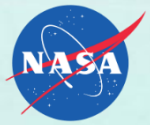
Real-Time NWP Simulations during the ICE-POP Field Campaign using the NASA Unified-WRF Modeling System

***Jonathan L. Case[1]**, Jayanthi Srikishen[2], Roger E. Allen[3], Xuanli Li[4], Walter A. Petersen[5], Paul J. Meyer[5], J. Brent Roberts[5], Emily B. Berndt[5], Andrew L. Molthan[5], Bradley T. Zavodsky[5], Wei-Kuo Tao[6], and Takamichi Iguchi[7]

[1]ENSCO, Inc./NASA Short-Term Prediction Research and Transition (SPoRT) Center; [2]Universtities Space Research Association; [3]Jacobs ESSCA; [4]University of Alabama – Huntsville; [5]NASA/Marshall Space Flight Center; [6]NASA/Goddard Space Flight Center; [7]University of Maryland



ENSCO SPORT UNIVERSITY OF MARYLAND USRA JACOBS ESSSA Group THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

28 November 2018

4th ICE-POP Workshop; 27-30 November; Jeju, South Korea

ICE-POP 2018

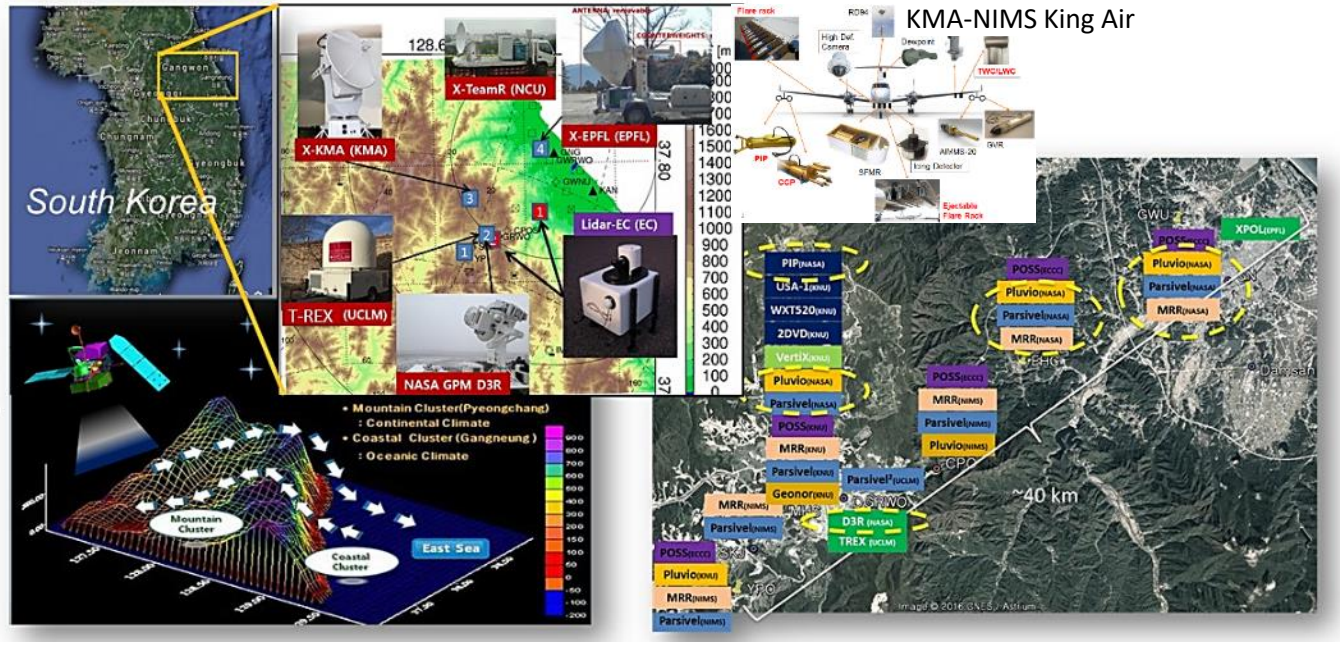
- KMA-led, WMO WWRP-sponsored winter precipitation project (Jan-Mar. 2018)
- Objective: Improve understanding and prediction of orographic falling snow

NASA Objective(s): Collaborate with interagency/international partners to:

- Evaluate and improve GPM estimates of orographic snow
- **Test and improve NWP, cloud model orographic snow physics**
- Serve/test new satellite products in a decision support environment

Coast to mountain SW-NE instrument transect/clusters

Addressing larger synoptic scale cyclone and cold-air northeasterly ocean-mountain snow events



Network, aircraft images courtesy Korean Meteorological Administration

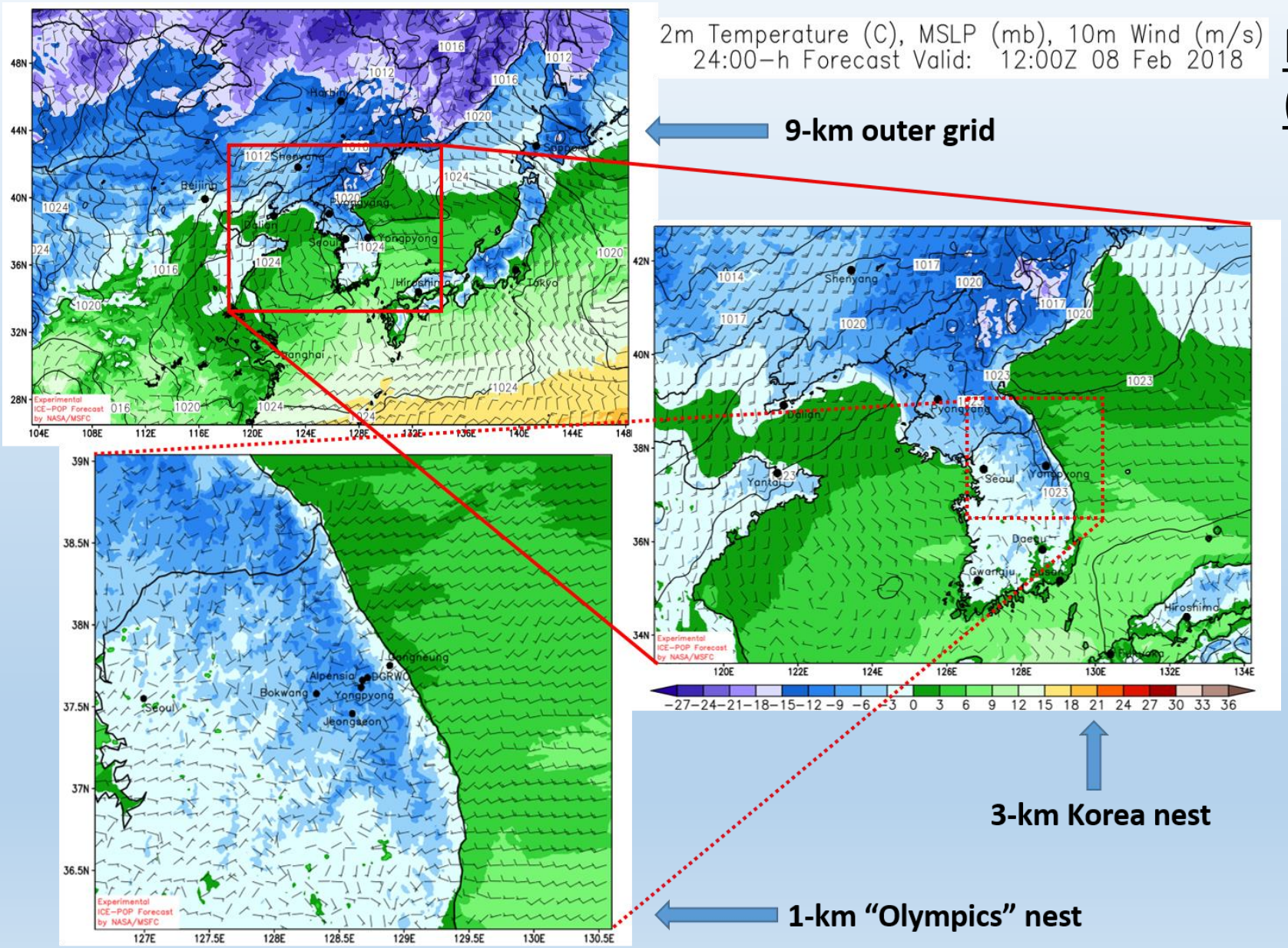
NASA Contributions:

- GPM GV Instruments- D3R, MRRs, PIPS, Pluvios, Parsivels
- **SPoRT GPM products (including NRT surface SH/LH fluxes)**
- **NU-WRF model forecasts/research**

Real-time NWP Objectives

- Design NWP system for high-resolution, frequent initialization runs to support ICE-POP short-term forecasting during Olympic and Paralympic Winter Games, and subsequent research activities
  - Olympics: 9-25 Feb 2018; Paralympics: 9-18 March
  - Design modeling framework to resolve orographic frozen precipitation processes in complex terrain
  - Model specifications and output format requirements defined for the Forecast Demonstration Project (FDP)
  - Establish foundation of Control simulations for Research and Development Project (RDP) [i.e., sensitivity and data assimilation experiments]
  - Develop a NASA-centric solution between NASA Marshall and Goddard Space Flight Centers (NASA Unified-Weather Research and Forecasting [WRF] model)
  - Document performance of NASA-developed WRF physics schemes
  - Inter-compare model output results to GPM datasets and retrievals

NU-WRF Real-time Model Configuration for ICE-POP



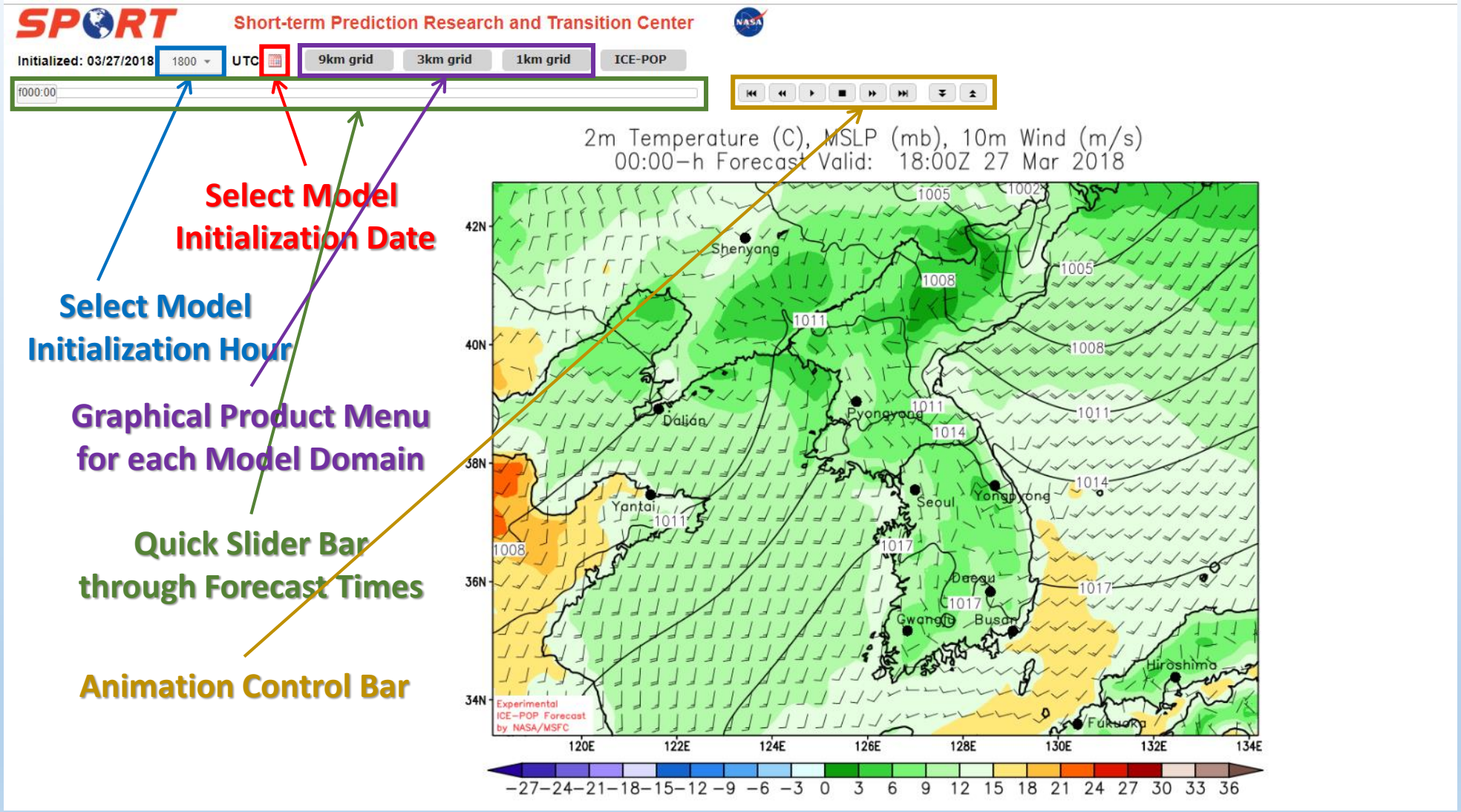
NASA Unified-WRF (NU-WRF) Model Features:

