# Evaluation strategies of coarse resolution SM products for monitoring deficit/excess conditions in the Pampas Plains, Argentina

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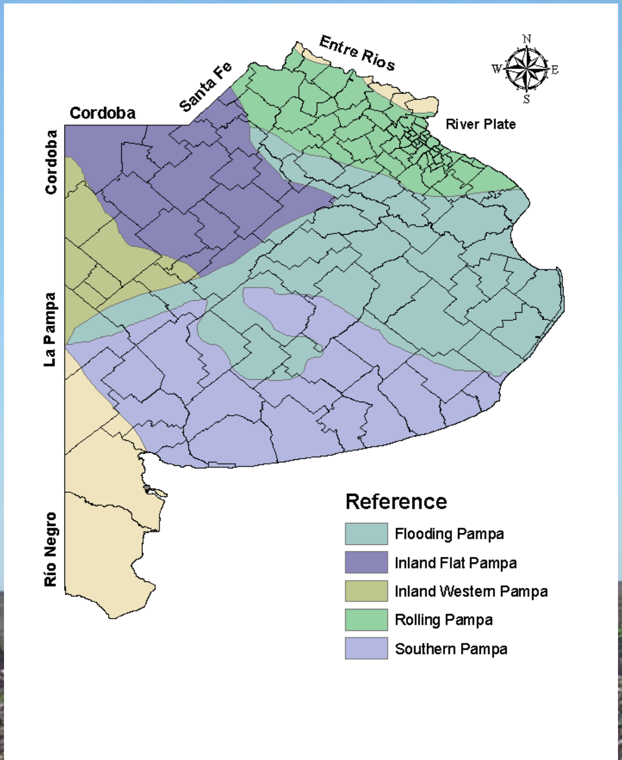
# Pampas Plains




❖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

# Motivations: question 1

Why evaluation strategies?

**Size of the footprint: 20km<footprint<100km**

✓How many points we need to validate a footprint this size?: too many, not available in most parts of the world

✓If we just have a few points, how comparable are these values with the footprint value?: a difficult question.....in this question many issues are addressed (soil type, precipitation pattern, heterogeneity in land cover, vegetation density, others)

✓The last but not the least: there are **several missions and products**

# Motivations: question 1

**AMSR-E** (two systems) Conical scanning radiometer, up to C Band (~40 x 70 Km, better resolution in higher frequency bands), single incidence angle (55°), 10 years data, previous heritage. Lifetime of Amsr-E 1 finished, AMSR-2 available.
*Several SM products based on the same theory but with different retrieval solving strategies: **NASA, LPRM (VUA), USDA, IAFE***

**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.
***One official SMOS product**, several alternative changes (**IAFE** among them)*

**AQUARIUS**: Pushbroom scanning radiometer. Three parallel cross-track beams: 28.7°, 37.8° and 45.6°. Spatial resolution ~ 100 Km. L band. Scatterometer (L band).
***USDA official global product**, IAFE product for Pampas Plains (see poster)*

**ASCAT:** Advanced SCATterometer, onboard Metop, real aperture radar operating at 5.255 GHz (C-band) and using vertically polarized antennas. ***SM product (TU WIEN) (produced by EUMETSAT)***

**SMAP to be launched in 2015**

# Motivations: question 2

Evaluation strategies for what application? (See paper Entekhabi et al, 2010) which performance metrics? Is the same what we need to monitor agricultural drought than for DA for hydrological modeling?

- flood forecasting
- land management
- weather and climate forecasting
- agricultural applications by assisting irrigation scheduling

- early drought prediction through better prediction of plant stress and the ability to quantitatively monitor drought in both space and time.

- Changes to soil moisture patterns are also expected to be an important indicator of global warming

**Consequently, there is a pressing need for soil moisture observations at a wide range of spatial scales, with sufficient temporal repetition to serve the hydrological, agricultural, meteorological and climatological applications**

# Motivations: local demand - objectives

A request for SM coarse resolution products from different application sectors in Argentina:

ORA (Agricultural Risk Office),
INA (National Water Institute,
SMN (National Meteorological Service),
INTA (Agriculture Technology Institute).

- The lack of an adequate SM in situ network in Argentina for validation
- The availability of different products (different algorithms and sensors)
- A basic question that arises: Is the same what it is required from a SM product for agriculture than for data assimilation in hydrology and/or meteorology?

With these motivations in mind, our **objectives** are:

1)To implement evaluation strategies of available coarse resolution SM products for different applications
2) since we are developing a IAFE SM product for the Pampas Plain, to use the same evaluation procedures for our own SM product.

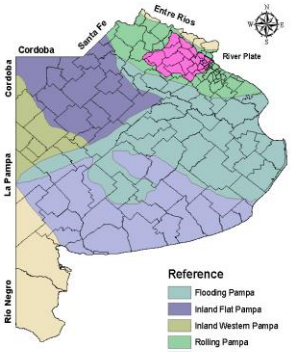
Radiometer brightness temperatures are computed based on a **zero-order radiative transfer model**, usually named ω-τ algorithm that includes vegetation and soil components as

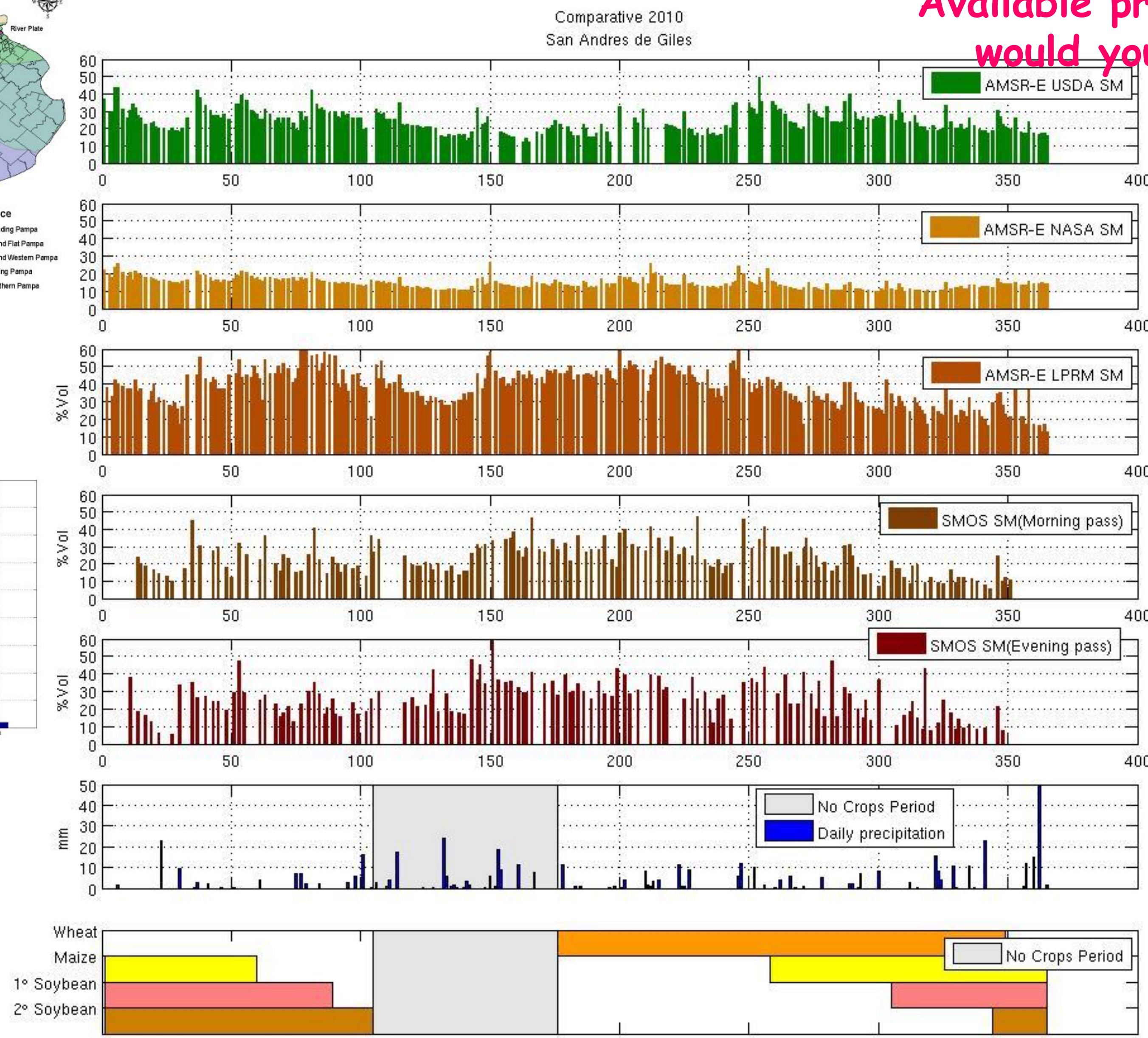
$$TB_p = T_S(1-r_p)\exp(-\tau/\cos\theta) + T_C(1-\omega)[1-\exp(-\tau/\cos\theta)][1+r_p\exp(-\tau/\cos\theta)]$$

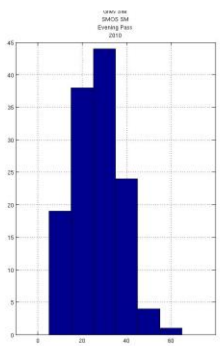
where $p$ refers to polarization, $T_S$ is soil temperature, $T_C$ is vegetation temperature, $r_p$ is the soil reflectivity, $\theta$ is the look angle, τ is the nadir vegetation opacity and ω is the vegetation single scattering albedo.

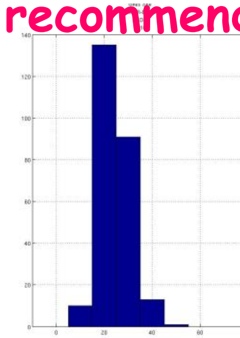
Vegetation opacity is assumed to be unpolarized and is defined as $\tau = bW$, where b is a land cover depending coefficient and W is vegetation water content (kg/m2). There are **different approaches** (all based on this expression), to estimate **the unknowns (soil moisture, vegetation opacity, surface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

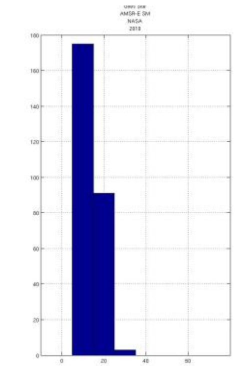
Available products: which would you recommend?

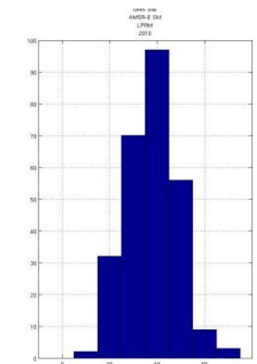








SMOS

AMSR-E

# Evaluation strategies: performance metrics (Hain, Crow and others, 2011)

Two performance metrics using anomalies (spatial and temporal) are used to diagnose the relative skill of each of the data sets considered:

In these comparisons, we compare anomalies rather than the actual SM values since we are primarily interested in the relative change detection skill of each. Studies have shown that SM retrievals tipically exhibit very large differences in the first two statistical moments mean (μ) and standard deviation (σ) yet can still provide representative information about seasonal cycles and departure from normal. If not explicitly corrected, the biases (differences in μ and σ) severely degrade the quantification of meaningful comparisons between data sets.

- Spatial anomaly analysis

It shows how similarly each of the data sets represent wet/dry SM anomalies over the **study spatial domain each year/growing season**

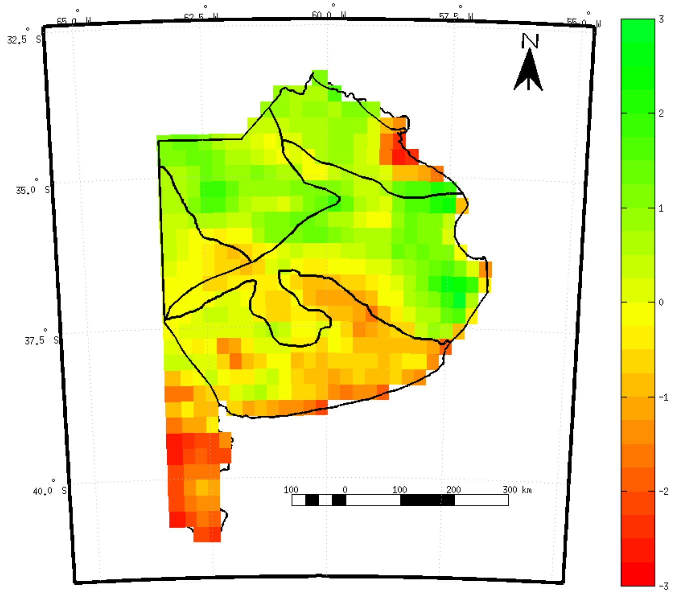
- Metric: correlation analysis

It identifies relationships between data sets as a **function of time at a given grid point,** rather than the spatial distribution of seasonal anomalies.

- Metric: correlation analysis

## Evaluation strategies: working with anomalies, standarized spatial anomalies (Hain, Crow and others, 2011

Standardized seasonal anomaly composites for ASCAT for the period 2007



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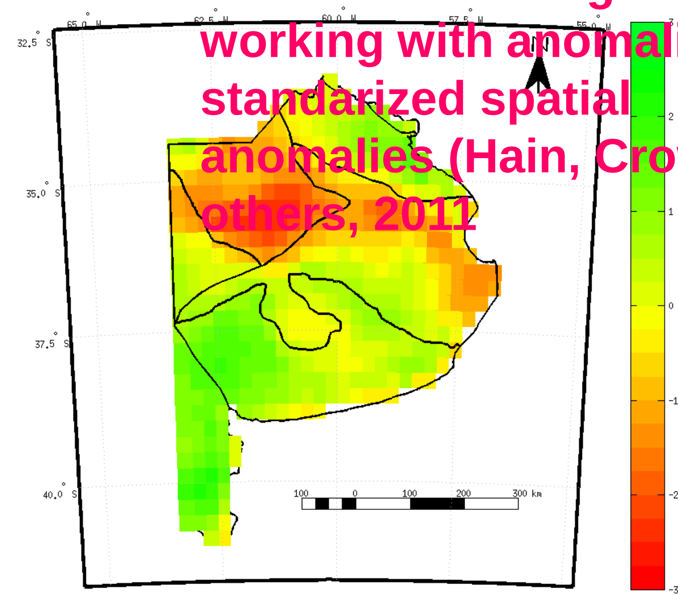
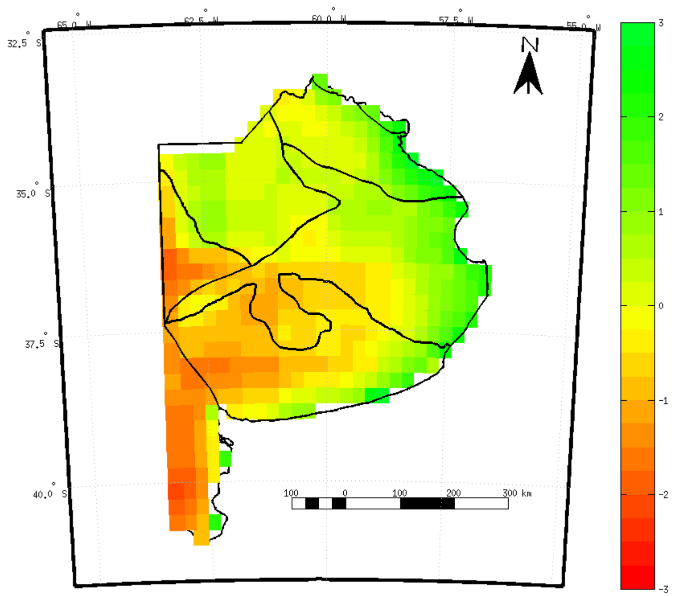


