OCEA 90: "Fundamentals of Climate"
Midterm Exam Study Guide

IMPORTANT: Exam format

You can take the midterm exam anytime during the period **02/16/2023-02/18/2024** (Friday to Sunday). The midterm will be delivered through Canvas as a "quiz". It is a timed quiz that will last a maximum of 60 minutes. To relieve any stress/anxiety that may arise from unforeseen circumstances, you have a chance to generate a second exam via Canvas. Also, if you feel unsatisfied with your first attempt, you should try to improve your score by taking a second exam in Canvas (it won't be the same version of the exam, but similar). If you take it twice, your grade will be the highest score of the two attempts.

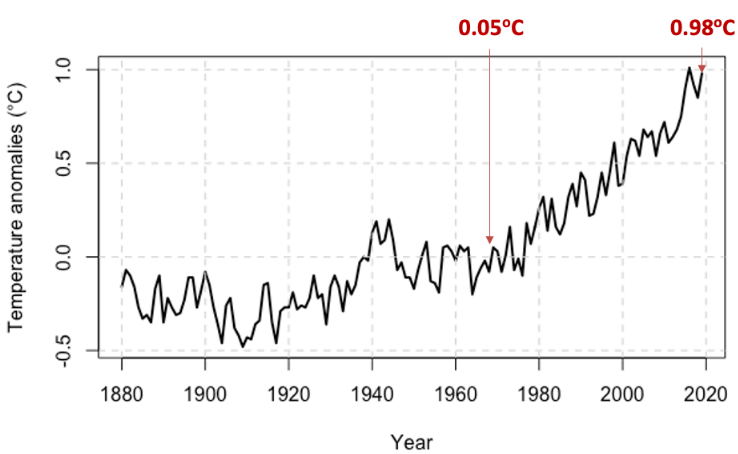
How to prepare:

- Take a careful look at the study guide below, which highlights the important concepts to study
- Make sure you understand why you got answers right/wrong on the assignments/activities
- Plan what time you will be taking the exam and make sure you have access to a quiet space with enough power for an hour and good wifi connection BEFORE you start
- If you are in a different time zone, make sure to change the time zone in Canvas in Account > Settings > Edit Settings, there you can select your current time zone. The accessibility window for the exam will be adjusted to your time zone.

Climate observations

You should be familiar with the concept of anomalies and rate of change. The figure below presents the global mean surface temperature anomalies with respect to 1951-1980. Negative (positive) anomalies indicate years when global temperatures were below (above) the 1951-1980 average. The temperature anomalies of 1969 and 2019 are marked as red text. The rate of change over the period of 1969-2019 is thus:

$$\Delta = \frac{0.98-0.05}{2019-1969} = 0.02 \quad {}^{o}C/year$$



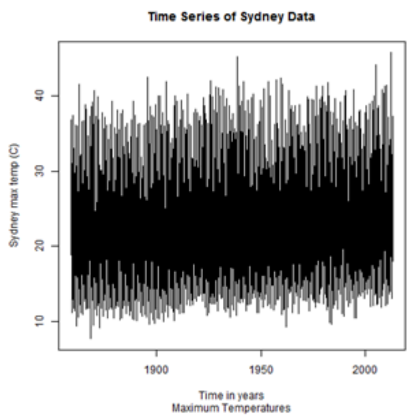
Histograms, Probability density functions and

Cumulative distribution functions

You should be familiar with the following:

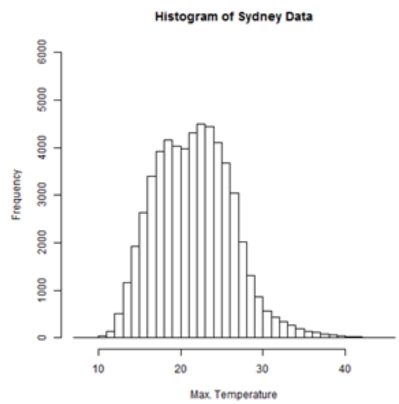
- The concept of a probability as a number between 0 and 1
- Data displayed as a time series
- Data displayed as a histogram, and the steps involved in building a histogram
- Data displayed as a *Probability Density Function* (PDF).

