Meteorology

Lecture 1

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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?

- 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.*

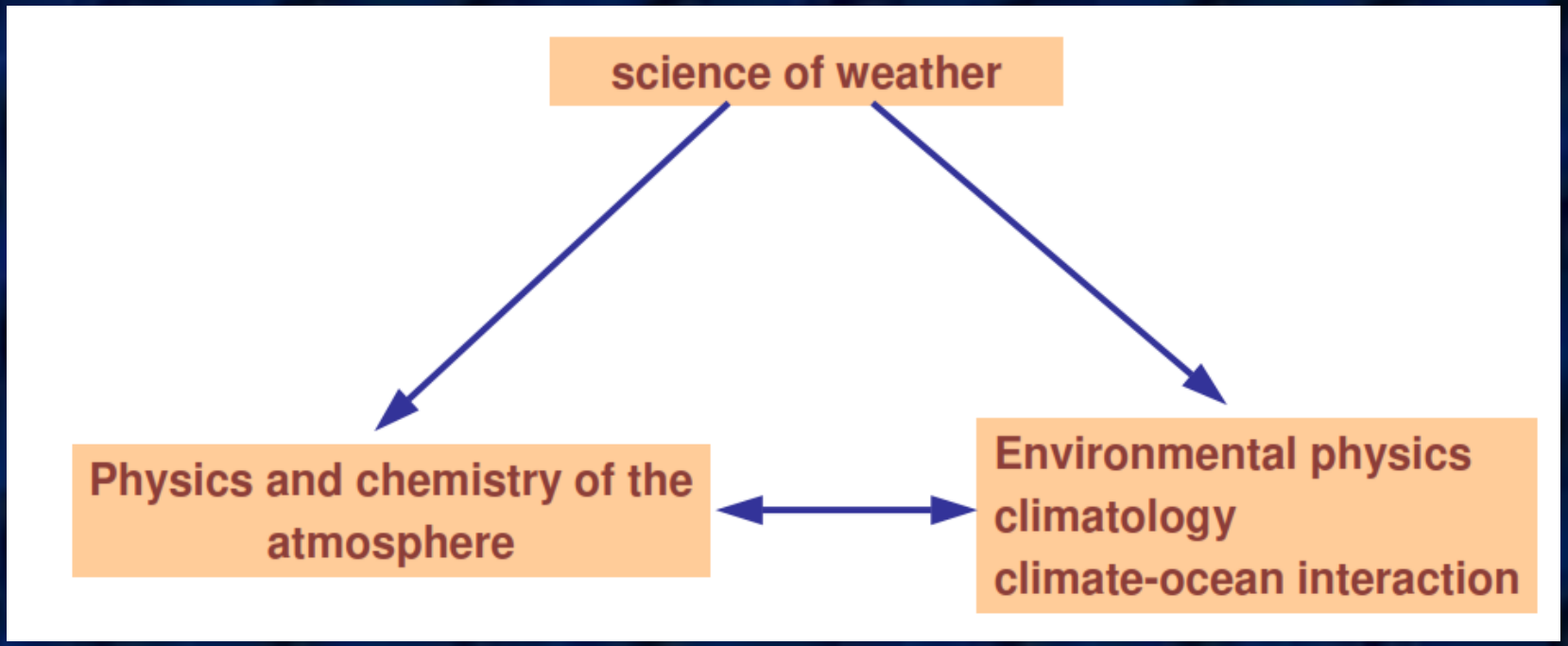
What do we want to know?

- 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.

What is meteorology?



Applied Meteorology

Most common career for meteorologists

Weather forecasting – most common and well known

Forecasting opportunities exist in public, military, private sector (industrial and commercial), and aviation

Weather, climate

What is *weather*?

- ➔state of the atmosphere at a given place and time (→ snapshot)
  - *theoretician*: pressure, temperature, water vapour pressure
  - *observer:* precipitation amount, visibility, cloud cover

➔But: weather also contains dynamical aspects

- Forecast, tendency (→ change with time)

What is *climate*?

