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Session 1 – ***Science underpinning meteorological observations, forecasts, advisories and warnings***

1.6 – Observation, nowcast and forecast of future needs

1.6.2 – Seamless nowcast and numerical weather prediction, probabilistic forecast and statistical methods

Utilising Radar and Satellite Based Nowcasting Tools for Aviation Purposes in South Africa

Erik Becker, South African Weather Service
erik.becker@weathersa.co.za
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co-authors: Morne Gijben, Stephanie Landman, Mary-Jane Bopape
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speaker: Erik Becker

1. Introduction

In an effort to improve nowcasting for aviation applications, the WMO has initiated a research and development project which started in 2015 – called the Aviation Research Demonstration Project (AvRDP). The aims of the project are to evaluate and improve on nowcasting techniques and product in and around the aerodrome of the airports as well as how to translate these nowcasting products to impact based nowcasts (WMO AvRDP, 2015). High density airports in different parts of the world were selected to take part in the initial phase where nowcasting techniques will be investigated and tested by means of various case studies. OR Tambo International Airport (ORTIA) in Johannesburg, South Africa, is one of the participating airports in this project, where convective weather dominates. Different nowcasting techniques related to convection will be investigated at this airport. The airport is situated at 26°S and 28°E and lies at an altitude of 1694m above mean sea level (AMSL). The airport is mostly affected by thunderstorms in the summer, with a rainfall maximum in December and January. Hail occurs roughly 5 days per year in the spring/early summer time (October to December). The South African Weather Service (SAWS) operates a radar network of 14 radars with a Doppler radar (S-Band, 10cm wavelength) just 25km North of ORTIA at Irene that provides reflectivity and velocity information. A lightning detection network (LDN) of 24 ground based sensors provides a 90% efficiency and 500m location accuracy of cloud-to-ground strikes country wide. The SAWS also makes use of Meteosat Second Generation (MSG) data and products as well as running a regional version of the Unified Model (UM) over Southern Africa including Madagascar with a 4km spatial resolution.

2. Current Nowcasting Capabilities

The AvRDP project resulted in a thorough evaluation of the current nowcasting capabilities at the SAWS. Radar reliability and sparseness in some regions – such as large parts of the African continent – have made satellite derived products very popular and useful. The Nowcasting Satellite Application Facility (based in Spain) developed various tools, which can be very useful for the nowcasting of severe weather events. The South African Weather Service runs the 2013 version of the software with input from the MSG satellite and also with auxiliary input from the local version of the UM as well as lightning data from the South African LDN to further enhance the performance of the software. Current operational products from the nowcasting software at the SAWS include: the Cloud Type, Cloud Top Temperature, Convective Rainfall Rate, and

Rapidly Developing Thunderstorms (RDT). The latest 2016 version of the software is being installed at the SAWS which will provide amongst others forecast tracks for the RDT and a Convection Initiation product (Gijben & de Coning, 2017). Output from the UM is further utilised through the development of a lightning threat index (LTI). The LTI gives the probability of lightning occurrence over southern Africa and provides 3-hourly and daily forecasts for day 1 and day 2 (Gijben et al., 2017). In terms of utilising radar data for nowcasting purposes, currently only the Thunderstorm Identification Tracking and Nowcasting (TITAN) software is operational to track and forecast the movement of thunderstorm activity (Wiener & Dixon, 1993)

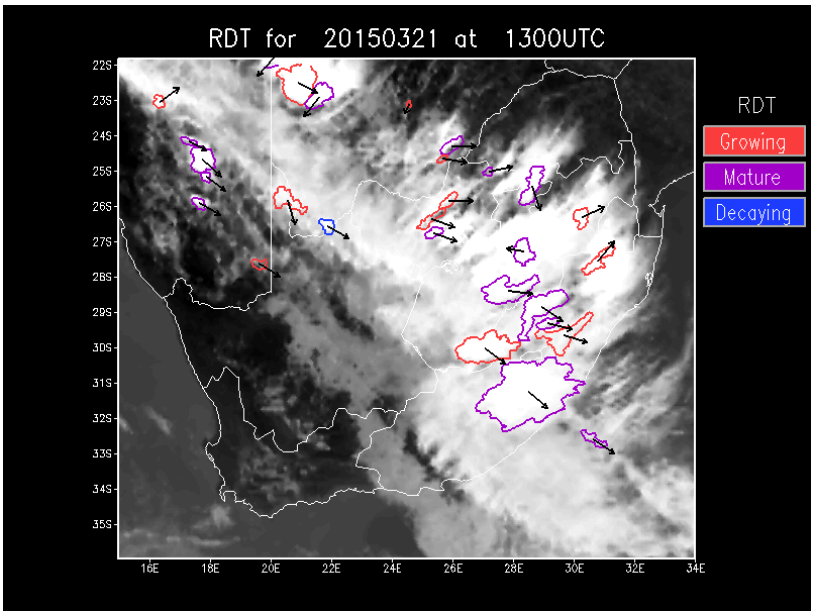


Figure 1: An example of the Nowcasting SAF RDT product over South Africa. The product has proven useful where there is no radar coverage.

