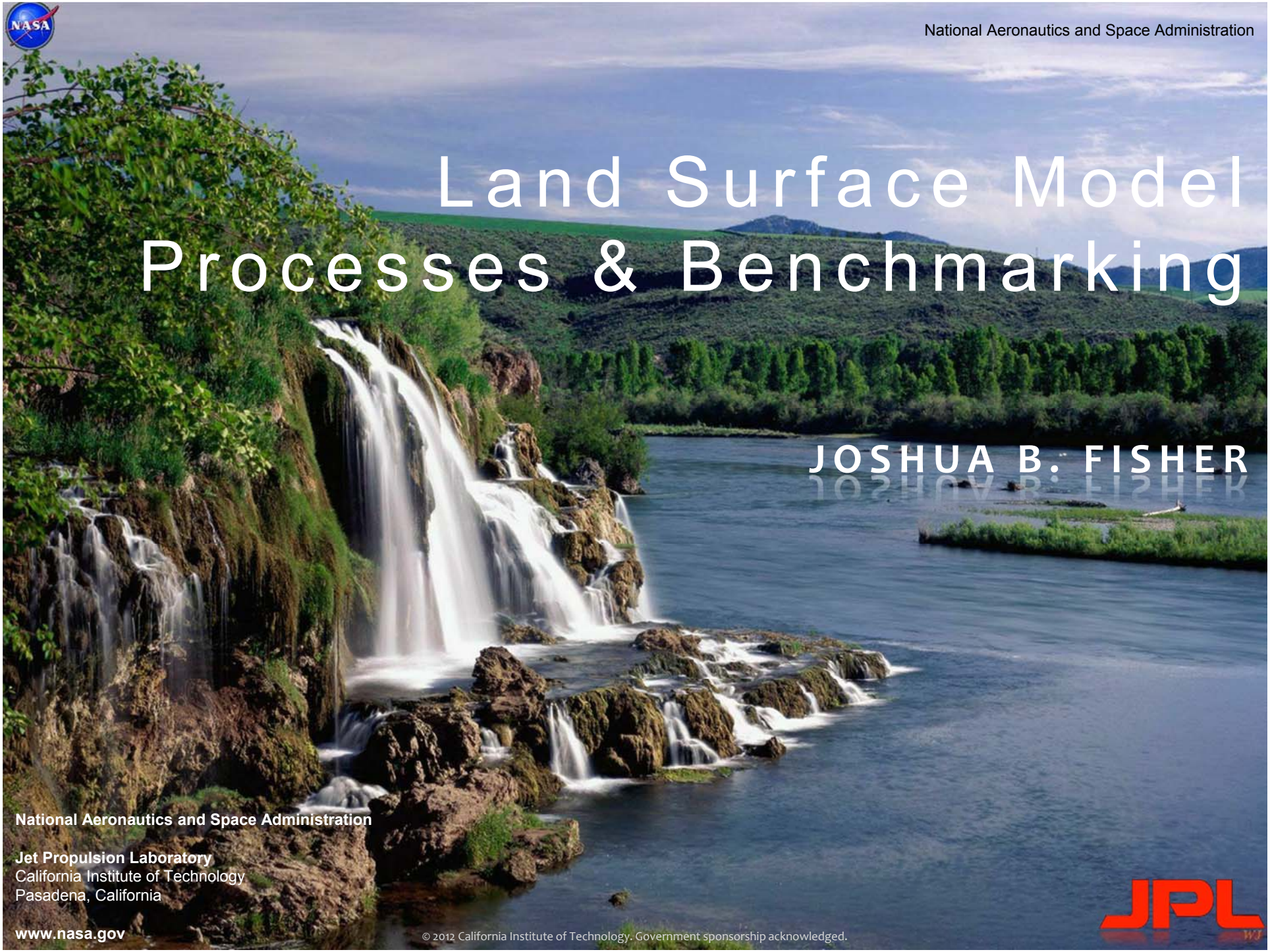

National Aeronautics and Space Administration

Land Surface Model Processes & Benchmarking

JOSHUA B. FISHER

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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Model ID, Vintage	Sponsor(s), Country	Atmosphere Top Resolution[a] References	Ocean Resolution[b] Z Coord., Top BC References	Sea Ice Dynamics, Leads References	Coupling Flux Adjustments References	Land Soil, Plants, Routing References
1: BCC-CM1, 2005	Beijing Climate Center, China	top = 25 hPa T63 (1.9° x 1.9°) L16 Dong et al., 2000; CSMD, 2005; Xu et al., 2005	1.9° x 1.9° L30 depth, free surface Jin et al., 1999	no rheology or leads Xu et al., 2005	heat, momentum Yu and Zhang, 2000; CSMD, 2005	layers, canopy, routing CSMD, 2005
2: BCCR-BCM2.0, 2005	Bjerknes Centre for Climate Research, Norway	top = 10 hPa T63 (1.9° x 1.9°) L31 Déqué et al., 1994	0.5°–1.5° x 1.5° L35 density, free surface Block et al., 1992	rheology, leads Hibler, 1979; Harder, 1996	no adjustments Furevik et al., 2003	Layers, canopy, routing Mahfouf et al., 1995; Douville et al., 1995;
3: CCSM3, 2005	National Cent Atmospheric F					
4: CGCM3.1(T47), 2005	Canadian Cen Modelling and Canada					
5: CGCM3.1(T63), 2005						
6: CNRM-CM3, 2004	Météo-France National de Re Météorologiqu					
7: CSIRO-MK3.0, 2001	Commonweal and Industrial Organisation (Atmospheric F Australia					
8: ECHAM5/MPI-OM, 2005	Max Planck In Meteorology, (					
9: ECHO-G, 1999	Meteorologica of the Univers Meteorologica Institute of the Meteorologica (KMA), and Mo Group, Germa					

Model ID, Vintage	Sponsor(s), Country	Atmosphere Top Resolution[a] References	Ocean Resolution[b] Z Coord., Top BC References	Sea Ice Dynamics, Leads References	Coupling Flux Adjustments References	Land Soil, Plants, Routing References
10: FGOALS-g1.0, 2004	National Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG)/Institute of Atmospheric Physics, China	top = 2.2 hPa T42 (~2.8° x 2.8°) L26 Wang et al., 2004	1.0° x 1.0° L16 eta, free surface Jin et al., 1999; Liu et al., 2004	rheology, leads Briegleb et al., 2004	no adjustments Yu et al., 2002, 2004	layers, canopy, routing Bonan et al., 2002
11: GFDL-CM2.0, 2005	U.S. Department of Commerce/ National Ocean Atmospheric Ad (NOAA)/Geophy Dynamics Labo USA	top = 3 hPa 2.0° x 2.5° L24	0.3°–1.0° x 1.0° depth, free surface Gnanadesikan et al.	rheology, leads Winton, 2000;	no adjustments Delworth et al.,	bucket, canopy, routing Milly and Shmakin, 2002;
12: GFDL-CM2.1, 2005						
13: GISS-AOM, 2004	National Aerona Space Administ Goddard Institu Studies (GISS),					
14: GISS-EH, 2004						
15: GISS-ER, 2004	NASA/GISS, US					
16: INM-CM3.0, 2004	Institute for Nur Mathematics, R					
17: IPSL-CM4, 2005	Institut Pierre S France					
18: MIROC3.2(hires), 2004	Center for Clim Research (Univ Tokyo), Nationa Environmental S Frontier Resear Global Change Japan					
19: MIROC3.2(medres), 2004						

Model ID, Vintage	Sponsor(s), Country	Atmosphere Top Resolution[a] References	Ocean Resolution[b] Z Coord., Top BC References	Sea Ice Dynamics, Leads References	Coupling Flux Adjustments References	Land Soil, Plants, Routing References
20: MRI-CGCM2.3.2, 2003	Meteorological Research Institute, Japan	top = 0.4 hPa T42 (~2.8° x 2.8°) L30 Shibata et al., 1999	0.5°–2.0° x 2.5° L23 depth, rigid lid Yukimoto et al., 2001	free drift, leads Mellor and Kantha, 1989	heat, freshwater, momentum (12°S–12°N) Yukimoto et al., 2001; Yukimoto and Noda, 2003	layers, canopy, routing Sellers et al., 1986; Sato et al., 1989
21: PCM, 1998	National Center for Atmospheric Research, USA	top = 2.2 hPa T42 (~2.8° x 2.8°) L26 Kiehl et al., 1998	0.5°–0.7° x 1.1° L40 depth, free surface Maltrud et al., 1998	rheology, leads Hunke and Dukowicz 1997, 2003; Zhang et al., 1999	no adjustments Washington et al., 2000	layers, canopy, no routing Bonan, 1998
22: UKMO-HadCM3, 1997	Hadley Centre for Climate Prediction and Research/Met Office, UK	top = 5 hPa 2.5° x 3.75° L19 Pope et al., 2000	1.25° x 1.25° L20 depth, rigid lid Gordon et al., 2000	free drift, leads Cattle and Crossley, 1995	no adjustments Gordon et al., 2000	layers, canopy, routing Cox et al., 1999
23: UKMO-HadGEM1, 2004		top = 39.2 km ~1.3° x 1.9° L38 Martin et al., 2004	0.3°–1.0° x 1.0° L40 depth, free surface Roberts, 2004	rheology, leads Hunke and Dukowicz, 1997; Semtner, 1976; Lipscomb, 2001	no adjustments Johns et al., 2006	layers, canopy, routing Essery et al., 2001; Oki and Sud, 1998

Notes:

[a] Horizontal resolution is expressed either as degrees latitude by longitude or as a triangular (T) spectral truncation with a rough translation to degrees latitude and longitude. Vertical resolution (L) is the number of vertical levels.

[b] Horizontal resolution is expressed as degrees latitude by longitude, while vertical resolution (L) is the number of vertical levels.

This chapter s

Randall, D.A., R.A.
and K.E. Taylor, 20
Working Group I to
Z. Chen, M. Marqu
York, NY, USA.

should be cited as:

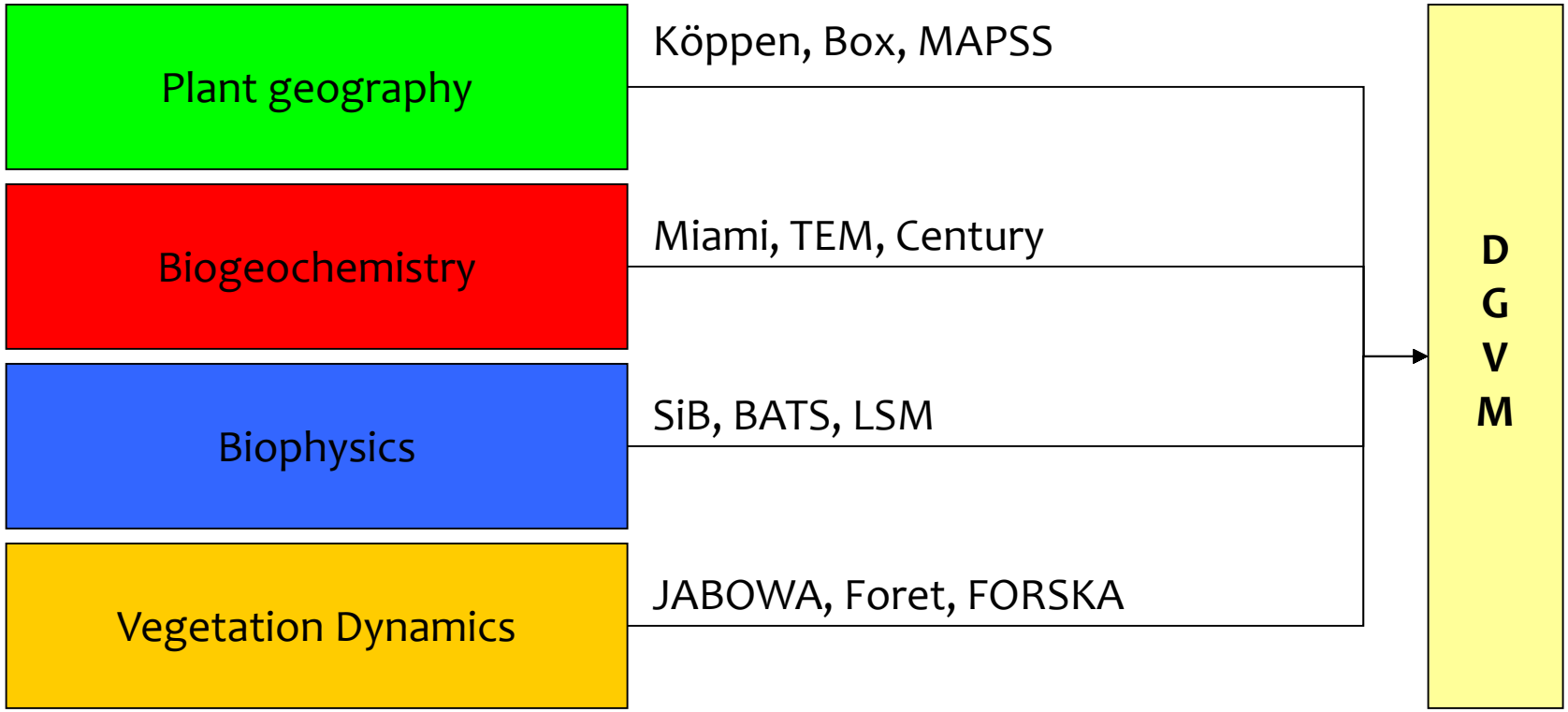
Wood, S. Rose, B. Santer, T. Ramaswamy, T. Karl, G. Stouffer, J. Taylor, K. Hegerl, G. Ramachandran, R.J. Trenberth, A. Sun, J. Climate Models and Their Evaluation. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

LAND SURFACE MODEL

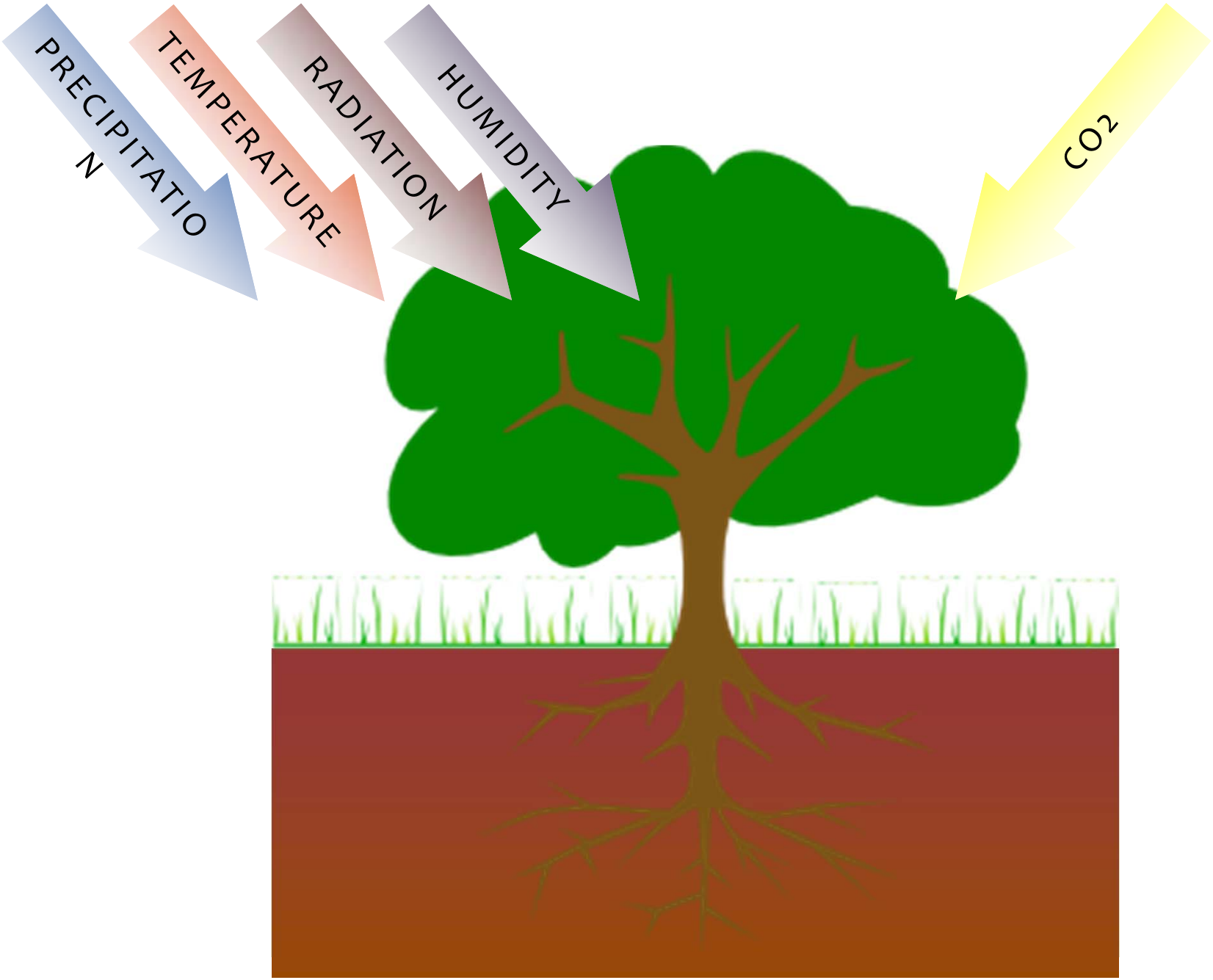
- Land Surface Model (LSM)
- Terrestrial Biosphere Model (TBM)
- Terrestrial Ecosystem Model (TEM)
- *Dynamic Global Vegetation Model (DGVM)
- NOT Ecological Model (Lotka-Voltera – Predator/Prey), Foodweb Model; not hydrological model
- Can we predict/understand ecosystem dynamics from mathematical equations?
  - Forced by climate (precipitation, temperature, radiation, humidity); constrained by substrate (topography, elevation, soil depth, soil texture)

