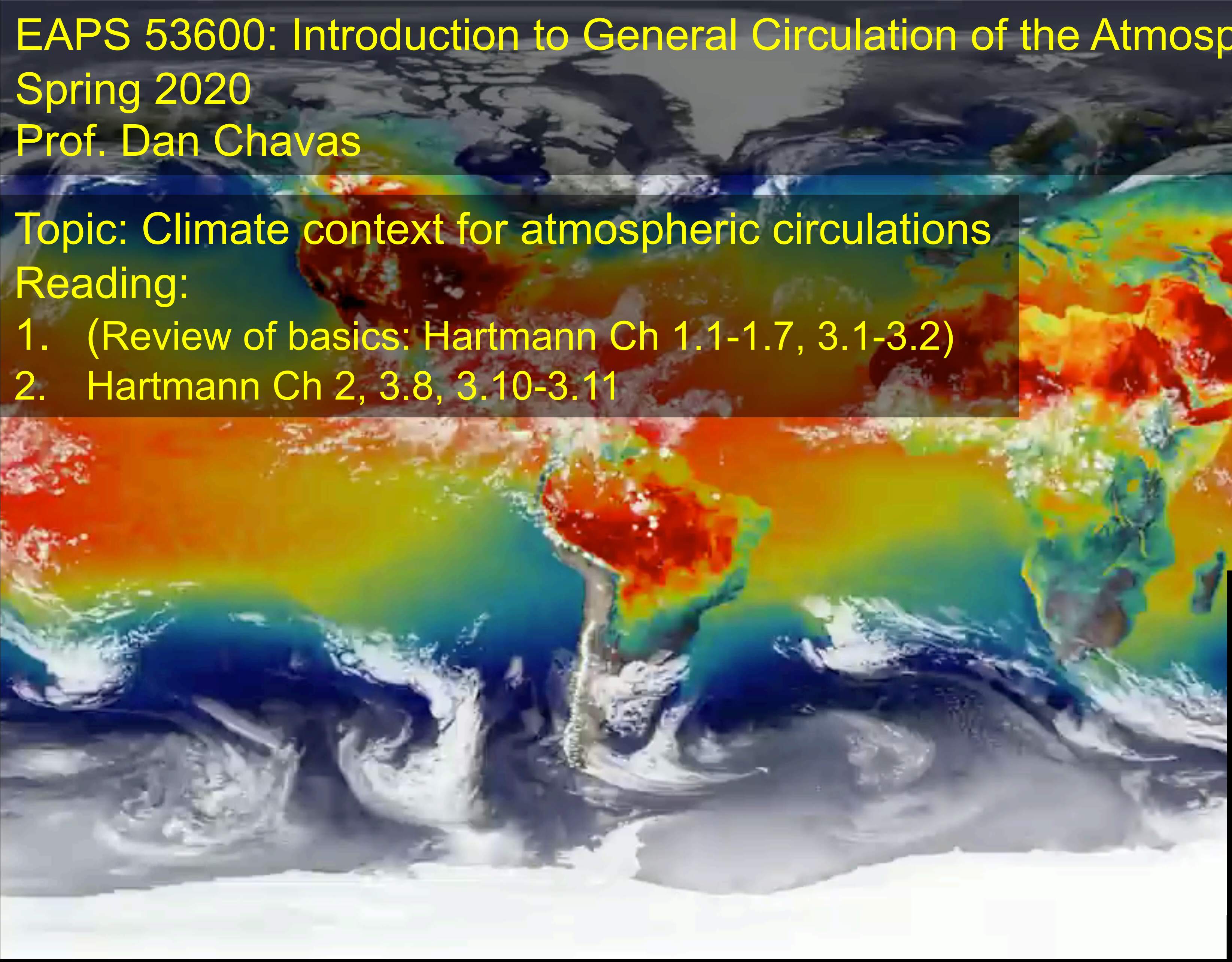
EAPS 53600: Introduction to General Circulation of the Atmosphere
Spring 2020
Prof. Dan Chavas

