AvRDP Seminar
O.R. Tambo International Airport, Johannesburg, South Africa (JNB)

Morné Gijben

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19 to 22 August 2019, Pretoria, South Africa

South African Weather Service

Content

- O.R. Tambo International Airport (Johannesburg)
- Phase 1 report
- Phase 2 report
- Plans
- Future work

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O.R. Tambo International Airport

- O.R Tambo International Airport (ORTIA) – Johannesburg, South Africa:
    - 26° 08′ 21″ S and 28° 14′ 46″ E
    - 20km east-north-east of the city of Johannesburg and 40km south of Pretoria,
    - situated almost on the plateau of South Africa with two runways, both above 5500ft (<u>1694m</u>) above MSL.

- The surrounding area consists of hilly country sloping gradually from south-west to north-east. The highest terrain within a radius of 40km is <u>1902m</u> to the south of the airport. Most of the areas directly around the airport are built up areas.

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Airport local climatology

- Thunderstorms, summer, pm, early evening
  - 70 days of lightning per year in vicinity of airport
  - Rain: max in Dec/Jan (600-800 mm per year)
  - Hail: 5 days per year, Oct-Dec
- Fog: radiation fog/advection from SE, mostly early am (2-3 days per month)
- Low clouds/poor visibility, early am
- Smog: temperature inversion, winter months, early am
- Frost: winter, 30 days per year
- Wind direction: Mostly NW wind
- Wind speed: 3.3 - 4.6 m/s

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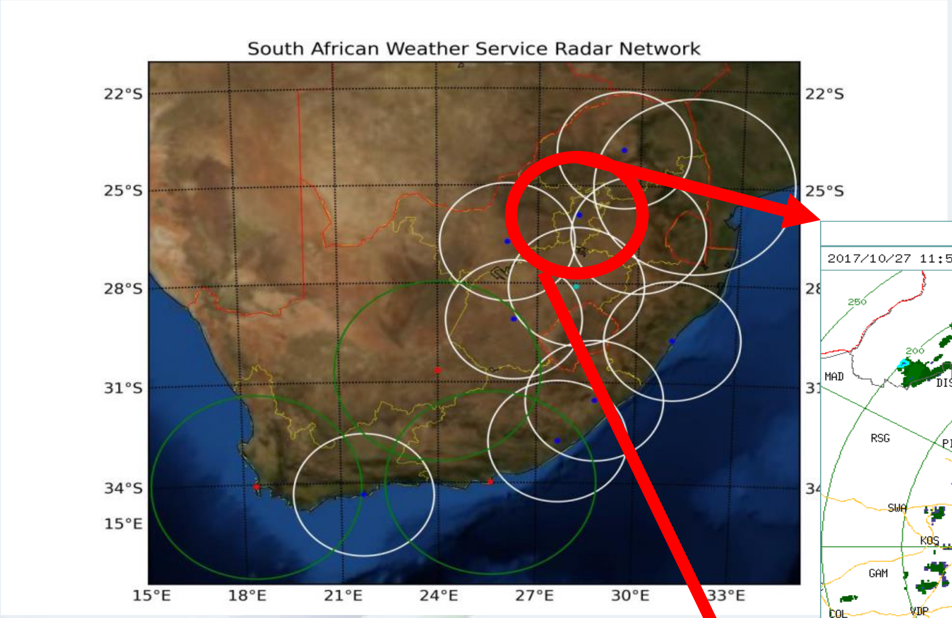
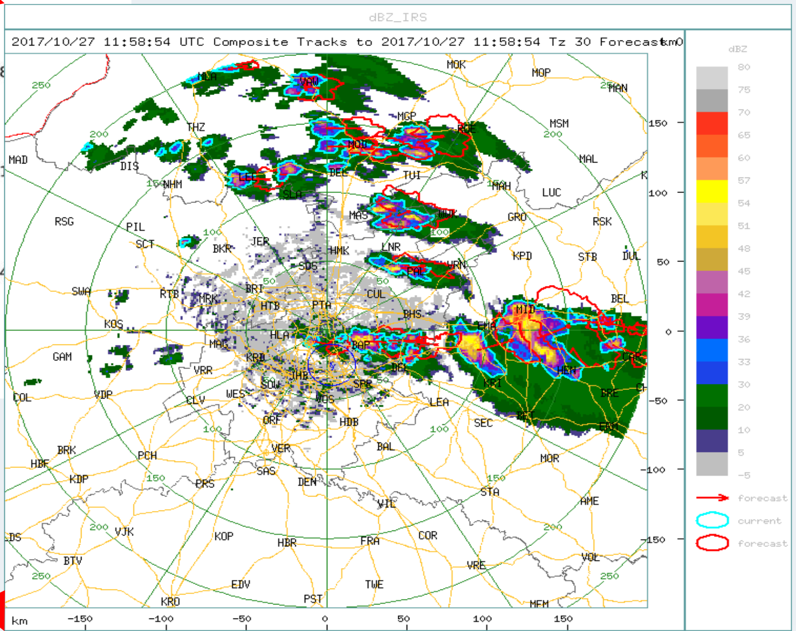
Phase 1
Meteorological capability research

Radar

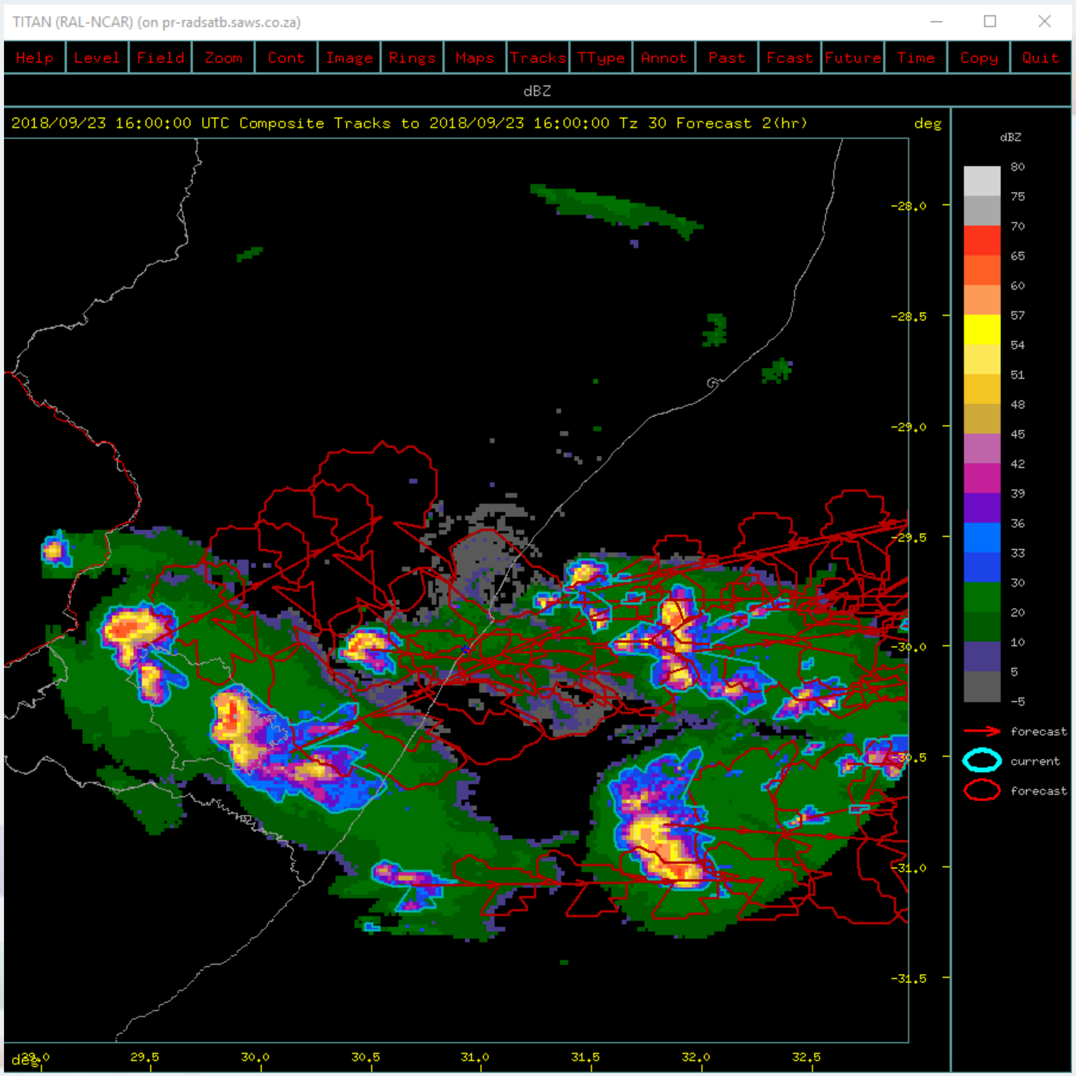
- SAWS operates a network of radars across South Africa
- 10 S-band and 3 C-band radars
- Domain of the S-band radar at Irene covers O.R. Tambo International Domain





Radar

Most important tool for nowcasting (focus for AvRDP)



- TITAN software
- Tracks thunderstorms
- Provides up to 2 hour forecast tracks
- Map becomes cluttered and needs to be interpreted
- Get an easier tool to predict the impact of storms on airport

