10. Sand and dust storms early warning

Chapter overview

The chapter provides a general overview of requirements for a sand and dust storms (SDS) warning system involving national meteorological and hydrological services (NMHS), national disaster management authorities (NDMAs) and a wide range of other stakeholders. The effectiveness of a warning system is demonstrated by how well individuals and other parties at risk take preventive actions to mitigate risks once a warning is received. The chapter discusses responsibilities for forecasts and warnings, warning dissemination, people-centred, impact-based warning, warning verification and the process by which individuals take action once a warning has been received. While the chapter content is general, it provides core guidance on developing SDS warning systems at the national or subnational levels.

10.1. Introduction

Warnings are a core part of disaster risk management processes, provided they are disseminated early enough to permit actions to reduce or avoid the impacts of hazards. This chapter provides an overview of early warning approaches to sand and dust storms (SDS) based on generally accepted practices.

SDS warning systems are complex and can operate in different ways and with different actors, depending on the country involved. As a result, individual users and countries are expected to adopt the overall early warning system concept described below to best meet their needs and capacities. This chapter should be read together with **chapters 3**, **9**, **12** and **13**, as well as World Meteorological Organization (WMO) (2018), WMO (2017) and WMO (2015a; 2015b), which provide additional details on developing a multi-hazard early warning system (MHEWS). Reference should also be made to the WMO Sand and Dust Storm Warning Advisory and Assessment System (WMO SDS-WAS) and its operational centres within the WMO Global Data-processing and Forecasting System (GDPFS) (see **chapter 9**).

10.2. Conceptualizing early warning for SDS

The core concept applied in early warning is that the individual at risk is the starting point for the warning process. The timing, content, reception and understanding of warnings should enable individuals, communities, businesses and organizations at immediate risk to take actions to reduce or avoid impacts from the risks they face (see **Box 16**).

While it can be difficult to ensure good and timely dissemination of warnings, individuals with a good understanding of warning factors can often initiate actions on their own to reduce or avoid SDS impacts.

As a result, at-risk individuals, communities, businesses and organizations should be empowered to understand warning signals and to take action to avoid or mitigate the impact of SDS. Educating individuals about SDS risks and warning signs, as discussed in this chapter, is an essential part of an effective early warning system.

Box 16. What is an early warning system?

An early warning system is "an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events".

Source: United Nations Office for Disaster Risk Reduction (UNDRR), 2018.

Traditional knowledge can also play a significant role in triggering warnings and taking action. This knowledge should be part of any warning system and should be used to integrate the overall warning process into the culture of individuals and societies that are the targets of a warning process.

The content of a warning message is dependent on (1) the knowledge (data and analysis) about weather events available to a forecaster, (2) the time available to take action, and (3) the nature of the actions to be taken.

Warnings of near-term events (minutes to days in advance) provide immediate guidance to at-risk populations to take action to address the expected impact of SDS. Such short-term (up to several days) warnings can be based on operational forecasts of dust concentrations (WMO, 2015a, also see **chapter 9**).

SDS warnings can also be based on medium- to long-term situations (months or longer). For instance, if data indicate a wetter than normal monsoon with expected early seasonal storms, a warning could be issued anticipating the development of more or more powerful haboobs at the beginning of the monsoon.

Based on seasonal warnings, individuals and institutions may take appropriate action, such as replacing filters or resealing windows to limit from entering buildings (see **chapter 13** for more on SDS preparedness and impact mitigation). This seasonal forecast would be followed by warnings when forecasts indicated actual haboob development or arrival at a location is expected.

An effective warning process is people-centred and impact-focused (WMO, 2018). The people-centred aspect recognizes that it is at-risk individuals who turn warning into action and that it is therefore the people who need to be involved in the design and operation of early warning systems from the start, making the last mile the first mile. The impact aspect of the warning system identifies how SDS can affect individuals, communities or assets, and what actions can be taken to reduce their threat.

10.3. Key components of early warning systems

An effective people-centred and impact-based early warning system has four components (United Nations General Assembly, 2016):

- detection, monitoring, analysis and forecasting, as discussed in **chapters 2**, **3**, **8** and **9**
- disaster risk and hazard knowledge, as discussed in **chapters 3**, **4**, **5**, **7**, **12** and **13**
- preparedness and response capacities as discussed in **chapter 13**
- warning dissemination and communication, as discussed in this chapter.