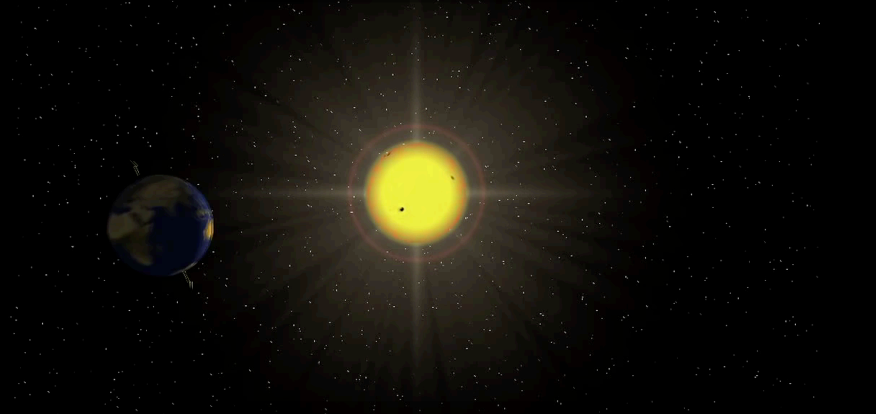
NASA GEOS-5 Computer Model

Topic: Climate context for atmospheric circulations

Reading:
1. (Review of basics: Hartmann Ch 1.1-1.7, 3.1-3.2)
2. Hartmann Ch 2, 3.8, 3.10-3.11



What's wrong with this animation?



Source: https://www.youtube.com/watch?v=R2lP146KA5A

Source: https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=30017

Introduce yourself: Name + year + research interest / major

If you have a preferred name that differs from
the official Purdue listing, please let me know!

Purdue is committed to creating and sustaining a welcoming campus for all.

Does everyone have a laptop?

Who has experience with MATLAB?
Python?

Course objectives (briefly)

1. Physics of the range of large-scale atmospheric circulations found on Earth
2. Hypothesis-driven inquiry using labs, models, and data

Large-scale circulations

2) Over long horizontal distances (L>100 km)

1) Movement of air

Student-driven (you)

Hypothesis-driven

Student-driven (you)

Hypothesis-driven

An example, right off the bat

Standard lecture

This is an equation for the gravitational acceleration at some radius r induced by an object of mass m:

$$\boldsymbol{g} = \frac{\boldsymbol{Gm}}{\boldsymbol{r}^2} \qquad [ms^{-2}]$$

Hypothesis-driven

"I'm wondering... would a ball hit the ground faster on the Earth or the Moon?"

↓

A testable hypothesis: A ball dropped from the same height would hit the ground **faster** on the **Earth** than the **moon**.

↓

Group:

1) **What do you need to know to test this hypothesis?**
2) **How could you test this hypothesis?**

Direct observation vs. Laboratory (i.e. physical) simulation vs. Model simulation (equations/computer)

Semester project

You:
- Propose a testable hypothesis – anything related to large-scale circulations
- Propose methodology for testing – could use data, computational model, laboratory (rotating tank)
- Execute
- Synthesize in oral presentation (last day of class) + final paper (due during finals week)

Projects are individual; undergrads can work in a pair if desired.

