

SEVIRI and VISSR SST Front and Gradient Datasets

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The Manhattan Club



Outline

Objective of this Presentation

- To describe an atlas for SST fronts and gradients.
- To highlight the difference between two classes of edge detection algorithms.
- To indicate how one might acquire these data.

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Lannion is Beautiful



Although They Could Improve on Their Plumbing

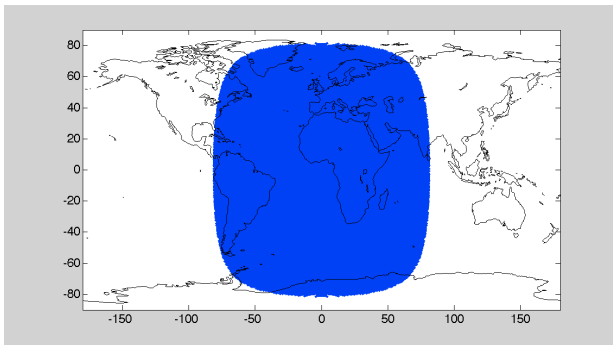


And they have in fact improved their plumbing, although . . .



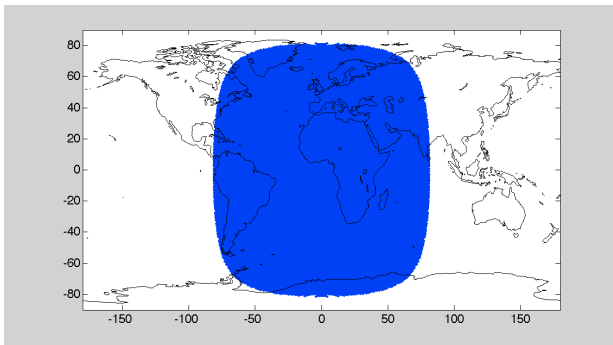
The Data - Two series of geostationary satellites

- SEVIRI on Meteosat 8 and 9
 - 12 June 2003 through 28 February 2011
 - Hourly data
 - $\approx 66,000$ 3712×3712 pixel images
- GOES) 8 and 12 Imagers
 - 20 February 2001 through 28 February 2011
 - Partial scans hourly
 - $\approx 73,000$ 1980×2400 pixel images



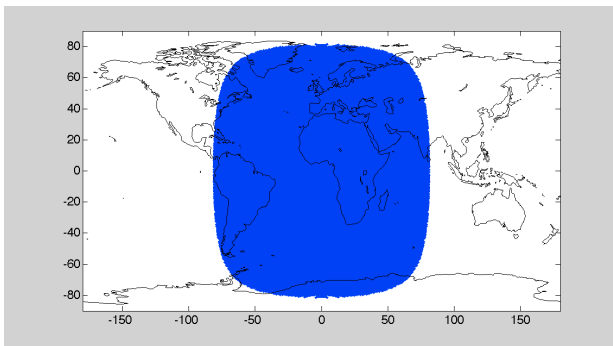
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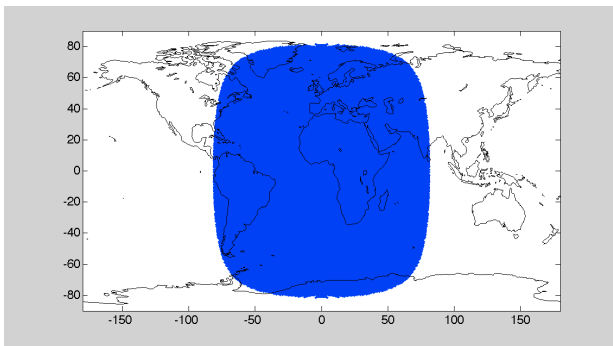
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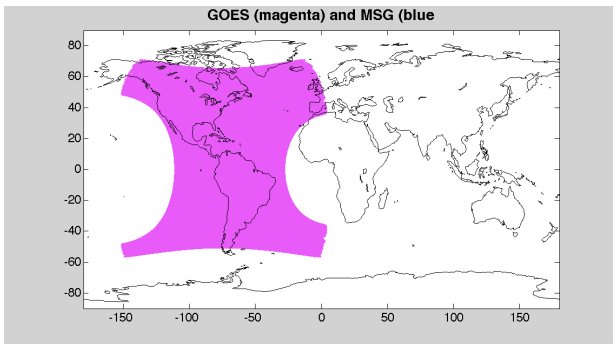
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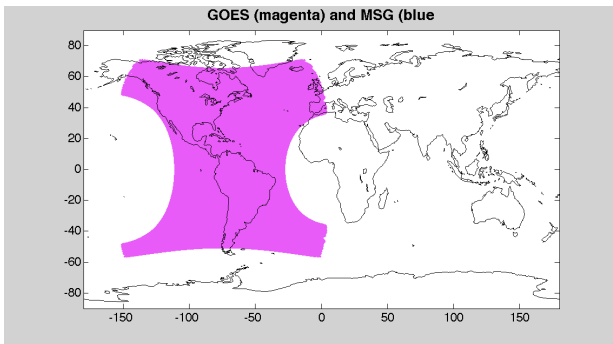
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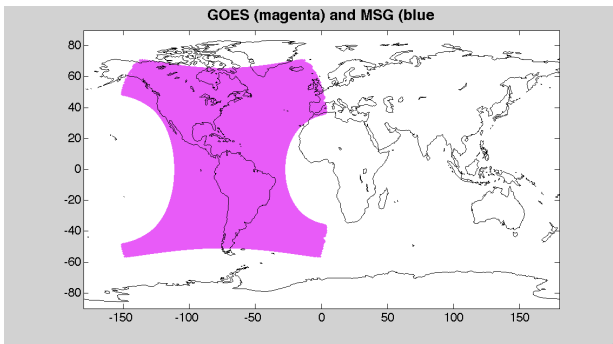
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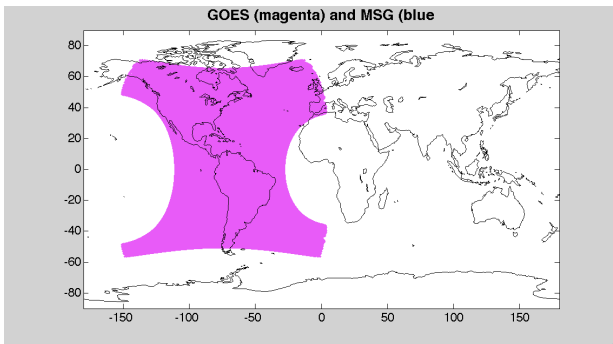
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Processing to SST

