Executive summary

This document presents the development philosophy and schedule in order to implement the SARWeather system into a marketable product.

SARWeather is an on demand software suite that brings the power of state-of-the-art weather forecasting models to the hands of ordinary people. In few easy steps the user places a new forecast order, defines the region of interest, verifies/modifies the choice and finally views the resulting highly accurate weather forecast.

An important feature of SARWeather is the potential of using on-site weather observations to improve the local forecast. Notably, 3D-observations made in real time using a small Unmanned Aerial Vehicle (UAV) can be used to enhance the forecast quality. To fulfil this need an improved version of the Small Unmanned Meteorological Observer (SUMO) has been developed.

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1. Service idea

SARWeather is a flexible, high-resolution weather forecasting system specially tailored to the needs of SAR (Search And Rescue) teams and rescue control centres. It includes a novel way of adding on-site weather observations to improve weather forecast quality.

An important feature of SARWeather is the potential of using on-site weather observations to improve the local forecast. Notably, 3D-observations made in real time using a small Unmanned Aerial Vehicle (UAV) can be used to enhance the forecast quality. To fulfil this need an improved version of the Small Unmanned Meteorological Observer (SUMO [1]) has been developed in close collaboration with Reykjavík University.

2. Development and progress

The objective was to have a functional version working by mid September 2010 for demonstration purposes in Zurich and to promote a beta-version in late October at the RESCUE 2010 conference (http://www.icesar.com/category.aspx?catID=297).

SARWeather will be run operationally by ICE-SAR, CPD and 112 in Q1 of 2011. Once an operational V2-SUMO is available (late Q1/early Q2 of 2011), SARWeather will reach it's full potential.

Development of SARWeather:

- Functional specifications worked out in collaboration with ICE-SAR and the Civil Protection Department of the Icelandic Police (CPD), August-November 2009.
- Forecasting system development 2009-2010.
- Infrastructure for scalability: Negotiations with Penguin Computing Inc. (http://www.penguincomputing.com) was done in the summer of 2010.
- On-site testing of meteorological data acquisition using the SUMO system was done in the summer of 2009.
- On-site meteorological data and communications – sending data in real time from the SUMO system was done in the summer of 2010.
  - Test flight with the modified SUMO system was done in July 2010. Data transmission was successful from all three flight locations.
- Building an improved SUMO airplane (V2-SUMO): Q3 of 2010 to Q1/Q2 of 2011.
  - The upgraded SUMO system is being finalized and integrated with the data base.
  - It is expected that a fully operational V2-SUMO will be ready in late Q1/early Q2 of 2011.
- All subcomponents of the V2-SUMO system have been individually tested with success
  - in-flight data transmission
  - data retrieval and storing in data base
  - use of SUMO data from data base, as input to WRF's data assimilation system

- ◦ data shown to improve the forecast
- Data assimilation of meteorological data and other techniques for forecast improvement: 2009-2010.
- Web interface: Design 2009, implementation summer 2010.
- End-user tests started in August 2010.
- A long term service contract between IMR, ICE-SAR, CPD (Civil Protection Department of the Icelandic Police), and 112 in Iceland is being negotiated. IMR will initially provide SARWeather's sub-system, SARWeather, as a 24/7 service to these bodies. Once V2-SUMO is operational, SARWeather will be brought to full SARWeather status.
- GalieoRescue has been officially included as a GDACS contributor. First to be used in upcoming exercises, but then with the idea to fully integrate it into GDACS. To assist with this process, UNOSAT is to become a Beta-tester of the system.
- GalieoRescue was promoted at the RESCUE 2010 conference with quite a success. Potential leads are being followed up on.
- SARWeather is being integrated into the D4H[1] software solution. This opens up the market to hundreds of individual SAR teams, worldwide.

No major show stoppers for a successful implementation of SARWeather have been identified. Once an operational V2-SUMO is available, the full potential of SARWeather can be demonstrated.

[1] http://www.decisionsforheroes.com

3. Service architecture, main components and interfaces

Weather forecasting system – components and interfaces

Fig 1: The WRF weather modeling system flow chart. Taken from the web: *http://www.mmm.ucar.edu/wrf/OnLineTutorial/Introduction/flow_WPS.htm*

Figure 1 shows the flow chart for the WRF weather modeling system. The observational data from the SUMO system falls into the "Standard Obs Data" external data source category, shown on the left in the figure. In addition SARWeather has a tailor suited post-processing system not shown on the flow chart from the WRF web page.

