HWRF Initialization -GSI customization

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Outline

- Data assimilation upgrades for FY13 HWRF
  - One-way hybrid ensemble-variational data assimilation system for HWRF
  - Assimilation of NOAA-P3 Tail Doppler Radar (TDR) observation
- GSI customization
  - Setup hybrid analysis
  - First guess (FGAT)
  - Observations
  - GSI namelist
  - GSI fix files
  - GSI standard output
  - Observation fitting statistics

HWRF domains

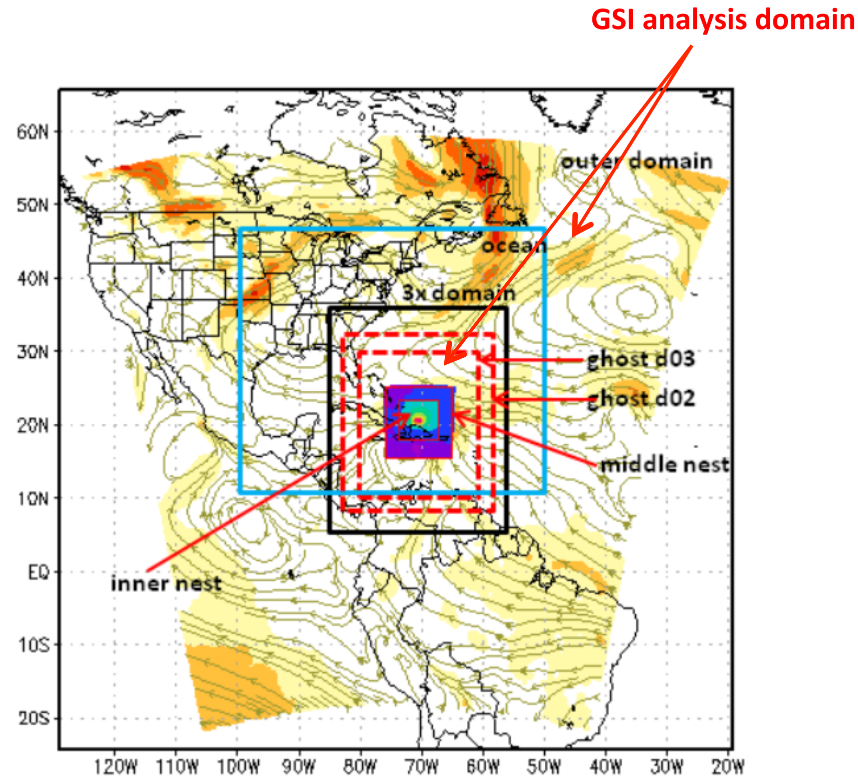
- **43 vertical levels with 50 hPa model top**

- **Model forecast domains**
  outer domain: 216x432 – 80°x80° ; 0.18°
  middle nest: 88x170 – 11°x10°; 0.06°
  inner nest: 180x324 – 7.2°x6.5°; 0.02°

- **HWRF vortex initialization domain**
  3x domain: 748x1504 – 30°x30°

- **GSI analysis domain**:
  outer domain
  ghost d03: 529x988 - 20°x20°; 0.02°

- After GSI analysis, model fields in ghost d03 are interpolated to inner nest, middle nest and outer domain. The area between ghost d03 and middle nest is a blending zone, where ghost domain analysis gradually merged to outer domain analysis.



HWRF domains (Fig 4.1 of HWRF USERS' GUIDE)

Assimilation System

- First guess
  - Outer domain: GDAS forecast after relocation
  - ghost d03: GDAS forecast (TC environment) + modified GDAS/HWRF vortex

- Hybrid data assimilation configuration
  - 80 ensemble member at T254L64
  - outer domain

    β_1^{-1}=0.25 – ¼ static and ¾ ensemble covariance

    horizontal localization: 1546km

    vertcial localization: 1.2 in natural log of pressure
  - ghost d03

    β_1^{-1}=0.2 – 1/5 static and 4/5 ensemble covariance

    horizontal localization: 387 km

    E-folding vertical localization: 10 vertical model levels for weak storms and 20 vertical model levels for strong storms (equal or greater than category 1)

Assimilation System

- GSI analysis variables
  - Analysis variables used for HWRF include streamfunction (ψ), unbalanced part of velocity potential (χ), unbalanced part of temperature (T), unbalanced part of surface pressure (Ps), normalized relative humidity, the extended control parameter α
  - ozone and cloud variables are not analyzed for FY13 HWRF

- Model variables updated
  - u, v, t, q, pd, pint

Assimilation System

❖ Observational data

- Conventional observations assimilated in the HWRF outer and ghost domains include:
  - Radiosondes
  - Dropsondes
  - Aircraft reports (AIREP/PIREP, RECCO , MDCRS-ACARS, TAMDAR , AMDAR)
  - Surface ship and buoy observations
  - Surface observations over land
  - Pibal winds
  - Wind profilers
  - VAD wind
  - WindSat scatterometer winds
  - GPS-derived integrated precipitable water
- NOAA P3 Tail Doppler Radar radial wind (TDR) data assimilated in ghost domain

