Introdução à Assimilação de Dados (MET 563-3)

Radiâncias e impacto de observação

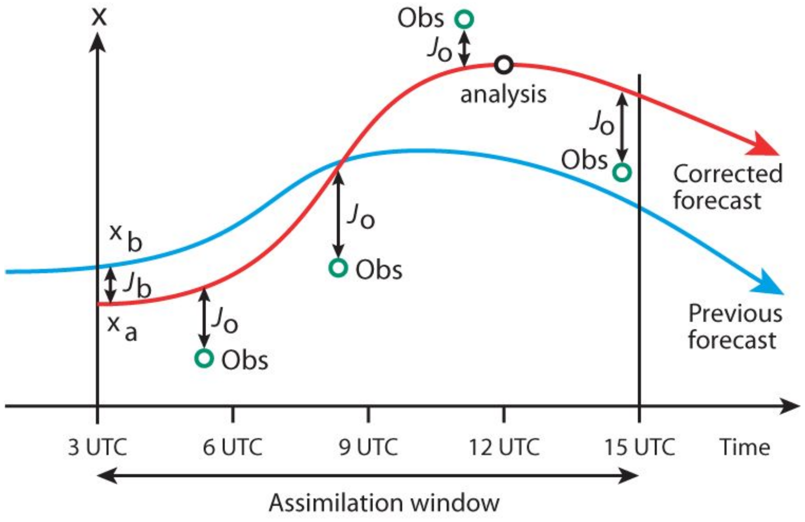
Helena Barbieri de Azevedo

01/12/2025

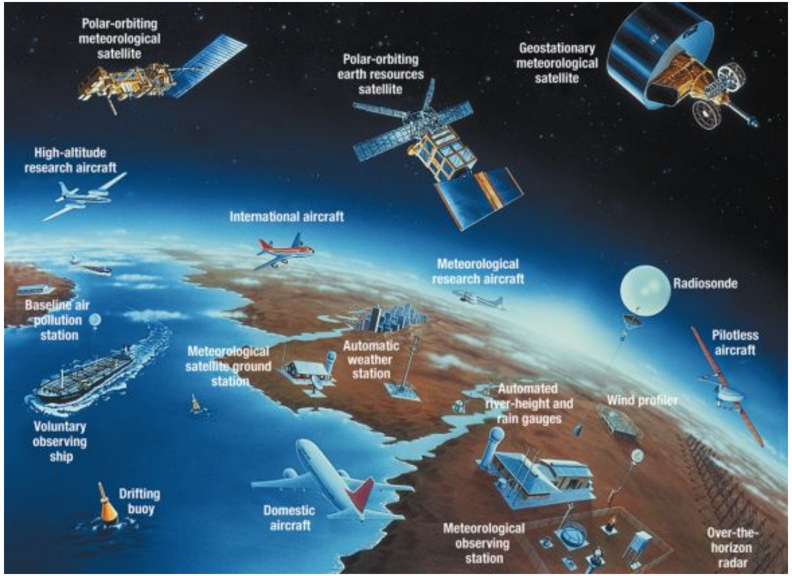
- Porque precisamos de dados?
- Porque precisamos de dados de satélites?
- Quais são os principais desafios na assimilação de radiâncias?
- O que temos de mais importante?
- Como estimar o impacto dos dados?
- Existe aplicação?

Assimilação de dados

Estamos interessados nas condições iniciais

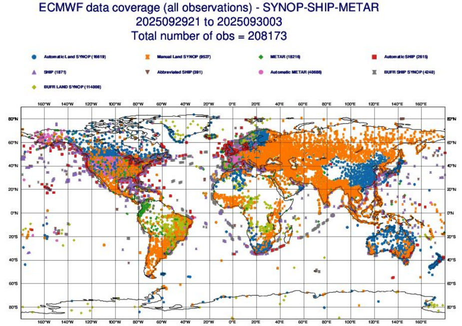


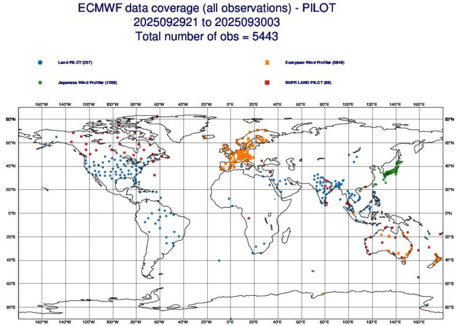
https://www.ecmwf.int/en/about/media-centre/news/2017/20-years-4d-var-better-forecasts-through-better-use-observations

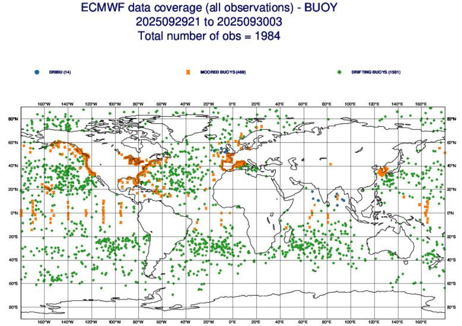


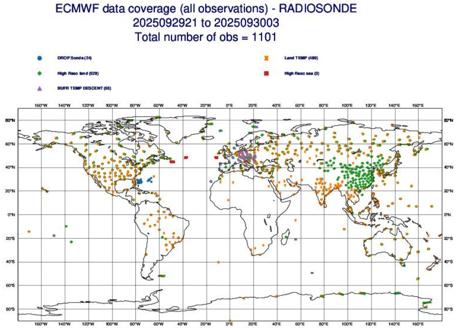
https://wmo.int/activities/wmo-integrated-global-observing-system-wigos/wmo-integrated-global-observing-system

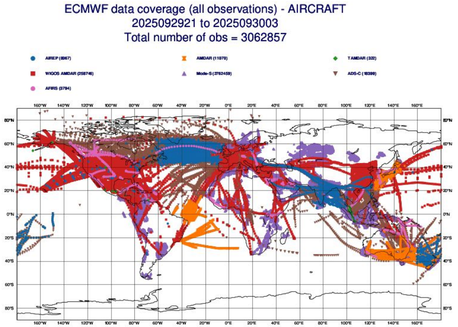
Dados ‘convencionais’





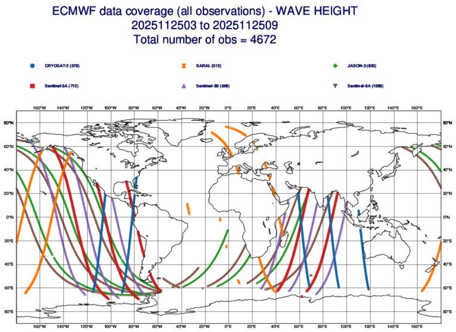


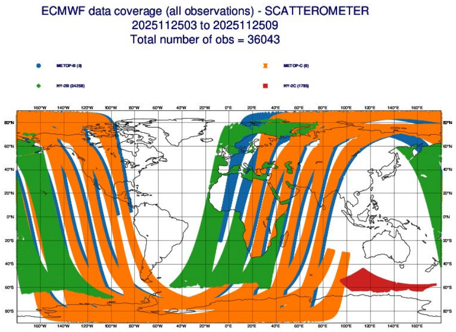


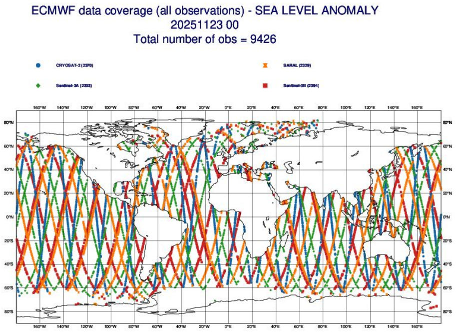


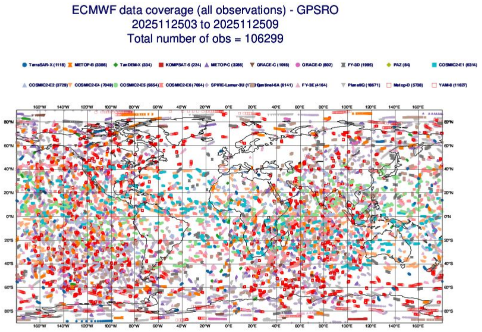
https://charts.ecmwf.int/catalogue/packages/monitoring/

Satélite





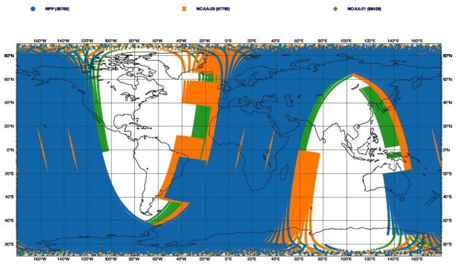




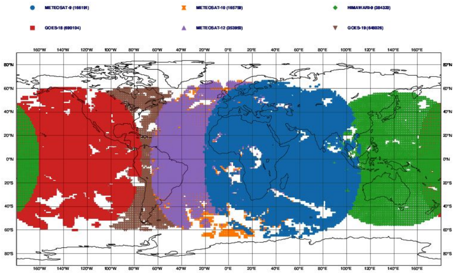
https://charts.ecmwf.int/catalogue/packages/monitoring/

