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Evolving Early Warnings with the Power of Impact Data

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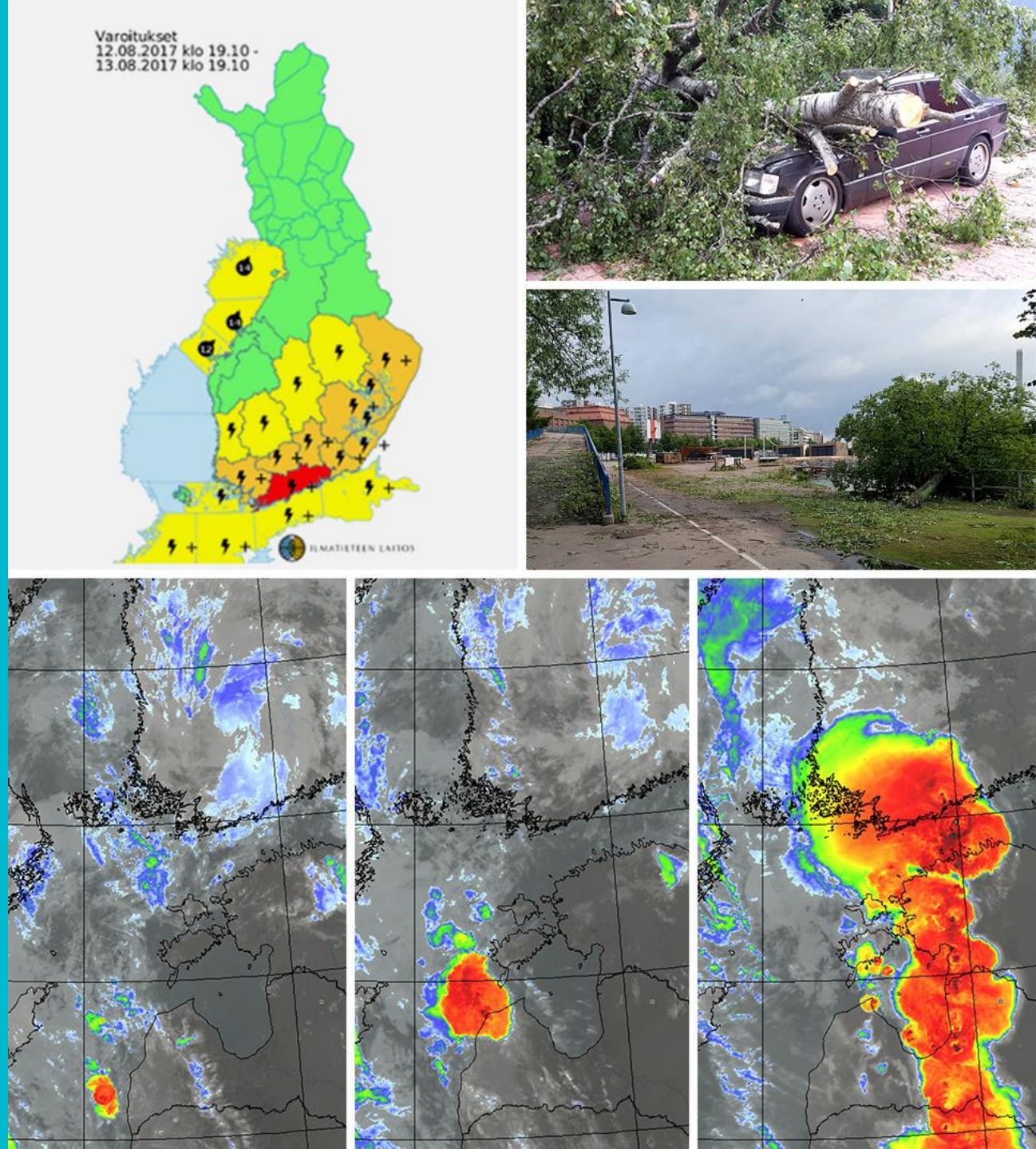

