A first attempt to assimilate satellite radiance observations in a deep convection case during RELAMPAGO using the WRF-GSI-LETFK system

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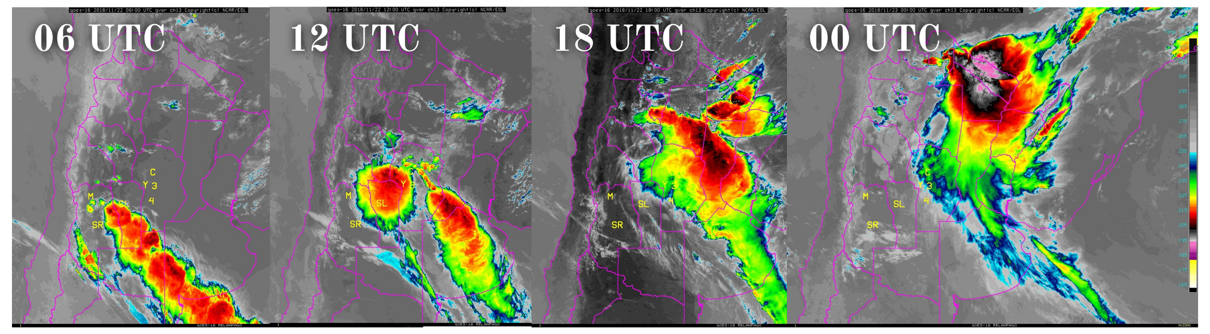
CASE STUDY: November, 22th

This poster presents a first attempt to use the WRF-GSI-LETKF system in Argentina as well as to assimilate satellite radiances in a regional context. We conducted a case study corresponding to a huge mesoscale convective system (MCS) developed over central and north-eastern Argentina during November, 22th. During Nov, 22th a cold front crossed the region generating isolated convection that later grew into a MCS north of the RELAMPAGO field campaign domain (see box bellow). The accumulated precipitation observed during the transit of the MCS was quite high with 200-300 mm over the north-east of Argentina.



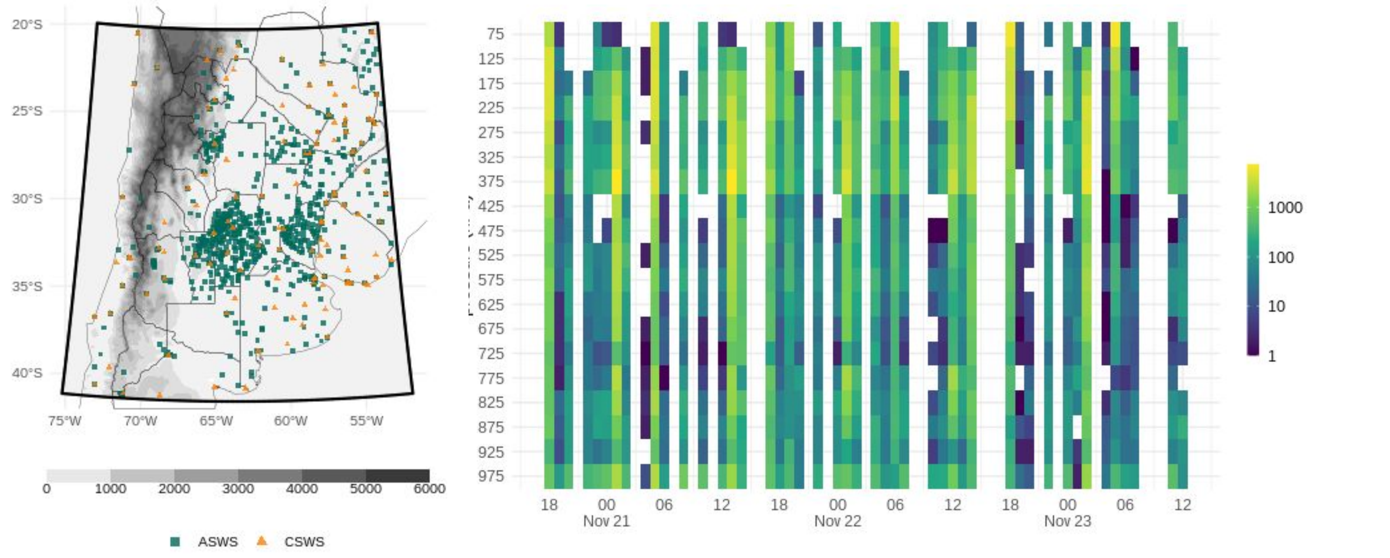
GOES-16 channel 13 (clean longwave-IR). From 11/22 06 UTC, every 6 hours. NCAR/EOL

