Simulation and impact study of future spaceborne Doppler wind lidar in Japan

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  - Lidar and satellite under discussion
- 2. Recent Development
  - Lidar simulator : ISOSIM-L
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- 4. Summary and Plans

1. Background

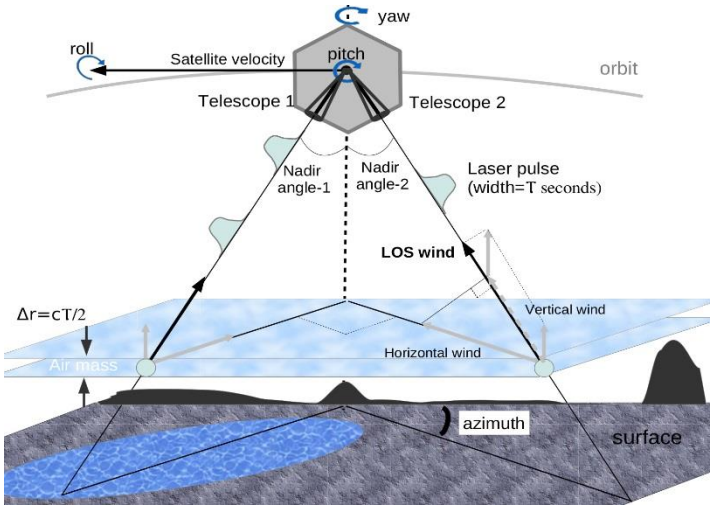
- 3-dimensional global wind measurements are important but deficient in the current global obs. system.
- Space-based Doppler Wind Lidar (DWL) is good candidate to fill the gap.

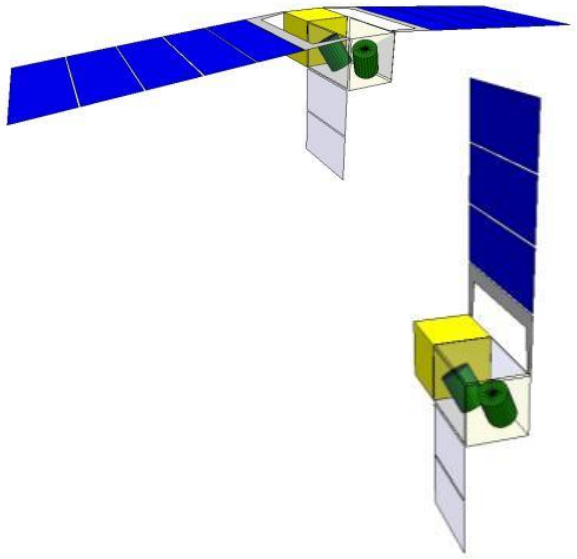
- The working group on Japanese space-based DWL was established in 2011
- NICT, JAXA and JMA/MRI made a collaborative research agreement on development and evaluation of space-based DWL in 2013
- → Began investigating the feasibility and impact of space-based DWL

- NICT : National Institute of Information and Communications Technology
- JAXA : Japan Aerospace Exploration Agency
- JMA/MRI : Japan Meteorological Agency / Meteorological Research Institute

Plans of Japanese DWL and satellite

- DWL
  - Coherent detection
  - Two laser with orthogonal direction (45 and 135 deg)
  - Vertical res: 0.25/0.5/1 km, horizontal res: <100 km
- Satellite
  - Super-low altitude satellites : altitude < 250km
    - Relax lidar's challenging requirement of high power and large telescope size
- Under discussion
  - Satellite orbit : sun-synchronous or low-inclination
  - Specific lidar parameters : Power, PRF, trade-off of SNR and resolution,,,
  - → Evaluate with OSSE



