Uncertainty in Operational Atmospheric Analyses

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Objectives/ of Study

1. **Quantify the uncertainty (differences) in current operational analyses of the atmosphere – height, temperature, winds**

2. **Consider implications of analysis uncertainty for NWP and plans for the future global observing network**

Analysis differences are a proxy for actual analysis error, which cannot be precisely quantified

Significance of Analysis Uncertainty/Error

- **Quality of NWP forecasts from short to medium-range**
- **Extended-range NWP?**
- **Short-range climate forecasts?**
- **Quality of forecast verification**
- **Accuracy of climate monitoring**

Can be a Misunderstood Subject

Question asked to a prominent climate scientist: "Given that there are differences between various atmospheric temperature re-analyses, does that uncertainty affect your ability to detect global climate trends?"

Answer: "There is only one correct analysis of the atmosphere and that is the one that we will use"

Causes of Analysis Differences and Error

- **Gaps/deficiencies in global observing network**
- **Errors /bias in observation data**
- **Choices in observation selection**
- **Observation quality control decisions**
- **Different and imperfect data assimilation techniques**
- **Errors in background forecast**

Methodology

- **Use multi-year, multi-model archive of operational analyses and forecasts, developed at NRL for research and diagnostic studies**
- **Quantify and examine differences in atmospheric analyses, trends over time …**
- **Examine systematic (monthly/seasonal) patterns**

Surprisingly sparse literature on the topic of atmospheric analysis uncertainty and error

Scholarly articles for **uncertainty in atmospheric analyses**
... of **analysis uncertainty** upon regional **atmospheric** ... - Wang - Cited by 60
Uncertainty analysis of climate change and policy ... - Webster - Cited by 195
On the assessment and **uncertainty** of **atmospheric** ... - Abrams - Cited by 42

[PDF] **Uncertainty in Atmospheric** CO2 Concentrations from a Paramet...
globalchange.mit.edu/files/document/MITJPSPGC_Rpt39.pdf
File Format: PDF/Adobe Acrobat - Quick View
Parametric **Uncertainty Analysis** of a Global Ocean Carbon Cycle Model. Gary Louis Holian. Submitted to the Department of Earth, **Atmospheric**, and Planetary ...

Uncertainty in atmospheric CO_2 predictions from a parametric ...
dspace.mit.edu/handle/1721.1/3565
by GL Holian - 2001 - Cited by 8 - Related articles
Uncertainty in atmospheric CO_2 predictions from a parametric **uncertainty analysis** of a global carbon cycle model. Show full item record. Citable URI: ...

Quantitative **uncertainty analyses** of ancient **atmospheric** CO2 ...
ajsonline.org/content/309/9/775.abstract
by DJ Beerling - 2009 - Cited by 9 - Related articles
Quantitative **uncertainty analyses** of ancient **atmospheric** CO2 estimates from fossil leaves. David J. Beerling*,†,; Andrew Fox* and; Clive W. Anderson** ...

Uncertainty in atmospheric temperature **analyses** | Langland | Tellus A
journals.sfu.ca/coaction/index.php/tellusa/article/view/15390
by RH Langland - 2008 - Cited by 9 - Related articles
This report illustrates and quantifies the unanticipated large **uncertainty** and differences in tropospheric temperature **analyses** within current global operational ...

Langland, Maue, Bishop, 2008: Tellus

[PDF] estimates, **uncertainty analysis**, and sensitivity **analysis** - ACP
www.atmos-chem-phys.net/11/2625/2011/acp-11-2625-2011.pdf
File Format: PDF/Adobe Acrobat - Quick View
by IMD Rosa - 2011 - Related articles
Atmospheric. Chemistry and Physics. **Atmospheric** emissions from vegetation fires in. Portugal (1990–2008): estimates, **uncertainty analysis**, and sensitivity ...

Uncertainty in atmospheric temperature **analyses** - LANGLAND ...
onlinelibrary.wiley.com › ... › Journal Home › Vol 60 Issue 4
by RH LANGLAND - 2008 - Cited by 9 - Related articles
Jul 8, 2008 – **Uncertainty in atmospheric** temperature **analyses**. ROLF H. LANGLAND1,*,; RYAN N. MAUE2,; CRAIG H. BISHOP1. Article first published ...

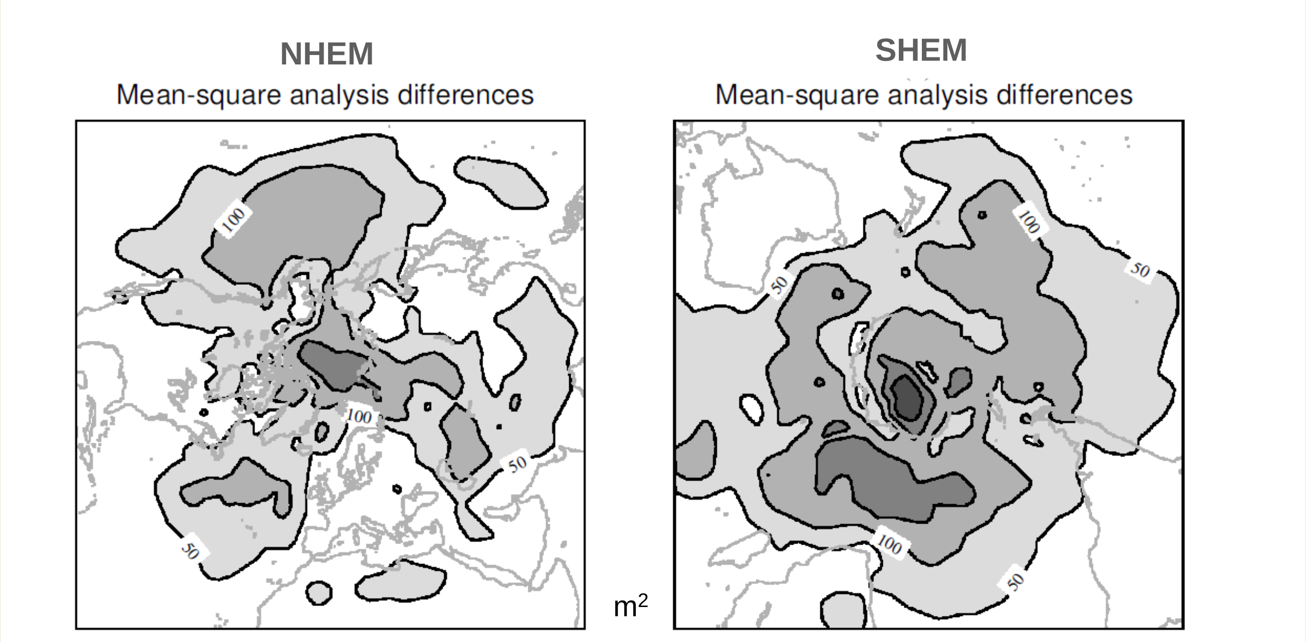
"Some aspects of the improvement in skill of numerical weather prediction, 2002: A.J. Simmons and A. Hollingsworth, QJRMS.