- 4x daily 24-hour forecasts
- ICs/BCs: NCEP/EMC GFS
- Initialized 00/06/12/18z with previous GFS cycle (e.g., 06z uses GFS 00z 6-h forecast as IC)
- SSTs: 2-km NASA SPoRT MODIS+VIIRS product
- Half-hourly output on nests
- 62 vertical levels (≤ 100m resolution in lowest 2km)
- PBL: MYJ; LSM: Noah
- SW/LW Radiation: NASA/GSFC schemes within NU-WRF
- Microphysics: NASA/GSFC 4-ice graupel+hail
- Cumulus: Grell-Freitas (9km only)

Formatting and Visualization of Model Output

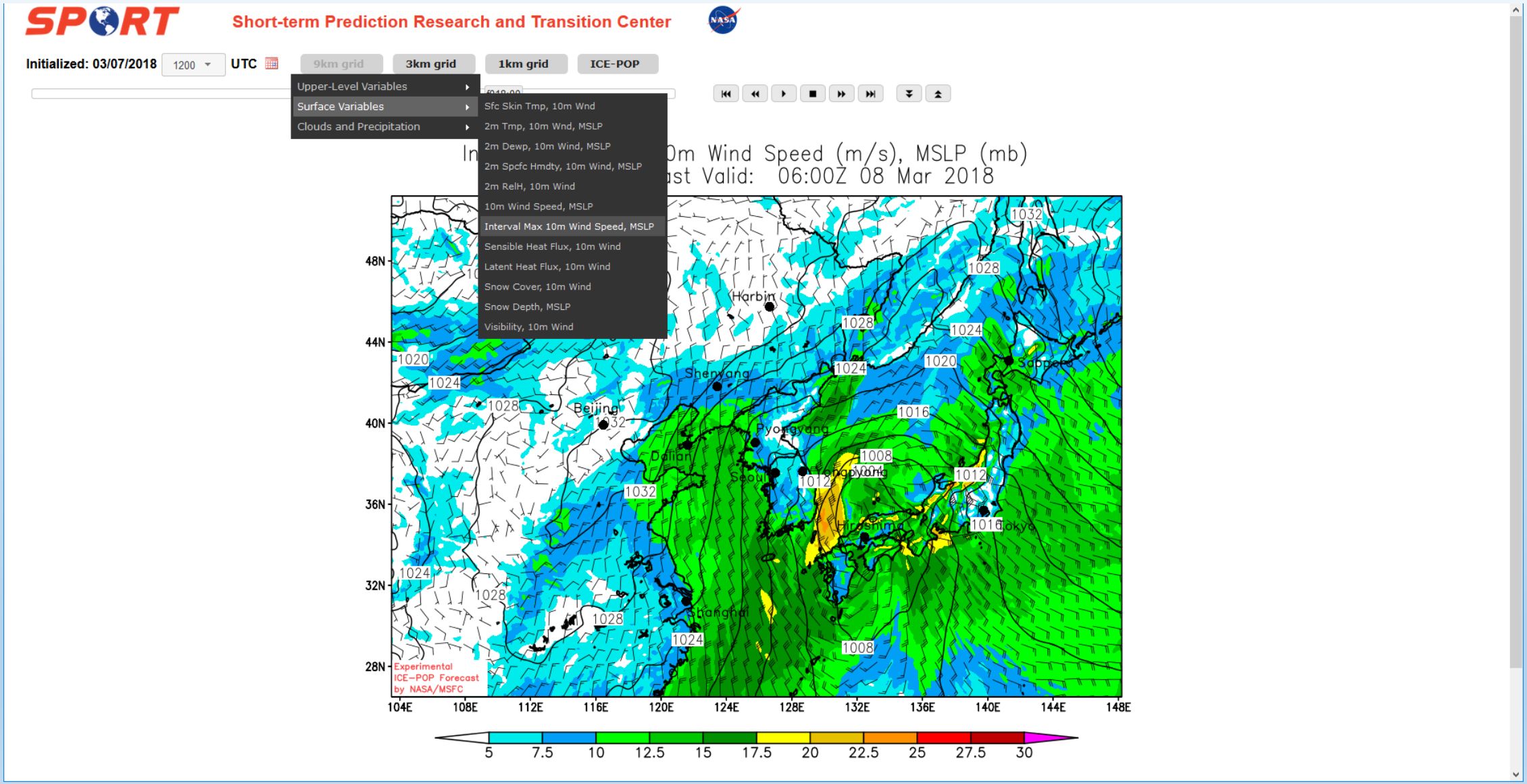
- Gridded model output
  - GRIB2-formatted files from 1-km nested grid
  - 3D fields post-processed: T, RH, u-/v-/w-wind components, Q_c, Q_r, Q_f (Q_i+Q_s+Q_g+Q_h)
  - AGL levels (for 3D vars): Surface/2m, 20m, 50m, 100-2000m every 100m
  - 2D fields post-processed: precip type (RA, SN, IP, FZRA), accumulated precip
  - Ship in real-time to KMA
- Extract ASCII point forecasts at 16 Olympic venues
  - Fields extracted at each point: Lightning (from Lightning Forecast Algorithm [LFA] total flash rates), precip type, RH, 1-h accum. rainfall, 1-h accum. snowfall, sky condition, 2m T, u-/v-wind components, wind speed & direction, visibility
  - 30-min interval model point forecasts from 1-km nested grid
- Designed internal project web page for real-time visualization
  - Developed by and hosted on NASA/SPoRT web server
  - Ability to display real-time graphics as well as previous archived simulations
  - https://weather.msfc.nasa.gov/cgi-bin/sportPublishModel.pl?dataset=icepop

Project Web Page for Visualizing [Archived] NU-WRF Runs



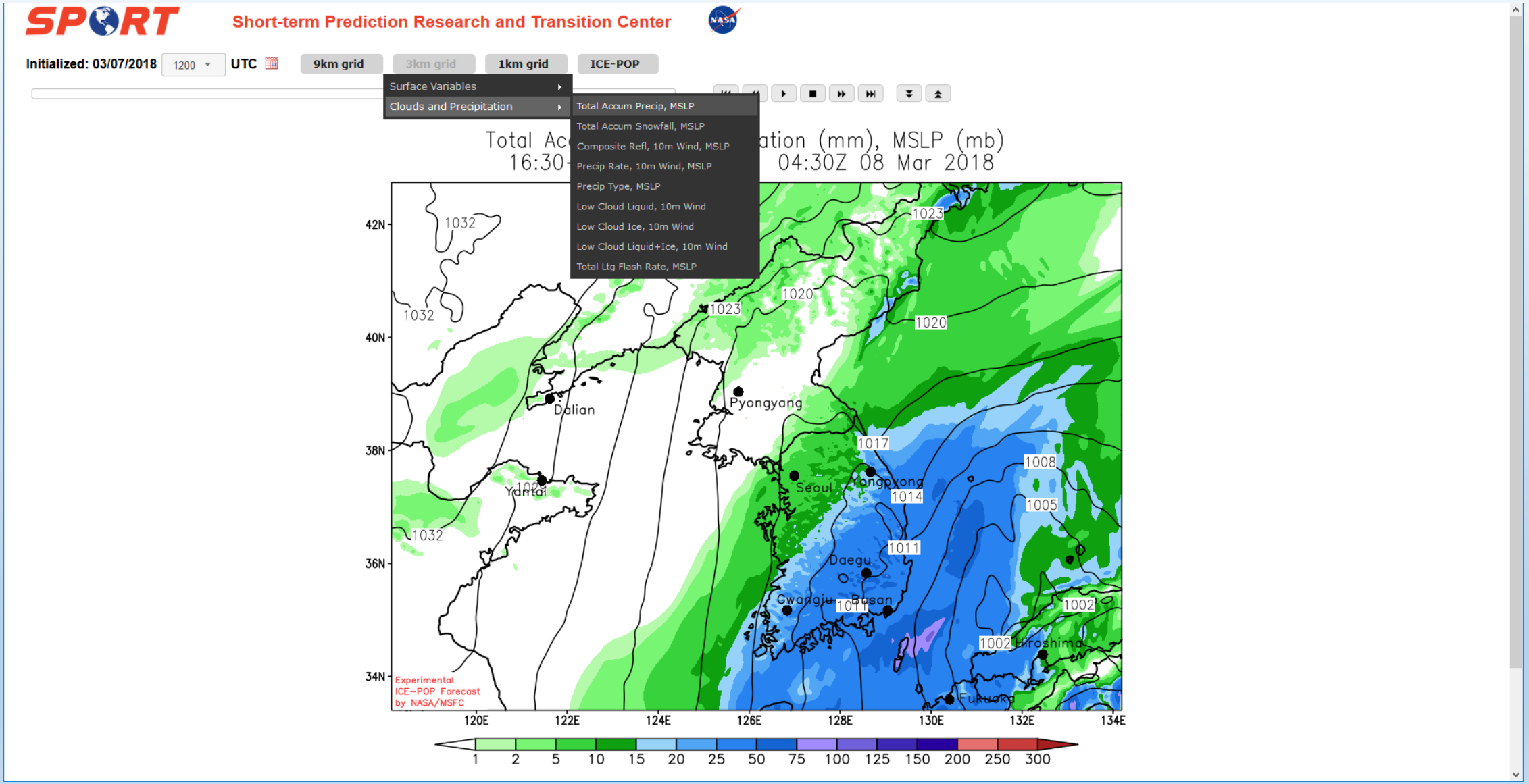
https://weather.msfc.nasa.gov/cgi-bin/sportPublishModel.pl?dataset=icepop

Project Web Page for Visualizing [Archived] NU-WRF Runs



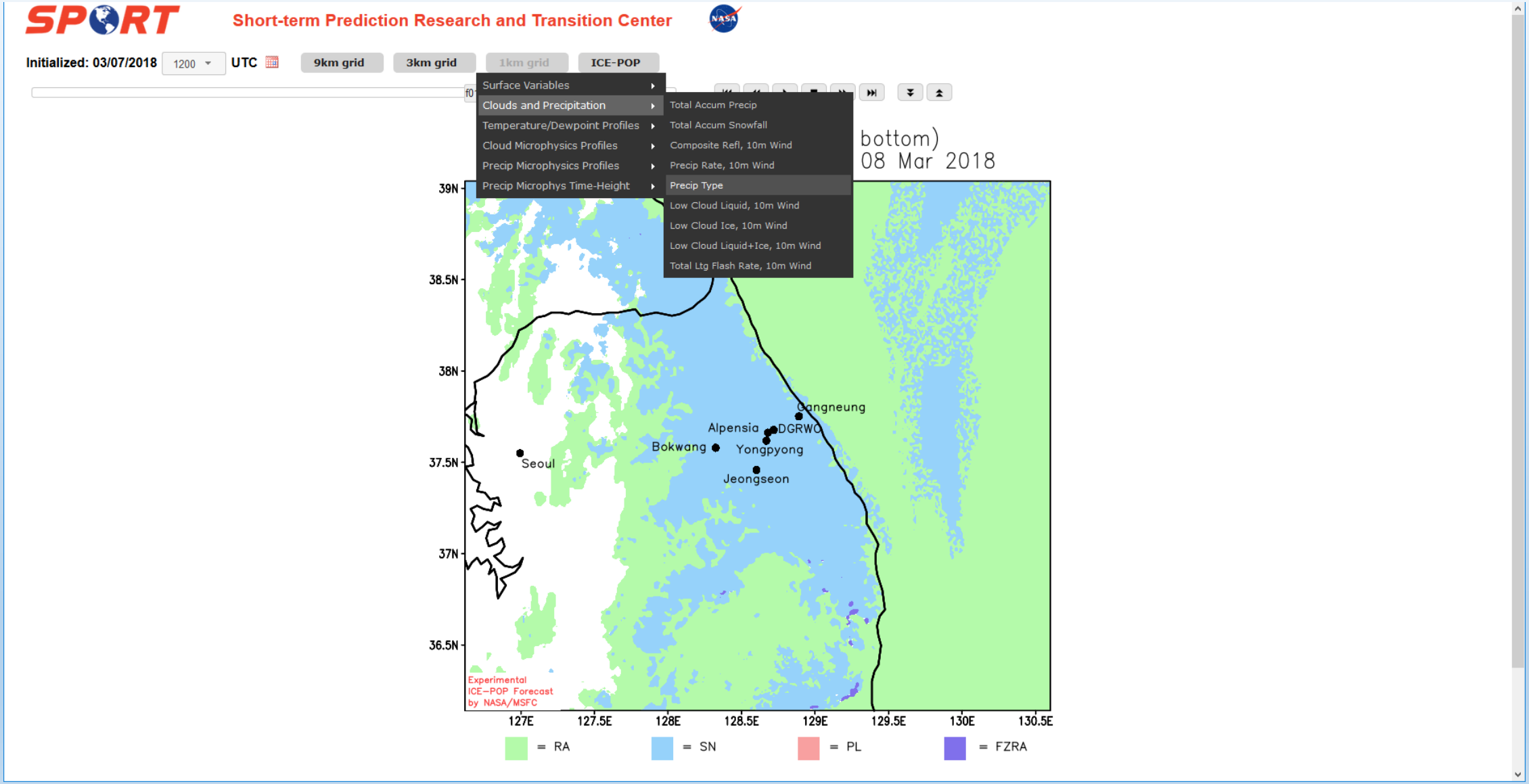
https://weather.msfc.nasa.gov/cgi-bin/sportPublishModel.pl?dataset=icepop

