Microwave observations of La Plata basin vegetated environments: analysis of AMSR-E, SMOS and Aquarius data

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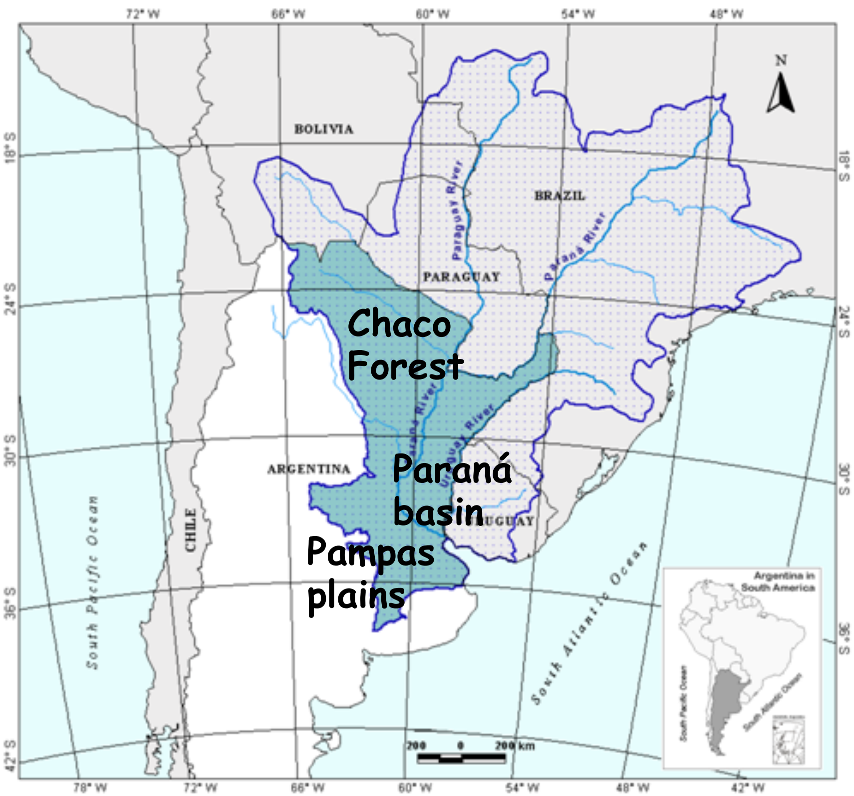
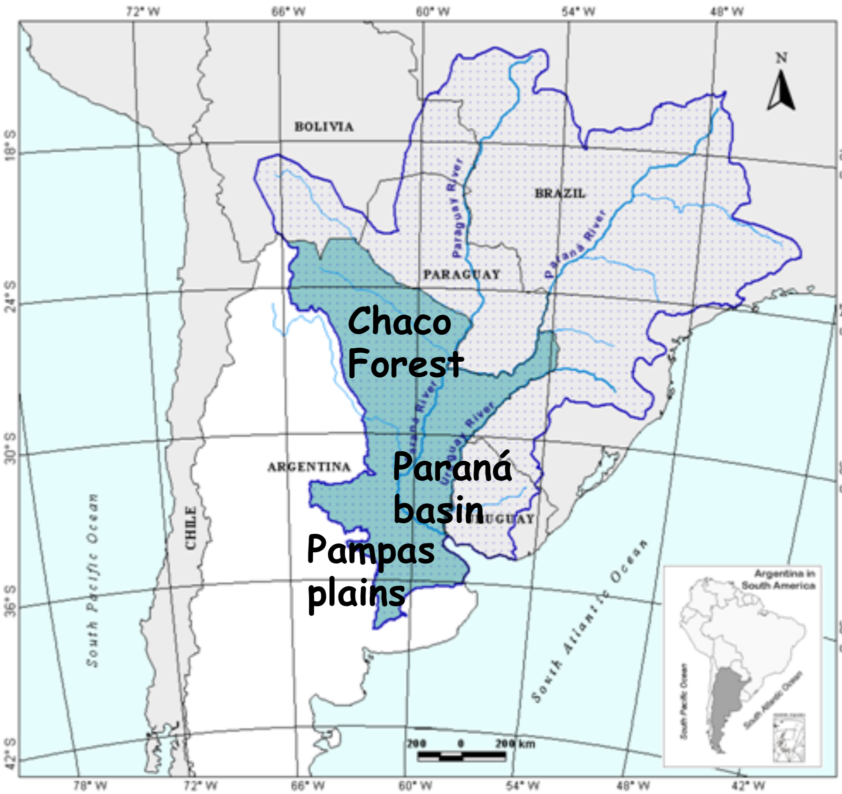


➢**La Plata Basin floods and droughts: Contribution of microwave remote sensing in monitoring and prediction**

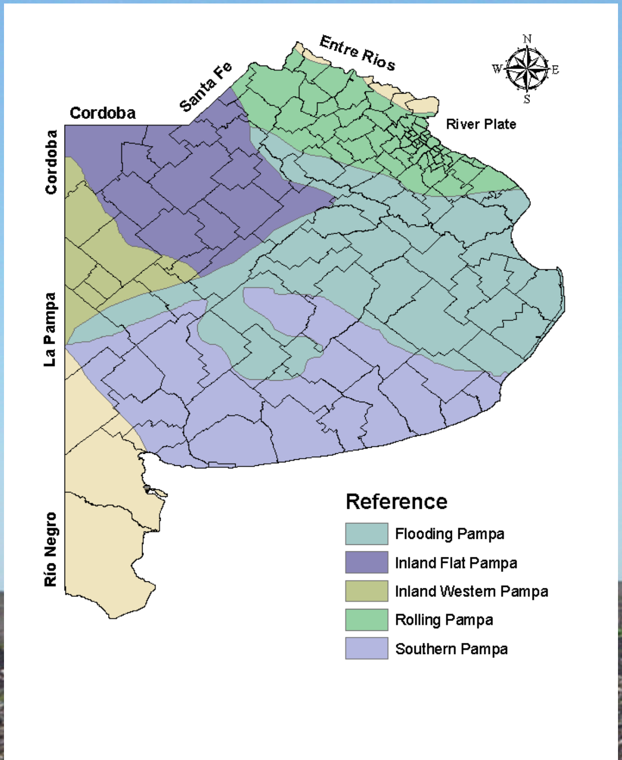
➢The **La Plata Basin (LPB)** (Spanish: *Cuenca del Plata*) (**blue contour**) **3,100,000 km** hydrographical area that covers parts of Argentina, Brazil, Bolivia, Paraguay, and Uruguay. Current working areas: **Chaco forest, Paraná basin and Pampas plains**.

➢ One of the main issues is the impact of **global change and land use change** (deforestation and replacement by intensive soy crop production) on regional weather, climate, hydrology and agriculture. More recently, extreme hydrological events (EHE) are affecting strongly different regions within this basin.



One of project main **goals** is **soil moisture retrieval** using passive and active systems within different **vegetated areas** (**forest, wetlands, agriculture**) with the aim of generating precedent soil condition data for **EHE** monitoring and prediction.

Pampas Plains



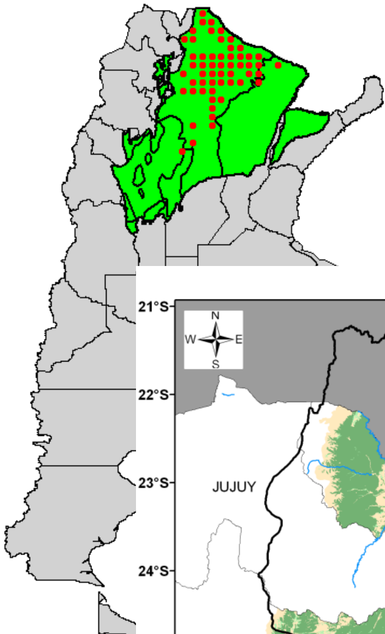
- The Argentine Pampas (33–351S, 62–641W) is a wide plain of around 50 million hectares of fertile lands suitable for cattle and crop production.

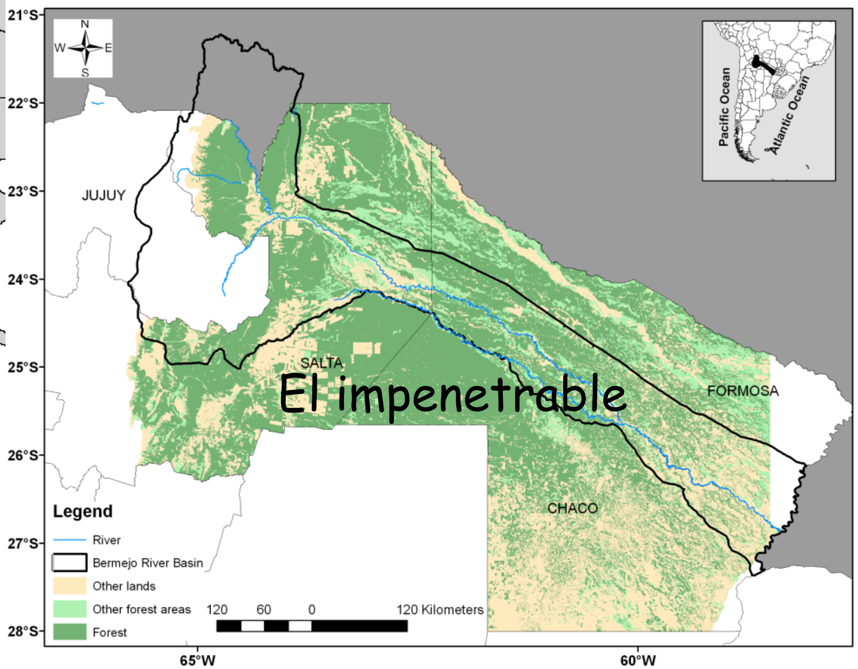
- The biome is not homogeneous, since soil quality varies and rainfall declines from NE to SW.

- Using these patterns, the region can be divided into five agro-ecologically homogeneous areas:, Rolling Pampas, Western Pampas, Flooding Pampas, inland Flat Pampas and Southern Pampas.

- Rainfall regimes vary across time and space, causing **cyclical drought and flood episodes** that affect both crop and cattle production

Gran Chaco Americano Forest





Bermejo basin

- ✓The total extent is of more than 100 millions of hectares.
- ✓There is a wide variability of climatic conditions and botanical species.
- ✓The forest is continuous, but the biomass is moderate. Extensive measurements, with a sampling interval of 0.5° x 0.5°, indicate biomass values typically in the range 70-125 tn/ha.
- ✓There is a wide variability of tree dimensions. The average value of diameter at breast height is about 15-20 cm, but some trees show values higher than 100 cm.

The species are characterized by dry and very hard wood
Low gravimetric moisture (~ 0.2 g/g)
Low ratio woody volume / biomass (~ 1.2 m3/t)

The instruments

AMSR-E: Conical scanning radiometer, up to C Band (~40 x 70 Km, better resolution in higher frequency bands), single incidence angle (55º), 10 years data, previous heritage. Lifetime finished.

SMOS: Synthetic aperture radiometer that uses small antennas and a measurement of the phase difference of incident radiation to synthesize the resolution of a large antenna (~40 x 40 Km, L Band). Sensitive to RFI. Capable of synthesize different incidence angles.

Aquarius: Pushbroom scanning radiometer. Three parallel cross-track beams: 28.7º, 37.8º and 45.6º. Spatial resolution ~ 100 Km. L band. Scatterometer (L band).

- All systems measure: **brightness temperature** (Tb, for H and V polarization).

- However, they measure it using **different strategies**, which presents pro/cons.

- In vegetated environments **Tbs** can be **modeled** as a function of: vegetation, water content, vegetation structure, soil roughness and soil moisture.

- Useful indicators are often defined in passive microwave studies: polarization index (PI) and frequency index (FI).

Radiometer brightness temperatures are computed based on a **zero-order radiative transfer model**, usually named ω-τ algorithm that includes vegetation and soil components as

$$TB_p = T_S(1-r_p)\exp(-\tau/\cos\theta) + T_C(1-\omega)[1-\exp(-\tau/\cos\theta)][1+r_p\exp(-\tau/\cos\theta)]$$

where p refers to polarization, T_S is soil temperature, T_C is vegetation temperature, r_p is the soil reflectivity, θ is the look angle, τ is the nadir vegetation opacity and ω is the vegetation single scattering albedo.