"Analysis differences and error variance estimates from multi-centre analysis data," 2010: M. Wei, Z. Toth, Y. Zhu, Aust. Met. and Ocean Journal.

Dec 2011 – WGNE presentation by Tom Hamill

ECWMF / Met Office
Analyses of 500hPa height

Simmons and Hollingsworth (2002)



From 12UTC analyses, 12Dec 2000 to 12 March 2001

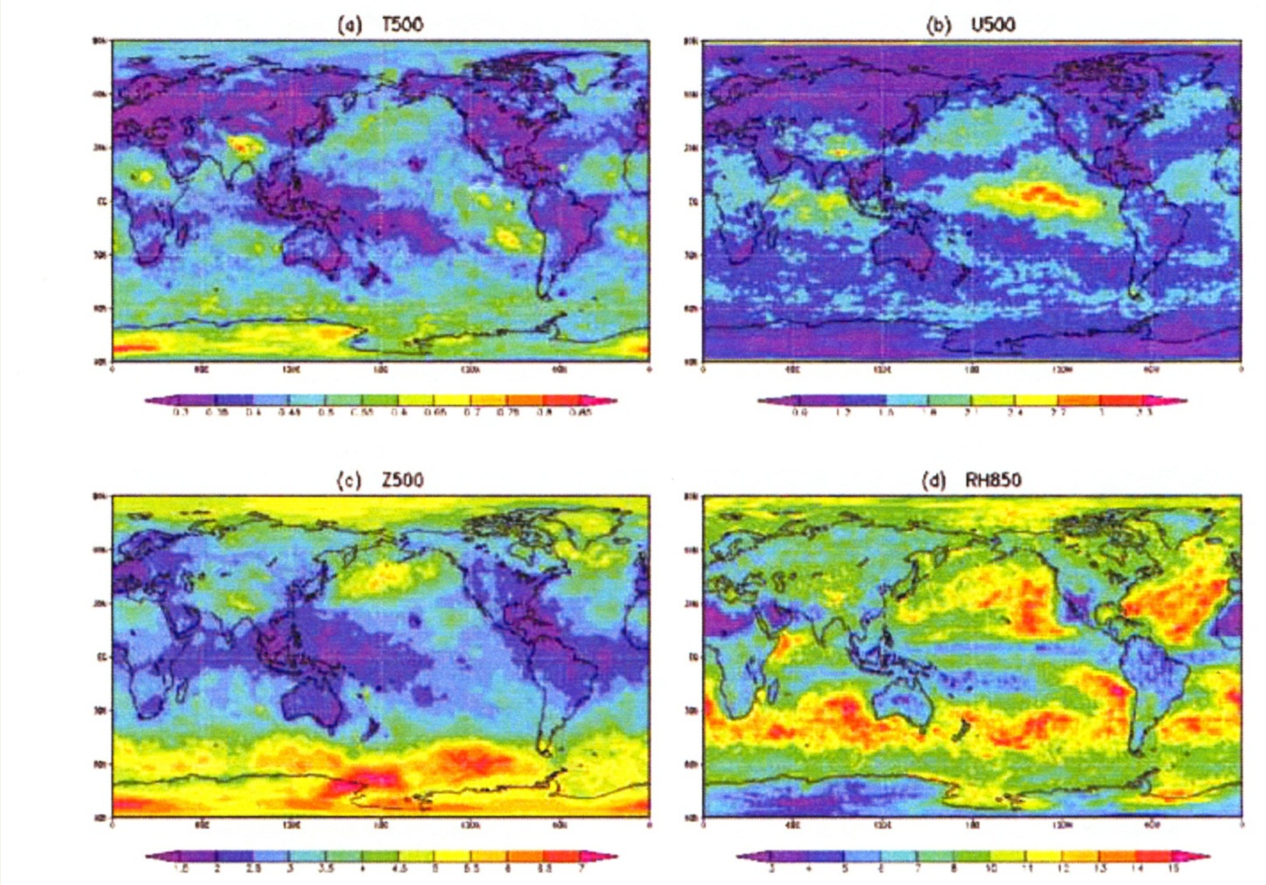
Analyses shown to be more similar in regions with in-situ observations (esp. radiosondes)

Analyses from NCEP, ECWMF, UKMO, CMC, FNMOC

00UTC: 1Feb 2008 to 30Apr 2008

Wei et al. (2010)

Time-averaged spread over the average anomaly



NEED LARGER NUMBERS ON COLOR BARS FOR ANALYSIS UNCERTAINTY PLOTS IN SLIDES 9-10-11

In general, smaller analysis spread in locations with in-situ observations (esp. raodiosondes, aircraft)

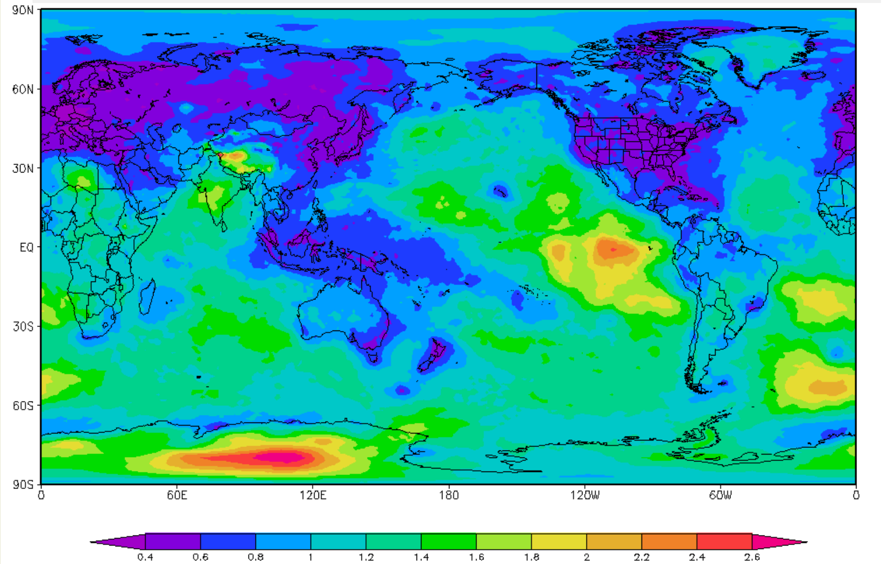
Analyses from NCEP, CMC, FNMOC

00UTC, 12UTC: 1Jan 2007 to 1Jun 2007

Langland et al. (2008)

