Springtime Simulations over Southeastern South America using a Coupled Plant-Soil-Atmosphere Model GEMRAMS

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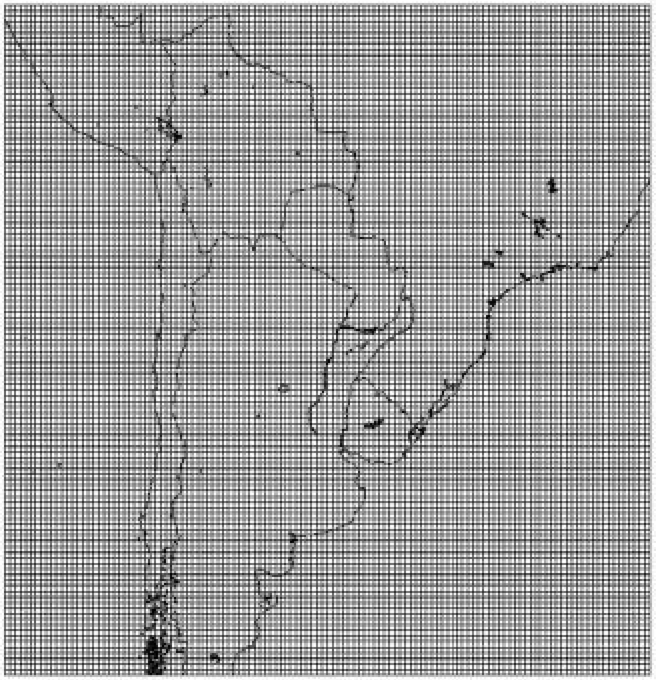
LTER Brown Bag Seminar

MOTIVATION

Interactions and feedbacks between the biosphere and atmosphere, that operate from diurnal to year time scale, constitutes and important component of the climate system.

Southern South America comprises a wide range of vegetation and soil types, and spatial and seasonal and interannual variability of atmospheric variables represent a distinctive characteristic of the climate in this region.

Land-surface changes has occurred due to human activities, such as overgrazing, a moderate increase of irrigation practices, deforestation/reforestation, urbanization and conversion to agriculture/animal husbandry of natural areas. These changes can affect ecosystem functioning (i.e. productivity) and structure (i.e vegetation types), which in turn, may affect both local and regional atmospheric conditions



These biosphere-atmosphere interactions, that operate from diurnal to year time scales, have not been fully explored in this region.

Tools to study these interactions:

The Regional Atmospheric Modelling System RAMS v4.3 coupled with a plant-scale model GEMTM will be used to evaluate the regional sensitivity of meteorological and biological variables to the inclusion of an interactive and growing canopy.

The main objective of this exercise will be to:

Analyze the biosphere-atmosphere interactions in southern South America at a weekly, seasonal and interannual time scales using an interactive atmospheric-plant model.

Two main questions to answer are:

- What are the effects of landcover/landuse changes on the sensible and latent heat fluxes, near-surface temperature and humidity, precipitation and atmospheric circulation?

- How do the interannual variability (i.e. El Niño-Southern Oscillation effects on precipitation) and the landcover/landuse changes combined affect the atmosphere-biosphere interactions?

The Regional Atmospheric Modeling System (**RAMSv4.3**) coupled with a plant-scale model (**GEMTM**) will be used as a tool to study these interactions (**GEMRAMS**)

RAMS

The Regional Atmospheric Modeling System (RAMS) is a three –dimensional primitive equation model, that addresses atmospheric dynamics and thermodynamics. Parameterizations for solar and terrestrial radiation, and moist processes are also considered. Land-surface processes are represented in RAMS by LEAF-2, the Land Ecosystem-Atmosphere Feedback model (Lee, 1992; Walko et al, 2000). LEAF-2 components (canopy air, vegetation, snow, soil and permanent water bodies) exchange heat and moisture between them and with the atmosphere. It includes prognostic equations for temperature and water content of the soil (for multiple layers), temperature and mixing ratio for the canopy air and vegetation temperature.

Seasonal variation of **LAI** is prescribed according to vegetation type and time of the year. Vegetation phenology affects the seasonal climate (Lu and Shuttleworth, 2002). Then, a better description of the phenology, according to temperature and water status or from satellite data, is needed to capture the interactions atmosphere-biosphere.

Water and CO2 exchange between the plant and the atmosphere are regulated by the **stomatal conductance.** In LEAF2 the stomatal conductance is computed using environmental stress factors, that depend on temperature, water vapor deficit, shortwave radiation and soil water potential. These environmental factors may actually vary simultaneously, interacting with each other. A complete model of the climate system should include a more biologically realistic parameterization of the stomatal conductance.

GEMTM

The general energy and mass transport model (GEMTM) is an ecophysiological process-based model, that can be used to simulate the dynamic interactions between the atmosphere and the growing canopy (Chen and Coughenour, 1994). It comprises plant and root submodels, and a detailed canopy radiation transfer.

The gross daily photosynthesis is calculated considering C3 and C4 photosynthetic pathways. Canopy photosynthesis is computed using the sunlit and shaded leaf fractions of the canopy. Some portion is respired. The available carbon pool is then allocated to leaves, stems, roots and reproductive organs, depending on temperature and water conditions. The total leaf carbon is related to the Leaf Area Index (LAI) by the vegetation-prescribed specific leaf area. Water and CO2 exchange between the plant and the atmosphere are regulated by the stomatal conductance. In GEMTM, a modified version of the Ball-Berry model is used to compute the stomatal conductance.

GEMRAMS Scheme

Input data List

NCEP/NCAR Reanalysis (Kalnay et al. 1996)

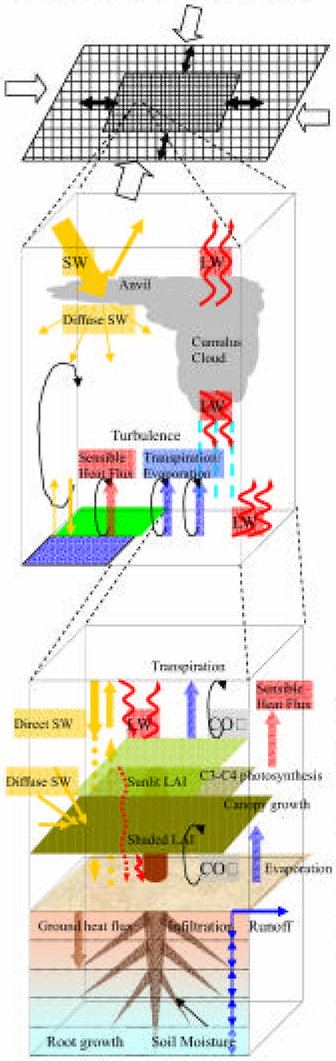
Digital Elevation Model (USDA)

BATS/LDAS land use land covers (Dickinson et al. 1986)

AVHRR/MODIS LAI (Myneni et al. 2002)

FAO global soil texture (Zobler 1986), USDA STATSGO (Miller and White 1998

VIC LDAS soil moisture (Maurer et al. 2002)



Model Scheme List

RAMS

Regional Atmospheric Modeling System (Pielke et al, 1992, Cotton et al. 2002)

- Radiative Transfer Scheme
  Simple (Mahrer and Pielke 1977)
  Two-stream (Chen and Cotton 1987)
  New two-stream (Harrington 1997)

- Microphysics Scheme
  Dump bucket (Cotton 1995)
  Single-moment bulk (Walko et al. 1995)
  Two-moment bulk (Meyers et al 1995)
  Spectral bin resolving (Reisin et al. 1996)

