HWRF Data Assimilation System

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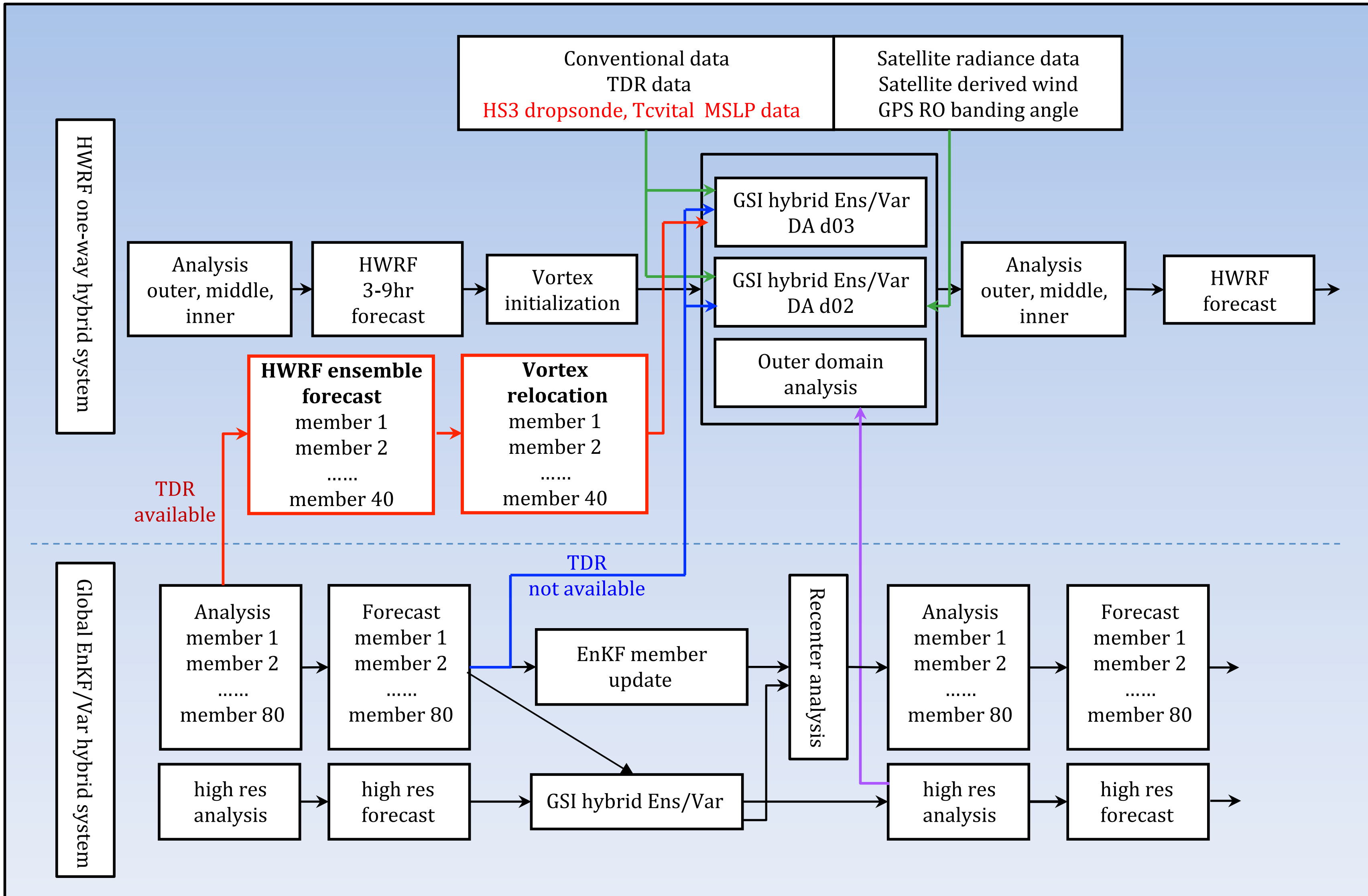
Outline

- HWRF Data assimilation system
- GSI customization
  - Data assimilation configuration
  - Set up hybrid DA
  - Control assimilation of observations
  - Conventional data preprocessing
  - TDR DA
  - Satellite DA