500mb Temperature Analyses

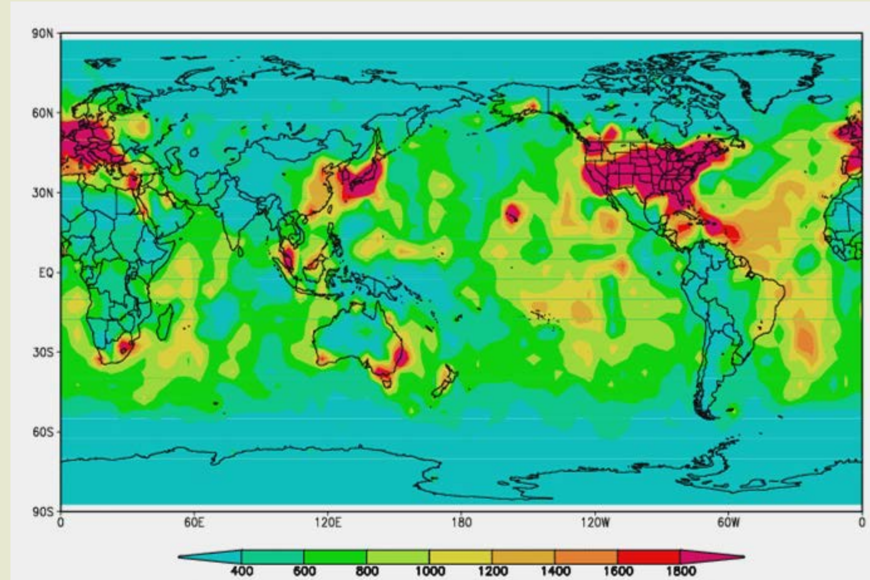
Root Mean Square Difference (CMC / AVN)



[RMS difference, K]

[proxy for analysis uncertainty]

Radiosonde observation count



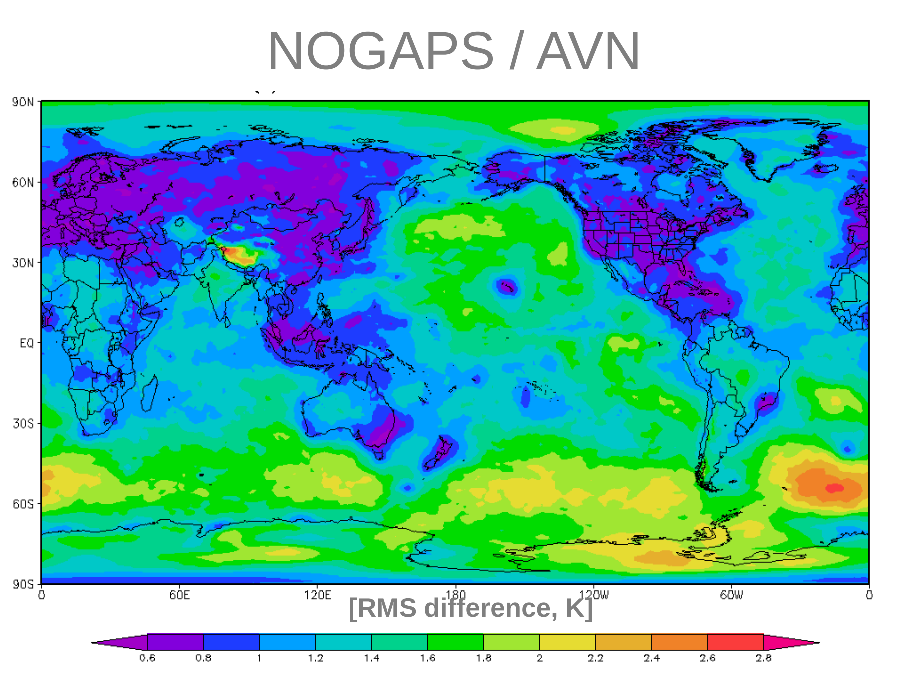
[Number of observations in 2° x 2° boxes]

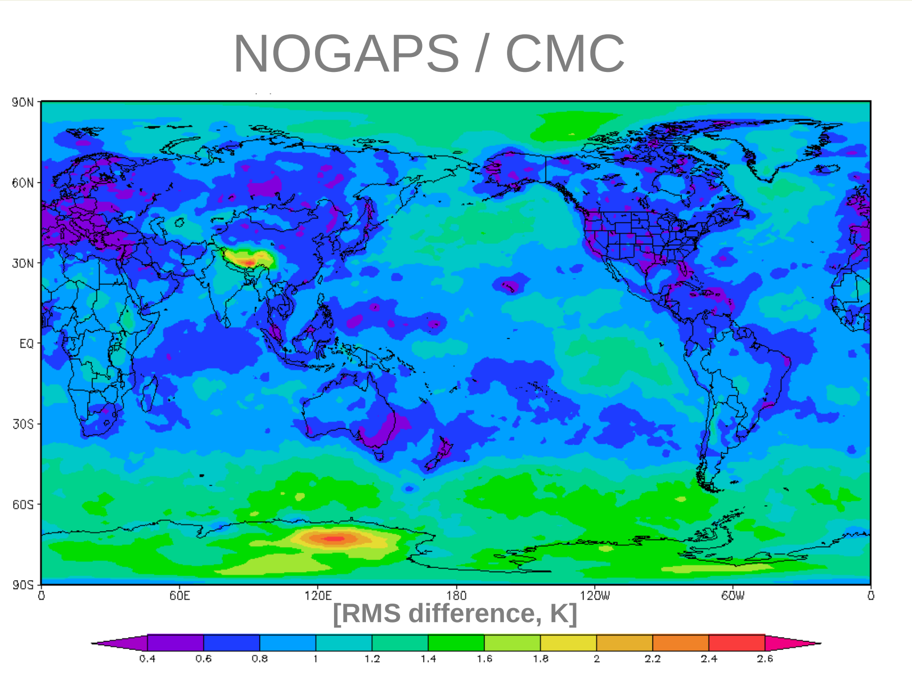
Indication that assimilation of high-quality in-situ observations (radiosondes, aircraft data) reduces analysis uncertainty more than assimilation of satellite observations (radiances and feature-track or scatterometer winds)

500mb Temperature Analyses

Root Mean Square Difference
1 Jan – 1 Jun 2007

Langland et al. (2008)





