Land use effects on the water balance and climate of large areas - regional climate models.

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University of Maryland

The loss of timber has denuded the hills and plains surrounding Athens and caused massive soil erosion (Plato, 500 BC)

Are there feedbacks between land and climate?

La Plata Basin

Driving questions:

1. Does land use affect climate?

2. How do climate models represent LCLUCs?

3. What is the sensitivity of regional climate to LCLUCs?

4. Land Cover Types or Ecosystem Functional Types (EFTs)?

5. What are the remote forcings and regional surface effects on droughts?

Statement on droughts, floods and land use change in the Buenos Aires Province

Diagnosis

Feedbacks

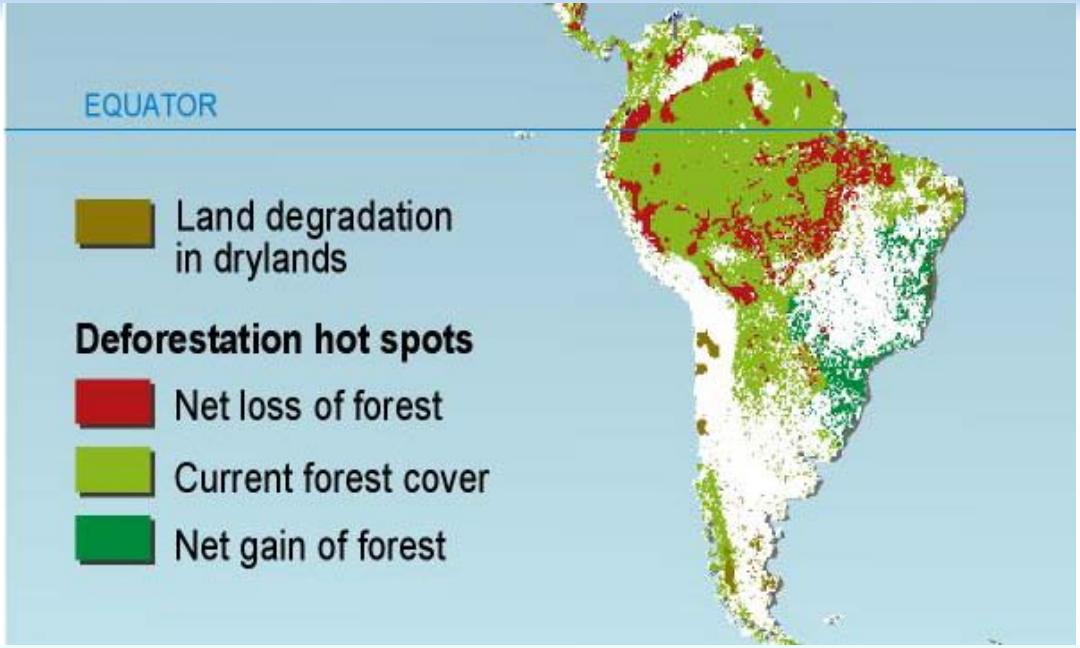
Changes in Climate

Warning on Geo-engineering to compensate climate change

- The construction of channels to remove water from flooded areas will reduce the water availability on the soil (water table) and make droughts much worse.

Florentino Ameghino (1854-1911)

LCLU changes in South America



1980-2000
Millennium Ecosystem Assessment

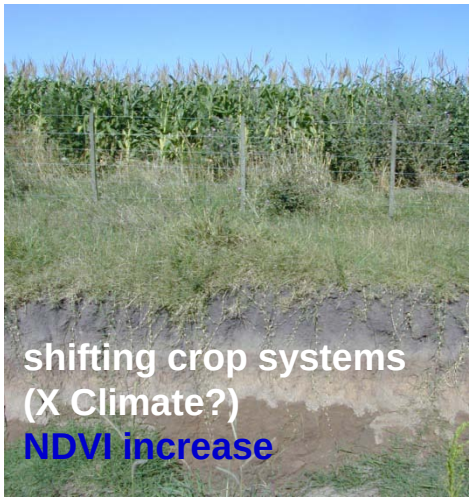
Significant deforestation not only over the Amazon, but over other regions as well:

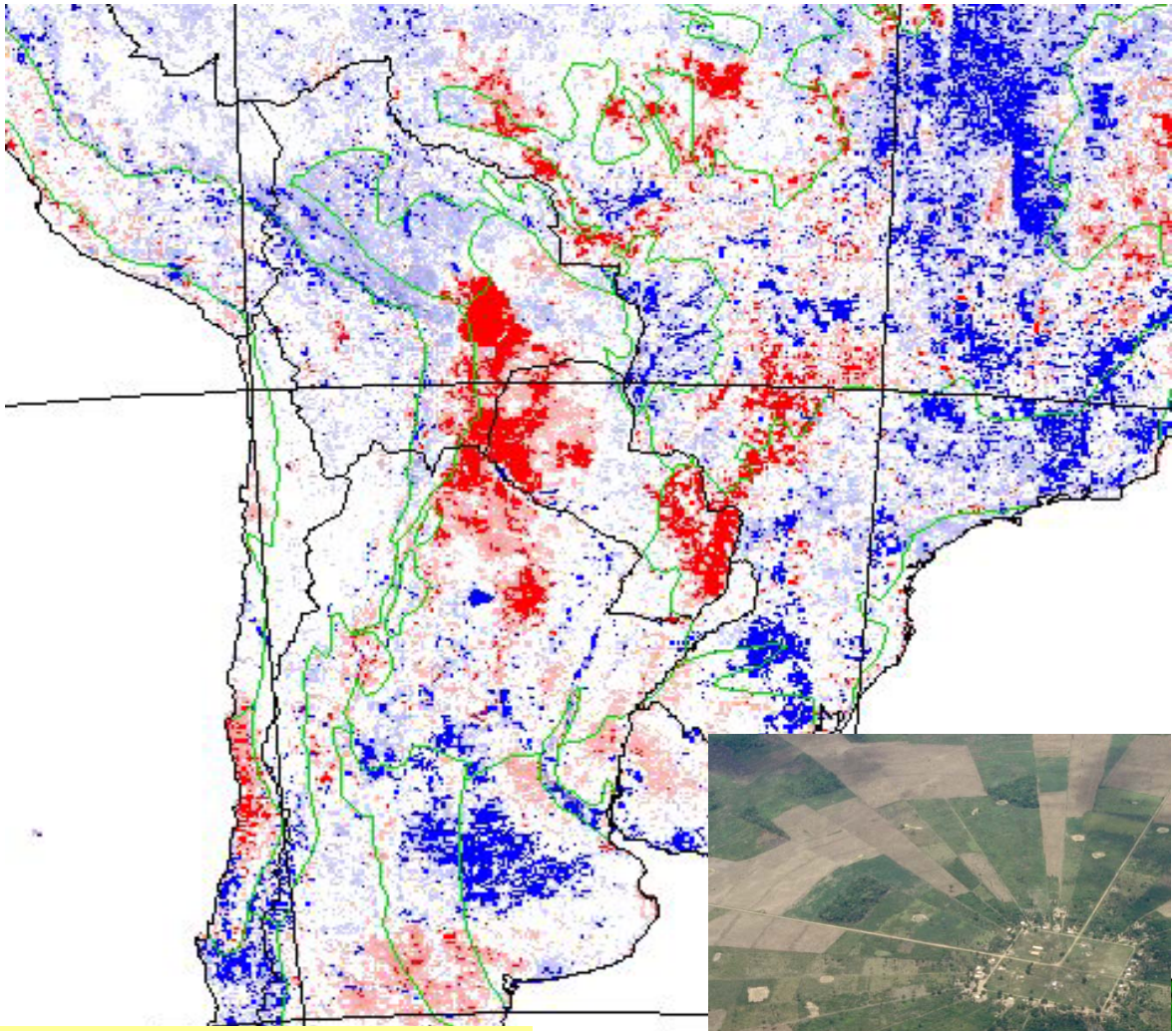
(1) The **forested area in eastern Paraguay decreased from 45% 50 years ago to 15% at the beginning of the 1990s** (Bozzano and Weik 1992).

(2) **Decreases in forested area in the Paraná basin from 90% to 17% over the 4 decades from about 1950 to 1990**, with the percentage of land use in annual crops increasing from near zero in the early 1960s to almost 60% by 1990 (Tucci and Clarke 1998).

Land use changes using remotely sensed biophysical variables

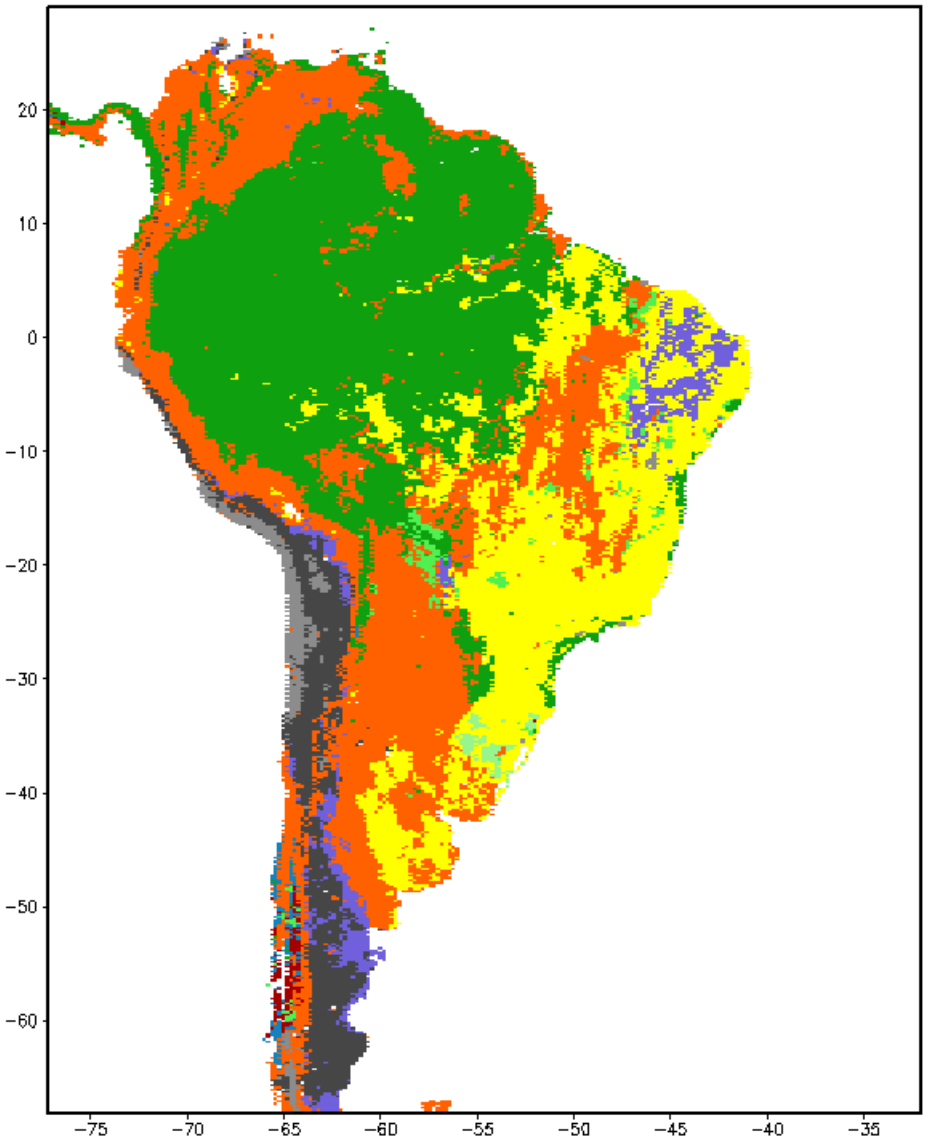
Normalized Difference Vegetation Index NDVI 1981-2000 trends
(surrogate for primary production)





Red: decrease of NDVI
Blue: increase of NDVI

NEW MAP



1: BROADLEAF-EVERGREEN TREES (TROPICAL FOREST)

2: BROADLEAF-DECIDUOUS TREES

3: BROADLEAF AND NEEDLELEAF TREES (MIXED FOREST)

4: NEEDLELEAF-EVERGREEN TREES

5: NEEDLELEAF-DECIDUOUS TREES (LARCH)

6: BROADLEAF TREES WITH GROUNDCOVER (CERRADO)

7: GROUNDCOVER ONLY (PERENNIAL)

8: BROADLEAF SHRUBS WITH PERENNIAL GROUNDCOVER

9: BROADLEAF SHRUBS WITH BARE SOIL

10: DWARF TREES AND SHRUBS WITH GROUNDCOVER (TUNDRA)

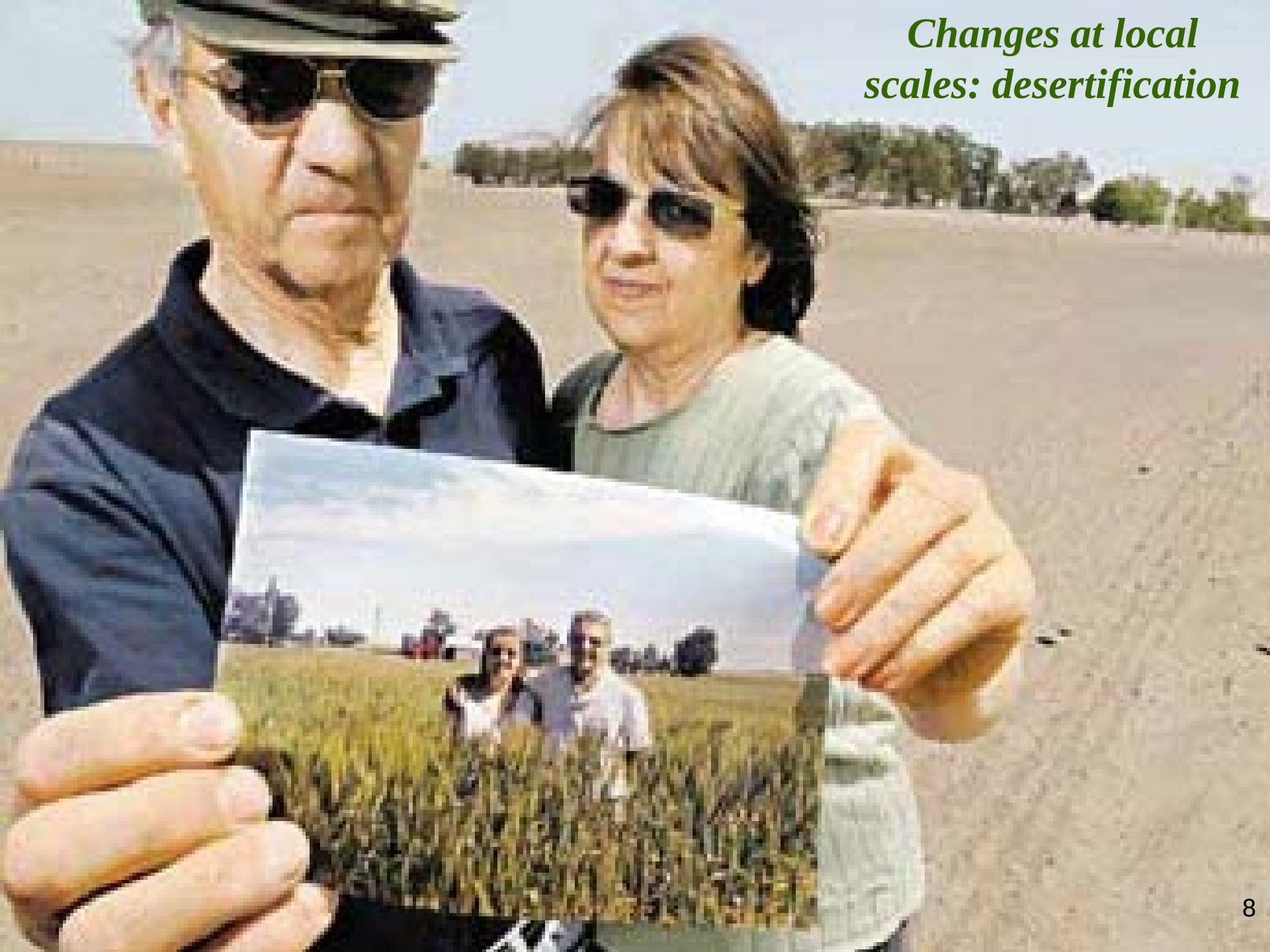
11: BARE SOIL

12: CULTIVATIONS

Changes at local scales

1973

2003



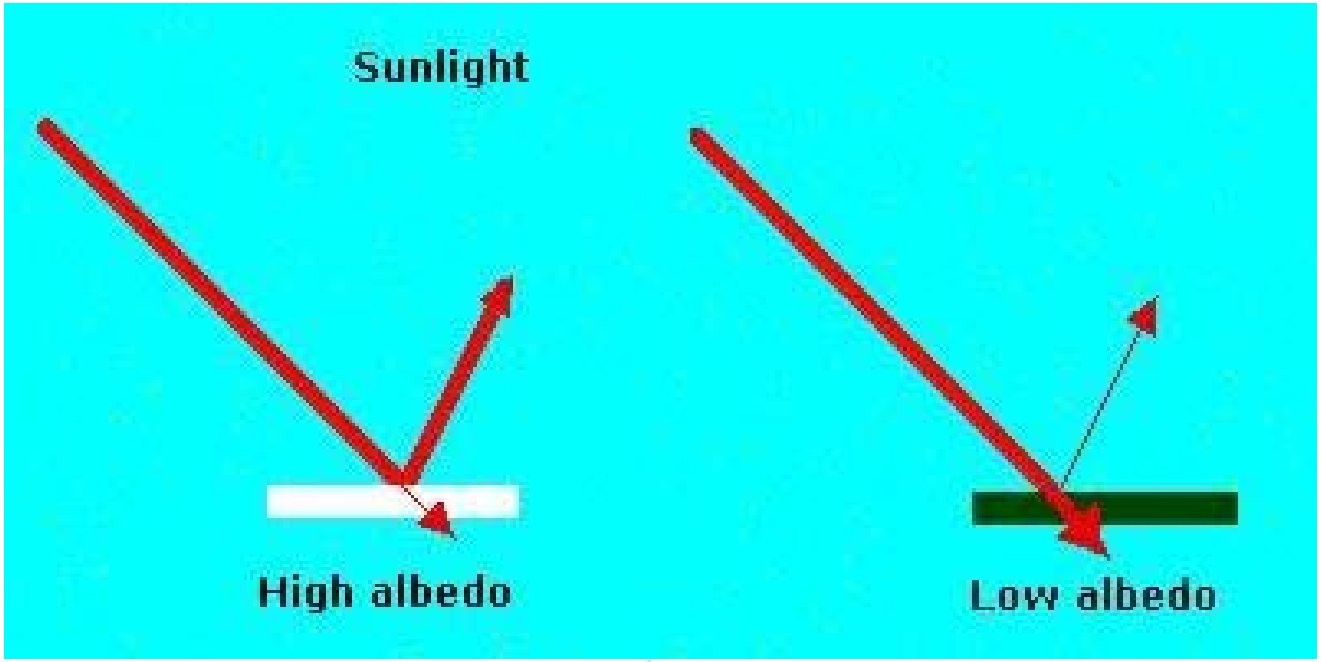
Changes at local scales: desertification

