Meteorology – Lecture 23

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Important notes

- These slides show some figures and videos prepared by Robert G. Fovell (RGF) for his "Meteorology" course, published by The Great Courses (TGC). Unless otherwise identified, they were created by RGF.

- In some cases, the figures employed in the course video are different from what I present here, but these were the figures I provided to TGC at the time the course was taped.

- These figures are intended to supplement the videos, in order to facilitate understanding of the concepts discussed in the course. *These slide shows cannot, and are not intended to, replace the course itself and are not expected to be understandable in isolation.*

- Accordingly, these presentations do not represent a summary of each lecture, and neither do they contain each lecture's full content.
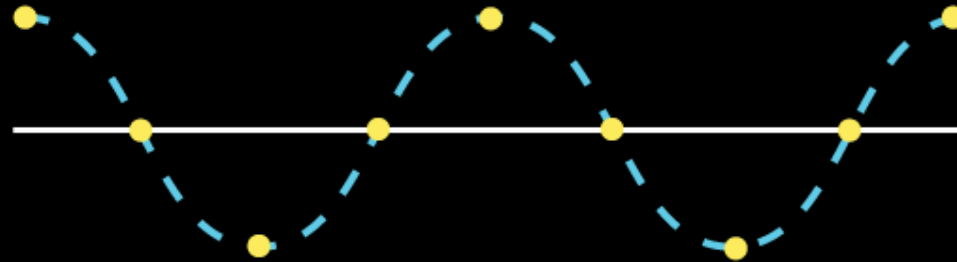
Animations linked in the PowerPoint version of these slides may also be found here:

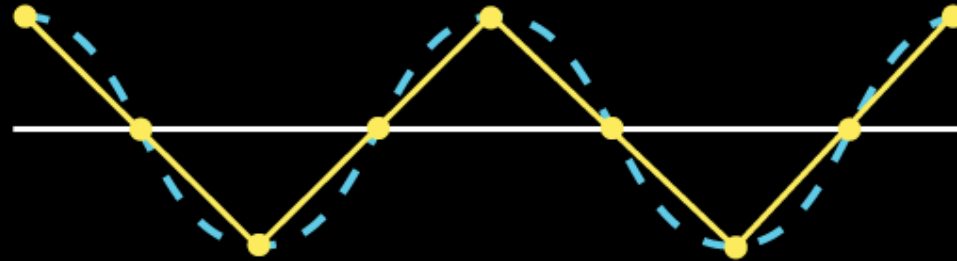http://people.atmos.ucla.edu/fovell/meteo/
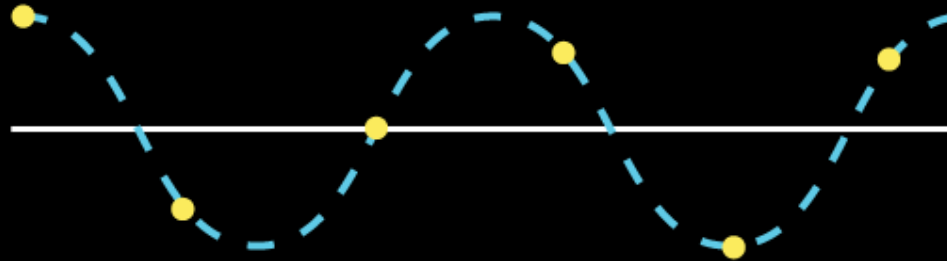
Model resolution
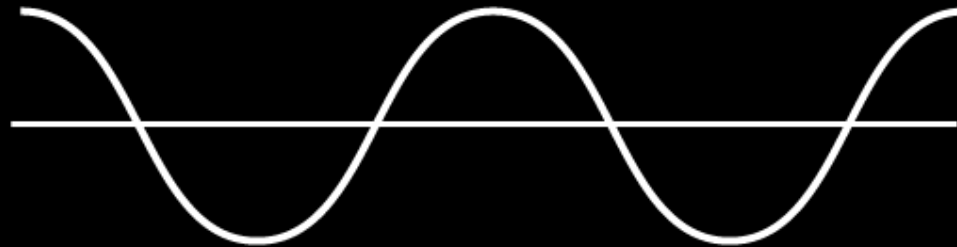
A simple wave. We see its structure.

The model, however, samples this wave only
at its grid points. Suppose there were 4 grid points
across each trough and ridge pair.

The model does not see the smooth, undulating structure we see. It connects the dots with lines. It sees something like this.

