Satellite Observations and Analyses of NOPAC Volcanoes

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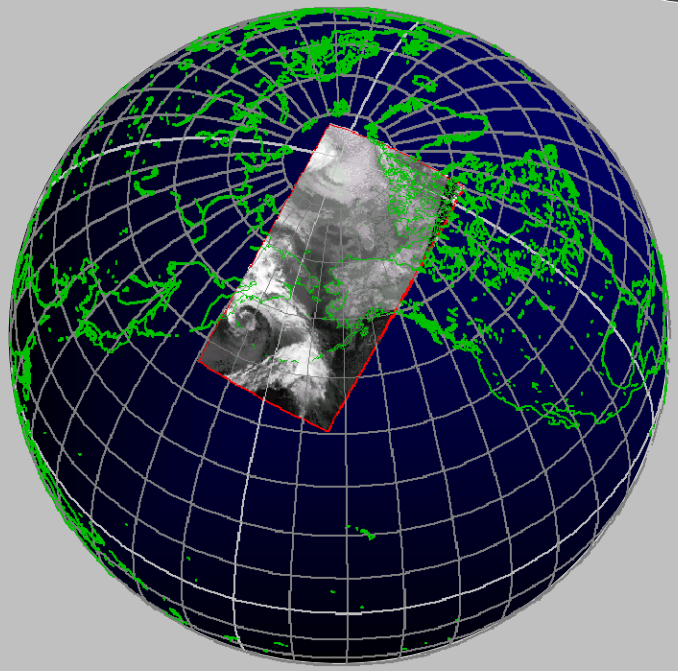
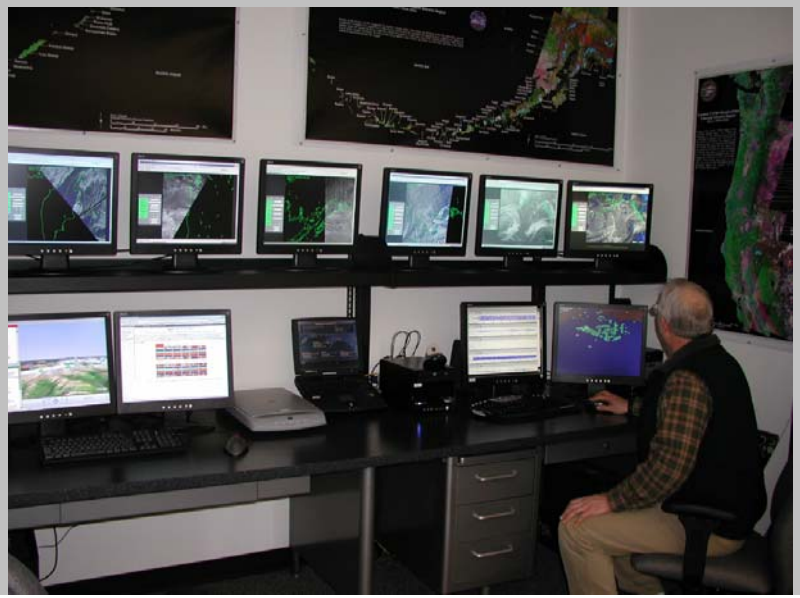
Geophysical Institute

University of Alaska Fairbanks

Graphics supplied by: Faculty, Staff and Students of the Satellite Volcano Crew





Outline

Subjects

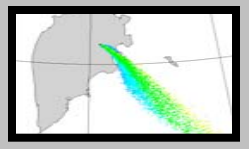
1. **Introduction and Perspective**

2. **Satellite Data Used for Detection**

3. **Satellite Analysis Techniques**

4. **Satellite Volcano Monitoring**

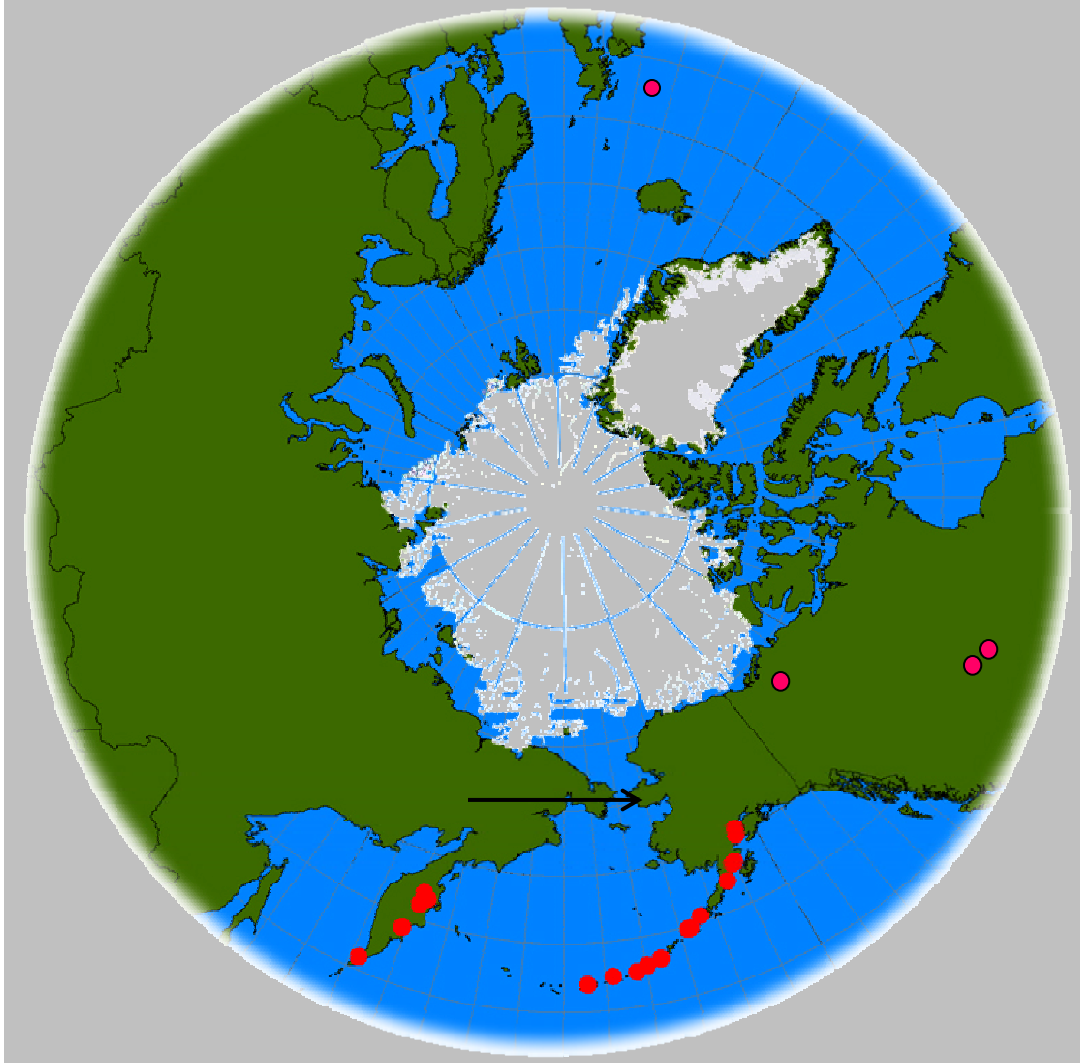
5. **Augustine Erupion 2006**



5. **New Developments**

5. **30 years of Eruptions**

Introduction: Volcanoes in the North Pacific Region



Approx. 70 historically active Volcanoes in region

Aleutian Islands
Alaska Peninsula
Alaska Mainland
Kamchatka Peninsula, Russia
Cascades

Prevailing Winds to East

Frequency of Eruptions in the North Pacific

Really Large Events

- **Ash over 60,000 ft, Katmai 1912**
  - **Largest eruption 20th Century**
- **Caldera forming events**
  - **3000 BP and 9000 BP**

Intermediate Events

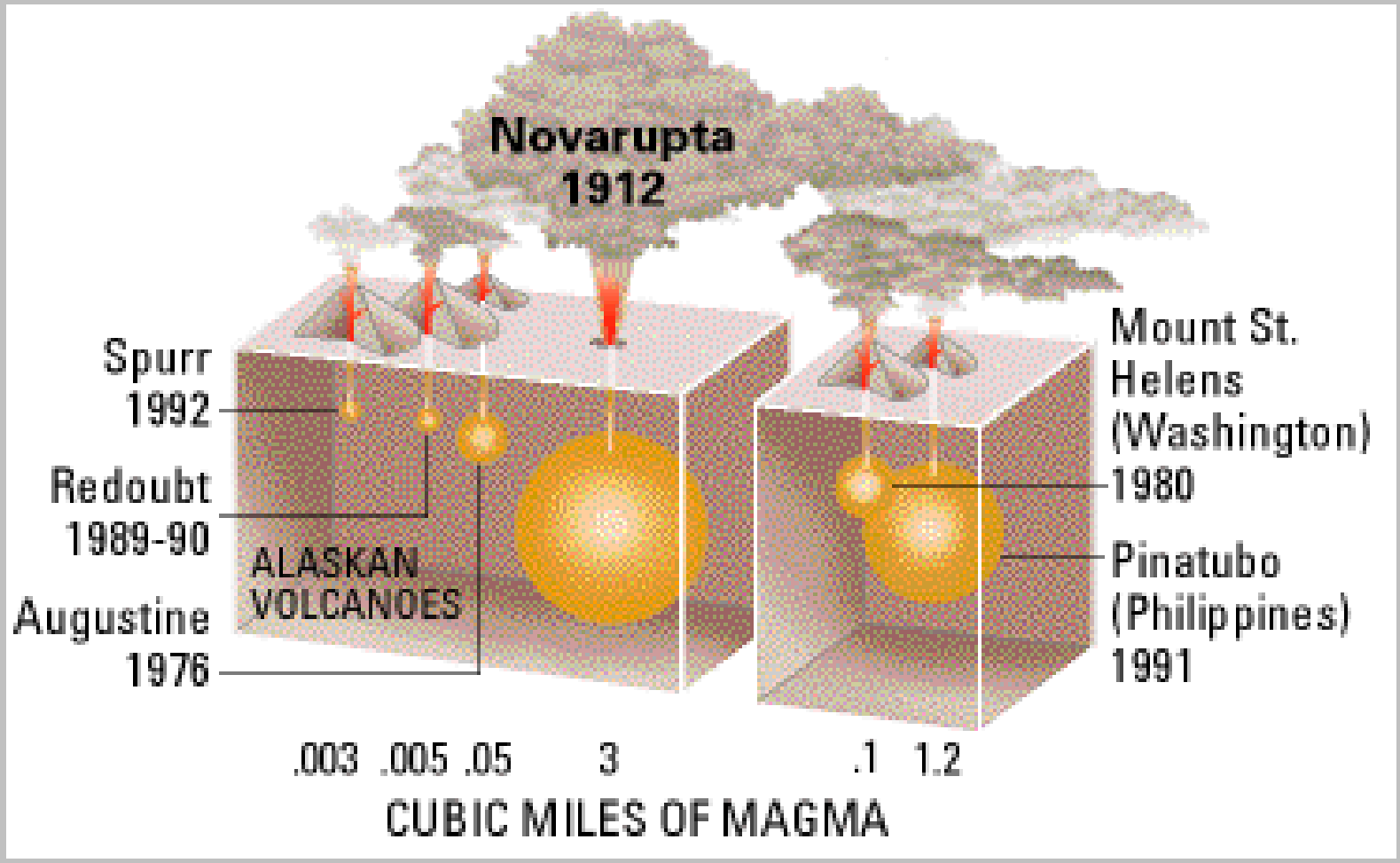
- **Ash over 20,000 ft. 3-4/year**

Small Events

- **Plumes to <10,000 ft, thermal anomalies, or seismic activity**
  - **Observed daily**

Any of these events may last from hours to many months

Size of Eruptions in the North Pacific

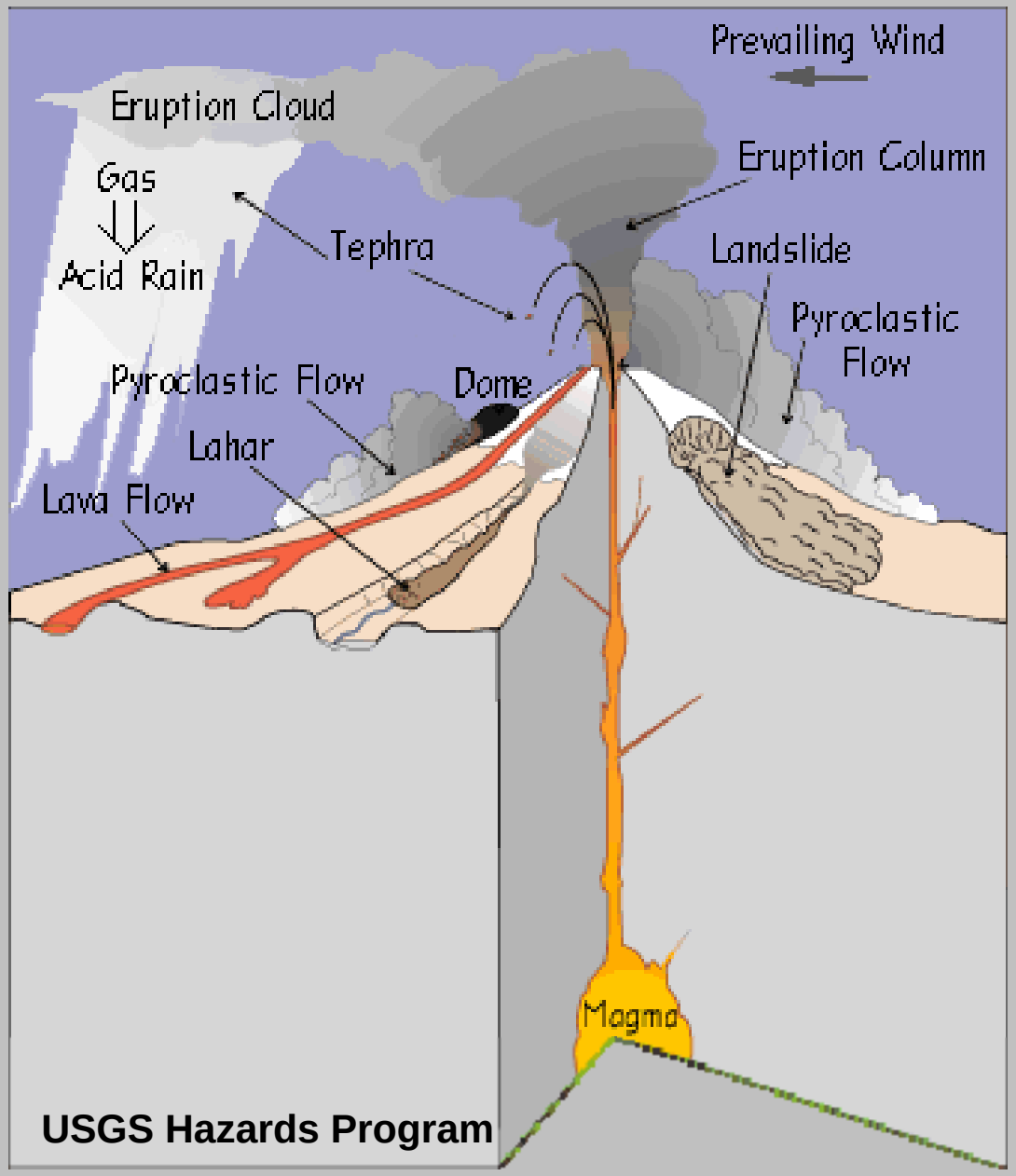


USGS Hazards Program

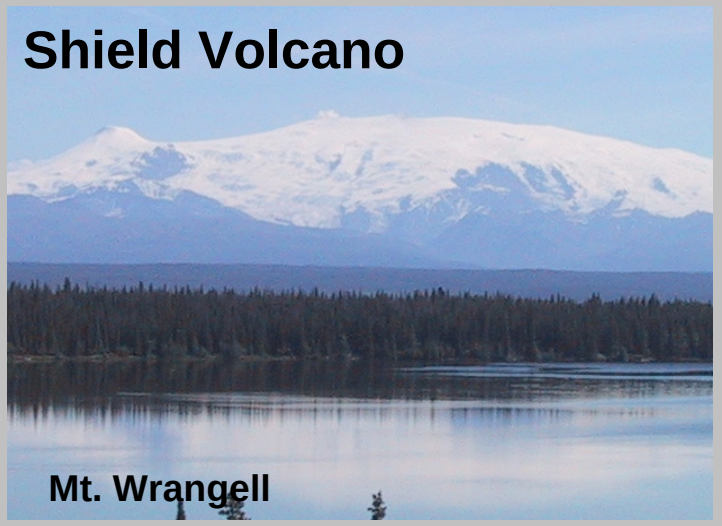
What volcanic features can we see from space?

<u>Depends upon the Resolution:</u>
Spatial
Temporal
Wavelengths

<u>Thermal Infrared Response:</u>
Eruption Cloud – Cold or Hot?
PF – Cold or Hot?
Dome – Cold or Hot?
Lahar – Cold or Hot?