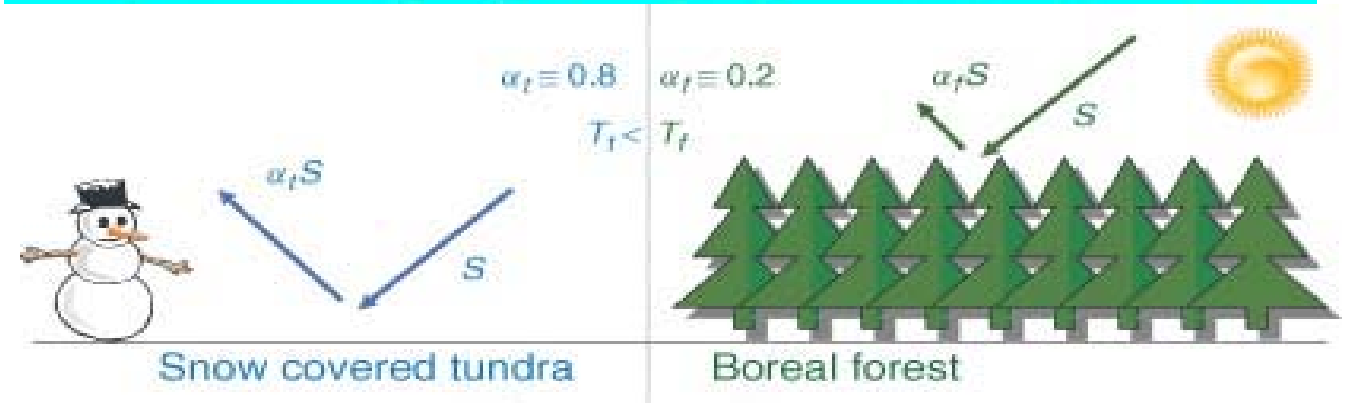
Depending on their physiological properties, ***vegetation types behave in different manners, for example the way they transpire or how they reflect and/or absorb radiation (changes in albedo)****, thus affecting the exchanges of energy between the ground and the atmosphere.*

Likewise, their ***roots absorb water differently****, thus impacting the soil moisture, deep runoff and ultimately river flows.*

Consequently, these large changes in land cover are expected to have major implications for the **surface water and energy budgets**, and possibly on the **hydrological cycle** of the basin

Efecto de la superficie en la radiacion del sol (albedo)

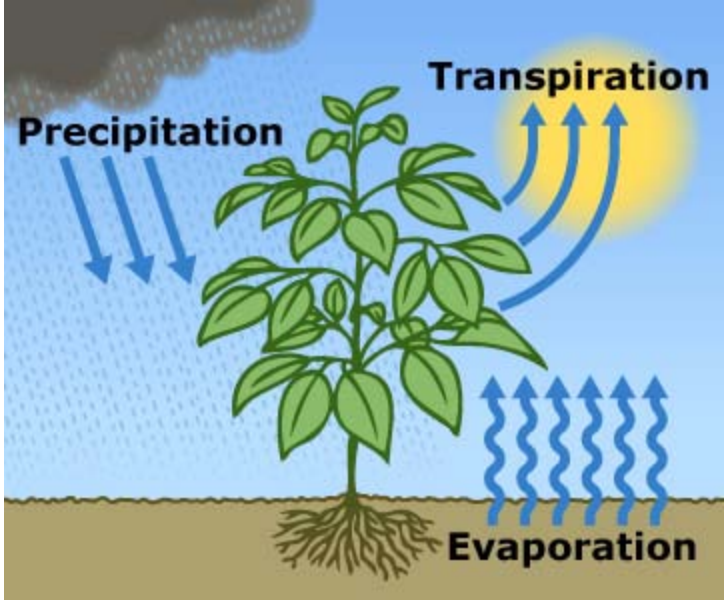


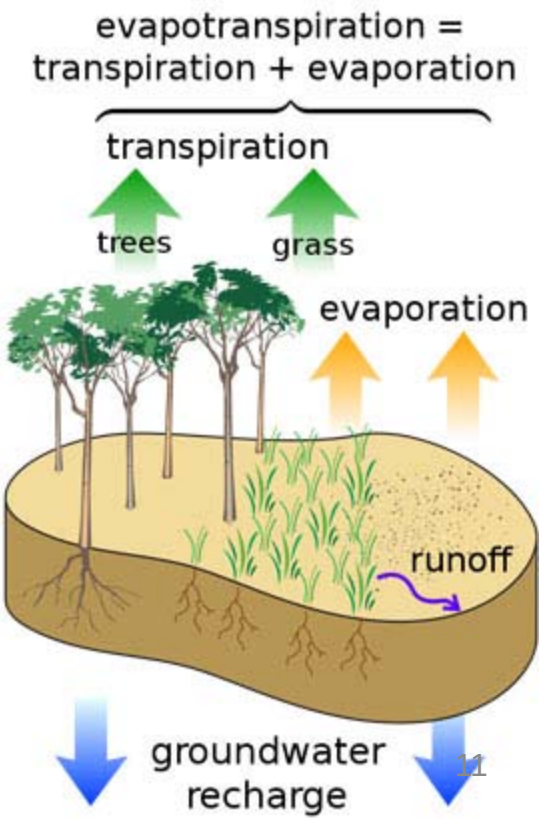


La tasa de evapotranspiracion (EVT) depende de factores climaticos, como temperatura, luz solar, viento y humedad.

EVT tambien depende de la especie de planta, porque las especies dependen de su abilidad de regular agua y adaptarse al stress inducido por la falta de agua.

El grado de cobertura vegetal, asi como la profundidad de las raices son elementos importantes tambien.

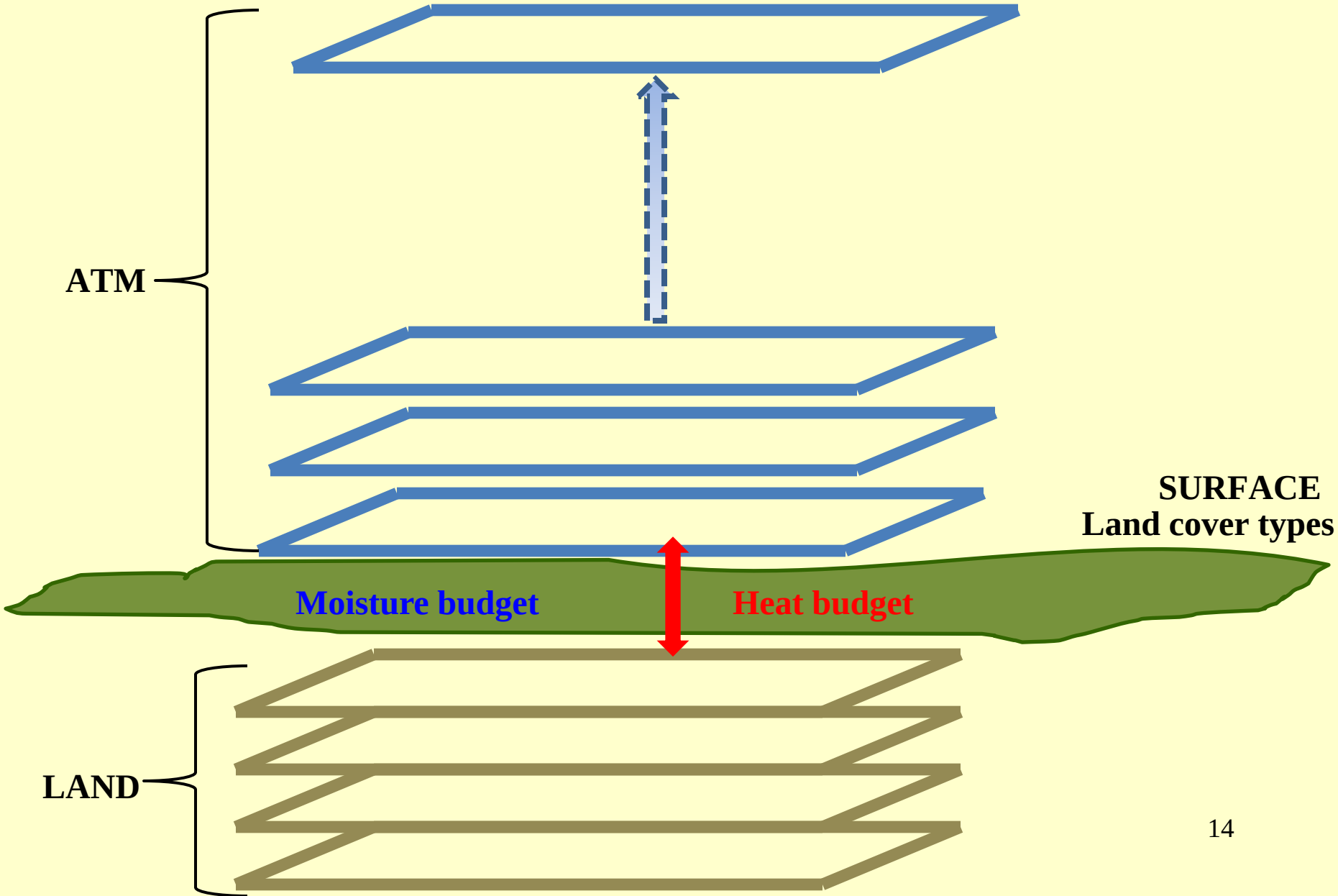




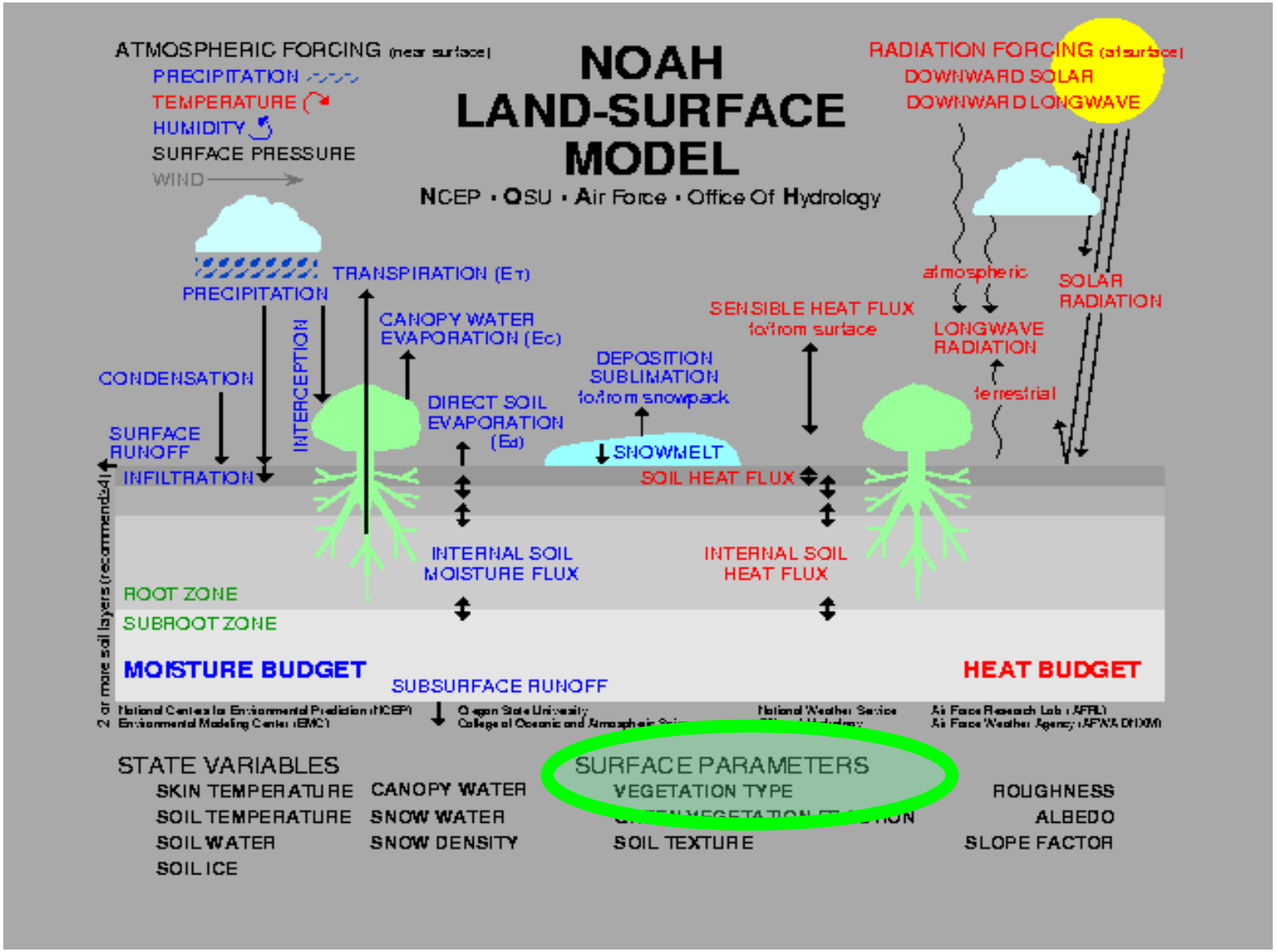
La rugosidad de suelo afecta a los vientos en capas bajas

How do models treat these processes?

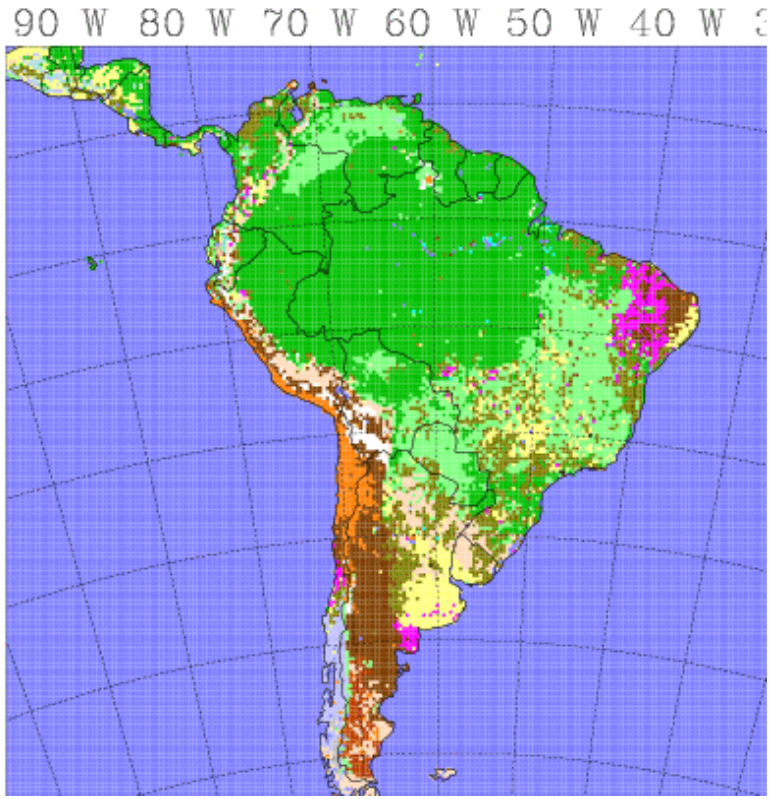
How do atmospheric models interact with the land?



The Noah land surface model

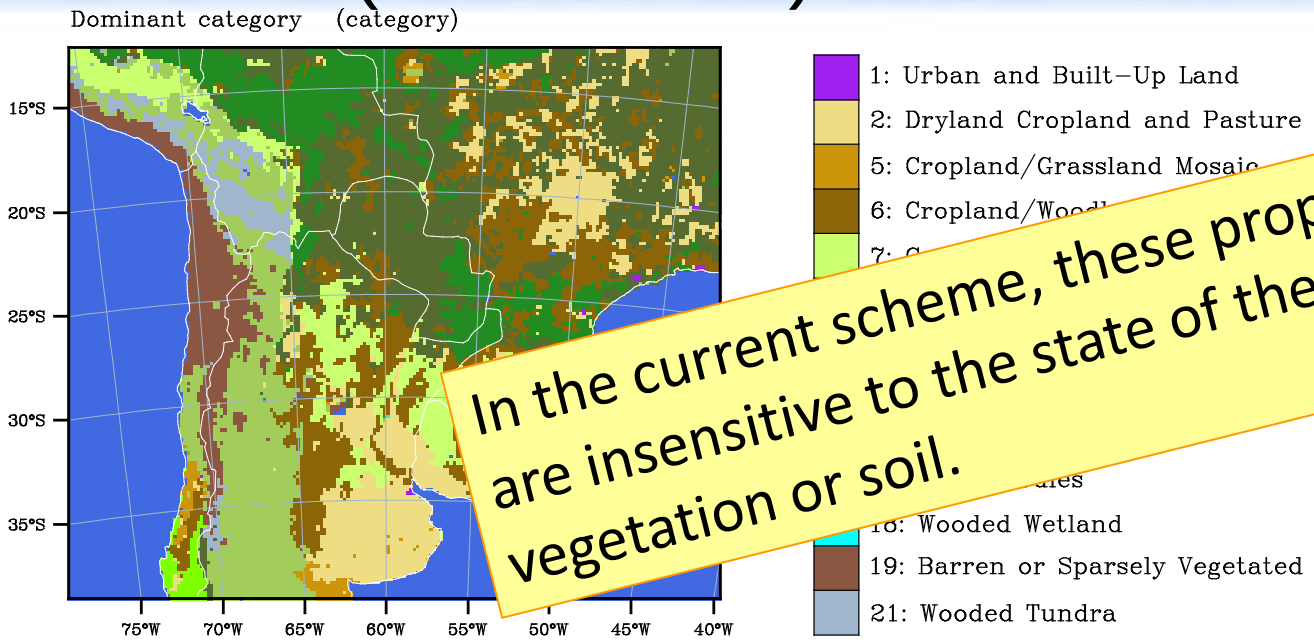


Model land cover



1 Urban and Built-Up Land
2 Dryland Cropland and Pasture
3 Irrigated Cropland and Pasture
4 Mixture of 2 and 3
5 Cropland/Grassland Mosaic
6 Cropland/Woodland Mosaic
7 Grassland
8 Shrubland
9 Mixture of 7 and 8
10 Savanna
11 Deciduous Broadleaf Forest
12 Deciduous Needleleaf Forest
13 Evergreen Broadleaf Forest
14 Evergreen Needleleaf Forest
15 Mixed Forest
16 Water Bodies
17 Herbaceous Wetland
18 Wooded Wetland
19 Barren or Sparsely Vegetated
20 Herbaceous Tundra
21 Wooded Tundra
22 Mixed Tundra
23 Bare Ground Tundra
24 Snow or Ice

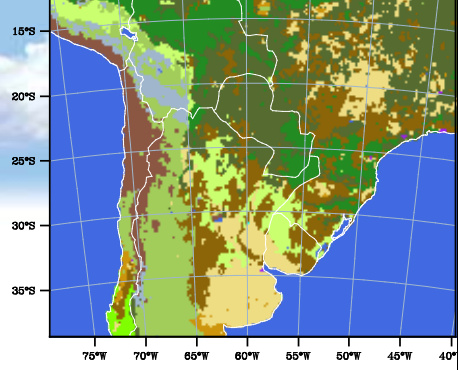
Land cover dominant category (fixed in time)



In the current scheme, these properties are insensitive to the state of the vegetation or soil.

