BIOPHYS

A PHYSICALLY-BASED CONTINUOUS FIELDS ALGORITHM
and Climate and Carbon Models

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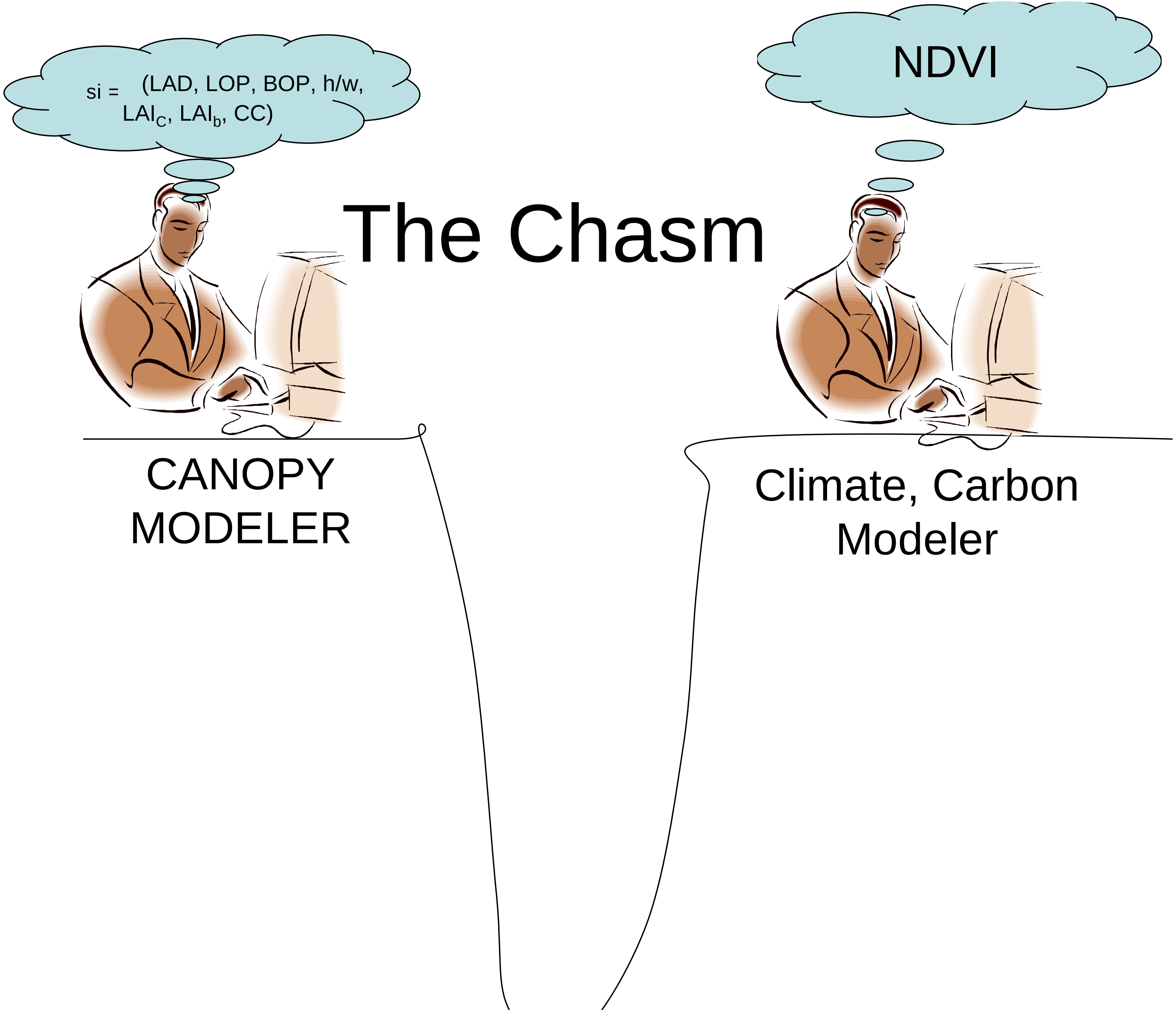
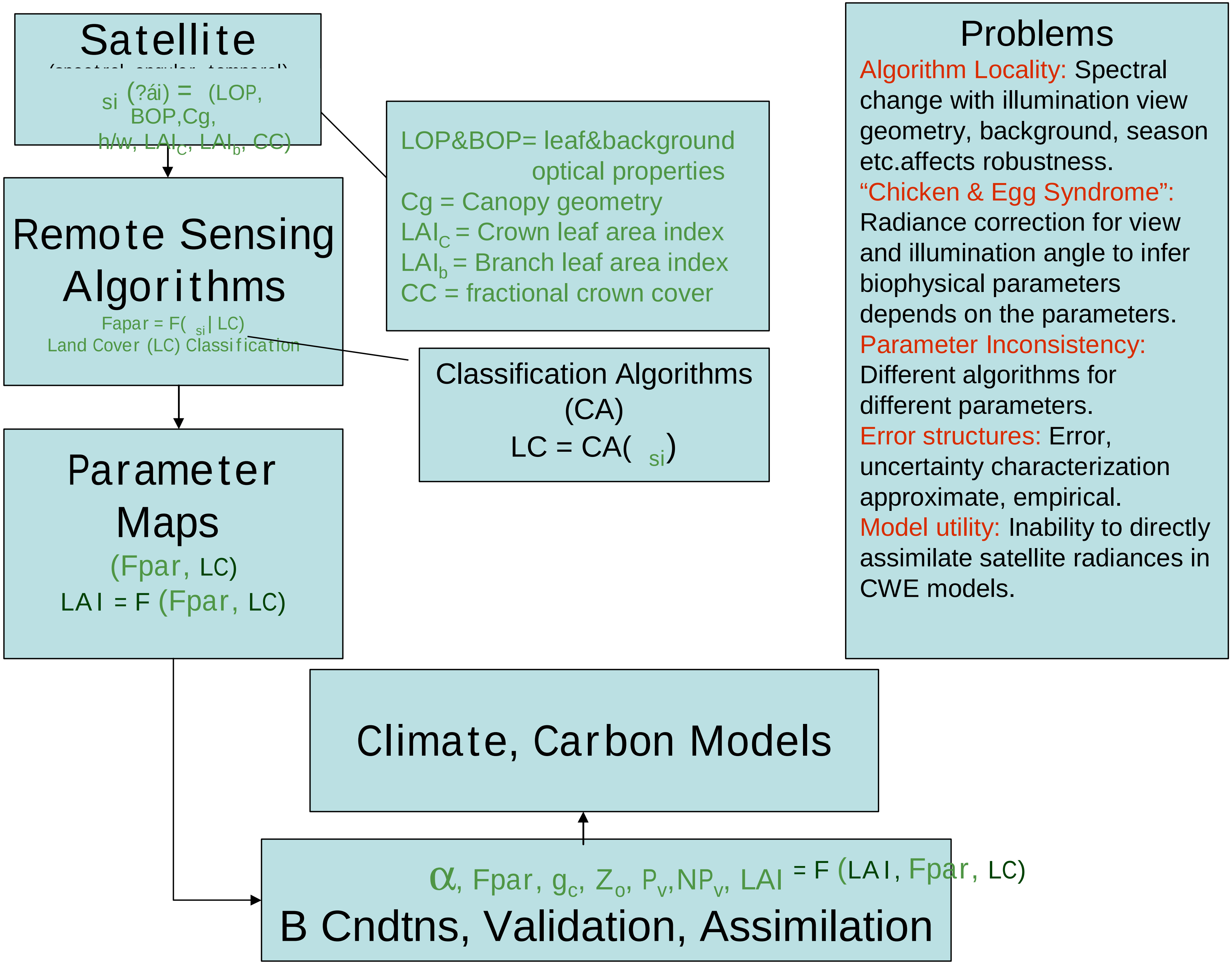
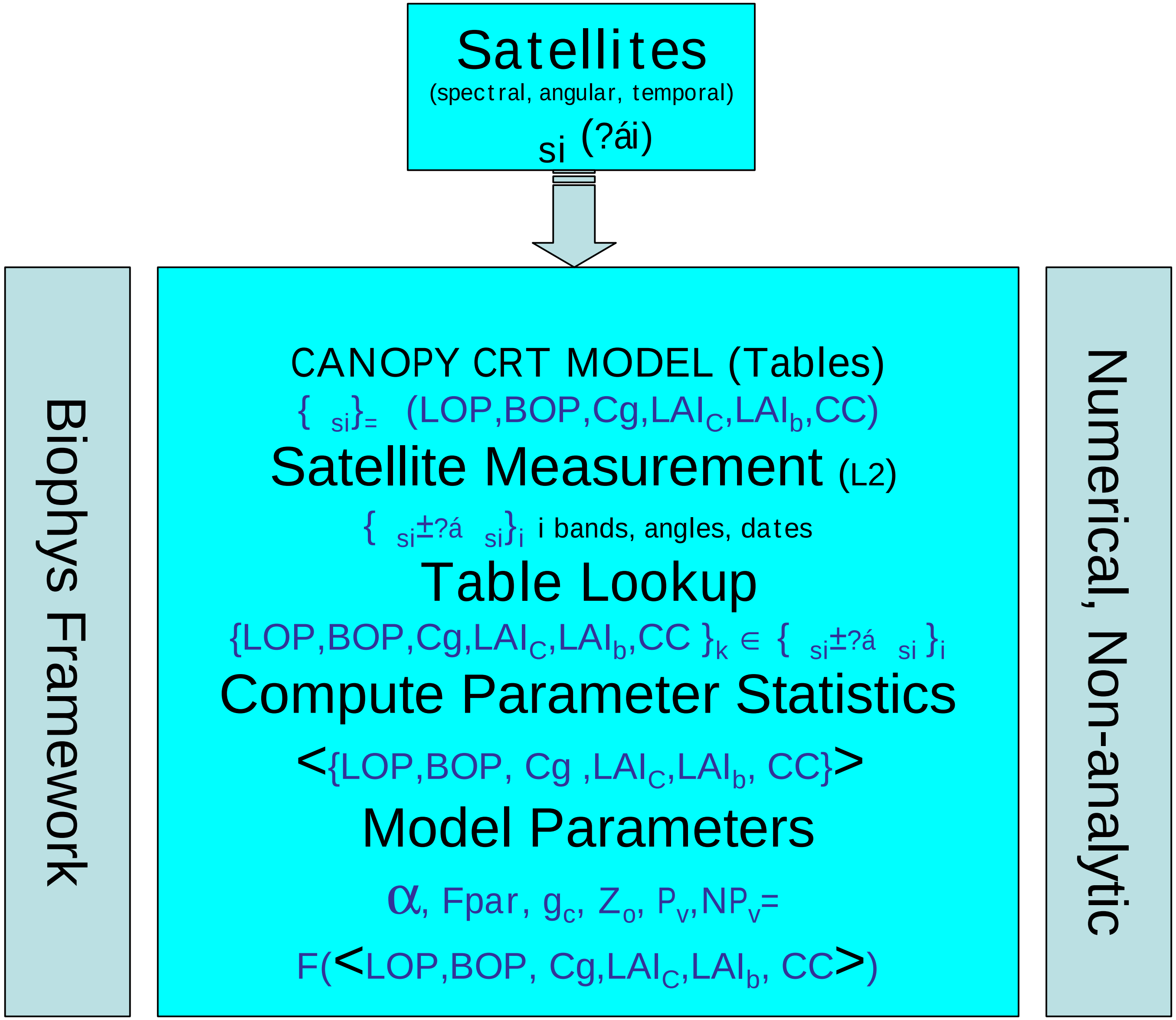
The Chasm

