WORLD METEOROLOGICAL ORGANIZATION
WEATHER CLIMATE WATER

CIMO TECHNICAL CONFERENCE ON METEOROLOGICAL AND ENVIRONMENTAL INSTRUMENTS AND METHODS OF OBSERVATION (CIMO TECO-2018)

Operational Early Warning System in Southern Brazil – Blending Remote and Surface Observations for Precipitation Nowcasting

Cesar Beneti[1], M. Jusevicius[1], L. Calvetti[2], C. Oliveira[1,3], N. Rozin[1,3], R. Neundorf[1,3], J. Ruviaro[1,3]

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[2]UFPel – Federal University of Pelotas, Brazil
[3]UFPR – Parana Federal University, Brazil

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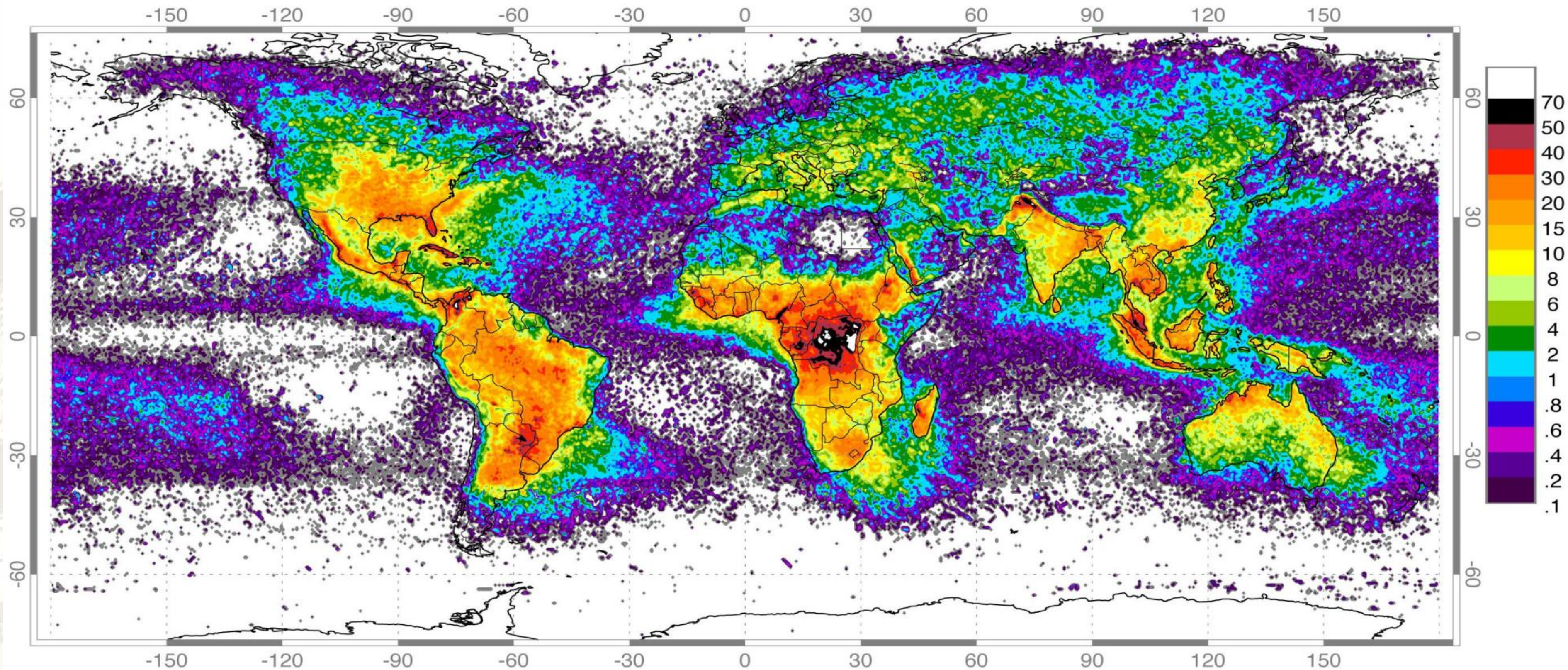
Operational Early Warning System in Southern Brazil

Lightning Incidence in Southeastern South America

Observed from Satellite (LIS/OTD)



High Resolution Full Climatology Annual Flash Rate

Global distribution of lightning April 1995-February 2003 from the combined observations of the NASA OTD (4/95-3/00) and LIS (1/98-2/03) instruments

(Adapted from Goodman & Cecil 2002)

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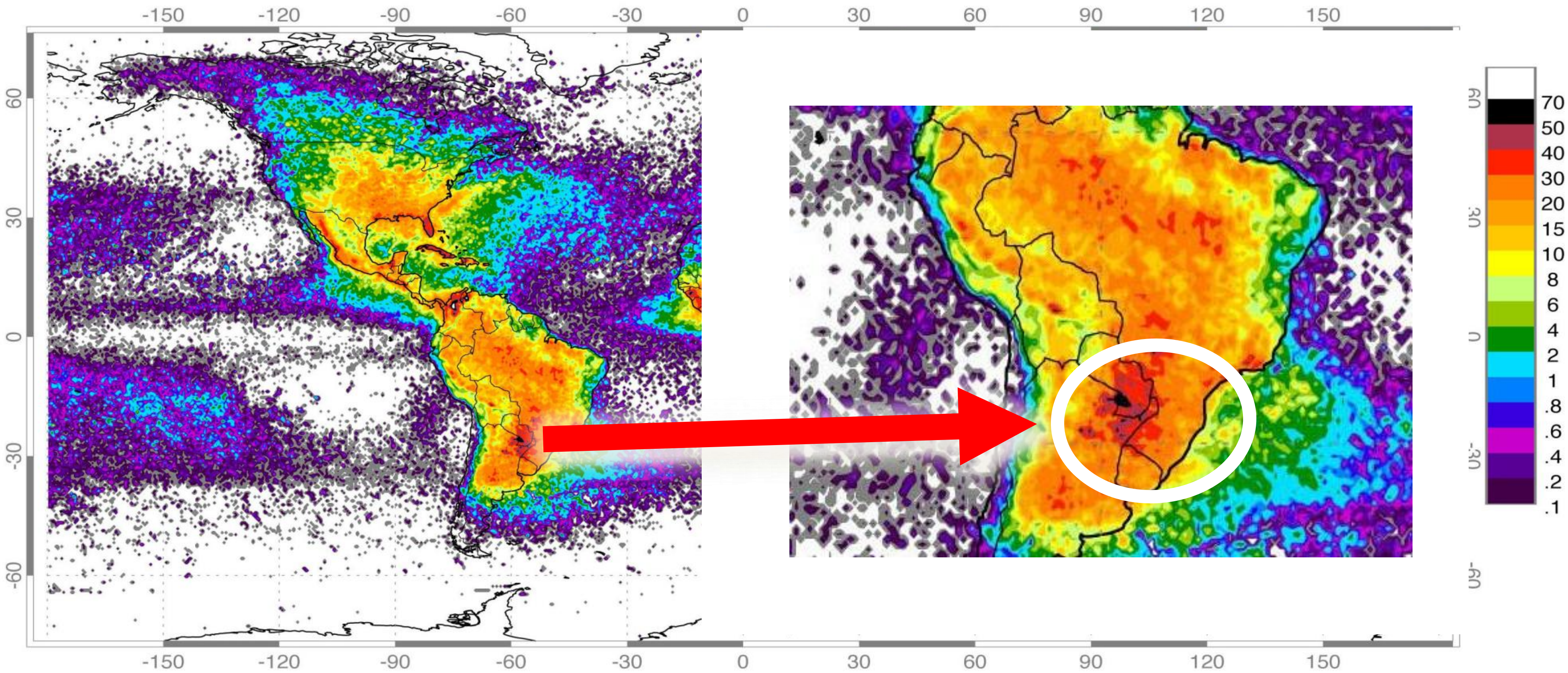

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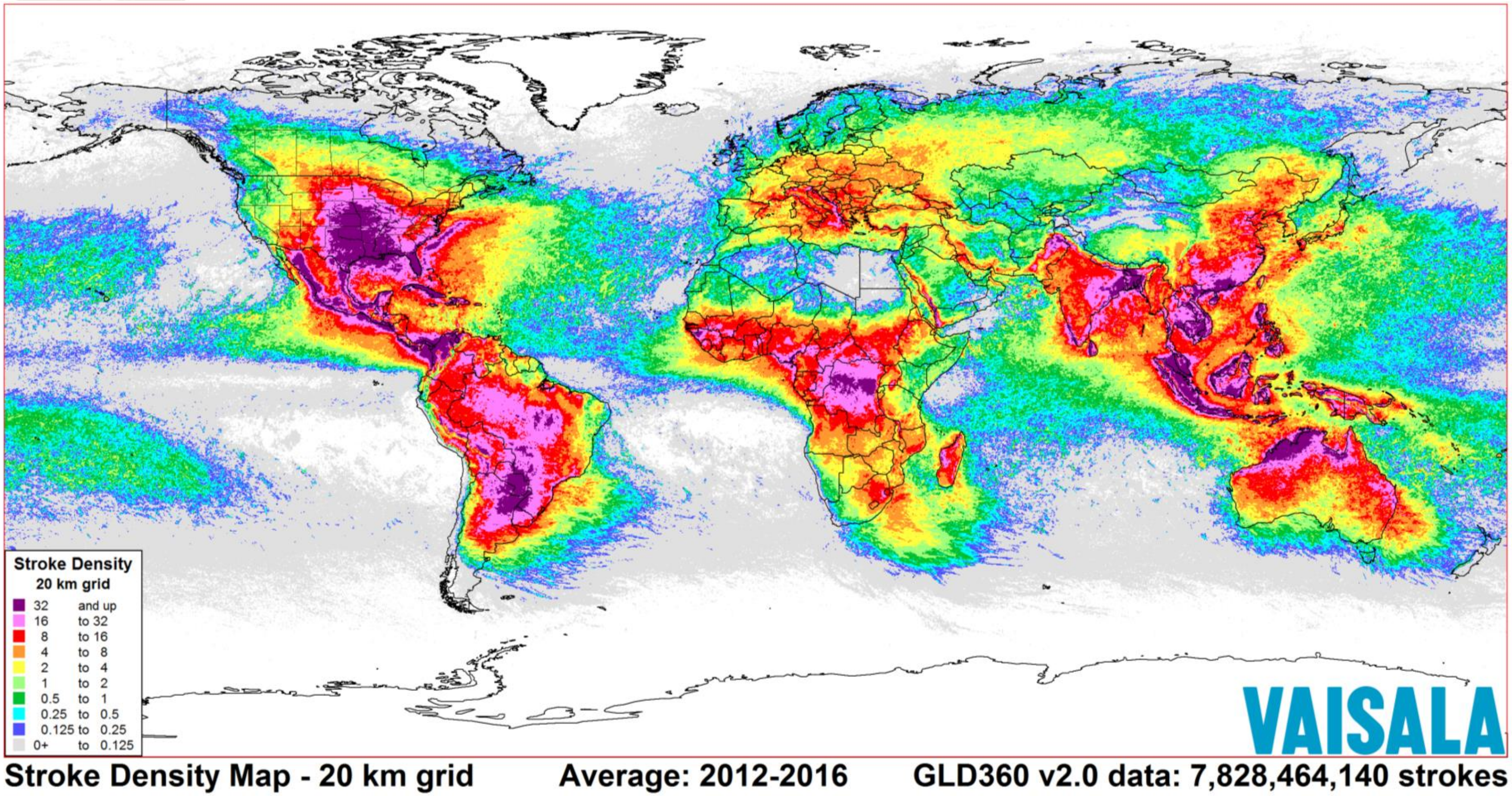
Operational Early Warning System in Southern Brazil

WMO OMM

Lightning Incidence in Southeastern South America

Observed from Surface Global Lightning Detection Network (GLD360)



Source: https://my.vaisala.net/VaisalaImages/Lightning/GLD_20km_avg_2012-2016_world_map.png?_ga=2.167773153.1580877388.1516191420-1581657620.1516191420

Operational Early Warning System in Southern Brazil

Lightning Incidence in Southeastern South America

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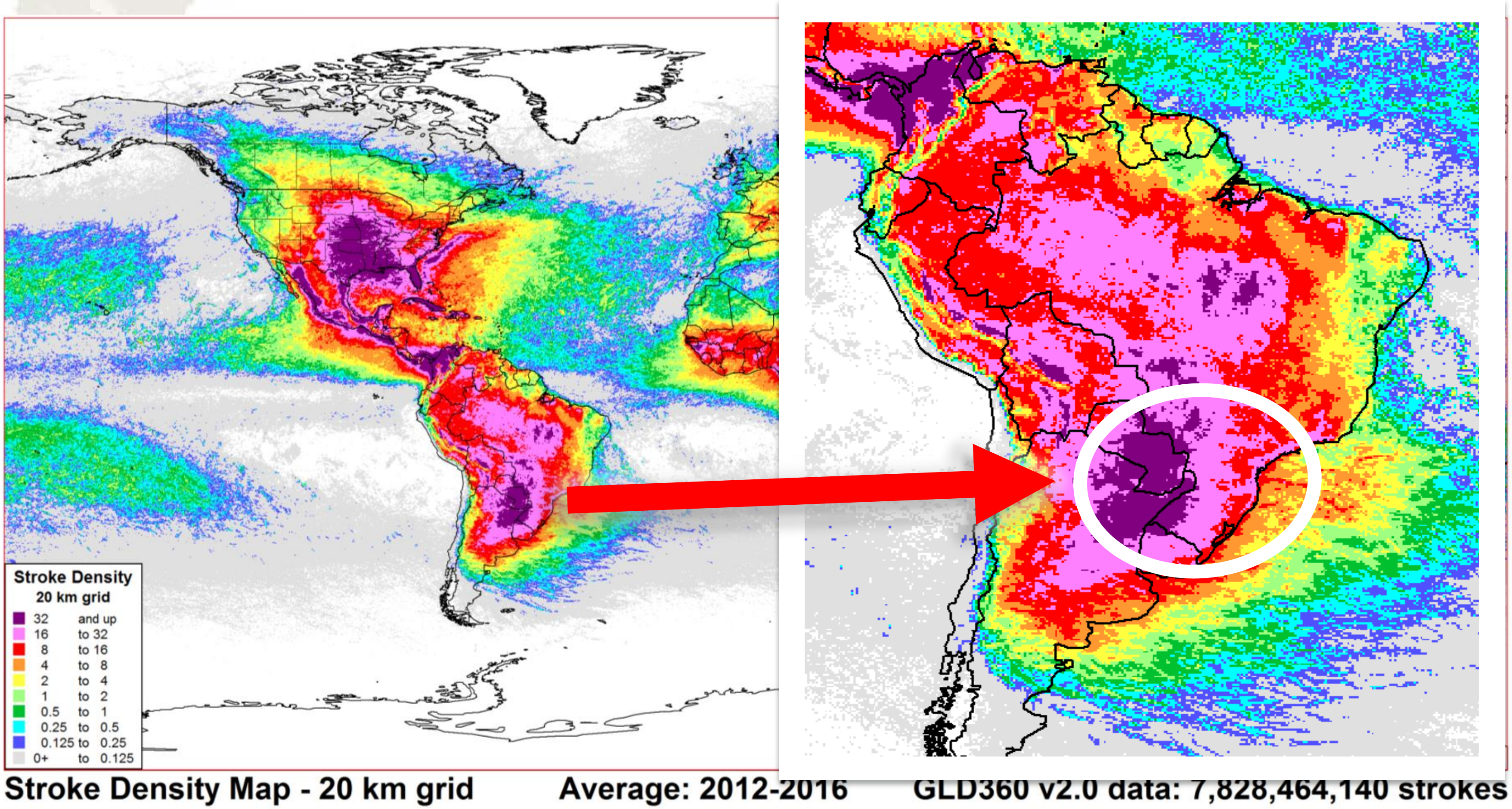

