Center report from JMA

Numerical Prediction Division,
Japan Meteorological Agency

Outline

- This report focuses on improving tropical cyclones (intensity and precipitation due to TCs) and mesoscale convective systems in the regional (2km - 5km) NWP systems
  - Important targets for JMA's NWP systems (as stated in the JMA NWP strategic plan https://www.jma.go.jp/jma/en/Activities/nwp.html)
- Operational system upgrades (for detail, please see extra slides)
  - Incorporation of an ocean mixed layer model into the mesoscale NWP system
    - Improvement in tropical cyclone intensity forecast
  - Incorporation of a hybrid 3DVAR system into the local NWP system
    - Improvement of prediction in mesoscale convective systems
- Model development and research: our recent experience
  - Feasibility study of convection permitting EPS

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Incorporation of a ocean mixed layer model

Aims: to mitigate over-deepening of TCs in the JMA Meso-Scale Model (MSM)

Price, Weller, and Pinkel (PWP) ocean mixed layer model (OML, Price et al., 1986, Price et al., 1994)
=> Consider vertical mixing driven by radiation, heat and momentum fluxes

Temperature

$$\frac{\partial T}{\partial t} = \frac{-1}{\rho_0 C}\frac{\partial F}{\partial z}$$

Salinity

$$\frac{\partial S}{\partial t} = -\frac{\partial E}{\partial z}$$

Horizontal current

$$\frac{\partial V}{\partial t} = -f \times V - \frac{1}{\rho_0}\frac{\partial G}{\partial z}$$

Sea surface boundary conditions:

$F(0) = Q$
radiation, sensible and latent heat fluxes

$E(0) = S(E - P)$: water flux

$G(0) = \tau$: wind stress

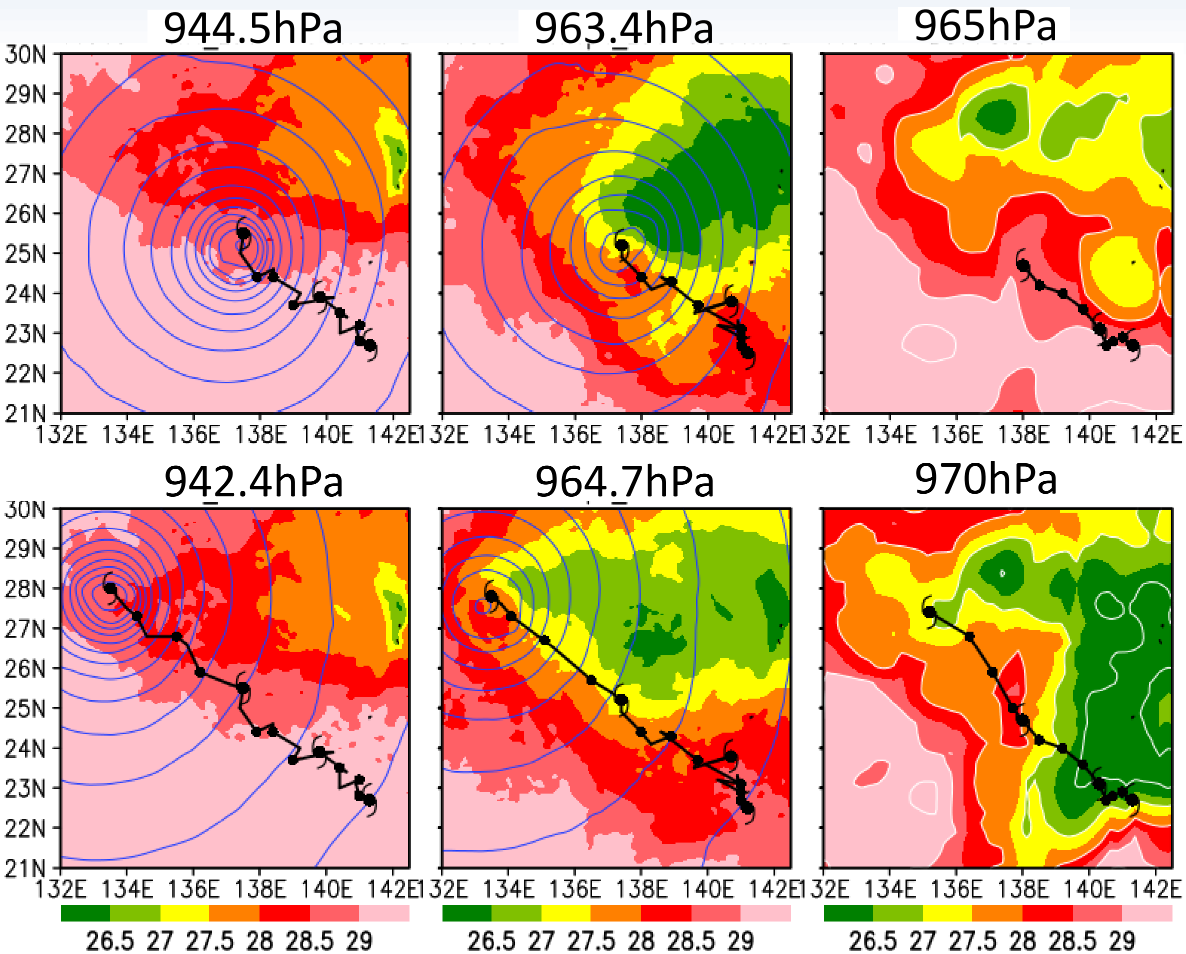
E: water vapor flux
P: precipitation flux
ρ_0: density of sea water
C: heat capacity

