Construction of a Range Reference Atmosphere for Woomera, Australia

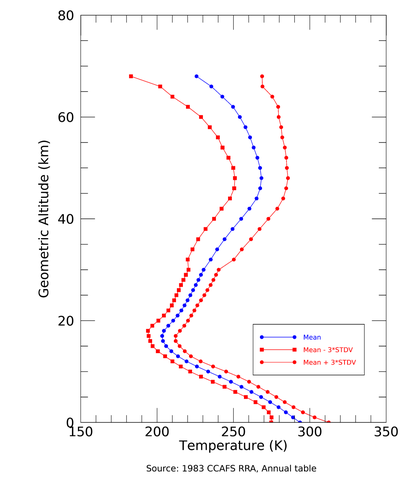
Corey Walker, Jacobs Space Exploration Group (JSEG)

INTRODUCTION

Range reference atmospheres (RRA) are tabulated, statistical measures of values such as atmospheric pressure, wind, temperature, and density over a set of altitudes [1] specific to a given geographical location. The MSFC Natural Environments Branch has developed a RRA for Woomera, Australia after receiving multiple requests from the Range and Aerospace meteorology community.

WHAT IS AN RRA?

The goal of a RRA is to provide a baseline for characterizing monthly and annual atmospheric conditions for applications in the aeronautic and aerospace industry. These include examples such as pressure altimeter calibrations, aircraft performance calculations, the development of ballistic tables and other purposes relating to aircraft design and advanced mission/test planning [2].



1983 RRA for Temperature Cape Canaveral Air Force Station [1]

WHY WOOMERA?

- NASA and US defense programs have used Australian Outback for rocketry and upper atmosphere research.
- The Woomera RRA would serve as dataset to assist in future Woomera launch applications.



Launch of a NASA Skylark sounding rocket from the Woomera Range Complex in c. 1961



Map of South Australia showing the land area covered by the RAAF Woomera Range Complex

NASA Skylark Mission at Woomera Range, left [4]. Map of Woomera with Range Complex highlighted in yellow, right [4].

DATA

SITE ID	DATA	RECORD	Number of Input Profiles
WOOM, WMO ID 94659 located at 31.14609S, 186.805E	Integrated Global Radiosonde Archive (IGRA) which is a product of the National Center for Environmental Information	1990 - 2023	19,384 atmospheric profiles

Meteorological Parameter	Units	Statistical Quantities
Geometric altitude (Z)	km	Vertical coordinate (independent variable)
Zonal wind component (U)	m/s	Mean, median, standard deviation
Meridional wind component (V)	m/s	Mean, median, standard deviation
Wind component correlation (R_{UV})	dimensionless	Linear product-moment correlation coefficient
Wind speed (WS)	m/s	Mean, median, standard deviation, skewness
Number of wind observations	dimensionless	Arithmetic sum
Atmospheric pressure (P)	mb	Mean, median, standard deviation, skewness
Atmospheric temperature (T)	C	Mean, median, standard deviation, skewness
Atmospheric density (D)	g/m^3	Mean, median, standard deviation, skewness
Number of thermodynamic observations	dimensionless	Arithmetic sum
Water vapor pressure (VP)	mb	Mean, median, standard deviation, skewness
Virtual temperature (Tv)	C	Mean, median, standard deviation, skewness
Dewpoint temperature (Td)	C	Mean, median, standard deviation, skewness
Number of humidity observations	dimensionless	Arithmetic sum

METHODS

STEP 1: Ingest Input Data
- Gather upper-air profiles from weather offices.
- Combine data from weather balloon flights since 1990.

STEP 2: Quality Control
- Conduct checks to remove bad data.
- Remove profiles with identified issues.

STEP 3: Interpolate Data
- Interpolate profiles to 0.5 km vertical resolution.
- Save interpolated profiles to separate files.

STEP 4: Compute Derived Quantities
- Calculate additional quantities like vapor pressure, virtual temperature and density using adapted equations and methods.

STEP 5: Compute Statistics
- Tabulate mean, median, and standard deviation values.
- Compute skewness.

STEP 6: Perform Diagnostic Testing
- Check standard deviations for all calculated variables.
- Flag profiles exceeding 6 standard deviations and remove.
- Iterate until envelope values are not exceeded.

STEP 7: Perform Validation Testing
- Conduct additional tests to validate statistical values.
- Address any identified issues through manual inspection.
- Repeat process until no validation test failures occur.

STEP 8: Output RRA Data files
- CSV Excel file with all computed RRA values

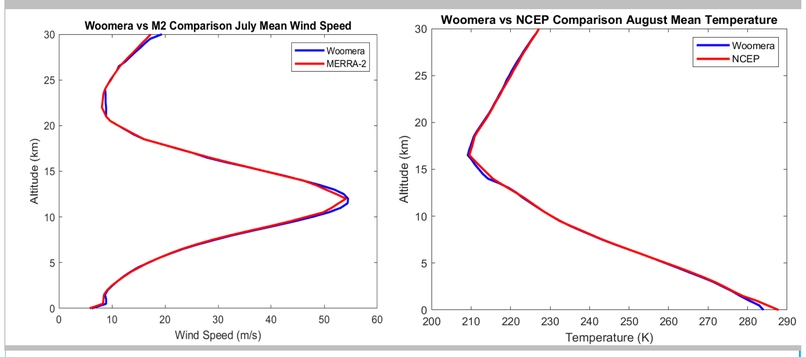
Global Reference Atmosphere Model (GRAM) outputs:
- Formatted Text file for wind statistics
- Formatted Text file for thermodynamics
- Formatted Text file for moisture values

