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Pronóstico y Alerta de Eventos de Inundaciones Repentinas

PREVENIR RQPE 1.0: Ground Radar Quantitative Precipitation Estimation development for nowcasting and hydrological applications

Paola Salio

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CIMA CONICET UBA
EXACTAS UBA
IFAECI CNRS CONICET IRD
SMN Argentina
大阪大学 OSAKA UNIVERSITY
RIKEN

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Forecast and Warning of Urban Flash Flood Events

Scientific collaboration between **Argentina** and **Japan** for the development of an early warning system to reduce the risk of flash urban floods

JST Japan International Cooperation Agency

JICA Japan Science and Technology Agency

SATREPS Association in Scientific and Technological Research for Sustainable Development

Leading institutions

Servicio Meteorológico Nacional Argentina

RIKEN

Co-working institutions

ICHARM

INA Instituto Nacional del Agua

OSAKA UNIVERSITY

CONICET

[CIMA] - [IMIT]
[IDIT] - [ICC]

Collaborating institutions

Ministerio de Relaciones Exteriores, Comercio Internacional y Culto Argentina

Provincia de Buenos Aires Government

Provincia de Córdoba Government

Japan Meteorological Agency

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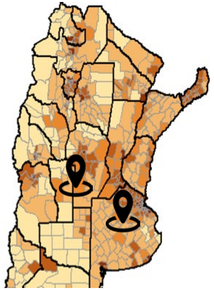
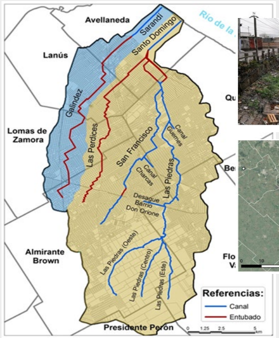


Sarandí-Santo Domingo Basin

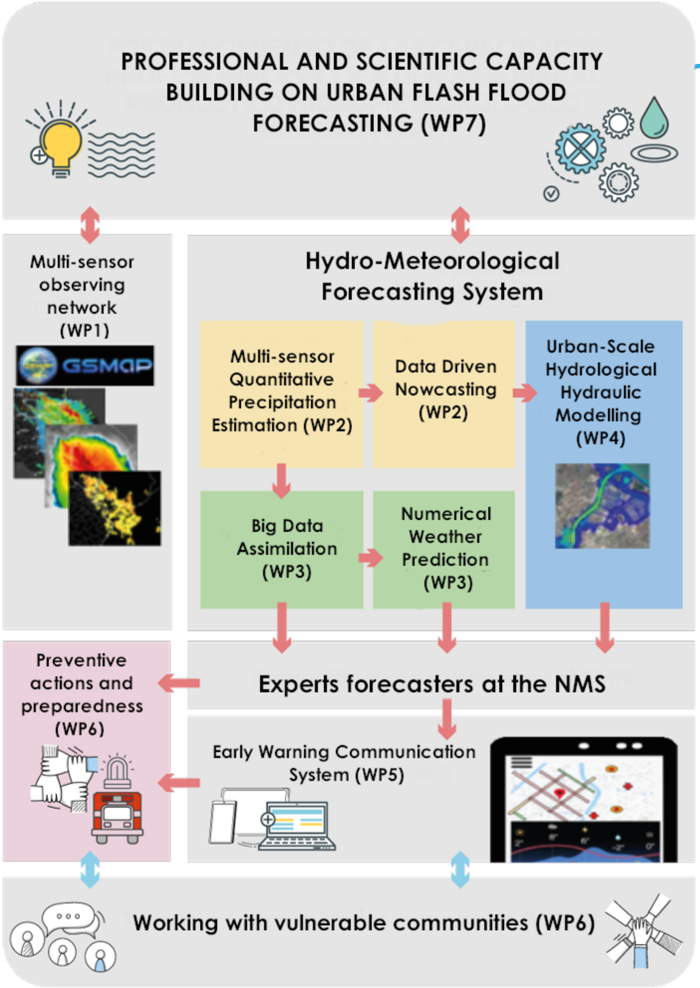
Plain and highly populated



Suquía Basin

Rural and urban basin. Step region

Pilot Basins



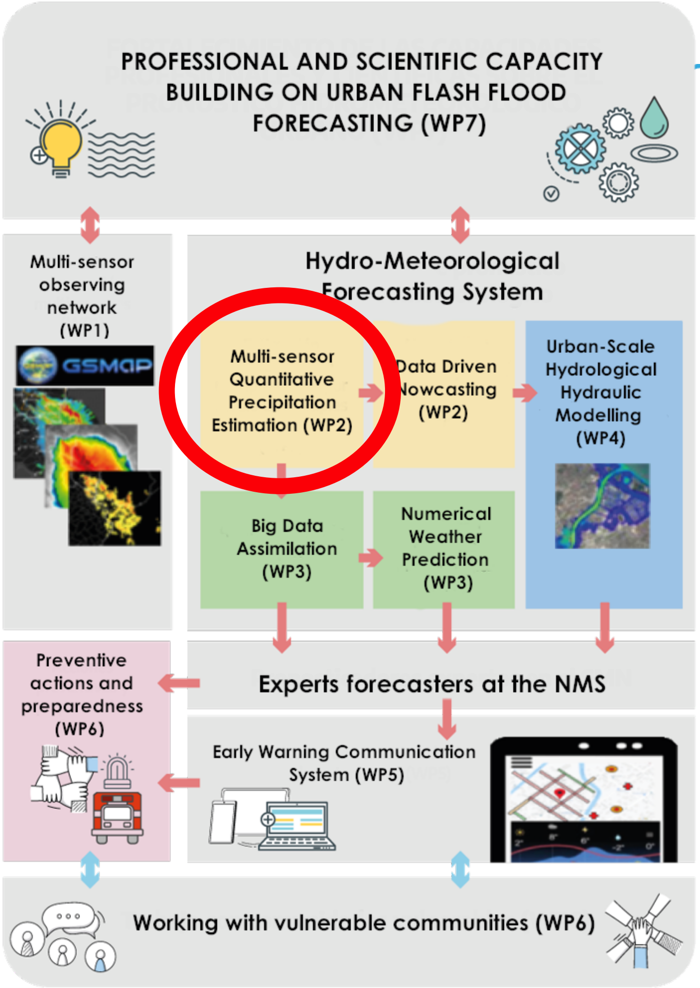
Monitoring

PREVENIR proposes the expansion of hydrometeorological observation networks and the implementation of real-time precipitation estimation methods using radar and satellite data.