On-site data acquisition and transmission

Figure 2 shows the upgraded V2-SUMO system. In order to facilitate the 3G/GSM modem, needed to transmit observational data in real time, it was necessary to add a new computer to the original SUMO system (cf. Gumstix). An additional bonus feature is that the upgraded system now has two additional sensor interfaces. This opens up the possibility for a Gyro system (to help keep the plane level), a dust sensor to be used for measuring e.g. volcanic ash, or even a small camera.

Fig 2: Schematics showing the upgraded V2-SUMO system. GNSS position connects to the original Tiny2 computer. The original transmission, i.e. wi-fi connection with the on-site laptop, is done through the Xbee module. The new, real time, long-range, data transmission is done through the UART modem.

In order to integrate the new computer (cf. Gumstix) with the original SUMO hardware and software, considerable system modification had to be done. This work was done by Mr. Símon E. Vilhjálmsson, as part of his project in fulfilment of a B.Sc. degree in electric engineering at the Reykjavík University [2]. The greatest hurdle was to re-program the

Gumstix microcomputer so it would communicate seamlessly with the original SUMO hardware.

The reason for using 3G/GSM system, instead of for example the Iridium system, is that 3G/GSM has both relatively good global coverage (cf. Fig. 3 and Fig.4). It is also considerably cheaper, more power conservative and lighter than any Iridium solutions on the market.

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Fig 3: Global coverage of the 3G system, also known as UMTS - Universal Mobile Telecommunication System. Note that although a country is "red", it does not indicate that 3G coverage is everywhere. See for example Fig. 4 of a detailed map of the 3G coverage in Iceland.

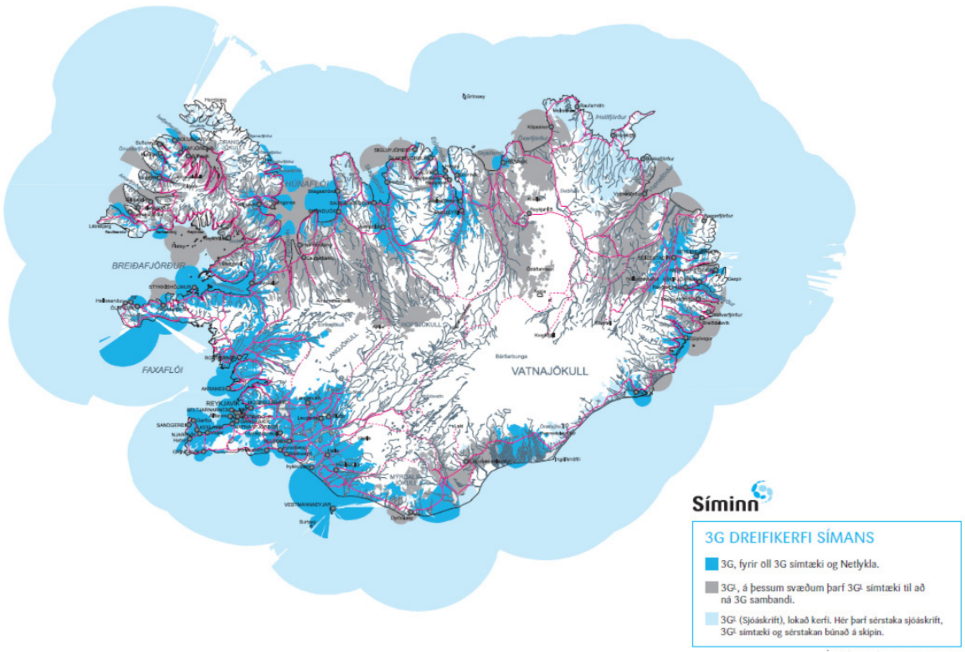

Fig 4: Same as Fig. 3, but a detailed map for Iceland (valid July 2010). Different colours indicate various data transfer capacity.

The new microcomputer (Gumstix) not only has to communicate with the original hardware, but also with the 3G/GSM modem (UART modem). This programming work was also done by Mr. Vilhjálmsson, and is documented in his B.Sc. thesis [2]. A number of test flights (cf. Fig. 5) where conducted in July were the robustness of the in-flight data transmission system was verified.