Case studies of Typhoon Hagibis (2019)

Fixed SST **With OML** **Best tracks + OISST**

T+48

T+72



00UTC 10 Aug. 2019 init.

Colors : SST [K]

Contours : Sea level pressure [hPa]

Black lines : TC tracks

Best tracks + OISST

SAWADA Masahiro et al.

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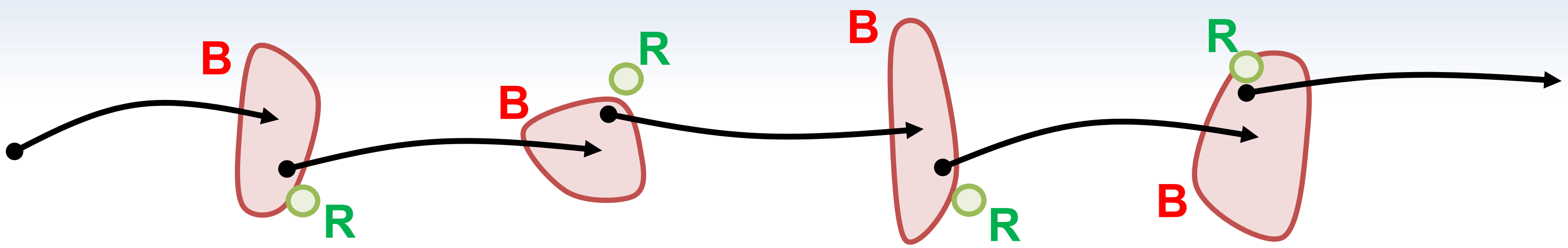
Hybrid 3DVAR aproach



Cost function:

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x}-\mathbf{x}^b)^T \mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}^b) + \frac{1}{2}[\mathbf{H}(\mathbf{x}-\mathbf{x}^b)-\mathbf{d}]^T \mathbf{R}^{-1}[\mathbf{H}(\mathbf{x}-\mathbf{x}^b)-\mathbf{d}]$$

