SOEE3151/5680
Dynamics of Weather Systems

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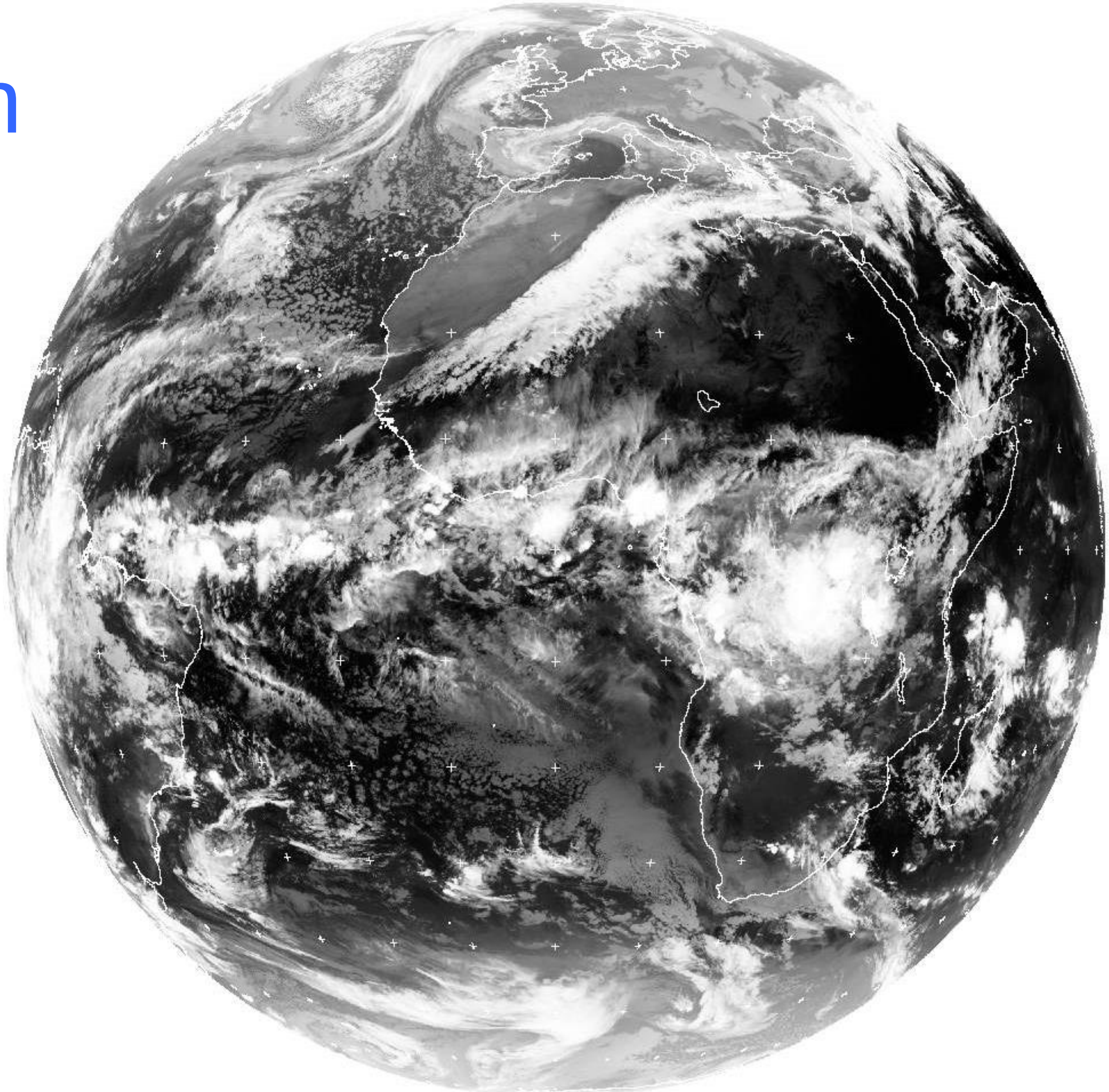
Module information and reading list on MINERVA.

Juliane Schwendike is the module leader and the first point of contact for any queries about the course.