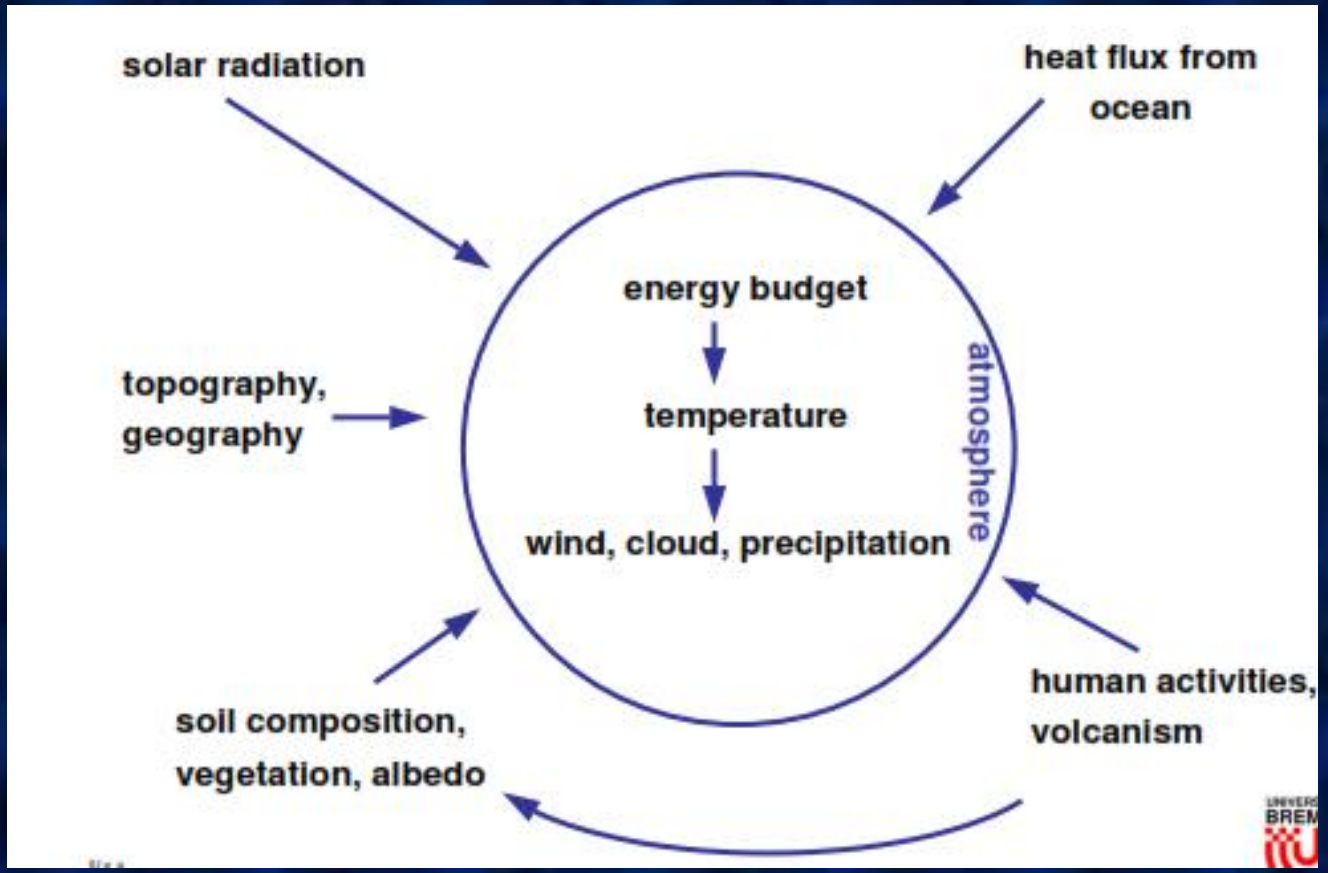
➔Climate is the summary of the atmospheric states which occur over a longer time period at a given location (local climate, micro climate) or in a larger region (regional climate)

diurnal variation

monthly, seasonal, annual averages (→climatological means)

in general: involves statistical quantities

Relationship between climate elements



Motivation to study meteorology

Better understanding of

→atmospheric processes

→anthropogenic influences on atmospheric processes (climate, weather)

