WRFDA 2019 Update

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NCAR/MMM

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NCAR

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History of WRFDA developments

- Developed from MM5 3DVAR beginning around 2002, first version (2.0) released December 2003
- Implemented radar radial velocity DA in 2005
- WRF-Var V3.0, April 2008, merged into WRF repository
- WRF-Var V3.1, April 2009, **4DVAR and Radiance DA**
- WRFDA V3.2, April, 2010, **Hybrid-3DEnVAR**, Adjoint sensitivity
- WRFDA V3.3, April 2011, WRFPlus up to data with WRF
- WRFDA V3.4, April 2012, parallel 4DVAR, precipitation DA
- WRFDA V3.5, April 2013, wind speed/direction DA
- WRFDA V3.6, April 2014, dual-res. Hybrid, aircraft humidity DA
- WRFDA V3.7, April 2015, new radar DA option, cv_options=7, new MP option for WRFPlus TL/AD
- WRFDA V3.8, April 2016, dynamic constraint, AMSR2 radiance
- WRFDA V3.9, April 2017, hybrid-4DEnVar, all-sky radiance DA
- WRFDA V4.0, June 8, 2018, **WRFPlus merged into WRF Github repository (fully public Github repository)**
- **WRFDA V4.1, released in April 12, 2019**

DA algorithms available in WRFDA

- 3DVAR and FGAT (First Guess at Appropriate Time)
  - Different options for choice of dynamic control variables (e.g., Psi/Chi or U/V) and cloud analysis variables
- 4DVAR
  - Need WRFPlus: TL/Adjoint of WRF model
  - Can calculate adjoint-based forecast sensitivity to obs (FSO)
- Hybrid-3D/4DEnVar
  - Can run in dual-resolution mode
- Ensemble analysis
  - ETKF (Ensemble Transform Kalman Filter) w/o covariance localization
  - Ensemble of hybrid-EnVar with perturbed observations

WRFDA Observations

- **In-Situ:**
  - SYNOP
  - METAR
  - SHIP
  - BUOY
  - TEMP
  - PIBAL
  - AIREP, AIREP humidity
  - TAMDAR
- **Bogus:**
  - TC bogus
  - Global bogus

- **Remotely sensed retrievals:**
  - **Atmospheric Motion Vectors (geo/polar)**
  - **SATEM thickness**
  - **Ground-based GPS TPW or ZTD**
  - **SSM/I oceanic surface wind speed and TPW**
  - **Scatterometer oceanic surface winds**
  - **Wind Profiler**
  - Radar data (reflectivity/retrieved rainwater, and radial-wind)
    - V3.9: No-rain echo radar DA (from KNU)
  - Satellite temperature/humidity/thickness profiles
  - GPS refractivity (e.g. COSMIC)
  - Stage IV precipitation/rain rate data (4D-Var only)

- **Radiances (VarBC, RTTOV & CRTM, All-sky radiance):**
  - HIRS   NOAA-16, NOAA-17, NOAA-18, NOAA-19, METOP-A
  - AMSU-A   NOAA-15/16/18/19, EOS-Aqua, METOP-A, METOP-B
  - AMSU-B   NOAA-15, NOAA-16, NOAA-17
  - MHS   NOAA-18, NOAA-19, METOP-A, METOP-B
  - AIRS   EOS-Aqua
  - SSMIS   DMSP-16, DMSP-17, DMSP-18
  - IASI   METOP-A, METOP-B
  - ATMS   Suomi-NPP
  - MWTS/MWHS   FY-3 A/B; MWHS2 from FY-3 C/D (new in 4.1)
  - SEVIRI   METEOSAT
  - AMSR2   GCOM-W1 (all-sky microwave radiance DA)
  - GOES-Imager, Himawari-AHI (new in 4.1)

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Now WRF code all on public github repository