The figures below illustrate three different ways of displaying Sydney daily maximum temperature data for the period 1859-2013.



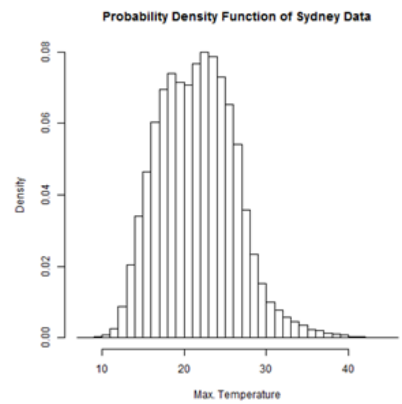
Sydney temperature data as a time series

T_i vs time



Sydney temperature data as a histogram

n_j vs T



Sydney temperature data as a PDF

p_j vs T

$$p_j = \frac{n_j}{N\Delta T}$$

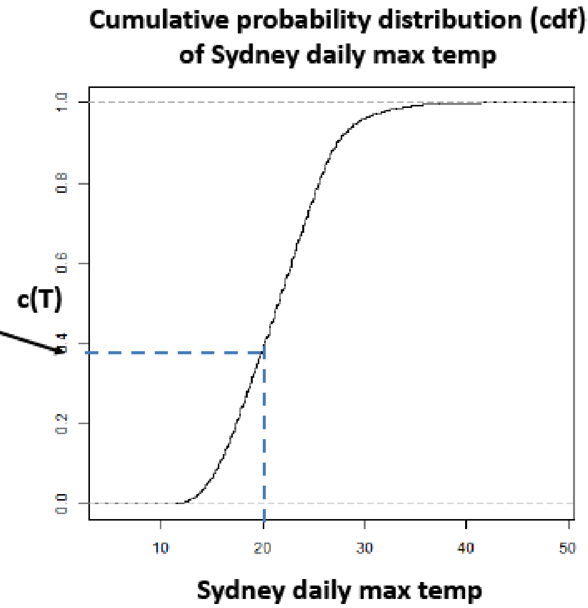
You should also be familiar with how to compute the probability of the outcome of a particular range of events using the PDF. For example, in the example above, bin *j* represents all of the occurrences of days when Sydney daily max temperature was in the range $T_j \le T < T_j + \Delta T$ where ΔT is the bin size. The probability that the temperature will fall within this range is $p_j \Delta T$ where p_j is the probability density of bin *j*.

You should be able to interpret and compute the probabilities of occurrence of a range of events using the *Cumulative Probability Distribution Function* (CDF). The examples below illustrate how the CDF can be used to compute the probability that the Sydney daily max temperature will be within a particular range.

Example 1:

The probability of *T* being *less than* 20°C is 0.38 (*i.e.* 38% chance).

The probability of *T* being *greater than or equal to* 20°C is 1-0.38=0.62 (*i.e.* 62% chance).

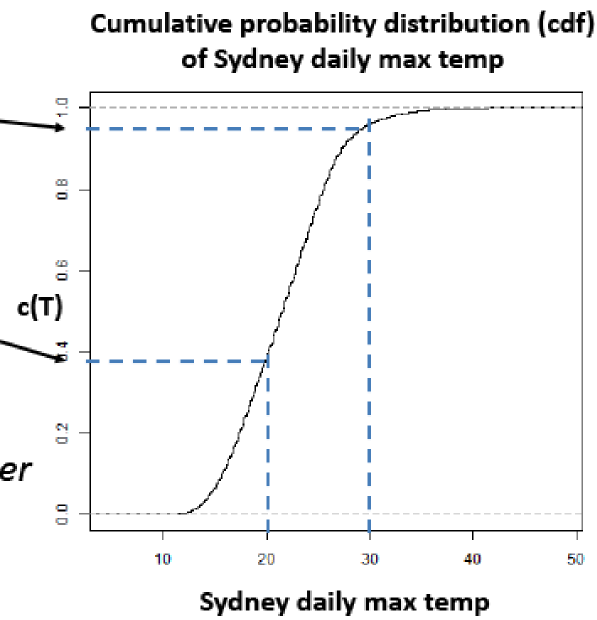


Example 2:

The probability of *T* being *less than* 30°C is 0.96 (*i.e.* 96% chance).