Standardized seasonal anomaly composites for LPRM for the period 2007



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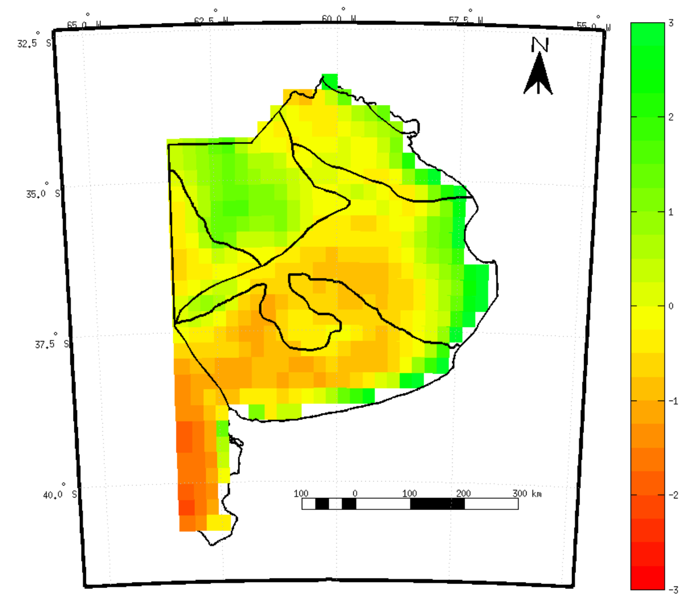
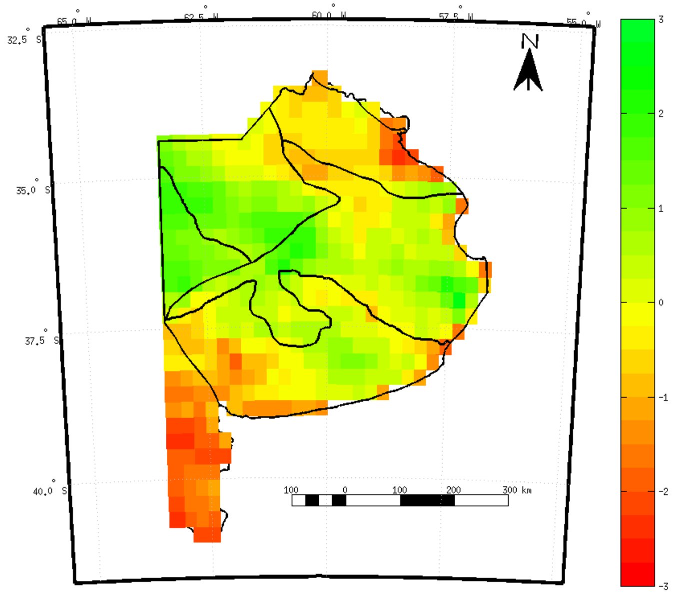


Standardized seasonal anomaly composites for ASCAT for the period 2008

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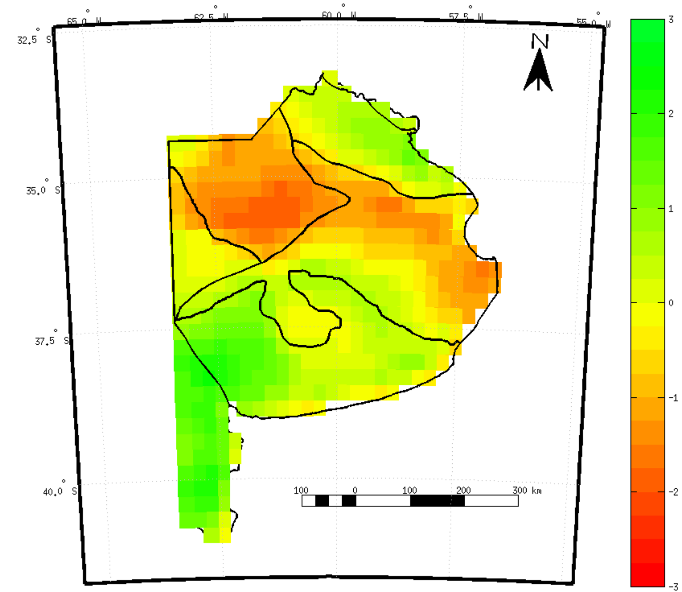


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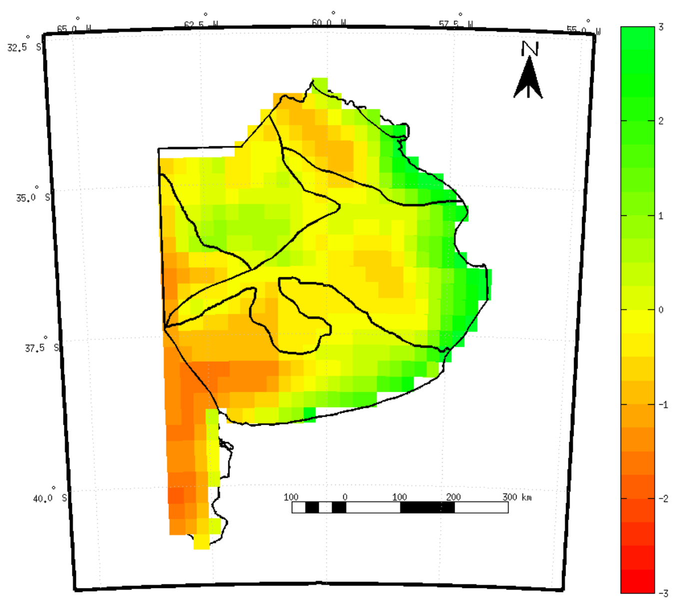


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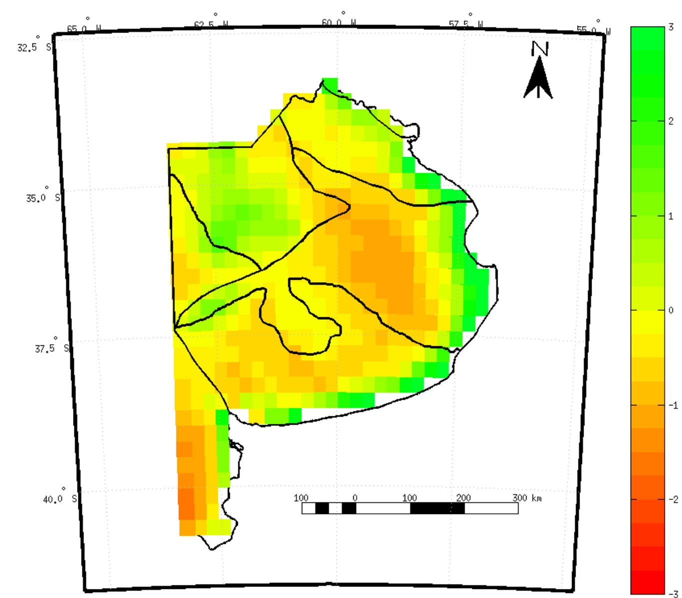

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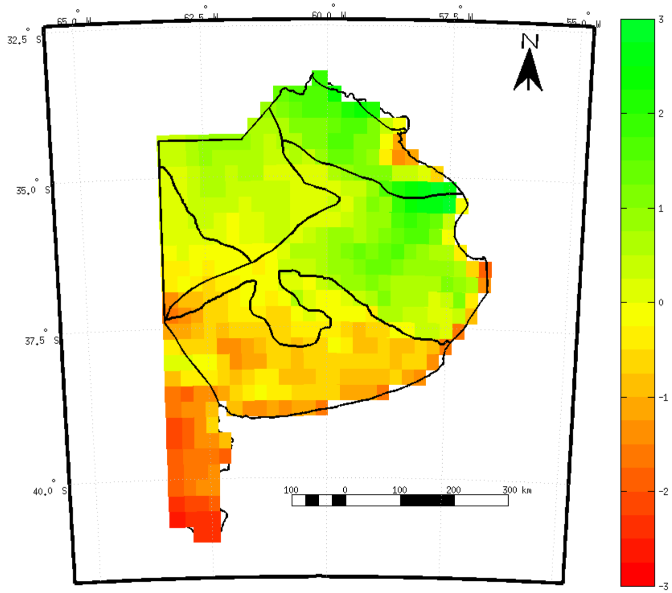


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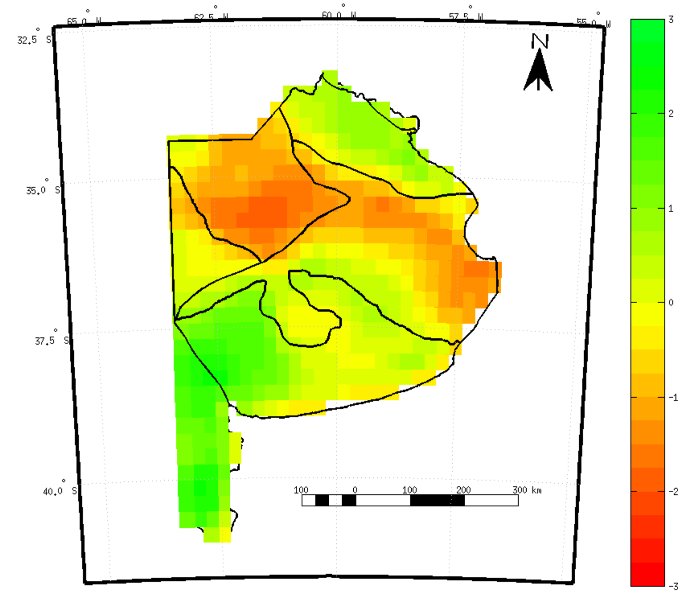


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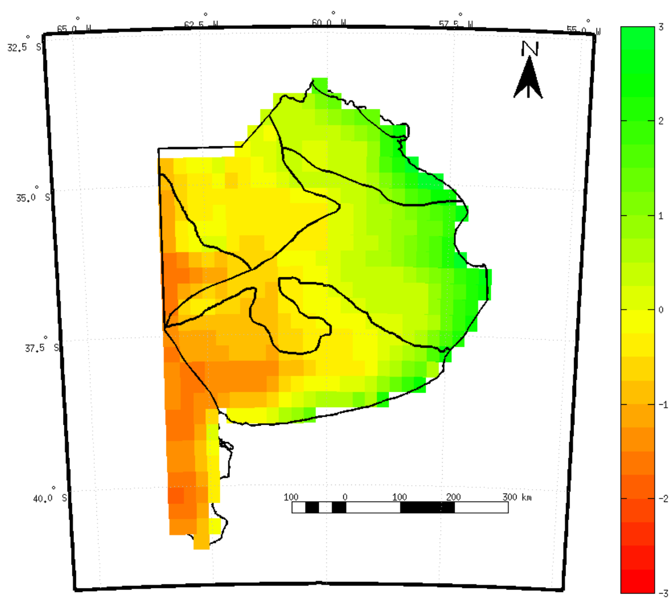


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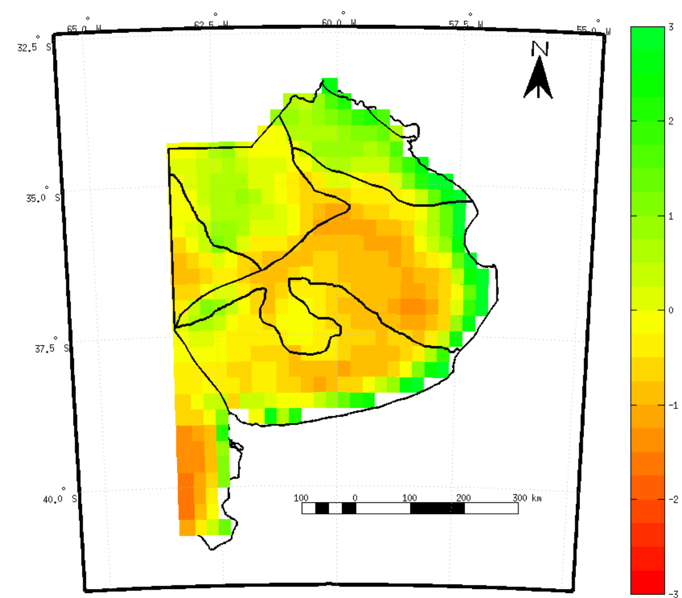

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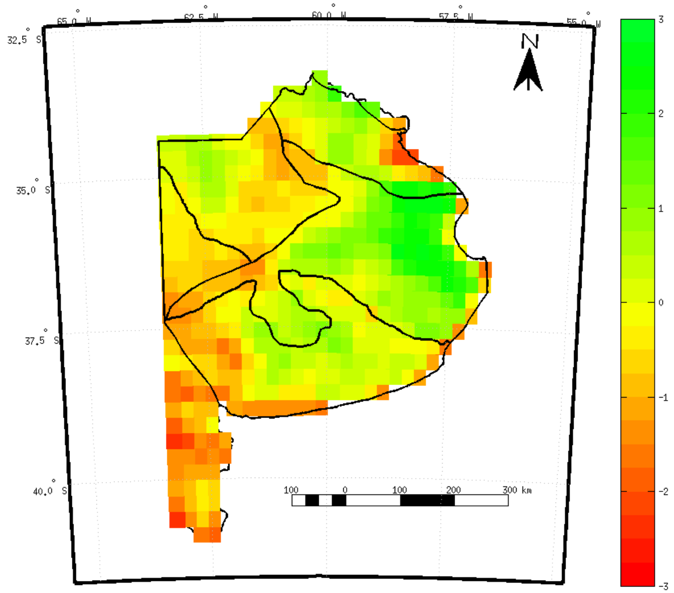


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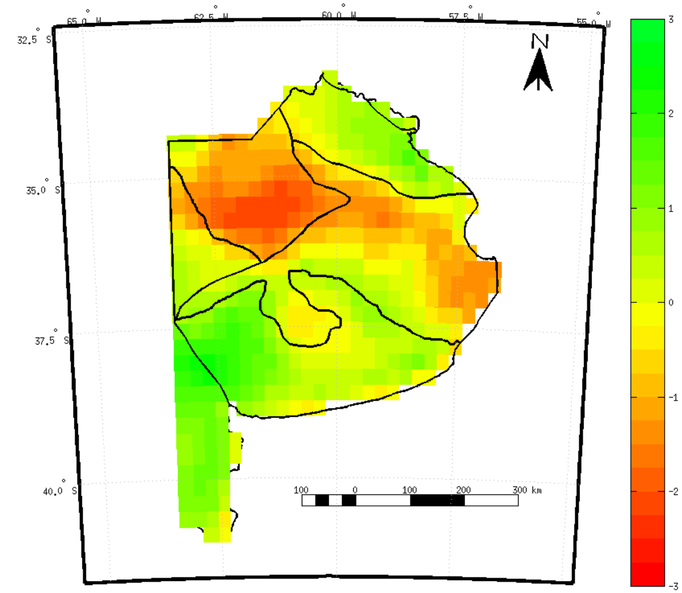
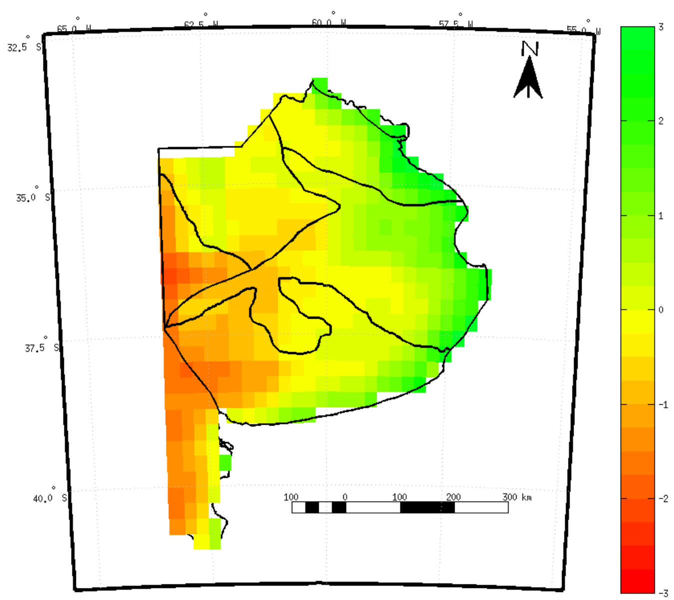



