Global Ecology and Remote Sensing

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4/9/2014 ESPM 111 Ecosystem Ecology

Ecosystem ecology spans many scales. Here we look at how we can address ecosystem ecology processes at the regional to global scales. To do so takes remote sensing coupled with models. The challenge is whether to use mechanistic models driven with remote sensing inputs, or use highly empirical models. Of course these products need validation and independent paramterization. Here is where the flux networks play a role.

Global Ecology and Remote Sensing

- What is Global Ecology?
  - History and Examples of Products
- Remote Sensing
  - Hyperspectral Reflectance, Satellite Sensors, Pros/Cons
- Vegetation Indices
- On towards Computing Global Photosynthesis

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What is global ecology and how can we accomplish such work.

Spaceship Earth, Apollo Mission, 1969

The Advent of Global Ecology

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The image of earth from the Moon and the Apollo space mission changed our view of Earth. We started to realize it is a fragile domain, that is not limitless. It called to arms a better efforts to be good stewards of our planet. Earth Day is an example of events on Earth that were stimulated by this new view..

Big Picture Question Regarding Predicting and Quantifying Global Photosynthesis and Evaporation:

- **How can We Evaluate Ecological Fluxes ‘Everywhere All the Time?’**

Wedding at Cana, Veronese, the Louvre, Paris

Remote Sensing, Scientific Persian Rug

Provides Spatial information on the Mosaic

Requires Validation on How Bright or How Large the pixels may be

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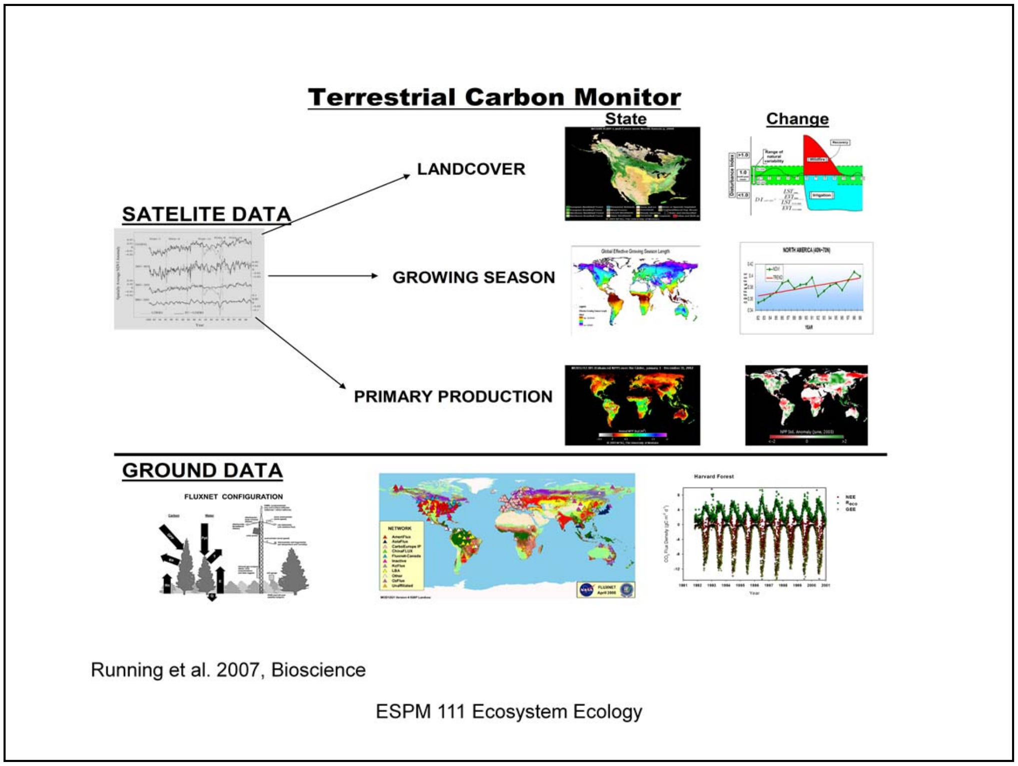
Challenge for Landscape to Global Upscaling

Converting Virtual ‘Cubism’ back to Virtual ‘Reality’

Realistic Spatialization of Flux Data
Requires the Merging Numerous Data Layers with varying:
Time Stamps (hourly, daily, weekly),
Spatial Resolution (1 km to 0.5 degree) and
Data Sources (Satellites, Flux Networks, Climate Stations) and Using these
Data to Force Mechanistic Biophysical Model

As noted we are dealing with a hierarchy of space scales. Different remote sensing sensors can view the ground at different spatial resolution, to build a spatial mosaic of the land surface.



Remote sensing can give us lots of different types of information that is of interest to ecosystem ecologist. GPP, leaf area index, evaporation, fire, disturbance, land use, change in land use, fraction of land cover, etc, etc

Satellites

- **Pros**
- Global, Regional and Local Coverage
- Can detect Seasonal trends, inter-annual Changes in Surface Properties
- Can Detect Change by Disturbance

- **Issues**
- Resolution of Spectral Bands
- Sampling Frequency
- Validate Algorithms with Direct Eddy Flux Measurements

- **Cons**
- Clouds, Clouds, Clouds
- Inferred estimates of NPP and LAI
- Relies on Empirical Algorithms
- Intermittent Coverage
- Can't Assess NEP

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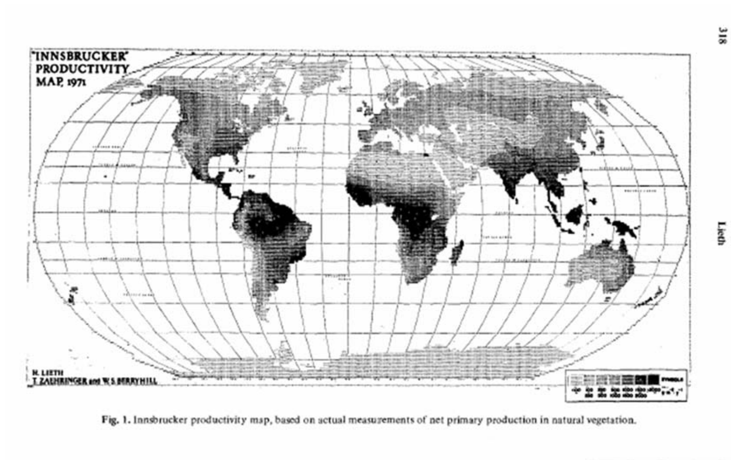
Remote sensing has a bunch of attendant pros and cons. The most glaring con is clouds. Most passive sensors can't see through clouds. Other issues are overpass times and view frequency.

First Global NPP Map



Helmut Lieth, circa 1971

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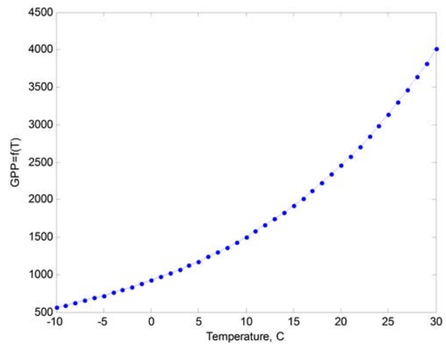
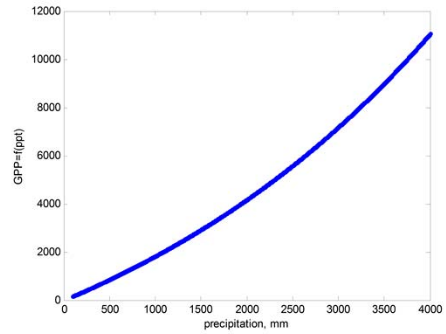
Scientists like Helmut Leith and Jerry Olson, who specialized in biogeography, were among the first to start thinking globa

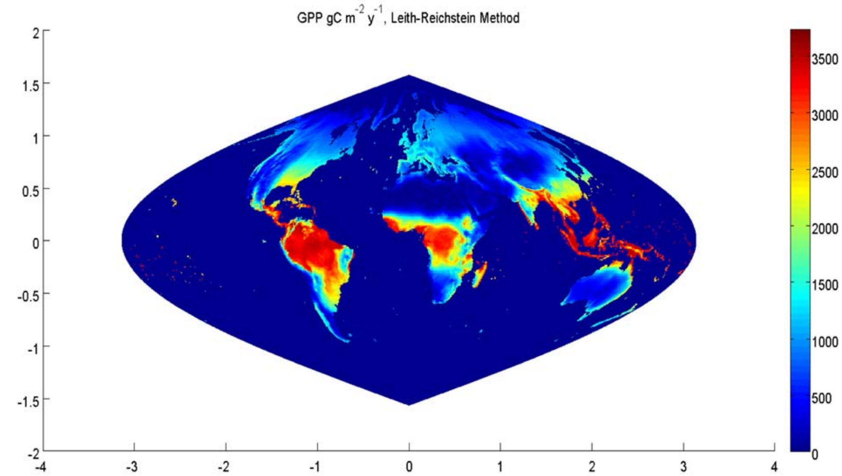
Leith-Reichstein Model

$$GPP = \min\left[f(MAT), g(P)\right] =$$
$$\min\left(GPP_{15^\circ C} \cdot \frac{1+e^{a_1-a_2\cdot 15^\circ C}}{1+e^{a_1-a_2\cdot MAT}}, GPP_{1000mm} \cdot \frac{1-e^{-k\cdot P}}{1-e^{-k\cdot 1000mm}}\right)$$





Map of Global GPP
What are Maximum Values? Where do they Occurr?



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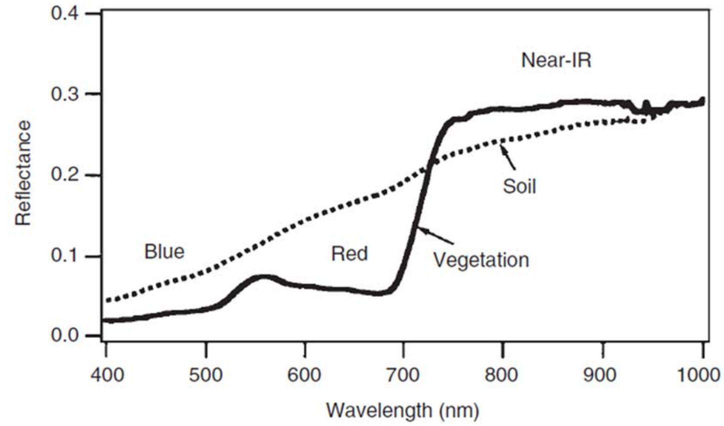
Classic Reflectance Spectra



Gamon, 2006, Functional Ecology

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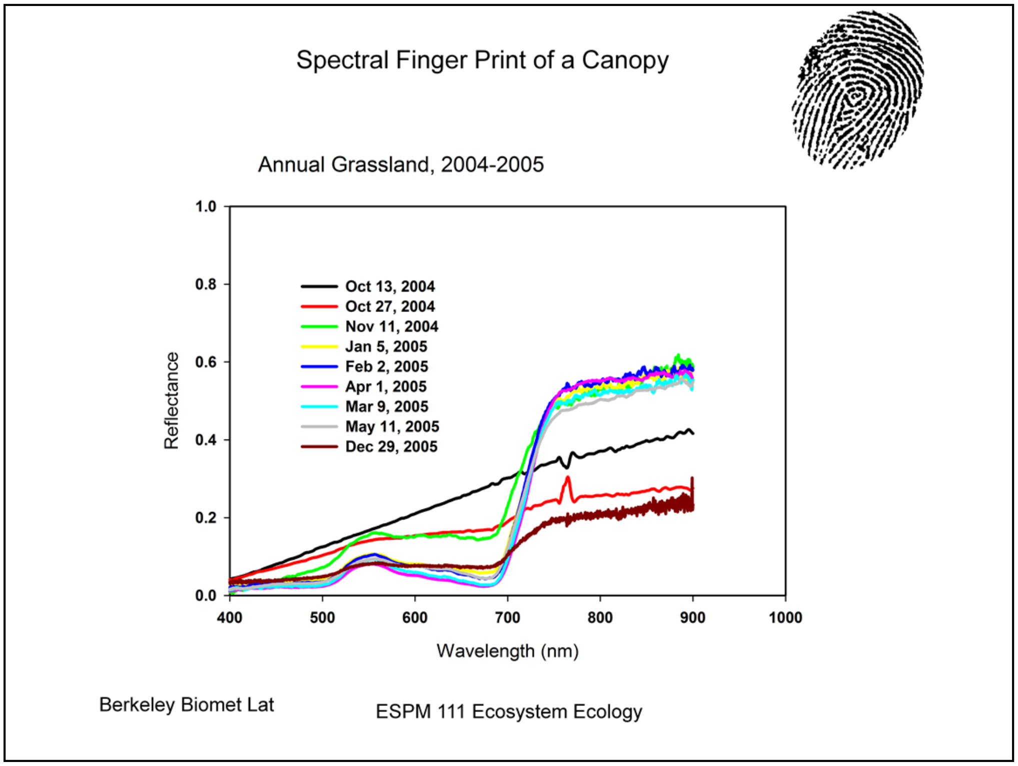
The key to remote sensing is to interpret the reflective spectrum of a surface and give it attribution to aspects of the land surface. Green vegetation and wet and dry soils have distinct spectral signatures.



