Statistical Evaluation of the Wet Season Atmospheric Mesoscale Campaign – LBA and GTS Observations used in RPSAS with CPTEC Eta model

Rosângela Cintra, Dirceu Herdies ,José A. Aravéquia, Julio Tóta,
Jose P. Bonatti
Centro de Previsão de Tempo e Estudos Climáticos - CPTEC/INPE
Rodovia Presidente Dutra, km 40
12630-000 -Cachoeira Paulista - SP
e-mail:rcintra@cptec.inpe.br

Abstract

To improve the skill of the CPTEC regional model was developed and implemented a analysis system, called Regional Physical-space Statistical Analysis System (RPSAS), that make use of the core system PSAS from Data Assimilation Office (DAO) on the GSFC/NASA. The RPSAS has ben designed as an improvement over the current Optimal Interpolation (OI) based on the Data Assimilation System (DAS). From January to February 1999, during AMC-WET/LBA campaign, comparisons of the Observation Data Stream (ODS) and the RPSAS analysis fields were made using the Eta six hour forecast fields (first guess). The Eta model was integrated daily for 00, 06, 12 and 18 GMT using initial conditions from RPSAS analyses. The statistical indexes were calculated with the purpose of evaluating the quality of the analysis. The observations minus analysis and the observations minus first guess for geopotential height and humidity at the levels 850, 500 and 300 hPa levels were used to generate mean bias score and standard deviation (RMS) for each region to produce a statistical evaluaton of the observing system for South America. The first results show mean bias score for geopotential height amplitude on 500 hPa of approximately 16 mgp at 00Z , 28 mgp at 06Z, 8 mgp at 12Z, and 14 mgp at 18Z.

1- Introduction

Data assimilation has long being regarded primarily as a mean of providing initial conditions for Numerical Weather Prediction (NWP) in meteorological centers. Increasingly, it is now being recognized that, through the constant confrontation of theory (under the form of a numerical model that discretized the physical laws governing the atmospheric flow) with reality (as depicted by meteorological observations), the data assimilation process has the potential to bring major advances in our scientific understanding of the atmosphere. An ideal assimilation should be able to process all the available information (i.e. the observations themselves, the meteorological model, and the known statistical properties of the flow) together with the uncertainties of these various sources of information to produce a complete and consistent description of the flow with its associated uncertainty. Data assimilation is, an estimation problem and Estimation theory constitutes the natural mathematical foundation for understanding data assimilation problems. It provides, in addition, a number of algorithms for approaching and addressing these problems. However, as it was pointed out by Cohn (1997), while engineering problems, for which Estimation Theory has primilary been developed, are generally small-scale and sometimes linear, atmospheric data assimilation problems are large-scale and generally non-linear. Sensible computational approximations have, therefore, to be made to implement these algorithms in atmospheric and oceanic application. Indeed, most of the research work performed on data assimilation is intended at determining cost effective simplifications to implement. The variational formalism is used to reformulate the data assimilation problem in term of optimization and it offers an efficient way to perform this optimization. Applied either as the so-called 3-Dimensional Physical Space Analysis System (PSAS) or the so-called 3-Dimensional Variational (3D-VAR) data assimilation system, the variational calculus has opened new horizons in the atmospheric and oceanographic data assimilation field. Recently, using a 3D-PSAS approach, Cohn and al. (1998) were able to solve the classical Optimal Interpolation problem without the traditional data selection procedure; an approximation that has been in force in meteorological centers for decades (Lorenc 1986). At the present time, 3D-VAR data assimilation systems are already operational at NCEP (Parrish and Derber 1992), ECMWF (Courtier et al. 1997), RPN in Canada, the UK Met Office and MeteoFrance, while the NASA Data Assimilation Office is routinely running a 3D-PSAS data assimilation procedure. The necessary components for a 3-dimensional data assimilation system are a forecasting model, an observing system and the statistics on the accuracy of the forecasts and measurements. At the mesoscale (1~100km), these statistics, and, in particular the information related to forecast errors, are certainly the least known and the most difficult to obtain of the three components. There is, therefore, an important research work to be accomplished in this domain and these notes describe the early results obtained in that domain with the Eta Model in CPTEC. Our researches has focused on the the PSAS and have the development of a mesoscale 3D-VAR system