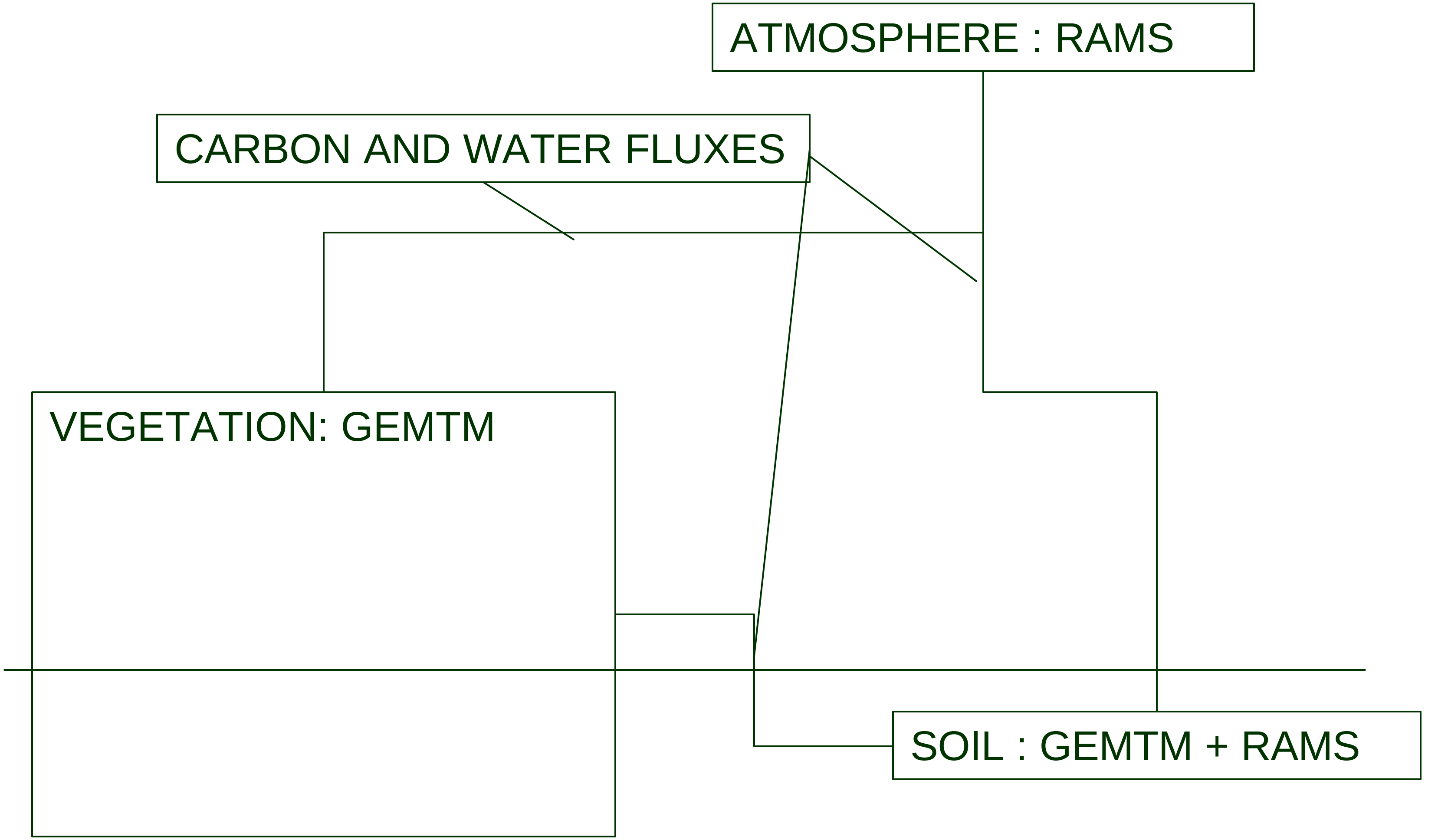
- Convection Scheme
  Simplified Kuo (Tremback 1990)
  Modified Kain-Fritsch (Castro et al. 2002)

- Turbulence Closure Scheme
  K-closure (Lilly 1962, Hill 1974)
  Eddy viscosity TKE (Deardorff 1980)
  Ensemble-average TKE (Mellor and Yamada, 1982)
  Sub-grid (Kosovic 1997)

GEMTM & LEAF2

- Subgrid land covers (Avissar and Pielke 1989)
- Multi-canopy Radiative Transfer Model (Goudriaan 1977)
- Sunlit/shaded leaf (Norman 1979)
- Photosynthesis Model: C3 & C4 path (Farquhar et al. 1980 , Chen et al. 1994)
- Evaporation/Transpiration Model (Walko et al. 2000)
- Canopy Air Turbulent Exchange (Lee 1992)
- Temporary Surface Water (Walko et al.1996)
- Soil Respiration (Norman 1992)
- Root Effluence, Uptake and Branching Model (Chen and Lieth 1992, 1993)
- Soil water and energy balance (McCumber and Pielke 1981, Walko et al. 2000)

By T. Matsui 2003

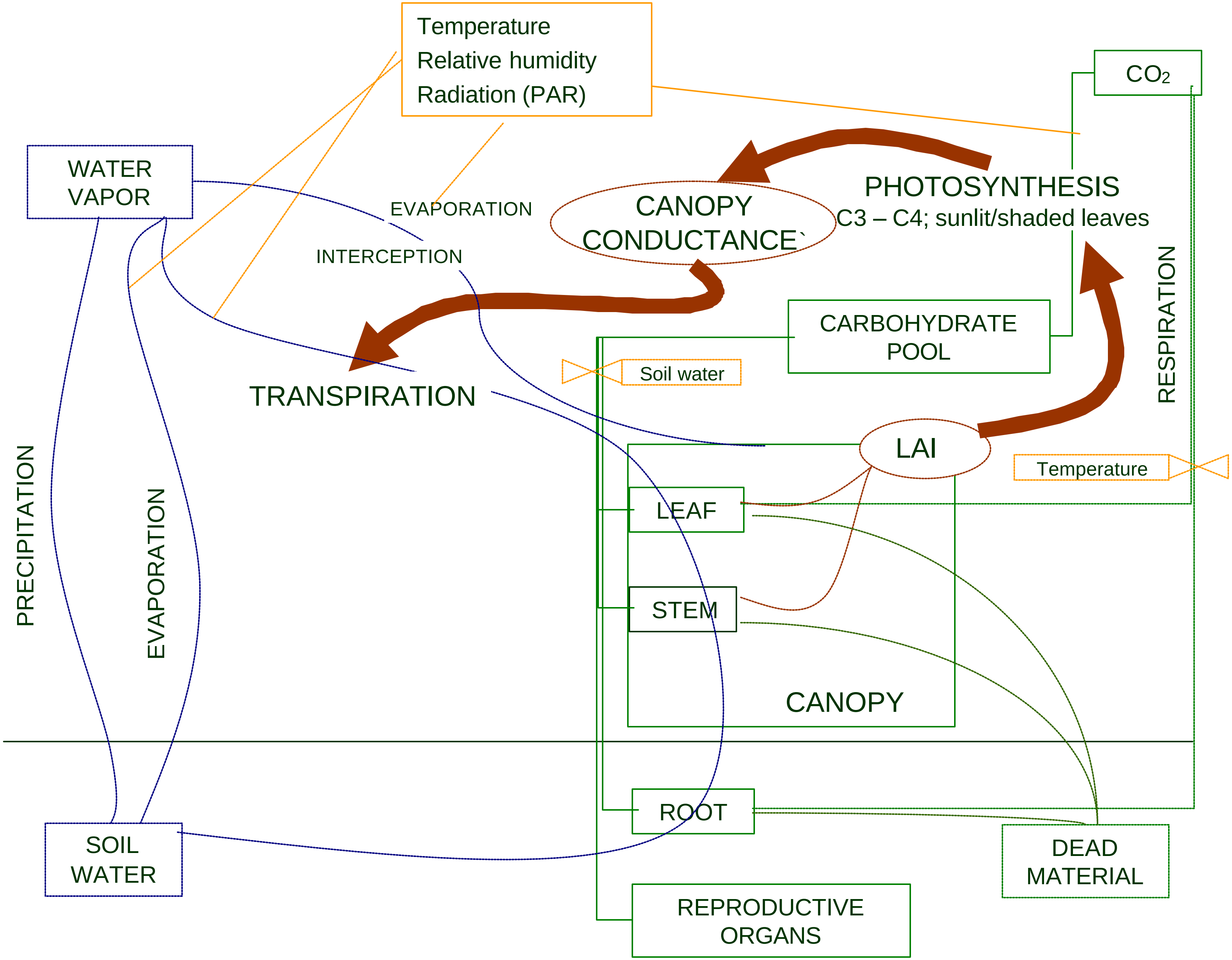


ATMOSPHERE : RAMS

CARBON AND WATER FLUXES

VEGETATION: GEMTM

SOIL : GEMTM + RAMS



Temperature
Relative humidity
Radiation (PAR)