The spectral signature of a landscape can vary with season as the grass grows, dies and senesces

Remote Sensing Instruments and Wavebands

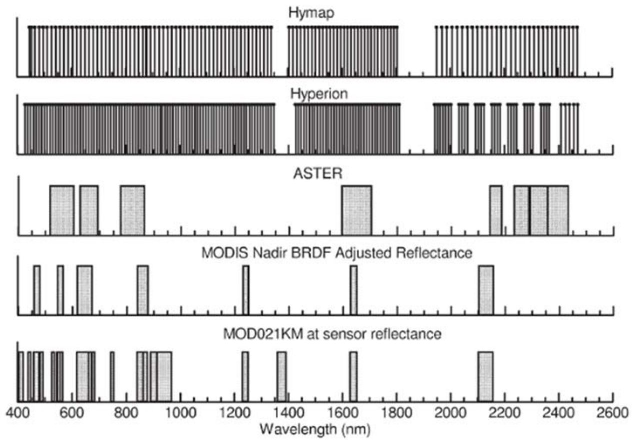


Fig. 3. Diagram showing the band distribution and wavelength coverage for HyMap, Hyperion, ASTER and MODIS NBAR.

Hill et al 2006 RSE

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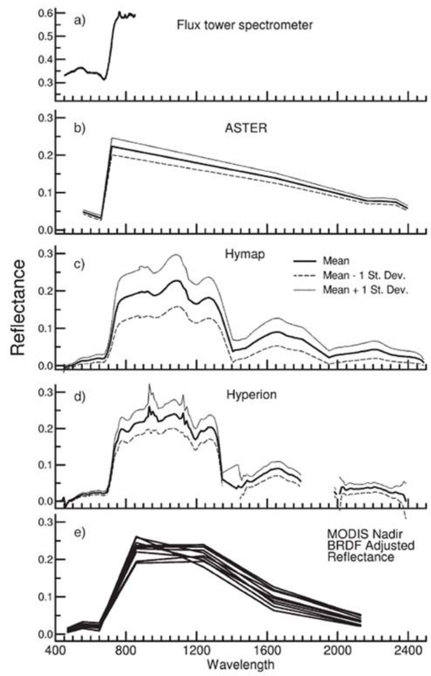
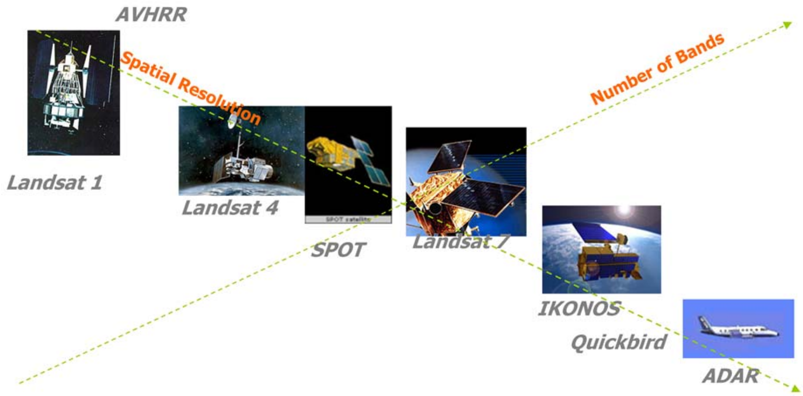
Different satellite sensors are able to measure a different suite of spectral bands.



Hill et al 2006 RSE

Here is an example of the spectral resolution of the surface defined by fine and coarse resolution sensors.

Remote Sensing
Trade offs between Sampling Duration and Frequency and Spatial and Spectral Resolution



Courtesy of Maggie Kelly

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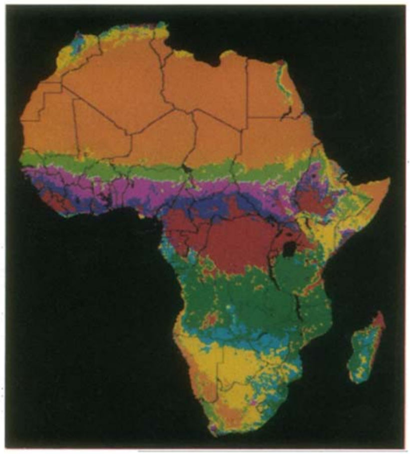
There tends to be an inverse relation between spatial resolution and spectral bands and frequency of sampling the surface

The first satellite derived view of continental vegetation

Derived from AVHRR,
Advanced Very High Resolution Radiometer, and
NDVI, Normalized Difference Vegetation Index



Tucker et al 1985, Science.

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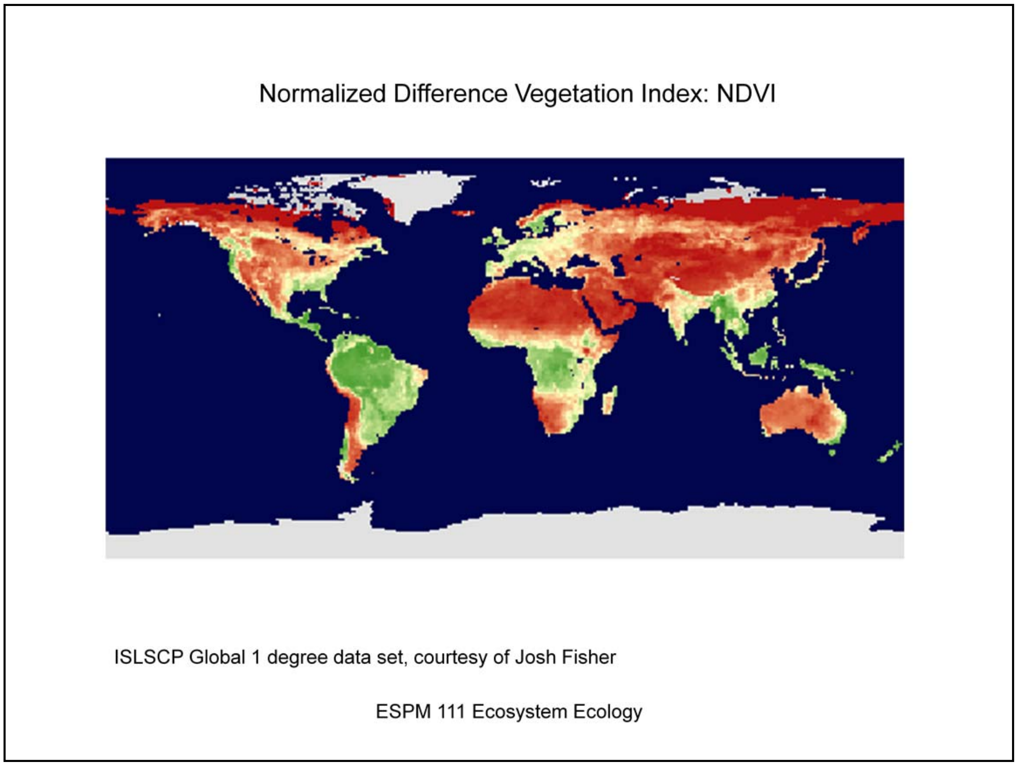
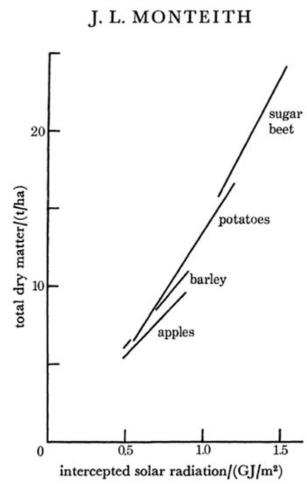
The era of global ecology can probably be dated back to the work of Jim Tucker and his use of data from AVHRR sensor on the fleet of NOAA GOES weather satellites. Tucker relaized we could deduce information about the greeness of the surface from the relative reflectance of light in the red and near infrared wavebands, yielding the widely used index NDVI



Today, products like NDVI are used to assess global maps of absorbed light and infer leaf area index. Correcting for clouds, time series of maps and changes can go back to the early 1980s.

Assessing NPP by Light Interception :
Fundamentals behind Remote Sensing of Plant Production

$$DM = a \cdot PAR \cdot fpar$$



- Monteith 1977. Phil Trans Roy Soc, B

Ideas about estimating net and gross primary productivity from space started with this famous figure from John Monteith, who found that the dry matter production of many crops was a tight linear function of INTERCEPTED light. So know incoming light, the light use efficiency (LUE) and the fraction of absorbed light and you can get a good guestimate of GPP.

Global GPP/NPP Models

- CASA, Field et al
- TURC, Ruimy et al
- Biome-BGC, Modis Running et al

$$NPP \approx IPAR \cdot fpar \cdot \varepsilon \cdot f(T) \cdot f(\theta)$$

IPAR: incident visible light
fPAR: fraction of absorbed light
ε: light use efficiency of photosynthesis

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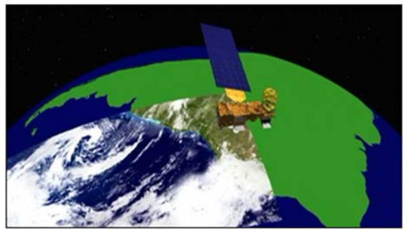
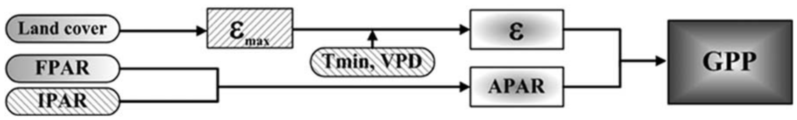
These light use efficiency, LUE, models are widely used by the remote sensing community. They are simple and empirical. They need to be validated with flux data and we need to know the functional response of reduced LUE with temperature and soil moisture stress. Measuring fpar, the fraction of absorb par accounts for phenology and developing LAI.

MODIS Approach

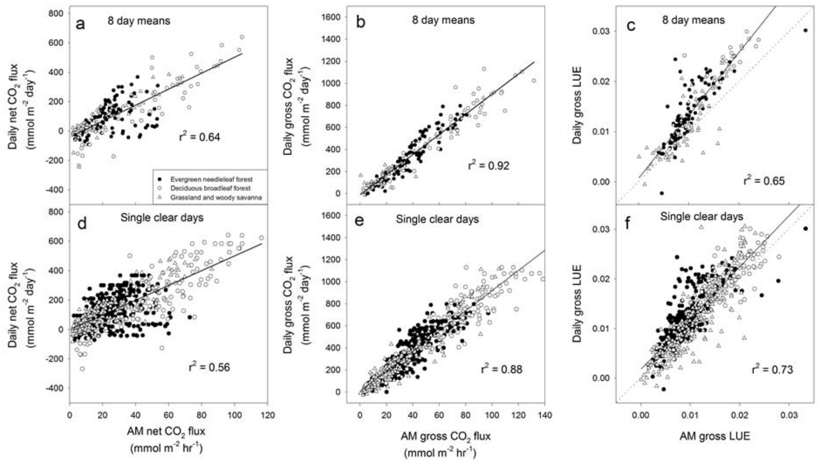




Heinsch et al 2006 IEEE

The launching of multi band spectral radiometers MODIS, gave scientists an instrument with more bands and higher spatial resolution. Using empirical relations between light absorptance and light USE efficiency, new efforts were made to model GPP

Role of Averaging Period:
Snap Shot vs Daily Integral



Sims et al 2005, AgForMet

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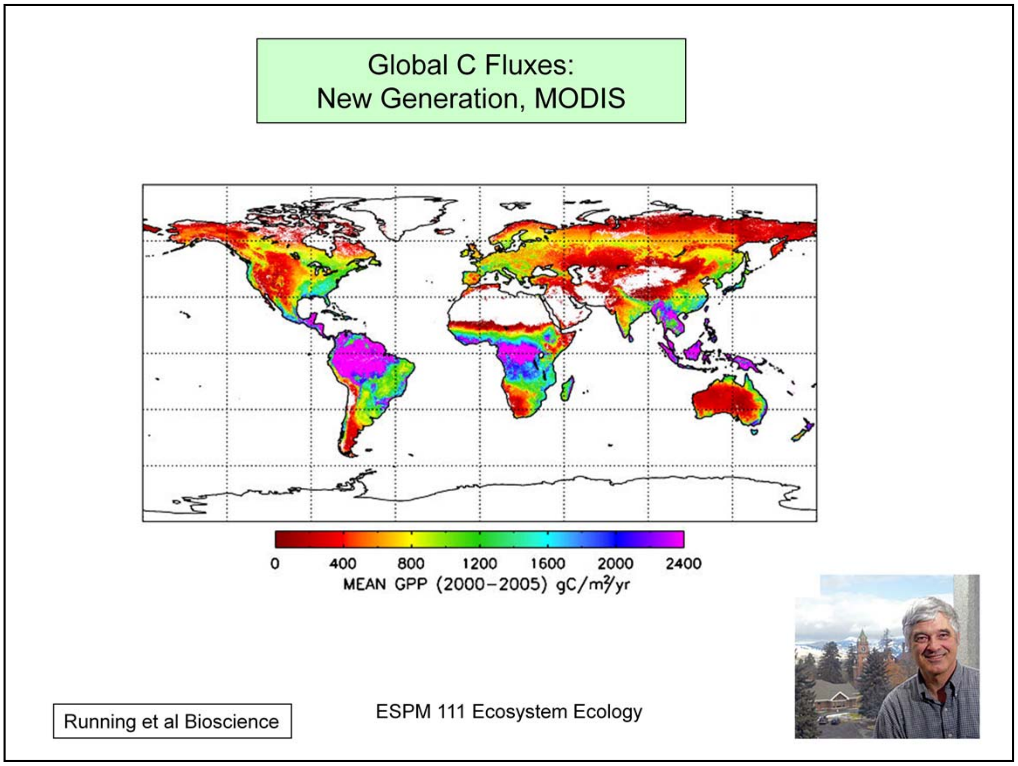
Big question relates to sampling. How does a snap shot from space scale with daily integrals of carbon fluxes. Luckily we found the relation to scale linearly!



