Developing a 40 year Australian region satellite cloud climatology for 1979-2018

by

Lynch, M.¹, Chedzey, H.¹, Nener, B.², Herne, D.¹, Foster, M.³, Heidinger, A.⁴, White, C.³, and Menzel, W.P.³

¹School of Electrical Engineering, Computing and Mathematical Sciences, Curtin University, Perth, Australia
²School of Electrical, Electronic and Computer Engineering, University of WA, Perth, Australia
³CIMSS, Space Science and Engineering Centre, University of Wisconsin, Madison, WI, USA
⁴NOAA/NESDIS/STAR, University of Wisconsin, Madison, WI, USA
Aims and applications

• Primarily for climatological studies using a long lifetime satellite series that includes cross-calibration of successively launched satellite sensors

• identifying any significant decadal trends in regional cloud climatology (distinct from the global cloud climatologies) over the 4 decades and throughout the diurnal cycle

• a database that may be researched together with other long term datasets eg precipitation records and implications for precipitating / non-precipitating cloud systems

• analysing and interpreting spatial and temporal cloud cover information aids decision-making related to identifying clear-sky conditions for optical telescope siting, space situational awareness observations, location of satellite-to-ground communication infrastructure etc

• Others?
The approach

• the database utilises 40 years (1979 to 2018) of PATMOS-x AVHRR 1-km satellite data
• the cloud products are extracted on a 0.1° by 0.1° grid
• aim was to produce a 40-year cloud climatology of the Australian continent and marine regions
• includes sampling of the climatology 4 times throughout the diurnal cycle
• products include decadal monthly averages of cloud fraction*, diurnal monthly averages, box-and-whisker plot representation of decadal dispersion statistics and monthly decadal differences
• analysing and interpreting spatial and temporal cloud cover information has been developed to aid in the decision-making process requiring clear-sky conditions
• other analysis approaches are being considered using more advanced statistical methods and data mining techniques to refine the analysis

* See Heidinger, Foster, Walther, and Zhao. 2014. The pathfinder atmosphere-extended AVHRR climate dataset, BAMS, 909 for PATMOS processing algorithms and product validation.
<table>
<thead>
<tr>
<th>Satellite name</th>
<th>Launch date</th>
<th>Service start</th>
<th>Service end</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAA-6</td>
<td>27 June 1979</td>
<td>27 June 1979</td>
<td>16 November 1986</td>
</tr>
<tr>
<td>NOAA-7</td>
<td>23 June 1981</td>
<td>24 August 1981</td>
<td>7 June 1986</td>
</tr>
<tr>
<td>NOAA-10</td>
<td>17 September 1986</td>
<td>17 November 1986</td>
<td>17 September 1991</td>
</tr>
<tr>
<td>NOAA-15</td>
<td>13 May 1998</td>
<td>13 May 1998</td>
<td>Present</td>
</tr>
<tr>
<td>NOAA-16</td>
<td>21 September 2000</td>
<td>21 September 2000</td>
<td>9 June 2014</td>
</tr>
<tr>
<td>NOAA-17</td>
<td>24 June 2002</td>
<td>24 June 2002</td>
<td>10 April 2013</td>
</tr>
<tr>
<td>NOAA-18</td>
<td>20 May 2005</td>
<td>30 August 2005</td>
<td>present</td>
</tr>
<tr>
<td>NOAA-19</td>
<td>6 February 2009</td>
<td>2 June 2009</td>
<td>present</td>
</tr>
<tr>
<td>Metop-A</td>
<td>19 October 2006</td>
<td>20 June 2007</td>
<td>present</td>
</tr>
<tr>
<td>Metop-B</td>
<td>17 September 2012</td>
<td>24 April 2013</td>
<td>present</td>
</tr>
<tr>
<td>Metop-C</td>
<td>7 November 2018</td>
<td>3 July 2019</td>
<td>present</td>
</tr>
</tbody>
</table>

## AVHRR Spectral Bands

<table>
<thead>
<tr>
<th>Band</th>
<th>NOAA 6,8,10 Wavelength µm</th>
<th>NOAA 7,9,11-14 Wavelength µm</th>
<th>NOAA 15-19, MetOp-A Wavelength µm</th>
<th>Band Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.580-0.680</td>
<td>0.580-0.680</td>
<td>0.580-0.680</td>
<td>Vegetation mapping, NDVI, daytime cloud, snow, ice</td>
</tr>
<tr>
<td>2</td>
<td>0.725-1.100</td>
<td>0.725-1.110</td>
<td>0.725-1.110</td>
<td>Vegetation mapping, NDVI, land/water interface, snow, ice</td>
</tr>
<tr>
<td>4</td>
<td>10.500-11.500</td>
<td>10.300 - 11.300</td>
<td>10.300-11.300</td>
<td>Day/night cloud and surface temperature mapping</td>
</tr>
<tr>
<td>5</td>
<td>None</td>
<td>11.500-12.500</td>
<td>11.500-12.500</td>
<td>Cloud and surface temperature, day/night cloud mapping</td>
</tr>
</tbody>
</table>
Spectral Reflectance Bands