Assimilation of NOAA-P3 Tail Doppler Radar Data

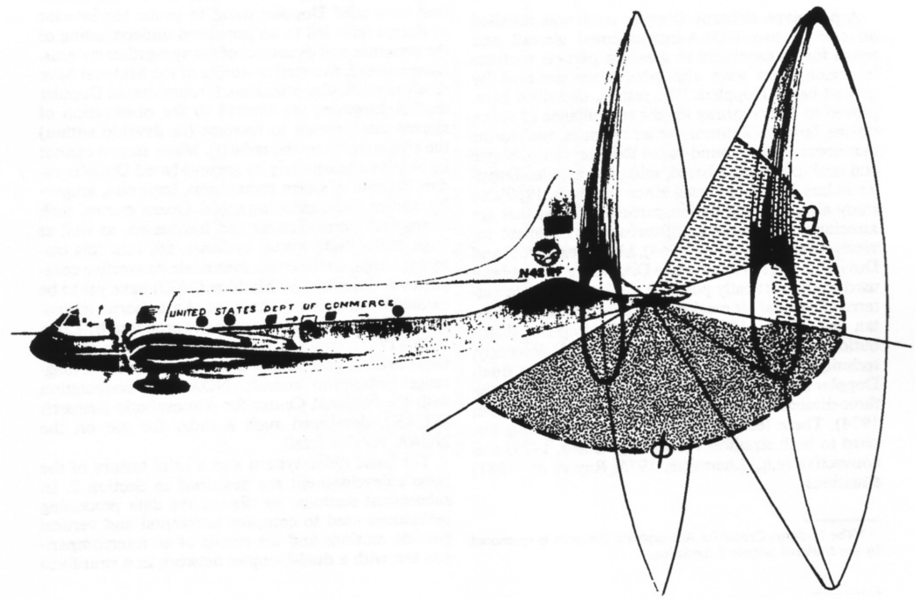
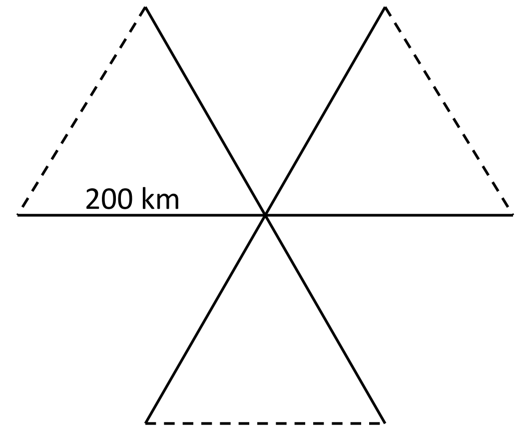


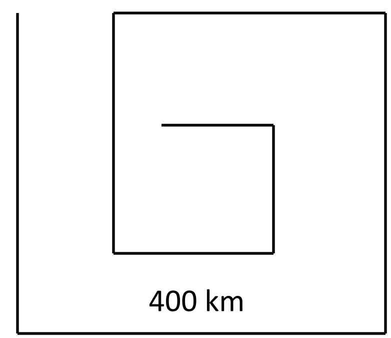
FIG. 1. Schematic diagram of the WP-3D tail radar scanning plane. The elevation angle (θ) is varied with azimuth (φ) to maintain an antenna pointing angle that is normal to the aircraft's ground track.

Jorgensen *et al.*, 1983, *J. Climate Appl. Meteor,* 22, 744-757



P-3 regular

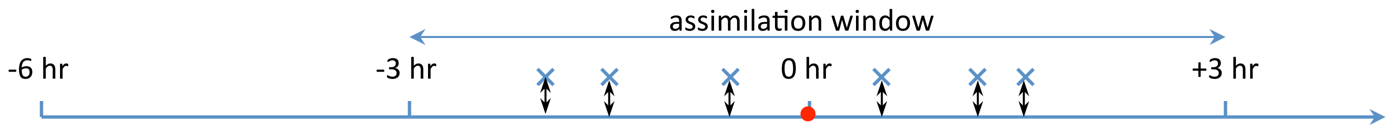
P-3 weak storm



P-3 weak storm

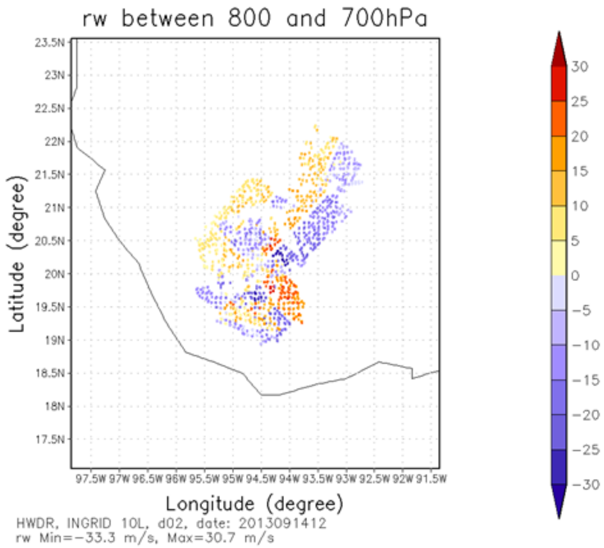
Assimilation of NOAA-P3 Tail Doppler Radar (TDR) Radial Velocity Data

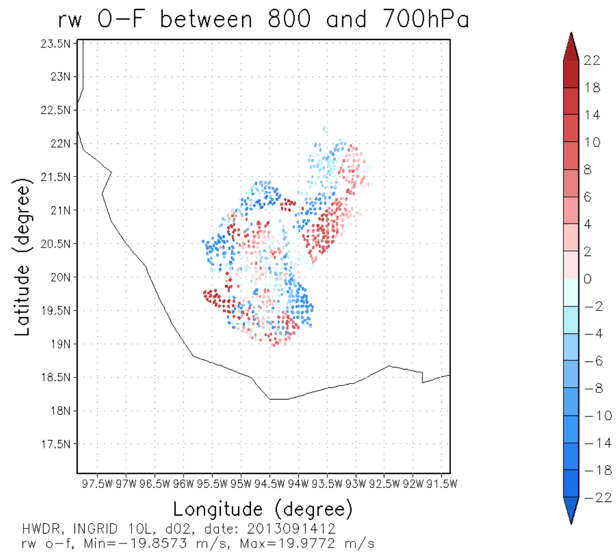
- TDR data are assimilate in ghost domain after vortex initialization
- Data with innovation (o-f) greater than 20 m/s are rejected
- Observation error is 5 m/s and gradually increases to 10 m/s as o-f is greater than 10 m/s
- Reject small data dump at the ends of assimilation window
- Data thinned to 9 km horizontal resolution
- Assimilation time window – analysis time ±3 hours
- To deal with the distribution of the inner core observations in hours of time window within 3D data assimilation framework, FGAT (First Guess at Appropriate Time) is used



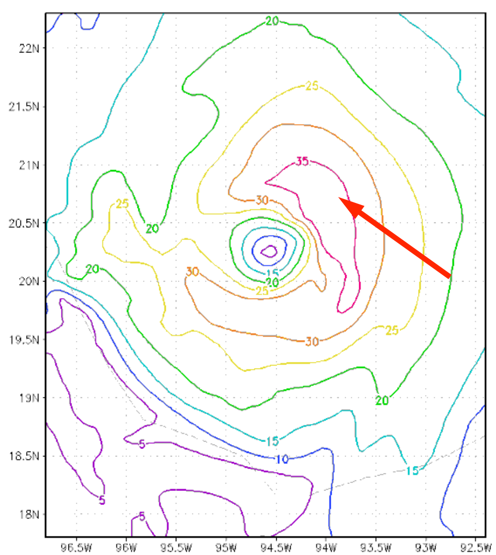
* FGAT - compares observations with the background at the observation time; In traditional 3DVAR scheme, observation is assumed to be valid at the analysis time and is used to compute the innovation

