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Probabilistic long-range rainfall forecasts for risk management of excessive water levels in mining

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Weather and mining

Chained service process ↓

1. Environmental measurements (e.g. weather radars) including open data, Big data, crowdsourcing and IOT
2. Diagnosis and probabilistic prediction of high-impact weather: nowcasting, numerical weather prediction, seasonal and climate forecasts
3. Diagnosis and prediction of weather-induced conditions (flooding, storm water hydrology and hydraulics, water and air pollution, working and process conditions):
   - Environmental impacts on mining processes
   - Mining process impacts on the environment
4. Support data for the adaptation of weather and water impacts in the mining process: risk management and process optimization.
5. Optimal solutions for situational awareness and proactive mitigation processes

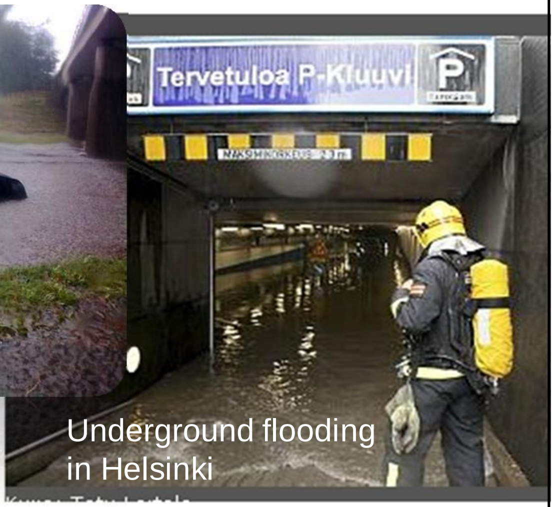
Content, quality and ICT specifications ↑

Objective:

Proactive optimization and risk management of mining processes that depend on high-impact weather*

Thunderstorm rain in Pori:

~120 mm in 3 hours
damage 15-20 M€

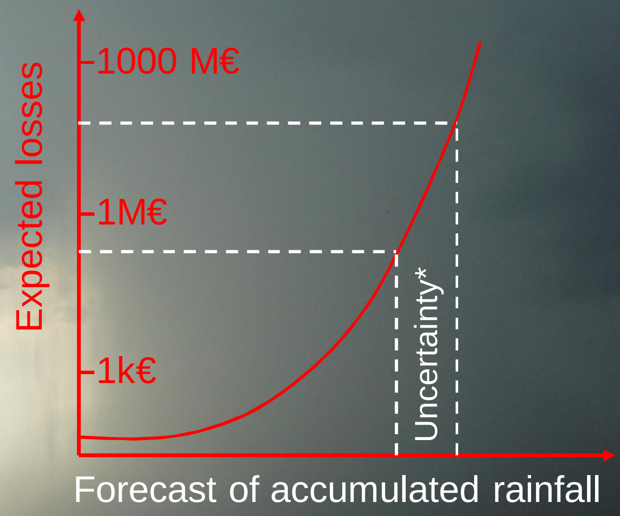


Underground flooding in Helsinki

* In most cases excessive rainfall and storm water, e.g. case Talvivaara

Economic risk of a future weather event =
{probability of the event} x
{expected losses induced by the event}
Example: 0.01 (1 %) x 1000 M€ = 1 (100 %) x 10 M€

Rainfall event = exceedance of a fixed accumulation during a period, e.g. 50 mm/h



*Uncertainty can be characterized with the aid of probabilities

Conclusion: Forecasts of exceedance probabilities are vitally important for decision making - and reasonable in meteorological sense

An example at a specific location and time period:

Probability of exceeding 1 mm/3h = 98 %
Probability of exceeding 10 mm/3h = 30 %
Probability of exceeding 100 mm/3h = 1 %

The tool for obtaining exceedance probabilities is **ensemble prediction system (EPS)** i.e. instead of a single forecast we compute multiple alternative scenarios that estimate probabilities of high-impact events.

Statistical matching of the predicted probabilities with observational data will improve event predictions – but it is not trivial!

Weather radar based movement of precipitating areas is the basis for 0 - 3 (-6) h long nowcasts

Ensemble forecasts:

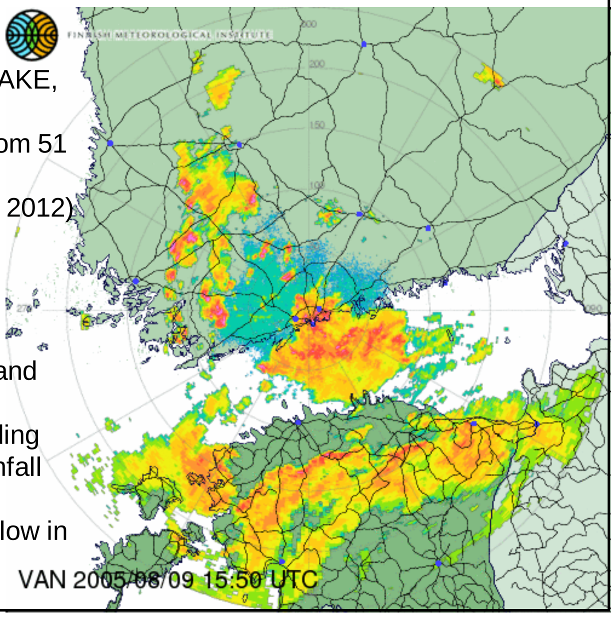
- Pilot projects (Tekes/RAVAKE, EU/HAREN & EDHIT): Probabilities computed from 51 members of ensemble forecasts (Koistinen et al. 2012)