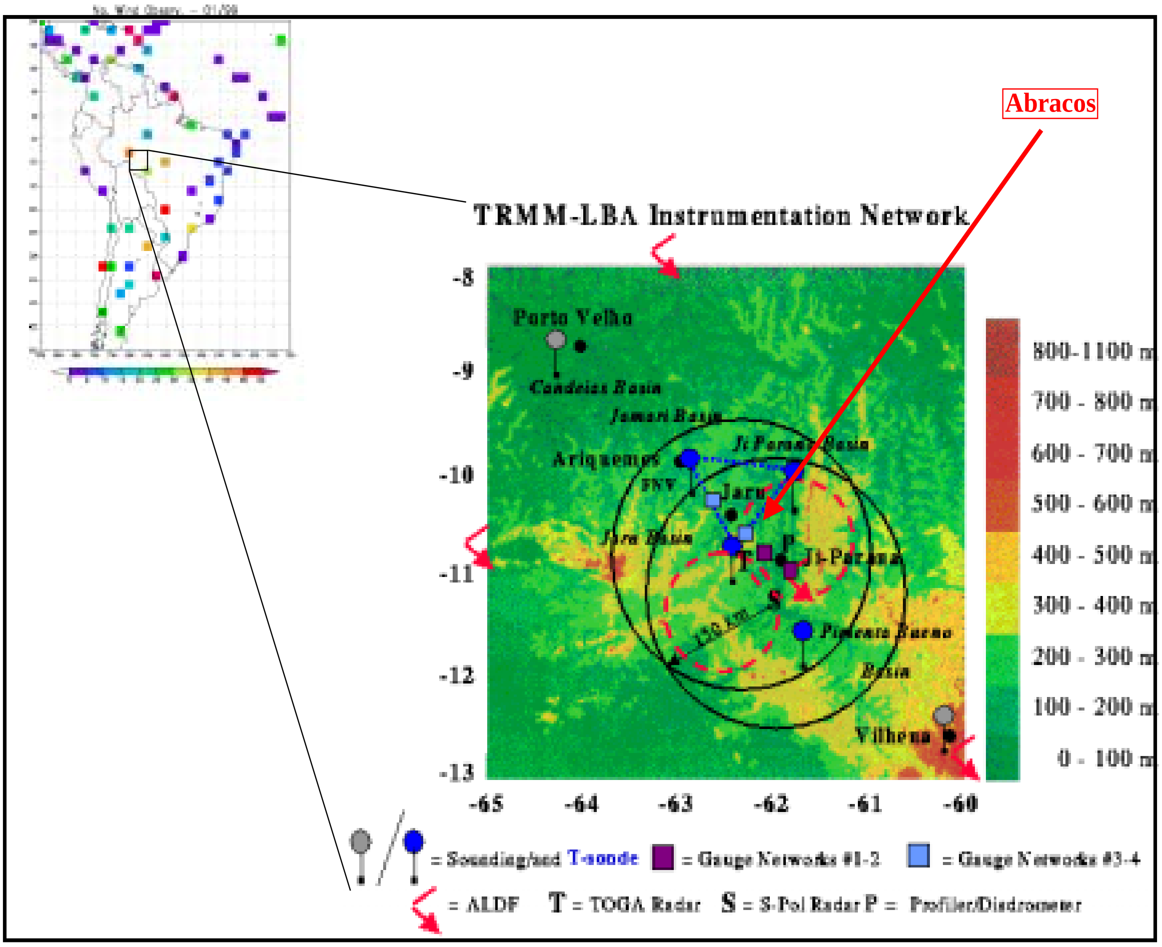


Figure 1 – Map of South America with the experimental area in the State of Rondonia. The enhanced map shows the WETAMC/TRMM-LBA sites with the instrumentation deployed. The colorbar indicates the number of radiosondes that were used by GEOS-2 assimilation. Porto Velho (top of enhanced map) and Vilhena (bottom of enhanced map) were the closest stations to the WETAMC/TRMM-LBA region to be assimilated in GEOS