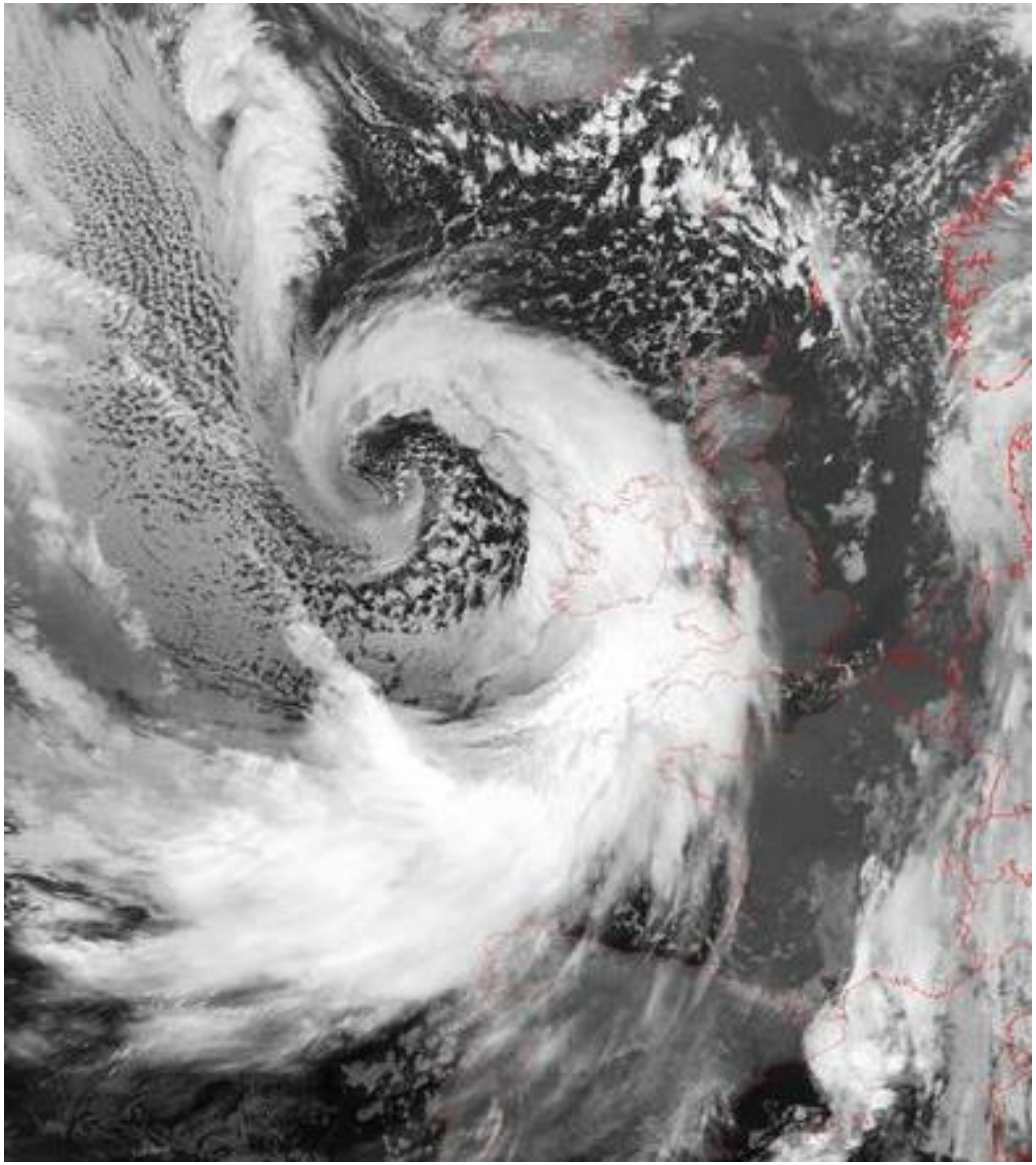
Motivation

- What causes these structures?
- How are they going to evolve?
- Where can we expect severe weather?



Motivation

- What caused this low affecting the UK?
- Is it going to intensify or to weaken?
- Is there heavy precipitation or strong winds associated with the frontal cloud band?
- How does it interact with hills in southern Wales?



Course Objectives

<u>On completion of this module, you should be able to:</u>

- Identify most important tropical and extratropical weather systems over a range of scales on satellite images & weather charts
- Describe fundamental atmospheric motions and storm development
- Explain physical mechanisms (the “dynamics”) that generate these systems and lead to their intensification and decay
- Diagnose vertical motion, which leads to cloud and cyclone formation
- Estimate the influence of mountains on the development of weather systems

Course Content

BASICS

- Lecture 1: *Introduction / course overview* Week 1
- Lecture 2: *Basic equations of atmospheric motion*
- Lecture 3: *Scale analysis & geostrophic balance* Week 2
- Lecture 4: *Vorticity & circulation*
- Lecture 5: *Rossby waves* Week 3
- Example Class 1

MIDLATITUDE WEATHER SYSTEMS

- Lecture 6: *Quasi-geostrophic theory* Week 4
- Lecture 7: *Potential vorticity*
- Lecture 8: *Dynamics of frontal cyclones I* Week 5
- Lecture 9: *Dynamics of frontal cyclones II*

Course Content

MIDLATITUDE WEATHER SYSTEMS Week 6

- SOEE5680M project introduction
- Example Class 2
- Lecture 10: *Hadley circulation*
- Lecture 11: *Walker circulation and ENSO*

No lectures Week 7

TROPICAL WEATHER SYSTEMS

- Lecture 12: *Monsoon systems and convection* Week 8
- Lecture 13: *Tropical waves*
- Lecture 14: *Tropical cyclones* Week 9
- Example Class 4

Course Content

MOUNTAIN METEOROLOGY

• Lecture 15: *Large-scale effects*	Week 10
• Lecture 16: *Local-scale effects*	
• Example Class 3	Week 11
• Revision Class	

