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Replies to Specific Comments Regarding the Final Report on the *"Establishing Operational Capacity for Building, Deploying and Using Numerical Weather and Seasonal Prediction Systems in SIDS Africa"* Project

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Prepared for UNECA

Short report
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ÍSOR Orkugarði Grensásvegi 9

Replies to specific comments regarding the final report on the *"Establishing Operational Capacity for Building, Deploying and Using Numerical Weather and Seasonal Prediction Systems in SIDS Africa"* project (ÍSOR-2017/028).

A- General: Compliance with report structure and the terms of the Agreement

Replies to comments regarding outputs #1 and #2

Question: Why was the infrastructure installed in Iceland, Cabo Verde and the Seychelles and not at UNECA and the other four SIDs countries (i.e. Guinea-Bissau, São Tomé and Príncipe, Comoros, and Mauritius)?

Answer: In the Letter of Agreement (LoA) signed by ÍSOR and UNECA in June 2015, the necessary infrastructure needed for operating the Weather On Demand forecasting system is described thusly (page 9):

1. Server room with a minimum of 2MB per second internet bandwidth
2. Un-interrupted power supply with a standby capacity of 10KW and air-conditioned in a regulated environment
3. A systems administrator and assistant to administer the system on a daily basis

Two configurations are described, one suitable for creating high resolution forecasts for individual SIDs countries, with estimated hardware cost around 35.000,00 USD. The second configuration was envisioned to be able to simulate a ten day, medium resolution forecast covering the Pan-African continent. The hardware cost of this configuration was estimated to be 150.000,00 USD.

At the time of signature of the LoA it had already been established that the INMG in Cabo Verde did fulfil the infrastructure criteria described above. This had been established during a visit of Dr. Ólafur Rögnvaldsson to the INMG headquarters on Ihla da Sal in spring 2015. Furthermore, the meteorological agencies of the Seychelles and Mauritius were deemed to have sufficiently strong infrastructure to host the forecasting systems. As the project progressed, Guinea-Bissau was added to the list, perhaps somewhat prematurely. In addition, the idea was to eventually host the largest hardware configuration at UNECA's headquarters in Addis Ababa.

In light of this, and funding available, it was decided to purchase three "small" and one "large" hardware configuration. The total cost of the computer hardware was 240.000,00 USD.

At the request of the project's leader, Dr. Joseph Intsiful at UNECA, the three small configurations were shipped to Cabo Verde, the Seychelles and Guinea-Bissau in the first and second quarter of 2016. The systems are fully operational at Cabo Verde and the Seychelles. The system in Guinea-Bissau is still off-line. However, UNDP and the National Institute of Meteorology of Guinea-Bissau are working on solutions to secure network and power connections, as well as the on-site installation of the forecasting system. The large configuration has been (and still is) operated by ÍSOR/Belgingur in Iceland, at their own cost.

Replies to comments regarding outputs #3, #4, and #6

Question: How does the operational forecasting system, both website and underlying software, comply with outputs #3, #4, and #6, i.e. community of practice and forecast verification?

Answer: In the LoA the metrics for verifying these outputs are listed as "Official installation reports". However, as the installation process, and consequently the system upgrade process, is fully automated this type of reporting would be overly technical. A more realistic metric of success are the websites[1,2,3] themselves were forecasts are automatically updated along with the verification metrics (cf. Figs. 1 to 5).

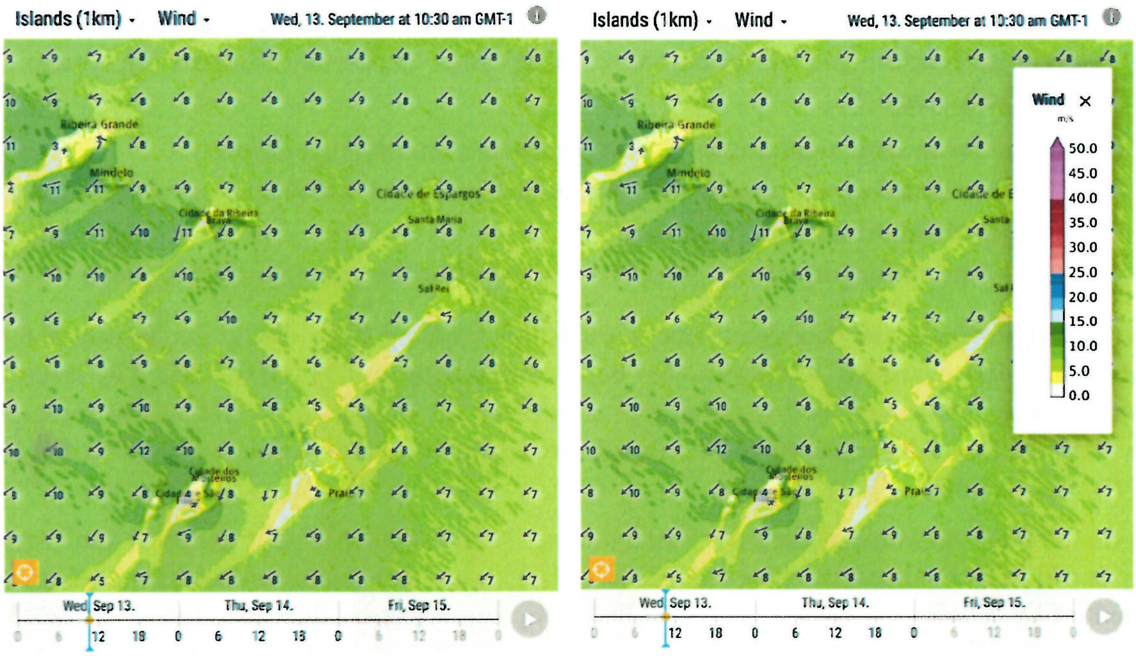

Figure 1. *Example of a high-resolution wind forecast for the Cabo Verde islands with (right panel) and without (left panel) wind speed caption. Downloaded from* http://www.inmg-wod.org/ *on 2017-09-13.*

1 http://inmg-wod.org/en

2 http://syn.meteo.gov.sc/

3 http://uneca.belgingur.is/

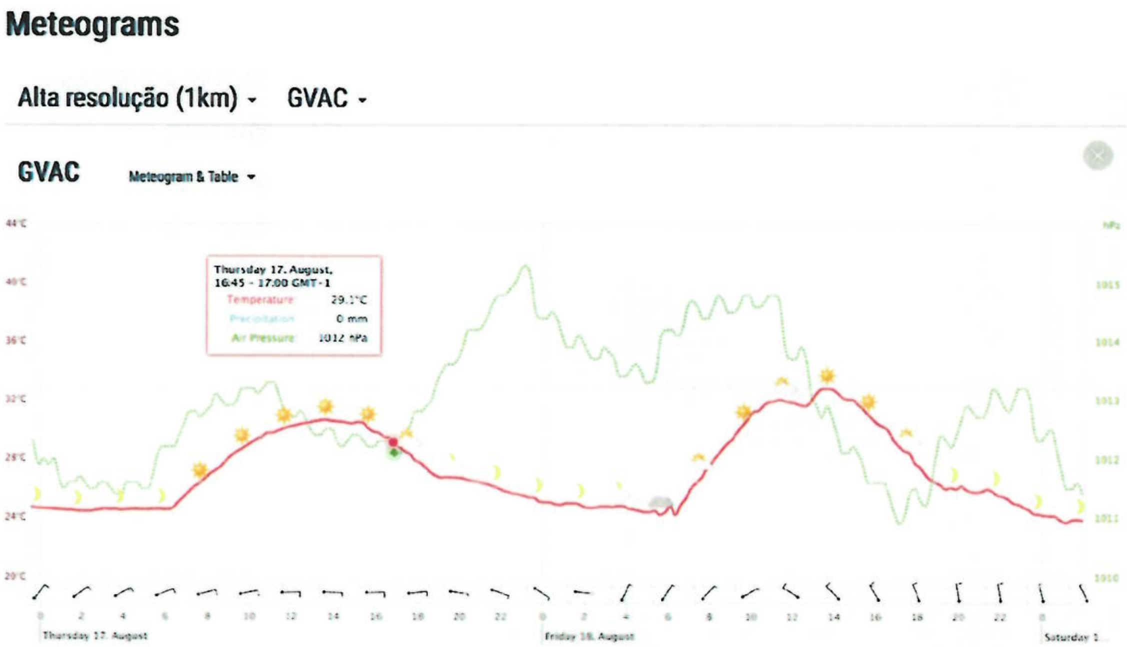

Figure 2. *Example of a meteogram depicting a 48-hour high-resolution forecast for Ihla da Sal on Cabo Verde. The user can also choose to view the forecast as an hour-by-hour table (not shown). Downloaded from* [*http://www.inmg-wod.org*](http://www.inmg-wod.org) *on 2017-09-13.*

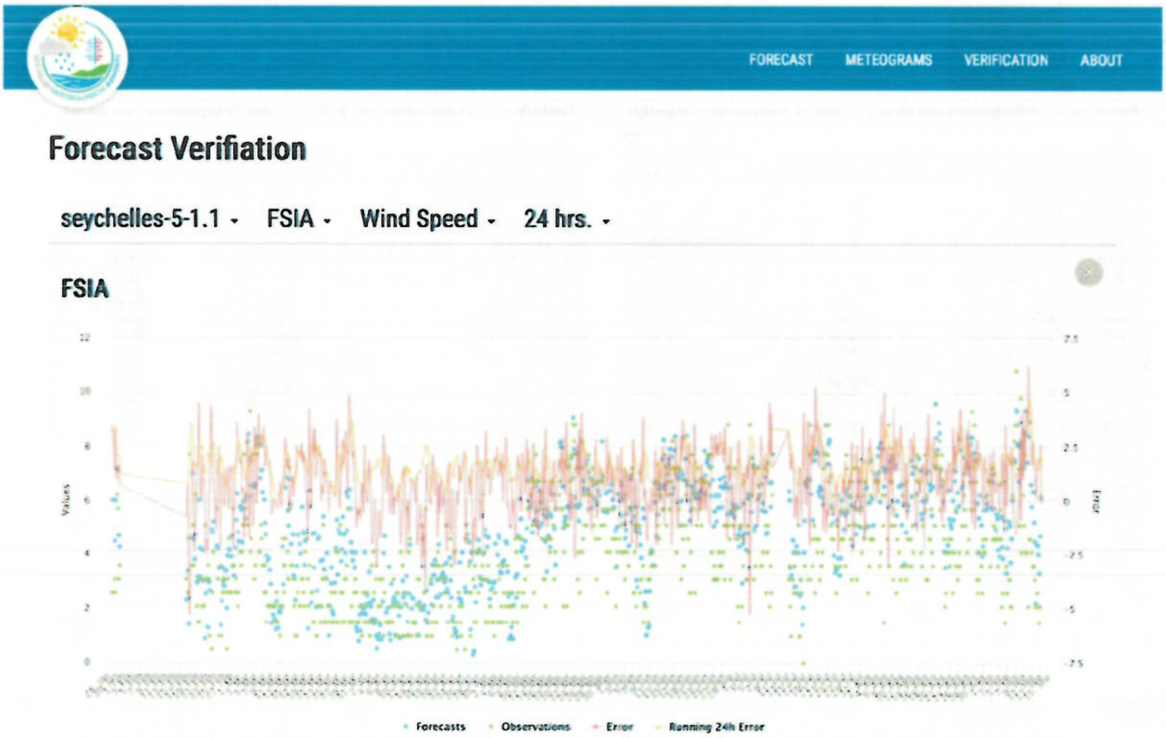

Figure 3. *Example of a histogram comparing 24-hour forecasts of wind speed to observations at the Seychelles international airport on the island of Mahe. Downloaded from* [*http://syn.meteo.gov.sc*](http://syn.meteo.gov.sc) *on 2017-09-13.*

