



Modernizing National Climate-Risk Intelligence and Emergency Operations Centres : A Technical, Governance, and Human-Security Imperative

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1.0 Climate-risk intelligence as essential public infrastructure

The protection of lives, livelihoods, ecosystems and national development requires governments to treat climate-risk intelligence and emergency coordination as essential public infrastructure. An effective system must connect scientific observations with an understanding of exposure and vulnerability, translate that understanding into actionable warnings, and enable institutions and communities to take protective measures within the time available.

This requires sustained investment across the entire warning-to-action chain. Observation equipment, forecasting models, databases, communication channels, Emergency Operations Centers (EOCs), local preparedness, and anticipatory financing must function as parts of a coherent national service. A failure of any connection can undermine the value of the other investments. Accurate forecasting has limited protective value when decision-makers cannot interpret its implications, warnings arrive late, evacuation routes are inaccessible, or responsible agencies lack the authority and resources to act.

The modernization agenda is particularly relevant to least developed countries, small island developing States and other countries facing substantial gaps in observation, institutional capacity, public finance and local service delivery. Priorities must nevertheless be determined through country-specific evidence. The Global South contains diverse institutions, capabilities, landscapes and successful practices; a credible reform program should build on existing strengths and identify the particular weaknesses that prevent services from reaching exposed populations.

The underlying objective is to make risk information usable. Governments should be able to identify which communities, productive activities, essential services and infrastructure may be affected; how severe the consequences could be; when protective decisions must be taken; which institution is responsible; and what resources are available. Communities should receive timely, understandable guidance that reflects their circumstances and enables feasible action.

UNDRR describes four interconnected components of an effective early warning system: risk knowledge; monitoring, analysis and forecasting; authoritative warning communication; and preparedness to respond. This provides a useful organizing framework for the modernization program proposed here¹.

¹ UNDRR. *Words into Action guidelines: Multi-hazard early warning systems*.

Strengthening authoritative institutions and observation services

1 Strengthen authoritative institutions



2 Assess usable data and priority coverage

Match locations, reporting frequency and data quality to priority decisions.



Check network performance

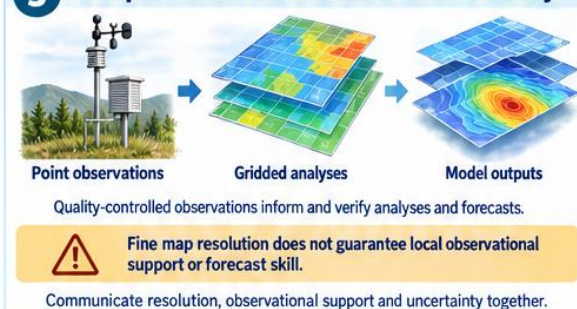
- ✓ Functionality and calibration
- ✓ Siting and representativeness

- ✓ Maintenance and reporting continuity
- ✓ Telemetry and communications

- ✓ Data latency and metadata
- ✓ Data quality and sharing

Protect long records: document changes and overlap old and new measurements where feasible.

3 Interpret observations and models correctly



4 Design for climate and hazard needs

Essential Climate Variables (ECVs)



Climate monitoring: sustained, comparable records

Hazard detection: additional measurements at shorter intervals

ECVs describe the climate system. Every station need not measure every variable.

5 Connect global foundations with national investment



GBON

Global Basic Observing Network

- Within the WMO Integrated Global Observing System (WIGOS)
- Essential surface-based observations and international data exchange
- Foundation for additional local hazard networks



SOFF

Systematic Observations Financing Facility

- Co-created by WMO, UNDP and UNEP
- Supports basic weather and climate observations and international exchange aligned with GBON
- Prioritizes least developed countries and small island developing States

Complementary financing

Define each funding instrument's scope and connection to the national system.



Hydrological monitoring



Local hazard detection



Impact analysis



Telecommunications



EOC operations
EOC: Emergency Operations Centre



Community preparedness

Reliable observations support authoritative services and informed decisions.

Sources: GCOS - Essential Climate Variables; WMO - GBON; WMO - SOFF

Illustrative national modernization framework

2.0 Strengthening authoritative institutions and observation services

National Meteorological and Hydrological Services (NMHSs) remain central to authoritative weather, water and climate services. Modernization should strengthen their scientific capabilities, professional independence, public-service mandates and operational relationships with other institutions. Geological agencies, public health authorities, water managers, disaster-management bodies and infrastructure operators bring complementary responsibilities and specialist knowledge.

National assessments should examine whether the existing observation network supplies reliable information at the locations, frequencies and quality levels required for priority decisions. A station inventory alone is insufficient. A country may possess numerous instruments yet receive little usable data because equipment is poorly maintained, telemetry is unreliable, records lack metadata, or observations are not shared with the agencies that need them.

Assessors should therefore examine station functionality, calibration, siting, maintenance history, reporting continuity, communications, data latency, and geographic representativeness. They should identify gaps in mountain areas, river basins, coastal zones, drylands, informal settlements, and other priority locations, in line with the national risk profile. Long historical records should be protected during equipment replacement through documented changes and, where feasible, overlapping measurements.

