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A STUDY OF CLIMATOLOGICAL TEMPERATURE PROFILES OVER THE NORTHERN HEMISPHERE

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ABSTRACT

Present day atmospheric and aeronautic applications use the ICAO (International Civil Aviation Organization) US Standard Atmosphere Standard Atmosphere, which is an average, piece-wise continuous, mid-latitude temperature profile of the earth's atmosphere. The ICAO temperature profile has been used in the aviation field for over 30 years. Nevertheless, seasonal changes in conjunction with latitudinal variations can produce temperature profiles that can significantly differ from the standard atmosphere, especially for geographical regions located at high latitudes. This study investigates a parameterization of the climatological temperature profiles in the Northern Hemisphere. The parameterization is based on neural network algorithm that uses archived radiosonde measurements, retrieved temperature profiles from remote sensors, the ICAO atmosphere supplement and the incoming solar insolation at the top of the atmosphere. Radiosonde temperature profiles from Santa Teresa, New Mexico were used as a test case to evaluate the temperature profile parameterization's performance. Specific practical applications are outlined and highlighted. Recommendations on improving or enhancing the current parameterization will be discussed and future studies will be summarized.

1. INTRODUCTION

1.1 Present day atmospheric and aeronautic applications use the ICAO (International Civil Aviation Organization) US Standard Atmosphere Standard Atmosphere (U.S. ICAO Standard Atmosphere, 1958, 1962, 1966, 1976), which is an average, piece-wise continuous, mid-latitude temperature profile of the earth's atmosphere. The ICAO temperature profile has been used in the aviation field for over 30 years. Nevertheless, seasonal changes in conjunction with latitudinal variations can produce temperature profiles that can significantly differ from the standard atmosphere, especially for geographical regions located at high latitudes. In today's modern world with very sophisticated applications utilizing atmsopheeric temperature profiles, it is imperative to

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the most accurate climatological temperature profiles available through extensive analysis.

This study investigates a method of calculating climatological temperature profiles in the Northern Hemisphere. The methodology is based on neural network algorithms that use archived radiosonde measurements, retrieved temperature profiles from remote sensors, climatological information and the incoming solar insolation at the top of the atmosphere. Radiosonde temperature profiles from Santa Teresa, New Mexico were used as a test case to evaluate the temperature profile parameterization's performance. Specific practical applications are outlined and highlighted. Recommendations on improving or enhancing the current parameterization will be discussed and future studies will be summarized.

1.2 The current US Standard Atmosphere is shown in figure 1. The temperature profile closely follows the constant lapse rate of -

6.5 degrees per kilometer in atmospheric height.

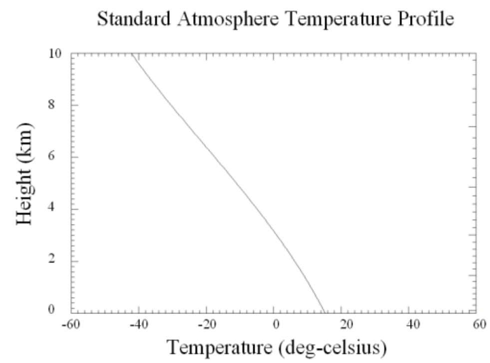

Figure 1 Standard Atmospheric Temperature Profile.

1.3 There are latitudinal variations of the standard atmosphere as evidence by global satellite temperature retrievals such as the AIRS global daytime air temperature retrievals at 700mb (figure 2).

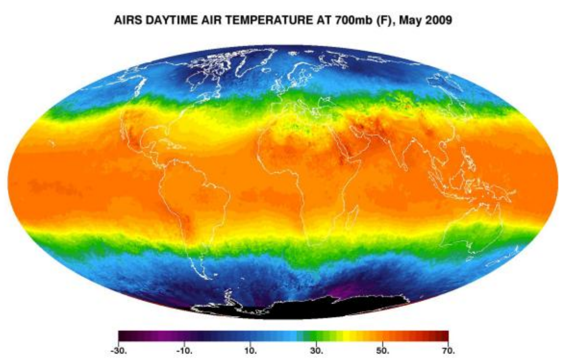

Figure 2. AIRS satellite measurement of the daytime air temperature over the world at 700mb for May 2009 showing latitudinal variations of temperatures at that level (NOAA product).

