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

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OUTLINE

- 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 a 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.

- Many of the deaths were caused by the storm surge that resulted from the wind, which reached a maximum ten-minute sustained velocity of 275 km per hour.

- 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.
Effective forecasts have to be tailored to specific user needs.

Throwing over Fence

- Public Safety
- Recreation
- Transportation
- Utilities
- Construction
- Agriculture
- Emergency
- etc.

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Operation Shifts needed

- Phenomenon-Based Forecasts → Impact-Based Forecasts
- Products-Based Services → Decision Support Services
- Meteorological Threshold-Based Warning → Impact Threshold-Based Warning (Risk based warning)

Deterministic (best forecast) → Probabilistic (uncertainty range) underway
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.

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

**Meteorology way**
- Ensemble of weather information
- Ensemble mean
- Weather hazard

**User (aviation) way**
- Ensemble of user-relevant information
- 2 lanes
- Most likely, hazard occurs

Most likely, 2 air lines open

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Weather Translation & Integration Concept

Weather Information & forecast data → Extraction of relevant information → Placing into situational context → Mitigation strategies

Weather Information provider

Weather-impacted user

Some examples:

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Sector: Air Traffic Management

Weather Information
- Weather analyses & forecast data
- Storm intensity & echo tops

Weather Translation
- Extraction of relevant information
- Aviation constraints or threshold events

Impact Estimation
- Placing into situational context
- Sector capacity & workload impact

Response Scenarios
- Mitigation strategies
- Strategic traffic flow management initiatives & tactical programs
Coping with Hurricanes/Typhoons

**Weather Information**
Weather analyses & forecast data

**Weather Translation**
Extraction of relevant information

**Impact Estimation**
Placing into situational context

**Response Scenarios**
Mitigation strategies

- Hurricane track, size, & intensity
- Storm surge, flooding, inundated areas
- Affected population & infrastructure, disruption of services, damages due to wind & water, etc.
- Implementation of evacuation & recovery plans
Water Resources Management

Weather Information

Weather analyses & forecast data

Runoff & flow into reservoir, water levels behind dam

Rainfall (or lack thereof)

Weather Translation

Extraction of relevant information

Dam overflow, water rights, or minimal streamflow for fish

Runoff & flow into reservoir, water levels behind dam

Impact Estimation

Placing into situational context

Controlled release of water & timing thereof

Response Scenarios

Mitigation strategies
Wind Energy

Weather Information

Weather analyses & forecast data

Weather Translation

Extraction of relevant information

Impact Estimation

Placing into situational context

Response Scenarios

Mitigation strategies

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

Wind & variability

Energy generated by entire windfarms

Balancing power grid using different energy sources
Winter Road Maintenance

Weather Information
- Weather analyses & forecast data
- Temperature, relative humidity, wind & precipitation

Weather Translation
- Extraction of relevant information
- Snow accumulation along road based on pavement temperature

Impact Estimation
- Placing into situational context
- Road mobility & traffic demand

Response Scenarios
- 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

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

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

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

Response mechanism and decision-making support

Observations & NWP

Integrated Operational Platform

Weather Service Platform

Multi-agency Coordination Mechanism

Weather Information

Translation & Impact estimation

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

\[ \text{Risk of impact}(x, t) \equiv \text{hazard}(x, t) \cup \text{vulnerability}(x, t) \cup \text{exposure}(x, t) \]
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