History (The Book)

Overview

- First GCM developed in mid-1950s
  - 5k of memory!
- First Modern GCM in 1960s along with first RC (Radio Convective) models
- First EBM described in 1969
- First SD (Statistical Dynamical) model in 1970
  - Evolved into EMIC (Earth Models of Intermediate Complexity)
- First GCMs evolved from smaller scale weather models used for forecasting

Notables

- Syukuro Manabe
  - Worked for NOAAs Geophysical Fluid Dynamics Laboratory
  - Spearheaded design of RC models, 1961
- Juli`an Adem
  - 1965, Low resolution thermodynamic model
    - Simpler than GCM and similar to EBM
- Mikhail Budyko and William Sellers
  - 1969, Described first EBM
  - Not dependent on complex weather prediction schemes
  - Suggested that climatic zones were roughly latitudinal
  - Motivated study of climate on geologic time scale
- John Green
  - Spearheaded SD models in early 1970s
  - Paved the way for 2D models
- The GCM
  - Took off by 1980
    - Highly nonlinear and highly complex
  - Mid to late 1980s
    - Correct results generated for wrong reasons
    - Push toward Hierarchy of climate modeling tools

Ocean GCMs

- Kirk Bryan
  - Developed model which is basis for modern ocean GCMs
  - Modern version is Bryan-Cox-Semtner model
  - Current resolution is 1/6 degree or 2 degrees with coupled atmo GCM
- First GCMs used treated oceans as infinite source of moisture
  - Based on monthly observations
  - difficult to disturb climate system
- late 1980s, mixed upper layer approach
  - Only good for less than 30 years

Todays challenges

- Non-equilibrium conditions
  - Transient forcing (solar variability, CO2, land surface change)
- Interdisciplinary efforts
  - Specialization (land-surface climatology)

Sensitivity of Climate Models

- Refers to models reaction when "poked"
- Albedo example
  - Earth changes from Ice-Covered -> Partially Covered -> No Ice depending on Critical temperature
  - Critical temperature ranges from 263K to 283K
  - Not a single equilibrium, all three equilibrium states are possible
- Sensitivity analysis is important for 'external' and 'internal stability'
  - 'External Stability', 2 solutions, bifurcation
    - *Unstable*: If Solar constant is reduced below mucS, the albedo is nearly 1, the global energy balance cannot be maintained, and an equilibrium solution is not possible.
    - *Stable*: Model functions as normal
  - 'Internal Stability'
    - If we started a transient model with a solution near an equilibrium soution, would the model tent toward that solution
    - *Transitive*: Different IC lead to same ending (normal) state
    - *Intransitive*: Different IC leads to different ending state
    - *Almost Intransitive*: Model acts transitively but eventually flips to alternate state. Extremely difficult to successfully.
- Sensitivity can take many forms, the quantifying of which can measure many things
  - Agreement with observations may even be misleading
    - Narrow record

Chaotic Systems

- Scientific Climate
  - Skeptical of Computers
  - Universe is well behaved, 'Belief in approximation and convergence'
    - 'Arbitrarily small influenced do not blow up to have arbitrarily large effects … approximately accurate input gives approximately accurate output'
- First discovered by Edward Lorenz
  - Meteorologist and Mathematician
  - Weather forecaster for Army in WWII
  - Embraced computers
  - Roundoff error lead to Lorenz first notice the phenomenon of chaos
- Slap in the face of the ideas and optimism of Von Neuman
  - Controlling the weather and knowing long term how the climate system will react