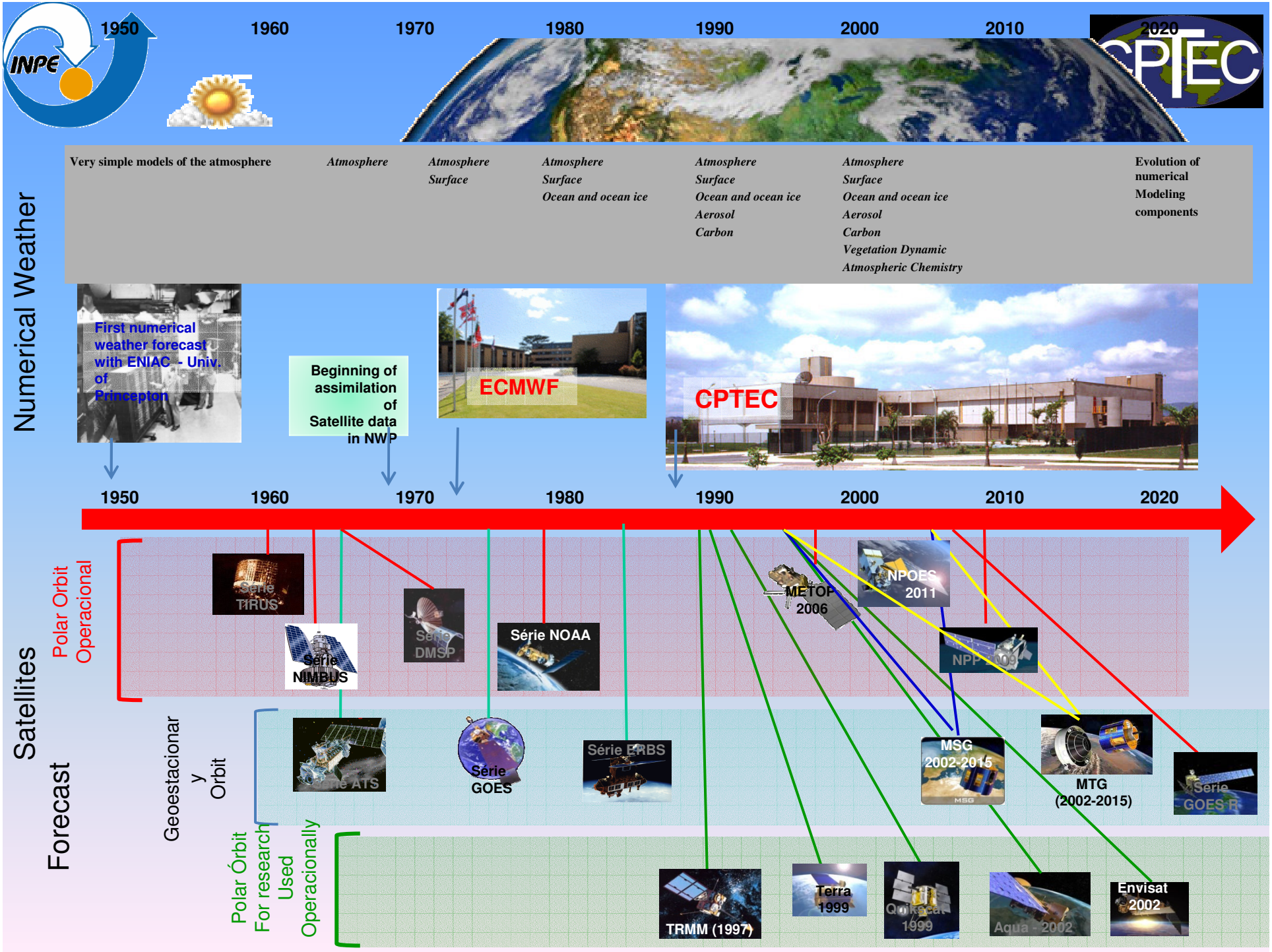
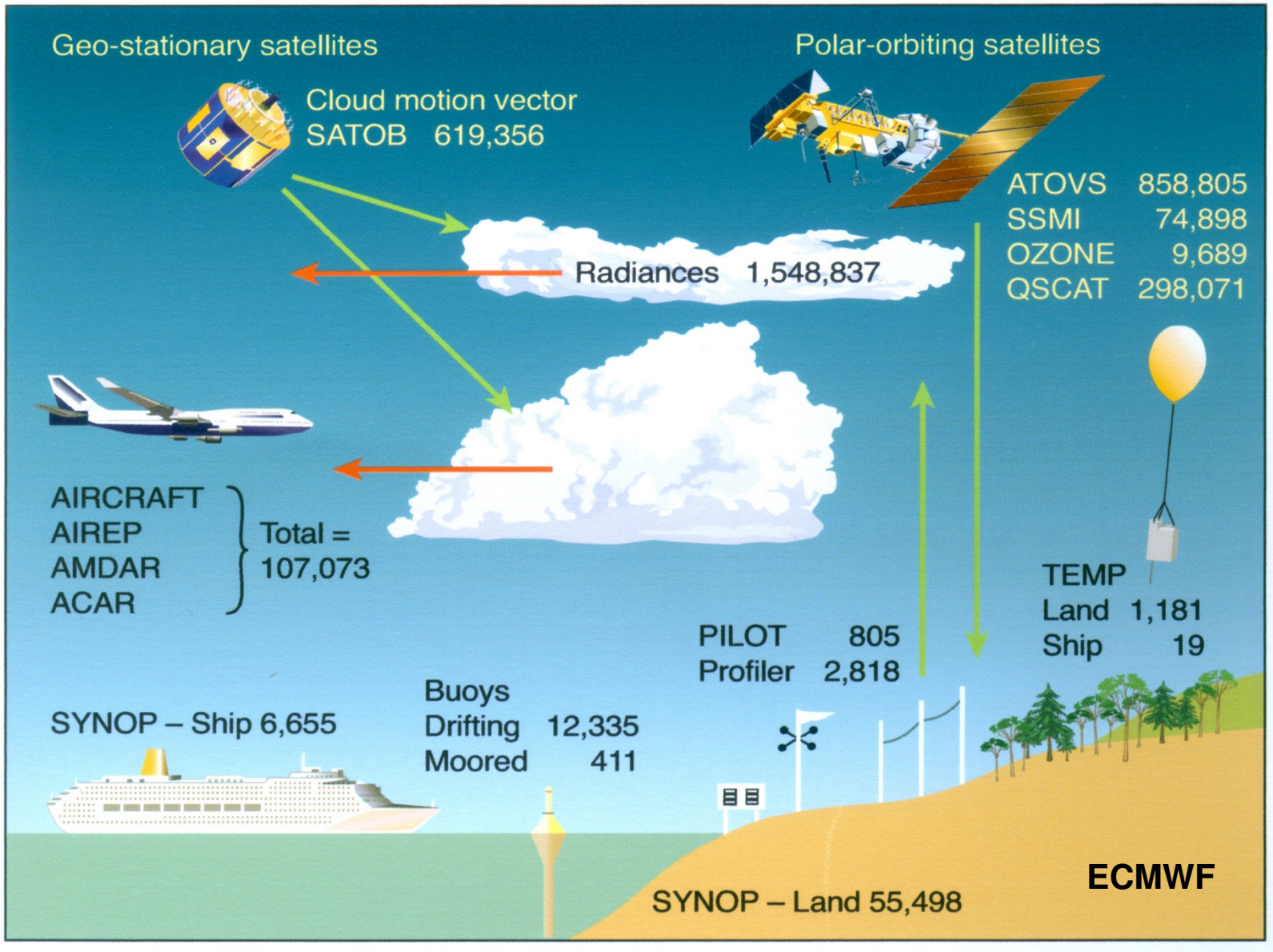
Data Assimilation: Observing System

Dirceu Luís Herdies
CPTEC/INPE

Intensive Course on Data Assimilation
Buenos Aires - 03/11/2008


1950
1960
1970
1980
1990
2000
2010
2020
INPE
CPTEC
Numerical Weather
Very simple models of the atmosphere
Atmosphere
Atmosphere
Surface
Atmosphere
Surface
Ocean and ocean ice
Atmosphere
Surface
Ocean and ocean ice
Aerosol
Carbon
Atmosphere
Surface
Ocean and ocean ice
Aerosol
Carbon
Vegetation Dynamic
Atmospheric Chemistry
Evolution of numerical Modeling components
First numerical weather forecast with ENIAC - Univ. of Princepton
Beginning of assimilation of Satellite data in NWP
ECMWF
CPTEC
Satellites
Forecast
Polar Orbit
Operacional
Série TIROS
Série NIMBUS
Série DMSP
Série NOAA
METOP 2006
NPOESS 2011
NPP 2009
Geoestacionary Orbit
Série ATS
Série GOES
Série ERBS
MSG 2002-2015
MTG (2002-2015)
Série GOES R
Polar Órbit
For research
Used
Operacionally
TRMM (1997)
Terra 1999
Quikscat 1999
Aqua - 2002
Envisat 2002



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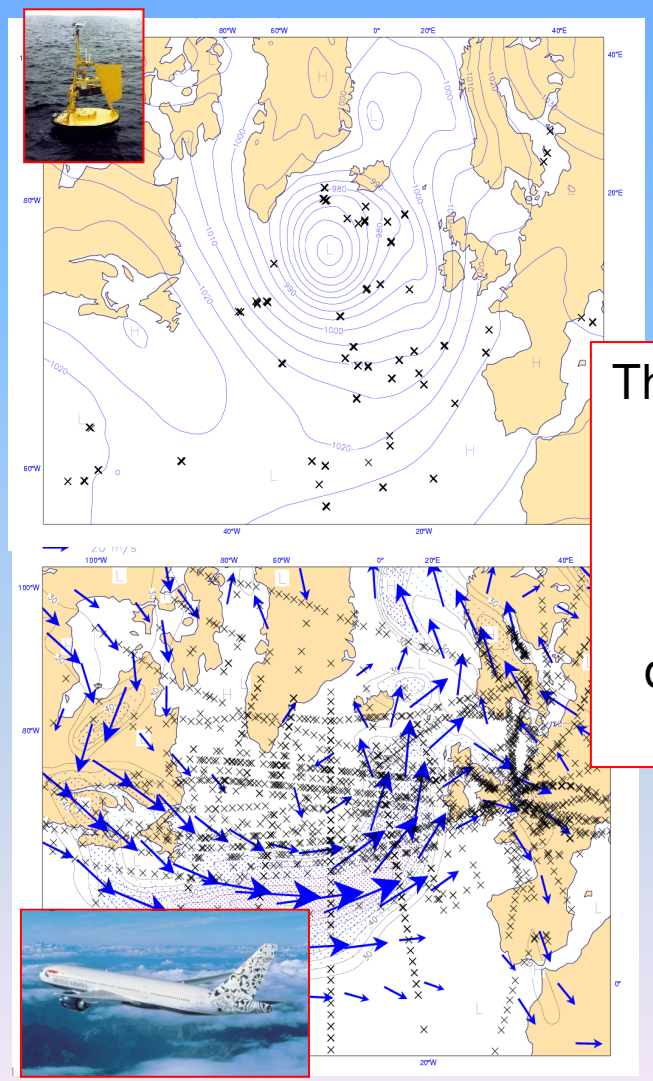
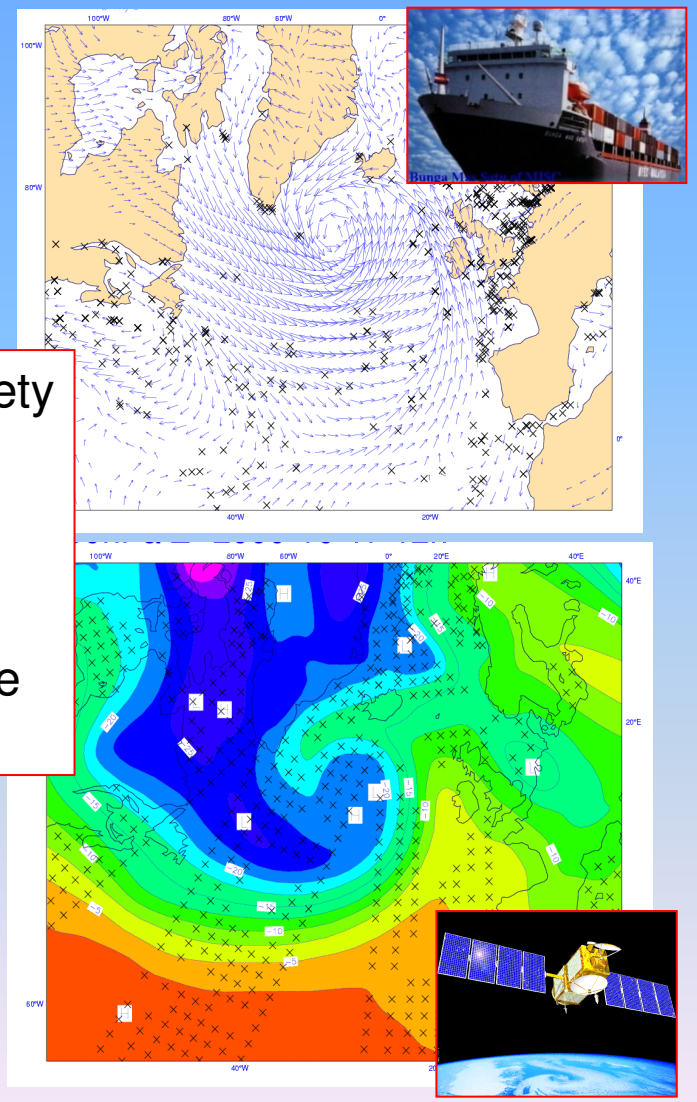
Observational data



There is a wide variety of observations, with different characteristics, irregularly distributed in space and time.



ECMWF-2008

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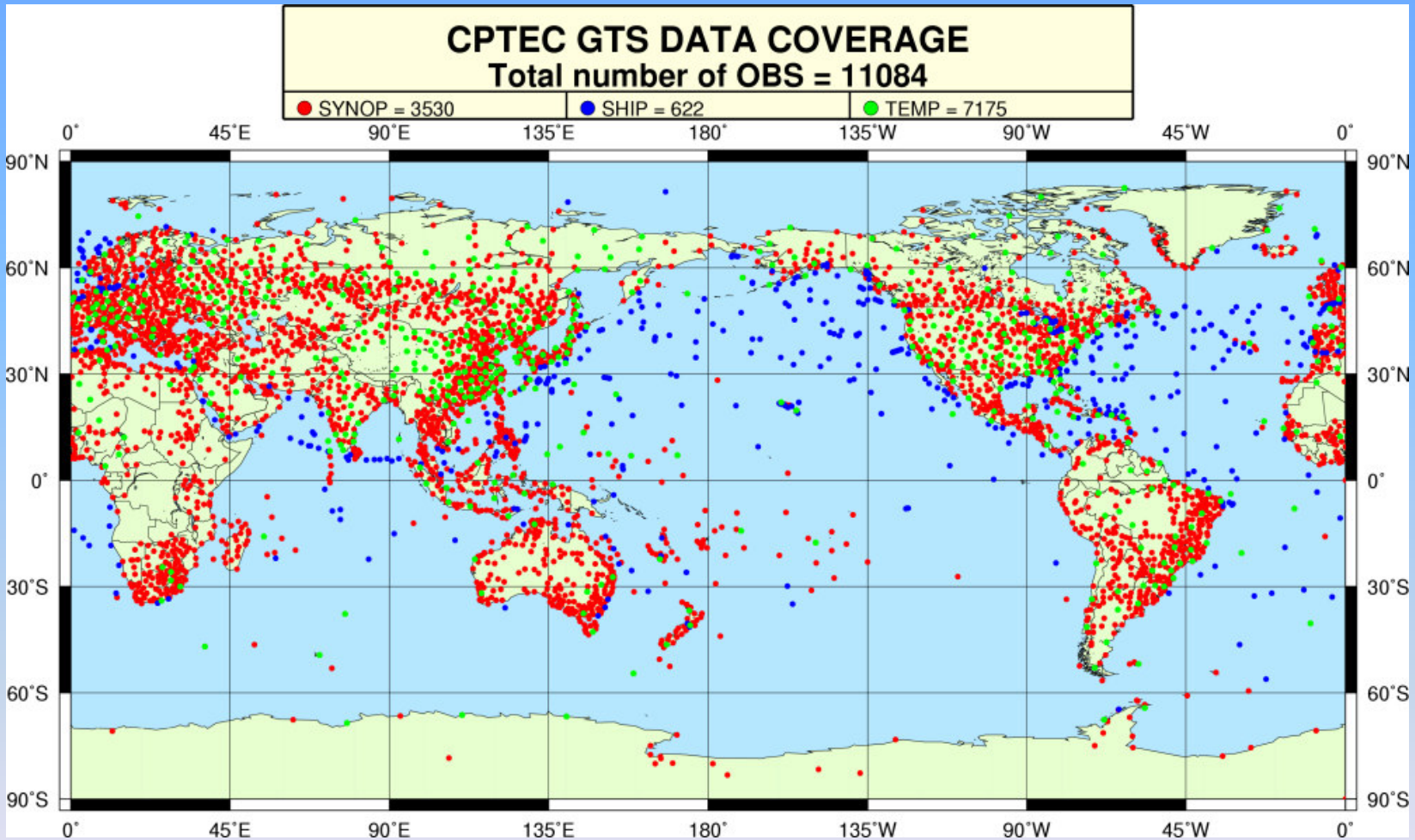
Conventional data at CPTEC/INPE



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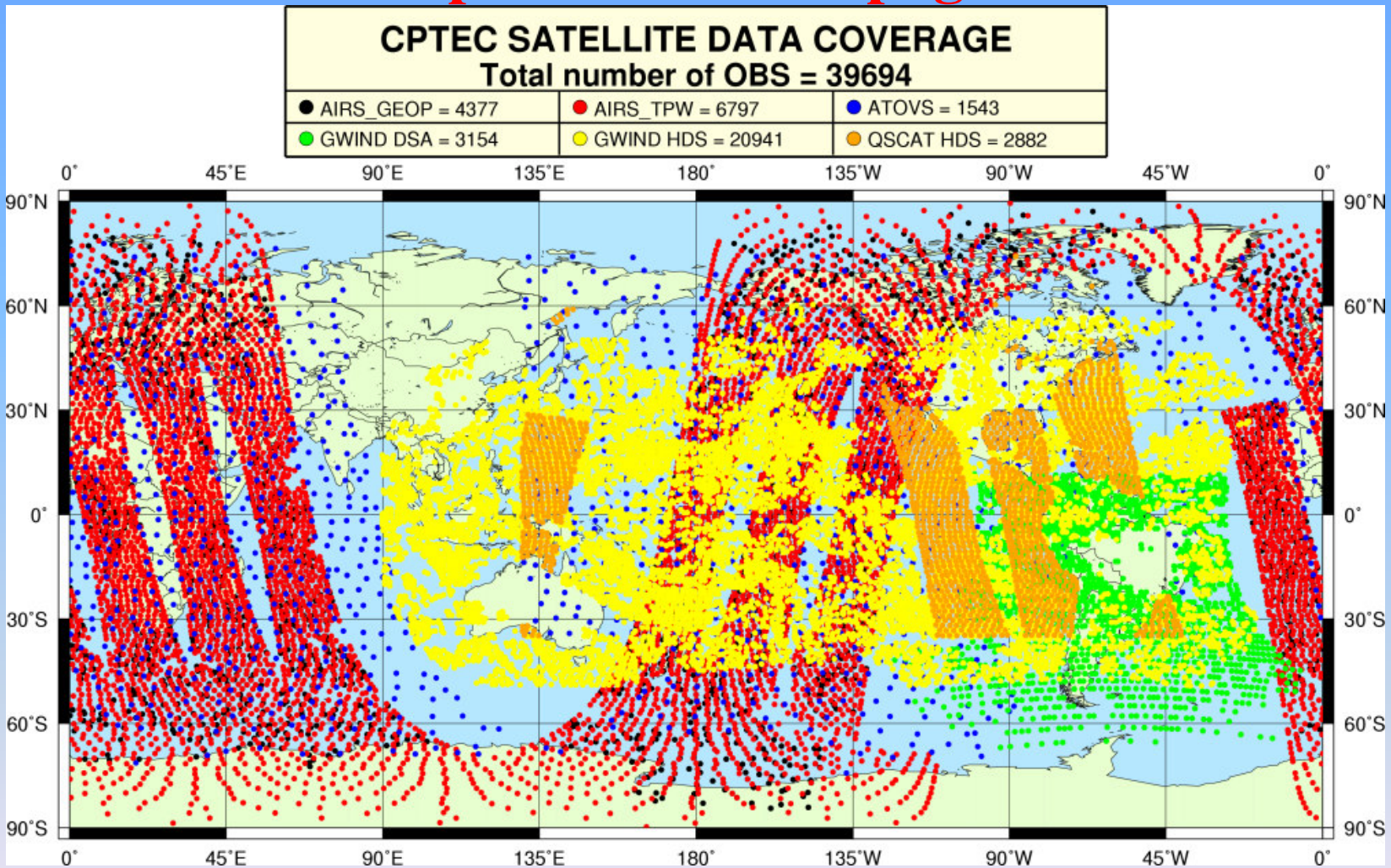
Operational Webpage



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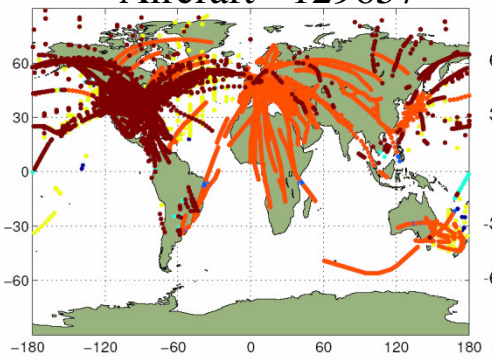
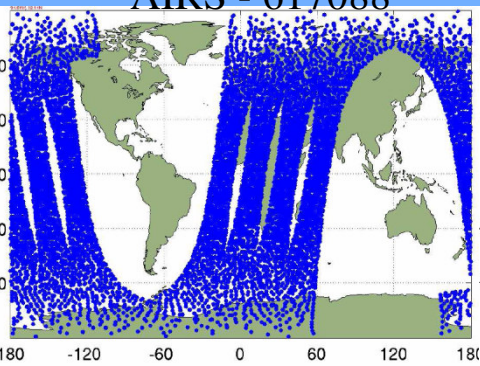
GMAO/NASA
Main Observing Systems Used in the GEOS-5 Analysis on 00 UTC 11 Nov 2007

