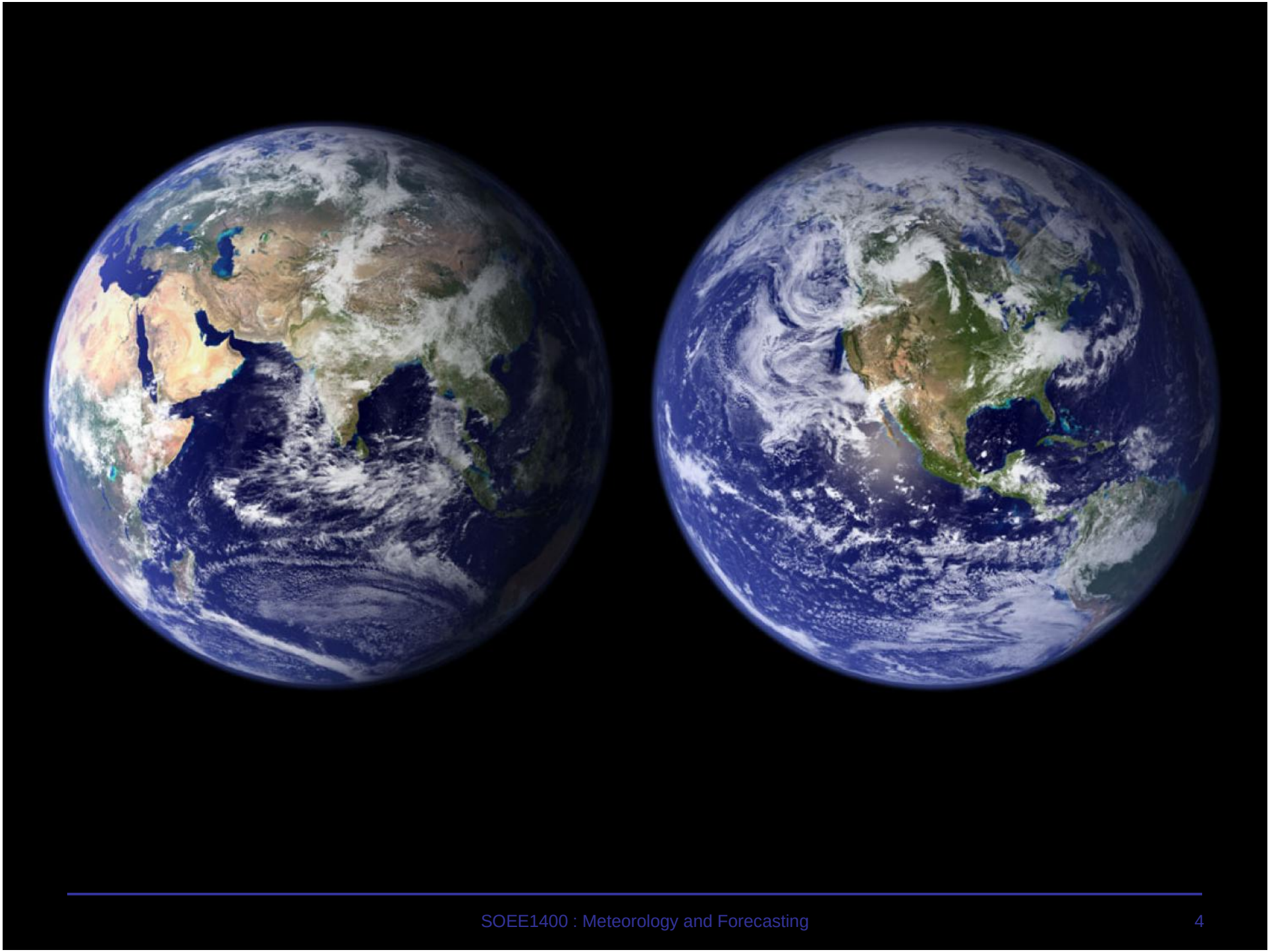
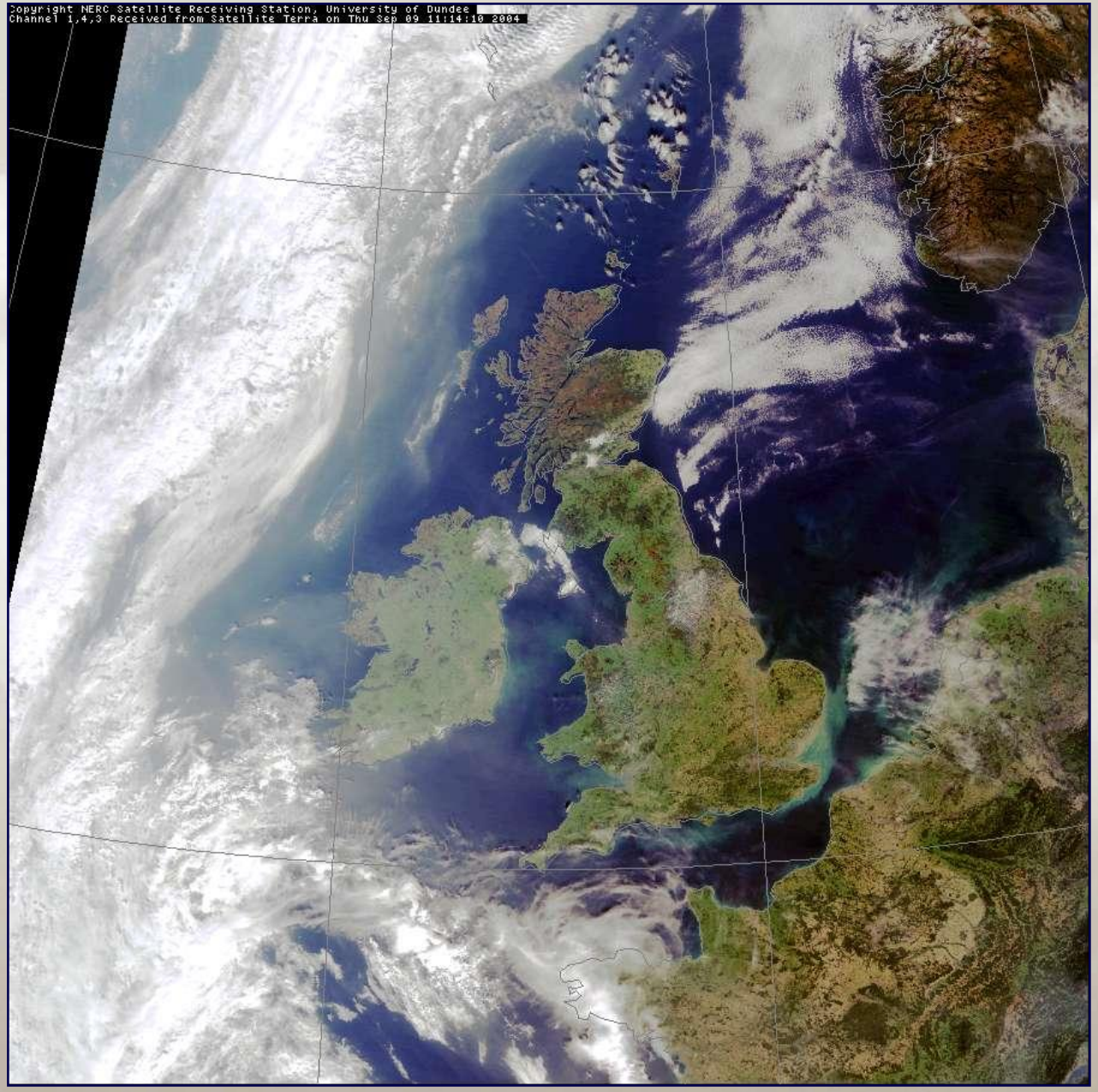
Introduction to Meteorology and Weather Forecasting