Figure 44 provides a set of core questions for each component as presented in **Multi-hazard Early Warning Systems: A Checklist** (WMO, 2018). The document was developed by several international organizations with a key role in early warning under the International Network for Multi-Hazard Early Warning Systems (IN-MHEWS) as an update of **Developing Early Warning Systems: A Checklist** (United Nations International Strategy for Disaster Reduction [UNISDR], 2006). The key questions for warning dissemination and communication are summarized in the lower left box of the figure.

An MHEWS addresses several hazards and impacts of similar or different types in contexts where hazardous events may occur alone, simultaneously, cascadingly or cumulatively over time, and takes into account the potential interrelated effects. The ability of an MHEWS to warn of one or more hazards increases the efficiency and consistency of warnings through coordinated and compatible mechanisms and capacities, involving various disciplines to ensure updated and accurate hazards identification and monitoring for multiple hazards (United Nations General Assembly, 2016).


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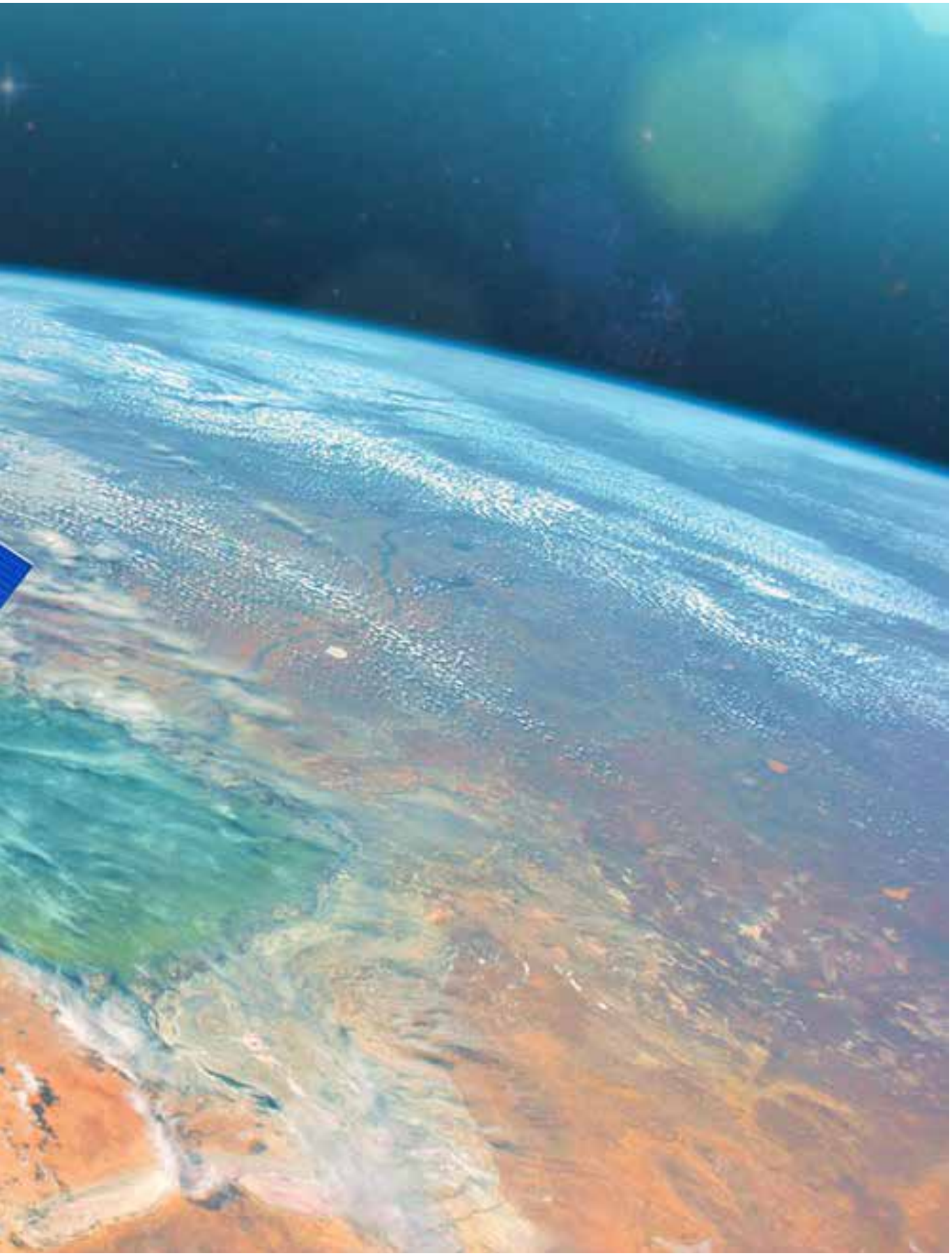