Network design must distinguish point observations from gridded analyses and model outputs. A ground station is not inherently incompatible with a gridded forecasting system: appropriately quality-controlled observations can inform and verify those systems. Similarly, a fine-resolution map does not establish that equally detailed observations or predictive skills exist at every location. Spatial resolution, observational support and uncertainty should be communicated together.

Essential Climate Variables (ECVs) characterize the climate system across atmospheric, oceanic and terrestrial domains. The term does not refer to a particular sensor configuration or require every station to measure every variable. Climate monitoring needs sustained, comparable records, while operational hazard detection may require additional measurements at much shorter intervals. National designs should address both purposes explicitly².

WMO's Global Basic Observing Network (GBON), within the WMO Integrated Global Observing System (WIGOS), supports the availability and international exchange of essential surface-based observations. It provides a foundation on which countries can build additional networks for specific local hazards and services³.

The Systematic Observations Financing Facility (SOFF), co-created by WMO, UNDP and UNEP, supports basic weather and climate observations and their international exchange in line with GBON requirements, prioritizing least developed countries and small island developing States⁴. Country modernization plans should connect this foundational support with complementary financing for hydrological monitoring, local hazard detection, impact analysis, telecommunications, EOC operations and community preparedness. Each funding instrument should have a defined scope and a clear connection to the wider national system.

3.0 Designing a hybrid observation network around priority risks

A hybrid network should combine reliable reference observations with additional technologies selected to meet specific operational needs. Equipment selection should follow an assessment of the hazard, required lead time, terrain, communication coverage, maintenance capacity and lifecycle cost. The purpose is to obtain decision-relevant information at an acceptable level of reliability.

² Global Climate Observing System. [About Essential Climate Variables](#).

³ WMO. [Global Basic Observing Network \(GBON\)](#)

⁴ WMO. [Systematic Observations Financing Facility \(SOFF\)](#).

The following options form an illustrative design menu. Each country should select and validate the combination appropriate to its risk profile and institutional capacity.

Observation layer	Potential contribution	Design and operating requirements
Surface and upper-air meteorological observations	Temperature, rainfall, humidity, pressure, wind and atmospheric profiles	Representative siting, calibration, metadata, reporting continuity and qualified maintenance
Hydrological and coastal instruments	River and reservoir levels, discharge estimates, soil moisture, groundwater, tides and coastal conditions	Basin-specific design, surveyed reference levels, maintained rating relationships where applicable, resilient telemetry and upstream-downstream coverage
Weather radar and satellite observations	Spatial information on storms, precipitation, clouds, vegetation, snow, flooding and environmental conditions	Local evaluation of products, ground verification, appropriate processing capacity and explicit recognition of coverage and retrieval limitations
Geological and cryospheric monitoring	Slope movement, seismic signals, glacier and lake changes, snow and other relevant indicators	Specialist interpretation, site-specific monitoring plans and validated links between signals and protective decisions
Drones and robotic platforms	Targeted surveys, local atmospheric sampling, inaccessible-site inspection and damage reconnaissance	Suitable payloads, trained operators, aviation permissions, weather operating limits, maintenance and safe contingency procedures
Low-cost and Internet of Things sensors	Additional measurements at selected hotspots or exposed assets	Comparison with reference instruments, device identification, secure communications, power autonomy and replacement arrangements
Community and sector reporting	Local impacts, blocked access, unusual environmental conditions, livestock stress and service disruption	Accessible reporting methods, training, verification, feedback and protection of sensitive information

WMO identifies uncrewed aircraft systems as a potential complementary source of meteorological, hydrological and climate observations⁵. Their deployment should therefore be tested against a defined information gap. The proposed design should account for wind, precipitation, icing, battery endurance, communications and operating permissions. Drone surveys should have alternative information pathways when flight conditions are unsuitable.

Community observations deserve a formal place within this architecture. Farmers, pastoralists, fishers, local volunteers, extension officers and municipal staff may provide information about conditions and impacts that national networks cannot resolve. Their reports should retain source, time, location and verification status. Contributors should receive feedback so that reporting becomes a continuing partnership.

The network should also monitor its own condition. Equipment faults, low battery levels, interrupted transmissions, delayed readings and inconsistent measurements should generate maintenance notifications. Procurement should include spare parts, calibration services, technician training, field access and replacement planning. Operational sustainability begins when equipment is specified.

4.0 Building an interoperable national risk-information architecture

Observations become useful risk intelligence through a managed sequence of acquisition, quality control, integration, analysis and interpretation. Countries should establish a shared architecture that links hazard information with exposure, vulnerability, critical infrastructure, available response resources, and verified impacts.

⁵ WMO. *Aircraft-based observations*

This architecture can connect institutional systems through agreed interfaces while allowing each agency to maintain responsibility for its authoritative datasets. Interoperability requires common identifiers, geographic references, time conventions, definitions, data-quality flags, and exchange arrangements. Buying a single software platform cannot resolve inconsistent records or unclear institutional ownership.

WMO Information System 2.0 (WIS 2.0) provides a framework based on open standards and web technologies for sharing Earth system data⁶. National modernization should connect relevant observation services to this exchange environment and establish appropriate interfaces with domestic sectoral and emergency management systems. Household vulnerability records and restricted operational information require their own access arrangements.

