Some Applications of Satellite data in the WMO THORPEX programme

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THORPEX International Programme Office
WMO, Geneva

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THORPEX
A World Weather Research Programme

Accelerating improvements in the accuracy of one-day to two weeks high-impact weather forecasts for the benefit of society, economy and environment

2005

2014...

A photographic collage depicting the societal, economic and ecological impacts of severe weather associated with four Rossby wave-trains that encircled the globe during November 2002.

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THORPEX - significant contribution towards the WMO effort to mitigate the effects of natural disasters

THORPEX - will help realise the societal and economic benefits of improved weather forecasts especially in developing and least developed countries

By

extending the range of skilful weather forecasts of high impact weather up to 14 days and beyond

Developing accurate and timely warnings in a form that can be readily used in decision-making support tools

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THORPEX - A WMO Sponsored Research Programme

- To provide the research underpinning the WMO strategy to help reduce by 50 per cent over the decade 2010-2019 the number of fatalities caused by meteorological, hydrological and climate related natural disasters compared with the ten-year average fatalities of 1995-2004.
- To increase the effectiveness of advanced warnings of high impact weather globally.
- To enable governments, societies and economic sectors to realise fully the benefit of weather and climate related information in critical decision-making.
- To demonstrate ways to increase cooperation and collaboration between National Meteorological Services to deliver the benefits of new global earth observations, advanced communications, and new global forecasting systems to all societies.

Approach

THORPEX builds upon ongoing advances within the basic-research and operational-forecasting communities. It makes progress by enhancing international collaboration between these communities, such as WGNE/WWRP/CBS and with end users of forecast products.

THORPEX

THORPEX - Organisational Structure

IPO/ICSC/EC

Regional Committees
Africa
Asia
Europe
North America
Southern Hemisphere

Predictability and Dynamical Processes Working Group

PDP WG

Data Assimilation and Observing Strategies Working Group

DAOS WG

Global Interactive Forecasting System – THORPEX Interactive Grand Global Ensemble Working Group

GIFS-TIGGE WG

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ASIAN REGIONAL COMMITTEE (ARC)

- *Representatives from Japan, China, Russia, Korea and India*

- *Focus on regional interests and programmes*

- *Collaborate and contribute to global THORPEX activities and initiatives*

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Science and Implementation Plans and regional plans – download from:

www.wmo.int/thorpex

Three sub-programmes

- **Predictability and Dynamical Processes**
- **Data Assimilation and Observing strategies**
- **Societal and Economic Applications**

And the THORPEX Interactive Grand Global Ensemble (TIGGE) project

GEOSS

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THORPEX - research priorities

- Global-to-regional influences on the evolution and predictability of weather systems
- Global observing-system design and demonstration
- Targeting and assimilation of observations
- Societal, economic, and environmental benefits of improved forecasts

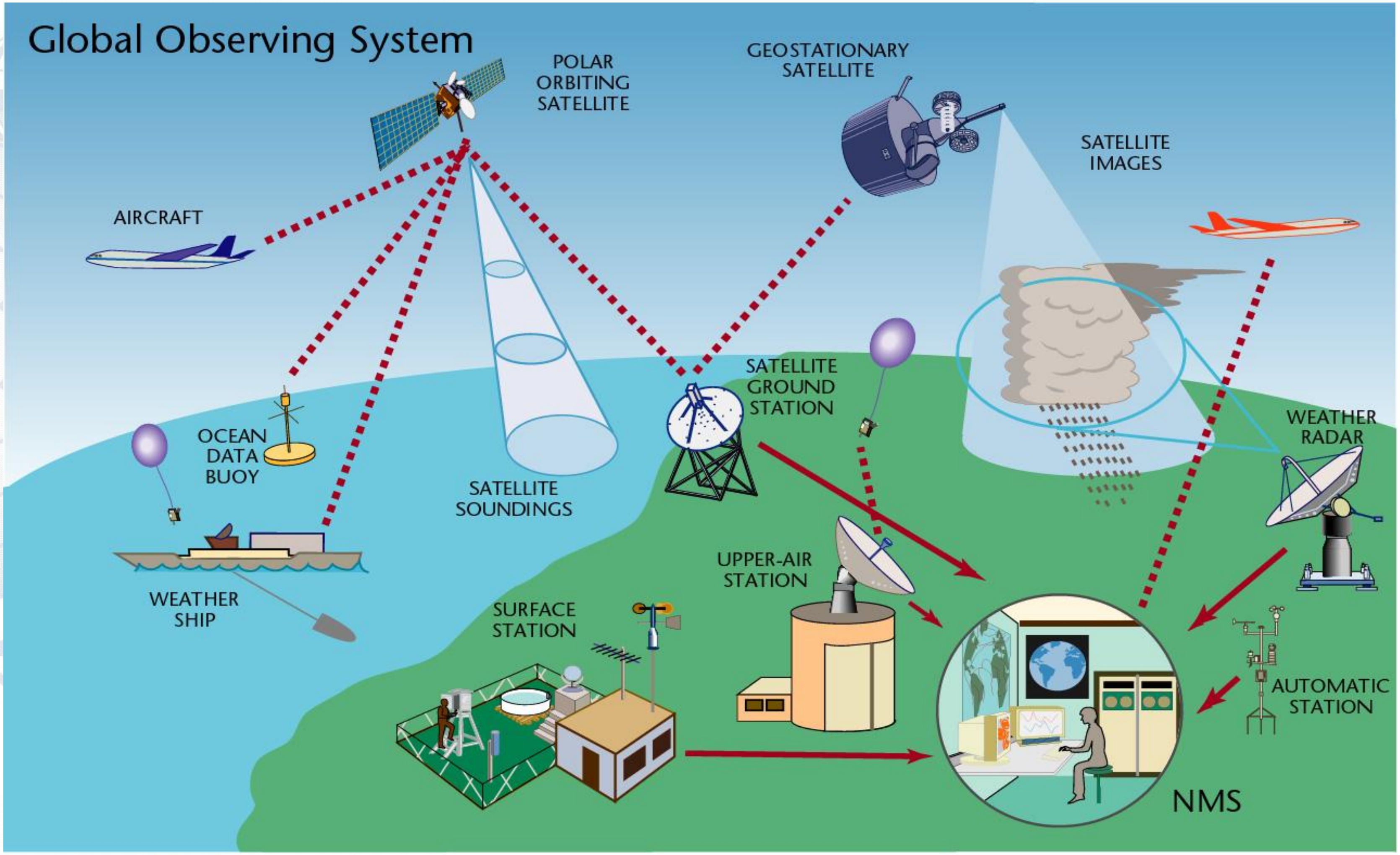
DAOS Observational objectives

Contribute to the evolution of the WMO Integrated Global Observing System (WIGOS) by:

- ***Refining adaptive observing strategies***
- ***Designing the strategy for targeted observations (and interactive forecasting).***
- ***Optimising the design of observational networks***
- ***Contributing to THORPEX Regional field Campaigns (TReCs)***
- ***Assessing new sensors and data sources***

The area of interest is all in-situ and satellite data relevant to Numerical Weather Prediction

COMPONENTS OF THE GOS



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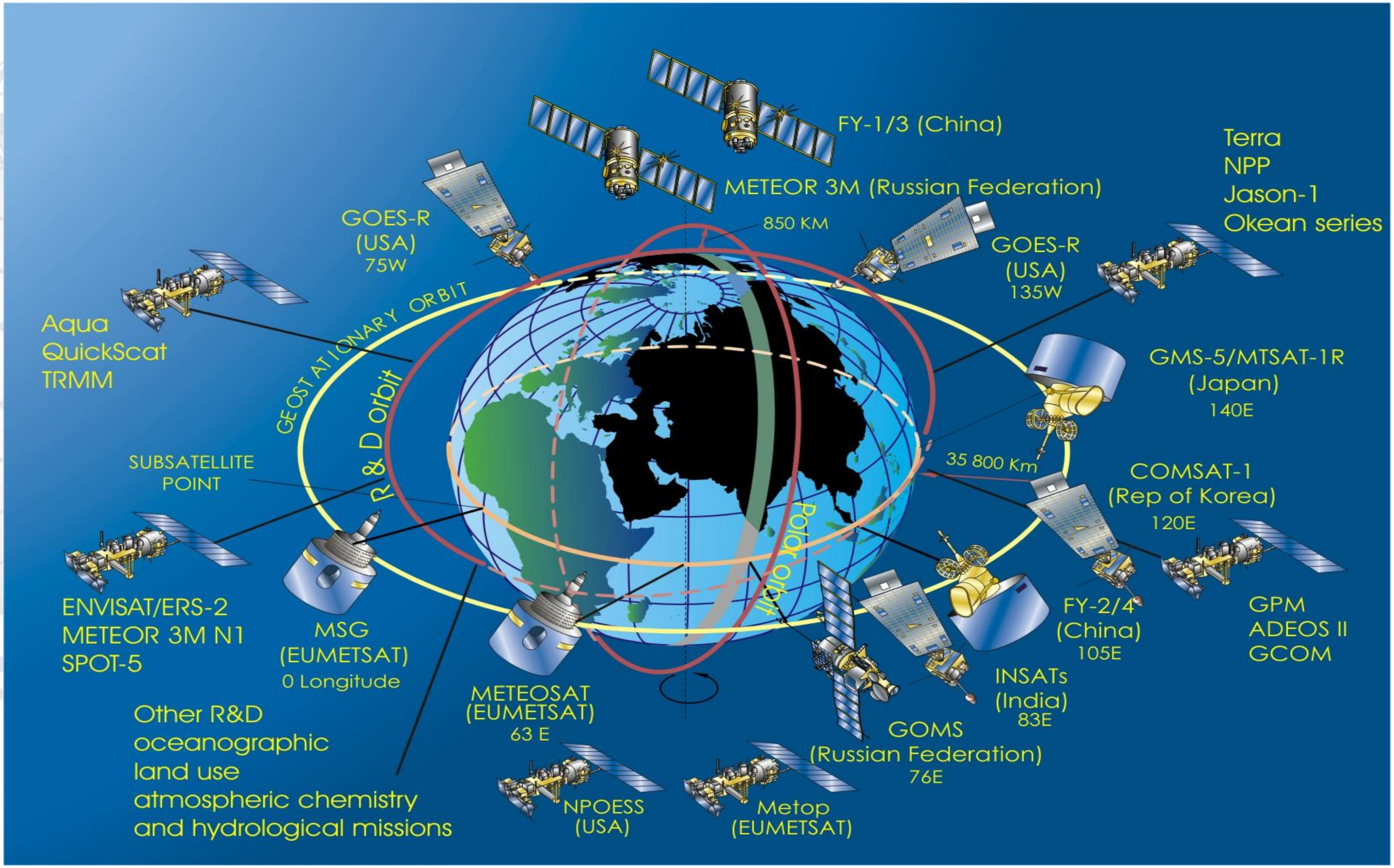
The spaced- based system



ISSUES FOR THE GOS

- **Evolving the GOS towards a truly integrated, optimised, flexible and efficient overall system**
- **Responding to the needs of the many application areas e.g. NWP, Nowcasting etc.,**
- **Understanding the contributions of the various sub-components and how they should evolve in the future**

This presentation will focus on the GOS in relation to NWP

DAOS Mission statement

To achieve its mission the DAOS WG, in collaboration with the CBS OPAG-IOS:

- Addresses Data Assimilation issues including the development of improved understanding of the sources and growth of errors in analyses and forecasts

- ***Promotes research activities that lead to a better use of observations and the understanding of their value in NWP***

- Provides input and guidance for THORPEX regional campaigns for the deployment of observations to achieve scientific objectives.

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Some studies

- EUCOS/EUMETSAT - impact of satellite data in global NWP
- THORPEX DAOS – assessment of the impact of satellite data in various NWP systems
- THORPEX – Pacific Asian Regional Campaign (T-PARC) – benefits of MTSAT rapid scan data
- Year Of Tropical Convection – NASA Giovanni visualisation system
- International Polar Year – THORPEX Cluster of projects – ConcordIASI

PERFORMANCE OF THE GOS

- Some results from experiments at ECMWF conducted by ;
- Graeme Kelly and Jean-Noel Thepaut
- Sponsored by EUCOS and EUMETSAT

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EUCOS /EUMETSAT studies - Impact of satellite data in global NWP

- (i): BASELINE: all conventional observations used in NWP (radiosonde + aircraft + profiler network + surface land data + buoy observations + ship data)

- (ii): REFERENCE=(i) BASELINE + Atmospheric Motion Vectors (AMVs) from GEO+MODIS
- (iii): (ii) add HIRS radiances
- (iv): (ii) add AMSUA radiances
- (v): (ii) add AMSUB radiances
- (vi): (ii) add SSMI radiances
- (vii): (ii) add GEO Clear Sky Radiances (CSRs)
- (viii): (ii) add AIRS radiances
- (ix): (ii) add SCATT winds
- (x): (i) add GEO AMVs (no MODIS)
- (xi):CONTROL full operational system (all above observations)

