

Introduction to Impact-Based Forecasting

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UCAR/COMET

**9th WMO/Meteo-France RA I Tropical
Cyclones Training Course**

**IBF input from Gerald Fleming, Chair, OPAG
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Ceasar, CIMH**



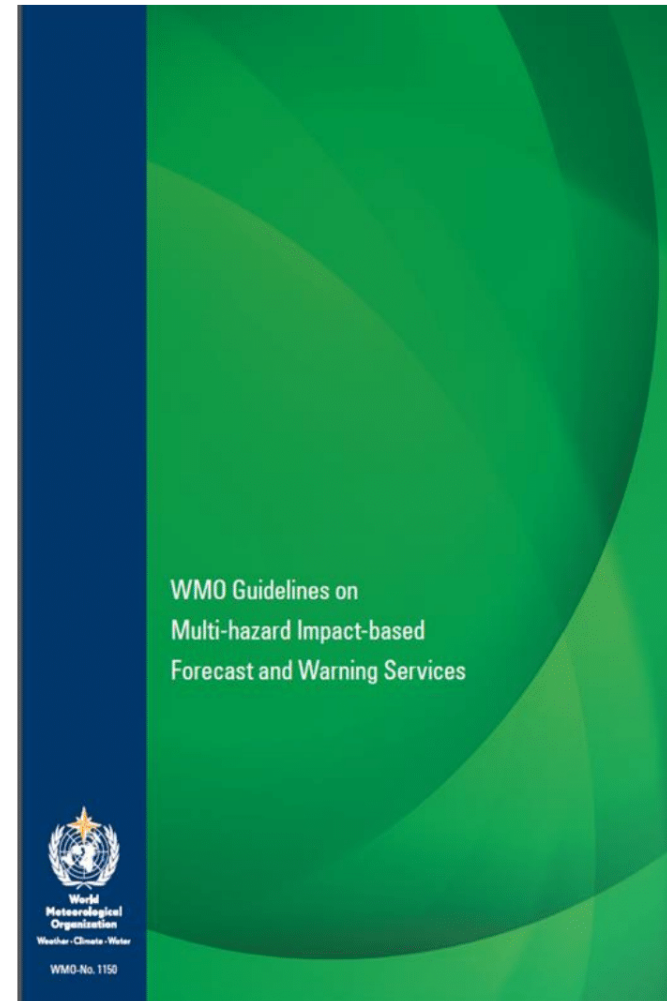
Course Outline

- **Introduction**
- **Introduction to IBF**
- **Weather Ready Nations – Barbados IBF**
- **Idealized case studies**
- **Development of hazard, impact, and response matrices exercise**
- **WRNs Case Studies Module: Impact-based Forecast Simulations**
https://www.meted.ucar.edu/wrn_sims/
- **Barbados Case Study**
- **Additional resources**

«WMO Guidelines on Multi-hazard Impact-Based Forecast and Warning Services»

WMO No. 1150: https://library.wmo.int/doc_num.php?explnum_id=7901

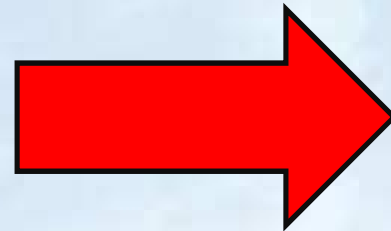
- PWSD Programme coordinated effort to produce the publication:
WMO No. 1150
- It provides a road map to assist members develop impact-based warning services
- Defines the necessary steps and explains likely levels of complexity
- Publication highly recommended for use by Members



WMO OMM

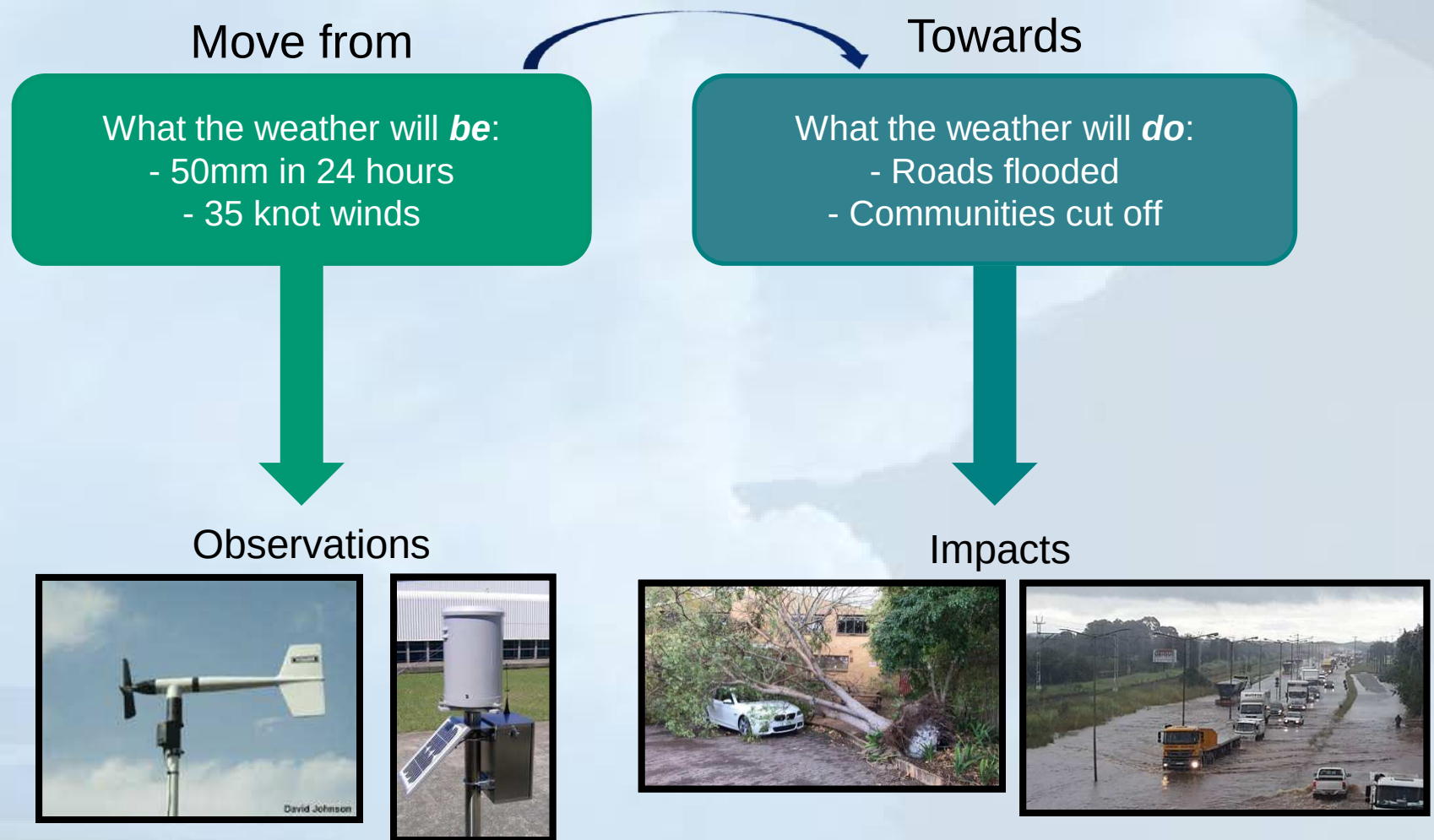
Why move to Impact-Based Forecasting?

