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

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

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

$J(x)$: 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 <u>small</u> corrections to a short-range forecast (**background**), which is assumed to be good, to produce a model **analysis**.

Global Observing System
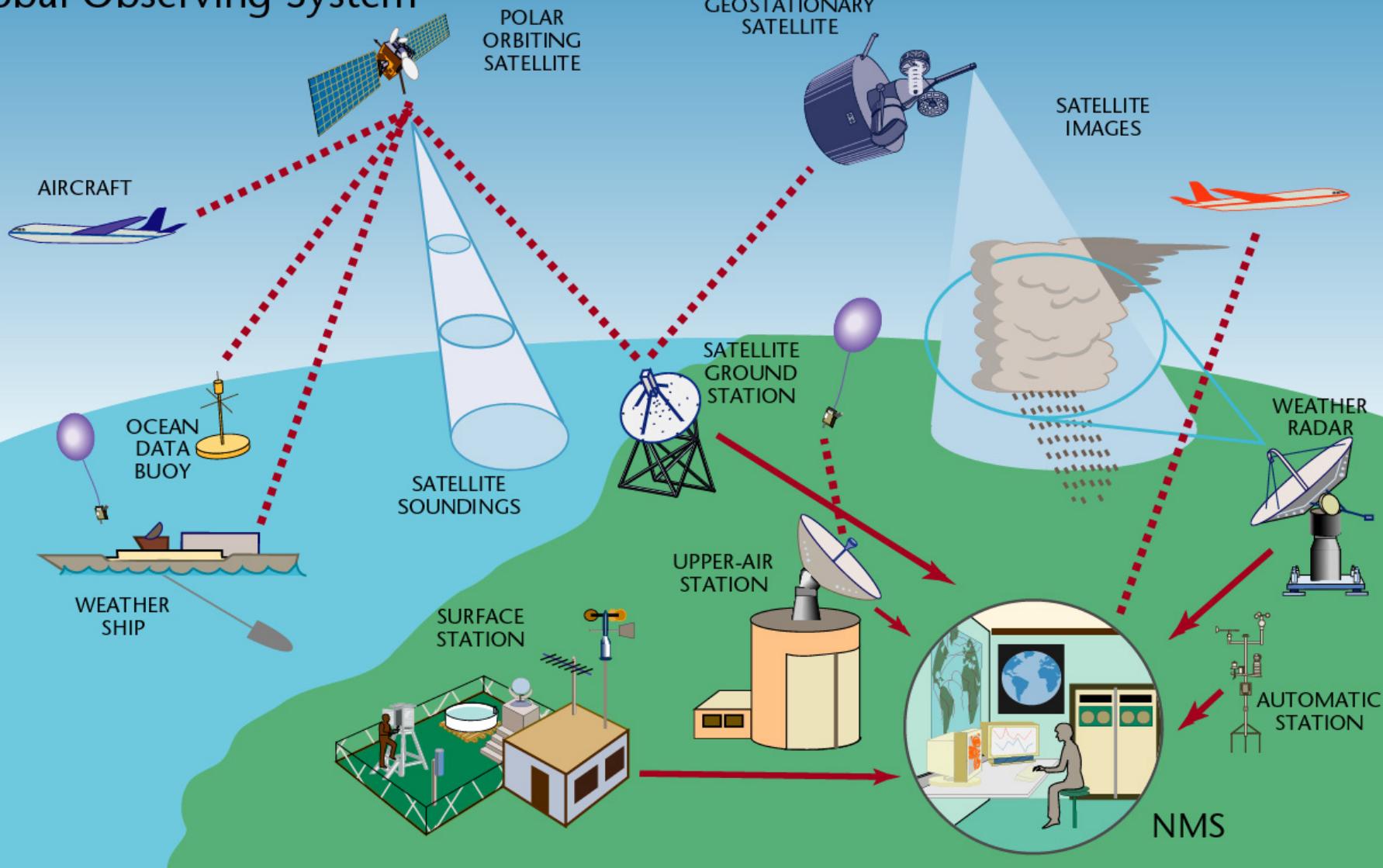
Space-based Global Observing System
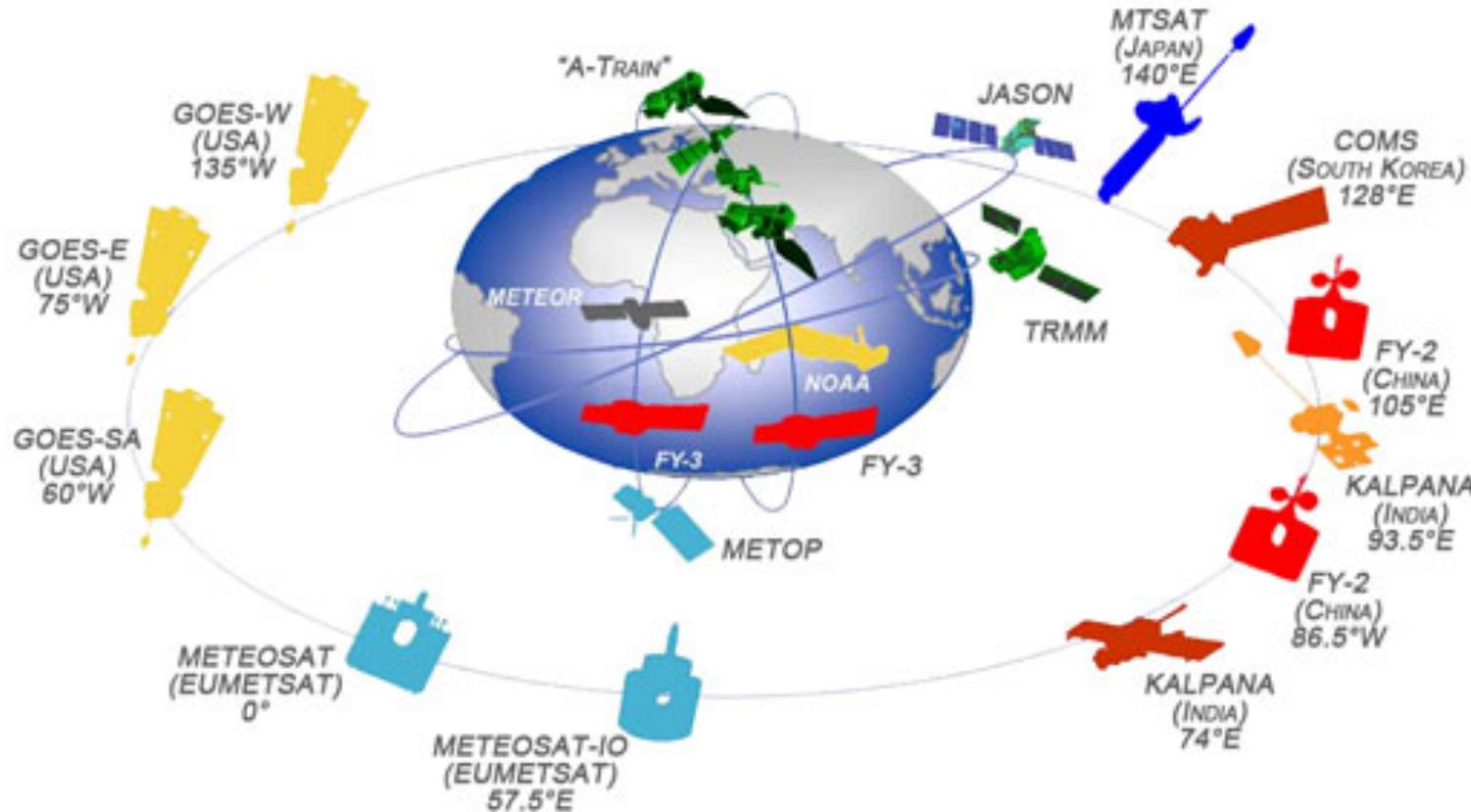
Image courtesy: WMO Space Programme

