What is an atmosphere model?

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and others

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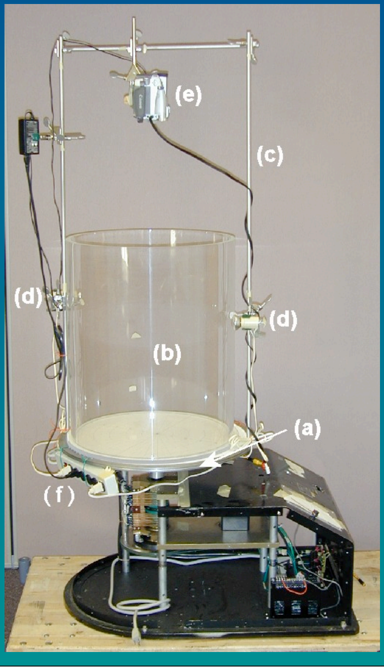
Atmosphere models

Mathematical model -- a mathematical representation of a physical process or system of processes.

A couple of other types of atmosphere models:

- Wind tunnels
- Spin tanks



Atmosphere models

Model development steps include

- Defining the purpose
  - Research?
  - Weather or climate prediction?
  - Regional or global?
- Defining the system
- Making assumptions
- Specifying the equations
- Determining method of solution
  - Analytical (continuous) or numerical (discrete)?
- Evaluating results

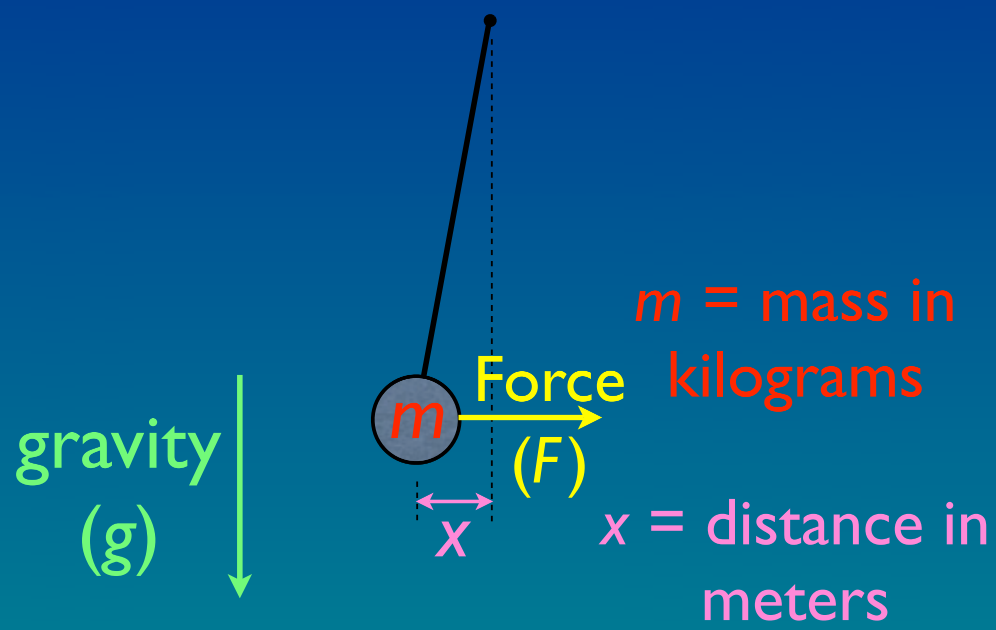
A simple example: Pendulum

- Purpose: Designing a clock? Or just want to have some fun? Need to know the period of oscillation.
- System: A pendulum