Vegetation opacity is assumed to be unpolarized and is defined as $\tau = bW$, where b is a land cover depending coefficient and W is vegetation water content (kg/m2). There are **different approaches** (all based on this expression), to estimate **the unknowns (soil moisture, vegetation opacity, surface temperature)**.

Key variables: Soil moisture, soil temperature, vegetation water content, vegetation temperature, soil texture, soil porosity, surface roughness, vegetation geometry parameter, single scattering albedo.

Observations: frequencies 6.9, 10.7, 18.7 GHz, H and V polarizations for AMSR-E, L band, H and V polarizations for SMOS.

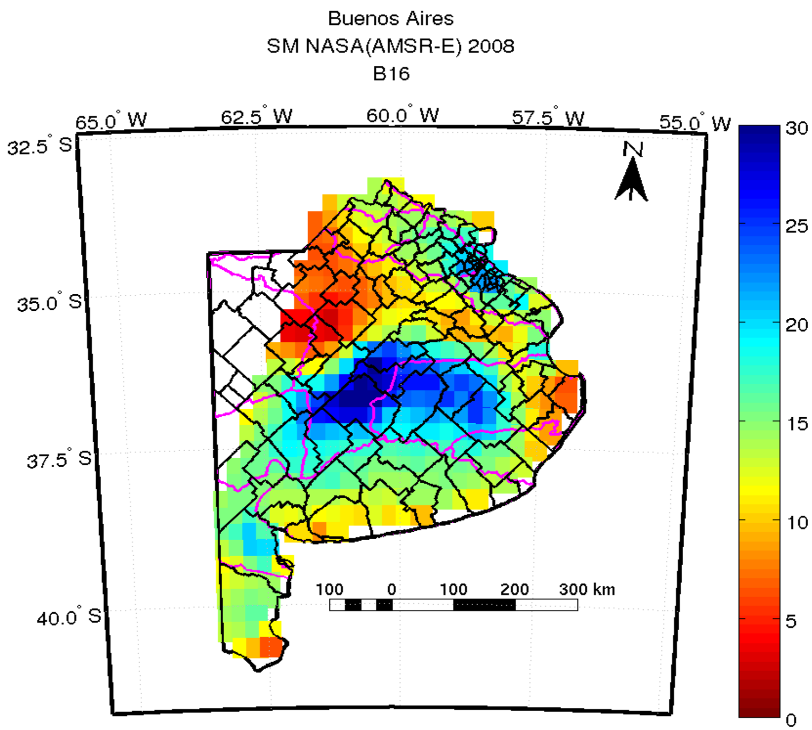
Current algorithms for SM retrieval

- USDA(AMSR-E): single channel algorithm (SCA) (Jackson, 2010): it retrieves soil moisture. It requires VWC and all other ancillay data as inputs.
- NASA(AMSR-E): three variable retrieval simultaneously (Njoku, 2003): soil moisture, vegetation water content and Ts. It uses three frecuencies and two polarizations.
- LPRM(AMSR-E): retrieval using polarization index and coupled with a LSM model (Owe, 2001).
- L2 SMOS Product: retrieval using an iterative procedure based on ECMWF initial values (SMOS team, Kerr, 2001). It retrieves soil moisture and optical depth.
- USDA(Aquarius): single channel algorithm (SCA) (jackson, previous talk)

Ancillary information

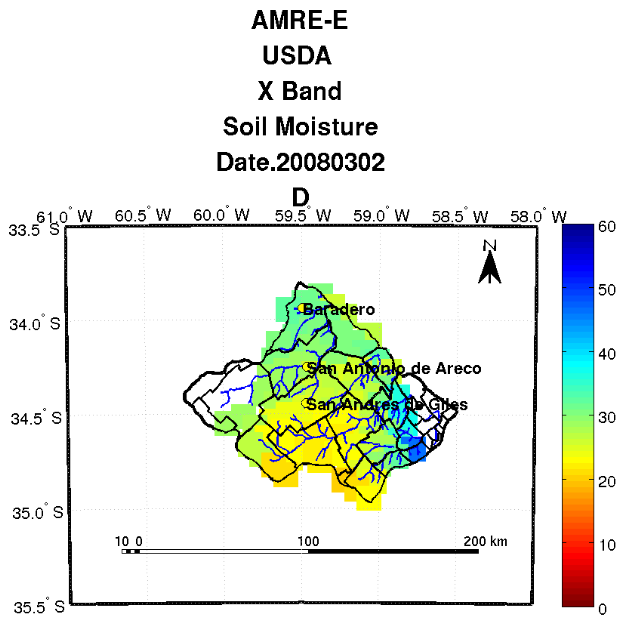
- Modis data: NDVI time series, land covers
- Precipitation data
- Crop calendar (INTA)
- Land cover and biomass maps produced in Argentina and provided by different institutions (UMSEF)
- Vegetation structure (trees) (Dr. I. Gasparri)
- Some field data for Pampas plains (INTA)
- Others

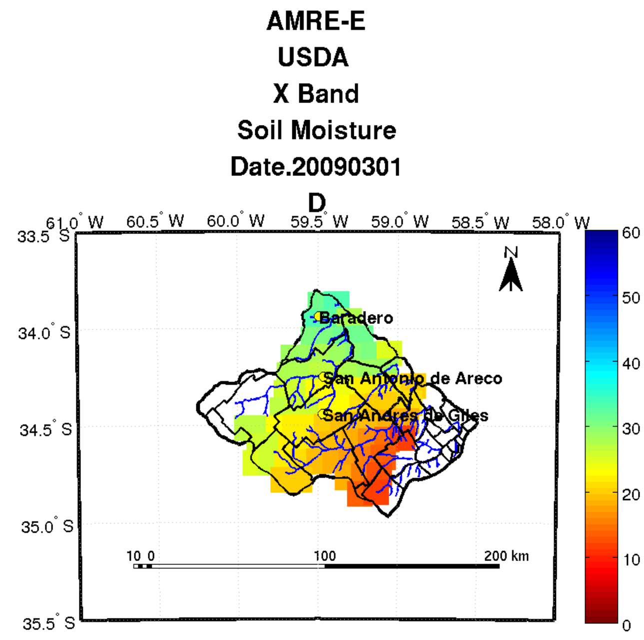
Buenos Aires Province Pampas plains: NASA product 2008



AMSR-E Four years of soils moisture data (NASA product): from drought to floods, back to drought:

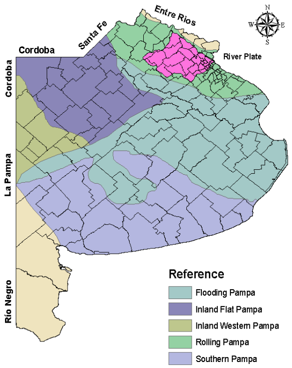
1.- Well defined spatial patters.
2.- <u>Dynamic range does not reach 30% even in saturated soils</u>.