Course objectives (paraphrased)

- To make you familiar with standard meteorological methods and terminology.
- To give you a scientific (but quite non-mathematical) understanding of how to analyse and forecast the weather.
- To link this understanding to the real world, and to everyday cases.
- To inspire you to find out more …

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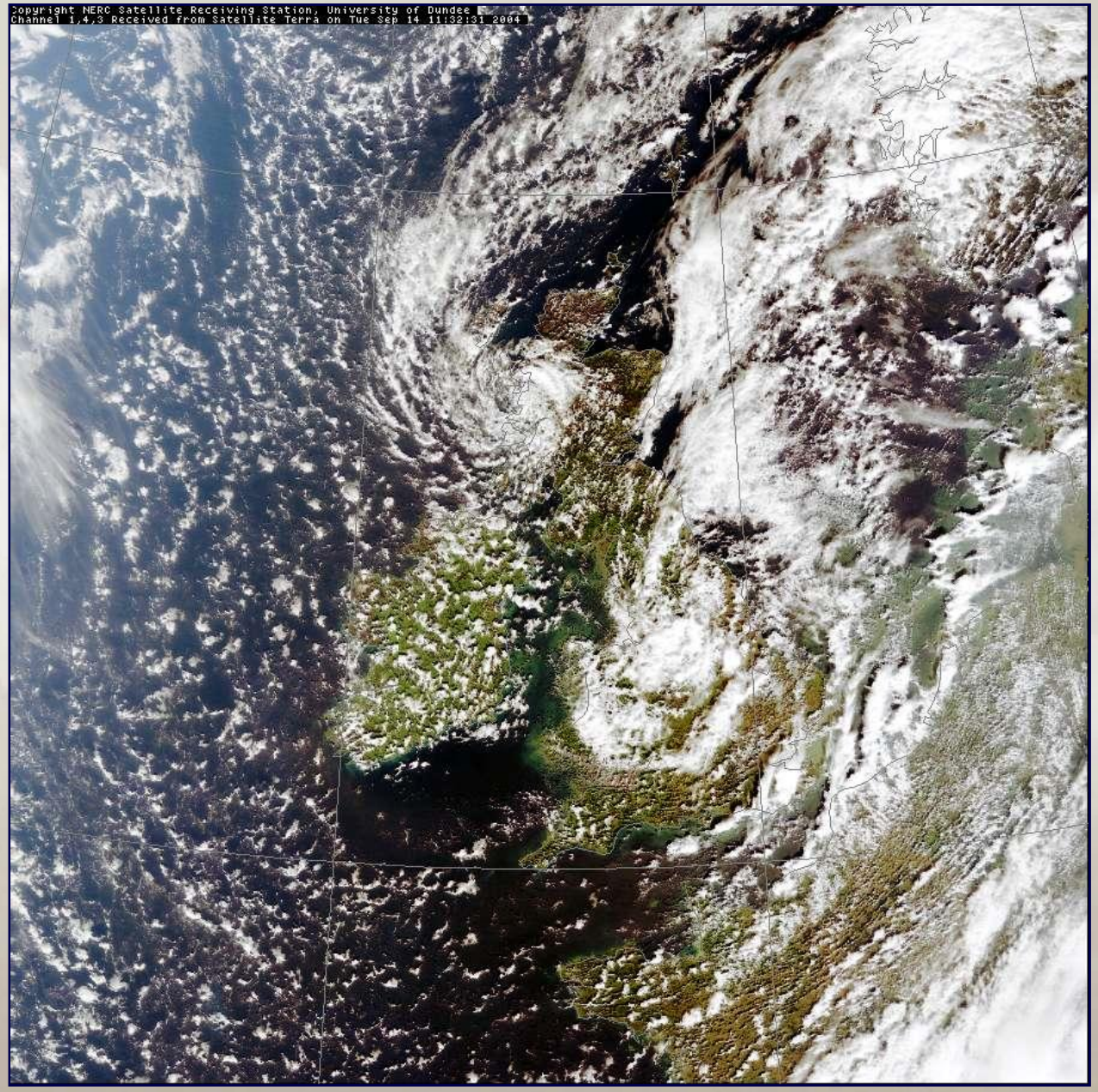
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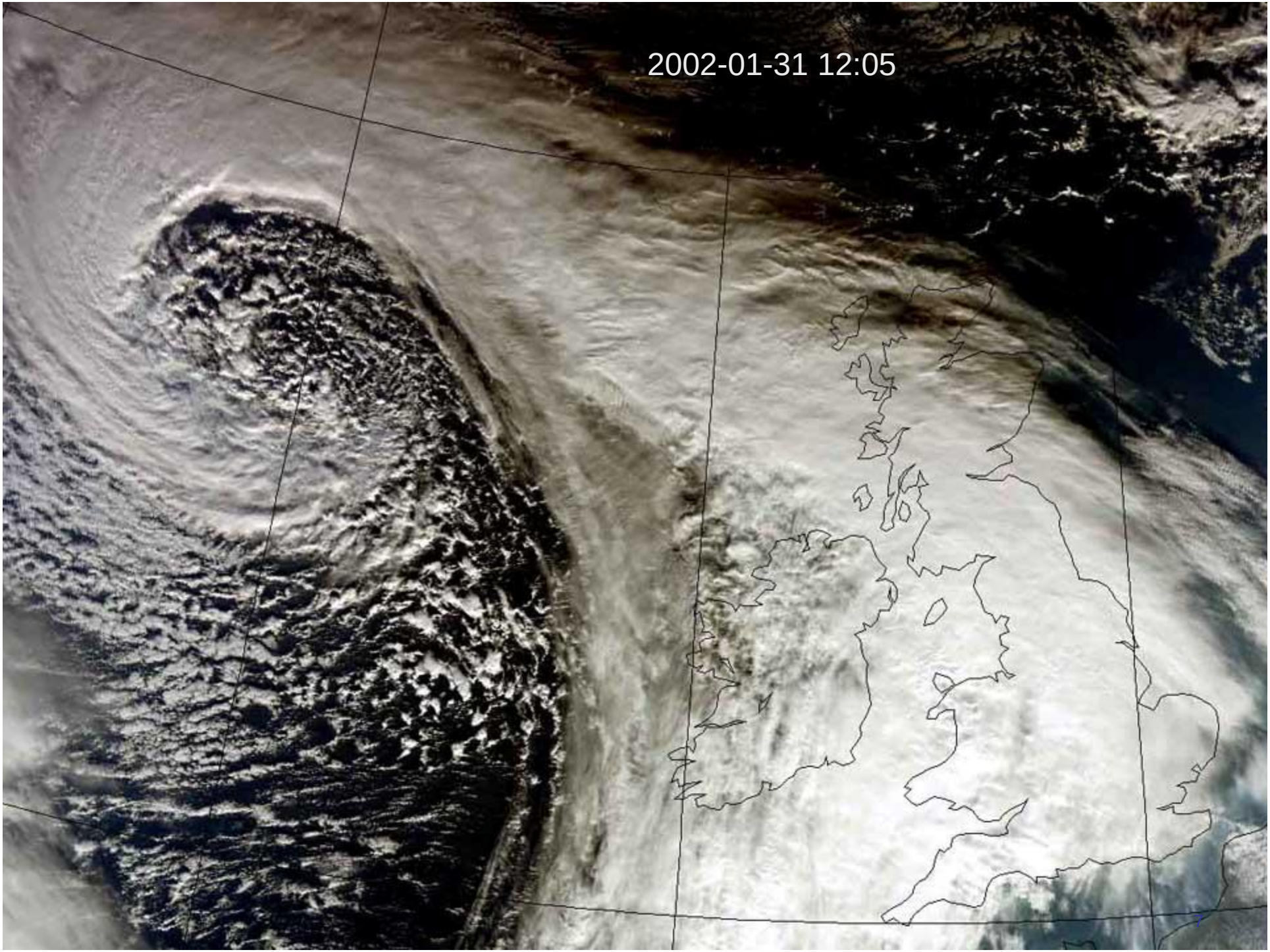
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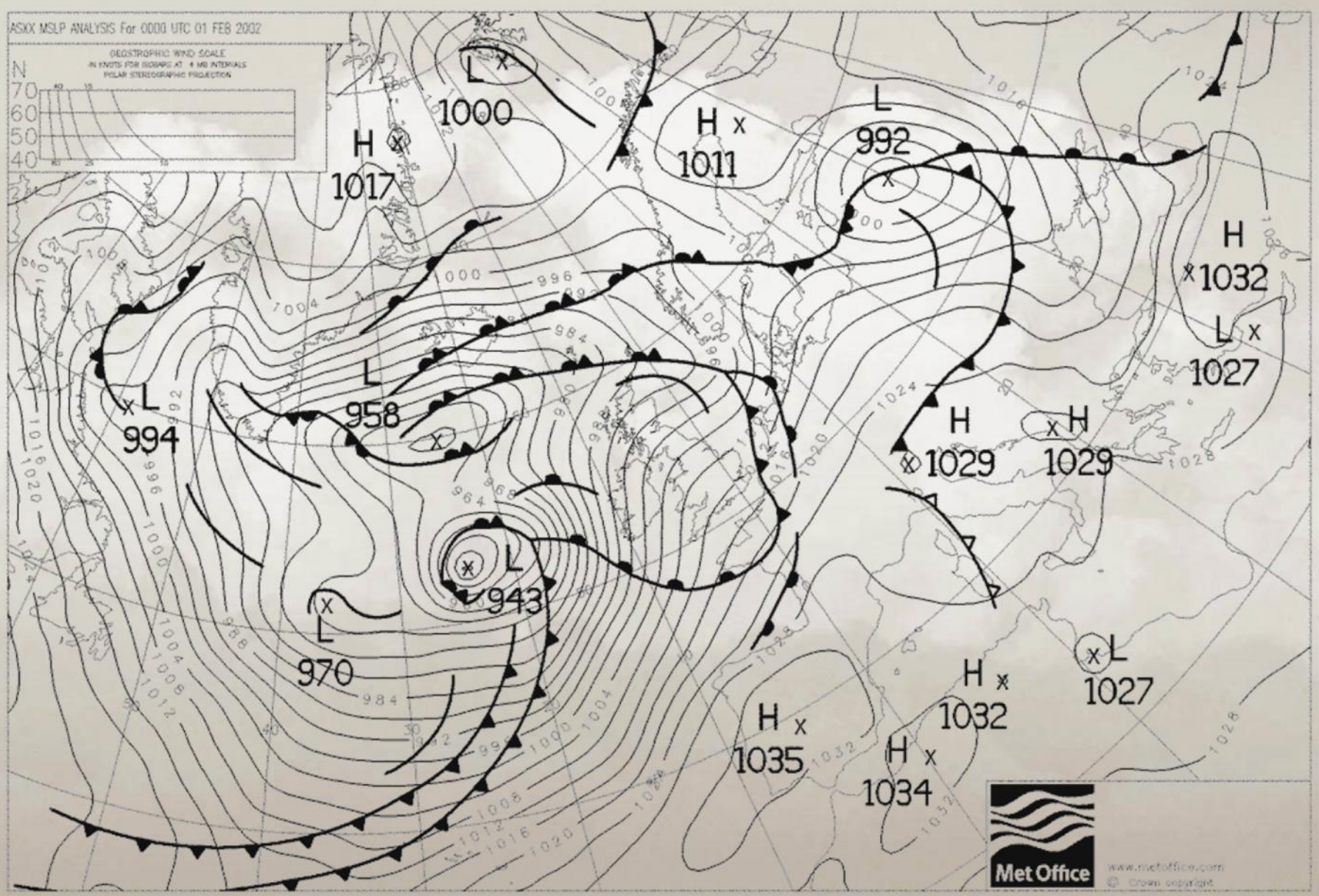
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GEOSTROPHIC WIND SCALE
IN KNOTS FOR ISOBARS AT 4 MB INTERVALS
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Course Outline