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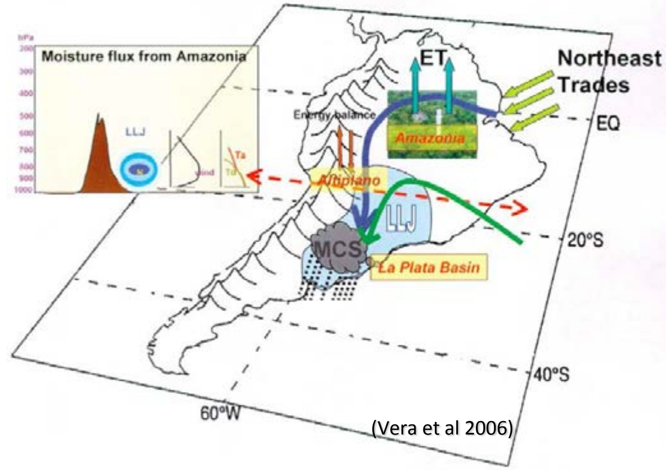
Operational Early Warning System in Southern Brazil

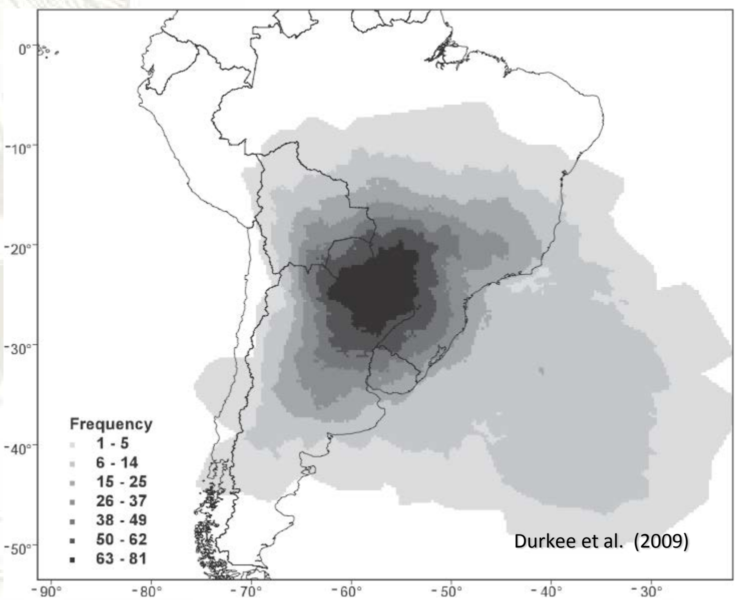
Synoptic Influence of Mesoscale Convective Systems in Southeastern South America



(Vera et al 2006)

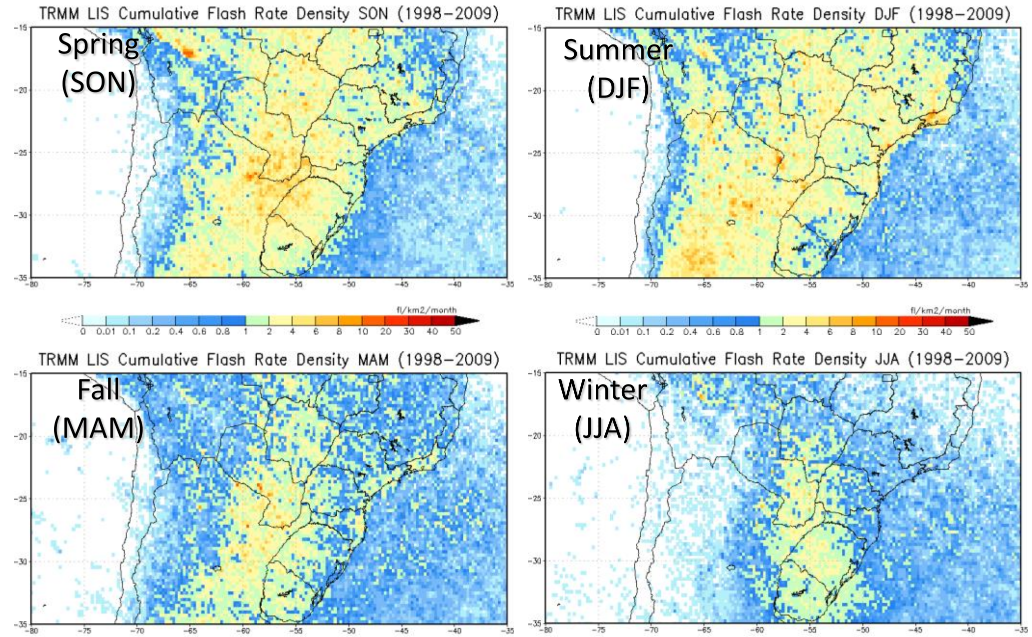
✓ South American Low Level Jet

MCC frequency during warm season (1998-2007)



Durkee et al. (2009)

Lightning Incidence in Southeastern South America



Operational Early Warning System in Southern Brazil

Synoptic Influence of Mesoscale Convective Systems in Southeastern South America

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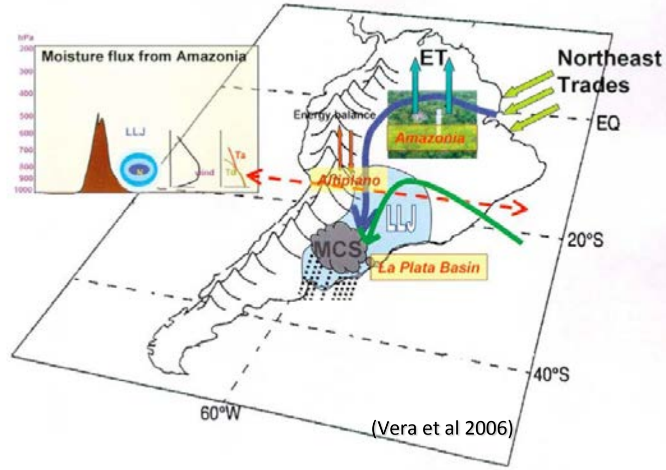

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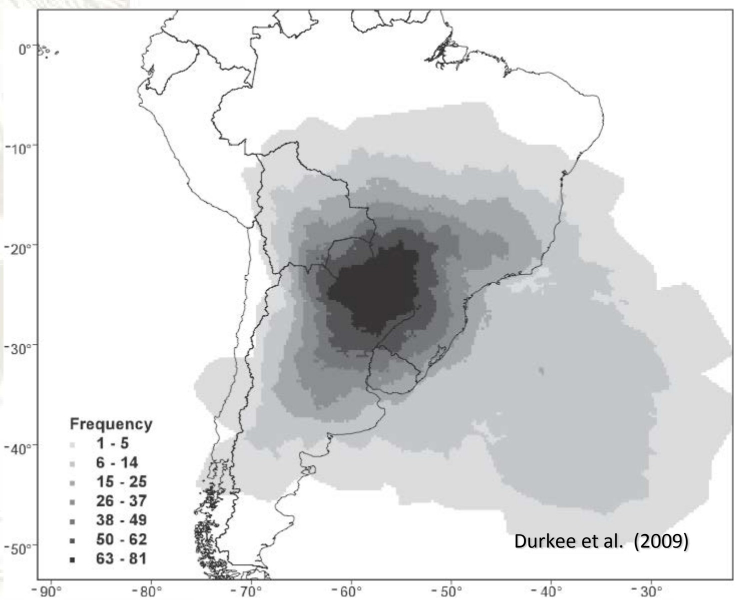
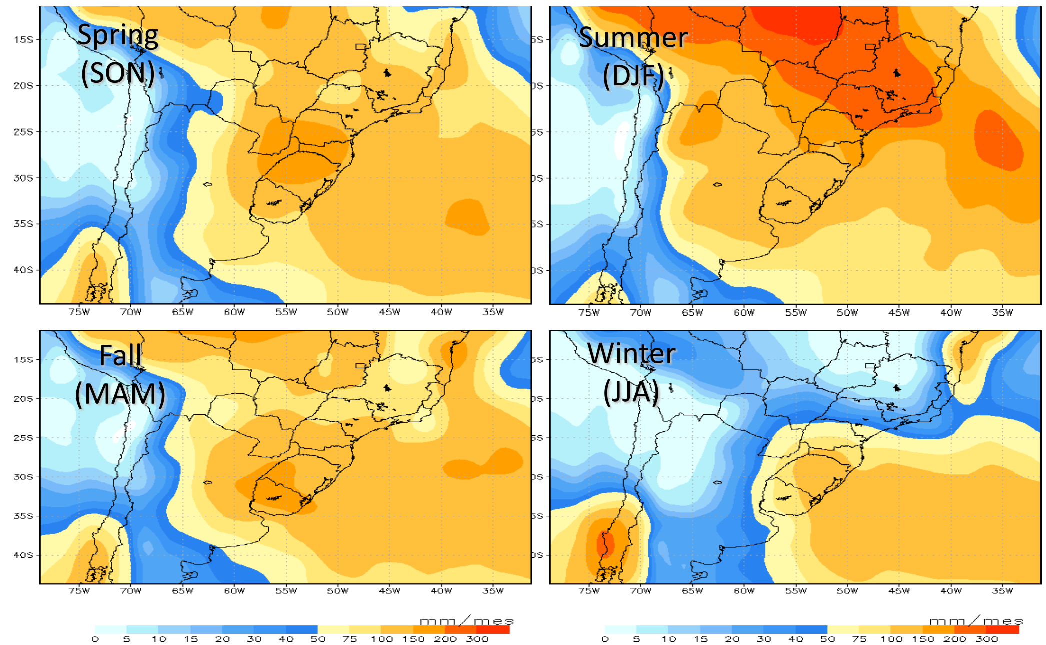


Durkee et al. (2009)

Precipitation Distribution Southeastern South America

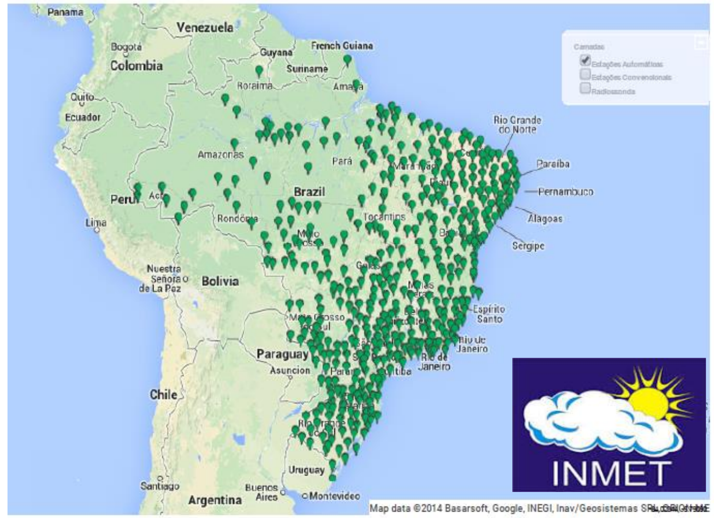


Operational Early Warning System in Southern Brazil

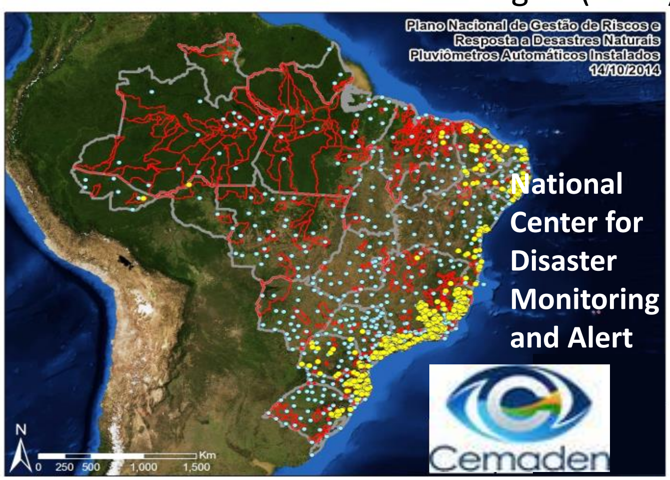
Hydrometeorological Monitoring Networks in Brazil

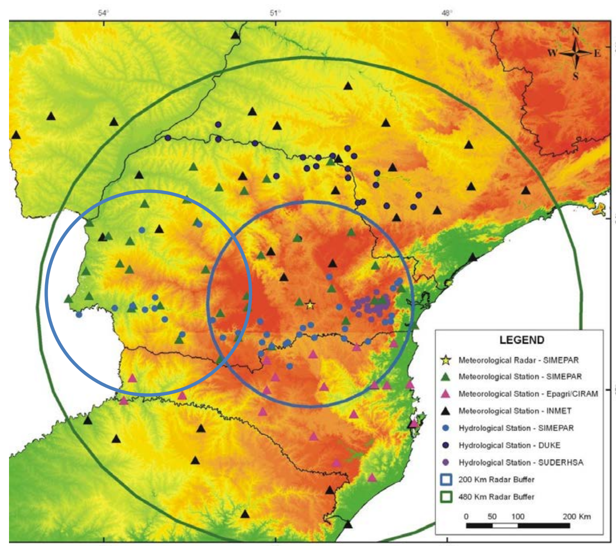
INMET Automatic Weather Stations (553)

INMET Conventional Weather Stations (446)



CEMADEN Automatic Rain Gauges (1581)





Regional Hydrometeorological Monitoring Networks in the South of Brazil

(+250 AWS)

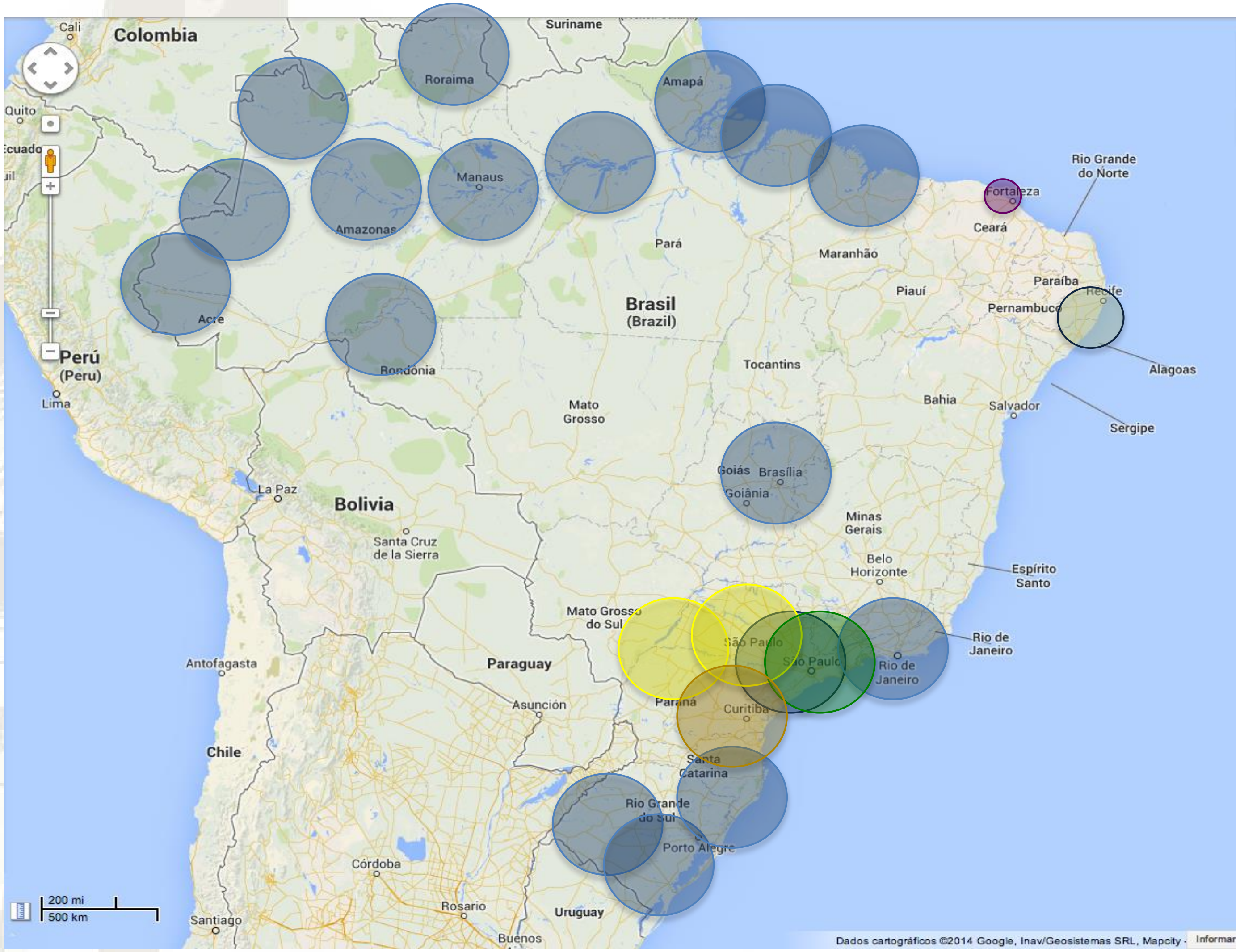
"a network of networks"

