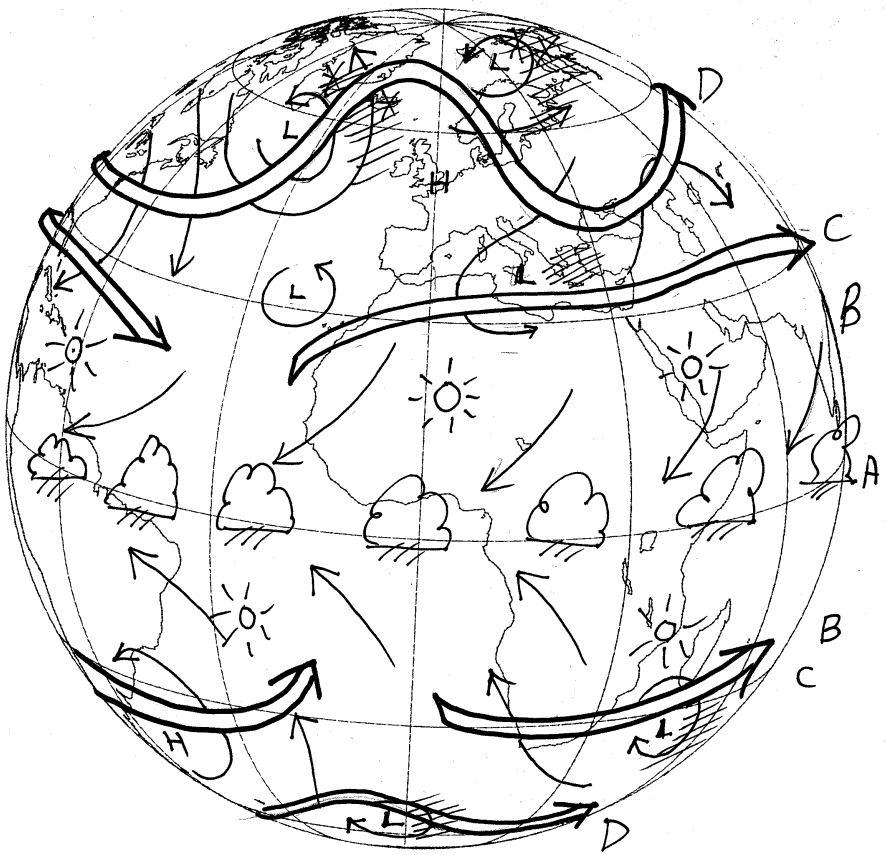
Dynamic meteorology without tears

Part I a:

Trade winds and the earth's rotation

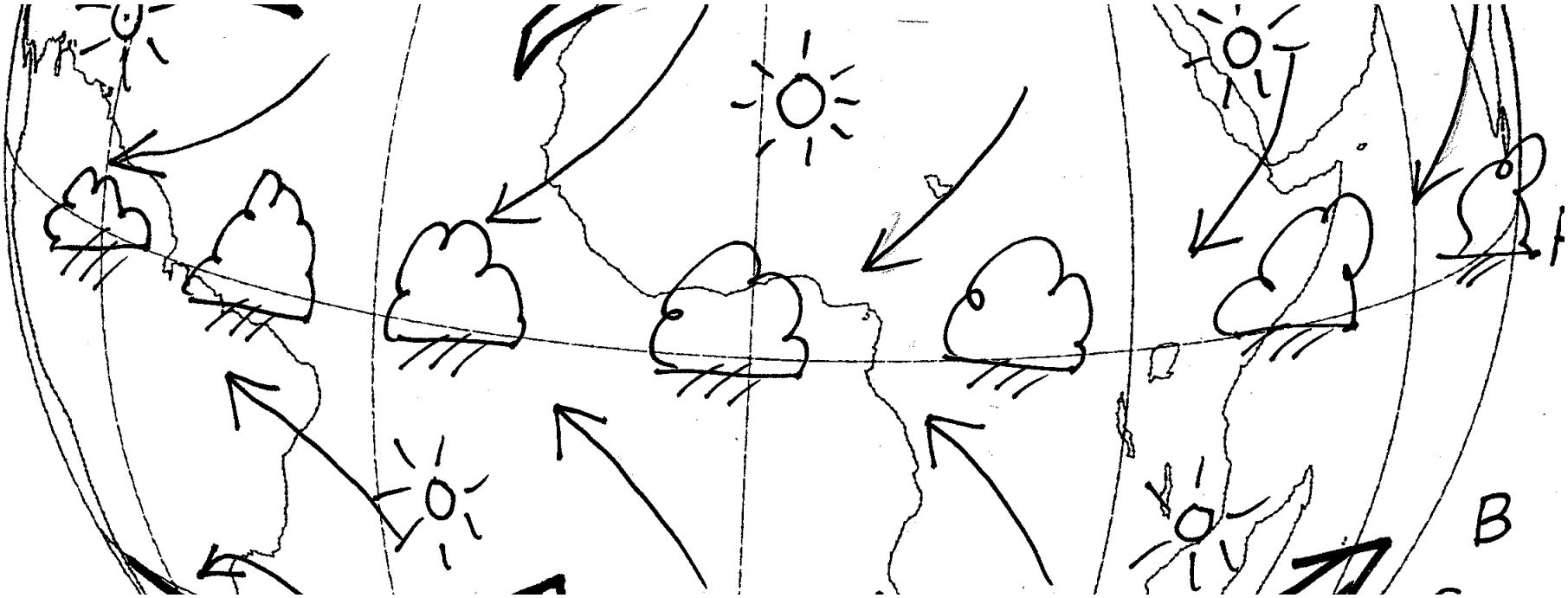
Can we explain the general circulation of the atmosphere?



"If you cannot explain to your granny what you are doing you do not really understand it yourself"

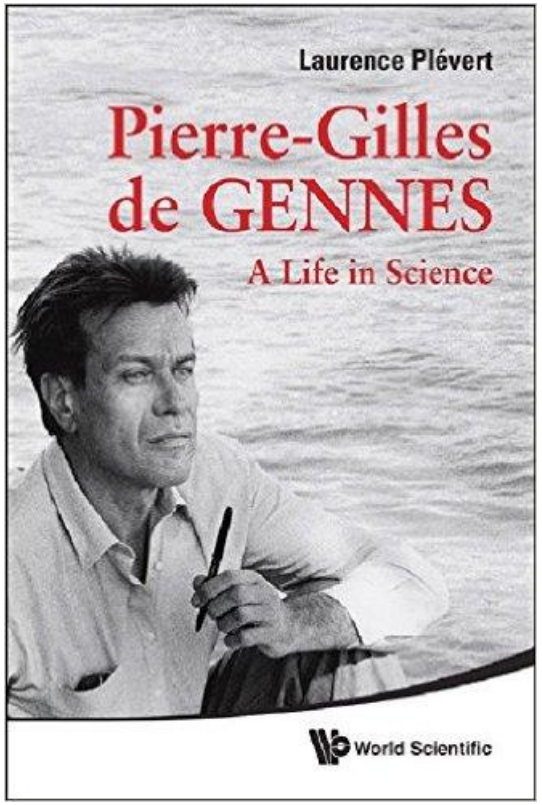
Albert Einstein (attributed)

Let us start with the part that early on was supposed to be the least complicated, the **Trade Wind** belt



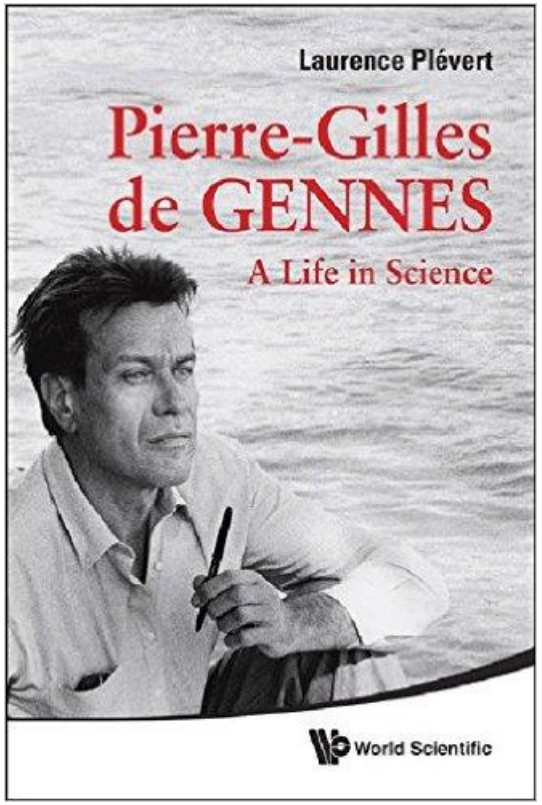
A correct theory might fit poorly with observation while an incorrect can be quite close to the truth

Пьер Жиль де Жен (фр. *Pierre-Gilles de Gennes*; 24 октября 1932, Париж — 18 мая 2007, Орсе) — французский физик, лауреат Нобелевской премии по физике в 1991году «за обнаружение того, что методы, развитые для изучения явлений упорядоченности в простых системах, могут быть обобщены на жидкие кристаллы и полимеры». Де Жен известен прежде всего тем, что открыл структуру, положившую начало производству ЖК-дисплеев. За множество фундаментальных открытий многие научные круги называют де Жена «Ньютоном нашего времени».



