Servicio Meteorológico Nacional
Argentina

Development of a forward operator for lightning data assimilation

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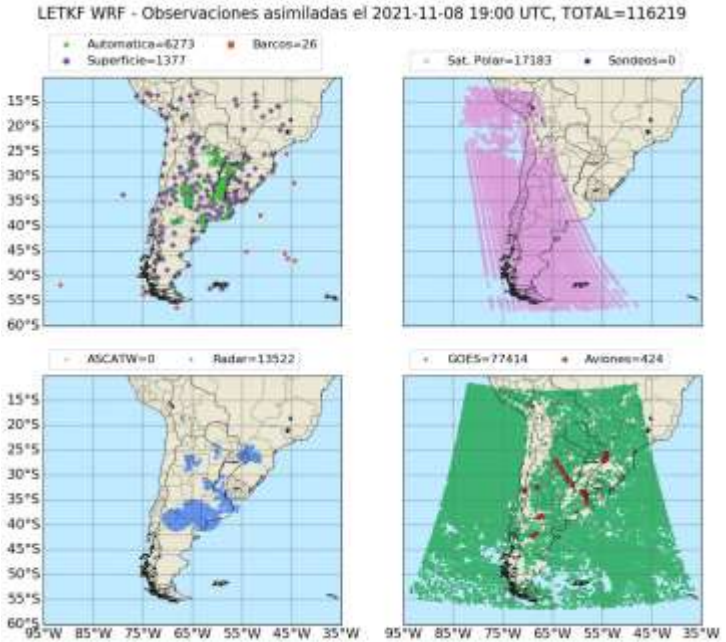
GLM Science Meeting 2023

Data Assimilation System (experimental 2023)

SAP.SMN-ANA: current implementation at the NMS

Data source	Assimilated variables
Conventional SWS	PSFC, T, U, V, RH
Automatic SWS (private +AWOS)	PSFC, T, U, V, RH
Ships, buoys	SLP, T, U, V, RH
Soundings	T, U, V, RH
Aircraft (AMDAR, AA)	T, U, V
Aqua (AIRS)	T, Q
Metop-B (ASCAT)	U, V
GOES-16	U, V
C-band Radar	Z

- 4D-LETKF method coupled with the WRF model (10-min slots) *(fortran implementation from Miyoshi T., Ruiz J.)*



- Hourly analysis with 4 km horizontal resolution.
- 40 multi-physics ensemble members.
- 18 cycles real-time implementation.

Lightning data assimilation

Motivation

GLM data will complement mesoscale observations particularly in those areas not covered by weather radar.

Challenges

- Have a good forward operator.
- Include lightning observations in the data assimilation workflow (code writing, tune observation errors, etc).
- Evaluate the impact of these new observations.

Forward operator

- Explicit solve of electrification process is too expensive.

- Statistical approach:
  - Empirical regressions using model state variables as predictors:
    - Maximum vertical velocity (W_{max}).
    - Vertically integrated ice content(ICE_INT).
    - Graupel flux at -15°C isotherm (WQ_g).
    - Combination of ICE_INT and WQ_g (McCaul et al. 2009).
    - Lightning Potential Index (LPI).

- Machine learning approach:
  - CNN with forecasted radar reflectivity as input.

Statistical approach

- More than 3000 forecast hours from 4 km deterministic and ensemble forecasts from operational SAP.SMN (Matsudo et al. 2022), from november 2022 to march 2023.

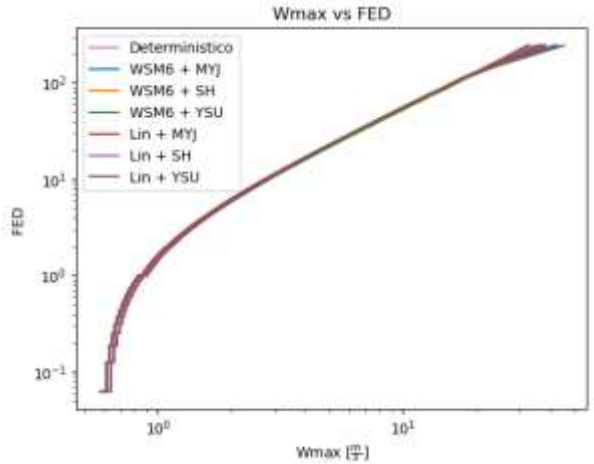
- Observations of Flash Extent Density (FED[1]) for the same time as forecasts.