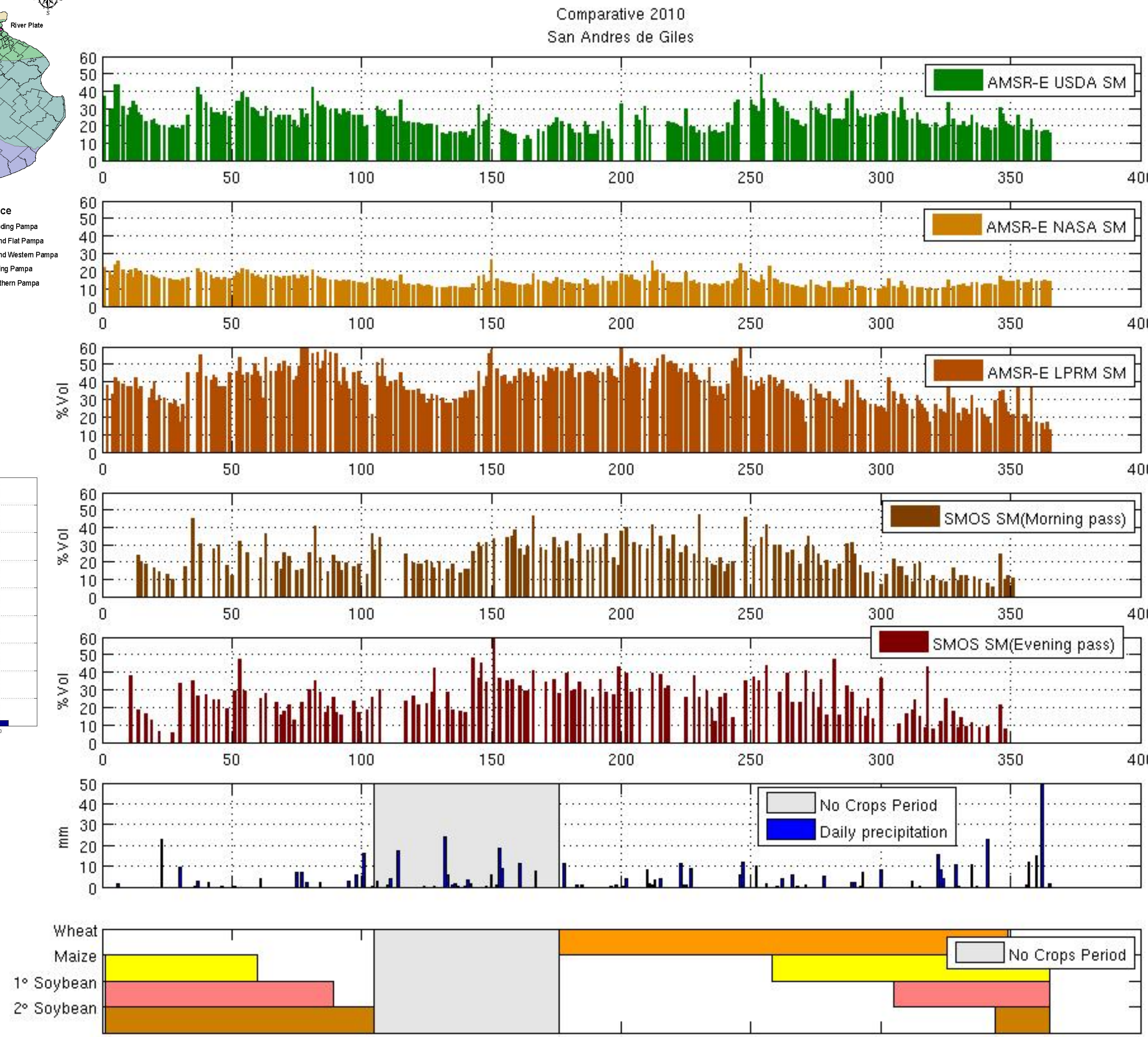


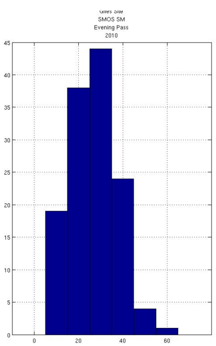


USDA SCA algorithm

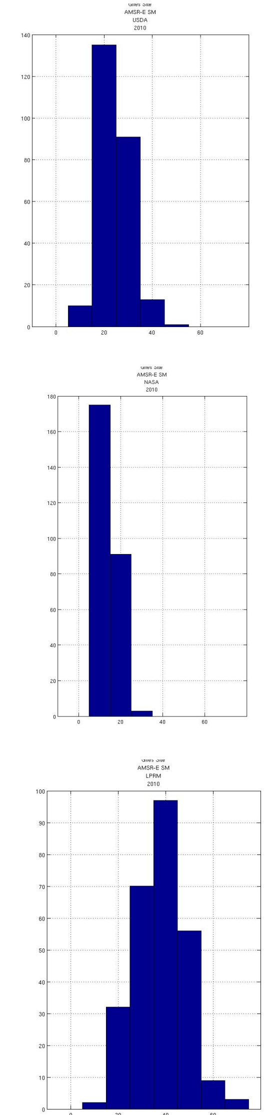
Examples





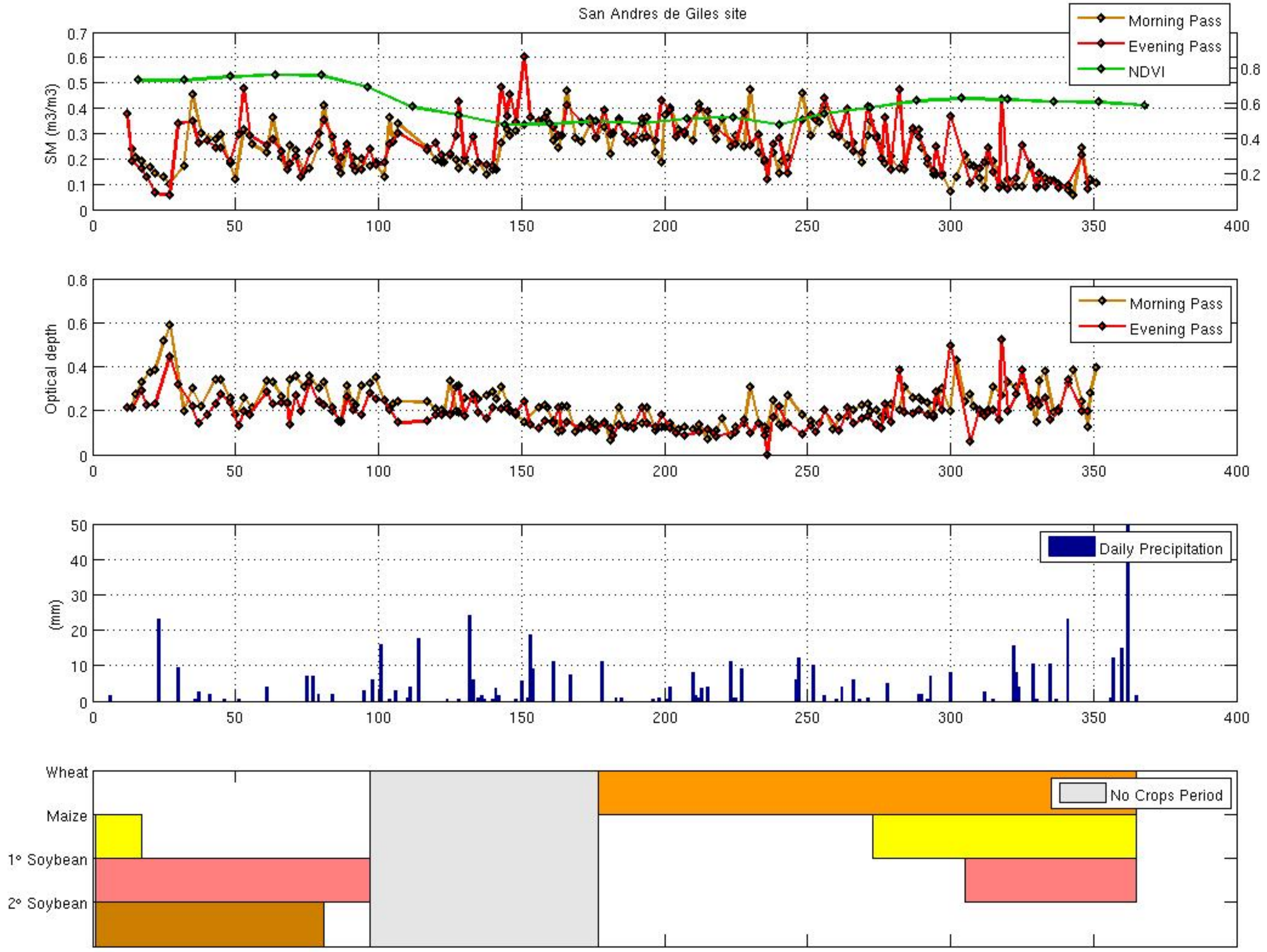


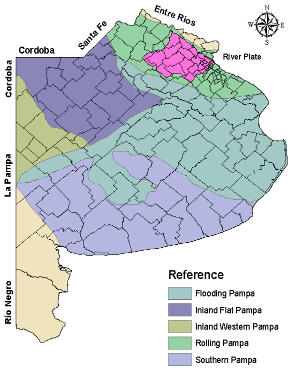
SMOS



AMSR-E

SMOS SM and Optical Depth products





SMOS

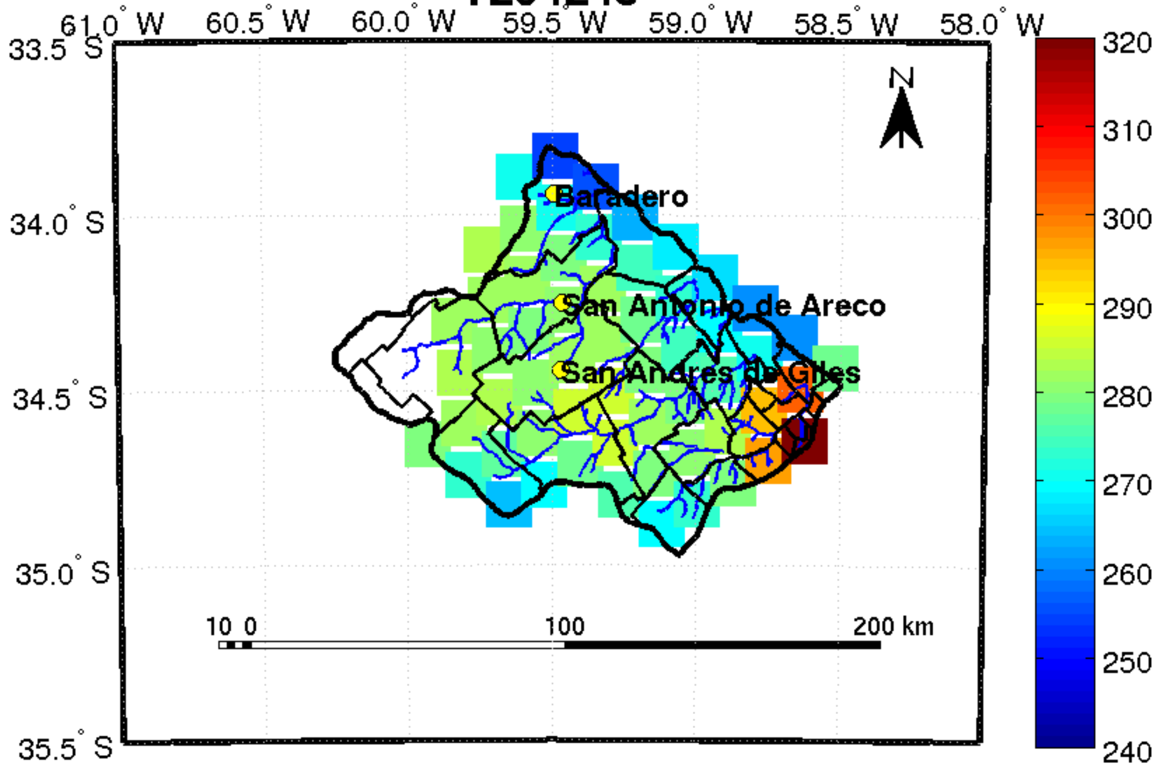
L Band

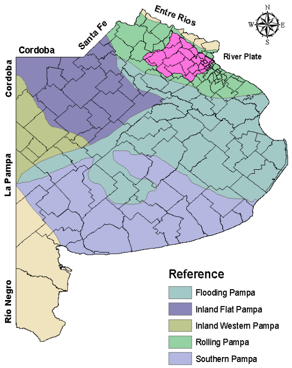
Tb H

DoY.2011346

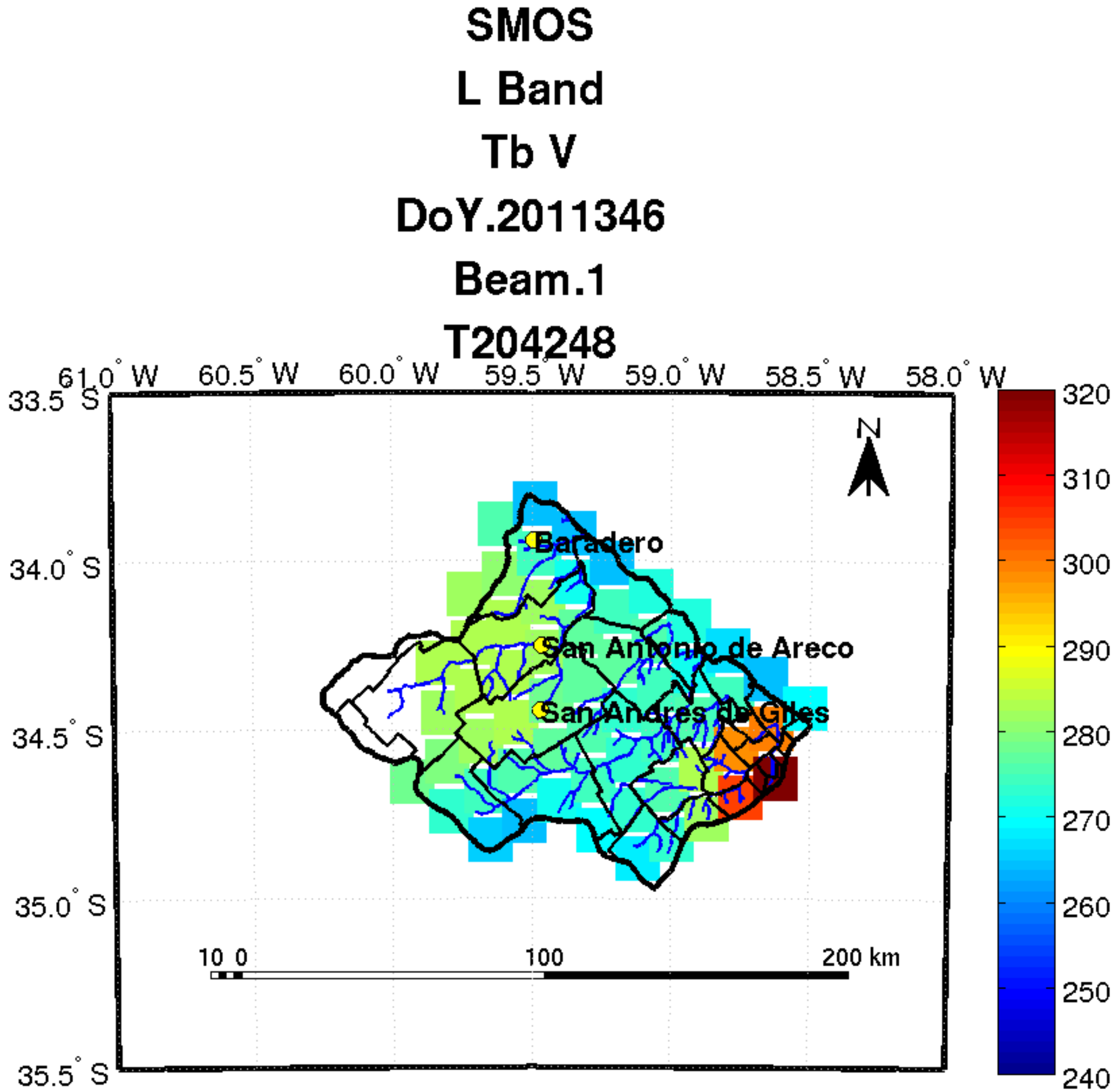
Beam.1

T204248

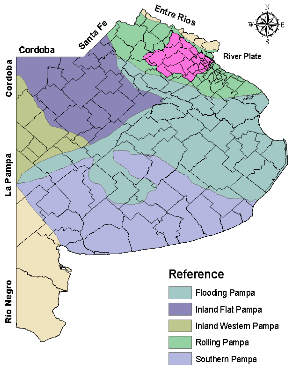




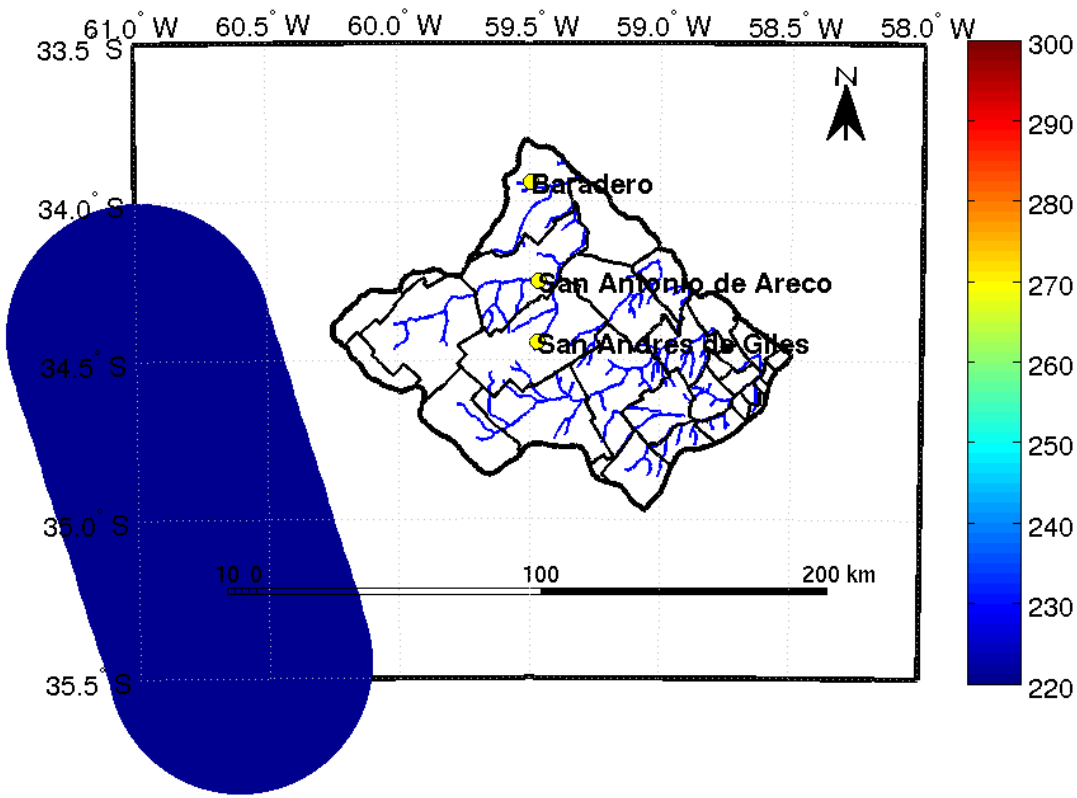
Entre Rios
Santa Fe
Cordoba
River Plate
Cordoba
La Pampa
Rio Negro
Reference
Flooding Pampa
Inland Flat Pampa
Inland Western Pampa
Rolling Pampa
Southern Pampa

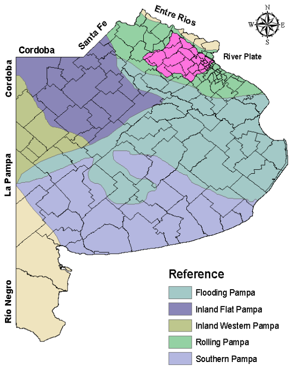


SMOS
L Band
Tb V
DoY.2011346
Beam.1
T204248
61.0° W
60.5° W
60.0° W
59.5° W
59.0° W
58.5° W
58.0° W
33.5° S
34.0° S
34.5° S
35.0° S
35.5° S
N
Baradero
San Antonio de Areco
San Andres de Giles
10 0
100
200 km
320
310
300
290
280
270
260
250
240