Total Observation Types
Processed: 4,061,237
Assimilated: 1,669,057

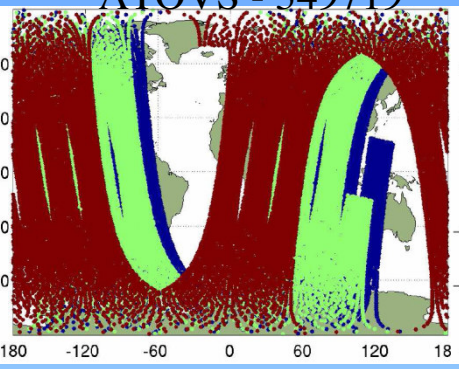
Aircraft - 129657



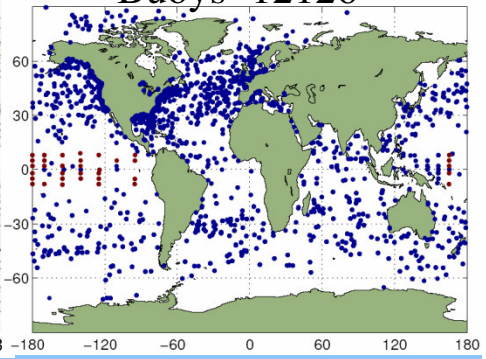
AIRS - 617088



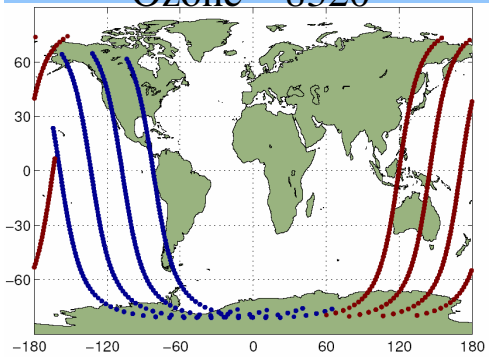
ATOVS - 349719



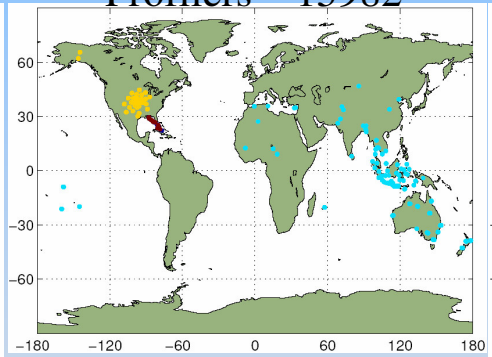
Buoys- 12126



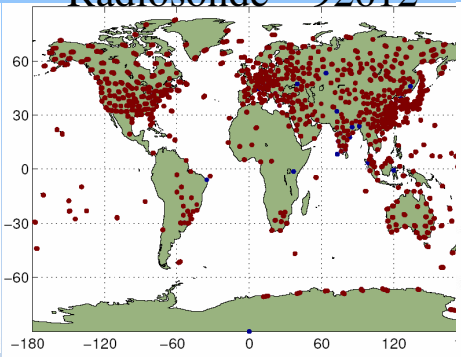
Ozone – 8320



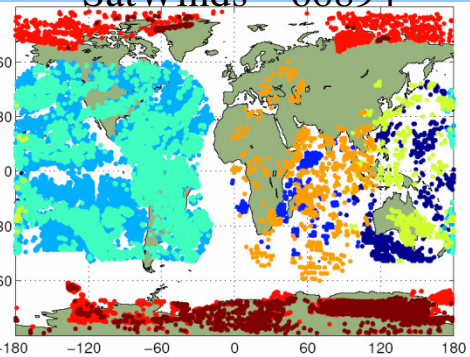
Profilers – 15982



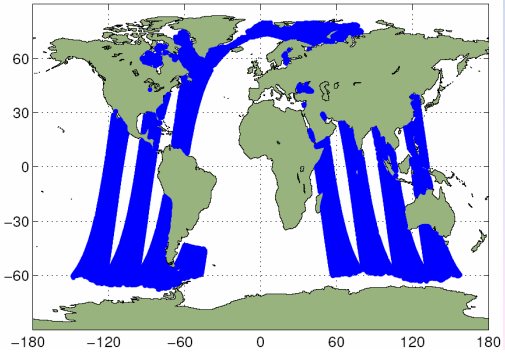
Radiosonde – 92612



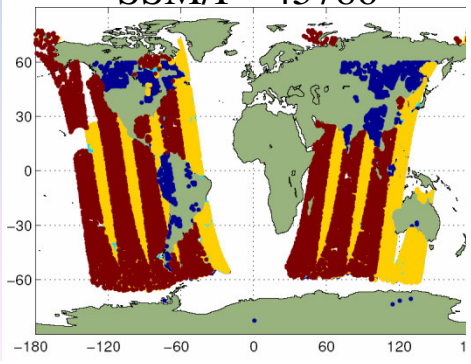
SatWinds – 66894



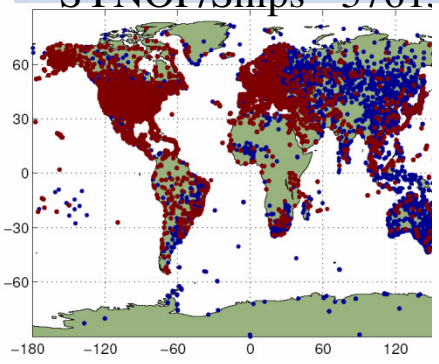
Scatterometer – 72008



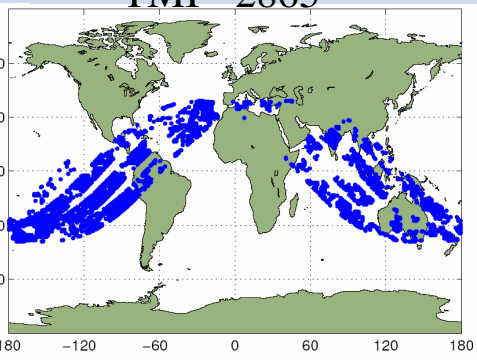
SSM/I – 45786



SYNOP/Ships - 37615



TMI - 2865

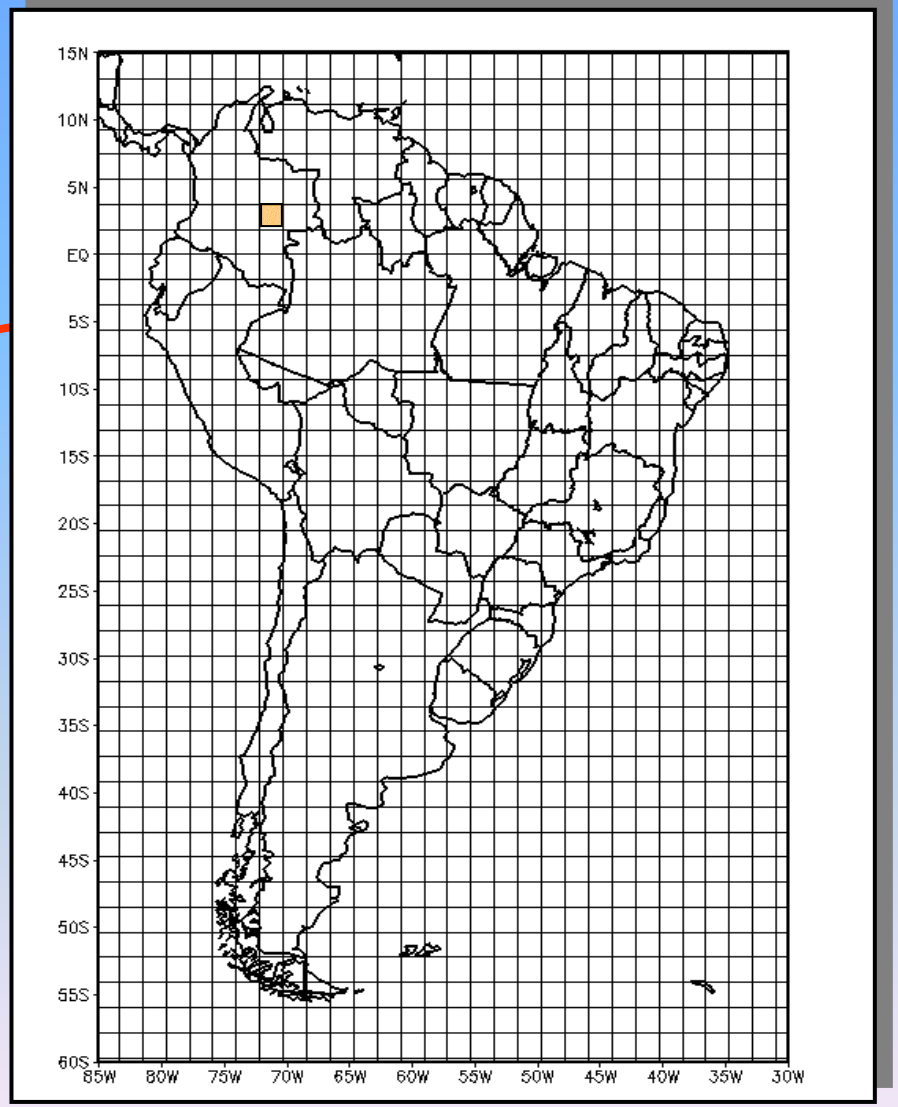


Operational Models at CPTEC

Global Model
AGCM

63 Km

63 Km

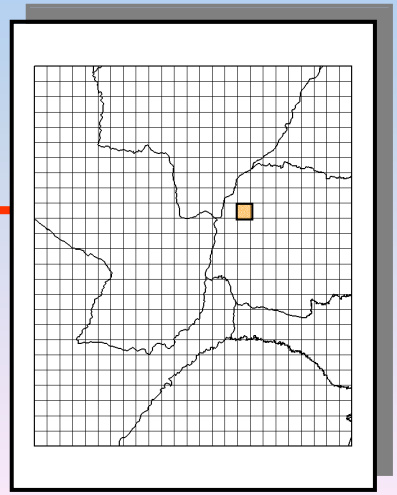


Regional Model

ETA

20 Km

20 Km



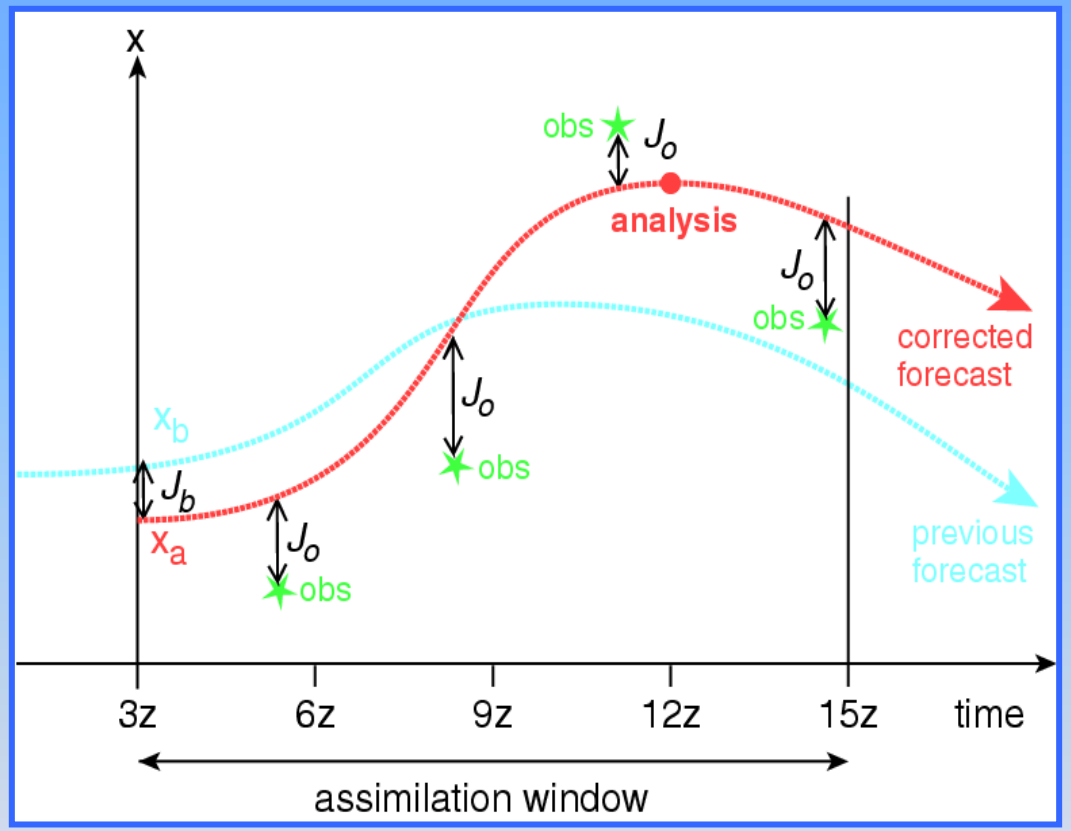
dirceu@cptec.inpe.br

Data Assimilation:
The bridge between modelling and observations

$$x_a = x_b + K\,[y_o - H(x_b)]$$

Observation Operator (H) provides the link between the model variables and the observations

dirceu@cptec.inpe.br



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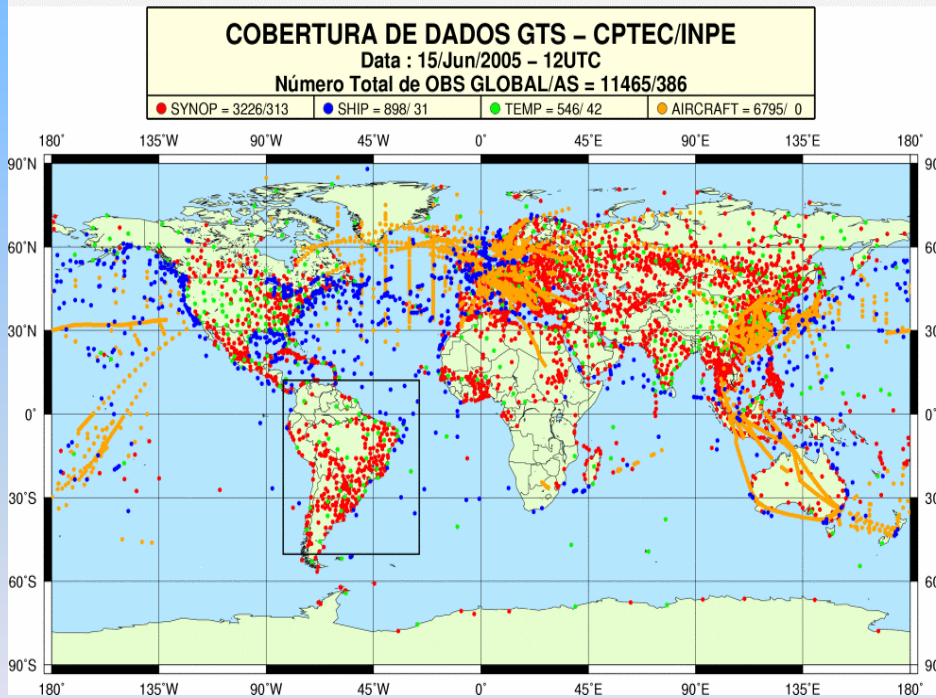
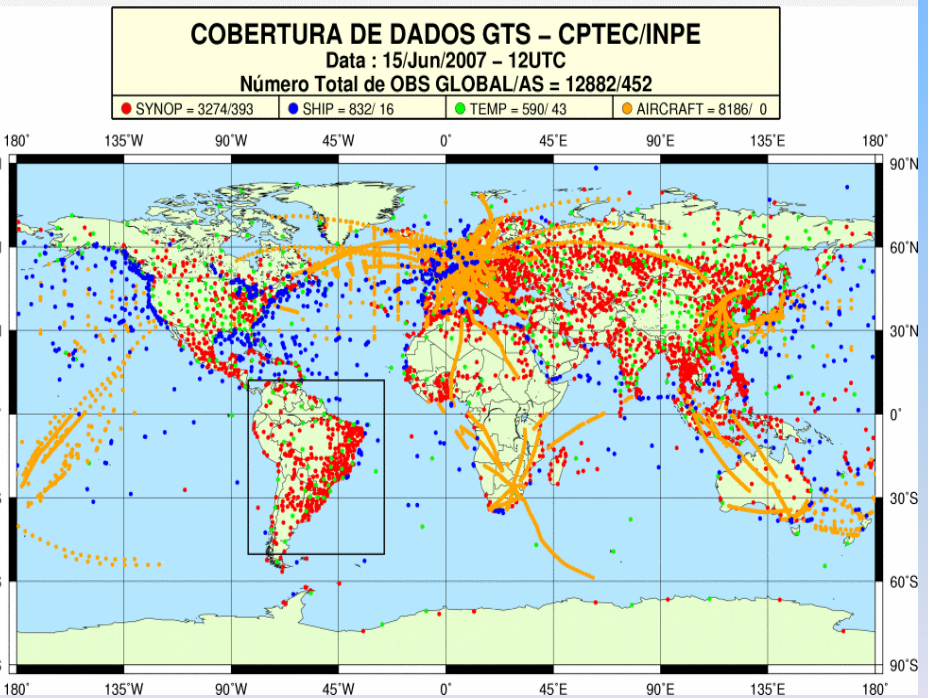
Conventional Data Coverage

15 June 2005 12 UTC



15 June 2007 12 UTC



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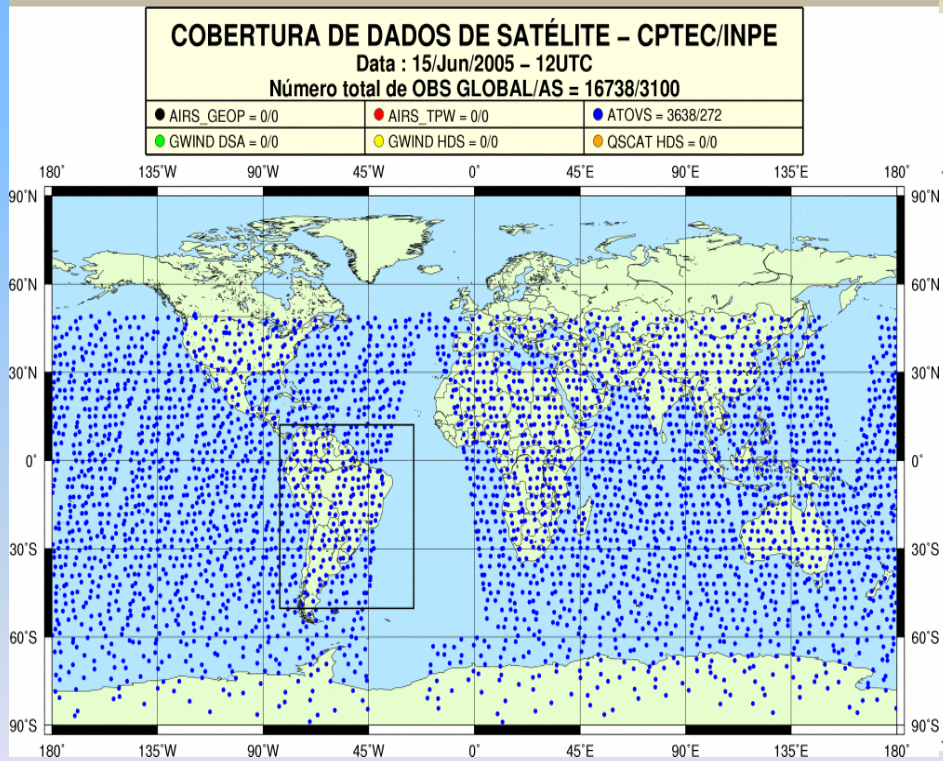
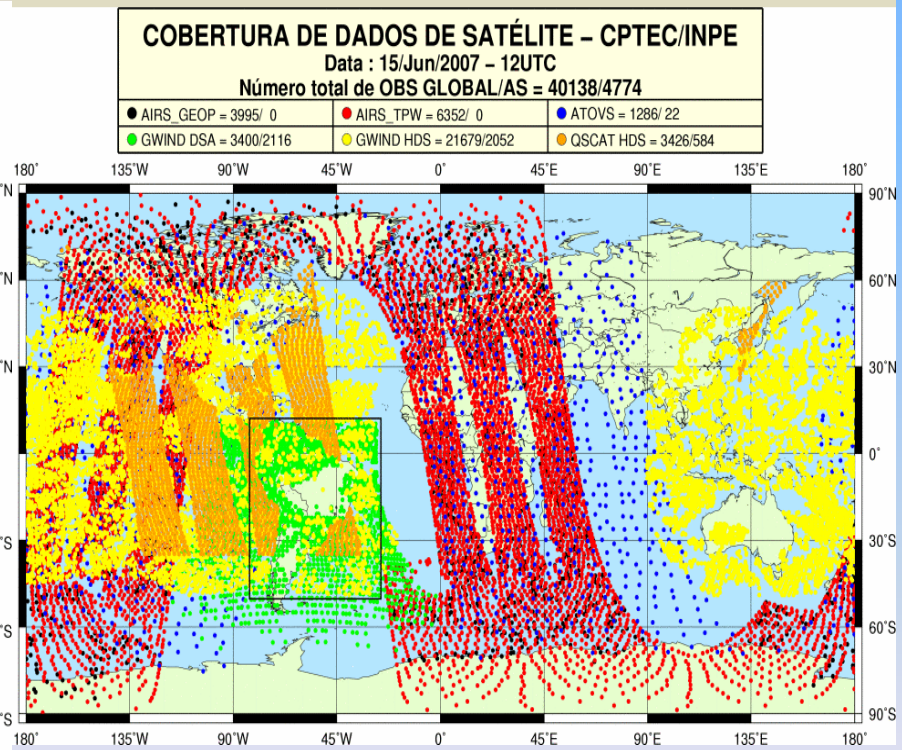
Satellite Data Coverage