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

2007030100
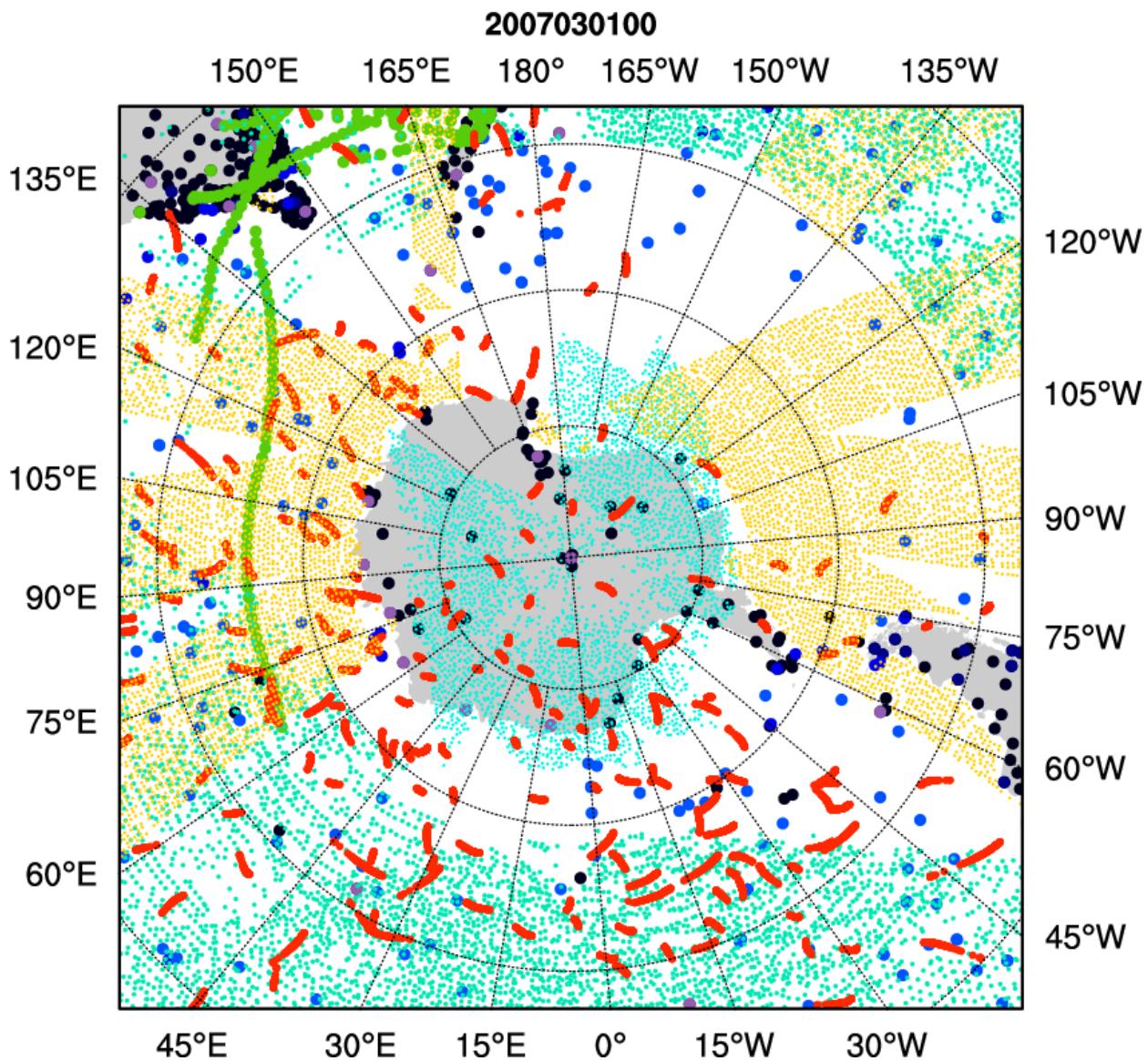
Surface
- SYNOP
- METAR
- BUOY
- SHIPS
- QuikSCAT winds

