Observation Pre-processing for WRFDA

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NCAR/MMM

WRFDA tutorial
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- What types of observations?
- Where to download observations?
- What does WRFDA's OBSPROC (OBServation PROCessor) do?
- How to run OBSPROC?
- Observation quality control
- Formats

WRFDA-3DVar Cost Function

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x}-\mathbf{x_b})^{\mathrm{T}}\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x_b}) + \frac{1}{2}(\mathbf{y}-H(\mathbf{x}))^{\mathrm{T}}\mathbf{R}^{-1}(\mathbf{y}-H(\mathbf{x}))$$

$$J = \frac{1}{2}\delta\mathbf{x}^{T}\mathbf{B}^{-1}\delta\mathbf{x} + \frac{1}{2}(\mathbf{d}-\mathbf{H}\delta\mathbf{x})^{T}\mathbf{R}^{-1}(\mathbf{d}-\mathbf{H}\delta\mathbf{x}) \qquad \mathbf{d} = \mathbf{y} - H(\mathbf{x}^{\mathbf{g}})$$

J(x): Scalar cost function

x: The analysis

x_b: Background field

B: Background error covariance matrix

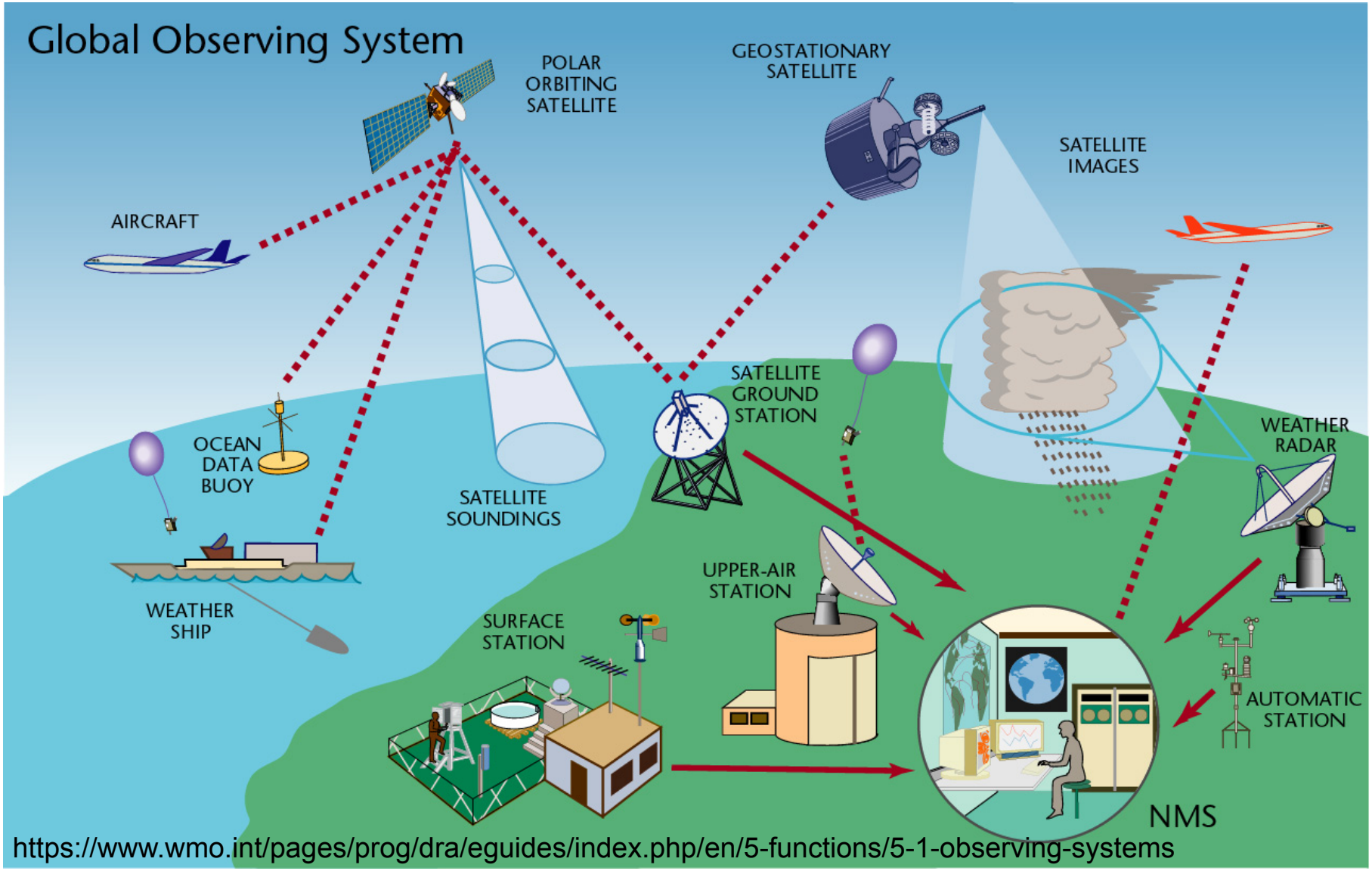
y: Observations

H: Observation operator

R: Observation error covariance matrix

y and **R** are discussed in this presentation

Data assimilation: **Observations** are used to make small corrections to a short-range forecast (**background**), which is assumed to be good, to produce a model **analysis**.



- ✓ Observation information is exchanged and distributed through the Global Telecommunication System (GTS)
- ✓ The format is being migrated from Traditional Alphanumeric Codes (TAC) to BUFR (Binary Universal Form for the Representation of meteorological data), Table-Driven Code Forms (TDCF)

Space-based Global Observing System

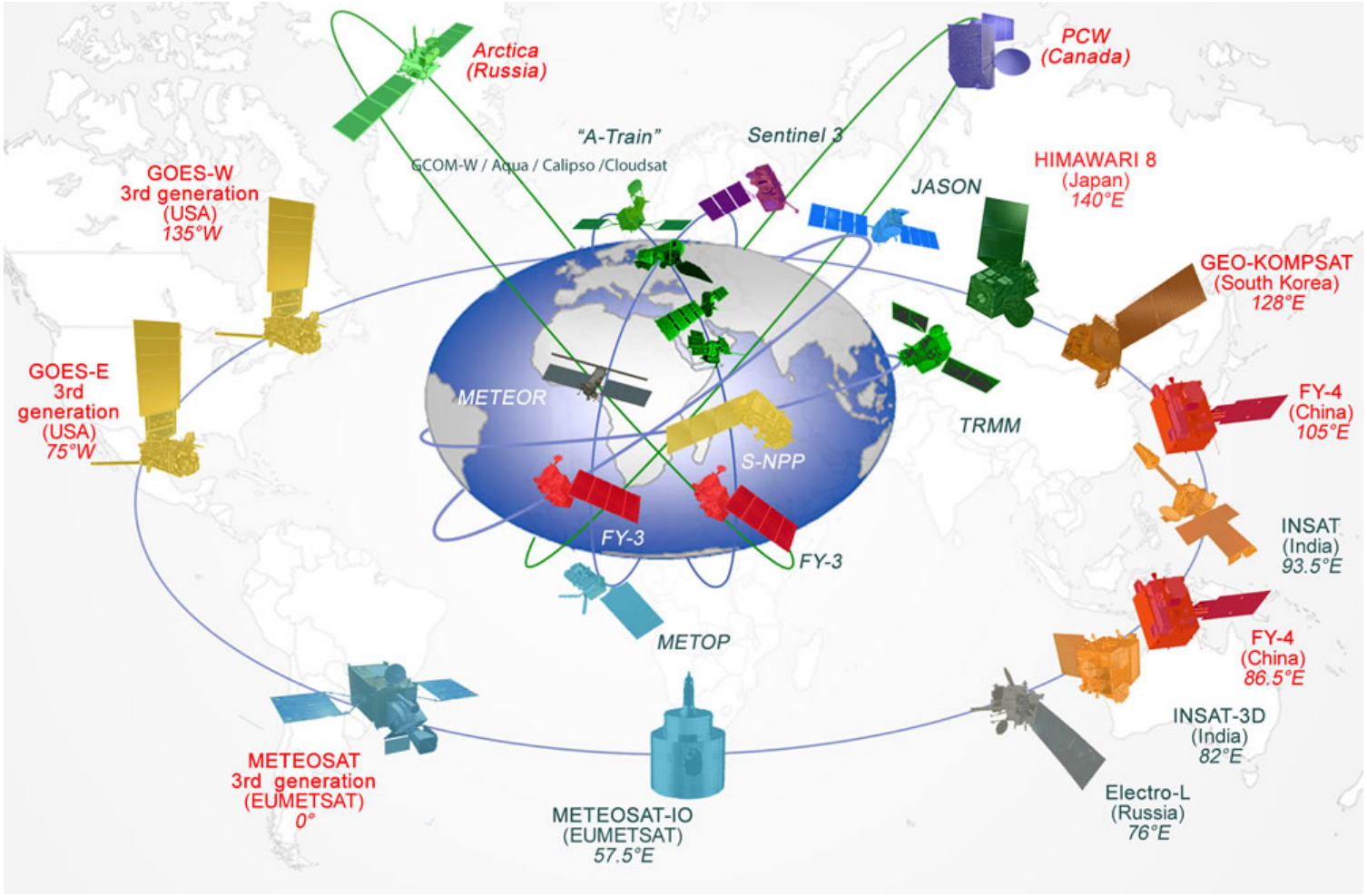
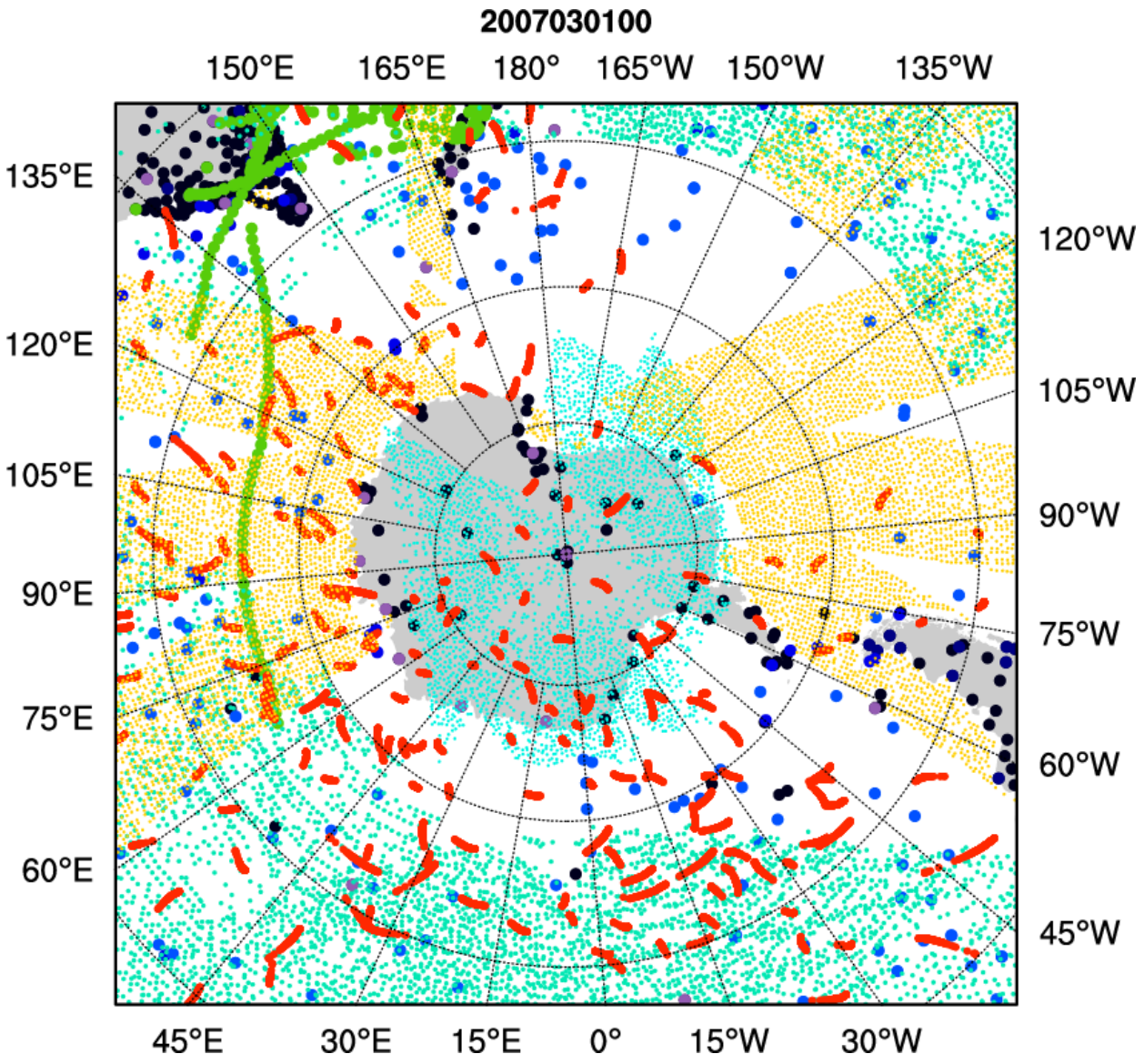


