Abstract

The F₂ region of the Ionosphere is a complex one. There are large irregular changes of foF₂ from day - to - day. This paper discusses the diurnal and seasonal variations of foF₂. While the diurnal variation of foF₂ has a maximum value at a time far from mid-day, the seasonal variation curve has two maximum points in the months of March and November respectively, with a minimum in July. Thus, indicating that the seasonal variation of foF₂ is a semi - annual one. It was also shown that for short time variations, the day-to-day variability in foF₂ is neither due to season nor relative sunspot number, Rz. The test of significance between the standard errors of foF₂ before and after correction for season and Rz show no significant difference at 95% level of significance.

The Ionosphere consists of a number of ionized regions above the earth's surface at a height of 60km to 100km containing ions which play an important role in the propagation of radio waves. It is made up of three layers namely; the D, E and F regions. The region in which this study is based is the F region - ionized region above E region which is further divided into fi and F₂ layer in day- time. It is the critical frequency of Fj region that is used for this study.

The predominant ions are No⁺ and O²⁺ in the F region produced by electromagnetic radiation. In particular, the phenomenology of F₂ region is very complex in that the F₂ region is very thick with electron density of about 10⁶/cm³. The F₂ region is highly anomalous. Some of these anomalies include geographic, diurnal, seasonal and eclipse. The diurnal variation of foFa has been observed to vary from time to time and occur with a valley near noon, often called the neon bite out effect. It has also been remarked that there is a well marked semi-annual variation in both maximum electron density and the total columnar ionization of the F₂ layer and hence foF₂ of the F₂ region (Bates, 1960). There is the world wide result summarized by (Retcliffe, 1960) in the expression

\[(foF₂) = (1 + 0.02Rz)\]

Where Rz is the mean Zurich sunspot number. This shows that foF₂ varies with sunspot number, hence establishing a kind of solar cycle variation (variation of 11 year periodicity) The purpose of this study therefore is to investigate all the above using Ibadan data.

Data Collection

The data used in this study were collected from the readings of an Ionosonde, which were recorded, into booklets. The Ionosonde is the ionospheric sounder used in Ibadan . Ibadan has geographical coordinates 07° 24’N, 03°54’. The period covered by data is January to December 1998. it was a year of sunspot maximum and when ionospheric recordings were adequately made.

The Nigerian Academic Forum Volume 22 No. 1, April, 2012

Criteria Used For Quiet Day and Terminologies Used.
The selection of quiet days was based on data readily available and the Ap indices (geomagnetic amplitudes) which are more influenced by short term transient variations for which a satisfactory estimate of Ap less than or equal to 10 (Ap < 10) was taken as indicating a magnetically quiet day (arbitrary) and the results, therefore describe the behaviour of the undisturbed F region.

Terminologies Used
Time: Time refers to as local mean time.
Daytime: Hours between 0600 and 1800 hrs.
Nighttime: Hours between 1900 and 0500 hrs.
Seasons: Following the division of the year into seasons by Danilov, and Mikhailov (2004), the different seasons are given by March and April representing March equinox, September and October representing September equinox, May to August representing June solstice, and November to February representing December solstice.
foFα is the ordinary wave critical frequency of the F2 layer.

Analysis
Diurnal Variation
The observed values of foF2 at each hour of the day, representing September equinox, June solstice and December solstice are shown in tables 1(A and B), 2(A and B) and 3(A and B) respectively.