**Weather
Forecasts
and
Warnings**



**Impact-Based
Forecast
and
Warning
Services**

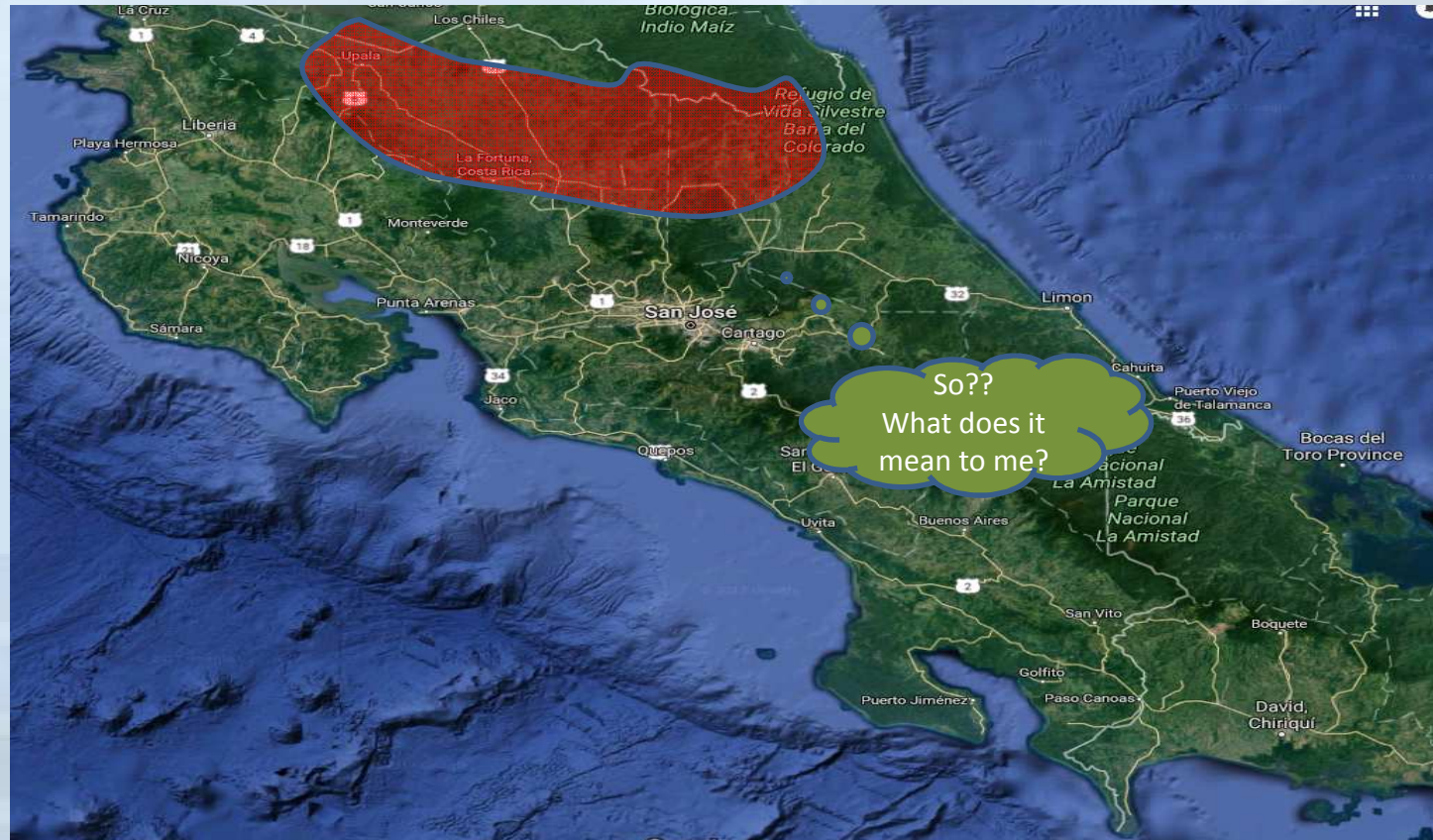
Impact-Based Forecasting



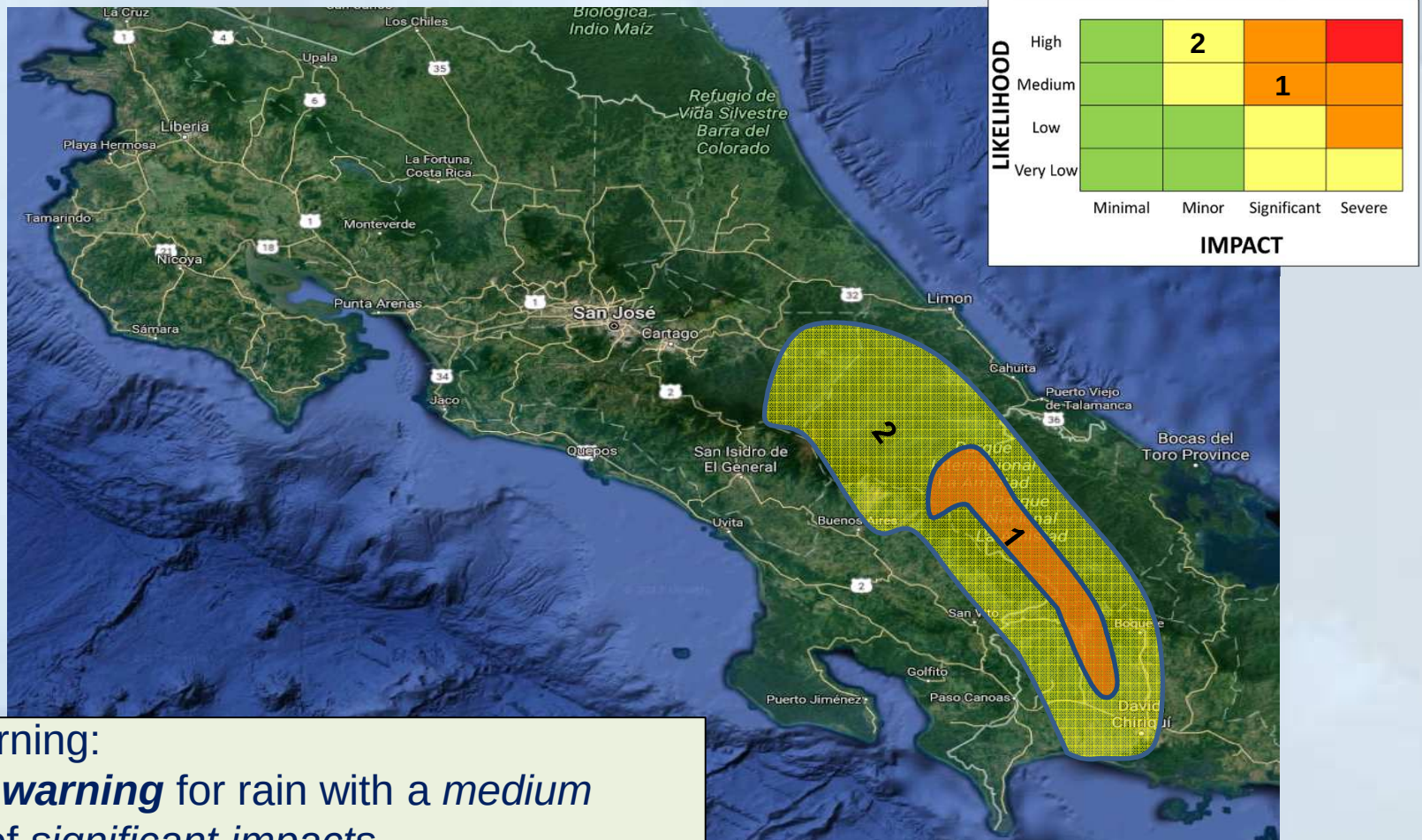
The goal is to change from this type of forecast ...

Warning:

Heavy rain of more than 100 mm in 24 hours is expected



To an Impact-based Early Warning Forecast System



Impact Warning:

1. **Orange warning** for rain with a *medium likelihood of significant impacts*
2. **Yellow warning** for rain with a *high likelihood of minor impacts*

Benefits of an Impact Warning Service

- Relays a message to enable those at risk to take appropriate actions
- Improved planning for different scenarios based on different impacts
- Contains information about level of confidence in the forecast for better decision-making
- Provides post-event analysis of multi-hazard impacts to assist in planning, response and mitigation of impacts
- Coordinated process to address disaster response and preparedness
- Common situational awareness

The Case for Impact-Based Forecasting

- **Good weather forecasts or warnings are not enough:**
 - Citizens expect information about what to do to ensure their safety and protect their property
- **Many people still lose their lives and incur socio-economic costs associated with hydrometeorological hazards**
 - Lack of appreciation and understanding of the impacts

Why Impact-Based Forecasting?

- An accurate and timely hydrometeorological warning does not guarantee safety of life or prevent major economic disruption...
- National Meteorological and Hydrological Services work more effectively with disaster / emergency managers, public, and stakeholders
 - Help people understand how hazards can affect them to ensure appropriate actions
- These can be done in two ways:
 - Subjective working alongside stakeholders
 - Objective way through developing an impact model using **vulnerability** and **exposure** datasets as well as meteorological information

Why Impact-Based Forecasting?

