Improvements to an AVHRR satellite derived sea surface temperature climatology

Edward Armstrong
Jorge Vazquez
Jet Propulsion Laboratory
California Institute of Technology

Nick Nalli
NOAA NESDIS
Spatial Characteristics

January

1 degree

1-5 January

Satellite-based 9 km
JPL climatology interpolation approach

Spatially and temporally interpolate daily data to a 9 km grid/5 day time step using a Gaussian function:

\[ e^{(-0.6931 \times (x-x_0/x_h)^2 + (y-y_0/y_h)^2 + (z-z_0/z_h)^2)} \]

\( x, y, z = \) satellite SST locations in space and time
\( x_0, y_0, z_0 = \) interpolation grid centers (9 km and 5 day)
\( x_h, y_h, z_h = \) “e-folding” scales
The JPL Pathfinder pentad (5 day) climatology

- Based on “all pixel” daily 9 km Pathfinder AVHRR SST data (day and night) from 1985-1999 using highest quality flag
- Gaussian interpolated approach
- No cloud erosion filtering as performed by Casey
Anomaly performance test

For a global long-term *in situ* SST data set determine the standard deviation (σ) of the anomaly data set formed by subtracting the climatological SSTs from the *in situ* SSTs

i.e., find the σ of the time series of anomaly values \((\text{SST}_{\text{anomaly}})\) calculated as:

\[
\text{SST}_{\text{anomaly}} = \text{SST}_{\text{insitu}} - \text{SST}_{\text{climate}}
\]
Anomaly Std Dev by Latitude Band

Global Anomaly Latitude Comparisons

- Reynolds climatology (1961–1990)
North Atlantic SST anomalies (1960-1996)
North Atlantic SST anomaly trends

<table>
<thead>
<tr>
<th>Climatology</th>
<th>Slope (°C/year)</th>
<th>$r^2$</th>
<th>Std error (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JPL</td>
<td>.009</td>
<td>.265</td>
<td>.159</td>
</tr>
<tr>
<td>Reynolds</td>
<td>.007</td>
<td>.191</td>
<td>.166</td>
</tr>
</tbody>
</table>
Limitations of satellite climatologies

- Cloud contamination
- Aerosol contamination
- Ice
- Relatively short time series – regime bias
Sea Surface Temperature Anomaly Climate Data Record
Monthly anomaly time series

Time series of monthly MPSST, ONSST, and OISST minus WOA98 climatological SST.

Satellite data are nighttime values.
Aerosol contamination in SST measurements?

<table>
<thead>
<tr>
<th>Mean bias (°C)</th>
<th>Std dev (°C)</th>
<th>Number of matchups</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.27</td>
<td>0.56</td>
<td>90</td>
</tr>
</tbody>
</table>
PATMOS AVHRR dataset

Pathfinder Atmosphere AVHRR data set (1981-2001)

- Global, daily one degree resolution
- Visible and Near IR solar reflectances (ch 1&2)
- IR channel brightness temps (ch 3,4 &5)
- Channel 1 aerosol optical depth (AOD)
- Other parameter: satellite zenith angles, cloud distribution
AVHRR Aerosol correction

- Described in Nalli and Stowe; JGR, 2002
- Uses two predictors of aerosols: AOD (slant path correction) and ch1/ch2 reflectance ratio. Uses Pathfinder Matchup database (in situ SST data).
- Define two aerosol regimes, stratospheric (i.e., volcanic) and tropospheric (i.e., continental dust, smoke, marine aerosols etc.)
- Regressions of SST residuals (SST_{sat} – SST_{insitu}) to linear and quadratic combinations of the predictors.
- Choose simple linear correction using the AOD predictor:

\[ \text{SST}_{\text{correction}} = b_0 + b_1 \times \text{AOD} \]
Daily aerosol correction files

3 May 1999 – all daily data

3 May 1999 – updated with 5 day data (1-5 May)
**Aug 1991 – Mt Pinatubo**

Matchups statistics (satellite SST – insitu SST)