Project Web Page for Visualizing [Archived] NU-WRF Runs



https://weather.msfc.nasa.gov/cgi-bin/sportPublishModel.pl?dataset=icepop

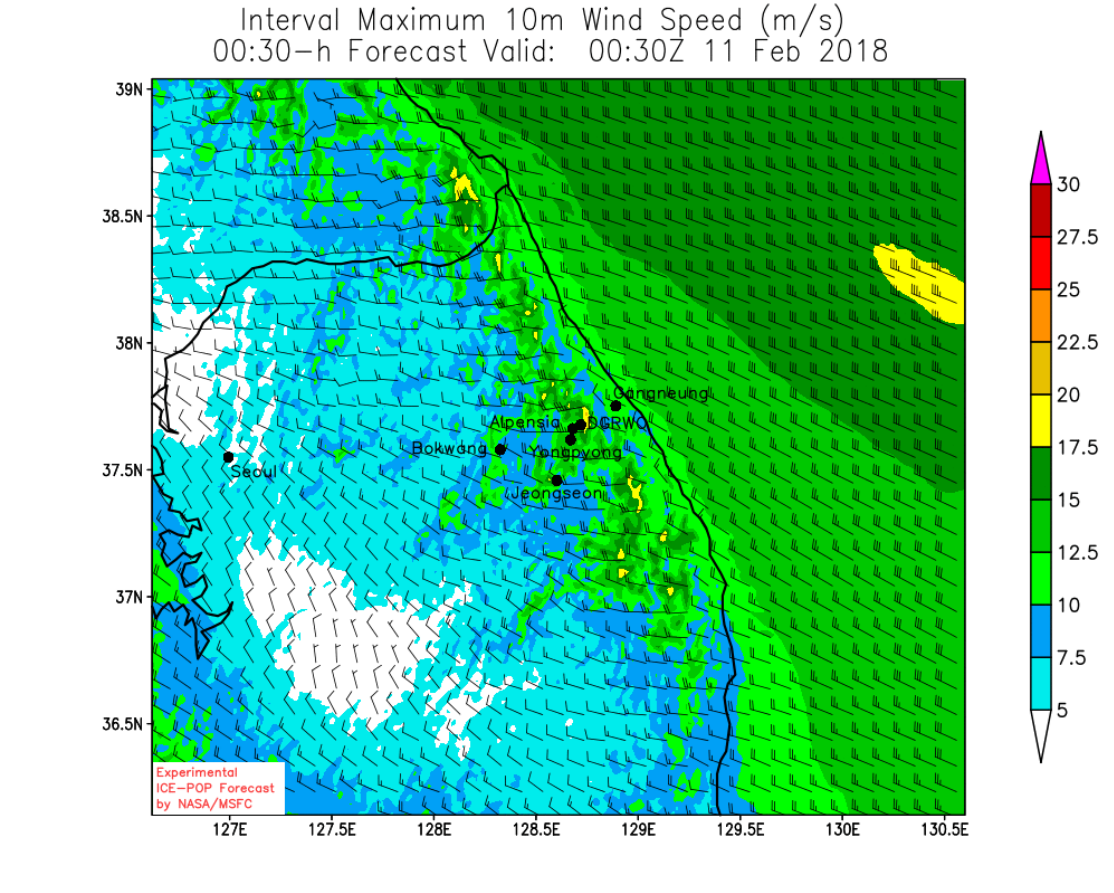
Project Web Page for Visualizing [Archived] NU-WRF Runs

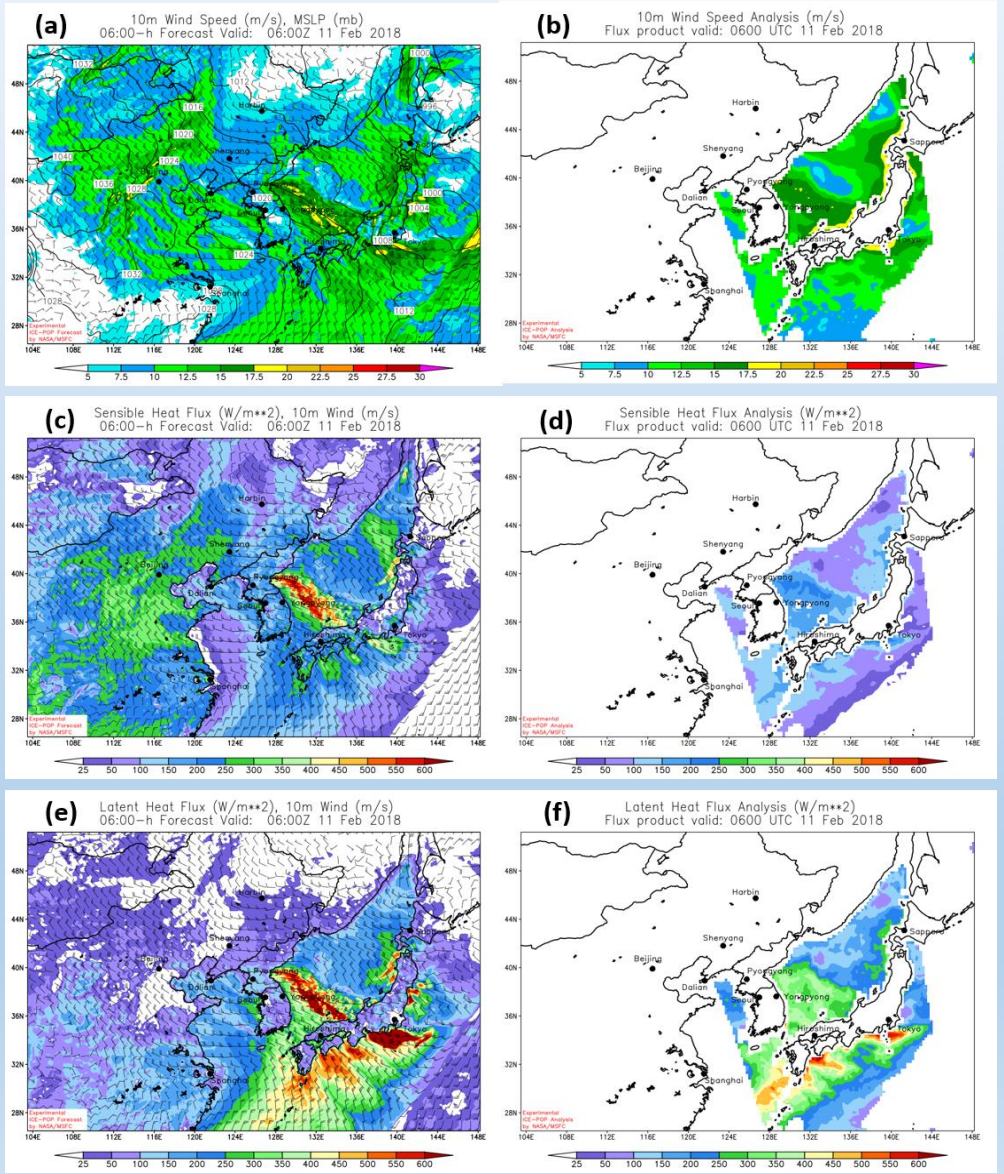


https://weather.msfc.nasa.gov/cgi-bin/sportPublishModel.pl?dataset=icepop

Observations and Simulations from High-Impact Events:

11 February High Winds Delayed Mens' Downhill



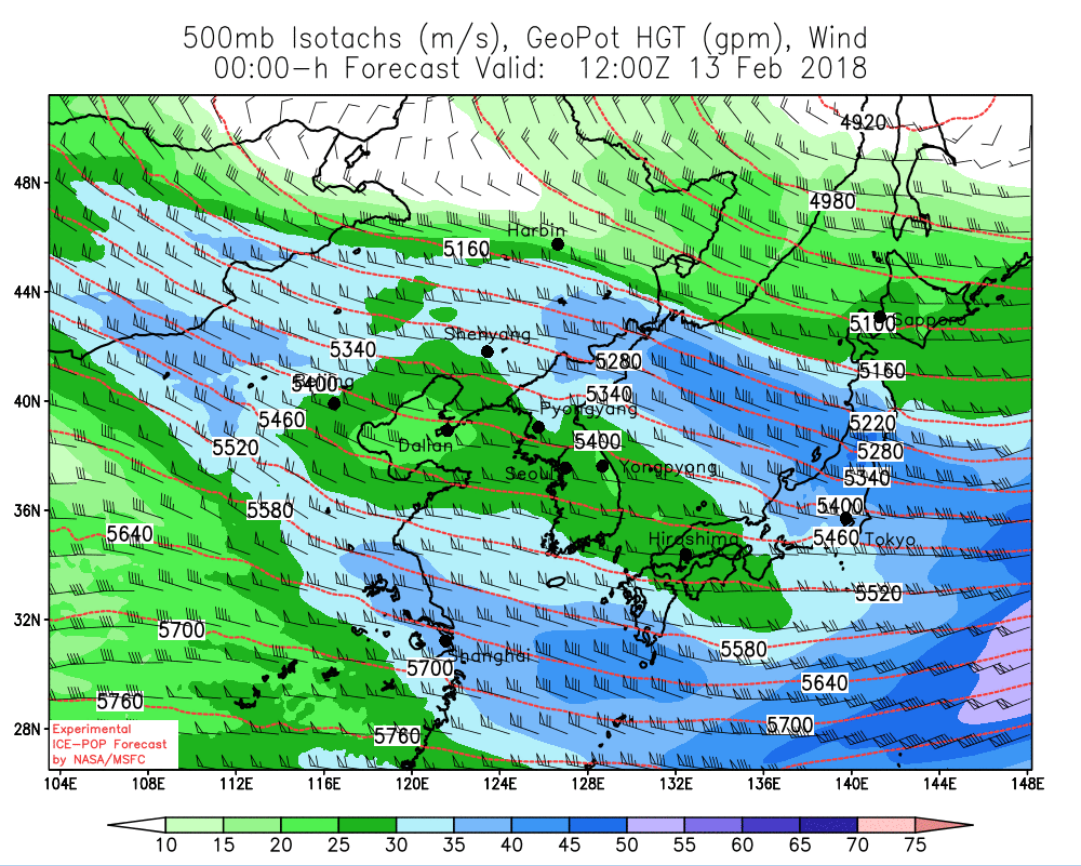


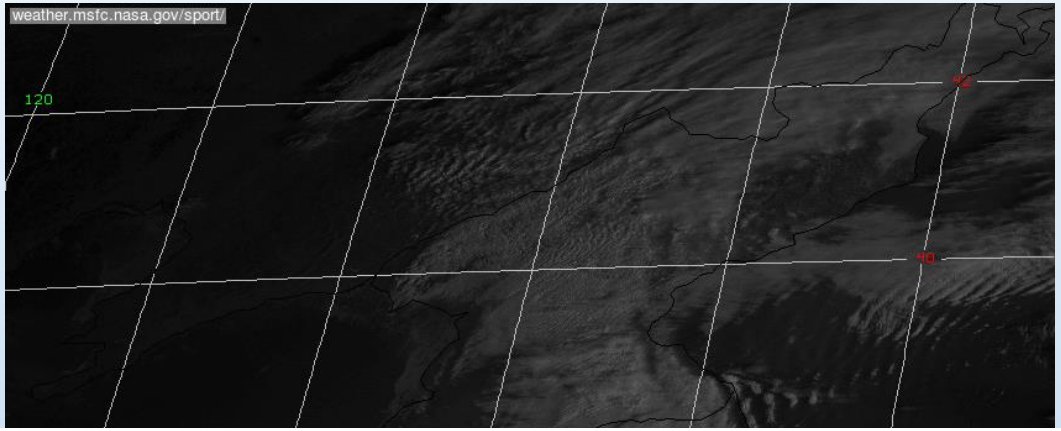
(above) Animation of 30-min interval maximum 10m wind speeds from NU-WRF 1km nested grid.

