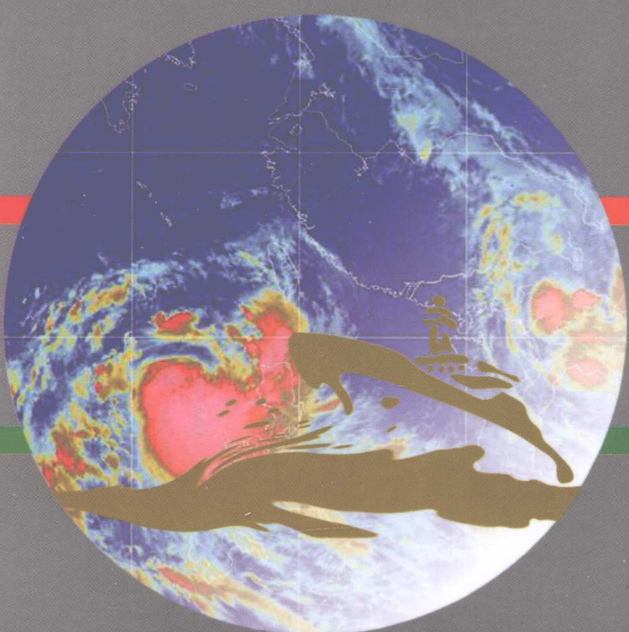
# 航海气象学与海洋学

## Meteorology and Oceanography for Mariners

（英文版）

刘大刚　冷　梅　主编

张永宁　主审



大连海事大学出版社

# 航海气象学与海洋学

## Meteorology and Oceanography for Mariners

（英文版）

刘大刚　冷　梅　主编

张永宁　主审

大连海事大学出版社

## Abstract

This book is applicable to the deck mates aiming at observing and recording weather conditions and in interpreting prevailing conditions to predict future weather patterns and also to professionally study weather forecasts. This book is organized into five sections. Starting with the basic knowledge of the meteorological elements, temperature, pressure, humidity, wind, cloud, visibility and weather phenomena are briefed. An emphasis on Buys – Ballot Law explains the formation of the wind and the relationship between the wind and air pressure field. Then weather systems often encountered at sea, such as fronts, cyclones and anticyclones, are covered. Tropical cyclones produce the most severe weather so we have much discussion on the topic. The following section is the summary of the ocean climatology. The fourth section is the introduction of ocean current, waves, and sea ice. The last section of the book recites the weather information and services available at sea. Fax charts are by far the most valuable forecasting tool at our disposal. We cannot emphasize too strongly the importance of understanding these charts, and having a reliable means to receive them.

This book is to be used as a textbook for the course of *Meteorology and Oceanography for Mariners* in Dalian Maritime University. This book may also be used by mariners as general reference.



**图书在版编目(CIP)数据**

航海气象学与海洋学 / 刘大刚,冷梅主编 . —大连 : 大连海事大学出版社, 2011. 3
ISBN 978-7-5632-2547-7

Ⅰ. ①航…　Ⅱ. ①刘… ②…冷　Ⅲ. ①航海学:气象学②海洋学　Ⅳ. ①U675. 12②P7

中国版本图书馆 CIP 数据核字(2011)第 032867 号

**大连海事大学出版社出版**

地址:大连市凌海路 1 号　邮政编码:116026　电话:0411-84728394　传真:0411-84727996

http://www. dmupress. com　E-mail:cbs@ dmupress. com

大连印刷三厂印装　大连海事大学出版社发行

2011 年 3 月第 1 版　2011 年 3 月第 1 次印刷

幅面尺寸:185 mm×260 mm　印张:9. 25

字数:180 千　印数:1~1000 册

责任编辑:董玉洁　版式设计:冰　清

封面设计:王　艳　责任校对:李继凯

ISBN 978-7-5632-2547-7　定价:19. 00 元

# Contents

CHAPTER 1 BASIC KNOWLEDGE OF THE ATMOSPHERE AND METEOROLOGICAL ELEMENTS ........ (1)
1.1 The Atmosphere ........ (1)
1.1.1 Introduction ........ (1)
1.1.2 Vertical Structure of the Atmosphere ........ (1)
1.1.3 Composition of the Atmosphere ........ (2)
1.2 Solar Radiation and Air Temperature ........ (4)
1.2.1 Solar Radiation ........ (4)
1.2.2 Air Temperature and Temperature Scales ........ (5)
1.2.3 Diurnal and Annual Variations of Air Temperature ........ (6)
1.3 Atmospheric Pressure ........ (6)
1.3.1 Air Pressure and Its Units ........ (6)
1.3.2 Variation of Pressure with Height ........ (7)
1.3.3 Diurnal and Annual Variations of Air Pressure ........ (8)
1.3.4 Isobars ........ (8)
1.3.5 Pressure Gradient ........ (8)
1.3.6 Common Types of Pressure Fields ........ (9)
1.4 Stability of the Atmosphere ........ (10)
1.4.1 Concept of Stability ........ (10)
1.4.2 Adiabatic Lapse Rate ........ (11)
1.4.3 Equilibrium of Stability ........ (11)
1.4.4 Stability and Weather ........ (12)
1.5 Air Humidity ........ (13)
1.5.1 Characteristics of Vapor in the Atmosphere ........ (13)
1.5.2 Description of Air Humidity ........ (13)
1.5.3 Variations of Absolute Humidity ........ (15)
1.5.4 Variations of Relative Humidity ........ (15)
1.6 Wind ........ (15)
1.6.1 Definition and Description of Wind ........ (15)
1.6.2 The Beaufort Scale of Wind Force ........ (16)
1.6.3 Geostrophic Wind and Gradient Wind ........ (18)
1.6.4 Buys Ballot's Law ........ (20)
1.6.5 The Effect of Friction ........ (20)
1.7 Clouds and Precipitation ........ (21)
1.7.1 The Formation of Clouds ........ (21)