<table>
<thead>
<tr>
<th>Type</th>
<th>Mean bias (°C)</th>
<th>Std dev (°C)</th>
<th>Number of matchups</th>
</tr>
</thead>
<tbody>
<tr>
<td>No corr.</td>
<td>-1.57</td>
<td>0.78</td>
<td>165</td>
</tr>
<tr>
<td>Aer. corrected</td>
<td>0.46</td>
<td>0.75</td>
<td>165</td>
</tr>
</tbody>
</table>
1-8 May 1999 - Atlantic

Matchups statistics (satellite SST – insitu SST)

<table>
<thead>
<tr>
<th>Type</th>
<th>Mean bias (°C)</th>
<th>Std dev (°C)</th>
<th>Number of matchups</th>
</tr>
</thead>
<tbody>
<tr>
<td>No corr.</td>
<td>-0.27</td>
<td>0.56</td>
<td>90</td>
</tr>
<tr>
<td>Aer. corrected</td>
<td>-0.03</td>
<td>0.48</td>
<td>90</td>
</tr>
</tbody>
</table>
Satellite climatology experiments

- Motivation: determine the effect of aerosol correction approach on Pathfinder satellite climatologies
- Assemble regional interpolated climatologies for 1985-1999
  - Atlantic off northwest Africa
  - Equatorial Pacific (NINO3 region)
- Apply aerosol correction using daily prepared files
- Use Pathfinder SST “all pixel” data with highest quality flag (flag 7)
- Performance test (SD of anomaly time series) with the WOD 2001 surface observations with spatial matchups of +/- one satellite pixel (9km).
mid-Atlantic climatology

Performance statistics

<table>
<thead>
<tr>
<th>Type</th>
<th>Mean bias (°C)</th>
<th>Std dev (°C)</th>
<th>Number of matchups</th>
</tr>
</thead>
<tbody>
<tr>
<td>No corr.</td>
<td>0.12</td>
<td>0.98</td>
<td>~240K</td>
</tr>
<tr>
<td>correction</td>
<td>-0.08</td>
<td>0.96</td>
<td>~240K</td>
</tr>
</tbody>
</table>
### NINO3 region climatology

#### Table

<table>
<thead>
<tr>
<th>Type</th>
<th>Mean bias (°C)</th>
<th>Std dev (°C)</th>
<th>Number of matchups</th>
</tr>
</thead>
<tbody>
<tr>
<td>no corr</td>
<td>0.08</td>
<td>1.24</td>
<td>&gt; 70K</td>
</tr>
<tr>
<td>corr</td>
<td>-0.02</td>
<td>1.24</td>
<td>&gt; 70K</td>
</tr>
<tr>
<td>“best pixel” w/ cloud erosion</td>
<td>0.10</td>
<td>1.29</td>
<td>&gt; 70K</td>
</tr>
<tr>
<td>“best pixel”</td>
<td>.152</td>
<td>1.25</td>
<td>&gt; 70K</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Satellite SST</th>
<th>Mean bias (°C)</th>
<th>Std dev. (°C)</th>
<th>Matchups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathfinder day Flag of 7</td>
<td>-0.28</td>
<td>0.64</td>
<td>373</td>
</tr>
<tr>
<td>Pathfinder night Flag of 7</td>
<td>-0.33</td>
<td>0.55</td>
<td>196</td>
</tr>
<tr>
<td>ASST2 daytime</td>
<td>-0.20</td>
<td>0.46</td>
<td>234</td>
</tr>
<tr>
<td>ASST2 nighttime</td>
<td>-0.03</td>
<td>0.41</td>
<td>128</td>
</tr>
</tbody>
</table>
Summary and Future Work

- Positive results are found using Nalli aerosol corrections approach. Improvements (increased SST warming) found in:
  - Mid-Atlantic (correcting for Saharan Dust)
  - Eastern eq. Pacific (primarily mitigating Mt. Pinatubo contamination)
- Possible overcorrection?? More experiments necessary to separate for the effects of AOD on the SST correction.
- Improvement seen from using highest quality “all pixel” data with flag 7
- Further work:
  - Assign probability based on distance from cloud
  - Merge selected ATSR-2 measurements
  - Add more years of Pathfinder data (data up to 2003)