Image credit: WMO Space Programme

check out this page for the status of current and future satellites
http://www.wmo.int/pages/prog/sat/satellitestatus.php

Observation snapshot of a 6-hour time window



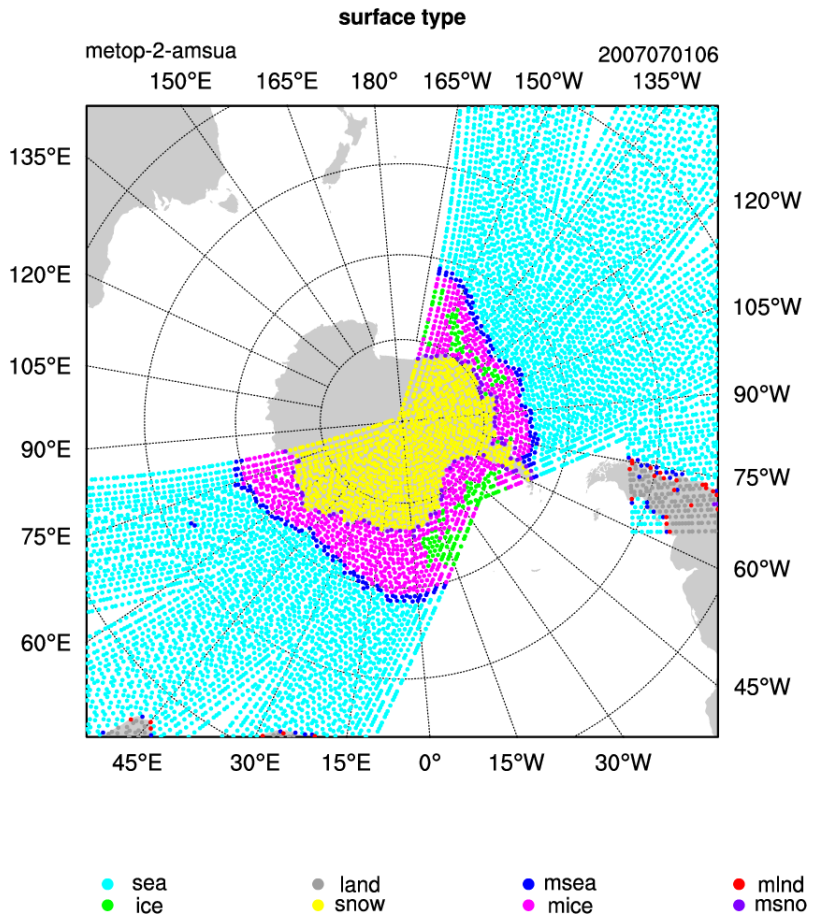
Surface

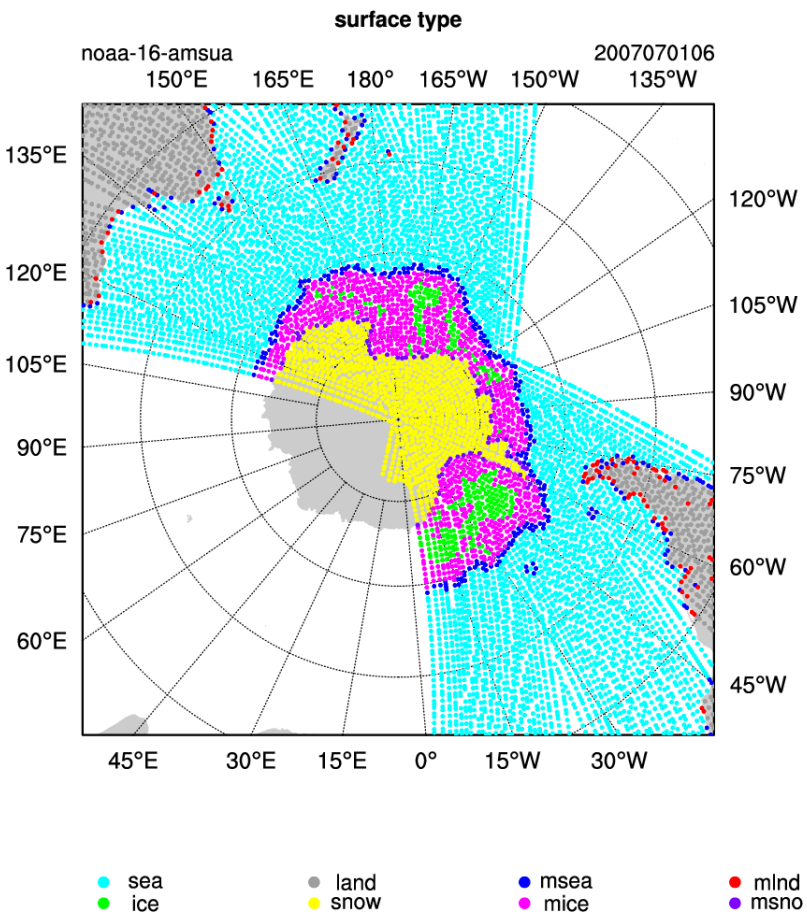
- SYNOP
- METAR
- BUOY
- SHIPS
- QuikSCAT winds

Upper-Air/ multiple levels

- SOUND
- geo AMV
- polar AMV
- GPS refractivity
- AIREP

Sample satellite radiances coverage of a 6-hour time window





* colors indicate model surface types

NOAA-16 was DECOMMISSIONED on 9 June 2014

More about radiance data will be covered in a separate talk about radiance data assimilation

WRFDA can assimilate …

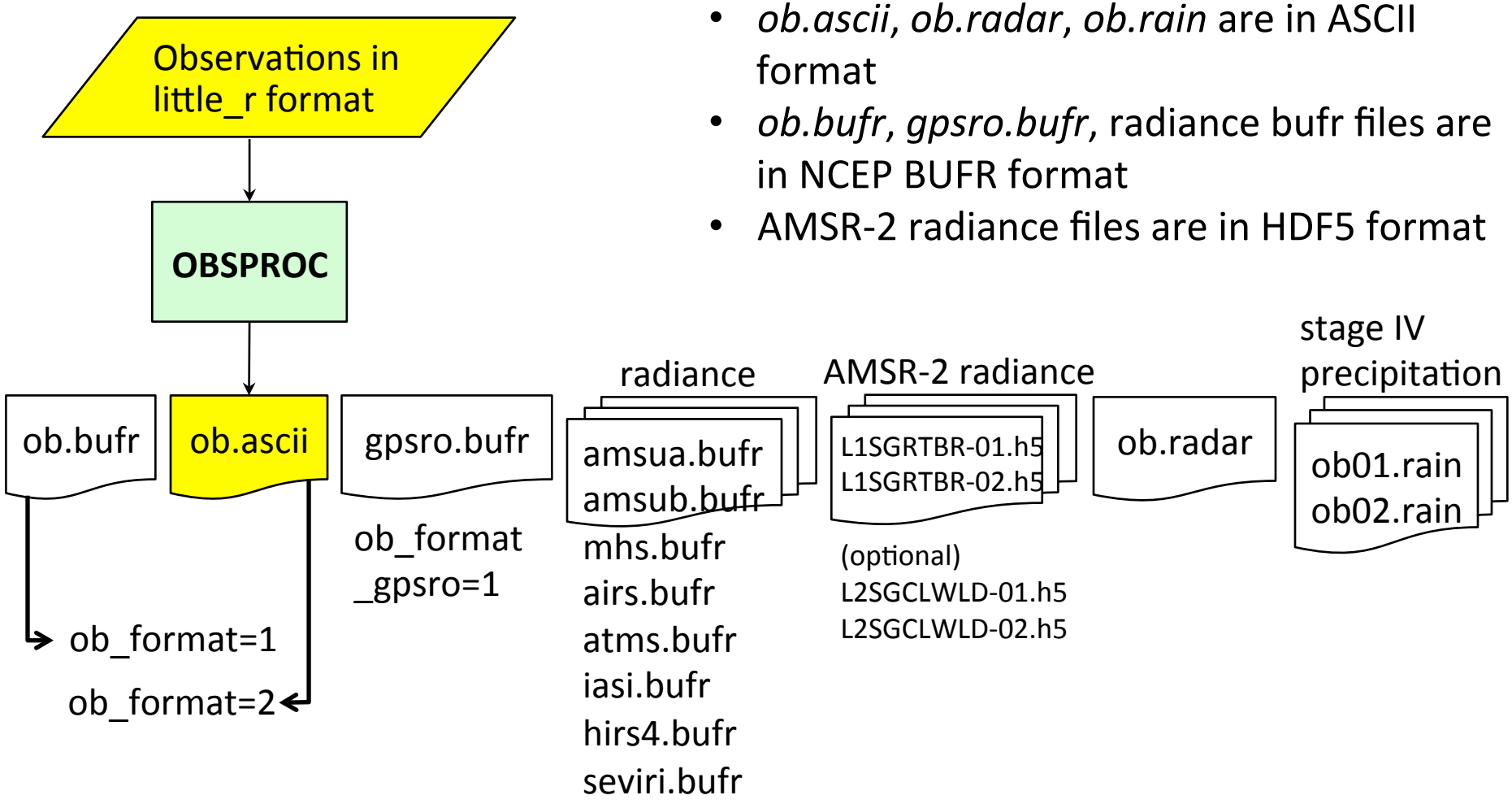
- **In-Situ conventional observations**:
  - Surface (SYNOP, METAR, SHIP, BUOY)
  - Upper air (TEMP, PIBAL, AIREP, ACARS, AMDAR, TAMDAR)