Data assimilation for HWRF

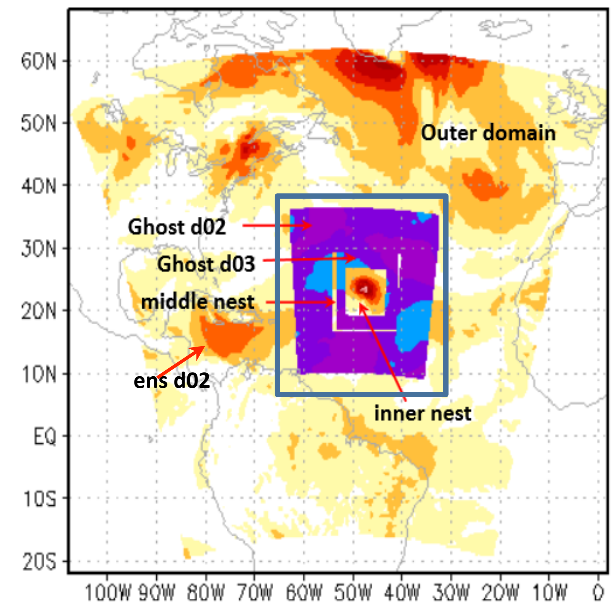
2013	❖ A GSI based one-way hybrid ensemble-variational data assimilation system was implemented for HWRF. The system uses the global ensemble from the NCEP GFS GSI/EnKF hybrid system to estimate flow-dependent background error covariance. ❖ The first time the assimilation NOAA P3 Tail Doppler Radar (TDR) data was implemented in operational HWRF.
2014	❖ Assimilation of satellite observations (radiance from IR, MW; satellite wind, GPS RO) was implemented in operational HWRF (E. Liu, B. Zhang) ❖ New technique implemented for radiance assimilation – use global-regional blended vertical coordinate in analysis (D. Parrish)
2015	❖ 40 member 'warm-start' HWRF ensemble for inner-core background error covariance ❖ Assimilation of HS3/Global Hawk dropsonde observations ❖ Assimilation of TC vitals Minimum Sea Level Pressure data

HWRF hybrid data assimilation system



HWRF Data Assimilation Configuration

- **61 vertical levels with 2 hPa model top**
- **Model forecast domains**
  outer domain: 288x576 – 80°x80° ; 0.135°
  middle nest: 142x274 – 12°x11°; 0.045°
  inner nest: 265x472 – 7.1°x6.5°; 0.015°
- **HWRF vortex initialization domain**
  3x domain: 748x1504 – 30°x30°
- **GSI analysis domain (configurable)**:
  ghost d02: 289x579 - 26°x26°; 0.045°
  ghost d03: 434x867 - 13°x13°; 0.015°
  GSI analysis domains are configurable.

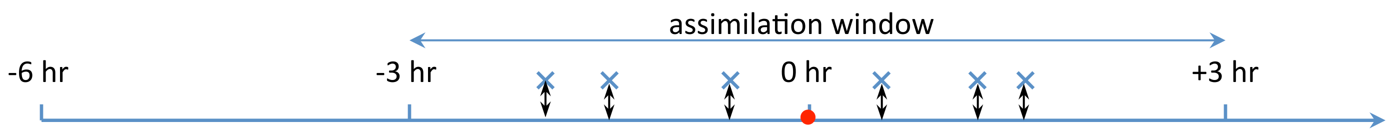


2015 domain configuration

Assimilation System

❖ First guess

- TC environment cold start from GDAS forecast
- TC vortex cycled from HWRF forecast + vortex relocation/initialization
- First Guess at Appropriate Time (FGAT) – configurable (3hourly , hourly)



❖ Hybrid data assimilation configuration

- 80 ensemble member at T254L64 (2013, 2014) T574L64 (2015)
- Localization
  - Horizontal: 773 km (ghost d02), 387 km (ghost d03)
  - Vertical: 1.28 scale height (in natural log of pressure)
- Static vs. ensemble covariance: 80% ensemble, 20% static

Assimilation System

❖ GSI analysis variables

- Analysis variables used for HWRF include streamfunction (ψ), unbalanced velocity potential (χ), unbalanced temperature (T), unbalanced surface pressure (Ps), normalized relative humidity,
- Balanced part of velocity potential , temperature and surface pressure (χ_b, T_b and P_{sb}) are calculated from ψ using pre-specified statistical balance relationship specified in the background error statistics file.
- Currently ozone, cloud variables and satellite bias correction coefficients are not analyzed for HWRF

