Impact of the assimilation of non-precipitating echoes reflectivity data on the short-term numerical forecast of SisPI.

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(1) Center for Atmospheric Physics, Institute of Meteorology, Cuba (CFA / INSMET)
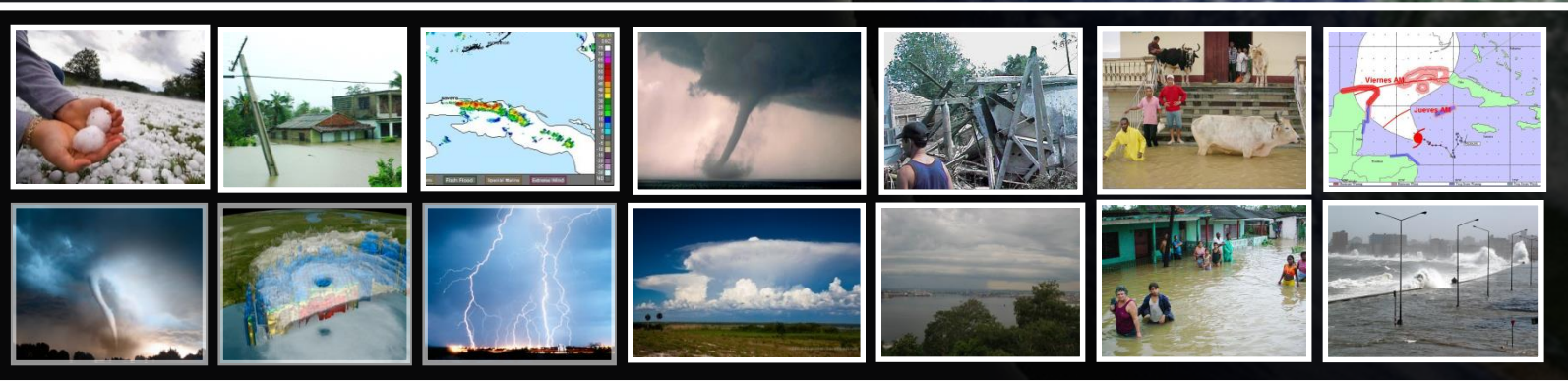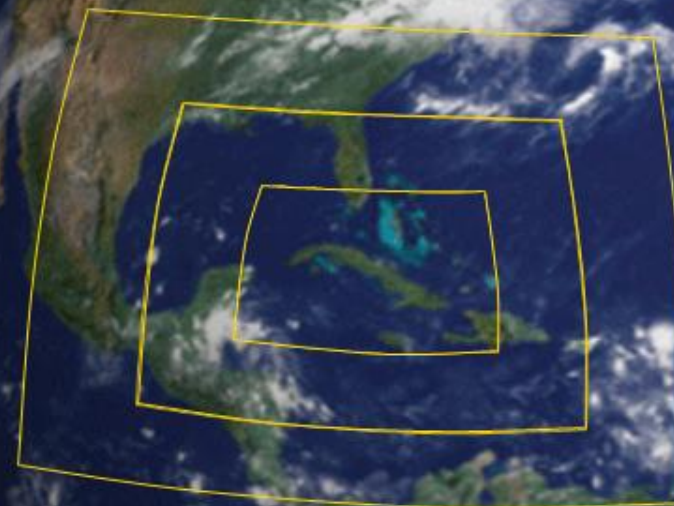
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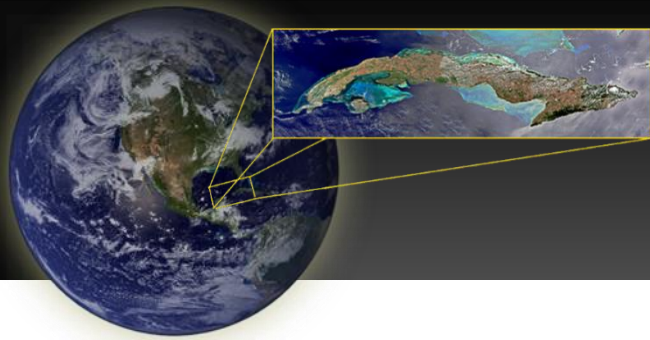
Adrian Luis Ferrer Hernández[1], Pedro Manuel González Jardines[1], Maibys Sierra Lorenzo[1], Darielis C. Aguiar Figueroa[1]

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Abstract

The research carries out an evaluation of the 3DVAR method with different options for the assimilation of reflectivity data, which are applied to the SisPI system with the purpose of determining which scheme presents the best results in the short-term numerical weather prediction. For this, data from 6 meteorological radars with coverage over a domain with 3km of spatial resolution are used, using the indirect method with (3DVAR-NoRain) and without (3DVAR) activate an option to also consider null-echoes of reflectivity without presence of precipitation. As a test case, the cold front that affected Cuba on December 10th, 2018 is taken.

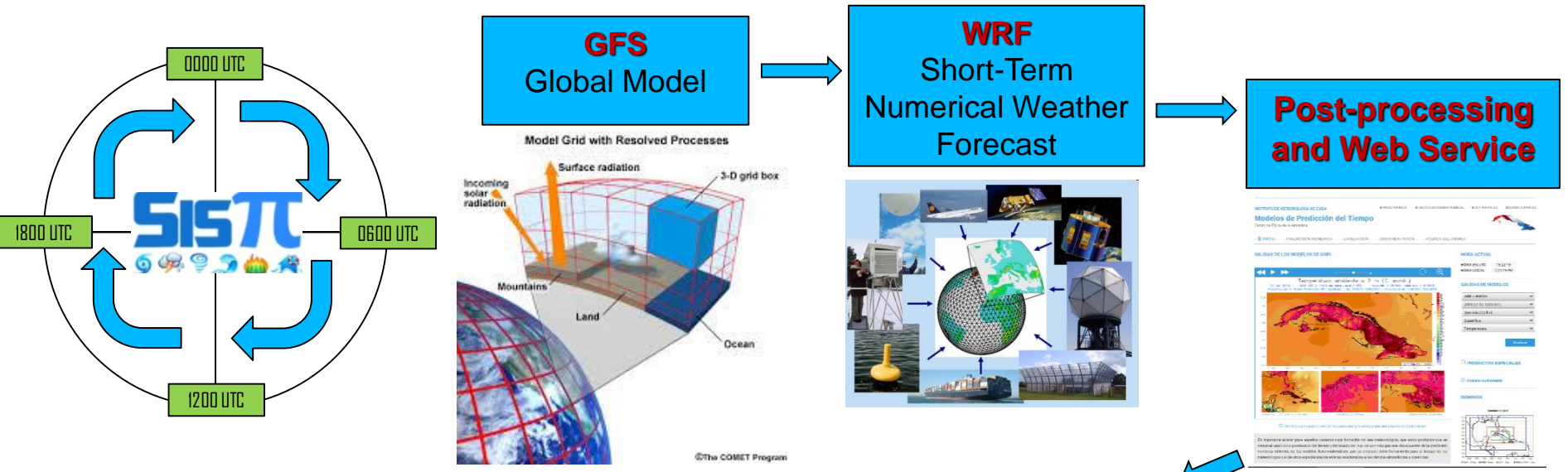**Keywords:** Data Assimilation; Numerical Weather Prediction; Mesoscale.

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Introduction

0000 UTC

1800 UTC

0600 UTC

1200 UTC

GFS Global Model

WRF Short-Term Numerical Weather Forecast

Post-processing and Web Service

Model Grid with Resolved Processes

Incoming solar radiation

Surface radiation

3-D grid box

Mountains

Land

Ocean

©The COMET Program

Users: Forecasters, Transportation, Energy, Agriculture, Communications, Construction, and Water Resources Management
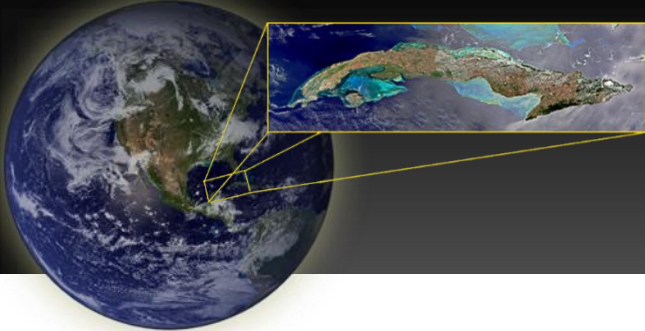
Forecaster

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SHORT-TERM NUMERICAL PREDICTION SYSTEM