Satélite - Radiância

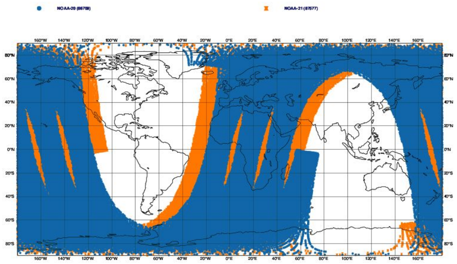
ECMWF data coverage (all observations) - ATMS
2025092921 to 2025093003
Total number of obs = 285984



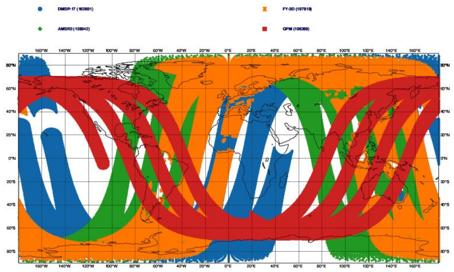
ECMWF data coverage (all observations) - GEOSTATIONARY RADIANCES
2025092921 to 2025093003
Total number of obs = 2408350



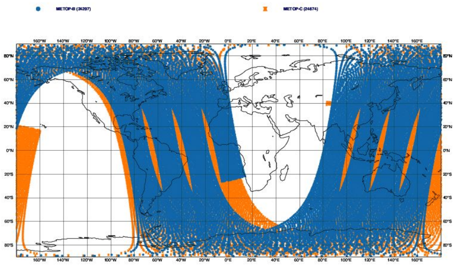
ECMWF data coverage (all observations) - CRIS
2025092921 to 2025093003
Total number of obs = 174286



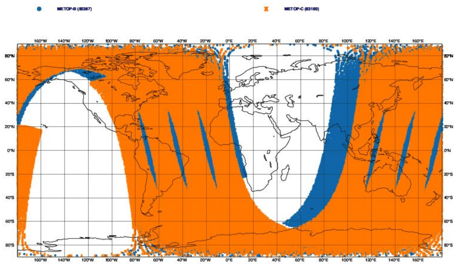
ECMWF data coverage (all observations) - MICROWAVE HUMIDITY IMAGERS
2025112503 to 2025112509
Total number of obs = 535951



ECMWF data coverage (all observations) - AMSUA
2025092921 to 2025093003
Total number of obs = 48881



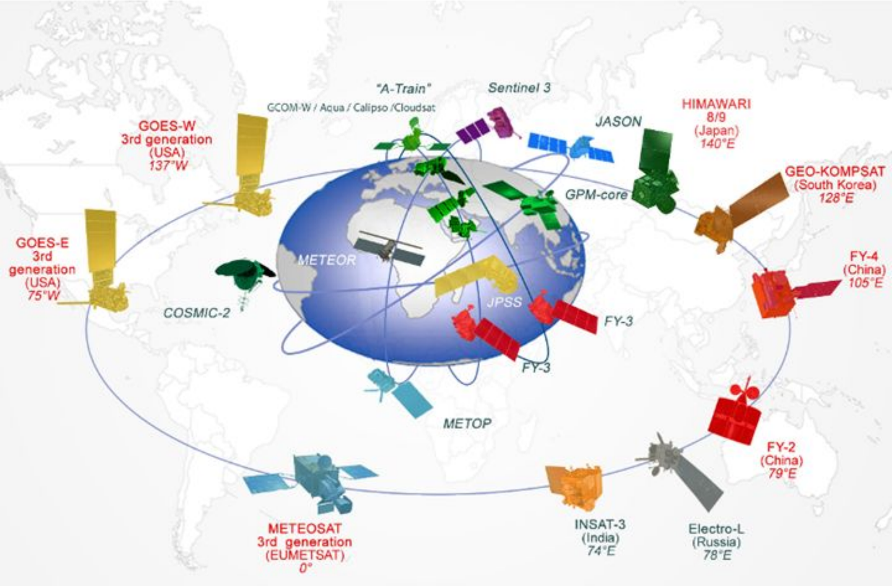
ECMWF data coverage (all observations) - IASI
2025092921 to 2025093003
Total number of obs = 168547



https://charts.ecmwf.int/catalogue/packages/monitoring/

Satélite

- Posicionamento
- Frequência de dados



https://wmo.int/activities/global-observing-system-gos/global-observing-system-gos

Desafios

- Medida
- Operador observação - MTR
- Erros do modelo
- Erros das observações
- Correção de viés
- Seleção de dados
- Controle de qualidade

Desafios

- **Medida**
- **Operador observação - MTR**
- Erros do modelo
- Erros das observações
- Correção de viés
- **Seleção de canais**
- Controle de qualidade

Medida

O que os sensores de satélites em microondas e infravermelho passivos medem?

Medida

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NÃO medem TEMPERATURA
NÃO medem UMIDADE
NÃO medem VENTO

Medida

O que os sensores de satélites em microondas e infravermelho passivos medem?

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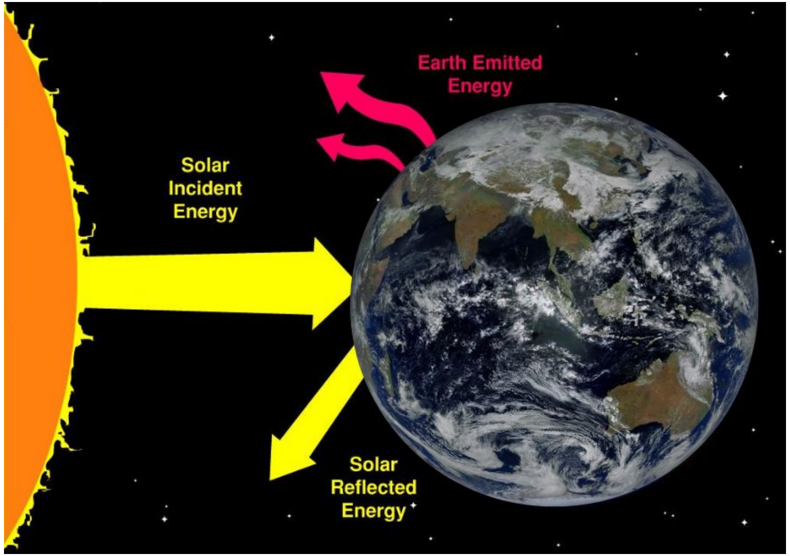

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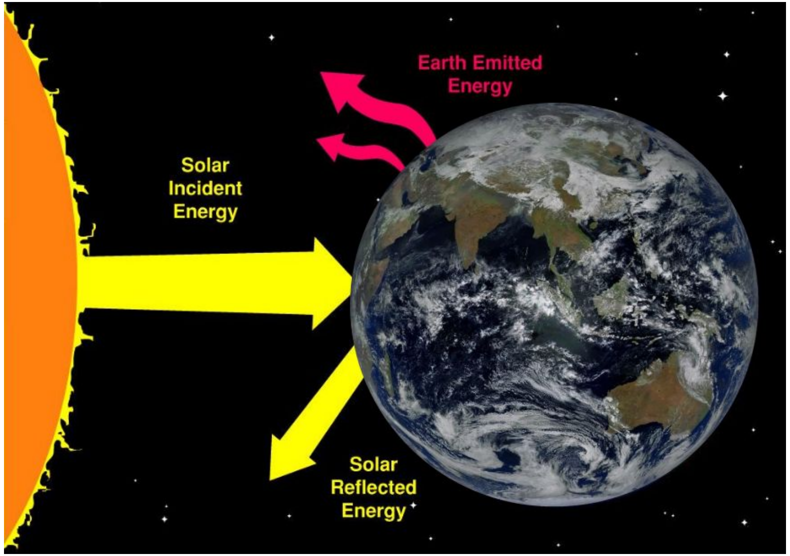
Medida

O que os sensores de satélites em microondas e infravermelho passivos medem?

NÃO medem TEMPERATURA
NÃO medem UMIDADE
NÃO medem VENTO

$(y - H[x_b])$?



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Modelo de transferência radiativa

Os instrumentos de satélite medem a radiação L que atinge o topo da atmosfera em uma determinada frequência v.

A radiância medida está relacionada a variáveis atmosféricas por meio da **equação da transferência radiativa**

medido pelo satélite

descrição da atmosfera

$$L(\nu) = \int_{0}^{\infty} B(\nu, T(z)) \left[\frac{d\tau(\nu)}{dz} \right] dz + \text{Emissão da superfície} + \text{Reflexão/espalhamento da superfície} + \text{Contribuição das nuvens/chuva} + \ldots$$

Função de Planck

Transmitância com relação a altura

Modelo de transferência radiativa

Dado um estado da atmosfera, qual é a radiância?