Operational Early Warning System in Southern Brazil

Weather Radar Coverage in Brazil

Period: 1980 – 2000

TOTAL = 23 Single Pol



17 S-Band SPol (DECEA)

1 S-Band SPol (CTH-SP)

2 S-Band SPol (UNESP-SP)

1 S-Band SPol (SIMEPAR)

1 C-Band SPol (UFAL-AL)

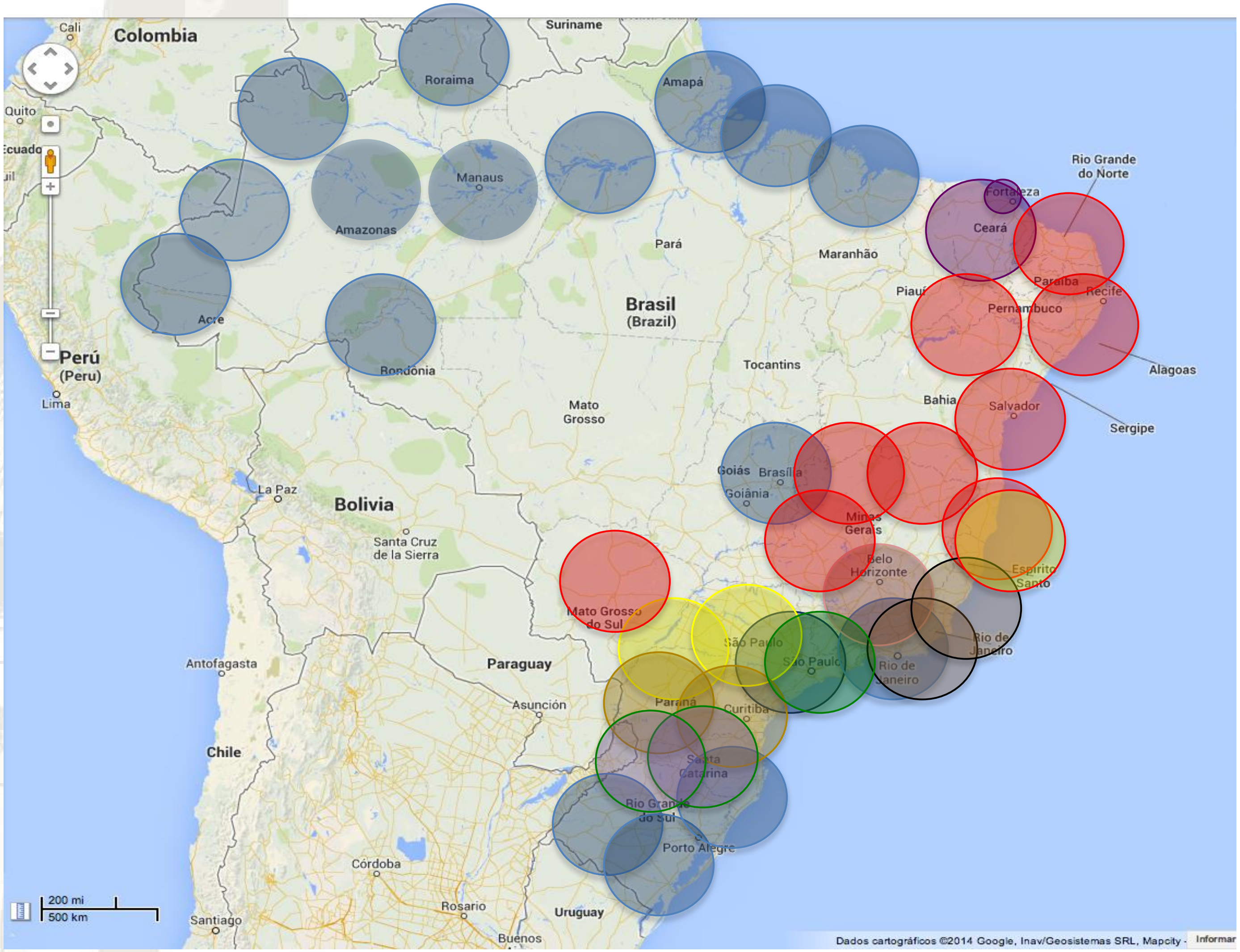
1 X-Band SPol (FUNCEME)

Operational Early Warning System in Southern Brazil

Weather Radar Coverage in Brazil

Period: 2011 – 2018

TOTAL = 25 Single Pol & 20 Dual-Pol



- 17 S-Band SPol (DECEA)
- 1 S-Band DPol (CTH-SP)
  1 X-Band DPol (CTH-SP)
  2 X-Band SPol (USP-SP)
  2 S-Band SPol (UNESP-SP)
- 1 S-Band SPol (SIMEPAR)
  1 S-Band DPol (SIMEPAR)
  1 X-Band DPol (SIMEPAR)
- 9 S-Band DPol (CEMADEN)
- 1 X, 2S SPol (FUNCEME)
- 2 S-Band DPol (INEA-RJ)
- 2 S-Band DPol (DefCiv-SC)
  1 X-Band DPol (DefCiv-SC)
- 1 C-Band DPol (CEMIG-MG)
- 1 S-Band DPol (VALE-ES)

Operational Early Warning System in Southern Brazil

Lightning Detection Networks in Brazil - RINDAT

RINDAT

Rede Integrada Nacional de Detecção de Descargas Atmosféricas

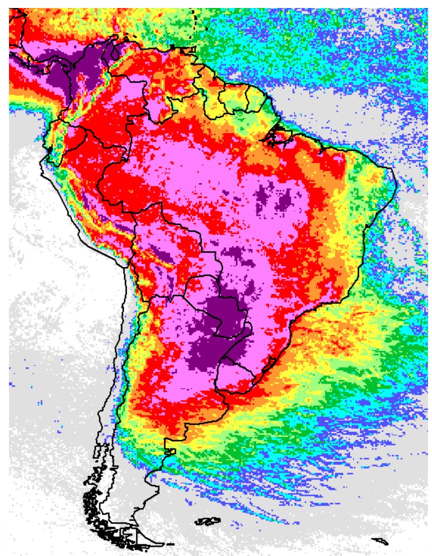
SIMEPAR Tecnologia e Informações Ambientais

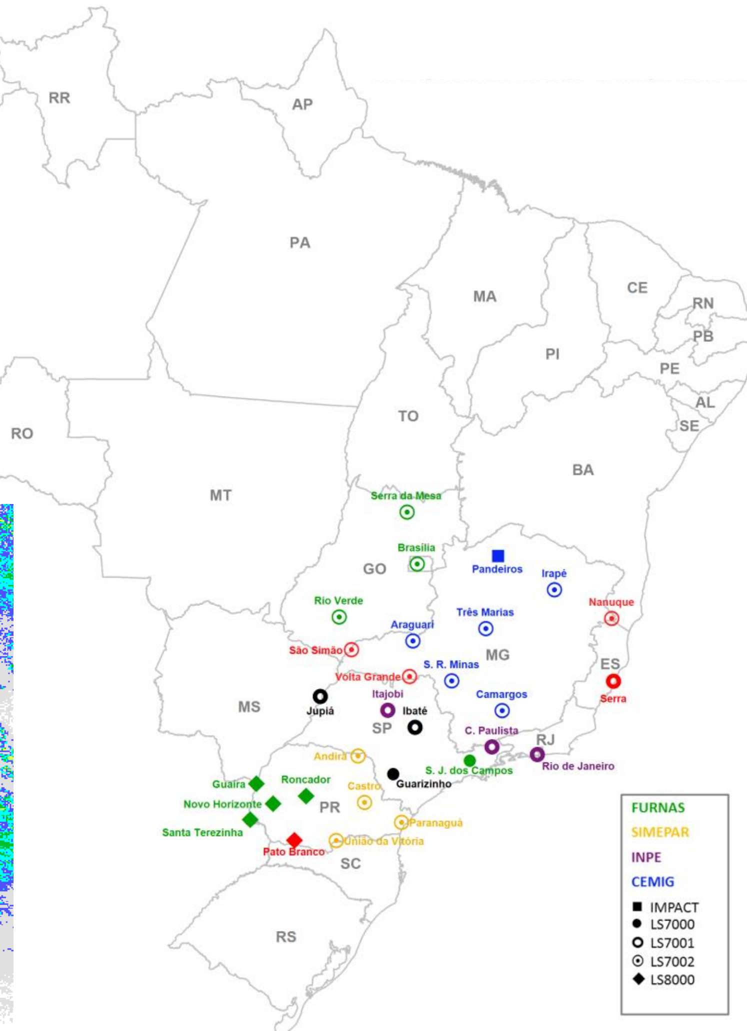
FURNAS

CEMIG

INPE

ELAT Grupo de Eletricidade Atmosférica





SIMEPAR

Operational Early Warning System in Southern Brazil

WMO OMM

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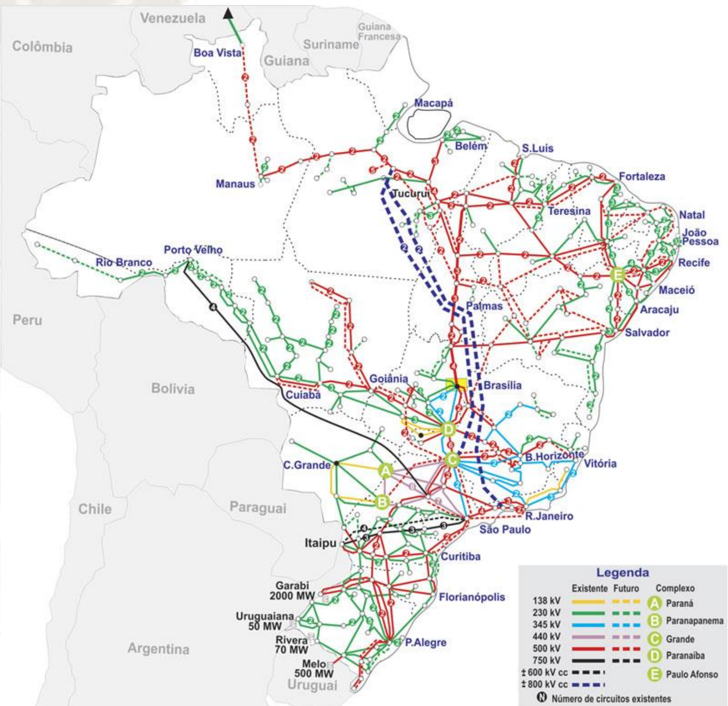

