BELGINGUR

Technical report

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Observed and simulated weather

Description of dynamical downscaling experiments for the water year 2014-2015 and comparison with observations

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Introduction

In the past decade and half, a number of dynamical downscaling experiments have been done for Iceland [see references 1 – 6]. In this report we compare the results of some of these [4, 5, 6] as well as a number of simulations spanning a single year, to observations of temperature, winds, precipitation and radiation for the water year[1] 2014-2015. The results are visualized as a stand-alone html-document [7].

Results of dynamical downscaling

The idea behind dynamical downscaling is relatively simple. Take output from a coarse resolution model, e.g. a Global Circulation Model (GCM), and use it to force a Limited Area Model (LAM) at a higher horizontal and vertical resolution. As resolution is increased, processes governed by the interaction of the large-scale flow and topography become better resolved by the models [4]. Here we present results from eleven different dynamical downscaling simulations. Ten of these have been created using the AR-WRF atmospheric model [8] and one using the Harmonie model [5]. Initial and boundary data are taken from the operational analysis from the European Centre for Medium range Weather Forecasts (ECMWF[2]) and the National Oceanic and Atmospheric Administration (NOAA[3]) as well as the ERA-Interim[4] and ERA-5[5] re-analysis projects. We also compare observations to Belgingur's operational weather forecasts, taken between forecast times T+6 and T+12 hours (i.e. 6 and 12 hours after the initiation of the forecast), run at 3 km horizontal resolution and forced by initial and boundary data from NOAA's global forecasting system[6].

Table 1 summarizes the abbreviations, different models, model versions and configurations used to create the various datasets.

Simulations are compared to observations from 198 surface station (cf. Figure 1) as well as observed winds and temperature from two height levels from a temporary mast that was erected in connection with the Búrfell wind farm project. The observation networks are operated by Landsnet (11), Landsvirkjun (48), Orkubú Vestfjarða (3), Siglingastofnun (11) and Veðurstofa Íslands (128).

For each location we calculate the following statistical parameters:

- Root Mean Square Error (RMSE)
- Mean Absolute Error (MAE)
- Bias
- Spearman's Rank correlation coefficient[7]
- Pearson correlation coefficient[8]

1 Here, water year is take from 1 September to 31 August
2 https://www.ecmwf.int
3 https://www.noaa.gov
4 https://www.ecmwf.int/en/elibrary/8174-era-interim-archive-version-20
5 https://www.ecmwf.int/en/elibrary/19027-global-reanalysis-goodbye-era-interim-hello-era5 and https://confluence.ecmwf.int/display/CKB/ERA5-Land%3A+data+documentation
6 https://nomads.ncep.noaa.gov/txt_descriptions/GFS_doc.shtml
7 https://en.wikipedia.org/wiki/Spearman%27s_rank_correlation_coefficient
8 https://en.wikipedia.org/wiki/Pearson_correlation_coefficient

This information is then gathered into box-plots, Q-Q and scatter plots for each variable[9] (cf. Figure 2). In addition, we compare observed seasonal and

