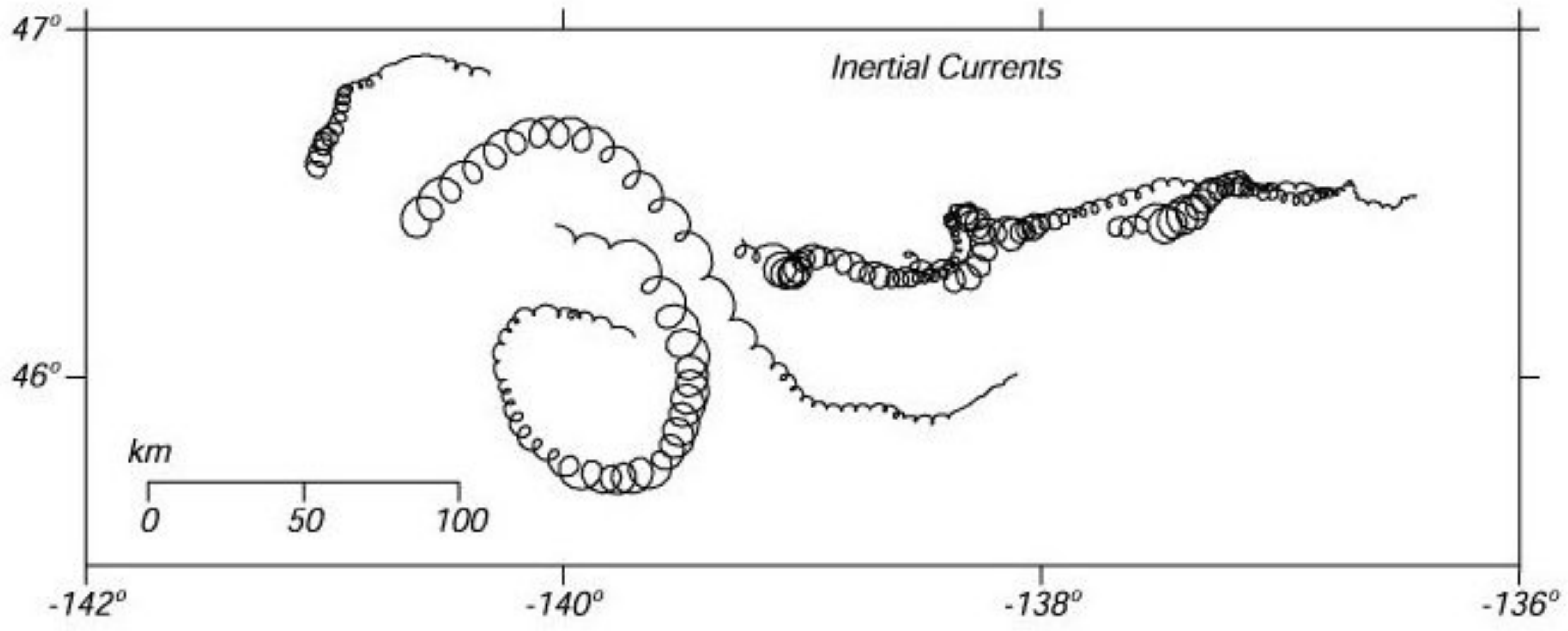
Friction

EPS131, Introduction to Physical Oceanography and Climate

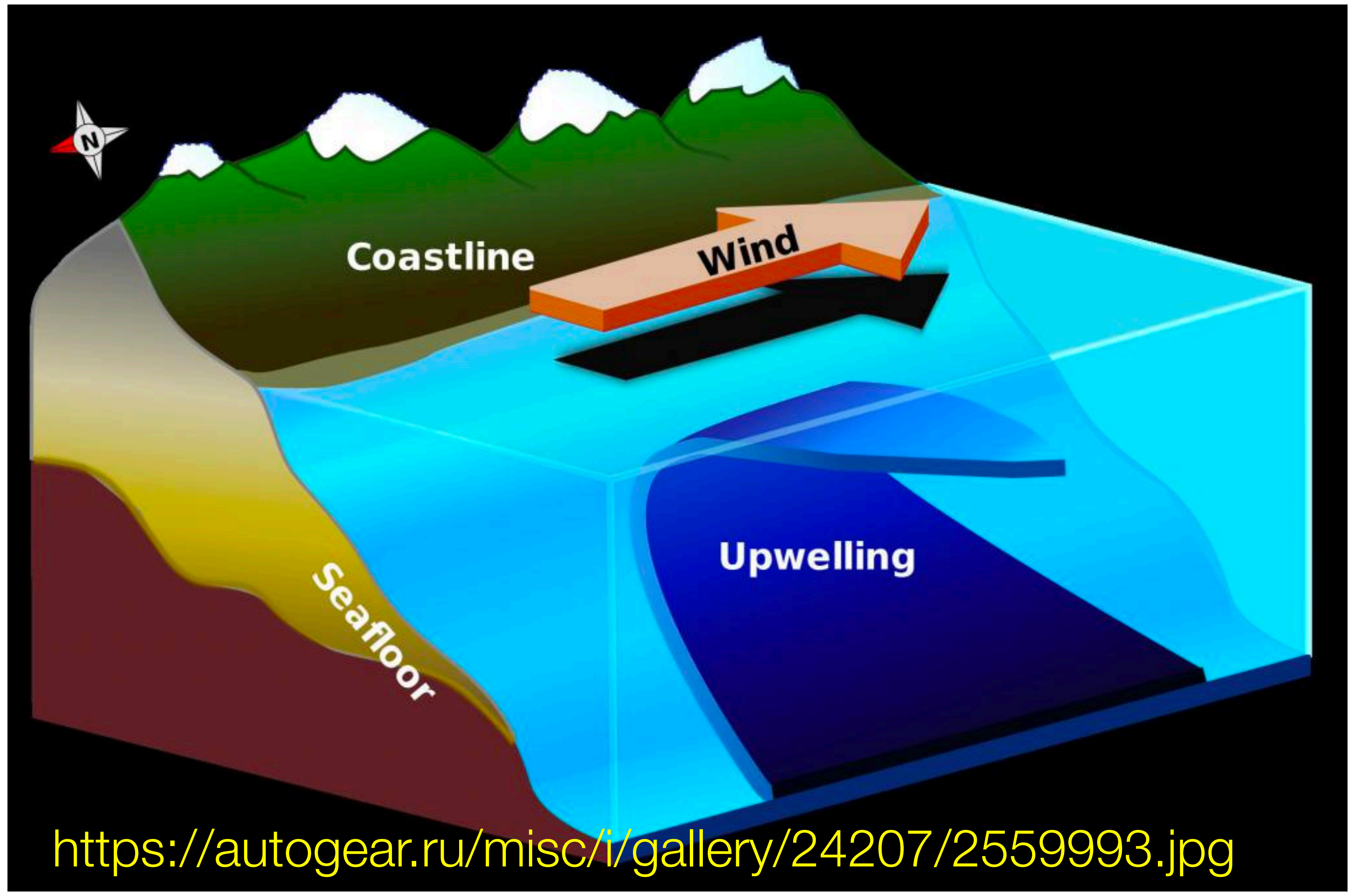
Dept of Earth and Planetary Sciences, Harvard University