Internet

http://190.115.188.235/haiti_web/sispi.php

Cuba

INSMET

UNITE HYDRO METEOROLOGIQUE HAITI

http://modelos.insmet.cu

República Dominicana

Haití
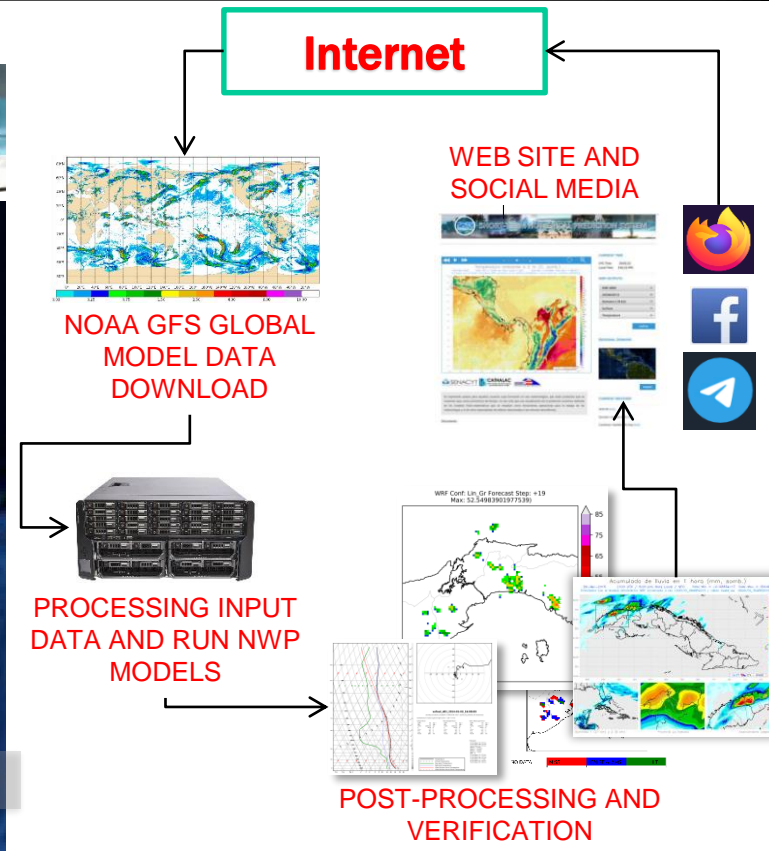
http://sispan.cathalac.int

ONAMET

http://186.149.199.244/sispi.php

Panamá

CATHALAC

WEB SITE AND SOCIAL MEDIA

NOAA GFS GLOBAL MODEL DATA DOWNLOAD

PROCESSING INPUT DATA AND RUN NWP MODELS

POST-PROCESSING AND VERIFICATION

D1   27 km
D2   9 km
D3   3 km

Dominios de las simulaciones

27 km
9 km
3 km

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Data Assimilation (DA) of meteorological observations

With DA

Without DA

RADAR OBS

Radar

Armas (2015)
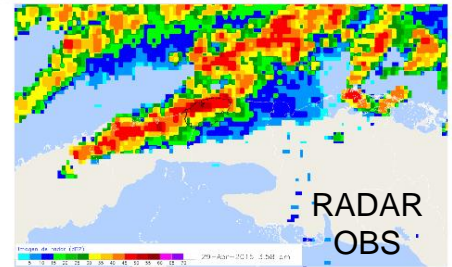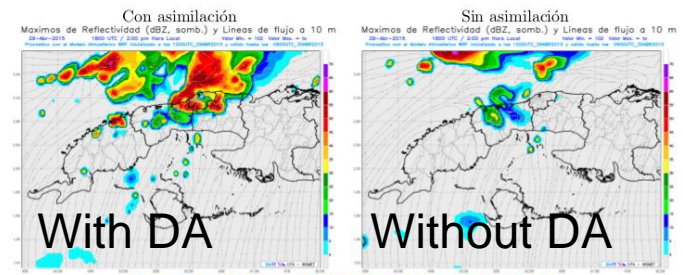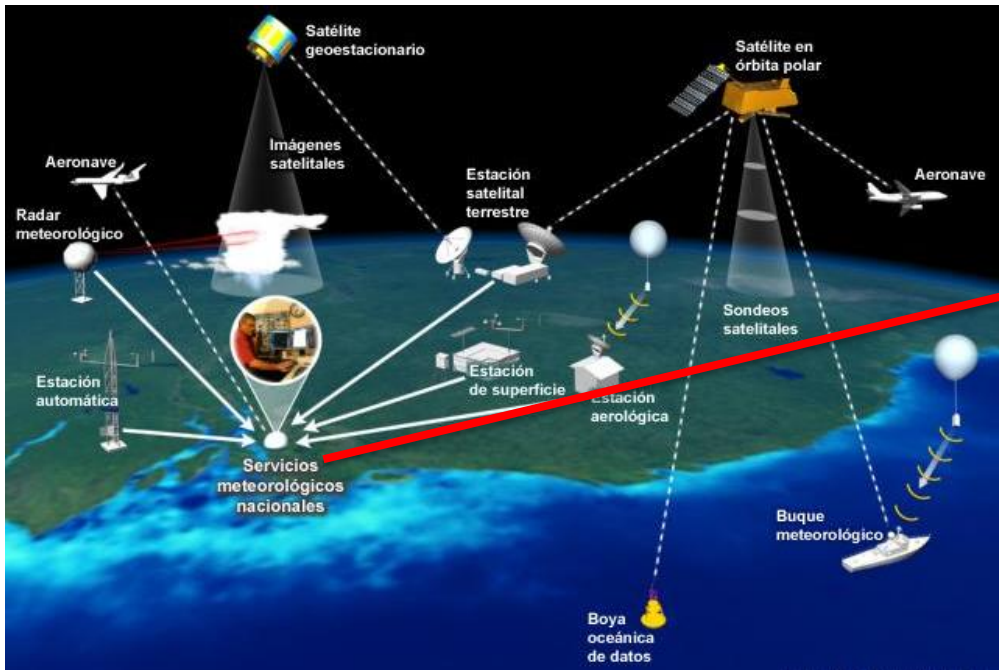
Insert the information from the meteorological observations in the Numerical Weather Forecast Models and apply consistency restrictions and dynamic balance between all the meteorological variables, to produce a field of analysis that constitutes the initialization of the model.

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Previous studies about DA in Cuba