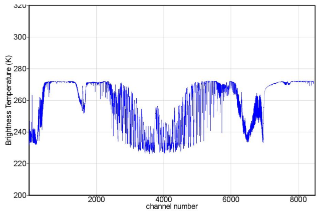
1DVar

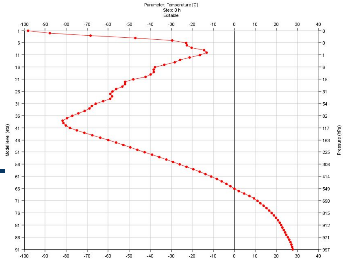
H - operador observação

$$(\mathbf{y} - \mathbf{H}[\mathbf{x}_b])$$

medido pelo satélite | **descrição da atmosfera**

$$L(\nu) = \int_0^\infty B(\nu, T(z)) \left[\frac{d\tau(\nu)}{dz} \right] dz + \text{Emissão da superfície} + \text{Reflexão/espalhamento da superfície} + \text{Contribuição das nuvens/chuva} + \ldots$$





Modelo de transferência radiativa

3DVar

Dado um estado da atmosfera, qual é a radiância?

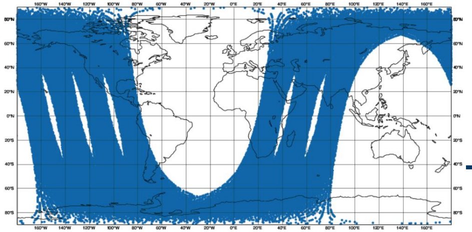
H - operador observação

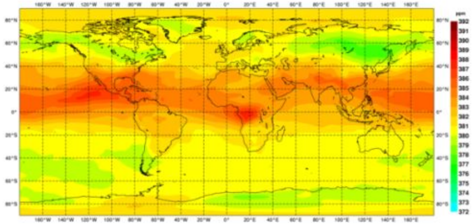
$$(\mathbf{y} - \mathbf{H}[\mathbf{x}_b])$$

medido pelo satélite

descrição da atmosfera

$$L(\nu) = \int_0^\infty B(\nu, T(z)) \left[\frac{d\tau(\nu)}{dz}\right] dz + \text{Emissão da superfície} + \text{Reflexão/espalhamento da superfície} + \text{Contribuição das nuvens/chuva} + \ldots$$





Modelo de transferência radiativa

Dado um estado da atmosfera, qual é a radiância?

4DVar

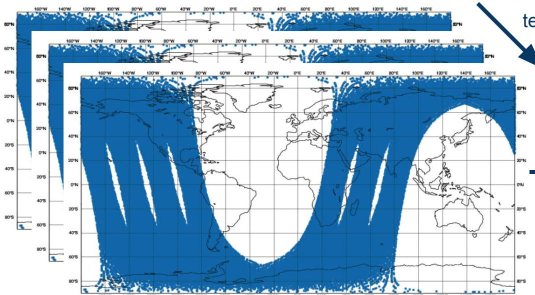
H - operador observação

$$(\mathbf{y} - \mathbf{H}[\mathbf{x}_b])$$

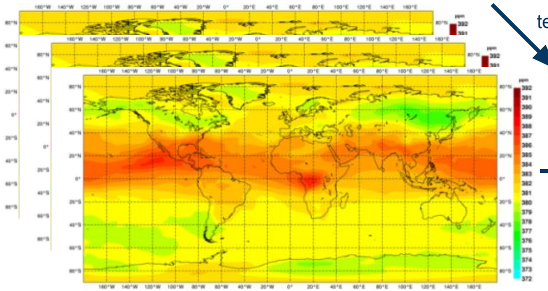
medido pelo satélite

descrição da atmosfera

$$L(\nu) = \int_0^\infty B(\nu, T(z)) \left[\frac{d\tau(\nu)}{dz} \right] dz$$ + Emissão da superfície + Reflexão/espalhamento da superfície + Contribuição das nuvens/chuva + ...



tempo



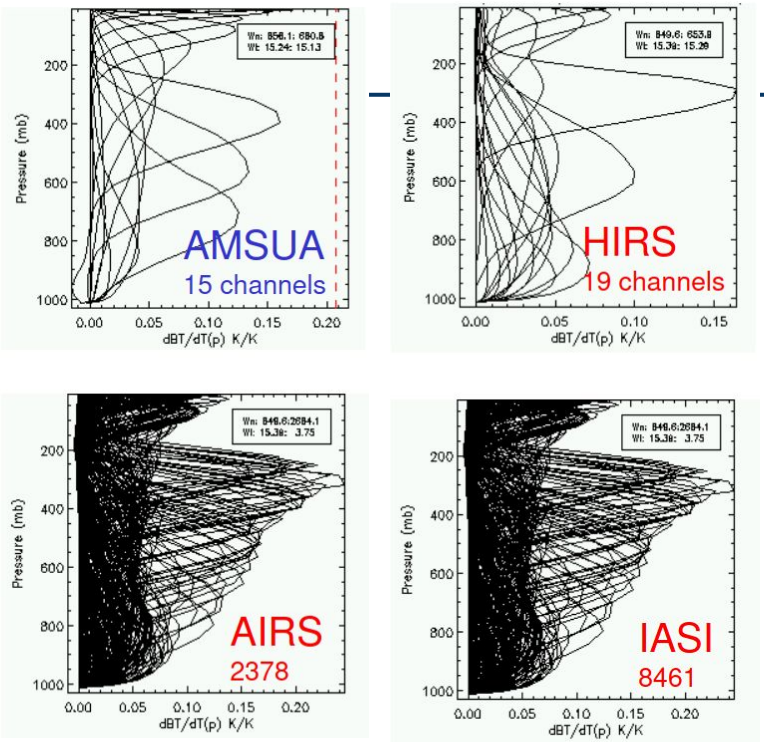
tempo

Seleção de canais

$$L(\nu) = \int_0^\infty B(\nu, T(z))\, \boldsymbol{H(z)}dz$$

Função peso

○ canais de sondagem
○ sensíveis a superfície



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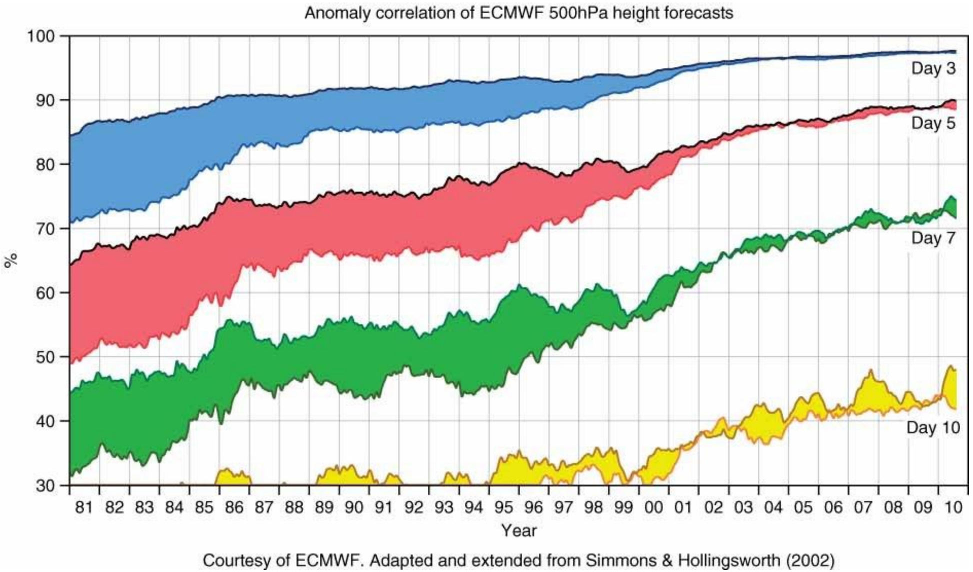
Impacto

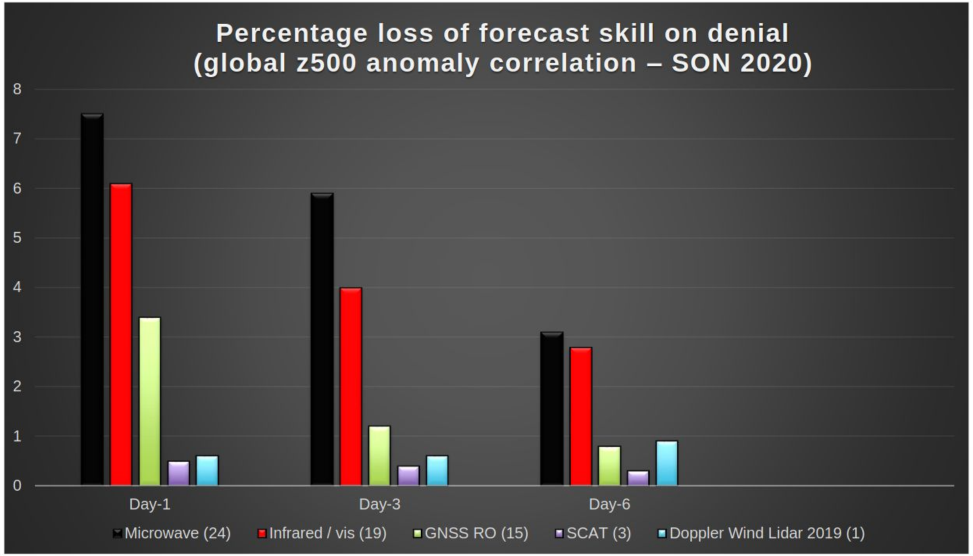
Qual a importância desses dados?



