A G-Polygon Based Spatial Prescreening Technique and Its Application to AIRS Data

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Introduction

- Why prescreening?
- G-polygon vs bounding box
- An accurate prescreening technique
- Its applications to AIRS data

The technique is described in A Spatial Pre-Screening Technique for Earth Observation Data, IEEE Geoscience and Remote Sensing Letters, Vol. 4, No. 1, January 2007 by Xin-Min Hua, Jianfu Pan, Dimitar Ouzounov, Alecei Lyapustin, Yujie Wang, Krishna Tewari, Gregory Leptoukh and Bruce Vollmer,
Why prescreening?

- EOS instruments (MODIS, AIRS ......) provide data granules covering large spatial areas, on the order of 1000 km.

- Many researches (e.g. comparative studies, validation by ground observations ......) focus on regional processes, requiring much less than full granules.

- Researchers want to know in advance if a given data granule covers the locations of interest to them.
An example: AERONET stations
Options

- No pre-screening: pixel-by-pixel comparison – slow.

- Bounding box (Max./Min. lat/lon) – inaccurate, needs special treatment for high-latitude and dateline/pole crossing granules.

- An accurate prescreening algorithm, capable of handling all data granules uniformly, regardless of their locations on the Earth, with no special treatment required for dateline/pole crossing granules. – Too good to be possible?
G-polygon vs Bounding box

Example 1: Bounding box at low latitudes
Example 2: Bounding box at high latitudes – crossing pole, dateline
An accurate prescreening technique

Definitions and Assumptions:

- Earth surface can be approximated by a sphere.

- An AIRS/MODIS granule (6/5 minutes) covers a rectangular region (swath) on the surface of Earth – approximated by 4-sided G-polygon.

- G-polygon -- polygon on a sphere with arcs of great circles as its edges.

- G-polygon divides the sphere into two domains – interior and exterior.

- Define the order of vertices of a G-polygon (G-Ring sequence) as follows: when one moves in the order along the boundaries, interior is always on the right-hand-side.
G-polygon: interior and exterior

Vertices order (G-ring sequence): 1-2-3-4-1

Clockwise!
Great circle equation

\( \phi \) – longitude, \( \theta \) – latitude

Great circle equation passing through point \( p_1 (\phi_1, \theta_1) \) and \( p_2 (\phi_2, \theta_2) \) with a direction from \( p_1 \) to \( p_2 \):

\[
f(\phi, \theta) = \tan \theta \sin(\phi_1 - \phi_2) + \tan \theta_1 \sin(\phi_2 - \phi) + \tan \theta_2 \sin(\phi - \phi_1) = 0.
\]

Great circle divides sphere into three domains:

- On great circle: \( f(\phi, \theta) = 0 \)
- On right-hand-side: \( f(\phi, \theta) > 0 \)
- On left-hand-side: \( f(\phi, \theta) < 0. \)
Criterion for G-polygon interior

A swath with 4 corners:
\( v_1(\phi_1, \theta_1), v_2(\phi_2, \theta_2), v_3(\phi_3, \theta_3), v_4(\phi_4, \theta_4). \)

Edges of the swath:
\( f_i(\phi, \theta) = 0, \ (i = 1,2,3,4) \)
with \((v_1,v_2), (v_2,v_3), (v_3,v_4), (v_4,v_1)\)
replacing \((p_1,p_2).\)

A point \((\phi, \theta)\) is inside swath
if \( f_i(\phi, \theta) > 0 \) for \( i = 1,2,3,4 \)
Application to AIRS data

Subsetting AIRVBRAD data for 36 sites in Coordinated Enhanced Observing Period Data Management (CEOP)

<table>
<thead>
<tr>
<th>Site</th>
<th>Lon</th>
<th>Lat</th>
</tr>
</thead>
<tbody>
<tr>
<td>RON</td>
<td>-61.93</td>
<td>-10.08</td>
</tr>
<tr>
<td>BRA</td>
<td>-47.92</td>
<td>-15.93</td>
</tr>
<tr>
<td>PAN</td>
<td>-57.01</td>
<td>-19.56</td>
</tr>
</tbody>
</table>
AIRVBRAD data
Geolocation information:
Longitude, Latitude
135 X 90 (=12150)

Vertices sequence:
Vertex  2-dim  1-dim
-------------------------------------
V1       [0,0]      [0]
V2       [134, 0]   [12060]
V3       [134, 89]  [12149]
V4       [0, 89]    [89]
Performance

CEOP AIRVBRAD subsetter using G-polygon based prescreening
Test on 406 granules of 2007.08.20, 21, 22

- **Before --**

Use bounding rectangle plus special treatments for dateline/pole crossing granules. Sometimes need to scan all pixels. Found **130** sites covered.

- **After --**

Only need to know lat/lon values of the 4 corners and blindly apply the technique. Treat all ground sites and granules equally. Found **131** sites covered.
Performance - accuracy

- Before –
  false negative (all marginal):
  2007.08.20 #181 PAN
  2007.08.21 #074 EIS
  2007.08.22 #119 NSA
  false positive:
  2007.08.21 #160 ES1
  2007.08.21 #193 ES1

- After --
  No false positive, no false negative.
Performance - efficiency

CEOP AIRVBRAD subsetter using G-polygon based prescreening
Test on 406 granules of 2007.08.20, 21, 22
checkSitePos -- function checking if a granule covers any sites
Time profiling results:
- Before --
  Computer time: 0.36 sec. 0.17 ms/call
- After –
  Computer time: 0.03 sec. 0.01 ms/call
Over 10 times faster!
Conclusion

- Accurate, reliable and efficient pre-screening method.

- Treats all granules, ground sites equally. Can be applied blindly as long as 4 corners are in clockwise order.

- Boundaries can be expanded or shrunk to meet users’ special requirement on marginal sites. (see the paper)

- Recommended for Matchup PGEs, V6 planning.