Types of Volcanoes in Alaska and Kamchatka



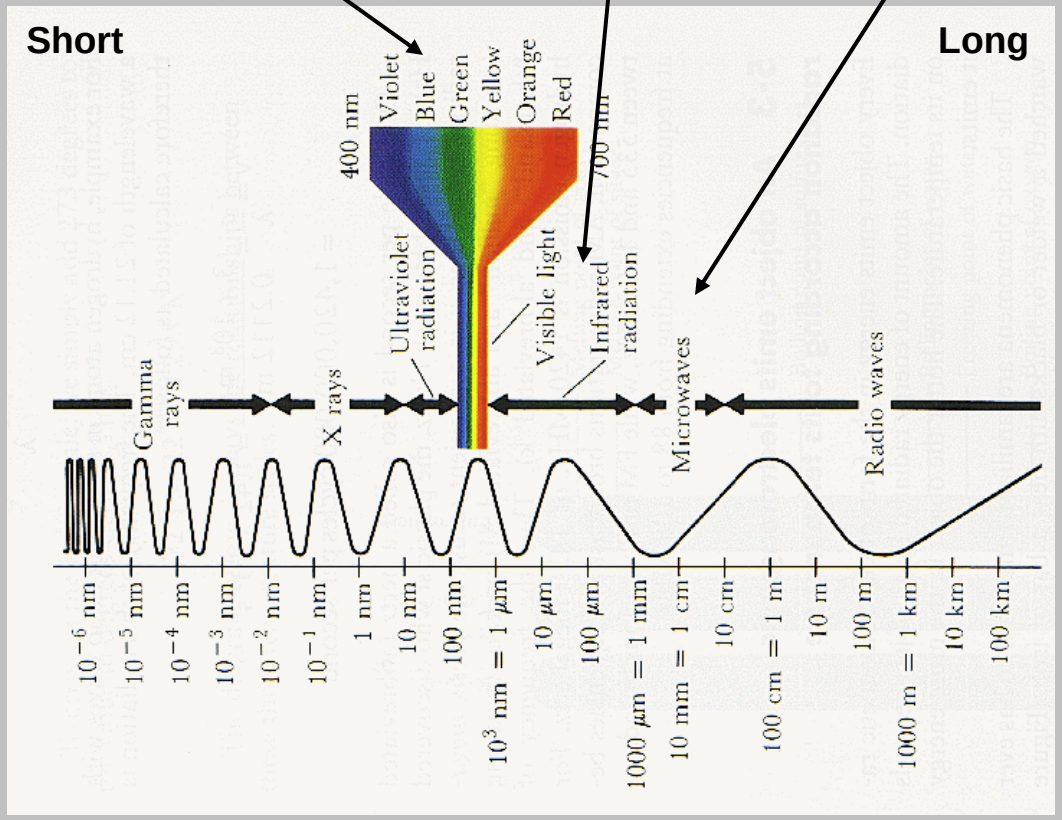
Satellite Sensor Wavelengths

Electromagnetic Spectrum

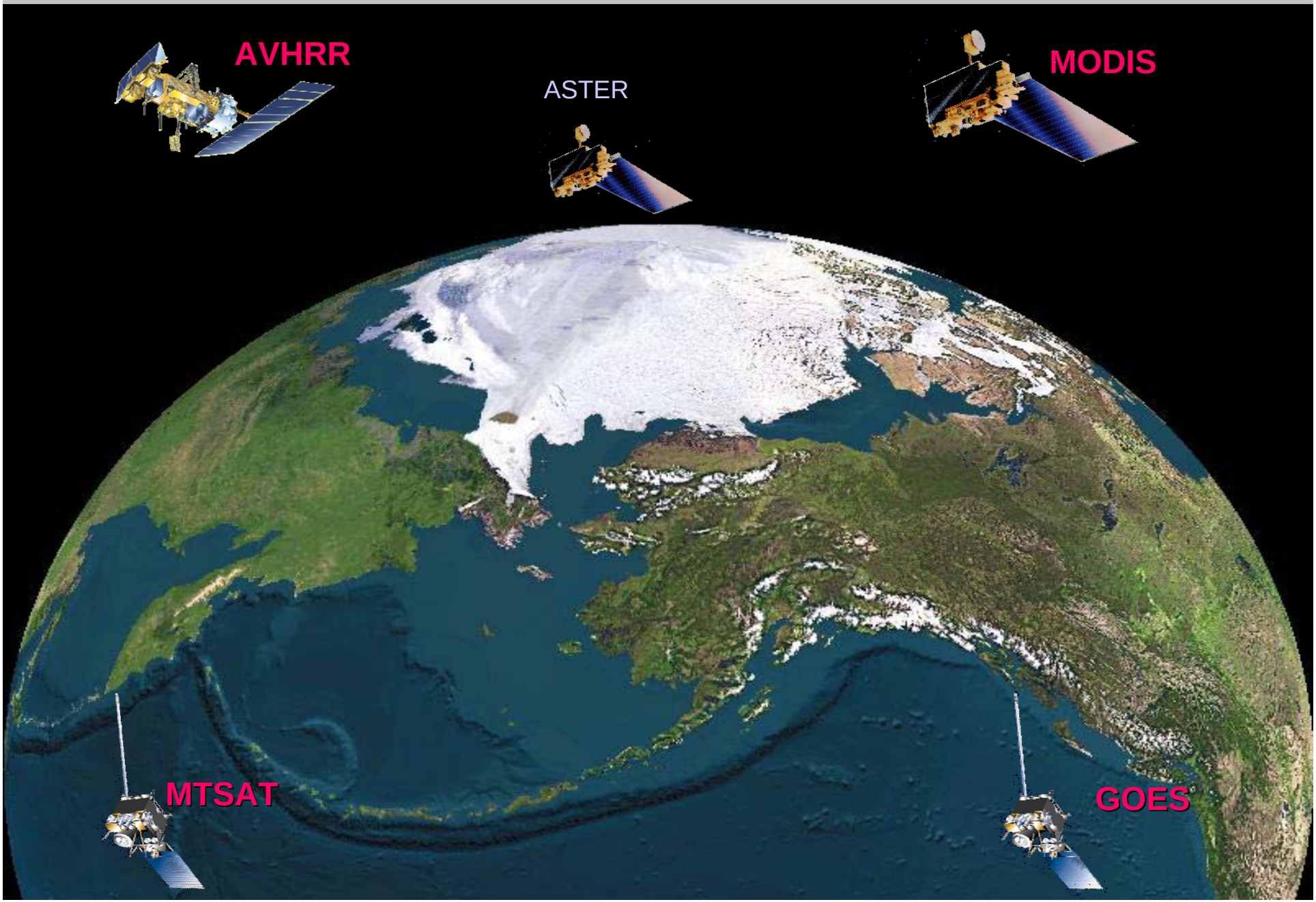
Bands: **Visible** **Thermal Infrared** **Radar**

Processes: (Surface chemistry) (Heat) (Topography, Deformation)

Viewing: Day Day & Night Day & Night, Clouds



Data Used for Monitoring



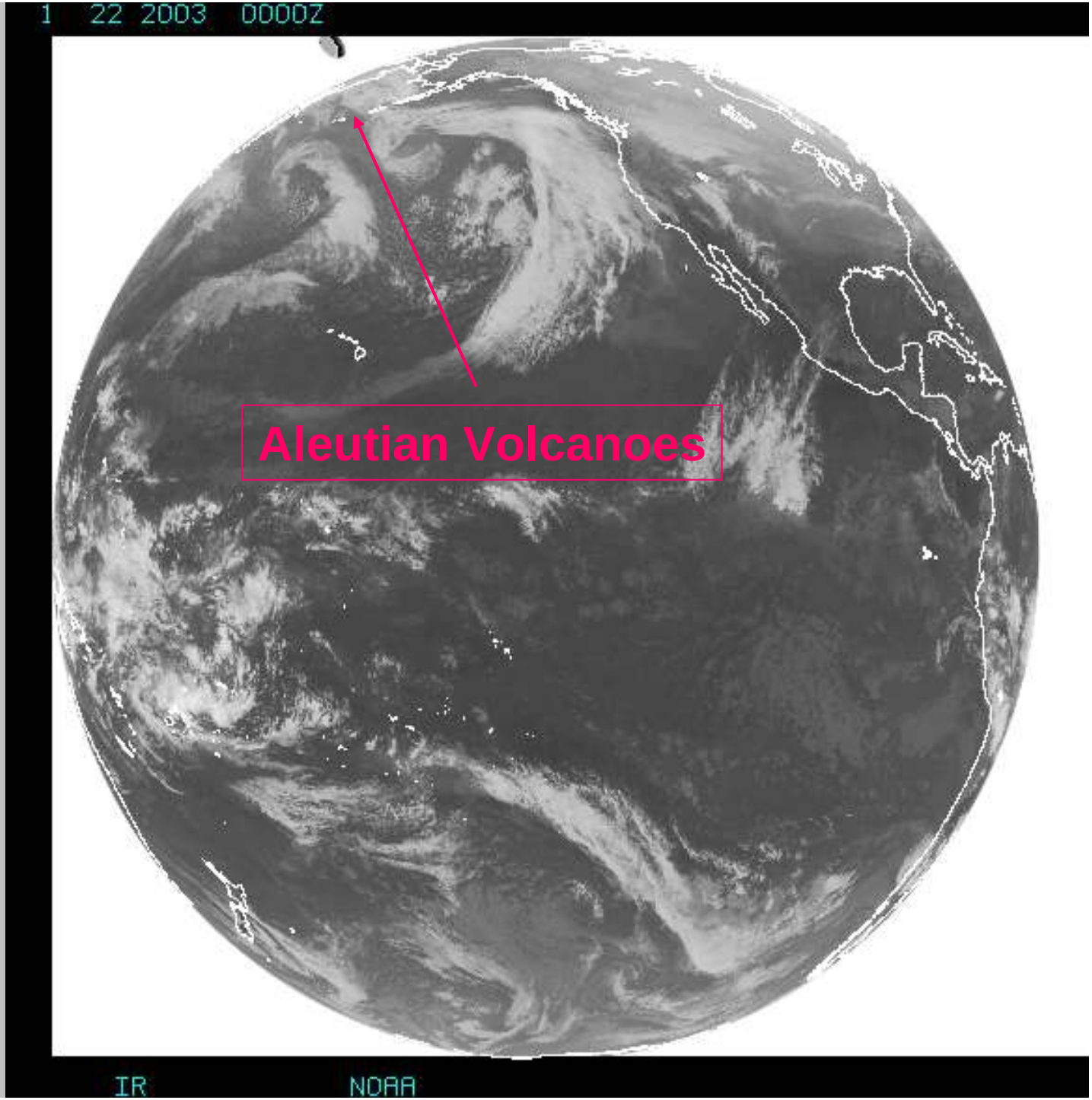
GOES

Orbit: Equatorial

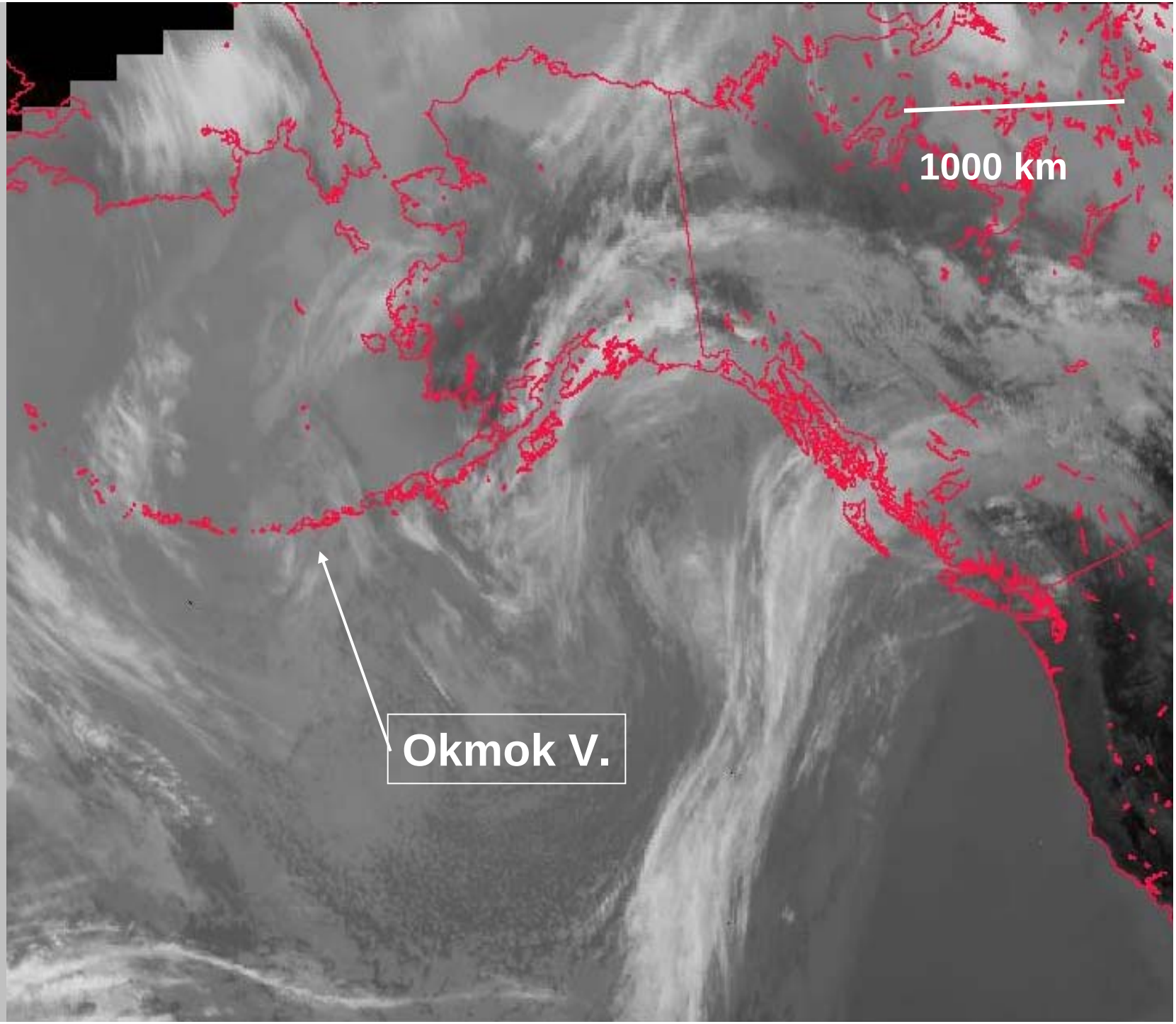
Temporal Res.:
15 – 30 min

Spatial Res.:
2-8km (Alaska)

Wavelength:
Visible
Thermal Infrared



GOES (Zoomed Image)

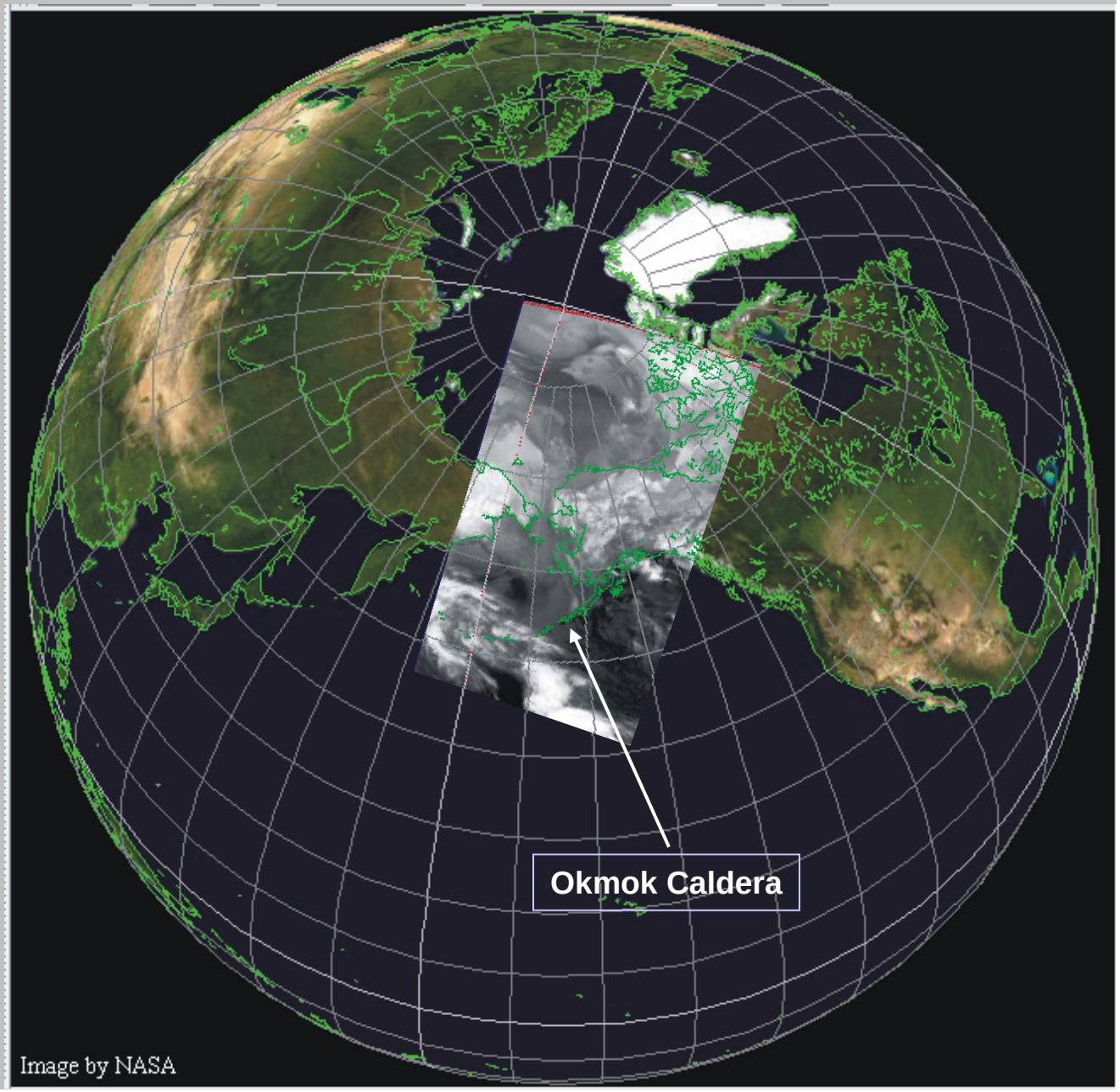


AVHRR
Orbit: Polar

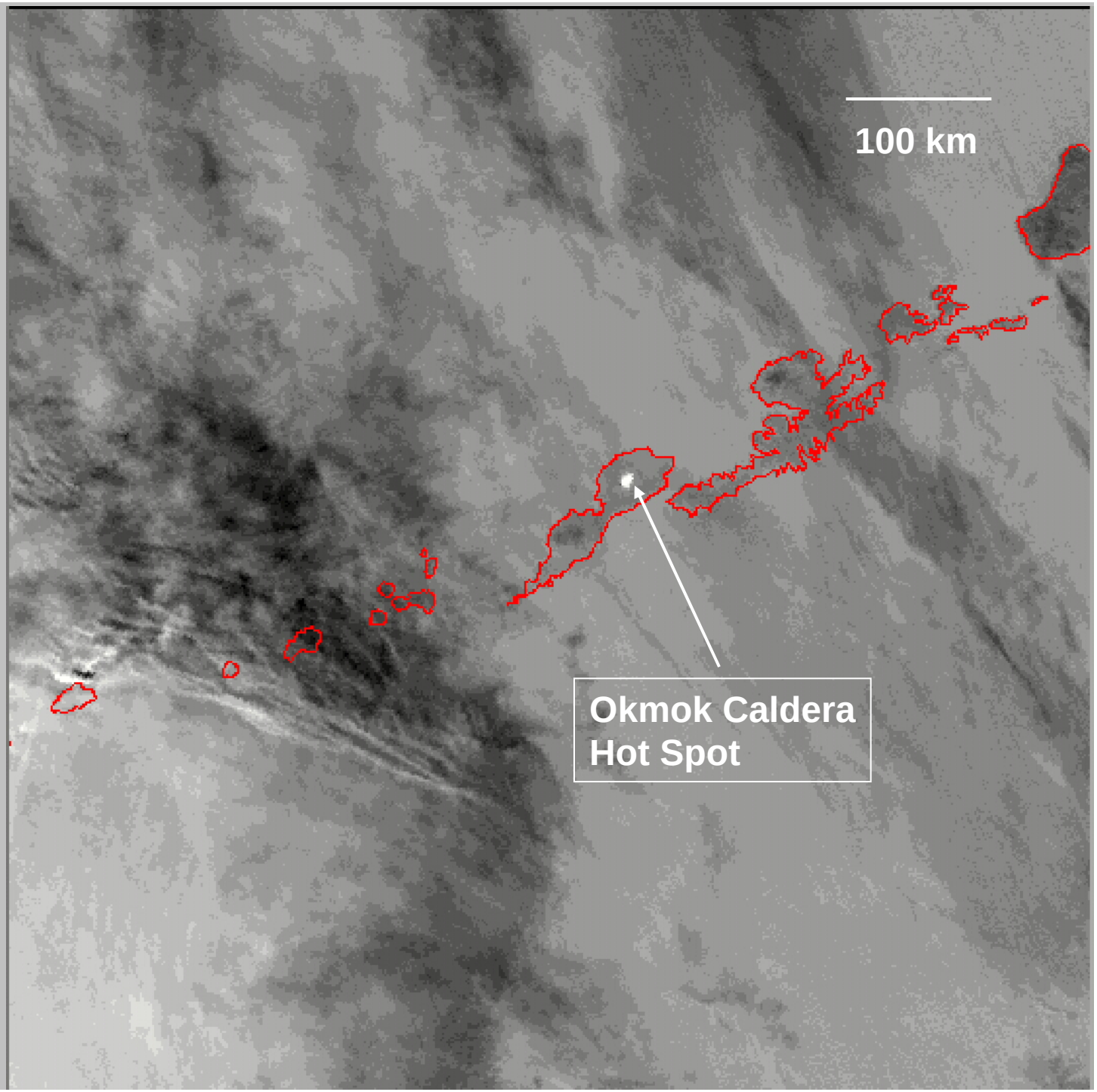
Temporal Res.: hourly

Spatial Res: 1km

Wavelength: Visible & Thermal Infrared



AVHRR (Zoomed image)

