Translating weather forecasts into impact-relevant information: Practice of impact-based forecast in weather forecast operation

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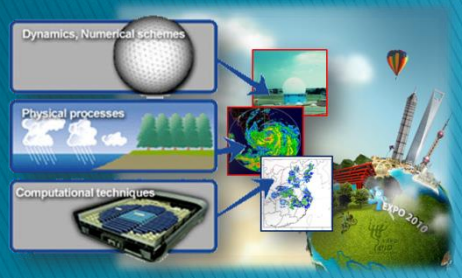

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OUTINE

- Background & Introduction
- From Phenomenon-Based Forecasts to Impact-Based Forecasts
- Impact-Based Forecast: Utilizing Probabilistic Weather Forecasts (Ensemble Forecasts) and Risk-based warning
- Practice in SMS and CMA
- Concluding Remarks

Special Thanks to Dr. Matthias Steiner of NCAR

Background & Introduction

- **National Meteorological and Hydrological Services (primary responsibility)**: to provide timely and accurate forecasts and warnings of hydrometeorological hazards and events.
- **Governments and Public:** to use forecasting and warning information and take effective action.

BUT even good forecasts are not always well used because they do not respond to the requirements of the users (e.g., emergency managers) in way that they can be of real use in decision-making and actions.

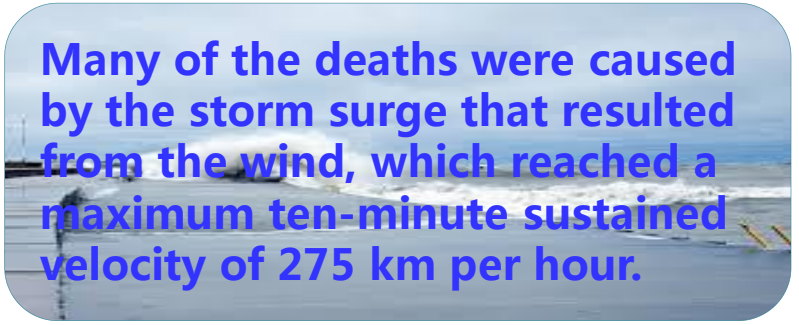
Why do good weather forecasts result in a poor response?

Example 1

Tropical Cyclone **Haiyan (Yolanda),** which struck the Philippines as a Category 5 storm on November 7 2013, as of 14 January 2014:

- 6,201 dead, 28,626 injured and 1,785 missing.
- More than sixteen million affected and more than US$827 million estimated for the damage of infrastructure and agriculture (NDRRMC 2014).

1. Accurate warnings were issued by the meteorological agency – PAGASA – for heavy rain and winds in time.
2. The government deployed planes and helicopters to the regions most likely to be affected.



- Accurate warnings issued
- Good indication of storm surge

Not enough knowledge of storm surge impacts

Why do good weather forecasts result in a poor response?

Example 2

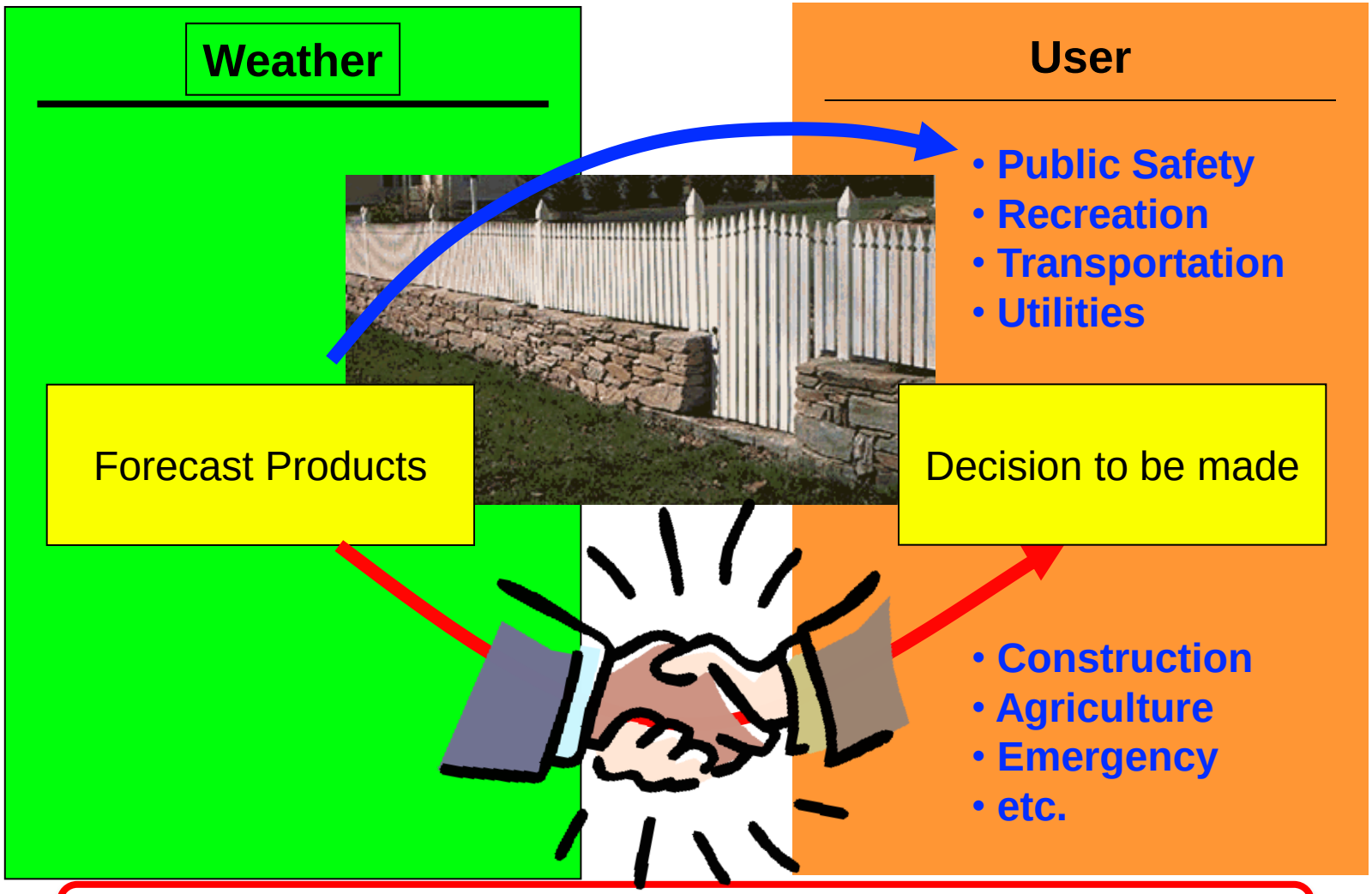
Tropical cyclone Fitow: Shanghai, China
Many roads and communities flooded, rivers overflowed, 1.2 million people directly impacted, direct economic loss 890 million RMB (app. US$ 150 million), one death

- Good weather forecasts of TC
- Highly developed multi hazard warning system
- Well prepared emergency management and first responders
- Good public communication using multiple channels
- Good rules and regulations for warnings and response
- Good standard operating procedures
- Over 18 million people alerted

But, gridlock and many people exposed to the hazard; flooded cars, buses, etc. 1,240,000 people directly affected

1. The actions recommended to take are usually quite general and do not provide specific guidance for a particular circumstance.
2. The forecaster does not usually consider the vulnerability and exposure of the population to the hazard.
3. The highest level of warning was not issued until well into the morning rush hour when the appropriate meteorological thresholds were exceeded.

