

Tradeoffs between ecosystem carbon sequestration and surface radiation budget under dry conditions

Dan Yakir, Eyal Rotenberg, Efrat Ramati, Shani Rohatyn and Feyodor Tatarinov

Earth & Planetary Sciences,



EEF Symposia: New emerging drivers of carbon and nutrient cycles under a drier and warmer climate

Support: KKL, Lewis & Wills, ISF, Minerva, Water Authority; WIS

Outline:

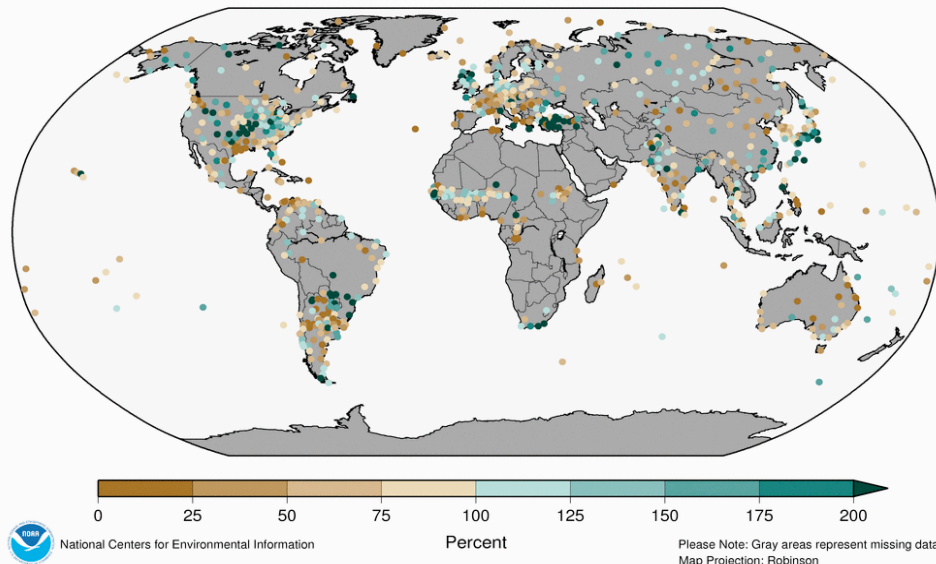
- Climate change update
- Carbon perspective and beyond: Biophys. & Biogeo.
- Semi-arid regions
- Extending the traditional flux tower approach...

I. Climate change update

The combined average temperature over global land and ocean surfaces for July 2015 was the highest for July in the 136-year period of record, at 0.81°C (1.46°F) above the 20th century average of 15.8°C (60.4°F), surpassing the previous record set in 1998 by 0.08°C (0.14°F). As July is climatologically the warmest month of the year globally, this monthly global temperature of 16.61°C (61.86°F) was also the highest among all 1627 months in the record that began in January 1880. The July temperature is currently increasing at an average rate of 0.65°C (1.17°F) per century.

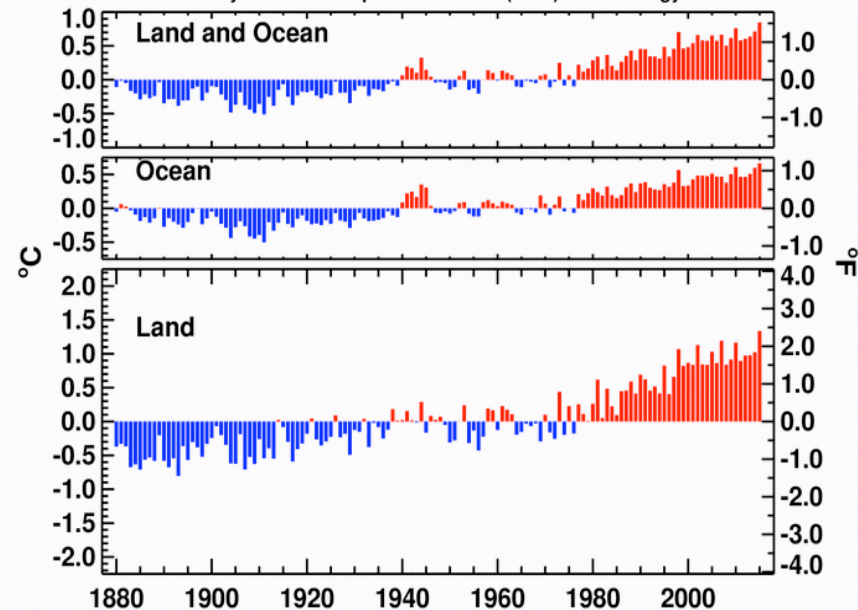
Land-Only Percent of Normal Precipitation Jul 2015
(with respect to a 1961–1990 base period)

Data Source: GHCN-M version 2



Jan-Jul Global Surface Mean Temp Anomalies
NCEI/NESDIS/NOAA

Analysis is based upon Smith et al. (2008) methodology.



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August US release: Wed, 9 Sep 2015, 11:00 AM EDT

Global Analysis - July 2015

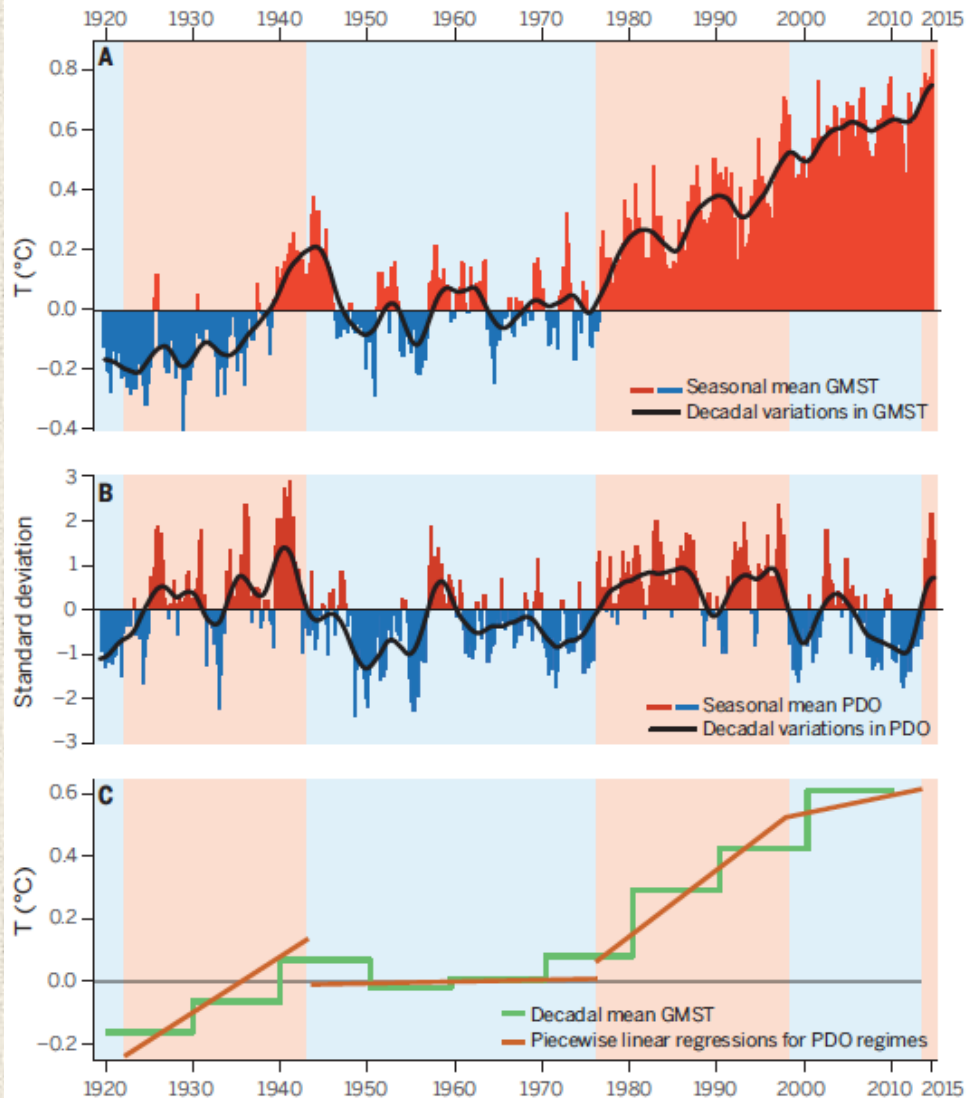
9/24/15

Has there been a hiatus?