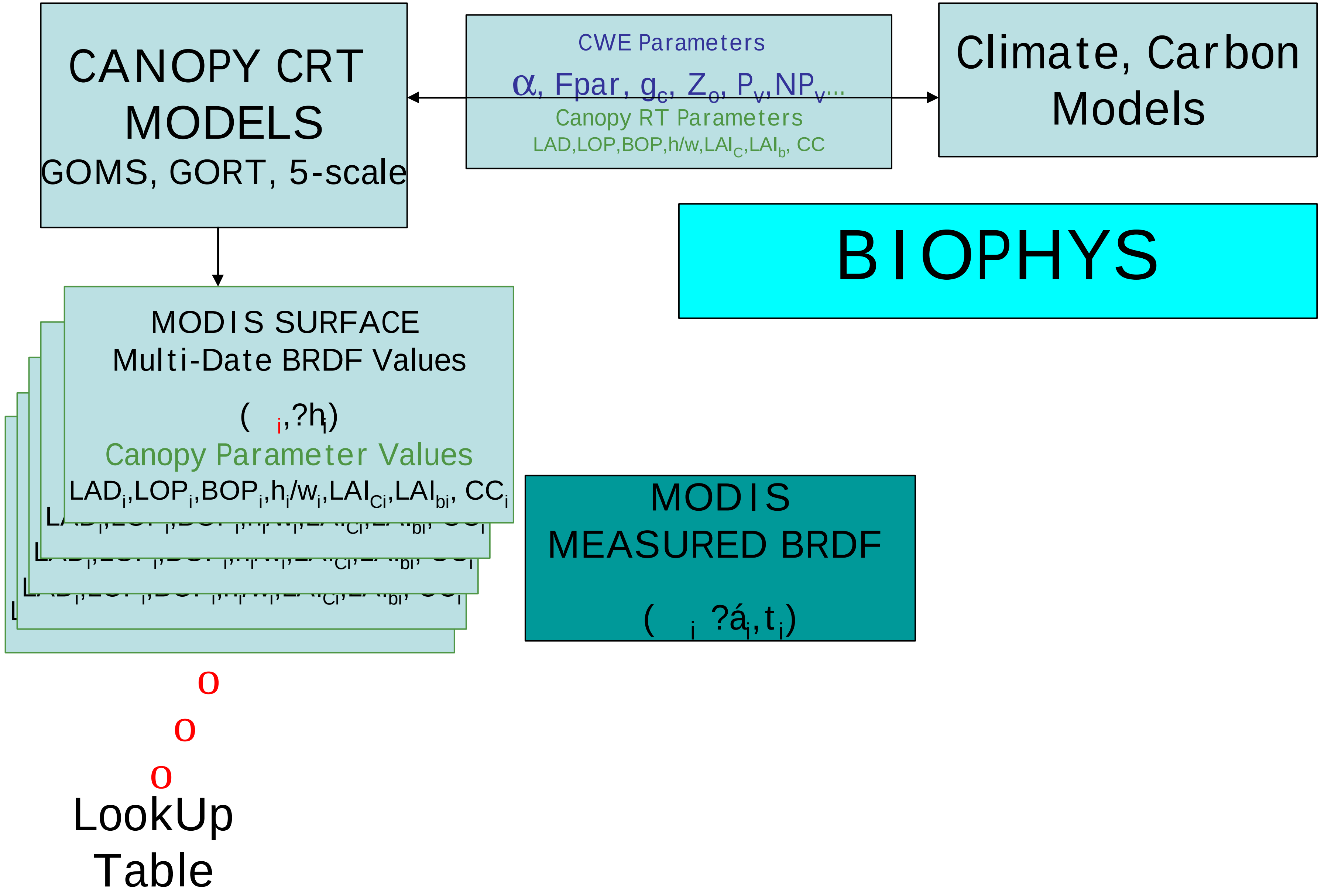

si = (LAD, LOP, BOP, h/w, LAI_C, LAI_b, CC)
NDVI
CANOPY MODELER
Climate, Carbon Modeler