A proposed national architecture should provide the following functions:

1. **Data acquisition and tracking:** Receive observations, forecasts and reports while preserving source, observation time, arrival time, location, units and processing history.
2. **Quality control and reconciliation:** Check plausibility, timing, duplication, consistency and instrument status; flag uncertain records and preserve original observations for review.
3. **Geospatial integration:** Link hazard information with settlements, land use, infrastructure, administrative areas, livelihoods, services and relevant environmental features.
4. **Analysis and decision support:** Generate scenarios, assess likely consequences, identify decision thresholds and display the evidence available to responsible officers.
5. **Operational exchange:** Supply authorized users with updated information, warning products, task records and resource status through documented interfaces.
6. **Archiving and learning:** Retain forecasts, warning versions, decisions, actions and observed impacts for verification and institutional review.

Sectoral institutions should nominate data custodians and agree on update schedules. Exposure data must reflect changes such as new settlements, damaged bridges, seasonal migration, school occupancy and livestock movements. A risk atlas should indicate when each layer was last updated and where uncertainty remains significant.

Data-sharing agreements should define permitted uses, reporting frequency, access rights, service expectations, escalation procedures and responsibilities for correcting errors. Sensitive personal information should be collected only where it serves an identified protection or service-delivery purpose. Public dashboards should generally use suitable aggregation, while authorized responders receive the detail necessary for their tasks.

5.0 Using artificial intelligence with operational accountability

Artificial intelligence and machine learning offer opportunities to improve data processing, anomaly detection and forecasting. WMO emphasizes that their integration into warning services requires professional judgment, governance, interoperability and sustained capacity development⁷.

The proposed approach is to introduce AI through specific, testable applications. Possible uses include identifying suspect sensor readings, extracting features from imagery, organizing large volumes of field reports, improving selected forecast products, and assisting analysts in recognizing changes that merit investigation. Each application should have a documented purpose, responsible owner, and performance assessment.

Evaluation should examine performance on locally relevant hazards, extreme events, missing-data conditions, and operational interruptions. Average accuracy alone may conceal unacceptable performance during rare but consequential events. Automated systems should therefore be compared with existing methods and reviewed for missed detections, false alarms, uncertainty, and changes in performance over time.

⁶ WMO Information System 2.0 will transform sharing of Earth System Data, 3 January 2025.

⁷ WMO Bulletin. Forecasting the Future: The Role of Artificial Intelligence in Transforming Weather Prediction and Policy, volume 74(2), 2025.

An AI-generated summary should remain linked to its underlying evidence. Unknown values should remain identified as unknown, and model-generated estimates should be distinguished from observations. Draft warning text should use approved terminology and protective actions, with authorization governed by the country's warning procedures.

Automation can reduce delays where validated rules, reliable inputs and clear authority already exist. For extremely rapid hazards, any automatic protective alert should operate under a formally approved, site-specific procedure, with fault detection, event logging, controlled testing, manual intervention and fallback arrangements. The design must consider both the consequences of a missed event and the consequences of false activation.

6.0 Turning hazard information into impact-based decisions

Impact-based forecasting requires an understanding of how hazards interact with exposed people, assets and services and with their vulnerability. WMO guidance emphasizes partnerships between forecasting institutions, disaster-management agencies and other users to develop meaningful impact information⁸.

The proposed national service should answer practical questions, such as which settlements might become isolated. Which roads or bridges may be disrupted? Where might livestock lack access to pasture or water? Which health facilities could lose essential services? Which population groups may need assistance before conditions deteriorate?

Developing these products requires agencies to agree on consequences that matter operationally, examine relevant historical events, and establish methods appropriate to available data. Detailed modeling may be feasible for some hazards and locations. Elsewhere, transparent scenarios and structured expert judgment can provide useful initial products, with a documented plan for improvement.

Impact assessments should consider changing exposure and cascading disruption. Flooding may disrupt transportation, delay access to health care and supplies. Drought may affect water availability, agricultural production, livestock, and energy services together. These are illustrative pathways for scenario design; their relevance and magnitude should be established locally.

Forecast products should connect to a continuum of decisions. Seasonal information can inform preparedness, procurement and resource allocation. Shorter-range forecasts can guide readiness and prepositioning. Nowcasts and rapid observations can support immediate protective decisions where the hazard and available information permit. Hourly updates should be introduced where they improve decisions and where the supporting data and service capacity can sustain them.

Each impact product should identify the area and period of concern, likely consequences, uncertainty, recommended actions, responsible institutions, and next update. Estimated future impacts, field-reported impacts, and confirmed losses should appear as distinct categories. This distinction supports both immediate coordination and subsequent assessment of loss and damage.

7.0 Operating EOCs as continuous coordination and decision services

A modern EOC should connect risk intelligence with operational coordination. WHO's framework for public health EOCs identifies coordination of information and resources in support of incident management as a core purpose⁹. The all-hazards arrangements proposed here apply organizing principles across relevant national and sectoral institutions in accordance with domestic mandates.

Countries should maintain continuous watch and notification capabilities, with staffing proportionate to risk, workload, and available resources. A core duty function can operate in between emergencies, supported by on-call specialists and a planned increase in staffing during periods of heightened risk. Duty rosters must include shift handover, backup coverage, staff welfare, and clear escalation when designated officers cannot be reached.