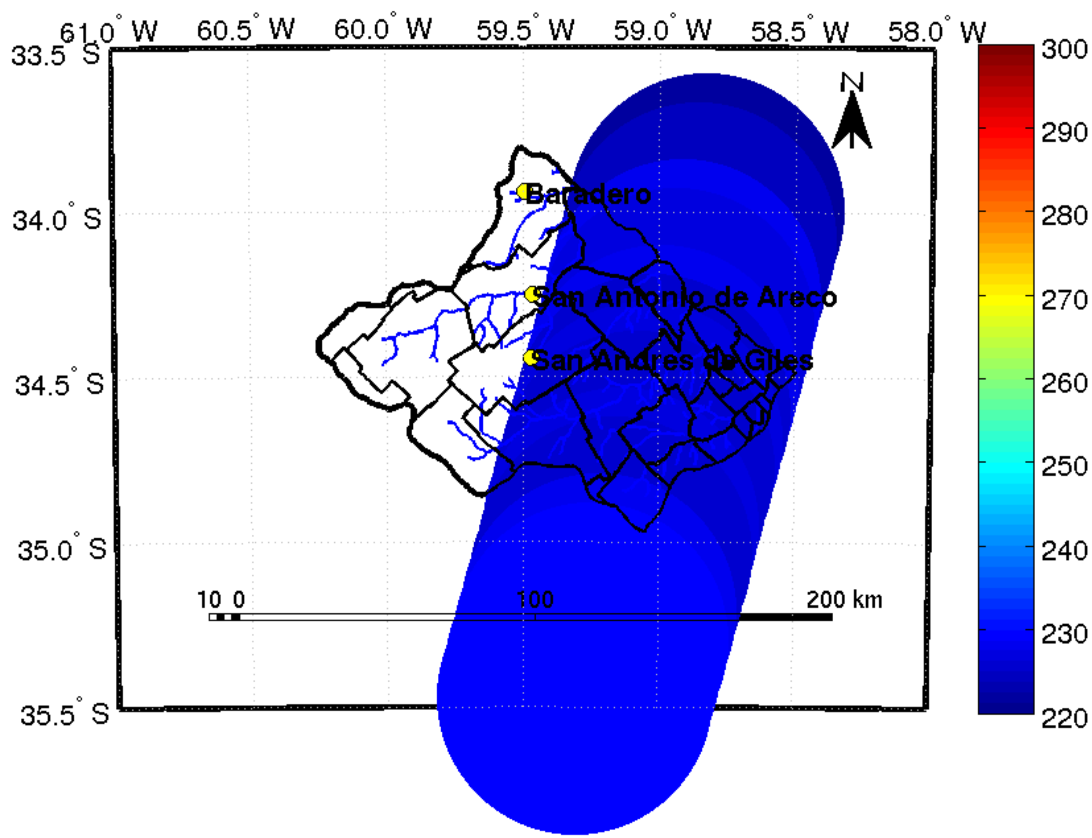


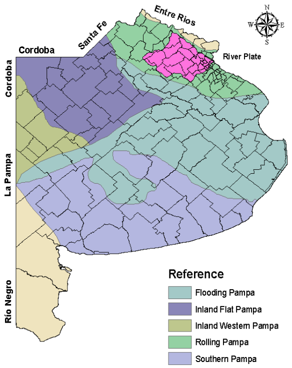
Aquarius
L Band
Tb H
DoY.2011240
Beam.3



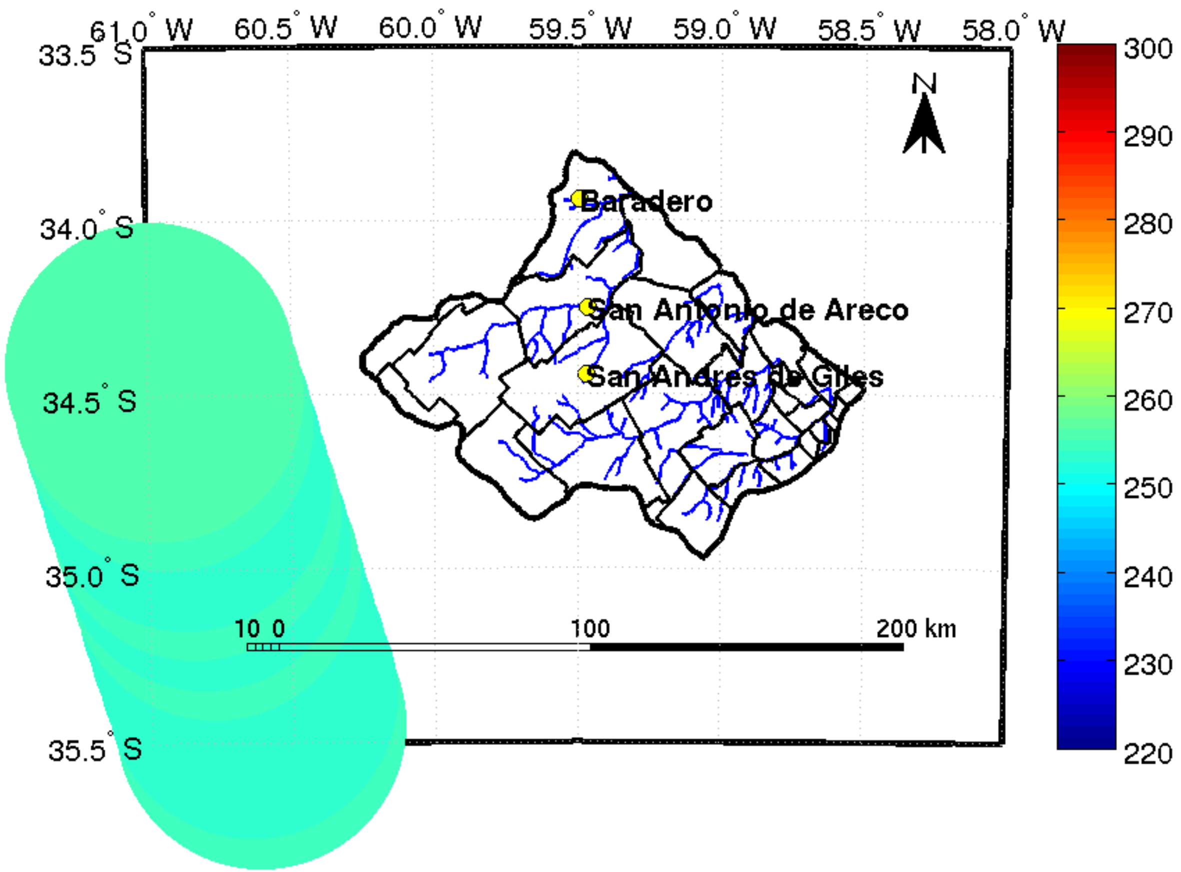


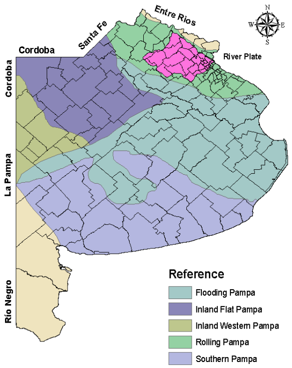
Aquarius
L Band
Tb H
DoY.2011240
Beam.1



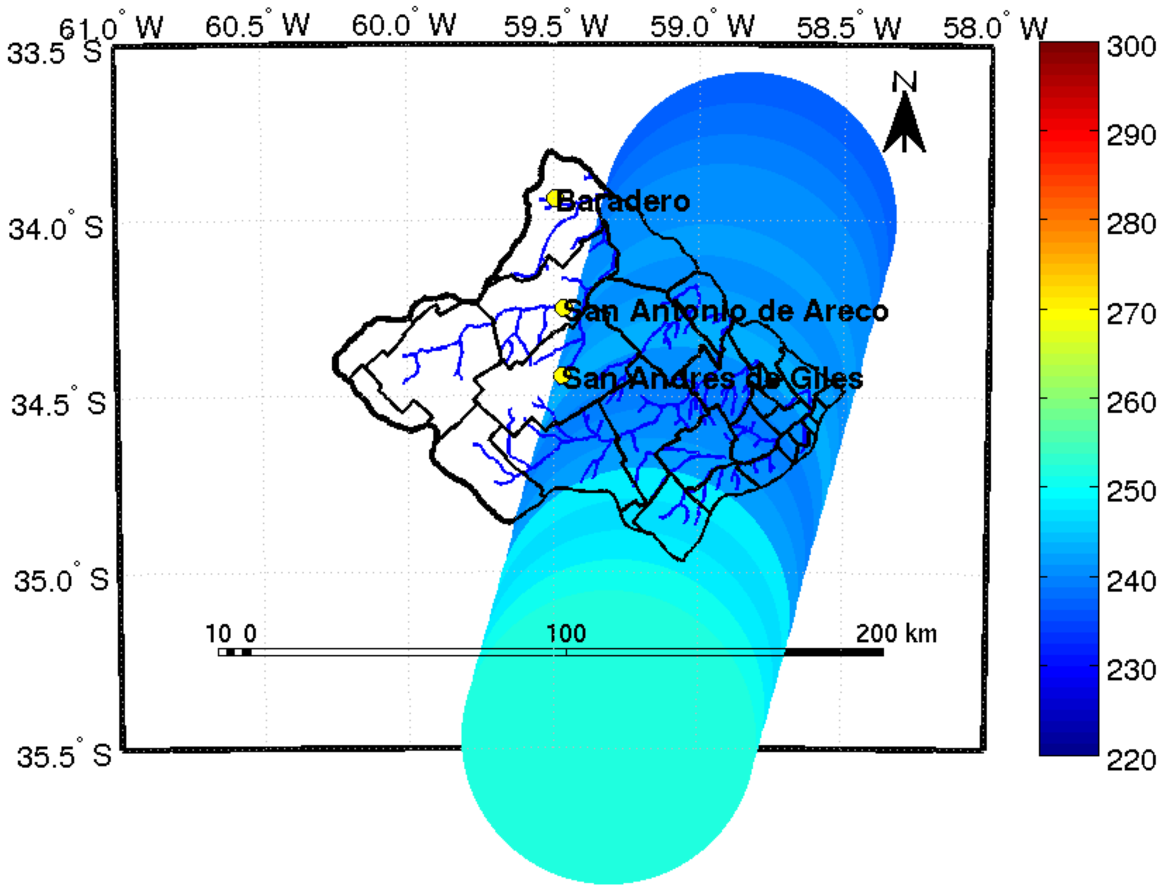


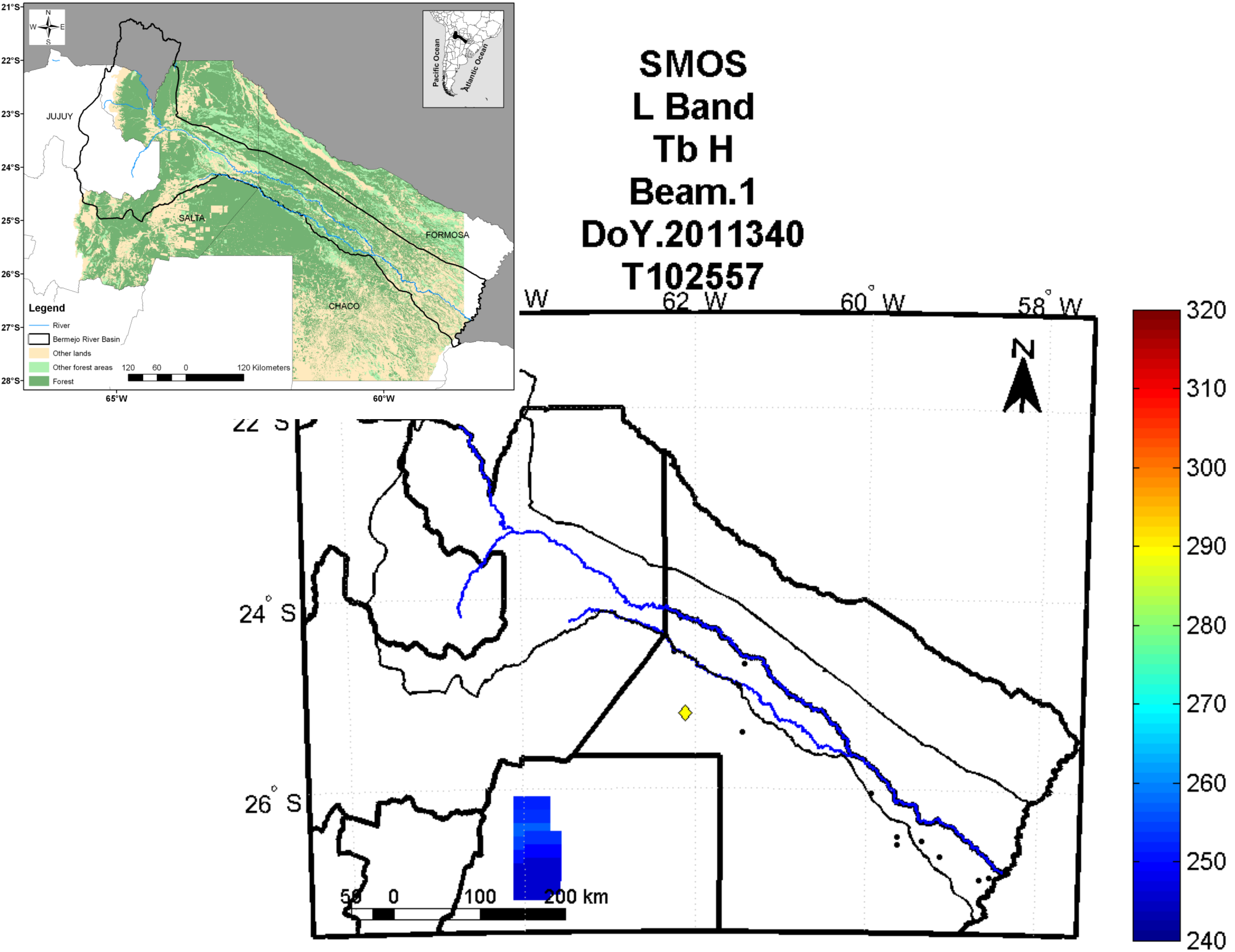
Aquarius
L Band
Tb V
DoY.2011240
Beam.3

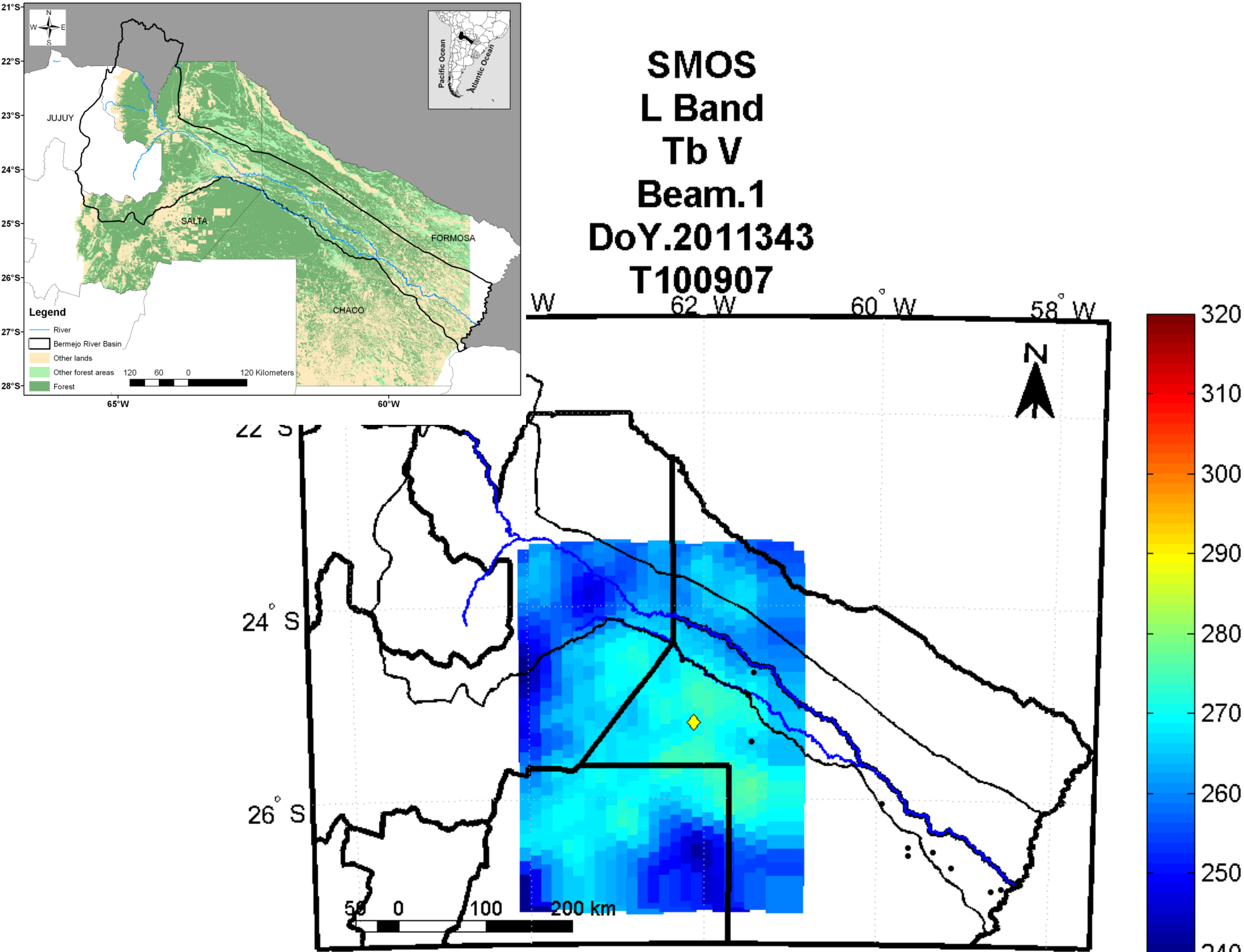




Aquarius
L Band
Tb V
DoY.2011240
Beam.1




SMOS
L Band
Tb H
Beam.1
DoY.2011340
T102557
21°S
22°S
23°S
24°S
25°S
26°S
27°S
28°S
65°W
60°W
JUJUY
SALTA
FORMOSA
CHACO
Pacific Ocean
Atlantic Ocean
Legend
River
Bermejo River Basin
Other lands
Other forest areas
Forest