Standardized seasonal anomaly composites for LPRM for the period 2010

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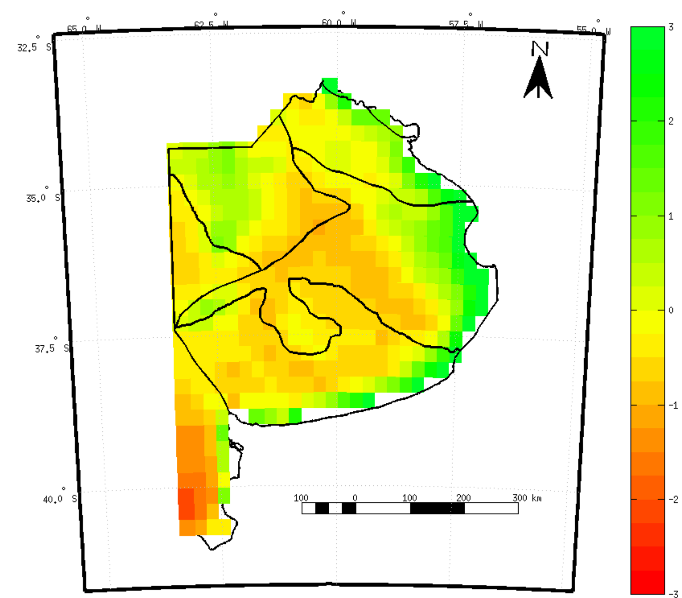

# Correlation values between pairs of products: calendar year

| | 'ASCAT-LPRM' | 'ASCAT-NASA' | 'ASCAT-USDA' | 'LPRM-NASA' | 'LPRM-USDA' | 'NASA-USDA' |
|---|---|---|---|---|---|---|
| **2007** | 0,278 | -0,535 | 0,452 | -0,460 | 0,803 | -0,486 |
| **2008** | 0,120 | -0,569 | 0,113 | -0,438 | 0,754 | -0,225 |
| **2009** | 0,442 | -0,441 | 0,185 | -0,417 | 0,605 | -0,094 |
| **2010** | 0.391 | -0.308 | 0.319 | -0.295 | 0.749 | -0.204 |
| **average** | 0,307 | -0,463 | 0,268 | -0,403 | 0,728 | -0,252 |

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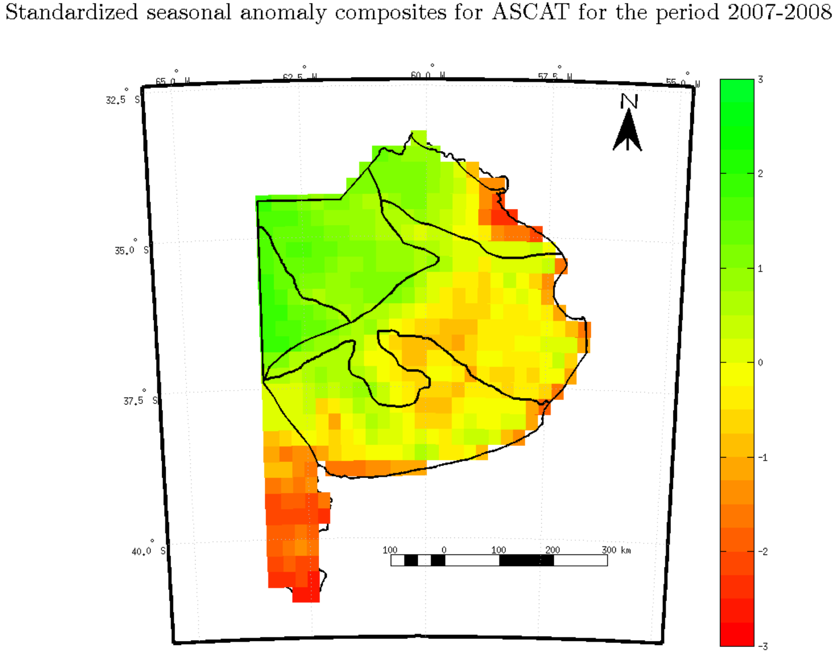
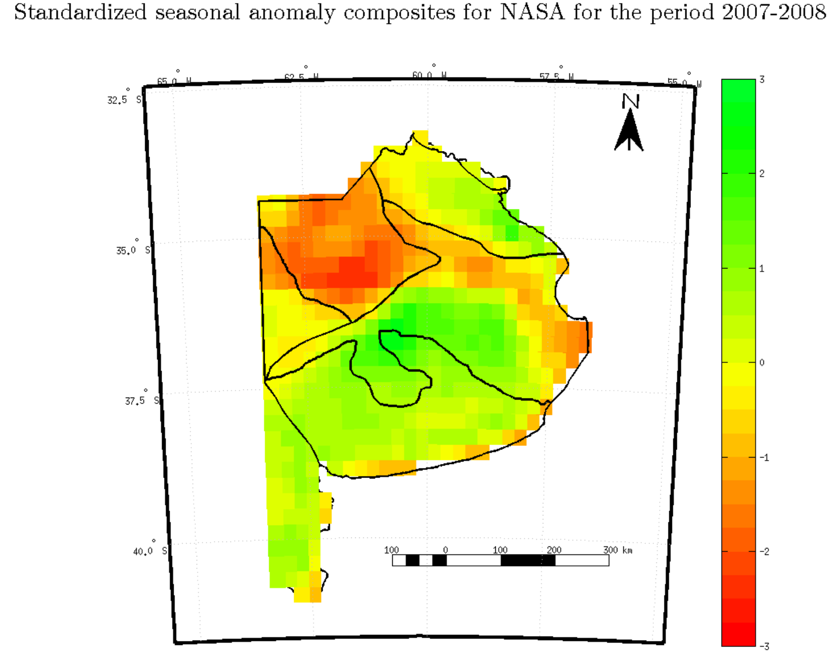
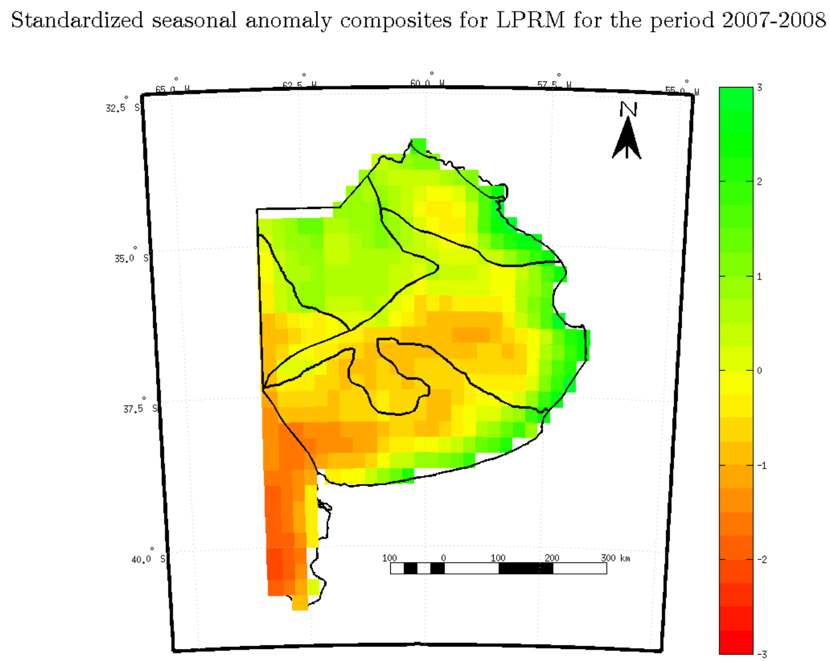
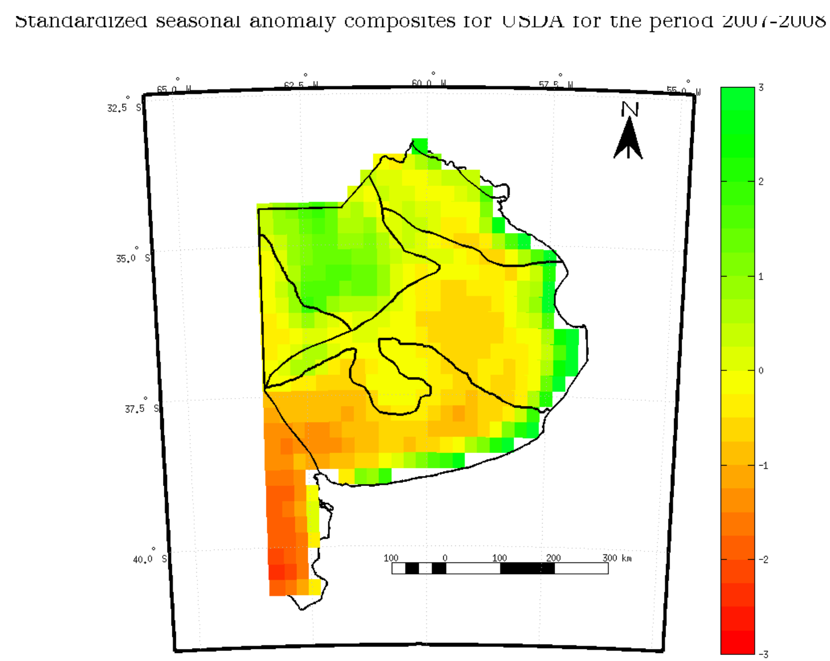
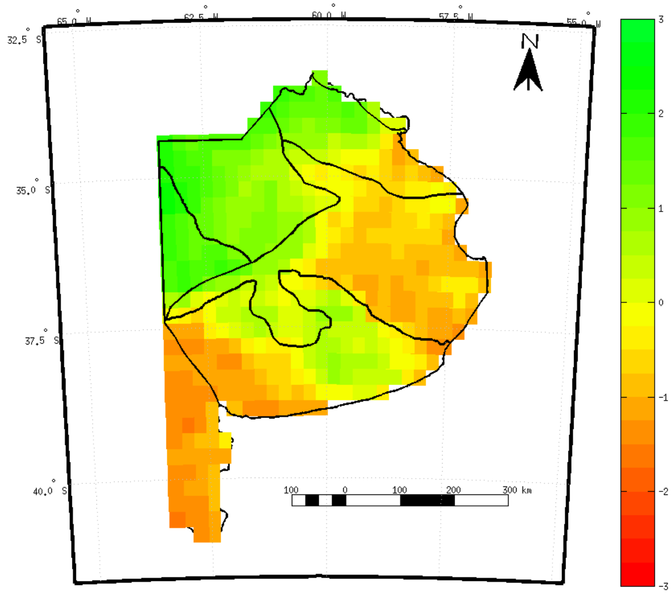

Standardized seasonal anomaly composites for ASCAT for the period 2007-2008


Standardized seasonal anomaly composites for NASA for the period 2007-2008


Standardized seasonal anomaly composites for LPRM for the period 2007-2008


Standardized seasonal anomaly composites for USDA for the period 2007-2008

Standardized seasonal anomaly composites for ASCAT for the period 2008-2009

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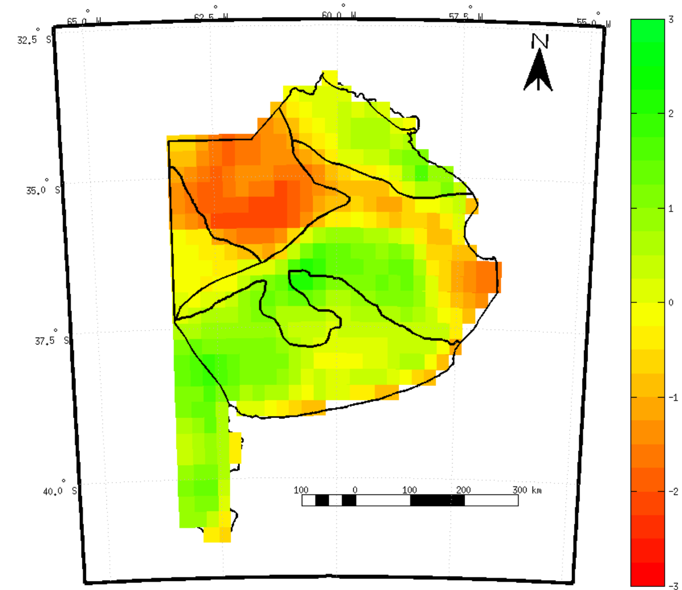
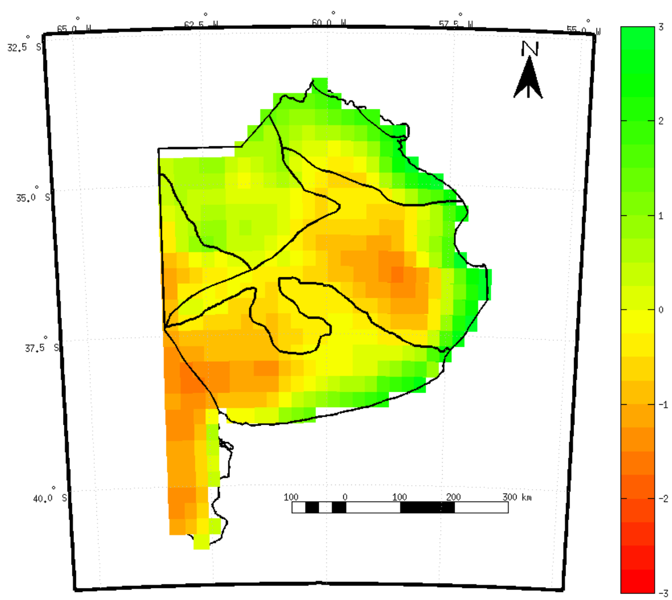