### September Equinox (Month of September) foF2 Values (Observed) MHZ

<table>
<thead>
<tr>
<th></th>
<th>00</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.3</td>
<td>7.1</td>
<td>8.7</td>
<td>8.4</td>
<td>8.5</td>
<td>7.9</td>
<td>9.3</td>
<td>122</td>
<td>148</td>
<td>143</td>
<td>129</td>
<td>125</td>
<td>121</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.1</td>
<td>7.9</td>
<td>8.6</td>
<td>8.7</td>
<td>8.5</td>
<td>8.5</td>
<td>9.0</td>
<td>121</td>
<td>148</td>
<td>152</td>
<td>145</td>
<td>133</td>
<td>127</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.8</td>
<td>7.6</td>
<td>7.4</td>
<td>7.6</td>
<td>7.2</td>
<td>5.3</td>
<td>8.5</td>
<td>118</td>
<td>134</td>
<td>128</td>
<td>130</td>
<td>121</td>
<td>119</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>8.6</td>
<td>10.0</td>
<td>8.6</td>
<td>8.4</td>
<td>7.0</td>
<td>3.7</td>
<td>8.3</td>
<td>119</td>
<td>135</td>
<td>-</td>
<td>145</td>
<td>143</td>
<td>141</td>
<td>136</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.3</td>
<td>6.3</td>
<td>8.3</td>
<td>118</td>
<td>136</td>
<td>148</td>
<td>149</td>
<td>139</td>
<td>132</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.1</td>
<td>112</td>
<td>114</td>
<td>108</td>
<td>7.7</td>
<td>6.2</td>
<td>8.5</td>
<td>118</td>
<td>135</td>
<td>140</td>
<td>136</td>
<td>125</td>
<td>129</td>
<td>121</td>
</tr>
<tr>
<td>0.8</td>
<td>109</td>
<td>8.5</td>
<td>8.2</td>
<td>6.2</td>
<td>3.6</td>
<td>7.9</td>
<td>112</td>
<td>131</td>
<td>140</td>
<td>146</td>
<td>-</td>
<td>142</td>
<td>143</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td>100</td>
<td>9.8</td>
<td>7.9</td>
<td>5.8</td>
<td>3.8</td>
<td>8.0</td>
<td>113</td>
<td>127</td>
<td>125</td>
<td>115</td>
<td>115</td>
<td>117</td>
<td>118</td>
<td></td>
</tr>
</tbody>
</table>

Day - To-Day Variability in Some Ionospheric Parameters in the Quiet Equatorial Ionosphere (Case Study: FαF2)

Table 1a

<p>| | | | | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>Rz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td>11.8</td>
<td>11.8</td>
<td>11.6</td>
<td>11.3</td>
<td>8.6</td>
<td>8.7</td>
<td>8.6</td>
<td>8.6</td>
<td>8.6</td>
<td>245</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2a

<table>
<thead>
<tr>
<th>12.1</th>
<th>11.1</th>
<th>11.1</th>
<th>-</th>
<th>9.4</th>
<th>7.5</th>
<th>6.6</th>
<th>7.2</th>
<th>6.6</th>
<th>7.5</th>
<th>268</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.2</td>
<td>12.5</td>
<td>12.5</td>
<td>11.7</td>
<td>11.2</td>
<td>9.8</td>
<td>7.5</td>
<td>7.2</td>
<td>7.2</td>
<td></td>
<td>265</td>
</tr>
<tr>
<td>13.2</td>
<td>12.4</td>
<td>11.7</td>
<td>-</td>
<td>-</td>
<td>6.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>233</td>
</tr>
<tr>
<td>11.7</td>
<td>11.6</td>
<td>11.3</td>
<td></td>
<td>8.5</td>
<td>8.4</td>
<td>8.5</td>
<td>10.1</td>
<td>10.7</td>
<td>187</td>
<td></td>
</tr>
<tr>
<td>12.6</td>
<td>12.6</td>
<td>12.3</td>
<td>11.6</td>
<td>11.3</td>
<td>9.5</td>
<td>10.4</td>
<td>10.8</td>
<td>10.8</td>
<td>10.9</td>
<td>156</td>
</tr>
<tr>
<td>12.2</td>
<td>11.9</td>
<td>11.7</td>
<td>11.5</td>
<td>8.6</td>
<td>8.7</td>
<td>8.7</td>
<td>9.0</td>
<td>8.8</td>
<td>172</td>
<td></td>
</tr>
<tr>
<td>14.3</td>
<td>14.2</td>
<td>13.8</td>
<td>11.7</td>
<td>11.3</td>
<td>8.3</td>
<td>8.5</td>
<td>8.5</td>
<td>10.5</td>
<td>10.8</td>
<td>175</td>
</tr>
<tr>
<td>12.3</td>
<td>12.4</td>
<td>12.5</td>
<td>-</td>
<td>10.3</td>
<td>6.9</td>
<td>8.4</td>
<td>8.3</td>
<td>8.4</td>
<td>8.5</td>
<td>174</td>
</tr>
</tbody>
</table>