CO2

WATER VAPOR

EVAPORATION

INTERCEPTION

CANOPY CONDUCTANCE`

PHOTOSYNTHESIS
C3 – C4; sunlit/shaded leaves

CARBOHYDRATE POOL

Soil water

TRANSPIRATION

RESPIRATION

LAI

Temperature

PRECIPITATION

EVAPORATION

LEAF

STEM

CANOPY

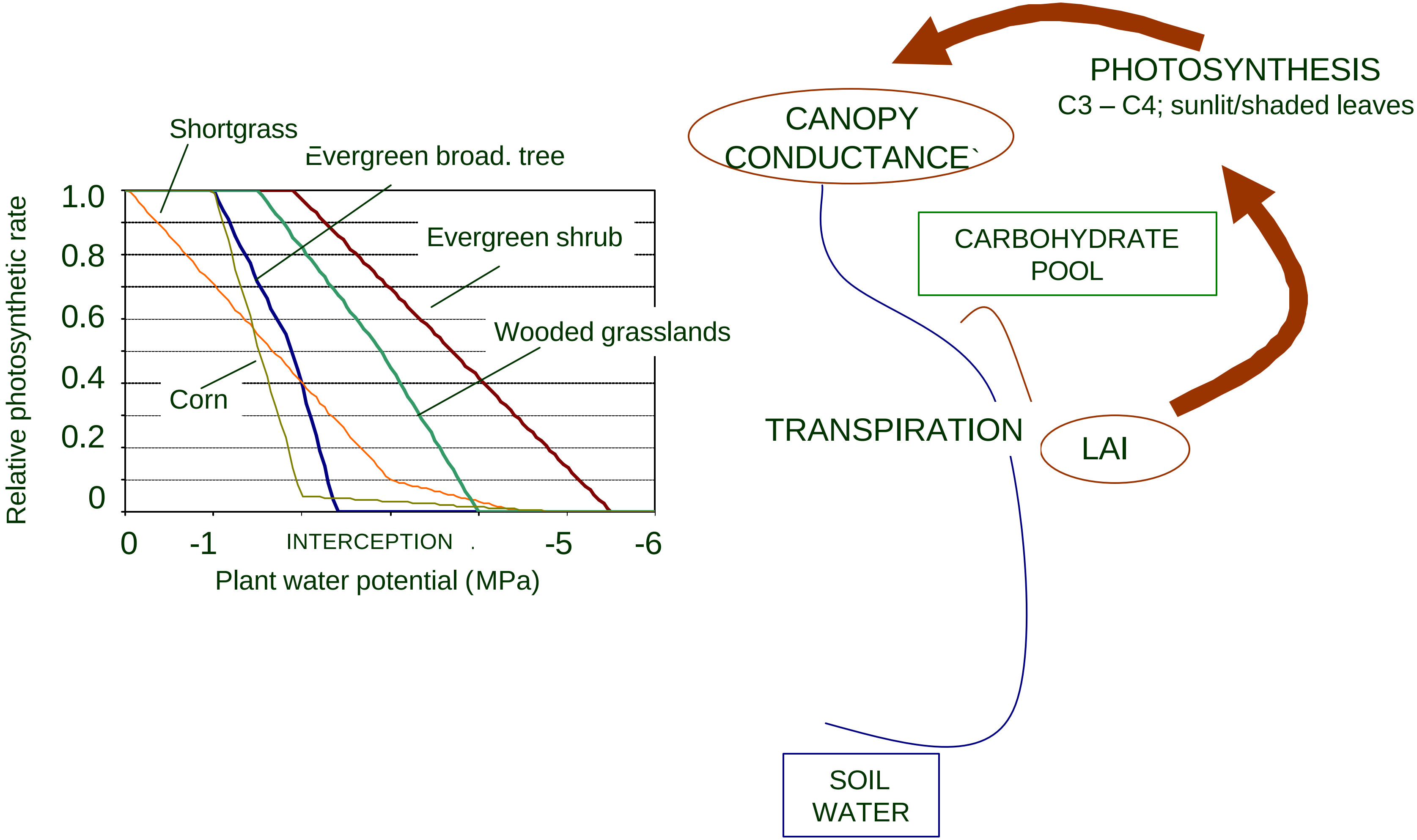
ROOT

SOIL WATER

DEAD MATERIAL

REPRODUCTIVE ORGANS

VARIABLE DESCRIPTION	UNITS
LAI for sunlit/shade leaves	m2 leaf m^{-2} ground
Total LAI, dead+live leaf	
Daily change in lai	
PAR for sunlit/shaded leaves	μmol m^{-2} s^{-1}
CO2 flux	μmol CO_2 m^{-2} s^{-1}
Soil respiration	
Canopy photosynthesis	μmol CO_2 m^{-2} s^{-1}
Canopy resistance	m s^{-1}
Accumulation of photosynthates	kgDM m^{-2} d^{-1}
Accumulated gain of weight (leaf, shoot,root, seed)	kg m^{-2}
Accumulated biomass (leaf, shoot, root, seed)	kgDM m^{-2}
Maintenance respiration (shoot, root, seed)	kgDM m^{-2} d^{-1}
Dead biomass (leaf, shoot, root)	kgDM m^{-2} d^{-1}
Accumulated litter	kgDM m^{-2}
Reallocated biomass (woody root to shoot/leaf; seed to root/hoot/leaf; shoot to leaf)	kgDM m^{-2}
Maintenance respiration coefficient (shoot, root, seed)	s^{-1}
Dry matter partition coefficients (leaf, shoot, root, seed).	unitless
Rate of tissue death (leaf, shoot, root).	d^{-1}
Rate of conversion standing leaf to litter.	
Root biomass distribution.	%
Total root resistances along the water transport pathway	Mpa s^{-1}
Root weight density.	kg m^{-3}
Root length density.	m m^{-3}
Soil water potential and temperature for the whole profile and each layer.	Mpa, °C
Plant water potential	MPa
Temperature and relative humidity at 2m	K, %
Maximum and minimum temperature 2 m	°C