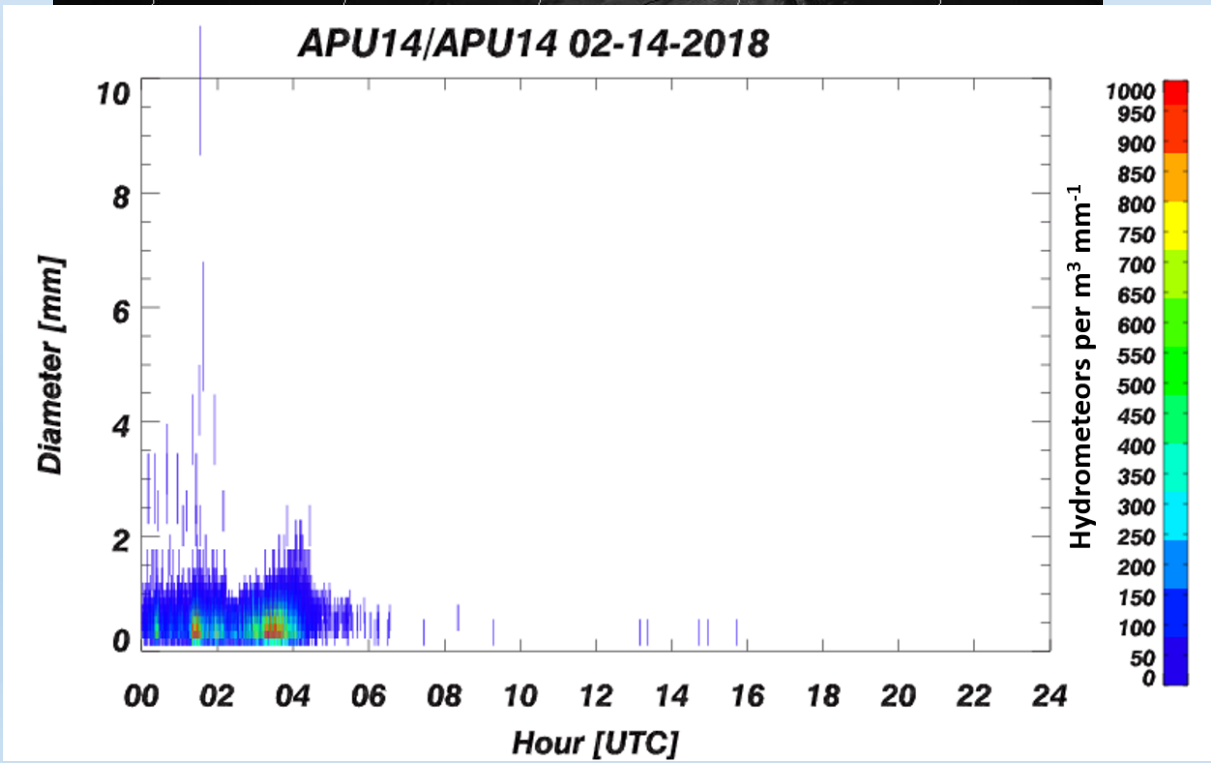
(right) Comparison between NU-WRF 9-km grid [left column] 10m winds, sensible, & latent heat flux to passive microwave oceanic retrievals [right column]

Observations and Simulations from High-Impact Events:

14 Feb Shallow Snow & High Winds Disrupted Skiing on Jeongseon Hill







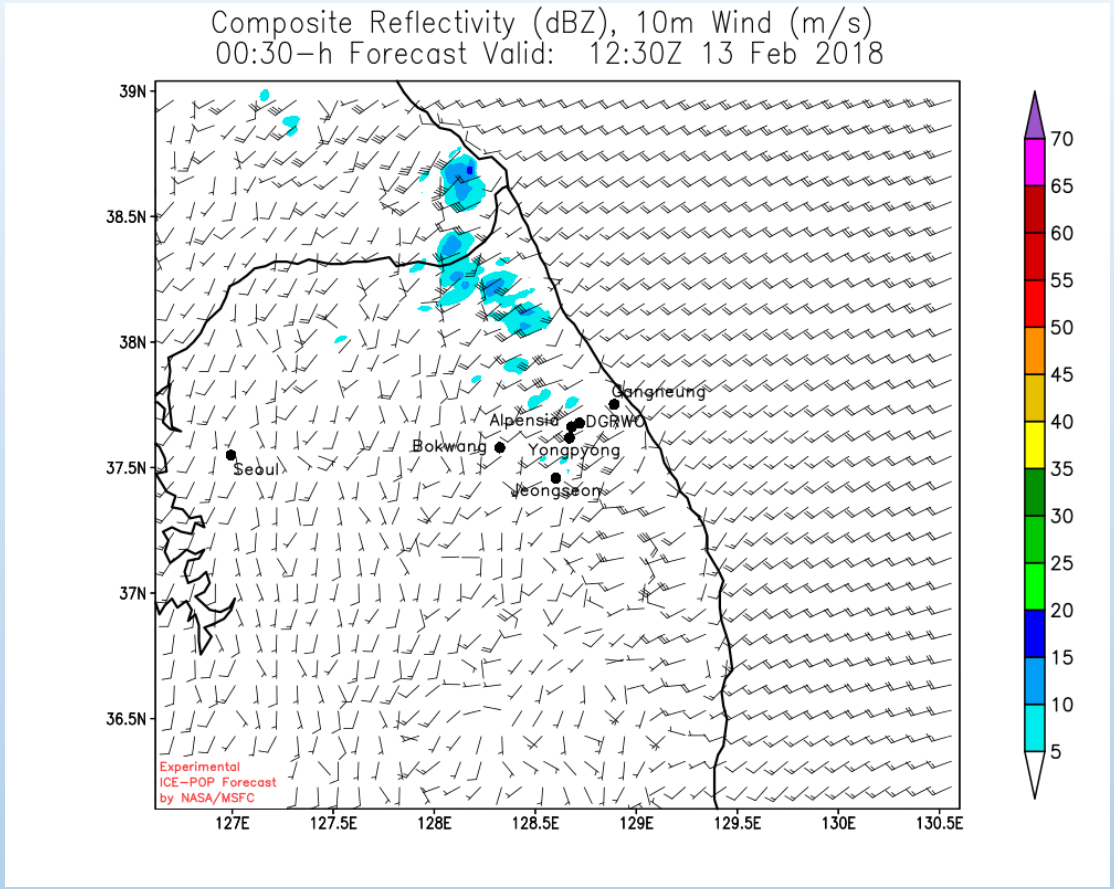
(above) Animation of 3-hourly 500-mb isotachs from NU-WRF 9km grid

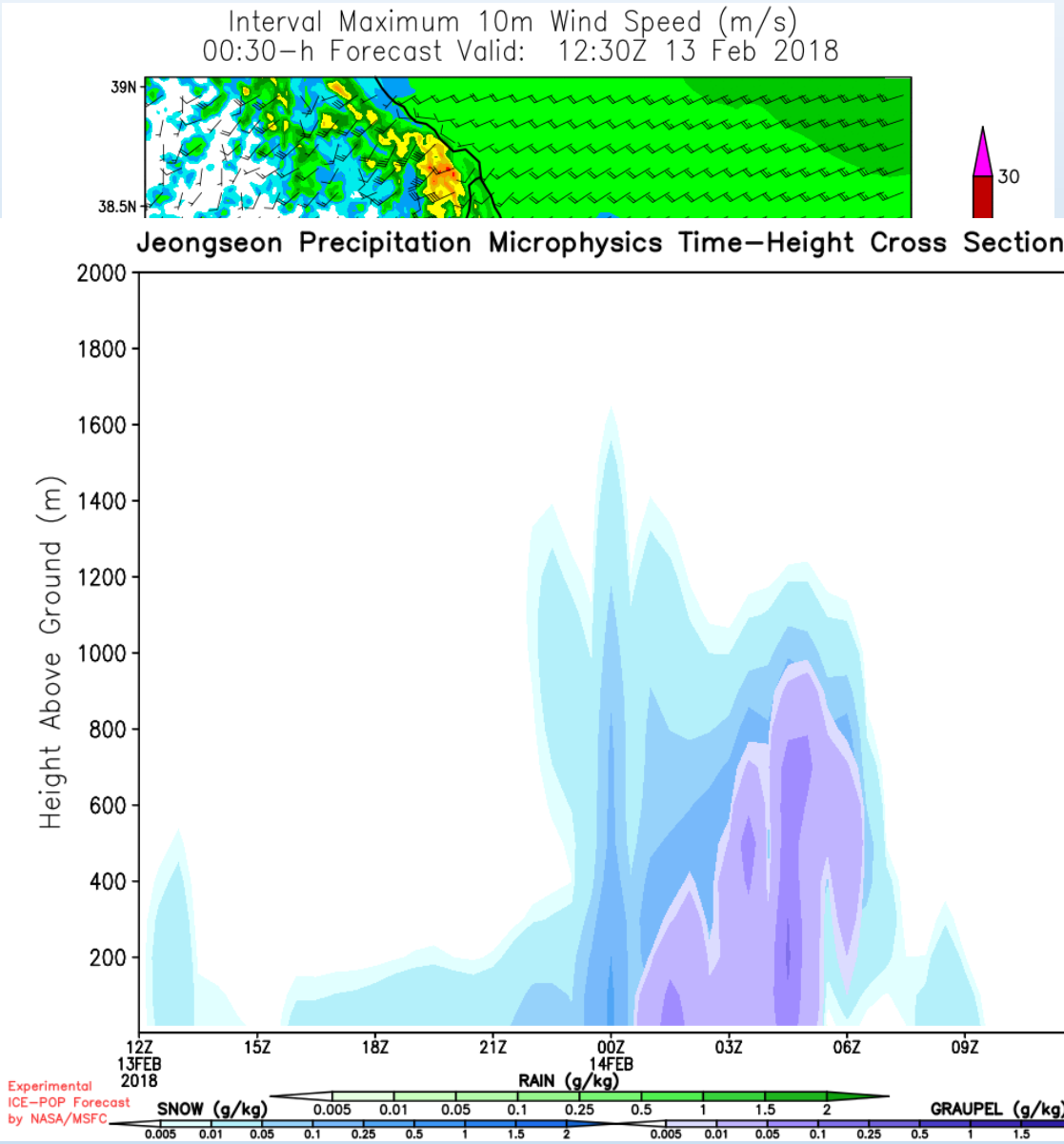
(right) Animation of visible satellite imagery from JMA Himawari

(bottom-right) Disdrometer measurements, showing high concentration of primarily small hydrometeors between 01-04z

Observations and Simulations from High-Impact Events:

14 Feb Shallow Snow & High Winds Disrupted Skiing on Jeongseon Hill





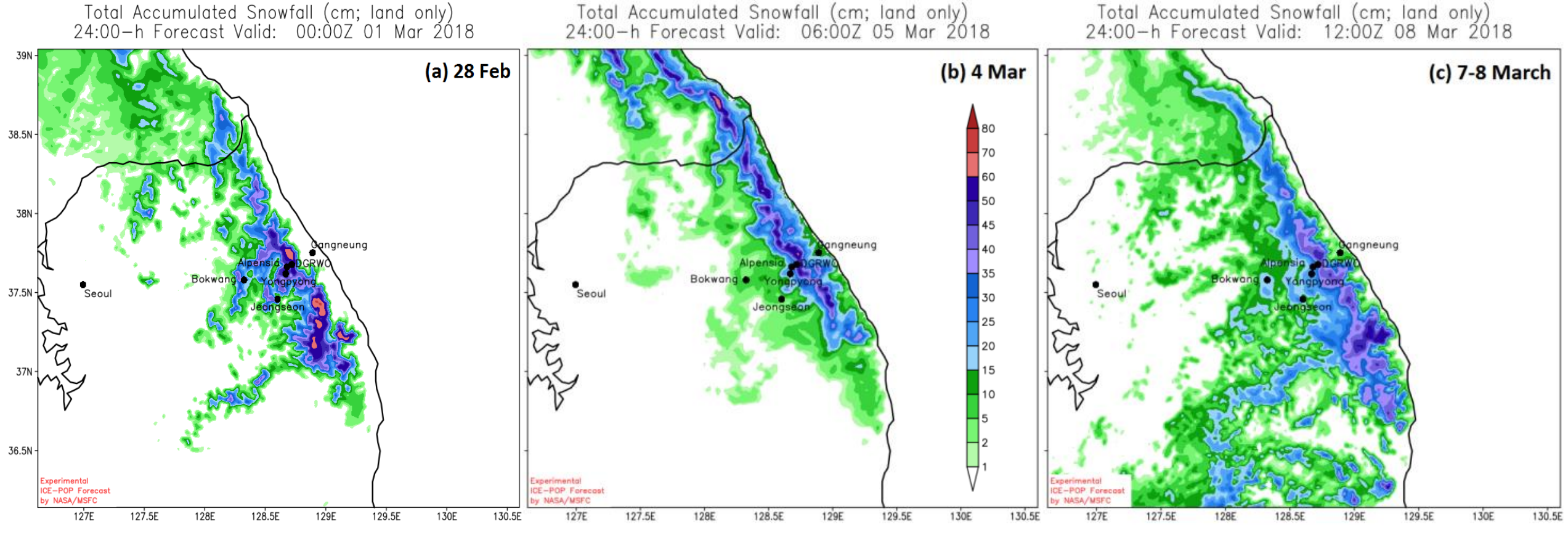
(above) Animation of 30-min Comp. reflectivity from 1-km grid

(right) Animation of 30-min interval maximum 10m wind speed

(bottom) Time-height cross section in lowest 2km AGL of precipitation microphysical mixing ratios

Observations and Simulations from High-Impact Events:

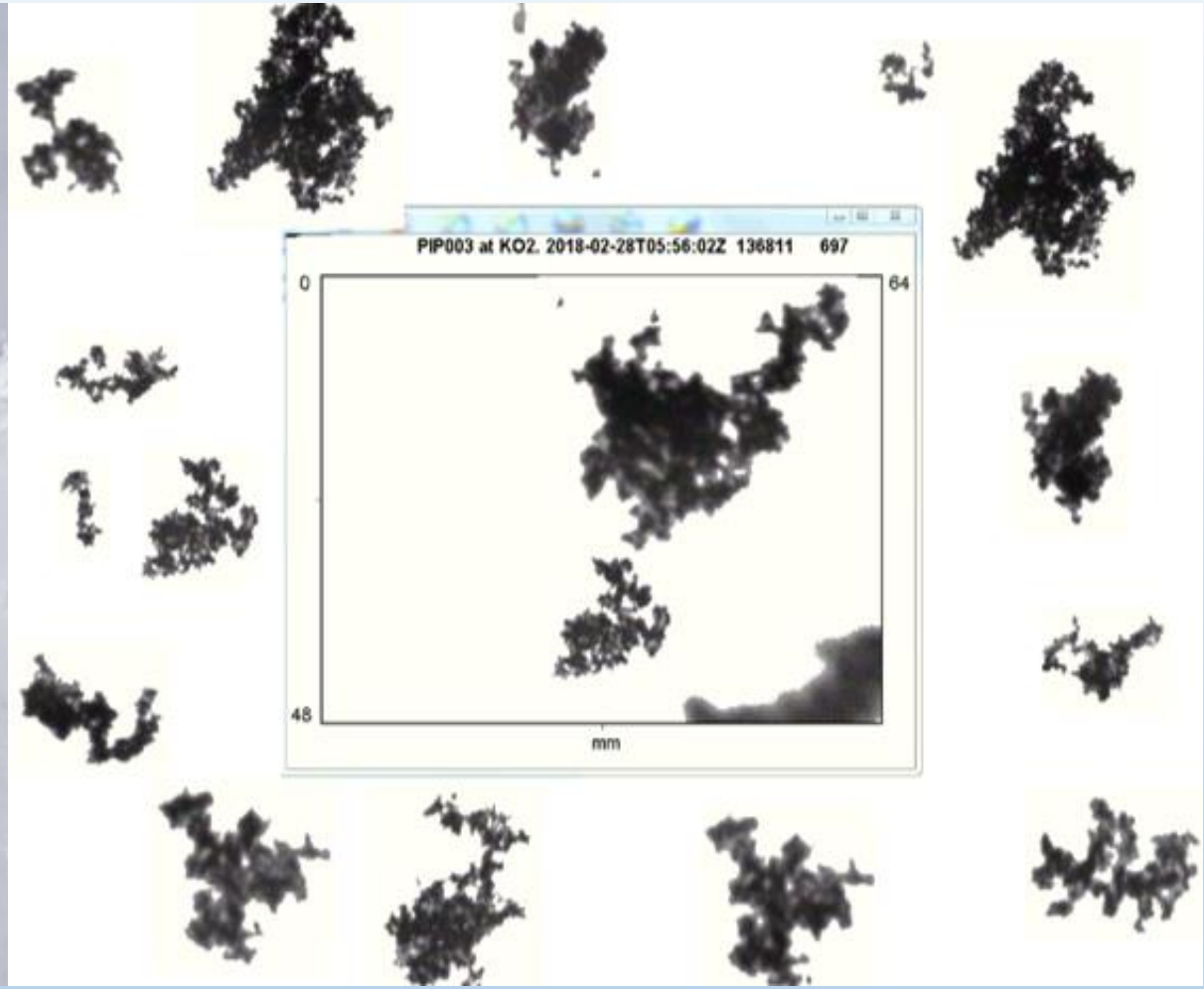
Three Significant Snowstorms between Olympics (Feb) and Paralympics (Mar)



Twenty four-hour simulated snow accumulation [in cm] from the NU-WRF 1-km grid for snowstorm events on (a) 28 February, (b) 4 March, and (c) 7-8 March 2018.

Observations and Simulations from High-Impact Events:

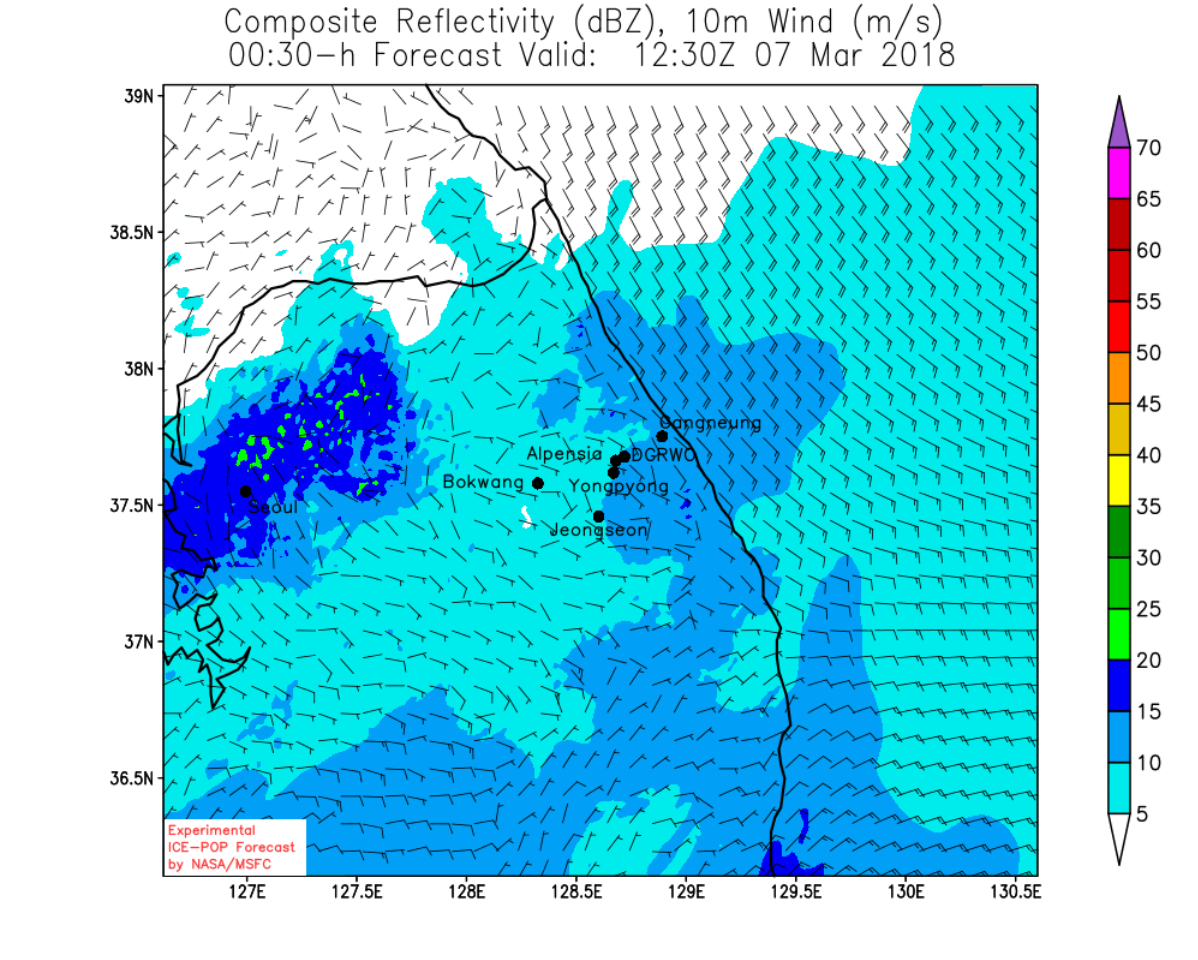
Three Significant Snowstorms between Olympics (Feb) and Paralympics (Mar)

