S-1

3-D Analysis with ARPS Data Assimilation System: ADAS Version 2.3

1. Analysis Program

The analysis program of the ARPS Data Assimilation System, ARPSDAS, or ADAS, interpolates observations onto the ARPS grid, combining the observed information with a background field. The background field can be provided by any of the ARPS initialization methods, for example from another ARPS file or from a single sounding. Typically, the background comes from a larger-scale model, by means of an ARPS file created by the external file conversion program, EXT2ARPS. This section describes the analysis technique in ADAS, how to use ADAS, and the parameters in the ADAS namelists.

While many operational centers have used a Statistical (or Optimal) Interpolation scheme (OI), Bratseth (1986) has shown that an iterative scheme will converge to OI. An iterative scheme can offer computational savings in that large matrix solutions need not be found. Balancing and other adjustments can be made at the end of each iteration to control stability and other aspects of the evolving analysis. More detailed data can be introduced after a few iterations using broad-scale data. Finally, iterations can be interspersed with model time-steps to form a dynamic initialization (nudging) process. Like the OI scheme, the Bratseth interpolation method accounts for the relative error between the background and the error in each observation source, and is relatively insensitive to large variations in data density. This type of scheme has been used successfully in research (*e.g.*, Sashegyi *et al.*, 1993) and operational mesoscale modeling (*e.g.*, Lorenc', 1991, Brewster, 1996).

In ADAS, five variables are analyzed on the ARPS σ_z coordinate: u and v grid-relative wind components, pressure, potential temperature and RH^*. RH^* is a moisture variable analogous to dew-point depression:

$$RH^* = \sqrt{RH_{\max} - RH}$$

where RH is the relative humidity and RH_{max} is the maximum relative humidity allowed (usually set to 1.0, though some might want to allow a greater value, for supersaturation). RH^* is selected over specific humidity due to the non-linear change in saturation specific humidity with height -- small absolute changes in surface specific humidity can cause unrealistic relative changes aloft in the 3-D observation weighting. Other variables could be added with straight-forward modification to the code.

The vertical velocity, *w*, is diagnosed from the horizontal winds, continuity, and a constraint that the wind velocity normal to the bottom (terrain) and either the top of the model domain or the bottom of the Rayleigh damping layer (*zbrdmp*) be zero. Any inconsistency between these constraints and the analyzed velocity field is resolved by distributing the apparent error in the horizontal divergence with height (using options defined by the input parameter *obropt*), and the *w* field is adjusted after that error is removed. After *w* has been found for each column, the horizontal wind fields are relaxed with the condition that the total mass divergence is zero everywhere. This is to help ensure a smooth start for the ARPS model.

Observed data are classified into four types, 1) single-level observations, typically surface observations, 2) multiple-level observations or upper-air (ua) observations (such as rawinsondes and wind profilers), 3) raw Doppler radar observations, and 4) radar-retrieved data, observations obtained from retrieval algorithms which use a time-sequence of Doppler radar data to deduce Cartesian wind components, temperature and pressure. Each observation type has its own data arrays. The user will need to know how many observations are available and adjust the array dimensions (in file *arpsdas.inc*) to provide ample space. Routines for reading sounding, wind profiler and surface observations in LAPS format (as are archived for the 1994 and 1995 VORTEX field project) have been implemented. Other sounding and surface data sources can be added easily. Raw radar data (Doppler winds and reflectivity) must first be averaged into data "columns", by using the program NIDS2ARPS (for NIDS data) or REMAPARPS (for WSR-88D data).

Upper-air observation error is specified as a function of height, and is read-in from tables, one per input data source. Tables for US rawinsondes, wind profiling radars, and radar-retrieved data are provided with the official code as files, *raoberr.tab*, *proferr.tab*, and *retrerr.tab*, respectively. Other observation error information is contained in data statements in the declaration section of *arpsdas.f*.

Users wishing to use data types not supported by the official code can add observation "sources" to the code. Each source carries its own error characteristics, which would have to be specified. Also, reading routines would have to be added that would append the new data to the arrays of data already read-in.

Many aspects of the analysis are controlled by parameters specified through namelist input, in special namelists following the mandatory ARPS namelists in the ARPS input file. ADAS uses the same input file as the ARPS model, which facilitates building companion input files for analysis and model integration. A description of the ADAS namelist parameters is provided in the table at the end of this section. The namelist items that are specific to the model time-integration (such as the time step, turbulence parameters, etc.) have no effect on ADAS, but ADAS does rely on the ARPS namelist parameters for grid specification, time, and terrain.

