The 2014 WRFDA Overview

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1. Overview

WRFDA - the Weather Research and Forecasting (WRF) Data Assimilation system is a component of the WRF modeling system developed at the National Center for Atmospheric Research. WRFDA is an advanced data assimilation system, built within the WRF software framework, that provides state-of-the-art 3D/4D variational (3D/4D-Var) and variational/ensemble hybrid techniques (Barker et al. 2012).

With the recent release, version 3.6, WRFDA can assimilate (new options are underlined):

- **In-Situ observations:**
  - Surface (SYNOP, METAR, SHIP, BUOY), AIREP.Q
  - Upper air (TEMP, PIBAL, AIREP, ACARS, TAMDAR)

- **Remotely sensed observations:**
  - Atmospheric Motion Vectors (geo/polar)
  - SATEM thickness.
  - Ground-based GPS Total Precipitable Water/Zenith Total Delay
  - SSM/I oceanic surface wind speed and TPW
  - Scatterometer oceanic surface winds
  - Wind profiler
  - Radar radial velocities and reflectivities
  - Satellite temperature/humidity/thickness profiles
  - GPS refractivity (e.g. COSMIC)
  - Stage IV precipitation data/rain rate (only in 4DVAR mode)

- **Radiances (using RTTOV or CRTM):**
  - HIRS NOAA-16, NOAA-17, NOAA-18, NOAA-19, METOP-A, METOP-B
  - AMSU-A NOAA-15, NOAA-16, NOAA-18, NOAA-19, EOS-Aqua, METOP-A
  - 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 FY-3
  - MWHS FY-3
  - SEVIRI MSG-1, 2, 3

- **Bogus data**
  - TC bogus
  - Global bogus
WRFDA is used in both applied and research settings. It is used as the analysis component of several international operational data assimilation systems. It is also used by those centers, as well as by university and research institutions, for data assimilation research.

WRFDA is a community data assimilation asset that is maintained and supported by NCAR. Since 2009, NCAR has developed and maintained the WRFDA website where one can browse or download WRFDA documentation, access tutorials and test data, participate in user forums, and obtain the latest code (http://www.mmm.ucar.edu/wrf/users/wrfda).

The international community interacts with the WRFDA team through various channels: (i) NCAR’s visiting scientist program, (ii) WRFDA user forums and workshops, (iii) annual tutorials, (iv) the WRF-help email service, (v) collaborative operational center research projects, and (vi) university/graduate student research projects. Most of the WRFDA workshops and tutorials are held at the NCAR facilities in Boulder, Colorado, USA. Occasionally they are offered overseas to accommodate users’ specific needs.
2. 2014 Updates

WRFDA 3.6 was released in April 2014. Many new features and options have been released to the community with this update. Details concerning the new updates, bug fixes, and code optimization can be found on WRFDA web page. The new features include the following:

- **Dual-resolution hybrid assimilation**: WRFDA-Hybrid can now be run in a dual-resolution configuration, i.e., a deterministic background in high resolution, ensemble input in low resolution (Schwartz et al., 2014).

- **Meteosat SEVIRI assimilation**: Meteosat 8, 9, and 10 (AKA MSG 1, 2, and 3) carry the Spinning Enhanced Visible and InfraRed Imager (SEVIRI). WRFDA can now assimilate radiance observations from this instrument, which are available in BUFR format from EUMETSAT. This is a limited implementation for now, only covering the 8 infrared channels.

- **Metop-B instruments**: Metop-B (AKA Metop 1) is a polar-orbiting satellite run by EUMETSAT, and is the sister satellite for Metop-A. Data from the IASI, AMSU-A, and MHS instruments from Metop-A could already be assimilated in prior releases of WRFDA. Starting with 3.6 this data can also be assimilated from Metop-B.

- **AIREP humidity observations**: AIREP (short for "aircraft report") is an automated weather observation from an airplane. WRFDA has had the ability to assimilate AIREP observations of temperature and wind for many years, but not moisture. These moisture observations can now be read and assimilated by WRFDA.

- **Observation thinning for conventional observations in ASCII format**: WRFDA now allows for the thinning of conventional observations assimilated in ASCII format; previously this options was only available for assimilating PREPBUFR-format observations.

- **GPSRO in different formats**: Users now have more flexibility when assimilating GPS Radio Occultation (GPSRO) observations. These observations can be read in ASCII text format (from file "ob.ascii", potentially along with other conventional observation types) or in NCEP PREPBUFR format (from file "gpsro.bufr"). Previously, users reading conventional observations from "ob.ascii" could not read GPSRO observations from "gpsro.bufr" at the same time, but that is now possible in Version 3.6.