WP2 | Radar QPE over available C-band radar network

WP2 | Calibration of GSMaP Precipitation estimates using local gauges

WP2 | GOES-16-based QPE using PDF matching and AI techniques



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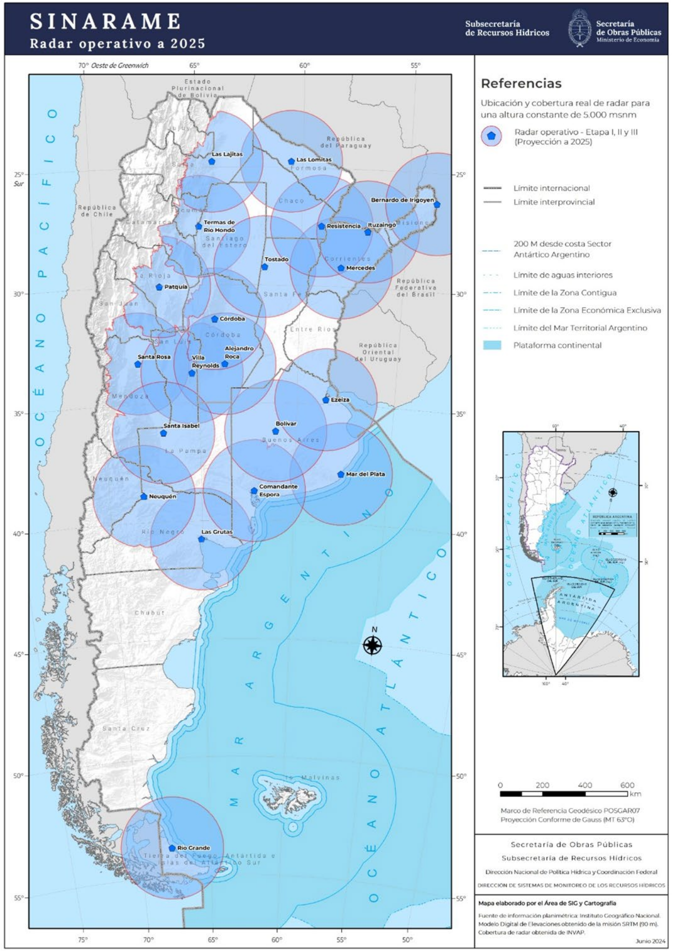

SINARAME

- C band - Doppler - Dual Polarization network over Argentina.
- Challenges on data quality to obtain a QPE for hydrological applications considering the precipitation regime over the area.
  - attenuation during strong convection events
  - wet radome

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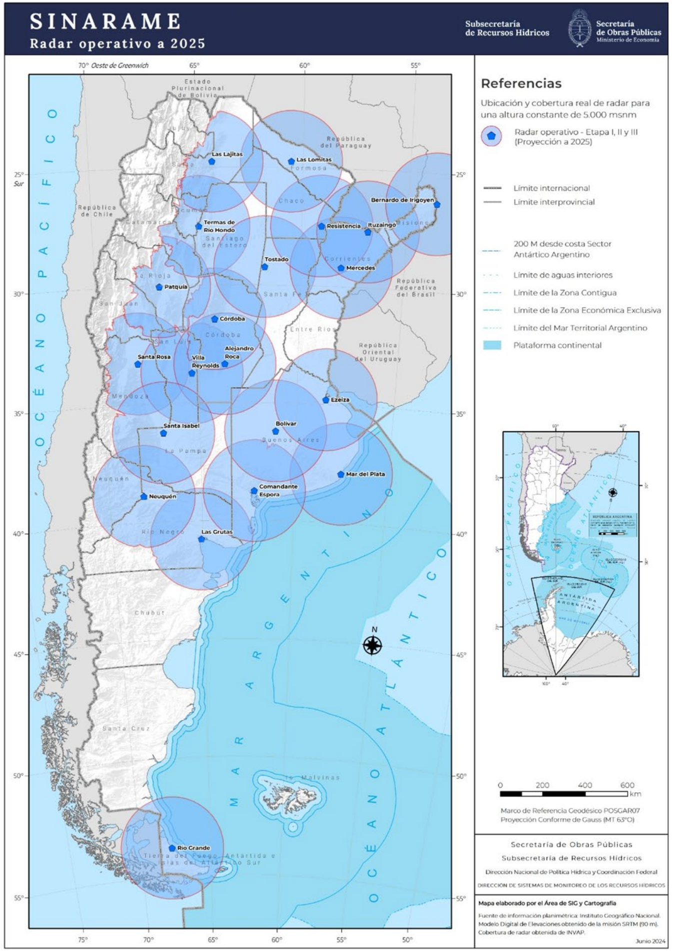

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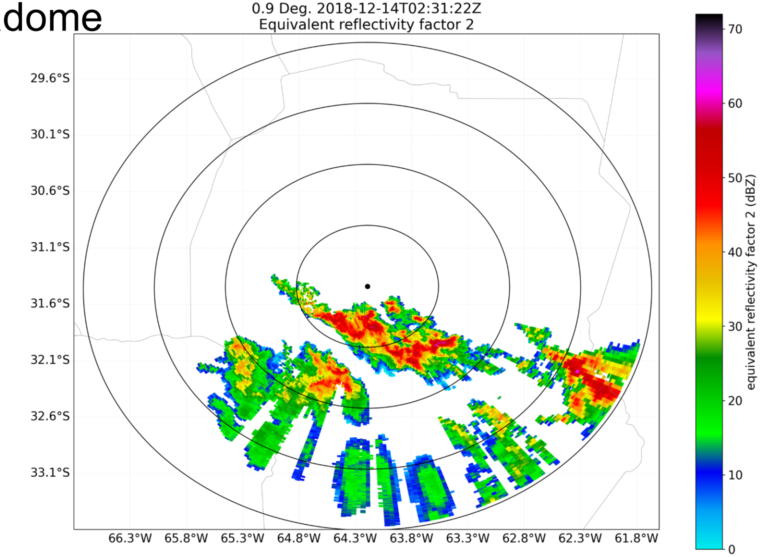