Throwing over Fence



Effective forecasts have to be tailored to specific user needs

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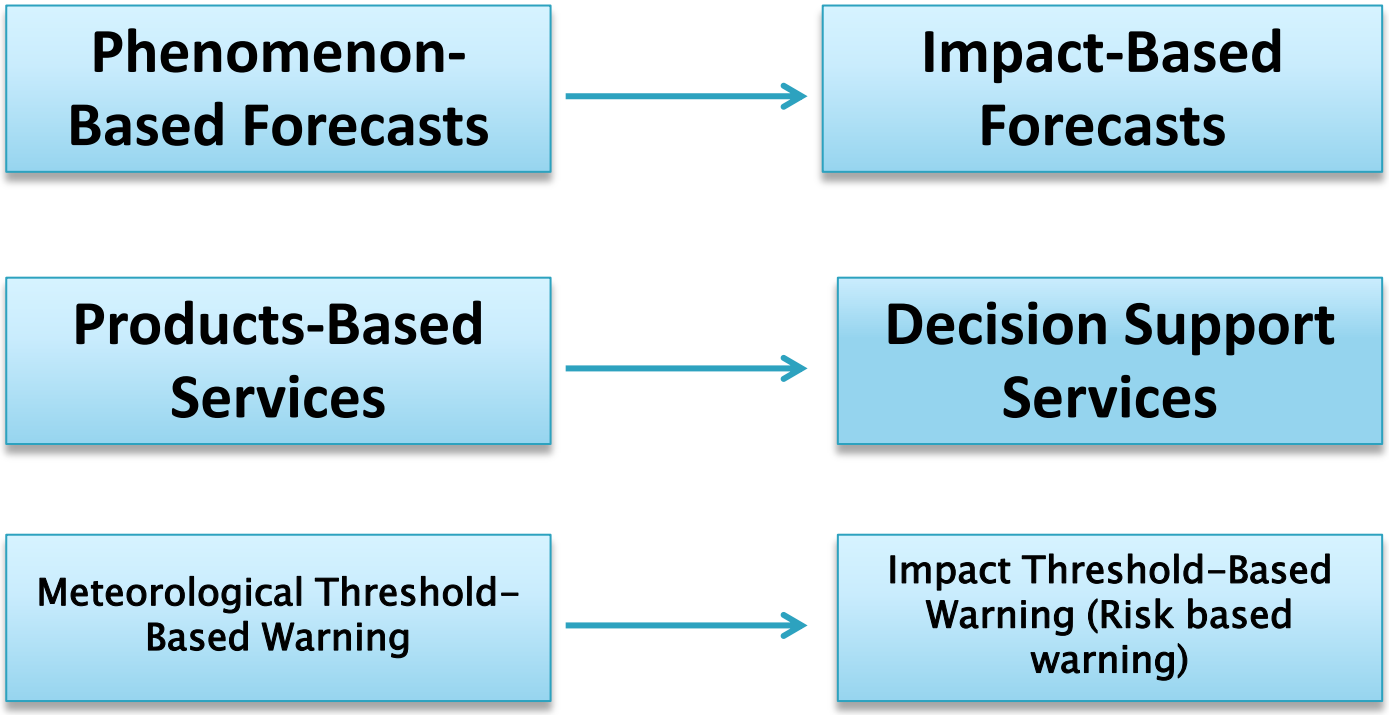
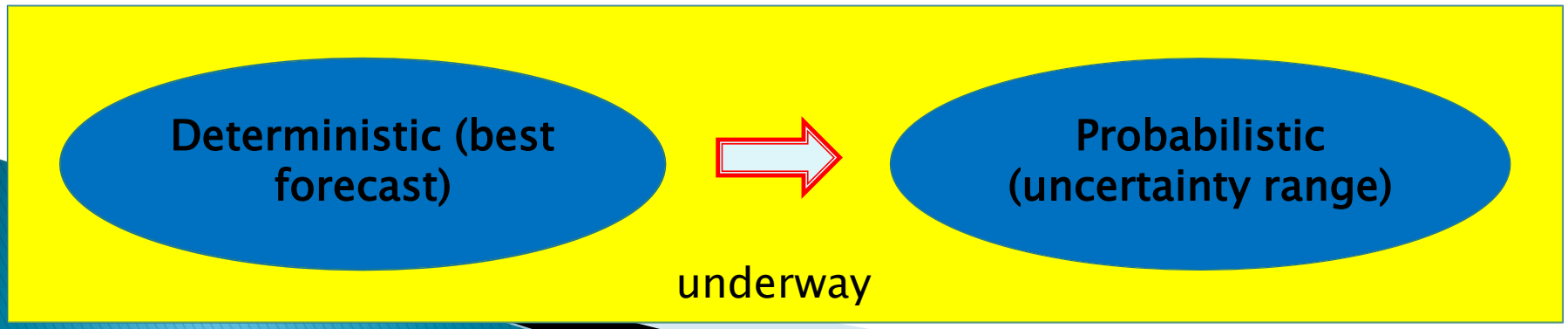
Operation Shifts needed

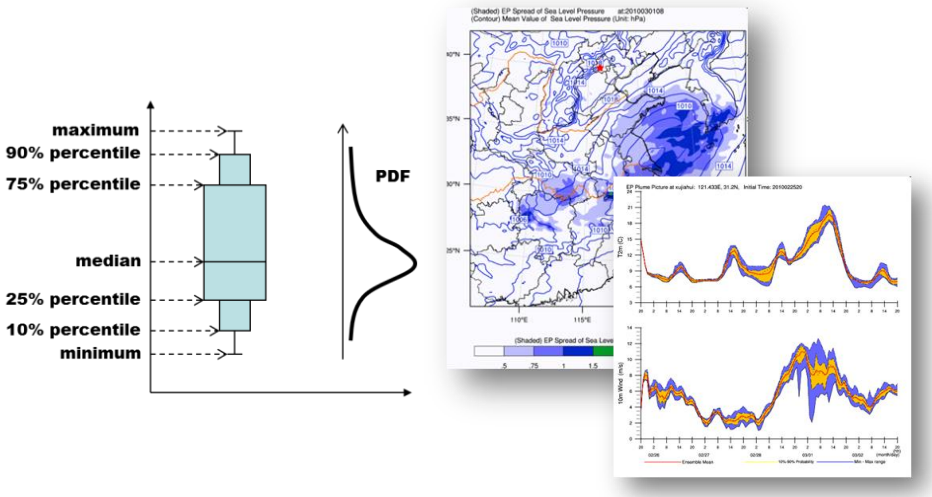




Translating weather forecasts (ensemble forecast) impact-relevant information

We live in an uncertain world, and uncertainty information is extremely important for decision making.

The growth of inevitable uncertainties and errors in making forecast is flow-dependent because of the atmosphere being a nonlinear dynamical system. Ensemble Prediction Systems (EPSs) have been developed to estimate such 'flow-dependent' forecast uncertainty.

