### WRFDA 2019 Update

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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

- 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
  - **dity** 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)

### Now WRF code all on public github repository

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## **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



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
	1	0.43 - 0.48	1 km RGB
VIS	2	0.50 - 0.52	1 km Composite
	3	0.63 - 0.66	0.5 km True Color
	4	0.85 – 0.87	1 km
NIR	5	1.60 - 1.62	2 km
	6	2.25 – 2.27	2 km
	7	3.74 – 3.96	2 km
	8	6.06 - 6.43	2 km
	9	6.89 – 7.01	2 km Water Vapor
	10	7.26 – 7.43	2 km
IR	11	8.44 - 8.76	2 km SO2
	12	9.54 – 9.72	2 km 03
	13	10.3 - 10.6	2 km
	14	11.1 - 11.3	2 km Atmospher Windows
	15	12.2 – 12.5	2 km
	16	13.2 – 13.4	2 km CO2
4			

#### 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

Chann	Channel Number		Central Frequency (GHz)			
MWHS-2	ATMS	MHS	MWHS-2	ATMS	MHS	
1	16	1	89 (H)	88.2 (V)	89(V)	
2	-	-	$118.75 \pm 0.08  (V)$	-	-	
3	-	-	$118.75 \pm 0.2$ (V)	-	-	
4	-	-	$118.75 \pm 0.3$ (V)	-	-	
5	-	-	$118.75 \pm 0.8$ (V)	-	-	
6	-	-	$118.75 \pm 1.1  (V)$	-	-	
7	-	-	$118.75 \pm 2.5$ (V)	-	-	
8	-	-	$118.75 \pm 3.0  (V)$	-	-	
9	-	-	$118.75 \pm 5.0  (V)$	-	-	
10	17	2	150 (H)	165.5 (H)	157 (V)	
11	22	3	$183\pm1.0(\mathrm{V})$	$183\pm1.0~(\mathrm{H})$	$183\pm1.0~(\mathrm{H})$	
12	21	-	$183\pm1.8~(\mathrm{V})$	$183\pm1.8~\mathrm{(H)}$	-	
13	20	4	$183\pm3.0(\mathrm{V})$	$183\pm3.0~(\mathrm{H})$	$183\pm3.0~(\mathrm{H})$	
14	19	-	$183\pm4.5~(\mathrm{V})$	$183\pm4.5~\mathrm{(H)}$	-	
15	18	5	$183\pm7.0(V)$	$183\pm7.0~(\mathrm{H})$	190.31 (V)	

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### **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 <u>hybrid</u> vertical coordinate (HVC) or <u>moist potential</u> 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

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# Welcome your contributions,

Use git/github and follow Pull Request examples

NOT send us your code in tar file