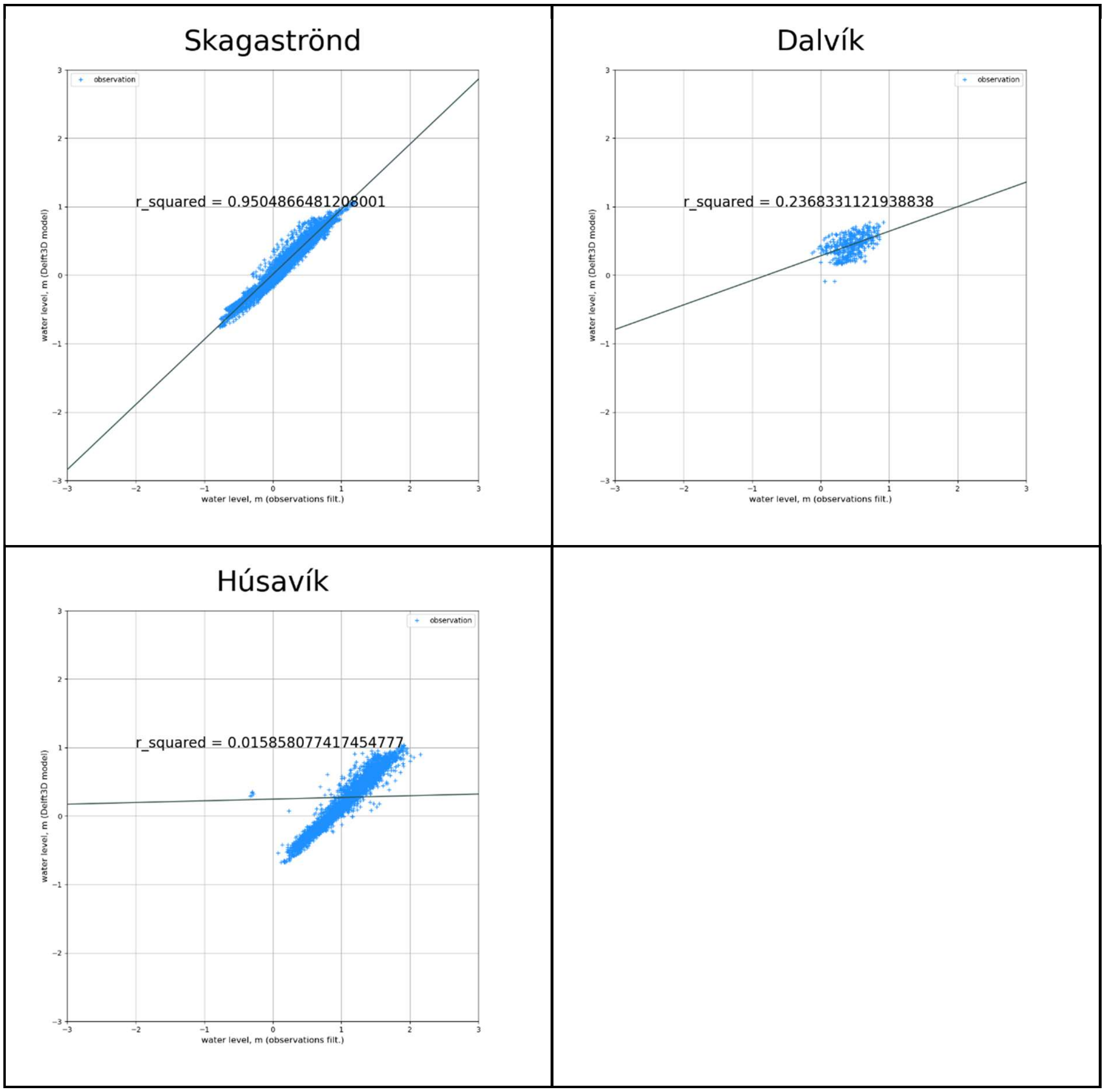



**S3**. Scattered plots for the comparison of observations (x-axis) and numerical model estimates (y-axis) for December 2006.