Type of land cover	Surface albedo [%]	Surface roughness [cm]	Stomatal resistance [s m^{-1}]	Surface emissivity [%]
Savanna	20	15	70	92
Evergreen Broadleaf Forest	12	50	150	95
Grassland	23	10	40	92
Dry Cropland and Pasture	20	5	40	92

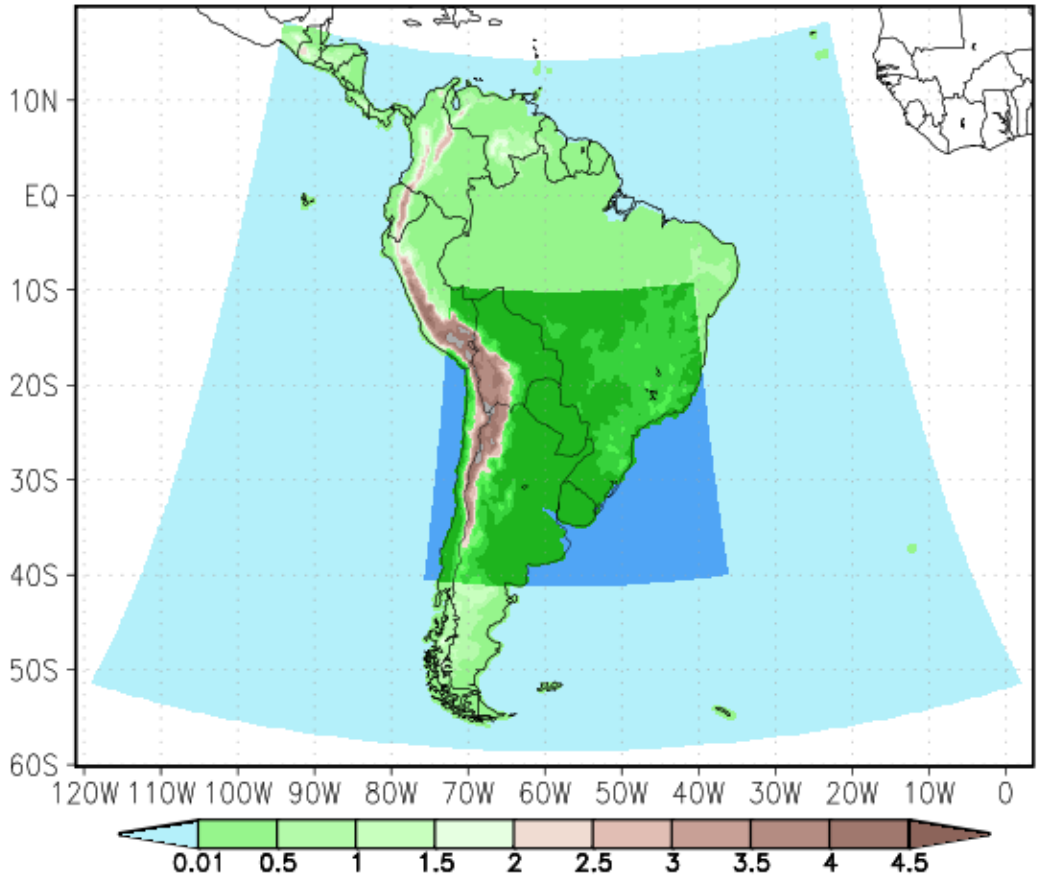
Land cover dominant category (fixed in time)



Croplands?

Is regional climate sensitive to land cover properties?

Model configuration



- Model: WRF ARW 2.2
- Grid spacing: 36km/12km
- Two way nesting
- BC: NCEP/NCAR Reanalysis

- Period: Sep-Nov 2002 (spring)

- Ensembles

Experimentos numericos

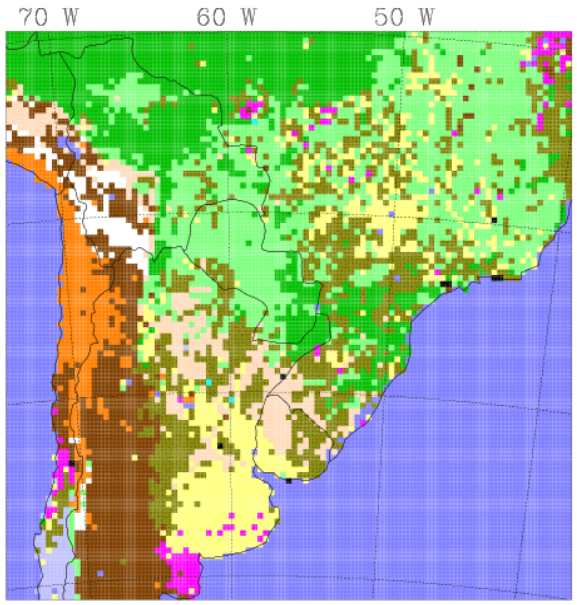
CNTL: Experimentos control (sin modificaciones en vegetacion)

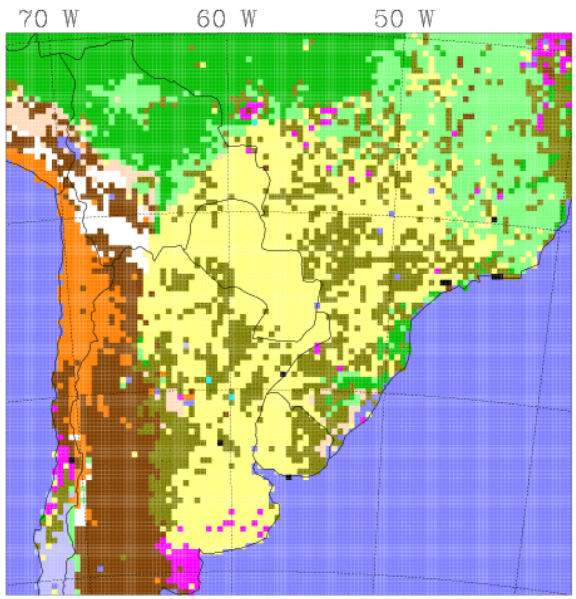
CROP: Se supone que todas las regiones de vegetacion natural dentro de la Cuenca del Plata son convertidas a cultivos

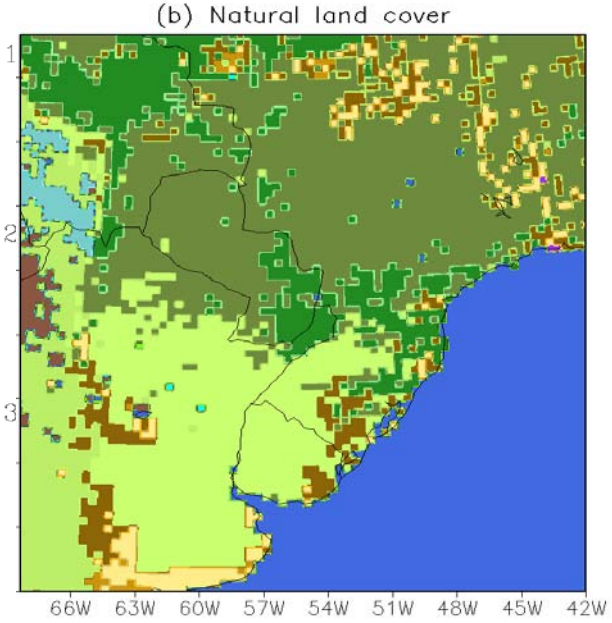
NATR: Se supone que no hay regiones con cultivos en la Cuenca del Plata (no hay influencia humana)

Land cover and its modifications

"Extreme" LULC Change







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24 Snow or Ice

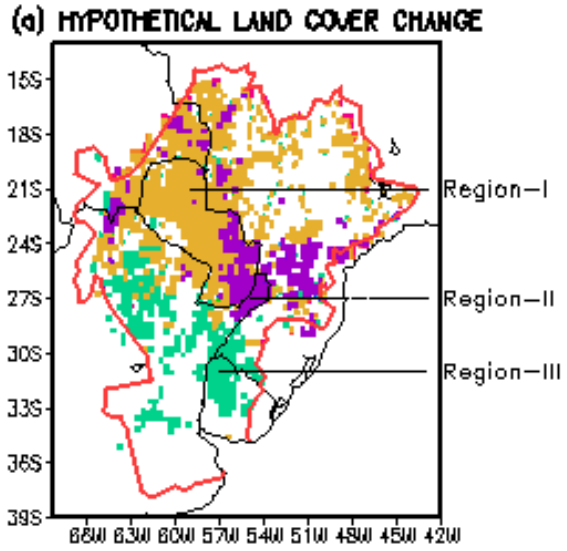
Case 1

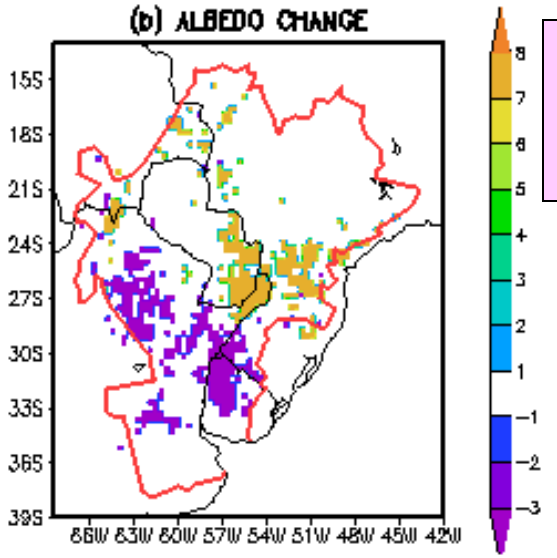
Savanna → Dry cropland
Evergreen → Dry cropland
Grassland → Dry cropland

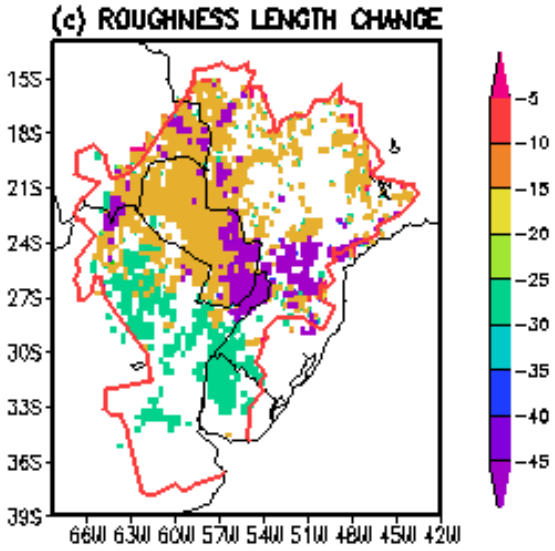
Case 2

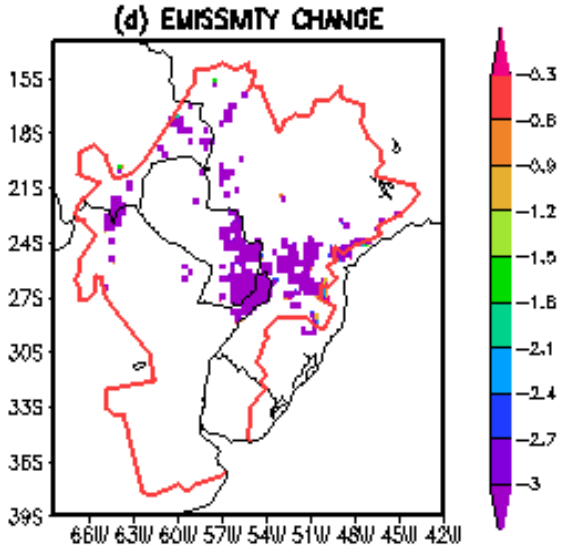
Dry cropland → grassland (south)
Dry cropland → savanna (north)

Land cover and its modification









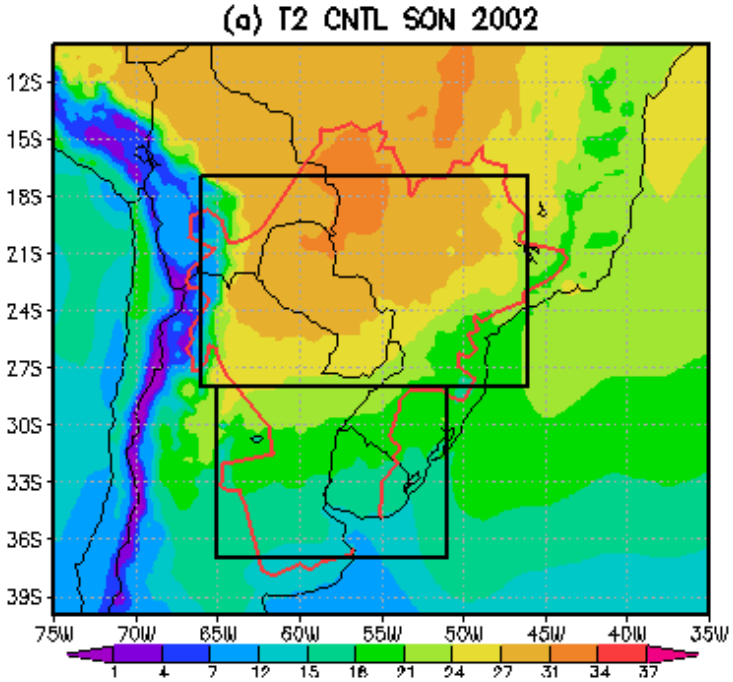
I Savanna → Dry cropland
II Evergreen → Dry cropland
III Grassland → Dry cropland

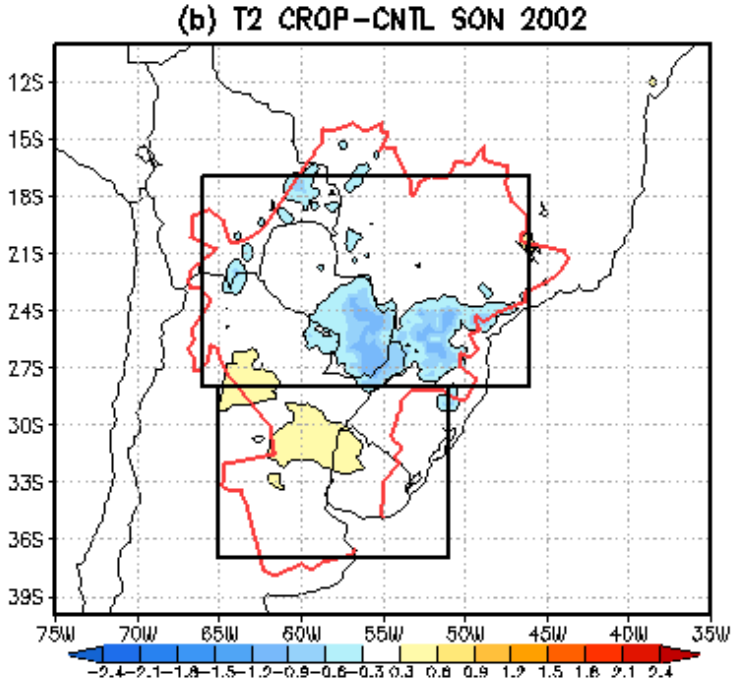
Area II: Albedo increase
Area III: Albedo decrease

Within the La Plata basin as a whole, the roughness length (Z0) decreased.