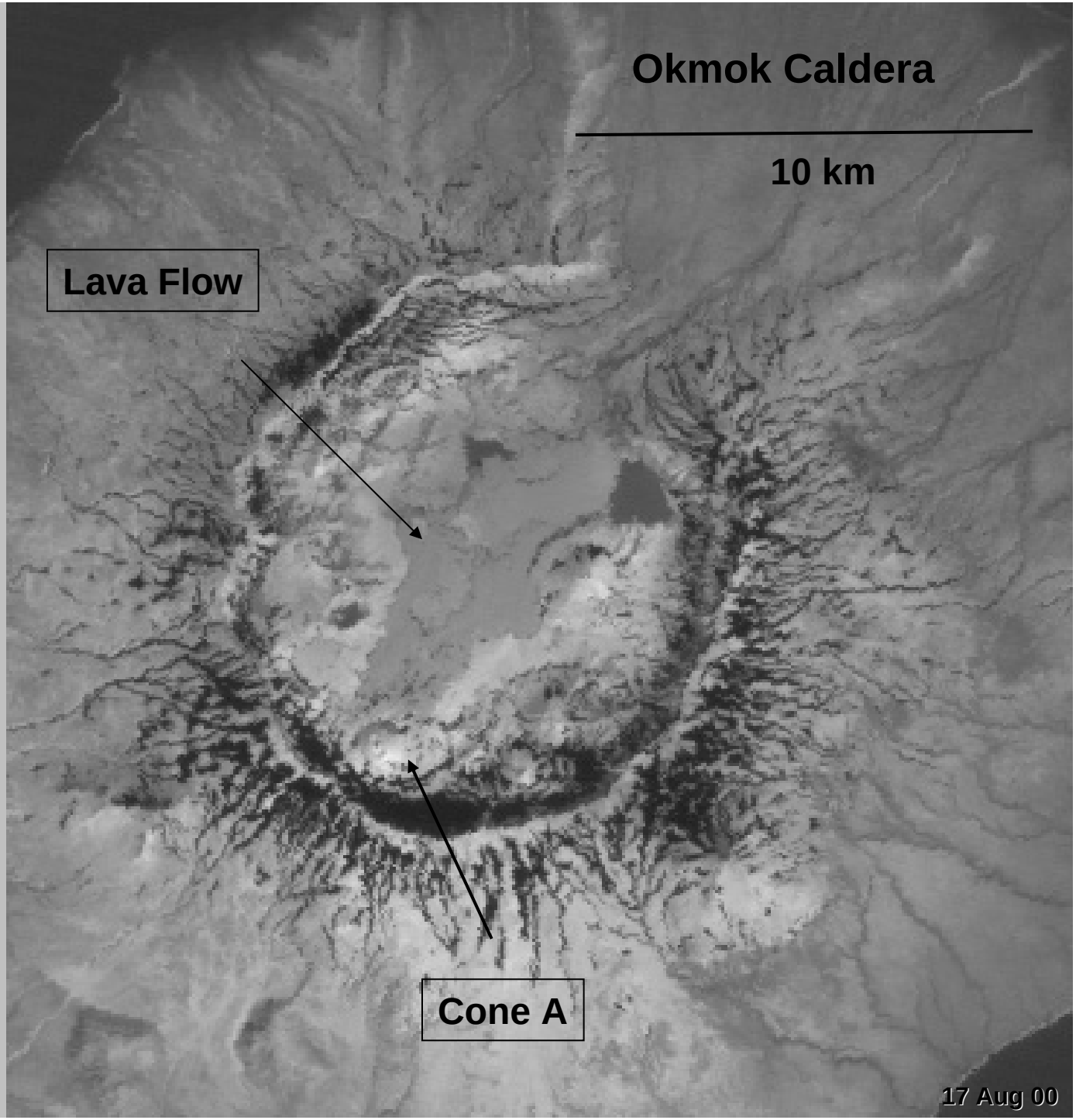


Landsat (TIR)

Temporal Res.:
2 monthly

Spatial Res:
15 – 60 m

Wavelength:
Thermal Infrared

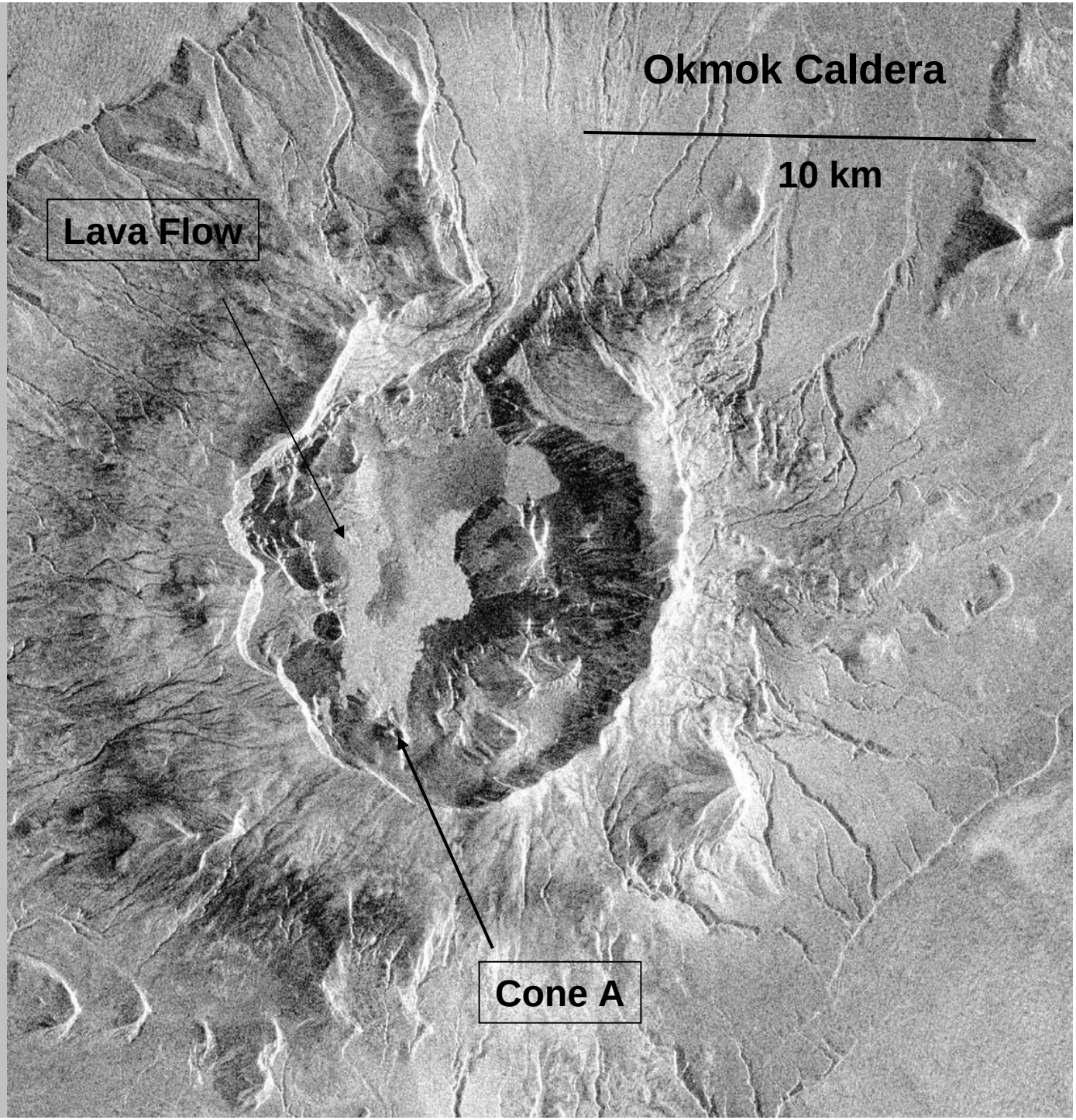


Radar

Temporal Res.:
2/month

Spatial Res:
25 m

Wavelength:
C-band Radar

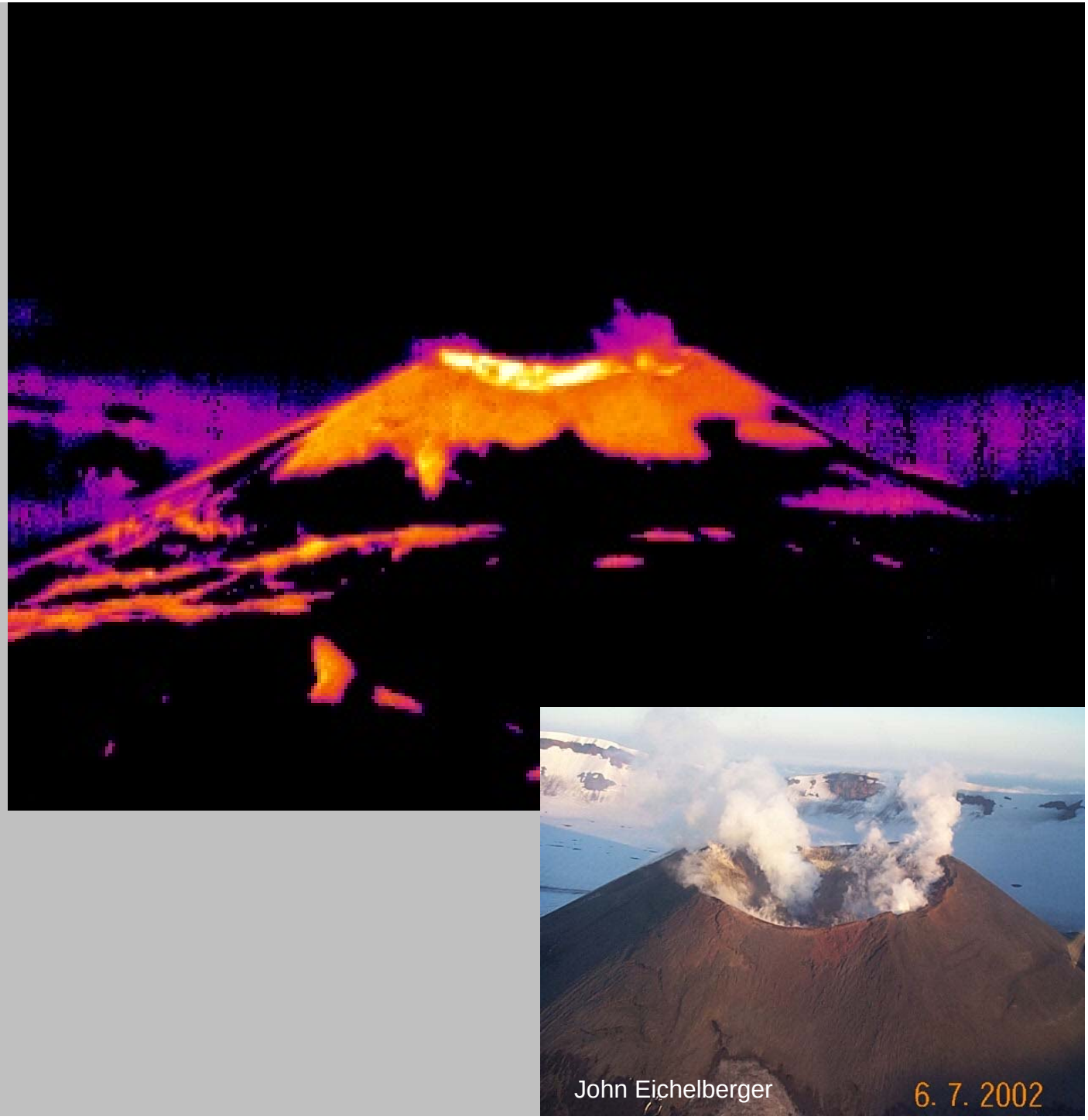


Field Observations
Orbit: No

Temporal Res.:
Varies

Spatial Res:
< 1 m

Wavelength:
Thermal Infrared
Visible



Satellite Observations of Eruptions: Critical Volcanic Features

Hot Spots (Thermal Anomalies)

Volcanic Clouds

Volcanic Cloud Movement

KVERT Staff Kliuchevskoi 7Oct03

Thermal Anomalies (Hot Spots)

Thermal Anomalies:

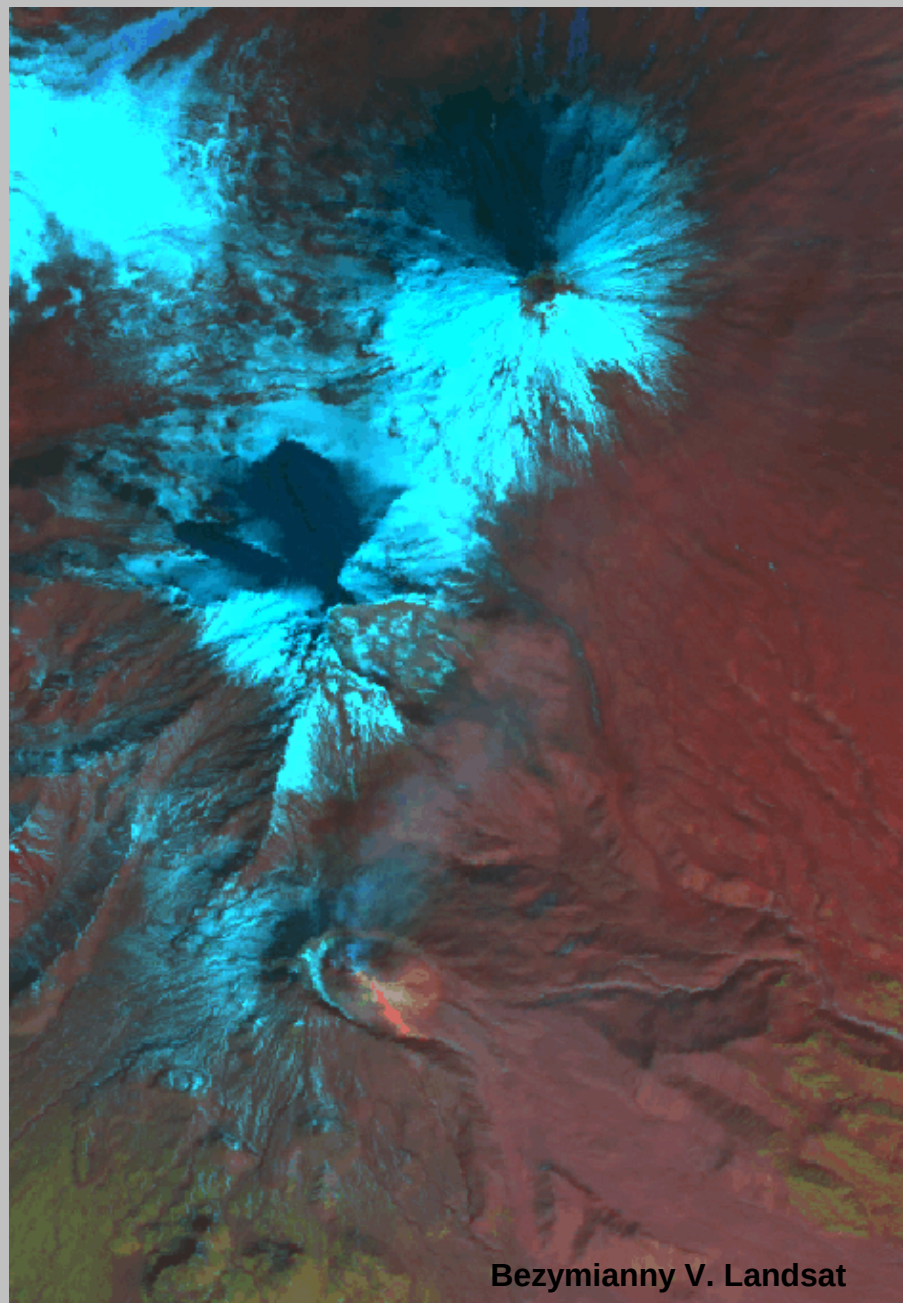
- Pixels with temperatures warmer than background

Importance

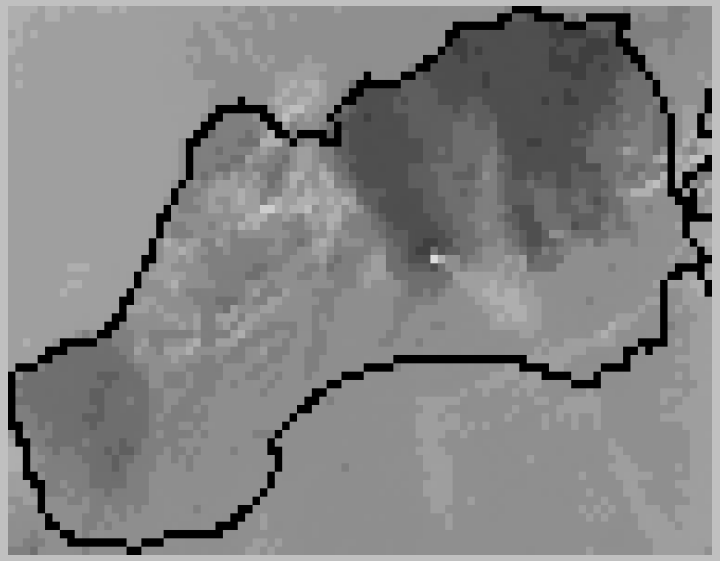
- Often precursor or early phase of an explosive eruption