⁸ WMO. WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services, WMO-No. 1150, 2015.

⁹ WHO. Framework for a Public Health Emergency Operations Centre, 2015.

The EOC's common operating picture should combine current hazards, forecast impacts, affected and potentially affected areas, warning status, response capacity, access constraints and outstanding decisions. Every operational layer should show its source, timestamp, and confidence or verification status. Missing reports should be visible so that the absence of data is not interpreted as an absence of danger.

The following allocation of functions is proposed for adaptation to national law and institutional arrangements.

Function	Accountable institutional role	Main operational output
Hazard monitoring and forecasting	NMHS and other mandated technical agencies	Validated observations, forecasts, hazard advice and warnings within their mandates
Impact assessment	Technical agencies, sector specialists and local authorities	Geographically specific assessment of likely consequences and priority needs
National coordination	Designated disaster-management authority and EOC leadership	Agreed priorities, task allocation, resource coordination and escalation decisions
Public warning authorization	Official issuing authorities designated for each hazard and action	Timely, authenticated warning and protective instructions
Local implementation	Local government, civil protection and responsible sector offices	Community communication, evacuation support and implementation of agreed actions
Dissemination services	Broadcasters, telecommunications operators and other contracted or mandated partners	Rapid distribution through tested channels and operational status reporting
Finance and logistics	Authorized finance, procurement and logistics functions	Timely release of approved resources, delivery tracking and expenditure records
Public information and feedback	Designated public-information staff and community partners	Consistent updates, accessible explanations and verified feedback from affected areas

EOC should not create an additional approval barrier for an agency already authorized to issue urgent warnings. Its procedures should specify which decisions require coordination, which can be taken under delegated authority, and how parallel dissemination and operational notification proceed when time is critical.

Incident coordination should include situation reports, incident objectives, task assignments, resource requests, logistics, public information, finance records and a decision log. The relationship between the EOC, field incident command and sectoral operations centres must be explicit. Activation, escalation, deactivation and transition to recovery should follow agreed criteria, with unresolved responsibilities formally handed over.

8.0 Ensuring continuity when infrastructure is disrupted

EOC reliability depends on the conditions under which it can continue to function. Site selection should consider hazard exposure, accessibility, security, communications and the needs of staff with disabilities. Critical equipment and fuel arrangements should reflect the site's flood, fire and other relevant risks.

The operating design should provide backup power, alternative communications, off-site data protection, documented recovery procedures and an alternate coordination location. Systems should be tested under realistic loss-of-power, connectivity and building-access scenarios. Procurement specifications should identify the duration and level of service the centre must sustain during disruption, based on a country-specific assessment.

Redundancy should be assessed across the whole service chain. Two communication providers may share a physical cable route; two servers may depend on one power supply; and several digital channels may rely on the

same mobile network. Identifying these shared dependencies allows planners to select alternatives that remain available under different failure conditions.

Cybersecurity should protect the authenticity of warnings, system availability, and the integrity of operational records. Proposed controls include appropriate access restrictions, secure administration, patch management, monitoring, tested backups, and rehearsed recovery. Offline maps, printed contact lists, radio procedures, and manually recorded situation reports should remain available to support essential functions during digital outages.

9.0 Establishing clear governance, mandates and accountability

Modern equipment needs an institutional framework that makes responsibilities enforceable and performance reviewable. National arrangements should specify who maintains each observation system, validates data, interprets hazards, authorizes warnings, disseminates messages, supports communities, activates financing, and records outcomes.

These responsibilities should be translated into operational agreements and standard operating procedures (SOPs). Each critical task needs a responsible institution, a duty role, a backup, a timeframe appropriate to the hazard, and an escalation route. Procedures should be tested with the staff who will use them and revised when exercises reveal impractical assumptions.

The governance framework should distinguish a forecast limitation from an operational failure. Reviews should examine the information available at the time, the authority of the officers involved, actual communication performance and the resources accessible to those expected to act. This allows accountability to address preventable failures while supporting timely professional judgment under uncertainty.

Public scrutiny is equally important. Governments should publish suitable information on service coverage, outages, investment priorities, warning performance and follow-up actions. Independent technical reviews, legislative oversight, audit institutions, civil society and community feedback can help identify weaknesses and track correction. Allegations of negligence, corruption or misuse of resources should be investigated through established procedures and assessed against evidence.

Accountability should reach the last mile. National authorities need to know whether a warning reached local offices; local authorities need to know whether exposed communities understood it; and the public needs a practical channel for reporting inaccessible warnings, unavailable assistance or recurring system failures. These findings should be fed into budget and management decisions.

10.0 Closing last-mile warning and risk-communication gaps

Last-mile communication deserves the same design attention as observation and forecasting. In African countries and elsewhere, assessments should examine the full path from the issuing authority to people in exposed locations, including delays caused by repeated institutional relaying. National coverage figures should be checked against the circumstances of rural communities, border settlements, pastoral populations, coastal livelihoods and underserved urban neighborhoods.

Communication planning should begin with audience research. Authorities need to understand which channels people actually use, which languages they understand, whom they trust, whether they have access to receivers or phones, and how these conditions change during the day, at night, and during emergencies. Women, persons with disabilities, older persons, displaced people, seasonal workers and other groups should participate directly in this assessment.