SYSTEM CONFIGURATION

- Horizontal resolution: 10 km.
- 37 vertical levels
- Initial and boundary conditions: GFS (deterministic 0.5°)
- Ensemble: 60 members with multi-physics squeme and random boundary perturbations.
  - 9 combinations of Cumulus and PBL

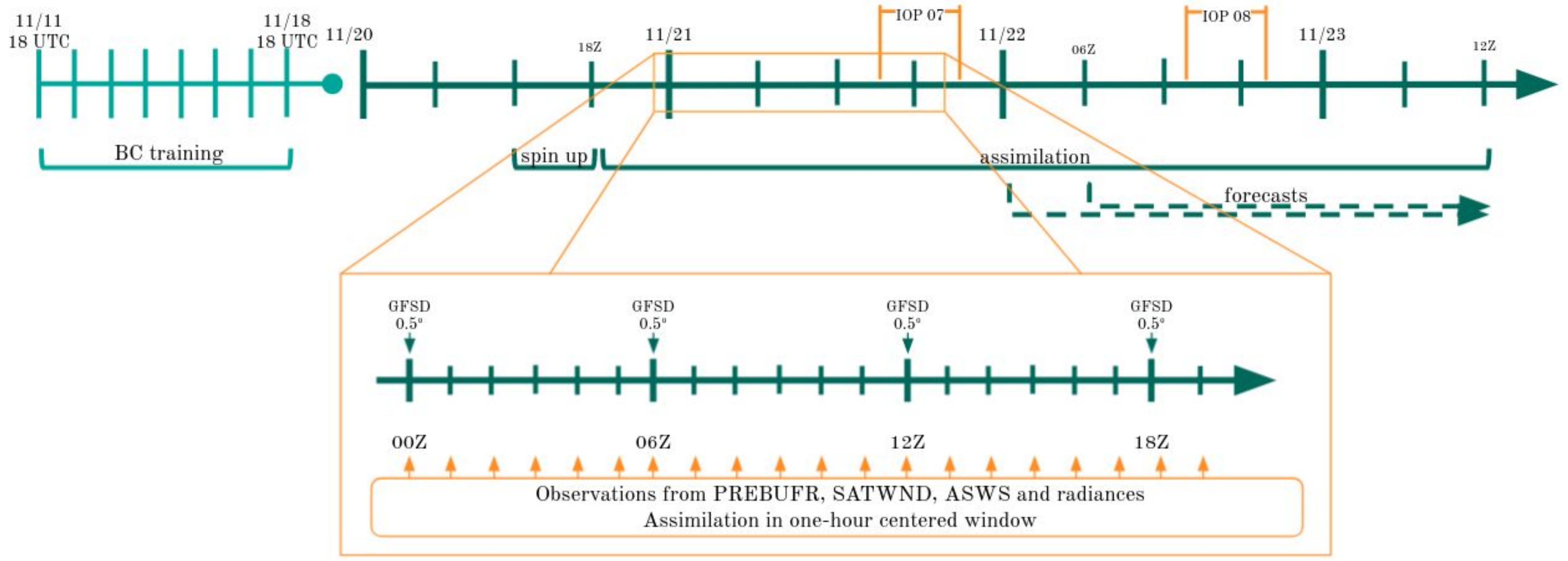
Obs type	Experiments			
	CONV	AUT	SATWND	RAD
PREPBUFR	x	x	x	x
ASWS		x	x	x
SATWND			x	x
RAD				x

We conducted 4 experiments with increased sources of observations including convecional observations from the PREPBUFR files, observations from local automatic surfacer stations networks (ASWS), satellite-derived winds and radiances



Left: The horizontal domain used on the simulations and the locations of Automatic Surface Weather Stations (ASWS, green squares) and Conventional Surface Weather Stations (CSWS, orange triangles). Right: Number of radiance observations assimilated at each analysis cycle and pressure level.