2. TEMPERATURE PROFILING MEASUREMENTS

Temperature profiling of the atmosphere can be measured either indirectly by remote sensing techniques or by point measurements such as balloon borne instrumentations. Ground based temperature measurements can be obtained by microwave, acoustic, or infrared sensors. Temperature profiles can also be obtained through satellite based sounders such as the TIROS Operational Vertical Sounder (TOVS) system and the GOES satellite. A brief description of these instruments is given. Table 1 is a tabulation of various meteorological sensors and their associated characteristics.

2.1 GROUND BASED MICROWAVE RADIOMETERS

The ground based microwave radiometer is capable of measuring temperature profiles from the surface up to 10 km height (Radiometrics, 1997; Measure and Yee, 1992; Yee and Measure, 1992). The microwave radiometer incorporates a frequency agile local oscillator permitting frequency tuning in the 22-30 GHz and 51-59 GHz regions. The tunable frequencies cover the oxygen band, water line, and window region thereby allowing measurements of temperature, water vapor, and liquid water. Past field experiments have shown the instrument to be reasonably reliable and portable.

2.2 SATELLITE REMOTE SOUNDERS

The GOES I-M Sounder is a 19-channel radiometer that senses specific data parameters for atmospheric temperature and moisture profiles, surface and cloud top temperature, and ozone distribution (Menzel, 1995; Hayden and Schmit, 1994). The satellite Sounder system is able to measure profiles over remote locations where ground-based balloon systems are absent. The Sounder has 4 sets of detectors:
visible (.7 micrometer)
long wave IR (12-14.7 micrometers)
medium wave IR (6.5-11 micrometers)
short wave IR (3.7-4.5 micrometers).

NOAA SATELLITE

The TIROS Operational Vertical Sounder (TOVS) system is used to infer temperature and winds. The system consists of three separate instruments: High Resolution Infrared Radiation Sounder (HIRS), Microwave Sounding Unit (MSU) and Stratospheric Sounding Unit (SSU). The

HIRS instrument is a step-scanned multi-channel spectrometer with 20 channels primarily in the infrared region of the spectrum. These 20 spectral bands permit the calculation of the vertical temperature profile from Earth's surface to about 40 km. Multispectral data from one visible channel (0.69 micrometers), seven shortwave channels (3.7 to 4.6 micrometers) and twelve longwave channels (6.5 to 15 micrometers) are obtained from a single telescope and a rotating filter wheel containing twenty individual filters. The instantaneous FOV (Field Of View) is 1.3 to 1.4 degrees from an altitude of 833 kilometers, encompassing an area of approximately 19-20 kilometers at nadir on the Earth. The swath width is about 2300 km. (Kidder & Vonder Haar, 1995)

2.3 RADIOSONDE

The radiosonde is a balloon-borne instrument for the simultaneous measurement and transmission of meteorological data producing vertical profiles of atmospheric pressure, temperature, humidity, and wind speed and direction. Newer radiosondes employ GPS (Global Positioning Satellites) to derive the winds as the balloon ascends. The balloon ascends from the surface up to 20-30 km height over approximately 1-2 hour period.

2.4 ROCKETSONDE

The rocketsonde is a sounding rocket which is composed of a rocket and meteorological instrumentations that can record the temperature, relative humidity, wind speed and direction, atmospheric pressure, air density, altitude and latitude/longitude (Marconi). A typical rocketsonde is capable of recording weather measurements up to an altitude of 75,000 m. Common meteorological rockets (rocketsondes) are the Loki and Super Loki. Rocketsondes allow exploration of the stratosphere and mesosphere (W.L. Webb).