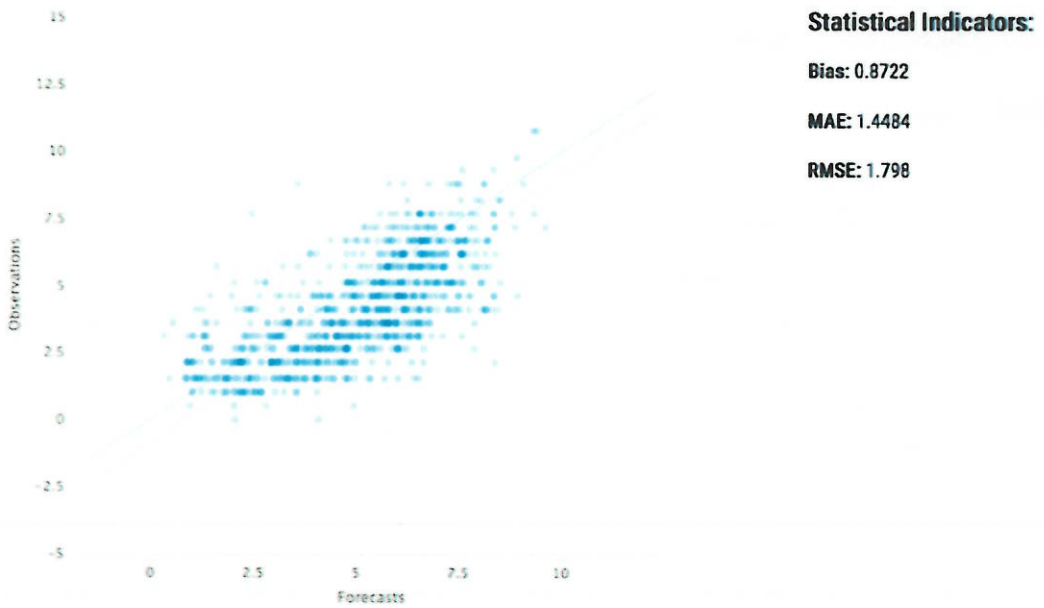

Figure 4. *Same data as shown in Fig. 3, but now depicted as a scatter-gram. Downloaded from http://syn.meteo.gov.sc on 2017-09-13.*

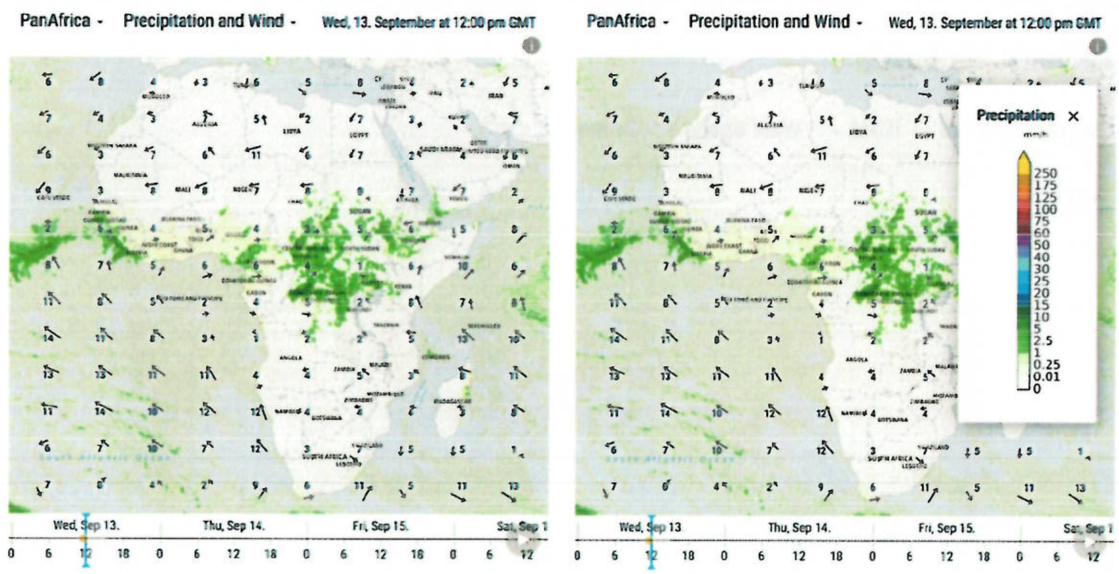

Figure 5. *Example of a medium-resolution wind and precipitation forecast for the Pan-Africa continent with (right panel) and without (left panel) precipitation amount caption. Downloaded from http://uneca.belgingur.is/ on 2017-09-13.*

Forecasts, and observations for individual locations can also be accessed directly from the WeatherHill database itself using standard SQL commands. The data can then be processed using standard software tools such as excel and/or software provided by ÍSOR/Belgingur and demonstrated during the WISER meeting in Addis Ababa in February 2017. The software code is available on-line[4] and the WISER concept-notes by ÍSOR/Belgingur are further attached to this report in appendices II to IV.

The system itself has also been documented [1,2], both in the form of written reports and, more recently, as a live wiki website[5] were all the latest developments and changes made to the system are documented. It is foreseen that this website will in due time make the written system documentation obsolete.

Replies to comments regarding outputs #5 and #7

Question: How is the system being used by national weather agencies to provide support and service to local stakeholders?

Answer: See attached document from Mr. Nelson Lalande, Principal Technical Support Officer of the Seychelles Meteorological Authority.

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4 ftp://ftp.betravedur.is/pub/code/wiser-cr4d-AddisFeb2017/

5 https://github.com/Belgingur/WOD-Documentation/wiki

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Admin Form 002

Dr. Ólafur Rögnvaldsson
Belgingur - www.belgingur.eu

Re: Seychelles Weather on Demand Forecasting System

The above mentioned system is basically being used by our local forecasters to provide meteorological support and services to stakeholders and the public as a whole.
Experimentation with such system within the last few months had enabled our institution to:
1. Compare WOD's forecast model with other regional and global models. Such allows us to come up with more refined forecast for the Seychelles islands as a whole.
2. The location specific forecasts also enable our forecasters to determine what is actually happening in terms of weather around various parts of the islands. The system can at least give indications of where weather events is expected to happen though accuracy is an issue in terms of weather parameters projected with timeline.
3. It is also of assistance in making comparison between high resolution and long term forecasts within our territorial jurisdictions
4. Within the interface, the meteogram button has 2 good options that would be quite meaningful to the public "Tabular and graphical". Such Information can basically allow people to plan and make decisions regarding their daily activities.
5. Disadvantage→ with the existing forecast verification method, forecasters cannot compare what is actually happening in terms of weather parameters and what was projected as forecast from the system models itself.
This is because we do not have AWS stations installed on all these sites; therefore we are limited in carrying out forecast verification exercises to validate the forecast provided by WOD.

N. Lalande (Mr)
Principal Technical Support Officer

For: Chief Executive Officer

I Love Seychelles
Mon Kontan Sesel
J'aime les Seychelles

B- Financial report

Summary of expenses

Item	Cost in USD
Hardware	239 897
Compiler	5 049
Belgingur work	347 507
Webdesign	75 008
Computer cluster work	10 998
Storm surge modeling	3 000
Item-Id (see page 66/114)	110 708
TOTAL	792 168

	Short description	Belgingur person-hours	Belgingur work	Hardware cost	Compiler	Webdesing	Computer cluster work	Storm surge modeling	Item-Id	Total cost per output
Output 1	Forecasting system established	86	17 298	83 964	1 767		7 149			110 178
Output 2	E-infrastructure for NWP, data and information management established	801	160 266	155 933	3 282		3 849			323 330
Output 3	Community of Practise in NWP established	170	34 066						33 213	67 279
Output 4	Community of Practise in development, use and management of E-infrastructure established	88	17 549			25 003		3 000	33 213	78 764
Output 5	Core products produced and validated	65	13 076			25 003			33 213	71 291
Output 6	Forecast verfication system established	418	83 531							83 531
Output 7	Prediction products widely disseminated	109	21 721			25 003			11 071	57 795
	TOTAL	1 738	347 507	239 897	5 049	75 008	10 998	3 000	110 708	792 168

ÍSOR Iceland GeoSurvey

FINANCE MANAGER

References

[1] Stanislawska, K., Ragnarsson, L., and Rögnvaldsson, Ó. (2016). *WOD – Weather On Demand System Description and User Manual*. Iceland GeoSurvey, short report, ÍSOR-16022.

[2] Stanislawska, K., and Rögnvaldsson, Ó. (2016). *General Description of Belgingur's Quality Assurance System for Automatic Weather Observations and the WeatherHills Database*. Iceland GeoSurvey, short report, ÍSOR-16059.