PHOTOSYNTHESIS
C3 – C4; sunlit/shaded leaves

CANOPY CONDUCTANCE`

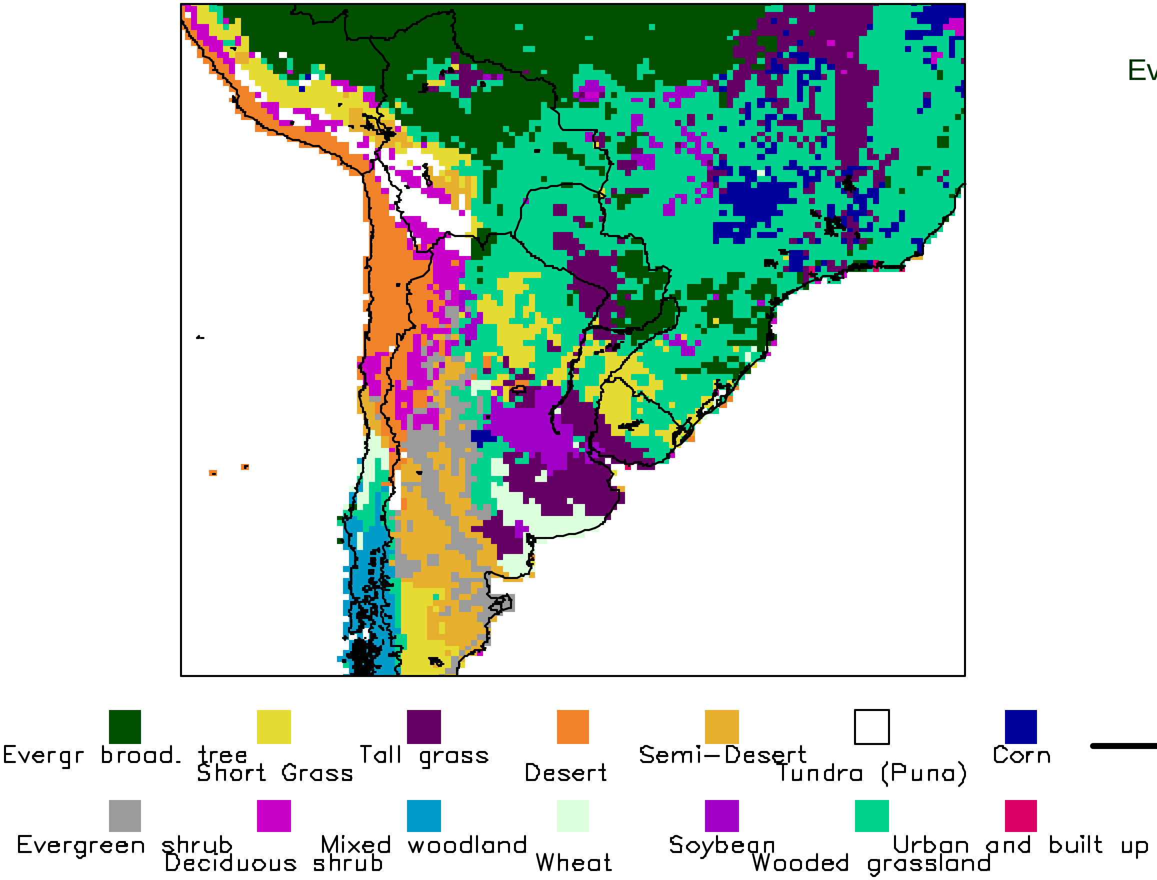
CARBOHYDRATE POOL

TRANSPIRATION

LAI

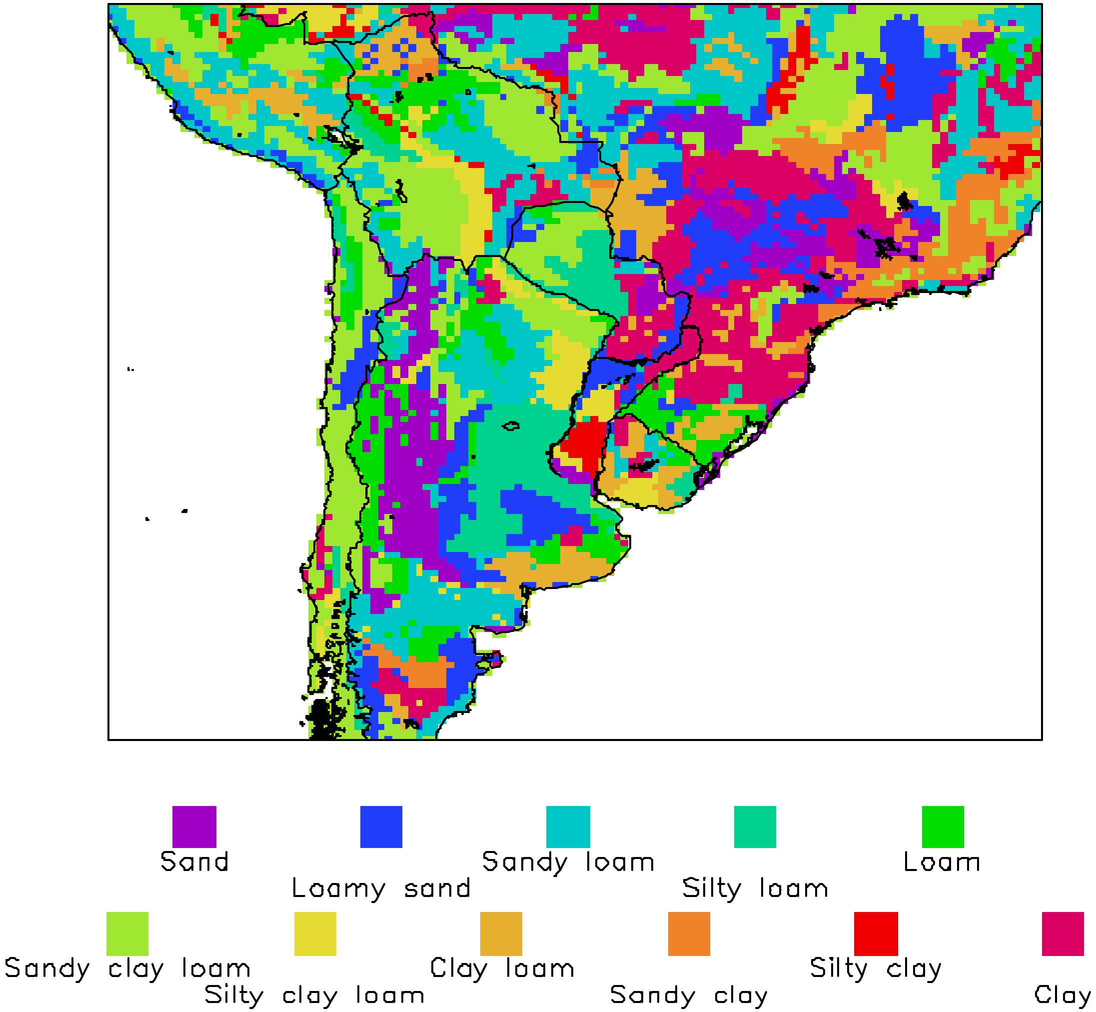
SOIL WATER

Vegetation types

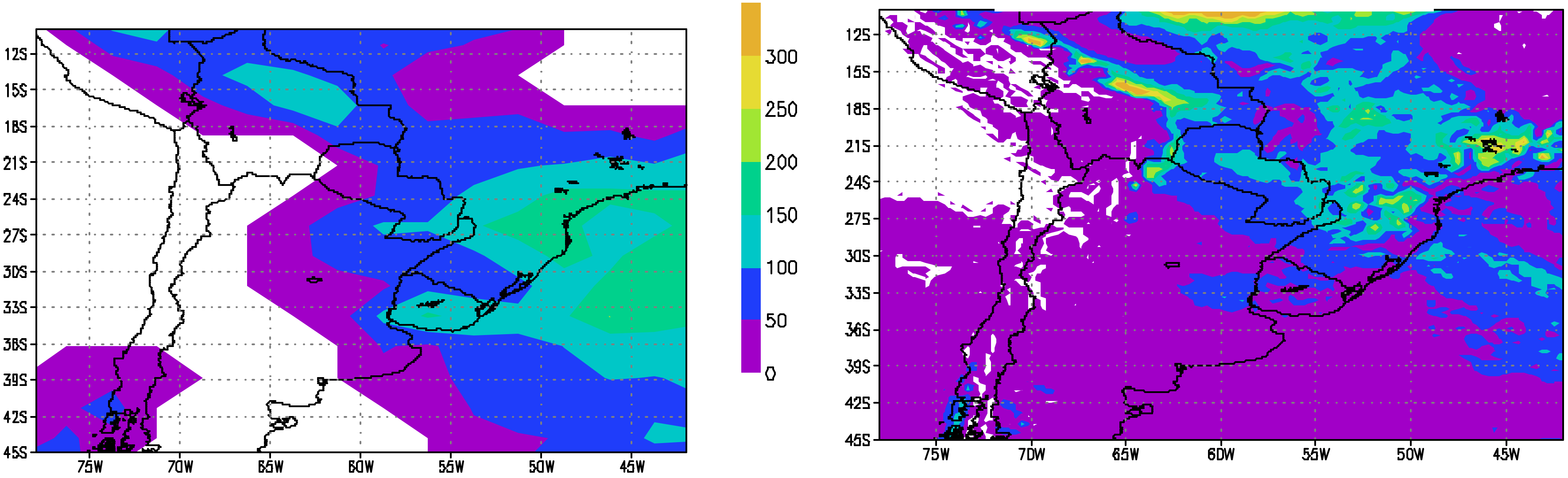


VEGETATION TYPE	GRID CELLS %
Wooded grassland	32.8
Evergreen broadleaf tree	19.6