❖ Model variables currently updated

- u, v, t, q, pd, pint

Assimilation System - Observations

2014 HWRF	2015 HWRF	Future
Conventional data radiosondes; dropwindsondes; aircraft reports (AIREP/PIREP, RECCO , MDCRS-ACARS, TAMDAR, AMDAR); surface ship and buoy observations; surface observations over land; pibal winds; wind profilers; radar-derived Velocity Azimuth Display (VAD) wind; WindSat scatterometer winds; and integrated precipitable water derived from the Global Positioning System.	Conventional data same as 2014	Conventional data
Satellite data •Radiances from IR instruments: HIRS,AIRS, IASI, GOES Sounders •Radiances from MW instruments: AMSU-A, MHS, ATMS •Satellite derived wind: IR/VIS cloud drift winds, water vapor winds •Satellite derived wind: IR/VIS cloud drift winds, water vapor winds •GPS RO bending angle	Satellite data same as 2014	Satellite data Hourly AMVs Cloudy radiance
Aircraft Reconnaissance observations P3 TDR	Aircraft Reconnaissance observations P3 TDR, GH dropsondes	Aircraft Reconnaissance observations Flight level, SFMR, G-IV radar, GH radar, UAS

GSI customization

Data Assimilation Configuration

- Set up DA configuration in parm/hwrf_basic.conf

[config]

run_gsi=yes ;; GSI and FGAT initialization

run_relocation=yes ;; vortex relocation

If run_gsi=no, initial condition = GFS analysis + vortex initialization

conditional_gsid03=no ;; run gsi_d03, only when high-res inner-core data are available

conditional_gsid02=no ;; run gsi_d02, only when high-res inner-core data are available

blend_innercore=yes ;; use vortex initialization in inner core region

- < 150 km from TC center: vortex initialization
- 150 km to 300 km: blending zone
- >300 km GSI analysis

Vertically (< 150 km from TC center):

- > 600 hPa: vortex initialization
- 600 hPa-400 hPa: blending zone
- < 400 hPa: GSI analysis

Data Assimilation Configuration

- Set up DA configuration in parm/hwrf.conf

[relocate]

initopt=0 ;; 0: full vortex initialization (relocation + size correction + intensity correction), 1: relocation only

tdrconditionalvinit=yes ;; if yes, relocation only when TDR data available

[fgat]

FGAT hours:

FGATSTR=-3 ;; FGAT starting hour (relative to analysis time)

FGATINV=3 ;; Step in hours between the FGAT hours

FGATEND=3 ;; FGAT end hour

[forecast_products]

wrfcopier_step=3 ;; Step between times WRF output is copied to COM (hours)

Change time levels of FGAT: e.g. hourly FGAT -> FGATINV=1, wrfcopier_step=1

Set up hybrid DA configuration

Using global ensemble

hwrf_basic.conf:
[config]
run_ensemble_da=no ;; run HWRF ensemble forecast for DA
This one controls if HWRF ensemble will be run

hwrf.conf:
[gsi_d02] /[gsi_d03]
use_hwrf_ensemble = no

[gsi_d02_nml]
REGIONAL_ENSEMBLE_OPTION=1

Using HWRF ensemble (non-cycled)

hwrf_basic.conf:
[config]
run_ensemble_da=yes ;; run HWRF ensemble forecast for DA
run_ens_relocation=no ;; Turn on/off relocation for ensemble members

hwrf.conf:
[gsi_d03]
use_hwrf_ensemble = yes

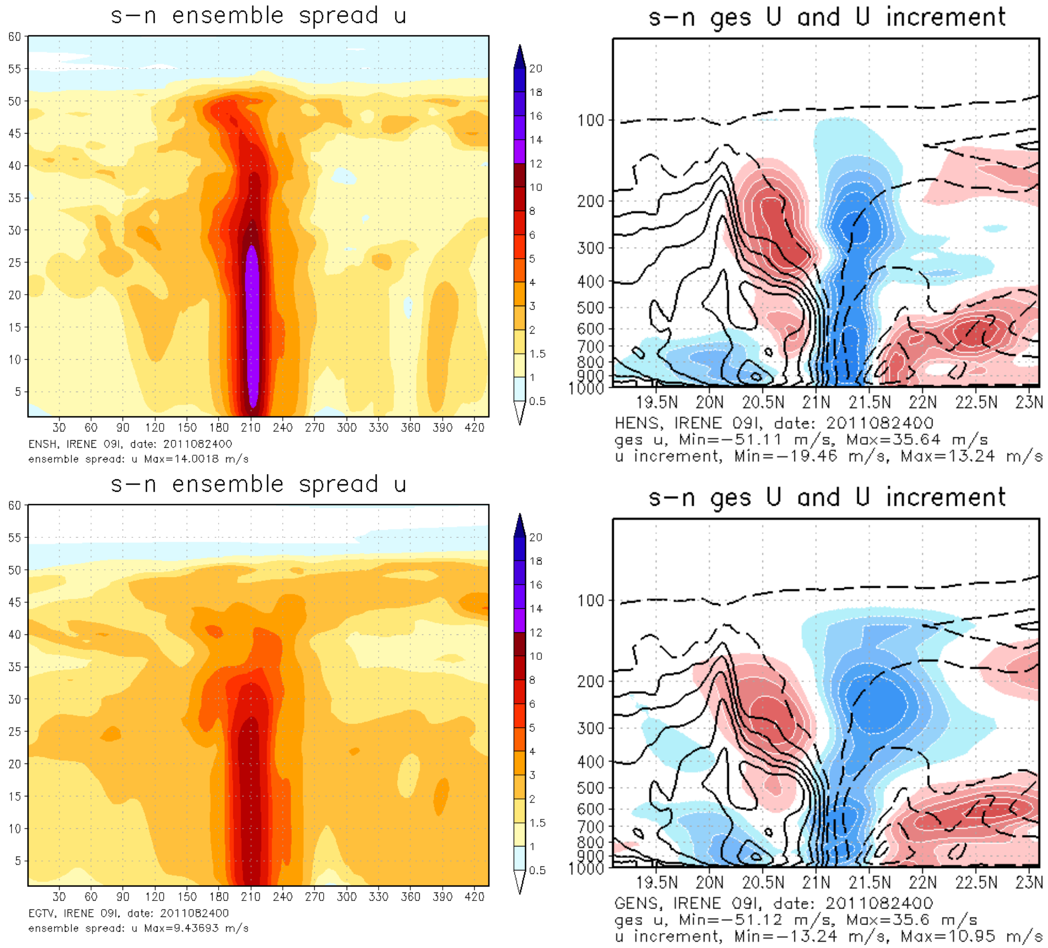
[gsi_d03_nml]
REGIONAL_ENSEMBLE_OPTION=2

