Bringing the Value Chain for High-Impact Weather Warnings into the Classroom

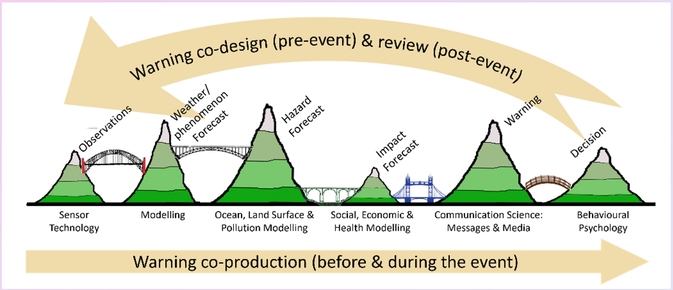
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What is a "Warning Value Chain"?

Warning for weather disasters is complex:

- The iterative process involves many connected outputs, processes, and disciplines
- As part of the World Meteorological Organization's (WMO) High-Impact Weather Project (HIWeather), the economic concept of a "value chain" has been applied to explore and evaluate the flow of information in weather warnings:



The WMO value chain project team was formed in 2020 to explore value chain approaches and create an evaluative framework with guidance and tools.

- >40 members across many countries and professions initiated a database of high-impact weather warning case studies.
- Scientists and practitioners can analyze previous experiences to better understand the warning value chain and identify potential improvements to mitigate future risk and damage.
- Common framework for evaluation across many weather events, via a questionnaire (available on https://doi.org/10.5281/zenodo.10457434).

Majumdar, S. J., D. Hoffmann, E. E. Ebert, and B. W. Golding, 2024: Bringing the Value Chain for High-Impact Weather Warnings into the Classroom. *Bull. Amer. Meteor. Soc.*, **105**, E1603–E1609, https://doi.org/10.1175/BAMS-D-23-0273.1.

Ebert, E. E., A. Perrels, C. Mooney, D. Hoffmann, A. Tupper, B. Mills, J. Pástor-Paz, X. Liang, H. Msemo, J. Da Costa, and J. Lazo, 2024: Value Chain Approaches to Describe, Improve, Value and Co-Design Early Warning Systems, WWRP 2024-4, World Meteorological Organization, 136 pp. https://library.wmo.int/idurl/4/69103.

Students' Evaluations of the Value Chain

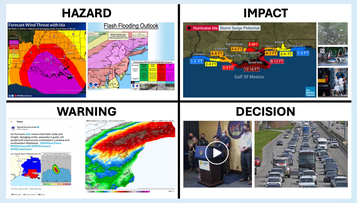
The University of Miami used the same approach for landfalling major hurricanes

- Tropical Weather and Forecasting (undergraduate course)
- Each class (6-13 students) worked in unsupervised teams
- 47 questions from Hazard, Impact, Warning, and Decision stages, e.g.:
  - *How reliable and accurate were weather forecasts at different lead times?*
  - *Of those exposed, who and what were vulnerable to the hazards and why?*
  - *To what extent were warning messages received and understood by the public?*
- Written responses edited and compiled into a report for the database

The Bureau of Meteorology developed several approaches

- 10 undergraduate honors and master's interns from several disciplines
- Supervised 3-month projects
  - First case studies:
    - Australian Black Summer Fires (2019-20)
      - Limited community knowledge of how to defend themselves in a state of disaster
    - Eastern Australian Floods (2022)
      - Many residents had a flood action plan and experience of prior floods
      - Difficulties receiving warnings due to communication outages
  - Second case studies: same hazard type, but for regions with varying socioeconomic status
    - Hurricane Isaias (2020) as it passed through Caribbean and United States
    - Heavy rain event in Durban, South Africa (2022)
  - Other interns helped build the prototype database or develop an annotated bibliography
  - Single 3-hour "flash case study" of an active hurricane.

Hurricane Ida (2021, class project)



- Oil shortages, toxic mold, flooded basements
- Abrupt shift in communication: "A lot of uncertainty" to "Prepare now!"
- Differences in urgency between "Cat-4 Hurricane Ida" and "Remants of Ida"
- Covid-19 and heat affected the response
- Contrasts in preparation between New Orleans and New York City

Hurricane Ian (2022, class project)

- Hazard and impact forecasts were dependent on the complex track forecast
- Some key forecast products were widely misinterpreted
- Positive and negative consequences of "disaster influencers" on social media
- Inconsistencies in evacuation protocols ("just-in-case" versus "just-in-time")
- Online resources such as preparedness programs, although their public uptake was questioned.

