We've talked a little bit about why there are overturning circulations in the atmosphere in the tropics. But outside the tropics, as I mentioned before, the circulation is dominated by eddies. And these eddies have horizontal dimensions of about 3,000 kilometers.

What causes those? Well let's first of all have a look at a weather map of the kind that you might see in a newspaper or on television. This typically shows the distribution of pressure at a given time . Everybody knows these pressure systems move, most often from west to east.

Here's a particular map for September, 2012 which shows a big high pressure system in the eastern part of the US. Because the air flow around these systems is nearly in geostrophic balance, we tend to have flow toward the south on the eastern side of these high pressure regions, flow toward the north on the western side. So clockwise flow around high pressure systems.

And here in Western Canada is a cyclone, or a low pressure system, with counter-clockwise flow, again pretty much parallel to the isobars [contours of constant pressure]. These weather maps, these high and low pressure systems, are manifestations of baroclinic eddies that we see commonly in middle and high latitudes.

Here is another way of looking at them. This is a map of a completely different kind showing the distribution of temperature at the tropopause. This is for the Northern Hemisphere. It happens to be for a date late in November in the year 2013. The North Pole is right in the center of this map. We're looking at the Northern Hemisphere, so we're looking down at the North Pole.

And one can see several interesting features. First of all, the temperature gradient-- the colored lines that you see here-- is typically highly concentrated, just like the jet streams are at particular latitudes. But it's wavy, OK. It's a wavy contour. We can see various regions of strong temperature gradient here.

These waves represent the eddies as they're seen near the tropopause. These are all part of the same systems, of which the high and low pressure systems at the surface are one particular manifestation. These eddies, again, typically move from west to east in the flow and are responsible for most of the day to day variations in weather that we experience in middle and high latitudes of the Earth.

It's very instructive to look at movies of maps like these. And I'm going to leave up here for a minute this

URL, which you can copy down, and in your own time play a movie of today's weather at this website. So you'll see maps like tropopause maps but you'll be able to advance them in time to see what the weather is actually doing.

Here is another animation showing the temperature near the surface in the Northern Hemisphere over a period of a few weeks. OK and this projection is, again, looking down at the North Pole, which is pretty much in the center of this diagram here. And when you look at the temperature you see primarily the low temperatures denoted by blue toward the poles or over the high latitude continents. But you see these beautiful eddies in the pattern that swirl around, mixing the temperature, and propagating from west to east. These are basically the so-called baroclinic eddies, which occur at middle and high latitudes.

Now why do these eddies exist? Well, that was a very hot topic in atmospheric research from its inception into recent decades. And it turns out that fundamentally the eddies are there because the thermal wind solution, our exact, non-linear solution of the equations-- at least on the idealized planet-- turns out to be unstable in middle and high latitudes.

And that brings us to the topic of stability and instability. What do we mean by that? Well we already encountered the notion of stability when we talked about convection. The fact that the radiative equilibrium solution is unstable to air motions in the vertical direction, and that causes the state to migrate away from the non-linear equilibrium that's unstable toward a different regime, one which may be, for example, highly time dependent.

Well let's just talk about stability in the simplest terms. And we'll do that in a mechanical system, where we have a series of valleys-- here for example-- and ridges-- here, here, so forth, OK. And we'll imagine a frictionless marble that is put into the system of valleys and ridges, subject to gravity, acting downward. And we'll ask about the stability of various solutions here.

Well, in this particular case, I've shown the three nonlinear equilibrium solutions for the marble. One is at the bottom of the valley. One is at the top of the hill. And one of them is in a little mini valley that is otherwise at the top of a crest, OK. These balls, if placed carefully in these places, will not accelerate. But it's intuitively obvious and it can be shown mathematically that this solution is stable.

All right, let's see what we mean by that. What we mean is that if we push that ball in one direction or the other, gravity will tend to accelerate it back in the direction whence it came. So it tries-- the forces acting on that marble tend to push it back to where it came. And we call that stable, right. It doesn't really want to move away from that.

And one characteristic of stable systems is that they oscillate. So for example, a pendulum hanging straight down, if pushed will come back. But it will continue to oscillate. So oscillations, or waves, are characteristic of stable equilibria.

Now on the other hand, the marble at the top of the ridge here is unstable. If it's pushed in either direction it will tend to accelerate in the same direction it was pushed and will wind up in a state very different from the state it started with. So while a marble balanced on top of the hill is an equilibrium solution, we don't expect to actually observe that equilibrium solution-- maybe, except in Roadrunner cartoons or something like that-- because the slightest perturbation away from equilibrium will result in the system going to some completely different state.

Now I've put in here this third example of a metastable solution. So this marble, if put in this particular place, will be stable to a small perturbation. But if I give it enough of a shove, it will go to a different state. So we call that a metastable solution.