120 60 0 120 Kilometers
W
62 W
60° W
58° W
22 S
24° S
26° S
N
50 0 100 200 km
320
310
300
290
280
270
260
250
240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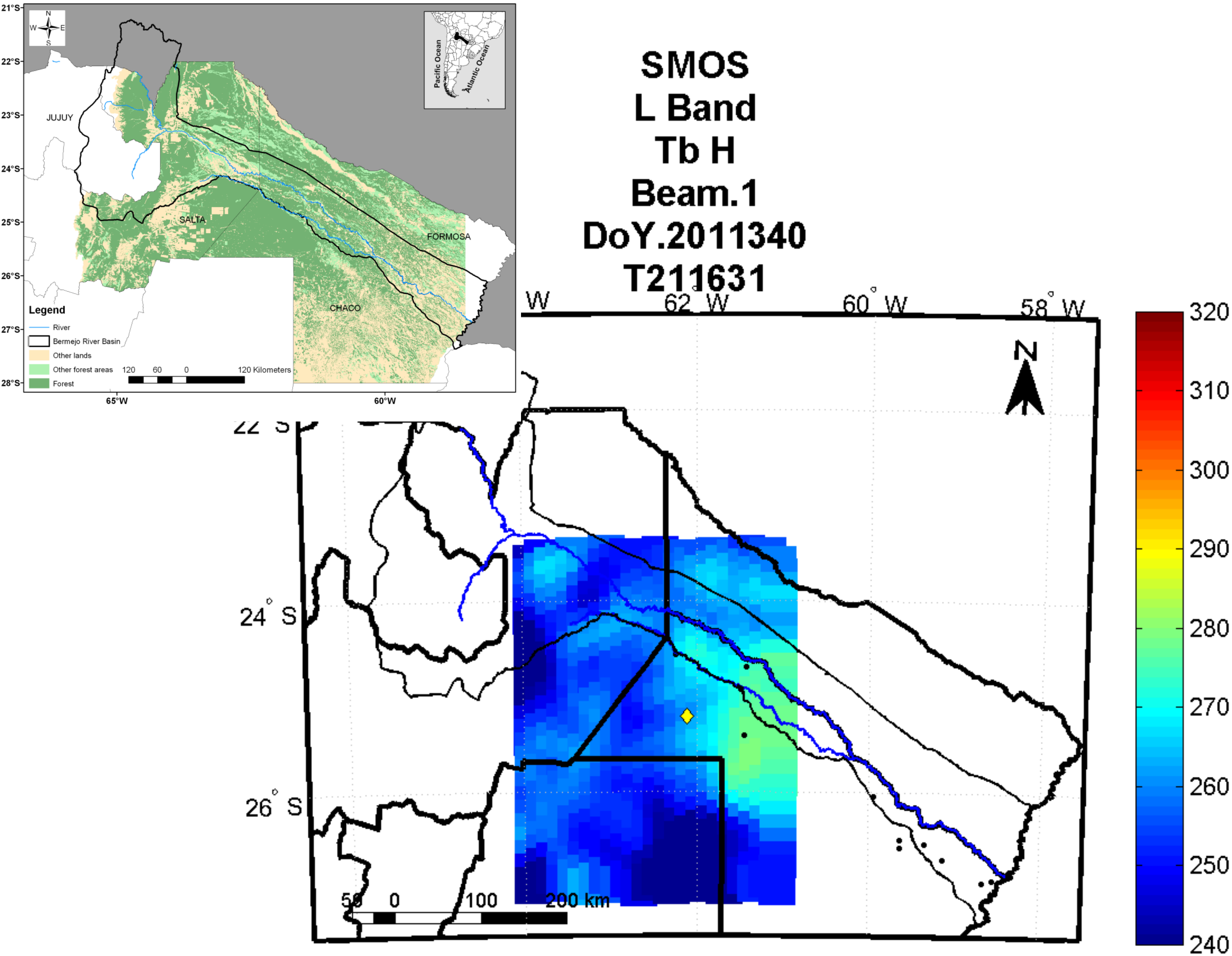
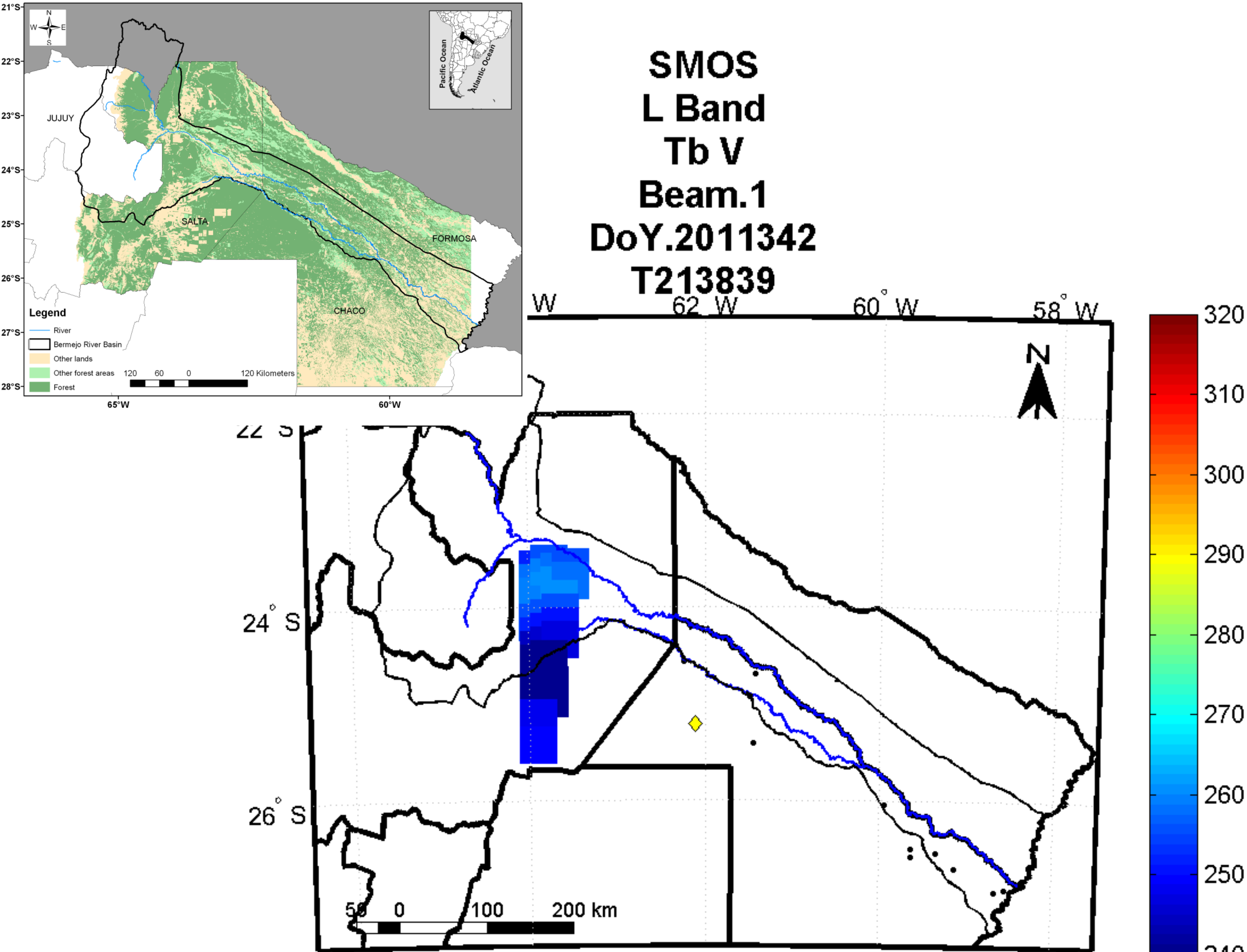
L Band
Tb V
Beam.1
DoY.2011343
T100907
W
62° W
60° W
58° W
22° S
24° S
26° S
N
50 0 100 200 km
320
310
300
290
280
270
260
250
240
JUJUY
SALTA
FORMOSA
CHACO
Pacific Ocean
Atlantic Ocean
Legend
River
Bermejo River Basin
Other lands
Other forest areas
Forest
120 60 0 120 Kilometers
21°S
22°S
23°S
24°S
25°S
26°S
27°S
28°S
65°W
60°W



SMOS
L Band
Tb H
Beam.1
DoY.2011340
T211631
21°S
22°S
23°S
24°S
25°S
26°S
27°S
28°S
65°W
60°W
JUJUY
SALTA
FORMOSA