Пьер Жиль де Жен (фр. *Pierre-Gilles de Gennes*; 24 октября 1932, Париж —

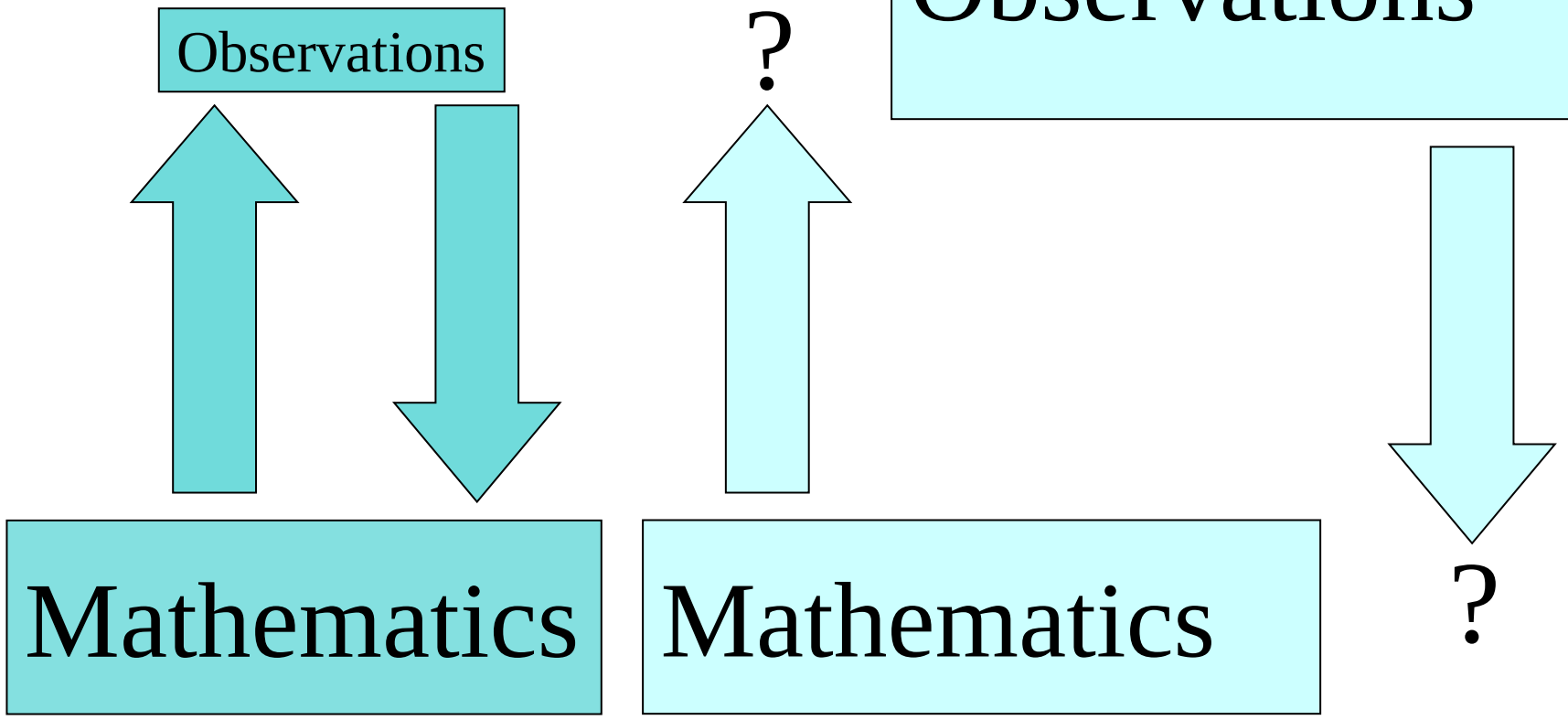
“The easiest thing in physics is the mathematics, the difficult bit is what it means”



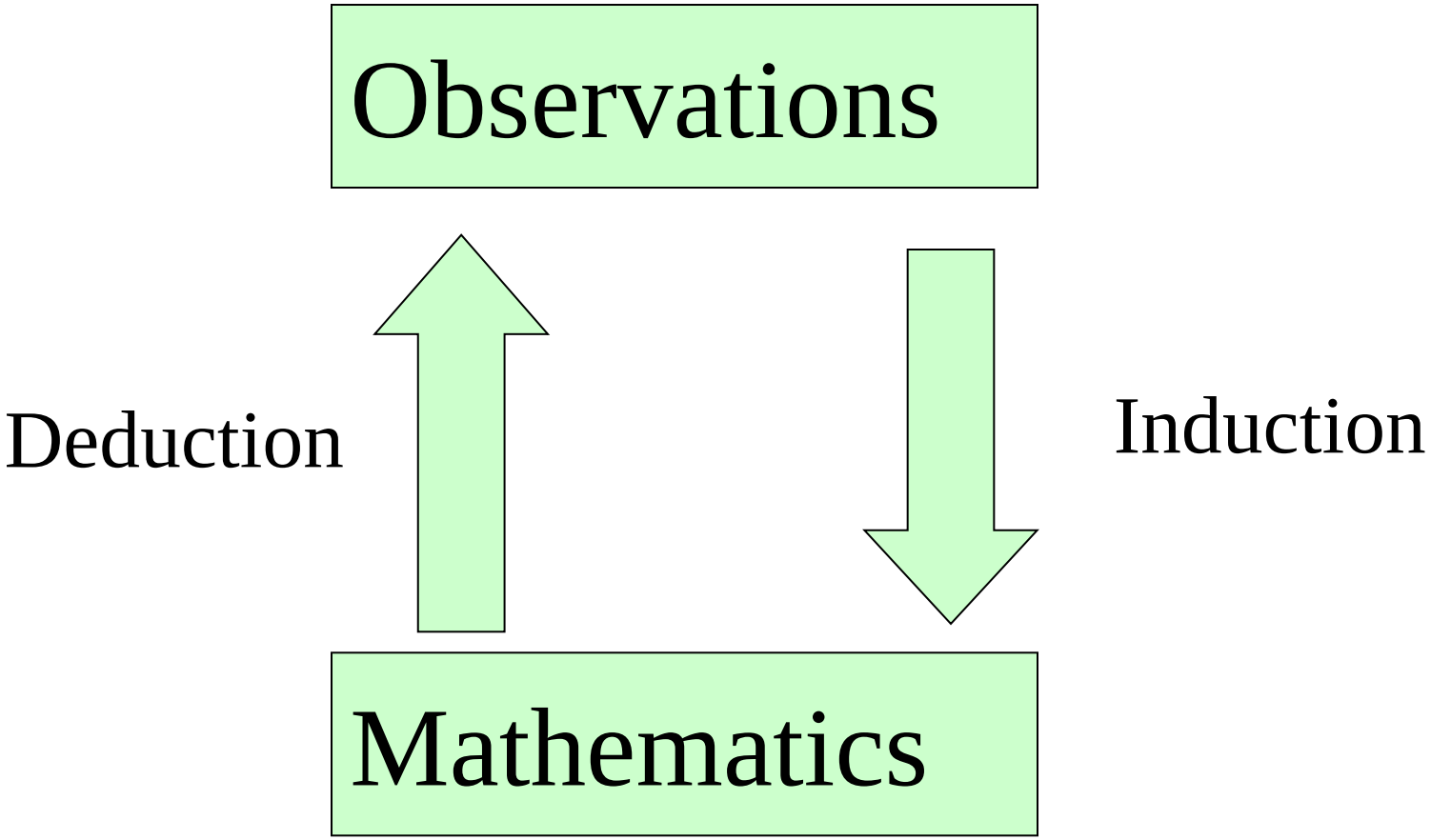
плеев. За множество фундаментальных открытий многие научные круги называют де Жена «Ньютоном нашего времени».

(Dynamic) meteorology

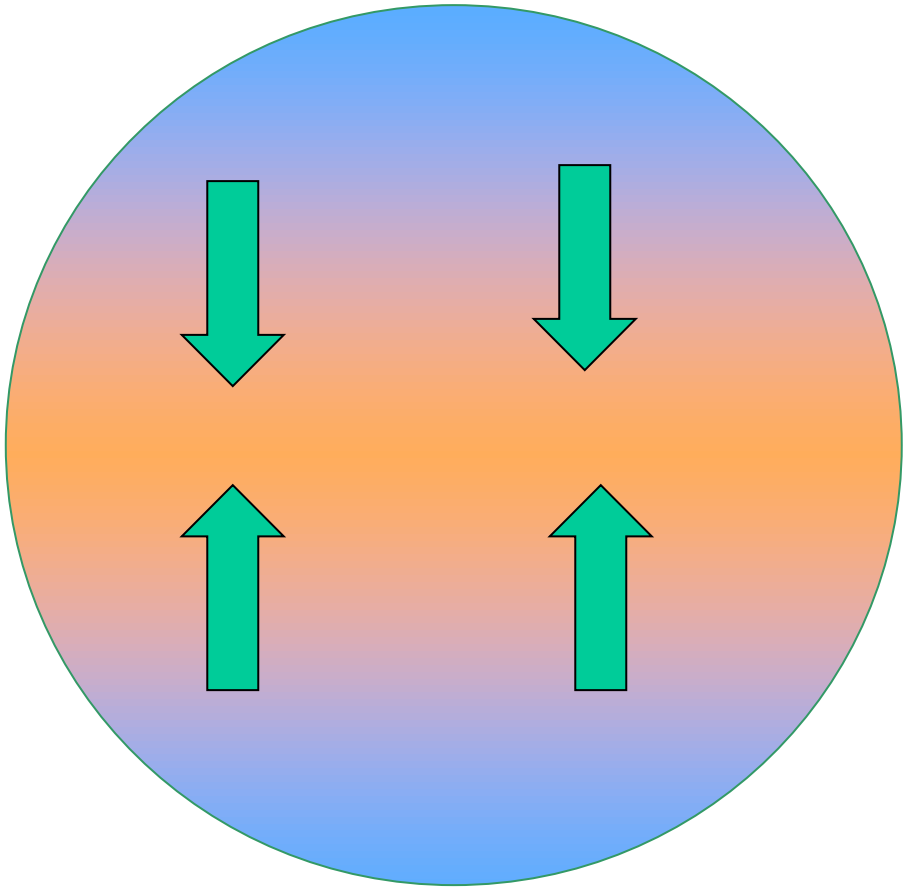
General Physics (and Dynamic oceanography)