- ABI-AHI
- GCOM-C
- MODIS
- AVHRR
- VIIRS
- OLI-Landsat 8
- MSI-Sentinel-2

Bands:
- 10 MIR/TIR Bands
- 2 TIR Bands
- 16 MIR/TIR Bands
- 3 MIR/TIR Bands
- MIR/TIR Bands

Wavelength (nm):
- 400.0
- 700.0
- 1000.0
- 1300.0
- 1600.0
- 1900.0
- 2200.0
- 2500.0

Bands include:
- O3
- H2O
- O2
- CO2
- CH4
Solar innovators forced to seek clearer skies than clouded site at Forbes, NSW

Company’s Comment:
"Unfortunately we don't have enough sun in Forbes ... we just have too many days with cloud."
Cloud amount for Forbes, NSW for 2009-2018

Decade of Mid–Morning and Mid–Afternoon Cloud Amount (2009 to 2018)
—from a pixel located near Forbes, New South Wales
Decadal-average mid-afternoon cloud amount over Australia between 1979 and 2018.
Decadal-average cloud amount over Australia calculated between 2009 and 2018 at four different times of the day.
Difference in Decadal (2009 to 2018) Average Cloud Amount
Mid-afternoon Cloud Amount minus mid-morning Cloud Amount

Cloud Amount Difference (unitless fraction)

Data Min = -0.29, Max = 0.33
Dispersion Statistics

Minimum, Quartile 1 (25%), Median, Quartile 3 (75%), Maximum
Ten years of monthly mid-afternoon cloud amount near Learmonth, Western Australia
One year of monthly cloud amount values near Learmonth, Western Australia at four different times of the day (early morning (N2), mid-morning (AM), mid-afternoon (PM), early evening (N1)).
Decadal differences in cloud amount across Australia at four different times of the day.
The four different 24-hour decadal cloud amount anomalies for July between 2009 and 2018.
Comparison of four decadal mid-afternoon cloud amount anomalies calculated during July

July mid-afternoon CA anomalies - 4 decades
40 years of Mid-afternoon Cloud Amount Anomalies (1979 to 2018)
- from a pixel located near Learmonth, Western Australia

Data Min = -0.18, Max = 0.17
Decreasing rainfall in SW Australia
## Annual Rainfall for Perth in Western Australia*

<table>
<thead>
<tr>
<th>Year</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>7.2</td>
<td>0.2</td>
<td>6.2</td>
<td>44.2</td>
<td>17.8</td>
<td>212.0</td>
<td>108.6</td>
<td>114.4</td>
<td>31.4</td>
<td>20.2</td>
<td>17.8</td>
<td></td>
<td>580.0</td>
</tr>
<tr>
<td>2018</td>
<td>106.2</td>
<td>0.2</td>
<td>2.6</td>
<td>20.6</td>
<td>67.4</td>
<td>126.4</td>
<td>152.0</td>
<td>186.0</td>
<td>35.2</td>
<td>40.0</td>
<td>3.2</td>
<td>1.8</td>
<td>741.6</td>
</tr>
<tr>
<td>2017</td>
<td>45.4</td>
<td>137.2</td>
<td>23.6</td>
<td>0.0</td>
<td>70.8</td>
<td>88.0</td>
<td>172.6</td>
<td>151.6</td>
<td>77.4</td>
<td>42.0</td>
<td>4.8</td>
<td>40.6</td>
<td>854.0</td>
</tr>
<tr>
<td>2016</td>
<td>15.2</td>
<td>0.6</td>
<td>16.8</td>
<td>68.2</td>
<td>112.0</td>
<td>109.4</td>
<td>139.6</td>
<td>123.2</td>
<td>68.8</td>
<td>37.4</td>
<td>14.4</td>
<td>10.2</td>
<td>715.8</td>
</tr>
<tr>
<td>AVE</td>
<td>16.7</td>
<td>13.0</td>
<td>21.0</td>
<td>37.2</td>
<td>88.7</td>
<td>126.9</td>
<td>146.6</td>
<td>122.1</td>
<td>87.0</td>
<td>38.7</td>
<td>23.2</td>
<td>11.7</td>
<td>732.8</td>
</tr>
<tr>
<td>AVE</td>
<td>9.7</td>
<td>12.5</td>
<td>19.5</td>
<td>44.2</td>
<td>116.9</td>
<td>173.1</td>
<td>167.7</td>
<td>132.9</td>
<td>81.0</td>
<td>51.5</td>
<td>22.4</td>
<td>13.1</td>
<td>844.5</td>
</tr>
</tbody>
</table>

* Source of data: Water Corporation of WA
The end