Eli Tziperman

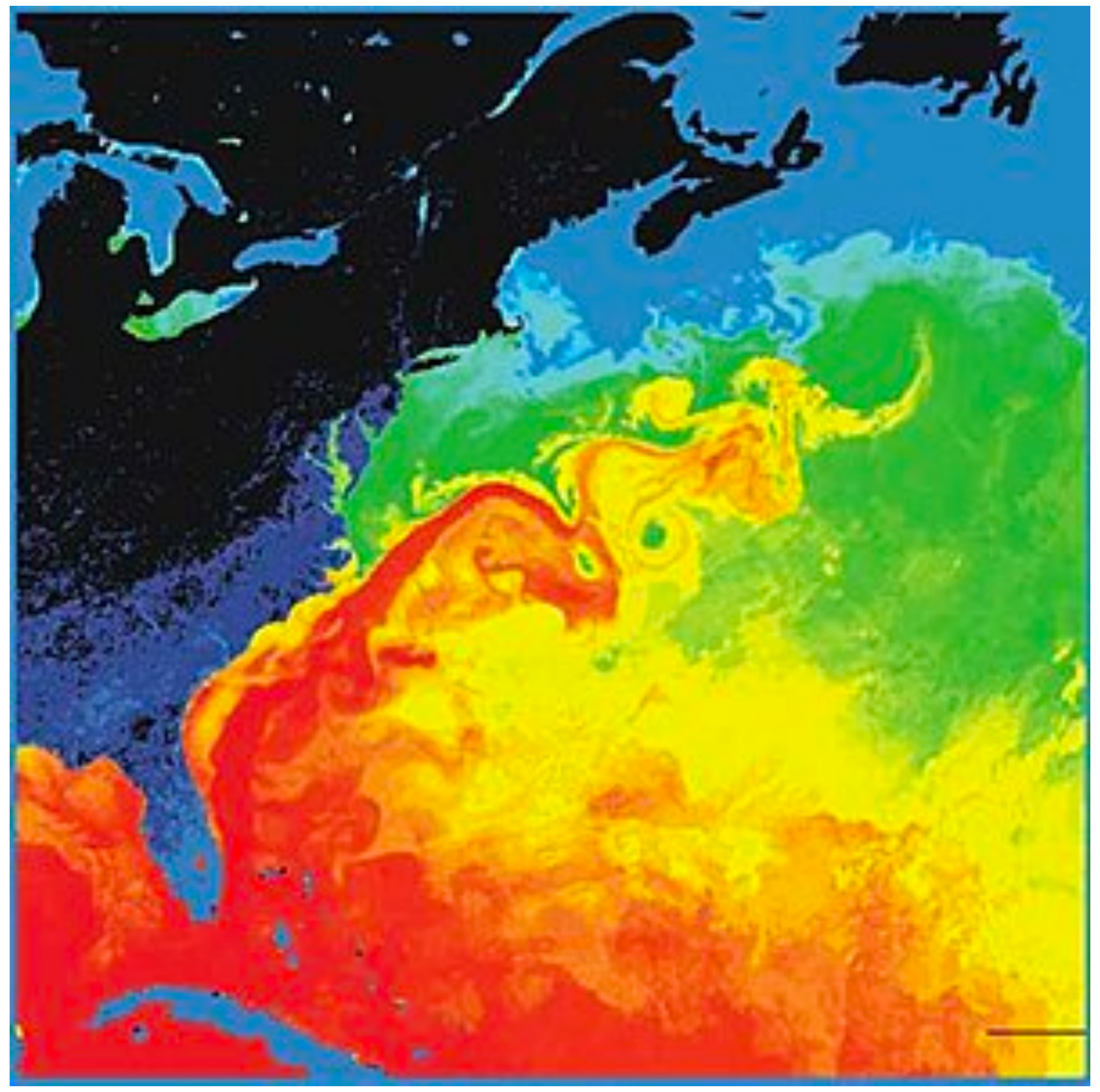
damping of inertial oscillations



https://www.ocean.washington.edu/courses/oc512/lec20-28-gfd1-2011.pdf