- **Remotely sensed observations**:
  - Atmospheric Motion Vectors (geo/polar) (SATOB)
  - SATEM thickness
  - Ground-based GPS Total Precipitable Water/Zenith Total Delay (GPSPW/GPSZD)
  - SSM/I oceanic surface wind speed and TPW
  - Scatterometer oceanic surface winds (QSCAT)
  - Wind profiler (PROFL)
  - Radar radial velocities and reflectivity
  - Satellite temperature/humidity/thickness profiles (AIRSR)
  - GPS refractivity (GPSRF/GPSEP)
  - Stage IV precipitation data/rain rate (only in 4DVAR mode)

QuikSCAT/SeaWinds – **ended in Nov 2009**
ASCAT (METOP-A)
ASCAT (METOP-B)
ASCAT (EARS)
OSCAT (Oceansat-2) –**ceased in April 2014**
WindSAT

- **Radiances** (using RTTOV or CRTM):
  - HIRS NOAA-16, NOAA-17, NOAA-18, NOAA-19, METOP-A, METOP-B
  - AMSU-A NOAA-15, NOAA-16, NOAA-18, NOAA-19, EOS-Aqua, METOP-A, METOP-B
  - AMSU-B NOAA-15, NOAA-16, NOAA-17
  - MHS NOAA-18, NOAA-19, METOP-A, METOP-B
  - AIRS EOS-Aqua
  - SSMIS DMSP-16, DMSP-17, DMSP-18
  - IASI METOP-A, METOP-B
  - ATMS Suomi-NPP
  - MWTS FY-3
  - MWHS FY-3
  - SEVIRI METEOSAT-8, METEOSAT-9, METEOSAT-10
  - AMSR-2 GCOM-W1

WRFDA can read in …



- *ob.ascii*, *ob.radar*, *ob.rain* are in ASCII format
- *ob.bufr*, *gpsro.bufr*, radiance bufr files are in NCEP BUFR format
- AMSR-2 radiance files are in HDF5 format

ob.radar

- In simple ASCII format

  Header record for Radar site information (site, lat0, lon0, elv etc)

  Header record for observation location (FM-128 RADAR, date, lat, lon, elv, levs)

  Data-level record (height<m>, Radial_V<m/s>, qc, err, Reflectivity<dbz>, qc, err)

- Preprocessing Doppler radar data is an important procedure before assimilation
  - ✓ Quality control
    - de-aliasing (folded velocity)
    - removal of clutters, second-trip echo, anomalously propagated clutter, and other noises
  - ✓ Mapping
    - Interpolation, smoothing, super-obing, data filling
  - ✓ Error statistics
    - Variance and covariance

- However, there is no standard radar data processing software included in WRFDA

  Contact Juanzhen (Jenny) Sun (sunj@ucar.edu) for collaboration

NCEP operational observation files in **BUFR** format can be directly used in WRFDA

- NCEP real-time data
  http://www.ftp.ncep.noaa.gov/data/nccf/com/gfs/prod

- NOAA National Operational Model Archive and Distribution System (NOMADS) archive
  http://nomads.ncep.noaa.gov/pub/data/nccf/com/gfs/prod/
  http://nomads.ncdc.noaa.gov/data/gdas

- NCAR CISL archive
  http://rda.ucar.edu/datasets/ds337.0 – for conventional data
  http://rda.ucar.edu/datasets/ds735.0 – for radiance data
  http://rda.ucar.edu/datasets/ds099.0 – data used in NCEP Climate Forecast System Reanalysis

- NCAR HPSS personal archive (requires NCAR HPC account)
  hsi:/LIUZ/GDAS/yyyymm/yyyymmddhh

Files to look for

gdas1.thhz.1bamua.tm00.bufr_d
gdas1.thhz.1bamub.tm00.bufr_d
gdas1.thhz.1bhrs3.tm00.bufr_d
gdas1.thhz.1bhrs4.tm00.bufr_d
gdas1.thhz.1bmhs.tm00.bufr_d
gdas1.thhz.airsev.tm00.bufr_d
gdas1.thhz.atms.tm00.bufr_d
gdas1.thhz.mtiasi.tm00.bufr_d
gdas1.thhz.sevcsr.tm00.bufr_d

} radiances

amsua.bufr
amsub.bufr
hirs4.bufr
mhs.bufr
airs.bufr
atms.bufr
iasi.bufr
seviri.bufr

gdas1.thhz.gpsro.tm00.bufr_d → gpsro.bufr

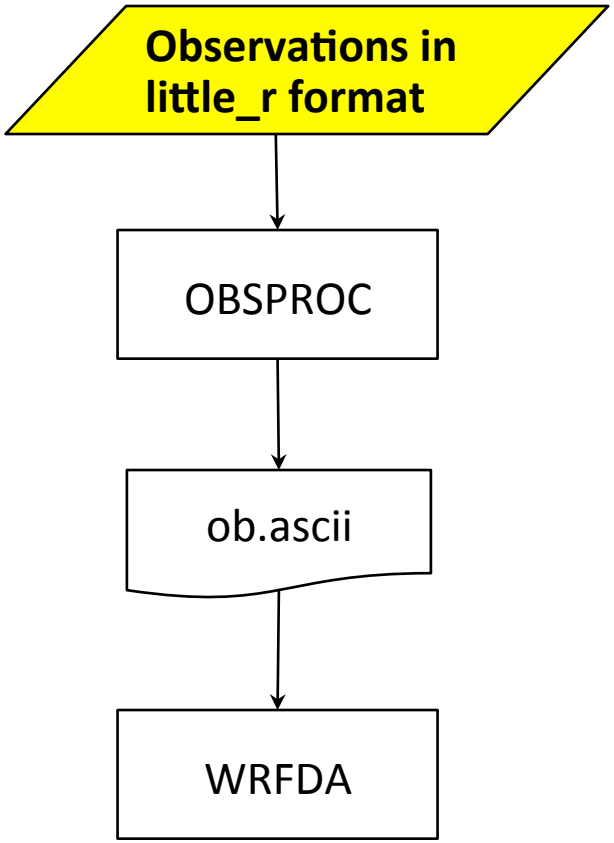
gdas1.thhz.**prepbufr**.nr → ob.bufr

hh is the analysis time: 00/06/12/18

- About NCEP BUFR format
  http://www.nco.ncep.noaa.gov/sib/decoders/BUFRLIB
  http://www.nco.ncep.noaa.gov/sib/decoders/BUFRLIB/toc/prepbufr

- About NCEP PREPBUFR (prepared BUFR, **quality controlled**) data processing
  http://www.emc.ncep.noaa.gov/mmb/data_processing/prepbufr.doc/document.htm

- Notes on using PREPBUFR in WRFDA
  https://wiki.ucar.edu/display/~hclin/prepbufr2wrfvar

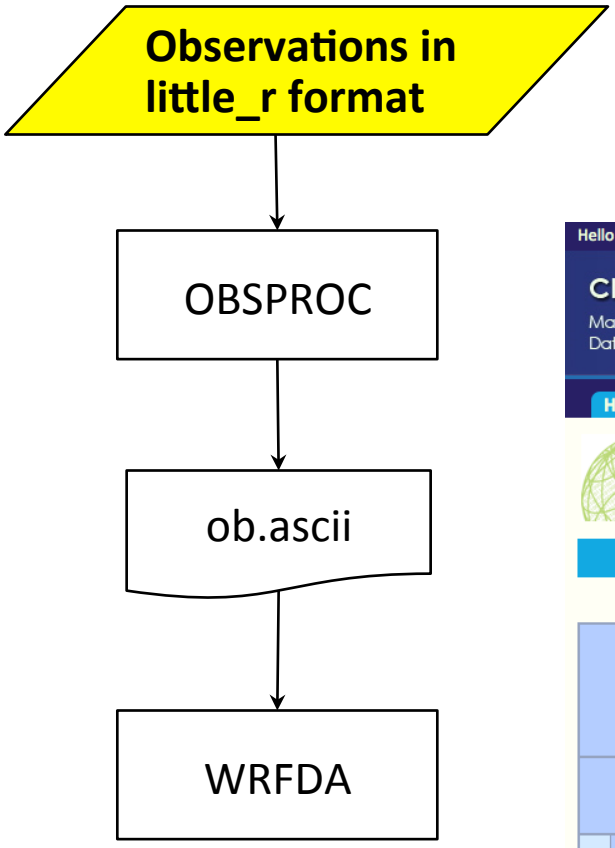


NCAR/MMM archived observations in little_r format on HPSS (requires NCAR HPC account)

hsi:/BRESCH/RT/DATA/yyyymm/obs.yyyymmddhh.gz

- Radiosondes: TTAA, TTBB, PPBB, etc.
- Surface obs: SYNOPS, METARS, AWS, ships, buoys, CMAN
- Profiler
- Sat winds: GOES, METSAT, MODIS, AVHRR
- Satem
- Aircraft: PIREPS, AIREPS, AMDAR, ACARS
- Dropsondes and "hurricane hunter" obs
- Quikscat
- Ground-based GPS PW
- GPS refractivity (COSMIC only)

Check out the notes about the data
http://www2.mmm.ucar.edu/people/bresch/data



NCAR/CISL archived observations in little_r format

http://rda.ucar.edu/datasets/**ds351.0**/?hash=!access

http://rda.ucar.edu/datasets/**ds461.0**/?hash=!access

Hello hclin@ucar.edu my profile my data requests sign out

CISL Research Data Archive

Managed by NCAR's Data Support Section
Data for Atmospheric and Geosciences Research

RDA

Go to Dataset: nnn.n

Home | Find Data | Ancillary Services | About/Contact | Data Citation | Web Services | For Staff

NCEP ADP Global Upper Air Observational Weather Data, October 1999 - continuing

ds351.0

For assistance, contact Grace Peng (303-497-1218).