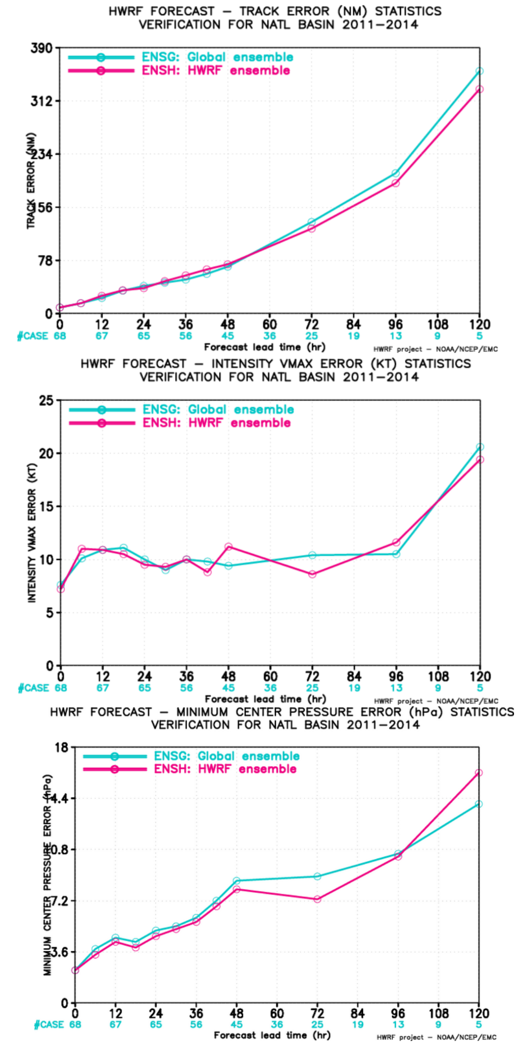
Set up hybrid DA Configuration - continued

- Set up GSI namelist through parm/hwrf.conf

[gsi_d02_nml]/[gsi_d03_nml]
# Namelist settings for domain 2 (6km) GSI as an example
HZSCL=0.25,0.5,1.0 ;; background error scale factor for horizontal smoothing
DELTIM=1200 ;; model timestep used for assimilation of precipitation rates
twind=3.0 ;; maximum half time window (hours) for observations
HYBENS_REGIONAL=T ;; logical variable, if .true., then turn on hybrid ensemble option
ENSEMBLE_SIZE_REGIONAL=80 ;; ensemble size
HYBENS_UV_REGIONAL=T ;; if T, then ensemble perturbation wind stored as u,v. if F, streamfunction and velocity potential
BETA1_INV_REGIONAL=0.2 ;; value between 0 and 1, relative weight given to static background B
HYBENS_HOR_SCALE_REGIONAL=300 ;; horizontal localization correlation length (km)
HYBENS_VER_SCALE_REGIONAL=-0.5 ;; vertical localization correlation length (>0. grid units, <0. lnp)
READIN_LOCALIZATION=F ;; if T, then read in localization information from external file
GENERATE_ENS_REGIONAL=F ;; if T, generate ensemble perturbations internally as random samples of static B.
integer, used to select type of ensemble to read in for regional application.
=1: use GEFS internally interpolated to ensemble grid.
=2: ensembles are WRF NMM format
=3: ensembles are ARW netcdf format.
=4: ensembles are NEMS NMMB format.
REGIONAL_ENSEMBLE_OPTION=1 (global ensemble)
PSEUDO_HYBENS=F ;; if T, use pseudo HWRF (NMM) ensemble
GRID_RATIO_ENS=1 ;; ratio of ensemble grid resolution to analysis grid resolution
MERGE_TWO_GRID_ENSPERTS=F ;; merge ensemble from two nests for HWRF (NMM)
PWGTFLG=F ;; if T, use vertical integration function on ensemble contribution of Psfc
BETAFLG=F ;; if T, use vertical weighting on beta1_inv and beta2_inv, for regional
HYBENS_ANISO_REGIONAL=F ;; if T, then use anisotropic recursive filter for localization
WRITE_ENS_SPRD=F ;; if T, write out ensemble spread