Collard et al., 2011
https://doi.org/10.1002/wea.736

Impacto

Quais são as observações de satélites mais importantes para a PNT?



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Impacto

Podemos quantificar?

Impacto

Podemos quantificar?

Sim!

- DFS (Degree of Freedom for Signal)
- OSE (Observing System Experiments)
- OSSE (Observing System Simulation Experiments)
- FSO (Forecast Sensitivity to the Observations), EFSO, HFSO

Impacto

Podemos quantificar?

Sim!

- DFS (Degree of Freedom for Signal)
- **OSE (Observing System Experiments)**
- OSSE (Observing System Simulation Experiments)
- FSO (Forecast Sensitivity to the Observations), EFSO, HFSO

Motivação

PSAS → **G3DVAR**

PSAS ↓

Retrievals
medidas recuperadas

G3DVAR ↓

Radiâncias
medidas diretas

Observing System Experiments (OSE)

- Uso da Técnica de OSE para Avaliar o Impacto de Observações no Sistema de Assimilação de Dados Global Variacional Tridimensional do CPTEC/INPE

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

sid.inpe.br/mtc-m18/2014/05.07.17.54-TDI

USO DA TÉCNICA DE OSE PARA AVALIAR O IMPACTO DE OBSERVAÇÕES NO SISTEMA DE ASSIMILAÇÃO DE DADOS GLOBAL VARIACIONAL TRIDIMENSIONAL DO CPTEC/INPE

Helena Barbieri de Azevedo

Dissertação de Mestrado do Curso de Pós-Graduação em Meteorologia, orientada pelo Dr. Luis Gustavo Gonçalves de Gonçalves, aprovada em 16 de maio de 2014.

URL do documento original:
<http://urlib.net/8JMKD3MGP8W/3G9DDAL>

INPE
São José dos Campos
2014

Observing System Experiments in a 3DVAR Data Assimilation System at CPTEC/INPE

HELENA BARBIERI DE AZEVEDO, LUIS GUSTAVO GONÇALVES DE GONÇALVES, CARLOS FREDERICO BASTARZ, AND BRUNA BARBOSA SILVEIRA

Instituto Nacional de Pesquisas Espaciais, Cachoeira Paulista, São Paulo, Brazil

(Manuscript received 1 December 2015, in final form 15 December 2016)

ABSTRACT

The Center for Weather Forecast and Climate Studies [Centro de Previsão e Tempo e Estudos Climáticos (CPTEC)] at the Brazilian National Institute for Space Research [Instituto Nacional de Pesquisas Espaciais (INPE)] has recently operationally implemented a three-dimensional variational data assimilation (3DVAR) scheme based on the Gridpoint Statistical Interpolation analysis system (GSI). Implementation of the GSI system within the atmospheric global circulation model from CPTEC/INPE (AGCM-CPTEC/INPE) is hereafter referred to as the Global 3DVAR (G3DVAR) system. The results of an observing system experiment (OSE) measuring the impacts of radiosonde, satellite radiance, and GPS radio occultation (RO) data on the new G3DVAR system are presented here. The observational impact of each of these platforms was evaluated by measuring the degradation of the geopotential height anomaly correlation and the amplification of the RMSE of the wind. Losing the radiosonde, GPS RO, and satellite radiance data in the OSE resulted in negative impacts on the geopotential height anomaly correlations globally. Nevertheless, the strongest impacts were found over the Southern Hemisphere and South America when satellite radiance data were withheld from the data assimilation system.

1. Introduction

The Center for Weather Forecast and Climate Studies [Centro de Previsão de Tempo e Estudos Climáticos (CPTEC)] at the Brazilian National Institute for Space Research [Instituto Nacional de Pesquisas Espaciais (INPE)] recently implemented the Gridpoint Statistical Interpolation analysis system (GSI; Wu et al. 2002; Kleist et al. 2009) [with a three-dimensional variational data assimilation (3DVAR) approach] in the CPTEC/INPE atmospheric global circulation model (AGCM-CPTEC/INPE). This implementation of the GSI system, known as the Global 3DVAR (G3DVAR) system, has been operational since January 2013 and initializes AGCM-CPTEC/INPE forecasts on a global grid every 6 h. This implementation of the GSI system has replaced the Physical-space Statistical Analysis System (PSAS; Cohn et al. 1998), which was previously used to initialize the AGCM-CPTEC/INPE. The transition to the GSI system has increased the maximum number of observations we can assimilate into our model and has provided the ability to assimilate satellite radiance data.

Since numerical weather prediction (NWP) is an initial value problem, the data assimilation process used to initialize forecasting models can have a significant impact on the quality of forecasts. Data assimilation is the process of combining observed data with short-range forecasts, therein considering the errors in the observations and errors associated with the numerical model, to generate an optimal estimate of the current state of the atmosphere (Talagrand 1997; Tsuyuki and Miyoshi 2007; Herdies et al. 2008). The information in the observing systems (i.e., the quantity and quality of the observations) plays a key role in the data assimilation process; it impacts the resulting analysis and consequently affects the quality of the forecasts. The resulting forecasts should benefit from a careful evaluation of how the different observing systems impact the NWP system since the inclusion of certain observations may degrade the forecasts. Furthermore, knowledge of which datasets provide better estimates of weather conditions can be used to optimize data assimilation systems by improving the process of selecting observations that contribute positively to the analysis.

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DOI: 10.1175/WAF-D-15-0168.1

Experimentos

Descrição	MCGA/CPTEC
Configuração do modelo	T299L64
Resolução horizontal	44km
Resolução vertical	64 níveis

- MCGA CPTEC/INPE
- Gridpoint Statistical Interpolation (GSI) - 3DVar
- G3DVAR
- ~~dezembro de 2012~~ e janeiro de 2013

Observações convencionais	Radiâncias de satélites/ Temperatura de brilho
Radiossondas	SBUV: n17, n18, n19
Vento sintético	GOES_IMG: g11, g12
Balão Piloto	HIRS: metop-a, metop-b, n17, n19
Perfiladores de vento	AIRS:aqua
Aeronaves	AMSU-A: metop-a, metop-b, n15, n18, n19
Dropsonda	AMSU-B: metop-b, n17
Vento por satélite	MHS: metop-a, metop-b, n18, n19
Precipitação estimada por satélite	SSMI: f14, f15
Vento por radar	SSMIS: f16
Velocidade radial Dopler	AMSRE: aqua
GPS radio ocultação	ATMS: NPP
GPS água precipitável	SNDR: g12
Observações sobre superficie continental	CRIS: NPP
Observações sobre superfície oceânica	IASI: metop-a, metop-b
Ozônio	GOME: metop-a, metop-b
	OMI: aura
	SEVIR: m08, m09, m10

Experimentos

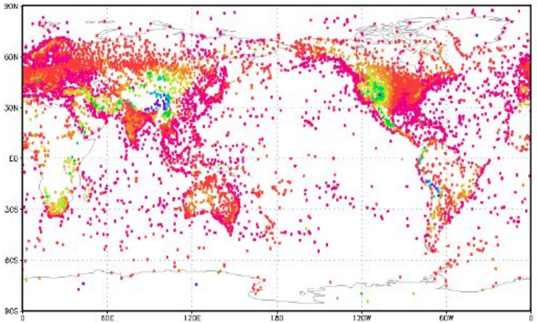
- Análises e previsões (120h)
- Data denial experiments
- Observing system experiments
- RMSE
- Correlação de anomalia
- Estudo de caso

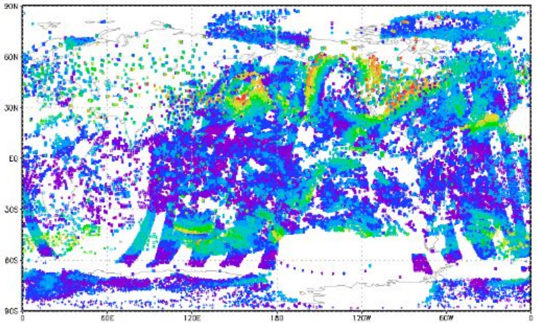
Descrição	CTRL	NO_RAD	NO_SAT	NO_GPS
Radiossonda	•	-	•	•
Dropsonda	•	•	•	•
Balão Piloto	•	•	•	•
Perfiladores	•	•	•	•
Superfície Continental	•	•	•	•
Aeronave	•	•	•	•
Vento por Satélite	•	•	•	•
Superfície Oceanica	•	•	•	•
Sintéticos	•	•	•	•
Vento por Radar	•	•	•	•
GPS RO	•	•	•	-
AMSU-A *	•	•	-	•
MHS *	•	•	-	•
HIRS-4 *	•	•	-	•
IASI *	•	•	-	•
AIRS *	•	•	-	•