CHACO
Pacific Ocean
Atlantic Ocean
Legend
River
Bermejo River Basin
Other lands
Other forest areas
Forest
120 60 0 120 Kilometers
62° W
60° W
58° W
24° S
26° S
N
50 0 100 200 km
320
310
300
290
280
270
260
250
240



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Tb V
Beam.1
DoY.2011342
T213839
JUJUY
SALTA
FORMOSA
CHACO
Legend
River
Bermejo River Basin
Other lands
Other forest areas
Forest
120 60 0 120 Kilometers
Pacific Ocean
Atlantic Ocean
65°W
60°W
62° W
60° W
58° W
24° S
26° S
N
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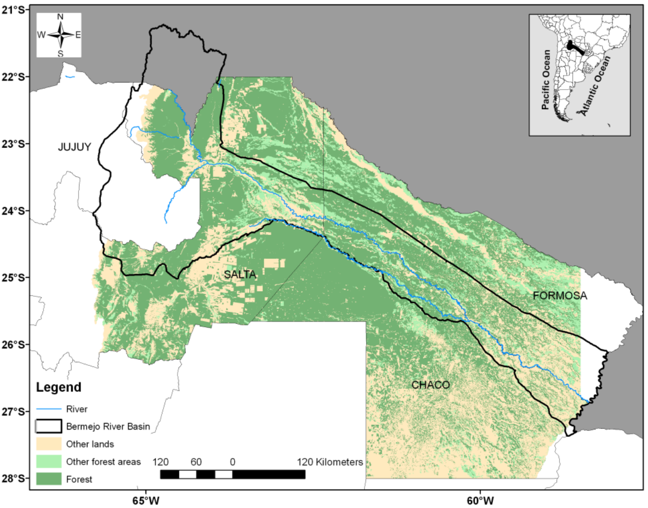
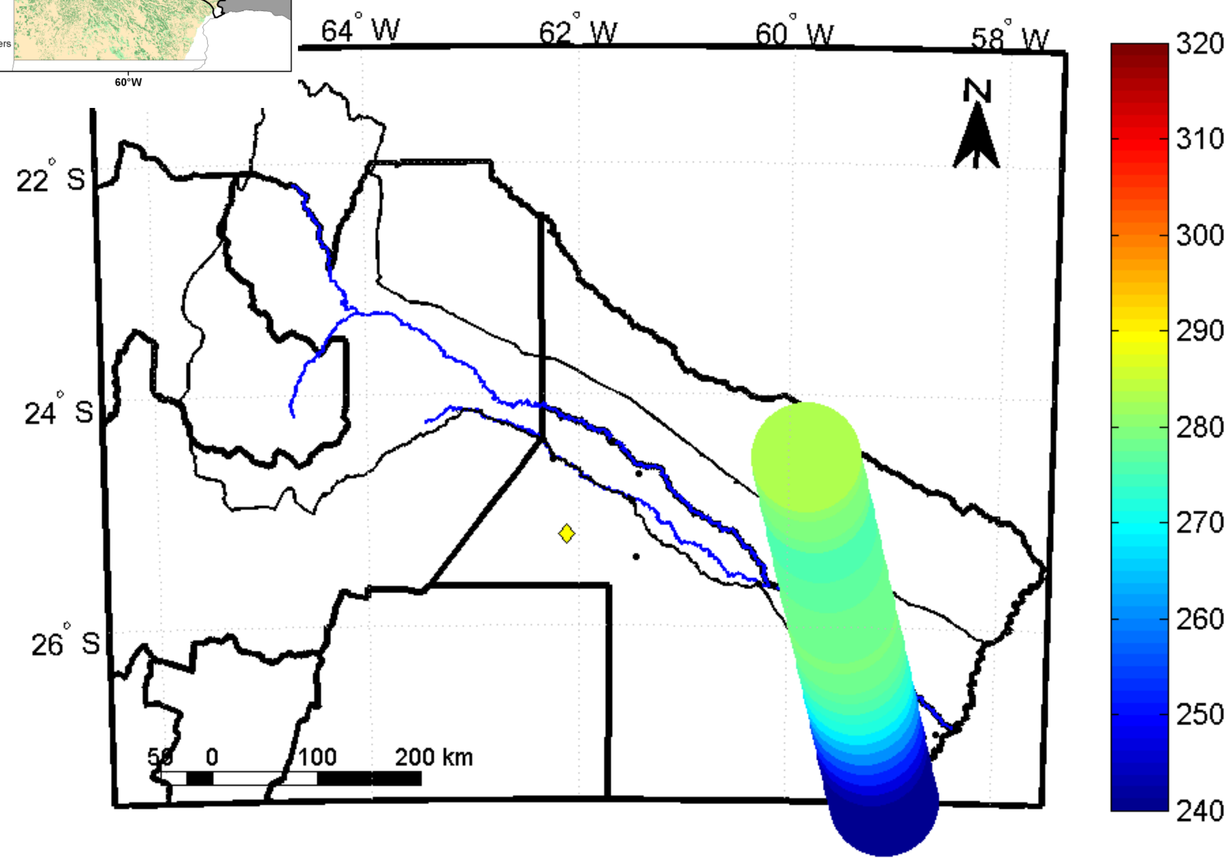
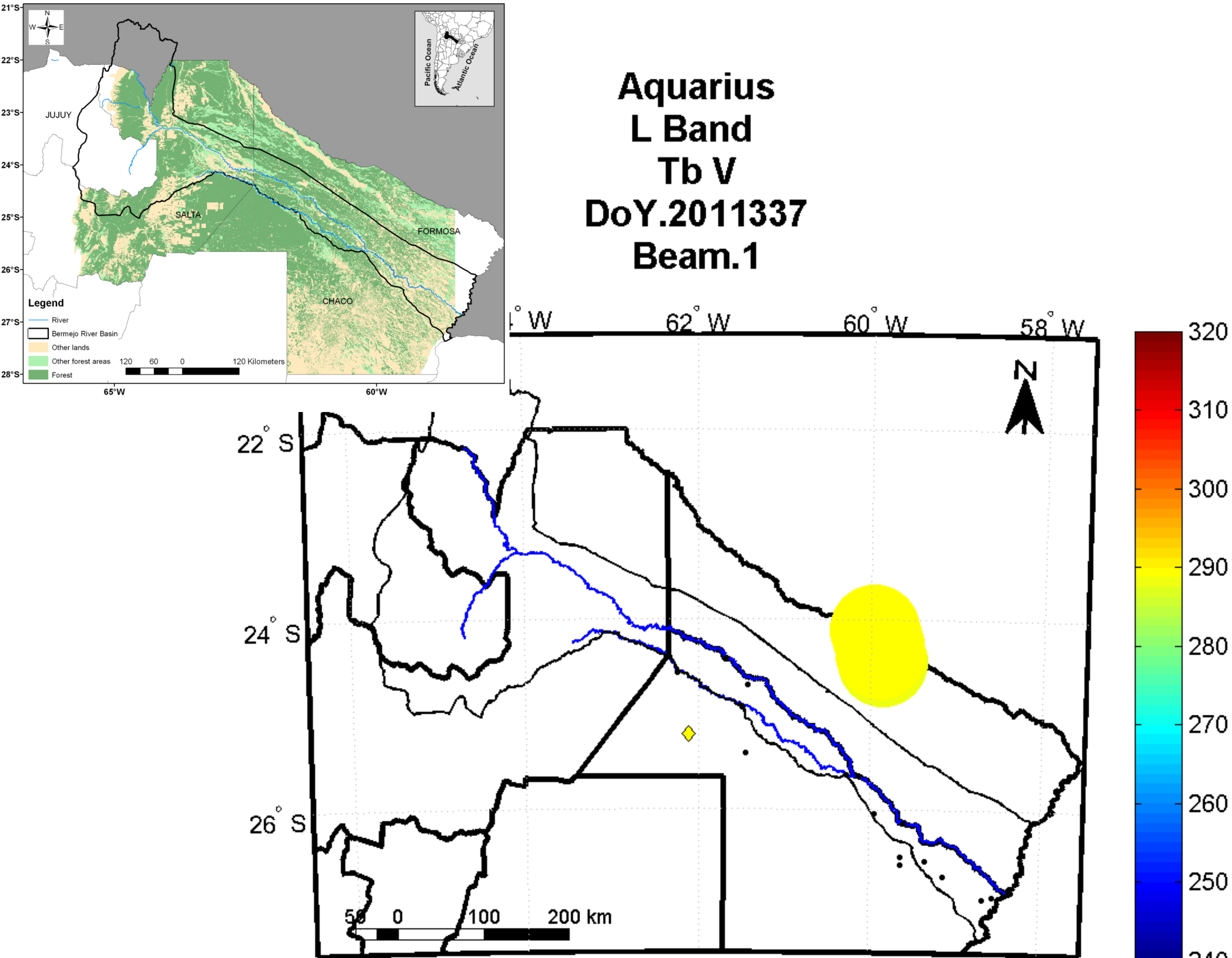
280
270
260
250
240