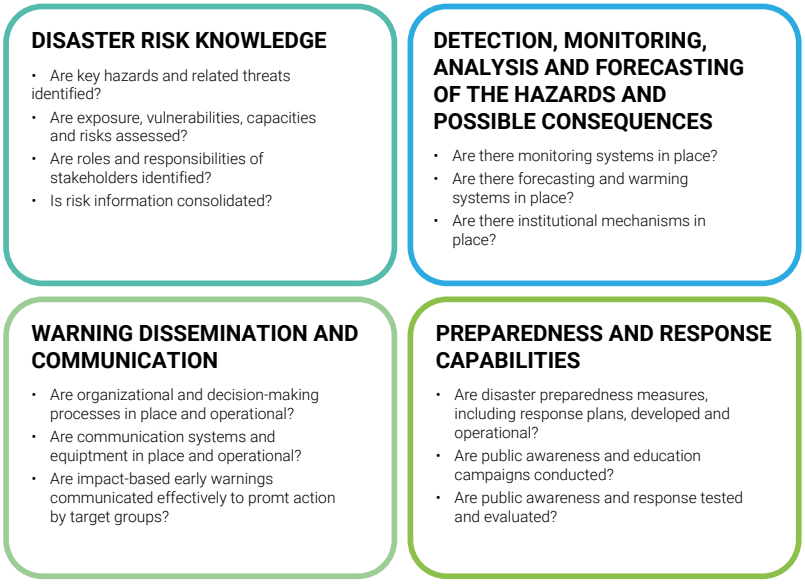


Figure 44. Four elements of end-to-end, people-centred early warning systems

Source: United Nations International Strategy for Disaster Reduction (UNISDR) (2006).

In terms of disaster risk management good practice, an effective SDS early warning system uses a *whole of community* approach (National Weather Service, 2018). In this approach, the actions by all stakeholders, especially at-risk and otherwise affected populations, are incorporated into a single approach to ensure that warnings are provided in a timely manner and that appropriate actions are taken to reduce or avoid negative impacts. An integrated process for defining, establishing and managing early warning systems requires the involvement of a wide range of stakeholders (see **Box 17**).

Box 17. Early warning stakeholders

A range of stakeholders in the forecast and warning process have important roles in developing, disseminating and using the SDS warning information. These include:

- specific at-risk groups that could experience significant negative health or other impacts from SDS
- regional forecast centres, including SDS forecasters, modellers and researchers
- national meteorological and hydrological services (NMHS), including forecasters, modellers and weather education specialists
- geological services or surveys, environment authorities and other national technical agencies and national alerting authorities
- national disaster management authorities (NDMA) and subnational counterparts, including planners, early warning system managers, response managers and trainers
- telecommunications officials, including technicians focused on system reliability and message management (including targeting messages to specific locations or audiences)
- health authorities and hospitals, including health specialists, facility managers, patient managers and emergency health care providers
- transport system management authorities (air, land, sea), including planners, maintenance crews and police (this should be separate under public safety or similar grouping) to ensure safety during SDS
- the media, including radio, TV and the Internet, as well as those working through these systems (for example, news readers, presenters, bloggers, etc.)
- agricultural and livestock producers, including agronomists, livestock specialists and infrastructure managers, to minimize SDS-related losses
- the private sector (businesses, industry and services, etc.), including those that can be affected by high airborne sand or dust loads, including high precision or low contamination production facilities and food preparation and sales
- education providers, including teachers providing education on SDS and school directors taking action to ensure student safety during SDS
- community welfare or care groups, which focus on assisting those more likely to be affected by SDS, including civil society organizations, non-governmental organizations and volunteers
- international (regional and global, inter-governmental and non-governmental) organizations.