- **11 Lectures**
  - Introduce basic concepts of meteorology
  - Emphasis on physical processes **not** theoretical or mathematical treatments
- **~ 6 x 1-hour workshops**
  - Hands-on forecasting exercises
  - Problem solving
  - Worksheets
- **1 tutorial, week 5**
  - SOEE1441 for those who take it – organised separately for others.

Meteorology, Weather, & Climate

- **Meteorology** is the study of *phenomena of the atmosphere* – includes the dynamics, physics, and chemistry of the atmosphere. (from the Greek *meteōros* – 'lofty')
- More commonly thought of as restricted to the dynamics and thermodynamics of the atmosphere as it affects human life.

- **Weather**
  - The state of the atmosphere; mainly with respect to its effects upon human activities. Short term variability of the atmosphere (time scales of minutes to months). Popularly thought of in terms of: *temperature, wind, humidity, precipitation, cloudiness, brightness, and visibility.*
  - A category of individual/combined atmospheric phenomena which describe the conditions at the time of an observation.
- **Climate**
  - Long term statistical description of the atmospheric conditions, averaged over a specified period of time - usually decades.

Why study meteorology? 1: Analysis

- Is it safe for my aircraft to take off?
- Is it safe for my ferry to leave harbour?
- Is it safe to go yachting / potholing / skiing / climbing today?
- How much rain fell over Ethiopia yesterday?
- There is a fire in a chemical plant – where is the pollution going?

Why study meteorology? 2: Forecasting

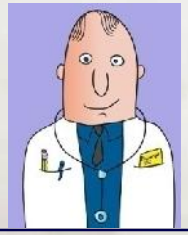
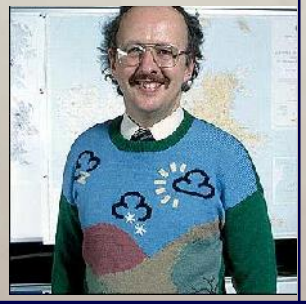
- Warning of severe weather
- Agriculture
  - Timing of planting, harvesting, etc to avoid bad weather, hazards to livestock
- Transport & services
  - Shipping, aviation, road gritting, flood warnings,…
- Commerce
  - Should a supermarket order BBQs and icecream, or umbrellas?

