Comparison between 3DVAR and 3DEnVAR methods for fog forecast applied to Short-range Forecast System.

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Abstract

The research's objetive is to compare the 3DVAR and 3DEnVAR's methods skill over fog forecasting applied to the Short-range Forecast System (SisPI). Prepbufr and radiances data joint to observations from the KBYX and KBMA radars data are assimilated in a combined way for a first time in Cuba. On the other hand, five differents hydrometeors species with the vertical velocity was included as control variables into a traditional covariance matrix CV7 used for these experiments. The evaluation is performed considering the phenomenon as a binary event. Dichotomous analysis uses the present weather code data with the visibility predicted by the model, which is obtained by an empirical algorithm. The results suggest that the hybrid scheme allows a more realistic representation of the environment where the phenomenon develop and leads to more accurate forecasts.

keywords:SisPI; WRFDA; fog, assimilation

Introduction

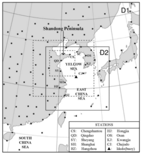
Fog forecasting in Cuba

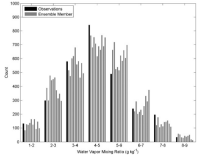
These events have resulted in it's shallow study

- fog synoptical patterns persistence
- evaluation the frequency and intensity according to the time of year

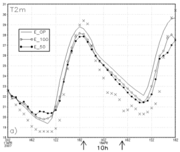
Neither considers the dynamic processes associated with the phenomenon and, in both cases, more weight is given to the volume of available data.

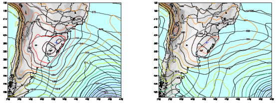
International research





- Satellite data assimilation using 3DVAR method for fog forecasting over Yellow Sea (Wang *et al* 2013) and visibility forecast using an ensemble method based on WRF model(W. Ryerson 2013).





(a) 19/06/2014 - 12UTC

(b) 20/06/2014 - 12UTC

- Vagner y Puhales *et al* 2015 y 2017. Validation of BRAMS and WRF models in fog events formation

International research

Algorithms based on hydrometeor concentrations

Kunkel, 1984; Stoelinga and Warner, 1999; Creighton *et al.*, 2014

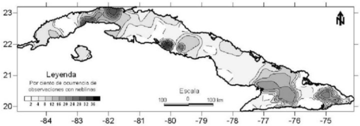
$$Vis_{K84} = \frac{-ln(0.02)}{\beta} \qquad \beta = 144.7C_{cw}^{0.88} \tag{1}$$

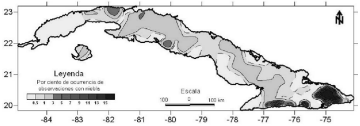
$$Vis_{SW99} = \frac{-ln(0.02)}{\beta} \qquad \beta = \beta_{cw} + \beta_{rw} + \beta_{ci} + \beta_{sn} \tag{2}$$

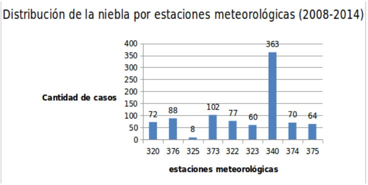
$$Vis_{C14} = min(Vis_{hydro}, Vis_{dust}, Vis_{fog}) \tag{3}$$

National research

- Alfonso 1980,Acosta 2012,Entenza 2006-2007:Frequency, space-time distribution and statistical behavior.

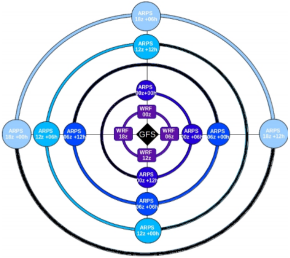


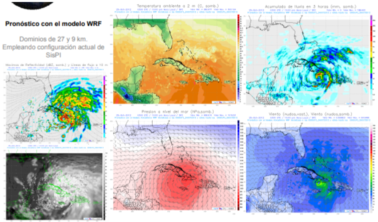


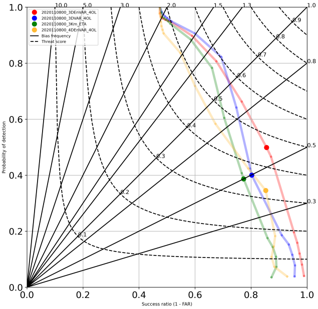


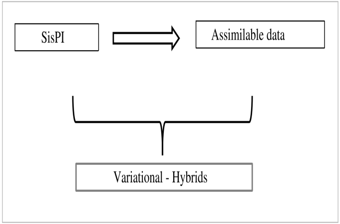
- Álvarez Escudero L. *et al* 2011 Spatial distribution of fog and haze in Cuba.
- Hernández Capote *et al* 2016. Fog forecast for Artemisa and Mayabeque provinces.