Operationally, an SDS early warning system is based on an overall warning plan, which includes sources of information and analysis, dissemination methods and standard operating procedures (SOPs) to ensure warnings are received in a timely manner. Such plans are complemented by subplans for specific sectors (for example, health) and specific facilities (such as clinics) or specific purposes (such as road safety). The planning and overall coordination of the warning process is usually led by the national disaster management authority (NDMA) or similar agency, with some countries decentralizing part of these responsibilities to the subnational level.

In some countries, the national meteorological and hydrological service (NMHS) may be involved in warning dissemination in coordination with the NDMA.

These NMHS-generated warnings can be issued by local offices based on local near-real-time assessments of warning needs.

The effectiveness of SDS early warning systems and plans is judged not only by the sophistication of the SDS forecast and modelling. Rather, success is also based on how well individuals at risk from SDS take action to avoid or reduce the impact of the SDS. The people-centred, impact-focused approach takes forecast and warning data and combines these with vulnerability and exposure data in order to assess potential impacts and yield practical actions to reduce the impact of SDS on individuals, livelihoods and society as a whole.

Box 18. SDS warning and the Sendai Framework

The overall people-centred, impact-focused concept of early warning systems is reflected in three priorities for action of the **Sendai Framework for Disaster Risk Reduction 2015–2030** (United Nations, 2015):

- Priority 1: Understanding disaster risk, which is addressed through the work on disaster risk knowledge (upper left box in **Figure 44**).
- Priority 2: Strengthening disaster risk governance to manage disaster risk, which is addressed by focusing on coordination and partnerships, improving the effectiveness of the overall early warning system at all levels and across stakeholders, and having feedback mechanisms in place to allow for the system to improve over time.
- Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction, which is addressed through building, maintaining and strengthening "people-centred multi-hazard, multisectoral forecasting and early warning systems" (Ibid, p. 21), especially elements three (warning dissemination and communication) and four (preparedness and response capabilities) (see **Figure 44**).

In addition, improving SDS early warning systems contributes to achieving global target G "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030" of the **Sendai Framework** (UNDRR, 2018, p. 155), to be reflected through respective monitoring and reporting within the **Sendai Framework Monitor** tool (see https://sendaimonitor.unisdr.org/).

10.4. Impact-based, people-centred forecasting and early warning process

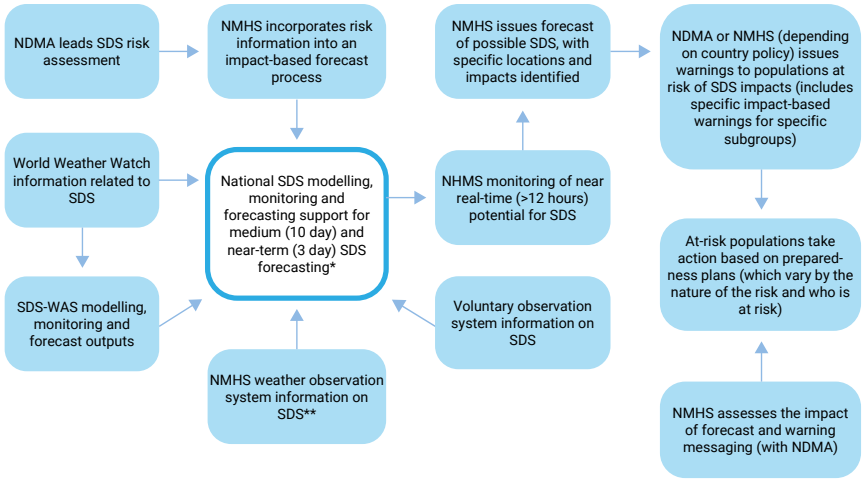
As discussed in **chapter 9**, SDS should be addressed through an impact-based, people-centred forecast and warning process. **Figure 45** graphically presents this process.