### Table 1b

**June Solstice (Month of May) F₀₂ Values (Observed) MHz**

<table>
<thead>
<tr>
<th>Values (Observed) Mhz</th>
<th>00</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.4</td>
<td>8.6</td>
<td>8.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>137</td>
<td>148</td>
<td>152</td>
<td>147</td>
<td>137</td>
</tr>
<tr>
<td>6.6</td>
<td>8.1</td>
<td>8.3</td>
<td>7.9</td>
<td>7.4</td>
<td>5.2</td>
<td>8.5</td>
<td>II</td>
<td>139</td>
<td>151</td>
<td>151</td>
<td>151</td>
<td>142</td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>9.8</td>
<td>9.5</td>
<td>8.0</td>
<td>3.7</td>
<td>2.7</td>
<td>8.7</td>
<td>105</td>
<td>133</td>
<td>140</td>
<td>129</td>
<td>129</td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>6.4</td>
<td>6.3</td>
<td>6.4</td>
<td>6.1</td>
<td>4.4</td>
<td>8.9</td>
<td>124</td>
<td>137</td>
<td>138</td>
<td>118</td>
<td>1B</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
<td>5.5</td>
<td>9.2</td>
<td>127</td>
<td>140</td>
<td>141</td>
<td>124</td>
<td>124</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>6.4</td>
<td>5.6</td>
<td>5.4</td>
<td>4.7</td>
<td>3.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>17</td>
<td>117</td>
<td>109</td>
</tr>
<tr>
<td>4.9</td>
<td>4.8</td>
<td>4.8</td>
<td>5.1</td>
<td>5.2</td>
<td>5.2</td>
<td>9.4</td>
<td>125</td>
<td>138</td>
<td>143</td>
<td>143</td>
<td>143</td>
<td>134</td>
<td></td>
</tr>
<tr>
<td>6.7</td>
<td>6.7</td>
<td>6.6</td>
<td>6.3</td>
<td>4.8</td>
<td>3.1</td>
<td>8.5</td>
<td>118</td>
<td>136</td>
<td>140</td>
<td>123</td>
<td>123</td>
<td>1B</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td>6.0</td>
<td>5.9</td>
<td>5.9</td>
<td>5.1</td>
<td>3.9</td>
<td>8.8</td>
<td>119</td>
<td>137</td>
<td>143</td>
<td>133</td>
<td>133</td>
<td>1B</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2a

<table>
<thead>
<tr>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>Rz</th>
</tr>
</thead>
<tbody>
<tr>
<td>126</td>
<td>124</td>
<td>122</td>
<td>121</td>
<td>118</td>
<td>104</td>
<td>9.4</td>
<td>7.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>150</td>
</tr>
<tr>
<td>134</td>
<td>125</td>
<td>114</td>
<td>109</td>
<td>109</td>
<td>106</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>166</td>
</tr>
<tr>
<td>120</td>
<td>117</td>
<td>119</td>
<td>109</td>
<td>8.7</td>
<td>-</td>
<td>8.3</td>
<td>7.7</td>
<td>6.6</td>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>115</td>
<td>115</td>
<td>115</td>
<td>115</td>
<td>115</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>132</td>
</tr>
<tr>
<td>115</td>
<td>115</td>
<td>114</td>
<td>115</td>
<td>1B</td>
<td>109</td>
<td>9.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>116</td>
<td>116</td>
<td>116</td>
<td>6.5</td>
<td>5.3</td>
<td>165</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>127</td>
<td>123</td>
<td>119</td>
<td>120</td>
<td>117</td>
<td>9.7</td>
<td>6.6</td>
<td>6.6</td>
<td>6.7</td>
<td>6.7</td>
<td>171</td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>106</td>
<td>108</td>
<td>113</td>
<td>111</td>
<td>-</td>
<td>8.6</td>
<td>8.2</td>
<td>6.3</td>
<td>204</td>
<td></td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>109</td>
<td>114</td>
<td>111</td>
<td>108</td>
<td>-</td>
<td>8.3</td>
<td>6.6</td>
<td>6.1</td>
<td>192</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3
### Table 2b
December Solstice (Month of December) foFz Values (Observed) MHz