coastal upwelling



Gulf Stream

Notes section 1
Damped inertial oscillations

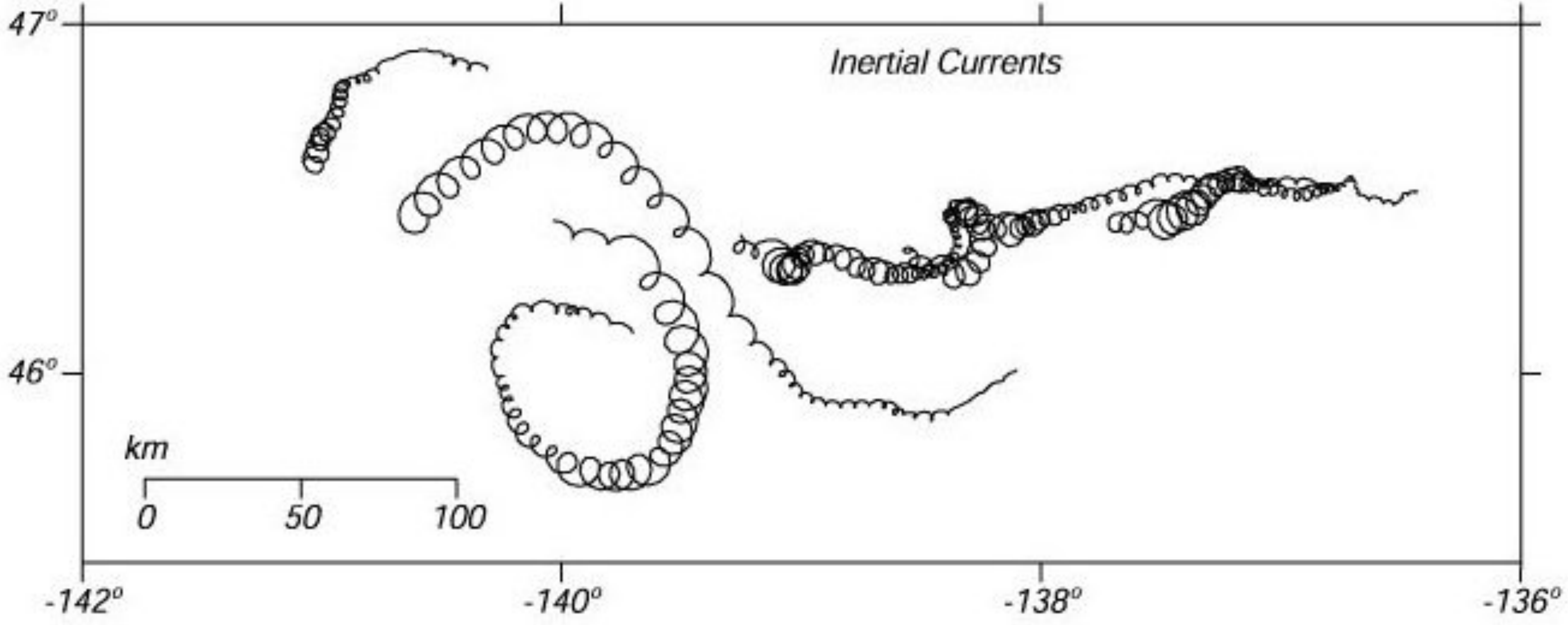
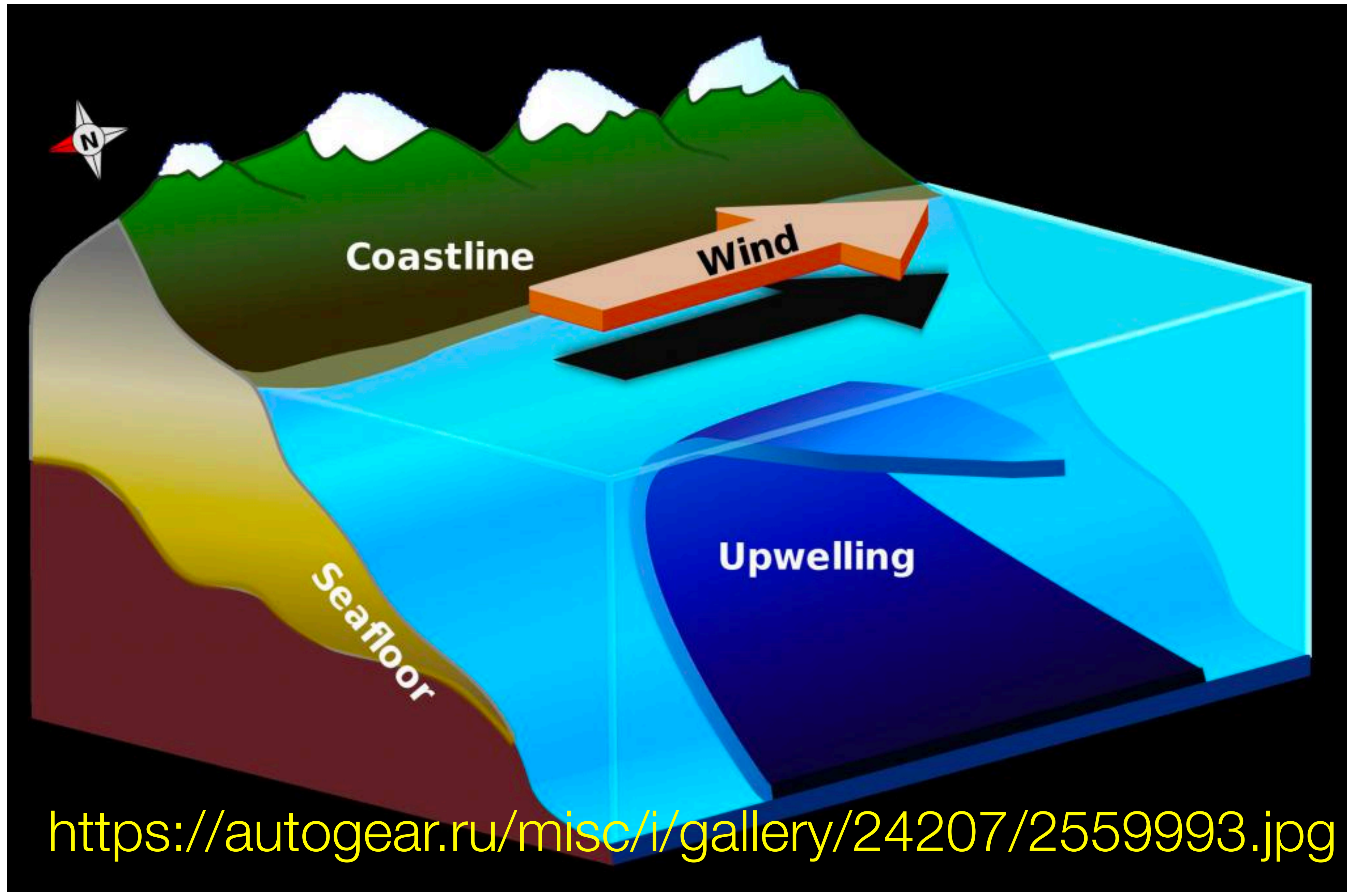