Among the ADAS input parameters is the scaling distance for the correlation function; it is set as a function of the iteration index. This allows one to direct the analysis to correct large-scale errors first, then reduce the scale and add higher resolution data with subsequent iterations. Also, the scaling distance may be set to be different for each analysis variable, as one may wish to analyze humidity at a smaller scale than pressure, for example. A target scaling distance (variable named *range*, given in meters) is specified, and all other distances are specified as a fraction of that distance. For example, the first pass default is 2.0 times *range*, and the correlation distance for humidity is 0.9 of that. Further hints on setting parameters will be discussed in the "Tips" section

2. Theoretical Formulation

ADAS uses a successive correction scheme, known as the Bratseth method, which is described in this section, (largely following Shashegyi *et al.* , 1993). The variable, s, is analyzed at grid points x using observations $s^o{}_j$. For iteration n:

$$s_x(n) = s_x(n-1) + \sum_{j=1}^{nobs} \alpha_{xj}\left[s_j^o - s_j(n-1)\right] \qquad \text{(S1.1)}$$

where the same equation has been applied at the observation locations, i, to arrive at the analysis at those points for the priveious iteration, s_i.:

$$s_i(n) = s_i(n-1) + \sum_{j=1}^{nobs} \alpha_{ij}\left[s_j^o - s_j(n-1)\right] \qquad \text{(S1.2)}$$

where

$$\alpha_{xj} = \frac{\rho_{xj}}{m_j} \qquad \text{and} \qquad \alpha_{ij} = \frac{\left(\rho_{ij} + \sigma_n^2\delta_{ij}\right)}{m_j} \qquad \text{(S1.3a,b)}$$

are the weights applied to each observation. In Eq. S1.3, $\sigma_n{}^2$ is the ratio of observation error variance to background error variance which and δ_{ij} is the Kronecker delta; it is zero unless i=j, when it is unity. The spatial correlations, ρ, are modeled as Gaussian:

$$\rho_{ij} = \exp\left(\frac{-\left|r_{ij}\right|^2}{R^2}\right)\exp\left(\frac{-\left|\Delta z_{ij}\right|^2}{R_z{}^2}\right) \qquad \text{(S1.4)}$$

where r_{ij} is the horizontal separation of each data-to-grid-point pair for Eq. S1.1 and each data pair for Eq. S1.2, while Δz is the vertical separation. The weights have been normalized by the density of observations around each observation location:

$$m_i = \sigma_n^2 + \sum_{j=1}^{nobs} \rho_{ij} \tag{S1.5}$$

Note that on the initial pass, *n=1*, the analysis at the observation locations, $s^o{}_j(0)$, is given by a tri-linear interpolation of the background field.

An option is provided to analyze data more in the fashion of an isentropic analysis. This option models the vertical correlation as a function of difference in potential temperature rather than height:

$$\rho_{ij} = \exp\left({-\left|r_{ij}\right|^2} \big/ {R^2} \right) \exp\left({-\left|\Delta\theta_{ij}\right|^2} \big/ {R_\theta{}^2} \right) \tag{S1.6}$$

In order to speed convergence, the horizontal correlation distance factor, *R*, is generally reduced from pass 1 to 4.

$$R(n) = \kappa_n \kappa_v R_o \tag{S1.7}$$

For example,
$\kappa_n = (2.0, 1.0, 0.8, 0.4)$

and κ_v represents the difference in the correlation model among the variables, allowing for shorter correlation distance (κ_v=0.9) for moisture, for example.

3. Treatment of Doppler Radar Data

The Doppler radial velocities are converted to increments to the *u* and *v* wind components by subtracting the observed radial wind, v_r, from the dot product of the analysis wind and the observing angle (radar azimuth). The imputed correction is assigned a direction parallel to the azimuth, *i.e.*

$$u'_j\left(x, y, \phi\right) = \cos\phi\left[v_{r_j} - \left(\cos\phi u(x,y) + \sin\phi v(x,y)\right)\right] \tag{S1.8}$$

$$v'_j\left(x, y, \phi\right) = \sin\phi\left[v_{r_j} - \left(\cos\phi u(x,y) + \sin\phi v(x,y)\right)\right] \tag{S1.9}$$

The covariance between two Doppler radial winds requires special treatment in that the correlation between two radial wind observations is affected by the azimuth angle separation between the data. As described by Cole (1994),

$$\operatorname{cov}\left(s_i, s_j\right) = \cos\left(\phi_i - \phi_j\right)\left[\operatorname{var}\left(s_i\right)\operatorname{var}\left(s_j\right)\right]\rho\left(\overset{\perp}{X}_i, \overset{\perp}{X}_j\right) \tag{S1.10}$$

So, for example, if radial velocities at a given point are available from two radars observing perpendicular to each other, the covariance model correctly indicates the observations are not correlated.

Similarly for mixed data types, the covariance is reduced from that of two complete wind observations:

$$\left(u_i', u_j'\right) = \cos\left(\phi_i - \pi/2\right)\left[\mathrm{var}\left(s_i\right)\mathrm{var}\left(s_j\right)\right]\rho\left(\vec{X}_i, \vec{X}_j\right) \tag{S1.11}$$

and

$$\left(v_i', v_j'\right) = \cos\left(\phi_i\right)\left[\mathrm{var}\left(s_i\right)\mathrm{var}\left(s_j\right)\right]\rho\left(\vec{X}_i, \vec{X}_j\right) \tag{S1.12}$$

Where u_i' and v_i' are increments from a radial wind observation and u_j' and v_j' are from a complete wind observation (e.g., an anemometer or a rawinsonde).