Here is an example of the global maps of GPP that can be produced by these products.

Information to be Deduced from Hyper Spectra Reflectance

- Chlorophyll
- Carotenoids
- Flavonoids
- Water
- Nitrogen
- Cellulose
- Lignin

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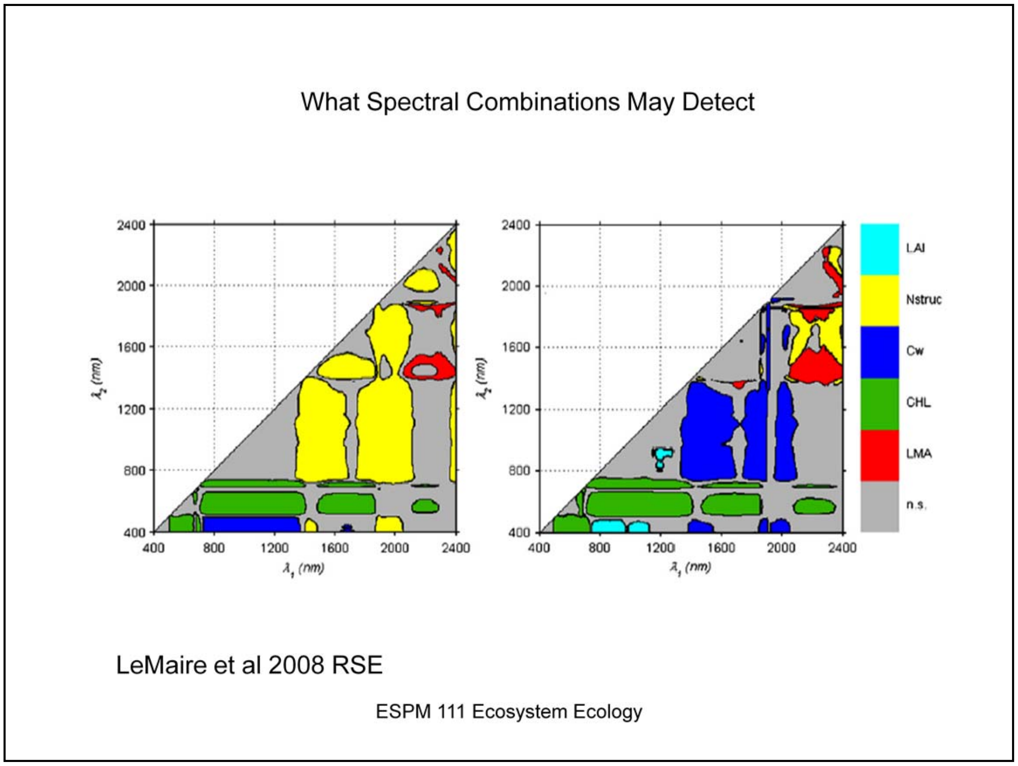
Here is a list of the type of information that can be deduced by hyper spectral reflectance



These are some of the reflectance band combinations associated with leaf area index, leaf nitrogen, chlorophyll, leaf mass per unit area and carbon mass

NDVI History

$$NDVI = \frac{NIR - \mathrm{Re}d}{NIR + \mathrm{Re}d}$$

The NOAA AHVRR instrument (circa 1978) on NOAA weather satellites (NOAA-7 through NOAA-12) has two sets detectors that are sensitive to wavelengths of light ranging from 0.55–0.70 (red) and 0.73–1.0 (near infrared) micrometers.

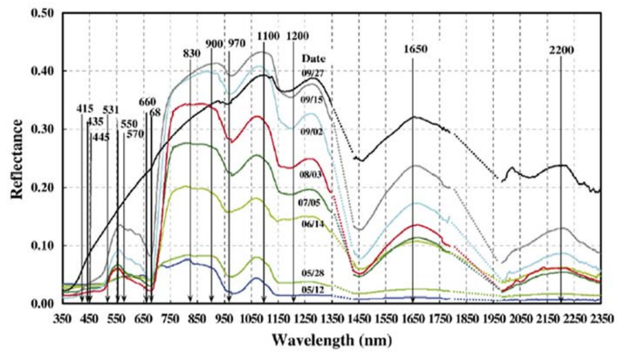
MODIS, (Terra launched in 1999; Aqua launched in 2002), senses reflectance in the red (620-670 nm) and near infrared (NIR) (841-876 nm)

NDVI is a useful index due to its long history and simplicity. It is not the best as it does saturate with high leaf area index.

Digesting the Data: Vegetation Indices

Normalized difference vegetation index	NDVI	$$\frac{NIR - \mathrm{Re}d}{NIR + \mathrm{Re}d} = \frac{R_{830} - R_{660}}{R_{830} + R_{660}}$$
Enhanced vegetation index	EVI	$$EVI = Gain\frac{NIR - \mathrm{Re}d}{C_1 + \mathrm{Re}d + (C_2\,\mathrm{Re}d - C_3 Blue)}$$
Soil adjusted vegetation index	SAVI	$$\frac{NIR - \mathrm{Re}d}{NIR + \mathrm{Re}d + L}(1 - L)$$
Photochemical reflectance index	PRI	$$\frac{R_{531} - R_{570}}{R_{531} + R_{570}}$$
Simple ratio	SR	$$\frac{NIR}{\mathrm{Re}d}$$

Next Generation of Vegetation Indices



PRI: [R531−R570]/[R531+R570]
WI: R900/R970
SIPI: [R800−R445]/[R800−R680]
NPQI: [R415−R435]/[R415+R435]
GRI: R830/R550
SWWI: R1650/R850
NDVI: [R830−R660]/[R830+R660]
SAVI: 1.5[R830−R660]/[R830+R660+0.5]
RVI: R830/R660
WDVI: R830−1.06R660
MSAVI: (1+0.5)[R830−R660]/[R830+R660+0.5]
EVI: 2.0[R830−R660]/[1+R830+6R660−7.5R460]
GEMI: $\eta(1-0.25\eta)-(R660-0.125)/(1-R660)$
NDMI1: [R1650−R830]/[R1650−R850]
NDMI2: [R2200−R1100]/[R2200+R11100]
BI: 6 [R460/R660]

Inoue et al 2008. RSE

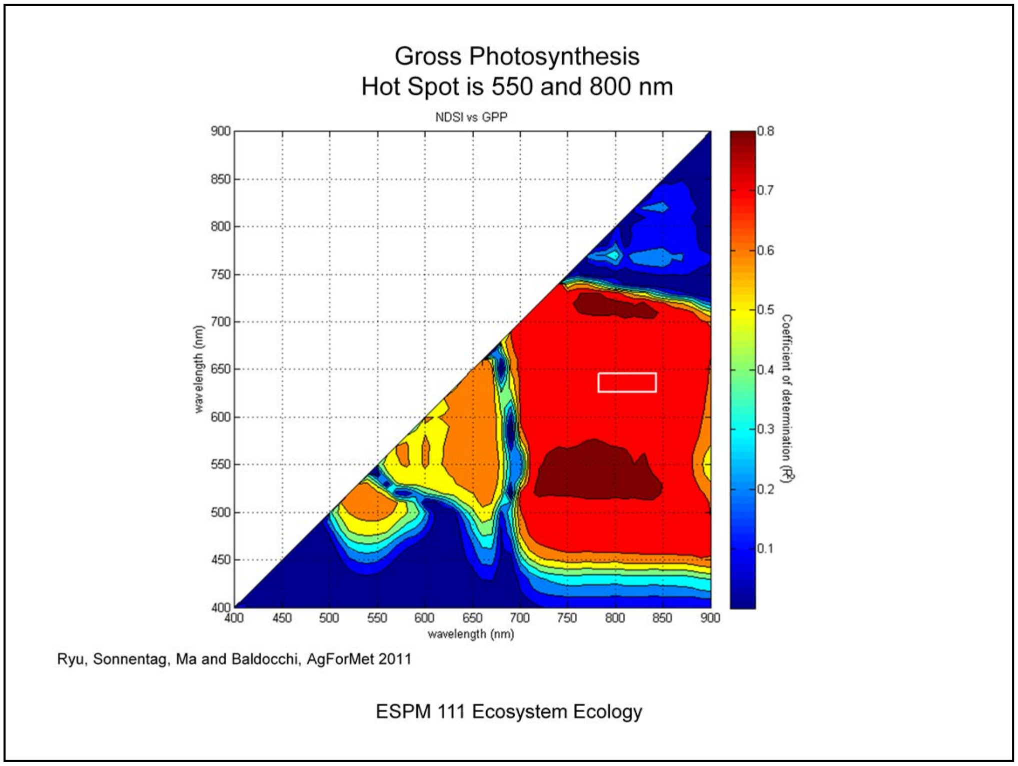
Other vegetation difference indices of use and their spectral bands

Index	Equation	Application	References
Carter & Miller stress (CMS); Carter stress (CSc and CSd)	$\frac{R_{694}}{R_{760}}, \frac{R_{605}}{R_{760}}, \frac{R_{710}}{R_{760}}$	Chl content	Carter & Miller (1994); Carter (1994)
Datts index (DattsCI)	$\frac{R_{850}-R_{710}}{R_{850}-R_{680}}$	Chl content	Datt (1999)
Difference vegetation index (DVI)	$R810-[(R610+R661)/2]$	Canopy Chl density	Broge & Leblanc (2001)
Enhanced vegetation index (EVI)[1]	$\frac{G(RNIR-Rred)}{RNIR+C_1(Rred)-C_2(Rblue)+L}$	Photosynthetic activity	Huete *et al.* (2002)
Gitelson & Merzlyak chlorophyll index (GM)	$\frac{R_{750}}{R_{700}}$	Chl content	Gitelson & Merzlyak (1994)
Green normalized difference vegetation index (GNDVI)	$\frac{R_{810}-[(R_{510}+R_{561})/2]}{R_{810}+[(R_{510}+R_{561})/2]}$	Chl content	Gitelson & Merzlyak (1997)
Modified red edge ratio (mSR)	$\frac{R_{750}-R_{445}}{R_{705}+R_{445}}$	Chl content	Sims & Gamon (2002)
Normalized difference vegetation index (NDVI)	$\frac{R_{800}-R_{680}}{R_{800}+R_{680}}$	Chl content and energy absorption	Gamon *et al.* (1997); Gamon & Surfus (1999)
Normalized difference water index (NDWI)	$\frac{R_{860}-R_{1240}}{R_{860}+R_{1240}}$	Liquid water content of vegetation canopies	Gao (1996)
Photochemical reflectance index (PRI)	$\frac{R_{531}-R_{570}}{R_{531}+R_{570}}$	Carotenoids; xanthophyll cycle	Gamon *et al.* (1992), (1997)
Pigment-specific normalized difference (PSND)	$\frac{R_{800}-R_{675}}{R_{800}+R_{675}}, \frac{R_{800}-R_{650}}{R_{800}-R_{650}}$	Chl*a* and Chl*b* content	Blackburn (1998)
Pigment-specific simple ratio (PSSRa, PSSRb and PSSRc)	$\frac{R_{800}}{R_{675}}, \frac{R_{800}}{R_{650}}, \frac{R_{800}}{R_{470}}$	Chl*a* and Chl*b* content; carotenoids	Blackburn (1998), (1999); Sims & Gamon (2002)
Plant senescence reflectance index (PSRI)	$\frac{R_{680}-R_{500}}{R_{750}}$	Carotenoids; Chl content	Merzlyak *et al.* (1999); Sims & Gamon (2002)
Ratio analysis of reflectance spectra ($RARS_a$, $RARS_b$ and $RARS_c$)	$\frac{R_{675}}{R_{700}}, \frac{R_{675}}{R_{650} \cdot R_{700}}, \frac{R_{760}}{R_{500}}$	Chl*a* and Chl*b* content; carotenoids	Chappelle *et al.* (1992); Blackburn (1999)
Ratio vegetation index (RVI)	$\frac{R_{800}}{R_{680}}$	Chl content	Pearson & Miller (1972); Broge & Leblanc (2001); Sims & Gamon (2002)
Red edge NDVI (rNDVI)	$\frac{R_{750}-R_{705}}{R_{750}+R_{705}}$	Chl content	Gitelson & Merzlyak, (1994), Sims & Gamon (2002)
Red/Green Index (RGI)	$\sum_{i=600}^{700} R_i / \sum_{i=500}^{600} R_i$	Anthocyanin	Gamon & Surfus (1999); Sims & Gamon (2002)
Second soil-adjusted vegetation index (SAVI2)[2]	$\frac{RNIR}{Rred+(a/b)}$	Canopy Chl density	Broge & Leblanc (2001)
Structure-insensitive pigment index (SIPI)	$\frac{R_{800}-R_{445}}{R_{800}-R_{680}}$	Carotenoids; Chl	Peñuelas *et al.* (1995); Sims & Gamon (2002)
Water index	$\frac{R_{900}}{R_{970}}$	Canopy water content	Peñuelas *et al.* (1997)

R, reflectance.
[1]EVI variables: *G*, gain factor; *L*, canopy background adjustment factor; $C_{1,2}$, aerosol influence coefficients.
[2]*a* and *b* in SAVI2 are soil line coefficients (e.g. $a = 1$ and $b = 0$ for bare soil).
Wavelength numbers are in nanometers.