15June 2005 12 UTC



15 June 2007 12 UTC



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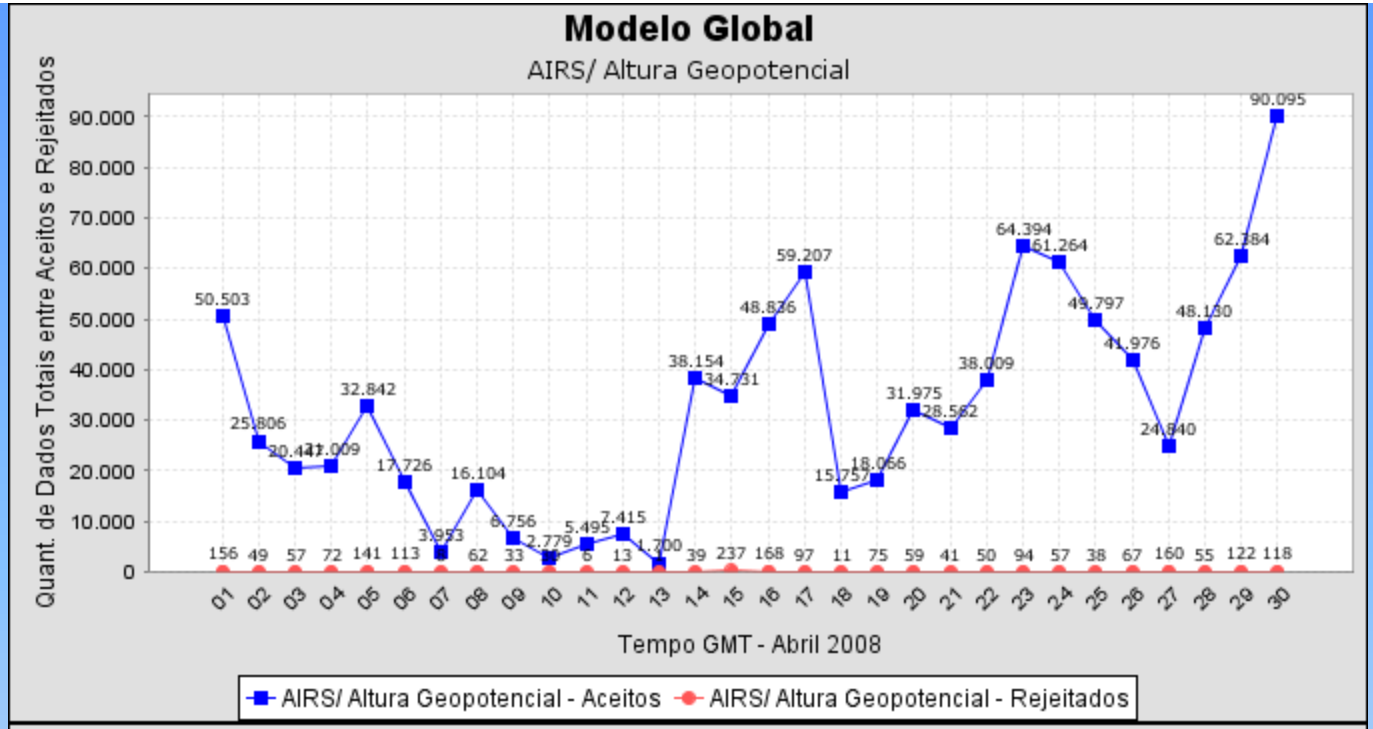
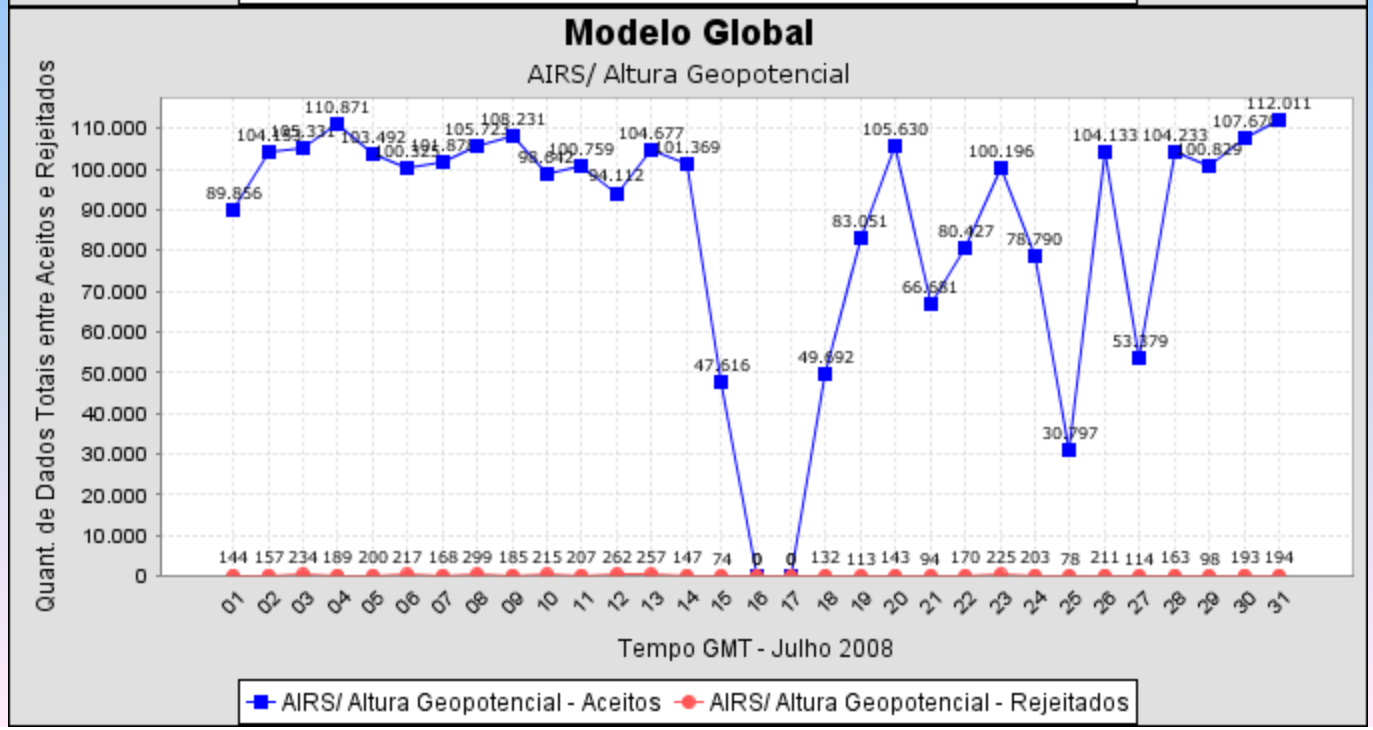
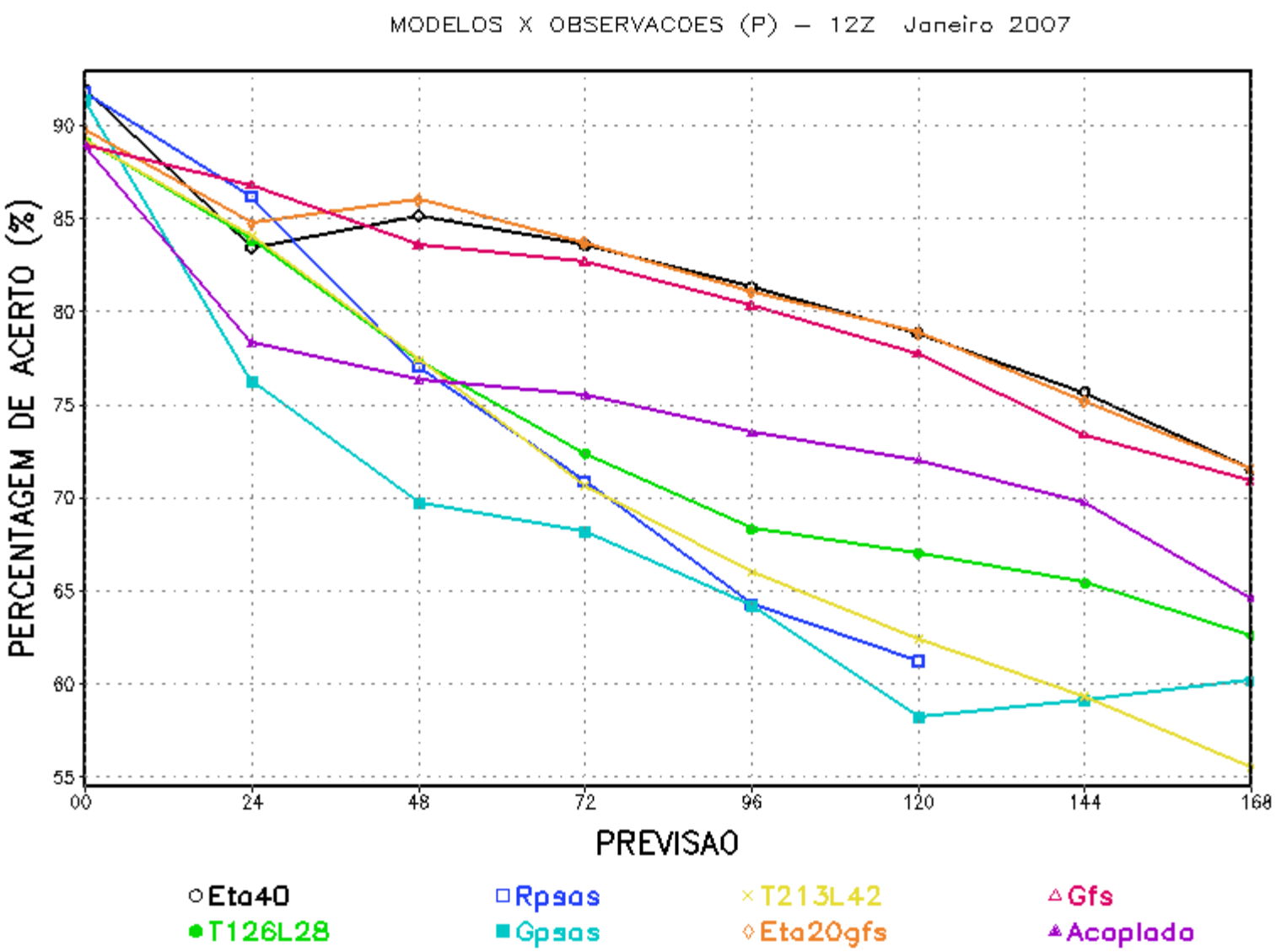

Modelo Global
AIRS/ Altura Geopotencial
Quant. de Dados Totais entre Aceitos e Rejeitados
Tempo GMT - Abril 2008
AIRS/ Altura Geopotencial - Aceitos
AIRS/ Altura Geopotencial - Rejeitados


Modelo Global
AIRS/ Altura Geopotencial
Quant. de Dados Totais entre Aceitos e Rejeitados
Tempo GMT - Julho 2008
AIRS/ Altura Geopotencial - Aceitos
AIRS/ Altura Geopotencial - Rejeitados

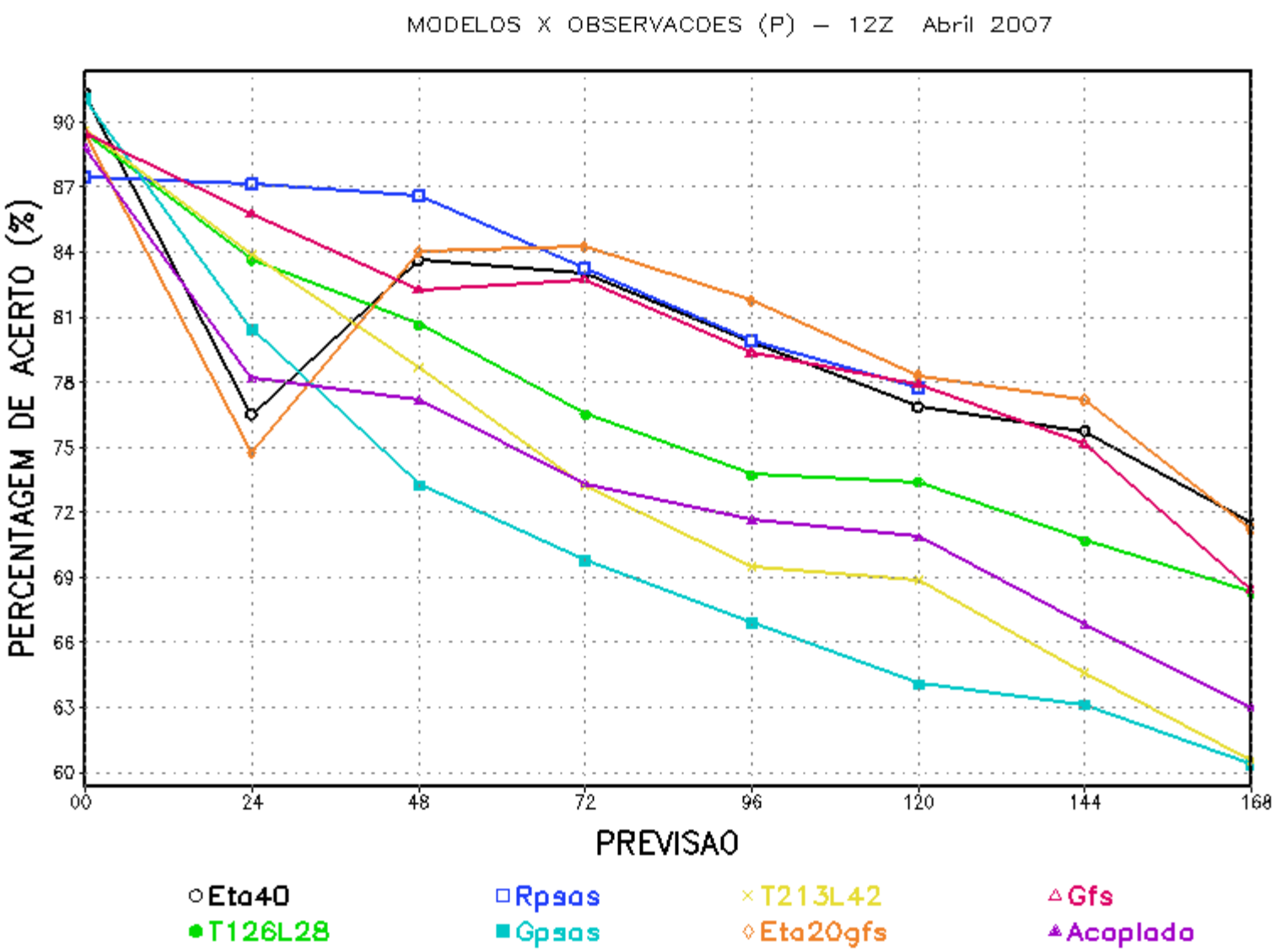
Regional Model

RPSAS – Eta 40 km



Regional Model

RPSAS – Eta 40 km



Data currently used - ECMWF

Conventional

- SYNOP/SHIP/METAR
  - Ps, Wind-10m, RH-2m
- AIREP
  - Wind, Temp
- AMVs (GEO and POLAR)
  - Wind
- DRIBU
  - Ps, Wind-10m
- TEMP/DropSONDE
  - Wind, Temp, Spec Humidity
- PILOT
  - Wind profiles
- Profilers: Amer./Eu./Japan
  - Wind profiles

Satellite

- ATOVS and AIRS
  - HIRS, AIRS and AMSU radiances
- SSM/I
  - Microwave radiances (clear-sky)
  - TCWV in rain and clouds
- Meteosat/MSG/GOES
  - Water Vapour IR-channel
- QuikSCAT and ERS-2
  - Ambiguous winds-10m
- GOME/SBUV
  - Ozone retrievals
- GPS-RO/ COSMIC
  - Bending angle
- SSMIS
- TMI
- AMSR-E
- ASCAT
- IASI

In preparation: ADM-Aeolus, GPS ground-based

Data currently used – CPTEC/INPE

Conventional

- SYNOP/SHIP/METAR
  - Ps
- AIREP
  - Wind, Temp
- AMVs (GEO)
  - Wind
- DRIBU
  - Ps, Wind-10m
- TEMP
  - Wind, Temp, Spec Humidity
- PILOT
  - Wind profiles

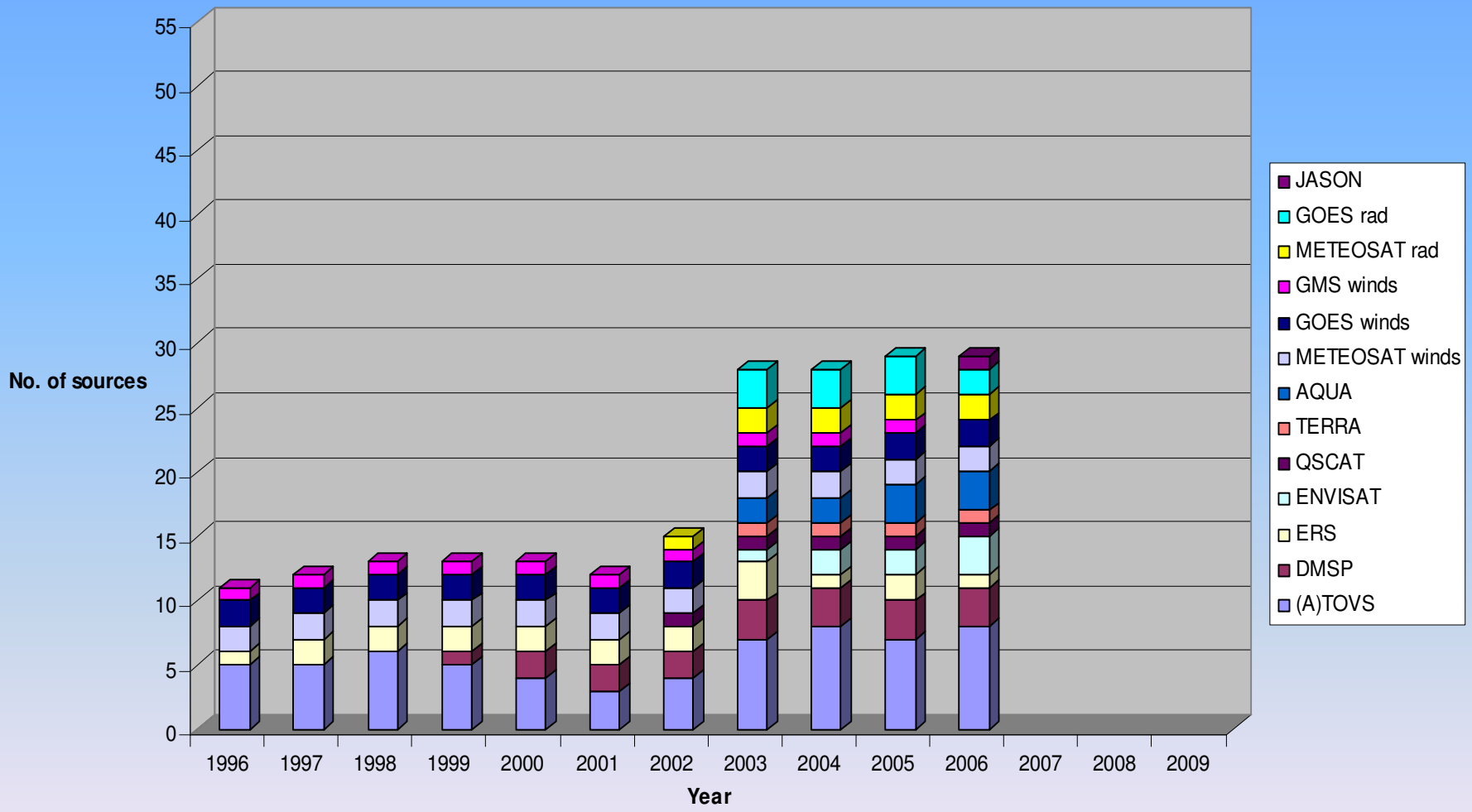
Satellite

- ATOVS and AIRS
  - HIRS, AIRS and AMSU retrievlas
- QuikSCAT and ERS-2
  - Ambiguous winds-10m
- SSMIS
- TMI
- AMSR-E

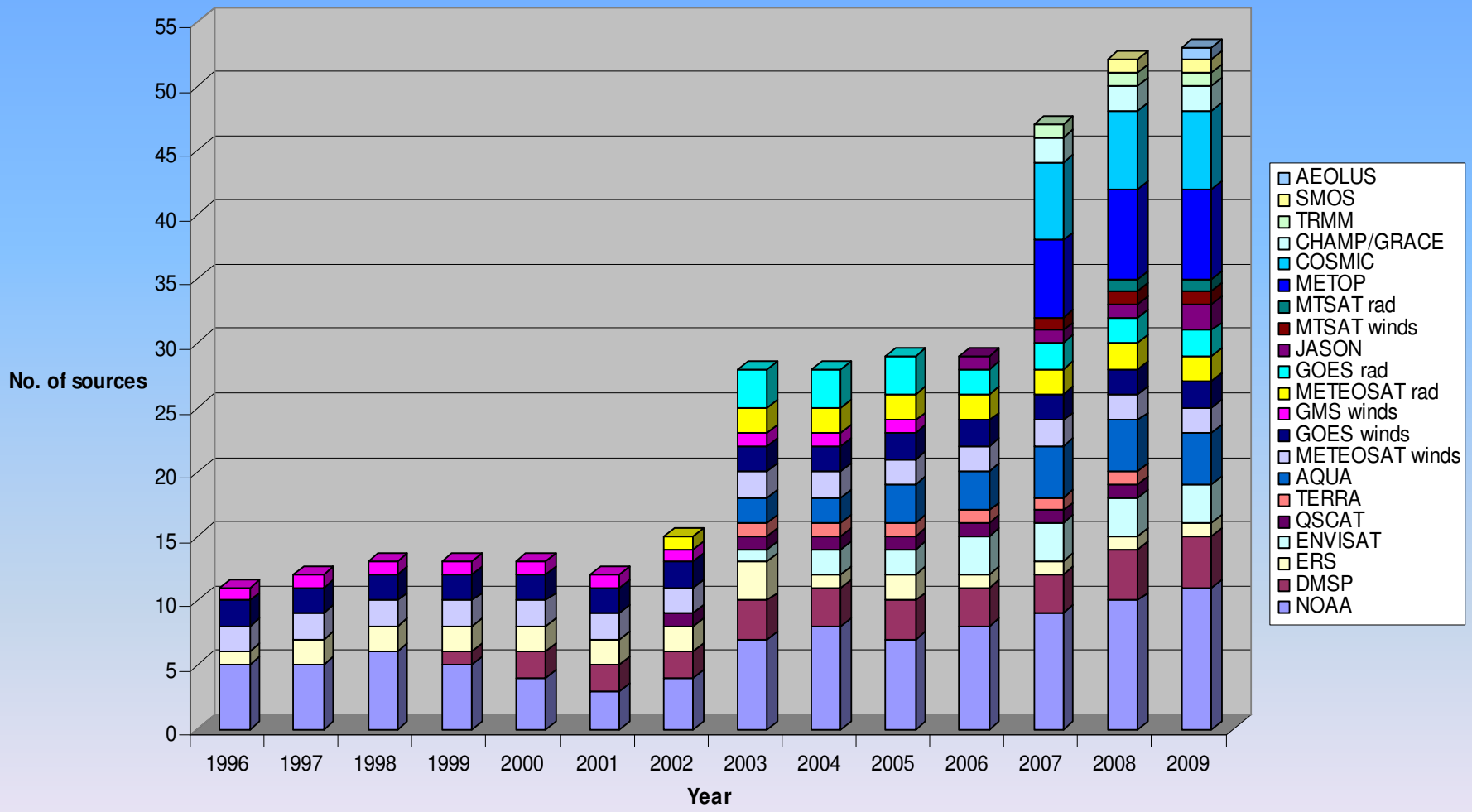
In preparation:

- GPS ground-based
- Meteosat/MSG/GOES - Water Vapour IR-channel
- GPS-RO/ COSMIC
  - Bending angle
- ASCAT
- IASI retrievals
- AIRS radiances (LETKF)