| Study	Description
Cruz 2010	Assimilation of stations data in the MM5V3 model.
Hernández 2013, Ferrer 2013	Assimilation of radar and stations data with the ADAS module in ARPS model for high resolution domains.
Sierra et. al. 2014	Assimilation of observations from eolic gradient towers and surface stations with WRFDA module (3DVAR method)
Armas 2015	Assimilation of Radiance and GDAS prepbufr data with the WRFDA using the 3DVAR method.
Ferrer and Borrajero 2019	Assimilation of GDAS Prepbufr and Nexrad Level II radar data with the WRFDA and using the 3DVAR method. The use of CV3, CV5 and CV7 covariance matrices is compared.
Fernández 2019	Performs radar data assimilation experiments with the 3DVAR method but with covariance matrices that employ previous runs from 1 week to 45 days.
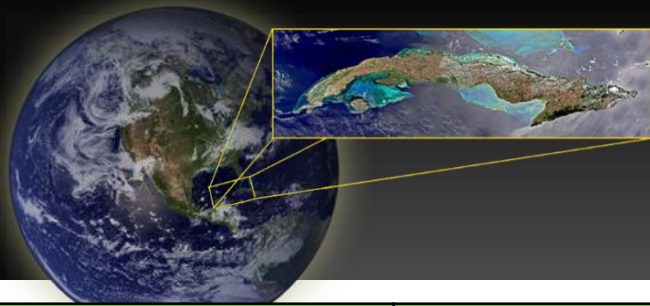
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Study	Description
González et al. (2021)	It was evaluated for the first time in Cuba different methods such as 3DVAR, 3DEnVAR and 4DEnVAR, highlighting the advantages and the best results obtained with hybrid schemes, with which the advantages can be appreciated over 3DVAR method, because the contribution of the members of the ensemble provide information about hydrometeors control variables even in areas where radar data is not available.
Aguiar (2021)	The author evaluates different options implemented in the WRFDA for the assimilation of reflectivity data, highlighting the indirect method with the inclusion of hydrometeors. These last works have been limited only to the use of NOAA radar data, hence in this work it was decided to make efforts to use complete coverage throughout the maximum resolution domain of SisPI, with also data from the radar network of the INSMET.
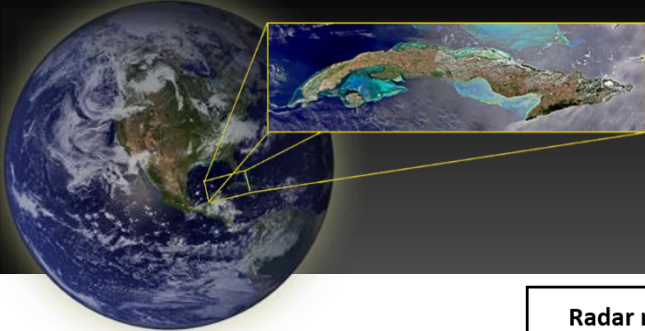
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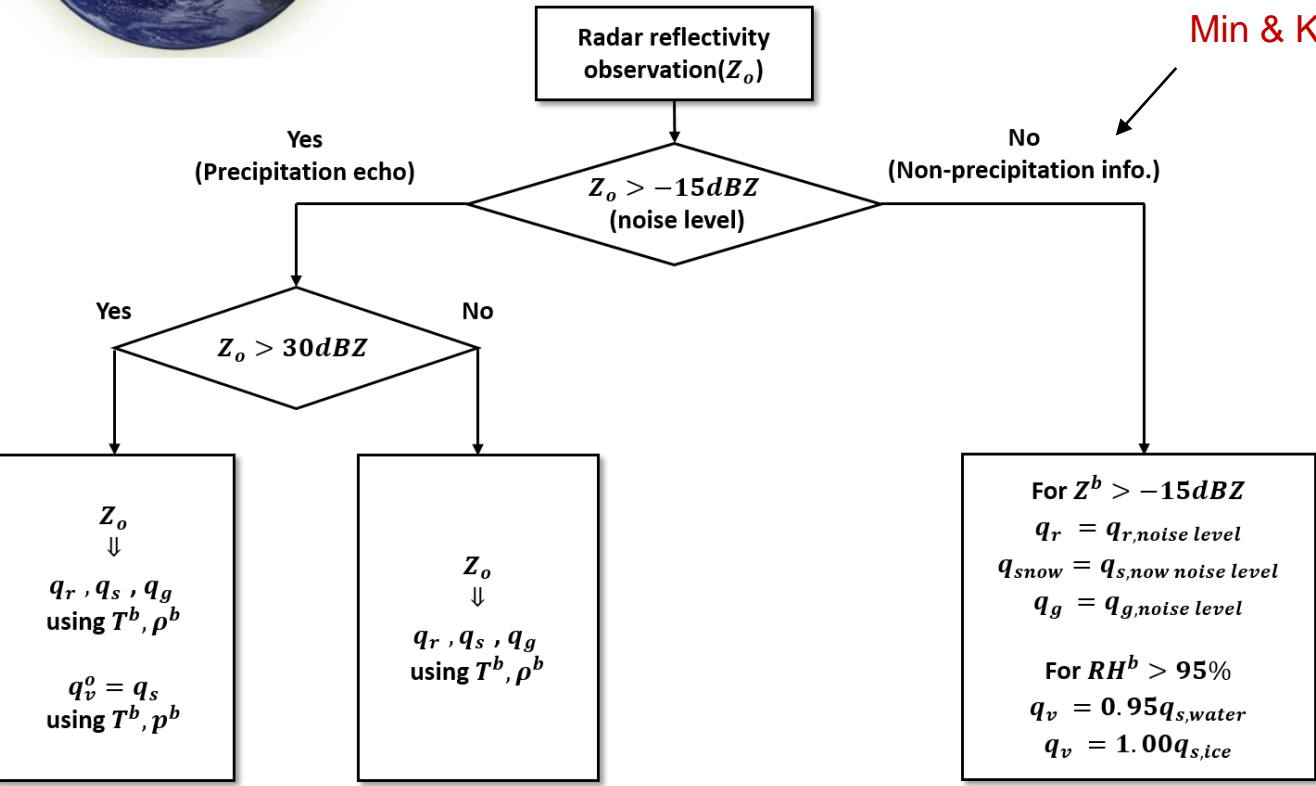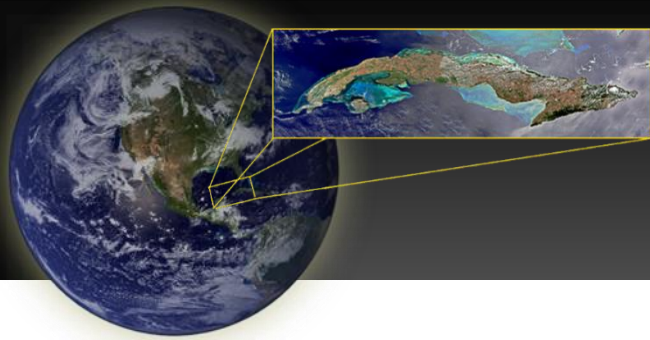**(1)** Center for Atmospheric Physics, Institute of Meteorology, Cuba (CFA / INSMET)

Min & Kim (2016)

Recently available in
WRFDA

radar_non_precip_opt

Lee et al. (2020)

A null-echo is defined as a region with non-precipitation echoes within the radar observation range. The model removes excessive humidity and four types of hydrometeors (wet and dry snow, graupel, and rain) based on the radar reflectivity by using a three-dimensional variational (3D-Var) data assimilation technique within the WRFDA system.

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Objectives

- The main objective of this research is to evaluate the impact of assimilating reflectivity data of non-precipitating echoes (radar_non_precip_opt parameter of WRFDA namelist) in the short-term numerical weather forecast of SisPI, which is a recently available option in the WRFDA module, and nowadays its use in the country has not been evaluated.

- On the other hand, it is also intended to carry out an experiment in which a total coverage of reflectivity information can be available in the domain of maximum spatial resolution.

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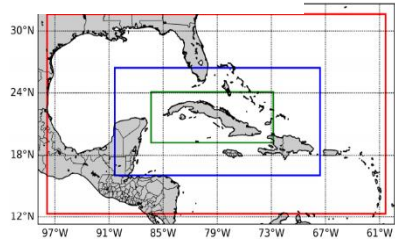**(1)** Center for Atmospheric Physics, Institute of Meteorology, Cuba (CFA / INSMET)

Materials and Methods

For the accomplishment of this work the WRF model (4.1.2) and the WRFDA module (4.3) are used. The assimilation of satellite and prepbufr data from the GDAS system is carried out for all domains, and in the case of domain 3, data from the INSMET and NOAA radar network are also assimilated, guaranteeing with this a total coverage of reflectivity information on the domain of maximum spatial resolution.
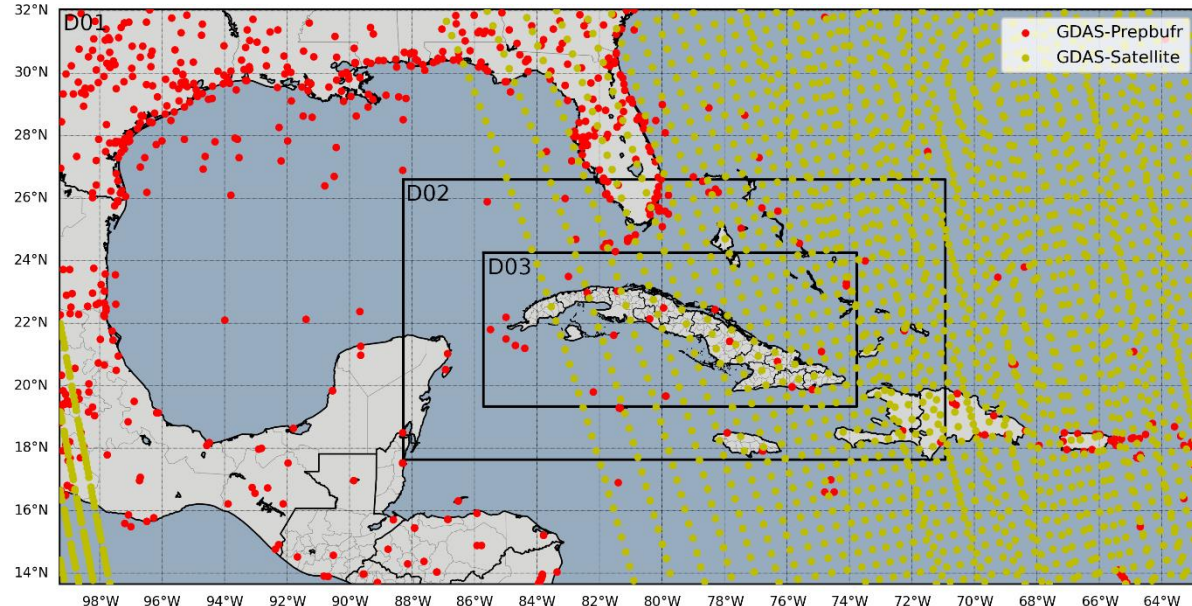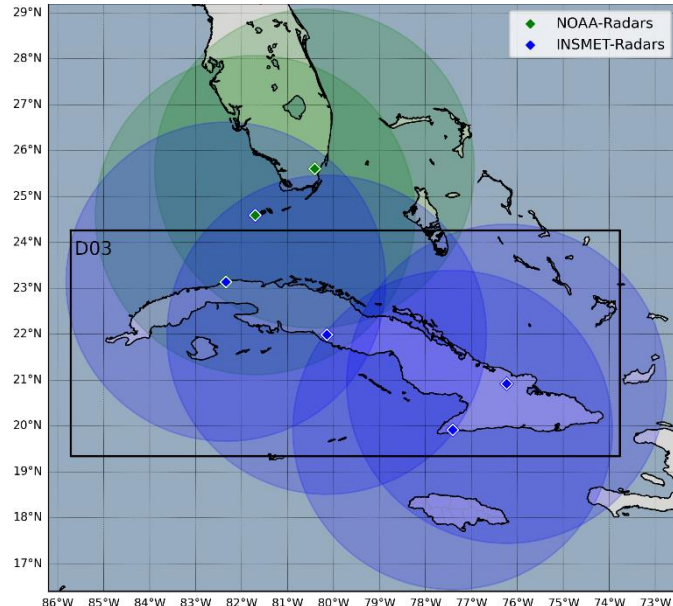
A radar data conversion tool in Nexrad Level II format to FM-128 format implemented in Python by Ferrer and Borrajero (2019) is used.