Satellite
si (?ái) = (LOP, BOP,Cg, h/w, LAIC, LAIb, CC)
LOP&BOP= leaf&background optical properties
Cg = Canopy geometry
LAIC = Crown leaf area index
LAIb = Branch leaf area index
CC = fractional crown cover
Remote Sensing Algorithms
Fapar = F(si | LC)
Land Cover (LC) Classification
Classification Algorithms (CA)
LC = CA(si)
Parameter Maps
(Fpar, LC)
LAI = F (Fpar, LC)
Problems
Algorithm Locality: Spectral change with illumination view geometry, background, season etc.affects robustness.
“Chicken & Egg Syndrome”: Radiance correction for view and illumination angle to infer biophysical parameters depends on the parameters.
Parameter Inconsistency: Different algorithms for different parameters.
Error structures: Error, uncertainty characterization approximate, empirical.
Model utility: Inability to directly assimilate satellite radiances in CWE models.
Climate, Carbon Models
α, Fpar, gc, Zo, Pv,NPv, LAI = F (LAI, Fpar, LC)
B Cndtns, Validation, Assimilation

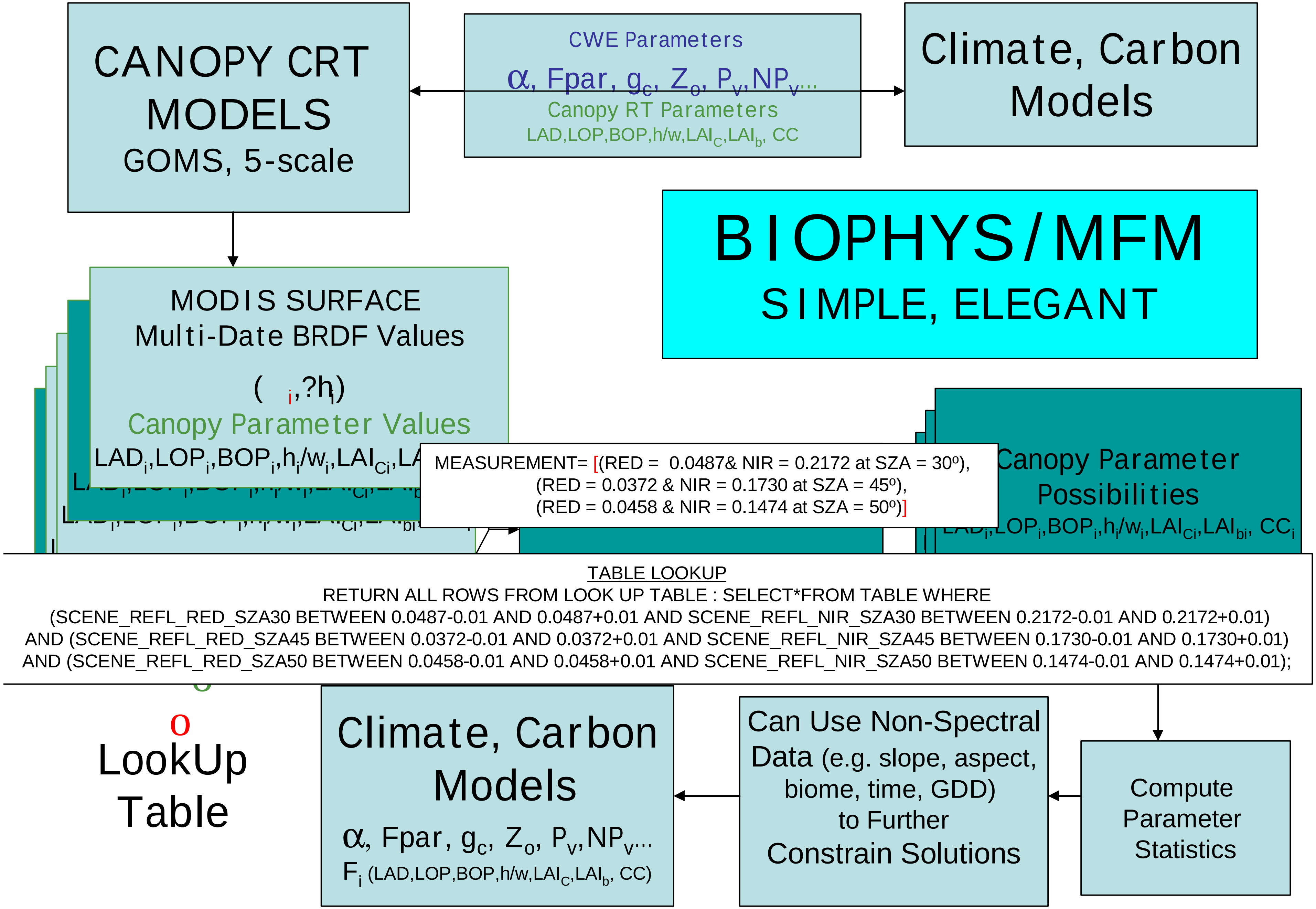
BIOPHYS

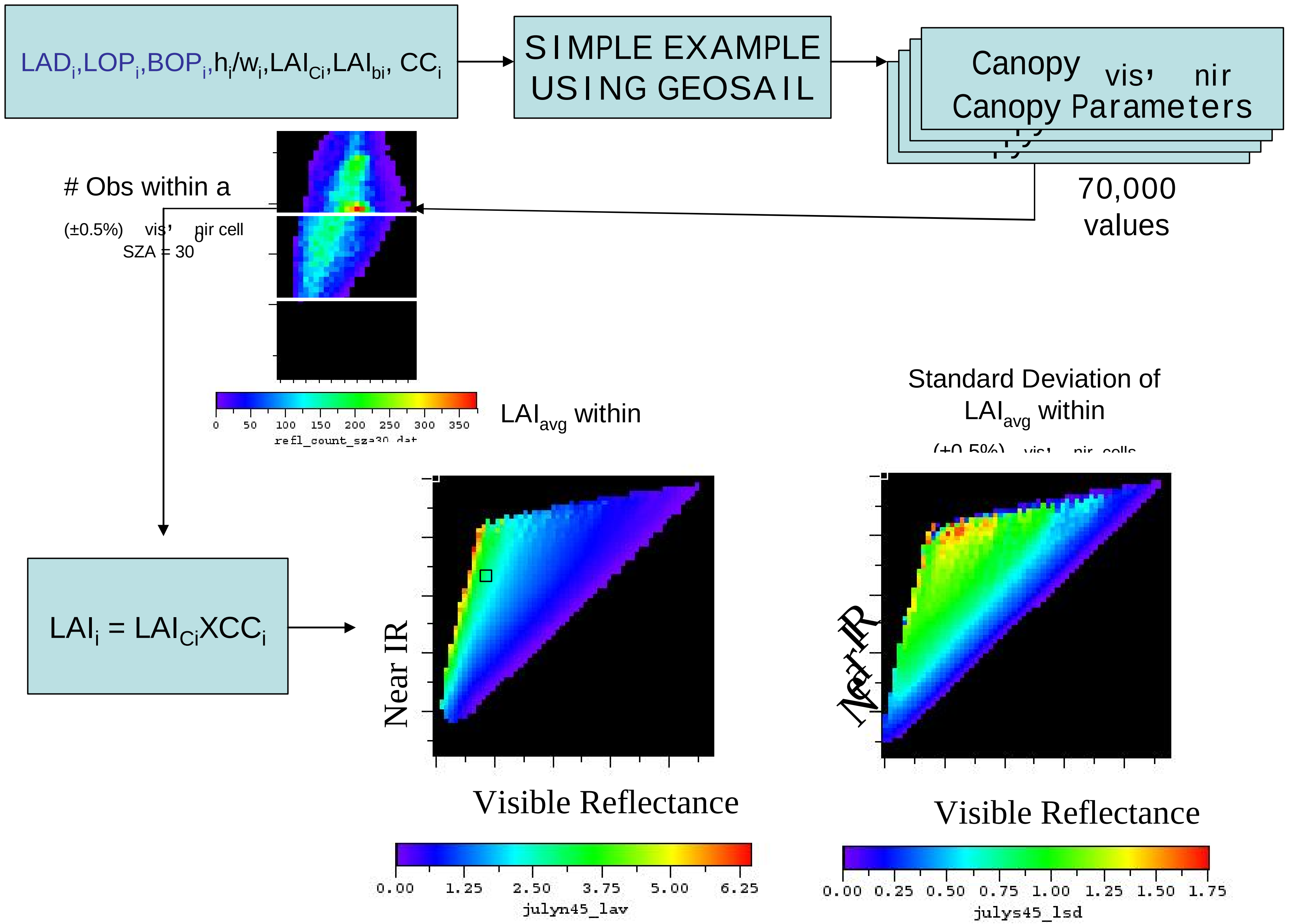
An Analysis Framework linking 30+ Years of Canopy Radiative Transfer Model Research Directly to Biophysical Parameter Retrieval