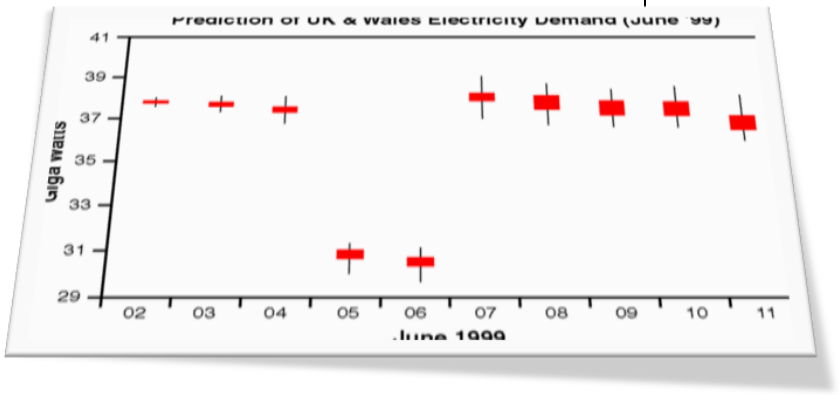


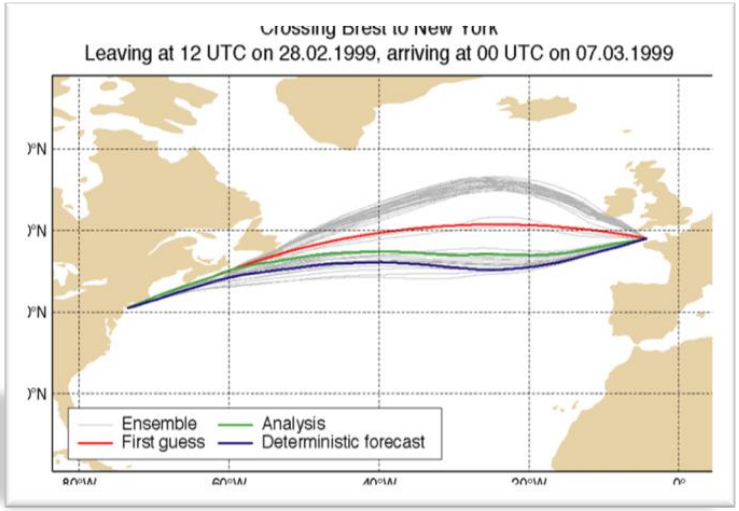
The real values of ensemble prediction are not only the probability forecasts per se, but also their ability to influence decisions across a range of applications sectors.

The economic value of ensemble forecasts as a tool for risk assessment: From days to decades, By T. N. Palmer of European Centre for Medium-Range Weather Forecasts, UK, Q. J. R. Meteorol. Soc. (2002), 128, pp. 747–774

End-to End Outcome Forecasting

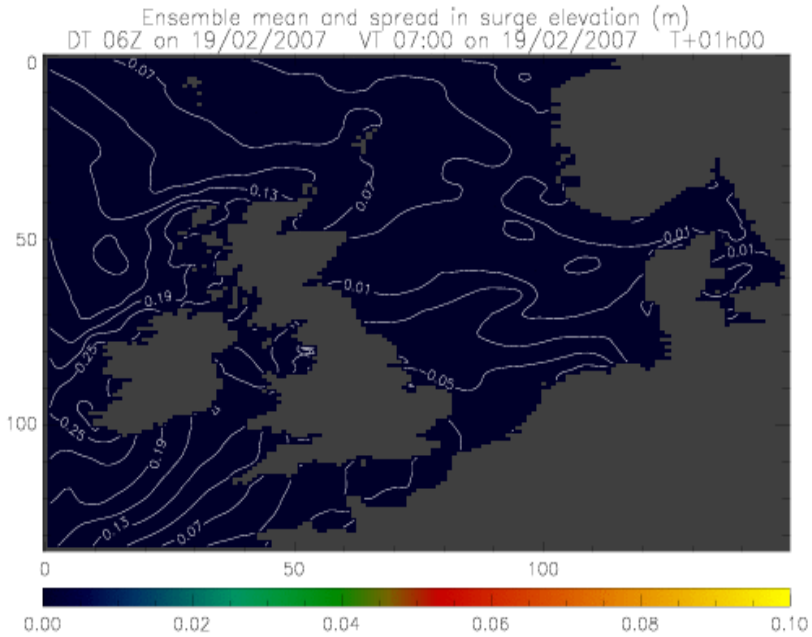
- An EPS forecast can be used to drive an ensemble of outcome models, e.g.:
  - **Tidal surge**
  - **Ocean waves**
  - **Wind power output**
  - **Energy demand**
  - **Hydrology – flood risk**
  - **Ship or aircraft routes**
  - **Public Health**