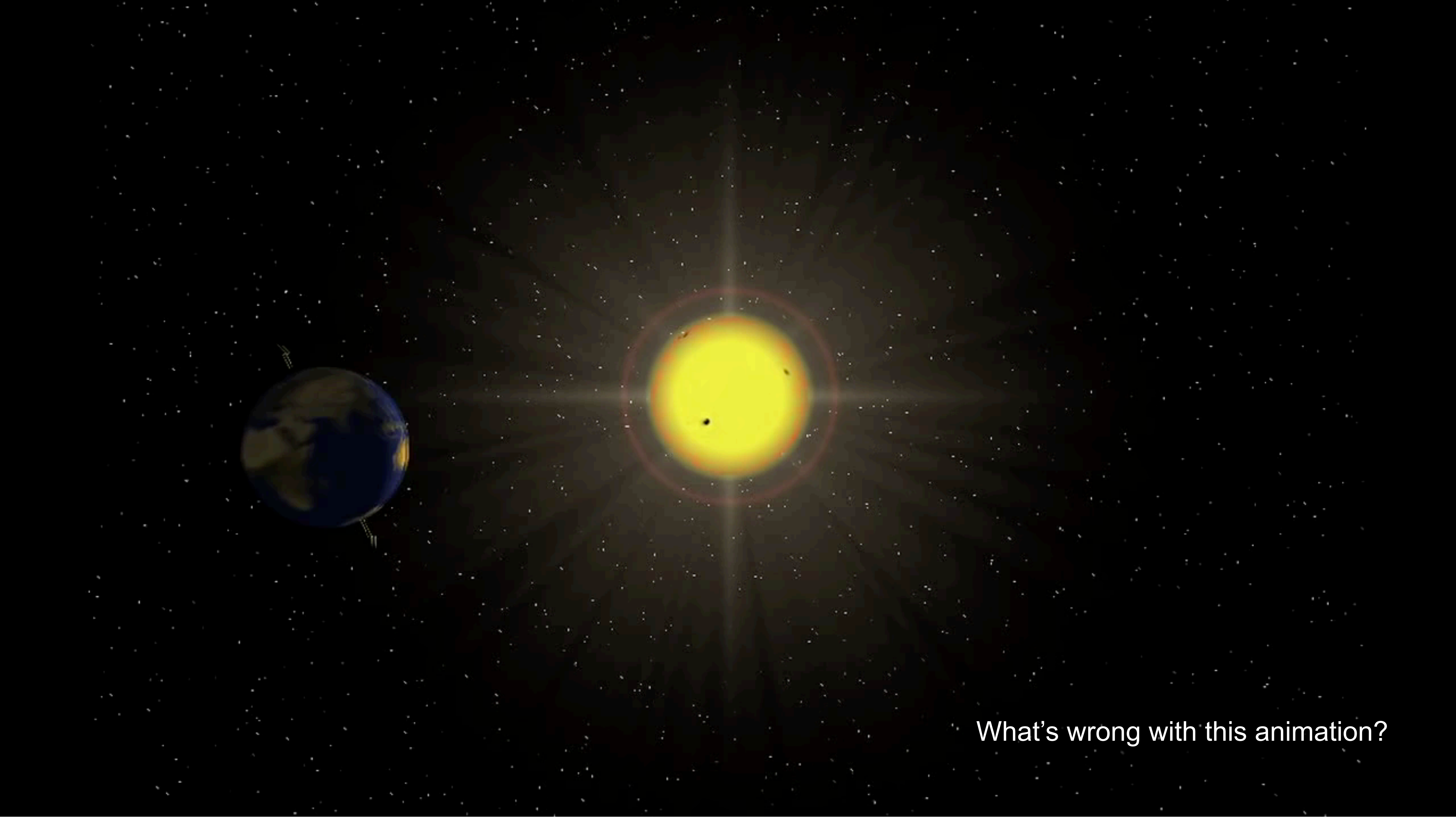
Milestones are on the course schedule.
- **First milestone (M1a) due week of 01/27: three hypotheses of interest + methods to test (as specific as possible)**
- **You will review each others milestones!**

Please bring your books to class!

You will be able to use figures / equations / your notes from the reading in group discussion.

