Meteorology: an introduction to weather, climate and the environment

Course content

Text references are to *Meteorology Today: an Introduction to Weather, Climate, and the Environment* by C. Donald Ahrens [Brooks-Cole/Thomson, 8th edition, 2007, ISBN 0495-01162-2]. The overheads include page or figure numbers to material in the 6th, 7th and 8th editions. The following course contents list will be helpful when you are revising. It has been drawn up before the course has begun so there may be some minor variations. Any significant deviations will be announced.

The Earth and its Atmosphere references to Chapter 1
Introduction, 200 years of observations at Aberdeen; extent of Earth's atmosphere, dynamic nature of atmospheric composition, major constituents of dry atmosphere, minor constituents; structure of atmosphere, definitions of density and pressure, units of pressure; decrease of pressure with altitude, exponential law of decrease of pressure with height; reasons for exponential law; consequences of exponential law; troposphere, stratosphere, mesosphere and higher regions; radiosondes and their purpose, rawinsondes, sensors for radiosondes, telemetry.

The Ozone Story references to Chapter 18
The ozone story (in chapter 17): where do we find ozone? Gordon Dobson at Aberdeen; is ozone beneficial? Effects of ozone reduction, the solar UV index, the ozone hole, ozone levels around the world, ozone formation, ozone destruction; the ozone threat, long-term trends, what's being done (Montreal and its successors), the UN and ozone; (returning to chapter 1) nature of weather and climate, areas of impact of weather on society.

Temperature & Energy: Warming the Earth and the Atmosphere Chapter 2
Nature of temperature, absolute zero, measuring temperatures in degrees Celsius and degrees Kelvin, need for absolute temperatures; The Sun's radiation; blackbody spectrum from a hot body, concept of radiant energy emitted and absorbed, total radiant energy given by Stefan - Boltzmann law; example use of Stefan - Boltzmann law, emissivity of real bodies; global warming requirement; wavelength of maximum radiation (Wien's law) with examples; long and short-wave radiation; radiation balance and Earth's radiative equilibrium temperature; atmospheric greenhouse effect, greenhouse gases, media's greenhouse effect, importance of CO_2 and CFCs; Earth's energy balance for short-wave radiation, Earth's total radiative energy balance.

Climate Change and Global Warming references to chapter 16
A topic of the times; 7-year span of daily temperatures; how do we find the facts?; proxies; the IPCC; climate change over 200 millennia; measurables from ice-cores; climate change conclusions; physical influences on climate; long-term greenhouse gas changes; CO_2 changes over the past half century; IR absorption spectra of greenhouse gases; the carbon cycle; stabilizing CO_2 emissions; CO_2 predictions for a range of scenarios; global warming predictions for this century; radiative forcing drivers; effects of global warming; some implications and conclusions; comments on response strategies.

Seasonal and Daily Temperatures Chapter 3 and reference to Chapter 16 **Climate Change**
Cause of the seasons, effect of Earth's elliptical orbit, Earth as seen from Sun, significance of the tropics, quantitative reduction in radiation on an inclined surface, sun tracks at different

latitudes, effect at Aberdeen of reduced solar radiation; inverse square law of radiation; irradiation in summer, irradiation in winter; energy balance over the globe, transport of energy from equatorial to polar regions, mechanisms involved; influences on global climate, comparison of radiation received on Earth in different seasons; general meteorological independence of hemispheres, radiation received by a tilted hemisphere, influences on climate of equinox precessions and changing of eccentricity of Earth's orbit; long-term climate changes (with reference to part of chapter 16); daily temperature changes, warmest time of day is in afternoon; temperature changes with height near the ground by day and by night; decrease of diurnal temperature variations with height; insulating effect of ice and snow; sea-level isotherms; influence of water on daily, monthly and annual temperatures; definitions of specific heat capacity and latent heat; the wind chill factor; measuring temperatures, meteorological enclosures.

Water Chapter 4
Atmospheric water exits in 3 phases, differences between the phases; phase changes - evaporation, condensation, sublimation and deposition; the hydrological cycle; measuring water vapour: humidity, specific humidity; parcels of air; average specific humidity around the globe; vapour pressure and partial vapour pressure in a mixed gas; saturation vapour pressure and exponential behaviour; relative humidity, daily change in relative humidity; dew point, as a measurement of humidity; measuring humidity, hygrometer, psychrometer, worked example, relative humidity calculations.

Condensation: Dew, Fog & Clouds Chapter 5
Condensation on the ground and in air; condensation nuclei, typical properties; staying aloft; radiation and valley fog; forming fog; advection fog; naming of clouds, common types and their appearance: Cirrus (Ci), Cirrocumulus (Cc), Cirrostratus (Cs), Altostratus (As), Altocumulus (Ac), Stratus (St), Nimbostratus (Ns), Cumulus(Cu), Cumulonimbus (Cb), other clouds; digression on Luke Howard; some of Luke Howard’s drawings and other historical cloud drawings; more examples of clouds; classifying sky conditions; satellite observations, geostationary satellites, polar orbiting satellites; Dundee satellite image receiving station; selection of satellite images, satellite average temperatures in North Sea.