1.7.2 The International Classification of Clouds …… (21)
1.7.3 Cloud Cover …… (24)
1.7.4 Types of Precipitation …… (24)
1.7.5 Intensity of Precipitation …… (25)
1.8 Visibility and Fog …… (26)
1.8.1 Definition and Classification of Visibility …… (26)
1.8.2 Definition and Classification of Fog …… (27)
1.8.3 Main Types of Fog …… (28)
1.9 Shipborne Observation and Shipborne Meteorological Instruments …… (29)
1.9.1 Shipborne Observations …… (29)
1.9.2 Code Used for the Transmission of Ships Weather Messages …… (29)
1.9.3 Non-Routine Reports …… (29)
1.9.4 Visibility Measurement …… (30)
1.9.5 Wind Measurement …… (31)
1.9.6 Temperature Measurement …… (31)
1.9.7 Air Pressure Measurement …… (32)
1.9.8 Weather Phenomena …… (33)
1.9.9 Cloud Types and Amounts …… (34)
1.9.10 Observing Ocean Waves …… (35)
**CHAPTER 2 WEATHER SYSTEMS** …… (36)
2.1 Weather Charts …… (36)
2.1.1 Outline of Weather Charts …… (36)
2.1.2 Weather Chart Projections …… (36)
2.1.3 Surface Charts …… (38)
2.2 Air Masses and Fronts …… (41)
2.2.1 Air Mass …… (41)
2.2.2 Front Classification …… (43)
2.2.3 Frontal Elements …… (44)
2.2.4 Weather and Fronts …… (45)
2.3 Extra-tropical Anticyclone …… (53)
2.3.1 Outline of Anticyclone …… (53)
2.3.2 Siberian High …… (54)
2.3.3 Weather Associated with the Extra-tropical Anticyclone …… (55)
2.3.4 Movement of Extra-tropical Anticyclone …… (55)
2.3.5 Cold Air Grades …… (56)
2.4 Subtropical High …… (56)
2.4.1 Formation and Distribution …… (56)
2.4.2 Monitoring of the Northwest Pacific Subtropical High …… (57)
2.4.3 Migration of Subtropical High …… (57)

2.4.4 Subtropical High Weather ······ (58)
2.5 Extratropical Cyclone ······ (59)
2.5.1 Outline Extratropical Cyclone ······ (59)
2.5.2 Cyclogenesis ······ (60)
2.5.3 Weather Associated with Extratropical Cyclones ······ (61)
2.5.4 Cyclone Tracking ······ (62)
2.6 Tropical Cyclones ······ (62)
2.6.1 Outline of Tropical Cyclone ······ (62)
2.6.2 Locations and Seasons ······ (64)
2.6.3 Classifications, Terminology and Naming ······ (66)
2.6.4 Chinese Warning System ······ (69)
2.6.5 Conditions Necessary for the Formation of TCs ······ (70)
2.6.6 Structure and Size ······ (70)
2.6.7 Dissipation of Tropical Cyclones ······ (73)
2.6.8 Movement and Track ······ (74)
2.6.9 Observation and Forecasting ······ (76)
2.6.10 Avoiding Tropical Cyclones ······ (78)
**CHAPTER 3 BASIC KNOWLEDGE OF CLIMATOLOGY** ······ (84)
3.1 Wind and Pressure Systems ······ (84)
3.1.1 Three-cell Circulation Model ······ (84)
3.1.2 Major Wind Patterns ······ (86)
3.1.3 Observed Wind and Pressure Fields ······ (88)
3.1.4 Monsoon ······ (89)
3.1.5 Sea and Land Breezes ······ (94)
3.2 Areas and Seasons of Strong Winds at Sea ······ (95)
3.3 Distribution of Sea Fog ······ (96)
3.3.1 General Distribution of Sea Fog ······ (96)
3.3.2 Foggy Locations in the Ocean ······ (97)
**CHAPTER 4 BASIC KNOWLEDGE OF OCEANOGRAPHY** ······ (99)
4.1 Ocean Currents ······ (99)
4.1.1 Outline of Ocean Currents ······ (99)
4.1.2 The Formation of Currents ······ (100)
4.1.3 Main Ocean Currents ······ (101)
4.1.4 El Niño-Southern Oscillation (ENSO) ······ (103)
4.2 Sea Waves ······ (104)
4.2.1 Description of Sea Waves ······ (104)
4.2.2 Formation of Waves ······ (105)
4.2.3 Types of Wind Waves ······ (105)
4.2.4 Effects of Currents on Waves ······ (107)

