RapidScat Near-Real-Time Observations of Ocean Surface Winds From the International Space Station

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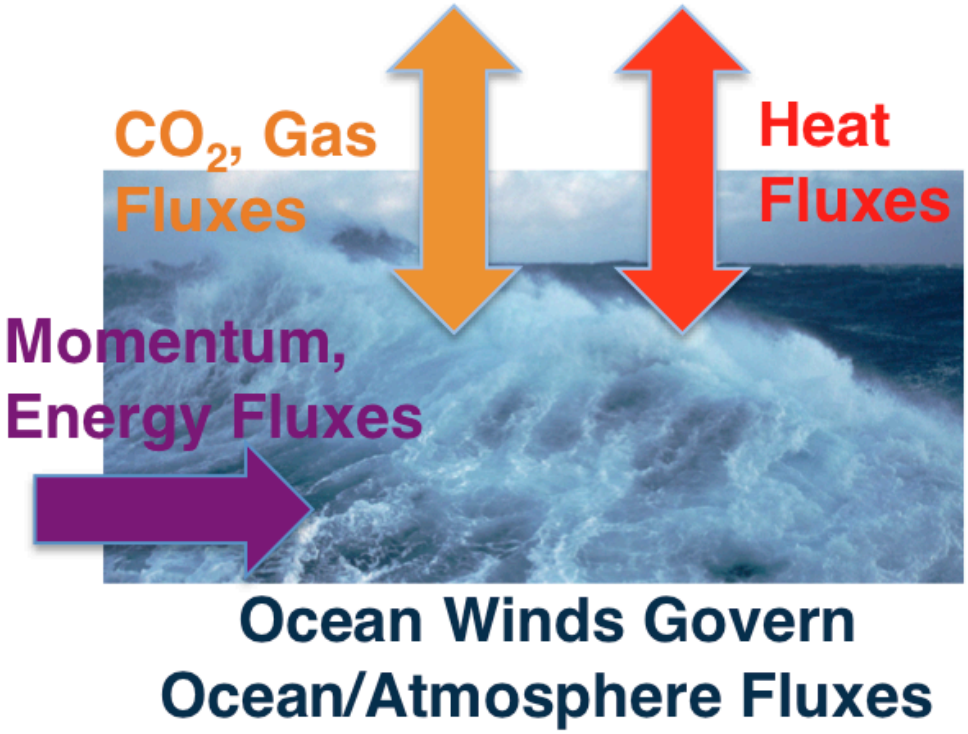
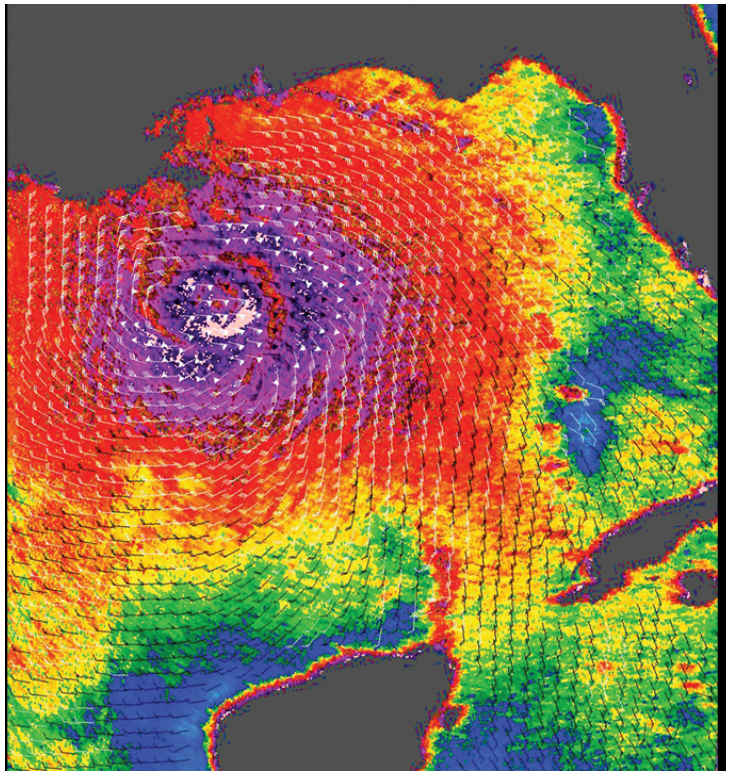
Why measure ocean winds?