94659 31.14609S 136.805E
TABLE I- 1. WIND STATISTICAL PARAMETERS
January
STATION = 94659 WOOMERA, AUSTRALIA

Z KM	MEAN U M/S	SD U M/S	R(U,V)	MEAN V M/S	SD V M/S	MEAN WS M/S	SD WS M/S	SKEW WS	NOBS
0.000	0.00	0.00	0.0000	0.00	0.00	0.00	0.00	0.00	100
0.169	-2.71	3.59	0.0881	2.66	5.73	7.09	3.13	0.68	459
0.500	-2.31	4.16	-0.0008	1.45	6.65	8.07	3.15	0.84	460
1.000	-0.88	4.40	-0.0753	-0.43	6.79	7.33	3.92	0.89	491
1.500	1.07	4.88	-0.0087	-0.64	6.02	6.73	4.08	0.82	492
2.000	2.13	5.27	-0.0877	-0.66	5.50	6.95	4.06	1.11	492
2.500	2.91	5.97	-0.1276	-0.40	5.58	7.61	4.49	1.08	492
3.000	3.54	6.50	-0.1317	0.02	5.82	8.14	4.86	0.87	492
3.500	4.16	6.83	-0.0963	0.52	5.97	8.70	5.05	0.82	492
4.000	4.83	7.11	-0.1087	0.95	5.97	9.16	5.30	0.91	492
4.500	5.37	7.20	-0.0731	1.21	5.89	9.36	5.54	0.97	492
5.000	5.96	7.22	-0.0324	1.36	5.91	9.80	5.58	1.02	492
5.500	6.69	7.44	-0.0326	1.57	6.18	10.43	5.80	0.95	492
6.000	7.45	8.02	-0.0652	1.57	6.31	11.16	6.21	0.79	492
6.500	8.32	8.49	-0.0879	1.56	6.44	11.98	6.66	0.71	492
7.000	9.09	9.11	-0.1112	1.57	6.73	12.80	7.22	0.73	492
7.500	10.15	9.74	-0.1209	1.40	7.33	13.91	7.80	0.74	492
8.000	11.22	10.23	-0.1282	1.43	7.72	15.09	8.20	0.67	491
8.500	12.35	10.78	-0.1405	1.81	8.00	16.16	8.84	0.60	491
9.000	13.78	11.58	-0.1364	1.98	8.31	17.53	9.65	0.62	491
9.500	15.37	12.49	-0.1341	2.07	8.74	19.08	10.53	0.63	491
10.000	16.94	13.22	-0.1300	2.37	9.42	20.79	11.28	0.56	491
10.500	18.65	14.09	-0.1479	2.61	10.07	22.62	12.09	0.52	490
11.000	20.30	14.64	-0.1750	2.70	10.41	24.19	12.59	0.50	490
11.500	21.79	14.88	-0.2040	3.09	10.73	25.68	12.90	0.39	489
12.000	23.11	15.17	-0.2198	3.50	10.98	27.04	13.04	0.36	489
12.500	24.13	15.33	-0.2409	3.62	11.06	27.95	13.16	0.32	488
13.000	24.28	15.37	-0.2708	3.55	11.08	28.17	13.13	0.32	488

Sample Output Data Produced from Python Code for GRAM [3]

RESULTS



Woomera vs MERRA-2 July Wind Speed, left. Woomera vs August Mean Temperature, right.

- The process defined in the prior steps reduced the number of usable profiles from 19,384 to 8,398.
- Validation of the RRA was conducted through comparison between the RRA and Earth-GRAM outputs.
- Earth-GRAM data used for comparison was generated utilizing the National Centers for Environmental Prediction (NCEP) and the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) data option in Earth-GRAM.

CONCLUSION

- The Woomera RRA shows good agreement with both MERRA-2 and NCEP datasets.
- The Woomera RRA will be released in the Spring 2024 GRAM Suite release.
  - Software Catalog: https://software.nasa.gov/software/MFS-33888-1
- Contact Earth-GRAM Lead Patrick White regarding requests for RRA development or upgrades:
  - Email: patrick.w.white@nasa.gov
- In near future, the RRA will be available on Air Force Reserve Command Weather website: https://weather.dfrc.nasa.gov/Climatology
- There will be periodic updates to RRAs

REFERENCES

[1] Burns, Lee. 2019. Range Reference Atmosphere 2019. Accessed 1 23, 2024. https://weather.dfrc.nasa.gov/data/rcc/RRA_2019_Dev_Report.pdf.

[2] Johnson, Dale L, and Barry C. Roberts. 2013. Reference and Standard Atmosphere Models. National Aeronautics and Space Administration. 9 7. Accessed 1 2024. https://ntrs.nasa.gov/api/citations/20020092087/downloads/20020092087.pdf.

[3] Diekmann, Anne. 2020. Range Reference Python Code Version 2019.1. Huntsville: Jacobs. Range Reference Atmosphere Python Code. Jacobs.

[4] Wikipedia contributors. (2024, February 26). RAAF Woomera Range Complex. In *Wikipedia, The Free Encyclopedia*. Retrieved 14:13, April 8, 2024, from https://en.wikipedia.org/w/index.php?title=RAAF_Woomera_Range_Complex&oldid=1210306705