4.2.5 Effects of Ice on Waves …… (107)
4.2.6 Tsunamis …… (107)
4.2.7 Storm Tides …… (109)
4.3 Sea Ice …… (109)
4.3.1 Types of Sea Ice …… (109)
4.3.2 Iceberg Drift …… (110)
4.3.3 Extent of Ice in the Sea …… (111)
**CHAPTER 5 WEATHER INFORMATION AND SERVICES** …… (113)
5.1 Weather Information for Shipping …… (113)
5.1.1 Introduction of WMO …… (113)
5.1.2 Receiving Marine Weather Forecast Products Onboard …… (114)
5.1.3 Radiofax Weather Charts …… (115)
5.2 Interpretation and Application of Weather Charts …… (116)
5.2.1 Interpretation and Application of Surface Charts …… (116)
5.2.2 Interpretation and Application of Wave Charts …… (121)
5.2.3 TC Warning Reports and TC Forecast Charts …… (124)
5.2.4 Interpretation and Application of Satellite Imagery …… (125)
5.2.5 Interpretation and Application of Other Charts …… (127)
5.3 Introduction to Weather Routing …… (130)
5.3.1 Outline of Weather Routing …… (130)
5.3.2 Ship and Cargo Considerations …… (131)
5.3.3 Environmental Factors …… (132)
5.3.4 Synoptic Weather Considerations …… (134)
5.3.5 Types of Recommendations and Advisories …… (135)
5.3.6 Communications …… (136)
**Bibliography** …… (137)

# CHAPTER 1 BASIC KNOWLEDGE OF THE ATMOSPHERE AND METEOROLOGICAL ELEMENTS

## 1.1 The Atmosphere

### 1.1.1 Introduction

**The atmosphere** is the envelope of gases surrounding the Earth.

Weather is a set of all the phenomena occurring in a given atmosphere at a given time. Weather refers, generally, to day-to-day temperature and precipitation activity, whereas climate is the term for the average atmospheric conditions over a much longer period of time.

**Meteorology** is the scientific study of the atmosphere. Maritime meteorology mainly deals with air and wave forecasts for ships operating at sea.

Commercial and recreational use of waterways can be limited significantly by wind direction and speed, wave periodicity and heights, tides, and precipitation. These factors can each influence the safety of marine transit. Consequently, a variety of codes have been established to efficiently transmit detailed marine weather forecasts to vessel pilots via radio, for example the MAFOR (marine forecast). Typical weather forecasts can be received at sea through the use of RTTY, Navtex and Radiofax.

Organizations such as the Ocean Prediction Center, Honolulu National Weather Service Forecast Office, United Kingdom Met Office, and JMA prepare high seas forecasts for the world's oceans.

### 1.1.2 Vertical Structure of the Atmosphere

The Earth's atmosphere contains several different layers that can be defined according to air temperature.

The troposphere is the lowest portion of the Earth's atmosphere. It contains approximately 75% of the atmosphere's mass and 99% of its water vapor and aerosols.

In the middle latitudes the average depth of the troposphere is approximately 12 km. It is deeper in the tropical regions, up to 20 km, and shallower near the poles, at 7 km in summer, and indistinct in winter.

The lowest part of the troposphere, where friction with the Earth's surface influences air flow, is the **planetary boundary layer.** This layer is typically a few hundred meters to 2 km deep depending on the landforms under neath and time of day.

The word troposphere derives from the Greek: tropos for "turning" or "mixing", reflecting the fact that turbulent mixing plays an important role in the troposphere's structure and behavior.

Weather elements (temp, humidity, stability) distribute unevenly in this layer.

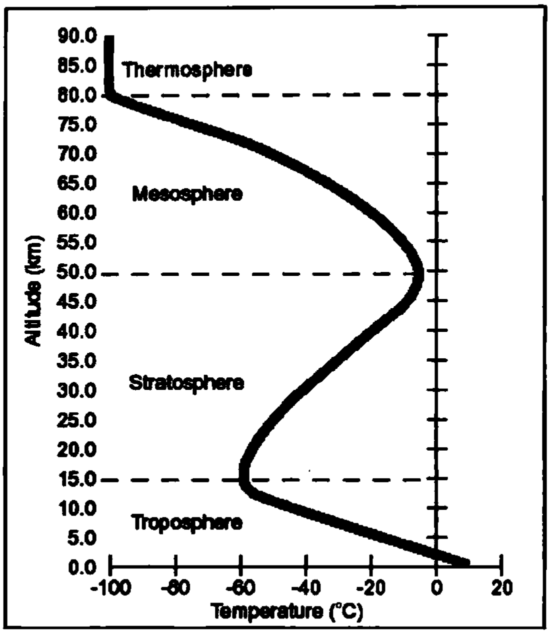



**Figure 1.1 Structure of the Atmosphere**

Most of the phenomena we associate with day-to-day weather occur in the troposphere.