Fig 5: In July three test flights were conducted in order to test the in-flight data transmission potential of the new SUMO system. The combined 3G/GSM system proved successful at all three locations, i.e. in all cases either the 3G or the GSM connection could be used to transmit data to the data server. Locations of flight sites are shown with red X-es. The sites were chosen as to represent the widest range of available connection, ranging from very good (Heiðmörk) to very poor (Mýrarnar).

There still remains to build a fully upgraded Version2-SUMO with all sensors connected to the new Gumstix microcomputer. Currently, only one of the original sensors has been connected and tested in-flight.

Effects of 3D observations on forecasts

To demonstrate the effects 3D observations from the SUMO-system can have on high resolution weather forecasts, data from test flights done on July 15 2009 have been used as input to the WRF modeling system. For this particular day and location, high resolution atmospheric simulations failed to produce north-easterly accelerated flow on the lee-side of Mt. Esja (900 m.a.g., SW-Iceland near Reykjavík), as was indeed observed in the SUMO test flight as well as at the ground. Instead, the atmospheric models produced a fictious westerly sea breeze in the early afternoon. Figure 6 shows results from three different simulations done with the WRF system at 1 km horizontal resolution. Top row show the standard simulation where the model in only forced with

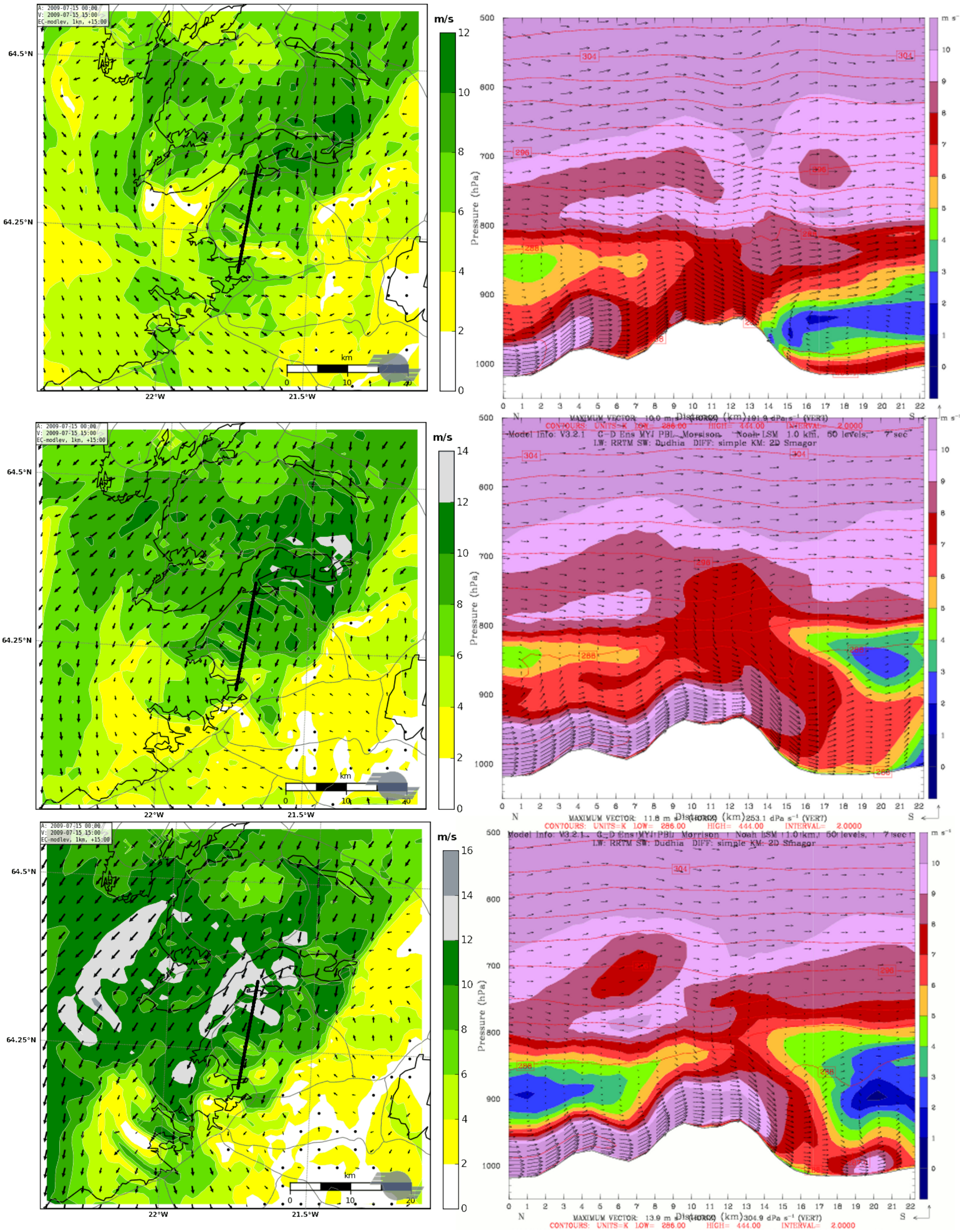

Fig 6: Simulated surface wind speed [m/s] and direction (left panel), as well as N-S oriented cross section across Mt. Esja of wind speed [m/s], circulation vectors and isentropes [K] (right panel). Top row shows results from a standard simulation, middle row when data from one SUMO flight is used to nudge the simulation. The bottom row shows results from a simulation where observations from five consequential SUMO flights were used to nudge the simulation. All panels are valid at 15:00 UTC with simulation starting at 00 UTC on July 15, 2009.

initial and boundary data from a global forecasting model. When applying the SUMO observations, there is a considerable improvement in the quality of the simulated atmospheric flow and the character of the flow in the lee of Mt. Esja is correctly captured.

On-demand computational resources

The SARWeather system is being installed on the Penguin-On-Demand (POD), pay per use computing system (http://www.penguincomputing.com/). When ready, this ensures sufficient computing power to run many operations simultaneously.