Benefit:

- Update cycle 5-15 min

Challenges:

- Measurement accuracy and quality (MMEA/WP 3)
- Computationally demanding
- Growth and decay of rainfall systems not covered => prediction skill becomes low in 1-6 hours



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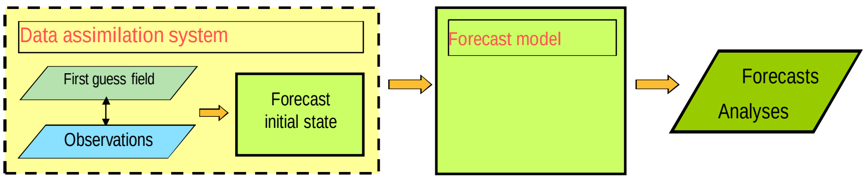
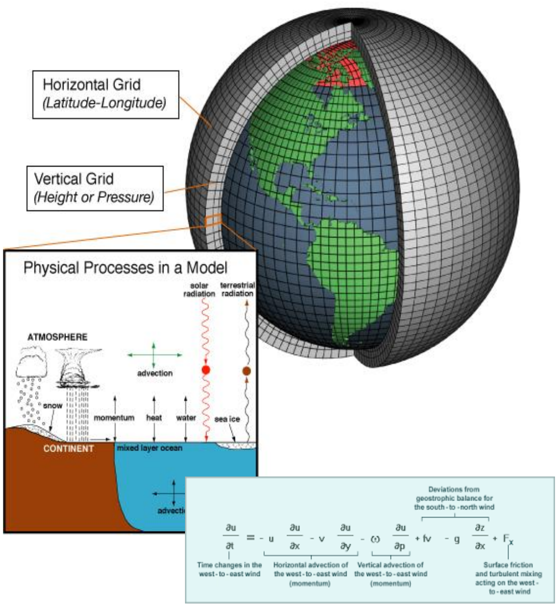
Numerical weather prediction NWP is required for lead times 3h - 15 days (- seasons)



- **Data assimilation**
  - chaotic equations → forecast initial state important
  - problem : observations inaccurate, spatially/temporally sparse
  - remedy : model gives a more complete state of the atmosphere
  - solution : combine observations with an earlier forecast ("first guess field") to form the initial state of the forecast = Data assimilation
    - Method used in Hirlam : 4DVAR = four-dimensional variational data assimilation
    - State-of-the-art : 4DVAR used only in very few LAM models worldwide
    - **Considerable resources devoted to pre-processing, quality control, tuning and assimilation of the data!**

Forecast model



Physical laws are presented in a form that a computer can compute the future state of atmosphere from present state of atmosphere.

All physical parameter (temperature, pressure, humidity, …) are presented in a grid with several layers.

The typical distance between grid points is 3-15 km. The number of vertical levels varies typically between 50 and 150.

Limitations:

- Update cycle (3-) 6 -12 h
- NWP not good in predicting the proper time and place of convective rain storms

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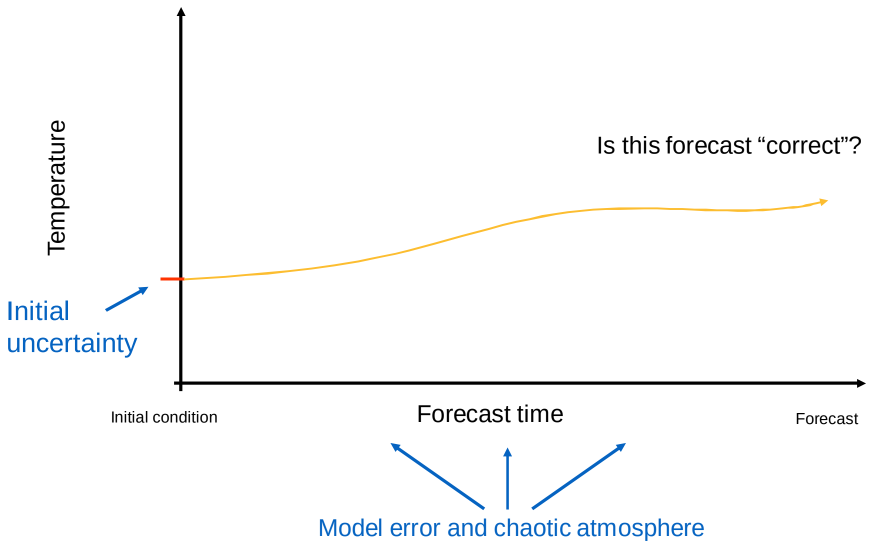
Deterministic Forecasting