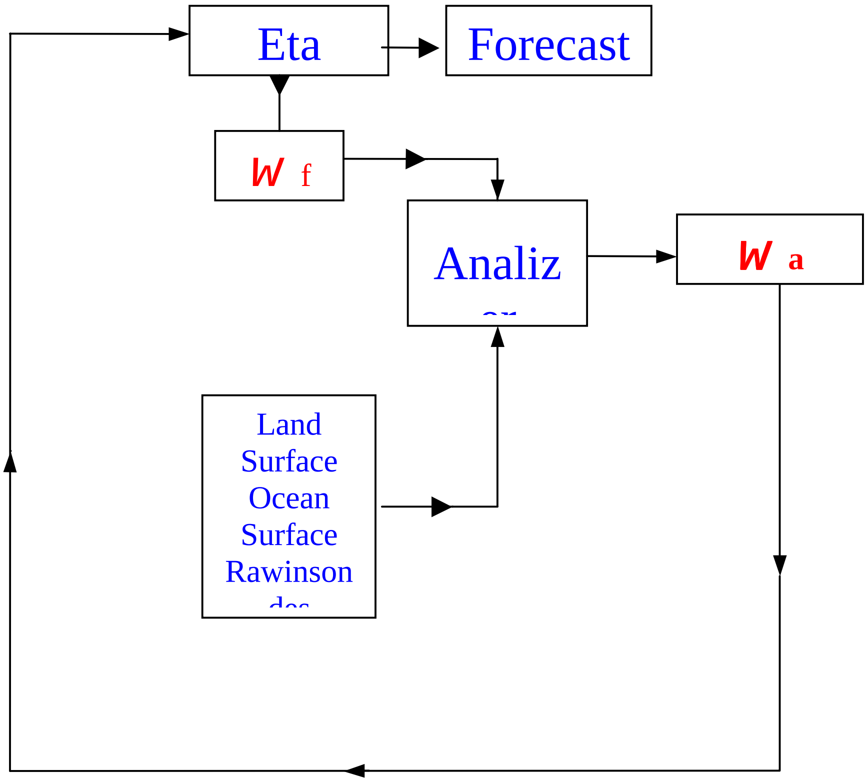
2- Overview of PSAS

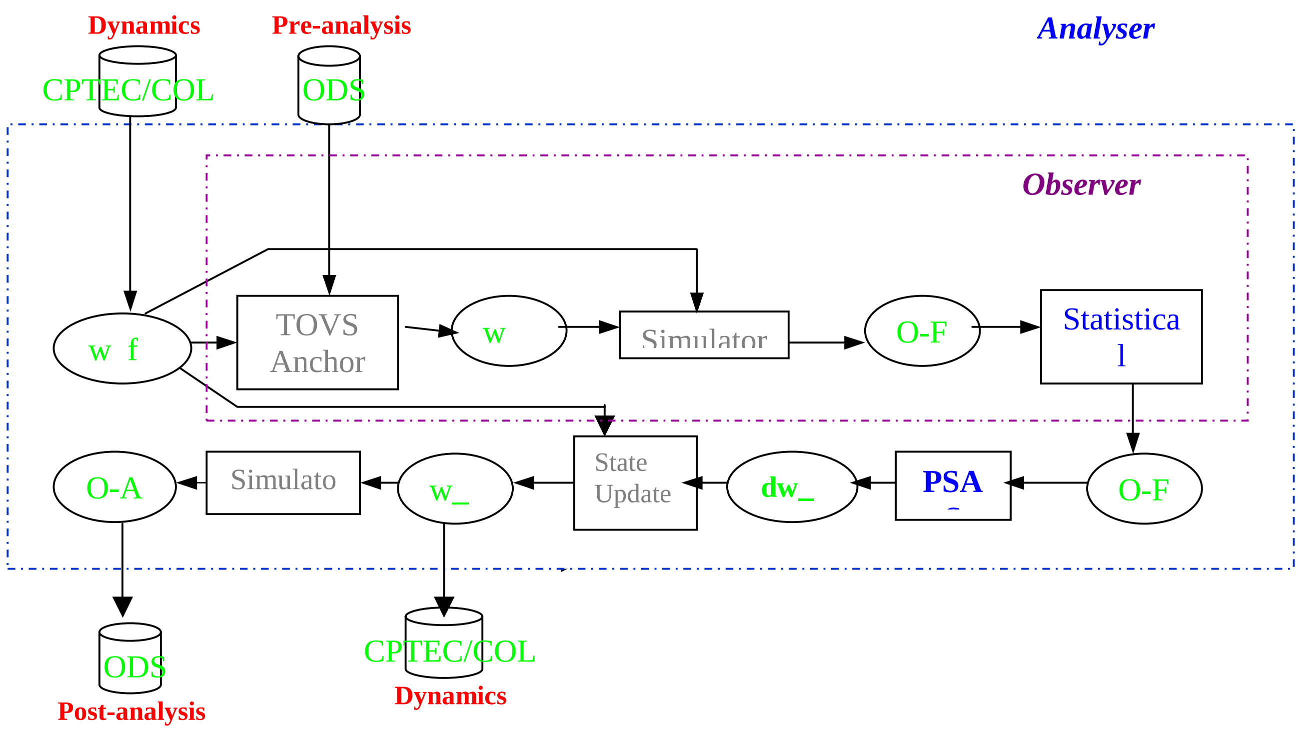
INTRODUCTION TO ETA/RPSAS

A Phisycal-space Statical Analysis System (PSAS) has been developed at Data Assimilation Office (DAO), NASA/GSFC. PSAS has been designed as an incremental improvement over the current Optimal Interpolation (OI) based in Data Assimilation System (DAS), and provide a framework to test advanced forecast error covariance models; a analysis Regional PSAS(RPSAS) resulting for the ETA system is being developed at Centro de Previsão de Tempo e Estudos Climáticos (CPTEC).