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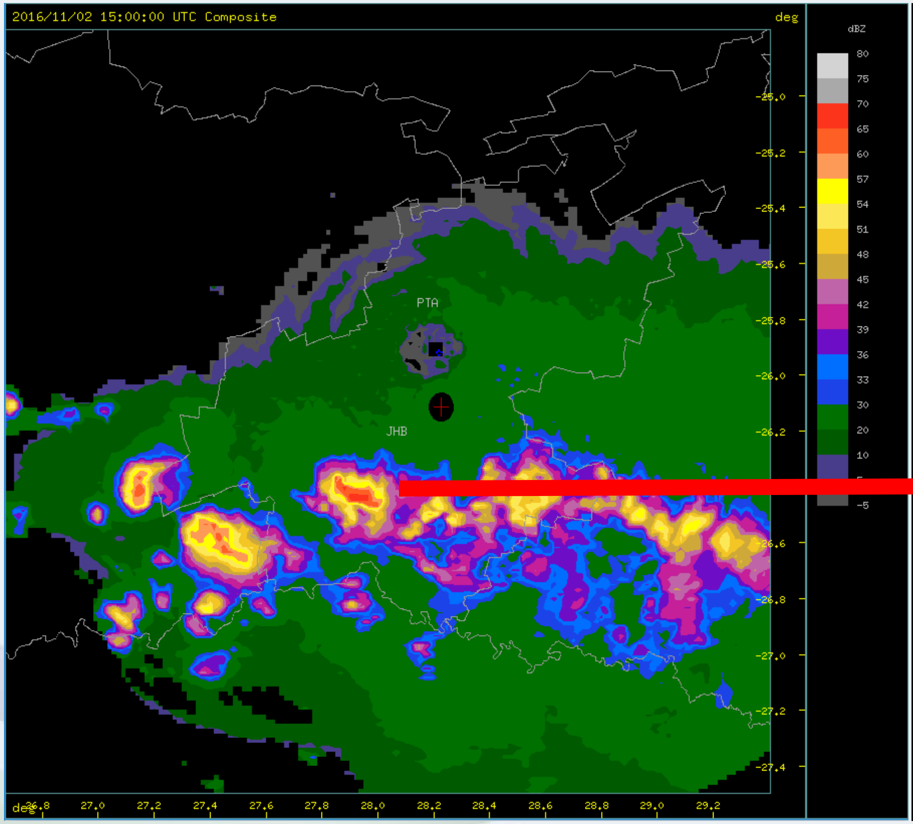
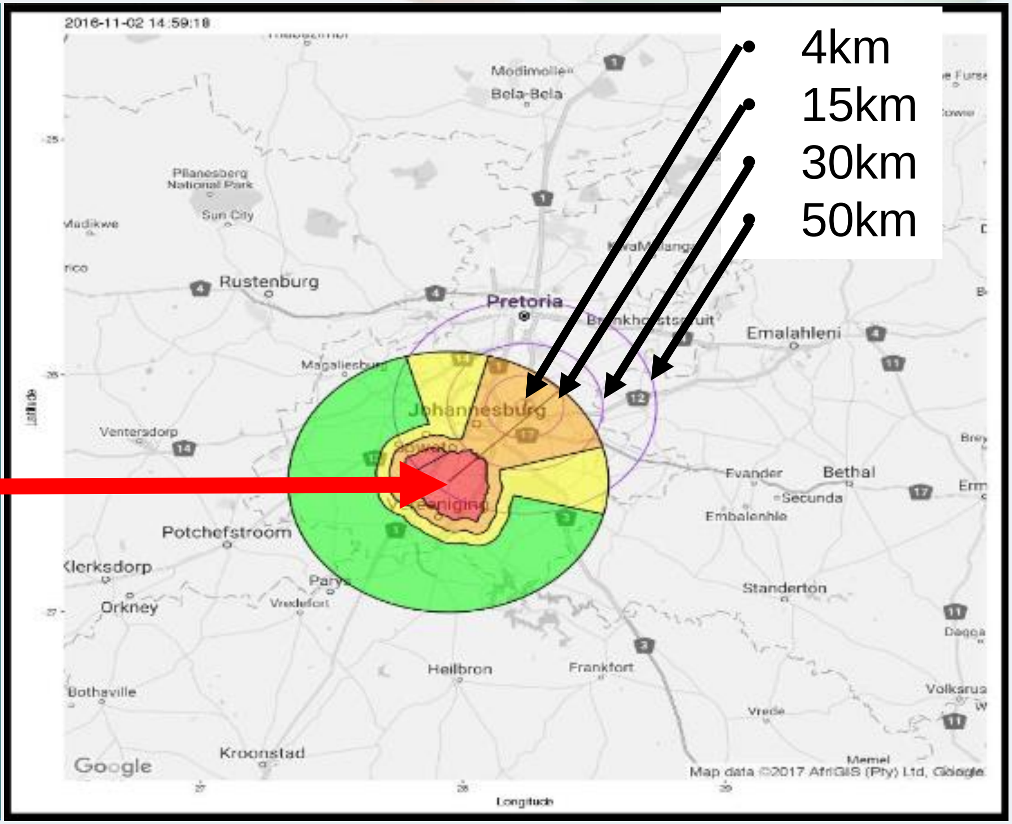
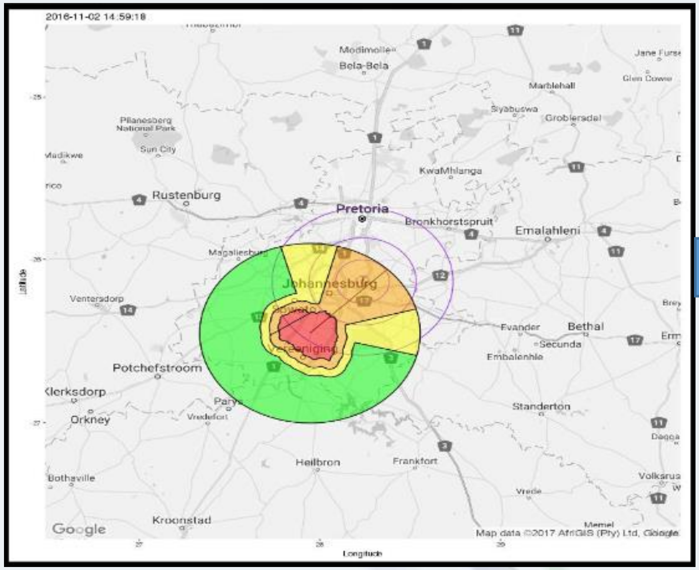
Radar

- Translate radar information into how the storm will affect the airport.





Thunderstorm Table

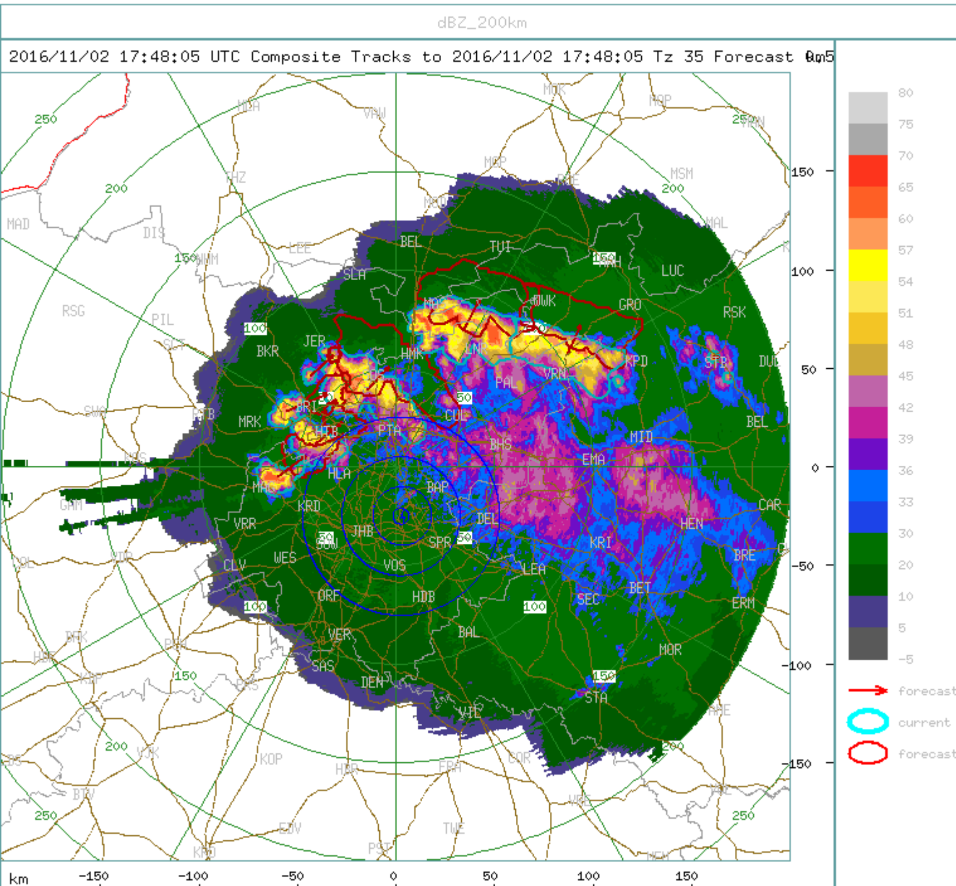


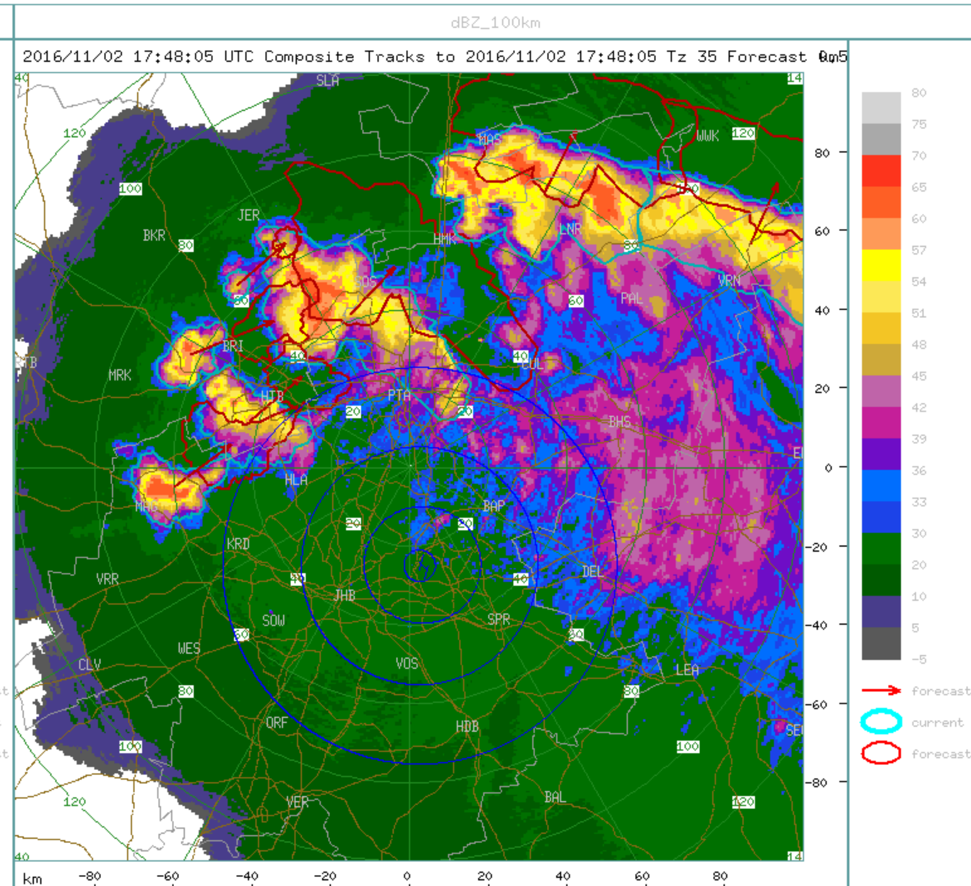
Very Low	Low	Moderate	High
0	1	2	3

Likelihood of impact

2016-11-02 17:48:05

	0 min	10 min	20 min	30 min	45 min	60 min	90 min	120 min
4 km								
15 km								
30 km								
50 km								