The Common Alerting Protocol (CAP) supports consistent emergency messages across multiple warning systems¹⁰. A national CAP arrangement should define authorized issuers, message authentication, geographic

¹⁰ ITU. Common Alerting Protocol and call to action

targeting, translation, updates, cancellations, testing, and connections to dissemination partners. Adopting the message format should be accompanied by operational agreements and testing of the actual delivery channels.

A public warning should state who is issuing it, what is happening or expected, the affected location and timeframe, the likely consequences, and the action recipients should take. Instructions should reflect what people can realistically do. Messages should use recognizable place names, accessible language and appropriate audio or visual formats, and explain how subsequent updates will be provided.

A complementary set of communication channels

The following comparison is intended to guide local coverage assessments and service design.

Channel	Useful role	Requirement to assess and test
AM and FM radio	Spoken warnings, repeated updates and local-language explanation	Actual signal reception, listening patterns, receiver access, emergency broadcasting arrangements and backup power
Television	Broad public information and visual explanation	Household access, power continuity, captions and accessible presentation
Cell broadcast	Rapid geographically targeted alerts through mobile networks	Operator integration, live network coverage, compatible handsets, configuration and routine testing
SMS and voice messaging	Additional access to registered or targeted audiences	Delivery delay, language, phone access, charging and usable contact information
Sirens and public-address systems	Immediate attention and locally understood protective cues	Acoustic coverage, distinct signals, public knowledge, activation authority and maintenance
Internet services and messaging applications	Maps, detailed updates, institutional coordination and public feedback	Connectivity, accessibility, authentication and control of obsolete or misleading messages
Satellite and operational radio links	Continuity for coordination when terrestrial links are unavailable	Equipment, trained operators, power, service arrangements and rehearsed procedures
Community networks	Local explanation, feedback and assistance to people facing access barriers	Trained and supported focal points, realistic lead times, backup personnel and safe operating limits

ITU promotes cell broadcast as a means of geographically targeted mobile warning¹¹. Its one-to-many delivery can avoid the per-recipient sending process used by SMS, but successful reception still depends on network operation and compatible, appropriately configured devices. It therefore needs to be combined with other channels and tested with the handsets and network conditions found in the target population¹².

Roadshows, scheduled programs and awareness campaigns can build preparedness before an event. Rapid-onset warnings require delivery mechanisms matched to the time available. Repeated manual relaying should be minimized where it consumes essential lead time, and parallel dissemination should be used where authorized and technically feasible.

Assessing the continuing value of AM and FM radio

Broadcast radio remains an important public-warning option because portable receivers can operate on batteries, and conventional reception does not require a subscription or a mobile data connection. ITU highlights the continuing emergency role of both AM and FM broadcasting, supported by resilient transmission facilities and emergency operating plans¹³.

¹¹ ITU. *Cell broadcast early warning system*

¹² GSMA. *Cell Broadcast for Early Warning Systems: A review of the technology and how to implement it*, November 2023, hosted by ITU.

¹³ ITU. *Broadcast radio: The most reliable medium for disaster updates*, 13 February 2023.

Medium-wave AM should be assessed for the wide-area contribution it may provide, especially where communities face limited mobile or internet access. Its practical coverage requires engineering assessment and field verification. ITU's ground-wave propagation guidance provides a technical basis for evaluating lower-frequency broadcasting services¹⁴.

Authorities should measure reception in priority locations under daytime and nighttime conditions, assess interference, confirm receiver availability, and compare lifecycle costs. Receiver purchase and power costs must be included when assessing affordability. Ordinary radios also need to be switched on and tuned to an appropriate station; a transmitter's coverage footprint alone does not prove that a warning will be heard.

Where the evidence demonstrates significant public-warning value, governments should retain, modernize or restore AM services and connect them with FM, television, mobile alerts, sirens and community communication. Decisions about closing any service should examine the protection available to existing audiences and the performance of proposed alternatives. Claims about AM withdrawal across Africa require a country-by-country inventory; the policy decision should rest on verified coverage needs.

Connecting receipt with protective action

Communities need agreed warning meanings, locally appropriate evacuation arrangements, accessible safe locations and assistance for people who cannot act independently. Preparedness exercises should examine the time needed to understand a warning, organize support, and reach safety. Volunteers and local officials should have clear limits on activities that would expose them to a developing hazard.

For rapid events, planners should examine every component of delay: detection, interpretation, authorization, transmission, receipt and action. Local triggering and delegated authority may be necessary where national relaying cannot meet the available lead time. Such arrangements require site-specific validation, resilient communications and public familiarity with the protective action.

Message transmission logs should be complemented by user feedback and exercises. A message sent, a device receiving it, a person understanding it and a household taking action are different outcomes. These distinctions should shape both performance measurement and investment decisions.

11.0 Connecting warnings to anticipatory action and finance

Early warning requires a practical mechanism to mobilize resources before impacts become severe. The IFRC-DREF Anticipatory Pillar illustrates an established approach for National Societies: risk analysis and forecasts inform agreed triggers, planned early actions and the release of pre-arranged funding¹⁵. Governments should develop their own arrangements consistent with national financial rules and institutional mandates. Each proposed early action protocol should specify the hazard and area, decision trigger, responsible authority, selected actions, target groups, implementation window, budget, delivery partners and reporting requirements. Public warning decisions and financing decisions should be coordinated, with their distinct purposes and authorities clearly documented.

