# Large Ensemble Climate Prediction


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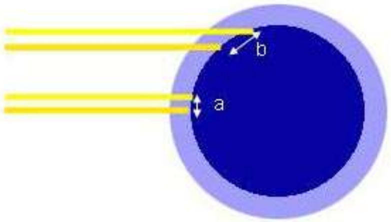
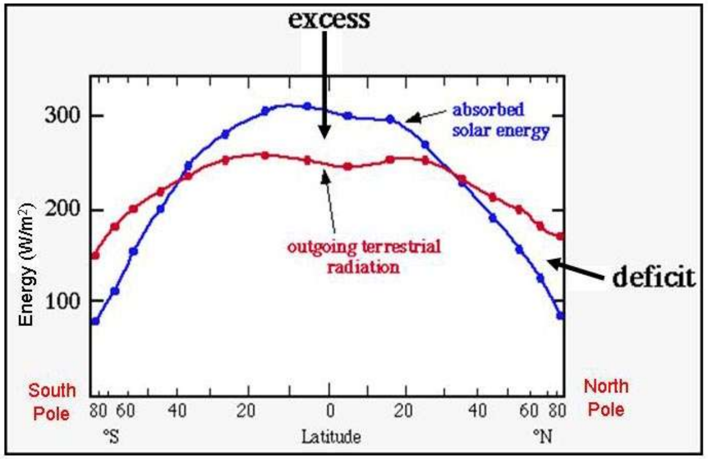
# Climate physical processes

- Energy budget
  - Incoming solar radiation = outgoing radiation
  - More energy received at equator than at poles




  - Once absorbed, emitted as thermal radiation
  - Energy deficit / excess varies with latitude




# Climate physical processes

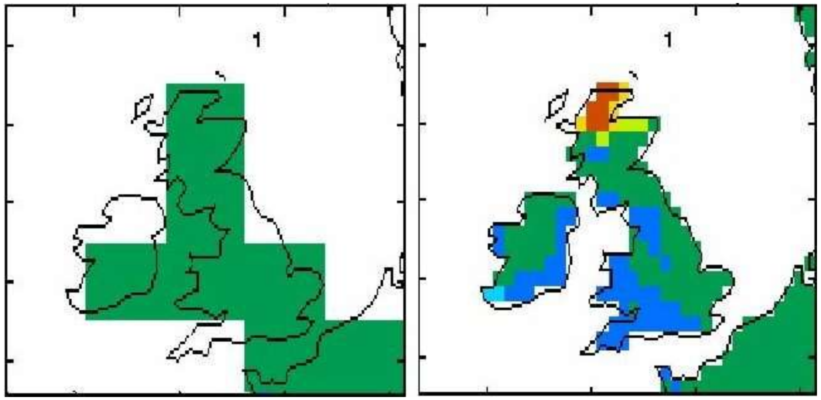
- Global atmospheric circulation
  - Hot air in the tropics, reduces surface pressure
  - Coriolis force causes westerly and easterly winds
- Oceanic circulation
  - Responsible for 50% energy transport
  - Warm surface currents -> polewards
  - Cold surface currents -> equatorwards
- Atmosphere / Ocean interaction
  - Many different interactions
  - Net exchange of heat, salt, water and momentum

# Climate physical processes

- The greenhouse effect
  - Radiated heat from the surface heats gases
  - Increases in the levels of gases increase feedback processes
- Clouds and rain
  - Formed when warm humid air is forced to rise
  - Surplus water (through cooling) forms as clouds
- The diurnal and seasonal cycle
- The land and sea
  - Land heats and cools more rapidly than sea

# Components of a climate model

- Horizontal resolution
  - Accuracy vs. computational expense
  - Small scale processes not represented accurately



- Vertical resolution
  - Not evenly spaced, 19 in atmosphere, 20 in ocean
  - Distributed according to pressure
- Time steps
  - Stability
  - Dynamics and radiation

# Components of a climate model

- **Parameterizations**
  - Many processes smaller than the cubes
  - Approximate these using a parameterization scheme
  - Many schemes exist in the model
- **Ocean and atmosphere interaction**
  - Interlinked processes
  - Oceans take longer to react to changes in the energy balance
  - Slab ocean – no deep ocean current

# Components of a climate model

- Chaos
  - Processes combine non-linearly
  - Sensitive to changes in the initial conditions
- Ensembles and probability
  - Simulate many climates with slightly different parameterizations
  - Increase predictive skill
  - Give a probabilistic forecast

# Experimental design

- **Parameters**
  - **Some parameterizations are poorly constrained**
  - **Ask modellers the potential range of these parameters**
- **Forcings**
  - **External influences on the climate**
  - **Solar radiation, sulphur cycle, greenhouse gases**
- **Initial conditions**
- **Vary parameters and IC in a Monte Carlo manner**

# Experimental design

- **Experiment 1:** **Explore model sensitivity to physical parameters**
  - **Using slab ocean model: HADSM3**
  - **Perturbed physics through adjusting parameters**
  - **Change initial conditions**
  - **Alter 1 forcing (CO2)**
  - **3 phase:**
    - **Model spin up (15 years)**
    - **Model control (15 years)**
    - **Double CO2 (15 years)**