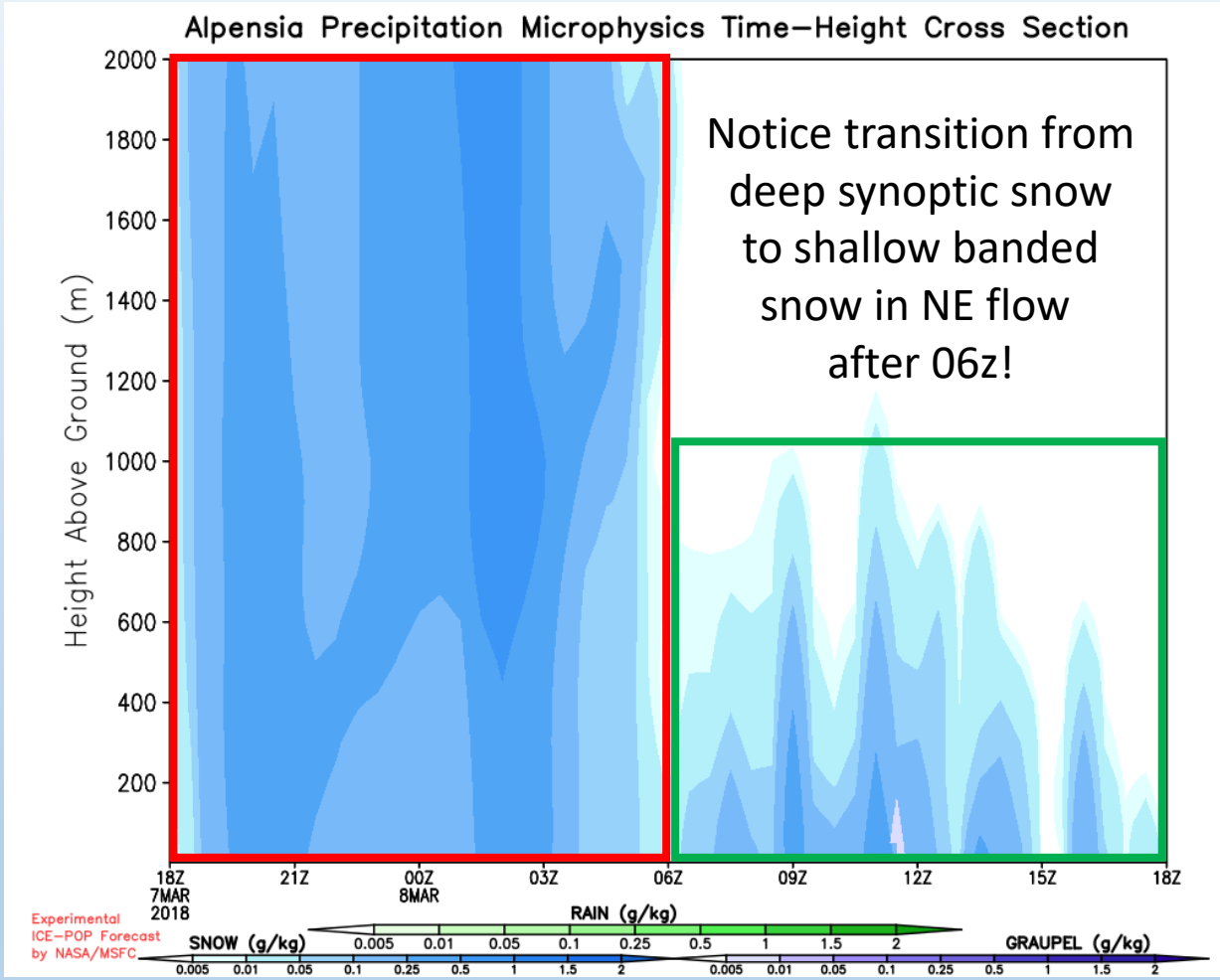


NASA Precipitation Imaging Package (PIP; left) and PIP observations of 2.5+ cm diameter snowflakes, associated with 28 February snowstorm (*courtesy: Kwonil Kim*)

Observations and Simulations from High-Impact Events:

Three Significant Snowstorms between Olympics (Feb) and Paralympics (Mar)





(left) Animation of NU-WRF 1-km grid simulated composite reflectivity, and
(right) Time-hgt X-section (lowest 2km AGL) of precip microphysical mixing ratios at Alpensia

ICE-POP Flux Product Data Assimilation

Objectives:

- Assimilate surface temp, moisture, and wind speed products retrieved from GPM L1C data
- Assess data impact on case studies of snow storm events observed during ICE-POP

Approach:

WRF-ARW model with 9 km + 3 km resolution (initially only outer 2 grids) and 62 vertical levels; Community GSI v3.6

Cases: Strong snow storm event 7-8 March 2018

Snow storm event 27-28 February 2018

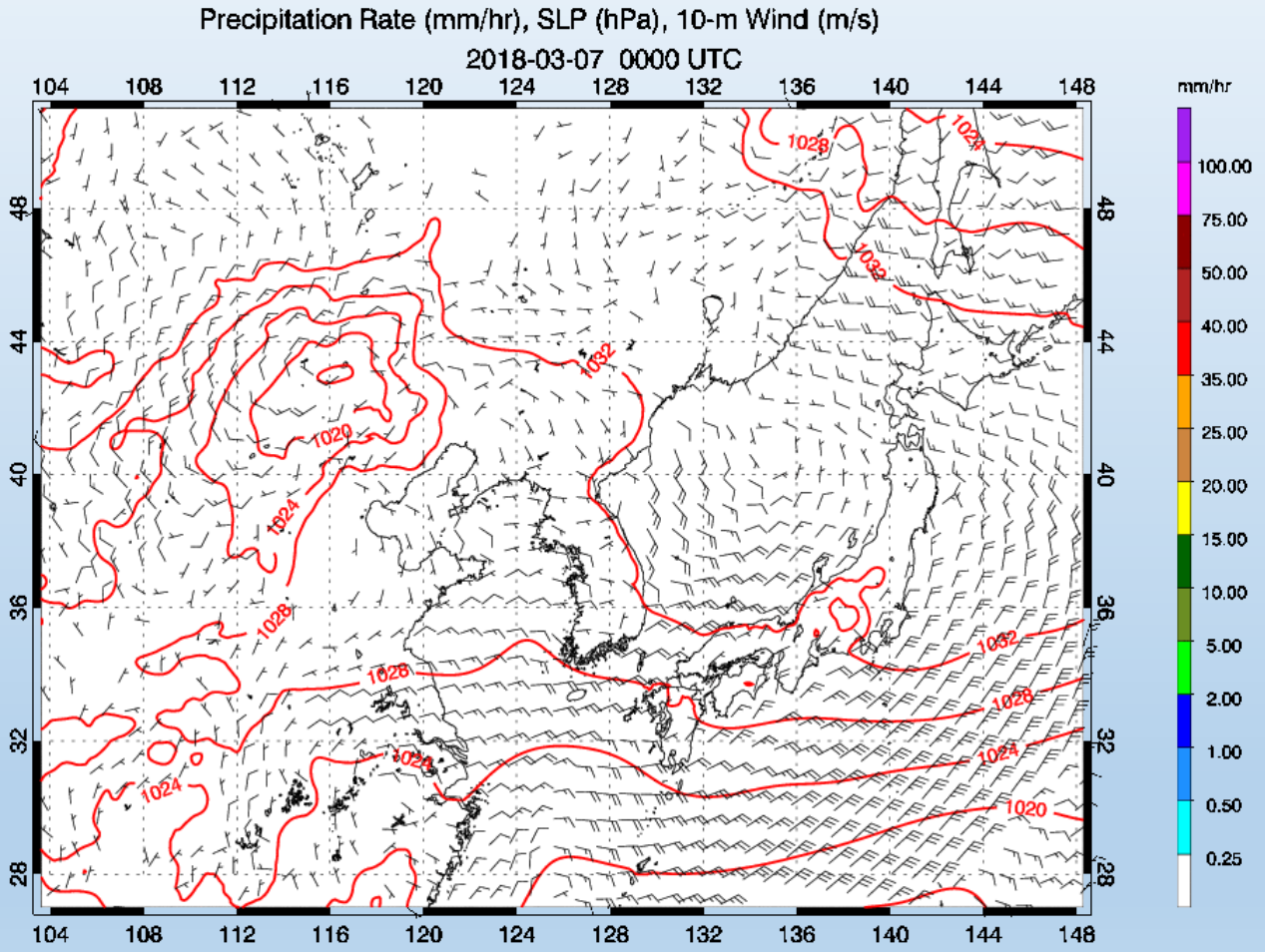
Sea of Japan-effect snowfall 15 February 2018

WRF ARW Forecast and Flux Data

1-h Precipitation forecast animation

2018/03/07- 2018/03/09

Over 25 mm/hr precipitation is predicted in WRF model

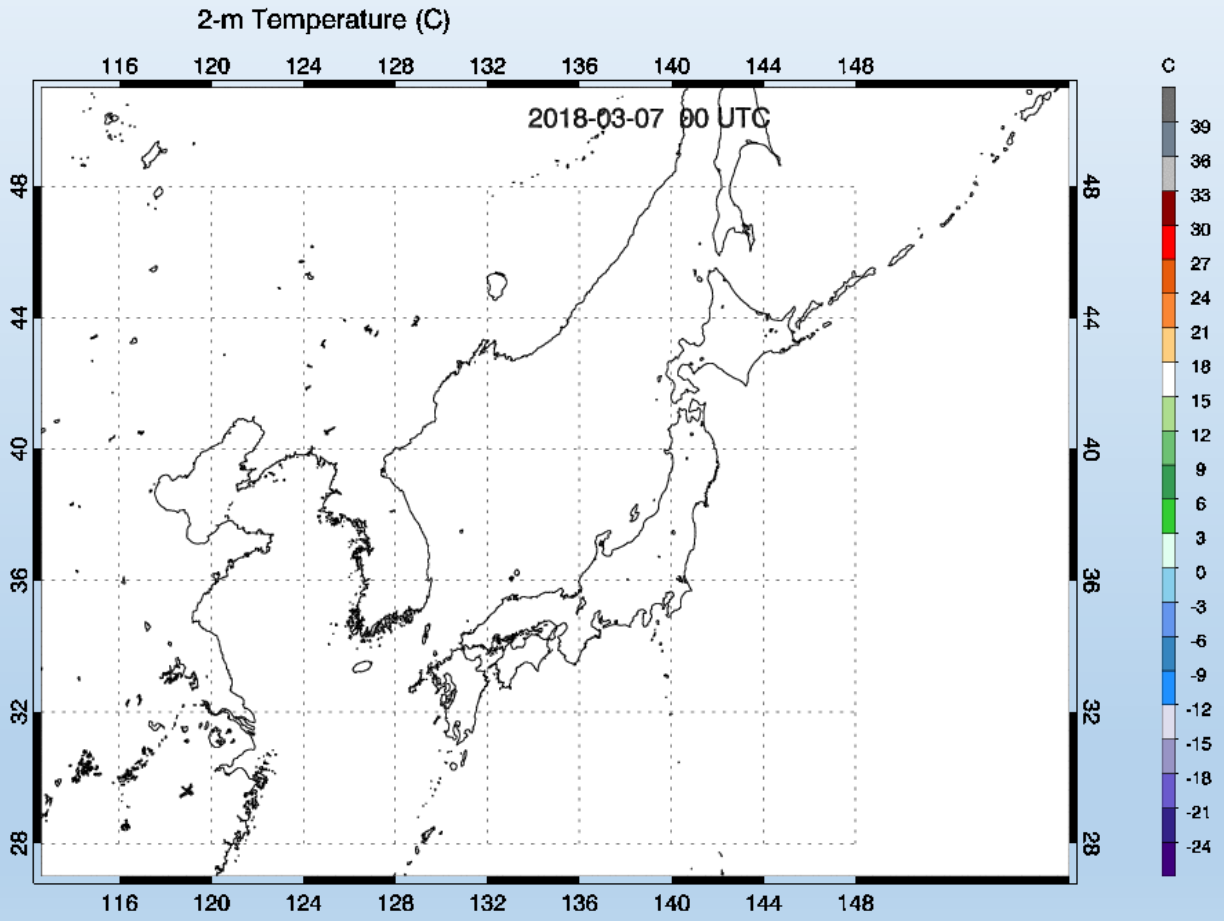


WRF ARW Forecast and Flux Data

Flux Product 2-m Temperature

Observation Animation

2018/03/07- 2018/03/09



Time with good data coverage:

2018/03/07: 06, 08, 10, 12, 18, 20, 22 UTC

2018/03/08: 06, 07, 08, 09, 11, 13, 18, 19, 20, 21, 22 UTC

Data assimilation time:

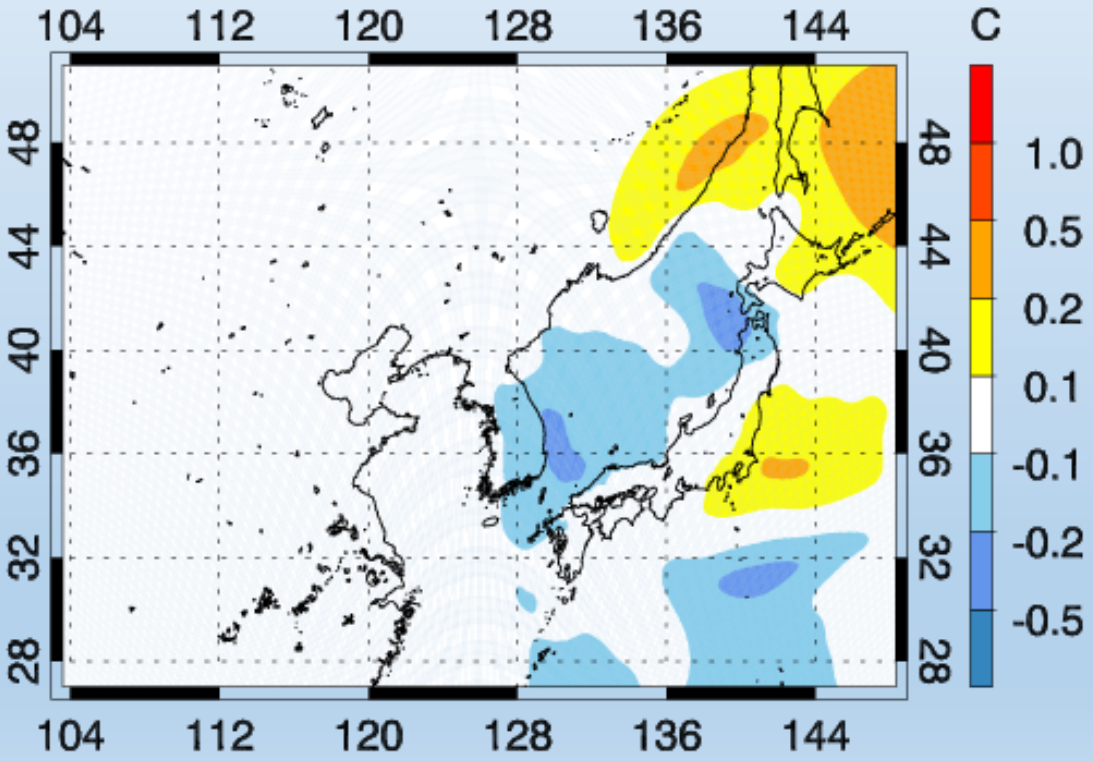
2018/03/07: 06, 09, 12, 18, 21 UTC

2018/03/08: 06, 09, 12, 18, 21 UTC

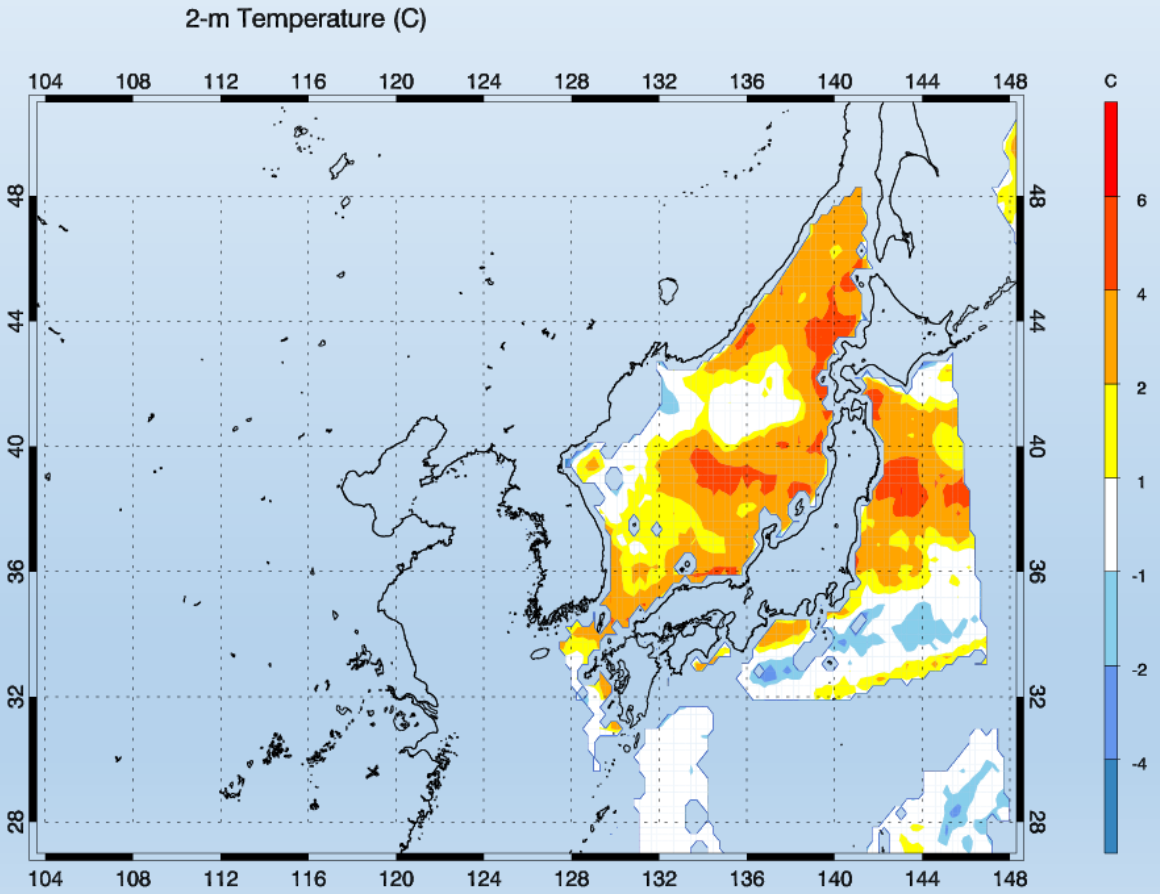
Data Impact of Assimilation of 2-m Temperature Retrieval

2018/03/07 0600 UTC

Analysis Increment in Temperature



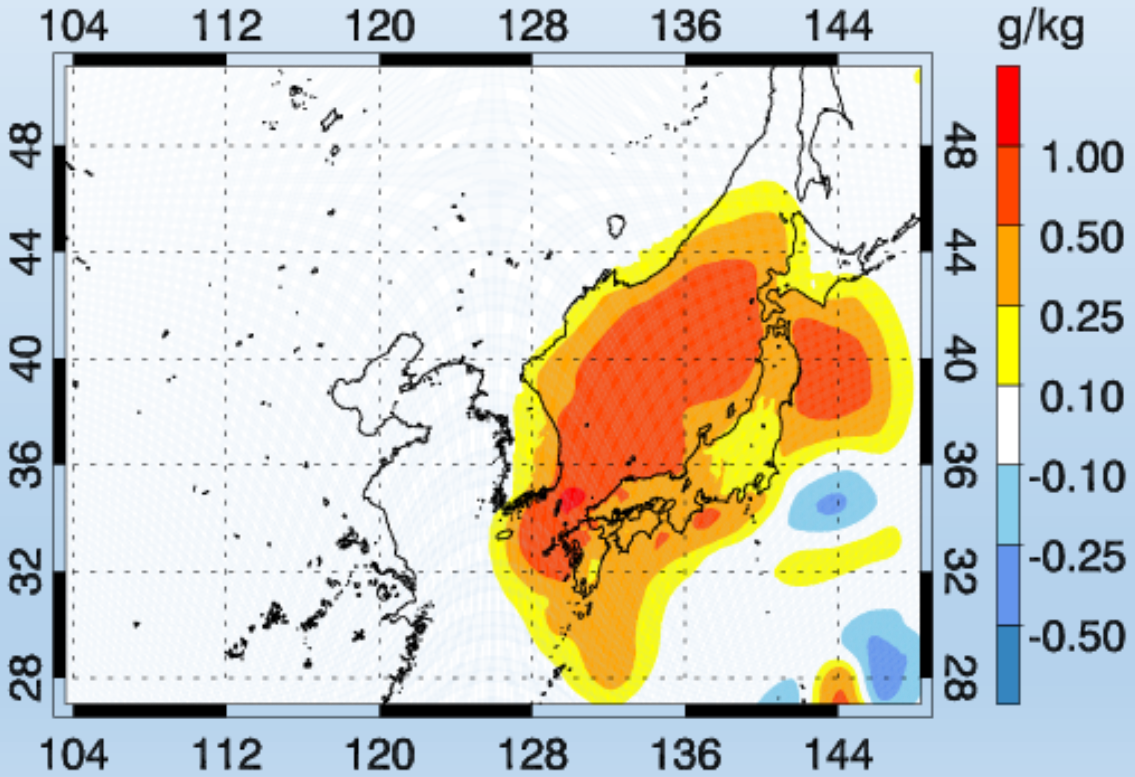
OBS – CTRL (Innovation)



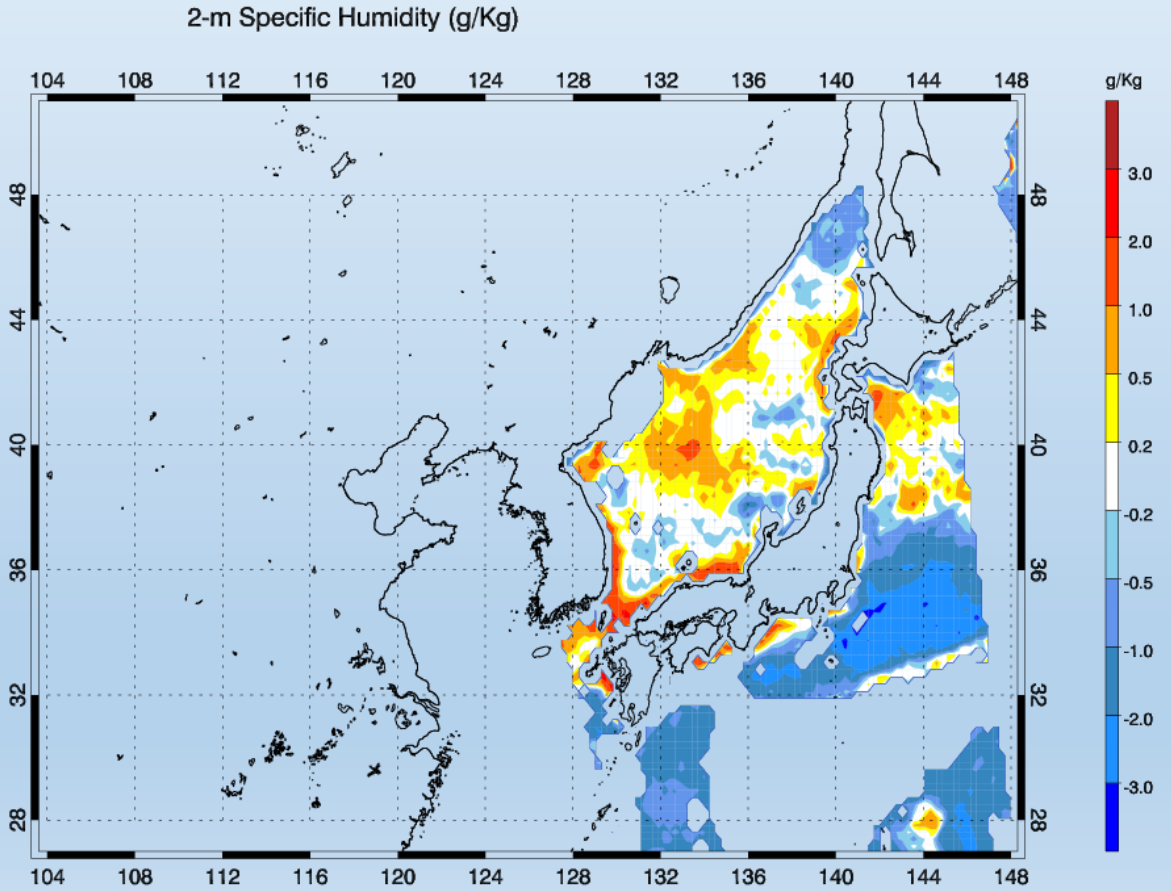
Data Impact of Assimilation of 2-m Specific Humidity Retrieval