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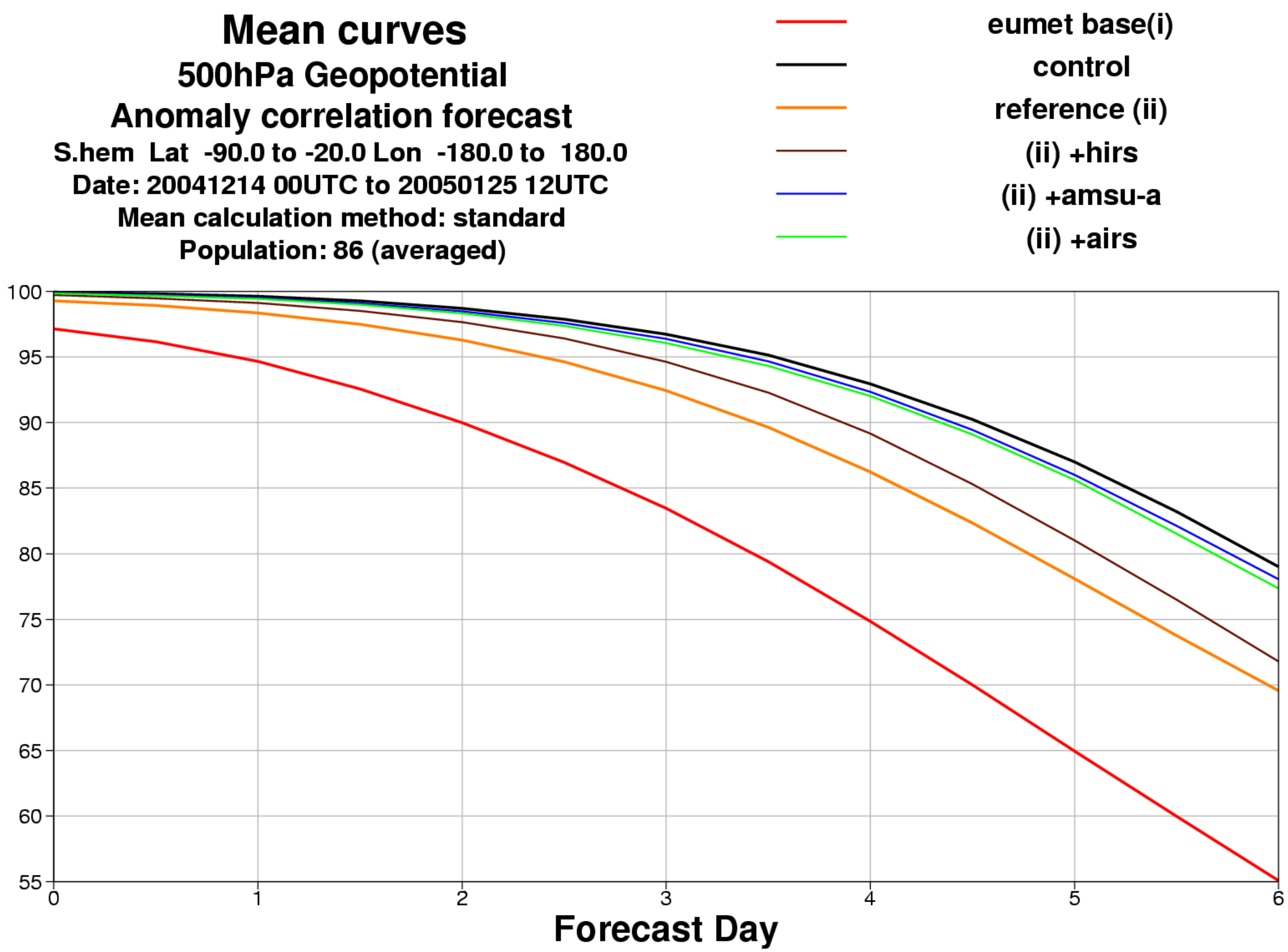
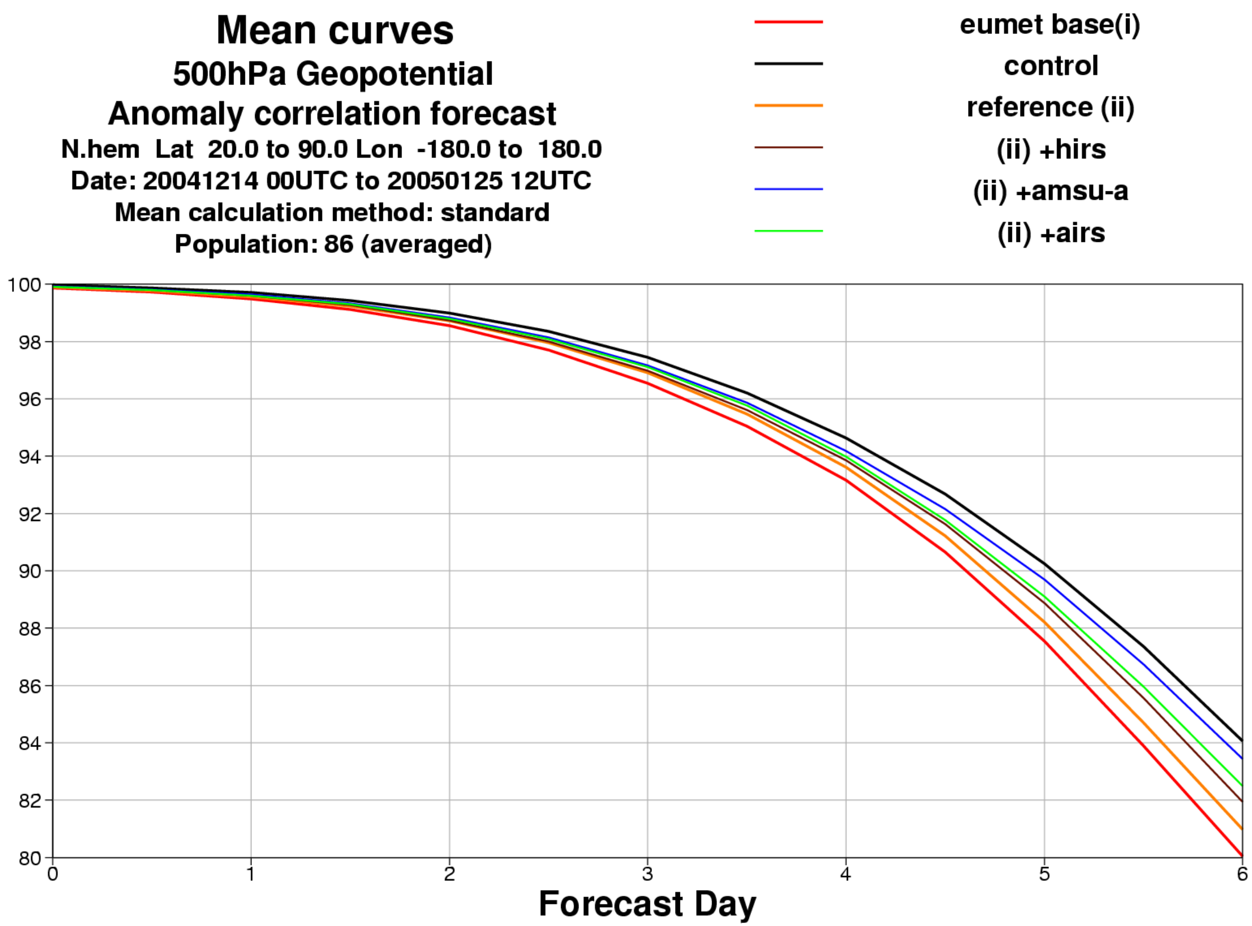
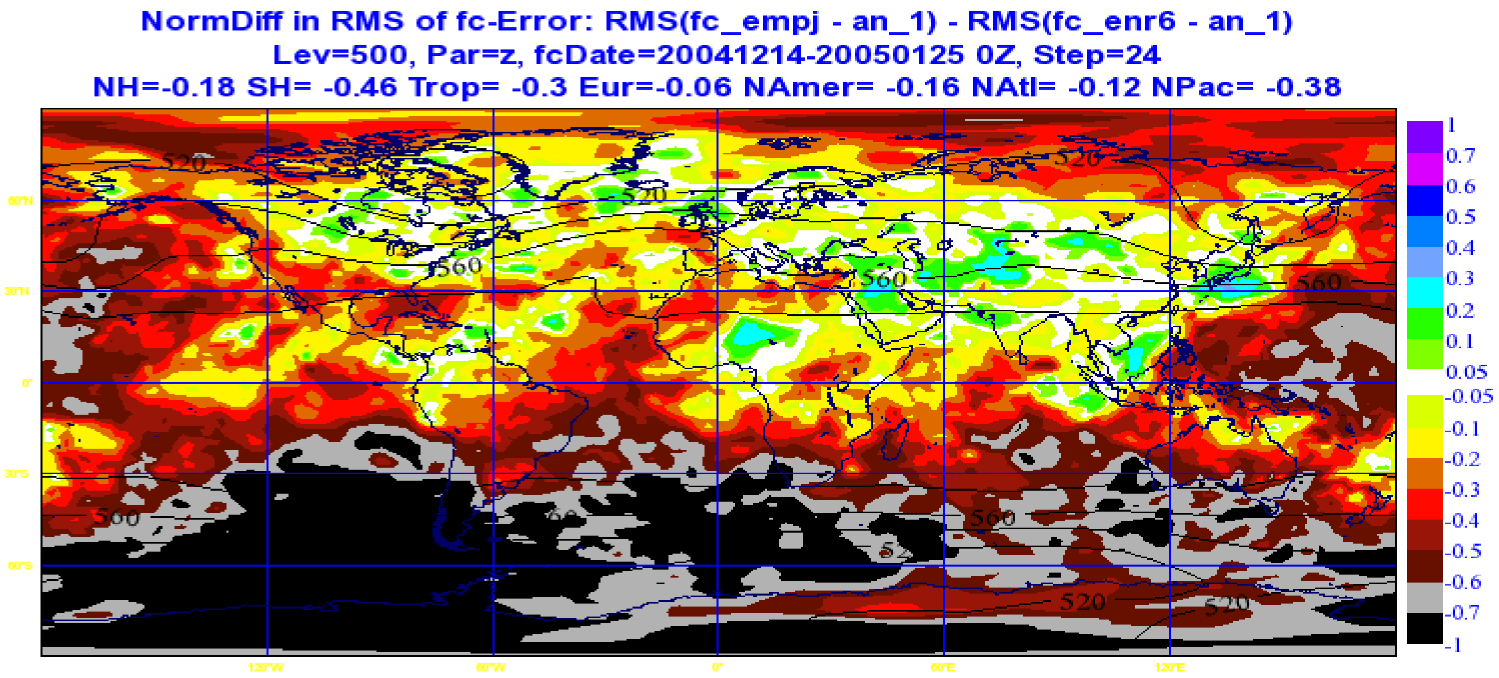
Winter results - SH



Winter results - NH

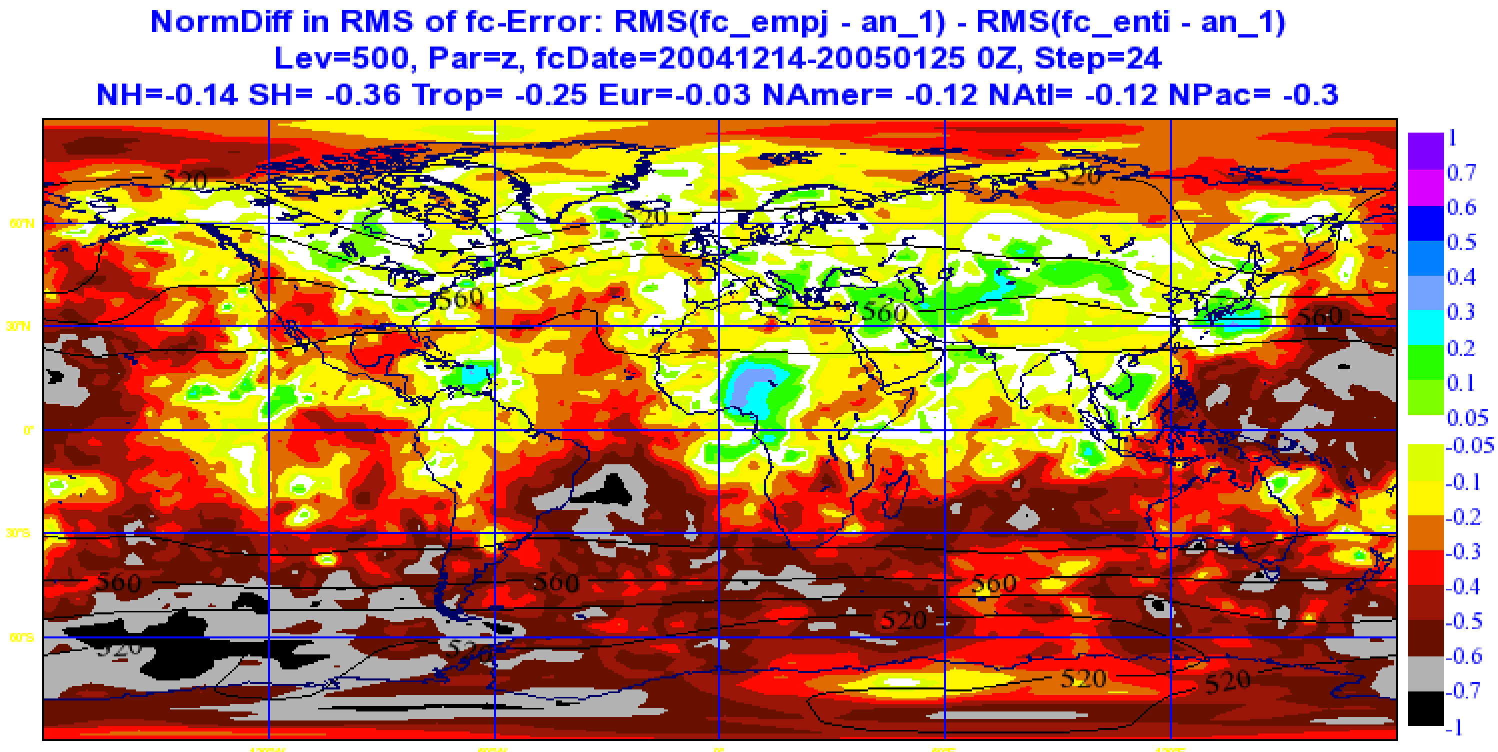


ALL SAT



NormDiff in RMS of fc-Error: RMS(fc_empj - an_1) - RMS(fc_enr6 - an_1)
Lev=500, Par=z, fcDate=20041214-20050125 0Z, Step=24
NH=-0.18 SH= -0.46 Trop= -0.3 Eur=-0.06 NAmer= -0.16 NAtl= -0.12 NPac= -0.38
1
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
-0.05
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-1

AMVs


NormDiff in RMS of fc-Error: RMS(fc_empj - an_1) - RMS(fc_enti - an_1)
Lev=500, Par=z, fcDate=20041214-20050125 0Z, Step=24
NH=-0.14 SH= -0.36 Trop= -0.25 Eur=-0.03 NAmer= -0.12 NAtl= -0.12 NPac= -0.3
1
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
-0.05
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-1

The inter-comparison experiment on the impact of observations

- A goal of THORPEX is to improve our understanding of the 'value' of observations provided by the current global network
  - optimize the use of current observations
  - inform the design/deployment of new obs systems

- In 2007, DAOS-WG proposed a comparison of observation impacts in several forecast systems, facilitated by the emergence of new (adjoint-based) techniques

- Experiments for a baseline observation set were designed by DAOS members from NRL, GMAO, EC, ECMWF, Météo-France