Successful impact-based forecasting requires collaboration with others:

- **Additional necessary expertise:**
 - Resources and knowledge (such as demographic data, crowd-sourcing techniques, geographical information systems (GISs))
 - Interoperability, and third-party data integration and usage) to deliver impact services that NMHSs cannot do on their own

Key Ideas in Impact-Based Forecast and Warning Services

Hazard

- **Meteorological or hydrological element that poses a threat**
 - Intense or prolonged rainfall
 - Strong winds

Forecast Uncertainty

- **The limit of predictability imposed by the nature of the atmosphere**

Key Ideas in Impact-Based Forecast and Warning Services

Exposure

- Who or what may be affected in an area where a hazard may occur

Vulnerability

- The liability of exposed human beings, their livelihoods and property, to suffer bad effects when affected by a hazard

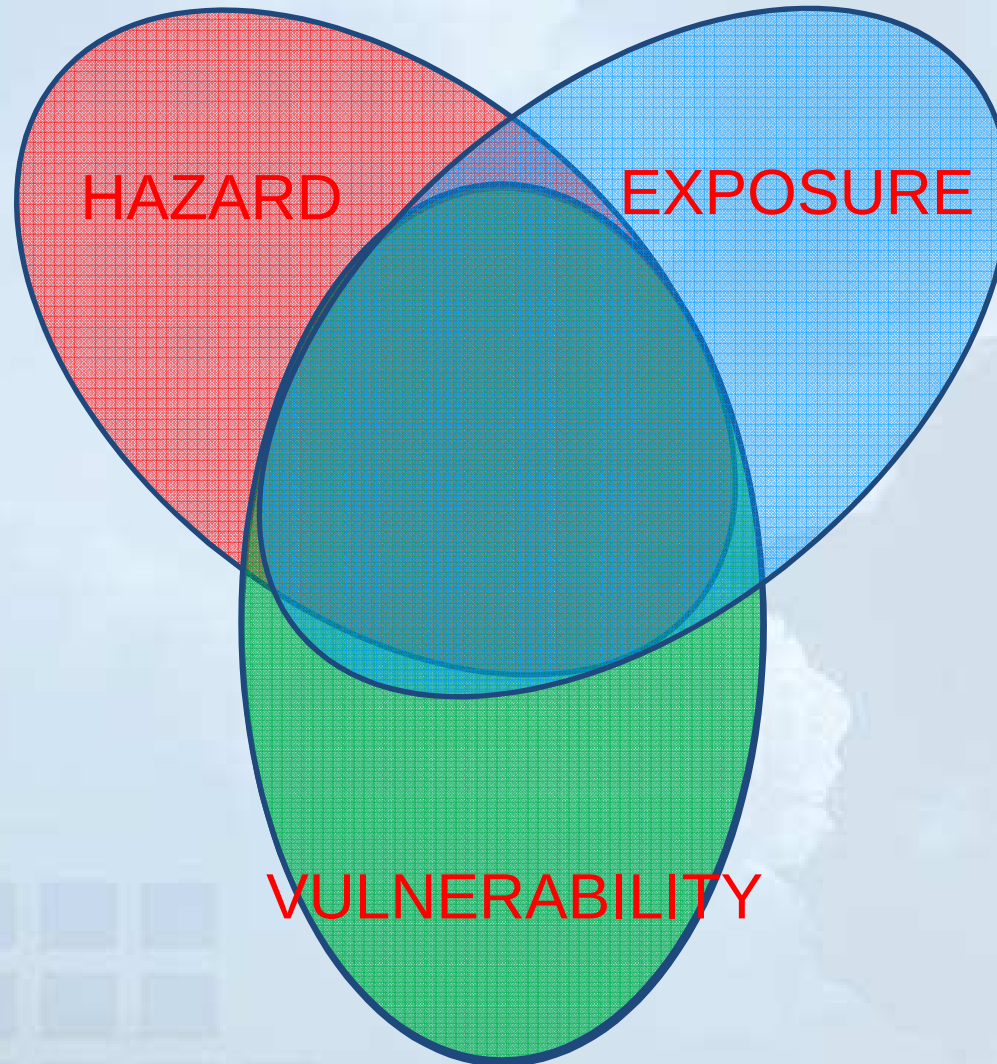
Risk

- The probability and magnitude of harm possible to humans, their livelihoods and assets because of exposure and vulnerability to a hazard

