Land, Water, Carbon and Climate
The Earth From Above

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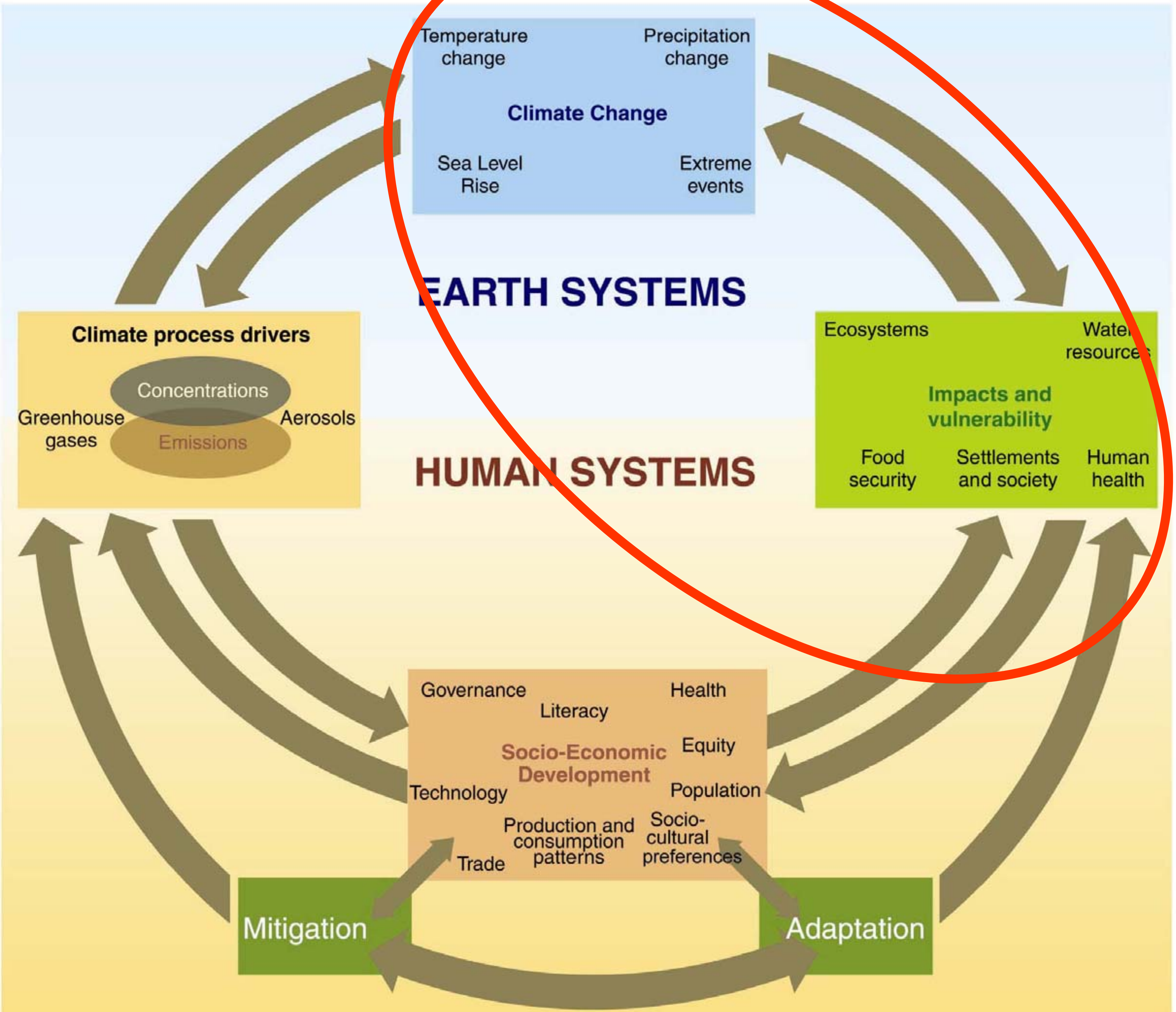
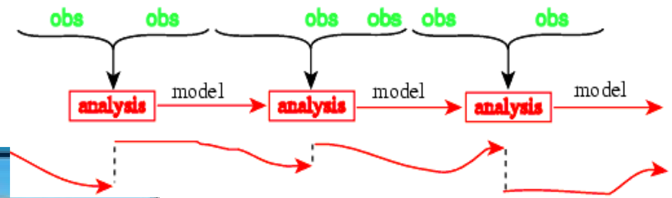
Schematic framework of anthropogenic climate change drivers, impacts and responses

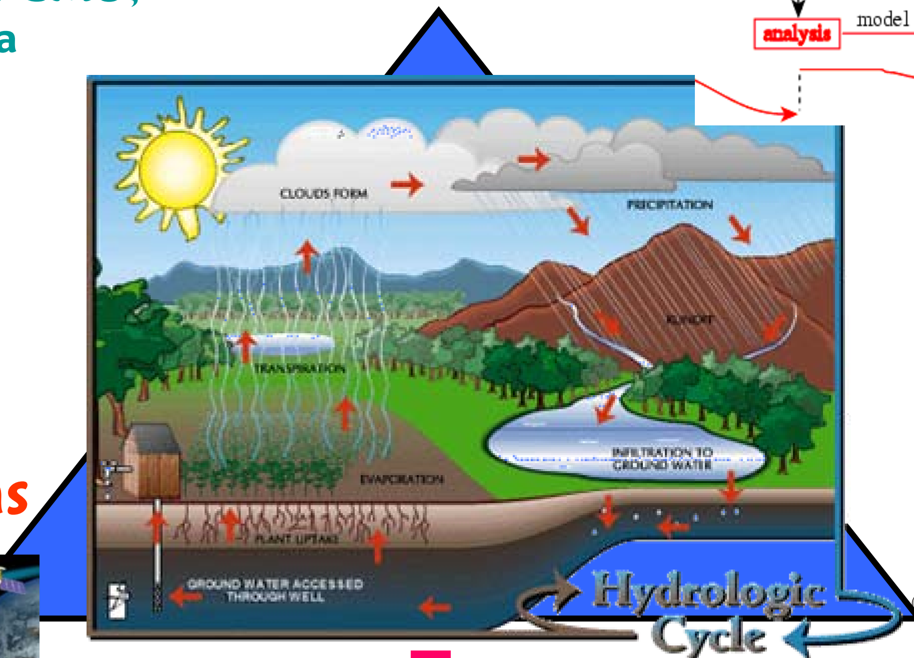


Summary of My Research Work

Funded by NASA
Collaborators: GMU, Australia

Data Assimilation

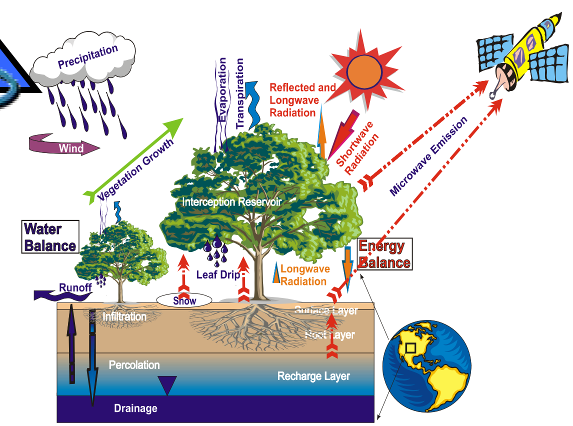




Observations

Funded by NASA
Collaborators: BU, Australia

Modeling



Funded by NASA
Collaborators: NASA, Harvard

Application

Funded by NASA, PSC-CUNY
Collaborators: NASA, Hunter

1. Modeling

Goddard Institute for Space Studies
at Columbia University in New York

Goddard Space Flight Center

CUNY The City University of New York

Harvard University

Ent:
A Dynamic Global Terrestrial Ecosystem Model (DGTEM) for Coupling with GCMs

Nancy Y. Kiang, Igor Aleinov, David Rind (GISS)