…so far, results obtained for 4 systems: NRL, EC, GMAO, UKMO

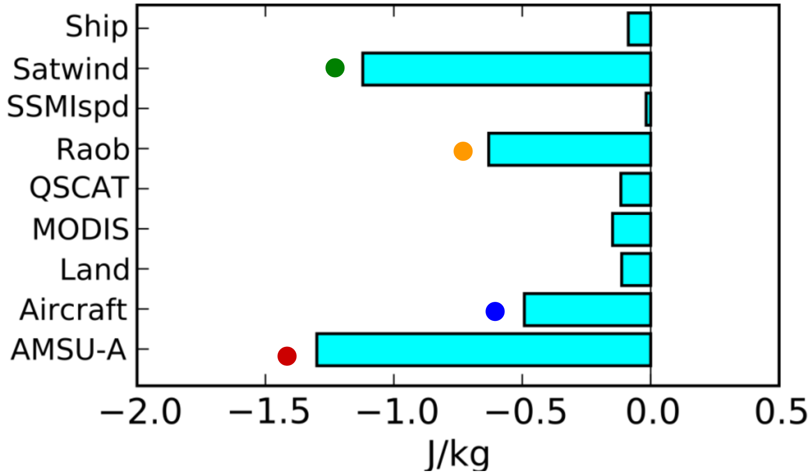
Environment Canada

Daily average observation impacts

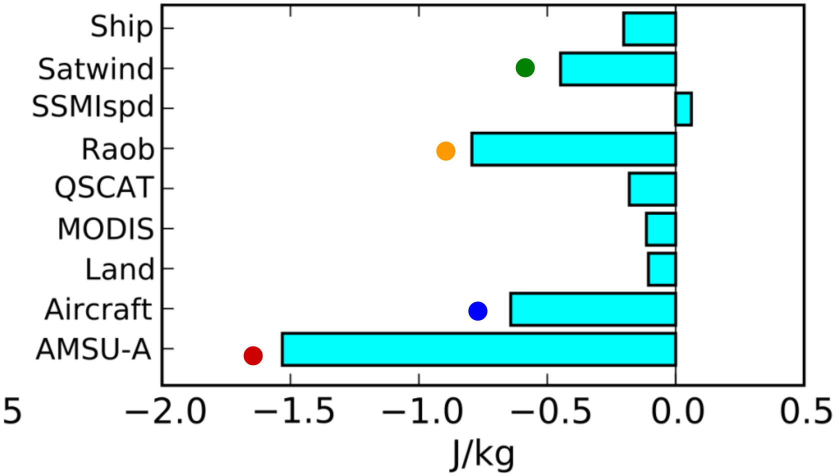
Global domain: 00+06 UTC assimilations Jan 2007

•AMSU-A, •Raob, •Satwind and •Aircraft have largest impact in all systems NWP systems

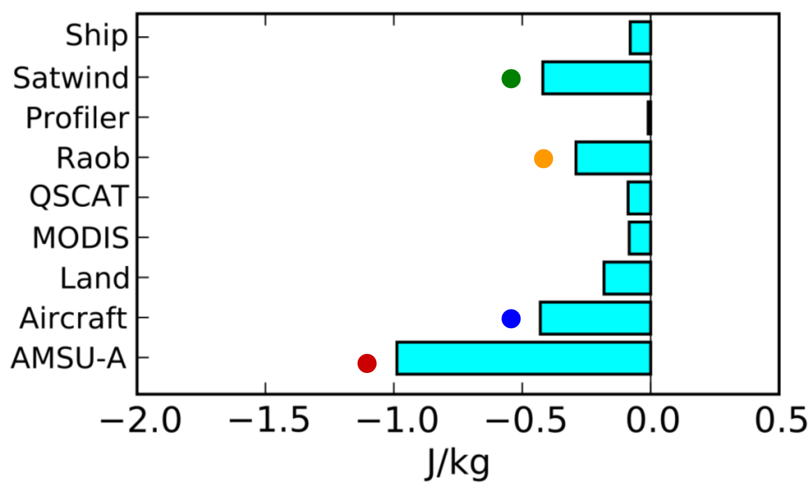
NRL NOGAPS

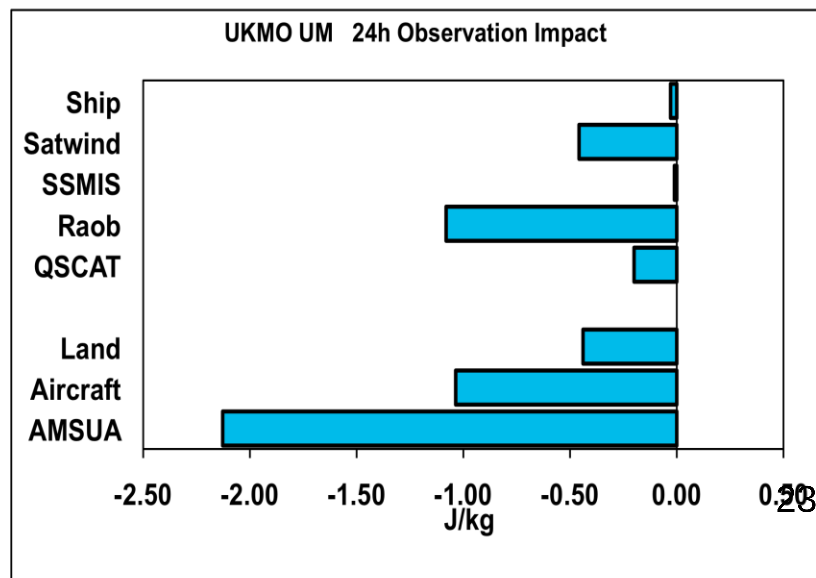


GMAO GEOS-5



EC GDPS





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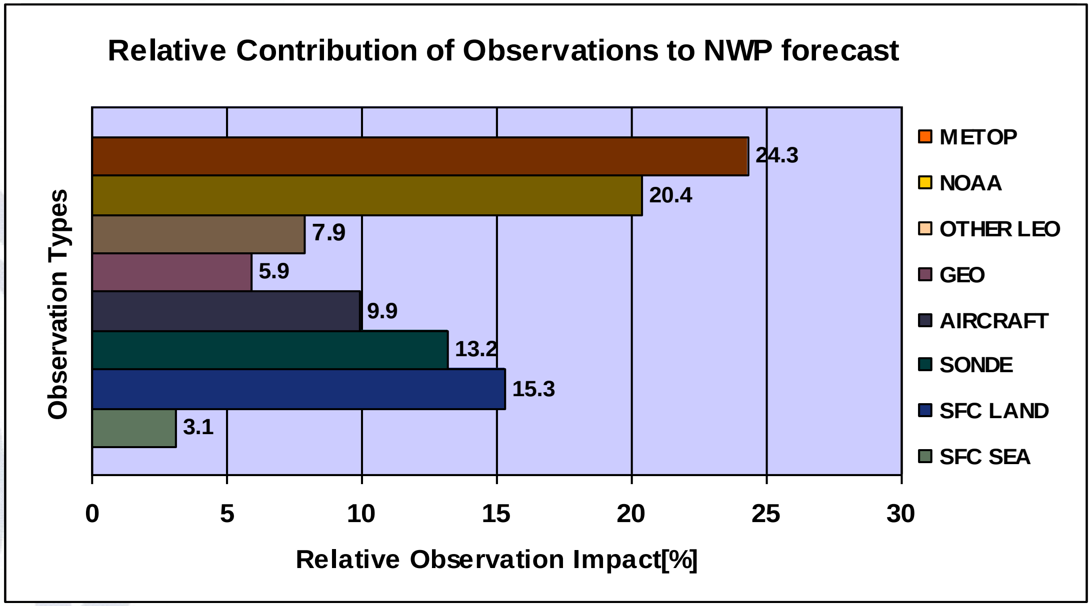
Impact of different observation platforms



METOP : MetOp ATOVS,MetOp IASI, MetOp ASCAT
NOAA : NOAA15 ATOVS AMSUA, NOAA17 ATOVS HIRS, NOAA18 ATOVS, NOAA19 ATOVS
OTHER LEO: EOS AIRS, F16 SSMIS, ERS, WINDSAT
GEO : GOES, MTSAT, MSG
Aircraft : AMDAR, AIREP
SONDE : PILOT, TEMP
SFC Land : SYNOP, BOGUS
SFC Sea : BUOY,SHIP

Total Impact = Number of soundings/profiles * mean observation Impact of each sounding/profile

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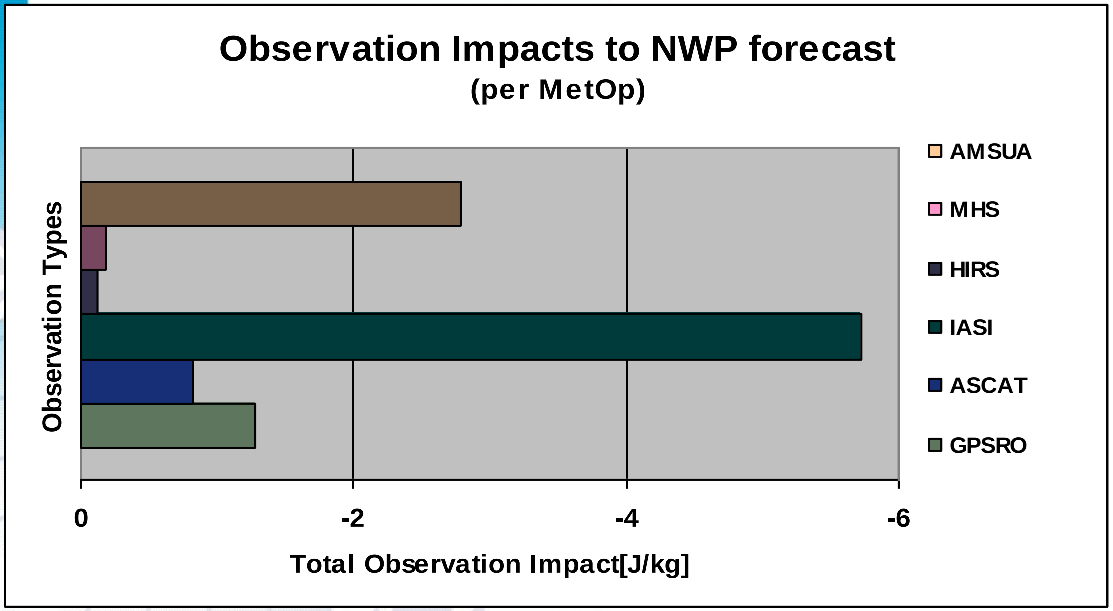
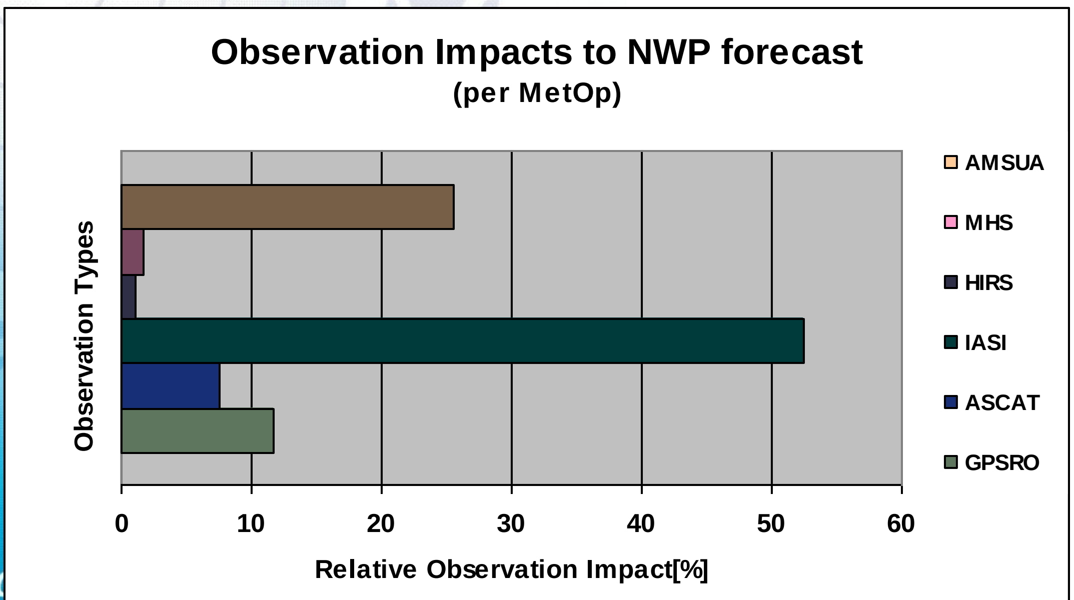
Observation Impact of each sensor in MetOp





AMSU-A:	MetOp-A
MHS:	MetOp-A
HIRS:	MetOp-A
IASI:	MetOp-A
ASCAT:	MetOp-A
GPSRO:	Metop-A/GRAS COSMIC GRACE

Note 1: 34% of GPSRO data is MetOp-A/GRAS in terms of soundings

Note 2: Impact measure is "dry energy norm" - underestimates value of humidity information

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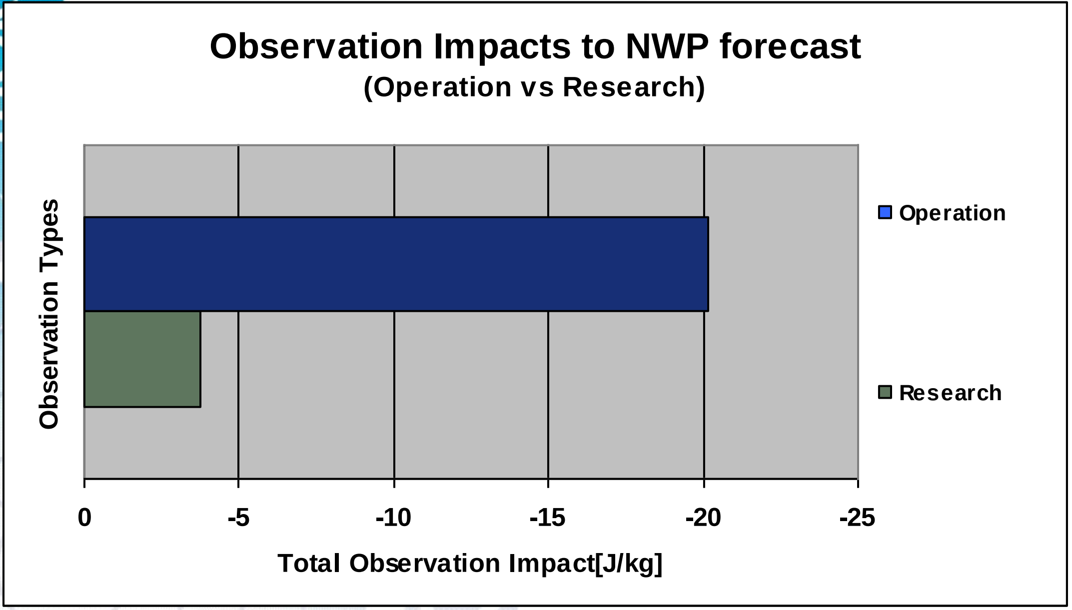
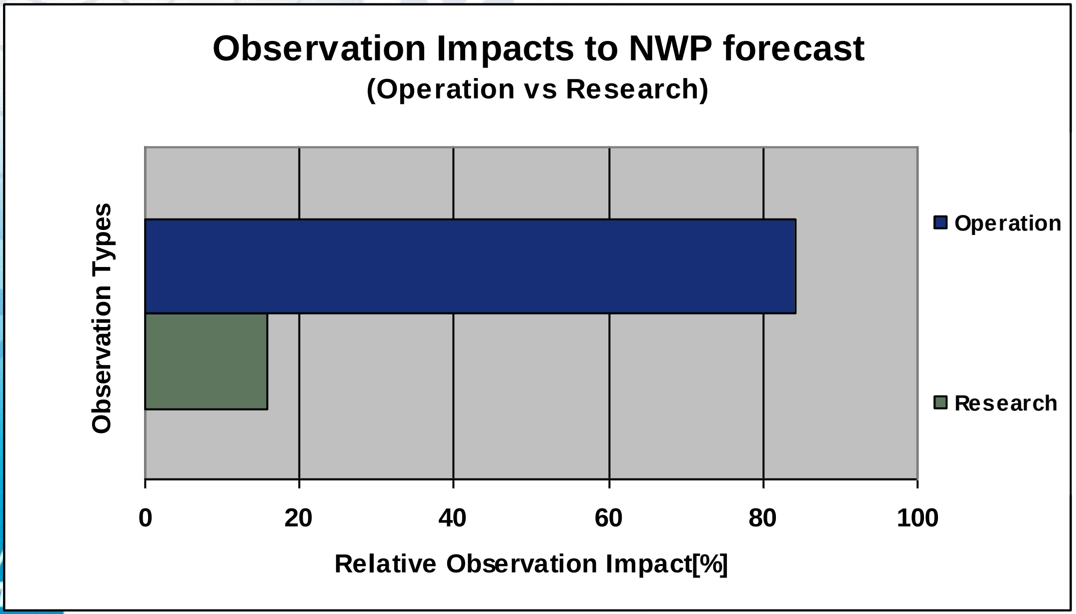
Satellite Observation Impact depending on purposes (Operation vs Research)





