Land Use and Climate Interactions [i.e. the role of land use within the climate system]

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NASA Land-Cover and Land-Use Change Science Team Meeting

UMUC Inn and Conference Center

April 4, 2007

What Are The New Conclusions Of The Role Of Land Use Within the Climate System

- The recognition that land use, land cover, land management and vegetation/soil dynamics are all part of the climate system
- Land use, through its role in the water, energy, carbon and other trace gas and aerosol effects, has a first order role in human and natural climate forcings and feedbacks
- The identification of global atmospheric teleconnections due to land use/land cover change which appear to alter weather and other aspects of the climate system as much or more than would occur due to the radiative effect of doubling CO2
- These conclusions are based on the outstanding research of many of our colleagues at this meeting!

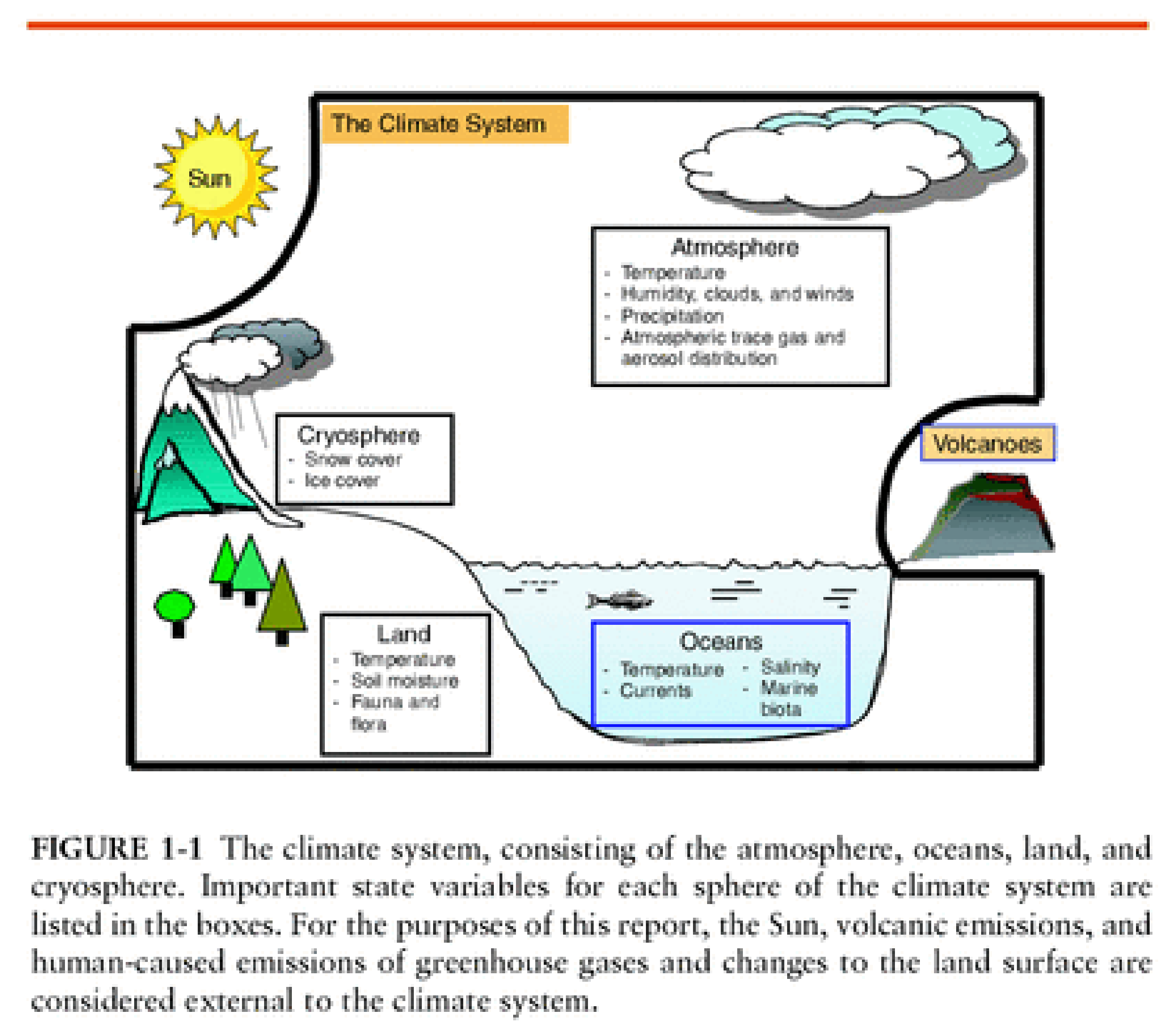
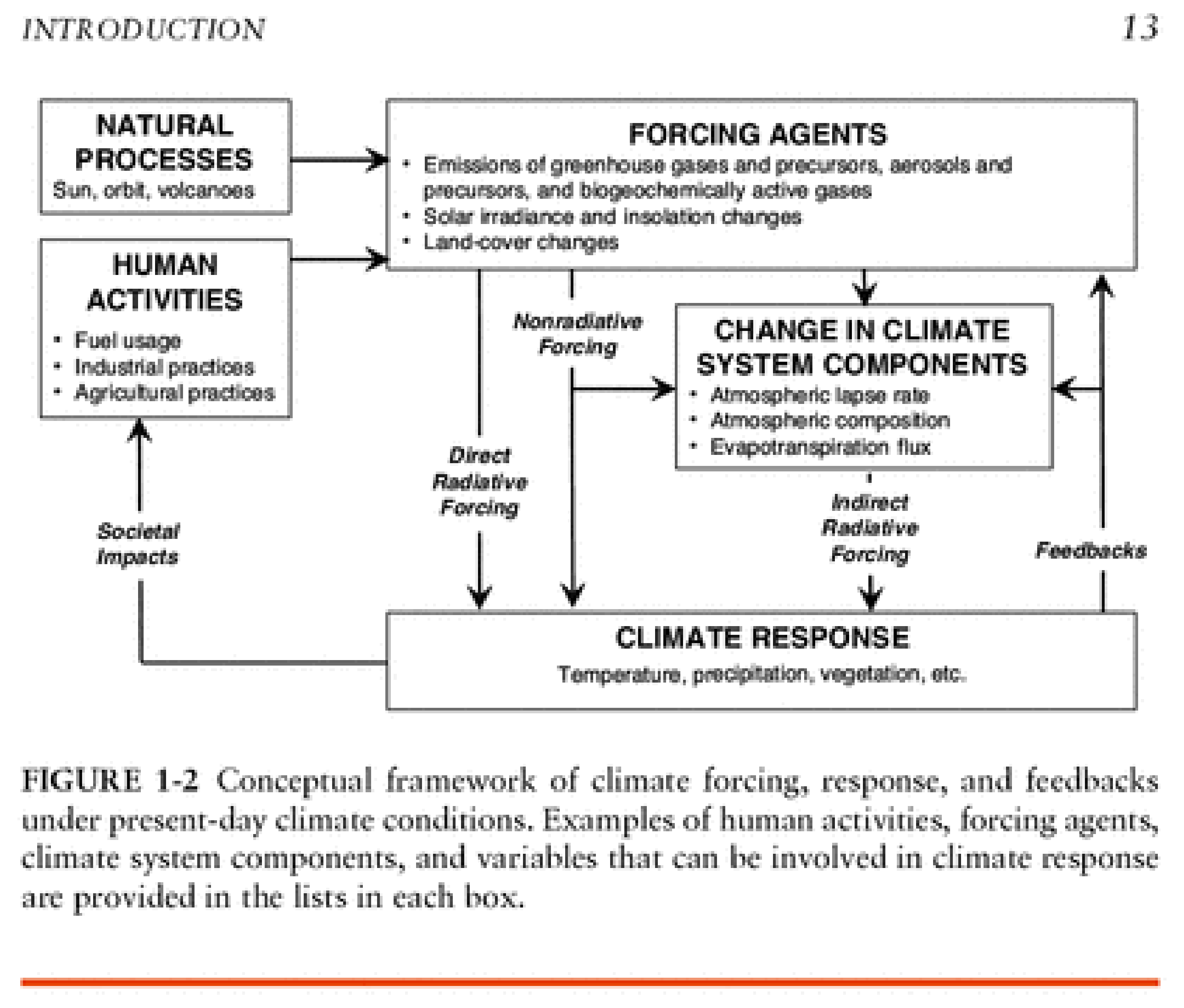


FIGURE 1-1 The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes to the land surface are considered external to the climate system.

From: National Research Council, 2005: Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties, Committee on Radiative Forcing Effects on Climate, Climate Research Committee, 224 pp.
http://www.nap.edu/catalog/11175.html



INTRODUCTION *13*

NATURAL PROCESSES
Sun, orbit, volcanoes

HUMAN ACTIVITIES
- Fuel usage
- Industrial practices
- Agricultural practices

FORCING AGENTS
- Emissions of greenhouse gases and precursors, aerosols and precursors, and biogeochemically active gases
- Solar irradiance and insolation changes
- Land-cover changes

CHANGE IN CLIMATE SYSTEM COMPONENTS
- Atmospheric lapse rate
- Atmospheric composition
- Evapotranspiration flux

CLIMATE RESPONSE
Temperature, precipitation, vegetation, etc.

Nonradiative Forcing

Direct Radiative Forcing

Indirect Radiative Forcing

Feedbacks

Societal Impacts

FIGURE 1-2 Conceptual framework of climate forcing, response, and feedbacks under present-day climate conditions. Examples of human activities, forcing agents, climate system components, and variables that can be involved in climate response are provided in the lists in each box.

From: National Research Council, 2005: Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties, Committee on Radiative Forcing Effects on Climate, Climate Research Committee, 224 pp.
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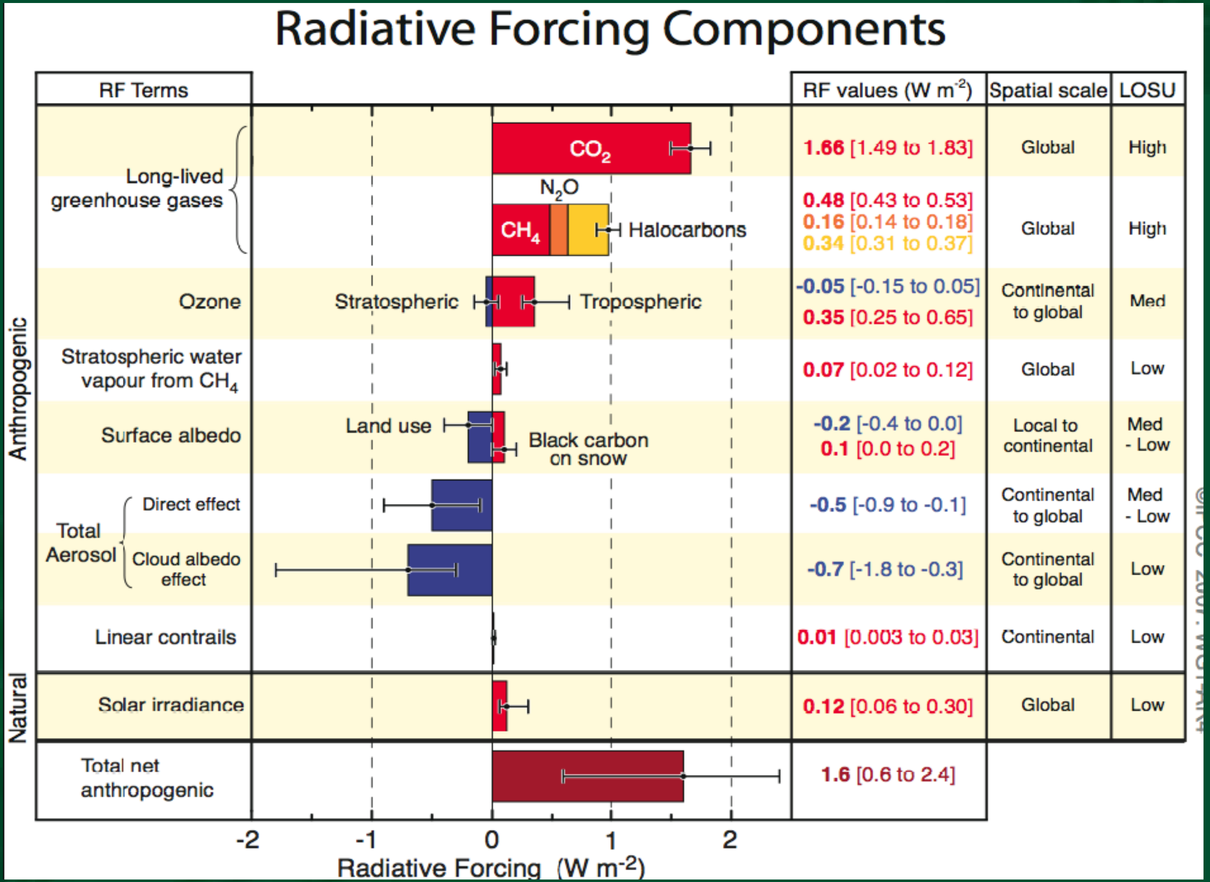
IPCC Perspective



Radiative Forcing Components

RF Terms	RF values (W m^{-2})	Spatial scale	LOSU
Long-lived greenhouse gases: CO_2	**1.66** [1.49 to 1.83]	Global	High
Long-lived greenhouse gases: CH_4, N_2O, Halocarbons	**0.48** [0.43 to 0.53] **0.16** [0.14 to 0.18] **0.34** [0.31 to 0.37]	Global	High
Ozone	**-0.05** [-0.15 to 0.05] **0.35** [0.25 to 0.65]	Continental to global	Med
Stratospheric water vapour from CH_4	**0.07** [0.02 to 0.12]	Global	Low
Surface albedo	**-0.2** [-0.4 to 0.0] **0.1** [0.0 to 0.2]	Local to continental	Med - Low
Total Aerosol: Direct effect	**-0.5** [-0.9 to -0.1]	Continental to global	Med - Low
Total Aerosol: Cloud albedo effect	**-0.7** [-1.8 to -0.3]	Continental to global	Low
Linear contrails	**0.01** [0.003 to 0.03]	Continental	Low
Solar irradiance	**0.12** [0.06 to 0.30]	Global	Low
Total net anthropogenic	**1.6** [0.6 to 2.4]		

- The 2007 IPCC Focuses On The Role of Global Average Human-caused Radiative Forcing Relative To Other Measures of Human Climate Forcings

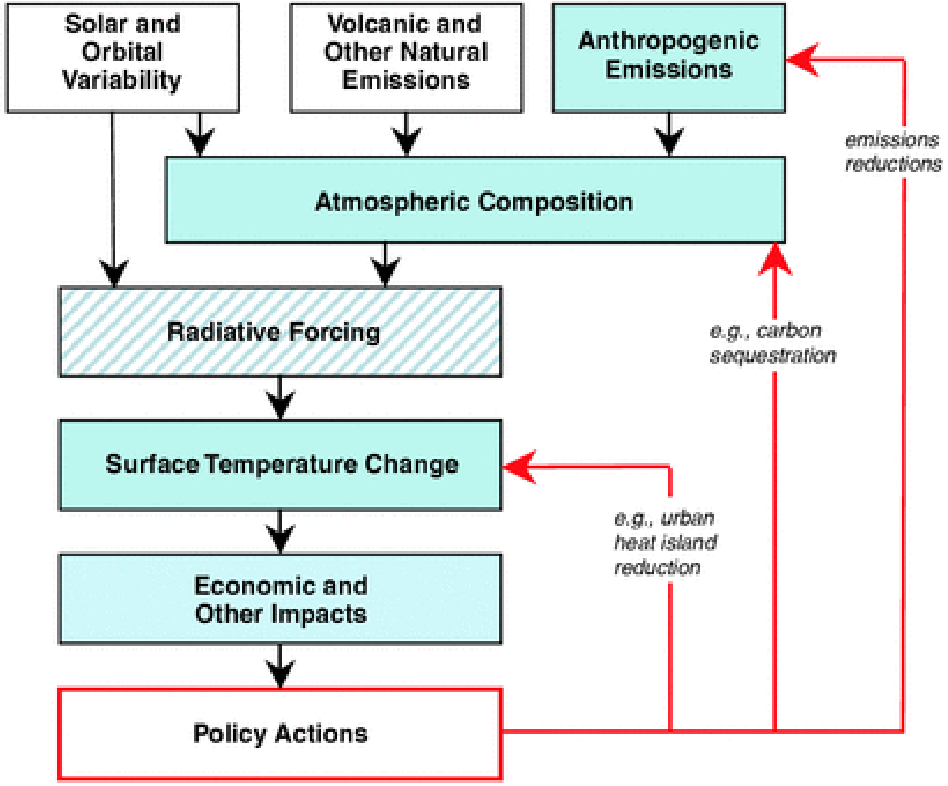


FIGURE 1-4 Conceptual framework for how radiative forcing fits into the climate policy framework. Blue-shaded boxes indicate quantities that have been considered as policy targets in international negotiations and other policy analyses. Radiative forcing (striped box) has not been treated as a policy target in the same explicit way that limiting emissions (e.g., Kyoto Protocol), limiting concentrations (e.g., greenhouse gas stabilization scenarios), and limiting temperature changes and impacts (e.g., environmental scenarios) have. That is, an explicit cap on anthropogenic radiative forcing levels has not been proposed analogous, for example, to the Kyoto Protocol cap on emissions. Note that land-use change has not received much attention as a forcing agent and is not included here, though this report recommends that it should be.