Components of the an Atmospheric Data Assimilation System are

- **Model**: Regional Circulation Model (RCM) to propagate information in time,
- **QC**: a Quality Control algorithm to flag and eliminate erroneous observations
- **Analysis**: a procedure to blend observations and a short-term forecast (6 hour) producing a gridded estimate of the state of the atmosphere. ETA/RPSAS uses the PSAS
- **Update**: A procedure to incorporate the analysis into the model.


Eta
Forecast
W f
Analiz
W a
Land
Surface
Ocean
Surface
Rawinson


Dynamics
Pre-analysis
Analyser
CPTEC/COL
ODS
Observer
w f
TOVS
Anchor
w
O-F
Statistica
l
O-A
Simulato
w_
State
Update
dw_
PSA
O-F
ODS
Post-analysis
CPTEC/COL
Dynamics

Description of the PSAS Solver

Analysis equation:

$$w^a = w^f + K\left(w^o - Hw^f\right)$$

where

w^a	analysis state vector	$\in \mathbb{R}^n$
w^f	forecast state vector	$\in \mathbb{R}^n$
w^o	observation vector	$\in \mathbb{R}^p$
H	observation operator	$\in \mathbb{R}^{p\times n}$
K	weight ("gain") matrix	$\in \mathbb{R}^{n\times p}$
	$n \sim 10^6, \quad p \sim 10^5$	

Weights K determined by minimizing $\langle ||\varepsilon_a||^2 \rangle$:

$$\left(HP^fH^T + R\right)K^T = HP^f$$

where

$$P^f = \langle \varepsilon_f \varepsilon_f^T \rangle \qquad \text{Fcst. error cov.}$$

$$R = \langle \varepsilon_o \varepsilon_o^T \rangle \qquad \text{Obs. error cov.}$$

Methods of Solution of the Analysis Eqn.

Solving $\left(HP^fH^T + R\right)K^T = HP^f$ by *brute force* is impractical (10^6 linear systems of size $10^5 \times 10^5$ each). Several methods of solution:

OI: Solve for weights on mini-volumes including a few grid-points, selecting a fixed number of observations (75, 150, 300 depending on the version).

3D-VAR: Solution w^a is the minimizer of the functional

$$\begin{aligned} J(w) &= \left(w - w^f\right)^T \left(P^f\right)^{-1} \left(w - w^f\right) \\ &+ \left(Hw - w^o\right)^T R^{-1} \left(Hw - w^o\right) \end{aligned}$$

Weights K are not calculated.

Methods of Solution of the Analysis Eqn, cont.

PSAS: Problem is solved in physical space in two steps:

$$
\begin{aligned}
(HP^fH^T + R)x &= w^o - Hw^f \qquad (*) \\
w^a &= w^f + P^fH^Tx
\end{aligned}
$$

The linear system is solved globally with an iterative pre-conditioned Conjugate Gradient algorithm. As in 3D-VAR weights K are not calculated.

Pre-conditioner: sphere is divided in several regions and (*) is solved locally in each region.

Approximations: A compactly supported correlation function is assumed. Regions separated by more than a pre-determined distance (usually 6,000 km) are assumed not correlated.

5

3- Metodology

The Wet Season Atmospheric Mesoscale Campaign (WETAMC) component of the Large Scale Atmosphere-Biosphere Experiment in Amazonia (LBA) and the Tropical Rainfall Measuring Mission (TRMM) field campaign, known as TRMM/LBA, were conducted in the southwest corner of the Amazon basin during the wet season months of January and February 1999 . The goal of the field campaigns was to provide a detailed study of tropical convection in Amazonia, with its different impacts, as well as on the regional response to the larger scale forcing. Together, the WETAMC/LBA and TRMM/LBA campaigns represent an opportunity to study tropical convection in Amazonia and its relation to the underlying forested and deforested regions [*Silva Dias et al., 2000; Silva Dias et al., 2002*].See Figure 1.

The observations is a powerful tool for data assimilation system in this region, to improve the skill of the CPTEC regional model . In this paper, we present statistical indexes calculated with the purpose of evaluating the quality of the analysis.

Four times daily analyses (00, 06, 12, 18 GMT), for January and February 1999. For this study we use GTS Observing System and the sounding data from WETAMC/TRMM-LBA A Regional Physical-space Statistical Analysis System (RPSAS). The data are available on a horizontal resolution of 2.0^{o} X 2.5^{o} latitude-longitude grid at 14 pressure levels (1040,1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 40 hPa).