‘Warm-start’ HWRF vs. global ensemble (2015)





‘warm-start’ HWRF ensemble:
- improves track forecast, has neutral impact on intensity forecast.
- larger spread with smaller scale structures
- larger analysis increments

Observations – control data usage

1. Presence or lack of input data – control through hwrf.conf

[gsi_d02]/[gsi_d03]

obstypes = hdob_obstype,sat_radiance_obstypes,sat_wnd_obstype,tdr_new_obstype ;; List of obstype sections

(data type not listed will not be linked for assimilated)

[sat_radiance_obstypes] **(instruments not listed here will not be linked for assimilated)**

gpsrobufr=gpsro ;; GFS/GDAS bufr_d name for gpsrobufr data
gsnd1bufr=goesfv ;; GFS/GDAS bufr_d name for gsnd1bufr data
amsuabufr=1bamua ;; GFS/GDAS bufr_d name for amsuabufr data
hirs4bufr=1bhrs4 ;; GFS/GDAS bufr_d name for hirs4bufr data
mhsbufr=1bmhs ;; GFS/GDAS bufr_d name for mhsbufr data
airsbufr=airsev ;; GFS/GDAS bufr_d name for airsbufr data
seviribufr=sevcsr ;; GFS/GDAS bufr_d name for seviribufr data
iasibufr=mtiasi ;; GFS/GDAS bufr_d name for iasibufr data
amsuabufrears=esamua ;; GFS/GDAS bufr_d name for amsuabufrears data
amsubbufrears=esamub ;; GFS/GDAS bufr_d name for amsubbufrears data
hirs3bufrears=eshrs3 ;; GFS/GDAS bufr_d name for hirs3bufrears data
# ssmitbufr=ssmit
# amsrebufr=amsre
# ssmisbufr=ssmisu
atmsbufr=atms ;; GFS/GDAS bufr_d name for atmsbufr data
crisbufr=cris ;; GFS/GDAS bufr_d name for crisbufr data

Observations – control data usage

2. GSI namelist

Data thinning grid size (km), work with dthin

```
&OBS_INPUT
dmesh(1)=90.0,dmesh(2)=45.0,dmesh(3)=45.0,dmesh(4)=45.0,dmesh(5)=90,time_window_max=<r:twind>,l_foreaft_thin=.false.,
/
OBS_INPUT::
```

Maximum half time window (hrs) work with twindow in convinfo

! dfile	dtype	dplat	dsis	dval	dthin	dsfcalc
prepbufr	ps	null	ps	0.0	0	0
prepbufr	t	null	t	0.0	0	0
prepbufr	q	null	q	0.0	0	0
prepbufr	pw	null	pw	0.0	0	0
prepbufr	uv	null	uv	0.0	0	0
satwndbufr	uv	null	uv	0.0	0	0
prepbufr	spd	null	spd	0.0	0	0
prepbufr	dw	null	dw	0.0	0	0
radarbufr	rw	null	rw	0.0	0	0
prepbufr	sst	null	sst	0.0	0	0
tcvitl	**tcp**	**null**	**tcp**	**0.0**	**0**	**0**
<s:tdrtype>	rw	null	rw	0.0	0	0
hdobbufr	uv	null	uv	0.0	0	0
hdobbufr	t	null	t	0.0	0	0
hdobbufr	q	null	q	0.0	0	0
hdobbufr	spd	null	spd	0.0	0	0
gpsrobufr	gps_bnd	null	gps	0.0	0	0
ssmirrbufr	pcp_ssmi	dmsp	pcp_ssmi	0.0	-1	0
tmirrbufr	pcp_tmi	trmm	pcp_tmi	0.0	-1	0
sbuvbufr	sbuv2	n16	sbuv8_n16	0.0	0	0
sbuvbufr	sbuv2	n17	sbuv8_n17	0.0	0	0
sbuvbufr	sbuv2	n18	sbuv8_n18	0.0	0	0
hirs3bufr	hirs3	n17	hirs3_n17	0.0	1	0

