Scientific articles (including abstracts) identified in the Web of Science database on September 2, 2019, applying the following categories in the search (see Table 5.1): ***(LaU OR LaC OR FoC) AND BpE AND ClV AND (ObD OR MoD) AND NoP*****, for studies published before 2000 (in reversed chronological order)**

Brovkin, V., et al. (1999). "Modelling climate response to historical land cover change." Global Ecology and Biogeography **8**(6): 509-517.

In order to estimate the effect of historical land cover change (deforestation) on climate, we perform a set of experiments with a climate system model of intermediate complexity - CLIMBER-2. We Focus on the biophysical effect of the land cover change on climate and do not explicitly account for the biogeochemical effect. A dynamic scenario of deforestation during the last millennium is formulated based on the rates of land conversion to agriculture. The deforestation scenario causes a global cooling of 0.35 degrees C with a more notable cooling of the northern hemisphere (0.5 degrees C). The cooling is most pronounced in the northern middle and high latitudes, especially during the spring season. To compare the effect of deforestation on climate with other forcings, climate responses to the changing atmospheric CO_2 concentration and solar irradiance are also analysed. When all three Factors are taken into account, dynamics of northern hemisphere temperature during the last 300 years within the model are generally in agreement with the observed (reconstructed) temperature trend. We conclude that the impact of historical land cover changes on climate is comparable with the impact of the other climate forcings and that land cover forcing is important for reproducing historical climate change.

Choudhury, B. J. (1999). "Evaluation of an empirical equation for annual evaporation using field observations and results from a biophysical model." Journal of Hydrology **216**(1-2): 99-110.

An empirical equation for annual evaporation (E) of the form, E = P/{1 + (P/R-n)(alpha))(1/alpha)}, where P is the annual precipitation, R-n the water equivalent of annual net radiation, and cu an adjustable parameter, is evaluated using held observations (water balance, and micrometeorologic measurements for areas ca. 1 km(2)) at eight locations having different types of vegetation, and results from a biophysical process-based model for four years (1987-1990) for ten river basins (areas larger than 10(6) km(2)). For the field observations, minimum value of the mean absolute error (MAE) was 33 mm (4% of the mean observed evaporation) obtained for alpha = 2.6, and the empirical equation was able to explain 99% of the variance under linear least square regression, with a slope of 0.99, intercept of 16 mm, and standard error of estimate (SEE) of 46 mm. For evaporation from the river basins, minimum value of the MAE was 36 mm (5% of the mean evaporation) obtained for alpha = 1.8, and the empirical equation was able to explain 97% of the variance, with linear regression slope of 1.01, intercept of - 11 mm, and SEE of 45 mm. The effect of spatial variations in P and R-n in determining evaporation from the empirical equation is analyzed to develop an understanding of the differences in the value of alpha for the held observations and the river basins.

Potter, C. S., et al. (1999). "Interannual variability in terrestrial net primary production: Exploration of trends and controls on regional to global scales." Ecosystems **2**(1): 36-48.

Climate and biophysical regulation of terrestrial plant production and interannual responses to anomalous events were investigated using the NASA Ames model version of CASA (Carnegie-Ames-Stanford Approach) in a transient simulation mode. This ecosystem model has been calibrated for simulations driven by satellite vegetation index data from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) over the mid-1980s. Relatively large net source fluxes of carbon were estimated from terrestrial vegetation about 6 months to 1 year following El Nino events of 1983 and 1987, whereas the years 1984 and 1988 showed a drop in net primary production (NPP) of 1-2 Pg (10(15) g) C from their respective previous years. Zonal discrimination of model results implies that the northern hemisphere low latitudes could account for almost the entire 2 Pg C decrease in global terrestrial NPP predicted from 1983 to 1984. Model estimates further suggest that from 1985 to 1988, the northern middle-latitude zone (between 30 degrees and 60 degrees N) was the principal region driving progressive increases in NPP, mainly by an expanded growing season moving toward the zonal latitude extremes. Comparative regional analysis of model controls on NPP reveals that although Normalized Difference Vegetation Index "greenness" can alone account for 30%-90% of the variation in NPP interannual anomalies, temperature or radiation loading can have a fairly significant Iyear lag effect on annual NPP at middle- to high-latitude zones, whereas rainfall amount and temperature drying effects may carry over with at least a 2-year lag time

to influence NPP in semiarid tropical zones.

Jansen, D. M., et al. (1999). "Ex-ante assessment of costs for reducing nitrate leaching from agriculture-dominated regions." Environmental Modelling & Software **14**(6): 549-565.