Tall grass	10.5
Short grass	6.6
Desert	5.2
Semi-desert	4.7
Corn	3.8
Deciduous shrub	3.5
Evergreen shrub	3.5
Soybean	3.1
Mixed woodland	2.3
Tundra	2.2
Wheat	2.1
Urban and build up	0.05

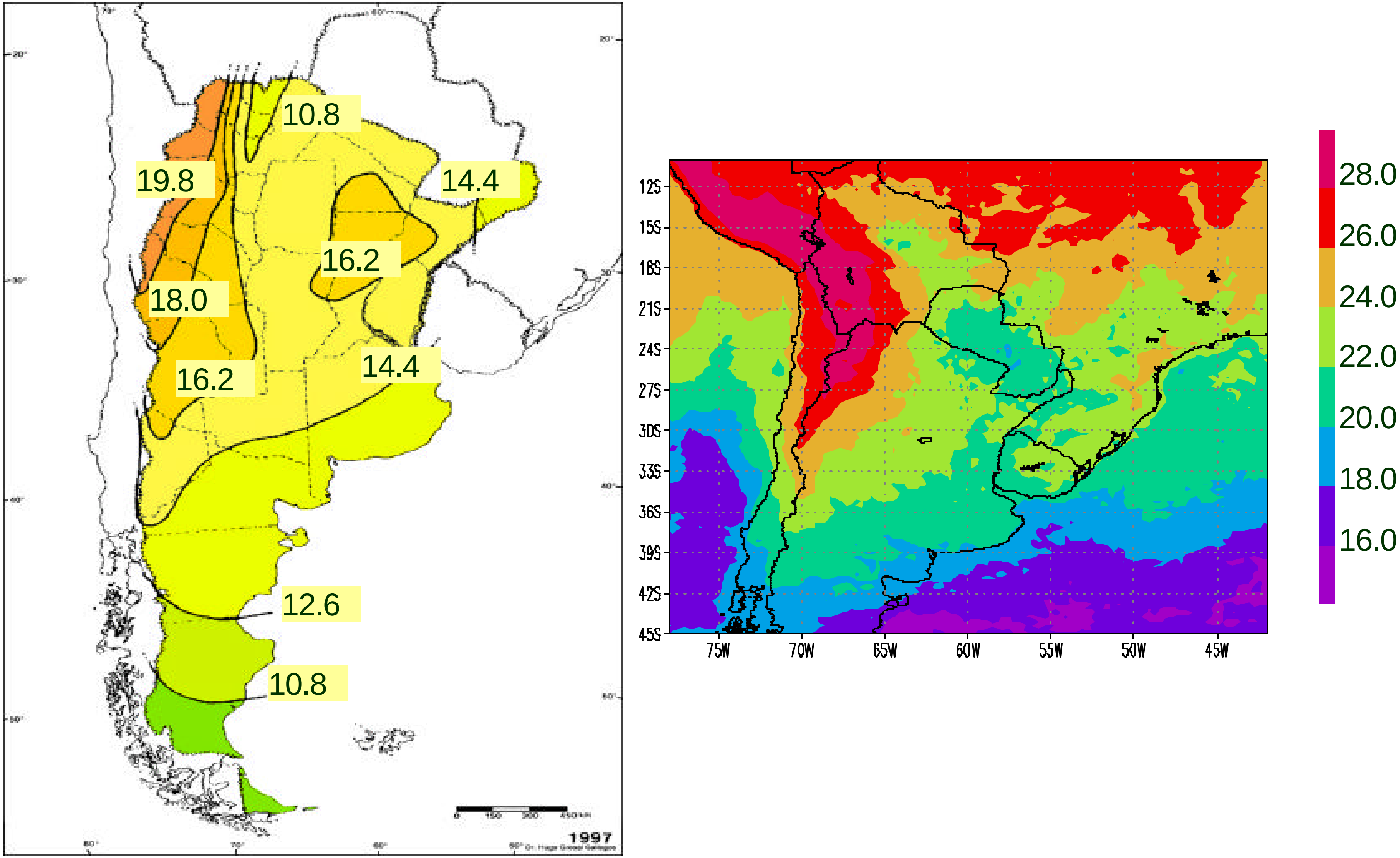
Soil texture



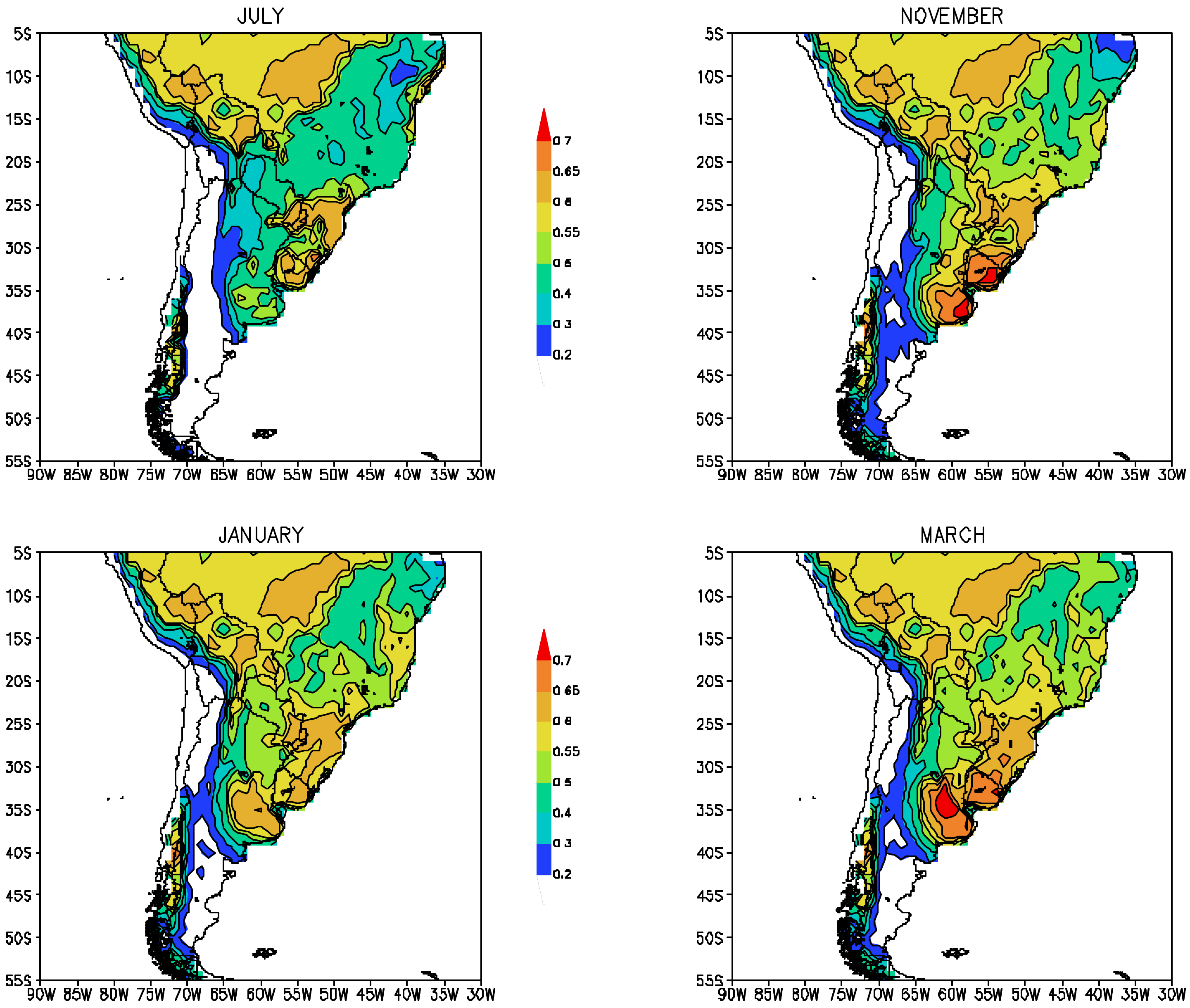
Observed and simulated precipitation
September 1996