Satellites
(spectral, angular, temporal)
si (?ái)
Biophys Framework
CANOPY CRT MODEL (Tables)
{ si}= (LOP,BOP,Cg,LAI$_C$,LAI$_b$,CC)
Satellite Measurement (L2)
{ si±?á si}$_i$ i bands, angles, dates
Table Lookup
{LOP,BOP,Cg,LAI$_C$,LAI$_b$,CC }$_k$ ∈ { si±?á si }$_i$
Compute Parameter Statistics
<{LOP,BOP, Cg ,LAI$_C$,LAI$_b$, CC}>
Model Parameters
α, Fpar, g$_c$, Z$_o$, P$_v$,NP$_v$=
F(<LOP,BOP, Cg,LAI$_C$,LAI$_b$, CC>)
Numerical, Non-analytic



CANOPY CRT MODELS
GOMS, GORT, 5-scale
CWE Parameters
α, Fpar, gc, Zo, Pv,NPv...
Canopy RT Parameters
LAD,LOP,BOP,h/w,LAIC,LAIb, CC
Climate, Carbon Models
BIOPHYS
MODIS SURFACE
Multi-Date BRDF Values
(i,?hi)
Canopy Parameter Values
LADi,LOPi,BOPi,hi/wi,LAICi,LAIbi, CCi
MODIS
MEASURED BRDF
(i ?ái,ti)
o
o
o
LookUp Table


CANOPY CRT MODELS
GOMS, 5-scale
CWE Parameters
α, Fpar, gc, Zo, Pv,NPv...
Canopy RT Parameters
LAD,LOP,BOP,h/w,LAIC,LAIb, CC
Climate, Carbon Models
BIOPHYS/MFM
SIMPLE, ELEGANT
MODIS SURFACE
Multi-Date BRDF Values
(i,?hi)
Canopy Parameter Values
LADi,LOPi,BOPi,hi/wi,LAICi,LA
MEASUREMENT= [(RED = 0.0487& NIR = 0.2172 at SZA = 30º),
(RED = 0.0372 & NIR = 0.1730 at SZA = 45º),
(RED = 0.0458 & NIR = 0.1474 at SZA = 50º)]
Canopy Parameter Possibilities
LADi,LOPi,BOPi,hi/wi,LAICi,LAIbi, CCi
TABLE LOOKUP
RETURN ALL ROWS FROM LOOK UP TABLE : SELECT*FROM TABLE WHERE
(SCENE_REFL_RED_SZA30 BETWEEN 0.0487-0.01 AND 0.0487+0.01 AND SCENE_REFL_NIR_SZA30 BETWEEN 0.2172-0.01 AND 0.2172+0.01)
AND (SCENE_REFL_RED_SZA45 BETWEEN 0.0372-0.01 AND 0.0372+0.01 AND SCENE_REFL_NIR_SZA45 BETWEEN 0.1730-0.01 AND 0.1730+0.01)
AND (SCENE_REFL_RED_SZA50 BETWEEN 0.0458-0.01 AND 0.0458+0.01 AND SCENE_REFL_NIR_SZA50 BETWEEN 0.1474-0.01 AND 0.1474+0.01);
LookUp Table
Climate, Carbon Models
α, Fpar, gc, Zo, Pv,NPv...
Fi (LAD,LOP,BOP,h/w,LAIC,LAIb, CC)
Can Use Non-Spectral Data (e.g. slope, aspect, biome, time, GDD) to Further Constrain Solutions
Compute Parameter Statistics



LADi,LOPi,BOPi,hi/wi,LAICi,LAIbi, CCi
SIMPLE EXAMPLE
USING GEOSAIL
Canopy vis, nir
Canopy Parameters
70,000
values
Obs within a
(±0.5%) vis, nir cell
SZA = 30
0 50 100 150 200 250 300 350
refl_count_sza30.dat
LAIavg within
Standard Deviation of
LAIavg within
LAIi = LAICiXCCi
Near IR
Visible Reflectance
0.00 1.25 2.50 3.75 5.00 6.25
julyn45_lav
Near IR
Visible Reflectance
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75
julys45_lsd

Initial Retrieval Test

Landsat, vis, nir (± 0.01)

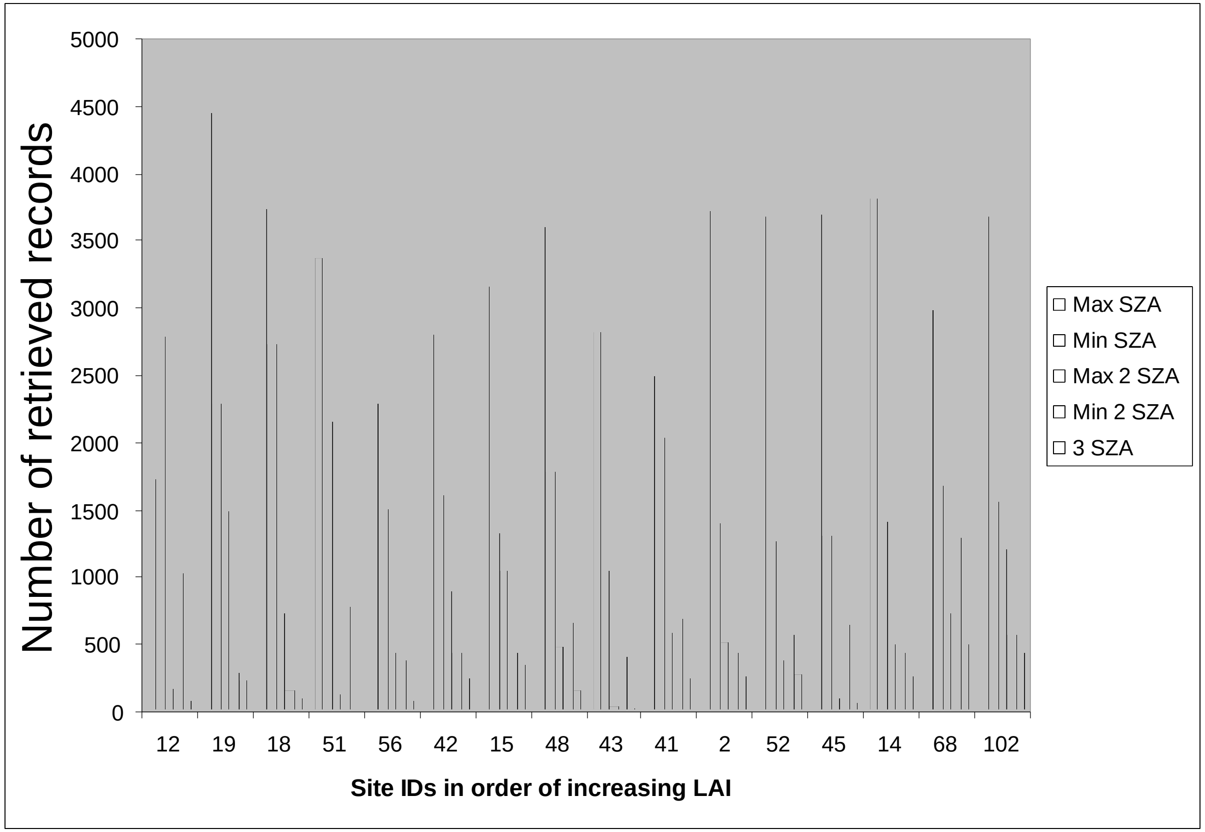
16 sites, 3 solar angles (3 dates)

