AOSC400-Fall 2015

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AOSC400-Physical Meteorology of the Atmosphere

- **Text book**: *Atmospheric Science: An introductory survey.* J. M. Wallace and P. V. Hobbs, Academic Press, 2006, ISBN-13: 978-0127329512.
- *Chapters 1, 4 and 9.*

Book placed on reserve in the Engineering Library.

Reading articles will be placed on ELMS.

Previous Title of Course :

The Atmosphere: Theory, Observations, Prediction

Title (and content) changed to:

Physical Meteorology of the Atmosphere

To satisfy Federal and American Meteorological Society guidelines for undergraduate degrees in meteorology and oceanography for accreditation**,** title and content was somewhat modified

- The course serves as an early course for majors and an advanced course for non-majors
- Attracts a diverse audience

Course Objective

- Application of basic classical physics, chemistry and mathematics to the study of the atmosphere.

- <u>Specifically:</u>

- Composition and structure of the atmosphere; energy sources and sinks; radiation in the atmosphere; radiative balance and radiative forcing of atmospheric processes; atmospheric electricity and optics; atmospheric boundary layer; evolution of the boundary layer; turbulence; *surface energy balance*; special effects in the boundary layer.

Grading:

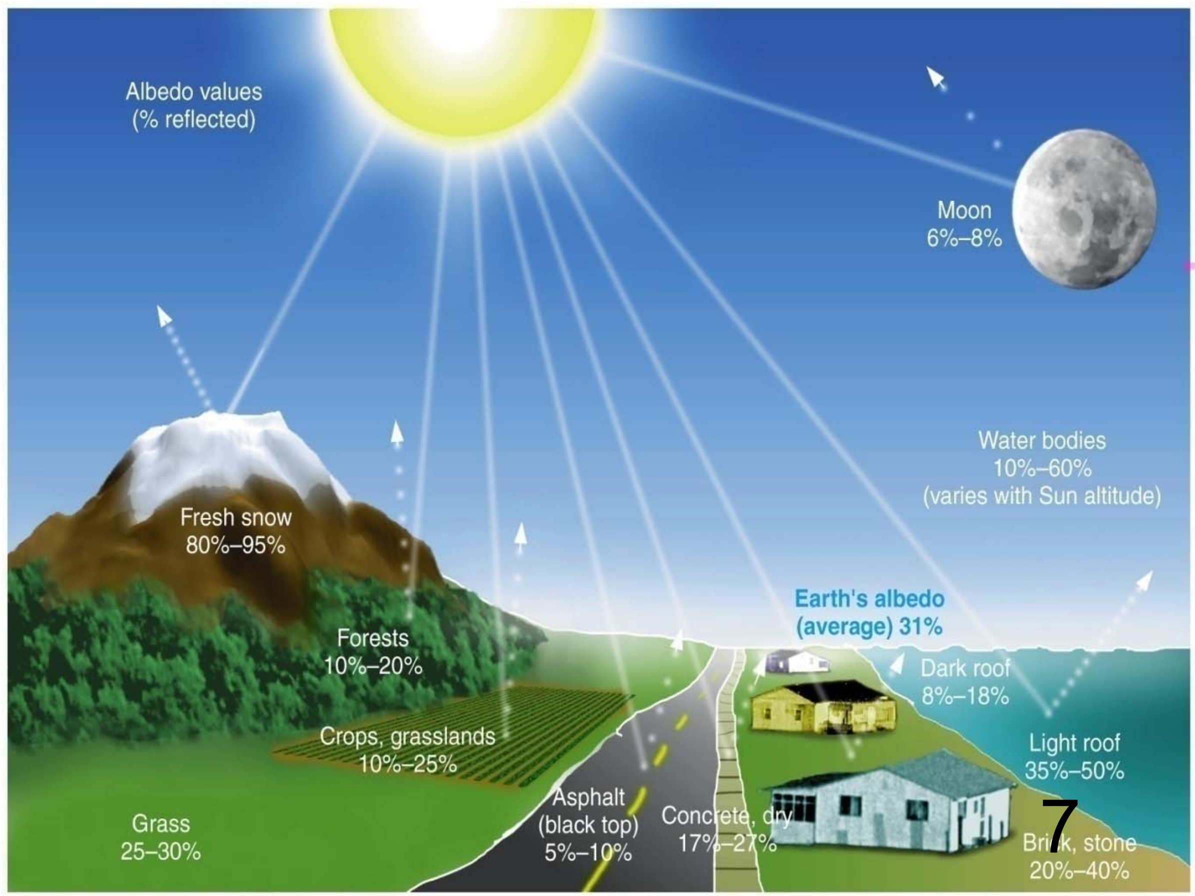
- Grades will be based on:
- Homework (20%): Total of 7-8 assignments, problem solving and/or multiple choice.
- Midterm exam (25%).
- Project (15%): Team or individual work on a selected and pre-approved topic.
- Final exam (35%): Cover the content of the whole semester, emphasizing second half.
- A final group presentation of 10-15 min on project. (5%).
- Pop-quiz-extra 2 points each, to be added to grade of Final Exam; no make-ups for pop-quiz.
- Reading references will be provided. They will be designated as *required* or *voluntary* reading.
- Will use ELMS.