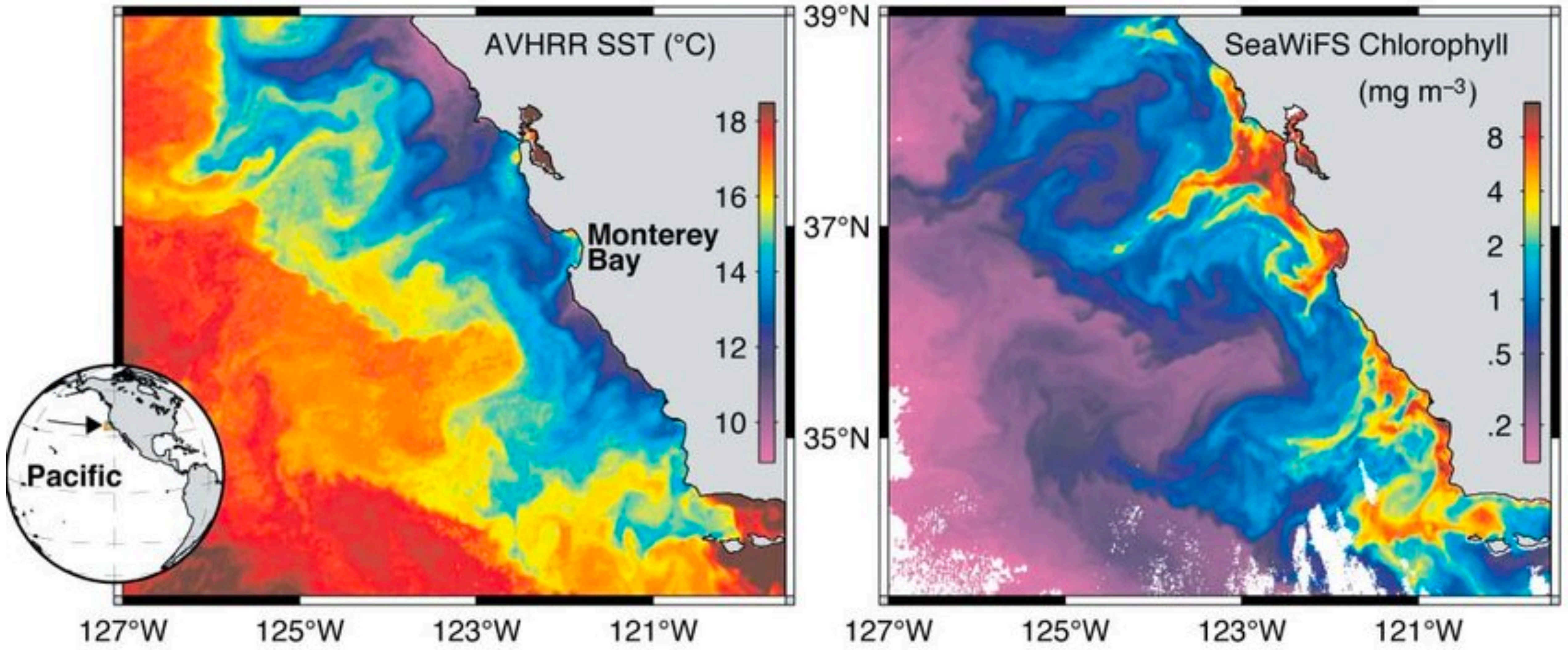
Figure 9.1 Inertial currents in the North Pacific in October 1987 (days 275-300) measured by holey-sock drifting buoys drogued at a depth of 15 meters. Positions were observed 10-12 times per day by the Argos system on NOAA polar-orbiting weather satellites and interpolated to positions every three hours. The largest currents were generated by a storm on day 277. Note: these are not individual eddies. The entire surface is rotating. A drogue placed anywhere in the region would have the same circular motion. From van Meurs (1998).