From: National Research Council, 2005: Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties, Committee on Radiative Forcing Effects on Climate, Climate Research Committee, 224 pp.
http://www.nap.edu/catalog/11175.html

EXPANDING THE RADIATIVE FORCING CONCEPT (NRC 2005 Recommendations)

- ➔Account for the Vertical Structure of Radiative Forcing
- ➔Determine the Importance of Regional Variation in Radiative Forcing
- ➔Determine the Importance of Nonradiative Forcings
- ➔Provide Improved Guidance to the Policy Community

Account for the Vertical Structure of Radiative Forcing

National Research Council Report PRIORITY RECOMMENDATIONS

- → Test and improve the ability of climate models to reproduce the observed vertical structure of forcing for a variety of locations and forcing conditions.
- → Undertake research to characterize the dependence of climate response on the vertical structure of radiative forcing.
- → Report global mean radiative forcing at both the surface and the top of the atmosphere in climate change assessments.

Determine the Importance of Regional Variation in Radiative Forcing

National Research Council Report PRIORITY RECOMMENDATIONS:

- → Use climate records to investigate relationships between regional radiative forcing (e.g., land use or aerosol changes) and climate response in the same region, other regions, and globally.

- → Quantify and compare climate responses from regional radiative forcings in different climate models and on different timescales (e.g., seasonal, interannual), and report results in climate change assessments.

Determine the Importance of Nonradiative Forcings

National Research Council Report PRIORITY RECOMMENDATIONS

- → Improve understanding and parameterizations of aerosol-cloud thermodynamic interactions and land-atmosphere interactions in climate models in order to quantify the impacts of these nonradiative forcings on both regional and global scales.
- → Develop improved land-use and land-cover classifications at high resolution for the past and present, as well as scenarios for the future.

Provide Improved Guidance to the Policy Community

National Research Council Report PRIORITY RECOMMENDATIONS

→ Encourage policy analysts and integrated assessment modelers to move beyond simple climate models based entirely on global mean TOA radiative forcing and incorporate new global and regional radiative and nonradiative forcing metrics as they become available.

New or Under-Recognized Human Climate Forcings

- → Biogeochemical Effect of CO_2
- → Nitrogen Deposition
- → Land-Use/Land-Cover Change
- → Glaciation Effect of Aerosols
- → Thermodynamic Effect of Aerosols
- → Surface Energy Budget Effect

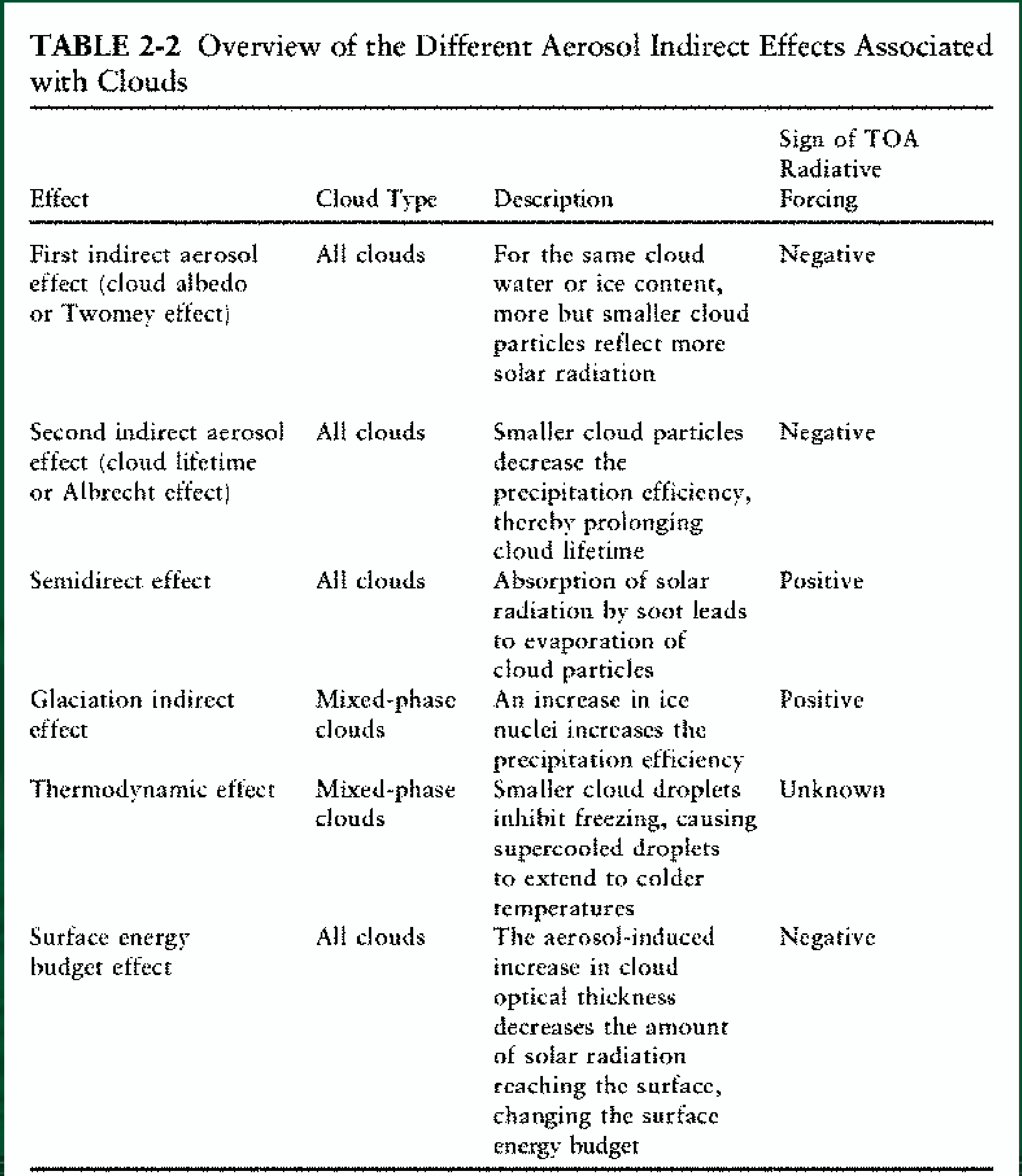


TABLE 2-2 Overview of the Different Aerosol Indirect Effects Associated with Clouds

Effect	Cloud Type	Description	Sign of TOA Radiative Forcing
First indirect aerosol effect (cloud albedo or Twomey effect)	All clouds	For the same cloud water or ice content, more but smaller cloud particles reflect more solar radiation	Negative
Second indirect aerosol effect (cloud lifetime or Albrecht effect)	All clouds	Smaller cloud particles decrease the precipitation efficiency, thereby prolonging cloud lifetime	Negative
Semidirect effect	All clouds	Absorption of solar radiation by soot leads to evaporation of cloud particles	Positive
Glaciation indirect effect	Mixed-phase clouds	An increase in ice nuclei increases the precipitation efficiency	Positive
Thermodynamic effect	Mixed-phase clouds	Smaller cloud droplets inhibit freezing, causing supercooled droplets to extend to colder temperatures	Unknown
Surface energy budget effect	All clouds	The aerosol-induced increase in cloud optical thickness decreases the amount of solar radiation reaching the surface, changing the surface energy budget	Negative

From: National Research Council, 2005: Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties, Committee on Radiative Forcing Effects on Climate, Climate Research Committee, 224 pp. http://www.nap.edu/catalog/11175.html

Potential Impacts of Aerosol-Land –Atmosphere Interactions

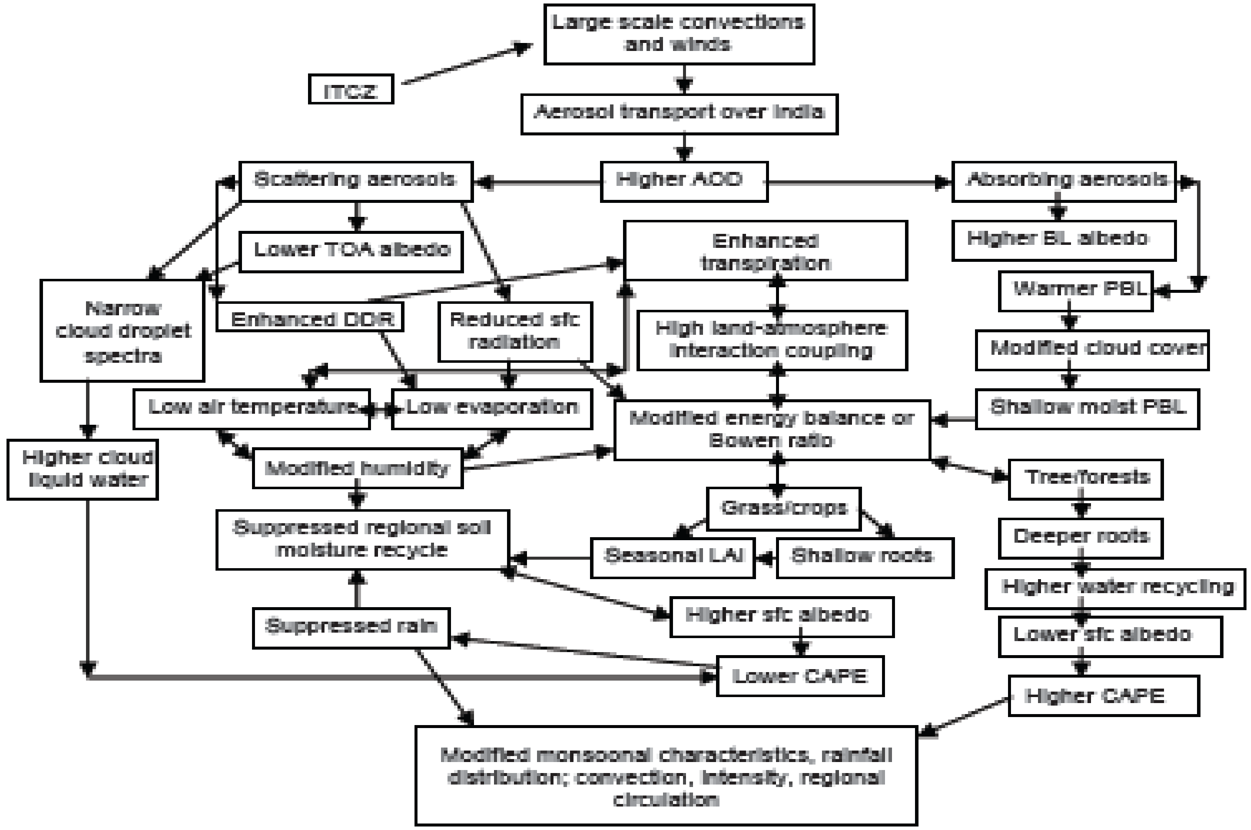
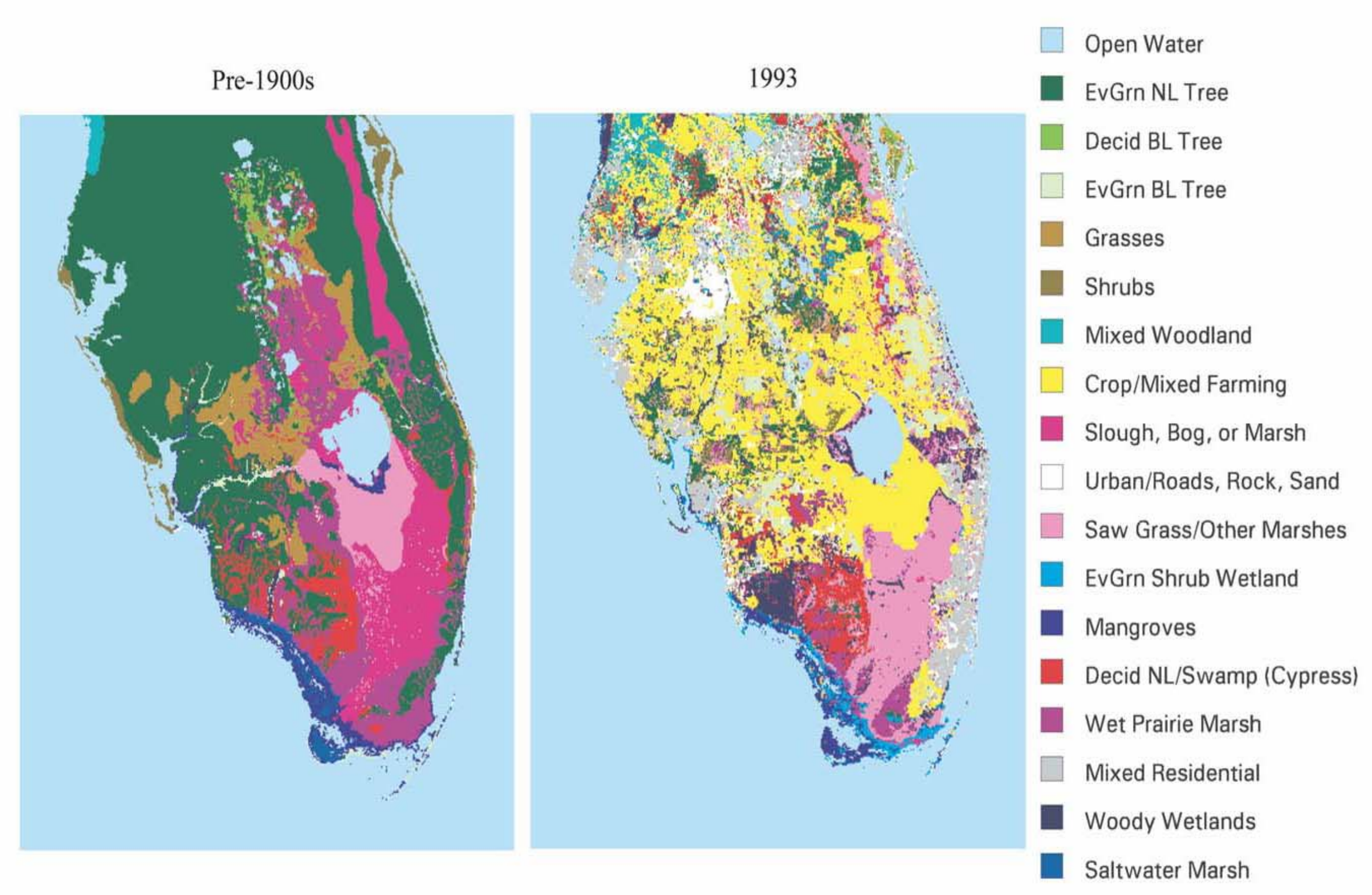