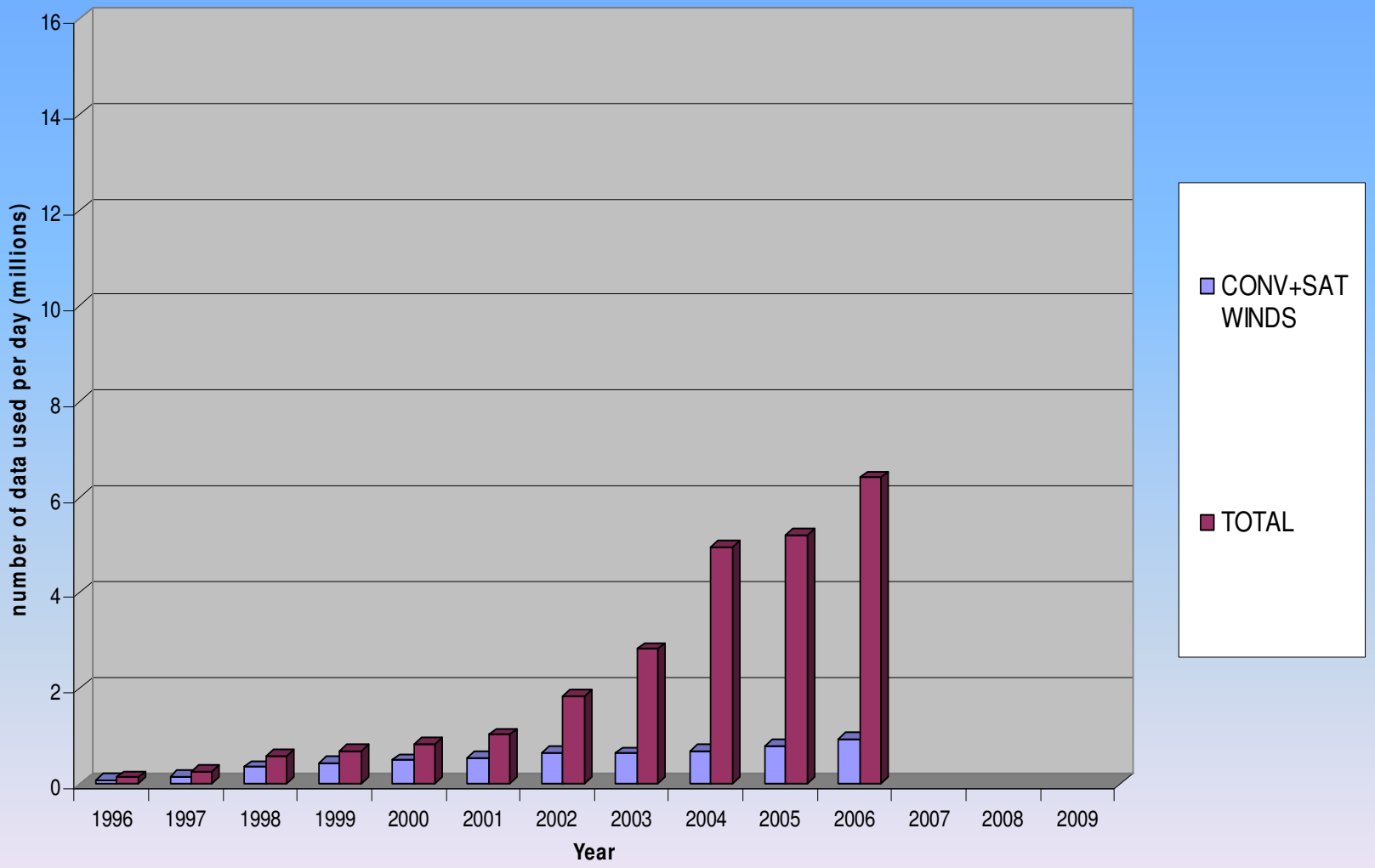
Satellite data sources in 2006



Satellite data sources in 2007+



Satellite data volume in 2006



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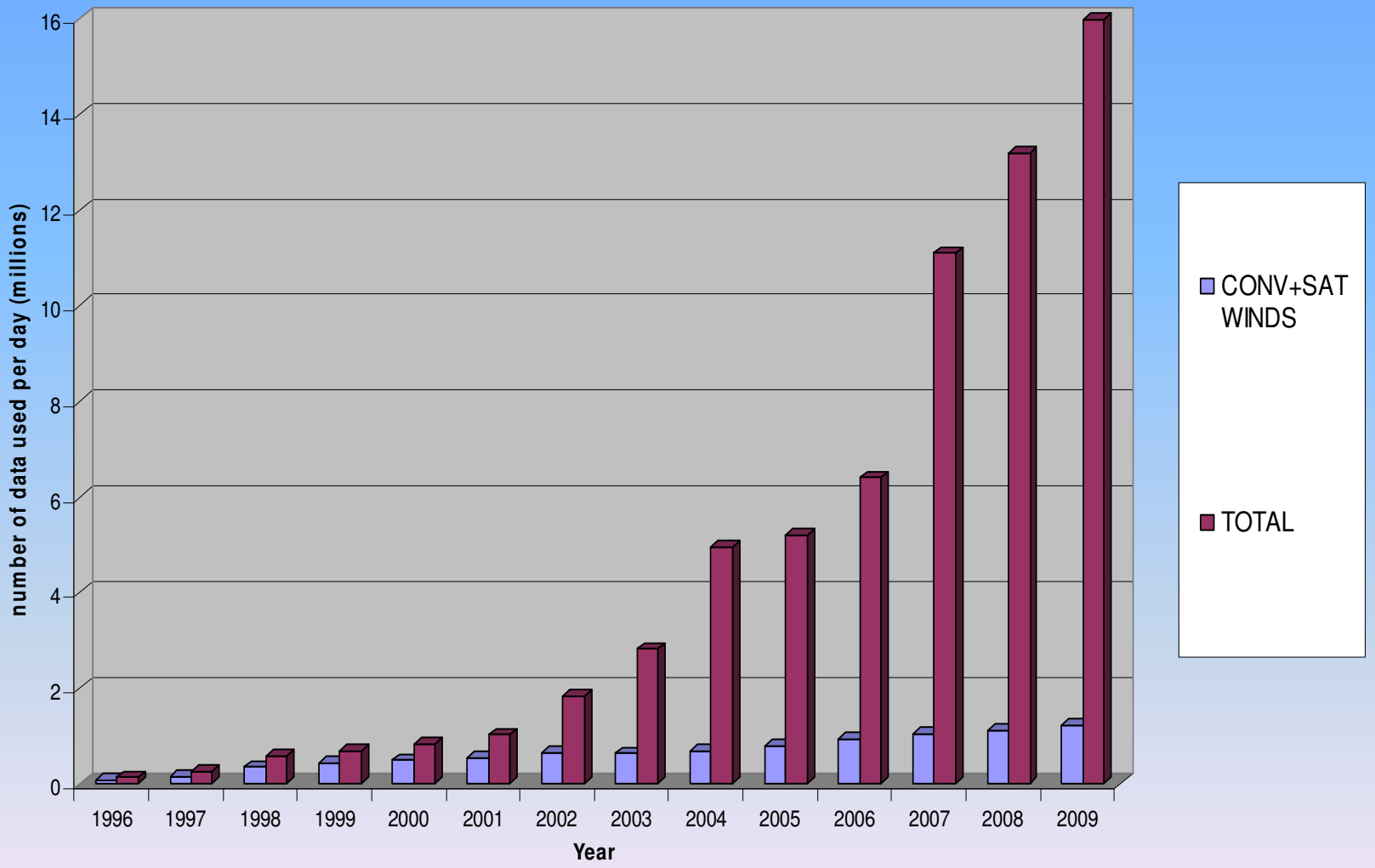
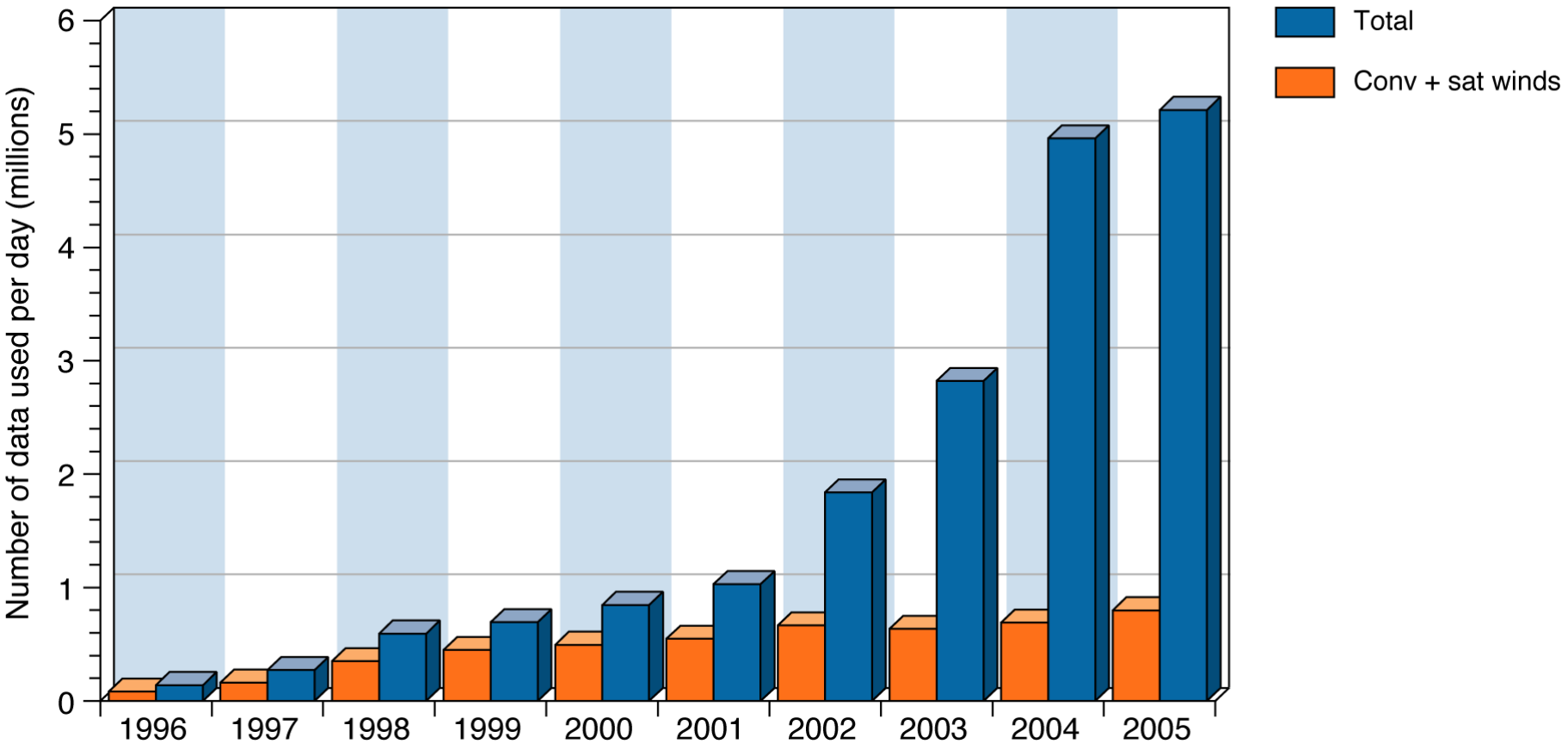
Satellite data volume in 2007+

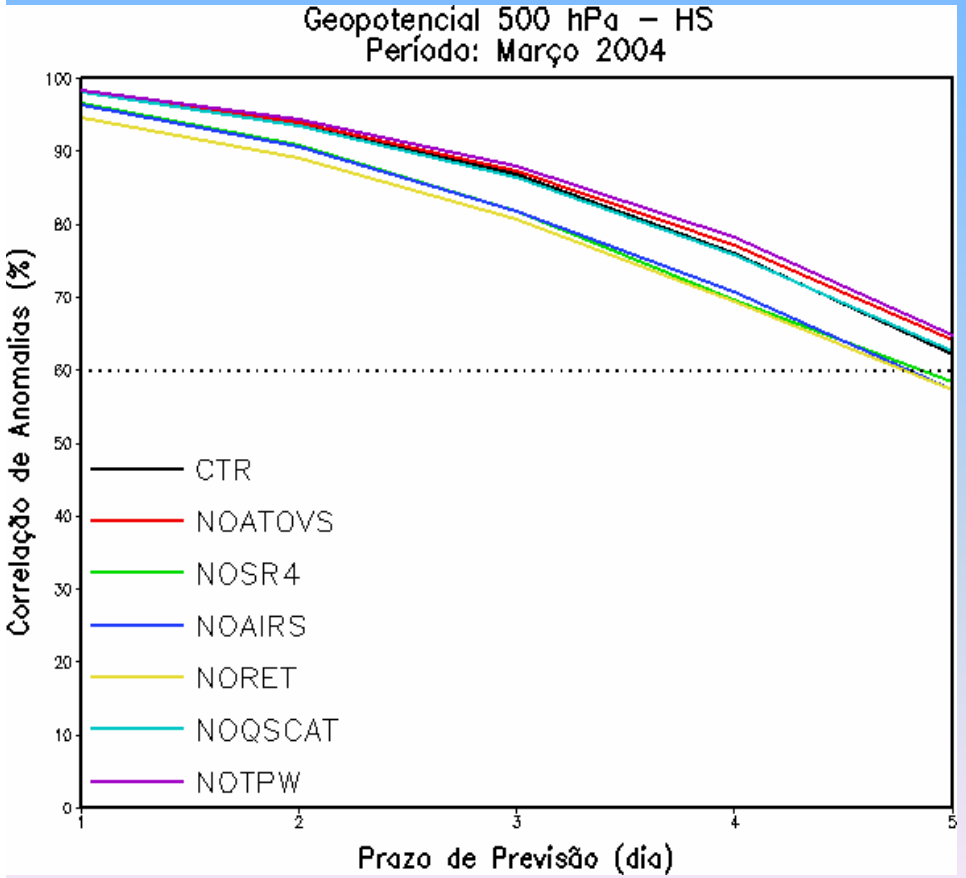


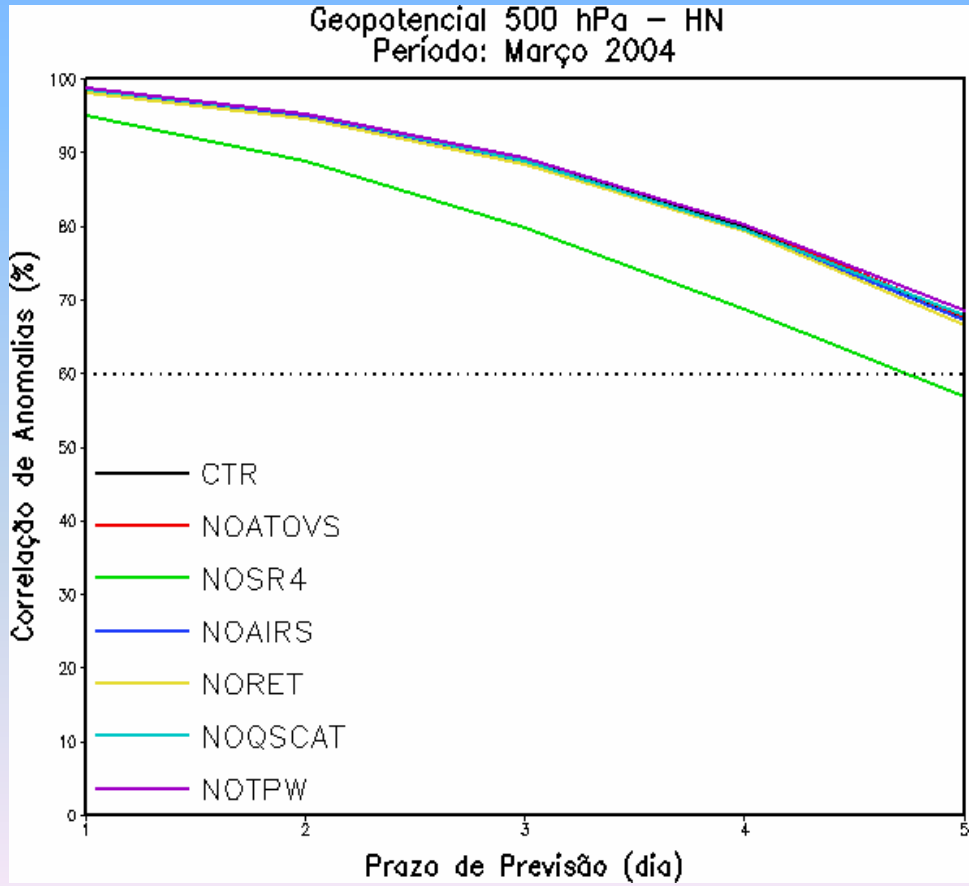
Large increase in number of data assimilated



A scientific and technical challenge

Observing System Experiments
CPTEC Model

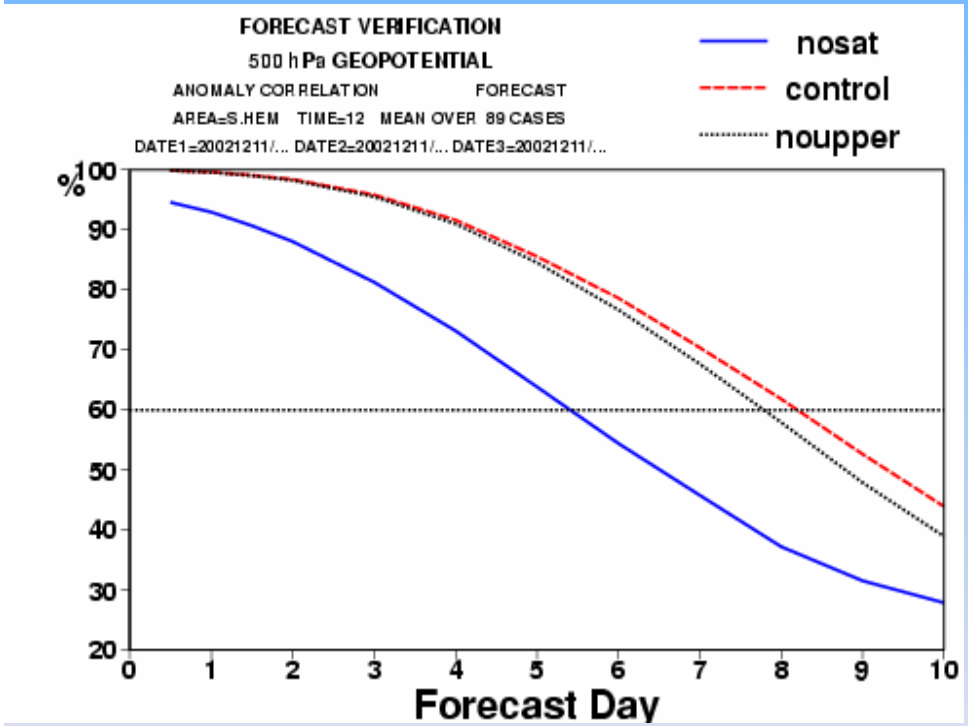




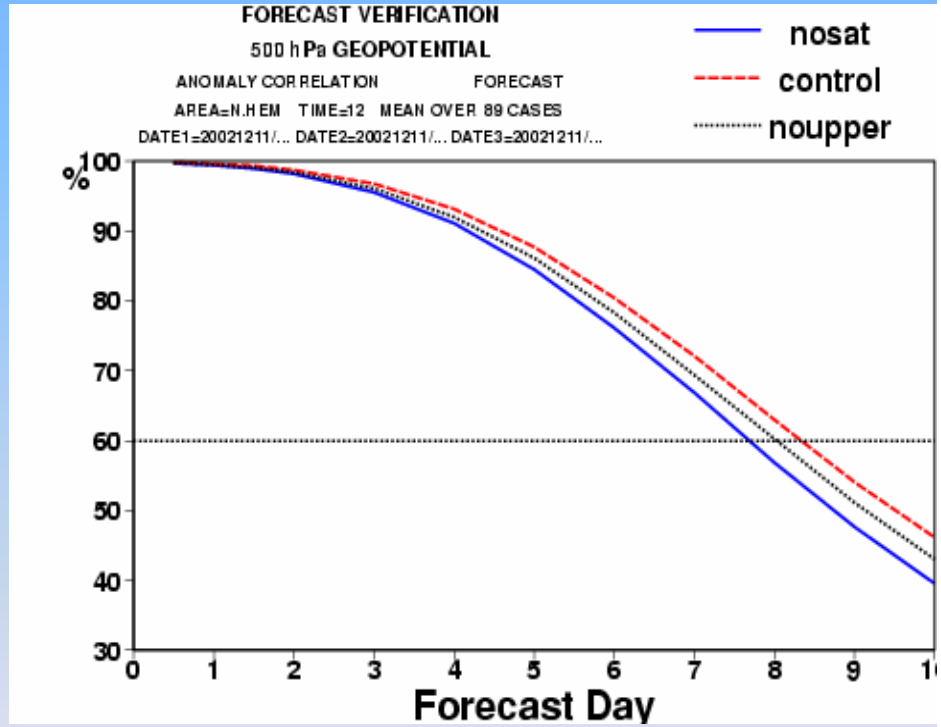
(CPTEC - Andreolli et al. 2007)

Observing System Experiments
ECMWF Model

500 hPa, S.Hem, 89 cases



500 hPa, N.Hem, 89 cases



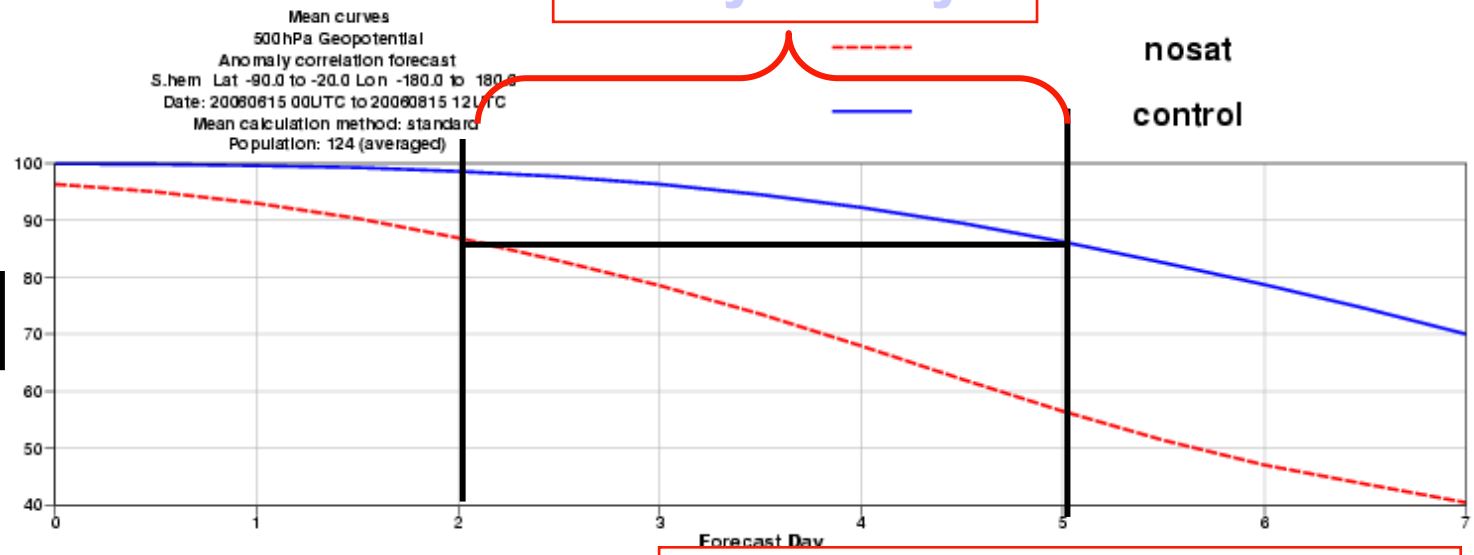
NoSAT= no satellite radiances or winds
Control= like operations
NoUpper=no radiosondes, no pilot winds, no wind profilers

(ECMWF - G. Kelly et al.)

What happens if we lose all satellites?