- **Updated external libraries**: Several external libraries included in the WRFDA code have been updated to the most recent versions.
  - BUFRLIB, for reading BUFR and PREPBUFR files, has been updated to version 10.2.3. The most important feature of this update is that BUFR files of any blocking or endianness can now be read.
  - CRTM, for assimilating radiance data, has been updated to version 2.1.3.
  - RTTOV, also available for assimilating radiance data, is not included in the WRFDA code due to licensing issues, but it can be downloaded separately and used instead of CRTM. The WRFDA-RTTOV interface has been updated for RTTOV version 11.1.

- **WRFPLUS (WRF adjoint and tangent linear model)** has been upgraded to V3.6 and can be used with the released WRF version 3.6.
Full details on these changes can be found on the WRFDA website (http://www2.mmm.ucar.edu/wrf/users/wrfda/updates-3.6.html)

In addition, the website and User's Guide have been updated and revised.

3. **Ongoing work**

The WRFDA team is working on the following aspects:

3.1 **4D-Var optimization**

- Finalizing the implementation of the tangent linear and adjoint codes of the GSFC short-wave radiation scheme to be used in future chemistry assimilation.

3.2 **Background Error Covariance improvement**

- Implementation of smoothing options at various stages of the GEN_BE utility.
- Development of a GEN_BE v2.0, which will be a generalized tool for atmospheric data assimilation purposes. The model for WRF data assimilation can separately estimate the variances and vertical auto-correlations via Empirical Orthogonal Functions (EOFs), horizontal auto-correlations via Recursive Filters, and cross-covariances via linear regressions. On the other hand, GSI estimates the horizontal and vertical auto-correlation in the physical space. Recent work to include new variables in the analysis such as cloud parameters and chemical species have required a fundamental restructuring of the software interface to allow for a simpler, flexible, robust, community-oriented framework. The interface has been developed for WRFDA and GSI applications. This version is documented in a paper submitted to GMD (Descombes et al. 2014) and it is currently tested for cloud data assimilation purposes in a multivariate approach.
- Use of u-wind, v-wind, temperature, surface pressure and pseudo relative humidity as new control variables for mesoscale and convective scale data assimilation (Wang et al. 2013c, Sun et al 2014).
- Test of a location-dependent new control variable (alpha control variable) scheme (Wang et al 2014)
- Implemented GSI BE regional setup in WRFDA as cv_options=31. The BE input file is same as that for cv_options=3, and the namelist variables as1, as2,… are set in different way. With the single ob tests, the increment responses are same as those from GSI system, and looked more reasonable than those from the old cv_options=3. Moreover, the convergence speed of minimization with cv_options=31 (38 iterations) is much faster than that with cv_options=3 (90 iterations) for our test case.

3.3 **Radiance data assimilation development**

- Capability to assimilate GOES Sounder and GOES Imager radiance data for standard bufr format.
- Update RTTOV and CRTM interfaces for newest release versions.
- Capability to assimilate GCOM-W1 AMSR2 radiance.
3.4 Radar data assimilation

- An indirect radar reflectivity data assimilation scheme (Wang et al. 2013a).
- Development of hourly cycles with radar data assimilation.
- Use of global analysis as a constraint in the cost function to suppress false alarms of precipitation.
- Added a divergence constraint in the cost function to control noise.
- The new version of radar data assimilation code was merged into the trunk.

3.5 GPS RO data assimilation

- Capability to assimilate GPS nonlocal excess phase on either the mean height of each model layer or the observed height (Chen et al. 2009, 2011).
- Implementation of GPS local bending angle operator (Yang et al. 2014).

3.6 Cloud Analysis

- Improved processing of cloud-and-rain-affected satellite radiances.
- Multivariate control variable transform for cloud parameters.
- Development of displacement WRF (dWRF) capability to perform displacement analysis within the variational data assimilation framework (Nehrkorn et al. 2014).
- Ensemble-Variational Integrated Localized (EVIL) scheme to update the ensemble perturbations within the variational framework.
- Retrieval and nowcasting of three-dimensional cloud fraction, based on satellite infrared instruments and WRF dynamical core: the Multi-sensor Advection Diffusion nowCast (MADCast).

3.7 General WRFDA development

- Online thinning capability for TAMDAR, SATOB, and Radar data.
- Background and analysis blending schemes using a spatial filter (Wang et al. 2014, Hsiao et al. 2014).

References