POD is a high-performance, scalable, on-demand High Performance Computing (HPC) environment with high-density compute nodes and direct attached high-speed storage. POD users have a persistent and secure compute environment that executes jobs directly on the compute nodes' physical cores. Both GigE and high performance Infiniband networks are available as the compute nodes' interconnect. Jobs run over a localized network topology to maximize inter-process communication (minimum latency and maximum bandwidth). Schematic of the system is shown in Fig. 7.

Fig 7: Schematic showing the POD system. Taken from the web: http://www.penguincomputing.com/POD/HPC_as_a_service.

End user system

Figure 8 shows the web interface of SARWeather's sub-system, SARWeather.

Fig 8: The end user interface is very simple, consisting of three simple steps to set up and run a high resolution weather forecast.

In step one the user defines the forecast area. This can be done in three different ways:

1. Define the latitude and longitude values of the lower left and upper right corner points of the requested forecast domain
2. Define the latitude and longitude value of the domain, as well as the preferred radius
3. Choose from a list of pre-defined domains

After having defined the forecast domain, the user is requested to visually confirm his/her choice (step two). In the third, and final, step the resulting forecast is disseminated to a web page for the user to view. Model output can also be disseminated to an ftp server for further use.

Integration of subcomponents

Figure 9 shows the schematic overview of the full SARWeather modelling system, i.e. SARWeather plus the V2-SUMO. The V2-SUMO observer uses GNSS system for accurate flight plan, the V2-SUMO is controlled from a ground base (cf. Regular connection). Data from the V2-SUMO system is sent via 3G/GSM modem to a database. This database could also ingest hybrid observational data from a variety of sources. The observed data is integrated to the WRF pre-processing system (cf. "Standard Obs Data" shown in Fig. 1) and becomes part of the initial and boundary data used to improve the high resolution forecast. The model results are visualised on the same web page used to initiate the forecast. The data can also be streamed to other decision support software, e.g. GalileoActive or ArgGIS.

Fig 9: Schematic overview of the SARWeather system.

4. On the use of EGNOS and EDAS for V2-SUMO

The European Geostationary Navigation Overlay Service (EGNOS) provides both correction and integrity information about the GPS system. As a satellite navigation augmentation system, EGNOS improves the accuracy of GPS by providing a positioning accuracy to within three metres. By comparison, someone using a GPS receiver without EGNOS can only be sure of their position to within 17 metres [3].