A simple example:
Pendulum

Assumptions

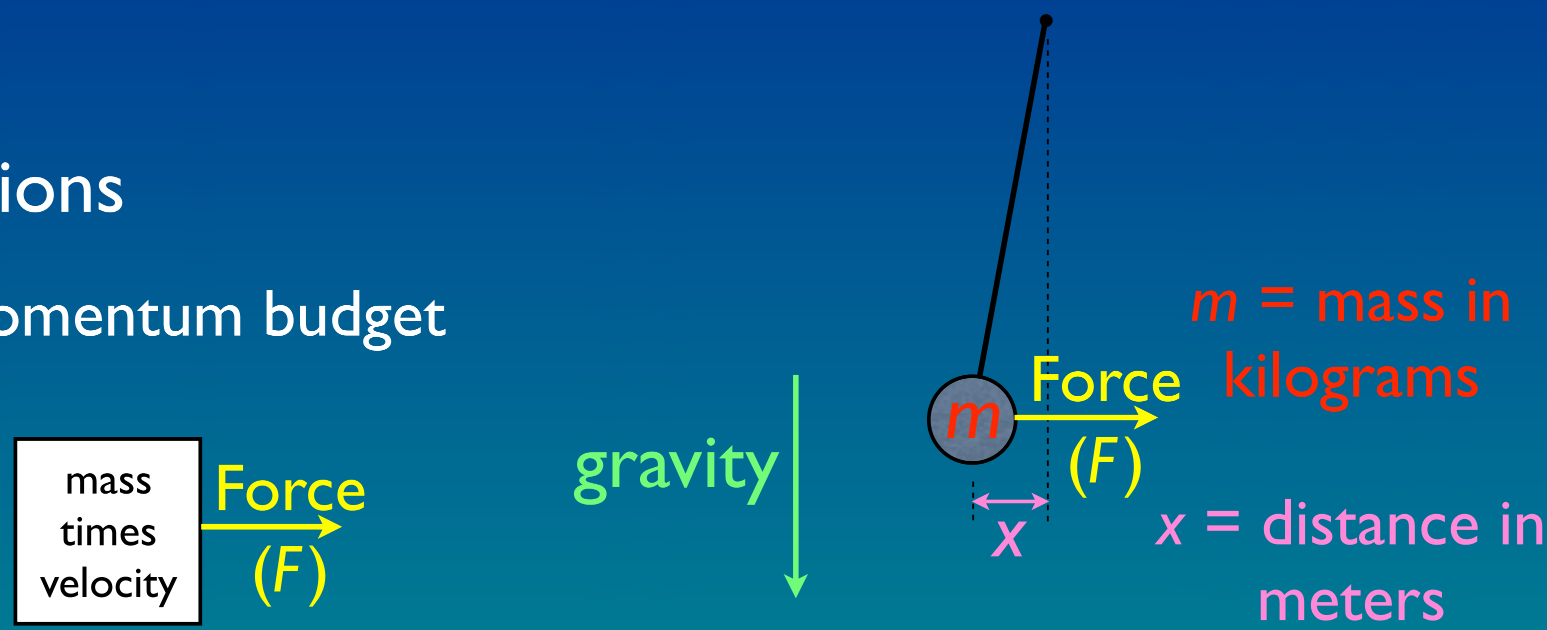
- No friction
- No air resistance
- Small-amplitude oscillations
- Massless string