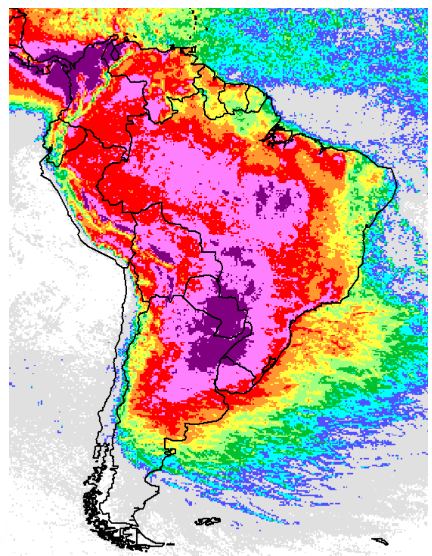

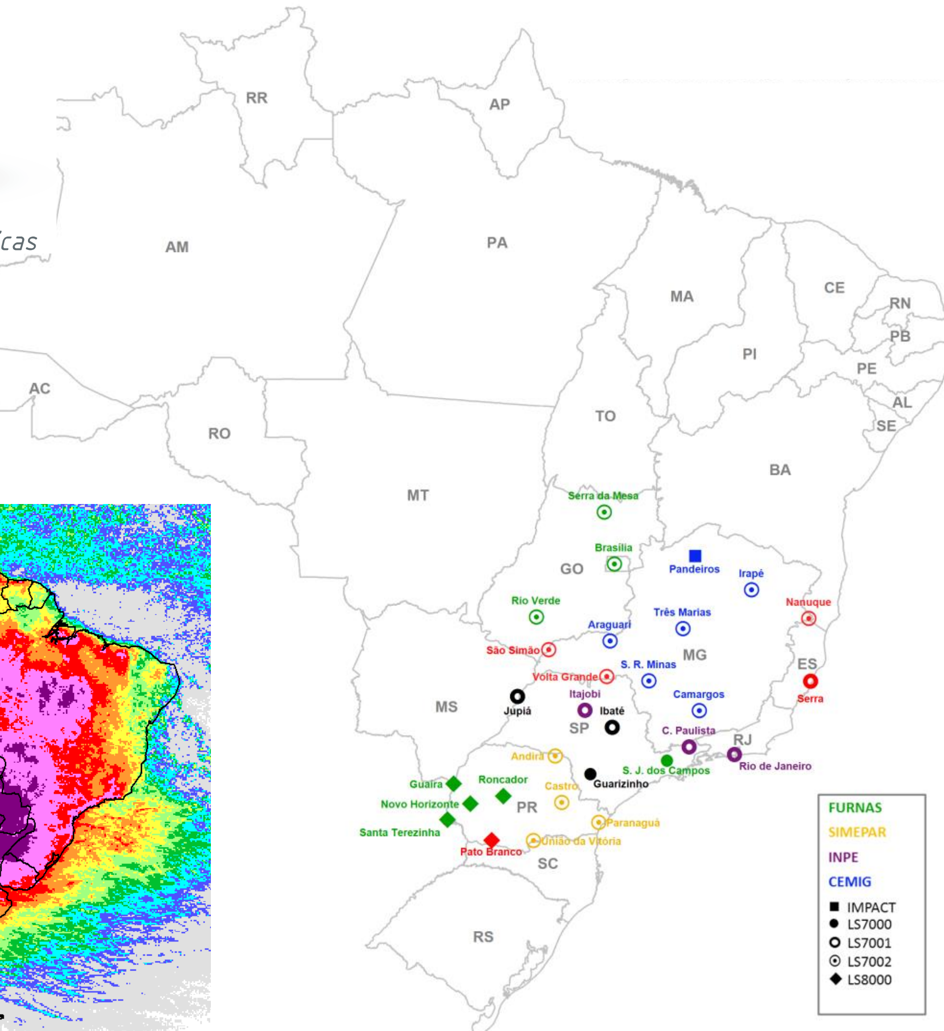

SIMEPAR

Operational Early Warning System in Southern Brazil

Lightning Detection Networks in Brazil - RINDAT

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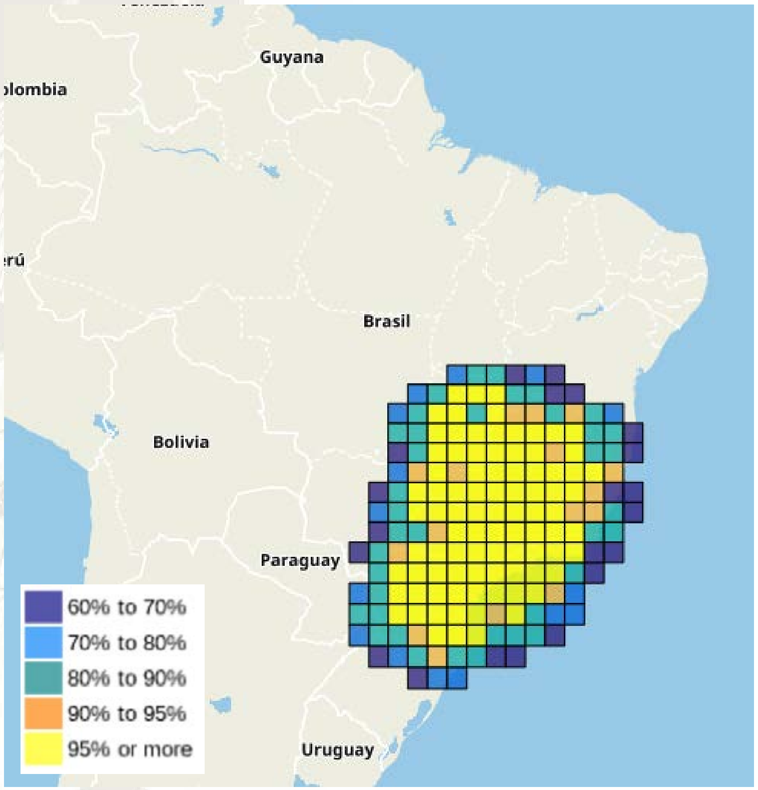
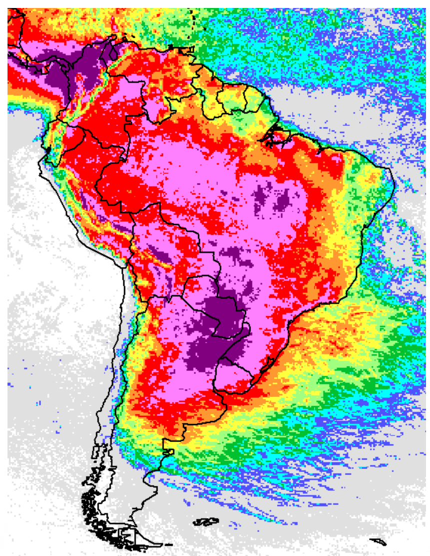
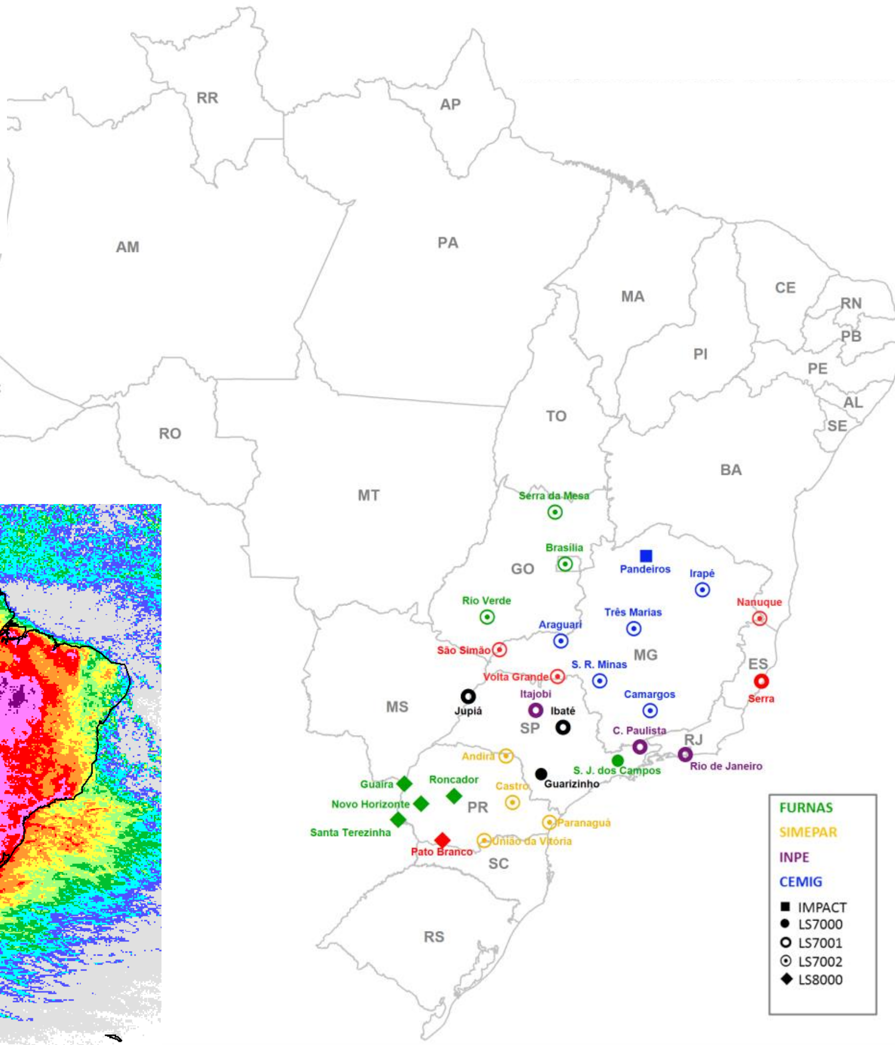
Rede Integrada Nacional de Detecção de Descargas Atmosféricas







SIMEPAR

Operational Early Warning System in Southern Brazil

WMO OMM

Lightning Detection Networks in Brazil - RINDAT

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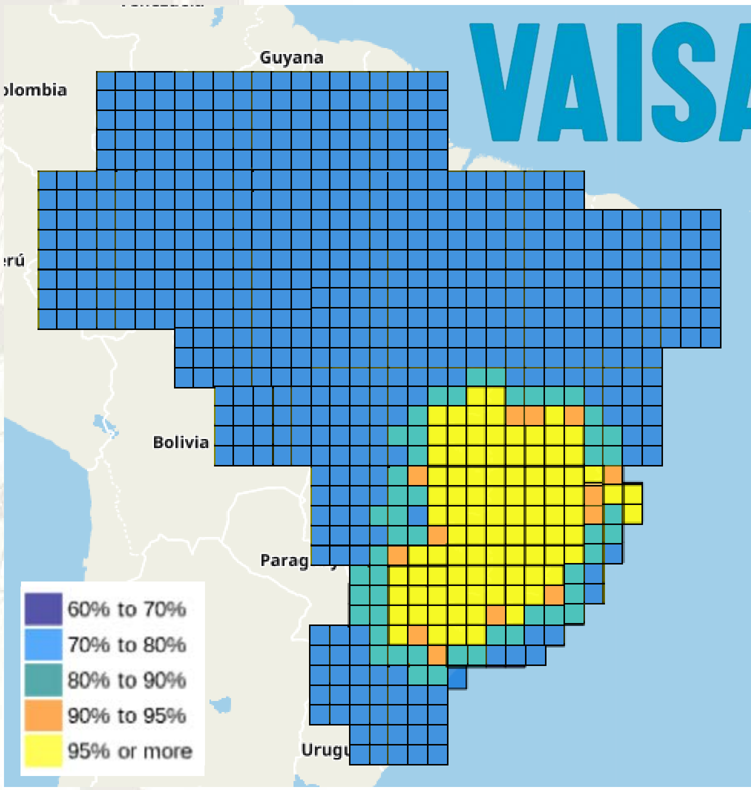
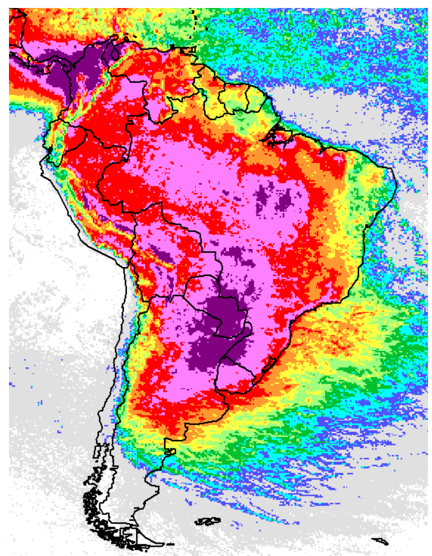
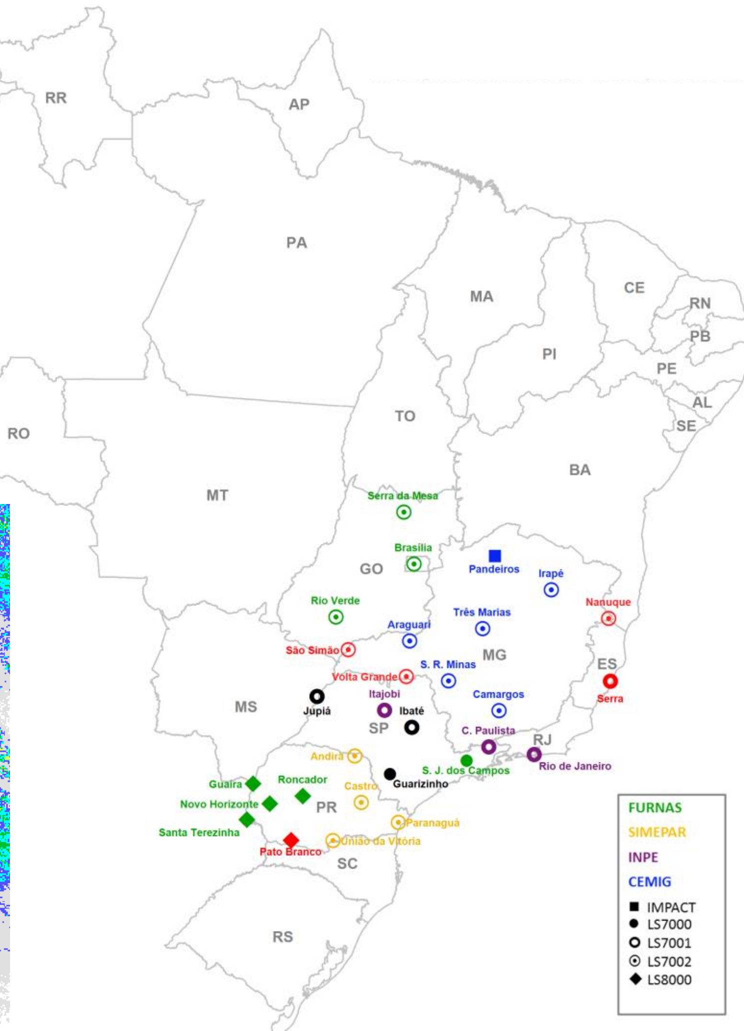
Rede Integrada Nacional de Detecção de Descargas Atmosféricas

