RELAMPAGO
Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations

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Motivation

• Lack of consistent, high-frequency, repeatable observations of thermodynamic, kinematic, diabatic processes, and land surface conditions where convection initiates and grows upscale. **NEXRAD and operational soundings not enough in US.** So we do field projects!

• In the US, where we have a great chance of doing this, the precipitation climatology widespread across the plains (e.g. PECAN), and the terrain is complicated.

• What if there existed a place where there are analogs to the US, where the precipitation climatology is reliable, and we could design a field campaign?
¿Por que Argentina?

RELAMPAGO/CACTI study region

Córdoba • Santa Fé
Mendoza •
Denver •

TRMM 3B42 rain rate Hovmöller diagram centered on the Sierras de Córdoba during Nov-Dec
Distributions of Severe Weather in SESA

Brooks and Doswell (2001)

Distribution of reported tornado intensities

Argentina 1930–1979, N=368.
There is a large uncertainty in climate and regional models in simulating precipitation.

Carril et al (2012)
RELAMPAGO/CACTI 2018-2019 is an international project...

• to study intense continental convective systems in subtropical South America
• to understand their interactions with local and regional meteorology, aerosols, topography, and land-atmosphere interactions
• to improve severe storm hazard prediction
• to place extreme continental convection in context with regional and global climate
## Science Steering Groups

### CACTI

Adam Varble, U. Utah, lead scientist

**Co-Investigators:**

- Eldo Avila, U. Cordoba
- Paul DeMott, CSU
- David Gochis, NCAR-RAL
- Robert Houze, UW/PNNL
- Michael Jensen, BNL
- Pavlos Kollias, Stony Brook/BNL
- Sonia Kreidenweis, CSU
- L. Ruby Leung, PNNL
- Greg McFarquhar, Illinois
- Steve Nesbitt, Illinois
- Kristen Rasmussen, NCAR MMM
- David Romps, Berkeley/LBNL
- Paola Salio, U. Buenos Aires
- Christopher Williams, U. Colorado
- Edward Zipser, U. Utah
- Sue van den Heever, CSU

### RELAMPAGO

Steve Nesbitt, Illinois (US NSF PI)
- Jeff Trapp, Illinois (US NSF Co-PI)
- Rita Roberts, NCAR-RAL (US NSF Co-PI)

Adam Varble, University of Utah (CACTI liason)
- Paola Salio, U. Buenos Aires, Argentina (Argentina lead)
- Luiz Machado, INPE, Brazil (Brazil lead)
- Francina Dominguez, Illinois
- Kristen Rasmussen, NCAR-MMM
- Jim Wilson, NCAR-RAL
- Karen Kosiba, CSWR
- Josh Wurman, CSWR
- Ed Zipser, Utah
- Robert Houze, U. Washington
- V. Chandrasekar, CSU
- Rachel Albrecht, U. São Paulo, Brazil
- Timothy Lang, NASA MSFC (US NASA/NOAA lead)
- Celeste Saulo (Servicio Meteorológico Nacional, Argentina)
What is RELAMPAGO?
Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations

RELAMPAGO’s proposed primary science questions:
1. Determine relevant environmental processes that lead to the initiation of convection near complex terrain features, and contrast the mechanisms near the Andean front and the lower mesoscale topography to the east.
2. Intensification and upscale growth of convection: Identify the kinematic, thermodynamic, and microphysical processes by which convection intensifies and grows upscale in the immediate vicinity of complex terrain features into extremely tall and broad convective systems.
3. Observe the processes by which high-impact weather events (flooding, hail, strong winds, and tornadoes) are generated in environments close to the Andes and lower mountains to the east of the Andes in two nearby regions: the Sierras de Cordoba, and Mendoza.