3. TEMPERATURE PROFILE METHODOLOGY

The temperature profile model is based on a neural network algorithm that uses archived radiosonde data, retrieved temperature profiles from remote sounders, climatological information and the solar insolation at the top of the earth's atmosphere.

Pioneer neural network research in atmospheric sciences was conducted at the former Atmospheric Sciences Laboratory in the early 1990's (Measure & Yee, 1992). The research involved experimentation with neural network methods to retrieve temperature profiles from ground based microwave radiometers (Yee & Measure, 1992) as well as from satellite radiance measurements. Neural networks were trained using simulated microwave radiometric measurements and archived radiosonde measurements to produce vertical profiles of temperature from the surface to approximately 10 kilometers. Those experiments yielded errors comparable to those achieved by other sounder based methods. Neural networks are ideally suited for processing and assimulating diverse data measurements and analyzing large data sets.

Features of the Algorithm

- The model produces a mean seasonal temperature profile with latitudinal dependence for the Northern Hemisphere.
- The model is a neural network based algorithm that uses the archived radiosonde measurements, retrieved temperature profiles from remote sensors, climatological information and the solar insolation at the top of the atmosphere.
- Valid from sea level up to 10 kilometers atmospheric height.

Figure 3 is an analysis the mean temperature profiles for four different latitudinal belts (20 deg N, 40 deg N, 60 deg N, and 80 deg N).

4. CASE STUDY

For the case study, radiosonde observations from the El Paso/Santa Teresa National Weather Service station (EPZ) for the month of January 2009. The data was screened for missing or questionable data values. The results are shown in figure 4. The RMS error between the model's mean temperature profile and the El Paso/Santa Teresa NWS mean temperature profile for January 2009 was 2.2 degrees Celsius. The RMS error between the standard profile and the El Paso/Santa Teresa January 2009 mean temperature profile was 6.5 degrees Celsius.

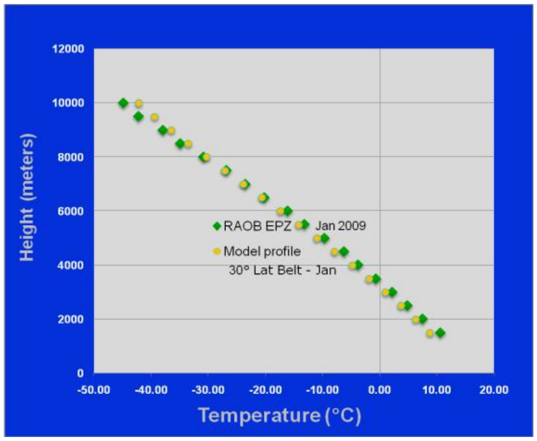

Figure 4. Comparison between model mean temperature for 30 degrees latitude and the mean temperature profile for January 2009 (EPZ station).

5. CONCLUSION

Latitudinal variations of the mean temperature profiles are shown to be significant. Modern day aeronautic and aerospace applications require more accurate mean temperature profiles than one, all-season standard atmosphere. For the test case the RMS error between the model and the mean temperature profile for the El Paso/Santa Teresa NWS station (Jan 2009) was 2.2 deg Celsius. The RMS error between the US Standard Atmosphere temperature profile and the El Paso/Santa Teresa station (Jan 2009) was 6.5 deg Celsius.

The investigators have proposed an augmentation of the standard atmosphere that can be used for atmospheric research, aerospace vehicle analysis and aircraft performance.