Observed (mean) and simulated shortwave radiation (MJm^{-2}d^{-1})
September 1996

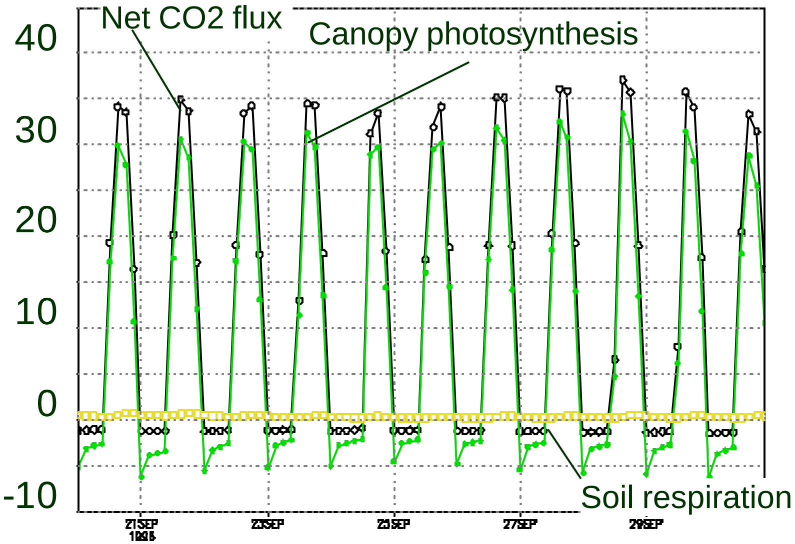


NDVI SPATIAL AND TEMPORAL DISTRIBUTION

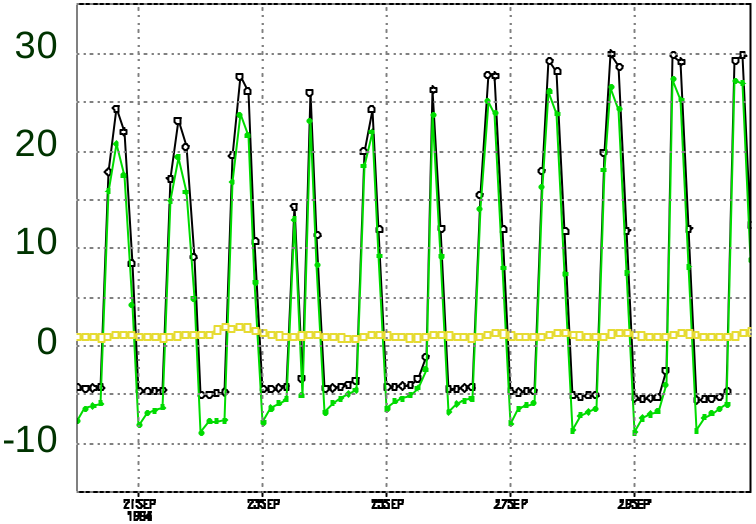


GEMRAMS outputs : CO2 fluxes (µmol m^{-2} s^{-1})