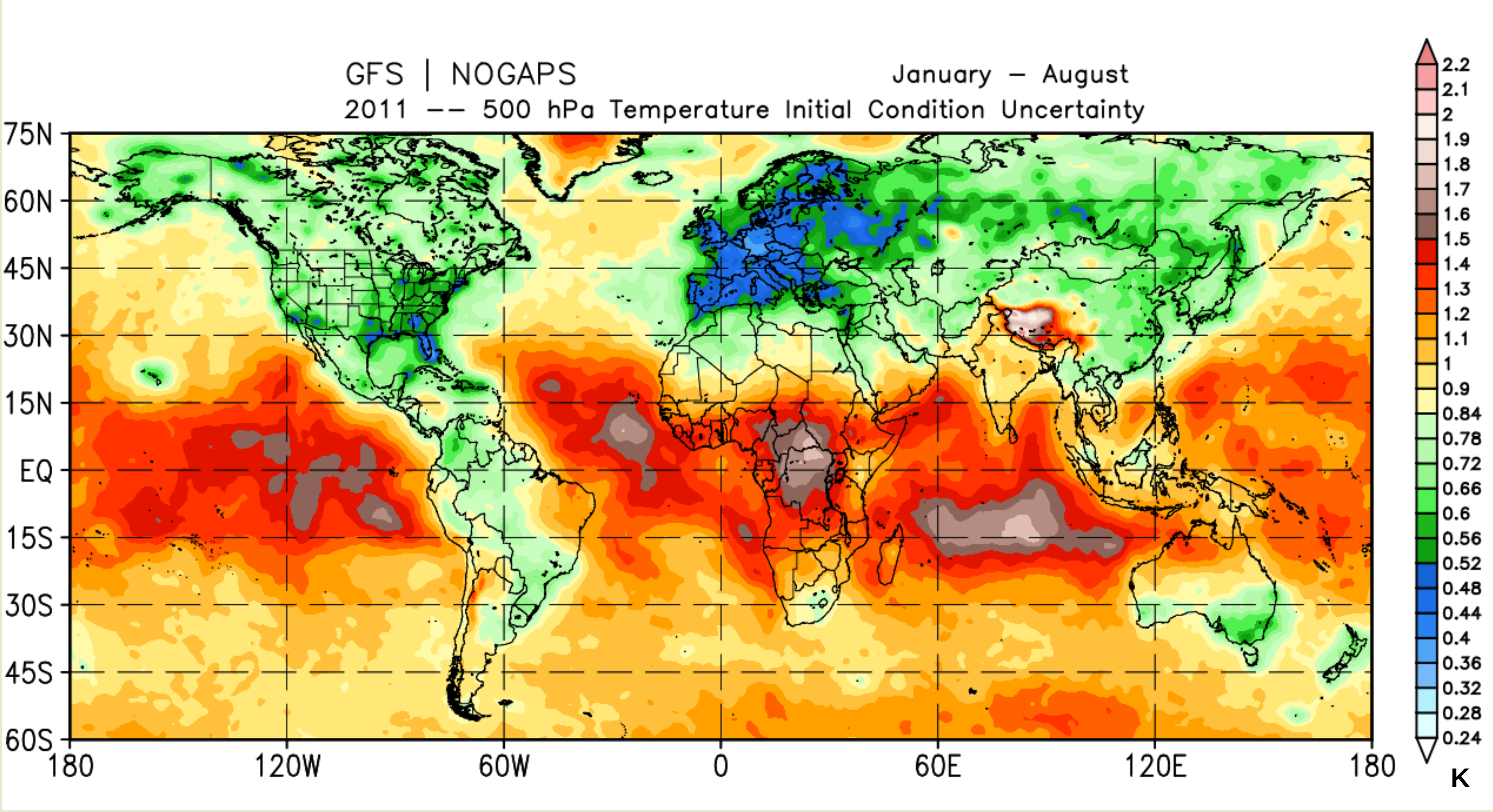
Smaller analysis uncertainty (<1K) where radiosonde data are provided
Larger uncertainty (1-2K) between analyses where satellite data predominates

UNCERTAINTY BETWEEN ANALYSES CAN BE LARGER THAN SHORT-RANGE "FORECAST ERROR" !!

2011: same pattern still in place!

[Many new radiance data have been added during 2007-2011]

Root-Mean Square of Analysis Differences: 500mb Temperature



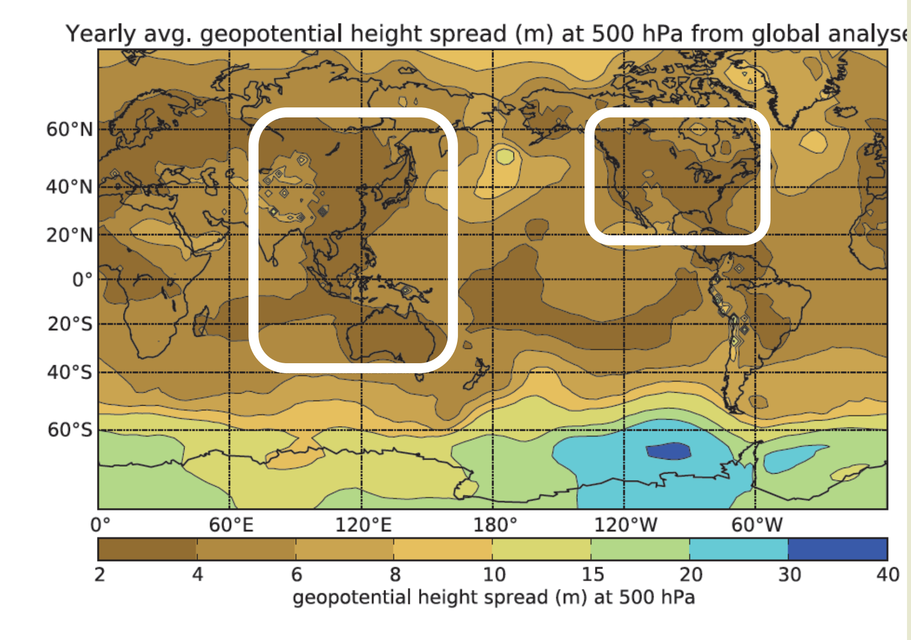
Langland and Maue 2011

Analyses from NCEP, ECWMF, UKMO, CMC, CMA

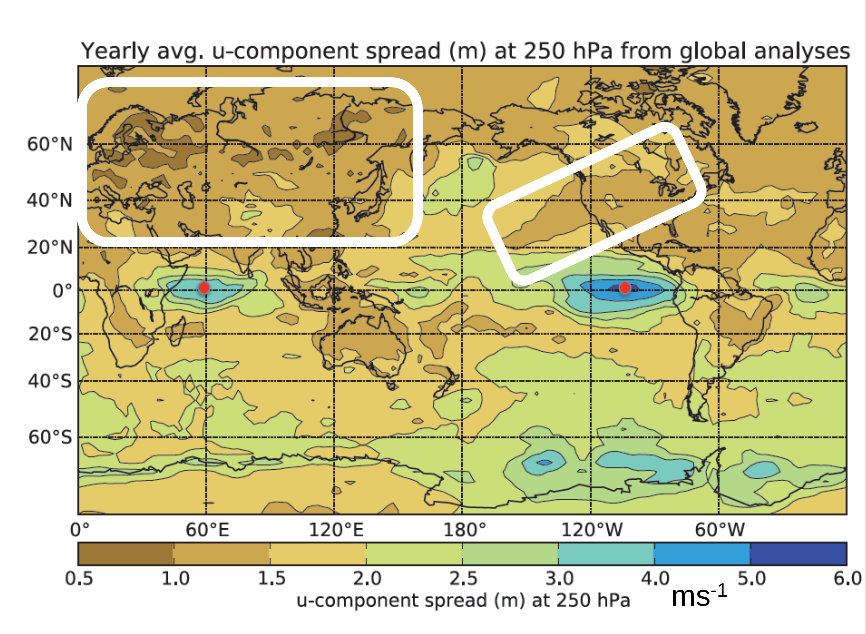
00UTC: 1OCT 2010 to 30Sep 2011

Hamill (WGNE, Dec 2011)