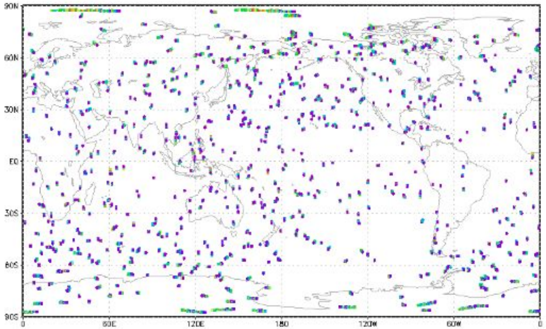
*dados de radiâncias

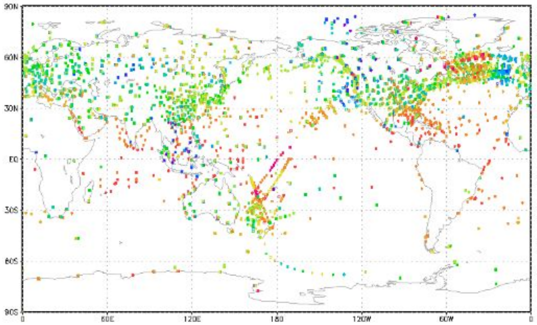
Dados

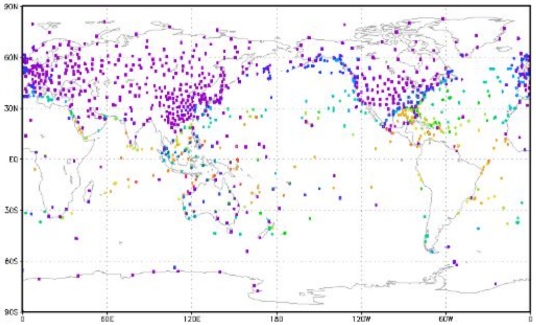
- pressão em superfície
- componente zonal e meridional do vento
- refratividade
- temperatura
- umidade





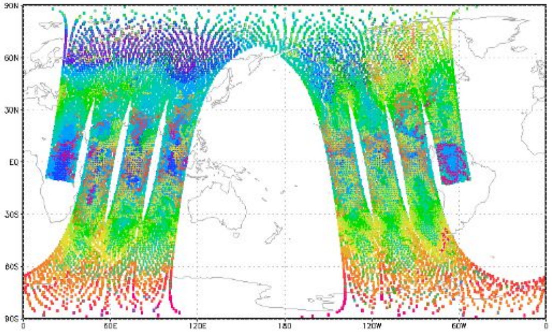


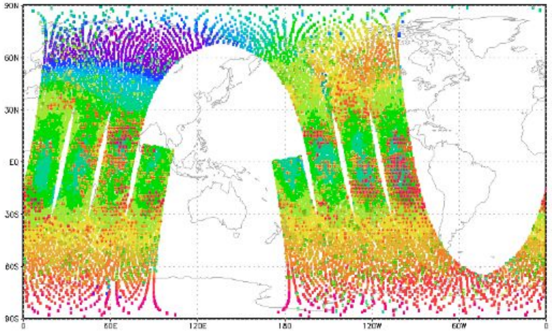


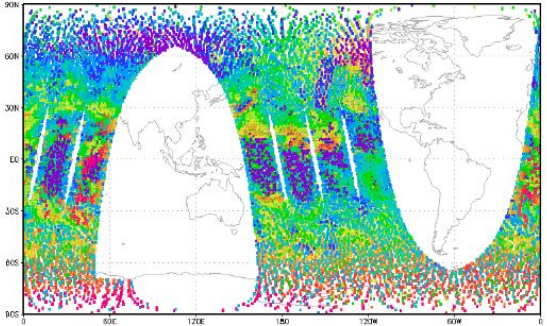


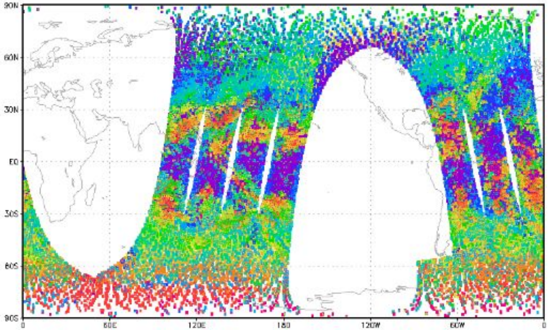
Dados

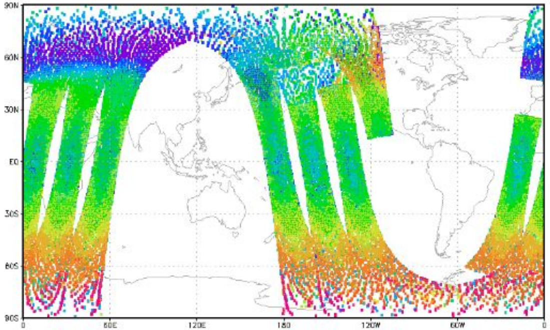
- NOAA-15
- NOAA-18
- NOAA-19
- METOP-A
- AQUA



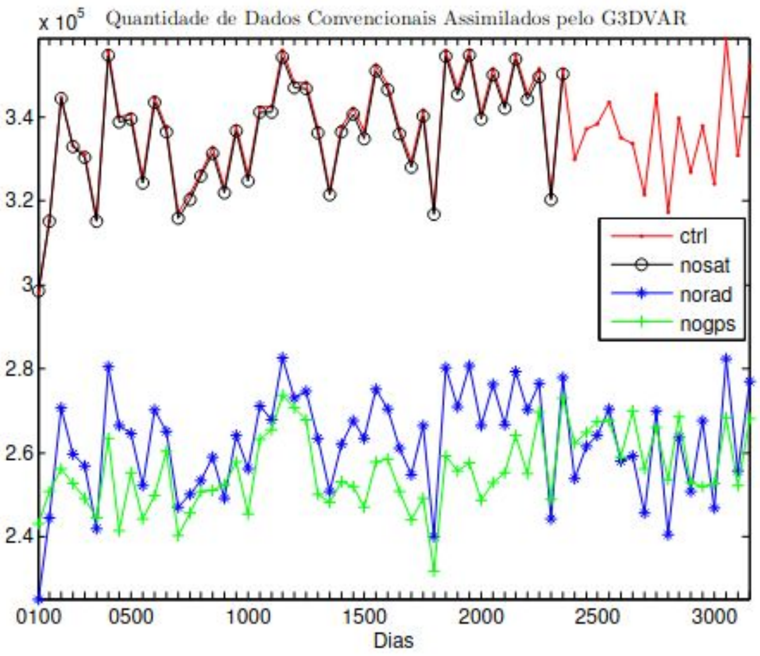


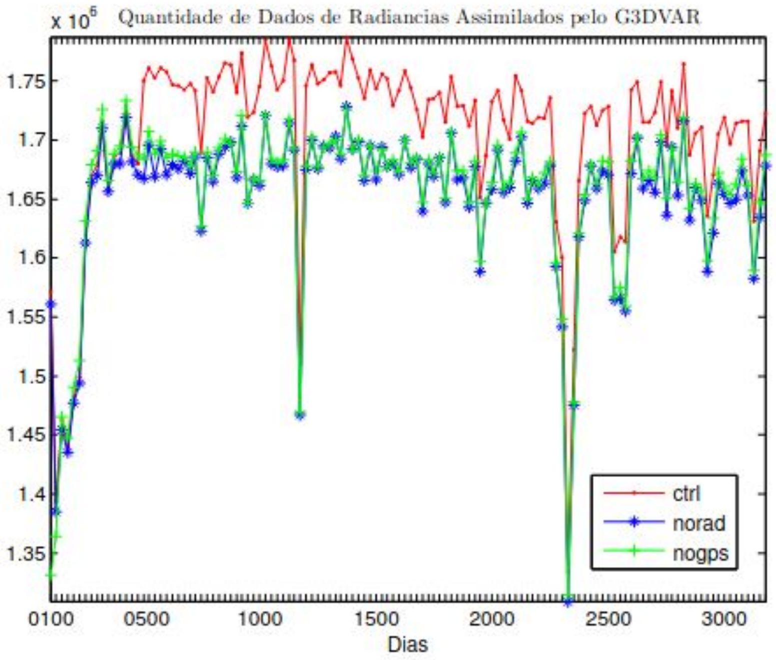




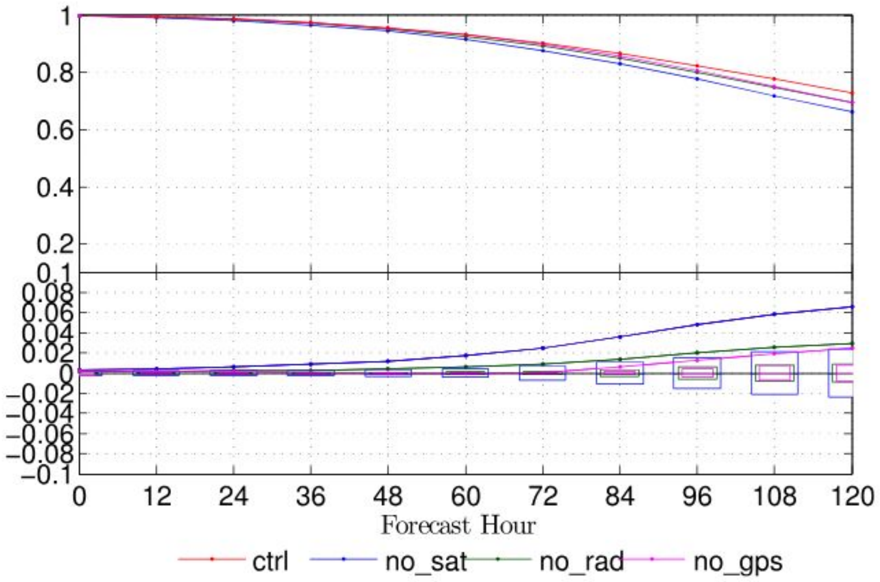


Dados


x 10^5
Quantidade de Dados Convencionais Assimilados pelo G3DVAR
3.4
3.2
3
2.8
2.6
2.4
ctrl
nosat
norad
nogps
0100
0500
1000
1500
2000
2500
3000
Dias


x 10^6
Quantidade de Dados de Radiancias Assimilados pelo G3DVAR
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
ctrl
norad
nogps
0100
0500
1000
1500
2000
2500
3000
Dias