REVISION	January

Detailed Lecture Timetable 2024-25

Semester One				
Week	**Date**	**Staff**	**Lecture 1**	**Lecture 2**
1	30 Sep./01 Oct.	JS	Introduction	Basic Equations of Motion
2	08/10 Oct.	JS	Scale Analysis and Geostrophic Balance	Vorticity and Circulation
3	15/17 Oct.	JS	Rossby Waves	Example Class 1 (Revision of Basics)
4	22/24 Oct.	JS	Mid-latitude Weather Systems I: Quasi-geostrophic Theory	Mid-lat. Weather Systems II: Potential Vorticity
5	29/31 Nov.	JS	Mid-lat. Weather Systems III: Dynamics of Frontal Cyclones I	Mid-lat. Weather Systems IV: Dynamics of Frontal Cyclones II
6	04/05 Nov.	JS	SOEE5680M project introduction	Example Class 2 (Mid-lat. Weather Systems)
6	06/07 Nov.	JS	Tropical Weather Systems I: Hadley circulation	Tropical Weather Systems II: Walker circulation and ENSO
7	12/14 Nov.	JS	*No lectures this week*	*No lectures this week*
8	18/19 Nov.	JS	Tropical Weather Systems III: Monsoon systems and convection	Tropical Weather Systems IV: Tropical waves
9	26/28 Nov.	JS	Tropical Weather Systems V: Tropical cyclones	Example class 4 (Tropical Weather Systems)
10	03/05 Dec.	AR	Mountain Meteorology I	Mountain Meteorology II
11	10/12 Dec.	AR/JS	Example Class 3 (Mountain Meteorology)	Revision class

JS Juliane Schwendike
AR Andrew Ross

Assessment – SOEE3151

I. Project report **50%**

- Create a report on weather & forecasting
- Choose topic from list on MINERVA or suggest your own topic until **Thursday 24th of October 2024** (inform by e-mail) – distinct from final year project.
- Detailed instructions on writing the report available on MINERVA.
- Finalize report until **Thursday 28th of November 2024, 2pm**.
  – Word limit 1500 words
  – Use scientific literature
  – Submission via Turnitin

II. Unseen exam **50%**

- 1 hour
- Chose 2 out of 3 blocks of questions
- Exercise classes will prepare you for this.

Assessment – SOEE5680

I. Project report **33.33%**

- Create report on weather & forecasting
- Choose topic from list on MINERVA or suggest your own topic until **Thursday 24th of October 2024** (inform by e-mail) – distinct from final year project.
- Detailed instructions on writing the report available on MINERVA.
- Finalize report until **Thursday 28th of November 2024, 2pm**.
  – Word limit 1500 words

II. Unseen exam **33.33%**

- 1 hour
- Chose 2 out of 3 blocks of questions
- Exercise classes will prepare you for this.

III. Independent Research Project **33.33%**

- Analysis of an intense extratropical cyclone
- Submission via Turnitin by Monday the **19th of December 2024, 2pm**.
- Word limit is 2500 words

Scientific report - module assessment

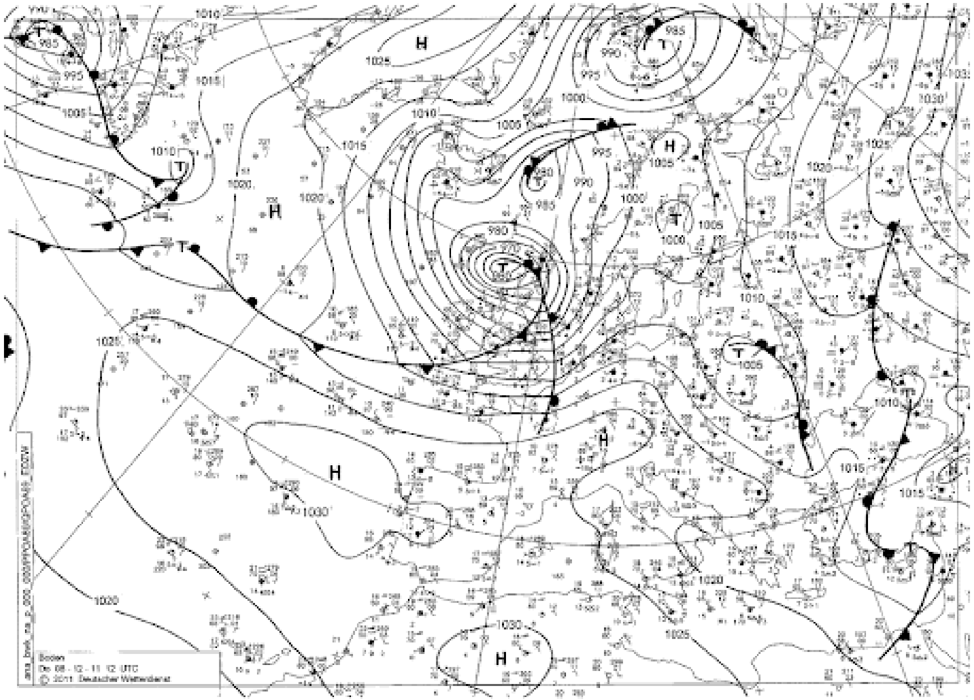
- Look at the information and suggested project titles on MINERVA.
- Send me (j.schwendike@leeds.ac.uk) your project title by **Thursday 24th of October 2024**.
- Minimum points to cover on your topic:
  - Why is subject important
  - Give overview of subject (from textbooks, web, etc.)
  - Describe some recent research (**journal articles**)
  - Summary and conclusions
- Report length 1500 words for SOEE3151and SOEE5680.
- Deadline: **Thursday 28th of November 2024, 2pm.**

Scientific report - module assessment

- Assessment criteria and feedback form on MINERVA.
- Use examples and illustrations, include figures and videos etc.
- Discuss the relevance, similarity/differences or applications of your topic to other situations or science fields.
- If your topic is a meteorological case study, you can add your own interpretations by collecting e.g. met charts, tephigrams, and satellite pictures. Make sure you do not only focus on the effects of the event but on the underlying dynamics.
- If your topic is about idealised models (e.g. Eady model, Lorenz model), you can perform your own modelling experiments and include some sensitivity experiments.