<table>
<thead>
<tr>
<th></th>
<th>00</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.0</td>
<td>8.5</td>
<td>8.9</td>
<td>9.2</td>
<td>8.4</td>
<td>-</td>
<td>-</td>
<td>114</td>
<td>119</td>
<td>117</td>
<td>131</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td>9.5</td>
<td>9.1</td>
<td>8.4</td>
<td>7.5</td>
<td>6.7</td>
<td>7.9</td>
<td>100</td>
<td>112</td>
<td>116</td>
<td>126</td>
<td>122</td>
<td>124</td>
<td></td>
</tr>
<tr>
<td>8.2</td>
<td>8.5</td>
<td>8.3</td>
<td>8.3</td>
<td>8.6</td>
<td>6.7</td>
<td>7.1</td>
<td>9.2</td>
<td>108</td>
<td>108</td>
<td>115</td>
<td>119</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>7.8</td>
<td>8.3</td>
<td>8.2</td>
<td>6.8</td>
<td>6.4</td>
<td>6.6</td>
<td>7.9</td>
<td>-</td>
<td>113</td>
<td>121</td>
<td>128</td>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.4</td>
<td>8.4</td>
<td>8.4</td>
<td>8.2</td>
<td>7.1</td>
<td>4.8</td>
<td>6.6</td>
<td>9.4</td>
<td>113</td>
<td>119</td>
<td>134</td>
<td>138</td>
<td>138</td>
<td></td>
</tr>
<tr>
<td>8.2</td>
<td>8.3</td>
<td>8.3</td>
<td>7.8</td>
<td>7.2</td>
<td>6.8</td>
<td>7.5</td>
<td>113</td>
<td>128</td>
<td>135</td>
<td>132</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9.2</td>
<td>-</td>
<td>-</td>
<td>118</td>
<td>119</td>
<td>119</td>
<td>-</td>
<td>105</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.3</td>
<td>8.3</td>
<td>8.4</td>
<td>9.0</td>
<td>8.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>124</td>
<td>117</td>
<td>112</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.9</td>
<td>8.7</td>
<td>9.6</td>
<td>9.3</td>
<td>8.4</td>
<td>5.5</td>
<td>5.4</td>
<td>9.1</td>
<td>113</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3a