In sandy regions of the Netherlands, current agricultural practices result in high nitrate concentrations in the upper groundwater, endangering water resources. A methodology to estimate costs of region specific solutions is applied to a groundwater protection area. It requires that for existing farms in the region variants of management are described that differ in nitrogen surplus. Costs of variants relate to investments and losses in income due to changes in farm management additional to those required by existing legislation. The expected nitrate concentration for each combination of variant and groundwater class is calculated from nitrogen and precipitation surplus and a leaching fraction. A linear programming model indicates the optimal spatial allocation of variants such that desired regional and sub-regional nitrate concentrations are reached at minimum regional costs. In the case study, current land use is grouped into non-dairy farms and various types of dairy farms and non-agricultural land use. Management variants are described for most of these groups. The LP model was used to analyze the effect of the following conditions: (a) the scale at which the tolerated maximum NO3 concentration is effectuated; (b) the level of this maximum; (c) the hydrological situation; (d) the way farms are grouped; and (e) the biophysical situation of farms. Total regional costs show a negative, but not necessarily linear, relation with the resulting regional nitrate concentration. This relation is strongly influenced by the actual situation regarding management at the farms and the groundwater table depths in the region. For each region a specific cost-benefit relation might apply. Higher groundwater tables result in strongly reduced costs for required changes in farm management. Depending on costs and physical feasibility, measures that result in a higher groundwater table could therefore be used in addition to or replacement of measures at farm level. Calculated costs are influenced by the method of grouping of farms into farm types, the largest effect due to differentiating intensities of production. Differences between farms need therefore be considered when analyzing possibilities for and costs of measures to reduce nitrate leaching. Political decisions, specifically about the scale at which the maximum nitrate level should be effectuated (farm-type or region) also have a strong effect on the cost-benefit relation. Requiring all farm types to comply with a given maximum nitrate concentration, resulting in a specific regional average, is more costly than setting a similar regional maximum and allowing regional averaging. Methodology and preliminary results were discussed with policy-makers and representatives of farmers, environmentalists and groundwater extracting companies. They felt that these discussions helped focussing the interaction between the various groups of stakeholders. This is due to the fact that assumptions about effects of changes in land use and costs involved are made explicit and to the possibility of a more objective weighing of interests since wishes and conditions are translated into goals and constraints of the linear programming model.

Prince, S. D. and M. K. Steiniger (1999). “Biophysical stratification of the Amazon basin." Global Change Biology **5**(1): 1-22.

In field measurement programmes, stratified sampling can optimize sampling efficiency, but stratification is often undertaken subjectively, and is frequently based on a priori classification schemes such as those used for vegetation maps. In order to avoid the problems associated with a priori subjective schemes, we explore here an objective procedure, Regression Tree Analysis (RTA). RTA has previously been used in local-scale studies, but here we apply it to a very large study domain, namely the entire humid tropical zone of South America. The aim of the study was to develop an optimal sampling design in preparation for the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA). Go-registered spatially continuous fields of rainfall, temperature, photosynthetically active radiation (PAR), the normalized difference index (NDVI), an index of surface moisture, and other independent variables were used to predict three dependent variables, annual net radiation (Rn), latent heat (LE) and net primary production (NPP). Rather than simply dividing the study area based on differing levels of the three dependent variables, empirical models were developed using RTA to indicate how the relationships between these and possible forcing variables vary across the study area. For each variable long-term seasonal indices such as annual average, monthly minimum and amplitude were used to exclude effects of temporal phase differences between the hemispheres. The resulting hierarchical models revealed variations in the interdependence of the forcing variables throughout the study area and therefore provided a basis for a stratified sampling and identifying the most important variables to be

collected in LBA for the Amazon basin as a whole as well as optimizing the sampling scheme for scaling up findings from the field scale to larger areas.

Morrow, N. and Friedl MA (1998). "Modeling biophysical controls on land surface temperature and reflectance in grasslands." Agricultural and Forest Meteorology **92**(3): 147-161.

The influence of soil moisture and vegetation density on land surface reflectance and temperature is investigated at a grassland site in northeastern Kansas. To do this, a forward model is developed and validated against measurements from a helicopter mounted multi-spectral sensor. Soil background reflectances are calculated as a function of soil type and moisture content and are incorporated into calculations of surface reflectance using a canopy radiative transfer model. Surface temperature is predicted using a two-layer framework that includes the effects of soil moisture on soil thermal properties. Variation in vegetation density is included in both models via the canopy leaf area index. Results from model simulations show good correlation between normalized values of modeled and observed surface spectral reflectance. Comparison of modeled vs. observed temperature data show that a relatively parsimonious set of variables (net radiation, air temperature, soil thermal properties, and leaf area index) may be used to model land surface temperature with good accuracy. These results support previous empirical and modeling studies suggesting that for land areas characterized by fractional vegetation cover, the slope of the relationship between spatially distributed NDVI and surface temperature measurements is diagnostic of mean soil moisture, while variation around the slope is indicative of local variation in soil moisture.

Wai, M. M. K. and E. A. Smith (1998). "Linking boundary layer circulations and surface processes during FIFE 89. Part II: Maintenance of secondary circulation." Journal of the Atmospheric Sciences **55**(7): 1260-1276.