A simple example: Pendulum

Equations

- Momentum budget

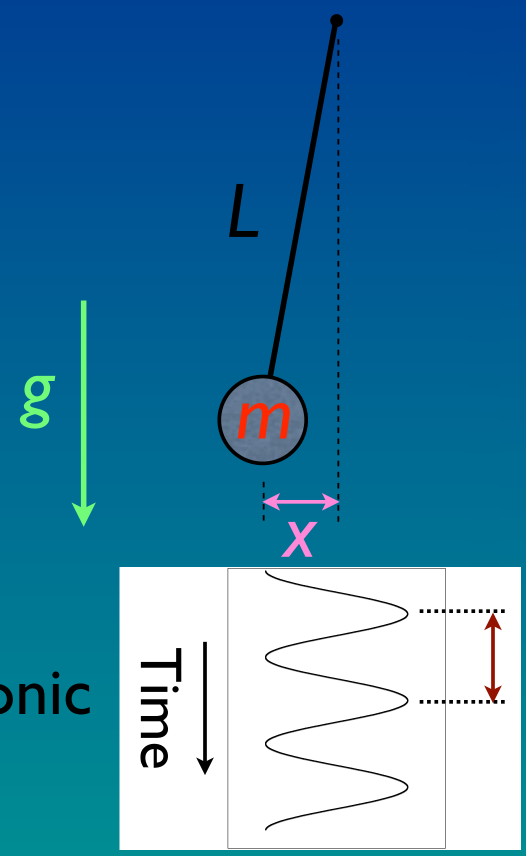


$$F = ma \longrightarrow \text{acceleration} = \frac{\text{change in velocity}}{\text{change in time}} \longrightarrow \text{velocity} = \frac{\text{change in position}}{\text{change in time}}$$

A simple example:
Pendulum

Solution

- Analytical (exact solution to mathematical equations)
- Force = $- \frac{mg}{L} x$ (linear)
- Period = $2\pi\sqrt{\frac{L}{g}}$



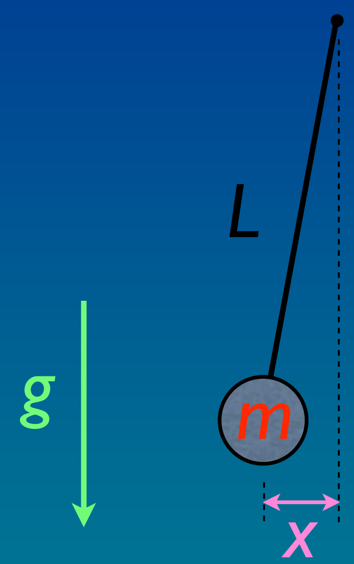
"Simple harmonic motion"

Period of oscillation (P)

A simple example: Pendulum

Solution

- Numerical (approximate solution to mathematical equations)
- Force = $- \frac{mg}{L} x$ (linear)



$F = ma$ → acceleration = $\frac{\text{change in velocity}}{\text{change in time}}$ → velocity = $\frac{\text{change in position}}{\text{change in time}}$