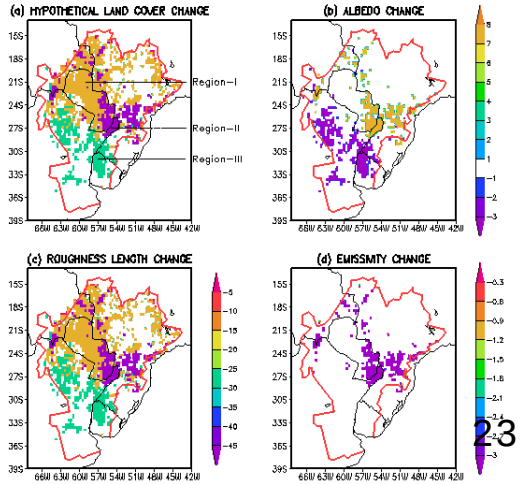
CROP – CNTL

T2m

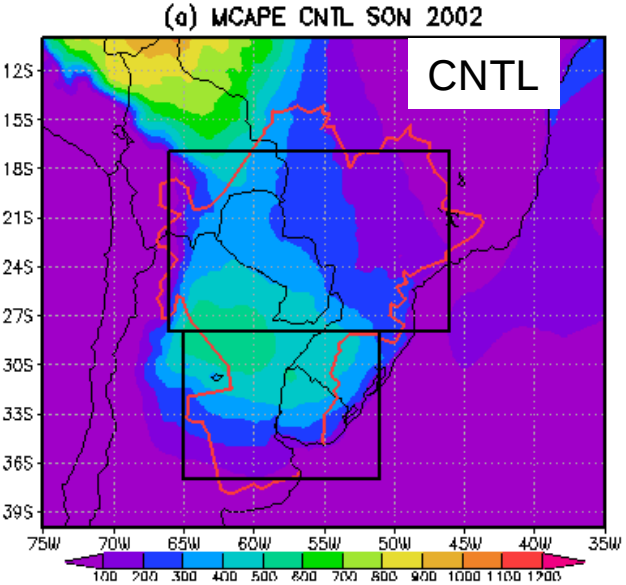


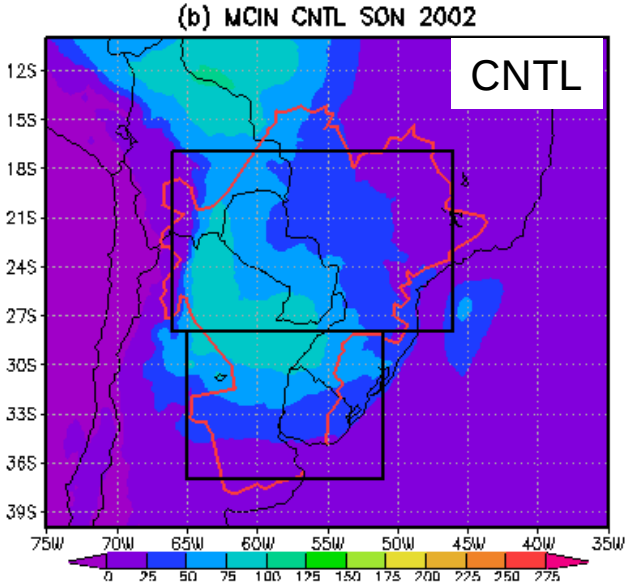


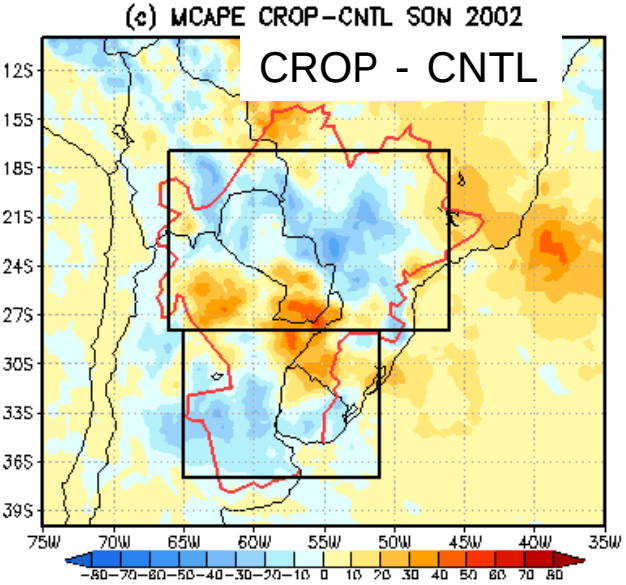
T2m

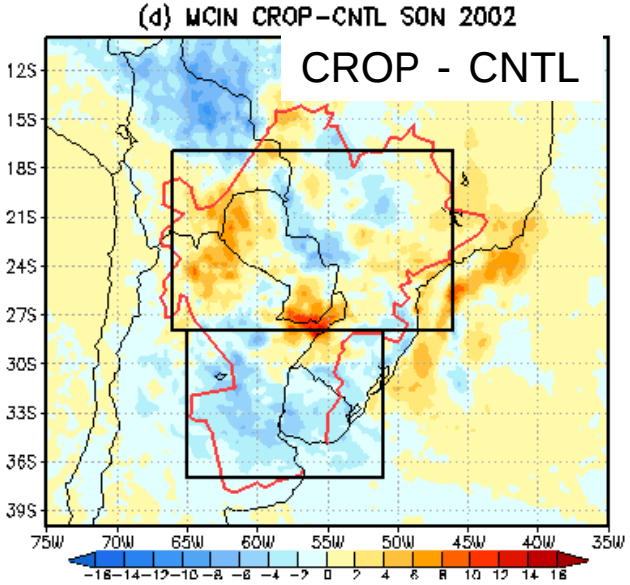


CROP – CNTL CAPE and CIN

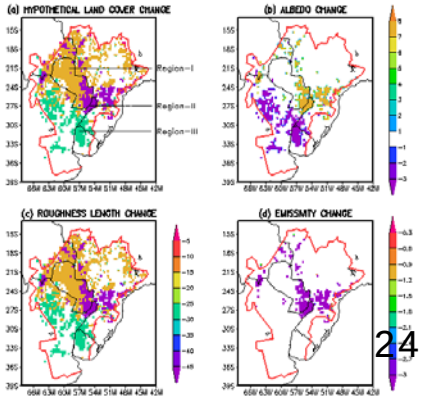






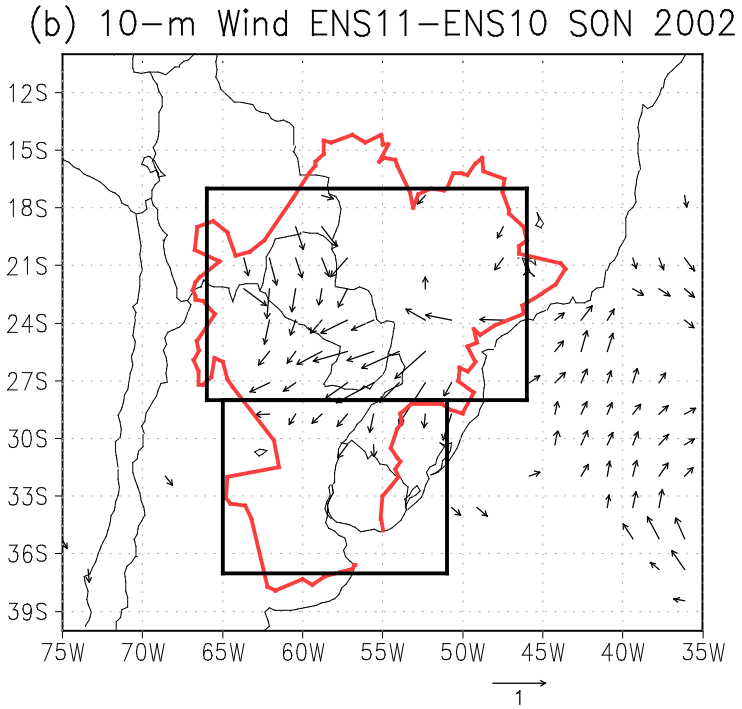


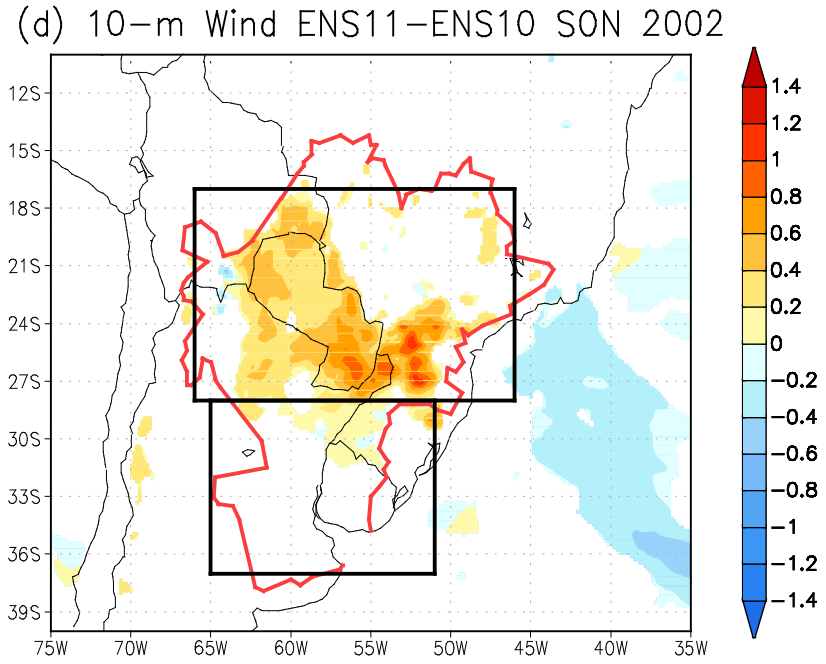
- There is relatively large MCAPE and MCIN in the western and southern parts of LPB.
- LULC change decreased CAPE and CIN in the central and northern part of LPB, while increased CAPE and CIN in the southern part of LPB and above the northern boundary of LPB.



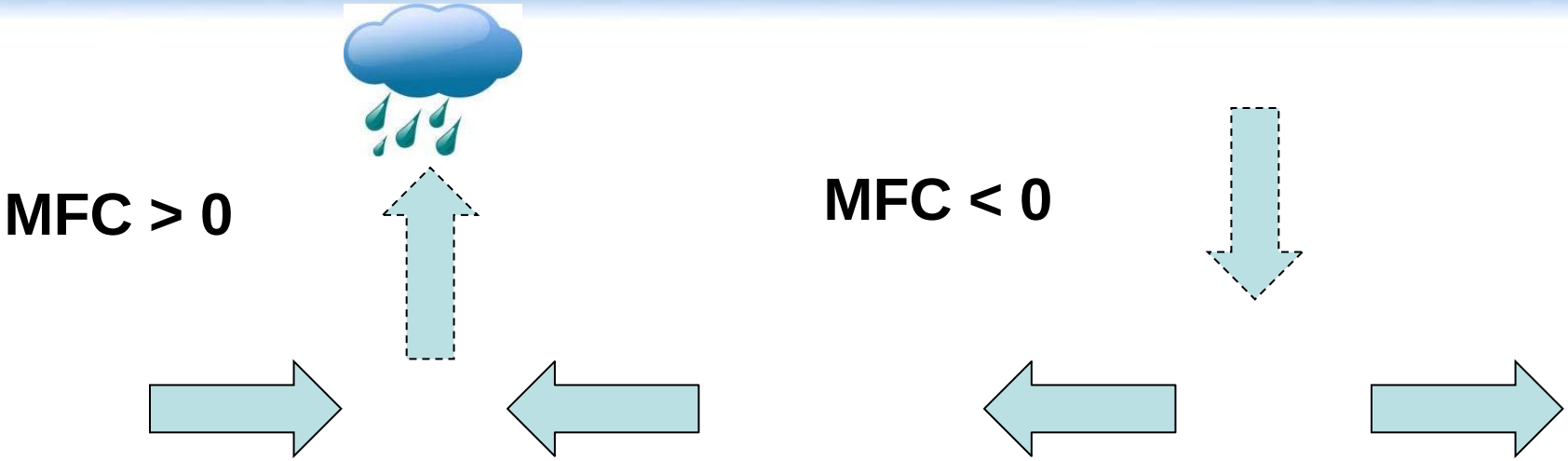
Como era de esperar, los vientos en niveles bajos son afectados por la reduccion de la rugosidad:

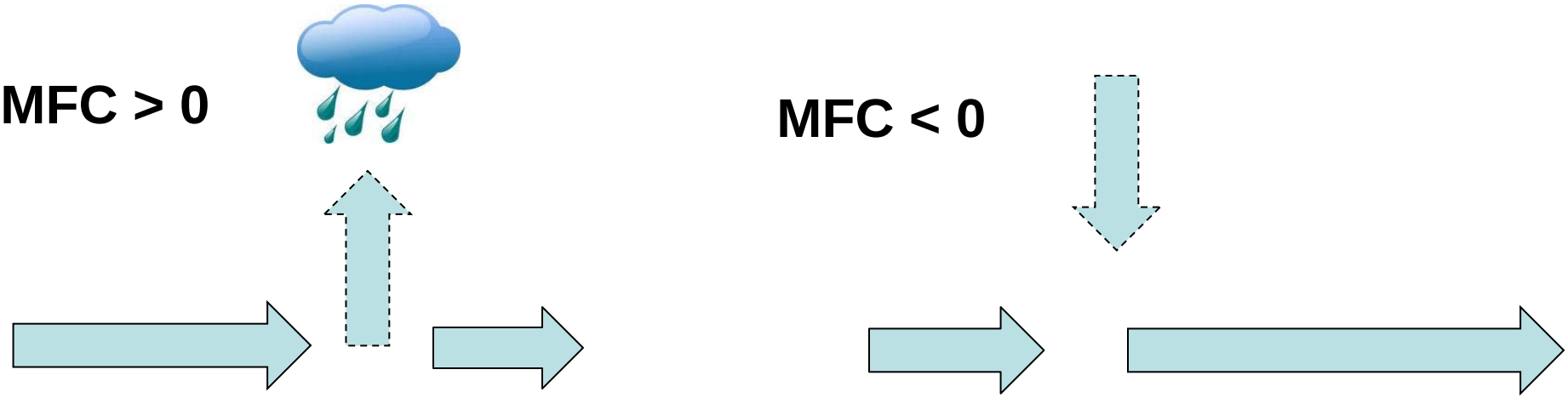
En la zona norte de la cuenca, los vientos se aceleran y sacan humedad de la region. En la zona sur, los vientos se "frenan" y se acumula humedad



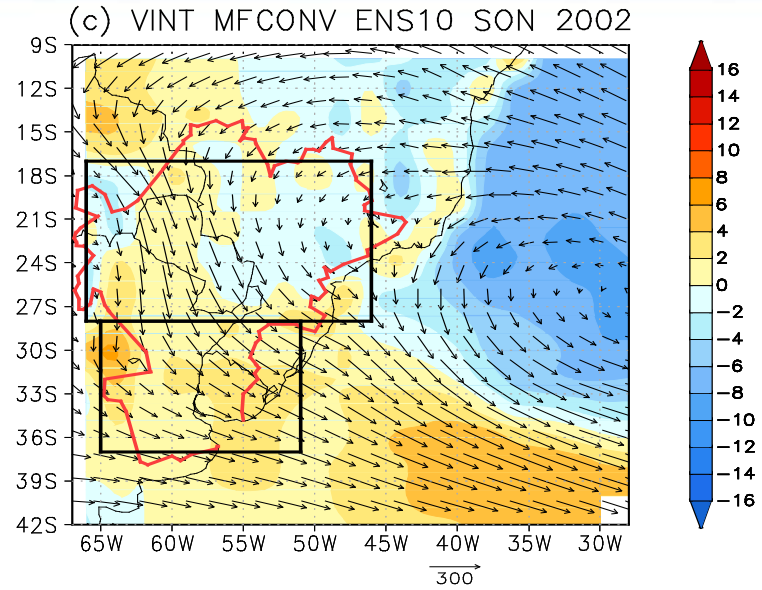


Flujos de humedad y convergencia de flujos de humedad (MFC)