Standardized seasonal anomaly composites for LPRM for the period 2008-2009

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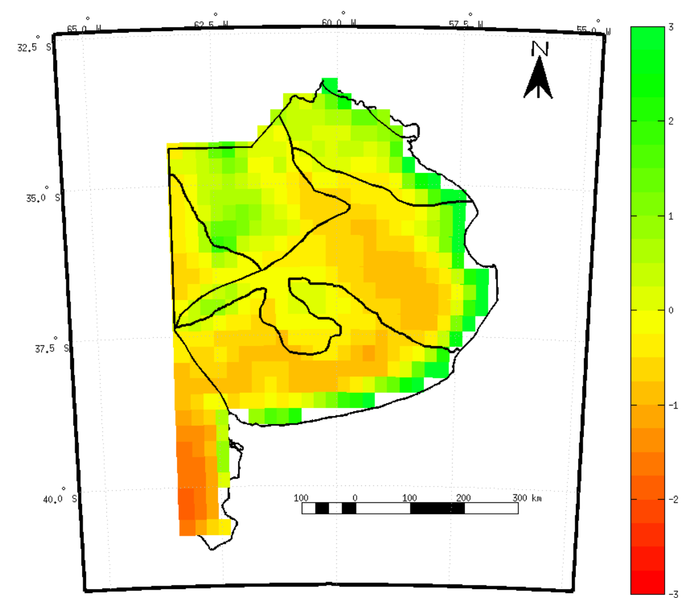

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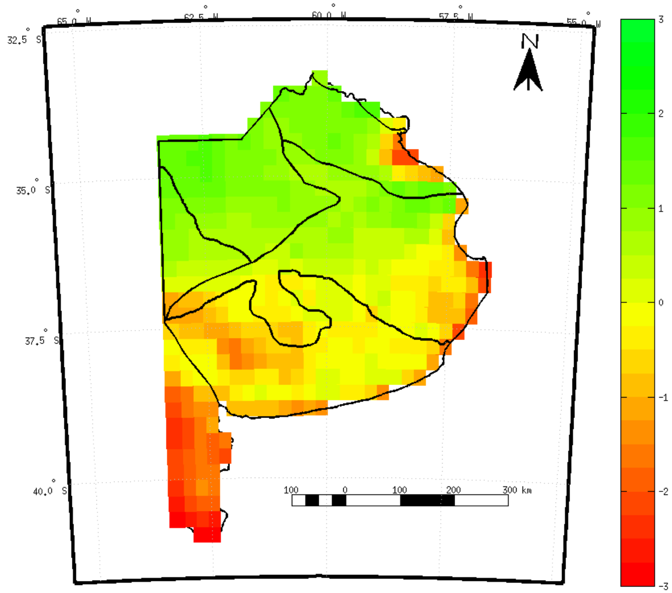


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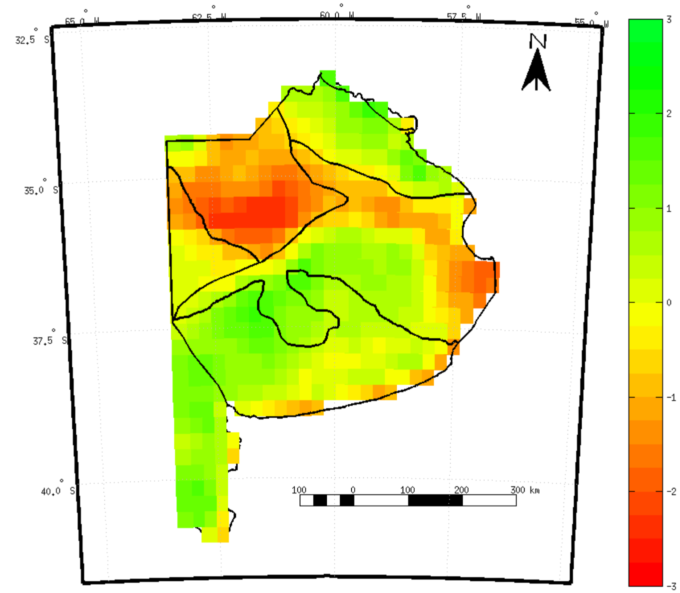


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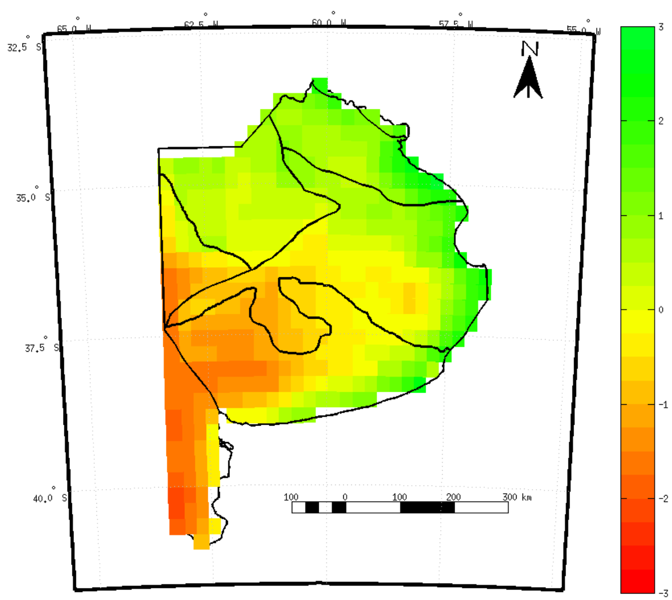


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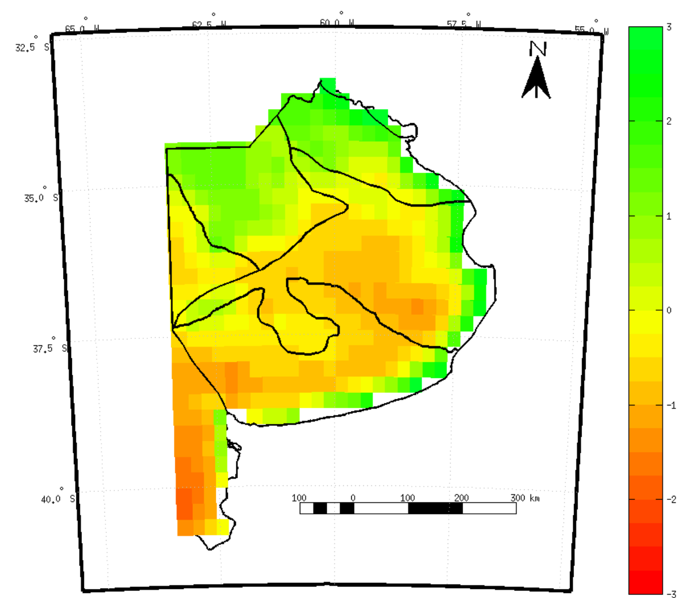
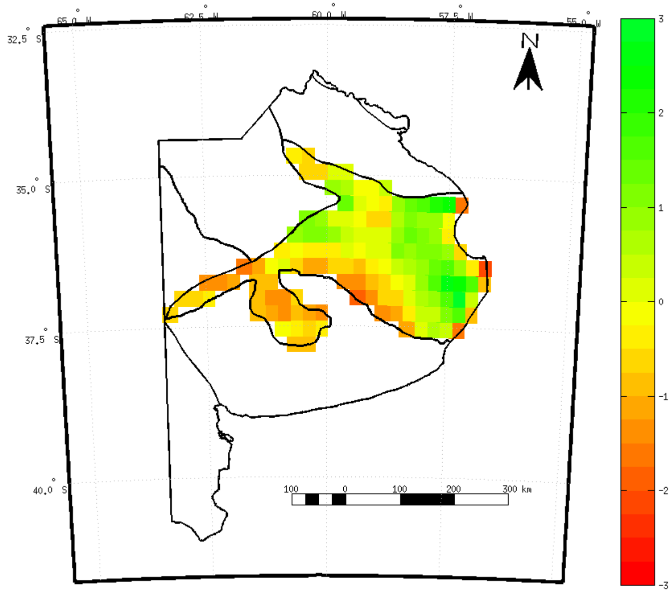


Correlation values between pairs of products:growing season

| | 'ASCAT-LPRM' | 'ASCAT-NASA' | 'ASCAT-USDA' | 'LPRM-NASA' | 'LPRM-USDA' | 'NASA-USDA' |
|---|---|---|---|---|---|---|
| **2007-2008** | 0,164 | -0,425 | 0,333 | -0,522 | 0,880 | -0,514 |
| **2008-2009** | 0,256 | -0,507 | 0,178 | -0,452 | 0,839 | -0,333 |
| **2009-2010** | 0,377 | -0,384 | 0,436 | -0,487 | 0,763 | -0,360 |
| **average** | 0,266 | -0,439 | 0,316 | -0,487 | 0,827 | 0,402 |

Standardized seasonal anomaly composites for ASCAT for the period 2007
Ecorregion: Flooding Pampa




Standardized seasonal anomaly composites for NASA for the period 2007
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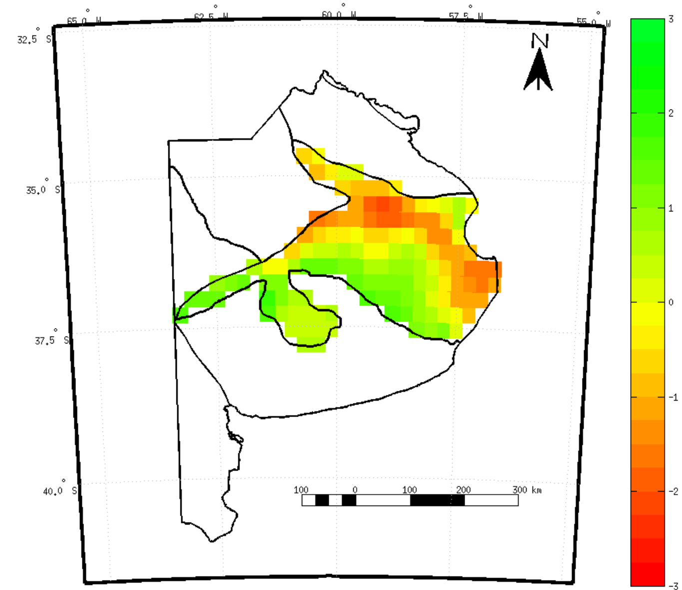


Standardized seasonal anomaly composites for LPRM for the period 2007
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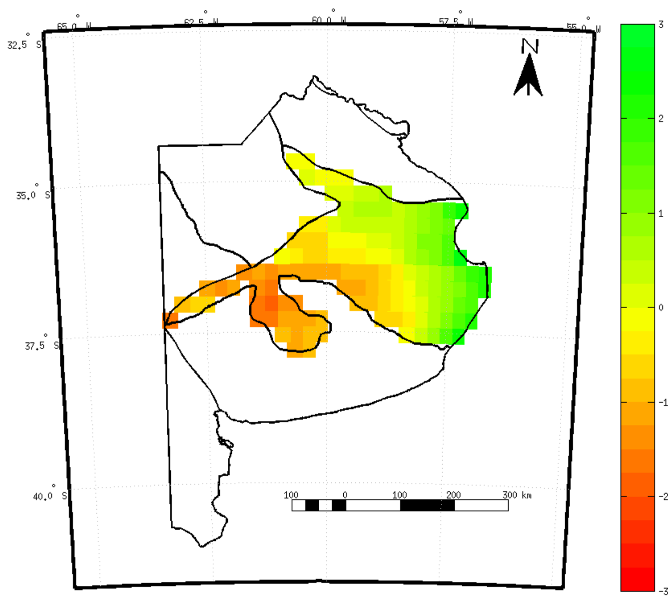


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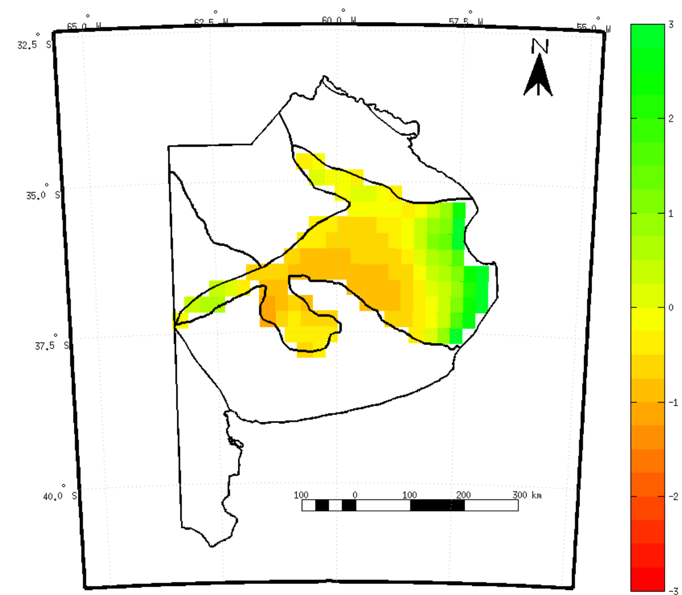

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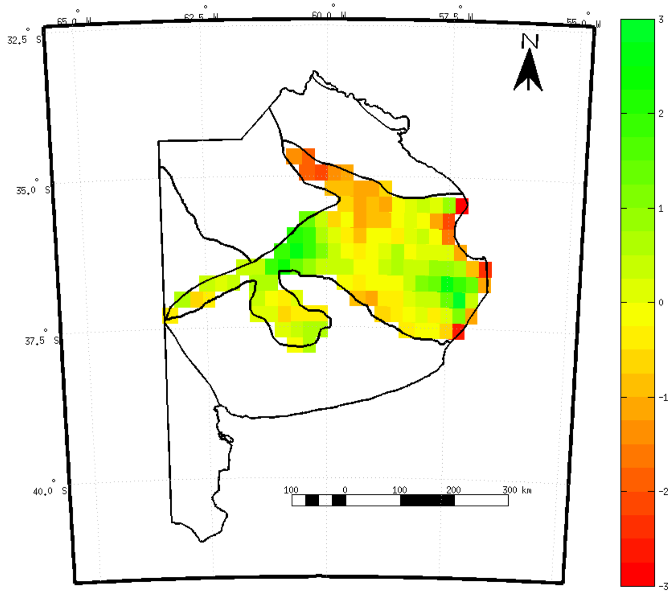


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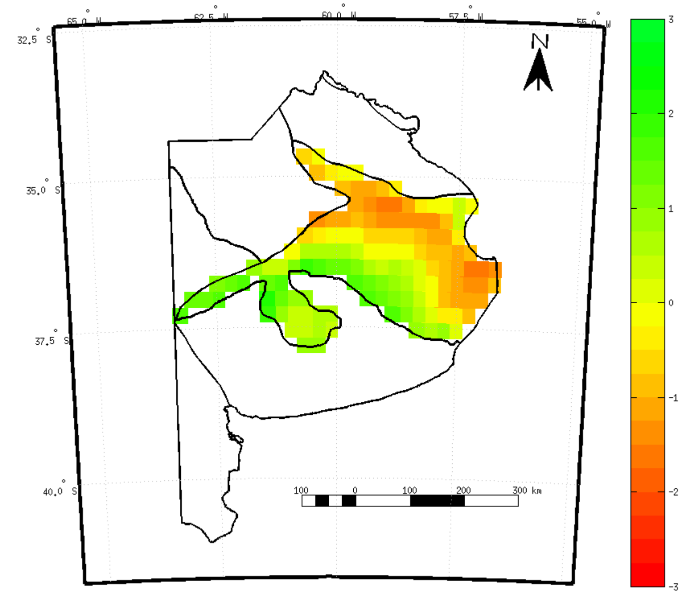