Internal climate variability masks climate-warming trends

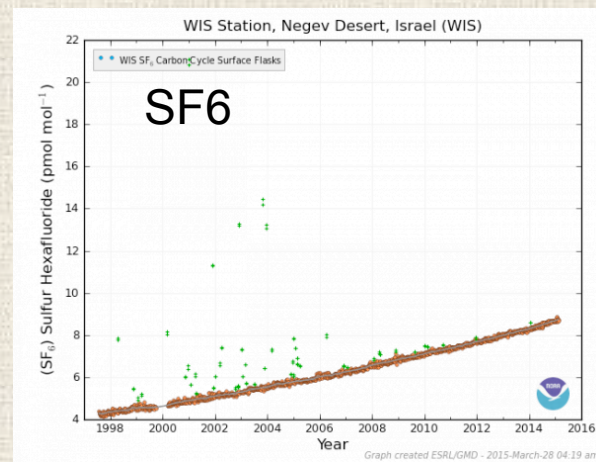
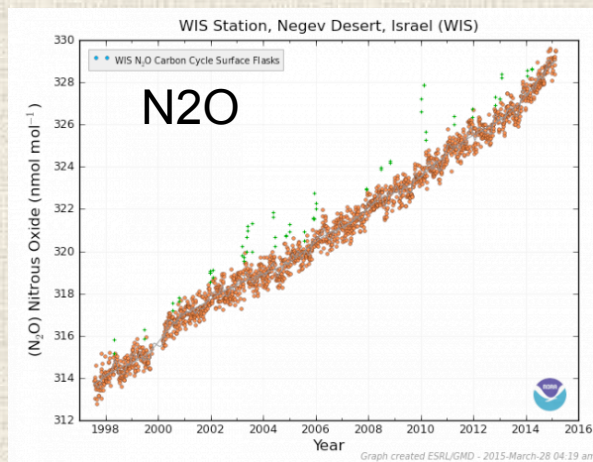
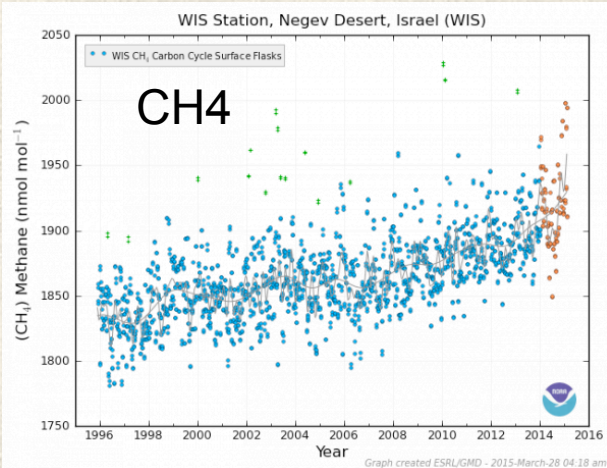
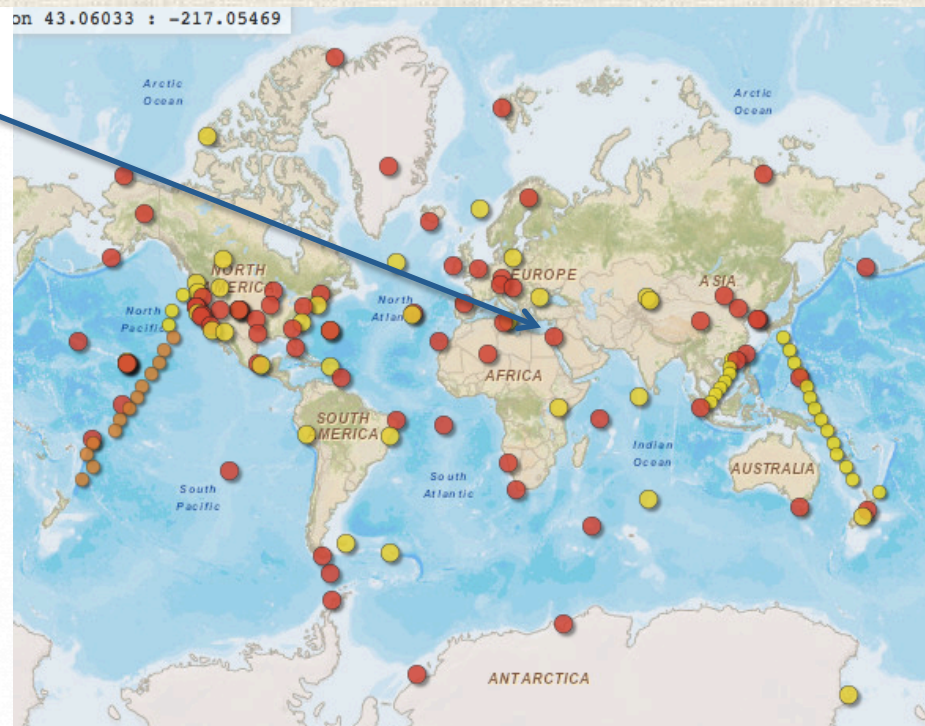
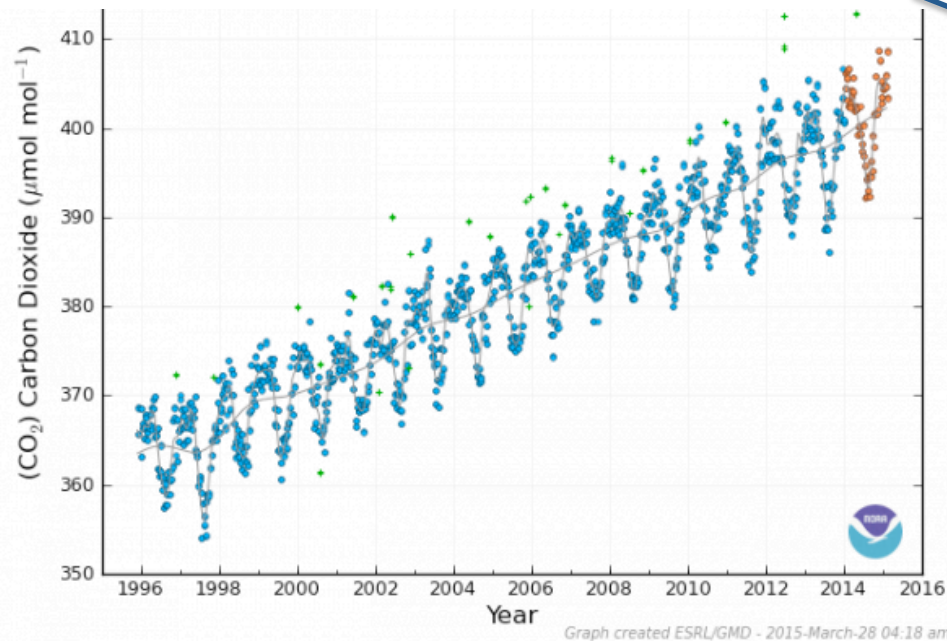
By Kevin E. Trenberth

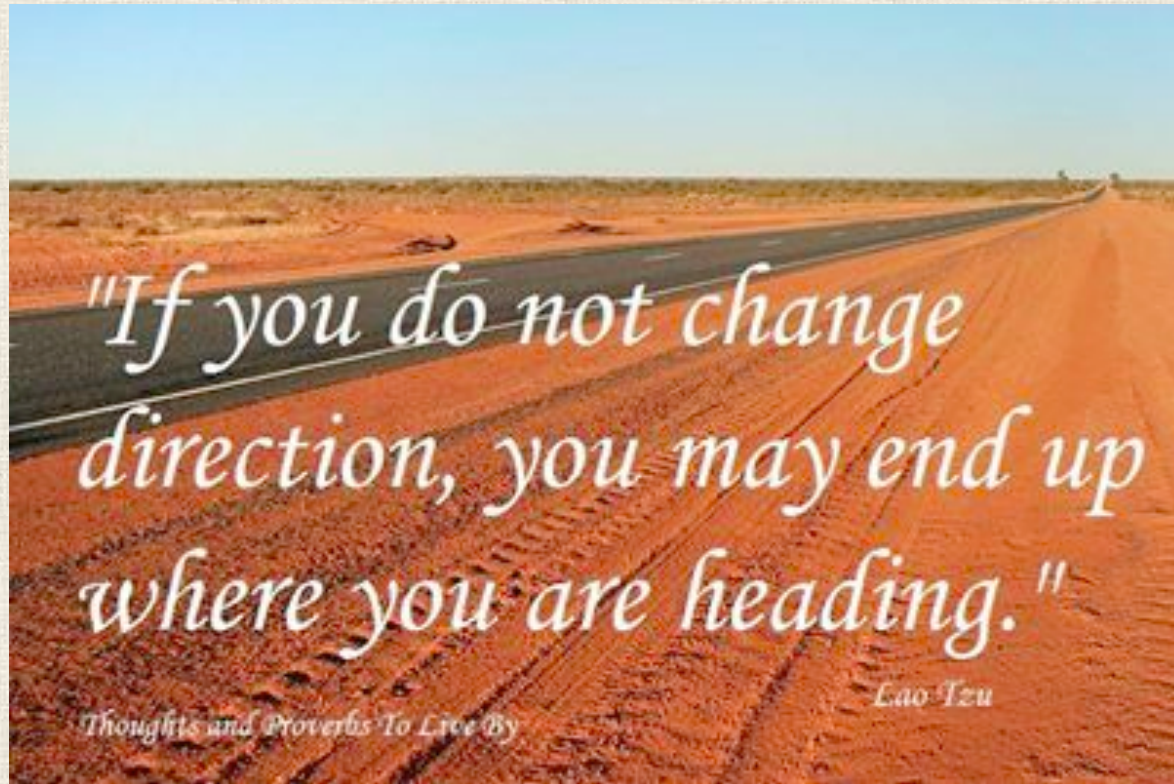
as a result of internal natural variability.