Appendices:

Appendix – I: Hardware list of computer clusters sent to Cabo Verde, Guinea-Bissau, and the Seychelles islands

Appendix – II: Ólafsson, H., and Rögnvaldsson, Ó, 2017: Application aspects of verification of numerical simulations of the atmosphere

Appendix – III: Rögnvaldsson, Ó., and Hackerott, J., 2017: Energy applications and tools

Appendix – IV: Ragnarsson, L., 2017: Forecast verification – hands-on exercises

Appendix I – Hardware list of computer clusters sent to Cabo Verde, Guinea-Bissau, and the Seychelles islands

Hardware list for the Cape Verde INMG

The system consists of:

- One Hewlett Packard Apollo 2000 server (S/N provided) with four internal compute nodes (individual S/N provided)
- One Hewlett Packard DL380 G9 server (S/N provided)
- One 8-port 10GBit switch from D-Link (S/N provided)
- One 12-port InfiniBand switch from Mellanox (S/N provided)
- One 8-port Ethernet switch from Planet (S/N not provided)
- Four InfiniBand cables
- Eleven Ethernet cables
- Nine power cords

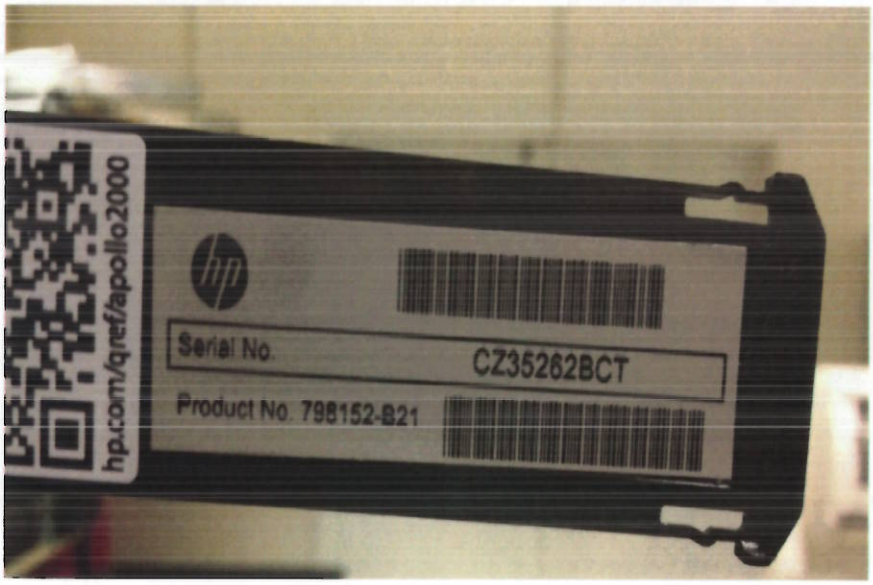

Figure 1: S/N of the Apollo 2000 server

Figure 2: S/N of the individual compute nodes of the Apollo 2000 server

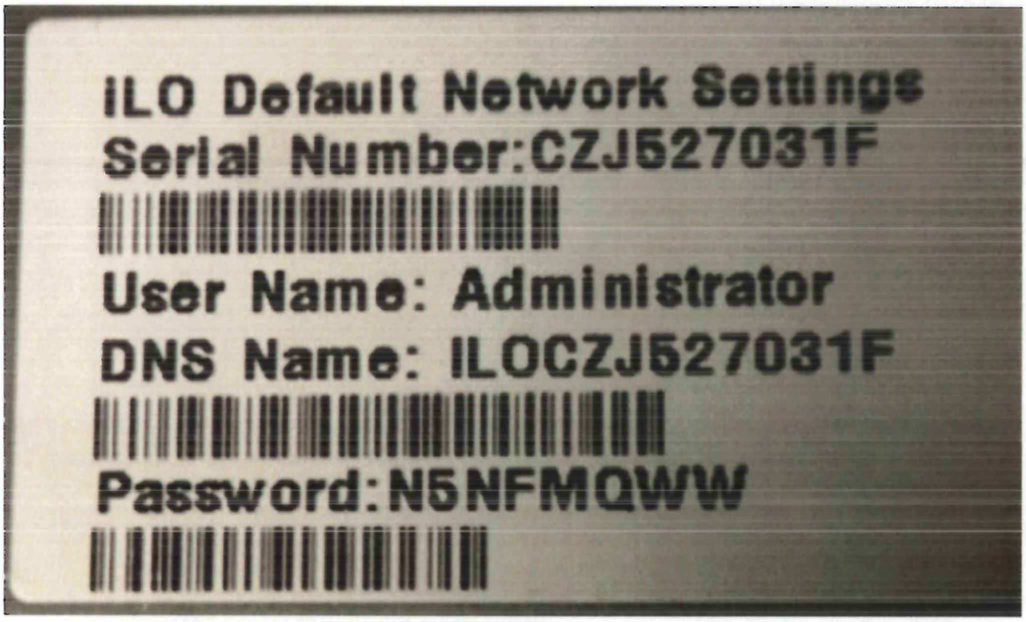

Figure 3: S/N of the DL380 G9 server

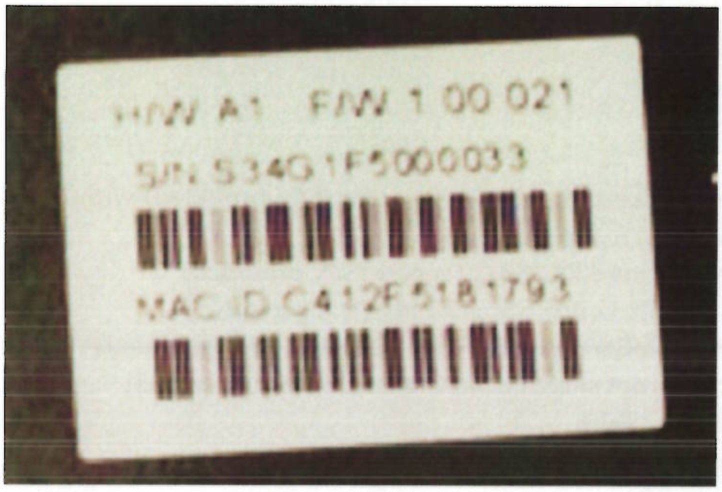

Figure 4: S/N of the 10GBit D-Link switch (S34G1F5000033)

Figure 5: S/N for the Mellanox InfiniBand switch

Break-down of the servers

The Apollo 2000 box consists of four servers. Each server has two 8-core Intel E5-2640 V3 CPUs, adding up to 64 cores. The Apollo box has 256 GB of RAM and eight 4-TB 3.5" SATA hard-drives (two per compute node). Each compute note has one 10Gbit card and one FDR InfiniBand card. The Apollo box has two 800W power supplies.

The DL380 G9 server has two 12-core Intel E5-2680 V3 CPUs, adding up to 24 cores. The server has 128 GB of RAM and eight 4-TB 3.5" SATA hard-drives. Like the Apollo box, the G9 server has one 10Gbit card. The server has two 500W power supplies.

Hardware list for the Guinea-Bissau Met. Office

The system consists of:

- One Hewlett Packard Apollo 2000 server (S/N provided) with four internal compute nodes (individual S/N provided)
- One Hewlett Packard DL380 G9 server (S/N provided)
- One 8-port 10GBit switch from D-Link (S/N provided)
- One 12-port InfiniBand switch from Mellanox (S/N provided)
- One 8-port Ethernet switch from Planet (S/N not provided)
- Four InfiniBand cables
- Eleven Ethernet cables
- Nine power cords

Figure 6: S/N of the Apollo 2000 server

Figure 7: S/N of the individual compute nodes of the Apollo 2000 server.

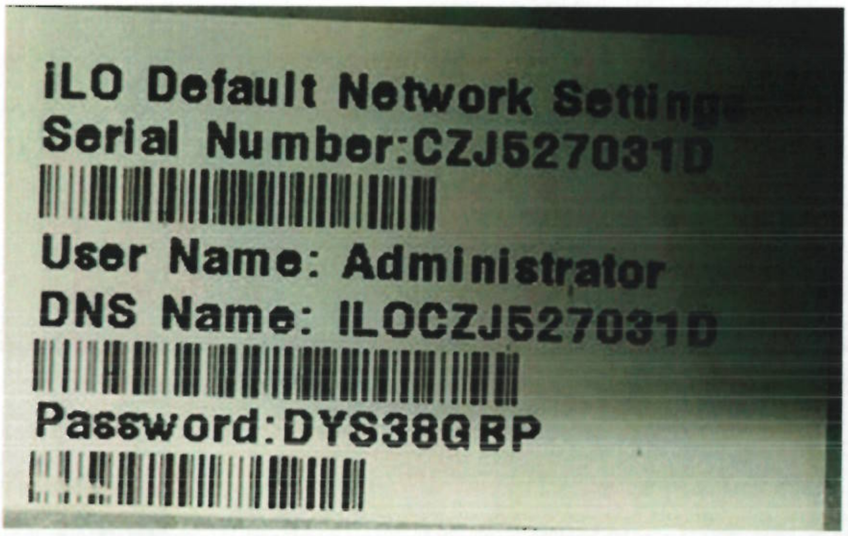

Figure 8: S/N of the DL380 G9 server

Figure 9: S/N of the 10GBit D-Link switch (S34G1F5000033)

Figure 10: S/N for the Mellanox InfiniBand switch

Break-down of the servers

The Apollo 2000 box consists of four servers. Each server has two 8-core Intel E5-2640 V3 CPUs, adding up to 64 cores. The Apollo box has 256 GB of RAM and eight 4-TB 3.5" SATA hard-drives (two per compute node). Each compute note has one 10Gbit card and one FDR InfiniBand card. The Apollo box has two 800W power supplies.

The DL380 G9 server has two 12-core Intel E5-2680 V3 CPUs, adding up to 24 cores. The server has 128 GB of RAM and eight 4-TB 3.5" SATA hard-drives. Like the Apollo box, the G9 server has one 10Gbit card. The server has two 500W power supplies.