Provide Student Information

- Your Name
- Standing (Year)
- Major
- Math and Physics Background
- Computer skills
- Topic of most interest
- Why are you taking this course?
- What type term project you prefer (presentation only, term paper, computer based research topic)

AOSC400 - 2015
September 1,   2015, Lectures # 1

- Introduction
- Atmosphere and its role in heating of the Earth



The atmosphere is characterized by:

- atmospheric composition
- atmospheric moisture
- vertical structure
- gas laws

- The atmosphere is a *differentially absorbing* medium of electromagnetic radiation. Thermodynamic variables depend on differential absorption of electromagnetic radiative energy
- The atmosphere is a *rotating fluid system*
- *Differences in pressure* between two points establish mechanical forces which may cause accelerations through the principle of conservation of momentum
- Thermodynamics is coupled with *fluid dynamics*
- The atmosphere is a coherently integrated system; all factors interact to produce the behavior of global weather and climate

Need to understand the role of the atmosphere in heating of the Earth:

First:

- Atmospheric layers
- Atmospheric composition
- Important atmospheric greenhouse gases
- Effect of atmospheric composition on Earth's temperature

<u>The atmosphere</u> is the thin blue region along the edge of the earth. Photo taken from the International Space Station on April 12, 2011, over western South America.

NASA/JSC

Atmosphere

- *Thin film* of gaseous mixtures.
- Distributed almost *uniformly* over the surface of earth.
- In the vertical, more than 99% of mass found *below 30 km*.
- Horizontal dimensions may be represented by distance between poles (20, 000 km); if proportion preserved, thickness of atmosphere on an office globe-a coat of paint.
- Yet-atmosphere-central component of climate system.

- Because the atmosphere is shallow, its motion is primarily horizontal.
- Horizontal wind speeds are significantly greater than vertical wind speeds.
- Yet, the small vertical displacements of air have an important impact on the state of the atmosphere.

Definitions and Terms of Reference

Atmospheric phenomena are adequately represented in terms of a spherical coordinate system, rotating with the Earth.