develop branch
Latest code

release-v4.1 branch
April 12, 2019

bug-fix branches

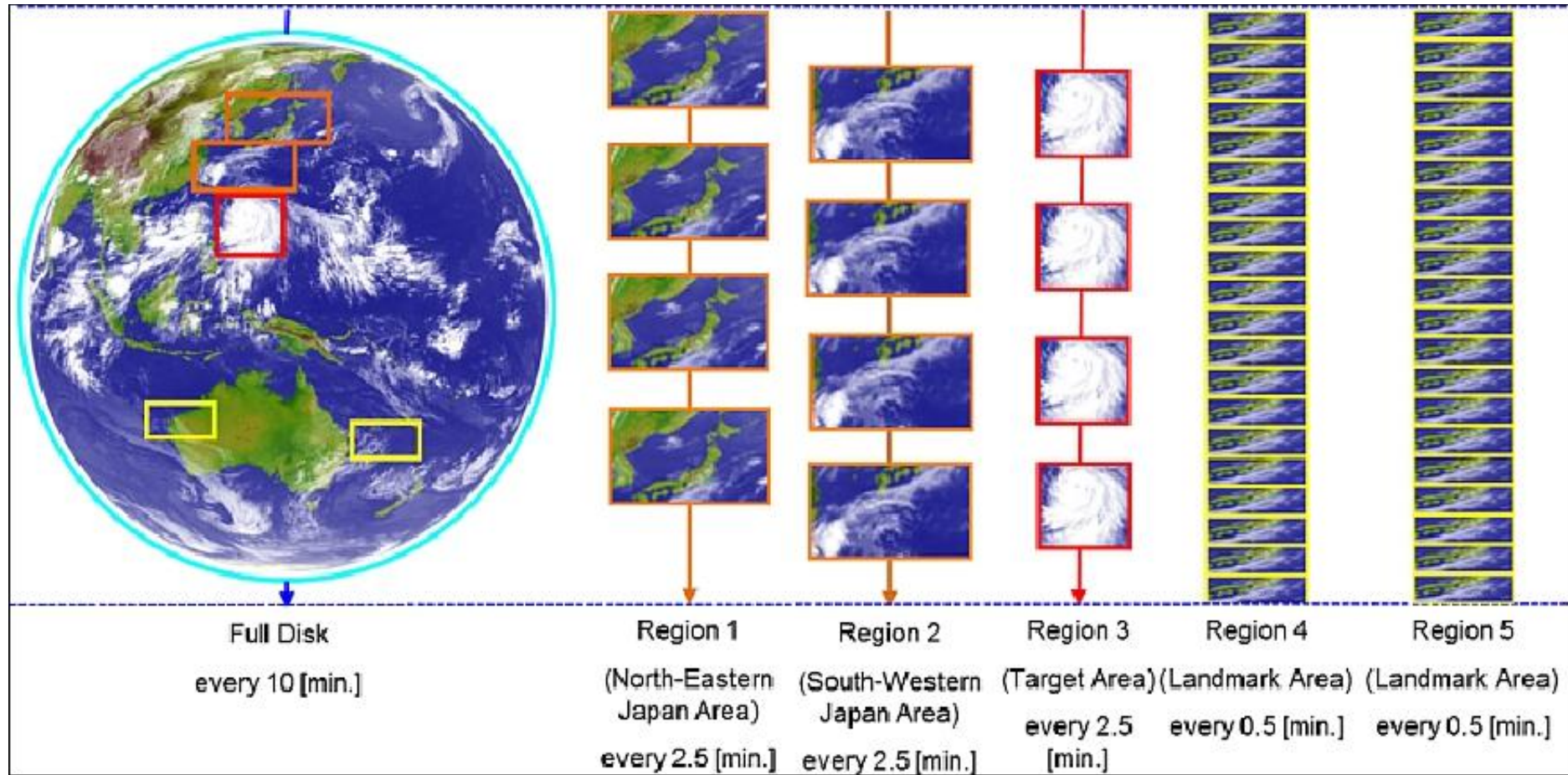# New Features in release-v4.1 branch
http://www2.mmm.ucar.edu/wrf/users/wrfda/updates-4.1.html

- **Add two new sensors for clear-sky radiance DA**
  - Geostationary Himawari **AHI** (Infrared sensor)
  - Polar orbiting FY-3 C/D **MWHS2** (Microwave sensor), contributed by Dr. Wei Sun from Chinese Academy of Sciences

- **3DVAR and hybrid-3D/4DEnVar now work with WRF's moist potential temperature (default from 4.1)**

Himawari-8 AHI scan pattern

Full Disk — every 10 [min.]

Region 1 (North-Eastern Japan Area) — every 2.5 [min.]

Region 2 (South-Western Japan Area) — every 2.5 [min.]

Region 3 (Target Area) — every 2.5 [min.]

Region 4 (Landmark Area) — every 0.5 [min.]

Region 5 (Landmark Area) — every 0.5 [min.]

Every 10-min full-disk data and every 2.5-min regional data!
2-km spatial resolution!

16 AHI channels, 10 IR channels

Wavebands of the Advanced Himawari Imager (AHI)

	Channel	Central Wavelength [μm]	Spatial Resolution	
VIS	1	0.43 – 0.48	1 km	RGB
	2	0.50 – 0.52	1 km	Composite
	3	0.63 – 0.66	0.5 km	True Color
NIR	4	0.85 – 0.87	1 km	
	5	1.60 – 1.62	2 km	
	6	2.25 – 2.27	2 km	
IR	7	3.74 – 3.96	2 km	
	8	6.06 – 6.43	2 km	Water Vapor
	9	6.89 – 7.01	2 km	
	10	7.26 – 7.43	2 km	
	11	8.44 – 8.76	2 km	SO_2
	12	9.54 – 9.72	2 km	O_3
	13	10.3 – 10.6	2 km	Atmospheric Windows
	14	11.1 – 11.3	2 km	
	15	12.2 – 12.5	2 km	
	16	13.2 – 13.4	2 km	CO_2

