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# Technology in weather forecasting

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#### WeADL 2021 Workshop

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# A definition for weather forecasting

Weather forecasting is the application of **technology** and **science** to predict the state of the atmosphere for a future time and a given location.













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# Development of meteorological technology

- first standardized rain gauge 1400s
- biggest developments in the 20th century
- 1947 first weather radar
- 1955 first computer forecasts
- 1959 first weather satellite





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#### **Computing weather - Numerical weather prediction**

NWP is about quantitatively predicting the evolution of atmospheric state, determined by temperature, wind, humidity, and pressure through numerical simulations. The current atmospheric state is determined by the interpolation of various observational data onto regularly spaced model grid points.





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#### Computing weather - Numerical weather prediction

- NWP is a method of weather forecasting that employs a set of equations that describe the flow of fluids.
- equations are translated into computer code
- NWP includes omissions, estimations, approximations and compromises, which are the primary sources of errors



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### Computing weather - Numerical weather prediction

- within any modern model there is a set of equations, known as the primitive equations, used to predict the future state of the atmosphere
- numerical methods obtain approximate solutions
- equations are initialized from the analysis data and rates of change are determined



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### Computing weather - Numerical weather prediction

- time increment for this prediction is called a time step
- time steps for global models are on the order of tens of minutes, while time steps for regional models are between one and four minutes
- The UKMET Unified Model is run six days into the future, ECMWF is run out to ten days into the future, the Global Forecast System model is run sixteen days into the future





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# NWP - Ensemble Forecasting

- different NWP forecasts
- rapid and scientifically based comparisons of multiple model forecasts
- multiple model runs, each based on slightly different initial conditions
- low spread vs. large spread



source: NOAA











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# Supercomputers in NWP

- always among the top supercomputers in the world
- in the range of millions of cores
- in the range of tens of petaflops or even > 100 petaflops
- weather and climate modeling are among the most power-hungry use cases for supercomputers



source: ECMWF



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# Machine learning - an alternative to NWP?

- Weather research community is increasingly aware of ML possibilities and employs them for data analysis, numerical modelling and postprocessing NWP
- specific properties of weather data require the development of new approaches beyond the ML tasks













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## Machine learning - an alternative to NWP?

- much less computational power needed
- ML models are much faster than regular NWP
- similar results on short time scales



source: Peter Dueben



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# Machine learning - an alternative to NWP?

Current constraints

- lack of explainability of deep neural networks
- lack of physical constraints
- constraints on predictions on long time periods
- simple ML models unsuited to capture the complexity of meteorological data











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# Machine learning - suited for nowcasting

- Nowcasting weather forecasting on a very short term, ranging from 0 to 6 hours
- Nowcasting mainly uses radar and satellite as primary data sources
- NWP unsuited for nowcasting
- Might be addressed as a computer vision problem, estimating the the evolution of meteorological phenomena from a sequence of input images
- Problem addressed by the WeaMyL team, ML based on radar and satellite data