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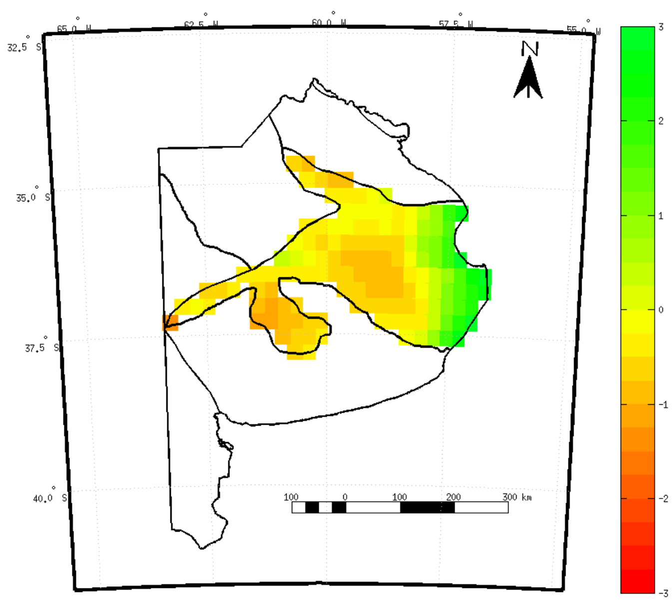


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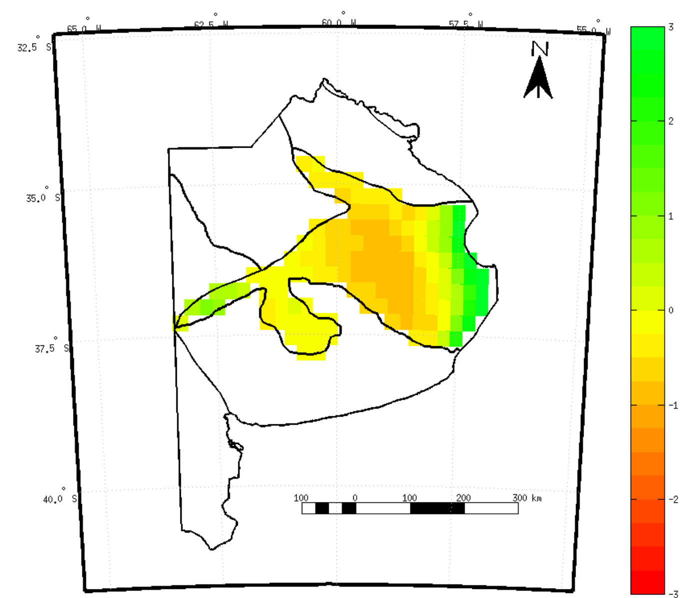

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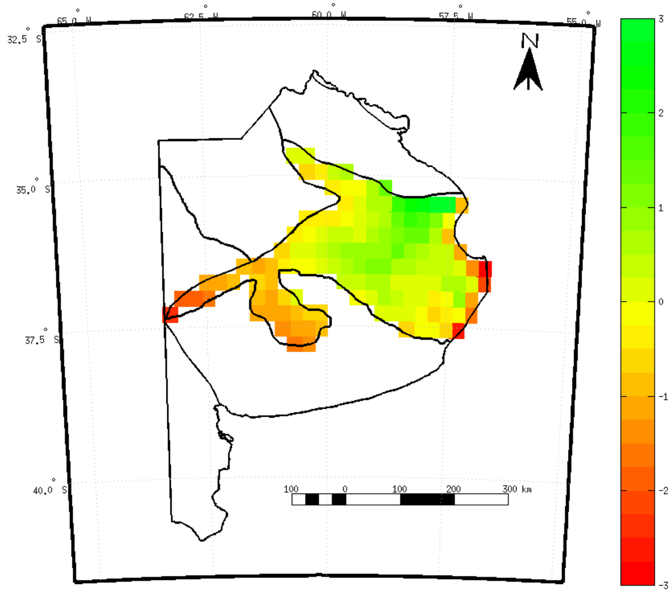


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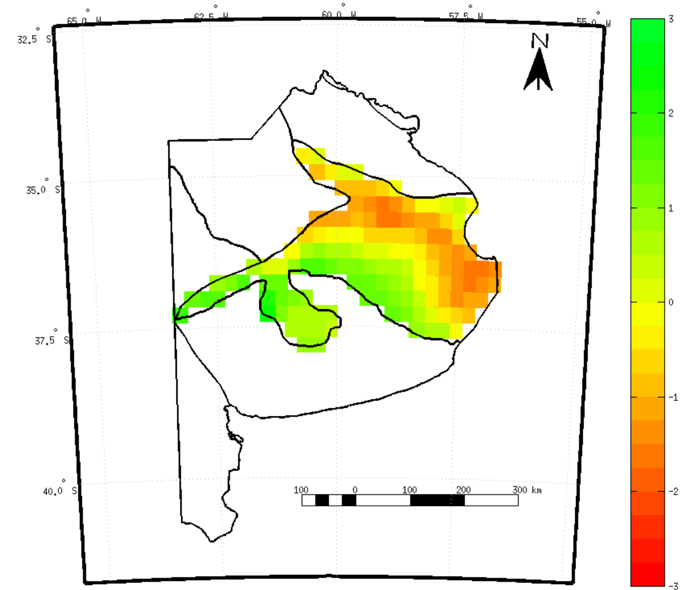
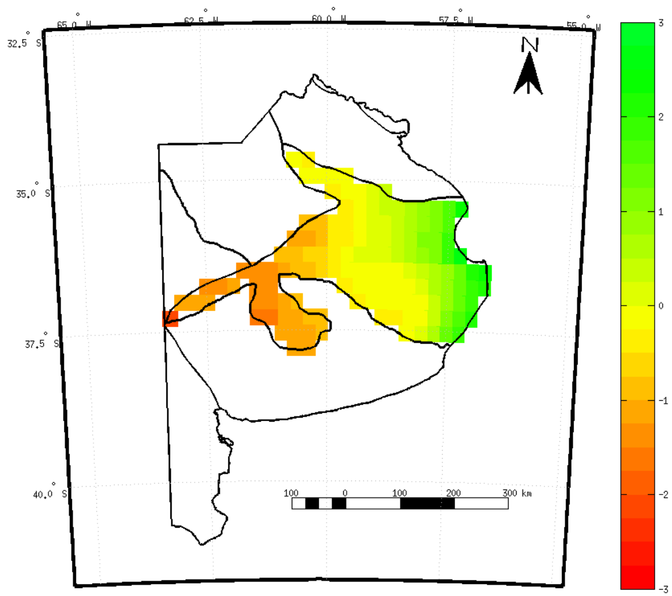



Standardized seasonal anomaly composites for LPRM for the period 2009
Ecorregion: Flooding Pampa

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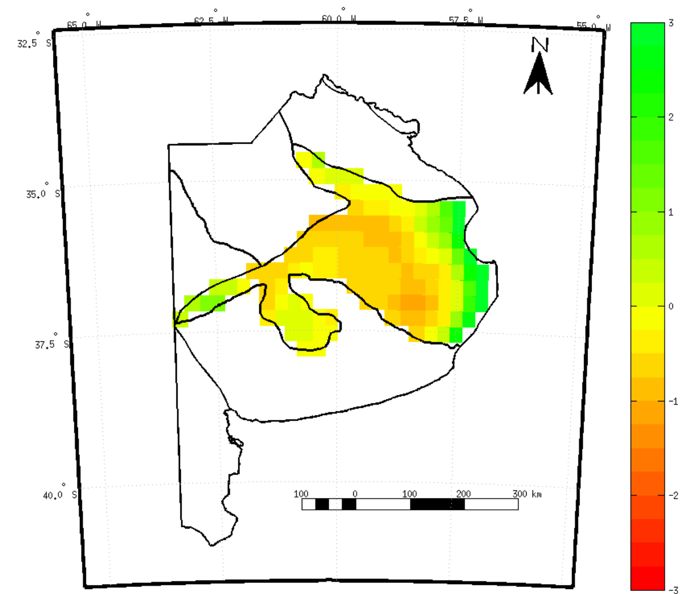

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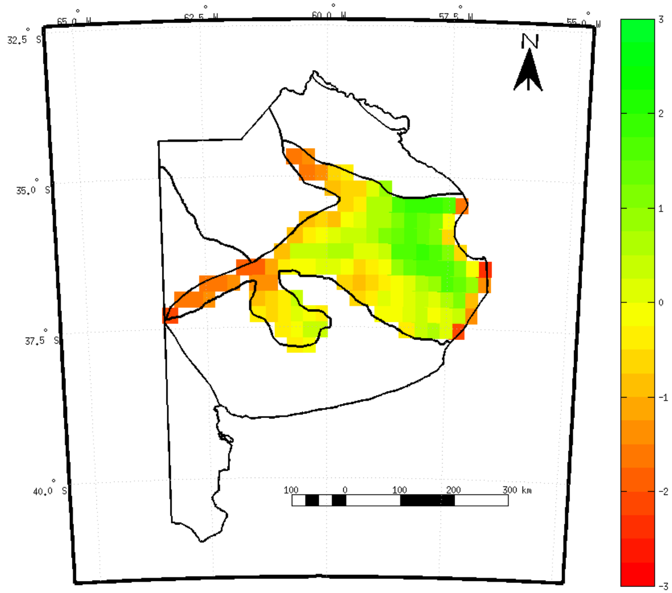


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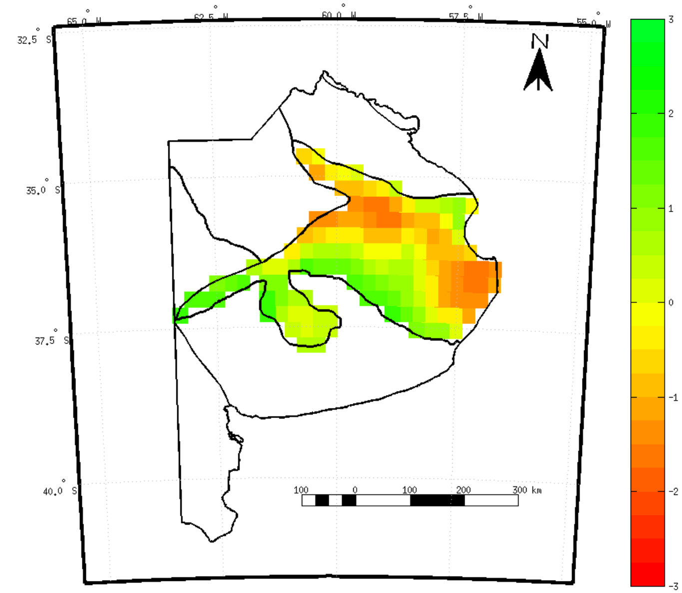


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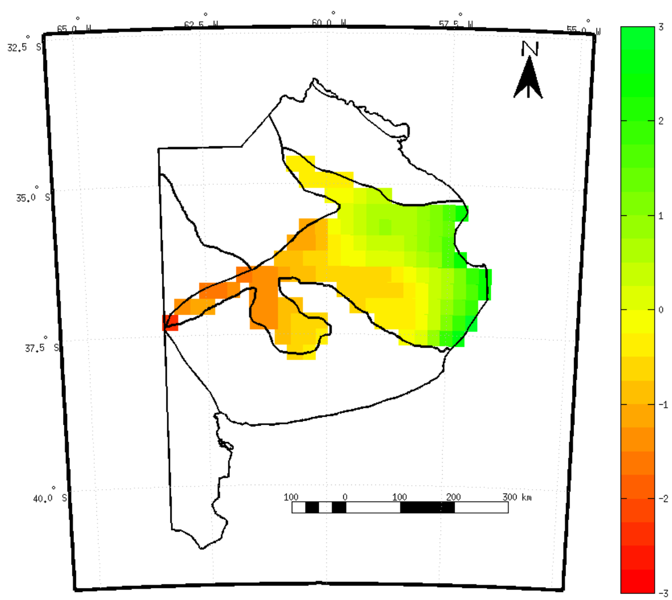


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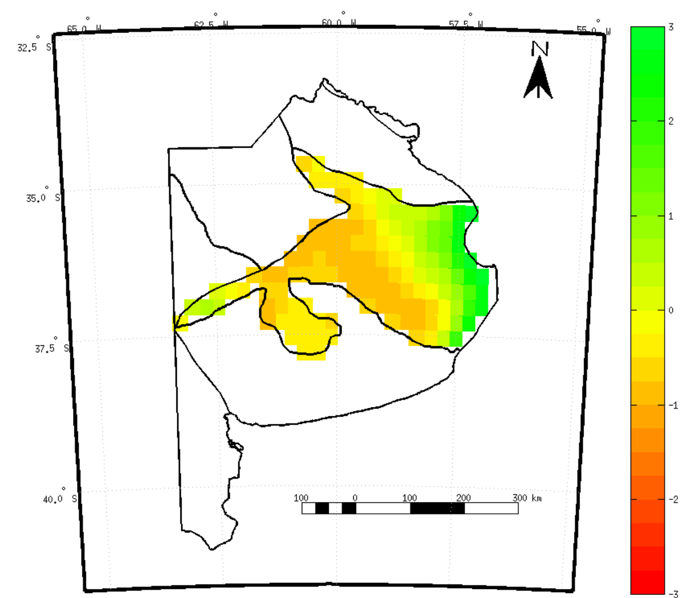
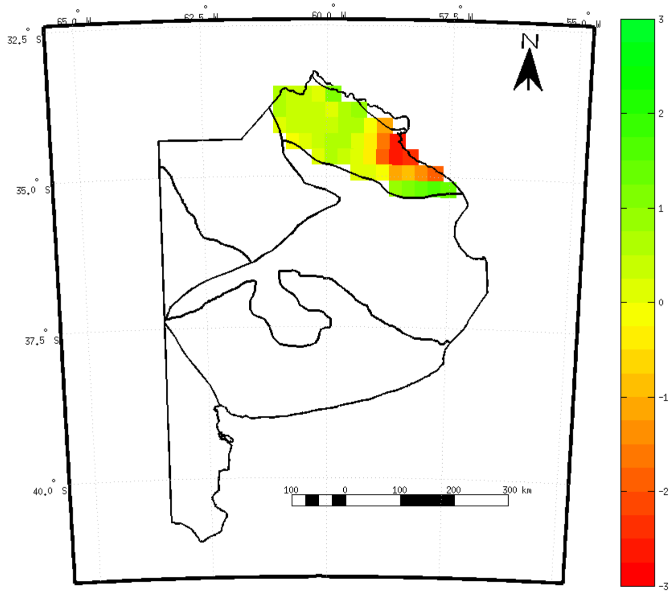
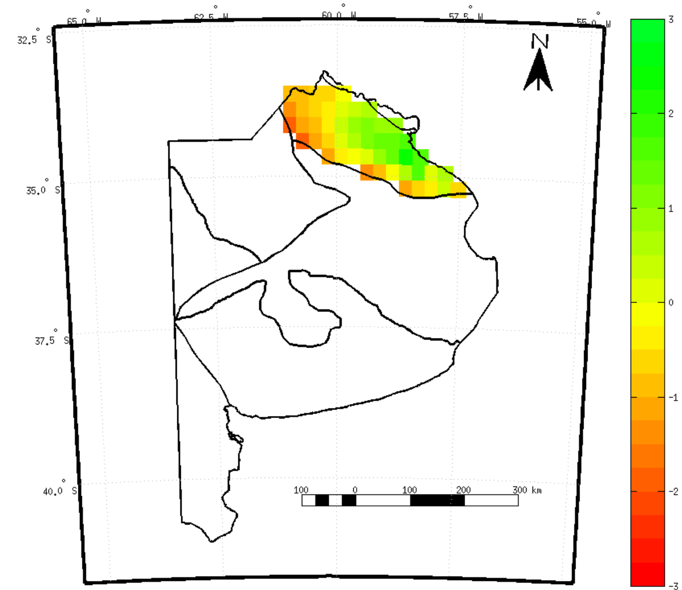