The probability of *T* being *less than* 20°C is 0.38 (*i.e.* 38% chance).

The probability of *T* being *greater than or equal to* 20°C and *less than* 30°C is 0.96-0.38=0.58 (*i.e.* 58% chance).



You should be familiar with the definitions of the *mean*, the *mode*, and the *median*, and you should be able to interpret them when given data, a PDF or a CDF.

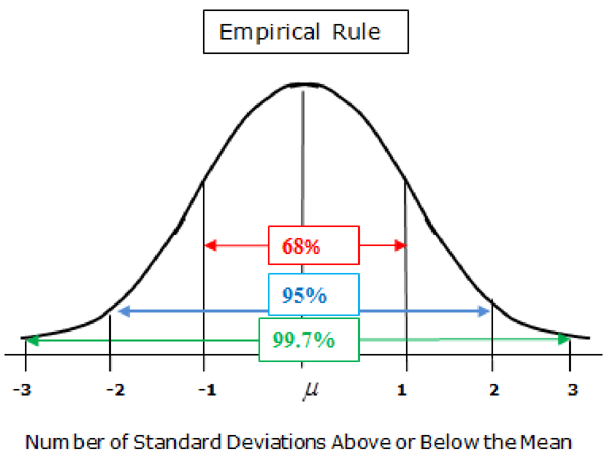
$$\text{The mean: } \bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

$$\text{The variance: } \sigma^2 = \frac{1}{(N-1)}\sum_{i=1}^{N}(x_i - \bar{x})^2$$

where x_i represents the values of a time series (e.g. Sydney daily maximum temperatures, the PNA index, etc). Remember that the standard deviation σ is the square root of the variance. Given a small dataset, you should be able to calculate the mean, standard deviation and variance.

You should be familiar with the normal distribution: it is uniquely determined by the mean and the standard deviation, and the mean, mode and median of a normal distribution are *identical*.

You should be familiar with the Normal distribution empirical rule and able to apply it to deduce probabilities from the mean and standard deviation of a Normally distributed climate variable.