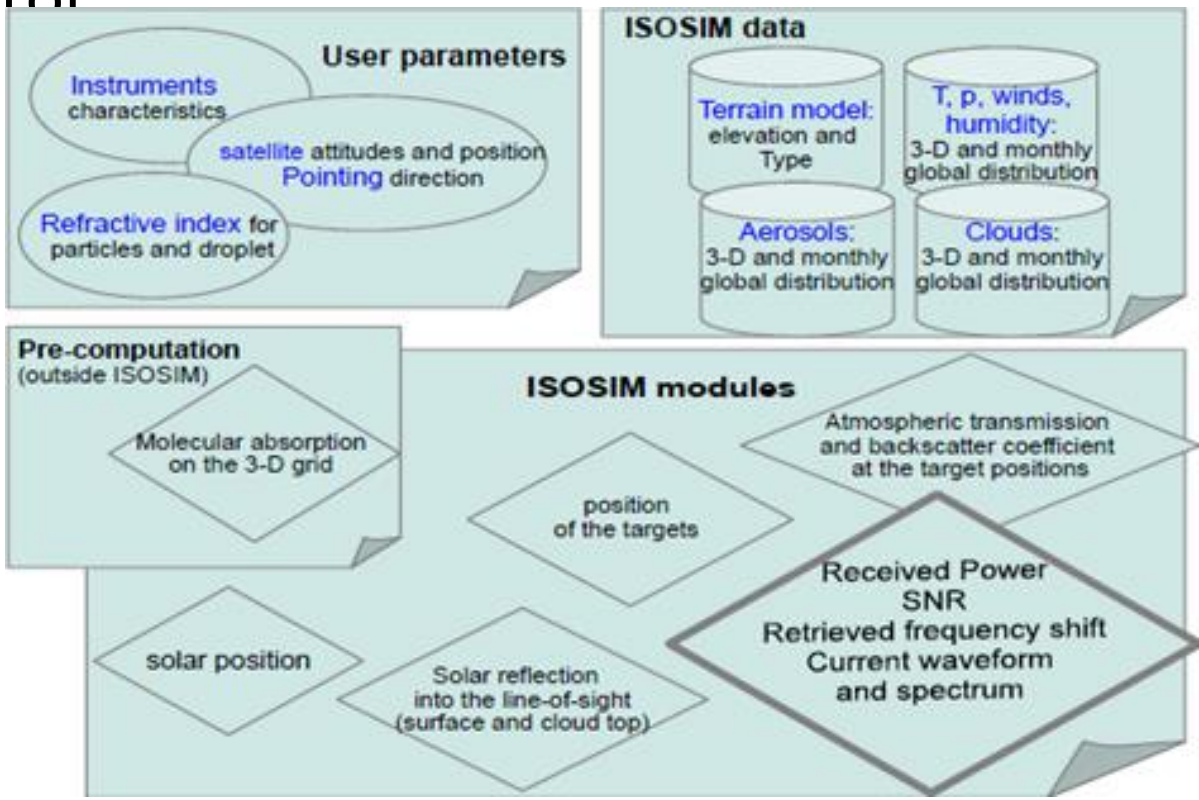


OSSE: SOSE approach

- Sensitivity Observing System Experiment (Marseille et al. 2008)
  - Pseudo-truth (PT) field is created by correcting first-guess based on adjoint sensitivity and assimilating real observations
    - PT field is consistent with obs and reduces forecast-errors
  - Simulation of existing observations is not necessary, unlike Nature-Run OSSE

Lidar simulator : ISOSIM-L

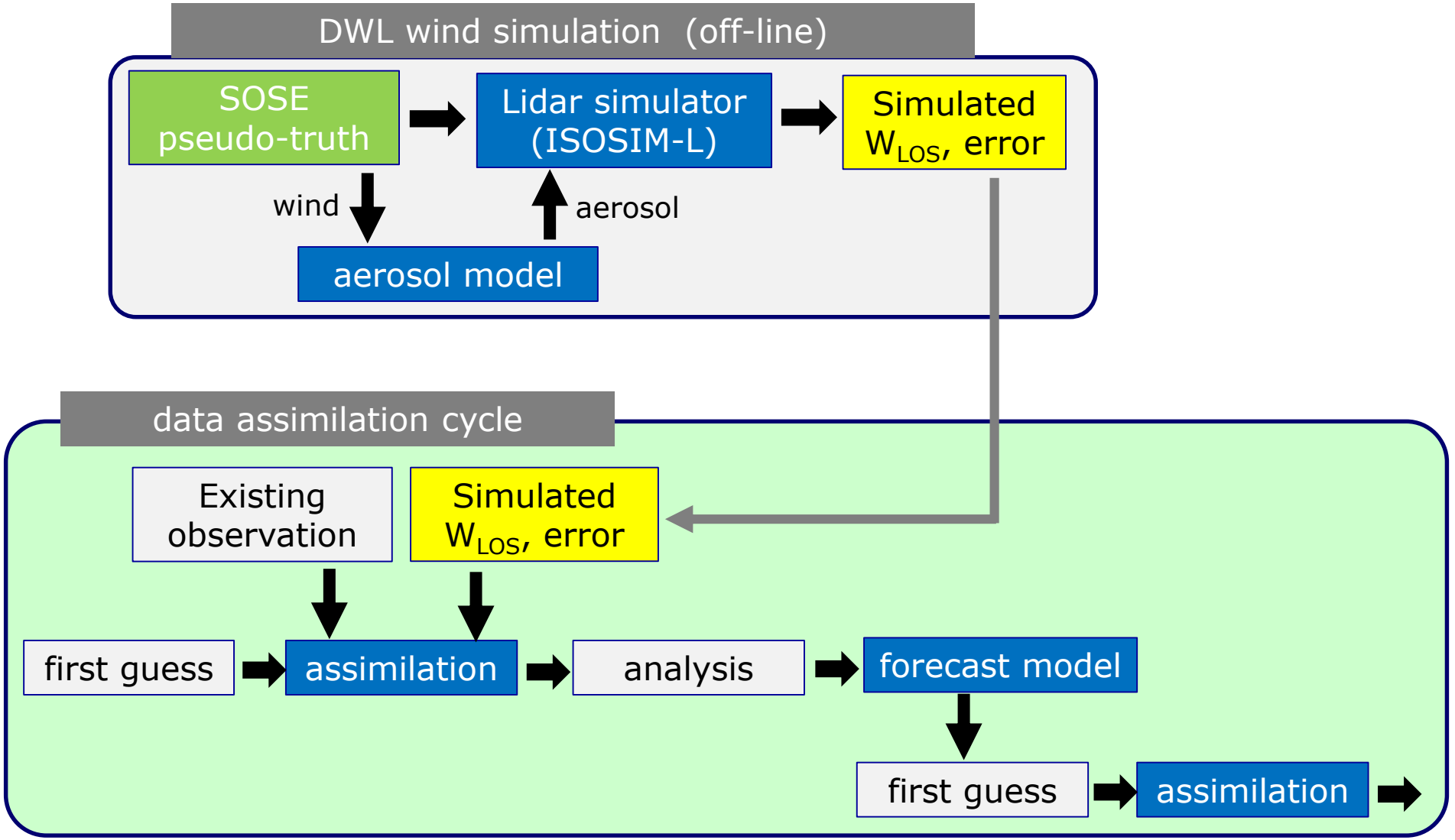
- the Integrated Satellite Observation SIMulator for a spaceborne coherent Doppler lidar
  - NICT originally developed in 2000 and significantly improved recently
  - Baron et al. (2016, JMSJ, in preparation)
- End-to-end simulator
  - Simulate each shot, backscattered power, background noise, SNR
  - Signal average and LOS wind retrieval, accuracy of the winds