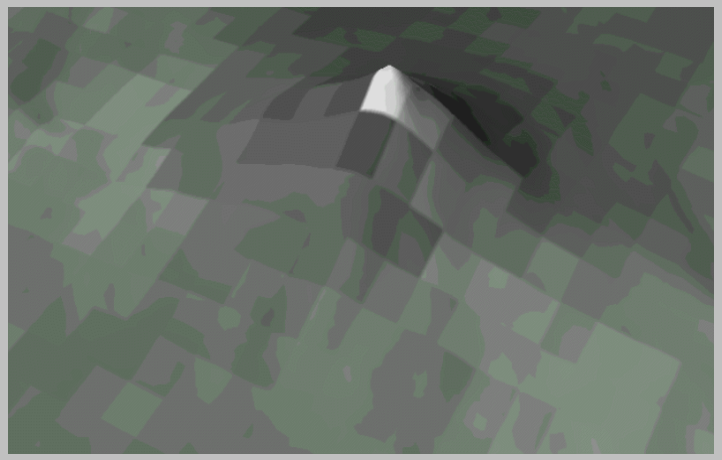
Source

- Heated Domes
- Lava Flows
- Pyroclastic Flows
- Debris Flows



Shishaldin: February 9, 1999

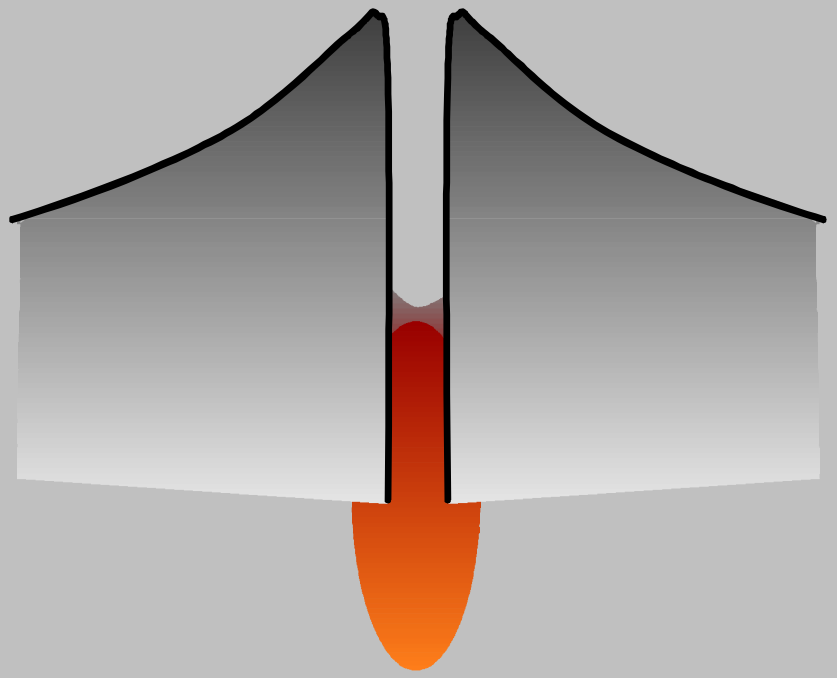




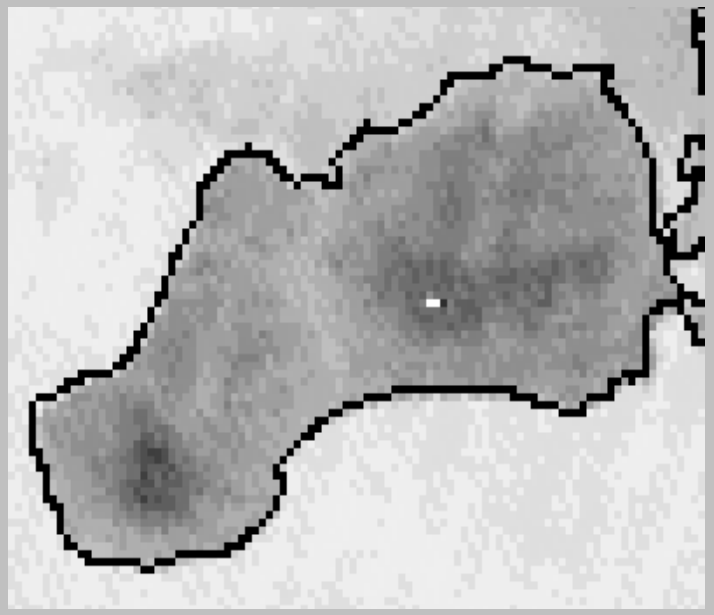
Thermal anomaly that led to a explosive eruption

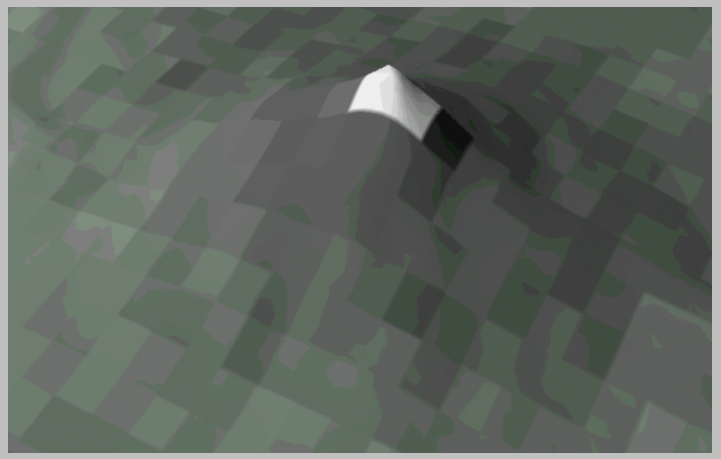
~400 m in crater,

Temperature 385°C.



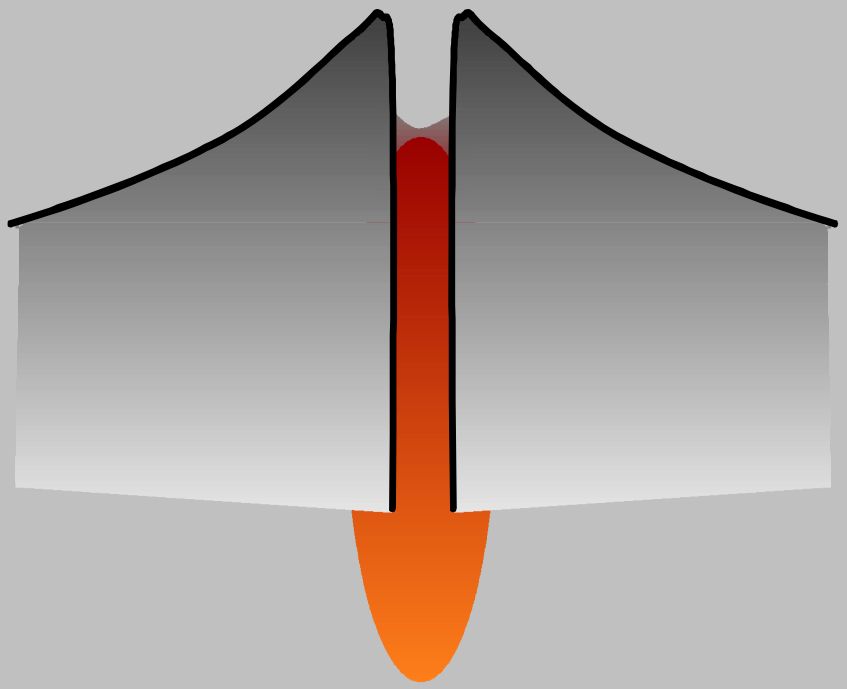
Shishaldin: March 1, 1999



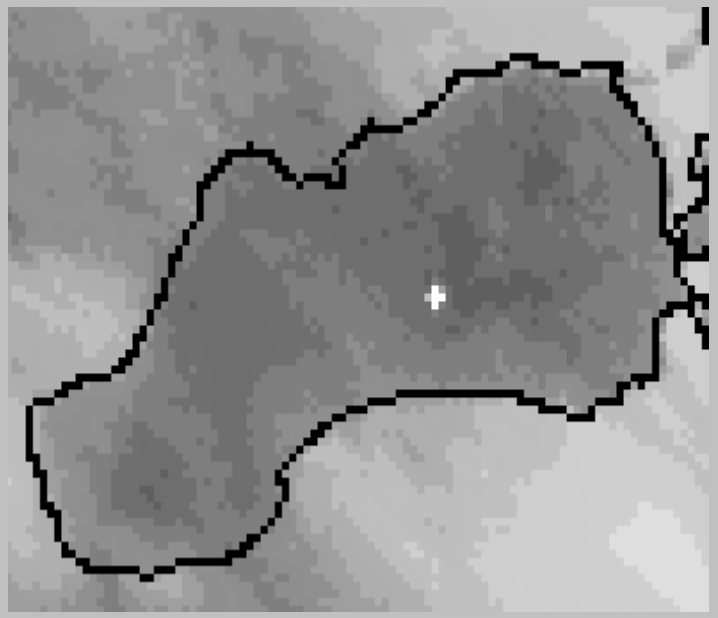


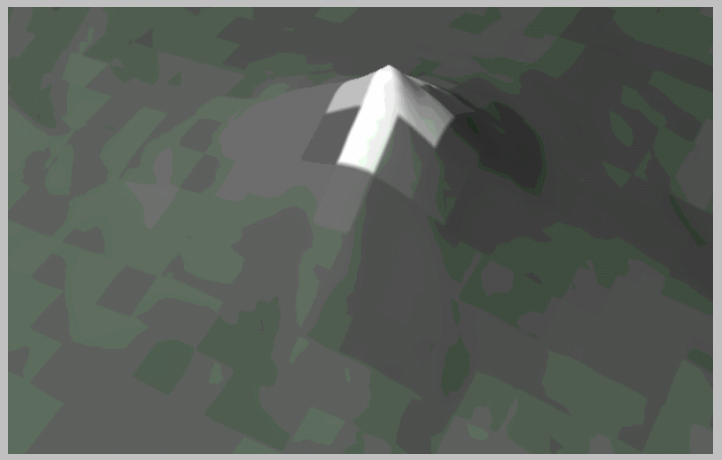
~ 100m below surface

Temperature 950°C



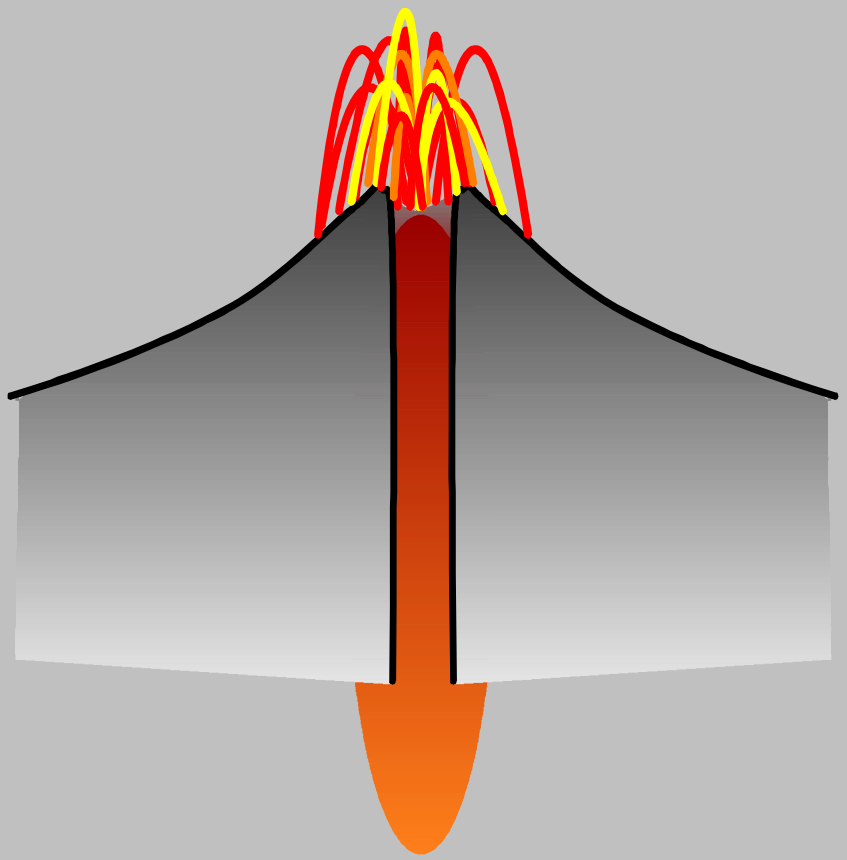
Shishaldin: March 7, 1999



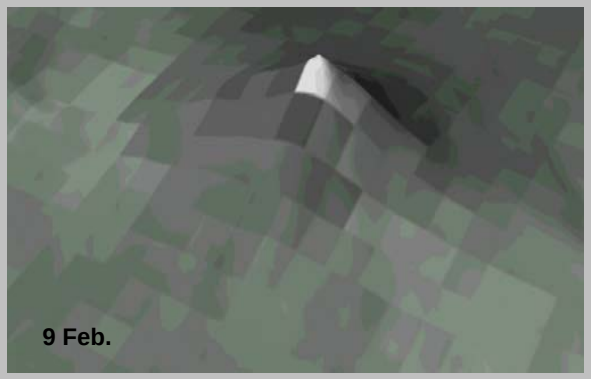


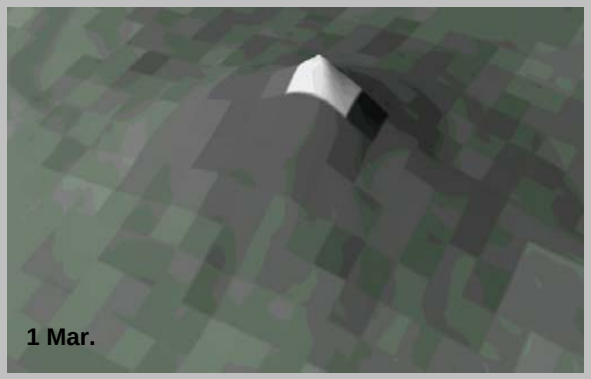
At surface, material airborne

Temperature 1060°C



Hot Spots: Precursor to Explosive Eruption
Shishaldin, 17 & 23 April 1999



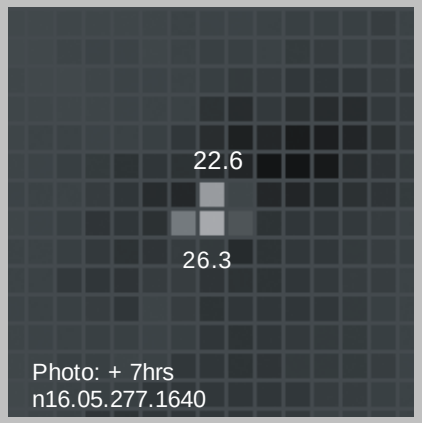


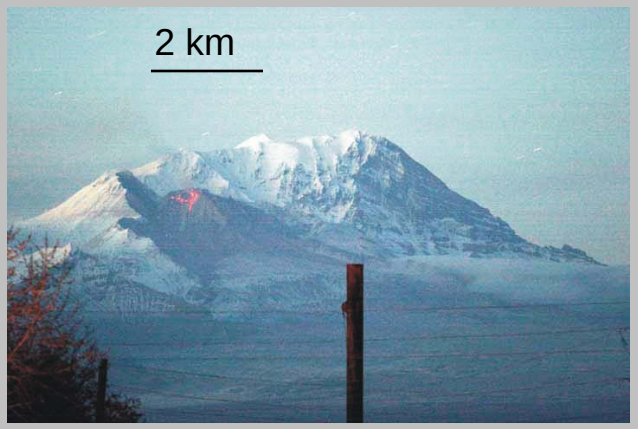
Sequence of thermal anomaly activity became two explosive eruptions in April

Are temperature or thermal flux predictors of eruptions?

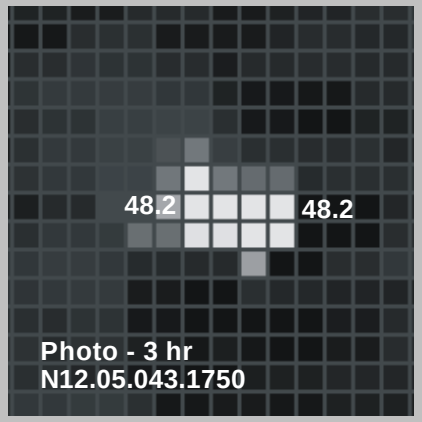
Hot Spots: Sources

Sheveluch V.
Lava at the dome
4 Oct. 05
Sat Image +7hrs

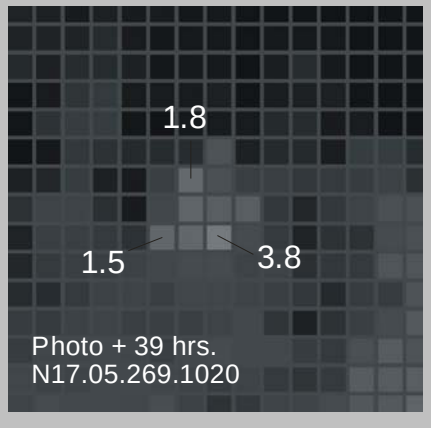




Kliuchevskoi V.
Lava flow on slope
13 Feb. 05
Sat Image -3 hrs



Karymsky V.
Heated dome w/gas
25 Sept. 05
Sat Image + 39 hrs



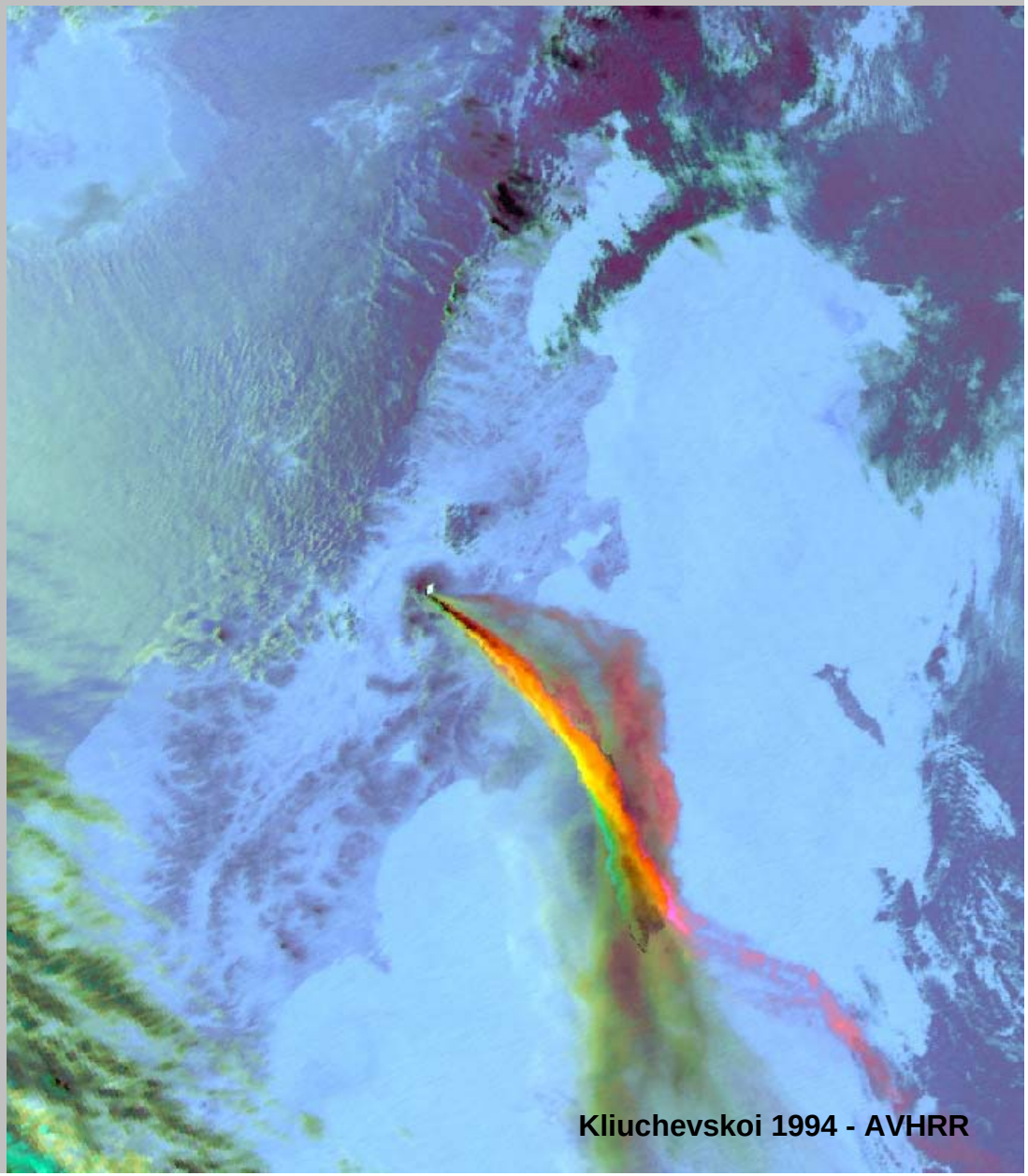
Volcanic Clouds

Clouds Evolve
- **Detection Evolves**

Detection
- **Height, Location,**
- **Presence of Ash**

Importance
- **Hazard to Aircraft**
- **Ground Infrastructure**
- **Health**

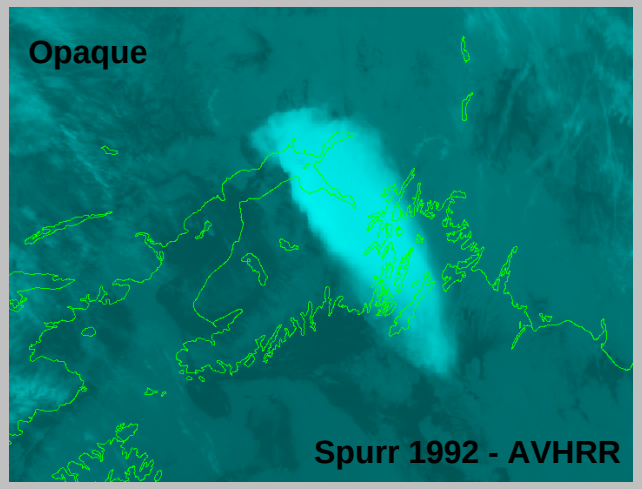
Source
- **Explosive Eruptions**
- **NOPAC Region**
  - **Primary Hazard**