- Performed at the Centre de Météorologie Spatiale
- Based on EUMETSAT's Ocean and Sea Ice Satellite Application Facility (OSI-SAF) basic processing chain.
- GOES-8 daytime and all Meteosat retrievals based on split window.
- GOES-8 nighttime retrievals based on triple window.
- GOES-12 nighttime retrievals based on $T_{3.7}$ and T_{11} .
- No GOES-12 daytime SSTs - no T_{12} .
- Quality flag from 0-no data to 5-good.
- Data processed to SST every hour.
- Data available in two projections: Platte-Carre and **Space View**.
 - Earth as seen by the satellite
 - Along the prime meridian, the Meteosat spatial resolution is:
 - 3 km at nadir,
 - 4.5 km at 40°N/S
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 - GOES resolution is a little coarser
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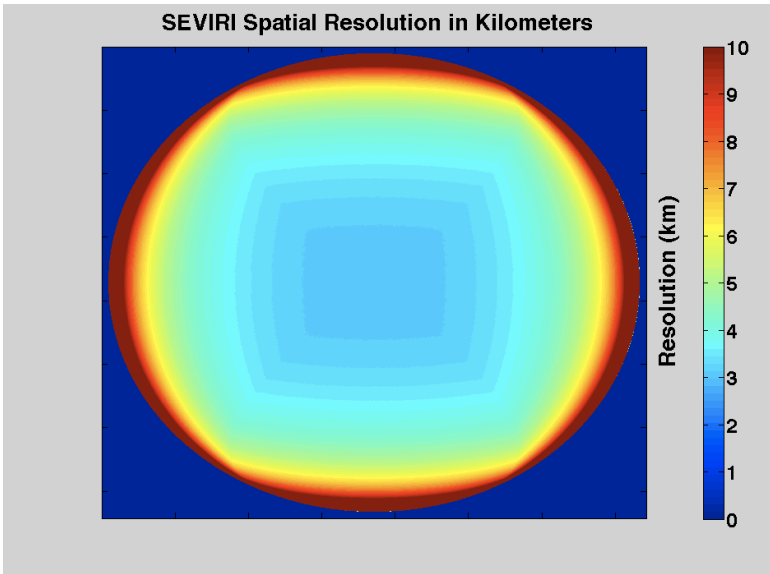
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Spatial Resolution



Outline

Two Approaches to Locating Fronts

- Two types of SST front algorithms

- Gradient based

- Fronts are defined by 'high gradient' pixels.
 - We used the Sobel gradient operator.

$$\begin{array}{ccc|ccc} -1 & 0 & 1 & & 1 & 2 & 1 \\ -2 & 0 & 2 & & 0 & 0 & 0 \\ -1 & 0 & 1 & & -1 & -2 & -1 \end{array}$$

- Population based

- Fronts are defined as pixels separating different populations.
 - We used the Cayula-Cornillon algorithm
– a.k.a. single image edge detection (SIED) algorithm.
 - Based on histograms of 32 x 32 pixel squares.

- These approaches are complimentary

- Both approaches require the definition of thresholds, but the thresholds are on different physical parameters hence the complementarity of the approaches.

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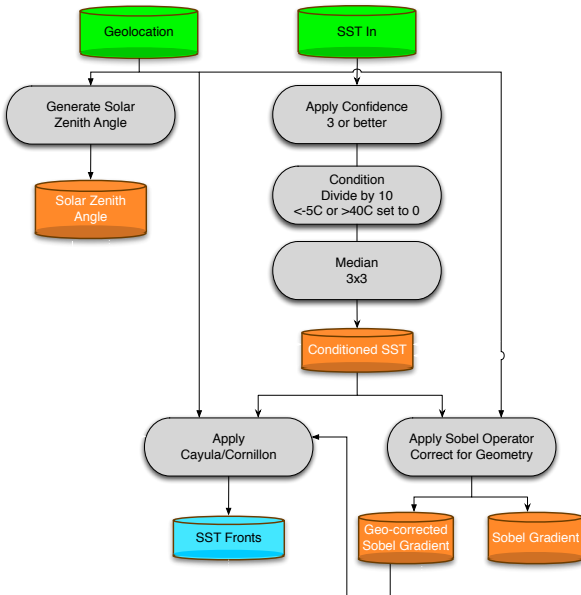
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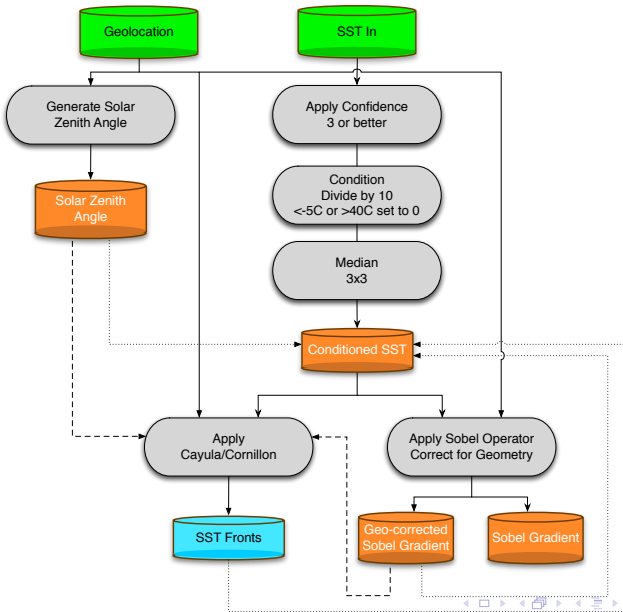
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Processing Steps – URI Workflow – For each image