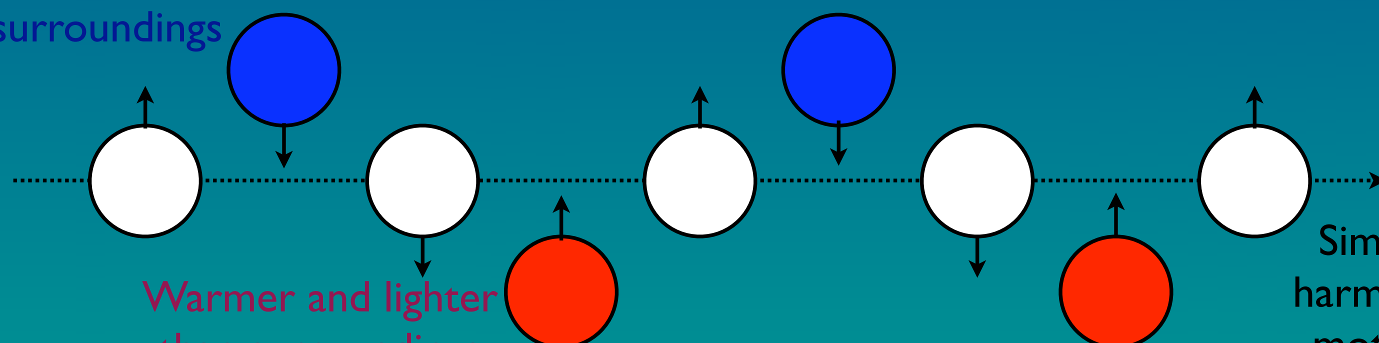
$= - \frac{mg}{L} x$

Next example: Atmospheric gravity waves

- Purpose: Explaining observed mountain wave patterns
- System: A parcel of air


Taken by Scott Hunziker - 2002 - Mount Rainier Washington State

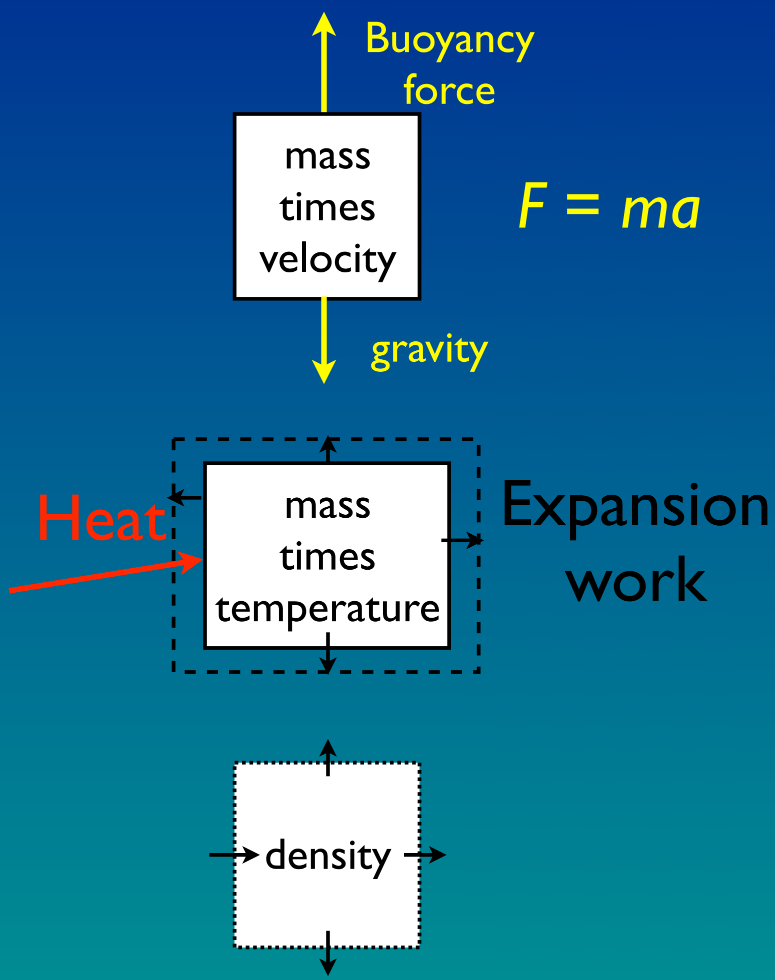
Buoyancy
(a restoring force in stable environments)