Land-atmosphere interactions are examined for three different synoptic situations during a 21-day period in the course of the First ISLSCP (International Satellite Land Surface Climatology Project) Field Experiment 1989 to better understand the relationship between biophysical feedback processes, boundary layer structure, and circulations in the boundary layer. The objective is to understand how the secondary circulation discussed in Part I of this paper was able to sustain itself throughout the duration of the 1989 intensive field campaign. The study is based on diagnostic analysis of measurements obtained from a network of surface meteorology and energy budget stations, augmented with high vertical resolution radiosonde measurements. Shallow convection associated with an undisturbed boundary layer situation and rainfall occurring during two different disturbed boundary layer situations-one associated with a surface trough, the other with the passage of a cold front-led to markedly different impacts on the surface layer and the boundary layer recovery timescale. In the undisturbed case, the growth of a cloud layer produced a negative feedback on the boundary layer by stabilizing the surface layer, and cutting off the turbulence transport of heat and moisture into the subcloud layer. The deficits in heat and moisture then led to cloud dissipation. During the surface trough development and cold front passage events, rainfall reaching the surface led to the collapse of the surface layer, decrease of surface and subsurface soil temperatures, depressed sensible heating, and a slow reduction and even temporary termination of evapotranspiration. After the rains subsided, the boundary layer recovery process began with vigorous evapotranspiration rates drying the upper soil layers on a timescale of 1-2 days. During this period, 55%-65% of the net surface available heating was used for evapotranspiration, whereas only 30%-35% went directly into boundary layer heating. As the near-surface soil moisture dropped, surface sensible heating became more important in influencing boundary layer energetics. The boundary layer required approximately two days to recover to its initial temperature in the case of the surface trough. After passage of the cold front, both the soil and boundary layer cooled and dried due to cold temperature advection. Evapotranspiration rates remained relatively large for about two days after the frontal passage. The boundary layer had not completely recovered by the end of the intensive data collection period after the frontal passage, so recovery time was at least a week. The analysis shows that with-the exception of three days during the surface trough event, and two-or three days during the frontal passage event, the surface-driven secondary circulation persisted.

O'Brien, K. L. (1998). "Tropical deforestation and climate change: What does the record reveal?" Professional Geographer **50**(1): 140-153.

Tropical deforestation is widely believed to directly influence the climate at a number of scales. Yet while much has been written about the tropical forest-climate relationship, there is little empirical evidence

showing if and hew local and regional climates are modified by deforestation. This study presents the results of an analysis of deforestation and climate change in a rain forest in southern Mexico. Records from 18 climate stations in the Selva Lacandona of Chiapas, Mexico were examined and related to an analysis of deforestation based on Landsat images. The area surrounding some stations has been deforested since the stations were established while the area surrounding others has remained forested. Strong climatic trends were generally evident at the deforested stations, including decreases in the average daily maximum temperature and temperature range. No precipitation changes were observed. A comparison of the results with microclimatic experiments and modeling studies suggests that the climatic impacts of deforestation are overgeneralized at the local scale. Landscape heterogeneity appears to influence the biophysical mechanisms linking tropical forests and climate and should be explicitly represented in modeling studies.

Schimel, D. S, et al. (1997). "Equilibration of the terrestrial water, nitrogen, and carbon cycles." Proceedings of the National Academy of Sciences of the United States of America **94**(16): 8280-8283.

Recent advances in biologically based ecosystem models of the coupled terrestrial, hydrological, carbon, and nutrient cycles have provided new perspectives on the terrestrial biosphere's behavior globally, over a range of time scales, We used the terrestrial ecosystem model Century to examine relationships between carbon, nitrogen, and water dynamics, The model, run to a quasi-steady-state, shows strong correlations between carbon, water, and nitrogen fluxes that lead to equilibration of water/energy and nitrogen limitation of net primary productivity. This occurs because sis the water flux increases, the potentials for carbon uptake (photosynthesis), and inputs and losses of nitrogen, all increase, As the flux of carbon increases, the amount of nitrogen that can be captured into organic matter and then recycled also increases, Because most plant-available nitrogen is derived from internal recycling, this latter process is critical to sustaining high productivity in environments where water and energy are plentiful. At steady-state, water/energy and nitrogen limitation ''equilibrate,'' but because the mater, carbon, and nitrogen cycles have different response times, inclusion of nitrogen cycling into ecosystem models adds behavior at longer time scales than in purely biophysical models, The tight correlations among nitrogen fluxes with evapotranspiration implies that either climate change or changes to nitrogen inputs (from fertilization or air pollution) will have large and long-lived effects on both productivity and nitrogen losses through hydrological and tract gas pathways, Comprehensive analyses of the role of ecosystems in the carbon cycle must consider mechanisms that arise from the interaction of the hydrological, carbon, and nutrient cycles in ecosystems.