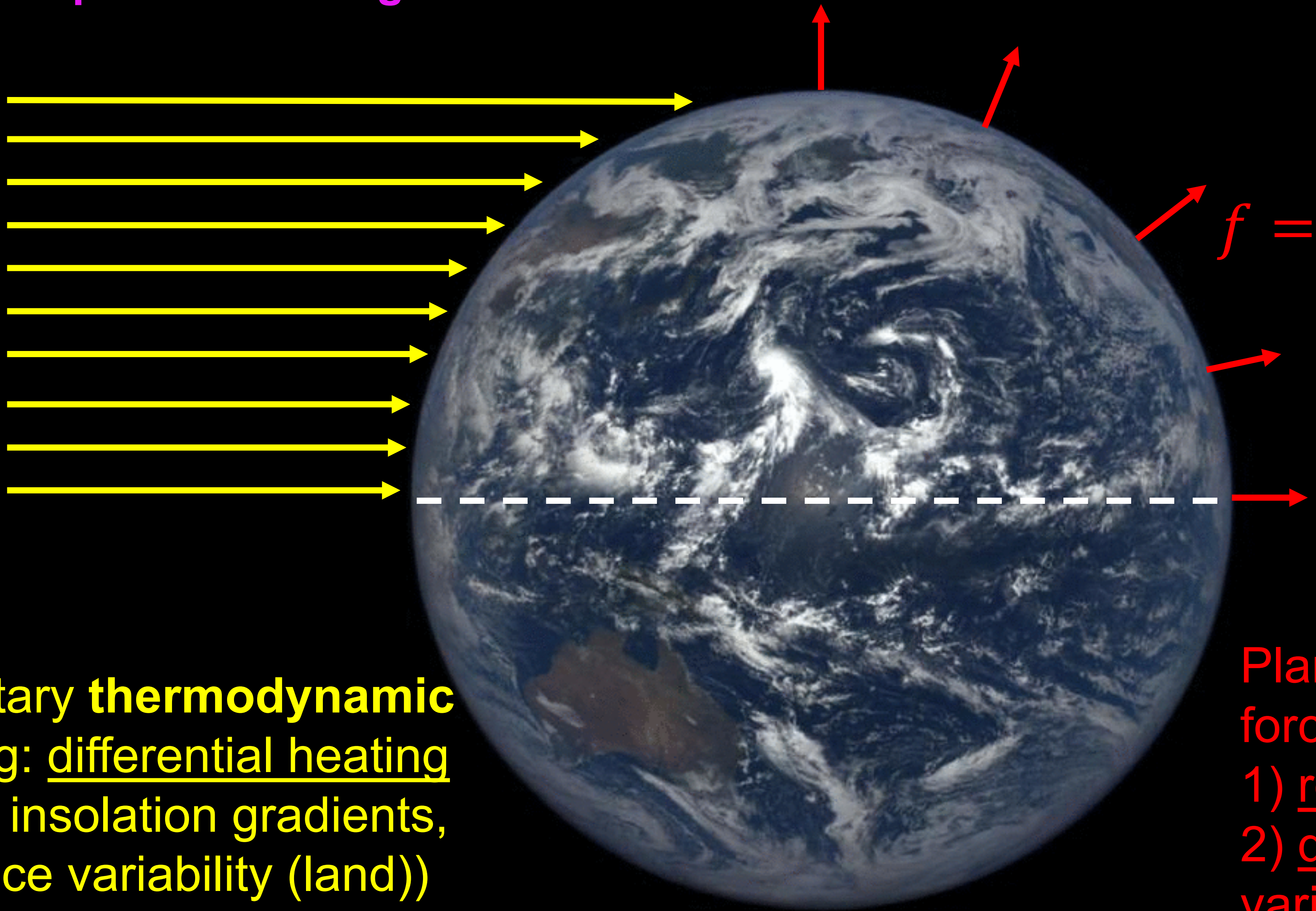
Other questions?

Climate context for atmospheric circulations



What’s wrong with this animation?

These simple external ingredients...