-> assimilate tcvitals MSLP data

Observations not listed here will not be assimilated

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	pmot	ptime	
tcp	112	0	1	3.0	0	0	0	75.0	5.0	1.0	75.0	0.000000	0	0.	0.	0	0.	0.	-> tcvital MSLP
ps	111	0	-1	3.0	0	0	0	5.0	3.0	1.0	5.0	0.000	0	0.	0.	0	0.	0.	
ps	120	0	1	3.0	0	0	0	4.0	3.0	1.0	4.0	0.000300	0	0.	0.	0	0.	0.	
ps	132	0	-1	3.0	0	0	0	4.0	3.0	1.0	4.0	0.000300	0	0.	0.	0	0.	0.	

- satinfo (for satellite data)

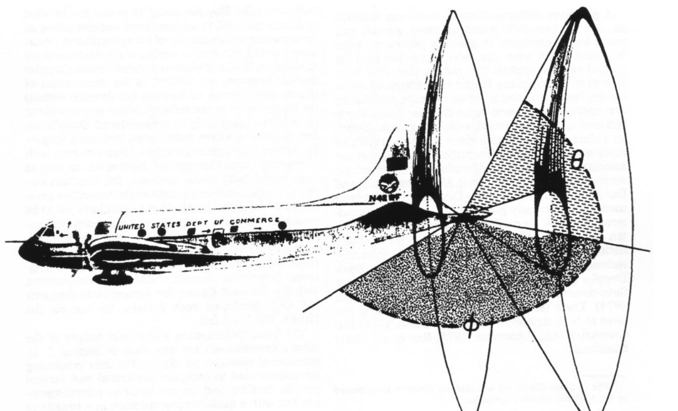
sensor/instr/sat	chan	**iuse**	error	ermax	var_b	var_pg
amsua_n15	1	1	3.000	4.500	10.00	0.000
amsua_n15	2	1	2.000	4.500	10.00	0.000
amsua_n15	3	1	2.000	4.500	10.00	0.000
amsua_n15	4	1	0.600	2.500	10.00	0.000
amsua_n15	5	1	0.300	2.000	10.00	0.000
amsua_n15	6	1	0.230	2.000	10.00	0.000

Conventional Data Pre-processing

Control through hwrf.conf

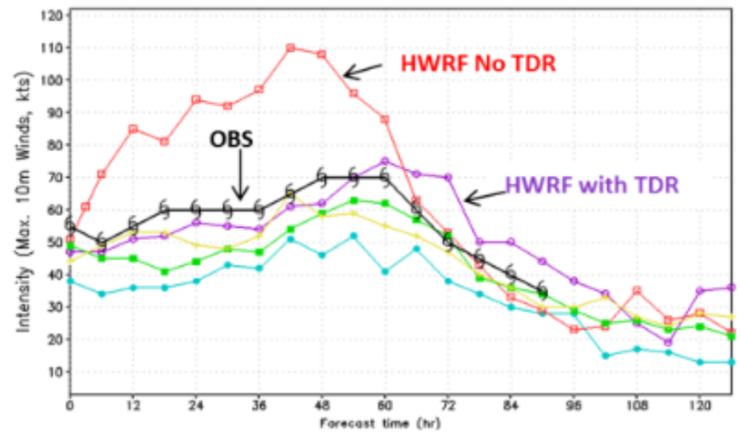
```
[bufrprep]
## options to preprocess prepbufr file
#
# 0: make no change
# 1: remove some inner-core data
# 2: flag/unflag mass and dropsonde u, v data
# 3: unflag HS3/Global Hawk dropsonde data (assimilate HS3 dropsonde in FY15 HWRF)
prepbufrprep=3 ;; parameter used to preprocess prepbufr file
## parameter used to define an area where inner-core data are removed/(un)flagged
#
# radius of a circle centered at TC center
# > 0. remove conventional data, when prepbufrprep=1
#      flag dropsonde wind data, when prepbufrprep=2
# < 0. unflag dropsonde wind data, when prepbufrprep=2
# = 0. no change for dropsonde wind data, when prepbufrprep=2
RRADC=50.
## parameter used to define a square area to flag pressure data
#
# half side length of a squre centered at TC center
# > 0. flag pressure data, when prepbufrprep=2
# <= 0. no change, when prepbufrprep=2
RBLDC=-200.
```