Input of ISOSIM-L simulation

- Pseudo-Truth (PT) winds
- 3-dimensional aerosol
  - Generated by aerosol data assimilation cycle nudged with PT winds
    - the global aerosol model of JMA/MRI (MASINGAR; Tanaka and Chiba 2005)
- 3-dimensional cloud
  - First-guess calculated through SOSE PT cycle

SOSE OSSE


DWL wind simulation (off-line)
SOSE pseudo-truth
Lidar simulator (ISOSIM-L)
Simulated W_{LOS}, error
wind
aerosol
aerosol model
data assimilation cycle
Existing observation
Simulated W_{LOS}, error
first guess
assimilation
analysis
forecast model
first guess
assimilation

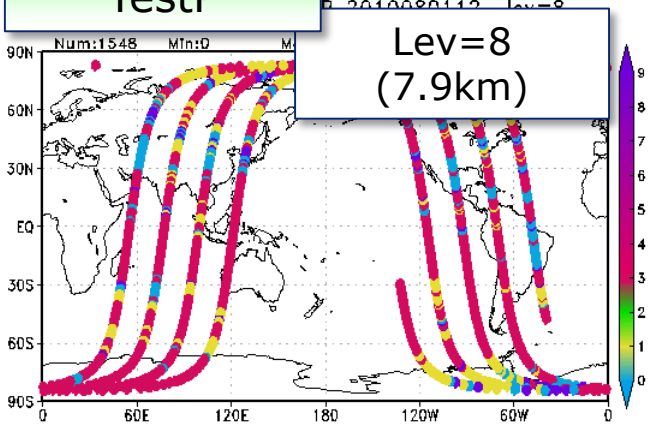
3. Preliminary results of OSSE

- DWL configurations
  - Coherent detection lidar
  - λ=2.0μm, Pulse energy=125mJ, Pule Repetition Frequency=30Hz, Nadir angle=35deg
  - Two lasers with orthogonal directions of 45 and 135 deg
  - Horizontal resolution after averaging : 100km
  - Vertical layers : 19 (surface~27km)
    - Resolution : 0.5km (Z<3km), 1km (3<Z<9km), 2km (9<Z<27km)
  - DWL LOS wind simulated for 1 – 31 Aug. 2010
- OSSE configurations
  - Low-res version of operational global DA system of JMA as of 2010.
    - 6-h cycle, incremental 4D-Var, H.res=60km/120km
  - Data assimilated
    - Control exp. (CNTL) : full operational data set
    - Test exp. CNTL + DWL LOS wind profiles
      - Assimilate each LOS wind profile, instead of U & V profile
      - TESTP : sun-syncronus polar orbiting satellite
      - TESTT : TRMM-like orbiting satellite