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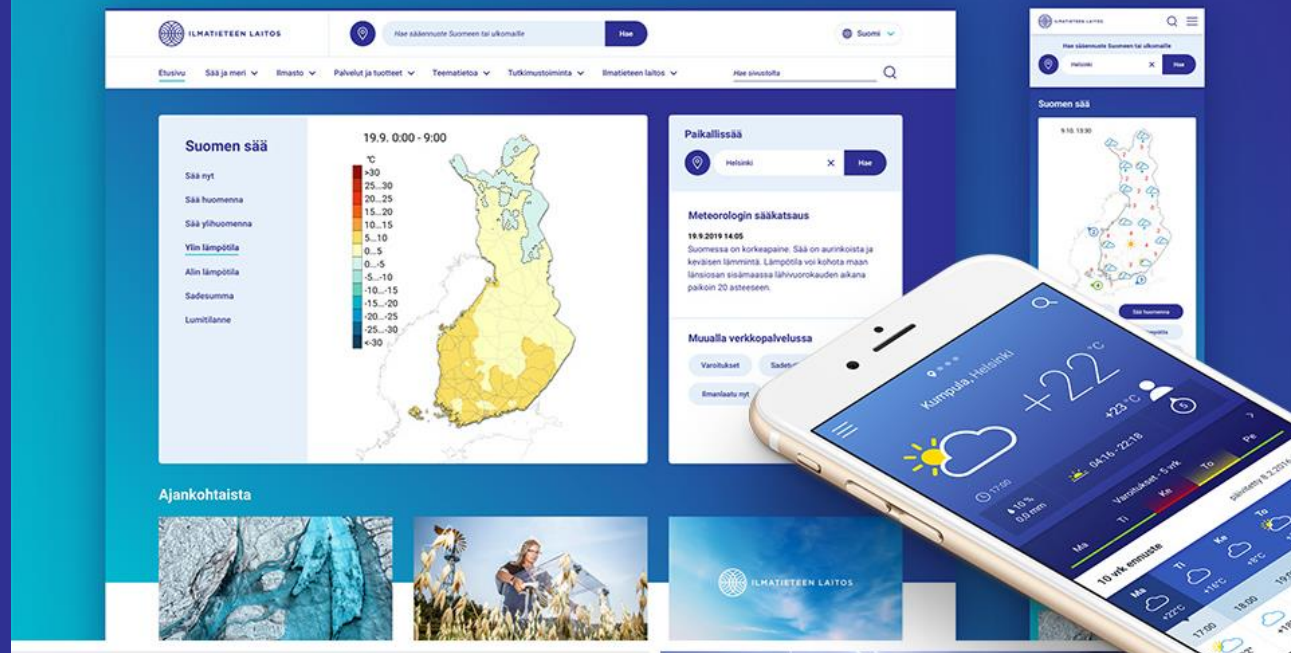
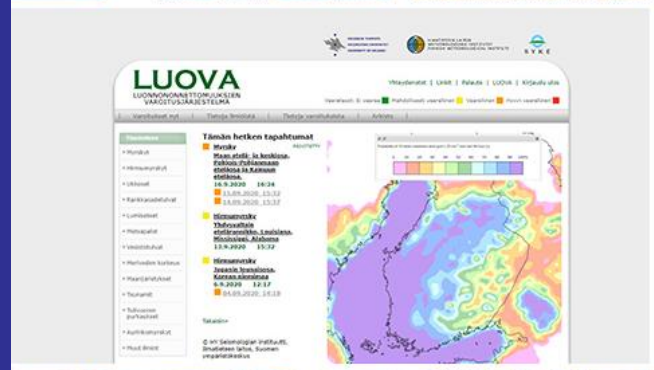
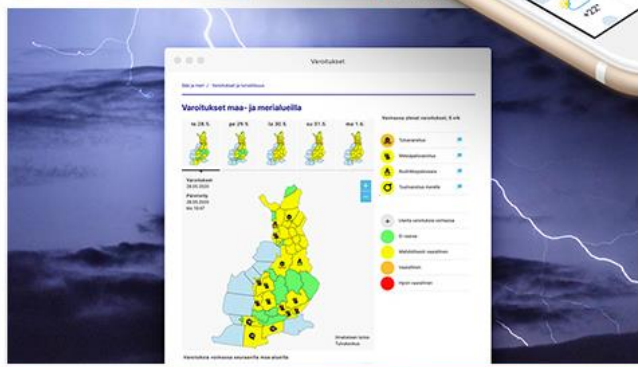
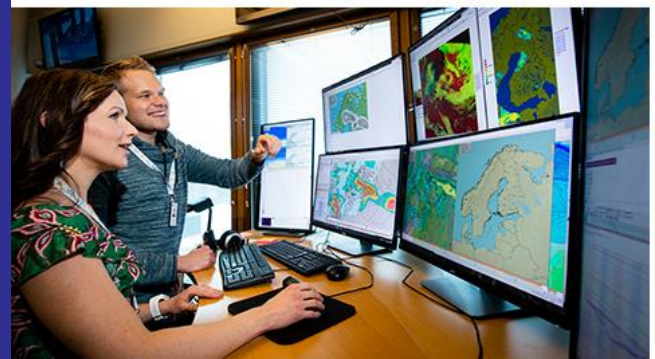
FMI is Finnish national met. service being responsible for atmospheric and marine observation, research and services

Weather service portfolio covers weather forecasts and warnings in several distribution channels









Contents

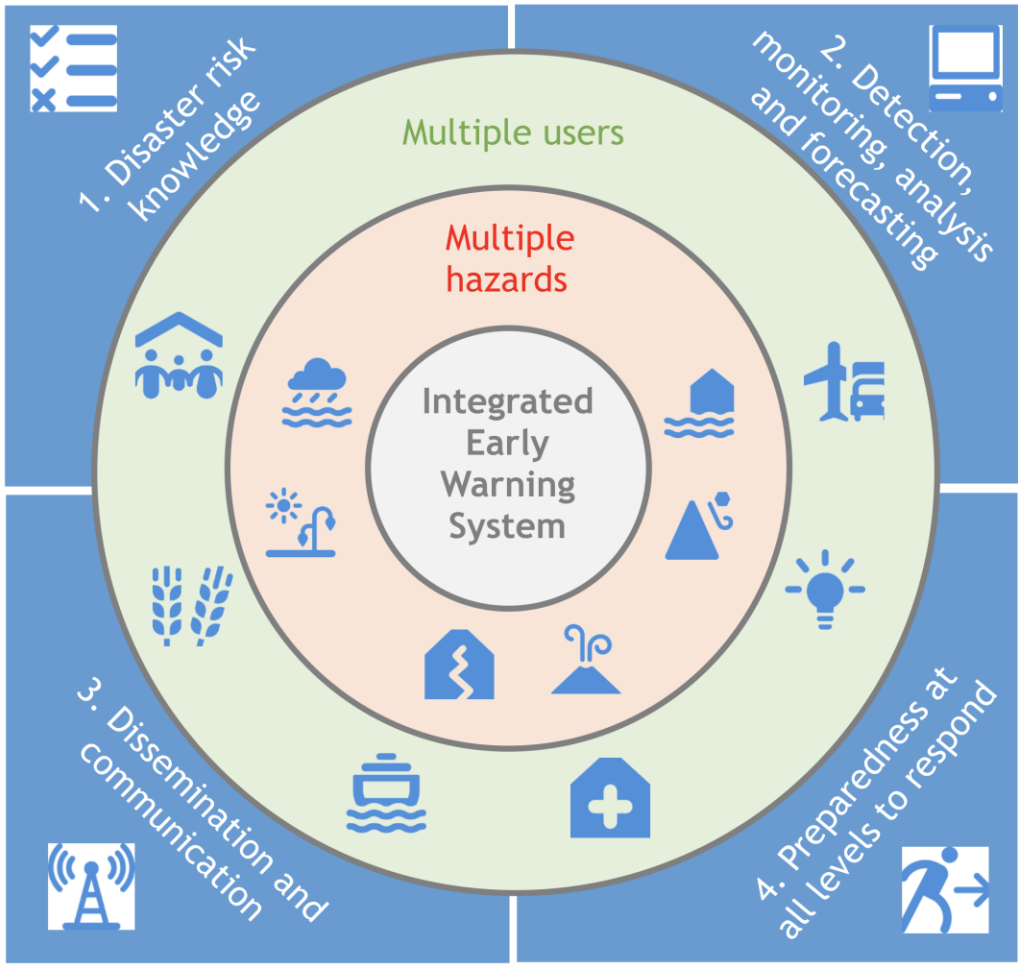
- Value chain and elements of warning services
- Examples of weather impact data available in Finland
- Impact based forecasting in FMI
- The development of AI and ML tools to weather forecasting in general