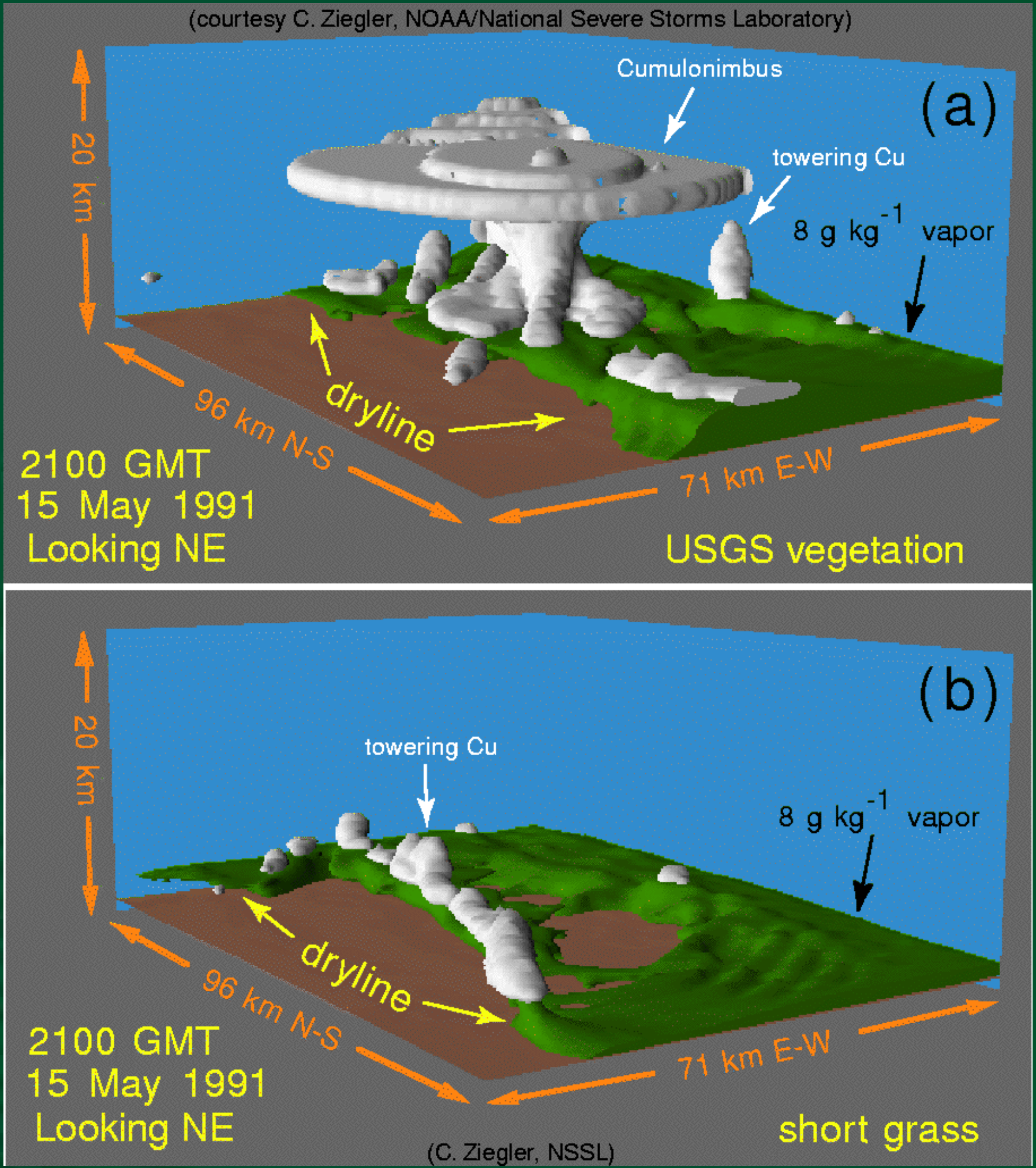
Figure 7: Possible aerosol-land-atmosphere interactions and surface, convection, and precipitation feedbacks in the monsoonal systems.

Niyogi et al., 2007. Accepted



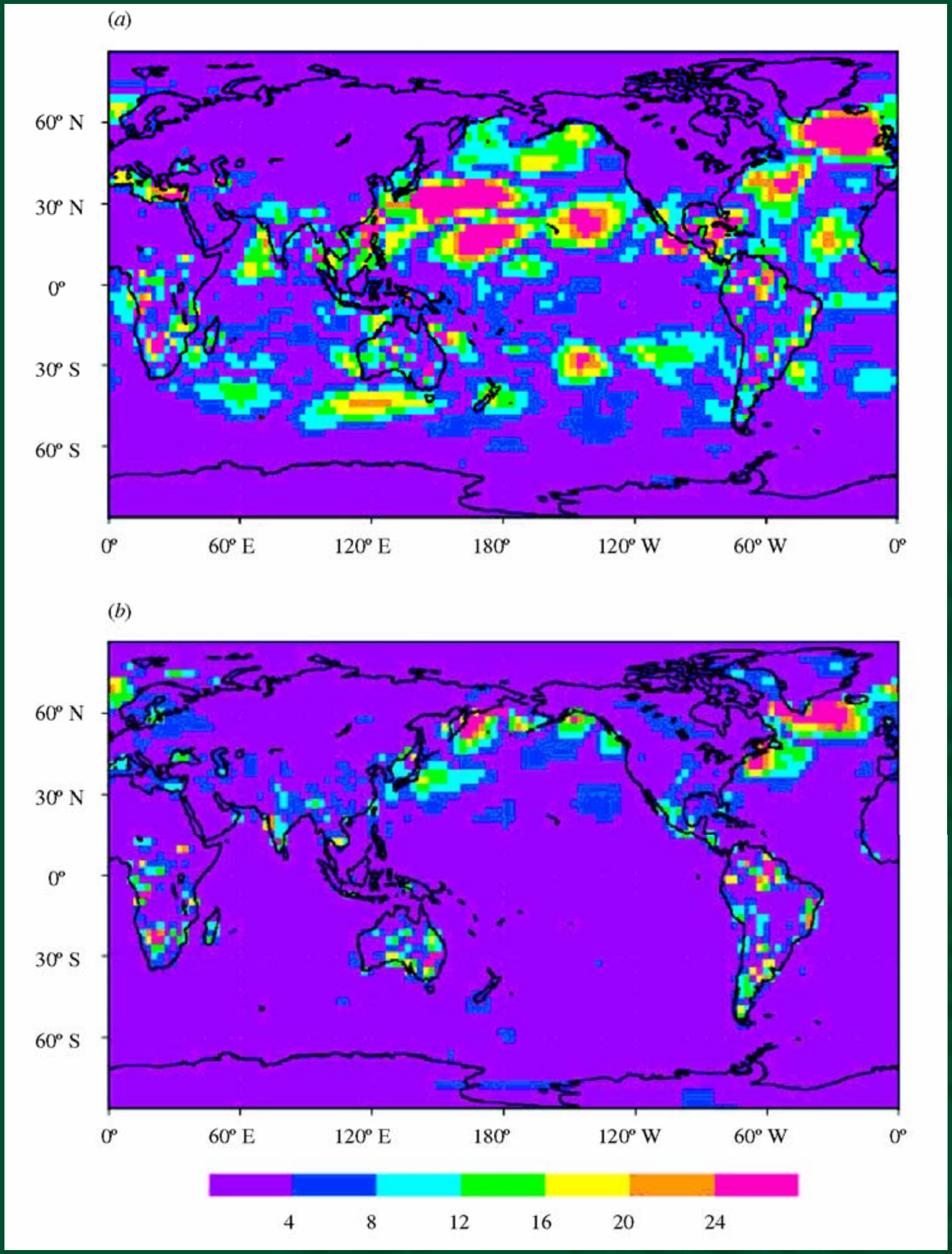
U.S. Geological Survey land-cover classes for pre-1900's natural conditions (left) and 1993 land-use patterns (right). From Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land-cover change on the Florida peninsula sea breezes and warm season sensible weather. Mon. Wea. Rev., 132, 28-52. http://blue.atmos.colostate.edu/publications/pdf/R-272.pdf

Effect of Land-Use Change on Deep Cumulonimbus Convection



From Pielke Sr., R.A., 2001: Influence of the spatial distribution of vegetation and soils on the prediction of cumulus convective rainfall. *Rev. Geophys*., 39,151-177.

http://blue.atmos.colostate.edu/publications/pdf/R-231.pdf



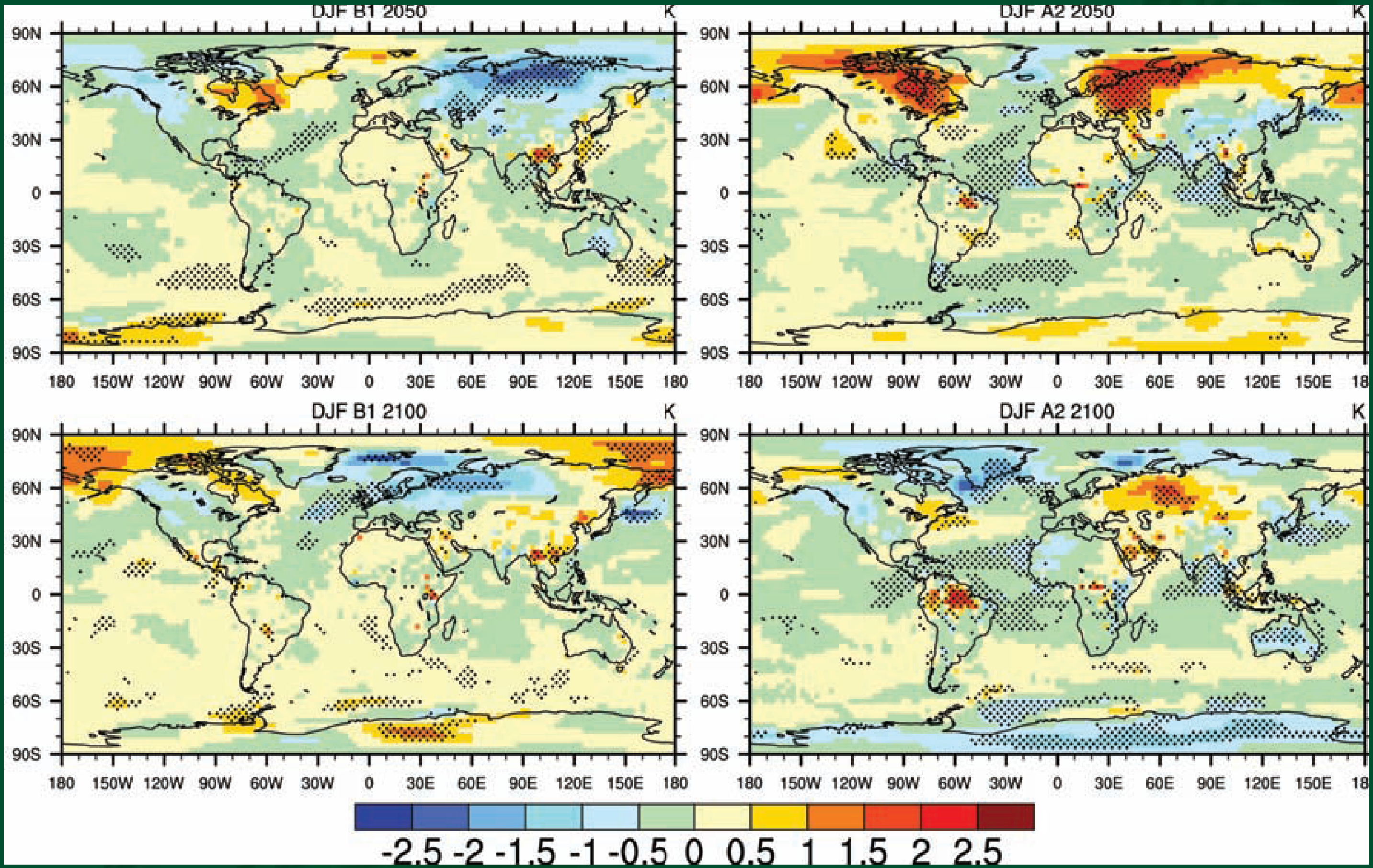
The ten-year average absolute-value change in surface latent turbulent heat flux in W m^{-2} worldwide as a result of the land-use changes for (a) January, and (b) July. (Adapted from Chase et al. 2000.)

From Pielke Sr., R.A., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D. Niyogi, and S. Running, 2002: The influence of land-use change and landscape dynamics on the climate system- relevance to climate change policy beyond the radiative effect of greenhouse gases. *Phil. Trans. A. Special Theme Issue*, 360, 1705-1719.

http://blue.atmos.colostate.edu/publications/pdf/R-258.pdf

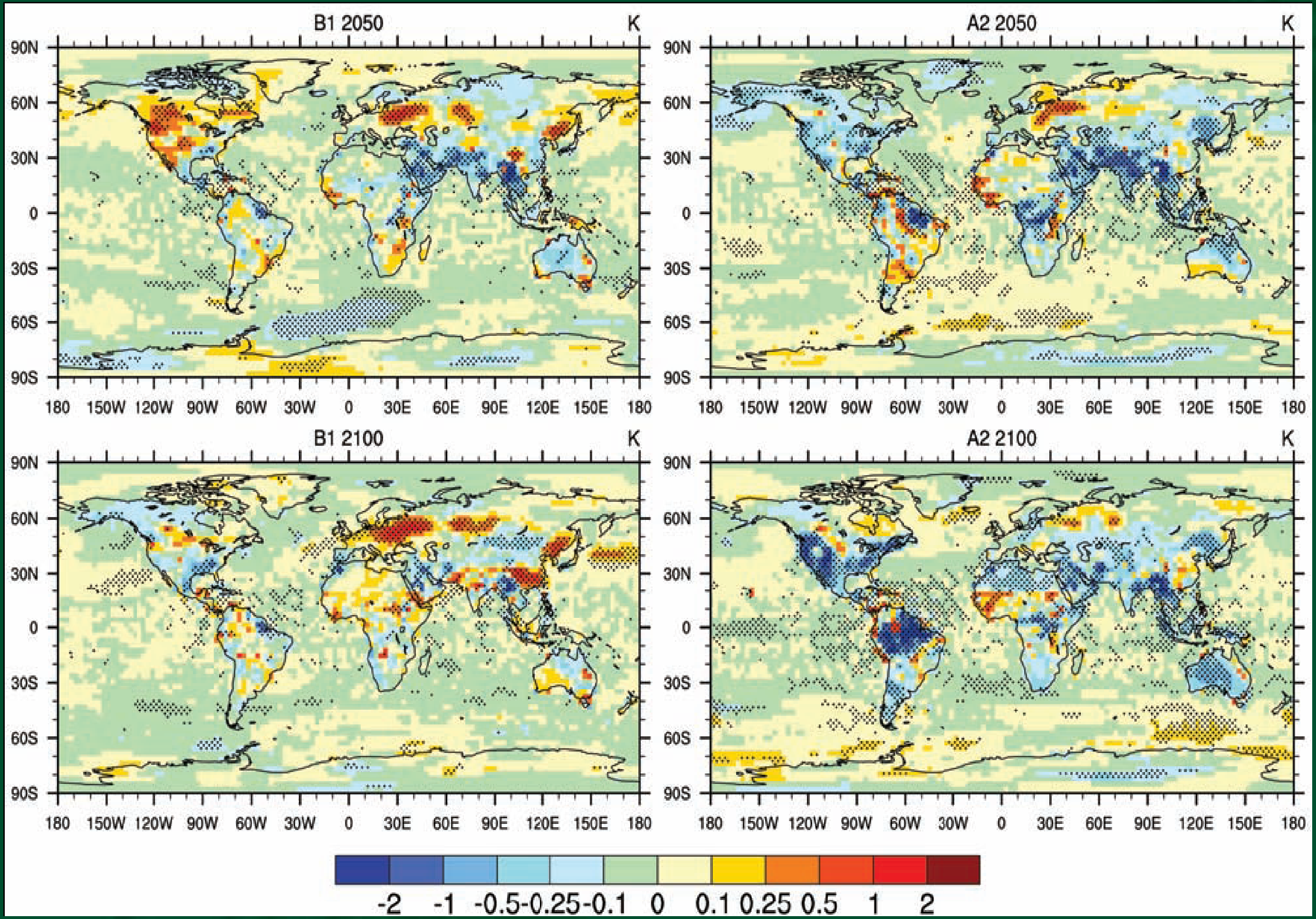
DJF temperature differences due to land-cover change in each of the scenarios. Values were calculated by subtracting the greenhouse gas–only forcing scenarios from a simulation including land-cover and greenhouse gas forcings.