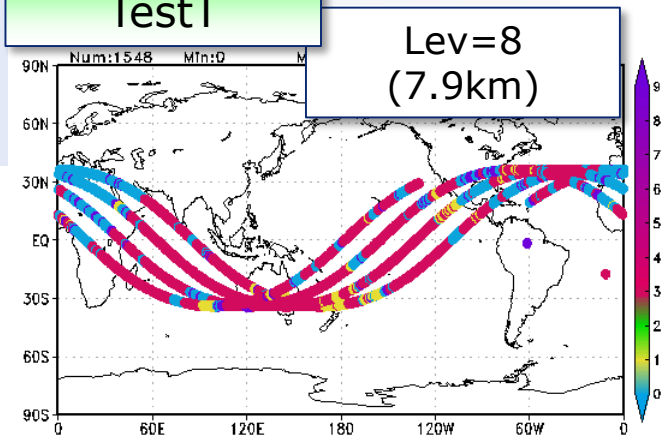
Simulated DWL data

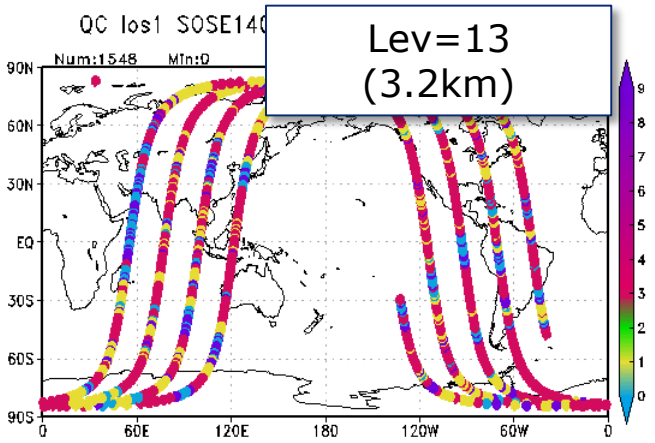
- 09~15UTC, 1 Aug 2010

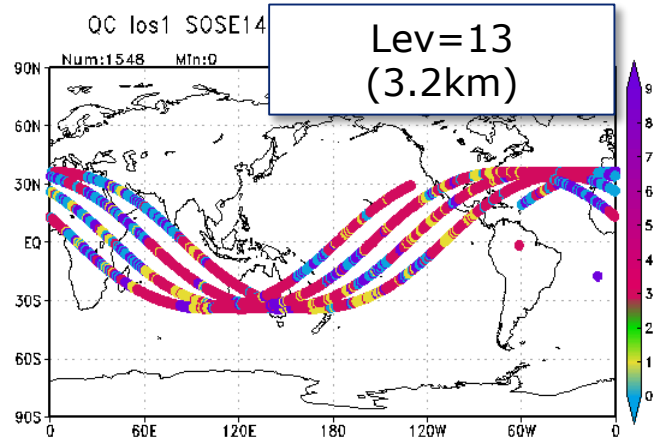
TestP

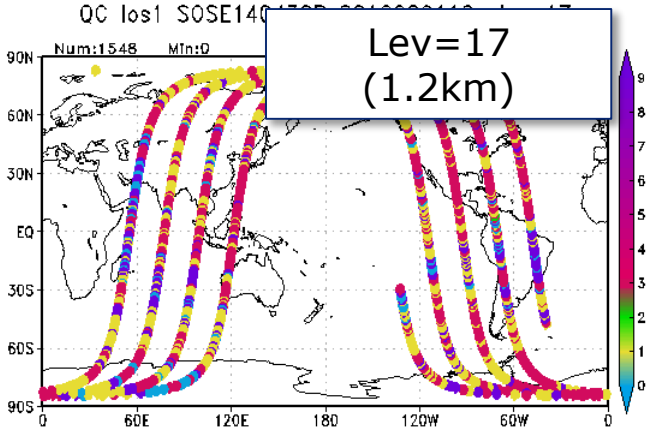


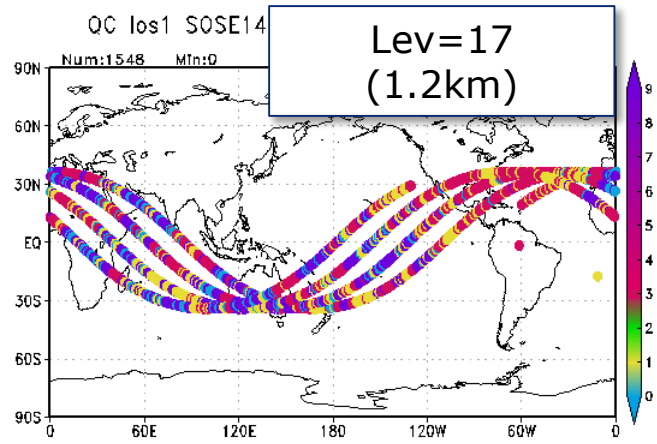
TestT











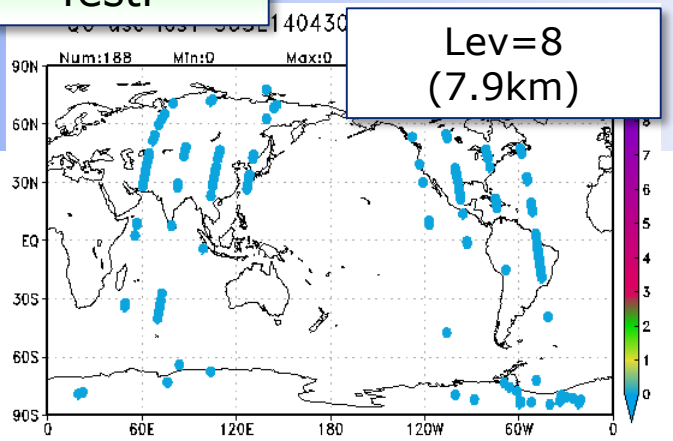
Pass all QC
Anomalous
Large Error
Gross Error