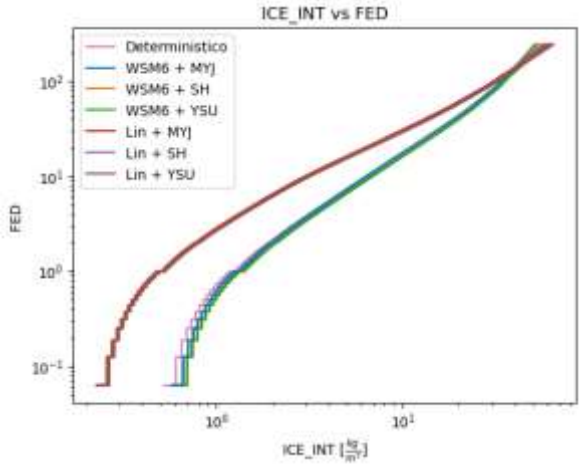
- PDF matching to transform forecasted variables distribution into the observed distribution.

[1] Calculated using glmtools (Bruning et al. 2019)

Statistical approach
Training

- Relationships grouped by microphysics scheme.





Statistical approach

Prediction

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- L

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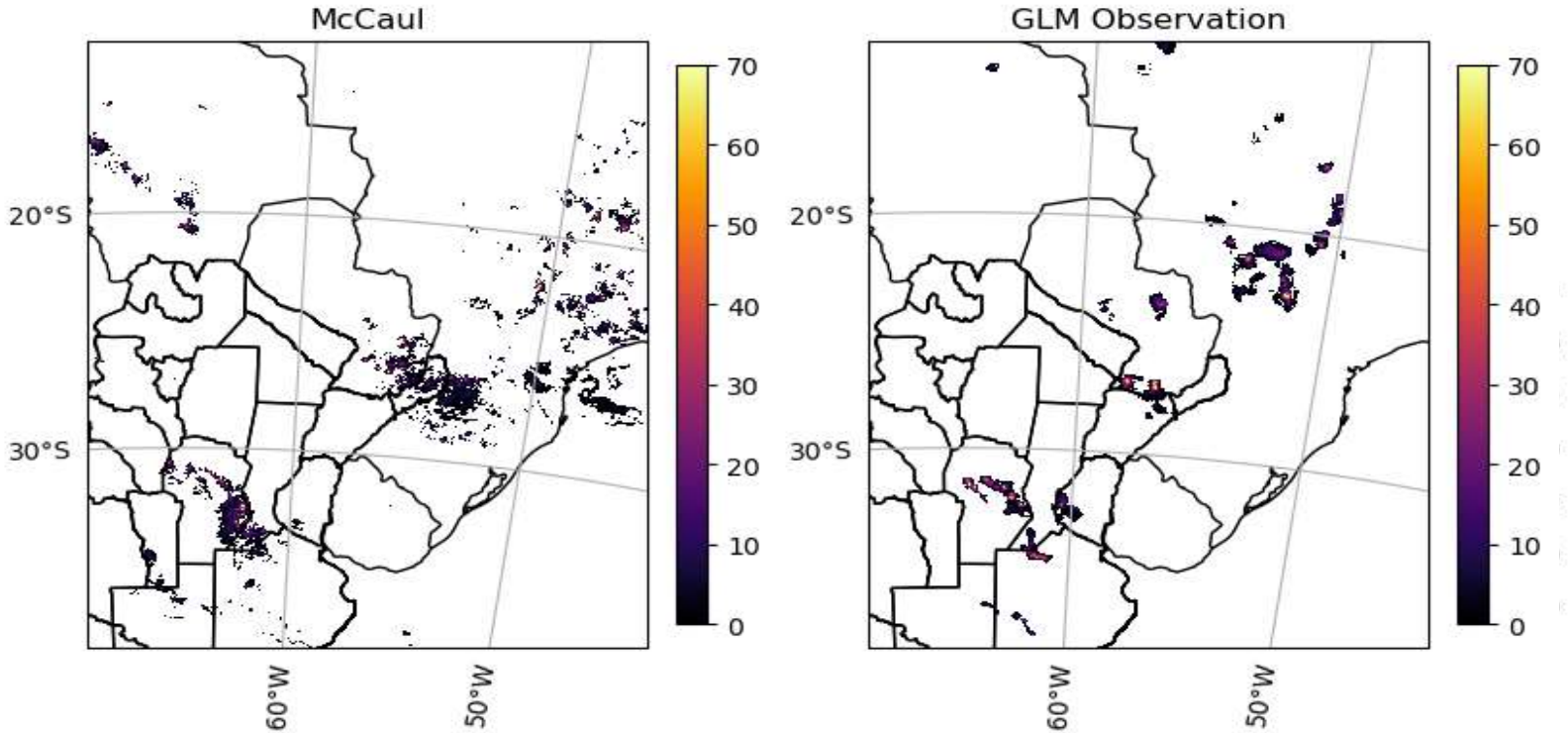
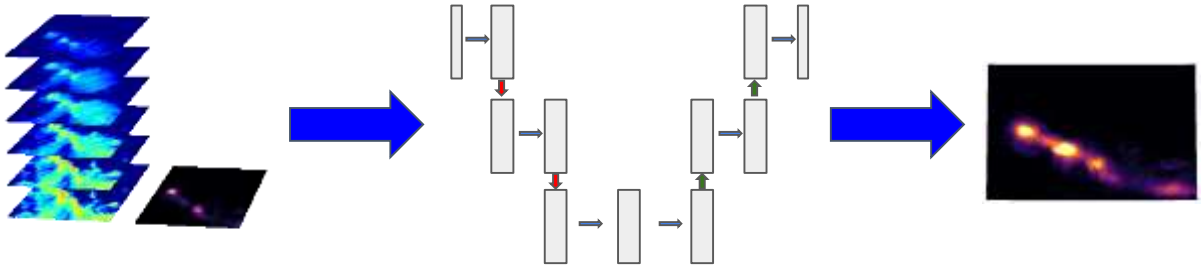