Impact of TDR data assimilation

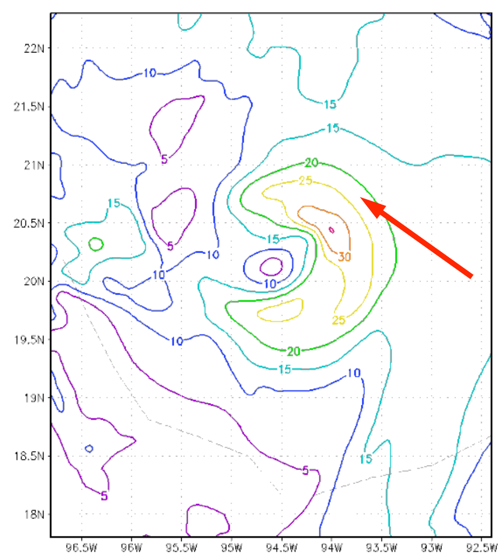


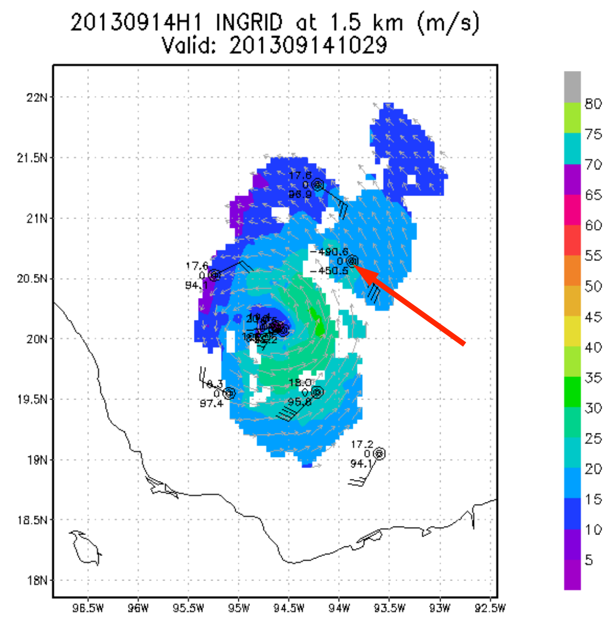


First guess at 850 hPa

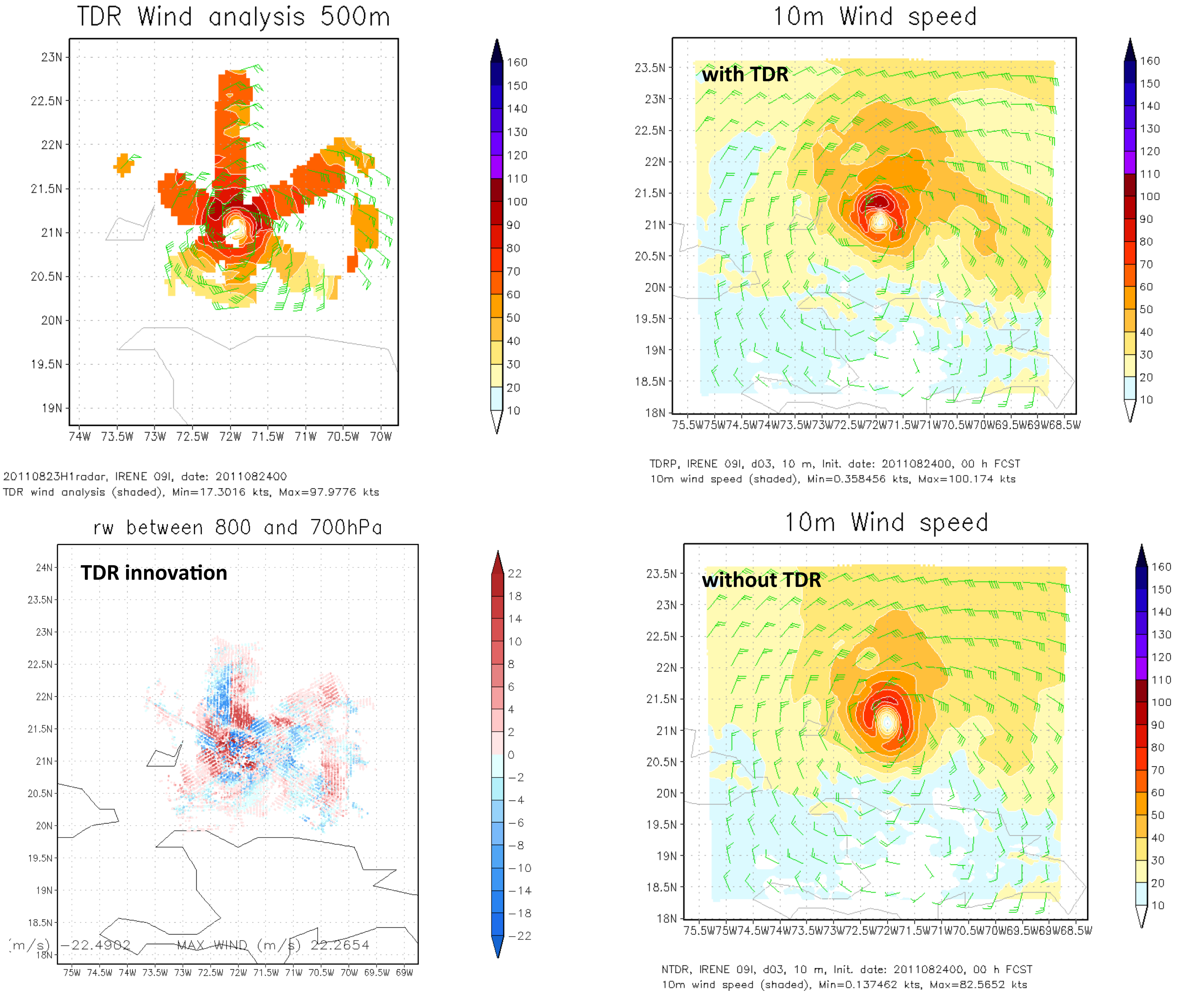


Analysis at 850 hPa





First guess vortex is much bigger than observed vortex HWRF analysis is consistent with HRD wind analysis