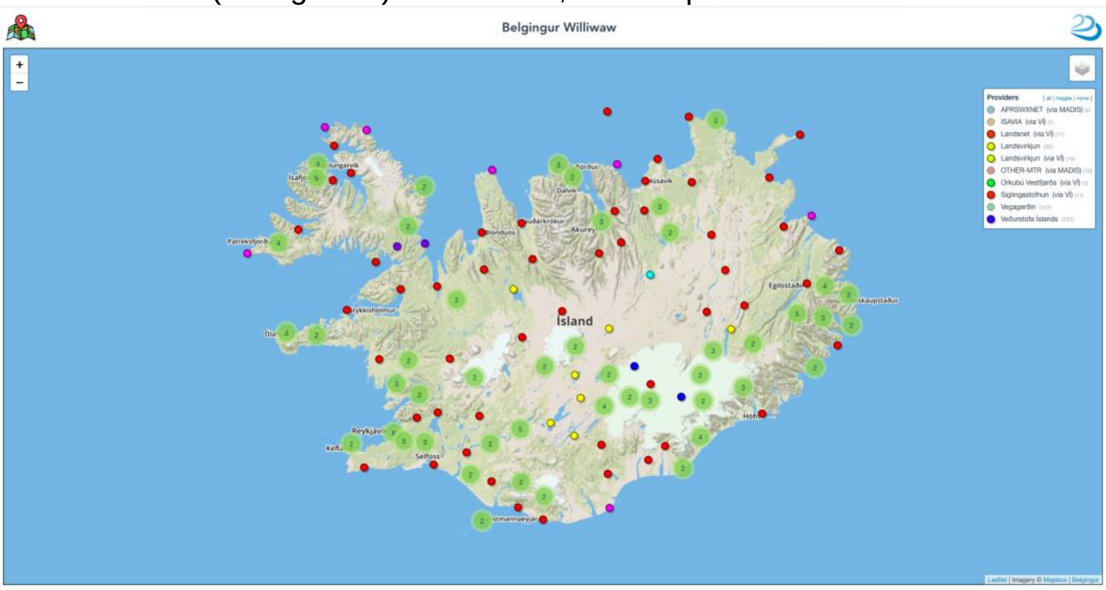

Figure 1: Overview map showing location of stations used for comparing observed and simulated values.

annual accumulated precipitation to simulated values. This certainly gives odd results for winter months as precipitation is notoriously difficult to observe in strong winds and cold weather [9].

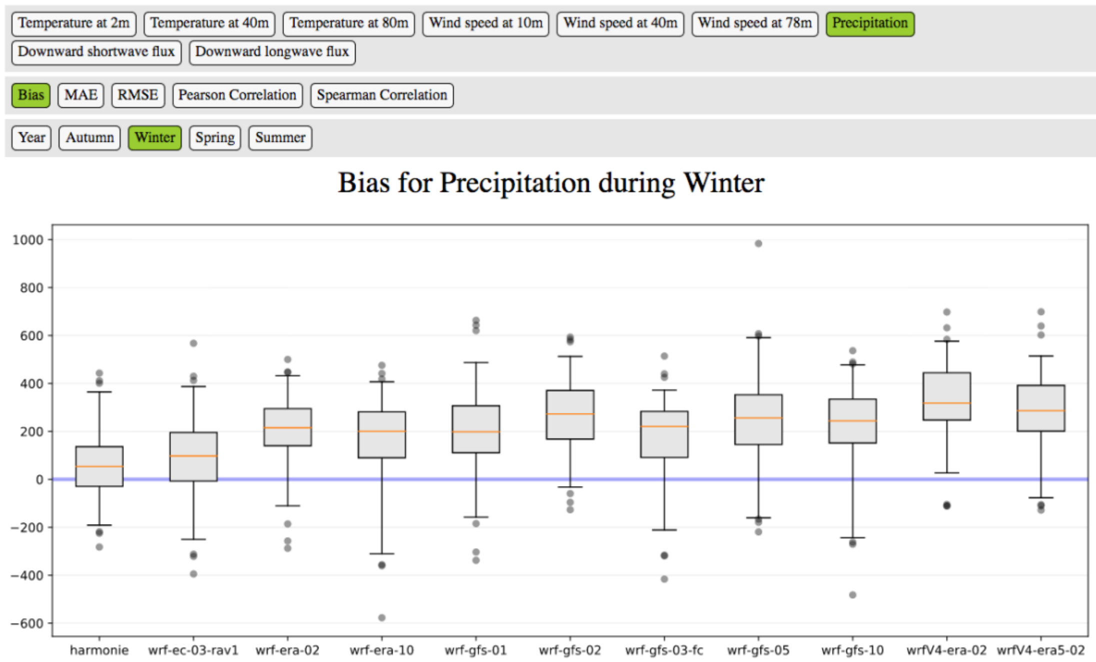

Figure 2: Snapshot from the html-document [7] depicting precipitation bias for the winter months (December, January and February) of 2014-2015.

To tackle these shortcomings, we also compare observed/modelled accumulated winter precipitation on chosen ice-caps to modelled precipitation for the same regions (cf. Figure 3 and [10]).

[9] Please note that inter-comparison plots for each location and variable are also available on-line - ftp://ftp.betravedur.is/pub/LV/lvc-itarefni.tar.gz