500 hPa height



250 hPa u-wind

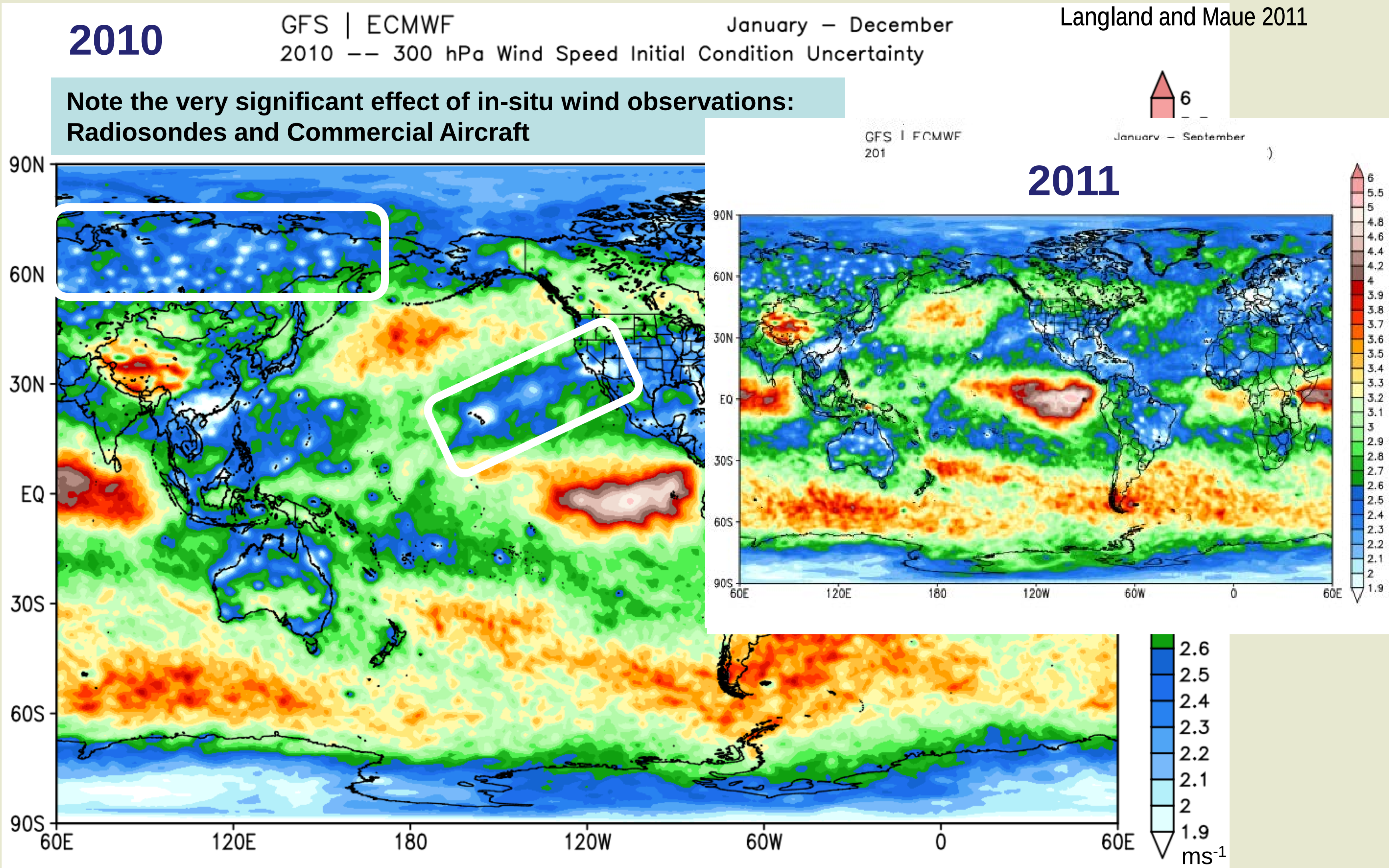


Time-average of daily spread (sample standard deviation) of analyses about their daily mean

“Analyses, assumed to be unbiased, do exhibit substantial bias Implications for ensemble perturbations (may be too small)”

300mb Wind Speed (2010)   GFS / ECMWF

Root-Mean Square of Analysis Differences: 300mb Wind Speed



Siberian Radiosonde Stations

A key component of the global observing network

Raob launch in Siberia

Radiosonde stations on the budget chopping block

Example: Eareckson Air Station (Shemya) 70414

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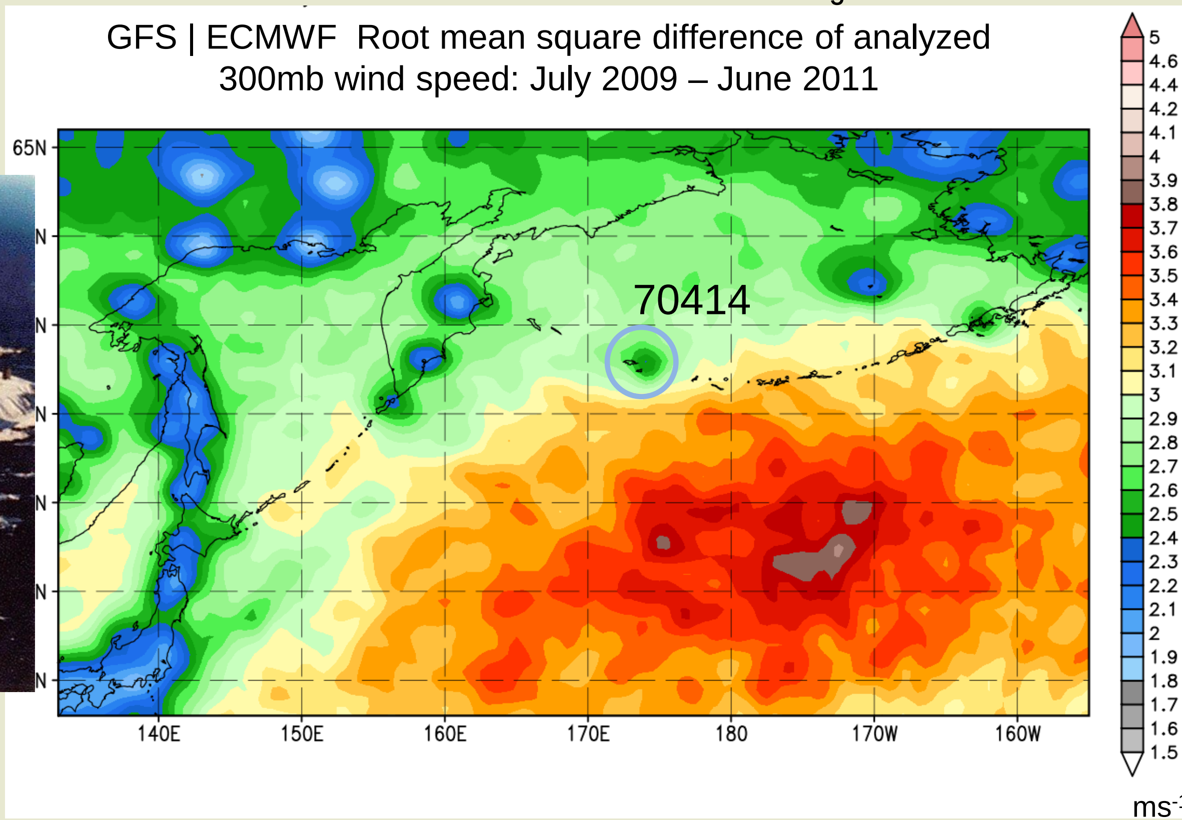
Shemya Island