Hurricane Katrina Observed by QuikScat

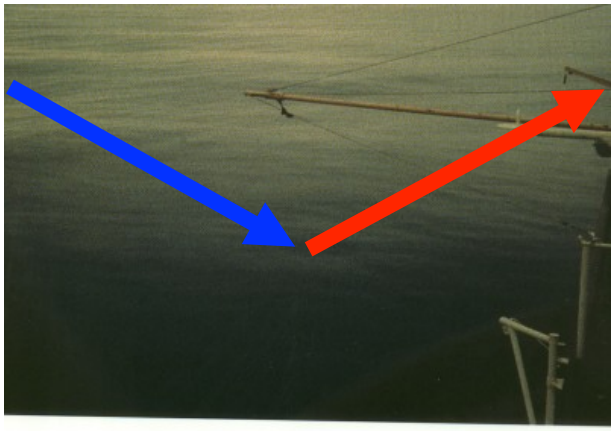


The ocean is the Earth's storehouse for heat, gases, and kinetic energy (currents). Winds over the ocean are the drivers of exchanges of energy and gases between the ocean the atmosphere.

Storms are generated far from land but affect shipping and the world's population:

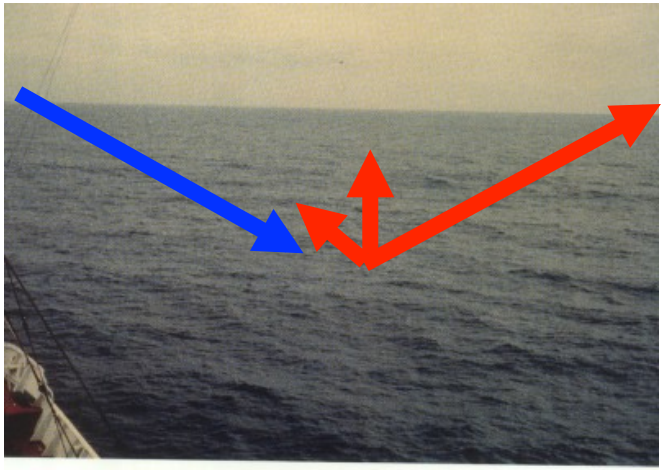
- Tropical cyclone landfall
- Storm surges

How to measure winds with a radar



BEAUFORT FORCE 0
WIND SPEED: LESS THAN 1 KNOT

SEA: SEA LIKE A MIRROR

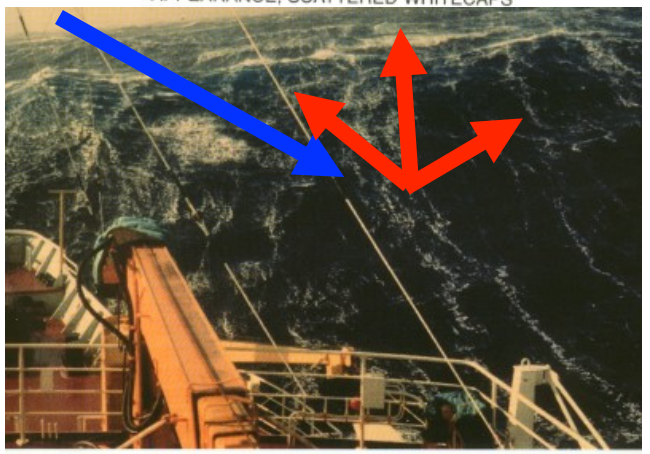


BEAUFORT FORCE 3
WIND SPEED: 7-10 KNOTS

SEA: WAVE HEIGHT .6-1M (2-3FT), LARGE WAVELETS, CRESTS BEGIN TO BREAK, ANY FOAM HAS GLASSY APPEARANCE, SCATTERED WHITECAPS