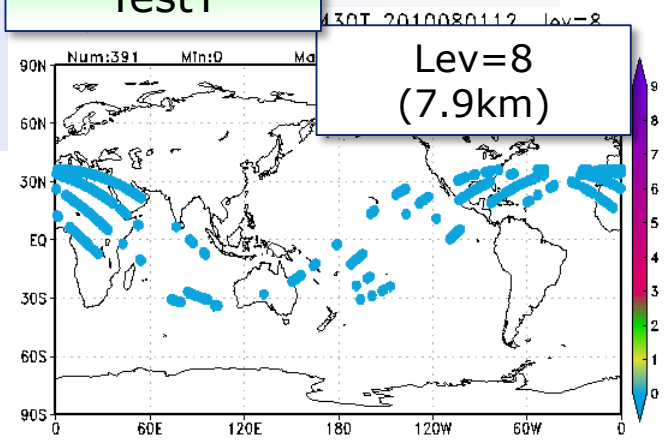
After QC

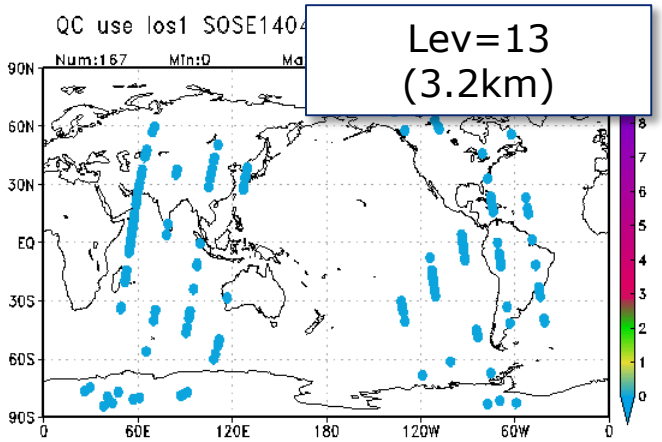
- 09~15UTC, 1 Aug 2010

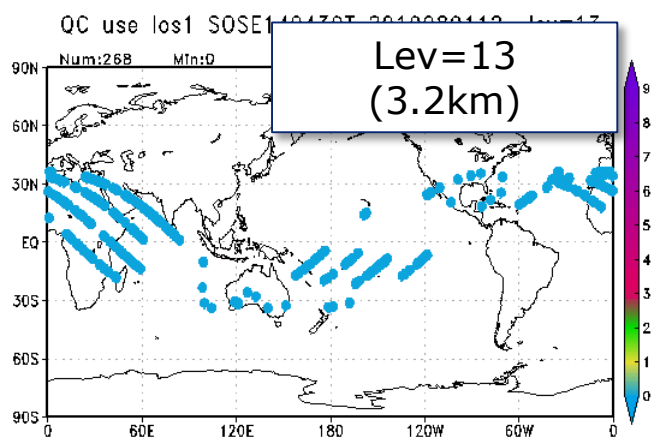
TestP

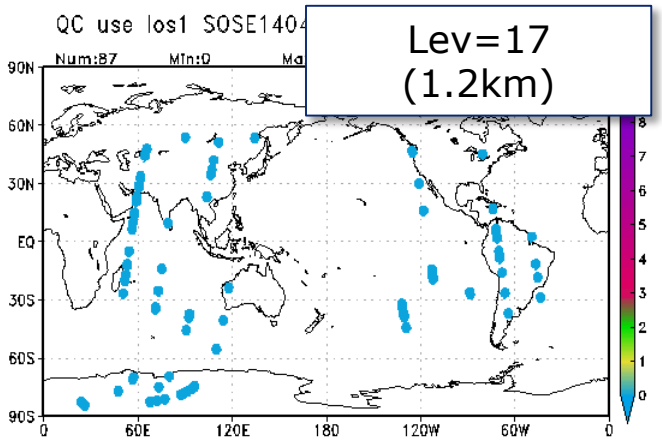