The trigger should reflect both the quality of the available forecast and the time required to complete the action. Protocol development should consider the consequences of acting when severe impacts do not occur and of failing to act when they do. Actions should be selected for their expected protective value, feasibility, timing and suitability for the affected population.

Financing arrangements should cover readiness, pre-positioning, activation and follow-up. Funds announced centrally must be usable by the agencies and local governments expected to deliver. Procurement, payment, transport and reporting procedures should therefore be rehearsed before an emergency, with alternative delivery arrangements for foreseeable disruptions.

¹⁴ ITU. Handbook on Ground Wave Propagation

¹⁵ IFRC. Anticipatory Pillar of the IFRC-DREF

Coordination is needed across national contingency resources, local funds, social protection systems, humanitarian mechanisms and other appropriate instruments. A protocol should identify what happens if the principal trigger is missed, the hazard develops differently, or available funding is insufficient. People affected by an event should retain access to the applicable response arrangements even when anticipatory measures were not activated.

12.0 Protecting climate-sensitive sectors and local livelihoods

Risk intelligence should be translated into sector decisions through collaboration with the institutions responsible for those services. Sector ministries and local offices should contribute exposure and vulnerability data, help develop impact thresholds, identify feasible protective measures and report the outcomes of action.

The following examples are proposed options for local adaptation. They are not universal instructions or evidence that a particular hazard is forecast.

Sector or service	Risk information needed	Examples of measures to assess and pre-agree
Crop agriculture and food systems	Crop stage, cultivated area, water conditions, storage and market access	Timely extension advice, protection of stored inputs and produce, and feasible adjustments to farm operations
Livestock and pastoral livelihoods	Herd location, pasture and water access, animal condition and seasonal movement	Feed and veterinary support, shelter readiness and locally agreed safe movement arrangements
Water and sanitation	Supply sources, contamination exposure, treatment capacity and service dependencies	Protection of facilities, backup supplies and continuity arrangements
Public health	Exposed populations, facility access, staffing and essential service dependencies	Facility preparedness, outreach, supply readiness and approved health-protection measures
Fisheries and coastal livelihoods	Marine conditions, fishing activity, landing sites and exposed assets	Timely marine advisories, safe harbour arrangements and protection of equipment
Forestry and ecosystems	Environmental conditions, exposed ecological assets and access constraints	Locally appropriate prevention measures, monitoring and response readiness
Energy, transport and infrastructure	Critical assets, network dependencies, access routes and operational thresholds	Approved operating precautions, protection of vulnerable components and continuity planning
Local government, education and social protection	Settlement exposure, school occupancy, mobility needs and service access	Shelter preparation, accessible assistance, continuity of essential services and authorized support to vulnerable households

Local governments require predictable fiscal transfers, staff capacity and access to risk information to carry out these responsibilities. Transfers should reflect exposure, vulnerability and service obligations, including the needs of poorer jurisdictions. Communities should participate in selecting investments and reviewing whether they improve protection.

13.0 Rebalancing public investment around resilience and human security

National expenditure priorities should be assessed against their contribution to public welfare, resilience and long-term development. Large infrastructure projects, urban expansion and security expenditure deserve scrutiny alongside less visible investments in observation networks, maintenance, early warning, local preparedness and climate-sensitive livelihoods.

Where governments repeatedly reconstruct exposed infrastructure without addressing siting, design, maintenance or underlying risk, public investment appraisal should examine the causes of recurring loss. Rehabilitation should assess feasible improvements in resilience, service continuity and lifecycle performance,

together with environmental and social consequences. Any proposed relocation should involve affected communities and appropriate safeguards.

Spending on prestige projects or disproportionate military expansion warrants particular examination where essential warning services, productive sectors and exposed communities lack basic protection. Legitimate security needs should be assessed within a broader understanding of national security that includes food, water, health, livelihoods, ecological stability and resilient infrastructure. Diplomacy, regional cooperation and peaceful conflict resolution can support this wider security agenda.

The proposed fiscal reform programme should require risk screening for major public investments, transparent appraisal criteria, credible maintenance allocations and disclosure of how spending benefits exposed groups. Climate- and disaster-related budget reporting should distinguish between approved allocations, actual releases, expenditures, and operational results. A labeled budget line is useful only when it supports a functioning service.

Investment appraisal should consider expected risk reduction, distributional effects, institutional capacity and the cost of maintaining the service. Benefits should be estimated transparently, with uncertainty and assumptions recorded. Projects should be reviewed for duplication, dependence on proprietary suppliers, and unfunded recurring costs.

Parliaments, finance ministries, audit bodies and citizens should be able to examine these choices. International partners can support technical appraisal and transparent reporting, while national institutions remain responsible for budget decisions. Claims of corruption, patronage or elite capture should be supported by evidence and examined through accountable processes.