Anderson, M. C., et al. (1997). "A two-source time-integrated model for estimating surface fluxes using thermal infrared remote sensing." Remote Sensing of Environment **60**(2): 195-216.

We present an operational two-source (soil+vegetation) model for evaluating the surface energy balance given measurements of the time rate of change in radiometric surface temperature (T-RAD) during the morning hours. This model consists of a two-source surface component describing the relation between T-RAD and sensible heat flux, coupled with a time-integrated component connecting surface sensible heating with planetary boundary layer development. By tying together the time-dependent behavior of surface temperature and the temperature in the boundary layer with the flux of sensible heat from the surface to the atmosphere, the need for ancillary measurements of near-surface air temperature is eliminated. This is a significant benefit when T-RAD is acquired remotely. Air temperature can be strongly coupled to local biophysical surface conditions and, if the surface air and brightness temperature measurements used by a model are not collocated, energy flux estimates can be significantly corrupted. Furthermore, because this model uses only temporal changes in radiometric temperatures rather than absolute temperatures, time-independent biases in T-RAD, resulting from atmospheric effects or other sources, do not affect the estimated fluxes; only the time-varying component of corrections need be computed. The algorithm also decomposes the surface radiometric temperature into its soil and vegetation contributions; thus the angular dependence of T-RAD can be predicted from an observation of T-RAD at a single view angle. This capability is critical to an accurate interpretation of off-nadir measurements from polar orbiting and geosynchronous satellites. The performance of this model has been evaluated in comparison with data collected during two large-scale field experiments: the first International Satellite Land Surface Climatology Project field experiment, conducted in and around the Konza Prairie in Kansas, and the Monsoon '90 experiment, conducted in the semiarid rangelands of the Walnut Gulch Watershed in southern Arizona. Both comparisons yielded uncertainties comparable to those achieved by models that do require air temperature as an input and to measurement errors typical of standard micrometeorological methods for flux estimation. A strategy for applying the two-source time-integrated model on a regional or continental scale is briefly outlined.

Estreguil, C. and E. F. Lambin (1996). "Mapping forest-cover disturbances in Papua New Guinea with AVHRR data." Journal of Biogeography **23**(6): 757-773.

Land management and land-use planning in a forested country such as Papua New Guinea, which is subject to various anthropogenic pressures, requires an accurate mapping of forest-cover disturbances. The central hypothesis of this study was that remote sensing indicators of forest-cover conditions can be used to measure and map the impact of long-term forest-cover disturbances. This was tested with single year NOAA's Advanced Very-High Resolution Radiometer sensor (AVHRR) data at 1.1 km resolution. First, an ordinal scale of forest-cover disturbance was defined from field observations, a set of thematic maps and high spatial resolution satellite sensor data. Secondly, we analysed the relationship between the forest-cover disturbance scale and several biophysical indicators derived from AVHRR data at two seasons. Thirdly, a statistical analysis identified the optimal combination of biophysical indicators and observation dates to discriminate between the forest disturbance levels defined previously. A forest cover disturbance map was then produced over part of Papua New Guinea. Finally, a regionalization of the study area in terms of aggregate degree of disturbance was produced and the spatial patterns of forest disturbances were interpreted for each region in terms of broad processes of forest-cover change. The overall accuracy of the forest cover disturbance map was 79%. Nine regions, homogeneous in regard to the distribution and spatial pattern of disturbance categories, were identified.

Pressey, R. L., et al. (1996). "How well protected are the forests of north-eastern New South Wales? - Analyses of forest environments in relation to formal protection measures, land tenure, and vulnerability to clearing." Forest Ecology and Management **85**(1-3): 311-333.

A large data set on the biophysical characteristics of north-eastern New South Wales, a region of 7.6 x 10(6) ha, was analysed to measure the level of protection of the region's forests from extractive uses. A classification of 81 environmental units was derived by subdividing the region according to combinations of mean annual rainfall, mean annual temperature, soil fertility and slope, All environmental units contain forest, although some also contain other vegetation formations, The units were used to separate the region's forests into 81 classes. This approach produced a consistent classification of environments for the entire region that could be applied across all land tenures and uses. Derivation of the classification from physical data also enabled the extent of clearing of each environmental unit to be accurately assessed, The coverage of the environmental units by all formal protection measures was measured, Strict reserves (secure areas with management dedicated to nature conservation) are highly biased in their regional distribution, being concentrated in the steep and/or infertile parts of the region, Other protection measures include a variety of tenures, classifications and zonings with different constraints on land use applied by Local, State and Commonwealth Governments. When all protection measures are combined, there is still a strong bias towards the steep, and to some extent the infertile, parts of the region, The reasons for these biases are explained in terms of the history of reservation and the types of land over which other measures have generally been applied, The result of the biases in protection measures is that environmental units most suitable for clearing have been given least protection. The potential for achieving levels of reservation of environmental units required under current Commonwealth Government policy was assessed in relation to tenure and degree of fragmentation of the remaining vegetation. While public land can contribute the required areas of new reserves for many environmental units, adequate reservation of other environments will have to rely heavily on private land and remnants of vegetation, Priorities for reservation were expressed in terms of two factors: (1) the percentage of the remaining vegetation in each environmental unit that will need to be reserved to achieve the policy target; and (2) the vulnerability of each environmental unit to clearing. Environmental units with high percentages required (few options in space) and high vulnerability (few options in time) have the highest priority for reservation or other effective protection, The vegetation that remains in these environmental units is mainly on private land. Reservation priorities will change to some extent if conservation goals are changed. Current priorities also need to be complemented by an analysis of the security and effectiveness of protection measures other than strict reservation.