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Where to Find the Data

All data output by the URI Fronts/Gradients workflow are available via OPeNDAP at:

<http://sstfronts.org/opendap>

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The Directory Structure: Base Directories

The output of the URI Fronts/Gradients workflow for each archive is divided into the following directories:

- Geolocation field(s): **GeoLoc** one file for L3, one per SST field for L2.
- The results of the first SIED pass: **Fronts_1st_Pass**
- The results of the second SIED pass: **Fronts_2nd_Pass**
- Sobel gradients in satellite coordinates (K/pixel): **Sobel**
- Sobel eastward and northward gradients (K/km): **GeoSobel**
- The solar zenith angle: **ZenithAngle**

Each of the above directories are arranged:

- By year.
- Then by month.

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In addition, the following statistical fields are created for each archive:

- Nighttime Sobel gradient magnitudes: **SobelSums**
 - Daily Sobel sums: **NighttimeSobelSums**
 - Monthly Sobel sums: **MonthlySobelSums**
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 - Dataset Sobel Sums: `sst_msg_DatasetSumSobelMag`
- Histograms of Sobel gradients: **SobelHistograms**
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An Example Directory Structure: MSG



Contents of /

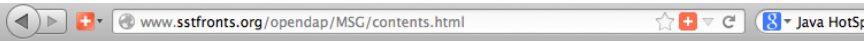
Name	Last Modified
<u>AVHRR/</u>	2013-02-06T17:05:24
<u>GOES/</u>	2013-02-06T19:03:33
<u>MSG/</u>	2013-02-04T18:41:38
<u>Pathfinder/</u>	2010-11-09T21:44:58

THREDDS Catalog [XML](#)

OPeNDAP Hyrax (1.8.8) ServerUUID=e93c3d09-a5d9-49a0-a912-a0ca16430b91-contents

Documentation

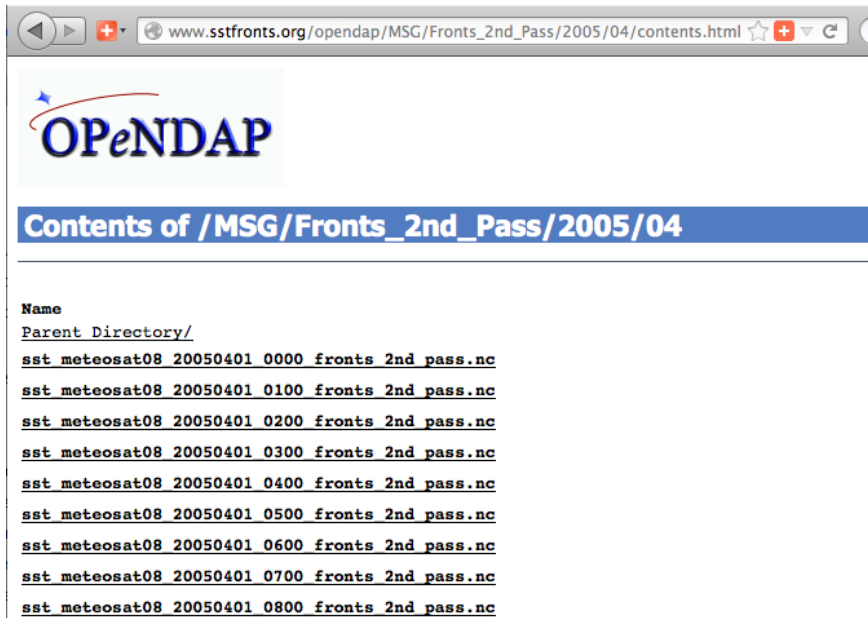
An Example Directory Structure: MSG



Contents of /MSG

Name	Last Modified	Size
<u>Parent Directory/</u>		
<u>FrontSums/</u>	2013-06-15T02:25:09	
<u>Fronts 1st Pass/</u>	2013-01-26T06:08:17	
<u>Fronts 2nd Pass/</u>	2013-02-04T05:50:11	
<u>GeoLocation/</u>	2013-02-04T21:11:59	
<u>GeoSobel/</u>	2013-02-13T14:36:33	
<u>LST/</u>	2012-05-25T16:57:28	
<u>Sobel/</u>	2013-01-24T14:45:16	
<u>SobelHistograms/</u>	2013-03-02T21:15:40	
<u>SobelSums/</u>	2013-03-12T22:57:50	
<u>ZenithAngle/</u>	2013-01-24T14:45:21	

An Example Directory Structure: MSG



The screenshot shows a web browser window with the address bar containing the URL `www.sstfronts.org/opendap/MSG/Fronts_2nd_Pass/2005/04/contents.html`. The OPeNDAP logo is displayed prominently. Below the logo, a blue header bar contains the text "Contents of /MSG/Fronts_2nd_Pass/2005/04". Underneath, a directory listing is shown with a "Name" header. The listing includes a "Parent Directory/" entry and several files named `sst meteosat08 20050401 0000 fronts 2nd pass.nc` through `0800 fronts 2nd pass.nc`, each underlined.

OPeNDAP

Contents of /MSG/Fronts_2nd_Pass/2005/04

Name

Parent Directory/

sst meteosat08 20050401 0000 fronts 2nd pass.nc

sst meteosat08 20050401 0100 fronts 2nd pass.nc

sst meteosat08 20050401 0200 fronts 2nd pass.nc

sst meteosat08 20050401 0300 fronts 2nd pass.nc

sst meteosat08 20050401 0400 fronts 2nd pass.nc

sst meteosat08 20050401 0500 fronts 2nd pass.nc

sst meteosat08 20050401 0600 fronts 2nd pass.nc

sst meteosat08 20050401 0700 fronts 2nd pass.nc

sst meteosat08 20050401 0800 fronts 2nd pass.nc

Outline

Sobel Gradients: Basic Dataset

For each SST field we determine:

- Sobel eastward gradient.
- Sobel northward gradient.
- Sobel gradient magnitude.