<table>
<thead>
<tr>
<th></th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>Rz</th>
</tr>
</thead>
<tbody>
<tr>
<td>117</td>
<td>116</td>
<td>116</td>
<td>114</td>
<td>111</td>
<td>11</td>
<td>8.8</td>
<td>-</td>
<td>6.6</td>
<td>-</td>
<td>8.1</td>
<td>8.2</td>
<td>200</td>
</tr>
<tr>
<td>120</td>
<td>121</td>
<td>116</td>
<td>-</td>
<td>116</td>
<td>16</td>
<td>9.7</td>
<td>8.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>210</td>
</tr>
<tr>
<td>115</td>
<td>117</td>
<td>118</td>
<td>117</td>
<td>114</td>
<td>113</td>
<td>8.1</td>
<td>-</td>
<td>-</td>
<td>8.7</td>
<td>8.9</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>121</td>
<td>124</td>
<td>-</td>
<td>113</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.3</td>
<td>-</td>
<td>-</td>
<td>192</td>
</tr>
<tr>
<td>143</td>
<td>143</td>
<td>-</td>
<td>138</td>
<td>116</td>
<td>116</td>
<td>8.4</td>
<td>8.7</td>
<td>8.7</td>
<td>8.1</td>
<td>7.9</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>128</td>
<td>129</td>
<td>120</td>
<td>117</td>
<td>117</td>
<td>-</td>
<td>8.9</td>
<td>8.8</td>
<td>8.5</td>
<td>8.2</td>
<td>8.3</td>
<td>-</td>
<td>210</td>
</tr>
<tr>
<td>108</td>
<td>112</td>
<td>117</td>
<td>114</td>
<td>113</td>
<td>-</td>
<td>8.6</td>
<td>-</td>
<td>-</td>
<td>8.2</td>
<td>-</td>
<td>-</td>
<td>250</td>
</tr>
<tr>
<td>113</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>185</td>
</tr>
<tr>
<td>-</td>
<td>115</td>
<td>115</td>
<td>114</td>
<td>114</td>
<td>104</td>
<td>9.0</td>
<td>8.2</td>
<td>8.4</td>
<td>8.2</td>
<td>8.4</td>
<td>-</td>
<td>100</td>
</tr>
</tbody>
</table>
These tables 1, 2 and 3 were used to plot the diurnal variation curves for the September equinox, June solstice and December solstice are shown in figs 1, 2 and 3 respectively.
It became imperative to estimate using student t-test, whether the difference in their standard errors is significant or not before and after correcting for season and Rz.

For example:

At 00hours and the chosen days,

Mean $f_0F_2$=8.3Mhz

If $d$=deviation from the mean and

$n$=number of observations,

\[
\text{Standard deviation } \sigma = \sqrt{\frac{\sum d^2}{n}} = 0.30\text{MHz}
\]

\[
\text{Standard error } \sigma_e = \frac{\sigma}{\sqrt{n}} = 0.10\text{MHz}
\]

Hence $f_0F_2 = 8.3\pm0.10$ MHz (see error bars on graphs)

Similar analysis was carried out at various times of the day on the variation curves.
Table 4 illustrate the result obtained.

September Equinox

<table>
<thead>
<tr>
<th>TIME</th>
<th>00</th>
<th>03</th>
<th>06</th>
<th>10</th>
<th>12</th>
<th>13</th>
<th>16</th>
<th>19</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.4</td>
<td>0.9</td>
<td>0.4</td>
<td>1.1</td>
<td>0.8</td>
<td>0.8</td>
<td>0.7</td>
<td>0.8</td>
<td>1.3</td>
</tr>
<tr>
<td>&lt;V</td>
<td>0.5</td>
<td>0.3</td>
<td>0.1</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>3a_m</td>
<td>1.5</td>
<td>0.3</td>
<td>0.3</td>
<td>0.9</td>
<td>0.6</td>
<td>0.6</td>
<td>0.9</td>
<td>0.9</td>
<td>1.2</td>
</tr>
</tbody>
</table>

June Solstice

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>1.4</th>
<th>1.0</th>
<th>0.3</th>
<th>0.6</th>
<th>1.1</th>
<th>0.8</th>
<th>0.3</th>
<th>0.7</th>
<th>0.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ora</td>
<td>0.5</td>
<td>0.3</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.3</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>3a_m</td>
<td>1.5</td>
<td>0.9</td>
<td>0.3</td>
<td>0.6</td>
<td>0.9</td>
<td>0.6</td>
<td>0.3</td>
<td>0.9</td>
<td>~</td>
<td>W</td>
</tr>
</tbody>
</table>