TestT

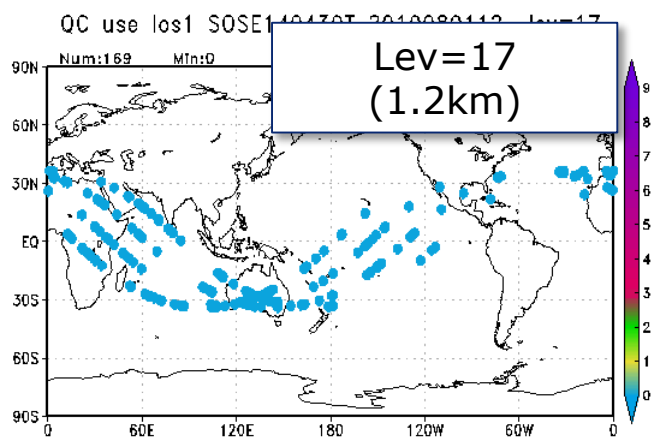








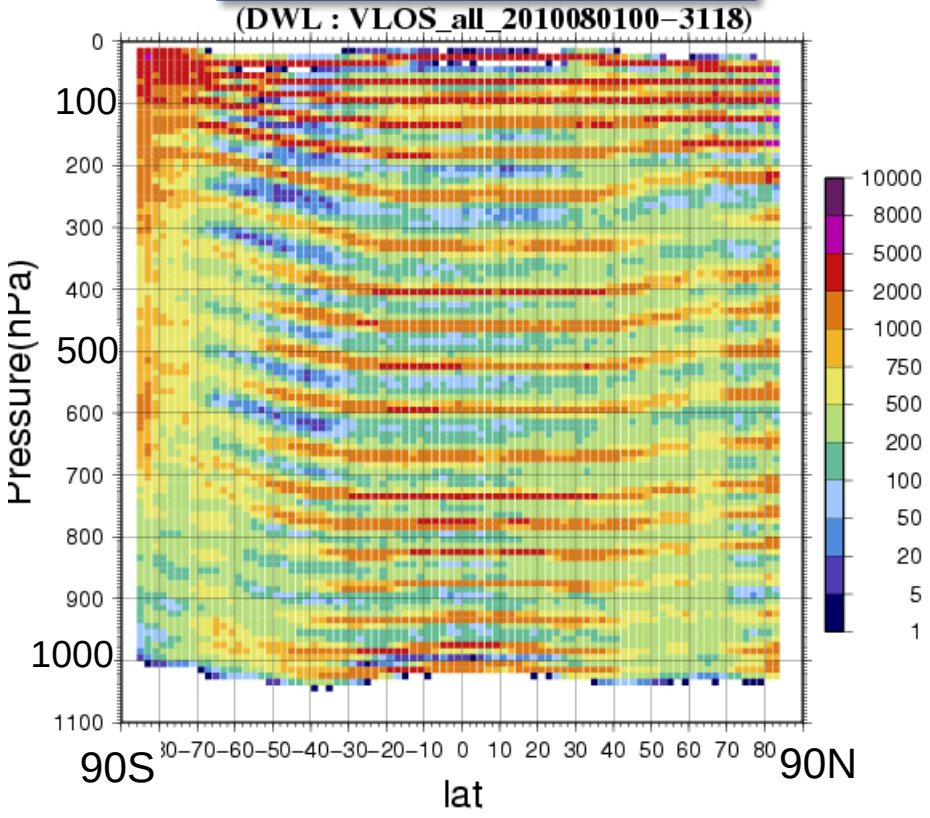




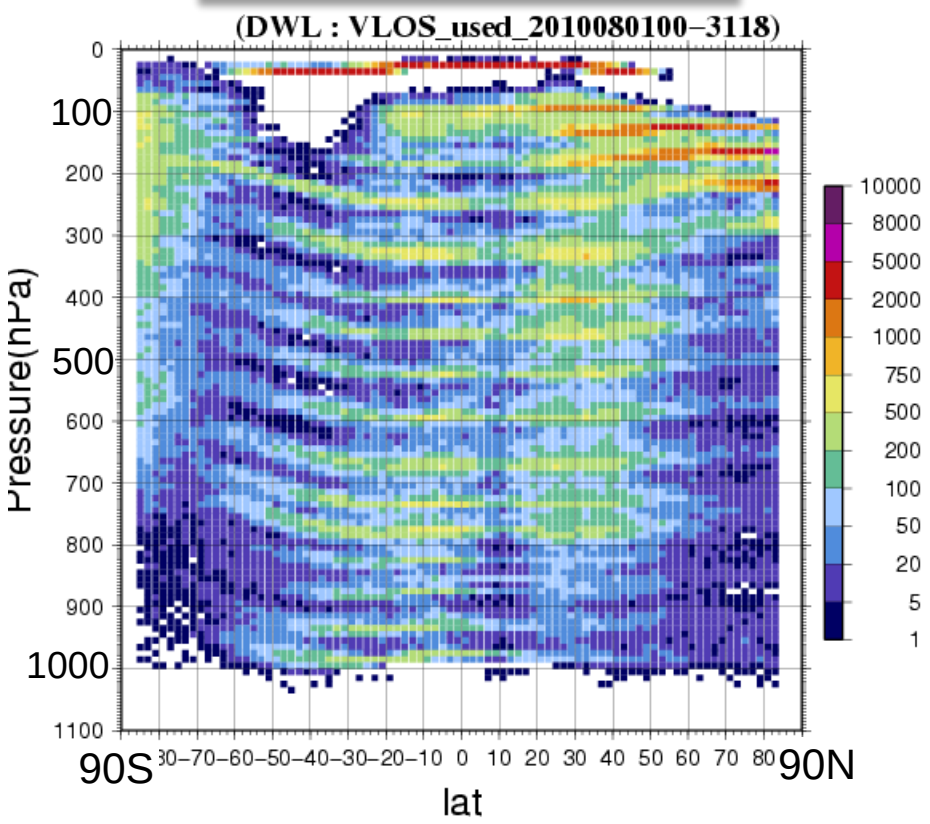
Pass all QC
Anomalous
Large Error
Gross Error