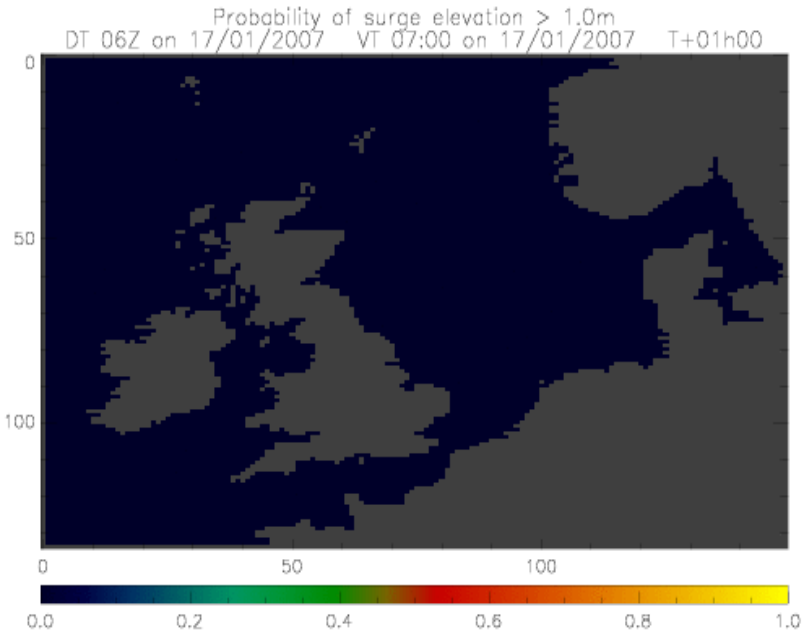


Storm surge Ensemble

Storm surge model coupled to EPS



Mean/spread of surge

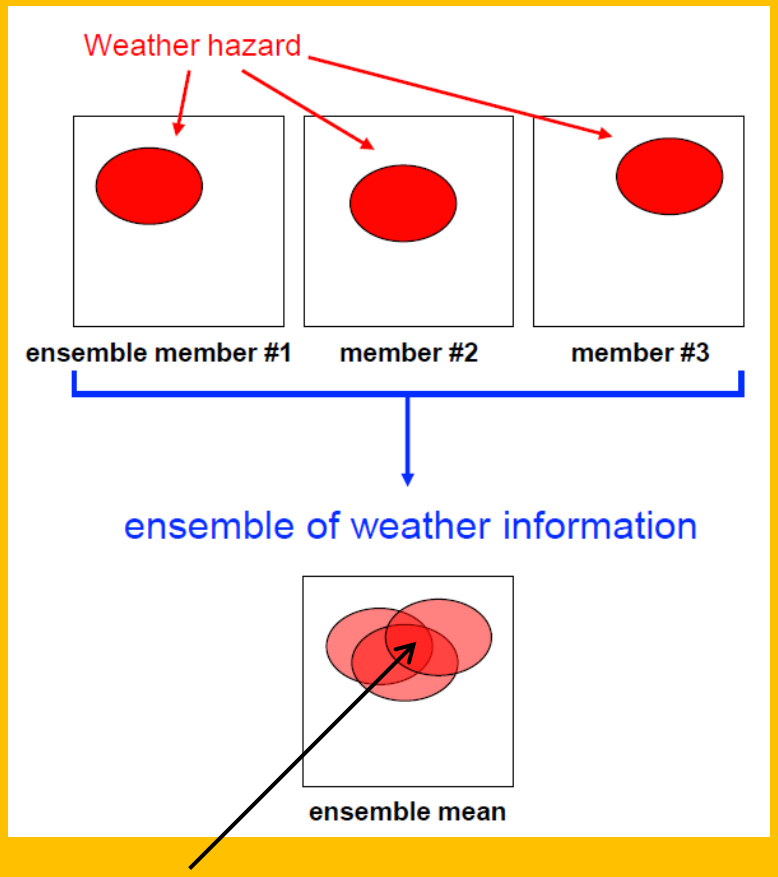


Probability of surge >1.m

Aviation Example

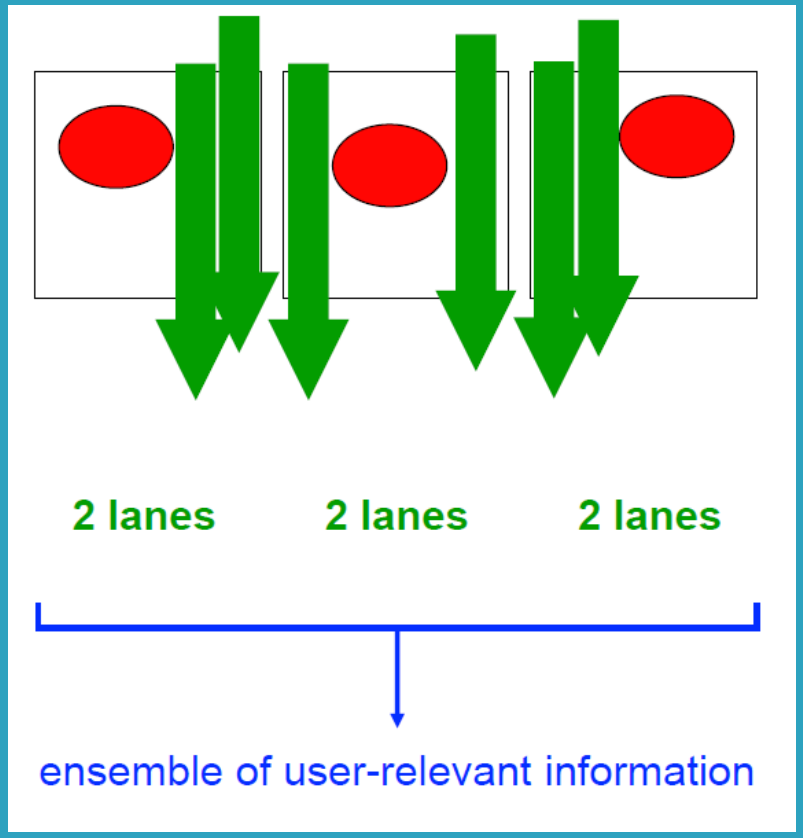
Translation

Meteorology way



Most likely, hazard occurs

User (aviation) way



Most likely, 2 air lines open

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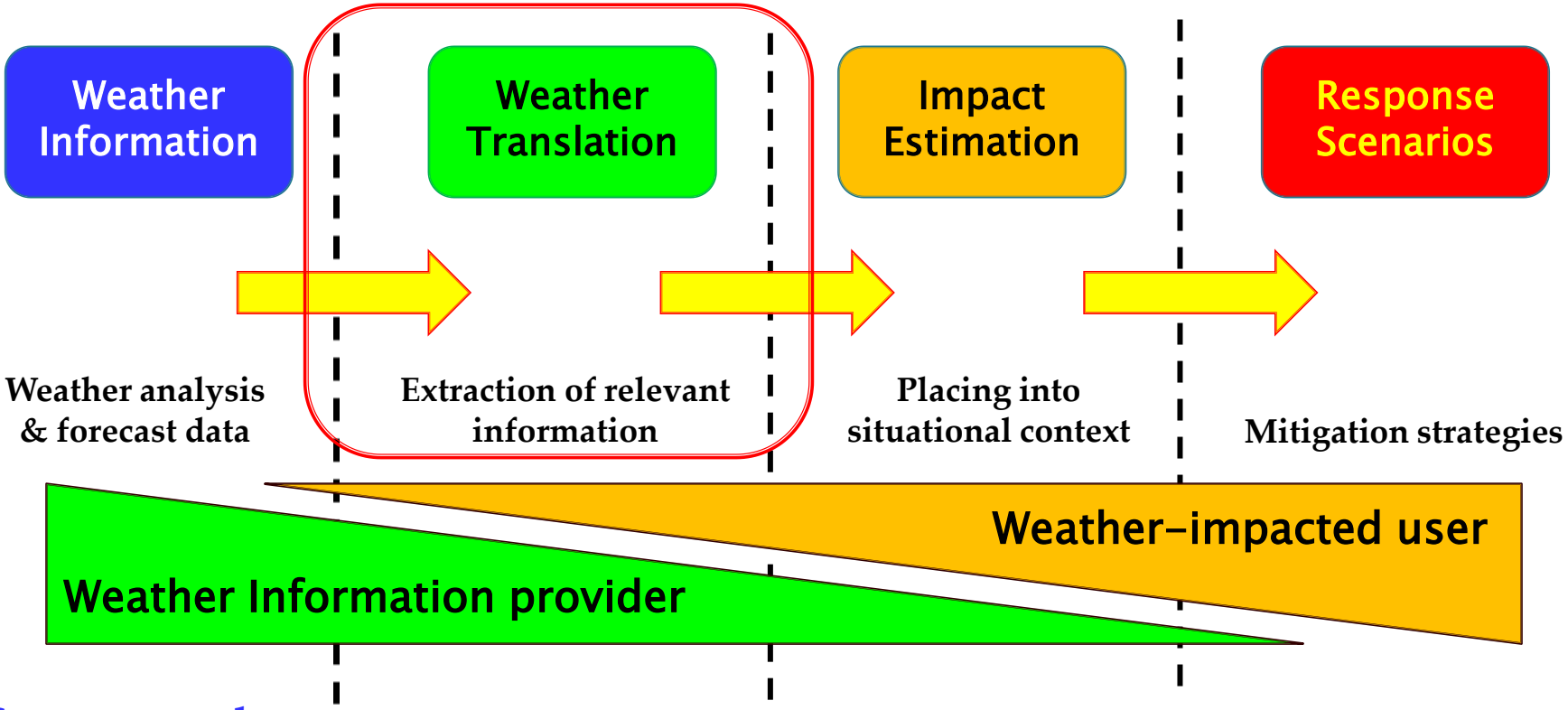
Weather Translation & Integration Concept



Some examples:

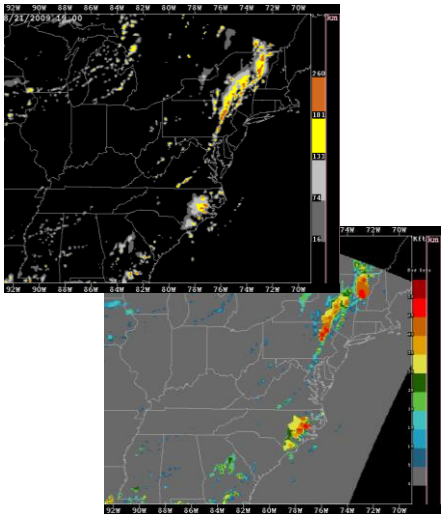
Airport operation	Ceiling & visibility (flight categories)	Reduced capacity (arrival rates)	Ground delay programs
Dam operation	Precipitation & runoff (water level)	Overflow or breaking, minimal discharge	Controlled release of water
Power plant operation	Winds below/above critical thresholds	Reduced power generation	Balancing grid with other power sources

Curtesy of Dr. Matthias Steiner of NCAR

Sector: Air Traffic Management

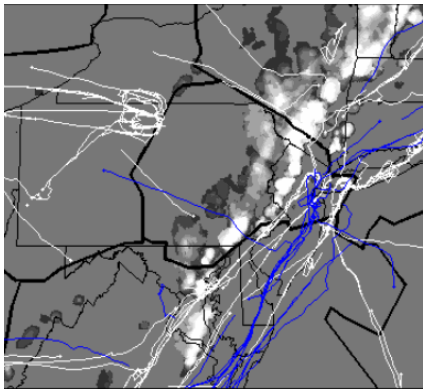
Weather Information → **Weather Translation** → **Impact Estimation** → **Response Scenarios**

Weather analyses & forecast data



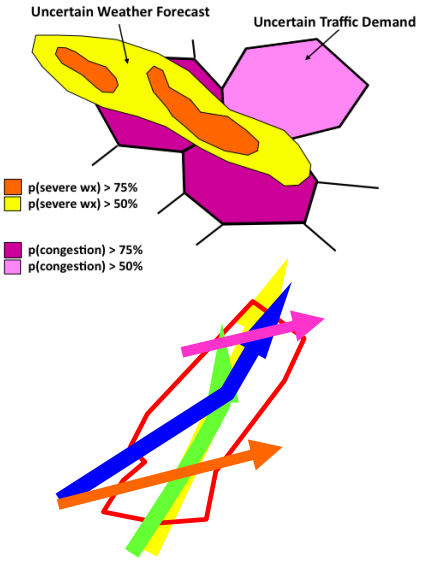
Storm intensity & echo tops

Extraction of relevant information



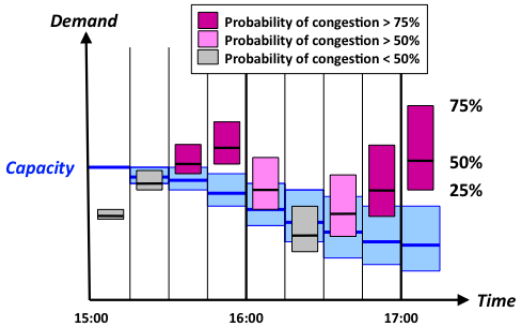
Aviation constraints or threshold events

Placing into situational context



Sector capacity & workload impact

Mitigation strategies

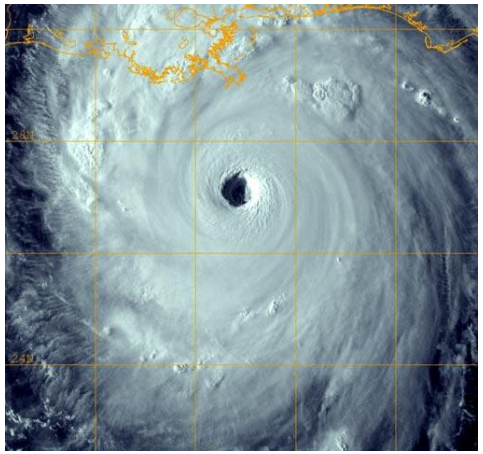


Strategic traffic flow management initiatives & tactical programs

Coping with Hurricanes/Typhoons

Weather Information → **Weather Translation** → **Impact Estimation** → **Response Scenarios**

Weather analyses & forecast data

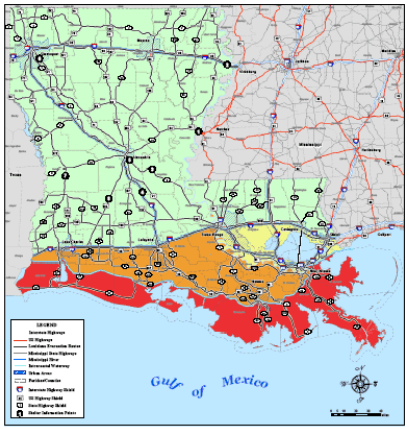


Hurricane track, size, & intensity

Extraction of relevant information

Storm surge, flooding, inundated areas

Placing into situational context



Affected population & infrastructure, disruption of services, damages due to wind & water, etc.

Mitigation strategies

Implementation of evacuation & recovery plans

Water Resources Management

Weather Information → **Weather Translation** → **Impact Estimation** → **Response Scenarios**

Weather analyses & forecast data

Rainfall (or lack thereof)

Extraction of relevant information

Runoff & flow into reservoir, water levels behind dam

Placing into situational context

Dam overflow, water rights, or minimal streamflow for fish

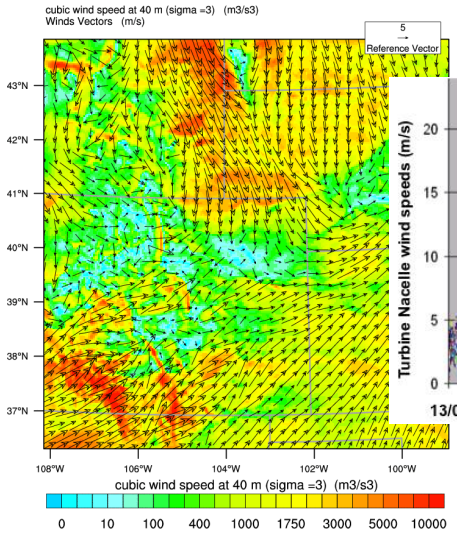
Mitigation strategies

Controlled release of water & timing thereof

Wind Energy

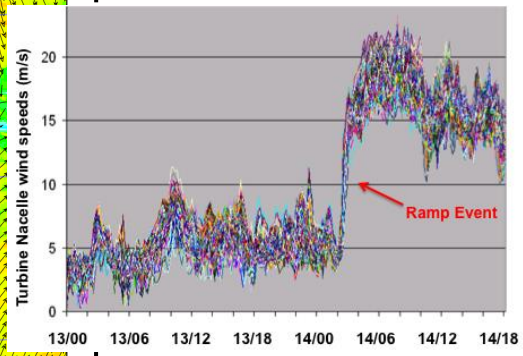
Weather Information → **Weather Translation** → **Impact Estimation** → **Response Scenarios**