Hardware list for the Seychelles Met. Office

The system consists of:

- One Hewlett Packard Apollo 2000 server (S/N provided) with four internal compute nodes (individual S/N provided)
- One Hewlett Packard DL380 G9 server (S/N provided)
- One 8-port 10GBit switch from D-Link (S/N provided)
- One 12-port InfiniBand switch from Mellanox (S/N provided)
- One 8-port Ethernet switch from Planet (S/N not provided)
- Four InfiniBand cables
- Eleven Ethernet cables
- Nine power cords

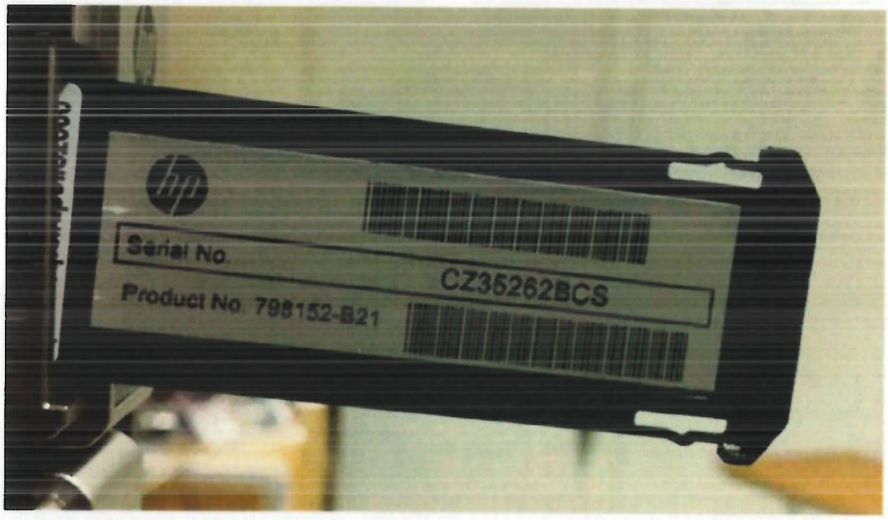

Figure 11: S/N of the Apollo 2000 server

Figure 12: S/N of the individual compute nodes of the Apollo 2000 server.

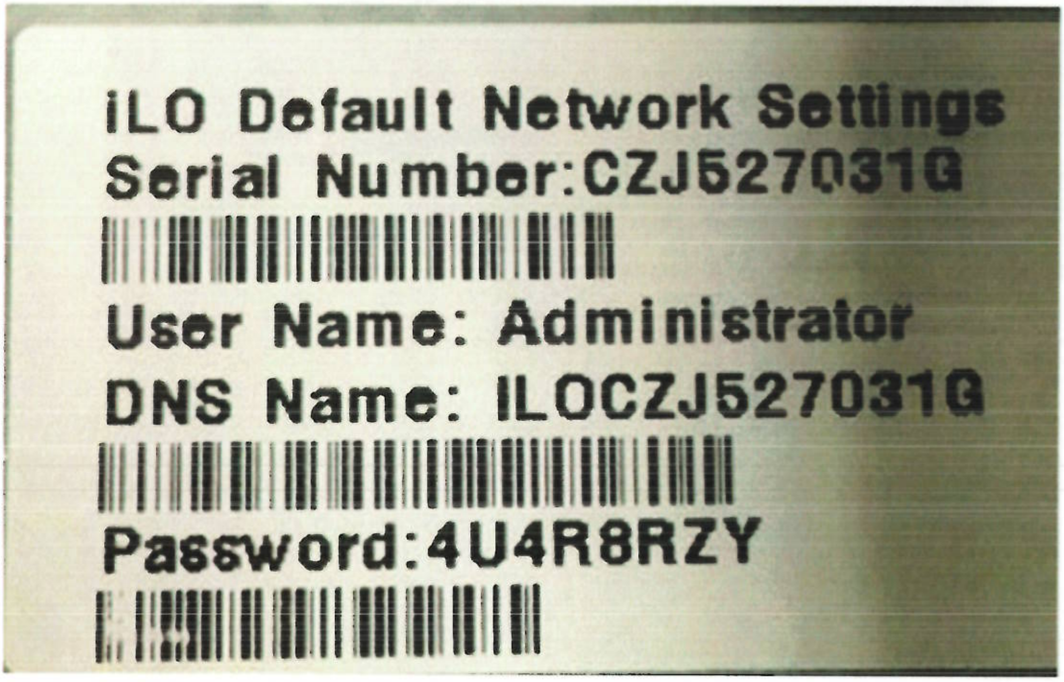

Figure 13: S/N of the DL380 G9 server

Figure 14: S/N of the 10GBit D-Link switch (S34G1F5000033)

Figure 15: S/N for the Mellanox InfiniBand switch

Break-down of the servers

The Apollo 2000 box consists of four servers. Each server has two 8-core Intel E5-2640 V3 CPUs, adding up to 64 cores. The Apollo box has 256 GB of RAM and eight 4-TB 3.5" SATA hard-drives (two per compute node). Each compute note has one 10Gbit card and one FDR InfiniBand card. The Apollo box has two 800W power supplies.

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Appendix II – Application aspects of verification of numerical simulations of the atmosphere

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Introduction

There are multiple reasons for verification of numerical simulations of the atmosphere. First of all, it is important for the user to know the quality of the numerical forecast, and more importantly, when it is reliable and when it is less reliable. Secondly, it is a fundamental element in the progress of improving the forecast systems to know their weaknesses and errors. Here, we shall introduce some elementary tools to monitor forecast quality quasi-automatically. We shall then discuss the importance of analyzing errors and linking them to specific weather conditions or situations. The concept of user driven verification will be discussed and a method of comparing good and bad forecasts will be introduced briefly.

Verification

A simple first thing to install together with a numerical weather prediction system is an automatic calculation of some basic functions that compare point observations to forecasts. Some of these functions are shown in Fig. 1. The MAE and RMSE show a similar pattern, but the RMSE penalizes large errors more than the MAE. Both functions are widely used so to facilitate comparison with others, it may be best to calculate both. The bias shows if the model deviates systematically to one side (gives systematically too low temperatures, too strong wind etc.). A simple way to improve the MAE or the RMSE is to subtract the bias from the direct model output. The Brier score is suitable for probabilistic forecasts and will not be discussed further here. The correlation coefficient is often used, not only in forecasts but in all sorts of comparison of datasets. If the correlation is 1, the forecast is perfect, while if the correlation is 0, there is no connection between the observed and forecasted values. The correlation coefficient may however not always be useful and Fig. 2 illustrates such an example. Let us consider a model predicting temperatures during day and during night corresponding to the two clusters in Fig. 2. Within the day-data and the night-data, the model has no skill. There is however a very high correlation between the model and the observations, if both the day and the night are binned together. We do however not need a model to tell us if it is day or night and the real value of the forecast is zero even if the correlation coefficient is high.

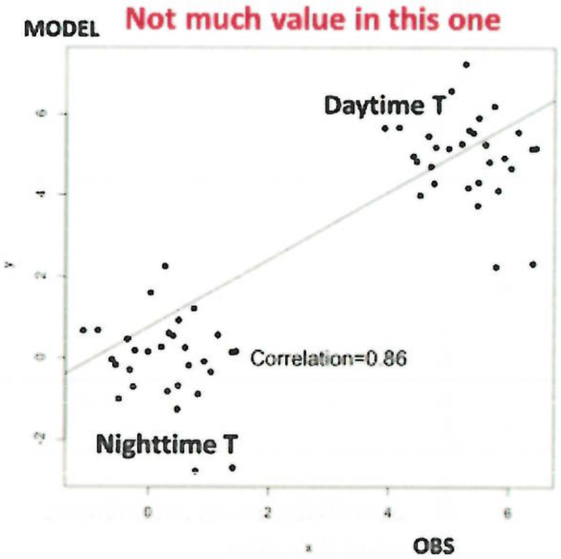
$$\mathrm{MAE} = \frac{1}{n}\sum_{j=1}^{n} |y_j - \hat{y}_j|$$ Mean absolute error

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(y_j - \hat{y}_j)^2}$$ Root mean square error

$$\mathrm{bias} = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)}{n}$$ Bias

$$BS = \frac{1}{N}\sum_{t=1}^{N}(f_t - o_t)^2$$ Brier score

Figure 1. Some statistical functions

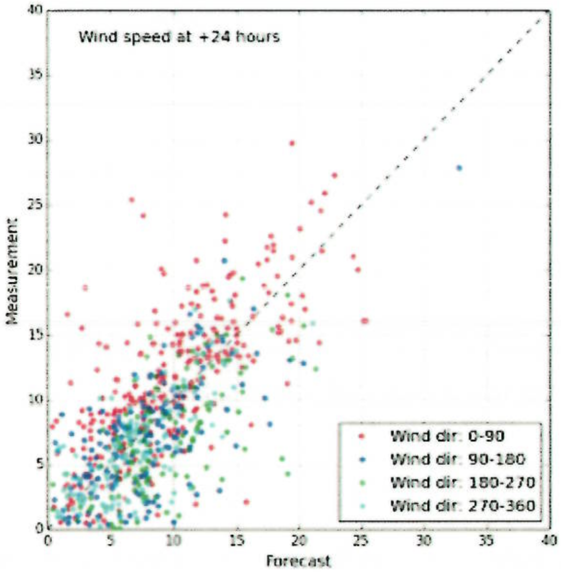


$$r_{fx} = \frac{\sum_{i=1}^{n}(f_i - \bar{f})(x_i - \bar{x})}{(n-1)s_f s_x}$$

Figure 2. The correlation coefficient and correlation between observed and modelled temperature where the correlation is high, but low within each datacluster.

Moving further leads us to an in-depth analysis of the errors. Figure 3 shows a comparison of observed and modelled wind speeds. There is a substantial number of cases where the forecast gives a much lower value than the corresponding observation. By binning the dataset according to wind direction (different colours), these cases are identified successfully being in winds from the NE. This result increases substantially the value of the wind forecast for all other wind directions! A natural next step would be to investigate the surroundings of the weather station to the NE to see if there are any non-resolved obstacles that may lead to local speed-up of the flow. A second step would be to check if the error is associated with any particular wind- or stability profile inside the atmospheric boundary layer and if this profile is particularly frequent in winds from the NE.

Northwesterly winds appear to result in a slight positive bias (appendix).



Classifying errors according to wind direction

Figure 3. Observed and modelled wind speed. The datapoints are coloured according to the observed wind direction.