Operational

MetOp-A: AMSUA, MHS, HIRS, IASI, ASCAT
NOAA-15: AMSU-A
NOAA-17: HIRS
NOAA-18: AMSU-A, MHS
NOAA-19: AMSU-A, HIRS
“GOES”: AMV (GOES,Terra, Aqua, NOAA)
DMSP-F16: SSMIS
MTSAT: AMV
Meteosat: AMV (M7, M9)

Research

EOS/Aqua: AIRS
GPSRO: GRAS, COSMIC,GRACE
ERS-2: AMI (scatterometer)
Coriolis: WINDSAT

Note1: “GOES” includes research satellites (Terra, Aqua, and NOAA AMVs)
Note2: GPSRO includes some operational data (MetOp-A/GRAS)

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SPECIAL SATELLITE DATA ANALYSIS AND NWP IMPACT STUDIES DURING T-PARC

C.S. Velden[1], R. Langland[2], Howard Berger[1] and C. A. Reynolds[2]

1-Cooperative Institute for Meteorological Satellite Studies, Univ.-Wisconsin

2-Naval Research Laboratory, Monterey, CA

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T-PARC
THORPEX - Pacific Asian Regional Campaign

•***International field campaign during August – October, 2008 with special observing periods to investigate the formation, structure, intensification and prediction of tropical cyclones in the western North Pacific.***

•***Unique data sets including the monitoring of the complete life cycle from genesis to ET and downstream impacts.***

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Outline

- **TPARC Experiment AMV Datasets**
  - **MTSAT Hourly**
  - **MTSAT Rapid-Scan**
  - **Diagnostic TC Studies**
- **TPARC Data Assimilation Studies**
  - **NOGAPS AMV Data Impact Experiments**

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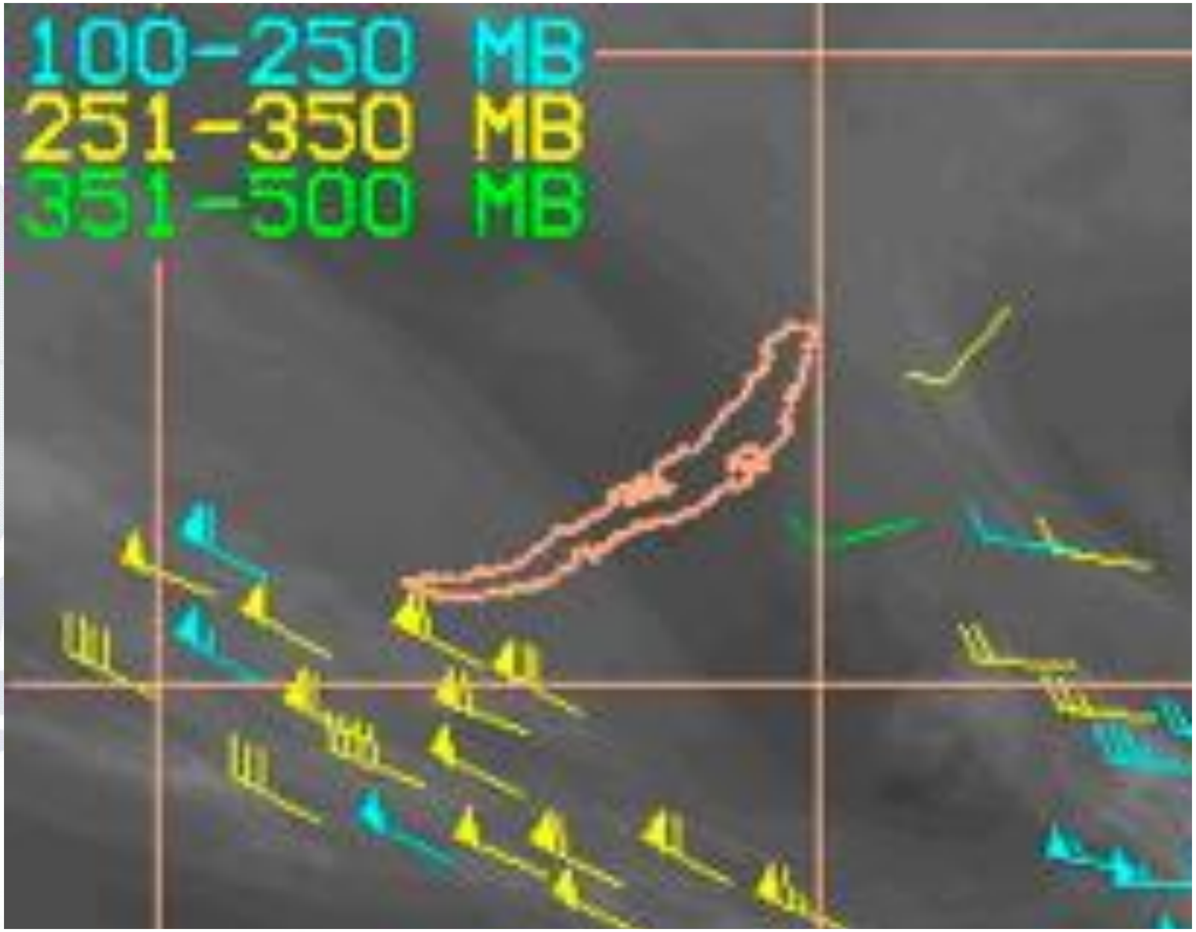
AMV Datasets

- **Generated at CIMSS (essentially the operational NESDIS algorithm) by objectively targeting and tracking clouds and WV structures in sequential JMA MTSAT multi-spectral geostationary satellite images**

- **AMV heights are assigned using multispectral and semi-transparency techniques**

- **Apply objective quality control and assign quality indicators (QI)**

MTSAT AMVs produced hourly (by UW-CIMSS) during TPARC
Example: Typhoon Sinlaku -- 11th Sep. 2008



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AMVs from special MTSAT-2 Rapid Scans

- **The routine, hourly MTSAT AMV datasets (shown in last slide) were produced from images that are 30-min apart**

- **Special images were also made available during selected periods of TPARC typhoon events, courtesy of JMA, at 4-15 minute sequences (rapid scans) from MTSAT-2**
  - **Allows for higher density and quality AMVs**

- **AMV datasets were produced by UW-CIMSS utilizing the rapid-scan imagery during Typhoons Sinlaku and Jangmi**

- **Studies are underway to utilize these high-res. AMVs to better capture mesoscale features in TC diagnostic analyses, and also to improve NWP TC forecasts**

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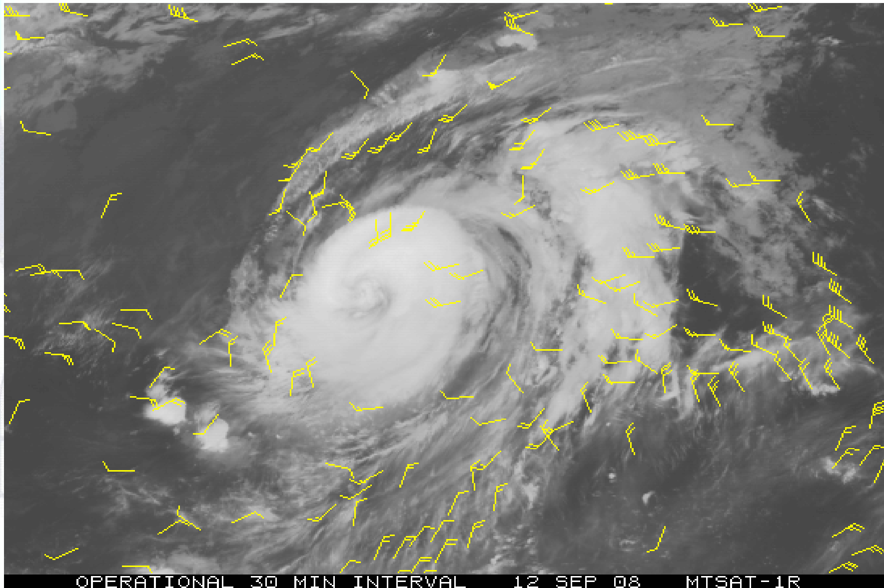
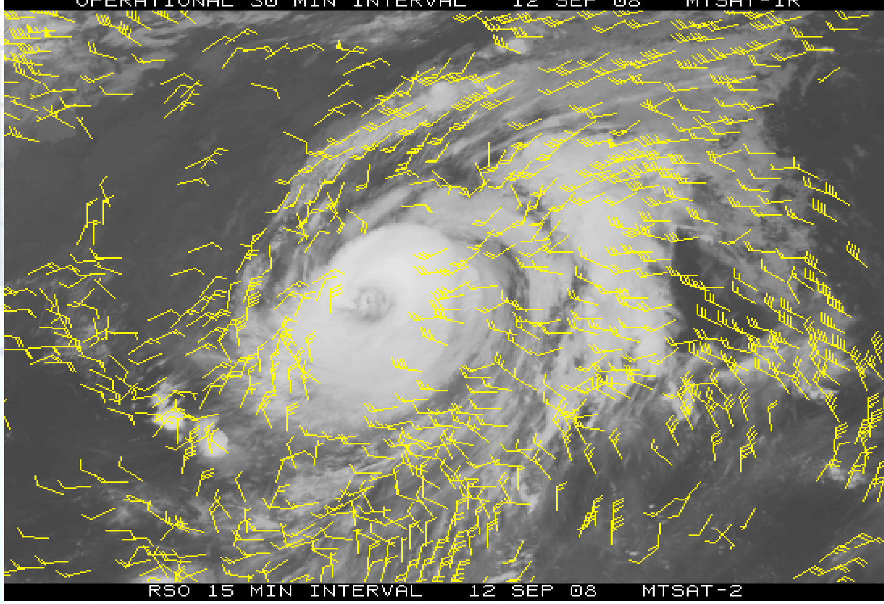
Example of AMVs from MTSAT-2 Rapid Scan images

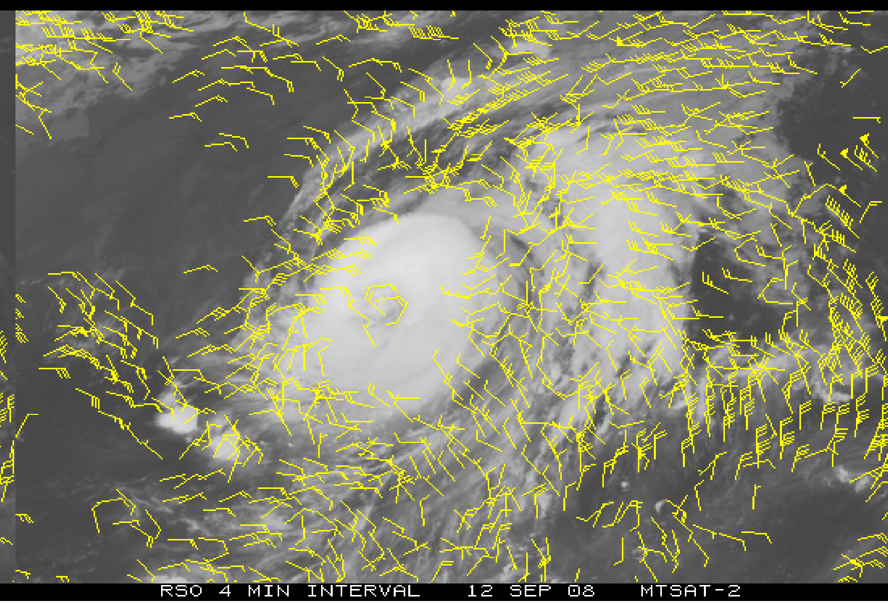


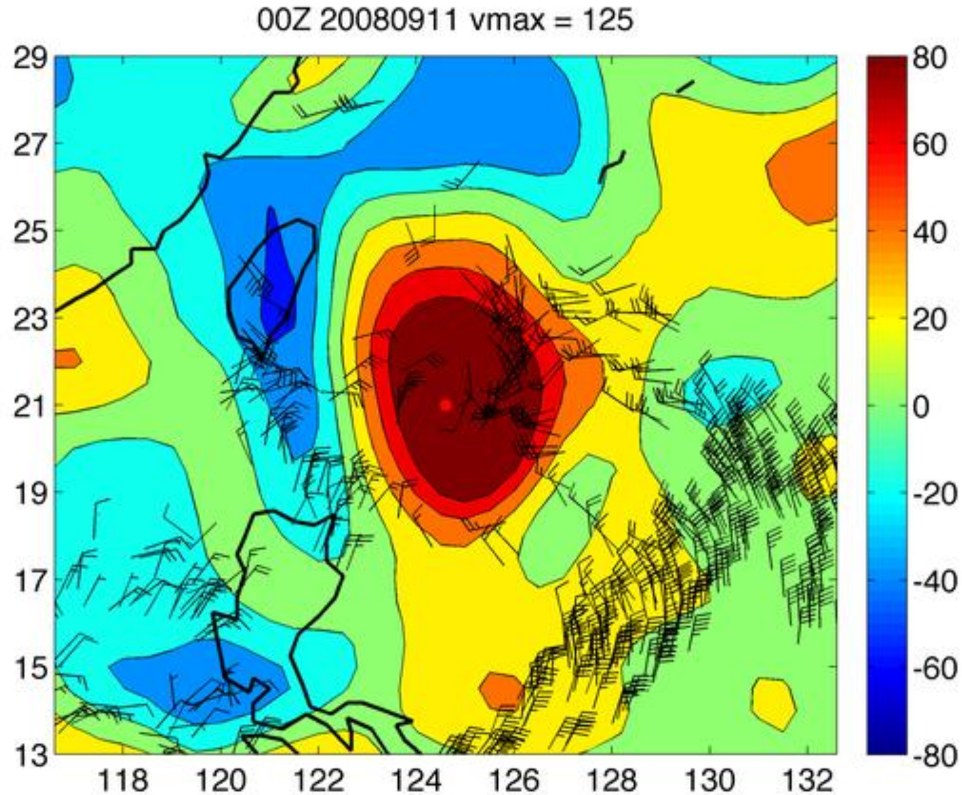
Left: AMV (IR-only) field produced from routinely available hourly sequence of MTSAT-1 images during Typhoon Sinlaku