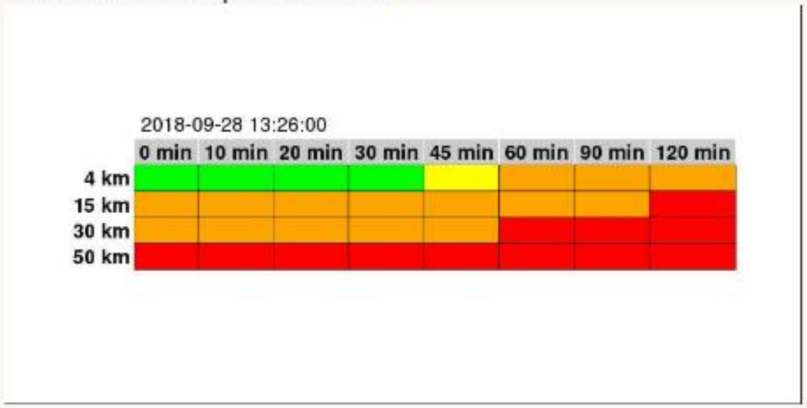




Information from ATM

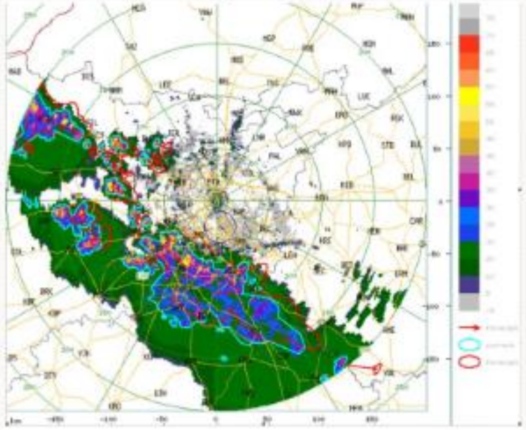
Collapse all

Moses Godwill Matshipi Chiloane 3:34 PM



Weather update at 15:26

Moses Godwill Matshipi Chiloane 3:41 PM



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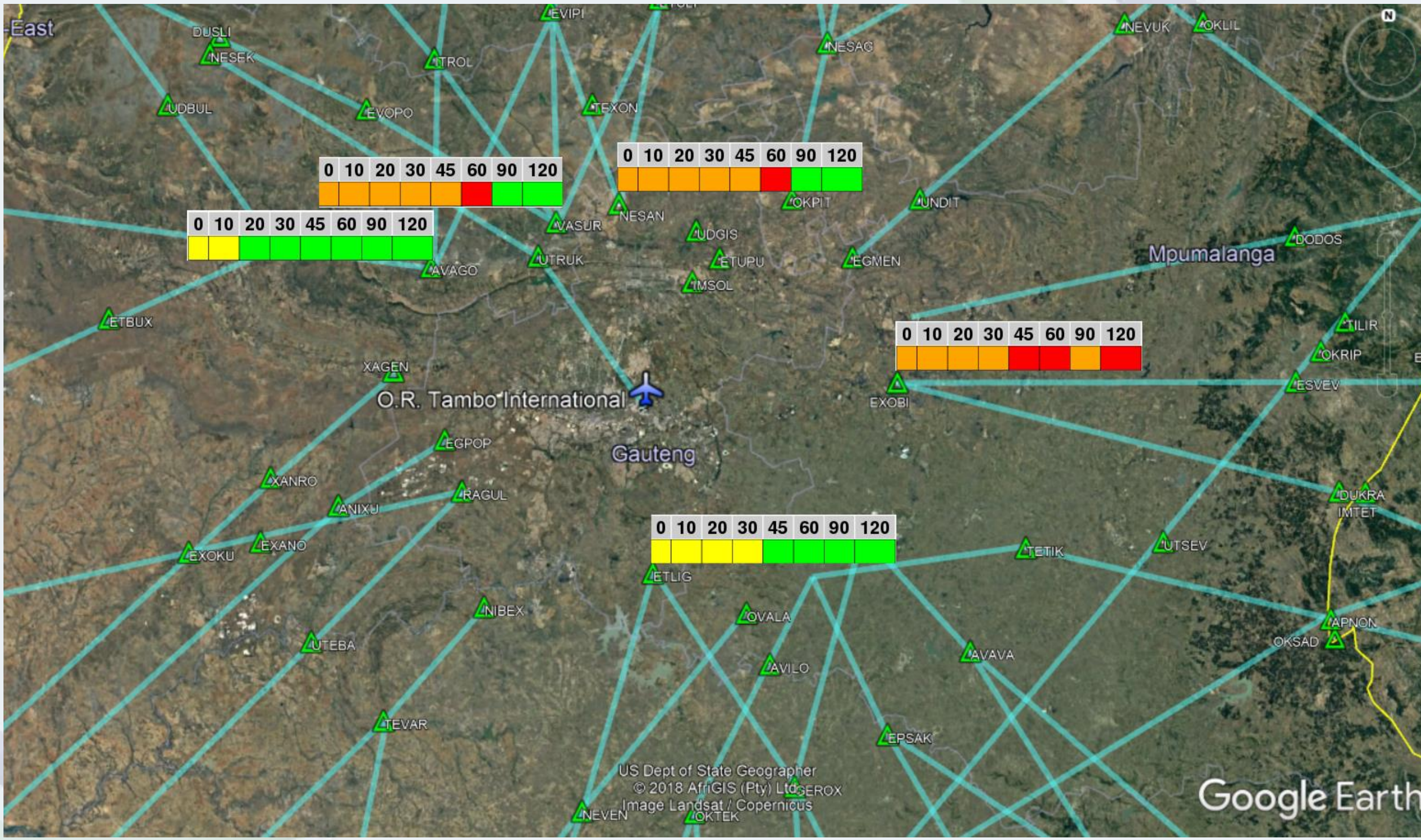
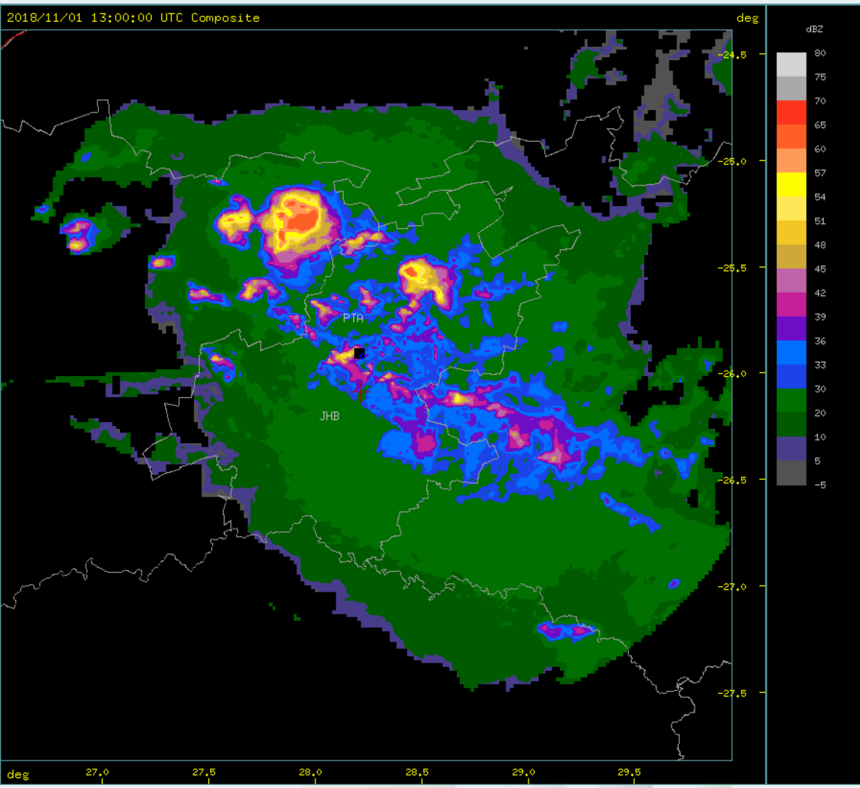
Thunderstorm Table for waypoints

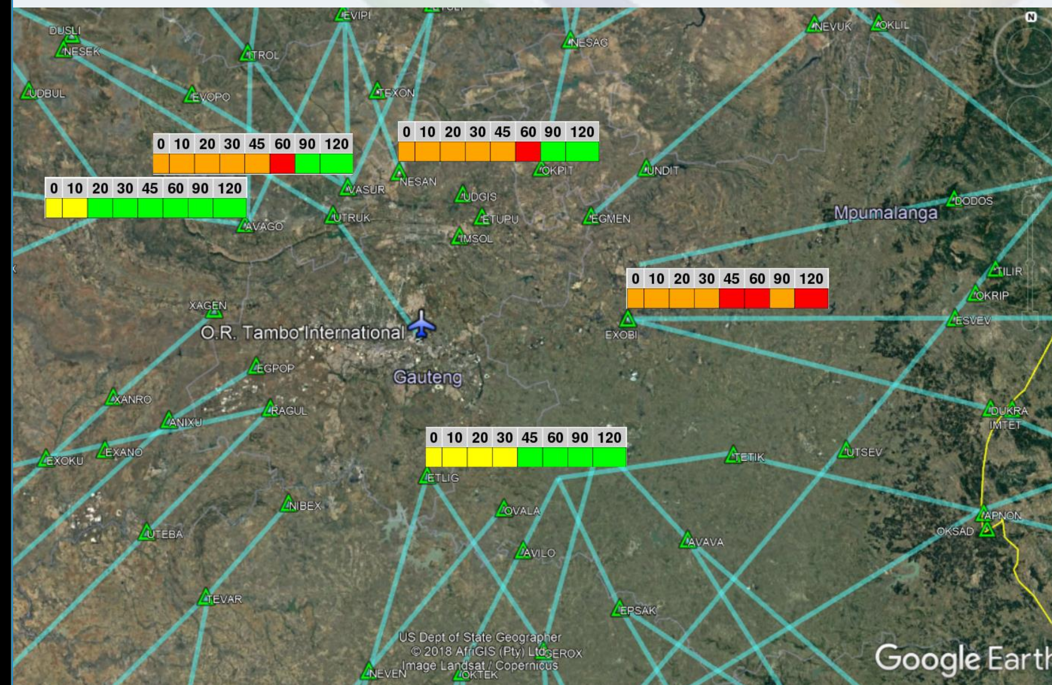
Looking into expanding mini thunderstorm table to waypoints along flight paths



Courtesy of Ngwako Mohale

Thunderstorm Table for waypoints





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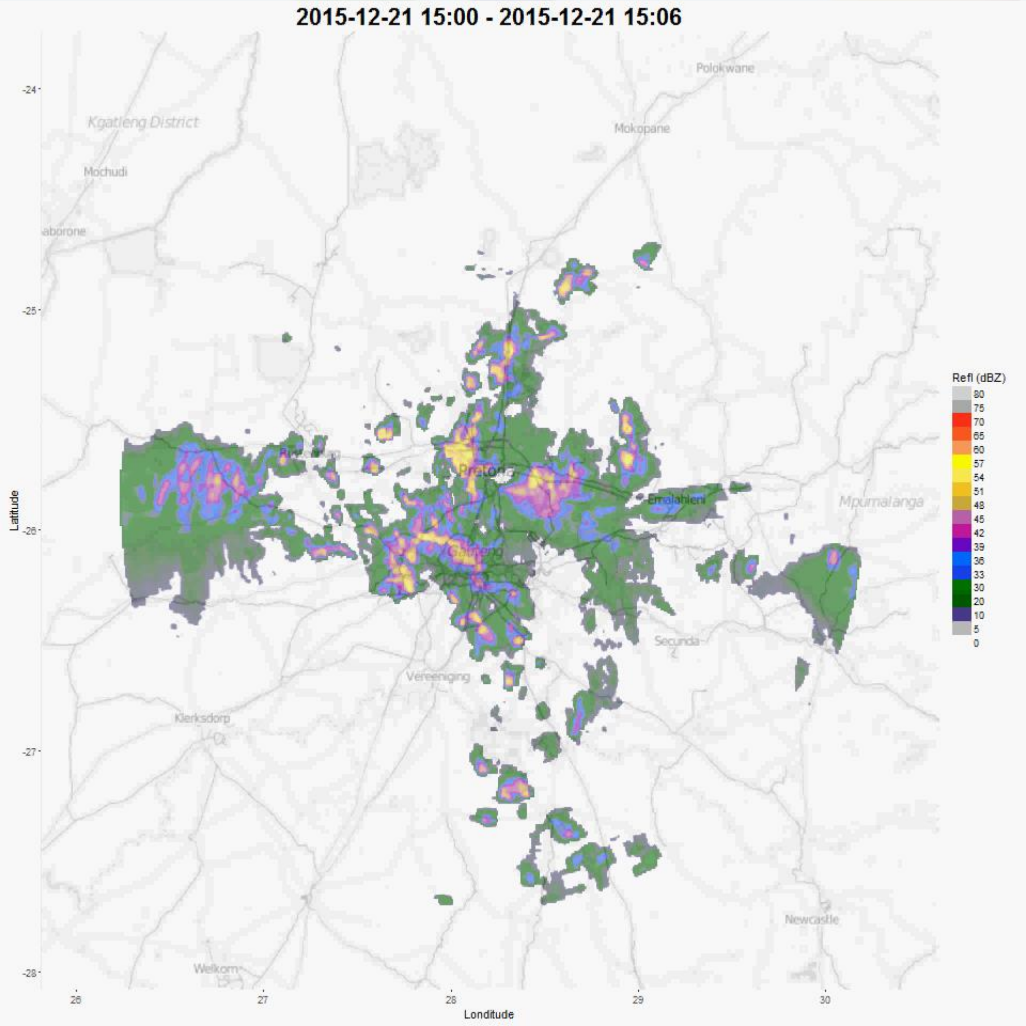
Courtesy of Ngwako Mohale