In the troposphere, the average environmental lapse rate is a drop of about 6.5 °C for every 1 km increase in height.

The border between the troposphere and stratosphere is called the tropopause.

The region of the atmosphere where the lapse rate changes from positive (in the troposphere) to negative (in the stratosphere), is defined as the tropopause. Thus, the tropopause is an inversion layer, and there is little mixing between the two layers of the atmosphere.

The **stratosphere** is located at about 20 to 55 km above the Earth's surface.

In the **stratosphere**, the temperature remains constant for a while and then increases with altitude because a localized concentration of ozone gas molecules absorbs ultraviolet sunlight creating heat energy.

The **mesosphere** is located at about 55 to 85 km above the Earth's surface and contains little in the way of trace gases so there is little to absorb heat from the sun. The lowest temp is about −90 °C.

**The thermosphere** is at a height of above 85 km. The temperatures there can be higher than 1000 °C.

The ionosphere extends from 80 to 400 km above the Earth's surface.

### 1.1.3 Composition of the Atmosphere

The chemical composition of the troposphere is essentially uniform, with the notable exception of water vapor.

**Table 1.1 Constituents of the Atmosphere**

| Gas Name | Chemical Formula | Percent Volume |
|---|---|---|
| Nitrogen | $N_2$ | 78.09 |
| Oxygen | $O_2$ | 20.95 |
| Argon | Ar | 0.93 |
| Water Vapor | $H_2O$ | 0 ~ 4 |
| Carbon Dioxide | $CO_2$ | 0.03 |
| Ozone | $O_3$ | 0.00006 |

The table shows that nitrogen and oxygen are the main components of the atmosphere by volume. Together these two gases make up approximately 99% of the dry atmosphere. Both of these gases have very important associations with life.

Another most abundant gas on the table is **water vapor**.

Water vapor varies in concentration in the atmosphere both spatially and temporally. The highest concentrations of water vapor are found near the equator over the oceans and tropical rain forests. Cold polar areas and subtropical continental deserts are locations where the volume of water vapor can approach zero percent. Water vapor has several very important functional roles on our planet.

It redistributes heat energy on the Earth through latent heat energy exchange. The condensation of water vapor creates precipitation that falls to the Earth's surface providing needed fresh water for plants and animals. It helps warm the Earth's atmosphere through the Greenhouse Effect.

**Carbon dioxide** in the Earth's atmosphere is considered a trace gas currently occurring at an average concentration of about 383 parts per million by volume or 582 parts per million by mass.

Atmospheric concentrations of carbon dioxide fluctuate slightly with the change of the seasons, driven primarily by seasonal plant growth in the Northern Hemisphere.

Concentrations of carbon dioxide fall during the northern spring and summer as plants consume the gas, and rise during the northern autumn and winter as plants go dormant, die and decay. Carbon dioxide is a greenhouse because it transmits visible light but strongly absorbs infrared and near-infrared energy.

**Ozone** in the lower atmosphere is an air pollutant with harmful effects on the respiratory systems of animals and will burn sensitive plants. However, the ozone layer in the upper atmosphere is beneficial, preventing potentially damaging ultraviolet light from reaching the Earth's surface. Ozone is present in low concentrations throughout the Earth's atmosphere.

The highest levels of ozone in the atmosphere are in the stratosphere, in a region also known as the ozone layer between about 10 km and 50 km above the surface.

In recent decades the amount of ozone in the stratosphere has been declining mainly because of emissions of CFCs (chlorofluorocarbons), and similar chlorinated and brominated organic molecules, which have increased the concentration of ozone-depleting catalysts above the natural background. Ozone only makes up 0.00006% of the atmosphere.

Technically, an **aerosol** is a suspension of fine solid particles or liquid droplets in a gas, such as smoke, oceanic haze, air pollution, smog and CS gas ("tear gas").

The word aerosol derives from the fact that matter "floating" in air is a suspension (a mixture in which solid or liquid or combined solid-liquid particles are suspended in a fluid). To differentiate suspensions from true solutions, the term sol evolved-originally meant to cover dispersions of tiny (sub-microscopic) particles in a liquid.

With studies of dispersions in air, the term "aerosol" evolved and now embraces liquid droplets, solid particles, and combinations of these.

## 1.2 Solar Radiation and Air Temperature

### 1.2.1 Solar Radiation

**Electromagnetic radiation** (often abbreviated **E-M radiation** or **EMR**) is a phenomenon that takes the form of self-propagating waves in a vacuum or in matter.