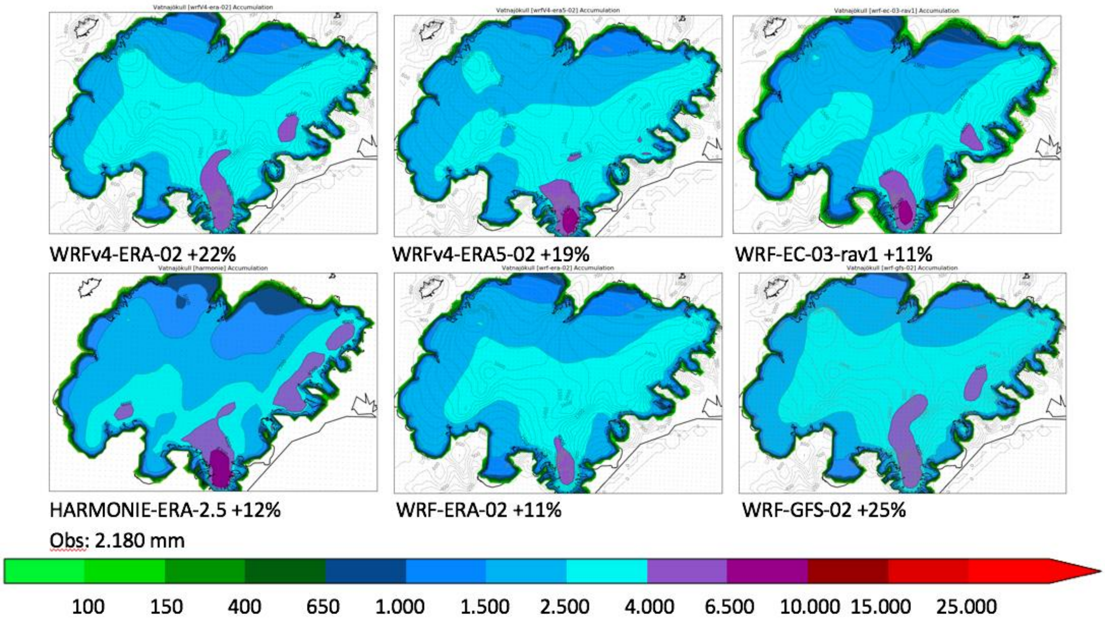

Figure 3: Example of inter-comparison of accumulated winter precipitation for Vatnajökull ice-cap from six of the eleven different model simulations. Percentage values show relative difference between observed and simulated.

Table 1: Summary of model configurations. The WRF-ERA-02 data is also known as the RÁV-II data series.

MODEL ABBREVIATION / VERSION	RESO-LUTION [KM] / # LEVELS	IC/BC DATA	CUMULUS SCHEME	PBL SCHEME	MICRO-PHYSICS	LW RAD SCHEME	SW RAD SCHEME	SURFACE LAYER	LAND SURFACE
HARMONIE / 38H1.2	2.5 / 65	ERA-Interim	AROME	AROME	AROME	AROME	AROME	SURFEX	SURFEX
WRF-EC-03-RAV1 / 3.0.1.1	3 / 55	ECMWF operational analysis	N/A	2EQ-Bao	Thompson	RRTM	Dudhia	ETA similarity	5-layer thermal diffusion
WRF-ERA-02 / 3.6.1	2 / 65	ERA-Interim	N/A	MYJ	Morrison	RRTMG	RRTMG	ETA similarity	NOAH
WRF-ERA-10 / 3.6.1	10 / 65	ERA-Interim	Grell-Freitas	MYJ	Morrison	RRTMG	RRTMG	ETA similarity	NOAH
WRF-GFS-01 / 3.6.1	1 / 65	GFS operational analysis	Grell 3D	MYJ	Morrison	RRTMG	RRTMG	ETA similarity	NOAH
WRF-GFS-02 / 3.6.1	2 / 65	GFS operational analysis	N/A	MYJ	Morrison	RRTMG	RRTMG	ETA similarity	NOAH
WRF-GFS-05 / 3.6.1	5 / 65	GFS operational analysis	Grell 3D	MYJ	Morrison	RRTMG	RRTMG	ETA similarity	NOAH
WRF-GFS-10 / 3.6.1	10 / 65	GFS operational analysis	Grell-Freitas	MYJ	Morrison	RRTMG	RRTMG	ETA similarity	NOAH
WRF-GFS-03-FC / 3.6.1	3 / 41	GFS operational forecast	N/A	MYJ	Morrison	RRTMG	RRTMG	ETA similarity	5-layer thermal diffusion
WRFV4-ERA-02 / 4.1	2 / 65	ERA-Interim	N/A	MYNN	Morrison	RRTMG	RRTMG	MYNN	NOAH MP
WRFV4-ERA5-02 / 4.1.2	2 / 51	ERA5 + ERA5-Land	N/A	MYNN	Thompson aerosol aware	RRTMG	RRTMG	MYNN	NOAH

General discussions

Precipitation (64 stations on annual basis)

When comparing precipitation observed by conventional rain gauges one would expect a different behavior during summer and winter months. In short, there is a greater loss in observed winter time precipitation due to stronger winds and colder temperatures (snow vs. liquid rain) compared to warmer (and calmer) summer months. Consequently, we would expect to see a greater bias in simulated winter time precipitation than in summer time precipitation, when compared with non-corrected values of observed precipitation from conventional rain gauges. This is indeed the case for the WRF simulations (cf. Figure 4) but not for the Harmonie simulation.