Background error covariance:

$$\mathbf{B} = \beta_c^2 \mathbf{B}_c + \beta_e^2 \mathbf{B}_e$$

Observation error covariance

$$\mathbf{d} \equiv \mathbf{y}^o - H(\mathbf{x}^b)$$

FG departure

Climatology-based B

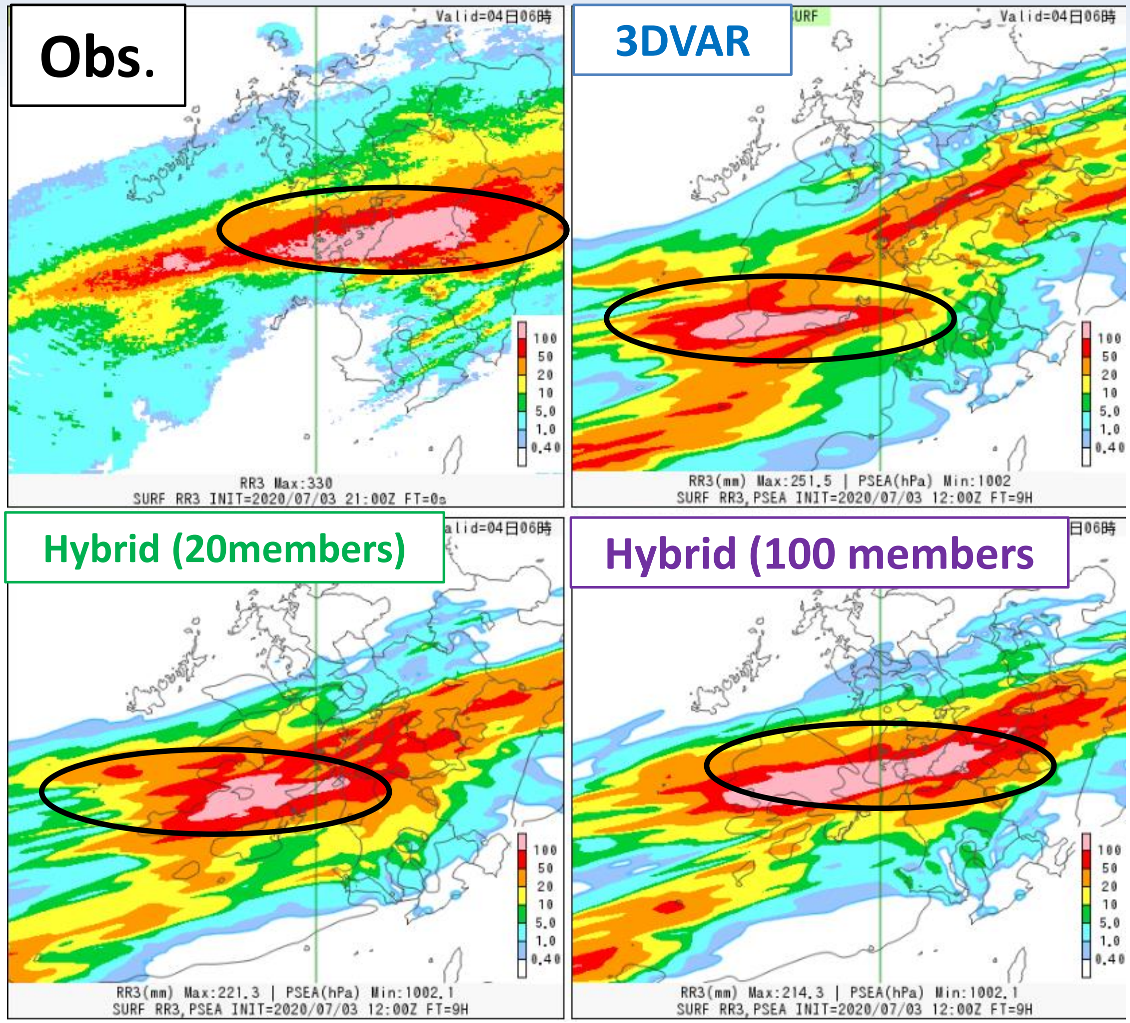
Ensemble−based B

$$\beta_c^2 = \beta_e^2 = 0.5$$

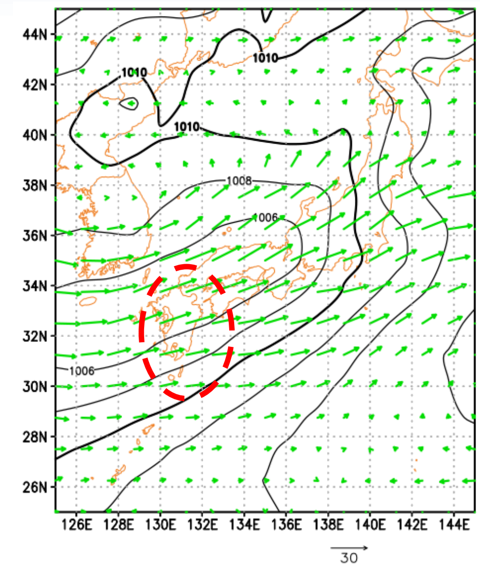
The Ensemble−based B is obtained from the **100 members of the operational Mesoscale EPS using lagged forecasts** (20 members / initial date.)