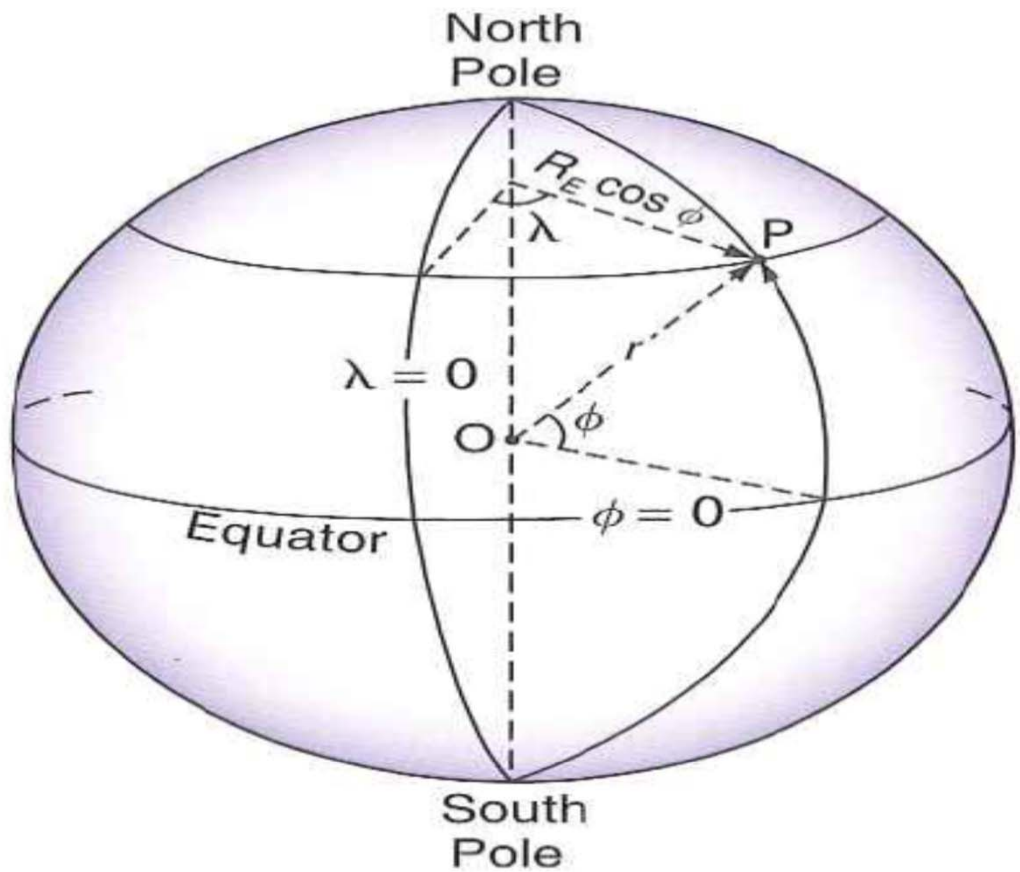
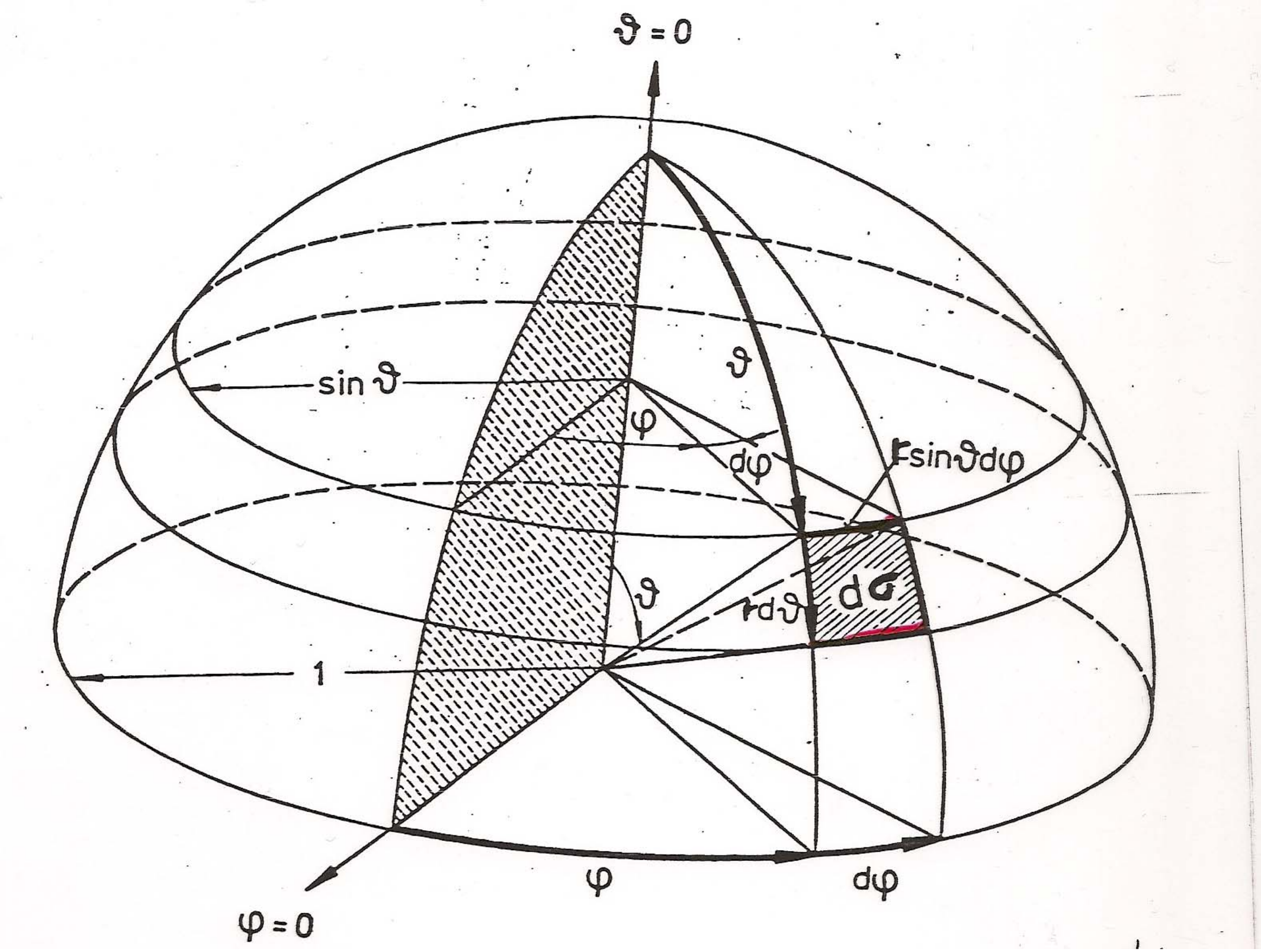