https://www.ocean.washington.edu/courses/oc512/lec20-28-gfd1-2011.pdf

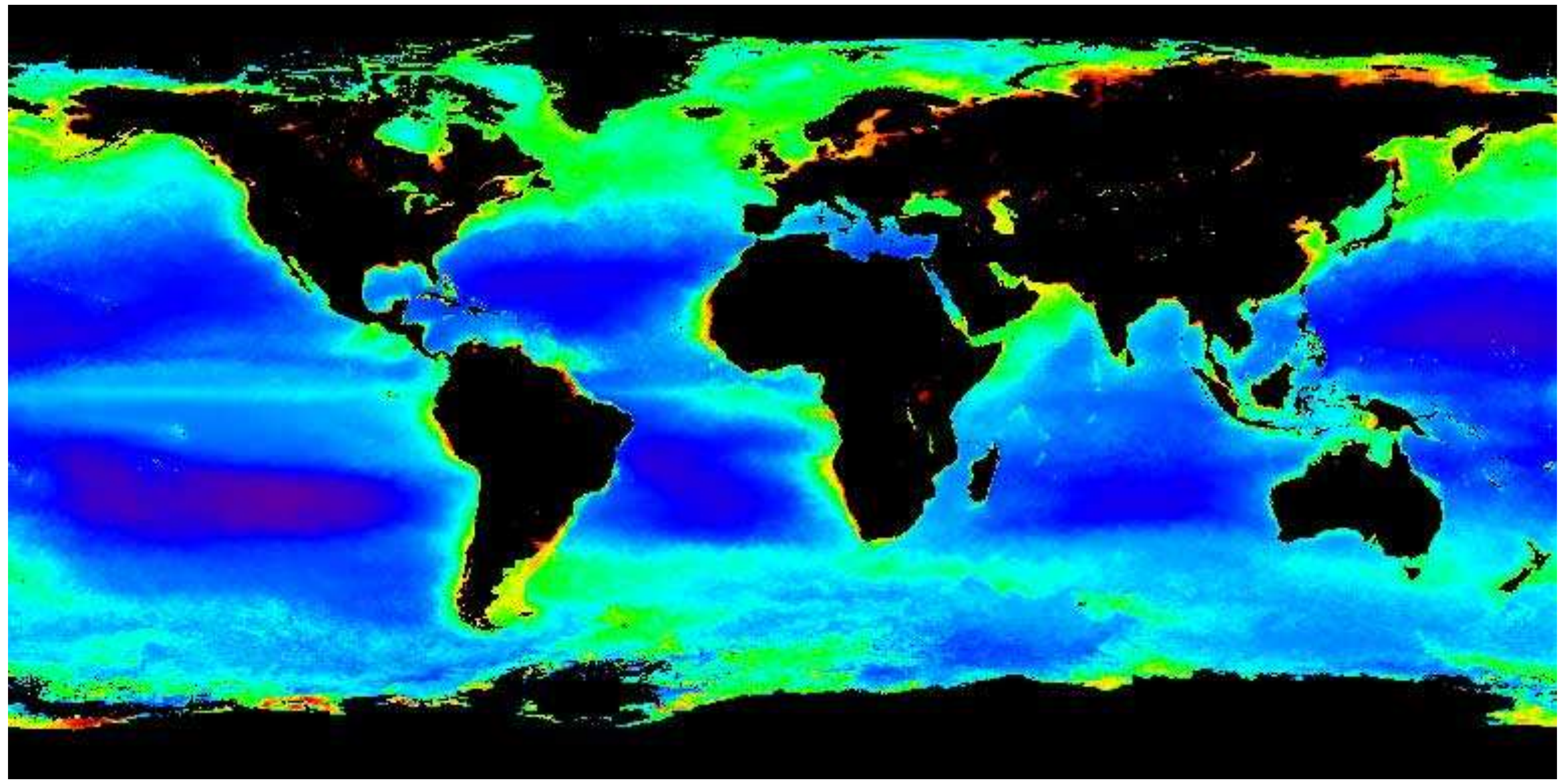
miniquiz
Damped inertial oscillations

Notes section 2
Ekman transport





Satellite data of California Current upwelling system. (a) SST (AVHRR) Aug 14, 2000, (b) surface chlorophyll (SeaWiFS) August 16, 2000; Ryan, Chavez, Bellingham 2005

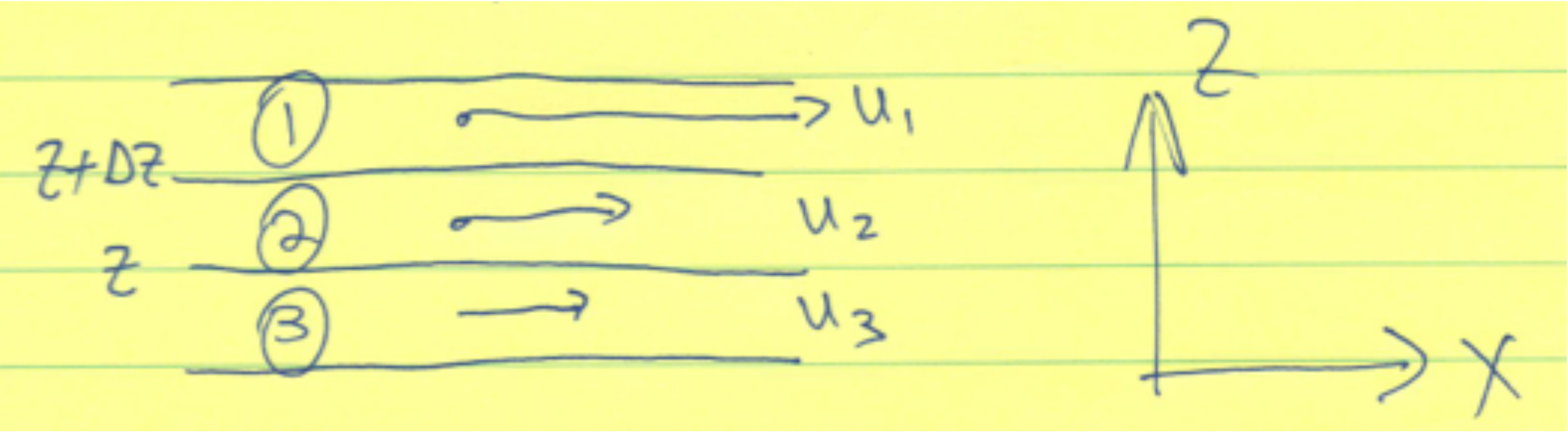