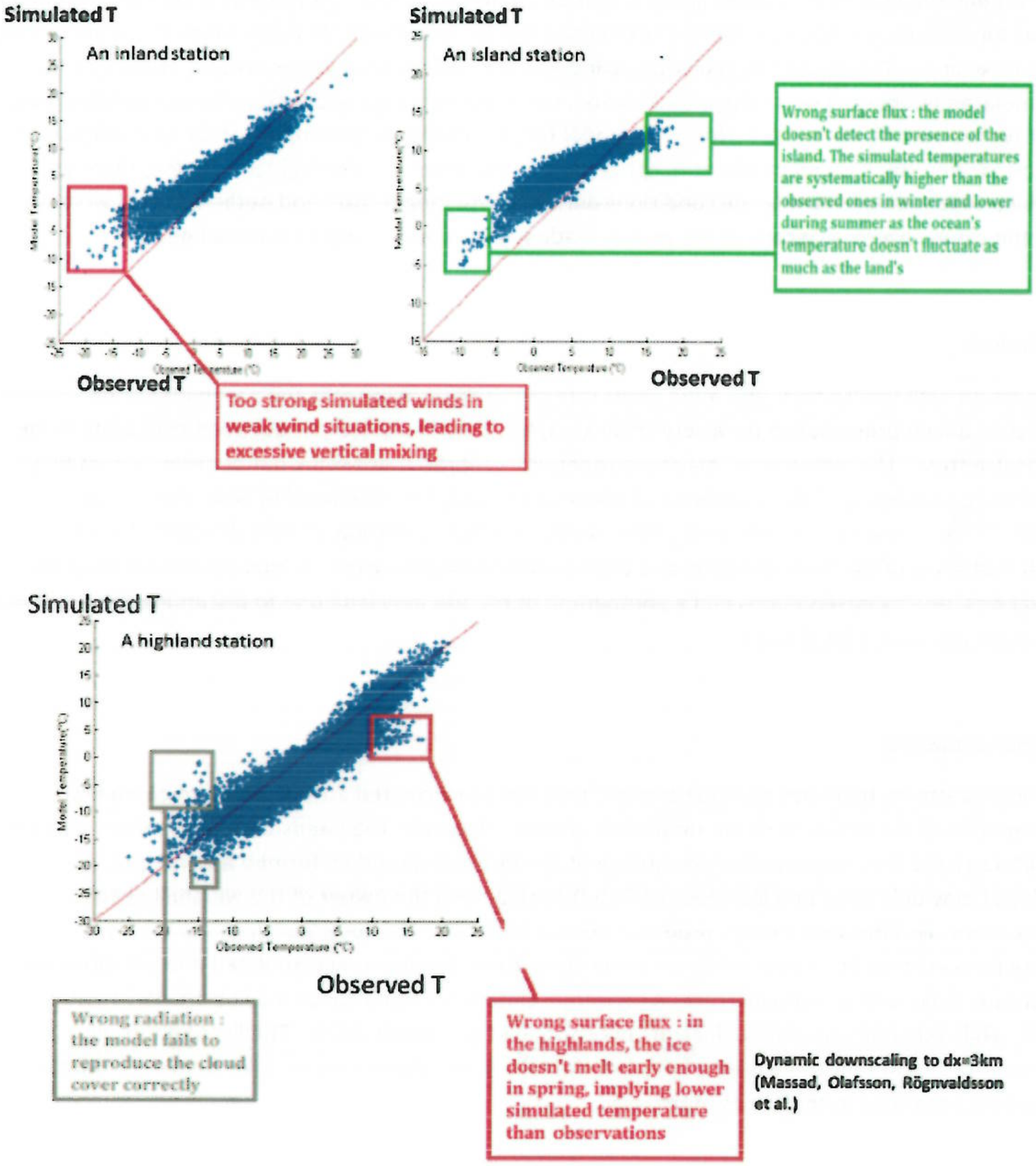


Figure 4. Comparison of observed and simulated temperature in dynamic downscalings at a horizontal resolution of 3 km.

Figures 3 and 4 show a similar analysis of errors in dynamic downscaling of atmospheric flow. Plotting a scatterogram often reveals characteristics that may never be discovered otherwise. Here we have examples of outliers in very limited parameter space that no simple function would detect. Investigation of the weather situation (all available surface observations, data from remote sensing, and the 4D simulation) in individual cases sheds a light on what goes wrong. At the inland station, the model gives far too high temperatures in cases of extremely low temperatures. In these cases, there are strong surface inversions. The model has too strong wind and the surface inversion is eroded, leading to too high simulated temperatures. At the island station, the extremely high and extremely low temperatures are not reproduced by the model. Here, the model fails to reproduce the impact of the land surface of the non-resolved small island on the atmosphere in calm weather. At the highland station, there are outliers corresponding to wrong soil conditions during the melting season and outliers in cold weather where the cloud cover was wrong in the model, leading to erroneous radiation conditions.

Observations

In connection with verification, one must never rule out the possibility that the observations are incorrect or only representative for a very small area, less than the distances between gridpoints in the numerical system. The instruments may be erroneously calibrated or simply out of order. Errors may occur in post-processing of observations and observations may be influenced by older numerical forecasts. Common errors involve wrong time-stamp, wrong installation of wind direction detector, not enough sheltering of the thermometers and objects obstructing the wind. A look at time-series of the observations, nearby observations and a photograph of the site may lead one to discarding the observation and save a lot of time.

The needs come first

As previously stated, there are several functions that can be calculated automatically to give a first approximation of the accuracy of the simulation system. However, the needs of different users may be very different and the assessment of the quality of the forecast should be formed accordingly. A hydrologist may only need precipitation, while a fisherman and the owner of the windmill needs accurate winds and the solar energy producer needs cloudiness. For flood warnings a short term intensity forecast may be crucial, while for some agricultural purposes, accumulated precipitation over several days may be of primary interest. A moderate shift in time and space may be crucial in some context, while for someone else such errors may not be of any importance. The list of different requirements of different users is very long, but the take home message is to tailor the verification to some extent according to the needs of the user.

Error tracking

Great errors in short- to medium range forecasts may be the result of wrong initial conditions in a numerical simulation. It is possible to track such errors in retrospective and such tracking may be useful for model development. Such a tracking has been described in Steensen et al. (2011) and here we show a similar example. The method is based on a comparison of two simulations with different lead times, one which gives a correct forecast and another (with longer lead time) which fails to give a correct forecast (Figs. 5 and 6). Figure 7 shows the difference between the mean sea level pressure in the two forecasts at the time of a high-impact weather. There is a very large difference in the pressure field and this anomaly can be traced back in time (Fig. 8) to the region of the upper level jet far to the south. The amplification of this anomaly is associated with an explosive development of an extratropical cyclone. This development can be linked to a primary temperature anomaly over NE Canada traveling to the east, over the N-Atlantic.

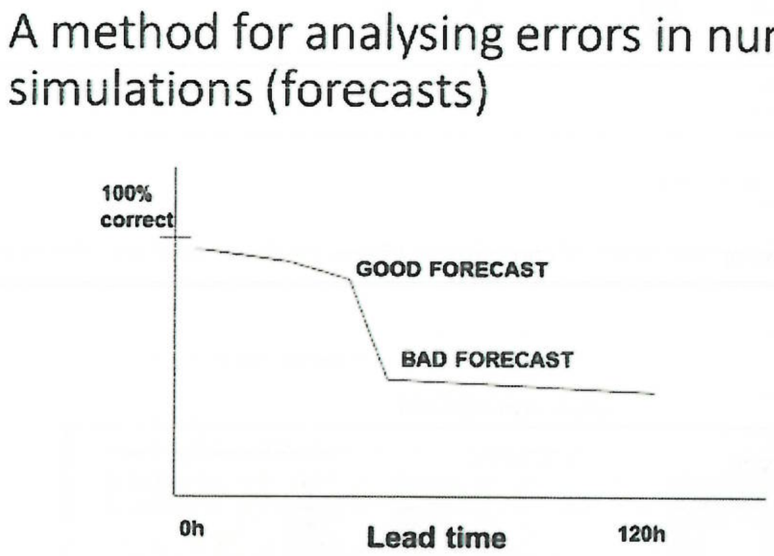
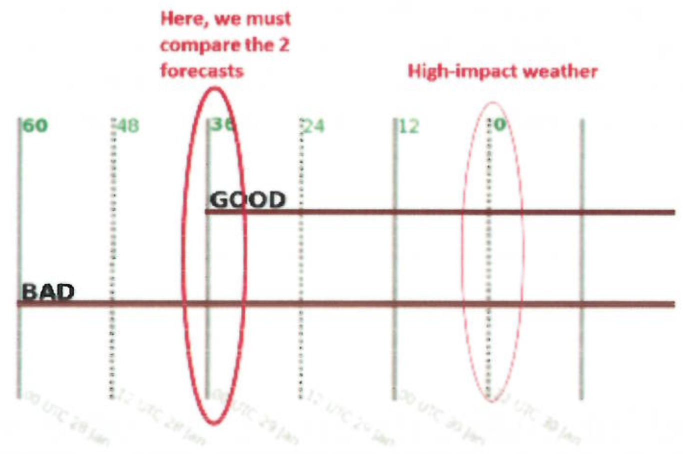


Figure 5. A schematic of the evolution of the quality of forecasts with different lead times (as one comes closer in time to the weather event in question).



Olafsson, Jonasson, Tellus 2011

Figure 6. A schematic showing the times of comparison of two forecasts with two different lead times.

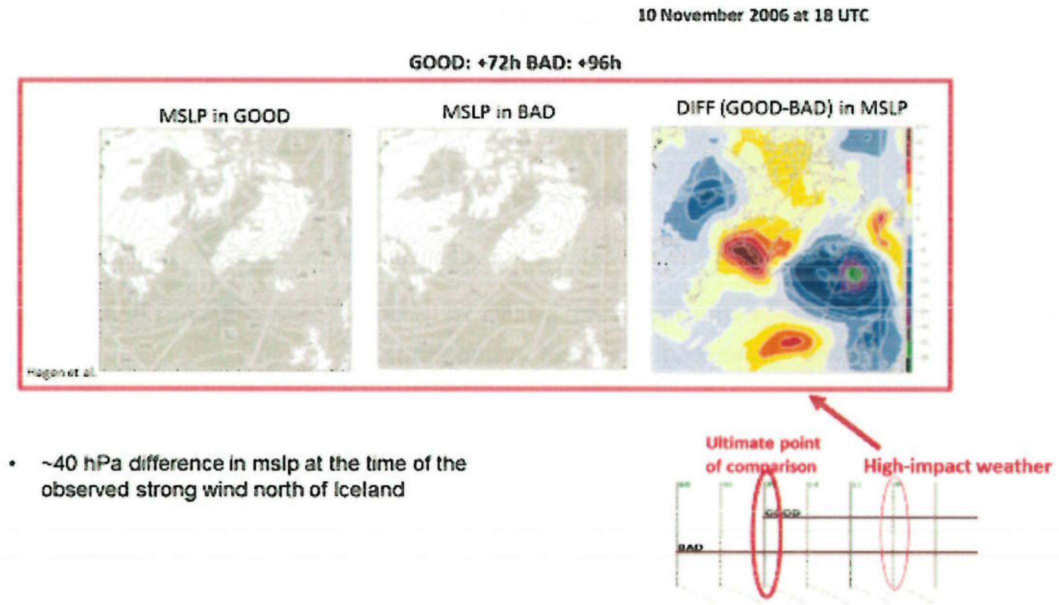


Figure 7. The mean sea level pressure field in the two forecasts and the difference between the two forecasts at the time of high-impact weather.