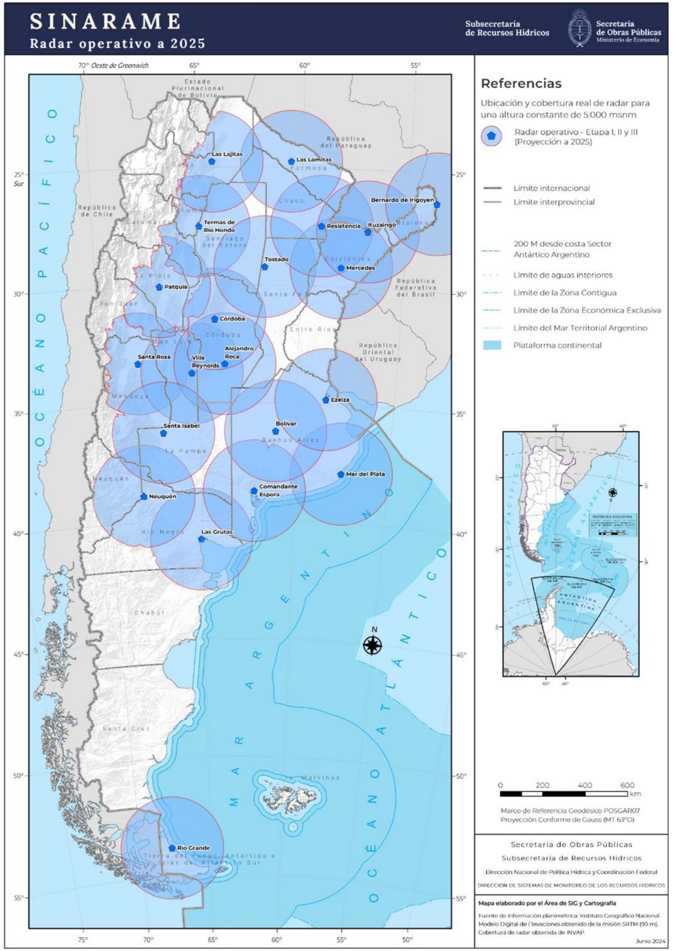

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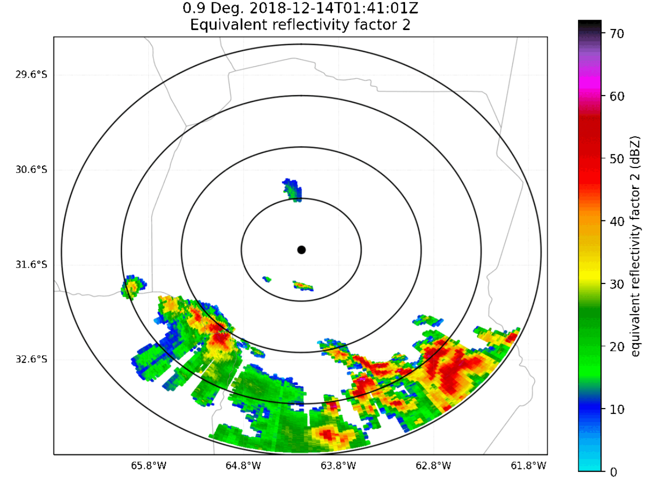

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Objective:

- PREVENIR RQPE 1.0 initiative seeks to address these challenges through the proposal of a technique centered on specific differential phase (KDP) estimation

- a monotonically increasing smooth spline function of PHIDP is proposed, facilitating the calculation of estimated KDP.

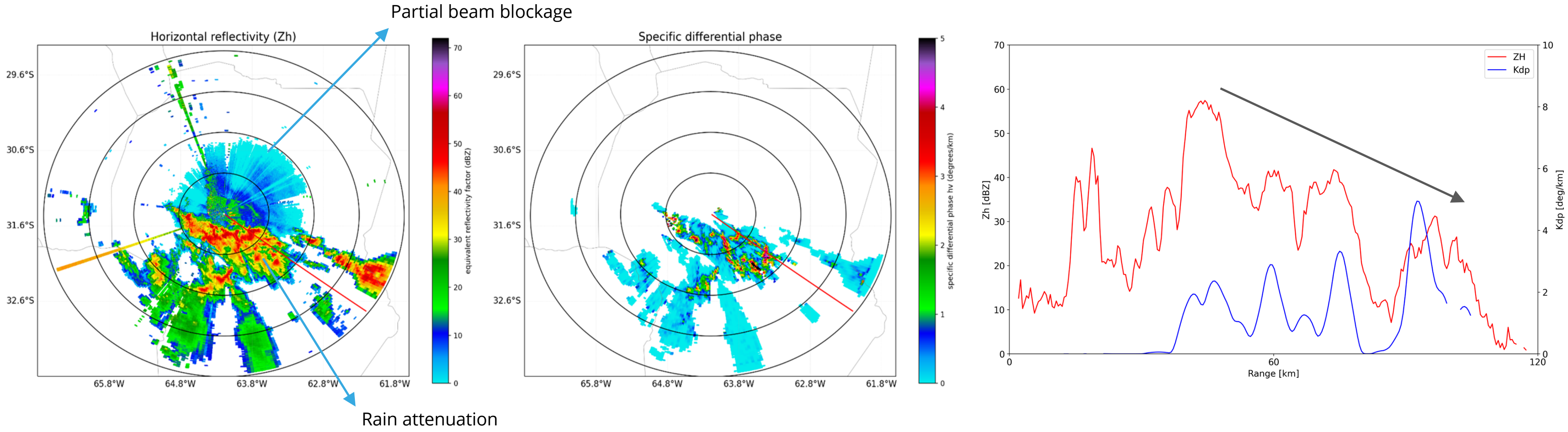
- evaluate performance during convective events and under the bright band for stratiform cases, alongside gauge measurements.

K_{DP} Estimation Technique

Poster presented at the 40th AMS radar conference - Kitahara et al, 2023

K_{DP} and RQPE

K_{DP} (specific differential phase [deg/km]) is a useful variable for QPE estimation since it is strongly correlated with rain rate. Unlike reflectivity, K_{DP} is robust to miscalibration, partial beam blockage, rain and wet radome attenuation.