1983 Superior National Forest

Site	Avg DBH (cm)	SD DBH (cm)	Stems per m2	Basal Fract	Avg BMI (kg/ m2)	SD BMI (kg/ m2)	Avg LAI	SD LAI	Tree Ht (ft)	Description
12	4.54	2.11	0.16413	0.00032	0.678	0.127	0.484	0.181	20	sparse, low black spruce
19	4.05	1.98	0.25564	0.00041	1.032	0.200	0.692	0.242	25	low black spruce
18	4.24	2.06	0.26062	0.00046	1.093	0.192	0.739	0.254	25	low black spruce
51	5.92	3.04	0.37799	0.00131	3.620	0.501	1.685	0.454	25	low density black spruce
56	8.09	4.29	0.25569	0.00168	5.280	0.345	1.834	0.329		medium density black spruce
102	5.92	2.34	0.91716	0.00292	7.246	0.736	3.670	1.228	50	high density black spruce
42	8.60	5.80	0.25863	0.00218	7.314	0.455	2.279	0.283	60	medium density black spruce
45	7.28	3.65	0.53387	0.00278	8.446	1.253	3.085	0.761	40	medium density black spruce
43	8.44	4.79	0.36305	0.00268	8.696	0.716	2.791	0.476	60	medium density black spruce
68	7.40	2.83	0.66002	0.00325	8.719	0.515	3.475	1.042	45	high density black spruce
48	9.83	3.19	0.33953	0.00285	9.149	1.665	2.700	0.795	50	medium density black spruce
52	9.92	3.91	0.35588	0.00318	10.036	0.574	3.034	0.588	60	low density black spruce
15	12.21	3.83	0.22381	0.00288	10.680	0.675	2.692	0.383	60	dense, mature black spruce
41	13.49	5.73	0.18303	0.00308	11.135	0.517	2.842	0.313	60	high density black spruce
2	14.52	4.43	0.17507	0.00317	12.378	0.830	2.884	0.340	50	dense, mature black spruce
14	13.22	4.13	0.24669	0.00372	13.643	0.587	3.266	0.427	60	dense, mature black spruce