We implemented a rapid update cycle approach with hourly analysis and a centered assimilation window, meaning that all the observations within ± 30 minutes of the analysis time are assimilated. The observations are assimilated in a 4D approach by comparing them with the corresponding first guess state at 10-minute intervals. For radiance observations, we used the Community Radiative Transfer Model version 2.3 (CRTM) as an observation operator to calculate model-simulated brightness temperatures.



RADIANCE observations

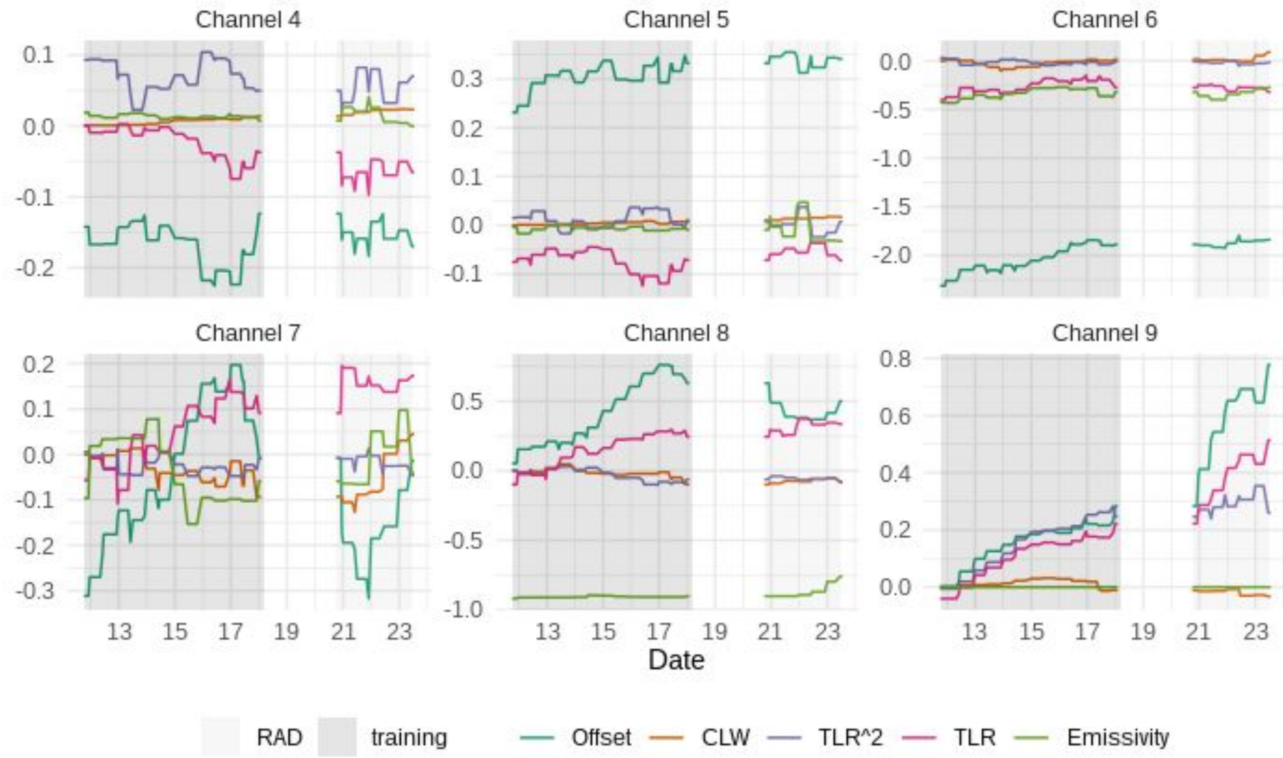
On the RAD experiment we included radiances from following sensors:

- Advanced Microwave Sounding Unit - A (AMSU-A),
- Advanced Technology Microwave Sounder (ATMS),
- Microwave Humidity Sounder (MHS),
- High-resolution Infrared Radiation Sounder (HIRS/4),
- Atmospheric Infrared Sounder (AIRS)
- Infrared Atmospheric Sounding Interferometer (IASI)