3. Currently in Development

It became clear that the advantages of radar data and Numerical Weather Prediction (NWP) were not fully exploited at the SAWS for nowcasting applications. Recently the focus has shifted towards improving in these areas. In order to improve the nowcasting capabilities of SAWS the community version of SWIRLS (Short-range Warning of Intense Rainstorms in Localized Systems), or com-SWIRLS was obtain from the Hong Kong Observatory (HKO). The software produces a deterministic forecast using extrapolation techniques from radar and satellite data (Li & Lai, 2004). Currently com-SWIRLS has been setup a the SAWS to run only with Irene weather radar data on a 400x400 pixel grid, with a 1km spatial resolution. A two hour lead-time forecast is produced every 6 minutes with the completion of each radar data volume scan. Four case days were used to evaluate the performance of com-SWIRLS over the ORTIA domain. The case days includes the 21st of December 2015, the 26th of July 2016, the 26th of October 2016 and the 2nd of November 2016. The skill (see figure 2) of the forecast shows a quick drop in the first 2 hours lead-time. Very little skill is observed after 2 hours and zero skill is observed after 4 hours lead-time. This is the typical skill observed with extrapolated forecasts. The position of the advected precipitation forecasts always lagged

behind the observed precipitation for all case days evaluated. A recalibration of the advection algorithm could provide a way to increase the forecast skill that may be worth investigating.

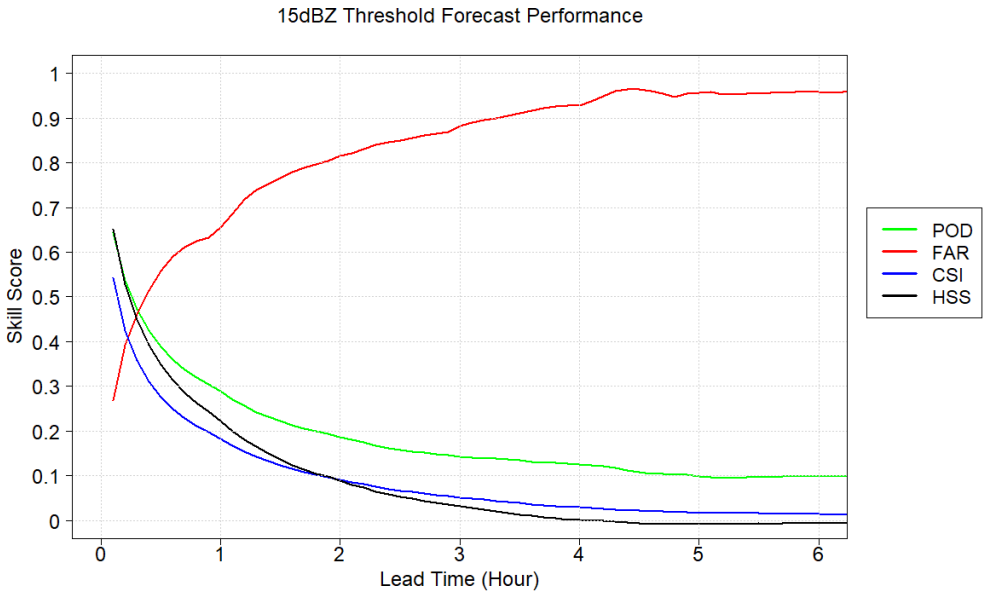


Figure 2: The graph illustrates the skill score for the com-SWIRLS extrapolated forecast for up to a 6 hour lead-time. The Probability of Detection (Green), False Alarm Ratio (Red), Critical Success Index (Blue) and Heidke Skill Score (Black) are shown for reflectivity values greater than 15 dBZ (~0.2 mm/h).