Upper-Air/
multiple levels
- SOUND
- geo AMV
- polar AMV
- GPS refractivity
- AIREP

Sample satellite radiances coverage of a 6-hour time window

surface type

metop-2-amsua   2007070106

surface type

noaa-16-amsua   2007070106

Legend:
- sea
- ice
- land
- snow
- msea
- mice
- mlnd
- msno
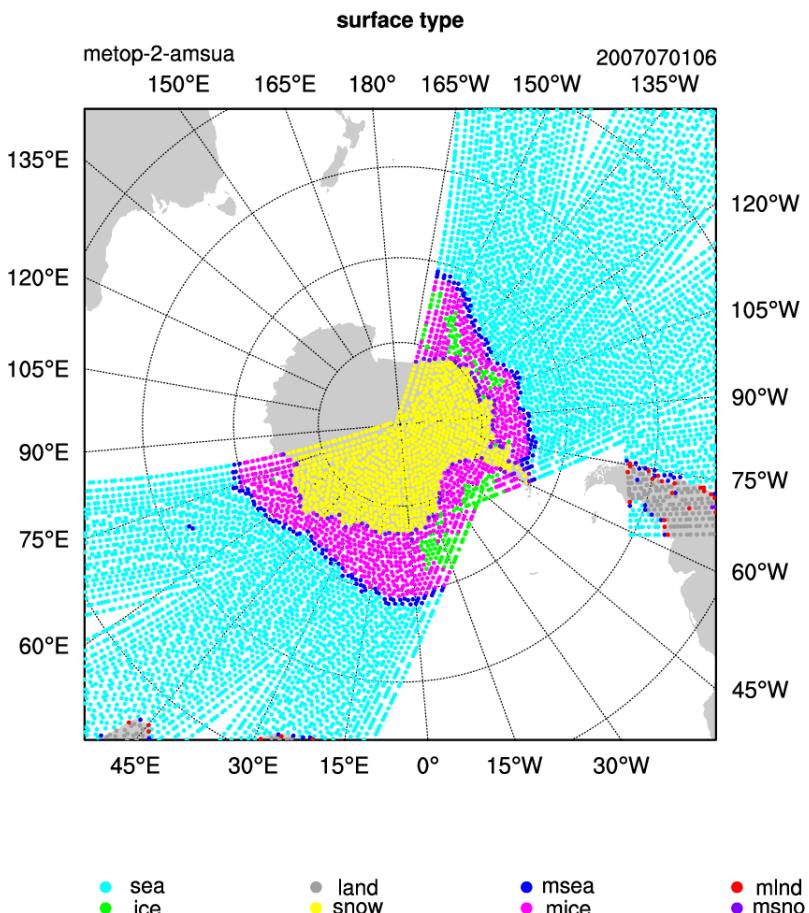
* colors indicate model surface types
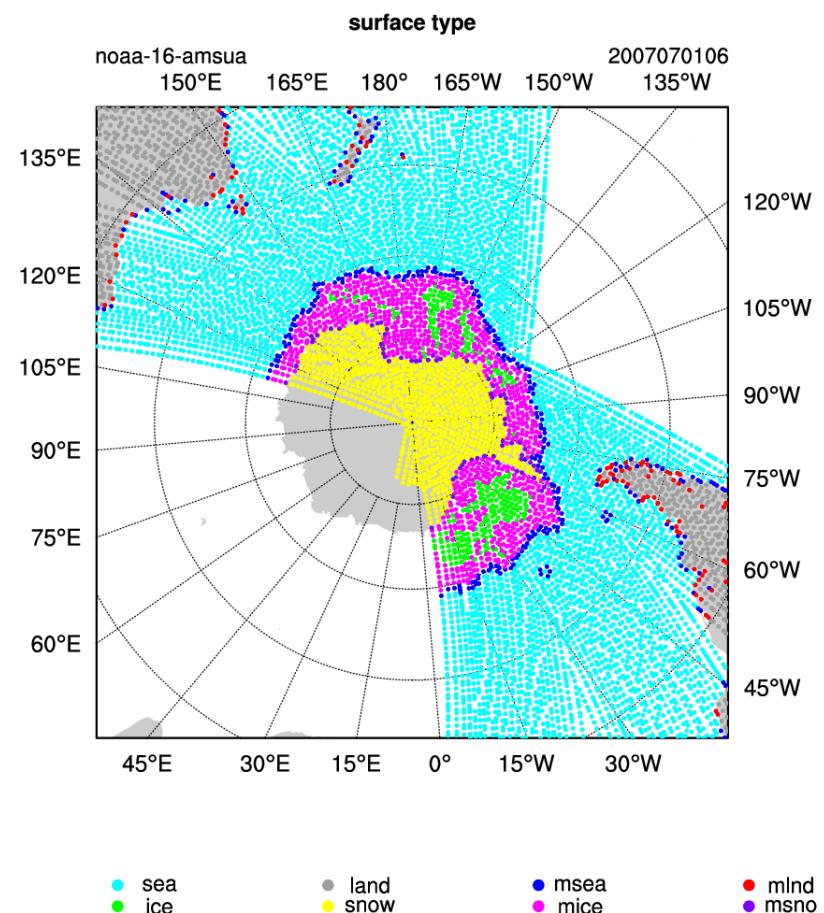
NOAA-16 was DECOMMISSIONED on 9 June 2014

