We ask, when is a fluid unstable to convection? There are three important concepts we need to discuss. First of these is the idea of stability. The second is the notion of pressure and hydrostatic equilibrium in fluids. And the third important concept is buoyancy.

Let's begin with stability. Now, suppose that we have a topography that you might think of as a series of troughs and hills like this. Now in that series of troughs and hills, I'm going to position a perfectly frictionless marble somewhere. So for example, suppose we put a marble down here, the bottom of one of the valleys.

Now, intuitively we know that if we were to push that marble uphill gravity would accelerate it back down in the direction from which it came. And that would be true also if we pushed it up the other way, gravity would accelerate it back down. And we would regard the position of that marble as being stable.

Now, note that the marble at the bottom of the valley is an equilibrium solution of the equations of motion. And the idea here is that if we perturb the marble away from equilibrium we ask, what forces act on the marble? And do they act to restore it toward the equilibrium position?

Now, another equilibrium solution for the marble has it balanced right on top of the hill. And if we were to push that marble in one direction or another, just slightly, we know that gravity would accelerate it away from the initial position. So we would say that the equilibrium of the marble on top of the hill is an unstable equilibrium. The slightest perturbation to that equilibrium would send it off toward another stable equilibrium point.

Now the point is that except perhaps in road runner cartoons, we don't usually observe marbles or boulders perched precariously on top of hills. We don't usually observe unstable states. If we went out and made observations we would usually observe systems in or near stable equilibria.

Another characteristic by the way of stable equilibrium points, is that perturbing them results in an oscillation. Think of a pendulum hanging straight down, perturbing that a little bit will cause the pendulum to rock back and forth. So oscillation is a characteristic of stable equilibrium. Where as if we had the pendulum pointing straight up, then perturbing it slightly away from its initial condition would result in an acceleration away from that equilibrium. So accelerating departures from equilibrium is a sign of an unstable equilibrium.

Now, what we want to do is apply this concept of stability to the atmosphere. What about this radiative equilibrium state? It is in fact a solution of the equations of radiative transfer. How do we know if that's a stable or unstable equilibrium?

And to address that question, we need to talk about the concept of stability applied to fluids. To do that, we have to talk about the full equilibrium state of the radiative equilibrium solution. Not just the thermal equilibrium, but the dynamic equilibrium. The gas as a gas is at rest in a gravitational field. And what governs the state of a fluid, which is at rest?