TDR Wind analysis 500m
20110823H1radar, IRENE 09I, date: 2011082400
TDR wind analysis (shaded), Min=17.3016 kts, Max=97.9776 kts
10m Wind speed
with TDR
TDRP, IRENE 09I, d03, 10 m, Init. date: 2011082400, 00 h FCST
10m wind speed (shaded), Min=0.358456 kts, Max=100.174 kts
rw between 800 and 700hPa
TDR innovation
(m/s) -22.4902 MAX WIND (m/s) 22.2654
10m Wind speed
without TDR
NTDR, IRENE 09I, d03, 10 m, Init. date: 2011082400, 00 h FCST
10m wind speed (shaded), Min=0.137462 kts, Max=82.5652 kts

GSI customization

Data Assimilation Configuration

- Setup DA configuration in

```
/glade/scratch/$USER/HWRF_v3.5a/sorc/hwrf-utilities/wrapper_scripts/global_vars.ksh

BKG_MODE=GDAS                 # Define first guess
```

If BKG_MODE=GFS means using GFS analysis and GSI will be turned off

```
RUN_GSI=T                     # T run GSI data assimilation
RUN_GSI_WRFINPUT=T            # T run GSI DA for outer domain
RUN_GSI_WRFGHOST=F            # T run GSI DA for ghost domain
INNER_CORE_DA=1               # 0=no inner core DA; 1=TDR only; 2=HDOB only; 3=TDR and HDOB
```

If INNER_CORE_DA > 0 and inner core data are found, RUN_GSI_WRFGHOST will be ignored and assumed T by other scripts, even if RUN_GSI_WRFGHOST=F in global_vars.ksh

If RUN_GSI_WRFGHOST=T, always turn on GSI for ghost domain, no matter whether there is inner core data or not

```
FGAT="-3,0,3"                 # FGAT window times relative to analysis time

GSI_ENS_REG=T                 # Option to run hybrid DA F = 3DVAR DA
GSI_ENS_REG_OPT=1             # Using global EnKF-3DVAR hybrid ensemble for HWRF hybrid DA
GSI_ENS_REG_SIZE=80           # Number of ensemble members
```

Setup hybrid DA in GSI script

1. Link ensemble forecast files

```
function cp_ens {
      typeset -Z3 n=1
      typeset d
      typeset jdn
      typeset p
      typeset f
      typeset x=0

      jdn=$(jdn ${START_TIME} )
      (( jdn -= (${FCST_INTERVAL} / 24.0) ))
      p=$(gtime -s $jdn)
      d=${GEFS_ENS_FCST_DIR}/${p:0:10}

      if [[   "$GSI_ENS_REG" =~ ^[T|t] \
         && "$GSI_ENS_REG_OPT" -eq 1 ]] ; then
          while [[ $n -le ${GSI_ENS_REG_SIZE} ]]; do
                f=${d}/sfg_${p:0:10}_fhr06s_mem${n}
                if [ -f $f ] ; then
                      ${LS} $f >> filelist      # *
                      (( ++x ))
                fi
                (( ++n ))
          done
          if [ $x -eq 0 ]; then
                error "No ensemble member files found."
          fi
      fi
}
```

```
function main {
   …
   if [[ "$GSI_ENS_REG" =~ ^[Tt] ]] ; then    # using global ensemble
            cp_ens
   fi
   …
}
```

* GSI read in global ensemble by first read in the file ‘filelist’ and then the files listed in filelist

Setup hybrid DA in GSI script

2. GSI namelist

```
&HYBRID_ENSEMBLE
   l_hyb_ens=HYBENS_REGIONALVALUE,               ! If true, then turn on hybrid ensemble option
   n_ens=80,                                     ! Number of ensemble members
   uv_hyb_ens=.true.,                            ! True for regional model
   beta1_inv=0.2,                                ! Weight given to static background error covariance
                                                   (0 <= beta1_inv <=1)
   s_ens_h=HYBENS_HOR_SCALE_REGIONALVALUE,       ! Horizontal localization length scale (km)
   s_ens_v=HYBENS_VER_SCALE_REGIONALVALUE,       ! Vertical localization length scale (lnP or grid units)
                                                 ! If in lnP, s_ens_v need to be a negative number
   readin_localization=.false.;                  ! Flag to read in external localization information file
                                                 ! (hybens_locinfo)
   generate_ens=.false.,
   regional_ensemble_option=REGIONAL_ENSEMBLE_OPTIONVALUE,
                              ! 1 use global ensemble internally interpolated to ensemble grid.
                              ! 2 ensembles are WRF NMM format (HWRF)
   grid_ratio_ens=1,          ! For regional runs, ratio of ensemble grid to analysis grid resolution
   pseudo_hybens=.false.,
   merge_two_grid_ensperts=.false.,
   pwgtflg=.false.,
   betaflg=.false.,
   aniso_a_en=.false.,
   nlon_ens=NLON_ENS_REGIONALVALUE,
   nlat_ens=NLAT_ENS_REGIONALVALUE,
   jcap_ens=0,
   jcap_ens_test=0,
/
```

First Guess (FGAT)

```
# Copy the WRF input and output file(s) for domain wrfghost
function cp_wrfghost {

…

if [ "${BKG_MODE}" = "GDAS" ]; then
   if [ $(check_inner_da) = "true" ] ; then
        for i in {$FGAT} ; do
           j=$(otime -o $i ${START_TIME} )
           (( k = FCST_INTERVAL + i ))
           src=${DOMAIN_DATA}/relocateprd/${j:0:10}
           if [ $i -eq 0 ]; then
              dst=wrf_inout      # Copy first guess valid at analysis time
           else
              dst=wrf_inou$k     # Copy first guess at other time levels for FGAT
           fi                    # i.e. as wrfinou3, wrfinou9
                                 # $k is forecast hour
           dfile=wrfghost_d02
           copy $src/${dfile} $dst
        done
   else
…

}
```