December Solstice

<table>
<thead>
<tr>
<th></th>
<th>&lt;3</th>
<th>0.3</th>
<th>0.7</th>
<th>0.8</th>
<th>0.7</th>
<th>1.0</th>
<th>1.0</th>
<th>0.8</th>
<th>0.3</th>
<th>0.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>O_m</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>3a_m</td>
<td>0.3</td>
<td>0.6</td>
<td>0.9</td>
<td>0.6</td>
<td>1.2</td>
<td>0.9</td>
<td>1.0</td>
<td>0.3</td>
<td>0.3</td>
<td></td>
</tr>
</tbody>
</table>

Table 4

Seasonal Variation

The mean values of the observed daily values of foFz at each hour of the day for each month was computed to study the yearly behaviour of foFz. Table 5 below shows the result obtained.

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APRIL</th>
<th>MAY</th>
<th>JUNE</th>
<th>JULY</th>
<th>AUGUST</th>
<th>SEPT</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>foFzMHz</td>
<td>12.0</td>
<td>12.5</td>
<td>13.5</td>
<td>13.1</td>
<td>12.4</td>
<td>11.7</td>
<td>11.3</td>
<td>11.7</td>
<td>12.3</td>
<td>12.8</td>
<td>13.0</td>
<td>12.0</td>
</tr>
</tbody>
</table>

Table 5
The Table was used to plot the seasonal variation curve shown in fig 4
Corrected $f_0F_2$

It is important to examine the effect of seasonal variation and $R_z$ on $f_0F_2$. Fig 4 is used to correct for season. (Yokoyama, 2004) showed that critical frequency of the $F_2$ layer is related to the relative sunspot number $R_z$ by $f_0F_2 = A + 0.028R_z$, where $A =$ constant dependent on magnetic dip (Maruyama, 1996) using Ibadan data, showed that for short time variations, the constant $A$ is approximately equal to 6.77MHz (magnetic dip for Ibadan = -6°). The above equation was used to correct for $R_z$. The corrected diurnal variation curves are as shown in figs 5, 6 and 7 for the solstice and equinox.
From the corrected $f_0F_2$ curves for season and Rz the standard errors were obtained as illustrated in the example below.

At 00 hours, means $f_0F_2$=8.0 MHz

If $d =$ deviation from the mean,

\[
\text{Standard deviation } \sigma = \sqrt{\frac{\sum d^2}{n}}
\]

$n =$ no of observations.

\[
\text{Standard error } \sigma_m = \frac{\sigma}{\sqrt{n}} = 0.7
\]

Similar analysis was carried out at various times of the day. Table 6 below shows the results obtained.

**September Equinox**

<table>
<thead>
<tr>
<th>TIME</th>
<th>00</th>
<th>03</th>
<th>06</th>
<th>10</th>
<th>12</th>
<th>13</th>
<th>16</th>
<th>19</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>1.8</td>
<td>1.5</td>
<td>0.7</td>
<td>0.8</td>
<td>1.1</td>
<td>0.8</td>
<td>0.3</td>
<td>0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>CFm</td>
<td>0.6</td>
<td>0.5</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.4</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**June Solstice**

<table>
<thead>
<tr>
<th>TIME</th>
<th>00</th>
<th>03</th>
<th>06</th>
<th>10</th>
<th>12</th>
<th>13</th>
<th>16</th>
<th>19</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>1.6</td>
<td>1.3</td>
<td>0.9</td>
<td>1.1</td>
<td>0.8</td>
<td>0.8</td>
<td>0.6</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>$\sigma$ m</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**December Solstice**

<table>
<thead>
<tr>
<th>TIME</th>
<th>00</th>
<th>03</th>
<th>06</th>
<th>10</th>
<th>12</th>
<th>13</th>
<th>16</th>
<th>19</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>0.7</td>
<td>1.0</td>
<td>1.5</td>
<td>0.7</td>
<td>1.0</td>
<td>1.0</td>
<td>0.8</td>
<td>0.8</td>
<td>1.1</td>
</tr>
<tr>
<td>$\sigma$ m</td>
<td>0.2</td>
<td>0.3</td>
<td>0.6</td>
<td>0.2</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
</tr>
</tbody>
</table>