November 14, 1854: A sudden storm devastated a joint British-French fleet near Balaklava in the Black Sea.

French astronomer Urbain Jean Joseph Le Verrier (1811-1877) demonstrated that telegraphed observations could have given the ships a day to prepare.

In England, Capt. Robert FitzRoy (1805-1865) started the ***Meteorological Office*** *as a small department of the board of trade. On September 3rd 1860, 15 stations began reporting 8am observations. February 5,1861 started issuing storm warnings to ports.*

Which other scientists predict the future?

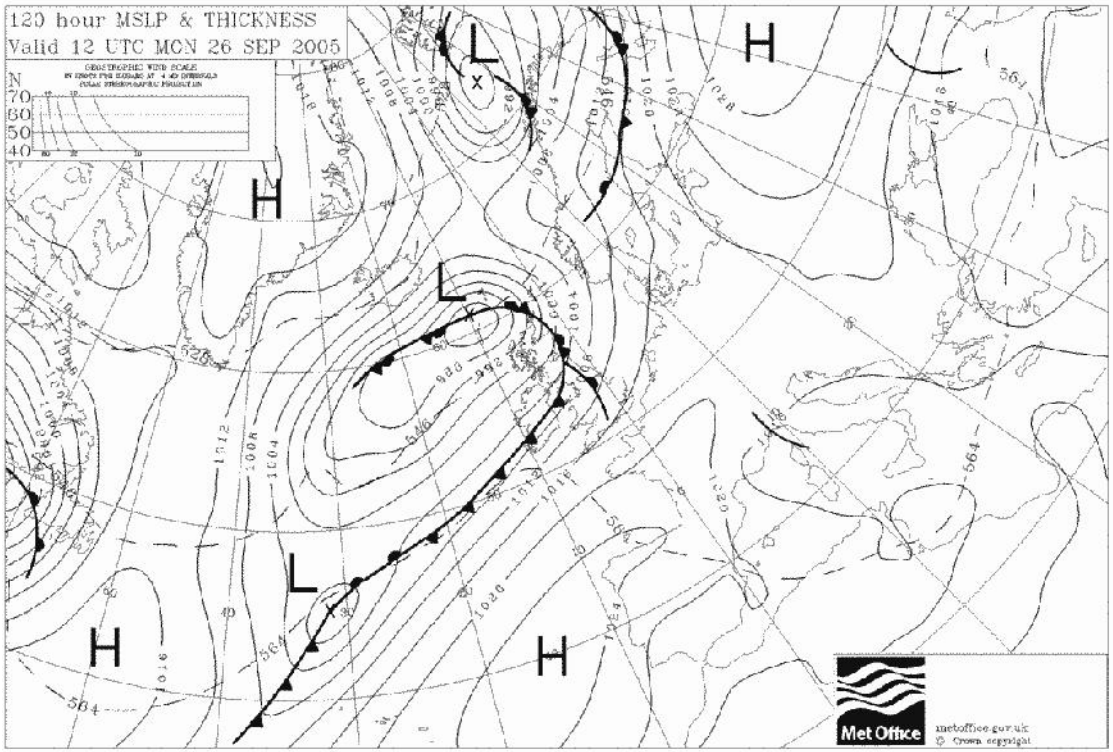
	Diagnosis or "analysis"	Prognosis or forecasting	Intervention
Medicine 	Check-up 	•Past case studies. •Physiology.	•Further tests? •Treatment
Weather 	Routine measure-ments 	•Past cases? •Atmospheric physics	•Targeted obs? • Weather modification?

What do we want to know?

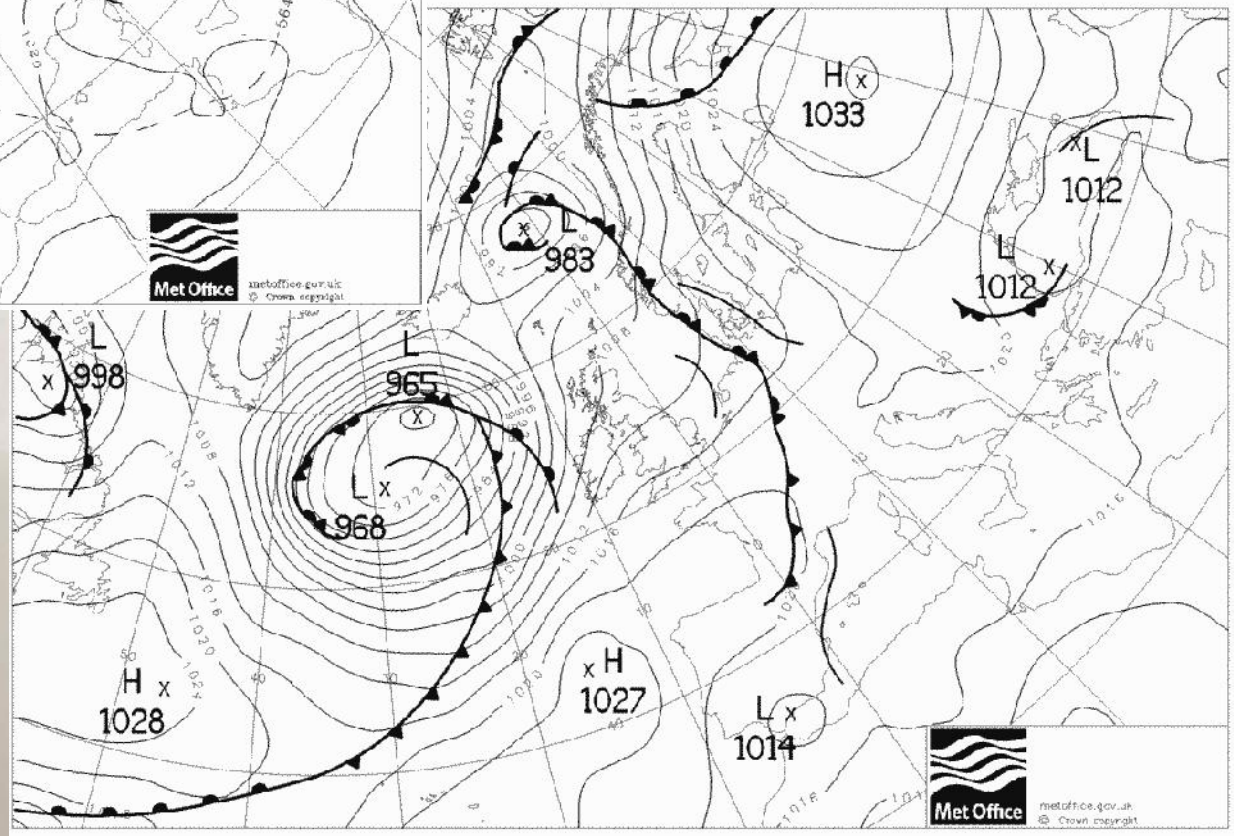
- Temperature
- Wind speed
- Wind direction
- Clouds
  - Type, extent, altitude
- Precipitation?
  - Type, amount, location
- Visibility
  - Fog, haze
- Humidity
- Trends in all of these
- Timing of significant changes
- Occurrence of extreme events

How far ahead?