Observations – control data usage

1. Presence or lack of input data

```
cp $datobs/${prefixa}.prepbufr          ./prepbufr      → conventional data
cp $datobs/${prefixo}.tldplr.${suffix}  ./tldplrbufr    → TDR data
cp $datobs/${prefixa}.goesfv.${suffix}  ./gsnd1bufr     ┐
cp $datobs/${prefixa}.1bamua.${suffix}  ./amsuabufr     │
cp $datobs/${prefixa}.1bamub.${suffix}  ./amsubbufr     │
cp $datobs/${prefixa}.1bhrs3.${suffix}  ./hirs3bufr     ├→ satellite data
cp $datobs/${prefixa}.1bhrs4.${suffix}  ./hirs4bufr     │
cp $datobs/${prefixa}.1bmhs.${suffix}   ./mhsbufr       │
cp $datobs/${prefixa}.airsev.${suffix}  ./airsbufr      ┘
```

Observations – control data usage

2. GSI namelist

horizontal resolution (km) of TDR data thinning grid

```
&OBS_INPUT
  dmesh(1)=120.0,dmesh(2)=60.0,dmesh(3)=60.0,dmesh(4)=60.0,dmesh(5)=120, dmesh(7)=9.0, time_window_max=$twind,
  dfile(01)='prepbufr',  dtype(01)='ps',      dplat(01)=' ',     dsis(01)='ps',          dval(01)=0.0,  dthin(01)=0,  dsfcalc(01)=0,
  dfile(02)='prepbufr'   dtype(02)='t',       dplat(02)=' ',     dsis(02)='t',           dval(02)=0.0,  dthin(02)=0,  dsfcalc(02)=0,
  dfile(03)='prepbufr',  dtype(03)='q',       dplat(03)=' ',     dsis(03)='q',           dval(03)=0.0,  dthin(03)=0,  dsfcalc(03)=0,
  dfile(04)='prepbufr',  dtype(04)='pw',      dplat(04)=' ',     dsis(04)='pw',          dval(04)=0.0,  dthin(04)=0,  dsfcalc(04)=0,
  dfile(05)='prepbufr',  dtype(05)='uv',      dplat(05)=' ',     dsis(05)='uv',          dval(05)=0.0,  dthin(05)=0,  dsfcalc(05)=0,
  dfile(06)='satwndbufr',dtype(06)='uv',      dplat(06)=' ',     dsis(06)='uv',          dval(06)=0.0,  dthin(06)=0,  dsfcalc(06)=0,
  dfile(07)='prepbufr',  dtype(07)='spd',     dplat(07)=' ',     dsis(07)='spd',         dval(07)=0.0,  dthin(07)=0,  dsfcalc(07)=0,
  dfile(08)='prepbufr',  dtype(08)='dw',      dplat(08)=' ',     dsis(08)='dw',          dval(08)=0.0,  dthin(08)=0,  dsfcalc(08)=0,
  dfile(09)='radarbufr', dtype(09)='rw',      dplat(09)=' ',     dsis(09)='rw',          dval(09)=0.0,  dthin(09)=0,  dsfcalc(09)=0,  <-- radar data including TDR
  dfile(10)='prepbufr',  dtype(10)='sst',     dplat(10)=' ',     dsis(10)='sst',         dval(10)=0.0,  dthin(10)=0,  dsfcalc(10)=0,
  dfile(11)='tcvitl'     dtype(11)='tcp',     dplat(11)=' ',     dsis(11)='tcp',         dval(11)=0.0,  dthin(11)=0,  dsfcalc(11)=0,
.......
  dfile(23)='hirs3bufr', dtype(23)='hirs3',     dplat(23)='n17',     dsis(23)='hirs3_n17',       dval(23)=0.0,  dthin(23)=1,  dsfcalc(23)=0,
  dfile(24)='hirs4bufr', dtype(24)='hirs4',     dplat(24)='metop-a', dsis(24)='hirs4_metop-a',   dval(24)=0.0,  dthin(24)=1,  dsfcalc(24)=1,
  dfile(25)='gimgrbufr', dtype(25)='goes_img',  dplat(25)='g11',     dsis(25)='imgr_g11',        dval(25)=0.0,  dthin(25)=1,  dsfcalc(25)=0,
......
  dfile(67)='amsuabufr', dtype(67)='amsua',     dplat(67)='metop-b', dsis(67)='amsua_metop-b',   dval(67)=0.0,  dthin(67)=2,  dsfcalc(67)=0,
  dfile(68)='mhsbufr',   dtype(68)='mhs',       dplat(68)='metop-b', dsis(68)='mhs_metop-b',     dval(68)=0.0,  dthin(68)=3,  dsfcalc(68)=0,
  dfile(69)='iasibufr',  dtype(69)='iasi',      dplat(69)='metop-b', dsis(69)='iasi616_metop-b', dval(69)=0.0,  dthin(69)=1,  dsfcalc(69)=0,
......
  dfile(78)='gsnd1bufr', dtype(78)='sndrd2',    dplat(78)='g15',     dsis(78)='sndrD2_g15',      dval(78)=0.0,  dthin(78)=5,  dsfcalc(78)=0,
  dfile(79)='gsnd1bufr', dtype(79)='sndrd3',    dplat(79)='g15',     dsis(79)='sndrD3_g15',      dval(79)=0.0,  dthin(79)=5,  dsfcalc(79)=0,
  dfile(80)='gsnd1bufr', dtype(80)='sndrd4',    dplat(80)='g15',     dsis(80)='sndrD4_g15',      dval(80)=0.0,  dthin(80)=5,  dsfcalc(80)=0,
```

Observations – control data usage

3. GSI info/fix files

- convinfo (for conventional data)

!otype	type	sub	**iuse**	twindow	numgrp	ngroup	nmiter	gross	ermax	ermin	var_b	var_pg	ithin	rmesh	pmesh	npred
ps	111	0	-1	1.5	0	0	0	5.0	3.0	1.0	10.0	0.000	0	0.	0.	0
ps	120	0	1	1.5	0	0	0	5.0	3.0	1.0	10.0	0.000	0	0.	0.	0
ps	132	0	-1	1.5	0	0	0	5.0	3.0	1.0	10.0	0.000	0	0.	0.	0
…																
rw	999	0	1	0.5	0	0	0	5.0	10.0	2.0	10.0	0.000	0	0.	0.	0

using radar data

…

- satinfo (for satellite data)

sensor/instr/sat	chan	**iuse**	error	ermax	var_b	var_pg
amsua_n15	1	1	3.000	4.500	10.00	0.000
amsua_n15	2	1	2.000	4.500	10.00	0.000
amsua_n15	3	1	2.000	4.500	10.00	0.000
amsua_n15	4	1	0.600	2.500	10.00	0.000
amsua_n15	5	1	0.300	2.000	10.00	0.000
amsua_n15	6	1	0.230	2.000	10.00	0.000