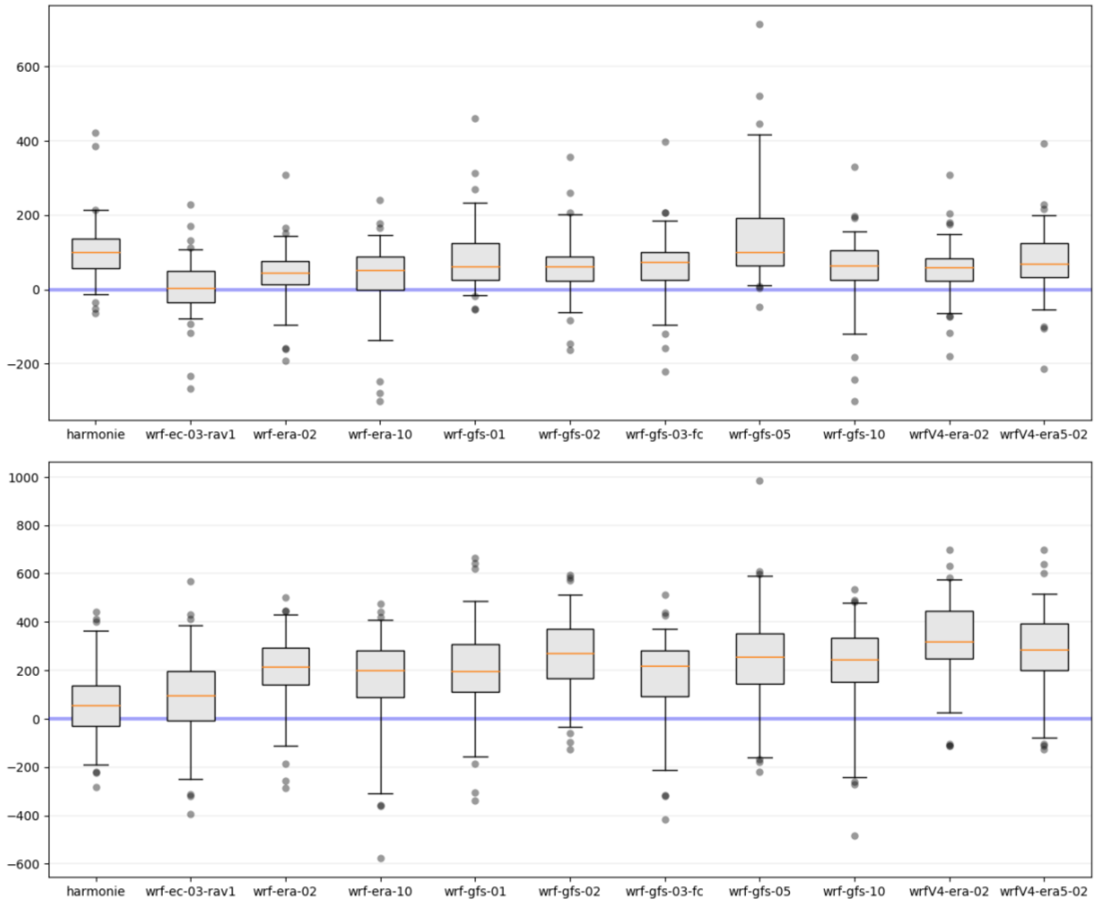

Figure 4: Observed summer (top) and winter time (bottom) bias for simulated precipitation.

Winds (138 stations on annual basis)

Comparisons of observed and simulated near-surface winds reveal that earlier versions of the WRF model tended to overestimate the wind speed. This overestimation has been greatly reduced in the most recent model versions leading to very similar biases to that of the Harmonie simulation. Observations of winds at height greater than 10 meters above ground level are sparse, but we do have relatively good data for the autumn months of 2014 (September through November) from a meteorological mast that was located close to Mt. Búrfell in S-Iceland (cf. Figure 5).