Weather and climate is the first world power

Early Warning System

- A Multi-Hazard Early Warning System (MHEWS) is an integrated system which allows people to know that hazardous weather or climate events are on their way, and informs how governments, communities and individuals can act to minimize **impacts**
- End-to-end MHEWS include risk knowledge, observations/forecasts, communication, and response

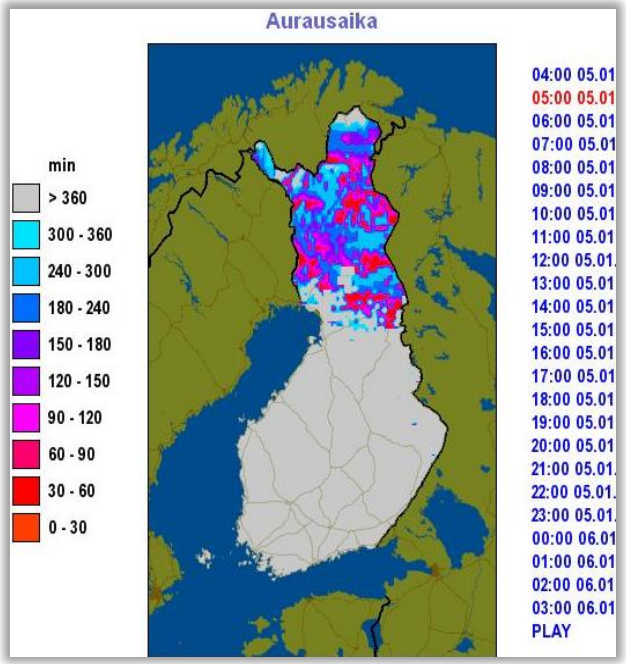
- Early warning systems save lives and assets worth at least ten times their cost
- Gain only if each element works and given warning leads to right decisions
  - Technical capabilities
  - Understanding the hazard impact
  - Multisectoral collaboration



Source: WMO

From threshold based to impact-based warnings

- Predicting what “weather will do” instead of what “weather will be”
- Forecasting weather impacts instead of weather parameters
- Weather explains various societal impacts across many sectors
- Huge momentum driven by increasing access to extensive impact data resources and implementation of ML techniques



The vital role of Impact Data across the value chain

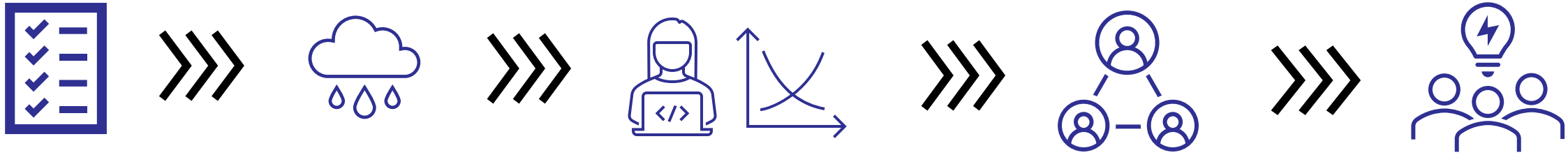
Disaster risk assessment

Weather forecast

Impact on different sectors

Distribution, Communication

Interpretation & action



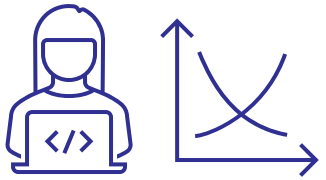
The vital role of Impact Data across the value chain