Next example: Atmospheric gravity waves

Equations: Process is a little more complex than a pendulum

- Momentum budget
- Energy budget
- Mass conservation



Next example: Atmospheric gravity waves

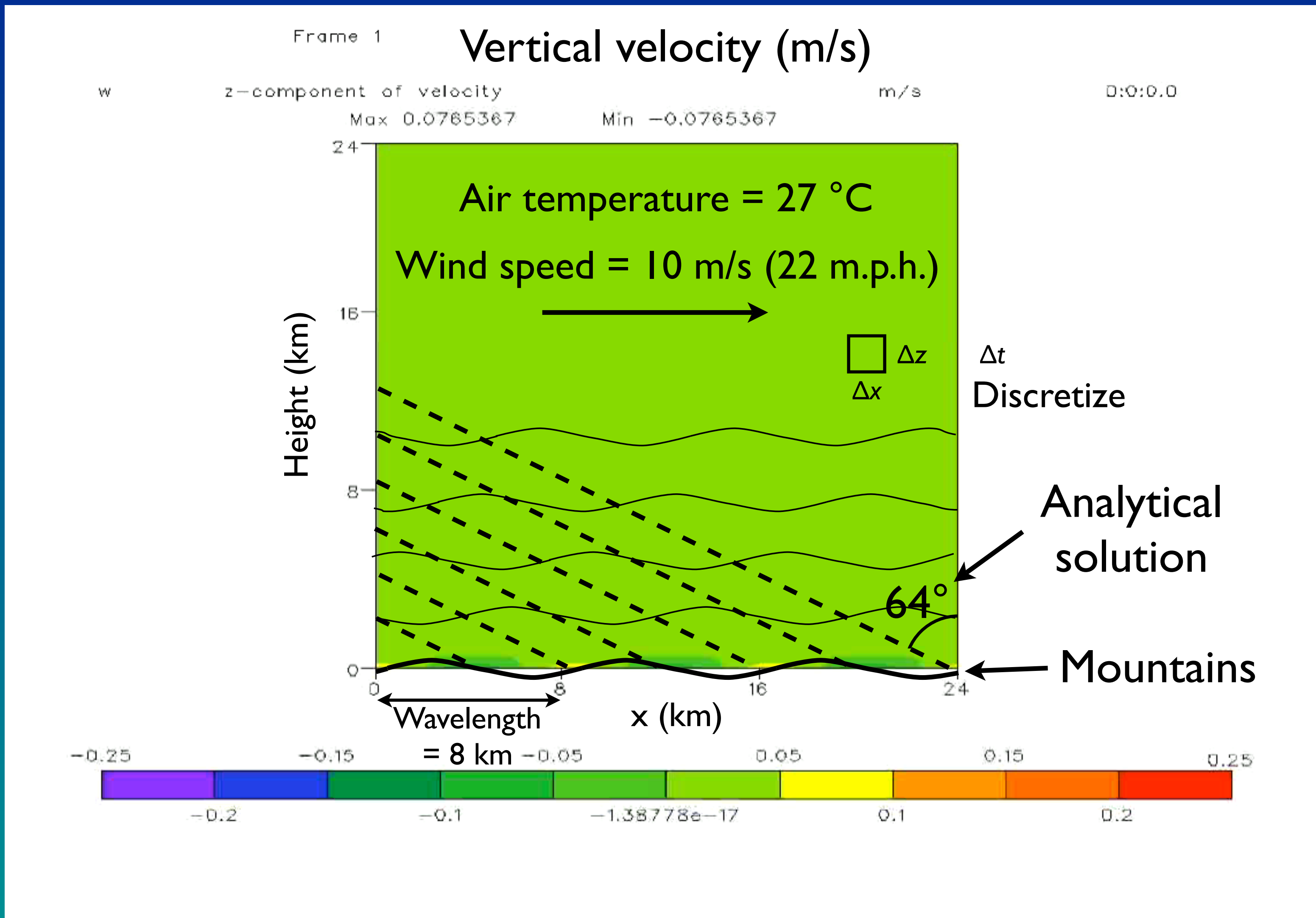
- Analytical solution (for an atmosphere at constant temperature):

$$\text{Period of oscillation} = 2\pi \frac{\sqrt{c_p \times Temperature}}{gravity}$$