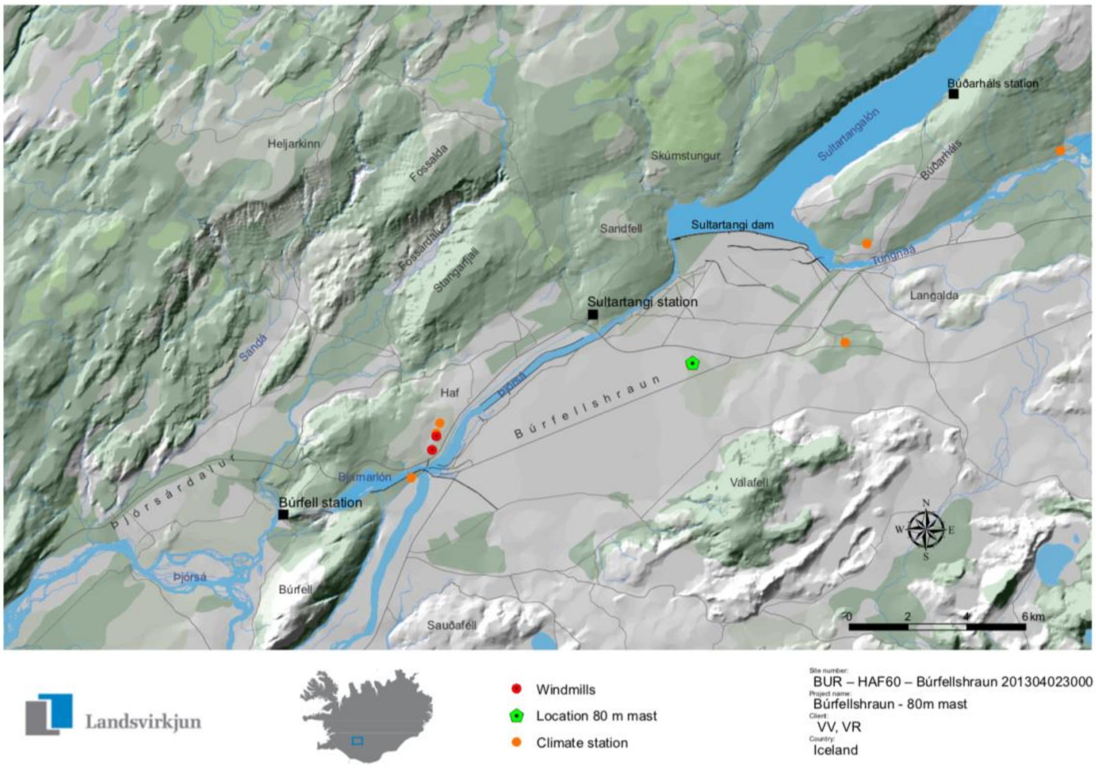

Figure 5: Location of Landsvirkjun meteorological mast is shown as a green dot approximately four kilometers south of the Sultartangi dam.

The 2 km resolution WRF simulations, that used the ERA-Interim and ERA5 re-analysis data, show a near zero bias when compared to observed winds at 40 and 78 meters height above ground level (magl). Furthermore, the simulation labeled as WRFV4-ERA5-02 in Table 1 is able to capture the statistical distribution of the observed wind speed at 40 and 78 magl with very good accuracy (cf. Figure 6).