Disaster risk assessment

Anticipate and mitigate potential hazards before they occur

Weather forecast

Impact on different sectors



Prior issuing warnings assess the impact of weather events

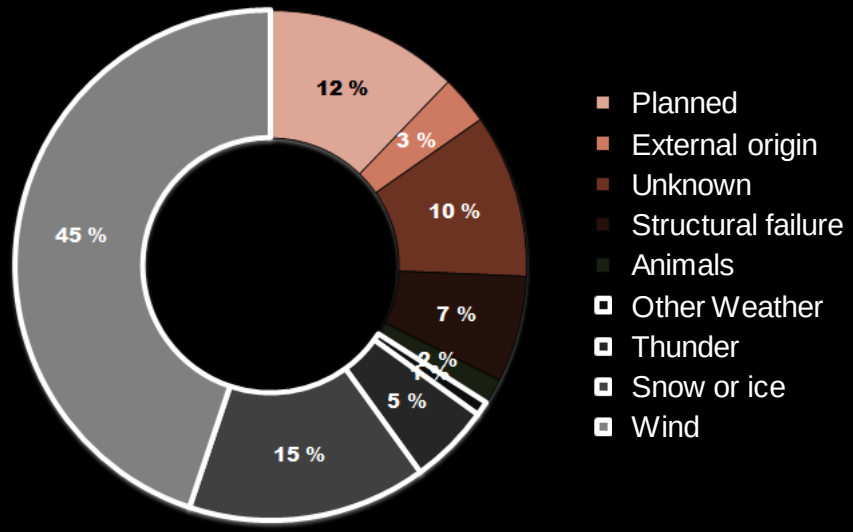
Distribution, Communication

Communicate warning severity

Interpretation & action

Issued warnings must translate into right decision by the end users

Majority of electricity outages have weather Origin



Sample length 2007 - 2017
Source: Finnish Energy

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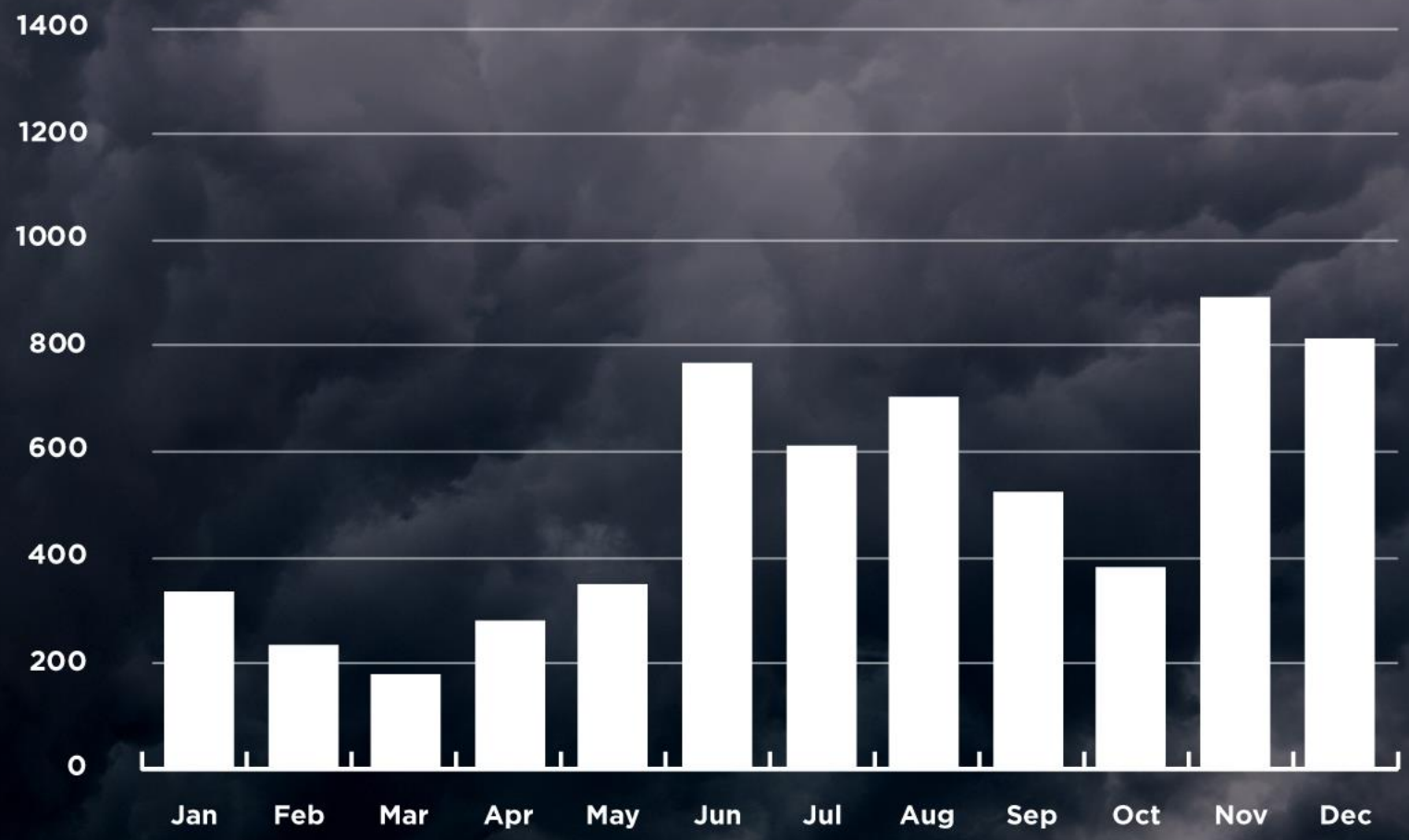
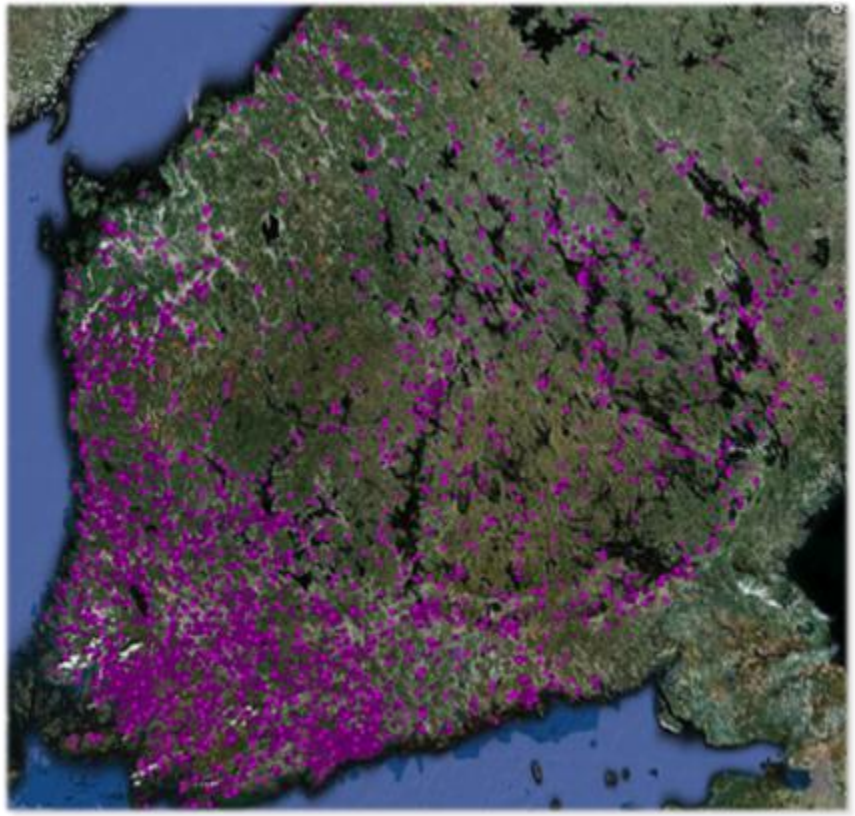
RESCUE OPERATIONS CAUSED BY SEVERE WEATHER 2001–2022