Experiments with high resolution NWP models in an attempt to increase the forecasting lead time to beyond the 2 hour extrapolated forecasts are being conducted. A mesoscale version of the UM is under development by the NWP research group at the SAWS. The dynamically downscaled regional domain will have ORTIA at the centre (-26.136S, 28.241E) with a resolution of ~300m with a 300X300 pixel grid. The model will have a vertical resolution of 70 levels (model top at 38.5km) using a tropical configuration with additional moisture conservation. The model is planned to be initialized by the GA (Global Atmosphere) 4 times a day at 00, 06, 12 and 18 UTC with a lead-time of 36-hours. The WRF model is also being investigated to determine whether it will be suitable for high resolution runs over the ORTIA domain. The investigation will determine whether the model can be initialized at hourly intervals and what resources and infrastructure would be required to do so. A lead-time to between 6 and 18 hours is being considered. A 300x300 nested domain with a grid resolution of ~500m is currently being defined using a 3DVAR configuration.

4. Nowcasting Products for ORTIA

A close working relationship between the Aviation Weather Centre (AWC) forecasters, Research and Development scientists and Air Traffic Management (ATM) departments has been established. From discussions held, it became clear that there is a need for a quick and easy way of interpreting the multiple sources of information for decision makers at the airport. Two proof-of-concept products have been developed. The first, a lightning proximity product, plots

lightning strikes detected by the LDN on a google map display that can be accessed with any device that can support a web browser. When lightning strikes within a defined threshold from the airport, a visible change in the colour of the range rings within the display is made. An automatic e-mail notification is also send out to key ATM staff. The second product is a thunderstorm tracking product based on TITAN storm cell tracking. Using buffer zones (4, 15, 30 and 50 kilometres) around the airport and the identified thunderstorm cells with their forecasted tracks (lead-time of 10, 20, 30, 45, 60, 90 and 120 minutes) a table can be constructed on whether the thunderstorms will move over the airport. The table will display 4 colours (red, orange, yellow and green) based on the tracked cell's speed and direction. An illustration of how a tracked cell is represented is shown in figure 3. All current and forecasted tracks are evaluated to determine whether they intersect with the buffer zones around the airport. The highest rank colour is then assigned to the corresponding buffer zone and forecast lead-time. The table provides an easy to interpret method on whether the airport will experience a thunderstorm for up to a 2 hour lead-time. Figure 4 illustrates the thunderstorm tables with the corresponding radar images. At 13:35 (top) on the 2nd of November 2016 thunderstorms were approaching the airport. The orange colour at the 4km buffer zone and 120 minute lead-time captured this. Two hours later at 15:35 (middle) the table has turned red due the thunderstorm moving in over the airport and at 19h23 (bottom) the table now displays green as they are moving north and no longer a threat to the airport. Initial feedback from AWC forecasters and ATM departments using these proof-of-concept products are positive and encouraging.

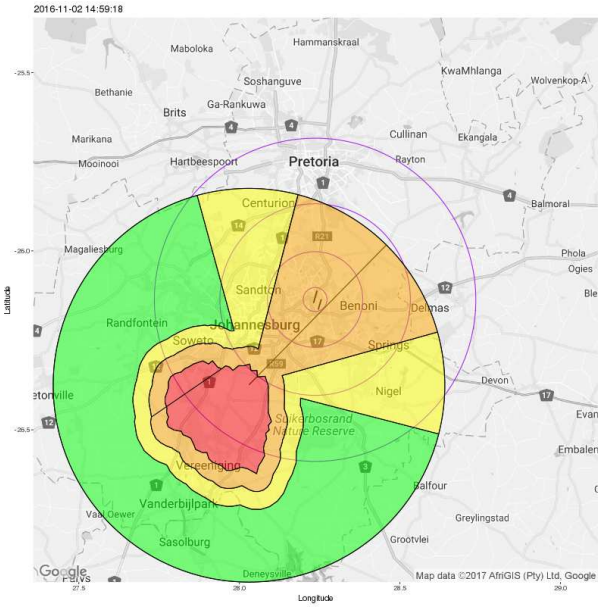


Figure 3: An illustration of how the tracked thunderstorm cell is represented in the thunderstorm table. The red area represents the thunderstorm track. The size of the circular buffer zone around the storm is the 2 hour lead-time position of the tracked cell determined by the thunderstorm's speed. The orange area indicated the direction of movement with a ±30° offset from the centre of the determined direction of movement. A buffer zone (~5km) around the storm is also included. The yellow area is constructed in a similar manner using an offset of between ±30° and ±60° from the direction of movement.