However, it cannot be calculated directly from the observed IQ signal, but must be estimated from the observed differential phase (Ψ_{DP}).

observed differential phase

$$\Psi_{DP,n} = \Phi_{DP,n} + \delta_n + \varepsilon_n = 2\int_0^{r_n} K_{DP}(r)\,dr + \Phi_{DP,0} + \delta_n + \varepsilon_n$$

differential propagation phase

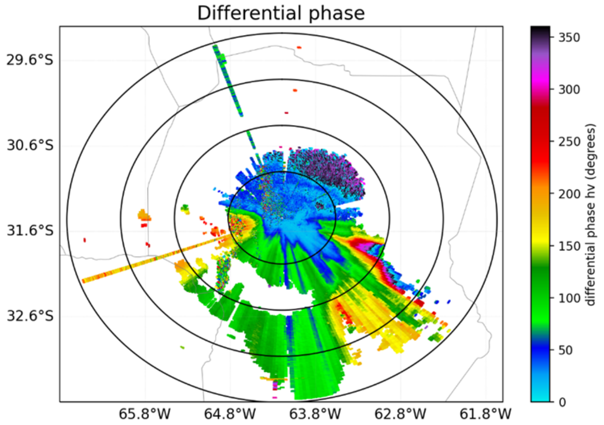
differential backscatter phase

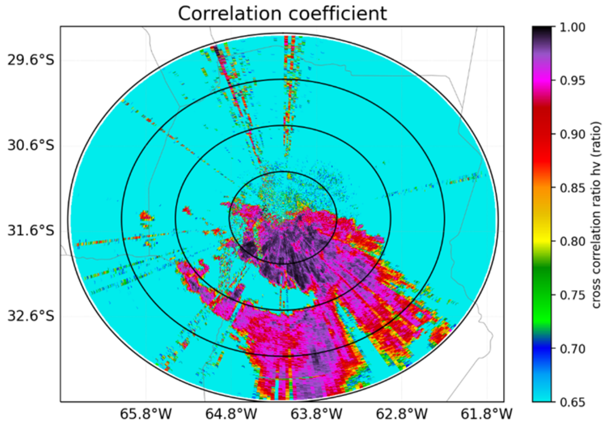
observation noise

specific differential phase to estimate

initial differential phase

Ψ_{DP} quality control





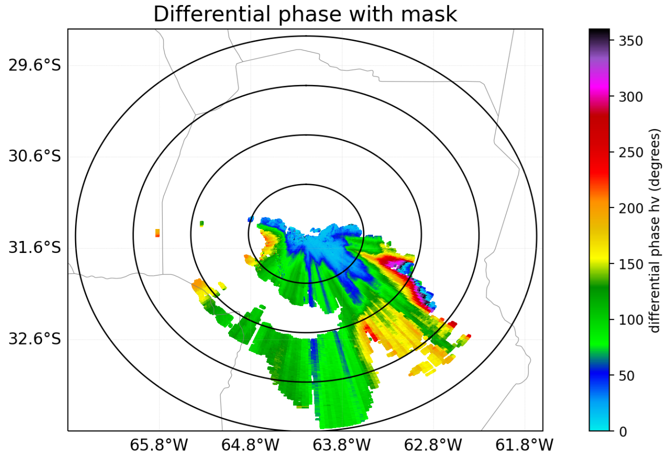
Two mask created:

reliable: There is Ψ_{DP} with **low** noise (precipitation pixel)

- $\rho_{hv} \geq 0.9$
- average ρ_{hv} of 9 adjacent pixels is greater than 0.9
- $Z_h \geq 10$ dBZ
- Ψ_{DP} is not NaN
- exclude the first 12 data (about 7km)

medium reliable: There is Ψ_{DP} with **large** noise (possible precipitation pixel)

- $\rho_{hv} \geq 0.65$
- average ρ_{hv} of 9 adjacent pixels is greater than 0.75
- $Z_h \geq 10$ dBZ
- Ψ_{DP} is not Nan
- exclude those that are more than 10 pixels away from the last reliable pixel



Existing and proposed K_{DP} estimation techniques

Local Linear (Polynomial) Fitting: US NWS Operational Algorithm

For each gate, create a local linear (polynomial) model $\Phi_{DP}(r) = 2\,K_{DP}(r)\,r + b_n$

Computation is very fast

Phase unwrapping is needed
Continuity of Φ_{DP} is not considered

Complex-Valued Spline Smoothing: Algorithm of Wang and Chandrasekar

Estimate angular Φ_{DP} profile $e^{j\frac{\pi}{180}\Phi_{DP}(r)}$ as a complex-valued cubic spline function.

Computation is fast
Phase unwrapping is not needed
Continuity of Φ_{DP} is considered

Negative K_{DP} in precipitation areas

Proposed Nonnegative Estimation with Self-Consistency (SC)

First "Denoised KDP" estimation

$K_{\mathrm{DP},i}^{\mathrm{SC}} = \dfrac{A_{\mathrm{H},i}}{\alpha}$, $A_{H,i}$ calculated with $A_H = a\left[Z_h^{cor}\right]^b$ and Z_h^{cor} obtained with ZPHI method with α-adjustment.