14.0 Advancing regional cooperation and shared risk governance

Risk-management arrangements should reflect the geography of hazards and exposure. Shared river basins, coastal systems, ecosystems and atmospheric processes require cooperation across administrative and national boundaries. The proposed whole-of-Earth, whole-of-society approach should translate this principle into practical agreements, services and responsibilities.

Countries should establish procedures for sharing relevant upstream observations, forecasting products, reservoir information and other risk data where applicable. Agreements should specify contact points, exchange frequency, emergency notification criteria, communication methods, data-quality responsibilities and fallback procedures. Joint exercises should test whether the arrangements hold up under time pressure and communication disruptions.

Regional organizations and specialist centres can support compatible methods, common training, technical assistance and shared analytical services. Small or resource-constrained institutions may benefit from pooled capabilities while retaining national authority for public warnings and domestic emergency decisions. Cross-border procedures should address language, time conventions, geographic references and the rapid reconciliation of conflicting information.

United Nations agencies, development partners and international financial institutions should support country-led programmes that connect observations, services, warning communication and action. Stronger stewardship can include transparent programme reviews, alignment of partner investments, support to national oversight institutions and sustained financing for local capacity. Such cooperation should work through agreed mandates and arrangements that respect sovereignty.

A multi-hazard approach must also preserve scientific distinctions. Climate-related, geophysical, technological and public health hazards may interact, but their causes, monitoring methods and warning possibilities differ. Cooperation should connect the relevant expertise while keeping these distinctions visible in analysis and public communication.

15.0 MHEWC's proposed contribution to national modernization

MHEWC's proposed contribution is to support countries in designing and implementing climate-risk intelligence and EOC services that connect technology, institutions and community protection. The support model should begin with national priorities and the operating needs of responsible agencies, then translate those needs into feasible technical and institutional improvements.

The proposed scope includes observation and data-system assessments; geospatial risk repositories; impact-based forecasting workflows; EOC operational design; CAP and dissemination arrangements; institutional SOPs; anticipatory action linkages; workforce development; and investment planning. These services should be organized through an agreed-upon work plan with defined responsibilities, deliverables, and acceptance criteria.

Implementation support should involve national specialists, local institutions, relevant research bodies, private service providers and community representatives. Knowledge transfer should include practical system administration, equipment maintenance, data stewardship, duty operations and documentation. Authorities should receive the access rights, configuration information and operational knowledge needed to manage the resulting systems.

MHEWC should support the responsible institutions in exercising their own mandates. Official warning authorization, public-resource decisions and emergency command remain with the designated authorities. Proposed technologies and analytical methods should be demonstrated through pilots and evaluated against their contribution to service reliability and protection.

16.0 A comprehensive assessment and modernization methodology

An effective assessment should examine the complete service through evidence review, interviews, technical inspection, data-flow analysis and operational exercises. The assessment team should trace representative hazards from observation through decision-making, warning dissemination, and community action, identifying where time, information, or responsibility is lost.

The proposed assessment comprises eight connected workstreams:

1. **Risk and service requirements:** Identify priority hazards, exposed sectors, users, decision windows and geographic gaps. Document the services each institution and community needs.
2. **Facilities and infrastructure:** Inspect EOC siting, accessibility, layout, workstations, communications, power, equipment protection, alternate facilities and physical operating conditions.
3. **Observation and information systems:** Review instruments, data quality, maintenance, databases, interfaces, model inputs, cyber controls, archives and restoration arrangements.
4. **Institutional and legal arrangements:** Map mandates, issuing authority, coordination mechanisms, agreements, delegation, accountability and national-local relationships.
5. **People and operational practice:** Review staffing, competencies, duty rosters, surge arrangements, handover, activation, incident planning, logistics, reporting and recovery transition.
6. **Warning communication and inclusion:** Map channel coverage, test message transfer and receipt, consult user groups and assess local preparedness and accessibility.
7. **Financing and sustainability:** Examine operating budgets, procurement, maintenance, technical support, local transfers, early action funds and long-term affordability.
8. **Performance and improvement:** Review selected past events and exercises, reconstruct decision timelines and identify corrective measures with named owners and completion dates.

Findings should distinguish documented strengths, verified gaps, untested capabilities, and information that remains unavailable. The team should avoid treating interview claims or equipment specifications as proof of operational performance. Significant conclusions should be supported by records, inspection, or practical demonstration wherever feasible.

The main deliverables should include a validated diagnostic report, institutional responsibility matrix, observation and communication gap maps, target service architecture, revised operating procedures, staffing and training plan, prioritized investment programme and cost implementation roadmap. Each recommendation should identify its purpose, dependencies, responsible agency, recurring costs, and the evidence required for acceptance.

17.0 A phased route from assessment to sustained operation

Implementation should combine urgent repairs with progressive system integration. The indicative sequence below is a planning proposal; timing should be adjusted to procurement, seasonal conditions, institutional readiness and funding availability.

