Research Paper PHYSICAL SCIENCE

Estimation of Error in Surface Refractivity Using Satellite Meteorological Dataset

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ABSTRACT

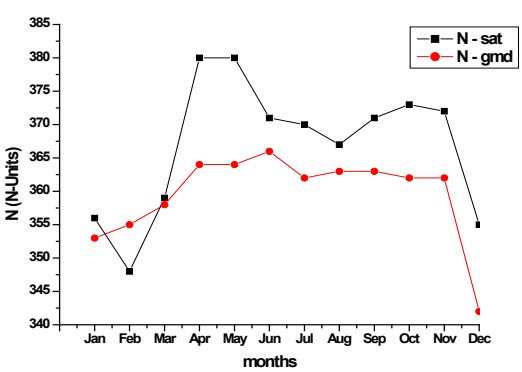
The problems associated with periodic sampling and thinning process of large amounts of satellite meteorological data usually bring about errors in measurement that lead to measured values being inconsistent when compared with data from ground meteorological stations. The meteorological data measured at Obafemi Awolowo University, Ile – Ife, Nigeria covering a period between January and December, 2010 were averaged daily and statistically analyzed to estimate mean and standard deviation of error with the aim of determining error contributions in dry term and wet term of surface refractivity when using satellite dataset.

The mean error was observed to have higher percentage in wet terms than in dry term. It was observed that the standard deviation in measurement of relative humidity was ±1.26% in wet season and ±4.66% in dry season. Measurement inconsistencies in satellite and ground station values of temperature and relative humidity were largely responsible for the error in surface refractivity estimated from satellite dataset.

KEYWORDS meteorological dataset, measurement error, surface refractivity error,

1.0 Introduction

The problems associated with periodic sampling and thinning process of large amounts of satellite meteorological data usually bring about errors in measurement that lead to measured values being inconsistent when compared with data from ground meteorological stations as shown in fig 1. Measurement errors may be caused by residual contamination of the observations from cloud, instrument calibration errors, or inaccurate specification of instrument spectral response filters (Azami *et al*., 2009). These limitations may restrict the extent to which surface refractivity values can be precisely assessed from satellite meteorological data.



Error in surface refractivity is therefore estimated to improve the capability of satellite dataset to offer values that are close to the ground station values. Ground station measurements of pressure, temperature, and relative humidity, at 2 m, collected at Obafemi Awolowo University (OAU: 7.28°N, 4.38°E), Ile-Ife and satellite dataset geo-referenced to the ground station in OAU were obtained. The data covering a period between January and December, 2010 were averaged daily and analyzed to estimate mean error and standard deviation of error with the aim of determining error contributions in dry term and wet term of surface refractivity when using satellite dataset.

Figure 1: Surface Refractivity Index Estimated from Satellite Dataset (N-sat) and Ground Measured Data (N-gmd) in Ile-Ife (2010)

2.0 Theoretical Background and Analysis

Suppose that ground station measurements P_{grd}, T_{grd}, e_{grd} are the precise and actual values of atmospheric pressure, temperature and vapour pressure while satellite dataset P_{sat}, T_{sat}, e_{sat} are the measured values of atmospheric pressure, temperature and vapour pressure. Whenever the measured parameters are used to calculate refractivity values, the errors observed in the measured parameter is as a result of inconsistency in the values of pressure, temperature and vapour pressure (ΔP, ΔT, Δe) which in turn lead to error in refractivity calculated (Niell, 2000). The estimation of error in dry term ($N_{d\text{-}error}$) and wet term ($d_{w\text{-}error}$) of refractivity with respect to actual values is therefore given as

$$N_{d-error} = \frac{\Delta P}{P_{grd}} + \frac{\Delta T}{T_{grd}} \quad 1.0$$

$\Delta P = P_{grd} - P_{sat}$ and $\Delta T = T_{grd} - T_{sat}$ (as shown in Table 1)

Also,

$$N_{w-error} = \frac{\Delta e}{e_{grd}} + 2\left(\frac{\Delta T}{T_{grd}}\right) \quad 2.0$$

$\Delta e = e_{grd} - e_{sat}$, and $\Delta T = T_{grd} - T_{sat}$ (as shown in Table 1)

Error analysis involves the estimation of likely deviation of the measured values from the actual values (Jean, 2002). The standard deviation of the mean error in Surface Refractivity Index, was therefore estimated using

$$SD = \sqrt{\frac{1}{N}\sum(x_i - \bar{x})^2} \quad 3.0$$

For the dry term, N_d, the error in annual estimation of daily means $x_i = N_{(d\text{-}error)i}$ (where i = 1, …., 365 and N = 365) was used to obtain corresponding standard deviation. Similarly, for wet term, N_w, the error in annual estimation of daily means $x_i = N_{(w\text{-}error)i}$ (where i = 1, …., 365) was used to obtain standard deviation. In the same way, mean error and standard deviation of dry and wet terms of refractivity was also obtained for dry and wet seasons; for dry season (Nov – Apr), i = 1 …, 181 and N =181.For wet season (May – Oct), i = 1 ……, 184 and N = 184. The results are shown in Table 1.