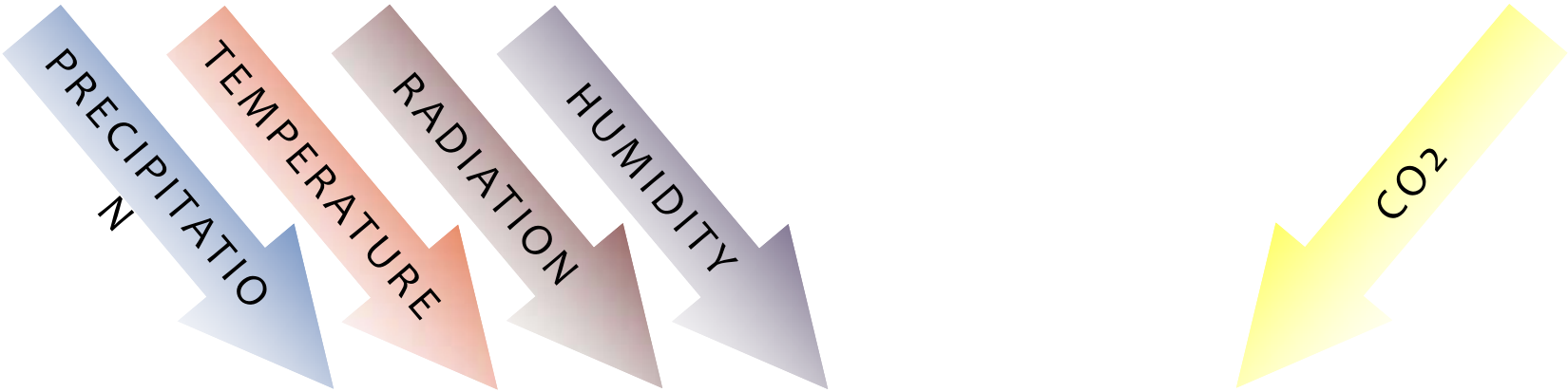
DEVELOPMENT

- *Integration of four groups of processes*



From Kaplan & Sitch

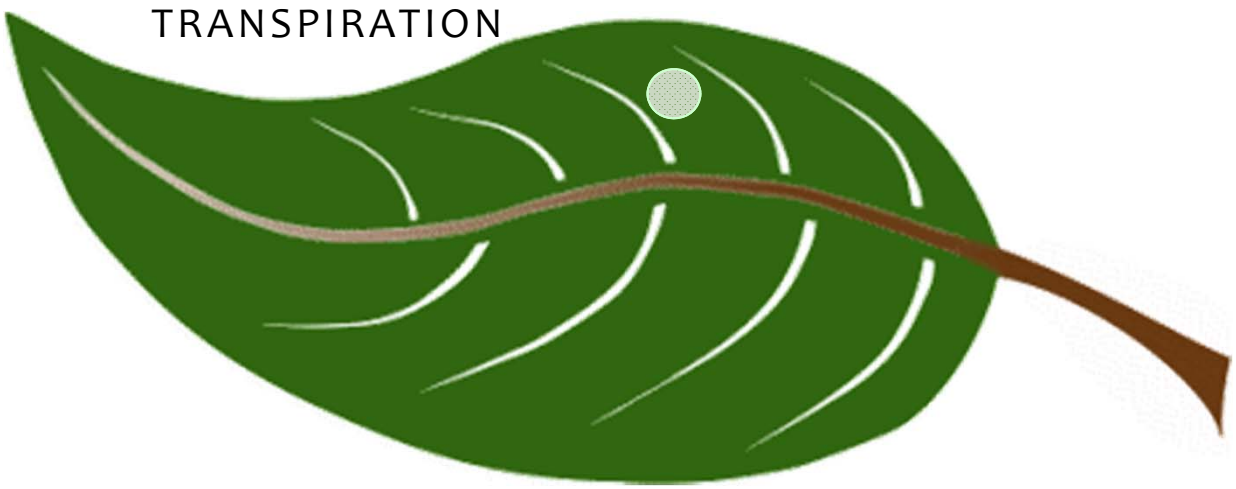

PRECIPITATION
TEMPERATURE
RADIATION
HUMIDITY
CO_2



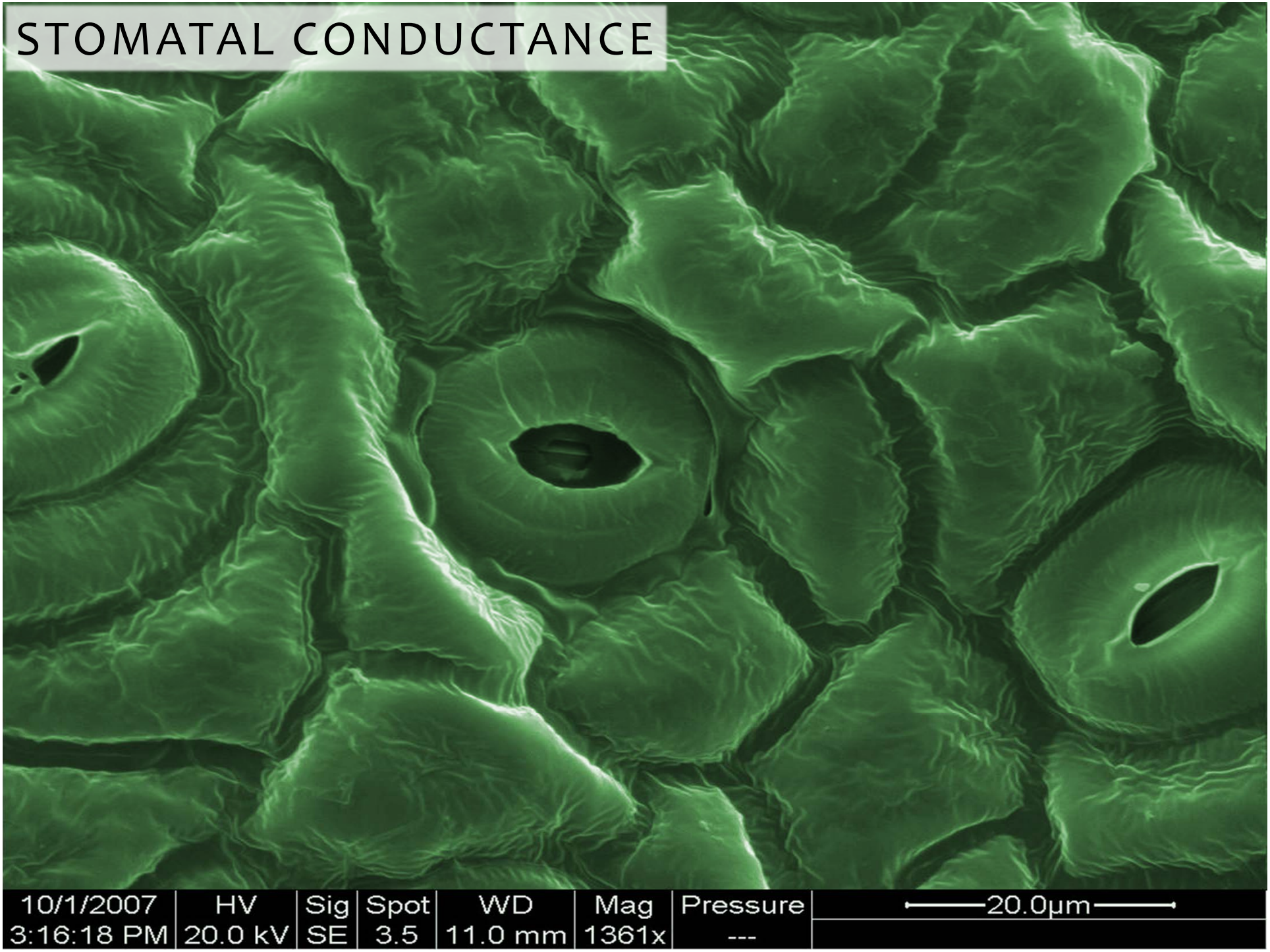
STOMATAL CONDUCTANCE

PHOTOSYNTHESIS → GROSS PRIMARY PRODUCTION (GPP)

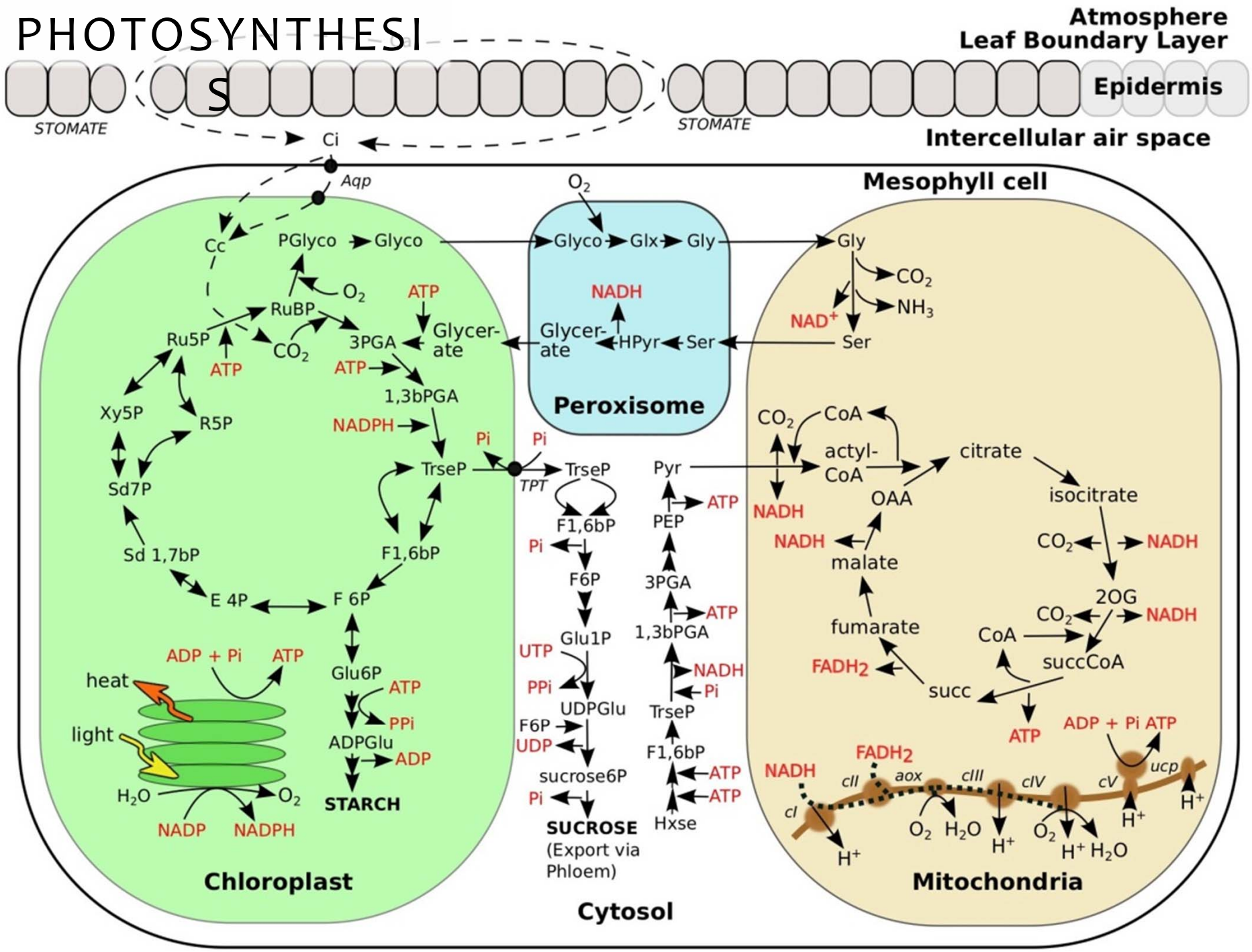
TRANSPIRATION



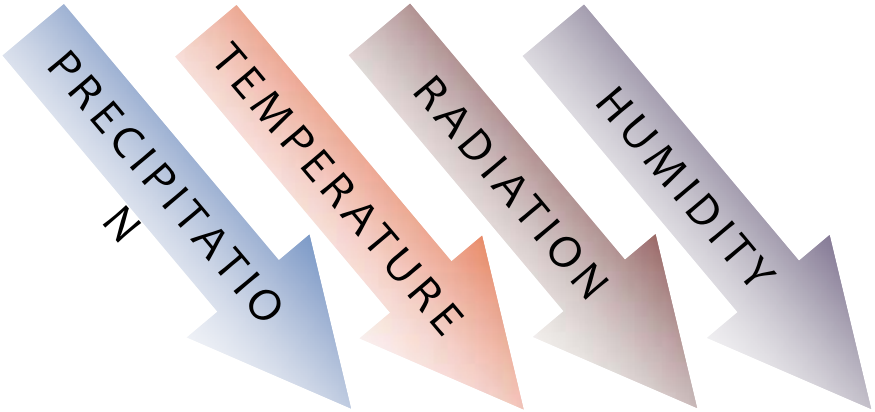
STOMATAL CONDUCTANCE

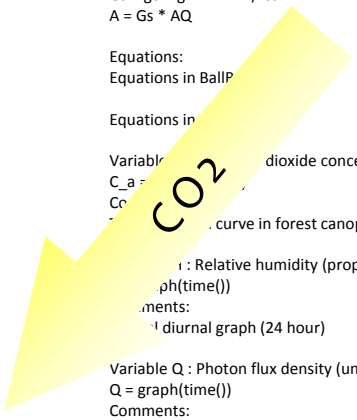


PHOTOSYNTHESIS



TRANSPIRATION

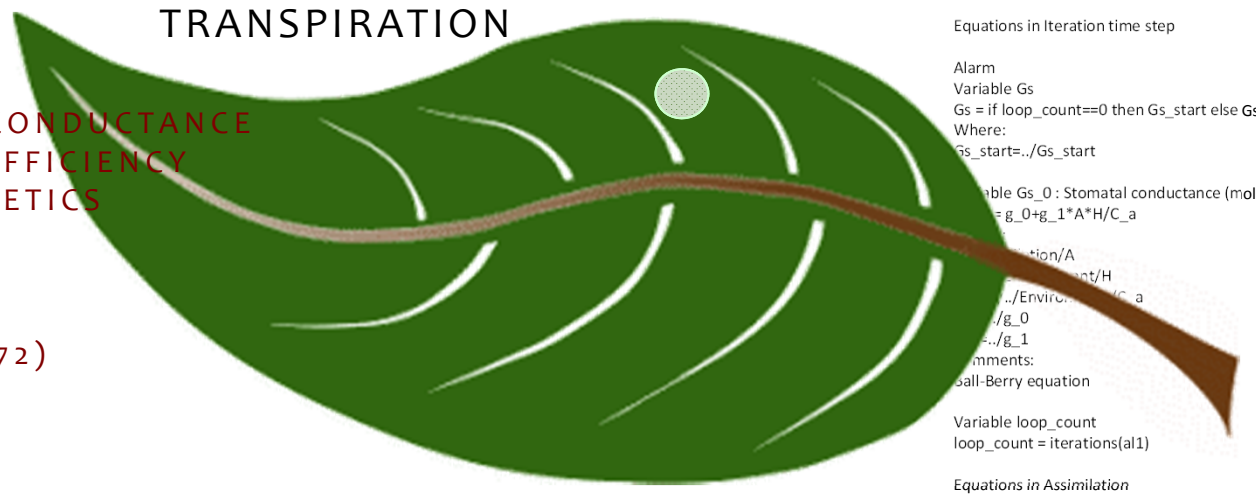




STOMATAL CONDUCTANCE

PHOTOSYNTHESIS → GROSS PRIMARY PRODUCTION (GPP)

TRANSPIRATION



STOMATAL CONDUCTANCE

- BALL ET AL. (1987)
- JARVIS (1976)
- LEUNING (1995)
- STEWART (1988)
- HAXELTINE & PRENTICE (1996)
- COX ET AL (1998)

PHOTOSYNTHESIS/GPP

- BASED ON STOMATAL CONDUCTANCE
- BASED ON LIGHT USE EFFICIENCY
- BASED ON ENZYME KINETICS

TRANSPIRATION

- MONTEITH (1965)
- PRIESTLEY-TAYLOR (1972)
- CAMPBELL (1977)
- BONAN (1989)
- OLESON ET AL (2010)
- MEDVIGY ET AL (2009)
- FRIEND & KIANG (2005)
- BALL ET AL (1987)
- MILLY & SHMAKIN (2002)
- FEDERER (1982)

Gs = g0 + g1 * A * H / Ca
A = Gs * AQ

Equations:
Equations in BallP

Equations in

Variabl dioxide concentration (umol CO2 (mol air)^-1)
C_a =
Co
curve in forest canopy

: Relative humidity (proportion)
ph(time())
ments:
diurnal graph (24 hour)

Variable Q : Photon flux density (umol m^-2 s^-1)
Q = graph(time())
Comments:
Graph for a sunny day (24 hours)

Equations in Ball-Berry

Variable Gs_start
Gs_start = if time()==0 then g_0 else last(Gs_0)
Where:
Gs_0=Iteration time step/Gs_0

Variable g_0 : Stomatal conductance in the dark (mol m^-2 s^-1)
g_0 = 0.01

Variable g_1 : Ball-Berry stomatal conductance coefficient
g_1 = 23

Equations in Iteration time step

Alarm
Variable Gs
Gs = if loop_count==0 then Gs_start else Gs_0
Where:
Gs_start=../Gs_start

ble Gs_0 : Stomatal conductance (mol m^-2 s^-1)
= g_0+g_1*A*H/C_a

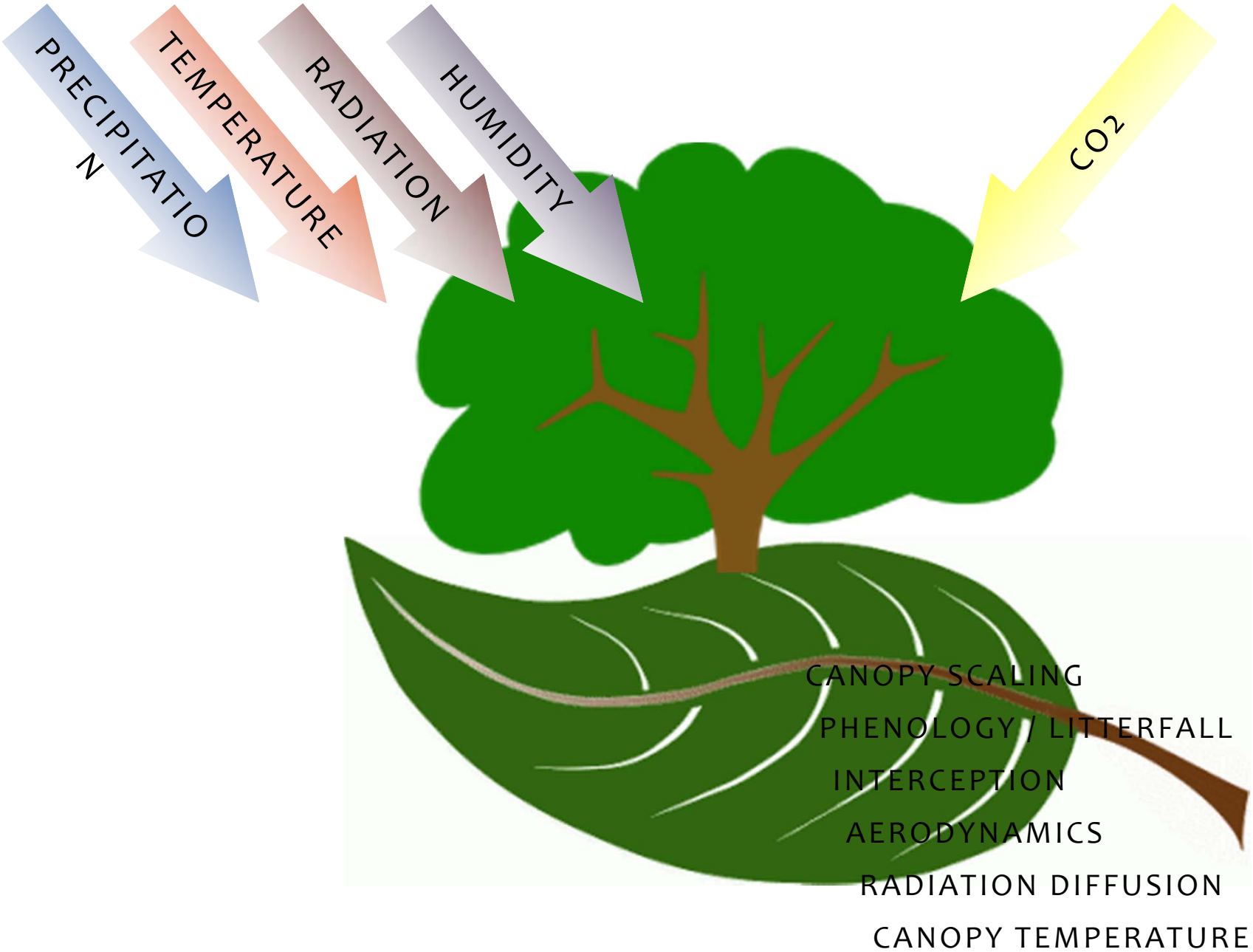
tion/A
nt/H
../Enviro /C_a
/g_0
../g_1
mments:
Ball-Berry equation