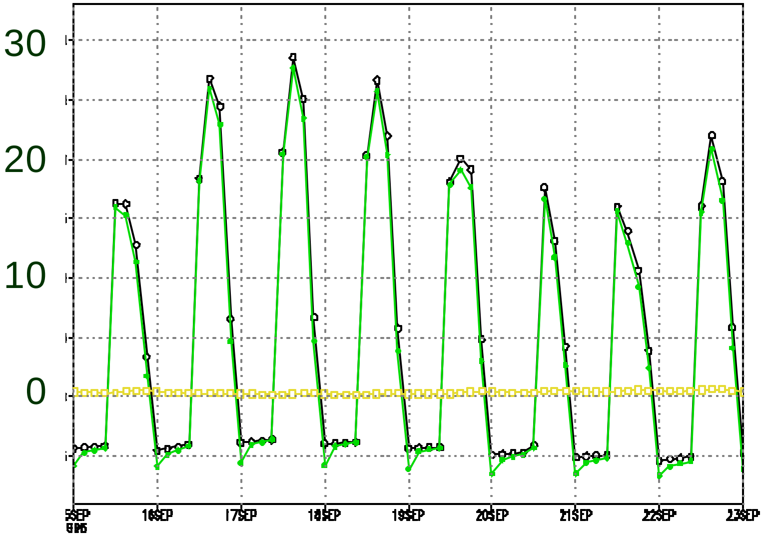
TALL GRASS



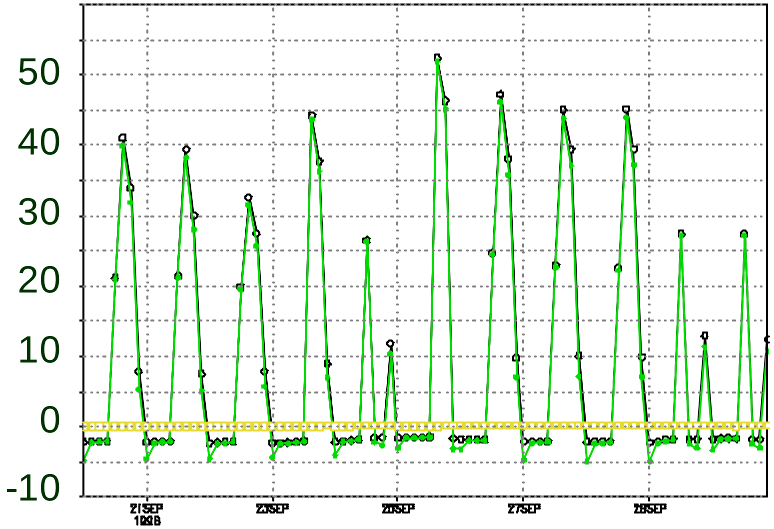
SHORT GRASS



WOODED GRASSLANDS

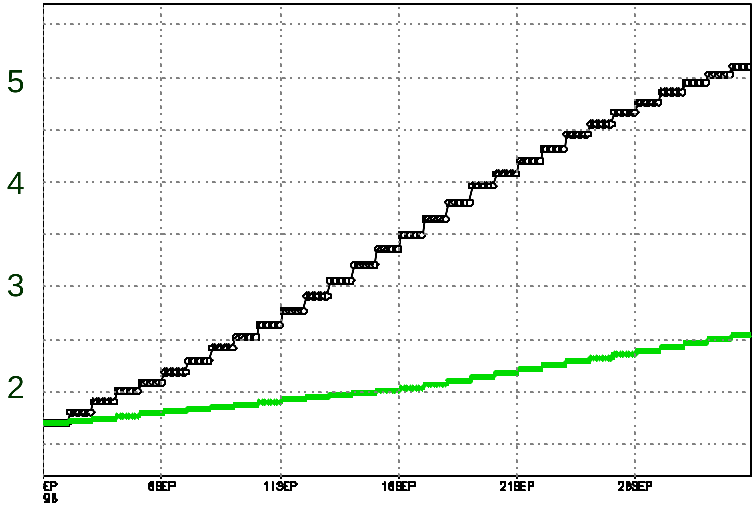


EVERGREEN TREES

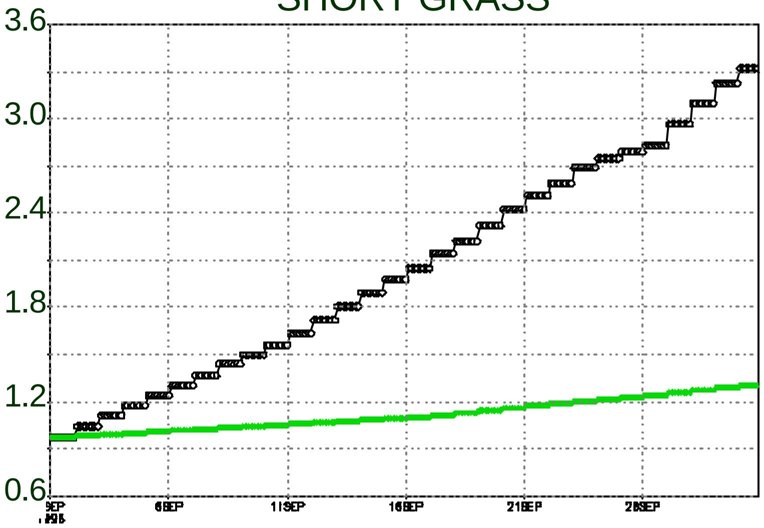


“Observed (green)” and simulated (black) Leaf Area Index
September 1996

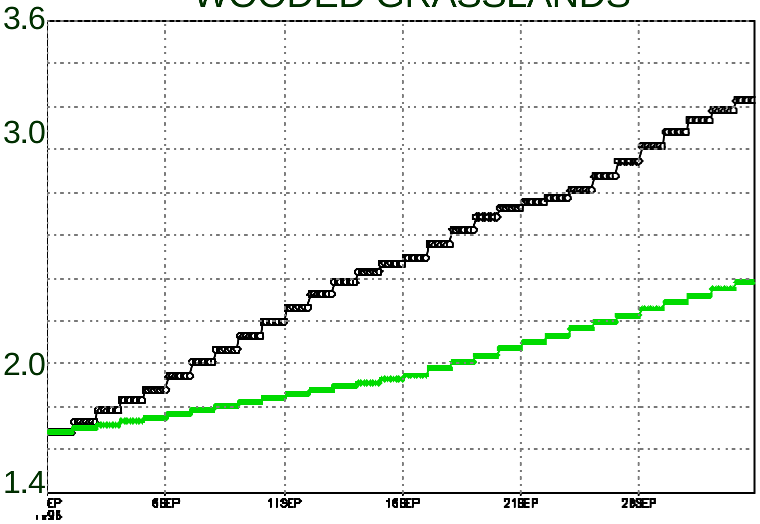
TALL GRASS



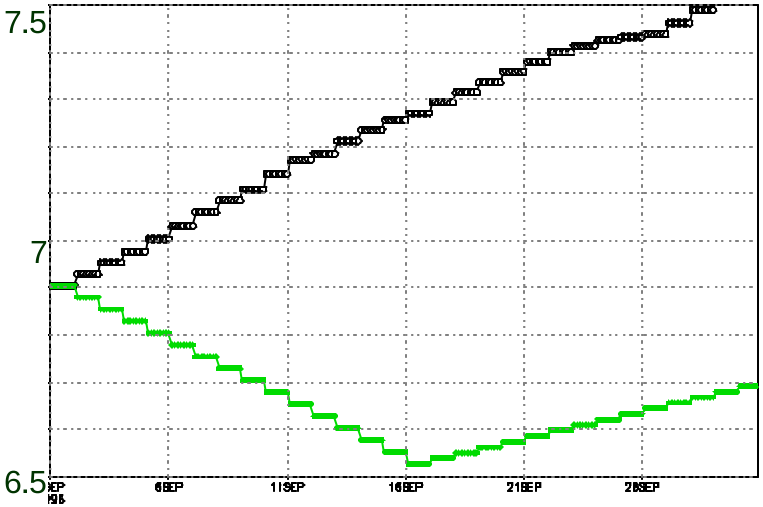
SHORT GRASS



WOODED GRASSLANDS

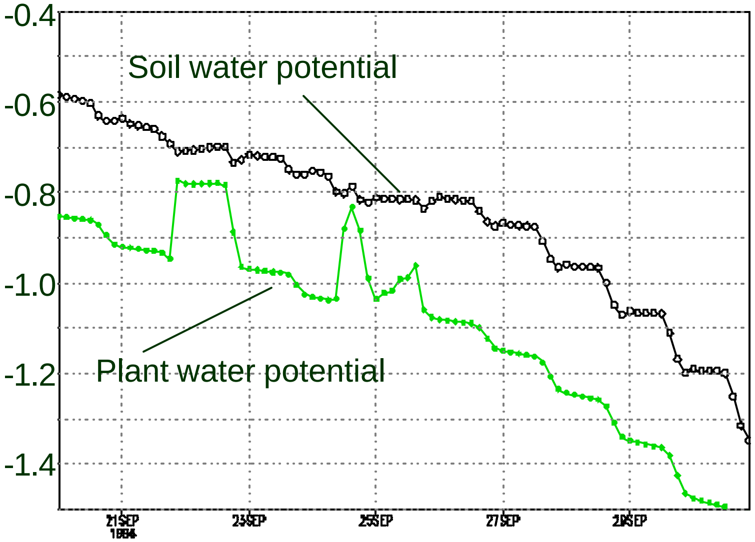


EVERGREEN TREES



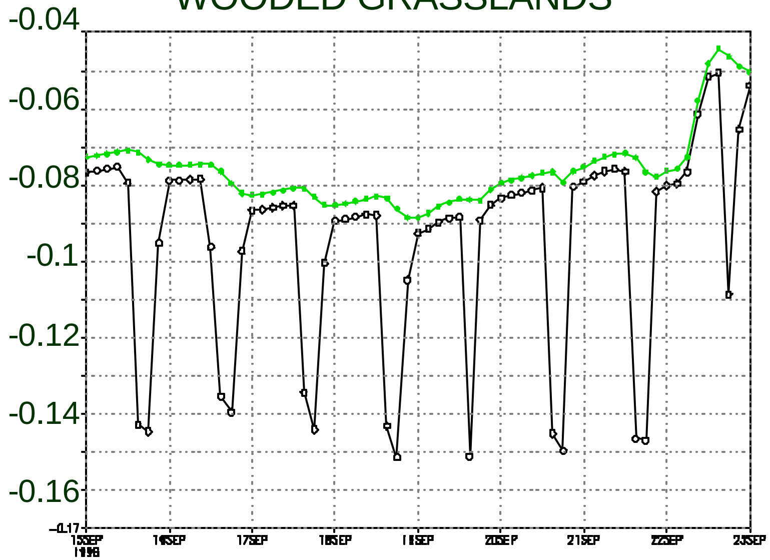
GEMRAMS outputs : plant and mean soil water potential (MPa)