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
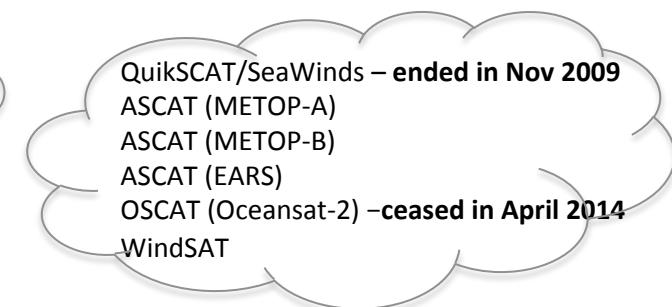
❑ **Radiances** (using RTTOV or CRTM):

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	

WRFDA can read in …

Observations in little_r format

OBSPROC

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

ob.bufr
gpsro.bufr

ob.ascii

radiance

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

ob.radar

stage IV precipitation

ob01.rain
ob02.rain

ob_format=1
ob_format_gpsro=1

ob_format=2

WRFDA

ob.radar
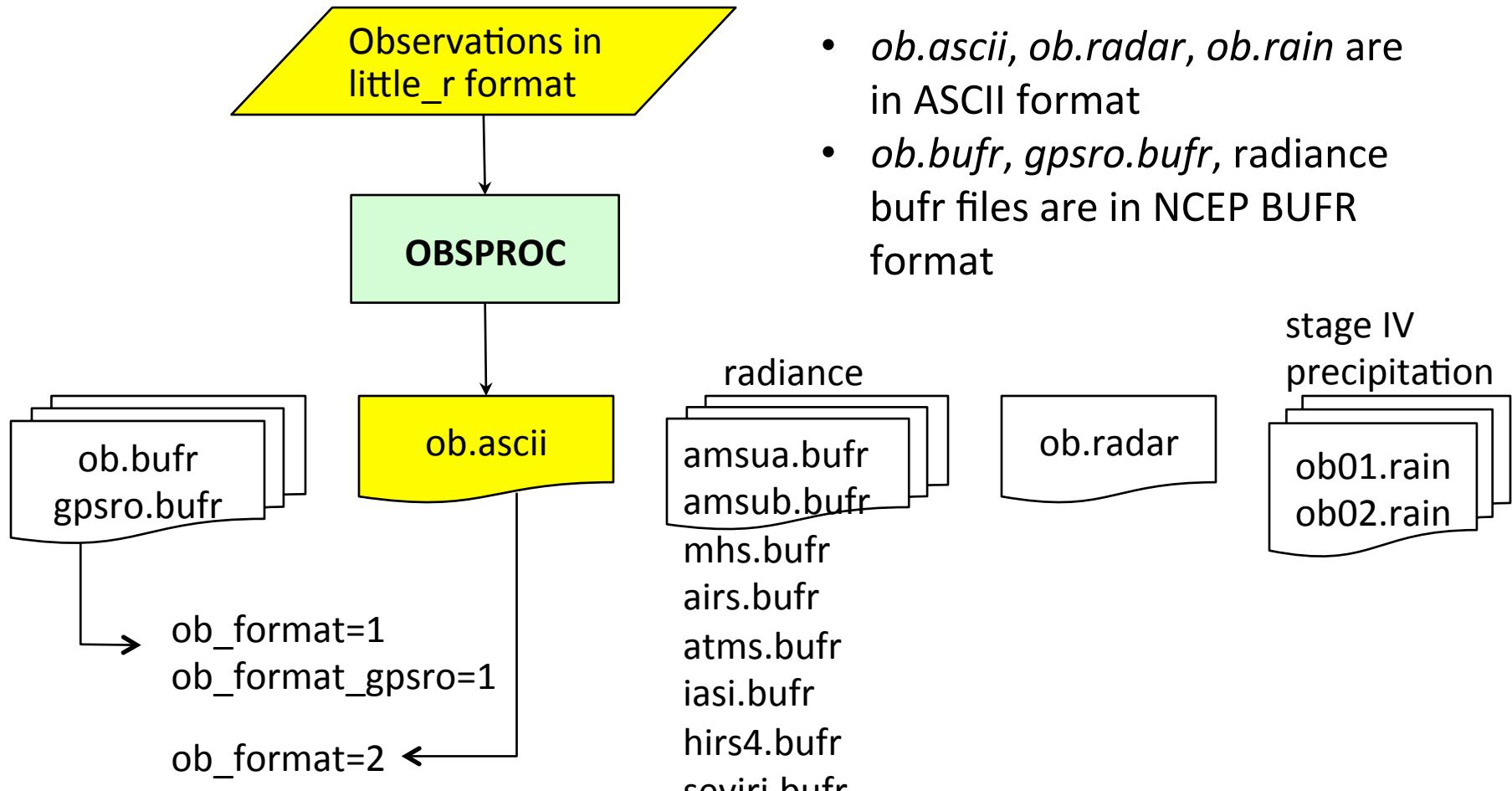
➢ In simple ASCII format

 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

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

ob.bufr
gpsro.bufr

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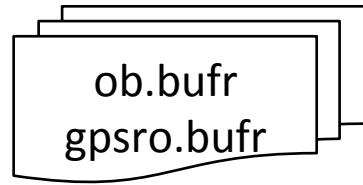
NCEP operational observation files in BUFR format can be directly used in WRFDA