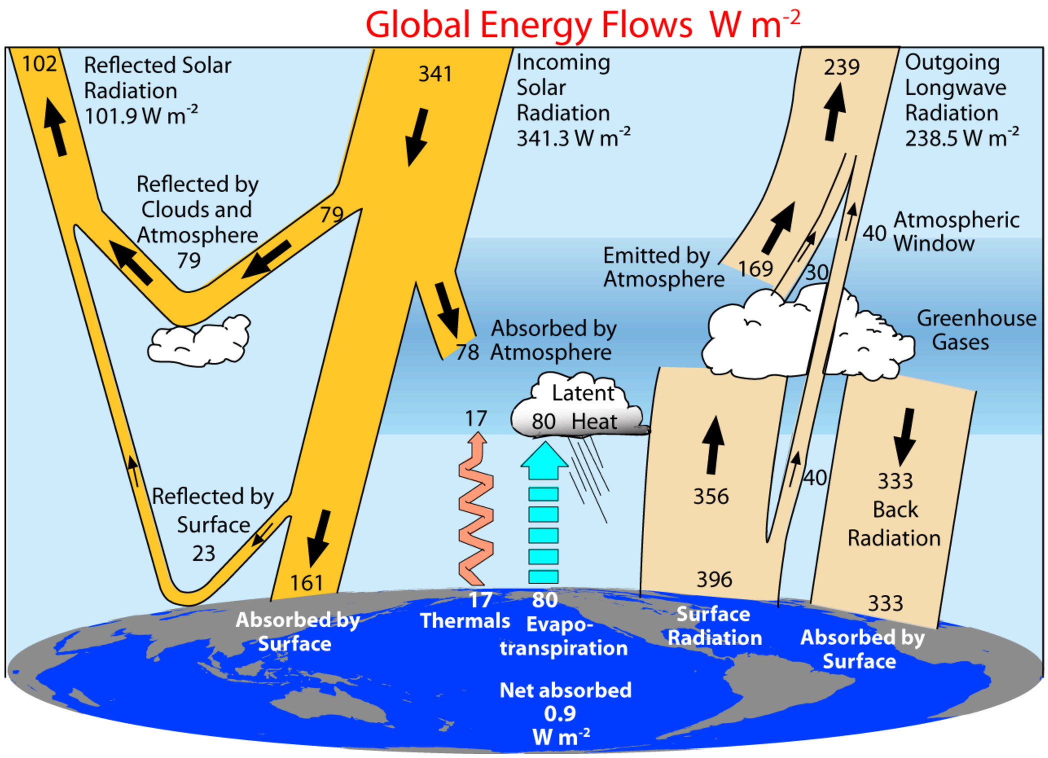


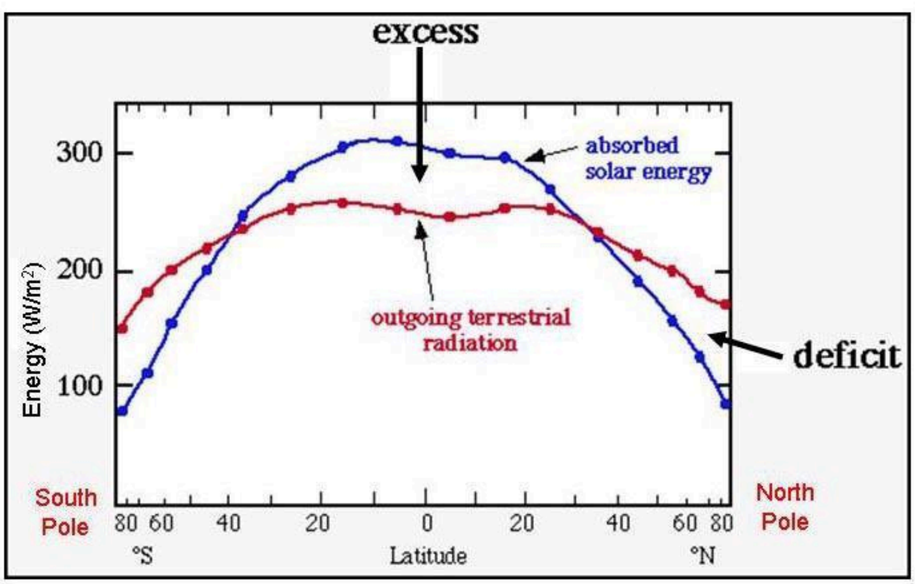
Atmospheric Energy Balance

You should be familiar with the following concepts:

- Radiative equilibrium and the global energy flows summarized in the figure below
- The geographical imbalance between solar radiation absorbed and the infrared radiation emitted by the earth as summarized in the figure below
- The essential role played by the atmospheric and oceanic circulation in removing excess energy from the tropics and transporting it to higher latitudes where there is a deficit