- Ideally:
  - as far ahead as possible!
- In practice
  - 3-5 days is the limit of reasonable quantitative forecasts.
  - Medium-range forecasts (5-10) days are made, but limited to large-scale pressure field and winds, NOT detailed conditions.



5-day forecast

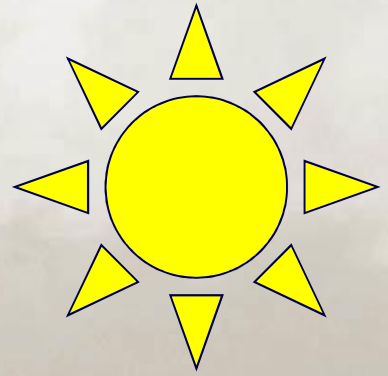


Analysis

Methods of Forecasting

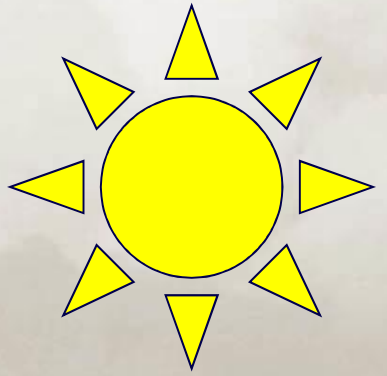
- Persistence Method:
  - Tomorrow will be much the same as today

Today's Weather



Clear skies, 19°C, low winds

Tomorrow's Forecast



Clear skies, 19°C, low winds

Works well when conditions change only slowly. Also surprisingly effective for general forecasts of periods >10 days, for which most other – more advanced – methods lose all their skill. Several weeks of hot sunny weather often followed by several more.

Statistical methods

Simple statistics: climatology

- Given a long record of past weather on every day of the year, forecast most frequently observed weather for day of interest.

  Works quite well, provided the general conditions are similar to the 'usual' or most common conditions for the time of year. Requires long records – many years – to provide reasonable statistics

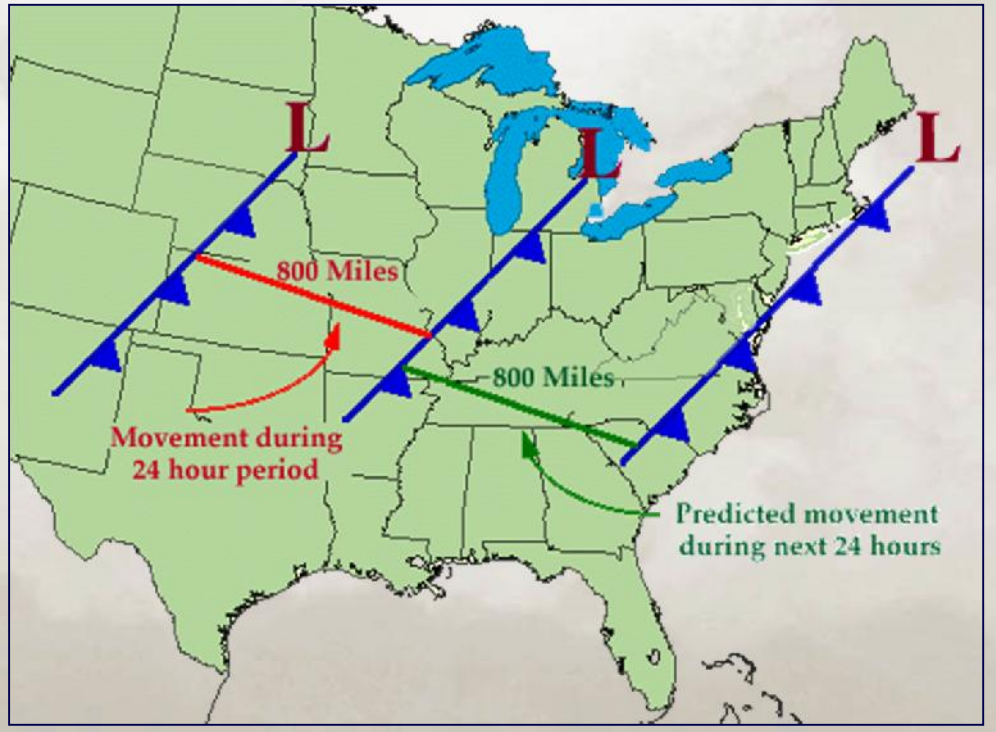
Analogue method

- Given a long record of the sequence of weather conditions, look for a past sequence that resembles the last few days to weeks, and forecast whatever followed it.

  Difficult to use effectively because of difficulty in finding a close match between current and past conditions. Again, requires records going back many years.

Trends:

- Estimate the speed at which features – fronts, pressure centres, etc – are moving. Allows estimation of time of arrival.
- Requires measurements over a wide area.
- Applied over a period of a few hours this method is called **NowCasting**. Very effective use of rainfall radar imagery (see Lecture 6).

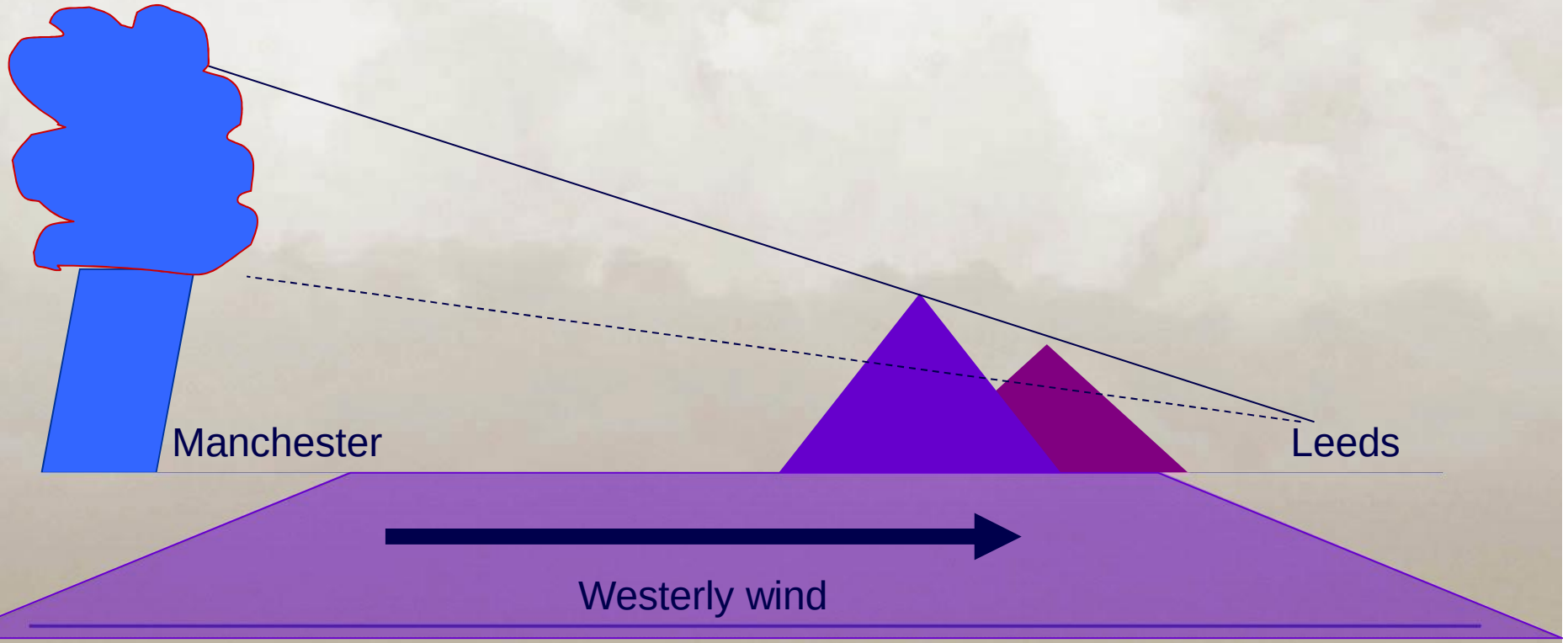


Physical Understanding

- An extensive set of measurements over a wide area, coupled with an understanding of the physical processes allows general conditions to be assessed and forecasts to be made for a wide area a day or two ahead.