Short-range Forecast System (SisPI)

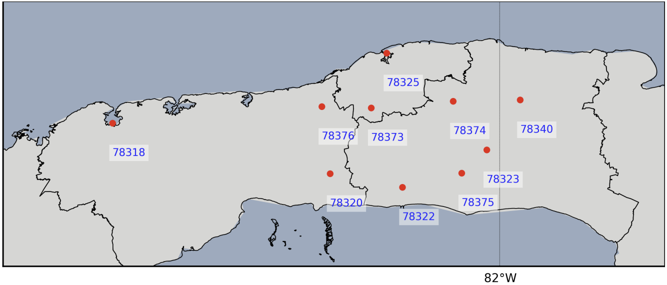








Study area



- Population density
- Strong agro-industrial sector
- Airport and port services
- Mariel's exclusive economic zone

Experiment desing

3DVAR: Three-Dimensional Variational

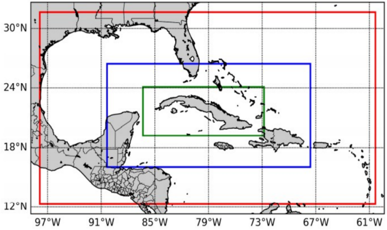
$$J(x) = \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \frac{1}{2}(y - H(x))^T R^{-1}(y - H(x)) \quad (4)$$

3DEnVAR: Three-Dimensional Ensemble-Variational. (Hybrid)

$$J(x_1, \alpha) = B_s \frac{1}{2}(x_1 - x_b)^T B^{-1}(x_1 - x_b) + B_e \frac{1}{2} \sum_{i-1}^{n} (\alpha_i^T C^{-1} \alpha_i)$$
$$+ \frac{1}{2}\left[y - H(x_1 - x_e)\right]^T R^{-1}\left[y - H(x_1 - x_e)\right] \quad (5)$$

α_i is the weight attributed to ensemble, where C is the correlation matrix for the effective location of ensemble perturbations.

Experiment desing



Data for assimilation:Prepbufr format, AMSU-A(NOAA-15/16/18/19), MHS (NOAA-18/19), SSMIS(DMSP-16), ATMS (Suomi-NPP).

Modifying the multiplicative weight of 3DVAR background error (CV7 matrix)

Parametrizations	Domain 27 km Domain 9 km	Domain 3 km
Microphysics	WSM5 (WRF-single moment 5)	Morrison 2-moment
Cumulus	GF (Grell-freitas)	not used
Boundary layer	MYNN 2.5 (Mellor-Yamada Nakanishi and Niino 2.5)	
Short wave radiation	Dudhia	Goddard
Long wave radiation	RRTM (Rapid Radiative Transfer Model)	
Surface border	Monin-Obukhov	
Surface	Unified Noah land-surface model	
Vertical levels	28	

3 Outers loops 3DVAR, **weight ensemble/CV7:** 75/25

adding five hydrometeors species and vertical velocity as control variables inside the hybrid scheme

Experiment desing

Empirical algorithm to estimate horizontal visibility (Cvis)

$$Vis_{Cvis} = min(SW_{99}, FSL) \tag{6}$$

$$Vis_{SW99} = \frac{-ln(0.02)}{\beta}$$

$$Vis_{FSL} = 1.609 * 6000 * \frac{T - Td}{rh^{1.75}}$$

Binary verification

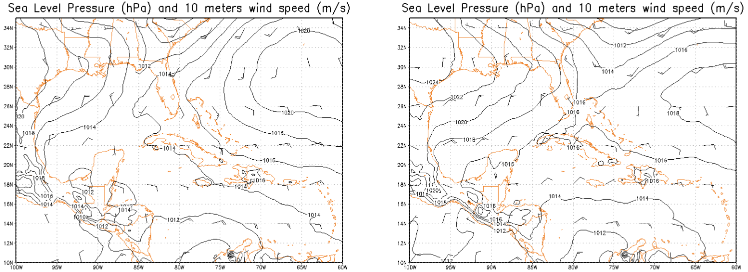
2X2 Contingency Table		Event Observed	
		Yes	No
Event Forecast	Yes	A	B
	No	C	D

$$Hit = \frac{a}{a+c} \qquad F = \frac{b}{b+d} \tag{7}$$

$$CSI = \frac{a}{a+b+c} \qquad EDI = \frac{Log(F) - Log(H)}{Log(F) + Log(H)} \tag{8}$$

Results

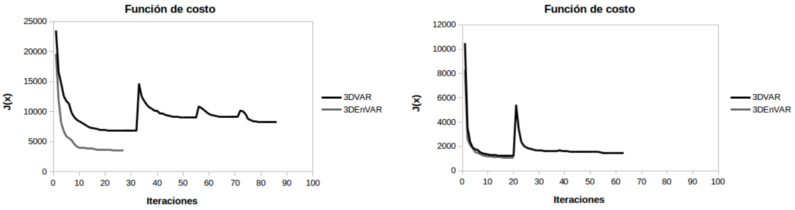
Synoptic flow



30/12/2019 12:00 UTC 31/12/2019 12:00 UTC

These days the western region was under the weak influence of the subtropical anticyclone, with a cold front advancing through the eastern portion of Gulf of Mexico toward east.