Bottom Left: Same as above, but using a 15-min rapid scan sequence from MTSAT-2
(better AMV coverage and coherence)

Bottom Right: Same as above, but using a 4-min rapid scan sequence (improved coverage/detail of typhoon flow fields)





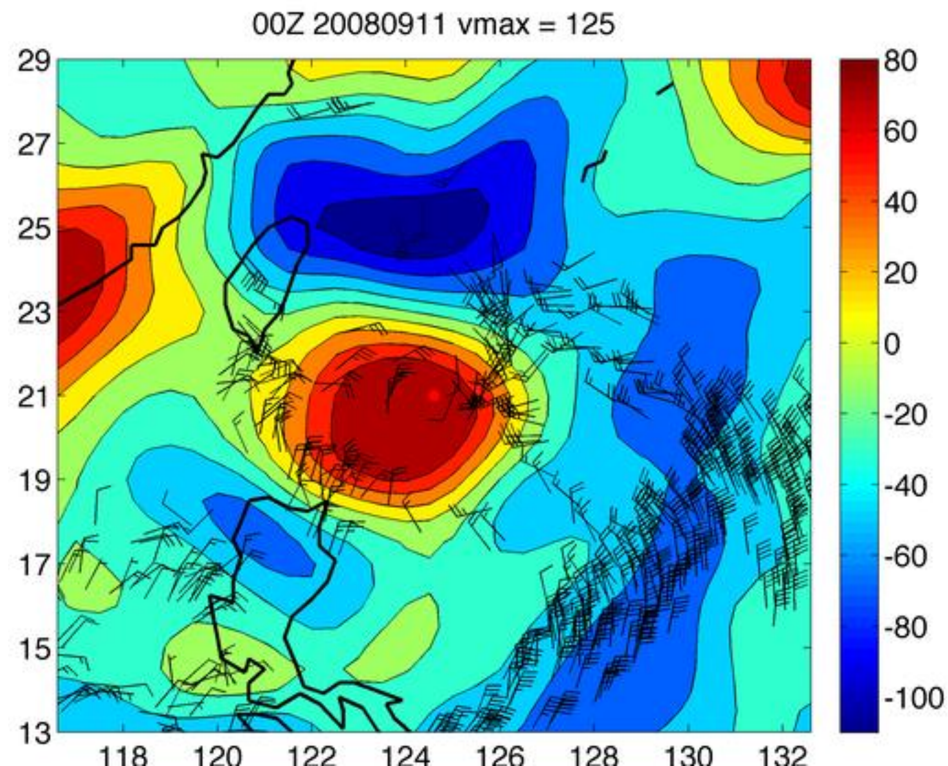


TC Diagnostic Studies using High-Res. Rapid-Scan AMVs

Example: Typhoon Sinlaku during TPARC

150 hPa Divergence analyzed from upper level R/S AMVs

150 hPa Vorticity analyzed from upper level R/S AMVs



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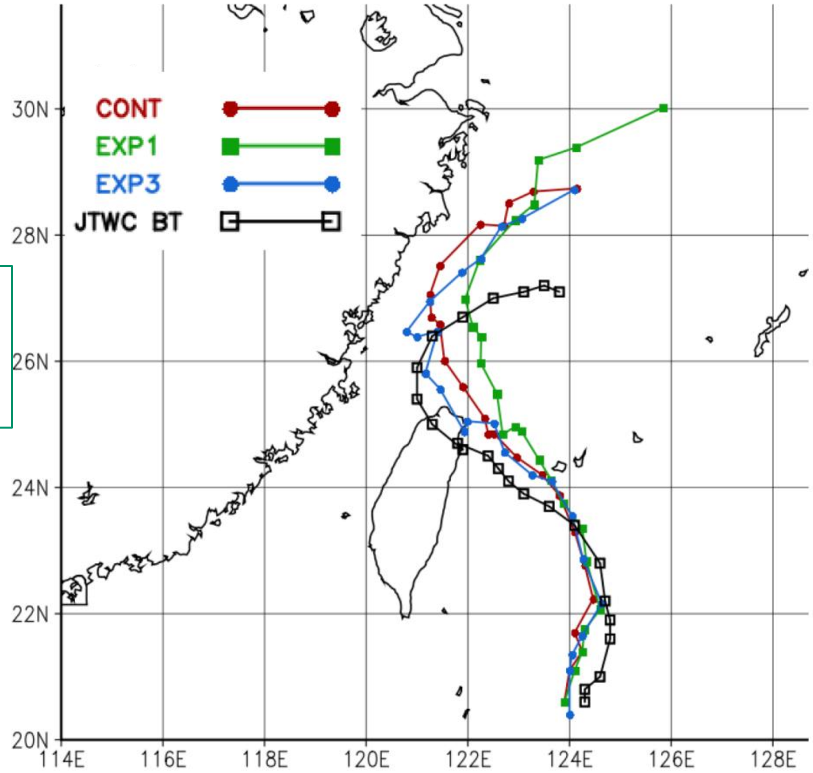
AMV Data Assimilation Experiments

Collaboration with Rolf Langland and Carolyn Reynolds at the US Naval Research Lab (NRL) in Monterey

- Continuously assimilate all hourly MTSAT AMV datasets using NRL 4DVAR during 2-month TPARC period

- Assess impact on NRL/FNMOC NOGAPS TC forecasts:
  - CTL – All conventional and available special TPARC observations (except for dropsondes), including hourly AMV datasets from MTSAT-1 (but no rapid-scan AMVs)
  - EX1 (NoAMV) – CTL with hourly AMVs removed
  - EX 3 (Rapid-Scan) – CTL with Rapid-Scan AMVs included



EXP3: Rapid-scan winds assimilated

Assimilation of MTSAT rapid-scan winds in TCS-08 improves NOGAPS track forecasts of typhoon Sinlaku

CONT: All operational observations including hourly AMVs.
EXP1: Same as CONT but excludes all AMVs processed by CIMSS.
EXP3: Same as CONT but with MTSAT rapid-scan winds assimilated between 1200 UTC 10 September 2008 and 0600 UTC 13 September 2008, over the region 84°E-180°E, 0°N-60°N.

For each numerical experiment, an average position of all forecasts initialized at 12-hourly intervals beginning 1200 UTC 10 September 2008 is plotted. Each solid circle or square corresponds to the average of all analyses and forecasts from the particular experiment, valid at a particular time. Note that these points vary in the number of forecasts and the forecast lengths that are provided in the composite; the points early in Sinlaku's life cycle only include short-range forecasts, whereas the points late in Sinlaku's life cycle represent a composite of 0-5 day forecasts.

Adapted from Berger et al. 2011, MWR, figure provided by Rolf H. Langland (NRL-Monterey)

NOGAPS track forecasts (nm) for TPARC

Forecast Time (hrs)	0	12	24	36	48	60	72	84	96	108	120
Contr w/ AMVs	22	39	70	93	114	151	213	195	167	248	317
No-AMV	22	40	67	91	108	154	227	248	245	365	450
Rapid-Scan	25	45	78	111	122	158	210	174	135	215	260
#CASES	22	20	18	16	14	13	12	11	9	8	7

- NOGAPS run with hourly and Rapid-Scan AMVs reduces TC track forecast errors notably at longer forecast times

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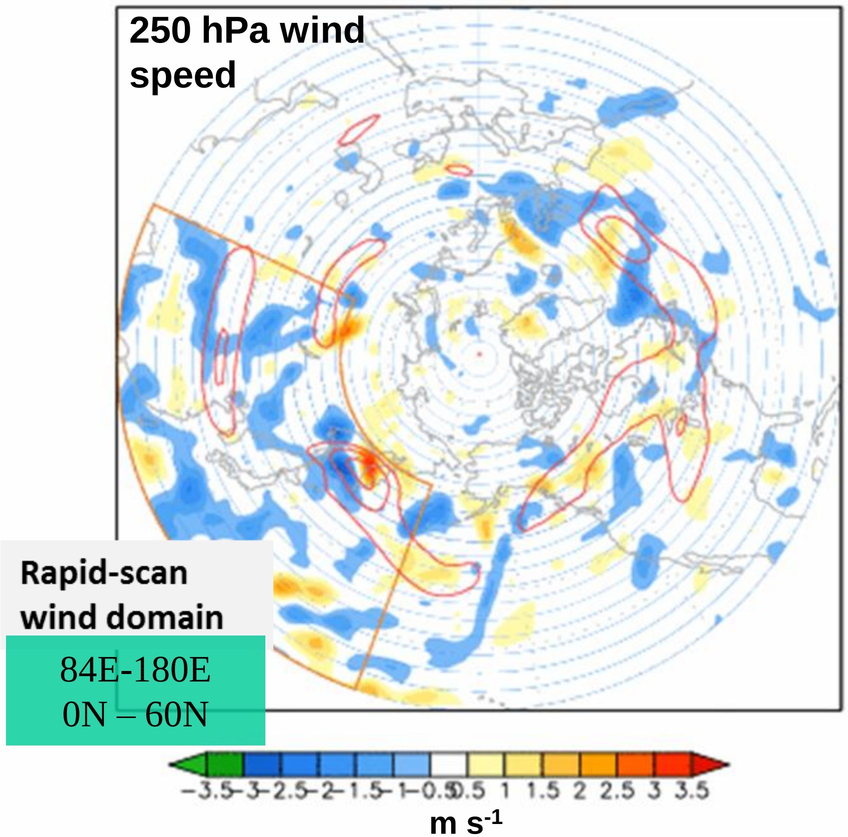
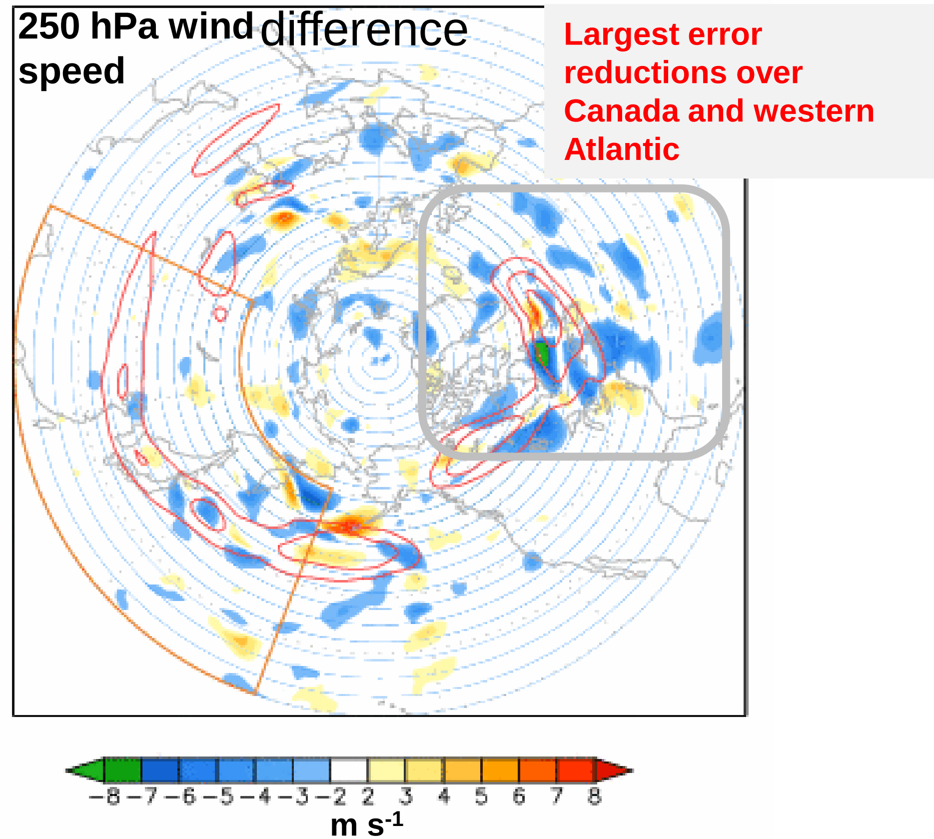
Assimilation of MTSAT rapid-scan winds in TCS-08 improves 5-day mid-latitude forecast skill

[With rapid-scan – control w/o rapid-scan]

Mean analysis difference



Mean 120-hr forecast error difference



Time Interval 18UTC 10 Sep – 06UTC 13 September [11 assimilation cycles]

Figure provided by Rolf H. Langland (NRL-Monterey)