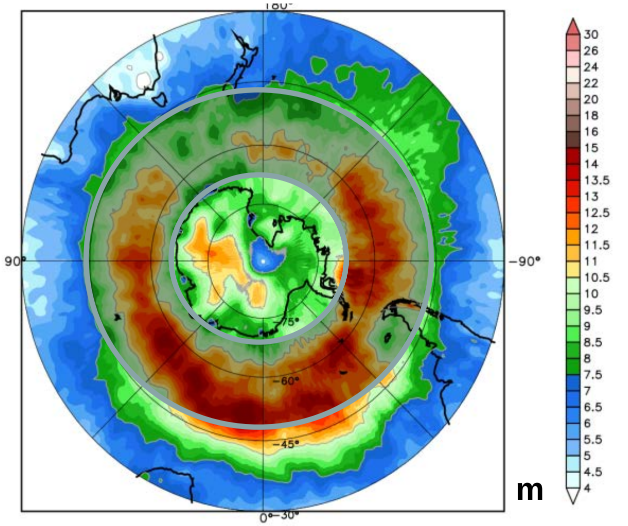


Unicertainty in atmospheric upper-tropospheric wind analyses is substantially lower in locations where radiosonde data is provided. The blue-shaded areas are locations where raobs provide soundings twice-daily (00z and 12z). Station 70414 provides data only at 12z, so the associated reduction in analysis error at that location is mitigated, but still significant.

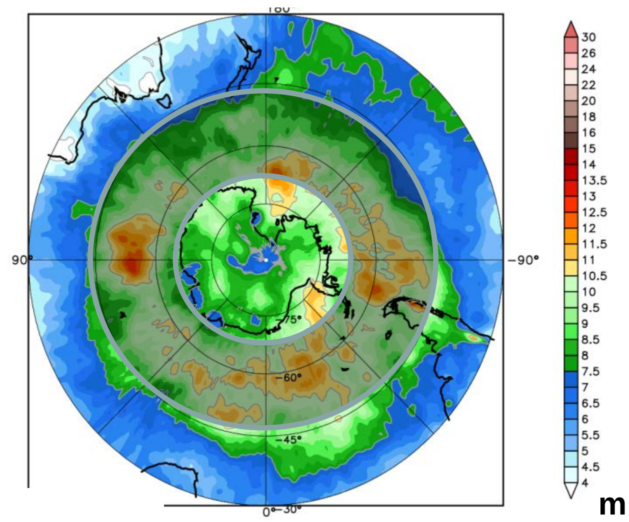
500mb ht root mean square analysis differences

South Polar Region: ECWMF | GFS

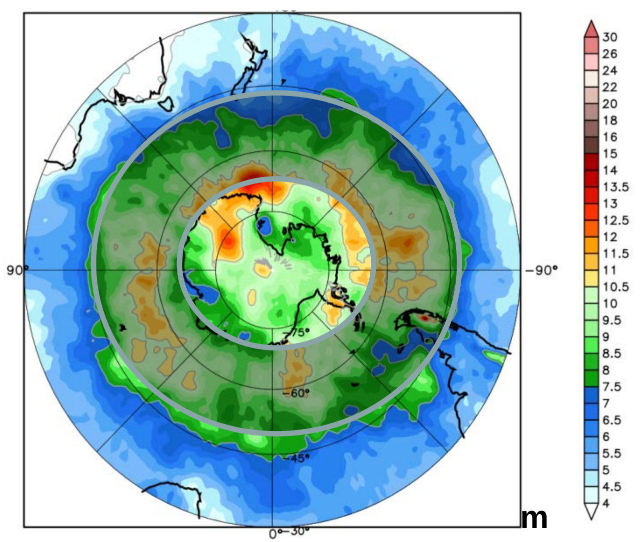
20Sep-20Dec 2008



20Sep-20Dec 2009



20Sep-20Dec 2010



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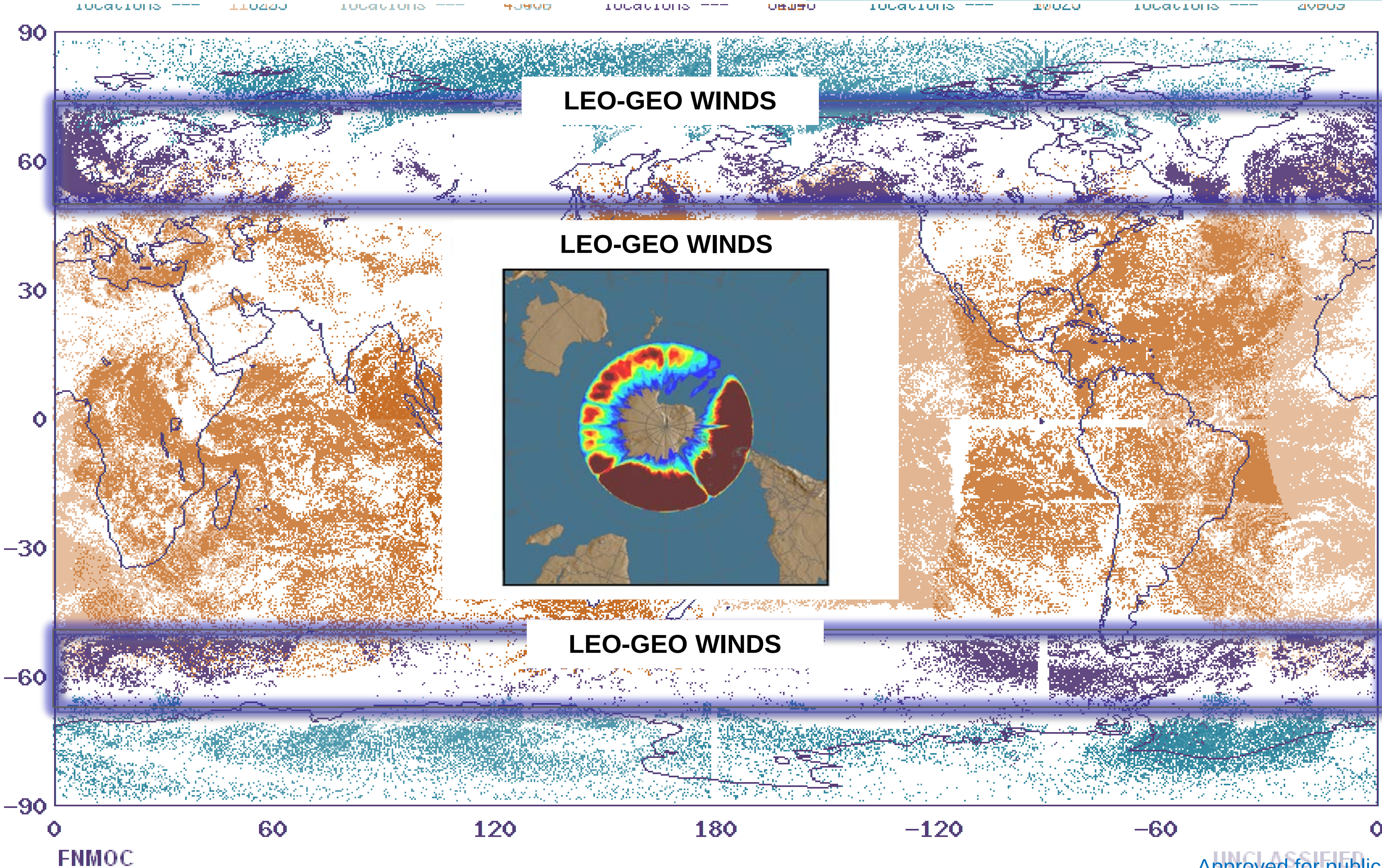
Data Overview—CIMSS/UW Polar/LeoGeo Winds