No cloud detection is provided in WRFDA

Users need to use the third party
Or your own software to do cloud
detection. e.g., GEOCAT package
from CIMSS of UW-Madison
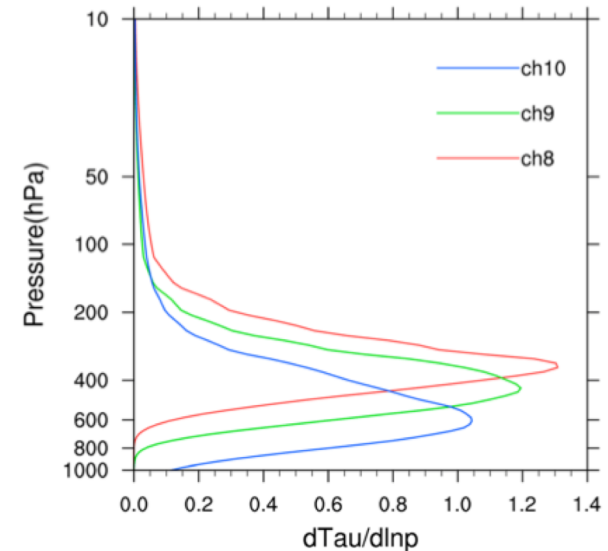
Wang et al., 2018: Added value of assimilating Himawari-8 AHI water vapor radiances on analyses and forecasts for "7.19" severe storm over north China. JGR.

FY-3C/3D MWHS2, hdf format
http://satellite.nsmc.org.cn/portalsite/default.aspx

Channel Number			Central Frequency (GHz)		
MWHS-2	ATMS	MHS	MWHS-2	ATMS	MHS
1	16	1	89 (H)	88.2 (V)	89(V)
2	-	-	118.75 ± 0.08 (V)	-	-
3	-	-	118.75 ± 0.2 (V)	-	-
4	-	-	118.75 ± 0.3 (V)	-	-
5	-	-	118.75 ± 0.8 (V)	-	-
6	-	-	118.75 ± 1.1 (V)	-	-
7	-	-	118.75 ± 2.5 (V)	-	-
8	-	-	118.75 ± 3.0 (V)	-	-
9	-	-	118.75 ± 5.0 (V)	-	-
10	17	2	150 (H)	165.5 (H)	157 (V)
11	22	3	183 ± 1.0 (V)	183 ± 1.0 (H)	183 ± 1.0 (H)
12	21	-	183 ± 1.8 (V)	183 ± 1.8 (H)	-
13	20	4	183 ± 3.0 (V)	183 ± 3.0 (H)	183 ± 3.0 (H)
14	19	-	183 ± 4.5 (V)	183 ± 4.5 (H)	-
15	18	5	183 ± 7.0 (V)	183 ± 7.0 (H)	190.31 (V)

Updated Features in release-v4.1 branch

- Updated WRFDA to interface RTTOV v12. New emissivity formulations are enabled as well as HDF-only emissivity atlas files. Compiling WRFDA for RTTOV now requires an HDF5 library.

- The code-base of CRTM carried with WRFDA is updated from v2.2.3 to v2.3.0.

- Enhanced the gts_omb_oma diagnostics by appending time slot information after the level information.

- New WRFDA namelist options for specifying errors for radar-retrieved hydrometeor profiles
  - radar_rhv_err_opt, radar_rhv_rrn_err, radar_rhv_rsn_err, radar_rhv_rgr_err

Note about WRFPlus and 4DVAR

- Neither WRFPlus nor 4DVAR work with **hybrid vertical coordinate (**HVC) or **moist potential temperature (**THM)

- To turn off HVC, set **hybrid_opt=0**; To turn off THM, set **use_theta_m=0** (this will lead to THM=T in WRF/WRFDA file) when running real.exe and wrf.exe

- No plan for now due to the lack of resource/funding

New features in **develop** branch

- A new cloud detection scheme for hyperspectral IR sensors (e.g., AIRS, IASI) based upon particle filter
  - Can keep high-peaking channels not affected by cloud
  - Xu et al., 2016: A method for retrieving clouds with satellite infrared radiances using the particle filter. Geosci. Model Dev., 9, 3919–3932

- New stand-alone "gen_be_v3" (from Jamie Bresch, NCAR/MMM) for
  - Generating ensemble perturbation and
  - Background error covariance file for cv_options=7 and cloud_cv_options=2 applications.
  - It is much more faster than the existing gen_be package.

Ongoing R&D

- 4DVAR + every 10-min AHI radiances
  - Afternoon presentation by Wu Yali
- GOES-ABI (and Himawari-AHI) all-sky radiance DA
  - See Poster by Guerrette et al.

- A new radar reflectivity operator with TL/AD for direct assimilation of reflectivity (Wang & Liu, 2019)
  - Take into account mixed-phase precip. in melting layer

- Extension for aerosol/chemical DA, funded by Beijing IUM of CMA
  - 3DVAR, can assimilate surface PM2.5, PM10, SO2, NO2, O3, and CO observations for WRF/Chem initialization
  - Can be flexible to use for different aerosol/chemical options
  - Dr. Wei Sun will give a lecture on this in July's WRFDA tutorial

Welcome your contributions,

Use git/github and follow Pull Request examples

NOT send us your code in tar file