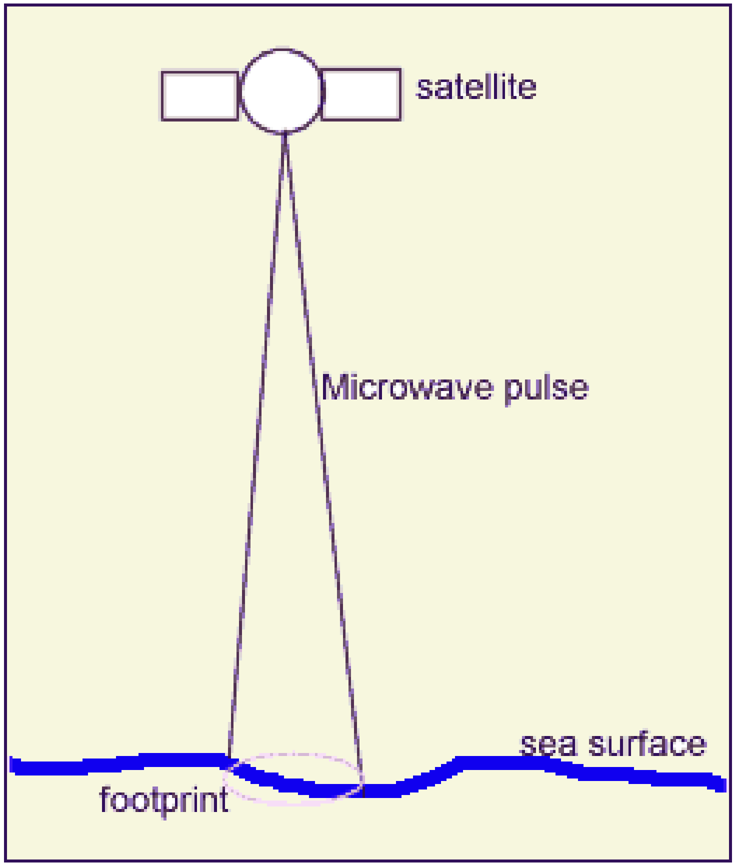
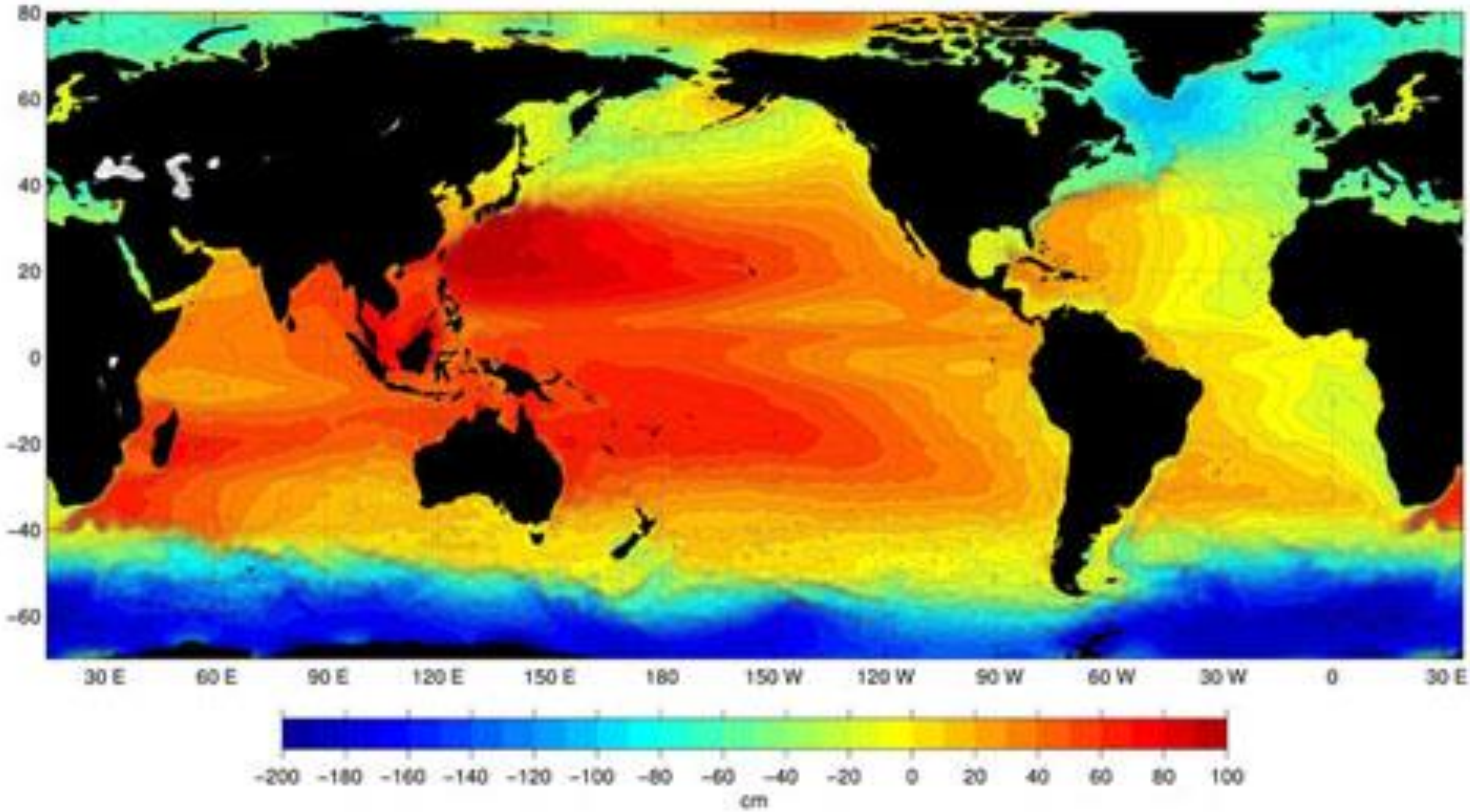
Ocean Surface Altimetry





