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 solution, 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