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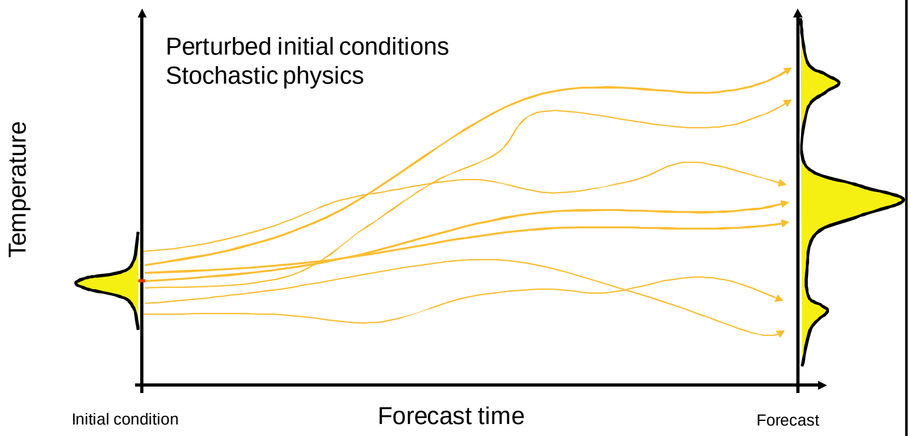
Ensemble Forecasting



Complete description of weather prediction in terms of a Probability Density Function (PDF)

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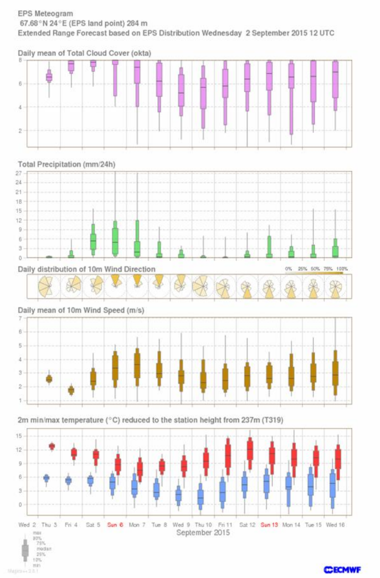
Global EPS system at ECMWF

- 1 control run + 50 perturbed runs
- An ensemble forecast provides probablities of (extreme) events e.g. probability of precipitation over 50 mm in next 10 days for a certain area or location.
- Forecasts are available 10-15 days ahead



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An example of forecast content for a mining location or for a river catchment interacting with the mine

An actual pilot exists at the Kittilä gold mine: Rainfall forecasts (FMI) -> Hydrological model of Seurujoki (SYKE) -> products (Agnico Eagle)

15 mm

probability > 10 mm = 95 %
probability > 20 mm = 40 %
probability > 30 mm = 10 %
Most likely accumulation = 17 mm

Gauge or radar measurements of rainfall, river flow measurements
Previous week-months

Present time

Rain and river flow forecasts,
Next week

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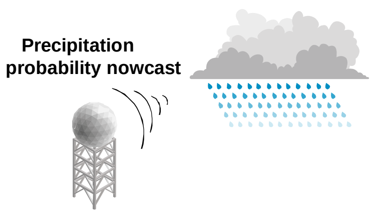
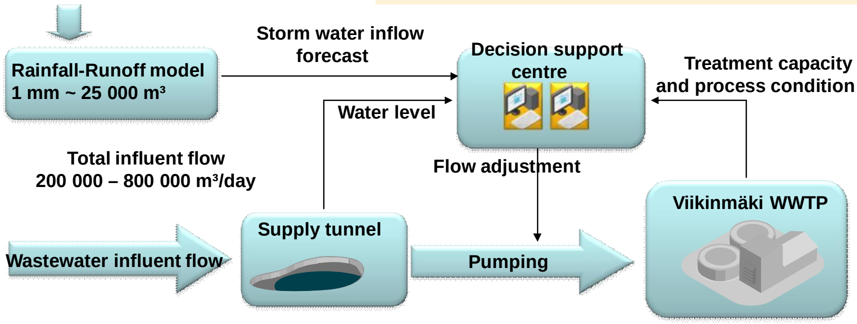
Operational application at HSY



Objectives

- **Alarming of predicted influent increase (capacity problems possible in extreme cases)**
- **Bypass flow minimization (environment risk)**
- **Adaptive process actions, e.g. optimize influent tunnel volume (pumping)**



Conclusions

- "Smart mine processes" are presently rather primitive in responding adaptively on future weather and water risks and impacts
- Probabilistic predictions of high-impact weather, especially rainfall, can be valuable for proactive risk management and optimization of mining processes
- Chaining of probabilistic weather predictions with impact models (e.g. hydrology, hydraulics, mining processes) can offer valuable automatic tools for decision support