TALL GRASS

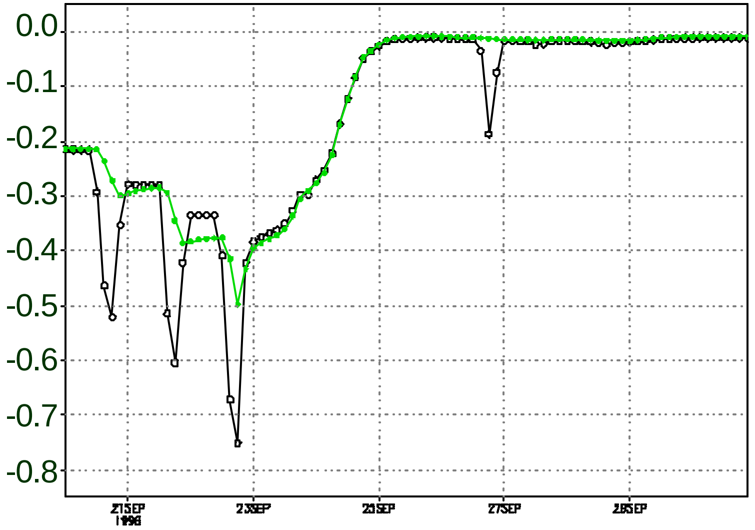


SHORT GRASS

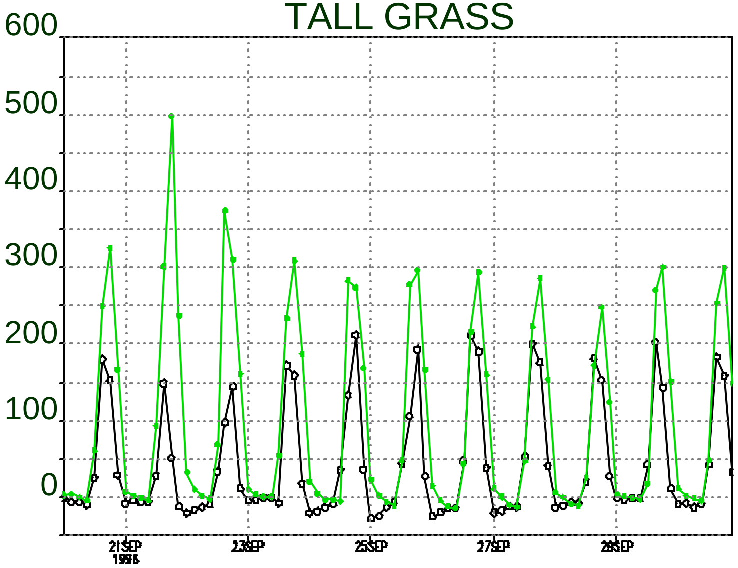
WOODED GRASSLANDS

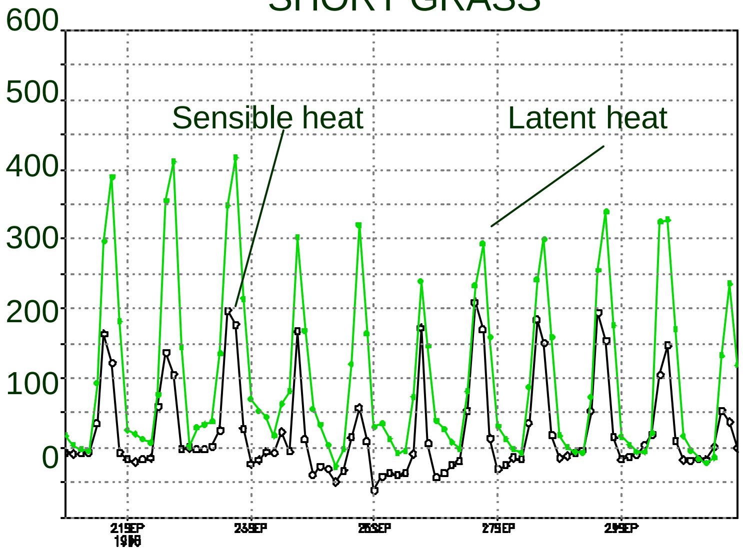


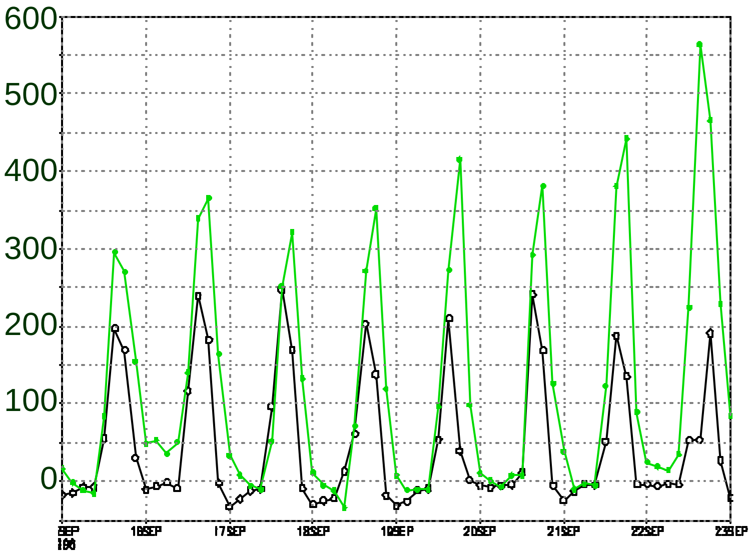
EVERGREEN TREES

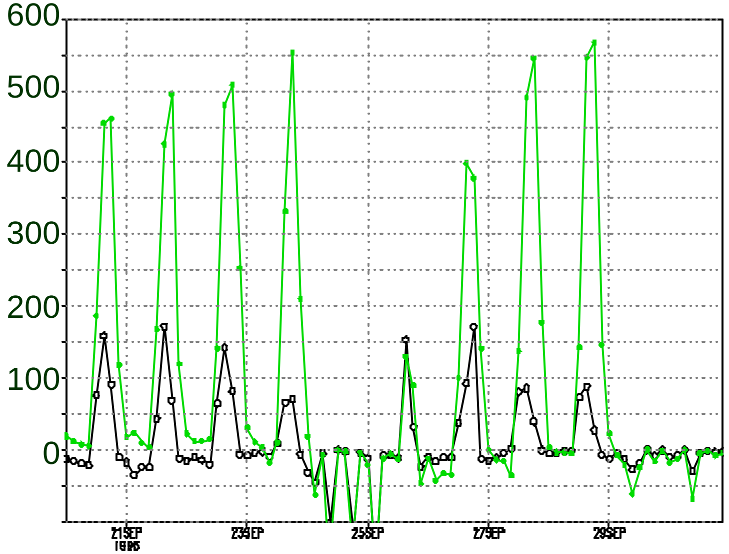


GEMRAMS outputs : Sensible and Latent heat (Wm^{-2})


TALL GRASS


SHORT GRASS


WOODED GRASSLANDS


EVERGREEN TREES

Ongoing work:

•Validation of GEMRAMS results with observed precipitation and temperature. There are very few measurements/estimations of sensible and latent heat, or LAI, and they mostly corresponds to crop fields.

•Offline simulations with GEMTM+LEAF2 to address the problem of “excess” of LAI.

* Validating GEMRAMS functions and coefficients for the Shortgrass Steppe, using the Bowen ratio towers and other experiments.

Different experiments will be carried out, that will allow us to answer the questions. They will be a combination of:

- interannual variability questions (with actual vegetation):

RAMS EL NIÑO (WET)
NEUTRAL
GEMRAMS LA NIÑA (DRY)

- landuse/land cover change (for "neutral" year) with respect to an actual crop distribution in Pampas:

GEMRAMS GRASSLANDS
DECIDUOUS TREES