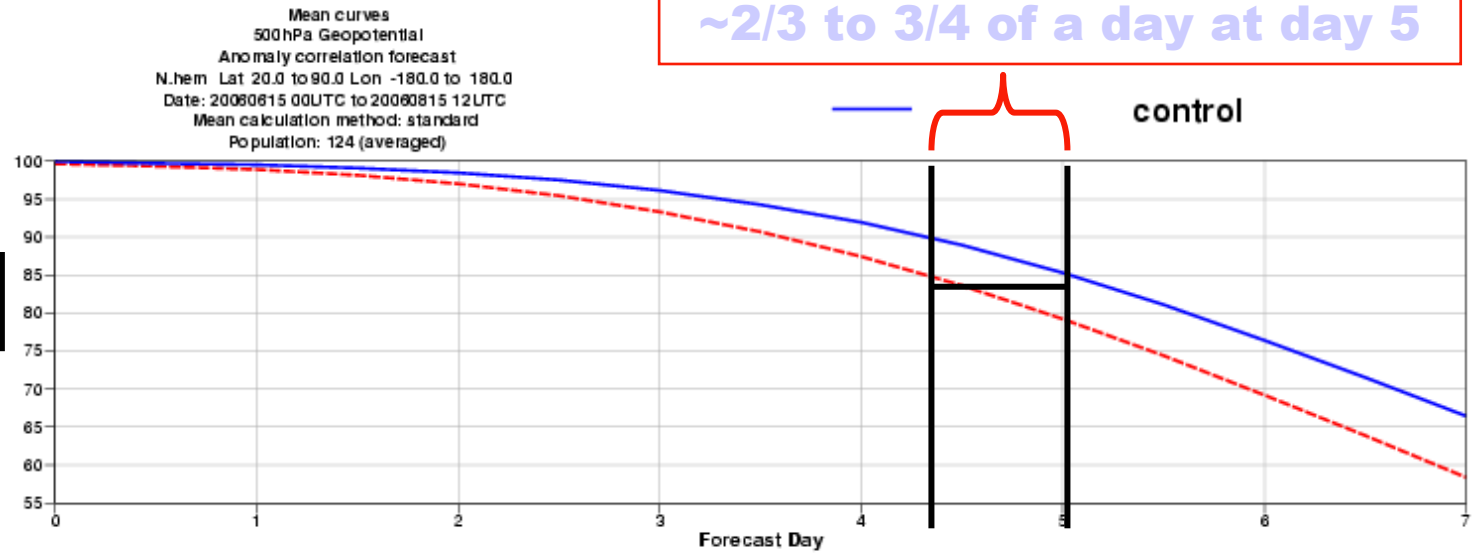
~3 days at day 5

S.H.



~2/3 to 3/4 of a day at day 5

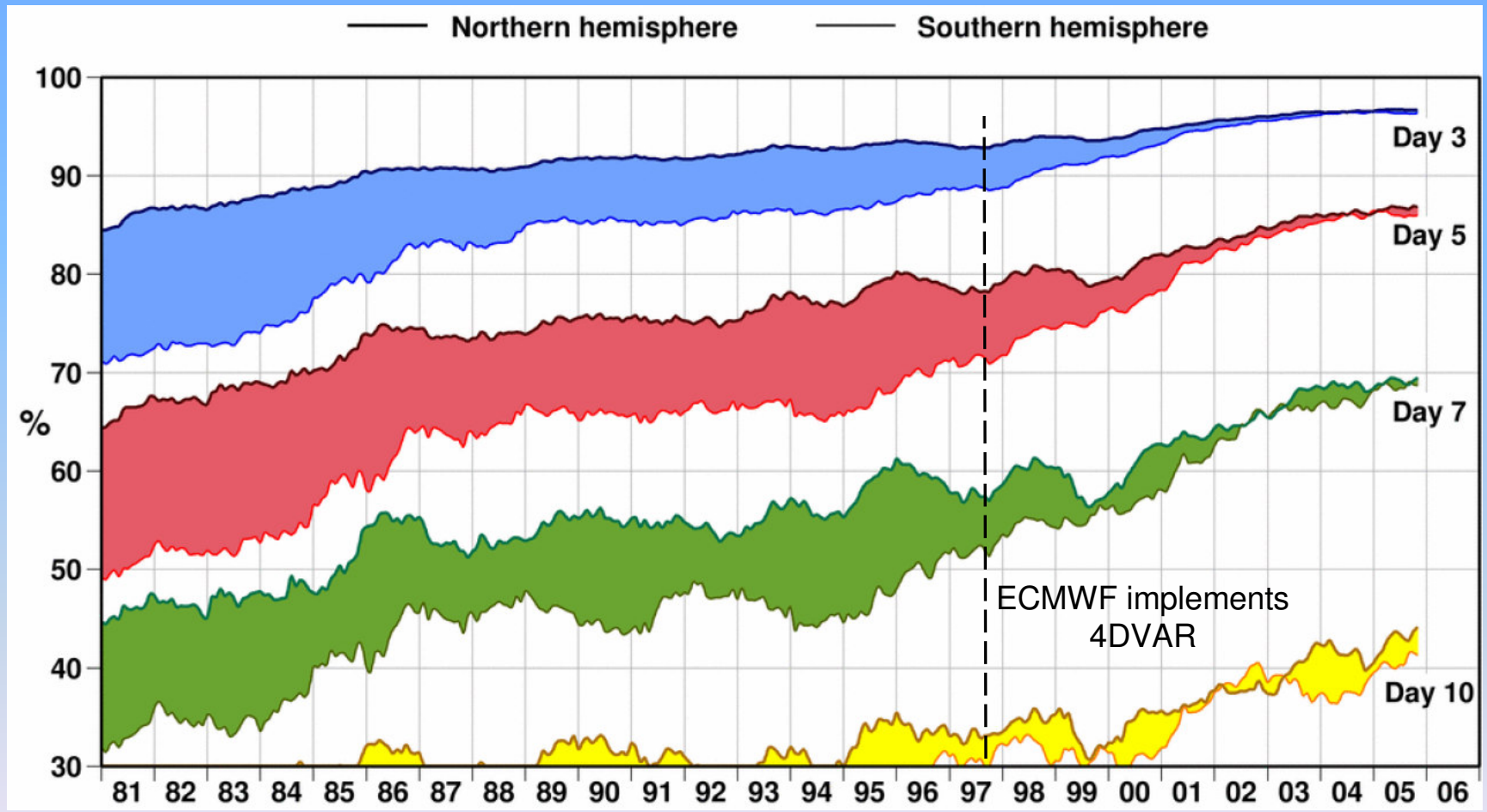
N.H.



Peter Bauer - ECMWF

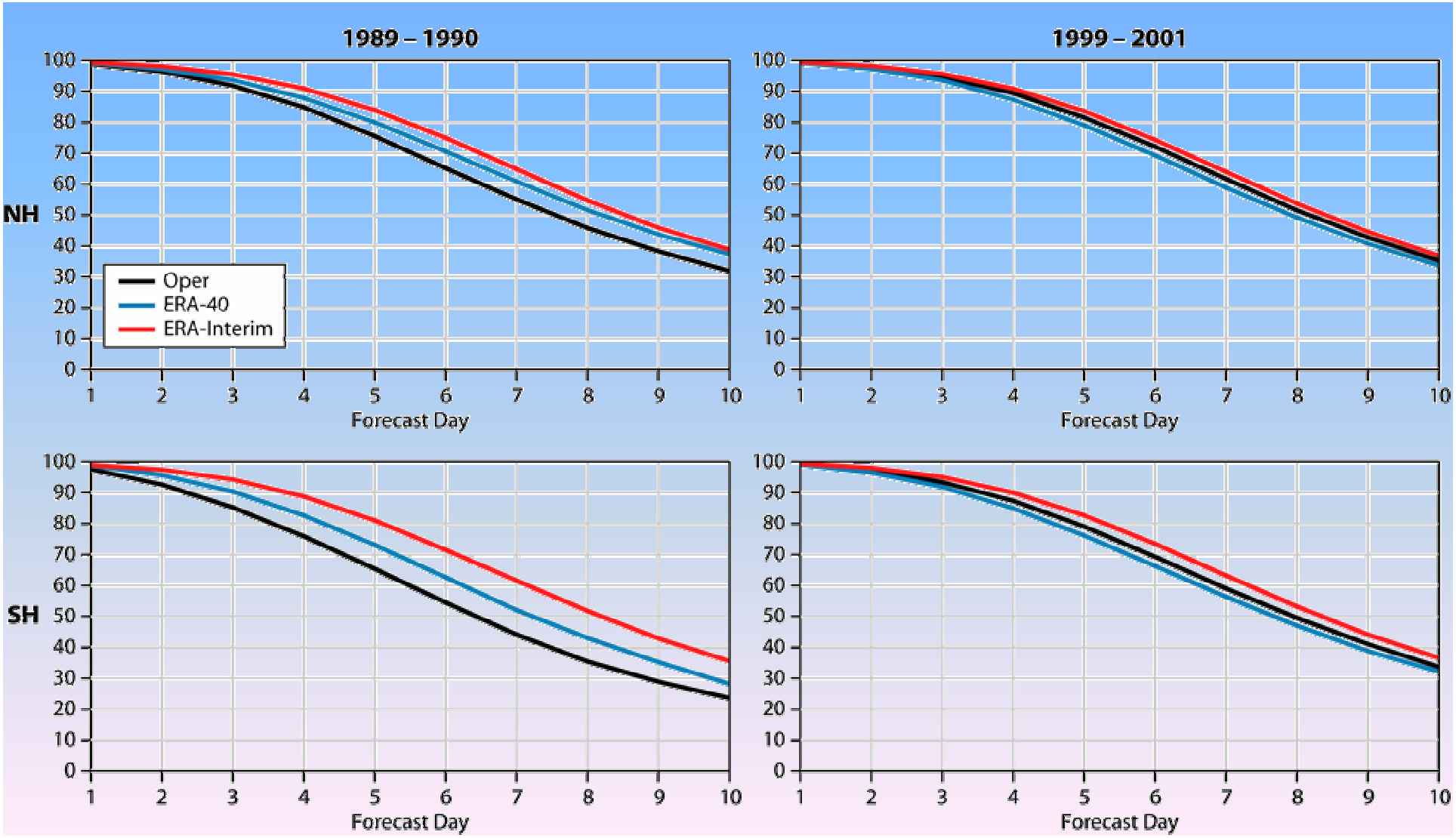
Increasing Skill of Numerical Weather Forecasts

ECMWF Anomaly Correlation of 500mb Height Forecasts



Forecast skill has improved steadily due to increased computing, better models and assimilation ⇒ *increased satellite data usage!*

Forecast performance, ERA-40, ERA-Interim and Operations



Observation data count for one 12h 4D-Var cycle 0900-2100UTC 3 March 2008 - ECMWF

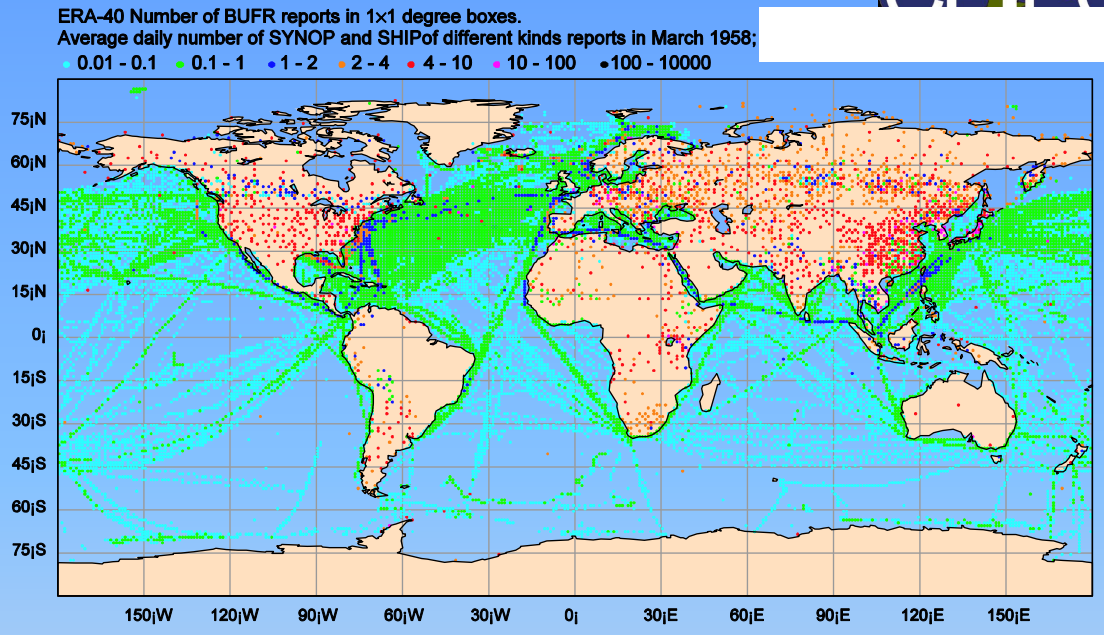
Screened			Assimilated		
Synop:	450,000	0.3%	Synop:	64,000	0.7%
Aircraft:	434,000	0.3%	Aircraft:	215,000	2.4%
Dribu:	24,000	0.02%	Dribu:	7,000	0.1%
Temp:	153,000	0.1%	Temp:	76,000	0.8%
Pilot:	86,000	0.1%	Pilot:	39,000	0.4%
AMV's:	2,535,000	1.6%	AMV's:	125,000	1.4%
Radiance data:	150,663,000	96.9%	Radiance data:	8,207,000	91.0%
Scat:	835,000	0.5%	Scat:	149,000	1.7%
GPS radio occult.	271,000	0.2%	GPS radio occult.	137,000	1.5%
TOTAL:	155,448,000	100.00%	TOTAL:	9,018,000	100.00%

99% of screened data is from satellites

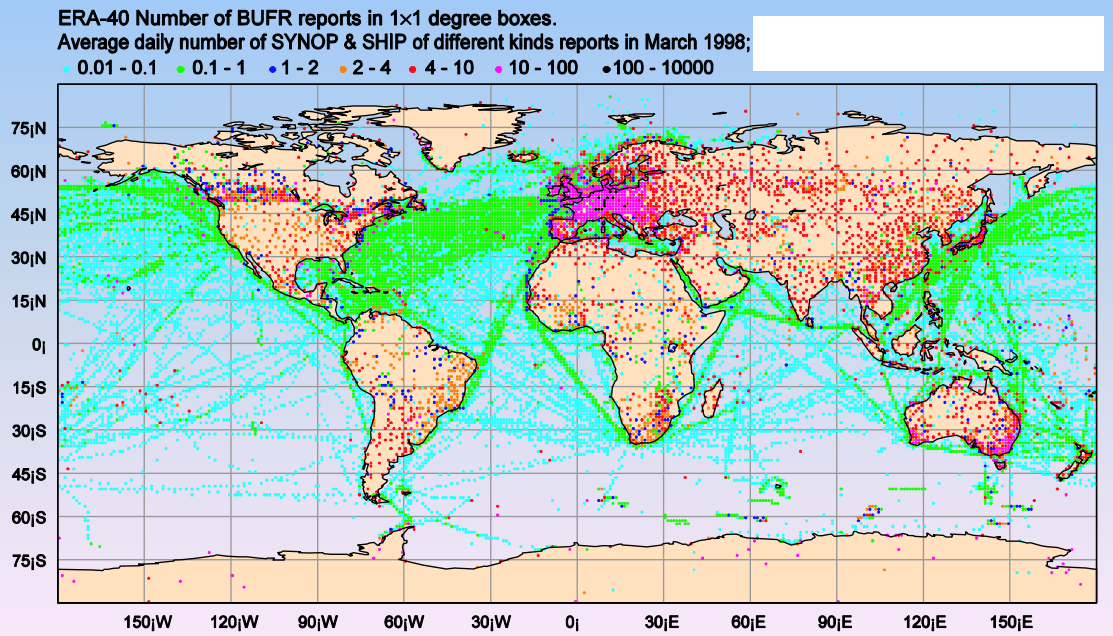
96% of assimilated data is from satellites

Surface data

1958 March



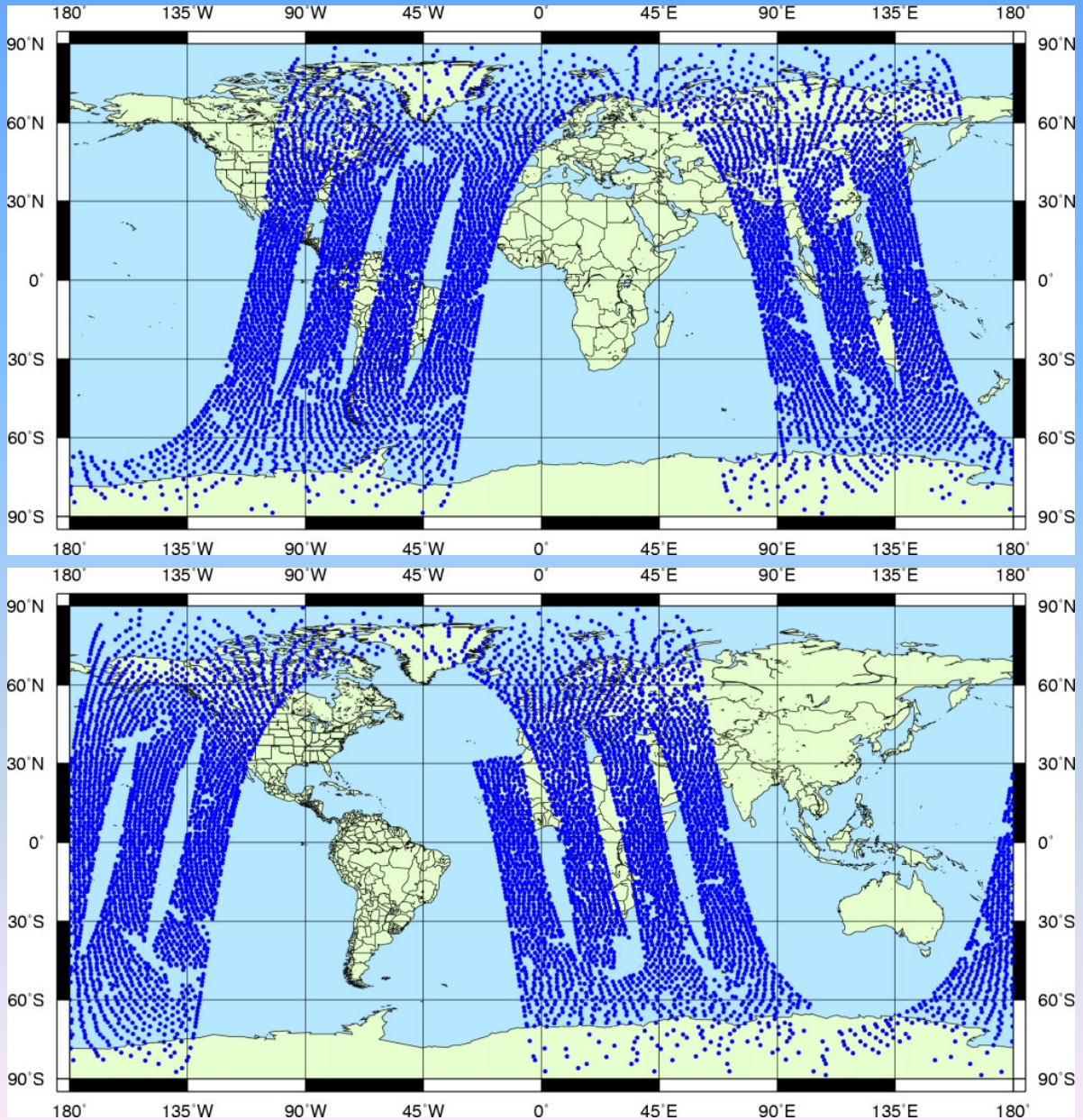
1998 March



Case Studies

dirceu@cptec.inpe.br

Geopotential from AIRS - AQUA



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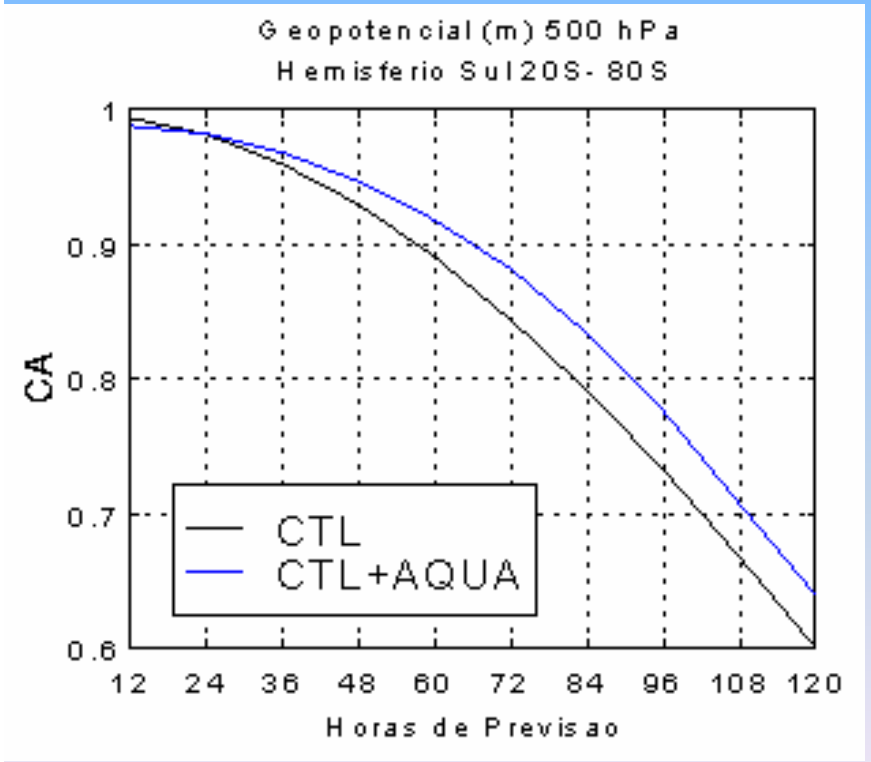
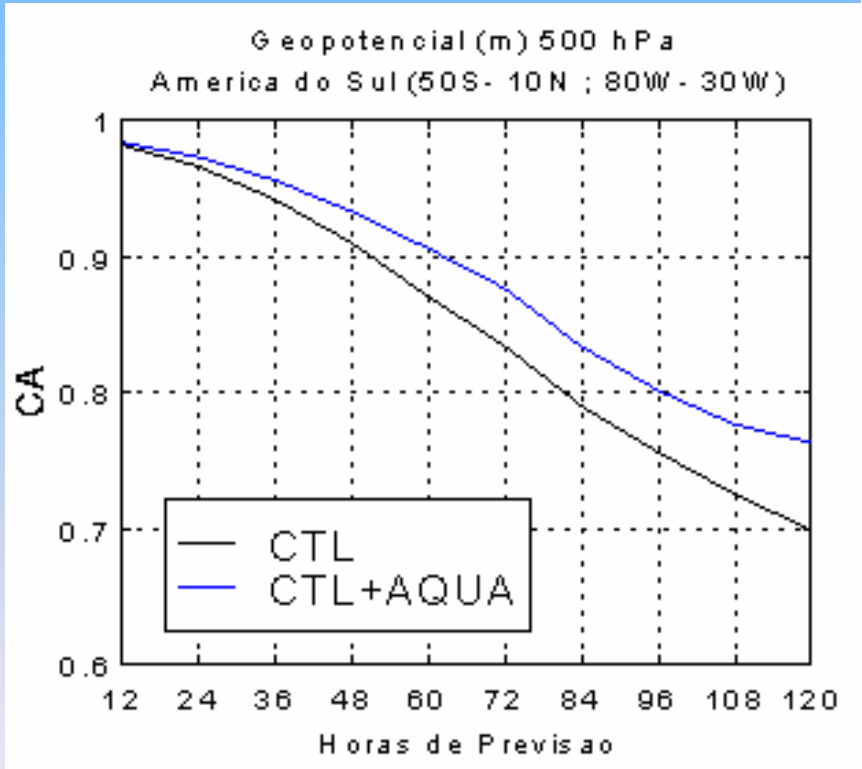
CPTEC/INPE AIRS Testing