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WRF-SisPI

Configuration of the work of Sierra et al. (2014, 2017) was taken into account

Forecast Range: 24 Hours

Parameters	Configuration
Spatial Resolution	27, 9, 3 km
Microphysics	WSM5, WSM5, Morrison 2 moment (Morrison et. al., 2009)
Cumulos	Grell-Freitas, Grell-Freitas, No Cumulos
PBL	Mellor-Yamada-Janjic, Mellor-Yamada-Janjic, Mellor-Yamada-Janjic

Experimental design	Description
NoDA	No data assimilation
3DVAR	GFS + GDAS + Radar
3DVAR_noRain	GFS + GDAS + Radar + Null echoes

Materials and Methods

WRFDA Configuration (González et al. (2021) and Aguiar (2021))	
DA Method: 3DVAR (3 outer loops) var_scaling = 1.0-0.5-0.25 , len_scaling = 1.0-0.5-0.25	**Reflectivity DA Method** Indirect (Wang et al., 2013)
BE Matrix Construction (GEN_BE_v3) 1 month of WRF-SisPI Data (Initialized at 00z and 12z)	**BE Matrix (NMC method)** CV7 with Hydrometeors and W

OBS Types	Domain 01	Domain D02	Domain D03
Airep	8	-	-
Soundings	15	4	-
Metar	325	32	11
Ship	43	21	9
Synop	76	10	3
Buoy	123	11	-
Radiance	1909	438	153
Radar	**-**	**-**	**2404**

INSMET Weather Stations Map

Not used in DA

Verification Data:

INSMET Weather Stations, GOES-16, Radar Observations, GPM-3IMERGHH product.

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Materials and Methods

As a test case, the cold front that affected the western region of Cuba on December 10th, 2018 is taken, which was preceded by a prefrontal squall line that caused heavy rains on the north coast of Havana with significant accumulations in less than three hours.

Test Case: Initialization 2018-12-10 0000 UTC
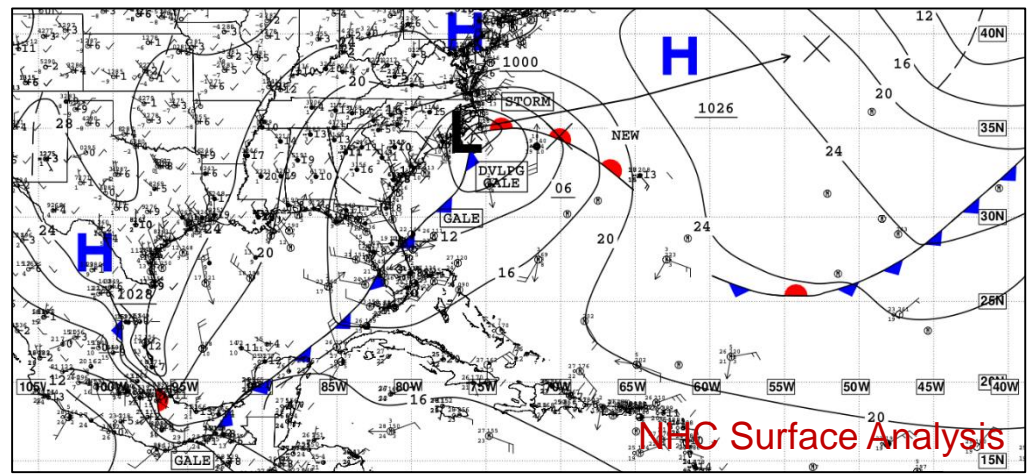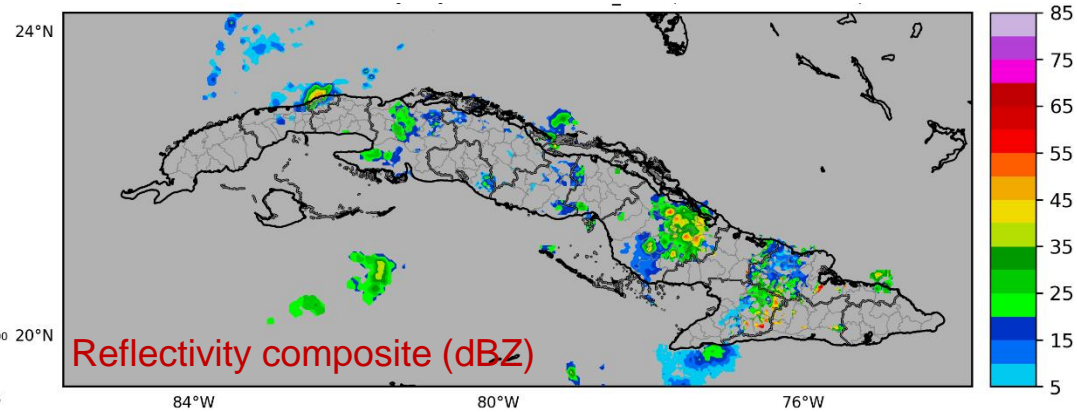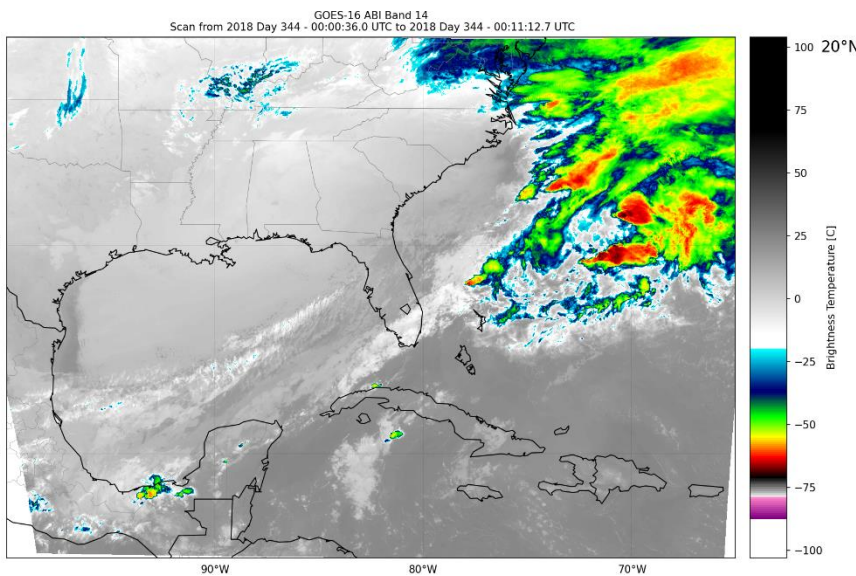
Reflectivity composite (dBZ)

GOES-16 CH-14 (IR)