Feddema et al. 2005: The importance of land-cover change in simulating future climates., Science 310



Changes in the annual average diurnal temperature range due to land-cover change in each of the scenarios. Values were calculated by subtracting the greenhouse gas–only forcing scenarios from a simulation including land-cover and greenhouse gas forcings. Shaded grid cells are significant at the 0.05 confidence level.

Feddema et al 2005



$$Q_N + Q_H + Q_{LE} + Q_G = 0$$

$$Q_N = Q_S(1 - A) + Q_{LW}^{\downarrow} - Q_{LW}^{\uparrow}$$

From Pielke Sr., R.A., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D. Niyogi, and S. Running, 2002: The influence of land-use change and landscape dynamics on the climate system- relevance to climate change policy beyond the radiative effect of greenhouse gases. *Phil. Trans. A. Special Theme Issue*, 360, 1705-1719. http://blue.atmos.colostate.edu/publications/pdf/R-258.pdf

Redistribution of Heat Due to the Human Disturbance of the Earth’s Climate System

Globally-Average Absolute Value of Sensible Heat Plus Latent Heat		
Only Where Land Use Occurred	July	1.08 Watts m^{-2}
	January	0.7 Watts m^{-2}
Teleconnections Included	July	8.90 Watts m^{-2}
	January	9.47 Watts m^{-2}

Global redistribution of heat is on the same order as an El Niño.

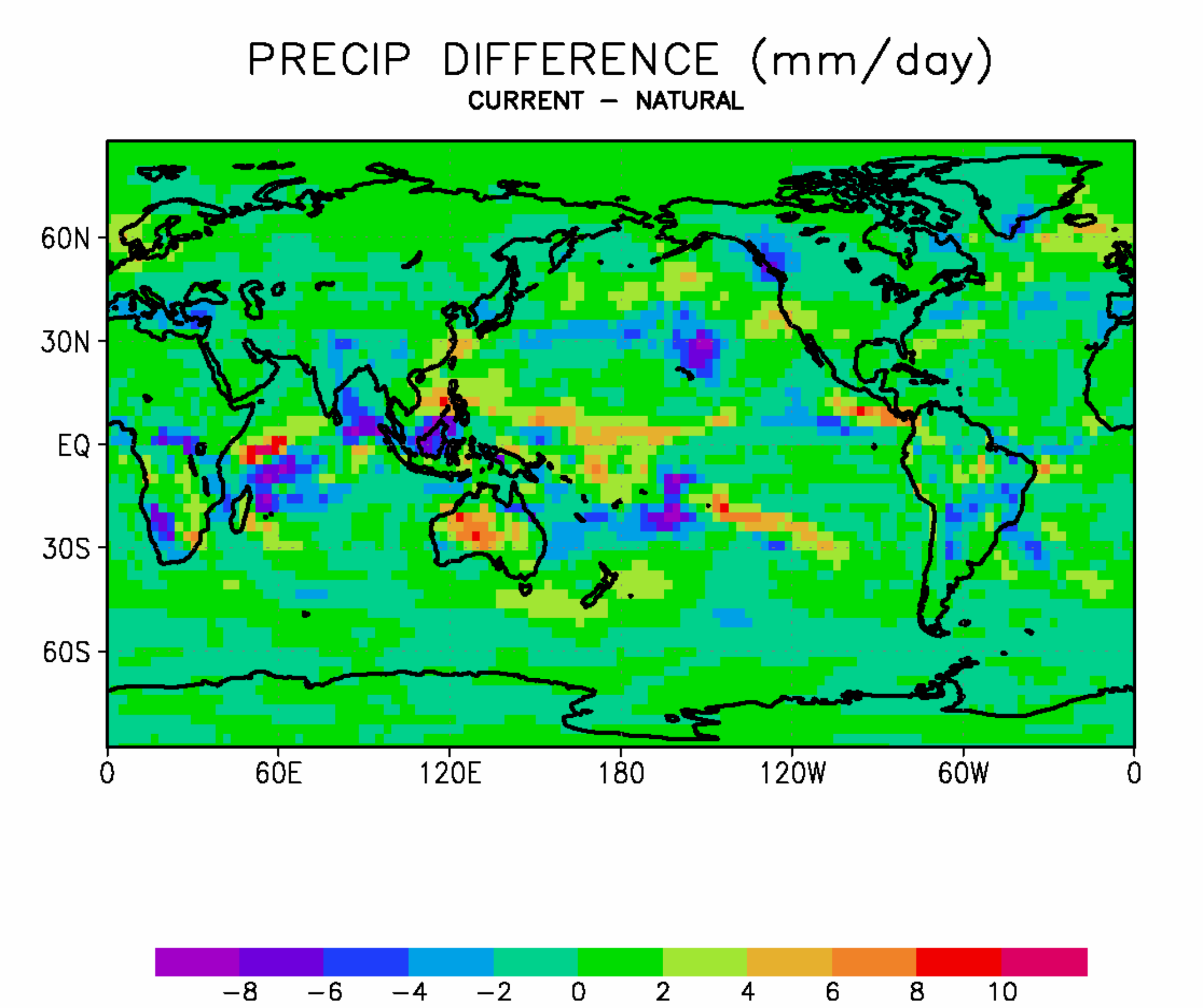
Spatial Redistribution of Heat is also Associated with a Spatial Redistribution of Water

$$R_N = Q_G + H + L(E+T)$$
$$P = E + T + RO + I$$

New Metric: $\;$ *Changes in* δP; δT; δRO; δI

From Pielke Sr., R.A., 2001: Influence of the spatial distribution of vegetation and soils on the prediction of cumulus convective rainfall. *Rev. Geophys*., 39,151-177. http://blue.atmos.colostate.edu/publications/pdf/R-231.pdf

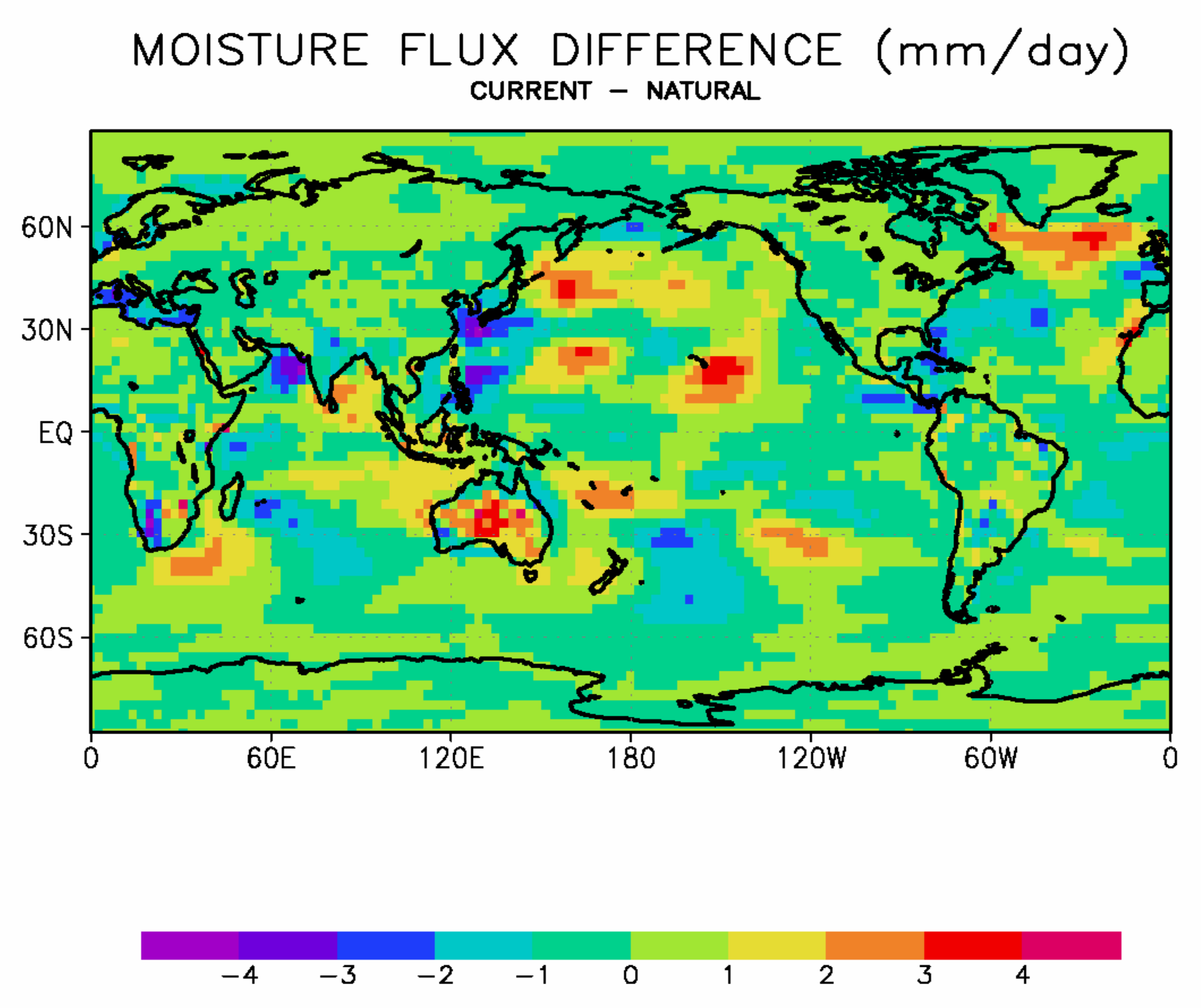
Global Water Cycle Metric



Absolute Value of Globally-Averaged Change is 1.2 mm/day.

Prepared by T.N. Chase, CU, Boulder, CO.

Global Water Cycle Metric



Absolute Value of Globally-Averaged Change is 0.6 mm/day

Prepared by T.N. Chase, CU, Boulder, CO.

Importance of Spatially Heterogeneous Heating

$$NGoRF = \frac{GoRF_{anthro}}{GoRF_{total}}$$

$$GoRF_{total} = \overline{\frac{\partial R_{total}}{\partial \lambda}}$$

$$GoRF_{anthro} = \overline{\frac{\partial R_{anthro}}{\partial \lambda}}$$

From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974.
http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

The Normalized Gradient of Radiative Forcing (NGoRF) is the fraction of the present Earth’s heterogeneous diabatic heating that can be attributed to human activity
on different horizontal scales

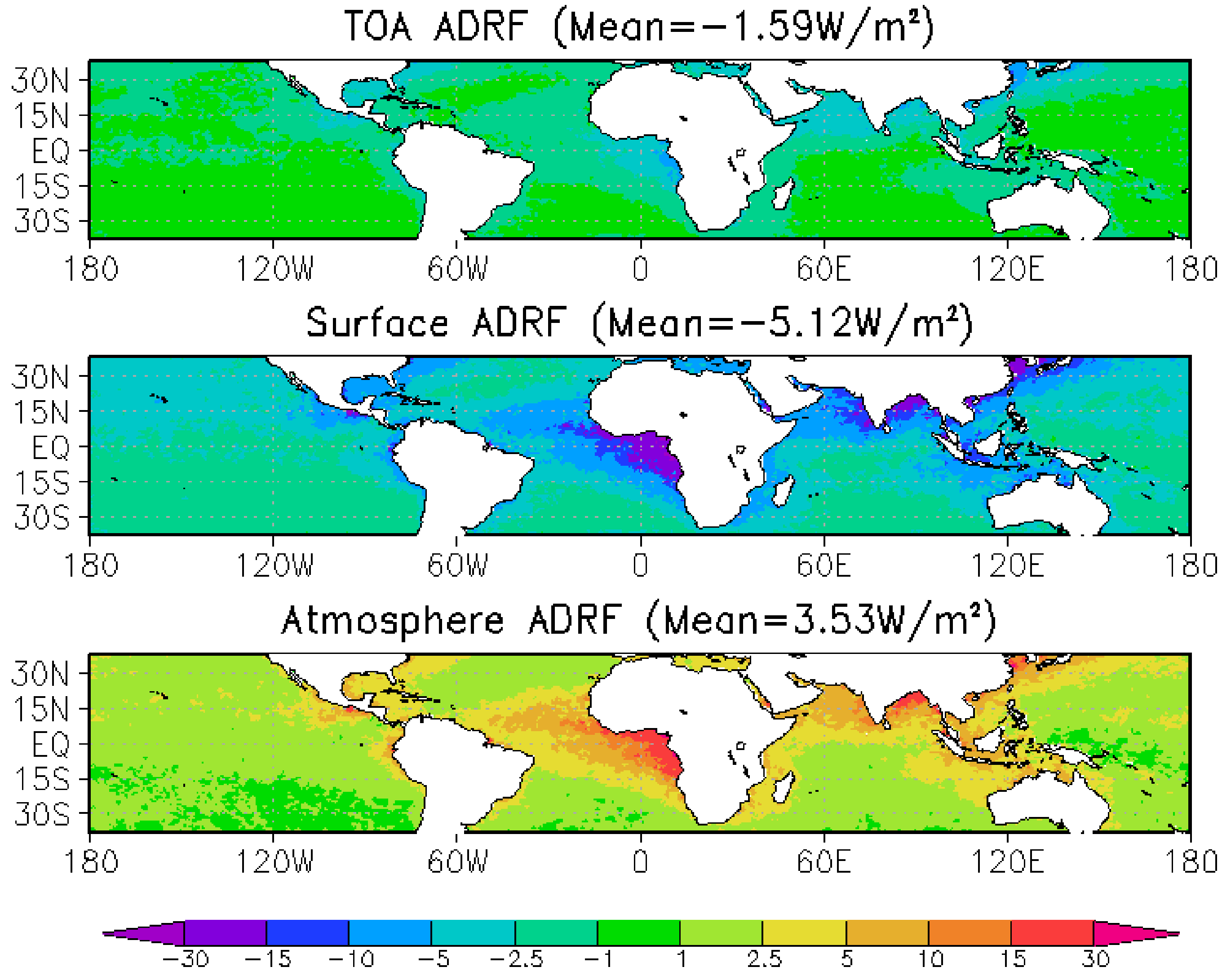


Figure 1. Shortwave aerosol direct radiative forcing (ADRF) for top-of atmosphere (TOA), surface, and atmosphere. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974. http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