VAISALA



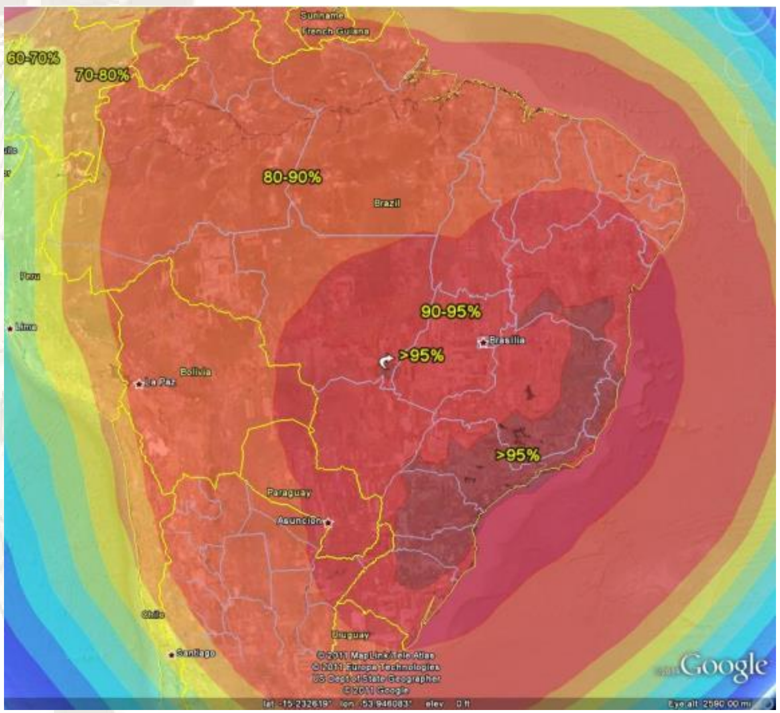


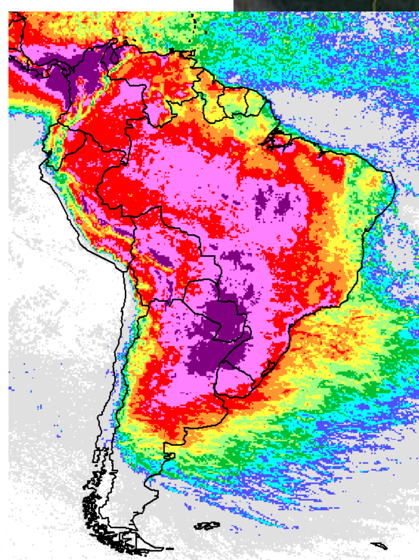


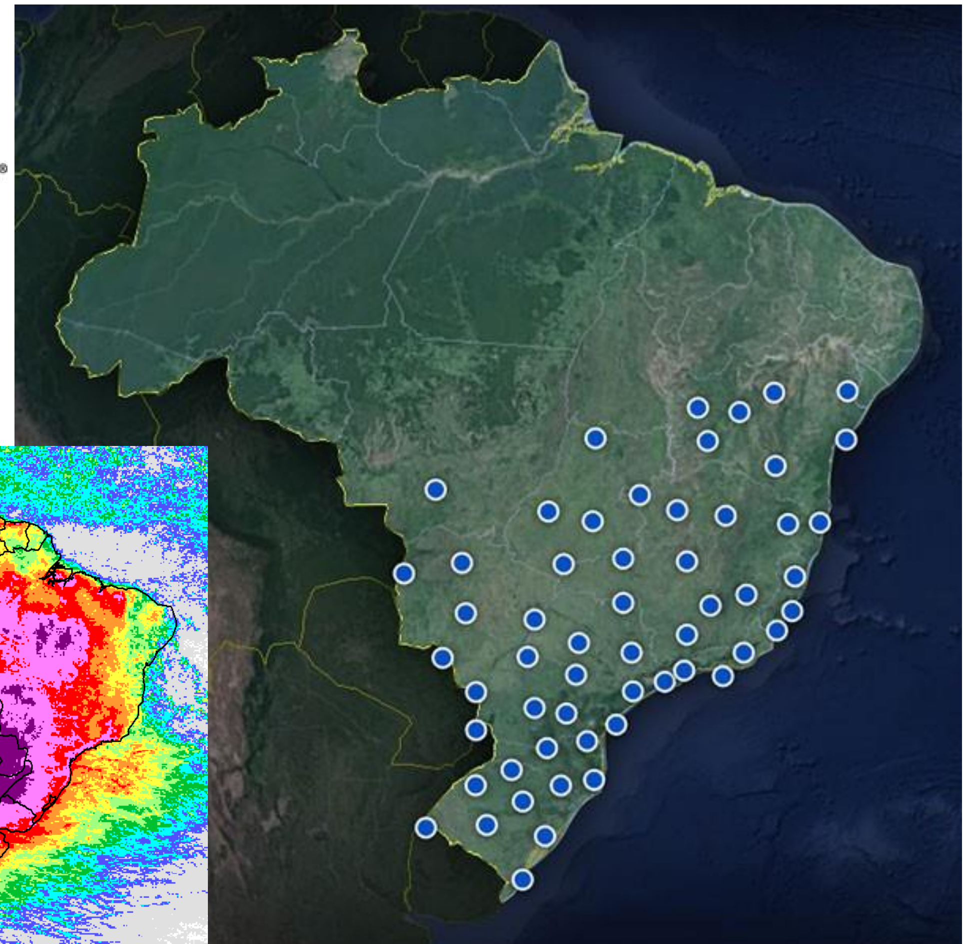
SIMEPAR

Operational Early Warning System in Southern Brazil

Lightning Detection Networks in Brazil – BRASILDAT

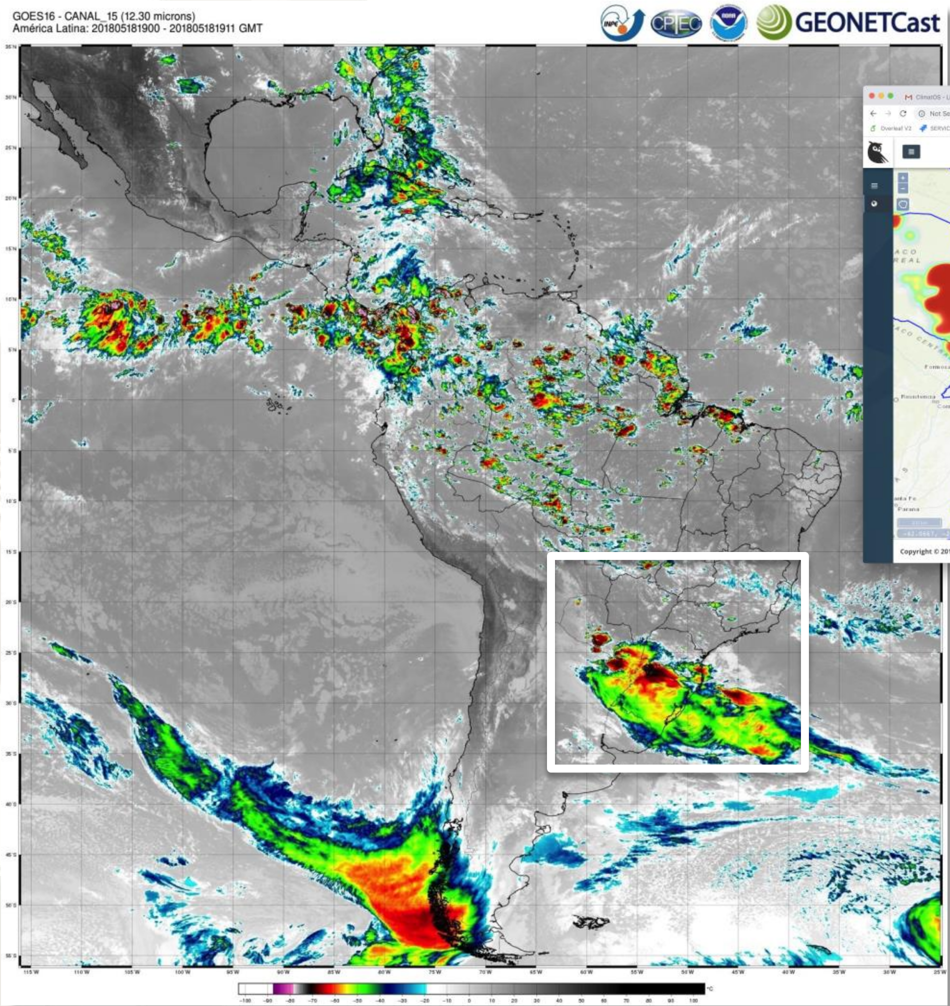




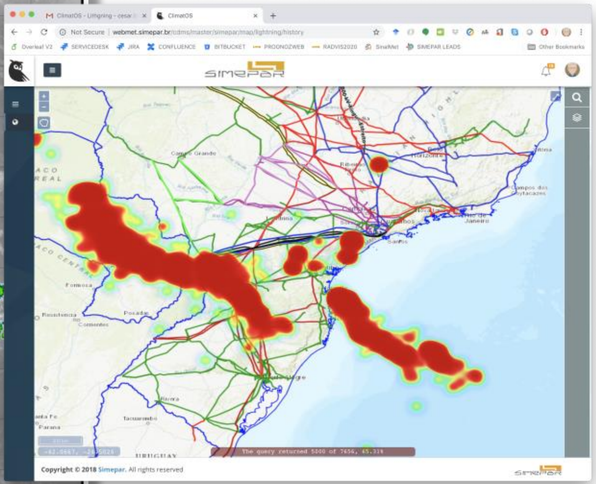


Operational Early Warning System in Southern Brazil

Lightning Detection Networks in Brazil – Examples



RINDAT



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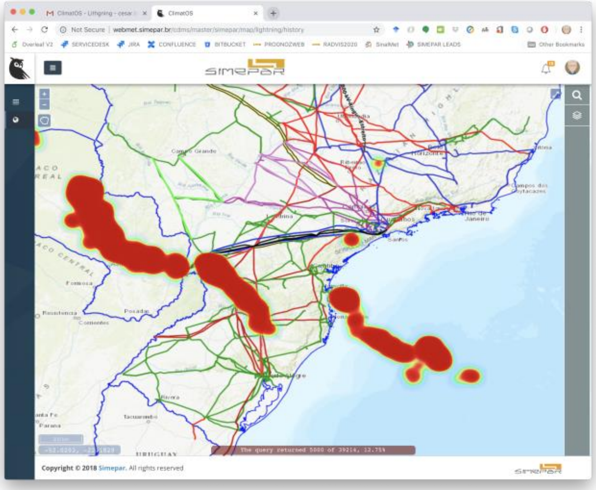
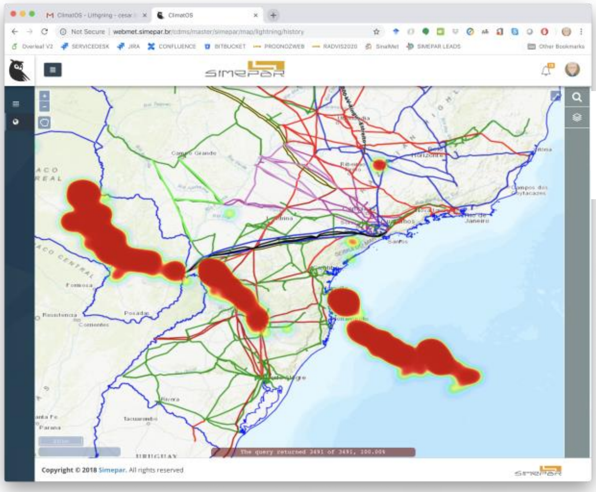




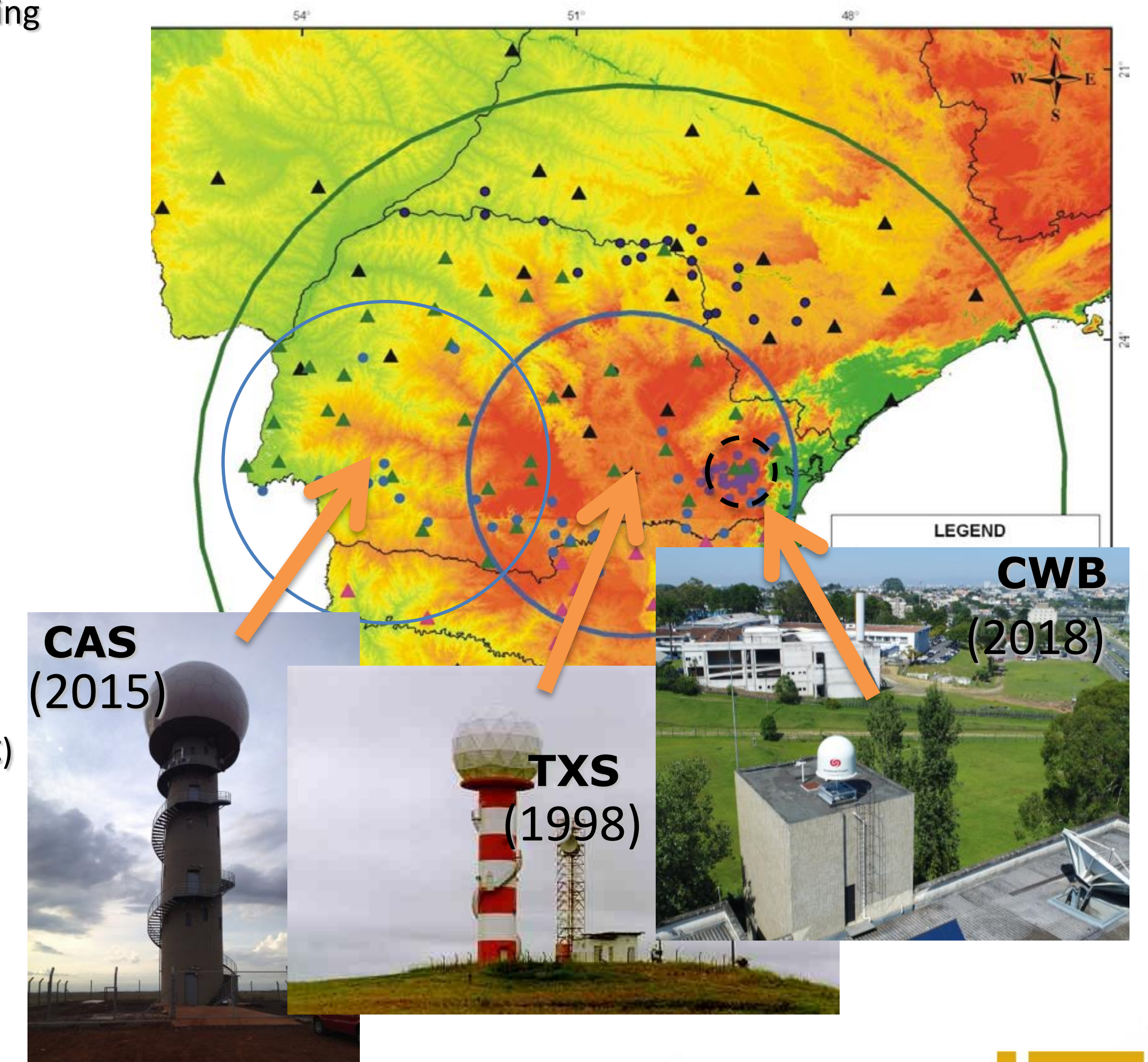
EARTH NETWORKS

Operational Early Warning System in Southern Brazil

WMO OMM

Regional Hydrometeorological Service - SIMEPAR

- Operational Hydro-Meteorological Monitoring (2 S-Band & X-Band Radars, Lightning Detection, +200 gauges & AWS) and Hydro-Met Forecasting (Nowcasting, Short-Term Forecasting, Hydrology Fcst)
- R&D in Meteorology, Hydrology, and Atmospheric Electricity
- Cooperation with:
  - Reg. Hydromet Centers
  - National Met Services (INMET, DINAC)
  - Natl. NWP Center (CPTEC)
  - Natl. Center for Disaster Monitoring and Alerts (CEMADEN)
  - Civil Protection



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Operational Early Warning System in Southern Brazil

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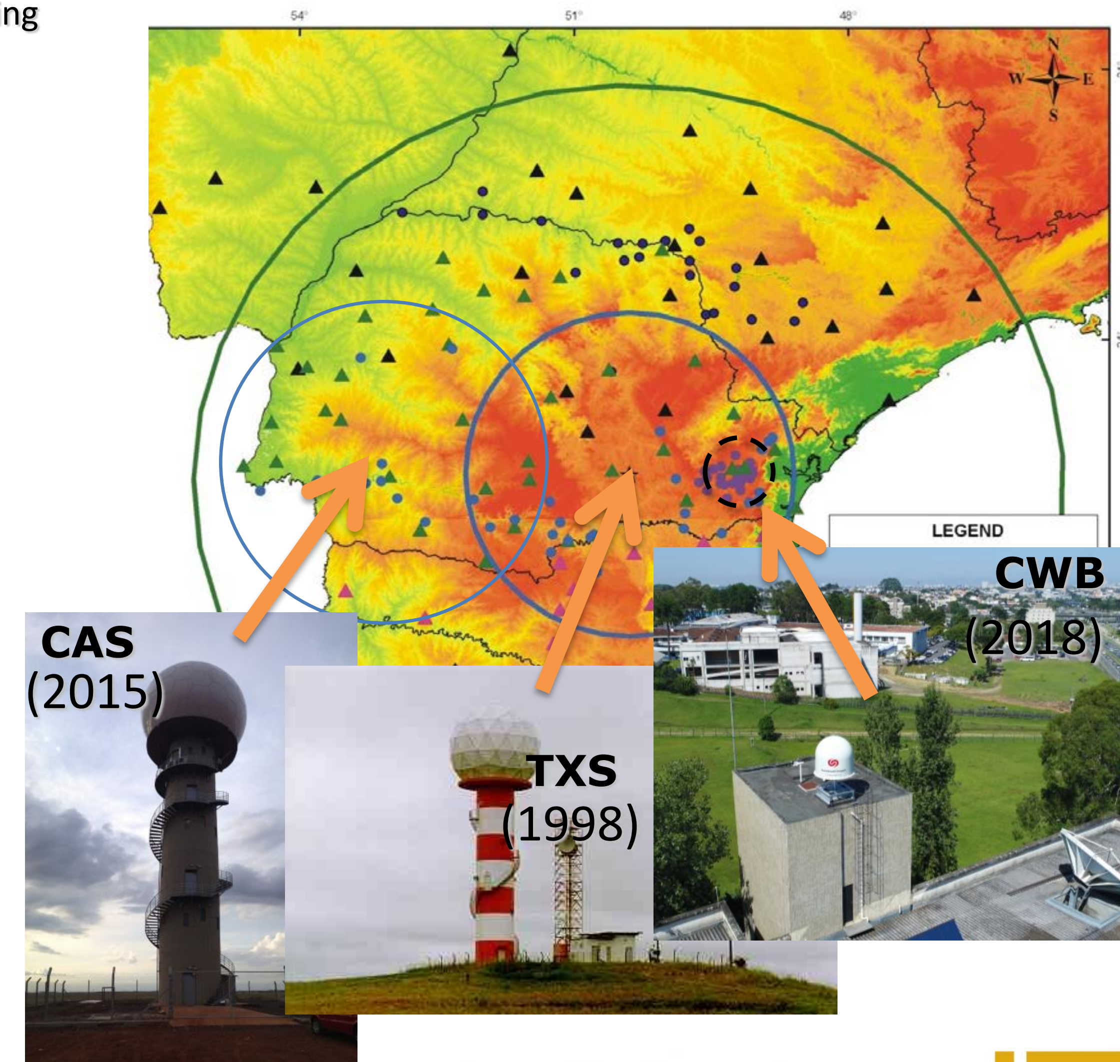


Energy Production and Transmission

- 85% is Hydro power in Brazil
- 35% is produced in Parana river basins
- Long transmission lines to urban centers

Agriculture

- 1st largest wheat and soy production
- 2nd largest corn and beans production

Operational Early Warning System in Southern Brazil

WMO OMM

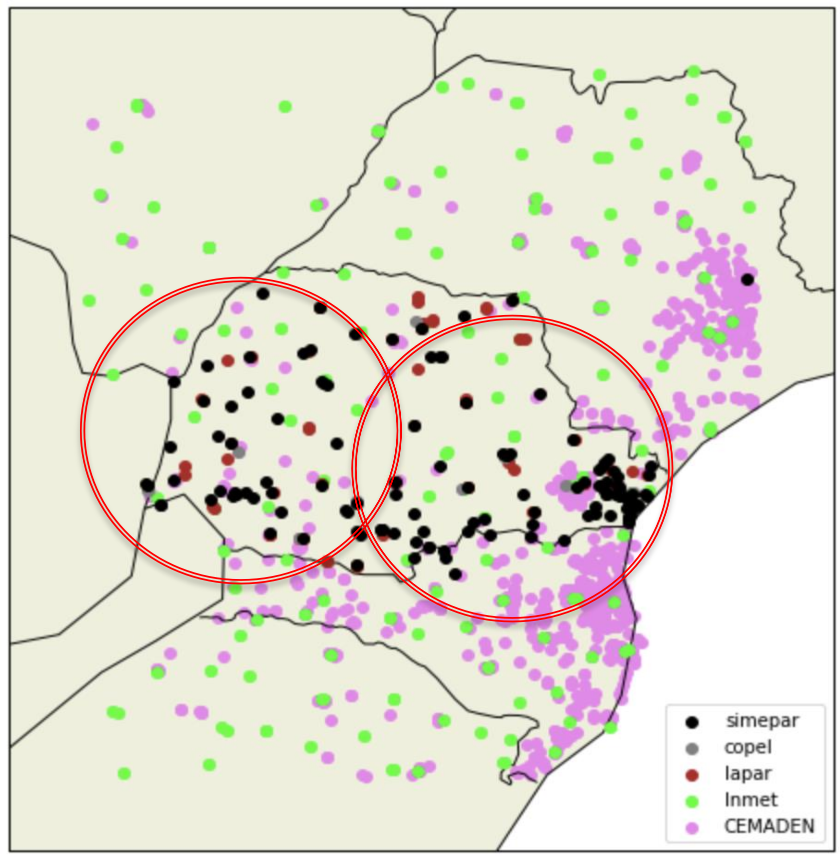
Dual Pol. Radar QPE and Multi-Sensor QPE (radar+satellite+gauge - SIPREC)

