Joe,

Below are the remaining items, raised by HRD and NSSL, deemed necessary to bring the MMR closer to being a research radar (e.g., compatible with NCAR software standards and sufficiently documented). I have specifically noted items where CfRadial 1.3 non-compliance may be an issue. All of the items below were assessed using the MMR test-flight data from 11 December 2019 after the latest software upgrade.

Item 0: Despite repeated requests (the latest written in an email from 10 Feb 2020, Item 1), we have not yet received (acceptable) documentation on how the data is calculated from a radar engineering perspective and a table of MMR mode and key radar parameters for each mode. We would expect such documentation for any research radar (as one example, see Table 1 and Section 2 discussion of Jorgensen et al. 1983 "Feasibility test of an airborne pulse-Doppler meteorological radar" in J. of Climate and Applied Meteorology). While we have gleaned some information on the MMR system from our various queries, we remain confounded as to why something as simple as a "radar characteristics" table cannot be provided. It is not possible to present MMR results in the scientific literature without such standard documentation of the radar system and data computation method.

Item 1: (1.3 compliance issue) According to the CfRadial file, 'meters_to_center_of_first_gate' is assigned a value of 0 m and the first element of the 'range' variable is 0 m (which seems implausible). Is the gate reported to be at 0 m really at 0 m, or some distance from the radar? We need to know the *actual* range to the first gate and thus the ambiguity of the gate range N-vector values. This is of first-order importance for accurate scientific analysis. We need to know this confirmed value to prepare output MMR files for community use. This information needs to be output via the updated MMR processor software.

Item 2: (1.3 compliance issue) The horizontal and vertical beam width values have not been written to the MMR output (although we previously requested: radar_beam_width_h and radar_beam_width_v as output data in the CfRadial file). We need to know these confirmed

values to prepare output MMR files for community use. These need to be output via the updated MMR processor software.

Item 3: Is the recorded MMR beam elevation aircraft-relative or meteorological (earth-relative)? What we are accustomed to with airborne radar is that azimuth and elevation are recorded in the raw data relative to the aircraft. Or is the antenna stabilized?

Item 4: (1.3 compliance issue) In the attributes for VEL and DBZ, the file *incorrectly* states that '_fillValue' is -9999.f. It is not. That is false. The _fillValue is actually 0 according to our investigation of the data. We do not *want* the "no data" value to be 0 (we want it to be -9999.f), but if it *must* be 0, then the '_fillValue' attribute should state that it is 0. We believe this is a CfRadial 1.3 compliance issue. Incorrect information should not be stated in CfRadial 1.3 files. All other fields should be checked by the contractor to ensure compliance. See HWX_2019_12_11_18_43_49.nc for an example where the "no-data" value appears to be 0 in DBZ and VEL. In the CfRadial 1.3 documentation, the "example ncdump from a valid CfRadial file" given there would suggest that -9999.f *must* be used as the "no data" flag. So an argument could be made that the contractor's use of 0 (e.g., in DBZ and VEL) is not CfRadial 1.3 compliant.

Item 5: (1.3 compliance issue) In the HWX 'units' attribute for DBZ, the CfRadial says 'dB (resolution=0.375)'. First, what is meant by 'resolution'? Or does this refer to a scale factor. In any event, it is our understanding that the HWX DBZ field no longer needs to be divided by 0.375 since the last software update. The DBZ values read directly from the CfRadial from the test flight *seem* reasonable to us. A similar attribute is listed for DBZ in the NAW file. If we plot the DBZ from the NAW file, it is too low. It appears that when we divide by 0.375, the values are more reasonable. Do we need to divide the NAW DBZ by 0.375? Perhaps the contractor needs to apply whatever change they made to HWX DBZ also to the NAW DBZ?

Item 6: During the 11 Dec test flight, we do not believe any recording was done with maximum range beyond 160 km. Since we observed the azimuthal "spoking" within sweeps primarily for

HWX recording with max range > 160 km, we could not assess whether any of the changes made by the contractor during the test flight improved this issue. A future test of the MMR is needed.

Item 7: We understand now why the junk files exist in the transition between modes. We agree that a filter based on file size should be adequate. What we cannot understand are occasional bad data written to HWX files (e.g., HWX_2019_12_11_18_43_49.nc). It seems that 'tx' (and we have no idea what 'tx' is) is usually 1, but can take on 0 and numbers much greater than 1 for periods. How do we interpret 'tx'? What is the source of this error? We also see this in NAW files (e.g., NAW_2019_12_11_18_44_33.nc). Below is an example from the referenced HWX file. The values appearing there are inconsistent with any _fillValue, so we don't know what to make of them.

netcdf HWX_2019_12_11_18_43_49 {
tx = 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,

1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,

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, 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, 104, 0, 231653574, -1090519021, 3655, 3665, 3666,

3667, 3668, 3669, 3670, 3671, 3672, 3673, 3674, 3675, 3676, 3677, 3678,

3679, 3680, 3681, 3682, 3683, 3684, 3685, 3686, 3687, 3688, 3689, 3690,

3691, 3692, 3693, 3694, 3695, 3696, 3697, 3698, 3699, 3700, 3701, 3702,

3703, 3704, 3705, 3706, 3707, 3708, 3709, 3710, 3711, 3712, 3713, 3714,

3715, 3716, 3717, 3718, 3719, 3720, 3721, 3722, 3723, 3724, 3725, 3726,

3727 ;

drift = -0.6168365, -0.6485672, -0.643074, -0.6375809, -0.6320877,

-0.6265945, -0.6211014, -0.6156082, -0.6101151, -0.6101151, -0.6046219,

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, 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, 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, 0, 0, 0, 0, 0, 0,

0, 0, 0, 0, 0, 1.45735e-43, 0, 1.274568e-30, -0.5000011, 35.98022,

39.97925, 41.17676, 42.29736, 43.43994, 44.57703, 45.74707, 46.86768,

47.98279, 49.06494, 50.18555, 51.35559, 52.45422, 53.56384, 54.646,

55.79407, 56.90918, 58.05725, 59.21082, 60.33142, 61.45203, 62.52319,

63.67676, 64.83032, 65.92896, 67.099, 68.16467, 69.27429, 70.42786,

71.53198, 72.65808, 73.74023, 74.92126, 76.08582, 77.20093, 78.35449,

79.48059, 80.62317, 81.72729, 82.88635, 83.98499, 85.08362, 86.18774,

87.25891, 88.3905, 89.56055, 90.6427, 91.7688, 92.97729, 94.13635,

95.26794, 96.39954, 97.49268, 98.64624, 99.76685, 100.9039, 102.0905,

103.2166, 104.3317, 105.4138, 106.474, 107.5507, 108.6493, 109.7534 ;

longitude = -81.2493057250977, -81.2491912841797, -81.249153137207,

-81.2491149902344, -81.2490844726562, -81.2490463256836,

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4.55714898631552e-270, 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, 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,

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, 0, 0, 0, 0, 0, 0 ;

Regards,
Paul