Case studies of MCS

Three-hour precipitation (mm) for 18 - 21 UTC in on 3 July 2020
T+9 initialized from 12 UTC 3 July 2020



Global analysis at 18 UTC 3 July 2020
Contours: Sea level pressure [hPa]
Vectors: horizontal wind at 500hPa



・The hybrid 3DVAR with more members can represent MCS and associated heavy rain due better.

Analysis increments

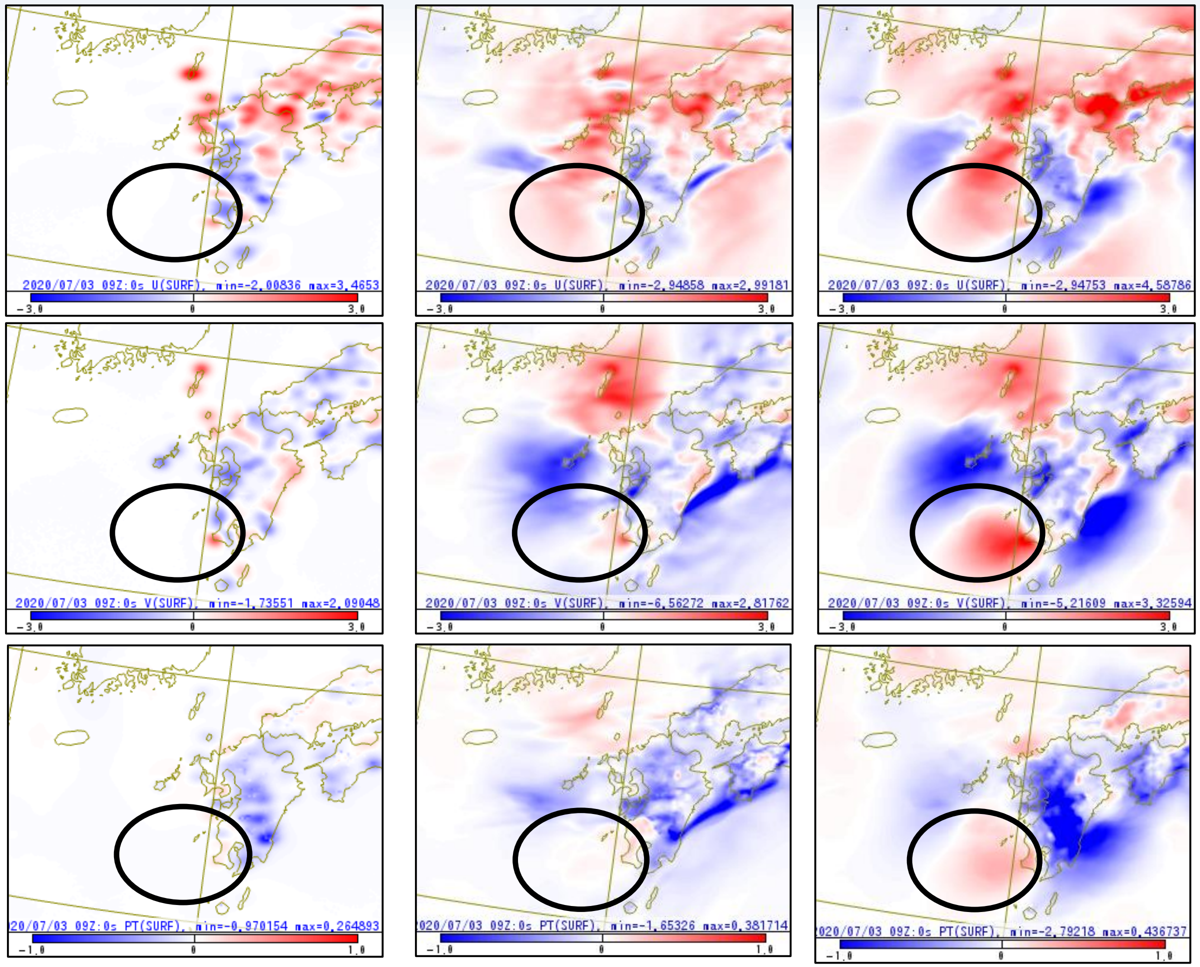
increments at 09 UTC 3 Jul. 2020 (first cycle toward 12 UTC 3 Jul. 2020)