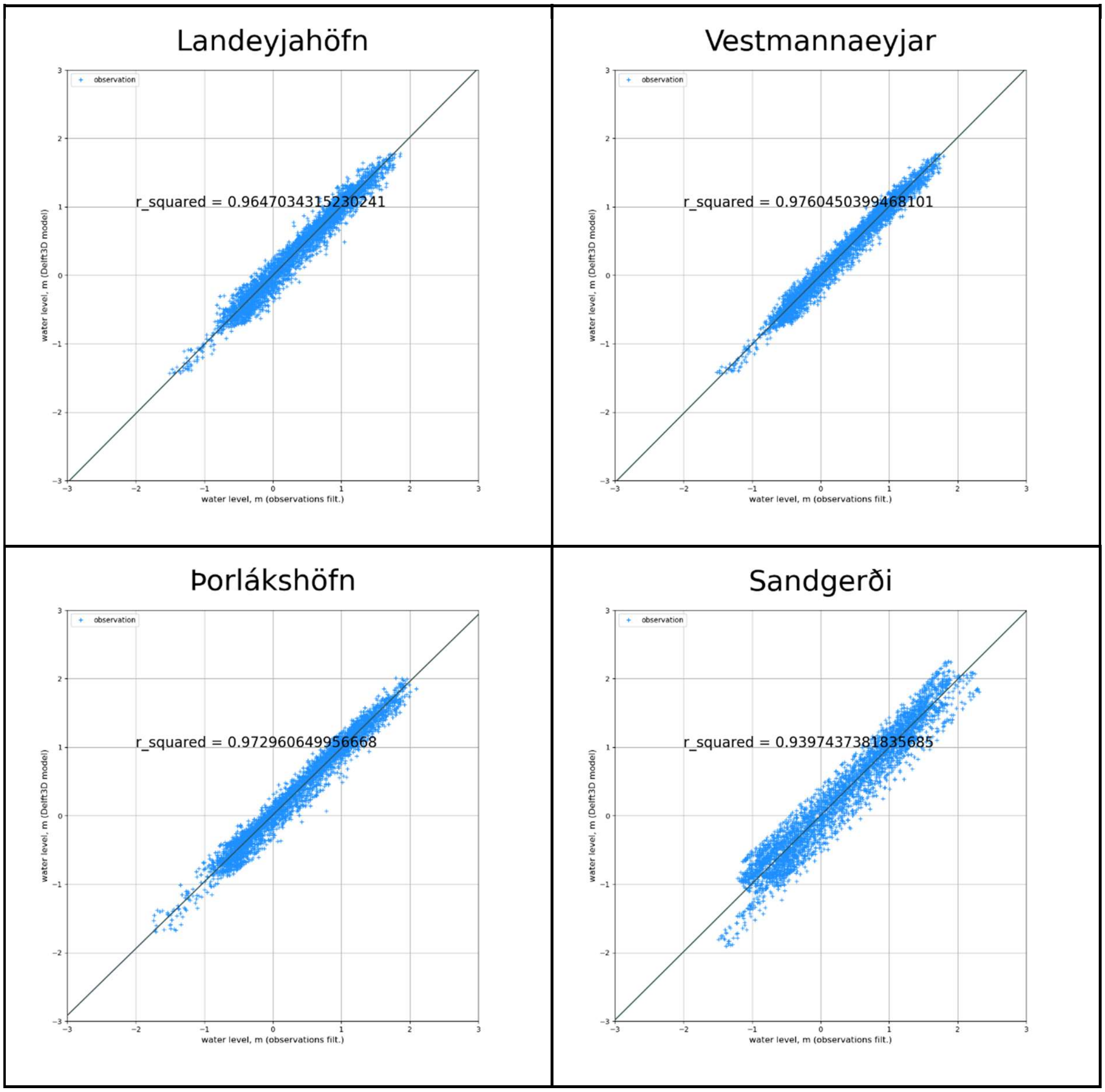
## October 2008

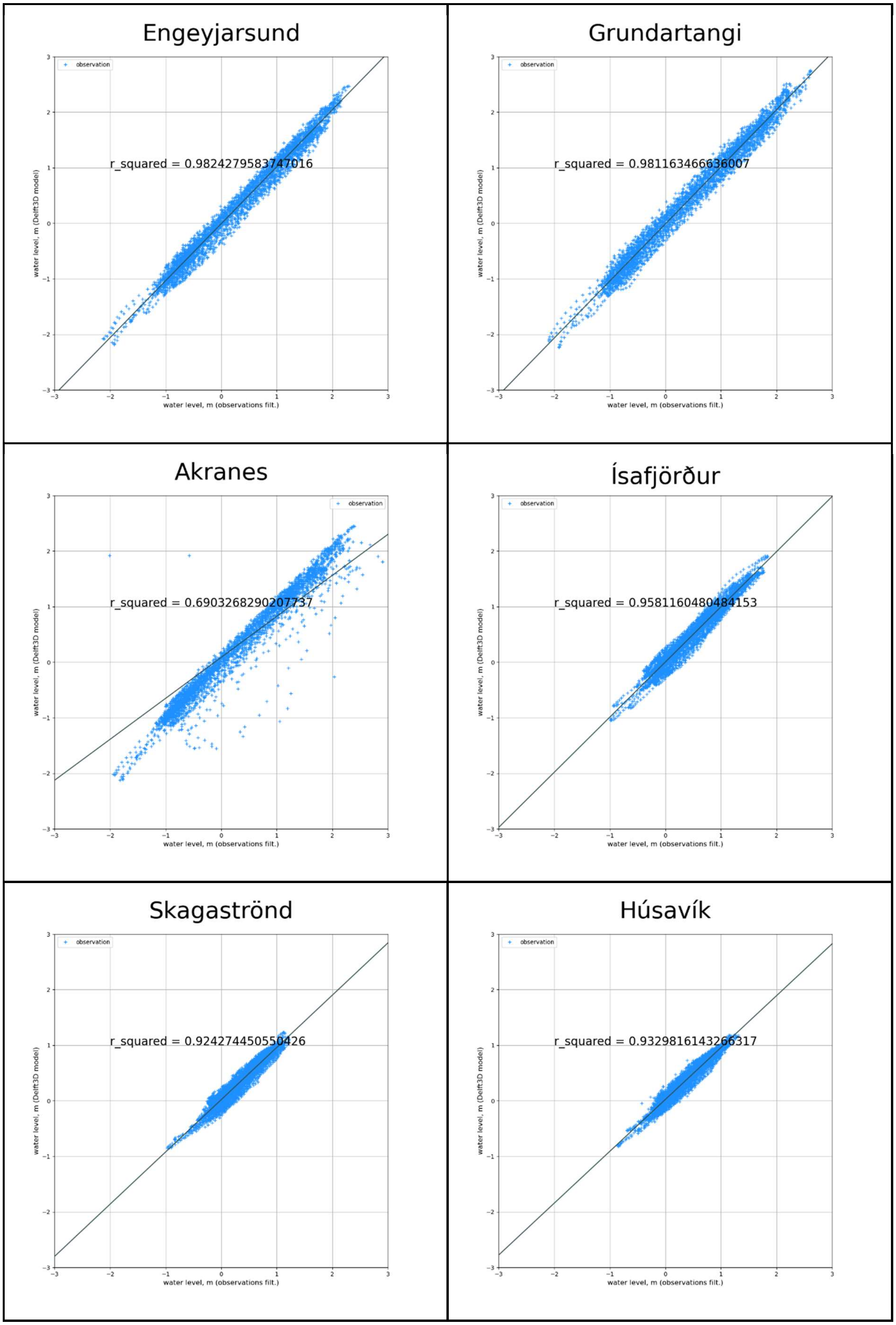





**S3**. Scattered plots for the comparison of observations (x-axis) and numerical model estimates (y-axis) for October 2008.