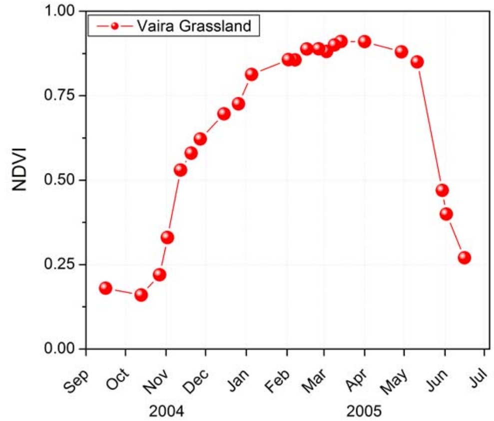
Ollinger 2011, New Phytologist

Another table repeating this data.



Here is the hot spot we see in our data for LAI. It differs from the NDVI index

$$NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}}$$



Falk, Ma and Baldocchi

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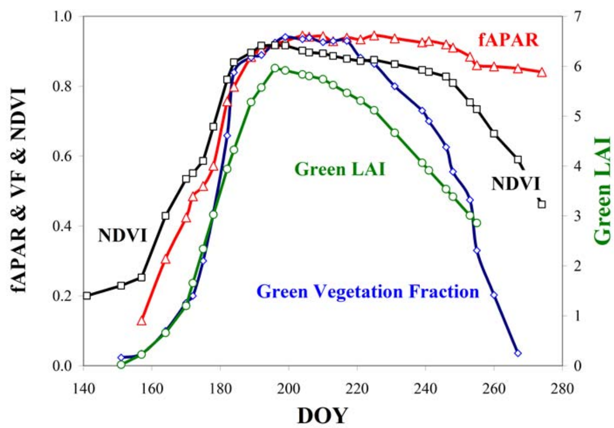
NDVI is powerful for telling us about seasonality of LAI, for instance

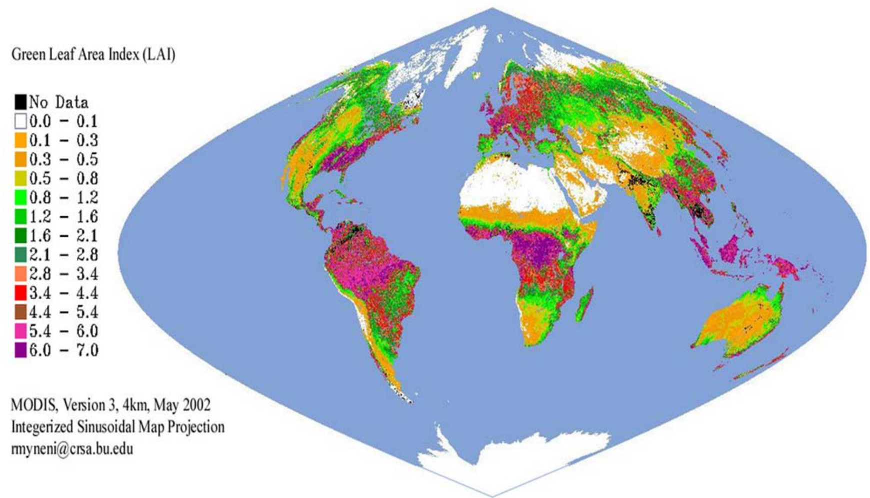
Seasonality of Maize



Anatoly Gitelson, GRL

How ndvi relates to direct measurements of LAI

$LAI = fAPAR$



4 km Resolution

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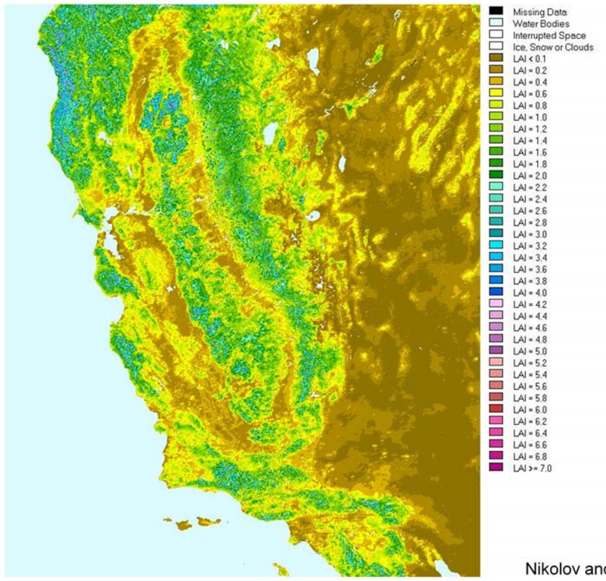
Ranga Myneni, Univ Boston..mapping LAI from space

Leaf Area of California



Nikolov and Zeller, 2006, Environ Poll

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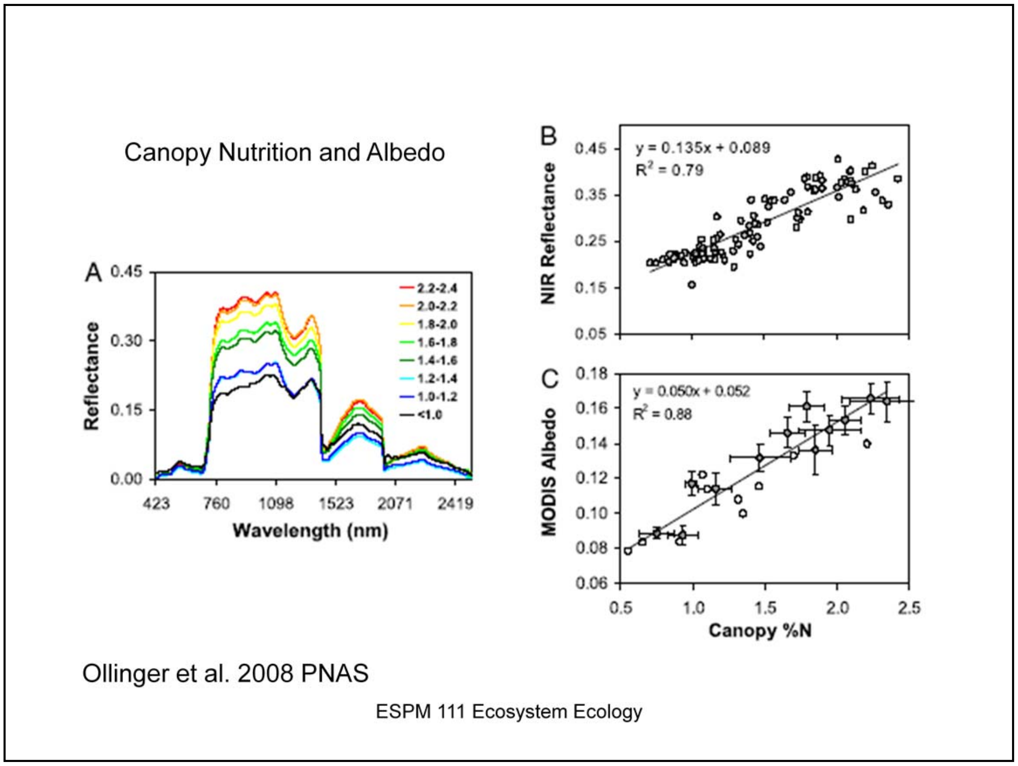
Ned Nikolov, unpublished..LAI of California



Here is a case showing good relations between reflectance and canopy nitrogen. This relation has UTILITY. Yet, it has received much criticism from remote sensing experts.

Cons,,critics claim it is an artifact. When the bidirectional reflectance is corrected for canopy structure there becomes a negative relation between N and reflectance and they claim the observations conflict with the physics of leaf reflectance in a 3D canopy and how those photons emerge from the canopy

Pros…see townsend

Nutrition (N) and Photosynthetic Capacity of Forests

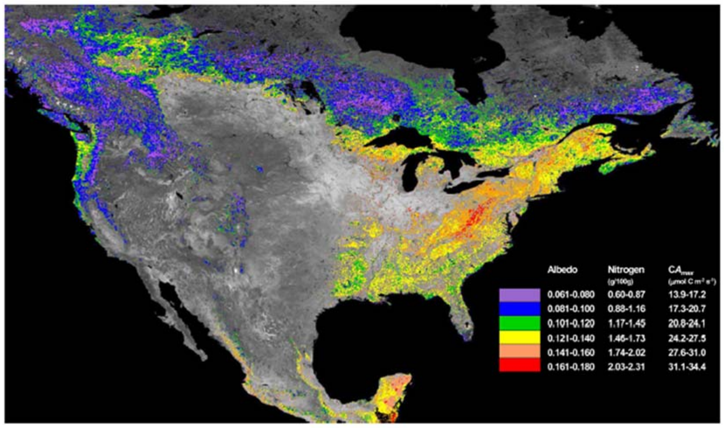
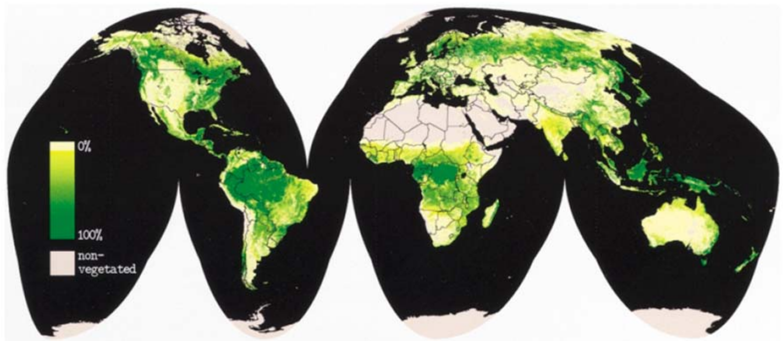


Fig. 4. Estimates of canopy %N and CA_{max} for forested areas of North America, along with the albedo values from which they were derived. Albedo data were from the midportion of the growing season and were converted to estimates of canopy %N and CA_{max} by using trends shown in Figs. 2*C* and 3*B*. Results were applied to forested grid cells only, identified by using the MOD44B continuous vegetation fields data product (41).