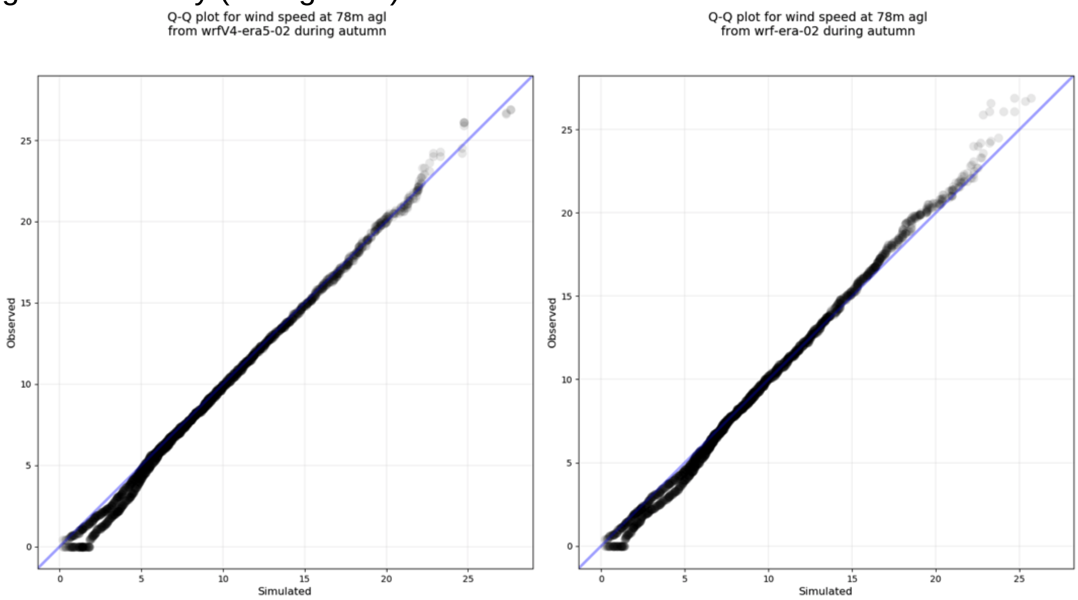

Figure 6: Q-Q plots of observed and simulated wind speed at 78 magl for the WRFV4-ERA5-02 (left) and WRF-ERA-02 (right) simulations. The WRFV4-ERA5-02 is successfully able to capture the distribution of the extreme observed values, values that are somewhat underestimated in the WRF-ERA-02 (aka RÁV-II) simulation.

Temperature (148 stations on annual basis)
The 2 km resolution WRF simulations, using ERA-Interim or the ERA5 re-analysis, and the Harmonie simulation show a very similar temperature bias during the winter months, or about -1°C. The 2 km resolution WRF simulation that is forced with the GFS analysis has about 0.5°C less bias. This may be

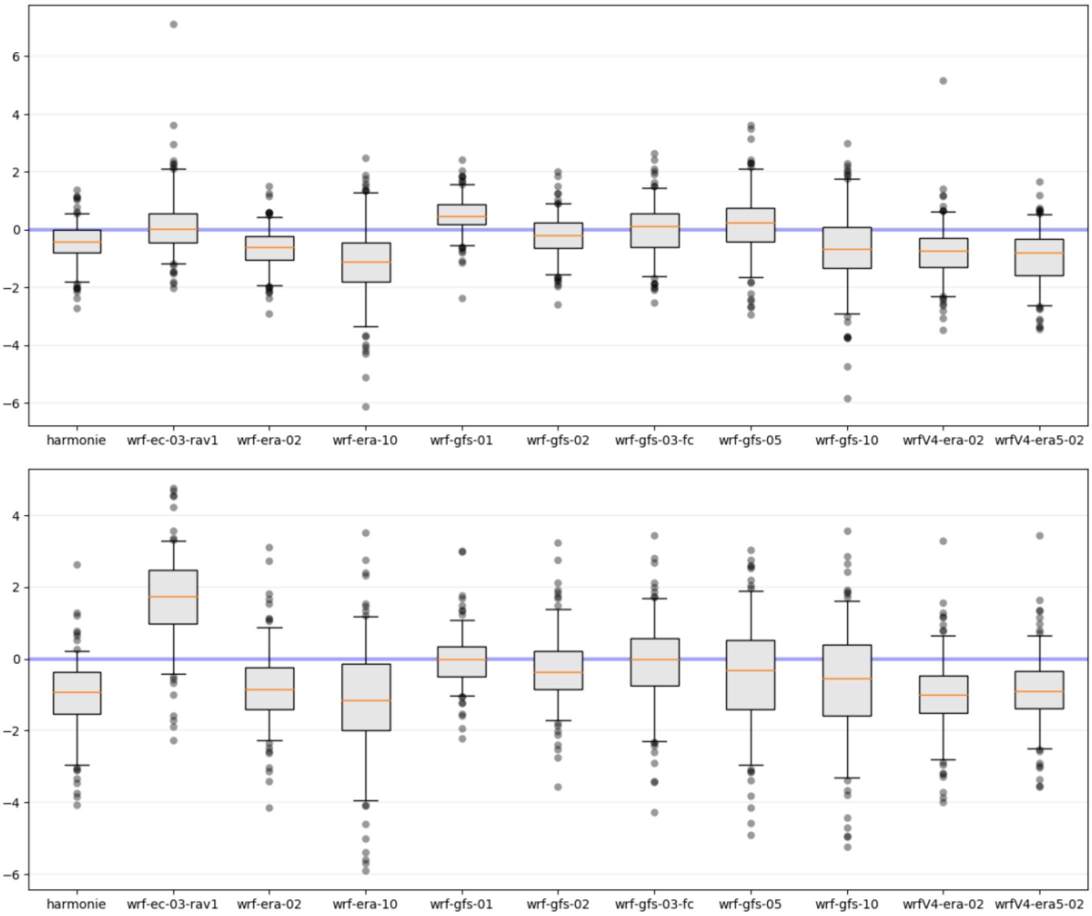

Figure 7: Observed model bias for temperature at 2 magl for summer (top) and winter (bottom).