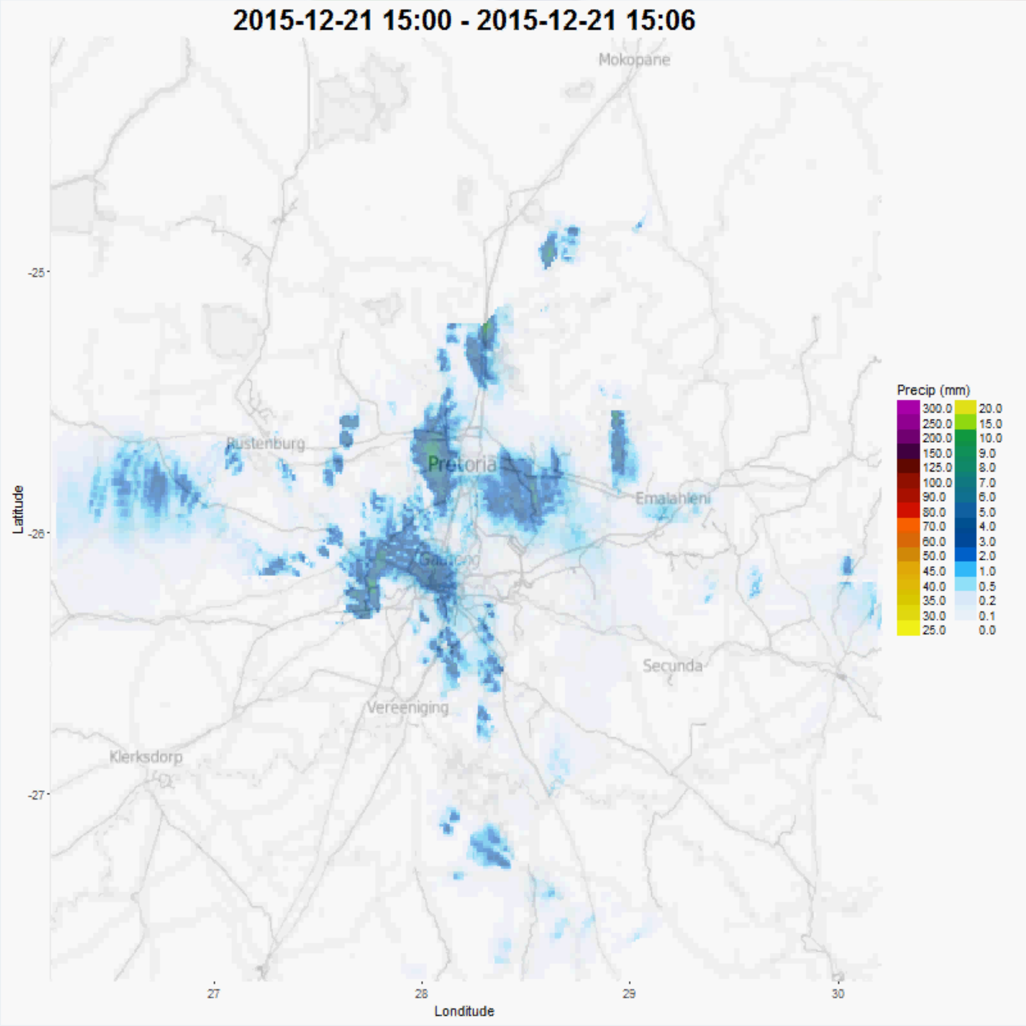
Installation of Community- Short-range Warning of Intense Rainstorms in Localized Systems (Com-SWIRLS)

- Produces extrapolated nowcasts from CAPPI reflectivity data
- Extrapolation is based on Optical Flow vector calculation using consecutive time steps.
- Growth and Decay not taken into consideration
- SWIRLS installed over:
  - Irene Radar domain – 200km range.
  - 400x400 pixels (1kmx1km)
  - 9hr extrapolation



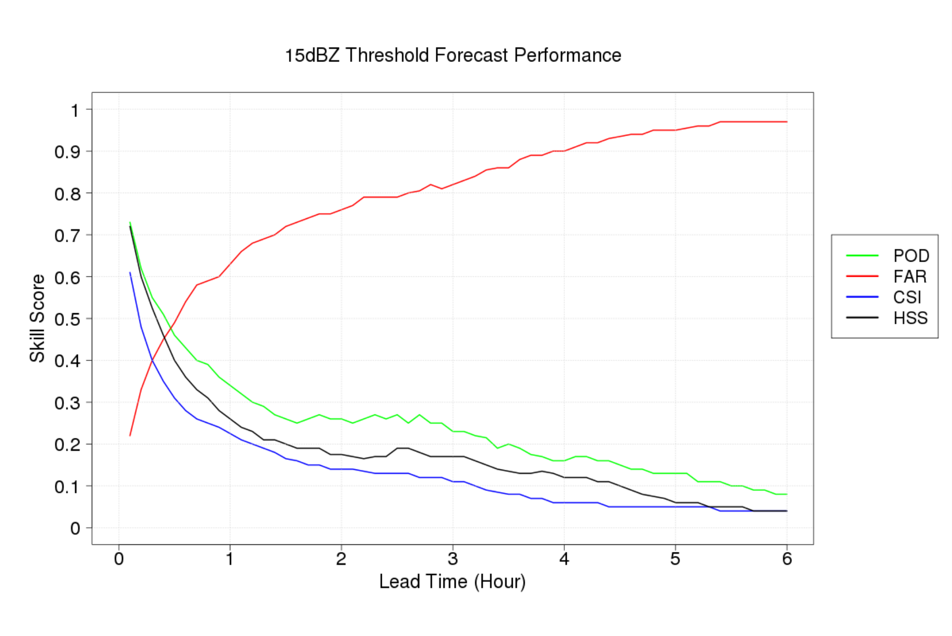
Com-SWIRLS Radar QPF

- Com-SWIRLS also running on SAWS QPE algorithm to produce QPF.
- First a one-hour accumulation
- Then a 9-hour extrapolation
- No growth and decay



Com-SWIRLS

- Extrapolated forecast slower than observation field in all cases.
- Growth and decay of thunderstorms not taken into account.
- Thunderstorm initiation not taken into account.



- Need to blend with NWP model to extend forecast from 2-9 hours.

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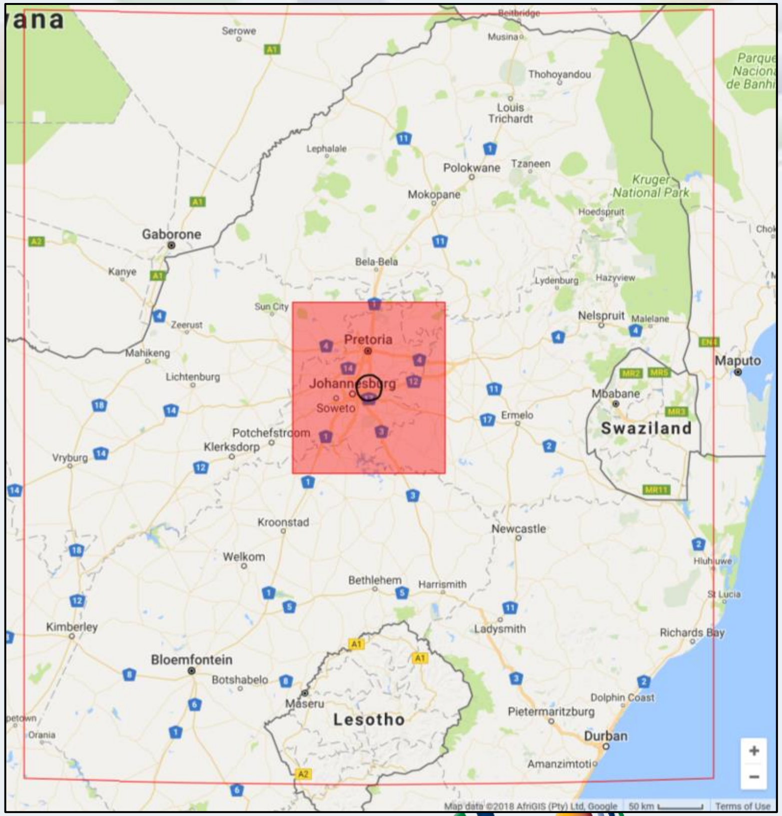
Sub-kilometer model

Convective scale model (333 m) using the UK Met Office Unified Model

- ORTIA nested domain
- Model simulations done with RA1 Nesting Suite
- 333 m resolution nested within 1.5 km resolution
  - Both 600 x 600 grid points
- Evaluated both RA1-T and RA1-M science configurations
- 7 high impact rainfall events which affected aviation operations and transport
- Compared against GPM, Radar QPE and LDN as well as operational runs
- All runs: 18Z analysis with all ~t+12 lead time



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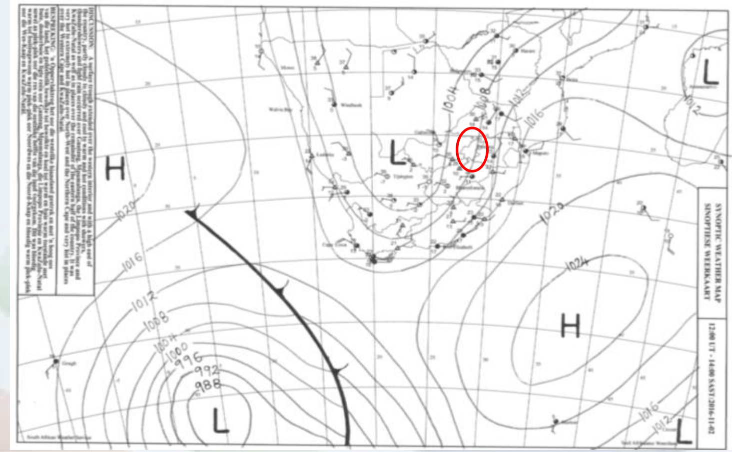
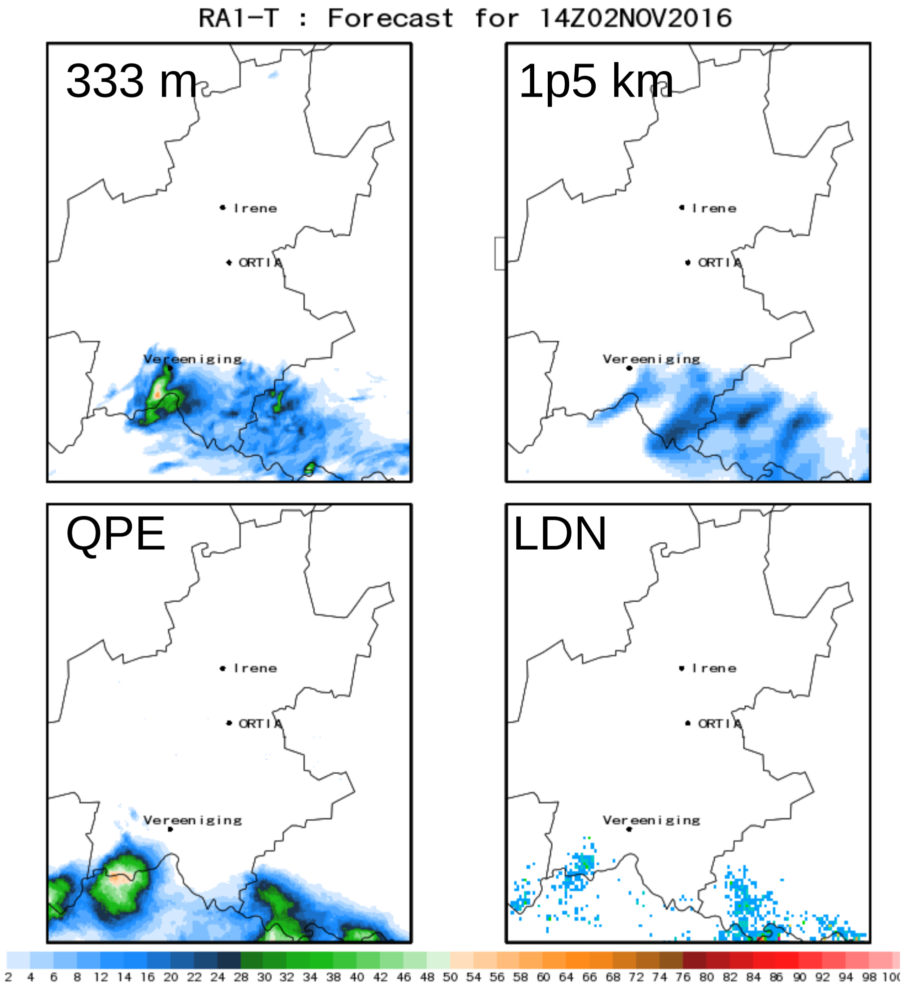
Slide courtesy from Stephanie Landman