Besides the wind corrections, observations of high relative humidity are introduced where the radar reflectivity exceeds a certain threshold (set by source code parameter). These relative humidity observations are used in the objective analysis, causing them to be spread somewhat from their observation point (these data should be applied only in iterations where κ*range* is appropriately small). This helps to "prime" the atmosphere in and near rainfall areas, providing the ingredients the model needs to spin-up and maintain precipitation.

More complex means of dealing with Doppler radar data include dual-Doppler wind algorithms and Doppler retrieval schemes. The Doppler retrieval schemes employ a time-sequence of radar-observed winds and reflectivity to diagnose the total wind field as well as temperature and pressure information. Wind data generated in any of those manners would be ingested by ADAS through the radar-retrieval-data arrays and aren't subject to this special treatment. Other codes are available from CAPS to generate dual-Doppler and radar-retrieved data.

4. Microphysical Adjustments Using Radar Data

A means of adjusting the model's microphysical variables (cloud water and ice, rainwater, snow and hail) and/or relative humidity based on radar data is provided by subroutine RADMCRO. The modification of the microphysical variables is based on locally observed reflectivity (no spreading of the effect via analysis). At each grid point, if there exists a radar column within the threshold distance, $\sqrt{(dx^2 + dy^2)}$, where dx and dy are the grid spacing in the x and y directions, the reflectivities in that column are compared to thresholds for increasing water vapor, cloud water and/or rainwater (specified in the input file by parameters *radqvopt, radqcopt* and *radqropt* , respectively). If the reflectivity is greater than the threshold (*refsat* or *refcld*), the water vapor or cloud water variables at the grid point at the level nearest the datum are adjusted. The amount of relative humidity in clouds is specified by input variable *rhrad*.. The amount of cloud water applied is a fixed value (input parameter *cldrad*) or while the rain water, snow and hail are determined from a function of the reflectivity. The function is the inverse of that used for plotting reflectivity based on model-produced rainwater, snow and hail. Since this function can produce large amounts of rainwater at high reflectivities, the user is given the option of applying a fractional amount of the rainwater (input parameter *cldsetrat*) and/or limiting the maximum reflectivity value used in the parameterizing equation (input parameter *cldreflim*).

Finally, since the radar typically only samples a few heights over each horizontal grid column, if there are two observed points within a certain distance (input file parameter *dzfill*) of each other in the vertical, the microphysical variables in that column are filled-in between those two observations. All microphysical adjustments are not allowed if the grid point is below a specified ceiling (cloud base) limit above ground level. The ceiling limit is specified as a fixed value, *ceilmin*, or is determined from the LCL of a surface parcel (when *ceilopt*=2). This is to help prevent ground clutter and/or non-precipitation echoes from creating spurious clouds or rain.

One risk of adding rainwater is that the vertical velocities initialized at the location where rainwater is added genrally will not support the rainfall, hence the model may create a downdraft (due to the weight of the rainwater) in an area where positive vertical velocity likely exists. It is thought that introducing high relative humidity might help induce condensation processes which in turn would produce latent heat release (adding buoyancy) in addition to the creation of cloud and rainwater. Alternatively, additional buoyancy can be added at the analysis step by means of input parameter *radptopt*. If the buoyancy balances the additional weight from the cloud and rainwater, the air/water mixture will be initially neutral and initial acceleration determined from other factors. However, the microphysical parameterizations in the model will cause the water itself to fall at its terminal velocity. If no more condensate is produced, the precipitation will entirely fall out.

Testing at CAPS is currently exploring various combinations of all these parameters. The best combination may vary depending on whether the model is begining for a cold start, or updates are being made via an intermittant assimilation cycle.

5. Complex Cloud Analysis

A module is included in ADAS to do a complete cloud analysis using surface observations of cloud cover and height, radar and satellite data (Zhang *et al.*, 1998). The procedure and code were adapted from the cloud analysis of the Local Analysis and Prediction System (LAPS, Albers *et al.*, 1996) developed at the NOAA Forecast Systems Lab. In ADAS, you can select which of the variables from the cloud analysis contribute to the final output file, and you can control the thresholds applied to radar data. Some of the same concerns about inserting microphysical variables raised in the previous section apply to the variables determined from the cloud analysis. The cloud analysis uses its determination of the cloud type (stratus, stratocumulus or cumulus) to estimate in-cloud vertical velocities. Tests using the ARPS model have shown that vertical velocities determined in this way generally do not last long in the model as the model forcing overwhelms the initial state. Since these initial velocities can trigger condensation in regions of conditionally unstable air masses, there is a risk that the initial vertical velocity can trigger convection,

convection that is sometimes spurios due to incorrect cloud type determination. For that reason, use of the cloud vertical velocity for initializing ARPS is not recommended (*cldwopt*=0 is recommended).

The complex cloud anlaysis is called after the RADMCRO routine and the two work independently, so the user has the option of using cloud water fields from the cloud analysis and rainwater fields from the radar data, for example.