Ollinger et al. 2008 PNAS

Forest Land Cover



deFries et al 2000 GCB

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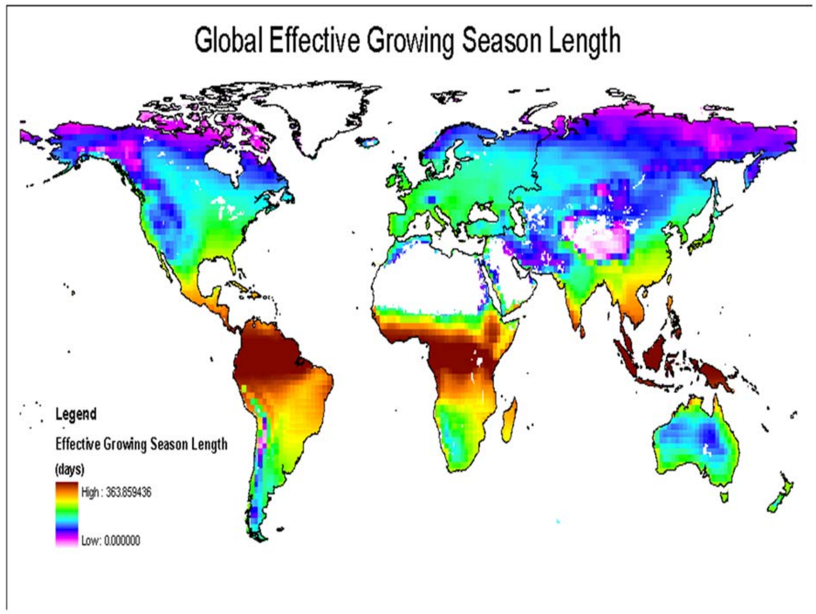
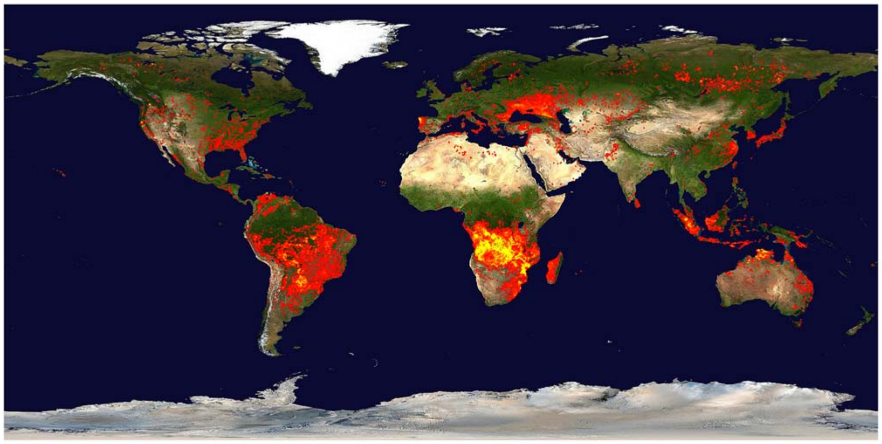
Land cover maps derived from space



Steve Running and M Jolly

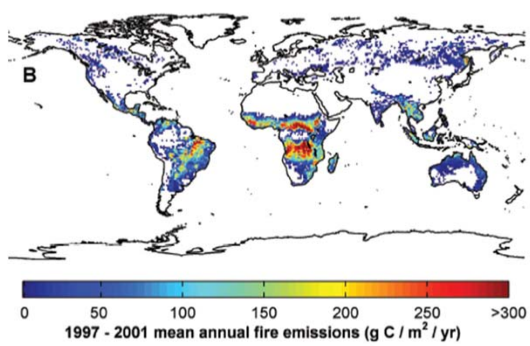
Effective growing season detected from space

Fire



Global map of fires detected by the MODIS satellite from Days 211-220 of 2006 (Giglio et al 2003). Fires add 2-3Pg of CO_2 to the atmosphere each year (van der Werf et al 2004).

Fire Emission

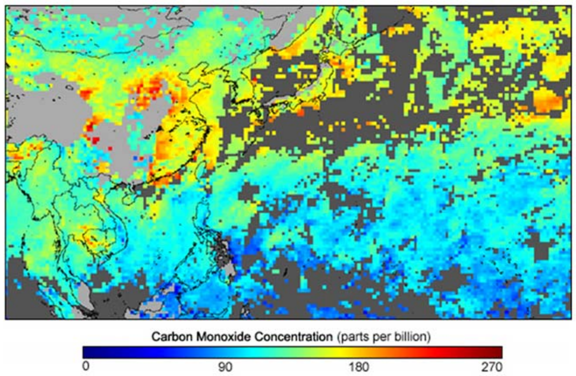


Fire: TRMM (Tropical Rainfall Measuring Mission)
Area Burned: MODIS
Carbon: CASA

Van der Werf et al. 2004, Science

MOPPIT: CO and CH4

Pollution over China



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Integrated columns of aerosols and IR absorption can tell us about pollutants

The Future

- Orbiting Carbon Observator: CO_2 concentrations!!
- Global Lidar for DEM and Canopy Height
- GRACE: Gravity anomalies for soil moisture

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OCO

704 D. Crisp et al. / Advances in Space Research 34 (2004) 700–709

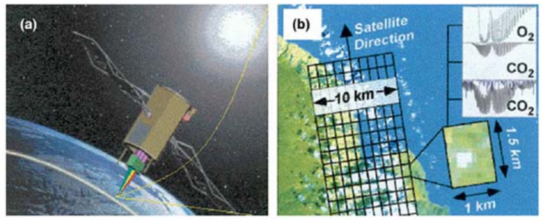

Fig. 3. (a) OCO spacecraft orbiting the Earth in Nadir Sounding mode, (b) Landsat image of Hilo Bay, Hawaii illustrating the OCO spatial sampling approach. Ten 1-km wide cross-track samples are collected in each of the three wavelengths at 4.5 Hz along the orbit track. At nadir this yields a footprint with dimensions of 1 km × 1.5 km.

- CO_2 bands: 1.61 and 2.06 microns
- Polar obital, Sun Synchronous
- Column integrated
- 1 ppm precision
- 10 km swath

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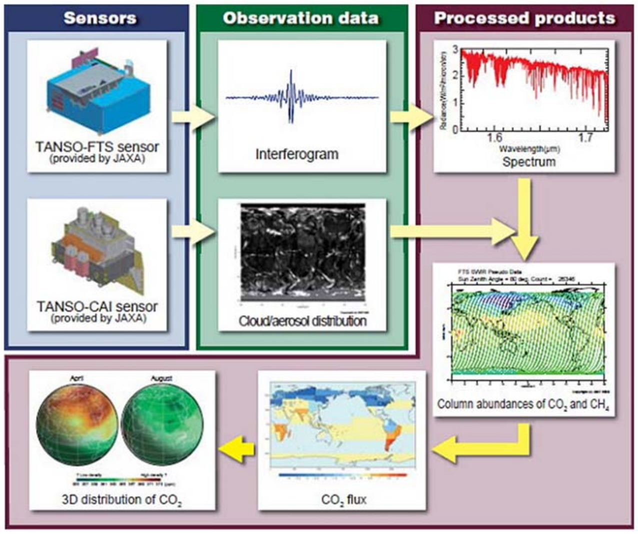
The first OCO crashed on launch A duplicate was built and there are plans to launch it.

GOSAT, Japanese CO2 Satellite



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Japan has a different CO2 satellite

GRACE

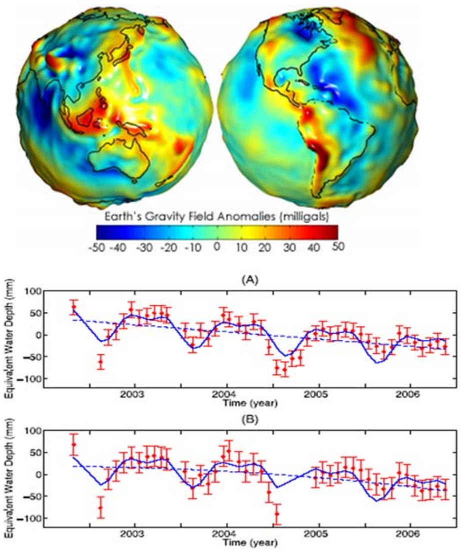
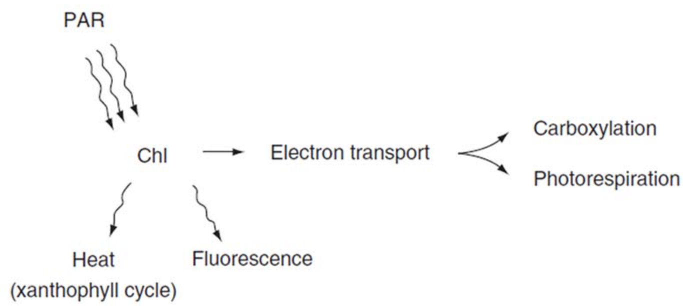


Figure 2. (a) Water storage anomalies for April, 2002–May, 2006 estimated from GRACE satellite gravity data (constrained solution) over the Congo basin. The estimates

Crowley et al 2006 GRL

Grace measures gravitational fields. It has been very powerful and detecting loss of ground water in the Central Valley.

Detecting Photosynthesis and Physiological Stress from Space



Gamon, 2006, Functional Ecology

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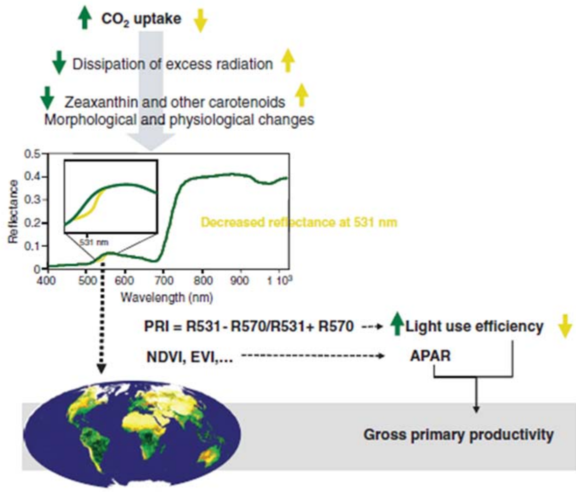
New efforts are to look at fluorescence from space and to detect other stresses.

Down Regulating Light Use Efficiency with Physiological Stress



Penuelas, 2011 New Phytologist

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Heat stress activates pigments like zeaxanthin and carotenoids, which alters reflectance in the 531 nm range relative to 570 nm. This index is called PRI and can be used to down regulate photosynthesis

Change in PRI with Drying

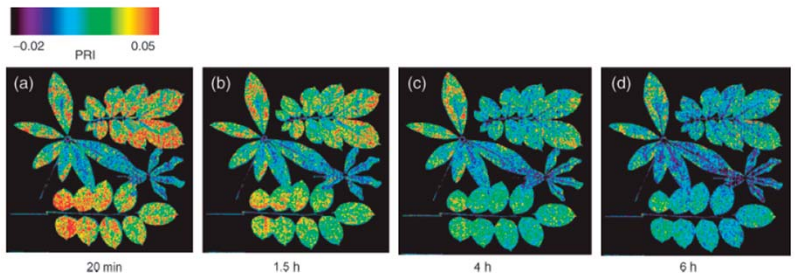
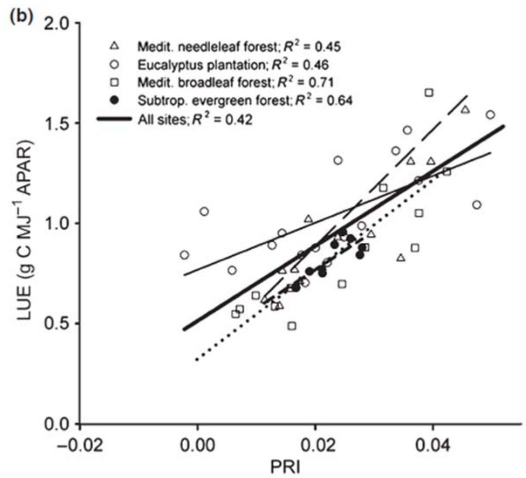


Fig. 2 Changes in photochemical reflectance index (PRI) of leaves of four tropical trees during drying. Leaf reflectance was measured after excising the leaves and allowing evaporation for 20 min, 1.5, 4, and 6 h. The species were *Pterocarpus indicus*, *Ceiba pentandra*, *Pachira aquatica* and *Inga cf. sapindoides*. From Rascher *et al.* (2006).

Grace et al 2007 GCB

Light Use Efficiency Scales with PRI



Penueals, 2011, New Phytologist

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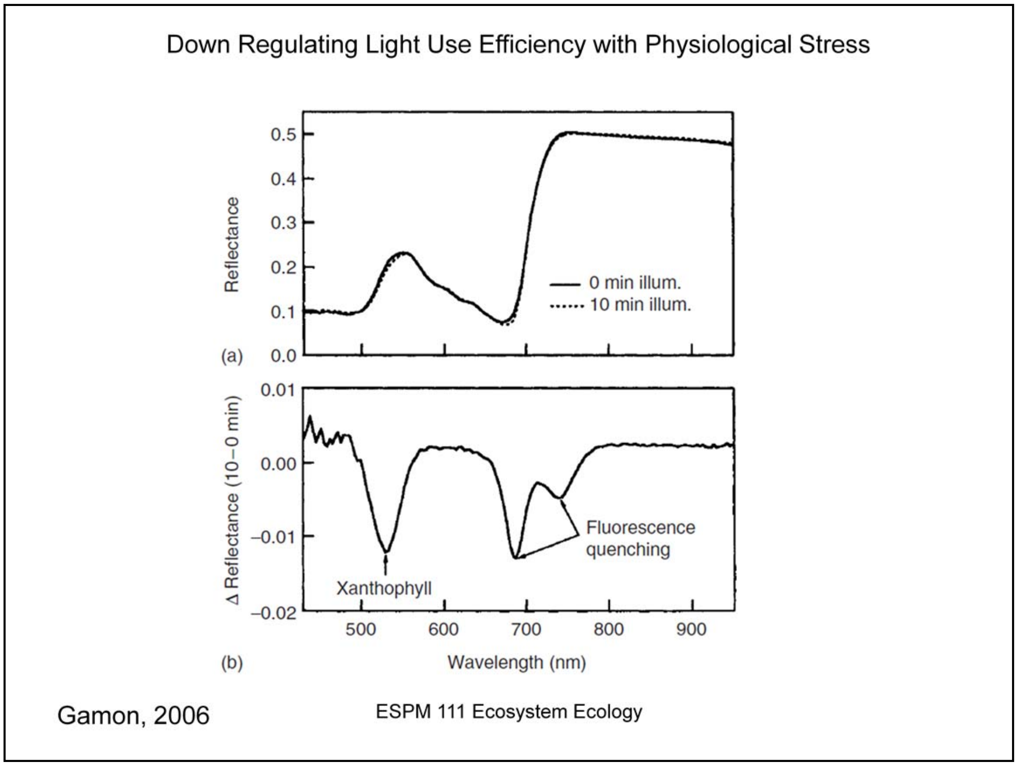
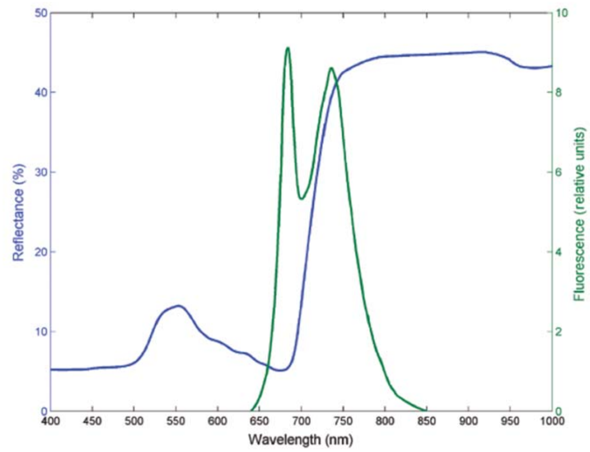
Example of PRI and LUE



Fluorescence is another form of dissipating energy not used by photosynthesis.