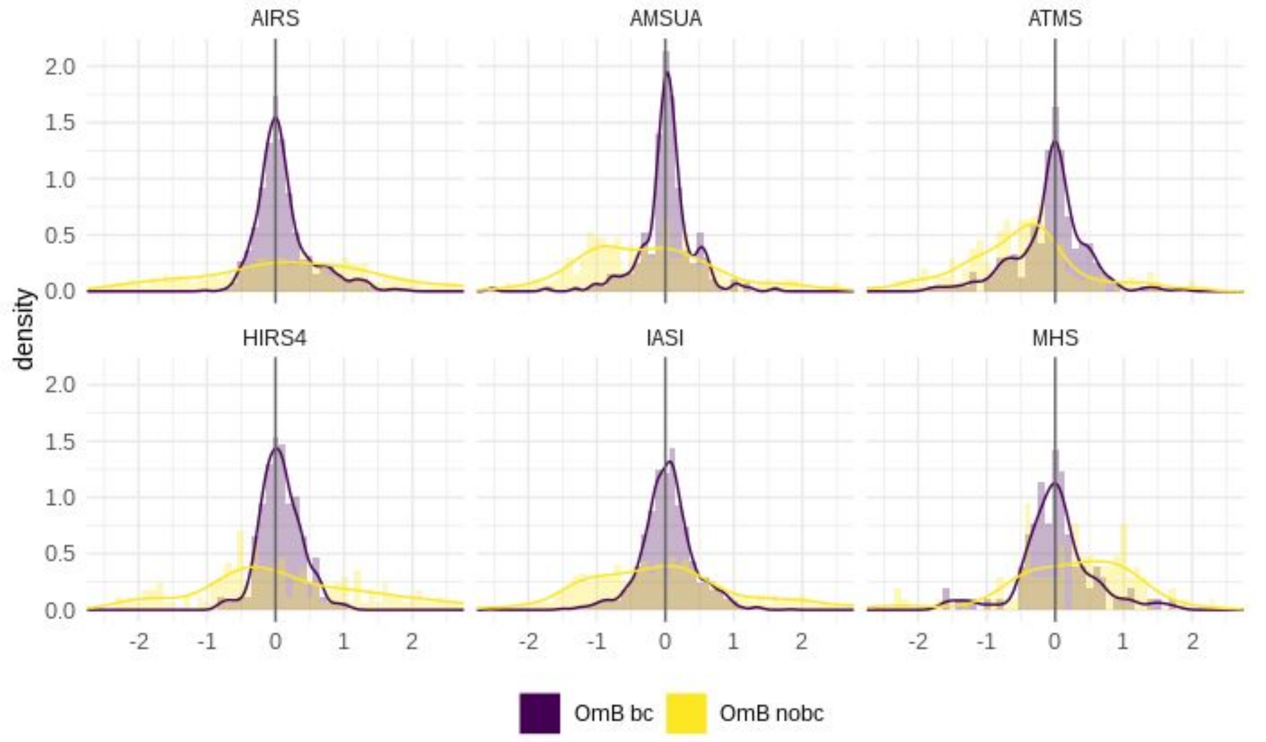
The data was processed using the GSI system including a thinning to a 60 km resolution, a bias correction (BC) and a quality control to reject observations affected by different issues.
The BC has an air-mass dependent and an angle-dependent component (Zhu et. al. 2014) and it is calculated as a multi-linear function of N predictors $p_i(x)$, with associated coefficients β_i. Then, the bias corrected brightness temperature can be obtained as: $BT_{bc} = BT + \sum \beta_i \, p_i(x)$
The following predictors are a global offset, the cloud liquid water content (CLW), the temperature lapse rate at the pressure of maximum weight (TLR), the square of the temperature lapse rate at the pressure of maximum weight (TLR^2) and the emissivity sensitivity. Scan angle dependent bias is modeled as a 4th-order polynomial.
The coefficients initialized from the 18 UTC Nov, 11 2018 GFS coefficients were trained during one week of continuous assimilation using the same setup as in the RAD experiment. Moreover, we used a constant background error variance of 0.01 to avoid large adjustments to the predictor coefficients during each cycle.

BIAS CORRECTION performance

To evaluate performance of the bias correction during the training period and the RAD experiment, we analysed the evolution of the different coefficients for each sensor and channel with time. As an example, here we show the coefficients for AMSU-A on board NOAA-15. Following Zhu et. al, we expected the coefficients to reach a stable range of values after a certain period of time, this is evident for channel 4, 5, 6 and 8 but we see a continuous variation in channels 7 and 9. This behavior repeats for other sensors.