Resultados



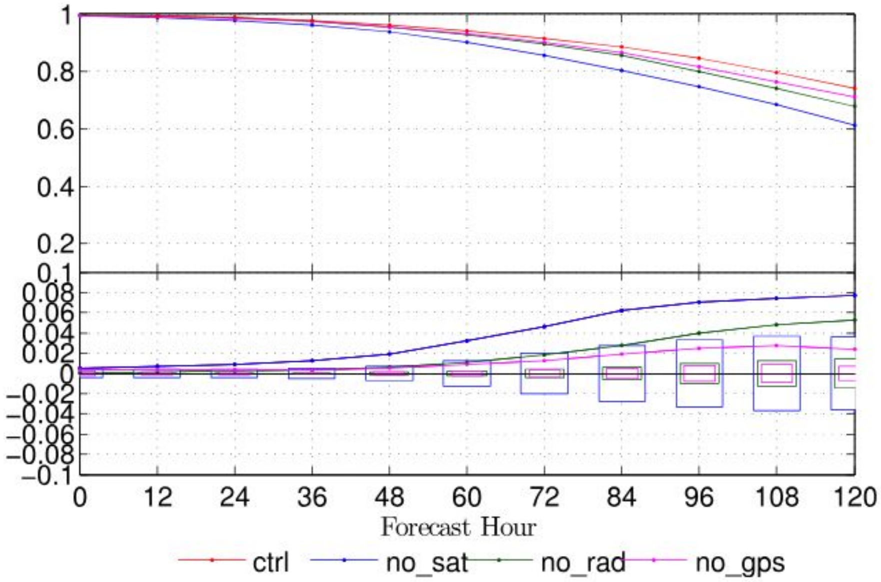


FIG. 4. As in Fig. 1, but for the SAAO.

Resultados

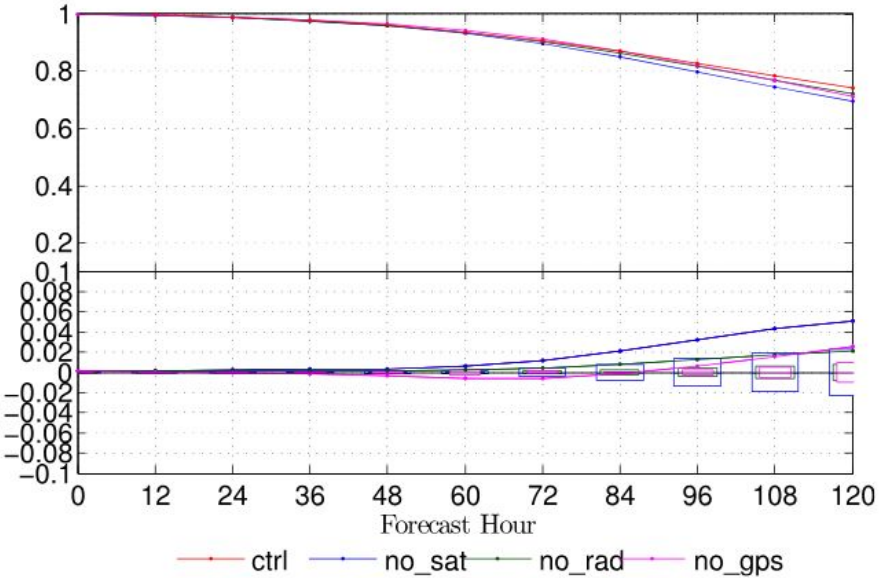


FIG. 2. As in Fig. 1, but for the NH.

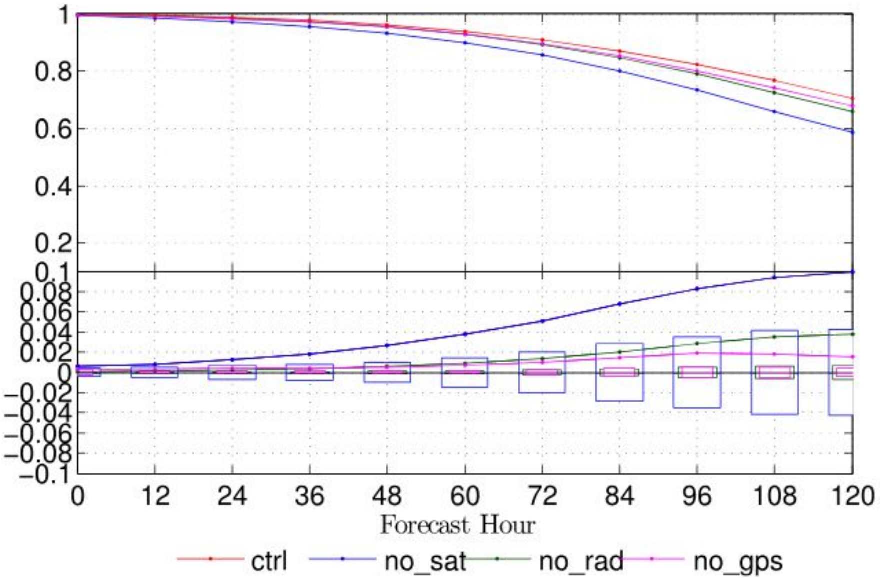


FIG. 3. As in Fig. 1, but for the SH.

Resultados

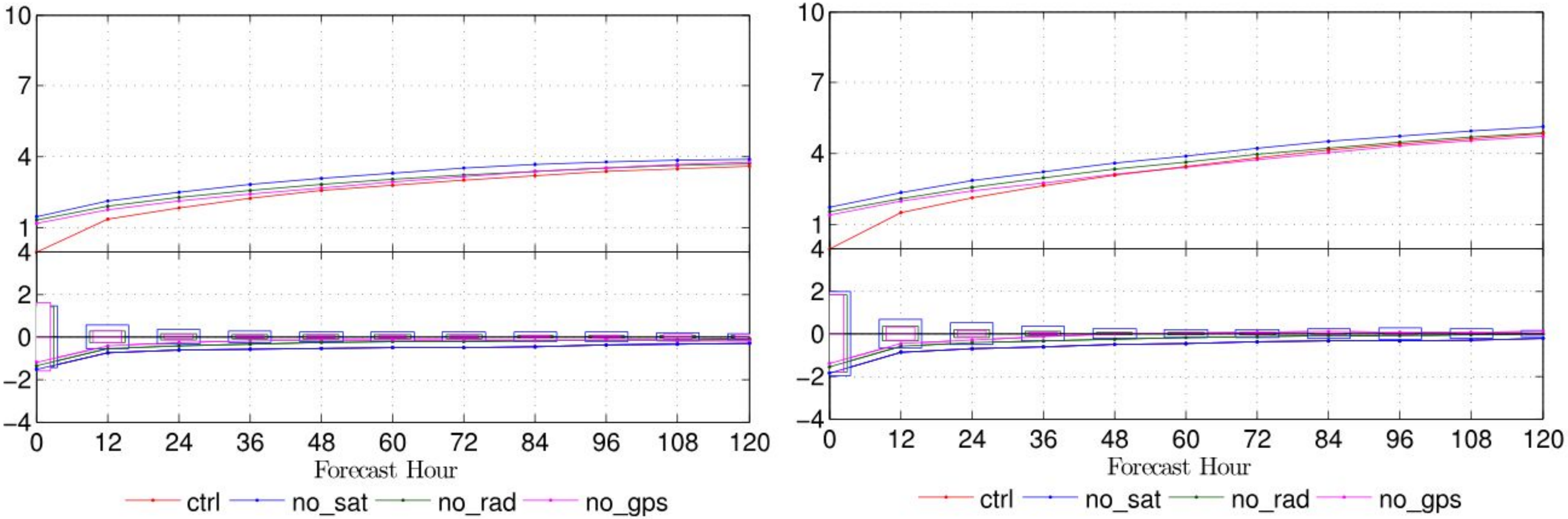


FIG. 7. As in Fig. 5, but for the meridional wind at 850 hPa.