Solar induced fluorescence, 685 and 740 nm

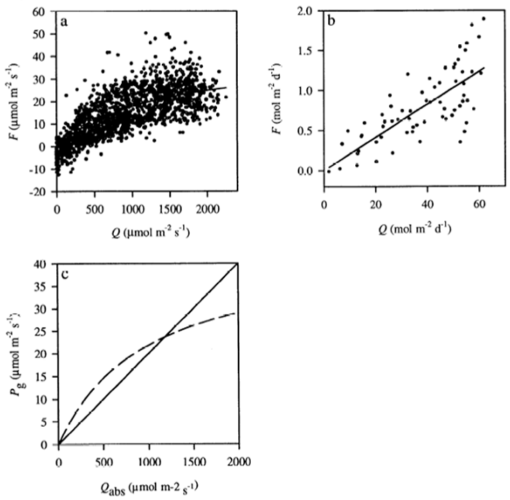


Grace et al. 2007 GCB

Summary Points

- Remote Sensing is a provides high resolution spatial information and frequent temporal information on canopy structure and function
- Information is INFERRED from the reflection of solar radiation
- Clouds and aerosols may obscure the surface and negatively affect the utility of remotes sensing
- Many indices saturate with high leaf area index

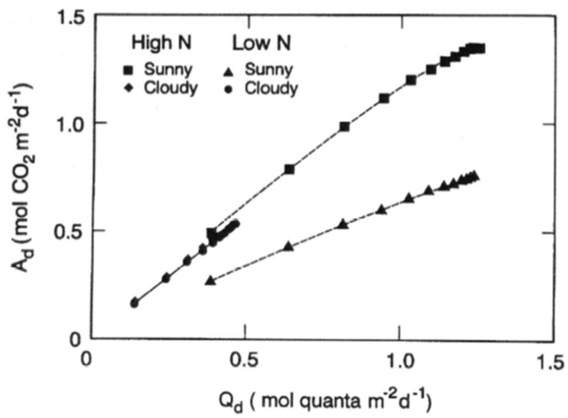
Comparing CO2 Eddy Fluxes and Absorbed Quanta



- Curvilinear on Hourly Time Scales
- Linear on Daily Time Scales

Ruimy et al. 1995 Adv Ecol Res

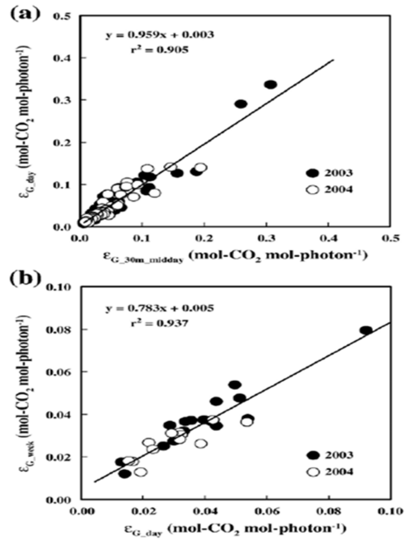
A_c vs Q_p: Daily Sums Become Linear!?



Light Use Efficiency, ε, is a function of plant nutrition, N, and sky conditions (diffuse light fraction)

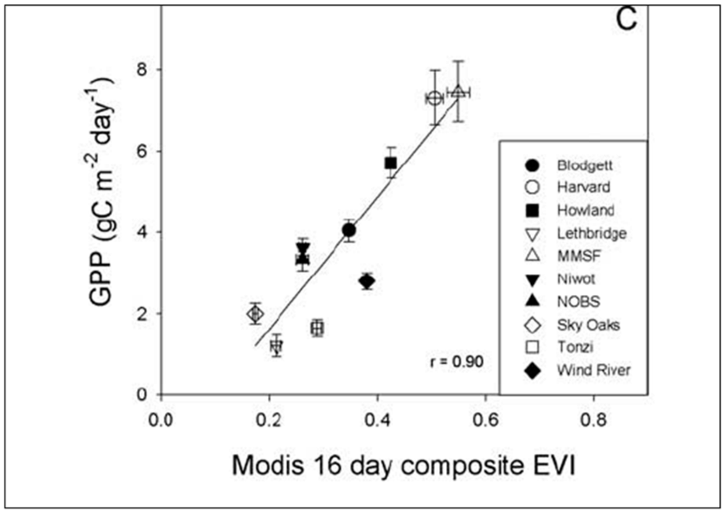
Leuning et al. 1995, PCE

Impacts of Temporal Averaging, Midday, Day, Week



Inoue et al 2008 RSE

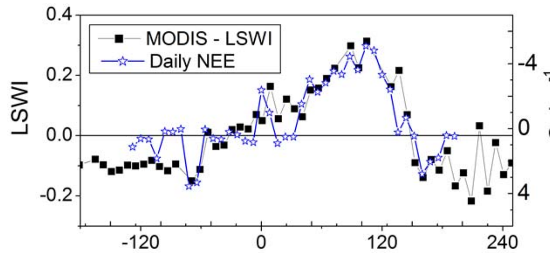
Be Careful, NDVI Saturates:
Consider other Indices

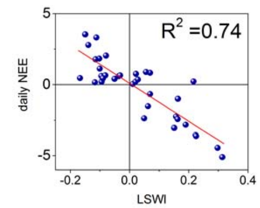


Rahman et al 2005 GRL

Land Surface Water Index (LSWI) plotted with daily NEE for 2004/2005

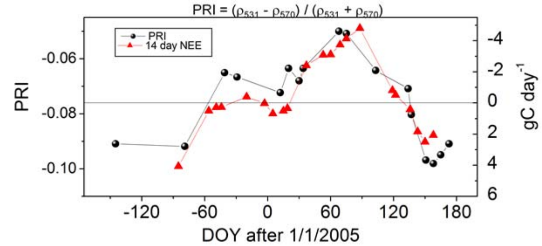
Land Surface Water Index LSWI = (ρ860 - ρ1640)/(ρ860 + ρ1640)





PRI and NEE

PRI = $(\rho_{531} - \rho_{570}) / (\rho_{531} + \rho_{570})$



Falk, Baldocchi, Ma

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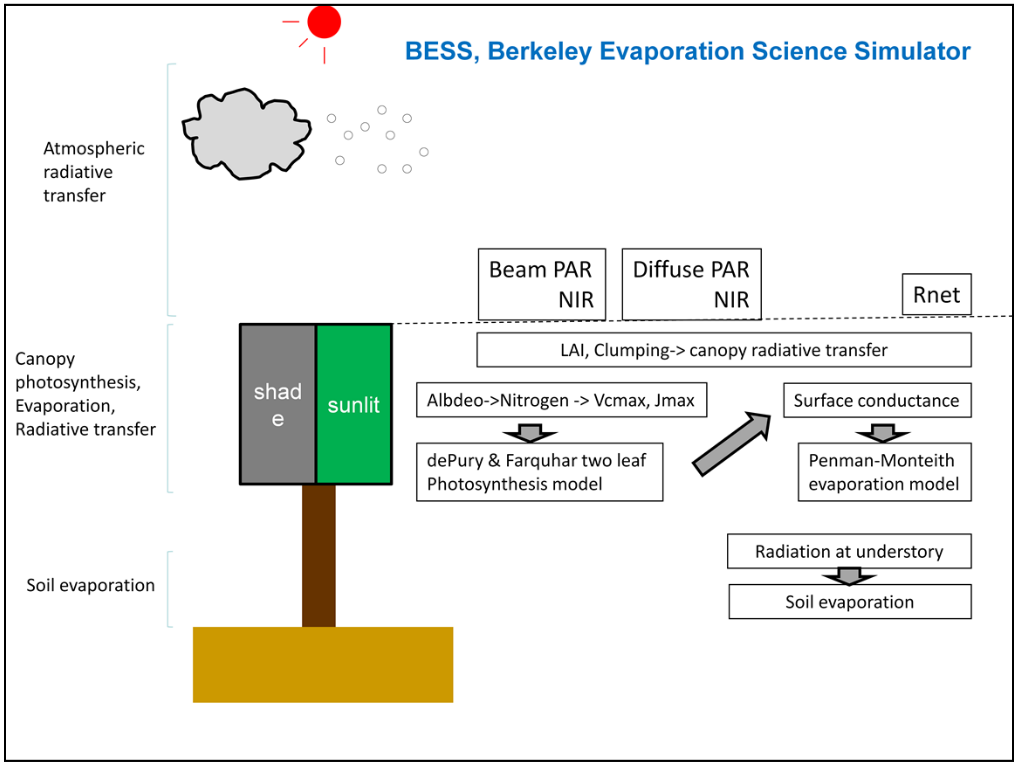
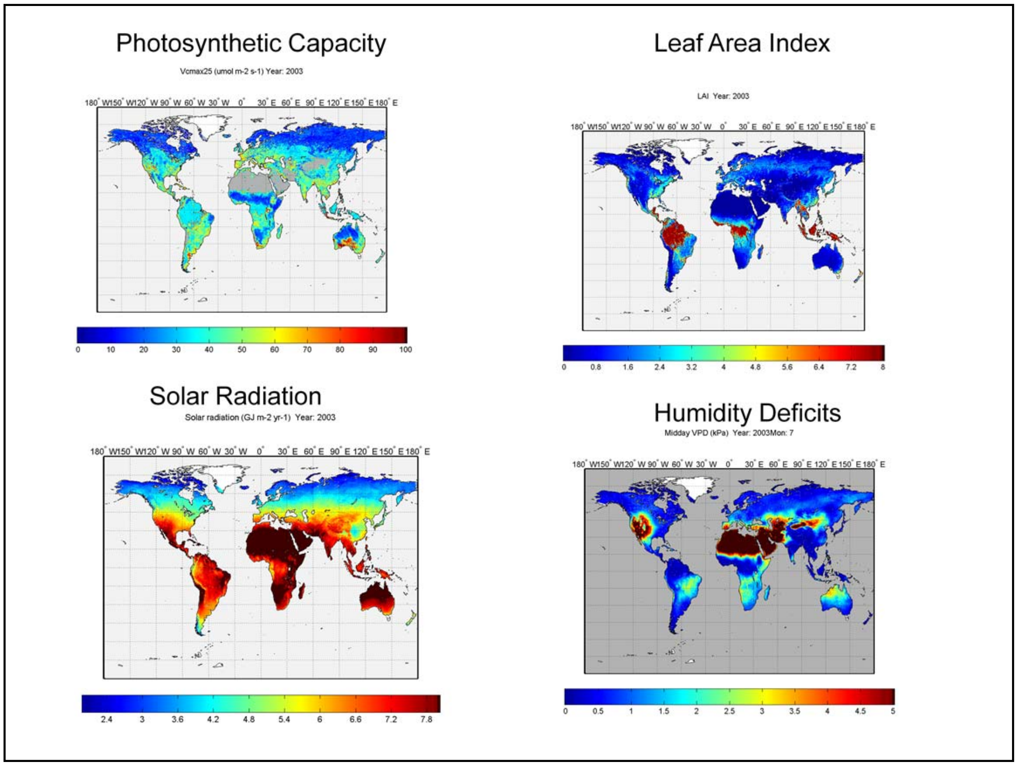
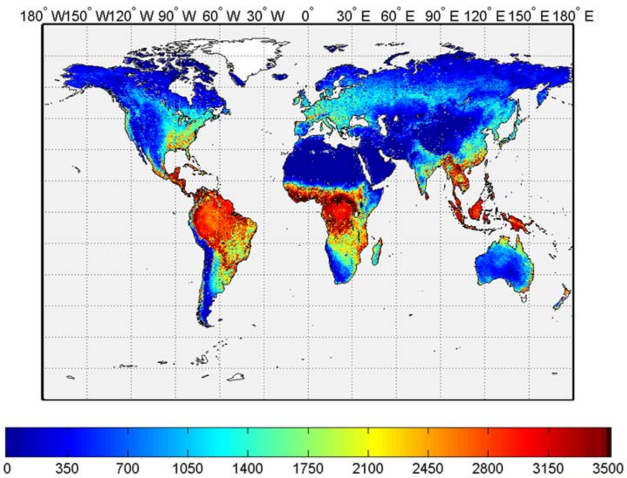