It could be better. Six grid points across each wave
would provide a better representation of the feature.
It could be a lot WORSE, too. Look what happens when
we have only 3 points across each wave.
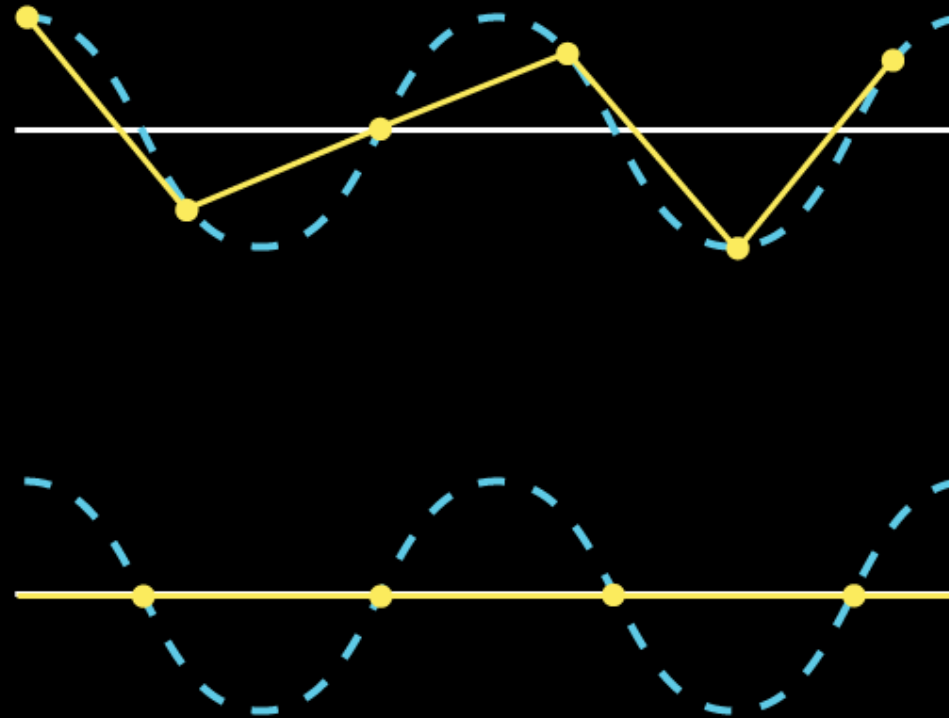
That doesn't look much like our actual wave at all.
And what if we only had two points across each wave?
We might not see it at ALL.
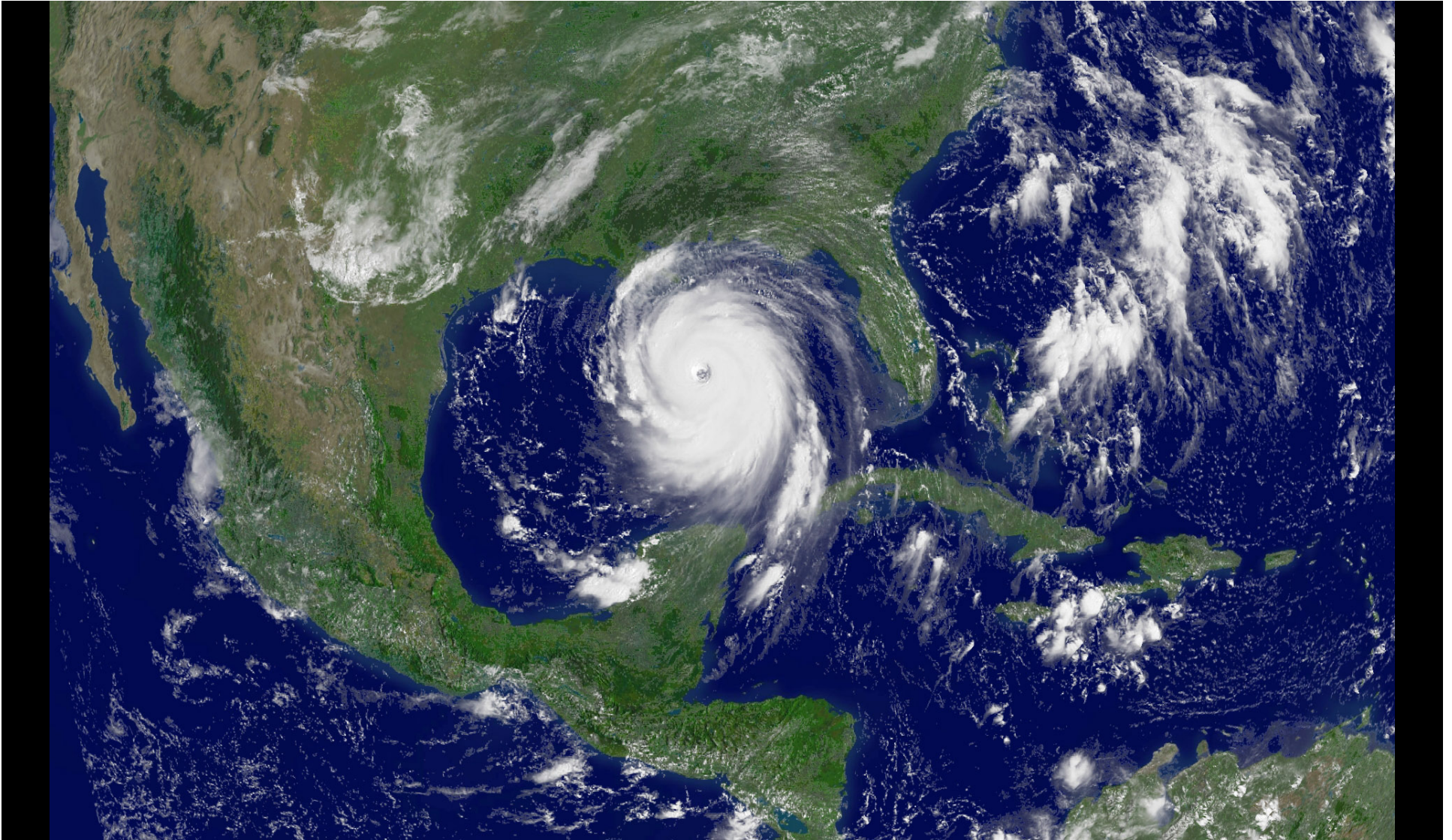
Satellite picture of Hurricane Katrina bearing down on the US Gulf Coast.

The same picture, now at somewhat lower resolution (about 10 km). We can still tell it's a hurricane, but the sharpness has been degraded. We can still see the eye, but a lot of the small features have merged or been lost.