Weather prediction.

1. Weather patterns move – “atmospheric dynamics” – equations known since ~ 1900.
2. Weather patterns change – “atmospheric physics” – still actively researched.



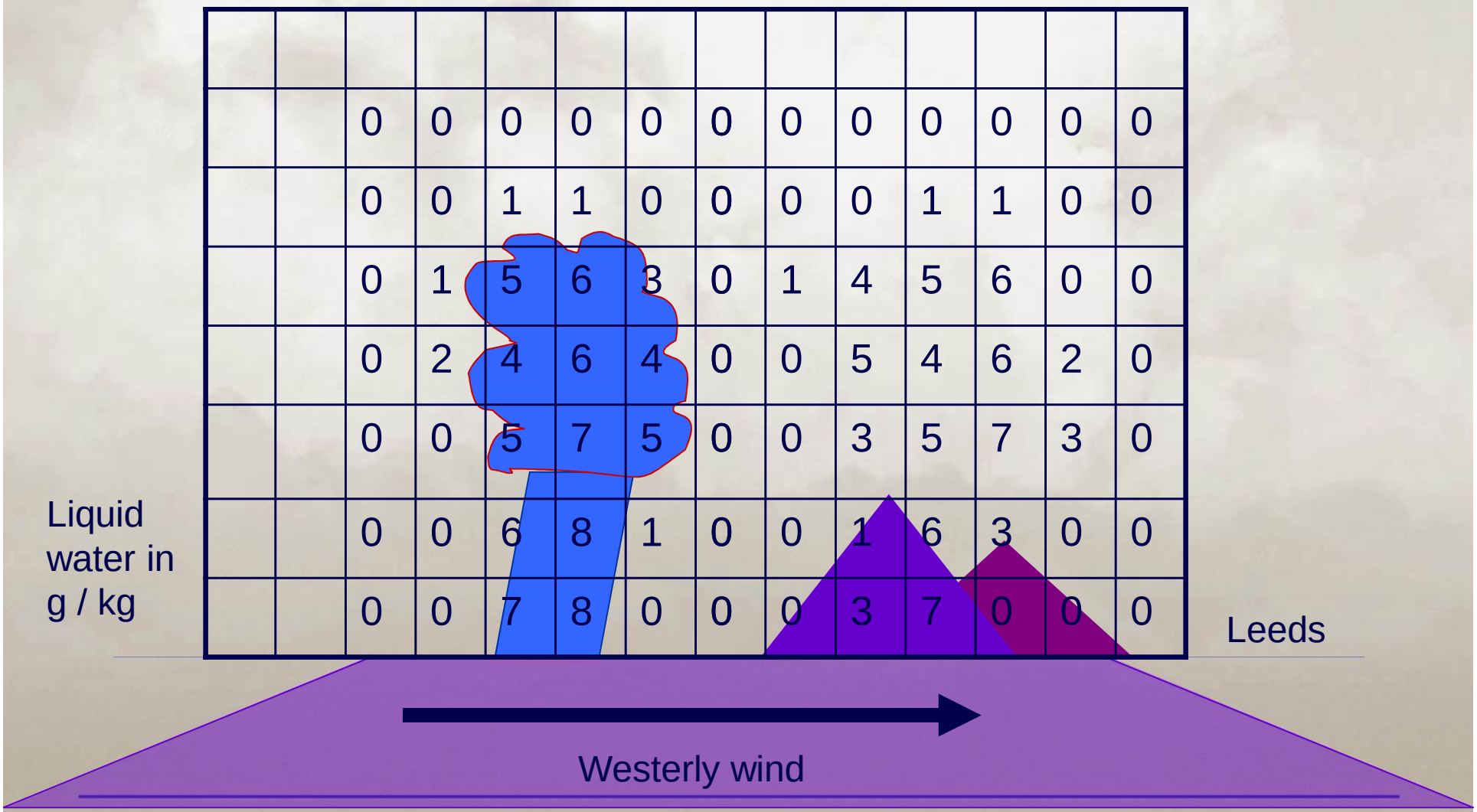
Physical Processes

- Thermal – atmospheric dynamics are ultimately driven by temperature gradients arising from uneven solar heating
- Pressure gradient forces – immediate cause of horizontal motions
- Moisture – effect of water vapour content on air density, and release of latent heat has a major impact on convection

Numerical Weather Prediction

- Physical processes are reduced to a (simplified) set of equations that describe changes of physical quantities in time & space. These are **initialized** with latest observations and **stepped** forward in time to produce a forecast.
- Requires:
  - an extensive set of simultaneous measurements over a wide area (*synoptic* observations) to initialize it
  - Fast, powerful computer
  - Adequate representation of the physical processes

Numerical weather prediction.



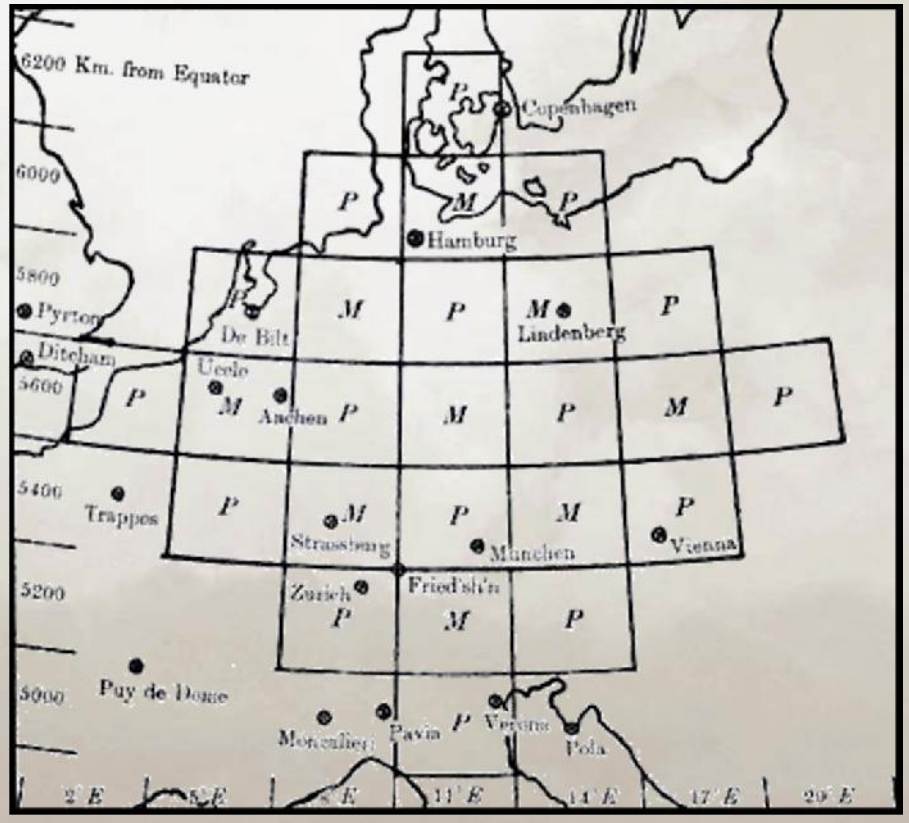
The first numerical weather forecast

First numerical forecast published in 1922 by Lewis Fry Richardson.