**December 2013**




Engeyjarsund
observation
r_squared = 0.9824279583747016
water level, m (Delft3D model)
water level, m (observations filt.)
Grundartangi
observation
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water level, m (Delft3D model)
water level, m (observations filt.)
Akranes
observation
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Ísafjörður
observation
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Skagaströnd
observation
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Húsavík
observation
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water level, m (observations filt.)

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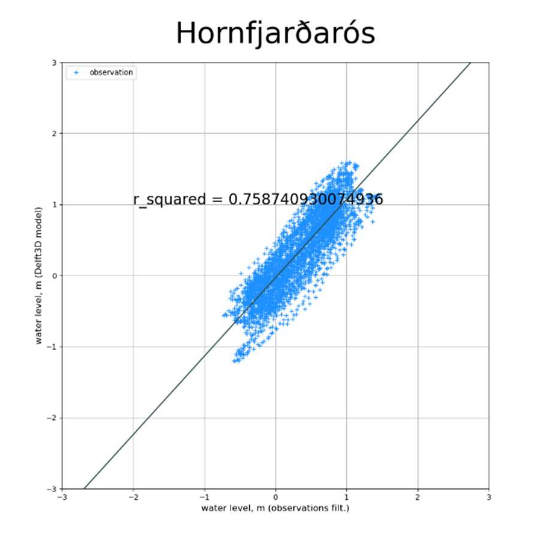
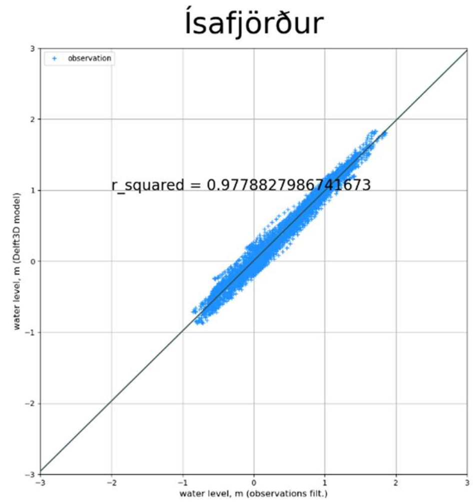