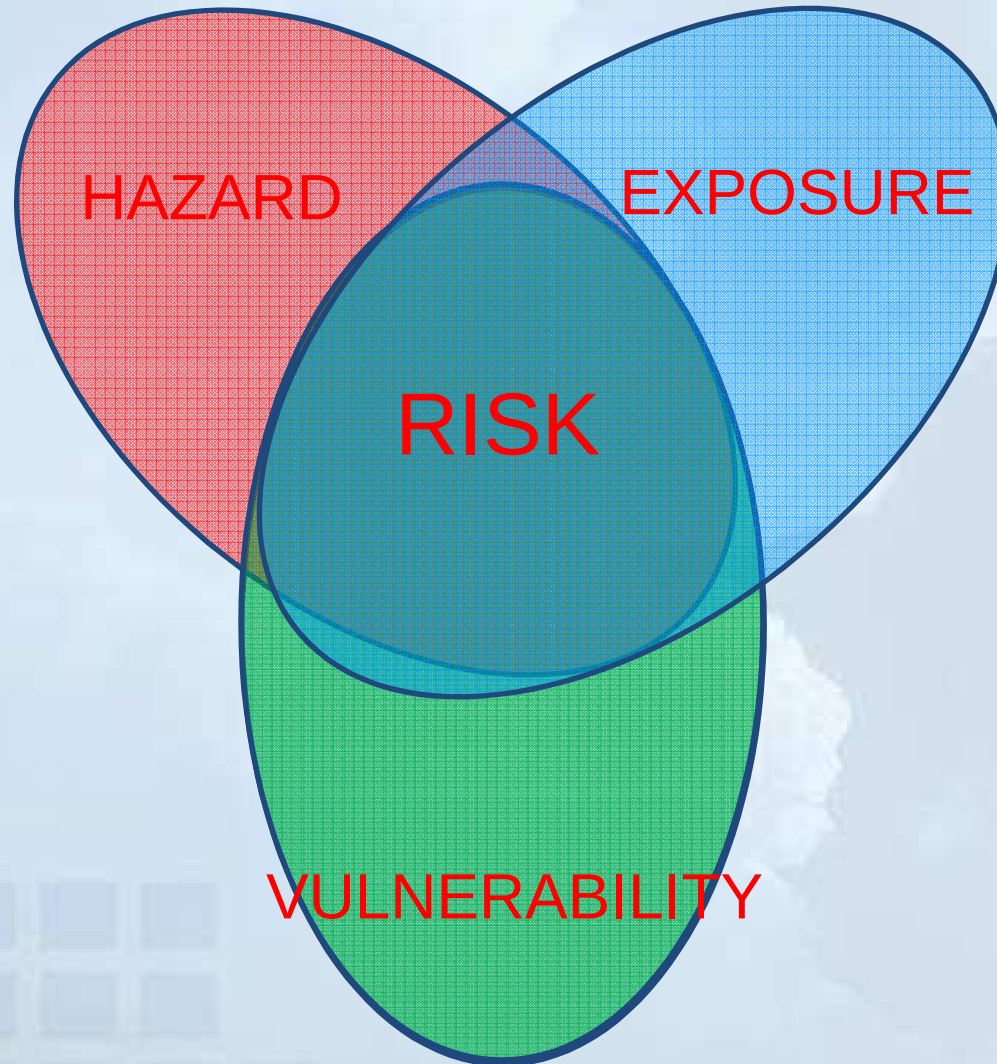
Evaluating Vulnerability

- **How to identify vulnerable areas?**
 - How to track those and adapt forecasts and warnings?
- **Location**
- **Timing**
- **Current Environmental Conditions**

Hazard, Exposure, Vulnerability



Hazard, Exposure, Vulnerability = Risk



Key Ideas in Impact-Based Forecast and Warning Services

Weather Warning:

- “Strong winds are expected tonight with wind speeds of 20m/s likely”***

Impact-based Warning:

- “Strong winds are expected tonight which may result in delays or cancellation to ferry services and keep small fishing boats tied up”***

Weather Warning Services

Different types of Weather Warning

- 1. Warnings with fixed thresholds**
- 2. Warnings with user-defined thresholds**
- 3. Warnings with variable thresholds**

Weather Warning Services

Different types of Weather Warning

1. Warnings with fixed thresholds

Saffir-Simpson Scale for strength of Tropical Cyclones / Hurricanes

Category	Sustained winds
1	74–95 mph 64–82 kt 119–153 km/h

Weather Warning Services

Different types of Weather Warning

2. Warnings with user-defined thresholds

Flash Flood Warning for City Authority

“50mm of rain expected during the next two hours which will cause problems with the street drainage system and lead to flooding on the roads”

Weather Warning Services

Different types of Weather Warning

3. Warnings with variable thresholds

High Temperature Warning, different thresholds for different cities

Minimum temperature (°C)				Maximum temperature (°C)			
Osijek	20.1	21.2	22.9	Osijek	35.2	36.7	38.8
Zagreb	20.2	21.3	22.9	Zagreb	33.7	35.1	37.1
Karlovac	20.0	21.1	22.7	Karlovac	34.5	35.9	38.0
Gospić	17.0	18.0	19.6	Gospić	32.1	33.4	35.4
Rijeka	22.7	23.7	25.1	Rijeka	32.7	33.9	35.5
Knin	20.5	21.6	23.1	Knin	35.5	36.9	39.0
Split	25.8	26.8	28.2	Split	33.9	35.1	36.7
Dubrovnik	25.4	26.3	27.6	Dubrovnik	32.3	33.2	34.7

Weather Warning Services

Different types of Weather Warning

Warnings with fixed thresholds	Rainfall accumulations of 30 mm to 40 mm expected tomorrow between 1400 and 2300.	Hazard
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Weather Warning Services

Different types of Weather Warning

Warnings with user-defined thresholds	Heavy rain expected tomorrow afternoon with rainfall intensities of 3 mm/10 mins possible, leading to overflow in the drainage system	Hazard + Vulnerability
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Weather Warning Services

Different types of Weather Warning

**Warnings
with variable
thresholds
(place to
place)**

Weather warning –
rainfall accumulations of
20 mm to 30 mm
expected tomorrow in
low-lying areas between
1400 and midnight, with
accumulations of 50
mm to 60 mm possible
at altitudes above 1,500
m

Hazard
+
Vulnerability

Weather Warning Services

Different types of Weather Warning

Warnings with variable thresholds (time to time)	Weather warning – rainfall accumulations of 15 mm to 20 mm expected tomorrow afternoon during rush hour	Hazard + Vulnerability
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Weather Warning Services