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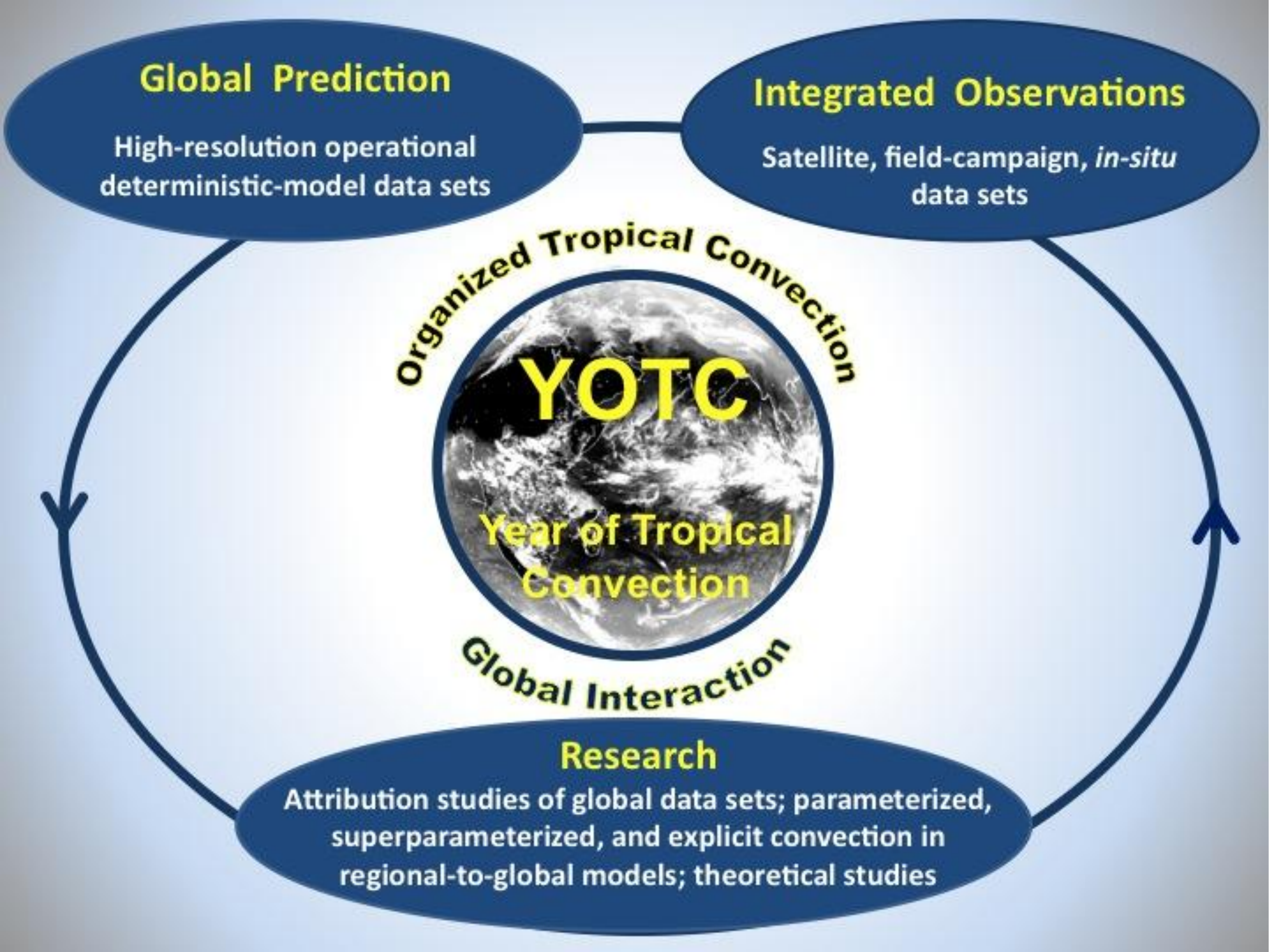
Summary

- ***Hourly satellite-derived AMVs allow for more consistent temporal coverage of the evolving atmospheric flow. The NRL 4DVAR DA can effectively utilize this frequently available information, resulting in improved NOGAPS TC track forecasts (e.g. TY Sinlaku), particularly at longer ranges (3-5 days).***

- ***Rapid-Scan AMVs can better capture mesoscale flow features such as present in rapidly evolving TCs, leading to more precise kinematic diagnostics. They also show positive impact in NOGAPS TC track forecasts, and have promising applications in mesoscale data assimilation.***


Global Prediction
High-resolution operational deterministic-model data sets
Integrated Observations
Satellite, field-campaign, in-situ data sets
Organized Tropical Convection
YOTC
Year of Tropical Convection
Global Interaction
Research
Attribution studies of global data sets; parameterized, superparameterized, and explicit convection in regional-to-global models; theoretical studies

Year of Tropical Convection (YOTC)
(and MJO Task Force)

Major/Recent Accomplishments and Plans

Mitch Moncrieff, NCAR
Duane Waliser, JPL/Caltech
Co-chairs, YOTC Science Planning Group

WWRP WORLD WEATHER RESEARCH PROGRAMME

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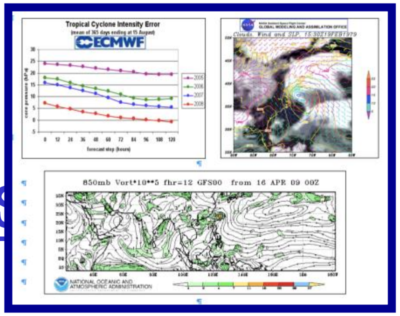
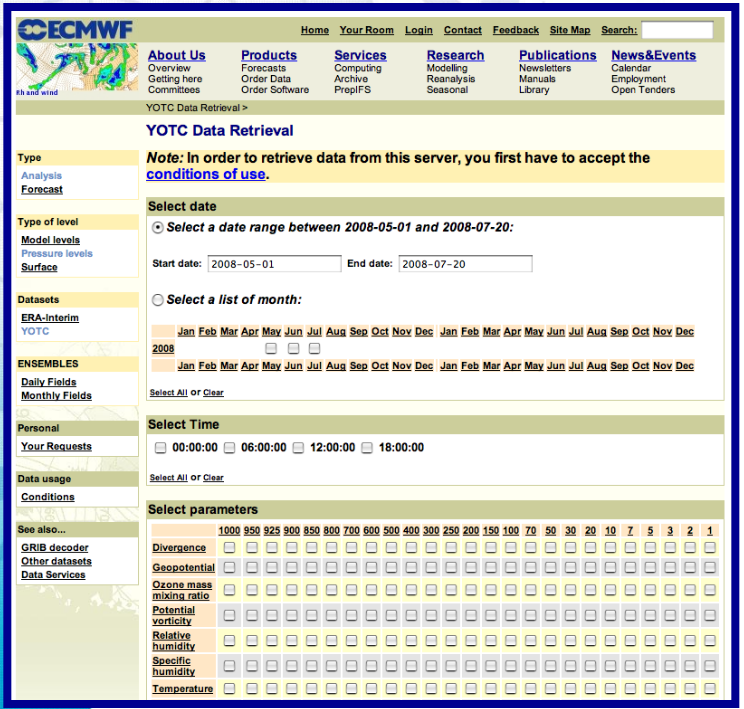
A Contribution to Seamless Weather-Climate Prediction

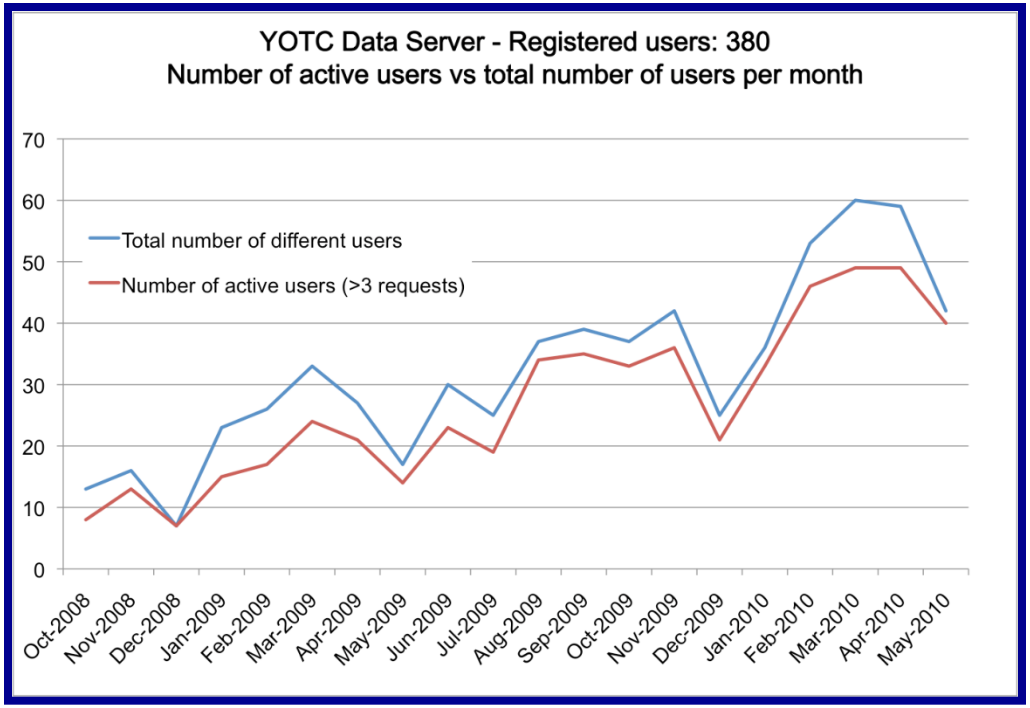
ICSC-9 For THORPEX
Geneva; September 2011

YOTC: Analyses, Forecasts & Special Diagnos



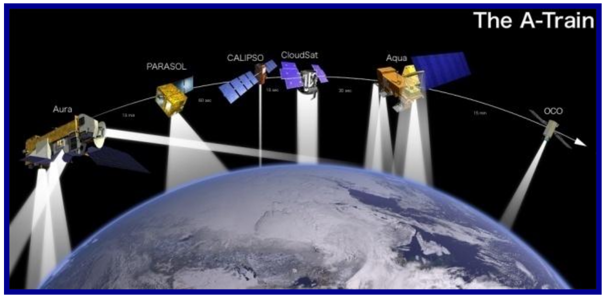
- High-resolution, global analysis and forecast data sets are being made available to the community from ECMWF, NCEP and GMAO/NASA. e.g. T799 = 25km ECMWF + diagnostic fields *(as of Jan'10, T1279 = 16kms)*



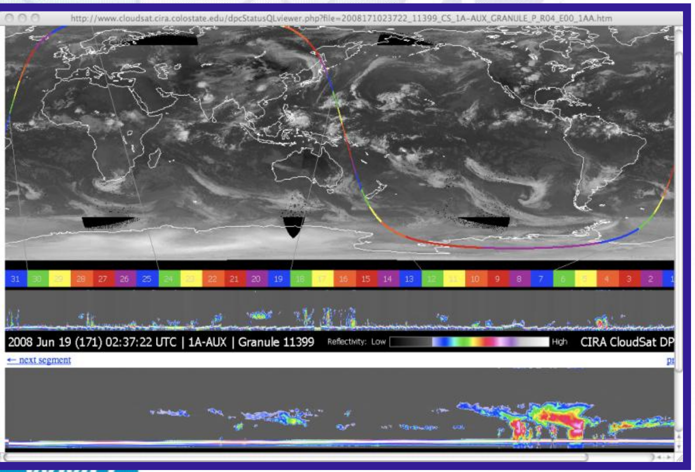


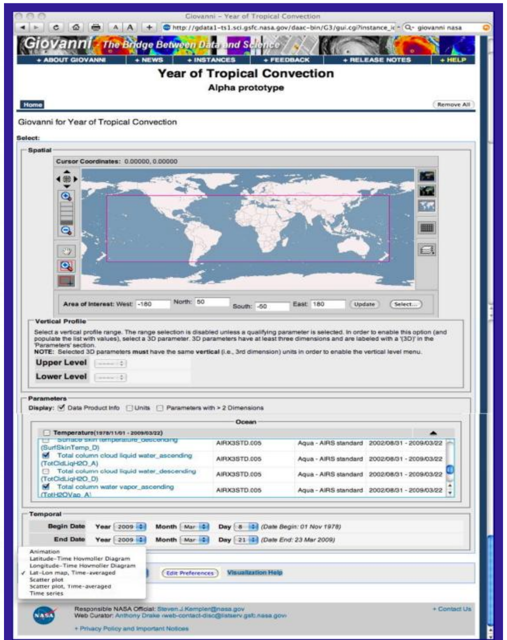
ECMWF-YOTC Replicated at NCAR.

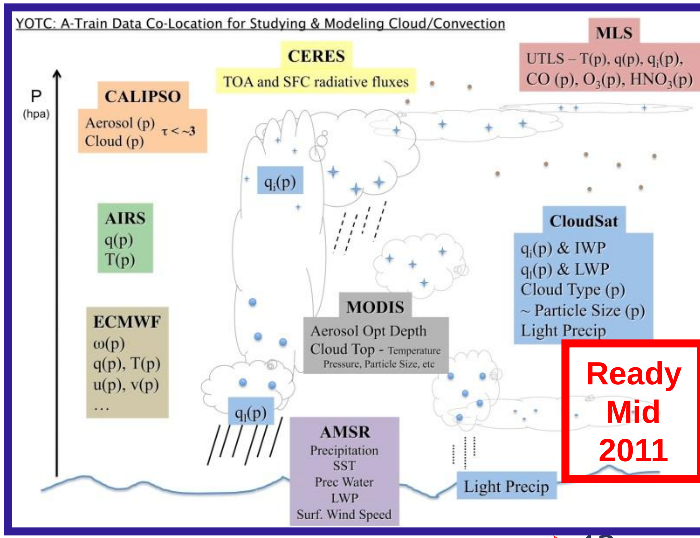
YOTC: Satellite Data



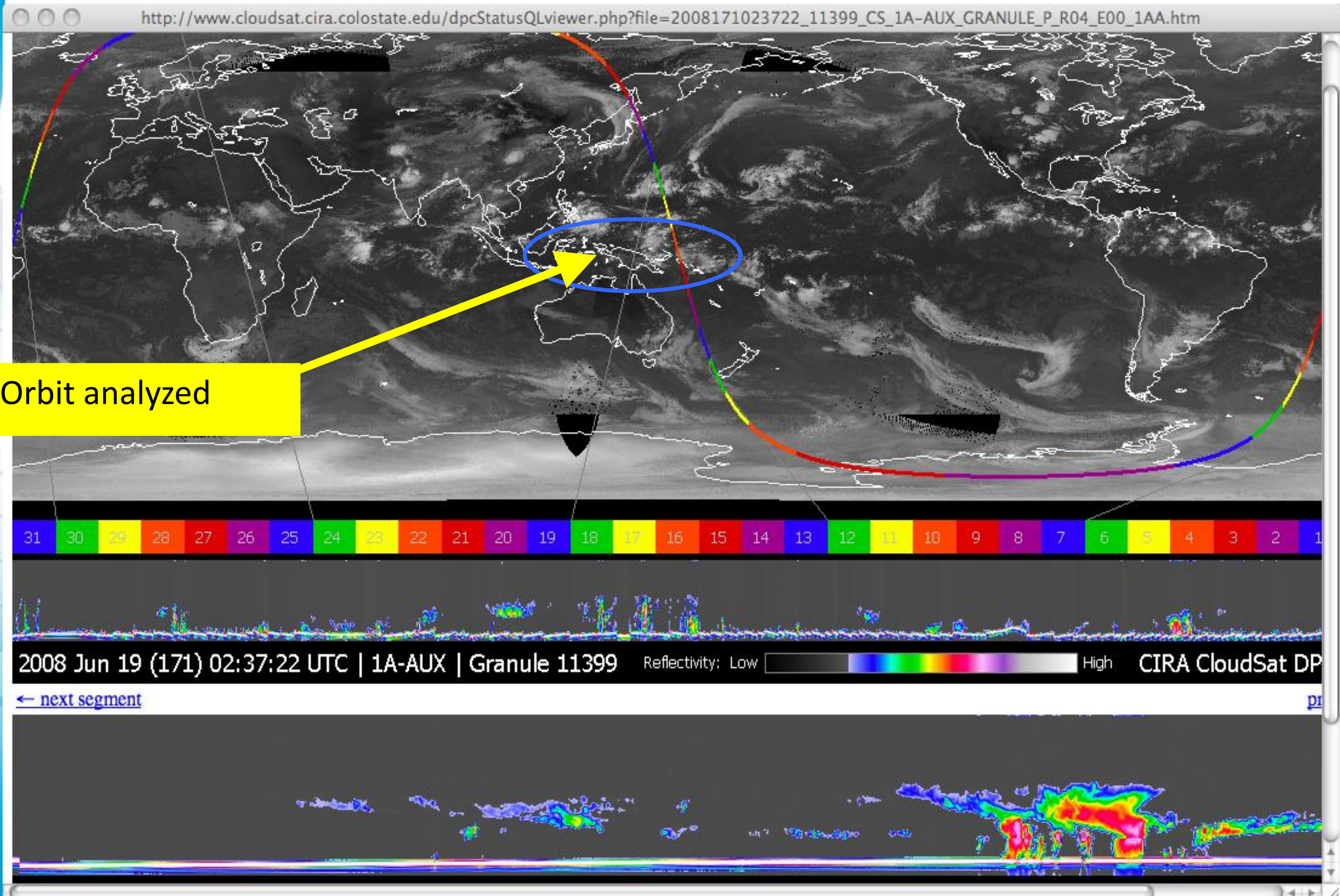
- Key satellite data (e.g., NASA A-Train, TRMM) have been identified.
- NASA has developed the Giovanni-based dissemination framework.
  - Multi-sensor CloudSat-Centric A-Train Data Set – archive & dissemination underway at CloudSat Data Processing Center.