3DVAR | Hybrid (20members) | Hybrid (100 members)

Surf. U [m/s]

Surf. V [m/s)

Surf. PT [K]



Flow-dependent increments in the hybrid DA improved positions of MCS.

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Development of LEPS (Local EPS)

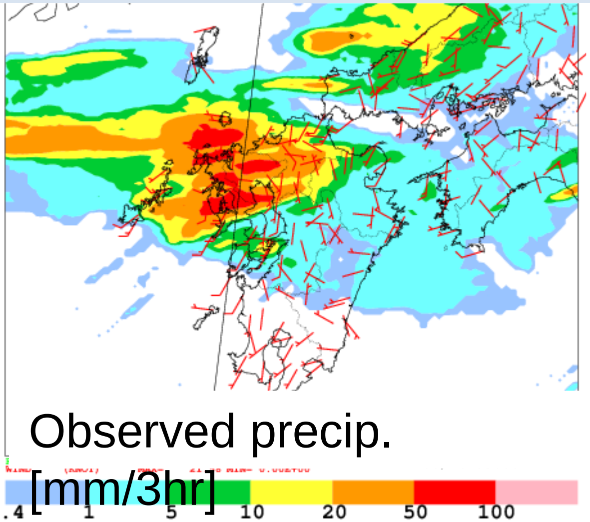
Aim: investigation on future specification of convection permitting EPS for probabilistic predicction of MCS

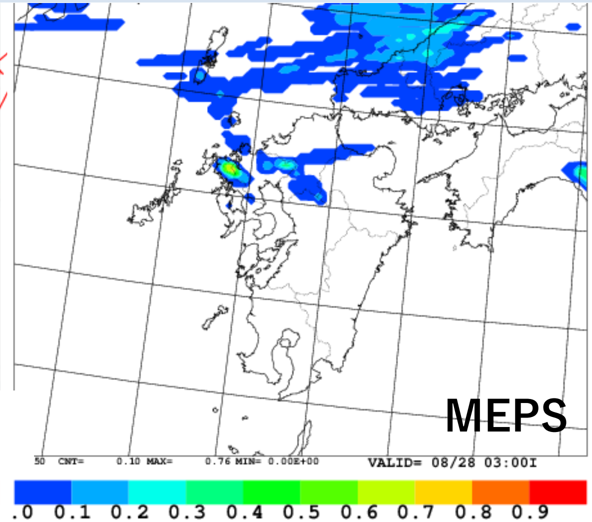
	MEPS (Meso-scale EPS, in operation)	LEPS (Local EPS, in research)
Horizontal resolution	5km	2km
Convective parameterization	Yes (non-convection permitting mode)	Yes (convection permitting mode: strength of mass fluxes are much weaker than MEPS by controlling closure)
Ensemble members	21	**21 or 101**
Initial conditions	Meso-scale analysis	Local analysis
Initial perturbations	Singular Vectors from the global and regional models	Based on MEPS (regridded to 2km)
Lateral boundary perturbations	Singular Vectors from the global model	None (to be considered in future research)