Conventional Data

- Dropsonde wind observations within max(111km, 3xRMW) were flagged (not used)

- Surface pressure data within the vortex area are flagged

- Data remove program – hwrf_data_remv (not used in FY13 HWRF)

Input

RRADC – radius from TC center

Function

Remove all conventional data within RRADC km from TC center

- Data flag program – hwrf_data_flag

Input

RRADC - radius from TC center for dropsonded wind

RBLDC - radius from TC center for surface pressure data

Function

Change the data usage flag from use to not use

GSI fix files

- background error covariance
  cp $GSI_FIXED_DIR/nam_glb_berror.f77.gcv   ./berror_stats

- observation error table
  cp $GSI_FIXED_DIR/prepobs_errtable.hwrf   ./errtable

- Radiance coefficient used by CRTM
  cp $GSI_CRTM_FIXED_DIR/EmisCoeff.bin   ./EmisCoeff.bin
  cp $GSI_CRTM_FIXED_DIR/AerosolCoeff.bin   ./AerosolCoeff.bin
  cp $GSI_CRTM_FIXED_DIR/CloudCoeff.bin   ./CloudCoeff.bin

GSI fix files

- Observation data control file

```
cp $GSI_FIXED_DIR/nam_regional_convinfo.txt    ./convinfo
cp $GSI_FIXED_DIR/nam_regional_satinfo.txt     ./satinfo
cp $GSI_FIXED_DIR/nam_global_pcpinfo.txt       ./pcpinfo
cp $GSI_FIXED_DIR/nam_global_ozinfo.txt        ./ozinfo
```

satinfo, pcpinfo and ozinfo are not used, because satellite radiance data, ozone data and precipitation rate observations are not assimilated into FY13 HWRF

- Satellite bias correction coefficients

```
cp $GSI_FIXED_DIR/gdas.t${CYCLE}z.satang    ./satbias_angle
cp $GFS_OBS_DIR/gdas.t${CYCLE}z.abias       ./satbias_in
```

GSI namelist

```
&SETUP
  miter=2,niter(1)=50,niter(2)=50,
  * two outer loop with 50 iterations each
  write_diag(1)=.true.,write_diag(2)=.false.,write_diag(3)=.true.,
  * output innovation diagnostic information
  gencode=78,qoption=2,
  * use normalized relative humidity as analysis variable
  ndat=16,
  * number of data listed in &OBS_INPUT
  oneobtest=.false.,retrieval=.false.,
  nhr_assimilation=6,l_foto=.false.,
  use_pbl=.true.,
```

GSI namelist

&GRIDOPTS

JCAP=$JCAP,JCAP_B=$JCAP_B,NLAT=$NLAT,NLON=$LONA,nsig=$LEVS,

* analysis domain dimensions. It's okay if wrong values are given to NLAT, NLON and nsig. For HWRF, domain dimensions are read in from input background data

hybrid=.true.,wrf_nmm_regional=.true.,wrf_mass_regional=.false.,

* if run GSI for HWRF, need to be set to 'true'. 'hybrid' means hybrid vertical coordinates, not hybrid analysis

&BKGERR

as=1.0,1.0,0.5 ,0.7,0.7,0.5,1.0,1.0,

vs=1.0

hzscl=0.373,0.746,1.50,

* static background error variance and correlation length scale parameter

bw=0.,fstat=.true.,

&ANBKGERR

anisotropic=.false.,

* anisotropic static background error covariance is not used for FY13 HWRF

GSI namelist

&JCOPTS

&STRONGOPTS

jcstrong=.false.,

* TLNMC constraint (Kleist et. al. 2009) is not used for HWRF

&OBSQC

dfact=0.75,dfact1=3.0,noiqc=.false.

&OBS_INPUT

dmesh(1)=120.0,dmesh(2)=60.0,dmesh(3)=60.0,dmesh(4)=60.0,dmesh(5)=120,dmesh(9)=9,time_window_max=1.5,

* dmesh – data thinning mesh size (km)
* time_window_max – observation time window

Standard Output

Details in User's Guide Section 4.1

Highlight several important points

Check Background Input

ZNW, RDX, RDY, MAPFAC_M, XLAT, XLONG, MUB, MU, PHB

Variable name in netcdf file

```
0:   rmse_var=T
0:   ordering=XYZ
0:   WrfType,WRF_REAL= 104 104
0:   ndim1= 3
0:   staggering= N/A
0:   start_index= 1 1 1 -7269735
0:   end_index= 69 64 45 -7269735
0:   k,max,min,mid T=  1 309.9411316 264.5114136 289.7205811
0:   k,max,min,mid T=  2 310.6200562 269.5698547 295.0413208
0:   k,max,min,mid T=  3 311.5386047 272.4312744 296.7247009

0:   k,max,min,mid T= 43 486.2092896 436.1306763 461.4866943
0:   k,max,min,mid T= 44 498.1362000 456.4700012 478.7089233
0:   k,max,min,mid T= 45 510.0127563 472.5627441 494.7407227
                      K   Maximum     Minimum     Central grid
```

QVAPOR, U, V, LANDMASK, XICE, SST,IVGTYP, ISLTYP, VEGFRA, SNOW, U10, V10, SMOIS, TSLB, TSK

Check Fix Files Input

convinfo

```
0:READ_CONVINFO: ps     120  0  1  3.0  0  0  0  4.0  3.0  1.0  4.0
0:READ_CONVINFO: ps     132  0 -1  3.0  0  0  0  4.0  3.0  1.0  4.0
0:READ_CONVINFO: t      120  0  1  3.0  0  0  0  8.0  5.6  1.3  8.0
0:READ_CONVINFO: t      180  0  1  3.0  0  0  0  7.0  5.6  1.3  7.0
0:READ_CONVINFO: uv     220  0  1  3.0  0  0  0  8.0  6.0  1.4  8.0
0:READ_CONVINFO: uv     280  0  1  3.0  0  0  0  6.0  6.1  1.4  6.0
0:READ_CONVINFO: spd    283  0  1  3.0  0  0  0  8.0  6.1  1.4  8.0
```