6. Automated Data Quality Control

ADAS includes a few quality-control steps. The surface data are pre-analyzed to compare with each other, and data are rejected if the pre-analysis of neighboring observations differs significantly from the observation. Other data are quality-controlled by comparing the observations to the background field interpolated to the observation site. Thresholds of allowed differences from the background are set fairly high (in the data error tables provided) to allow for instrument error and errors in representativeness. Representativeness error is especially important in the case of radar data being compared to large-scale gridded forecasts. Statistics are reported in the standard output showing the number and percentage of data points rejected in this manner.

Also part of the quality control system is a means to manually exclude data at specified surface stations. This is useful for manual editing and for real-time use when there may be stations that regularly have grossly unrepresentative observations or instrument faults. A file is read containing a list of stations and variable numbers which are excluded from the analysis (they are flagged as rejected by the quality control). The file is named *blacklist.sfc*. At this time the blacklist procedure is only implemented for surface data.

7. Steps to Run ADAS

• obtain raw data, reformat into LAPS-formatted ASCII files using the FORMAT statements in the source for the various reading routines as a guide, or contact CAPS for examples of data files. Contact CAPS for information on programs to process NIDS or WSR-88D radar data into the ADAS format or for information on radar retrieval programs.

• create background file (generally using EXT2ARPS or an ARPS forecast)

• edit *dims.inc*
Specify the ARPS dimensions -- must match those used in EXT2ARPS if that is what created the background file.

• edit *arpsdas.inc*
Specify the size of each of the data categories. Specify dimension as 1 (one) for unused data categories to save memory. Its OK to have unused array space, counters keep track of how much data has actually been ingested.

• **makearps arpsdas**

• edit *arps.input*

Edit the namelist variables controlling the ARPS grid, ADAS control, and output naming and formatting. Be sure to specify the proper directory and file names for input of the background field and terrain.

• **arpsdas < arps.input >! adas.out**

• examine output file and ARPS gridded data file using ARPSPLT
The gridded-data output file will be named according to the input parameter *runname* and the history file options.

8. Tips on Setting Parameters and Running ADAS

Use the instructions for initializing the ARPS model to initialize the background fields for ADAS. If you're using an ARPS file (from an ARPS forecast or output from EXT2ARPS), use *initopt=3* and specify the file using *inifile* and *inifmt.*

When specifying the names of the sources and source error files in the input file, keep in mind that these items are indexed by <u>source</u>, and not by data <u>file</u>. That is the number of data sources need not correspond to the number of files, as some files (such as the surface data files) contain more than one source, and at the same time, it is common to use multiple radar files but they all might come from a single source.

It is common to have *xyrange* decrease gradually with each pass. Execution time will be saved if you introduce dense data (such as radar data) only after first doing iterations to correct the broader scale errors. It is wise to drop coarsely spaced data when *xyrange* is dictating a correlation range smaller than the average spacing of the data. This prevents the drawing of bullseyes around ioslated stations. The inclusion/exclusion of data types is controlled by switches in the input namelists. See the description of *usesng*, *useua*, *userad*, and *useret* in the table.

When the data are very dense, such as a radar data set containing on the order of 10^4 data points, execution time can become long. Using a cut-off radius can prevent the execution time from becoming excessive. The cut-off radius (distance beyond which a data point has zero influence) is controlled by the input parameter *wlim*. This parameter is the least value of the correlation function that is allowed, so that a smaller value of *wlim* will yield a larger cut-off radius. Setting *wlim* to 10^{-3} is recommended for very large datasets. The output file indicates what physical distance this limit represents.

How well does the analysis fit the data? The fit to the data is largely controlled by the expected errors specified for the observations and the background, and to some extent by the correlation ranges used. Smaller *xyranges* yield analyses that fit the data more closely. If the data are "overfit", the analysis will have unwanted wiggles in the contours and possibly bullseyes, especially near observation sites. You can see how the analysis is fitting the data by the root-mean-square difference (*rms*) statistics printed in the standard output file after each iteration. Regardless of whether *kappa* decreases with successive iterations, the *rms* statistics should decrease with each pass, and after the final pass the *rms* values should approximate the error associated with that observation type. Also in the *rms* table you will see counters of the data. These counters and the diagnostic printing of the reader routines should inform you of the successful ingest of all the data. The reader routines will print warnings if they had to stop reading data because insufficient space was allocated to the data arrays. Generally, ADAS continues processing even if the arrays become full. Recall that data array sizes are specified in *arpsdas.inc*.

You can also examine the fit to the surface data by using ARPSPLT and specifying the observation overlay option (parameter *ovrobs =1* in *arpsplt.input*). Plot the second ARPS vertical level (*slice_xy*, *k=2*) and compare the observations to the contours of the analysis.

9. References

Albers, S.C., J.A. McGinley, D.A. Birkenhuer, and J.R. Smart, 1996: The local analysis and Prediction System (LAPS): Analysis of clouds, precipitation and temperature. *Wea. and Forecasting*, **11**, 273-287.

Bratseth, A.M., 1986: Statistical interpolation by means of successive corrections. *Tellus*, **38A**, 439-447.