Bias correction coefficients as function of time for the training and experiment period. Channels 4 to 9 of AMSU-A on NOAA-15.

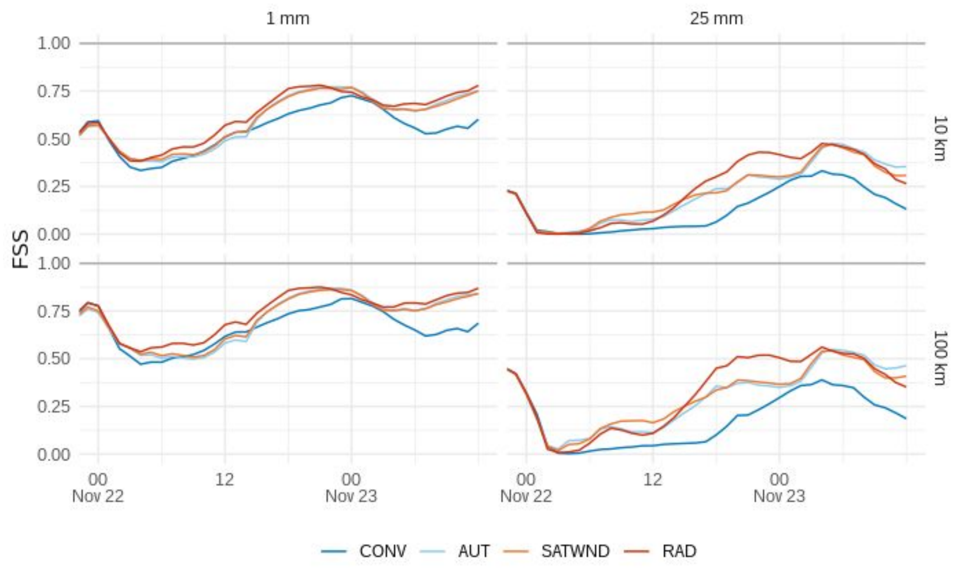


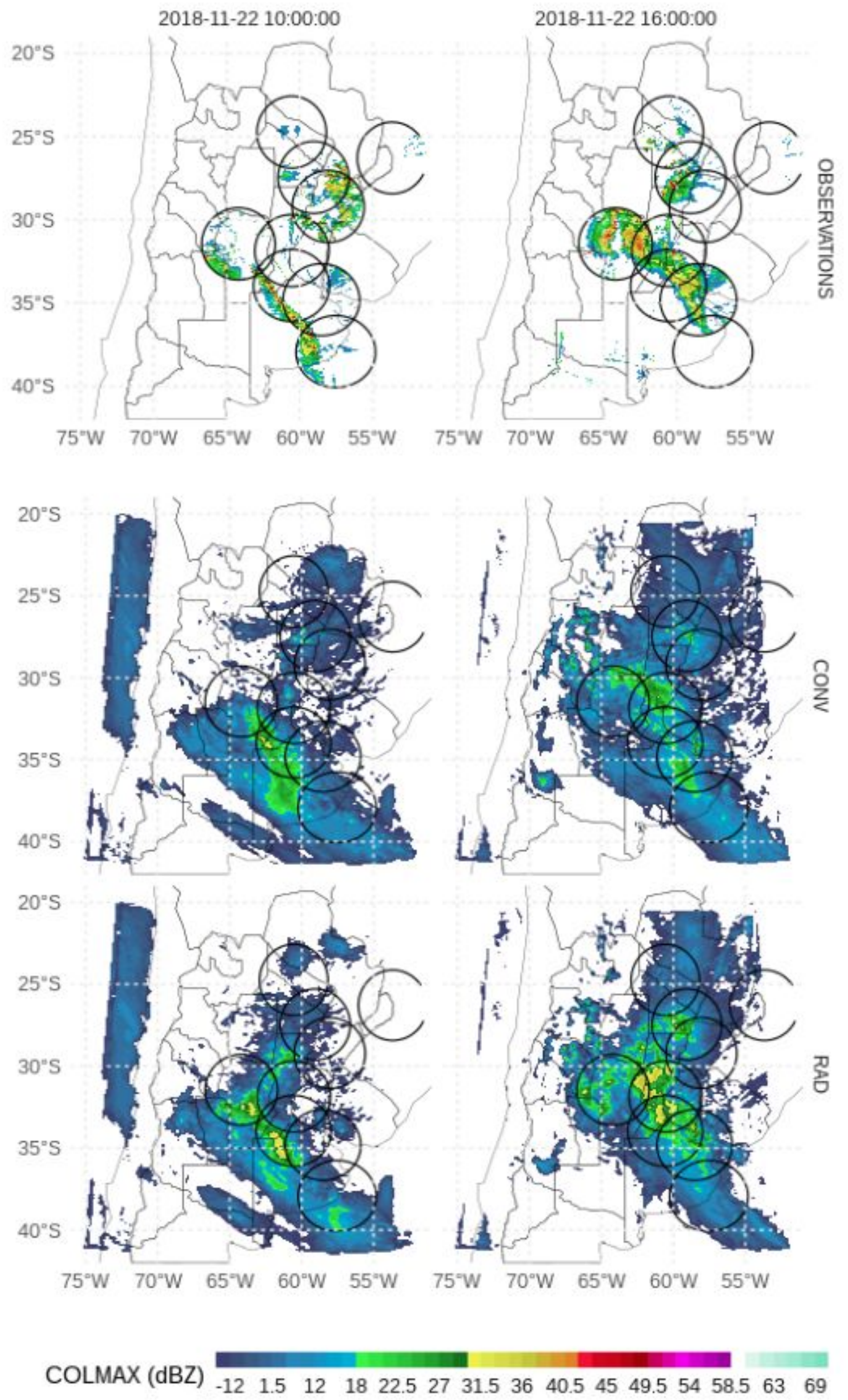
Mean difference between observations and first-guess after and before the correction of the bias calculate for the RAD experiment and each sensor.