The essence of the mathematical sciences

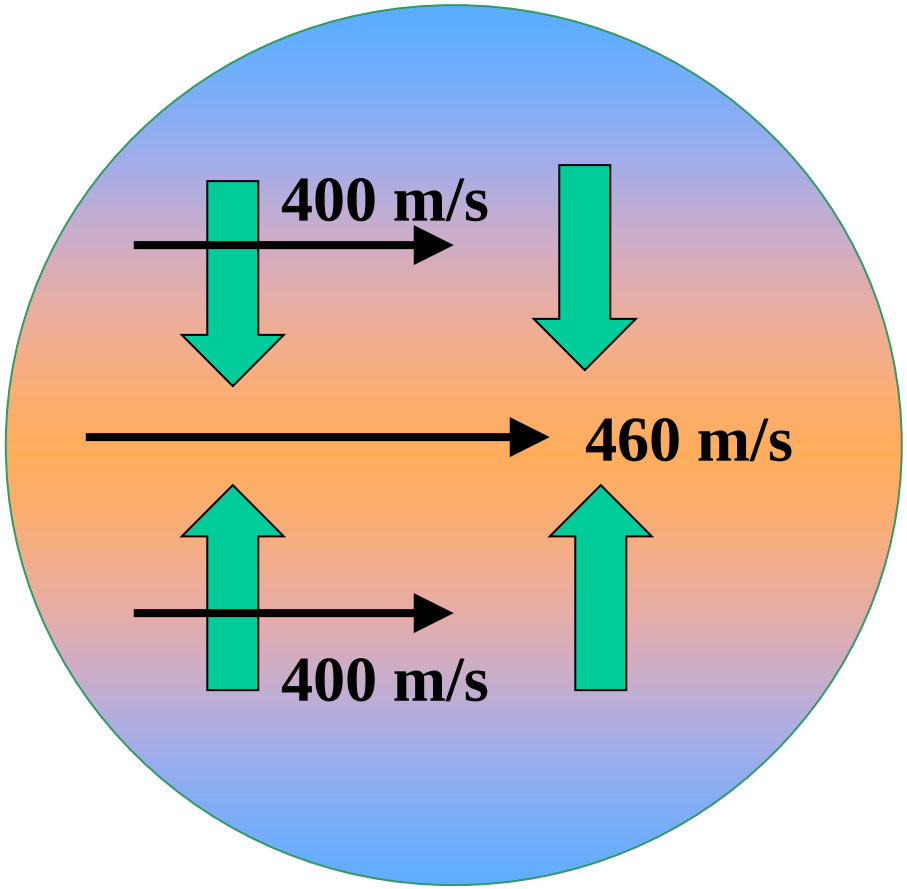


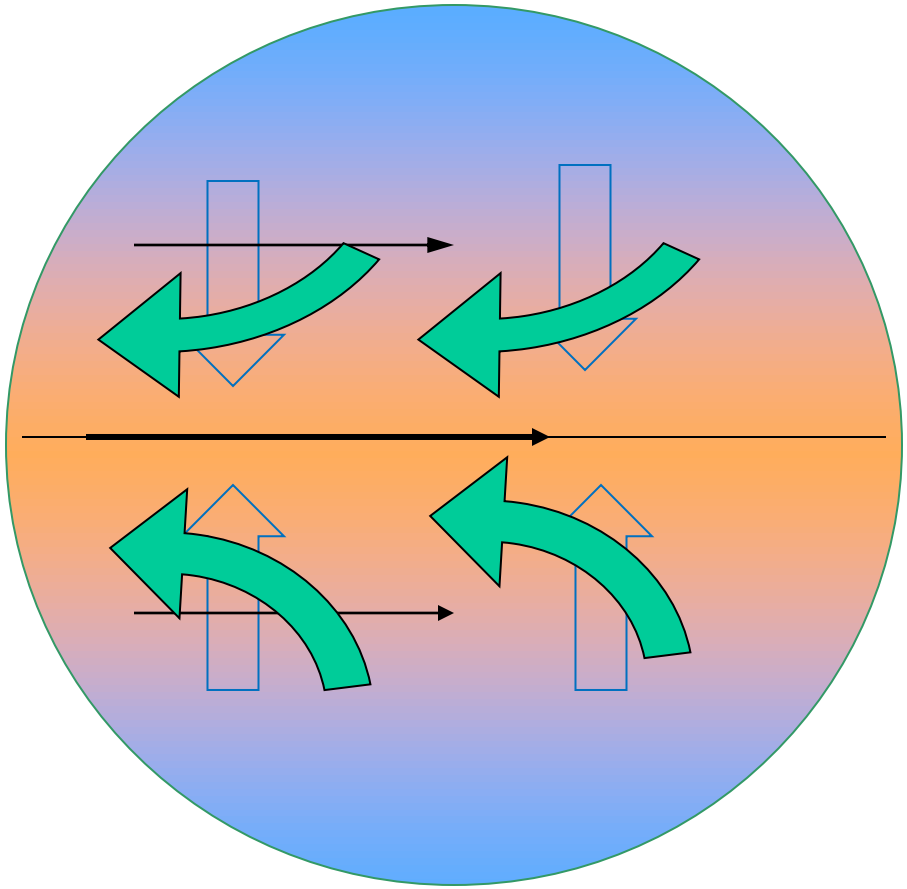
George Hadley's **famous** but **erroneous** model of the trade winds (1735) took the rotation into account (different speeds of latitudes) and the differential heating



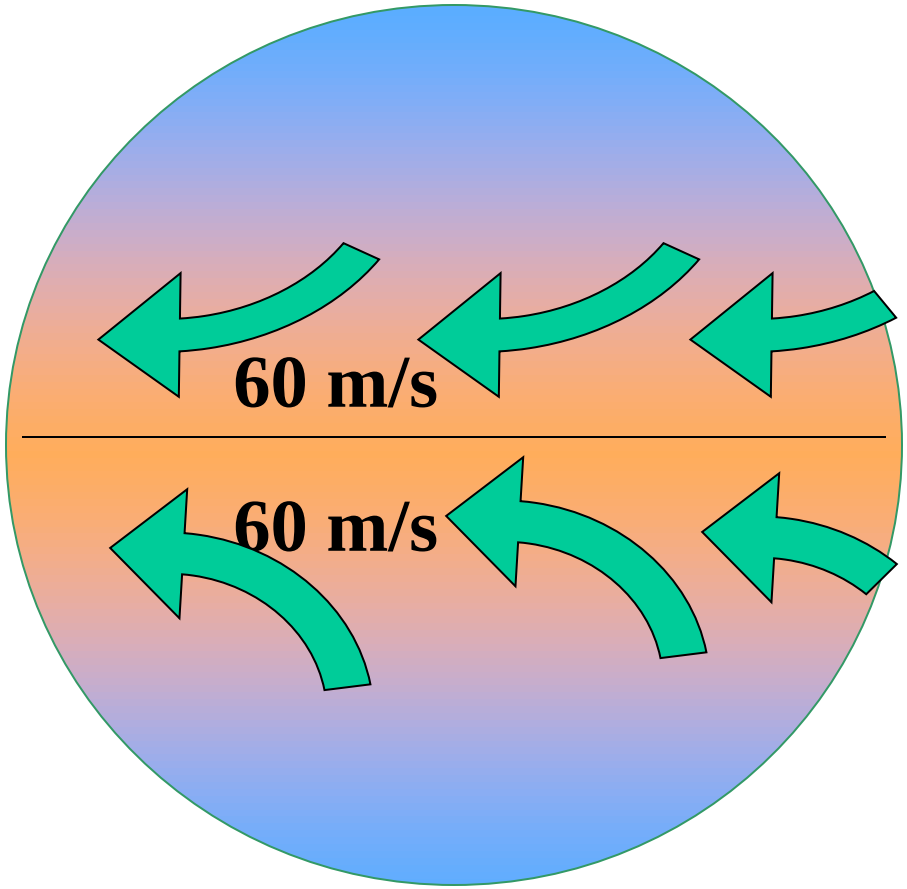
The differential heating sets up a global "sea breeze" circulation

Air moves from the equinoxes where the earth moves with 400 m/s to the equator where the speed is 460 m/s



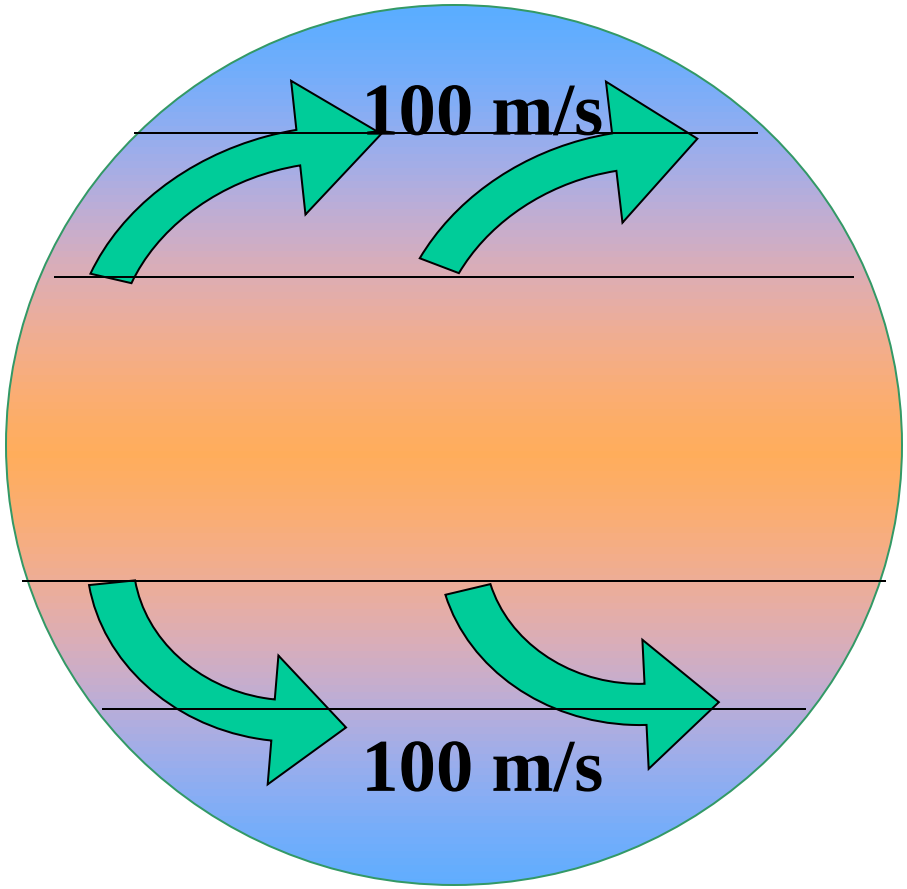


The air lags behind when it arrives in areas with higher rotational speeds and a north easterly trade wind is formed, south easterly south of the equator



A complicating result was that the trade winds should be of the order 60 m/s, something Hadley explained away with the effects of friction

Hadley's model of the trade winds applied on the mid-latitudes

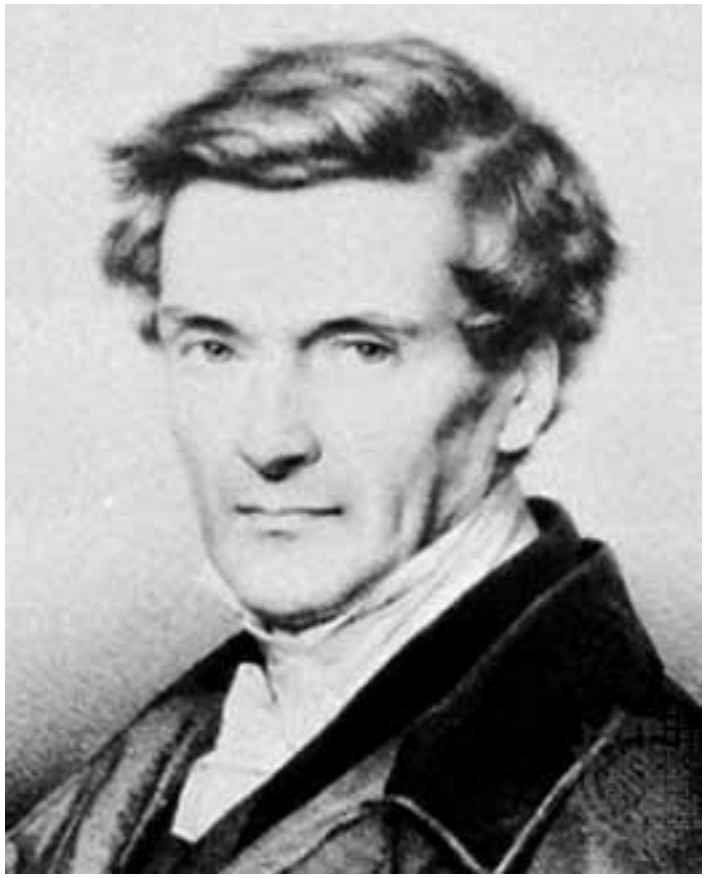


A wind blowing from 40º to 60º would experience an increase by 100 m/s

This and other strange results from Hadley's model made British meteorologists doubt if the earth's rotation played any significant role at all for the atmospheric circulation

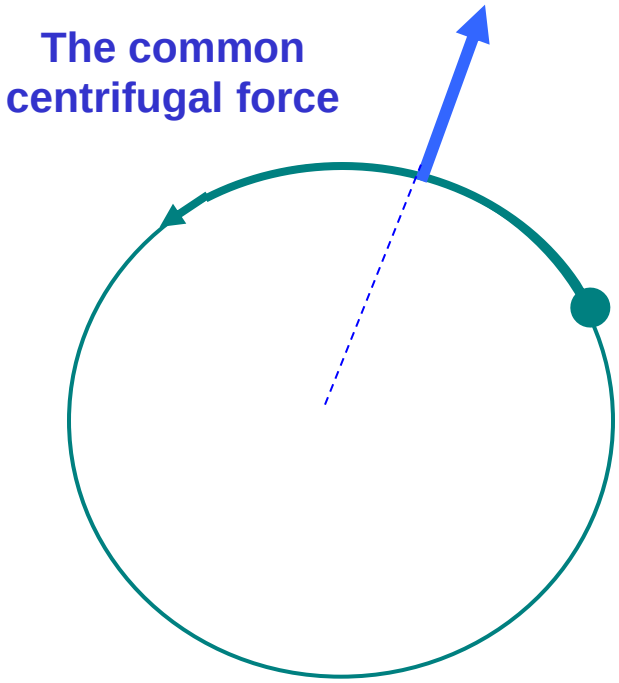
But what about Coriolis?