Sellers, P. J., et al. (1996). "A revised land surface parameterization (SiB2) for atmospheric GCMs. 2. The generation of global fields of terrestrial biophysical parameters from satellite data." Journal of Climate **9**(4): 706-737.

The global parameter fields used in the revised Simple Biosphere Model (SiB2) of Sellers et al. are reviewed. The most important innovation over the earlier SiB1 parameter set of Dorman and Sellers is the use of satellite data to specify the time-varying phenological properties of FPAR, leaf area index, and canopy greenness fraction. This was done by processing a monthly 1 degrees by 1 degrees normalized difference vegetation index (NDVI) dataset obtained from Advanced Very High Resolution Radiometer red and near-infrared data. Corrections were applied to the source NDVI dataset to account for (i) obvious anomalies in the data time series, (ii) the effect of variations in solar zenith angle, (iii) data dropouts in cold regions where a temperature threshold procedure designed to screen for clouds also eliminated cold land surface points, and (iv) persistent cloud cover in the Tropics. An outline of the procedures for calculating the land surface parameters from the corrected NDVI dataset is given, and a brief description is provided of source material, mainly derived from in situ observations, that was used in addition to the NDVI data. The datasets summarized in this paper should be superior to prescriptions currently used in most land surface parameterizations in that the spatial and temporal dynamics of key land surface parameters, in particular those related to vegetation, are obtained directly from a consistent set of global-scale observations instead of being inferred from a variety of survey-based land-cover classifications.

Nemani, R. R., et al. (1996). "Global vegetation cover changes from coarse resolution satellite data." Journal of Geophysical Research-Atmospheres **101**(D3): 7157-7162.

Land cover plays a key role in various biophysical processes related to global climate and terrestrial biogeochemistry. Although global land cover has dramatically changed over the last few centuries, until now there has been no consistent way of quantifying the changes globally. In this study we used long-term climate and soils data along with coarse resolution satellite observations to quantify the magnitude and spatial extent of large-scale land cover changes attributable to anthropogenic processes. Differences between potential leaf area index (LAI), derived from climate-soil-leaf area equilibrium, and actual leaf area index obtained from satellite data are used to estimate changes in land cover. Further, changes in LAI between potential and actual conditions are linked to climate by expressing them as possible changes in radiometric surface temperatures (T-r) resulting from changes in surface energy partitioning. As expected, areas with high population densities, such as India, China, and western Europe showed large reductions in LAI. Changes in global land cover expressed as summer, midafternoon T-r, ranged from -8 degrees to +16 degrees C. Deforestation resulted in an increase in T while irrigated agriculture reduced the T-r. Many of the current general circulation models (GCMs) use potential vegetation maps to represent global vegetation. Our results indicate that there are widespread changes in global land cover due to deforestation and agriculture below the resolution of many GCMs, and these changes could have a significant impact on climate. Potential and actual LAI data sets are available for climate modelers at 0.5 degrees x 0.5 degrees resolution to study the possible impacts of land cover changes on global temperatures and circulation patterns.

Smith, E. A. and H. J. Cooper (1996). “Pilot study using SPOT satellite imagery over Apalachicola national forest to determine appropriate spatial scale for area-wide aggregation of surface fluxes." Meteorology and Atmospheric Physics **58**(1-4): 179-192.

High resolution radiances from SPOT satellite imagery converted to Normalized Difference Vegetation Indices (NDVI) over a 16 x 16 km(2) mixed ground cover study-area in the Apalachicola National Forest in northwest Florida, along with in situ measurements from a Bowen ratio surface flux monitoring system and physical modeling techniques, are used to determine the length manifold beyond which degraded resolution satellite imagery fails to capture flux variability over the scene. The investigation is relevant to an understanding of how bias error is generated in methods designed to produce scaleinvariant surface flux estimates from satellite measurements. Error estimates are based on assigning characteristic NDVI values to the four predominant types of ground cover found within the study-area. An open site near the center of the study-area, which satisfies the conditions for surface flux monitoring, is used for obtaining input data for a biosphere-atmosphere exchange model designed to calculate representative fluxes for the different ground covers. Continuous 6-minute meteorological and surface flux measurements were made at the monitoring site for a period of 22 days. These measurements are used in conjunction with surface layer theory to provide surface layer profile estimates of wind speed, temperature, and relative humidity at the tops of the