Indicative period	Priority work	Evidence required before expanding
Months 0-3: Establish priorities and restore essential functions	Confirm leadership, complete the diagnostic, repair critical faults, update duty contacts and test existing warning routes	Agreed baseline, assigned responsibilities and demonstrated essential communication functions
Months 3-6: Design and prepare	Approve service architecture, data agreements, staffing, SOPs, procurement specifications and financing arrangements	Reviewed designs, funded operating responsibilities and approved pilot criteria
Months 6-12: Pilot integrated services	Connect selected observation and sector datasets, develop impact products, test alert distribution and rehearse early action in priority locations	Recorded end-to-end exercises, user feedback, corrected critical defects and demonstrated operating capability
Months 12-24: Extend and institutionalize	Expand successful components, strengthen local coverage, embed recurrent budgets and transfer routine operation to designated teams	Demonstrated maintenance, sustained service performance, completed handover and regular public reporting
Continuing operation	Update risk information, train staff, exercise procedures, renew equipment and review incidents	Periodic performance reports and verified completion of improvement actions

Contracts should make service performance, documentation, interoperability and knowledge transfer reviewable. Acceptance should include realistic failure scenarios and demonstrations by the staff who will operate the system. National expansion should follow evidence from pilots and resolution of critical weaknesses.

18.0 Measuring whether the system protects people

Modernization should be evaluated through the quality, timeliness, reach and use of the service. Equipment installed, software delivered and workshops completed are useful implementation records, but protection requires evidence that the resulting functions operate together.

The following scorecard is proposed for national adaptation. Definitions, baselines, reporting periods, targets and responsible data owners should be agreed before measurement begins.

Performance area	Illustrative measure	Suitable evidence
Observation reliability	Proportion of expected observations received, on time and passing agreed quality checks	Station and data-ingestion logs
Forecast and detection performance	Relevant measures of accuracy, missed events, false alarms and available lead time	Verification against observed events using documented methods
Warning timeliness	Time spent in detection, review, authorization and dissemination	Timestamped event and warning records

Performance area	Illustrative measure	Suitable evidence
Communication reach	Proportion of the defined exposed population receiving warnings through usable channels	Representative surveys, field tests and appropriately interpreted service records
Understanding and action	Proportion of recipients understanding instructions and completing feasible protective actions	Exercises, interviews and post-event assessment
Institutional readiness	Availability of duty staff, tested SOPs, alternate arrangements and essential resources	Rosters, exercise reports and readiness inspections
Finance and delivery	Time from authorized trigger to usable funds and completion of planned actions	Financial, logistics and implementation records
Equity and accessibility	Differences in warning receipt and action across relevant population groups and locations	Appropriately disaggregated assessments with privacy safeguards
Continuity and recovery	Ability to sustain essential functions and restore disrupted services	Outage records and practical recovery tests
Accountability and learning	Completion of assigned corrective measures by their due dates	Review reports, action registers and independent verification where appropriate

Performance indicators should avoid rewarding superficial compliance. Alert issuance cannot establish population reach, and reach cannot establish understanding or action. Likewise, changes in disaster losses should be interpreted in light of differences in hazard severity, exposure and vulnerability. Claims about avoided losses need an explicit method and credible assumptions.

Major events, significant false alarms, missed warnings and exercises should trigger a structured review. The review should identify which decisions worked, which barriers prevented action, and what changes are required in equipment, staffing, procedures, finance or community support. Each improvement needs an owner, deadline and follow-up check.

a) A public commitment to protection

Modernizing national climate-risk intelligence and EOCs requires political commitment expressed through dependable public services. Countries need authoritative science, functioning observations, shared risk knowledge, accountable institutions, sustainable finance and local capacity to act. These capabilities should be maintained between emergencies and improved through continuous learning.

Governments should make a clear public commitment: exposed communities will receive understandable warnings through channels they can access, responsible institutions will have the authority and resources to act, and failures will lead to transparent review and correction. International and regional partners should support that commitment through coordinated assistance and sustained investment in national and local capability.

Human security depends on the protection of people, livelihoods, essential services and the natural systems that sustain them. A modern warning and emergency coordination system should be judged by how reliably it delivers that protection when decisions matter most.

Technical references

The references support specific technical concepts cited in the text. The institutional arrangements, assessment workstreams, investment priorities, indicative timetable and performance scorecard are proposed implementation measures for adaptation to each country's context.

1. UNDRR. [Words into Action guidelines: Multi-hazard early warning systems](#).
2. Global Climate Observing System. [About Essential Climate Variables](#).
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4. WMO. [Systematic Observations Financing Facility \(SOFF\)](#).
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8. WMO. [WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services](#), WMO-No. 1150, 2015.
9. WHO. [Framework for a Public Health Emergency Operations Centre](#), 2015.
10. ITU. [Common Alerting Protocol and call to action](#).
11. ITU. [Cell broadcast early warning system](#).
12. GSMA. [Cell Broadcast for Early Warning Systems: A review of the technology and how to implement it](#), November 2023, hosted by ITU.
13. ITU. [Broadcast radio: The most reliable medium for disaster updates](#), 13 February 2023.
14. ITU. [Handbook on Ground Wave Propagation](#).
15. IFRC. [Anticipatory Pillar of the IFRC-DREF](#).

Original illustration links

The following links are retained from the supplied article for use when preparing its illustrated layout. The expansion addresses the article's text; these illustrations have not been revised.

- [Original satellite illustration](#)
- [Original observation and EOC illustration](#)
- [Original EOC modernization illustration](#)
- [Original NMHS illustration](#)
- [Original EOC illustration](#)
- [Original governance illustration](#)
- [Original investment-priorities illustration](#)