Description | Data Access | Documentation | Software

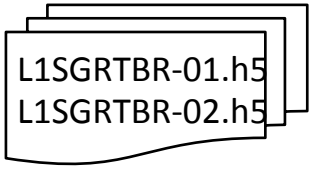
Mouse over the table headings for detailed descriptions

	Data Description	Data File Downloads	Customizable Data Requests	NCAR-Only Access	
		Web Server Holdings	Subsetting	Central File System (GLADE) Holdings	Tape Archive (HPSS) Holdings
	Union of Available Products	Web File Listing		GLADE File Listing	HPSS File Listing
PRODUCTS	GDAS Upper Air Observations (daily tar files)	Web File Listing	Get a Subset	GLADE File Listing	HPSS File Listing
PRODUCTS	GDAS ADPUPA Upper Air Observations (sonde data only)	Web File Listing		GLADE File Listing	
PRODUCTS	GDAS Upper Air Observations (synoptic BUFR files)			GLADE File Listing	
PRODUCTS	GDAS Upper Air Observations (little_r format) for use with MM5 and WRF data ingest software	Web File Listing		GLADE File Listing	

http://gcom-w1.jaxa.jp

http://suzaku.eorc.jaxa.jp/GCOM_W/data/data_w_index.html

AMSR-2 radiance



GW1AM2_201210271433_082A_**L1SGRTBR**_1110110.h5

(optional)
L2SGCLWLD-01.h5
L2SGCLWLD-02.h5

GW1AM2_201210271433_082A_**L2SGCLWLD**1100100.h5

WRFDA reads AMSR-2 **Level 1R** Brightness Temperature (L1SGRTBR)

WRFDA can read AMSR-2 Level 2 CLW (Integrated Cloud Liquid Water) product (L2SGCLWLD) for quality control purpose

The naming rules of the above GW1AM2 files are described in Figure 5 of http://suzaku.eorc.jaxa.jp/GCOM_W/data/doc/amsr2_data_user_guide.pdf

- Other data sources that require additional converters

  - MADIS
    http://www2.mmm.ucar.edu/wrf/users/wrfda/download/madis.html
    http://madis.noaa.gov/

  - GPS refractivity
    http://cdaac-www.cosmic.ucar.edu/cdaac/products.html

  - AIRS Retrieval
    http://disc.gsfc.nasa.gov/ (requires registration to get data)
    http://disc.sci.gsfc.nasa.gov/uui/datasets/**AIRX2RET**_NRT_V006/summary?AIRX2RET_NRT
    http://disc.sci.gsfc.nasa.gov/uui/datasets/**AIRX2RET**_V006/summary?keywords="AIRS"

  - Scatterometer surface winds
    http://www.knmi.nl/scatterometer

  - Stage IV precipitation
    http://data.eol.ucar.edu/codiac/dss/id=21.093

- **What is little_r format?**

  A format used by MM5/Little_r objective analysis program, a successor of **R**AWINS

  Little_r format is also used by WRF/OBSGRID objective analysis program

- **What does OBSPROC do?**

  Ingest multiple types of observations that are converted to little_r format and concatenated to one file, process the observation data and output the ASCII file(s) suitable for WRFDA needs − 3DVAR, FGAT (**F**irst **G**uess at **A**ppropriate **T**ime), 4DVAR

- **What is in ob.ascii (output of OBSPROC/input to WRFDA)?**

OBSPROC output name

WRFDA input name

obs_gts_yyyy-mm-dd_hh:00:00.3DVAR (**ob.ascii**)

```
TOTAL =  29596, MISS. =-888888.,
SYNOP =    463, METAR =    156, SHIP  =     25, BUOY  =     54, BOGUS =      0, TEMP  =     31,
AMDAR =    501, AIREP =     78, TAMDAR=      0, PILOT =     31, SATEM =      0, SATOB =   9318,
GPSPW =      0, GPSZD =      0, GPSRF =     49, GPSEP =      0, SSMT1 =      0, SSMT2 =      0,
TOVS  =      0, QSCAT =  18890, PROFL =      0, AIRSR =      0, OTHER =      0,
PHIC  = -87.40, XLONC = 180.00, TRUE1 = -71.00, TRUE2 = -91.00, XIM11 =   1.00, XJM11 =   1.00,
base_temp= 268.00, base_lapse=  50.00, PTOP  =  1000., base_pres=100000., base_tropo_pres= 20000., base_strat_temp=   215.,
IXC   =    217, JXC   =    165, IPROJ =      2, IDD   =      1, MAXNES=      1,
NESTIX=    217,
NESTJX=    165,
NUMC  =      1,
DIS   =  60.00,
NESTI =      1,
NESTJ =      1,
INFO  = PLATFORM, DATE, NAME, LEVELS, LATITUDE, LONGITUDE, ELEVATION, ID.
SRFC  = SLP, PW (DATA,QC,ERROR).
EACH  = PRES, SPEED, DIR, HEIGHT, TEMP, DEW PT, HUMID (DATA,QC,ERROR)*LEVELS.
INFO_FMT = (A12,1X,A19,1X,A40,1X,I6,3(F12.3,11X),6X,A40)
SRFC_FMT = (F12.3,I4,F7.2,F12.3,I4,F7.3)
EACH_FMT = (3(F12.3,I4,F7.2),11X,3(F12.3,I4,F7.2),11X,3(F12.3,I4,F7.2))
#------------------------------------------------------------------------------#
FM-18 BUOY    2008-10-31_21:00:00 Platform Id >>> 55956                    1      -41.973                -166.164                  0.000                  55956
  101090.000   0 200.00 -888888.000 -88  0.200
  101090.000   0 100.00 -888888.000 -88   1.40 -888888.000 -88   5.00          0.000   0   6.00 -888888.000 -88   2.00 -888888.000 -88   2.00          -888888.000 -88  10.00
FM-35 TEMP    2008-10-31_21:00:00 CHATHAM ISLAND / NEW ZEALAND              19      -43.950                -176.560                 48.000                  93986
 -888888.000 -88 200.00 -888888.000 -88  0.200
  100400.000   0 100.00       7.202   0   1.40     330.000   0   5.00         48.000   0   7.00     284.348   1   1.80     279.848   1   1.80              73.609   1  10.00
  100000.000   0 100.00 -888888.000 -88   1.40 -888888.000 -88   5.00         83.000   0   7.00     284.024 -10   1.80     279.024 -10   1.80              71.046 -10  10.00
   99800.000   0  99.82 -888888.000 -88   1.41 -888888.000 -88   5.00        100.000   3   7.01     283.861   1   1.80     277.861   1   1.80              66.222   1  10.00
   92700.000   0  93.36 -888888.000 -88   1.64 -888888.000 -88   5.00        707.000   3   7.21     277.935   1   1.69     275.935   1   1.69              86.823   1  10.00
   92500.000   0  93.18 -888888.000 -88   1.65 -888888.000 -88   5.00        724.000   0   7.22     277.763   1   1.69     275.563   1   1.69              85.579   1  10.00
   91400.000   0  92.17 -888888.000 -88   1.69 -888888.000 -88   5.00        822.000   3   7.25     277.150   0   1.67     272.250   0   1.67              70.338   0  10.00
   90300.000   0  91.17 -888888.000 -88   1.72 -888888.000 -88   5.00        920.000   3   7.29     277.750   0   1.66     258.750   0   1.66              23.873   0  10.00
   85000.000   0  86.35 -888888.000 -88   1.90 -888888.000 -88   5.00       1410.000   0   7.46     275.750   0   1.57     263.750   0   1.57              40.903   0  10.00
   84600.000   0  85.99 -888888.000 -88   1.91 -888888.000 -88   5.00       1449.000   3   7.47     275.350   0   1.57     263.350   0   1.57              40.794   0  10.00
   78300.000   0  80.25 -888888.000 -88   2.12 -888888.000 -88   5.00       2072.000   3   7.69     273.550   0   1.46     249.550   0   1.46              14.884   0  10.00
   70000.000   0  72.70 -888888.000 -88   2.40 -888888.000 -88   5.00       2964.000   0   8.00     270.050   0   1.30     256.050   0   1.30              33.387   0  10.00
   69000.000   0  71.79 -888888.000 -88   2.42 -888888.000 -88   5.00       3078.000   3   8.03     269.450   0   1.30     256.450   0   1.30              36.084   0  10.00
   65700.000   0  68.79 -888888.000 -88   2.49 -888888.000 -88   5.00       3463.000   3   8.11     267.250   0   1.30     247.250   0   1.30              19.399   0  10.00
   64000.000   0  67.24 -888888.000 -88   2.52 -888888.000 -88   5.00       3669.000   3   8.16     267.450   0   1.30     228.450   0   1.30               3.148   0  10.00
   57700.000   0  61.51 -888888.000 -88   2.65 -888888.000 -88   5.00       4471.000   3   8.34     261.850   0   1.30     247.850   0   1.30              31.074   0  10.00
   56400.000   0  60.32 -888888.000 -88   2.67 -888888.000 -88   5.00       4646.000   3   8.39     262.050   0   1.30     239.050   0   1.30              13.679   0  10.00
   50100.000   0  54.59 -888888.000 -88   2.80 -888888.000 -88   5.00       5545.000   3   8.60     256.650   0   1.30     241.650   0   1.30              26.971   0  10.00
   50000.000   0  54.50 -888888.000 -88   2.80 -888888.000 -88   5.00       5560.000   0   8.60     256.650   0   1.30 -888888.000 -11   1.30          -888888.000 -11  10.00
   49700.000   0  54.23 -888888.000 -88   2.81 -888888.000 -88   5.00       5606.000   3   8.72     256.650   0   1.31 -888888.000 -11   1.31          -888888.000 -11  10.00
```

ob numbers

domain information

Header

✓ content not used in WRFDA

Data format

observation errors

How WRFDA categorizes observations

http://www.wmo.int/pages/prog/www/**WMOCodes**/WMO306_vI1/Publications/2014update/Sel2.pdf

Name	WMO code/ Platform ID	WMO code name
SYNOP	12, 14	SYNOP, SYNOP MOBIL
SHIP	13, 17	SHIP
BUOY	18	BUOY
METAR	15, 16	METAR, SPECI
PILOT	32, 33, 34	PILOT, PILOT SHIP, PILOT MOBIL
TEMP	35, 36, 37, 38	TEMP, TEMP SHIP, TEMP DROP, TEMP MOBIL
AMDAR	42	AMDAR
SATEM	86	SATEM
SATOB	88	SATOB
AIREP	96, 97	AIREP
TAMDAR	101	TAMDAR
GPSPW	111	GPSPW (Ground-based GPS precipitable water)
GPSZD	114	GPSZD (Ground-based GPS Zenith Total Delay)
GPSRF	116	GPSRF (Space-based GPS Refractivity)
PROFL	132	WIND PROFILER
AIRSR	133	AIRSRET
BOGUS	135	TCBOU (Typhoon bogus), BOGUS (other bogus)
QSCAT	281	Quik SCAT level-2B SeaWind

made-up code

WRFDA combines AMDAR and AIREP as AIREP

WRFDA separates SATOB as geoamv and polaramv

In WRFDA, each observation type is identified by its platform ID

Quality flags assigned by obsproc

```
missing_data            = -88,      ! Data is missing with the value of missing_r
outside_of_domain       = -77,      ! Data outside horizontal domain or time window, data
                                    ! set to missing_r
wrong_direction         = -15,      ! Wind vector direction <0 or> 360 => direction set to
                                    ! missing_r
negative_spd            = -14,      ! Wind vector norm is negative => norm set to missing_r
zero_spd                = -13,      ! Wind vector norm is zero => norm set to missing_r
wrong_wind_data         = -12,      ! Spike in wind profile =>direction and norm set to
                                    ! missing_r
zero_t_td               = -11,      ! t or td = 0 => t or td, rh and qv are set to missing_r
t_fail_supa_inver       = -10,      ! super-adiabatic temperature
wrong_t_sign            = - 9,      ! Spike in Temperature profile
above_model_lid         = - 8,      ! height above model lid => no action
far_below_model_surface = - 7,      ! height far below model surface => no action
below_model_surface     = - 6,      ! height below model surface => no action
standard_atmosphere     = - 5,      ! Missing h, p or t =>Datum interpolated from standard
                                    ! atmosphere
from_background         = - 4,      ! Missing h, p or t =>Datum interpolated from model
fails_error_max         = - 3,      ! Datum Fails error max check => no action
fails_buddy_check       = - 2,      ! Datum Fails buddy check => no action
no_buddies              = - 1,      ! Datum has no buddies => no action
good_quality            =   0,      ! OBS datum has good quality
convective_adjustment   =   1,      ! convective adjustment check =>apply correction on t,
                                    ! td, rh and qv
surface_correction      =   2,      ! Surface datum => apply correction on datum
Hydrostatic_recover     =   3,      ! Height from hydrostatic assumption with the OBS data
                                    ! calibration
Reference_OBS_recover   =   4,      ! Height from reference state with OBS data calibration
Other_check             =  88,      ! passed other quality check
```

data with quality flags >= 0 will be used in WRFDA

Observation re-formatting and conversion

Sample METAR report from GTS

```
METAR KDEN 071553Z 15016G22KT 3SM HZ FEW060 SCT120 BKN150 19/11 A3019
```