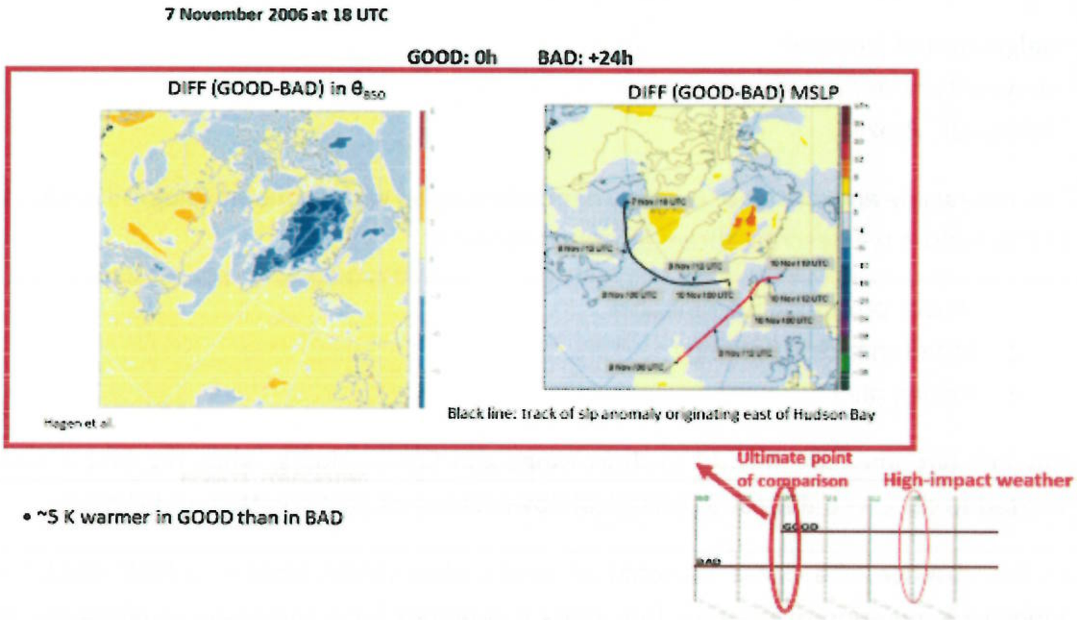


Figure 8. The difference in potential temperature and the mean sea level pressure at the time of initialization of the "good" forecast. The tracks of the anomalies are shown in the mslp panel.

References

Steensen B. M. , Ólafsson, H. & Jonassen M. O.: An extreme precipitation event in Central Norway. *Tellus* (2011), 63A, 675–686.

Hagen, B., H. Ólafsson, B. Tveita and A. Sandvik: Unpublished document based on the thesis of B. Hagen, Univ. Bergen, 2008.

Massad, A., H. Ólafsson, Ó. Rögnvaldsson, H. Ágústsson and G. N. Petersen. Errors in dynamic downscaling of atmospheric flow. Manuscript in preparation.

Appendix III – Energy applications and tools

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The renewable energy sector is highly dependent upon various meteorological products. In this lecture we describe three different scenarios:

1. Power production estimation
2. Maintenance scheduling
3. Pricing plan

The last two ones are related to short range and S2S products, while the first is more related to observed data and dynamical downscaling of past weather and climate.

In the absence of a dense mesonet of in-situ observation system, a high resolution hindcast simulation of the past few years is required for a successful implementation plan. We presented as an example our solar energy study for the state of Bahia, in Brazil, where the regional map of solar radiation was created using high-resolution simulations (cf. Figure 1, top panel). Another example of the use of dynamical downscaling of past weather is the map of simulated mean winds at hub height (cf. Figure 1, bottom panel). Simulations of past weather can also be used as input to hydrological models. Properly calibrated, such a coupled modelling system can be used to optimize the outflow of water reservoirs.

Every kind of renewable energy production demands a maintenance plan that can be scheduled up to few weeks in advance. This plan is based on a weather forecast report, since it usually requires a team to be reallocated under ideal weather conditions. Furthermore, for a good business plan, the price of the energy that will be generated in the next few weeks needs a forecast as well. Therefore, it is necessary to have a reliable S2S forecast, displayed in an understandable format. We propose a calendar with probabilistic forecast based on ensemble products. The ensemble system consists basically in a weighted average of different model results taken from the combination of data (cf. Figure 2):

- Evaluated on neighboring points
- Estimated by simulations started in different dates
- Estimated by different model configurations

The probabilistic forecast is displayed in a 27 day calendar, showing for each day the probability of a pre-defined alert occurring (cf. Figure 3). We use three colors to distinguish different levels of alert.

Short range forecasts, and even now-casts in case of spot-market prices, are also important for renewable power production. This is in particular true for wind, where the energy production is proportional to the cube of the wind speed (cf. Figure 4). Hence, relatively small errors in wind forecast can lead to much larger production errors. In the case of high quality observations, it is possible to use statistical methods to reduce the forecast error considerably (cf. Figure 5).

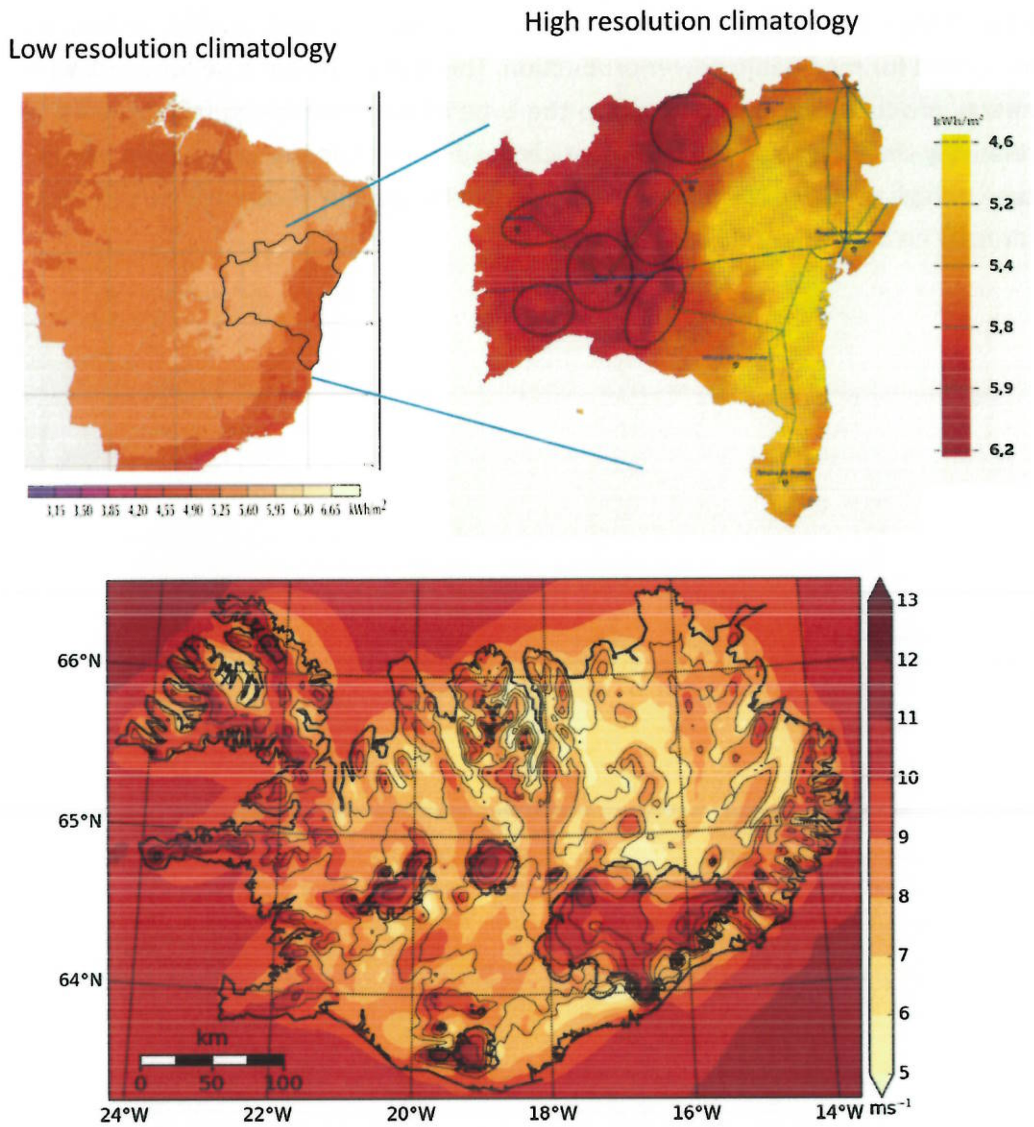
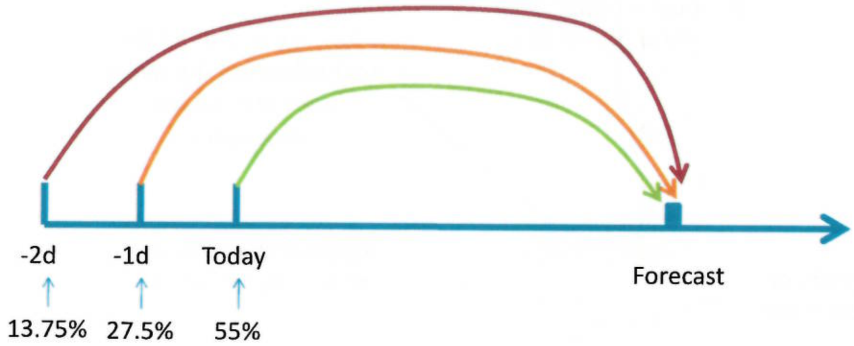
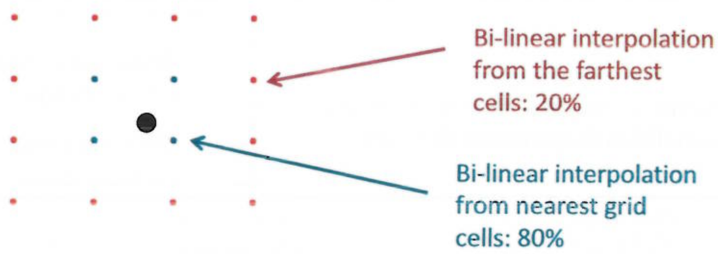


Figure 1 Example of how dynamical downscaling of past climate can shed more light on potential power production within a given region. Top panel shows simulated (coarse resolution – left, high resolution – right) incoming solar radiation [kWh/m²] in Brazil. Bottom panel shows simulated mean annual wind speed [m/s] in Iceland at 100 meters above ground level.