Interaction between humankind and atmosphere

→SO_2 emission from burning fossile fuels (coal, oil, gasoline)

acidification of precipitation and lakes (Scandinavia and Canada)

→CO_2 emission from industry and biomass burning

global warming (→ Kyoto Protocol)

➔Reduction of O_2 production due to cuts in rain forrest (Brasil, Africa)

➔CFC (chloro-fluoro-carbon) emission from refrigerants and foaming agents

stratospheric ozone depletion (→ Montreal Protocol and amendments)

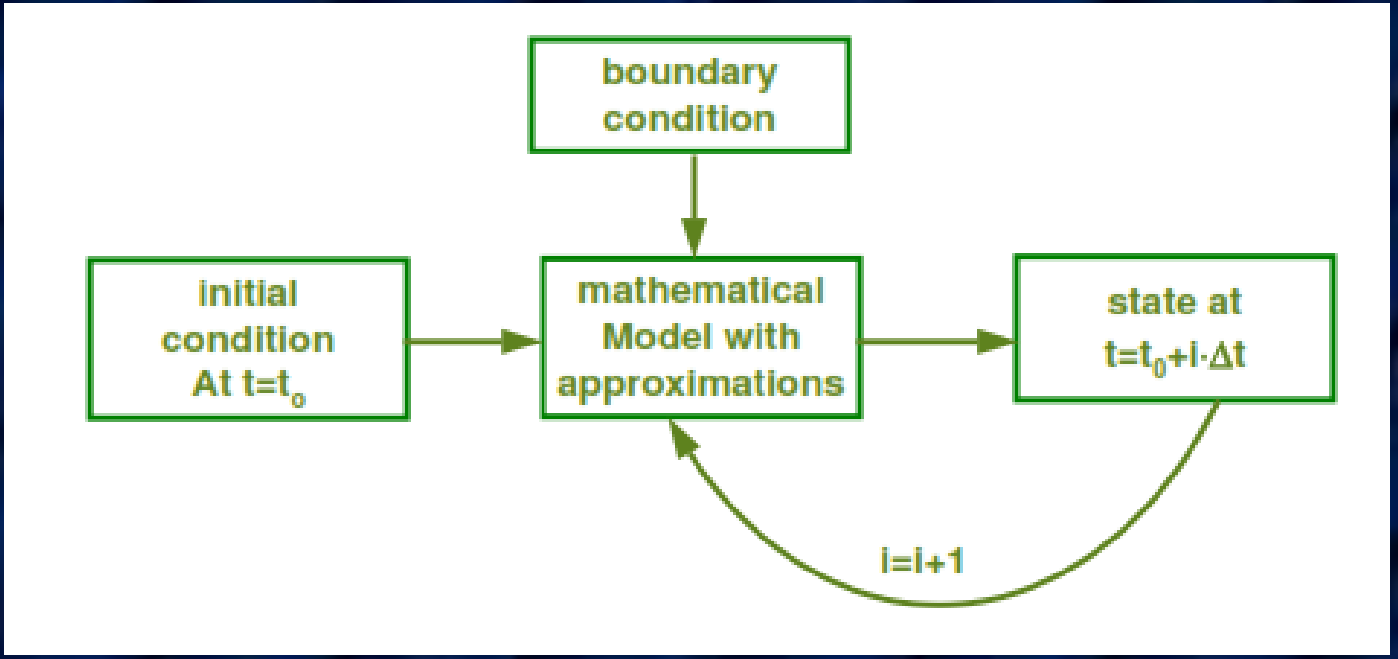
➔Aridisation due to forrest clearing and over-exploitation of soils (example: Mediteranean)