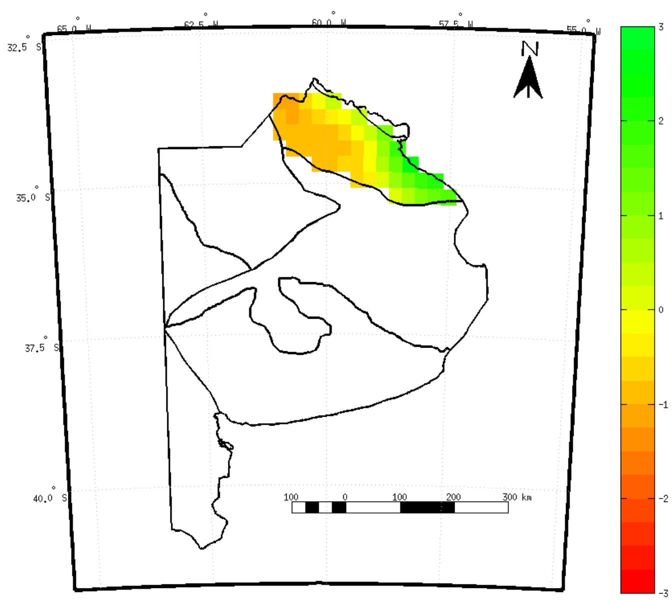
Standardized seasonal anomaly composites for ASCAT for the period 2007
Ecorregion: Rolling Pampa



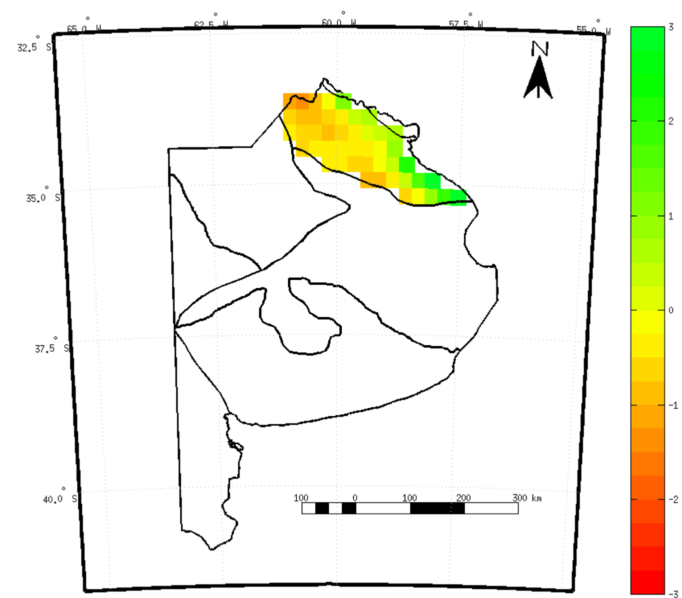

Standardized seasonal anomaly composites for NASA for the period 2007
Ecorregion: Rolling Pampa



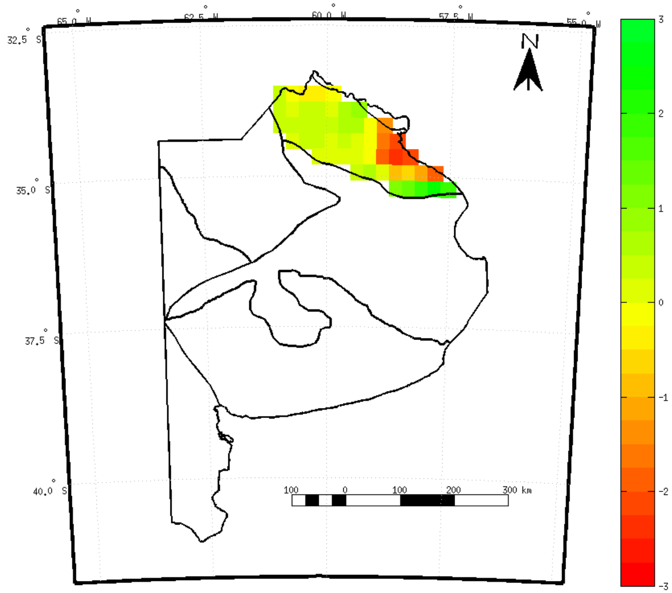

Standardized seasonal anomaly composites for LPRM for the period 2007
Ecorregion: Rolling Pampa



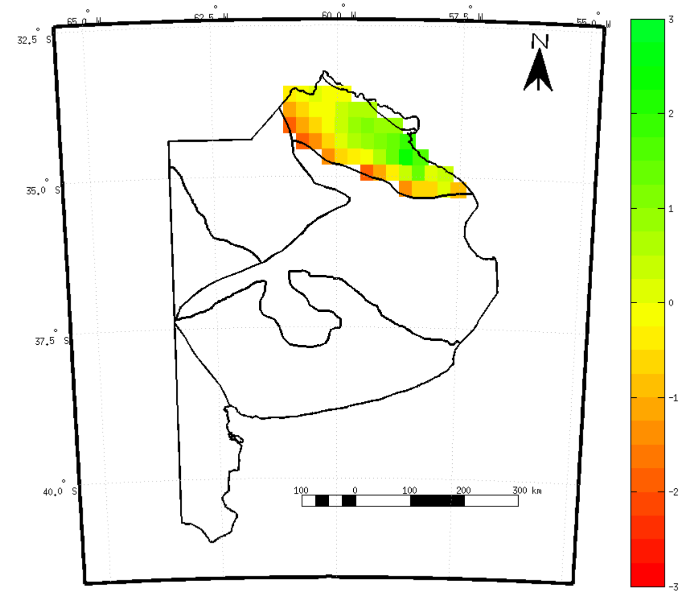

Standardized seasonal anomaly composites for USDA for the period 2007
Ecorregion: Rolling Pampa



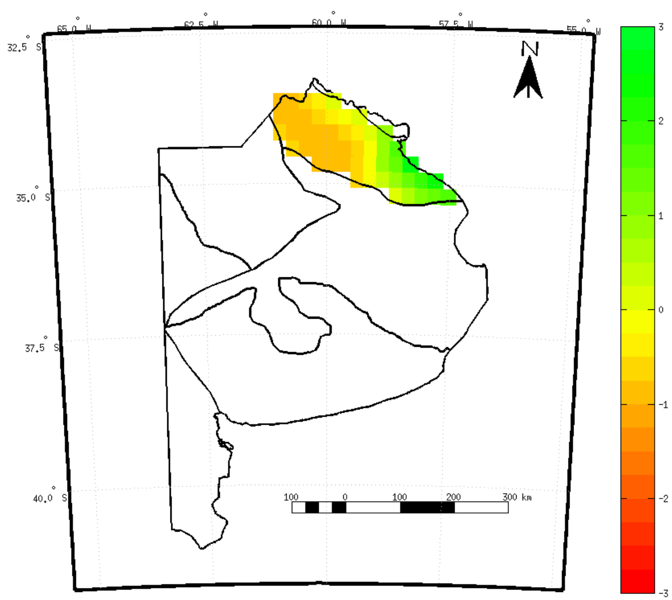
Standardized seasonal anomaly composites for ASCAT for the period 2008
Ecorregion: Rolling Pampa



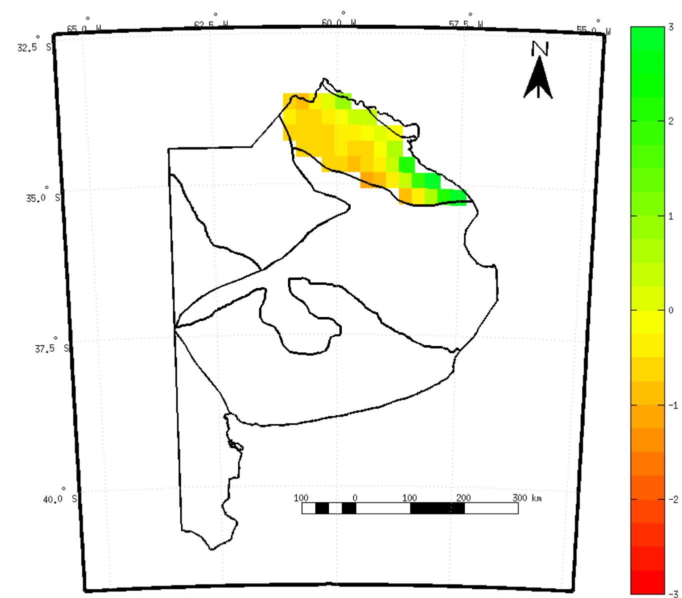

Standardized seasonal anomaly composites for NASA for the period 2008
Ecorregion: Rolling Pampa



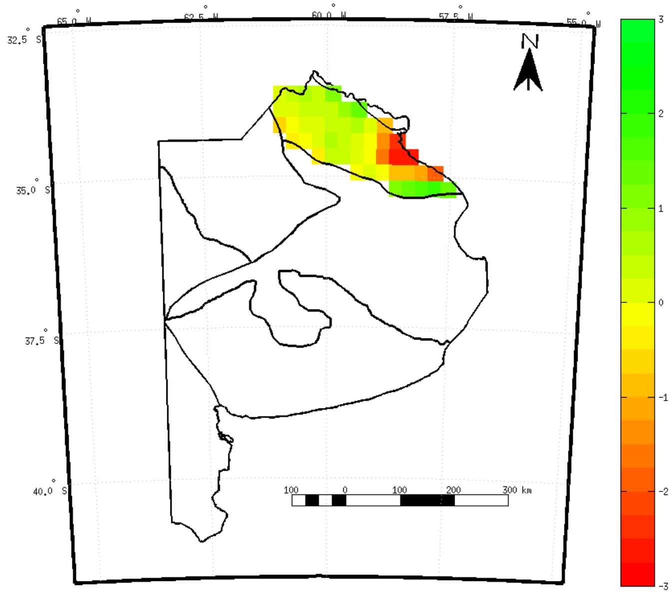

Standardized seasonal anomaly composites for LPRM for the period 2008
Ecorregion: Rolling Pampa



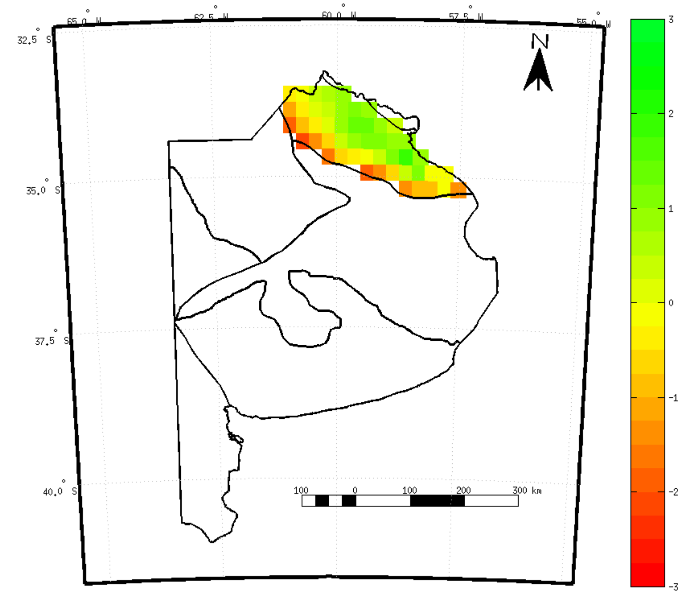

Standardized seasonal anomaly composites for USDA for the period 2008
Ecorregion: Rolling Pampa



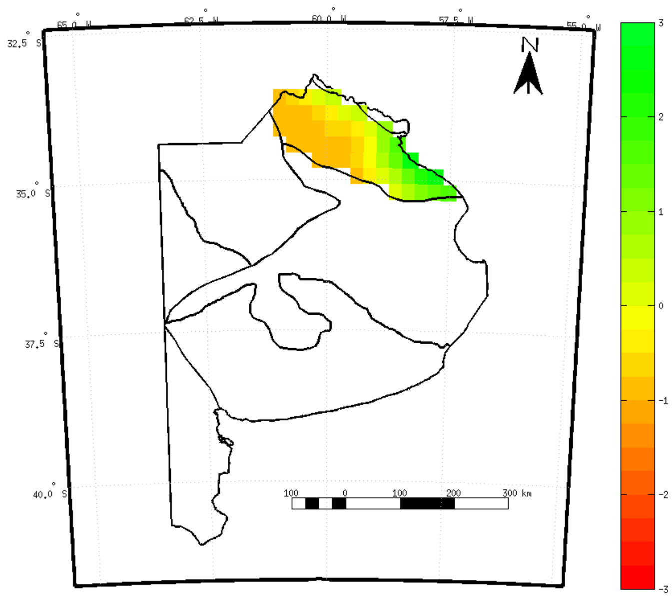
Standardized seasonal anomaly composites for ASCAT for the period 2009
Ecorregion: Rolling Pampa



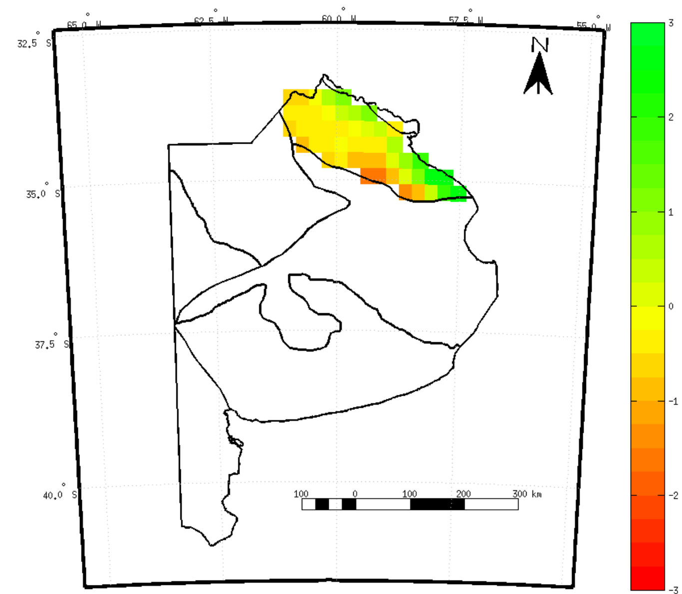

Standardized seasonal anomaly composites for NASA for the period 2009
Ecorregion: Rolling Pampa



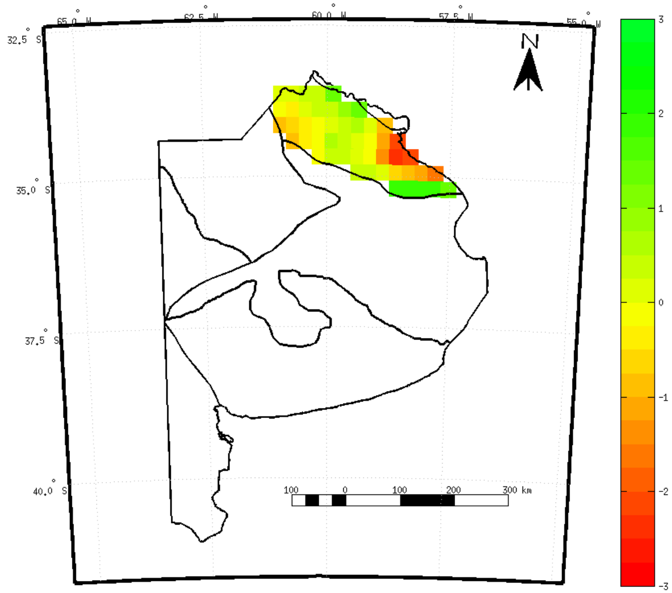

Standardized seasonal anomaly composites for LPRM for the period 2009
Ecorregion: Rolling Pampa