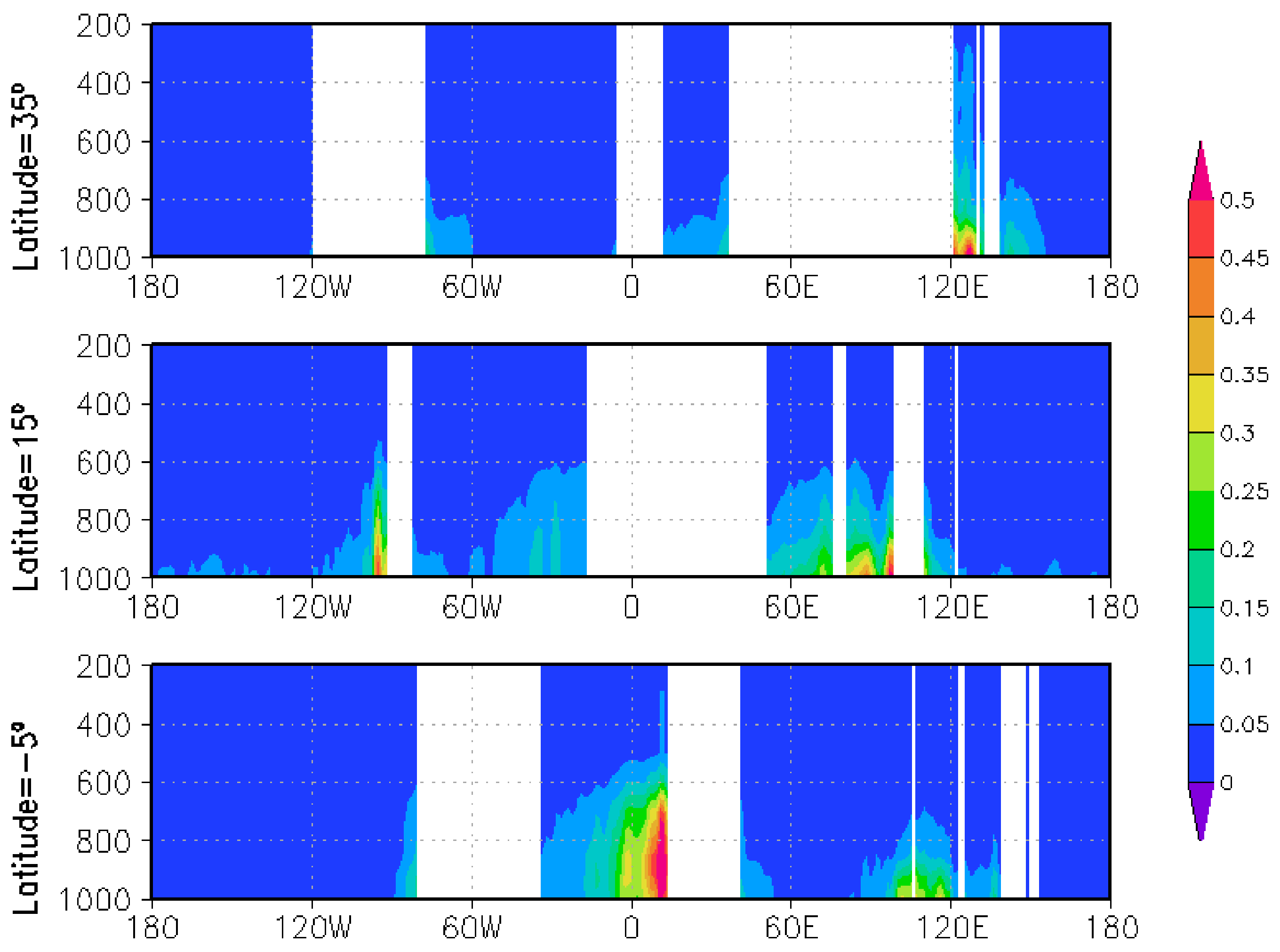


Figure 2. Vertical profile of atmospheric heating rate (K day^{-1}) due to shortwave ADRF. Vertical coordinate is pressure level (mb). From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974. http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

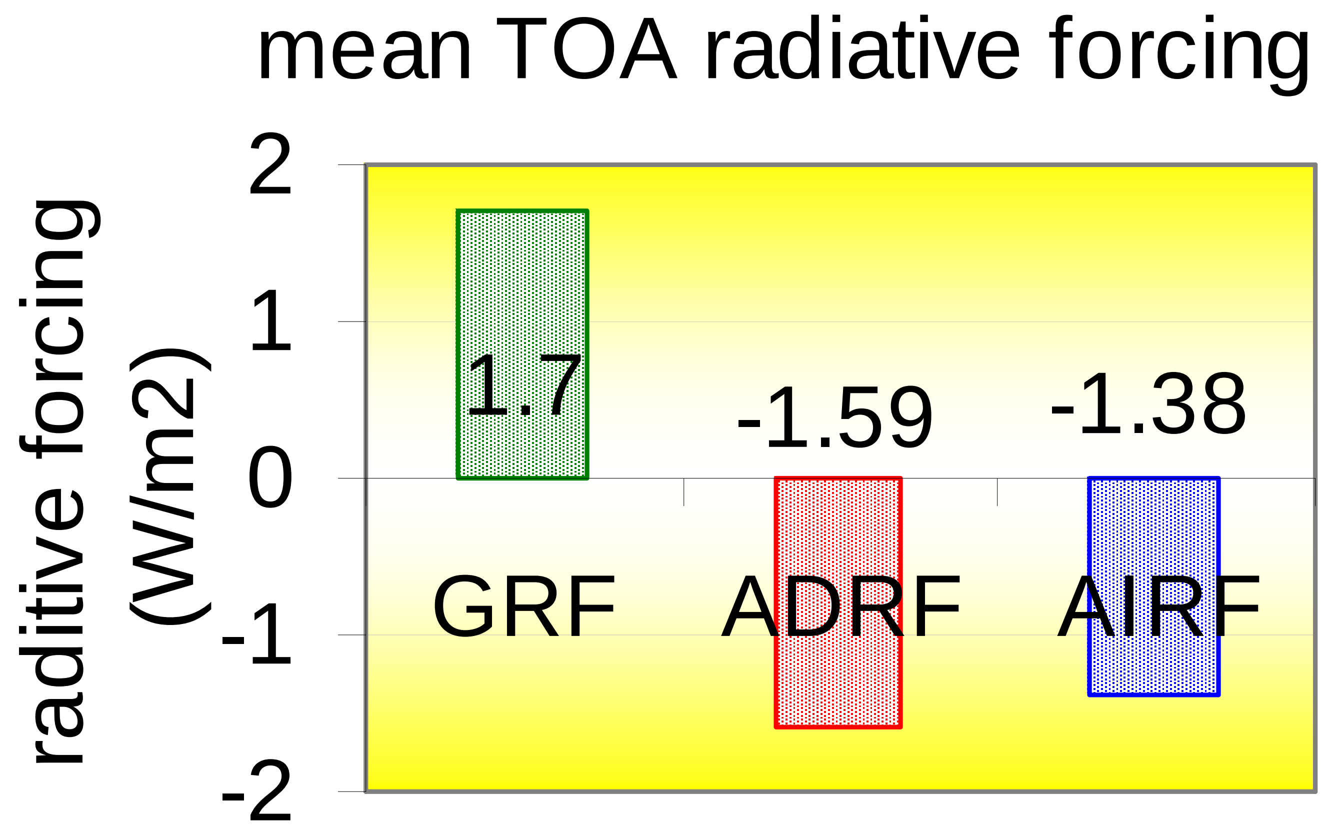


Figure 4. Comparison of Mean TOA radiative forcing between infrared GRF, shortwave ADRF, and shortwave AIRF. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974. http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

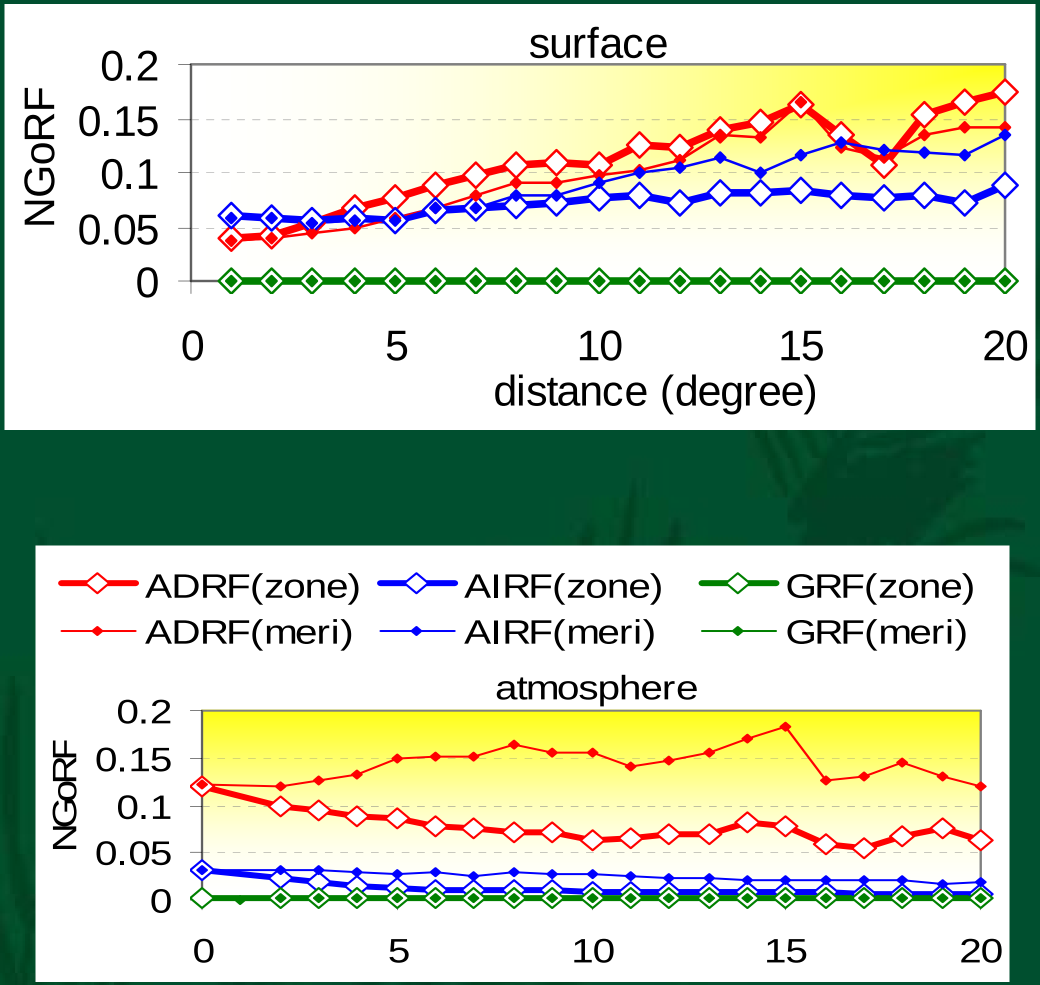


Figure 5. Comparison of the meridional and the zonal component of NGoRF between infrared GRF, shortwave ADRF, and shortwave AIRF for atmosphere and surface. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974.

http://blue.atmos.colostate.edu/publications/pdf/R-312.pdf

The Same Analysis Needs To Be Applied For Land Surface Forcings

What is the fraction of the present Earth’s heterogeneous diabatic heating from land use/land cover change and vegetation/soil dynamics that can be attributed to human activity on different horizontal scales?

Importance of Vegetation/Soil Feedbacks

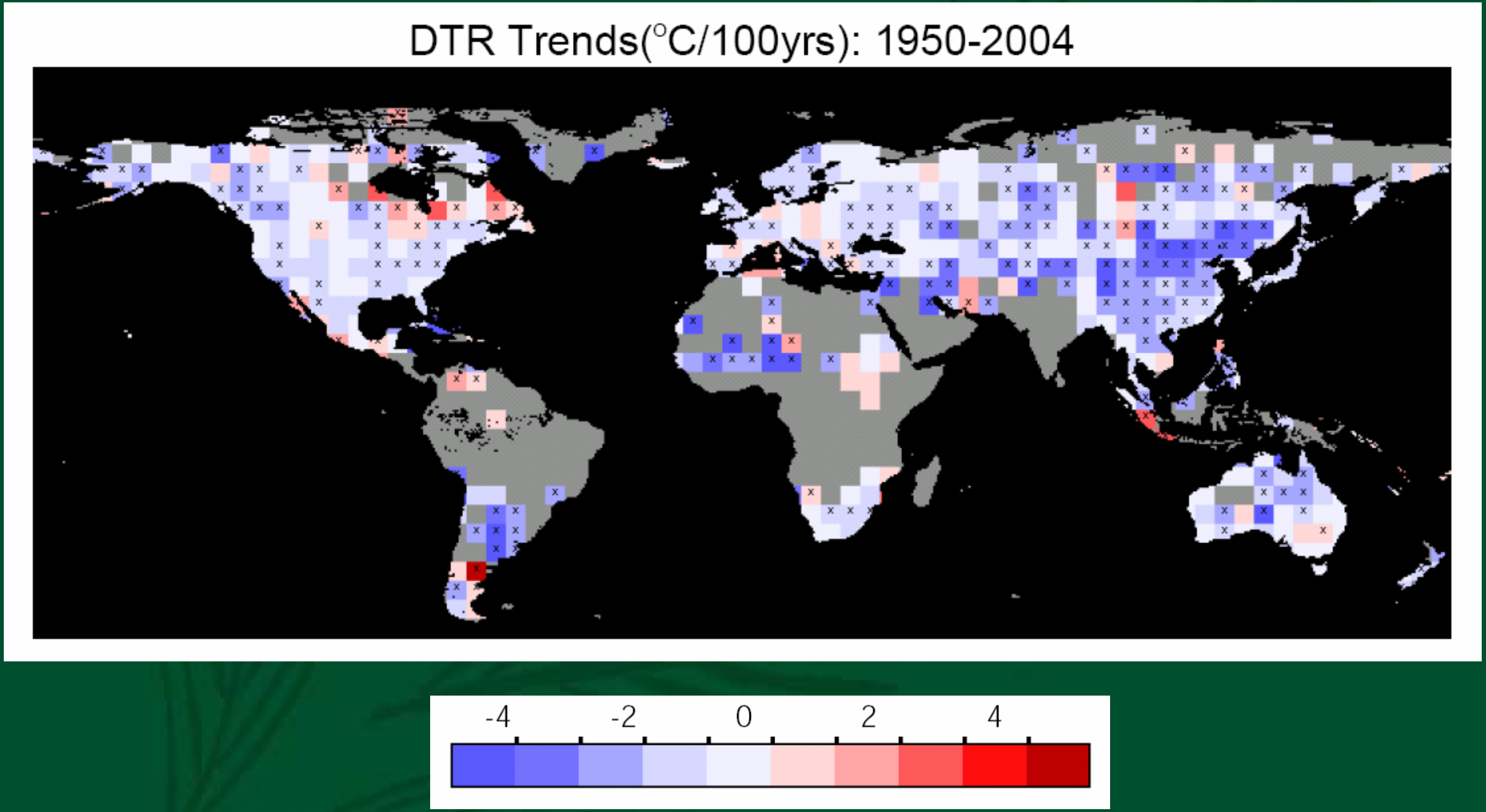
Assessing Effects of Drought and Land Use Change on Diurnal Temperature Range over the Sahel

