Handling of hydrometeors in WRFDA

There is a namelist option (cloud_cv_options) in &wrfvar7 for choosing at run-time how to model cloud control variables. The default is cloud_cv_options=1. The other available options (2 and 3) require WRFDA to be compiled differently (by activating CLOUD_CV macro) to allow the allocation and handling of additional cloud-related control variables and processes. For now, the implementation of cloud_cv_options=2 and cloud_cv_options=3 is still preliminary and ad hoc. Additional coding effort is expected from the user.

cloud_cv_options = 1 (default)

> Total water is the moist/cloud control variable. Cloud water and rainwater are combined with water vapor as total water. A warm-rain scheme is used to partition the total water into water vapor, cloud water and rainwater during minimization. See Xiao et al., 2007 for the methodology.

To compile WRFDA with additional cloud variables included for cloud_cv_options=2 or cloud_cv_options=3, set the shell environment variable "CLOUD_CV" equal to 1 before running the `configure` script.

```
setenv CLOUD_CV 1
./configure wrfda
./compile all_wrfvar
```

cloud_cv_options = 2

> Moist control variable is pseudo relative humidity (defined as Q/Q_b,s , where Q_b,s is the saturated specific humidity from the background field). The additional 5 cloud control variables are cloud water, rainwater, cloud ice, snow and graupel. Both horizontal and vertical correlations are considered. This option requires the background error statistics information of the aforementioned 5 cloud variables to be included in the be.dat file.

cloud_cv_options = 3

> Moist control variable is pseudo relative humidity. The additional 5 cloud control variables are cloud water, rainwater, cloud ice, snow and graupel. Only horizontal correlation is considered. Length scales and variances are hard-coded in *var/da/da_setup_structures/da_setup_be_regional.inc*.

Note that CLOUD_CV-enabled WRFDA will be slower and need more memory even when cloud_cv_options are not set to be 2 or 3. It is recommended that you only activate the CLOUD_CV compilation if you intend to assimilate radar reflectivity data using the indirect method (`use_radar_rhv = .true.`) as described in Wang et al., 2013.

Also note that cloud_cv_options are not implemented for cv_options=3 (NCEP Background Error model option).

For radiance data assimilation, to include cloud effects in the CRTM calculations, set the namelist option `crtm_cloud=.true.` in &wrfvar14. The first guess should contain cloud information and is usually from a model forecast. Also, set `cloud_cv_options=1` in &wrfvar7 to get cloud water and rainwater analysis increments through the total water control variable modeling via a warm-rain scheme.

For now, proper quality control procedures and observation error assignments for cloudy radiances are only implemented for AMSR-2 instrument (as described in Yang et al., 2016). The capability is not in the released WRFDA V3.8, but is available through a patched tar file.

In *var/run/radiance_info/gcom-w-1-amsr2.info*, the values in the sixth column are clear-sky observation errors. An additional eighth column (not required if assimilating clear-sky radiances) specifies the cloudy-sky observation errors. For all-sky radiance assimilation, the observation errors are calculated using symmetric error model as described in Geer and Bauer, 2011.

References:

Xiao, Q., Y. Kuo, J, Sun, D. M. Barker, and E. Lim, 2007: An approach of Doppler reflectivity data assimilation and its assessment with the inland QPF of Typhoon Rusa (2002) at landfall. J. Appl. Meteor. Climatol., 46, 14–22. http://journals.ametsoc.org/doi/full/10.1175/JAM2439.1

Wang, H., J. Sun, S. Fan, and X.-Y. Huang, 2013: Indirect assimilation of radar reflectivity with WRF 3D-Var and its impact on prediction of four summertime convective events. J. Appl. Meteor. Climatol., 52, 889–902. http://journals.ametsoc.org/doi/full/10.1175/JAMC-D-12-0120.1

*Yang, C., Z. Liu, J. Bresch, S. R. H. Rizvi, X.-Y. Huang, and J. Min, 2016: AMSR2 all-sky radiance assimilation and its impact on the analysis and forecast of Hurricane Sandy with a limited-area data assimilation system. Tellus A 2016, **68**, 30917, http://dx.doi.org/10.3402/tellusa.v68.30917.*

Geer, A. J. and P. Bauer, 2011: Observation errors in all-sky data assimilation. Q. J. R. Meteorol. Soc. 137: 2024-2037