Randal D. Koster (GSFC)

Paul R. Moorcroft (Harvard University)

Wenge Ni-Meister (Hunter College of CUNY)

Postdocs: Pushker Kharecha (Columbia)

Michael Puma (Columbia)

Yeonjoo Kim (Harvard)

NASA-GISS, June 7-8, 2007

Existing Coupled DGVM-GCM's

- IBIS-CCM3 (Foley, U. Wisc; NCAR)
- TRIFFID-HadCM3 (Cox, Hadley Ctr.)
- LPJ-Bern CC (Max Planck, Potsdam, Bern)
- LPJ-NCAR Community Climate Model (Bonan)
- ED-GFDL (Pacala, GFDL)

- In progress:

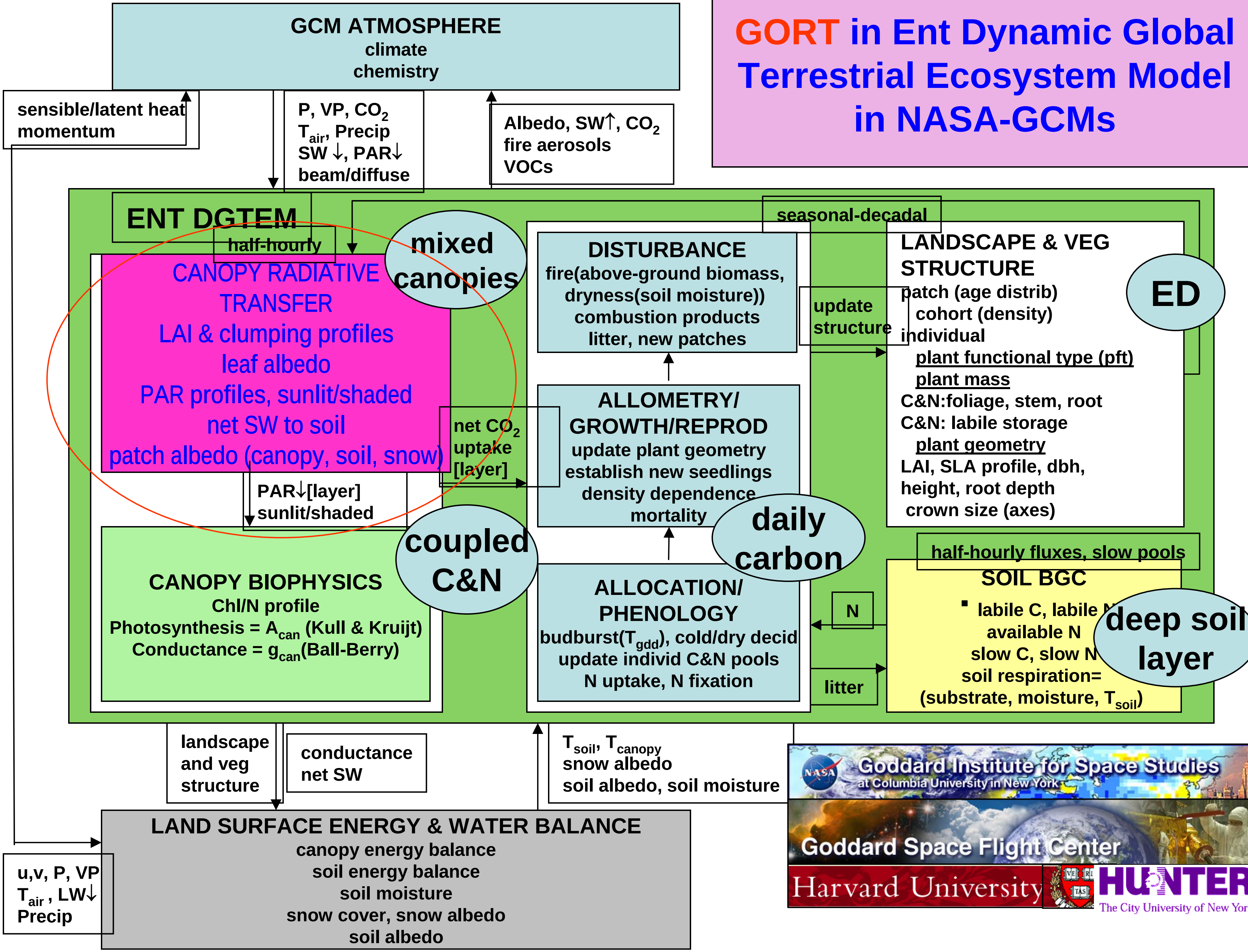
  MAPSS revision (Neilson, Oregon State U.)

SCIENTIFIC COMMUNITY GOALS:

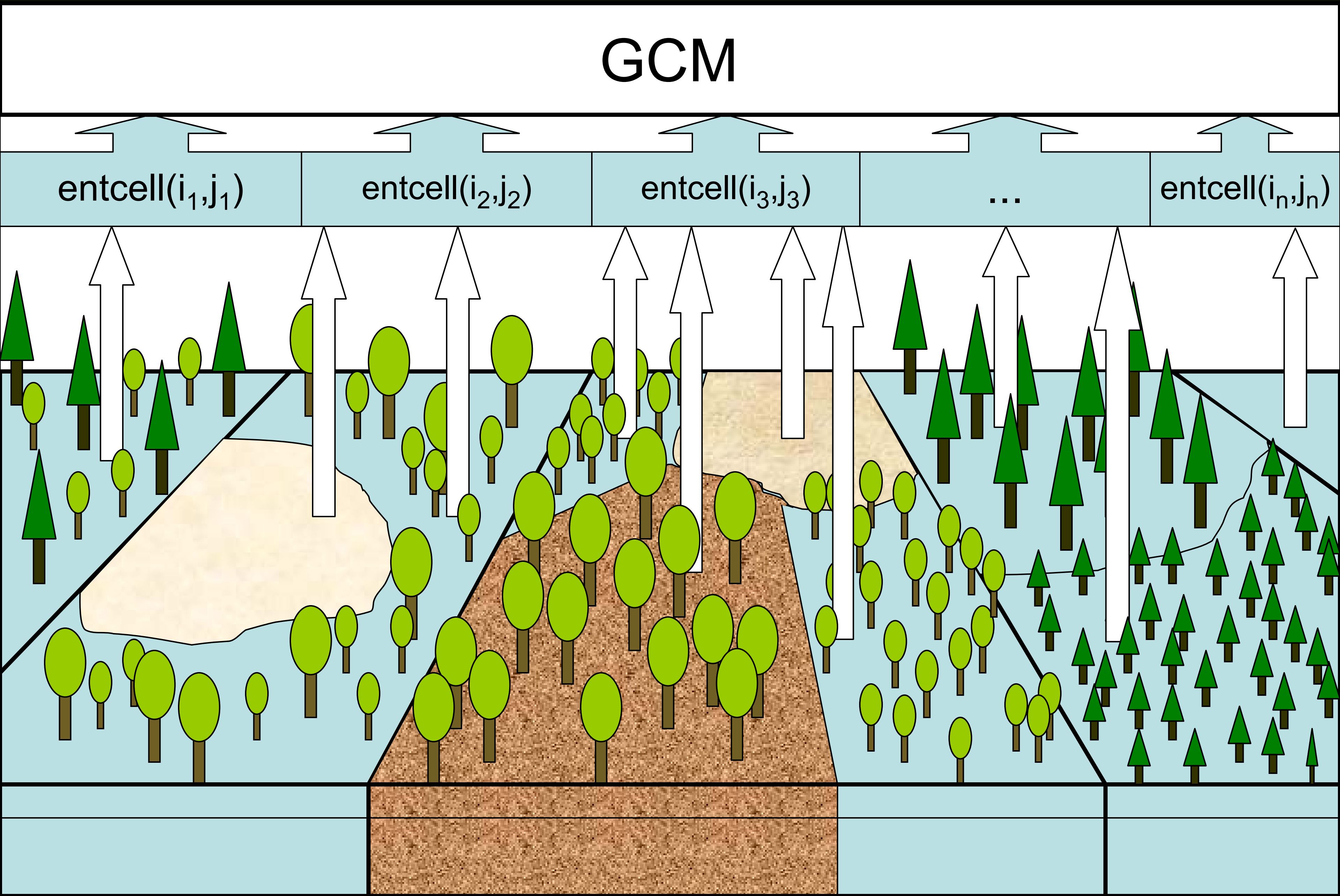
ENT will be a standalone set of modules that can be used by the climate modeling community to couple with land hydrology models and atmospheric GCMs