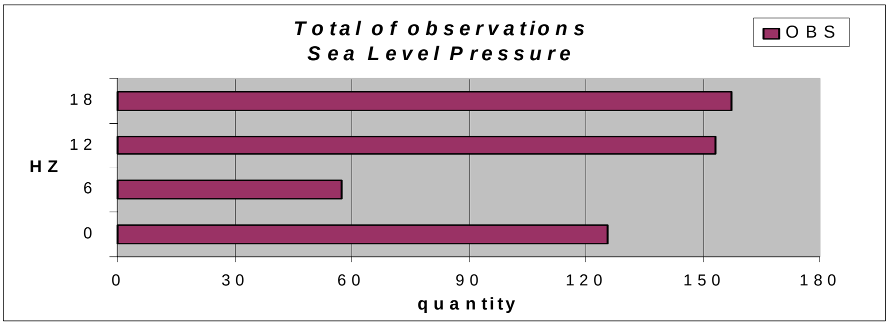
An important factor to show the stability of an assimilation system is the accompaniment of the temporary variation of O-A (observation less Analyzes) and O-F (observation less first-guess), after a wheeled static, to be verified that the values of O-A they are smaller than O-F, indicating that the fields of the analysis are approximately similar to the field of observations as the expected. This temporary variation is shown for the levels of 850 and 500 mb for the geopotential height and sea level pressure
It can be observed that the values of O-A are smaller than the values of O-F, being verified this way the stability of RPSAS, close to the observations for him used. This is the waited result of a Assimilation System.

Soundings for WETAMC/TRMM-LBA

- Abracos: (10^{o}75'S-62^{o}52'W)
- Rebio Jaru: (10^{o}14'S-61^{o}91'W)
- Rancho Grande: (10^{o}17'S-62^{o}37'W)
- Rolim de Moura: (11^{o}70'S-61^{o}78'W)

Observing System

- Land Surface observations: slp
- Ocean surface observations: slp, u, v, and q
- Rawinsondes: h, u, v and q at mandatory levels
- Aircraft winds: u and v, conventional & ACARS
- Cloud track winds: u and v
- Satellite: h,u,v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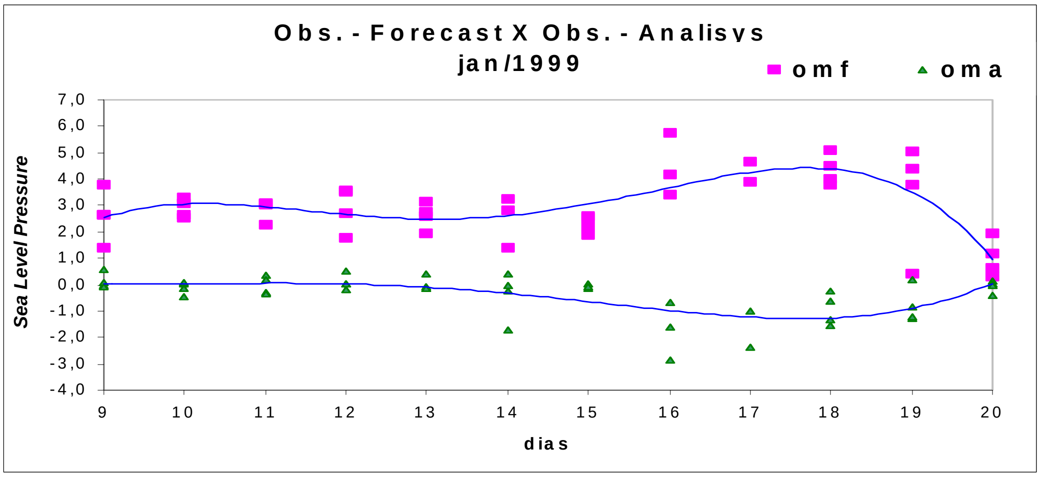
Sea Level Pressure
OBS
HZ
18
12
6
0
0
30
60
90
120
150
180
quantity


Obs. - Forecast X Obs. - Analisys
jan/1999
omf
oma
Sea Level Pressure
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
-1,0
-2,0
-3,0
-4,0
9
10
11
12
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14
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16
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18
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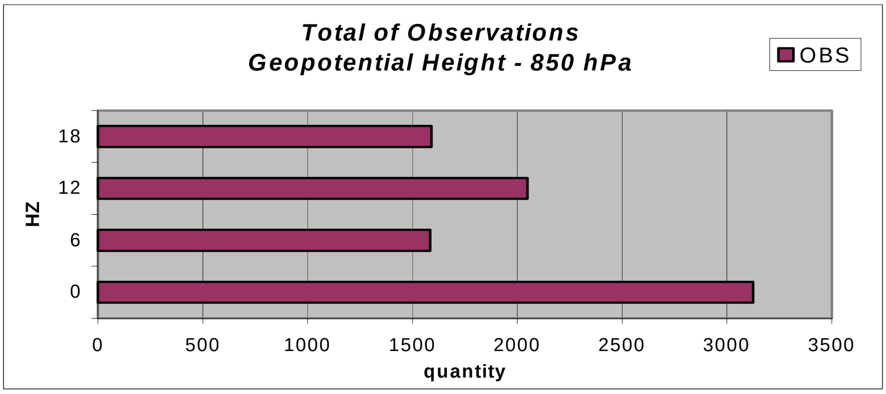
20
dias