Brewster, K., 1996: Implementation of a Bratseth analysis scheme including Doppler radar. *Preprints*, *15th Conf. on Weather Analysis and Forecasting*, AMS, Boston, 92-95.

Cole, R.E. and F.W. Wilson, 1995: ITWS Gridded Wind Product, *Preprints, 6th Conf. on Aviation Wetaher Systems*, AMS, Boston.

Lorenc, A.C., R.S. Bell and B. MacPherson, 1991: The Meteorological Office analysis correction data assimilation scheme. *Quart. J. Roy. Meteor. Soc.*, **117**, 59-89.

Sashegyi, K.D., D.E. Harms, R.V. Madala, S. Raman, 1993: Application of the Bratseth scheme for the analysis of GALE data using a mesoscale model. *Mon. Wea. Rev.*, **121**, 2331-2350.

Zhang, J., F. Carr, and K. Brewster, 1998: ADAS cloud analysis. *Preprints, 12th Conf. on Num. Wea. Prediction*, Phoenix, AZ, AMS, Boston, 185-188.

ADAS Constants
(&adas_const)

Parameter	Definition/Purpose	Options/Suggested Values
npass	Number of analysis passes or iterations of the Bratseth or Barnes schemes.	Typical: 3 or 4 passes
sprdist	Super-ob distance (m). Surface observations closer than *sprdist* will be combined into a single-superob before beginning the analysis.	Scale (*dx*) dependent, approximately 15000 m. (15 km)
wlim	Smallest value of horizontal correlation (ND) that will contribute to the analysis. This serves to define a cut-off radius, outside of which an observation has no influence. When the dataset is very large (10^4 observations), increasing *wlim* (decreasing cut-off radius) can improve execution time.	1.0E-03
zwlim	Smallest value of vertical correlation (when height is used as the vertical separation, see *ianxtyp*) allowed to contribute to the analysis. This serves to define a cut-off height-difference, outside of which an observation has no influence.	1.0E-03
thwlim	Smallest value of vertical correlation (when potential temperature is used as the vertical separation, see *ianxtyp*) allowed to contribute to the analysis. This serves to define a cut-off potential temperature difference, outside of which an observation has no influence.	1.0E-03

hydradj	Hydrostatic balance option. Option for adjusting pressure to balance temperature field to create a balanced state for model initialization. Formerly known as *boycor*.	0=no pressure adjust. 1=use model eqs, beginning at bottom 2=use model eqs, beginning at top 3=hydrostatic pressure, beginning at bottom *hydradj*=3 recommended
windadj	Option for adjusting wind field after horizontal winds have been analyzed.	0=no wind adjust. 1=*w* is set so *wcont*=0 no changes to *u*, *v* 2=*w* is set using horiz divergence and O'Brien method for top bc see *obropt* 3=as in 2, but *u,v* are relaxed to create zero 3-D divergence *windadj*=2 recommended
obropt	Option for distribution of horizontal divergence error in O'Brien adjustment of vertical velocities (to enforce vertical boundary conditions on *w*). Add 10 to values at right to adjust vertical velocities so that *w=0* at physical height *obrzero*. Otherwise the scheme forces *w=0* at the top of the model physical domain.	0= No O'Brien adjust. 1=linearly in model z 2=linearly in physical z 3=linearly in theta *obropt*=12 recommended
obrzero	Height (m) at which the O'Brien scheme enforces zero *w*. This should roughly correspond to the tropopause, and be consistent with the bottom of the Rayleigh damping layer (*zbrdmp*) if used for model initialization	Grid dependent.

ADAS Radar Options
(&adas_radaropt)

Parameter	Definition/Purpose	Options/Suggested Values
raduvobs	Option for using Doppler radial winds in analysis step	0 = do not use radial winds 1 = use radial winds
radrhobs	Switch to create pseudo-obs of high relative humidity for use in *qv* analysis (effect will be spread in space) where reflectivity is high	0 = do not create high-RH obs from reflectivity data 1 = create obs
refrh	Radar reflectivity (dBZ) threshold above which pseudo-observations of high relative humidity (*rhrad*) are created for analysis.	*refrh* must be greater than the level of "clear air" returns in the data *refrh=20* dBZ recommended
rhradobs	Relative humidity for pseudo-observations of humidity in high reflectivity regions. If the background has a relative humidity higher than *rhradobs* no observation is created (this cannot dry the background).	0. < *rhradobs* < 1.0 0.80 < *rhradobs* < 0.95 recommended
radcldopt	Option for calling the routine that assigns cloud and rain water variables based on radar reflectivity. If this is set to zero, the *radqvopt*, *radqcopt* and *radqropt* input options do not apply.	0 = do not call RADMCRO routine 1 = call RADMCRO
radqvopt	Option for using reflectivity to locally adjust (no spreading via analysis) relative humidity (*qv*) where reflectivity is high	0 = do not adjust *qv* locally based on reflectivity data 1 = Adjust *qv*