In the impact-based, people-centred forecast process:

- The NDMA leads the development and updating of SDS risk assessments (see **chapters 4**, **5**, **7**, and **6** for economic impacts).
- The NMHS integrates the risk assessment outputs into the forecasting and warning process.
- Results of assessments are integrated into the SDS modelling, monitoring and forecasting process, which also incorporates inputs from the WMO SDS-WAS modelling, monitoring and forecast process, as well as inputs from the NMHS observation system and voluntary SDS observations (see **chapter 9** on the Community DustWatch network).[1]
- The NMHS, or subnational branches, monitor SDS development on a near-real-time basis (over the next 12 hours).
- The NMHS, or subnational branches, issue specific SDS (impact-based, if possible) forecasts focusing on specific locations where SDS are expected.
- Depending on policies, the NDMA or NMHS issues warnings when justified by the available modelling, monitoring and observations.
- At-risk individuals take action based on the warnings and an understanding of the SDS impacts in order to avoid or reduce the expected impacts.
- After SDS events, the NMHS, together with the NDMA and other stakeholders, assesses the impact of the forecast and warning messages on whether at-risk individuals took action to avoid or mitigate SDS impacts. These assessments feed back to the system to improve the forecasting and warning process and product.

As described in **chapter 9**, if an NMHS does not have access to risk or vulnerability assessments, a pragmatic approach is recommended through which the NMHS and NDMA agree on impact matrices for SDS events and classify them in terms of the severity of the impact for various user groups.

1 See https://www.environment.nsw.gov.au/topics/land-and-soil/soil-degradation/wind-erosion/community-dust-watch



* Level of capacity varies between countries.
** National data provided to SDS-WAS via World Weather Watch.

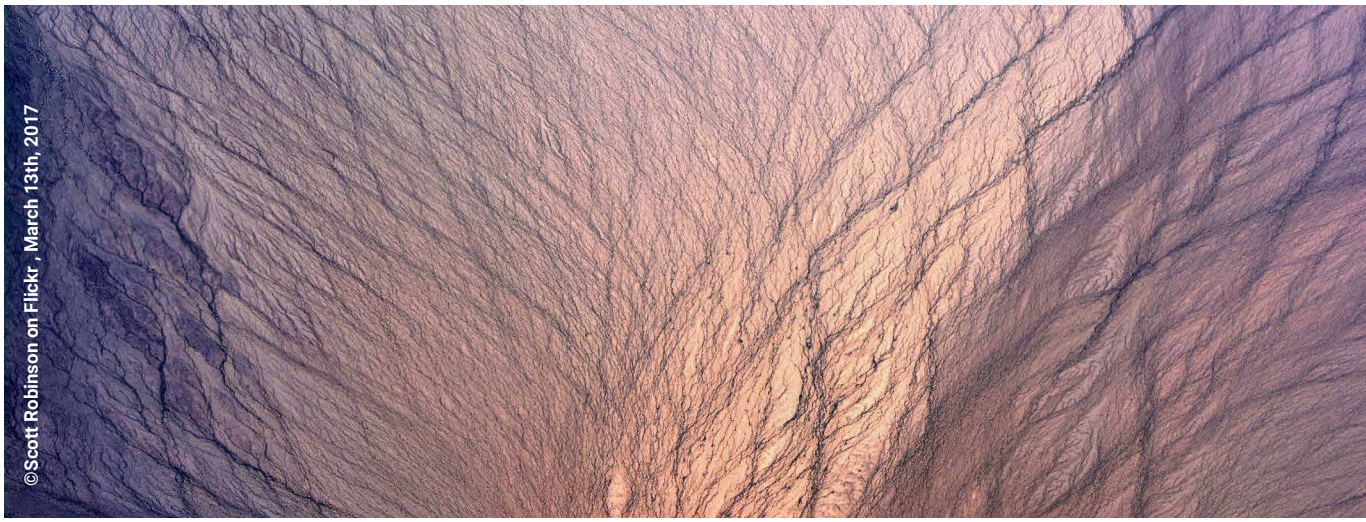
Figure 45. Impact-based, people-centred forecast and warning systems for sand and dust storms

Table 22 provides an example of how the warning process can be integrated into tactical, strategic and research aspects of managing the impacts of SDS on specific sectors, in this case, agriculture. This type of planning can be integrated into SDS source mitigation (**chapter 12**) and impact mitigation and response (**chapter 13**) plans and procedures.