weather forecast impact - more than 12 h



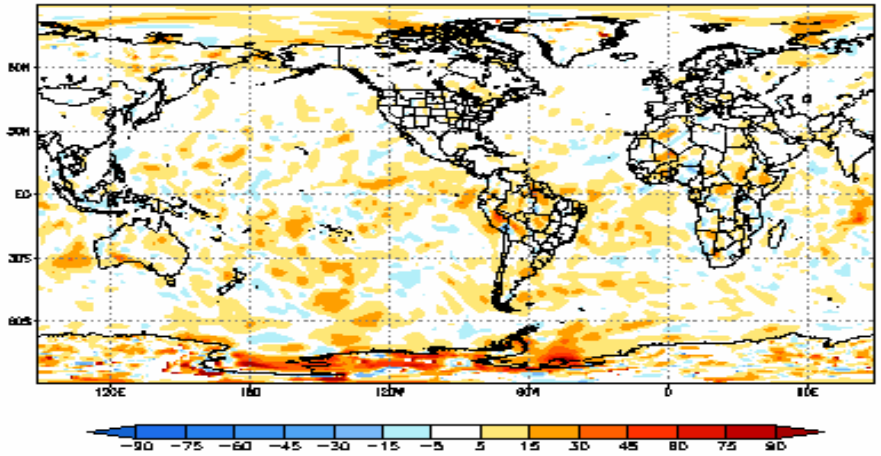


Andreoli et al. 2006

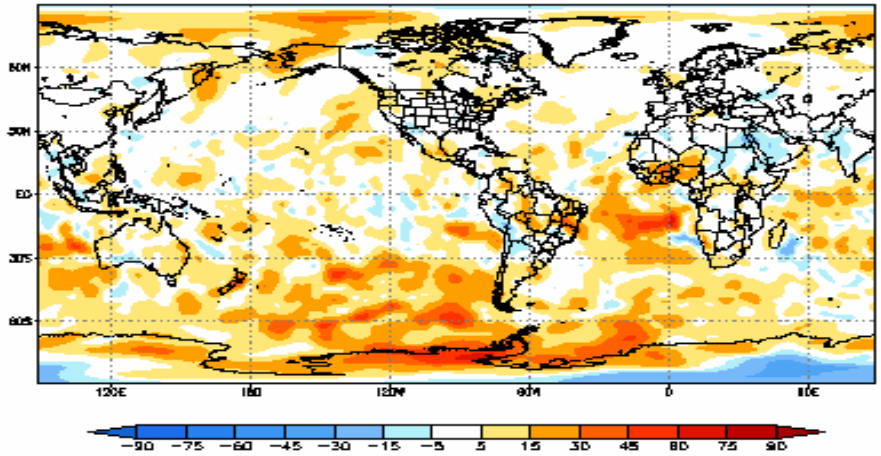
dirceu@cptec.inpe.br

Impact of AIRS retrievals over the 48 h forecast

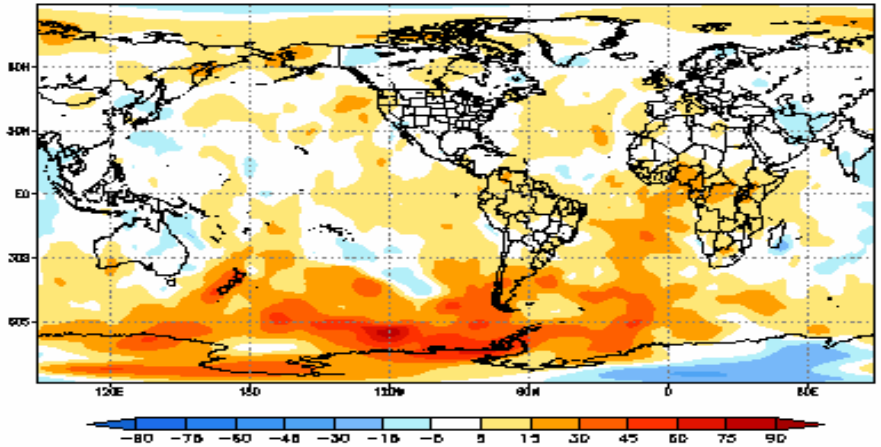
UmRl 850 hPa



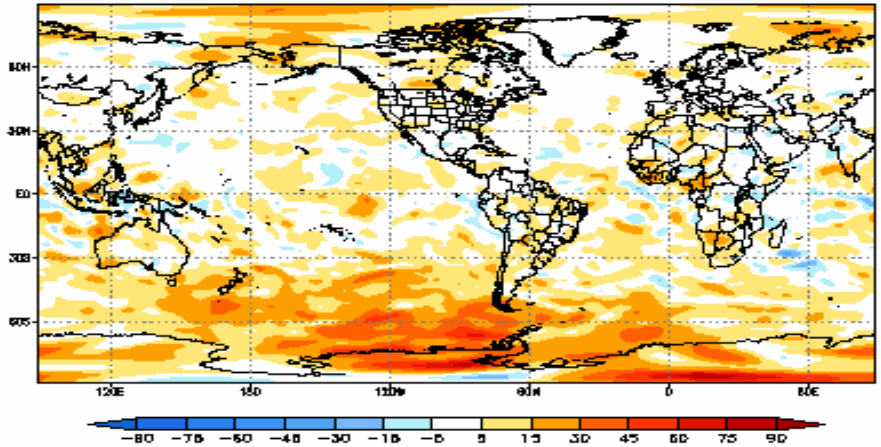
Temp 500 hPa



ZGeo 500 hPa



u-Comp 300 hPa

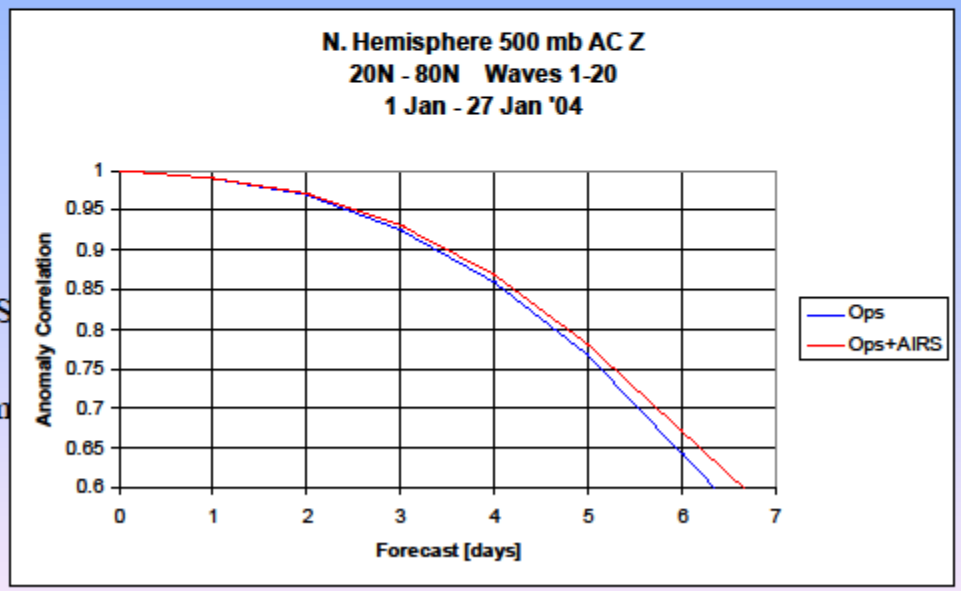


Andreoli et al. 2006

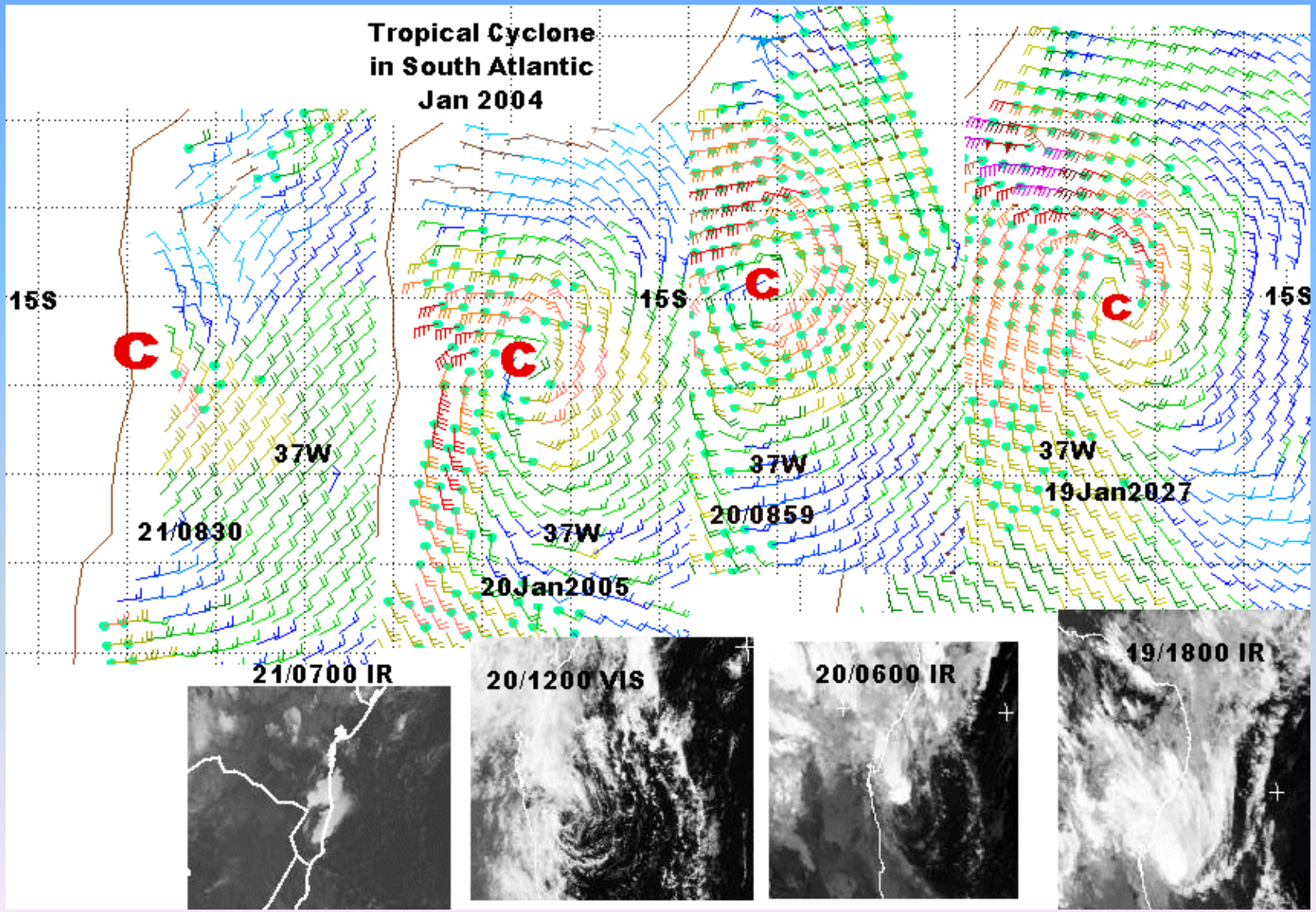
dirceu@cptec.inpe.br

JCSDA AIRS Testing

- NCEP operational system
  - Includes first AIRS data use
- Enhanced AIRS data use
  - Data ingest includes all AIRS footprints
  - 1 month at 55 km resolution
  - Standard data selection procedure

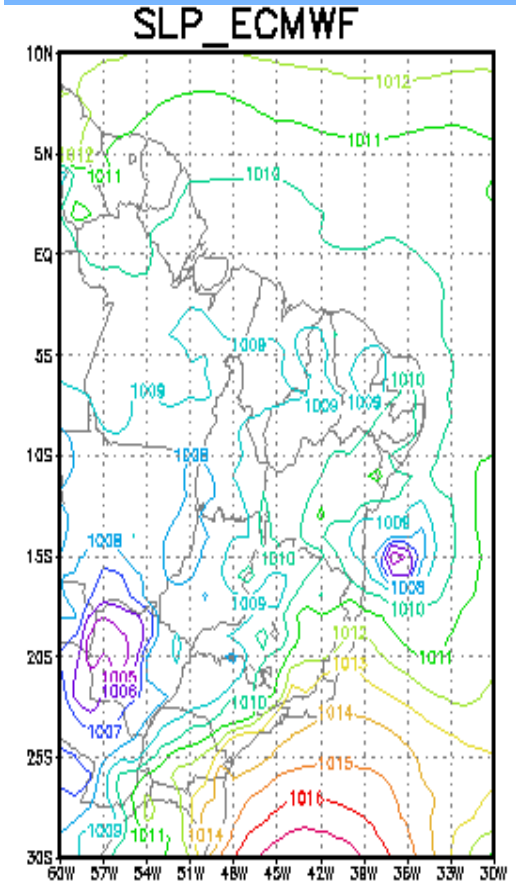


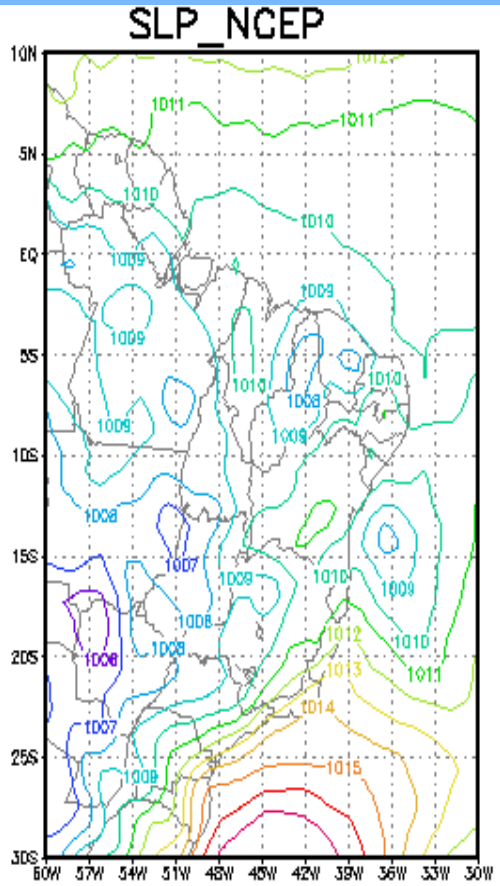
QuickScat

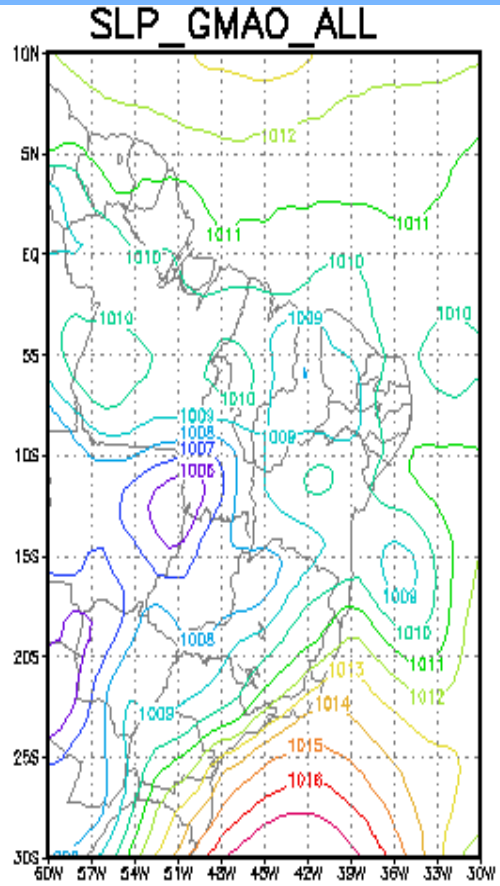


dirceu@cptec.inpe.br

Analysis from ECMWF, NCEP and GMAO



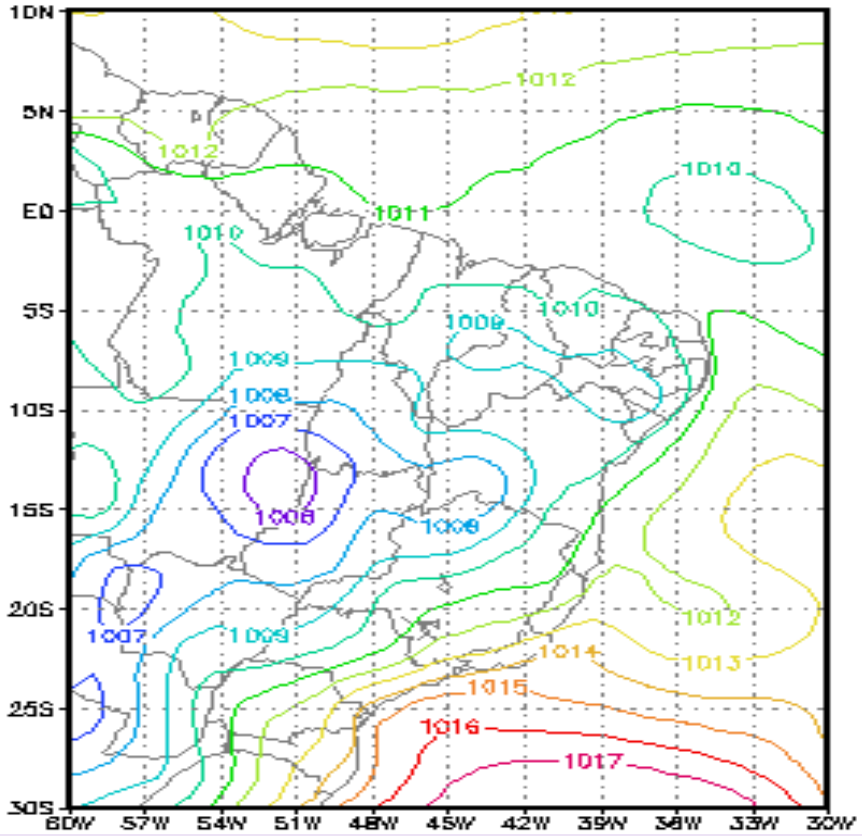




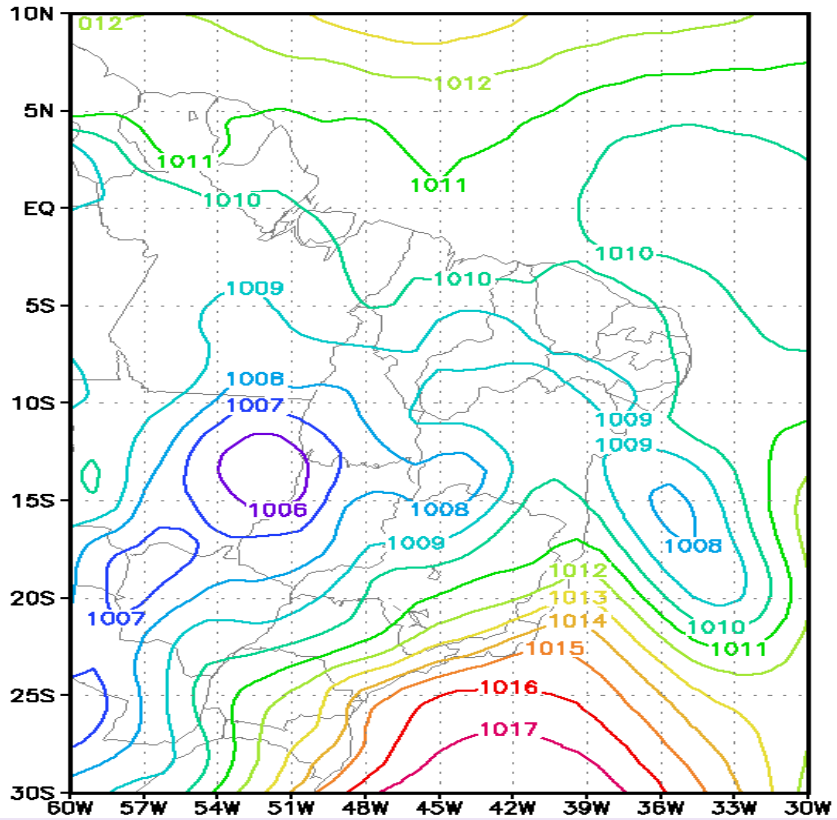
dirceu@cptec.inpe.br

CPTEC/INPE Analysis

No QuikScat



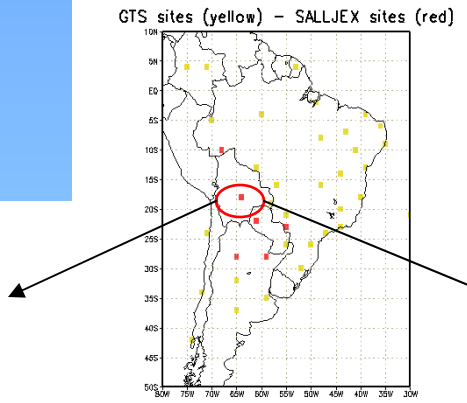
including QuikScat

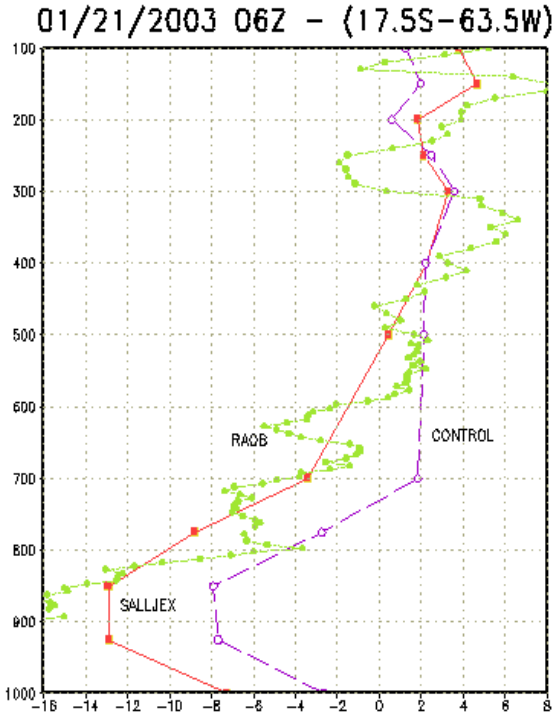


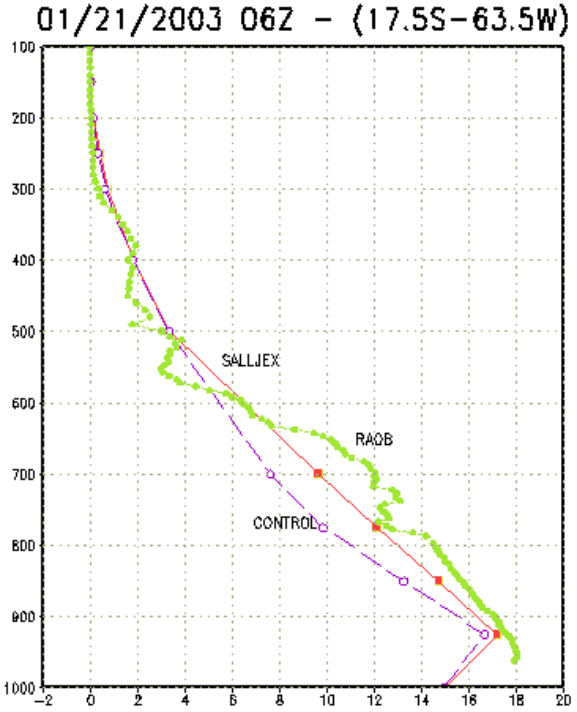
dirceu@cptec.inpe.br

Including SALLJEX data –CPTEC/INPE

SALLJEX (2002-2003)