radqcopt	Option for using reflectivity to locally adjust (no spreading via analysis) cloud water (*qc*) where reflectivity is high	0 = do not adjust *qc* locally based on reflectivity data 1 = adjust *qc* using fixed cloud water mixing ratio 2 = adjust *qc* using cloud water mixing ratio that is a function of observed reflectivity.
radqropt	Option for using reflectivity to locally adjust (no spreading via analysis) rainwater (*qr*) where reflectivity is high	0 = do not adjust *qr* locally based from reflectivity data 1 = adjust *qr* using rain water mixing ratio that is a function of observed reflectivity.
radptopt	Option for adjusting potential temperature to create a net zero buoyancy change in combination with the weight added by increasing *qr* and *qc* and/or the weight removed by increasing *qv*.	0 = do not adjust potential temperature 1 = adjust temperature for rain and cloud water only 2 = adjust temperature for humidity adjustment only 3 = adjust for **all** changes to *qr, qc, and qv*
refsat	Reflectivity threshold (dBZ) to use in local "saturation" adjustment.	10. < *refsat* < 35. dBZ recommend
rhrad	Relative humidity (0.0-1.0) to apply in local saturation adjustment. No adjustment is made if background humidity is higher.	0.80 < *rhrad* < 1.0 recommended
refcld	Radar reflectivity (dBZ) threshold above which cloud water (amount specified by *cldrad*) is created.	20. <*refcld* < 30. dBZ recommended

cldrad	Value of cloud mixing ratio (kg m^{-3}), *qc*, to assign in areas of reflectivity > *refcld*.	*cldrad*=1.0E-03 recommended
ceilopt	Option for preventing the creation of cloud below a specified ceiling. This can be used to reduce false clouds due to ground-clutter returns.,	0=Do not limit ceiling 1 = minimum ceiling is a fixed height (AGL) specified by *ceilmin* 2 = minimum ceiling is lifting condensation level, LCL, of surface based parcel. *ceilopt*= 2 recommended
ceilmin	Ceiling height (m AGL) minimum for use when *ceilopt*=1.	Situation dependent. Generally: 100 < *ceilmin* <2000 m
dzfill	Vertical distance (m) over which two adjacent "cloud" radar observations will be "filled" with cloud and or rain water. This is necessary to account for vertical gaps between radar observation elevation angles.	Generally: 1000. < *dzfill* < 3000. m *dzfill = 3000*. m recommended.
refrain	Radar reflectivity (dBZ) threshold above which rain water (amount specified by *cldrad*) is created.	25 < *refrain* < 35 dBZ recommended
cldsetrat	Ratio (0.0-1.0) of rain and cloud water adjustment applied to the radar-reflectivity equivalent value of rain and cloud water. Used when *radqcopt*=2 or *radqropt*=2 .	0.5 < *cldsetrat* < 1.0
cldreflim	Upper bound on reflectivity (dBZ) to use in calculating the rain and cloud water when *radqcopt*=2 or *radqropt*=2.	40 < *cldreflim* < 50 dBZ

ADAS Cloud Options (&adas_cloudopt)

Parameter	Definition/Purpose	Options/Suggested Values
cloudopt	Option for calling the ADAS complex cloud analysis. The routine uses all available data sources to assign cloud coverage. Cloud microphysical variables can be assigned in the model based on the final cloud analysis (see options, below). The cloud analysis is Jian Zhang's modification of the FSL LAPS cloud analysis.	0 = do not run the complex cloud analysis. 1 = run the complex cloud analysis
clddiag	Option for printing voluminous diagnostics related to the cloud analysis.	0 = do not print the extra diagnostics. 1 = print diagnostics.
range_cld	Horizontal distance (m) for use in the horizontal spreading of analyzed clouds from point observations.	*range_cld*=10^4-10^5 m (10-100 km) recommended
refthr1	Reflectivity threshold (dBZ) for assigning cloud based on radar data below *hgtrefthr*. Generally, *refthr1* is set to eliminate false ground clutter	*refthr1*=25. recommended
refthr2	Reflectivity threshold (dBZ) for assigning cloud based on radar data above *hgtrefthr*. Generally, *refthr2* is set to eliminate insect or non-precipitation scatter returns.	*refthr2*=20. recommended
hgtrefthr	Height (m AGL) of transition from using *refthr1* to using *refthr2*.	*hgtrefthr*=2000. m recommended
wmhr_cu	Parameter (ms^{-1}/m) used to set the maximum vertical velocity in cumulus clouds. Maximum vertical velocity (parabola) is set based on *wmhr_cu* and analyzed cloud depth. *w_max=wmhr_cu*depth*	*wmhr_Cu* = 0.0005 recommended