forested sites. The measured and derived meteorological parameters, together with representative biophysical parameters, are used as input to the biosphere-atmosphere exchange model. By representing sensible and latent heat flux distributions due to the variable ground cover with characteristic NDVI values at 20-m resolution, baseline area-wide sensible and latent heat flux quantities are calculated. Error-growth curves as a function of spatial resolution for the fluxes are found by degrading the resolution of the SPOT radiances used to calculate NDVI, and ratioing the associated area-wide fluxes to the baseline values. The point at which an error-growth curve becomes invariant represents the edge of a length manifold beyond which the satellite input no longer contains information on surface flux variability, even though NDVI variability continues at all scales up to that of the complete SPOT scene. The errorgrowth curves are non-linear, with all the error build-up taking place between 20m and 1.6km. Decreasing the spatial resolution of the NDVI information down to or below 1.6km, introduces bias errors in the area-wide surface flux estimates of 10% for sensible heat and 8% for latent heat. The underlying assumptions and modeling produce uncertainty in estimating the manifold limits, however, the principal objective is to show that in using satellite data for scale-invariant surface flux retrieval, there is an optimal spatial resolution factor that can be objectively quantified.

Yang, Z. L., et al. (1995). “The impact of implementing the Bare Essentials of Surface Transfer land-surface scheme into the BMRC GCM." Climate Dynamics **11**(5): 279-297.

This study describes the first order impacts of incorporating a complex land-surface scheme, the bare essentials of surface transfer (BEST), into the Australian Bureau of Meteorology Research Centre (BMRC) global atmospheric general circulation model (GCM). Land seasonal climatologies averaged over the last six years of integrations after equilibrium from the GCM with BEST and without BEST (the control) are compared, The modeled results are evaluated with comprehensive sources of data, including the layer-cloud climatologies from the international satellite cloud climatology project (ISCCP) data from 1983 to 1991 and the surface-observed global data of Warren et al., a five-year climatology of surface albedo estimated from earth radiation budget experiment (ERBE) top-of-the-atmosphere (TOA) radiative fluxes, global grid point datasets of precipitation, and the climatological analyses of surface evaporation and albedo, Emphasis is placed on the surface evaluation of simulations of land-surface conditions such as surface roughness, surface albedo and the surface wetness factor, and on their effects on surface evaporation, precipitation, layer-cloud and surface temperature. The improvements due to the inclusion of BEST are: a realistic geographical distribution of surface roughness, a decrease in surface albedo over areas with seasonal snow cover, and an increase in surface albedo over snow-free land. The simulated reduction in surface evaporation due, in part, to the biophysical control of vegetation, is also consistent with the previous studies. Since the control climate has a dry bias, the overall simulations from the GCM with BEST are degraded, except for significant improvements for the northern winter hemisphere because of the realistic vegetation-masking effects. The implications of our results for synergistic developments of other aspects of model parameterization schemes such as boundary layer dynamics, clouds, convection and rainfall are discussed.

Bonan, G. B., et al. (1995). "Boreal forest and tundra ecosystems as components of the climate system." Climatic Change **29**(2): 145-167.

The effects of terrestrial ecosystems on the climate system have received most attention in the tropics, where extensive deforestation and burning has altered atmospheric chemistry and land surface climatology. In this paper we examine the biophysical and biogeochemical effects of boreal forest and tundra ecosystems on atmospheric processes. Boreal forests and tundra have an important role in the global budgets of atmospheric CO_2 and CH_4. However, these biogeochemical interactions are climatically important only at long temporal scales, when terrestrial vegetation undergoes large geographic redistribution in response to climate change. In contrast, by masking the high albedo of snow and through the partitioning of net radiation into sensible and latent heat, boreal forests have a significant impact on the seasonal and annual climatology of much of the Northern Hemisphere. Experiments with the LSX land surface model and the GENESIS climate model show that the boreal forest decreases land surface albedo in the winter, warms surface air temperatures at all times of the year, and increases latent heat flux and atmospheric moisture at all times of the year compared to simulations in which the boreal forest is replaced with bare ground or tundra. There effects are greatest in arctic and sub-arctic regions, but extend to the tropics. This paper shows that land-atmosphere interactions are especially important in arctic and sub-arctic regions, resulting in a

coupled system in which the geographic distribution of vegetation affects climate and vice versa. This coupling is most important over long time periods, when changes in the abundance and distribution of boreal forest and tundra ecosystems in response to climatic change influence climate through their carbon storage, albedo, and hydrologic feedbacks.

Sellers, P. J., et al. (1994). "A global 1-degrees-by-1-degress NDVI data set for climate studies. 2. The generation of global fields of terrestrial biophysical parameters from the NDVI." International Journal of Remote Sensing **15**(17): 3519-3545.