Variable loop_count
loop_count = iterations(al1)

Equations in Assimilation

Variable A : Assimation (umol CO2 m^-2 s^-1)
A = A_Q*Gs
Where:
Gs=../Gs

Variable A_Q : Assimilation light response curve
A_Q = graph(Q)
Where:
Q=../../../Environment/Q


PRECIPITATION
TEMPERATURE
RADIATION
HUMIDITY
CO2
CANOPY SCALING
PHENOLOGY / LITTERFALL
INTERCEPTION
AERODYNAMICS
RADIATION DIFFUSION
CANOPY TEMPERATURE

CANOPY SCALING

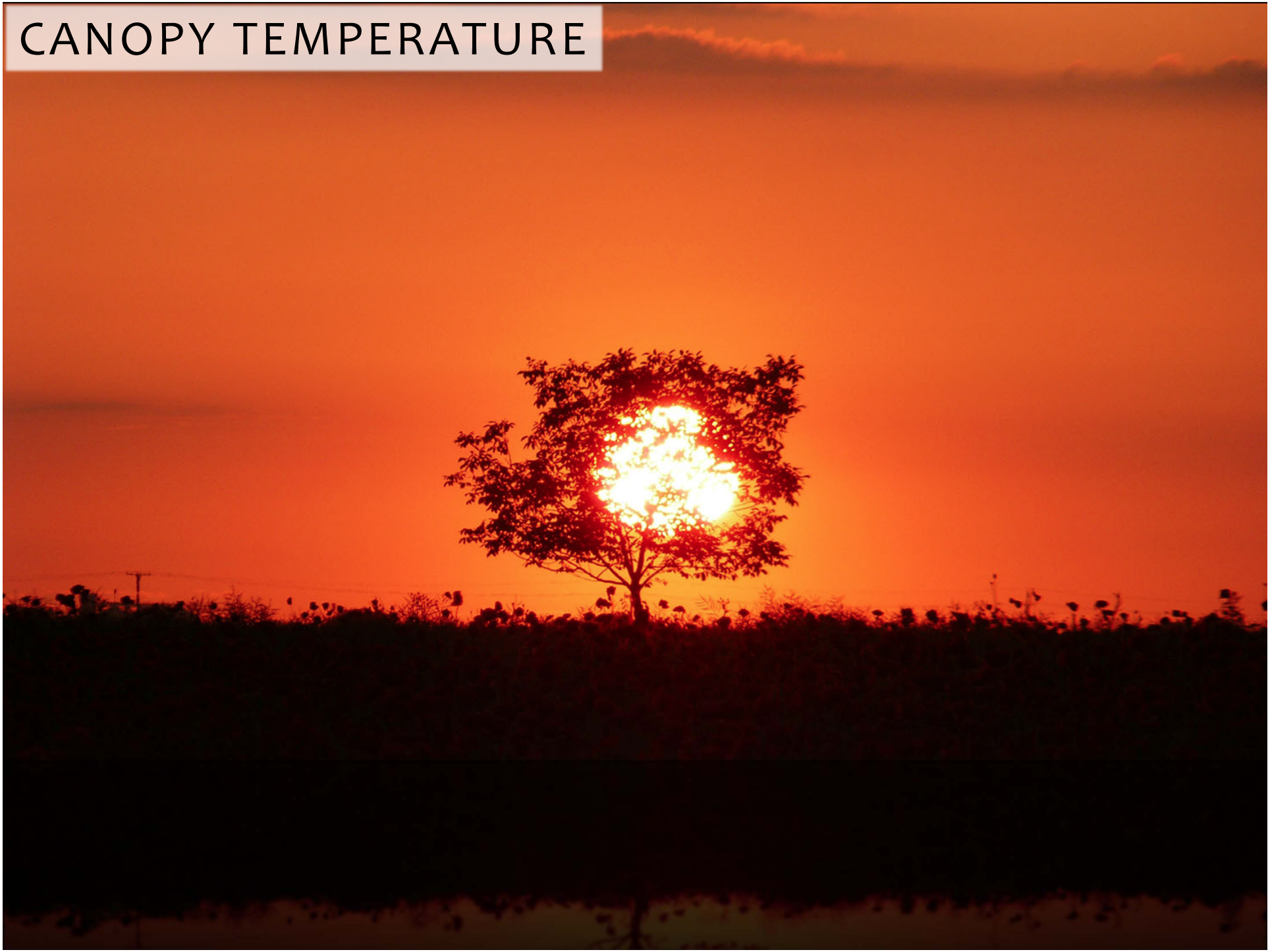
PHENOLOGY/LITTERFALL

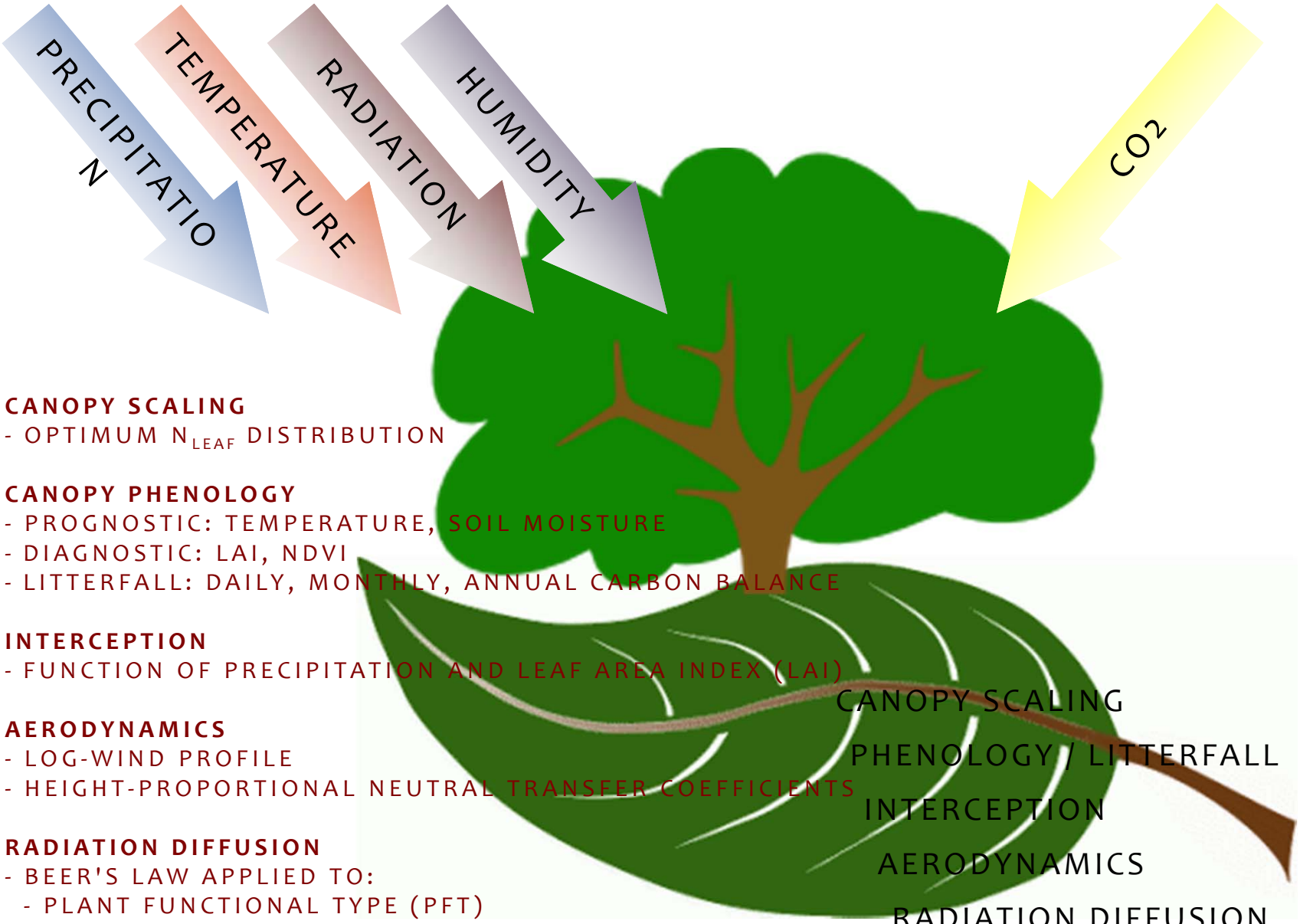
INTERCEPTION

AERODYNAMICS

RADIATION DIFFUSION

CANOPY TEMPERATURE





CANOPY SCALING
- OPTIMUM N_{LEAF} DISTRIBUTION

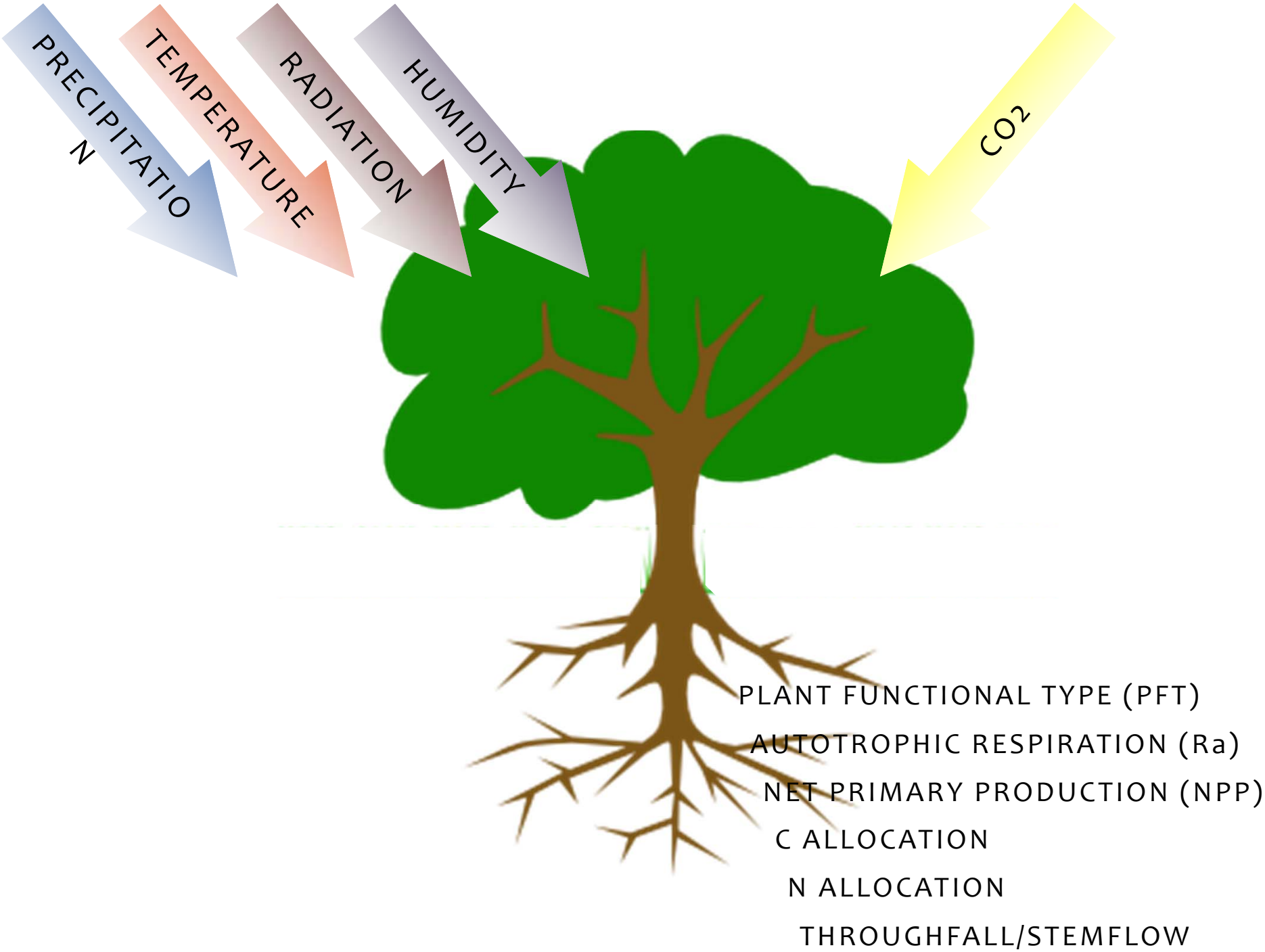
CANOPY PHENOLOGY
- PROGNOSTIC: TEMPERATURE, SOIL MOISTURE
- DIAGNOSTIC: LAI, NDVI
- LITTERFALL: DAILY, MONTHLY, ANNUAL CARBON BALANCE

INTERCEPTION
- FUNCTION OF PRECIPITATION AND LEAF AREA INDEX (LAI)

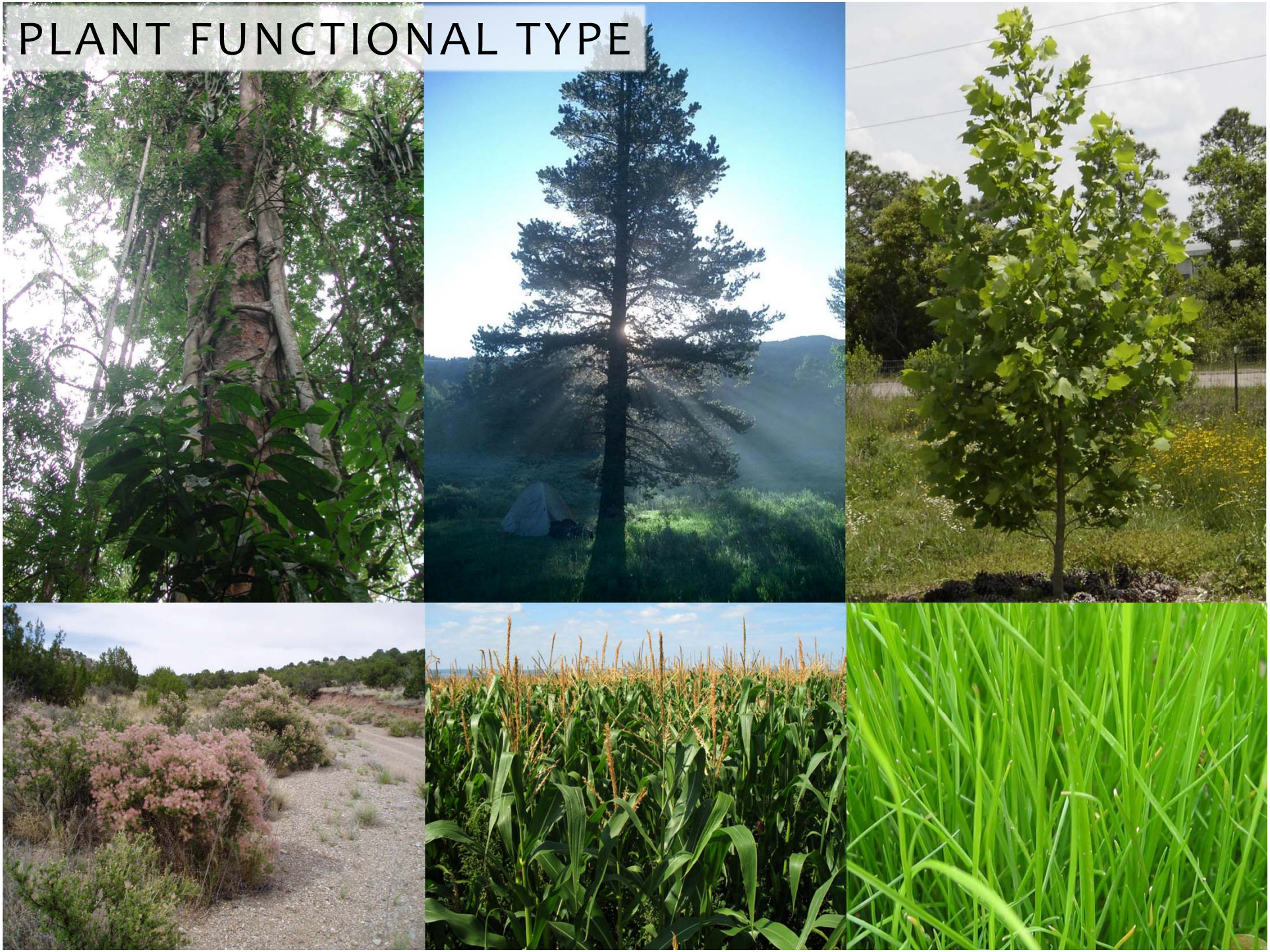
AERODYNAMICS
- LOG-WIND PROFILE
- HEIGHT-PROPORTIONAL NEUTRAL TRANSFER COEFFICIENTS

RADIATION DIFFUSION
- BEER'S LAW APPLIED TO:
  - PLANT FUNCTIONAL TYPE (PFT)
  - TOTAL VEGETATION
  - VEGETATION FRACTION

CANOPY TEMPERATURE
- ENERGY BALANCE


PRECIPITATION
TEMPERATURE
RADIATION
HUMIDITY
CO_2
PLANT FUNCTIONAL TYPE (PFT)
AUTOTROPHIC RESPIRATION (Ra)
NET PRIMARY PRODUCTION (NPP)
C ALLOCATION
N ALLOCATION
THROUGHFALL/STEMFLOW

PLANT FUNCTIONAL TYPE



AUTOTROPHIC RESPIRATION

NET PRIMARY PRODUCTION

C, N ALLOCATION

THROUGHFALL/STEMFLOW

PLANT FUNCTIONAL TYPE
- TREES EVERGREEN:
  - BROADLEAF EVERGREEN
  - TROPICAL BROADLEAF EVERGREEN
  - TEMPERATE BROADLEAF EVERGREEN
  - TEMPERATE NEEDLELEAF EVERGREEN
  - BOREAL NEEDLELEAF EVERGREEN
- TREES DECIDUOUS:
  - TROPICAL RAINGREEN
  - TEMPERATE SUMMERGREEN
  - BOREAL SUMMERGREEN
  - BROADLEAF DECIDUOUS
  - NEEDLELEAF DECIDUOUS
- GRASSES/FORBS:
  - C3 HERBACEOUS
  - C4 HERBACEOUS
  - DEPENDENT ON SOIL MOISTURE, CARBON BALANCE, CLIMATE ZONE
- SHRUBS