Research questions:	GISS	GMAO	NAI	Science community
synoptic/seasonal weather evolution	☐	☒	☐	☒
data assimilation	☐	☒	☐	☒
vegetation phenology	☒	☒	☐	☒
global carbon budget	☒	☒	☐	☒
global change: past, present, and future	☒	☐	☐	☒
vegetation-climate feedbacks	☒	☒	☒	☒
astronomical biosignatures	☐	☐	☒	☒

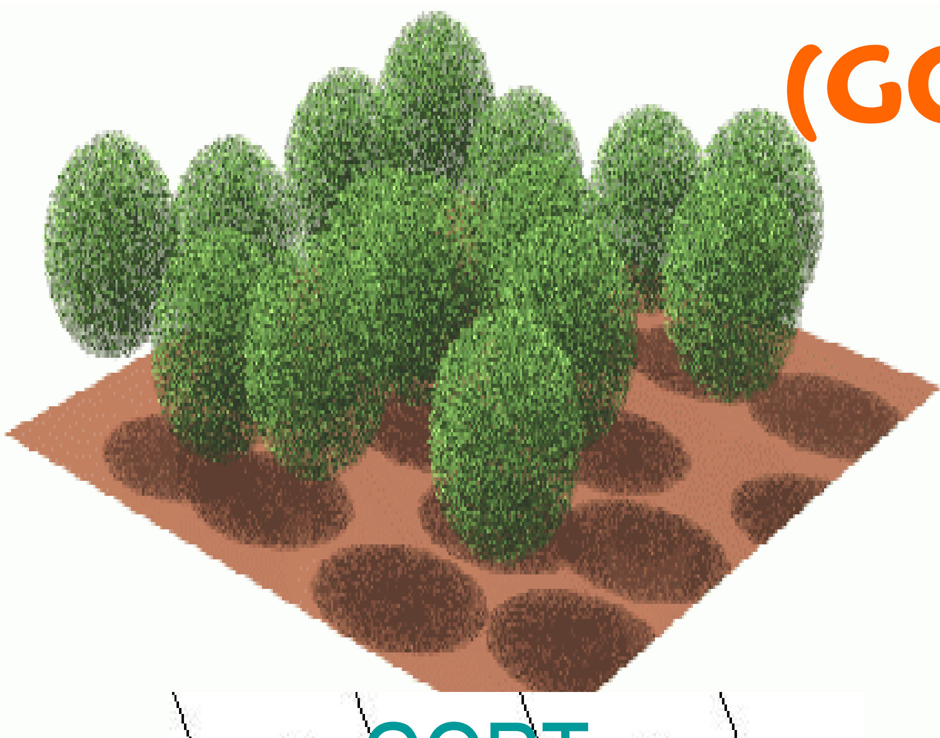
GORT in Ent Dynamic Global Terrestrial Ecosystem Model in NASA-GCMs

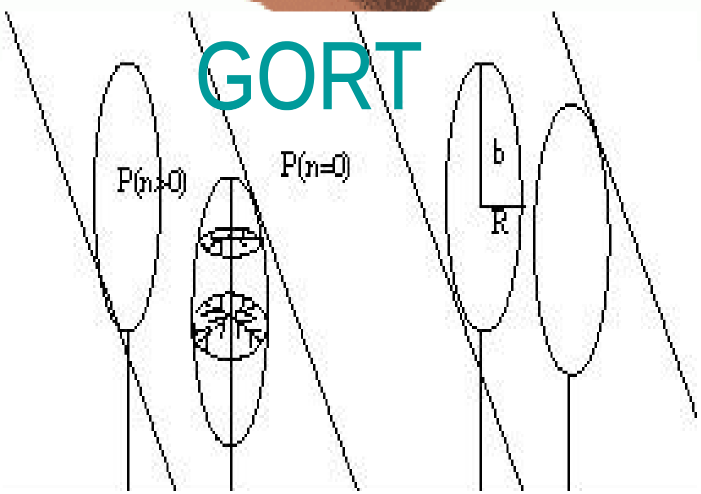


Ent subgrid heterogeneity and mixed canopies



Geometric Optical and Radiative Tansfer Model (GORT)





Geometric Optics (GO) theory:

- **Gap Probabilities**
- **areal proportions of sunlit and shaded scenes**

Radiative Transfer (RT) theory:

- **Multiple Scattering**

Ent Canopy Radiative Transfer

Analytical Model for Clumping Factor

(based on Li and Strahler, 1988)

Beer's Law with clumping factor, γ

$$\tau_s(h) = \exp\left(\frac{-\gamma G L(h)}{\cos\theta}\right)$$

I_s: penetration function (fraction) for beam radiation
G: leaf orientation function
L: leaf area density
θ: solar zenith angle

Clumping factor, γ
Non-overlapping crowns

$$\gamma = \frac{3}{4\Gamma R}\left(1 - \frac{1-(2\Gamma R+1)e^{-2\Gamma R}}{2(\Gamma R)^2}\right)$$