## RELAMPAGO + CACTI
### Potential Contributions

<table>
<thead>
<tr>
<th>NSF (US)</th>
<th>NASA (US)</th>
<th>SMN (AR)</th>
<th>INPE (BR)</th>
<th>CONyCET (CH)</th>
<th>DOE (US) CACTI</th>
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<tbody>
<tr>
<td>Deployment pool</td>
<td>Disdrometers</td>
<td>C-Band DP op network</td>
<td>Mobile X-Band DP radar</td>
<td>Sounding sites</td>
<td>AMF-1 (cloud/profiling suite, aerosol measurements)</td>
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<tr>
<td>S-PolKa</td>
<td>Rain gauges</td>
<td>Mobile soundings</td>
<td>Precip/profileing supersite</td>
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<td>C-Band DP Radar?</td>
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<tr>
<td>DOWs Soundings + Expendables</td>
<td>Micro-rain radars</td>
<td>Enhancement of operational radiosondes</td>
<td>Lightning mapping array Sticknet</td>
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<td>G-1 microphysical and aerosol aircraft?</td>
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<td>Mesonet/Pods (CSWR)</td>
<td>NPOL?</td>
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<td>S-Band DP radars</td>
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<td>DIAL LIDAR</td>
<td>ER-2?</td>
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<td>downstream</td>
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<td>Hydromet measurements (RAL)</td>
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<td>(Proposed)</td>
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<td>NOAA (US)</td>
<td>GOES-R validation</td>
<td>DSD + rainfall</td>
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<td>Lightning mapping array</td>
<td>FUNDED!</td>
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<td>Field mills</td>
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RELAMPAGO-CACTI broad study domain
Radars to complement CACTI observations

AR Existing + SIRANAME Network:
Critical for surveillance. Need to demonstrate consistent calibration.

**S-PolKA:** 4-D distribution of precipitation, microphysics, cloud liquid water, moisture

**3 DOW radars:** Dual-pol, dual-Doppler kinematics, low level structures

**Brazil X-Pol mobile radar:**
Lagrangian tracking of systems

These radars will compliment each other, allowing the objectives of each radar to be fully accomplished without sacrificing measurement capabilities.
4 cases from 2015-16 warm season
Córdoba INVAP Dual-pol C-Band radar
Installed April 2015
Why do we need NSF radars to accomplish these science objectives?