AUTOTROPHIC RESPIRATION (Ra)
- PRECIPITATION, AIR TEMPERATURE, RADIATION, HUMIDITY
- SOIL TEMPERATURE
- SOIL MOISTURE
- VEGETATION C
- GPP
- LEAF N
- FIPAR
- PROPORTIONAL TO GROWTH
- SAPWOOD RESPIRATION:
  - GIFFORD (1995)
  - LLOYD & TAYLOR (1994)
  - TEMPERATURE, MASS, C:N
  - Q10
- FINE ROOT RESPIRATION:
  - TEMPERATURE, C, N

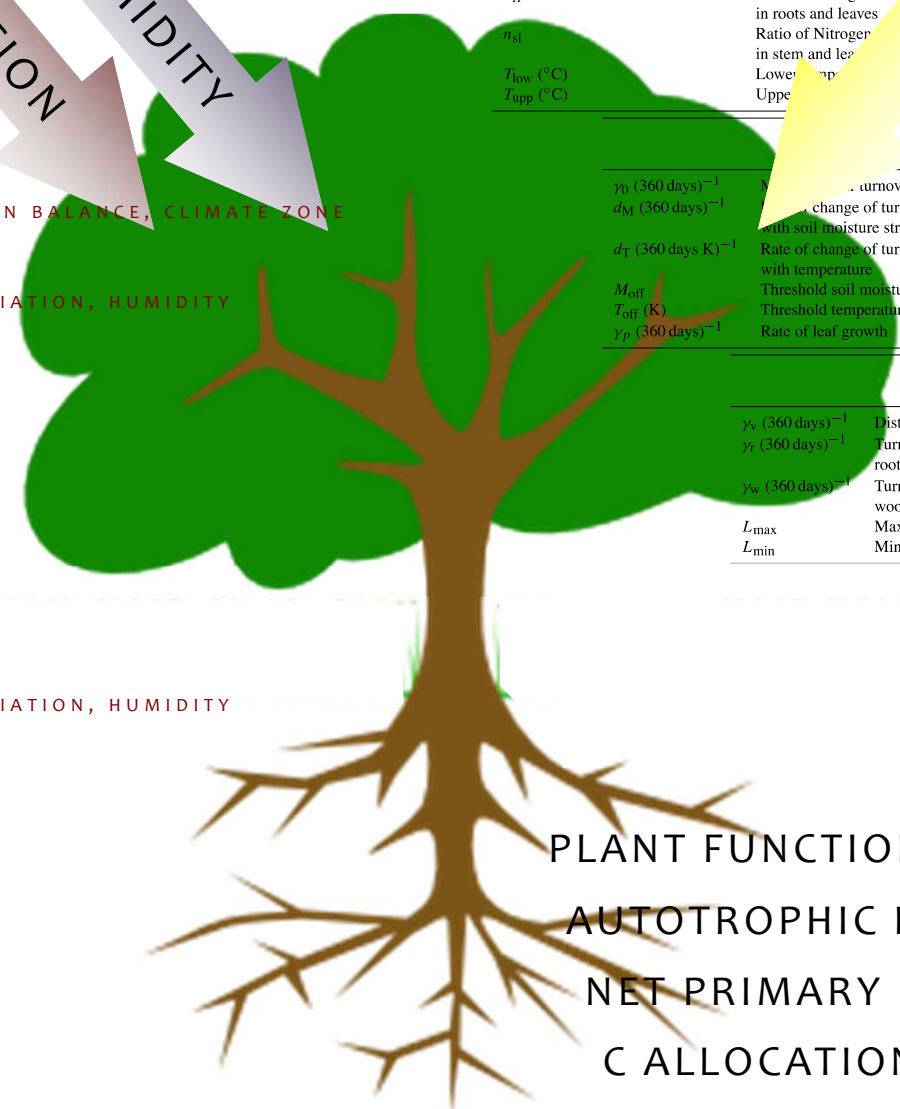
NET PRIMARY PRODUCTION (NPP)
- GPP MINUS Ra
- PRECIPITATION, AIR TEMPERATURE, RADIATION, HUMIDITY
- SOIL MOISTURE
- VEGETATION C
- GPP
- LEAF N
- FAPAR
- LAI
- CO2
- SOIL N
- POTENTIAL EVAPOTRANSPIRATION (PET)
- LIGHT USE EFFICIENCY

C ALLOCATION
- ALLOMETRIC RELATIONSHIPS
- RESOURCE OPTIMIZATION

N ALLOCATION
- FIXED C:N
- VARIABLE WITH LIGHT
- RESOURCE OPTIMIZATION

THROUGHFALL/STEMFLOW
- N/A

PRECIPITATION
TEMPERATURE
RADIATION
HUMIDITY
CO2



		Broadleaf tree	Needleleaf tree	C_3 grass	C_4 grass	Shrub
k	Extinction coefficient for PAR	[illegible]	0.50	0.50	0.50	0.50
α (mol CO_2 [mol PAR photons]$^{-1}$)	Quantum efficiency	[illegible]	0.08	0.12	0.060	0.08
ω	Leaf scattering coefficient for PA[illegible]	[illegible]	0.15	0.15	0.17	0.15
f_{dr}	Dark respiration coefficient	[illegible]	0.015	0.015	0.025	0.015
r_g	Growth respiration coefficie[illegible]	[illegible]	0.25	0.25	0.25	0.25
n_0 (kg N [kg C]$^{-1}$)	Top leaf Nitrogen concen[illegible]	[illegible]46	0.033	0.073	0.060	0.060
n_{rl}	Ratio of Nitrogen con[illegible] in roots and leaves	1.00	1.00	1.00	1.00	1.00
n_{sl}	Ratio of Nitrogen [illegible] in stem and lea[illegible]	0.10	0.10	1.00	1.00	0.10
T_{low} (°C)	Lowe[illegible]er	0.0	−10.0	0.0	13.0	0.0
T_{upp} (°C)	Uppe[illegible]eter	36.0	26.0	36.0	45.0	36.0

		Broadleaf tree	Needleleaf tree	C_3 grass	C_4 grass	Shrub
γ_0 (360 days)$^{-1}$	[illegible] turnover rate	0.25	0.25	0.25	0.25	0.25
d_M (360 days)$^{-1}$	[illegible] change of turnover with soil moisture stress	0.0	0.0	0.0	0.0	0.0
d_T (360 days K)$^{-1}$	Rate of change of turnover with temperature	9.0	9.0	9.0	9.0	9.0
M_{off}	Threshold soil moisture stress	0.00	0.00	0.00	0.00	0.00
T_{off} (K)	Threshold temperature	278.15	233.15	278.15	278.15	233.15
γ_p (360 days)$^{-1}$	Rate of leaf growth	15.00	20.00	20.00	20.00	20.00

		Broadleaf tree	Needleleaf tree	C_3 grass	C_4 grass	Shrub
γ_v (360 days)$^{-1}$	Disturbance rate	0.005	0.007	0.20	0.20	0.05
γ_r (360 days)$^{-1}$	Turnover rate for root biomass	0.25	0.15	0.25	0.25	0.25
γ_w (360 days)$^{-1}$	Turnover rate for woody biomass	0.005	0.005	0.20	0.20	0.05
L_{max}	Maximum LAI	9.00	5.00	4.00	4.00	3.00
L_{min}	Minimum LAI	1.00	1.00	1.00	1.00	1.00

PLANT FUNCTIONAL TYPE (PFT)

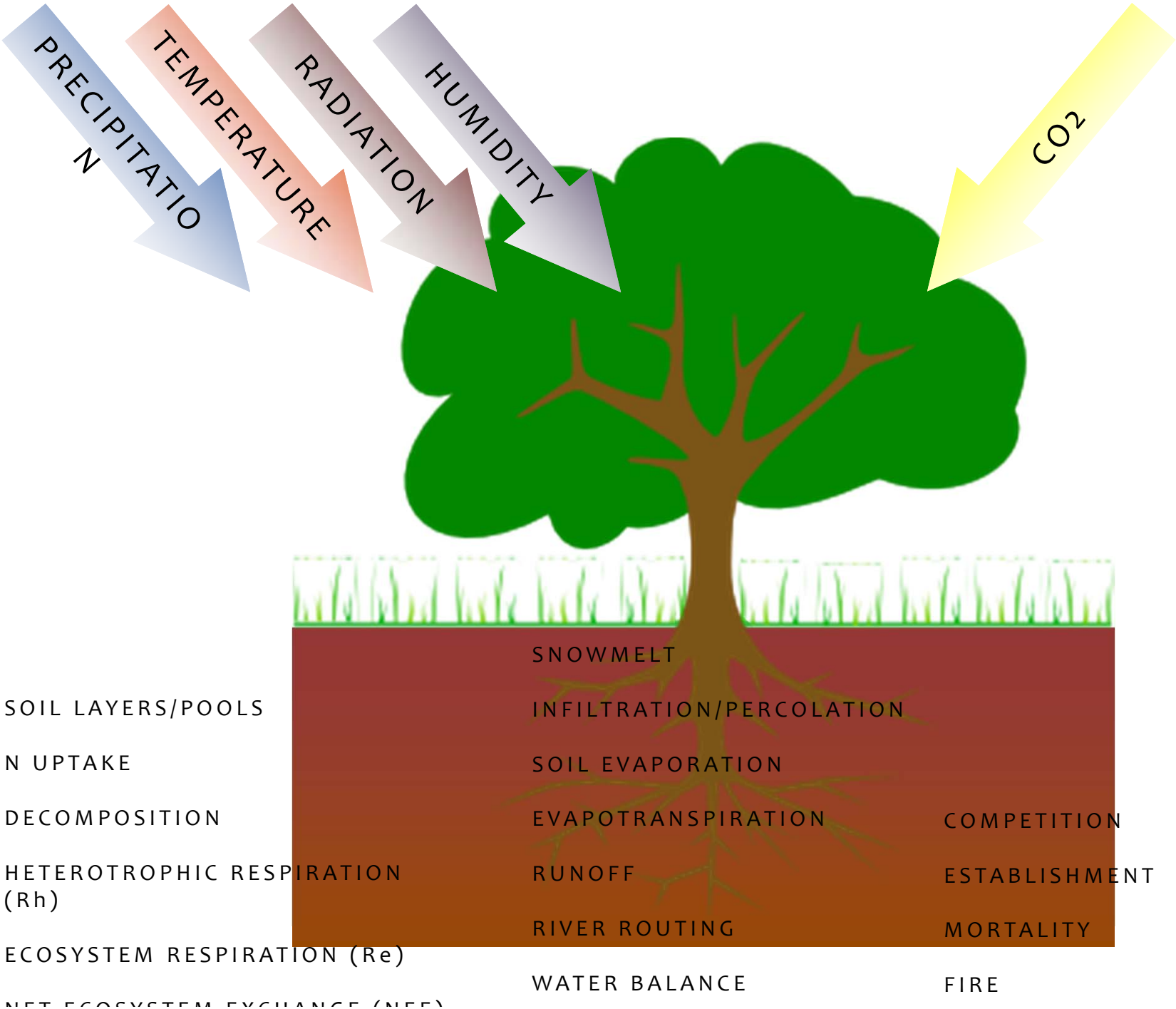
AUTOTROPHIC RESPIRATION (Ra)

NET PRIMARY PRODUCTION (NPP)

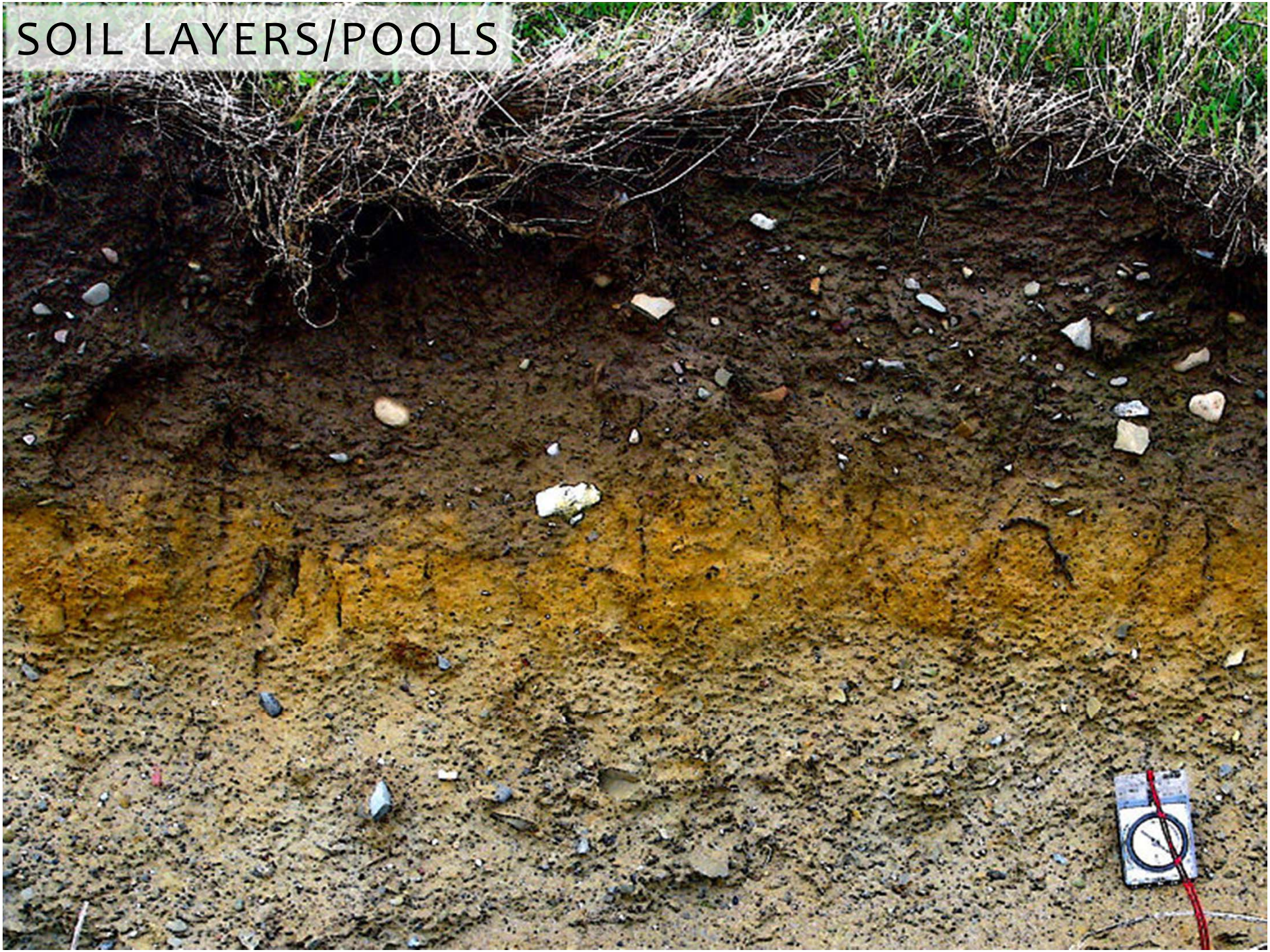
C ALLOCATION

N ALLOCATION

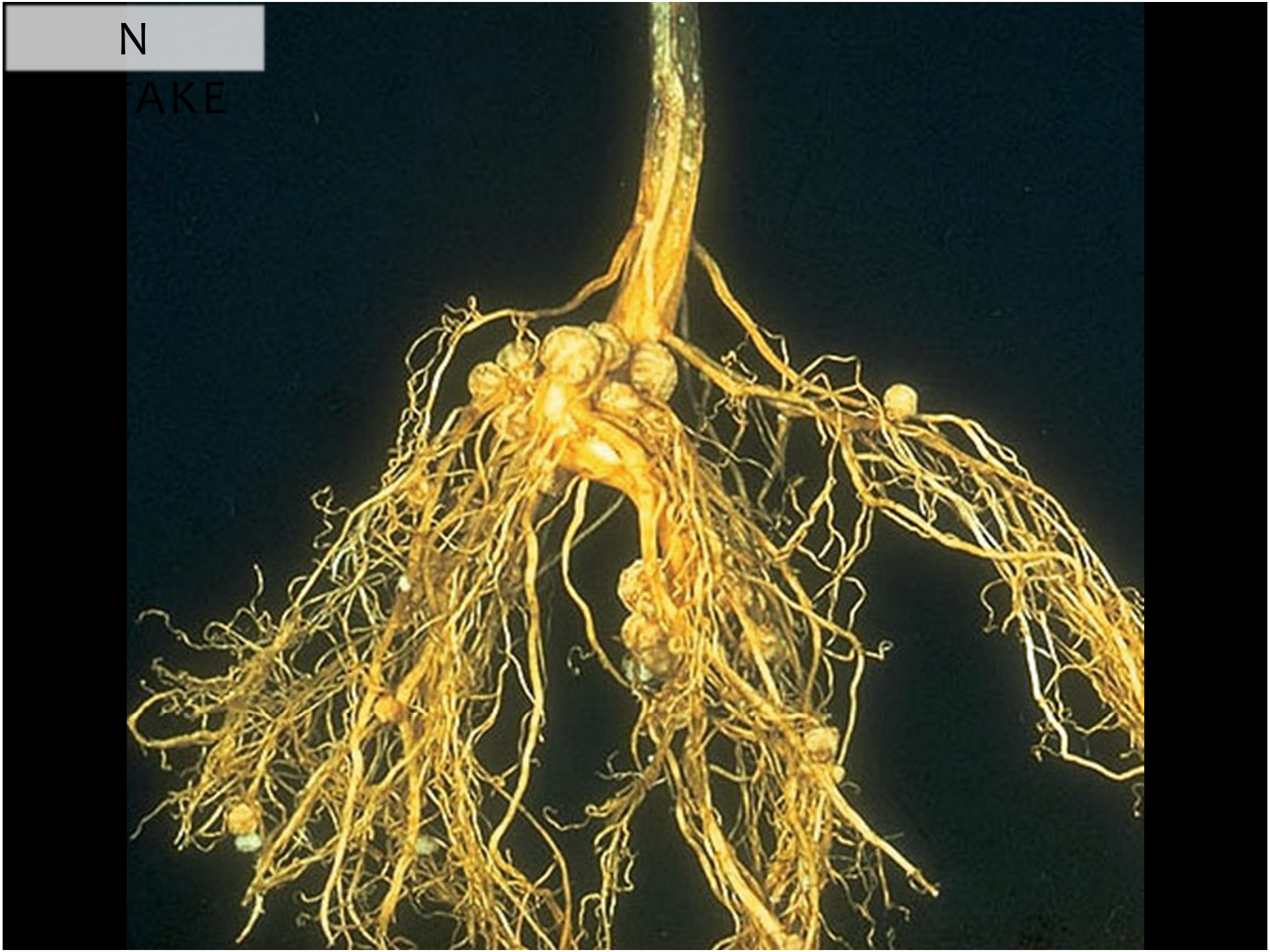
THROUGHFALL/STEMFLOW


PRECIPITATIO
N
TEMPERATURE
RADIATION
HUMIDITY
CO2
SOIL LAYERS/POOLS
N UPTAKE
DECOMPOSITION
HETEROTROPHIC RESPIRATION (Rh)
ECOSYSTEM RESPIRATION (Re)
SNOWMELT
INFILTRATION/PERCOLATION
SOIL EVAPORATION
EVAPOTRANSPIRATION
RUNOFF
RIVER ROUTING
WATER BALANCE
COMPETITION
ESTABLISHMENT
MORTALITY
FIRE