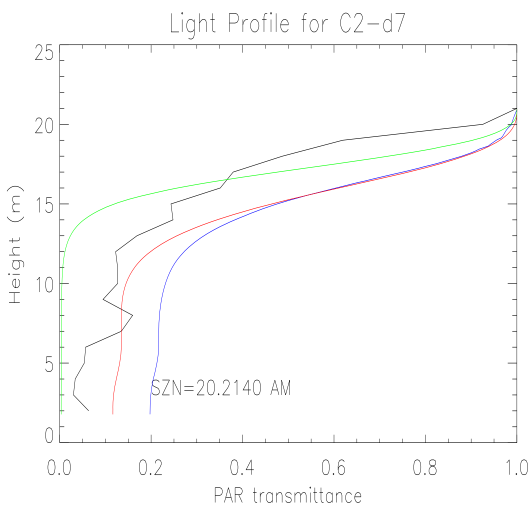
γ: clumping factor
- $\gamma=1$, no clumping, leaves random
- $\gamma<1$, clumped
- $\gamma>1$, uniform/dispersed

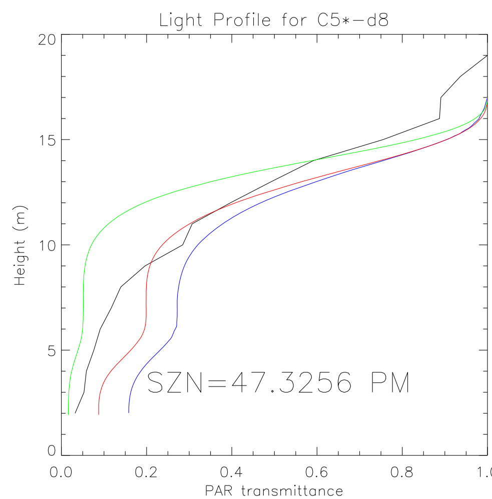
where:

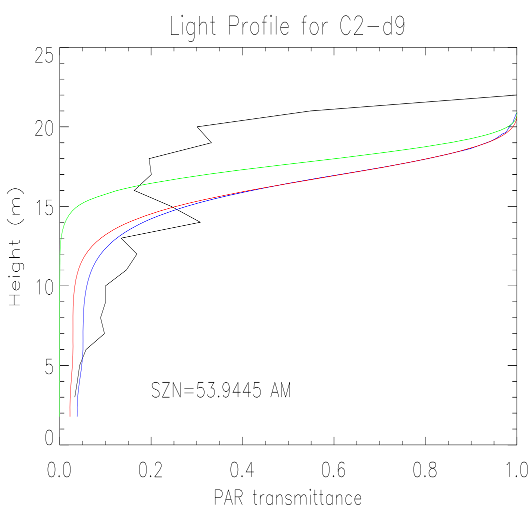
$$\Gamma R = GFaR\left(\frac{1+\tan^2\theta}{1+\left(\frac{b}{R}\right)^2\tan^2\theta}\right)^{\frac{1}{2}} = \frac{3GLAI}{4\lambda\pi R^2}\left(\frac{1+\tan^2\theta}{1+\left(\frac{b}{R}\right)^2\tan^2\theta}\right)^{\frac{1}{2}}$$

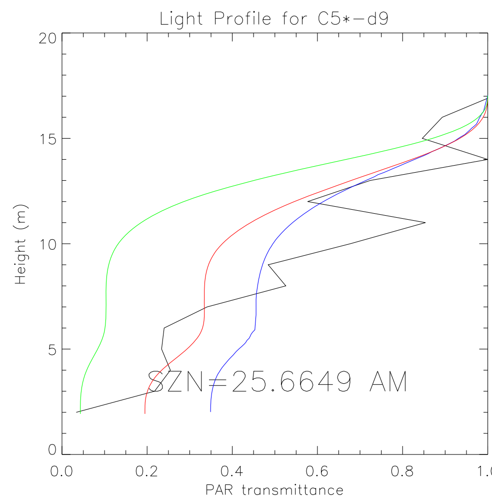
θ= solar zenith angle, Fa = foliage area volume density,
R = crown radius, b/R = crown ellipticity, λ = tree density