NHC Surface Analysis

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Results Discussion

Cost Functions
(3DVAR RADAR DA vs 3DVAR NO-RAIN DA)
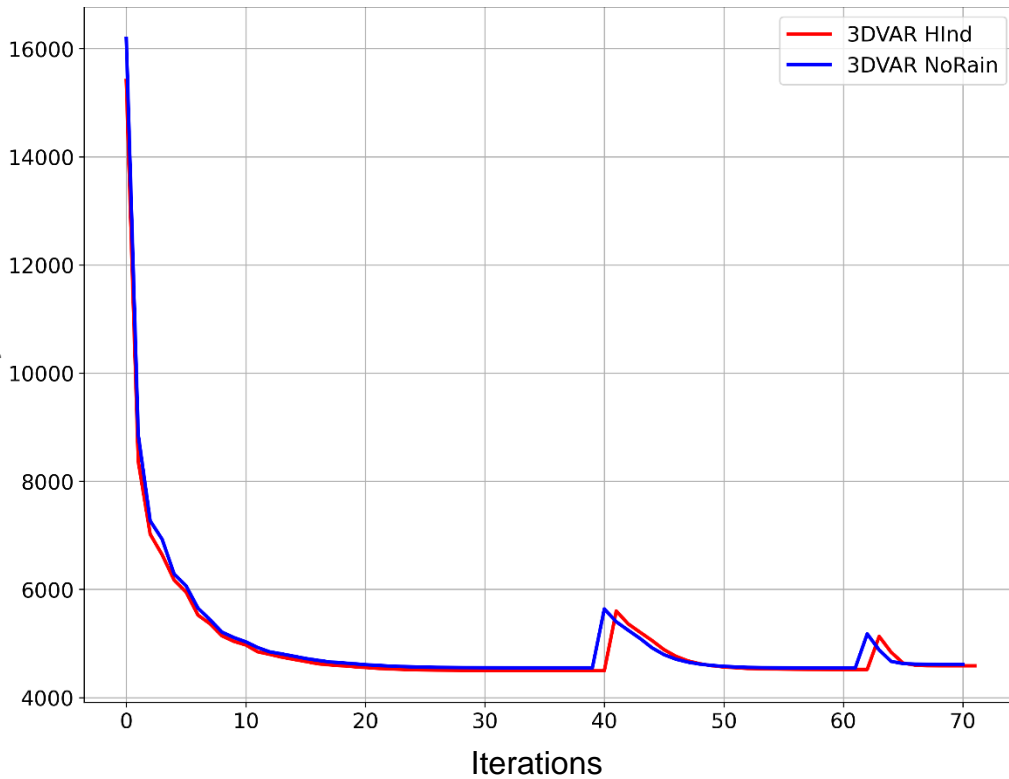
3DVAR NO-RAIN DA
Resulting analysis of reflectivity composite (dBZ)
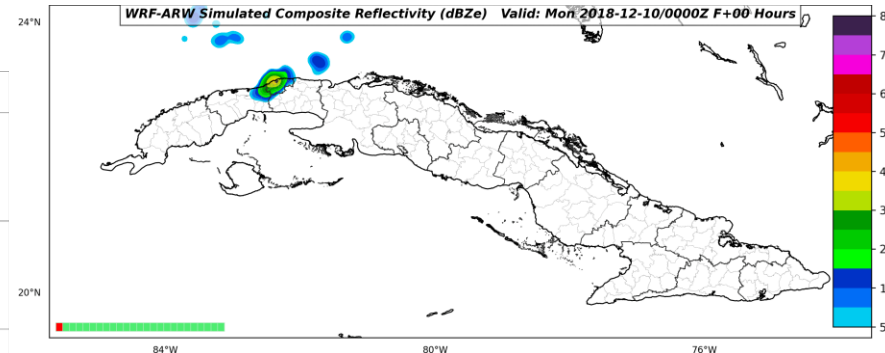
3DVAR NO-RAIN DA
Increments of reflectivity composite (dBZ)
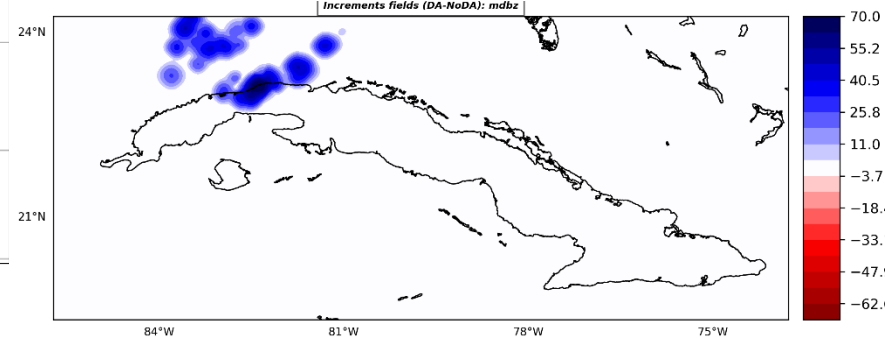
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Results Discussion

3DVAR RADAR DA
RH (850 mb level) Increments

3DVAR NO-RAIN DA
RH (850 mb level) Increments
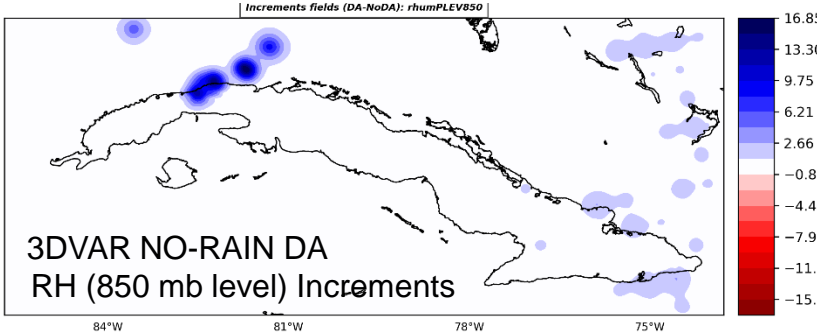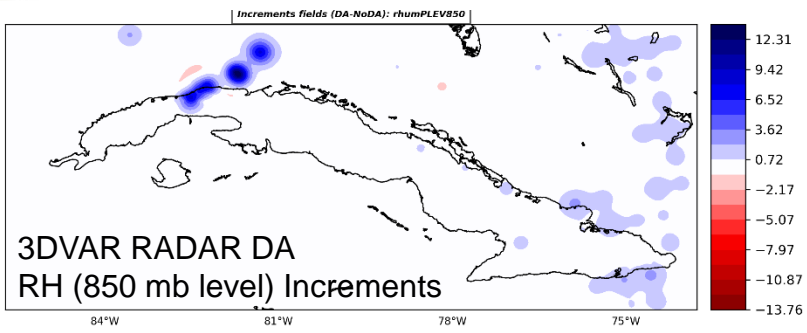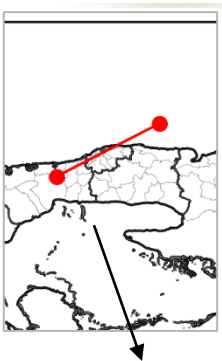
Relative Humidity (%) vertical cross-sections
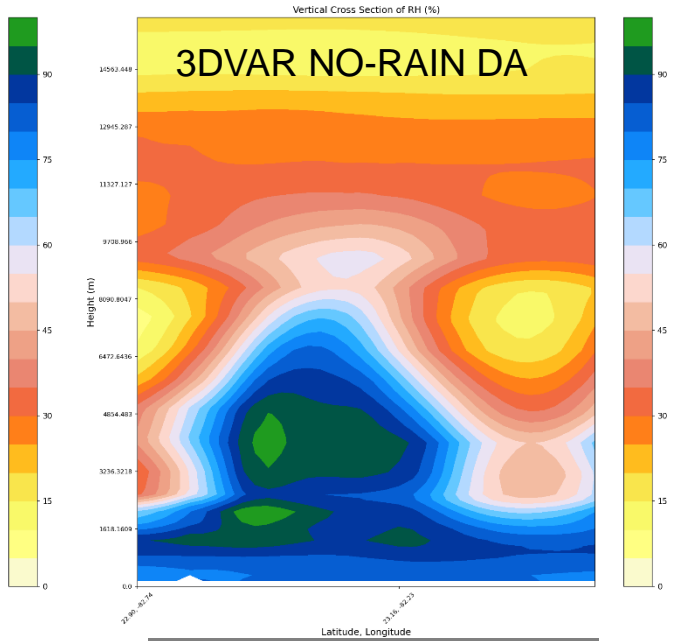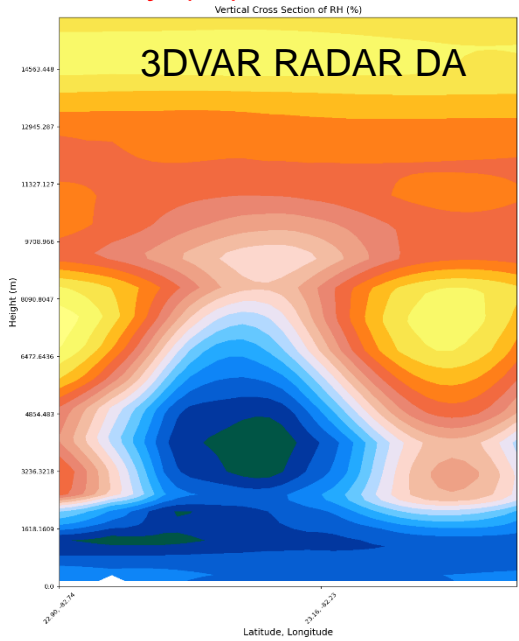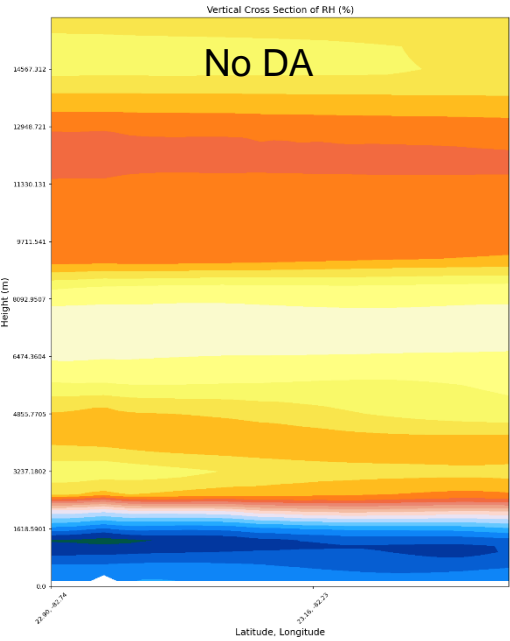
No DA