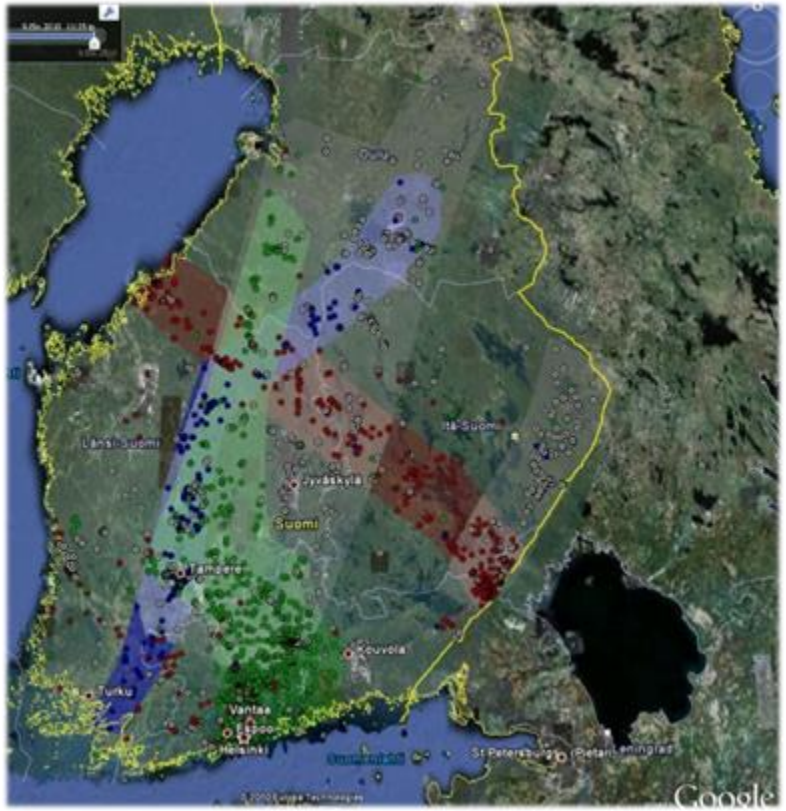


Extensive Storm Damage in Finland

Locations of weather-related tasks for civil defence authorities



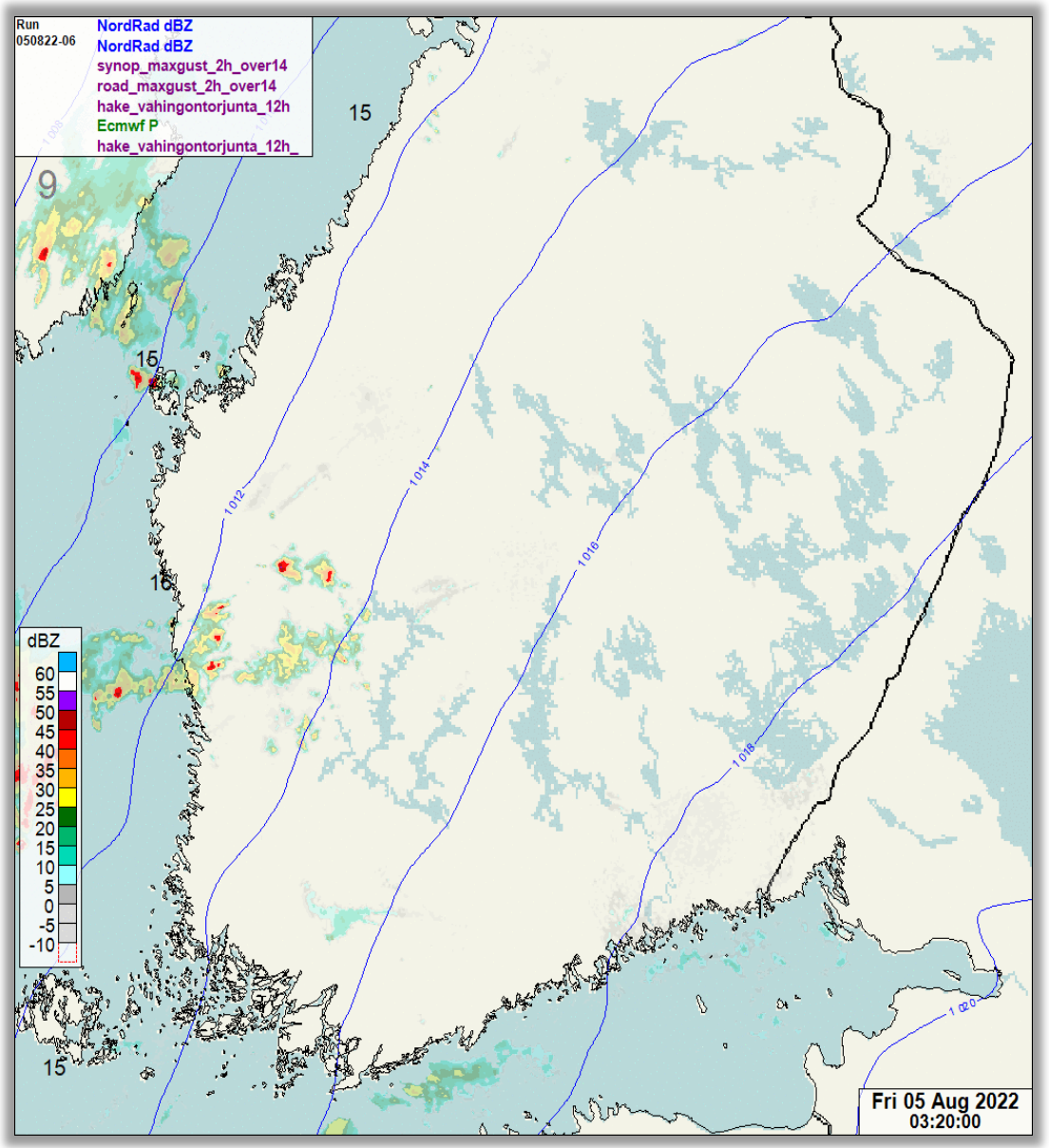
Christmas storm Dec 2011



Severe thunderstorm outbreak Jul-Aug 2010

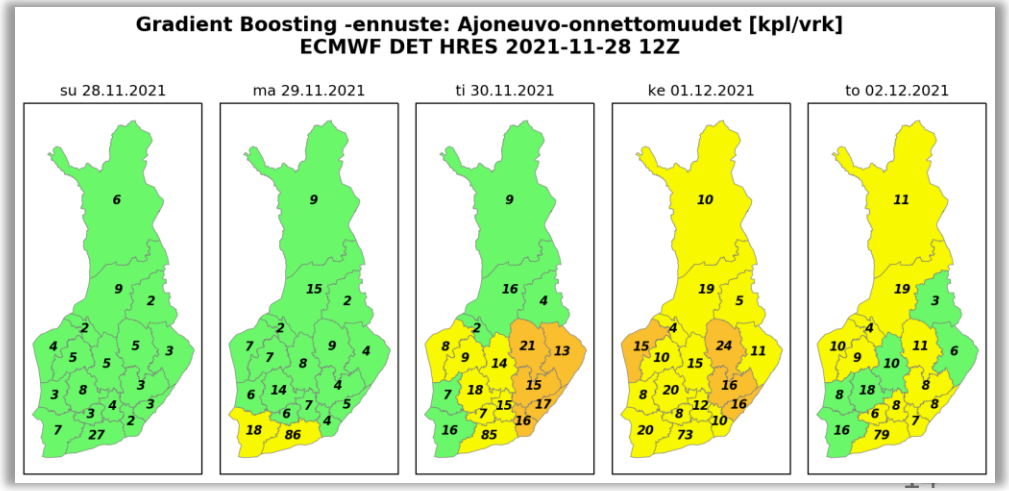
Storm 6th Aug 2022

- Snapshot from meteorological workstation showing impact of weather
  - Pressure, radar echo
  - Rescue tasks

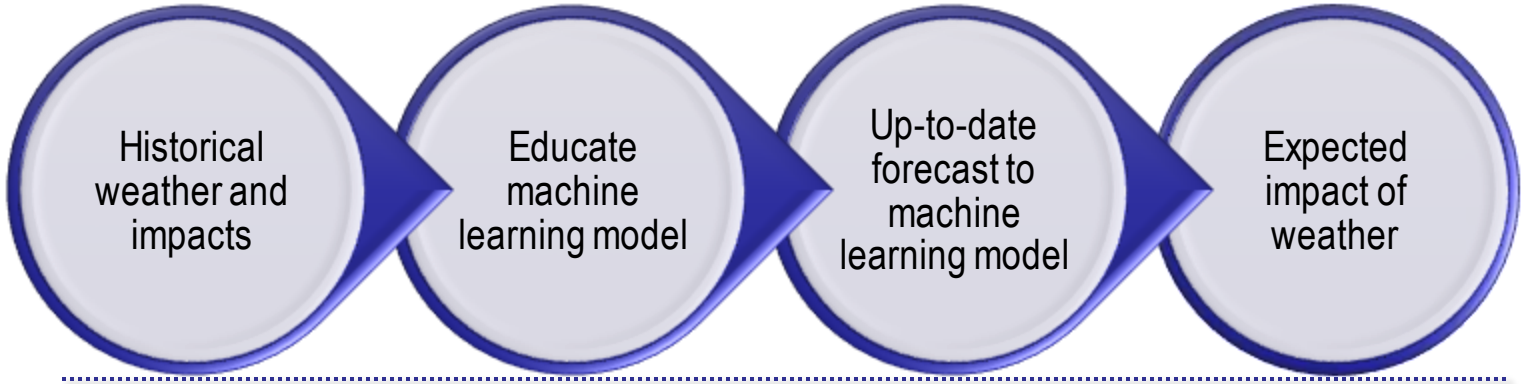


Developing Impact-based forecasting capabilities in FMI

- SILVA project collected and processed weather-related impact data. Project aimed at better situational awareness and preparedness among safety-related authorities and companies
- Funded by Finnish National Emergency Supply Agency
- Examples
  - Forecast for traffic accidents (cars)
  - Forecast for slipping accidents (pedestrians)
  - Wind-damage clearance task load for fire brigades