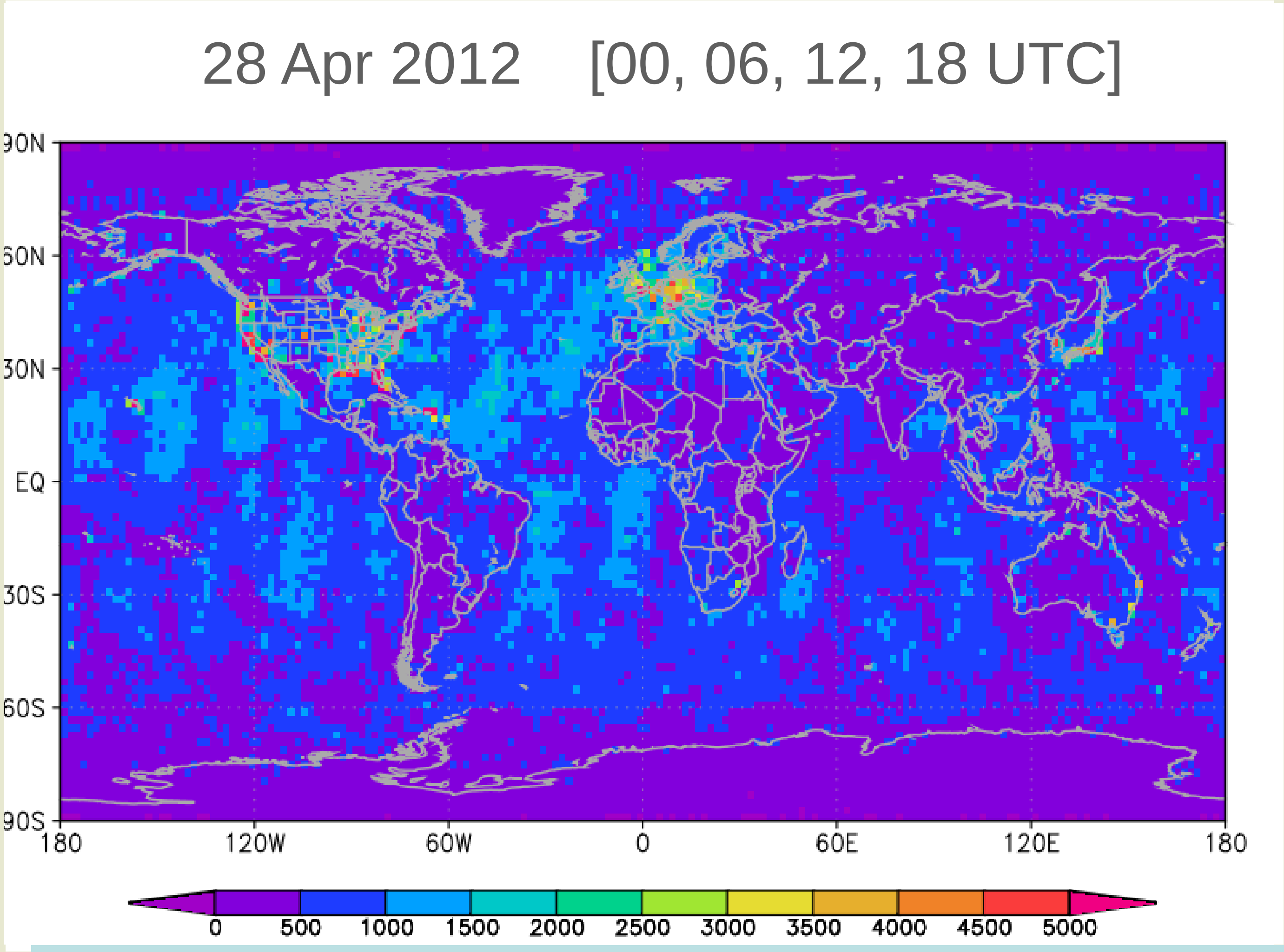
Geostationary winds—orange
Polar winds—aqua (MODIS operational in Oct 2004, AVHRR operational in Nov 2007)
LeoGeo winds—purple (operational in Nov 2010)

Assimilated at NRL, but not all other centers



Approved for public release

About 19 million observations assimilated in global domain each day in NAVDAS-AR [4d-Var]



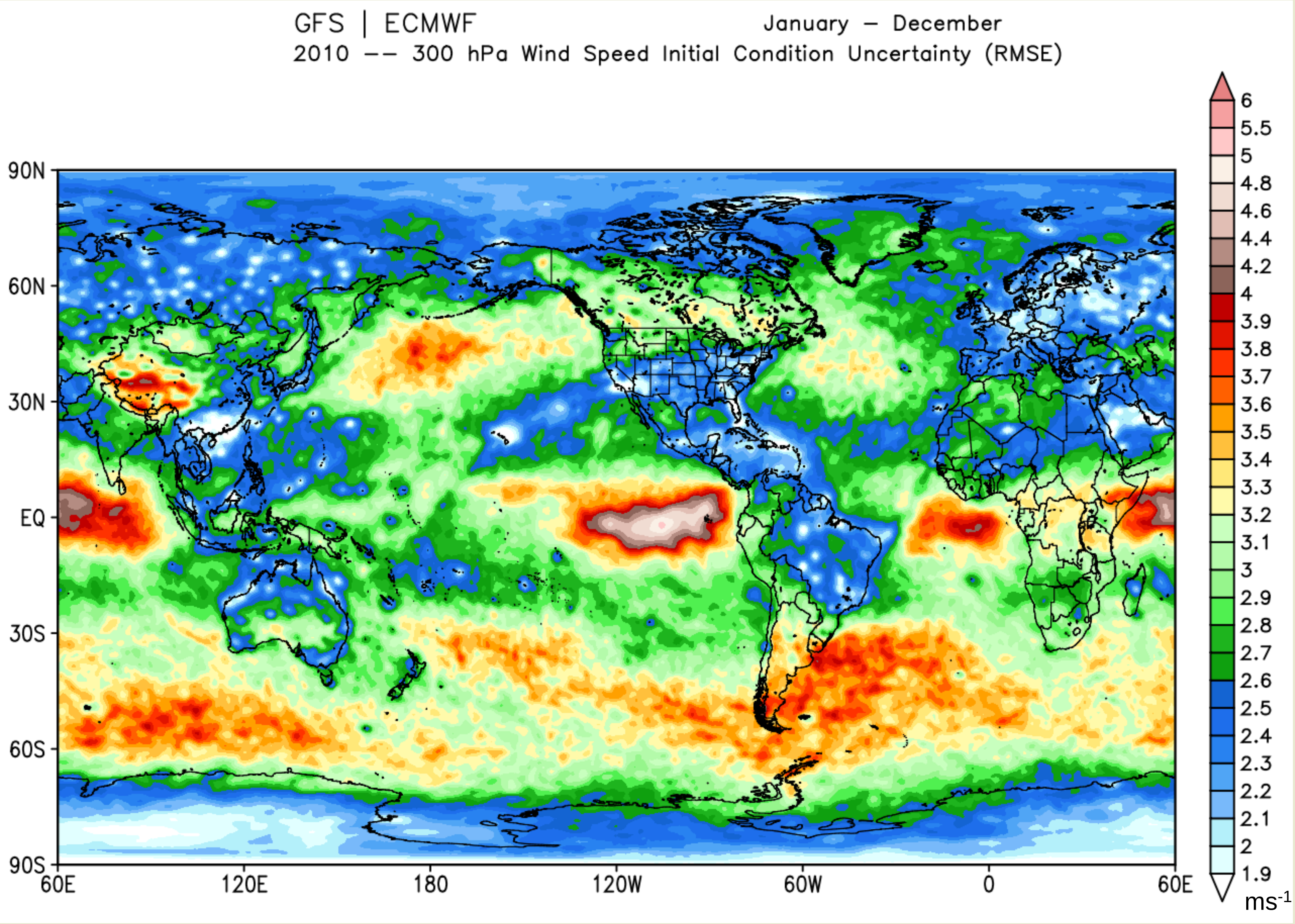
HIGH OBSERVATION DENSITY DOES NOT GAURANTEE ANALYSIS QUALITY !!