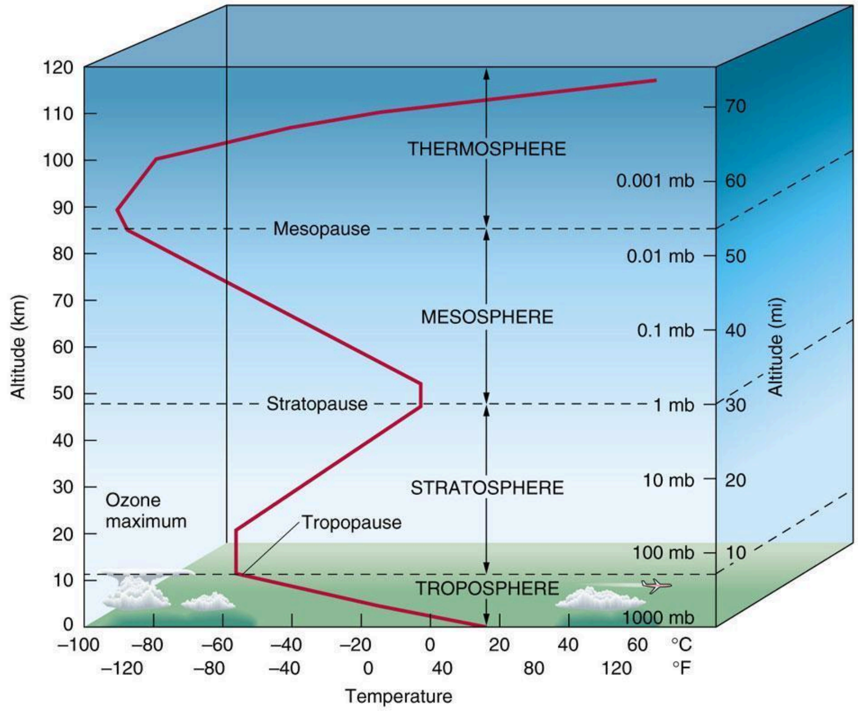
- Stefan-Boltzman and Wien's law (no need to memorize them, but need to be able to apply them).



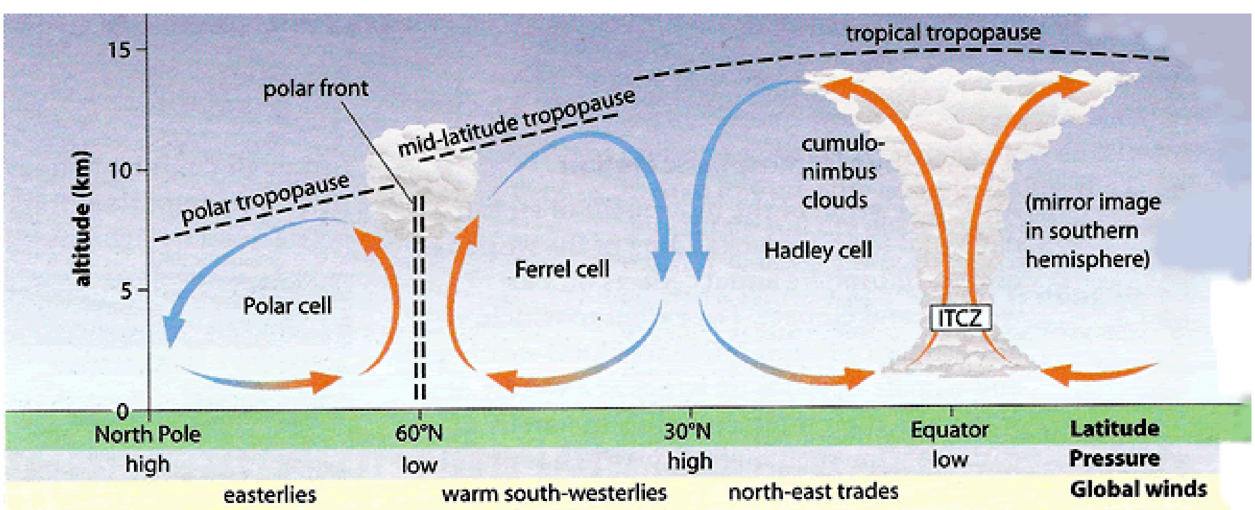


Vertical Structure of the Atmosphere

You should be familiar with the vertical temperature structure of the atmosphere (shown below), and the heat sources associated with the temperature maxima at various altitudes.