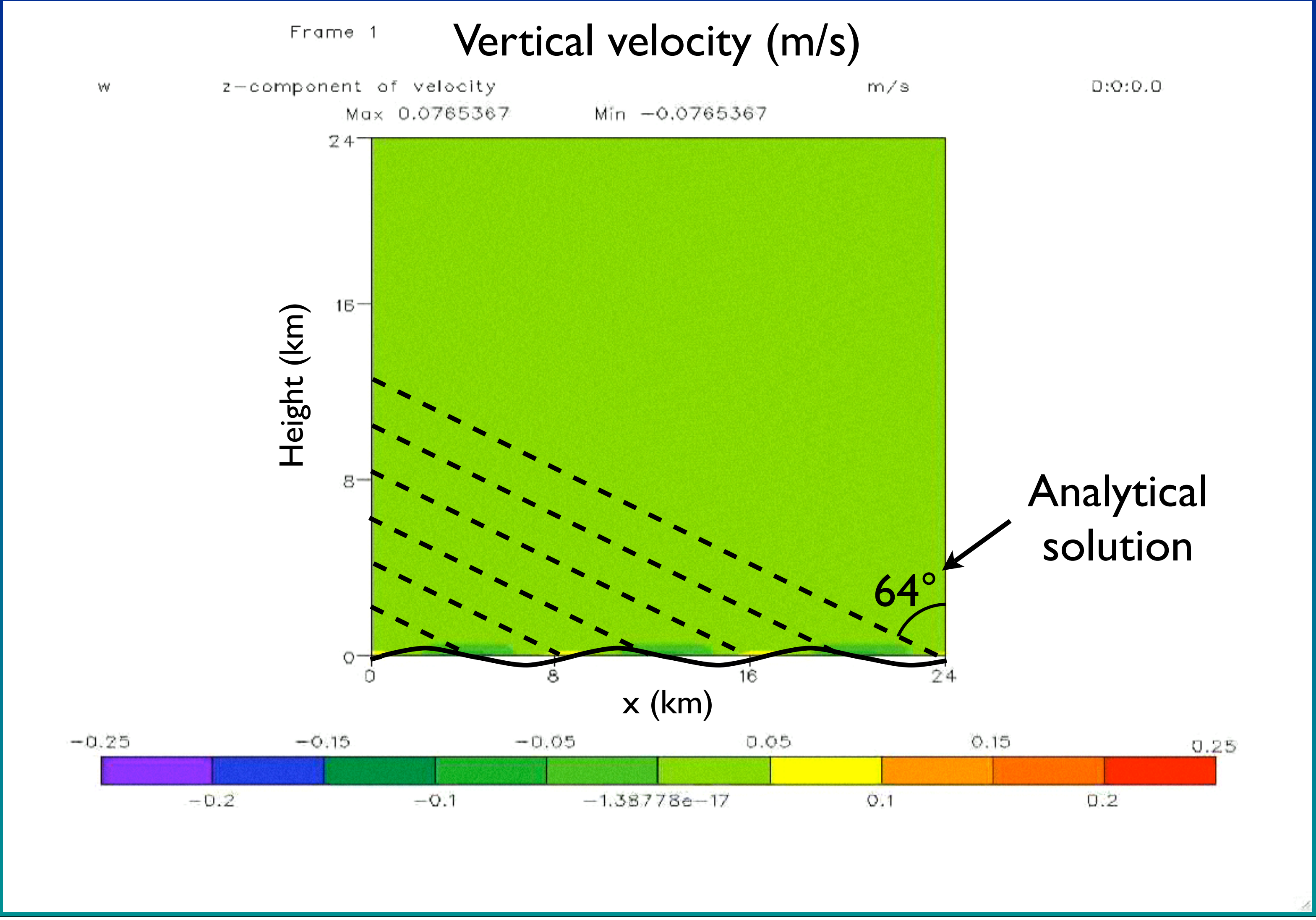
- Recall for pendulum:

$$\text{Period of oscillation} = 2\pi \sqrt{\frac{Pendulum\ arm\ Length}{gravity}}$$