Validation – Balloon Data, Harvard Forest









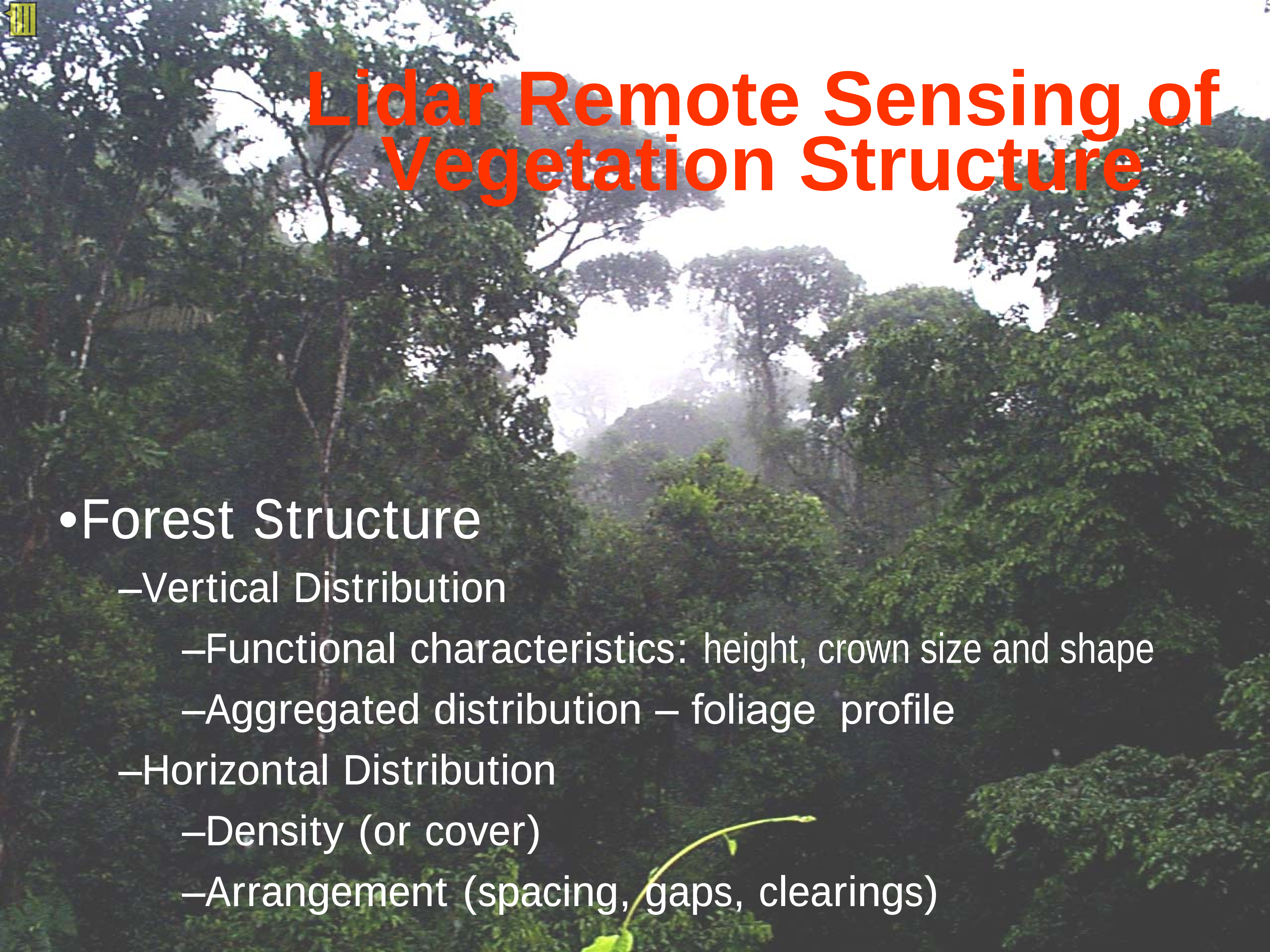
Balloon data

Full GORT

Ana GORT, Clump

Ana GORT, No Clump

2. Satellite Observations

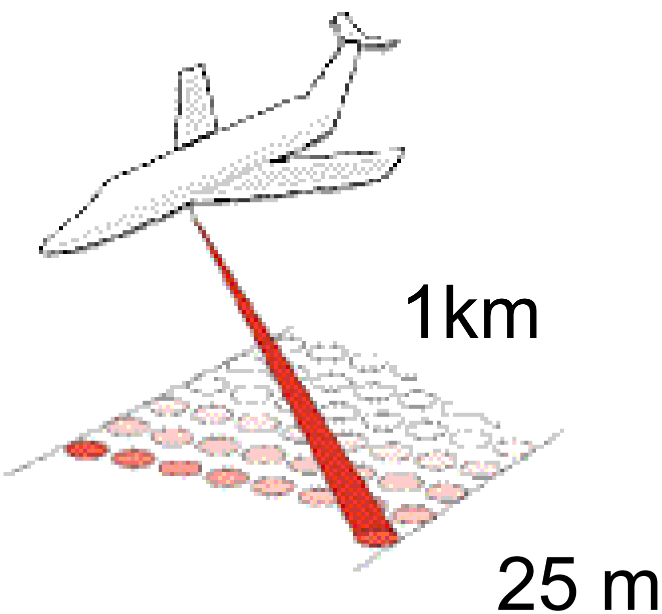


Lidar Remote Sensing of Vegetation Structure

- Forest Structure
  - Vertical Distribution
    - Functional characteristics: height, crown size and shape
    - Aggregated distribution – foliage profile
  - Horizontal Distribution
    - Density (or cover)
    - Arrangement (spacing, gaps, clearings)