Atmospheric Stability & Cloud Development Chapter 6 and Chapter 18 on **Air Pollution**
Concepts of stable, neutral and unstable equilibrium; revision of concepts of pressure, density and moisture content; buoyancy of air parcels depends on their density compared with that of their surroundings; stable and unstable parcels; ideal gas law describes link between pressure, volume and temperature; relation between density and temperature; concept of an adiabatic change in a parcel of gas; dry, moist and environmental lapse rates; measuring and plotting the environmental lapse rate; concept of absolutely stable air, stability accompanying a temperature inversion; meteorological conditions favouring stable air; chimney plume fanning, with references to the role of stability and inversions in chapter 18; conditional instability; unstable conditions; meteorological conditions favouring unstable air; instability encouraged; more on chimney plume dispersal with references to chapter 18: fumigation, looping, coning, lofting; summary of processes giving rise to cloud development; cumulus cloud formation; dew point and the base height of cumulus clouds; calculating cloud base height; structure of cumulus clouds; alto- and cirro- cumulus formation.

Precipitation Chapter 7
Comparative sizes of condensation nuclei, cloud droplets and rain drops; growing a cloud droplet, reason why most clouds don't produce rain; growing a rain drop, importance of

collision and coalescence; terminal velocity; rain, drizzle and heavy rain; ice-crystal clouds, mixed clouds, growth mechanisms for ice crystals, growth of ice crystals at the expense of supercooled drops; different forms of ice crystals, pictorial summary of generating precipitation; snow; sleet, freezing rain and hail; effect of atmospheric vertical temperature profile; measuring precipitation, rain radar; effectiveness of rain radar; its availability.

The Atmosphere in Motion: Air Pressure, Forces & Winds Chapter 8
Atmospheric pressure is the key to understanding atmospheric motion; example of pressure difference aloft between warm and cold air columns; measuring pressure, the mercury barometer and aneroid barometer; sea-level pressure charts, isobars; chart features: depressions, anticyclones, ridges, troughs and fronts; upper-level charts, isobaric surfaces showing heights of constant pressure; Newton's second law of motion; special case of no force acting; summary of forces determining wind; pressure gradient force (PGF), relation to isobars; origin of Coriolis force; consequences of Coriolis force; Coriolis effect on winds; nature of geostrophic wind, balance of PGF and Coriolis force; strength of geostrophic wind; cyclonic flow and the gradient wind, rôle of centripetal force, direction of wind in a cyclonic system; anticyclonic flow, direction in N hemisphere; sailor's version of Buys-Ballot's law; surface winds and effect of surface friction; summary, with modification of Buy's Ballot's law for surface winds; drawing wind arrows; use of wind arrows; Beaufort wind scale; Francis Beaufort; measuring wind: anemometer, Robinson cup, mechanical and electronic wind vanes; what use is a barometer?; example observatory.

Wind: Global Circulation Chapter 10
General circulation patterns in the atmosphere; global circulation models; Lewis Fry Richardson; evolution of global models over the past 3 decades; the Hadley cell; 6 cell (pole-pole) model, location of permanent highs and lows; global winds, the ITCZ; a global view of Earth's clouds; winds from satellite measurements; ocean surface winds; real world winds, regions of semi-permanent highs and lows, changes from January to July; global precipitation; importance of winds aloft; jet streams, polar front jet; origin of jet stream; definition of angular momentum and effect of its conservation on poleward moving air; ocean currents, gyres; the Ekman spiral; El Niño; normal and El Niño circulation; TAO and monitoring the Equatorial Pacific ocean and atmosphere, sea-surface temperature records; atmosphere-ocean connection and the Southern Oscillation; El Niño and La Niña; wider effects of El Niño.

Air Masses & Fronts Chapter 11
Concept of an air mass, source regions; types of air mass; general features of an air mass, cold advection and warm advection re-visited; front as a transition zone, recognizable characteristics; typical weather as a cold front passes, winds, temperature, pressure changes, clouds, precipitation, visibility and dew point; typical weather as a warm front passes; warm and cold occluded fronts and their weather; example of a warm occluded front arriving; radar example of a warm front approaching; stationary fronts; example pressure map showing fronts superposed on a satellite picture; separation of motion of weather system and its associate winds; example of weather associated with a week of winter high; example of high and low near Britain; example, snowy Easter; example of a sequence of passing lows.

Cyclogenesis: Middle Latitude Cyclones Chapters 12 and a little on forecasting in chpt. 13
Cyclogenesis, the birth of cyclones; Polar front theory developed by Norwegian meteorologists; first days of development of a mid-latitude cyclone; day1 - the start; days 2-5; up above: need to know what is happening aloft; convergence and divergence of air aloft;

Rossby waves; cyclone tracks guided by Rossby waves; influence of Rockies on N. Atlantic weather; Polar lows; recap of weather when warm and cold fronts pass; (see chapter 13 for more extensive forecasting coverage than in the lectures) forecasting strategies; ingredients for making a modern forecast; the computer generated forecast.

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