1. Compare many different model configurations to observations;
2. Choose 4 configurations that in average provide different forecast results;
3. Rank the model configurations based in statistical comparison with observations.

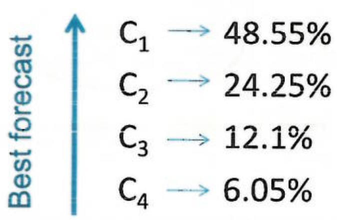


Figure 2 Example of how the weighting parameters for an ensemble system are determined. Starting time weight (top), neighboring weight (middle), and model configuration weight (bottom).

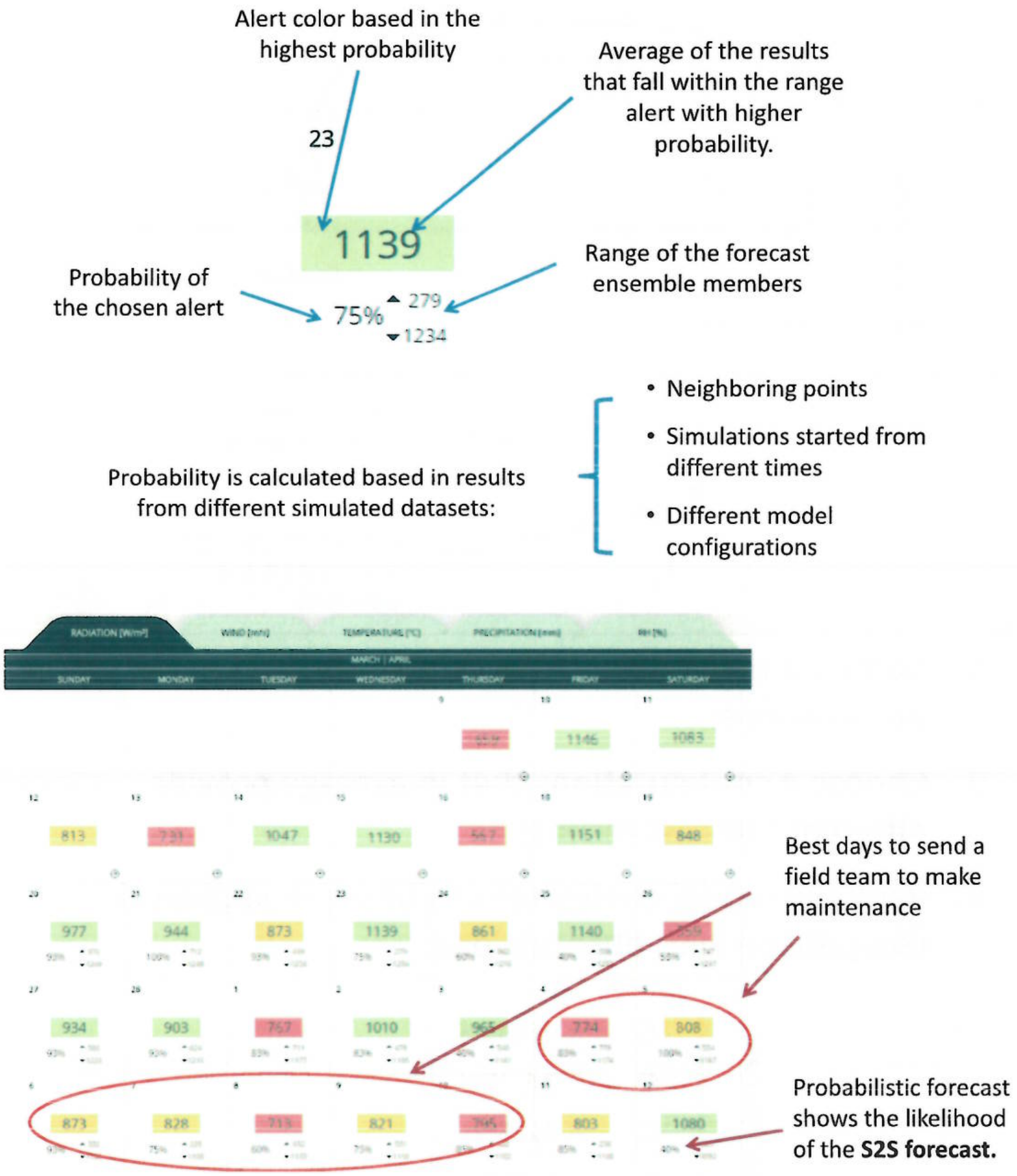


Figure 3 With proper data post-processing and presentation, long range ensemble forecasts can provide valuable information regarding both maintenance planning and pricing of energy.

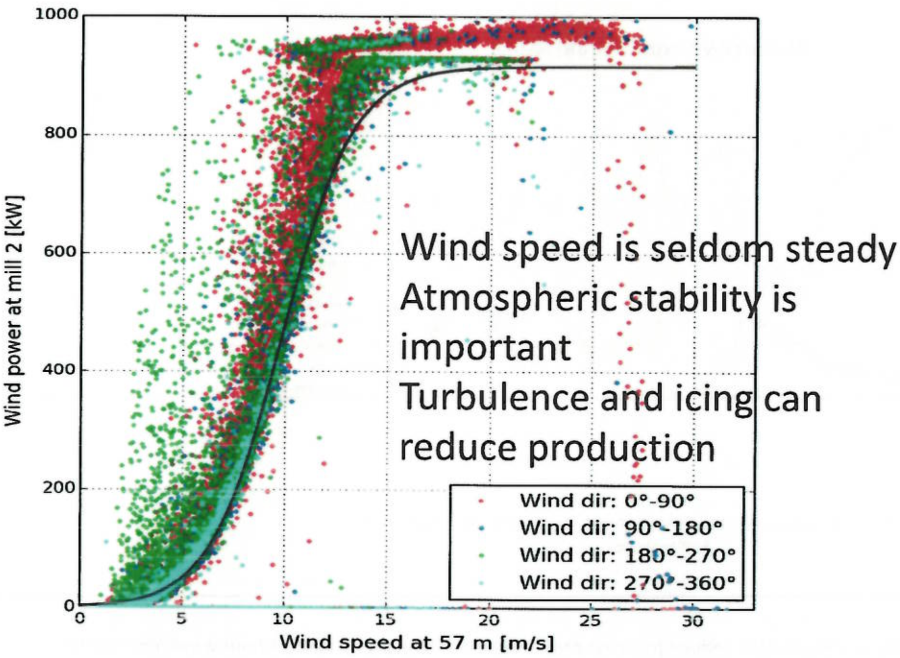


Figure 4 Power production plotted as function of wind speed for location Hafið, in S-Iceland. The structure of the lowest part of the planetary boundary layer is of great importance when it comes to estimating wind energy power production.

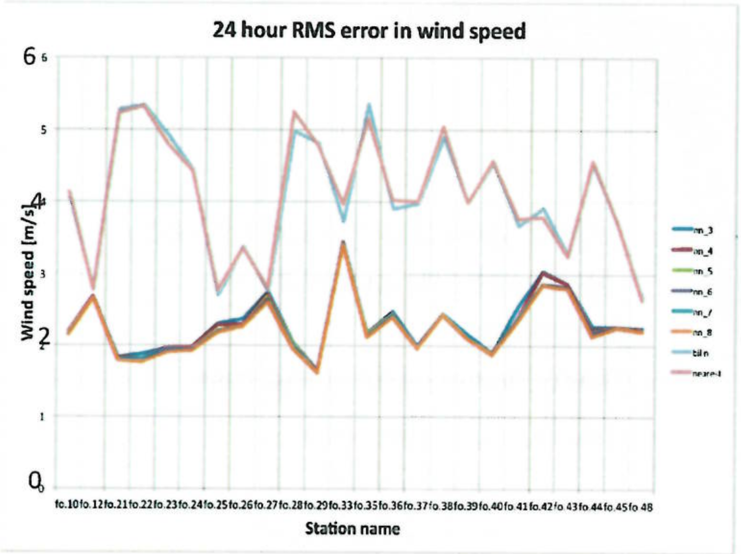


Figure 5 Observations can be used to reduce forecast errors. Here is an example of a 24 hour wind forecast for twenty-four stations in the Faroe Islands. By using a linear regression model to post-process the forecast it is possible to reduce the Root Mean Square error by 45% on average.

Appendix IV – Forecast verifications, hands-on exercises

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This talk described in brief the Weather On Demand (WOD) forecasting system, with emphasis on the *forecast verification* module. After the introduction came a hands-on session where the audience was assisted in installing the Anaconda environment (https://docs.continuum.io/), which is very useful for running scientific python code. The audience was also given a collection of data for a number of weather stations in Africa (cf. Figure 1), and software tools written in the open-source Python environment. Both data and software is available on-line (ftp://ftp.betravedur.is/pub/code/wiser-cr4d-AddisFeb2017/cr4d-addis.zip).

For each station we had both observations as well as forecast data from the UNECA-Belgingur's PanAfrica forecasting system (https://uneca.belgingur.is), interpolated to those same points. We applied a number of simple python utilities for viewing these time series and comparing forecasts with observations (cf. Figure 2 and Figure 3).