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Sobel Gradients: Statistics - SobelSums

Nighttime ONLY - solar zenith angle $> 90^\circ$ at each pixel.

- At each pixel location for each night **NighttimeSobelSums**:
 - Count the # of times the pixel was clear.
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 - Determine the maximum Sobel gradient magnitude for that night.
 - Get the time of the maximum gradient magnitude.
 - Calculated the mean Sobel gradient magnitude.

- Accumulate the above by:
 - Climatological day: **DailyClimatologicalSobelSums**
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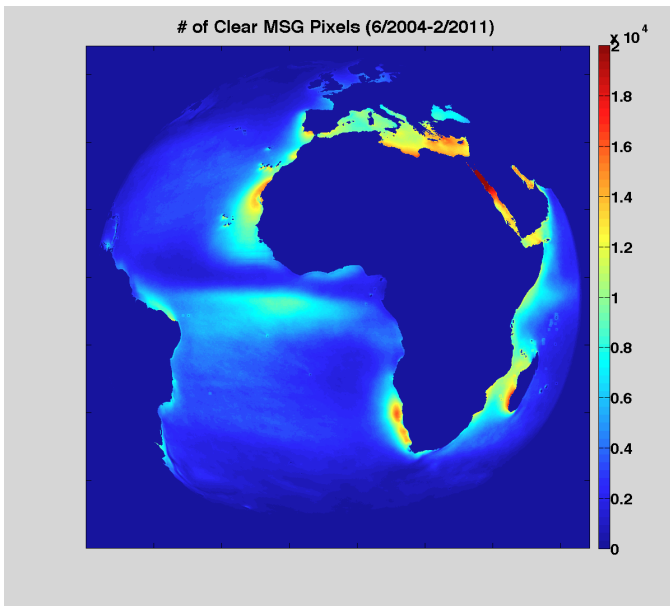
Sobel Gradients: Statistics - SobelSums

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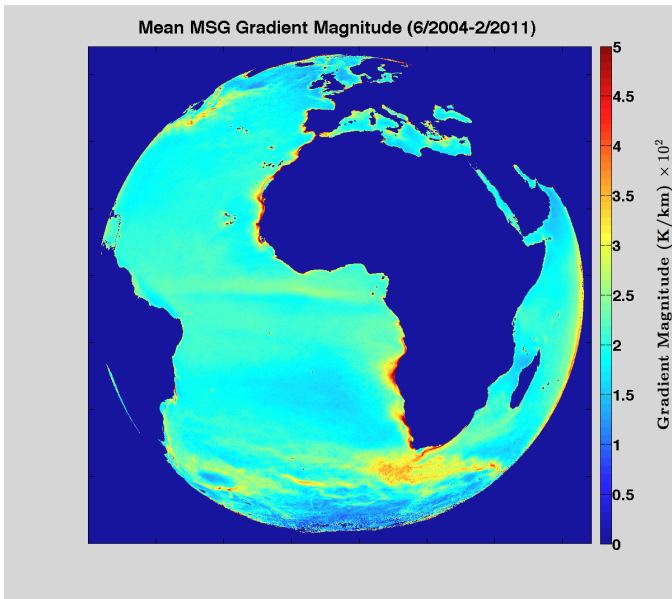
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⇒ All the information required to calculate the mean *and* the variance for any aggregation is available.

Outline

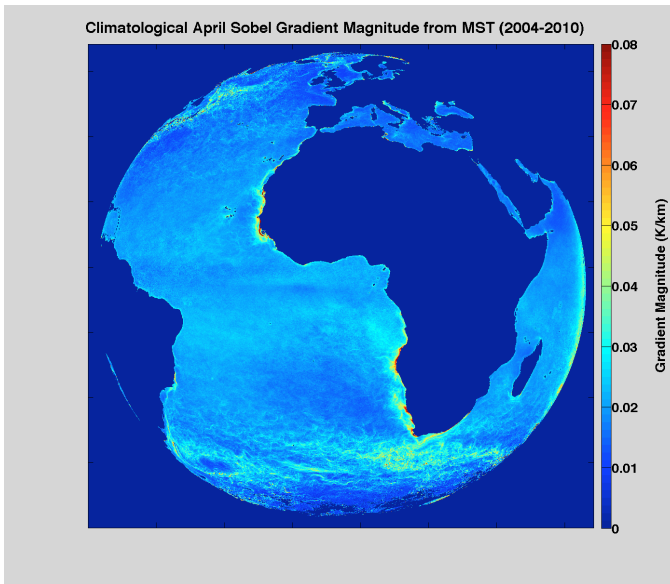
Number Clear Nighttime Pixels June 2003 through February 2011