80
60
40
20
0
-20
-40
-60
30 E
60 E
90 E
120 E
150 E
180
150 W
120 W
90 W
60 W
30 W
0
30 E
-200
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
cm

The next lectures deal with *fluid dynamics*

We study the forces acting on fluid elements (parcels) and how these forces affect the velocity of a parcel, and therefore its position

Recall *Newton's laws of motion*:

-An object at rest will remain at rest unless acted on by a force

-An object in motion will remain in motion unless acted on by a force

-Forces are related to the parcel acceleration (time rate of change of velocity) via the *equation of motion*.

- Parcel acceleration is proportional to the sum of forces acting on the parcel

$m \cdot \mathbf{a} = \sum \mathbf{F}$ where, $\mathbf{a} = \frac{d\mathbf{V}}{dt}$ and $\mathbf{V} = \frac{d\mathbf{x}}{dt}$

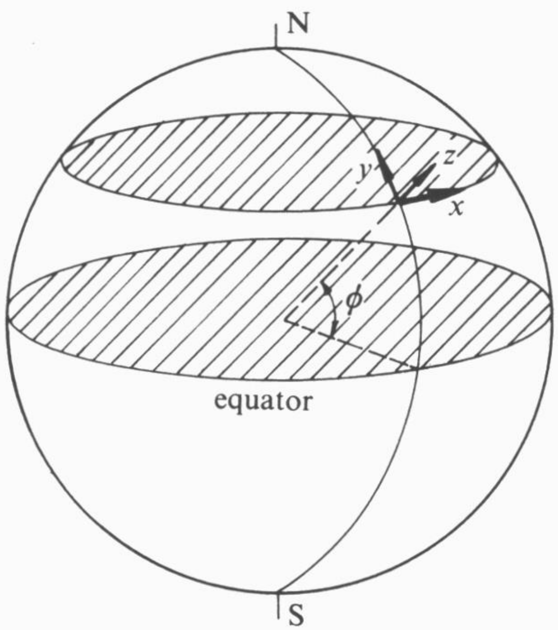
In these lectures I am going to focus on *horizontal* motion (currents)

1) Currents are “driven” by the horizontal pressure gradient force

2) In the absence of other horizontal forces, the pressure gradient force directs water from regions of high pressure to regions of low pressure

A convenient set of axes at any point on the earth's surface (fig. 7.2) has x directed towards the east, y towards the north and z vertically upwards (or more precisely in the direction of the vector defined by (7.5)). This set is not strictly Cartesian because the directions of the axes are functions of position on the spherical earth. If u, v, w are the components of the velocity $\mathbf{V}$ in the x, y, z

Fig. 7.2



Horizontal equations of motion (velocity component form):

$$\frac{du}{dt} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + 2\Omega \sin(\varphi)\cdot v + A_z \frac{\partial^2 u}{\partial z^2}$$

$$\frac{dv}{dt} = -\frac{1}{\rho}\frac{\partial p}{\partial y} - 2\Omega \sin(\varphi)\cdot u + A_z \frac{\partial^2 v}{\partial z^2}$$

u	v	p
west-to-east velocity	south-to-north velocity	pressure

Ω	φ
Angular velocity of the earth	Latitude angle

A_z	ρ
Turbulent diffusivity	water density

x	y	z
west-to-east direction	south-to-north direction	upward direction

The *Coriolis parameter*:

$$f = 2 \cdot \Omega \cdot \sin(\varphi)$$

Some things to note about the *Coriolis parameter*:

1. The Coriolis parameter is positive (>0) in the northern hemisphere and negative (<0) in the southern hemisphere

2. This sign change from NH to SH changes the sense of the Coriolis force and thus changes the sense of circulations (more on this below)

Substituting the definition of the Coriolis parameter:

$$\frac{du}{dt} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + f \cdot v + A_z \frac{\partial^2 u}{\partial z^2}$$

$$\frac{dv}{dt} = -\frac{1}{\rho}\frac{\partial p}{\partial y} - f \cdot u + A_z \frac{\partial^2 v}{\partial z^2}$$

Geostrophy or *geostrophic flow*:

1. Ignore acceleration and friction terms in the equation of motion. A reasonable assumption for large-scale motions in the ocean

2. *Geostropy* or *geostrophic flow* imply that the horizontal pressure gradient force is balanced by the horizontal Coriolis force

Here is the x and y *component equations of motion* assuming geostrophy:

$$0 = -\frac{1}{\rho}\frac{\partial p}{\partial x} + f \cdot v$$

$$0 = -\frac{1}{\rho}\frac{\partial p}{\partial y} - f \cdot u$$

Vector velocity assuming geostrophy:

$$\mathbf{V} = \frac{1}{\rho \cdot f}\mathbf{k} \times (\nabla p) \qquad (2)$$

$$u\mathbf{i} + v\mathbf{j} = \frac{1}{\rho \cdot f}\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 0 & 1 \\ \frac{\partial p}{\partial x} & \frac{\partial p}{\partial y} & 0 \end{vmatrix}$$

Definitions of introduced vector quantities:

$\mathbf{V} \equiv$ The horizontal velocity vector, also known as the “flow” or current vector

Application of Equation (2) to Figure 6.2 **Note: Northern Hemisphere**

Assuming geostrophy, we can infer the direction of the Coriolis force in a flow field around high pressure (H) and low pressure (L) in the northern hemisphere