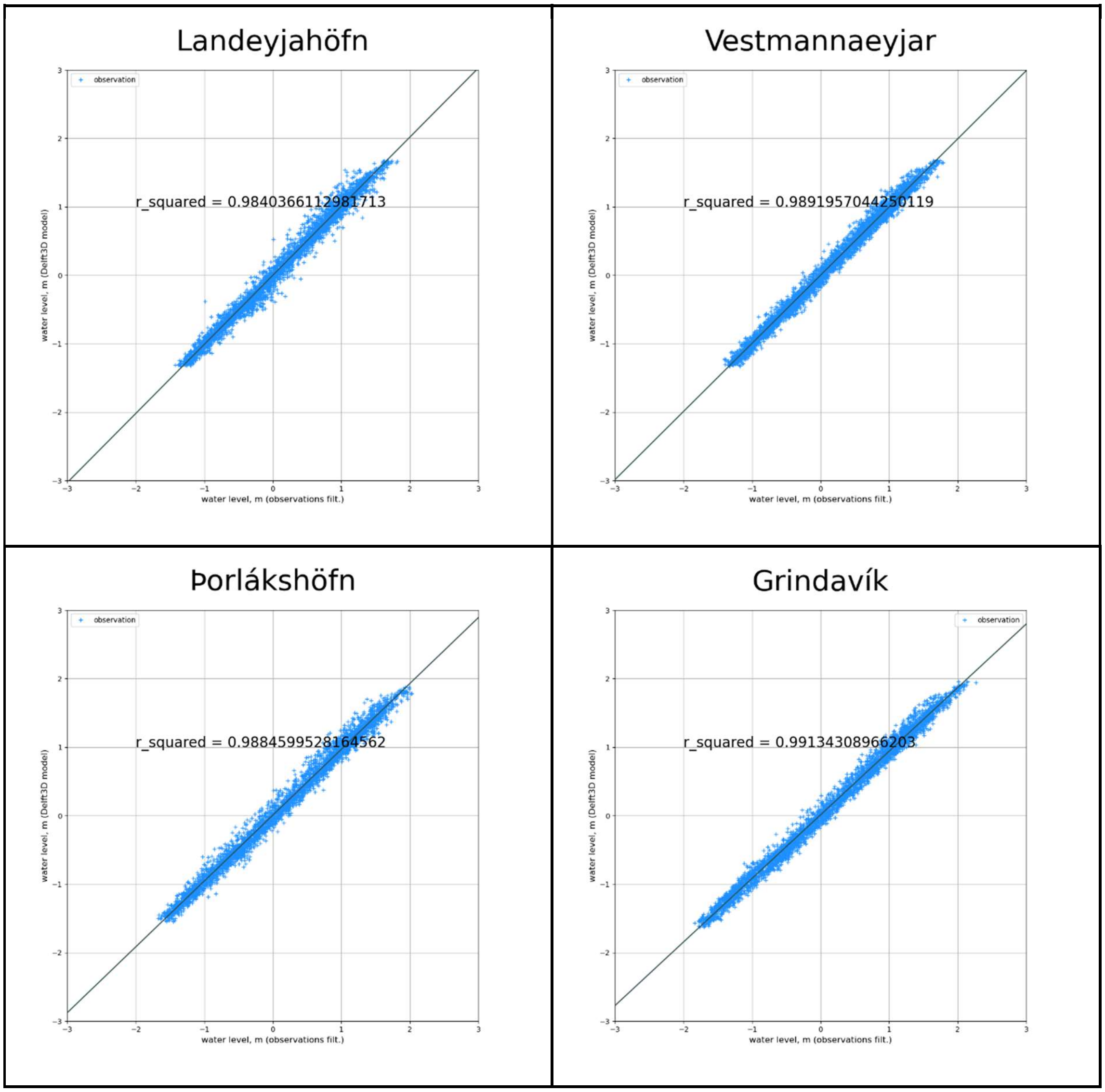

**S3**. Scattered plots for the comparison of observations (x-axis) and numerical model estimates (y-axis) for December 2013.