Sample SYNOP report from GTS

```
AAXX 07154 72565 31748 61616 10172 20111 38392 40167 58002 705// 91453 333 91022 555 90715
```

<u>variables in ob.ascii</u>

- wind speed
- wind direction
- sea level pressure
- pressure
- height
- temperature
- dew point temperature
- relative humidity
- total precipitable water
- **GPS refractivity**
- **SATEM thickness**

non-conventional observations got stuck to formats originally designed for conventional data

<u>state variables in WRFDA</u>

- x-component wind u (relative to model grid)
- y-component wind v (relative to model grid)
- temperature
- specific humidity
- surface pressure
- pressure

A few things to bear in mind when dealing with observations

- What are observed and contained in the original observation reports
- What are the variable definitions in little_r, ob.ascii, ob.bufr files
- What variables are used in WRFDA

WRFDA code that reads in observations

- `ob.ascii`
  `var/da/da_obs_io/da_scan_obs_ascii.inc`
  `var/da/da_obs_io/da_read_obs_ascii.inc`

- `ob.bufr`
  `var/da/da_obs_io/da_read_obs_bufr.inc`

- `gpsro.bufr`
  `var/da/da_obs_io/da_read_obs_bufrgpsro.inc`

- `ob.rain`
  `var/da/da_obs_io/da_read_obs_rain.inc`

- `ob.radar`
  `var/da/da_obs_io/da_read_obs_radar.inc`

- `radiances`
  `var/da/da_radiance/da_read_obs_*.inc`

The places where the exact Fortran statements can be found for the format.

What does OBSPROC do?

- domain checks
- time checks and binning
- sort and merge duplicate reports
- assign observation errors
- gross check
- vertical consistency check and adiabatic check
- data completeness check
- assign quality flags
- thinning for SATOB and QSCAT
- write out files in ASCII format as the WRFDA input

- ✓ Model meteorological fields are NOT used in OBSPROC
- ✓ Time and domain checks are also done in WRFDA
- ✓ for 3DVAR and FGAT, observations (at the same locations) nearest to the analysis time are kept
- ✓ for 4DVAR, the observations nearest to the central time of each of the time slots are kept.

What does OBSPROC do?

- **assign observation errors**

  according to observation types and observed variables

  Sources of the observations errors:

  - ✓ Directly from the observation reports (GPS PW/ZTD, QSCAT, etc.)
  - ✓ US Air Force Weather Agency (AFWA) OBS error table: **obserr.txt**

  The AFWA OBS errors for each type of observations are written out in different formats after running obsproc:

  WIND.txt, TEMP.txt, RH.txt, PRES.txt, HEIGHT.txt

TEMP.txt

TEMP SENSOR ERRORS

level	synop	ship	buoy	metar	pilot	profl	sound	satem	satob	airep	tamdar	ssmt1	ssmt2	tovs	ssmi	airsr	other
10.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.6	1.6	1.0	1.0	1.8	1.8	1.8	1.8	1.0	1.6
20.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.9	1.9	1.0	1.0	1.6	1.6	1.6	1.6	1.0	1.9
30.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.8	1.8	1.0	1.0	1.9	1.9	1.9	1.9	1.0	1.8
50.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.6	1.6	1.0	1.0	1.7	1.7	1.7	1.7	1.0	1.6
70.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.8	1.8	1.0	1.0	1.6	1.6	1.6	1.6	1.0	1.8
100.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.6	1.6	1.0	1.0	2.4	2.4	2.4	2.4	1.0	1.6
150.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.9	1.9	1.0	1.0	2.7	2.7	2.7	2.7	1.0	1.6
200.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	2.2	2.2	1.0	1.0	3.0	3.0	3.0	3.0	1.0	2.1
250.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	2.2	2.2	1.0	1.0	3.1	3.1	3.1	3.1	1.0	2.2
300.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	2.4	2.4	1.0	1.0	3.0	3.0	3.0	3.0	1.0	2.5
400.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	2.3	2.3	1.0	1.0	3.1	3.1	3.1	3.1	1.0	2.4
500.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	2.6	2.6	1.0	1.0	3.2	3.2	3.2	3.2	1.0	2.6
700.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	2.7	2.7	1.0	1.0	3.6	3.6	3.6	3.6	1.0	2.9
850.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	3.5	3.5	1.0	1.0	3.9	3.9	3.9	3.9	1.0	3.7
1000.	2.0	2.0	2.0	2.0	1.0	1.0	1.0	3.7	3.7	1.0	1.0	3.8	3.8	3.8	3.8	1.0	3.8

obserr.txt

```
 0.5   0.5   0.5   0.5   0.5      BOGUS      TEMP SENSOR ERRORS
 0.5   0.5   0.5   0.5   0.5        :
 0.5   0.5   0.5   0.5   0.5        :
 0.0   0.0   0.0   0.0   0.0       NU
 0.0   0.0   0.0   0.0   0.0        :
 0.0   0.0   0.0   0.0   0.0        :
 0.0   0.0   0.0   0.0   0.0       NU
 0.0   0.0   0.0   0.0   0.0        :
 0.0   0.0   0.0   0.0   0.0        :
 0.0   0.0   0.0   0.0   0.0       NU
 0.0   0.0   0.0   0.0   0.0        :
 0.0   0.0   0.0   0.0   0.0        :
 1.0   1.0   1.0   1.0   1.0      RAOBS
 1.0   1.0   1.0   1.0   1.0        :
 1.0   1.0   1.0   1.0   1.0        :
 1.0   1.0   1.0   1.0   1.0      PIBALS
 1.0   1.0   1.0   1.0   1.0        :
 1.0   1.0   1.0   1.0   1.0        :
 0.0   0.0   0.0   0.0   0.0       NU
 0.0   0.0   0.0   0.0   0.0        :
 0.0   0.0   0.0   0.0   0.0        :
 0.0   0.0   0.0   0.0   0.0       NU
 0.0   0.0   0.0   0.0   0.0        :
 0.0   0.0   0.0   0.0   0.0        :
 1.0   1.0   1.0   1.0   1.0      AIREPS
 1.0   1.0   1.0   1.0   1.0        :
 1.0   1.0   1.0   1.0   1.0        :
```

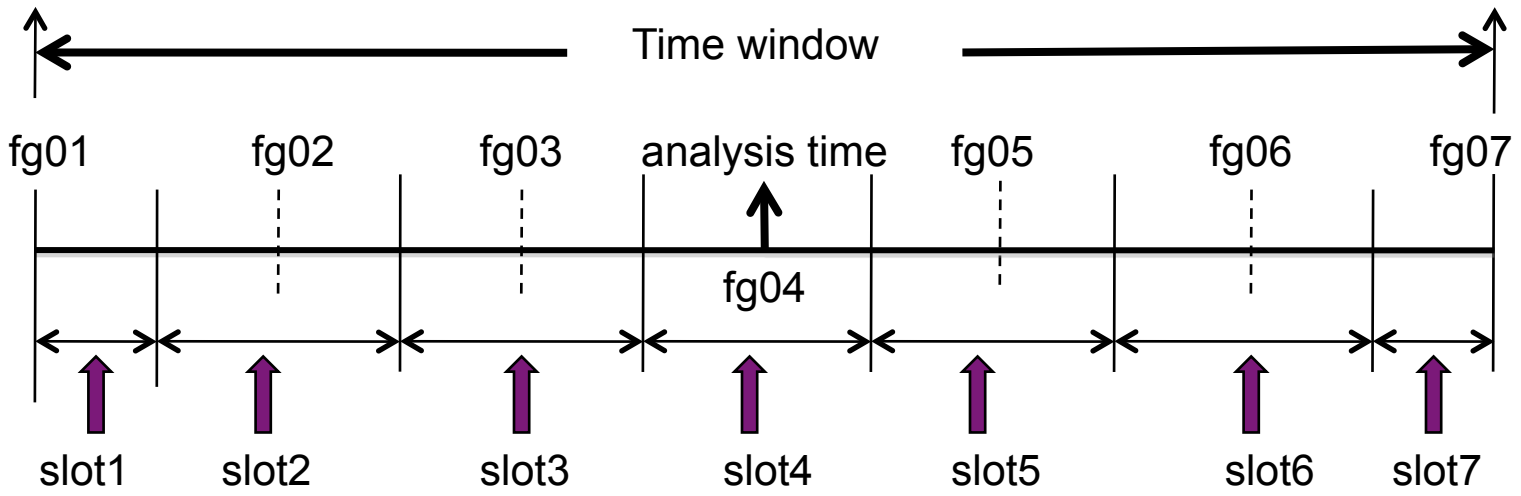
a snippet of obserr.txt

```
*. ***************************************************************
*.
*. INSTRUMENT ERROR FILE
*.
*. PURPOSE: PROVIDES SENSOR ERROR DATA USED IN OI ANALYSIS AT PRESSURE LEVELS
*. -------
*.
*. 1) FOR HEIGHT, TEMPERATURE, PRESSURE AND RELATIVE HUMIDITY (IN hPa):
*.
*.    1000,  850,  700,  500,  400,
*.     300,  250,  200,  150,  100,
*.      70,   50,   30,   20,   10
*.
*. 2) FOR WIND:
*.
*.      10,   20,   30,   40,   50,  100,  150,
*.     200,  250,  300,  350,  400,  450,  500,
*.     550,  600,  650,  700,  750,  800,  850,
*.     900,  950, 1000, 1050, 1100, xxxx, yyyy
*.    (last two values are place holders).
*.
*.     Beware the additional levels and the reverse order for wind.
```

description of the file can be found near the end of obserr.txt

observation binning for WRFDA

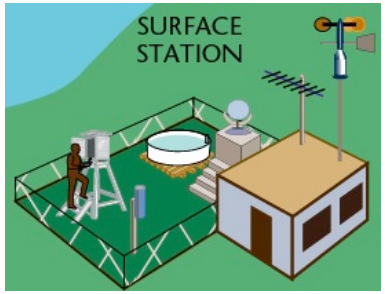
- 3DVAR
  - all observations within the time window are considered valid at the analysis time
  - when multiple reports from a fixed station are available within the time window, only one report that is closest to the analysis time will be kept
- FGAT (First Guess at Appropriate Time)
  - multiple time slots (model first guesses) within the time window
  - observations are binned in different time slots
  - when multiple reports from a fixed station are available within the time window, only one report that is closest to the analysis time will be kept
- 4DVAR
  - multiple time slots (model first guesses) within the time window
  - observations are binned in different time slots
  - time duplicate observations not allowed within each time slot



observation binning for WRFDA

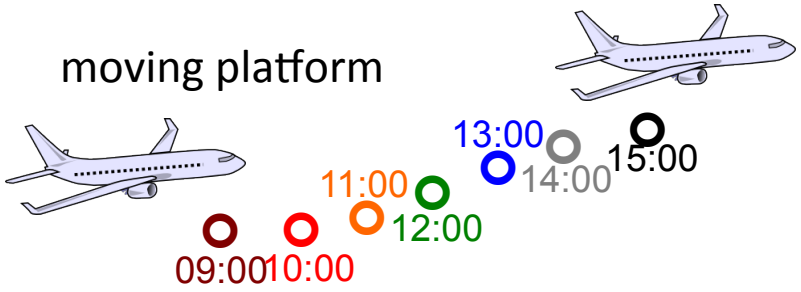
For analysis time at 12:00 with ± 3 hour time window

fixed platform



09:00
10:00
11:00
12:00
13:00
14:00
15:00

moving platform



For calculating the departure of model background from observations, what observations should be considered?