  - Households without electricity
  - Forest fires



Machine learning as the basis for impact forecasting

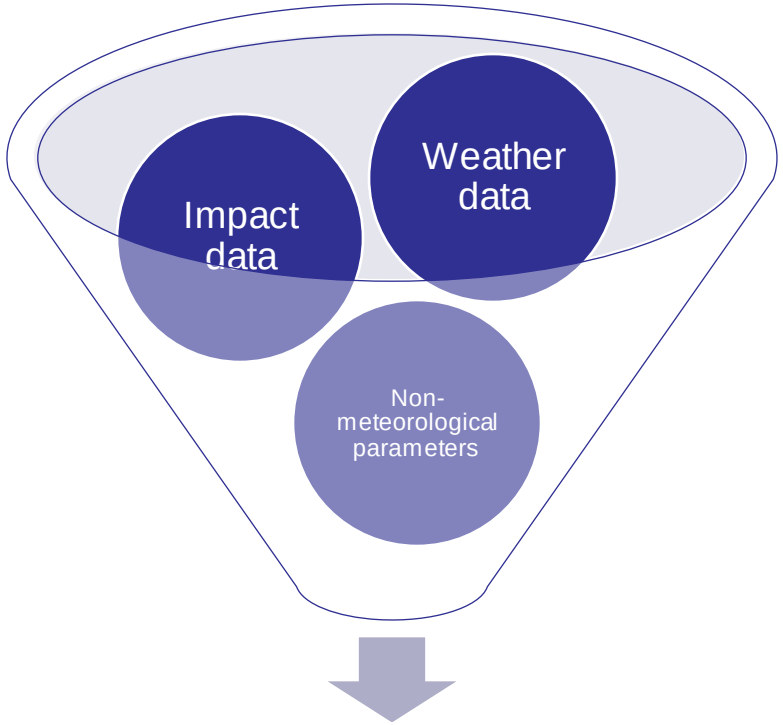


- To make it easier to understand weather forecasts, we can create statistical machine learning models that work quickly, objectively, and accurately.
- The (impact) data we want to predict, needs to be a long and comprehensive historical record so that the model can learn the relationships correctly.
- Besides impact data, we also use past weather information to help make predictions
- To predict the effects of future weather conditions, we use weather forecasts as input for a machine learning model that has been trained using historical data

Parameters defining impact based output

- Variables varies significantly depending on the event to be predicted
- ML model identify the importance of variables and prioritize them based on their significance

