EXPLAINER

The Walker Circulation and trade winds

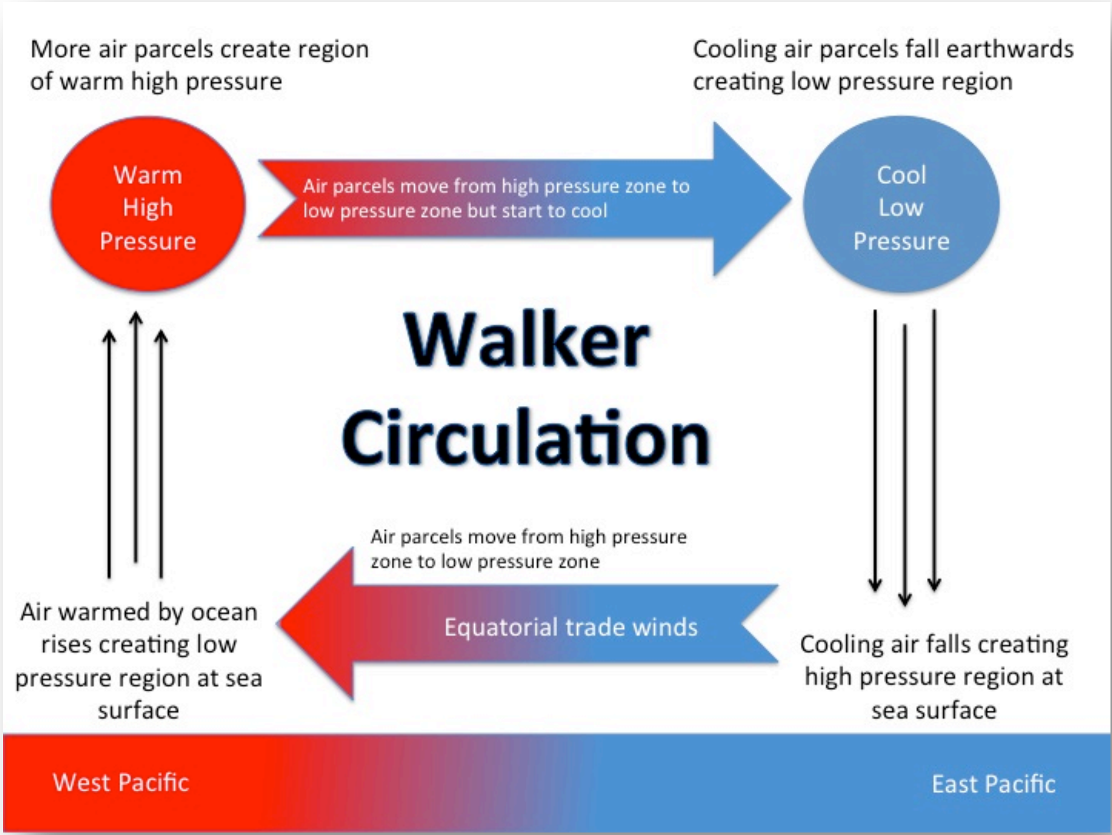

Fig 1: The *Walker Circulation shown is typical of a La Nina phase and is similar to what is currently occurring with the increased surface strength of Pacific Equatorial trade winds.*

Winds in the Pacific equatorial region are generated by air masses rising and falling.

Warm air that has been heated by the Earth or the ocean rises, creating a void of air (low pressure) at the surface and an excess of air (high pressure) aloft.

By contrast, air that has been cooled by the earth or ocean surface leads to a sinking motion that creates an excess of air (high pressure) at the surface and a void of air (low pressure) aloft.

Winds in equatorial regions blow from regions with excess air (higher pressure) towards regions needing air (low pressure), which when combined with the vertical motion creates an atmospheric circulation cell. Outside of the tropical regions the earth rotation distorts this phenomenon.

Those living close to the coastline may experience a localised version of this on a long hot summer day, when cooler ocean (sea) breezes start to blow around midday (this time varies depending on how far away from the coast you live). This is because the land surface is so hot the overlying air rises leaving a void (low pressure) at the surface, while the air overlaying the relatively cool ocean (which has higher pressure) moves in to replace it.

This circular movement of air in response to differences in air temperature occurs on large continental scales across entire ocean basins on or near the equator. It is known as Walker Circulation, named after the pioneering British meteorologist Sir Gilbert Walker.

Because of its size, the Pacific has a very large Walker Circulation driven by the differences in ocean temperatures between the Western and Eastern Pacific.

In neutral or La Niña conditions, where the Western Pacific is warmer than the Eastern Pacific, surface trade winds consequently blow from east to the west.

The strength of these trade winds depends on the difference in ocean temperatures between the cooler and warmer regions of the Pacific. The greater the difference, the stronger the Walker Circulation and consequently the stronger the equatorial surface trade winds.

For this reason, surface trade winds blow much harder during a La Niña, where the difference between temperatures is greater than in relatively neutral conditions.

During El Niño events the difference in ocean temperatures between the east and west is weakened, and may even be reversed (i.e., the ocean in the Eastern Pacific ma even be warmer than the Western Pacific) for extremely strong El Niño events.

As warm air rises in the east and sinks in the west during an El Niño, the Walker Circulation can be seen to reverse its motion. This can stop or even reverse the movement of surface trade winds.