Using the resulting coefficients from the training period we performed the RAD experiment and calculate the mean difference between the observations and the first-guess (OmB) before and after the correction of the bias for each sensor and the whole experiment period. We see an evident improvement as the mean OmB after the BC is now centered around zero and the its standard deviation is smaller. This indicate that the BC correction worked as expected. Similar results are obtained for other channels and sensors, even for those channels whose coefficients did not reach a stable value.

ANALYSIS validation

To perform a qualitative validation we compared the analysis of the experiments with radar observations from the local C-band radar network (black circles). We see the RAD experiment outperforms CONV producing a more intense MCS which is closer to the observations. As this is the ensemble mean, the reflectivity is underestimated but we still see the development of the convection on the center at 10 UTC and on north to the domain at 16 UTC.
We also calculate the Fraction Skill Score (FSS) in 6-hours moving windows to quantify the spatial match between the observed precipitation (IMERG half-hourly Final Run of 0.01° resolution, estimated from satellite) and the 1-hour forecasted precipitation. The assimilation of radiances improves the skill of the 1-hour forecasted precipitation, particularly for the 25 mm threshold during the period of heaviest precipitation on Nov, 22.





Left: FSS calculated over a 6-hours moving window for different thresholds and scales. Right: Observed maximum reflectivity in the column (upper row) and ensemble mean maximum reflectivity for CONV and RAD at different times (bottom two rows).

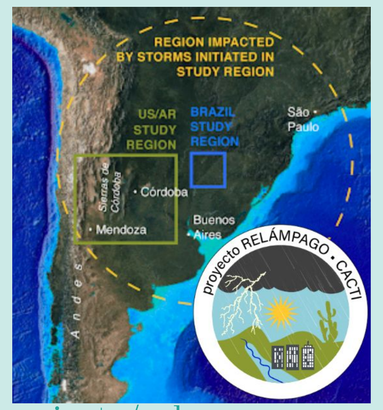
CONCLUSIONS

- The data processing for the radiance observations works as expected. In particular, the bias correction produced a considerable reduction in the bias even when the coefficient used varies with time.
- The assimilation of radiance observations produces a better development of the convection mainly during the mature state of the MCS leading to an increase in the accumulated precipitation.

FUTURE work

- Analyse the independent forecasts initialized from this experiments to assess the potential predictability improvements for this case study and the.
- Work on the assimilation of GOES-16 radiances from water vapor channels to study the potential improvements on severe events forecasts.

The international field campaign **RELÁMPAGO** investigated different phases of the life cycle of thunderstorms that occur in Argentina and took place from June 1, 2018, to April 30, 2019.



https://www.eol.ucar.edu/field_projects/relampago

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