The relentless increase in “greenhouse” gases

Weizmann Inst. Station Negev Desert Israel (WIS)

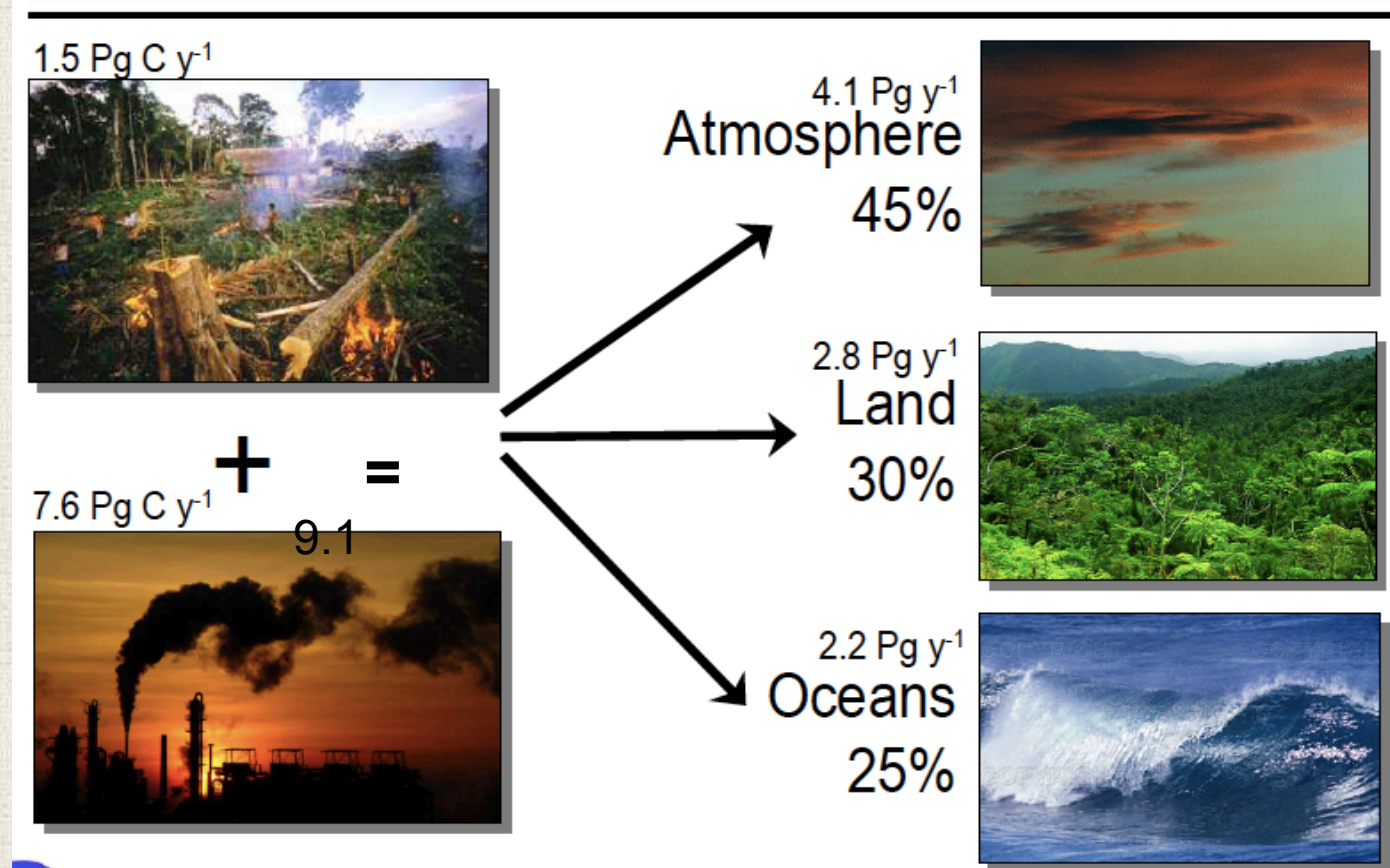




II. The carbon perspective and beyond...

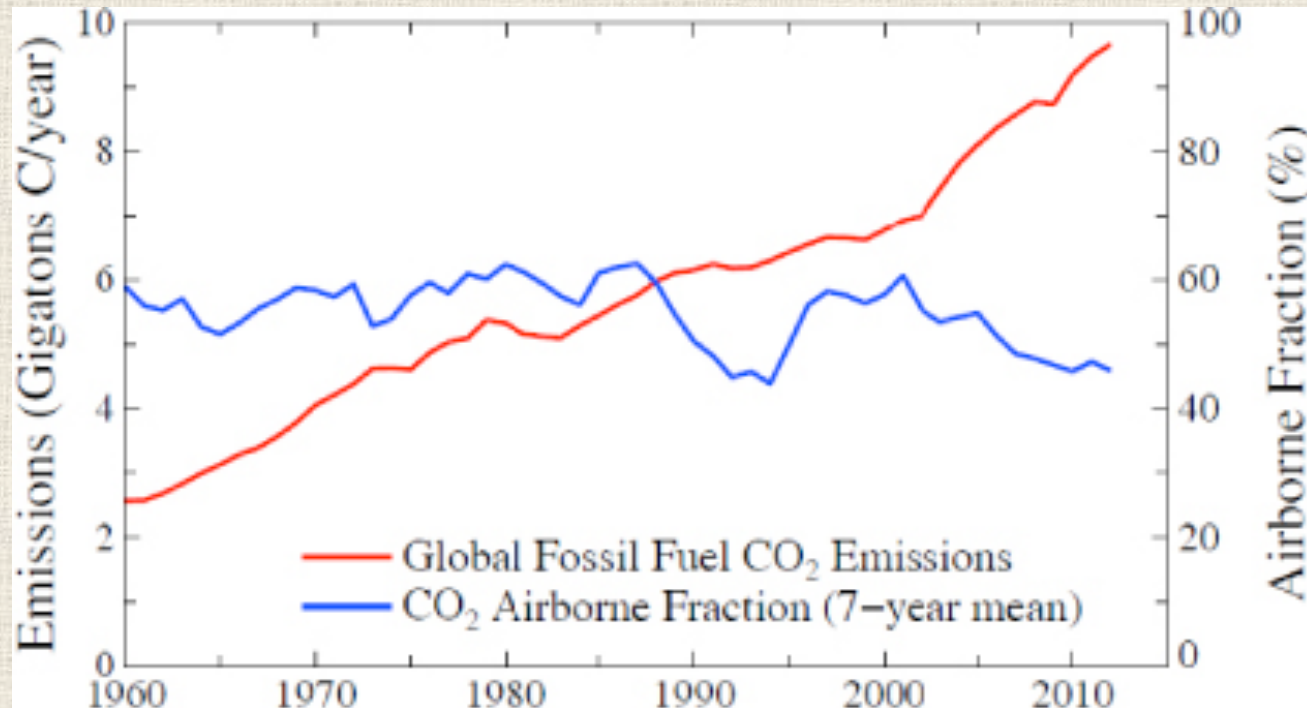
...To consider the interactions of land ecosystems with the climate system we cannot limit ourselves to carbon.

Carbon sinks and the 'Airborne Fraction' ($4.1/9.1 = 0.45$)



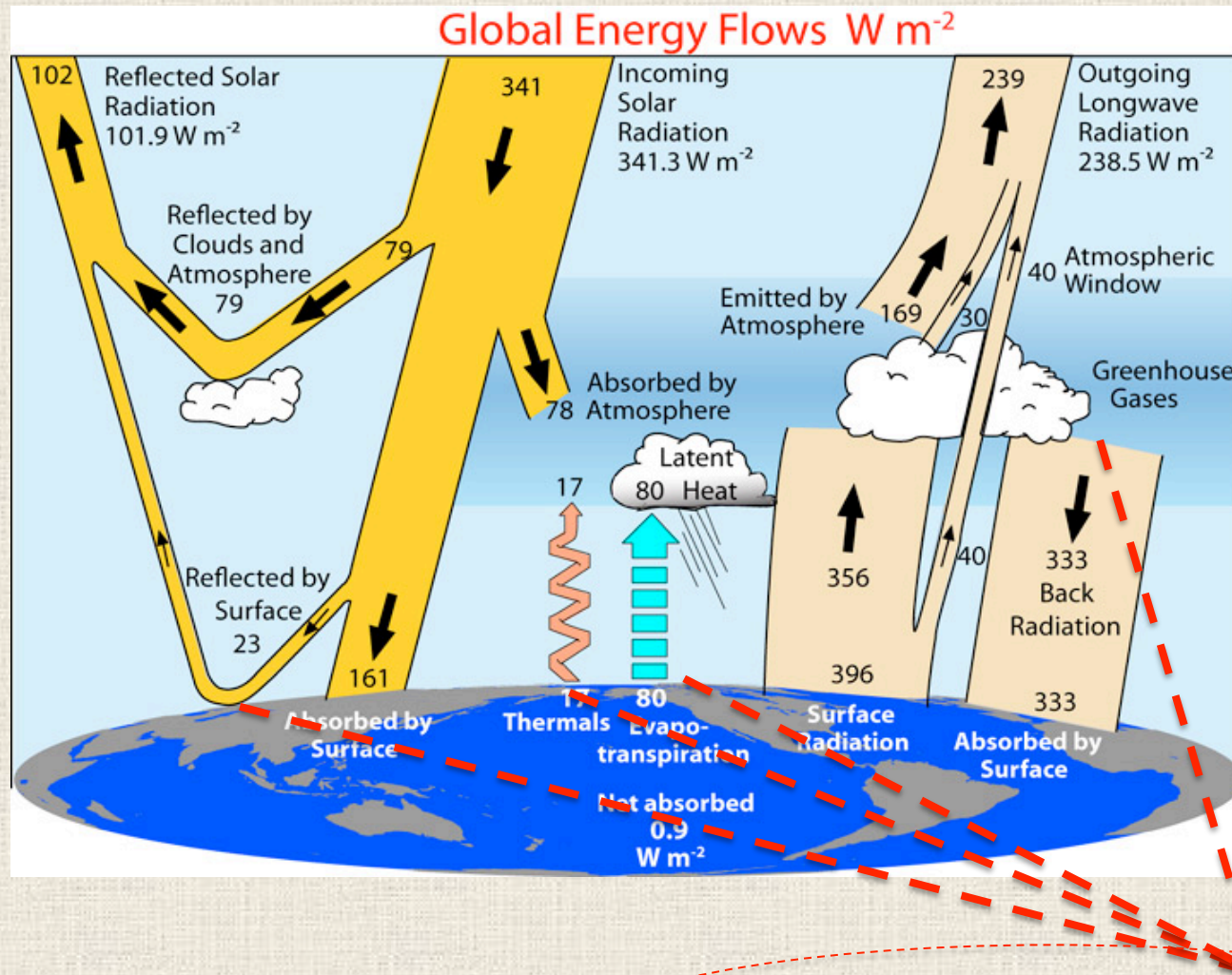
The constant and even decreasing Airborne fraction:
CO₂ fertilization is likely the major effect..