RECOMMENDATIONS

• Collect and assemble climatological temperature profiles for other latitudinal belts for the different seasons to compile more complete data sets.
• Perform test and evaluation at other geographical locations
• Perform sample tests to determine value to the aeronautic and aerospace community
• Investigate broader applications of the model

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MET SENSOR	**METEOROLOGICAL MEASUREMENT**	**MEASUREMENT METHOD**	**RANGE**
Microwave Radiometer	Temperature	Ground-based, Remote Sensing, Continuous sampling (minutes)	near surface to 10 km, vertical
Rocketsonde	Temperature, Pressure, Relative Humidity, Winds	Rocket point measurements, Continuous sampling (minutes, seconds)	as high as 1000 km depending on the boosters
Sounders on GOES Satellite	Inferred temperature and winds from Infrared/Microwave Radiances	Satellite-based, Remote Sensing, Geostationary, Hemispheric sampling (hourly)	Top of Atmosphere to Surface depending on the spectral channel
Sounders on NOAA Satellite	Inferred temperature and winds from Infrared/Microwave Radiances	Satellite-based, Remote Sensing, Polar Orbiting, 1-2 passes/day	Top of Atmosphere to Surface depending on the spectral channel
Radiosonde	Temperature, Pressure, Relative Humidity, Winds	Balloon-based, Point measurement, 2 Launches/day operationally	Ascension from surface to typically 40 km depending on wind drift

Table 1. Table of meteorological sensors for atmospheric temperature measurements

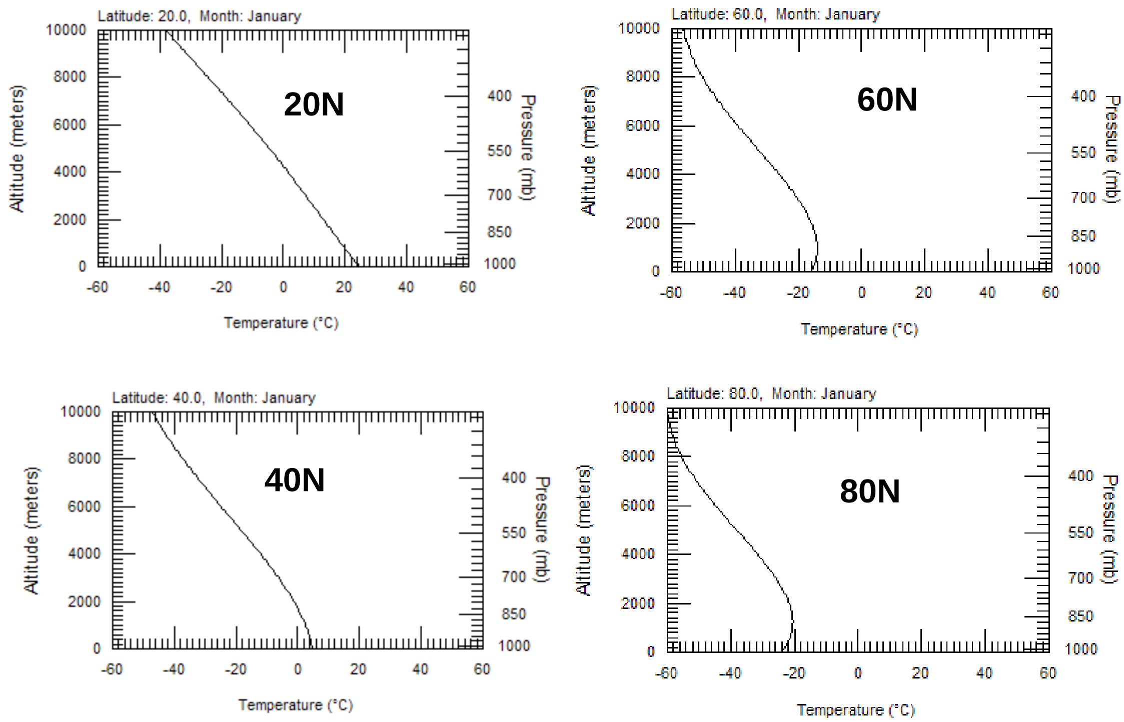

Figure 3. The model's mean temperature profiles for January at different latitudes (20 deg N, 40deg N, 60 deg N, and 80 deg N).