BEAUFORT FORCE 6
WIND SPEED: 22-27 KNOTS

SEA: WAVE HEIGHT 3-4M (9.5-13 FT), LARGER WAVES BEGIN TO FORM, SPRAY IS PRESENT, WHITE FOAM CRESTS ARE EVERYWHERE



BEAUFORT FORCE 9
WIND SPEED: 41-47 KNOTS

SEA: WAVE HEIGHT 7-10M (23-32FT), HIGH WAVES, DENSE STREAKS OF FOAM ALONG DIRECTION OF THE WIND, WAVE CRESTS BEGIN TO TOPPLE, TUMBLE, AND ROLL OVER. SPRAY MAY AFFECT VISIBILITY.

www.wikipedia.org

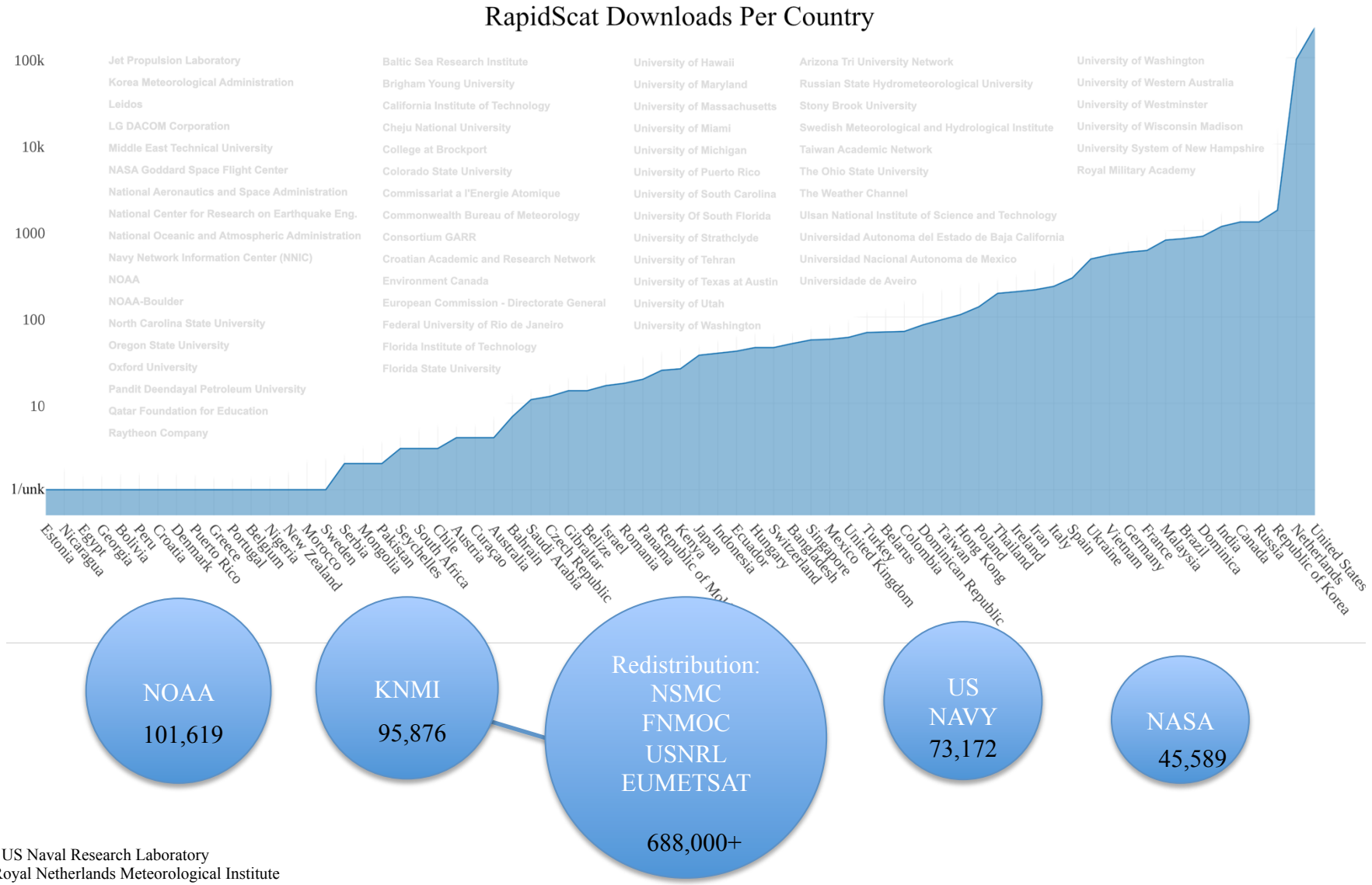
History of NRT Scatterometer Data

- Long history of near-real-time scatterometer data:
  - QuikSCAT 1999-2009
  - ASCAT A/B 2006-current
  - OSCAT 2009-2014
  - RapidScat 2014-2016
- Will continue to be operated for global observation of ocean winds.
  - India's SCATSAT launched yesterday!
  - Europe will operate ASCAT follow-on missions to 2040 time frame.
- All are / were used globally for now-casting and forecasting:
  - Tropical cyclones
  - Ship storm warnings
  - Assimilated into numerical weather prediction models