Atmospheric gravity waves: Numerical model solution

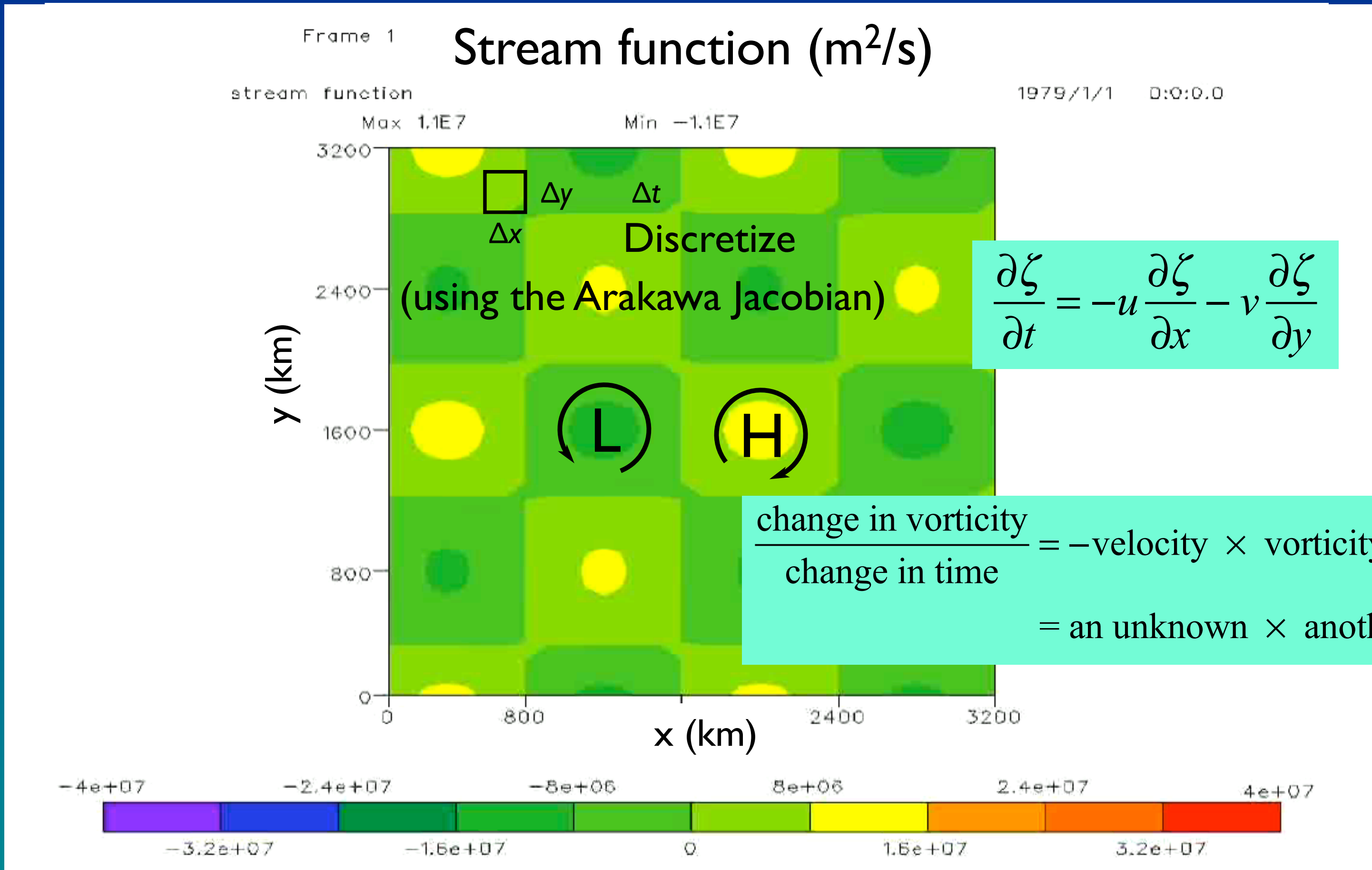


Atmospheric gravity waves: Numerical model solution



A nonlinear case: 2D nondivergent flow

(there is no analytical solution -- must solve with numerical model)