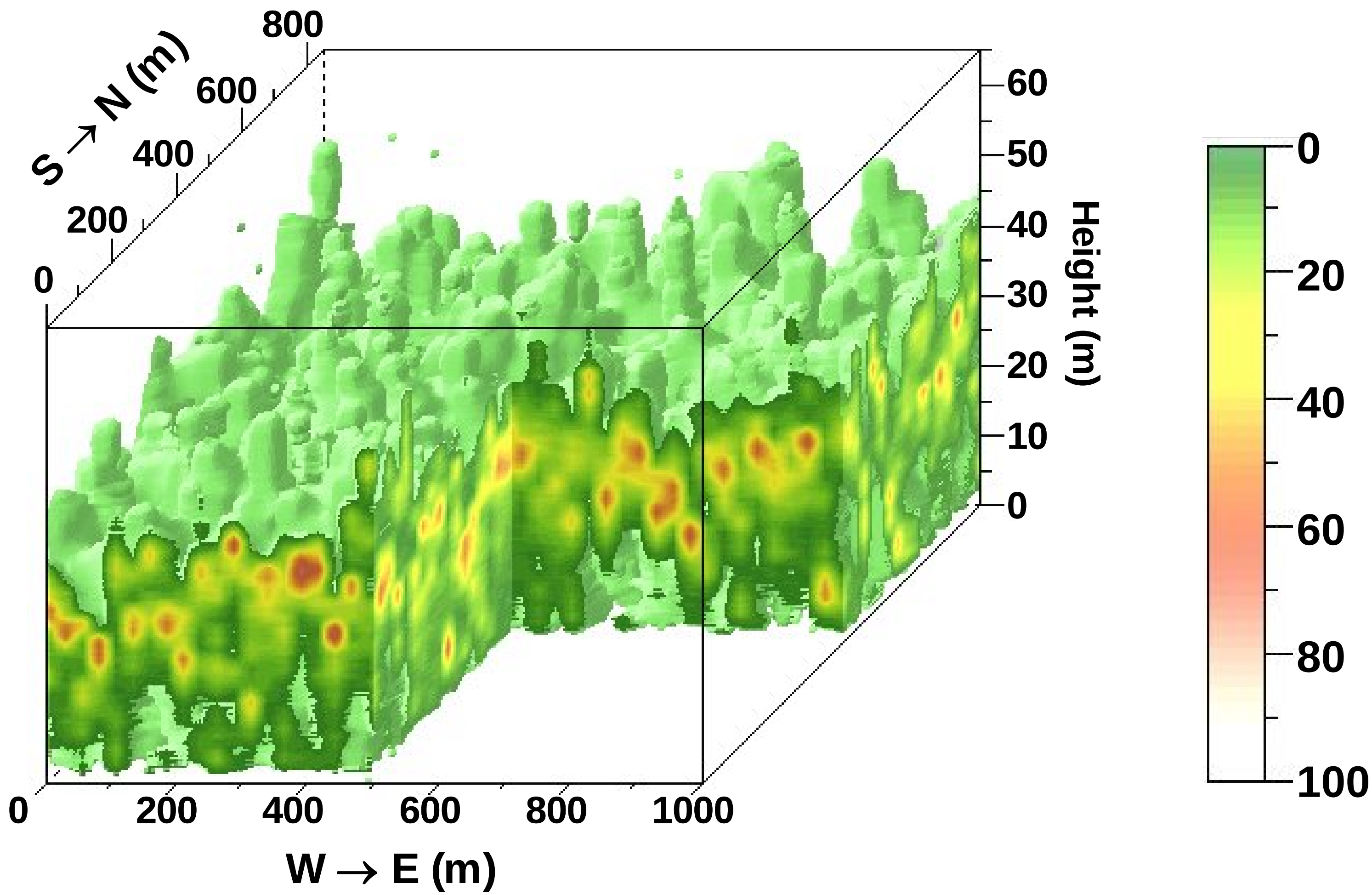
Lidar Remote Sensing

Laser altimetery



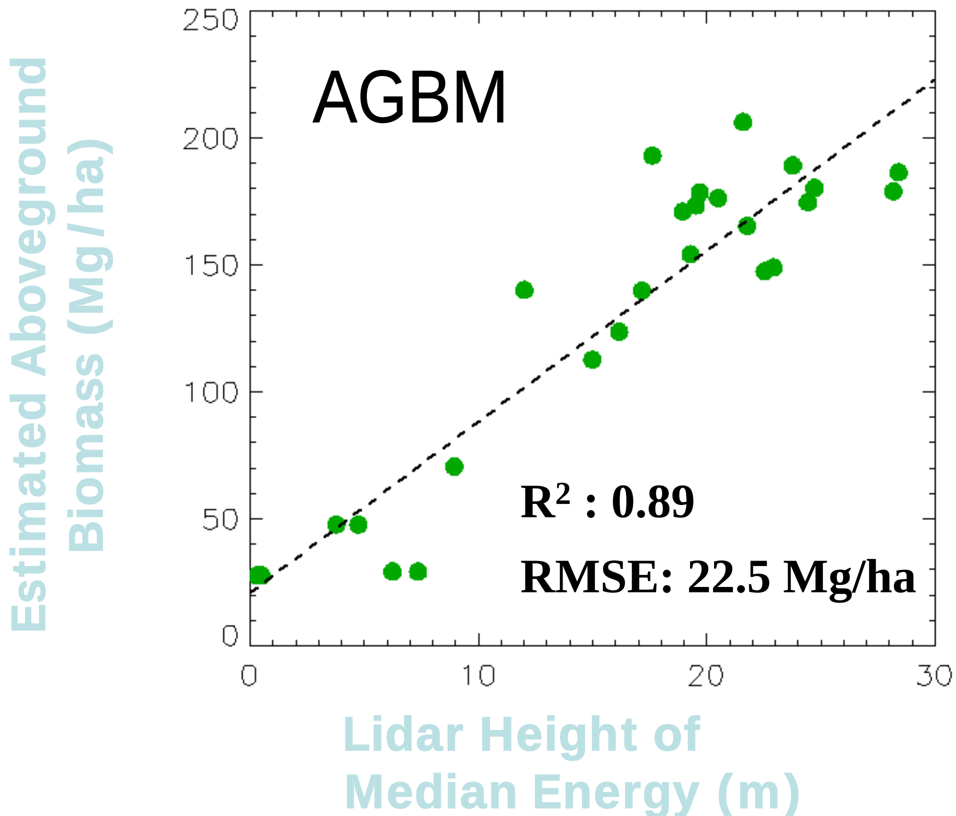
3D mapping and imaging

Lidar Remote Sensing of Forests



3D Forest Canopy Volume

Empirical Relationship of Lidar with AGBM

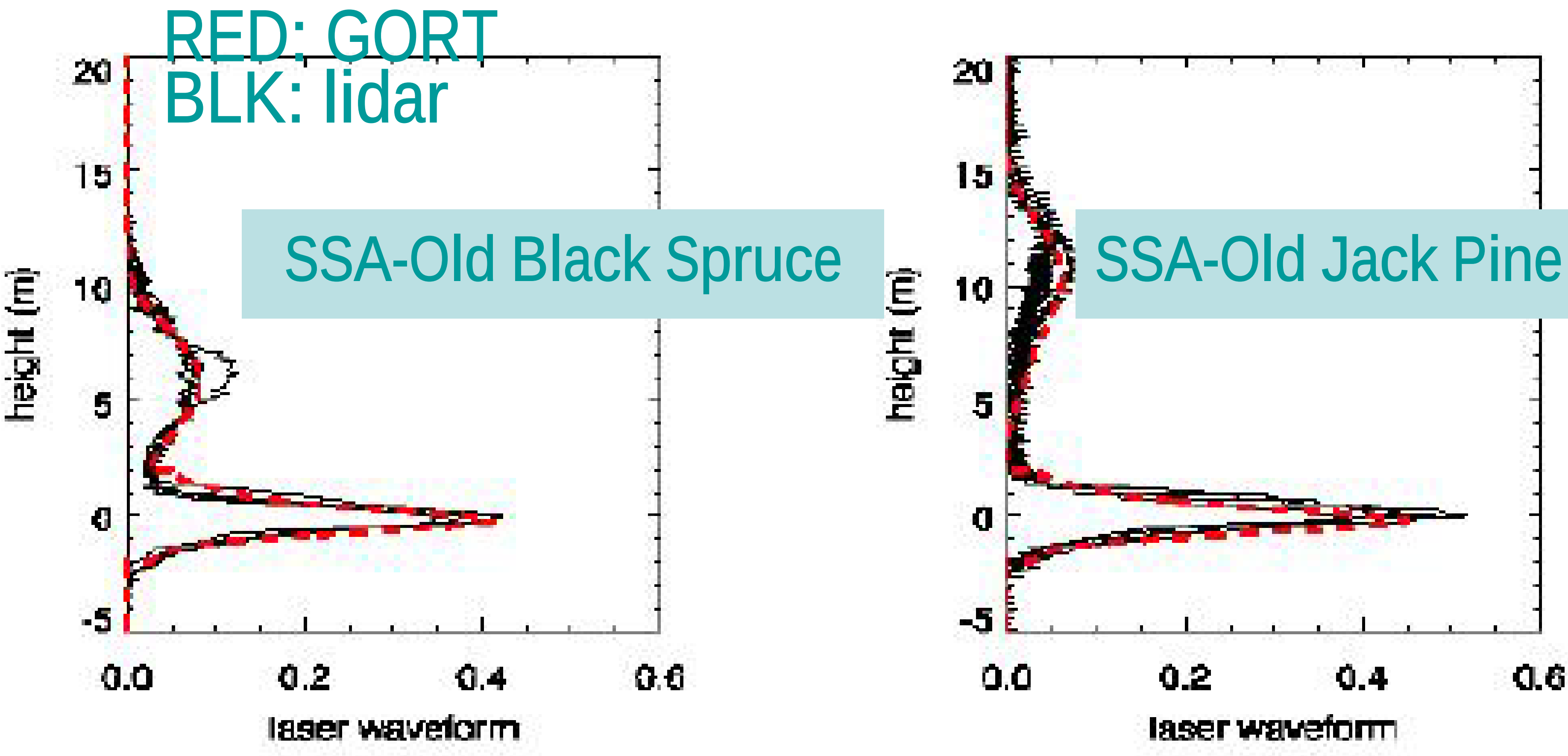


Drake et al, 2000

Simple Model: log transformation to link waveforms and vertical foliage profile
Assume vegetation canopy homogeneous:

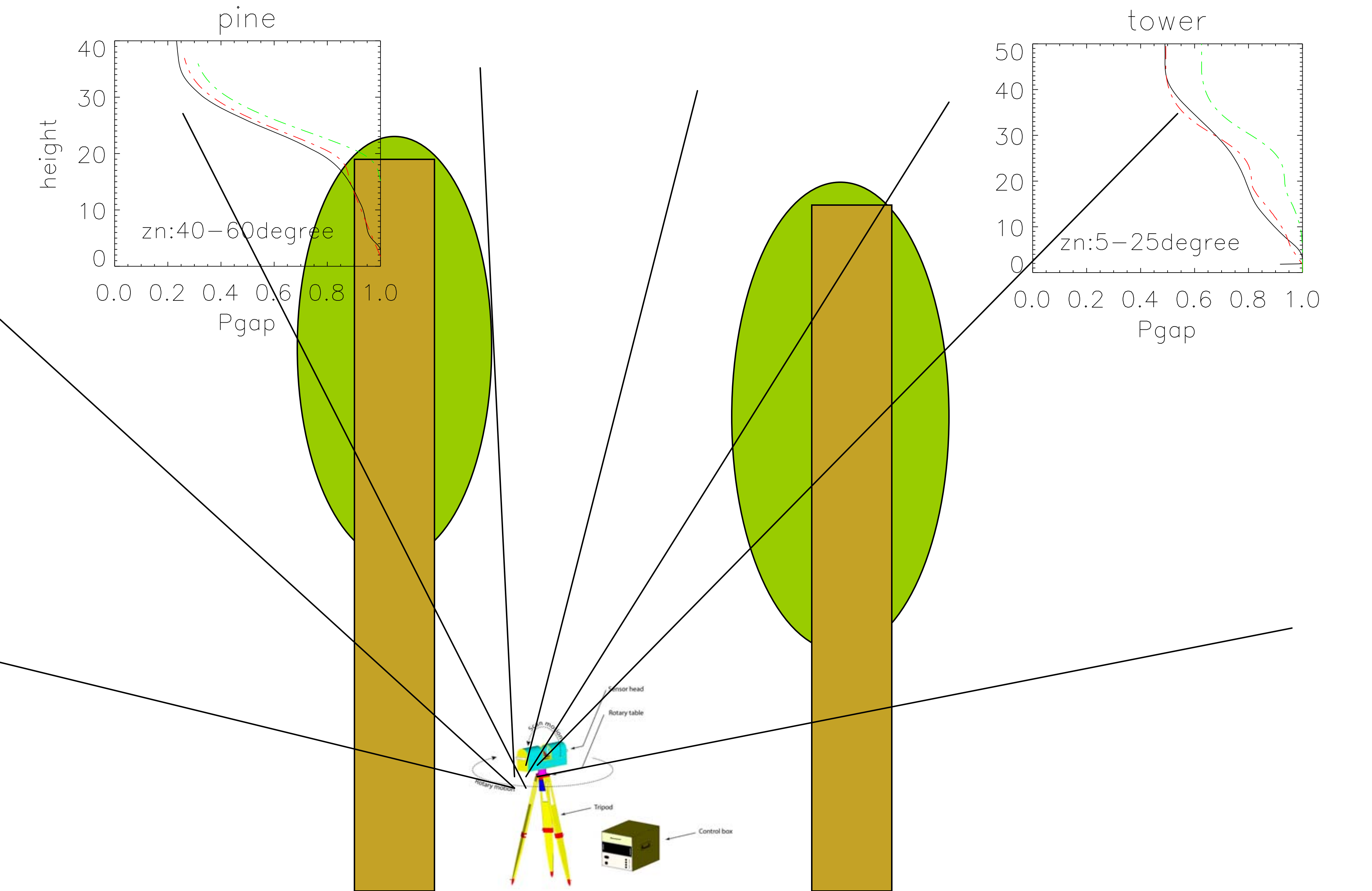
Lefsky et al, 1999

Above Canopy Lidar Modeling

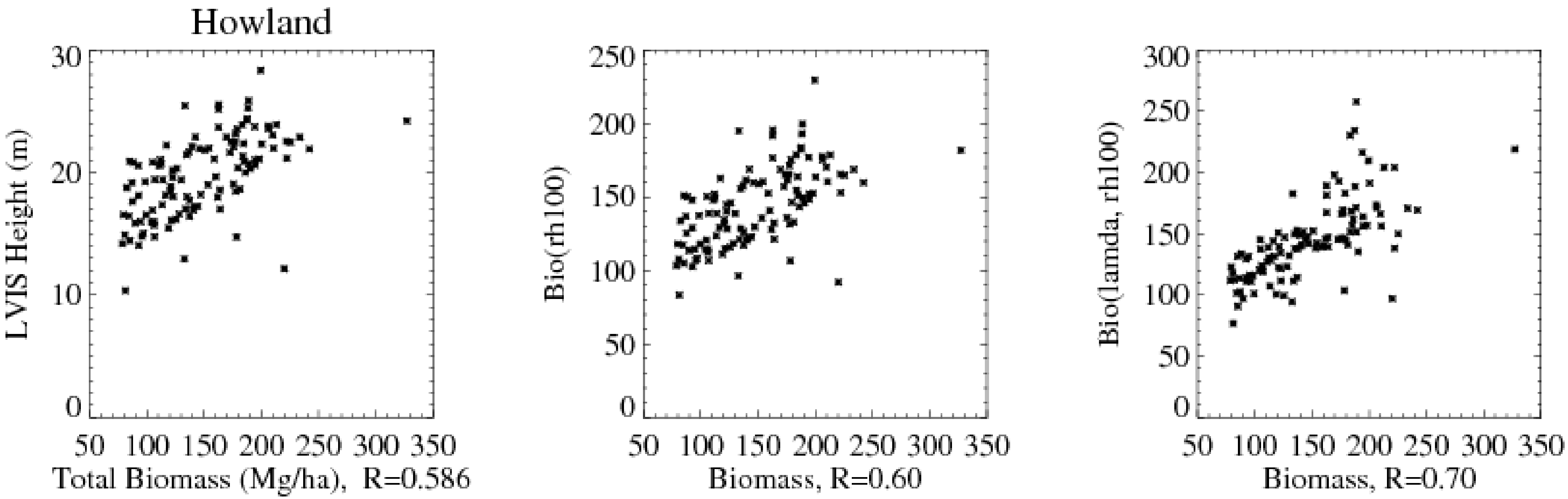


Ni-Meister et al (2001)

Below Canopy Lidar Modeling



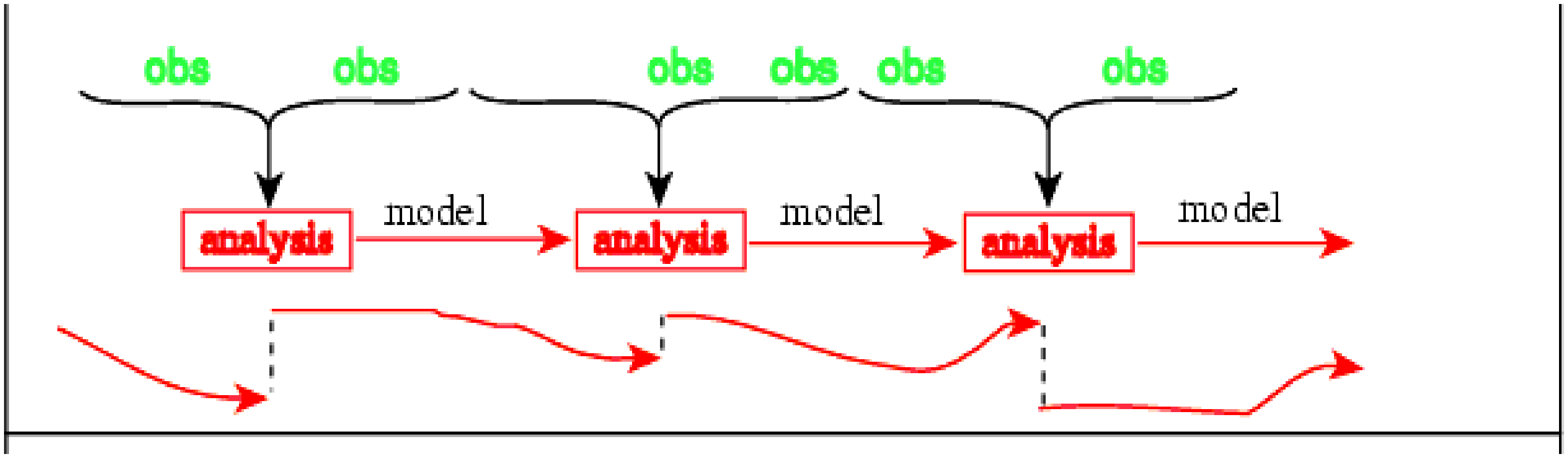
Above Ground Biomass Estimate from Above- and Below- Canopy Lidar