A satellite-based 1-degrees by 1-degrees normalized difference vegetation index (NDVI) data set has been processed to derive land surface parameters for general circulation models of the atmosphere (GCMs). Prior to calculation of the land surface parameters, corrections were applied to the source NDVI data set to account for (i) obvious anomalies in the data time-series, (ii) the effect of variations in solar zenith angle, (iii) data dropouts in cold regions where a temperature threshold procedure designed to screen for clouds also eliminates cold land surface points, and (iv) persistent cloud cover in the tropics. An outline of the procedures for calculating land surface parameters from the corrected NDVI data set is given, and a brief description is provided of source material that was used in addition to the NDVI data. The data sets summarized in this paper should represent improvements over prescriptions currently used in land surface parameterizations in that the spatial and temporal dynamics of key land surface parameters, in particular of those related to vegetation, are obtained from direct measurements rather than indirectly inferred from survey-based land cover classifications.

Hall, F. G., et al. (1992). "Satellite remote-sensing of surface-energy balance – success, failures, and unresolved issues in FIFE." Journal of Geophysical Research-Atmospheres **97**(D17): 19061-19089.

The FIFE staff science group, consisting of the authors, developed and evaluated process models relating surface energy and mass flux, that is, surface rates, to boundary layer and surface biophysical characteristics, that is, surface states. In addition, we developed and evaluated remote sensing algorithms for inferring surface state characteristics. In this paper we report the results of our efforts. We also look in detail at the sensor and satellite platform requirements (spatial resolution and orbital requirements) as driven by surface energy balance dynamics and spatial variability. We examine also the scale invariance of the process models and remote sensing algorithms, that is, to what degree do the remotely sensed parameters and energy balance relations translate from the patch level where they were developed to the mesoscale level where they are required? Finally, we examine the atmospheric correction and calibration issues involved in extending the remotely sensed observations within a season and between years. From these investigations we conclude that (1) existing formulations for the radiation balance and latent heat components of the surface energy balance equation are valid at the patch level. (2) Many of the surface physiological characteristics that parameterize these formulations can be estimated using satellite remote sensing at both local and regional scales; a few important ones cannot. (3) The mathematical structures relating radiation and surface energy flux to remote sensing parameters are, for the most part, scale invariant over the First International Satellite Land Surface Climatology Project (ISLSCP) Field Experiment (FIFE) study area. The conditions for scale invariance are derived. (4) The precision of satellite remote sensing estimates of surface reflectance, calibrated and corrected for atmospheric effects, is no worse than about 1% absolute. The errors may actually be smaller, but an upper bound of 1% results from sampling variance caused by differences among the satellite and ground sensors in spatial resolution, atmospheric effects, and calibration. (5) Afternoon cumulus in the study area required both the Landsat and the SPOT satellites for monitoring of the vegetation dynamics. This result implies the need for multiple polar orbiters, or geosynchronous satellites in an operational implementation. We found that canopy Fpar, the fraction of incident photosynthetically active radiation absorbed by a canopy, can be estimated with an error of about 10% using remote sensing, provided that regional variability in the reflectance of the canopy substrate is dealt with properly. We also found that spectral vegetation indices (VIs) respond primarily to the photosynthetically active radiation absorbed by the live or green component of the canopy as opposed to its necrotic or dead vegetation. This is of critical importance since radiation absorption by the live part of the canopy is the rate-limiting process for photosynthesis and other key process rates such as evaporation. We found for the FIFE study area the surface moisture content at 0 to 10 cm to be another key rate-limiting variable in photosynthesis and evaporation. At gravimetric soil moisture levels below 20%, photosynthesis and evaporation were strongly attenuated. Only microwave sensors have shown potential for satellite remote sensing of soil moisture and only in the top few centimeters. Hydrological models may also play a critical role in monitoring root zone soil moisture levels, but additional research is needed. From our review of the research of others in FIFE we conclude that downwelling shortwave radiation and surface albedo are also amenable to remote sensing. Unfortunately, from our research we also found that the remote estimation of surface temperature to useful accuracies is problematical; consequently, the use of thermal infrared measurements to infer sensible heat flux is probably not feasible to acceptable accuracies.

Bonan, G. B. and L. Sirois (1992). "Air-temperature, tree growth, and the northern and southern range limits to Picea-Mariana." Journal of Vegetation Science **3**(4): 495-506.