  - *Large and experienced user base*
- Many applications beyond ocean winds
  - Sea ice extent monitoring / iceberg tracking
  - Biomass
  - Soil moisture

RapidScat is QuikSCAT on ISS

- RapidScat mission concept: Put QuikSCAT instrument on ISS
  - Hardware is mostly left over QuikSCAT parts.
  - About 2 years from development to launch.
  - NRT data flow to users began 5 weeks after instrument turn-on after rapid calibration validation period.
- Provided NRT data to users within 2-3 hours of aquisition:
  - Two operational NRT streams due to ISS -> TDRSS line-of-sight dropouts.
  - Very fast adaption of forecasting agencies to RapidScat data globally.
- Unique in that ISS in non-sun synconous orbit
  - Observations samples all local time of day over 2 month period
  - Enables new science resolving dialy cycles in land/ocean

RapidScat Data Around the World



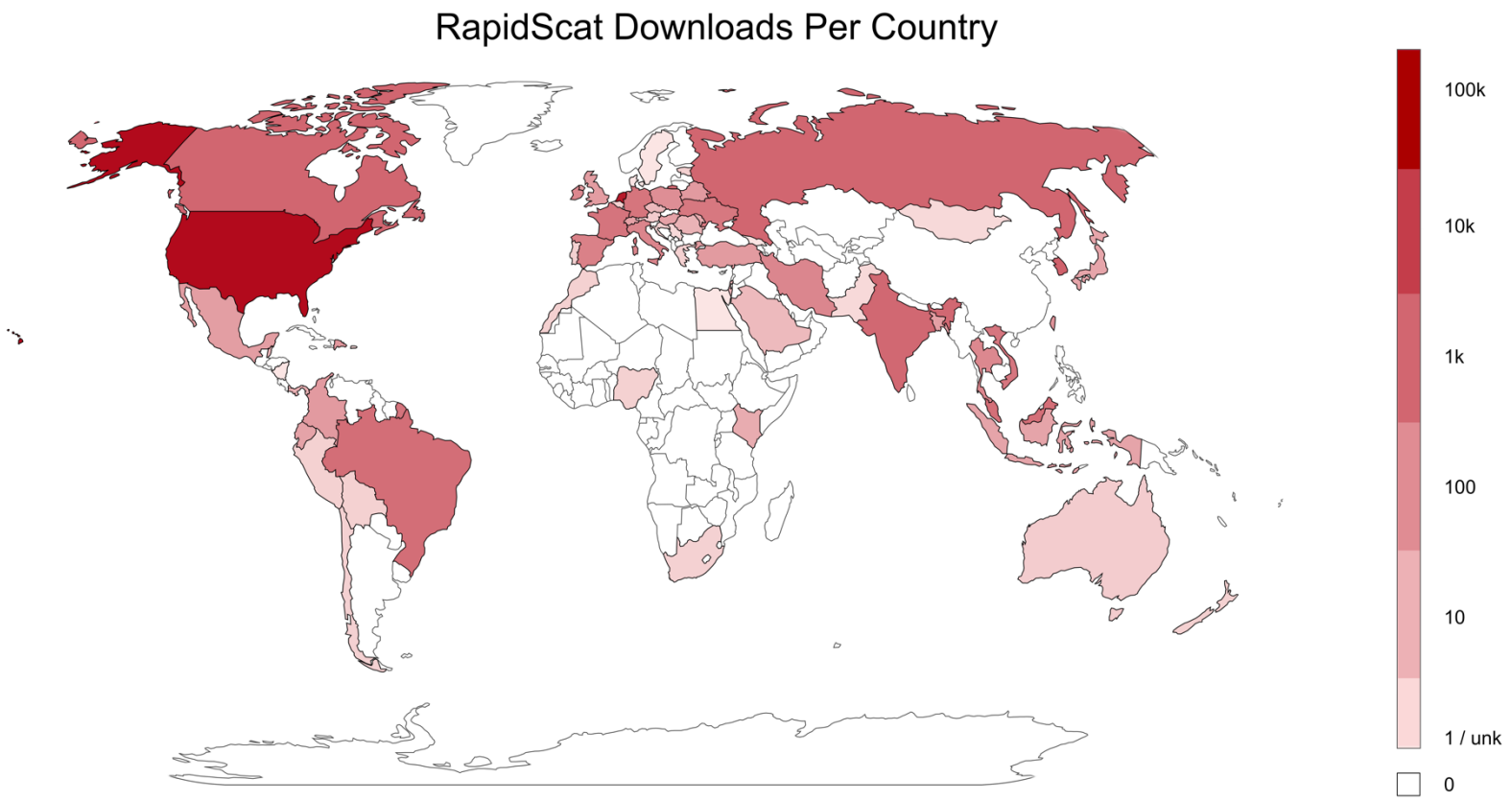
USNRL = US Naval Research Laboratory
KNMI = Royal Netherlands Meteorological Institute