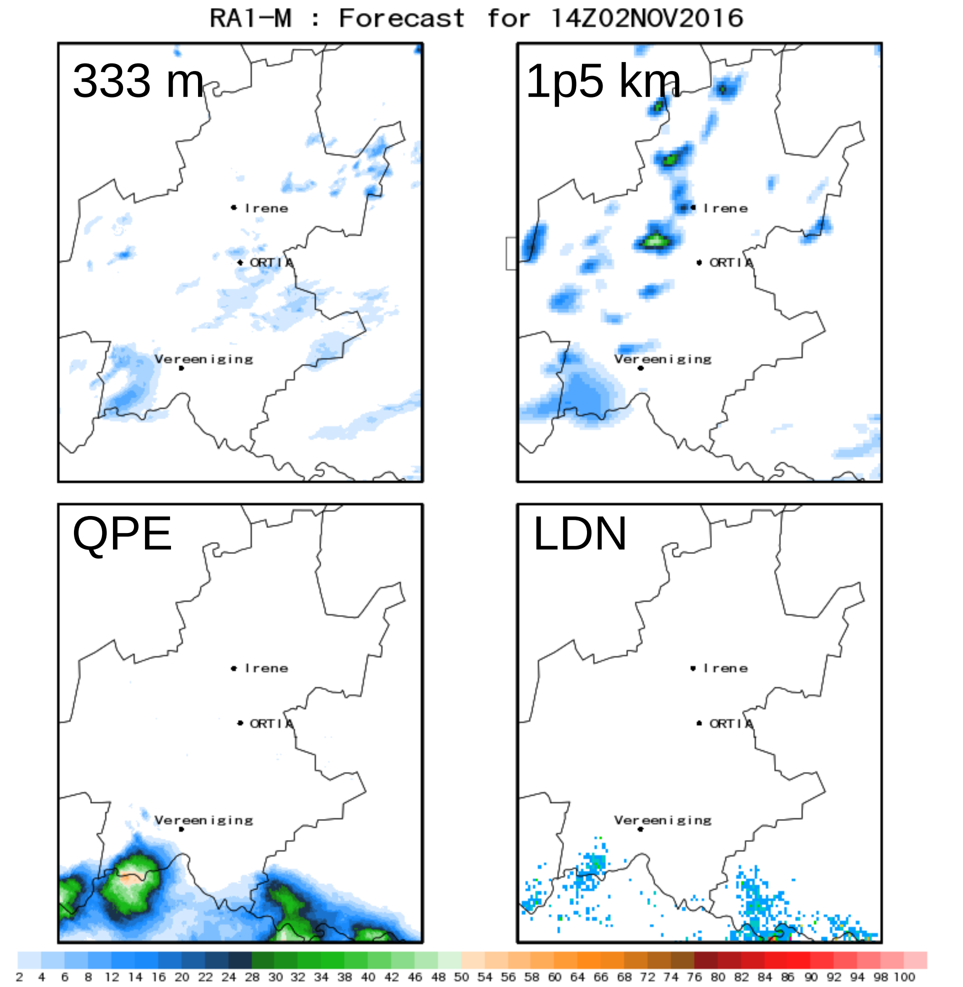
2016-11-02

RA1-T vs. RA1-M

- Surface trough; heat-induced TS to east of SA
- RA1-T is much more structured than RA1-M

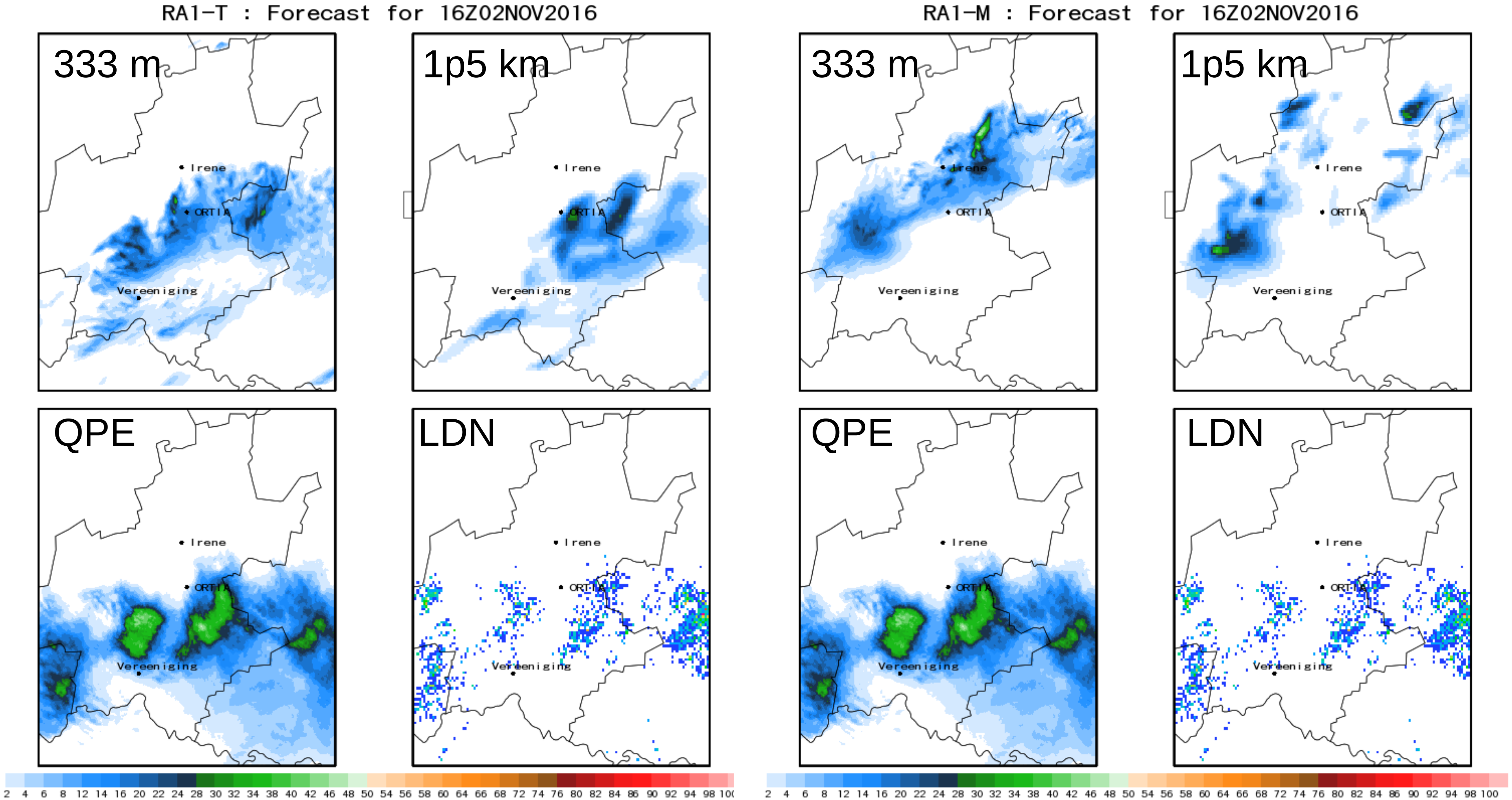






2016-11-02
RA1-T vs. RA1-M

- Both RA1-T and RA1-M sub-k capture spatial extend relatively well (bit north) with different intensities
- RA1-T 1p5 km performs better



NWP models

- 333 m resolution model tested on 7 cases
- Unfortunately we currently don’t have the computing resources available on our HPC
- Current focus on the implementation of a convective scale ensemble as well as data assimilation.
- Near-term focus for aviation products will be on the operational 1.5 and 4.4 km resolution models operational at SAWS.

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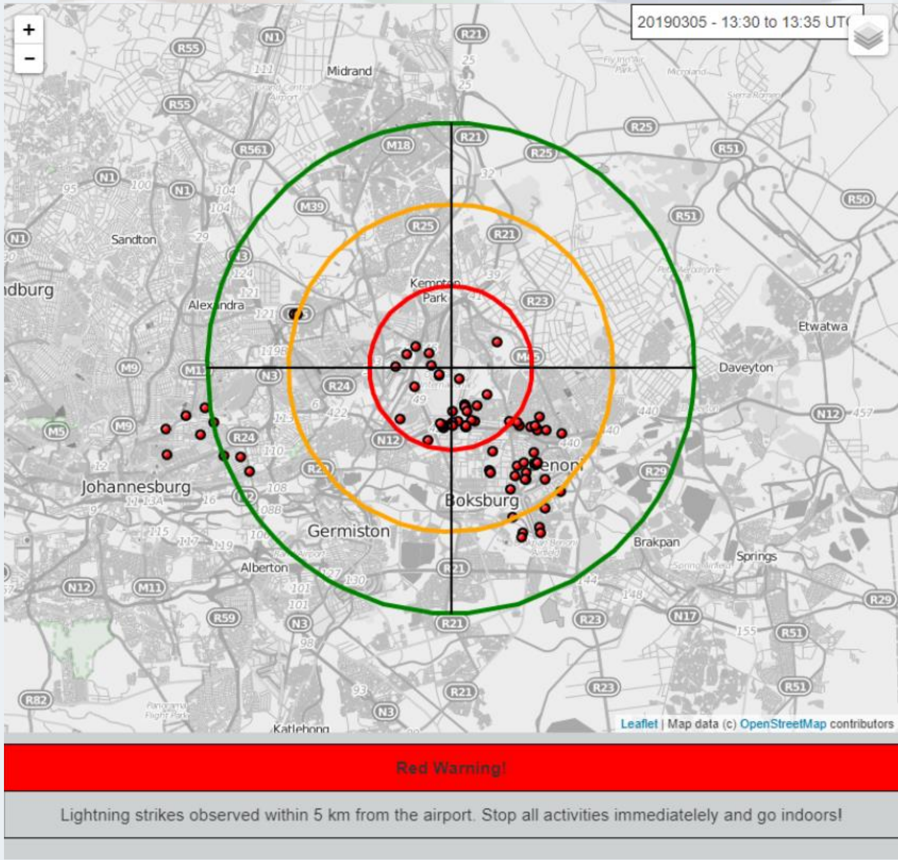
Lightning Monitoring and Alert

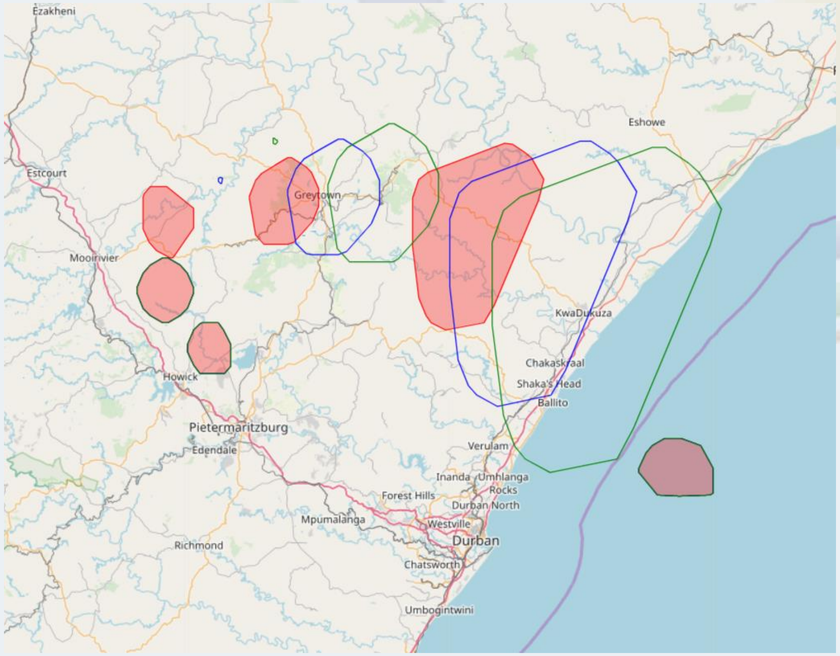
- A lightning monitoring and alert product was developed for ORTIA.