Table 1: Measurement Inconsistency in Satellite Meteorological Dataset

Month	ΔP	ΔT	Δe
1	-0.41	0.66	0.71
2	-1.21	2.49	3.87
3	-1.22	2.38	1.83
4	-1.14	0.94	-2.23
5	-1.89	-0.33	-1.89
6	-1.29	0.62	0.24
7	-0.83	-0.23	-0.81
8	0.84	0.04	0.43
9	-0.54	-0.44	-0.81
10	0.31	0.6	-1.41
11	1.88	0.49	-0.93
12	0.79	0.37	-1.76

3.0 Discussion of Results

The results of the analysis are shown in table 2. The mean error was observed to have higher percentage in wet terms than in dry term. The error in wet term had significant influence in the total surface refractivity error. The error in wet term of surface refractivity was found to vary substantially and it largely depends on measurement difference in relative humidity. The error in wet term can be minimized by improving on sampling sensitivity of satellite to surface moisture measurement. Error in dry term was caused by temperature measurement differentials while error in wet term was caused by moisture measurement differentials. The errors tended to increase in wet term during the wet months most especially in zones where large range of moisture variation occurred. The error in dry term would be more pronounced at latitudes above 15^0N where there is large diurnal range of temperature while the error in wet term would be more pronounced at latitudes below 10^0N where there is dense distribution of moisture. This climatic zone usually experience slight change in seasonal temperature variation; the error in dry term would be minimal in the zone.

Table 2: Mean and Standard Deviation of Error in Surface Refractivity Estimates from Satellite Dataset

Terms of Refractivity	Mean Error	Standard Deviation
Dry term (annual) (N_d)	0.002	0.004
Wet term (annual) (N_w)	1.041	0.215
Dry term (dry season) (N_{dd})	0.004	0.004
Wet term (dry seaon) (N_{wd})	1.035	0.295
Dry term (wet season) (N_{dw})	-0.001	0.003
Wet term (wet season) (N_{ww})	1.047	0.083

The standard deviation of error for surface refractivity in dry term was constant in dry season; this was because of small standard deviation in the measurement of temperature both from satellite and ground station dataset (±1.03). The standard deviation of error for surface refractivity in wet term was more pronounced in dry season than in wet season. It was observed that the standard deviation in measurement of relative humidity was ±1.26% in wet season and ±4.66% in dry season. Evaporation is more rapid in dry season due to low moisture at the earth surface thereby increasing the diurnal variation of water vapour at the boundary layer. Evaporation is minimal in the wet season and slight daily variation of water vapour was noticed. These are factors determining the standard deviation of error in dry term and wet term of surface refractivity.

The atmosphere often contains a significant amount of water vapour close to the earth surface due to evaporation from earth water bodies. As water vapour measurement difference makes major contributions to error in surface refractivity, problems associated with accurate estimation of surface refractivity do arise at locations close to the boundary layer. As moisture increases, attenuation of radio wave becomes severe.

The discrepancy in the measurement of relative humidity was more significant than that of pressure and temperature most especially in the dry season. The measurement error in relative humidity was most significant while that of pressure was least significant. The mean error and standard deviation for wet term had higher values than dry term in annual, dry and wet seasons. The tropical region below latitude 15^oN was observed to hold large amount of moisture most especially at heights close to earth surface. The spatial distribution of moisture and temperature across the latitude has played a major role in error observed in dry and wet term of surface refractivity for dry and wet season. The highest error and standard deviation occurred in dry season. The contribution of measurement difference in relative humidity was accountable for error in wet term and measurement difference in temperature was responsible for error in dry term.

4.0 Conclusion

Measured differences in satellite and ground station values of temperature and relative humidity were largely responsible for the error in surface refractivity estimated from satellite dataset. The mean and standard deviation of refractivity error in dry term was 0.004 in dry season; there is significant increase that is up to 1.047 during the wet season. The wet term has the highest range of standard deviation in dry season and the lowest range in wet season; this is an indication that error in surface refractivity was more pronounced in dry season than in wet season.

5.0 Acknowledgement

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