Many forecasting models have to use a roughly 30 km grid -- 19 miles. At that resolution, we can't see Katrina's eye anymore. A lot of the little clouds we saw over the SE US are gone.
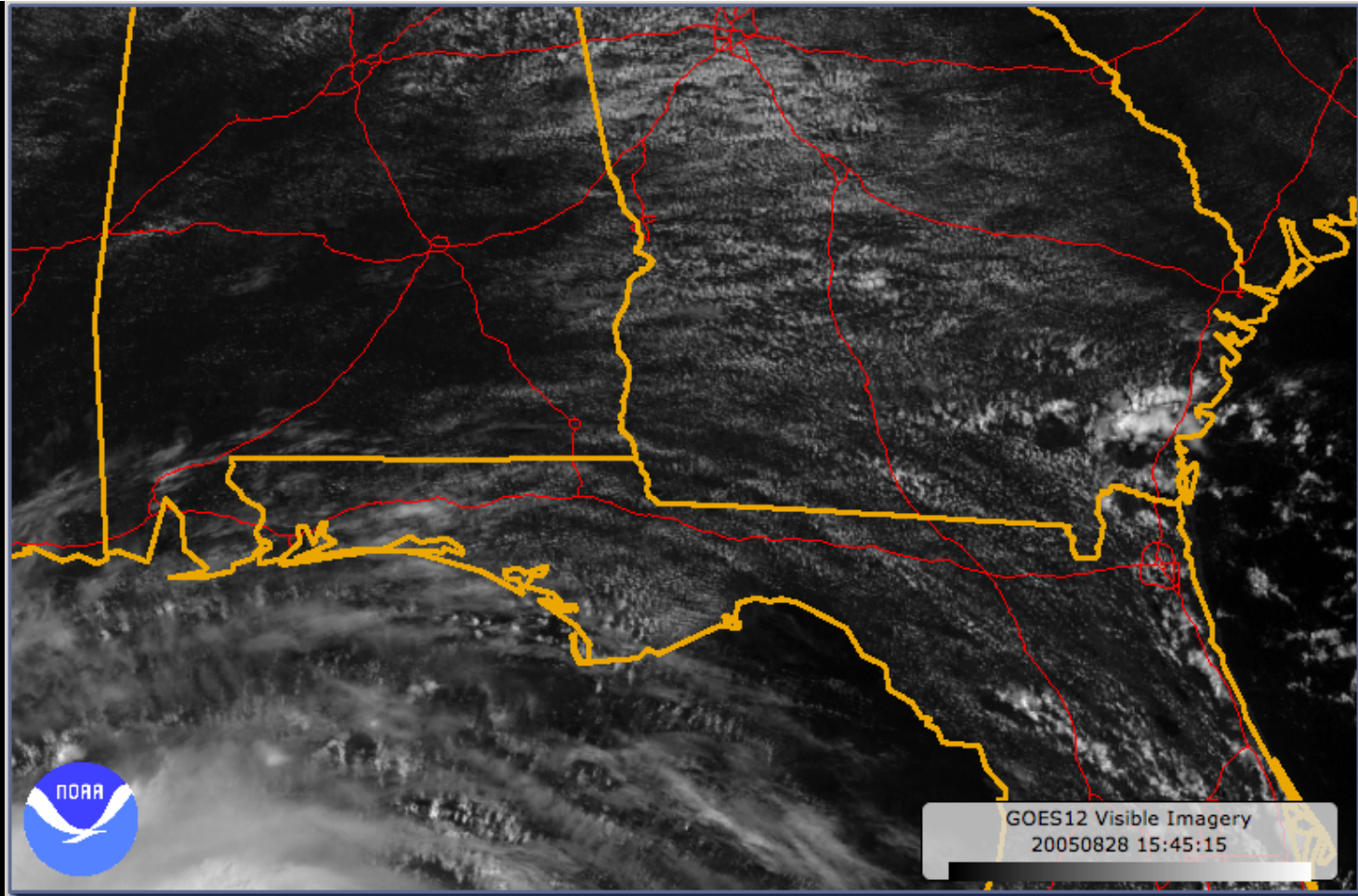
More compromise. At what point would we not be able to tell that's a hurricane if we had not known it from the start?

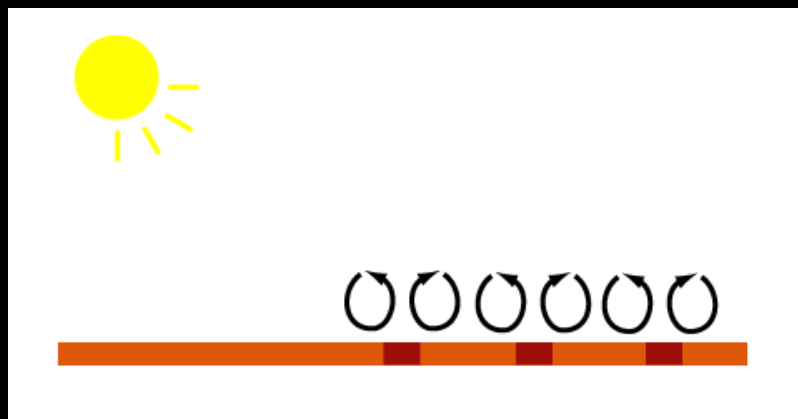This is the world as seen through the eyes of global models not so long ago. Smudged. Myopic.
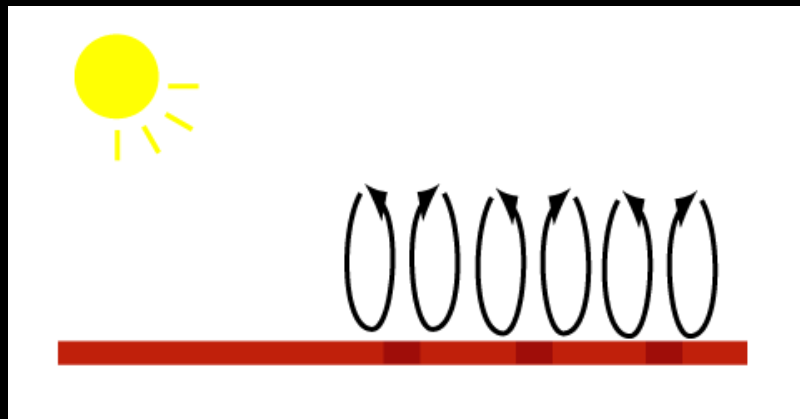
Parameterization discussion
(roll cloud example)

Another view of Katrina before landfall. This time, I'm focusing on all those small clouds over land… roll clouds, which form owing to uneven surface heating
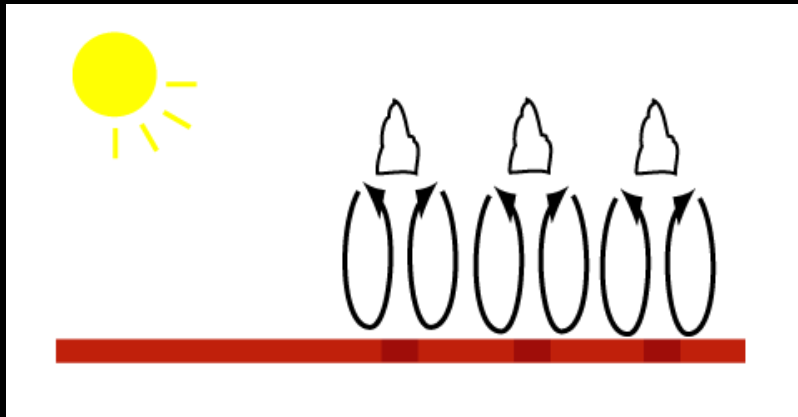
- Consider the sun warming the land during the day

- With uneven heating, wind and vertical wind shear, roll-like circulations can start

- As the land warms, the rolls get deeper
- They accomplish what conduction cannot… mixing heat vertically from the heated ground to the much more poorly heated air