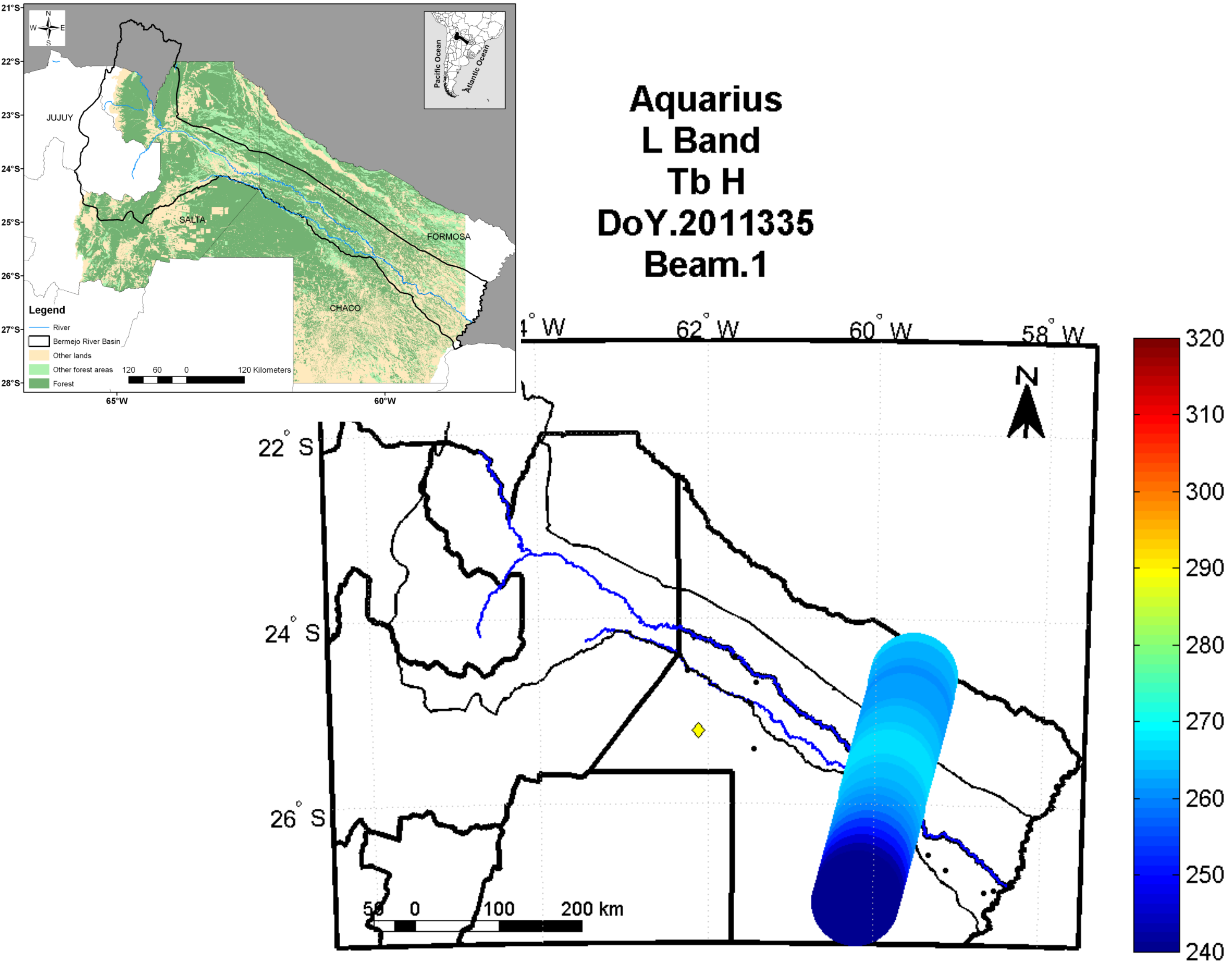


Aquarius
L Band
Tb H
DoY.2011337
Beam.1





Aquarius
L Band
Tb V
DoY.2011337
Beam.1
62° W
60° W
58° W
22° S
24° S
26° S
N
50 0 100 200 km
320
310
300
290
280
270
260
250
240
21°S
22°S
23°S
24°S
25°S
26°S
27°S
28°S
65°W
60°W
JUJUY
SALTA
FORMOSA
CHACO
Pacific Ocean
Atlantic Ocean
Legend
River
Bermejo River Basin
Other lands
Other forest areas
Forest
120 60 0 120 Kilometers



Aquarius
L Band
Tb H
DoY.2011335
Beam.1
21°S
22°S
23°S
24°S
25°S
26°S
27°S
28°S
65°W
60°W
N
W
E
S
JUJUY
SALTA
FORMOSA
CHACO
Pacific Ocean
Atlantic Ocean
Legend
River
Bermejo River Basin
Other lands
Other forest areas
Forest
120 60 0 120 Kilometers
4° W
62° W
60° W
58° W
22° S
24° S
26° S
N
50 0 100 200 km
320
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250
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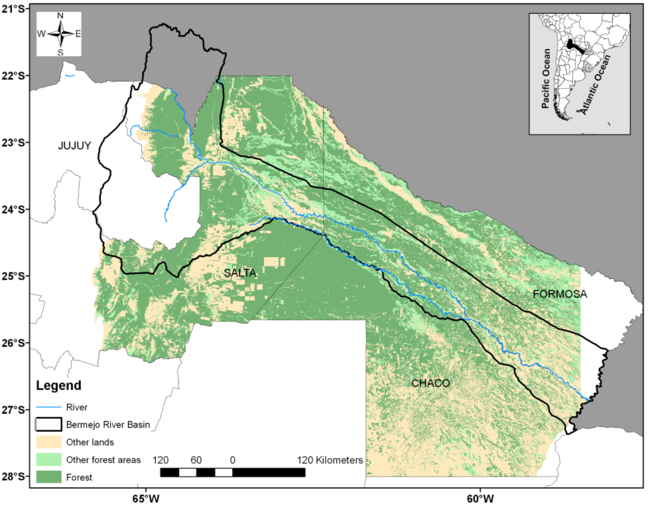
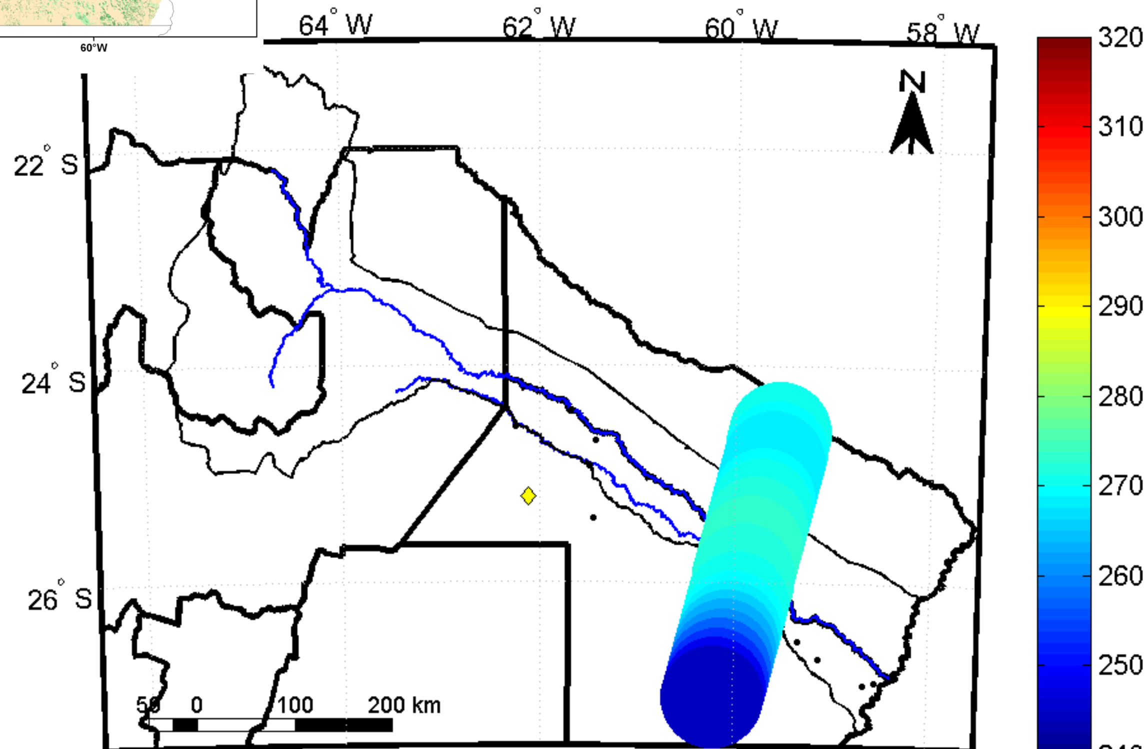
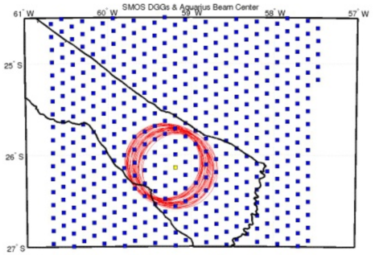
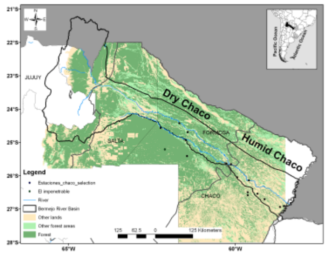
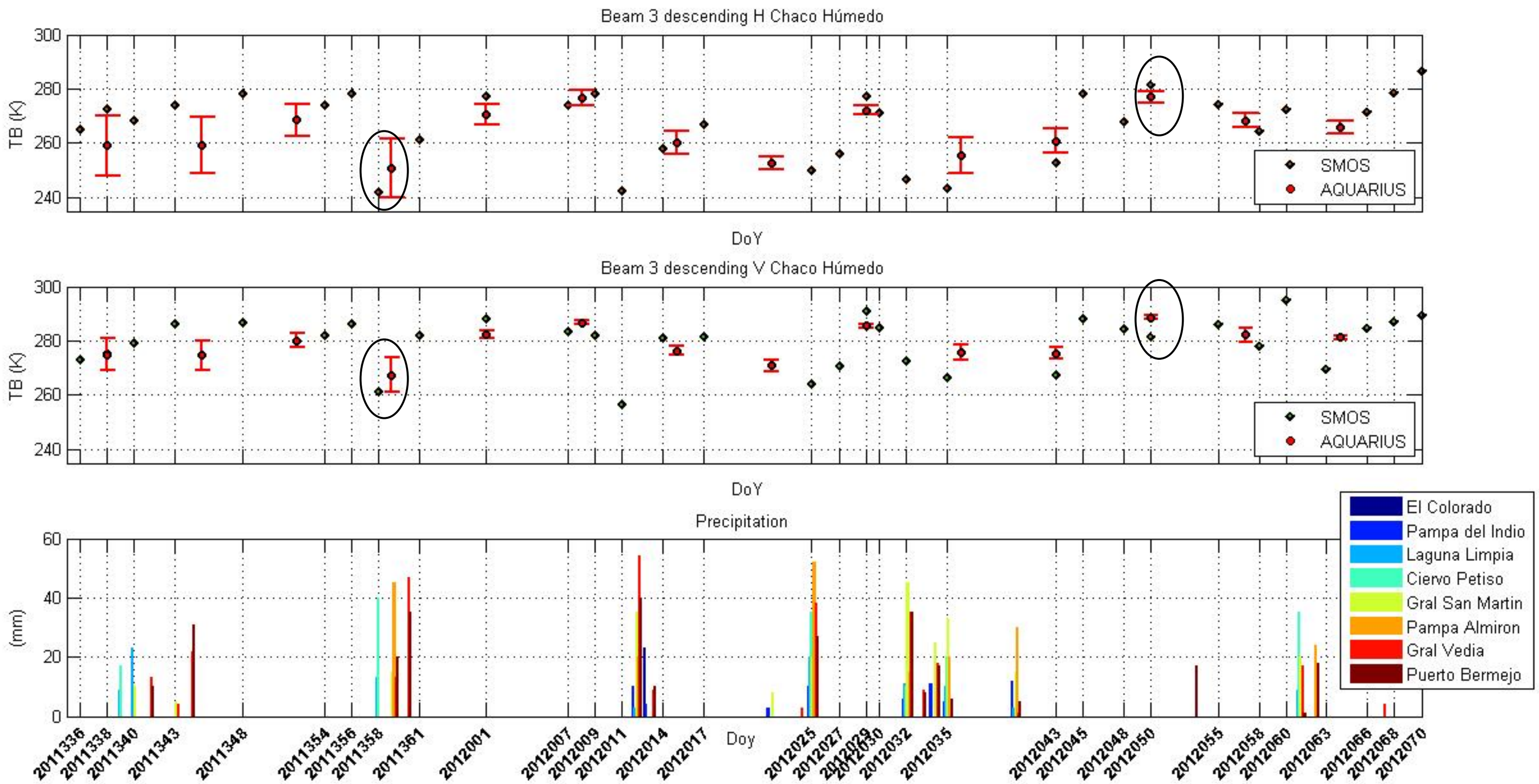