Electromagnetic radiation is classified into several types according to the frequency of its wave; these types include (in order of increasing frequency and decreasing wavelength): radio waves, microwaves, terahertz radiation, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays. A small and somewhat variable window of frequencies is sensed by the eyes of various organisms; this is what is called the visible spectrum, or light.

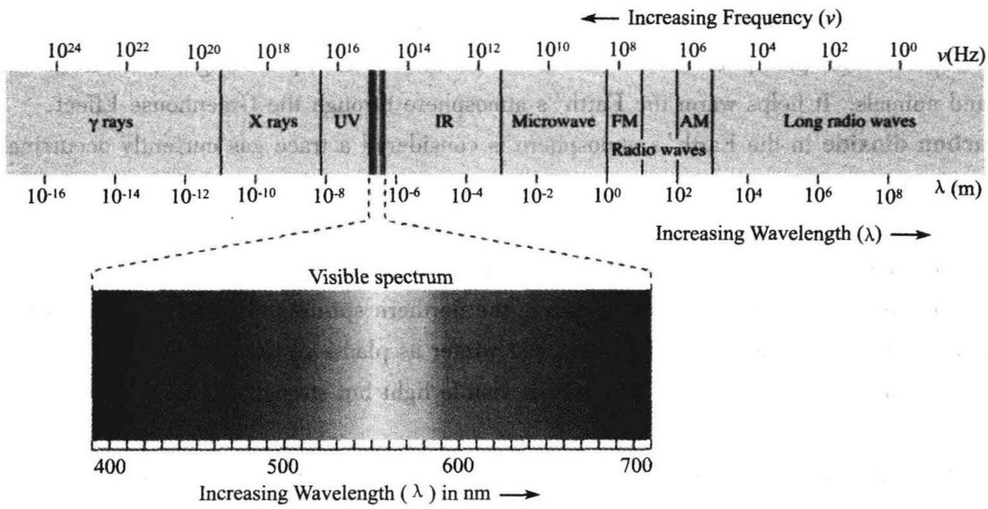



**Figure 1.2 Electromagnetic Radiation**

The behavior of E-M radiation depends on its wavelength. Higher frequencies have shorter wavelengths, and lower frequencies have longer wavelengths.

**Thermal radiation** is electromagnetic radiation emitted from the surface of an object which is due to the object's temperature.

**Outgoing Long-wave Radiation (OLR)** is the energy leaving the Earth as infrared radiation at low energy.

The Earth's radiation balance is very closely achieved since the OLR very nearly equals the **Shortwave Absorbed Radiation (SAR)** received as high energy from the sun. Thus, the first law of thermodynamics (energy conservation) is satisfied and the Earth's average temperature is very nearly stable. See Figure 1.3.

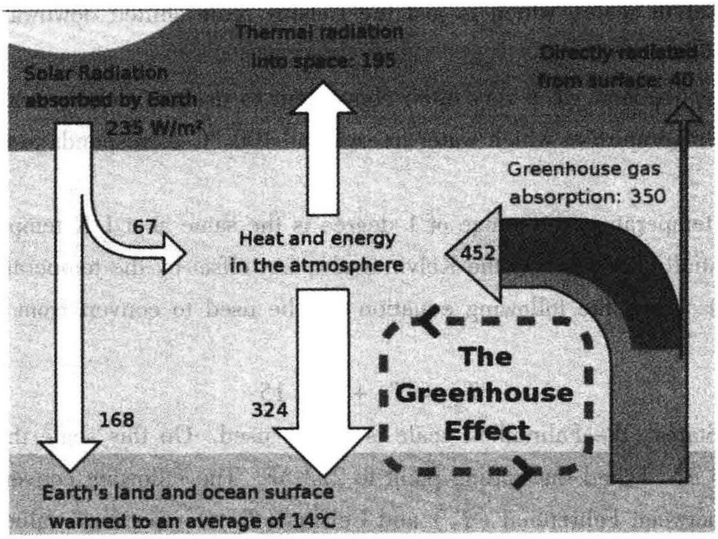



**Figure 1.3  Exchanges of Energy Between outer Space, the Earth's Atmosphere, and the Earth's Surface**

The OLR is affected by clouds and dust in the atmosphere, which tend to reduce it below clear sky values.

The OLR is dependent on the temperature of the radiating body.

The ability of the atmosphere to capture and recycle energy emitted by the Earth surface is the defining characteristic of the **Greenhouse Effect.**

The Greenhouse Effect is caused by an atmosphere containing gases such as water vapor and $CO_2$ that absorb and emit infrared radiation.

**Greenhouse gases**, such as methane ($CH_4$), nitrous oxide ($N_2O$), water vapor ($H_2O$) and carbon dioxide ($CO_2$), absorb certain wavelengths of OLR adding heat to the atmosphere, which in turn causes the atmosphere to emit more radiation. Greenhouse gases trap heat within the surface-troposphere system, causing heating at the surface of the planet. Some of this radiation is directed back towards the Earth, increasing the average temperature of the Earth's surface.