Many models that simulate the long-term response of forests to climatic change use the assumption that northern and southern range limits are caused by the deleterious effects of cold and hot air temperatures, respectively, on individual tree growth and that growth declines symmetrically with air temperatures above and below some optimal value in between these extremes. To test the validity of this assumption, we combined physiological data for black spruce, Picea mariana, growing near the treeline in subarctic Quebec with a model of the biophysical and biochemical effects of temperature on photosynthesis. The physiological conditions allow black spruce to grow over a wider range of air temperatures than is reflected in its geographic distribution. In particular, the physiological data suggest that the northern range limit of black spruce is not caused by the direct effects of cold growingseason air temperatures on tree growth and that growth is optimal, with respect to temperature, at the southern range limit. While pollen data indicate large geographic changes in spruce abundance with past climatic changes, the current analyses suggest that the direct effect of air temperature on individual tree growth has not caused these changes. Until we better understand the effects of air temperature on ecological processes, the efficacy of climatic change analyses must be evaluated in terms of model assumptions.

Argentini, S., et al. (1992). "Testing a detailed biophysical parameterization for land air exchange in a high-resolution boundary-layer model." Journal of Applied Meteorology **31**(2): 142-156.

A large data set on the In order to properly model the influence of land surface properties on mesoscale atmospheric phenomena, it is important to include physically realistic parameterizations of major biophysical processes involved. The primary influence of the surface on the atmosphere occurs via its control of the surface energy budget and the consequent turbulent exchange with the planetary boundary layer (PBL). The physical parameterization of the complex surface processes may not be confidently incorporated into a three-dimensional model without first undergoing testing in a simpler, more controlled setting. It has been accepted practice to first validate the parameterization in a one-dimensional version of the intended parent model. The purposes of this paper are to present the results of such a validation and to provide deeper insight into a key aspect of the parameterization by presenting some sensitivity tests involving the leaf stomatal control of water vapor flux. The performance of the new parameterization in the parent model is compared to three different observational datasets characterized by widely different surface and vegetation conditions; the individual fluxes from the new model are found to simulate the observations well and to be a significant improvement compared to the predicted fluxes from the original model. Last, the values of latent heat flux, obtained using two independent stomatal resistance formulations, are compared. For the three experimental datasets studied, the difference in predicted latent heat flux between the two formulations is less than 10 W m-2 at all times. Although sensitivity tests showed greater differences under certain circumstances, it is concluded that most of the biophysical controls that enter into the stomatal resistance formulation, but defy simple field measurements, do not need to be specified with great accuracy in order to produce a prediction of latent heat flux that falls within the envelope of usual observational error.

Kustas, W. P., et al. (1991). "An interdisciplinary field-study of the energy and water fluxes in the atmosphere-biosphere system over semiarid rangelands – description and some preliminary-results." Bulletin of the American Meteorological Society **72**(11): 1683-1705.

Arid and semiarid rangelands comprise a significant portion of the earth's land surface. Yet little is known about the effects of temporal and spatial changes in surface soil moisture on the hydrologic cycle, energy balance, and the feedbacks to the atmosphere via thermal forcing over such environments. Understanding this interrelationship is crucial for evaluating the role of the hydrologic cycle in surface-atmosphere interactions. This study focuses on the utility of remote sensing to provide measurements of surface soil moisture, surface albedo, vegetation biomass, and temperature at different spatial and temporal scales. Remote-sensing measurements may provide the only practical means of estimating some of the more important factors controlling land surface processes over large areas. Consequently, the use of remotely sensed information in biophysical and geophysical models greatly enhances their ability to compute fluxes at catchment and regional scales on a routine basis. However, model calculations for different climates and ecosystems need verification. This requires that the remotely sensed data and model computations be evaluated with ground-truth data collected at the same areal scales. The present study (MONSOON 90) attempts to address this issue for semiarid rangelands. The experimental plan included remotely sensed data in the visible, near-infrared, thermal, and microwave wavelengths from ground and aircraft platforms and, when available, from satellites. Collected concurrently were ground measurements of soil moisture and temperature, energy and water fluxes, and profile data in the atmospheric boundary layer in a hydrologically instrumented semiarid rangeland watershed. Field experiments were conducted in 1990 during the dry and wet or "monsoon season" for the southwestern United States. A detailed description of the field campaigns, including measurements and some preliminary results are given.

Bonan, G. B. (1991). "A biophysical surface-energy budget analysis of soil-temperature in the boreal forests of interior Alaska." Water Resources Research **27**(5): 767-781.

Observed soil degree-days (SDD) for 20 forest stands in the discontinuous permafrost zone of interior Alaska range from 483 to 2217. These stands differ in terms of forest structure, topography, and soils. A biophysical model that solves the surface energy budget of a multilayer forest canopy was used to examine which site factors were most important in controlling the observed soil temperature gradient. Simulated soil temperature averaged 851 SDD for the 20 sites. Sensitivity analyses indicated that this average could vary by 0-88 SDD (0-10% of the mean) because of possible parameter error. Removing the forest canopy and the moss cover caused the soil to warm, on average, by 408 and 345 SDD, respectively. Elevation and soil drainage differences among sites were of secondary importance, causing SDD to deviate by 71 and 66 SDD, respectively. Slope and aspect had little effect on soil temperature.