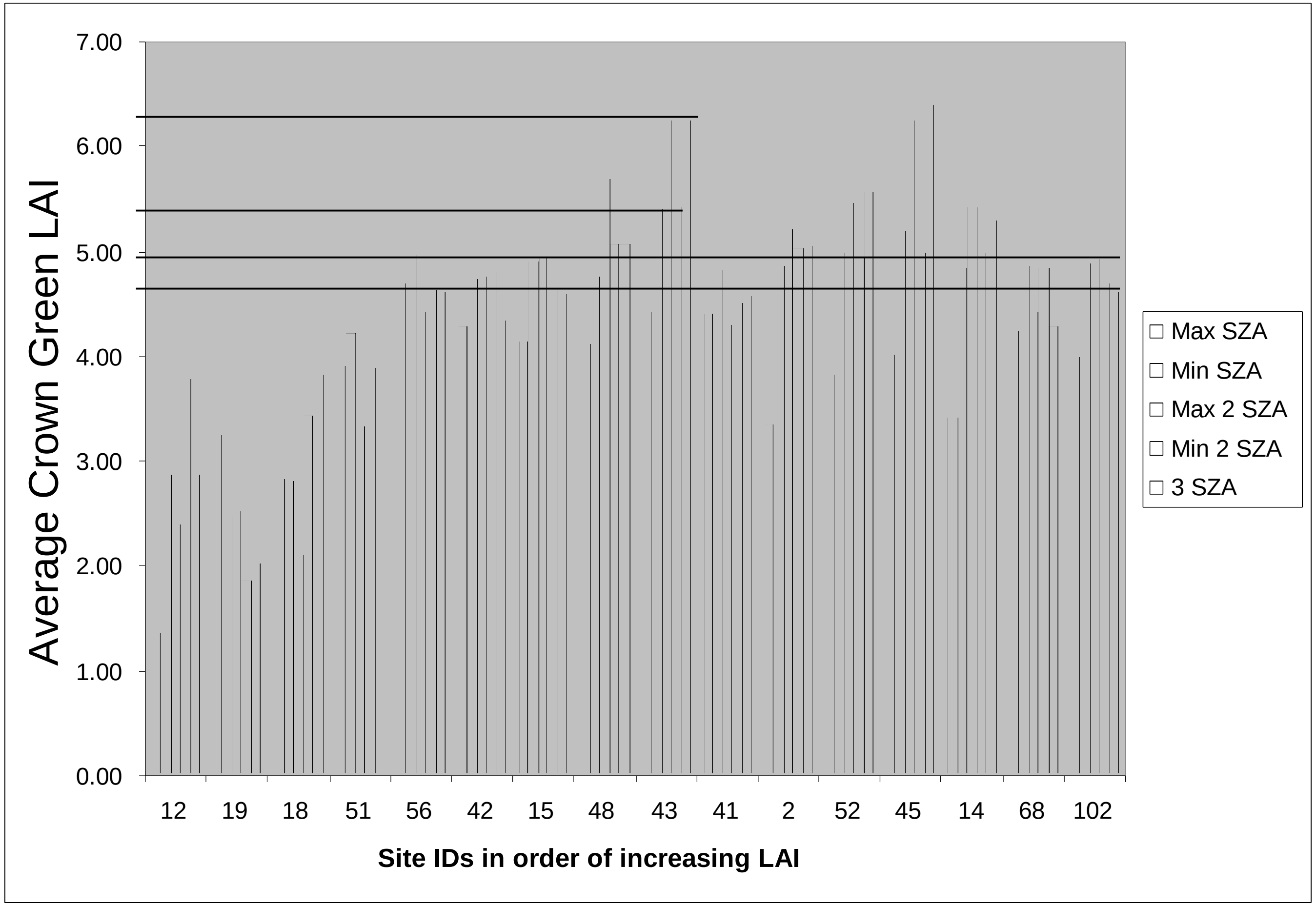
Retrieval Test

Landsat, vis, nir, 3SZA's
Crown Green LAI



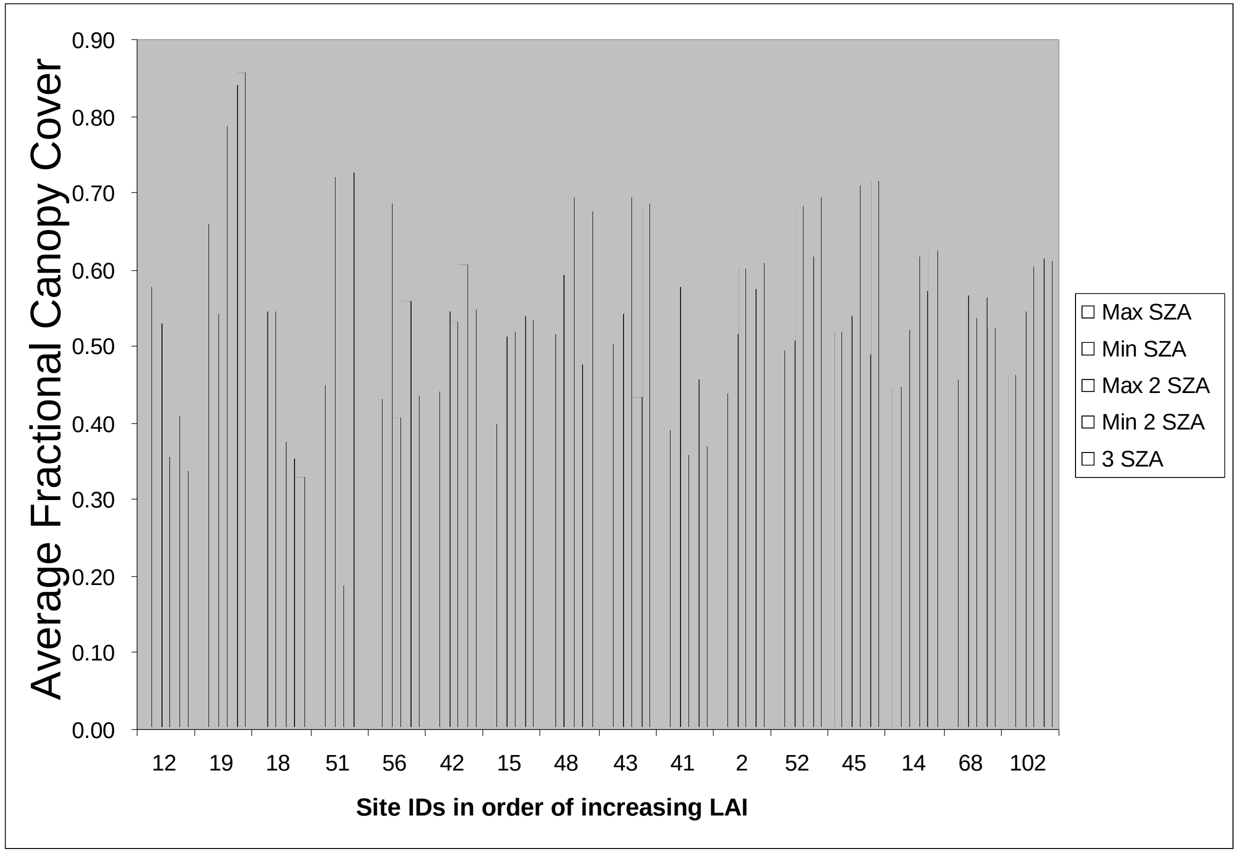
- Three SZA retrievals drastically reduced the number of records returned.
- For only one SZA, generally the maximum SZA returned more records.
- With two SZA either the low pair or the high pair returned the most records.

Average Retrieved Crown Green LAI



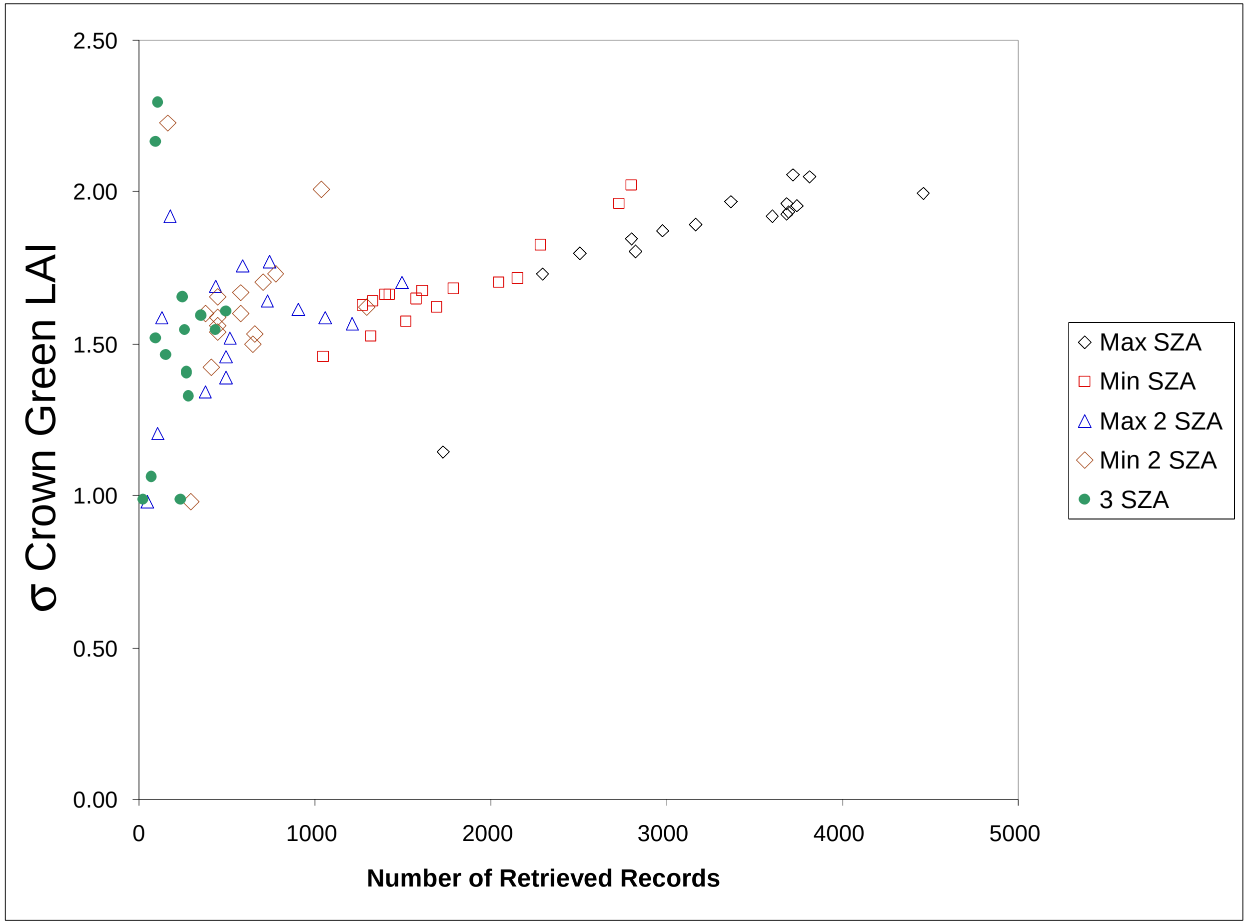
•Average Retrieved Crown Green LAI varied little using 2 or more SZAs.