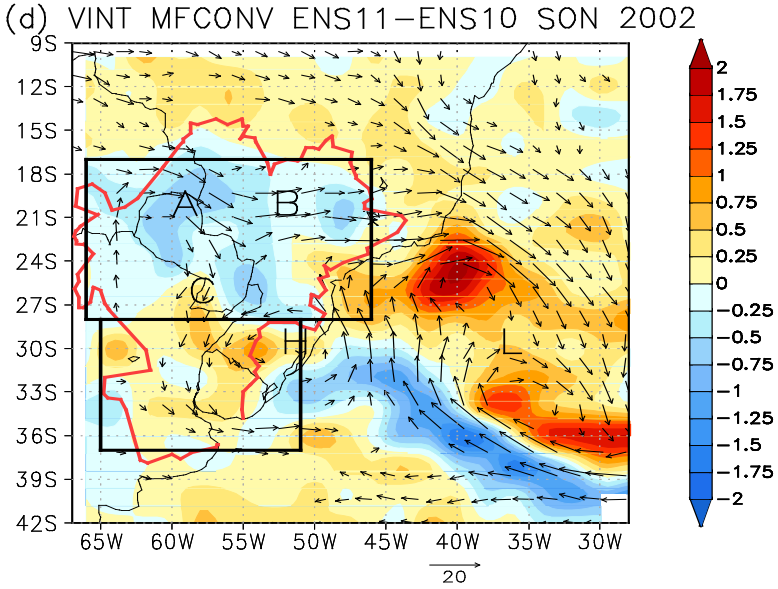




CROP – CNTL Vertically integrated MFC



CNTL

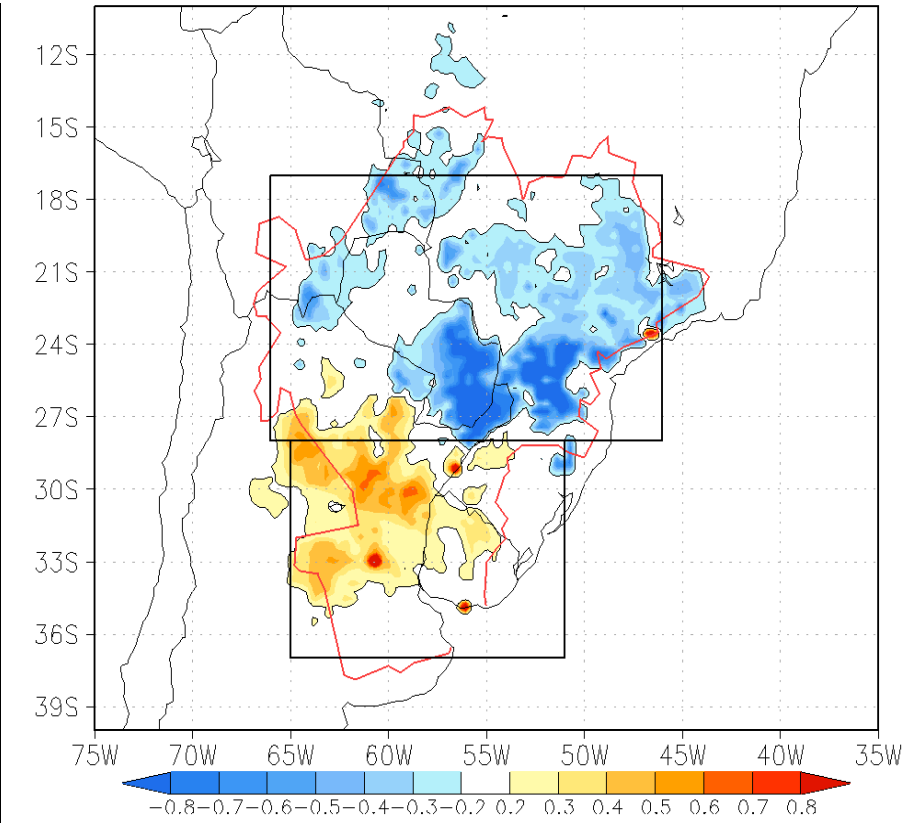


CROP - CNTL

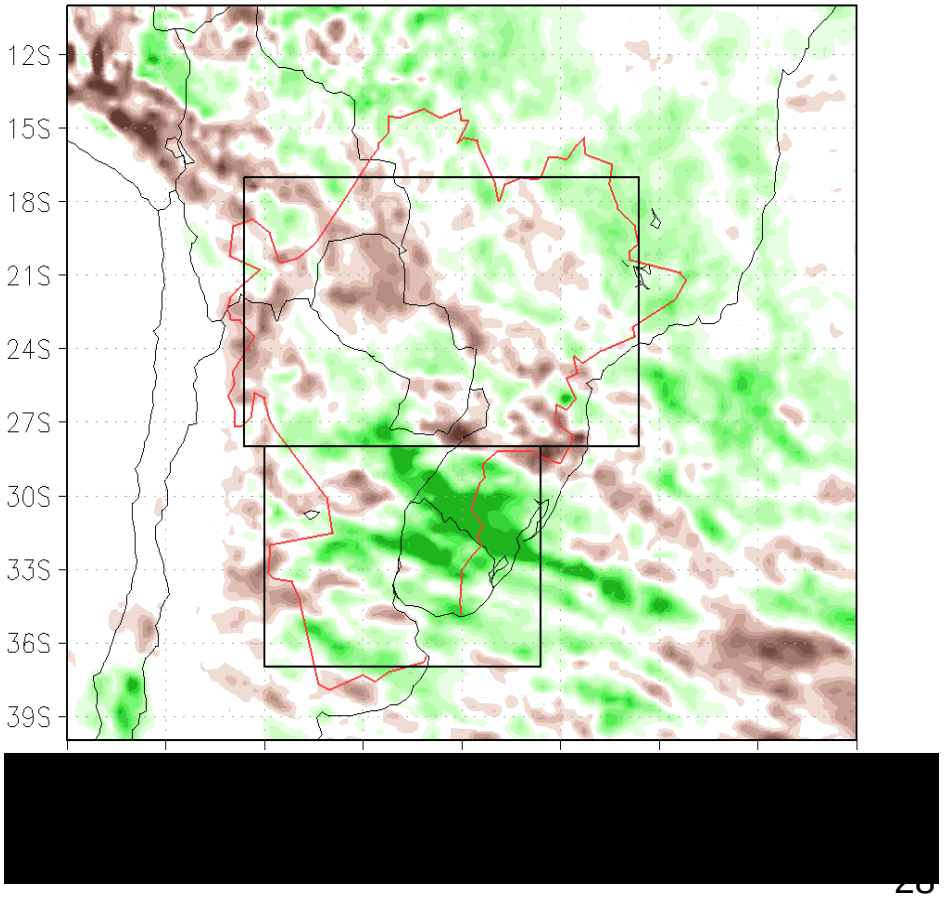
The changes in moisture flux and its convergence over LPB are related with the increased surface wind speed due to reduction in roughness length.

Land cover and its modification

Two-meter temperature differences between CROP and NATR experiments

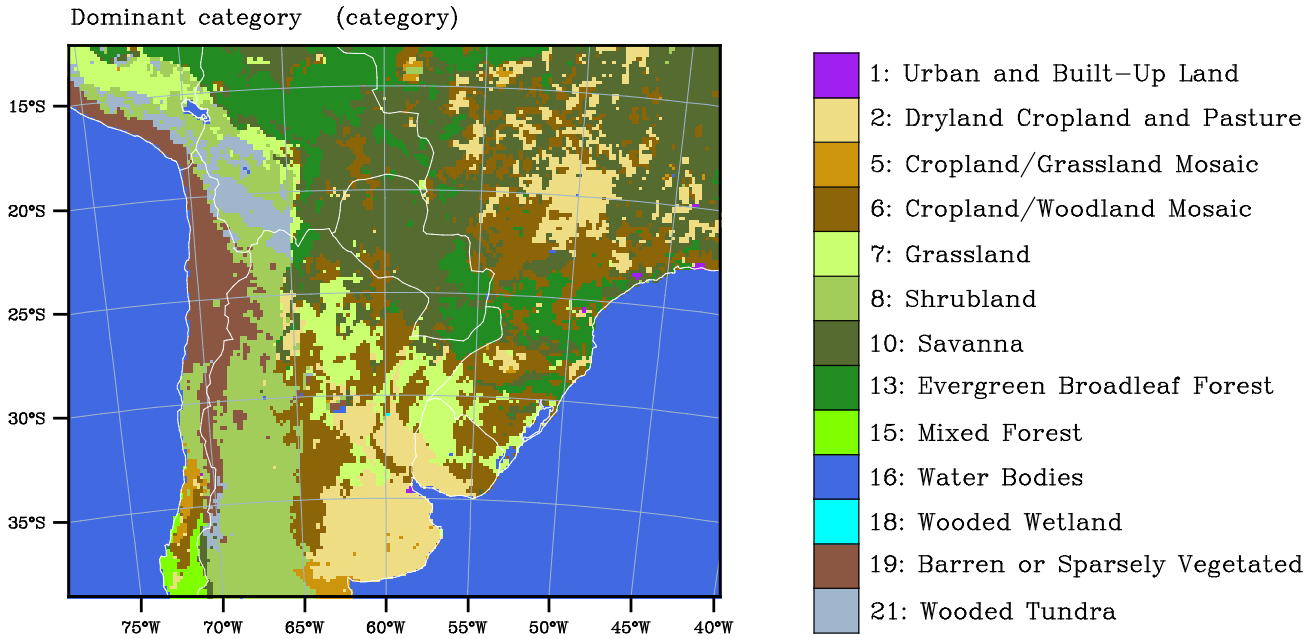


Precipitation differences between CROP and NATR experiments



Given the interannual variability in land cover and its corresponding biophysical properties (e.g., Zo, LAI, Alb)

…is there a <u>consistent</u> way for models to account -at least in part- for those changes in the land surface states?

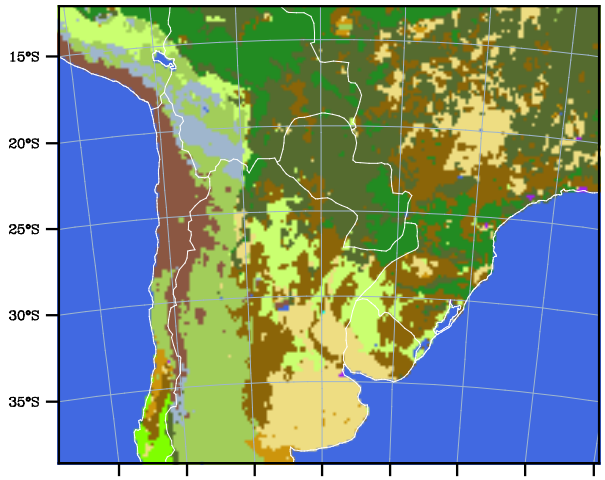


Ecosystem Functional Types

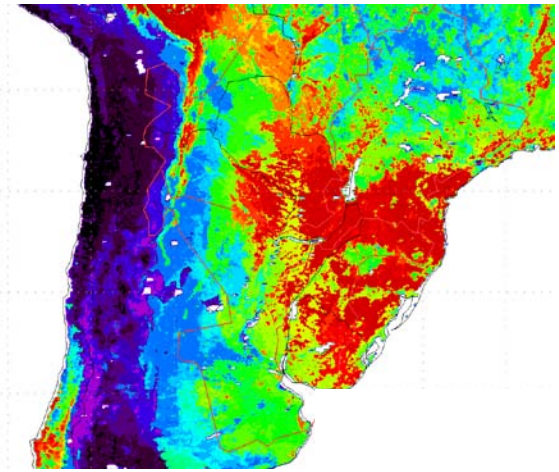
Our objective

To use *Ecosystem Functional Types as an alternative to Land Cover Types* to characterize the dynamics of land surface-atmosphere interactions and their interannual variability

Land cover – constant in time



EFTs –time varying



Plant Functional Types (PFTs) and Ecosystem Functional Types (EFTs)

Plant Functional Types (PFTs)

Groups of plants that have similar functioning (N fixation, photosynthetic pathways, etc.)

Ecosystem Functional Types (EFTs)

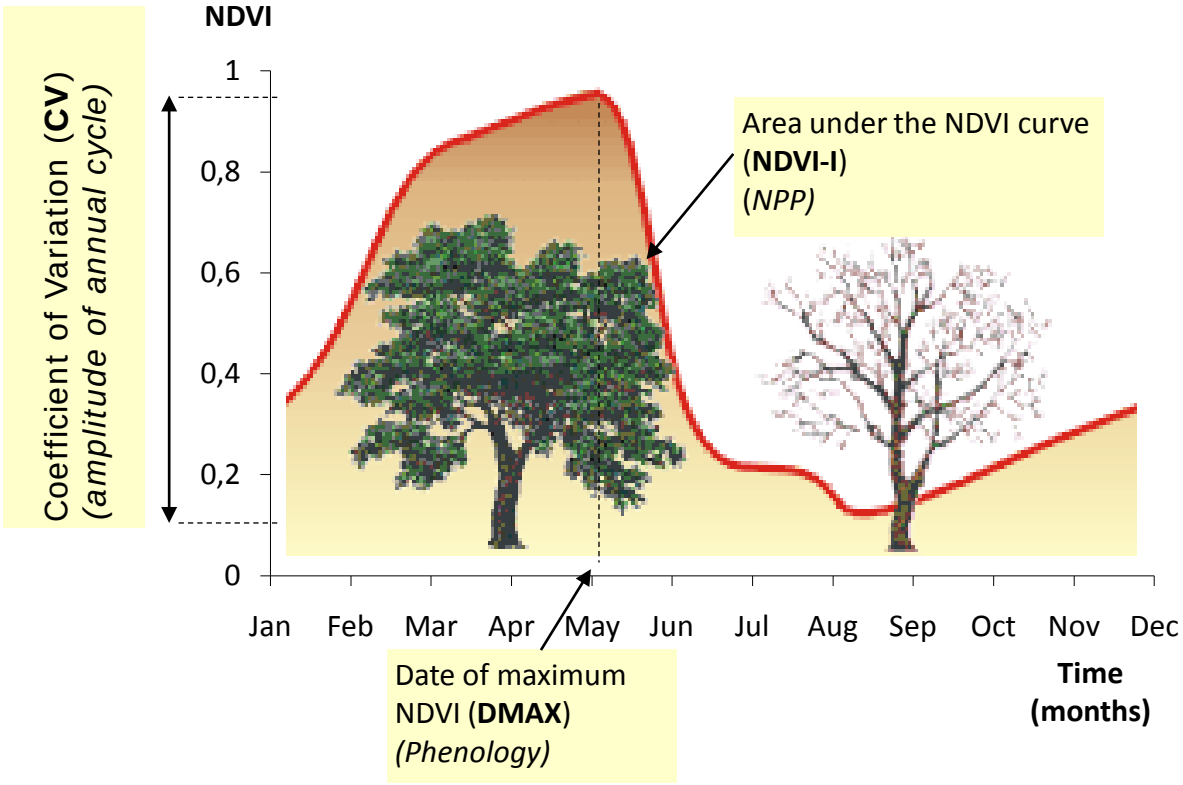
Groups of ecosystems that share functional characteristics in relation to the amount and timing of the exchanges of matter and energy between the biota and the physical environment, showing a coordinated and specific response to environmental factors.

Soriano & Paruelo (1992), Scholes et al. (1997), Valentini et al. (1999), Paruelo et al. (2001), Alcaraz-Segura et al. (2006)

Methodology to compute EFTs

Attributes of the *Normalized Difference Vegetation Index (NDVI)* used to identify Ecosystem Functional Types

NDVI-I, **CV**, and **DMAX** capture 95% of the variance in a Principal Component Analysis of NDVI.



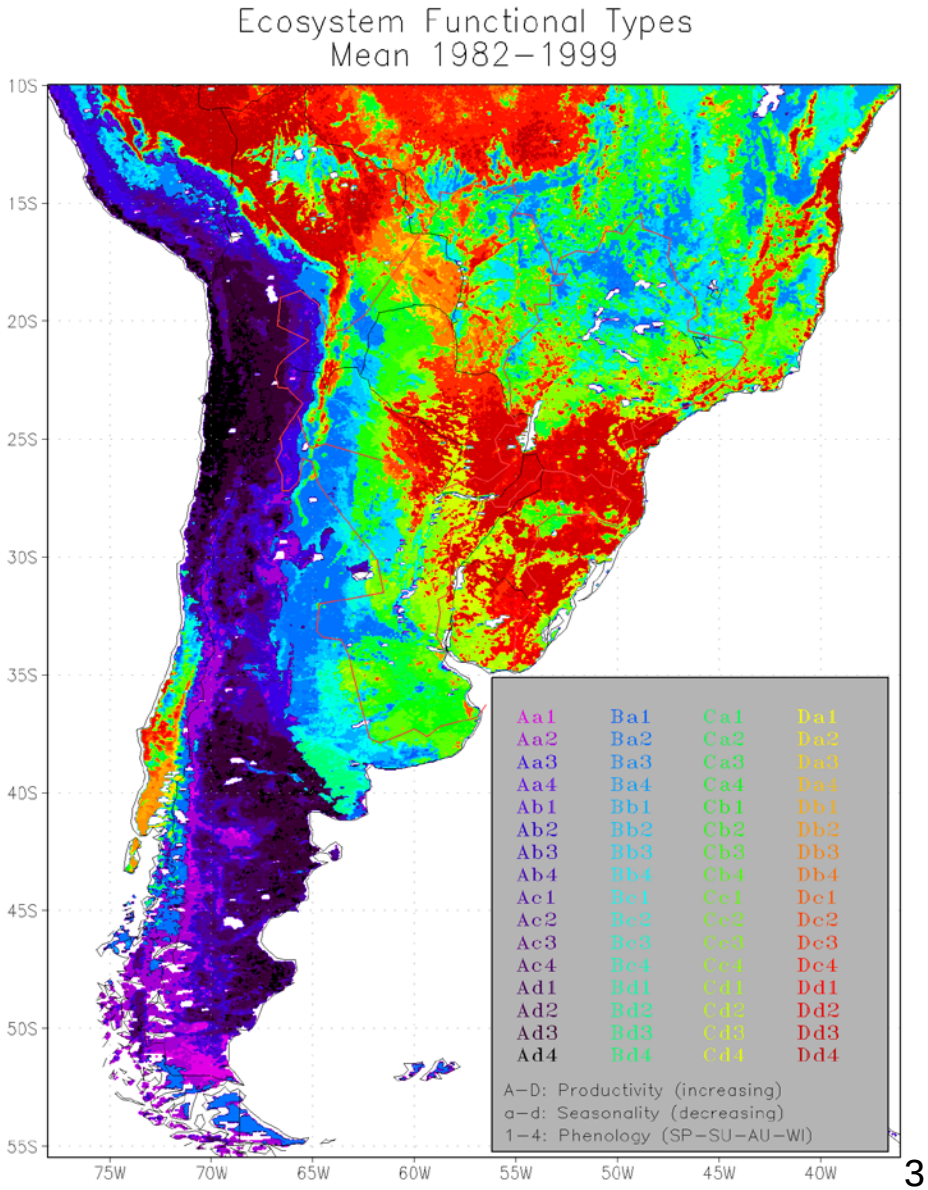
- **MODIS:** 1 km 2000-2010
- **NESDIS**: 16 km 1982-2010
- **LTDR-AVHRR**: 5 km 1982-1999

Ecosystem Functional Types

1982-1999

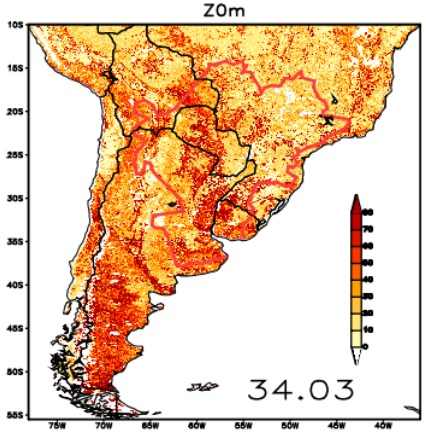
The three attributes (*NDVI-I, amplitude of the annual cycle and phenology*) can be combined to define the EFTs

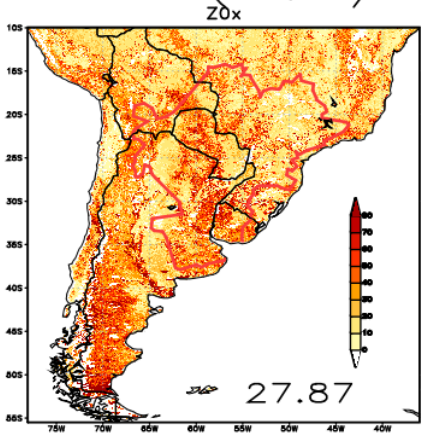
(And they can be computed for individual years)

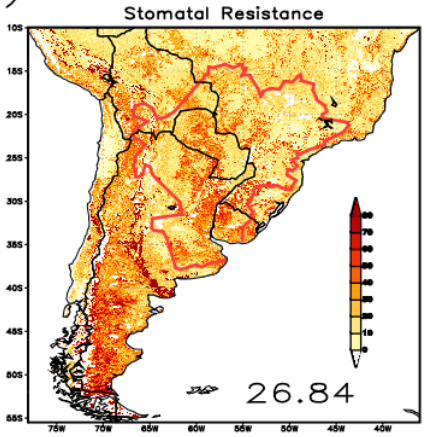


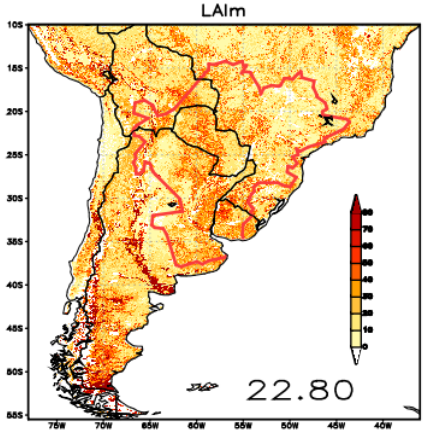
Interannual variability of the physical properties