Fig. 1.4 Coordinate system used in atmospheric science. Angle ϕ is latitude, defined as positive in the northern hemisphere and negative in the southern hemisphere, and λ is longitude relative to the Greenwich meridian, positive eastward.

Element of solid angle



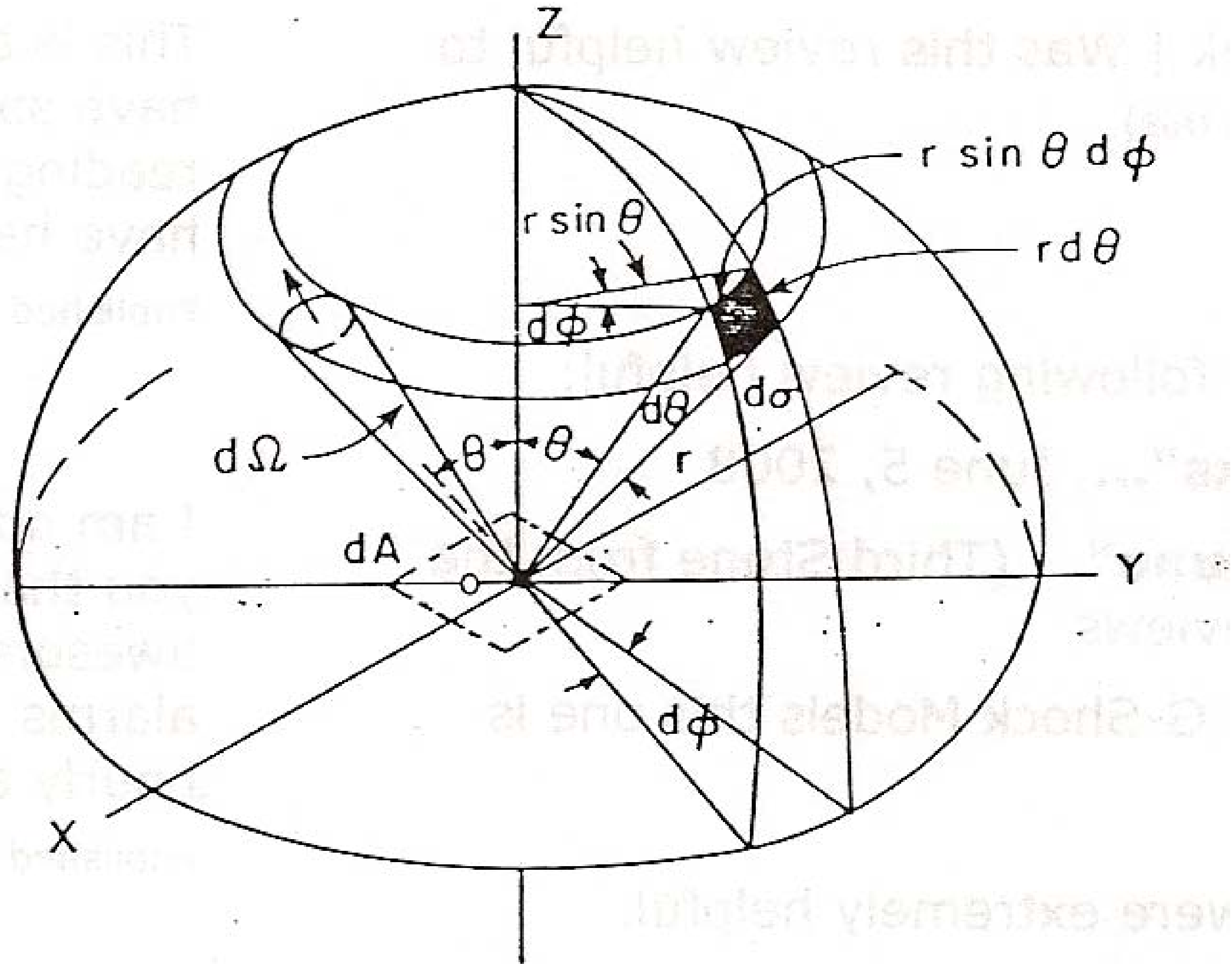


Illustration of a solid angle in polar coordinates and a pencil of radiation through an element of area dA in directions confined to an element of solid angle dΩ

Definitions and Terms of Reference

- Latitude- *φ;* longitude –λ; height -*z* above sea level. Or:

$$dy = r\, d\varphi$$

$$dx = r\, d\lambda \cos \varphi \qquad (1.1)$$

x is distance east of the Greenwich meridian along a latitude circle, *y* is distance north of the equator, r is distance from center of Earth.

In second figure:

$$dy = r d\theta$$

$$dx = r\, d\varphi \sin \theta$$

The three velocity components used in describing atmospheric motions are defined as

$$u \equiv \frac{dx}{dt} = R_E \cos\phi \frac{d\lambda}{dt} \quad \text{(the \textit{zonal velocity component})},$$

$$v \equiv \frac{dy}{dt} = R_E \frac{d\phi}{dt} \quad \text{(the \textit{meridional velocity component})},$$

and

$$w \equiv \frac{dz}{dt} = \frac{dr}{dt} \quad \text{(the \textit{vertical velocity component})}.$$

Zonal average - an average around latitude circles;
Meridional cross section - a north-south slice through the atmosphere.

The *horizontal velocity vector* **V** is given by

$$\mathbf{V} = u\mathbf{i} + v\mathbf{j}$$

where **i** and **j** are the unit vectors in the zonal and meridional directions, respectively.
Positive and negative zonal velocities are referred to as *westerly* (from the west) and *easterly* (from the east) winds, respectively;
Positive and negative meridional velocities are referred to as *southerly* and *northerly* winds.