Aquarius
L Band
Tb V
DoY.2011335
Beam.1

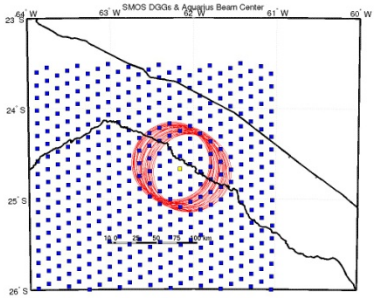


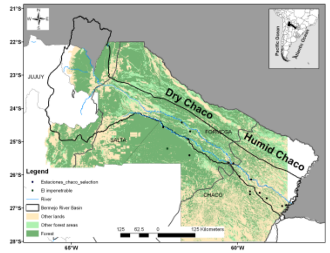

SMOS DGGs & Aquarius Beam Center
61° W
60° W
59° W
58° W
57° W
25° S
26° S
27° S

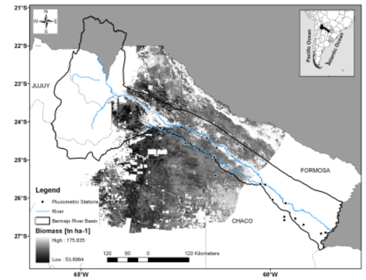

Dry Chaco
Humid Chaco
Legend

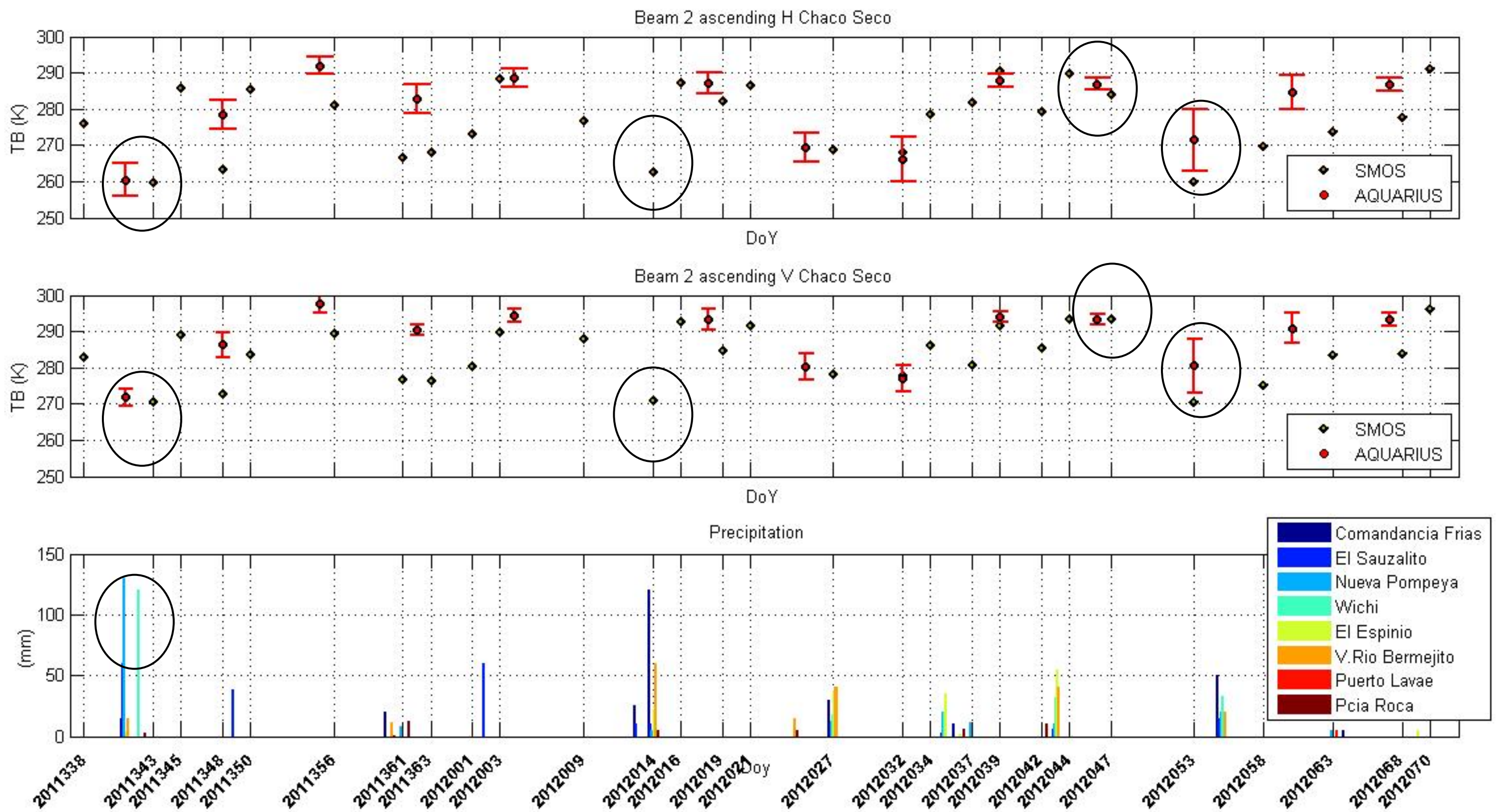

Beam 3 descending H Chaco Húmedo
TB (K)
DoY
SMOS
AQUARIUS
Beam 3 descending V Chaco Húmedo
TB (K)
DoY
SMOS
AQUARIUS
Precipitation
(mm)
Doy
El Colorado
Pampa del Indio
Laguna Limpia
Ciervo Petiso
Gral San Martin
Pampa Almiron
Gral Vedia
Puerto Bermejo

Beam 3


SMOS DGGs & Aquarius Beam Center


Dry Chaco
Humid Chaco
Legend


Legend
Biomass [tn ha-1]


Beam 2 ascending H Chaco Seco
TB (K)
DoY
SMOS
AQUARIUS
Beam 2 ascending V Chaco Seco
TB (K)
DoY
SMOS
AQUARIUS
Precipitation
(mm)
Doy
Comandancia Frias
El Sauzalito
Nueva Pompeya
Wichi
El Espinio
V.Rio Bermejito
Puerto Lavae
Pcia Roca
2011338
2011343
2011345
2011348
2011350
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Beam 2

Concerns, comments

Two main issues:

-retrieval algorithm performance

-radiometric comparisons

Retrieval algorithm performance

- Retrieval procedures, although promising, not satisfactory at this time in this region.
- In NASA algorithm,VWC presents strong temporal variability uncorrelated to NDVI: are minimization procedures convenient to simultaneously obtain SM, VWC and Ts? Maybe constraints to VWC temporal variability are needed.
- IN LPRM (based on the assimilation of data into complex climatology models), the relative weight of SM retrieval is difficult to evaluate.
- Parametrization: landcover is not representative of most of Pampas. b parameter is constant for all crop types and independent of polarization and vegetation condition (NDVI).
- USDA SCA looks promising, but accurate local ancillary data is required (see simulations in Bruscantini poster presentation).

SMOS/Aquarius Radiometric comparison:

✓Different sensor configuration, engineering, acquisition strategies and temporal characteristics make comparison difficult.

✓Too few simultaneous data at this time in this region.

✓Nevertheless, sensitivity to rain events in Chaco forests in both SMOS and Aquarius is observed with close responses.

Work in progress:

- Area comparison between SMOS and Aquarius brightness temperatures at H and V polarization

- Aquarius, SMOS and MWR based SM retrieval procedure valid for the Pampas plains (not global) optimized to monitor extreme hydrological events (EHE).

- Retrieval using VWC derived from other sources (Ej, from MODIS NDVI, from scatterometer Radar vegetation index, (RVI) [Jackson12]).

- Parametrization: b parameter dependent on H and V polarizations and on landcover type/condition. This can be accomplished using theoretical model simulations and in situ measurements.

Thanks!!!!