$\Delta\Phi_{DP}$ is needed, so it is calculated with Wang and Chandrasekar since no phase unwrapping is needed

An edge-preserving denoising of with median filter is applied ⇒ **"Denoised KDP" estimation**

✓ Computation is fast (about 5 seconds per ppi)

✓ Phase unwrapping is not needed

✓ Self-consistency considered

Final proposed K_{DP} estimation

Monotonically Increasing Spline Smoothing (Final Re-Fitting)

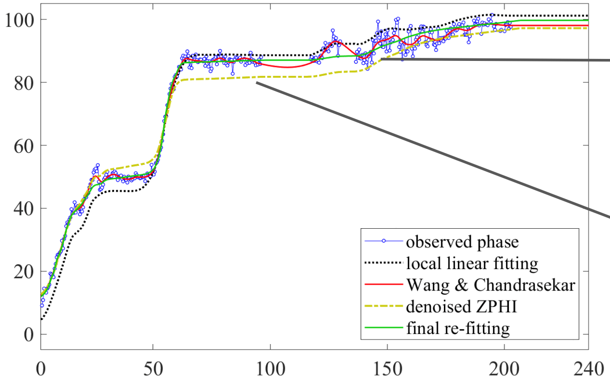
Main points:

- Φ_{DP} is estimated as **a smooth piecewise polynomial, i.e., a spline function *s(r)***
- Φ_{DP} is **monotonically increasing**, i.e., is **nonnegative <u>under the melting layer</u>** ⇒ ***s′(r)* ≥ 0**
- Consider an optimization problem similar to the problems of Giangrande and Wang & Chandrasekar
- The problem is **convex** and can be solved by **quadratic programming**

absolute error | absolute error | roughness penalty

$$\text{minimize} \sum_{n=1}^{N} w_n \left| \Psi_{DP,n} - s(r_n) \right| + \sum_{n=1}^{N} w_n^{SC} \left| K_{DP,n}^{SC} - \frac{s(r_n+\Delta r/2) - s(r_n-\Delta r/2)}{2\Delta r} \right| + \sum_{n=1}^{N} q_n \int_{r_n-\Delta r/2}^{r_n+\Delta r/2} \left| s''(r) \right|^2 dr$$

Φ_{DP} observed and estimated over an azimuth



Linear approximation and Wang & Chandrasekar generate negative K_{DP} over light rain areas

Improvement in final re-fitting compared with denoised KDP

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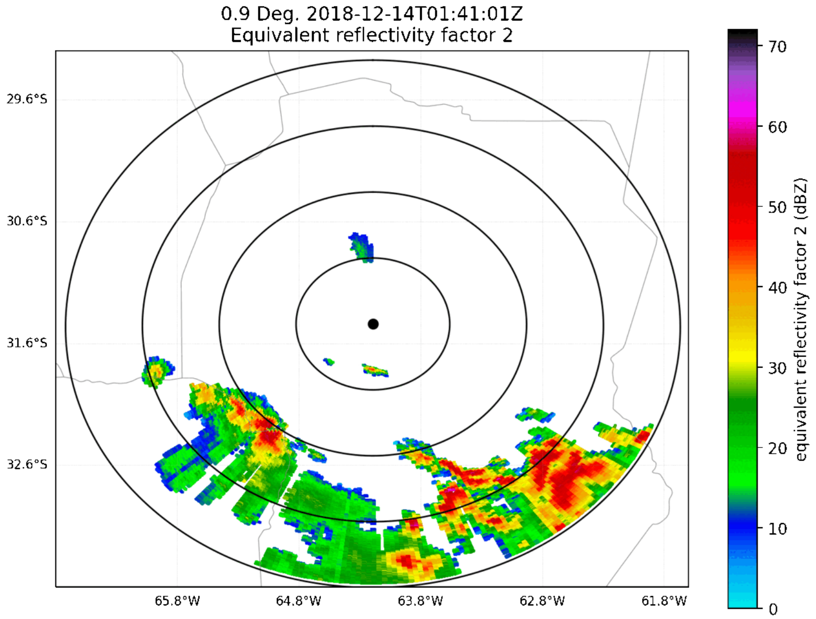
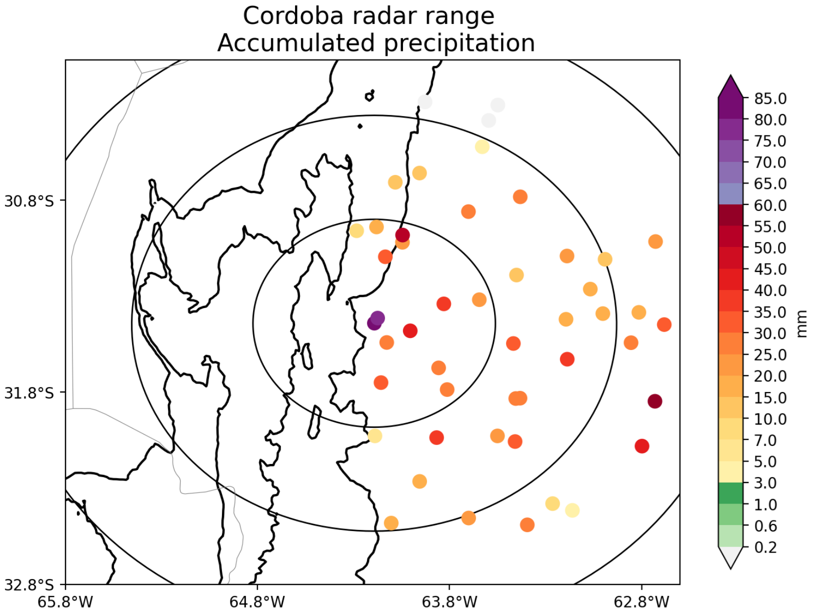
Validation

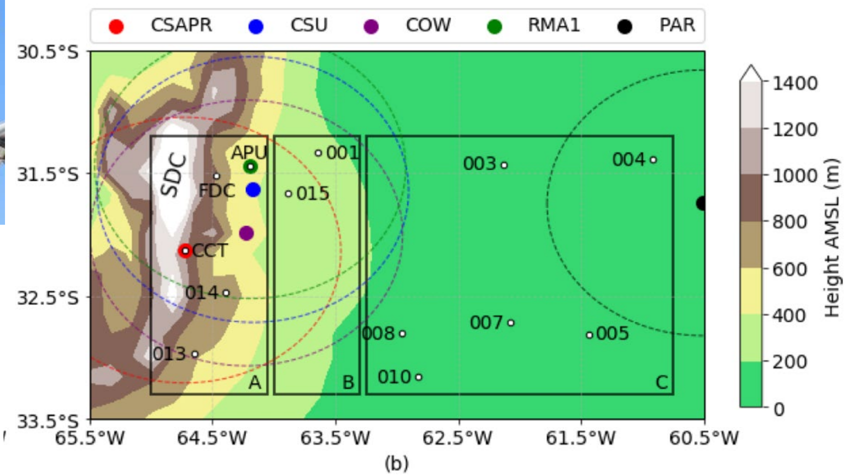
Poster to be presented at the ERAD European radar conference - Cancelada et al, 2024