BESS, Berkeley Evaporation Science Simulator
Atmospheric radiative transfer
Canopy photosynthesis, Evaporation, Radiative transfer
Soil evaporation
Beam PAR NIR
Diffuse PAR NIR
Rnet
shade
sunlit
LAI, Clumping-> canopy radiative transfer
Albdeo->Nitrogen -> Vcmax, Jmax
dePury & Farquhar two leaf Photosynthesis model
Surface conductance
Penman-Monteith evaporation model
Radiation at understory
Soil evaporation

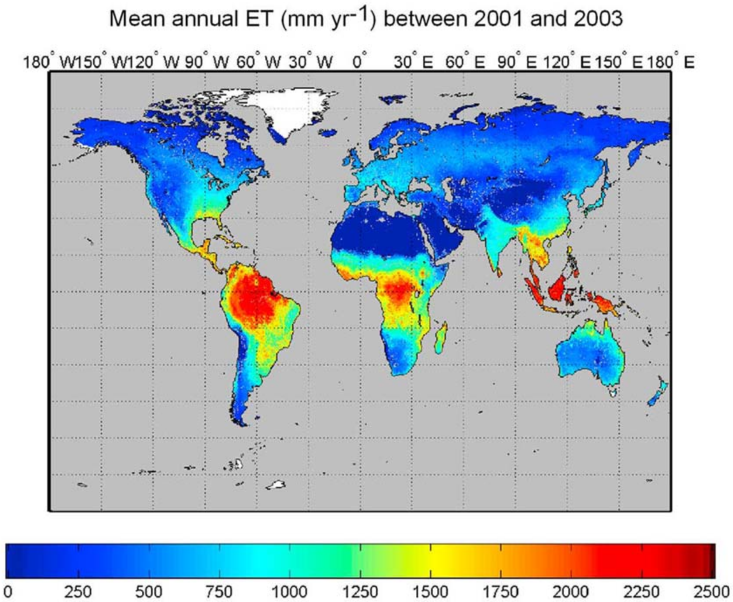

Photosynthetic Capacity
Vcmax25 (umol m-2 s-1) Year: 2003
Leaf Area Index
LAI Year: 2003
Solar Radiation
Solar radiation (GJ m-2 yr-1) Year: 2003
Humidity Deficits
Midday VPD (kPa) Year: 2003Mon: 7

The Berkeley Biomet View

GPP (gC m-2 yr-1) Year: 2003



Ryu et al 2012 GBC



Ryu et al 2012 GBC

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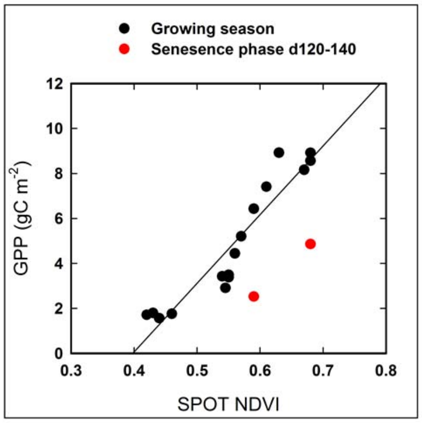
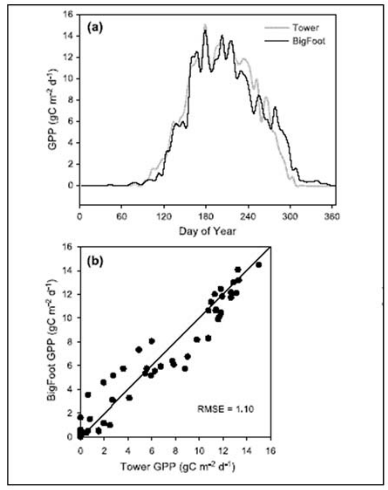
Tests of Remote Sensing, Eddy Fluxes and GPP



Xu, Gilmanov, Baldocchi



Turner et al. 2003 RSE

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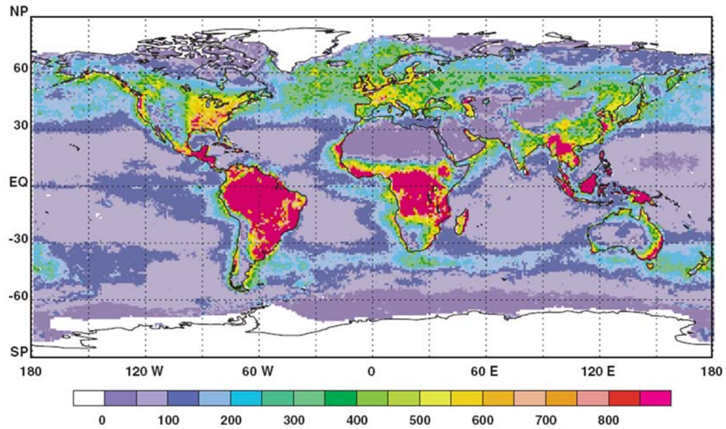
CASA Annual NPP (gC m^{-2} y^{-1})



$$NPP = f(NDVI) \cdot PAR \cdot \varepsilon \cdot f(T) \cdot f(\theta)$$

Global NPP, land+ocean= 104.9 Pg C

Field et al. 1998 Science

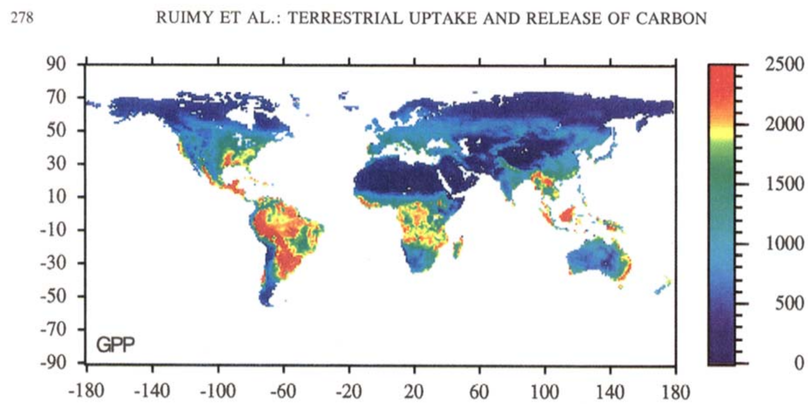
Table 1. Model Assumptions and Parameter Values for Model TURC, Standard Version (T0).

Model Assumptions	Parameter	Value	Unit
Gross primary productivity: GPP			
$P_g = \varepsilon' S_{p,abs} = \varepsilon' c f S_g$	c	0.48	
Absorption efficiency: $f = a_{max} f_i$	a_{max}	0.95	
Interception efficiency: $f_i = a + b N$	a	-0.025	
	b	1.25	
Photosynthetic efficiency	ε'	0.020	mol mol^{-1}
Autotrophic respiration: $R_a = M + G$			
Maintenance respiration			
$M = \Sigma_i M_{T,i} W_i = \Sigma_i M_{0,i} (x + y T) W_i$	x	1	
	y	0.16	
Leaf maintenance coefficient at 20°C	$M_{20,l}$	11	mg g^{-1} d^{-1}
Fine root maintenance coefficient at 20°C	$M_{20,r}$	7	mg g^{-1} d^{-1}
Sapwood maintenance coefficient at 20°C	$M_{20,s}$	0.5	mg g^{-1} d^{-1}
Leaf area index: $L = -\frac{\ln(1 - f_i)}{k}$	k	0.6	
Leaves, roots biomass: $W_l = W_r = W_{ls} L$	W_{ls}	70	g(DM) m^{-2}
Sapwood biomass: $W_s = \frac{pqW_w}{p + qW_w}$	p	71.5	t(DM) ha^{-1}
	q	0.89	
Growth respiration			
$G = g' (P_g - M)$	g'	0.28	

Additional constants: 4.6 mol(photon) J (PAR)$^{-1}$, 0.45 g(C) g(DM)$^{-1}$

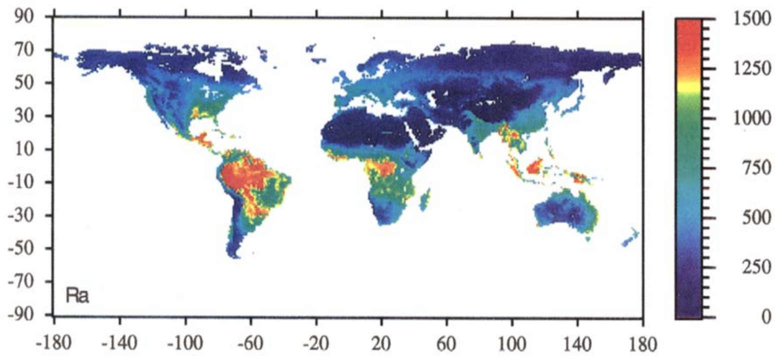
TURC Ruimy et al

Gross Primary Productivity



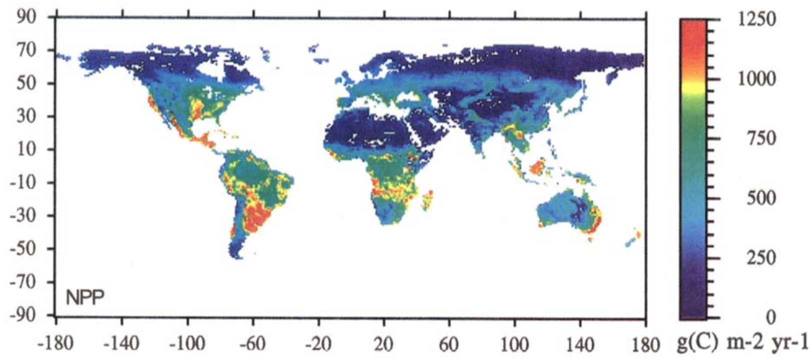
Ruimy et al 1996, JGR

Autotrophic Respiration



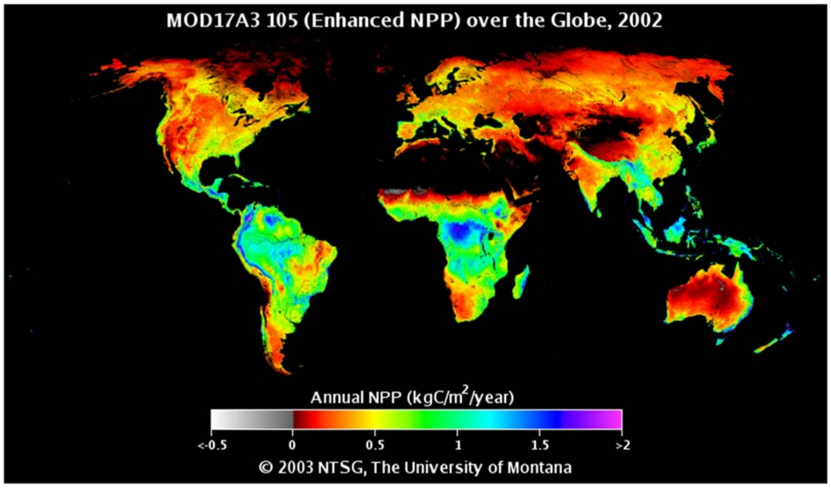
Ruimy et al 1996, JGR

Net Primary Productivity



Ruimy et al 1996, JGR

Global C Fluxes:
New Generation, MODIS



Running et al

Lessons Learned from the CanOak Model

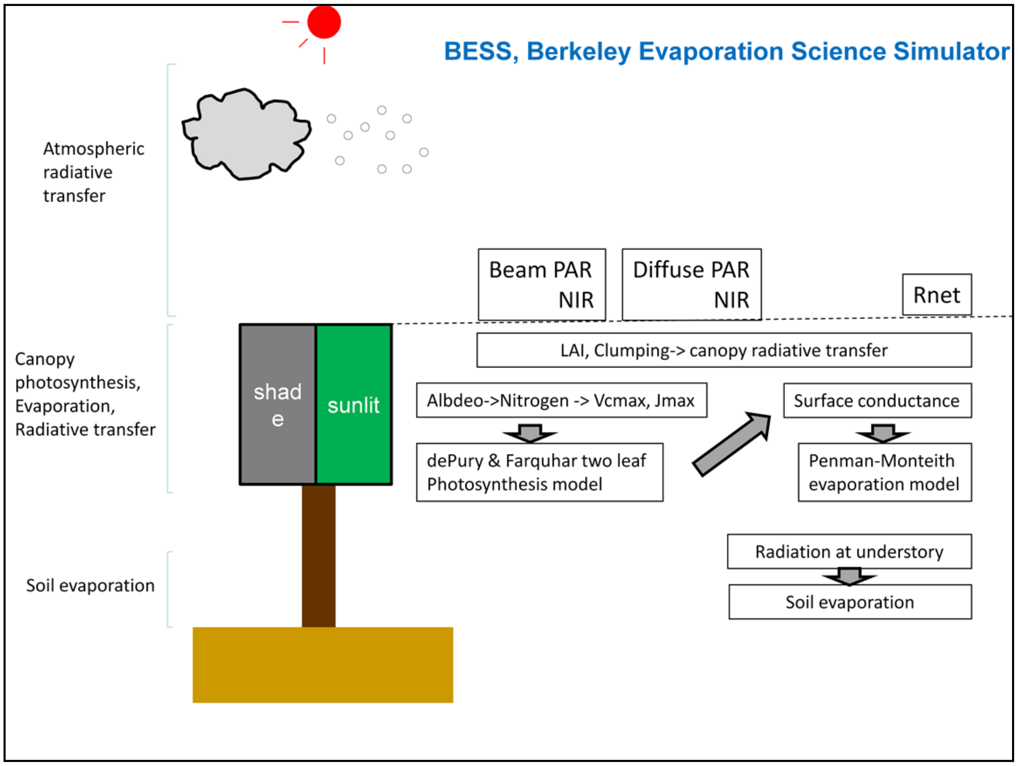
25+ years of Developing and Testing a Hierarchy of Scaling Models with Flux Measurements at Contrasting Oak Woodland Sites in Tennessee and California