Dickinson research group

Georgia Institute of Technology

Observed DTR Trends: Global View

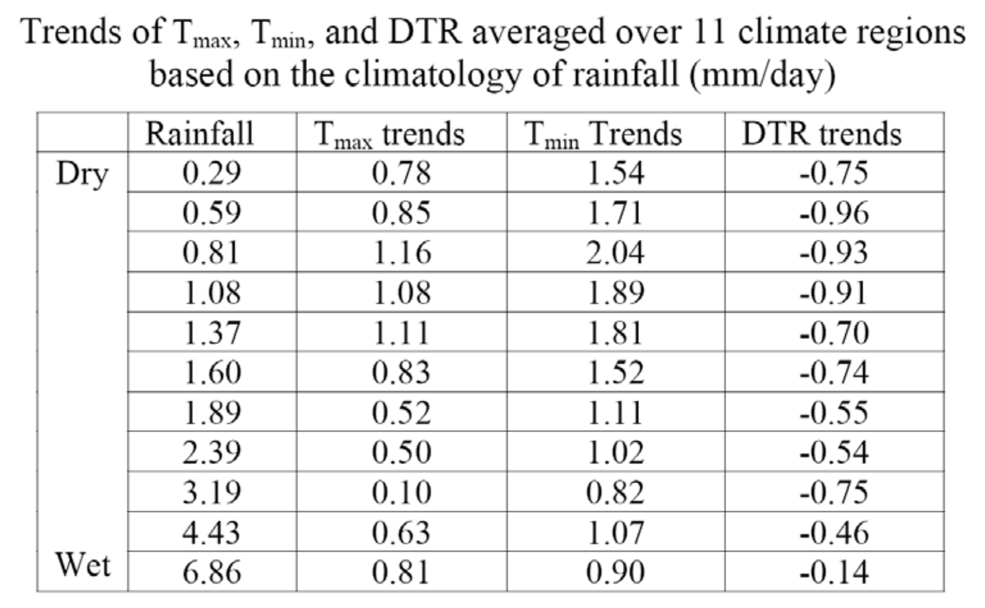
- DTR declines most over semi-arid regions such as the Sahel



(Data sources: Vose et al., 2005)

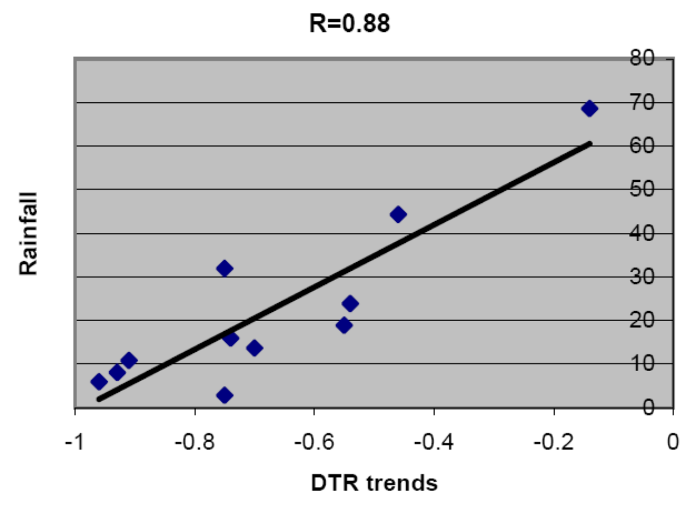
Observed DTR Trends: Global Statistics

- The drier the climate, the stronger the warming in Tmax and Tmin, and the larger the DTR reduction - the warming and the reduction of DTR are strongest over the driest regions.



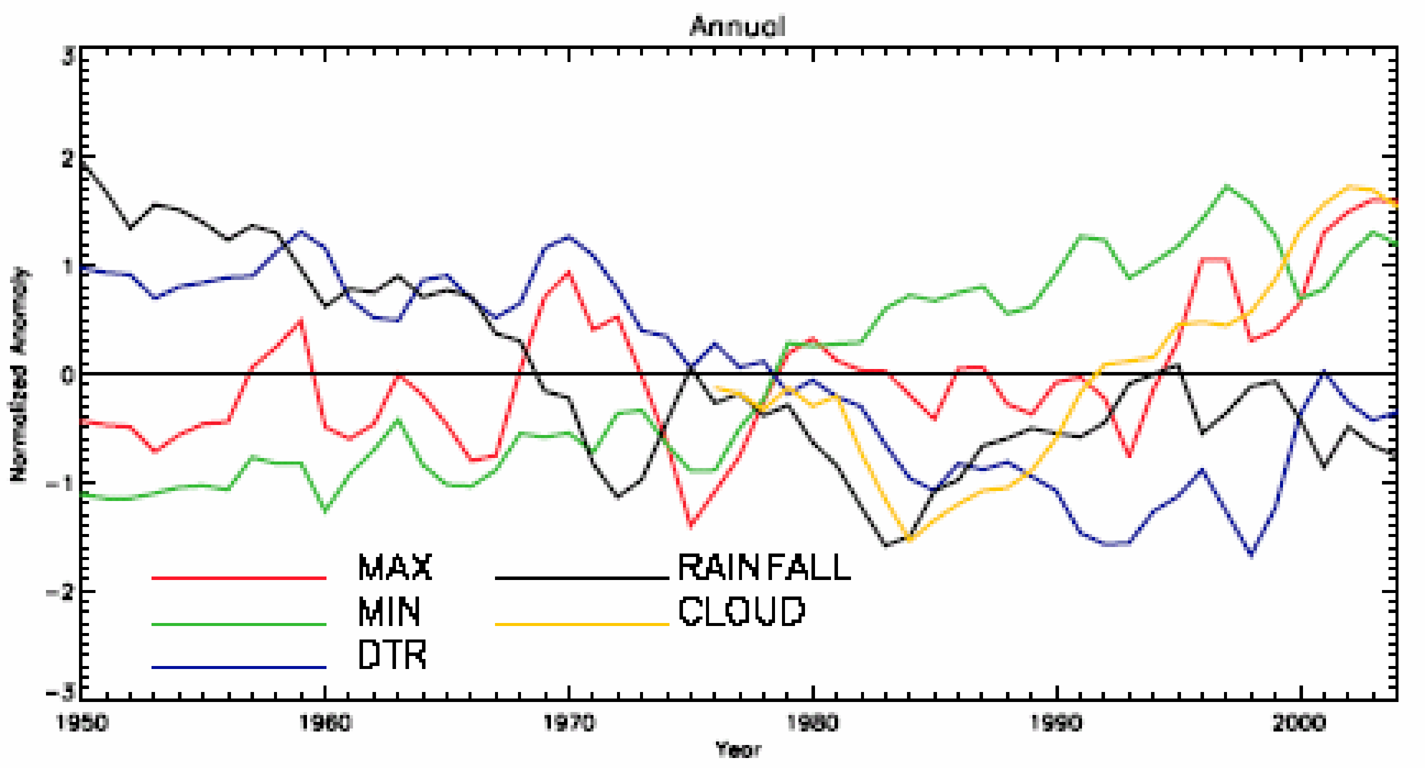
Trends of T_{max}, T_{min}, and DTR averaged over 11 climate regions based on the climatology of rainfall (mm/day)

	Rainfall	T_{max} trends	T_{min} Trends	DTR trends
Dry	0.29	0.78	1.54	-0.75
	0.59	0.85	1.71	-0.96
	0.81	1.16	2.04	-0.93
	1.08	1.08	1.89	-0.91
	1.37	1.11	1.81	-0.70
	1.60	0.83	1.52	-0.74
	1.89	0.52	1.11	-0.55
	2.39	0.50	1.02	-0.54
	3.19	0.10	0.82	-0.75
	4.43	0.63	1.07	-0.46
Wet	6.86	0.81	0.90	-0.14



Observed DTR Trends: The Sahel

- T_{min} has a strong/significant warming trend while T_{max} shows a small/insignificant trend, and thus the DTR declines.



Normalized time series anomalies of annual mean T_{max},T_{min}, DTR, cloud cover and rainfall for the period of 1950-2004.

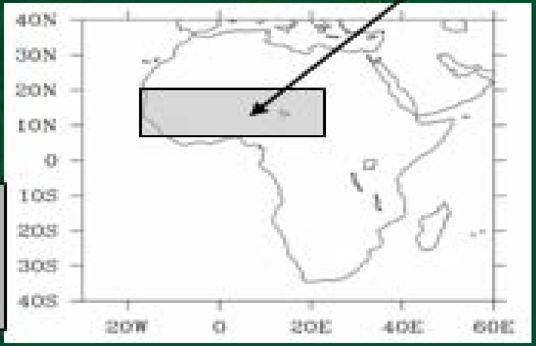
Climate Model Sensitivity Tests

- Three 20 yr simulations using NCAR CAM3/CLM3:
  - Control run (CTL): no changes in vegetation and ε_g =0.96
  - Exp A: remove all vegetation and ε_g =0.89
  - Exp B: remove all vegetation and ε_g =0.96

Typical soil emissivity:
$\varepsilon_g = 0.96$
Desert soil emissivity:
ε_g =0.89

A-CTL: effects of vegetation + emissivity
B-CTL: effects of vegetation only

Test region: Sahel



Observed vs Simulated Temp: Spatial Pattern

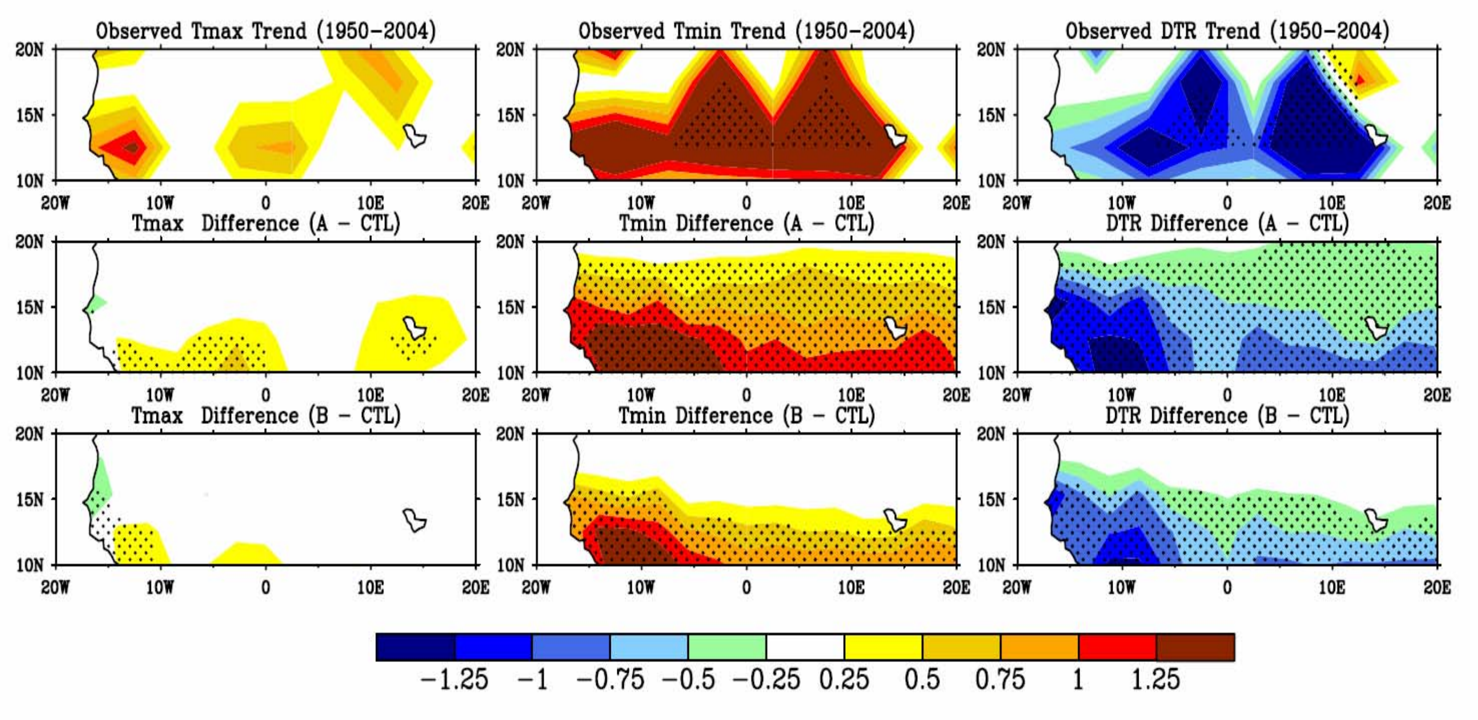
- Stronger warming for Tmin than Tmax over the Sahel

Tmax Tmin DTR

OBS

A-CTL

B-CTL



Observed and simulated annual mean T_{max},T_{min}, and DTR

Control run (CTL): no changes in vegetation and ε =0.96

Exp A: remove all vegetation and ε =0.89 Exp B: remove all vegetation and ε =0.96

Conclusions

- Our simulations show that the reduction in vegetation and soil emissivity warms T_{min} much faster than T_{max} and thus substantially declines the DTR.

- Drought and land use change induced vegetation removal and soil aridation over semiarid regions like the Sahel could initiate an important soil-vegetation positive feedback on warming land surface air temperature and decreasing the DTR.

Results from:

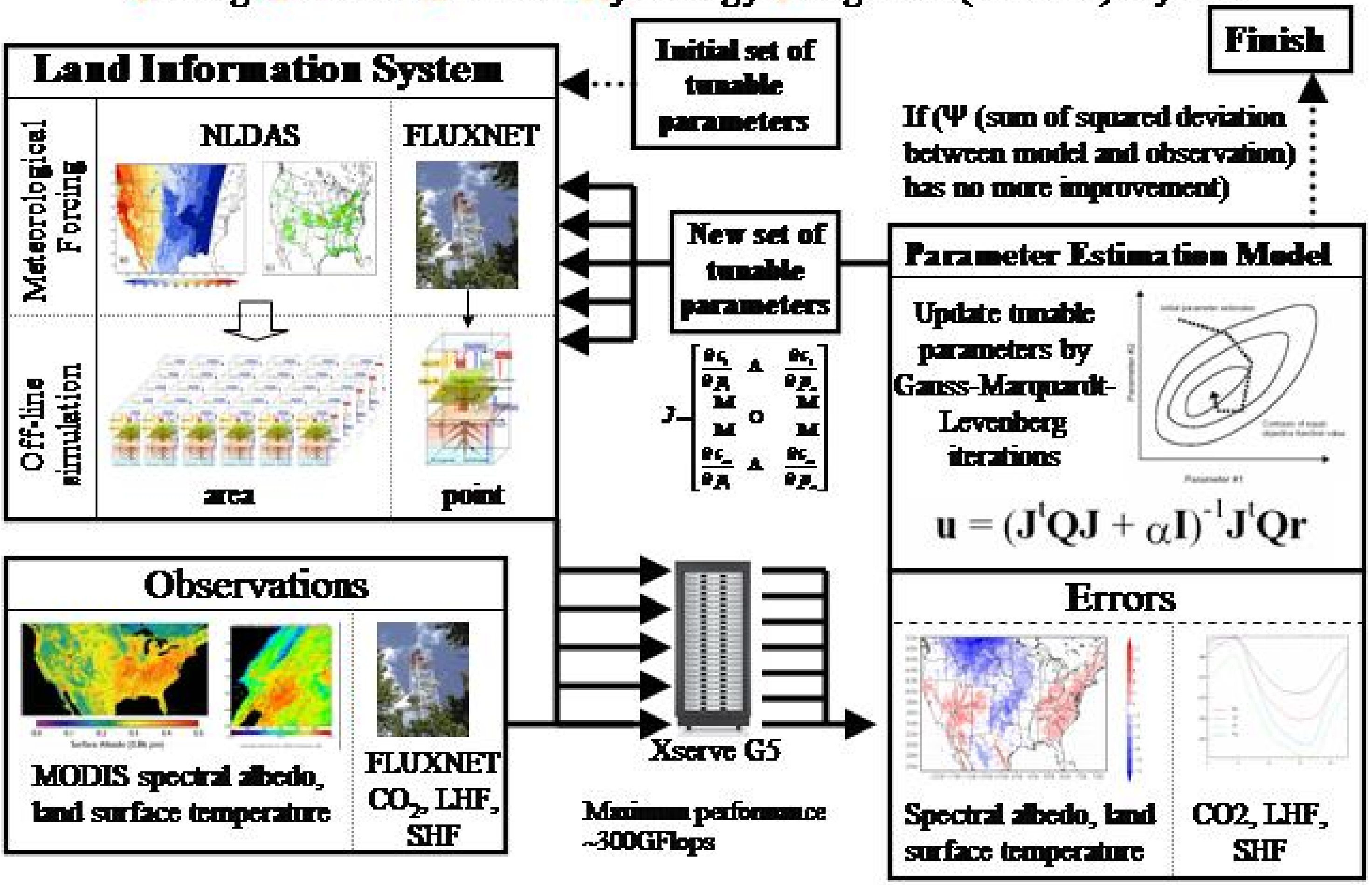
Zhou, Dickinson, et al., *PNAS*, in revision, 2007
Zhou, Dickinson, et al., *JGR*, to be submitted, 2007

Prescription of Land Use

Land Surface Model Calibration

How can we improve the model?