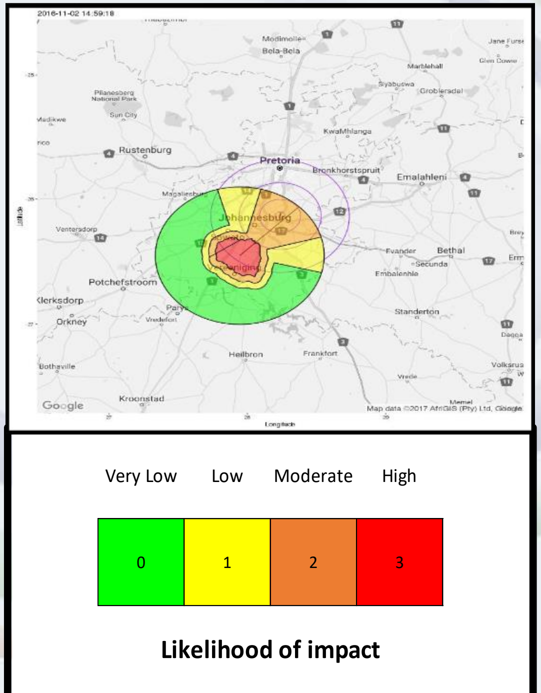
- Three different range rings are drawn at 5, 10 and 15 km around the airport.
- Lightning strikes are represented by red dots on the maps.
- If lightning is observed:
  - No lightning within 15 km of the airport all range rings remain black lines.
  - within 10 to 15 km from the airport, the 15km range ring turns green.
  - within 5 and 10 km from the airport, the 10 km range ring turns orange.
  - within 5 km from the airport, the 5 km range ring turns red.
- The system also has the capability to provide a audible warning once lightning is within say 5 km of the airport and can also send emails to the appropriate user.

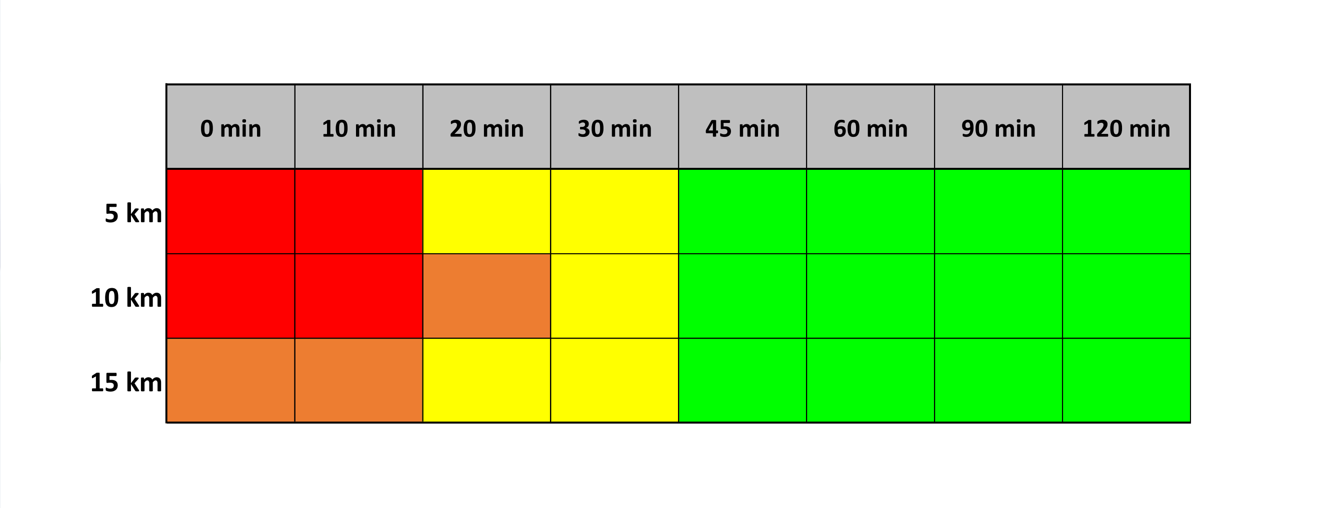


Lightning Monitoring and Alert

- Tracking algorithm was applied to lightning data and is being incorporated into the product.
- Finalising a lightning alert table for ORTIA







Phase 2
Impact-based Products

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Airport Management Centre

- Airports Company South Africa (ACSA) launched an Airport Management Centre (AMC) in 2009 in preparation for the 2010 FIFA world cup soccer event.
- The purpose of the AMC is to have all role-players in one centre to solve problems quickly and to improve the performance of the airport to enhance passenger experience and the performance of the airport
- AMC is to improve daily airport operations by stimulating collaboration between airport partners, namely the service providers and airlines

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Airport Management Centre

- The effective approach of an AMC covers communication and cooperation between partners, operational transparency through shared information, and governance through sustainable improvement of business performance.

- The facility has already demonstrated an improvement of departure times and airport efficiency.

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Airport Management Centre

- The facility ensures coordination between all stakeholders, including:
  - Airports Company South Africa (ACSA)
  - Air Traffic Management (ATM) and Navigation Services
  - Airlines

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Airport Management Centre

- Forecasters from our Aviation Weather Centre (AWC) in direct contact with AMC with all weather information and forecasts.
- Dedicated aviation weather forecaster now in the AMC.
- With AvRDP we have established a really good relationship with AMC.
- AMC direct link with ATM
- AMC receiving Thunderstorm table every 6-minutes since end of 2017 – Feedback very positive.
- Receiving vital information for AvRDP.

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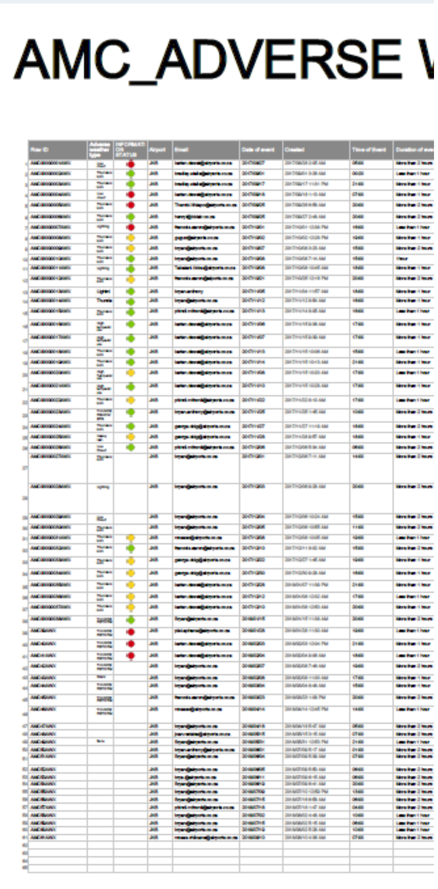
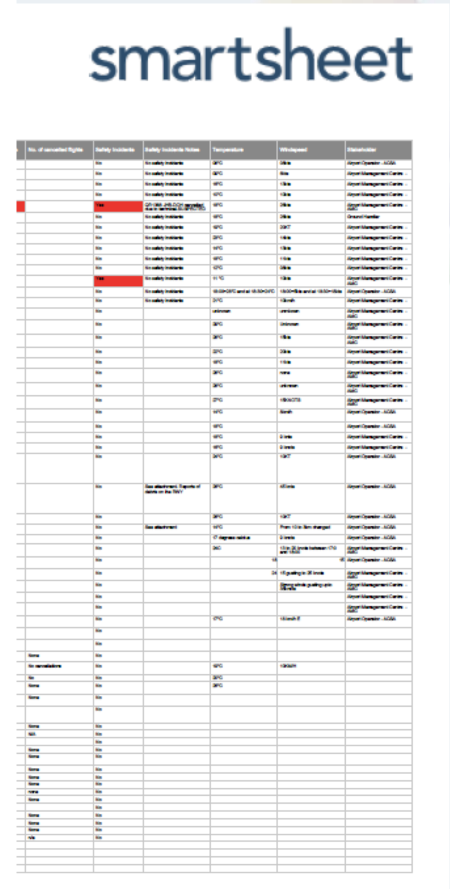
Information from ATM



AMC_ADVERSE WEATHER

Row 2

Row ID	AMC62AWX
Adverse weather type	Thunderstorm
Airport	JNB
Date of event	2018/09/28
Delays	Yes
No. of flights delayed	46
Delay minutes	1669
Diversions	Yes
No. of flights diverted	1
Cancellations	No
No. of cancelled flights	none
Safety Incidents	No



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Information from ATM

Central Airspace Management Unit **Demand Forecast for 28 September 2018**

Telephone Number: 011 928 6433 Email: camuhelpdesk@atns.co.za	Last Update: Thursday, 27 September 2018 16:44 South African local time Teleconference commences at 0630UTC daily

Weather Conditions – Qualitative Overview for 28 Sep 18

	Thunderstorms AM	Thunderstorms PM	Low Cloud/Visibility AM	Low Cloud/Visibility PM	Wind/Turbulence AM	Wind/Turbulence PM
FAOR	FM 1200Z	UNTIL 1800Z				
FACT			UNTIL 0600Z			
FALE						
FALA						
FAGG			FM 0600Z	UNTIL 1200Z		
FAPE			FM 0900Z	UNTIL 1200Z		
FAEL						
FABL						
FAKN						
FAPP						
FAKM						

Favourable	Minimal impact to operations expected
Marginal	Some potential for operations to be impacted on
Unfavourable	Impact on operations likely

Adverse Weather Impact Data

Adverse weather type	Date of event	Time of Event	Duration of event	Weather condition	Rate reduction	Rate Reduction Details	Stoppage	Stoppage note	Delays	No. of flights delayed	Delay minutes	Diversions	No. of flights diverted	Cancellations	No. of cancelled flights	Safety Incidents	Safety Incidents Notes
Thunderstorm	2019/01/25	18:00	More than 2 hours	Thunderstorm	Yes	Arrival rates adjusted to 25 per hour	No	No stoppage	Yes	3	113	No	0	No	0	No	None
Thunderstorm	2019/01/26	17:00	More than 2 hours	Thunderstorm	No	0	Yes	17:07 to 17:44	Yes	2	29	No	0	No	0	Yes	TK043 aircraft struck by lightning.declared safe to depart
Thunderstorm	2019/01/27	20:00	More than 2 hours	Thunderstorm	No	None	No	n/a	Yes	7	141	Yes	7	No	n/a	No	None

Information we have:

- Rate Reduction
- Stoppages
- Delays
- Diversions
- Cancellations

- 87 events
- Thunderstorms

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Delays

- We have the information of number of flights delayed.
- We have the radar reflectivities (dBZ)
- Goal is to predict the number of flights delayed based on the radar reflectivities.
- Performed a linear regression with:
  - Number of flights delayed – Dependant Variable
  - Radar dBZ – Independent Variable

$$y = \beta_0 + \beta_1 x_1 + \varepsilon$$

where β_0 and β_1 are the regression coefficients, x_1 is the independent variable and ε the error due to measurements.