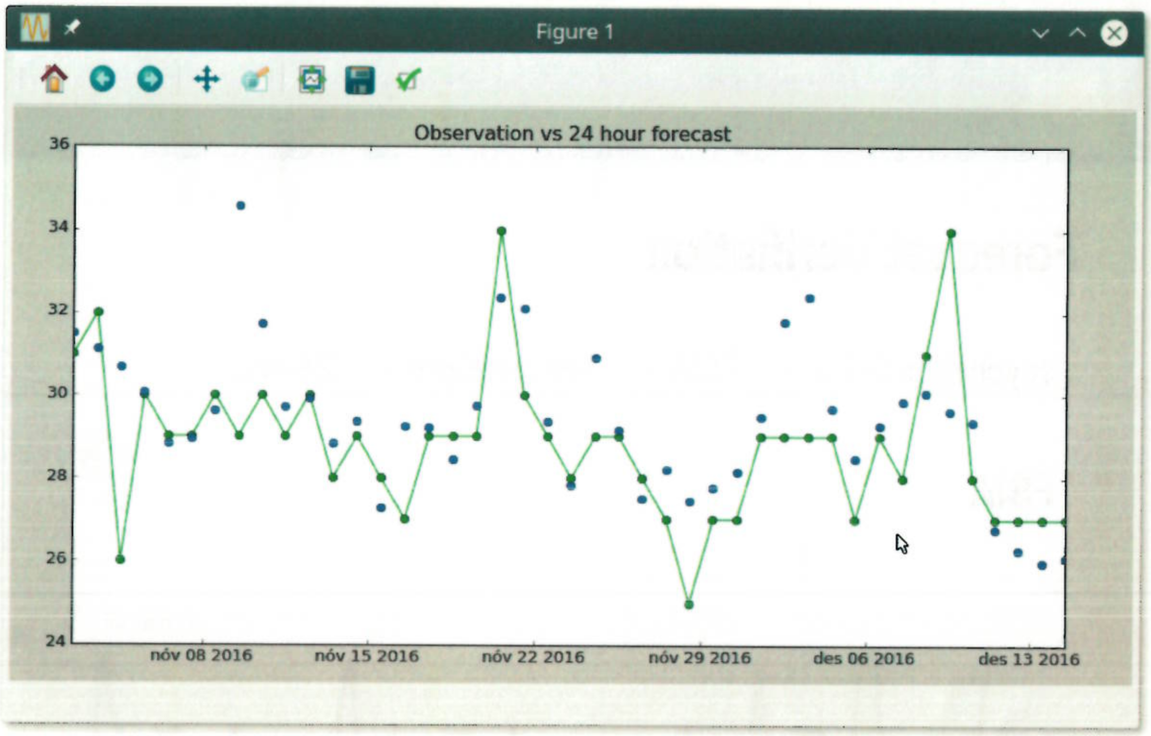
This showed a much simplified version of the forecast verification which Belgingur is deploying in co-operation with UNECA in Seychelles, Cabo Verde and Guinea-Bissau initially. See e.g. http://syn.meteo.gov.sc/verification and Figure 4.

Figure 1 Location of observation sites used in the hands-on exercises.

```
(addis) logi@saxi:~/belgingur.is/cr4d-addis$ ./compare_series.py data/obs_gooy.csv data/fcst36hr_gooy.csv
Loading data from: data/obs_gooy.csv
Data Series: Observations
  1224 data points from 2016-10-28 09:00:00+00:00 to 2016-12-17 12:00:00+00:00
Loading data from: data/fcst36hr_gooy.csv
Data Series: Forecast
  43 data points from 2016-11-02 12:00:00+00:00 to 2016-12-14 12:00:00+00:00

Quality Indicators:
  bias: 0.622
  rmse: 1.776
  good: 81.4%
```

Figure 2 Point forecasts can be compared to observations from chosen locations by running a simple python program, providing the user with basic statistical information on the quality of the forecast at a glance.



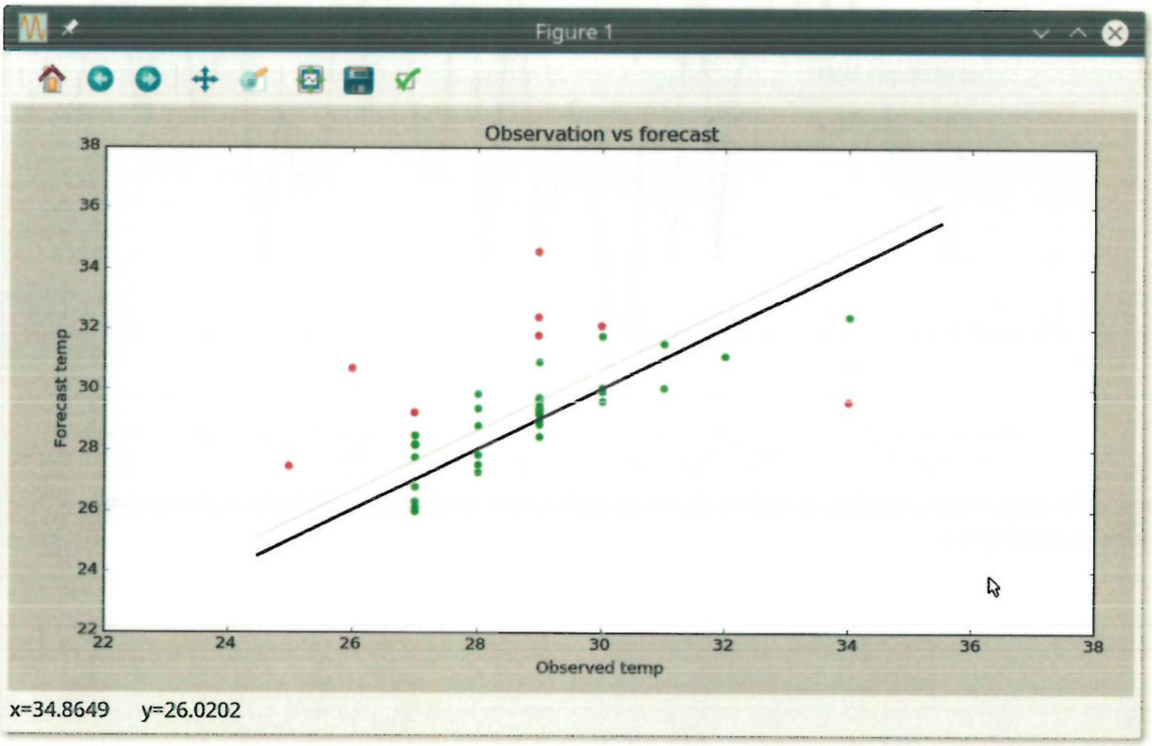


Figure 3 Data can both be viewed as time-series (top) or scatter plots (bottom).

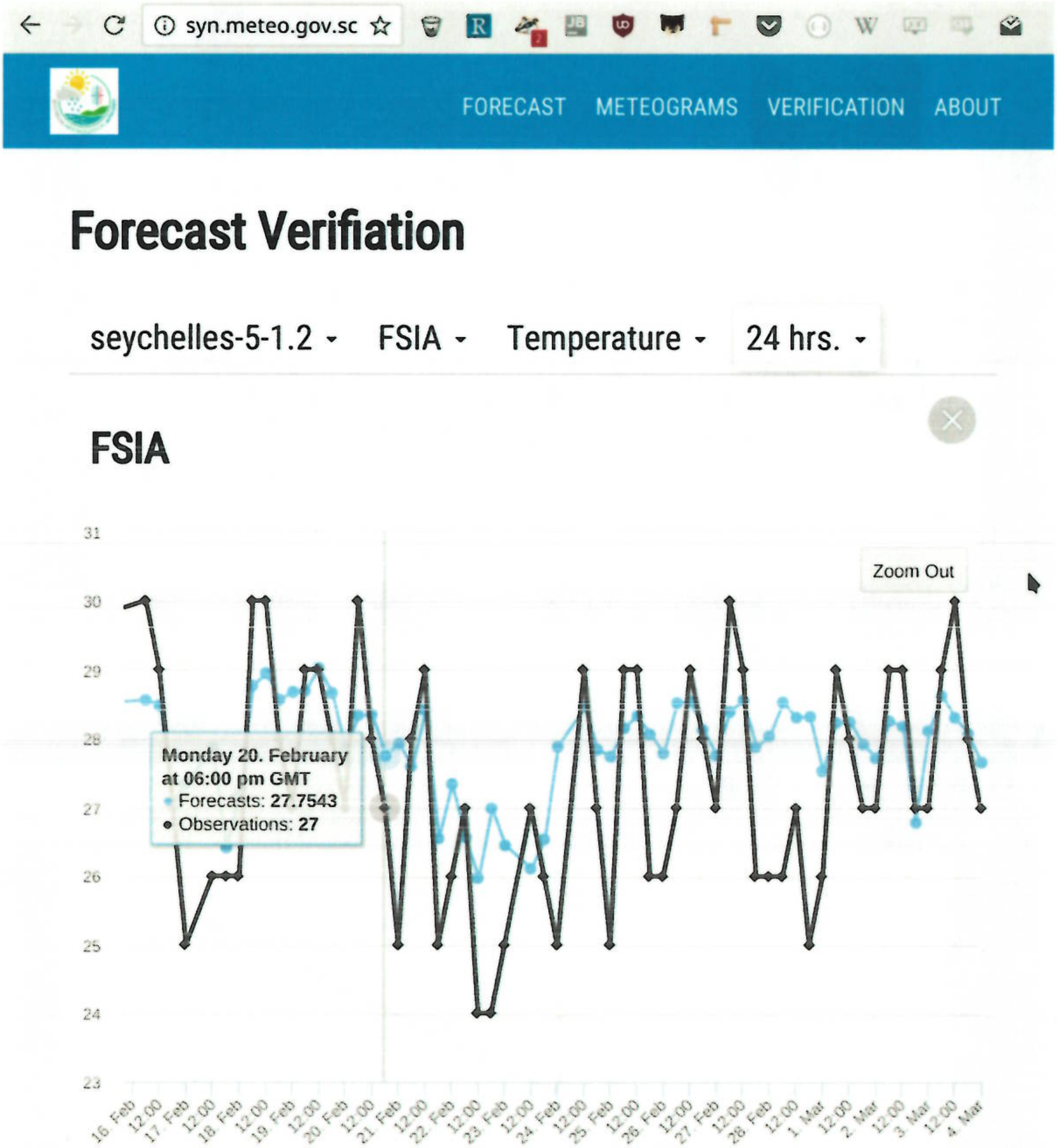


Figure 4 Screen shot of the forecast verification part of the WOD system currently being deployed at the Seychelles Meteorological Agency.