Independent Research Project (SOEE5680M)

- Assessment criteria and feedback form in module handbook.
- Question sheet with detailed instructions available on MINERVA.
- Use ERAI reanalysis data to analyse the storm's dynamics applying QG-thinking.
- Use your favourite scripting language. Example scripts are given in NCL and Python.

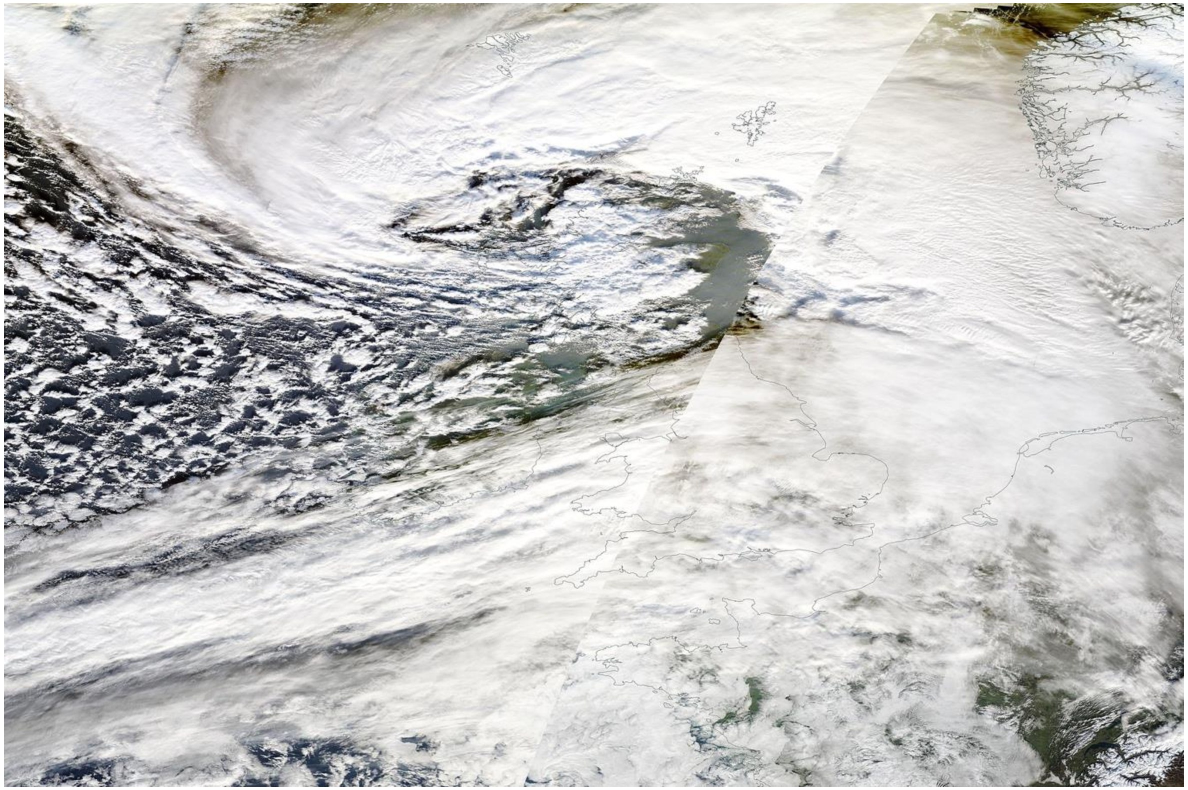


Weather chart on 08/12/11 from DWD.

- Winter storm Friedhelm 7-13 December 2011.
- Brought strong winds to the UK.

Independent Research Project (SOEE5680M)

- Word limit: 2500
- Write a scientific report including a selection of your own figures, referencing literature, and following the typical report structure.
- Submission via Turnitin by Monday the **19th of December 2024 at 2pm**.



Friedhelm crossing the British Isles on 8 December 2011. Image: NASA.

INTRODUCTION

What is a Weather System?