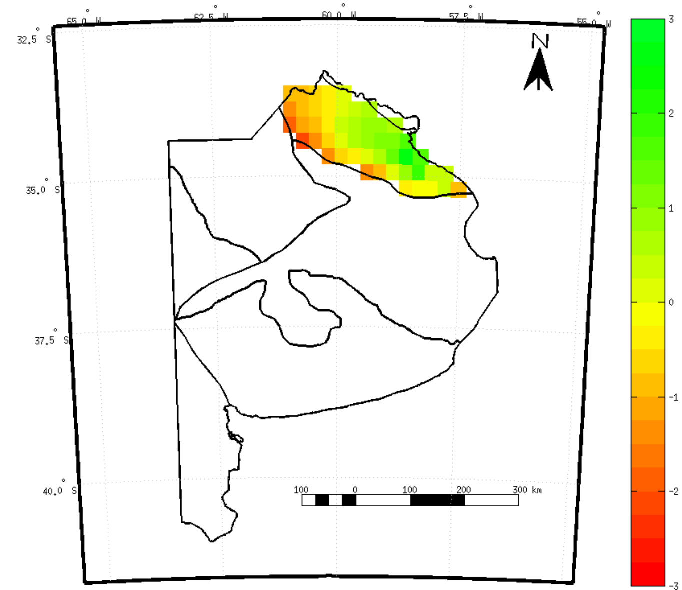

Standardized seasonal anomaly composites for USDA for the period 2009
Ecorregion: Rolling Pampa



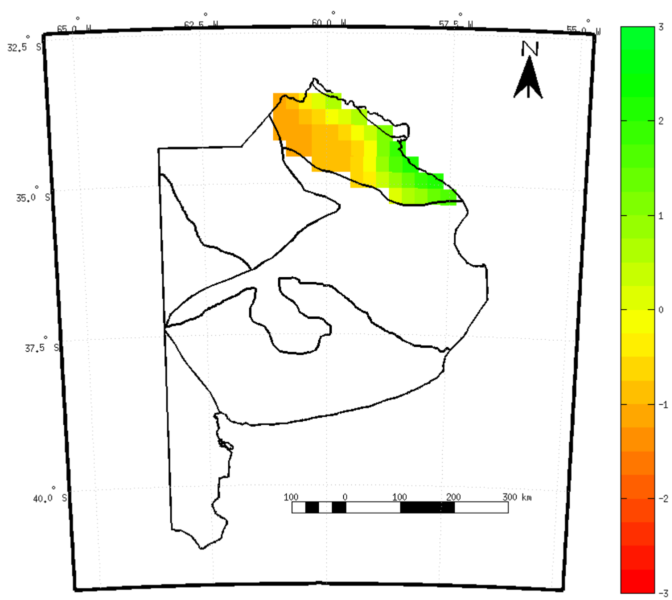
Standardized seasonal anomaly composites for ASCAT for the period 2010
Ecorregion: Rolling Pampa



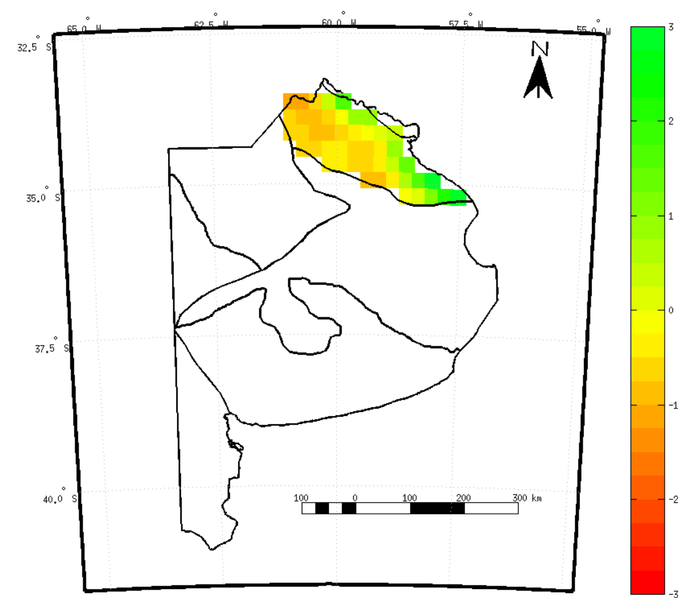

Standardized seasonal anomaly composites for NASA for the period 2010
Ecorregion: Rolling Pampa




Standardized seasonal anomaly composites for LPRM for the period 2010
Ecorregion: Rolling Pampa




Standardized seasonal anomaly composites for USDA for the period 2010
Ecorregion: Rolling Pampa



# Spatial correlation: calendar year

| | 'ASCAT-LPRM' | 'ASCAT-NASA' | 'ASCAT-USDA' | 'LPRM-NASA' | 'LPRM-USDA' | 'NASA-USDA' |
|---|---|---|---|---|---|---|
| **2007** | 0,278 | -0,535 | 0,452 | -0,460 | 0,803 | -0,486 |
| **2008** | 0,120 | -0,569 | 0,113 | -0,438 | 0,754 | -0,225 |
| **2009** | 0,442 | -0,441 | 0,185 | -0,417 | 0,605 | -0,094 |
| **2010** | 0.391 | -0.308 | 0.319 | -0.295 | 0.749 | -0.204 |
| **average** | 0,307 | -0,463 | 0,268 | -0,403 | 0,728 | -0,252 |

# Spatial correlation: growing season

| | 'ASCAT-LPRM' | 'ASCAT-NASA' | 'ASCAT-USDA' | 'LPRM-NASA' | 'LPRM-USDA' | 'NASA-USDA' |
|---|---|---|---|---|---|---|
| **2007-2008** | 0,164 | -0,425 | 0,333 | -0,522 | 0,880 | -0,514 |
| **2008-2009** | 0,256 | -0,507 | 0,178 | -0,452 | 0,839 | -0,333 |
| **2009-2010** | 0,377 | -0,384 | 0,436 | -0,487 | 0,763 | -0,360 |
| **average** | 0,266 | -0,439 | 0,316 | -0,487 | 0,827 | 0,402 |

# Spatial correlation: flooding pampas ecoregion

| | 'ASCAT-LPRM' | 'ASCAT-NASA' | 'ASCAT-USDA' | 'LPRM-NASA' | 'LPRM-USDA' | 'NASA-USDA' |
|---|---|---|---|---|---|---|
| **2007** | 0,484 | -0,504 | 0,545 | -0,652 | 0,805 | -0,402 |
| **2008** | -0,096 | 0,098 | 0,107 | -0,518 | 0,866 | -0,244 |
| **2009** | 0,265 | -0,254 | -0,051 | -0,649 | 0,633 | -0,269 |
| **2010** | 0,357 | -0,320 | 0,318 | -0,579 | 0,812 | -0,375 |
| **average** | 0,253 | -0,245 | 0,229 | -0,599 | 0,779 | -0,323 |

## Evaluation strategies: working with anomalies, standarized temporal anomalies (Hain, Crow and others, 2011

It identifies relationships between data sets as a **function of time at a given grid point**, rather than the spatial distribution of seasonal anomalies.

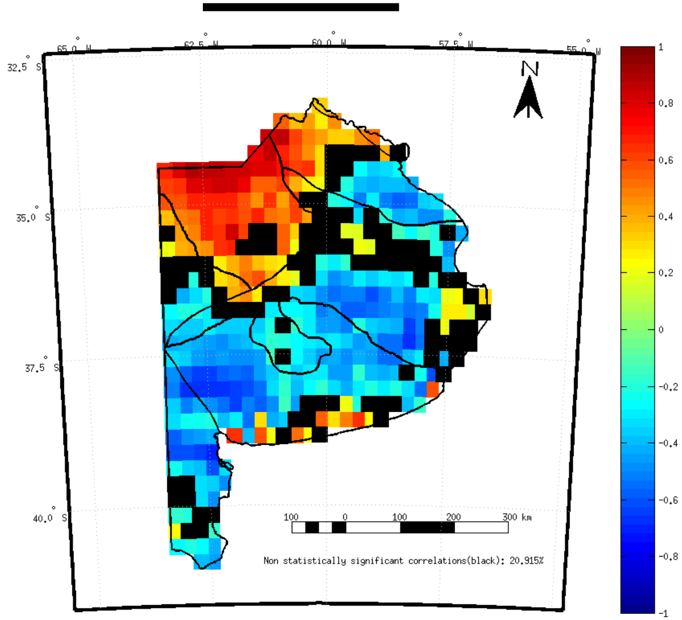
Black denotes pixels where either one of the sets did not exhibit statistically significant correlations.

Redish colors denote pixels with increasing positive r that were significant up to 95% confidence interval.

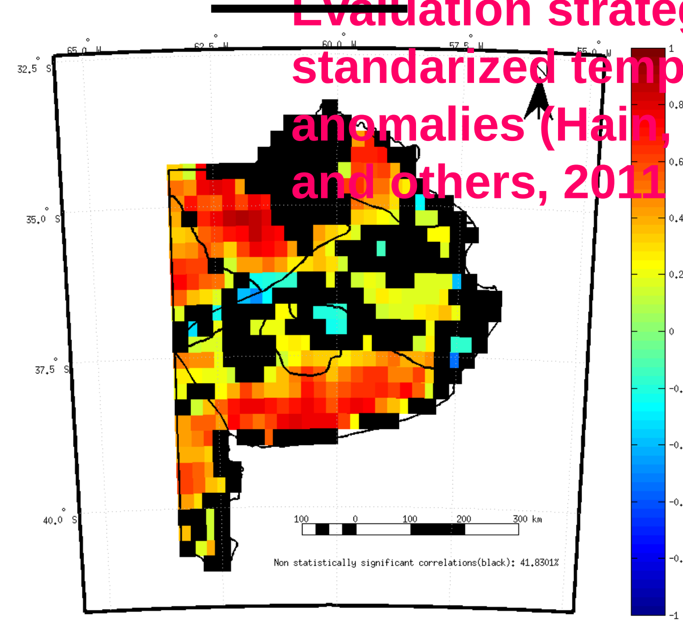
Bluish color denote pixels with increasing negative values

## Evaluation strategies: standarized temporal anomalies (Hain, Crow and others, 2011

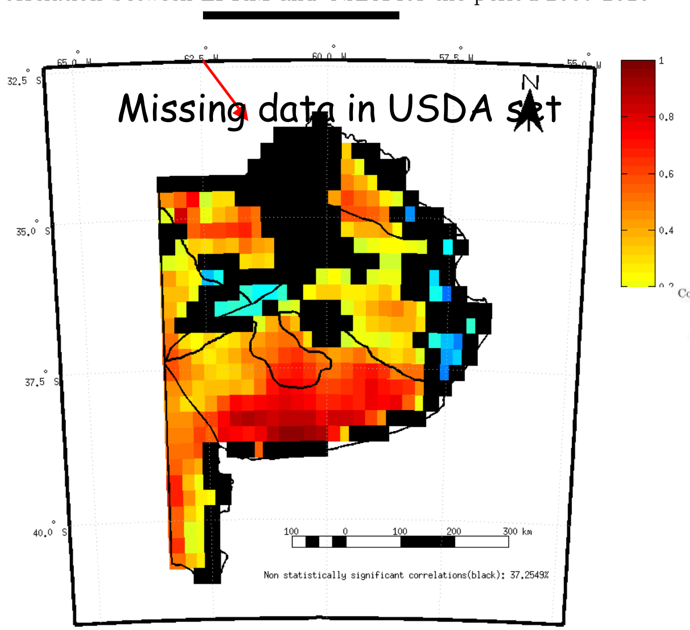
Correlation between ASCAT and NASA for the period 2007-2010