Monthly and zonally accumulated number for TestP

All (before QC)

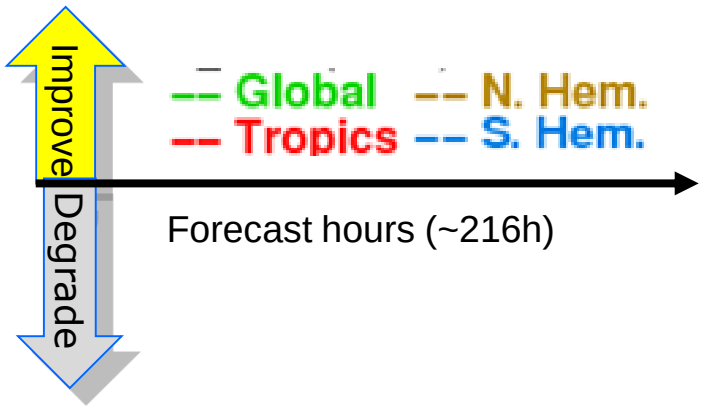


Used (after QC)

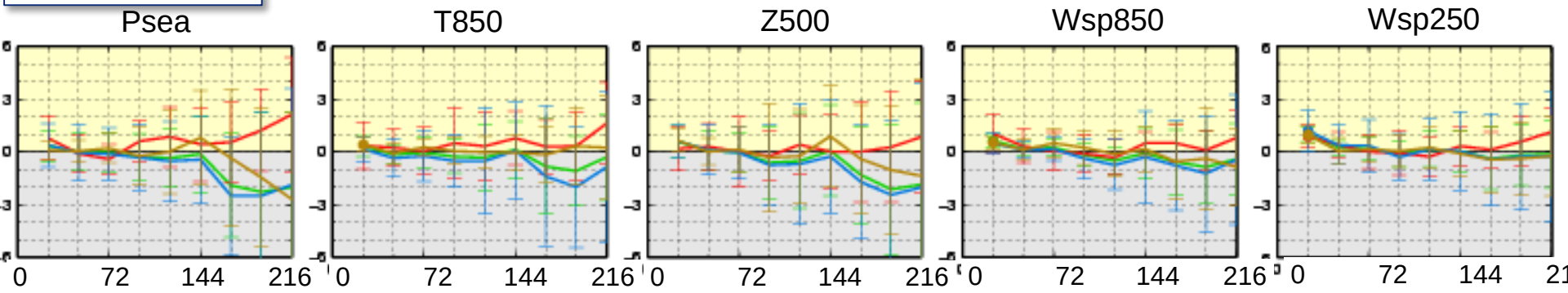


Forecast improvement rate

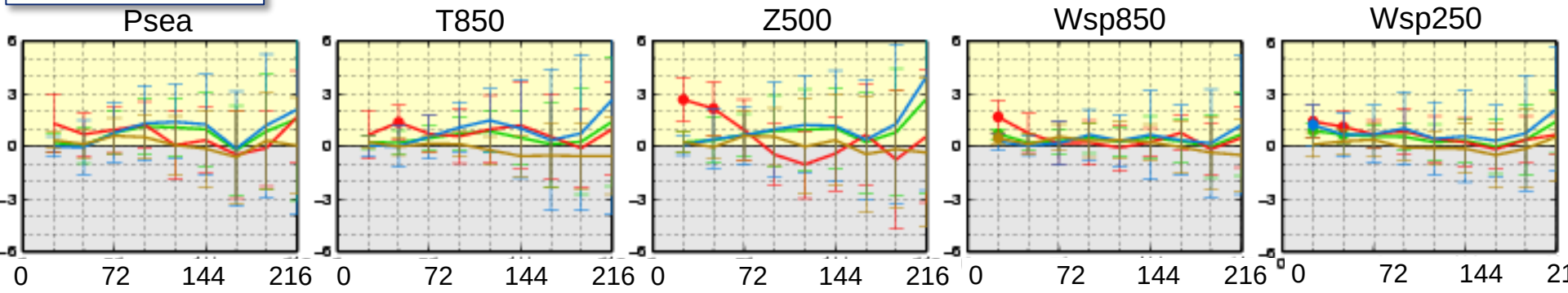
- Normalized RMSE difference as a function of forecast hours
- +ve shows improvement. Statistically significance is indicated by circles