**Test of Significance For Diurnal Variations**

The students "t" test was used to test the significant difference between the standard errors of the diurnal variations before and after correction during the day and night at 95% level of significance. The results obtained are as shown. 1. Month of May (June Solstice)

Daytime (1000hours)

Before $= 0.22$

After $= 0.28$

$t=0.11$

$\text{t}_{95\%}=2.31$

$t_{95\%}>t$ ($t=0.11$)
Month of September (September Equinox)
Daytime (1000 hours)
**Before** - 0.38

After - 0.40 \( t = 0.02 \)
\( t_{95\%} > t \) (\( t = 0.02 \))

Month of December (December Solstice)
Daytime (1000 hours)
**Before** - 0.24

After - 0.24
\( t_{95\%} > t \) (\( t = 0 \))

The above result in each case show no significance at 95% level of significance by day.

2. Month of May (June Solstice)
Night time (2300 hours)
Before = 0.21
After - 0.74 \( t = 0.52 \)
\( t_{95\%} > t \) (\( t = 0.52 \))

Month of September (September Equinox)
Night time (2300 hours)
Before - 0.49
After = 0.54 \( t = 0.07 \)
\( t_{95\%} > t \) (\( t = 0.07 \))

Month of December (December Solstice)
Night time (2300 hours)
Before-0.18
After - 0.49 \( t = 0.46 \)
\( t_{95\%} > t \) (\( t = 0.46 \))

Hence no significant difference between the two standard errors before and after correction for season and Rz at 95% level of significance, by day and by night.

Summary of Results and Discussion

From the diurnal variation curves, it is observed that they are large irregular changes of fbF2 during individual days. The amplitude of variation is greater in daytime than at night. Essentially, foF2 at midday (1200hrs) varies from day to day. While it's value is 2.5MHZ between day 23 and 24 at the equinox (September), it is 2.1MHZ at the solstice (June).

From the results obtained in error estimation, it is clearly shown that the errors associated with the mean values of foFi are less than 3 times the standard errors. The seasonal variation curve has two maximum points in the months of March and November respectively with a minimum in July. This indicates that the seasonal variation of foF2 is more of a semi-annual variation.

The test of significance carried out indicates that neither seasonal variation nor Rz are responsible for the day-to-day variability in the F2 region.

Conclusion

The results obtained in this study compared favourably with some other studies. For example Bhuyan, P.K et al (2003) indicated that the general features of the diurnal variation of $\Psi F2$ could readily
be explained by a loss coefficient, which was substantially greater by day than at night. (Kuriyan, 1983)

also discussed the night time decay of total columnar ionization of the F2 layer. This is likely to be a
cause of diurnal variation. He also remarked that there is a well-marked semiannual variation in both
maximum electron density and foF2 of the F2 region. (Adeniyi, 2004) showed that there is a seasonal variation
of foF2 using Ibadan data.

One would therefore hope that the data and results established by this study be proposed as
equatorial input values for the development of a variability model for the international reference
ionosphere.

References

in space research, Elsevier 34(9), 1901-1906.


P.K et al (2003): Diurnal seasonal and latitudinal variations of electron density in the topside F-region
of the Indian ionosphere at solar minimum and comparison with IRI. Journal of atmospheric

Danilov, A. D. & Mikhailov A.V (2004) Long-term trends in F2 layer parameters at Argentine Island and
Port Stanley Stations. Annales of Geophysics, 41(4) 488-496

Terr. Phys, 5, 285-285


Ractliffe, J. A. (1951), Some regularity in the F2 region Ionosphere, J. Geophys. Res; 56(4), 487-507

Yokoyama, T, et al (2004). Relationship of the on set of the equatorial F region irregularities with the
sunset terminator observed with the equatorial atmosphere. Radar Geophys. Res. Lett 31, L24804,