Hansen et al 2013



...around 2000, change of emission rate from 1:5%/yr to
3:1%/yr; airborne fraction-down from ~55 to ~45

The many ways vegetation interacts with the climate system



Forests and land cover, land use effects

Increasing consideration of “biogeophysical” effects

Offset of the potential carbon sink from boreal forestation by decreases in surface albedo

Richard A. Betts

Hadley Centre for Climate Prediction and Research, The Met Office, Bracknell, Berkshire RG12 2SY, UK

Separating the effects of albedo from eco-physiological changes on surface temperature along a successional chronosequence in the southeastern United States

Jehn-Yih Juang,^{1,2} Gabriel Katul,^{1,3} Mario Siqueira,^{1,4} Paul Stoy,^{1,5} and Kimberly Novick¹

Received 24 July 2007; revised 2 October 2007; accepted 15 October 2007; published 15 November 2007.

nature
climate change

LETTERS

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Human land-use-driven reduction of forest volatiles cools global climate

Nadine Unger

REVIEWS REVIEWS REVIEWS

Biophysical considerations in forestry for climate protection

Ray G Anderson^{1*}, Josep G Canadell², James T Randerson¹, Robert B Jackson³, Bruce A F Dennis D Baldocchi³, George A Ban-Weiss⁶, Gordon B Bonan⁷, Ken Caldeira⁶, Long Cao⁶, Noah S Diffenbaugh^{8,9}, Kevin R Gurney⁸, Lara M Kueppers¹⁰, Beverly E Law¹¹, Sebastiaan and Thomas L O'Halloran¹¹

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Int. J. Climatol. 34: 929–953 (2014)
Published online 21 June 2013 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.3736

RMetS
Royal Meteorological Society

Review

Land cover changes and their biogeophysical effects on climate

Rezaul Mahmood,^{a*} Roger A. Pielke, Sr.^b Kenneth G. Hubbard,^c Dev Niyogi,^{d,e} Paul A. Dirmeyer,^f Clive McAlpine,^g Andrew M. Carleton,^h Robert Hale,ⁱ Samuel Gameda,^j Adriana Beltrán-Przekurat,^k Bruce Baker,^l Richard McNider,^m David R. Legates,ⁿ Marshall Shepherd,^o Jinyang Du,^p Peter D. Blanken,^q Oliver W. Frauenfeld,^r U.S. Nair^{m,s} and Souleymane Fall^l

Biogeophysical versus biogeochemical climate response to historical anthropogenic land cover change

J. Pongratz,^{1,2,3} C. H. Reick,² T. Raddatz,² and M. Claussen^{2,4}

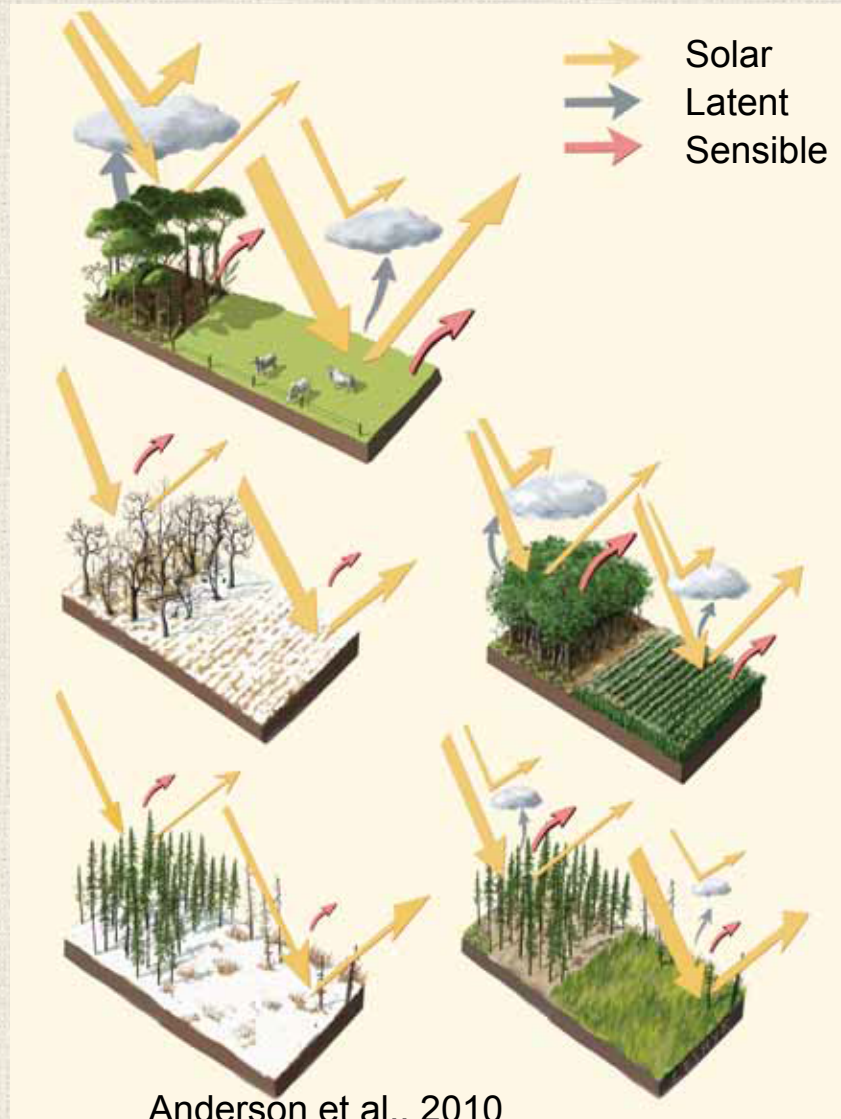
Received 22 February 2010; revised 11 March 2010; accepted 15 March 2010; published 22 April 2010.

Climatic Impact of Global-Scale Deforestation: Radiative versus Nonradiative Processes

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Forest / non-forest ecosystems and surface energy fluxes



III. The semi-arid regions' perspective...

≈ 1/3 of the world 's
population lives in dry,
arid, subhumid regions.

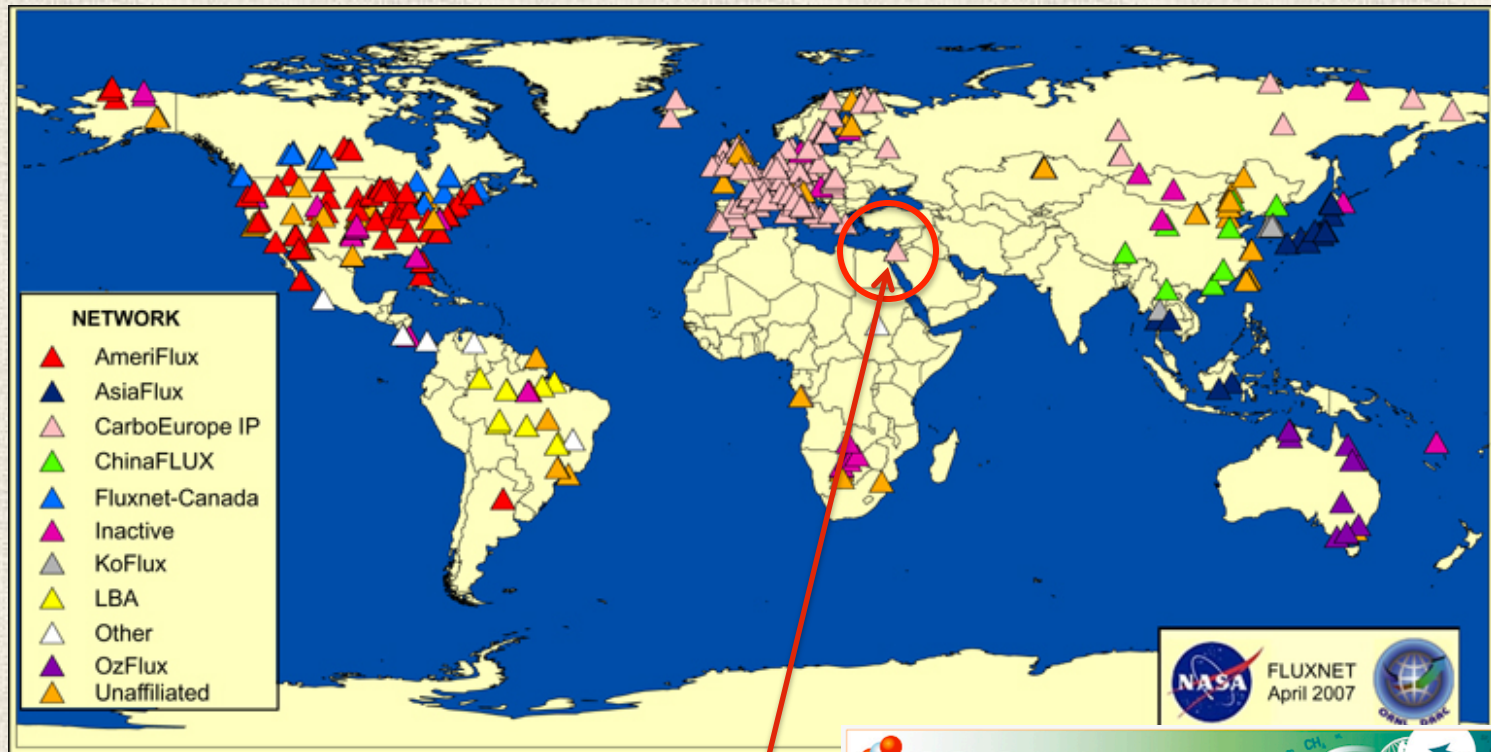
≈ 38% - 47% of the Earth 's
land area are such areas.