3DVAR RADAR DA

3DVAR NO-RAIN DA

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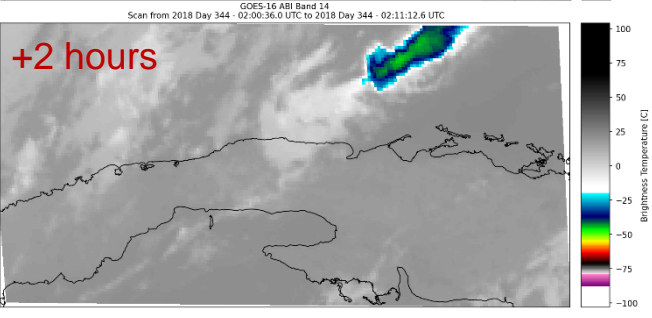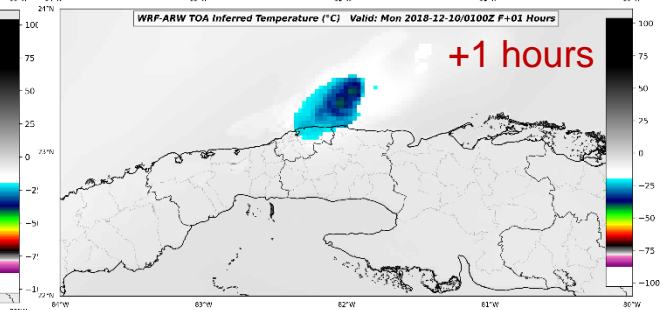
Results Discussion

Reflectivity Composite (dBZ)
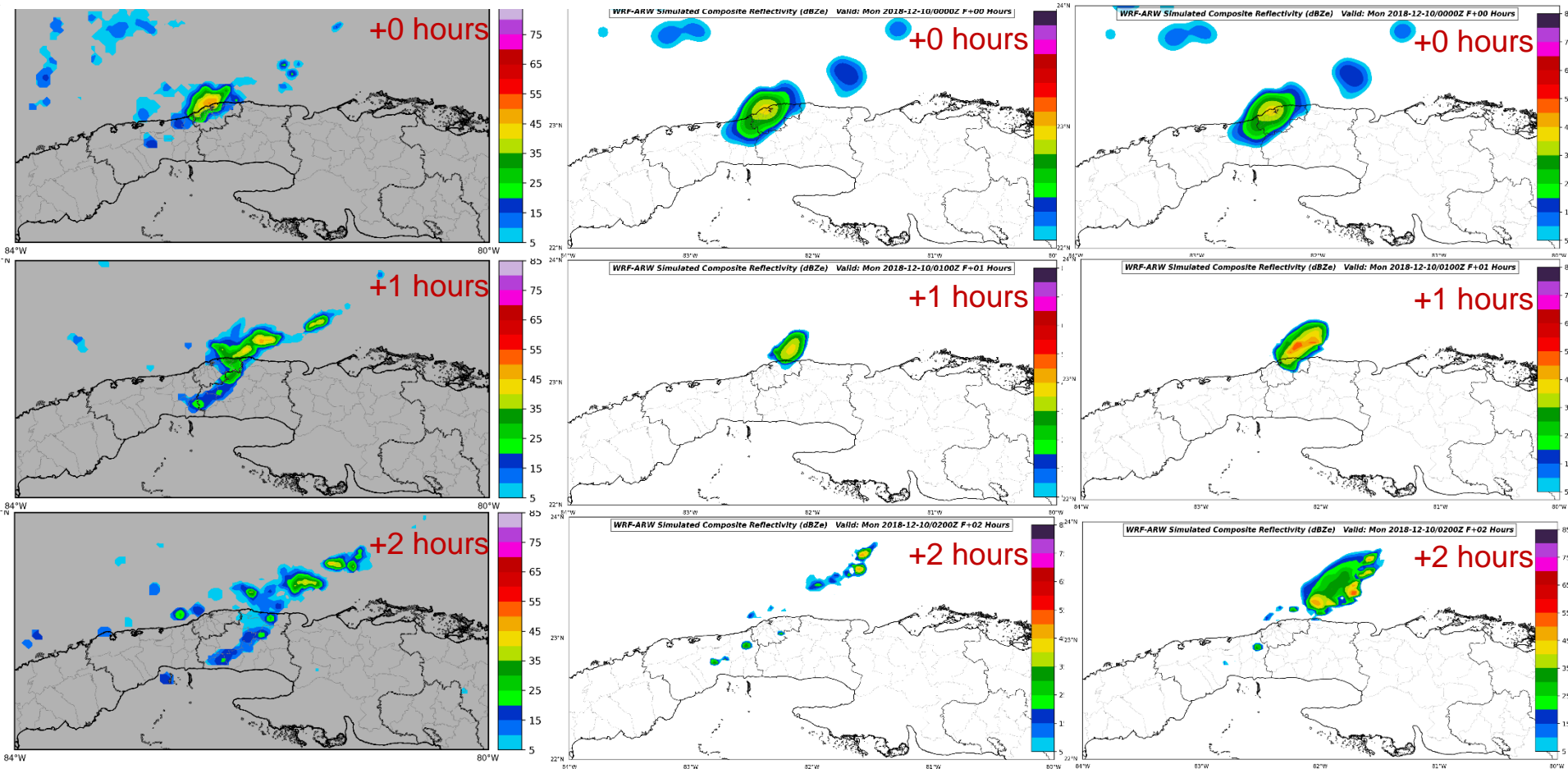
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Results Discussion

Cloud Tops Temperature
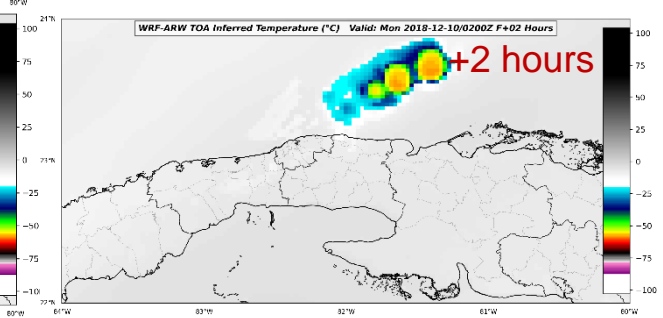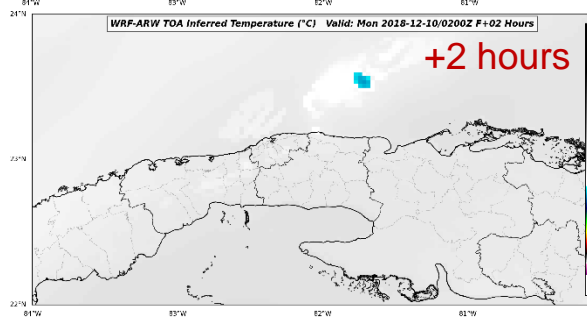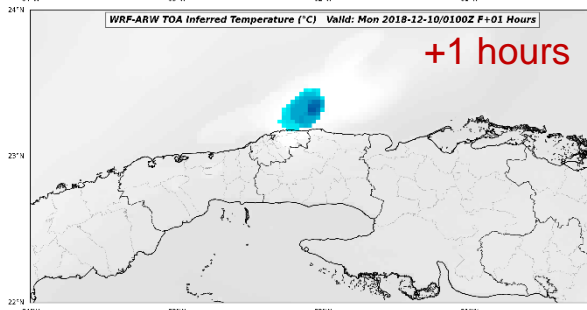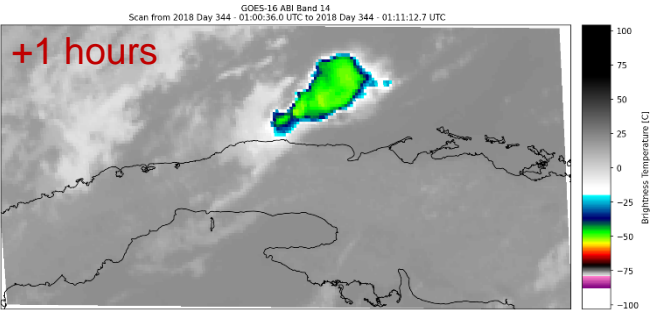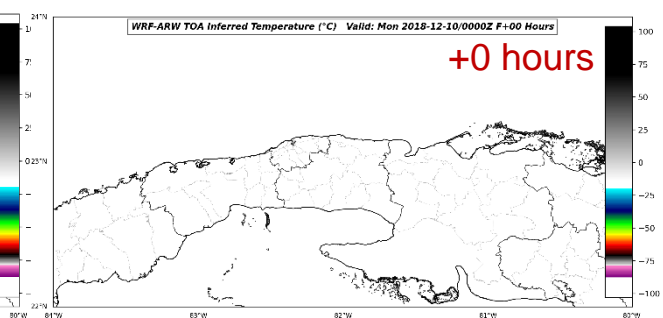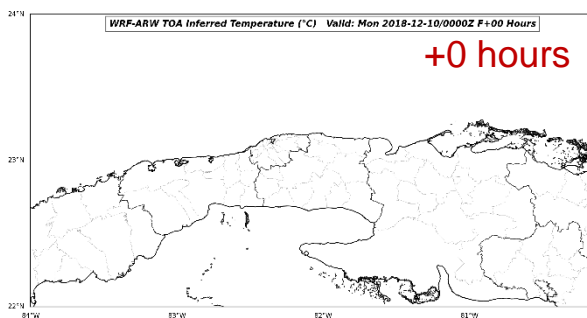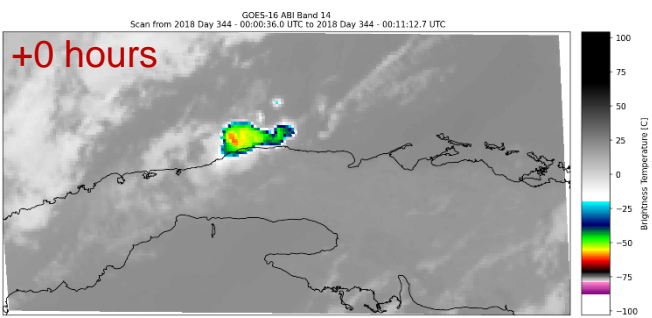
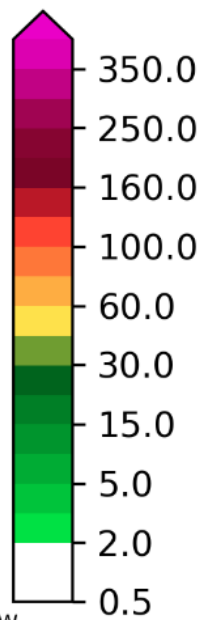GOES-16 CH-14 (IR) | 3DVAR RADAR DA | 3DVAR NO-RAIN DA