Tactical (short term)	Strategic (long term)	Research
• Near-term warnings for agricultural communities to take preventive action: • harvesting maturing crops • sheltering livestock • strengthening infrastructure (houses, roads, crop storage).	• Improved SDS climatology for long-term planning for agricultural communities: • planning windbreaks and shelterbelts (direction, size, etc.) • planning for infrastructure and crops • post-storm crop damage assessments.	• Forecasting locust movement. • Improving soil/wind erosion and land degradation models. • Forecasting plant and animal pathogen movement and the relationship of SDS to disease outbreaks. • Archiving SDS warning system products for forensic use.

Table 22. Potential agricultural applications of an SDS warning system

Source: Stefanski and Sivakumar, 2009



10.5. Authority to issue forecasts and warnings

There is a significant distinction between:

- forecasts, which include details of weather and atmospheric dust conditions and how they may change, and
- warnings, which are issued by a mandated authority and intended to trigger specific (compulsory or voluntary) actions and legal authorities, for example, requiring that facilities close or traffic be stopped.

It is important to note that forecasts may include alerts or watches and may be issued by the same authority (such as an NDMA) that issues warnings.

Due to the difference between forecasts and warnings, clarity is needed. In terms of plans and procedures, there should be a policy defining who has the authority to:

- issue forecasts, alerts and watches
- issue warnings
- order actions based on these warnings, such as closing facilities, restricting travel or implementing emergency contingency plans.

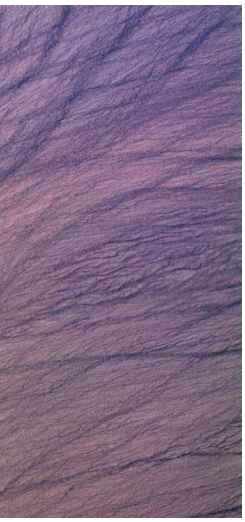
How forecast or warning information is provided to the public can vary between countries. In some cases, written-text watches and warnings are the norm, while in other countries, colours or numbers may be used to indicate the significance of information about hazard events. Understanding the warning mechanisms and terminology used by authorities and how it relates to decisions taken when a warning is received is an important component of an SDS early warning system.

While forecasts are normally provided by an NMHS, the authority to issue official warnings may rest, for example, with the:

- NMHS, based on established protocols, SOP and warning plans, with additional information on actions to be taken
- NDMA, which receives forecasts and warnings from the NMHS and then retransmits these with or without additional information, based on emergency response plans
- Office of the Prime Minister or President, when authority to initiate the legal authorities associated with warnings rests with these officials
- state commissions charged with emergency management, having the statutory authority to provide warnings and manage disasters.

It should also be noted that in many countries, disaster risk management is delegated to the subnational (province, state) level, with the NDMA playing a supporting role. In these cases, it may be the head of the state or province, the head of the provincial or state disaster management office or another official, such as a senior police officer, who has the authority to issue warnings. Subnational warnings may be based on information from subnational NMHS offices with a capacity to generate forecasts or on information provided by a centrally located forecast office, usually the national NMHS office.

In addition, disaster management authorities at the national, provincial/state or county/city administrative levels may use commercial forecasting services and other services (such as social media) for additional localized information on which to base localized warnings. The use of commercial services does not replace the NMHS, but should provide a level of local detail which may not be available from a NMHS.



In addition to NMDA and NMHS warnings being issued, specific sectoral warnings may also be issued by various authorities, including aviation, road transport, health and education, based on forecasts of the NHMS or other technical agencies. Public authorities and the private sector can also use commercial forecast services to anticipate and prepare for hazard events, issue internal warnings and alter standard practices based on warning and response plans.

To summarize, because the SDS warning process can vary considerably between countries, the following questions need clear answers:

- Who has the mandate and authority to issue forecasts, alerts, warnings or watches?
- Who has the legal authority to issue warnings?
- Who ensures that a warning is acted upon? The parties responsible for ensuring that warnings are followed can be different from the party which issues the warning. For instance, while it may be the NMHS that issues a warning, the police may have the authority to take action, such as restricting traffic, based on the warning.
- To whom does the NMHS or subnational offices provide forecasts and warnings and how?
- How can the NMHS and NDMA ensure that warnings are issued in a timely manner?

10.6. Warning plans and mechanisms

The need for clarity on the roles and responsibilities for forecasting and issuing warnings is usually addressed through detailed planning, resulting in plans and procedures for forecasts and warnings. In general, forecast plans are developed internally by the NMHS, with the development of warning plans led by the NDMA (if there are separate forecast and warning authorities in the country).