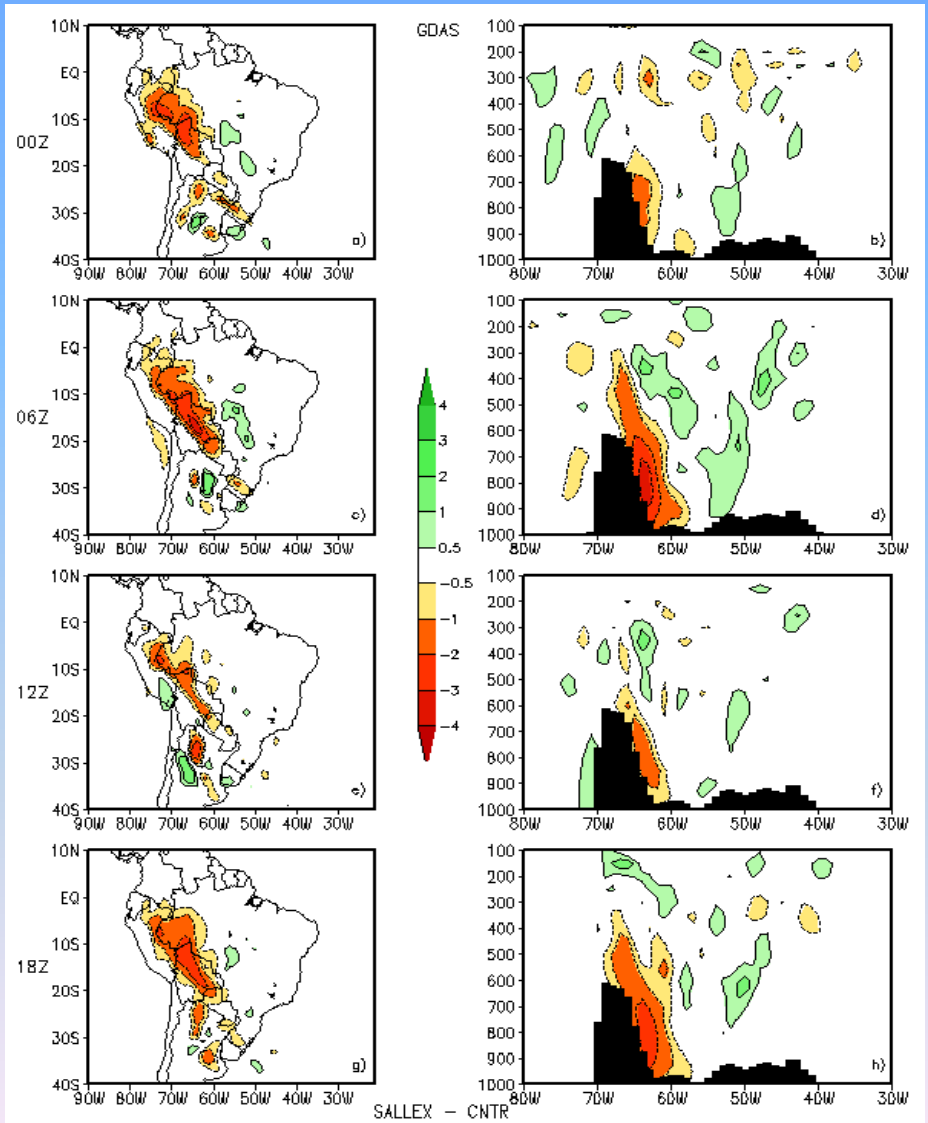






dirceu@cptec.inpe.br

Including SALLJEX data - NCEP



SALLJEX (2002-2003)

dirceu@cptec.inpe.br

Data Assimilation at CPTEC/INPE

RPSAS 40 km L38 – conventional dataset, AMV, ATOVS, QuikScat and AIRS

RPSAS 20 km L38 (Eta WS) – pre-operational

GPSAS T213 L42 – Conventional dataset, CTW, ATOVS, QuikScat, TPW e AIRS

BRAMS/PSAS – same as RPSAS

LETKF – Global Model, Regional Model and Oceanic Model

dirceu@cptec.inpe.br

Data Assimilation Team

Dr. Dirceu L. Herdies
Dr. José A. Aravéquia
Dr. Julio Pablo R. Fernandes
Dr. Luciano P. Pezzi
Dr. Luiz F. Sapucci
Dra. Solange Souza
M.Sc. Joao Gerd de Mattos (PhD student)
M.Sc. Sergio H. Ferreira (PhD Student)

Data Assimilation System: PSAS (oper.) e LETKF (res.)
Model: Global, Regional Eta, BRAMS and MOM-4

dirceu@cptec.inpe.br

Collaborators

Dr. Arlindo da Silva and Dr. Ricardo Todling – GMAO/NASA

PSAS, QC

Dr. Luís Gustavo G. de Gonçalves – ESSIC and NASA

SALDAS

Dra. Eugenia Kalnay – University of Maryland

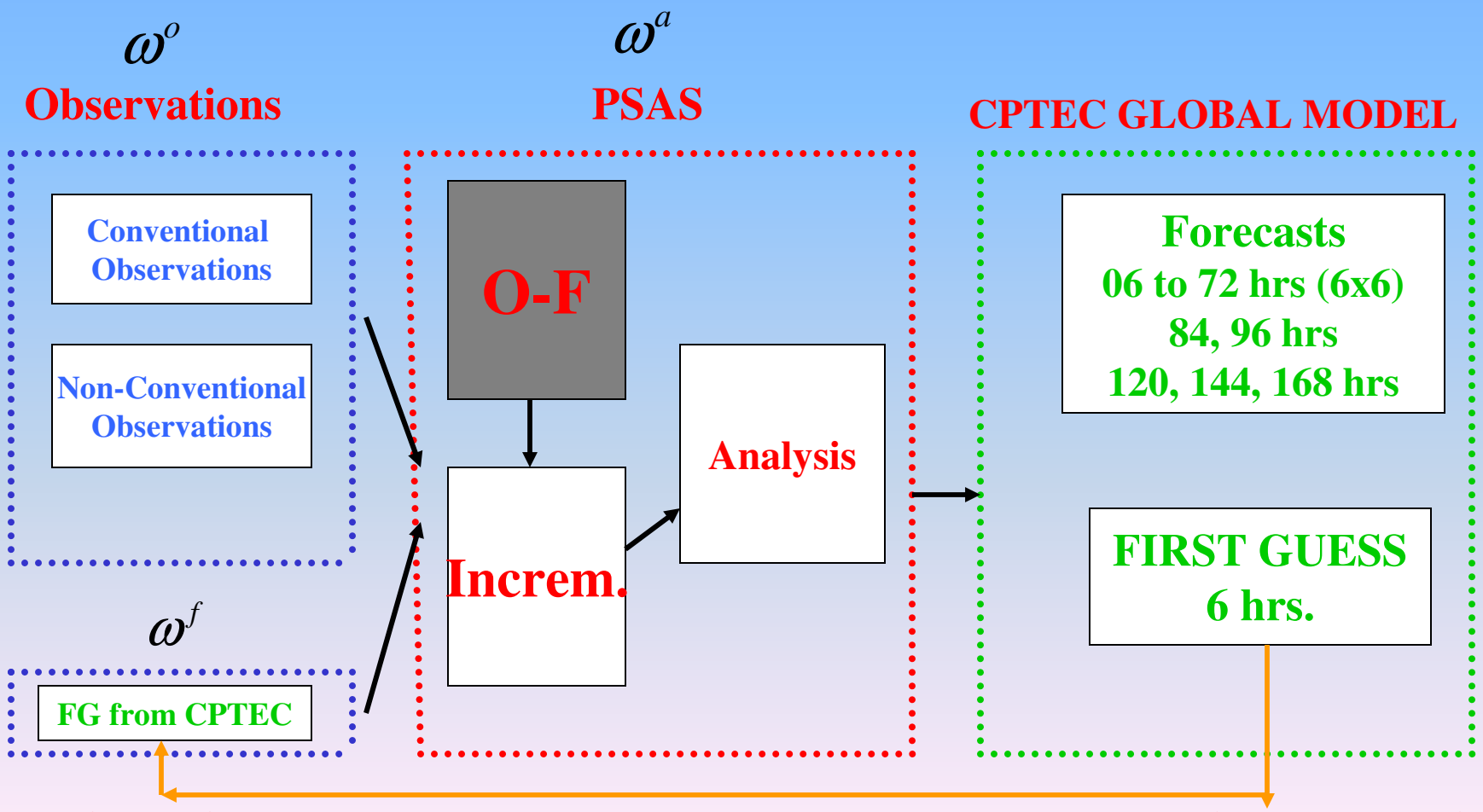
LETKF

Dr. Steve English – UKMet

new dataset (IASI, GPS-RO, radar)

dirceu@cptec.inpe.br

Data Assimilation Cycle



dirceu@cptec.inpe.br

South America Regional Reanalysis – SARR
High Lights

Eta Model

- 40 km resolution over South America
- 38 levels
- NCEP horizontal boundary conditions

Data Assimilation

- RPSAS – Regional Physical-space Statistical Analysis System
- Four daily analyses from jan2000-dec2004

1,2 TB of the disk space
6 months to run using a NEC/SX6 computer

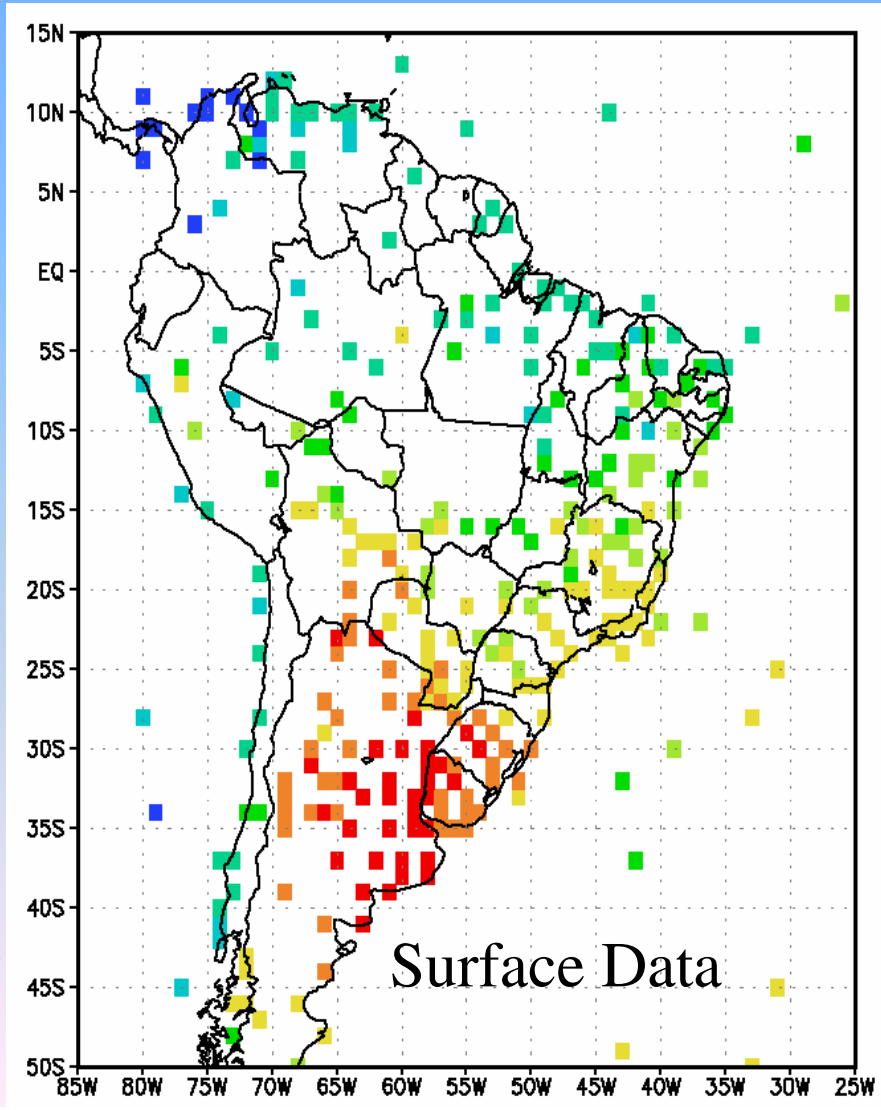
SOUTH AMERICA REGIONAL REANALYSIS

CPTEC/INPE, SARR-5 2000 - 2004
CPTEC/INPE, SARR-30 1979 →

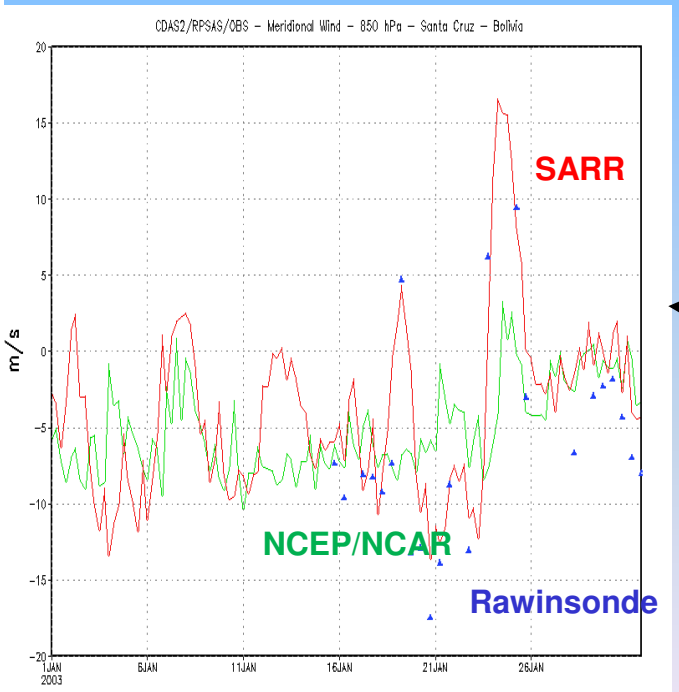
dirceu@cptec.inpe.br

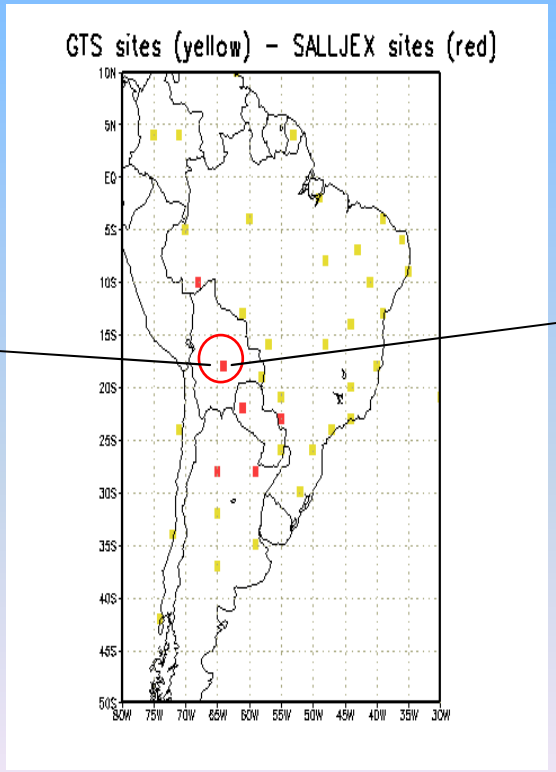
South American Regional Reanalysis SARR

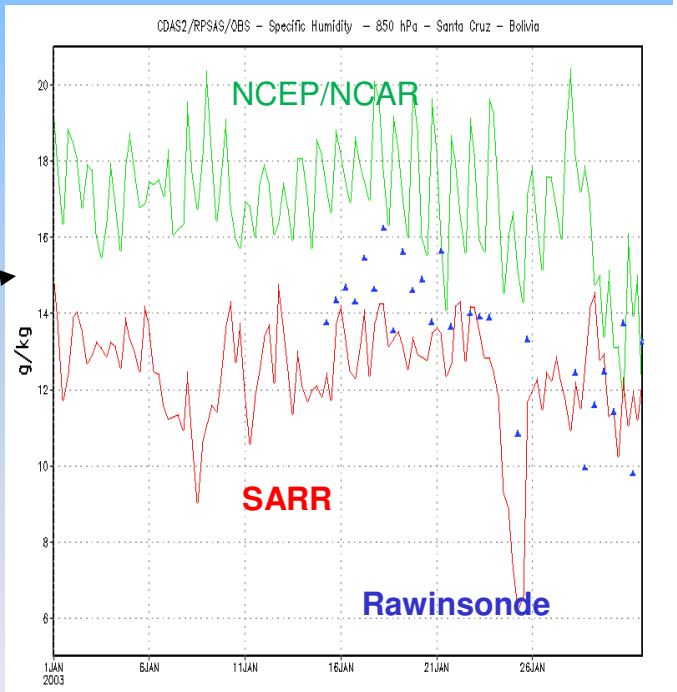
- **Modelo Regional ETA;**
- **RPSAS (Regional Physical-space Statistical Analysis System);**
- **Janeiro 2000 – Dezembro 2004;**
- **Resolução horizontal de 40 km com 38 níveis na vertical;**
- **Dados utilizados: convencionais e de satélite;**
- **Análises (6 h) e Precip, Tmed, Tmax e Tmin - (24 h);**
- ***LBA- DIS (ftp://lba.cptec.inpe.br/lba_archives/PC/PC-404/regional _reanalysis/)***



Validation over SALLJEX area



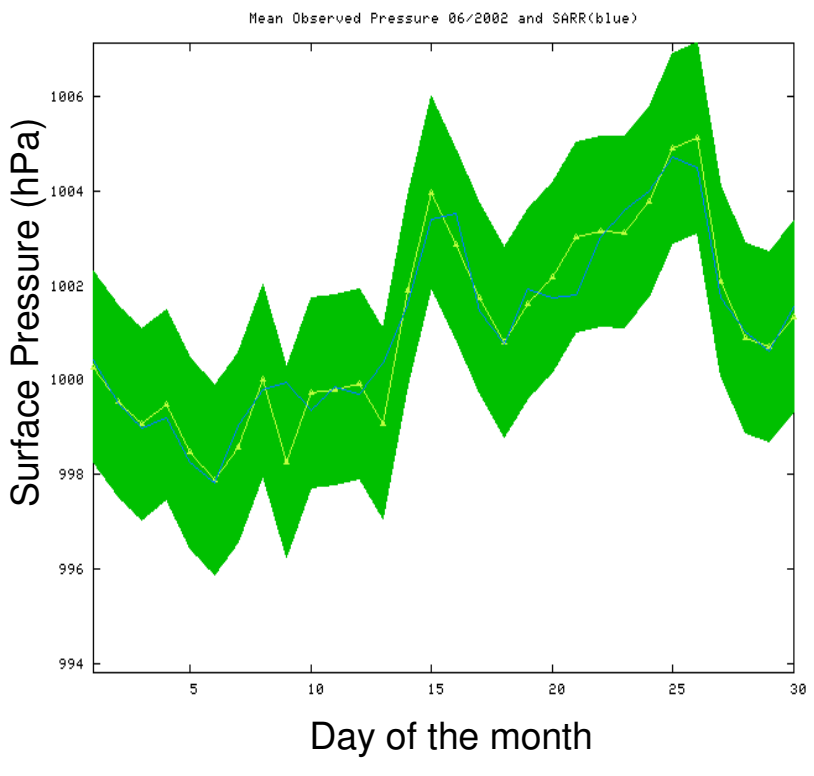


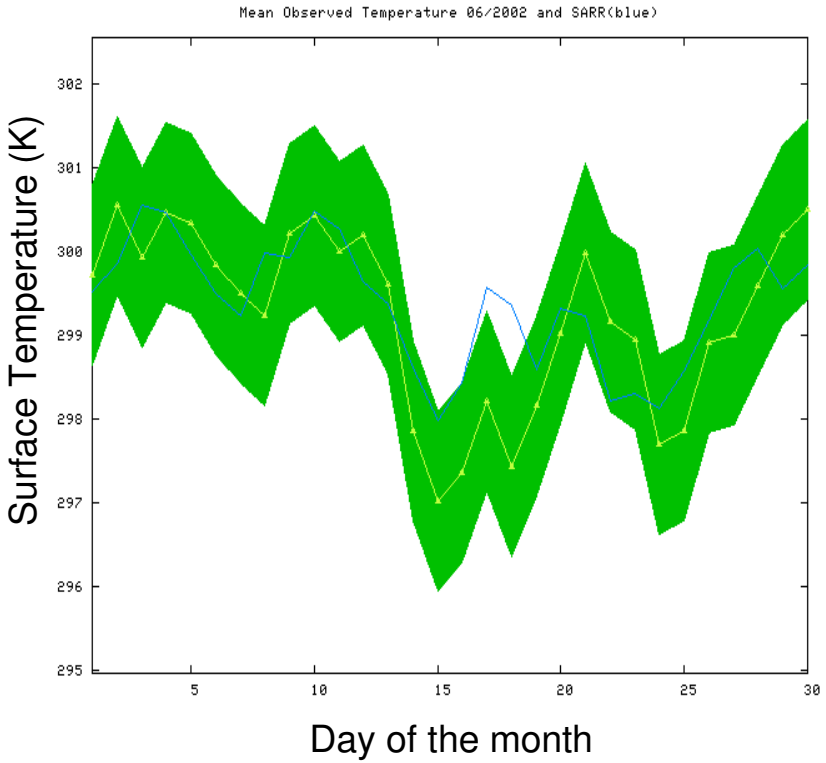


dirceu@cptec.inpe.br

South American Land Data Assimilation SALDAS

Evaluating SALDAS forcing derived from SARR and observation based precipitation and radiation over the LBA region