You should familiarize yourself with the 3 cell structure of the atmosphere comprised of the Hadley cells in the tropics and subtropics, the Ferrel cells between subtropical and the subpolar latitudes, and the polar cells poleward of subpolar latitudes.



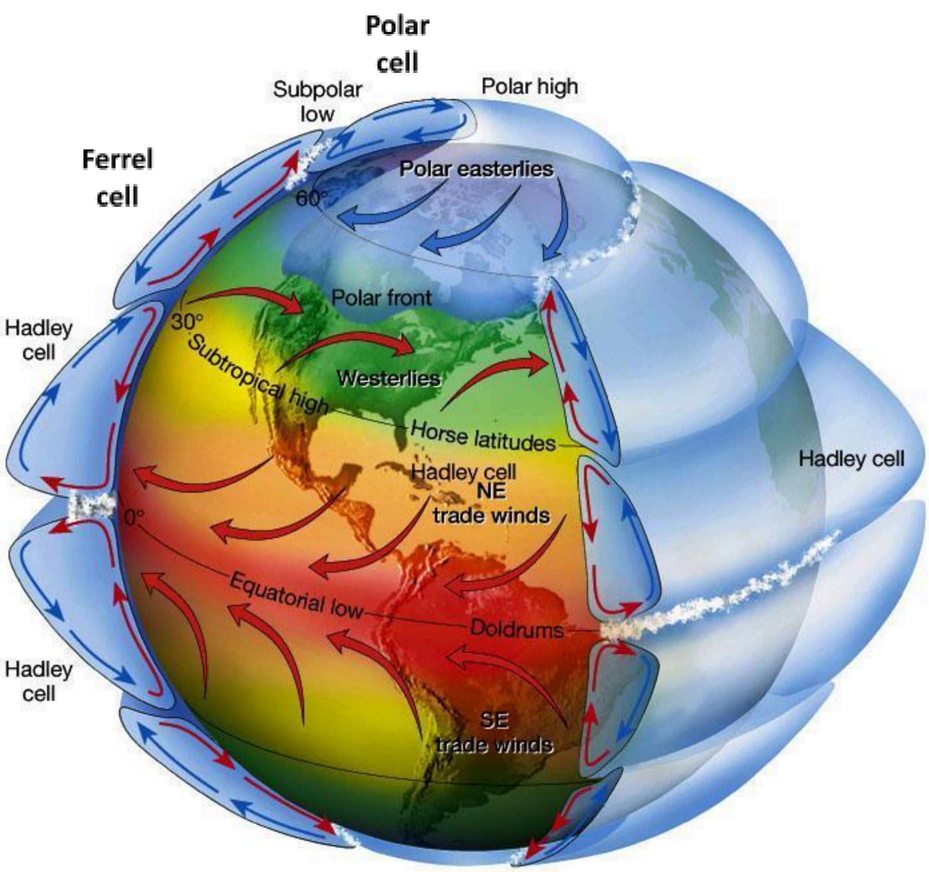
Pressure gradient force and Coriolis force

You should be familiar with the concepts that underpin the two primary forces that control the circulation of the atmosphere:

- The pressure gradient force that ***always*** points from high pressure toward low pressure
- The Coriolis force which is a consequence of observing the motion of the atmosphere on the rotating earth. Recall that the Coriolis force is to the right (left) of the direction of motion in the northern hemisphere (southern hemisphere).

You should be able to describe how these two forces shape the direction of the winds at different latitude bands.

The combination of these two forces has tremendous ramifications for the direction of the winds, and the figure below shows how they shape the surface winds associated with surface branches of the Hadley cell, Ferrel cell, and polar cell, leading in turn to the major wind bands comprised of: the tropical easterly trade winds (east to west winds), the mid-latitude westerlies (west to east winds), and the polar easterlies (east to west winds).