SIMEPAR

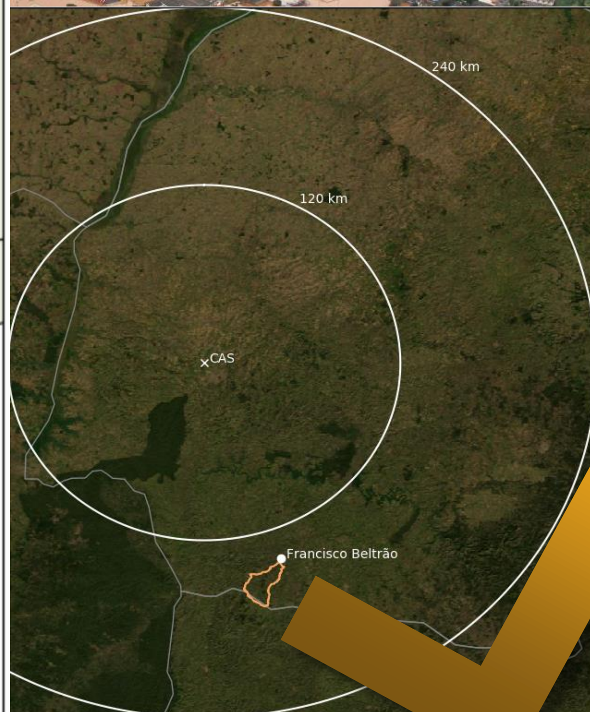
Operational Early Warning System in Southern Brazil

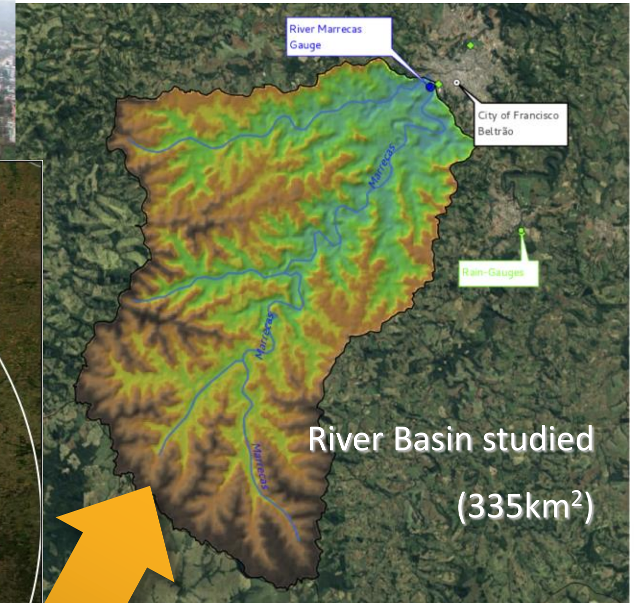
Dual Pol. Radar QPE and Multi-Sensor QPE (radar+satellite+gauge - SIPREC)

Flooding in Urban Area



(Beneti et al, AMS 2018)



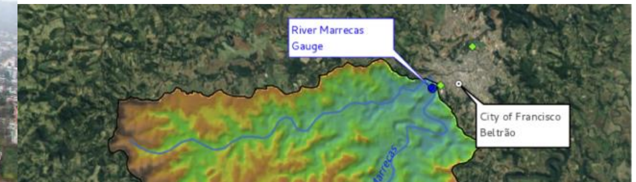


Operational Early Warning System in Southern Brazil

WMO OMM

Dual Pol. Radar QPE and Multi-Sensor QPE (radar+satellite+gauge - SIPREC)

Flooding in Urban Area



CAS weather radar: S-Band, Dual Polarization

Quantitative Precipitation Estimation

Reflectivity – Rainfall Rate Relationships

Marshall-Palmer: $Z = 200\ R^{1.6}$

NEXRAD: $Z = 300\ R^{1.5}$

SIMEPAR Distrometric: $Z = 288\ R^{1.4}$ (Calheiros et al 2017)

Polarimetric – Rainfall Rate Relationships

$R\ (Z,ZDR) = (1.42 \times 10^{-2})\ Z^{0.770}\ Z_{dr}^{-1.67}$

$R\ (Z,KDP) = 44.0|K_{DP}|^{0.822}\ \mathrm{sign}(K_{DP})$

(Ryzhkov & Zrnic 1996, Gorgucci et al 1999, Ryzhkov et al 2005, Vulpiane & Baldini 2013, among others)

Multi-Sensor QPE: Radar + Satellite + Gauge

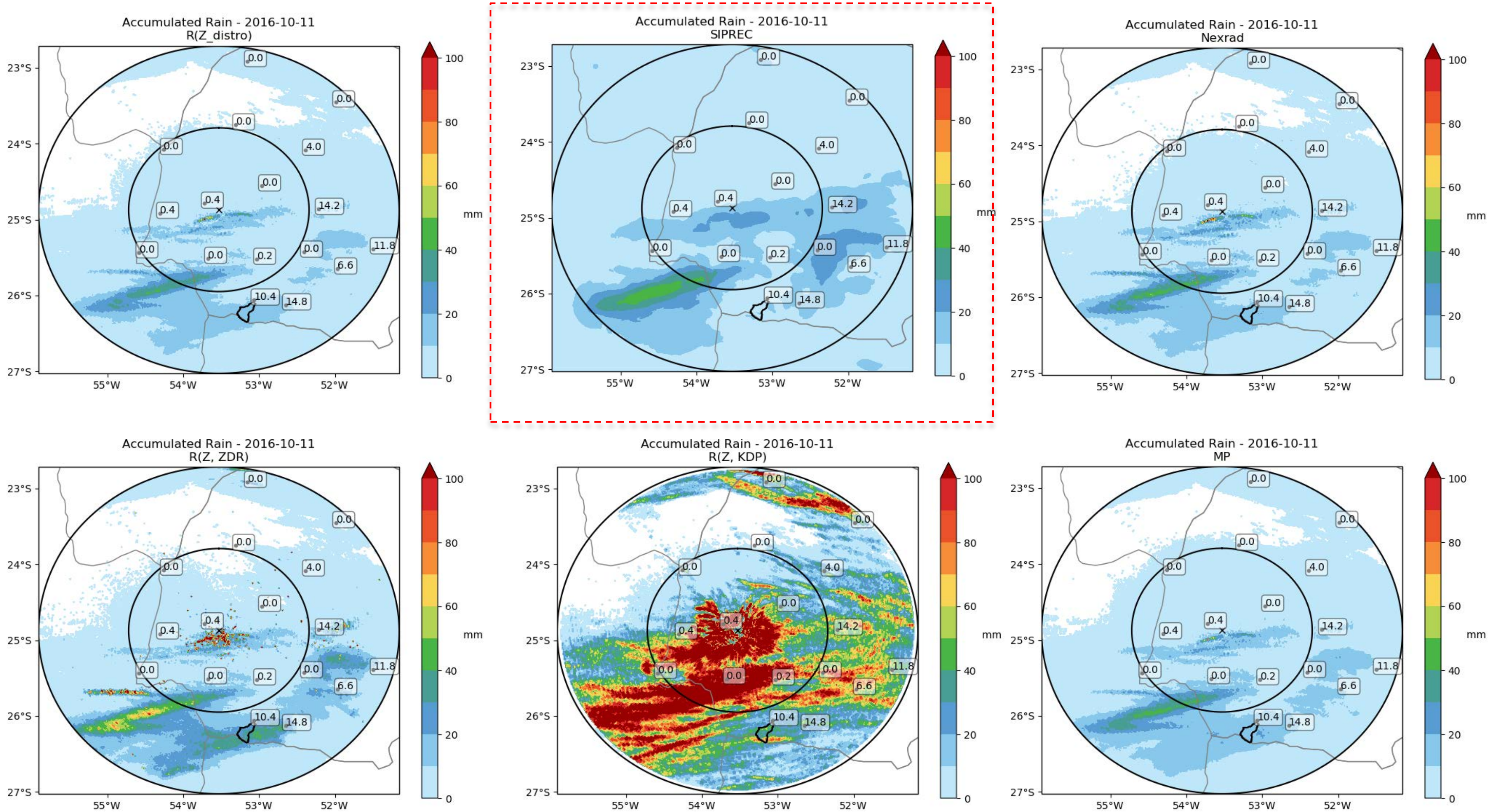
$$\nabla^2(R_{radar}+R_{satellite}) = P_{Gauge}$$ (Calvetti et al 2015)

(Beneti et al, AMS 2018)

Operational Early Warning System in Southern Brazil

Dual Pol. Radar QPE and Multi-Sensor QPE (radar+satellite+gauge - SIPREC)

<u>Case: 2016-10-11</u>

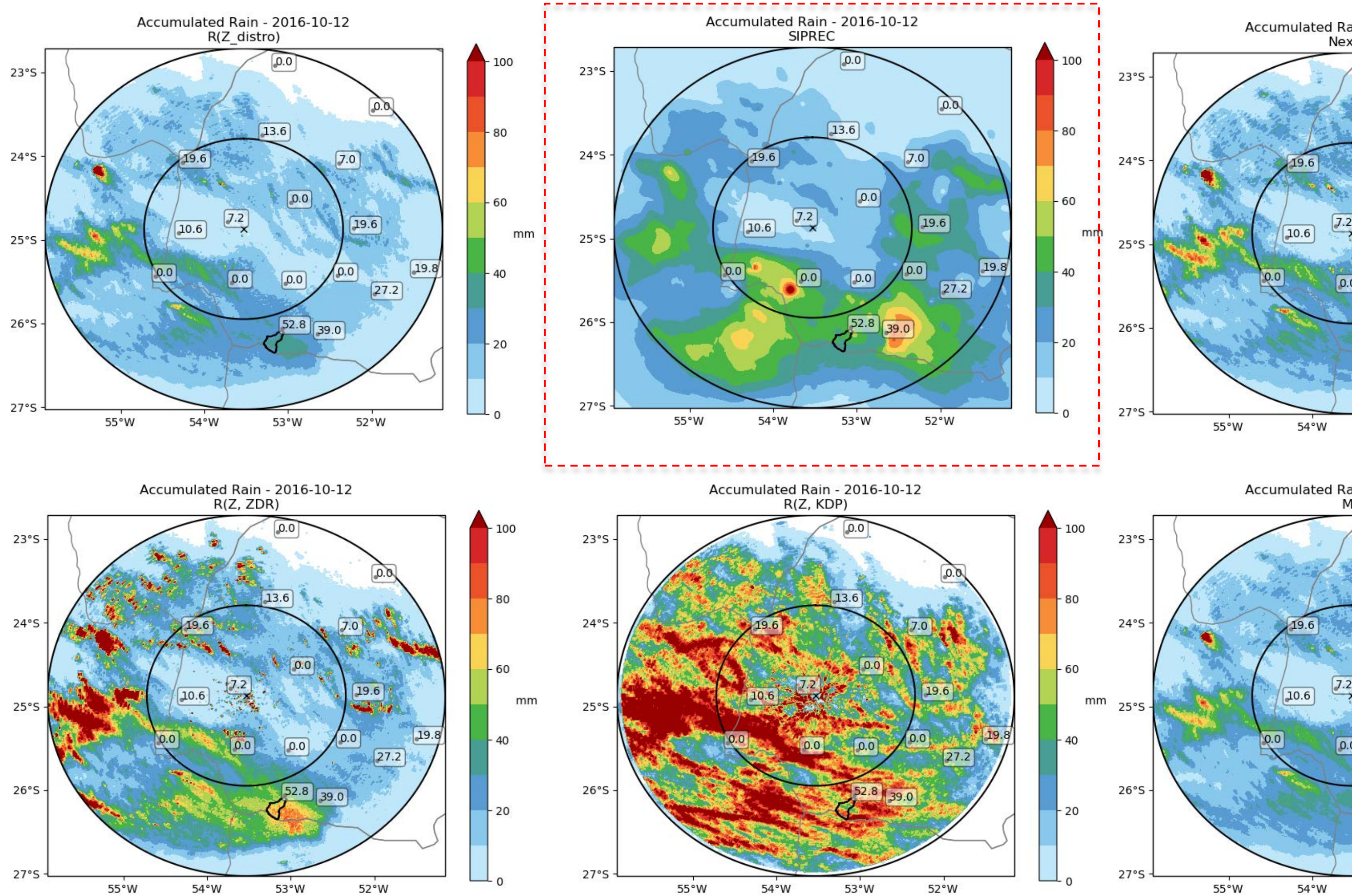


(Beneti et al, AMS 2018)

Operational Early Warning System in Southern Brazil

Dual Pol. Radar QPE and Multi-Sensor QPE (radar+satellite+gauge - SIPREC)

Case: 2016-10-12



(Beneti et al, AMS 2018)

Operational Early Warning System in Southern Brazil

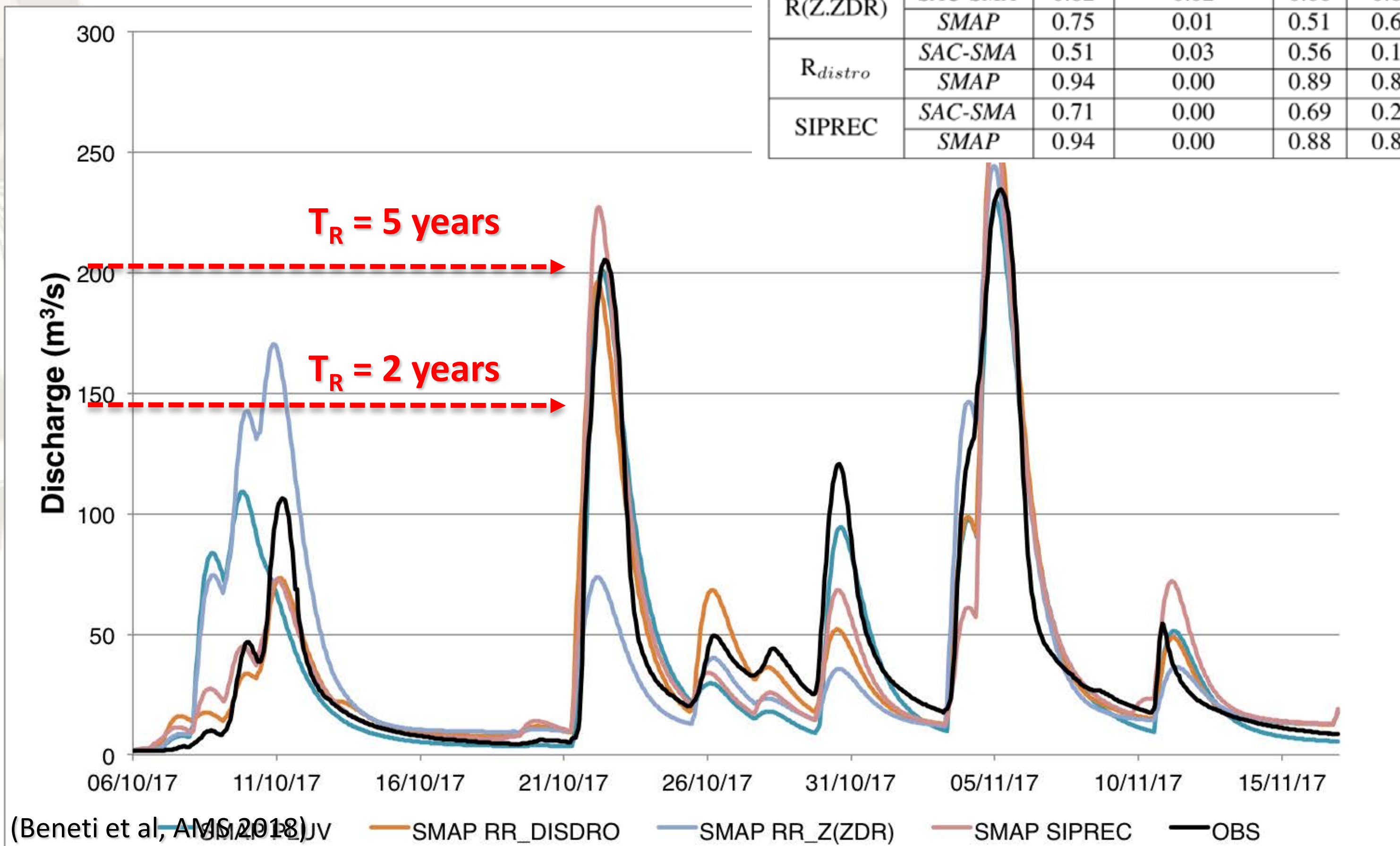
Dual Pol. Radar QPE and Multi-Sensor QPE (radar+satellite+gauge - SIPREC)