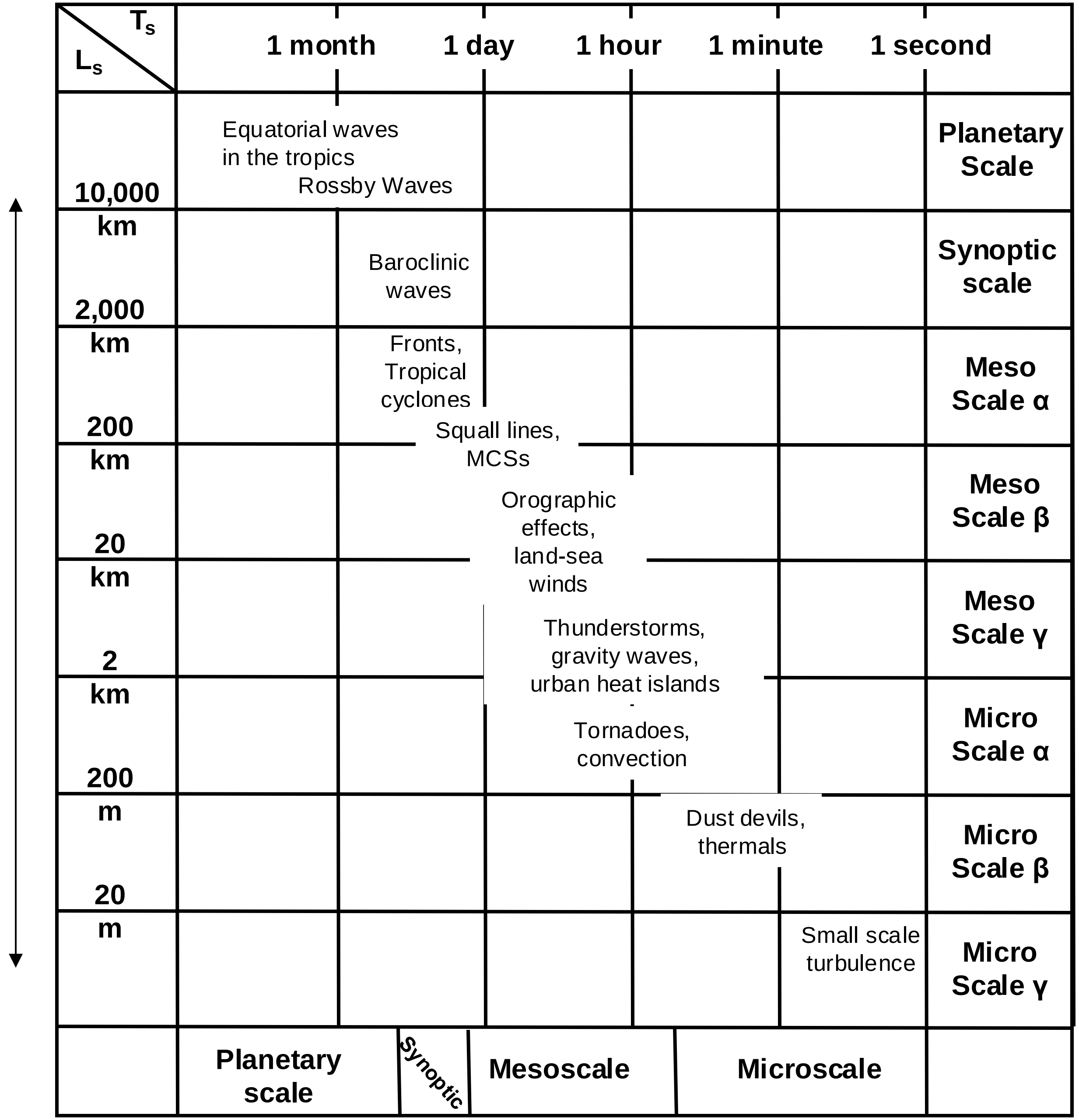
- Definition: "A weather system is a specific set of weather conditions, reflecting the configuration of air movement in the atmosphere, which affects a region for a period of time."

- Weather systems can be distinguished according to their
  – region of occurrence (e.g. tropical vs. midlatitude)
  – physical mechanism (e.g. baroclinic waves vs. convective instability)
  – scale in time and space (e.g. synoptic vs. mesoscale)

- Examples: Jet streams, midlatitude cyclones & anticyclones, fronts, tropical cyclones, downslope winds, rotors, thunderstorms, tornadoes, dust devils ...

Scales of Weather Systems

6 orders of magnitude



What is Dynamical Meteorology?

Meteorology

→ Systematic application of basic physical principles to phenomena in the lower atmosphere of the Earth

Physical Meteorology

– radiative transfer

– physics of clouds & precipitation

– atmospheric electricity

– composition

– ...

→ quasi-steady diabatic processes

→ **SOEE 2092**

Dynamical Meteorology

Analysis, interpretation, understanding and prediction of atmospheric flow on all scales

→ quasi-adiabatic flow processes

→ **SOEE 3151**

Adequate understanding requires appreciation of combined effects!

Fundamental questions of Dynamical Meteorology

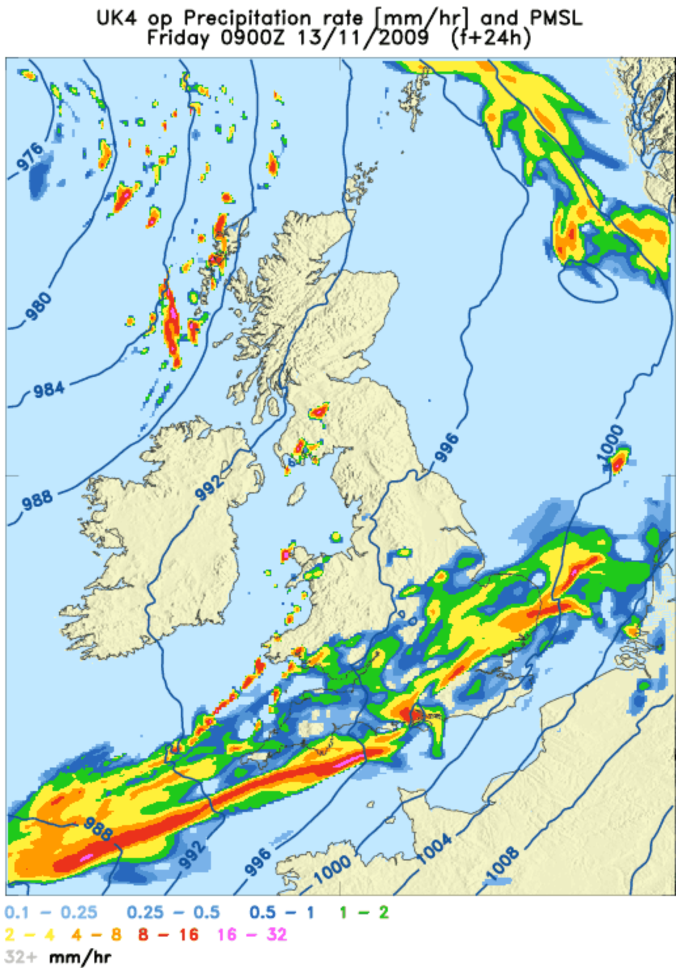
- What is the origin of weather systems (e.g. fronts, storms, waves) ?
- What determines their frequency?
- What determines their spatial scale and duration?
- Are systems independent from one another?
- Are they predictable?
- In what way do human activities (e.g. climate change) lead to changes of these systems?