Question

Why is analysis uncertainty over oceanic regions still much larger than over North America and Europe, despite the addition of massive amounts of radiance data? [Now as much as 90% of all assimilated data.]

Basic patterns of analysis differences and analysis uncertainty in 2012 remain similar to those reported in 2002.

Do the analysis differences shown in these studies have implications for design of the global observing network?



Summary

Availability of radiosonde and aircraft data appear to substantially reduce uncertainty in upper-air analyses of temperature and wind

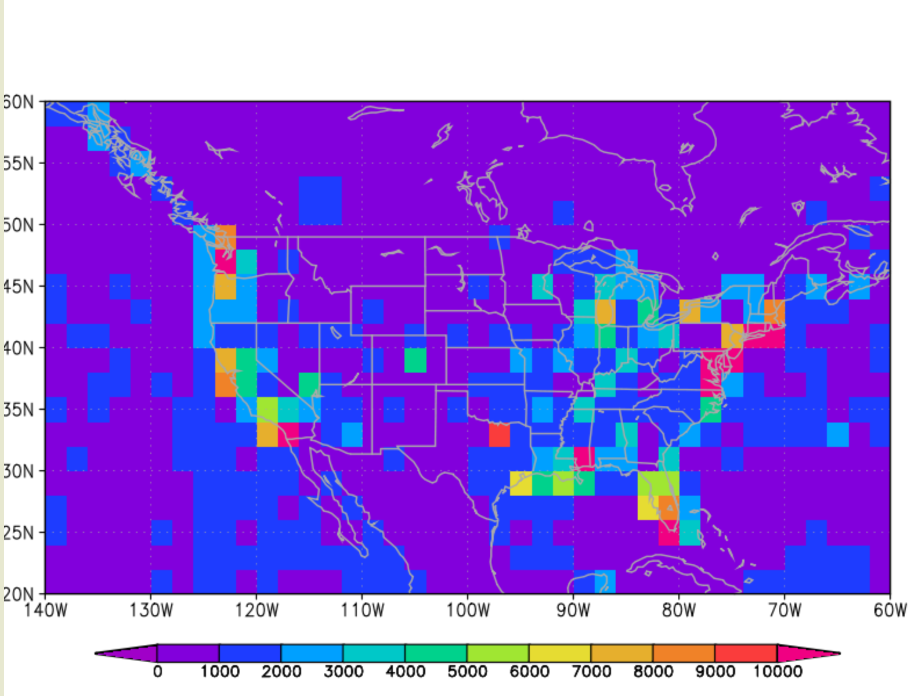
Analysis uncertainty is larger where the analysis relies primarily on radiance observations

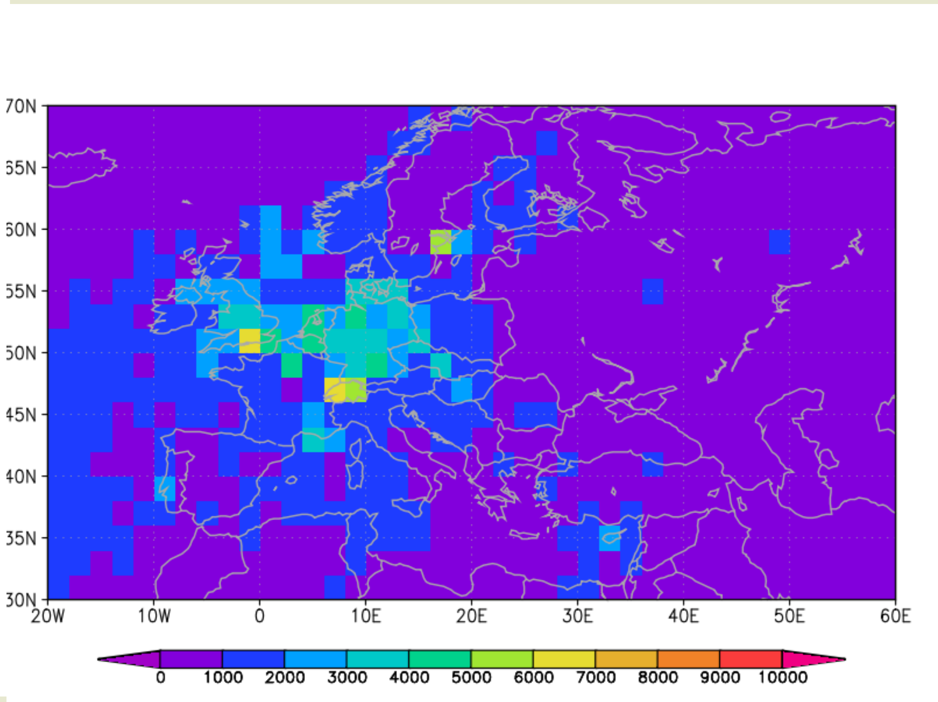
What new observing instruments and variables are most-needed to reduce analysis uncertainty?

Where is the greatest need to reduce the current magnitude of analysis uncertainty? Polar regions? Oceanic storm tracks?

Count of observations assimilated by NAVDAS-AR

28 Apr 2012 [00, 06, 12, 18 UTC]





Data count in 2° x 2° lat/lon bins

The largest density of observations is due to in-situ data [radiosondes, aircraft, land-surface and ocean-surface observations]