- If the heating is strong enough...
- If the lapse rate becomes steep enough...
- If the vapor supply is high enough...
- ...clouds will form above the roll updrafts
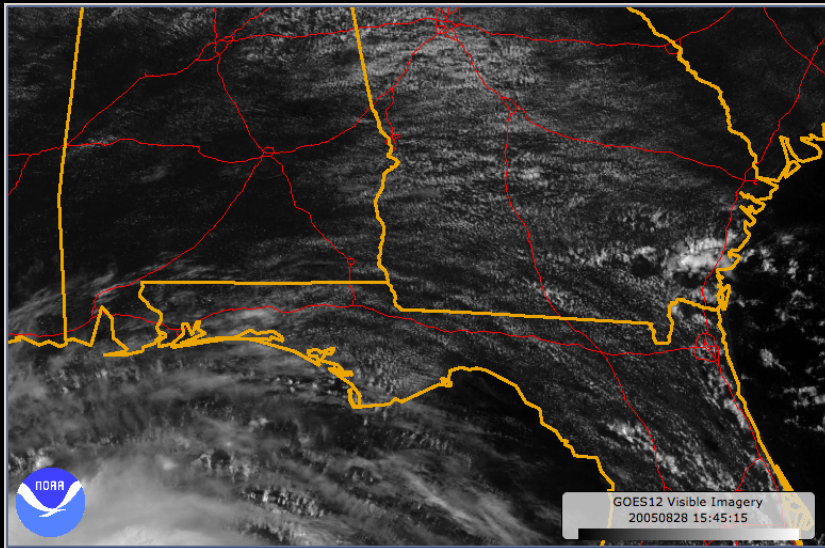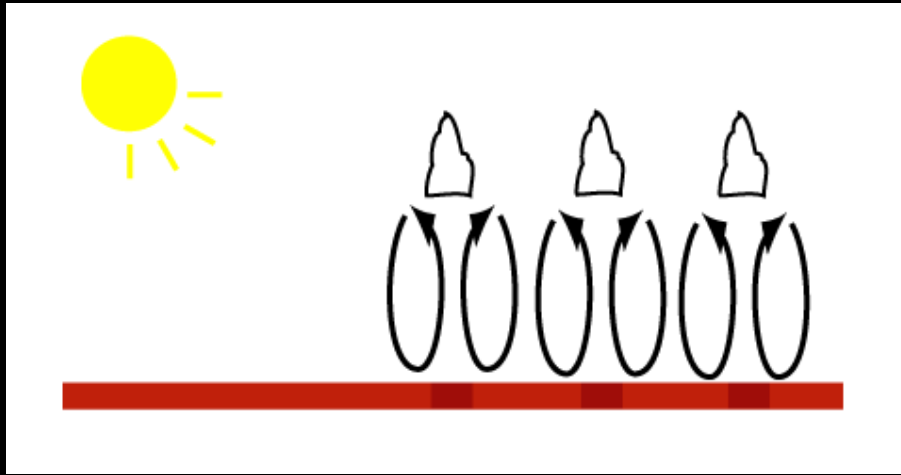
- And we will see those roll clouds on satellite pictures

- In a sense, being able to **simulate** the roll clouds means we've gotten many things right -- radiation, winds, mixing, saturation processes...