Took several months, calculating by hand, to produce a 6-hour forecast.

It failed…badly!

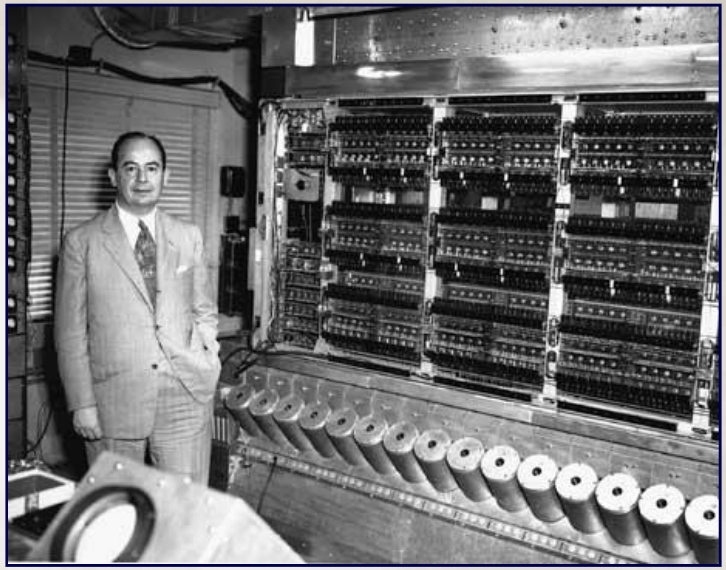
But, it demonstrated the means of producing quantitative forecasts. Its failure has since been shown to be due to the limited understanding of some atmospheric processes at the time.

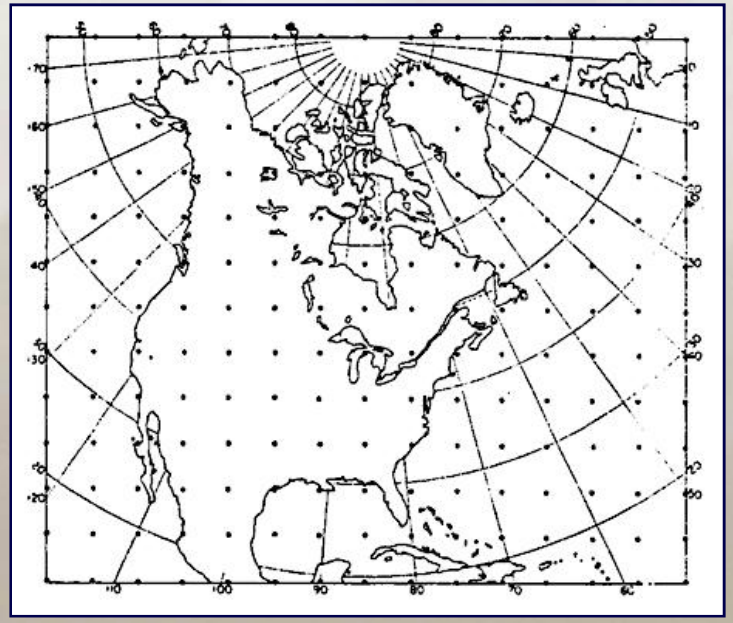


L. F. Richardson's computational grid: Pressure is determined in squares marked 'P', momentum in those marked 'M'.

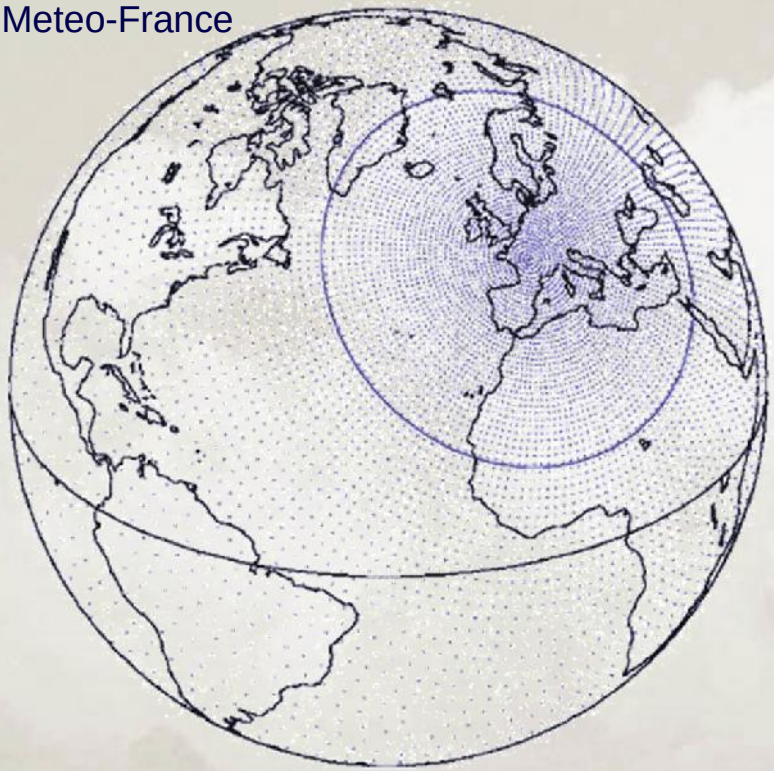
First successful forecast: 1950 by Jule Charney, Fjörtoft, and von Neumann, using ENIAC.

A **24-hour forecast** took **33 days** to produce, working day and night.