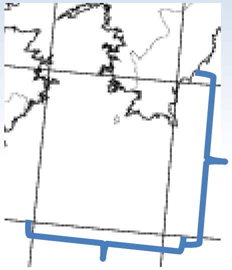
Note: lower boundary / model perturbations are to be considered in future research

Probabilistic forecast of Precipitation > 50mm/3hr

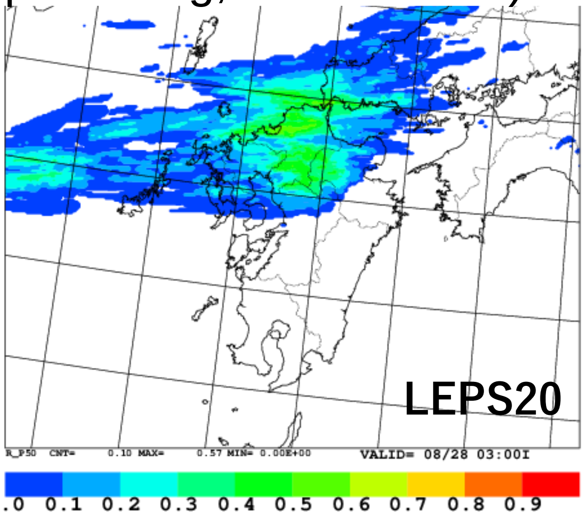
MEPS (dx=5km, non-convection permitting, 21members)



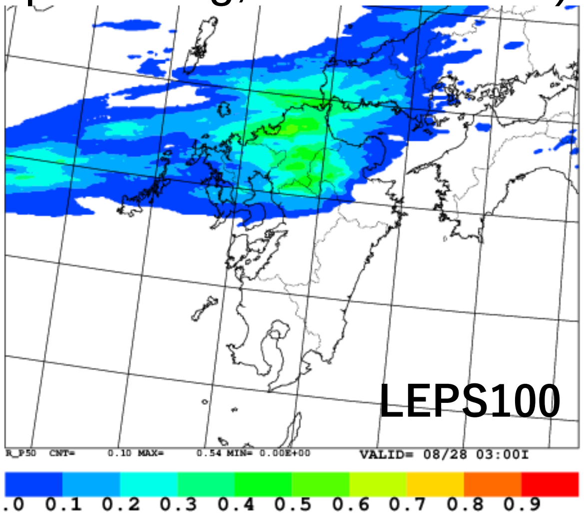




LEPS (dx=2km, convection permitting, 21 members)