Gaspard Gustave Coriolis 1784-1843

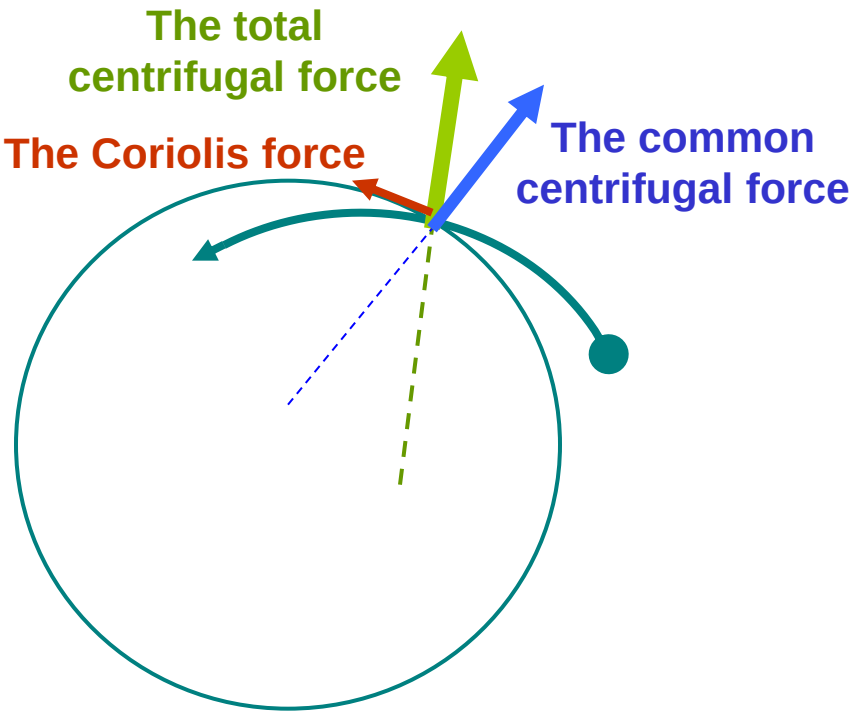


Coriolis was interested, neither in the atmosphere nor in the oceans – ***but in machines***

Coriolis was interested in how the centrifugal effect acted on moving parts in rotating machines



A stationary object in the rotating system

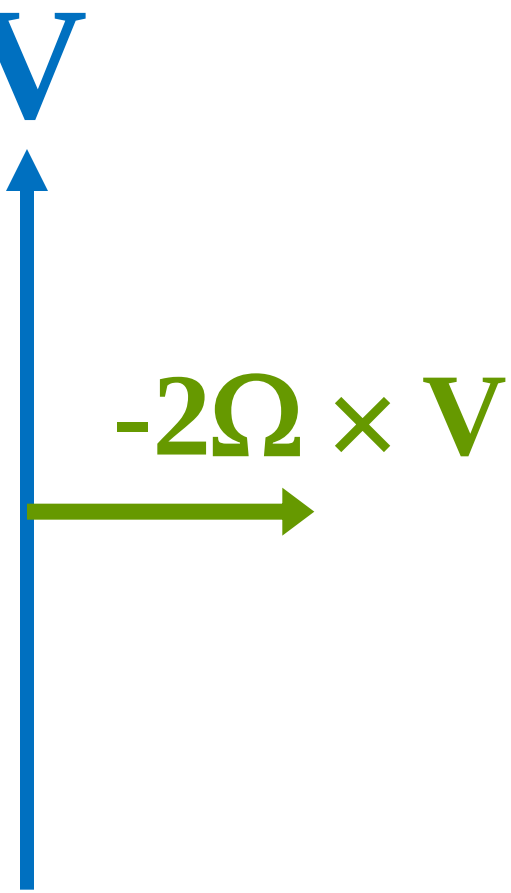


An object moving (inwards) in the rotating system

The Coriolis force was the extra force that had to be added to the common centrifugal force for an relatively moving object

What does the Coriolis term say?

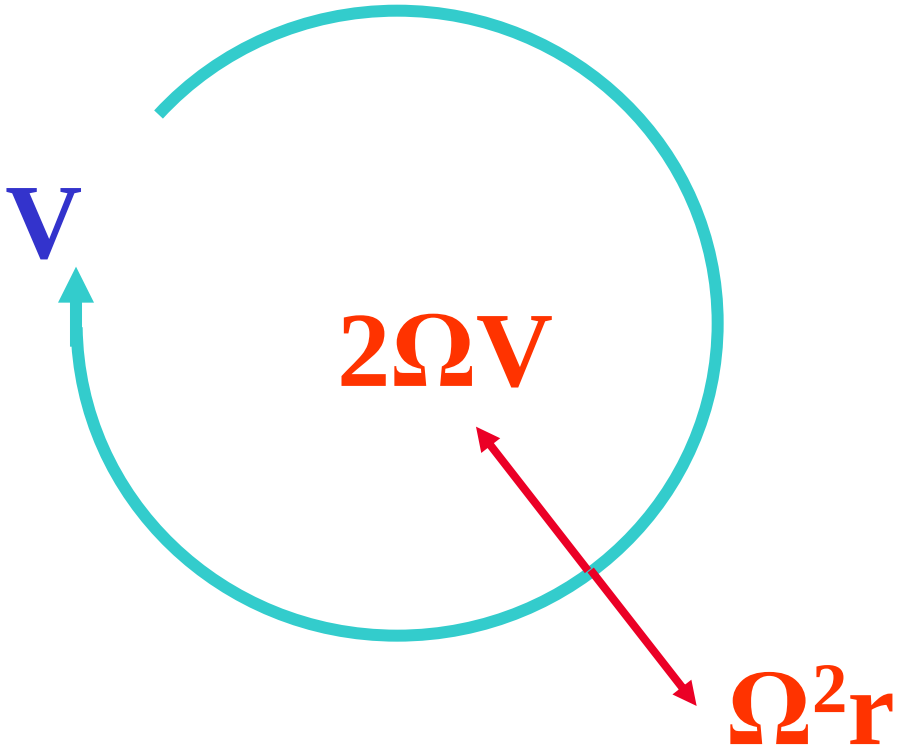
$$-2\Omega \times \mathbf{V}$$



. . . . and what does this mean?

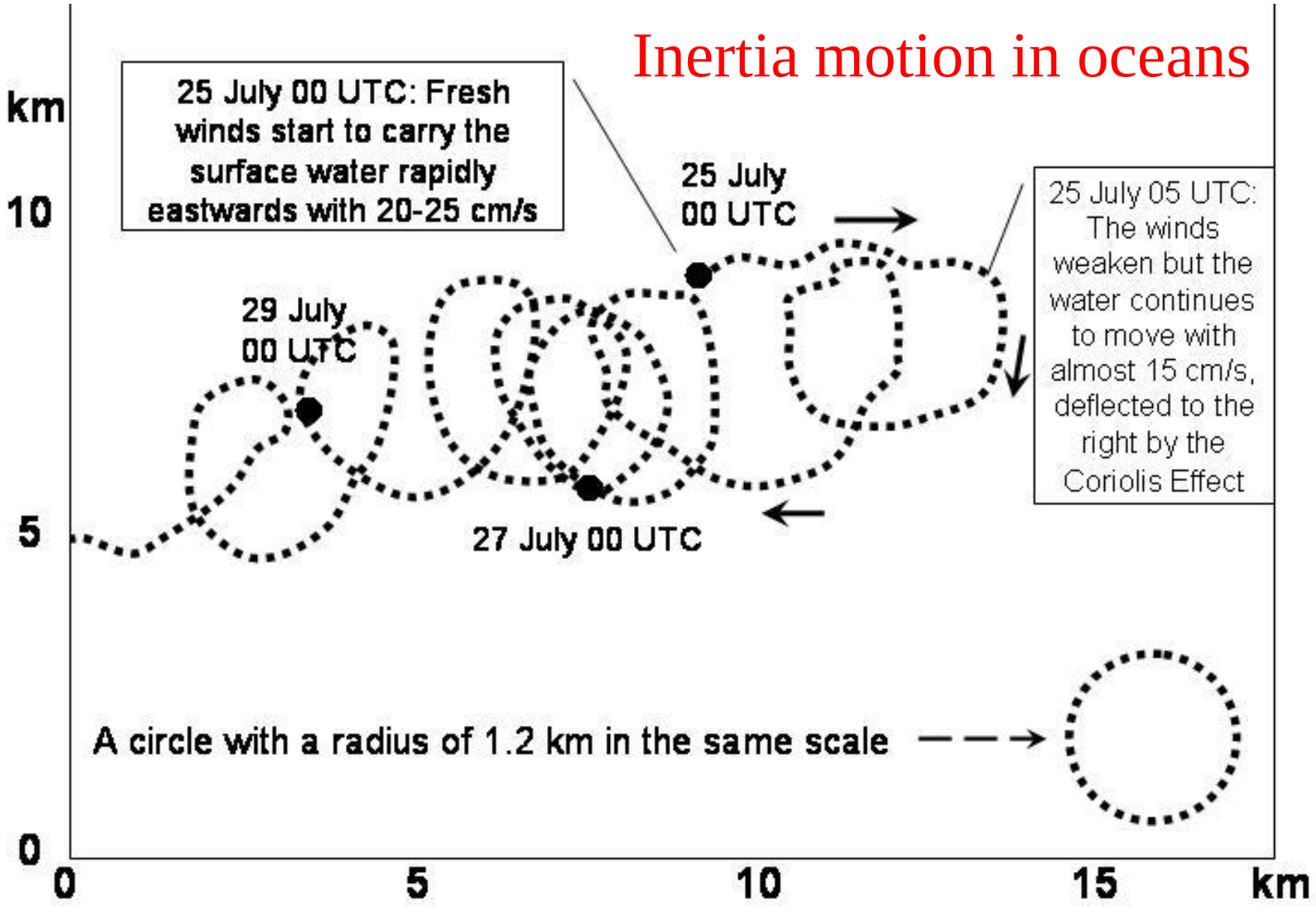
What does -2Ω×V mean???

