Building Regional Resilience through Strengthened Meteorological, Hydrological and Climate Services in the Indian Ocean Commission (IOC) Member Countries

Rationale for the selection of the Radar type

1. Types of radars

There are 3 different types of electromagnetic wavelength commonly used for weather radar applications i.e. S band (10cm), C band (5cm) and X band (3cm). Table 1 provides a description of the characteristics of each type of radar.

Table 1 – Typical specifications of weather radars for the 3 most commonly used operational frequencies

	S-Band (10cm)	C-Band (5cm)	X-Band (3cm)
Typical Frequency Range	2.7-2.9 GHz	5.6-5.65 GHz	9.3-9.5 GHz
Polarization	Dual	Dual	Dual
Antenna Diameter	8.5 m	4.2 m	2.4 m
Beam Width / Angular Resolution	1.0 Degree	1.0 Degree	1.0 Degree
Antenna Gain	44.5 dB	44.5 dB	44.5 dB
Transmitter Peak Power	750 kW	250 kW	100 kW
Typical Coverage	400 km	255 km	100 km
Minimum Range Resolution	100 m	75 m	50 m
Typical Range Resolution	500 m	300 m	100 m
Pulse Repetition Frequency (PRF)	250-1200 Hz	250-1300 Hz	250-2500 Hz
Rotation Rate	1-6 rpm	1-6 rpm	1-6 rpm
Typical Elevation Range	0-90 Degrees	0-90 Degrees	0-90 Degrees
Attenuation in Heavy Rain	~0.015 dB/km	~0.15 dB/km	~1.5 dB/km
Strengths	Immune to attenuation	Cheaper than S-band	Cheaper than C or S-band
Weaknesses	More expensive	Attenuation issues	Severe attenuation issues

2. Technical considerations for the selection of the radar type

2.1 Radar wavelength

Shorter wavelengths can detect smaller particles (e.g. drizzle) but this type of electromagnetic signal is also more readily absorbed (or attenuated) by the water in the atmosphere/precipitation.

Attenuation at X-band is very severe and is therefore only used for short distance purposes, e.g. monitoring the weather conditions in a surrounding area of an airport to guide the take-off and landing; and hydrometeorological monitoring in a small catchment and dam.

C-band radar can also be subject to serious attenuation during severe storm events although these occurrences are much less frequent at C-band than at X-band.

At S-band, the electromagnetic signal is not affected by attenuation and therefore this wavelength is commonly the preferred option for areas of the globe prone to the most intense storms, such as tropical cyclones.

Modern techniques such as dual polarization provide algorithms to automatically detect and correct for attenuation of the radar signal which is useful for operating C and X-band radars. However, in some cases (which are more frequent at X-band), 'total extinction' of the signal occurs where all forward electromagnetic power in the beam is absorbed by the water inside a storm; in those cases no signal can be detected beyond the storm and in this circumstance, dual-polarization does not help since there is simply no information received. This is a serious problem because the most severe storms (such as tropical cyclones) are those likely to cause serious impacts. Noting that the **South West Indian Ocean (SWIO) region is a tropical cyclone prone area**, the selection of C and X-band radars are not practical solutions; therefore, as far as concern the radar wavelength, **the preferred option in terms of radar type is the S-Band radar**. Countries not in tropical cyclone prone areas (e.g. Burkina Faso) may have selected an S-Band radar, however C- or even X-Band radars would be appropriate as the most severe storms are not so severe as tropical cyclones and therefore the attenuation would not be significant.

2.2 Range Resolution/Coverage

As described in Table 1, S-Band radar's coverage can go up 500km, while C- and X-Bands go up to 300km and 100km, respectively, which can significantly reduce (or even do not provide a signal) in case of a storm. Noting that the target countries in the SWIO region are islands, whose distance between them varies, and in some cases over 1,000 km, it will be appropriate to have the highest coverage to allow superposition, where possible, for establishing a composite/mosaic of the radar imageries for monitoring and extrapolating into the near future (nowcasting) regional events such as tropical cyclones. Other countries prone to tropical cyclones (e.g. Indonesia – various islands) has decided to have multiple C-Band radars, taking into account the lowest potential coverage to still superpose the radar imagery, i.e. it has a very dense network. But this approach is not suitable to the Southwest Indian Ocean due to the distance between islands/countries.

2.3 Dual polarization

Dual polarization technology is an essential tool for weather radar application. As opposed to conventional single polarization radar, dual polarization radars transmit and receive vertical and horizontal electromagnetic signals (Figure 1) to provide valuable information regarding the origin of the echo observed by the radar, it being reflected from airborne particles/object (such as hydrometeors, birds, insects, or plans) or from the ground and the sea. With dual-pol, the additional vertical information allow us to build a more accurate and complete image of the atmosphere.

Under normal propagating condition of the atmosphere (standard refraction) the radar beam travel through the atmosphere in a straight line with the curvature of the earth pushing the radar beam higher in the atmosphere as it travels away from the radar. During super refraction events, caused by sharp increase of temperature with altitude the radar beam is bent downward towards the ground or the sea. Under those conditions, echoes originating from the ground (anaprop) or the sea (sea clutter) can severely contaminate radar images and are often difficult to separate from echoes originating from precipitation. Dual polarization radars provide additional information which drastically improve the identification and removal of spurious echoes from the radar images. This will be particularly important to the four target countries due to the radar close proximity to the sea.