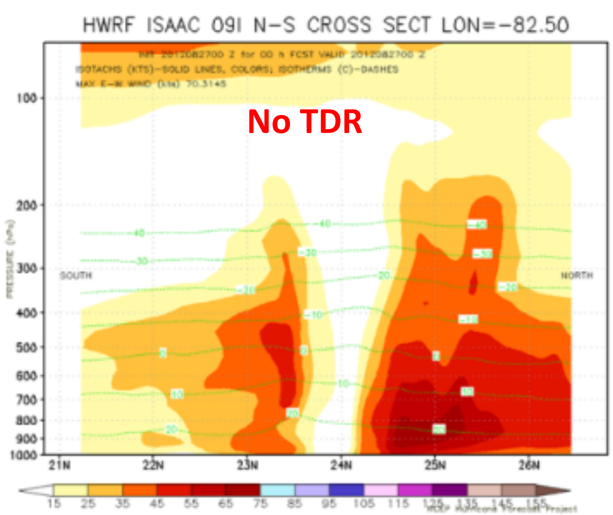
Assimilation of NOAA P3 TDR data

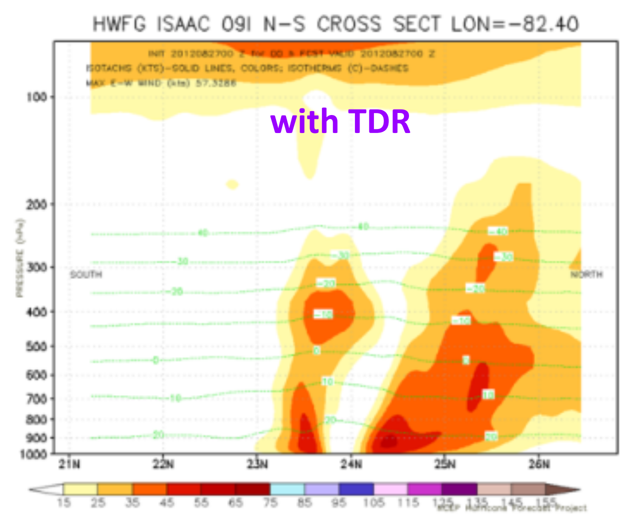


Jorgensen *et al.*, 1983, *J. Climate Appl. Meteor*, 22, 744-757

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.







TDR Data Assimilation

parm/hwrf.conf:

[gsi_d02]/[gsi_d03]

obstypes = hdob_obstype,sat_radiance_obstypes,sat_wnd_obstype,**tdr_new_obstype**

parm/hwrf_gsi.nml

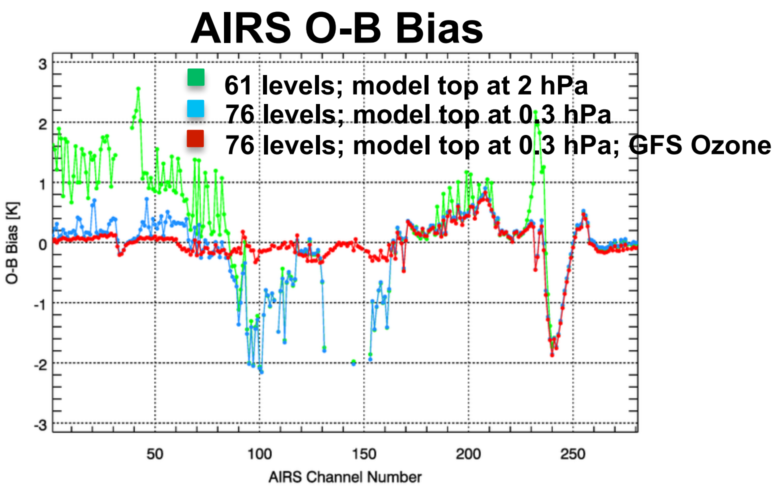
OBS_INPUT::

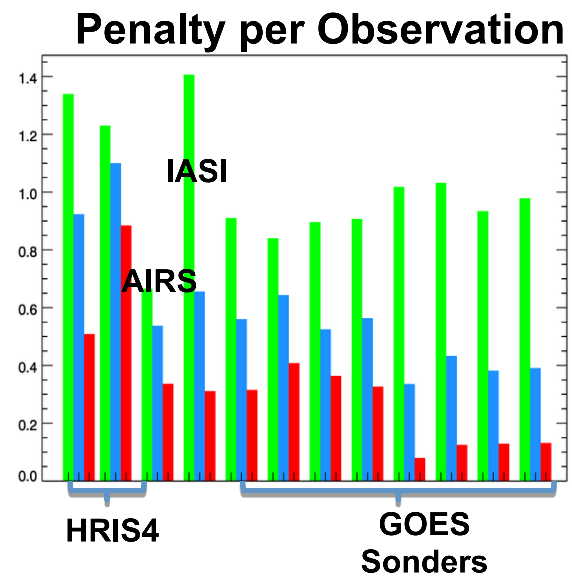
```
! dfile        dtype     dplat  dsis          dval dthin dsfcalc
  prepbufr     sst       null   sst            0.0    0     0
  tcvitl       tcp       null   tcp            0.0    0     0
  <s:tdrtype>  rw        null   rw             0.0    0     0
```