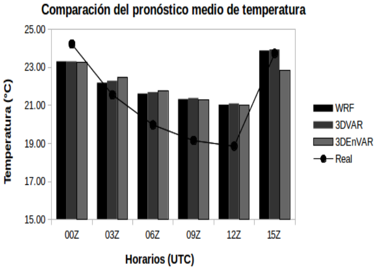
Results



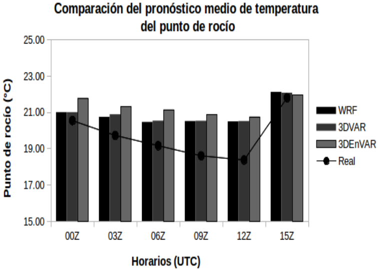
(a) (b)

- hybrid scheme allow to propagate the corrections of observations more successful than variational method
- multiple OLs do not achieve minimization as effective as in the hybrid case

Results



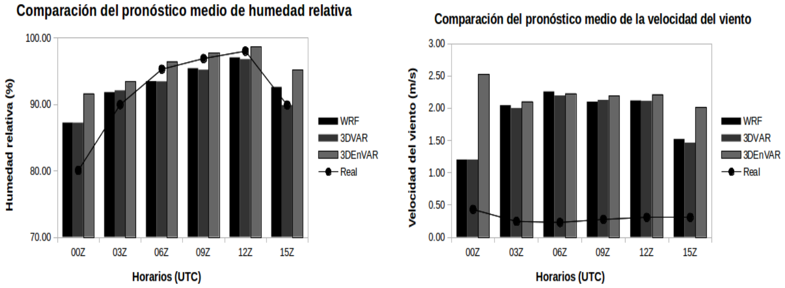
(a)



(b)

- temperature forecasts show a tendency to forecast warmer environments
- the assimilation methods fail to improve significantly

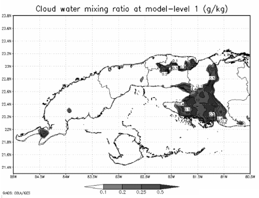
Results



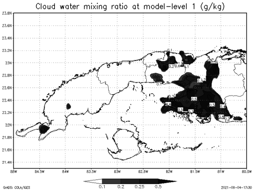
(a) (b)

- differences between SisPI and 3DVAR are small, 3DEnVAR predict the most moisture environments
- the mean error of this variable is around 1.63 m/s and the assimilation schemes fail to significantly improve this value

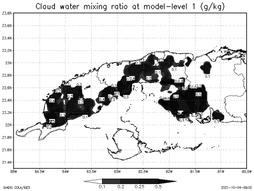
Results



SisPI



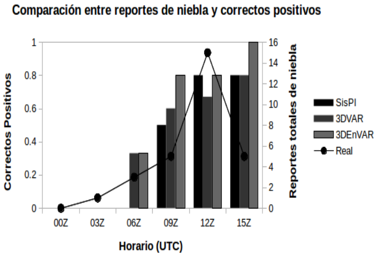
3DVAR



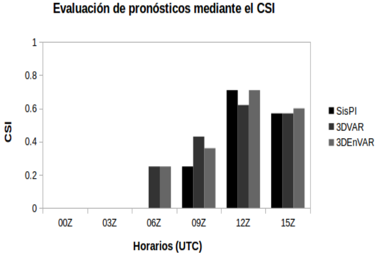
3DEnVAR

- SisPI and 3DVAR have low skill for to simulate the concentrations of hydrometeors
- the inclusion of a covariance matrix with hydrometeors in 3DEnVAR substantially modifies the background field

Results



(a)



(b)

POD:
SisPI:62%
3DVAR:64%
3DEnVAR: 79%

PODF:
SisPI:35%
3DVAR:26%
3DEnVAR: 25%

EDI:
SisPI:69%
3DVAR:70%
3DEnVAR: 83%

Conclusions

- With Cvis algorithm applied to SisPI the detection does not occur until at least the first 9 hours after the instant of initialization.
- The 3DVAR method manages to improve the CSI values by only 1% and the correct detections by 2%, these improvements are mainly due to the obtention of correct forecasts at the first 6 forecasting hours.
- 3DEnVAR method contributed to greater cooling in the superficial layers allowed early detections in relation to SisPI.
- 3DEnVAR present correct detection values up to 17% and CSI of 11% higher than SisPI and similar results for 3DVAR.

Thanks!