**ANNEX 1.D. OPERATING EQUIPMENT IN EXTREME ENVIRONMENTS**

Extreme weather events and harsh climatic environments have direct impacts on observing networks leading to interruption of the core functions of National Meteorological and Hydrological Services (NMHSs). The damage to real time observing and monitoring systems during a weather event can severely limit the effectiveness of forecasting and warning services. The loss of delayed mode observations effects the capacity to plan for extreme events and understand their climatology.

The WMO DRR country-level survey (2006) identified droughts, flash and river floods, extreme winds, severe storms, tropical cyclones, storm surges, forest and wildfires, heat waves, landslides and aviation hazards were the top ten hazards of concern to all Members. Maintenance of high-quality observational records (historical and real-time) is critical for DRR applications. These observations are critical to -

1. risk identification;
2. risk reduction through the provision of early warnings to support emergency preparedness and response as well as climate services for medium- and long-term sectoral planning; and
3. risk transfer through insurance and other financial tools. Thus, interruptions in monitoring caused by damages to instruments and observing networks as a result of natural hazards, hamper NMHSs capacities in delivering effective services not only during and following a disaster but also in the long-term, if these systems are not rebuilt. In this regard, the Commission stressed that it is critical to ensure that instrumentation and observing networks are designed per standards that would withstand the impact of extreme weather events.

There are a number of factors that influence the robustness of equipment, both infrastructure and sensors in the field. The most straightforward and most efficient way of ensuring the availability of a system is to design it in from the beginning.

Availability - one of the first factors to consider is the availability of the data required. Are there other similar sources of information nearby? Is this the only information available to the forecasters and therefore critical in extreme event? If so, more effort will be needed in the design and planning of the station to ensure availability of data. What type of outages can you tolerate? Does it matter the data is not available on a regular basis for five minutes, but it does matter if it is out for a day? All these questions inform the way the system is designed for robustness and supported.

Threats - What are the extreme weather events that will impact the weather station at a particular location? In an ideal world all parameters would be monitored to the highest standard however funding realities generally mean this is not possible. Identify the critical parameters and concentrate on ensuring their availability.

Environmental impacts - every location presents its own challenges. Review topography to ensure any ground work will not be subject to water erosion. Including your consideration soil type, local pollution sources, proximity to the sea and salt corrosion, vandalism risk, …. These threats all impact both the design and the maintenance regimen.

Once the need for the observation is appreciated, and the strengths and weaknesses of the location have been assessed then a range of mitigation strategies can be considered to maximise the availability of observations and minimise operational cost. These approaches fall into one of several categories listed in Table 1 below.

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| --- | --- | --- | --- |
| Approach | Method | Strength | Weakness |
| Network Redundancy | Increase the density of equipment in critical areas | Increased density of measurements reduces the impact of the loss of information from a single site. | Increased capital works and maintenance efforts. |
|  |  | Potential to use lower cost solutions | Risk of overall lower quality data and reliability |
|  |  | Greater effort into network quality control to potentially reducing maintenance costs and predict system failures. |  |
| Sensor/Site redundancy | Duplicate sensitive or vulnerable sensors at a particular site | Increased availability of data | Increase in capital cost |
|  |  | Greater flexibility to manage outages and maintenance |  |
| Use of environmentally appropriate infrastructure materials | Choose materials that are designed to survive in's extreme environments. e.g. Marine and high-grade steel, UV resistant plastics, high oil containing timbers | Depending on usage, these materials will last longer and be stronger | Tend to be more expensive both as raw materials and in construction. |
|  |  | Reduces maintenance burden |  |
|  | Use appropriately rated enclosures and glands | reduces the risk of damage to equipment caused by water ingress or dust | in the short term can be slightly more costly |
| Design | Use of structural engineers for design of infrastructure such as masts | Ensures the infrastructure will withstand extreme weather conditions | In the short term can be slightly more costly |
|  |  | Lengthen the life of infrastructure by minimising the stress caused by environmental impacts |  |
|  |  | Reduces over engineering and associated costs |  |

Table general approaches for mitigating the impact of extreme weather on observation instrumentation and infrastructure.

Specific examples of event types and the threat they pose to infrastructure and sensors in the immediate and longer term are given in Table 2. Methods of mitigation of these threats are also provided. These mitigation are in line with the fours approaches mentioned in Table 1. While extensive the mitigations are not exhaustive, they are a compilation of general knowledge and experience of a variety of National Meteorological organisations. In applying any of these methods, the user will need to consider the impact on measurements in their situation. While one mitigation may work for a particular problem, it may also cause issues for another parameters. The user needs to consider their specific environment before employing any of these solutions.