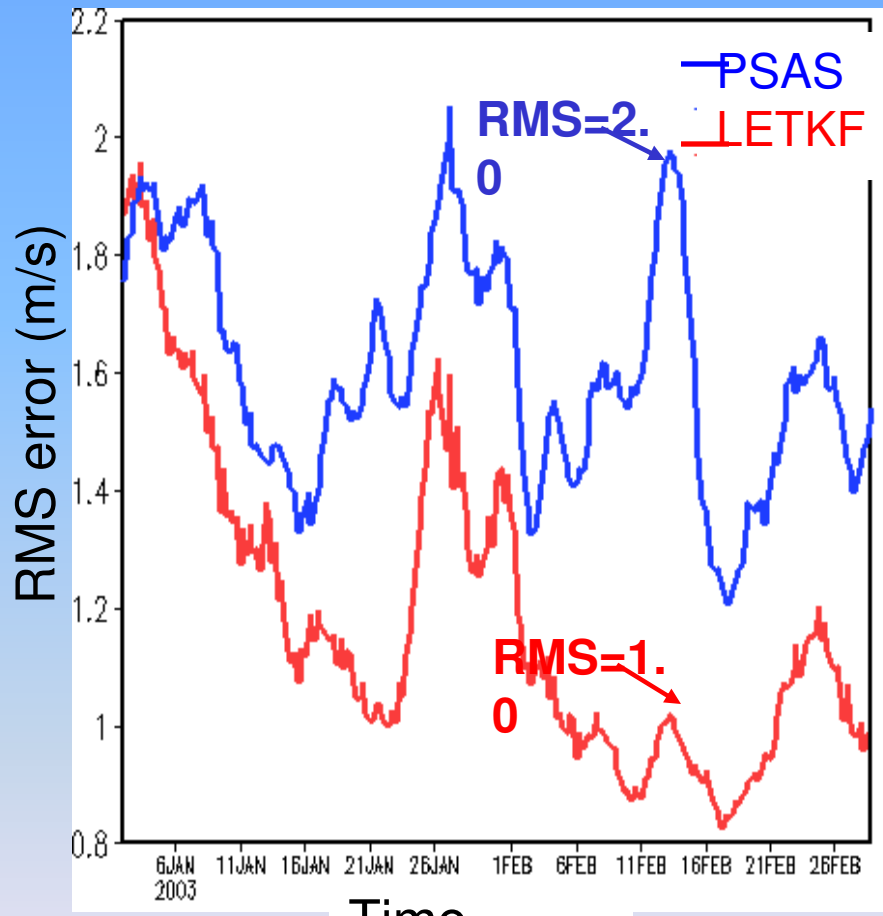




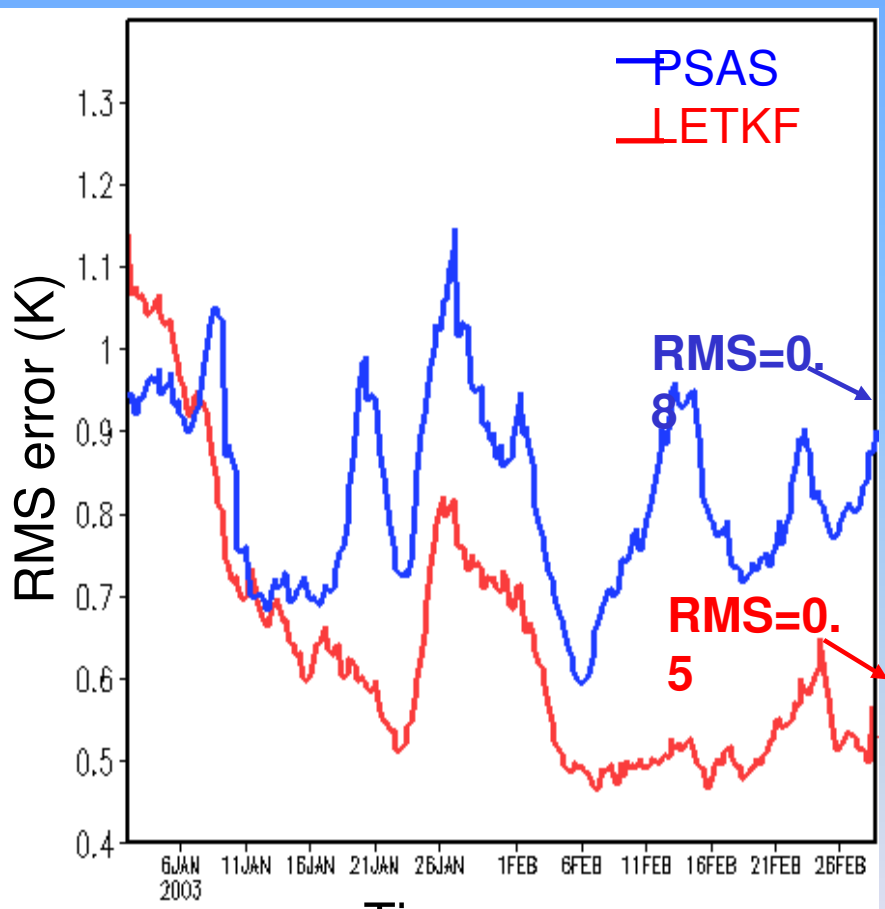
Bias reduced surface Pressure (left panel) and surface temperature are compared against NCDC surface stations over the LBA region. The average observed values are shown in light green while the region that comprises the observations standard deviation is shown in dark green. Model (SARR) derived values are shown in blue

dirceu@cptec.inpe.br

500hPa analysis RMS error (Global average)



Zonal Wind

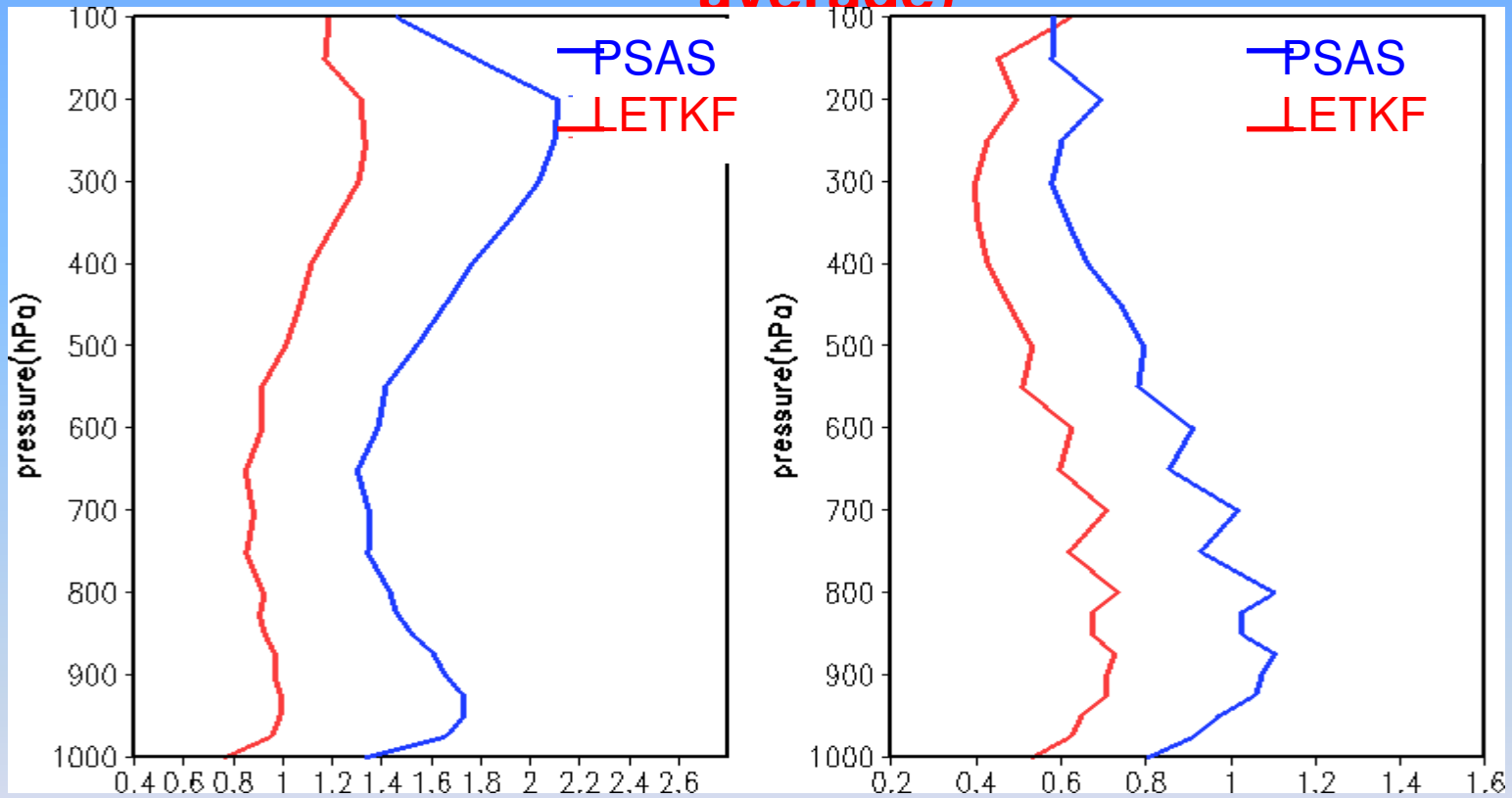


Temperature

Hong Li et al. 2006

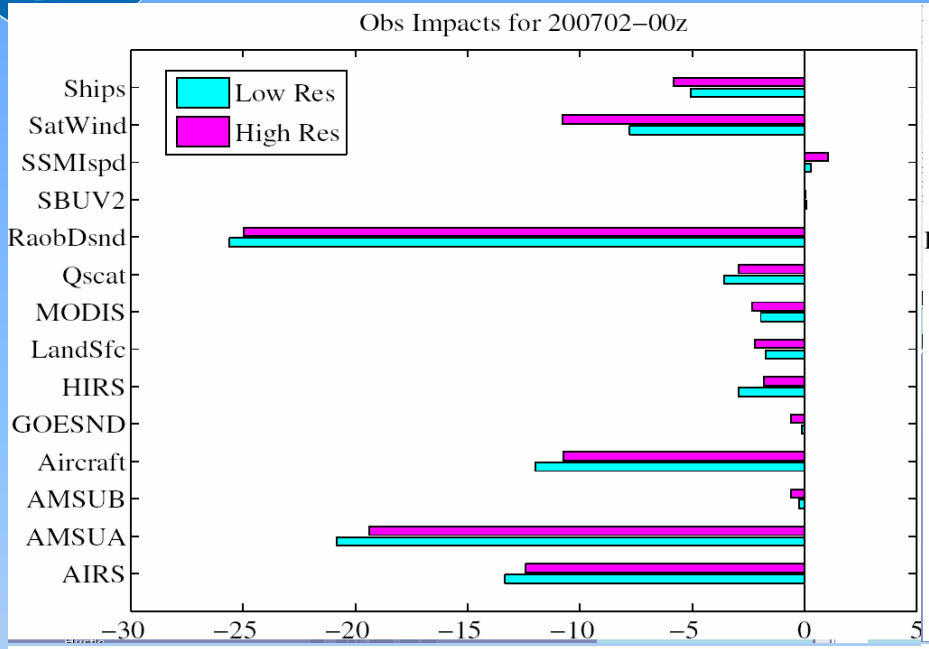
dirceu@cptec.inpe.br

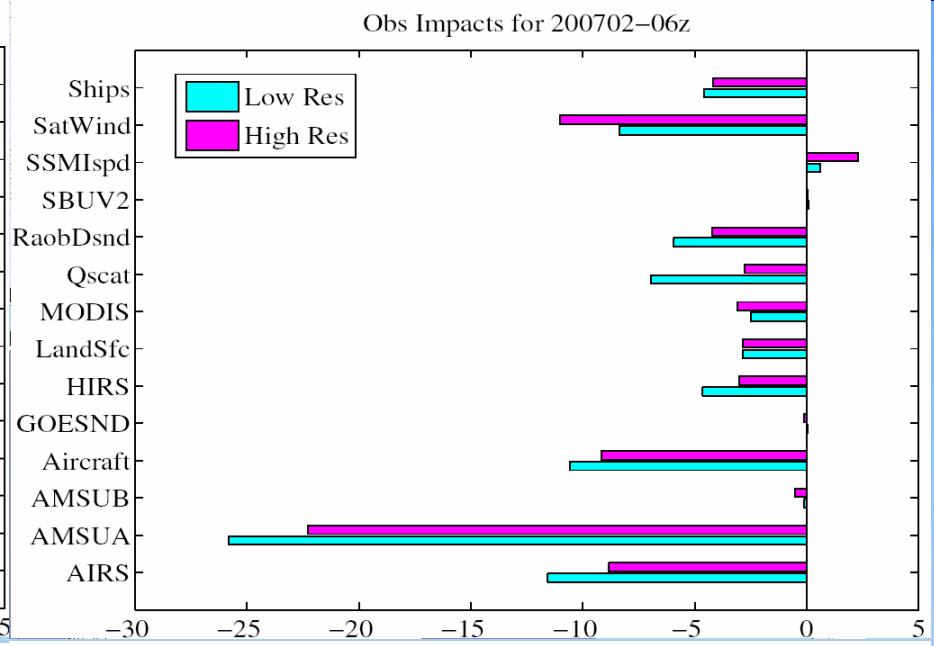
Feb. average analysis RMS error at different levels (Global average)

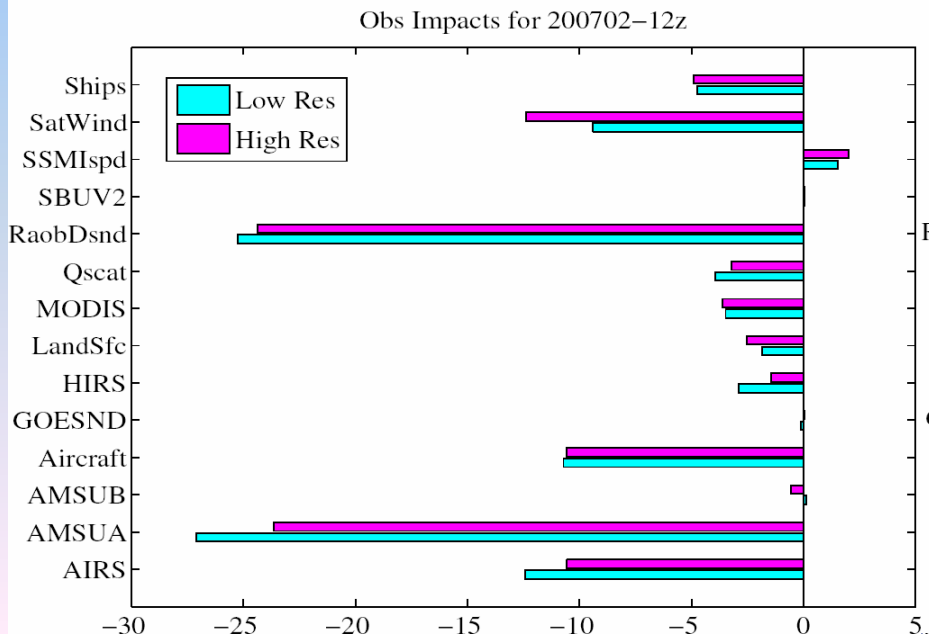


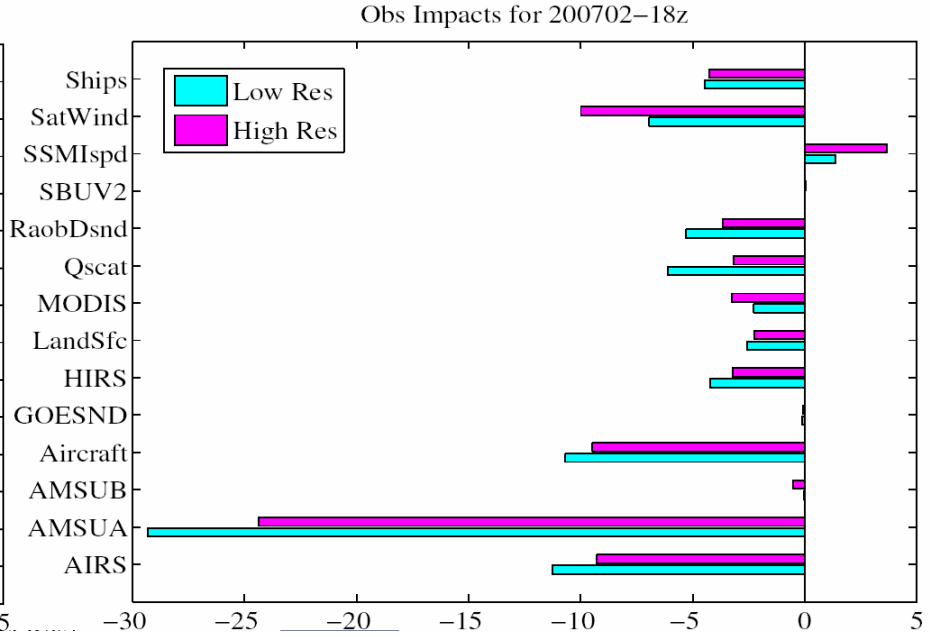
Hong Li et al. 2006

Observations Impact for Two Resolutions of Full DAS









FUNDAMENTALS OF ATMOSPHERIC DATA ASSIMILATION

Roger Daley

Naval Research Laboratory,
Monterey CA, USA

Fifteen years ago, data assimilation was a minor and often neglected sub-discipline of numerical weather prediction. The situation is very different today. Data assimilation is now felt to be important for all climate/environmental monitoring and estimating the ocean state. There have been great advances in both modelling and instrumentation for a variety of atmospheric phenomena and variables, and data assimilation provides the bridge between them….

CENTRO DE PREVISÃO DO TEMPO E ESTUDOS CLIMÁTICOS
CENTER FOR WEATHER FORECAST AND CLIMATE STUDIES
CPTEC

INPE

INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

NATIONAL INSTITUTE FOR SPACE RESEARCH

Data Assimilation Context

- Over 1.43B observations received per day (most satellite data – global system does not include radar radial winds).
- Over 7M observations per day used.
- Data selection and quality control eliminate many observations
- Data selection applied because of:
  - redundancy in data
  - reduction in computational cost
  - eliminate non-useful observations

•Most applied research in atmospheric data assimilation done at operational centers

• Much of expertise and knowledge is undocumented or minimally documented – papers are not the priority at operational centers

• Many opportunities to use new observations and to improve forward models for DA.

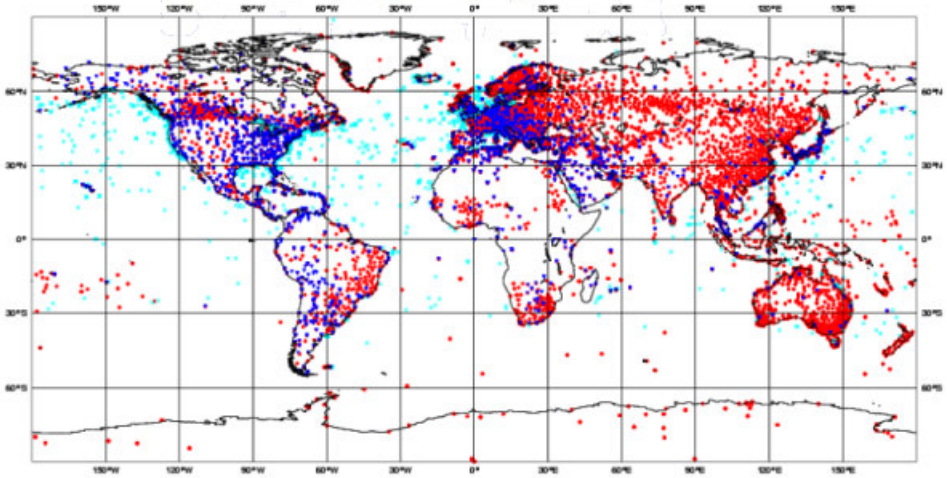
• Data assimilation is where everything comes together

– To use new observations properly requires one to become an expert in that particular instrument

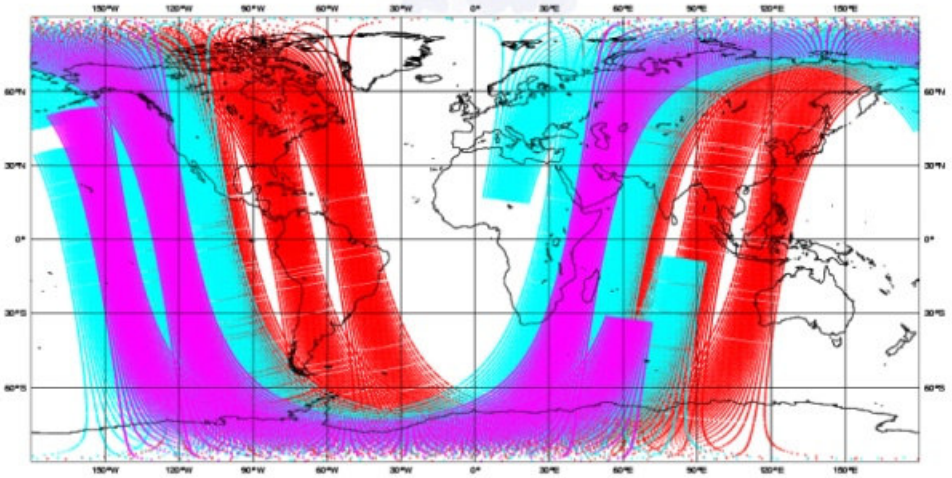
– One must be knowledgeable on forecast model dynamics and physics to understand background errors

– Computational techniques are necessary to improve efficiency

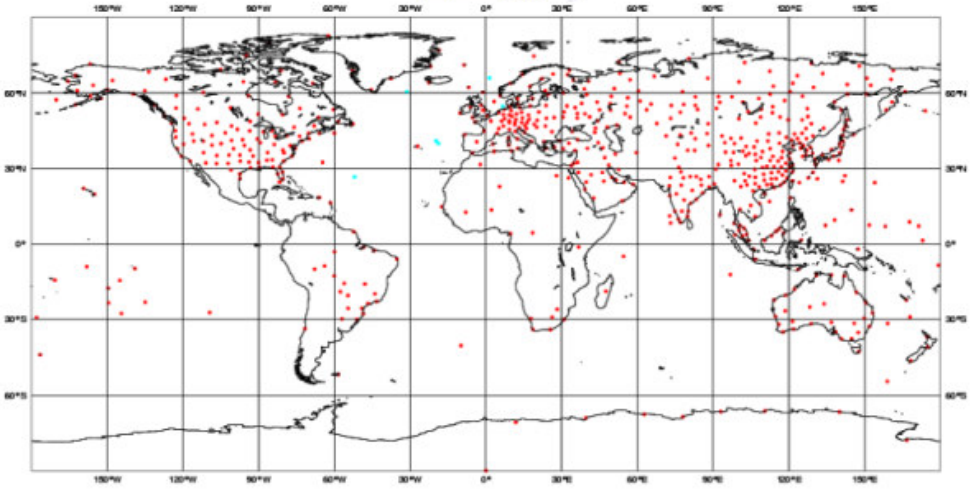
SYNOP/SHIP/METAR



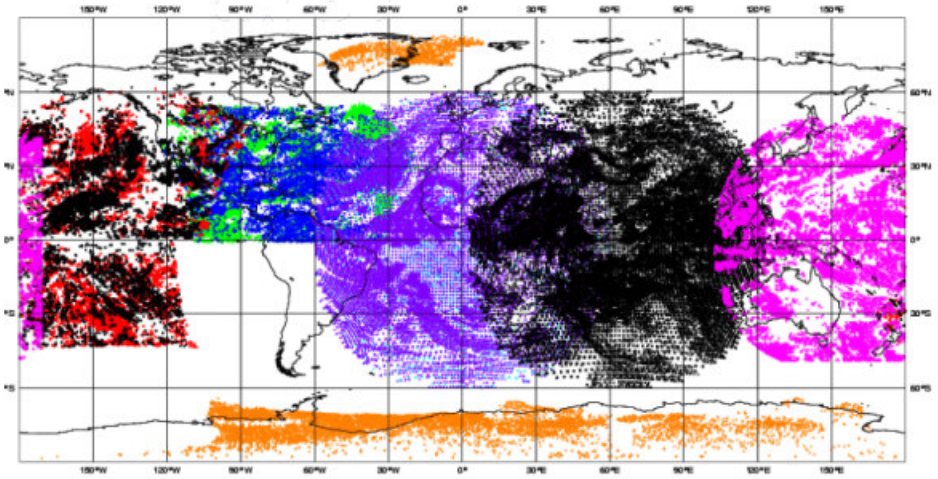
ATOVS



TEMP



SATOB



dirceu@cptec.inpe.br

Projetos do Grupo de Assimilação de Dados

Assimilação de dados de IWV, AIRS e AMSU – AQUA ok
Assimilação de Radiâncias AIRS – AQUA - 2007/2008
Desenvolvimento do novo sistema LEKF - 2007/2008
Desenvolvimento do Sistema PSAS/BRAMS - 2007/2008
Assimilação de dados de superfície - 2007/2008
Inclusão de dados sintéticos - a ser implementado
Assimilação de dados oceânicos - em andamento

Assimilação de dados de radar proj. de doutorado
Assimilação de dados de precipitação a ser iniciado
Assimilação de Aerossóis a ser iniciado

dirceu@cptec.inpe.br