3DVAR:

FGAT:

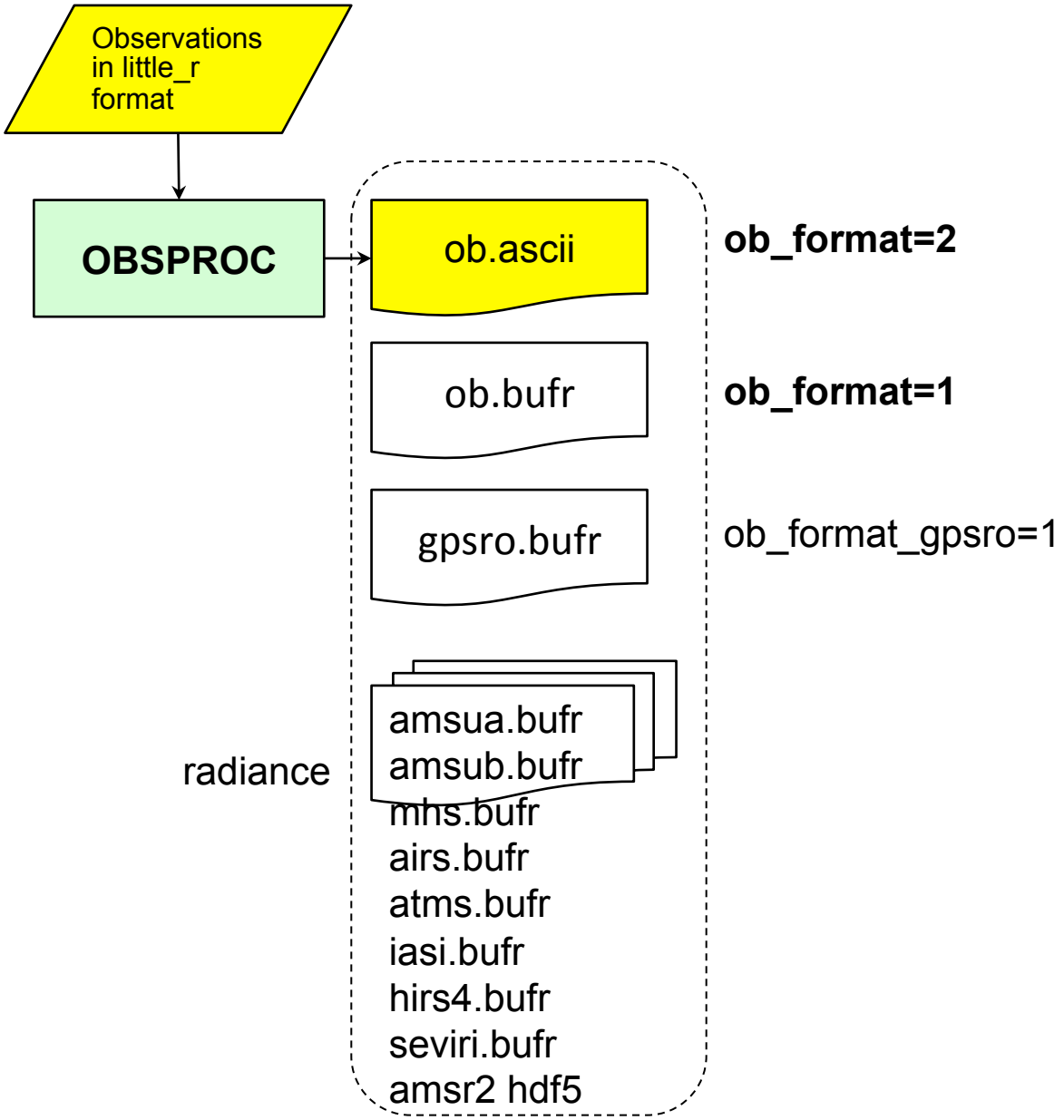
bin 01	
bin 02	
bin 03	
bin 04	
bin 05	
bin 06	
bin 07	

4DVAR:

bin 01	
bin 02	
bin 03	
bin 04	
bin 05	
bin 06	
bin 07	

WRFDA keeps only one observation closest to the analysis time from a fixed station in non-4DVAR mode. Other DA system may use multiple observations by giving time-dependent weights.

observation binning for WRFDA



WRFDA

For conventional data:

- With ob_format=2, observation binning is done in OBSPROC
- With ob_format=1, binning is done inside WRFDA

For radiance data:
binning is done inside WRFDA

Compiling and Running OBSPROC

- To compile
  - *./configure wrfda*
  - *./compile all_wrfvar*

  WRFDA/var/obsproc/src/obsproc.exe is generated after a successful WRFDA build

- To run
  - edit **namelist.obsproc**
  - have input files ready in the working directory:
    - obs.2012020100 little_r observation file (user provided)
    - obserr.txt observation error file
    - obsproc.exe obsproc executable file
    - namelist.obsproc obsproc namelist file
  - execute

    ./obsproc.exe >&! obsproc.log

- Files to look for
  - obs_gts_yyyy-mm-dd_hh:00:00.3DVAR one ASCII file for 3DVAR

    or obs_gts_yyyy-mm-dd_hh:00:00.FGAT multiple ASCII files for FGAT

    or obs_gts_yyyy-mm-dd_hh:00:00.4DVAR multiple ASCII files for 4DVAR
  - obsproc.log: execution log file
  - A list of diagnostic files: *.diag files

namelist.obsproc

WRFDA/var/obsproc/README.namelist

examples:

WRFDA/var/obsproc/namelist.obsproc.3dvar.wrfvar-tut

WRFDA/var/obsproc/namelist.obsproc.4dvar.wrfvar-tut

```
&record1    (Defines the input file names)
 obs_gts_filename = 'obs.2008020512',          Little_r file name
 obs_err_filename = 'obserr.txt',              Observation error file name
 fg_format = 'WRF'                             Mapping in WRF convention
 gts_from_mmm_archive = .false.
                                (set to .true. if little_r files are from hsi:/BRESCH/RT/DATA)
/

&record2    (Defines the analysis time and time window)
 time_window_min  = '2008-02-05_11:00:00',
 time_analysis    = '2008-02-05_12:00:00',
 time_window_max  = '2008-02-05_13:00:00',
/
```

namelist.obsproc

```
&record3   (Defines the maximum number of observations allowed)
 max_number_of_obs        = 400000,    Maximum number of observations to be loaded
 fatal_if_exceed_max_obs  = .TRUE.,
/

&record4   (Defines the quality control switches)
 qc_test_vert_consistency = .ture.   Perform a vertical consistency check on sounding
 domain_check_h = .true.,            Discard the observations outside the domain
 remove_above_lid = .false.  (.false. is recommended) remove the observation above model lid
 thining_satob = .true.
 thining_qscat = .true.
 calc_psfc_from_QNH = .false. (valid for gts_from_mmm_archive=.true. only)
                              (set to .true. to calculate Psfc from METAR QNH reports)
 …
/

&record5   (Print a series of diagnostic file)
  print_gts_read        = .TRUE.,    Write the diagnostic little_r obs into file obs_gts_read.diag
…
/
```

namelist.obsproc

```
&record6   (Defines the reference state)
 ptop =  1000.0,                  reference pressure at model top
 base_temp  = 290.0,              mean sea level temperature
 base_lapse = 50.0,               temperature lapse rate
 base_pres = 100000.0,            reference sea level pressure
 base_strat_temp = 215.0,         isothermal temperature above tropopause
 base_tropo_pres = 20000.0,       tropopause pressure
/

&record7   (Defines geographical parameters)
 IPROJ = 1,                       0 = Cylindrical Equidistance, 1 = Lambert Conformal,
                                  2 = Polar stereographic, 3 = Mercator)
 PHIC  = 40.0,                    central latitude of the domain
 XLONC = -95.0,                   central longitude of the domain
 TRUELAT1= 30.0,
 TRUELAT2= 60.0,
 MOAD_CEN_LAT = 40.0,             central latitude for the Mother Of All Domains
 STANDARD_LON = -95.0,            standard longitude
/
```