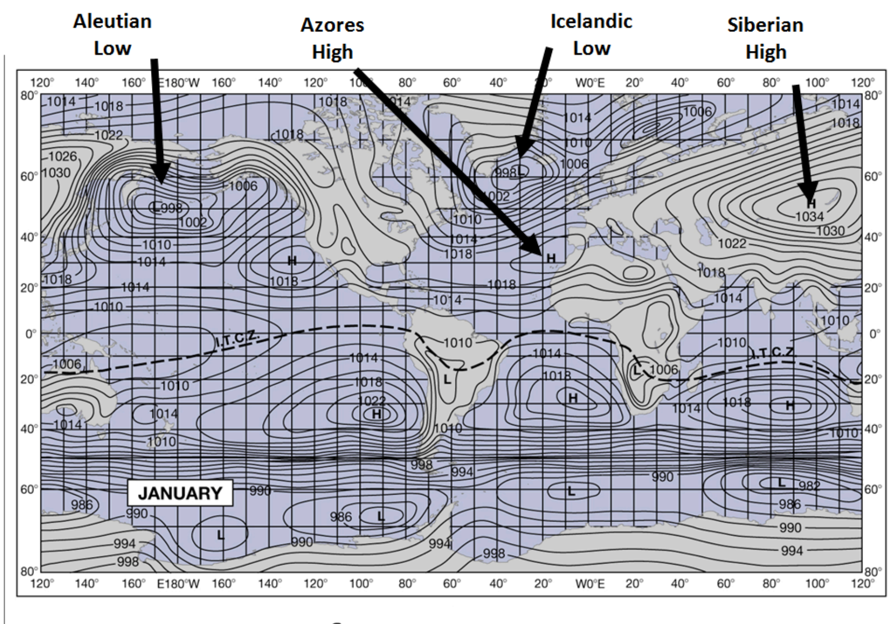
General Circulation of the Atmosphere

You should be familiar with the following important concepts:

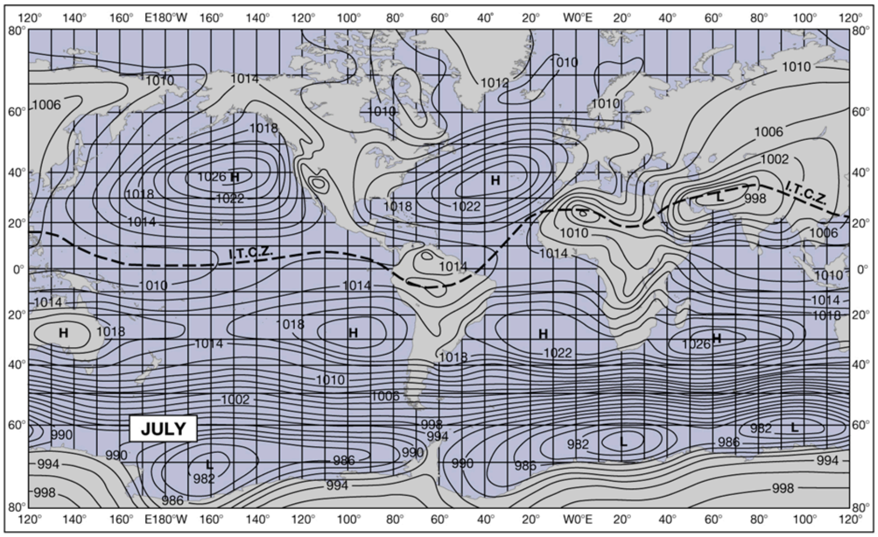
- Seasonal variations in the heating of the earth surface due to the tilt of the earth axis of rotation and the orbit of the earth around the sun
- Seasonal movements of the Hadley cell, the Ferrel cell, and the polar cell
- Specific heat capacity, and its influence on the distribution of surface pressure over land and ocean during the course of the seasons

The mean surface pressures during January and July are shown below. You should be familiar with the general character of the surface pressure distribution (*i.e.* high over land in the winter, low over the ocean in the winter, low over land during summer, high over ocean during summer).

You should also be able to describe the direction of the *geostrophic winds* around the high and low pressure systems.



Mean Surface Pressure - January



Mean Surface Pressure - July