Machine learning approach

Architecture

- Convolutional Neural Network with a U-Net architecture to transform observed radar reflectivity into FED observations.
- Six partial column maximum reflectivity as input.



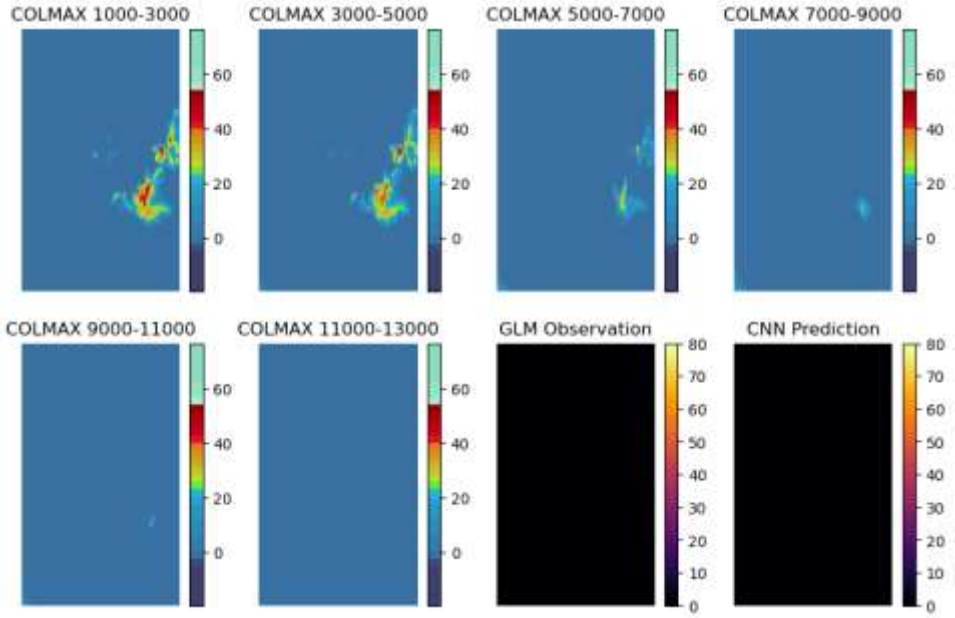
- Forecasted reflectivity into forecasted FED.