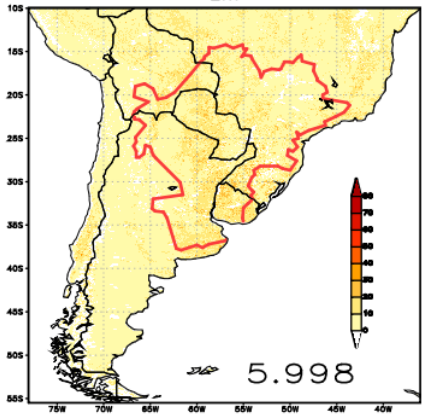
(IQR/M)*100

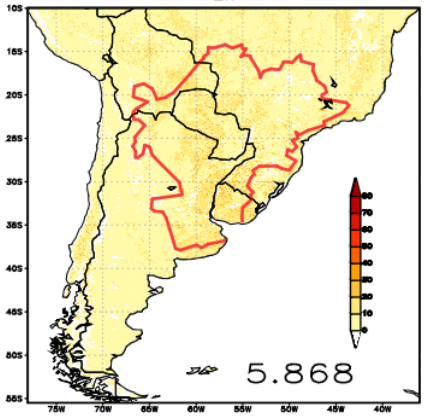


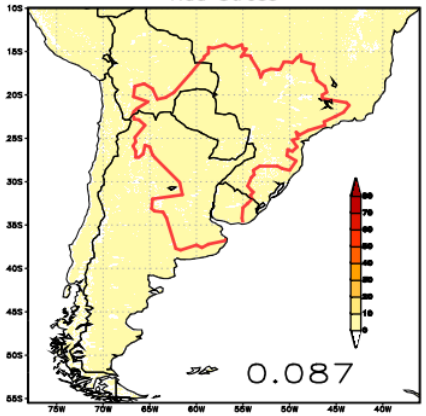






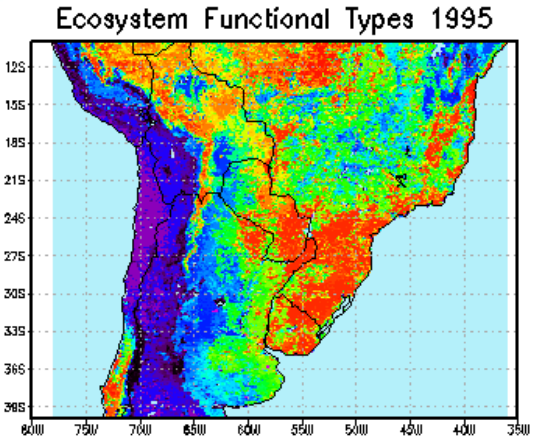


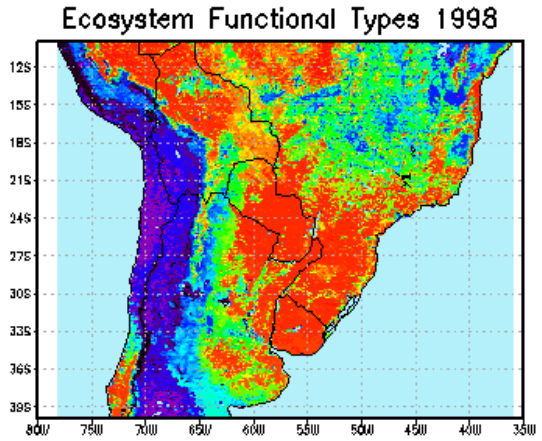


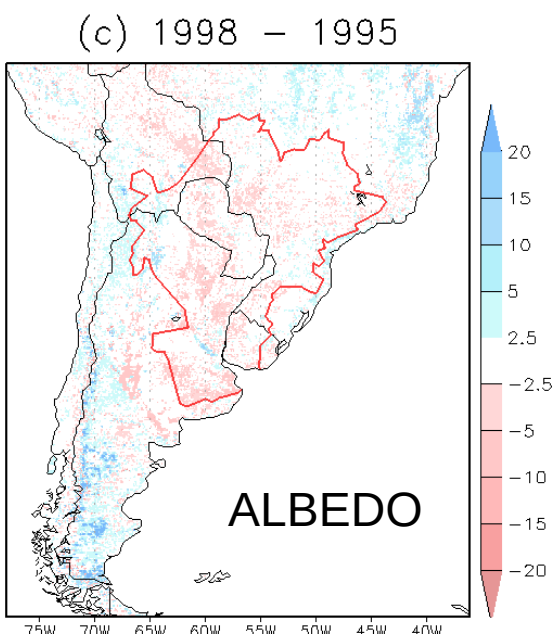


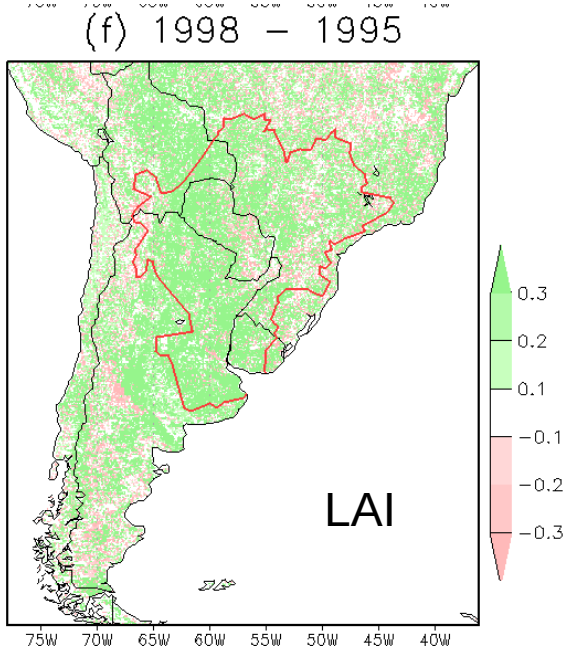
IQR: Interquartile range
M: Median

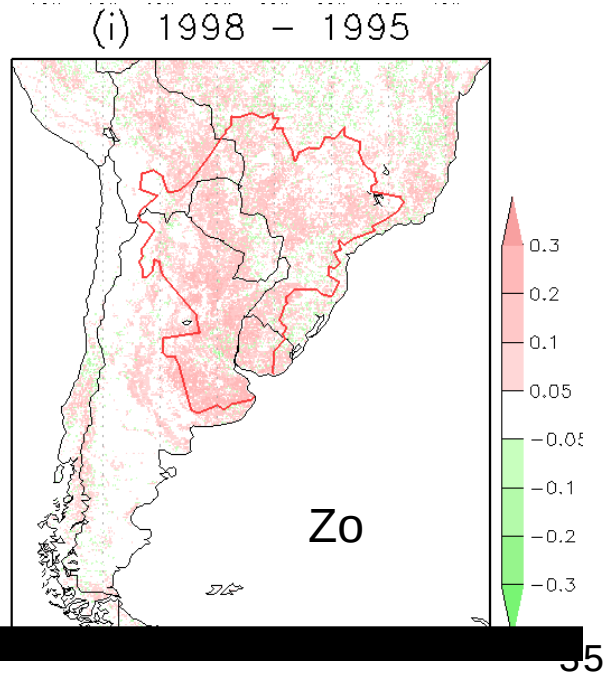
EFTs for two different years and The differences in physical properties



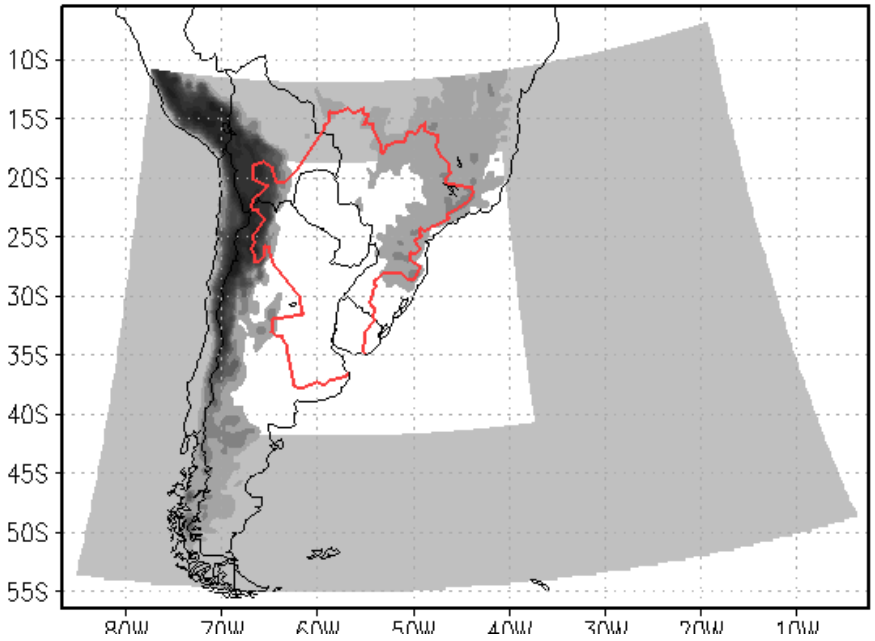








EFTs in a regional model

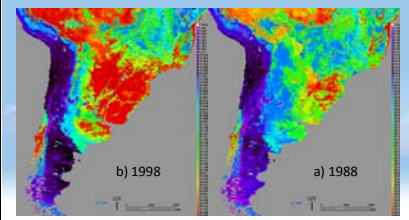


- Resolution: 30km/10km
- Two way nesting
- BC: NCEP/NCAR Reanalysis
- **Lower BCs: EFTs**

-Periods:

Sep-Nov 1988 (austral spring)

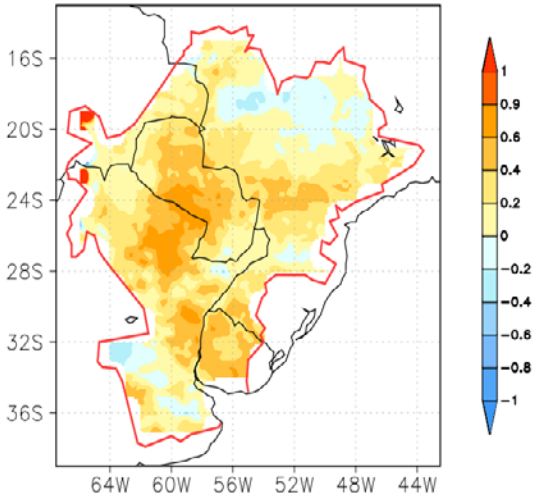
Sep-Nov 1998 (austral spring)

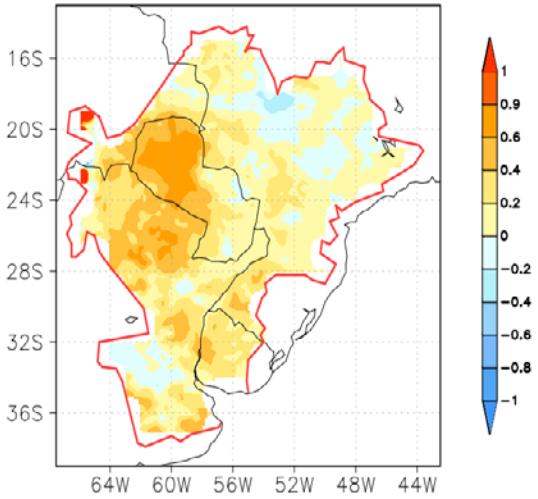


Sensitivity of temperature and precipitation to changes in land cover (EFTs)

T2m difference resulting from LBCs: High EFT – Low EFT

SON 1988

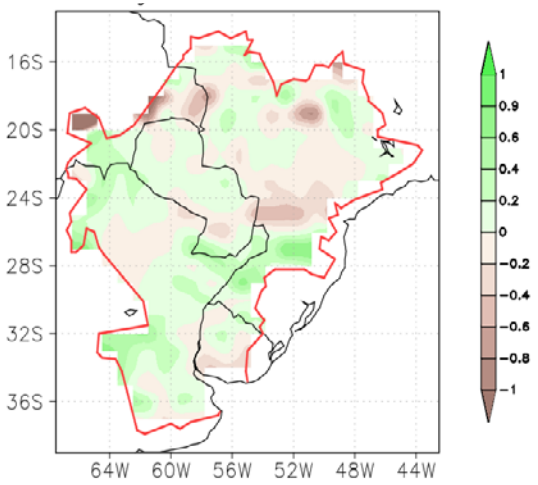


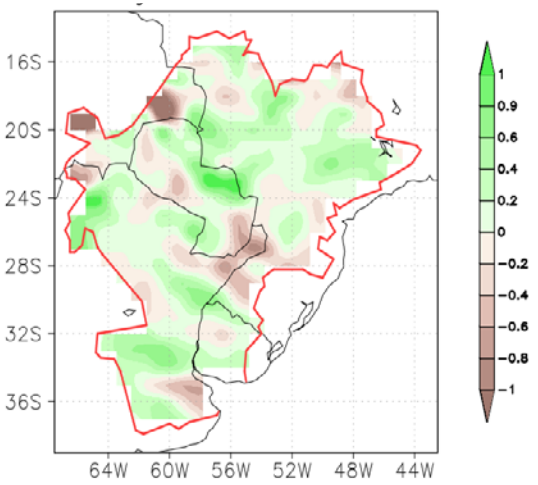


SON 1998

P difference resulting from LBCs: High EFT – Low EFT

SON 1988





SON 1998

SUMMARY SO FAR

- It was shown that Land Cover in southern South America is subject to large interannual variability and longer term changes

- Ecosystem Functional Types (EFTs) were identified on a yearly basis, as well as their corresponding physical properties.

- Model simulations show the sensitivity of P and T to LCCs as represented by the EFTs

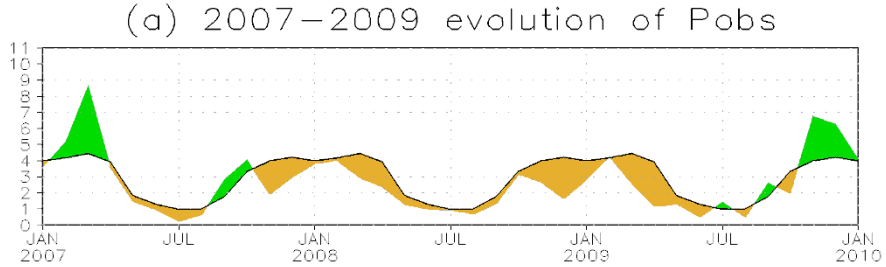
We have shown that the model has sensitivity to the lower boundary conditions…

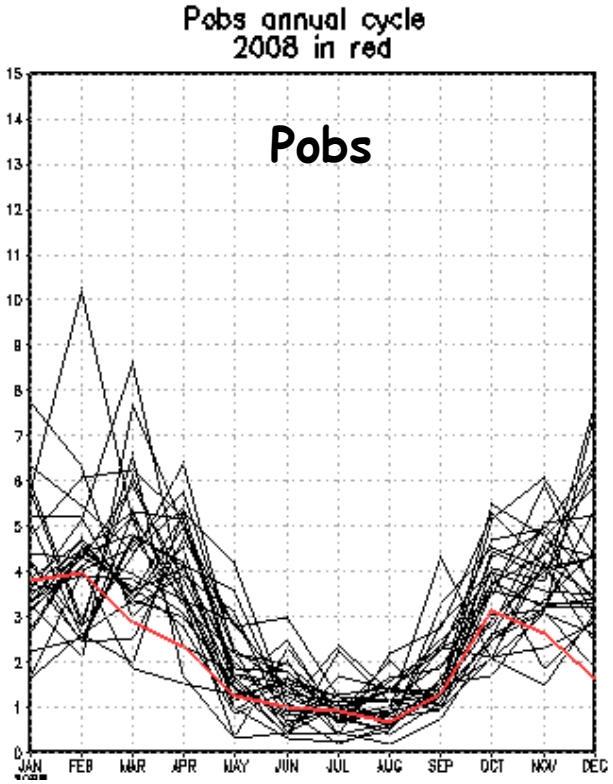
… but is the use of EFTs an improvement over the traditional Land Cover types?

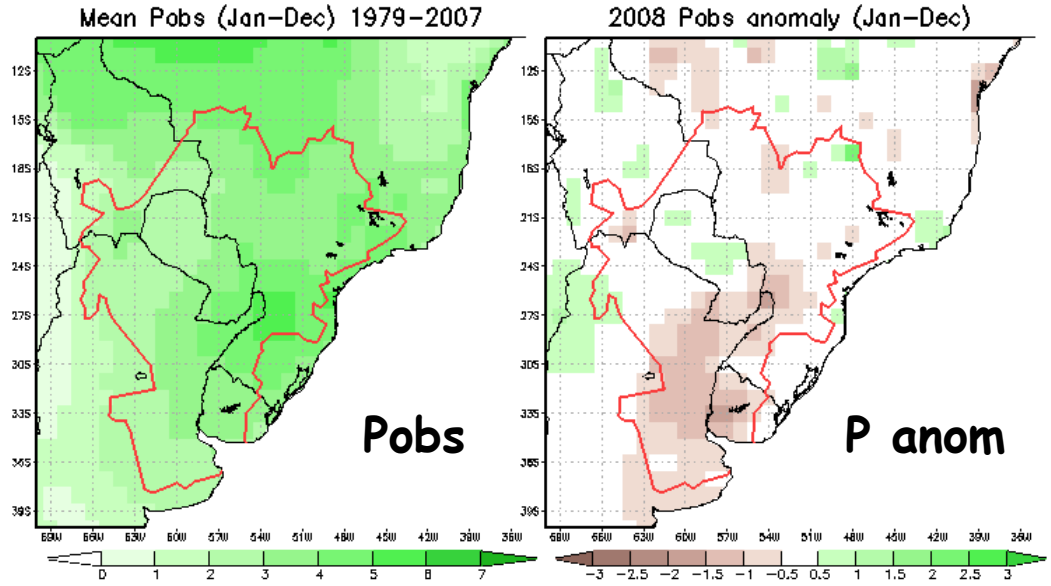
A number of simulations were performed:

Period: Sep 2007 – Jul 2009
LBCs: USGS; IGBP; EFTs

The 2008 drought in southern La Plata Basin







The 2008 drought in southern La Plata Basin

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La Niña seguirá con sus travesuras

Un informe del climatólogo Eduardo Sierra, distribuido por la Bolsa de Cereales de Buenos Aires, plantea cuáles pueden ser los ejes centrales de lo que viene en la materia en los próximos meses y, más allá, para la campaña siguiente. En esta nota se resumen sus párrafos centrales:

Afortunadamente, los indicadores climáticos más recientes señalan que la sequía prevista para enero podría ser más corta que lo estimado, permitiendo que las precipitaciones se reactiven en forma temprana, trayendo un oportuno alivio a los cultivos de verano que se encuentran al borde de su colapso.