✓ `ncdump –h wrfinput_d01` for domain information

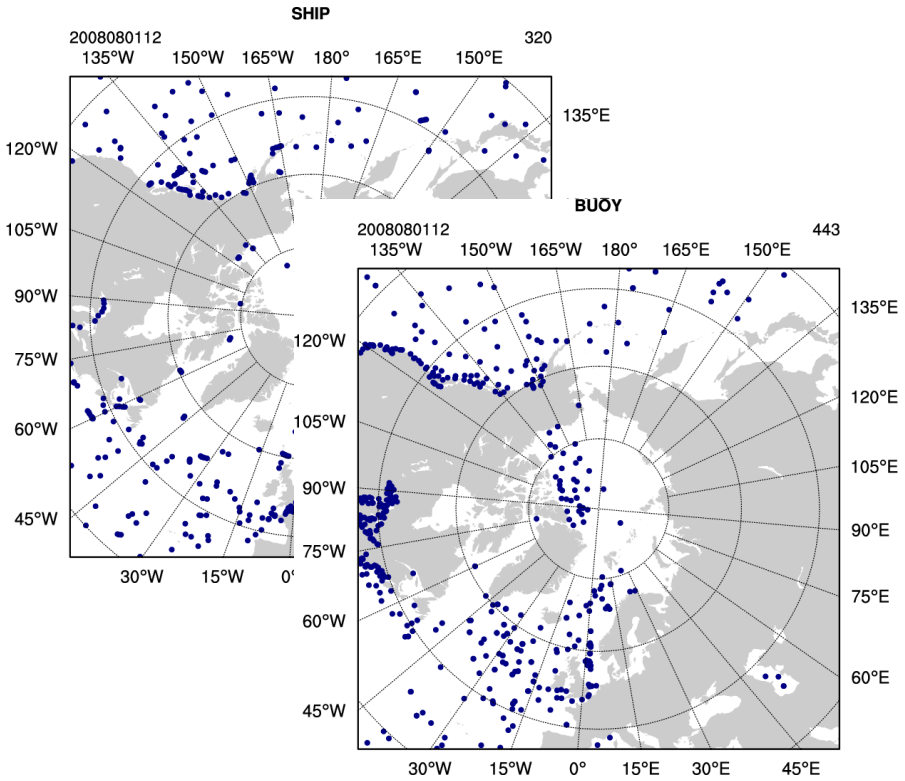
namelist.obsproc

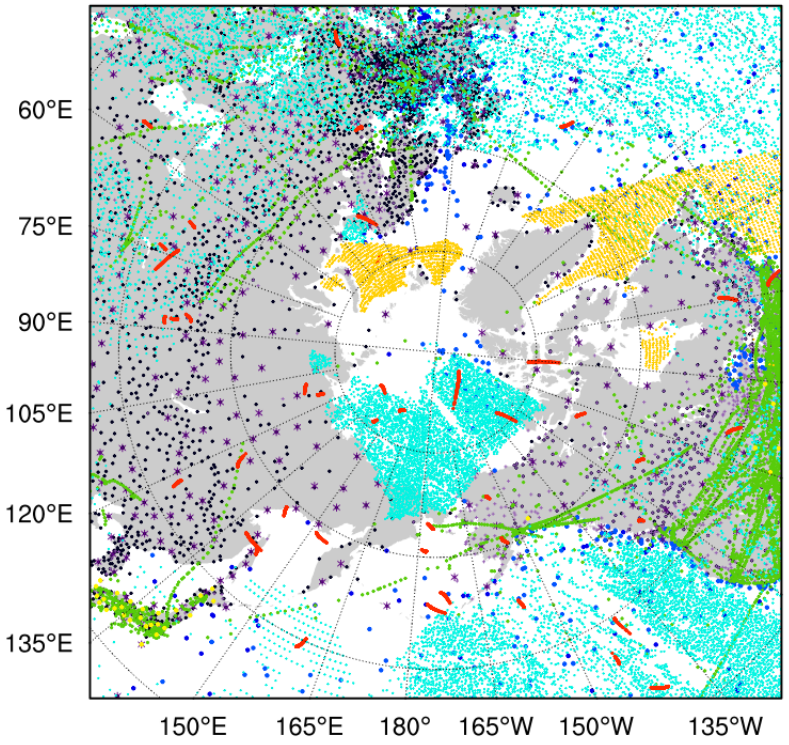
```
&record8     (Defines the domain settings)
 IDD    =   1,          when XLONC /= STANDARD_LON, set IDD=2, otherwise set to 1
 MAXNES =  1,       set to 1
 NESTIX =  60,      I(y) direction dimension of the domain
 NESTJX =  90,      J(x)-direction dimension of the domain
 DIS    =  60,      grid size of the domain
 NUMC = 1,          set to 1
 NESTI = 1,         set to 1
 NESTJ = 1,         set to 1
/

&record9     (Defines the output)
 use_for         = '3DVAR',          FGAT; 4DVAR
 num_slots_past   = 3,               number of time slots before time_analysis
 num_slots_ahead  = 3,               number of time slots after time_analysis
/
```

- ✓ OBSPROC was developed in the MM5 era when I referred to Y direction and J referred to X direction

Plotting observation locations



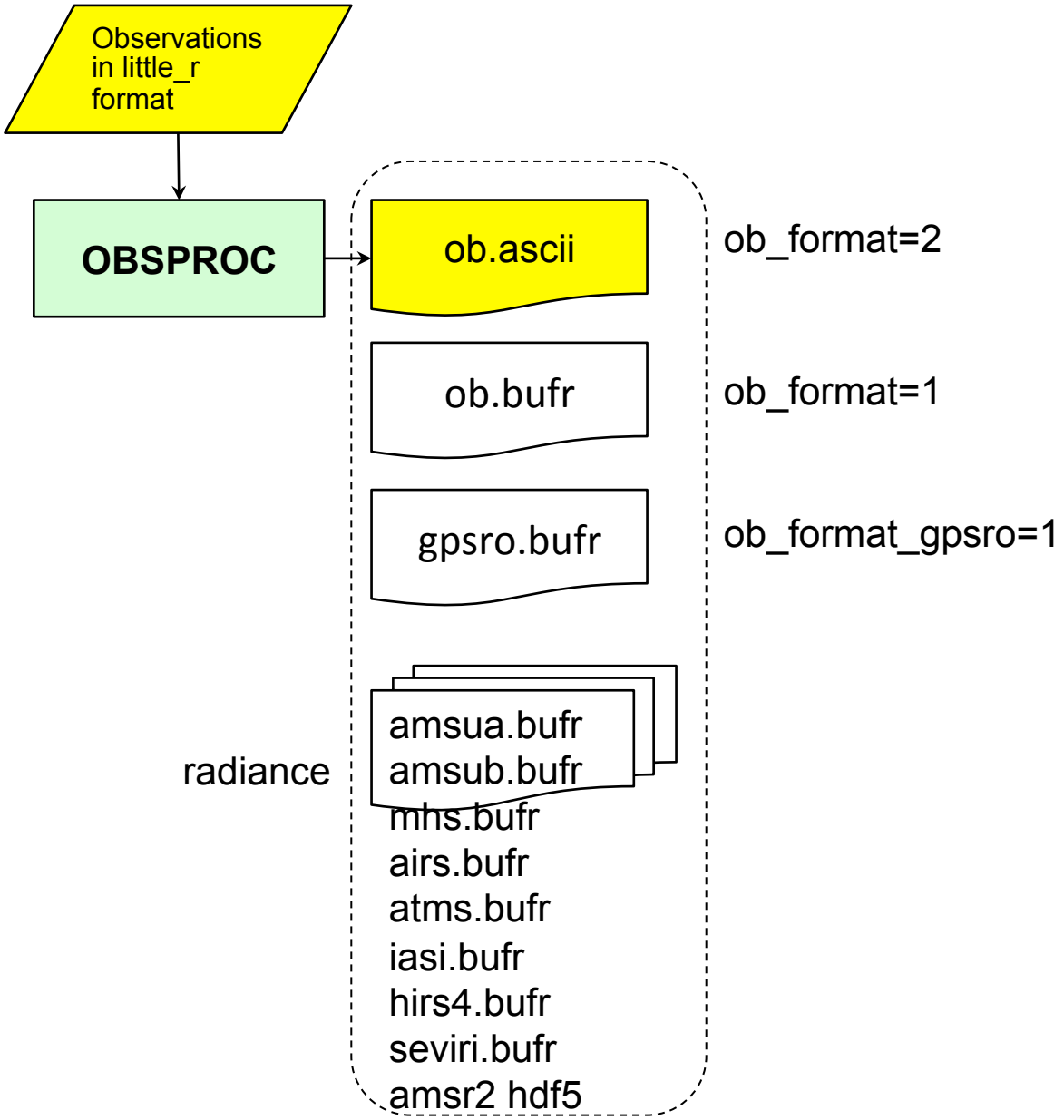


http://www2.mmm.ucar.edu/wrf/users/wrfda/download/tools.html

var/graphics/ncl/plot_ob_ascii_loc.ncl
– a sample NCL script to plot observation locations

Refer to http://www.ncl.ucar.edu/Applications/station.shtml for more station plotting examples

Observation Quality Control

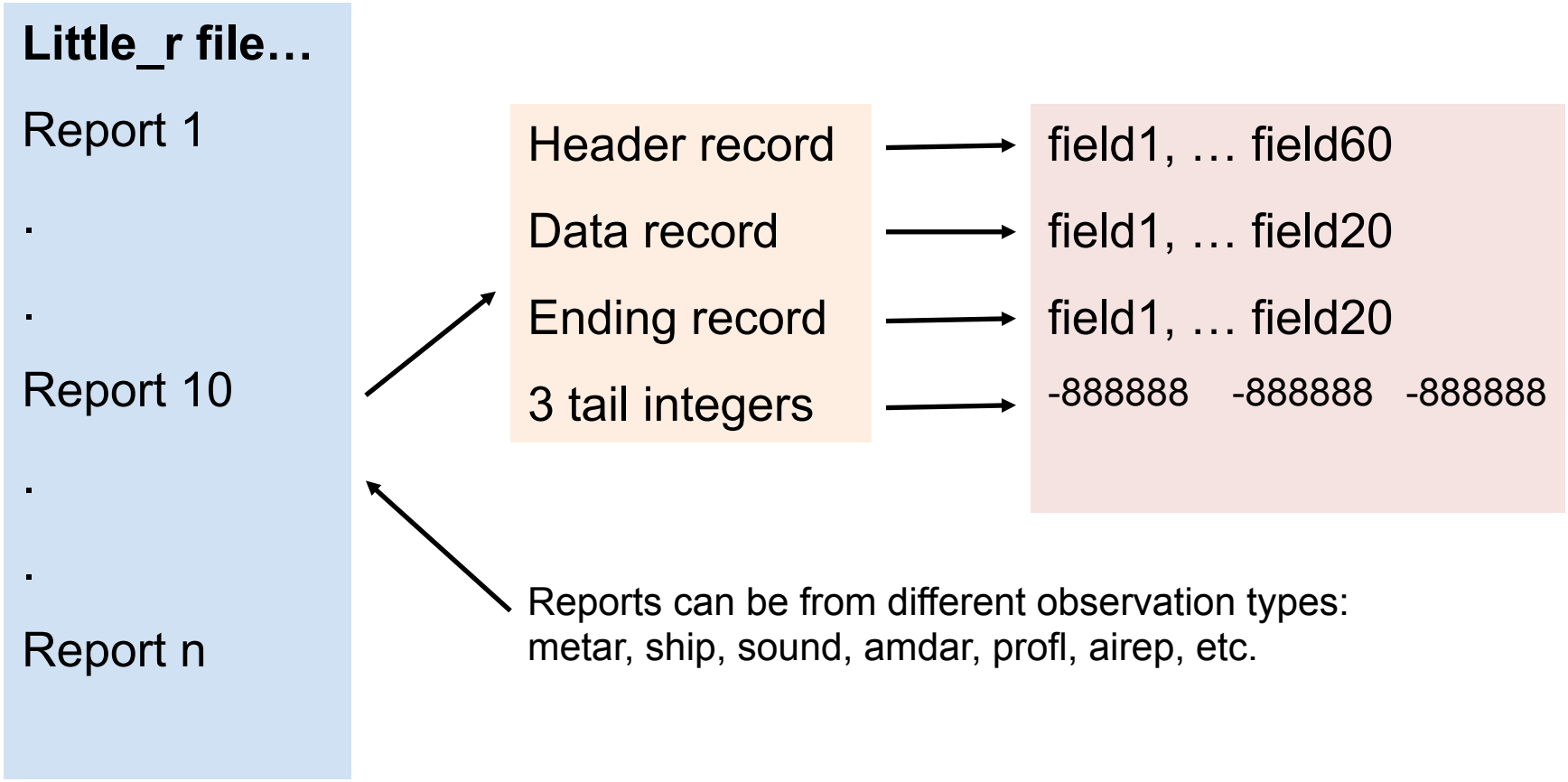


WRFDA

- ✓ limited quality check done in OBSPROC
- ✓ quality check of radiances and GPS refractivity is done in WRFDA
- ✓ WRFDA honors quality flags embedded in ob.bufr (NCEP's prepared, quality controlled PREPBUFR file)
- ✓ WRFDA does innovation check

little_r format

- little_r file is a report-based ASCII file
- different observation files can be concatenated (cat) together to one file