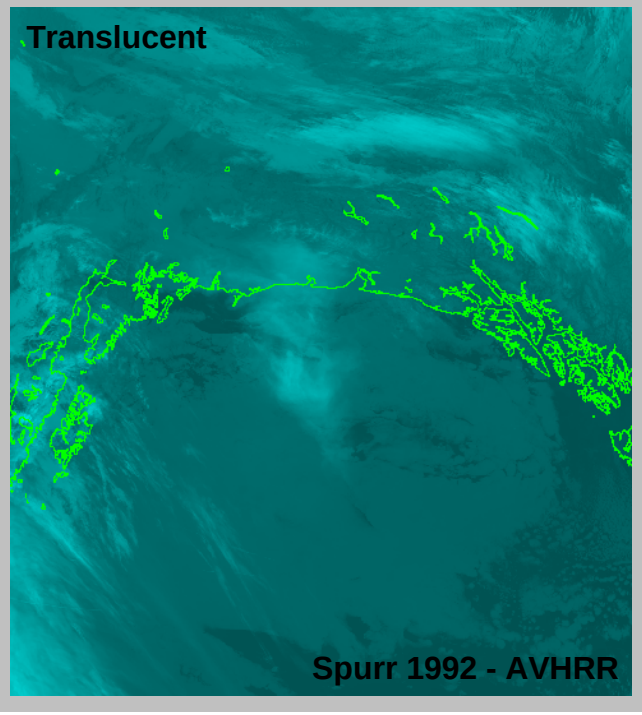
Volcanic Cloud Analysis

Plumes Evolve:

Opaque plumes = derive height



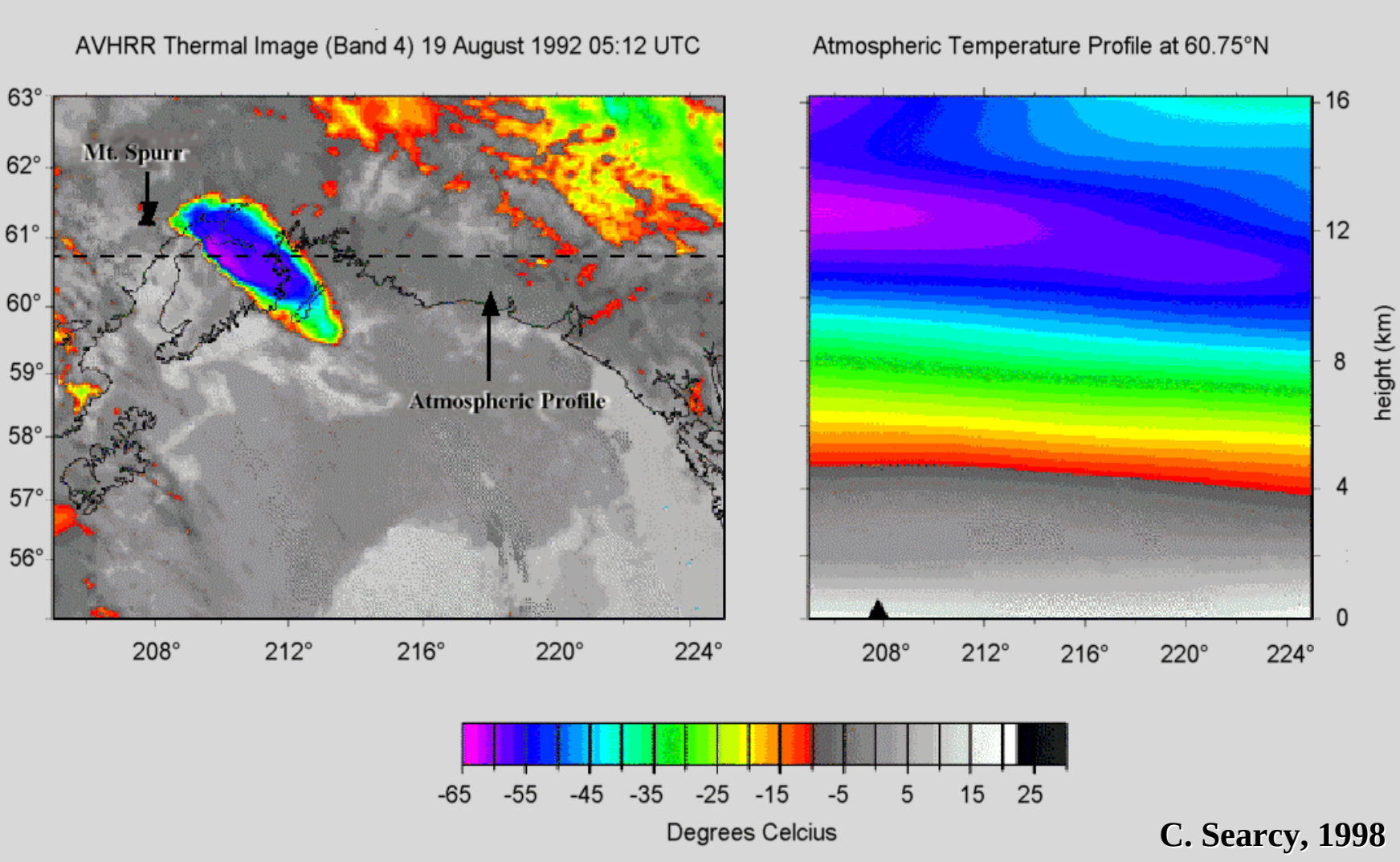
Translucent = presence of ash
Band subtraction of 2 TIR Channels



Volcanic Cloud Height Estimate

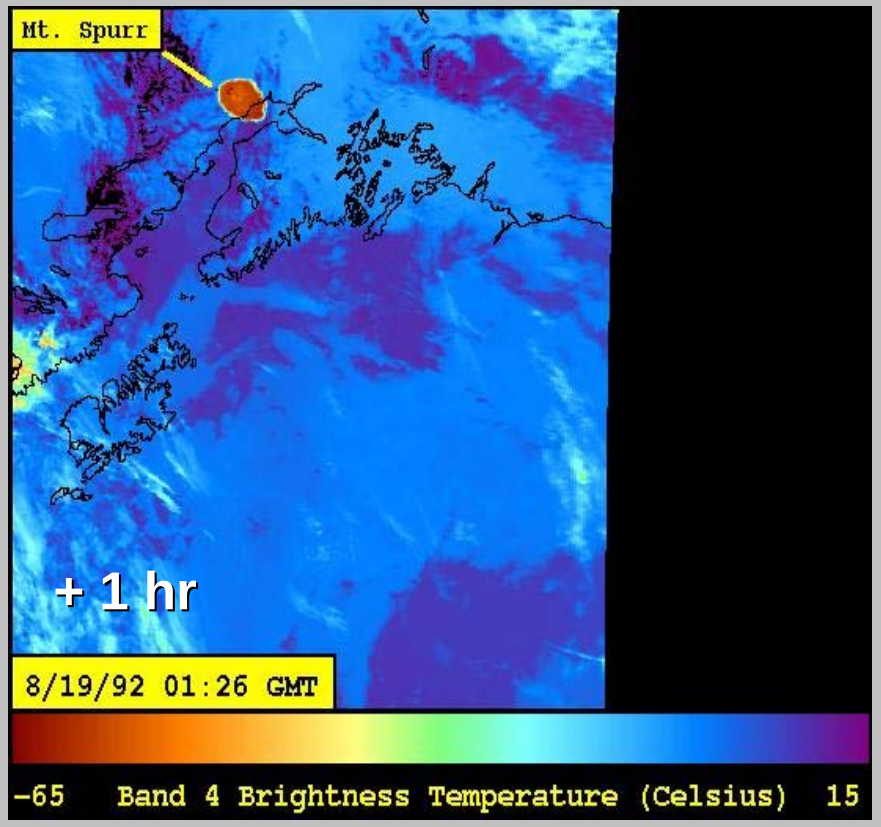
3 Methods: Cloud temperature, cloud shadow & wind shear

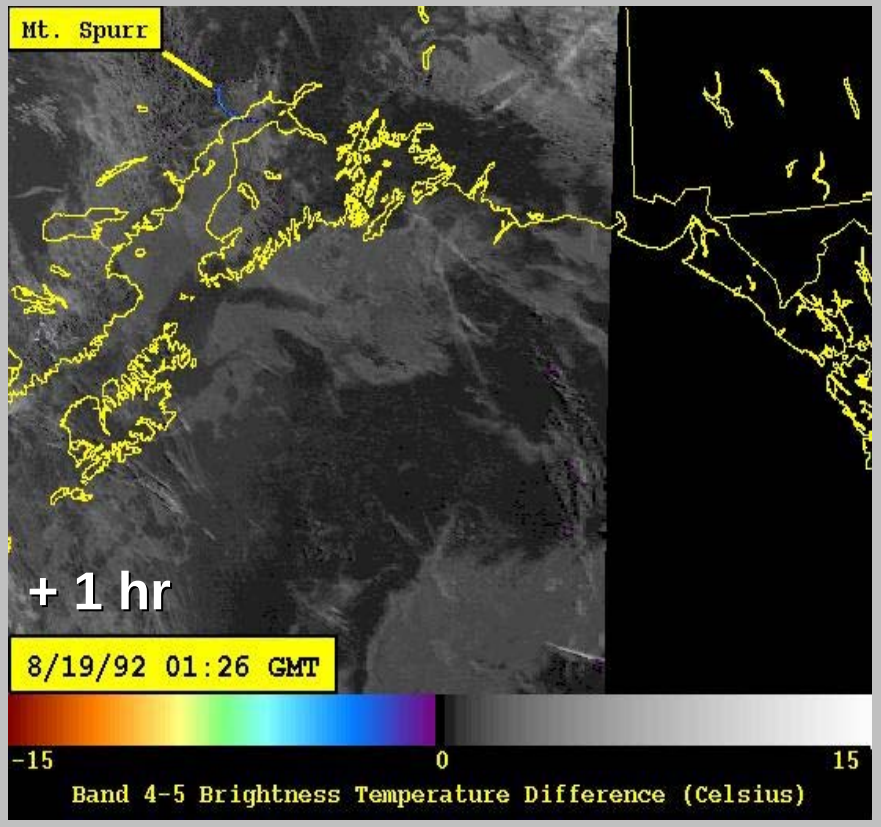
Use 10-12 μm data, derive temp. compare to atm. temp.



C. Searcy, 1998

Volcanic Cloud Evolution



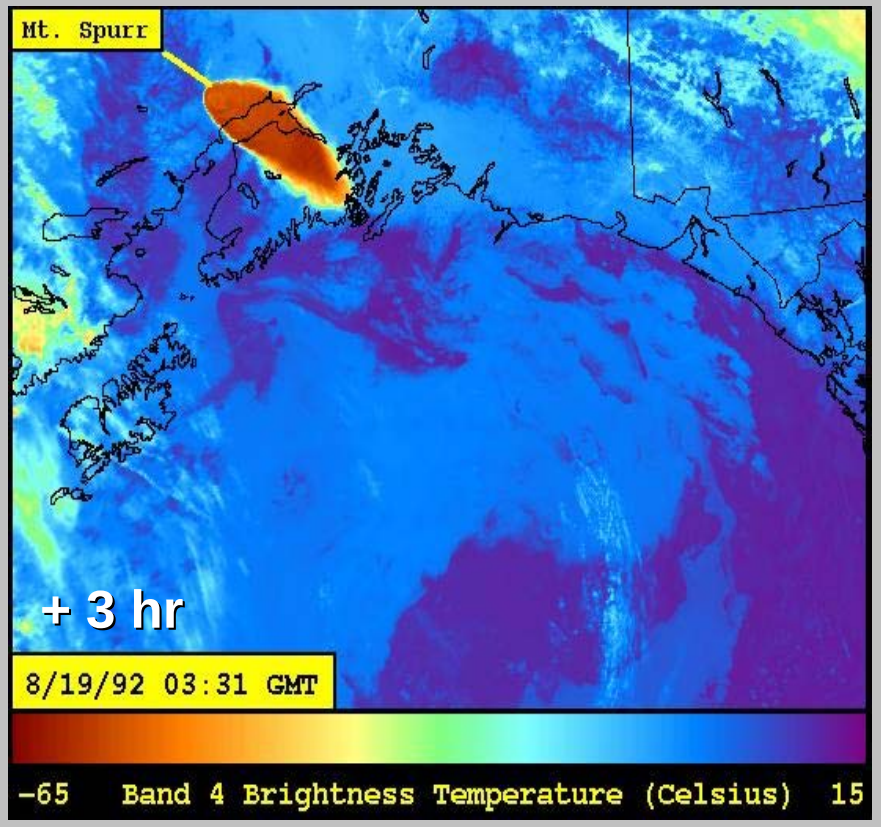


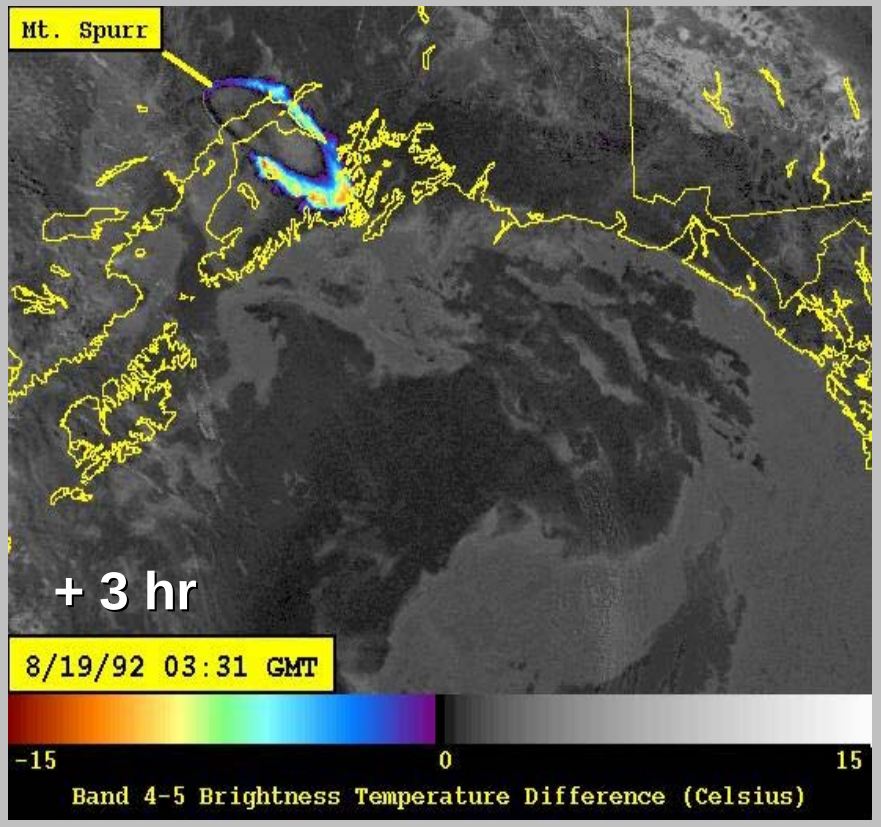
AVHRR: Single Band (B4)
Plume Clear evident
Determine Cloud height

AVHRR: Split Window B4 minus B5
Ash signal not evident

D. Schneider

Volcanic Cloud Evolution



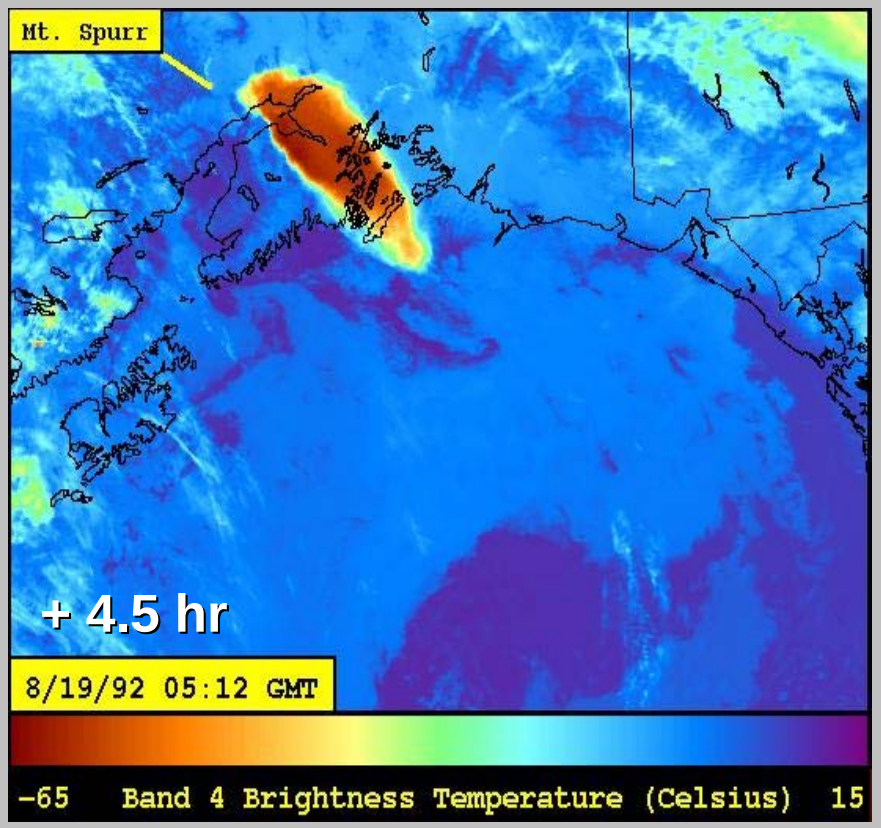


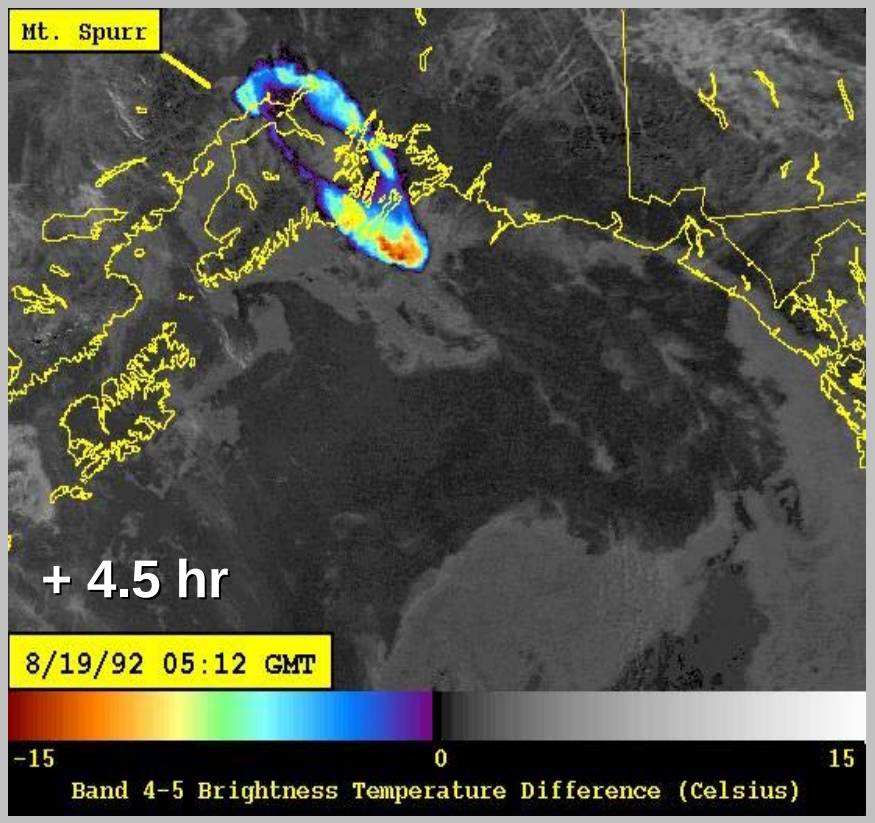
AVHRR: Single band (B4)
Plume clear evident
Determine cloud height