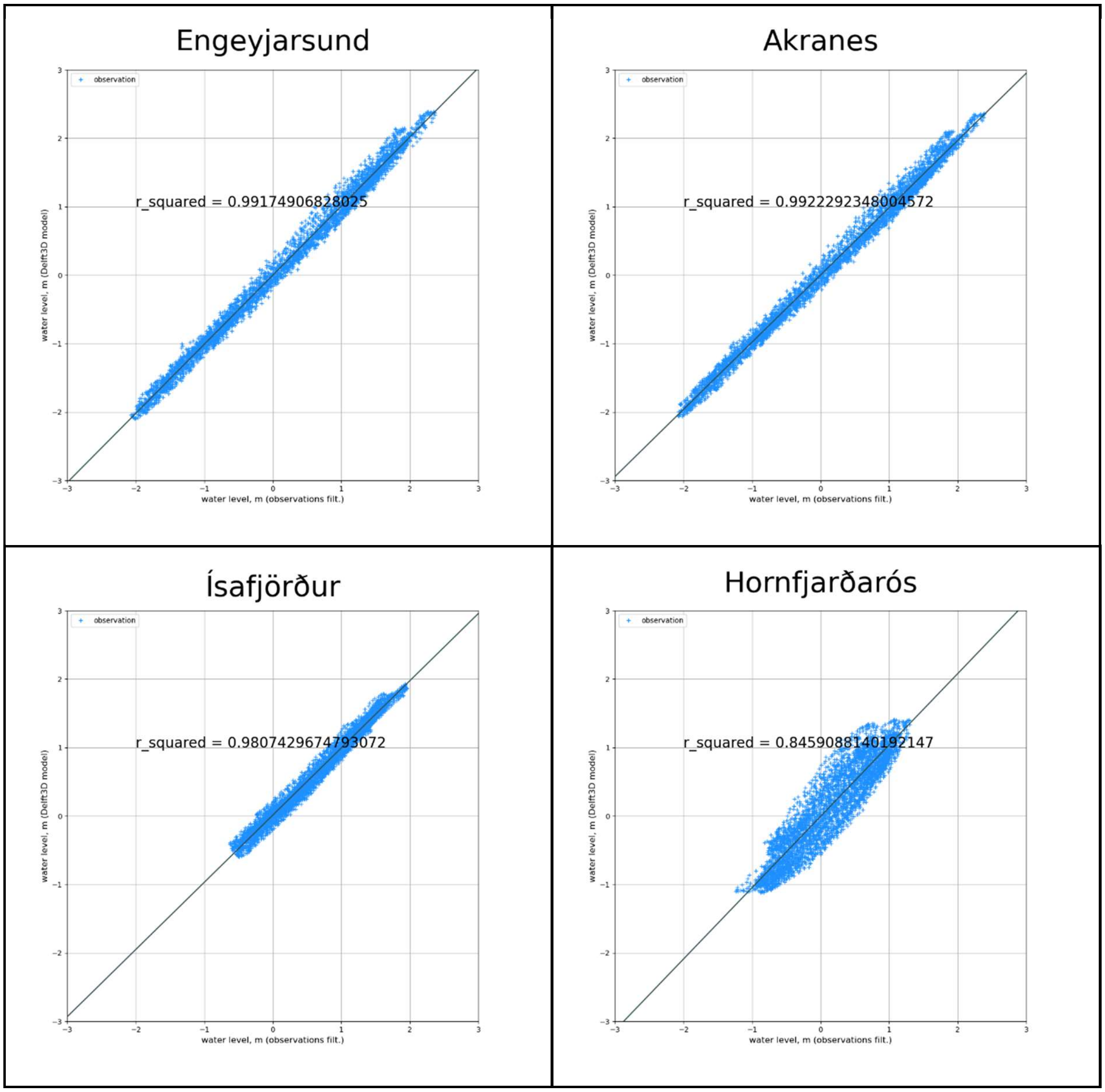
**December 2015**




**S3**. Scattered plots for the comparison of observations (x-axis) and numerical model estimates (y-axis) for December 2015.

## February 2016






**S3**. Scattered plots for the comparison of observations (x-axis) and numerical model estimates (y-axis) for February 2016.

**Details on the model setup**

Figure 1 in the main text shows the grid employed in the simulations. Figure S.4 shows detailed maps zooming in Reykjavík and Grindavík areas, showing the size of the meshes for those two regions. As mentioned previously the mesh size was designed to be about 150m along the coastline. The computational core of Delft3D FM is the D-Flow Flexible Mesh engine for hydrodynamical simulations on unstructured grids (Deltares, 2021). D-Flow solves the 2D and