However, due to the end-to-end and overlapping nature of these plans and a need for forecast and warning authorities to work collaboratively, a single severe weather forecast and warning plan can be considered good practice. Such forecast and warning plans also need to involve other stakeholders, as summarized in **Box 17**.

Warning plans need to specifically consider the mechanisms that will be used to disseminate warnings. The general concept is that every at-risk individual who should receive an SDS warning is to be contacted through at least two warning mechanisms (see **chapter 10.8** on the process by which people react to warnings).

Common mechanisms for warning dissemination include print media, radio, TV, the Internet (including emails, social media and warning websites) and mobile phone messaging. Sirens and traditional face-to-face communication are also still important mechanisms. WMO provides guidance on disseminating and communicating SDS warnings. See https://public.wmo.int/en/our-mandate/focus-areas/natural-hazards-and-disaster-risk-reduction/mhews-checklist/warning-dissemination-and-communication. Which includes information that can be adapted for use by a NMHS or another authority that disseminates and communicates SDS warnings.

Redundancy should be built into early warning systems to address the risk that any warning mechanism may fail. This redundancy is both for the mechanisms used to warn (for example, sirens and radio both being used to issue warnings) and for the communication systems which link those issuing the warnings to specific warning mechanisms (for example, two ways to trigger a warning siren).

Under a multi-hazard warning approach, SDS warnings would generally be sent out through the same warning systems used for other hazards. This would increase the frequency with which warning systems are used and allow for more frequent verification that a multi-hazard warning system is working as expected.

10.7. Warning verification

Once warning messages and systems are developed and functioning it is necessary to verify both the accuracy and usefulness of the messages being delivered as well as the effectiveness of the system. This can be done in two ways:

- Message and system testing: This process involves testing messages with possible target audiences to verify that the messages result in the intended actions. This verification can be done through focus groups, simulation exercises or surveys (including commercial survey or feedback services). The feedback on the messages and their dissemination allows for the content of messages to be adjusted to improve the mechanisms' results.
- Post-event review: This process is carried out after an actual SDS event and involves asking those who should have received warning messages to review the usefulness and effectiveness of the messages they received (if they were received). This is usually conducted through some form of survey, the results of which helps to improve the forecast and warning system, including the formulation and dissemination of alert and warning mechanisms.

The importance of verifying warnings should not be underestimated. Without this feedback, an NMHS, NDMA or other parties involved in the warning process could find it hard to know whether the warnings issued helped people to avoid or mitigate the impact of SDS. Identifying whether, how and why warnings resulted in protective actions can improve warning messaging and dissemination, which in turn should increase the likelihood of individuals receiving warnings to take protective actions.

10.8. Warning education

For warnings to be successful, it is crucial that those receiving the warning understand the information provided and the corresponding actions to be taken to reduce SDS impacts in both the short term and long term, acting and adapting their general response to warnings as necessary. Warning education processes involve two aspects:

- understanding how and why warnings are or are not acted upon by those who receive them, and
- implementing a campaign to increase and sustain the knowledge of those receiving warnings so that they can take the appropriate action when warnings are received, thereby triggering longer-term and systematic behavioural changes.

The first point is of critical importance. If a warning is issued and not used, then it has no value. As summarized in **Emergency Alert and Warning Systems: Current Knowledge and Future Research Directions** (National Academies of Science, Engineering, and Medicine, 2018, p. 20), individuals who receive a warning message go through a process of:

- understanding whether the message is relevant to the person receiving it
- determining whether the warning is real or not
- personalizing the message as something for which action is needed
- deciding whether action needs to be taken
- confirming whether the information is correct and actions should be taken.

Unless warning messages and work to prepare people for warning messages take these points into account, it is unlikely that warning messages will be fully effective. The role of a continual education campaign is twofold:

- Educating those receiving a warning helps them move through the five aforementioned steps. If an individual is aware of the types of warnings that may be issued, the typical content of the messages, the expected or recommended action to be taken following a warning and how to confirm the veracity of messages and

actions (if they are needed), then they will complete the five-step process quicker and with more certainty.