wmhr_sc	Parameter (ms^{-1}/m) used to set the maximum vertical velocity in stratocumulus clouds. Maximum vertical velocity (parabola) is set based on *wmhr_sc* and analyzed cloud depth. *w_max=wmhr_sc*depth*	*wmhr_Sc* = 0.00005 recommended
wc_st	Constant vertical velocity (ms-1) used in stratus clouds.	*wc_St* = 0.05 recommended
thresh_ cvr	Threshold of sky cover (0.0-1.0) to set cloud water and vertical velocity. Below *thresh_cvr* no cloud water or *w* adjustments are made.	*thresh_cvr*=0.5 recommended
ir_fname	Name of remapped IR satellite data file. Set to 'NULL' or a dummy filename if no IR data are available.	Character string in quotes.
vis_fnam e	Name of remapped visible satellite data file. Set to 'NULL' or a dummy filename if no visibile satellite data are available.	Character string in quotes.
calib_ fname	Name of file containing IR calibration data	Character string in quotes.
cbgqcopt	Option for using relative humidity in the background field to create cloud water (*qc*) within the cloud analysis. Note that the ARPS output file cloud field is not changed unless the *cldqcopt* option (below) is set to 1.	0 = do not adjust *qc* locally based on background relative humidity. 1 = adjust *qv*
cldqvopt	Option for using results of the cloud analysis to locally adjust (no spreading via analysis) relative humidity (*qv*).	0 = do not adjust *qv* locally based on cloud analysis. 1 = adjust *qv*
cldqcopt	Option for using results of the cloud analysis to locally adjust (no spreading via analysis) cloud water (*qc*).	0 = do not adjust *qc* locally based on cloud analysis 1 = adjust *qc*

cldqropt	Option for using results of the cloud analysis to locally adjust (no spreading via analysis) rainwater (*qr*).	0 = do not adjust *qr* locally based on cloud analysis. 1 = adjust *qr*
cldptopt	Option for adjusting potential temperature to create a net zero buoyancy change in combination with the weight added by increasing *qr* and *qc* and/or the weight removed by increasing *qv* in the cloud analysis.	0 = do not adjust potential temperature 1 = adjust for **all** changes to *qr, qc, and qv*
cldwopt	Option for setting the vertical velocity based on the results of the cloud analysis. Where there are clouds a profile of *w* is specified within the cloud based on a diagnosis of the cloud type (stratus, stratoclumulus or cumulus).	0 = do not adjust potential temperature 1 = set *w* in clouds. 0 is recommended for initializing ARPS runs.
cld_files	Option to output files containing intermediate cloud fields (cloud base, cloud top, ceiling, and column VIL) into separate files (for diagnostics, unused by the ARPS model).	0 = do not output extra diagnostic files 1 = output files

ADAS Analysis Types
(&adas_typ)

Parameter	Definition/Purpose	Options/Suggested Values
ianxtyp (ipass)	Type of analysis for each pass.	11=Barnes, height vert 12=Barnes, theta vert 21=Bratseth, height vert 22=Bratseth, theta vert Default: 21

ADAS Range
(&adas_range)

Parameter	Definition/Purpose	Options/Suggested Values
sfcqcrng	Scale distance (m) for the Barnes weighting function used in the quality control of surface data.	Data spacing dependent. Generally: 30.E03 < *sfcqcrng* < 100.E03 m
xyrange (ipass)	Horizontal scale for the correlation function in the analysis. See body of this document for guidelines on setting the correlation range.	Depends on data density and data switches. Example: *xyrange(1)*=100.E03 *xyrange(2)*=60.E03 *xyrange(3)*=5.E03

ADAS Kappa Variable
(&adas_kpvar)

Parameter	Definition/Purpose	Options/Suggested Values
kpvar (ivar)	Scaling factor (ND) which multiplies *xyrange* making the scale different for each variable. One for each variable, where variable 1: u wind component variable 2: v wind component variable 3: pressure variable 4: potential temperature variable 5: humidity	Generally: 0.5 < *kpvar* < 2.0 Default: *kpvar(1)*=0.9 *kpvar(2)*=0.9 *kpvar(3)*=1.0 *kpvar(4)*=1.0 *kpvar(5)*=0.9

ADAS Z-range
(&adas_zrange)

Parameter	Definition/Purpose	Options/Suggested Values

zrange (ipass)	Range (m) for vertical correlation model when analysis using height separation is used. A value is specified for each pass even though the options may be set to use theta in the vertical.	Typical: 500. < *zrange* < 1800.

ADAS Theta-range
(&adas_thrange)

Parameter	Definition/Purpose	Options/Suggested Values
thrange (ipass)	Range (K) for vertical correlation model when analysis using potential temperature separation is used. A value is specified for each pass even though the options may be set to use height in the vertical.	Typical: *thrange(ipass)*= 5 K.

ADAS Background Error File
(&adas_backerf)

Parameter	Definition/Purpose	Options/Suggested Values
backerrfil	Name of background error file character*132	Typical: *backerrfil*= 'ruc3herr.adastab'

ADAS Single-Level Data Specifications
(&adas_sng)