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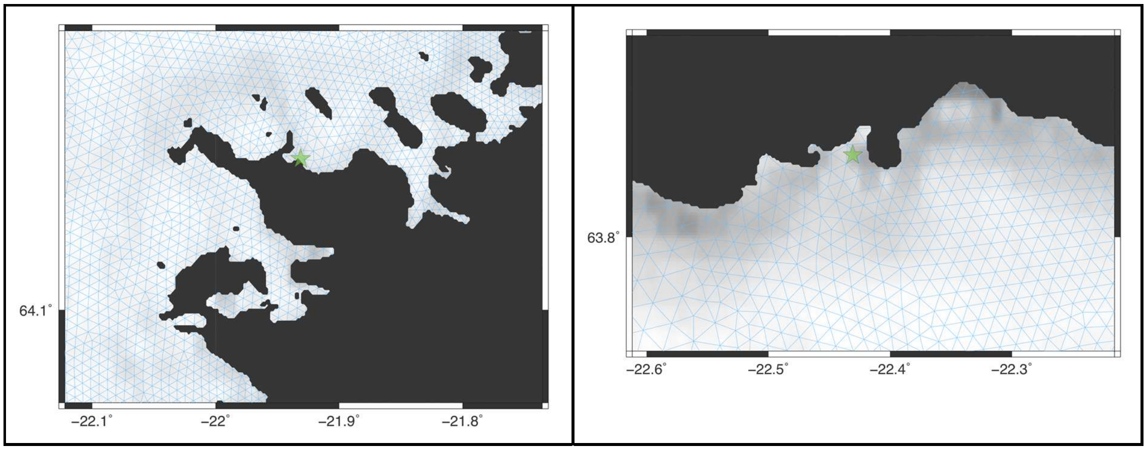
3D Shallow Water Equations and given the variable mesh size, the time solver also employs an adaptive time step, set to not exceed 70% of the CFL criterion, here 60 seconds.




**S4.** Left: Map of Reykjavík region with the computational mesh corresponding to this study. Right: Similar plot for the region of Grindavík. The plots also show the location of the computational point used for comparison in this study.

**Details on the filter used**

We used the same filter parameters as in our pilot study from South-West of Iceland.

The filter used to remove the high frequency variability in the observations is a standard Butterworth (1930) lowpass filter. In the setup here, it was important only to dampen variations faster than a 100 min but to retain slower variations, associated with the surge and the tides. Using a Buttwerworth lowpass filter with a 100 minutes cutoff, Figure S5 shows on the right panel, the power spectral density for the observations in Grindavik in February 2016, showing the tidal components with a large peak at M2 tide and furthermore, showing that the higher frequencies above 100 min (1e-02 1/min) have been removed from the spectrum. The resulting signal from this filter is shown on the right panel (red) comparing it with the original signal including its high frequency content.

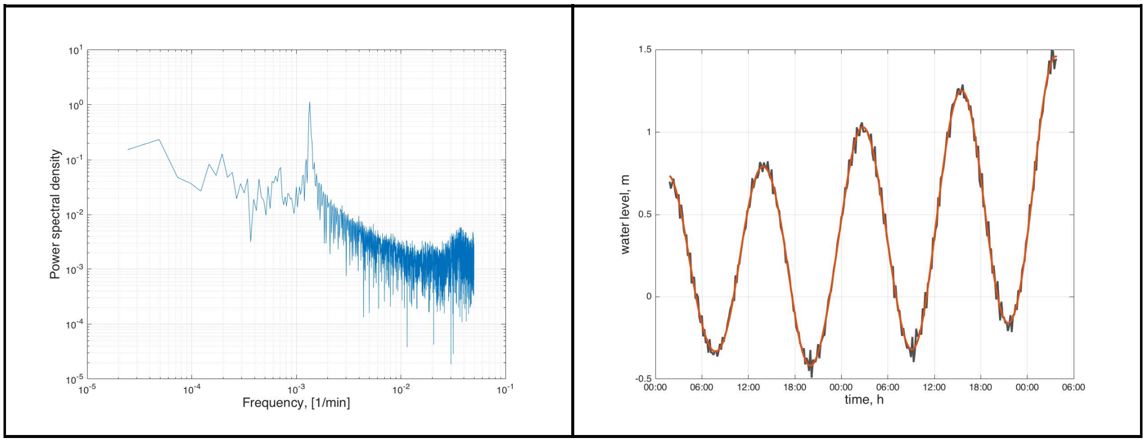



Figure S5. Left: Power spectral density for the water level observations at Grindavík in February 2016, showing the tidal constituents peaks but with the high frequency values removed, above 1e-02 (1/min) corresponding to values below 100 minutes. Right: The resulting signal shown in red and the original signal shown in gray.