Córdoba - December 13 and 14th 2018





Disdrometer data and R(K_{DP}) relationship

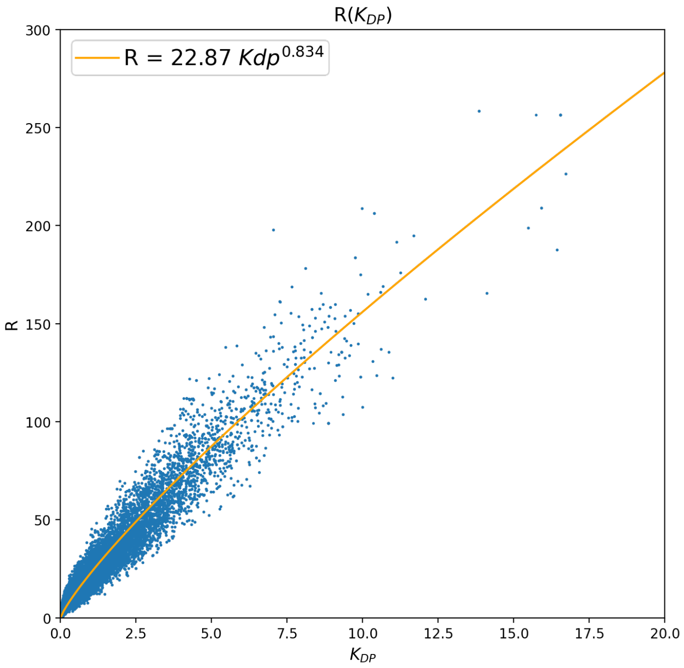


Period: May 2018 - April 2019 - RELAMPAGO dataset - **No operational data**

QC performed (Casanovas et al. 2021):

- ➢ Removed drops whose measured fall speed V*j* differed by more than 50% from the expected terminal velocity for a drop of its size
- ➢ Only 1 min DSD data with at least 100 total drops and R > 0.05 mm/h during at least 3 consecutive minutes

Radar parameters calculation with Pydsd and pyTmatrix libraries



Relationship obtained via the Levenberg–Marquardt (LM) algorithm

Less impacted by the more frequent, lower-intensity observations and better fit in more relevant heavy rain

Gridded and interpolated radar QPE

- Instantaneous QPE calculated with R(K_{DP}) relationship

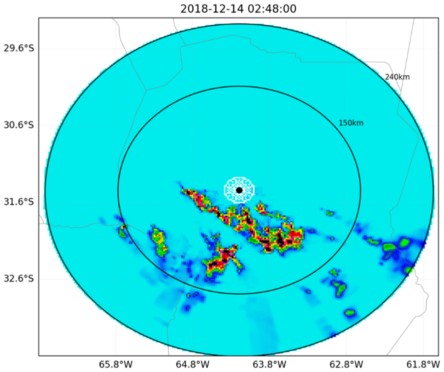
- Gridded data necessary to perform temporal interpolation and calculate hourly accumulated precipitation

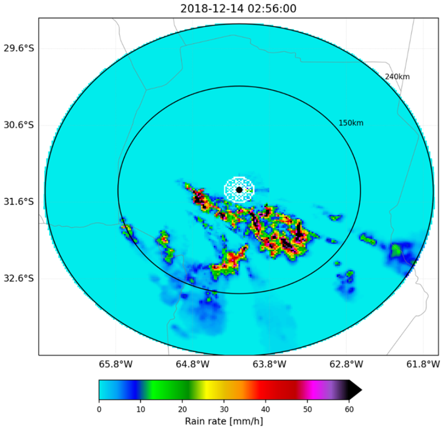
⇒ **2km x 2km grid**

Higher resolution grid tested and no sensitivity was found, besides higher computational times

- Melting layer for December 13th at 4500m above ground level, corresponding approximately to 150 km radar range

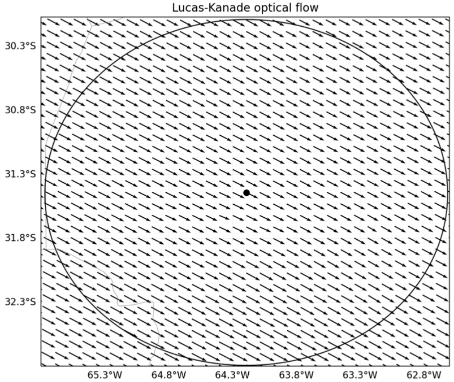
⇒ **Analysis restrained to 150km from radar position**

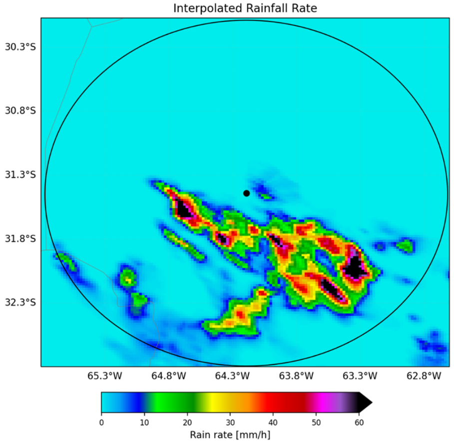




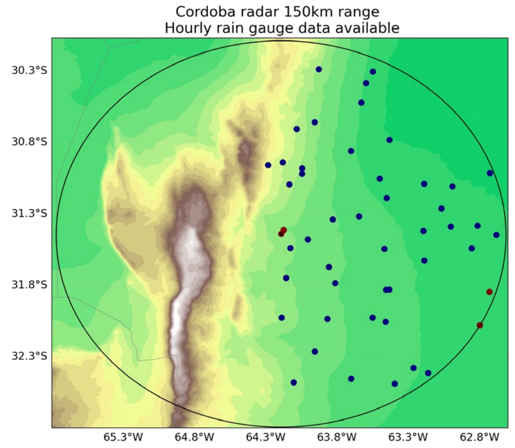
- Advection correction (Anagnostou and Krajewski, 1999) implemented in PySTEPS library.
  - ➢ Temporal interpolation procedure to correct for the shift of rainfall patterns between consecutive radar rainfall maps.
  - ➢ Shift significant for long radar scanning cycles and in presence of fast moving precipitation features.