Total of Observations
Geopotential Height - 850 hPa
OBS
HZ
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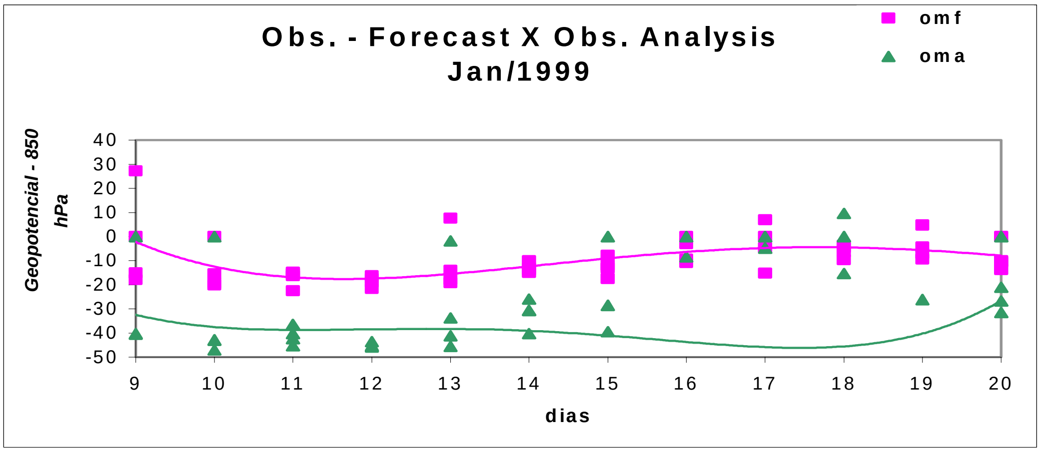
12
6
0
0
500
1000
1500
2000
2500
3000
3500
quantity


Obs. - Forecast X Obs. Analysis
Jan/1999
omf
oma
Geopotencial - 850 hPa
40
30
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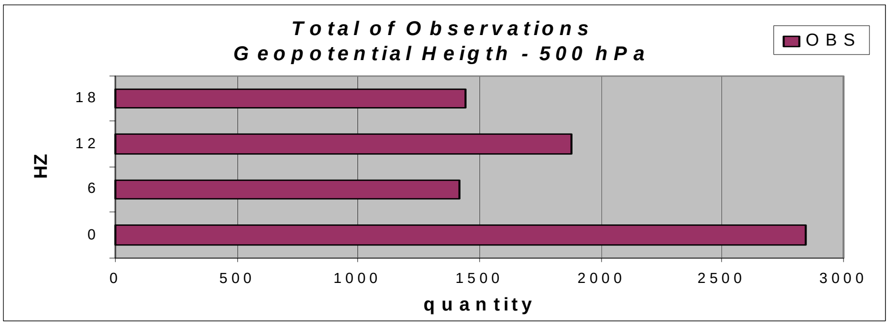
dias