➤ 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

➤ 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
    gdas1.thhz.gpsro.tm00.bufr_d
    gdas1.thhz.**prepbufr**.nr
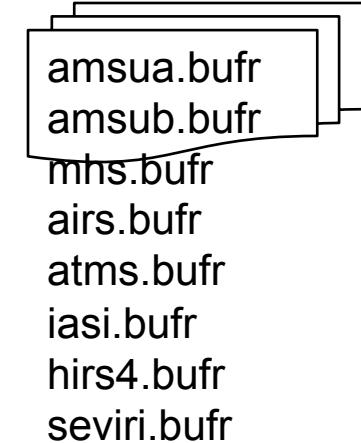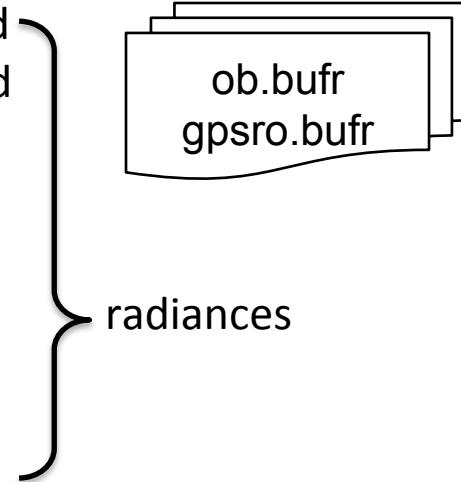
        hh is the analysis time: 00/06/12/18

ob.bufr
gpsro.bufr

radiances

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

- 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

Observations in little_r format

OBSPROC

↓

ob.ascii

↓

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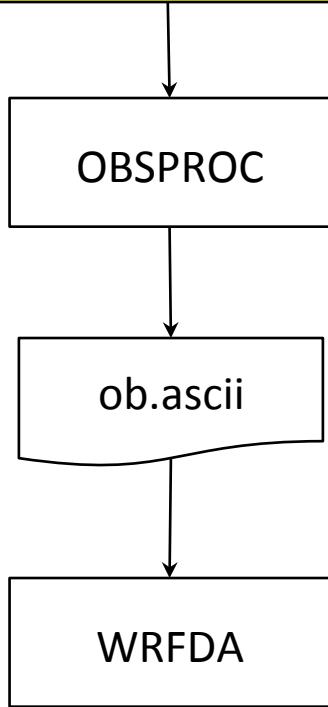
NCAR/MMM archived observations in little_r format on HPSS (requires NCAR HPC account)

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

Observations in little_r format
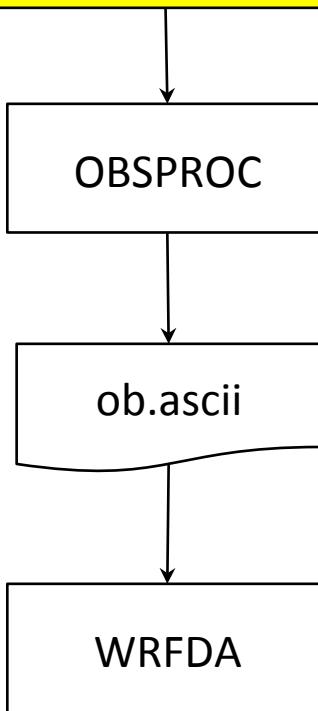
NCAR/CISL archived observations in little_r format
http://rda.ucar.edu/datasets/**ds351.0**/?hash=!access

OBSPROC

ob.ascii

WRFDA

❖ Issues about temperature values (both T and Td) in ds351.0/little_r files were reported in June. ~0.05 degree information is dropped by their DUMPBUFR to Little_r decoder

- 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

    ftp://airspar1u.ecs.nasa.gov/ftp/data/s4pa/Aqua_AIRS_Level2/AIRX2RET.006

  - 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)?**

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  3  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