SOIL LAYERS/POOLS



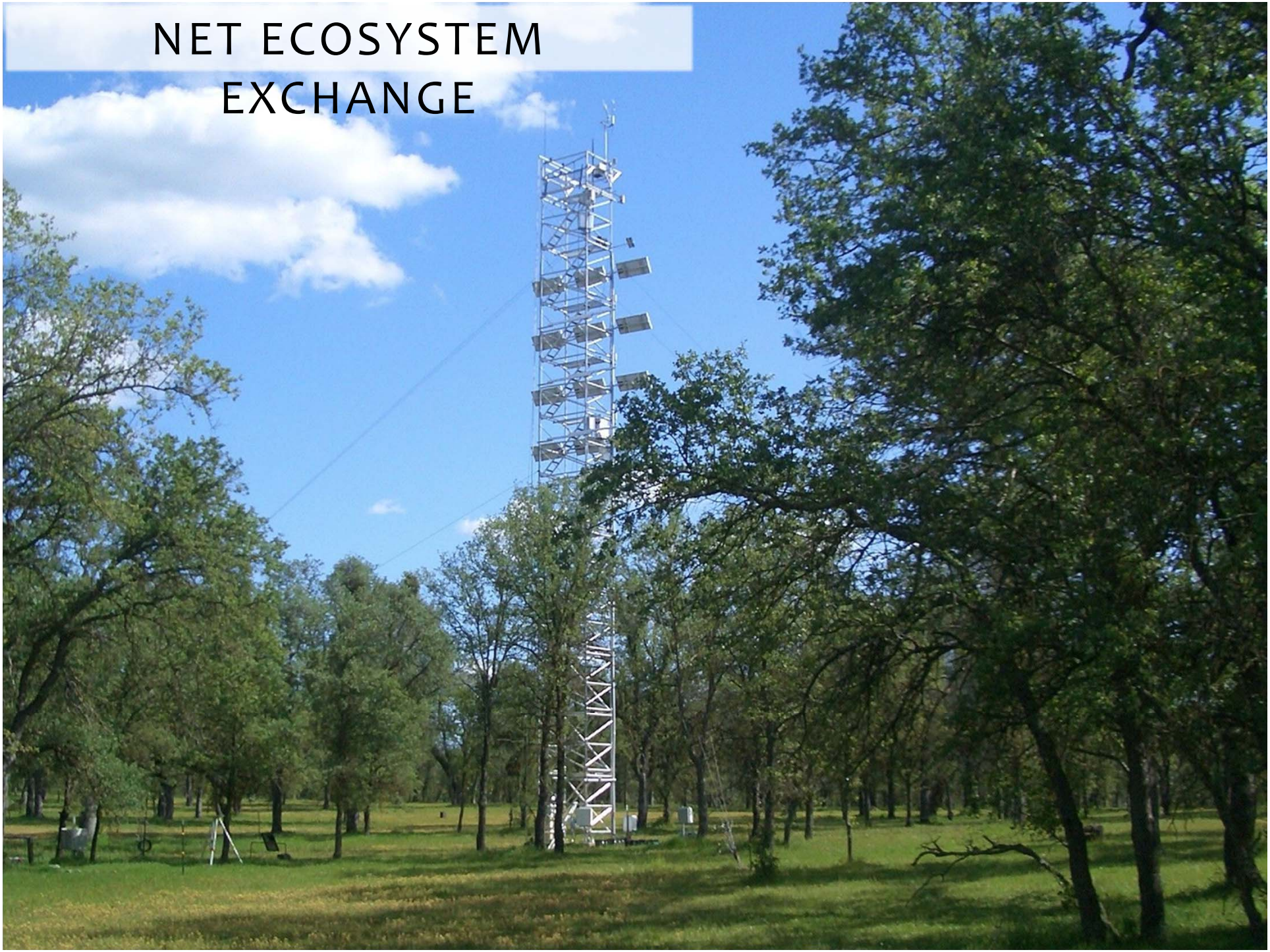
N TAKE



DECOMPOSITION

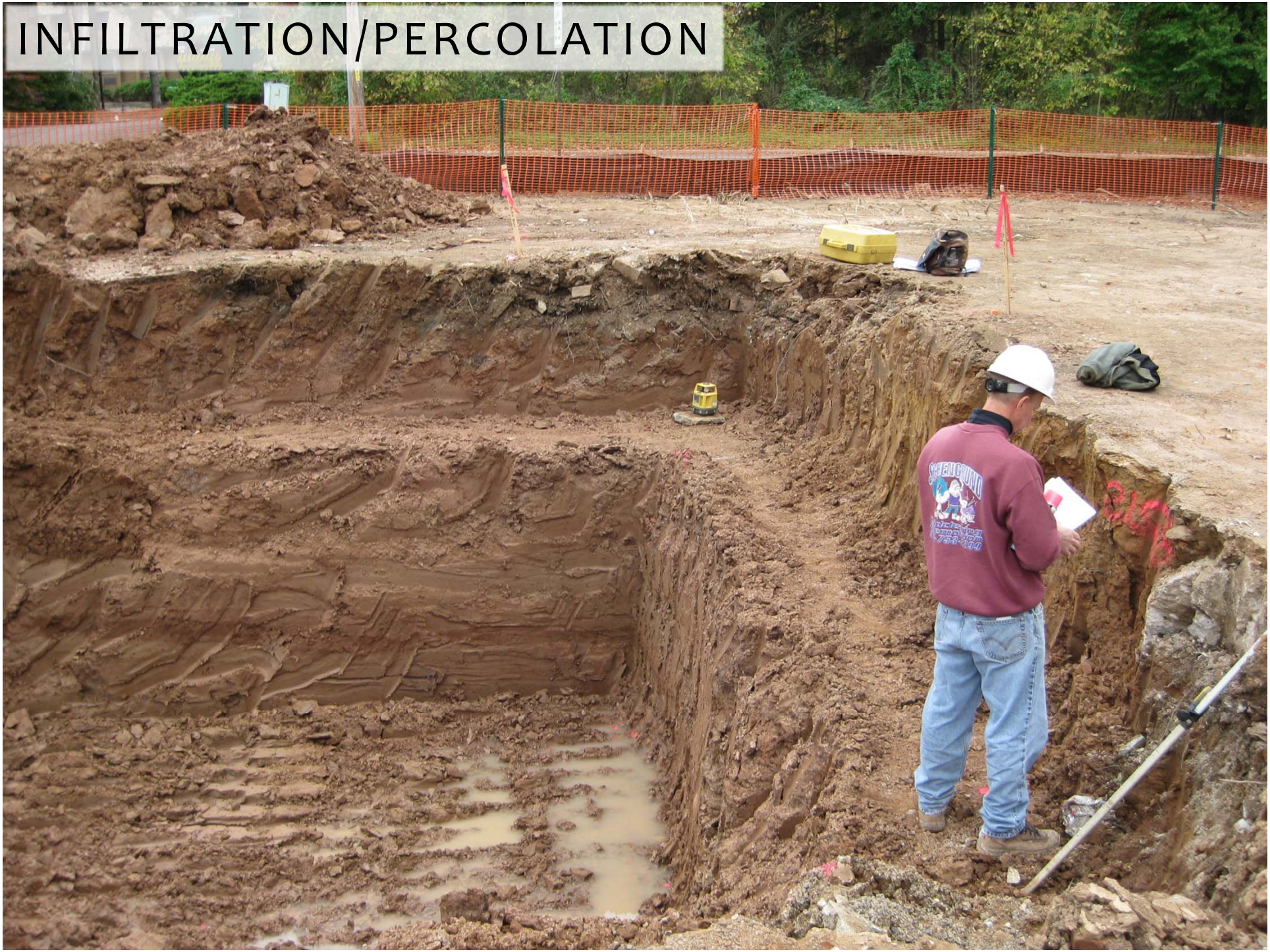
HETEROTROPHIC RESPIRATION

NET ECOSYSTEM EXCHANGE



SNOWMELT

INFILTRATION/PERCOLATION



SOIL EVAPORATION

EVAPOTRANSPIRATION

RUNOF
F

RIVER ROUTING

WATER BALANCE

COMPETITION

ESTABLISHMENT

MORTALITY

FIR
E

SOIL LAYERS
- 2-14

SOIL POOLS
- 0-15

N UPTAKE
- Resource optimization
- At demand
- Soil C, N decomposition, soil T, moisture

DECOMPOSITION
- CENTURY
- Parton et al (1988)

HETEROTROPHIC RESPIRATION (Rh)
- Zero-order Model
- First or Greater Order Model
- Air temperature, soil temperature, precipitation, soil moisture, ET, soil carbon, soil N
- CO_2 diffusion, dissolved C loss, vegetation C, leaf N, radiation

ECOSYSTEM RESPIRATION (Re)
- Ra+Rh
- Air temperature, soil temperature, soil moisture, soil carbon, vegetation carbon, LAI
- Forced annual balance

NET ECOSYSTEM EXCHANGE (NEE)
- NPP-Rh
- Soil temperature, soil moisture, radiation, VPD
- GPP-Re

SNOWMELT
- Temperature
- Energy balance
- Degree-day
- Coughlan & Running (1997)
- Walko et al (2000)
- Hansen et al (1983)
- Ito & Oikawa (2002)

INFILTRATION/PERCOLATION
- All; upward movement when wilting point is reached in a soil layer
- Uniform soil porosity
- Green-Ampt
- Time derivative from rain and snow
- Soil texture, organic matter content, soil thickness
- Root zone water storage<Field capacity
- P-ETi-ETs

SOIL EVAPORATION
- Scheiter & Higgins (2009)
- Priestley-Taylor (1972)
- Campbell (1977)
- Bonan (1979)
- Oleson et al (2010)
- Soil moisture, humidity, surface resistance, PET
- Mahfouf & Noilhan (1991)
- Huang et al (1996)
- Monteith & Unsworth (1990)
- Deardorff (1972)

EVAPOTRANSPIRATION
- Penman-Monteith

RUNOFF
- >Field capacity
- >Saturated water content
- Beven & Kirkby (1979)
- Pollard & Thompson (1995)

RIVER ROUTING
- None
- Variable velocity routing
- River Transport Model

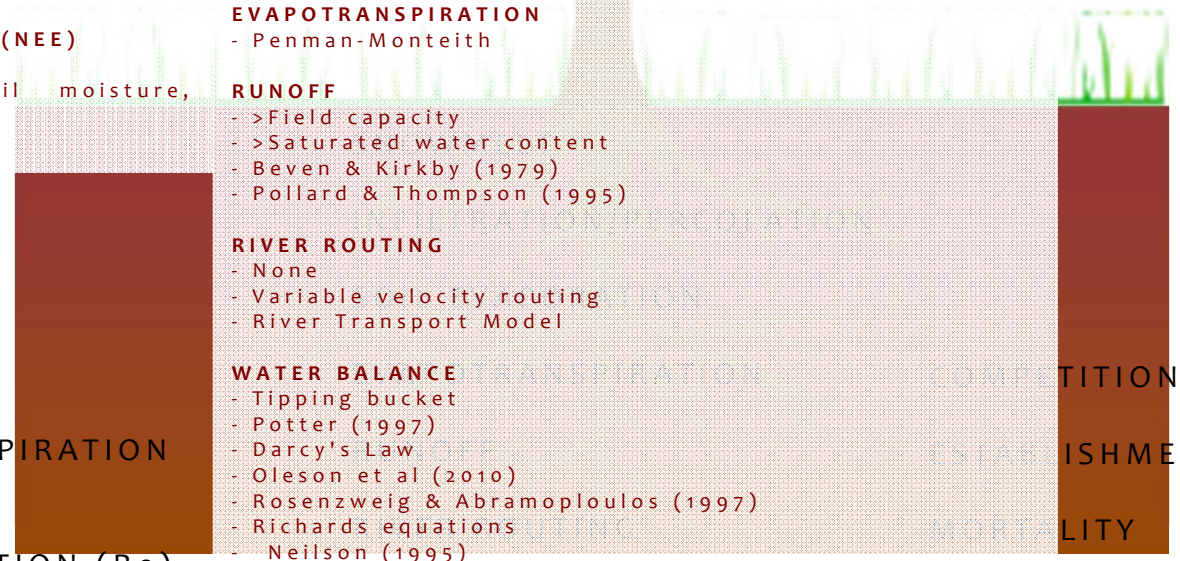
WATER BALANCE
- Tipping bucket
- Potter (1997)
- Darcy's Law
- Oleson et al (2010)
- Rosenzweig & Abramoploulos (1997)
- Richards equations
- Neilson (1995)

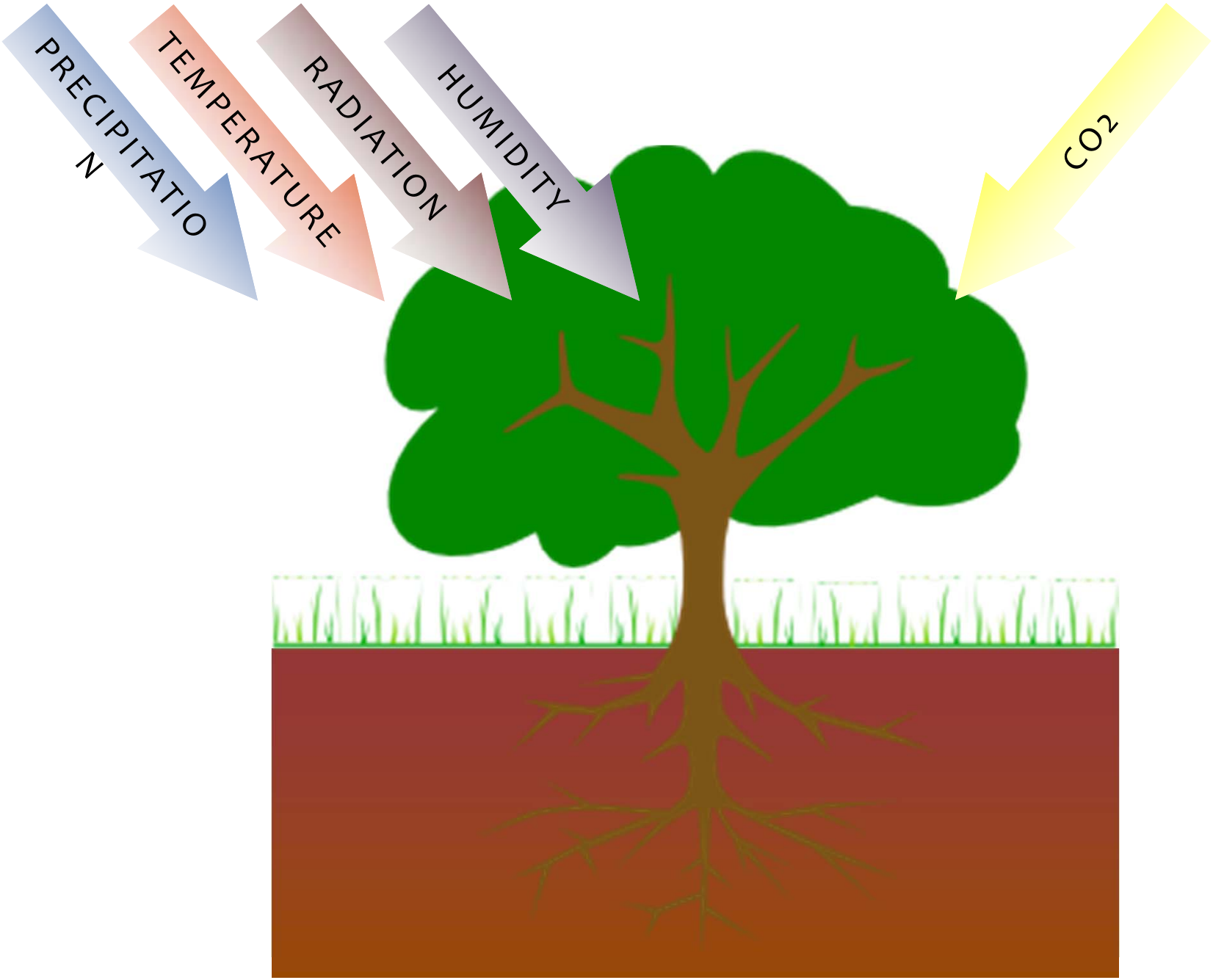
COMPETITION
- Light
- Water

ESTABLISHMENT
- Uniform
- Climatically favored PFTs establish in proportion to area available

MORTALITY
- Carbon pools
- Deterministic baseline; prescribed per PFT
- Fire
- Extreme temperatures
- Wind throw

FIRE
- No/yes




PRECIPITATION
TEMPERATURE
RADIATION
HUMIDITY
CO_2

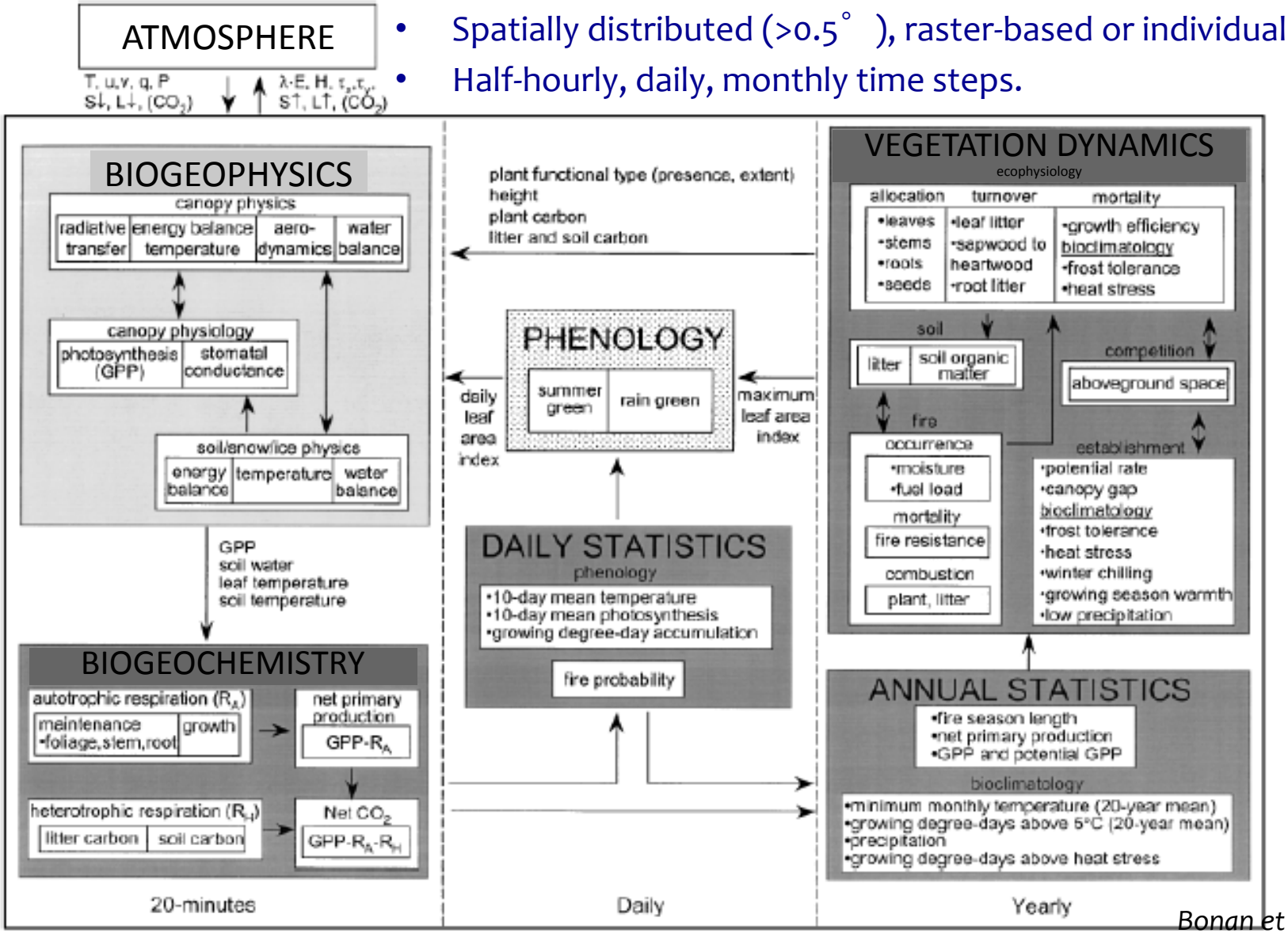
STOMATAL CONDUCTANCE
PHOTOSYNTHESIS → GROSS PRIMARY PRODUCTION (GPP)
TRANSPIRATION
PLANT FUNCTIONAL TYPE (PFT)
AUTOTROPHIC RESPIRATION (Ra)
NET PRIMARY PRODUCTION (NPP)
C ALLOCATION
N ALLOCATION
STEMFLOW
CANOPY SCALING
PHENOLOGY / LITTERFALL
INTERCEPTION
AERODYNAMICS
RADIATION DIFFUSION
CANOPY TEMPERATURE
SNOWMELT
SOIL LAYERS/POOLS
INFILTRATION/PERCOLATION
N UPTAKE
SOIL EVAPORATION
DECOMPOSITION
EVAPOTRANSPIRATION
COMPETITION
HETEROTROPHIC RESPIRATION (Rh)
RUNOFF
ESTABLISHMENT
RIVER ROUTING
MORTALITY
ECOSYSTEM RESPIRATION (Re)
WATER BALANCE
FIRE