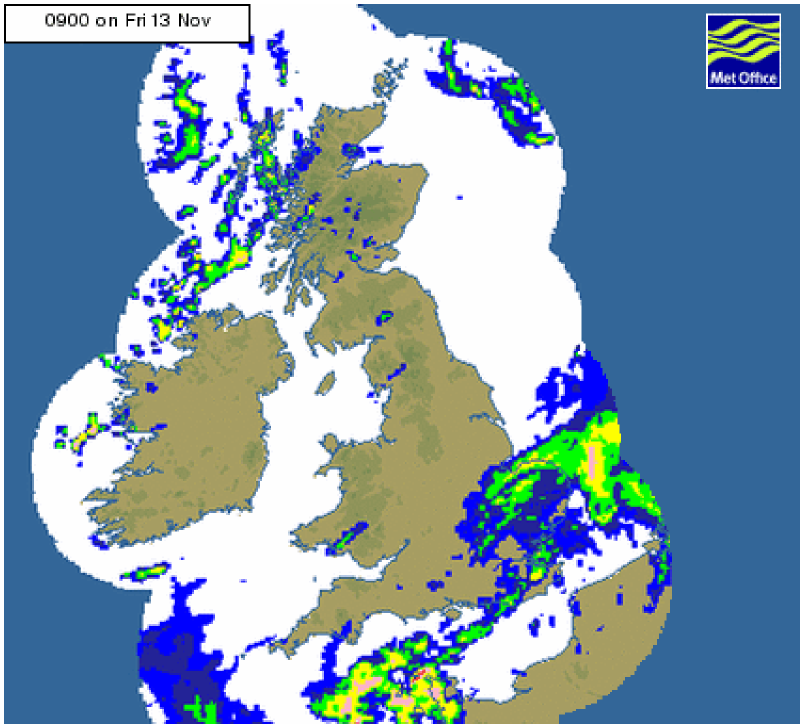
Why do we need conceptual models of weather systems?

- Computer models of the atmosphere have become more and more accurate and reliable during recent years due to:
  – better model physics
  – larger computer capacities
  – higher resolution
  – longer forecast periods
  – better observations (satellites)
- One could argue that this provides us with all necessary information on the atmosphere.
- So why bother with simplified conceptual models such as the quasi-geostrophic system?

Reason 1: Forecasting

Computer models are still far from being perfect!

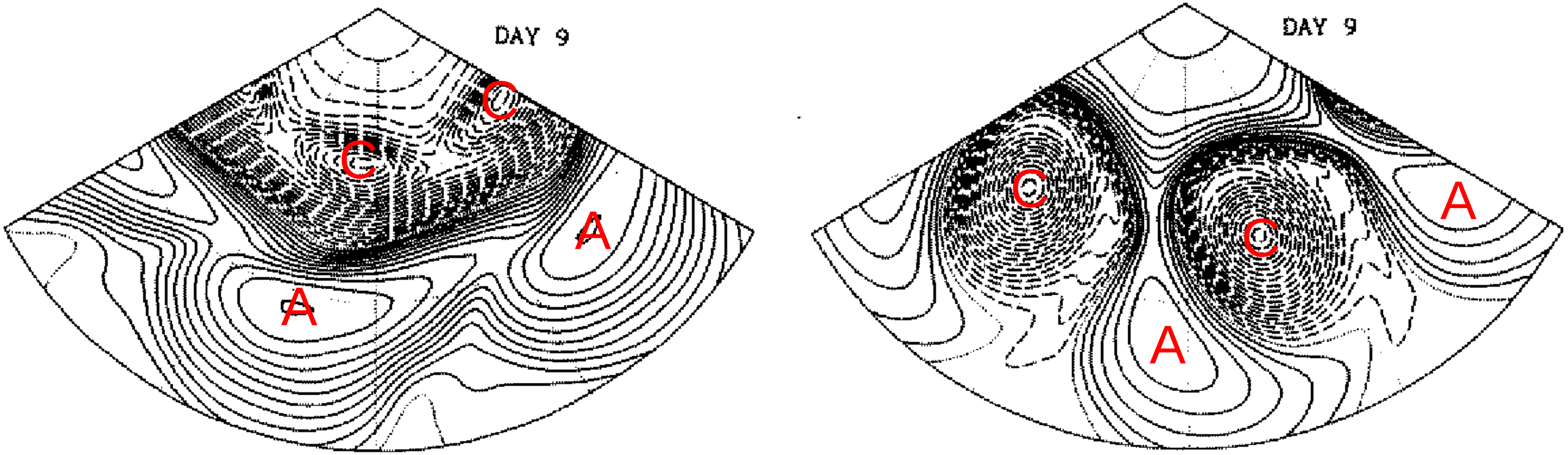




Reason 2: Research

Idealized, simplified models allow the isolation of single processes.