an indication of that the ERA-based re-analysis have a slightly colder bias than the operational GFS analysis. The old RÁV1 configuration has a very distinct warm winter bias compared to all the other simulations. The results for the Harmonie simulation need to be taken with a pinch of salt as the model was nudged with observations of surface temperature. We have however been unable to find out which stations were used for this. Hence, we are surely comparing modeled temperature to, at least to some extent, to station data that have been used to nudge said model simulation.

Radiation (11 stations over summer months)
Landsvirkjun operates a number of weather stations that observe incoming short-wave radiation fluxes during summer and autumn months. This data has been compared to simulated values. The observed bias is in general within ±50 W/m2 (cf. Figure 8), the exception being the old RÁV1 configuration and the 5 and 1 km resolution WRF simulations.

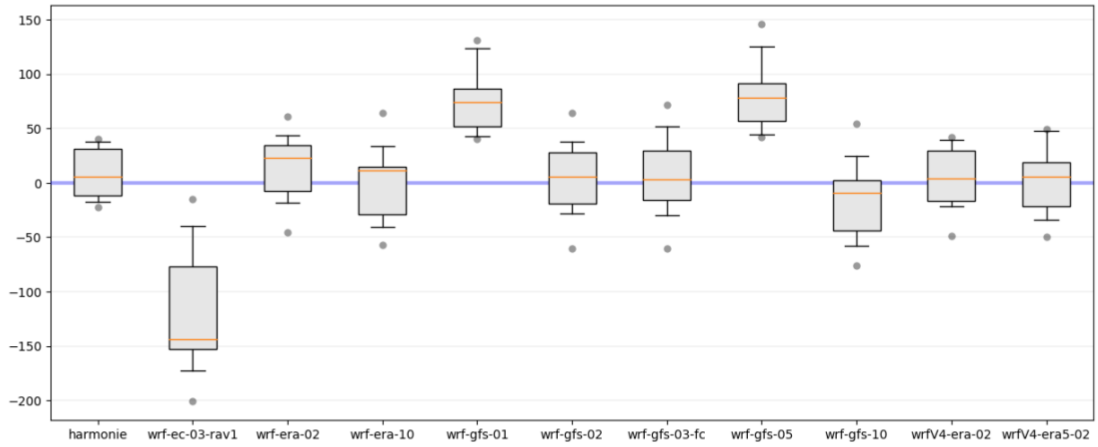

Figure 8: Model bias of incoming short-wave solar radiation fluxes [W/m2] for the summer months of 2015 (June through August).

None of the models are however able to capture the maximum observed fluxes (cf. Figure 9) that are most likely linked to downward reflection from low level clouds and/or fog over snow covered or glaciated surface.

