What do earth system models actually do?

Why do we need more than one?

What is the status of the GFDL/Princeton development effort?
What are the components of an Earth System Model?

A. **Dynamical cores** (atmosphere, ocean, ice):

1. Compute the pressure field.

2. Compute the flows resulting from this pressure field.

3. Use these flows to transport the quantities (heat, mass, etc.) that determine the pressure field.

Equations are standard... **numerics are not.**
Pressure is an example of a variable that can be predicted relatively well.

High-to-low pressure swings are \(~30\text{mb.}\) Errors are 3!
What are the components of an Earth System Model?

B. Parameterizations of subgridscale processes

1. Vertical mixing
2. Lateral mixing
4. Clouds and their effects.

Relationship between parameterizations and mean state differs substantially between models.
Example of an important parameterization: Stratus Clouds

More clouds (in climatological sense) when boundary layer is more stable.

Potential positive feedback.

+Ts => -LC => +Ts
Low cloud amount is one of our poorer predictions.

Correlations are good over Atlantic, East Pacific Sector, poor over high latitudes, Indian Ocean.
A second example: Ocean eddies
Do differences in parameterization matter?

Overturning: Low Mixing

Overturning: High Mixing

Biogenic Particle Production

Air–Sea CO₂ Flux
Components of an Earth System Model: Biological models

Some effects are well-known and documented.

No standard mathematical representation for system as a whole.
Biomass predicted by the biological model

Desert regions

Tropical rain forests
What can these models tell us?

There will be global warming.

It will be amplified in northern polar regions and delayed in southern polar regions.

It will produce changes in the hydrological cycle, which will affect ecosystems.

Given our current understanding, are these changes likely to be significant or insignificant.

What sorts of unintended consequences might be brought about by mitigation strategies.
Uncertainties that we will have to live with for many years

Are there things left out of the models that could cause the answers to be substantially different?

Stratosphere-troposphere interactions could enhance effect of solar variability (but also of CO2).

Inclusion of a real freshwater flux into ocean models could change Arctic circulation substantially.

Vegetation-climate feedbacks could change answers.