Global distribution of chlorophyll averaged over the period from 1 January 2002 to 28 February 2005 using data collected from MODIS on the Aqua satellite. Chlorophyll values range from 0.01 mg/m^3 (purple) to 60 mg/m^3 (red). From NASA Goddard Space Flight Center.

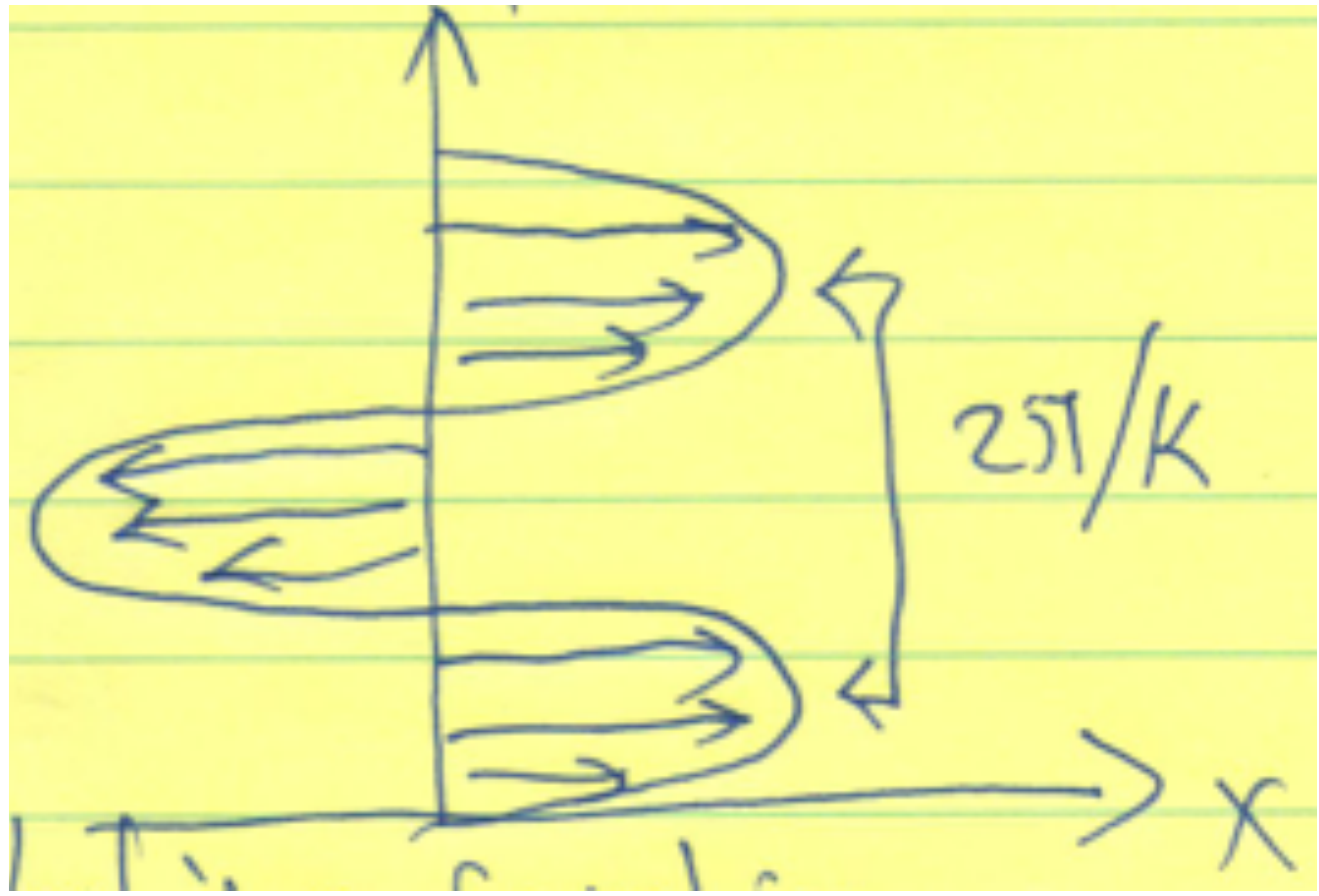
Global distribution of chlorophyll
Our ocean planet, oceanography in the 21st century, an online book, Robert Stewart