≈ 0.04 % desertification
increase yr^{-1} (3 times
Israel).



Der Spiegel, 2009

Great global effort, but imperfect coverage...



Yatir Research Site

icos integrated carbon observation system
A European infrastructure dedicated to high precision monitoring of greenhouse gas fluxes

Welcome to ICOS
A new research infrastructure to decipher the greenhouse gas balance of Europe and adjacent regions

Coordination:
Philippe Clais, Laboratoire des Sciences du Climat et de l'Environnement. Institut Pierre-Simon Laplace, CEA-CNRS-UVSQ, France

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Kim Pilegaard, RISØE	Janusz Olejnik, PULS
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Martin Helmmann, MPI	Anders Lindroth, ULUND
Frank McGovern, EPA	Nina Buchmann, ETH Zurich
Dan Yakir, WIS	John Grace, UEDIN
Riccardo Valentini, UNITUS	

Mission statement
To provide the long-term observations required to understand the present state and predict future behavior of the global carbon cycle and greenhouse gas emissions

Increasing consideration of “biogeophysical” effects

CARBON CYCLE

The dominant role of semi-arid ecosystems in the trend and variability of the land CO₂ sink

Anders Ahlström,^{1,2*} Michael R. Raupach,^{3,†} Guy Schurgers,⁴ Benjamin Smith,¹ Almut Arneth,⁵ Martin Jung,⁶ Markus Reichstein,⁶ Josep G. Canadell,⁷ Pierre Friedlingstein,⁸ Atul K. Jain,⁹ Etsushi Kato,¹⁰ Benjamin Poulter,¹¹ Stephen Sitch,¹² Benjamin D. Stocker,^{13,14} Nicolas Viovy,¹⁵ Ying Ping Wang,¹⁶ Andy Wiltshire,¹⁷ Sönke Zaehle,⁶ Ning Zeng¹⁸

LETTER

doi:10.1038/nature13376

Contribution of semi-arid ecosystems to interannual variability of the global carbon cycle

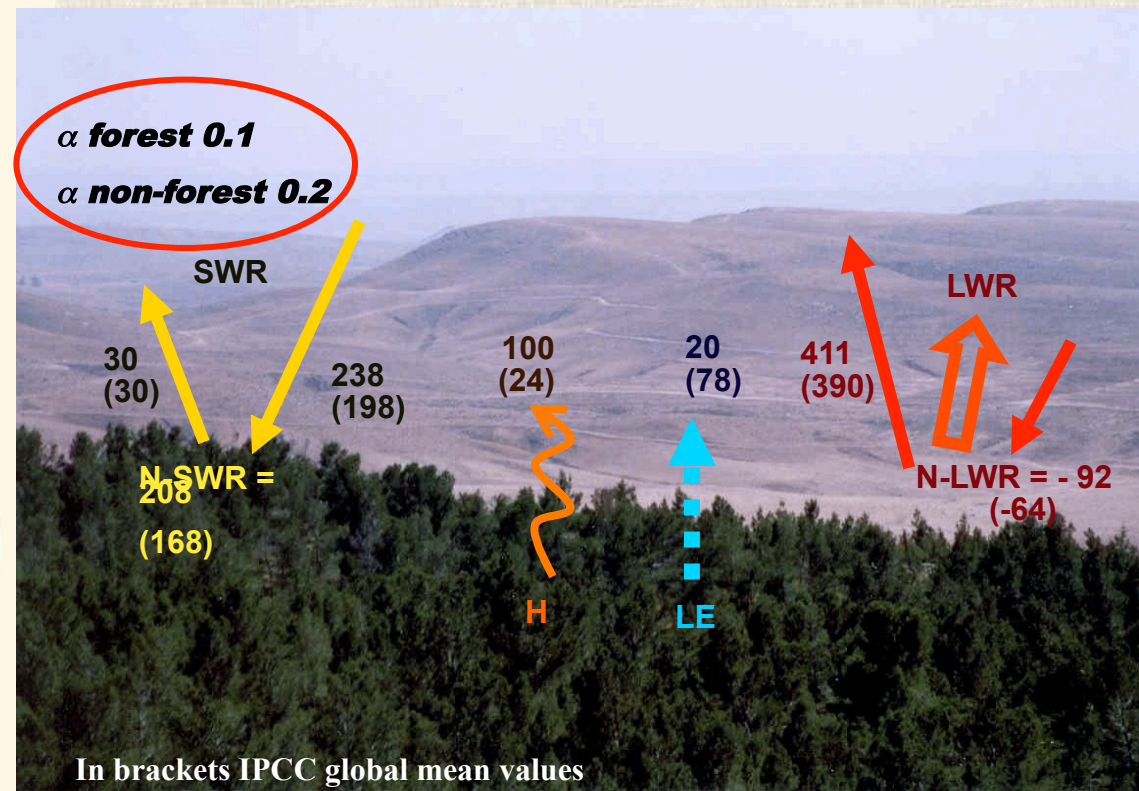
Benjamin Poulter^{1,2}, David Frank^{3,4}, Philippe Ciais², Ranga B. Myneni⁵, Niels Andela⁶, Jian Bi⁵, Gregoire Broquet², Josep G. Canadell⁷, Frederic Chevallier², Yi Y. Liu⁸, Steven W. Running⁹, Stephen Sitch¹⁰ & Guido R. van der Werf⁶



Contribution of Semi-Arid Forests to the Climate System

Eyal Rotenberg and Dan Yakir
Science **327**, 451 (2010);
DOI: 10.1126/science.1179998

Forest/non-forest surface energy fluxes--the semi-arid part



Anderson et al., 2010

The direct forest site in the global FLUXNET (290 mm)



Carbon sequestration in semi-arid forest

Table 1. Indicators of carbon use efficiency in pine forests: Gross primary productivity (GPP), ecosystem respiration (R_e) and net ecosystem exchange (NEE) of carbon for the 12 European pine forest sites (62 data years, 36), for the entire global Fluxnet network (43), and for semiarid forest (Yatir; 44).

Pine forest	GPP	R_e	NEE	NEE/GPP
European (Carboeurope)	1142	944	200	0.17
Global (FluxNet)	1540	1280	260	0.17
Semi-arid (Yatir)	820	600	220	0.27

gr carbon m⁻²

Large albedo effect, $+24 \text{ Wm}^{-2}$
(high radiation, no clouds)



Air-cooled canopy...
(‘convector effect’)



Water-cooled canopy...