Mean Sobel Gradient Magnitude for June 2003 through February 2011

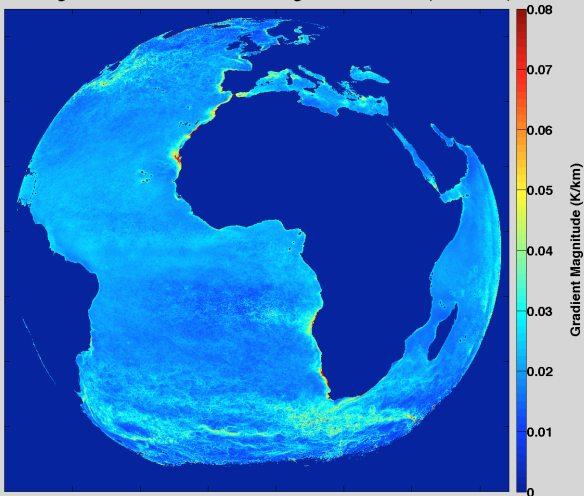


Climatological Sobel Gradient Magnitudes April

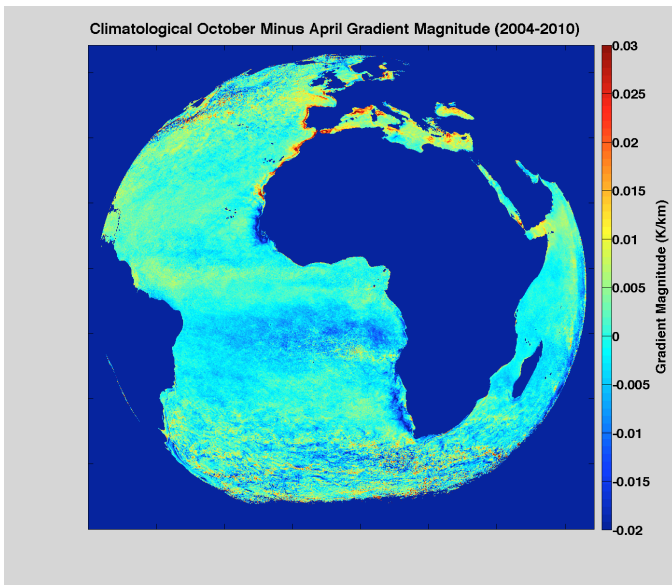


Climatological Sobel Gradient Magnitudes October

Climatological October Sobel Gradient Magnitude from MST (2004-2010)



Climatological Sobel Gradient Magnitudes October minus April



Outline

Front Segments

For each image the SIED is passed over the data twice yielding fronts for both passes:

- The primary fields are:
 - A list of SST front pixels, and
 - A list of SST front segments - one pixel wide lines of contiguous frontal pixels.
 - The starting location of the segment in the front pixel list, and
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The Cross-Front Array

For each front pixel there is a lot of information, much of which is based on an $n \times 17$ pixel array associated with each frontal segment.

- At each pixel location a cross-frontal line is defined:
 - 17 pixels long,
 - Normal to the segment - based on 5 pixels centered on the pixel of interest
 - Centered on the pixel of interest.
- For each 17 pixel line following is determined:
- The cross-front SST step:

$$\frac{\sum_{i=1}^8 SST_i}{8} - \frac{\sum_{j=10}^{17} SST_j}{8}$$

- In-front SST gradient:

$$\frac{\sum_{i=8}^{10} \nabla_{E,N} SST_i}{3} \quad \text{where E is eastward and N is northward}$$

- Background SST gradient:

$$\frac{\sum_{i=1}^4 \nabla_{E,N} SST_i + \sum_{j=14}^{17} \nabla_{E,N} SST_j}{8}$$

The Cross-Front Array

For each front pixel there is a lot of information, much of which is based on an $n \times 17$ pixel array associated with each frontal segment.

- At each pixel location a cross-frontal line is defined:
 - 17 pixels long,
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 - Centered on the pixel of interest.
- For each 17 pixel line following is determined:
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$$\frac{\sum_{i=1}^8 SST_i}{8} - \frac{\sum_{j=10}^{17} SST_j}{8}$$

- In-front SST gradient:

$$\frac{\sum_{i=8}^{10} \nabla_{E,N} SST_i}{3} \quad \text{where E is eastward and N is northward}$$

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Problems

Things were looking ' bad; Matlab was Broken.

Problems

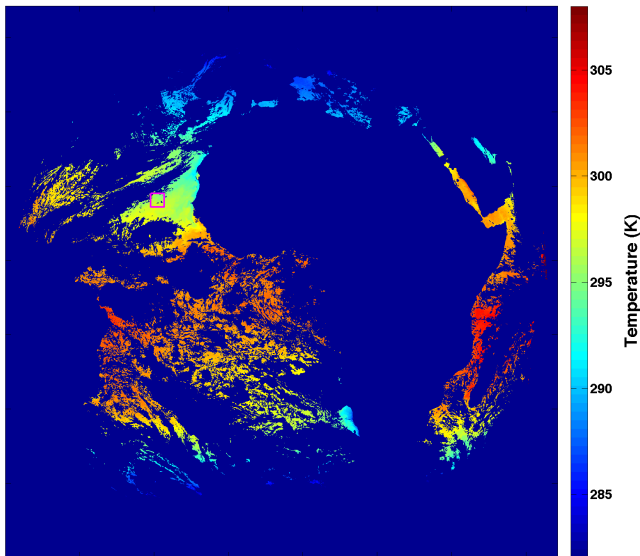
And then along came John.

Problems



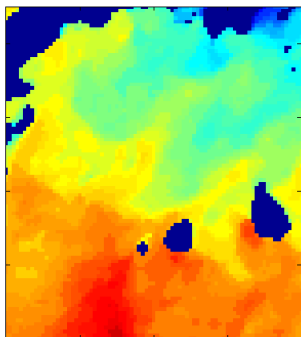
A Front: 1 April 2005 0000 GMT

MSG SST 1 April 2005



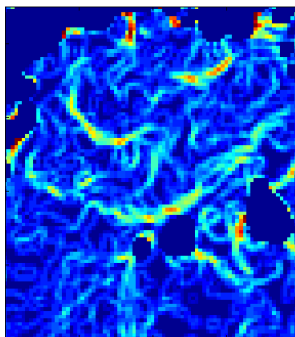
A Front: SST and ∇ SST

MSG SST 1 April 2005



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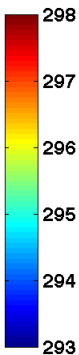
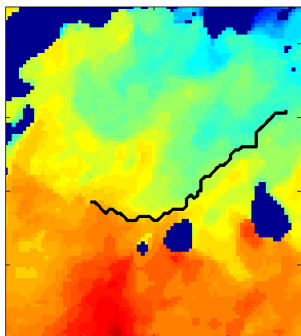
MSG ∇ SST 1 April 2005