Meteo-France



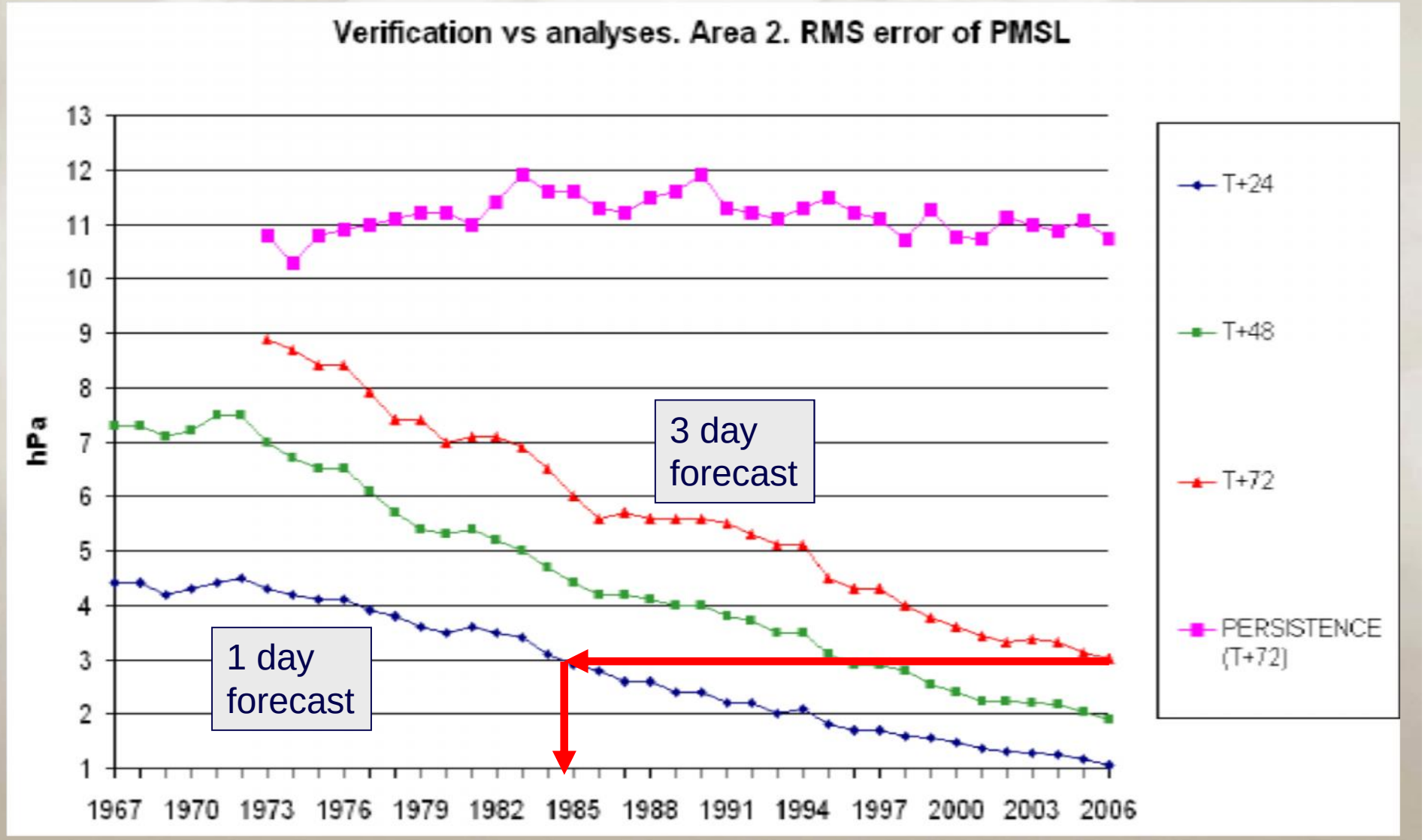
MetOffice

Modern forecast models include the whole globe at a horizontal resolution of up to ~1° (~111km).

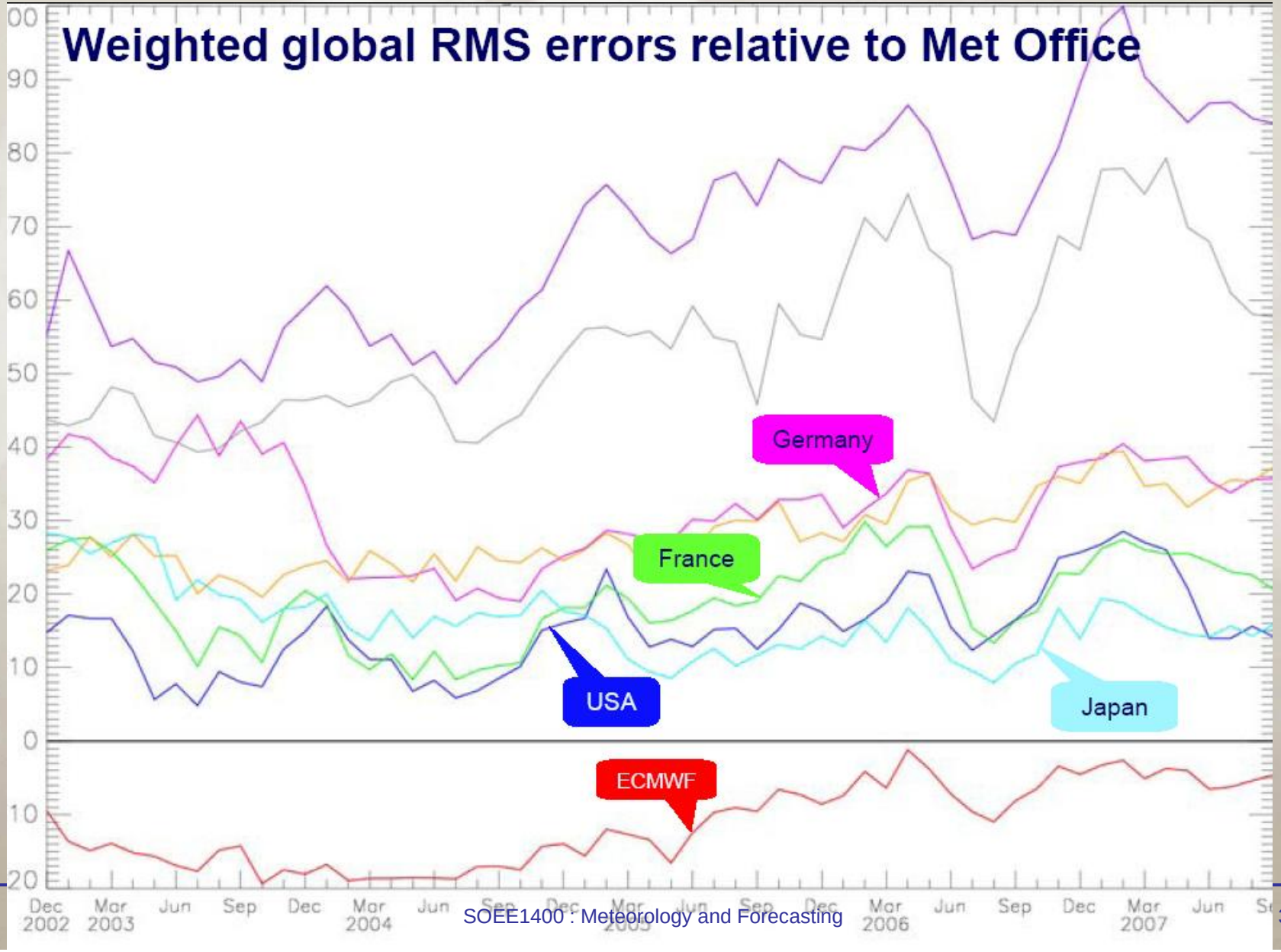
Region of interest modelled at ~10km resolution.

Forecasts made every 12 or 24 hours for 0000 and 1200 GMT (sometimes 0600 and 1800) for up to 5 days ahead.

UK Met Office model performance (RMS surface pressure error)



The Met Office is currently the best short-range prediction centre



Summary

- Meteorology is important to a wide variety of activities
- A huge array of meteorological information is freely available
- With a basic understanding of the physical processes involved YOU can make timely and accurate forecasts