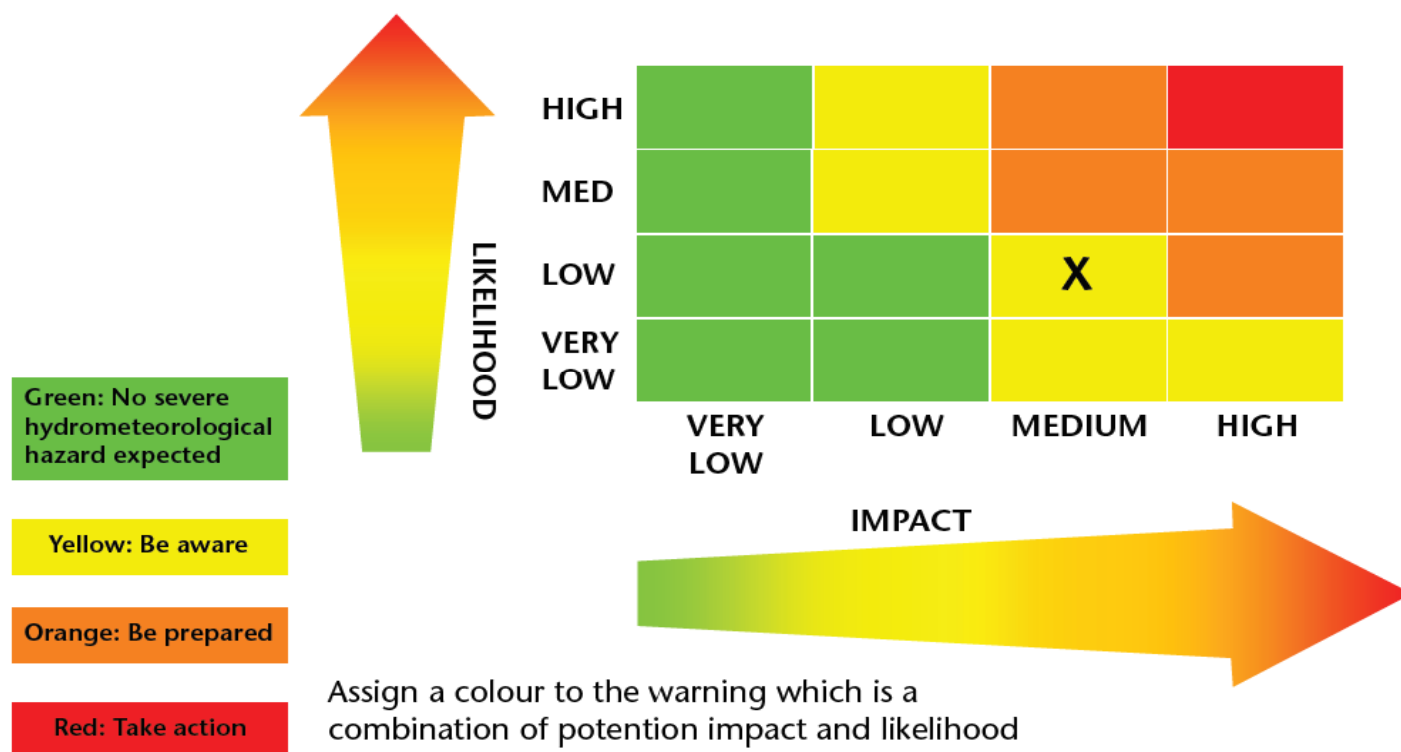
Different types of Weather Warning

Impact-Based Warning	Rainfall accumulations of 20 mm to 30 mm expected tomorrow between 1400 and midnight, resulting in possible road closures due to flooding across the southeast	Hazard + Vulnerability
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Risk Matrix

14

WMO GUIDELINES ON MULTI-HAZARD IMPACT-BASED FORECAST AND WARNING SERVICES



(Source: Met Office, United Kingdom)

Figure 2. Risk matrix

Likelihood/Probability Threshold Example

Impact Threshold Example – Rain

Rainfall Impacts Table

Minimal	Minor	Significant	Severe
- Water on roads, driving conditions affected by water - Isolated flooding of low-lying areas - Traffic congestion	- Some minor roads impassable - Low-lying bridges experience typical flooding - Major roads affected causing increased travel times - Areas cut off temporarily - Minor flooding occurring on some basins	- Flooding of major roads disrupting transport routes - Some minor route bridges impassable - Danger to life - Damage to roads - Communications and travel disrupted - Flash floods affecting many communities - One or two local municipalities affected	- Danger to life from fast flowing deep water - Evacuations and search and rescue operations may be needed - Roads impassable, road closures - Large-scale damage to major and minor roads - Widespread Flash floods - Large communities cut off - Bridges impassable or damaged - Houses flooded - More than two local municipalities affected
1-hour Rainfall > 25 mm (particularly sensitive areas like urban basins, steep slopes) 6-hour Rainfall > 75 mm			
	1-hour Rainfall > 50 mm (particularly sensitive areas like urban basins, steep slopes) 6-hour Rainfall > 150 mm		
		1-hour Rainfall > 100 mm 6-hour Rainfall > 200 mm	

What is your advice for rain impacts?

Response Matrix: Rainfall

Very Low - Business as usual	Low - Be Aware	Medium - Be Prepared	High - Take Action
The Met service will continue to monitor for any changing weather conditions.	Be aware of flooding and stay out of flood waters. Evaluate inventory of emergency supplies (food, water, medical supplies), restock supplies as needed. Monitor roads and properties for localized flooding and possible traffic and public transportation disruptions.	Be prepared for flooding and stay out of flood waters Check emergency supplies, purchase additional supplies if needed, fill gas tanks, etc. Be prepared for localized flooding of roads and properties in [...locations...], and land slippages that could block roads. Prepare for possible delays or cancellation of public transportation services	Stay out of flood waters and prepare to use emergency supplies. Avoid walking or driving through moving water and seek safer/higher ground if in [...locations...]. Don't drive and stay off roads in flood prone areas or areas with frequent land slippage/landslides. Plan to shelter in place in non-flood areas.