- If we cannot resolve them, we must **parameterize** their effects

# Numerical weather prediction (NWP) discussion
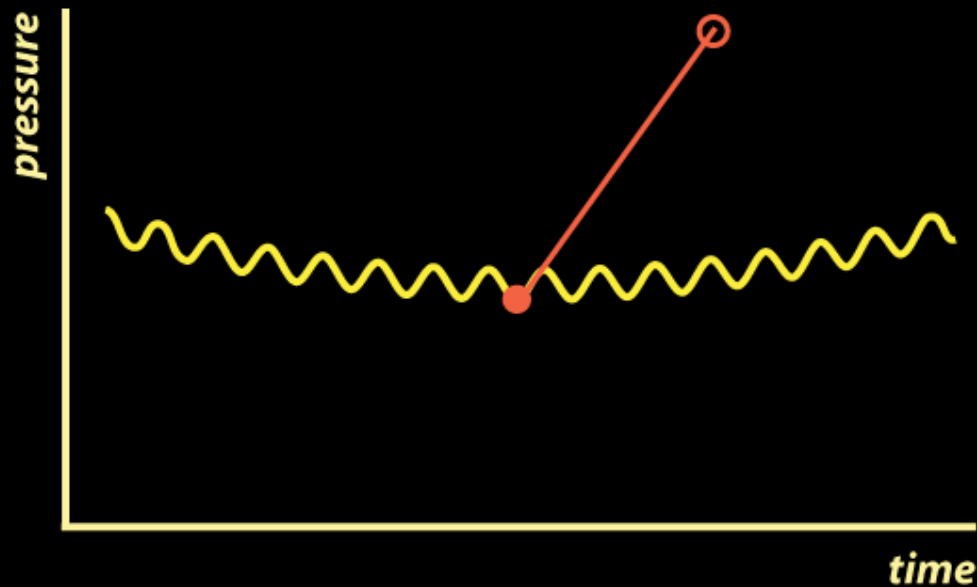
What went wrong in Richardson's experiment? He EXTRAPOLATED too far. His technique made monsters out of meaningless oscillations that happen as air wiggles up and down in a stable atmosphere.
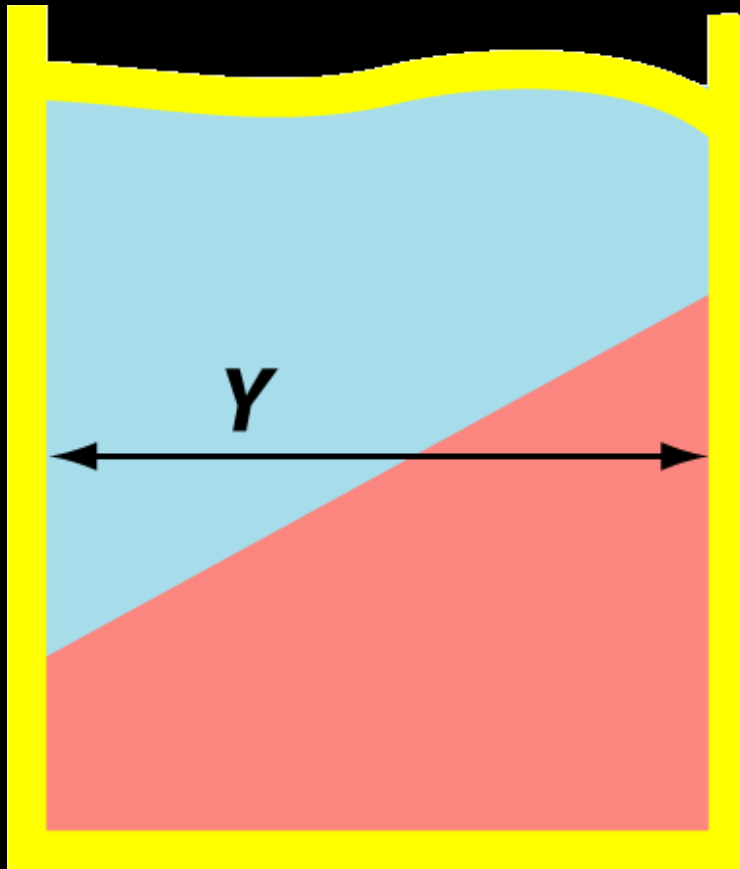
The Lorenz experiment
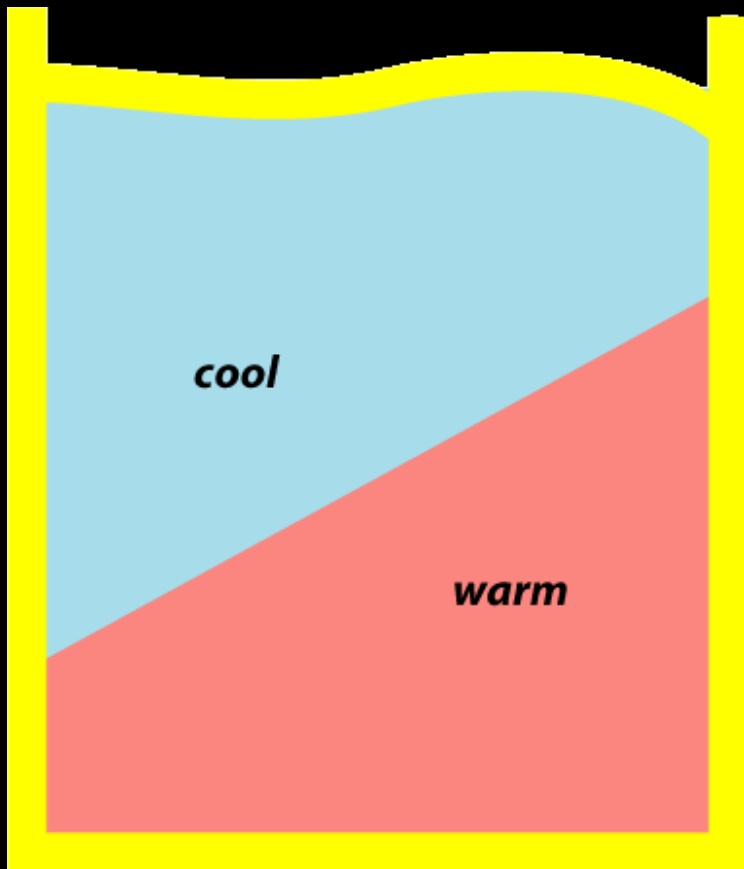
- Lorenz' model wasn't an NWP model, and didn't even have grid points
- It was 3 simple equations, intended to describe fluid flow in a cylinder heated from below
- He called his variables X, Y and Z
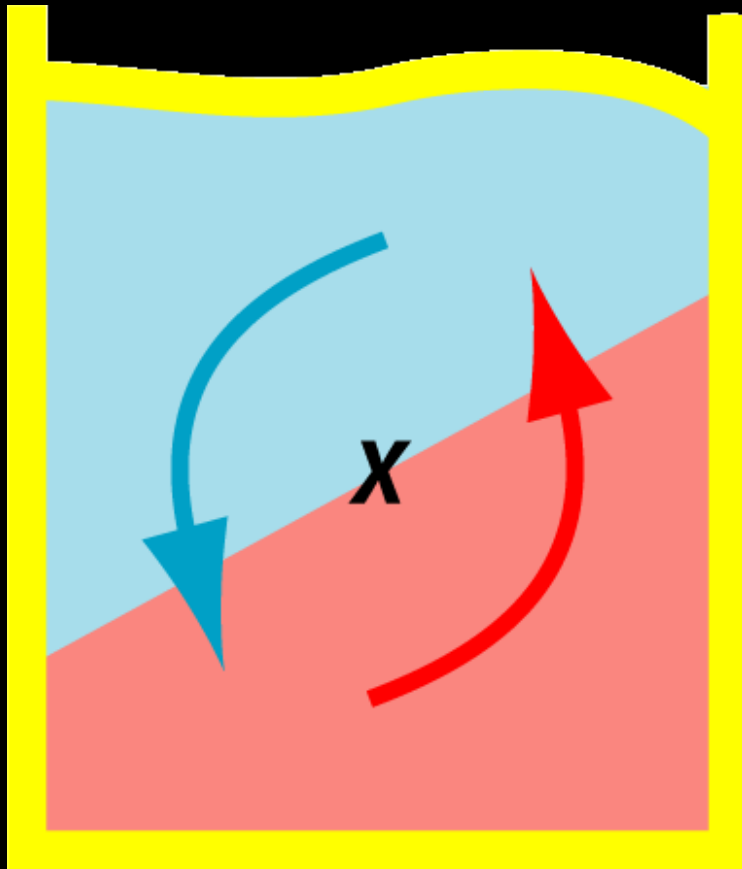
- X indicated the magnitude and direction of the overturning motion