Methods used in meteorological research

measurements

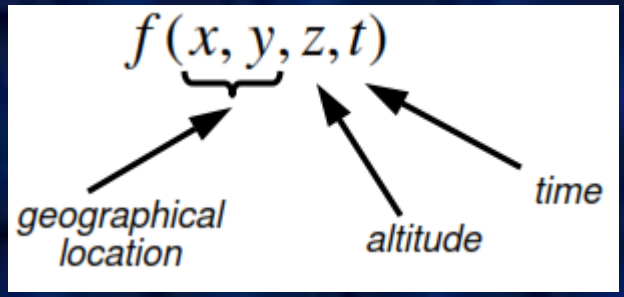
experiments	→ very difficult to simulate the atmosphere in an controlled experiment
description	✓ visual observations with sometimes very subjective criteria, such as visibility, cloud cover
modelling	✓ chemical-transport models, weather prediction models
theory	✓ mathematical descriptipn of phenomena, based upon physical laws
simulation	✓ forecasts, coupled climate model for prediction in fuure 100y

Mldelling


boundary condition
initial condition At t=t$_o$
mathematical Model with approximations
state at t=t$_0$+i·Δt
i=i+1

atmospheric modelling needs observables (except for simulations):

meteorological quantity



radio sondes measure temperature and relative humidity as a function of altitude → world wide network → used in weather forecast

very difficult to obtain time series of observables for more than one century, global and regular satellite measurements only since 70s

atmospheric processes are often chaotic → weather!

most measurements are only limited to a certain region → spatial and time interpolation needed

Branches in meteorological research

general meteorology (this course!)

➔ basic laws, description of phenomena, survey of all relevant topics

theoretical meteorology

➔ theoretical physics (and chemistry) applied to atmosphere, contains thermodynamics (statics), hydrodynamics (motion & circulation), and radiative transfer (radiation budget, dynamical forcing)

experimental meteorology

➔ measurement techniques, instrumentation, atmospheric measurements

applied meteorology

→ *synoptic meterology*

weather analysis and forecast

→ *flight meteorology*

flight security (turbulences, visibility, lightning warning9

→ *technical meteorology*

traffic, air traffic, trace gas emission

→ *bio-meteorology*

influence of waether on health, local climate for animals and plant ecology

special topics according to location

➔ *aerology*

meteorology of higher atmosphere (based upon balloon soundings generally below 30 km altitude)

➔ *aeronomy*

meteorology of high atmosphere above 50 km altitude

➔ *boundary layer meteorology*

surface to 2000m altitude

➔ *glacial, alpine, maritime, polar and tropical meteorology* (regional meteorology)

branches according to time scales

→ *climatology*

covering larger periods, averaging proberties, interaction between hydrosphere (ocean), biosphere (land), and cryosphere (polar ice region)

branches according to instrumentation

→ *satellite meteorology*

→ *radar meteorology*

branches according to spatial scales

branch	scale	phenomenas
synoptic meteorology	global, > 1000km	cyclonic waves
mesoscale meteorology	<1000 km	sea wind circulation, frontal systems
regional meteorology	~100 km	mountain winds, foehn, hurricanes
micro meteorology	< 100 km	turbulence, lightning, tornadoes