Average Retrieved Crown Cover Fraction

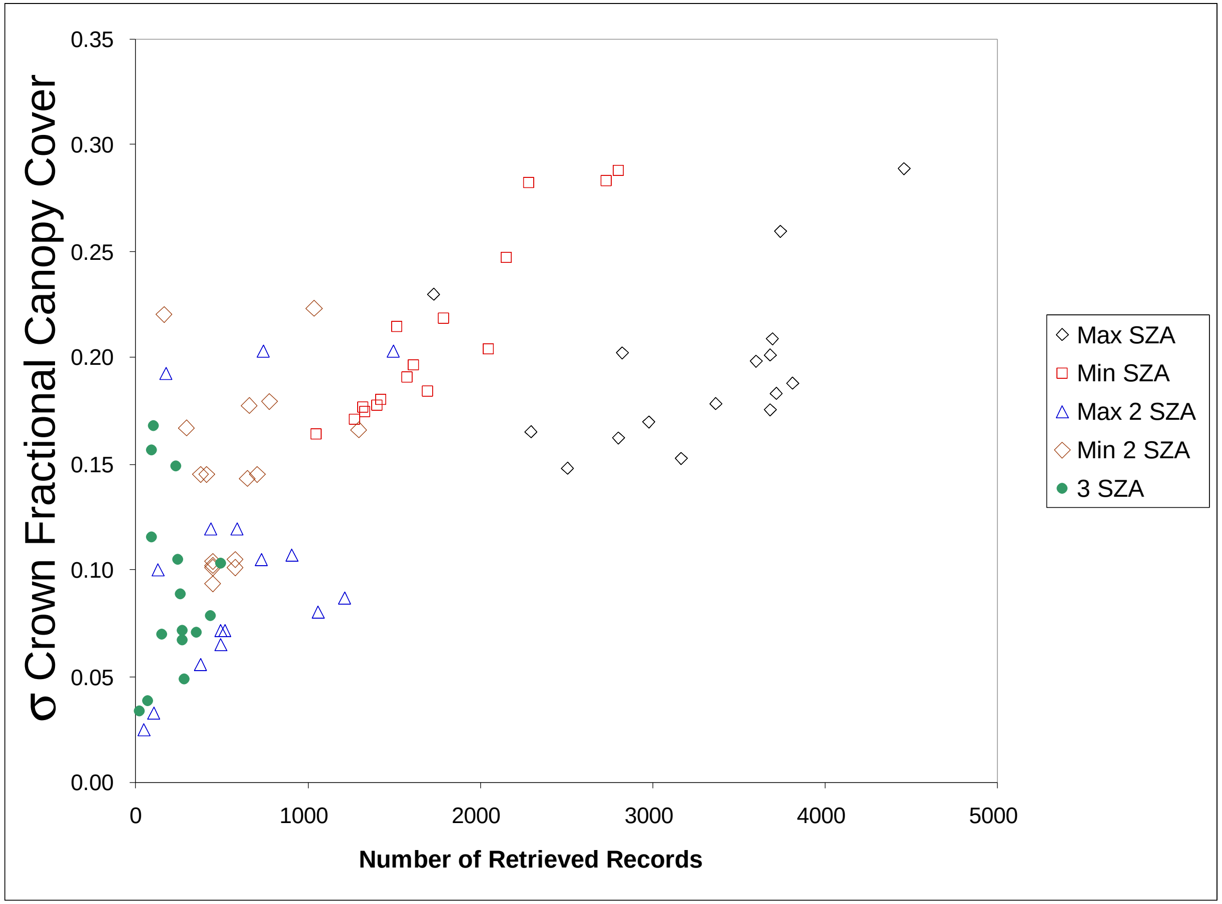


•Average Retrieved Crown Cover Fraction Sensitive to SZA

Retrieval Precision vs Number of Records Retrieved-Crown Green LAI



Retrieval Precision vs Number of Records Retrieved-Crown Cover



Distribution of LAI Retrievals

16 sites,3 solar angles (3 dates)

1983 Superior National Forest

Site	Avg DBH (cm)	SD DBH (cm)	Stems per m2	Basal Fract	Avg BMI (kg/ m2)	SD BMI (kg/ m2)	Avg LAI	SD LAI	Tree Ht (ft)	Description
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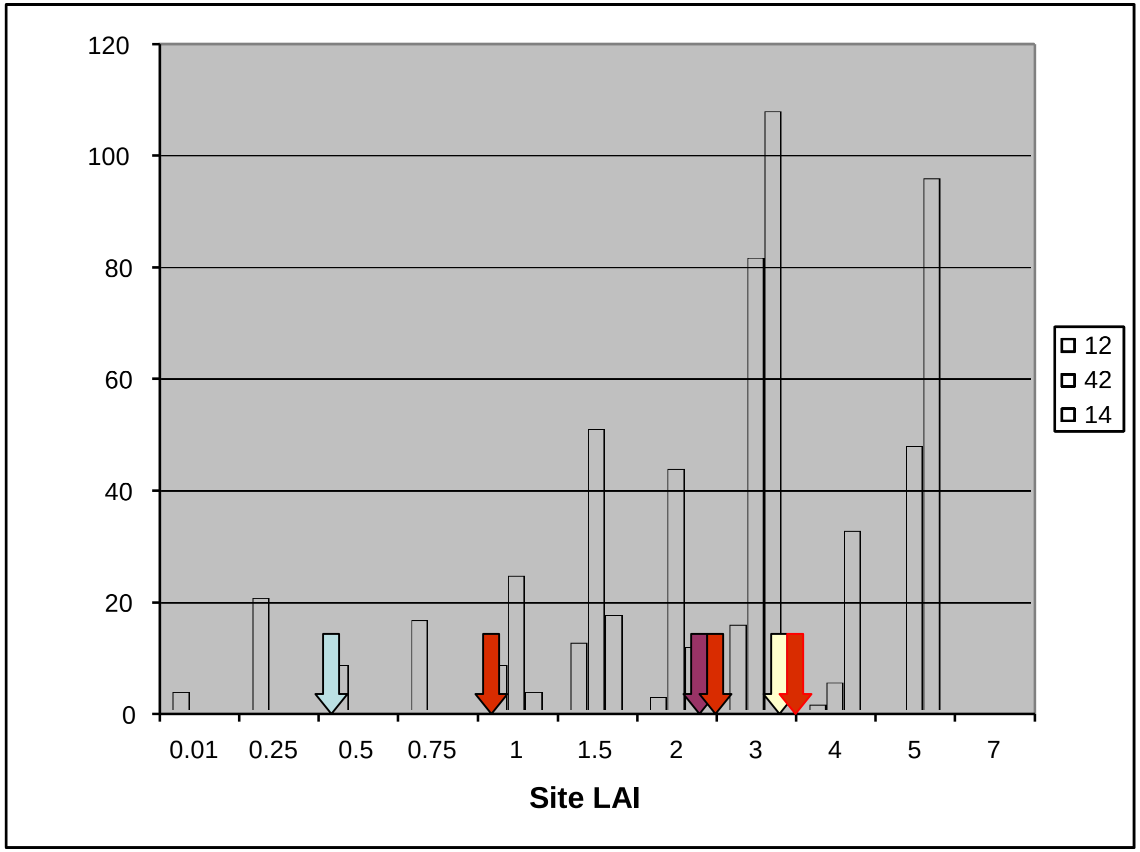
14	13.22	4.13	0.24669	0.00372	13.643	0.587	3.266	0.427	60	dense, mature black spruce