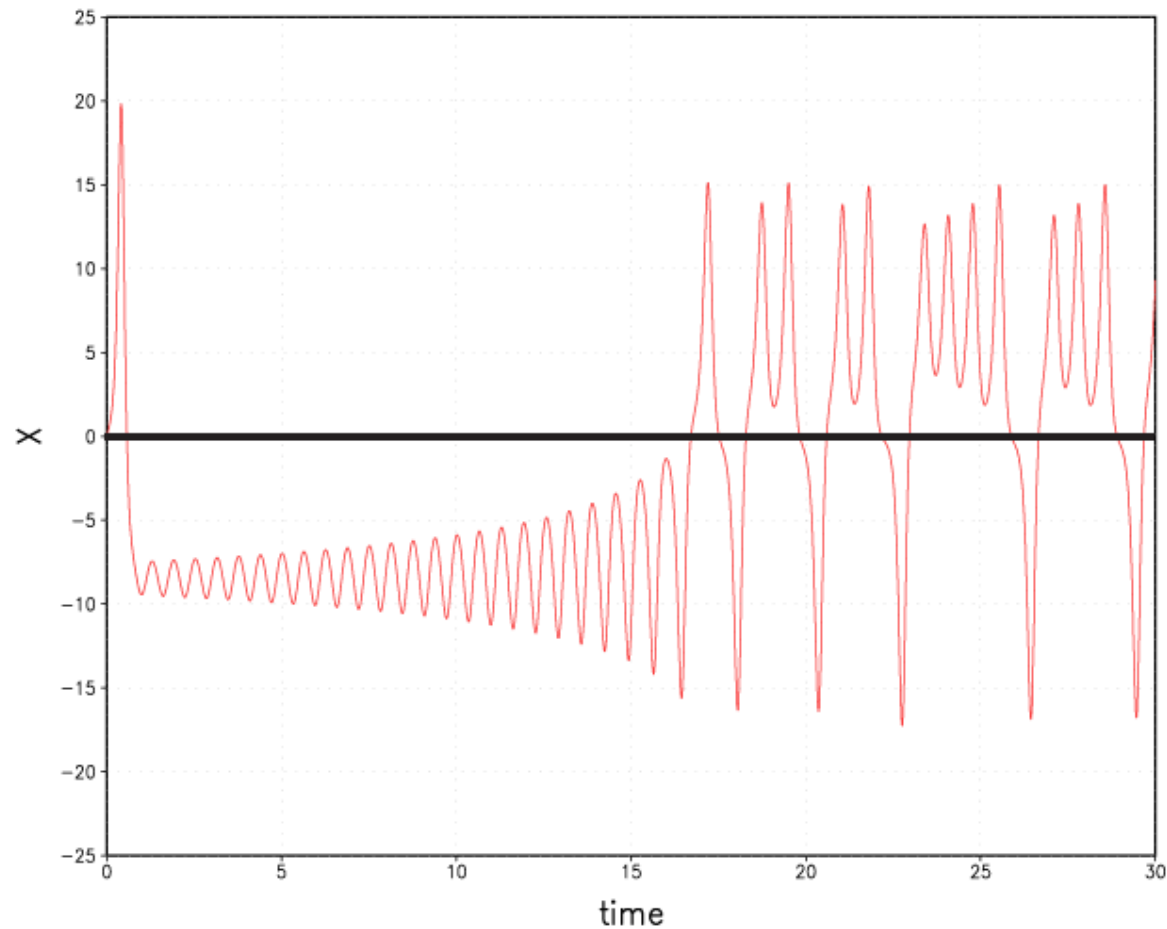- As X changed sign, the fluid circulation reversed

- Y was proportional to the horizontal T gradient
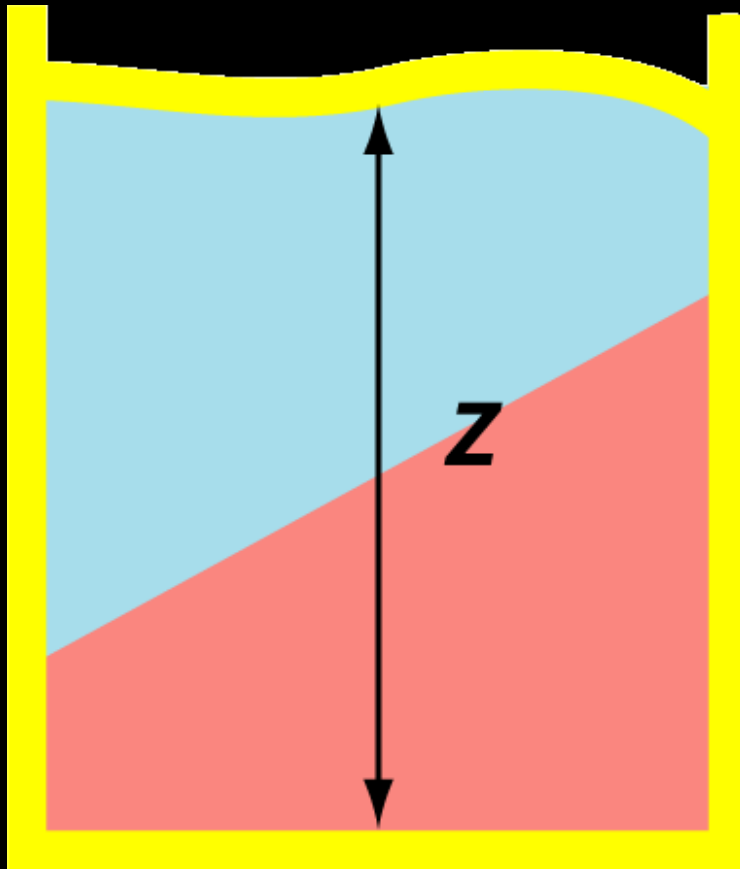
- And Z revealed the fluid's stability

$$\frac{dX}{dt} = -\sigma X + \sigma Y$$

$$\frac{dY}{dt} = -XZ + rX - Y$$

$$\frac{dZ}{dt} = XY - bZ$$

- Three simple equations
- But in important ways they were like the equations we use in weather forecasting
- They are COUPLED and NONLINEAR