Weather analyses & forecast data



Wind & variability

Extraction of relevant information



Wind at hub height, min/max thresholds, & ramp events

Placing into situational context

Energy generated by entire windfarms

Mitigation strategies

Balancing power grid using different energy sources

Winter Road Maintenance

Weather Information → **Weather Translation** → **Impact Estimation** → **Response Scenarios**

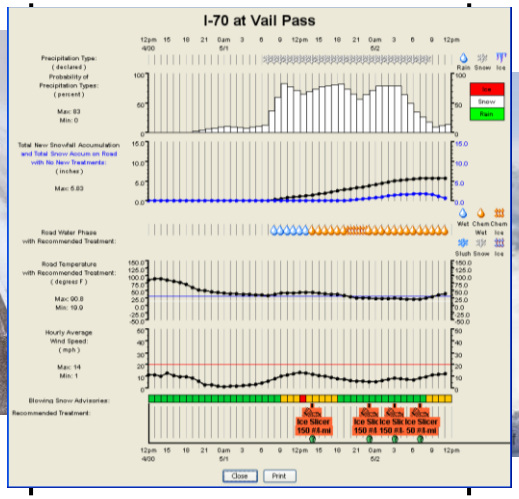
Weather analyses & forecast data

Temperature, relative humidity, wind & precipitation

Extraction of relevant information

Snow accumulation along road based on pavement temperature

Placing into situational context

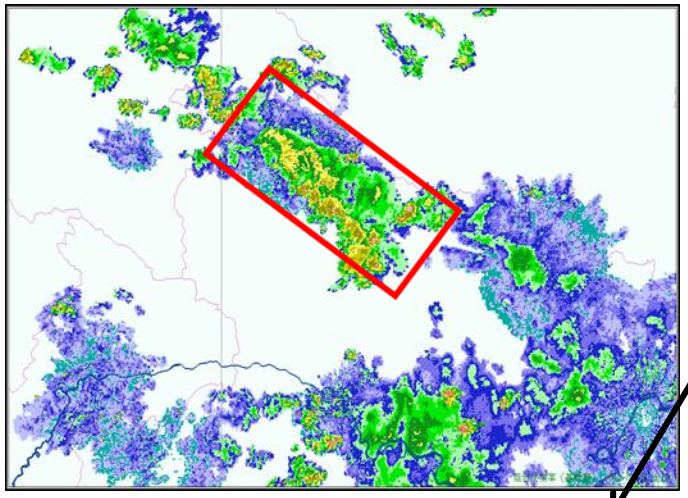


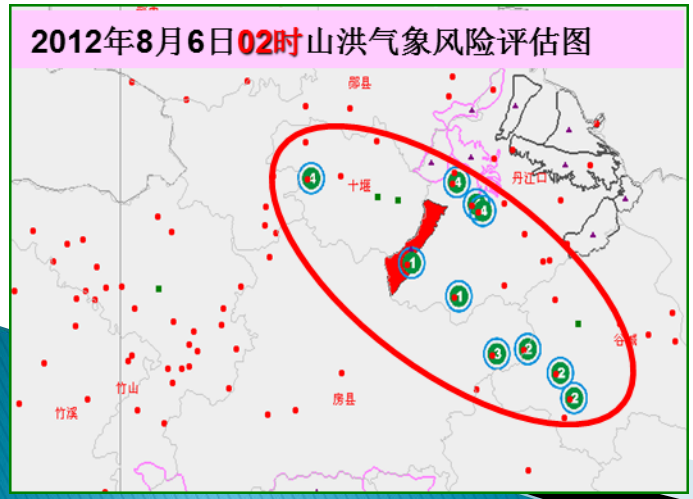
Road mobility & traffic demand

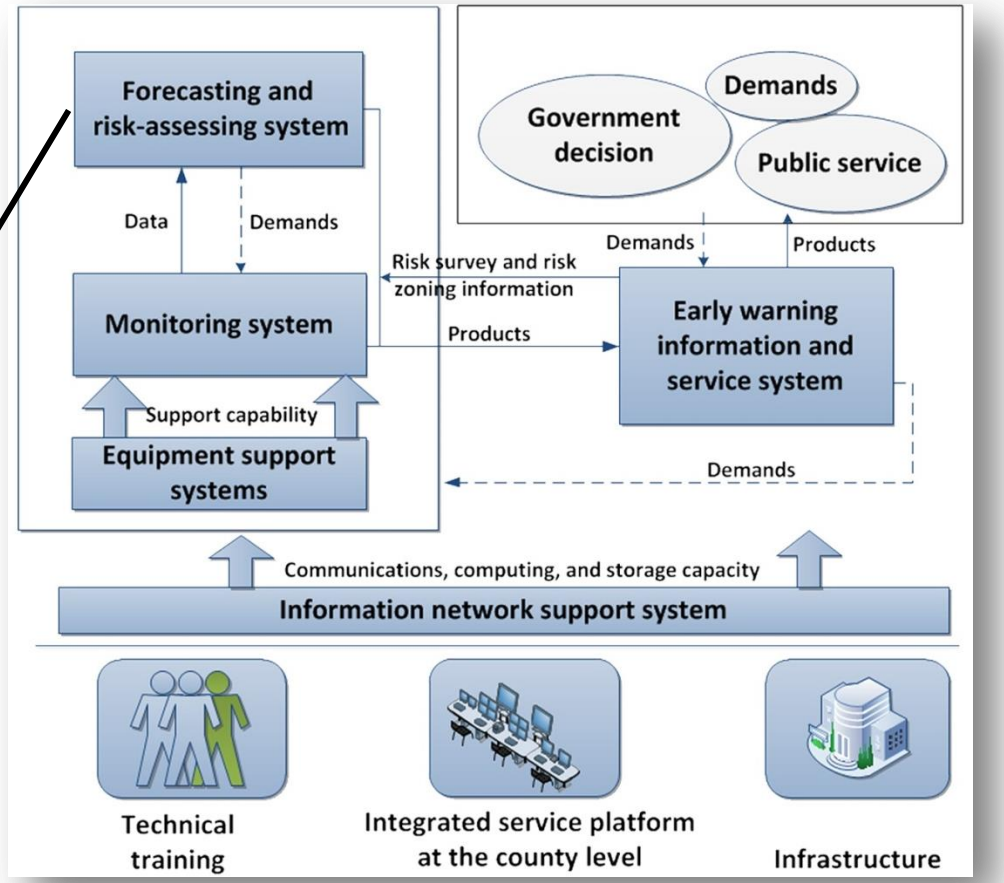
Mitigation strategies

Timing of snow plows & application of chemicals

CMA: Meteorological Support Project for Preventing Flash Floods and Geographical Disasters