How the Pacific and Atlantic Walker Circulations interact

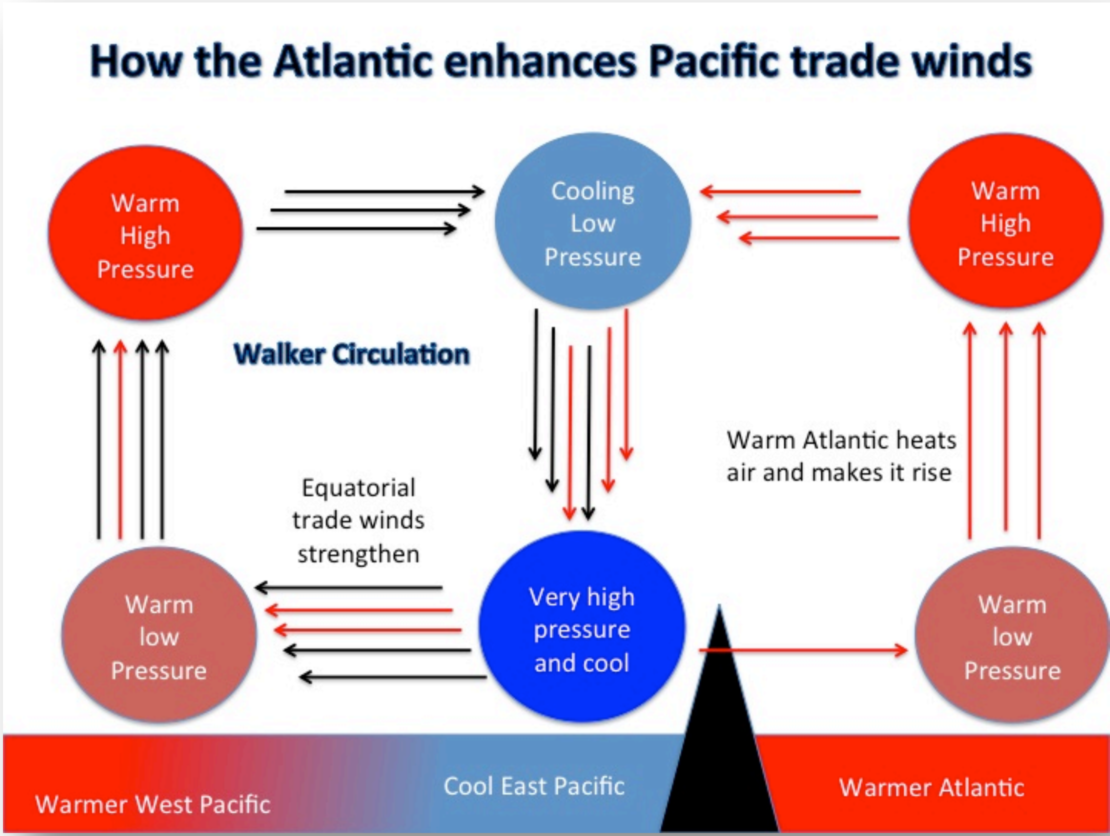

Fig 2: *The "roundabout effect" that has been accelerating Pacific Equatorial Trade Winds.*

The rapid warming of the Atlantic since the late 1990s, which is at least partly due to greenhouse gas forcing, has created widespread rising motion over most of the tropical Atlantic Ocean.

This has led to lower surface pressures and an increase in pressure in the upper atmosphere over the Atlantic region.

As a lower than normal pressure exists high above the eastern Pacific, the high Atlantic pressures aloft allow upper atmospheric winds to blow from the Atlantic to the Pacific basin.

This additional convergence of air high above the eastern Pacific acts to increase the sinking motion in the cool eastern Pacific and accelerates the Pacific's surface trade winds.

It is perhaps easiest to imagine this impact as like pushing a playground roundabout to make it go faster and faster, with the faster moving Atlantic

Walker Circulation giving the Pacific Walker Circulation an extra boost as it goes past.

The domino effect of an increased Walker Circulation

As the Pacific Walker Circulation accelerates surface trade winds it has a range of knock-on effects. These include:

- **Increased ocean overturning**: As the trade winds increase in strength, it causes more energy to be imparted into the ocean, increasing its overturning motion.
- **More heat enters the deeper ocean layers:** The increased overturning of the ocean means more heat is taken out of the atmosphere and goes into the deep ocean, which can act to offset global warming. This appears to be responsible for the recent slowdown in the rise of global average surface temperatures.
- **Increased sea level rise in western tropical Pacific Islands:** Stronger Equatorial Pacific trade winds push warm waters across to the western Pacific, resulting in an expansion of the ocean volume and a regional sea-level rise of up to 1 cm/year (3 times the global mean value), which has caused widespread inundations in low-lying islands.
- **Persistence of droughts in part of the US:** Sustained cool eastern Pacific conditions continue to make California and some other areas in the US, drier than normal. It is similar to the impact of La Nina conditions
- **Slowdown in rise of global average temperatures:** With more heat going into the ocean than the atmosphere, global average temperatures are likely to still increase but at a slower rate to that expected by global warming.
- **Potential extreme acceleration in global average temperatures over a very short timeframe:** Should these intensified trade winds return to normal strength, the release of heat that has been stored in the ocean is likely to be extensive and cause a rapid increase in global average surface temperatures over a relatively short period.

What we are seeing here is a change in just one phenomenon, Atlantic ocean surface temperatures, that has already created ripple effects around the world. Of greater concern is that it may also be masking profound changes to our climate that could appear dramatically should the Walker Circulations return to normal.