PROCESSES NOT GENERALLY INCLUDED

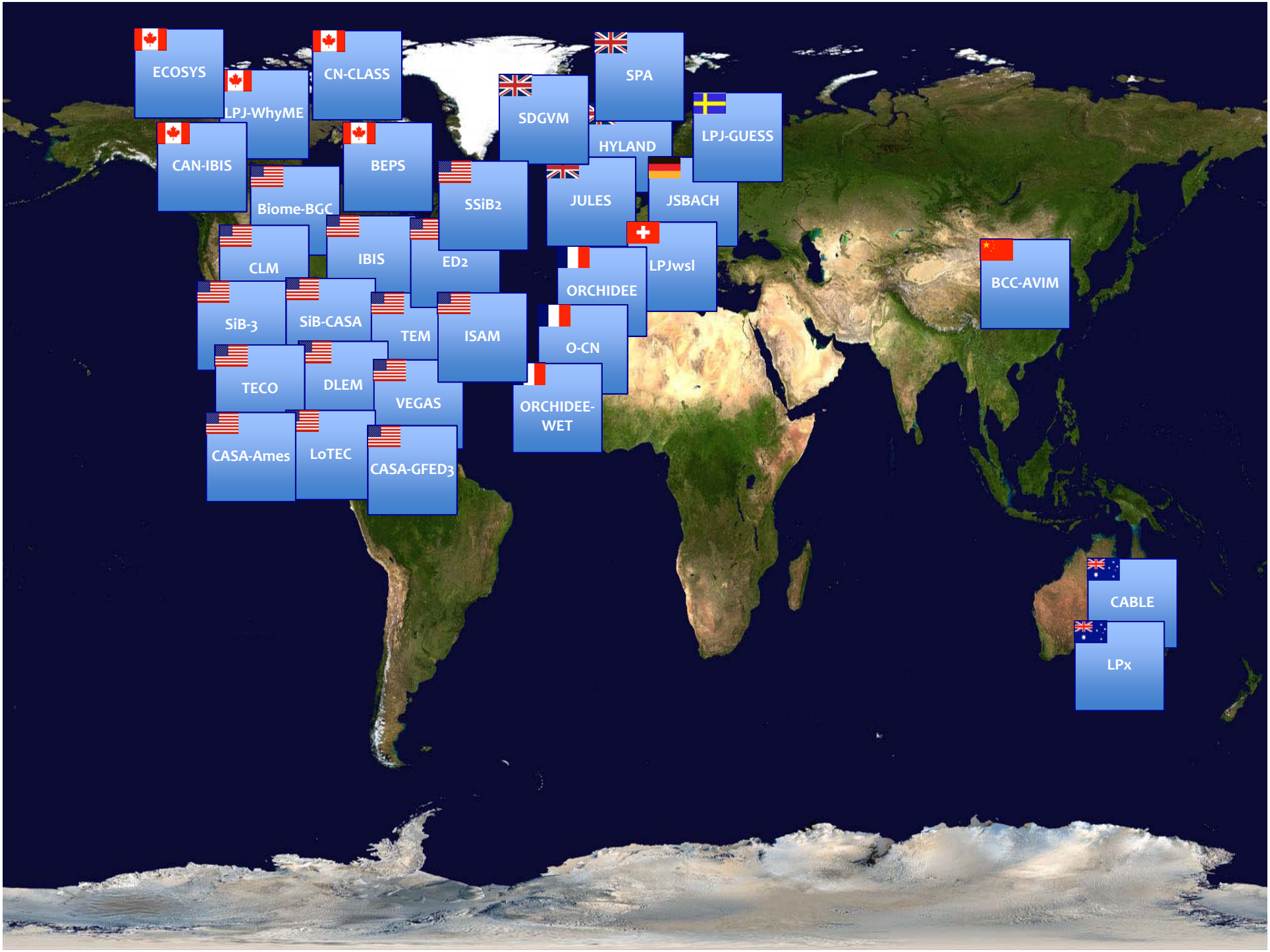
- Fire
- CH_4
- N_2O
- Mycorrhizae
- Hydraulic redistribution
- Drought-induced mortality
- Plant community dynamics
- Nutrient limitation (N, P, …)
- Land use change/deforestation
- Thermal acclimation of respiration
- Thermal acclimation of photosynthesis
- High CO_2 acclimation of photosynthesis
- Autotrophic respiration sensitivity to drought

ARCHITECTURE

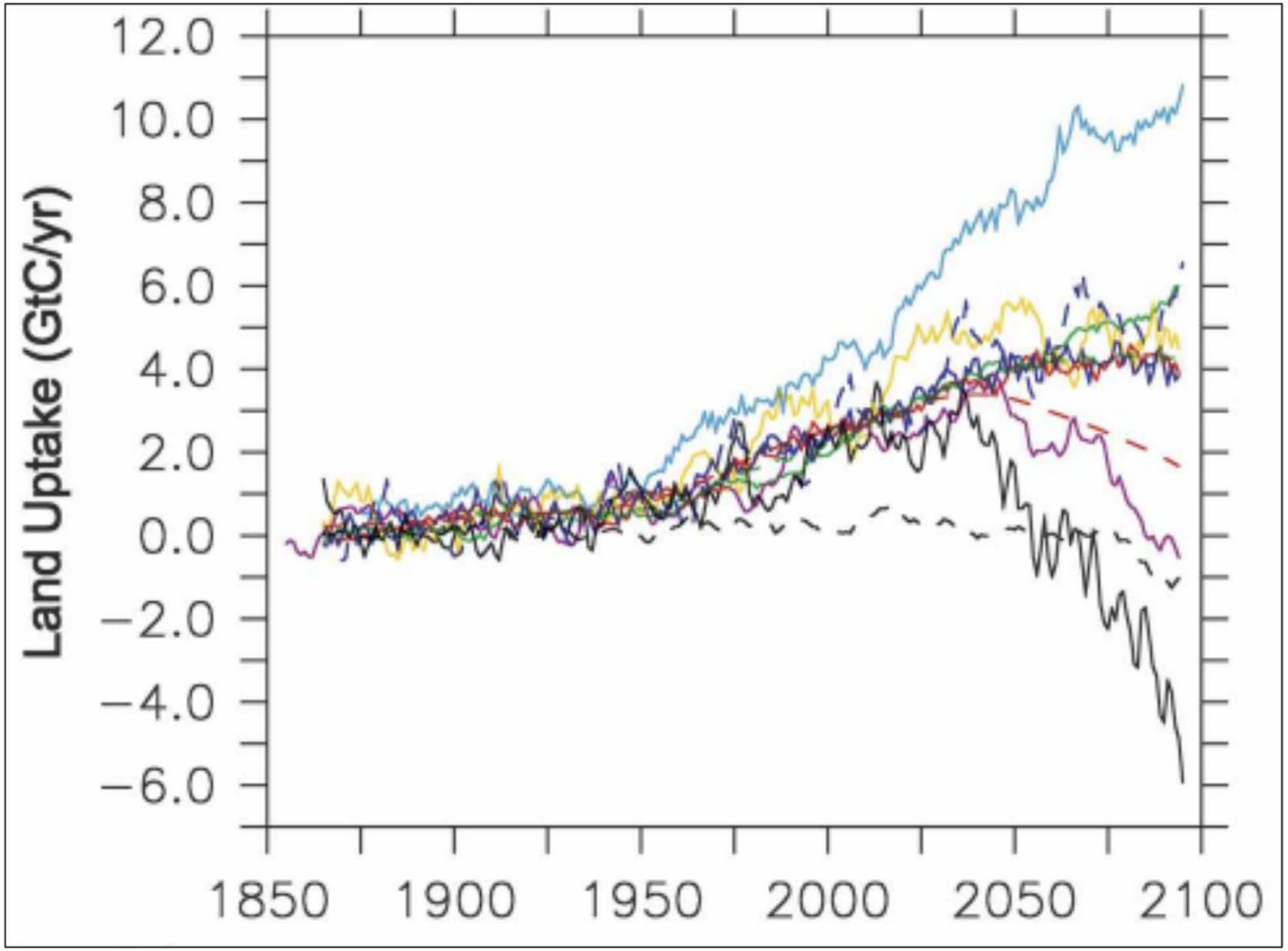
- Spatially distributed (>0.5°), raster-based or individual site.
- Half-hourly, daily, monthly time steps.



Bonan et al. 2003


ECOSYS
LPJ-WhyME
CN-CLASS
CAN-IBIS
BEPS
Biome-BGC
SDGVM
SPA
HYLAND
LPJ-GUESS
SSiB2
JULES
JSBACH
CLM
IBIS
ED2
ORCHIDEE
LPJwsl
BCC-AVIM
SiB-3
SiB-CASA
TEM
ISAM
O-CN
TECO
DLEM
VEGAS
ORCHIDEE-WET
CASA-Ames
LoTEC
CASA-GFED3
CABLE
LPx

INTERCOMPARISON



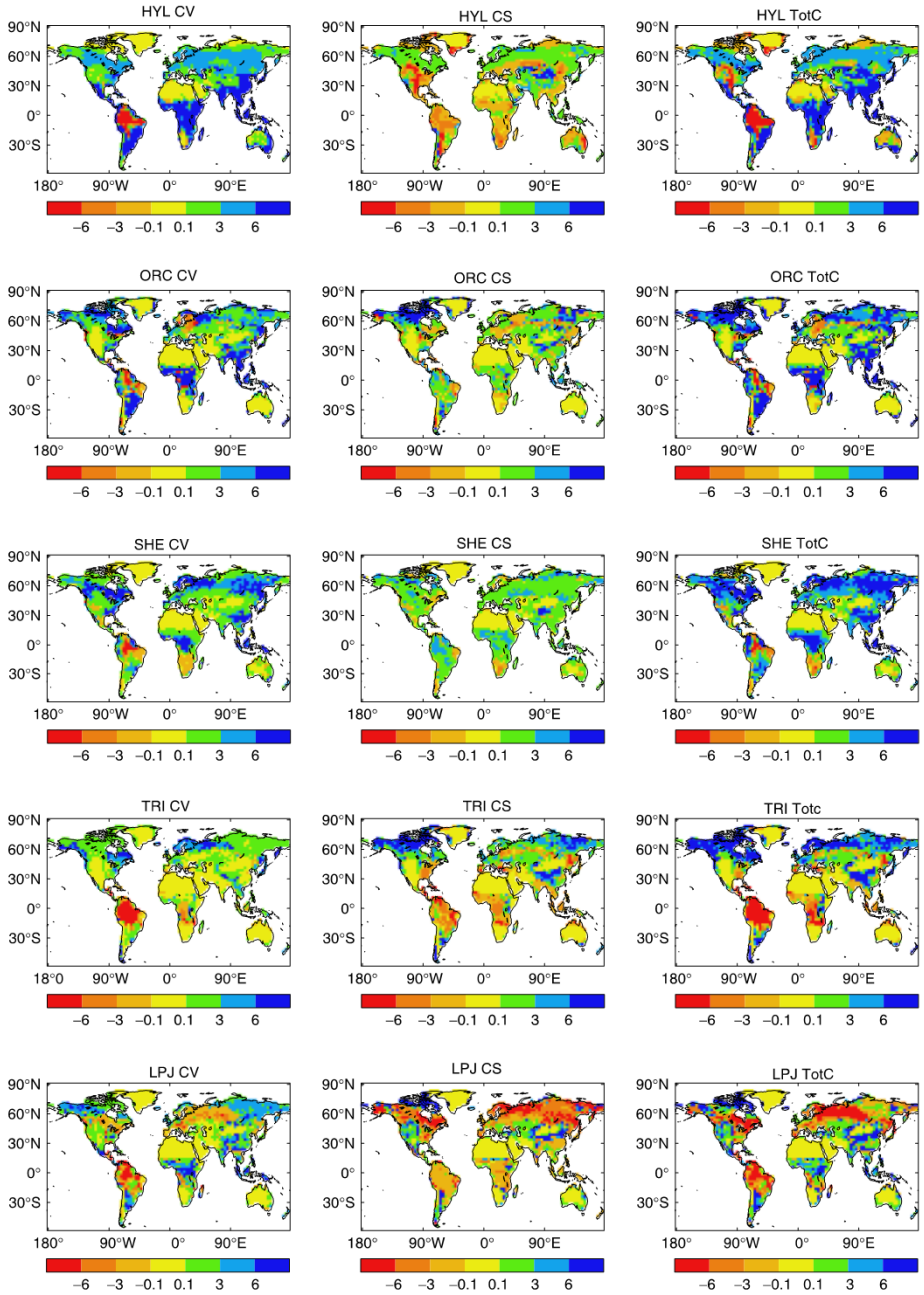


Fig. 7 Change in land carbon storage (TotC) and component vegetation (CV) and soils (CS) carbon stocks between 1860 and 2099 from the coupled climate-carbon cycle simulation under Special Report Emission Scenarios (SRES) emission scenario A1F1 (units are Pg C) for HyLand (HYL), Lund–Potsdam–Jena (LPJ), ORCHIDEE (ORC), Sheffield (SHE) and TRIFFID (TRI).

NACP REGIONAL SYNTHESIS

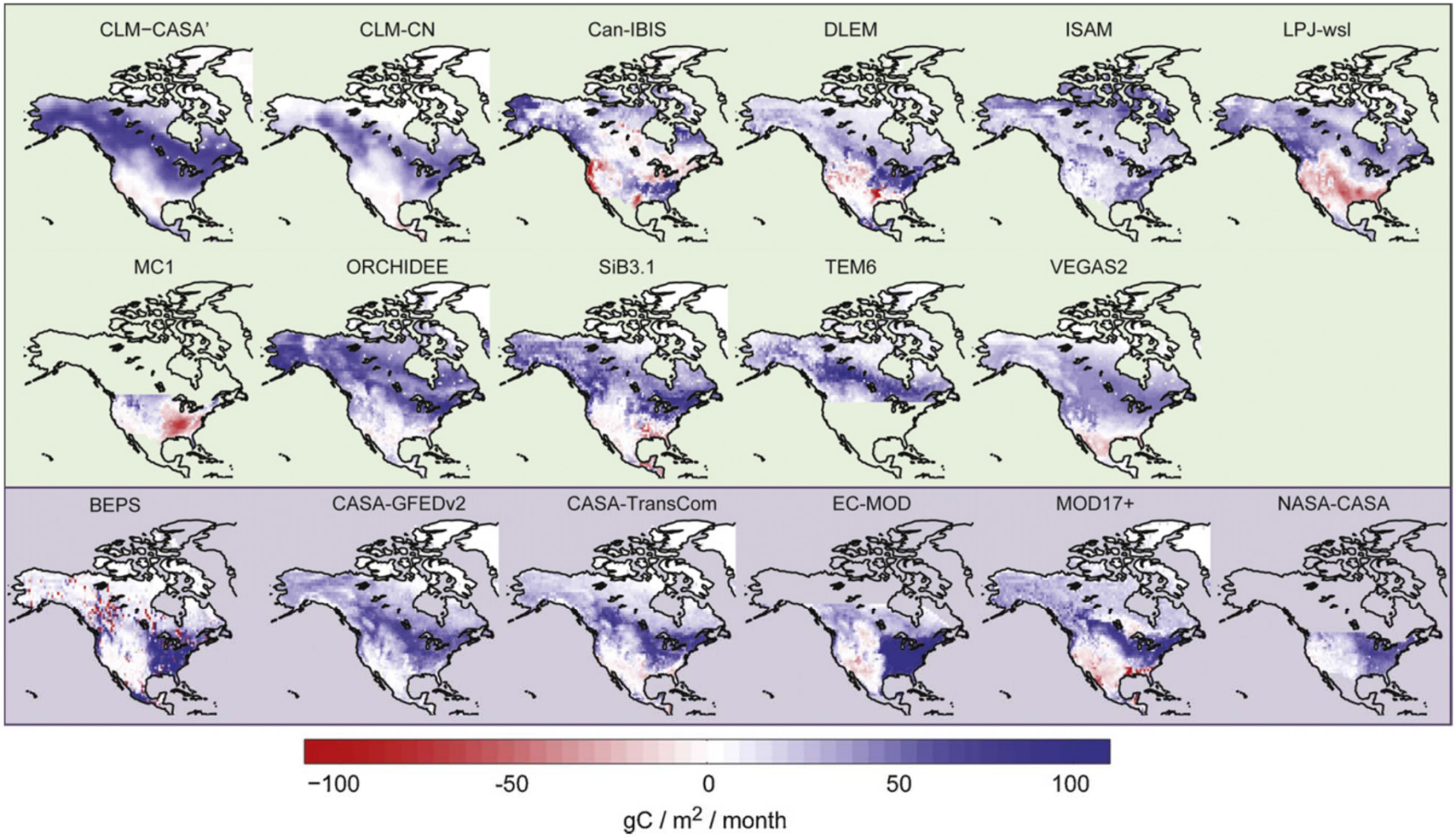


Fig. 1. Long-term mean summer (June, July, August) net ecosystem productivity by model (2000–2005). A positive sign indicates net terrestrial carbon uptake from the atmosphere, while a negative sign signifies net carbon release to the atmosphere. Prognostic models are shown above with a green background; diagnostic models are below with a purple background.