Tuning-Oriented Satellite-Hydrology-Integrated (TOSHI) Cycles



Land Information System

Meteorological Forcing

Off-line simulation

NLDAS

FLUXNET

area

point

Initial set of tunable parameters

New set of tunable parameters

$$J = \begin{bmatrix} \frac{\partial e_1}{\partial p_1} & \cdots & \frac{\partial e_1}{\partial p_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial e_m}{\partial p_1} & \cdots & \frac{\partial e_m}{\partial p_n} \end{bmatrix}$$

Finish

If (Ψ (sum of squared deviation between model and observation) has no more improvement)

Parameter Estimation Model

Update tunable parameters by Gauss-Marquardt-Levenberg iterations

$$u = (J^t Q J + \alpha I)^{-1} J^t Q r$$

Observations

MODIS spectral albedo, land surface temperature

FLUXNET CO_2, LHF, SHF

Xserve G5

Maximum performance ~300GFlops

Errors

Spectral albedo, land surface temperature

CO2, LHF, SHF

Development and Sensitivity Analysis of High Resolution Land Surface Parameters for Mesoscale Atmospheric Modeling of Urban Areas

Christopher Small[1], Roni Avissar[2], Robert Walko[2], Kathy Voyko-Walko[2]

[1] *Lamont Doherty Earth Observatory*
Columbia University

[2] *Dept. of Civil and Environmental Engineering*
Pratt School of Engineering, Duke University

- *Influence of Sub/Urban Land Cover on Atmospheric Processes*
- *Biophysical Land Surface Parameters from Spectral Mixture Analysis*
- *Heterogeneity of Urban Land Cover Parameters*
- *Mesoscale Sensitivity Analysis & Scale Dependence*

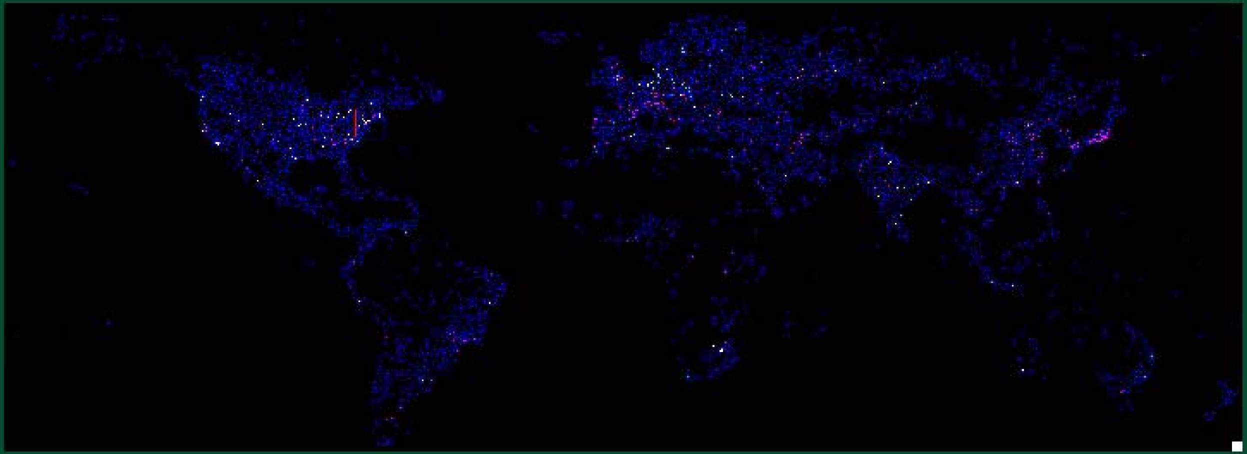
Preliminary Results

- Coalesence of suburbs & large cities into very large conurbations can dominate regional land cover and LC-related land surface processes.
- Spectral Mixture Analysis (SMA) yields robust spatial estimates of bio-physical endmember (EM) fractions (e.g. *water, vegetation, soil, snow*) & shadow.
- Multiscale validation of urban vegetation fraction gives ~6% error.
- Comparative SMA of Landsat dat of 28 cities quantifies inter-urban and intra-urban LC heterogeneity not represented in thematic classes.

Current Work

- Estimate continuous LS parameter fields from EM fractions and incorporate parameter distributions into OLAM (Ocean Land Atmosphere Model).
- Quantify spatial scaling relationships between LS parameters and EM fractions to determine optimal scale for LS parameter estimation.
- Sensitivity & Scale Analysis of Parameter Fields vs. Thematic Maps.

Multiscale Influence of Urban Land Cover

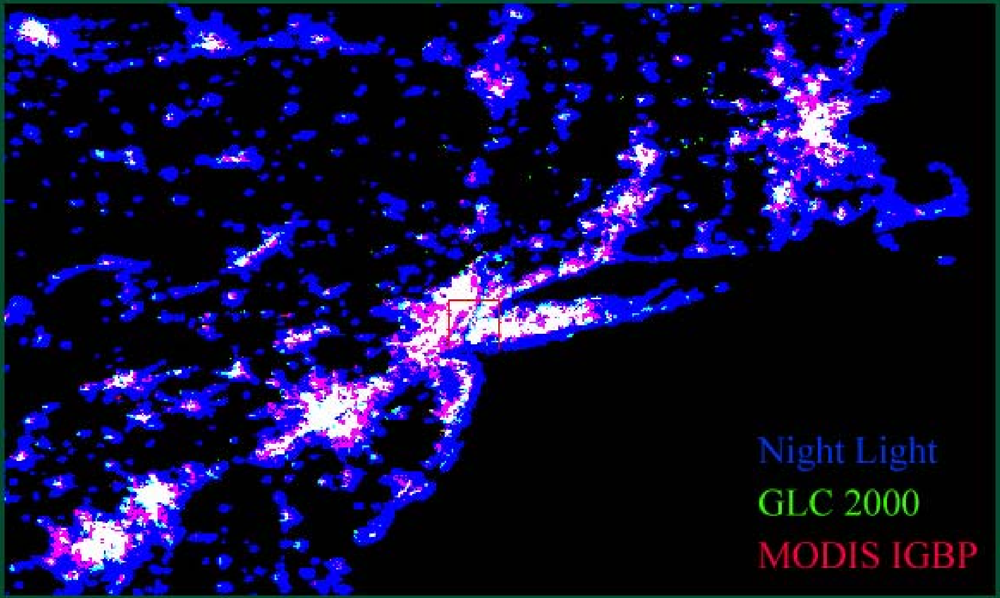


Global Scale

~3% of land area
strongly clustered

Regional Scale *(meso-β)*

some connurbations 30-50%
of land area at regional scales.



Local Scale *(< meso-γ)*

100% of land area

Alternative Representations of Land Cover

Discrete Thematic vs. Continuous Physical

The Problem: Land surface parameters derived from thematic classifications assume discrete transitions in physical properties and cannot represent spatial variability within classes or gradational transitions in land cover.

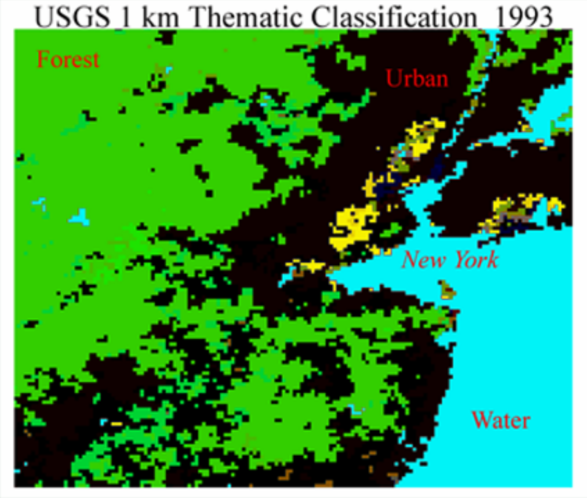
The Question: Can some physical properties (***Vegetation Fraction, LAI, Soil Exposure, Albedo, Surface Roughness***) be derived directly from spectral endmember fractions of moderate resolution optical & thermal imagery without thematic classification?

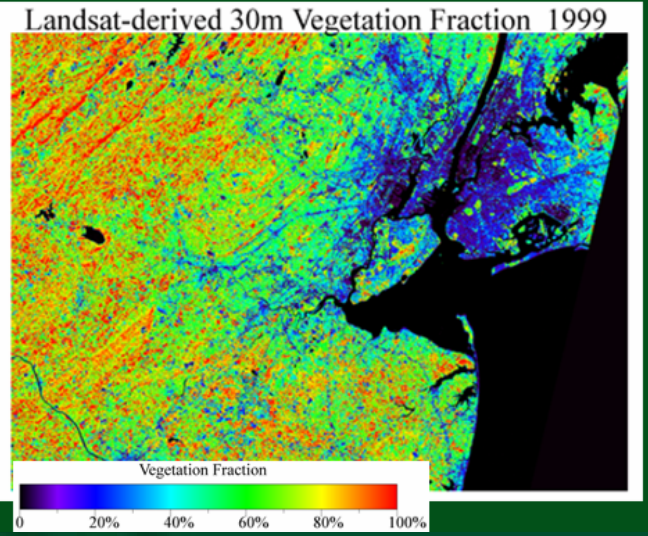
If so, does it matter?

Is model performance better for continuous physical fields than for discrete thematic?

If so, what, where and when?

What is the magnitude and scale dependence for which parameters?


USGS 1 km Thematic Classification 1993


Landsat-derived 30m Vegetation Fraction 1999

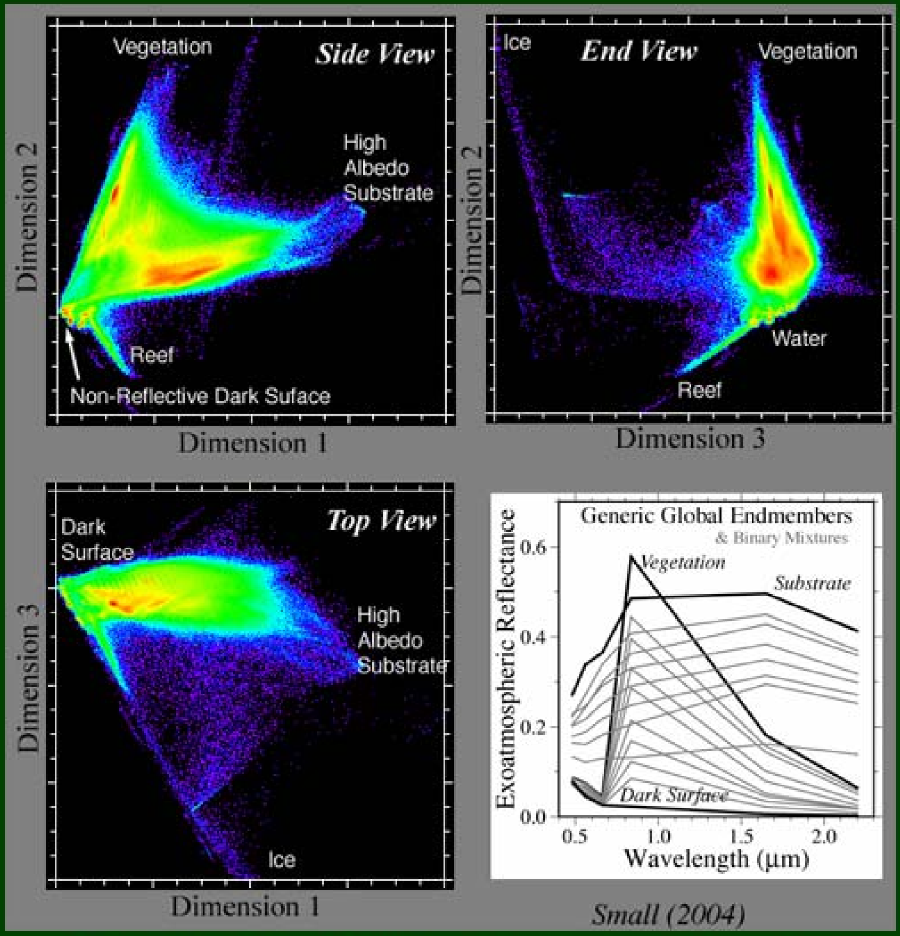
Physical Properties & Spectral Mixture Analysis

Spectral Mixture Analysis (SMA) represents spectrally mixed pixels as linear mixtures of spectrally pure endmembers.

Global analysis of spectrally diverse landscapes consistently reveals similar, biophysically distinct, spectral endmembers.

Estimates of endmember area fraction can be validated at multiple spatial scales.

Linear scaling properties can facilitate upscaling and downscaling of landcover fraction parameters.