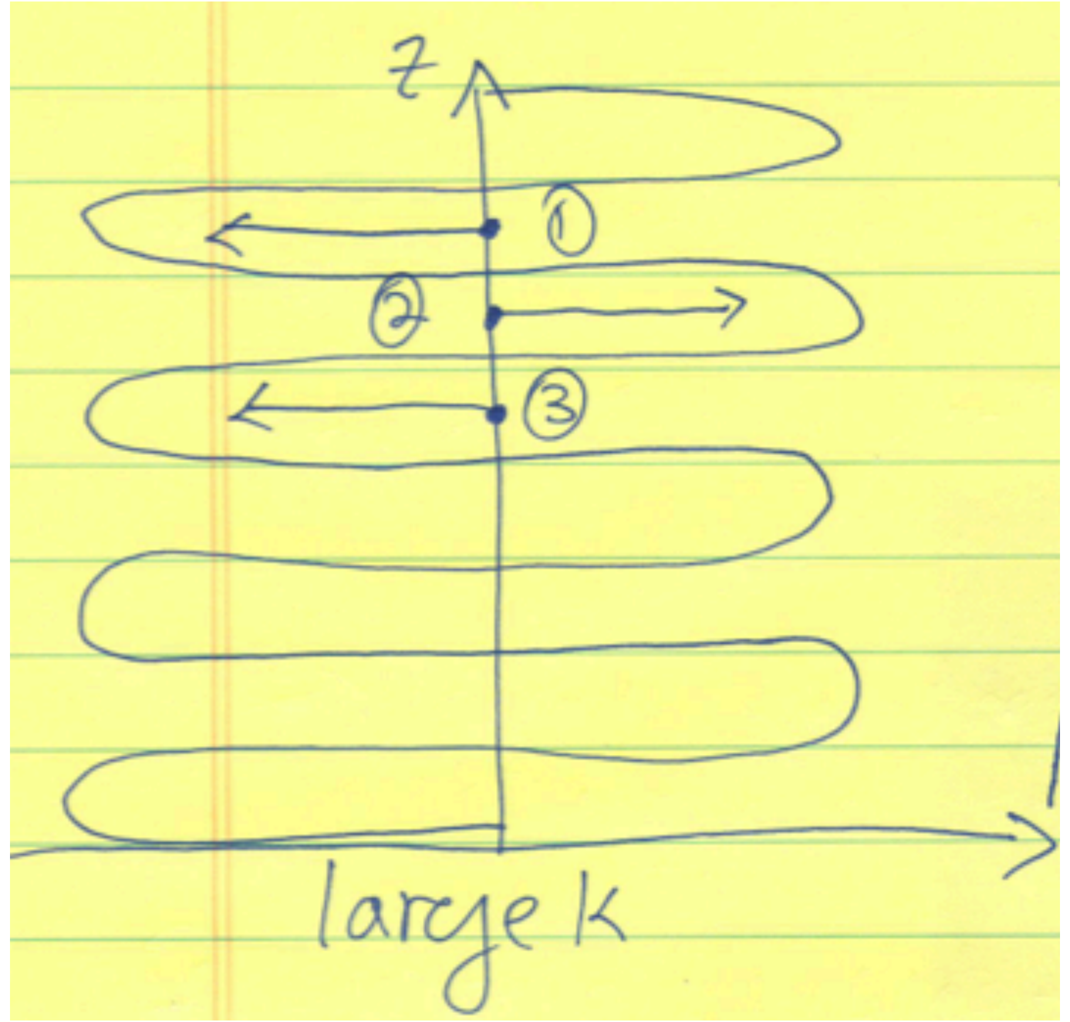
http://oceancolor.gsfc.nasa.gov/

Notes section 3
Ocean-interior vertical friction



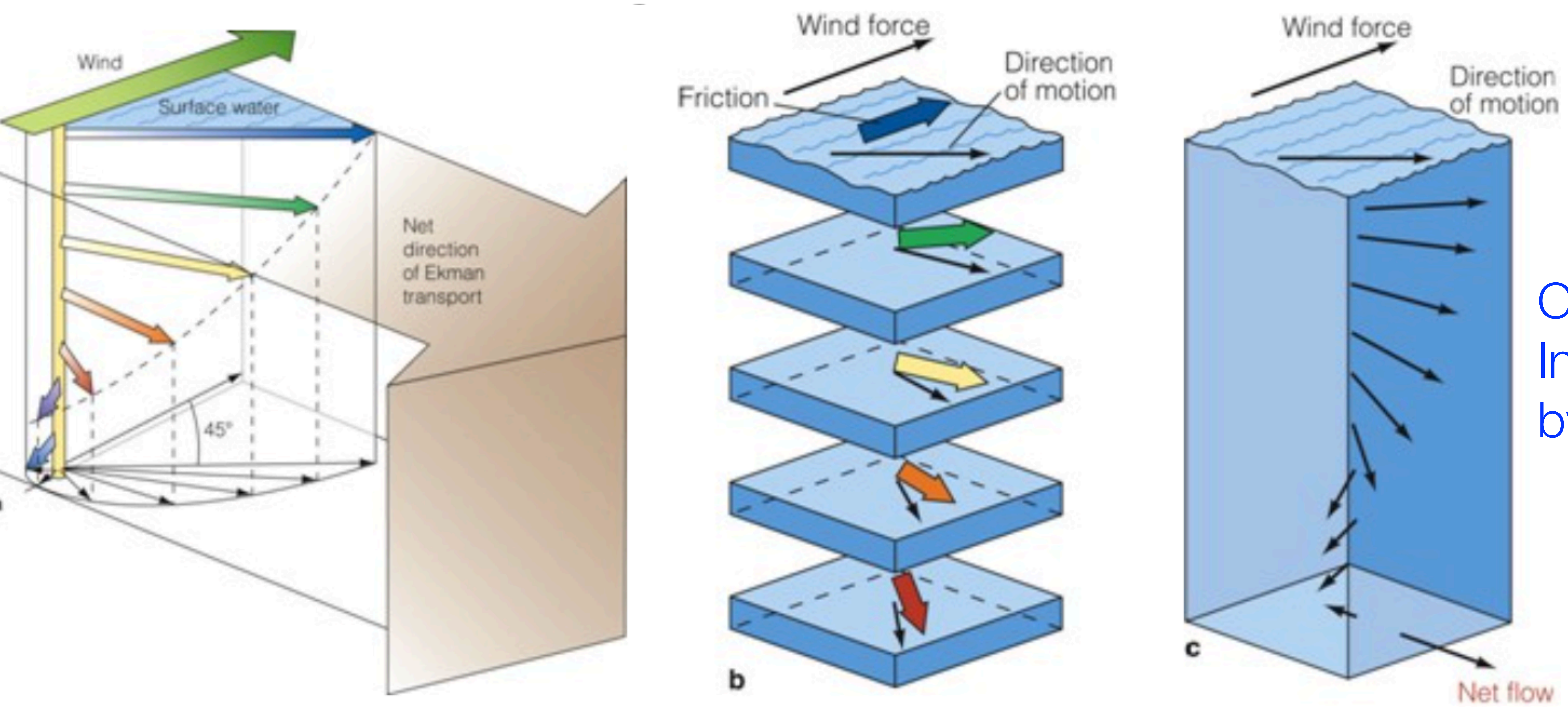
Notes section 4
Scale-selective vs non scale-selective friction





miniquiz
scale selective vs non scale-selective friction

Notes section 5
Ekman spiral



Oceanography: An Invitation to Marine Science by Tom S. Garrison

The Ekman spiral and the mechanism by which it operates. The length of the arrows in the diagrams is proportional to the speed of the current in each layer. (a) The Ekman spiral model. (b) A body of water can be thought of as a set of layers. The top layer is driven forward by the wind, and each layer below is moved by friction. Each succeeding layer moves with a slower speed and at an angle to the layer immediately above it – to the right in the Northern Hemisphere, to the left in the Southern Hemisphere – until water motion becomes negligible. (c) Though the direction of movement varies for each layer in the stack, the theoretical net flow of water in the Northern Hemisphere is 90° to the right of the prevailing wind force.