- Dual-Doppler scanning requires good low-level coverage and coordinated sector scans, which take away from microphysical scans (RHIs, volume scanning), mobile X-Bands (DOWs) can do this in a network configuration to mitigate attenuation.
- C-band Argentinian radars, and CSAPR-2 will suffer from attenuation and backscatter differential phase effects, plus we will lack operational control.
- S-PolKa can help with calibration and algorithm development for C-Band radars, critical in hail, large drops, and heavy precipitation.
Moisture observations from new remote sensing observations and traditional observations to examine moisture variability, convective initiation and meso-convective scale structures.
0.5° beam blockage for existing radars indicated by white areas within range rings
<table>
<thead>
<tr>
<th>Required Measurement</th>
<th>W-band</th>
<th>Ka-band</th>
<th>X-band</th>
<th>C-band</th>
<th>S-band</th>
<th>Profilers</th>
<th>OR</th>
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<tbody>
<tr>
<td>Bragg scatter (boundaries, elevated moisture variations)</td>
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<td></td>
<td>SPOLKa</td>
<td>OR1</td>
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<tr>
<td>3-D kinematics (multi-Doppler analysis or assimilation)</td>
<td></td>
<td></td>
<td>DOW6</td>
<td>DOW7</td>
<td>DOW8</td>
<td>RWP</td>
<td>OR1</td>
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<tr>
<td>Vertical air motion (using Bragg scatter)</td>
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<td>RWP</td>
<td>OR6</td>
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<tr>
<td>Velocity-azimuth display wind profiles</td>
<td>WSACR</td>
<td>KaSACR</td>
<td>DOW6</td>
<td>DOW7</td>
<td>DOW8</td>
<td>CSAPR2</td>
<td>OR1</td>
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<tr>
<td>Quasi-vertical profiles in precipitation</td>
<td>WSACR</td>
<td>KaSACR</td>
<td>DOW6</td>
<td>DOW7</td>
<td>DOW8</td>
<td>CSAPR2</td>
<td>OR1</td>
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<tr>
<td>Non-precipitating clouds</td>
<td></td>
<td>KaSACR</td>
<td></td>
<td></td>
<td></td>
<td>RMA</td>
<td>OR2</td>
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<tr>
<td>Light rain</td>
<td>WSACR</td>
<td>WACR</td>
<td>SPOLKa</td>
<td>KaSACR</td>
<td>KaZR</td>
<td>SPOLKa</td>
<td>OR2</td>
</tr>
<tr>
<td>Moderate rain</td>
<td></td>
<td></td>
<td>SPOLKa</td>
<td>KaSACR</td>
<td>KaZR</td>
<td>SPOLKa</td>
<td>OR2</td>
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<tr>
<td>Heavy rain</td>
<td></td>
<td></td>
<td>SPOLKa</td>
<td></td>
<td></td>
<td>RWP</td>
<td>OR2</td>
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<tr>
<td>Hail, hail mixed with rain</td>
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<td></td>
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<td>RWP</td>
<td>OR2</td>
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<tr>
<td>Water vapor (refractivity)</td>
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<td></td>
<td>SPOLKa</td>
<td>OR1</td>
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<tr>
<td>Water vapor (dual-wavelength)</td>
<td>SPOLKa</td>
<td>KaSACR</td>
<td></td>
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<td></td>
<td>SPOLKa</td>
<td>OR1</td>
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<tr>
<td>Cloud water</td>
<td>SPOLKa</td>
<td>KaSACR</td>
<td></td>
<td></td>
<td></td>
<td>SPOLKa</td>
<td>OR2</td>
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<tr>
<td>Hydrometeor ID</td>
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<td>SPOLKa</td>
<td>OR2</td>
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<tr>
<td>Multi-wavelength retrievals (using dual wavelength ratio, polarization)</td>
<td>WSACR</td>
<td>SPOLKa</td>
<td></td>
<td></td>
<td></td>
<td>SPOLKa</td>
<td>OR2</td>
</tr>
<tr>
<td>Microphysical retrievals (using single or multi-wavelength Doppler spectra)</td>
<td>WSACR</td>
<td>WACR</td>
<td>KaSACR</td>
<td>KaZR</td>
<td></td>
<td>RWP</td>
<td>OR6</td>
</tr>
</tbody>
</table>
The idealized flight plan for mature orographic cumulus events is shown in Figure 7. The flight strategy will be similar to the one mid-south sampling strategy, but following initiation, the flight strategy will be designed to characterize convection downstream (east) of clouds at multiple altitudes in the vicinity of the AMF1 site. Secondary foci will be on observations in and out of aerosol plumes in the vicinity of the clouds. The focus will be on obtaining convective inflow properties at altitudes of between 3 km and 7.5 km, constant altitude legs will be flown across the range at low environmental conditions. Additional atmospheric state measurements and their imageries for flight planning will be provided by the ARM radars, and potential RELAMPAGO radars will be used with rapid update satellite imaging for flight planning. The AAF (G1) will be staged at Las Higueras approximately November 5 to December 20, and the additional instrumentation funded, additional funding will be available.

Should CACTI be flown across the range in adjacent North, the range is characterized. At altitudes of between 3 km and 7.5 km, constant altitude legs will be flown to sample droplet residuals. Residual counterflow virtual impactor (CVI) will be used to sample droplet residuals more important during these flights than for situations at high altitudes. CACTI – DOE Sampling is crucial for validating high control. The fast integrated mobility spectrometer (FIMS), if available, the UHSAS, the Passive Cavity Aerosol Spectrometer (PCASP), and cloud aerosol spectrometer (CAS) measured through a combination of instruments that are wing kinetic ambient inlet.

The AMF1 observations into context and for providing input to numerical modeling will be the aerosol size distribution (UHSAS and SMPS) and aerosol properties will be important for putting systems. In-situ measurements and their characterization north-south variations around the growing deep convection and in adjacent congestus clouds is shown in Figure 8. Secondary focus will be placed on obtaining convective inflow and outflow situations of

In horizontal and vertical plan views. Typical circulations of the range at low environmental conditions would connect Villa Yacanto to the top of the mountain ridge 1150 m. CACTI – DOE Sampling Villa Yacanto 1150 m.
# Radiosonde Facilities in RELAMPAGO

