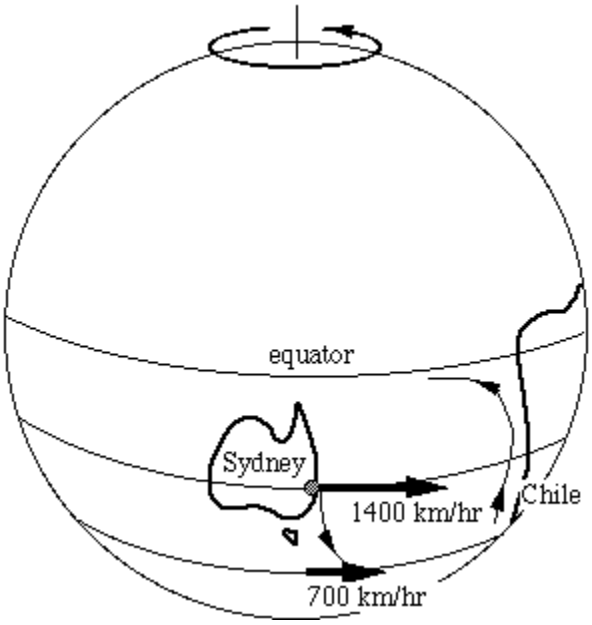
Newton's Law: What are coriolis forces?

Coriolis forces – what are they? And why do the large scale winds and ocean currents move clockwise in the Northern hemisphere and anticlockwise in the Southern hemisphere? This is a simple, non-mathematical explanation. There are links to related material below.

Imagine that you fly a hot air balloon, starting at Sydney. Further, let's imagine that an astronaut on the moon is watching you. As it happens, the wind is going due South, according to your compass. You check your GPS and, sure enough, you latitude is increasing and your longitude is (for the moment) staying the same: you are travelling South – with respect to the earth.



Meanwhile, the astronaut on the moon can see that the Earth is rotating, and he sees both you and Sydney travelling in a circle around the Earth's axis. (His view is shown at right.) The rotation of the Earth means that both you and Sydney are travelling towards the East at about 1400 km/hr. The inhabitants of Sydney cannot feel this motion, partly because everything around them except the moon, stars etc is moving, and partly because the motion is smooth (ie very little acceleration is involved). In your frame of reference, you are going due South, with no Easterly component of velocity, but the astronaut knows better.

Imagine that you continued travelling with the same South and East components of velocity (as viewed from the moon). What would happen? Well, by the time you get down to the Southern Ocean, you will be over a point on the Earth that, according to the astronaut on the moon, is still travelling East, but a speed of only 700 km/hr. So, if somehow you still had the Eastward velocity you had when you were above Sydney, you would now be travelling 700km/hr faster than the Earth in an Easterly direction. In other words, you would be travelling mainly East! Your path would be a little like the thin line on the diagram: you headed South from Sydney, but you turned left, and

you are starting an anti-clockwise motion.

We could reverse the argument for a balloonist travelling North along the West coast of South America. This surprised tourist will arrive at the tropical latitudes to find that the Earth is travelling East much faster than she is. In other words, relative to the Earth, the tourist is travelling West. Again a left turn, and again anti-clockwise motion. (Thin line at right of diagram.)

So the winds (and the ocean currents) in the South Pacific go mainly anti-clockwise: South along the East coast of Australia, East across the coast of Antarctica, North along the West coast of South America, and then West across the middle of the Pacific.

But what made you turn? Well, according to the man in the moon, it was more a case of the Earth turning: viewed from the South, the Earth's rotation is clockwise. The surface of the Earth is turning, and turning means changing direction, and changing direction means accelerating. In an accelerating frame of reference such as the surface of the Earth, Newton's laws don't work. In order to make them appear to work, we can invent fictitious forces. *The name of the fictious force that appears to have caused you to turn is the Coriolis force.*

In the case of the surface of the Earth, the acceleration is very small, because the rotoation rate is very slow - only slightly more than one turn per day. So, the approximation that Newton's laws hold on the surface of the Earth is good enough for most applications. To see the error in Newton's laws as applied to this frame, one needs a carefully set up, slow experiment such as a Foucault pendulum.)

It is important to remember that centrifugal forces and Coriolis forces are purely fictitious, they are artifacts of making measurements in a frame of reference that is accelerating. However, the surface of the Earth is an extremely convenient frame of reference: any observing instruments that are in an inertial frame disappear from the view of an Earth-based observer rather quickly! So, for convenience in measuring and analysing motion on the Earth, we often use the Earth-based frame of reference. (To see how much convenience is gained, you might like to try doing a simple ballistics problem in inertial coordinates and then relating the result to a coordinate system on the surface of the Earth.)

A footnote: **Does the rotation of the earth affect the way in which water runs down the plug hole when you empty the bath?** Some people say that the water goes down clockwise in the Southern hemisphere and anticlockwise in the Northern

hemisphere. Such people have probably never, or very rarely, looked. In some bathtubs (or basins etc) and under some conditions, the water runs out clockwise, in others it runs out anticlockwise. **There is no correlation with the hemisphere**. Other effects may lead to the direction of draining. For instance, some basins have separate cold and hot water taps that are positioned symmetrically left and right. If you fill the basin using the left hand tap, you set up a rotation in one direction, and this will determine the direction in which it drains. Using the other tap reverses the direction. Many basins and baths are sufficiently symmetrical that it is possible, with some care, to have the water drain with no observable rotation. Alistair Fraser has a page devoted to silly comments about Coriolis forces and water in basins.

Every now and then, someone (usually from the Northern hemisphere) writes to tell me that they have checked the bath, the sink, the hand basin and the laundry basin and that all of them drain the same way. Now, in either hemisphere, the chance that a basin drains clockwise is about 50% (unless you drain it carefully enough to have no rotation at all, which requires a bit of patience and thought). So, with four basins in a typical house, there is a 1 in 16 chance that they will all drain clockwise, and a 1 in 16 chance that they all drain counterclockwise. So about 6% of people would get the result that all their basins drain in the direction of cyclones in their hemisphere, and another 6% would get the result that all drain in the opposite direction. Perhaps the people who write to me are from one of these groups. However, I rather suspect that some of them have never looked, or never looked more than once or twice. Rather, I think that they have been told this, have stored it away as a 'fact', and are really upset to discover that it is not a fact.

Source: http://www.animations.physics.unsw.edu.au/jw/coriolis.html