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Accumulated precipitation in 24 hours (from 20181210_00z to 20181211_00z)

Radar KBYX (Precipitation estimation)

WRF Experiments (mm/24 hours)

No DA simulation

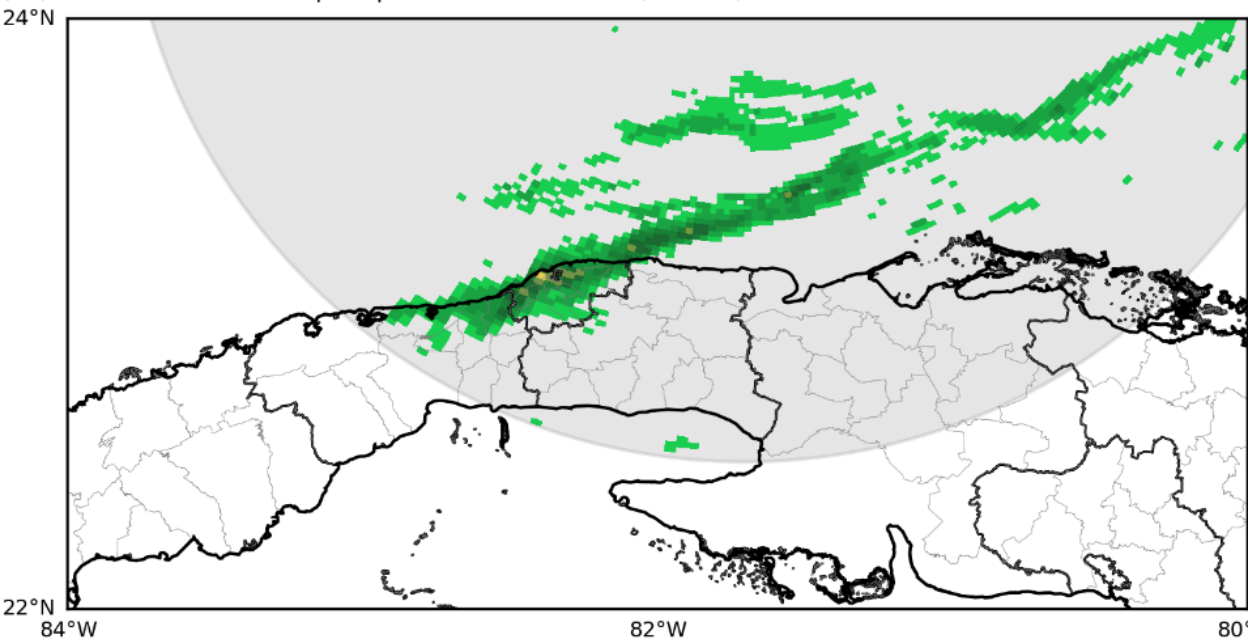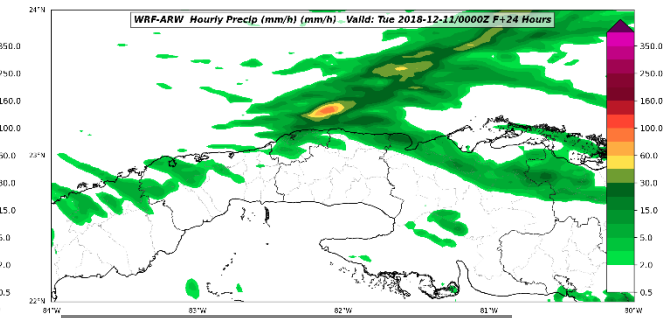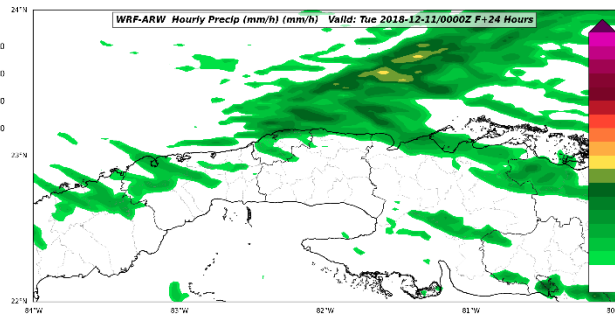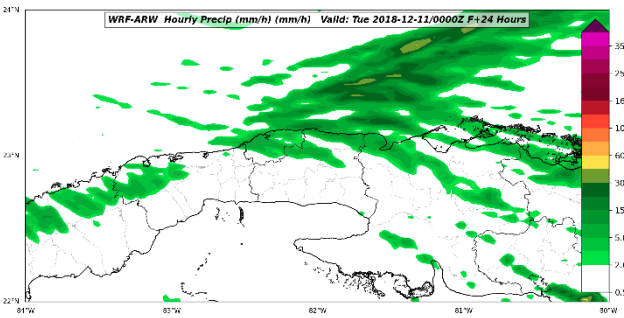3DVAR RADAR DA

3DVAR NO-RAIN DA

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Results Discussion

Mean Absolute Error (mm/3 hours) of precipitation forecast

Verification with all INSMET stations (68 synoptic stations)

Verification with Casablanca Station (WMO 78325)