Therefore, an increase in the concentration of a greenhouse gas would contribute to global warming by increasing the amount of radiation that is absorbed and emitted by these atmospheric constituents.

### 1.2.2 Air Temperature and Temperature Scales

Air temperature is a measure of the average energy of motion, or kinetic energy, of particles in the air.

Temperature is measured with thermometers that may be calibrated to a variety of temperature scales.

Temperature measurement using modern scientific thermometers and temperature scales goes back at least as far as the early 18th century, when Gabriel Fahrenheit adapted a thermometer (switching to mercury) and a scale.

The scientific world measures air temperature using the Celsius scale and thermodynamic temperature using the Kelvin scale, which is just the Celsius scale shifted downwards so that 0 K = −273.15 °C, or absolute zero.

For everyday applications, it's very often convenient to use the Celsius scale, in which 0 °C corresponds to the temperature at which water freezes and 100 °C corresponds to the boiling point of water at sea level.

In this scale a temperature difference of 1 degree is the same as a 1 K temperature difference, so the scale is essentially the same as the Kelvin scale, but offset by the temperature at which water freezes (273.15 K). Thus the following equation can be used to convert from degrees Celsius to Kelvin:

$$T_K = T_C + 273.15 \tag{1.2.1}$$

In the United States, the Fahrenheit scale is widely used. On this scale the freezing point of water corresponds to 32 °F and the boiling point to 212 °F. The following conversion formulas may be used to convert between Fahrenheit ($T_F$) and Celsius ($T_C$) temperature values:

$$T_C = \frac{5}{9}(T_F - 32) \tag{1.2.2}$$

$$T_F = \frac{9}{5}T_C + 32 \tag{1.2.3}$$

### 1.2.3 Diurnal and Annual Variations of Air Temperature

Diurnal variation of air temperature means the systematic change of the temperature of the atmosphere during an average of 24-hour period. Usually, the minimum and maximum air temperatures are attained at about 1 hour after sunrise and 1500LMT, and in winter days the maximum air temperature occurs at 1400LMT.

The annual variation of air temperature is linked to the annual cycle of net radiation. Near the equator, there are no temperature seasons, net radiation is positive and shows only two minor peaks (equinoxes). In higher northern, the peak occurs in July on land and August at sea, and in January and February. The temperatures are the accordingly lowest. The annual range increases with latitude, especially over Northern Hemisphere continents. Continental locations have a larger range of daily and annual temperature than coastal locations, even if they are located at the same latitude.

## 1.3 Atmospheric Pressure

### 1.3.1 Air Pressure and Its Units

The atmospheric pressure or air pressure refers to the force which a column at air exerts on unit area of a given point.

**Mean sea level pressure** (MSLP) is the pressure at sea level or (when measured at a given elevation on land) the station pressure reduced to sea level assuming an isothermal layer at the station temperature.

This is the pressure normally given in weather reports on radio, television, and newspapers or on the Internet. When barometers at home are set to match the local weather reports, they measure pressure reduced to sea level, not the actual local atmospheric pressure.

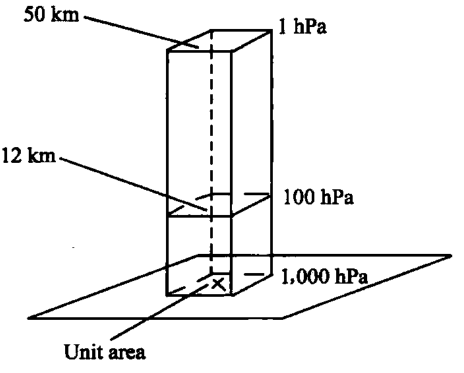



**Figure 1.4 Definition of Air Pressure**

Atmospheric air pressure is often given in millibars (mbar). Despite millibars not being an **SI unit**, meteorologists and weather reporters worldwide have long measured air pressure in millibars. After the advent of SI units, some meteorologists began using hectopascals (symbol **hPa**) which are numerically equivalent to millibars.

The exchange relations are as follows:

$$1\ \text{hPa} = 1\text{mbar} \qquad (1.3.1)$$

$$1\ \text{hPa} = \frac{3}{4}\text{mmHg} \qquad (1.3.2)$$

The **standard atmosphere** is an international reference pressure defined as **101,325 Pa** and formerly used as unit of pressure (symbol: atm). For practical purposes it has been replaced by the bar which is 100,000 Pa (**1,000 hPa**).

Atmospheric pressure varies widely on the Earth. The highest MSL pressure ever recorded on Earth was 1,084 hPa, measured in Agata, U. S. S. R., on December 31, 1968. Agata is located in northern Siberia. The weather was clear and very cold at the time, with temperatures between −40°C and −58°C.

The lowest MSL pressure ever measured was 870 hPa, set on October. 12, 1979, during Typhoon Tip in the western Pacific Ocean. The measurement was based on an instrumental observation made from a reconnaissance aircraft.