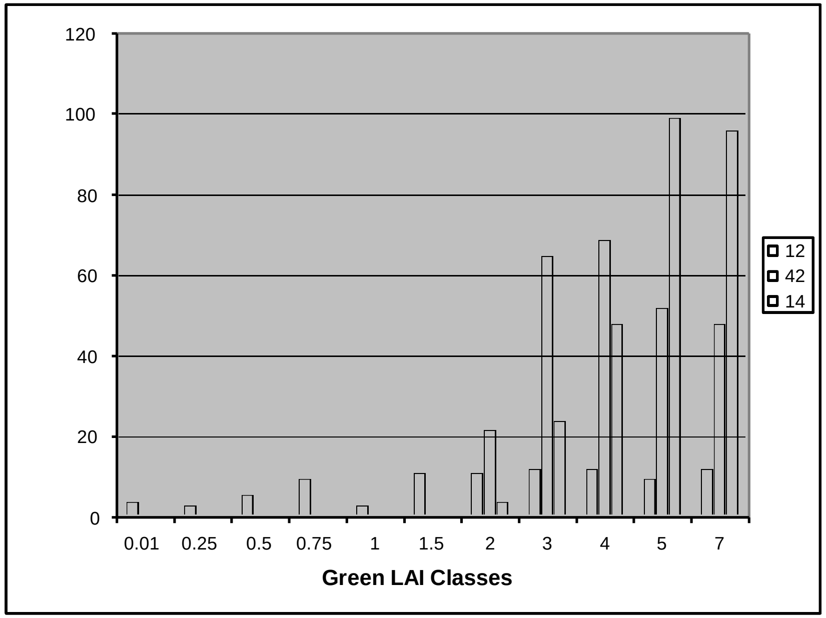
Retrieval Results

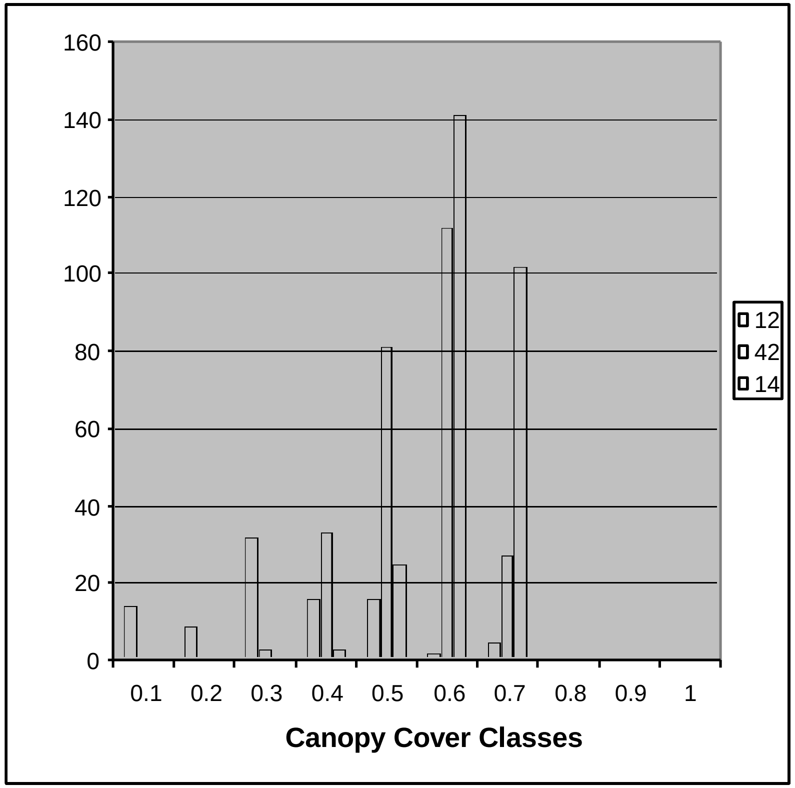
Distribution of Site LAI Retrievals



Retrieval Results

Distribution of Canopy Component Retrievals - Crown LAI and CC

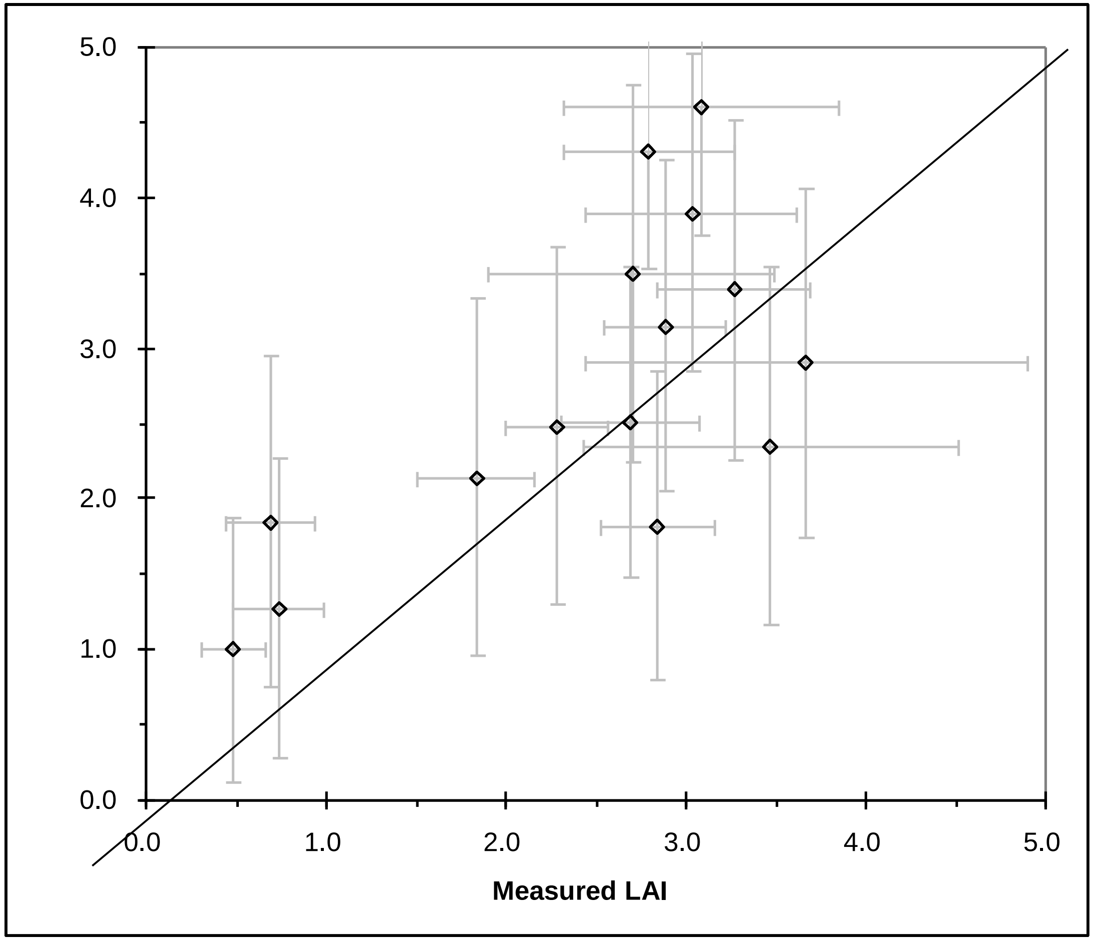




$LAI = LC_i \times CC_i$

Retrieval Results

All SNF Spruce Sites



Accuracies roughly equivalent to empirical approach
Error structure automatically retrieved

Problems

Algorithm Locality: Spectral change with illumination view geometry, background, season etc.affects robustness.

"Chicken & Egg Syndrome": Radiance correction for view and illumination angle to infer biophysical parameters depends on the parameters.

Parameter Inconsistency: Different algorithms for different parameters.

Error structures: Error, uncertainty characterization approximate, empirical.

Model utility: Inability to directly assimilate satellite radiances in CWE models.

BIOPHYS

Solutions

Algorithm Locality: Physically-based retrievals incorporate reflectance responses to exogenous variables.

"Chicken & Egg Syndrome": BIOPHYS uses spectral dependence on view and illumination angle to improve retrieval accuracies.

Parameter Inconsistency: BIOPHYS Parameter retrievals from a single algorithm using common input data.

Error structures: Error, uncertainty an integral part of the retrieval.

Model utility: BIOPHYS structure can assimilate data directly from within CWE models.

BIOPHYS FRAMEWORK & OSSEs

- OBSERVING SYSTEM SIMULATION EXPERIMENT (OSSE)
  - OSSEs compute sensor/platform reqts in terms of biophysical parameter reqts.
- BIOPHYS FRAMEWORK provides a physically-based framework for computing
  - Retrieval precision as a function of sensor S/N
  - Retrieval bias as a function of sensor cal bias
  - Retrieval error as a function of band selection
  - Retrieval error as a function of CRT models

Finally

- BIOPHYS Framework Can Bridge the Chasm
- What’s Next
  - Wrap up exploratory work
    - Investigate convergence of mean to actual
  - Select RT Model (GOMS, GORT …). Build the LUTs
  - Complete MODIS BIOPHYS Algorithm
  - Evaluate MODIS Products and Iterate
- PRODUCE PROVISIONAL DATA SETS WITH BIOPHYS OVER SELECTED STUDY REGIONS.
- PLACE PROVISIONAL DATA SETS ONLINE; INITIATE USER EVALUATION.

The Chasm

CANOPY RT MODELER

Circa 1972- Modeling

Circa 1980 - Inversion

Circa 1996 Physically - Based Classification/MFM For Landsat

Climate, Carbon Modeler

BIOPHYS

2000 MODIS LAI, FPAR