How Evaporative Cooling Works



*Thermal emission
suppression of $+25 \text{ W m}^{-2}$

*Cooling vs. non-forest area:
 $\sim 5\text{C}$ annual mean;
up to $\sim 30\text{C}$ in mid-day

Semi-arid afforestation balance sheet:

Variable	Forest	Shrubland
Global radiation (Eg, Wm^{-2})	238	238
Albedo (unit-less)	0.11	0.21 <i>d=+23.8 Wm^{-2}</i>
Net solar radiation (Sn, Wm^{-2})	212	188
Net longwave radiation (Ln, Wm^{-2})	-96	-121 <i>d=+25 Wm^{-2}</i>
Net radiation (Rn=Sn+Ln, Wm^{-2})	115	67 <i>d=+48 Wm^{-2}</i>
Skin temperature [$^{\circ}\text{C}$]	19	24*

1. **Cooling** effect: C sequestration $\sim 2.2 \text{ t ha}^{-1}$
 $< 1 \text{ W m}^{-2}$
2. **Warming** effect: Increased surface radiation
load $\sim 48 \text{ W m}^{-2}$
3. **Balance** achieved only after ~ 50 years of C
sequestration (worst case scenario)

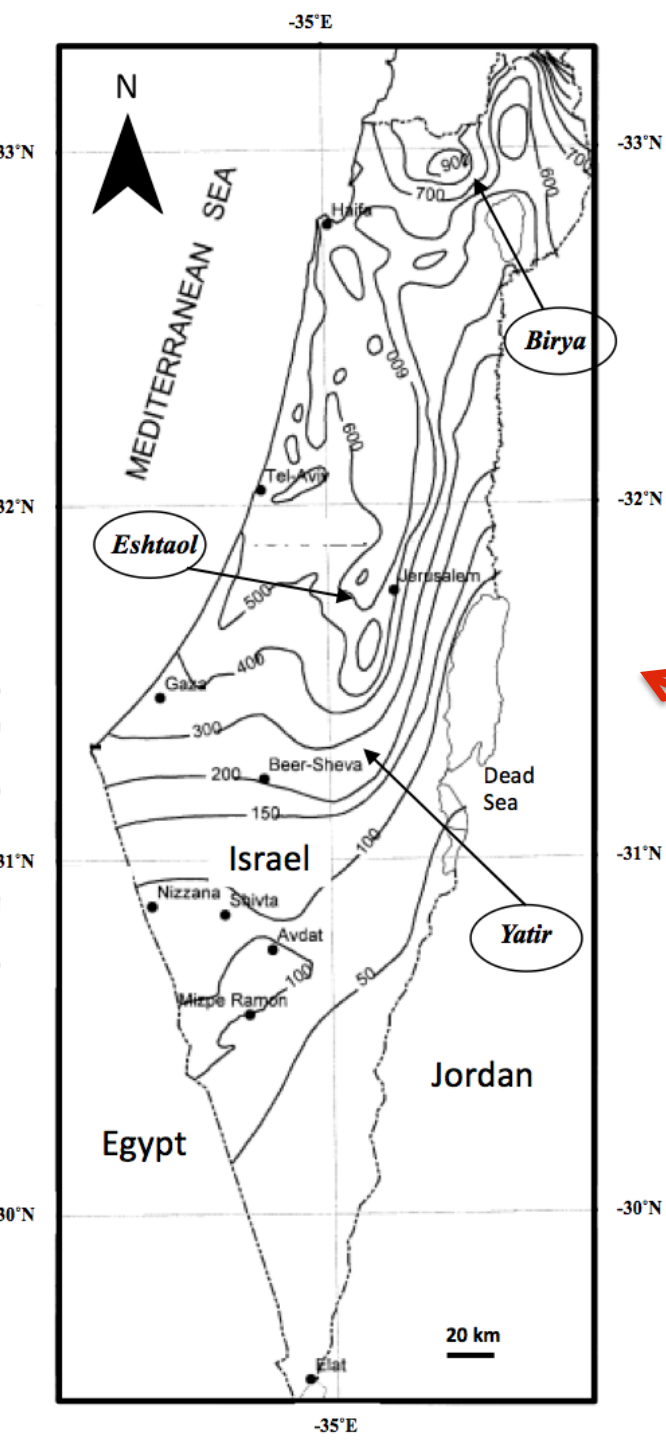


Contribution of Semi-Arid Forests to the Climate System
Eyal Rotenberg, *et al.*
Science **327**, 451 (2010);
DOI: 10.1126/science.1179998

IV. Extending the traditional flux tower approach...

Extending the range with the WIS Mobile flux lab



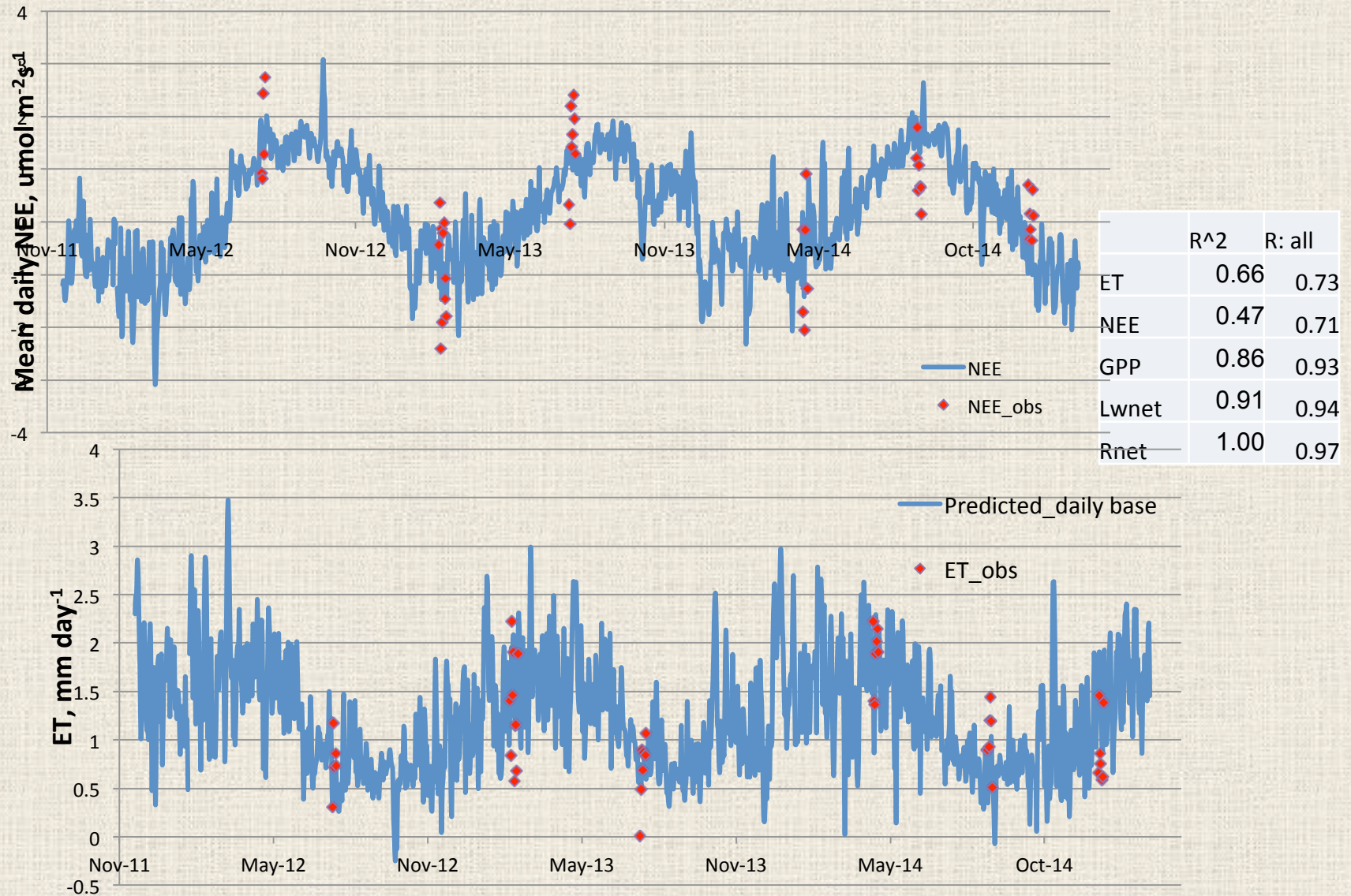


Climatic Gradient: precipitation data

Forest	Location	records	mean (mm)	SE	min (mm)	min year	max (mm)	max year
Yatir	South	61	282	12	78	62/63	541	91/92
Eshtaol	Center	108	524	15	201	59/60	1107	91/92
Birya	North	74	750	21	412	78/79	1319	91/92

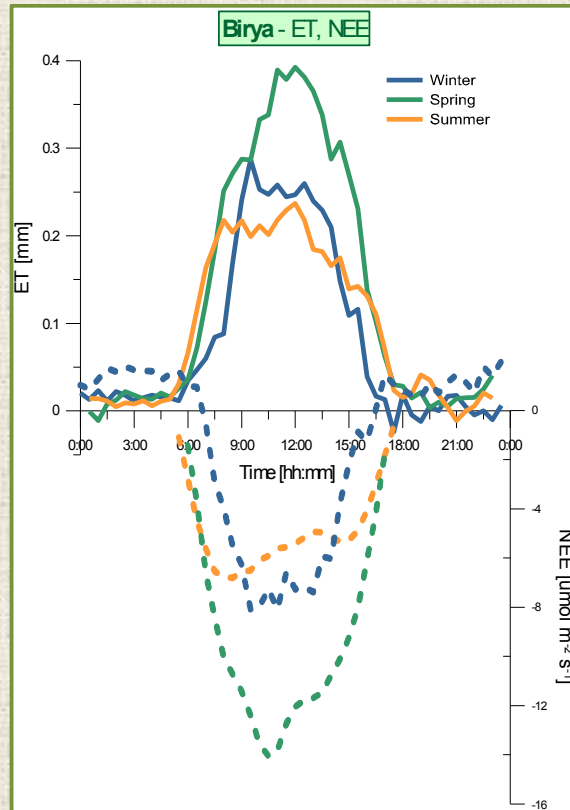


Extrapolations: single regression for all campaigns, daily-based (540 mm non-forest site)