Flooding in Urban Area:

Hydrological Model Application

Table 1: Rainfall-runoff model performance for SAC-SMA and SMAP - flood events in nov/2017

Forcing	Model	KGE	ΔV (*1e2%)	NS	logNS	PEARSON	RMSE
Raingauge	*SAC-SMA*	0.93	0.01	0.87	0.80	0.93	17.64
	SMAP	0.91	0.00	0.82	0.73	0.91	20.50
R(Z.ZDR)	*SAC-SMA*	0.82	0.02	0.66	0.68	0.82	28.68
	SMAP	0.75	0.01	0.51	0.66	0.75	34.08
R_{distro}	*SAC-SMA*	0.51	0.03	0.56	0.13	0.78	32.42
	SMAP	0.94	0.00	0.89	0.83	0.94	16.48
SIPREC	*SAC-SMA*	0.71	0.00	0.69	0.29	0.83	27.19
	SMAP	0.94	0.00	0.88	0.81	0.94	17.21



(Beneti et al, AMS 2018)

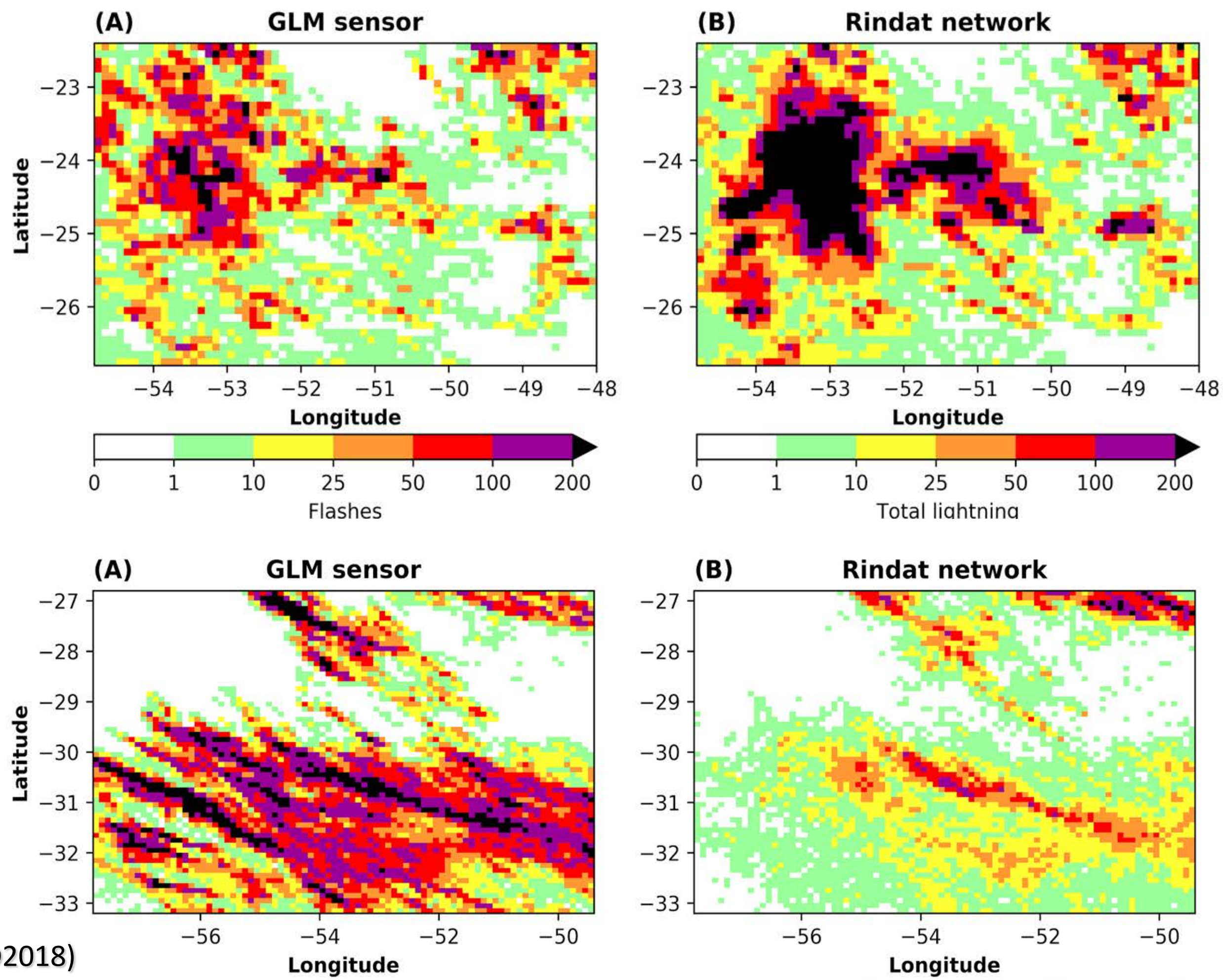
Operational Early Warning System in Southern Brazil

Multi-Sensor QPE (radar+satellite+gauge + LIGHTNING?)

Evaluating GOES16/GLM vs RINDAT for Convective Storm Identification and QPE

Area inside RINDAT network

Area outside RINDAT network



Case: 2018-03-15

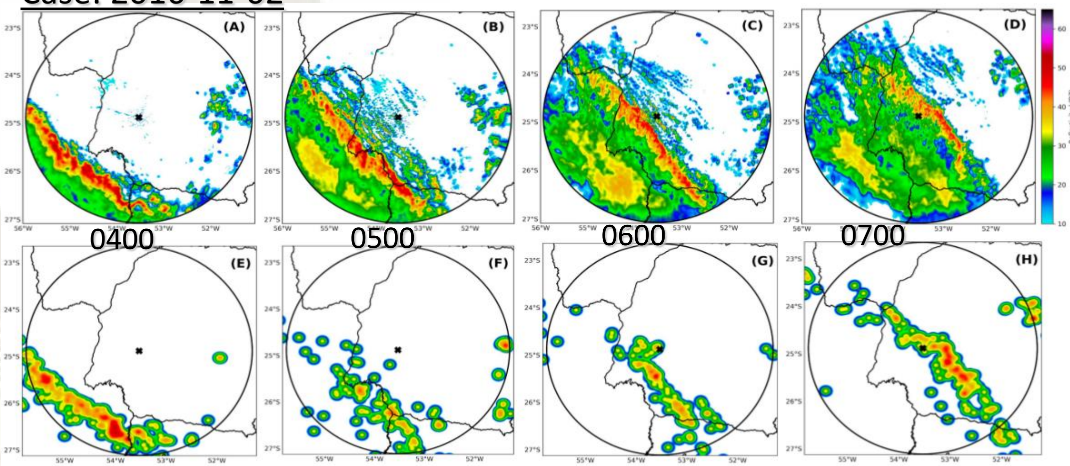
(Calvetti et al, ERAD2018)

Operational Early Warning System in Southern Brazil

Multi-Sensor QPE (radar+satellite+gauge + LIGHTNING?)

Evaluating EN (PulseRad) vs Dual-Pol S-Band Radar for Convective Storms Identification and QPE

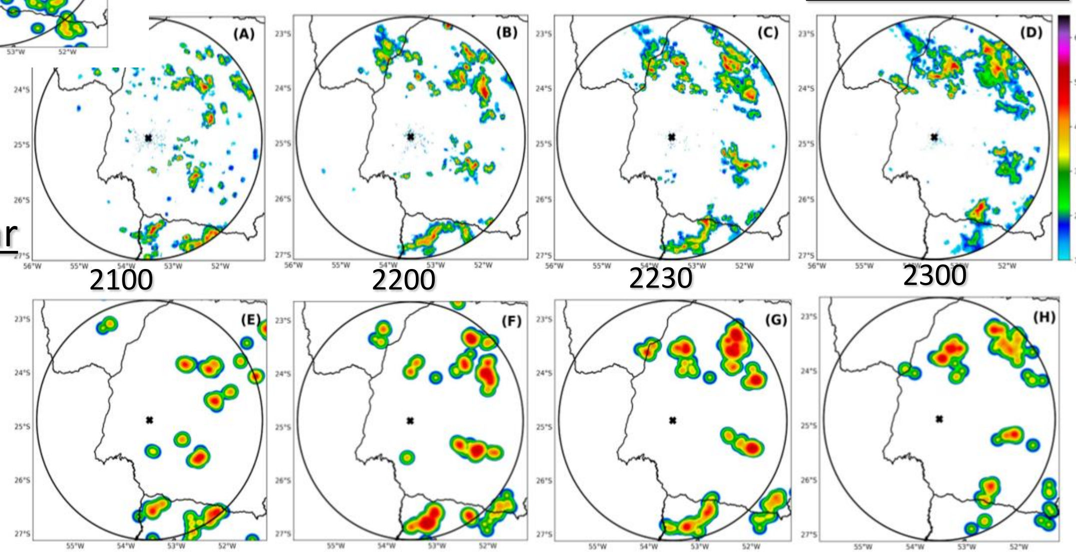
Case: 2016-11-02



Weather Radar

EN PulseRad

Case: 2017-01-09



Weather Radar

EN PulseRad

(Calvetti et al, ERAD2018)

Operational Early Warning System in Southern Brazil

WMO OMM

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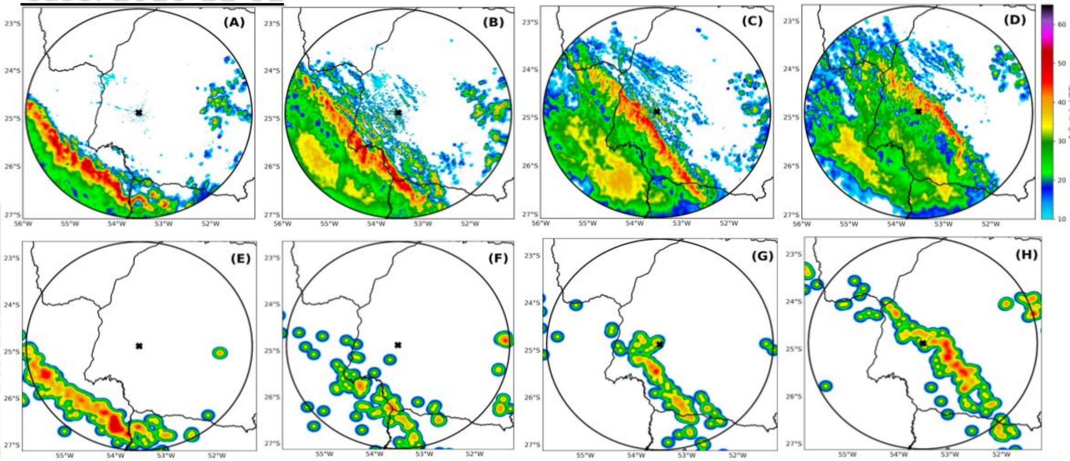
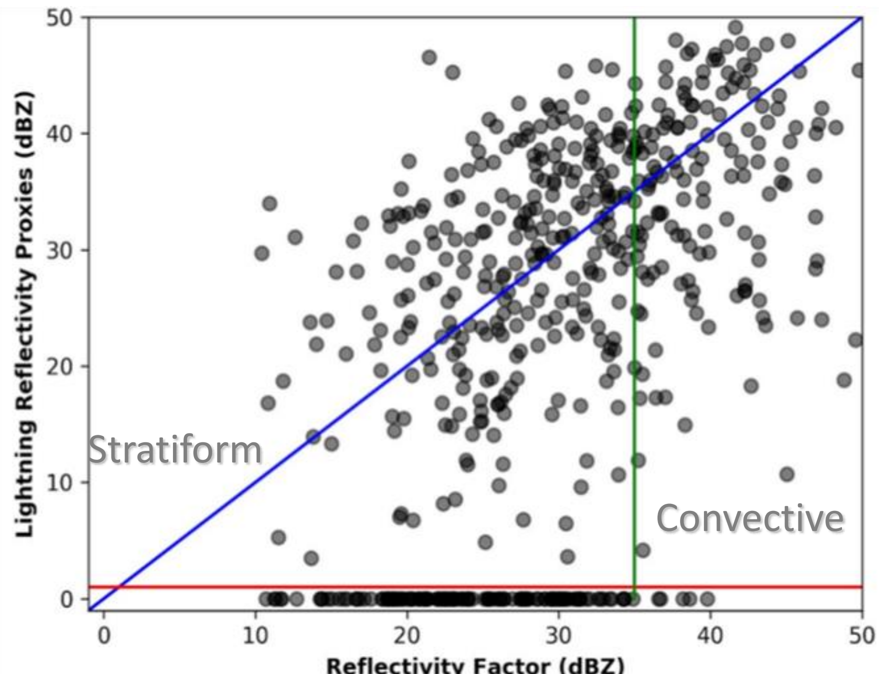


Comparison of Lightning and Radar Reflectivity



(Calvetti et al, ERAD2018)