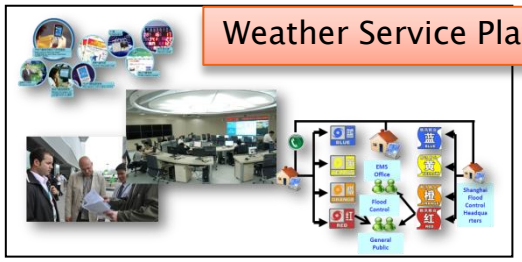




MHEWS within Shanghai Meteorological Service

Observations & NWP

Integrated Operational Platform



Multi-agency Coordination Mechanism

1. Multi-Hazard Detection & Monitor
2. Forecasting Information Product (e.g. NWP)

Weather Information

1. Impact information generating
2. Hazard Risk Analysis and Assessment

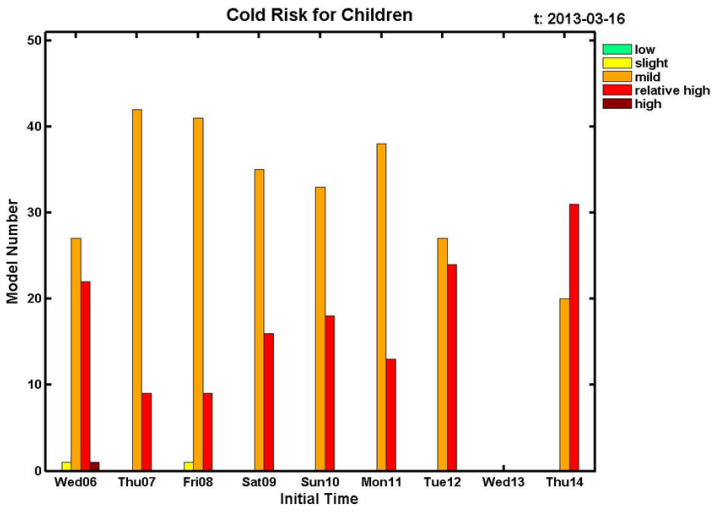
Translation & Impact estimation

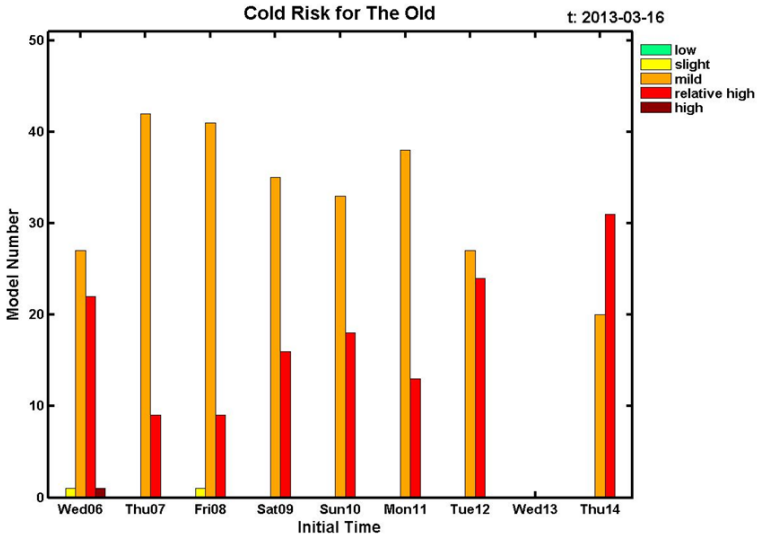
Impact & Risk based warning Issuing (users based situational context)

Response mechanism and decision-making support

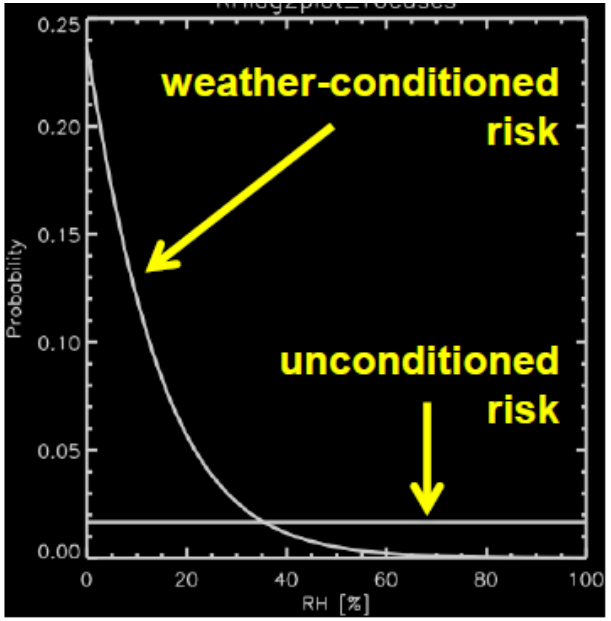
Response Scenarios

Shanghai Meteorological Service's public health related impact products



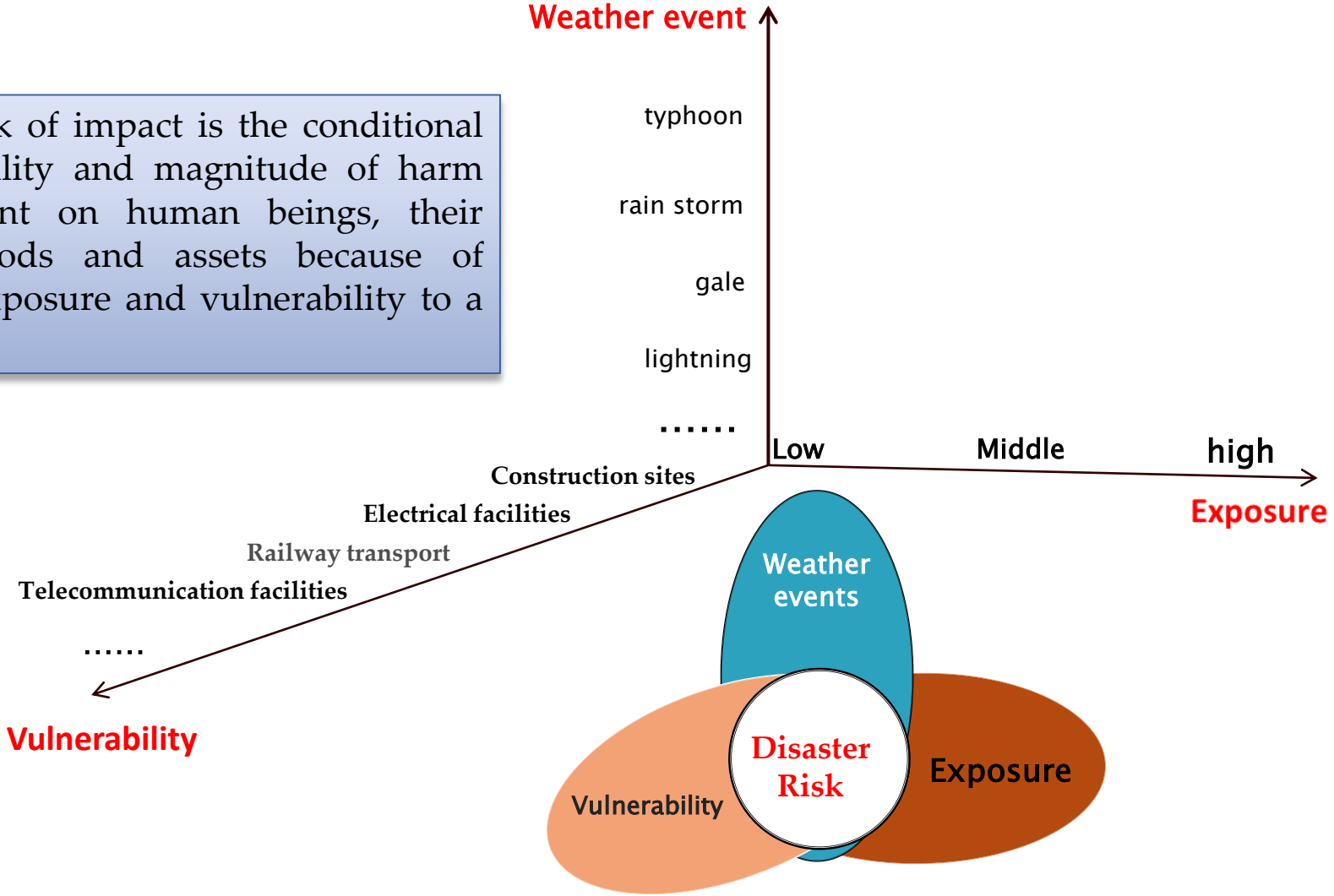


Translating the ECMWF ensemble forecast products into flu occurrence probability in next few days by using a flu epidemics model.