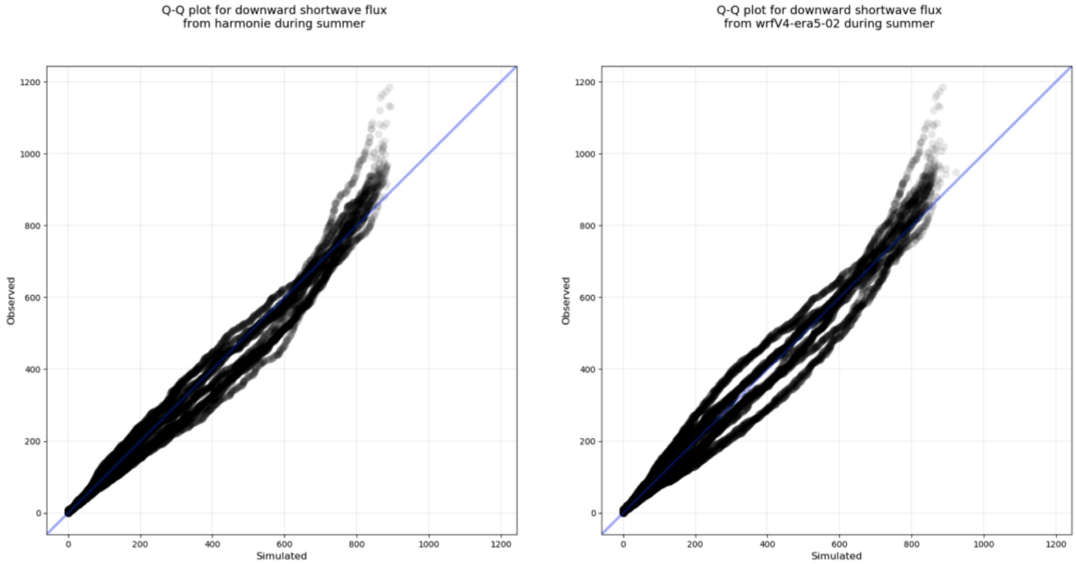

Figure 9: Q-Q plot comparing observed (vertical axis) and simulated (horizontal axis) incoming short-wave solar radiation [W/m2] from the Harmonie (left) and WRFV4-ERA5-02 (right) models.

Accumulated winter time precipitation on ice-caps

Table 2 shows the relative difference between observed (with a dash of modeling) and simulated accumulated winter precipitation for the Hofsjökull, Langjökull and Vatnajökull ice-caps in central and SE-Iceland.

Table 2: Comparison of observed and simulated winter time precipitation for the three large ice-caps in central and SE-Iceland.

	OBSERVED	WRF-ERA10	WRF-GFS10	WRF-GFS05	WRF-GFS03	Harmonie	WRF-ERA02	WRF-GFS02	WRF-GFS01	WRF-EC-03-rav1	WRFv4-ERA-02	WRFv4-ERA5-02
Hofsjökull	2010	1638	1794	2485	2161	2496	1739	1945	2469	2159	1931	2200
Langjökull	2440	2115	2217	3052	2611	3212	2183	2353	2966	2628	2494	2688
Vatnajökull	2180	2321	2591	2739	2821	2431	2426	2725	2734	2420	2662	2603
Hofsjökull	100 %	-19 %	-11 %	24 %	8 %	24 %	-13 %	-3 %	23 %	7 %	-4 %	9 %
Langjökull	100 %	-13 %	-9 %	25 %	7 %	32 %	-11 %	-4 %	22 %	8 %	2 %	10 %
Vatnajökull	100 %	6 %	19 %	26 %	29 %	12 %	11 %	25 %	25 %	11 %	22 %	19 %

More detailed information can be found in [10]. The least successful simulations are the 5 and 1 km WRF configuration. Why this is the case is unclear, but a couple of reasons come to mind. One is that the choice of using a cumulus scheme, even if it is meant to be suitable for resolution less than 5 km, was a poor one. Also, it may be that a horizontal resolution of 5 km (the resolution of the outer domain) simply falls within the so-called gray zone for convective processes (for references discussing the gray zone we refer to [11] and [12]).

The (relatively) old RÁV1 configuration is quite successful in simulating the accumulated winter time precipitation on the three large ice-caps. But it is by far the least successful when it comes to simulating radiation fluxes, near surface winds and temperature.

The 10 km resolution WRF simulations, driven by the ERA-Interim and GFS analysis, underestimate the accumulated precipitation on the central ice-caps Hofsjökull and Langjökull (as does the 2 km WRF-ERA-02, aka RÁV-II, simulation). All simulations overestimate the accumulation on Vatnajökull ice-cap, compared to the observed/modelled value. The results from the Harmonie simulation differ from the one's from the WRF model in the sense that the relative overestimation (again, as compared to the observed/modelled values) of winter precipitation on the central ice-caps is considerably greater than that of Vatnajökull ice-cap. For WRF, the simulated values on the central ice-caps are either less than observed one's, or no more than 10% in excess. Note that the 5 and 1 km configuration is an exception from this rule.

Summary

Results from simulated weather, using eleven different models and/or model configurations, have been compared to observations from over 320 weather stations in Iceland for the water year 2014-2015. In addition, simulations have been compared to observations from two height intervals in the Búrfell meteorological mast as well as to accumulated winter time precipitation from three large ice-caps in Iceland.

These findings have been integrated into a stand-alone html-document, made available on the internet [7]. Once downloaded, the user can view various statistical parameters for a number of variables and time periods.

Acknowledgements

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