GSI fix file – hwrf.convinfo

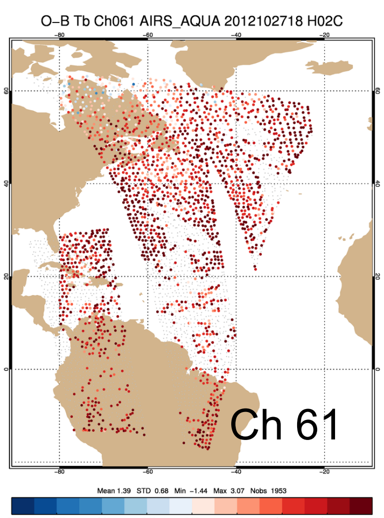
```
!otype  type  sub iuse twindow numgrp ngroup nmiter gross ermax ermin var_b   var_pg ithin  rmesh  pmesh  npred  pmot  ptime
……
t      134   0   1    3.0     0     0     0   7.0   5.6   1.3   7.0  0.004000    0   0.    0.    0   0.    0.
……
rw     999   0  -1    2.5     0     0     0  10.0  10.0   2.0  10.0  0.000000    0   0.    0.    0   0.    0.
rw     990   0   1    3.0     0     0     0   5.0  10.0   2.0  10.0  0.000000    1   9.    0.    0   0.    0. -> P3
rw     991   0   1    3.0     0     0     0   5.0  10.0   2.0  10.0  0.000000    1   9.    0.    0   0.    0. -> P3
rw     992   0  -1    3.0     0     0     0   5.0  10.0   2.0  10.0  0.000000    1   9.    0.    0   0.    0. -> G-IV
rw     993   0   1    3.0     0     0     0   5.0  10.0   2.0  10.0  0.000000    1   9.    0.    0   0.    0. -> P3
```

Assimilation of satellite radiance observations

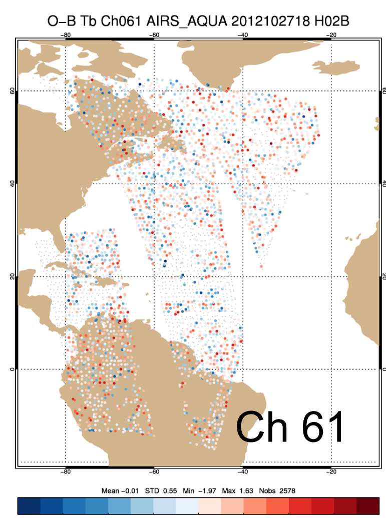




61 levels; model top at 2 hPa



76 levels; model top at 0.3 hPa; GFS Ozone



- Use GFS ozone
- Use bias correction coefficients from GDAS

Benefit of blended vertical coordinate and GFS ozone in the analysis:

- AIRS biases are greatly reduced when blended vertical coordinate and GFS ozone are used in the analysis
- Cost function for IR instruments reduced more than 50%

Emily Liu, David Parrish, Yanqiu Zhu

Satellite Data Assimilation

parm/hwrf.conf

[gsi_d02]/[gsi_d03]

sat_wnd_da = no ;; Enable assimiation of **satellite wind**?

sat_radiance_da = no ;; Enable satellite **radiance** data assimilation?

use_newradbc=yes ;; Use new bias correction data for 2015 GFS and later

use_gfs_stratosphere = yes ;; Use **blended global-regional vertical coordinate** for satellite radiance DA

obstypes = hdob_obstype,**sat_radiance_obstypes**,**sat_wnd_obstype**,tdr_new_obstype

GSI fix file - anavinfo

use_gfs_stratosphere = yes -> fix/hwrf-gsi/anavinfo_hwrf_L75

(analysis grid has 75 vertical levels – blended global-regional coordinate)

= no -> fix/hwrf-gsi/anavinfo_hwrf_L60

(analysis grid has 60 vertical levels – model grid)

- More information about GSI can be found from documentations and tutorial slides at DTC GSI webpage

http://www.dtcenter.org/com-GSI/users/