Resultados

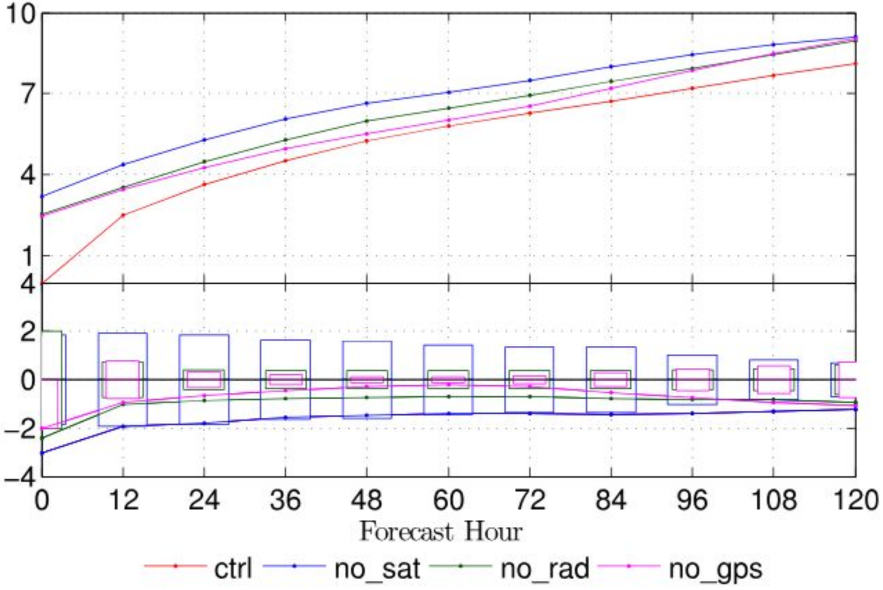


FIG. 8. As in Fig. 5, but for the meridional wind at 250 hPa.

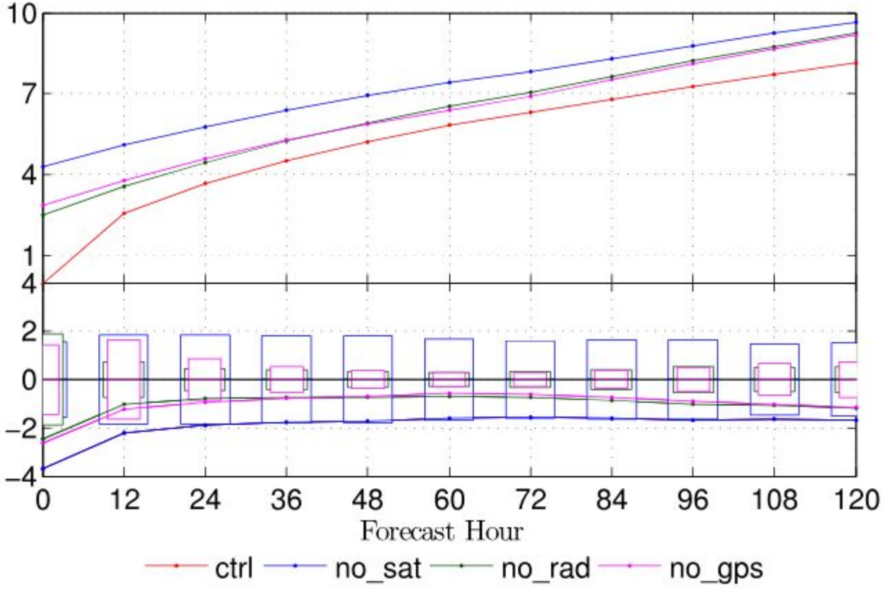
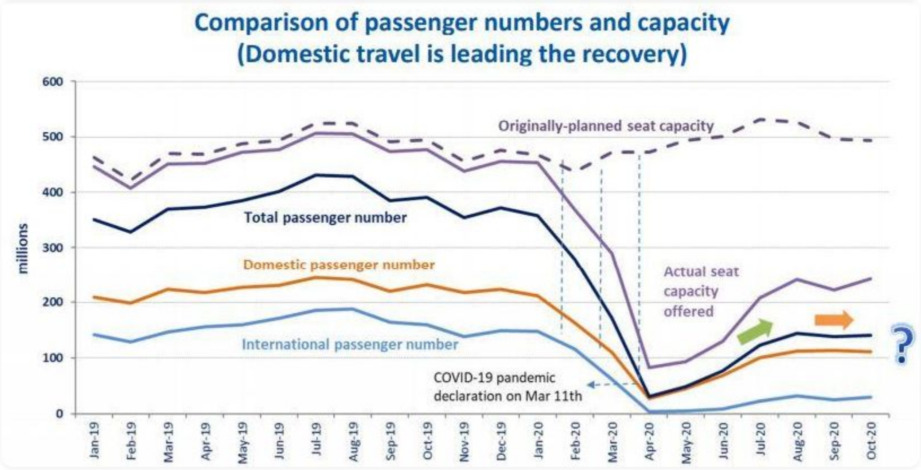
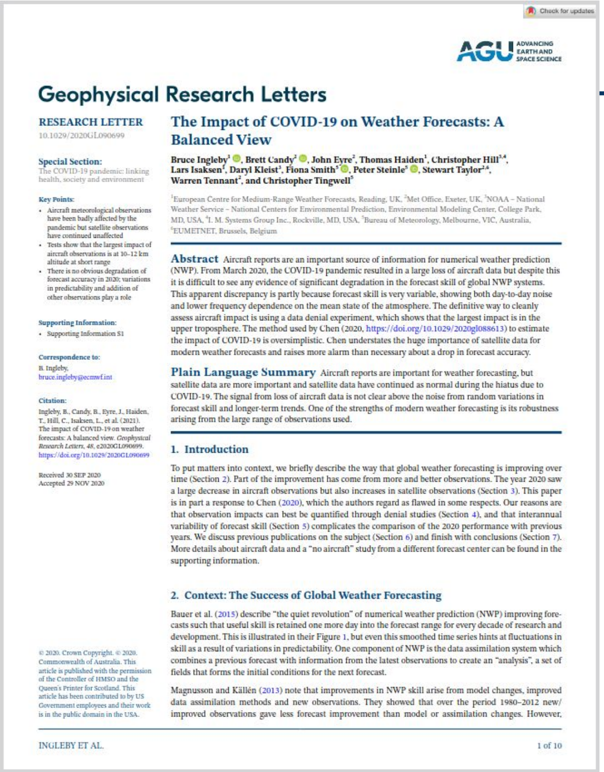


FIG. 6. As in Fig. 5, but for the zonal wind at 250 hPa.

Covid-19



https://www.netweather.tv/weather-forecasts/news/10584-the-impact-of-covid-19-on-weather-observations-used-by-weather-models



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Geophysical Research Letters

RESEARCH LETTER
10.1029/2020GL090699

The Impact of COVID-19 on Weather Forecasts: A Balanced View

Bruce Ingleby[1], Brett Candy[2], John Eyre[2], Thomas Haiden[1], Christopher Hill[3,4], Lars Isaksen[1], Daryl Kleist[3], Fiona Smith[5], Peter Steinle[5], Stewart Taylor[2,6], Warren Tennant[2], and Christopher Tingwell[5]

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Special Section:
The COVID-19 pandemic: linking health, society and environment

Key Points:

- Aircraft meteorological observations have been badly affected by the pandemic but satellite observations have continued unaffected
- Tests show that the largest impact of aircraft observations is at 10–12 km altitude at short range
- There is no obvious degradation of forecast accuracy in 2020; variations in predictability and addition of other observations play a role

Supporting Information:

- Supporting Information S1

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Abstract Aircraft reports are an important source of information for numerical weather prediction (NWP). From March 2020, the COVID-19 pandemic resulted in a large loss of aircraft data but despite this it is difficult to see any evidence of significant degradation in the forecast skill of global NWP systems. This apparent discrepancy is partly because forecast skill is very variable, showing both day-to-day noise and lower frequency dependence on the mean state of the atmosphere. The definitive way to cleanly assess aircraft impact is using a data denial experiment, which shows that the largest impact is in the upper troposphere. The method used by Chen (2020, https://doi.org/10.1029/2020gl088613) to estimate the impact of COVID-19 is oversimplistic. Chen understates the huge importance of satellite data for modern weather forecasts and raises more alarm than necessary about a drop in forecast accuracy.

Plain Language Summary Aircraft reports are important for weather forecasting, but satellite data are more important and satellite data have continued as normal during the hiatus due to COVID-19. The signal from loss of aircraft data is not clear above the noise from random variations in forecast skill and longer-term trends. One of the strengths of modern weather forecasting is its robustness arising from the large range of observations used.