Impact Threshold Example – Wind

Minimal		Minor		Significant		Severe	
- Isolated trees branches damaged - Few transport routes affected		- Localized tree damage blocking roads - Localized transport routes affected and longer travel times needed - Isolated loss of communication and electricity supply due to damaged power lines		- Weakly constructed houses suffer blown roofs or house collapse - Some trees blown over or damaged and blocking roads - Localized loss of communication and electricity supply due to damaged power lines - Transport routes affected - Localized problems with high profile vehicles on wind-prone routes - One to two local municipalities affected		- Widespread damage to structures, houses destroyed, roofs blown off, weak structures overturned or blown away - Falling trees and electrical power lines blocking major roads - Widespread and long duration disruption to power supply and other services - Dangerous driving conditions - More than two local municipalities affected	
Strong winds 20-33 kts							
		Gale / Tropical storm force winds 34-50 kts					
				Strong Tropical storm > 50 kts			

What is your advice for wind impacts?

Response Matrix: Wind

Very Low - Business as usual	Low - Be Aware	Medium - Be Prepared	High - Take Action
We will notify you if weather conditions change.	Be aware of possible tumbling of unsecured objects, falling tree limbs, sea spray, and choppy seas in [...locations...]. Also be aware of possible traffic delays.	Be prepared for downed power lines, tumbling and rolling of unsecured objects, falling tree limbs and trees, sea spray, choppy seas and large breaking waves in [...locations...]. Also be prepared for road closures and traffic delays.	Expect downed power lines, tumbling and rolling of unsecured objects, falling tree limbs and trees, sea spray, choppy seas and large breaking waves in [...locations...]. Also expect road closures and traffic delays.

The Weather Warning Risk Matrix

Benefits of using a risk matrix:

- **Early advisories about potential impact, well before a significant hydrometeorological event**
- **Update the changing expected of risk, depending on changing exposure, vulnerability and likelihood for each forecast**

The Weather Warning Risk Matrix - Benefits

- **Improved planning for different scenarios based on impacts or combinations of impacts;**
- **Better contingency planning (best, reasonable worst-case and most likely outcomes)**
- **Information about level of confidence in the forecast (a more informed risk assessment)**
- **New information to facilitate wider social benefits**
- **A comprehensive and coordinated process to address disaster response and preparedness**
 - Meteorological services -> emergency services -> public

The Weather Warning Risk Matrix

How should the risk matrix be used?

Likelihood	High				
	Med				
	Low				
	Very low				
		Very low	Low	Med	High
	Impact				

The Weather Warning Risk Matrix - Example

4 Days before a Tropical Cyclone arrives

Likelihood	High				
	Med				
	Low				
	Very low				X
		Very low	Low	Med	High
	Impact				

The Weather Warning Risk Matrix - Example

3 Days before a Tropical Cyclone arrives

Likelihood	High				
	Med				
	Low			X	
	Very low				
		Very low	Low	Med	High
	Impact				

The Weather Warning Risk Matrix - Example

2 Days before a Tropical Cyclone arrives

Likelihood	High				
	Med			X	
	Low				
	Very low				
		Very low	Low	Med	High
	Impact				

The Weather Warning Risk Matrix - Example

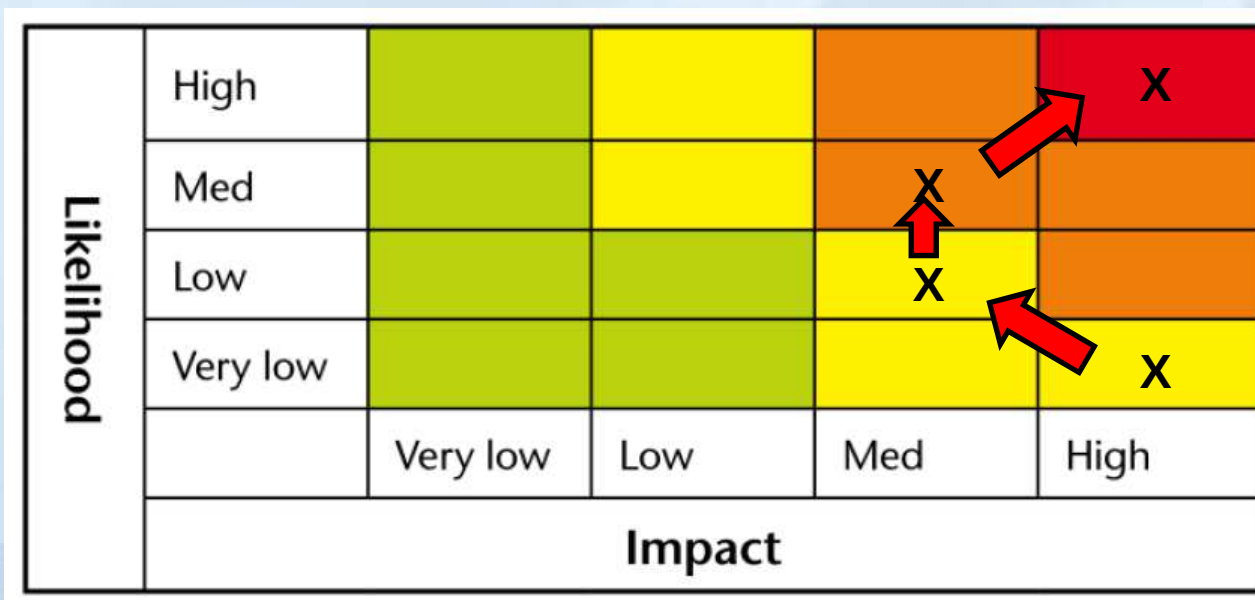
1 Day before a Tropical Cyclone arrives

Likelihood	High				X
	Med				
	Low				
	Very low				
		Very low	Low	Med	High
	Impact				

The Weather Warning Risk Matrix - Example

Path of Risk over many days

Likelihood	High				X
	Med			X	
	Low			X	
	Very low				X
		Very low	Low	Med	High
Impact					



Developing an Impact-based Forecast System

Assessing Risks

Are the hazards and the vulnerabilities well known?