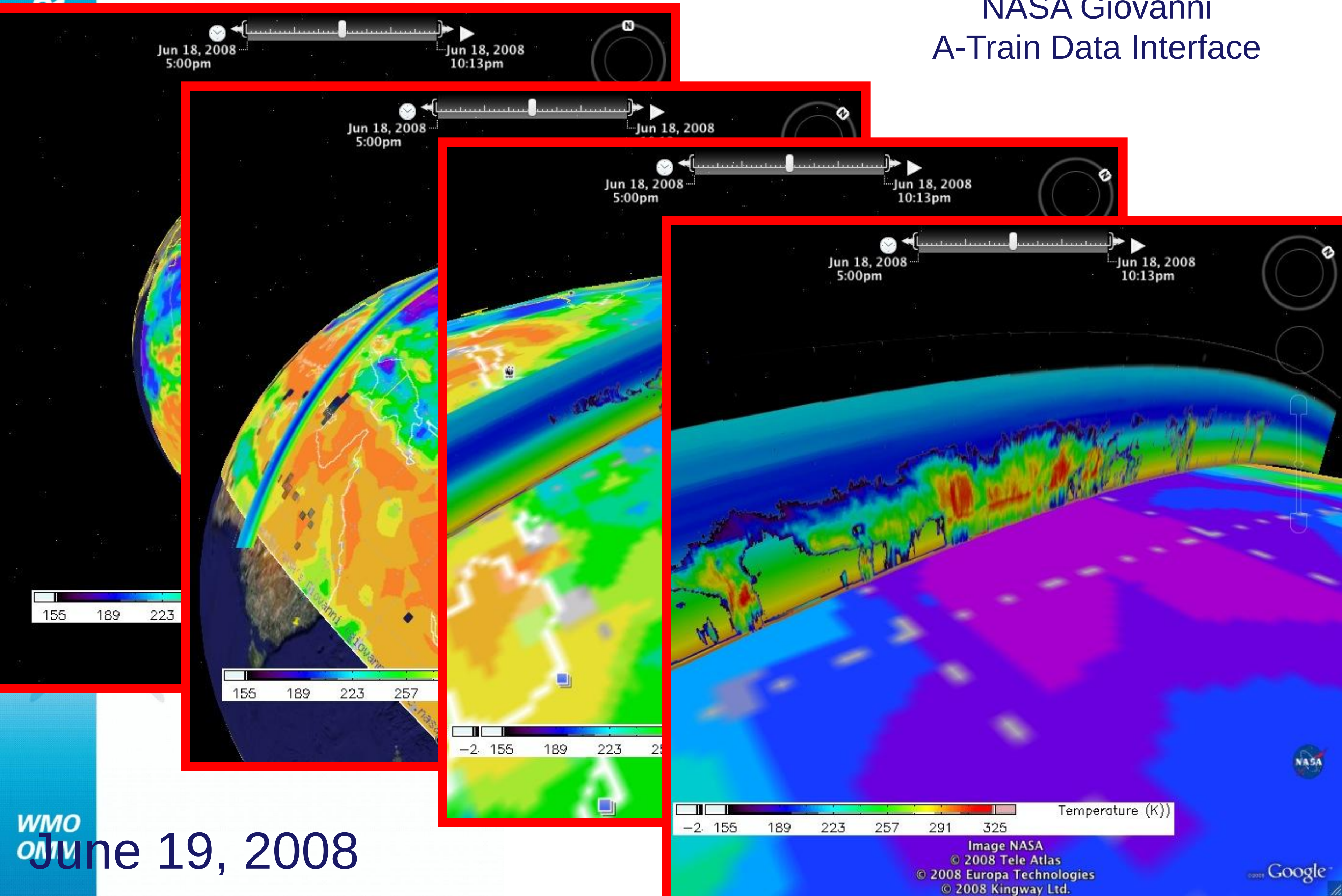


Kelvin Waves and tropical convection: June 19, 2008



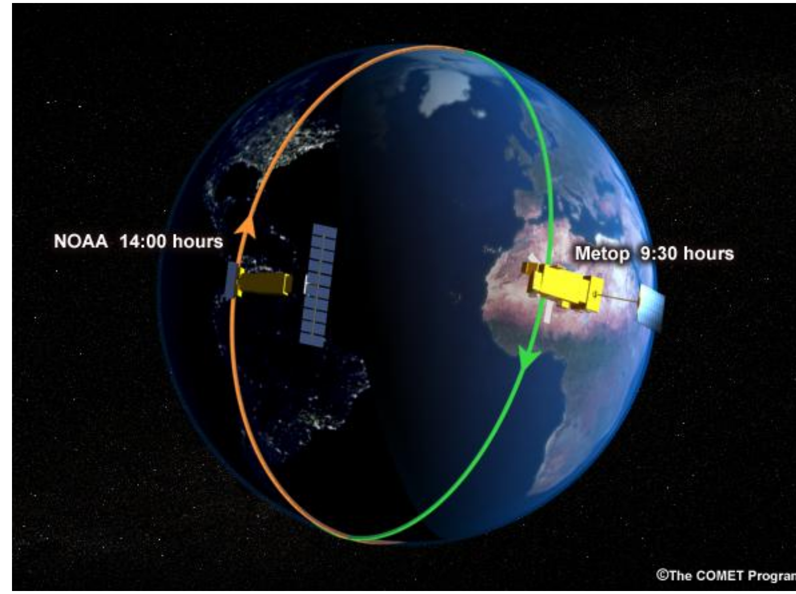
Satellite Data Analysis & Dissemination

NASA Giovanni
A-Train Data Interface



June 19, 2008

International Polar Year (IPY) –THORPEX Cluster of Projects
The International Project Concordiasi



IPEV Institut Polaire Français Paul Émile Victor

cnes

CNRS

Programma Nazionale di Ricerche in Antartide — ItaliAntartide

NSF

LASP Laboratory for Atmospheric and Space Physics

Purdue

LMD/CNRS

LGGE Laboratoire de Glaciologie et Géophysique de l'Environnement

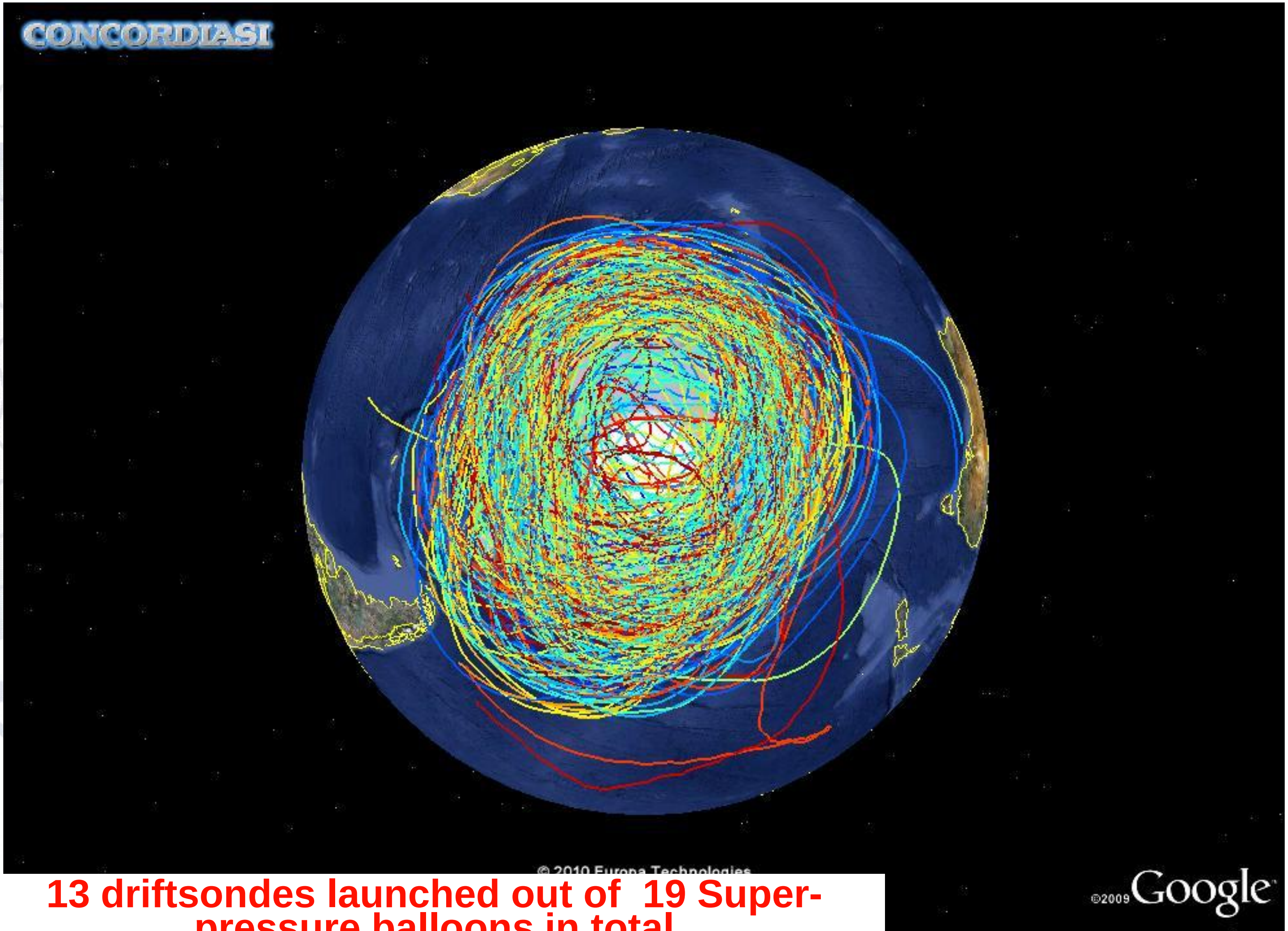
University of Wyoming — New Thinking

NCAR

WMO OMM

THORPEX

CONCORDIASI
Driftsdonde flights overview Sept 2010-January 2011



13 driftsondes launched out of 19 Super-pressure balloons in total

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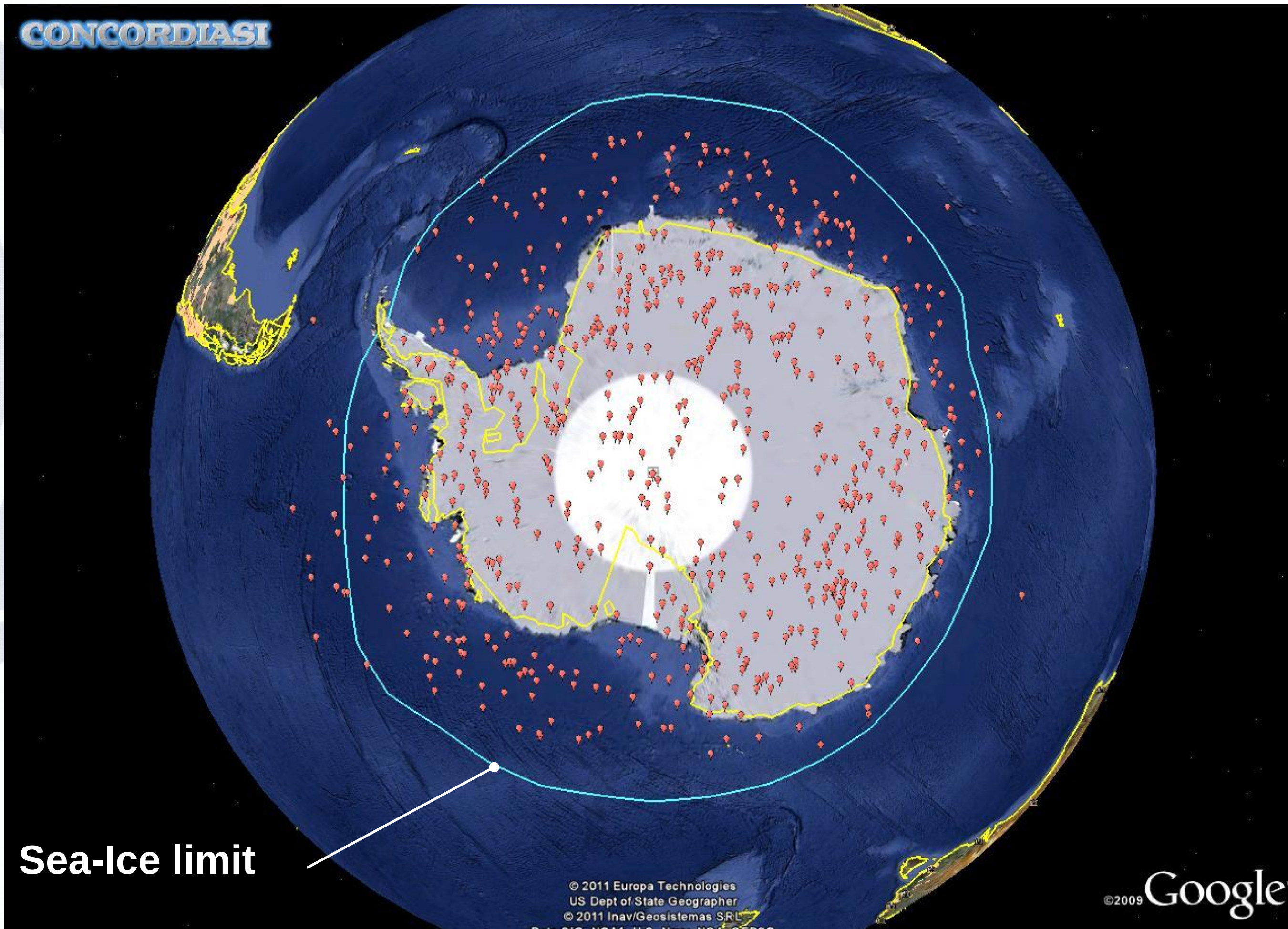
640 Dropsondes