Total of Observations
Geopotential Heigth - 500 hPa
OBS
HZ
18
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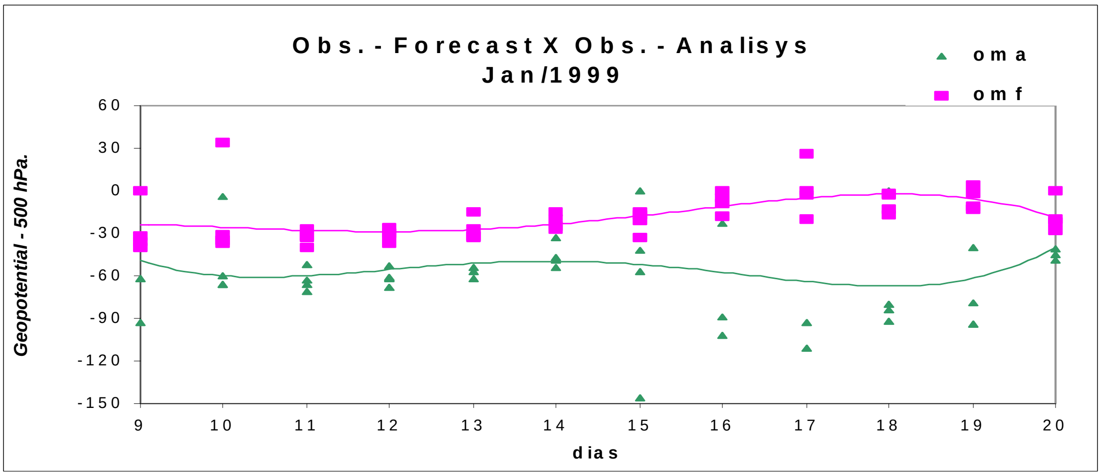
Obs.- Forecast X Obs.- Analisys
Jan/1999
oma
omf
Geopotential - 500 hPa.
60
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0
-30
-60
-90
-120
-150
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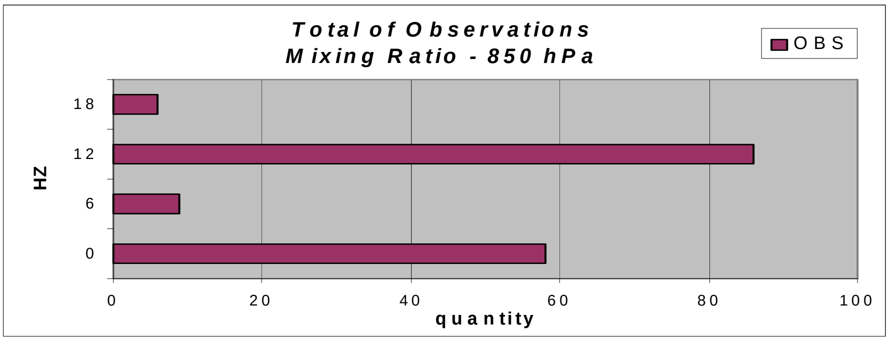
dias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Mixing Ratio - 850 hPa
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HZ
18
12
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0
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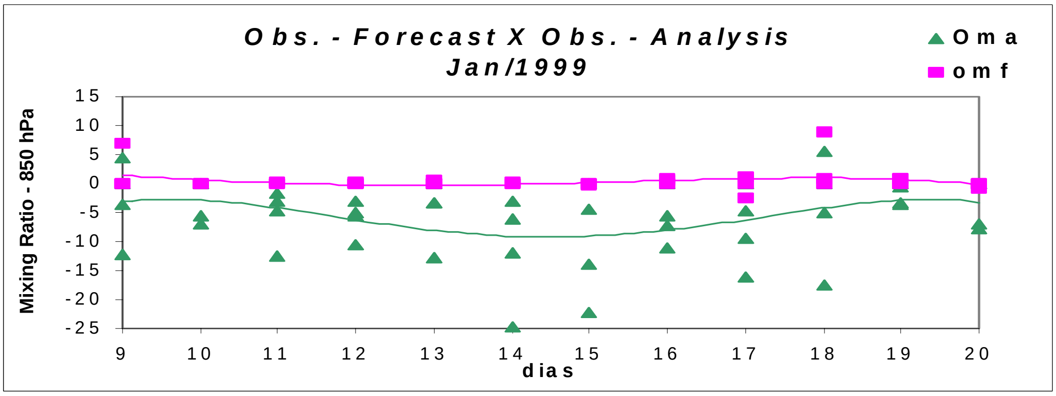
60
80
100
quantity


Obs.- Forecast X Obs.- Analysis
Jan/1999
Oma
omf
Mixing Ratio - 850 hPa
15
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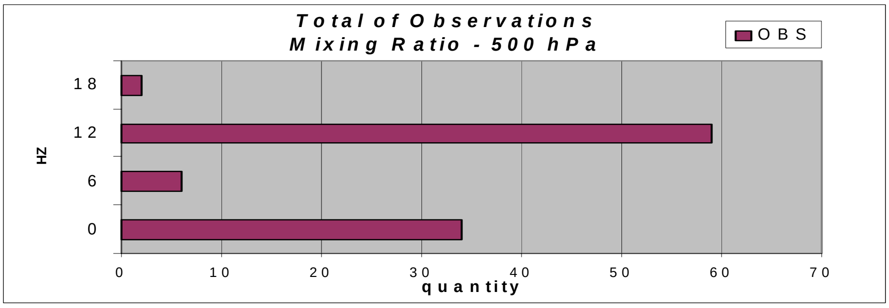
dias


Total of Observations
Mixing Ratio - 500 hPa
OBS
HZ
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12
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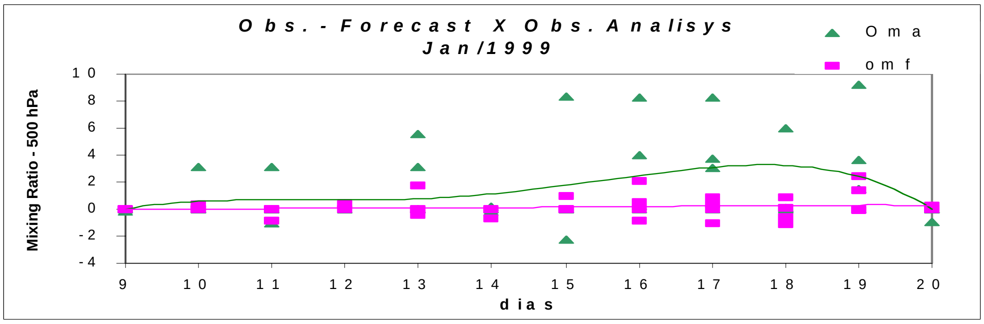
quantity