This is a plot of one of the variables, X, vs. time,
for a simulation similar to Lorenz' original experiment.
X was the variable that indicated the circulation strength
and magnitude.
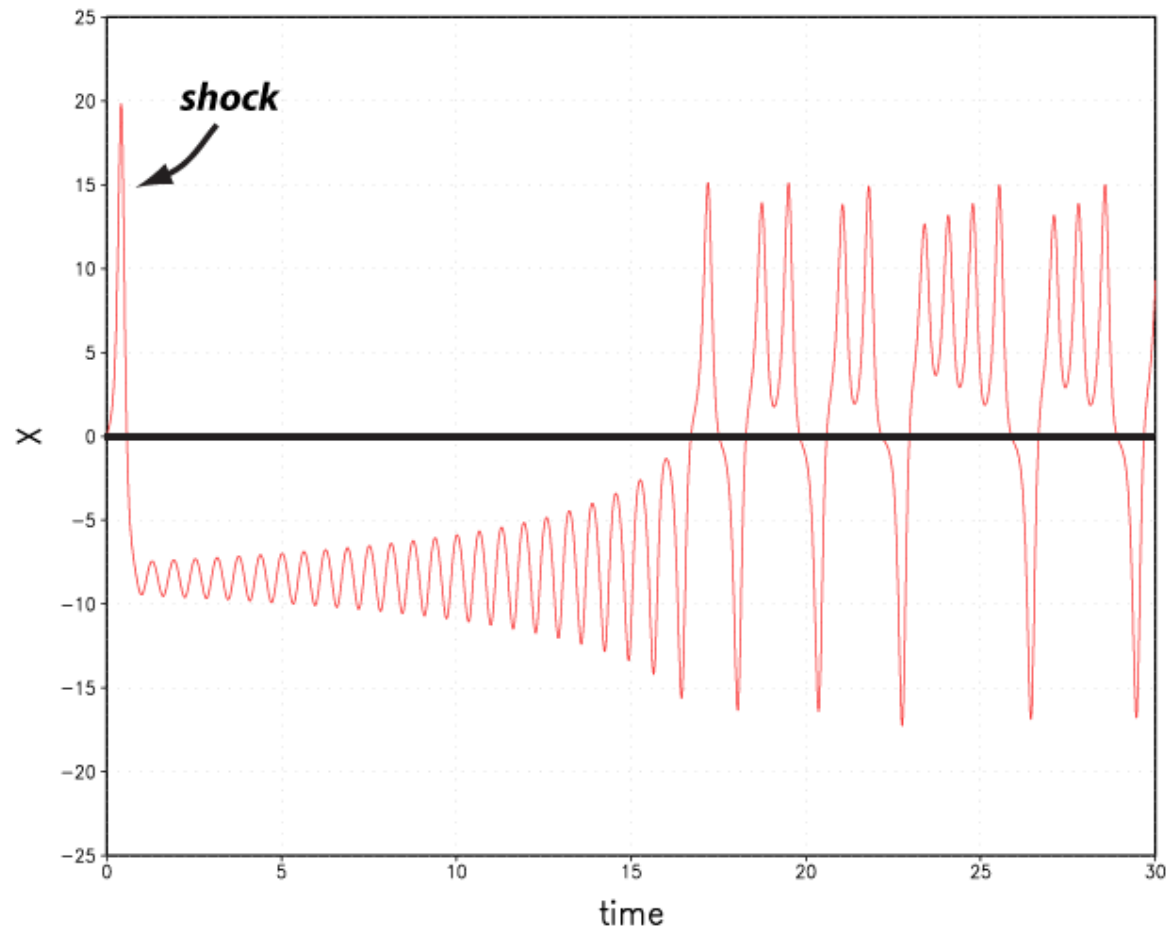
The model was started with initial values for X, Y and Z. But they weren't very well balanced values, so the model experienced a SHOCK on startup. The model was scurrying to find a suitable balance.
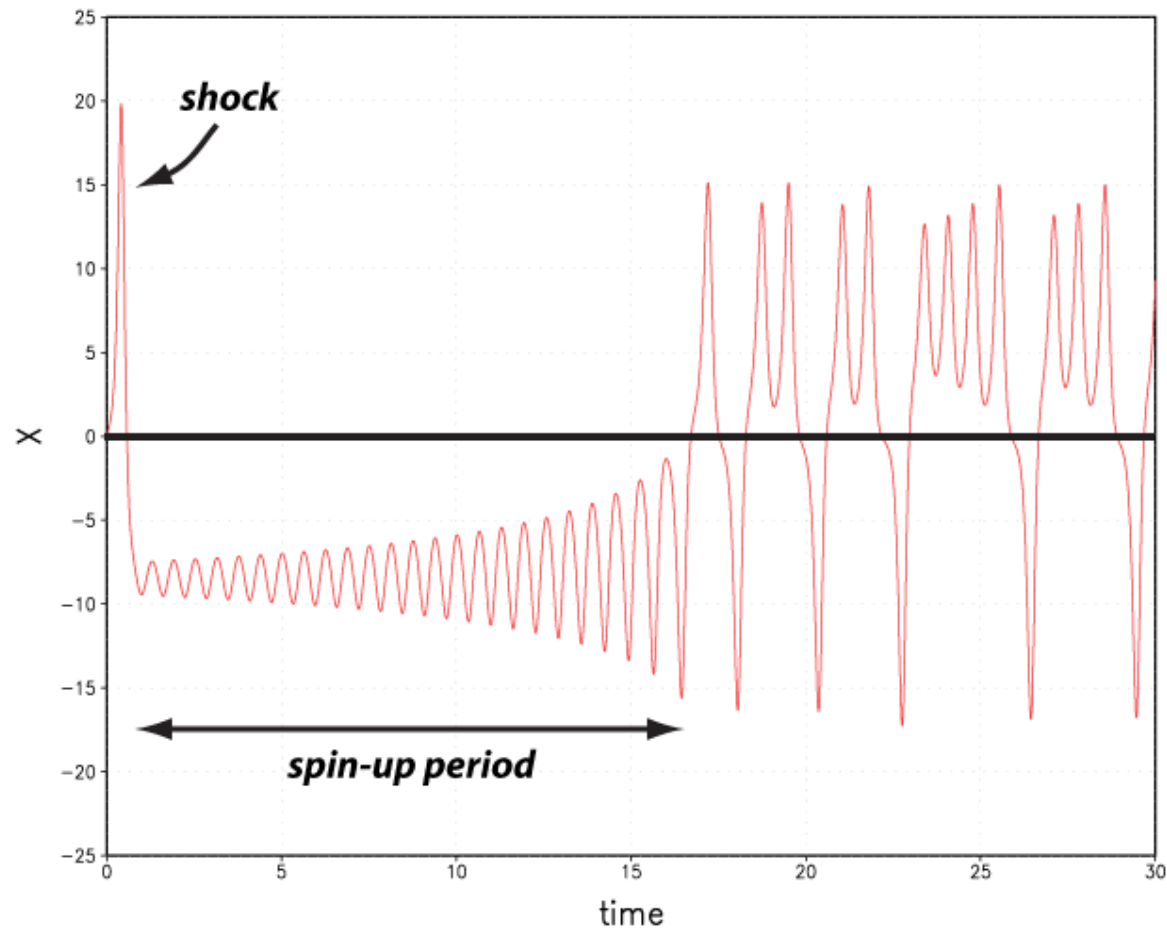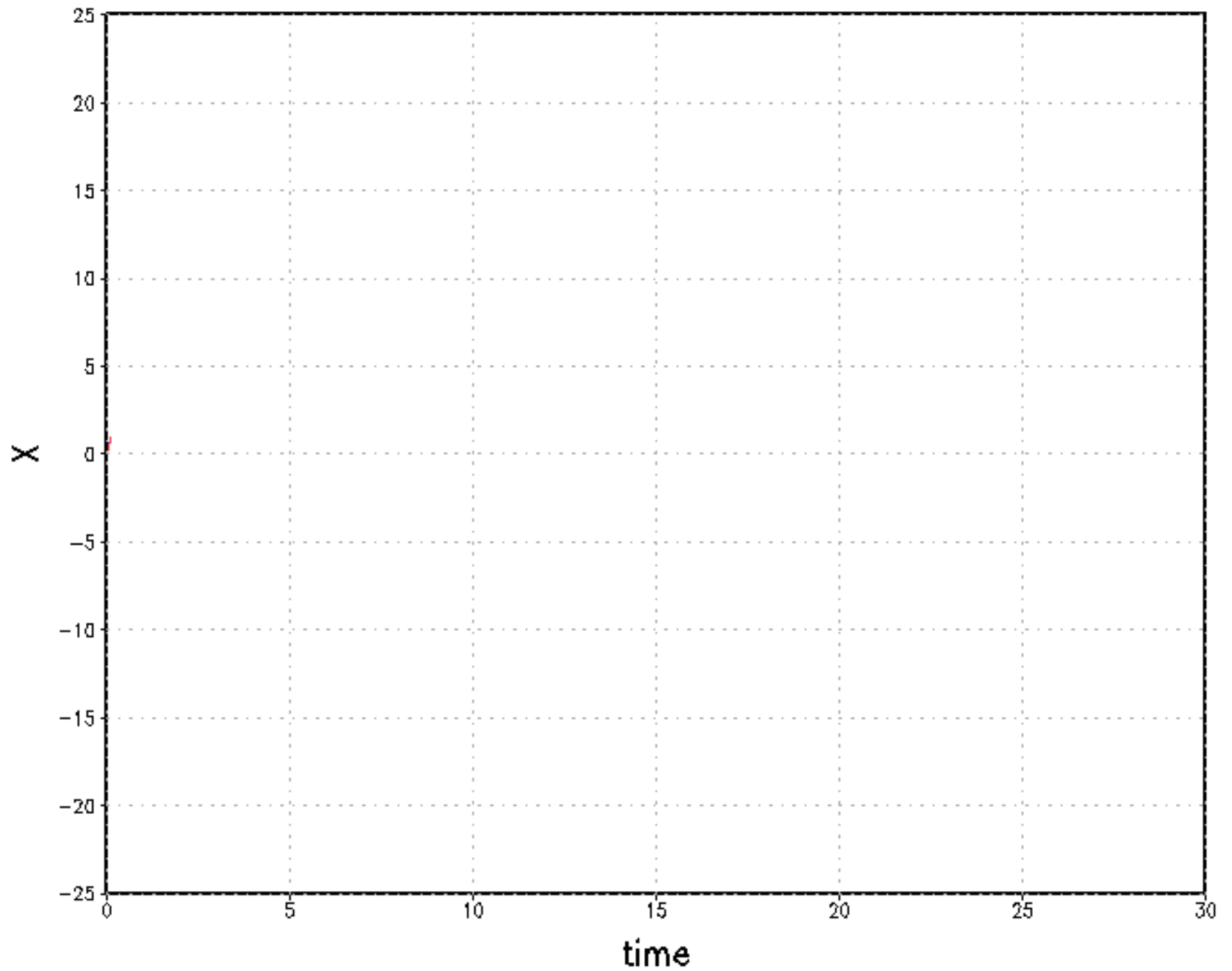