Machine learning approach

Training

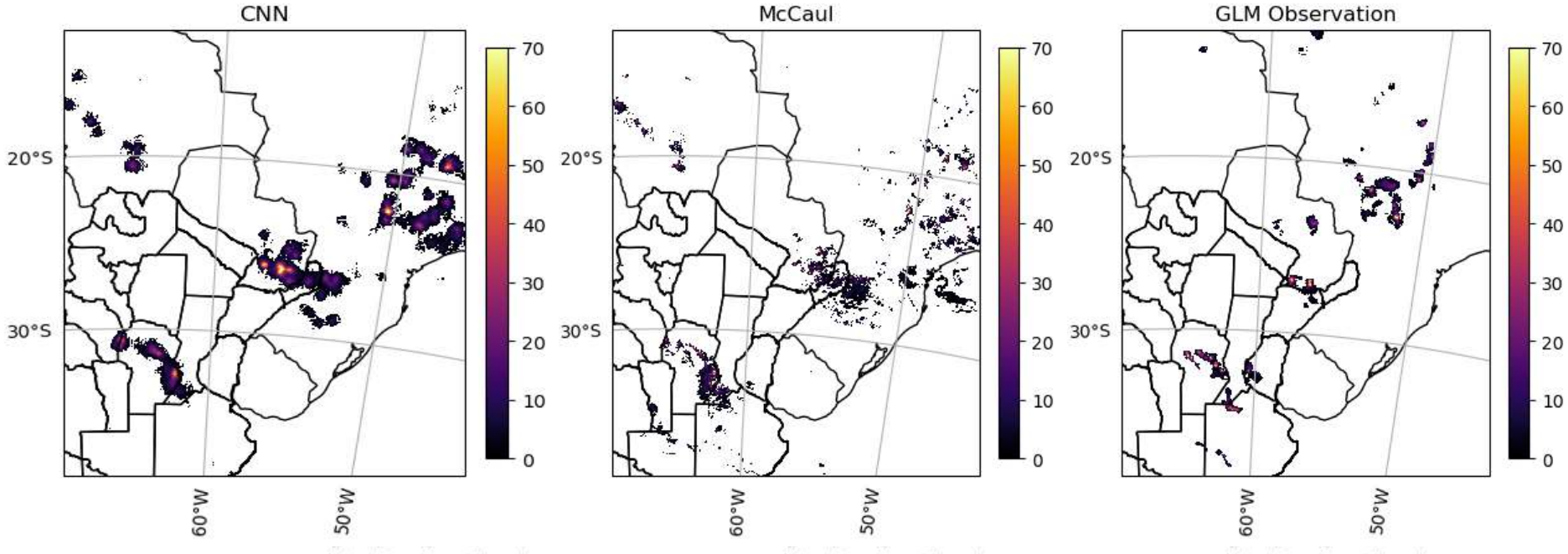
- 2 years of quality controlled data from 4 different radars for training (30000 cases).

- Hyperparameters:
  - Contraction/expansion layers: 2
  - Filters: 12
  - Batch size: 64
  - Learning rate: $1x10^{-5}$
  - Activation function: ReLU
  - Loss function: MSE



Machine learning approach

Prediction



Conclusions and future work

- Lightning prediction with the statistical approach shows good results but has some cons.
- Machine learning approach shows promising results but is still an ongoing work.
- 2023/4 summer will be use to determine the best approach to employ in the context of data assimilation.

Thank you for your attention

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