CRTM coefficients

0: **Read_SpcCoeff_Binary**(INFORMATION) : FILE: ./**hirs3_n16.SpcCoeff.bin**;
0: SpcCoeff RELEASE.VERSION: 7.01 N_CHANNELS=19
0: **Read_TauCoeff_Binary**(INFORMATION) : FILE: ./**hirs3_n16.TauCoeff.bin**;
0: TauCoeff RELEASE.VERSION: 5.04 N_ORDERS=10 N_PREDICTORS= 6 N_ABSORBERS= 3
N_CHANNELS= 19 N_SENSORS= 1
0: Read_CloudCoeff_Binary(INFORMATION) : FILE: ./CloudCoeff.bin;
0: CloudCoeff RELEASE.VERSION: 2.02 N_FREQUENCIES(MW)= 31 N_FREQUENCIES(IR)= 701
N_RADII(MW)= 6 N_RADII(IR)= 6 N_TEMPERATURES= 5 N_DENSITIES= 3
N_LEGENDRE_TERMS=38 N_PHASE_ELEMENTS= 6

Check Observations Input

```
0: READ_OBS:  read  1 ps      ps          using ntasks= 1 0 2 1
0: READ_OBS:  read  2 t       t           using ntasks= 1 0 3 1
0: READ_OBS:  read  3 q       q           using ntasks= 1 0 0 1
0: READ_OBS:  read  4 uv      uv          using ntasks= 1 0 1 1
0: READ_OBS:  read  5 spd     spd         using ntasks= 1 0 2 1
0: READ_OBS:  read  7 dw      dw          using ntasks= 1 0 3 1
0: READ_OBS:  read  8 sst     sst         using ntasks= 1 0 0 1

READ_PREPBUFR: messages/reports = 681 / 71658 ntread = 1
READ_PREPBUFR: file=prepbufr type=t sis=t nread= 11452 ithin= 0 rmesh=120.000
               isfcalc= 0 ndata= 11280 ntask= 1
READ_PREPBUFR: messages/reports = 681 / 71658 ntread = 1
READ_PREPBUFR: file=prepbufr type=q sis=q nread= 11379 ithin= 0 rmesh=120.000
               isfcalc= 0 ndata= 10186 ntask= 1
```

Observation distribution in an analysis using 4 processors

```
3:OBS_PARA: ps               291     508    1140    1561
3:OBS_PARA: t                484     887    1730    2729
3:OBS_PARA: q                464     868    1642    2568
3:OBS_PARA: uv              1146    2067    2766    5162
3:OBS_PARA: sst                0       0      47       0
3:OBS_PARA: pw                13      18      44      17

3:OBS_PARA: hirs3    n16      21      21       0       0
3:OBS_PARA: amsua    n15     179     189     149     224
```

Check outer loop and inner iteration

1st outer loop

Inner iteration

```
0:grepcost J,Jb,Jo,Jc,Jl =   1   0  1.6048921E+04  0.0E+0  1.60489216E+04 0.0E+0 0.0E+0
0:grepgrad grad,reduction=   1   0  4.62290685479066 79176E+02  1.00000000000000000E+00
0:pcgsoi: cost,grad,step =   1   0  1.60489216E+04  4.6229068547E+02  1.4816403979E-02
0:pcgsoi: gnorm(1:2),b=  1.24089076555E+05  1.24089076553E+05  5.8063507409044E-01
0:  stprat  0.518838814777991403E-01
0:  stprat  0.246311812999037177E-15
0: Minimization iteration 1
0:grepcost J,Jb,Jo,Jc,Jl =   1   1  1.288246E+04  4.6915E+01  1.283555E+04 0.0E+0 0.0E+0
0:grepgrad grad,reduction=   1   1  3.522627947361617657E+02  7.61994143081457076 0E-01
0:pcgsoi: cost,grad,step =   1   1  1.28824682486E+04  3.522627947E+02  1.408558895E-02
0:pcgsoi: gnorm(1:2),b=  3.9226971306926E+04  3.9226971306926E+04  3.1611945544163E-01
0:  stprat  0.364906062575707624
0:  stprat  0.156431139151674278E-14224
```

2nd outer loop

Inner iteration

```
0: Minimization iteration 0
0:grepcost J,Jb,Jo,Jc,Jl =   2   0  9.9610405E+03  8.5076644E+02  9.1102740E+03 0.0 0.0
0:grepgrad grad,reduction=   2   0  2.291813874420873560E+02  1.00000000000000000E+00
0:pcgsoi: cost,grad,step =   2   0  9.96104052193E+03  2.29181387442E+02  7.15279261E-03
0:pcgsoi: gnorm(1:2),b=  1.13035507282E+04  1.13035507282E+04  2.15206903713E-01
0:  stprat  0.319264972580440953
0:  stprat  0.577830902990640559E-14
0: Minimization iteration 1
0:grepcost J,Jb,Jo,Jc,Jl =   2   1  9.58534646E+03  8.7366356E+02  8.7116829E+03 0.0 0.0
0:grepgrad grad,reduction=   2   1  1.0631815803646677217E+02  4.63903981135176724 0E-01
0:pcgsoi: cost,grad,step =   2   1  9.58534646763E+03  1.06318158036E+02  1.05074549E-02
0:pcgsoi: gnorm(1:2),b=  5.4234537548554E+03  5.4234537548554E+03  4.7980089488985E-01
0:  stprat  0.410968433100896591
0:  stprat  0.157538354385690312E-13
```

Check Analysis Result Output

```
0:  ordering=XY
0:  WrfType,WRF_REAL= 104 104
0:  ndim1= 2
0:  staggering= N/A
0:  start_index= 1 1 1 -7269735
0:  end_index1= 69 64 45 -7269735
0:  k,max,min,mid T=  1 309.9584656 264.4796753 290.9471130
0:  k,max,min,mid T=  2 310.6225281 269.6447144 296.2458191

0:  k,max,min,mid T= 44 496.4794922 457.3758850 478.2719116
0:  k,max,min,mid T= 45 509.2687378 475.0305481 494.7050171
0:  rmse_var=T
```

rmse_var=T | K | Maximum | Minimum | Central grid

QVAPOR, U, V, SMOIS, XICE, SST, TSK

Variable name in netcdf file

Observation Fitting Statistic

Details in User's Guide Section 4.5

Why need to check fitting statistic

- Data Analysis: adjust background fields based on observation data so that analysis fields fit the observation better.