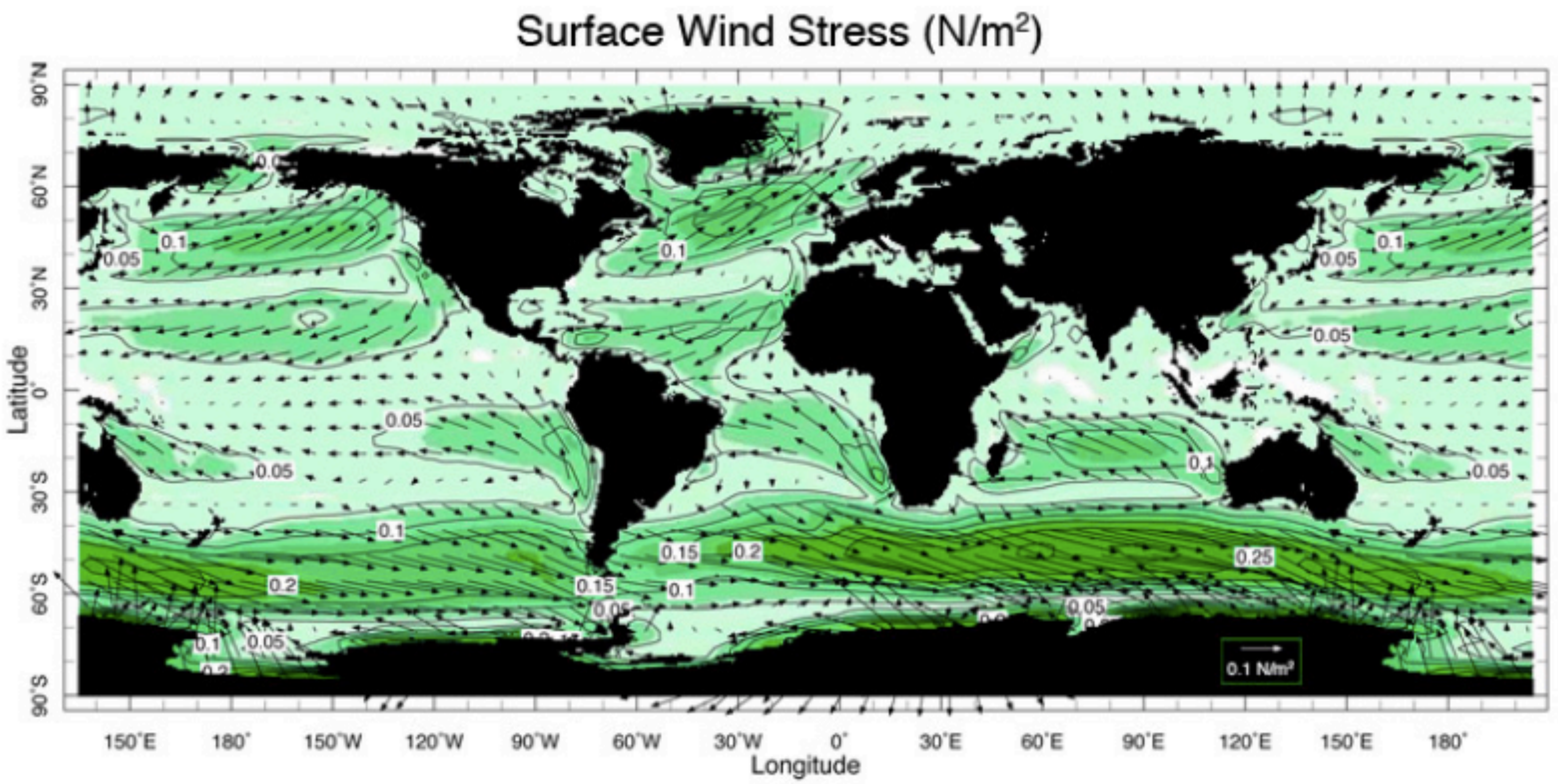
miniquiz
Ekman spiral

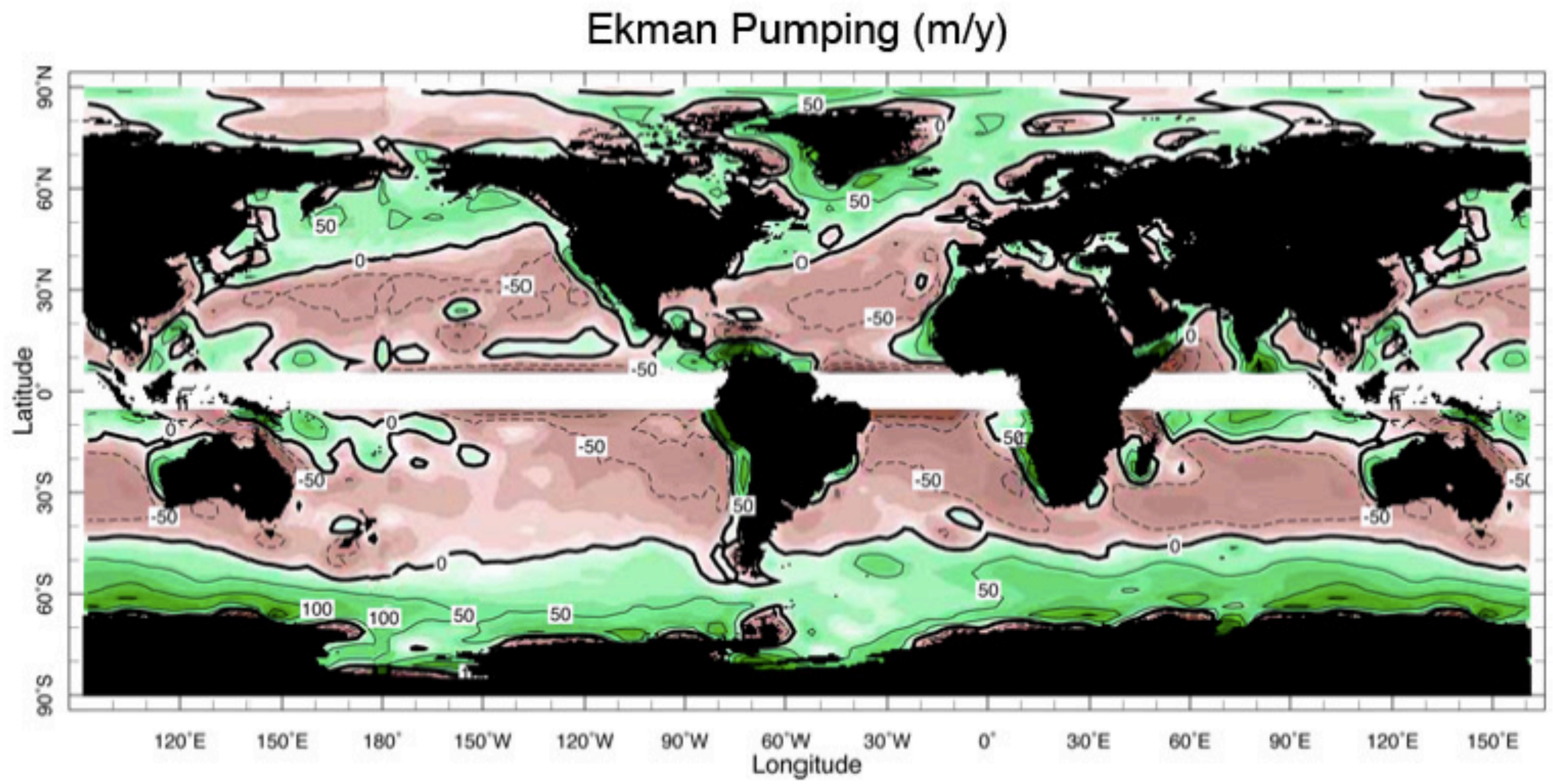
notes

6 Mass conservation/ continuity equation

7 Ekman pumping

Global wind stress and wind curl





Marshall and Plumb 2008

Figure 10.2: Annual mean wind stress on the ocean. A contour of 1 represents a wind-stress of magnitude 0.1 $\mathrm{N\,m^{-2}}$. Stresses reach values of 0.1 to 0.2 $\mathrm{N\,m^{-2}}$ under the middle-latitude westerlies, and are particularly strong in the southern hemisphere. The arrow is a vector of length 0.1 $\mathrm{N\,m^{-2}}$. Note that the stress vectors circulate around the high and low pressure centers shown in Fig.7.27, as one would expect if the surface wind, on which the stress depends, has a strong geostrophic component.

Figure 10.11: The global pattern of Ekman vertical velocity ($\mathrm{m\,y^{-1}}$) computed using Eq.(10.7) from the annual mean wind-stress pattern shown in Fig.10.2. Motion is upward in the green areas, downward in the brown areas. w_{Ek} is not computed over the white strip along the equator because $f \longrightarrow 0$ there. The thick line is the zero contour. Computed from Trenberth et al (1989) data. The broad regions of upwelling and downwelling delineated here are used to separate the ocean in to different dynamical regimes, as indicated by the colors in Fig.9.13.

The End