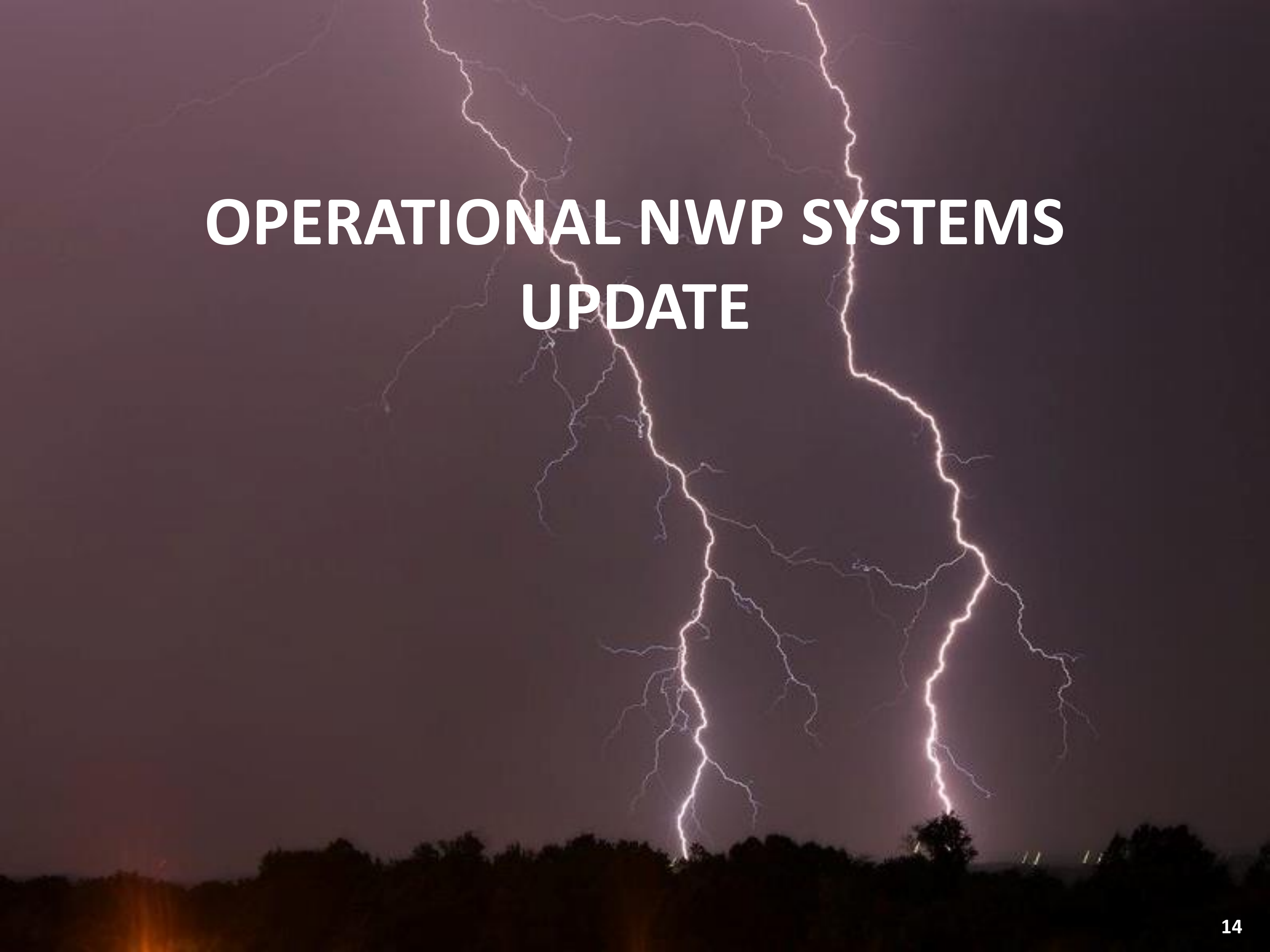
LEPS (dx=2km, convection permitting, 101 members)



* LEPS (convection permitting EPSs) captured the potential of MCS Better than in MEPS.

* Increase of EPS members makes the PDF less noisy.

EXTRA SLIDES



OPERATIONAL NWP SYSTEMS UPDATE

NWP systems upgrade since WGNE-36 (Nov.2021-Oct. 2022)

- Global NWP (incl. Global EPS)
  - Major upgrade of GEPS in Mar. 2021 (Yamaguchi et al. 2022, WGNE Bluebook)
    - Enhanced horizontal resolution from 40 km (TL479) to 27 km (TQ479) up to Day+18 (55 km (TL319) to 40 km (TQ319) up to Day+34)
      - With improvement to effective resolution by refinement of orography filters, and numerical diffusion coefficients for the atmospheric model
    - Physics parametrizations upgrade
      - Optimization of parameters for subgrid orography using COORDE type experiments (Matsukawa 2022, WGNE Bluebook)
      - Upgrade of diagnostics for effective size of cloud ice for radiation
      - Improvement for treatment of lake surface temperature
      - Upgrade of ozone climatological data based on reanalysis using JMA's latest chemical transport model (MRI-CCM2; Deushi and Shibata 2011) and satellite observation