Gracias a esta pausa temporaria en el accionar de "La Niña", febrero y marzo aportarán adecuadas cantidades de lluvias, que permitirán que los cultivos de verano completen su ciclo en condiciones adecuadas.

lanacion.com

Sequía / La peor de los últimos años

"La Niña", un fenómeno que llegó para quedarse

El otoño y el invierno, nuevamente amenazados; después de una probable pausa en los últimos días de enero, febrero y marzo, a partir de abril reaparecería la falta de lluvias en vastas zonas del país

lanacion.com

No llovía tan poco desde 1961

Lunes 12 de enero de 2009 | **Publicado en edición impresa** Noticias de Economía: anterior | siguiente

Un informe del Departamento de Climatología del Servicio Meteorológico Nacional (SMN) no deja lugar a dudas: desde 1961 no llovía tan poco en el país.

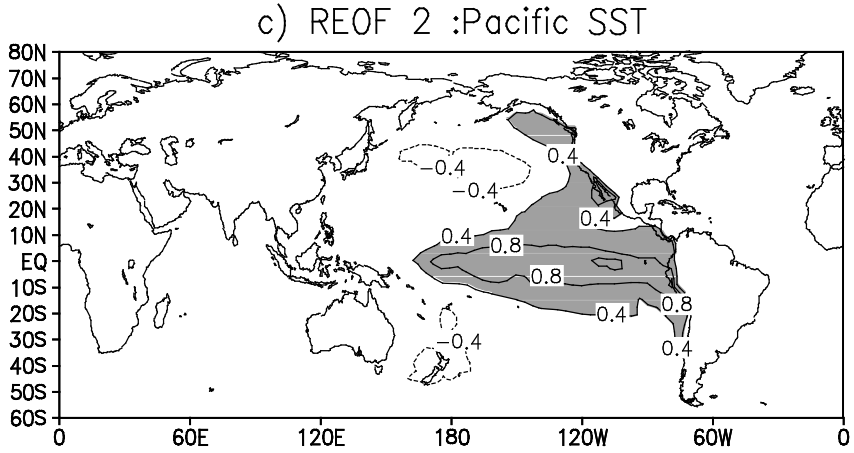
Los especialistas en climatología adjudican la persistente sequía de 2008 al fenómeno que describen como La Niña. Aluden así al enfriamiento inusual que sufre la superficie del océano Pacífico y suele

Droughts in southern South America

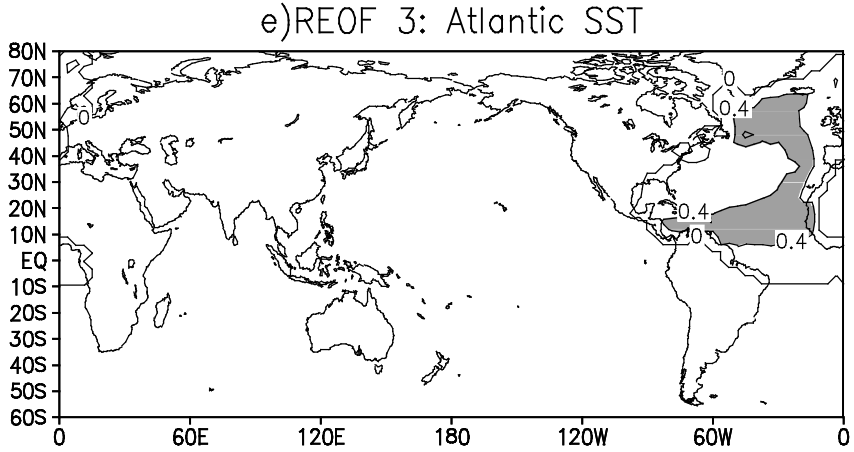
La Niña + Tropical Atlantic effects

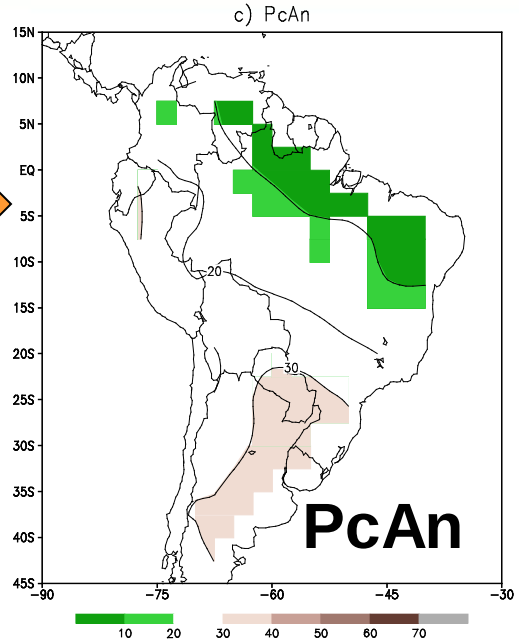
(Mo and Berbery 2011)