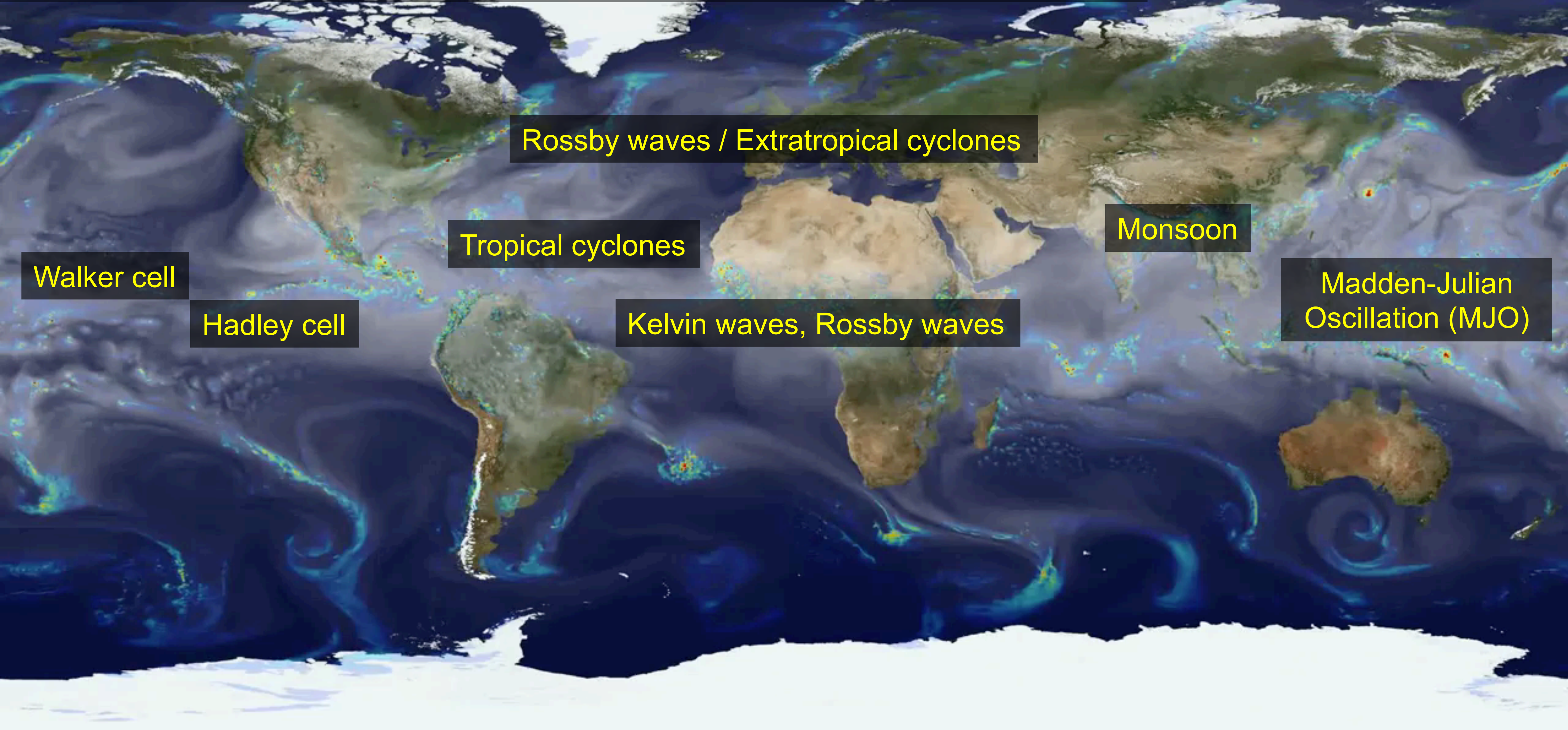
Planetary **thermodynamic** forcing: differential heating (solar insolation gradients, surface variability (land))

Planetary **dynamical** forcing:
1) rotation (f);
2) differential rotation (f varies with latitude)

https://media.giphy.com/media/o2XbUUi1CXK

... generate many types of horizontal circulations!

NASA GEOS-5 Computer Model



White: total precipitable water (brigher white = more water vapor in column)

Colors: precipitation rate ($0 - 15\,\frac{mm}{hr}$, red=highest)

Source: https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=30017

A couple of contrasts to think about

1) Tropics (**weakly-rotating**) vs. extra-tropics (**strongly-rotating**) ← You will investigate this with the rotating tank!

2) Waves vs. overturning circulations
   - **Waves** (gravity, Rossby…): require a **dynamical restoring force**
   - **Overturning circulations** (Hadley, Walker...): principally a response to **differential heating** (less dense fluids tend to rise...)

Student-driven (you)

Hypothesis-driven

Question: would our atmosphere be different if air didn't move?

One specific,
testable hypothesis

Hypothesis: If air didn't move, the equator-pole surface temperature gradient would be larger than it is on the real, present-day Earth.

Test this hypothesis using Hartmann Ch 2-3.

This is Homework 1 (posted on blackboard): due next Thursday 01/16.
You will start today in class – groups of 3.

Hypothesis: If air didn't move, the equator-pole surface temperature gradient would be larger than it is on the real, present-day Earth.

Group (10 min):

1) **What information do you need to test this hypothesis?**
2) **What methods could you use to obtain that information?**

Options:

1. ~~Direct observation~~
2. ~~Laboratory (i.e. physical) simulation~~
3. Model simulation ← only option... how could you do it? What assumptions would you make?

An experimental tool: a model for a single column of surface + atmosphere in **radiative equilibrium** http://singh.sci.monash.edu/Nlayer.shtml

This model finds the solution with 1 or more atmospheric layers, and each layer is 1) transparent to shortwave radiation (i.e. shortwave emissivity = 0), and 2) can have a longwave emissivity $\epsilon \leq 1$.

Group (10 min each):

1) **What experiments would you propose with this model to test this hypothesis?**
2) **What assumptions will you be making in your methodology?**

see Hartmann Ch 2.5, 3.8

A second experimental tool: a model for a single column of surface + atmosphere in **radiative-convective equilibrium:** http://rcmodel.mit.edu/

see Hartmann Ch 3.10