Small (2004)

Global Landsat ETM+ spectral mixing space with physically distinct endmembers

Reconstructed Historical Land Cover and Biophysical Parameters for Studies of Land-Atmosphere Interactions Within the Eastern United States

L.T. Steyaert and
R.G. Knox

Manuscript in Review

NASA Land-Cover and Land- Use Change
Science Team Meeting

April 4-6, 2007

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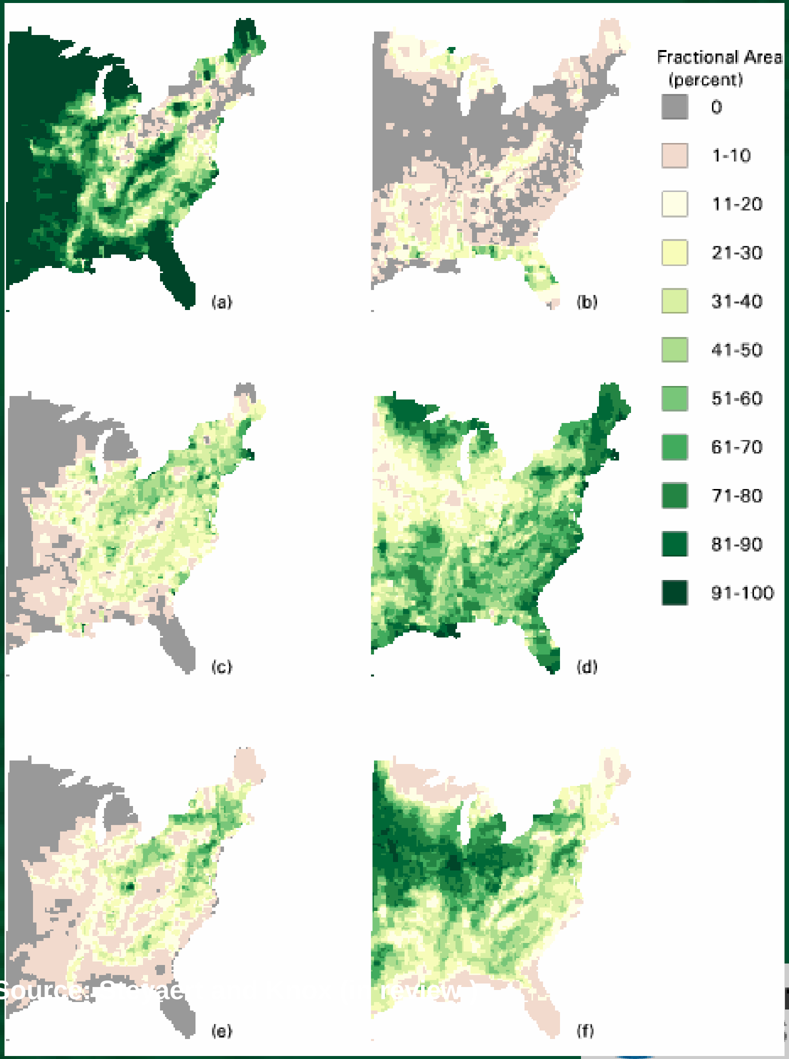
Land Use Intensity: 1850 vs 1920

Reconstructed Historical Land Use Intensity Showing Fractional Areas:

Top: Remaining Old-Growth and Pre-settlement Vegetation (a) 1850 and (b) 1920

Middle: Disturbed/Semi-natural Vegetation/Village (c) 1850 and (d) 1920

Bottom: Mixed Agriculture (e) 1850 and (f) 1920

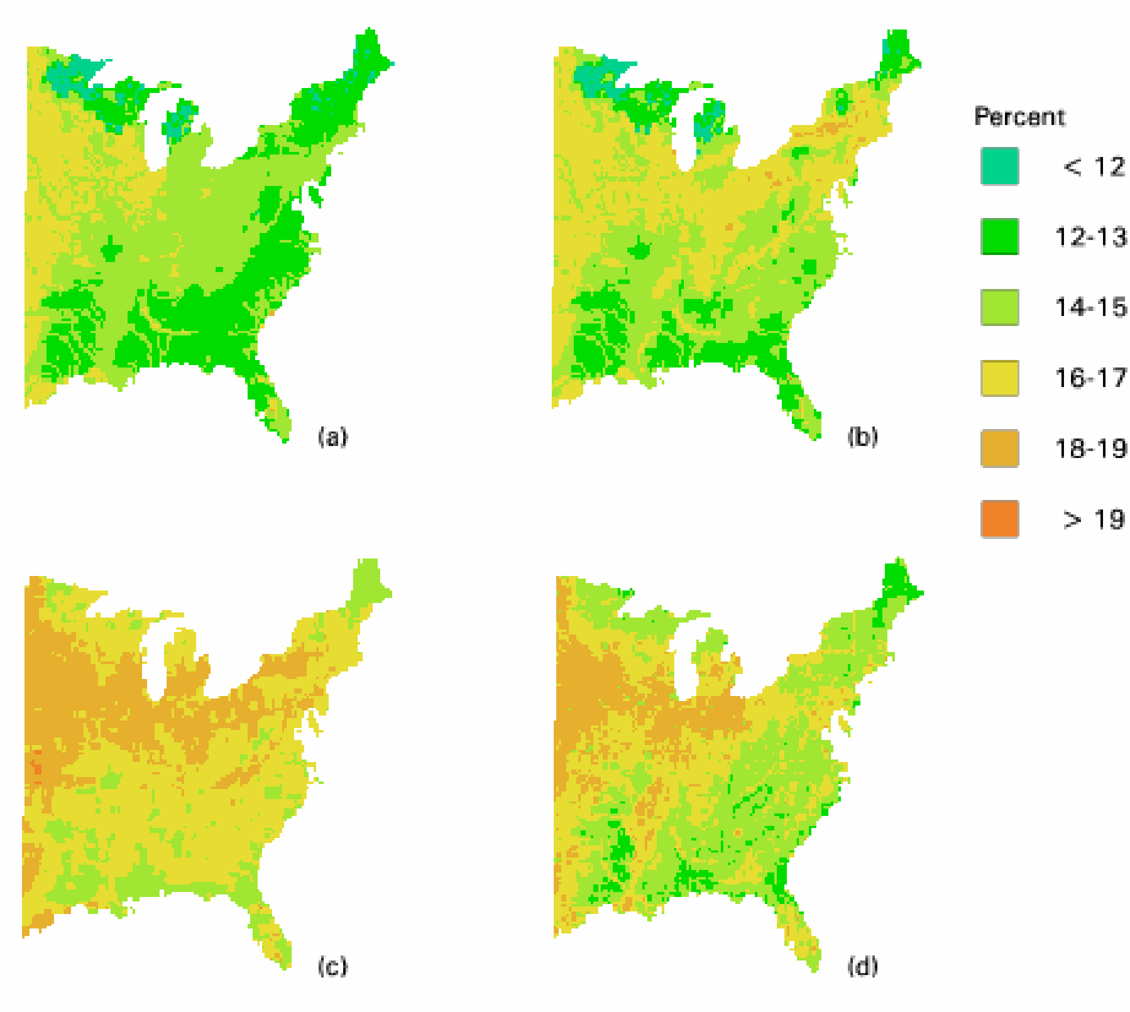


Source: Steyaert and Knox (in review)

Albedo: 1650, 1850, 1920, 1992

Historical Patterns of Broadband Solar Albedo:

- **(a) 1650**
- **(b) 1850**
- **(c) 1920**
- **(d) 1992**



Source: Steyaert and Knox (in review)

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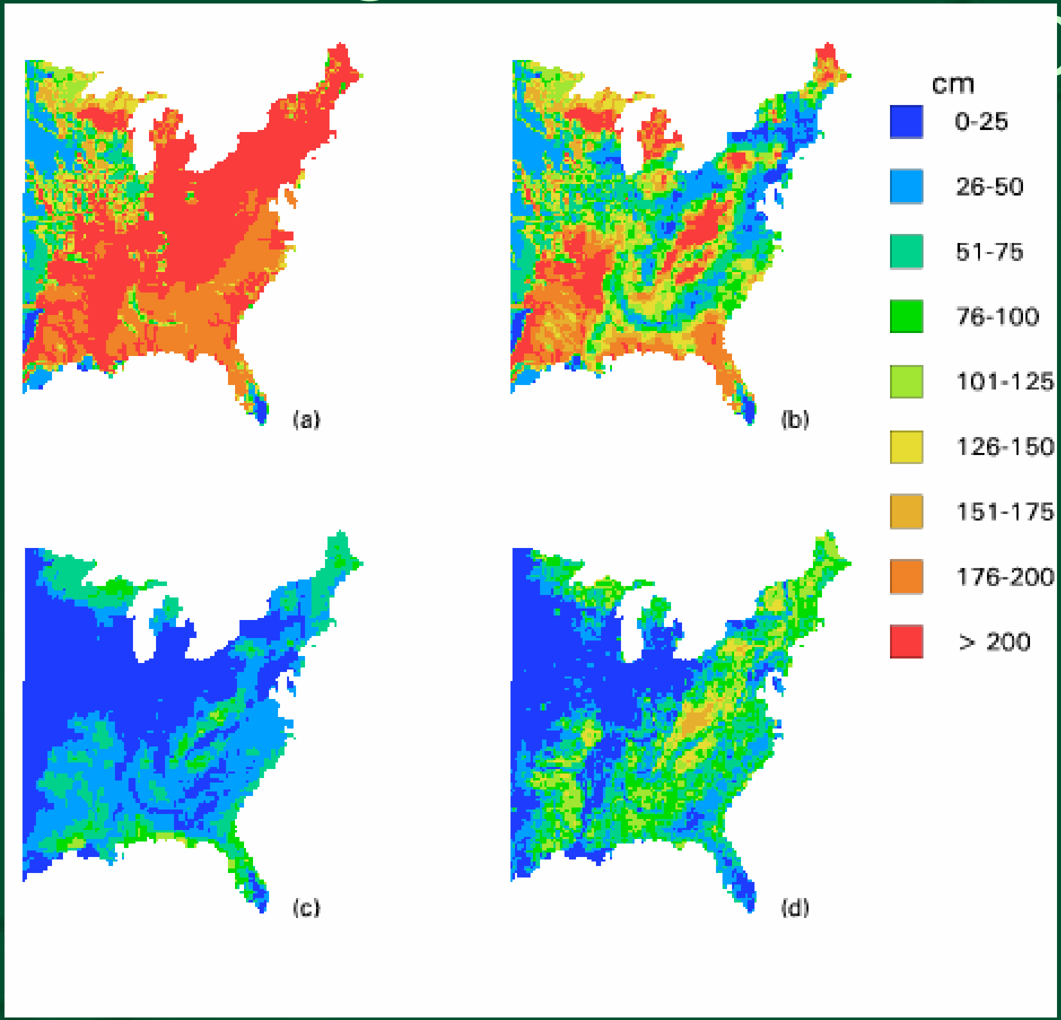
Surface Roughness Length:

Historical Patterns of Surface Roughness Length (cm):

- **(a) 1650**
- **(b) 1850**
- **(c) 1920**
- **(d) 1992**



Source: Steyaert and Knox (in review)

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Results for the Eastern United States

- Land-use intensity maps characterize major historical changes in land cover between the 1650, 1850, 1920, and 1992 time-slices.

- Land use fractions were mapped to biophysical land cover classes and parameters for each time-slice.

- The effects of land cover change are evident in the maps of average biophysical parameters.

- These changes potentially affect land-atmosphere interactions, altering the water, energy, and carbon cycles.

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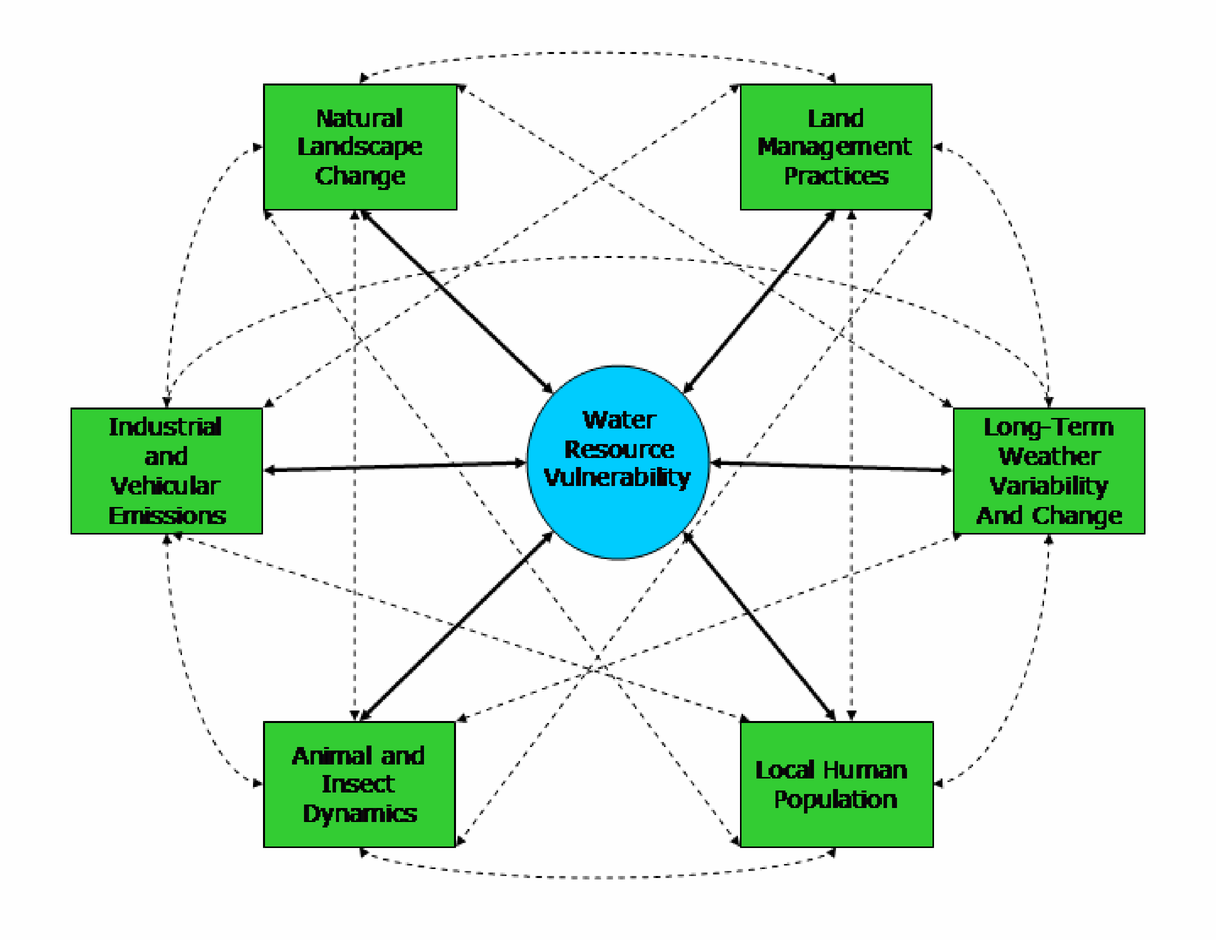
Where Do We Go From Here

- The quantification of all of the first order climate forcings and feedbacks that affect the land surface part of the climate system
- The need to further assess the role of land surface processes in altering regional and global weather patterns including not just TOA radiative forcing but also the gradient of radiative forcing and precipitation processes

Where Do We Go From Here

- The improvement in the prescription of the landscape and the provision of scenarios of land use change in the future
- The identification of important land surface related vulnerabilities and the risks posed to critical resources



Schematic of the relation of water resource vulnerability to the spectrum of the environmental forcings and feedbacks (adapted from [3]). The arrows denote nonlinear interactions between and within natural and human forcings. From: Pielke, R.A. Sr., 2004: Discussion Forum: A broader perspective on climate change is needed. IGBP Newsletter, 59, 16-19. http://blue.atmos.colostate.edu/publications/pdf/NR-139.pdf

Vulnerability – An Overarching Theme

- What are the critical threats to important societal and environmental resources?
- Many of these resources involve land use/land cover and vegetation/soil dynamics
- Can we use “impacts” models to identify risks to these resources from climate and other environmental variability and change?

Humans are significantly altering the global climate, but in a variety of diverse ways beyond the radiative effect of carbon dioxide. The IPCC assessments have been too conservative in recognizing the importance of these human climate forcings as they alter regional and global climate. These assessments have also not communicated the inability of the models to accurately forecast the spread of possibilities of future climate. The forecasts, therefore, do not provide any skill in quantifying the impact of different mitigation strategies on the actual climate response that would occur.

Roger A. Pielke Sr. Research Group Weblog

http://climatesci.colorado.edu

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