It defines the "inertia circle" motion

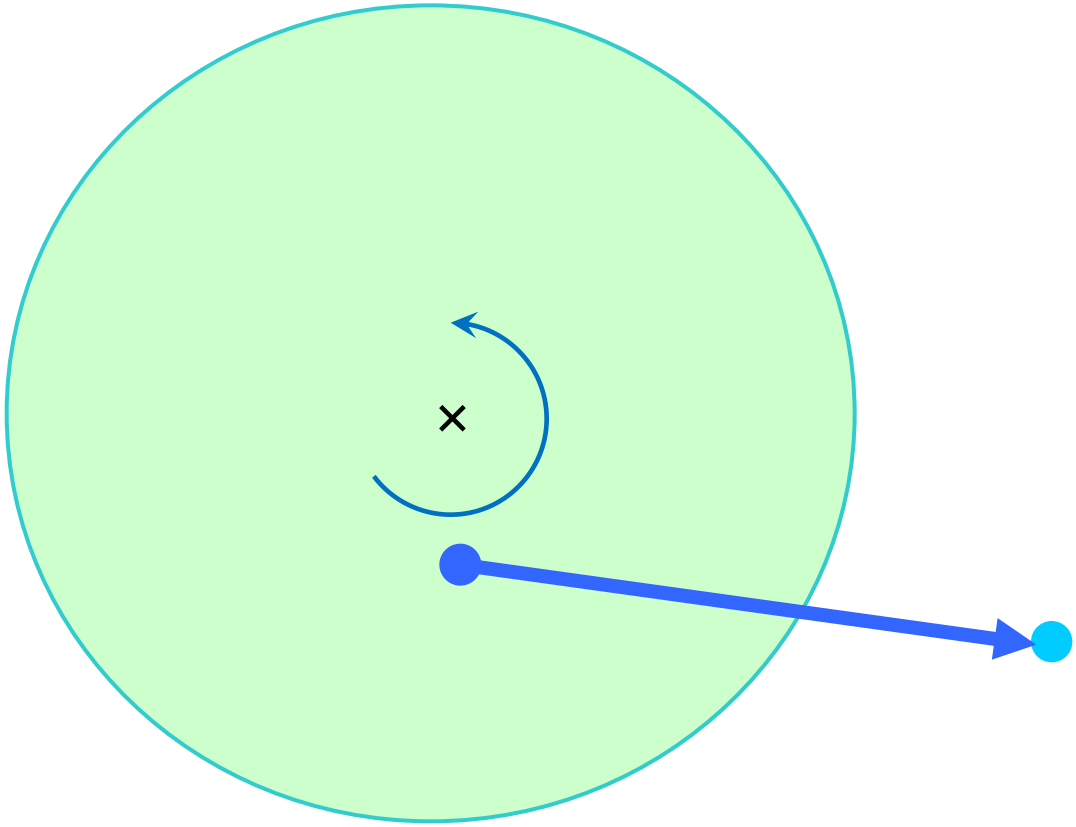


The radius of the inertia circle
r = 2V/Ω

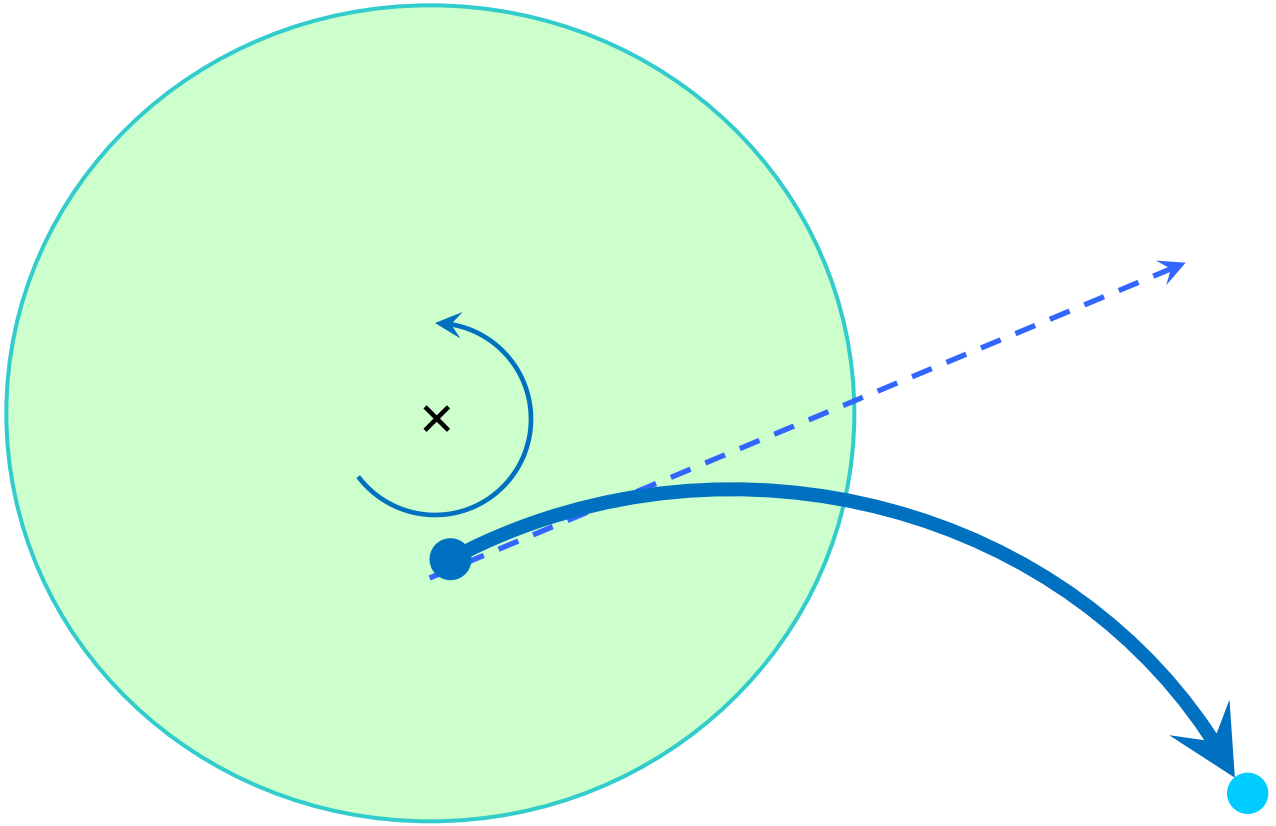
Inertia motion in oceans



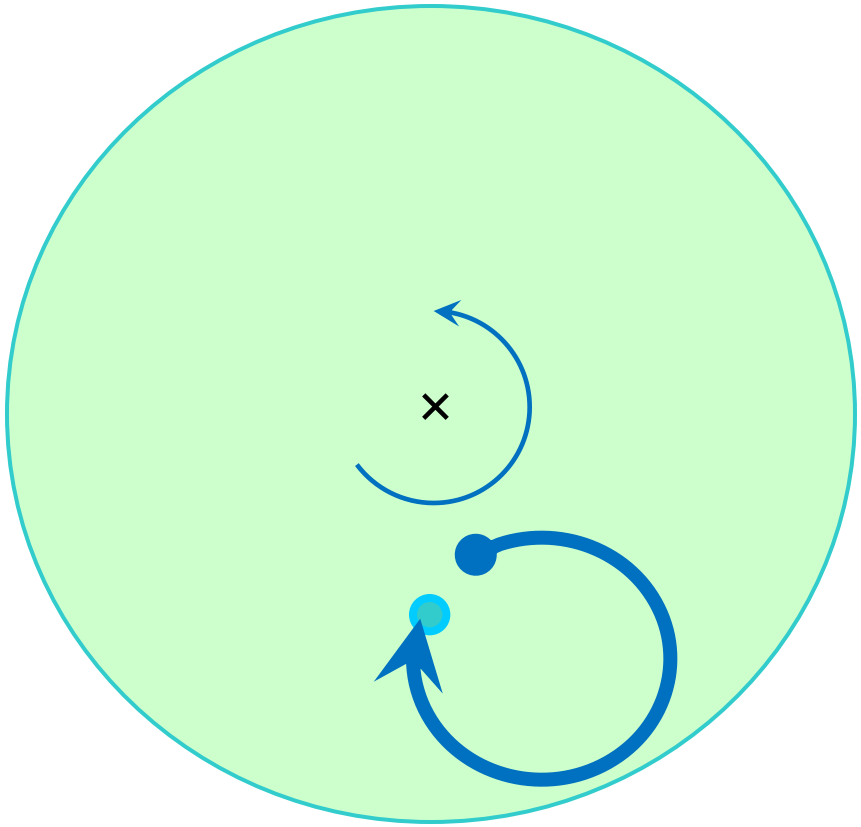
Seen from outside a body is moving out from a rotating carrousel ...



The deflection relative the rotating carrousel is described by the combined effect of the Coriolis and centrifugal forces

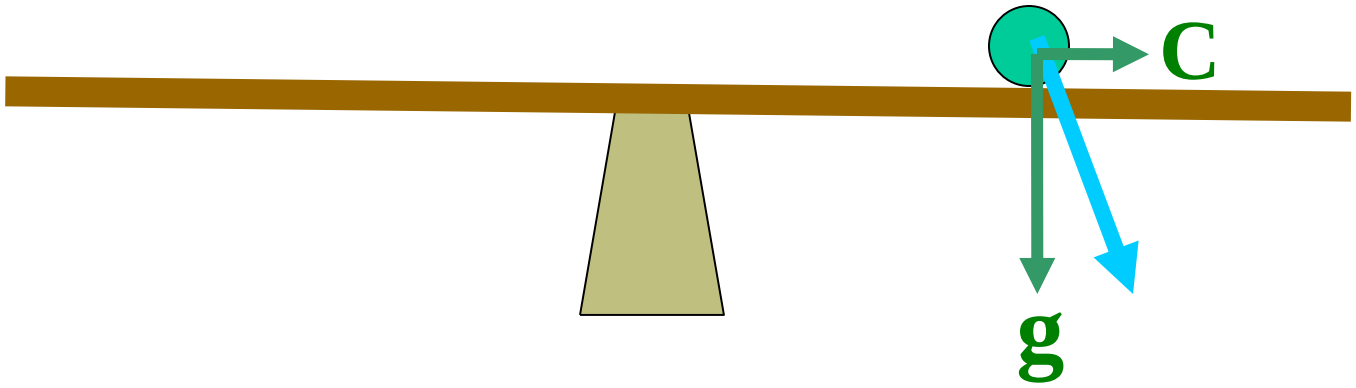


If only the Coriolis force had been active, and not the centrifugal forcem the relative path would have been a closed “inertia” circle



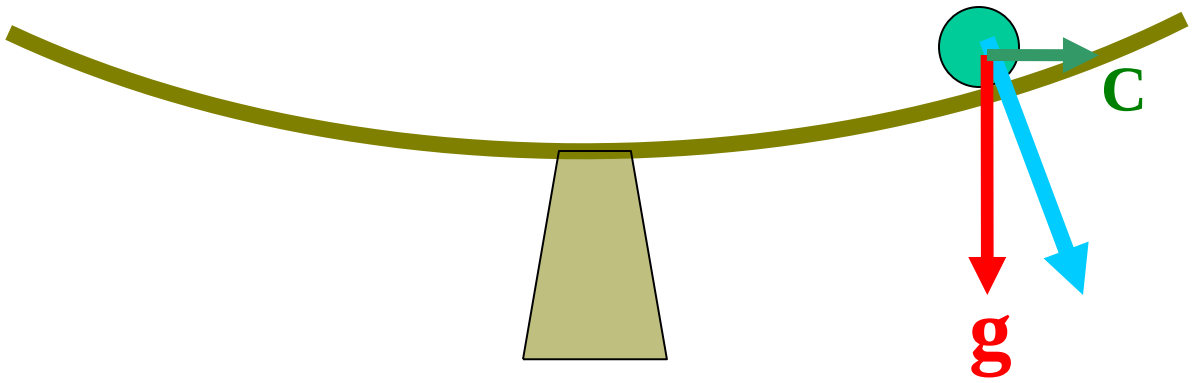
But how can we get rid of the centrifugal force?