- To evaluate the advection occurred between two successive radar images, the Lucas-Kanade optical flow routine is used. Local features are tracked in a sequence of two radar images.

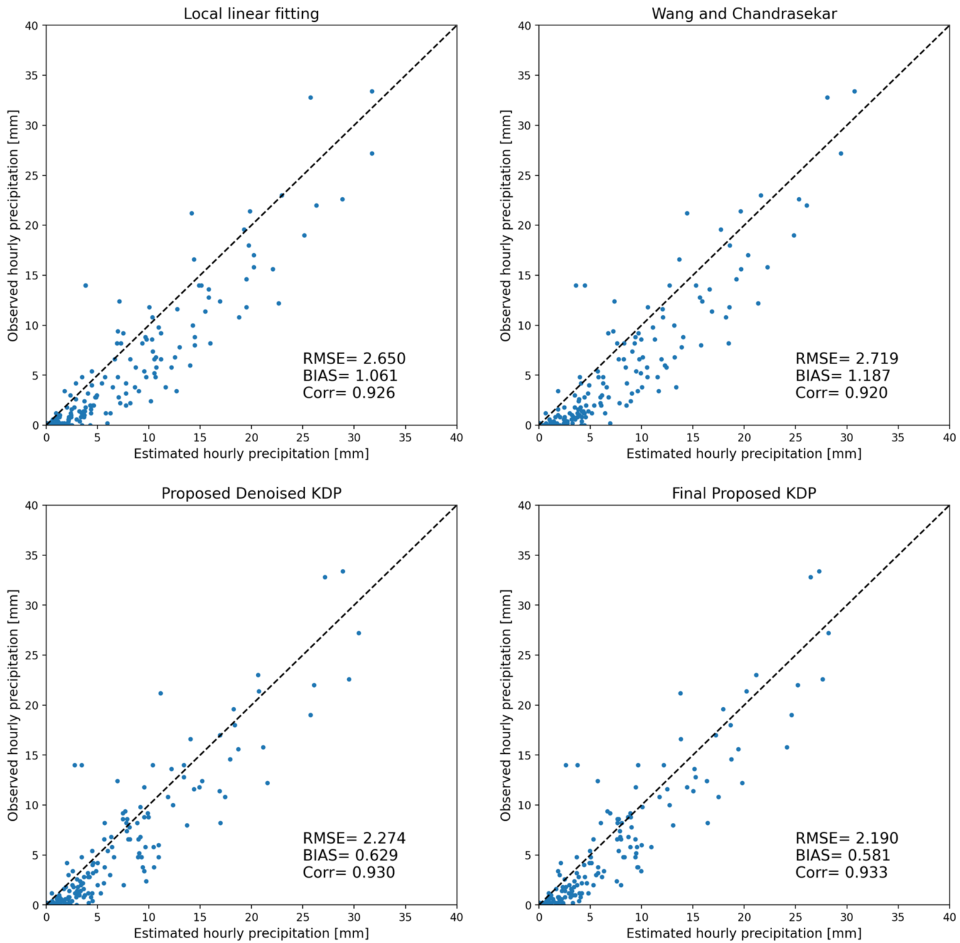




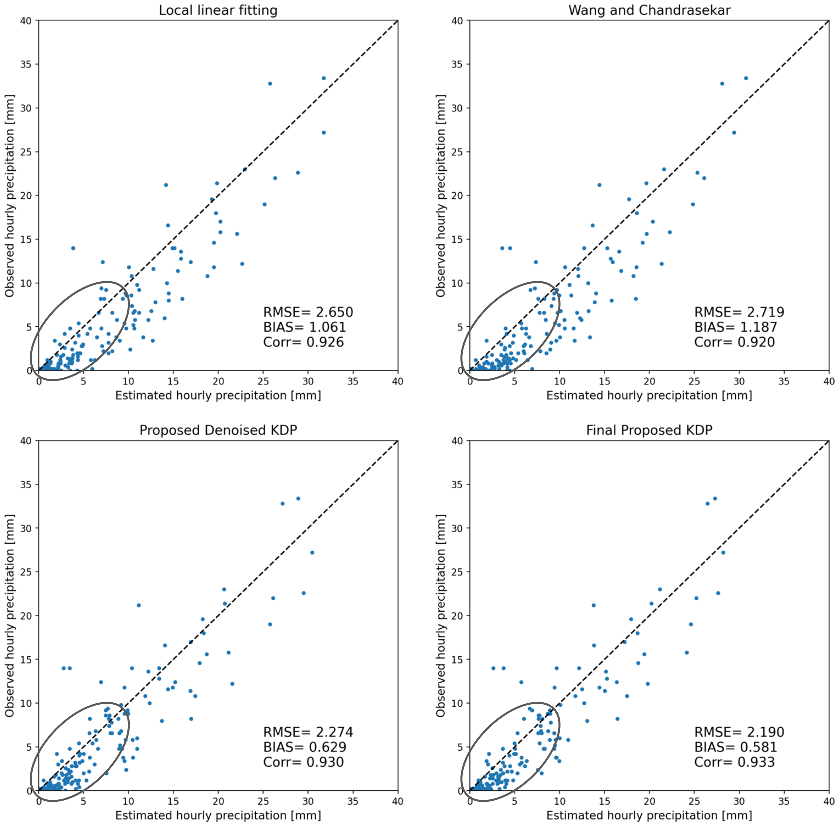
Rain-gauge data and validation



- 49 stations available for this situation
- Stations west to the radar were not considered due to topography impact on radar measurements
- **Stations removed from analysis:**
    - Too close to the radar, no K_{DP} estimations
    - Affected by full radar ray extinction, not possible to obtain K_{DP}



Final results



- Both proposed methods (denoised ZPHI & final re-fitting) **improved RMSE, estimation bias, and correlation coefficient <u>mainly in light rain areas by introducing the self-consistency</u>**