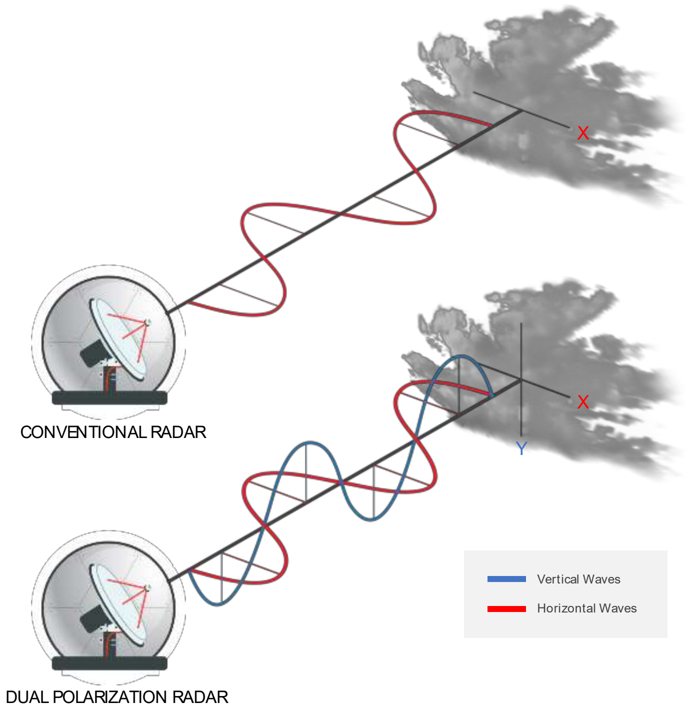

Figure 1 – Conventional versus dual polarization radars.

Furthermore, dual polarization radar provide additional parameters that can be combined to ascertain the drop size distribution and ice-to-water content within the radar field of view. These can be used to produce better identification of the hydrometeor type and size, hence delivering higher accuracy rainfall rate data for hydrological and weather forecasting models.

2.4 Radar Tower

S-band radar system is a much larger system than C- or X-Band radars; therefore the associated infrastructure must be designed to support such large installations. There is various options:

(i) metal tower, which is a less expensive option with the equipment cabin located directly below the radar platform; this type of structure can be fabricated off site and assembled later; examples of such radars exist in Barbados, Brunei, Paraguay; and

(ii) concrete tower that will need to be constructed on site; the tower provides shelter from ground to radar platform levels. At the beginning of the Hydromet project, a cost-benefit analysis of the two solutions must be carried out in order to select the most cost-effective solution to the target countries. This is due to the fact that metal tower may be a less expensive option at the time of the construction, but ongoing costs are higher than for the concrete structure owing to the need for more frequent inspections.

3. O&M considerations

3.1 Staffing for Operations

A weather-radar is a sophisticated mixture of hardware and software engineering. To ensure its availability, it is essential to have access to support engineers with a wide range of skills. These skills include mechanical and electronic engineering, necessary for carrying out routine maintenance and calibration of the system as well as fault diagnosis and repair; it also requires skills in radar signal processing and data processing as well as IT engineers; all these are necessary to manage the data outputs. The outcome is operational and sustainable support to the weather-radar, which is an important component in an early warning service. Such expertise exist in the region, both in Mauritius, and La Réunion (an important partner in the region).

The proposed Hydromet project is a regional project that will support capacity building on the NMHSs' staff and the creation of a regional pool of experts. By applying the same technology across the countries, and establishing a regional O&M and calibration lab, the required skills will be available in the region to effectively operate the radar systems. A capacity development program will be developed and implemented for mobilizing staff to fill in the technical capacity gaps among the four countries in the SWIO region, while also building the capacity of newly recruited staff through a comprehensive education and training program.

3.2 Maintenance

Applying the same technology across the countries, and **establishing a regional O&M and calibration lab** as part of the proposed Hydromet project, **contribute to efficiencies and optimization of infrastructure costs, to facilitate integration within the region**, and to affordable operation and maintenance costs to be supported by governments. At the same time, a spare parts package will be added to the technical specifications in the bidding process, as well as a maintenance and repair contract, while building the capacity of the staff.

Governments of Mauritius and Seychelles will be able to support the costs associated with the maintenance of the weather radars; while alternative solutions will be sought to support O&M in Comoros and Madagascar, as those described in the O&M plan (provided separately). These include making arrangements with ASECNA, who is responsible for meteorological services for international air navigation on behalf of Comoros and Madagascar.

3.3 Integration in support of EWS

The proposed Hydromet project is a **regional project** that **promotes regional integration**, and therefore one of the major outputs of the project is to **develop a radar composite/mosaic for the benefit of all countries in the region**, as a result of data-sharing among the four target countries. **Using the same technology across the countries will facilitate integration, and the development and operation of the radar composite/mosaic for the SWIO region, which is extremely useful in support of EWS.**

4. Use of the radar versus satellite imagery

Satellites use a camera to get images of the Earth's weather from space. However, there are several weather obstructions that can affect the whole process. For this reason, they are using different lenses and filters to beat around. Satellites are especially good at showing cloud cover; and with special instruments, they can measure the temperature of the Earth's surface.

A radar transmits an electronic signal that bounces off objects and returns for analysis. Both systems can detect stationary or moving objects, but the display presented on a viewing screen can differ immensely. Weather radar can show the locations of areas of precipitation very clearly. The radar images are also able to show the intensity of the precipitation.

Satellite cameras can show images as they actually appear, but radar can create three-dimensional representations to show things the camera may not reveal, and therefore they are complementary systems.

5- Conclusion

In conclusion, of what is developed above, technically we recommend the installation of the S-band category of the radar and to provide all countries with the same equipment to ensure the integration of regional systems and the efficiency and mutualization of operation and maintenance costs.

End of the note.