After the shock, there was a spin-up period in which the fluid circulated in only one direction with waxing and waning strength. But the swings between the faster and slower motions were becoming larger… until…
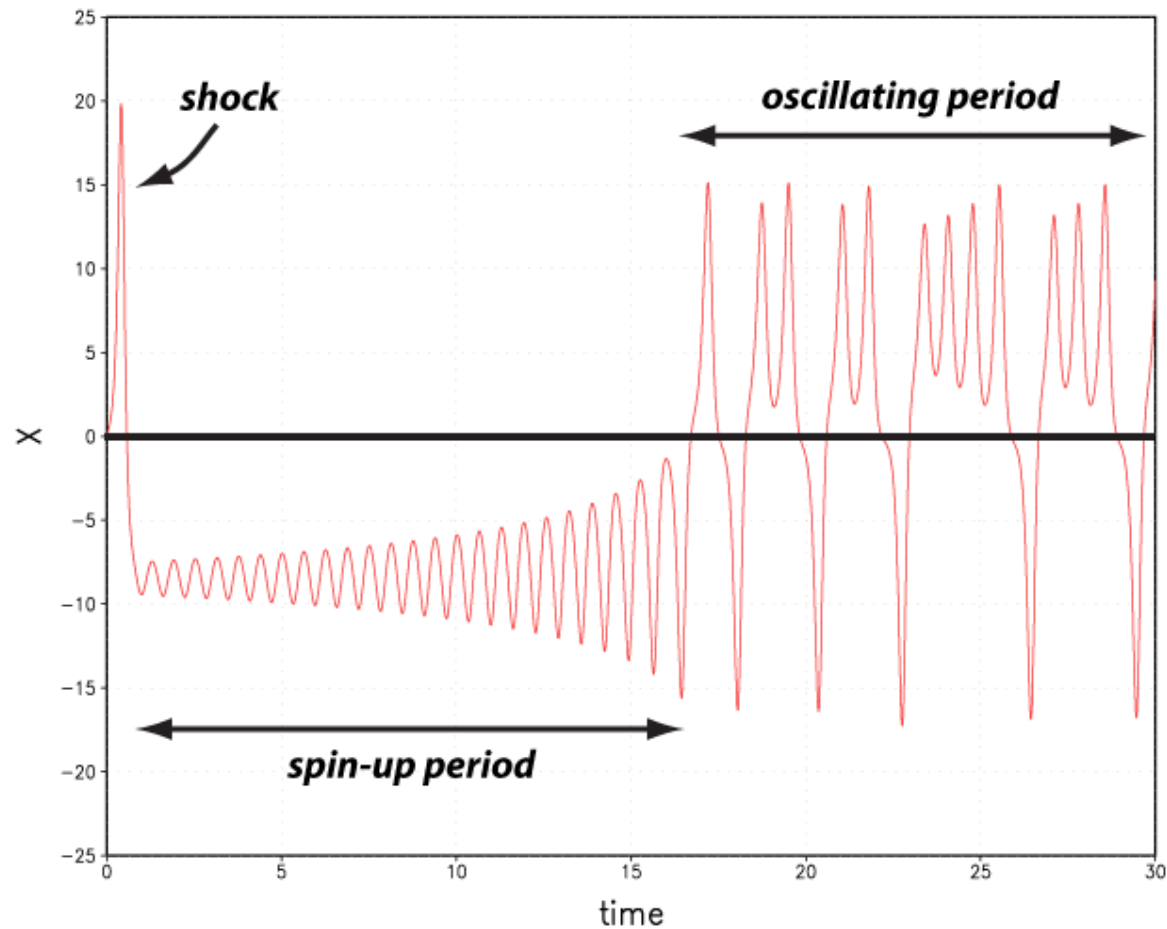
The fluid started chaotically shifting between CW to CCW circulations. The system spent one time in one circulation direction, then suddenly lurched to the other, only to lurch back yet again.

Animation of sensitive dependence on initial conditions in Lorenz' model

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