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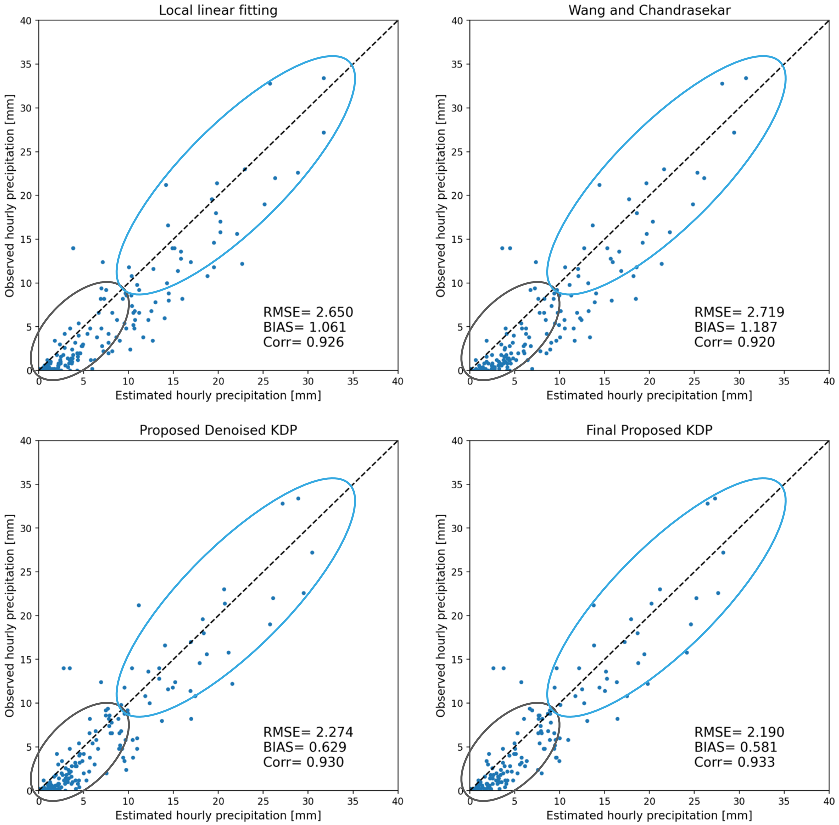

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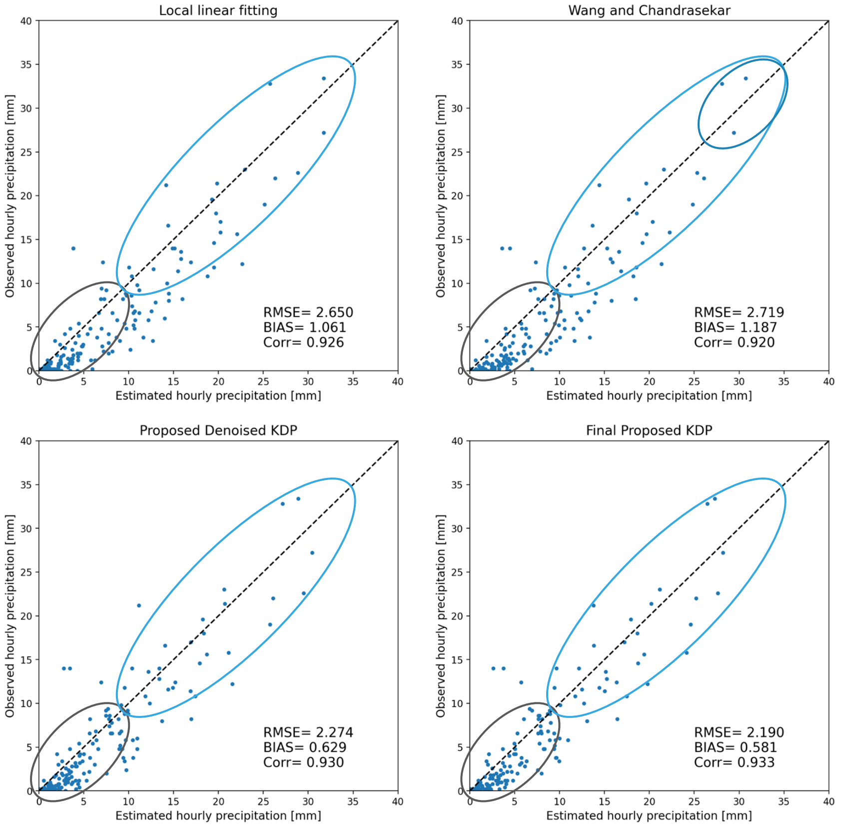
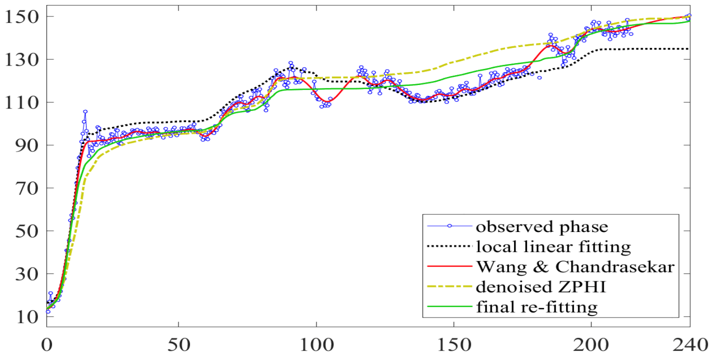


- Both proposed methods (denoised ZPHI & final re-fitting) **improved RMSE, estimation bias, and correlation coefficient <u>mainly in light rain areas by introducing the self-consistency</u>**
- In the proposed framework, the **accuracy for heavy rain areas can be improved from** denoised ZPHI results by final re-fitting
- Algorithm of Wang & Chandrasekar had the lowest average score in this case, but high accuracy for very heavy rain areas



- Nonnegativity of K_{DP} does NOT hold at far areas in some azimuths
  ⇒ Leads to accuracy degradation of final re-fitting K_{DP} estimates

Steps Forward

- Dr. Kitahara will stay for two months in Argentina to implement the KDP estimation technique at the National Meteorological Service.

- Develop RQPE techniques over complex terrain.

- Validation over multiple precipitation regimes. Implement on other C-band radars.

- Improve multi-sensor QPE including RQPE into microwave and/or infrared based precipitation estimation by using PDF matching and/or AI techniques.

Thanks

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Acknowledgment: The authors would like to thank JICA and JST (Grant #JPMJSA2109) for supporting this work under the SATREPS program.