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Delays

- The output of the linear regression then gives:

Delays per hour = -5.992865 + (0.266400 x dBZ) + 0.0232608

- Since the number of planned flights during different times of the day are different, a regression analysis was also performed for every hour of the day

- For example between 16:00 and 17:00 UTC the following equation applies:

Delays per hour = -0.805463 + (0.147277 x dBZ) + 0.024355

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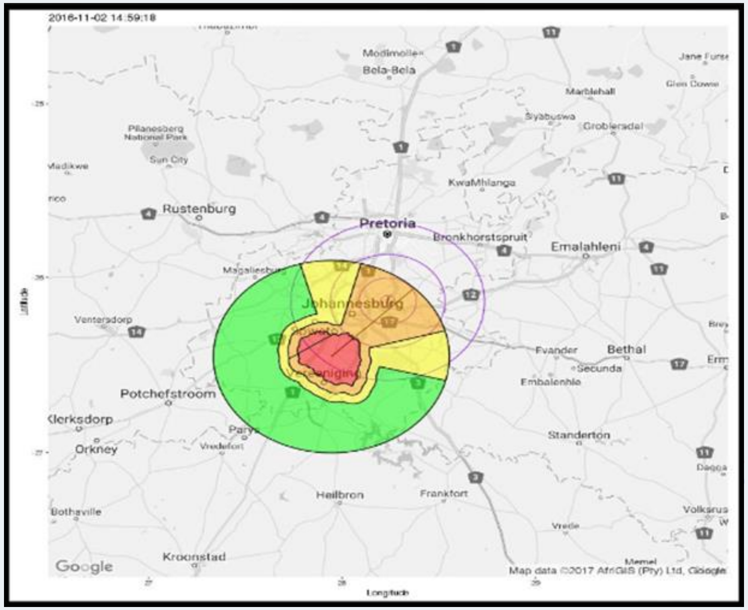
Delays

- We have the equations to forecast the number of delays

Delays per hour = -5.992865 + (0.266400 x dBZ) + 0.0232608

- We have the information on the likelihood of a storm reaching the airport.
- Based on this information a risk matrix table can be compiled

Likelihood		Impact: Minimal	Impact: Minor	Impact: Significant	Impact: Severe
	High		4	12	20+
	Medium		2	10	18
	Low		1	8	16
	Very low			6	14



Rate Reductions

- Unfortunately in the impact data received, for most cases (apart from 7) the rate reduction figures were not provided.
- Only yes and no confirmations for rate reductions were available.
- A binary logistical regression analysis was performed to predict the probability of a rate reductions based on the radar reflectivity values.
- Logistical regression is often used to predict the probability of an event by means of a set of predictors

$$p_i = \frac{1}{1+e^{-(\hat{\alpha}+\sum \widehat{\beta_i} X_i)}}$$

where p_i is the probability of the event as a function of independent variables X. The regression coefficients are $\hat{\alpha}$ and $\hat{\beta}$

Rate Reductions

- The output of the binary logistical regression gave:

$$Probability\ of\ Rate\ Reduction = \frac{e^{-9.113631+0.210179dBZ}}{1+e^{-9.113631+0.210179dBZ}}$$

- The output is value between 0 and 1 which is translated to a probability between 0 and 100

- As with the delays, the rate reduction regression analysis was also performed for every hour, where a different equation for every hour of the day is available.

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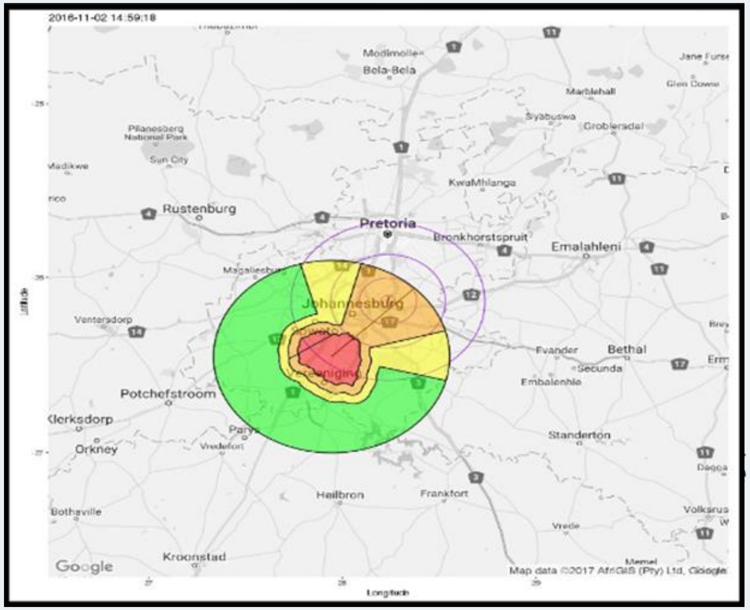
Rate Reductions

- We have the equations to forecast the probability of rate reductions

$$Probability\ of\ Rate\ Reduction = \frac{e^{-9.113631+0.210179dBZ}}{1+e^{-9.113631+0.210179dBZ}}$$

- We have the information on the likelihood of a storm reaching the airport.
- Based on this information a risk matrix table can be compiled

Likelihood of storm reaching airport					
	High		20	60	100
	Medium		10	50	90
	Low			40	80
	Very low			30	70
		Minimal	Minor	Significant	Severe
		Likelihood of reduced rates			



Stoppages

- Stoppages also a yes and no event
- As with rate reductions a binary logistical regression analysis was performed on the stoppages data.
- The following equation was derived:

$$Probability\ of\ Stoppages = \frac{e^{-11.842685+0.263810dBZ}}{1+e^{-11.842685+0.263810dBZ}}$$

- This gives the probability of stoppages based on the radar

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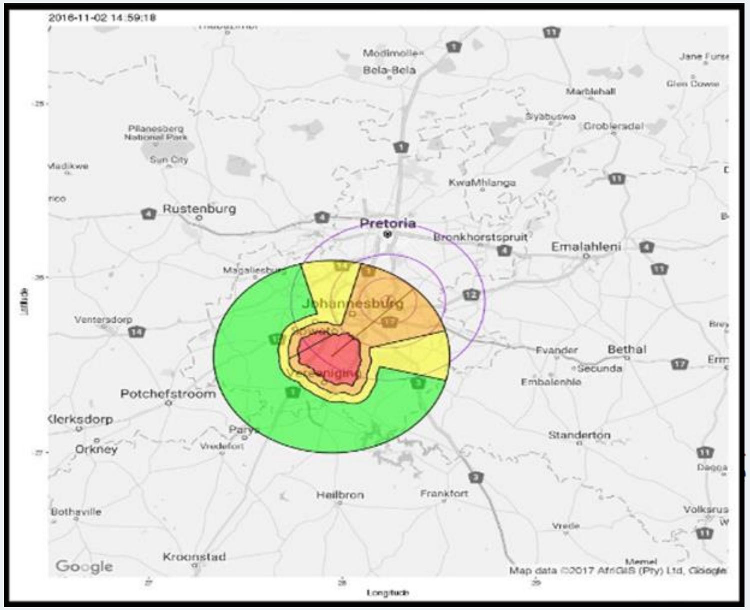
Stoppages

- We have the equations to forecast the probability of stoppages

$$\text{Probability of Stoppages} = \frac{e^{-11.842685+0.263810dBZ}}{1+e^{-11.842685+0.263810dBZ}}$$

- We have the information on the likelihood of a storm reaching the airport.
- Based on this information a risk matrix table can be compiled

Likelihood of storm reaching airport	Minimal	Minor	Significant	Severe
High		20	60	100
Medium		10	50	90
Low			40	80
Very low			30	70
	Likelihood of stoppages			



Combining the information

- Based on the impact-based forecasts and risk matrix a table showing the impact at the airport could be compiled
- Available for the next 2-hours

	0 min	10 min	20 min	30 min	45 min	60 min	90 min	120 min
Stoppages	94%	97%	68%	8%	0%	0%	0%	0%
Reduced Rates	96%	98%	64%	3%	1%	0%	0%	0%
Delays	9	10	7	2	1	0	0	0

Verification

- Thunderstorm table has been used extensively at AMC with positive feedback
- Impact data received for 87 cases were used in the development of the regression models
- New impact-based products will be tested during the 2019/20 summer season

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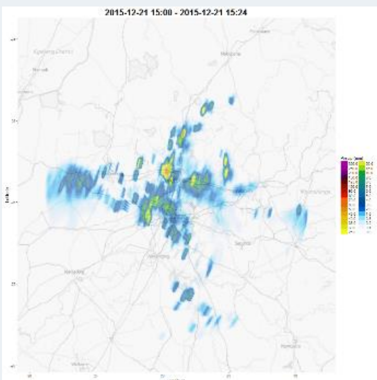
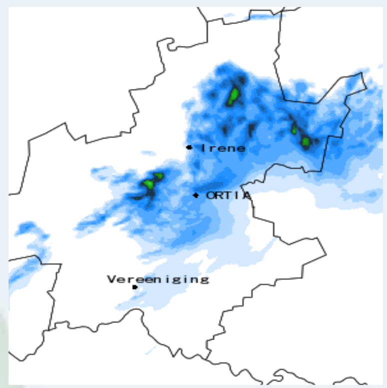
Plans

- Implement operational 1.5 or 4.4 km NWP models into products to extend products to up to 48 hours in advance.
- Blending of 1.5 or 4.4 km model with Com-SWIRLS to extend thunderstorm table from 2 to 9 hours ahead





Blended Product

	0 min	10 min	20 min	30 min	45 min	1 hr	1.5 hr	2 hr	3 hr	4 hr	5 hr	6 hr	7 hr	8 hr	9 hr	10 hr	11 hr	12 hr	13 hr	14 hr	15 hr	16 hr	17 hr	18 hr	19 hr	20 hr	21 hr	22 hr	23 hr	24 hr
4 km																														
15 km																														
30 km																														
50 km																														

Radar (and NWP blend)	Radar + NWP Blend	NWP

Plans

- Finalize lightning system – tracking incorporated and warning table
- Finalize thunderstorm tables for waypoints along routes
- Testing of all impact-based products at the airport during the 2019/20 summers season.
- Adjusting products based on evaluations.
- Request historic impact data from airport (as well as additional information) to further enhance products/new products
- Display system for all the products