GEOS-5 Data Assimilation and Forecast Impacts for Concordiasi

GEOS-5 configuration:

- GEOS-5 AGCM + GSI analysis (~0.5° L72)
- 20 Sep – 20 Dec 2010
- 6-h assimilation cycle, 3D-Var
- NCEP observation set, ~2.5 million obs assimilated / 6 h

Adjoint-based observation impacts:

- 24-h forecasts at 00z and 12z (89 Drop cases)
- Dry total energy norm: **60°S-90°S, sfc – 50 hPa**
- Dry adjoint model physics*

** impacts of moisture observations likely under-represented in current results and should be interpreted with proper caution*

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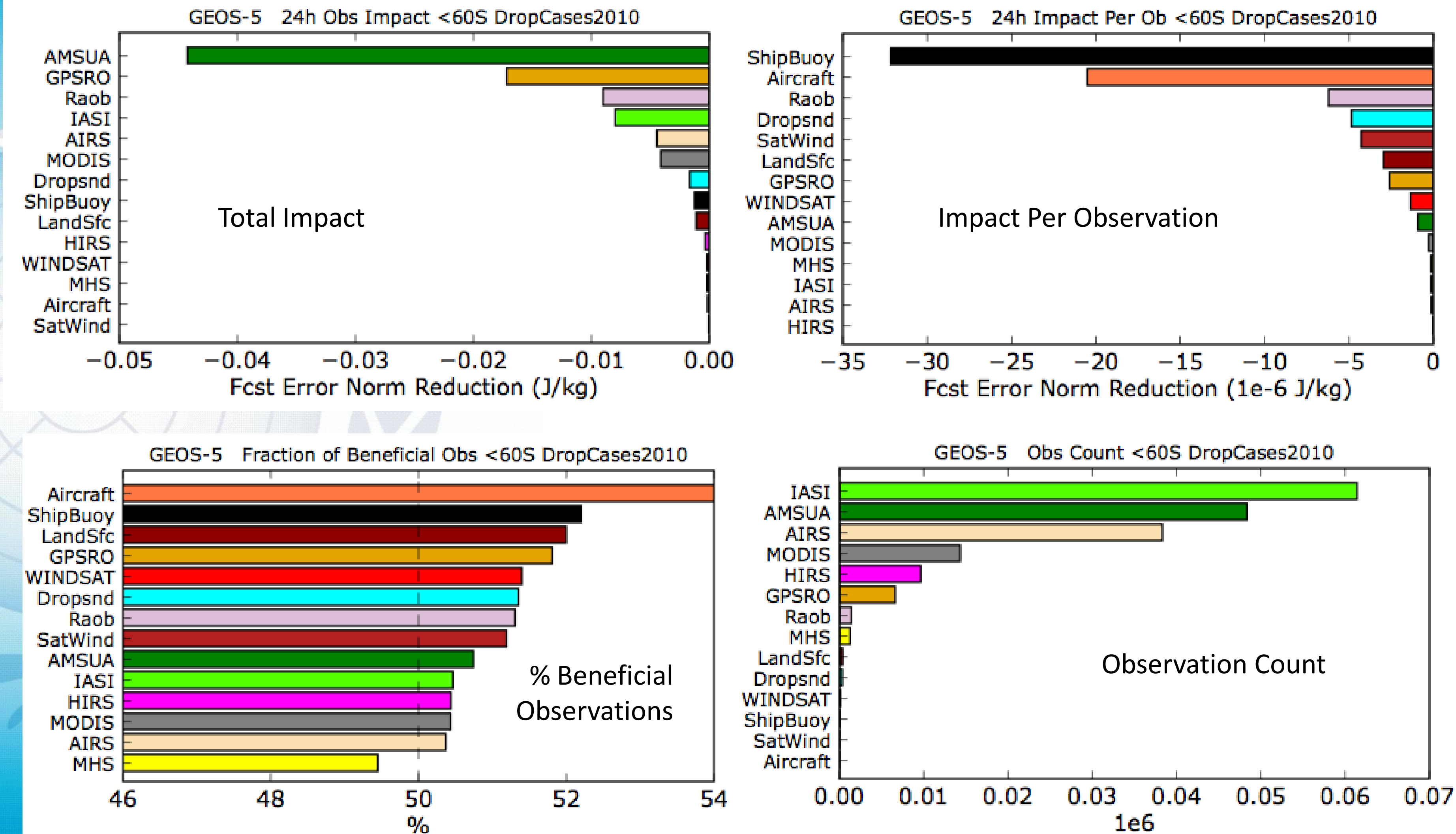
GEOS-5 Observation Impacts for Concordiasi

Average for All Drop Cases – 60°S-90°S Observations



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Concluding remarks

- Concordiasi provided an unprecedented data coverage of meteorological observations over Antarctica
- Both dropsonde and gondola information seem to have a positive impact on forecast performance (preliminary results from NRL, DWD and MF)
- Gondola temperature data at 60hPa shows the largest model errors in areas of strong gravity-wave activity
- Dropsonde information confirms statistics obtained with radiosondes and provide a more global view
- Most models have problems predicting the lowest level temperatures

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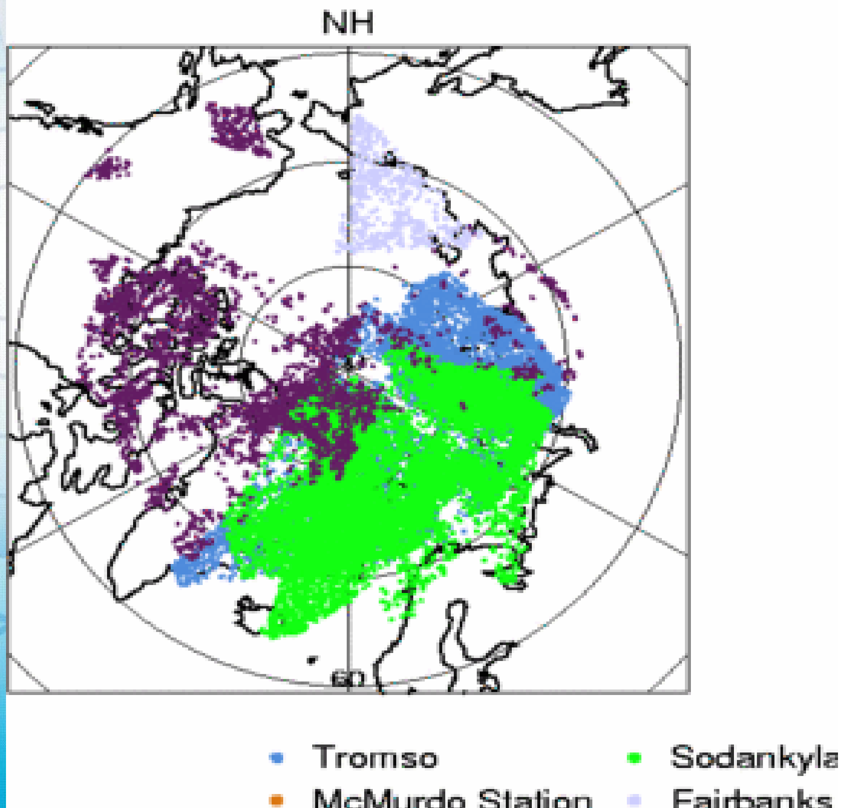
Some satellite issues relevant to THORPEX

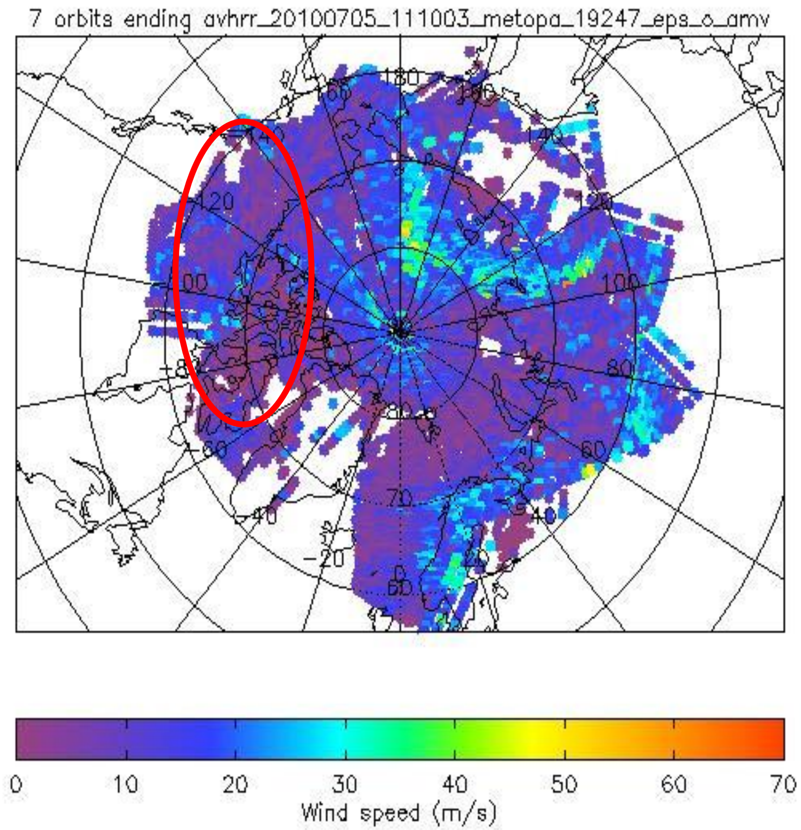
Roger Saunders with input from Chris Velden and others

New METOP polar AMVs

MODIS AMVs
Triplets



METOP AMVs
Image pairs

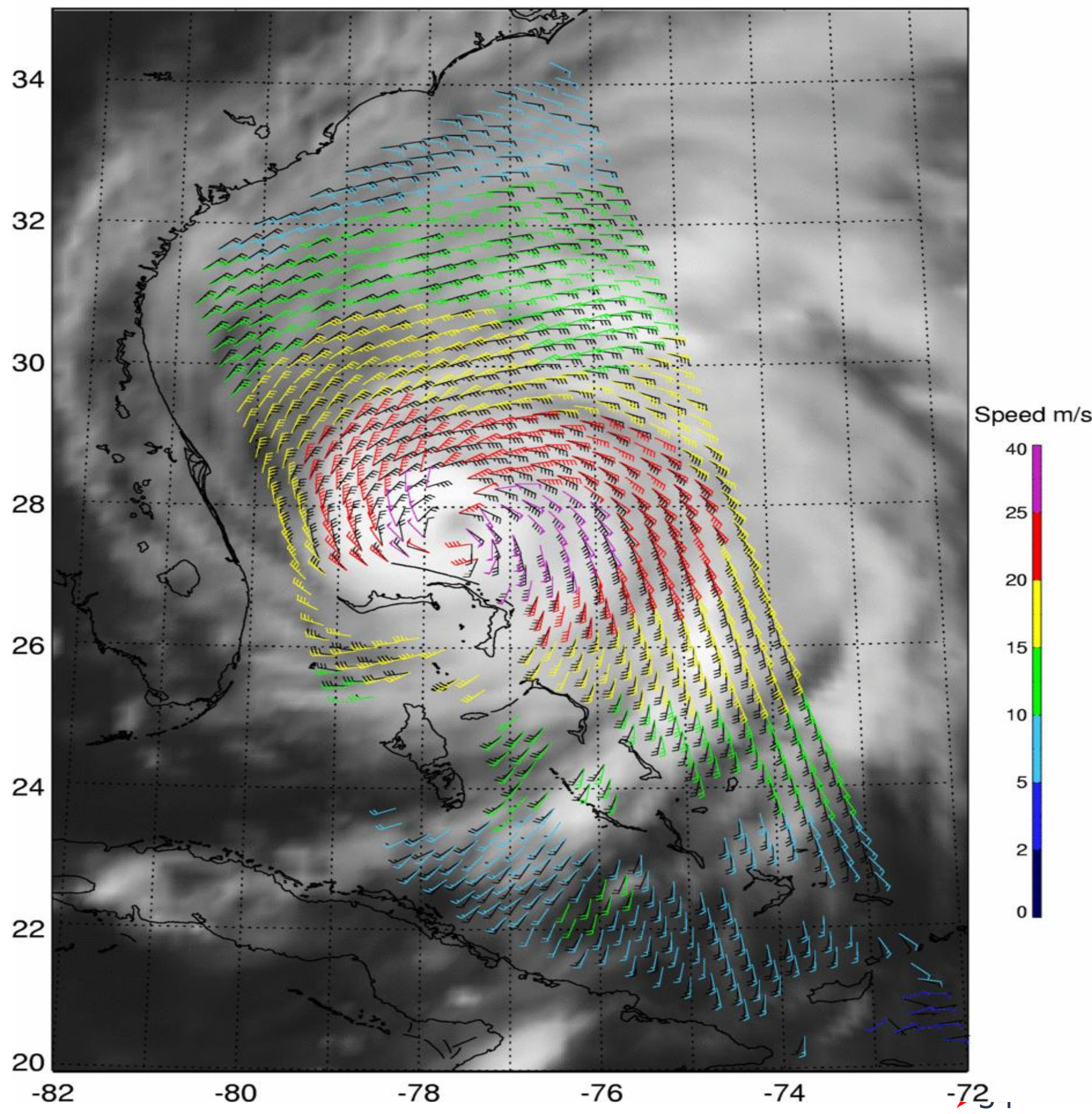


More coverage

Importance of Scatterometer winds

- ASCAT winds for Irene and model background
- Only one scat now used for NWP
- Trials using scatterometer on Oceansat-2

ASCAT 25km: 0152z 20110826, GOES IR10.7, IRENE (3)



THORPEX - some messages

- Extended life of some research satellites helps to mitigate losses elsewhere
- Reduced thinning of AMSU-A shown to beneficial
- Hyperspectral sounder in GEO orbit now approved by Europe on MTG, assimilation new area of research
- Contribution to GOS by nations increasing (e.g. FY-3, Oceansat-2) to fill future gaps in GOS
- Challenge of assimilation of satellite data in high resolution local area models and extend use of advanced IR sounders.

THORPEX

- Thank you for your attention

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Current Status

- All geostationary satellites operational GOES 11/13 &12 to S. America, JMA switched from MTSAT-1R to -2
- New Geostationary satellites COMS (1 Vis, 4IR channels) and GOMS-2 (3 Vis, 7IR channels) -look good
- Indian Oceansat-2 scatterometer looks promising to replace Quikscat.
- Chinese FY-3 series providing good MW sounder data for NWP. ECMWF ready to assimilate MWHS radiances.
- NPP and METOP-B to launch 2011/12
- Extension of EOS (~2015) and ENVISAT (~2014)
- McMurdo is coming online will reduce data delay by 50%