Parameter	Definition/Purpose	Options/Suggested Values
nsngfil	Number of single-level data files. Single level data include surface data and pilot report data.	Data dependent. Typical: 1 or more *nsngfil* ≤ *mx_sng_file* (*mx_sng_file* is set in **adas.inc**)

sngfname (ifile)	Name of single-level data file Repeat for *nsngfil*s. character*132	Typical: *sngfname(1)*= 'jun08/951591500.lso'
sngtimchk (ifile)	Name of data file used for time consistency check of respective *sngfname* data. Dataset of the same type from a previous time period. Specify a dummy filename if no such data are available. character*132	Typical: *sngtimchk(1)*= 'jun08/951591400.lso'
srcsng (isrc)	Following are repeated for each data source in the single-level data file(s). Note that a single-level file can contain one or more sources. Largest index, *isrc*, used must be less than or equal to *nsrc_sng* (*nsrc_sng* is set in **adas.inc**). Name of data source. These must match the source name(s) in the data file(s). character*8	Typical: *srcsng(1)*='SA'
sngerrfil (isrc)	Name of file containing error specification table for each source. character*132	Typical: *sngerrfil(1)*= 'saoerr.adastab'
iusesng (isrc, ipass)	Integer switch indicating whether the data source should be used on each pass. A switch is required for each pass, i.e. *iusesng(1,1)*, *iusesng(1,2)*...	0: Do not use data from this source on this pass. 1: use data Example: *iusesng(1,1)*=0, *iusesng(1,2)*=1, *iusesng(1,3)*=0

ADAS Multiple-Level Data Specifications (&adas_ua)

Parameter	Definition/Purpose	Options/Suggested Values

nuafil	Number of multiple-level data files. Multiple level data include radiosonde data and profiler data.	Data dependent. Typical: 1 or more *nuafil* ≤ *mx_ua_file* (*mx_ua_file* is set in **adas.inc**)
uafname (ifile)	Name of multiple-level data file Repeat for *nuafils*. character*132	Typical: *uafname(1)*= 'jun08/951591500.snd'
srcua (isrc)	Following are repeated for each data source in the multiple-level data file(s). Note that a multiple-level file usually contains one source, but more than one file may have the same source. Largest index, *isrc*, used must be less than or equal to *nsrc_ua*. (*nsrc_ua* is set in **adas.inc**). Name of data source. character*8	Typical: *srcua(1)*="NWS RAOB'
uaerrfil (isrc)	Name of file containing error specification table for each source. character*132	Typical: *uaerrfil(1)*= 'snderr.adastab'
iuseua (isrc, ipass)	Integer switch indicating whether the data source should be used on each pass. A switch is required for each pass, i.e. *iuseua(1,1)*, *iuseua(1,2)*...	0: Do not use data from this source on this pass. 1: use data Data dependent Example: *iuseua(1,1)*=1, *iuseua(1,2)*=0, *iuseua(1,3)*=0

ADAS Radar Data Specifications (&adas_radar)

Parameter	**Definition/Purpose**	**Options/Suggested Values**

nradfil	Number of remapped radar data files. Remapped radar data files are created by mapping raw data onto a regular grid, which need not match the final analysis grid.	Data dependent. Typical: 0 or more *nradffl* ≤ *mx_rad_file* (*mx_rad_file* is set in **adas.inc**)
radfname (ifile)	Name of radar data file(s) Repeat for nradfils. character*132	Typical: *radfname(1)*= 'KTLX.950507.1756'
srcrad (isrc)	Following are repeated for each data source in the radar data file(s). Note that a radar data file contains one source, but more than one file may have the same source. Largest index, *isrc*, used must be less than or equal to *nsrc_rad* (*nsrc_rad* is set in **adas.inc**). Name of data source. character*8	Typical: *srcrad(1)*='88D-AII'
raderrfil (isrc)	Name of file containing error specification table for each source. character*132	Typical: *raderrfil(1)*= '88derr.adastab'
iuserad (isrc, ipass)	Integer switch indicating whether the radar data source should be used on each pass. A switch is required for each pass, i.e. *iuserad(1,1)*, *iuserad(1,2)*...	0: Do not use data from this source on this pass. 1: use data Data dependent Example: *iuserad(1,1)*=0, *iuserad(1,2)*=0, *iuserad(1,3)*=1

ADAS Retrieved Radar Data Specifications (&adas_retrieval)

Parameter **Definition/Purpose** **Options/Suggested Values**

nretfil	Number of radar retrieved data files. Retrieved data files are created by separate radar retrieval programs.	Data dependent. Typical: 0 or more *nretfil* ≤ *mx_ret_file* (*mx_ret_file* is set in **adas.inc**)
retfname (ifile)	Name of radar retrieval data file Repeat for *nretfil*s. character*132	Typical: *retfname(1)*= 'KTLXret.960526.1700'
srcret (isrc)	Following are repeated for each data source in the retrieval data file(s). Note that a retrieval data file contains one source, but more than one file may have the same source. Largest index, *isrc*, used must be less than or equal to *nsrc_ua*. (*nsrc_ret* is set in **adas.inc**). Name of data source. character*8	Typical: *srcret(1)*='88D-RET'
reterrfil (isrc)	Name of file containing error specification table for each source. character*132	Typical: *reterrfil(1)*= '88dreterr.adastab'
iusesret (isrc, ipass)	Integer switch indicating whether the data source should be used on each pass. A switch is required for each pass, i.e. *iuseret(1,1)*, *iuseret(1,2)*...	0: Do not use data from this source on this pass. 1: use data Data dependent Typical: *iuseret(1,1)*=0, *iuseret(1,2)*=0, *iuseret(1,3)*=1