AVHRR: Split Window B4 minus B5
Ash signal along fringes of plume

D. Schneider

Volcanic Cloud Evolution





AVHRR: Single band (B4)
Plume clear evident
Determine cloud height

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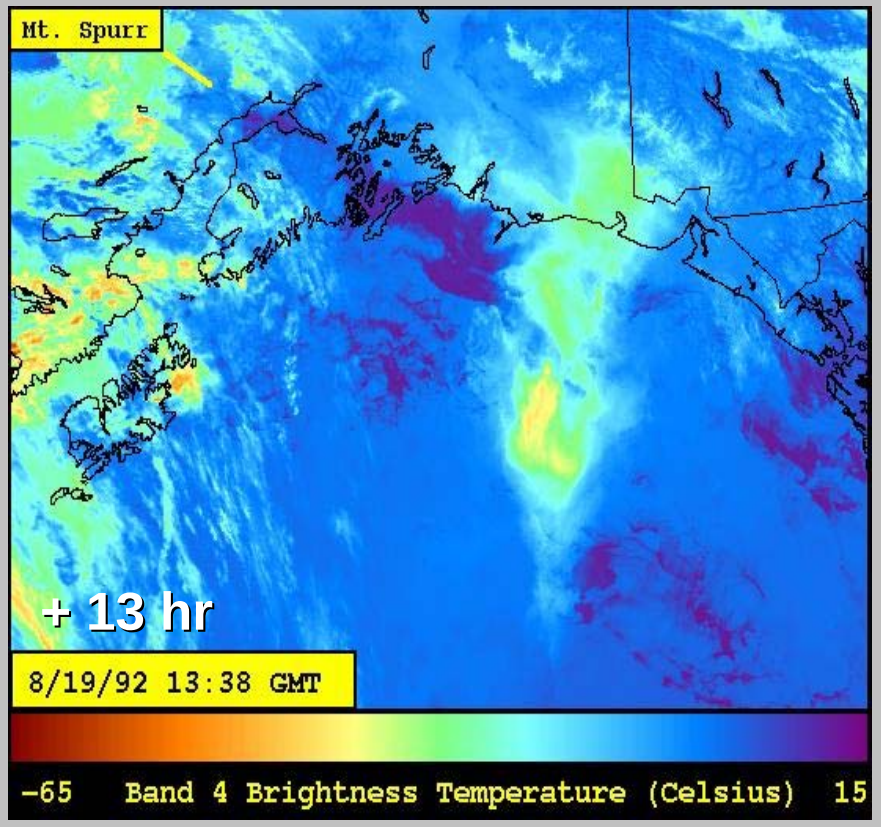
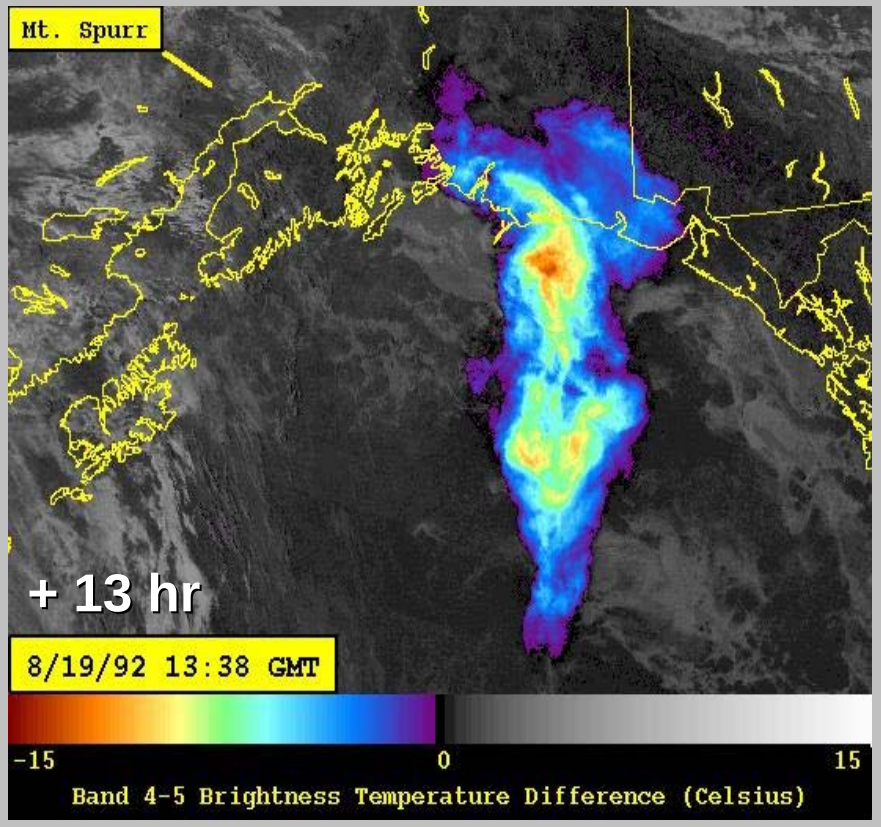
Ash signal along fringes of plume

D. Schneider

Volcanic Cloud Evolution



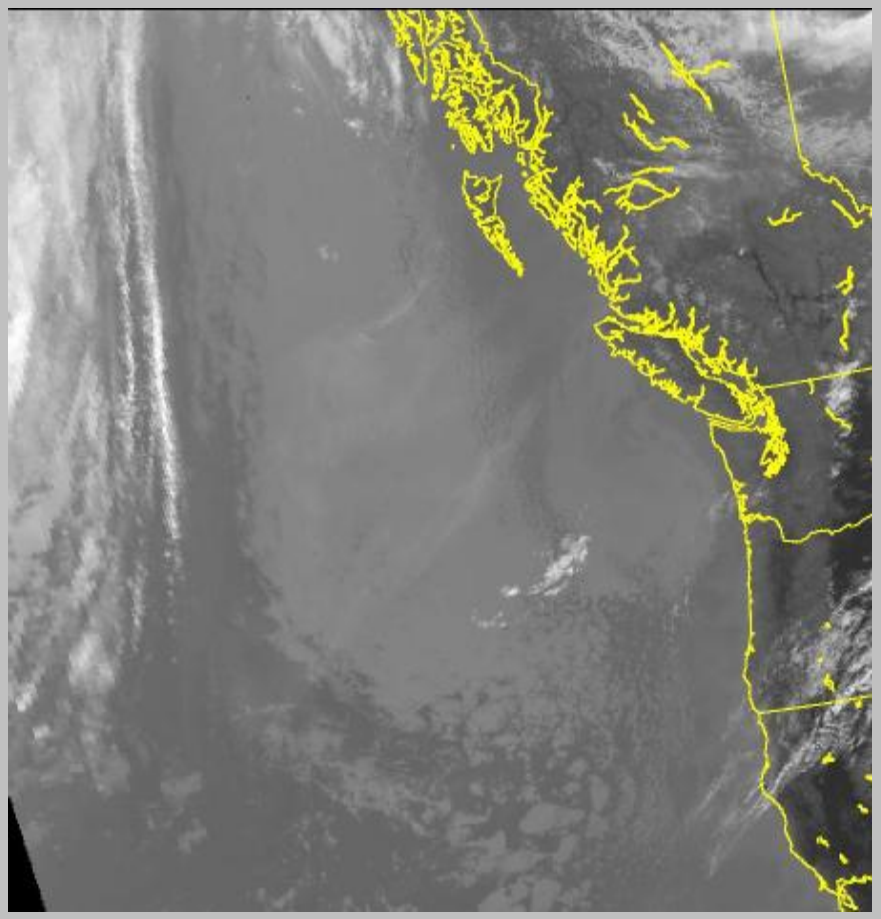


AVHRR: Single band (B4)
Plume is translucent
No cloud height

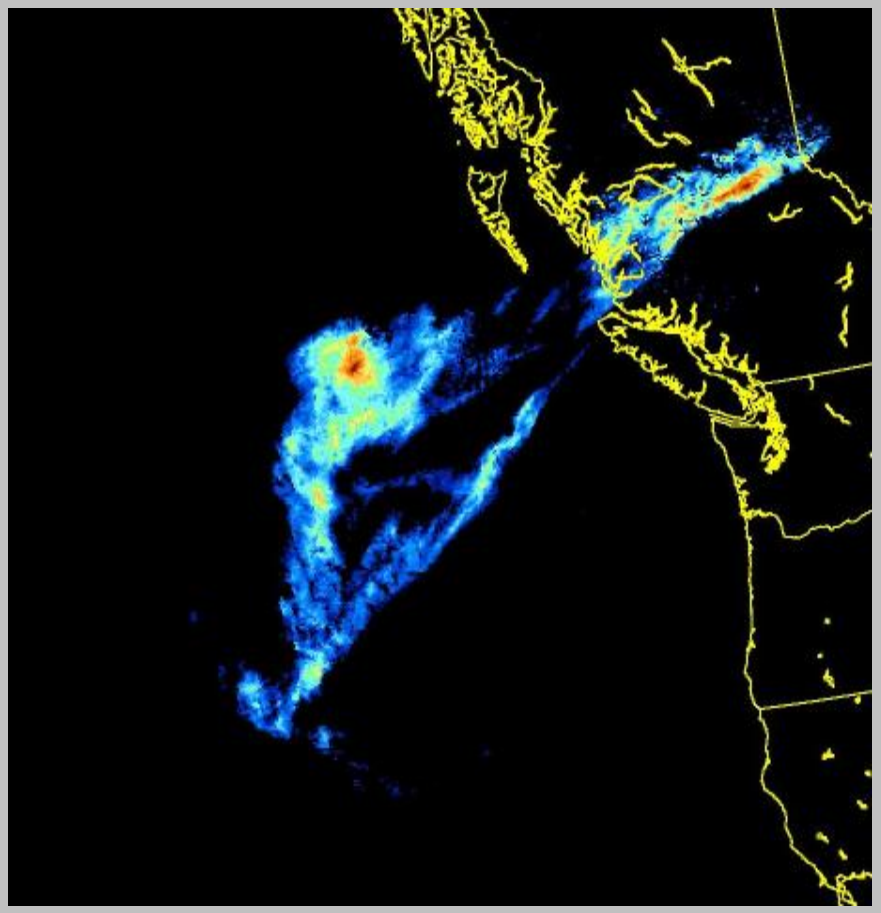
AVHRR: Split Window B4 minus B5
Clear ash signal

D. Schneider

Volcanic Cloud Evolution



AVHRR: Single band (B4)
Plume not seen
No cloud height

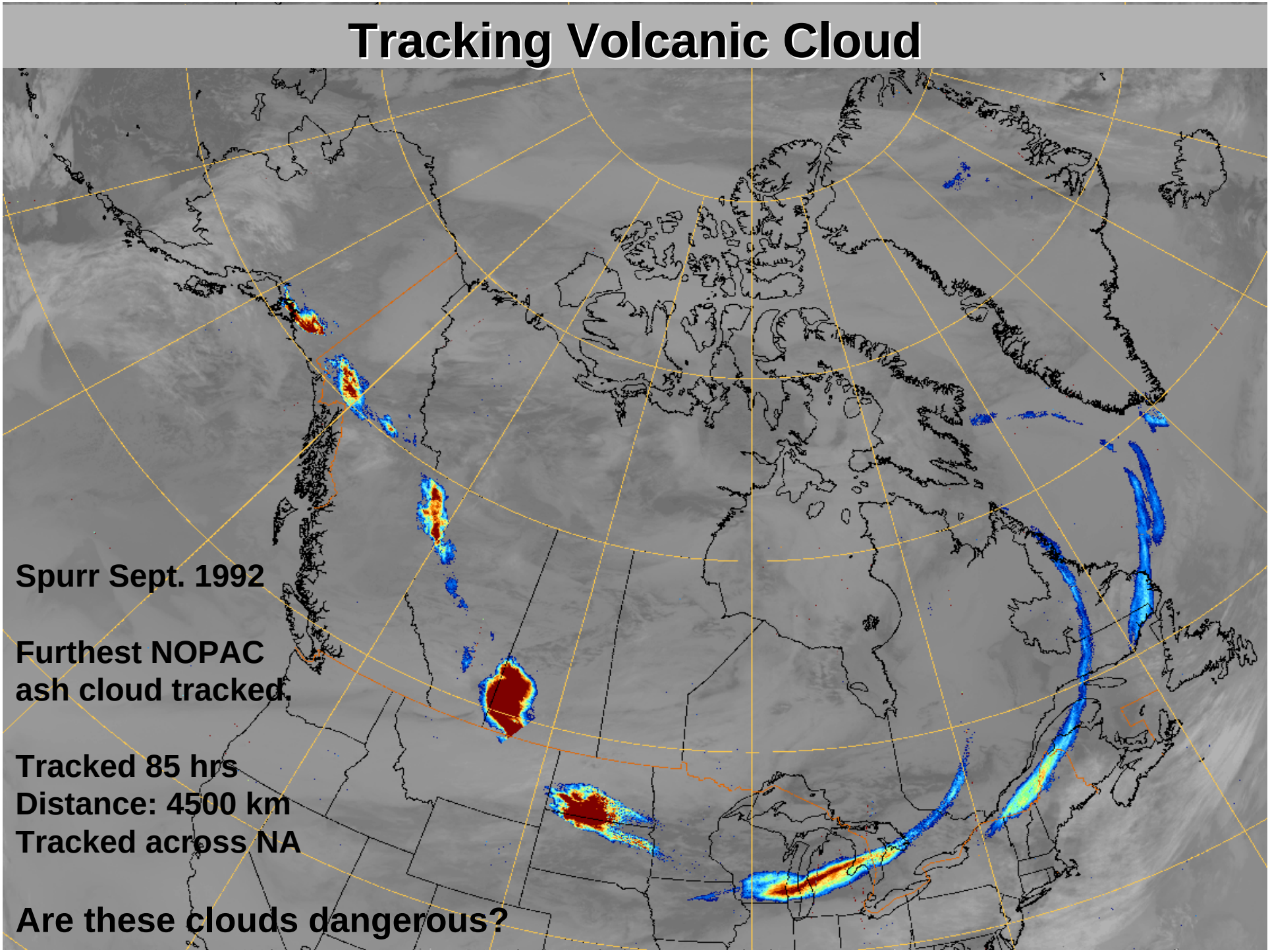


AVHRR: Split Window B4 minus B5
Clear ash signal

What is the concentration of the ash?

D. Schneider

Tracking Volcanic Cloud



Spurr Sept. 1992

Furthest NOPAC
ash cloud tracked.

Tracked 85 hrs
Distance: 4500 km
Tracked across NA

Are these clouds dangerous?

Predicting Plume Movement: Puff Model

- **Specifically tailored for volcanic ash and 3D tracking of volcanic ash particles**

- **Hypothetical particles released over volcano**
- **Particles tracked over time**

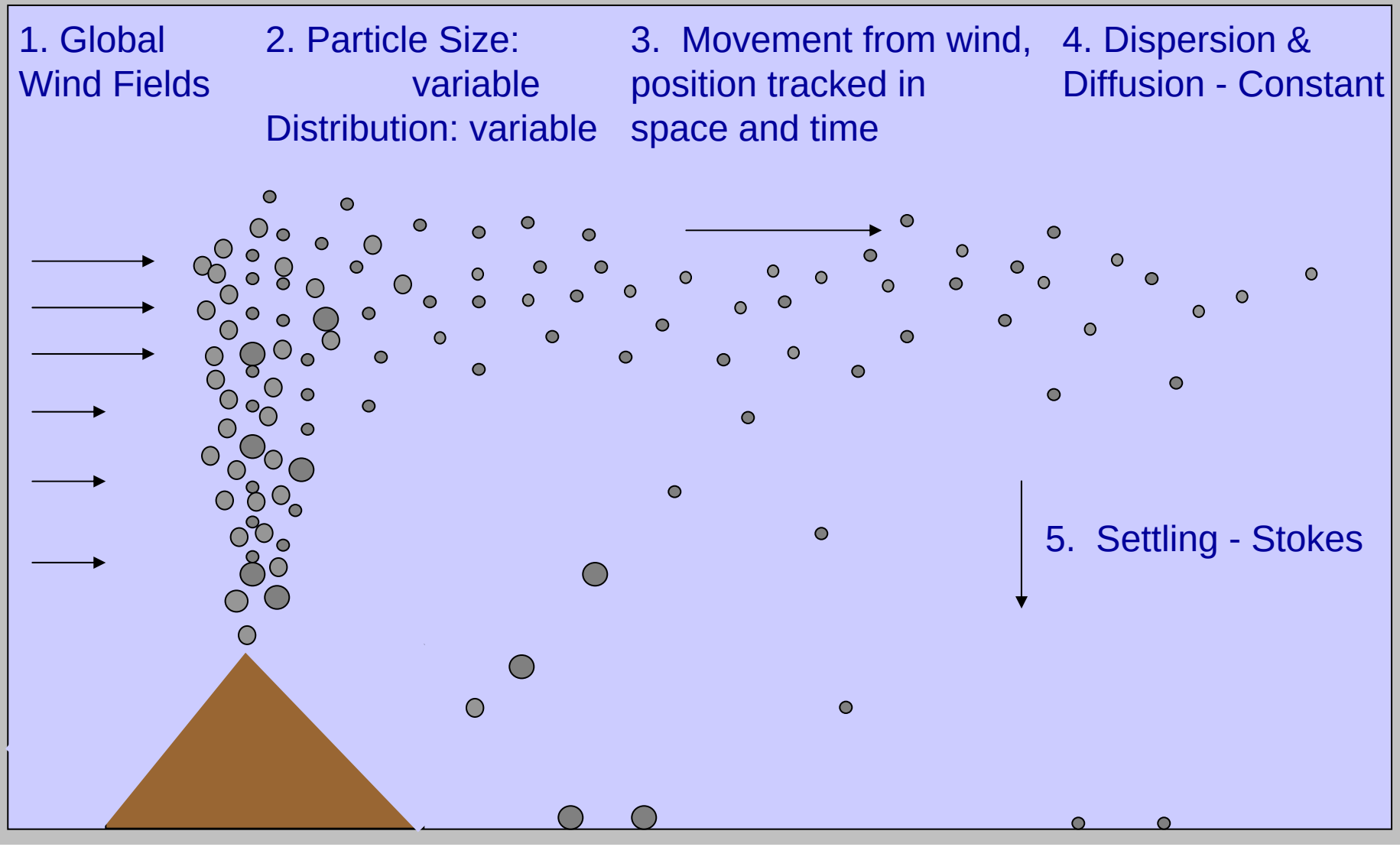
- **Uses meteorological wind fields**

- **Initialization parameters include**
  - **Volcano name and location**
  - **Number of particles**
  - **Mean Particle size and spread**
  - **Plume dimensions (height, width and shape)**
  - **Length of model prediction and length of eruption**
  - **Output time step**
  - **Horizontal and Vertical Diffusion**
  - **Wind field model**