2018/03/07 0600 UTC

Analysis Increment in water vapor mixing ratio

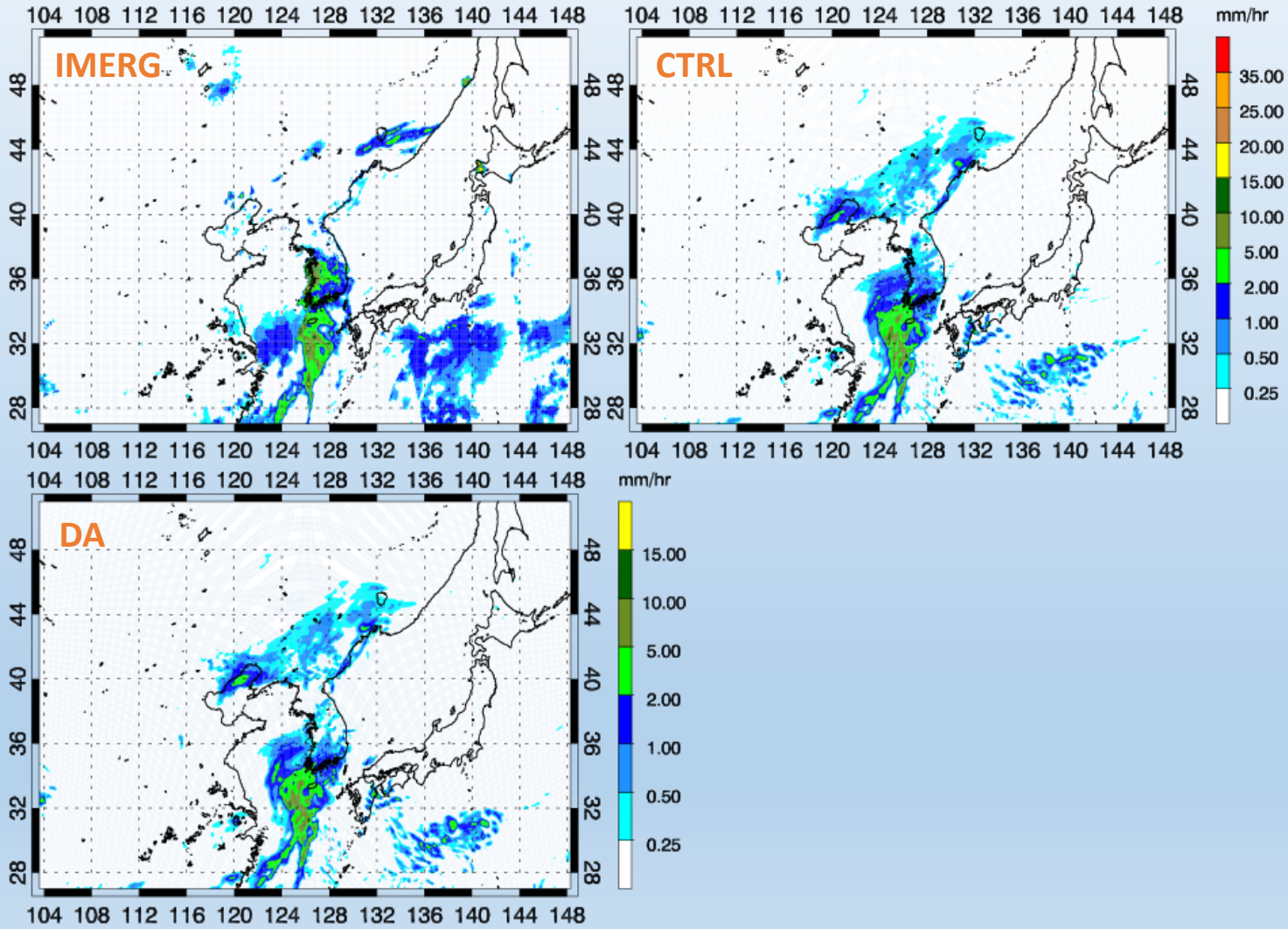


OBS – CTRL



Data Impact on Precipitation Forecast

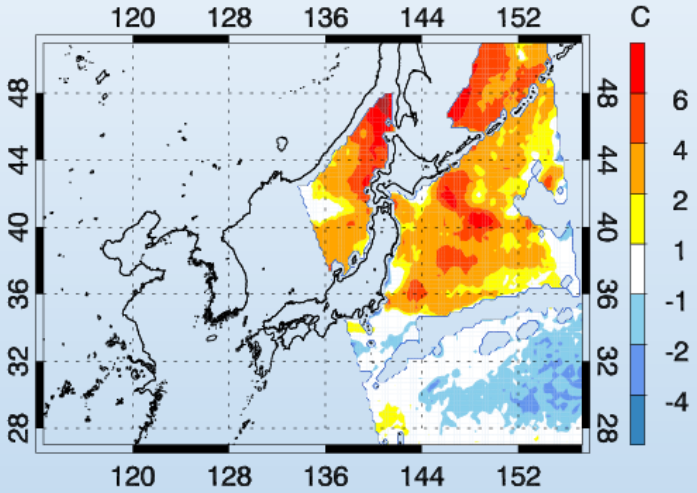
2018/03/07 1500 UTC



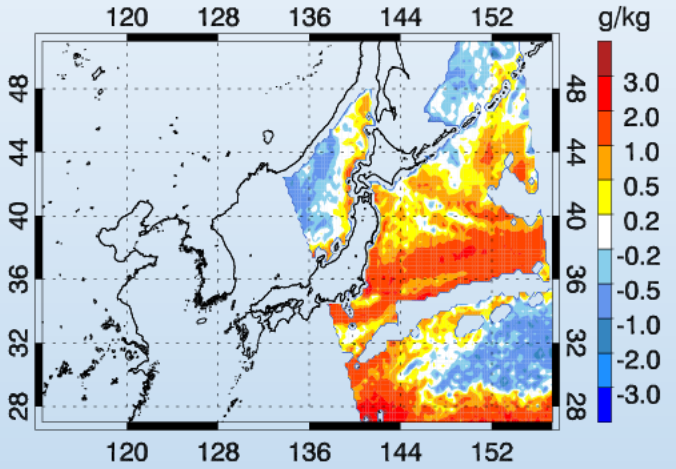
Case #2　Snow Storm on 2018/02/15

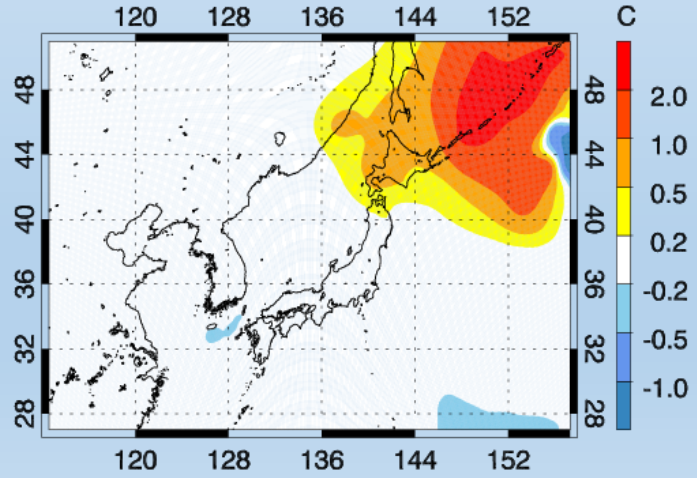
2018/02/15 0600 UTC

Obs-CTRL (Temperature)

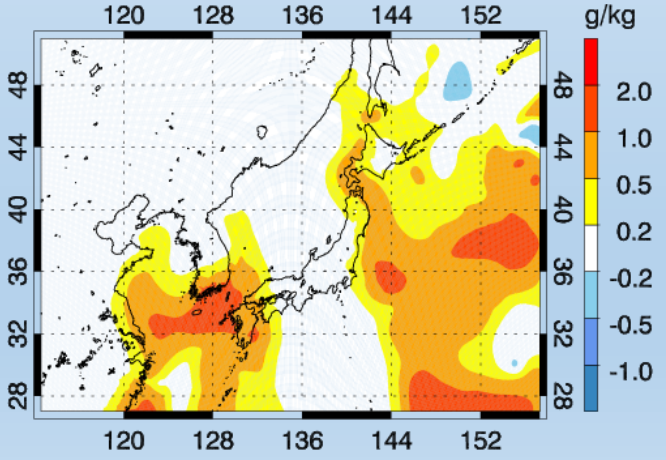


Obs-CTRL (Specific Humidity)





DA-CTRL (Temperature)



DA-CTRL (Specific Humidity)

Ongoing and Future RDA/DA Work

Data Impact: Preliminary result indicates an increment of ~1°C in low level temperature and 1-2 g/kg in moisture field. Impact on precipitation forecast is also found.

Ongoing Work: Improve data assimilation performance by generating and tuning the domain specific flow-dependent background error for the nested domains; Complete data assimilation for 07-08 March 2018 case; Case study for snow storm event on 27-28 February 2018.

Next Steps: Statistic assessment of data impact on initial condition and short-term forecast; Sensitivity experiments with GSI EnKF assimilation method.

*****Request for access to ICE-POP Korean datasets for data assimilation and validation.***

Thank you!!

Questions and Comments Welcome

NASA/SPoRT web: https://weather.msfc.nasa.gov/sport/

Twitter: @NASA_SPoRT

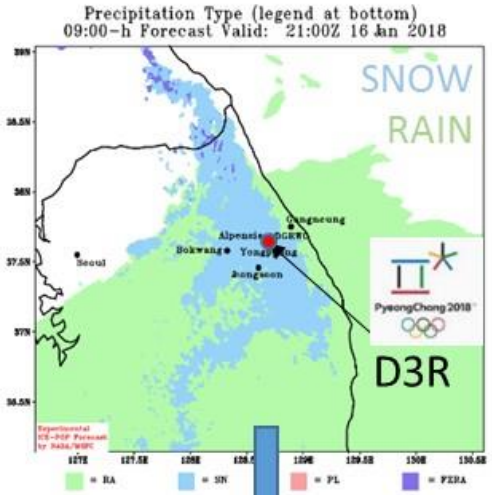
Facebook: NASA.SPoRT

Acknowledgement: *We are grateful for the opportunity provided by the Korean Meteorological Agency (KMA) and to the support provided by the World Meteorological Organization (WMO) making possible the ICE-POP 2018 weather research and development projects during the Olympic and Paralympic Winter Games PyeongChang2018.*

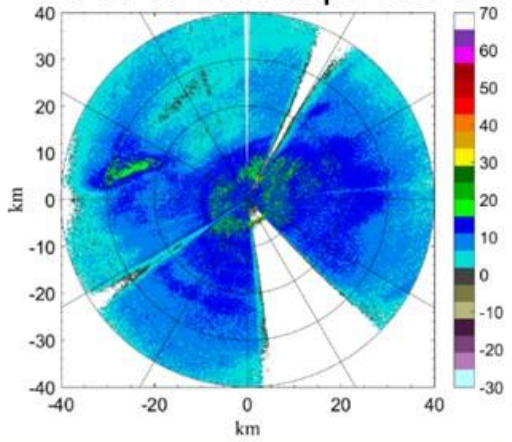
ICE-POP Campaign examining agreement between forecast and remote/in situ snowfall observations over complex terrain

Precipitation Type (Rain or Snow)

Forecast is Snow

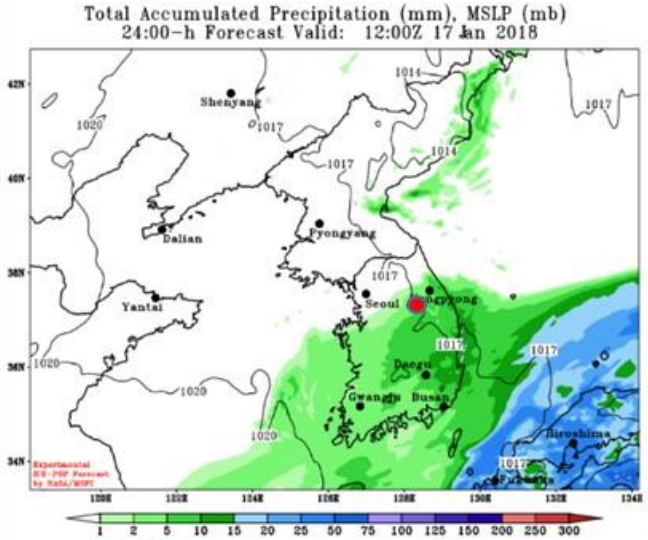


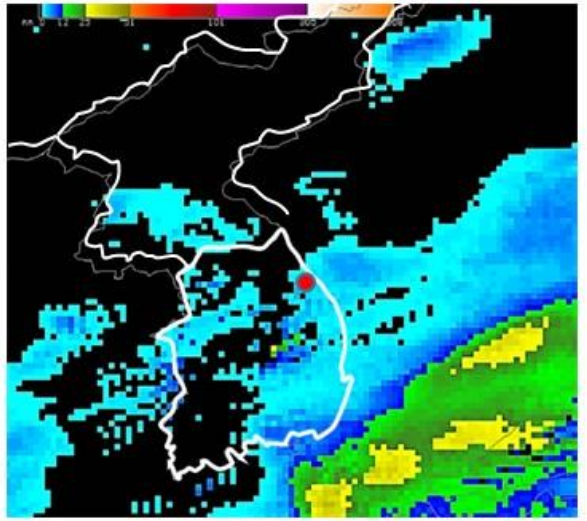
NASA D3R Maps Snow



Precipitation Amount (24-hr estimate)

Forecast is for 2-5 mm → IMERG Estimates 1-2 mm





NASA and KMA ground-based observations measure ~1.5 mm

Forecast, GPM IMERG, and ICE-POP observations agree on precipitation type and amount for an early ICE-POP snow event near PyeongChang.

These comparisons occurred throughout ICE-POP campaign