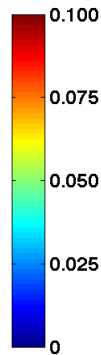
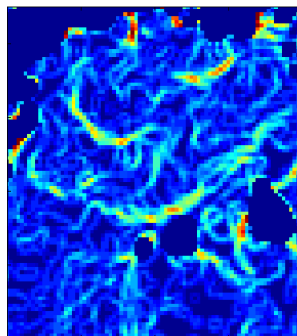
0.100
0.075
0.050
0.025
0

A Front: Front Pixel Locations

MSG SST 1 April 2005

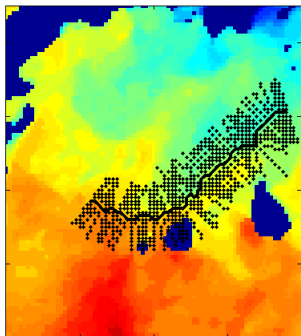


MSG ∇ SST 1 April 2005



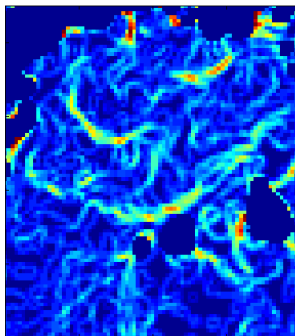
A Front: The $n \times 17$ Locations

MSG SST 1 April 2005



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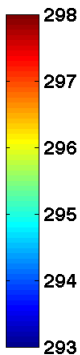
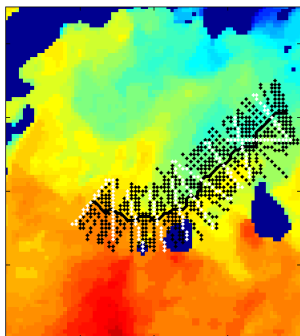
MSG ∇ SST 1 April 2005



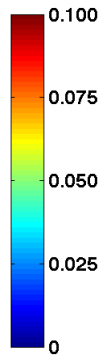
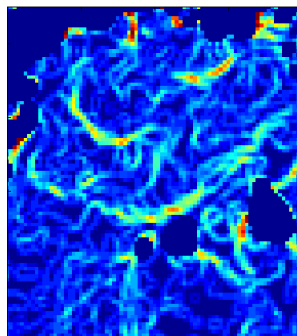
0.100
0.075
0.050
0.025
0

A Front: Representative Cross-Front Lines

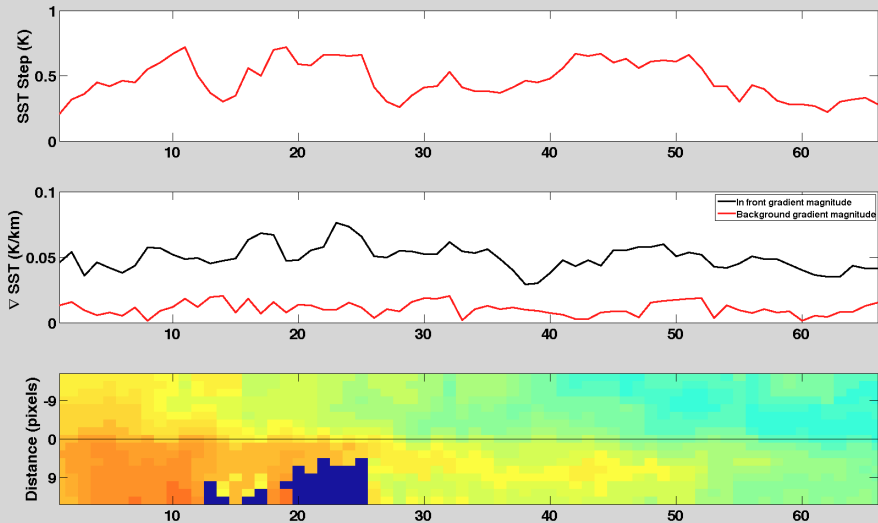
MSG SST 1 April 2005



MSG ∇ SST 1 April 2005



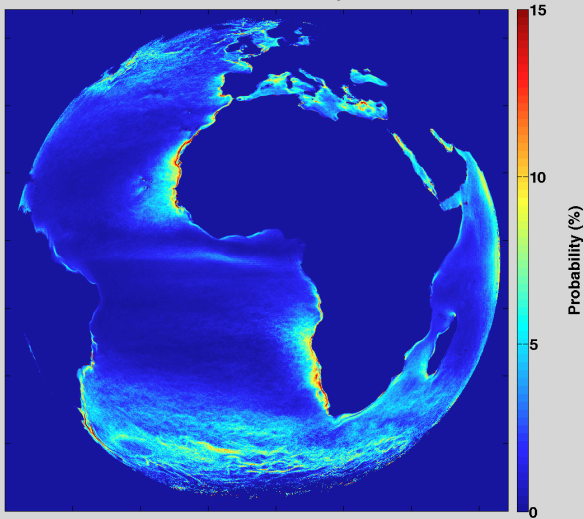
A Front: Cross-Front Properties



Outline

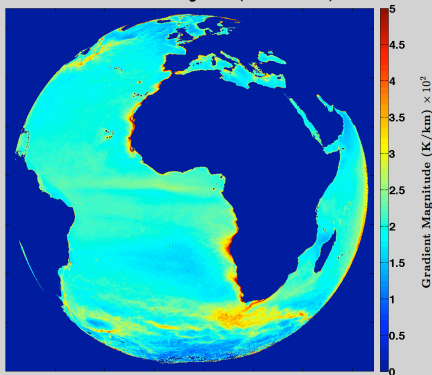
Nighttime Front Probability for June 2003 through February 2011

MSG Two Pass SIED Front Probability (6/2004-2/2011)

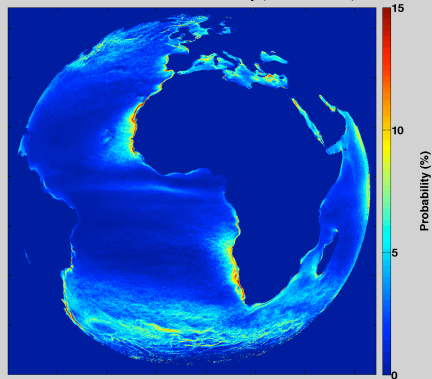


Nighttime Front Probability vs Mean Gradient Magnitude (2003–2011)