(http://puff.images.alaska.edu)

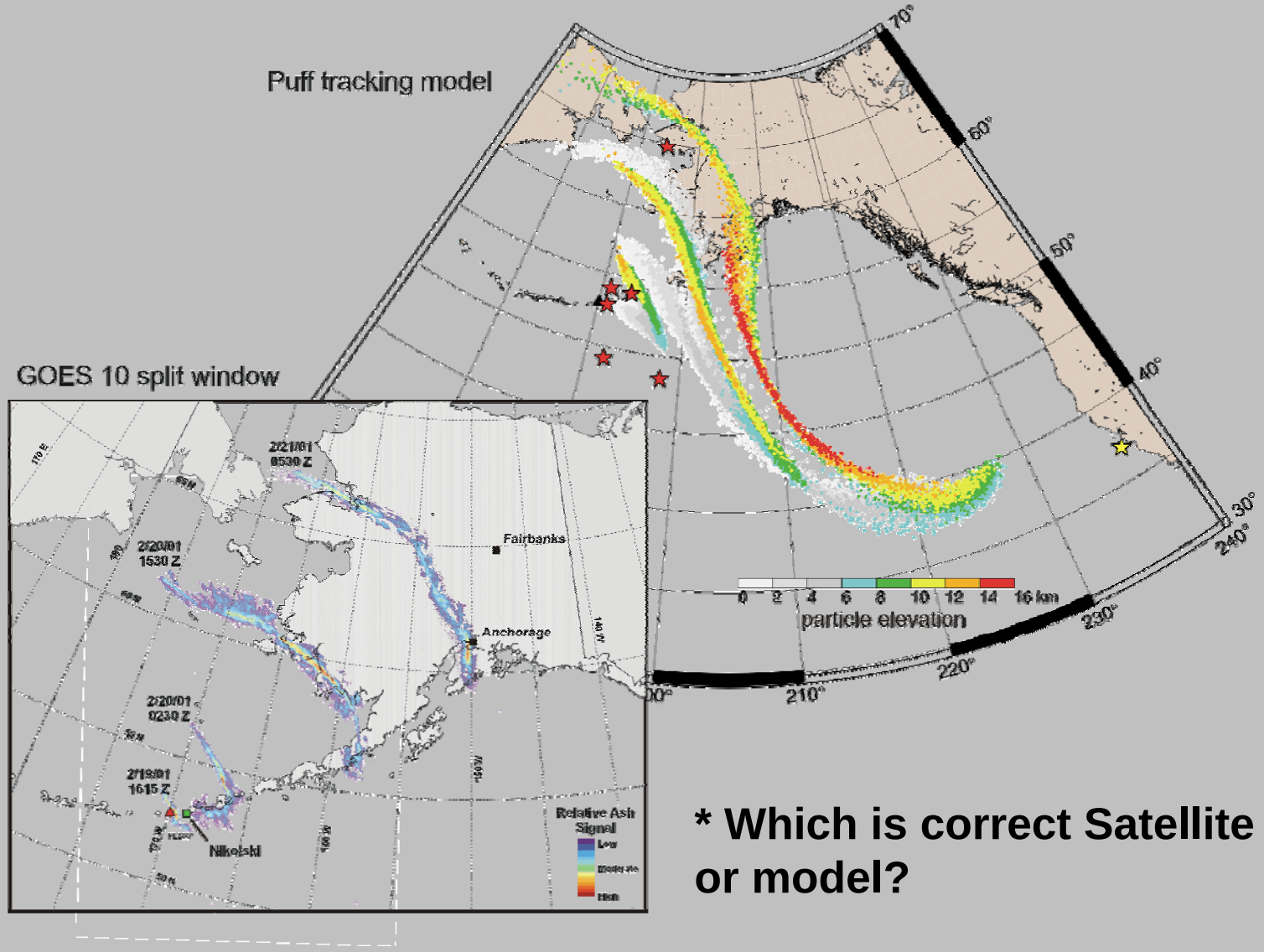
Dispersion Models

Predicts volcanic cloud movement
Information when satellite data is not available
Use satellite data for validation and calibration



Comparison Puff and GOES Images, Mt. Cleveland Eruption

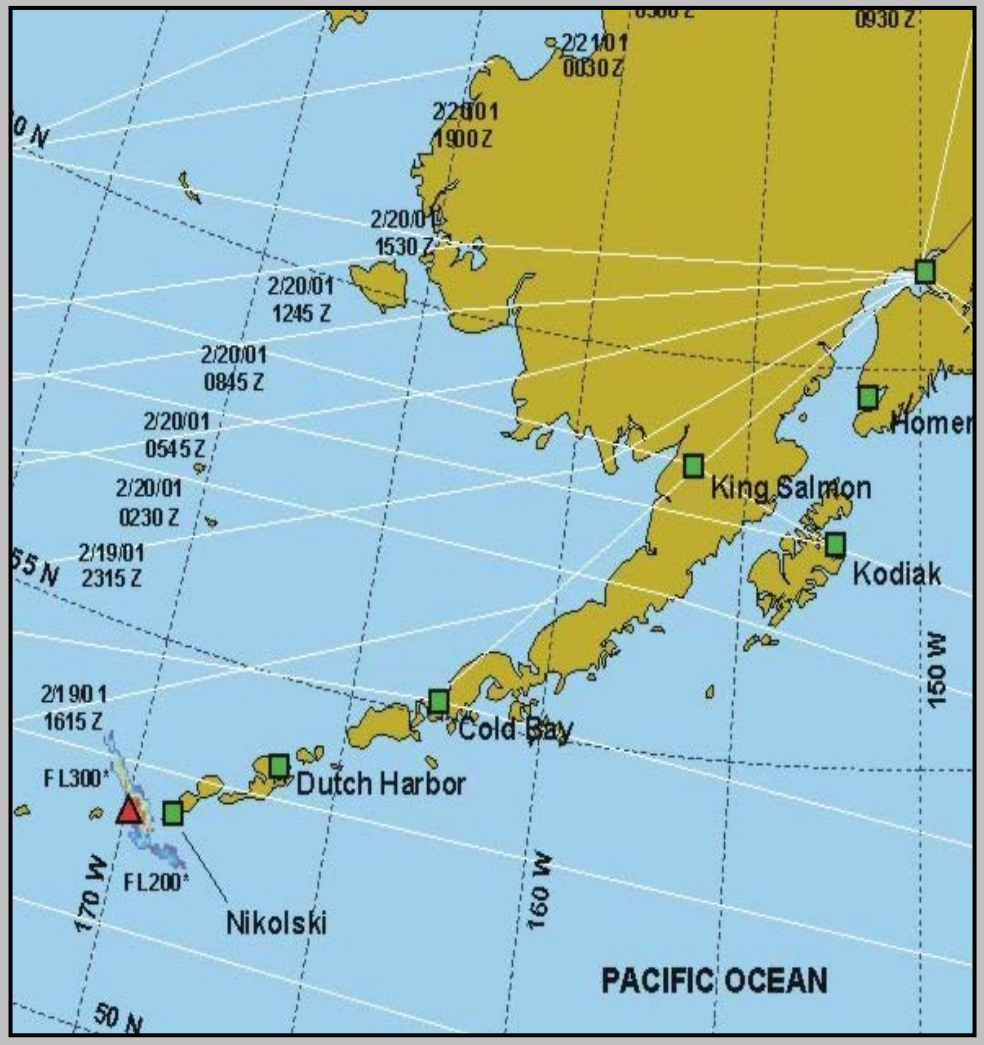
Satellite data is used to validate models.
Satellite data detects less than the model.

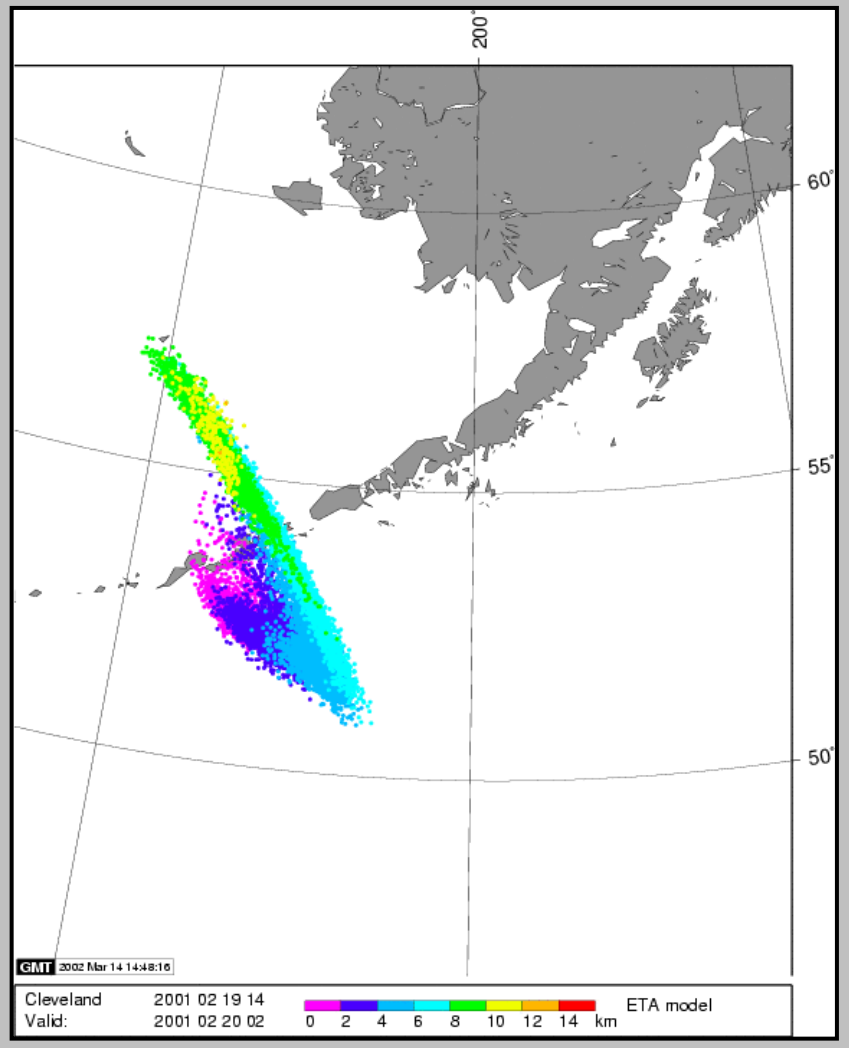


*** Which is correct Satellite data or model?**

Dispersion Models: Cloud Height Estimation

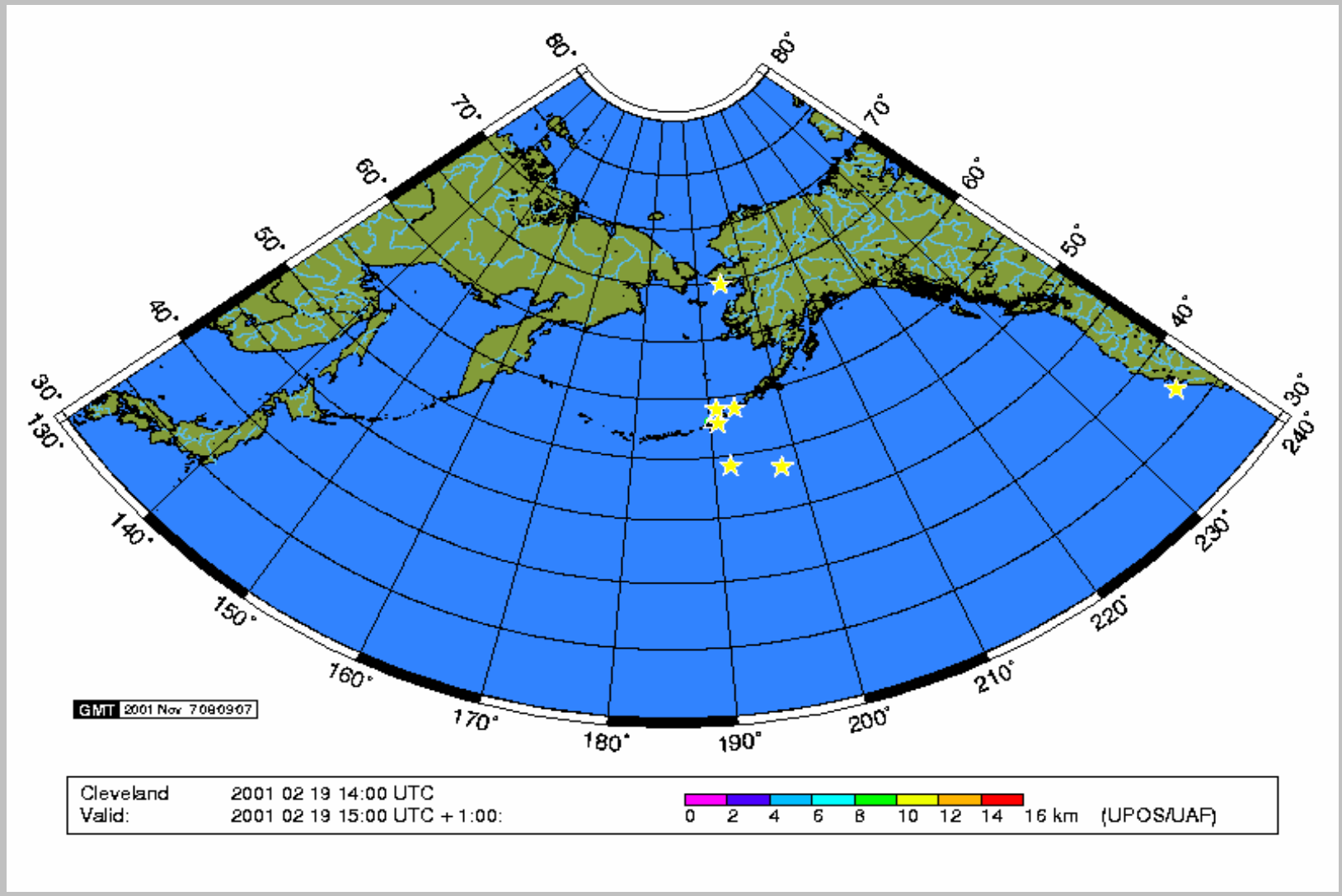
GOES shows cloud to NW and SE
Puff shows clouds > 8km to NW & < 8km to SE





Dispersion Models

Puff model run: take minutes on PC
Significance Cleveland Eruptions 2001: Distal particles are valid