Predicted event	Slipping accidents (pedestrians)	Traffic accidents (cars)
Most important weather variables	1. Snow depth 2. Atmospheric pressure 3.Snowfall 4.Soil temperature 5.Min and max temperatures 6.Total precipitation 7.Solar radiation 8.Freezing layer 9.Wind speed	1. Freezing layer 2. Solar radiation 3. Snow depth 4. Total precipitation 5. 2m temperature 6. Soil temperature 7. Min and max temperatures

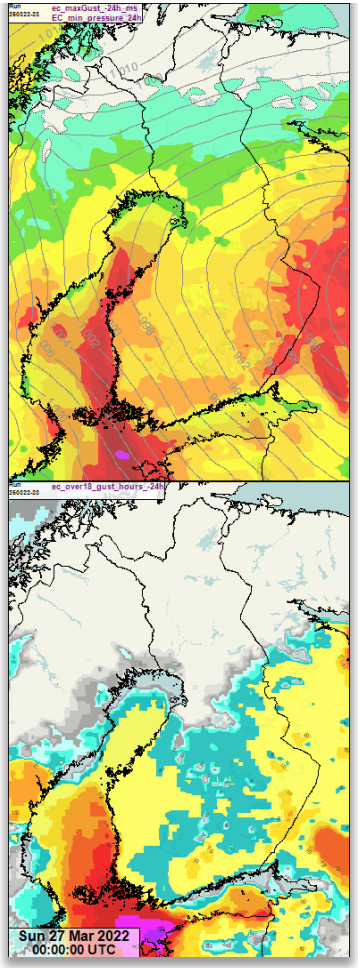


Quantity prediction of an impact according to weather forecast and surrounding circumstances

Storm 26th March 2022

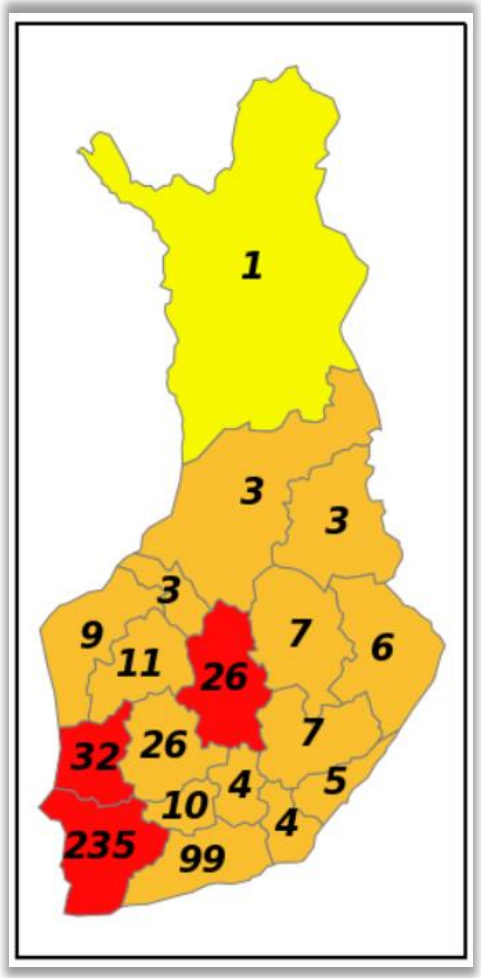
Forecasted max. Wind gust and duration of an event (>18m/s)

Max wind gust



Duration of event (>18 m/s)

Forecasted Rescue tasks



- The machine learning model provided a strong signal of the situation's significance
- The emphasis of the signal was on vulnerable areas (considering regional features such as population density)

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Some preliminary results from FMI

- Thorough objective verification not in place yet
- In general, prediction of impact quantity seem to give a good guidance both for weather forecasters and end users
- Due to the lack of teaching material, there is higher uncertainty associated with smaller scale events (thunderstorms)
- Large scale low pressure system are more reliable
  - During frost-free periods, weaker wind gusts lead to relatively significant impacts

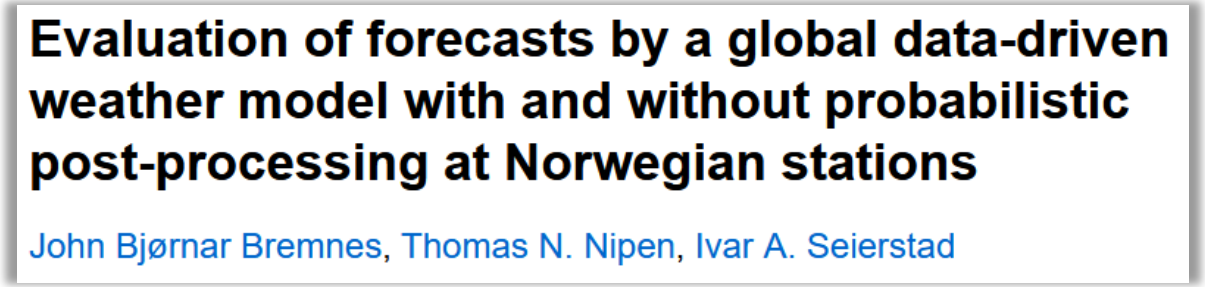
- Excellent development/application opportunities when utilising
  - More post-processed input data
  - Ensemble forecasts

Is Artificial Intelligence & Machine Learning a game changer in the whole weather prediction?

- The development of AI and ML applications to weather forecasting have been rapid over the last months
- AI and ML will have an impact on the entire value chain of weather forecasting
  - Collection of observations
  - Prediction of weather parameters
  - Weather warnings
  - Impact based forecasting

- Shift from physical models to data-driven AI-models?
- Big companies have developed their own data-driven models: Pangu-Weather (Huawei), GraphCast (Google), ClimaX (Microsoft), FourCastNet (Nvidia)

More to read



- “Results show that the performances of the global models are on the same level with Pangu-Weather being slightly better than the ECMWF models for temperature and slightly worse for wind speed. The MEPS model clearly provided the best forecasts for both parameters.”