✓ skipped in WRFDA reading code

Data format

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,      ! heigh above model lid => no action
far_below_model_surface = - 7,      ! heigh 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
```

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

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

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

A few things to bear in mind when dealing with observations
- o What are observed and contained in the original observation reports
- o What are the variable definitions in little_r, ob.ascii, ob.bufr files
- o 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 and time checks

- 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

Time window

| fg01 | fg02 | fg03 | analysis time | fg05 | fg06 | fg07 |

fg04

| slot1 | slot2 | slot3 | slot4 | slot5 | slot6 | slot7 |
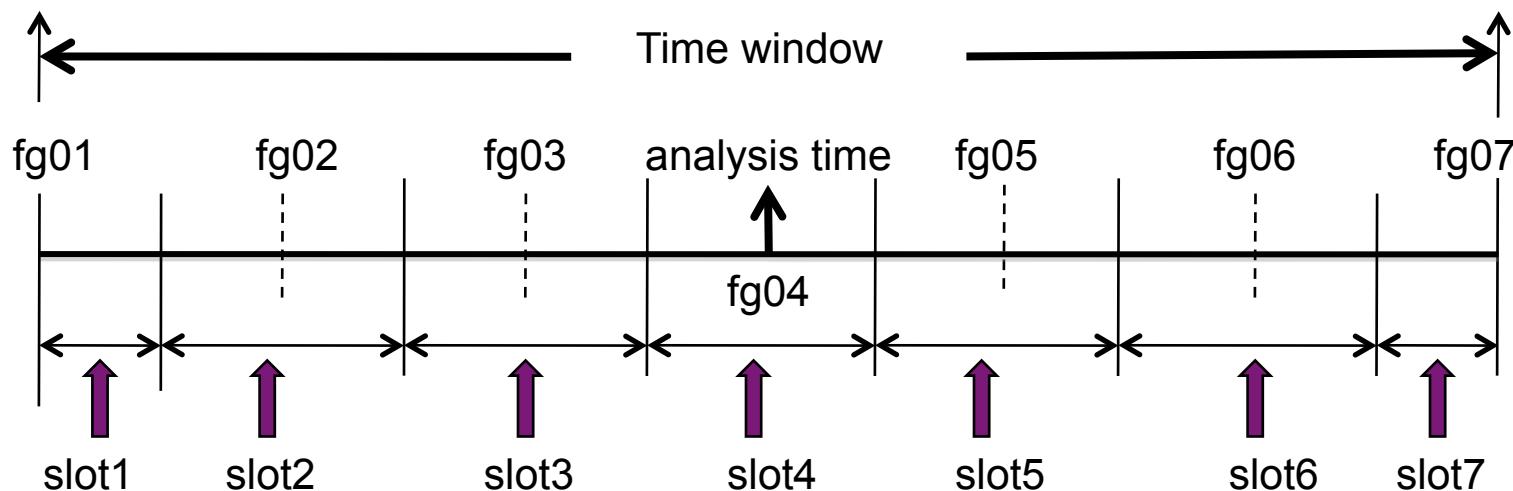
observation binning for WRFDA

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

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

fixed platform
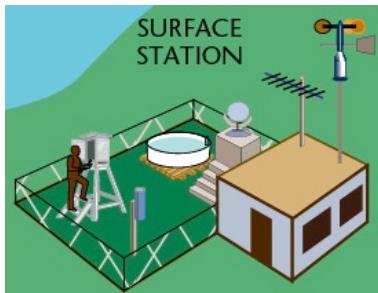
＋ 09:00
＋ 10:00
＋ 11:00
＋ 12:00
＋ 13:00
＋ 14:00
＋ 15:00

3DVAR: **＋ ○○○○○○○**

FGAT:		4DVAR:	
bin 01	○	bin 01	＋ ○
bin 02	○	bin 02	＋ ○
bin 03	○	bin 03	＋ ○
bin 04	＋ ○	bin 04	＋ ○
bin 05	○	bin 05	＋ ○
bin 06	○	bin 06	＋ ○
bin 07	○	bin 07	＋ ○

moving platform

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

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

Observations in little_r format

OBSPROC

ob.ascii — **ob_format=2**

ob.bufr
gpsro.bufr — **ob_format=1**
ob_format_gpsro=1

radiance

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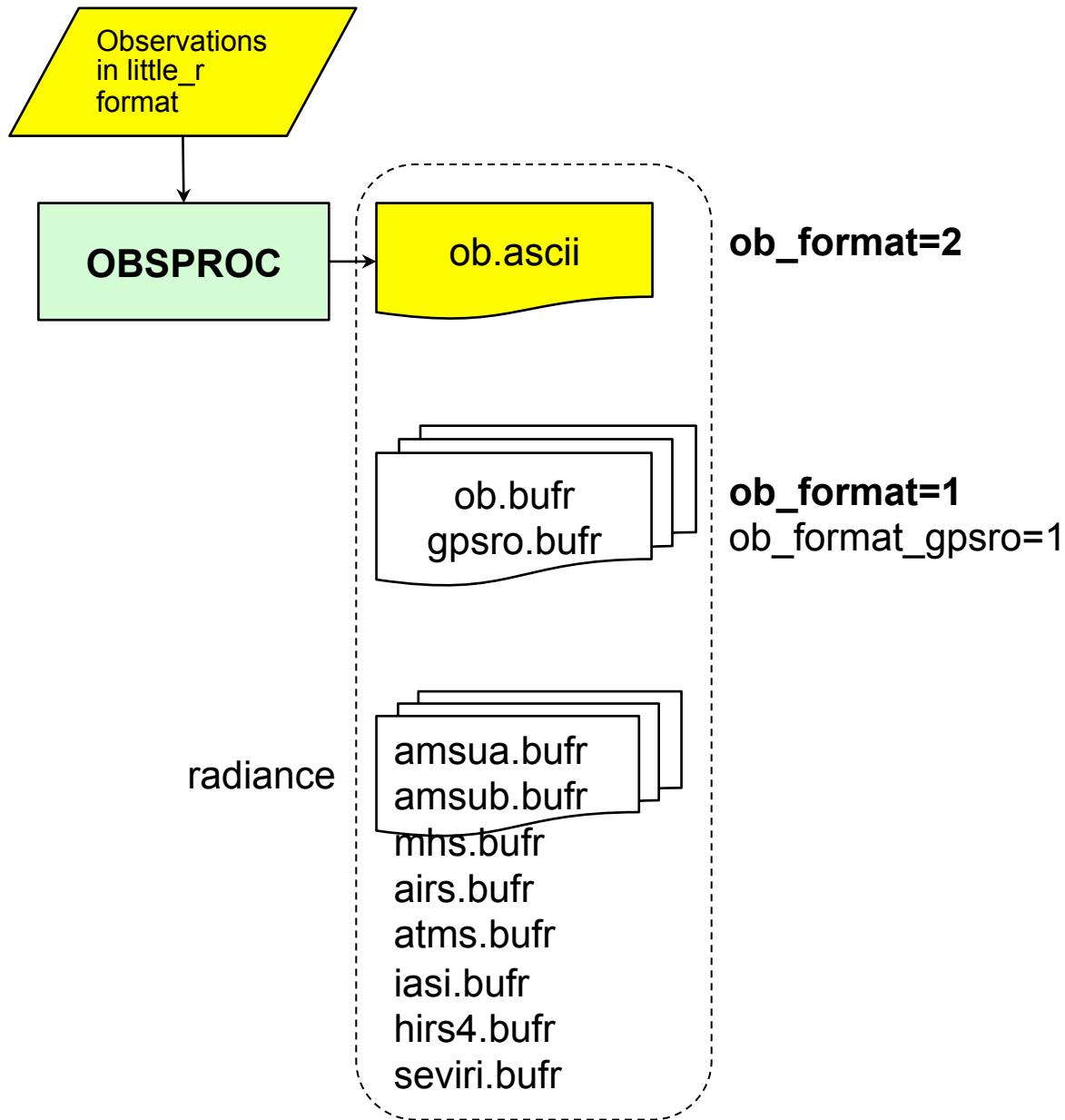
WRFDA

For <u>conventional</u> data:

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

For <u>radiance</u> 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 = .true. (**.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 = 300.0,   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
 /
```