<table>
<thead>
<tr>
<th>Institution</th>
<th>System Type</th>
<th>Mobile vs. Fixed (location)</th>
<th>Nominal Release Frequency: RELAMPAGO-IOP</th>
<th>Nominal Release Frequency: CACTI-EOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMN</td>
<td>Vaisala RS90 + IMET</td>
<td>Fixed: Córdoba, Mendoza/ (Resistencia, Santa Rosa, Ezeiza, Salta)</td>
<td>8 x day/(2 x day)</td>
<td>2 x day</td>
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<tr>
<td>SMN</td>
<td>Vaisala RS90</td>
<td>Portable: Alta Gracia</td>
<td>1 x hr</td>
<td></td>
</tr>
<tr>
<td>SMN</td>
<td>Vaisala RS90</td>
<td>Mobile</td>
<td>1 x hr</td>
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</tr>
<tr>
<td>DOE</td>
<td>Vaisala RS92</td>
<td>Fixed: Villa Yacanto/ (Villa Dolores)</td>
<td>IOP: 8 x day/(2 x day)</td>
<td>2 x day</td>
</tr>
<tr>
<td>Chile</td>
<td>Vaisala RS92</td>
<td>Fixed*: Santo Domingo, Antofogasta</td>
<td>2 x day</td>
<td>2 x day</td>
</tr>
<tr>
<td>Brazil</td>
<td>Vaisala RS92</td>
<td>Fixed: Uruguaiana</td>
<td>2 x day</td>
<td>2 x day</td>
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<tr>
<td>CSWR</td>
<td>GRAW (x 2)</td>
<td>Mobile</td>
<td>1 x hr</td>
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<tr>
<td>CSU</td>
<td>MW41 Digicora</td>
<td>Mobile</td>
<td>1 x hr</td>
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<tr>
<td>UIUC</td>
<td>IMET (x 3)</td>
<td>Mobile</td>
<td>1 x hr**</td>
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</tbody>
</table>
**RAOBs**

**Surface stations:**
- SMN surface stations
- Board of Cereals, Córdoba Province
- Universidad de La Punta
- DACC, Mendoza Province
Lightning in RELAMPAGO

- GOES-R/S GLM validation and science
- Demonstrate use of real time lightning information for nowcasting
- Documents thunderstorm environments, allowing investigation of link between pre-storm environment and subsequent electrification (e.g., anomalous/inverted charge structures common in dry, high-cloud-base environments)
- Provides validation dataset for thunderstorm electrification models

Courtesy S. Goodman
RELAMPAGO Hydrometeorology Extended Observing Period (~1 year)

“What is the role of the land surface in modulating the observed variability of heavy precipitation and flooding in the Carcarañá River Basin?“

• Precipitation gauges
• Surface flux towers
• Meteorological stations
• Streamflow observations
• Groundwater observations
Mobile sampling strategies – Under the umbrella of fixed observations
RELAMPAGO+CACTI
International Endorsements

• June 2013. WMO World Weather Research Programme (WWRP) – JSC endorsement in June 2013

• August 2014. Steve and Paola were invited to present RELAMPAGO during Nowcasting working group sessions before the WWRP-OSC

• August 2014. Steve, Celeste Saulo, and Paola went to WWRP-OSC in Montreal August 2014 and RELAMPAGO was included as an experiment of High Impact Weather Project together with T-NAWEX. RELAMPAGO will focus on heavy precipitation storms/flooding under HIWEATHER project.

• RELAMPAGO is a Forecast Demonstration Project and Research Demostration Project recommended by the WMO Nowcasting and Mesoscale Numerical Modeling Group.

• RELAMPAGO is seeking endorsement from the GEWEX Hydroclimatology Panel; has received positive feedback so far
Science and societal impact

Much research has been done on US Great Plains organized convection, impact?

We believe that addressing RELAMPAGO/CACTI objectives will not only help the community gain a better perspective on extreme convection globally, as it differs in its characteristics and forcing from region to region.

The knowledge gained from RELAMPAGO/CACTI will improve understanding, models, and high impact weather and climate prediction around the world.

Tailor existing and develop new tools for emergency management for HIWeather informed by the user community
¡Gracias!
¿Preguntas?

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