Impact of the assimilation of non-precipitating echoes reflectivity data on the short-term numerical forecast of SisPI.
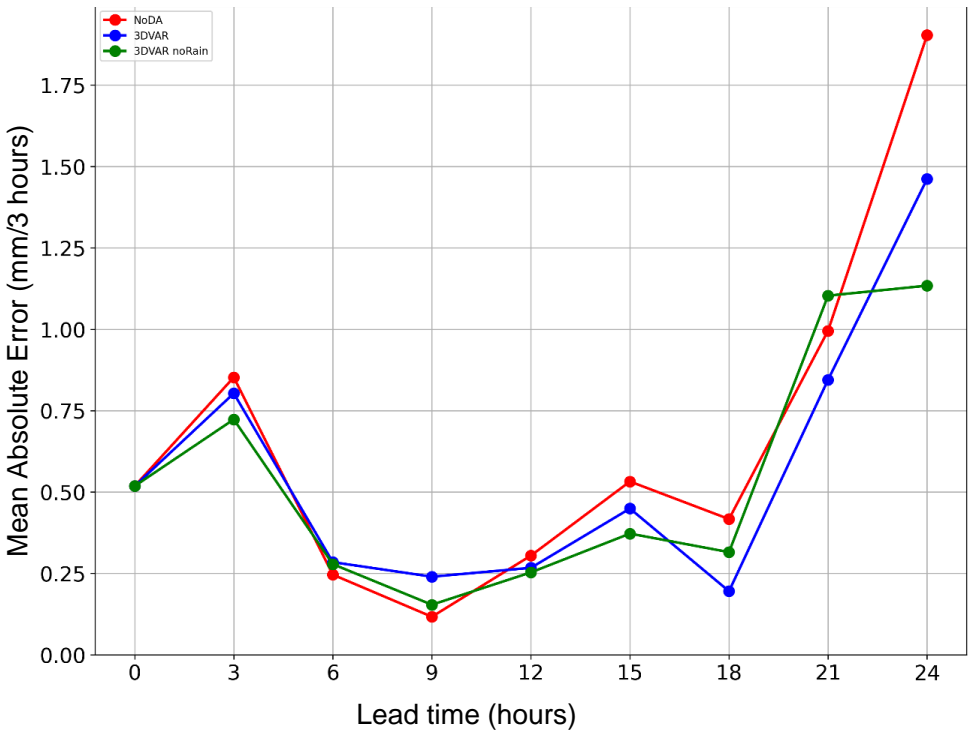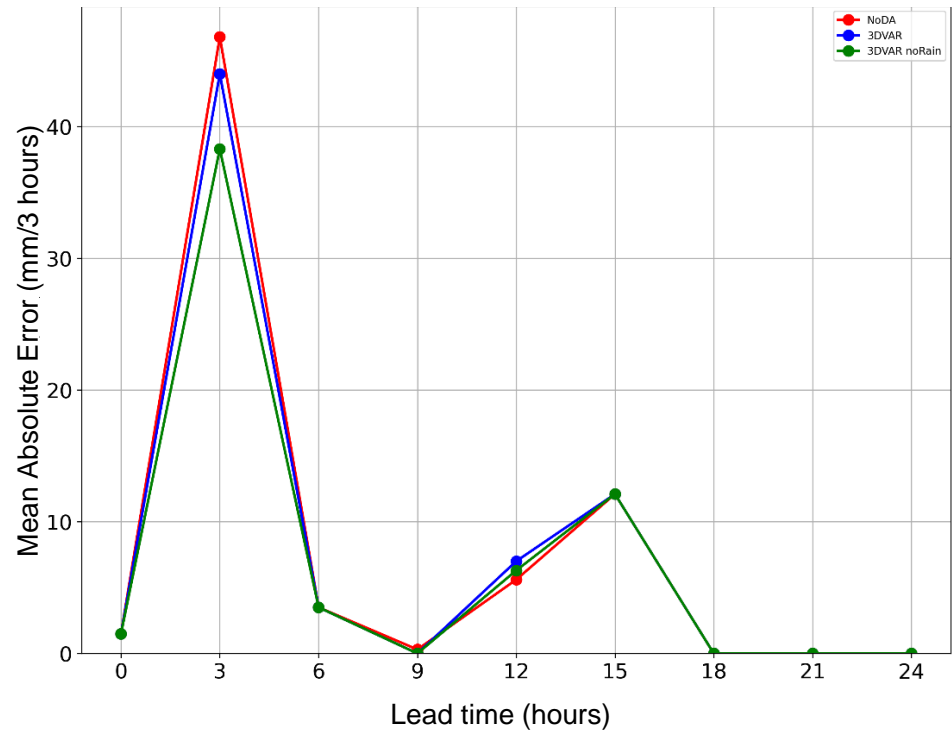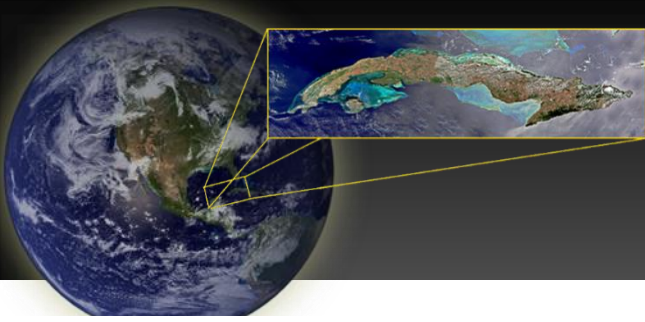
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Conclusions

- The Null-echoes assimilation option proved to be an important option in the assimilation of radar data. It allows more realistic construction of moisture fields and its vertical structure in areas of observed reflectivity echoes.

- The use of this option contributes to improving the precipitation forecast and adequately reproduces the convective processes in the first time steps.

- The simulation with radar data assimilation but without the use of this option did not adequately represent the reflectivity echoes and the brightness temperatures of cloud tops in the first 2 hours of simulation.

- The verification with synoptic stations data showed that the use of the radar_non_precip_opt option made it possible to obtain lower Mean Absolute Error values in the forecast of accumulated precipitation in the first 3 hours of simulation.

Impact of the assimilation of non-precipitating echoes reflectivity data on the short-term numerical forecast of SisPI.

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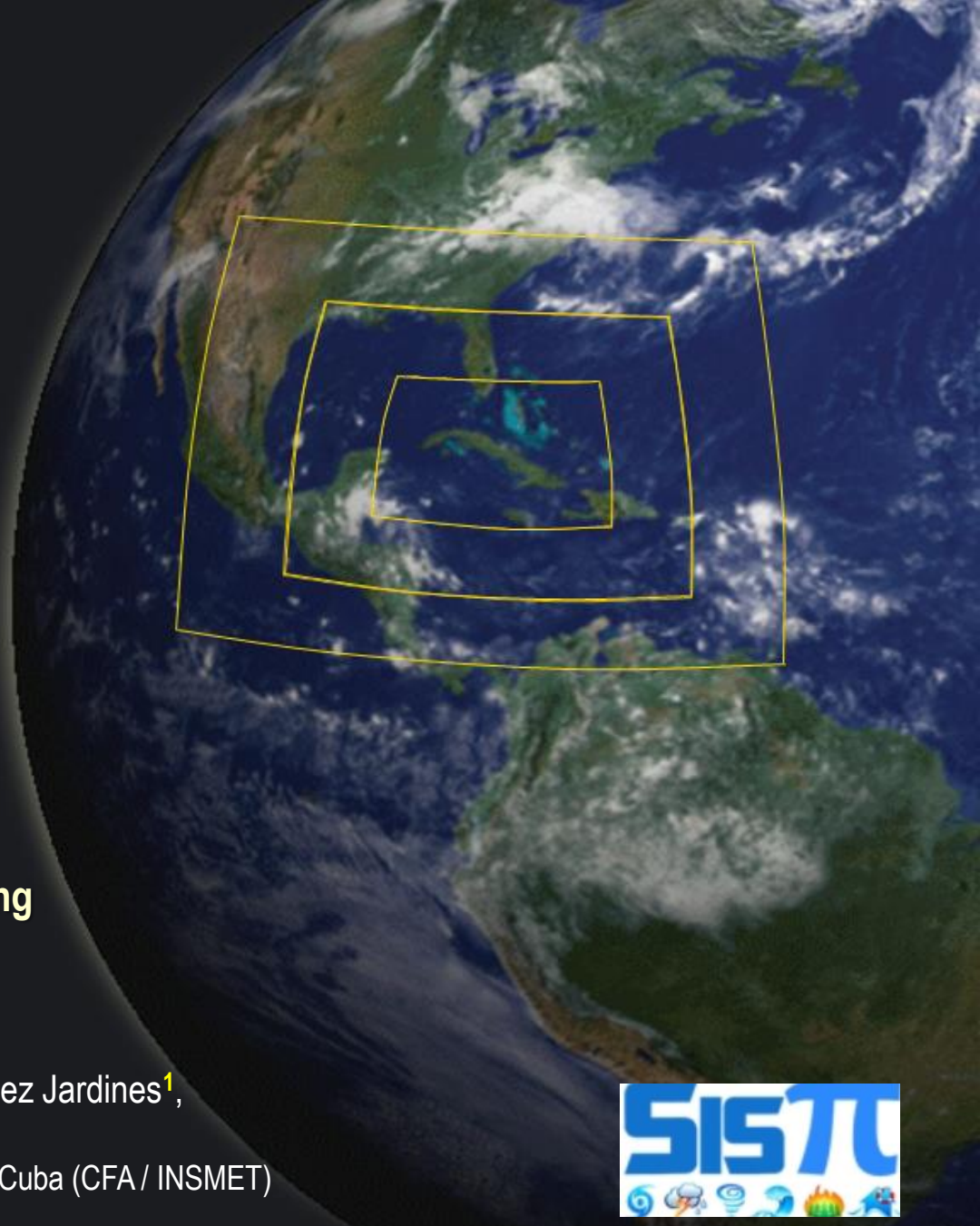**(1)** Center for Atmospheric Physics, Institute of Meteorology, Cuba (CFA / INSMET)

Recommendations

- Explore the impact of assimilating reflectivity data of non-precipitating echoes (radar_non_precip_opt) using hybrids DA methods (3DEnVAR and 4DEnVAR).

- Insert in the initialization the data of the network of meteorological stations of the INSMET.

- Work on implementing quality control of Cuban radars data.

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QUESTIONS?

Thanks

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