Obs. - Forecast X Obs. Analisys
Jan/1999
Oma
omf
Mixing Ratio - 500 hPa
10
8
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-2
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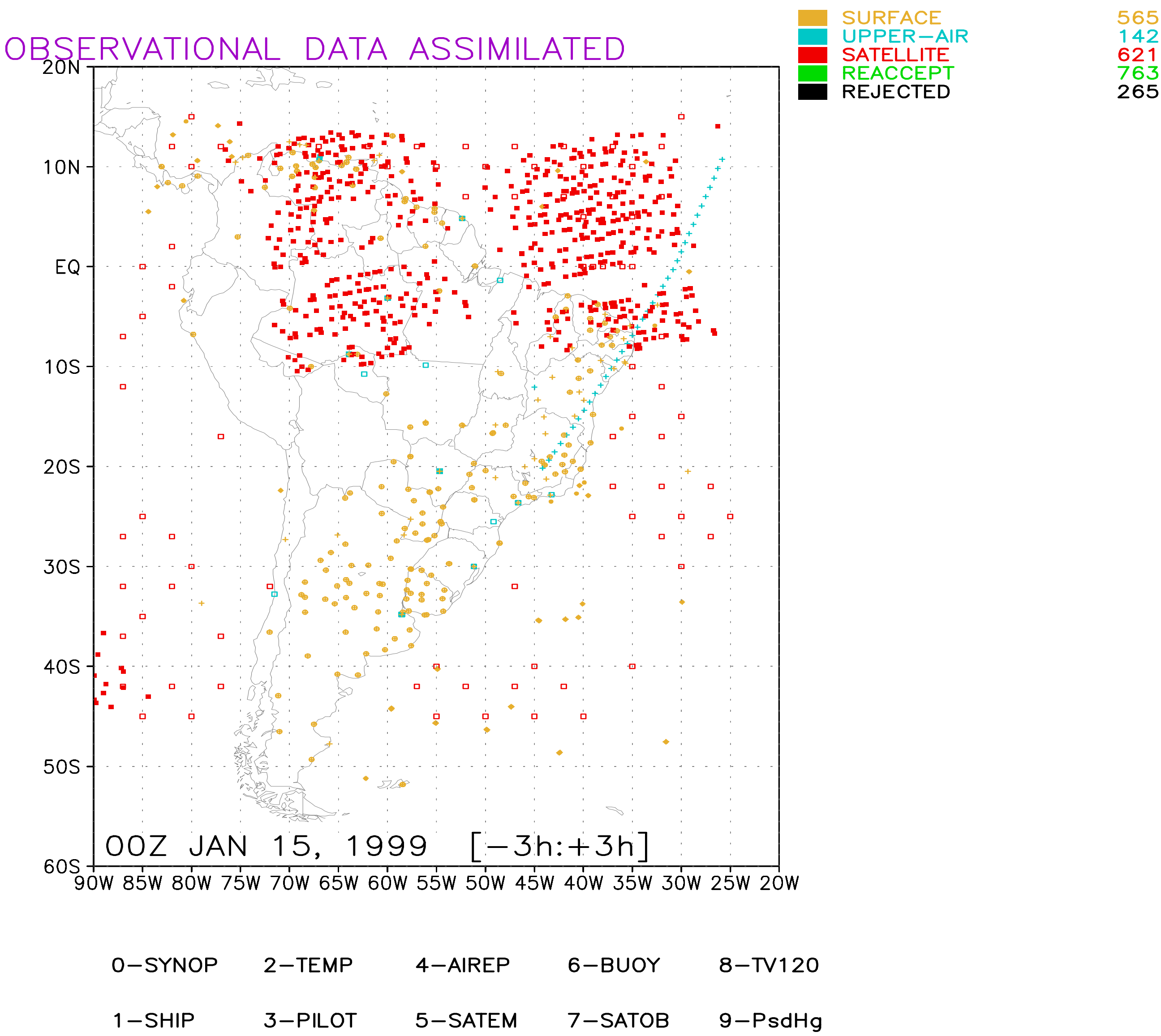
dias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UPPER-AIR 142
SATELLITE 621
REACCEPT 763
REJECTED 265
20N
10N
EQ
10S
20S
30S
40S
50S
60S
90W 85W 80W 75W 70W 65W 60W 55W 50W 45W 40W 35W 30W 25W 20W
00Z JAN 15, 1999 [-3h:+3h]
0-SYNOP
2-TEMP
4-AIREP
6-BUOY
8-TV120
1-SHIP
3-PILOT
5-SATEM
7-SATOB
9-PsdHg

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