Are risk maps and data widely available?

Monitoring and Early Warning

Develop hazard monitoring and early warning services

Are the right parameters being monitored?

Can accurate and timely warnings be generated?

Dissemination and Communication

Communicating risks and early warnings

Do warnings reach those at risk?

Is the warning information clear and actionable?

Response Capability

Build national and community response capabilities

Are response plans up to date and tested?

Are people prepared and ready to react to warnings?

Developing Impact-Based Forecast and Warning Services

- **Partnerships are very important...**

Stakeholders/Customers

- **Who uses your forecasts?**
 - What sectors do they represent (public, aviation, agriculture, marine)?
 - What are their concerns?
- **How do you learn about their needs?**
 - What challenges do you face?
 - Do you have agreements in place on communicating?
- **Do you receive feedback from them on your products and services?**
- **What information do they provide you related to evaluating vulnerability?**

Developing Impact-Based Forecast and Warning Services

- Which government bodies and other stakeholders can support impact-based forecasting?
- Develop governance between parties including steering committees and advisory groups
- Establish program management - roles and responsibilities for development, implementation, delivery
- Develop a communications strategy – what are the expected services, the respective roles of partners, and outreach activities
- Develop a plan for quality management and assurance of products and services
- Is international cooperation required?

Developing Capacity for NMHSs in IBFWS

- **What are the required competencies and skills?**
- **Cross-training with users on requirements and procedures**
- **Educating users on how to use impact-based forecast and warning services**
 - Special Users (transport, electricity, city authorities...)
 - Media
 - Public

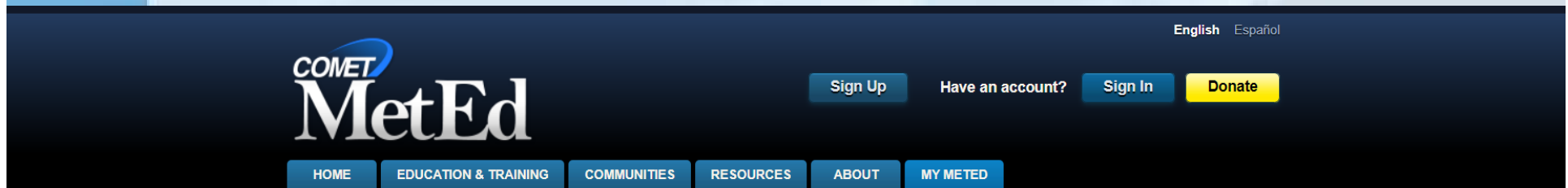
Example of IBF Application

- Using Multi-hazard, Impacts-based Forecast and Warning Services You Tube Video:
<https://www.youtube.com/watch?v=UaFFBg1opBU&t=>

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Recent Publications



NBM v3.2 Winter Weather Guidance

Winter weather is one of the more challenging aspects of operational weather forecasting. Factors affecting the impact of winter storms include precipitation type, timing of precipitation onset and precipitation type changeovers, winds, visibility, temperature,...

News and Updates

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Posted on: 2019-03-07

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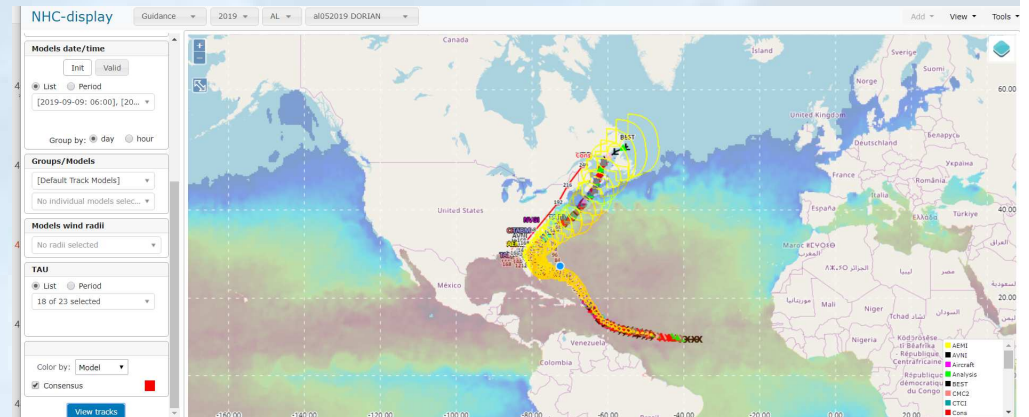
Example of IBF Application

- WRNs Case Studies Module: Impact-based Forecast Simulations

https://www.meted.ucar.edu/wrn_sims/

Tropical Cyclone Resources from NCAR

- The NHC Display and Diagnostic System
 - <http://www.hfip.org/nhc-display>



- The Tropical Cyclone Guidance Project
 - <http://hurricanes.ral.ucar.edu/>