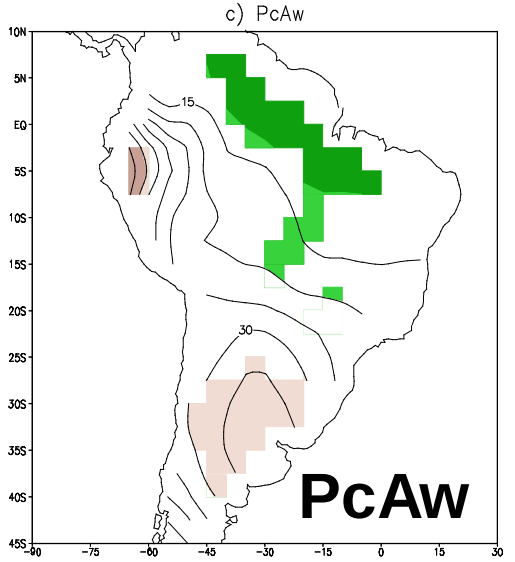
Pacific SST



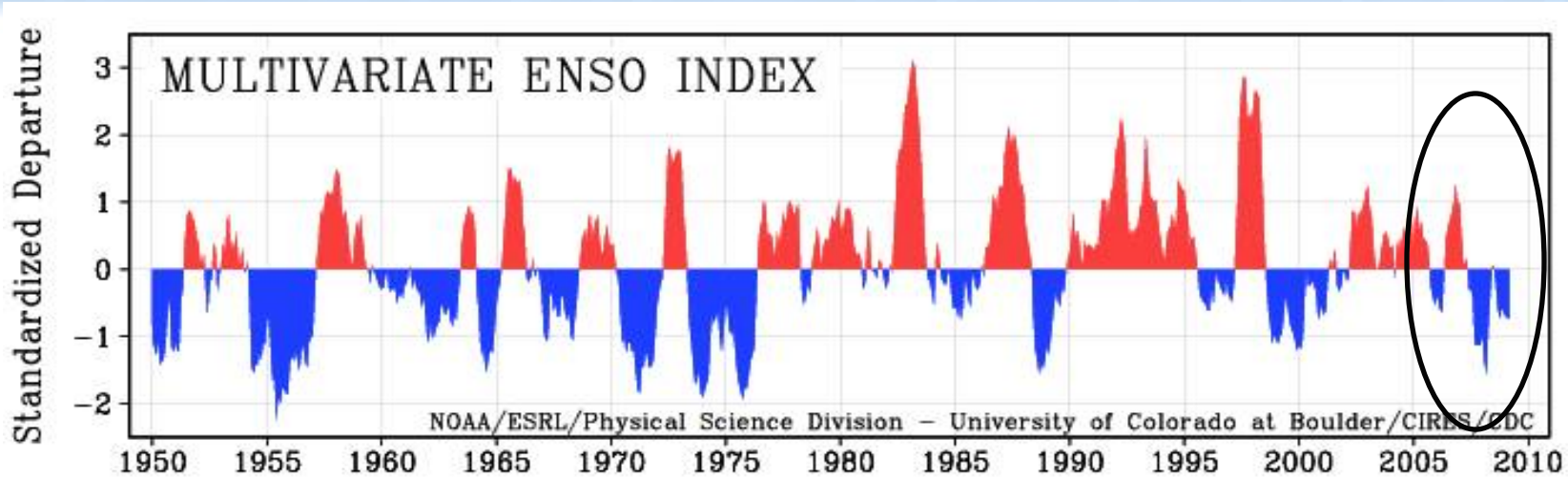
Atlantic SST



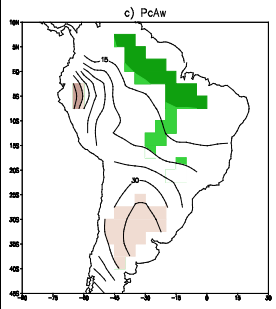


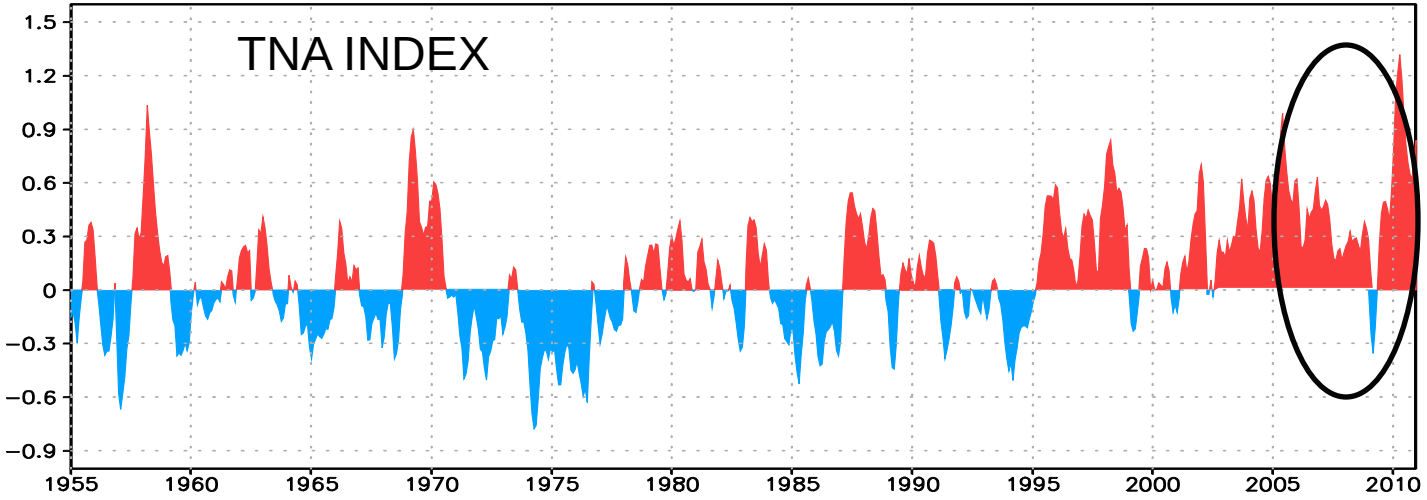


The 2008 drought in southern La Plata Basin: remote forcings

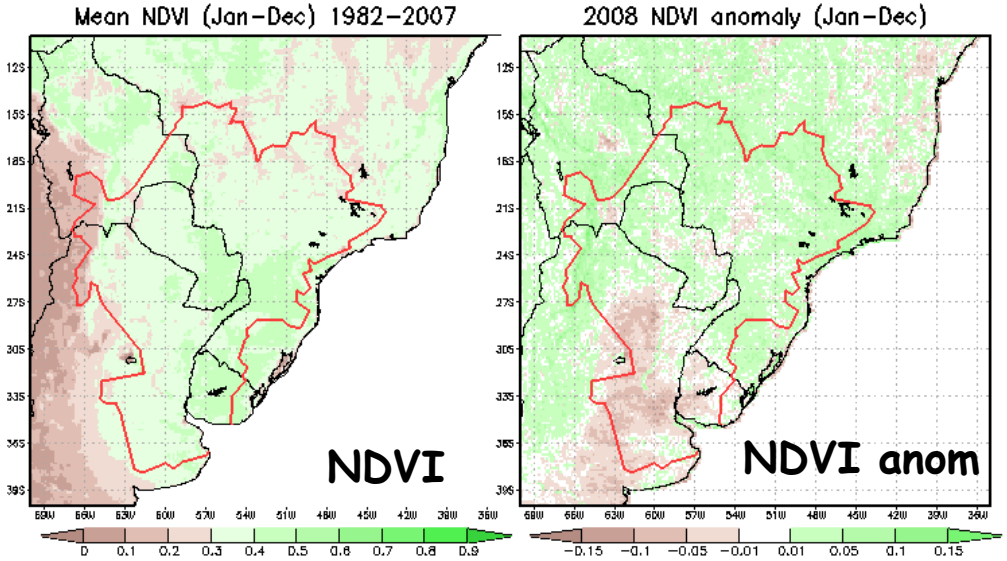


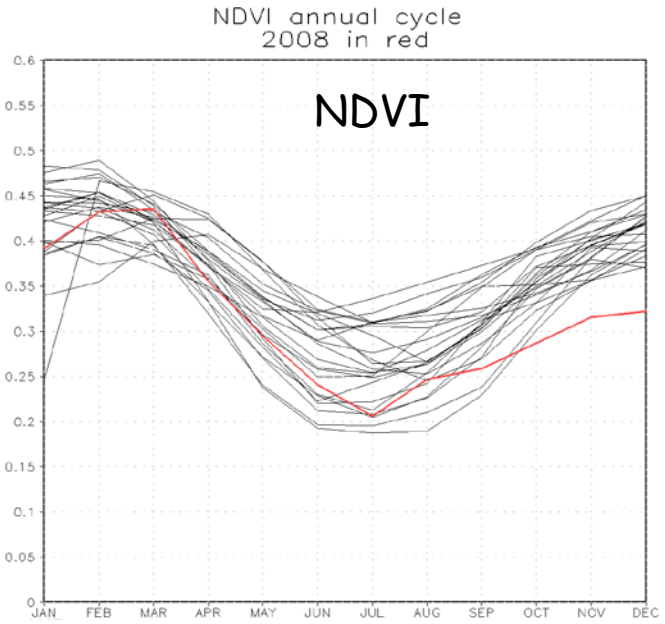
PcAw

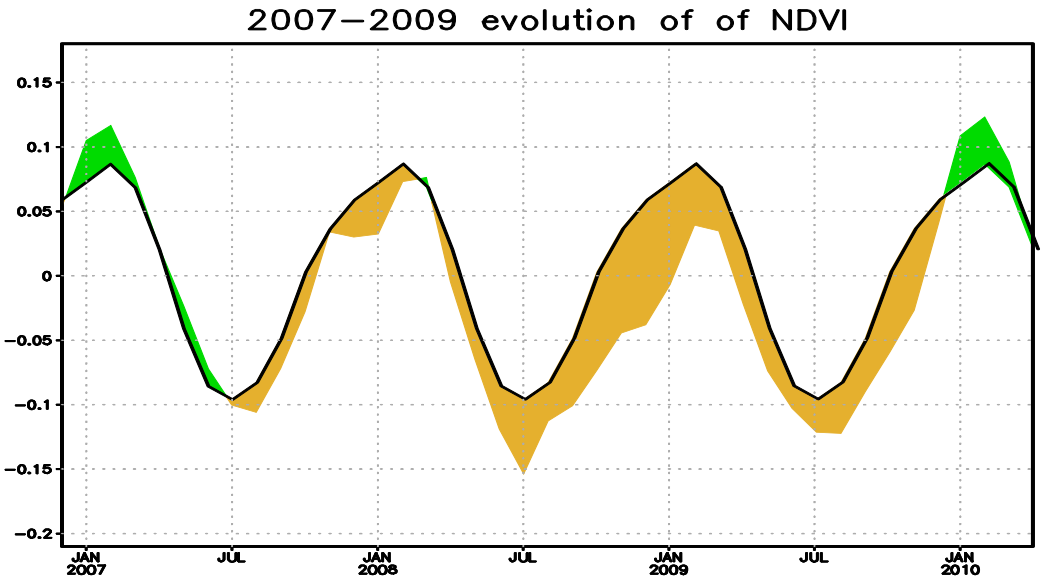




The 2008 drought in southern La Plata Basin: effects on vegetation

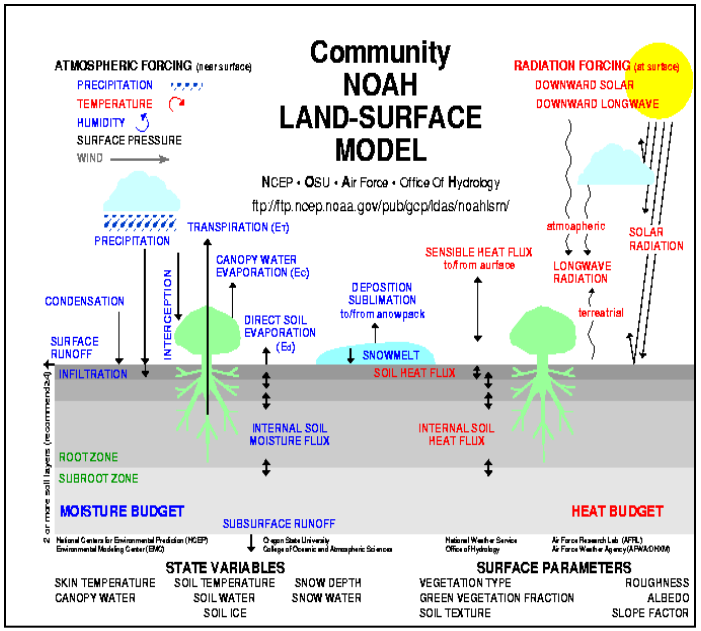




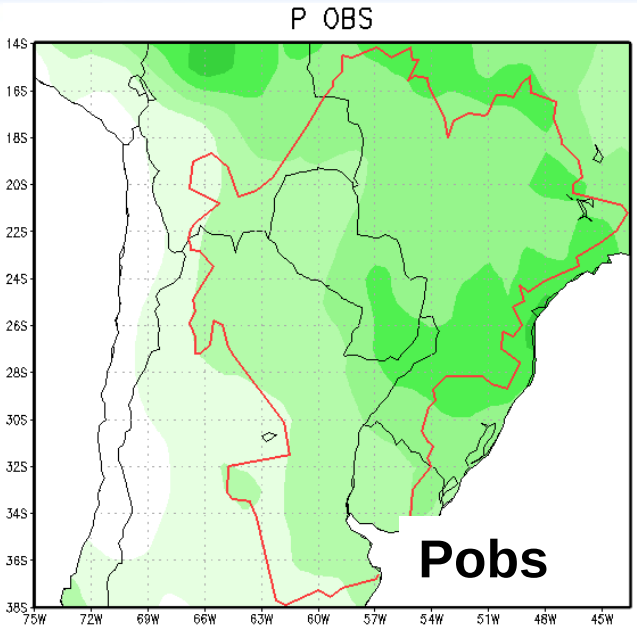


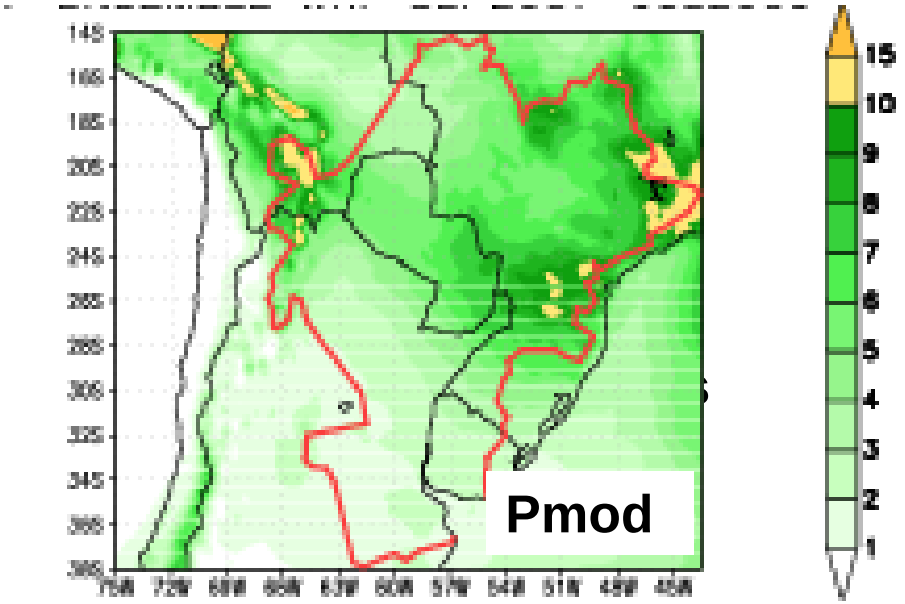
Do the changes in vegetation affect the character of the drought?

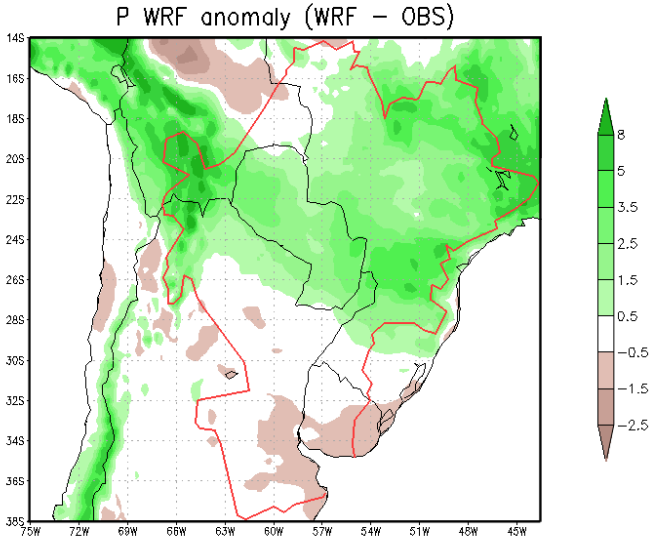
WRF model simulations of the 2008 drought



WRF Model simulations of the 2008 drought

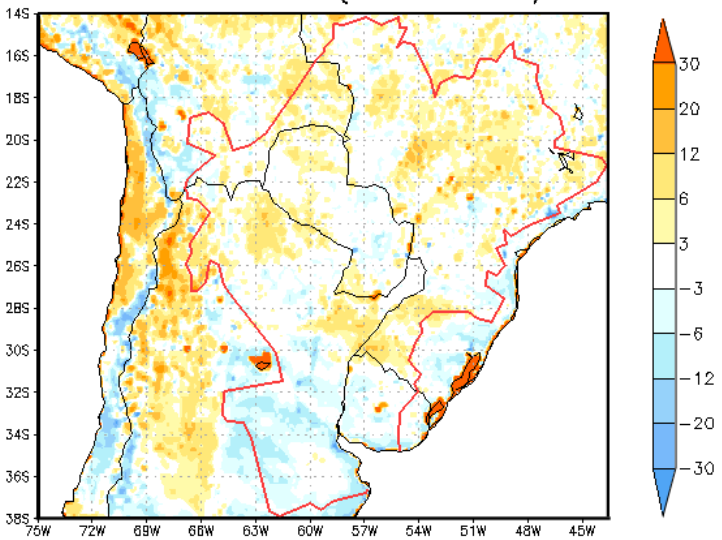




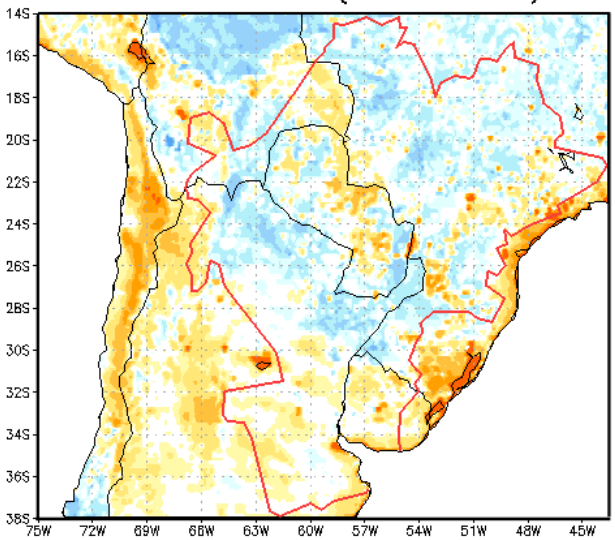


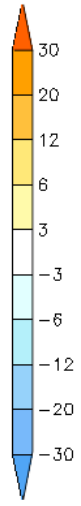
Model Biases wrt to Pobs

SHF difference (EFTs – WRF)

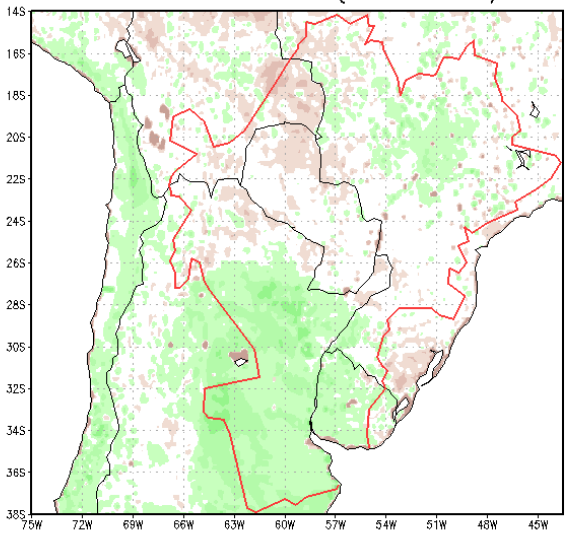


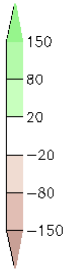
LHF difference (EFTs – WRF)





S. Moist. difference (EFTs – WRF)





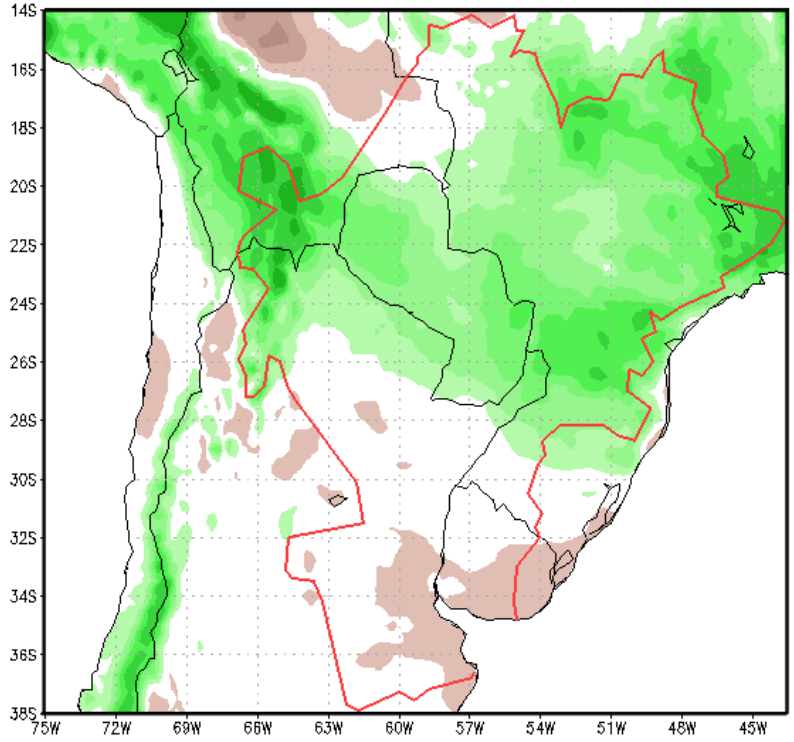
WRF Model simulations of the 2008 drought

Period: Sep 2007 – Jul 2009

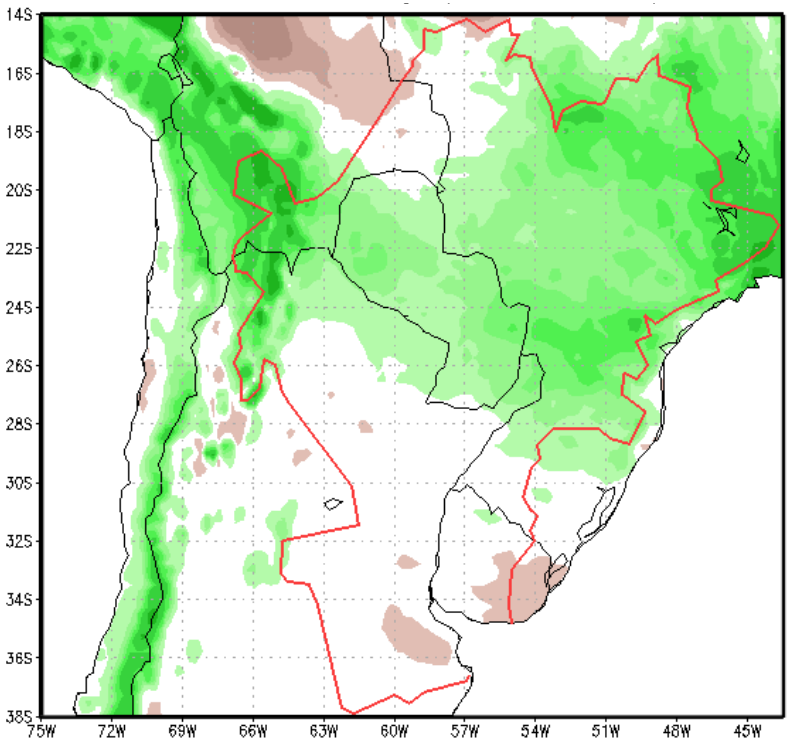
Is the use of EFTs an improvement over the traditional Land Cover types?

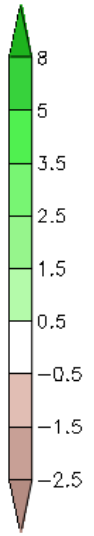
Model Biases wrt to Pobs

Pm - Pobs



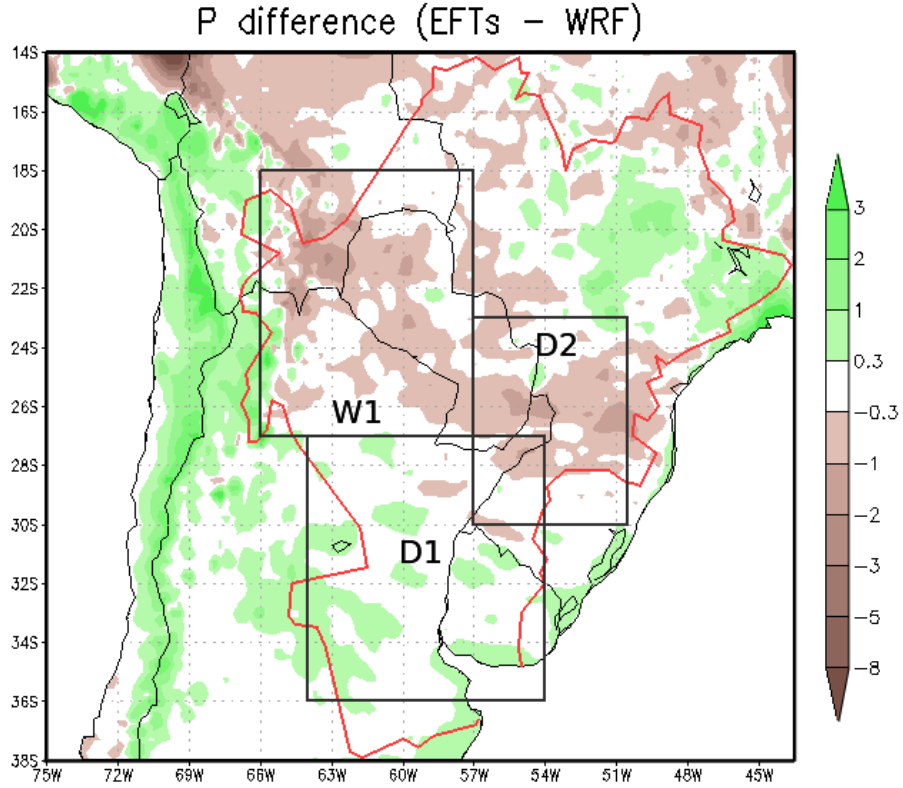
Peft – Pobs



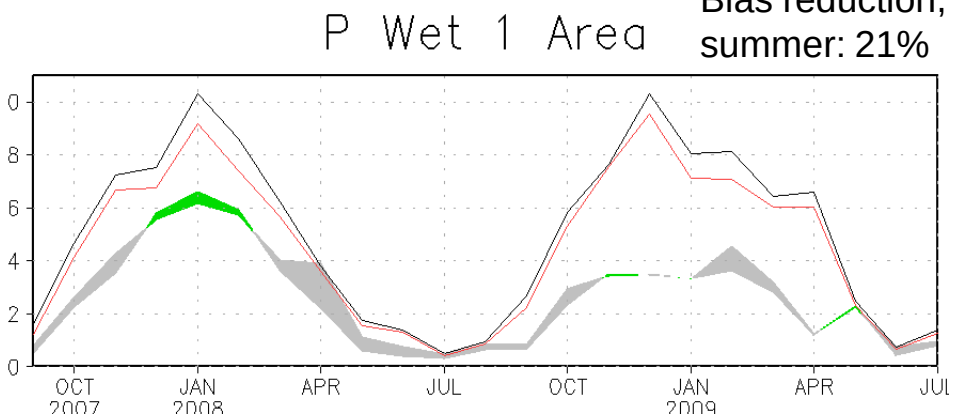


Model Biases wrt to Pobs

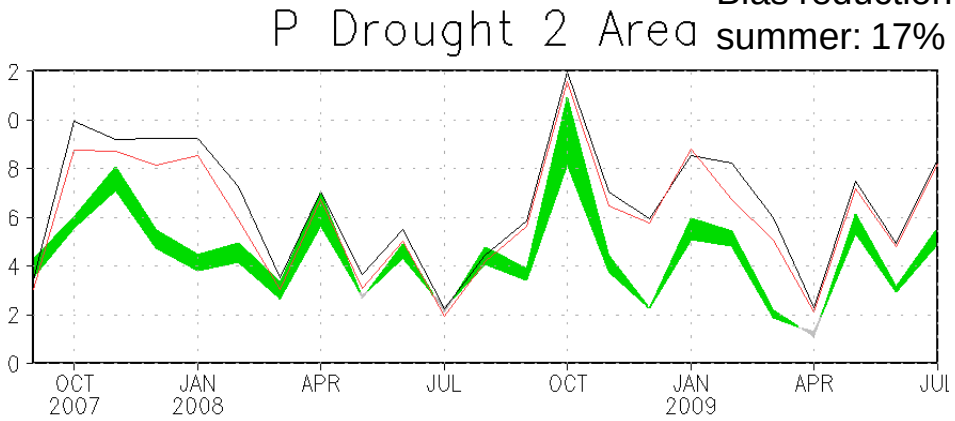
Bias reduction



The brown shades represent a reduction in the bias when using EFTs



Bias reduction, summer: 21%



Bias reduction, summer: 17%

Green: Ptrmm > Pobs
Gray: Ptrmm < Pobs
Red: Pm w/EFTs
Black: Pm (ctl)

SUMMARY

- Los cambios de cobertura vegetal influyen en el clima regional

- Sud America tiene grandes variaciones interanuales de cobertura vegetal que no es representada en tipicosmodelos regionales

- La identificacion annual de "Ecosystem Functional Types (EFTs)" permite definir condiciones de superficie mas realisticas, reduciendo los biases de los modelos.

- Pero no olvidar los efectos de gran escala de las temperaturas del mar, con influencias tanto del oceano Pacifico como del Atlantico


Thank you!