3. Data Assimilation

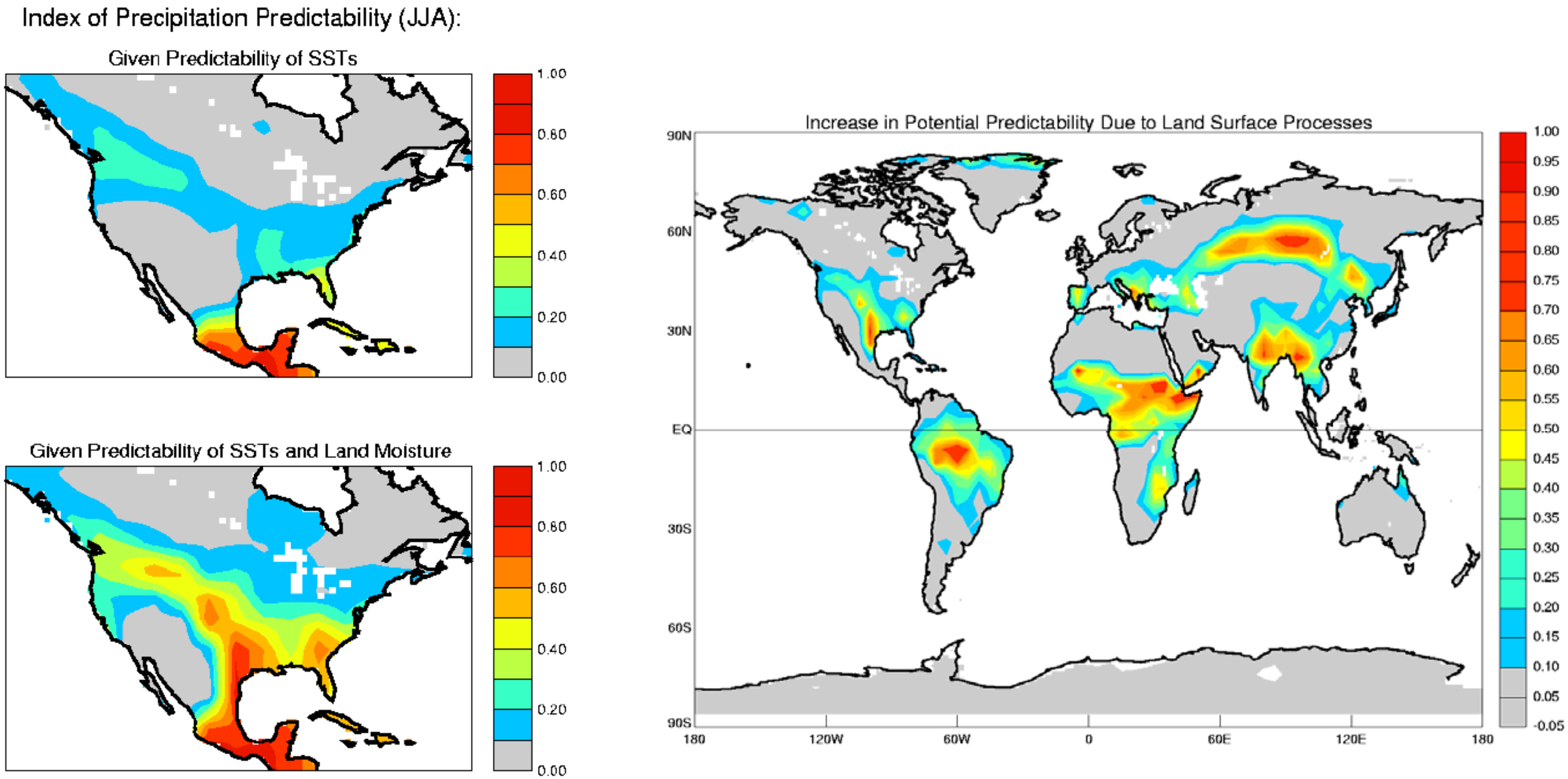
Data Assimilation

Data Assimilation merges observations & model predictions to provide a superior state estimate.



Motivation: Impacts of Soil Moisture On Climate Prediction

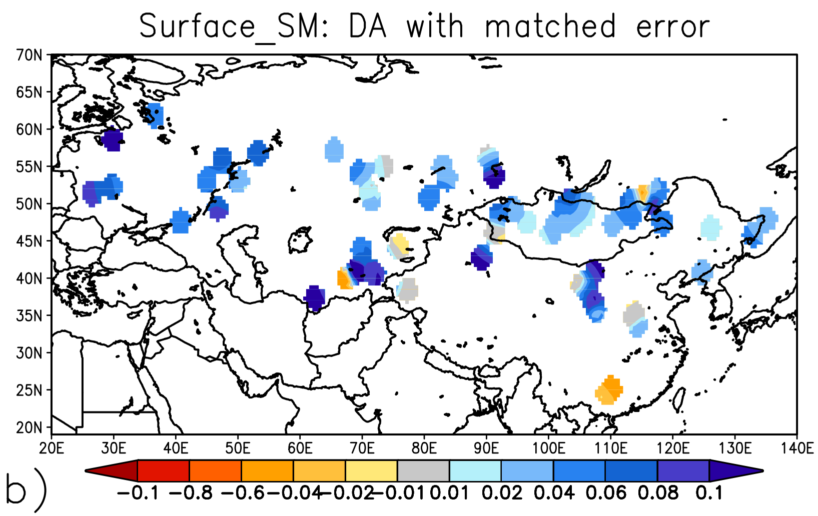
- Knowledge of soil moisture has a greater impact on the predictability of summertime precipitation over land at mid-latitudes than Sea Surface Temperature (SST).

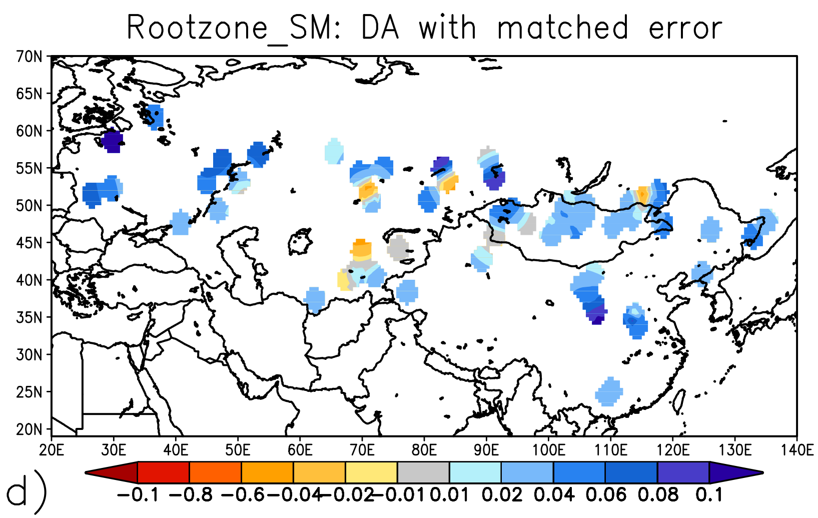


- Soil moisture persists for months and can impact weather through evaporation
- Due to lark of long term observations over large areas, such impacts are often seen in AGCM studies

Koster et al, 2001

Assimilate Microwave Remote Sensed Soil Moisture into a Land Surface Model





SM estimate improvement through DA

Summary

- Global Dynamic Ecosystem Model
  - Simulate tree growth
  - Estimate fluxes of C, N, energy,H2O
- Lidar Remote of Forest Structure
  - Estimate above-ground C store
  - Initialize models
- Data Assimilation
  - Integrate model and remote sensing data