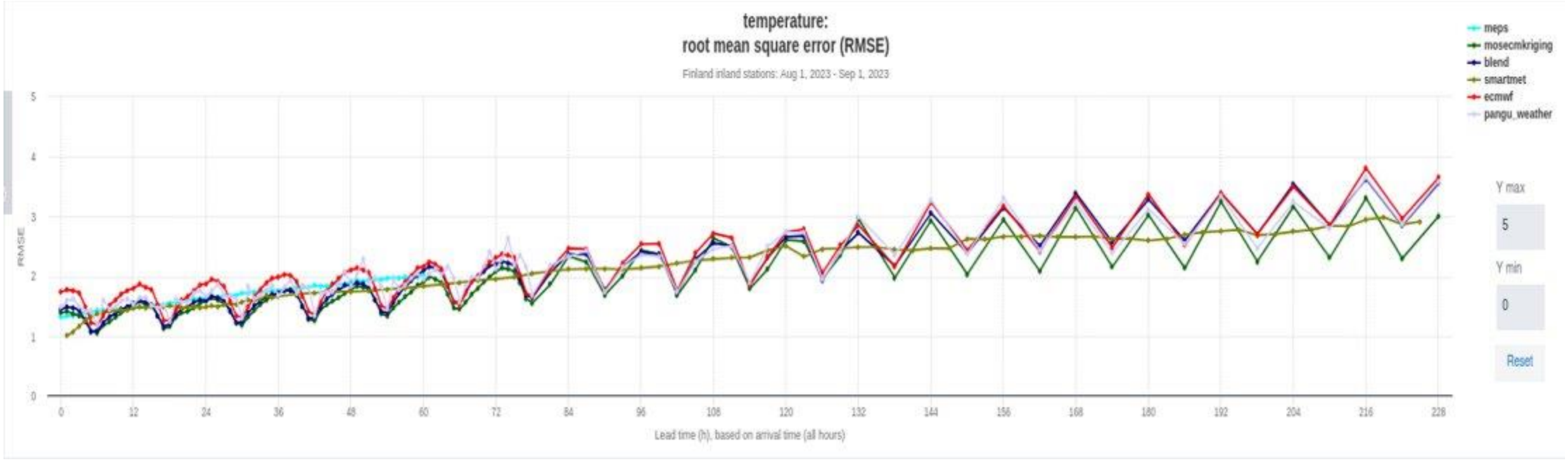
- https://arxiv.org/abs/2309.01247

- “Weather models generated by AI are faster and cheaper than conventional, government-run models”
- “It’s still up for debate if and when AI models could become the primary tools used by meteorologists to make forecasts”

- https://www.washingtonpost.com/weather/2023/07/04/ai-weather-forecasts-hurricanes-tornadoes/

Preliminary verification of temperature at FMI

Pangu data driven forecast vs. other data sources



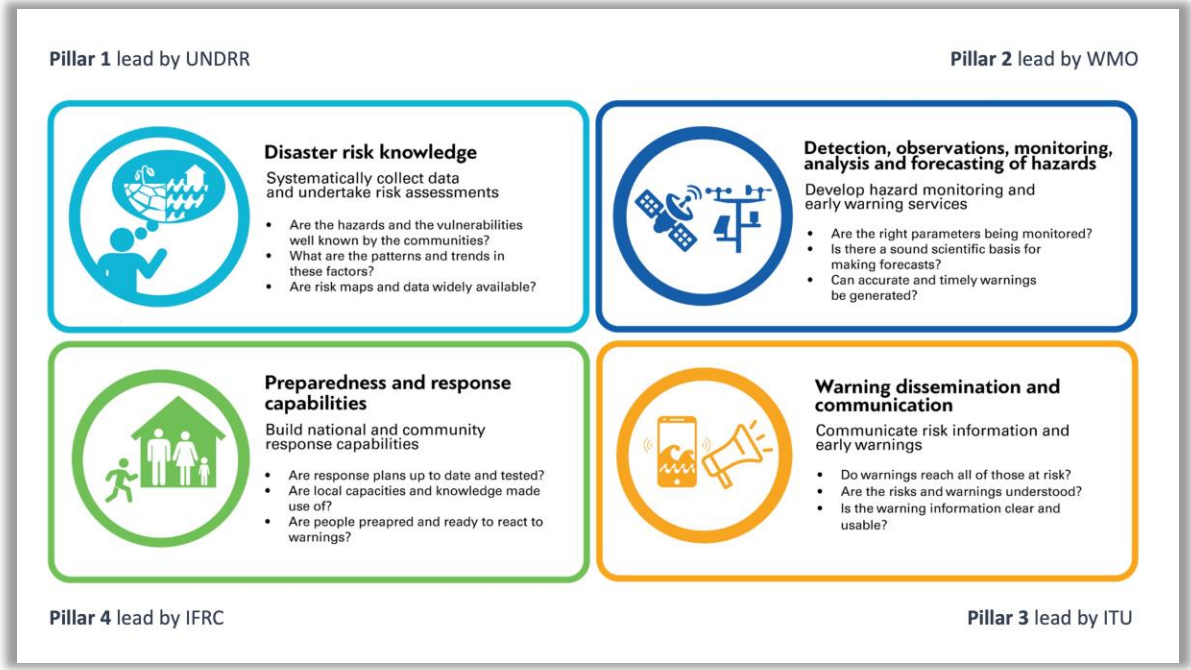
Preliminary verification of winds at FMI

Pangu weather

FMI official forecast

WMO initiatives for warnings

- Early warning for all: to ensure that everyone on Earth is protected from hazardous weather, water, or climate events through life-saving early warning systems by the end of 2027
- Initiative is built around four key pillars representing a new collaborative approach of warning services and disaster risk management
- Different funds available to promote warning services in developing countries (CREWS, SOFF)



Conclusions

- The sensitivity to weather has been and continues to be high throughout the world
- There has been an ongoing shift from threshold based to impact based warnings
- The effectiveness of ML models for impact-based warnings is tied to the availability and quality of impact data (large scale vs. smaller scale events)

- The meteorological community is riding a wave of momentum
  - Increasing access to extensive impact data resources
  - Implementation of ML techniques for the entire value chain of weather forecasting
  - Recognizion the importance of weather and its effects on society.
  - Worldwide efforts led by the WMO to implement the weather warning systems