This is the equation for a moving body on a rotating carrousel where gravity and the centrifugal force are perpendicular



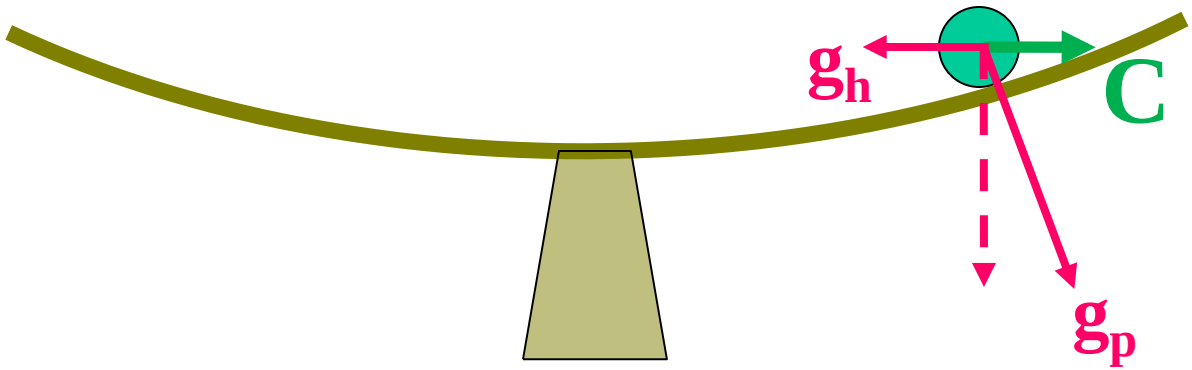
We can “get rid of” the centrifugal force by making the carrousel concave-

This makes the horizontal component of gravity cancel the centrifugal force

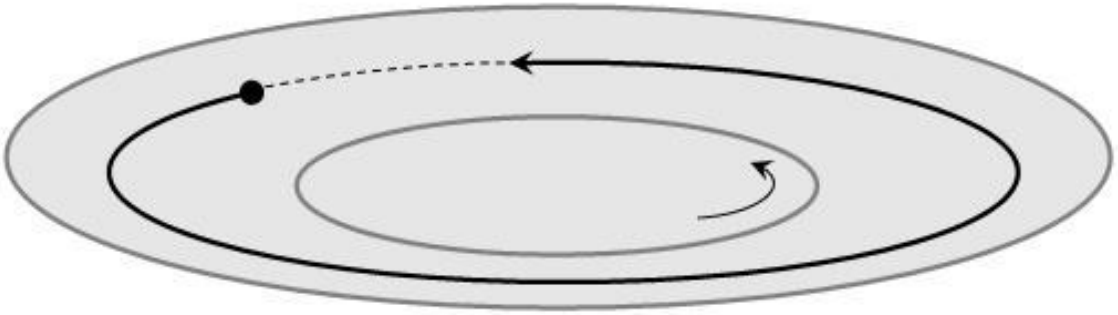


Resolve gravity g into one horizontal (h) and one perpendicular (p) vector.

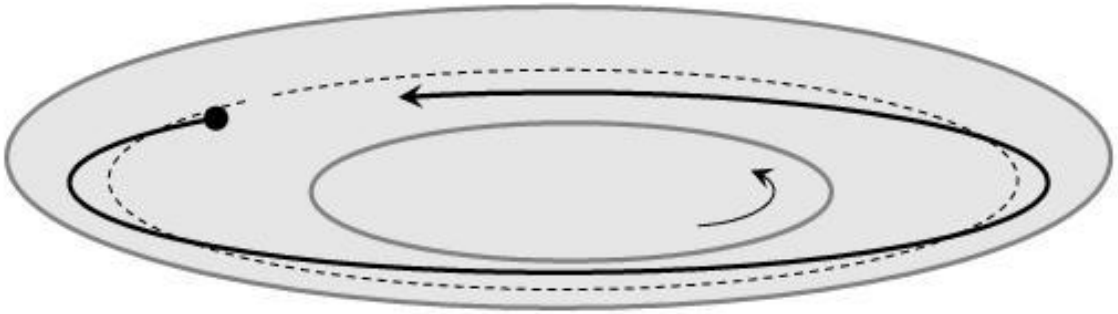
The "horizontal" component of gravity balances the centrifugal force