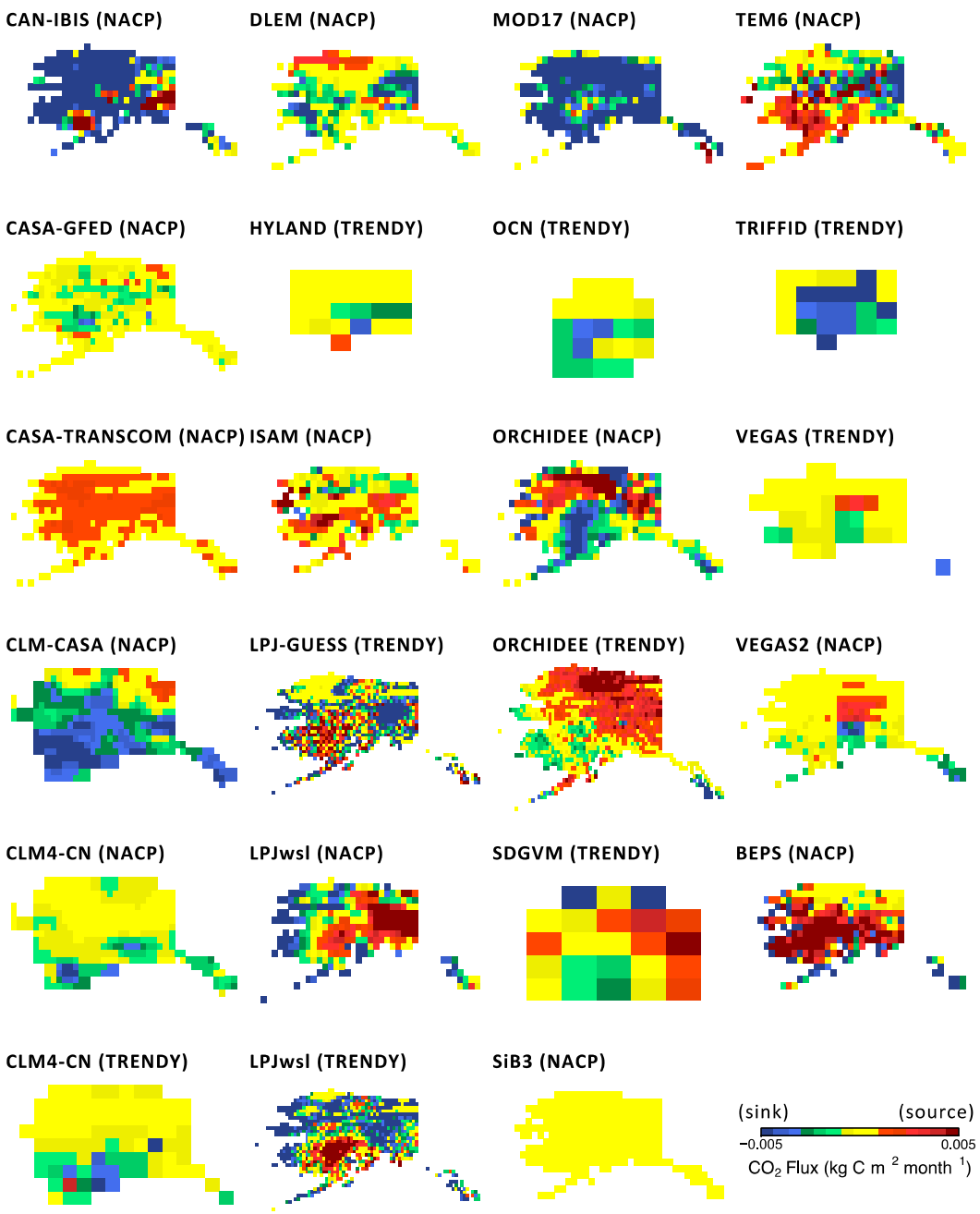
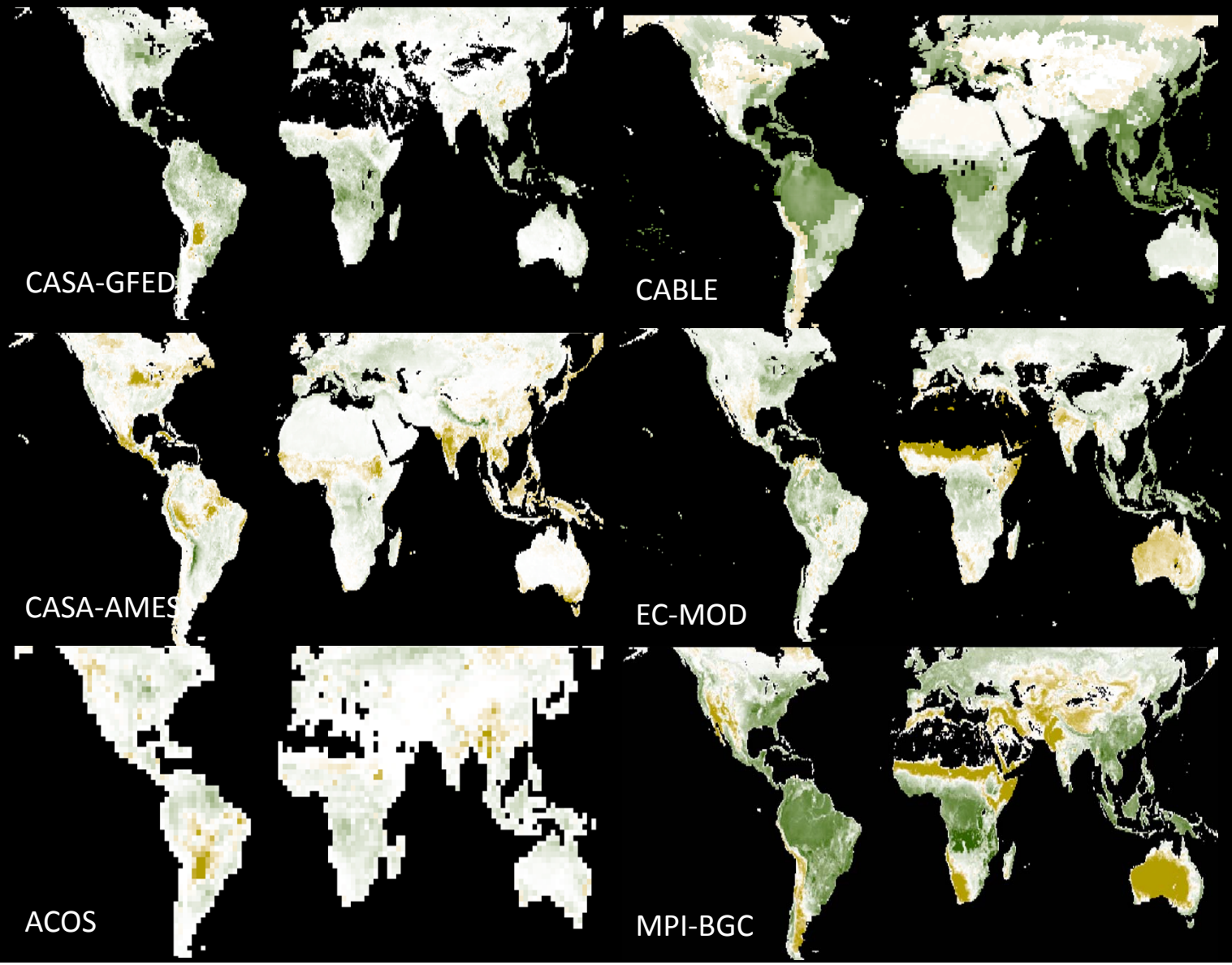


Figure 3. Mean annual net CO_2 flux for Alaska for 2003. Model output was part of the TRENDY (common forcing) and NACP Regional (variable forcing) syntheses.

CMS NEE



BENCH-MARKING

C-LAMP

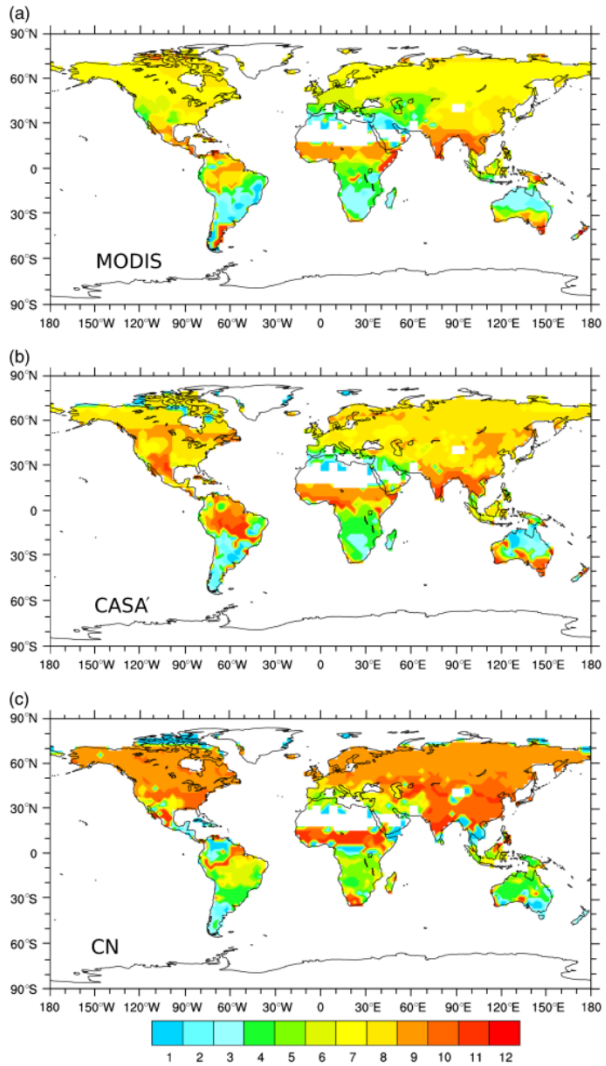
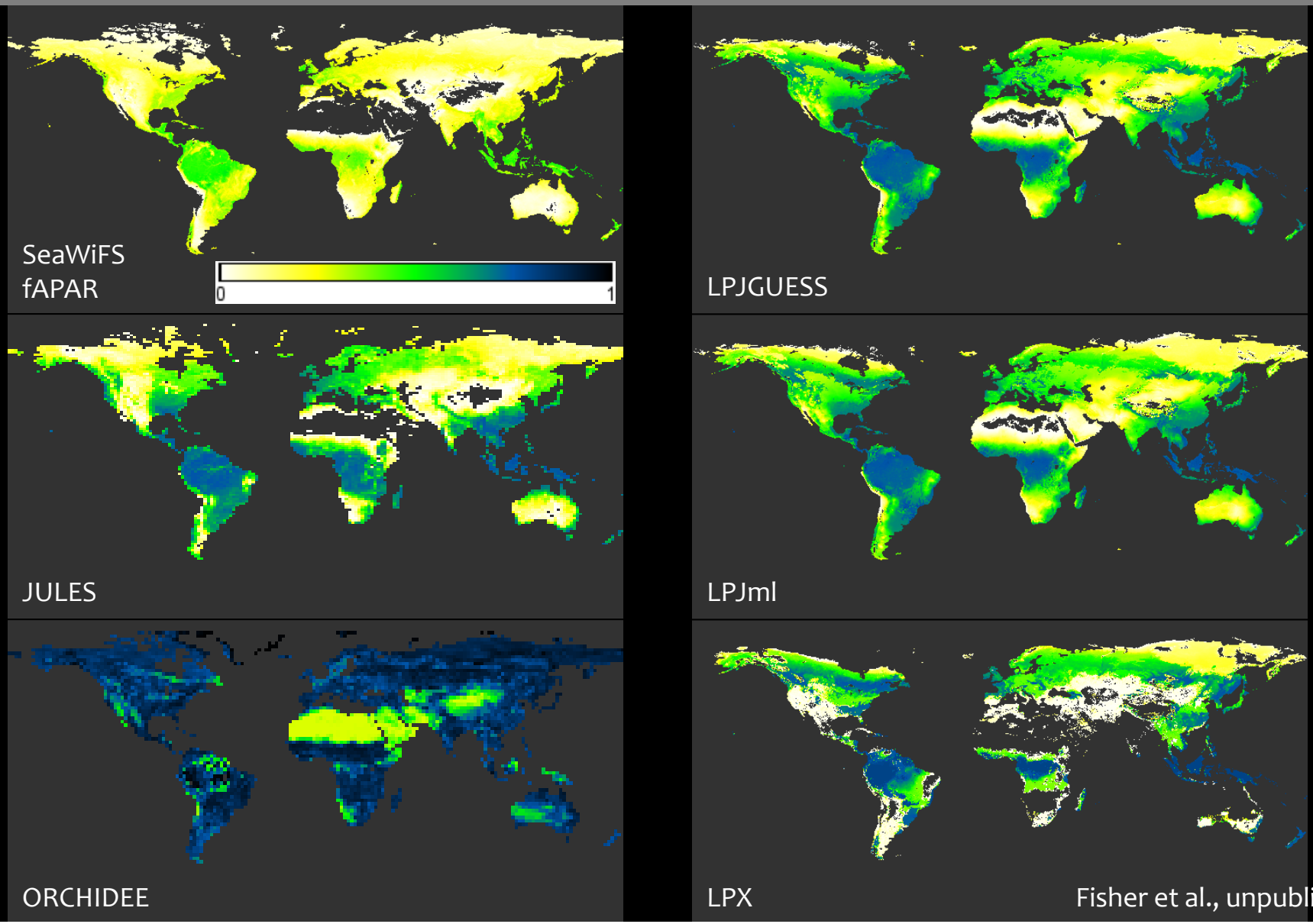
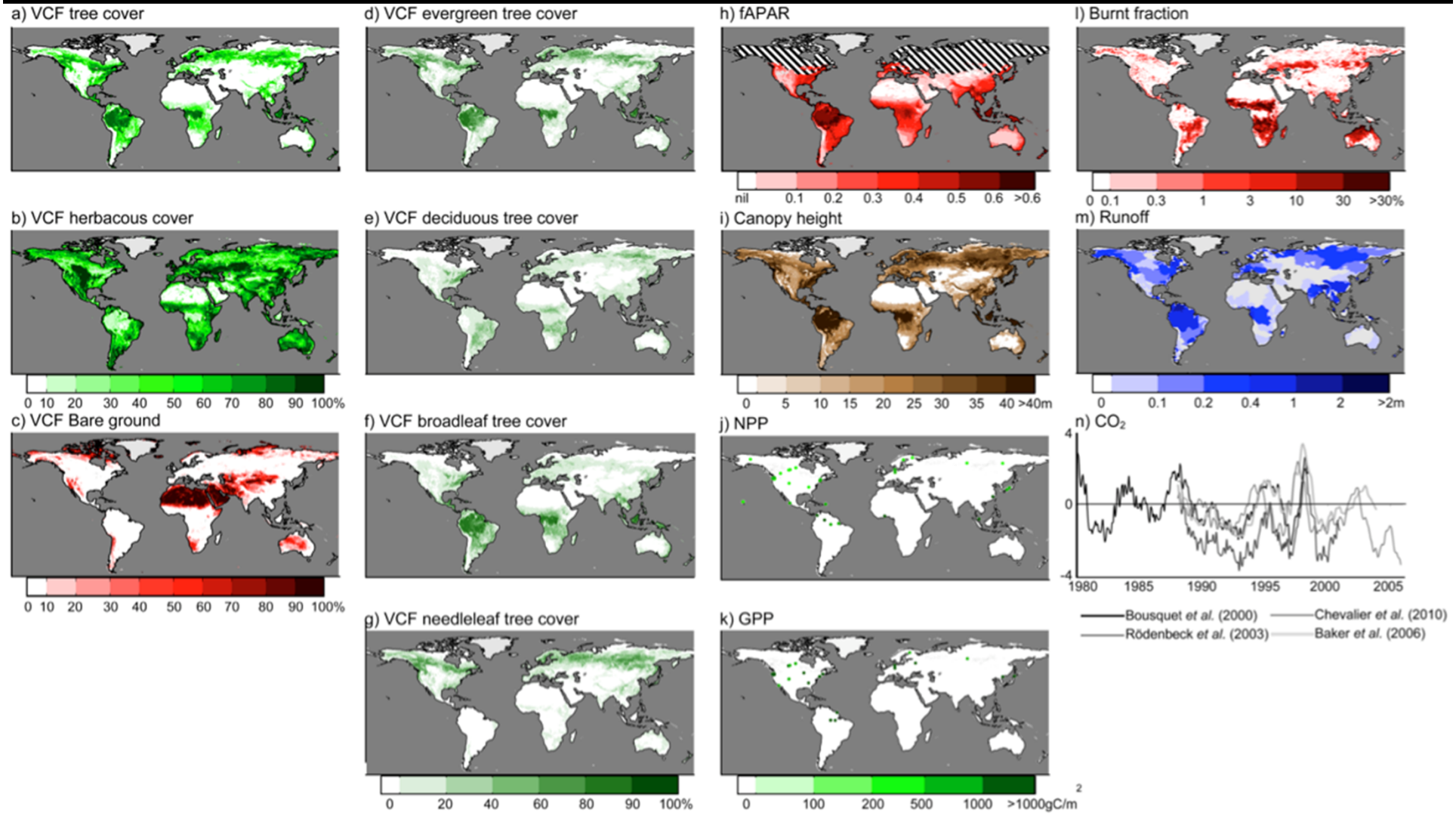


Fig. 1 Month of maximum leaf area index from (a) MODIS, (b) CASA′, and (c) CN. The observations are from the MOD15A2 collection 4 LAI product from MODIS (Myneni *et al.*, 2002) with additional adjustments to interpolate across periods of cloud contamination as described by Zhao *et al.* (2005). CASA, Carnegie-Ames-Stanford Approach; CN, carbon–nitrogen; LAI, leaf area index; MODIS, MODerate Resolution Imaging Spectroradiometer.