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

&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
 /
```

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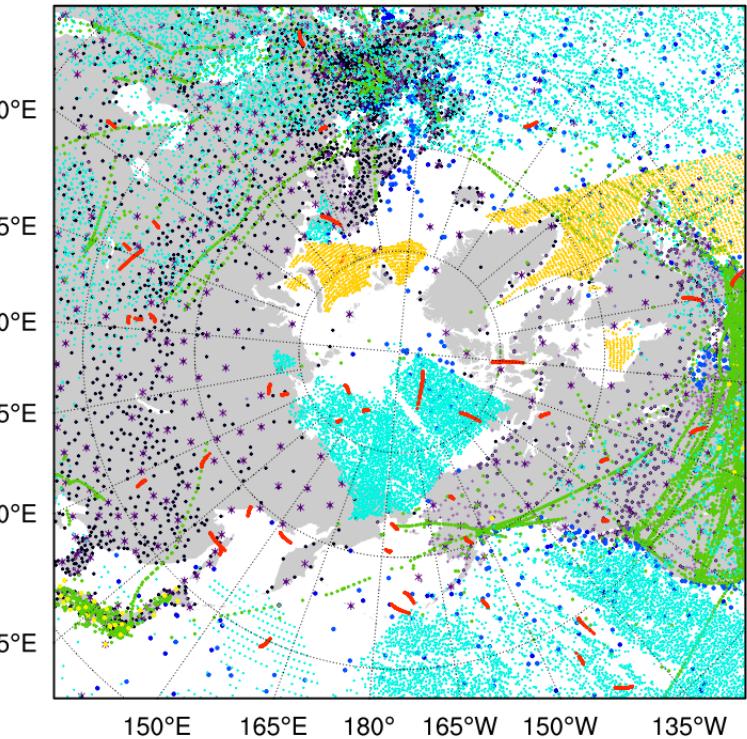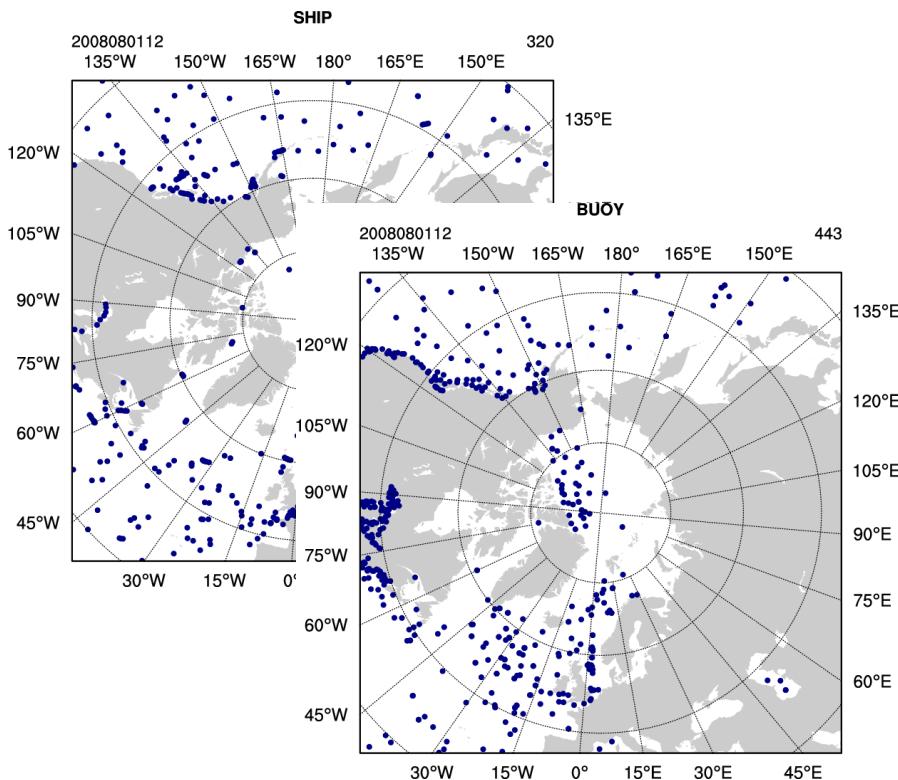
http://www2.mmm.ucar.edu/wrf/users/wrfda/download/tools.html

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

Observations in little_r format

OBSPROC

ob.ascii — ob_format=2

ob.bufr
gpsro.bufr — ob_format=1
ob_format_gpsro=1

radiance

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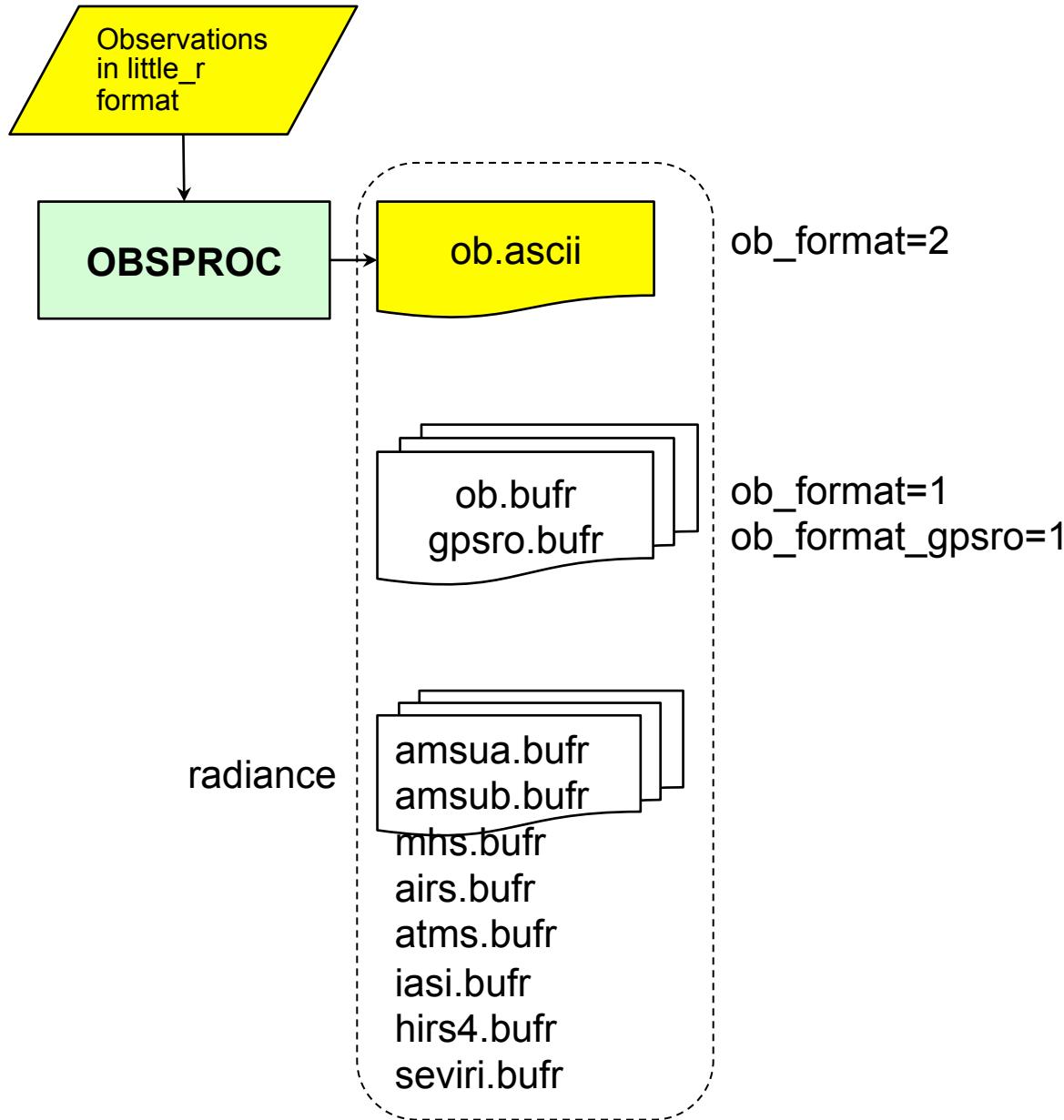
WRFDA

✓ 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

Little_r file…

Report 1

.

.

Report 10

.

.

Report n

Header record ⟶ field1, … field60

Data record ⟶ field1, … field20

Ending record ⟶ field1, … field20

3 tail integers ⟶ -888888   -888888   -888888

Reports can be from different observation types:
metar, ship, sound, amdar, profl, airep, etc.

✓ WRF User's Guide Chapter 7

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

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little_r format

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

No	Field	No	Filed	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)	47	Tb19v%data (f13.5)	48	Tb19v%qc (i7)