TestP

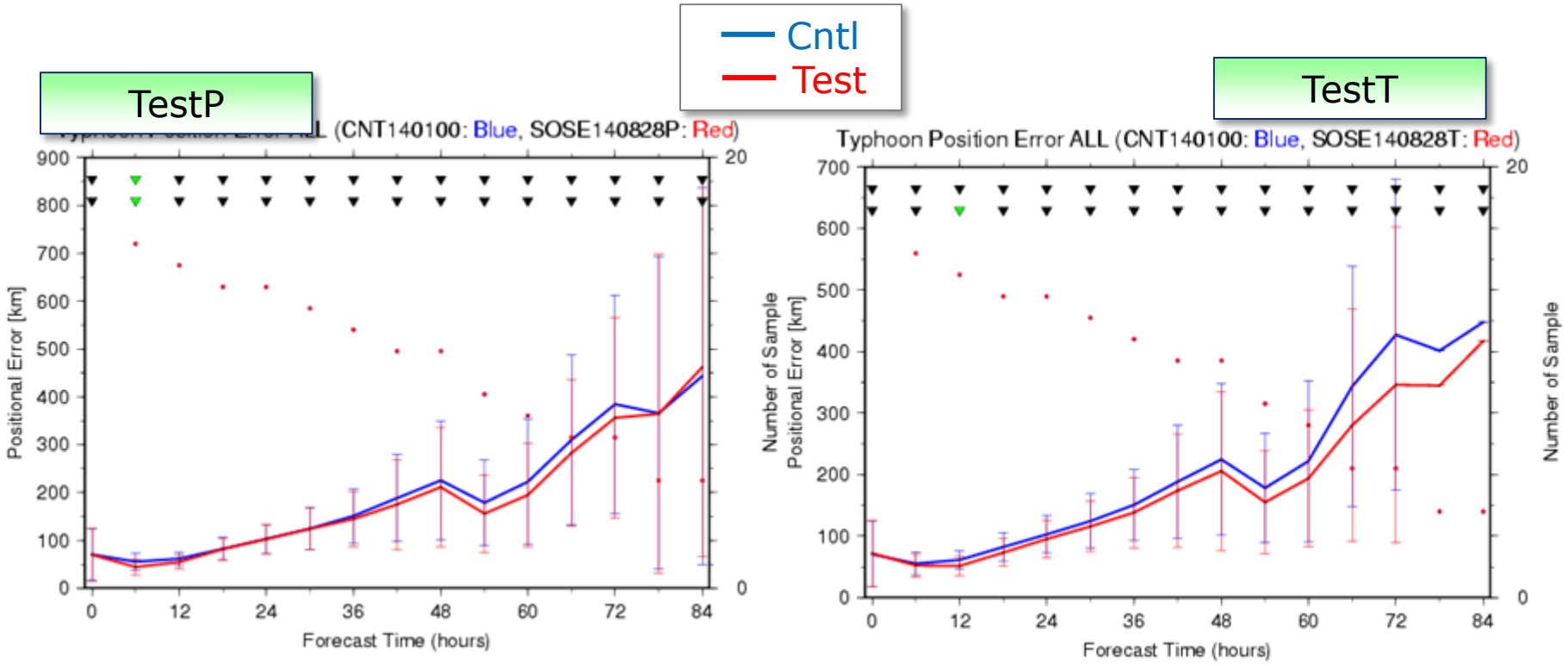


TestT



Typhoon track forecast errors

- Position errors (km) as a function of forecast hours up to 84-h



Summary and Plans

- Feasibility study on space-based DWL has begun in Japanese research community
- Lidar simulator and OSSE system were developed
  - The simulator (ISOSIM-L) was improved to more flexibly and accurately simulate lidar signals, retrieve LOS winds and analyze errors
  - OSSE system based on the SOSE approach was constructed
- Preliminary results of one-month cycle assimilation experiments showed
  - Positive impacts on short-range forecasts of W250, W850, and T850
  - Improve Typhoon track forecasts at short-range (6-h or 12-h)
- However, there were some issues (bugs) in optical parameter computation and aerosol dataset
  - Prepare to re-run experiments after completing the system replacement in the new super computer

- Plans
  - Verify impacts for different lidar parameters, processings and satellite number and orbits
  - Compare results from different OSSE approach (e.g. NR-OSSE) and analysis method (e.g. EnKF)