NSMC = Chinese National Satellite Meteorological Center
FNMOC = USA Fleet Numerical Meteorology and Oceanography Center

EUMETSAT = European Organization for the Exploitation of Meteorological Satellites

Alex Wineteer, Qi Chen, David Moroni
NASA/JPL-Caltech

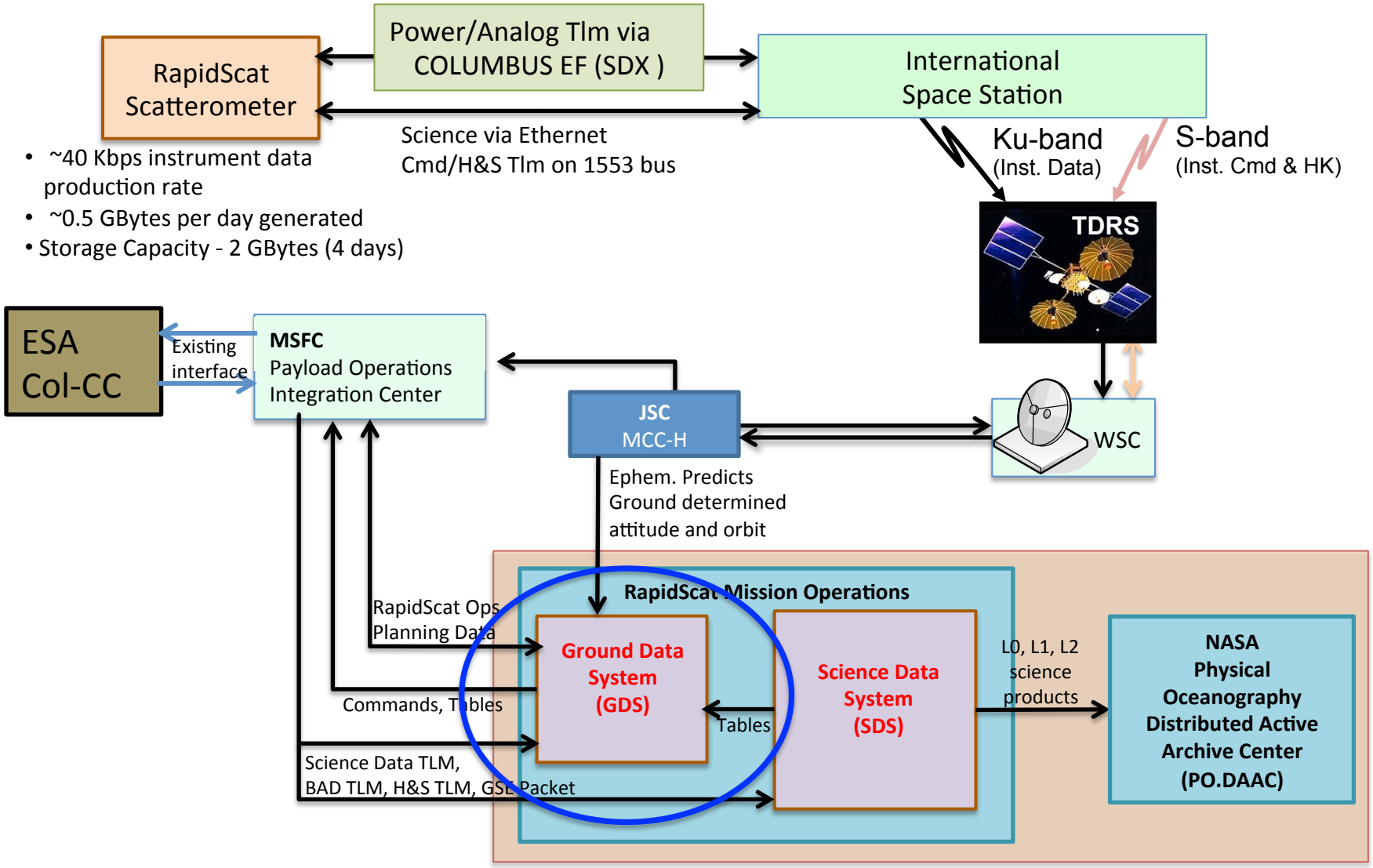
Global RapidScat Downloads



RapidScat data is being used all over the world by government laboratories, scientists, private companies, students, and individuals alike.

Alex Wineteer, Qi Chen, David Moroni
NASA/JPL-Caltech

RapidScat GDS Architecture and Data Flow



Issues / Challenges of NRT from ISS

- Data flow from ISS to JPL: JPL maintenance of 15 cyclic data queries
  - MSFC Maintenance impacts
    - MSFC maintenance activities impacts software subsystems (EPC/EHS) resulting in data outages and automated query re-submissions.
    - Waiting for the maintenance to complete often times meant loss of data for a number of hours.
  - Frequent cyclic data request restarts
    - Cyclic requests only can iterate 999 times.
    - Re-submission of the 15 data queries every three weeks.
  - Frequent EPC re-authentication
    - RapidScat requires automated uplink of tables to instrument from JPL.
    - EPC logins valid for 72 hours; GDS team had to re-authenticate 3 times per week to maintain data quality.
- Line of sight dropouts between ISS and TDRSS