We Must:

- Couple Carbon and Water Fluxes
- Assess Non-Linear Biophysical Functions with Leaf-Level Microclimate Conditions
- Consider Sun and Shade fractions separately
- Consider effects of Clumped Vegetation on Light Transfer
- Consider Seasonal Variations in Physiological Capacity of Leaves and Structure of the Canopy

Necessary Attributes of Global Biophysical ET Model: Applying Lessons from the Berkeley Biomet Class and CANOAK

- Treat Canopy as Dual Source (Sun/Shade), Two-Layer (Vegetation/Soil) system
  - Treat Non-Linear Processes with Statistical Rigor (Norman, 1980s)
- Requires Information on Direct and Diffuse Portions of Sunlight
  - Monte Carlo Atmospheric Radiative Transfer model (Kobayashi + Iwabuchi,, 2008)
- Light transfer through canopies MUST consider Leaf Clumping
  - Apply New Global Clumping Maps of Chen et al./Pisek et al.
- Couple Carbon-Water Fluxes for Constrained Stomatal Conductance Simulations
  - Photosynthesis and Transpiration on Sun/Shade Leaf Fractions (dePury and Farquhar, 1996)
  - Compute Leaf Energy Balance to compute Leaf Saturation Vapor Pressure, IR emission and Respiration Correctly
  - Photosynthesis of C_3 and C_4 vegetation Must be considered Separately
- Use Emerging Ecosystem Scaling Rules to parameterize models, based on remote sensing spatio-temporal inputs
  - Vcmax=f(N)=f(albedo) (Ollinger et al; Hollinger et al;Schulze et al.; Wright et al.)
  - Seasonality in Vcmax is considered (Wang et al.)


BESS, Berkeley Evaporation Science Simulator
Atmospheric radiative transfer
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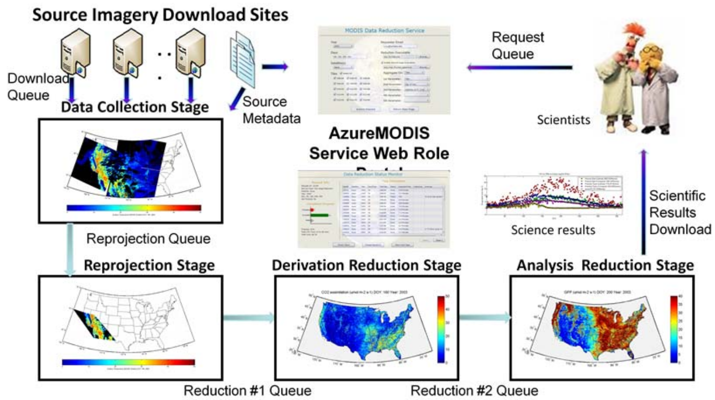
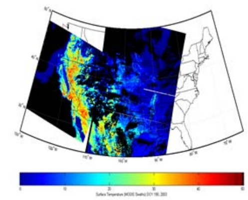
dePury & Farquhar two leaf Photosynthesis model
Surface conductance
Penman-Monteith evaporation model
Radiation at understory
Soil evaporation

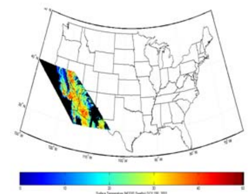
Help from ModisAzure -Azure Service for Remote Sensing Geoscience



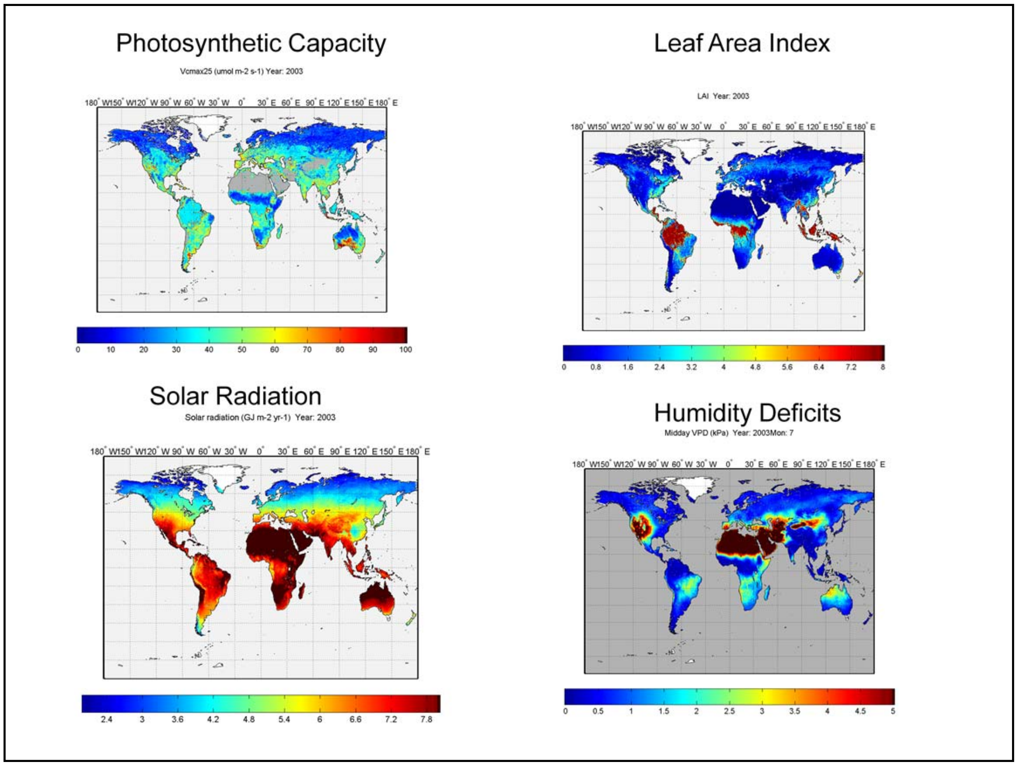
Puts the Small Biomet Lab into the Global Ecology, Computationally-Intensive Ball Park

Tasked Performed with MODIS-AZURE

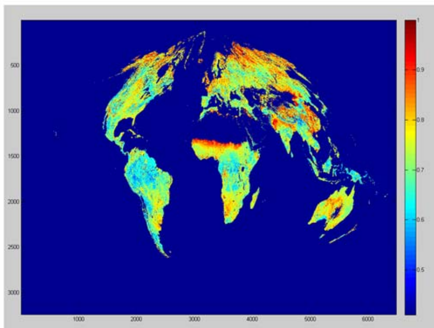




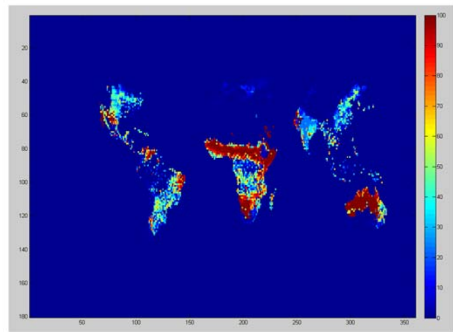
- Automation
  - Downloads thousands of files of MODIS data from NASA ftp
- Reprojection
  - Converts one geo-spatial representation to another.
  - Example: latitude-longitude swaths converted to sinusoidal cells to merge MODIS Land and Atmosphere Products
- Spatial resampling
  - Converts one spatial resolution to another.
  - Example is converting from 1 km to 5 km pixels.
- Temporal resampling
  - Converts one temporal resolution to another.
  - Converts daily observation to 8 day averages.
- Gap filling
  - Assigns values to pixels without data either due to inherent data issues such as clouds or missing pixels.
- Masking
  - Eliminates uninteresting or unneeded pixels.
  - Examples are eliminating pixels over the ocean when computing a land product or outside a spatial feature such as a watershed.

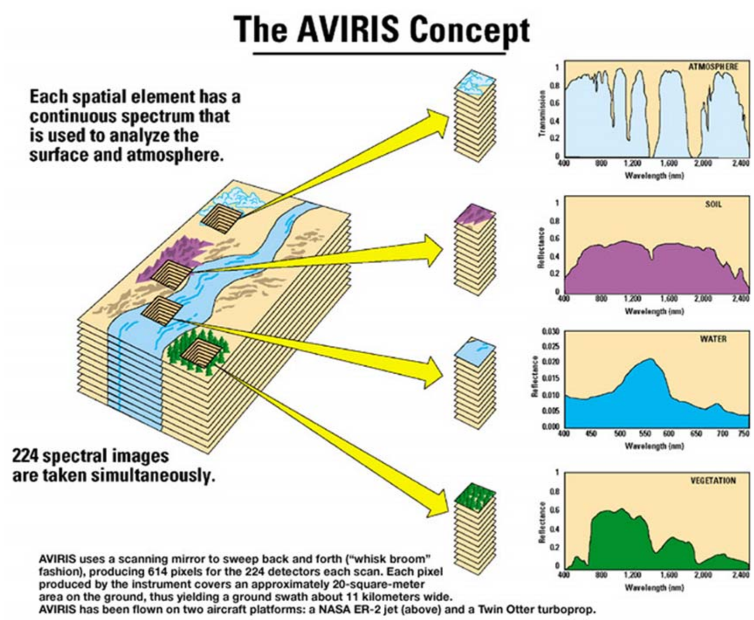

Photosynthetic Capacity
Vcmax25 (umol m-2 s-1) Year: 2003
180° W150° W120° W 90° W 60° W 30° W 0° 30° E 60° E 90° E 120° E 150° E 180° E
0 10 20 30 40 50 60 70 80 90 100
Leaf Area Index
LAI Year: 2003
180° W150° W120° W 90° W 60° W 30° W 0° 30° E 60° E 90° E 120° E 150° E 180° E
0 0.8 1.6 2.4 3.2 4 4.8 5.6 6.4 7.2 8
Solar Radiation
Solar radiation (GJ m-2 yr-1) Year: 2003
180° W150° W120° W 90° W 60° W 30° W 0° 30° E 60° E 90° E 120° E 150° E 180° E
2.4 3 3.6 4.2 4.8 5.4 6 6.6 7.2 7.8
Humidity Deficits
Midday VPD (kPa) Year: 2003Mon: 7
180° W150° W120° W 90° W 60° W 30° W 0° 30° E 60° E 90° E 120° E 150° E 180° E
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5

Leaf Clumping Map, Chen et al. 2005



C_4 Vegetation Map, Still et al. 2003





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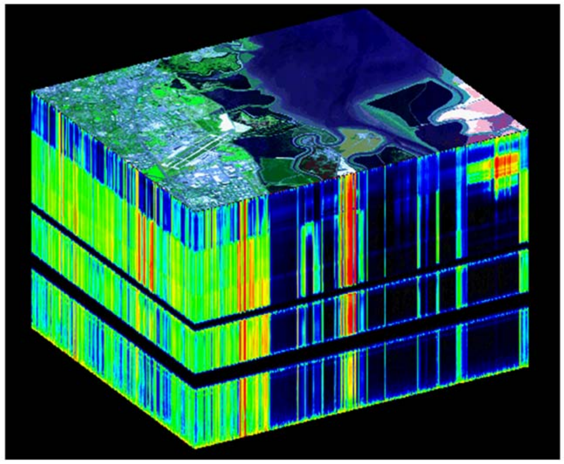
AVIRIS Data Cube



Spectral Resolution 10 nm, 400-2500 nm; Spatial Resolution, 3.5 m