# Experimental design

- **Experiment 1b:** **Sulphur cycle**
  - **As experiment 1 but add one extra forcing, aerosol emission**
  - **5 phase:**
    - » **Spin up, control, double CO2**
    - » **Control with sulphur cycle**
    - » **Double CO2 with sulphur cycle**

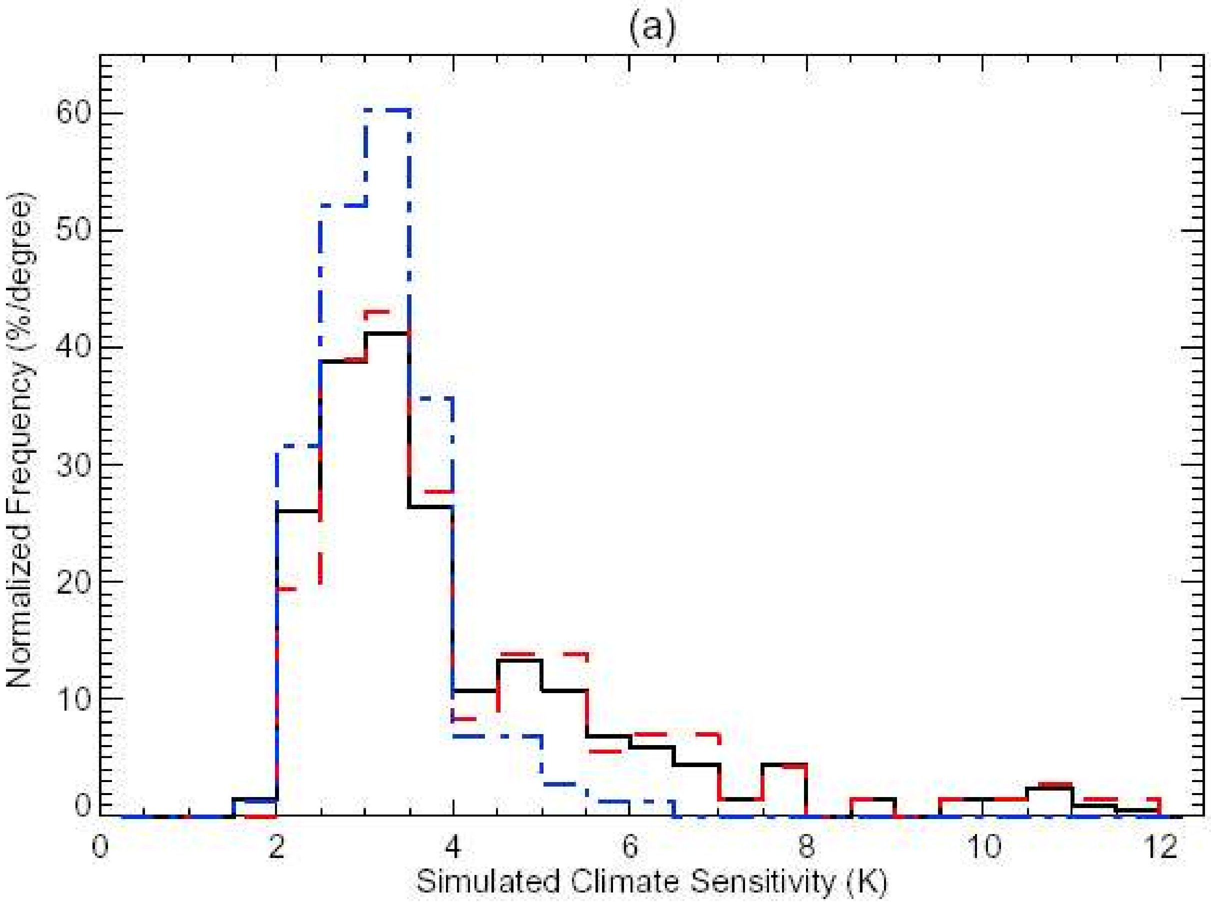
# Experimental design

- **Experiment 2:** **Explore model sensitivity to initial conditions, historical forcings**
  - **Use full ocean model: HADCM3**
  - **Hindcast of climate 1950-2000**
  - **Assess predictive model skill**
- **Experiment 3:**
  - **Using full ocean model**
  - **Probablistic forecast of 2000-2100**

# Some results

- Paper in Nature:
  - Stainforth et al.: “Uncertainty in predictions of the climate response to rising levels of greenhouse gases”
  - Wide spread media coverage
  - ~10,000 new users in the following 3 weeks
  - http://www.climateprediction.net/science/pubs/nature_first_results.pdf

# Wide range of sensitivities



# Stainforth et al.

- Used 2,578 model simulations from CPDN
- 2,017 unique simulations, 561 duplicates
- Wide range of sensitivities (S) : 2K< S <11K
- IPCC : 1.5K < S < 4.5K
- Models that give us high sensitivities not yet ruled out by observations