Earth's Atmosphere and Sun

chemical composition

Criterium	term	altitude
life forms	biosphere	0-20 km
composition	homosphere	0-100 km
	homopause	100-120 km
	heterosphere	>120 km
temperature	troposphere	0-12 km
	tropopause	~12 km
	stratosphere	12-50 km
middle atmosphere	stratopause	~50 km
	mesosphere	50-85 km
upper atmosphere	mesopause	~85 km
	thermosphere	85-500 km
	exosphere	>500 km
radio physics	ionosphere	50 –600 km
	magnetosphere	>300 km

atmospheric mass:

troposphere 90%

stratosphere 9.5%

mesosphere 0.5%

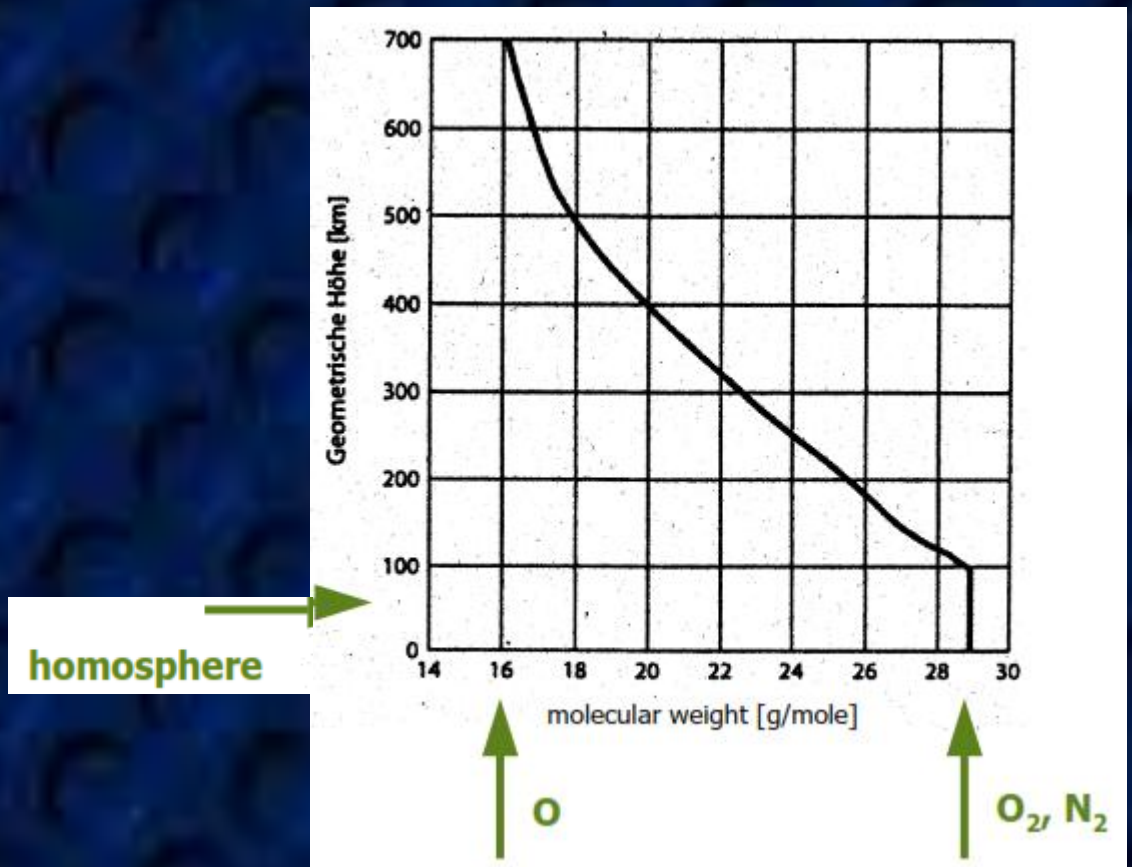
other criteria:

➔ aerodynamical state (planetary boundary layer)

Prandtl layer 0-50 m

Ekman layer 50-1000 m

free atmosphere (above boundary layer > 1000 m)


homosphere
Geometrische Höhe [km]
700
600
500
400
300
200
100
0
14
16
18
20
22
24
26
28
30
molecular weight [g/mole]
O
O2, N2