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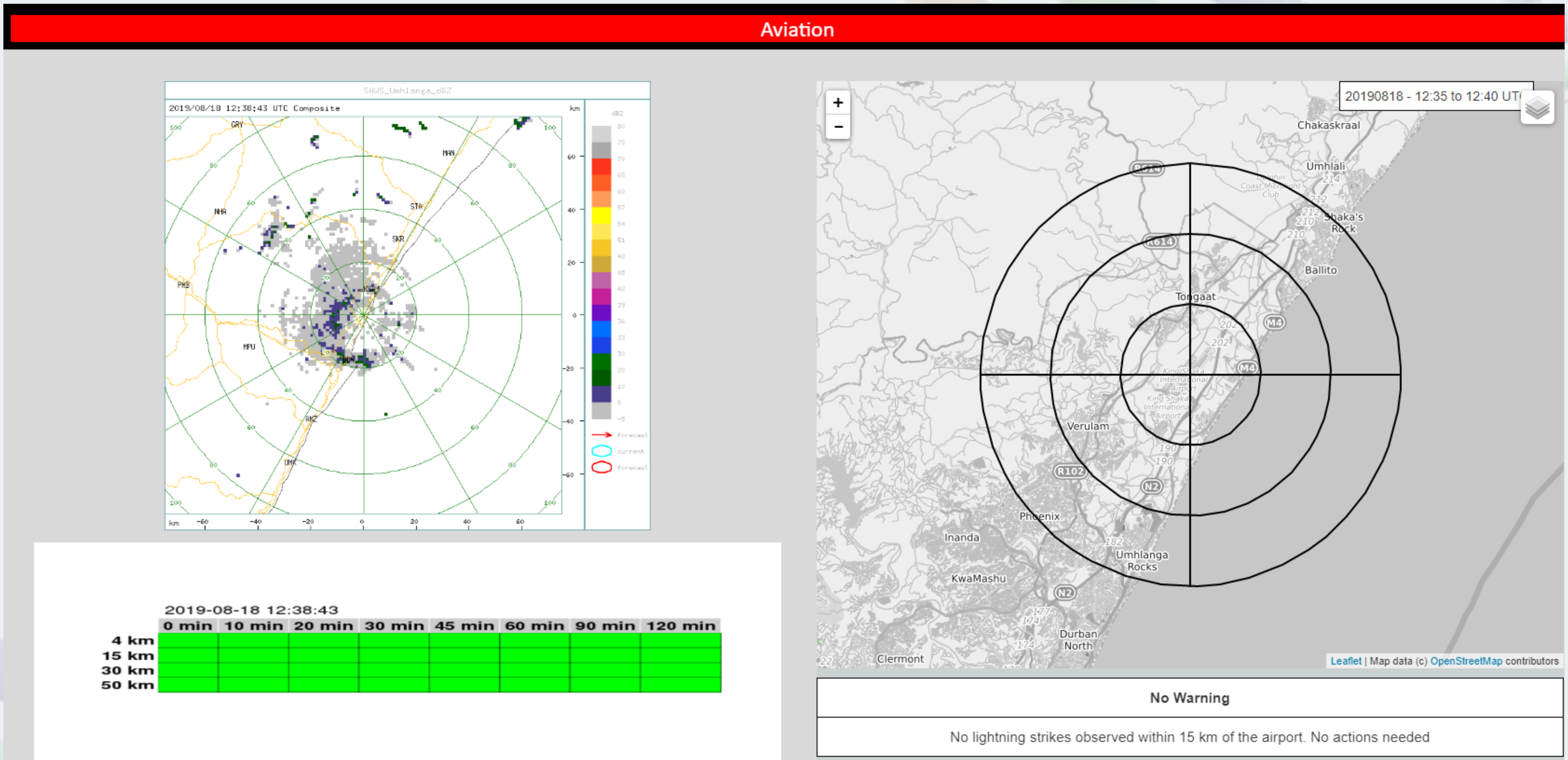
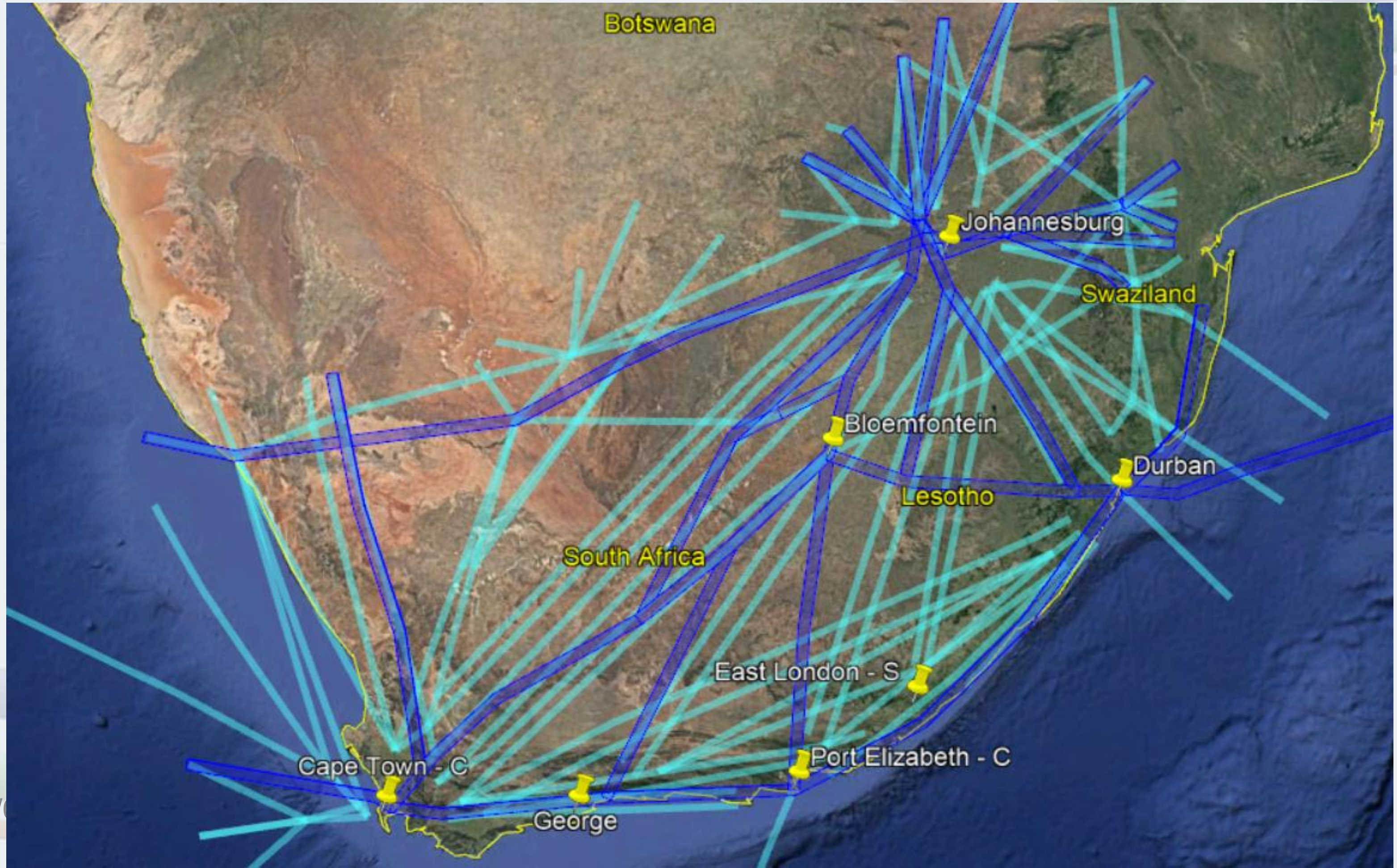
Future Work

- Extension of all products to other airports in South Africa



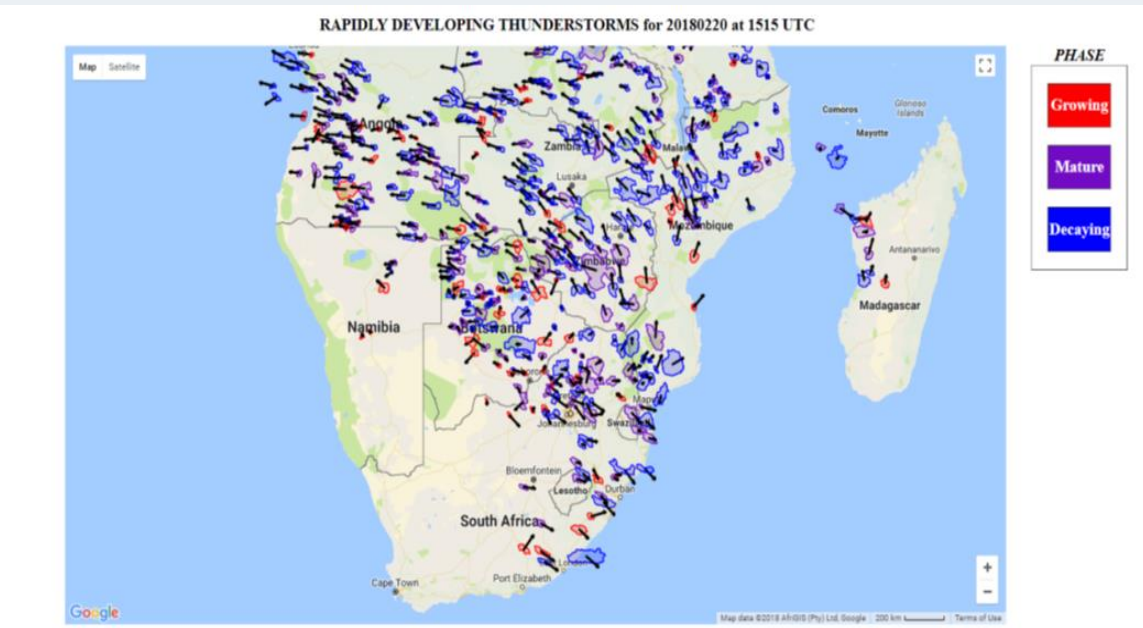
Future Work

- Extending products to flight routes between airports in South Africa



Future Work

- Extending products to flight corridors to Africa.



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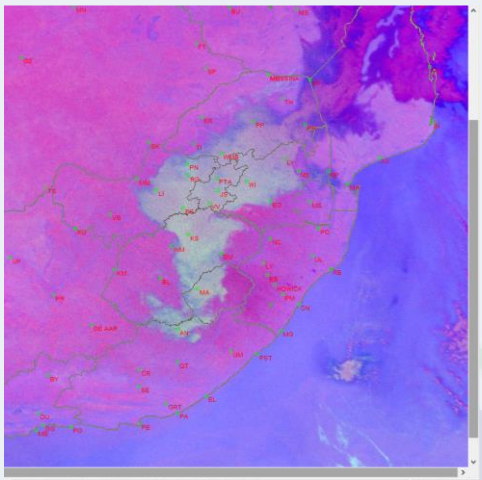
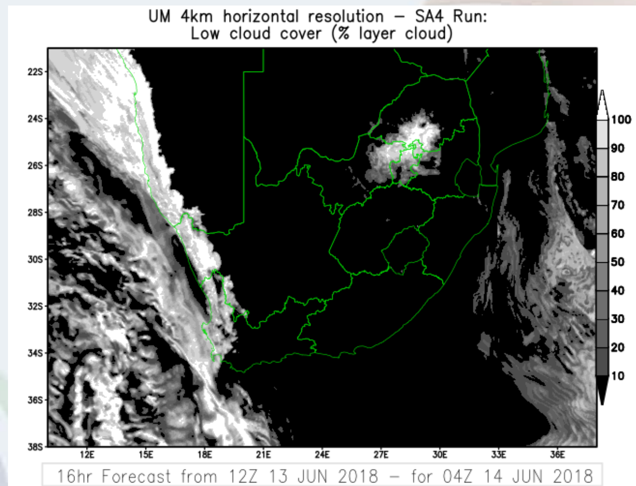
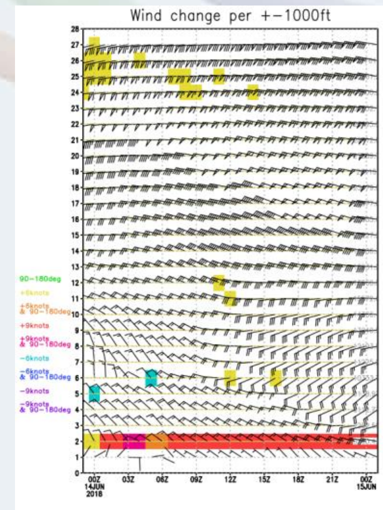
Future work

- Investigate other weather conditions such as fog, low visibility, winds, turbulence and frost.







- Incorporate new ideas from other airports

South African Weather Service

Thank You

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