- Building the knowledge of populations at risk from SDS about these phenomenon and how they can impact society, along with the measures that can be taken to address their impacts. This knowledge-building needs to be an ongoing process for three reasons:

    1. A knowledgeable population is a prepared population.
    2. At-risk populations are constantly changing in terms of numbers, the composition of vulnerable groups and location.
    3. The means that a population may have to address SDS impacts can change over time. An ongoing education process can influence individuals, families, government services, businesses and others to improve the level of protection from and resilience to SDS. People and society need to know how to reduce the impacts of SDS before they can take action. Some risk reduction measures should be taken long before warnings are received.

10.9. Integrating forecasts and warnings into preparedness

Chapter 13 discusses preparing for and mitigating SDS. Within the preparedness process, SDS forecasting and warning have four key roles. First, understanding the nature of SDS – which involves developing data sets, modelling and analysis needed to make the forecasts – creates the basis for understanding SDS as a hazard for which preparedness is needed. This understanding provides input into SDS management plans and procedures, including source and impact mitigation.

Second, the technical process and procedures for transforming information on SDS into a forecast lead to a result which does, or does not, trigger a warning. In other words, the content of a forecast can tell individuals to be prepared for SDS or can inform them that there is no need for concern.

Third, forecasts can trigger warnings, based on established warning criteria/ thresholds, plans and procedures. While a forecast can indicate a possible need to prepare for SDS (or not), the warning generated by a forecast triggers a set of actions to reduce the impact of SDS (see **chapter 13**). This triggering process is at the core of the impact-based forecasting and warning concept and is what activates short-term plans to reduce SDS impacts and hasten recovery.

Finally, the process of educating those at risk about SDS so that warnings can be effective (**chapter 10.8**) not only improves capacities to respond once the warning has been received, but also improves the level of individual and societal preparedness for SDS. This preparedness is important when SDS threats are imminent, but can also result in those at risk taking additional actions before a warning is issued or received in order to reduce the actual impact of SDS. The development of an effective warning system therefore improves preparedness and also reduces risk.

10.10. Conclusions

SDS forecasts and warnings are important to reduce the impact of these hazards on individuals, communities, organizations and society as a whole. For effective warnings that lead to protective actions, an SDS warning system needs plans that bring together the forecast capacities of an NMHS and the warning and response capabilities of an NDMA into a common plan.

These plans need to be clear on who is responsible for issuing warnings, how these warnings are to be issued and what information the warnings should contain. In general, following the people-centred, impact-based forecasting approach, warnings should include information about specific expected impacts of forecasted SDS, along with specific actions to address these impacts which also detail specific locations if possible.

10.11. References

National Academies of Sciences, Engineering, and Medicine (2018). *Emergency Alert and Warning Systems: Current Knowledge and Future Research Directions*. Washington, D.C.: The National Academies Press.

National Weather Service (2018). *National Weather Service (NWS) Service Description Document (SDD). Impact-Based Decision Support Services for NWS Core Partners.*

Stefanski, Robert, and Mannava Sivakumar (2009). Impacts of sand and dust storms on agriculture and potential agricultural applications of a SDSWS. WMO/GEO Expert Meeting on an International Sand and Dust Storm Warning System. *IOP Conference Series: Earth and Environmental Science*, vol. 7.

United Nations (2015). *Sendai Framework for Disaster Risk Reduction 2015–2030*.

United Nations General Assembly (2016). Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction. 1 December. A/71/644.

United Nations International Strategy for Disaster Reduction (UNISDR) (2006). *Developing Early Warning Systems: A Checklist*. Available at https://www.unisdr.org/2006/ppew/info-resources/ewc3/checklist/English.pdf.

United Nations Office for Disaster Risk Reduction (UNDRR) (2018). *Technical Guidance for Monitoring and Reporting on Progress in Achieving the Global Targets of the Sendai Framework for Disaster Risk Reduction. Collection of Technical Notes on Data and Methodology* (new edition).

World Meteorological Organization (WMO) (2015a). *Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS). Science and Implementation Plan 2015–2020*. Geneva.

_____ (2015b). *WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services*. Geneva.

_____ (2017). *Manual on the Global Data-processing and Forecasting System*. Annex IV to the WMO Technical Regulations. WMO Report 485.

_____ (2018). *Multi-hazard Early Warning Systems: A Checklist*. Geneva.