- GSI has a series of text files to provide statistic information on how outer loop fields fit to the certain observation variable (fort.2*)

- GSI also has a series of binary files to save diagnostic information for each observation (diag*)

Statistic fitting files

File name	Variables in file	Ranges/units
fort.201 or fit_p1.analysis_time	fit of surface pressure data	mb
fort.202 or fit_w1.analysis_time	fit of wind data	m/s
fort.203 or fit_t1.analysis_time	fit of temperature data	K
fort.204 or fit_q1.analysis_time	fit of q data,	percent of guess $q_{saturation}$
fort.205	current fit of precipitation water data	mm
fort.206	fit of ozone observations from sbuv6_n14 (, _n16, _n17, _n18) and sbuv8_n16 (, _n17, _n18, _n19)	

File names are from fort.201 to fort.215 (or fit_*)
Each file is for one observation variable

Statistic fitting files (Continue)

File name	Variables in file	Ranges/units
fort.207 or fit_rad1.analysis_time	fit of satellite data including: amsua_n15(, n16, n17, n18, metop-a, aqua, n19), amsub_n15(, n16, n17,), hirs3_n16(, n17), hirs4_n18 (, metop-a, n19), mhs_n18(, metop-a, n19), hirs2_n14, iasi616_metop-a, airs281SUBSET_aqua, avhrr3_n16(, n17, n18), amsre_aqua, ssmi_f13(, f14, f15), ssmis_f16, msu_n14, sndr_g11(, g12, g13), imgr_g11(, g12, g13), sndrD1(, 2, 3, 4)_g11(, g12,g13),	
fort.208	pcp_ssmi, pcp_tmi	
fort.209	Rw	
fort.210	Dw	
fort.211	srw1, srw2	
fort.212	GPS RO	
fort.213	fit of conventional sst data	C
fort.214	Tropical cyclone central pressure	
fort.215	Lagrangian data	

Satellite radiance

Radar radial wind

GPS RO

Example: fit_t1.2010050700 (fort.203)

current fit of temperature data, ranges in K

				ptop	1000.0	900.0	800.0	600.0	400.0	300.0	250.0	200.0	150.0	100.0	50.0	0.0
it	obs	type	styp	pbot	1200.0	999.9	899.9	799.9	599.9	399.9	299.9	249.9	199.9	149.9	99.9	2000.0
o-g 01	t	120	0000	count	44	180	214	381	405	200	93	147	247	334	396	3432
o-g 01	t	120	0000	bias	3.67	2.12	0.51	0.23	-0.33	-0.63	-0.66	-1.49	-0.45	-1.04	-1.21	-0.40
o-g 01	t	120	0000	rms	4.36	2.77	1.45	1.19	0.83	1.04	1.43	2.09	1.74	1.89	2.38	**1.81**
o-g 01	t	130	0000	count	0	0	0	0	0	0	3	12	2	0	0	18
o-g 01	t	130	0000	bias	0.00	0.00	0.00	0.00	0.00	0.00	-0.55	-0.50	2.33	0.00	0.00	-0.04
o-g 01	t	130	0000	rms	0.00	0.00	0.00	0.00	0.00	0.00	0.57	1.31	2.51	0.00	0.00	1.48
o-g 01	t	180	0000	count	714	79	0	0	0	0	0	0	0	0	0	793
o-g 01	t	180	0000	bias	2.65	-0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.38
o-g 01	t	180	0000	rms	3.66	1.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.51
o-g 01		all		count	758	259	214	381	405	200	96	159	249	334	396	4243
o-g 01		all		bias	2.70	1.46	0.51	0.23	-0.33	-0.63	-0.65	-1.41	-0.42	-1.04	-1.21	0.12
o-g 01		all		rms	3.70	2.47	1.45	1.19	0.83	1.04	1.41	2.04	1.74	1.89	2.38	**2.23**

O-B

current fit of temperature data, ranges in K

				ptop	1000.0	900.0	800.0	600.0	400.0	300.0	250.0	200.0	150.0	100.0	50.0	0.0
it	obs	type	styp	pbot	1200.0	999.9	899.9	799.9	599.9	399.9	299.9	249.9	199.9	149.9	99.9	2000.0
o-g 03	t	120	0000	count	44	180	214	381	405	200	93	147	247	334	396	3432
o-g 03	t	120	0000	bias	2.38	1.36	0.13	0.13	-0.07	-0.10	-0.03	-0.50	0.03	-0.24	-0.27	0.02
o-g 03	t	120	0000	rms	2.75	1.94	1.06	0.90	0.59	0.61	1.02	1.23	1.37	1.19	1.90	**1.34**
o-g 03	t	130	0000	count	0	0	0	0	0	0	3	12	2	0	0	18
o-g 03	t	130	0000	bias	0.00	0.00	0.00	0.00	0.00	0.00	-0.06	-0.04	1.70	0.00	0.00	0.29
o-g 03	t	130	0000	rms	0.00	0.00	0.00	0.00	0.00	0.00	0.26	1.08	1.87	0.00	0.00	1.24
o-g 03	t	180	0000	count	714	79	0	0	0	0	0	0	0	0	0	793
o-g 03	t	180	0000	bias	0.84	-0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74
o-g 03	t	180	0000	rms	2.34	1.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.27
o-g 03		all		count	758	259	214	381	405	200	96	159	249	334	396	4243
o-g 03		all		bias	0.93	0.88	0.13	0.13	-0.07	-0.10	-0.03	-0.46	0.04	-0.24	-0.27	0.16
o-g 03		all		rms	2.37	1.79	1.06	0.90	0.59	0.61	1.01	1.22	1.37	1.19	1.90	**1.56**

O-A

Results from test case using 2 outer loops with 10 inner iterations in each outer loop

Observation departure for each obs

- Diagnostic files:

```
diag_amsua_metop-a_anl.2010050700   diag_amsub_n16_anl.2010050700
diag_amsua_metop-a_ges.2010050700   diag_amsub_n16_ges.2010050700
diag_amsub_n17_anl.2010050700       diag_conv_anl.2010050700
Diag_amsub_n17_ges.2010050700       diag_conv_ges.2010050700
```

- To get these files, has to turn write_diag on:

  write_diag(1)=.true.,write_diag(2)=.false.,write_diag(3)=.true.,

- To read this binary information:
  - Code to read these files (/util/diag)
    - read_diag_conv.f90 (diag_conv*)
    - read_diag_rad.f90 (diag_amsub_n16* …)
  - see User’s Guide appendix A.2 for details