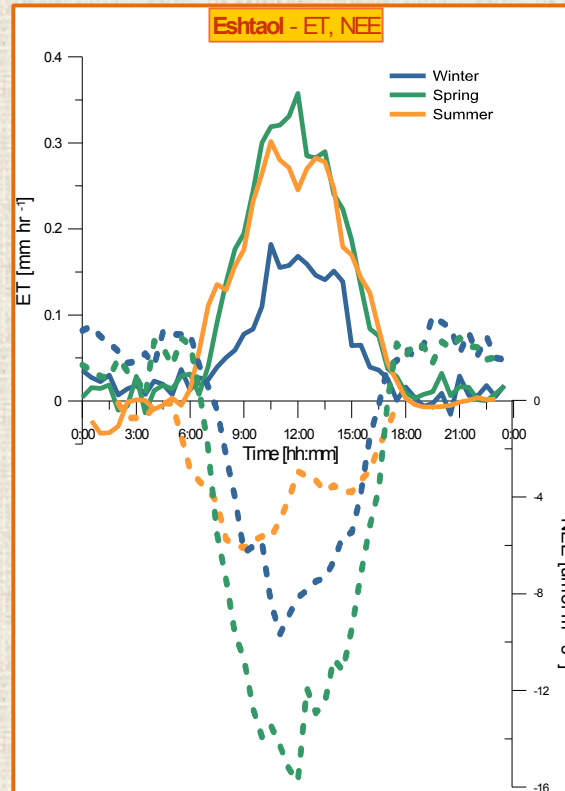


Forest scale NEE & ET diurnal curves Along the climatic gradient

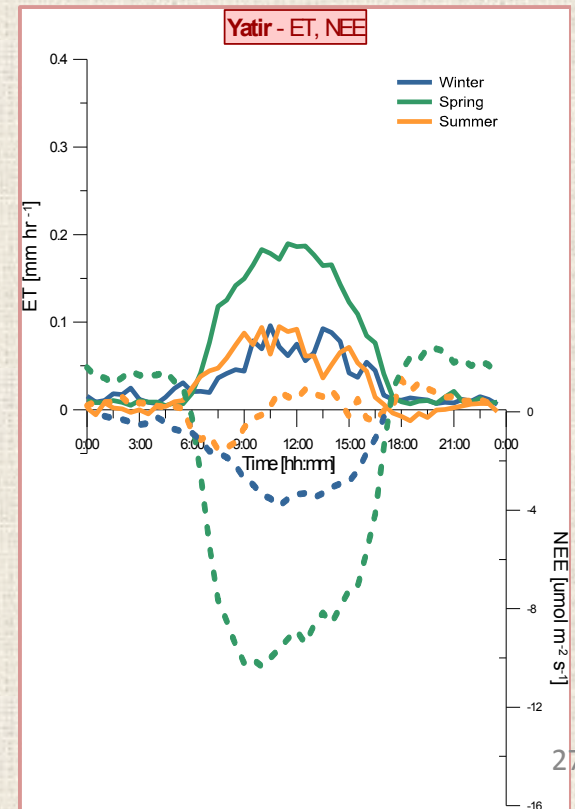
Campaign's daily average flux



Sub-humid

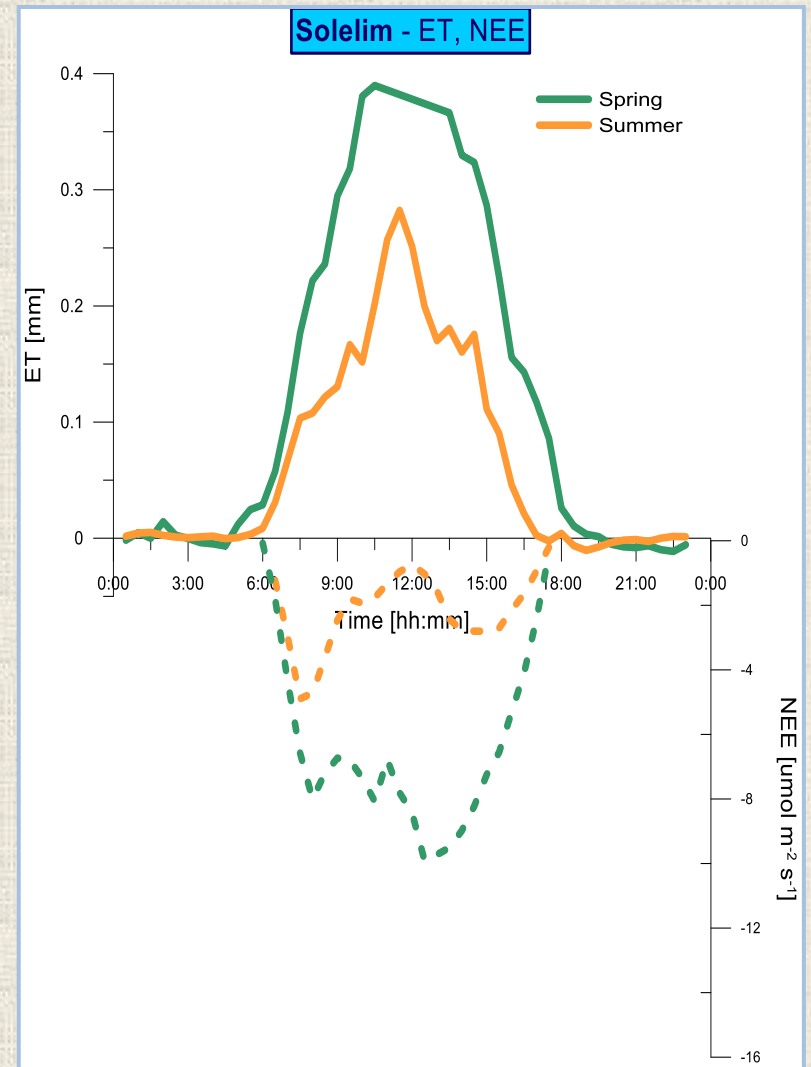
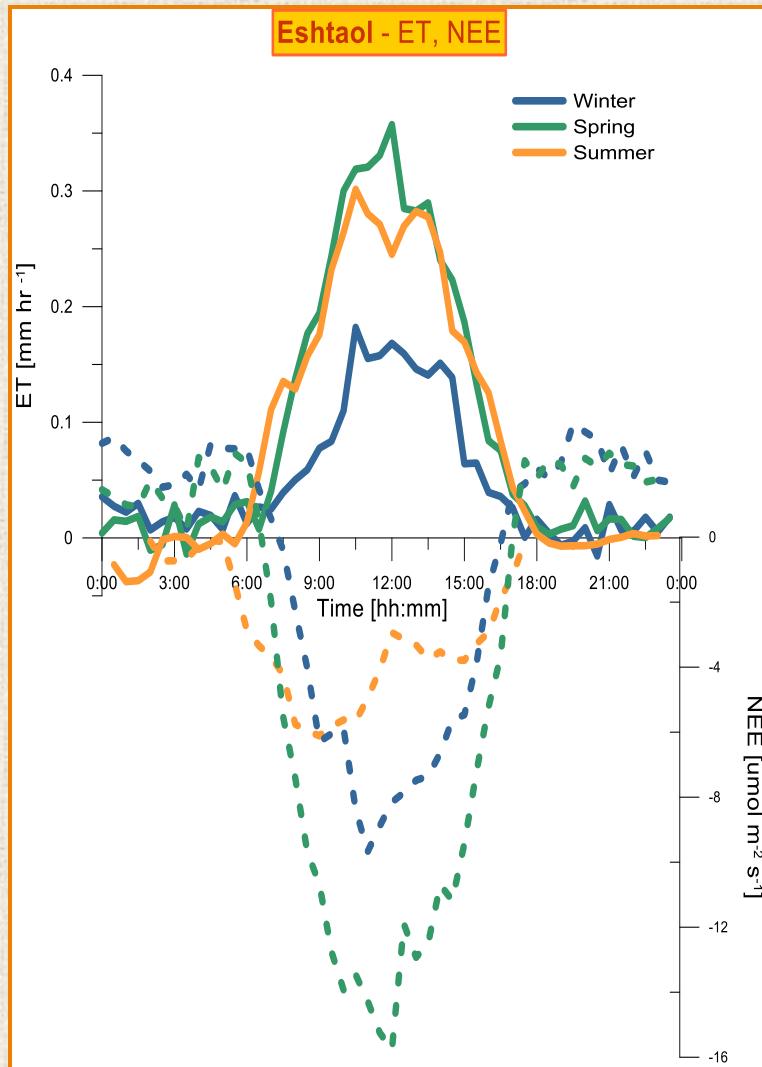