Multi-hazard Risk Analysis and Assessment

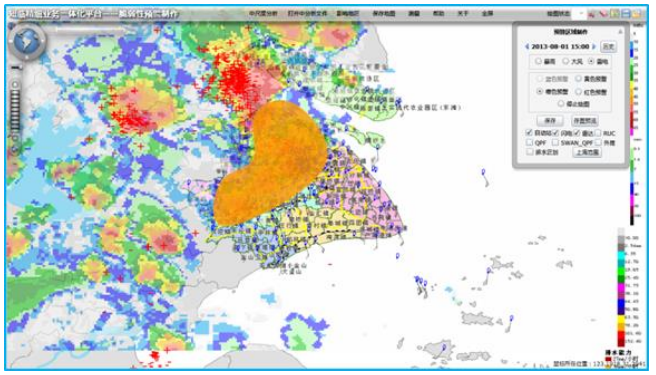
The risk of impact is the conditional probability and magnitude of harm attendant on human beings, their livelihoods and assets because of their exposure and vulnerability to a hazard.



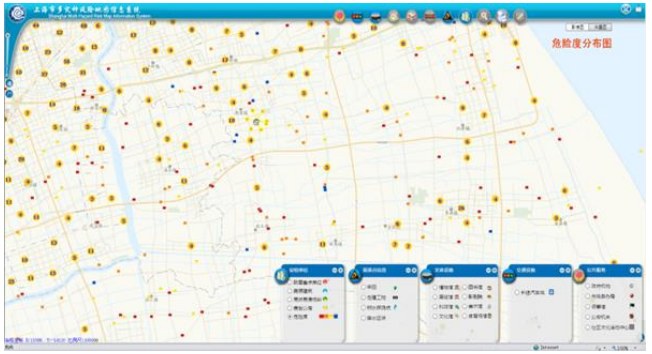
$$\left|Risk\_of\_impact(x,t)\right| \equiv \left|harzard(x,t)\right| \bigcup \left|vulnerability(x,t)\right| \bigcup \left|exposure(x,t)\right|$$

SMS's risk-based warning (Heavy Rain, Gale and Lightning)

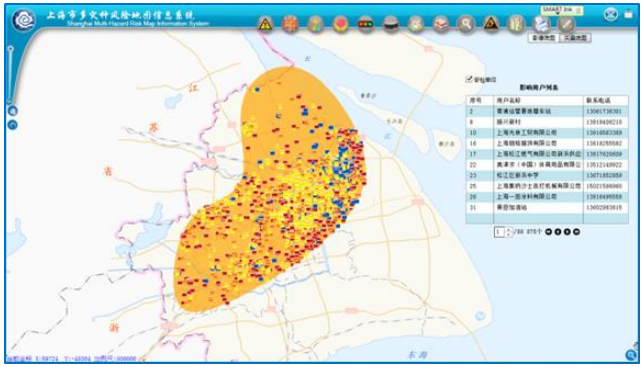
Impacting area (from weather impact forecast)



Risk projection and assessment based vulnerability and exposure of different sectors (users)

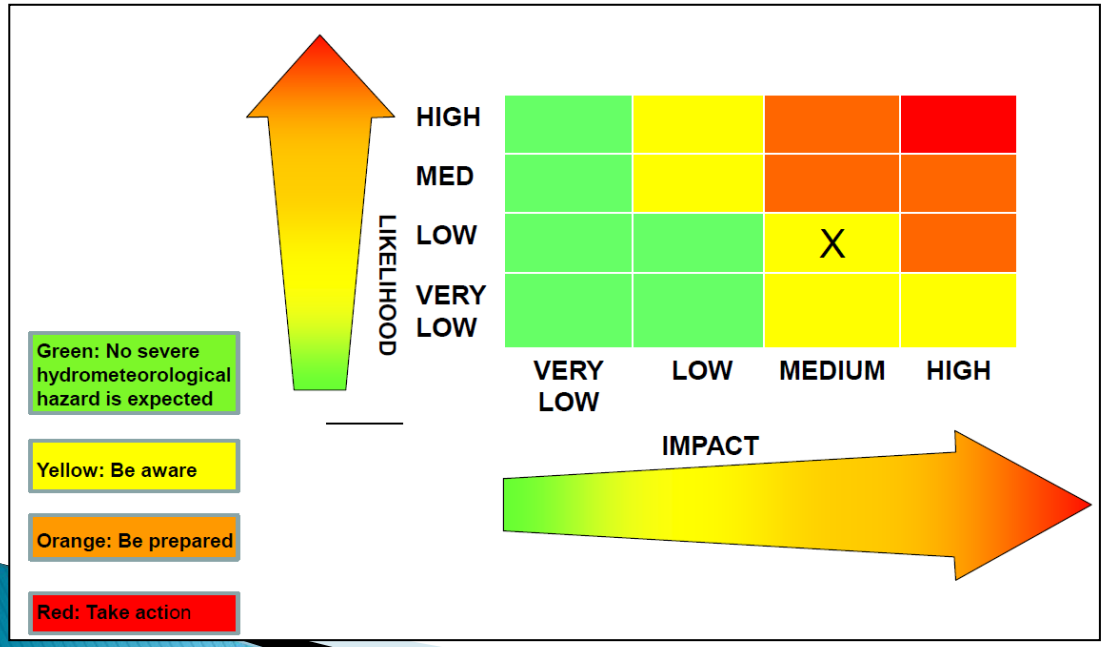


Detailed warning map from risk analysis and assessment



Risk-based Warnings (Risk Matrix)

- **Risk matrix** to identify likelihood of event and potential impact
- Likelihood related to uncertainty (location or severity of event)
- Impact related to vulnerability and exposure and can:
  - define strain on emergency services
  - identify specific groups of people or communities at risk
  - Determine the scale of responsibility from local to national



Assign a color to the warning which is a combination of potential impact and likelihood (source: **Met Office**)

Concluding Remarks

- understanding of information needs, but also communicating capabilities & limitations
- Gaining as much as possible knowledge of vulnerability and exposure（often not easily accessible by meteorologists）
- translation of weather into user-relevant information (extraction of relevant information from each ensemble member)
- integration of weather into user's decision making process (impact estimation & response scenarios utilizing decision support tools)
- calibration of probabilities & including some measure of confidence
- training for understanding & utilizing (probabilistic) forecasts
- close collaboration between weather forecast providers & end users / decision makers
- development of trust in translated forecasts & decision support tools
- embracing change & possibly adjusting operational procedures
- more ……

Thank you for your attentions

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