1. Introduction

To put matters into context, we briefly describe the way that global weather forecasting is improving over time (Section 2). Part of the improvement has come from more and better observations. The year 2020 saw a large decrease in aircraft observations but also increases in satellite observations (Section 3). This paper is in part a response to Chen (2020), which the authors regard as flawed in some respects. Our reasons are that observation impacts can best be quantified through denial studies (Section 4), and that interannual variability of forecast skill (Section 5) complicates the comparison of the 2020 performance with previous years. We discuss previous publications on the subject (Section 6) and finish with conclusions (Section 7). More details about aircraft data and a "no aircraft" study from a different forecast center can be found in the supporting information.

2. Context: The Success of Global Weather Forecasting

Bauer et al. (2015) describe "the quiet revolution" of numerical weather prediction (NWP) improving forecasts such that useful skill is retained one more day into the forecast range for every decade of research and development. This is illustrated in their Figure 1, but even this smoothed time series hints at fluctuations in skill as a result of variations in predictability. One component of NWP is the data assimilation system which combines a previous forecast with information from the latest observations to create an "analysis", a set of fields that forms the initial conditions for the next forecast.

Magnusson and Källén (2013) note that improvements in NWP skill arise from model changes, improved data assimilation methods and new observations. They showed that over the period 1980–2012 new/improved observations gave less forecast improvement than model or assimilation changes. However,

Ingleby et al., 2020
https://doi.org/10.1029/2020GL090699

Covid-19

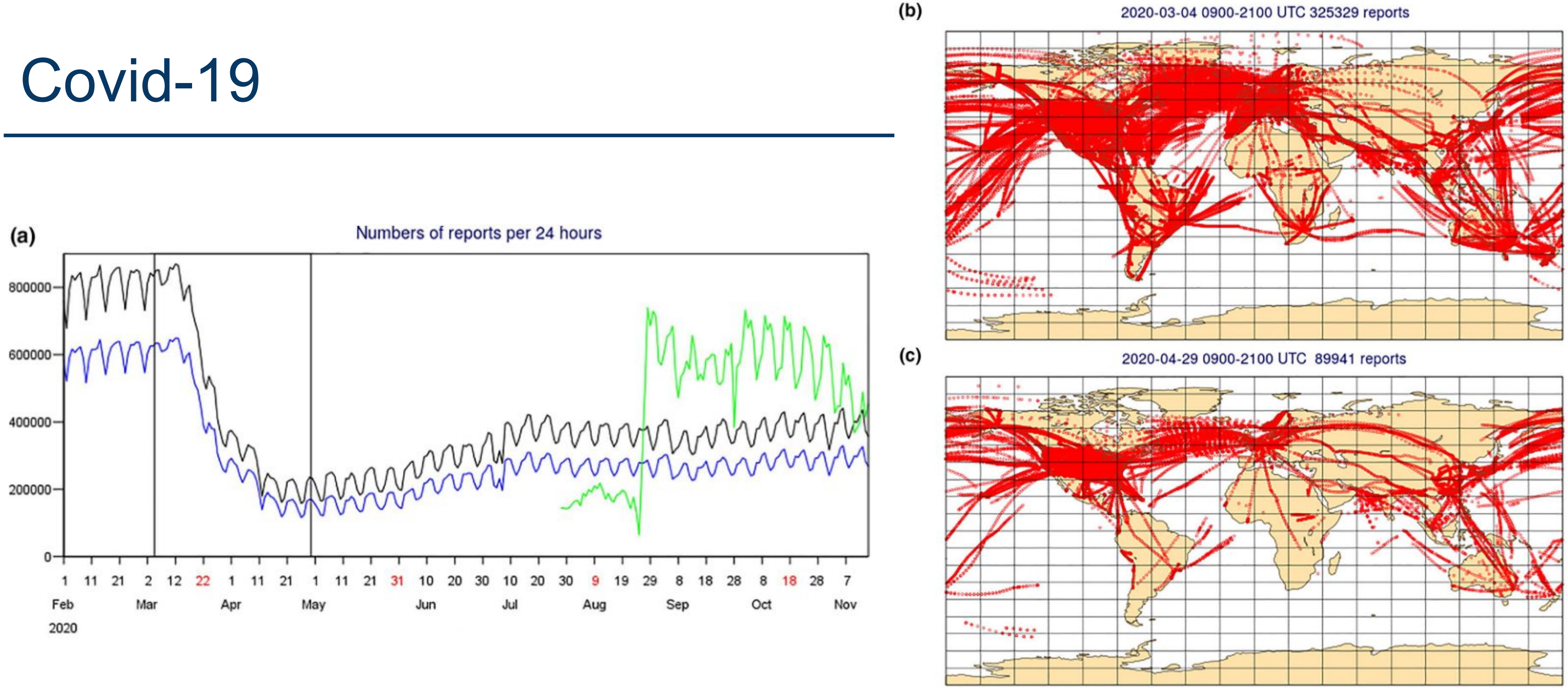
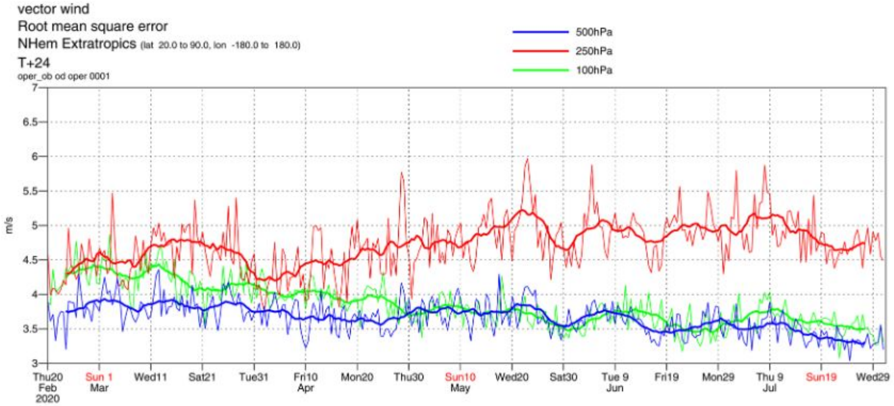
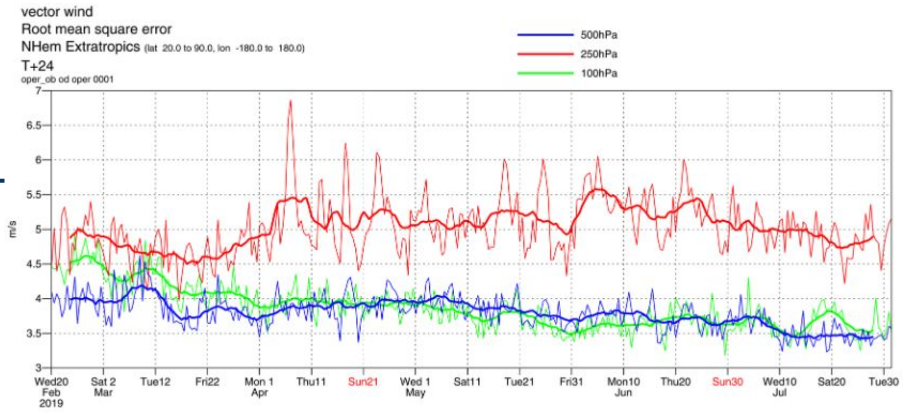


Figure 1. (a) Number of aircraft wind reports processed (black) and used (blue) at ECMWF—excluding Mode-S, green line shows the number of used Mode-S winds. The vertical lines show the dates used in (b) and (c). (b) and (c) Positions of used aircraft reports in a 12-h period (09-21 UTC) on 2020-03-04 and 2020-04-29, respectively.

Covid-19





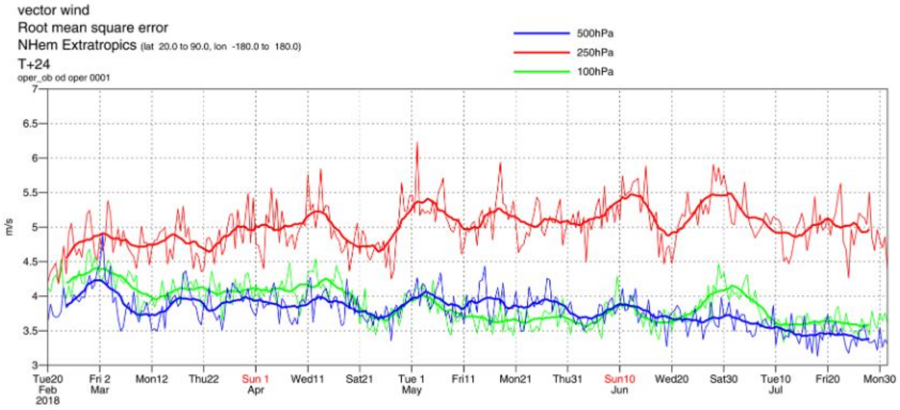


Figure 3. Verification of operational ECMWF 24-h wind forecasts for 20°N-90°N against analyses at three levels for 2018 (bottom), 2019 (middle), and 2020 (top). The thin lines show values every 12 h, the thick lines a 7-day running mean.

Covid-19

- Radiossondas extras
- Aeolus (janeiro)
- Mode-S aircraft
- RO COSMIC-2 (março)

Dúvidas?

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sala 18.19