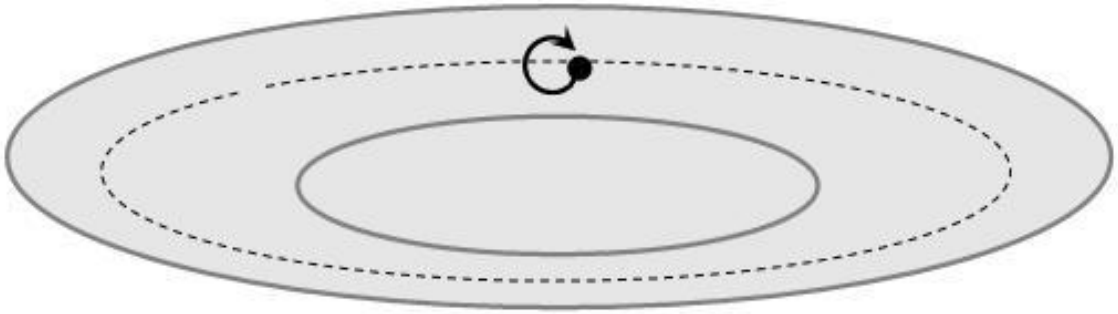
The motion seen from outside



The small body is not perturbed

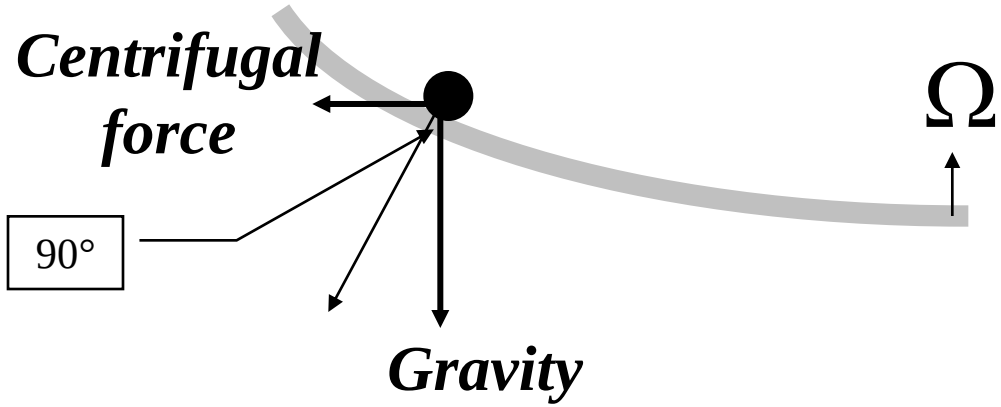


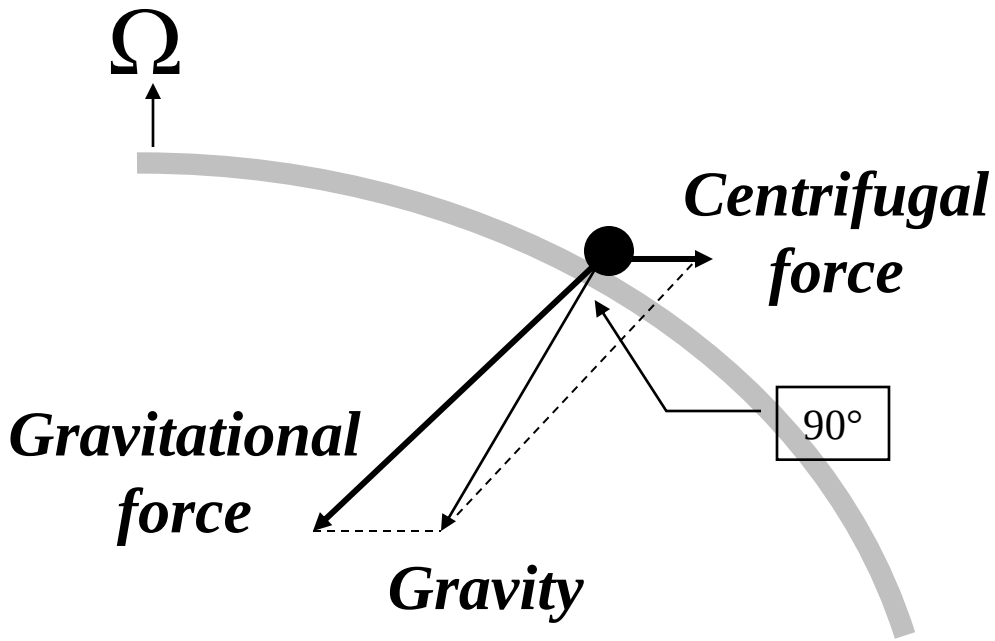
The small body is perturbed



The same seen from “inside” the rotating parabola

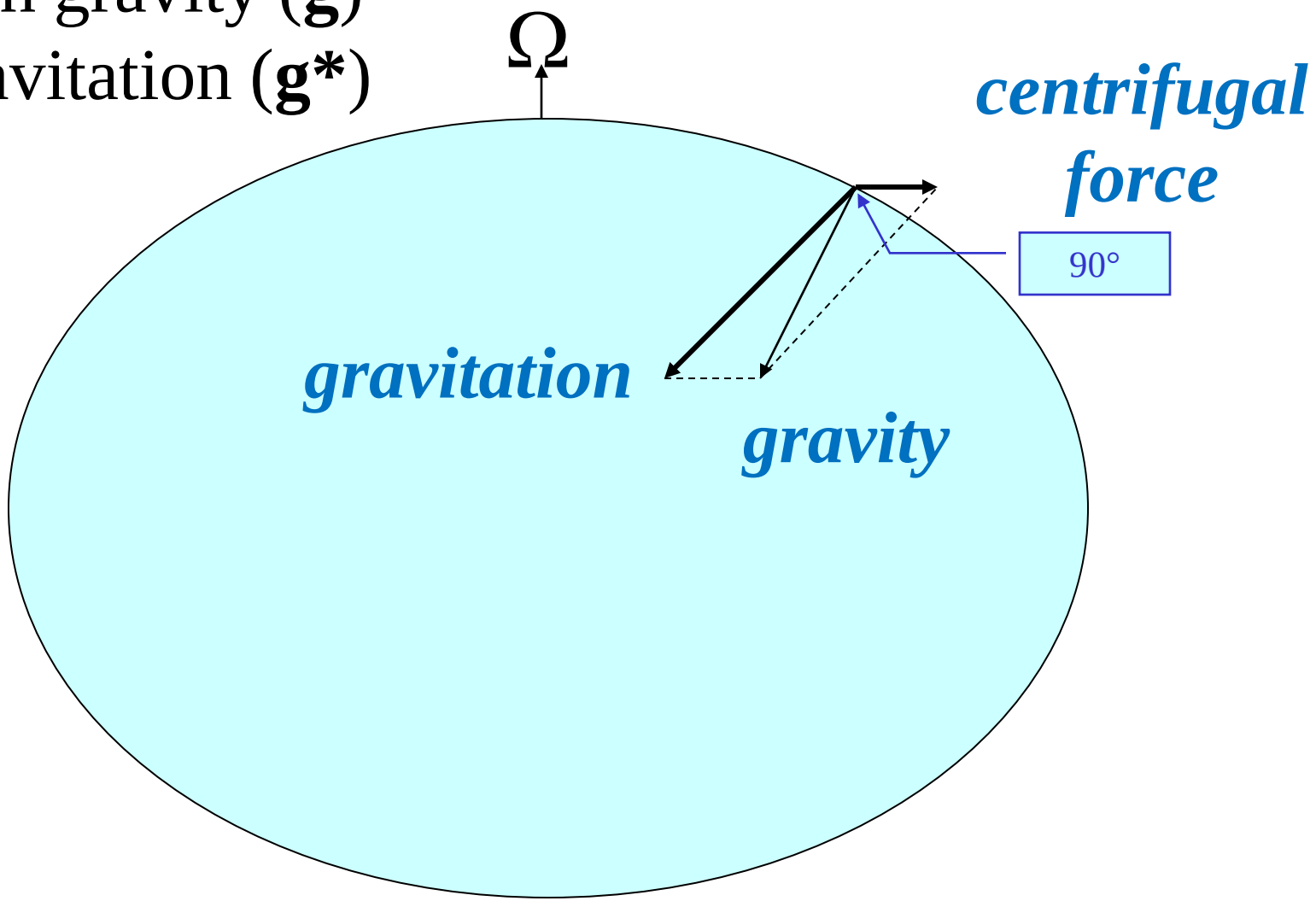
So now we know how to “get rid of” the centrifugal force on a carousel, but what about the earth?



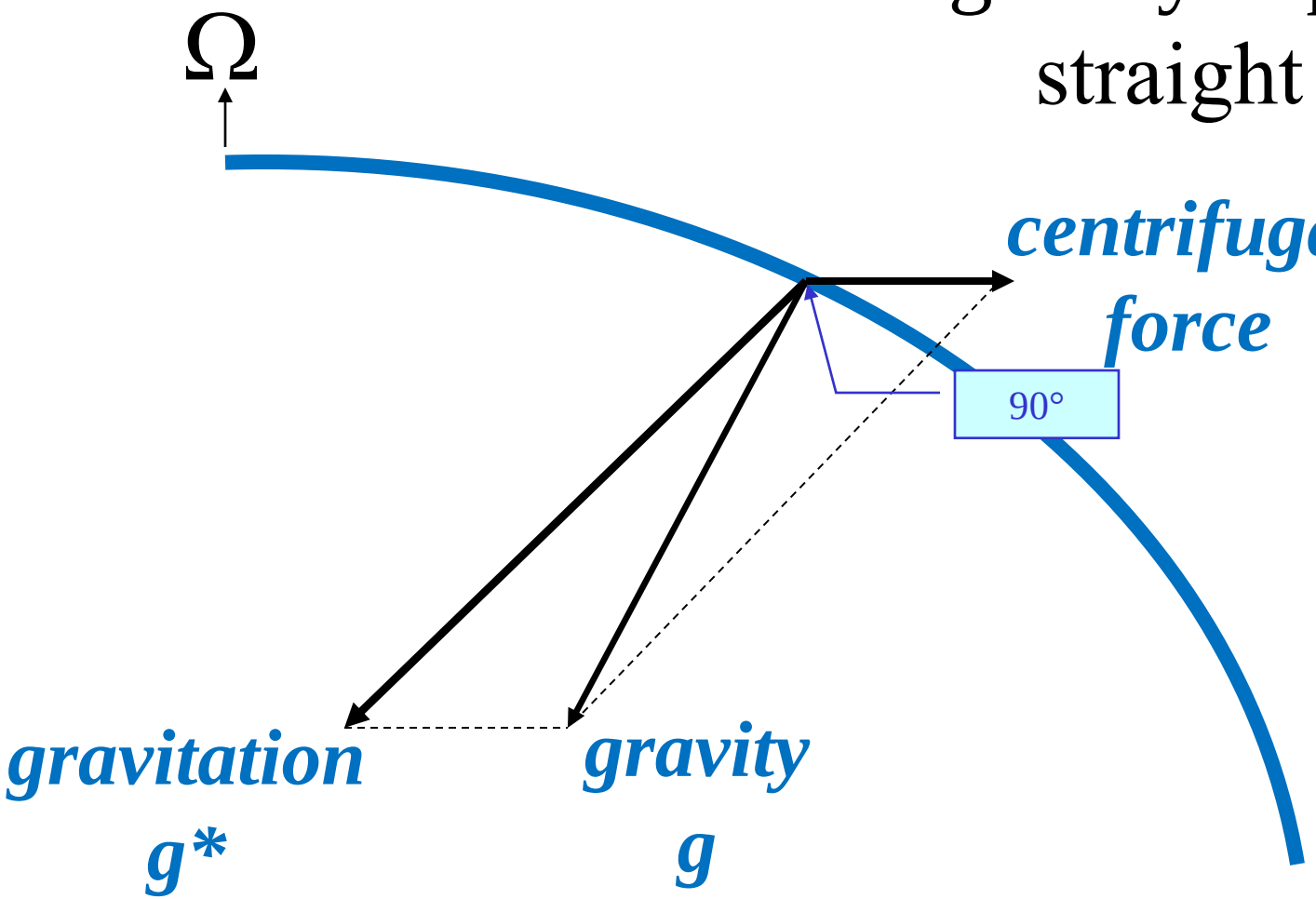


Exactly in the same way, by making use of the shape of the earth

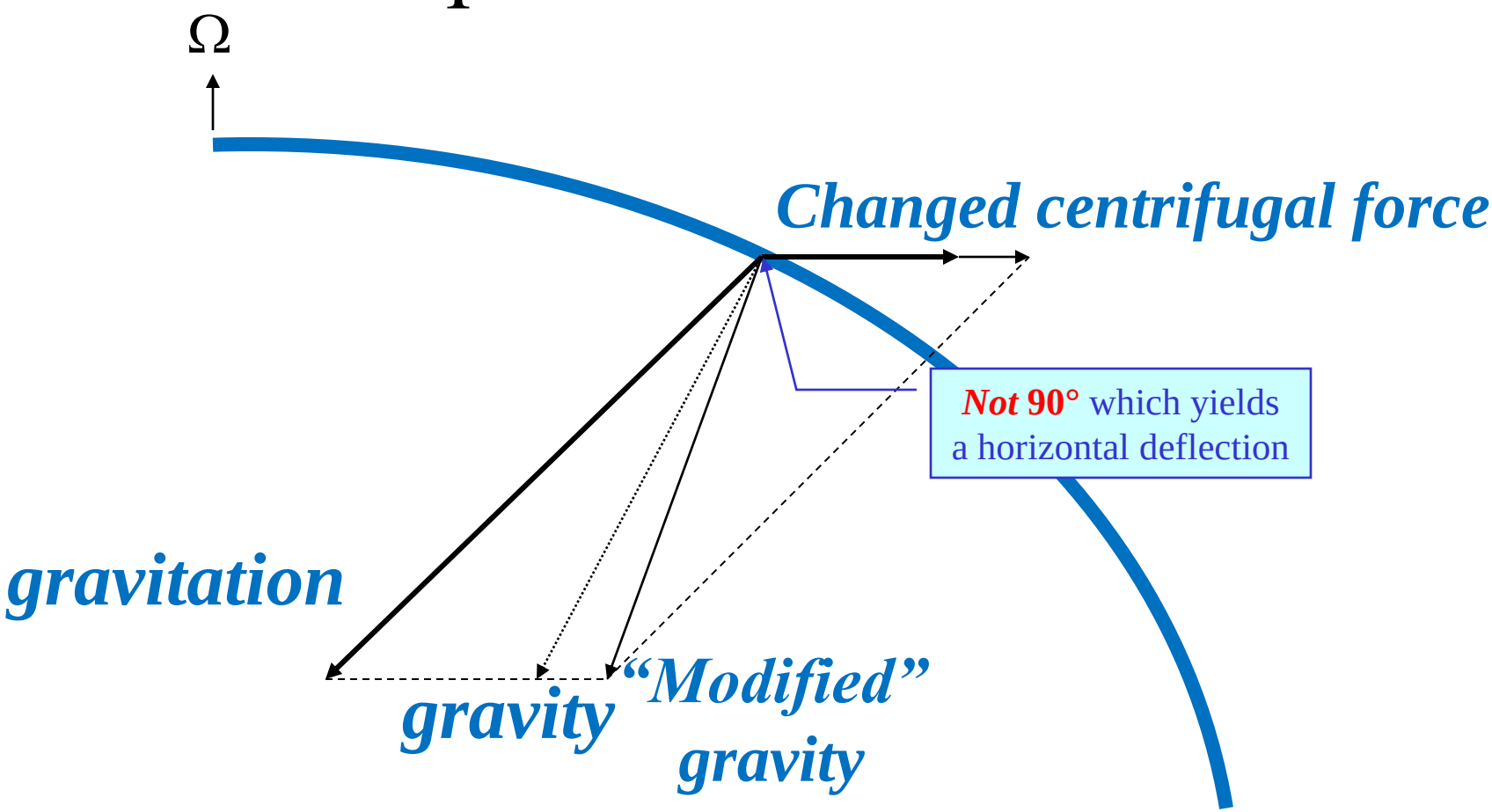
The crucial difference between gravity (**g**) and gravitation (**g***)