### 1.3.2 Variation of Pressure with Height

From the definition of air pressure we can see that low pressure areas have less atmospheric mass above their location, whereas high pressure areas have more atmospheric mass above their location.

**Table1.2 Air Pressures with the Corresponding Average Altitudes**

| Air Pressures | Average Altitudes |
|---|---|
| 850 hPa | 1,500 m |
| 700 hPa | 3,000 m |
| 500 hPa | 5,500 m |
| 300 hPa | 9,000 m |

Similarly, as elevation increases there is less overlying atmospheric mass, so that pressure decreases with increasing elevation. Table 1.2 gives a rough idea of air pressure at various altitudes.

The rate at which the pressure decreases with altitude is not a constant. A good approximation of this is that for every 100 m higher you go in the atmosphere, pressure will decrease by about 10 hPa. This works well up to about 3,000 m above sea level, but the actual rate at any given time is governed by temperature.

Cold air is denser and heavier per unit volume than the warm air, and pressure difference in the cold air column is larger than in the warm air column. Thus pressure falls with height must be greater in the cold column.

In the altitudes close to sea level, it can be considered as a decrease of 1 hPa per 8 m.

### 1.3.3 Diurnal and Annual Variations of Air Pressure

Atmospheric pressure shows a diurnal (twice-daily) cycle caused by global atmospheric tides. This effect is strongest in tropical zones, with amplitude of a few hectopascal, and almost zero in polar areas.

Except when weather systems are present, there are two maximum and two minimum pressures per day, and they occur at a constant local time every day. From a maximum at 1000, the pressure falls to a minimum at 1600, rises to another maximum at 2200, and falls again to a second minimum at 0400 local time.

Annual variation of air pressure refers to the periodic variation of the monthly mean pressure during a year. There is one maximum and one minimum pressure every year. The difference of the two values is called annual range. For continental areas the pressure rises to a maximum in the winter and falls to a minimum in the summer, for oceanic areas the pressure rises to a maximum in the summer, and falls to a minimum in the winter. The annual range on land is greater than that at sea.

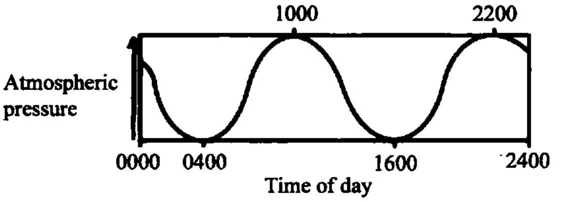



**Figure 1.5 Variation of Pressure During One 24 h Period**

### 1.3.4 Isobar

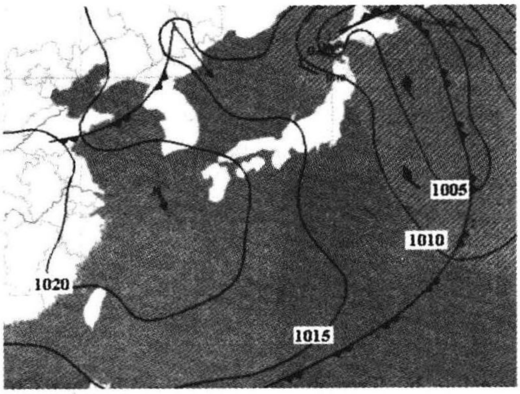
Isobars are lines connecting points of equal atmospheric pressure. On a surface chart, the interval between isobars is always constant, usually being 2.5 or 5 hPa in China, and 2 or 4 or 5 hPa in other countries.

### 1.3.5 Pressure Gradient

The pressure gradient is a physical quantity that describes in which direction and at what rate the pressure changes the most rapidly around a particular location. The pressure gradient is a dimensional quantity expressed in units of pressure per unit length.

The pressure gradient is the vector quantity defined as:

$$-\nabla p = -\left(\frac{\partial p}{\partial x}, \frac{\partial p}{\partial y}, \frac{\partial p}{\partial z}\right) \quad (1.3.3)$$



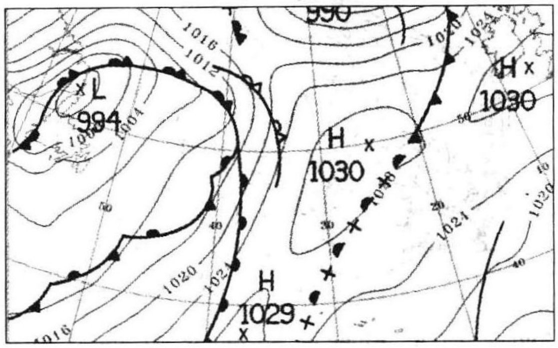




**Figure 1.6.a  Isobars on a Chinese Weather Chart**    **Figure 1.6.b  Isobars on a British Weather Chart**

The horizontal pressure gradient is a 2 – dimensional vector resulting from the projection of the pressure gradient onto a local horizontal plane.

