The 2011 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, contained with the WRF software that provides state-of-art 3D/4D variational (3D/4D-Var) and variational/ensemble hybrid techniques (Barker et al. 2004; Huang et al. 2009; Wang et al. 2008).

With the recent release, version 3.3, WRFDA can assimilate:

- In-Situ observations:
  - Surface (SYNOP, METAR, SHIP, BUOY).
  - 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).
- Radiances (using RTTOV or CRTM):
  - HIRS NOAA-16, NOAA-17, NOAA-18, NOAA-19, METOP-2
  - AMSU-A NOAA-15, NOAA-16, NOAA-18, NOAA-19, EOS-Aqua, METOP-2
  - AMSU-B NOAA-15, NOAA-16, NOAA-17
  - MHS NOAA-18, NOAA-19, METOP-2
  - AIRS EOS-Aqua
  - SSMIS DMSP-16
- 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. From 2009, NCAR developed the WRFDA website where one can browse,

or download WRFDA documentation, tutorials, 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) WRF-help, (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. 2011 Updates

WRFDA 3.3 was released in April 2011. Many new features and options have been released to the community in 2011. Details concerning the new updates, bug fixes, and code optimization can be found on WRFDA web page. The new features include the following:

a) The WRFPLUS (WRF adjoint and tangent linear model) has been upgraded to V3.3 and it is consistent with the released WRF version 3.3;
b) WRFDA is also upgraded with WRFPLUS version 3.3 and the new 4D-Var system is a single executable application;
c) RTTOV interfaces has been upgraded to version 10.0;
d) Updated forecast sensitivity to observation (FSO) with WRFPLUS V3.3;
e) Updated background error statistics option CV6, which the fully multivariate formulation including humidity.

3. Ongoing work

3.1 4D-Var optimization

The WRFDA team is working on the optimization of the WRFDA 4D-Var including the following aspects:

- Further reduction of the memory use and exchange in 4D-Var, in particular in WRFPLUS;
- Parallelization of WRFPLUS code;
- Recoding the multi-incremental formulation, which allows resolution changes between innovation calculations and minimizations;
- Precipitation assimilation, which is expected to improve short-term quantitative precipitation forecasts;
- Finalizing the implementation of the tangent linear and adjoint codes of GSFC short-wave radiation scheme to be used in future chemistry assimilation.

The current plan is to release all these new functions in the next major release.

3.2 Hydrometeors

a. New control variables

To assimilate cloud- and precipitation-affected observations, the total water is used as moisture control variable in the released WRFDA. A warm-rain process is employed to partition the total water into water vapor, cloud water and rainwater. To enhance the capability of WRFDA to assimilate cloud- and precipitation-related observations, three new control variables are introduced. They are cloud water, rainwater and ice. For the three new control variables, the background errors are assumed Gaussian, spatially homogeneous and isotropic. A recursive filter is used to model the horizontal auto-covariance, and Empirical Orthogonal Functions (EOFs) are used to model the vertical correlations.

b. Tangent-linear and adjoint of a Kessler scheme

A tangent-linear model of microphysical process is needed to propagate the perturbation of hydrometeor variables and an adjoint model is needed to propagate the influence of observations to the beginning of the assimilation window in 4DVAR. As the first step toward the hydrometeor assimilation in 4DVAR, we started from a Kessler warm-rain scheme that includes water vapor, cloud water, and rain water. The microphysical processes included are: the production, fall, and evaporation of rain; the accretion and autoconversion of cloud water; and the production of cloud water from condensation. The original Kessler scheme was reorganized and modified for the components that have high degree of nonlinearity to avoid producing singular values. The tangent-linear and adjoint codes were then developed, checked and incorporated into WRFPLUS.

3.3 Further development of the hybrid variational/ensemble option

The WRFDA hybrid trunk has been modified to include: (i) the various ETKF inflation factors, (ii) vertical localization of the hybrid extended control variable, (iii) a WRFDA/LETKF experimental hybrid based on the work of Ott et al. (2004), and (iv) a WRFDA/EnKF experimental hybrid based on DART. Presently, the ETKF and its various inflation factor schemes are available for community use. The vertical localization and experimental hybrids (WRFDA/LETKF and WRFDA/EnKF hybrids) are completed and undergoing internal evaluation.

3.4 The Lanczos minimization

The Lanczos minimization has been improved to include the following:

1) The stopping criterion is based on information content (i.e. the relative analysis increment) rather than the gradient norm. This avoids expensive unnecessary calculation for the gradient. This results in similar, but slightly different iteration numbers between the Lanczos (LZ) and the Conjugate Gradient (CG) minimization.

2) The Lanczos eigenpairs produced during the minimization can be stored into files. The WRFDA data assimilation can read these files a) to avoid re-running the assimilation for the observation impact and/or b) to precondition subsequent minimizations and converge faster.

Both applications result in significant speed-up. This development will be committed soon to the community trunk.

References

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