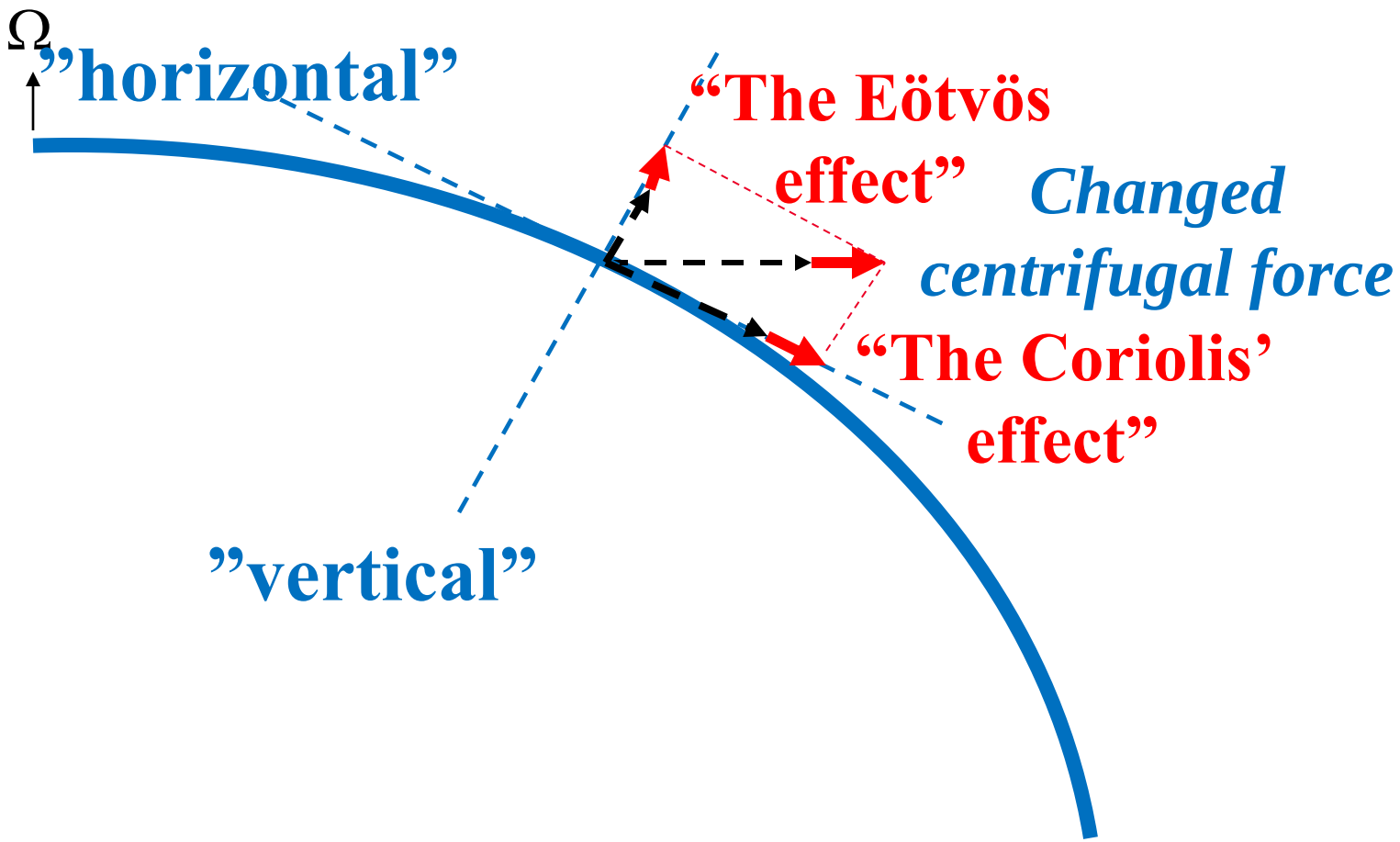
The force of gravity is pointing straight “down”



… except when there is motion



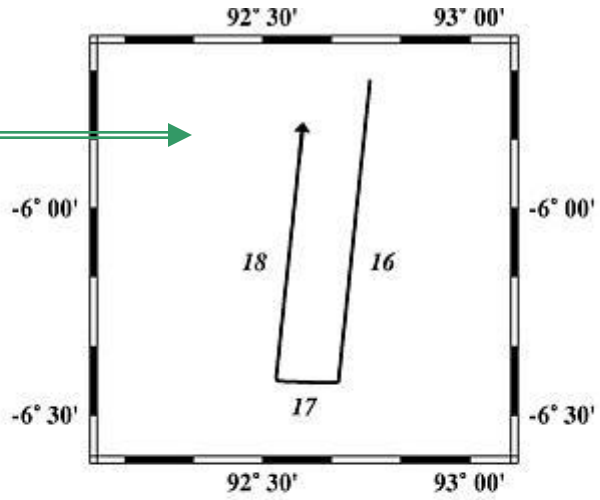
The sibling to the Coriolis Effect



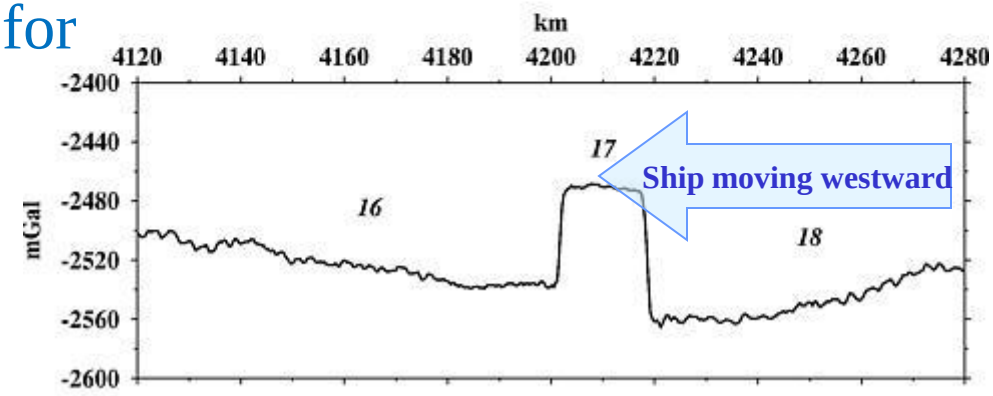
The Eötvös effect: We become lighter, weight less, when we move eastward, heavier when we move westward

Example of the Eötvös effect

Results from a French research vessel moving around in the Indian Ocean

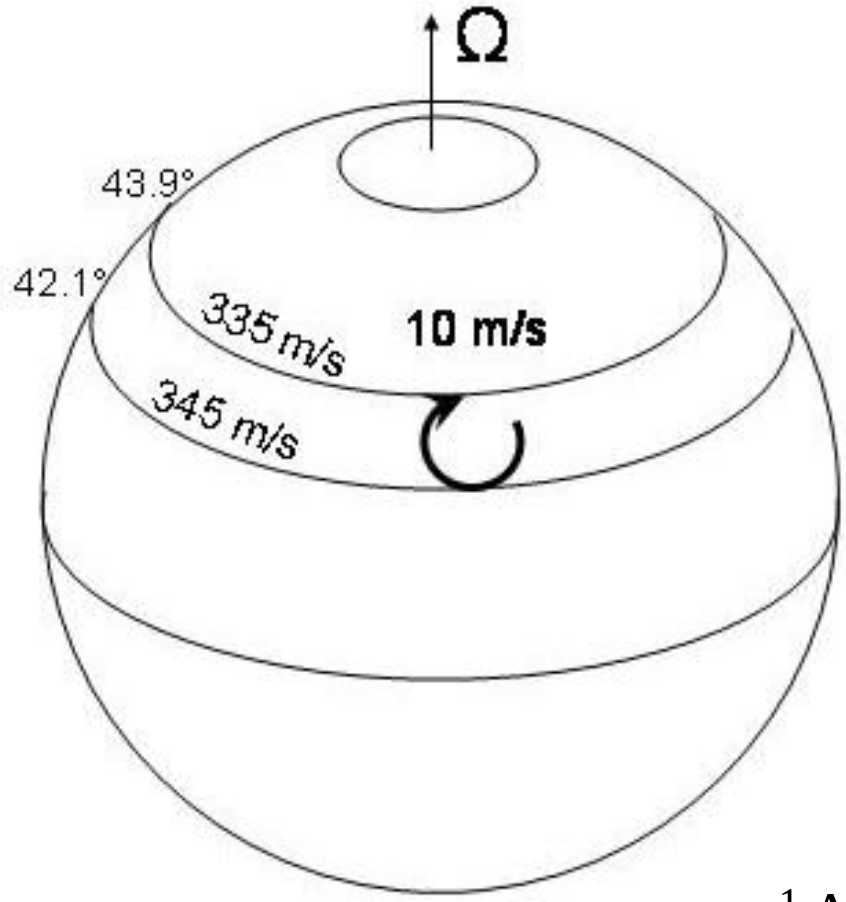


The gyration between profiles 16 and 17 produces a 60 mGal increase in the gravity values which is not associated with any bathymetric variations. Gravity values are more noisy for NS profiles than for EW ones. (Helene Hebert, personal communication)



http://www.geologie.ens.fr/~hebert/THESE/CHAP2/FIGURES/fig1.html)

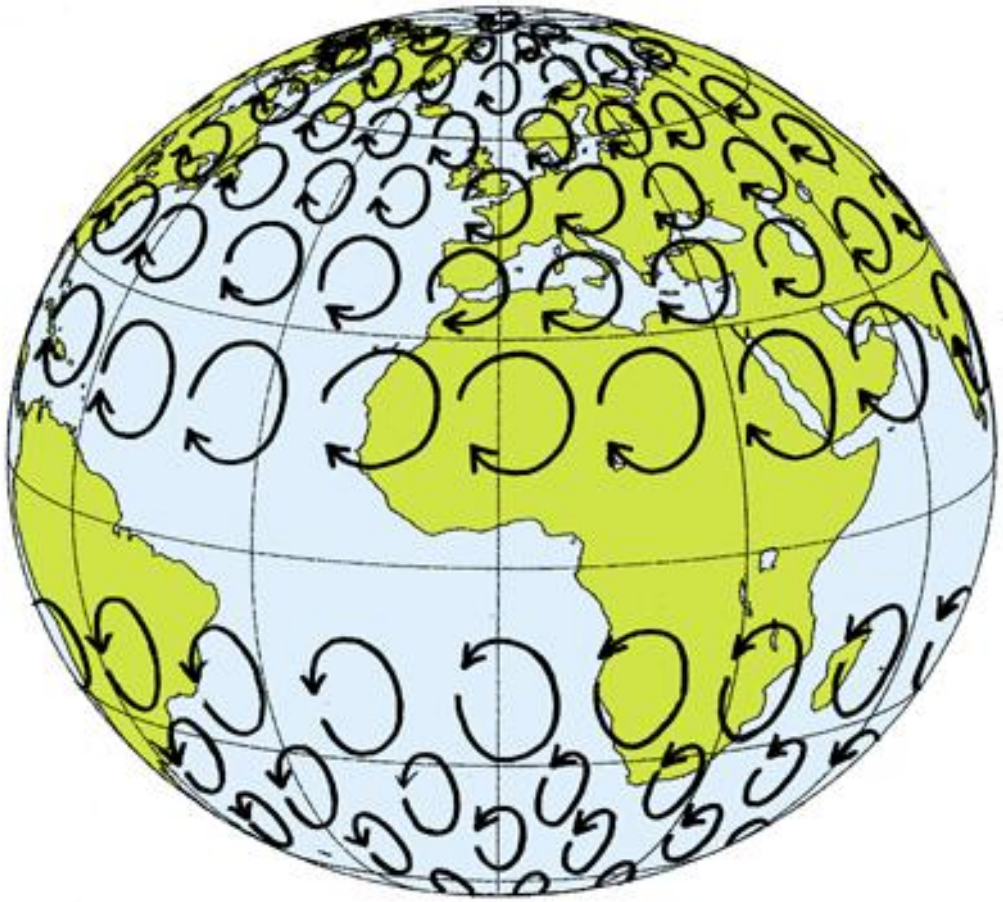
Frictionless motion along the earth's surface[1] are confined to small inertia circle trajectories



There is no increase in speed (kinetic energy)

[1] Away from the tropical latitudes

The “woollen cap” effect



break