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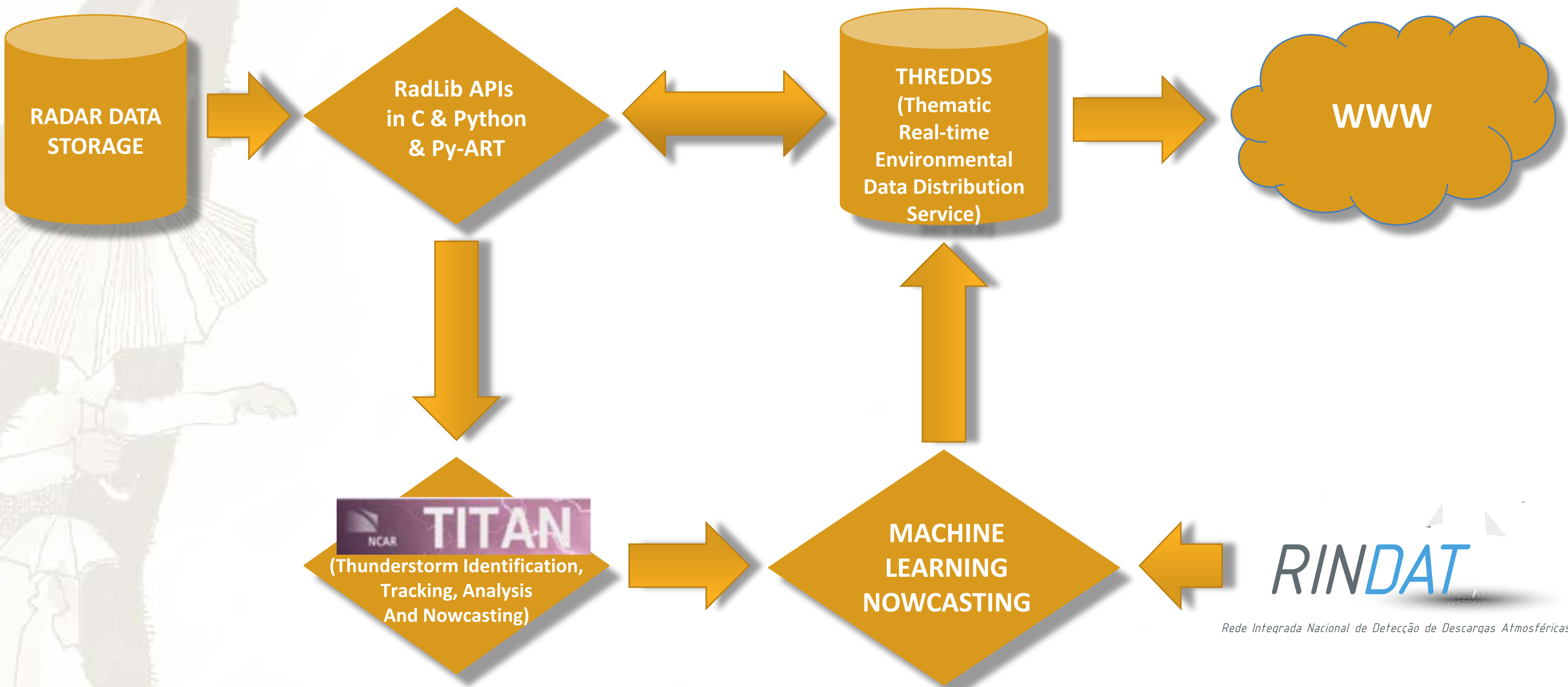
Operational Early Warning System in Southern Brazil

High Impact Weather Nowcasting Using Machine Learning

Data from several radar formats are received, processed, converted (to MDV) and a Weather Radar Mosaic is created and used for the Machine Learning Nowcasting Algorithm



Operational Early Warning System in Southern Brazil

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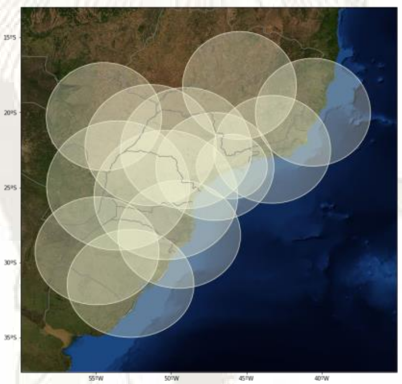
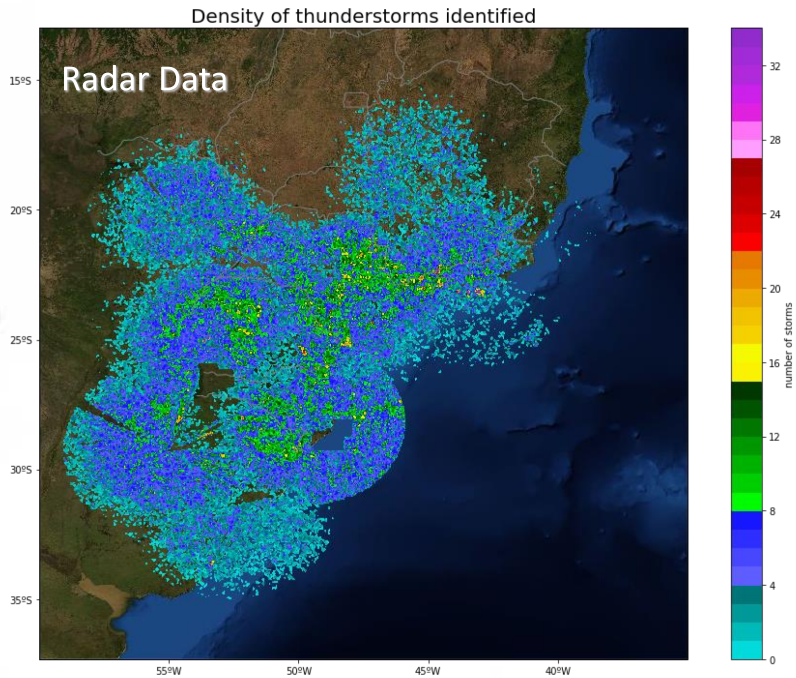
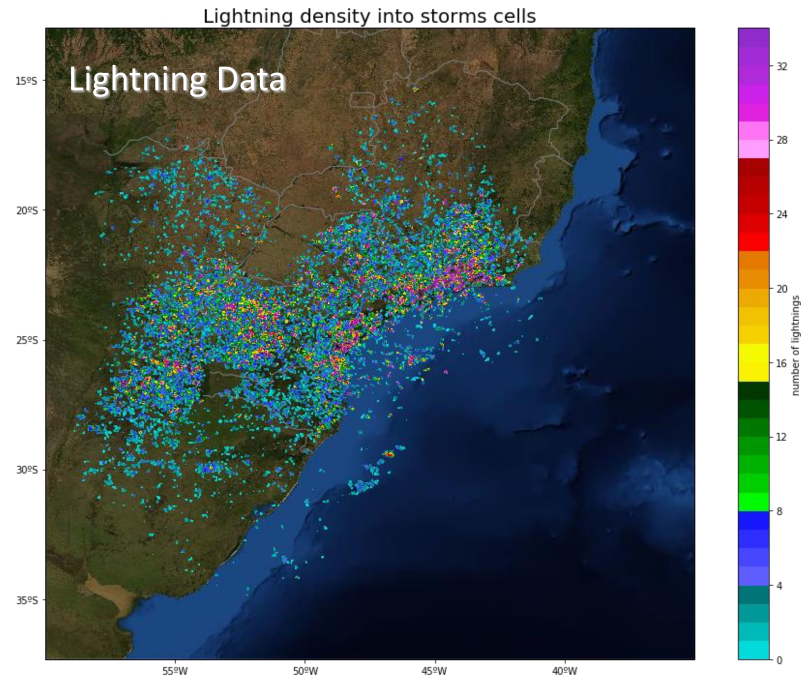
- RINDAT Lightning: Density maps (4 km^2) separated in $+CG_s$ and $-CG_s$







(Beneti et al, ERAD2018)

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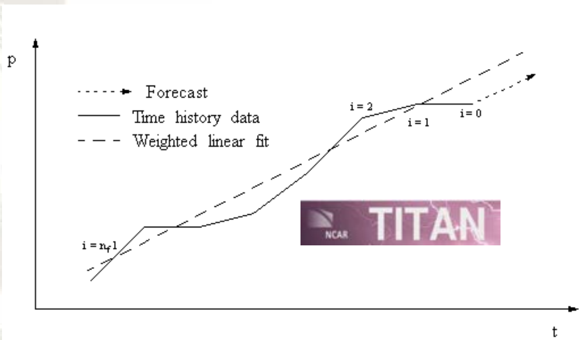
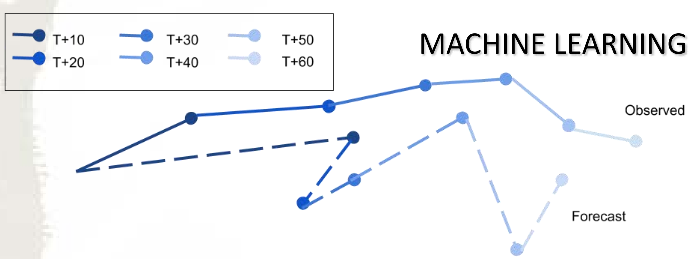
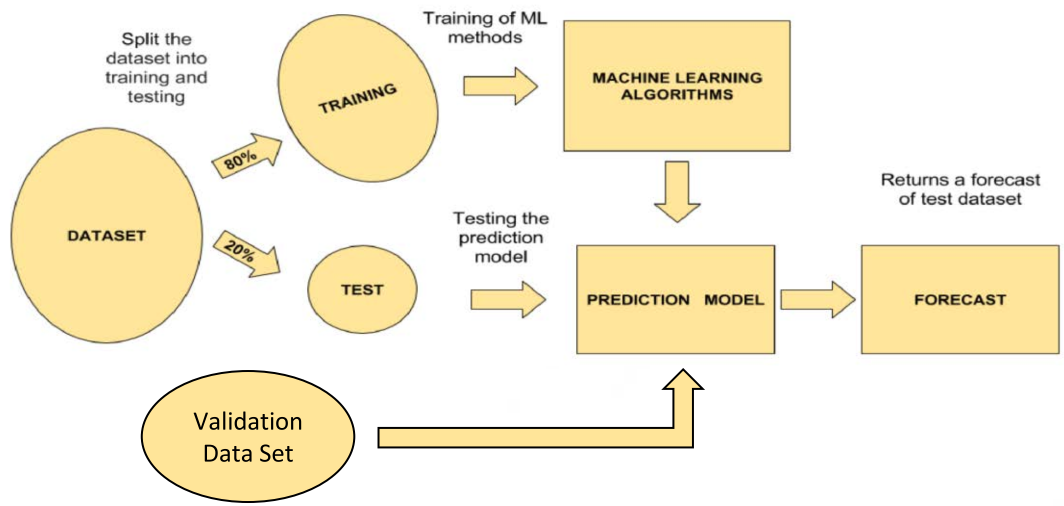


SUPERVISED

MACHINE LEARNING MODEL





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Operational Early Warning System in Southern Brazil

High Impact Weather Nowcasting Using Machine Learning

WMO OMM

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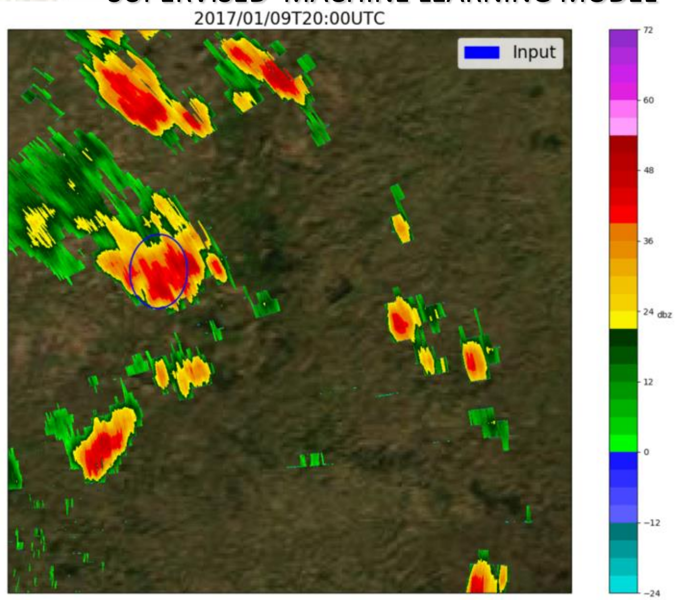

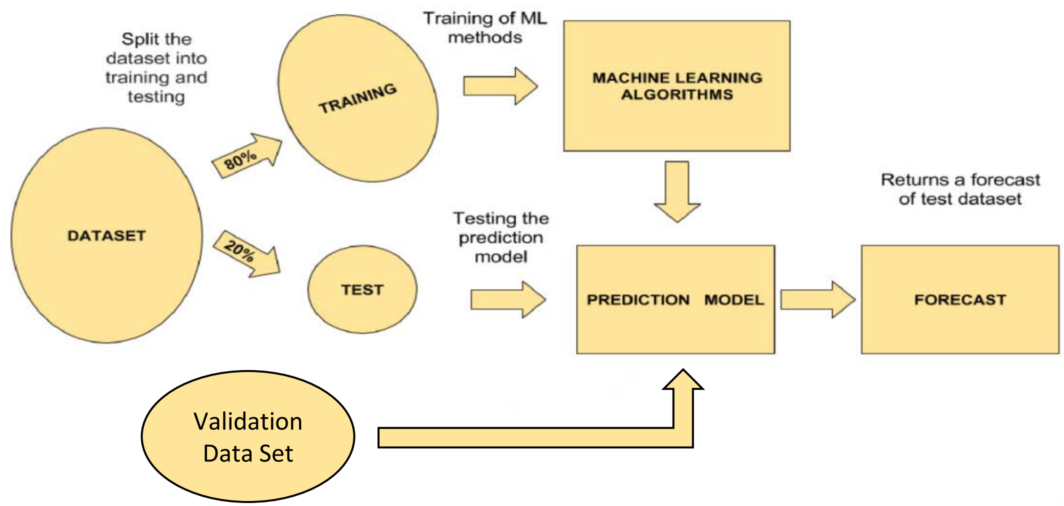

(Beneti et al, ERAD2018)

simepar

Operational Early Warning System in Southern Brazil

High Impact Weather Nowcasting Using Machine Learning

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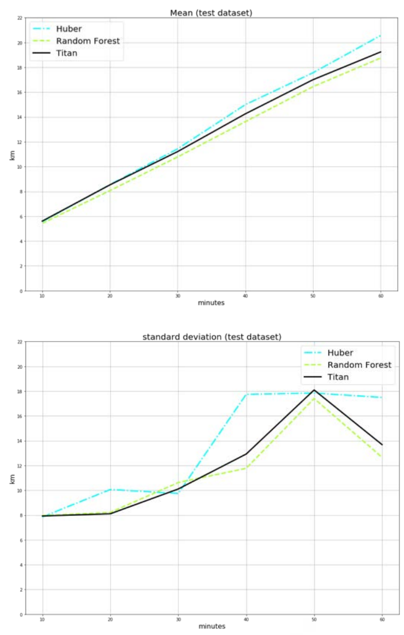
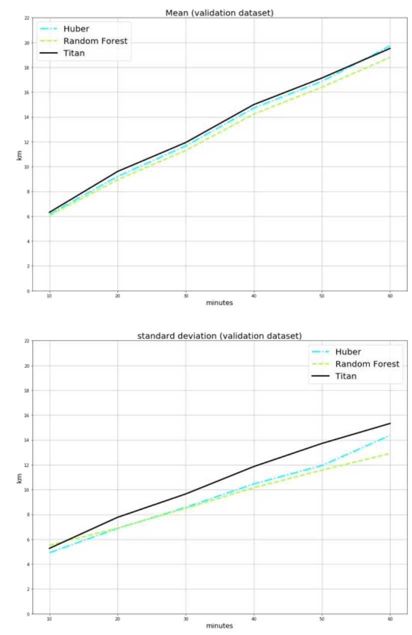
Results using Linear Regression Model (Huber) and Ensemble Model (Random Forest)

- Test data set (20% of random sampled from original dataset – Aug 2016 to Aug 2017)
- Validation data set (from Sept 2017 to Jan 2018)

Test Data Set



Validation Data Set



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Operational Early Warning System in Southern Brazil

WMO OMM

Conclusions and Future Work

- Multi-sensor QPE (Radar + Satellite + Gauge) has been in use for over 10 years, in hydrology applications (input for stream flow forecast model) in operational hydropower companies, with better results than using gauge or gauge+radar alone.

- Radar QPE, with dual polarization, can be improved if considered not only a Z-R relation or R(Z,ZDR,KDP) alone, which has been applied to the Brazilian weather radar network, but with particle identification and stratification of the R(Z,ZDR,KDP) relation.

- Although a lightning QPE can be tricky to obtain/use, satellite lightning observations (GLM) and total lightning detection networks have demonstrated that there is good agreement specially to identify convective regions within the storms, which can then be used to improve QPE algorithms.

- Machine learning algorithms applied to thunderstorms forecasting/nowcasting showed better results than TITAN algorithm alone. **Random Forest** model presented better results for the storm centroid location and ellipses sizes/shape.

- An algorithm for nowcasting precipitation, using machine learning to forecast storm displacement and also multi-sensor QPE data fusion is under development.

Thank You!

Bedankt!