For scales of motion in the atmosphere in excess of 100 km, the length scale greatly exceeds the depth scale, and typical magnitudes of the horizontal velocity component v exceed those of the vertical velocity component *w* by several orders of magnitude. For these scales the term *wind* is synonymous with *horizontal velocity component.* The SI unit for velocity (or speed) is $m\ s^{-1}$. One meter per second is equivalent to 1.95 knots (1 knot = 1 nautical mile per hour). Vertical velocities in large-scale atmospheric motions are often expressed in units of $cm\ s^{-1}$: 1 $cm\ s^{-1}$ is roughly equivalent to a vertical displacement of 1 kilometer per day.

Throughout this book, the local derivative

$$\partial/\partial t$$

refers to the rate of change at a fixed point in rotating *(x, y, z)* space and the total time derivative *d/ dt* refers to the rate of change following an air parcel as it moves along its three-dimensional trajectory through the atmosphere. These so-called *Eulerian and Lagrangian rates of change are related by the chain rule*

$$\frac{d}{dt} = \frac{\partial}{\partial t} + u\frac{\partial}{\partial x} + v\frac{\partial}{\partial y} + w\frac{\partial}{\partial z}$$

$$\frac{\partial}{\partial t} = \frac{d}{dt} - u\frac{\partial}{\partial x} - v\frac{\partial}{\partial y} - w\frac{\partial}{\partial z}$$

The terms involving velocities in above Eq. including the minus signs in front of them, are referred to as *advection terms.* At a fixed point in space the Eulerian and Lagrangian rates of change of a variable *ψ,* differ by virtue of the advection of air from upstream, which carries with it higher or lower values of *ψ.* For a hypothetical *conservative tracer,* the Lagrangian rate of change is identically equal to zero, and the Eulerian rate of change is

$$\frac{\partial}{\partial t} = -u\frac{\partial}{\partial x} - v\frac{\partial}{\partial y} - w\frac{\partial}{\partial z}$$

Learning Objectives

- Overview of course
- Plan for the semester *(possible minor modifications)*
- The structure of the atmosphere and its role in heating of the Earth *(to be continued)*
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