  - 20% data missing for query of data [40, 10] minutes old; typically over Indian Ocean.
  - 5% missing data for query of data [90, 60] minutes old.

Issues / Challenges for a Scatterometer on the ISS

- Platform is not ideal for a radar:
  - Attitude is not very stable.
  - Attitude states tend to vary based on what is docked to ISS.
  - *Addressing these issues were a critical part of the RapidScat mission planning to ensure mission success.*
- Have to turn off for periodic dockings -> 8% of data lost.
- Near dockings ISS typically has large attitude variations -> 2% of data lost.
- Prolonged periods of sub-optimal pointing: 5% of data reduced quality.
- Remaining: 85% of data is of good quality
- Calibration of RapidScat not as good as QuikSCAT due to attitude variations and knowledge errors.

Summary

- RapidScat demonstrated the capability of ISS for an always-on NRT mission.
  - Non sun-synchronous orbit => can sample diurnal cycle.
  - *Very inexpensive* compared to traditional launch + spacecraft.
- Main Complications:
  - ISS attitude variability (in mean and variation about mean).
  - Flow of data to JPL from ISS.
  - Data gaps due to TDRSS coverage.
- RapidScat was extremely successful given its cost.
  - Mature mission => 5 weeks to NRT data distribution.
  - Mature users => very fast adoption of NRT data into forecasting / now-casting.
  - Data to NRT users within 2 hours of acquisition.