Mean MSG Gradient Magnitude (6/2004-2/2011)

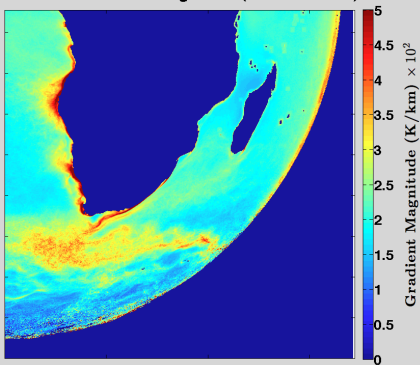


MSG Two Pass SIED Front Probability (6/2004-2/2011)

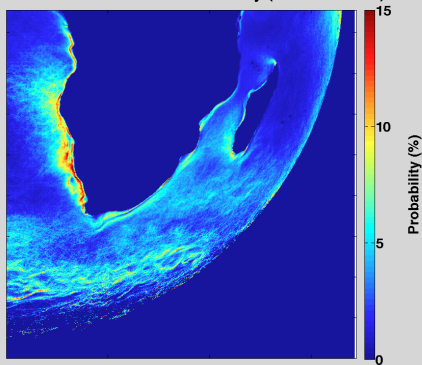


Nighttime Front Probability vs Mean Gradient Magnitude for June 2003 through February 2011

Mean MSG Gradient Magnitude (6/2004-2/2011)



MSG Two Pass SIED Front Probability (6/2004-2/2011)



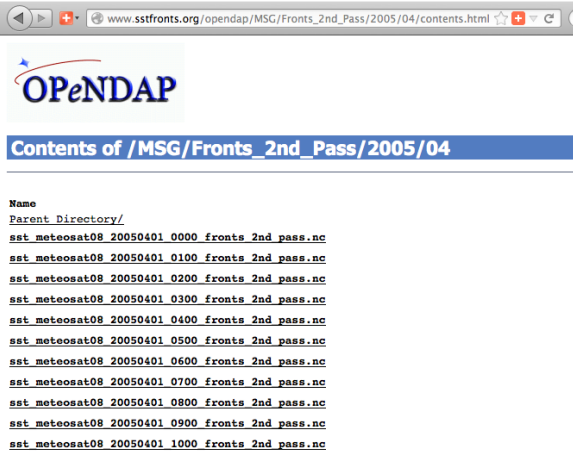
Outline

Accessing the Data via a Browser

The data are easy to access via a browser at: <http://sstfronts.org/opensdap>

Accessing the Data via a Browser

Tree down to the file of interest



The screenshot shows a web browser window with the address bar containing the URL `www.sstfronts.org/opepdap/MSG/Fronts_2nd_Pass/2005/04/contents.html`. The page features the OPeNDAP logo at the top left. Below the logo is a blue header bar with the text **Contents of /MSG/Fronts_2nd_Pass/2005/04**. Underneath the header is a table listing files in a directory.

Name
Parent Directory/
sst_meteosat08_20050401_0000_fronts_2nd_pass.nc
sst_meteosat08_20050401_0100_fronts_2nd_pass.nc
sst_meteosat08_20050401_0200_fronts_2nd_pass.nc
sst_meteosat08_20050401_0300_fronts_2nd_pass.nc
sst_meteosat08_20050401_0400_fronts_2nd_pass.nc
sst_meteosat08_20050401_0500_fronts_2nd_pass.nc
sst_meteosat08_20050401_0600_fronts_2nd_pass.nc
sst_meteosat08_20050401_0700_fronts_2nd_pass.nc
sst_meteosat08_20050401_0800_fronts_2nd_pass.nc
sst_meteosat08_20050401_0900_fronts_2nd_pass.nc
sst_meteosat08_20050401_1000_fronts_2nd_pass.nc

Accessing the Data via a Browser

Click on the filename

OPeNDAP Server Dataset Access Form

Action:

Data URL:

Global Attributes:

Variables: **segment_start:** Array of 32 bit Integers [segment = 0..1915]

segment_length: Array of 16 bit Integers [segment = 0..1915]

minimum_latitude: Array of 32 bit Reals [segment = 0..1915]

maximum_latitude: Array of 32 bit Reals [segment = 0..1915]

minimum_longitude: Array of 32 bit Reals [segment = 0..1915]

Accessing the Data via a Browser

Select the elements (and range if desired) of variables from the list.

maximum_longitude: Array of 32 bit Reals [segment = 0..1915]

segment:

units: degrees
_FillValue: 3.40282347e+38

latitude: Array of 32 bit Reals [record = 0..26245]

record:

long_name: latitude
units: degrees
_FillValue: 3.40282347e+38

longitude: Array of 32 bit Reals [record = 0..26245]

record:

long_name: longitude
units: degrees
_FillValue: 3.40282347e+38

i: Array of 32 bit Integers [record = 0..26245]

record:

long_name: along-scan_location_in_the_original_image
_FillValue: -2147483647

i: Array of 32 bit Integers [record = 0..26245]

Accessing the Data via a Browser

Click “Get as NetCDF”:

OPeNDAP Server Dataset Access Form

Action:

Data URL:

Global Attributes:

```
NC_GLOBAL.title: Cayula-Cornillon Fronts in Conditioned Meteosat/MSG
SST from CMS
NC_GLOBAL.summary: This file consists of three sets of variables. One
set corresponds to characteristics of front segments. A front segment
is a set of contiguous front pixels found with the Cayula-Cornillon
SIED algorithm. Variables in this set are, for each segment, the
```

Variables: **segment_start:** Array of 32 bit Integers [segment = 0..1915]

segment:

long_name: first_pixel_of_front_segment

Accessing the Data via a Browser

Click “Get as NetCDF”:

OPeNDAP Server Dataset Access Form

Action:

Get ASCII

Get as NetCDF

Binary (DAP) Object

Show Help

Data URL:

http://www.sstfronts.org/pendap/hyrax/MSG/Fronts_2nd_Pass/2005/04/sst_meteosat0f

Global Attributes:

```
NC_GLOBAL.title: Cayula-Cornillon Fronts in Conditioned Meteosat/MSG
SST from CMS
NC_GLOBAL.summary: This file consists of three sets of variables. One
set corresponds to characteristics of front segments. A front segment
is a set of contiguous front pixels found with the Cayula-Cornillon
SIED algorithm. Variables in this set are, for each segment, the
```

Variables: **segment_start:** Array of 32 bit Integers [segment = 0..1915]

segment:


```
long_name: first_pixel_of_front_segment
```

Accessing the Data via a Browser

Select action on your system:

Opening sst_meteosat08_20050401_0400_fronts_2nd_...

You have chosen to open:

 **sst_meteosat08_20050401_0400_fronts_2nd_pass.nc.nc**

which is a: netCDF Dataset

from: <http://www.sstfronts.org>

What should Firefox do with this file?

Open with Panoply (default)

Save File

Do this automatically for files like this from now on.

Accessing the Data via a Browser

And voila:

The screenshot shows a web browser interface with a top navigation bar containing 'Introduction', 'URI Workflow', 'The Atlas', and 'Accessing'. Below the navigation bar is a large heading 'Accessing the Data via a Browser'. Underneath, the text 'And voila:' is displayed. The main content area is divided into two panels. The left panel, titled 'Sources', contains a table with columns 'Name', 'Long Name', and 'Type'. The right panel displays the metadata for the selected dataset, including dimensions, variables, and global attributes.

Name	Long Name	Type
▼ sst_meteosat08_20050401_0400_front...	sst_meteosat08_20050401_0400_fronts_2nd_pa...	Local File
▶ cross_front_sst	cross front sea surface temperature profile	—
▶ latitude	latitude	—
▶ longitude	longitude	—
▶ segment_length	number of pixels in front segment	—
▶ segment_start	first pixel of front segment	—

File "sst_meteosat08_20050401_0400_fronts_2nd_pass.nc"

Dataset type: NetCDF-3/CDM

```
netcdf file:/Users/petercornillon/Downloads/sst_meteosat08_20050401_0400_fronts_2nd_pass.nc {
dimensions:
    segment = 1916;
    record = 26246;
    cross_front = 17;
    cross_front_record = 26246;
variables:
    int segment_start(segment=1916);
        :long_name = "first_pixel_of_front_segment";
    short segment_length(segment=1916);
        :long_name = "number_of_pixels_in_front_segment";
    float cross_front_sst(cross_front=17, cross_front_record=26246);
        :long_name = "cross_front_sea_surface_temperature_profile";
        :units = "Kelvin";
        :Description = "The program finds the approximate normal to the front";
    float latitude(record=26246);
        :long_name = "latitude";
        :units = "degrees";
        :FillValue = 3.4028235E38f; // float
        :CoordinateAxisType = "Lat";
    float longitude(record=26246);
        :long_name = "longitude";
        :units = "degrees";
        :FillValue = 3.4028235E38f; // float
        :CoordinateAxisType = "Lon";

// global attributes:
:NC_GLOBAL.title = "Cayula-Cornillon Fronts in Conditioned I";
:NC_GLOBAL.summary = "This file consists of three sets of v";
:NC_GLOBAL.Conventions = "CF-1.5";
:NC_GLOBAL.standard_name_vocabulary = "CF-1.5";
:NC_GLOBAL.Metadata_Conventions = "Unidata Dataset Discovery";
:NC_GLOBAL.uid = "B1226E67-742B-4D85-B998-9F5B6506927";
:NC_GLOBAL.date_created = "20130204 204120.761";
:NC_GLOBAL.history = "{20130204 204120.761 : SIED_Main vers: ";
:NC_GLOBAL.creator_name = "Peter Cornillon";
```

Accessing the Data via wget

- The data are also readily accessible/subsettable via wget:

```
>> wget http://www.sstfronts.org/opensap/hyrax/MSG/Fronts_2nd_Pass/  
2005/04/sst_meteosat08_20050401_0400_fronts_2nd_pass.nc.nc?  
segment_start,segment_length,latitude,longitude,cross_front_sst
```

Note the second **.nc** at the end of the filename. (.nc4 in a few weeks will get a chunked/compressed response.)

- Or you could access the data directly from Matlab substituting the filename (without the extra **.nc**) in the Matlab netCDF commands.

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Archives

- Available today:

- MSG-SEVIRI
- GOES-east-VISSR

- Available within a week:

- AVHRR
 - AVHRR Global
 - AVHRR North America - Medium Resolution
- MODIS 4 km Global
 - MODIS 4 km Global

Archives

- Available today:

- MSG-SEVIRI
- GOES-east-VISSR

- Available within a week:

- AVHRR
AVHRR 2 km Global
AVHRR 2 km Global - Medium Resolution
AVHRR 2 km Global - Medium Resolution
- MODIS 4 km Global
MODIS 4 km Global

Archives

- Available today:
 - MSG-SEVIRI
 - GOES-east-VISSR
- Available within a week:
 - AVHRR
 - MODIS 4 km Global

Archives

- Available today:
 - MSG-SEVIRI
 - GOES-east-VISSR
- Available within a week:
 - AVHRR
 - 4 km Global V5.2
 - 1 km Wester North Atlantic - Wallops Island receiving station.
 - MODIS 4 km Global
 - Aqua, Terra
 - NSST
 - SST4
 - SST
 - Chlorophyll

Archives

- Available today:
 - MSG-SEVIRI
 - GOES-east-VISSR
- Available within a week:
 - AVHRR
 - 4 km Global V5.2
 - 1 km Wester North Atlantic - Wallops Island receiving station.
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