NWP systems upgrade since WGNE-36 (Nov.2021-Oct. 2022)

- Global NWP (incl. Global EPS, cont.)
  - Major upgrade of GEPS in Mar. 2021 (Yamaguchi et al. 2022, WGNE Bluebook)
    - Improvement to SST boundary conditions.
      - Use SST predicted by JMA's atmosphere-ocean coupled Seasonal
      - EPS model (JMA/MRI-CPS3; Kubo and Ochi 2022), which was launched in Feb.2022, from Day+6
  - Improvements to observation processing.
    - Switch from Meteosat-CSR to Meteosat-CSR included in ASR (Oct. 2022)
    - Upgrade to RTTOV 13 (modules only), assimilation of Dual-Metop AMV and switch from Meteosat-8 to Meteosat-9 (Jun. 2022).
    - Assimilation of Metop-C / IASI global data (Nov. 2021)

NWP systems upgrade since WGNE-36 (Nov.2021-Oct. 2022)

- Seasonal forecast system
  - Upgrade JMA/Meteorological Research Institute - Coupled Prediction System from Ver.2 to Ver. 3 in Feb. 2022 (Kubo and Ochi 2022, WGNE Bluebook)
    - Atmospheric model: Improved version of the physical process of JMA-GSM2003 (Yonehara et al. 2020) with horizontal resolution of 55 km (TL319) for seasonal forecasting
    - Ocean model: MRI.COM (Tsujino et al. 2017) with horizontal resolution of 0.25 deg. X 0.25 deg
    - Initial conditions:
      - Atmosphere: Operational global analysis
      - Ocean: MOVE/MRI.COM-G3 (Low-res. 4DVAR + High res. downscaling)
      - Land: Land: Offline model runs (forced by JRA-3Q and JMA Global Analysis)

NWP systems upgrade since WGNE-36 (Nov.2021-Oct. 2022)

- Meso-scale NWP system
  - Major upgrade of MSM in Mar. 2022 (Sawada et al. 2022, WGNE Bluebook)
    - Increase vertical levels from 76 to 96 with extension of the upmost level from 21.8 km to 37.5 km
    - Physics parameterization upgrade:
      - Incorporation of an ocean mixed layer model (Price et al. 1986)
      - Improvement to diagnosis of mixed-length scale in the PBL scheme
      - Update of the critical relative humidity for condensation in the cloud macro physics
      - Improvement to formulation of evapotranspiration in the land surface model
      - Update of ancillary data for the land surface process (soil moisture, thermal roughness over urban area and land surface albedo climatology, and LAI)
      - Update absorption coefficients for water vapor in the radiation scheme
  - Forecasts at 00 and 12UTC are extended from 51 hours to 78 hours (Jun. 2022)

NWP systems upgrade since WGNE-36 (Nov.2021-Oct. 2022)

- Meso-scale NWP system (cont.)
  - Improvements to observation processing
    - Assimilation of water vapor channels of ATMS, upgrade to RTTOV 13 (modules only) and improvement to usage of GPM/DPR (Jun. 2022)
    - Assimilation of 9,10 and 11 chs of AMSU-A associated with the increase of vertical levels in the model (Mar. 2022)
    - Assimilation of Metop-C/ASCAT (Dec. 2021)

NWP systems upgrade since WGNE-36 (Nov.2021-Oct. 2022)

- Local NWP system
  - Major upgrade of the data assimilation System in Mar. 2022 (Yokota et al. 2022, WGNE Bluebook)
    - Incorporation of a hybrid 3DVAR system
      - Use the regional EPS to estimate ensemble-based background error covariance
  - Improvements to observation processing
    - Assimilation of water vapor channels of ATMS and upgrade to RTTOV 13 (modules only) (Aug. 2022)
    - Assimilation of Metop-C/AMSU-A and MHS (Nov. 2021)