According to the EGNOS webpage [3] there are three types of services offered within the EGNOS/EDAS framework

- Open service, with no guarantee of liability.
- Safety-of-life Service. Once certified, EGNOS will provide a valuable integrity message warning the user of any malfunction of the GPS signal within six seconds.
- Commercial service. Data will be disseminated through the EGNOS Data Access Service (EDAS). This dissemination is done through the internet, and not via satellite.

From the SARWeather/V2-SUMO point of view the increased horizontal accuracy is of great importance as well as the possibility of the data integrity flag. It should be noted that even with the EGNOS/EDAS system, vertical resolution will not be sufficient for safe takeoffs and landings in full automatic mode. For that to become reality one would need to supplement the vertical resolution with guidance through barometric instruments. As the modified version of the SUMO is in a way a flying IP-number (via its 3G/GSM data link) it should be able to digest the EGNOS data through the EDAS system.

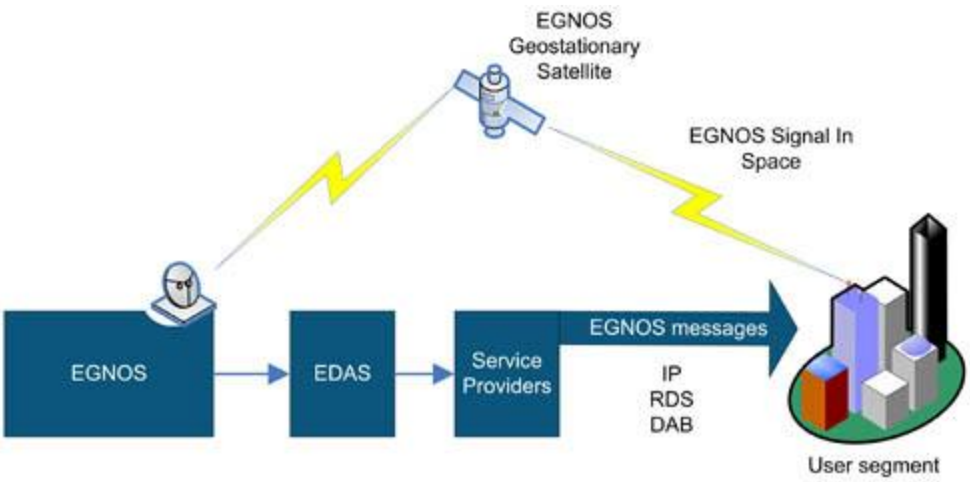

Fig 10: Overview schematics of the EGNOS/EDAS system. EDAS is a single point of access for the data collected and generated by the EGNOS infrastructure [4].

The geographical coverage of the EGNOS system extends to Europe and Northern Africa. As the use of UAV's (like the V2-SUMO) is strictly regulated in large parts of Europe (or not allowed at all) the benefits of the EGNOS/EDAS system will unfortunately be difficult to test unless the regulatory environment becomes less strict.

5. Conclusions

IMR has developed a unique software solution that makes it simple for regular people to create highly accurate weather forecasts for any location worldwide and on demand. The first version of the on demand software solution has been named SARWeather, and fulfils the demanding needs of search and rescue operators.

An important feature of SARWeather is the potential of using on-site weather observations to improve the local forecast. Notably, 3D-observations made in real time using a small Unmanned Aerial Vehicle (UAV) can be used to enhance the forecast quality. To fulfil this need an improved version of the Small Unmanned Meteorological Observer (SUMO) has been developed.

6. References

[1] J. Reuder, P. Brisset, M. Jonassen, and S. Mayer, 2008. *SUMO: A Small Unmanned Meteorological Observer for atmospheric boundary layer research.* 14th International Symposium for the Advancement of Boundary Layer Remote Sensing. IOP Conf. Series: Earth and Environmental Science **1** (2008) 012014. DOI: 10.1088/1755-1307/1/1/012014.

[2] Símon Elvar Vilhjálmsson, 2010. *Fjarskiptavæðing mannlausra flugvéla. Lokaverkefni í rafmagnstæknifræði B.Sc.* Thesis for the partial fulfillment of a B.Sc. degree in electrical engineering. School of Science and Engineering, Reykjavík University, Iceland. In Icelandic.

[3] EGNOS webpage: http://www.egnos-portal.eu/index.cfm?objectid=B73432D1-AC0C-11DE-AAA50013D3D65949

[4] EDAS webpage: http://www.gsa.europa.eu/go/egnos/edas