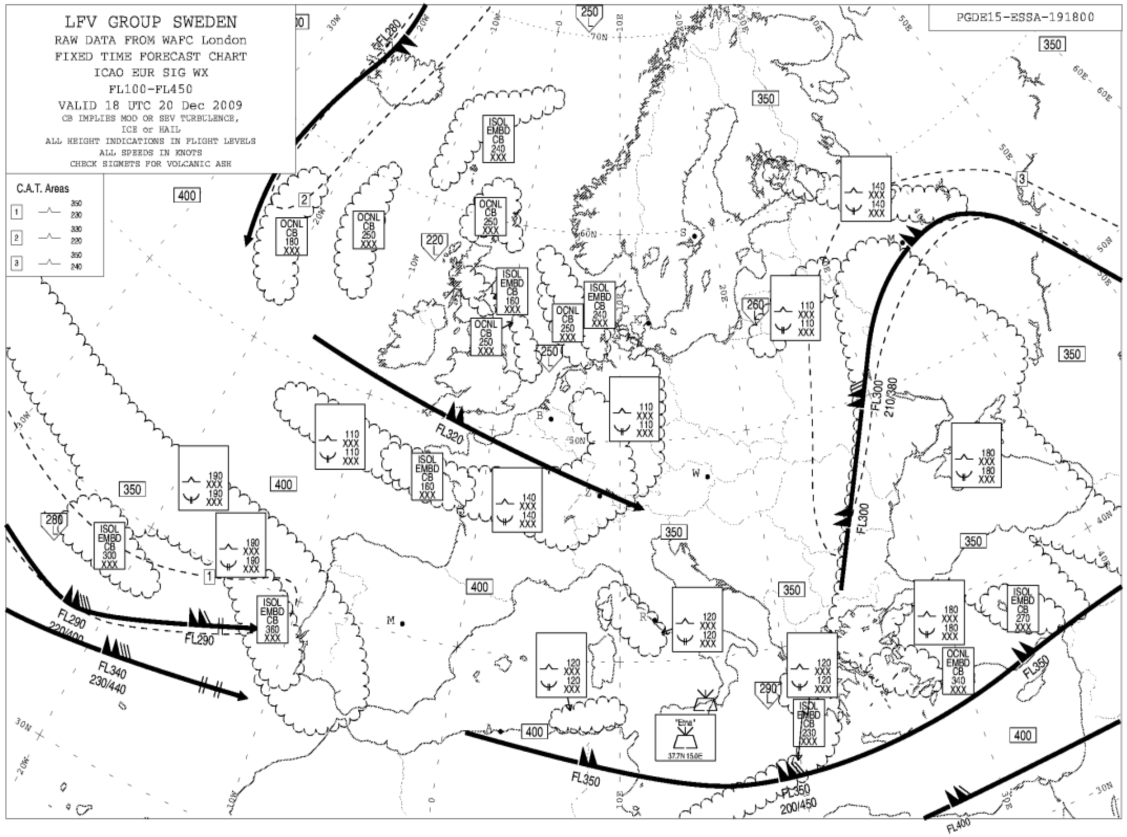
Example: Evolution of cyclones / anticyclones from 2 typical (fairly similar) basic states



from *Thorncroft et al. 1993*

Reason 3: Communication

- For the public, weather forecasts contain information about temperature, precipitation, wind, clouds etc. for a given location at the surface.
- For aviation, shipping, expeditions etc. the complex 3-D structure of the atmosphere and its evolution needs to be known.



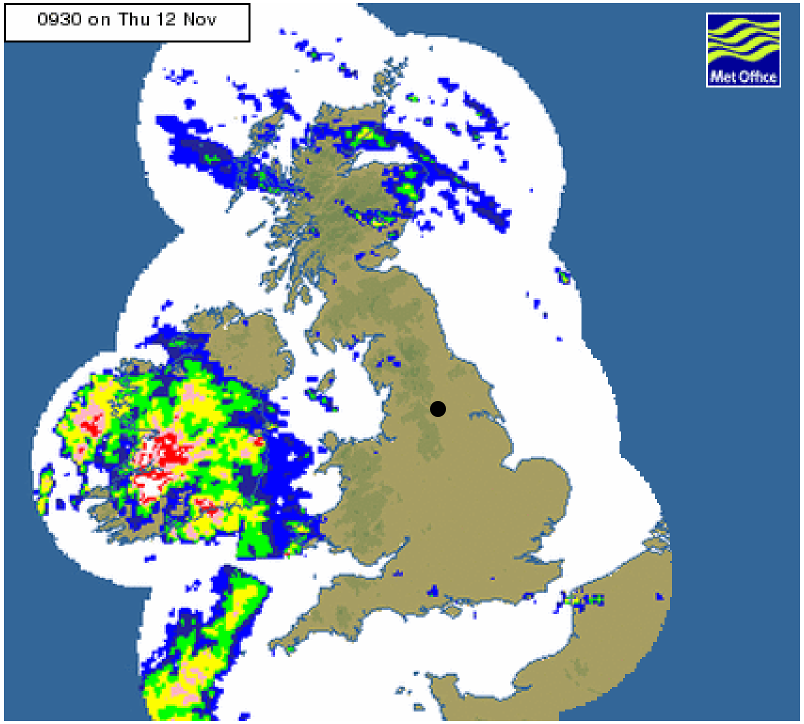
A simple conceptual model: Advection

If we know the state of the atmosphere at a given time and assume that weather patterns move with the wind, we can make a forecast.