Near the Earth's surface, this horizontal pressure gradient is typically pointing towards low pressure, and noted as $-\frac{\Delta p}{\Delta n}\vec{n}$.

Its particular orientation at any one time and place depends strongly on the weather situation.

The magnitude of the pressure gradient can be assessed by noting the spacing of the isobars. If the isobars are close together, the pressure gradient is large; if the isobars are far apart, the pressure gradient is small.

### 1.3.6 Common Types of Pressure Fields

Centers of surface **high** and **low** pressure areas are found within closed isobars on a surface weather chart where there is absolute maxima and minima in the pressure field, and can show a user in a glance what the general weather is in their vicinity.

Weather charts in English-speaking countries will depict their highs as Hs and lows as Ls, while Spanish-speaking countries will depict their highs as As and lows as Bs, and in China sometimes as Gs and Ds.

A **ridge** is an elongated region of relatively high atmospheric pressure, the opposite of a **trough**. The area of almost constant pressure (and therefore few isobars) between two highs and two lows is known as a **col**. Between two highs is a **low belt**, and between two lows is a **high belt**.

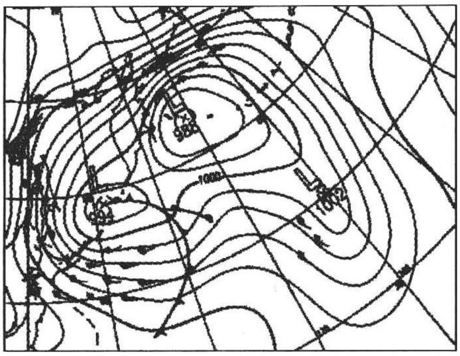


Figure 1.7.a Ridge on a Chinese Weather Chart

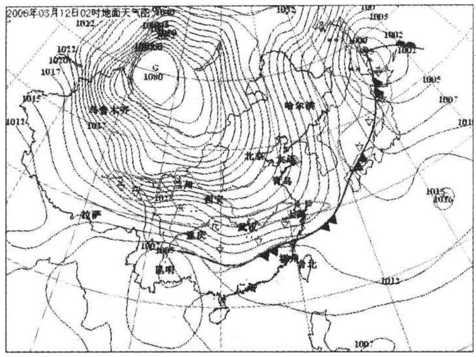


Figure 1.7.b Trough on a Japanese Weather Chart

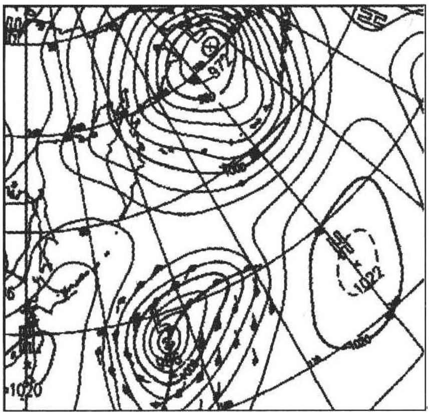



Figure 1.7.c Col on a Chinese Weather Chart

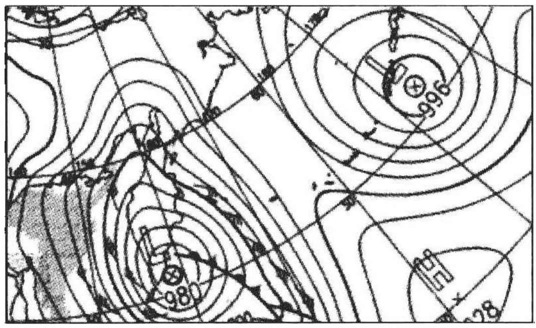



Figure 1.7.d High Belt on a Japanese Weather Chart

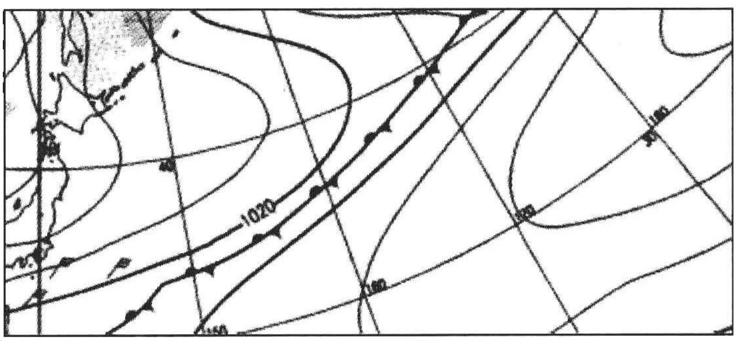



Figure 1.7.e Low Belt on a Korean Weather Chart

## 1.4 Stability of the Atmosphere

### 1.4.1 Concept of Stability

When someone pushes you on a swing, do you keep going in the same direction or do you swing back the other way? If it wasn't a really strong push, you come back. That's because a swing set is a stable system. That means if you don't do anything after you get pushed then you will return to