ENSEMBLES – FAPAR



Fisher et al., unpublished



Kelley et al., in review

NACP SITE SYNTHESIS

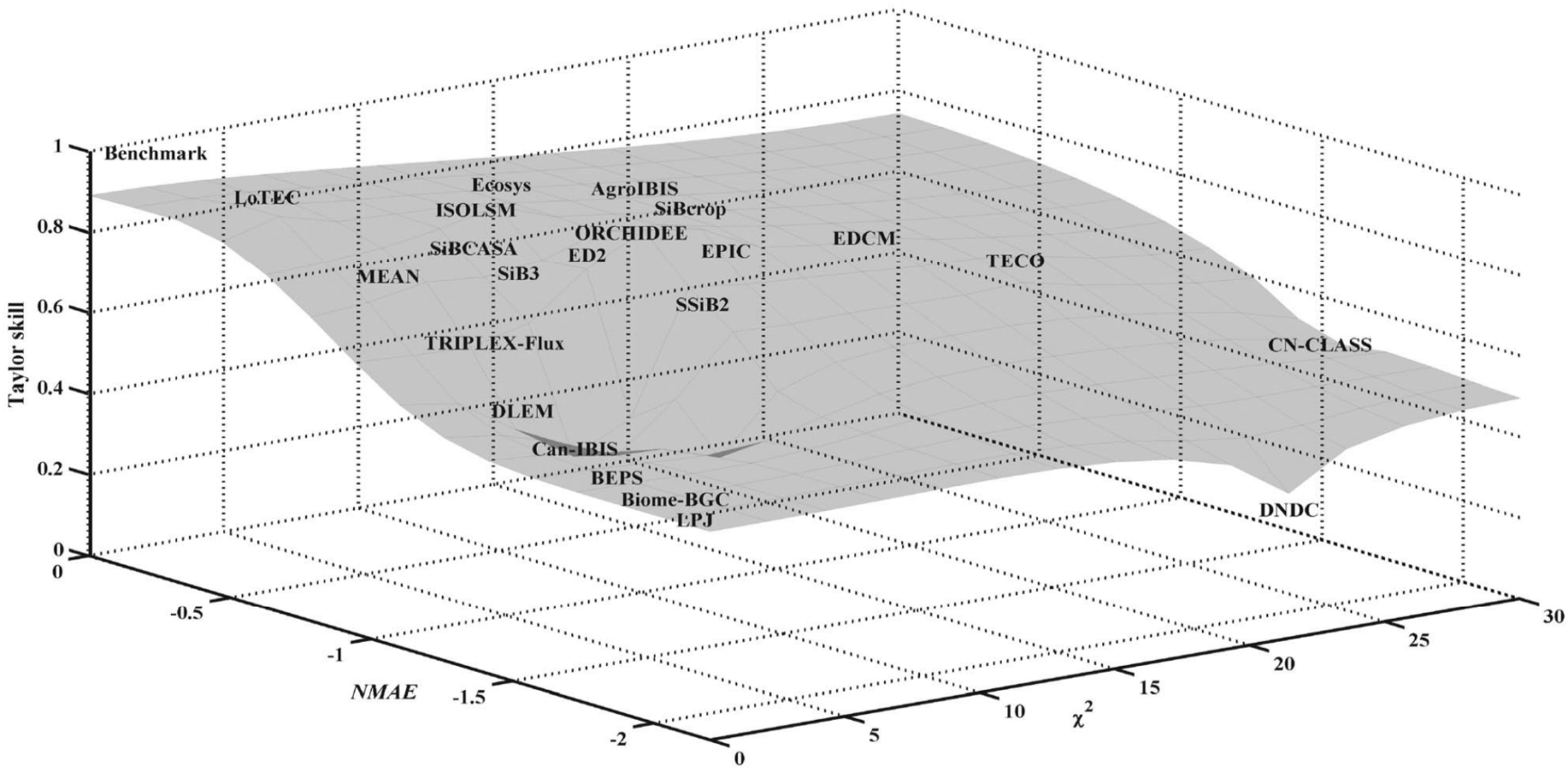


Figure 3. Model skill metrics for all 22 models. Skill metrics are Taylor skill (S; equation (3)), normalized mean absolute error (NMAE), and reduced χ^2 statistic (χ^2). Better model-data agreement corresponds to the upper left corner. Benchmark represents perfect model-data agreement: $S = 1$, $NMAE = 0$, and $\chi^2 = 1$. Gray interpolated surface added and model names jittered to improve readability.

NACP SITE SYNTHESIS

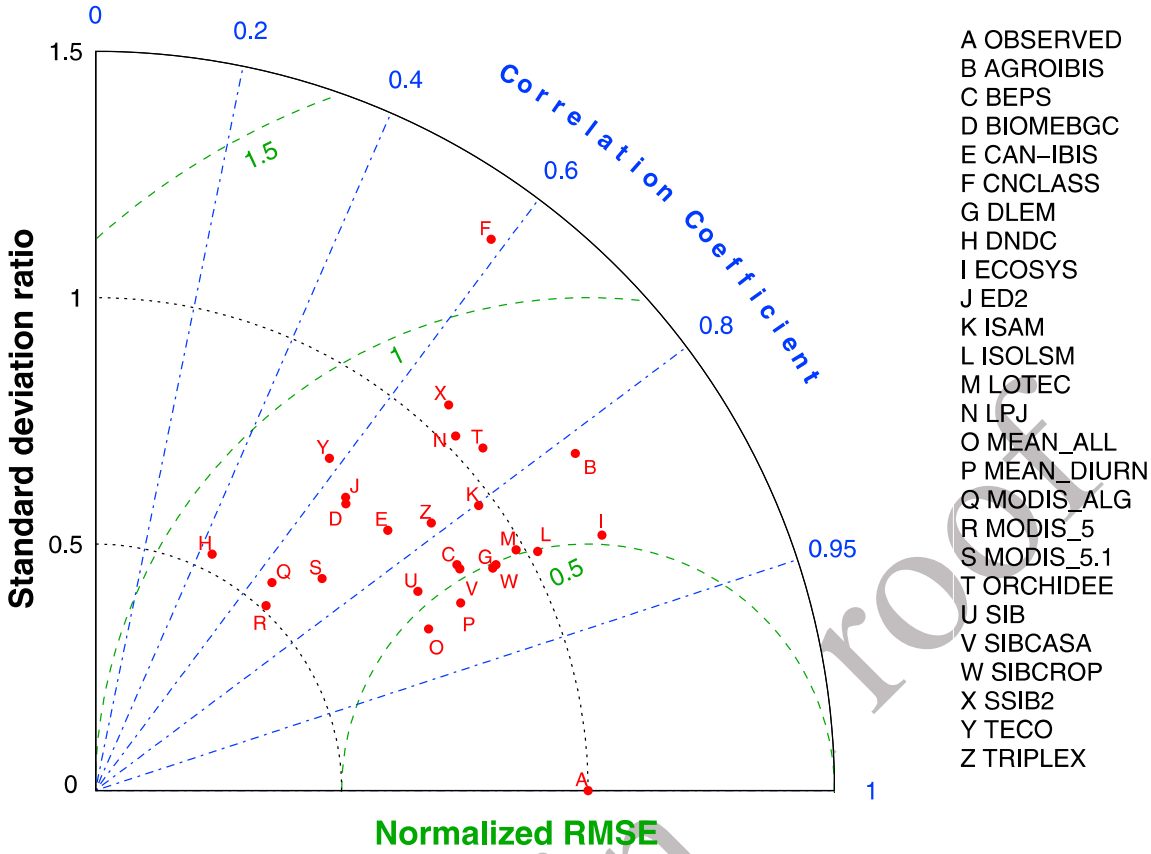
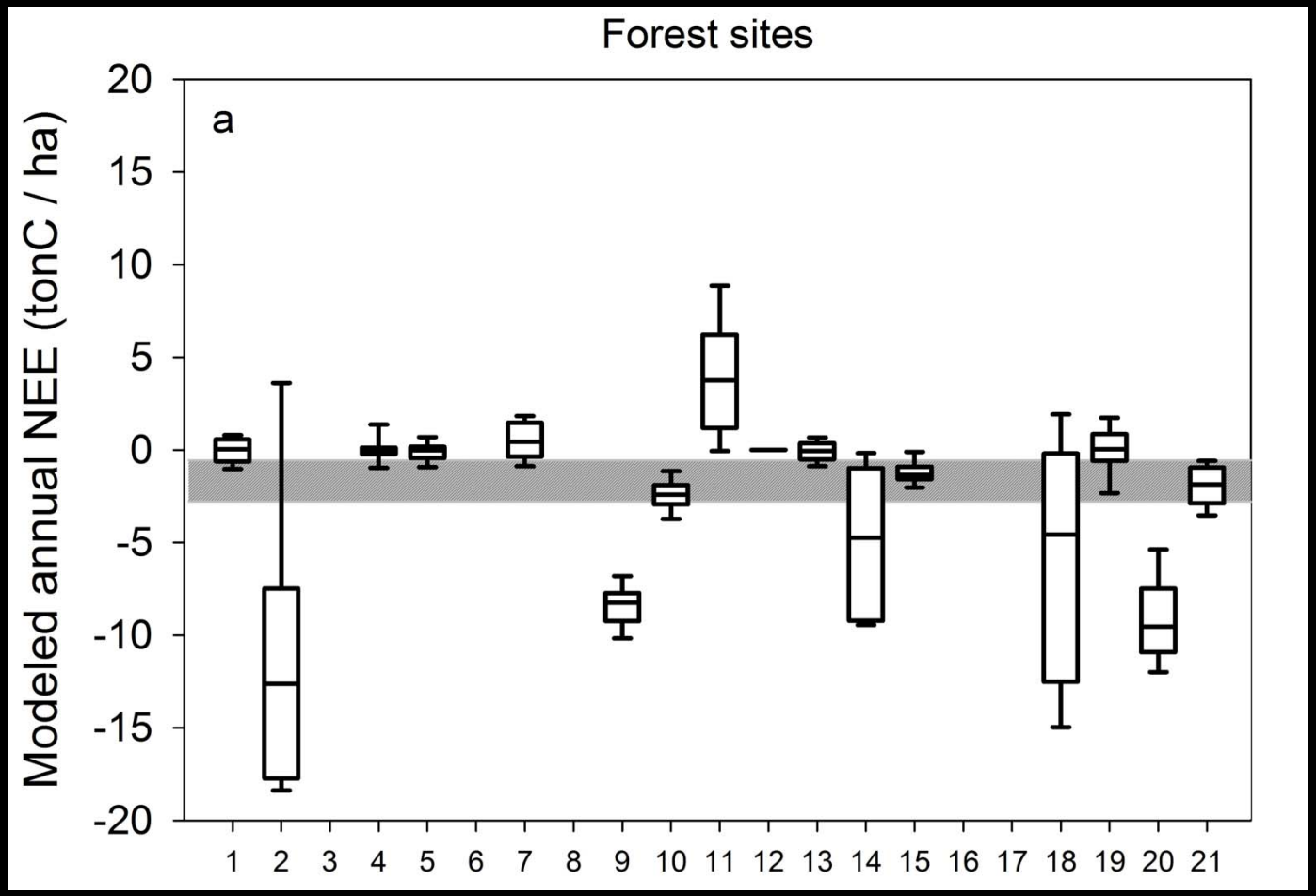


Figure 4. Taylor plot by model for all sites. A Taylor plot is a polar plot where the cosine of the angle from the *x* axis is the correlation coefficient between simulated and observed gross primary productivity (GPP). The correlation coefficient measures how well the simulated GPP captures the phasing and timing of the observed GPP. The radial direction is the ratio of simulated to observed standard deviation. The green lines represent RMSE normalized by standard deviation. An ideal model would have a standard deviation ratio of 1.0 and a correlation of 1.0 (point A).

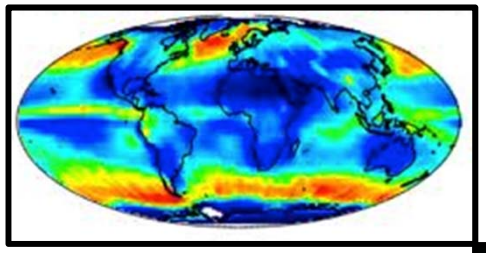
In proof

LBA-DMIP

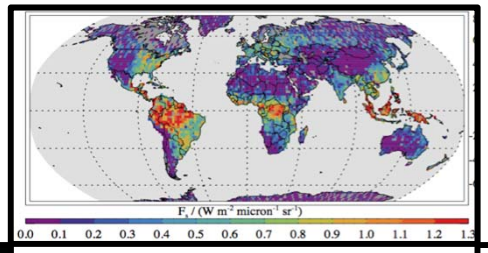


von Randow et al., in review

JPL LAND DATA

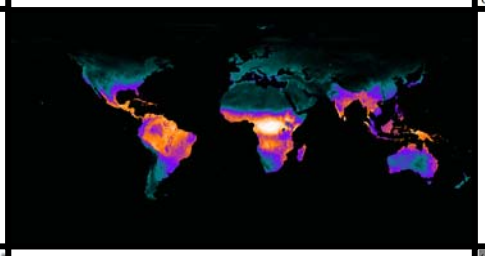


PRECIPITATION
- GRAEME STEPHENS
- ALI BEHRANGI, ZIAD HADDAD, MATT LEBSOCK, JOE TURK

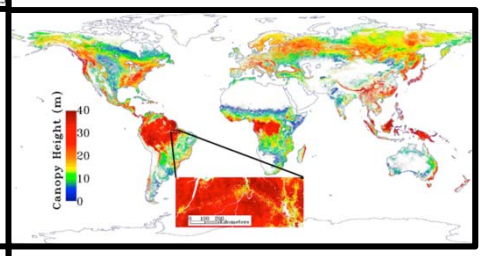


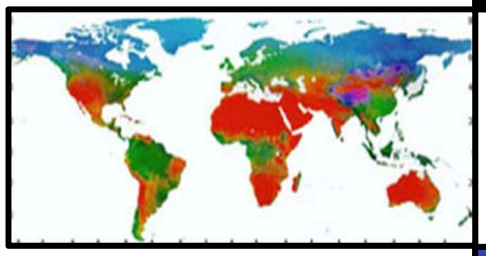
FLUORESCENCE/GPP
- CHRISTIAN FRANKENBERG
- JOSHUA FISHER, JUNG-EUN LEE

EVAPOTRANSPIRATION
- JOSHUA FISHER

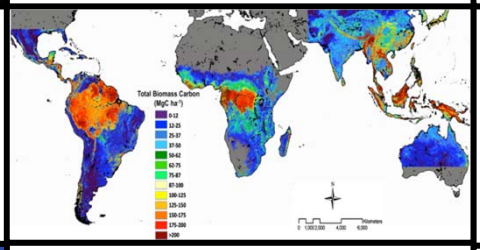


CANOPY HEIGHT
- MARC SIMARD
- JOSHUA FISHER



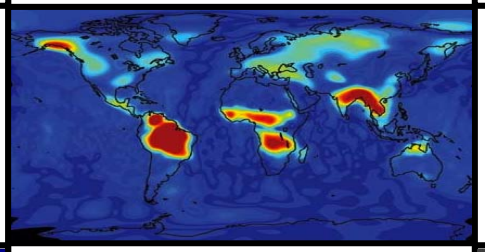


SOIL MOISTURE
- ENI NJOKU
- SMAP TEAM (CHAN, COLLIANDER, DAS, FISHER, KIM, MCDONALD, PODEST)

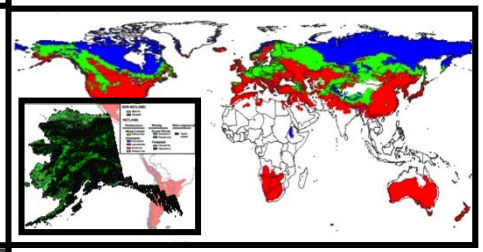


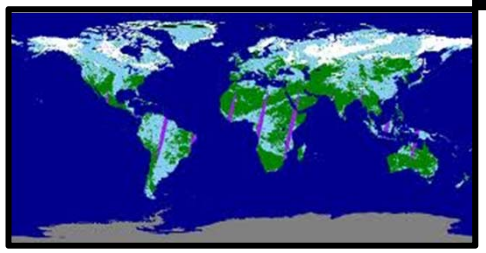
BIOMASS
- SASSAN SAATCHI

GROUNDWATER TOTAL WATER STORAGE
- FELIX LANDERER
- TOM FARR
- CARMEN BOENING

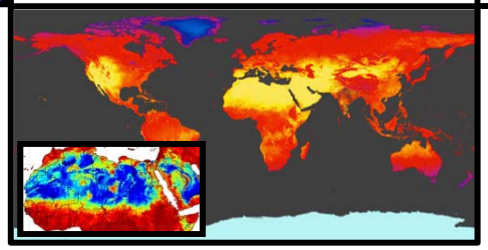


CLASSIFICATION: WETLANDS | INUNDATION FREEZE/THAW
- ERIKA PODEST
- KYLE MCDONALD

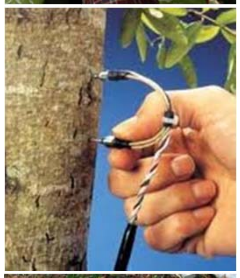




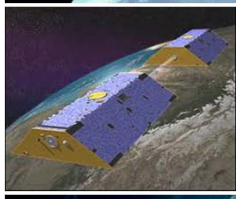
SNOW
- TOM PAINTER

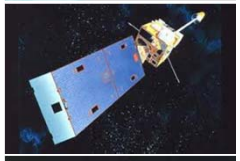


LAND SURFACE TEMPERATURE & EMISSIVITY
- SIMON HOOK
- GLYNN HULLEY



	Field	Ecosystem (eddy flux)	Remote Sensing
LEAF (→CANOPY)			
Stomatal conductance	LiCOR	Invert PM	MODIS***
Photosynthesis | GPP	LiCOR	**NEE-Re**	**Fluorescence**
Transpiration	LiCOR, Sap flow	ET-subcanopy ET	MODIS*
CANOPY			
Scaling	LAI-2000		LiDAR
Phenology	Video camera	NEE	**VIS/NIR**
Litterfall	Litterfall traps	-	VIS/NIR; LiDAR
Interception	Interception traps	ET post-rain	MODIS*
Aerodynamics	Wind measurements	-	-
Radiation diffusion	LiCOR	-	LAI***, fAPAR**
Canopy temperature	IR	-	**LST**
PLANT			
Plant Functional Type (PFT)	Census	-	MODIS**
Autotrophic Respiration (Ra)	Stem respiration	NEE-GPP-Rh	
Net Primary Production (NPP)	C balance	NEE-Rh	MODIS***
C allocation	C balance	-	ICESat**
N allocation	N balance	-	Hyperspectral**
Stemflow	Stemflow traps	-	-
ECOSYSTEM			
Soil layers/pools	Pits	-	-
N uptake	Isotopes, tracers	-	-
Decomposition	Litterbags	-	-
Heterotrophic Respiration (Rh)	Soil respiration	NEE-NPP	-
Ecosystem Respiration (Re)	-	**Nighttime NEE relationship**	Upscaled EC***
Net Ecosystem Exchange (NEE)	C balance	**NEE**	Column CO_2 flux inversion*
Snowmelt	Snow monitor	-	MODIS**
Infiltration/percolation	Soil moisture	-	-
Soil evaporation	Chamber, lysimeter	Sub-canopy ET	MODIS* | SMOS*→SMAP*
Evapotranspiration	-	**ET**	MODIS*
Runoff	River gauge	-	SWOT*
River routing	Topo	-	DEM
Water balance	-	-	**GRACE**
Competition	Census	-	-
Establishment	Census	-	LiDAR
Mortality	Census	-	LiDAR
Fire	Census	-	**TIR**





North American Carbon Program

MsTMIP

MULTI-SCALE SYNTHESIS AND TERRESTRIAL MODEL INTERCOMPARISON PROJECT

Multi-scale Synthesis and Terrestrial Model Intercomparison Project - MsTMIP

Model Evaluation

The MsTMIP will develop model evaluation tools using available observational data sets, through the use of automated quantitative performance measures based on the existing C-LAMP project (Hoffman et al. 2007; 2008). TBMs will be evaluated by direct comparison with observations, and by comparing simulated fluxes with those estimated with atmospheric

Designed by: JOSHUA B. FISHER JBFISHER@JPL.NASA.GOV

Land Surface Processes & Benchmarking

questions | comments