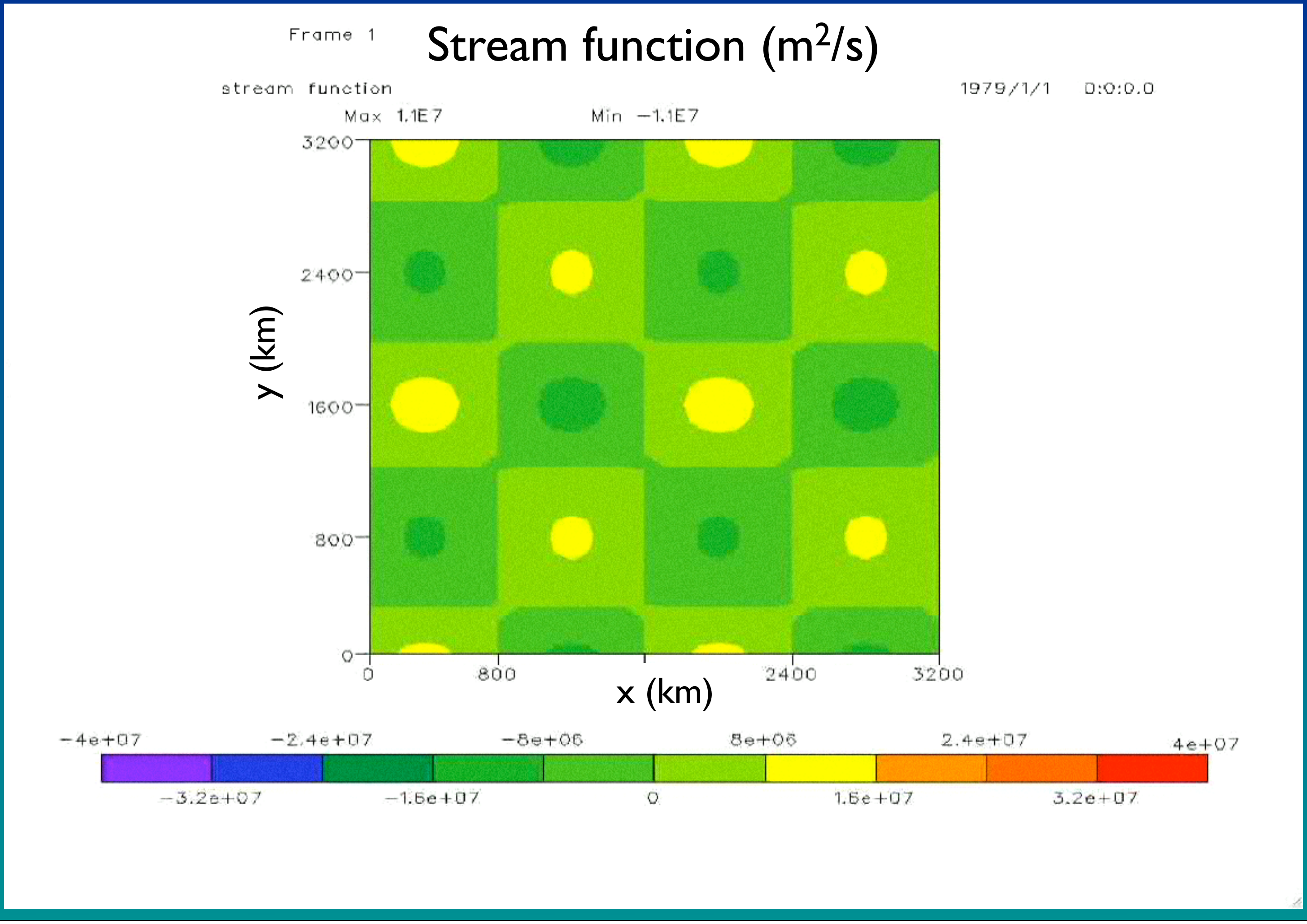
$$\frac{\partial \zeta}{\partial t} = -u\frac{\partial \zeta}{\partial x} - v\frac{\partial \zeta}{\partial y}$$

$$\frac{\text{change in vorticity}}{\text{change in time}} = -\text{velocity} \times \text{vorticity gradient}$$

$$= \text{an unknown} \times \text{another unknown}$$

A nonlinear case: 2D nondivergent flow

(there is no analytical solution -- must solve with numerical model)



Next steps

Just add water and some radiation (from the sun, that is), set on spin cycle, and you have a climate model !!!