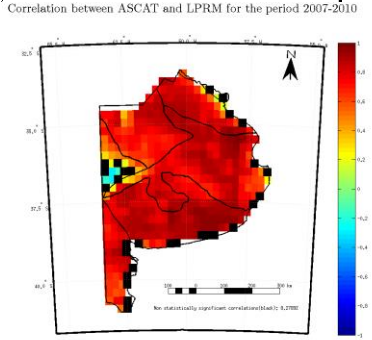

Correlation between ASCAT and USDA for the period 2007-2010




Correlation between LPRM and USDA for the period 2007-2010

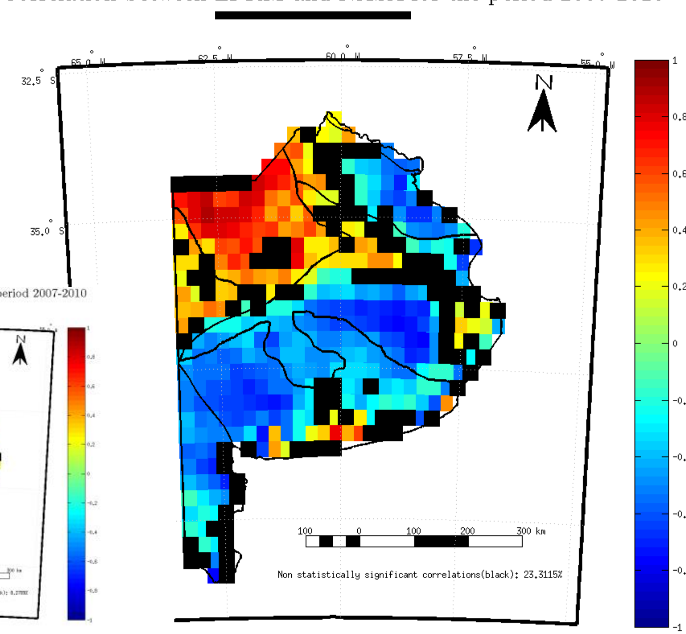



Correlation between ASCAT and LPRM for the period 2007-2010

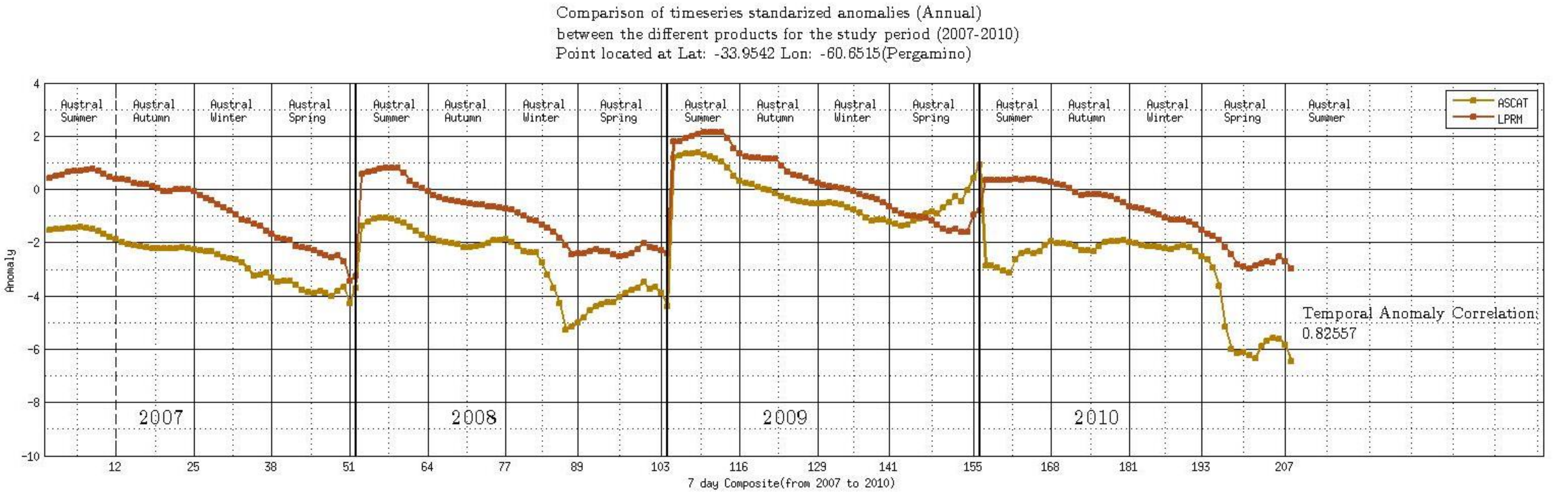


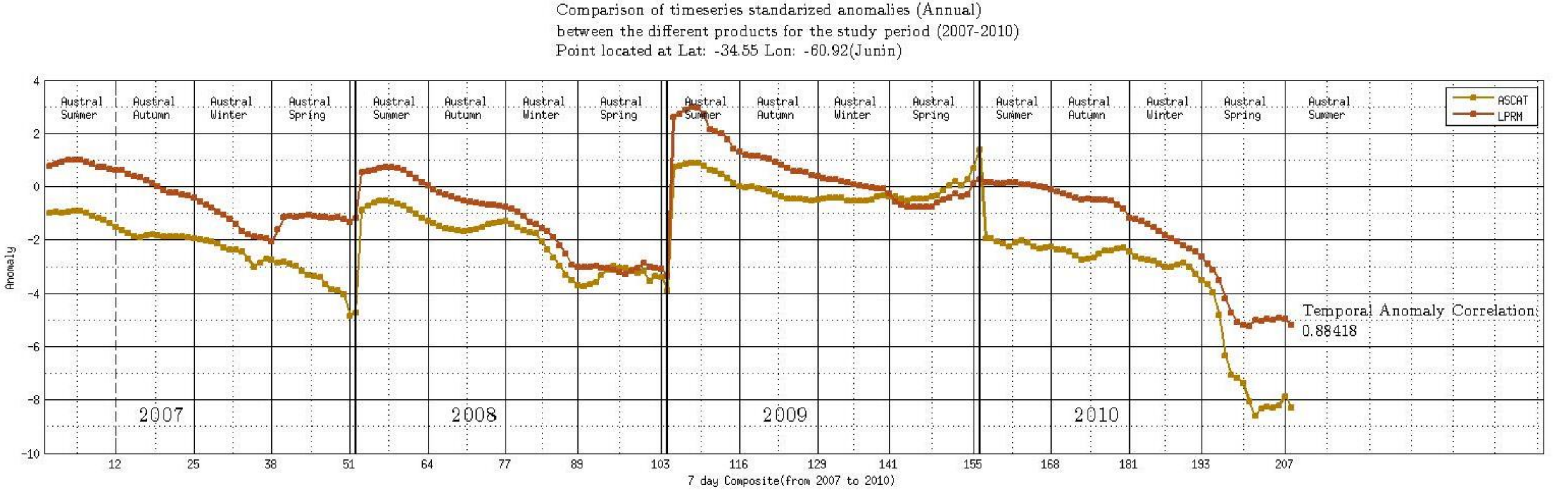
ASCAT- LPRM

Correlation between LPRM and NASA for the period 2007-2010



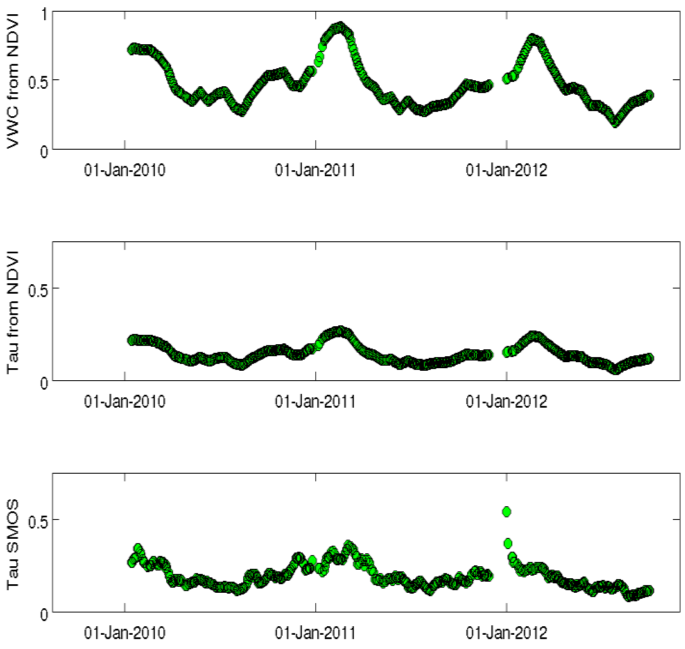
Comparison of timeseries standarized anomalies in an Annual period for the period 2007-2010, between ASCAT and AMSR-E (LPRM).



# Evaluation strategies: comparison with simplified hydrological models: example SMOS data and SH model

**SMOS data over crop areas of Argentina: analysis of soil moisture and optical depth products, presented at the SMOS meeting in Frascatti (2013).**

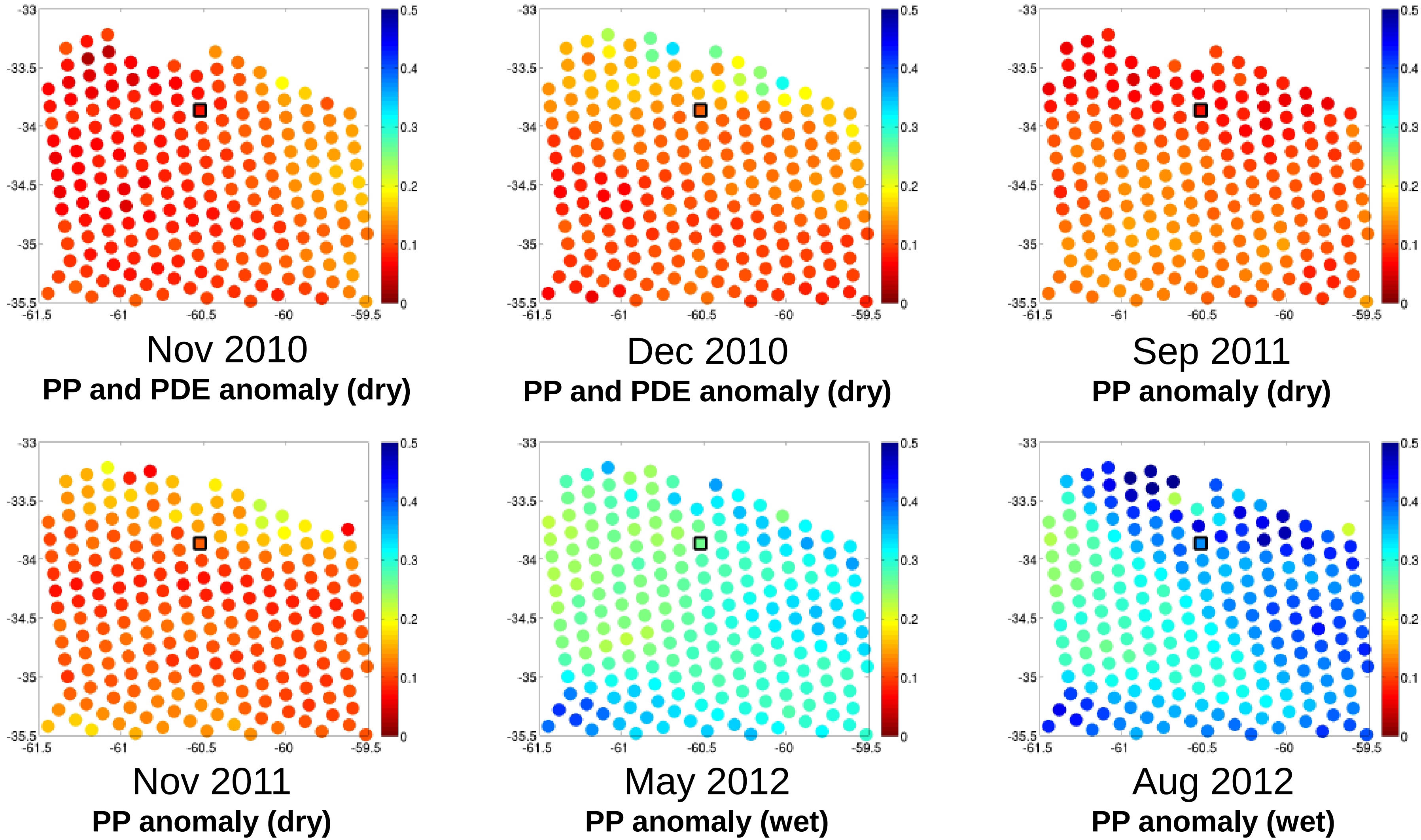



Vegetation optical depth (OD) is simultaneously retrieved with soil moisture from SMOS brightness temperature. Identifying errors on the retrieved OD can give valuable information on possible errors on the soil moisture retrieval.

The following is a summarized list of OD features seen in the analysis:
In general, OD ranged from 0.06 to 0.45 kg/m^2, exhibiting mean values around 0.25 kg/m^2.

As expected, since the area of study is covered with crops, a clear seasonal pattern was captured in OD temporal series. It consisted of an increase from austral spring until austral summer and a decrease in austral autumn during harvesting.

Therefore, consistent with the typical vegetation phenology of land covers in Pampas Plains, December, January, February and March displayed the highest OD values. On the other hand, July, August and September (austral winter) were the months with lowest OD values.




Examples of monthly averaged SMOS L2 SM maps for months where extremes (dry/wet) were seen by both SM and PP or PDE datasets. Black square indicates DGG ID 6031374.

# Evaluation strategies: Triple collocation, "official" SMAP strategy

While cross comparisons between anomalies provide a good qualitative understanding of relative SM skill, the actual parametrization of DA systems requires quantitative error variance values to represent the absolute uncertainty in all assimilated observations.

In order to derive this in regions with inadequate insitu observations Scipal etal 2009, oulined a methodology that exploits a triple collocation (TC) error estimation technique.

The TC requires at least three independent SM data sets, each with mutually independent errors. At this time, we are using ASCAT, SMOS and AMSRE (for each retrieval algorithm NASA, USDA, LPRM, IAFE).

This work is in progress (code development) (in colaboration with Wade Crow, USDA)

# Evaluation strategies: Comments

- When obtaining standarized anomalies (filter, compositing, etc), good coincidences are obtainend between USDA and LPRM, suggesting that any of the two could be a good option, but if an application needs the absolute values and a performance metrics of absolute values, is it possible to extend the anomalies results to absolute values? This is not a simple question, a lot of statistics is behind.

- In general, the anomaly analysis provides relative information about the relationships bewteen data sets, however this information is not easily adaptable to improved quantification of observation error specification in a DA system.

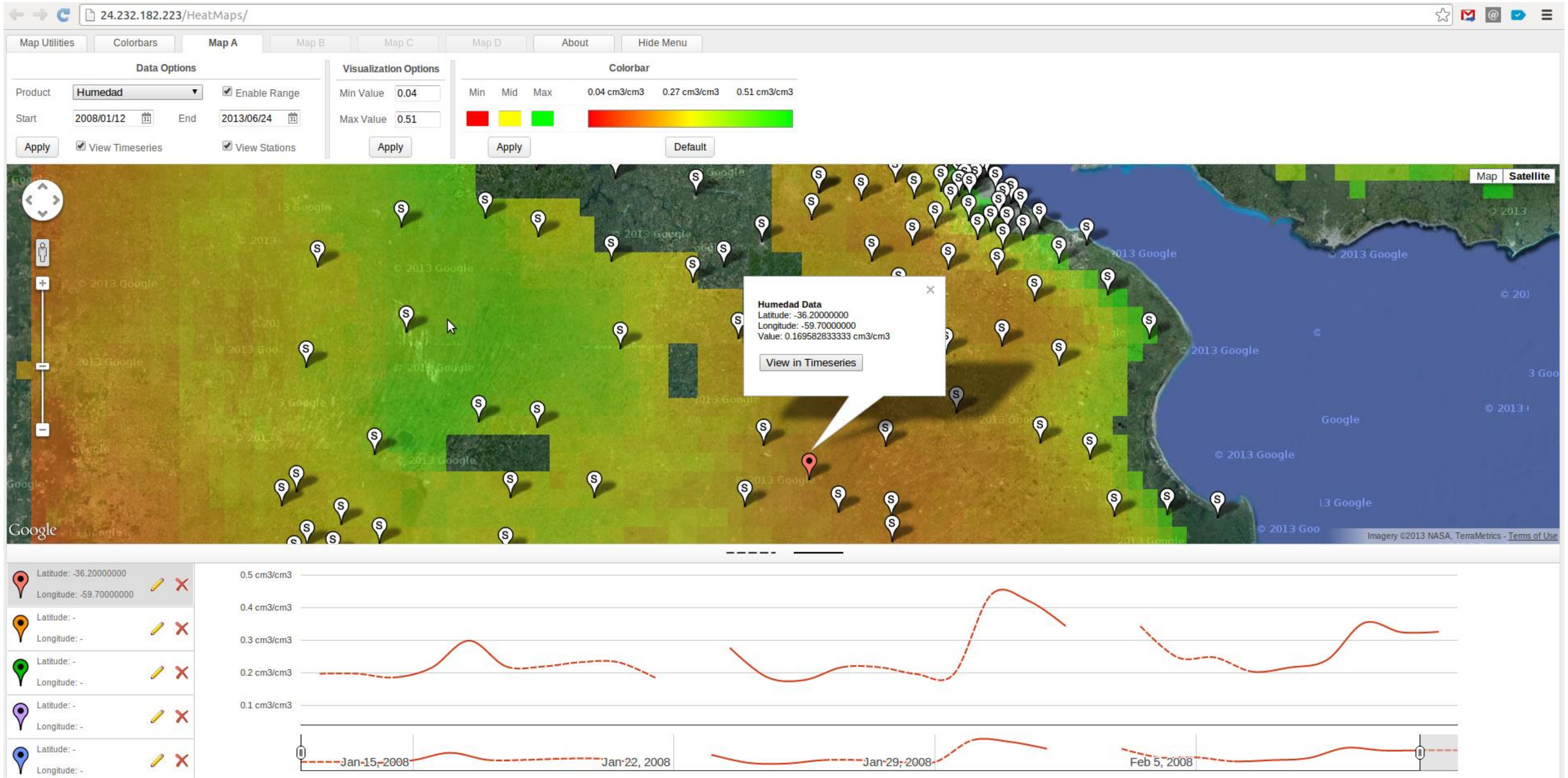
- In contrast, the results from TC analysis provides relative observation error values that can be directly applied in a DA system.

- Different algorithms anomalies (spatial and temporal) correlations are rather soft metrics and there is need for hard metrics. Triple collocation looks like it will provide the solution.

- Nevertheless, correlation analysis of anomalies constitute a good option for monitoring deficit and excess conditions for large scale agricultural applications. Interpretation of results are in progress.

# Our Goal

# In progress



Thanks!!!!!