Dry Mediterranean

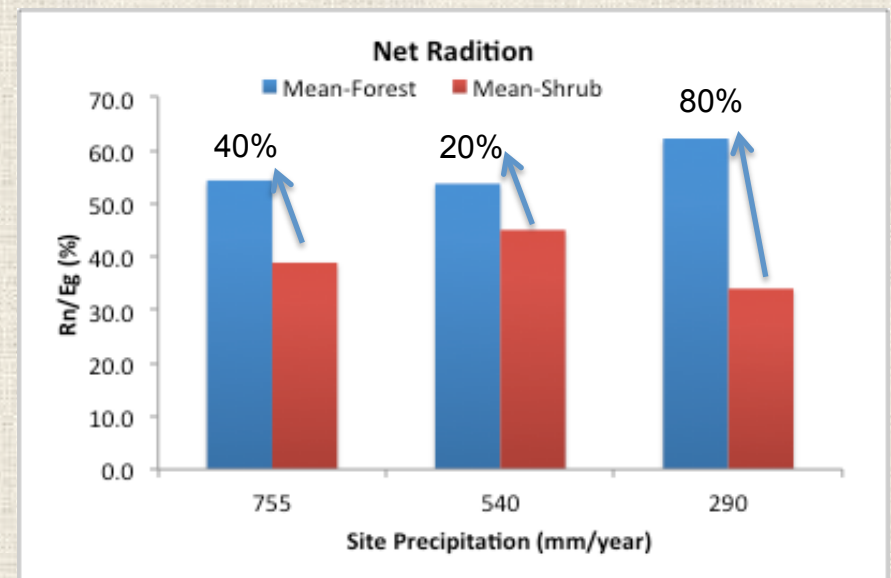
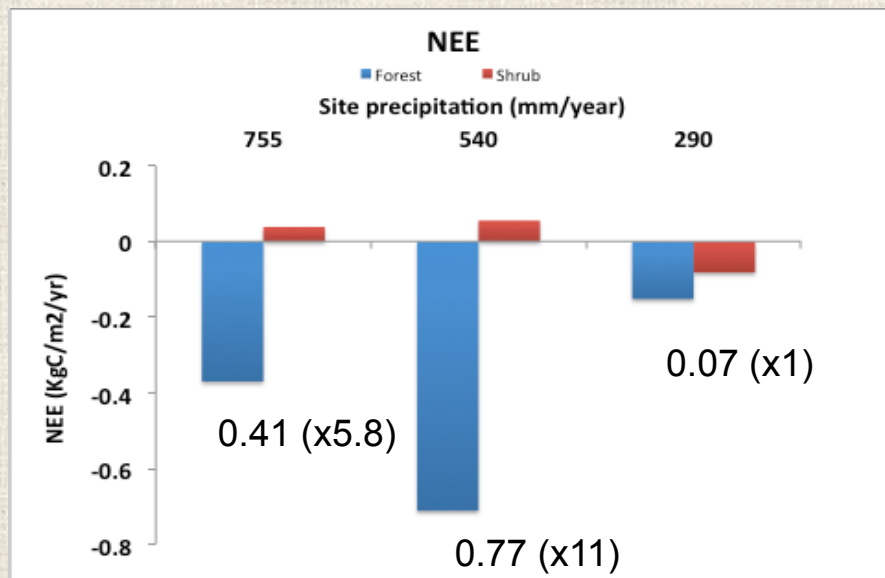
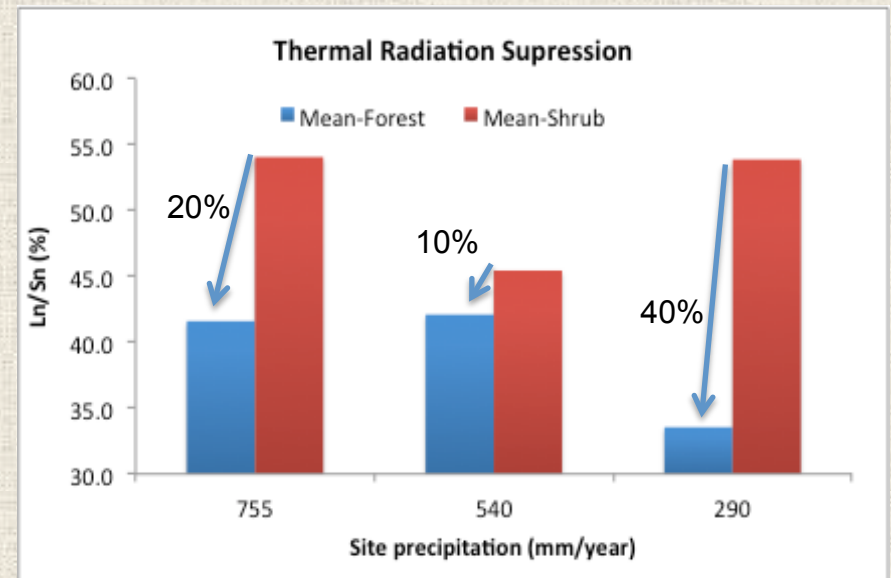
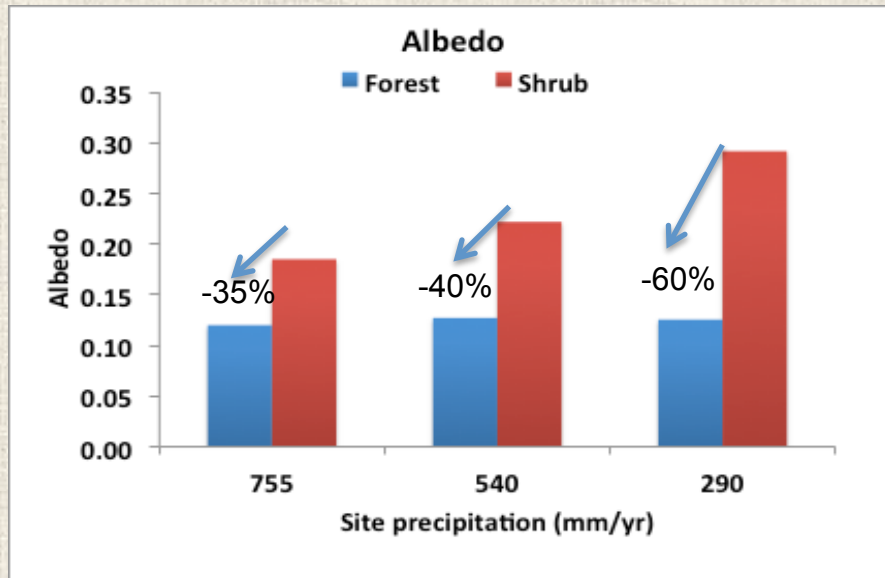


Semi-arid/arid

Canopy scale NEE & ET diurnal curves: Pine vs. Oak at the



Annual scale estimates of changes in forestation effects



Afforestation along precipitation gradient: Preliminary balance sheet

Variable	<u>Yatir</u> (290 mm)	<u>Birya</u> (870 mm)
Albedo (W m ⁻²)	24	12
Net Long Wave (W m ⁻²)	25	16
Carbon uptake (NEE, Kg ha ⁻¹)	2	6
Net “Warming”	49	28
Net “Cooling”	<1	~5
Time to balance (years)	>50	<6

Tradeoffs between biogeochem. and biogeophys. effects occurs at higher resolution in the semi-arid transition zones—the regions with the largest potential for afforestation

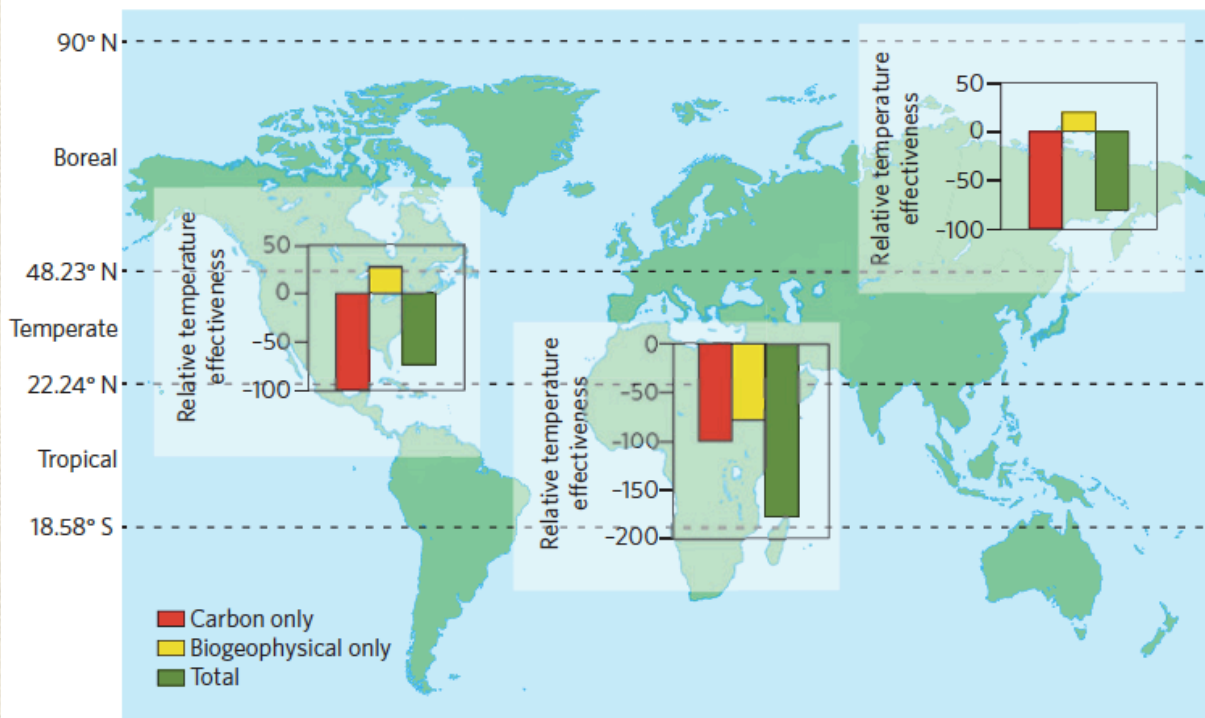
CLIMATE SCIENCE

Afforestation cools more or less

Forests affect climate not only by taking up carbon, but also by absorbing solar radiation and enhancing evaporation. In the tropics, the climate benefit of afforestation may be nearly double that expected from carbon budgets alone.

?

Richard A. Betts



--- Thank you for your attention ---



... No escape