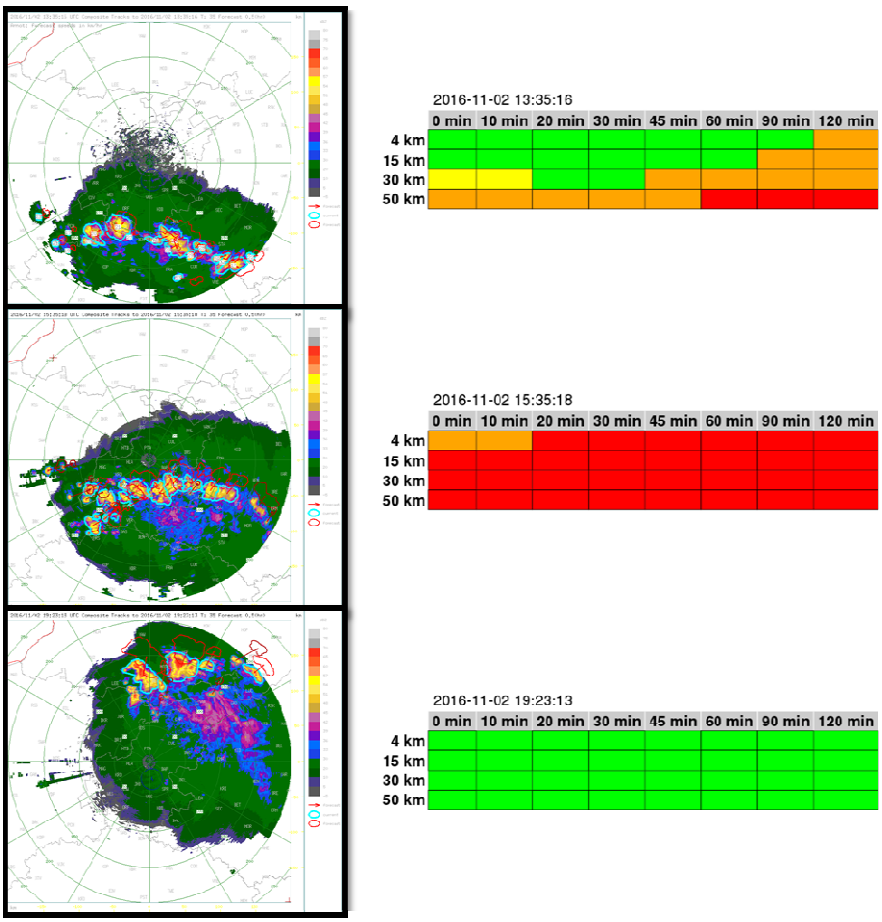


Figure 4: An illustration of the thunderstorm tables for the ORTIA with the corresponding radar images for the 2nd of November 2016. The ORTIA aerodrome is represented by the blue circle just south of the radar (centre of the images).

5. Discussion

The com-SWIRLS extrapolated forecast has demonstrated the benefits of a quantitative radar nowcasts. A 2 hour lead-time of extrapolated nowcast has been running in real-time at the SAWS since mid-September 2017. The operational implementation of com-SWIRLS for use by forecasters is aimed to be in place by the end of 2017. Development and testing of both WRF and UM high resolution models will continue into 2018. The aim will be to implement one or both operationally. The timelines for the operational deployment of the models is highly dependent on available resources, which are limited. Once the initial investigation into the performance of these models is concluded a clear picture of exactly when the models can be implemented will be available. The obvious next step once the WRF model setup is complete is to utilise WRFDA to assimilate radar data into the WRF model forecast. Development to translate SAWS radar data into the required WRFDA format has already begun. The aim is to ultimately produce a seamless 0 – 6 hour forecast through blending of the extrapolated forecasts with NWP forecasts.

The thunderstorm tables have showed that it was possible to how sufficient warning without the need to interpreting complex radar images. Although feedback and initial investigation into

the thunderstorm tables were encouraging, data will be collected and stored until the end of the current thunderstorm season which will come to an end by April 2018. The stored data will be used to follow a more objective validation approach. If the results are favourable it may be useful to also represent the RDT tracks in such a table format. This could have the benefit of being used as a backup when the radar is not available or in other African countries with no weather radar coverage. Similar tables using output from com-SWIRLS are planned to be developed and validated using reflectivity (dBZ) thresholds for the different colour representation. Additional data such as waypoints, aerodromes, flight paths, etc. available from South Africa's Air Traffic Navigation Services (ATNS) will also be implemented to provide further value added products. Meetings has been scheduled with the different ATM departments to discuss the way forward to further develop these proof-of-concept products into impact based products that talk to the specific operational needs of each department.

6. References

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