✓ WRF User's Guide Chapter 7

✓ **http://www2.mmm.ucar.edu/wrf/users/wrfda/OnlineTutorial/Help/littler.html**

little_r format

- A little_r format observation file is composed of Reports
- Report is composed of Records (header, data,…, and ending) and 3 tail integers (3i7):
- Record is composed of fields
  - fields in the header record
  - fields in the data record
  - fields in the ending record

Example: one sounding report in a little_r file

```
13.48000          2.1600061052                    NIAMEY-AERO / NIGER              FM-35 TEMP                  GTS (ROHK) USNR20 DRRN 242300
227.00000  1  -888888  -888888   55  -888888   T   F   F  -888888  -888888 20100824230000-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000
0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
98600.00000  0  227.00000  0  300.75000  0  293.75000  0  4.11556  0  240.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
100000.00000  0  97.00000  0  -888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
92500.00000  0  788.00000  0  299.94998  0  290.94998  0  6.68778  0  255.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
85000.00000  0  1530.00000  0  295.94998  0  284.94998  0  1.54333  0  225.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
70000.00000  0  3187.00000  0  283.35001  0  278.75000  0  7.71667  0  75.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
50000.00000  0  5900.00000  0  267.04999  0  256.04999  0  12.86111  0  85.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
40000.00000  0  7610.00000  0  256.64999  0  240.64999  0  6.68778  0  75.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
30000.00000  0  9720.00000  0  242.64999  0  239.04999  0  6.68778  0  165.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
25000.00000  0  10990.00000  0  232.64999  0-888888.00000  0  6.17333  0  145.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
20000.00000  0  12470.00000  0  220.25000  0-888888.00000  0  3.60111  0  135.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
15000.00000  0  14260.00000  0  205.84999  0-888888.00000  0  18.00556  0  100.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
10000.00000  0  16640.00000  0  194.04999  0-888888.00000  0  9.77444  0  70.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
-777777.00000  0-777777.00000  0  13.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0-888888.00000  0
 58     0     0
```

Header record Data record Ending record 3 tail integer

little_r format

The fields in the **header record** (Fortran format in parenthesis)

No	Field	No	Field	No	Field
1	Latitude (f20.5)	2	Longitude (f20.5)	3	ID (a40)
4	Name (a40)	5	Platform (a40)	6	Source (a40)
7	Elevation (f20.5)	8	Num_vld_fld (i10)	9	Num_error (i10)
10	Num_warning (i10)	11	Seq_num (i10)	12	Num_dupd (i10)
13	Is_sound (L10)	14	Bogus (L10)	15	Discard (L10)
16	Valid_time%sut (i10)	17	Valid_time%julian (i10)	18	Valid_time%date_char(a20)
19	Slp%data (f13.5)	20	Slp%qc (i7)	21	Ref_pres%data (f13.5)
22	Ref_pres%qc (i7)	23	Ground_t%data (f13.5)	24	Ground_t%qc (i7)
25	SST%data (f13.5)	26	SST%qc (i7)	27	Psfc%data (f13.5)
28	Psfc%qc (i7)	29	Precip%data (f13.5)	30	Precip%qc (i7)
31	T_max%data (f13.5)	32	T_max%qc (i7)	33	T_min%data (f13.5)
34	T_min%qc (i7)	35	T_min_night%data (f13.5)	36	T_min_night%qc (i7)
37	P_tend03%data (f13.5)	38	P_tend03%qc (i7)	39	P_tend24%data (f13.5)
40	P_tend24%qc (i7)	41	Cloud_cvr%data (f13.5)	42	Cloud_cvr%qc (i7)
43	Celling%data (f13.5)	44	Celling%qc (i7)	45	Pw%data (f13.5)
46	Pw%qc (i7)				

Mandatory (non-blank) fields are fields 1 - 44

little_r format

A sample "**header record**" (a long continuous line) of one sounding report

```
|            13.48000|             2.16000|61052
|NIAMEY-AERO / NIGER                      |FM-35 TEMP
|GTS (ROHK) USNR01 DRRN 051100 RRA        |           227.00000|         1|   -888888
-888888|       299|   -888888|         T|         F|         F|   -888888|   -888888|
20080205110000|-888888.00000|      0|-888888.00000|      0|-888888.00000|
0|-888888.00000|      0|-888888.00000|      0|-888888.00000|      0|-888888.00000|
0|-888888.00000|      0|-888888.00000|      0|-888888.00000|      0|-888888.00000|
0|-888888.00000|      0|-888888.00000|      0|
```

No	Field	No	Field	No	Field
1	Latitude (f20.5)	2	Longitude (f20.5)	3	ID (a40)
4	Name (a40)	5	Platform (a40)	6	Source (a40)
7	Elevation (f20.5)	8	Num_vld_fld (i10)	9	Num_error (i10)
10	Num_warning (i10)	11	Seq_num (i10)	12	Num_dupd (i10)
13	Is_sound (L10)	14	Bogus (L10)	15	Discard (L10)
16	Valid_time%sut (i10)	17	Valid_time%julian (i10)	18	Valid_time%date_char(a20)
19	Slp%data (f13.5)	20	Slp%qc (i7)	21	Ref_pres%data (f13.5)
22	Ref_pres%qc (i7)	23	Ground_t%data (f13.5)	24	Ground_t%qc (i7)

little_r format

The fields in the **data record** (Fortran format in parenthesis)

no	Field	no	Field
1	Pressure%data (f13.5)	2	Pressure%qc (i7)
3	Height%data (f13.5)	4	Height%qc (i7)
5	Temperature%data (f13.5)	6	Temperature%qc (i7)
7	Dew_point%data (f13.5)	8	Dew_point%qc (i7)
9	Speed%data (f13.5)	10	Speed%qc (i7)
11	Direction%data (f13.5)	12	Direction%qc (i7)
13	U%data (f13.5)	14	U%qc (i7)
15	V%data (f13.5)	16	V%qc (i7)
17	RH%data (f13.5)	18	RH%qc (i7)
19	Thickness%data (f13.5)	20	Thickness%qc (i7)

The 0s after each piece of data are quality control identifiers to be defined in the MM5/ little_r objective analysis program. They have no meanings for WRFDA.

little_r format

The fields in the **ending record**

no	field	no	field	no	field	no	field
1	-777777.00000	2	0	3	-777777.00000	4	0
5	-888888.00000	6	0	7	-888888.00000	8	0
9	-888888.00000	10	0	11	-888888.00000	12	0
13	-888888.00000	14	0	15	-888888.00000	16	0
17	-888888.00000	18	0	19	-888888.00000	20	0

-777777.00000 0-777777.00000 0 13.00000 0-888888.00000 0-888888.00000 0-888888.00000 0-888888.00000 0-888888.00000 0-888888.00000 0-888888.00000 0

little_r format

a snippet of Fortran code that writes **sounding** data in little_r format

```
! header:

   WRITE ( UNIT = iunit , FMT = rpt_format )                              &
           xlat, xlon, string1, string2 ,                                 &
           string3, string4, ter, kx*6, 0, 0, iseq_num, 0,                &
           .TRUE., .FALSE., .FALSE.,                                      &
           -888888, -888888, date_char, slp,  0,                          &
           -888888.,0, -888888.,0, -888888.,0, -888888.,0, -888888.,0,    &
           -888888.,0, -888888.,0, -888888.,0, -888888.,0, -888888.,0,    &
           -888888.,0, -888888.,0

! report:

   DO k = 1 , kx
      WRITE ( UNIT = iunit , FMT = meas_format )                  &
              p(k), 0, z(k),0, t(k),0, td(k),0,                   &
              spd(k),0, dir(k),0,                                 &
              -888888.,0, -888888.,0,-888888.,0, -888888.,0
   END DO

! end of report line:

   WRITE ( UNIT = iunit , FMT = meas_format )   &
           -777777.,0, -777777.,0,float(kx),0,  &
           -888888.,0, -888888.,0, -888888.,0,  &
           -888888.,0, -888888.,0, -888888.,0,  &
           -888888.,0

! end of message line:

   WRITE ( UNIT = iunit , FMT = end_format )  kx, 0, 0
```

little_r format

a snippet of Fortran code that writes **surface** data in little_r format

```
! header:

   WRITE ( UNIT = iunit , FMT = rpt_format )                              &
           xlat, xlon, string1, string2 ,                                 &
           string3, string4, ter, 6, 0, 0, iseq_num, 0,                   &
           .FALSE., .FALSE., .FALSE.,                                     &
           -888888, -888888, date_char, slp,  0,                          &
           -888888.,0, -888888.,0, -888888.,0, -888888.,0, -888888.,0,    &
           -888888.,0, -888888.,0, -888888.,0, -888888.,0, -888888.,0,    &
           -888888.,0, -888888.,0
! report:

      WRITE ( UNIT = iunit , FMT = meas_format )                          &
              p, 0, z, 0, t, 0, td, 0,                                    &
              spd, 0, dir, 0,                                             &
              -888888.,0, -888888.,0,-888888.,0, -888888.,0

! end of report line:

   WRITE ( UNIT = iunit , FMT = meas_format )   &
           -777777.,0, -777777.,0,float(kx),0,  &
           -888888.,0, -888888.,0, -888888.,0,  &
           -888888.,0, -888888.,0, -888888.,0,  &
           -888888.,0

! end of message line:

   WRITE ( UNIT = iunit , FMT = end_format )  kx, 0, 0
```

little_r format

QSCAT: U and V fields are used to store observation errors of wind speed and wind direction

press	geo height	temp	dew-p	speed	dir	u	v	rh	thickness
						obs error of wind speed	obs error of wind direction		

✓ 1.0 m/s minimum obs error imposed by WRFDA

GPS Refractivity

press	geo height	temp	dew-p	speed	dir	u	v	rh	thickness
	height (m)		Refractivity (N)	Impact parameter (x1.e-3)	azimuth angle (degree)	latitude	longitude	Bending angle (radx1.e7)	Opt. bending

- ✓ little_r format and OBSPROC were developed before some observation types became available
- ✓ OBSPROC was extended to handle some “non-conventional” observation types in a non-standard way

little_r format

Special notes for GPSPW / GPSZD

No	Field	No	Field	No	Field
1	Latitude (f20.5)	2	Longitude (f20.5)	3	ID (a40)
4	Name (a40)	5	Platform (a40)	6	Source (a40)
7	Elevation (f20.5)	8	Num_vld_fld (i10)	9	Num_error (i10)
10	Num_warning (i10)	11	Seq_num (i10)	12	Num_dupd (i10)
13	Is_sound (L10)	14	Bogus (L10)	15	Discard (L10)
16	Valid_time%sut (i10)	17	Valid_time%julian (i10)	18	Valid_time%date_char(a20)
...	...	...	...	...	...
...	...	...	...	...	...
43	Celling%data (f13.5)	44	Celling%qc (i7)	45	Pw%data (f13.5)
46	Pw%qc (i7)				

- ✓ **Pw%data** can be either GPSPW (FM-111) or GPSZD (FM-114) and the unit is in **cm**.
- ✓ **Pw%qc** is used to store the error in units of **0.1 mm**.

For example, Pw%qc=100 means the error is 1 cm as it appears in the output ob.ascii file.

If the little_r pw%qc field is 0 or missing, then the default assigned in var/obsproc/src/module_err_afwa.F90 is 0.2 cm for GPSPW and 0.5 cm for GPSZD.

Questions?

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