Rain radar

12 Nov 2009

09:30 am



When is it going to start raining in Leeds?

And how heavy will the rain be ?

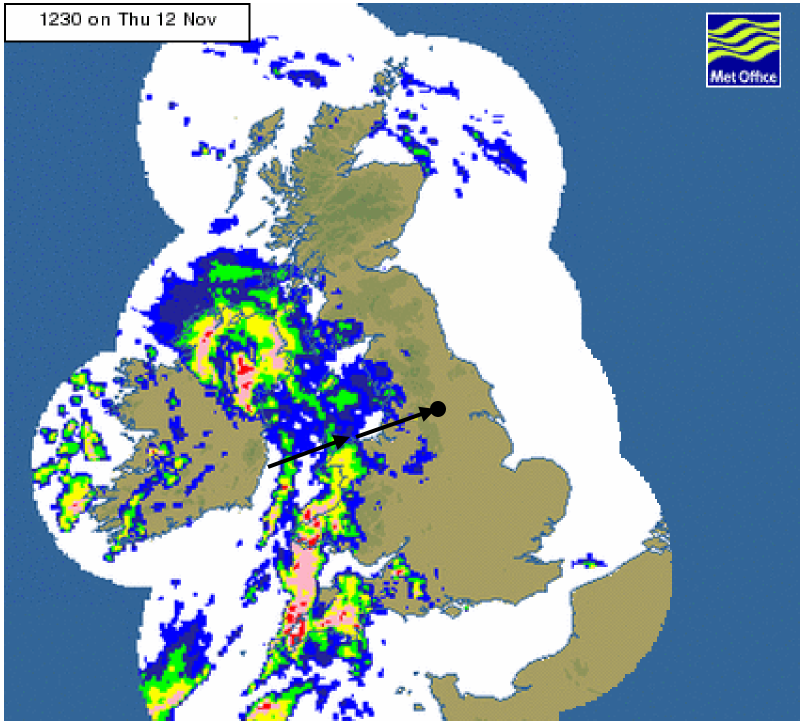
A simple conceptual model: Advection

If we know the state of the atmosphere at a given time and assume that weather patterns move with the wind, we can make a forecast.

Rain radar

12 Nov 2009

12:30pm



Forecast: rain in Leeds in about 3 hours!

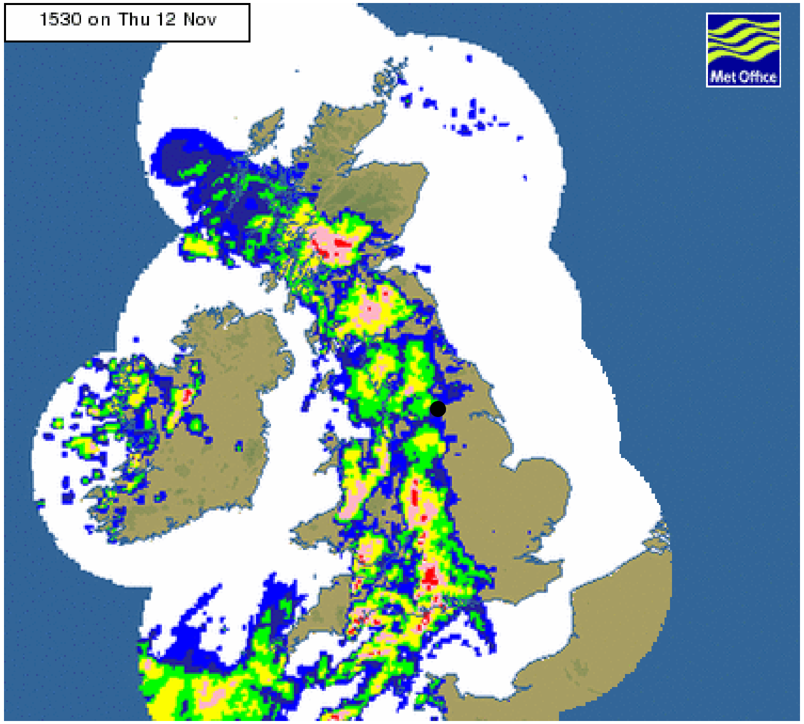
A simple conceptual model: Advection

If we know the state of the atmosphere at a given time and assume that weather patterns move with the wind, we can make a forecast.

Rain radar

12 Nov 2009

15:30pm



Forecast OK!

What if showers had developed ahead of front?

Summary

- Overview of the module
- Weather systems occur all over the planet on a wide range of scales
- Dynamical meteorology aims to analyse, interpret, understand and predict atmospheric flow
- Simplified conceptual models of weather systems help us to evaluate and communicate model forecasts and in researching the fundamental physics of weather systems
- Advection is a simple model that is useful in very short-term forecasts of precipitation
- More complex models will be covered in the rest of the module!