Hurricane Idalia (2023, class project)

- More encouraging responses than for Ian (2022)
- Higher confidence in Idalia's forecast led to lower uncertainty in storm surge and wind forecasts, likely resulting in more consistent messaging which facilitated emergency preparation and decision-making
- Recency of Ian may have bolstered the public response
- Damage was mitigated by Idalia striking a sparsely populated area
- The multiple methods of public communication, together with strong dissemination and communication between agencies, were noted for all three hurricanes

Hurricane Helene (2024, class project)



- Multiple hazards: storm surge; extreme wind; mountain-induced flooding
- Accurate forecasts of track, intensity, rainfall distribution (extremes were difficult)
- Ground saturation from a Predecessor Rain Event (PRE)
- Population density, property value, and flood insurance policies are crucial relative to storm features when determining human impact and monetary impact
- Many issues related to lack of preparedness in North Carolina

Hurricane Beryl (2024) (Mackenzie Carr, ongoing individual research)

- Contrasts between Caribbean and United States in data availability, hazards, communication, response

Students' Feedback

- Students expressed gratitude for the opportunity to contribute to the WMO Value Chain project.
- Examples of educational benefits:
  - Enhancement of students' research, team collaboration, critical thinking and composition skills
  - Building a comprehensive view of weather events and their impacts, learning from classmates
  - Exposure to disciplines that are not traditionally in meteorology curricula
    - Communication, psychology, law, economics, business operations, public health …
  - Learning about how information is provided to and used by emergency managers vs public
  - Learning what goes into disaster planning and recovery efforts; and identifying gaps in practices
  - Reflecting on how to improve elements of the warning value chain
  - Value of interacting with professionals in the field
  - Expanded students' interest in future career paths outside weather forecasting
  - Consensus: working on the project was "interesting, beneficial, and fun."

Lessons Learned

- The value chain questionnaire facilitated the opportunity for students to contribute directly to WMO and the global community of researchers, forecasting agencies, stakeholders, and decision-makers at an early stage of their career
- One reason to conduct these exercises during or shortly after a high-impact event is to capture many graphics and articles that quickly disappear
  - On the other hand, immediately available information is incomplete and inaccurate
  - Resulting reports should not be viewed as comprehensive
- Most questions elicited a detailed response, with a spectrum of answers in some cases
- The archiving of products facilitated informed responses about the evolution of the forecasts and official warnings, although formal evaluations require gridded data and rigorous statistical methods
- There are additional limitations of our approach to case study compilation:
  - Information can be fragmented, and stories may be anecdotal and not fully representative
  - The most difficult questions to address were those on impact forecasting (flooding, road closures, etc.) which remains in its infancy, and internal coordination between agencies
  - Quantifying impacts such as economic losses take months or years to complete
  - While some negative instances of poor communication may be identifiable, the positive impact of good communication is less straightforward to evaluate
  - The students also had to use their own judgment on the reliability of the information
- Given that the questionnaire was well-structured and vetted, we found it straightforward to pass to the students, needing only limited additional guidance
- The more experienced students were able to pursue the case study research in more depth. The students thrived on their elevated responsibility, and their enthusiasm and commitment to preparing their written responses and presentations was the main reason for its success
- Based on the students' feedback, our approaches generally worked to the first order

Suggestions for Educators

- We encourage the incorporation of value chain exercises in meteorology curricula
- Opportunity for students to broaden their understanding of societal issues by taking the responsibility of being an evaluator
- With high-impact events as the context, it offers students an opportunity to be introduced to important questions in disciplines that normally appear distant from meteorology
- There is flexibility in how the value chain exercises can be set up:
  - People at all levels, from high school through to experienced researchers, can contribute
  - The inclusion of students from a range of disciplines adds depth and breadth to the evaluations
  - The approach could range from a homework assignment to an in-depth publication
  - Flexibility in which sections of the value chain to focus on
  - Value chains can be compared across different events, and multiple groups can contribute to a single case
  - Can be extended to all types of high-impact weather events such as snowstorms or tornado outbreaks, and to geophysical hazards such as volcanic eruptions and tsunamis
- Engagement with operational centers and stakeholders would deepen the assessments further

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