49	Tb19h%data (f13.5)	50	Tb19h%qc (i7)	51	Tb22v%data (f13.5)
52	Tb22v%qc (i7)	53	Tb37v%data (f13.5)	54	Tb37v%qc (i7)
55	Tb37h%data (f13.5)	56	Tb37h%qc (i7)	57	Tb85v%data (f13.5)
58	Tb85v%qc (i7)	59	Tb85h%data (f13.5)	60	Tb85h%qc

SSMI TB can be omitted

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)

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

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 data in little_r format

```
C header:

     WRITE ( UNIT = iunit , ERR = 19 , FMT = rpt_format )
     *         xlat,xlon, string1 , string2 ,
     *         string3 , string4 , ter, kx*6, 0,0,iseq_num,0,
     *         logical1, logical2, logical3,
     *          -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

C report:

     do 100 k = 1 , kx
        WRITE ( UNIT = iunit , ERR = 19 , 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
100    continue

C end of report line:

     WRITE ( UNIT = iunit , ERR = 19 , FMT = meas_format )
     * -777777.,0, -777777.,0,float(kx),0,
     * -888888.,0, -888888.,0, -888888.,0,
     * -888888.,0, -888888.,0, -888888.,0,
     * -888888.,0

C end of message line:

     WRITE ( UNIT = iunit , ERR = 19 , 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

Questions?

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