Satellite Volcano Monitoring Program

GEOPHYSICAL INSTITUTE University of Alaska Fairbanks

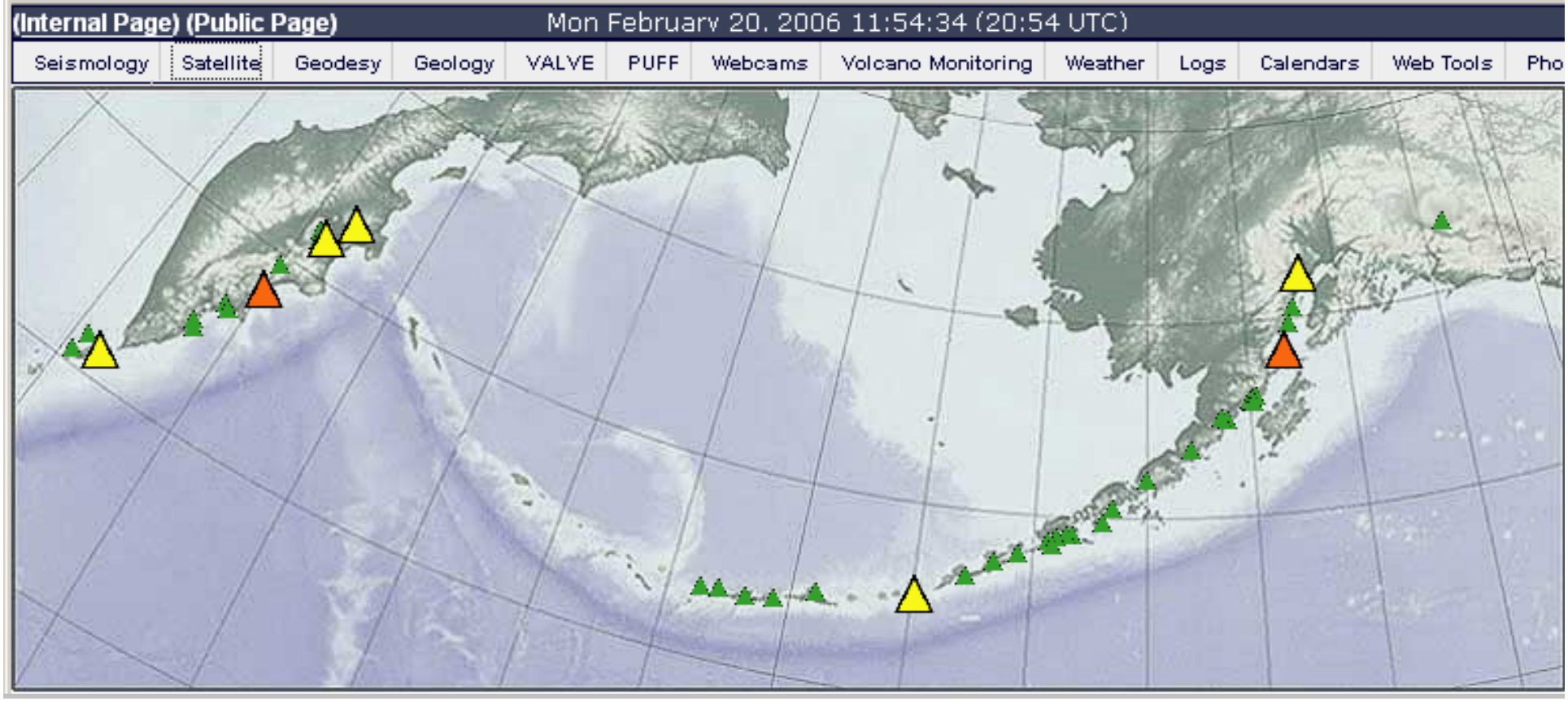
USGS science for a changing world

ALASKA GEOLOGICAL AND GEOPHYSICAL SURVEYS

=

Alaska Volcano Observatory

Divisions of AVO: Remote Sensing, Seismic, Geodesy, Geology



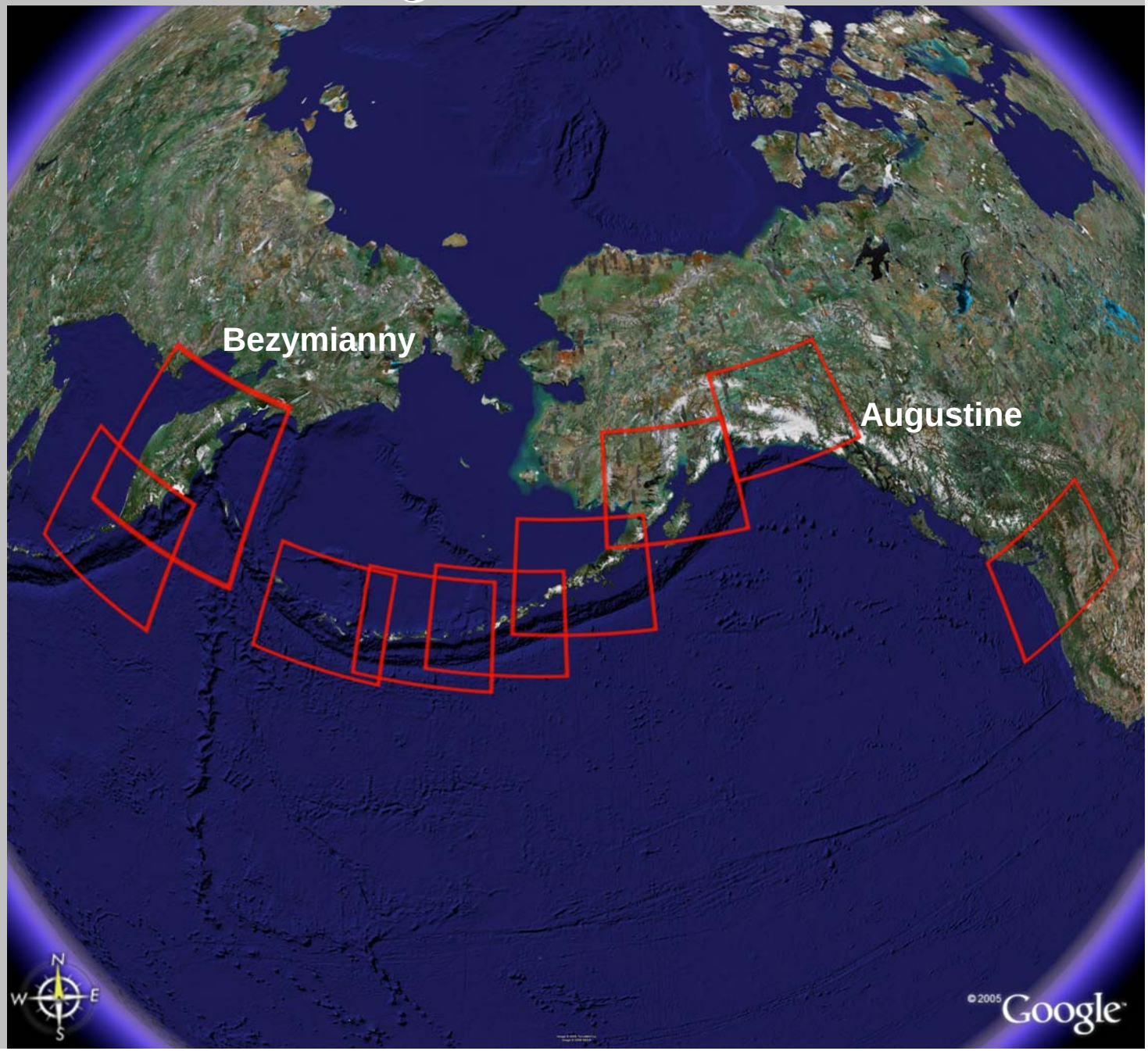
British Air 747 (Speedbird 9): encounters ash cloud (Indonesia, Galunggung, 1983)

Monitoring Sectors

NOPAC Region

10 Sectors

Multiple Volc. in each sector



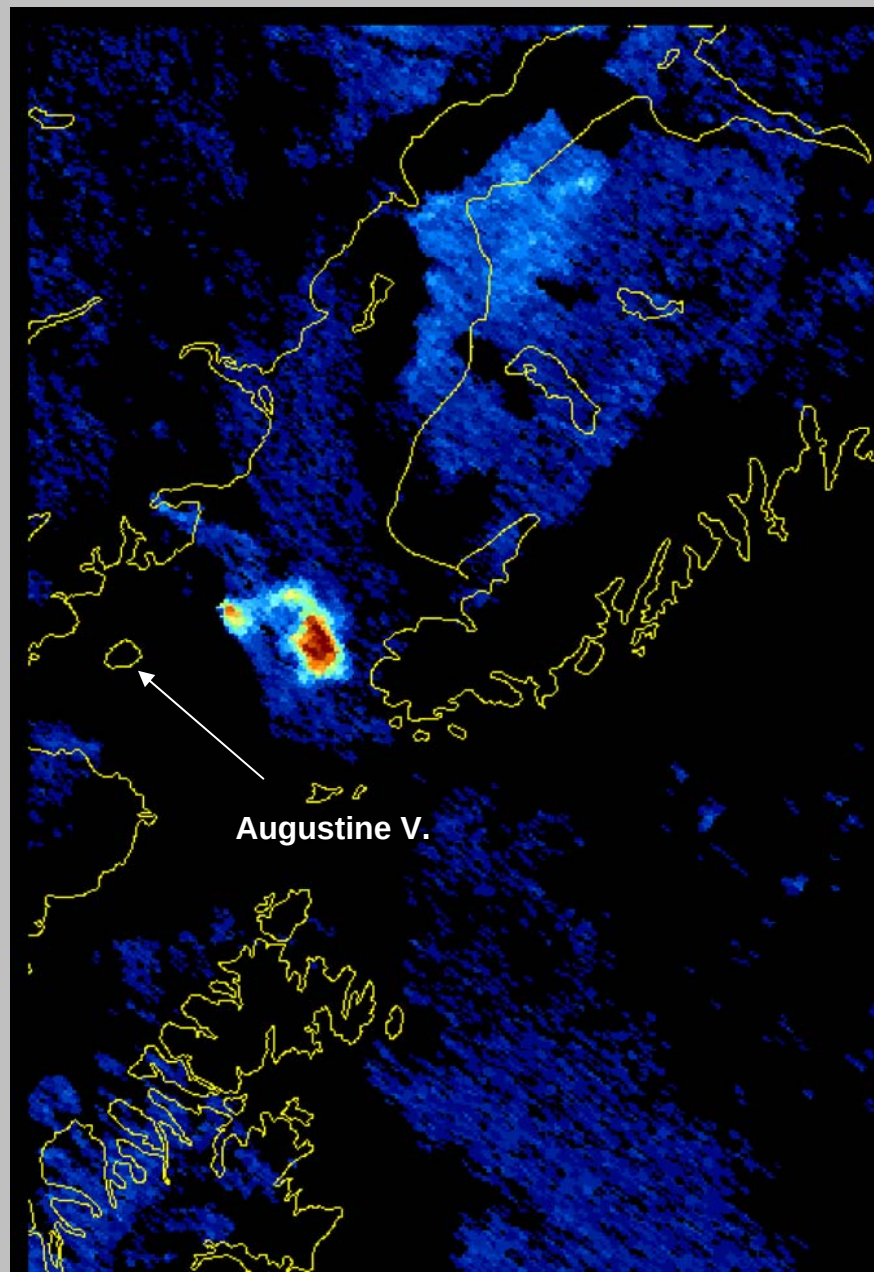
Critical Features for Volcanic Cloud Monitoring

Plumes (Eruption Clouds)

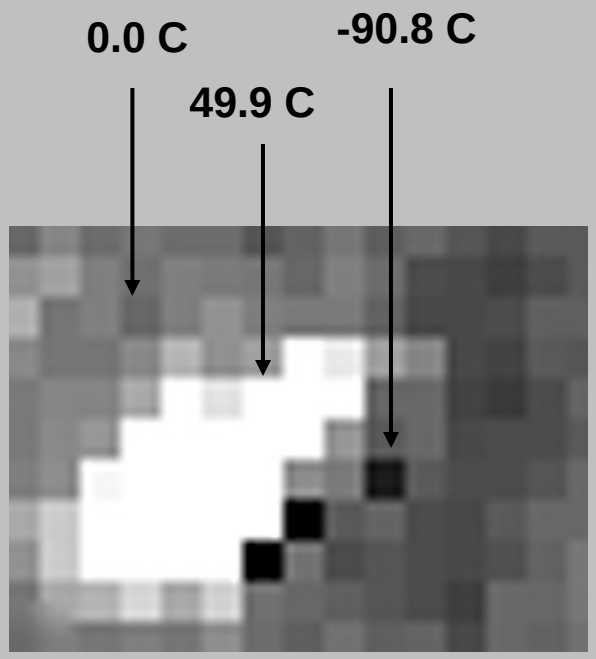
Health hazard, dangerous to Aircraft, local and global carriers

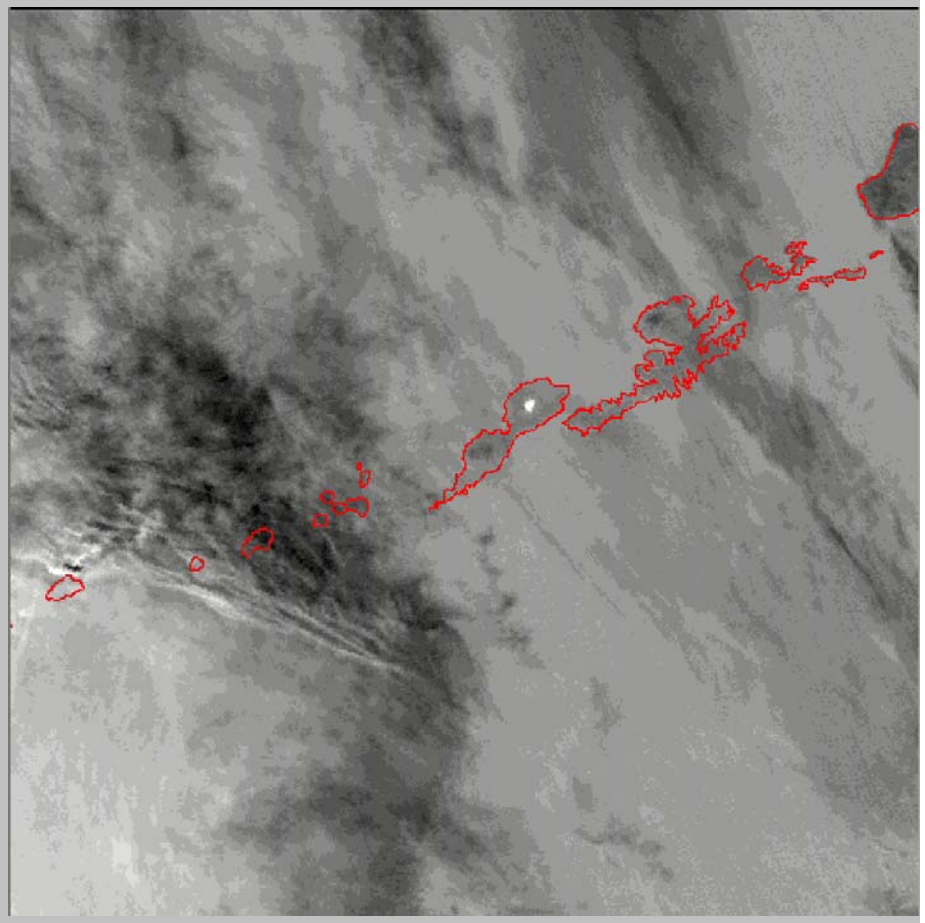
Measured Parameters:

- **Plume Direction: East**
- **Distance: 40 km**
- **Ash Signal:**
- **Temperature: NA**
- **Height: Puff**
- **Predictions Puff**
- **Ashfall (under development)**



Critical Features for Thermal Anomaly Monitoring





Measured Parameters:

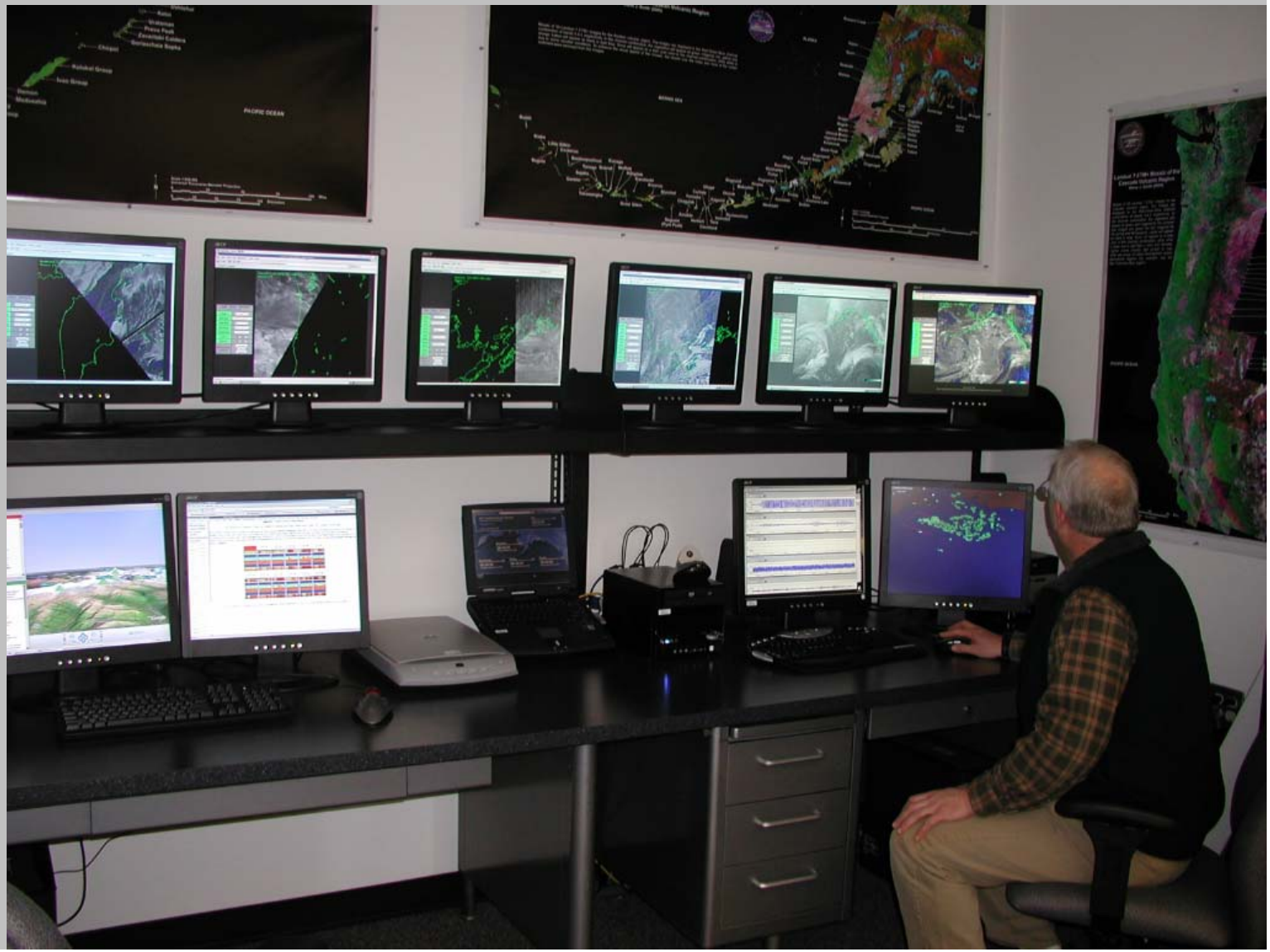
Location: Okmok V.
Hottest Temp.: 49.9°C
No. of Pixels: 24
Thermal Flux ----
Effusion Rate ----

Volcano Monitoring Systems

2 Types:

Manual

Automated

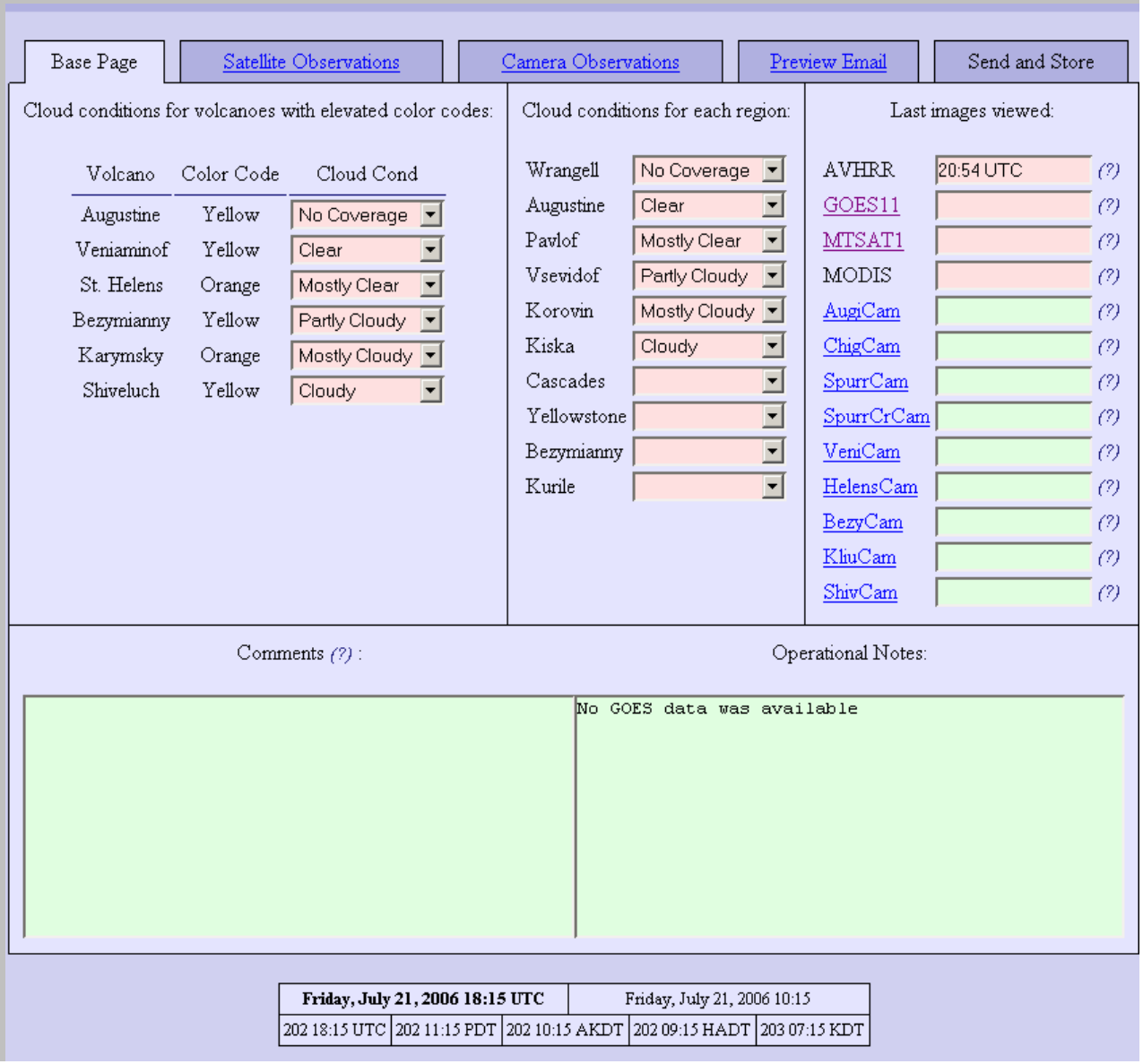


Manual: Web-based Monitoring Database

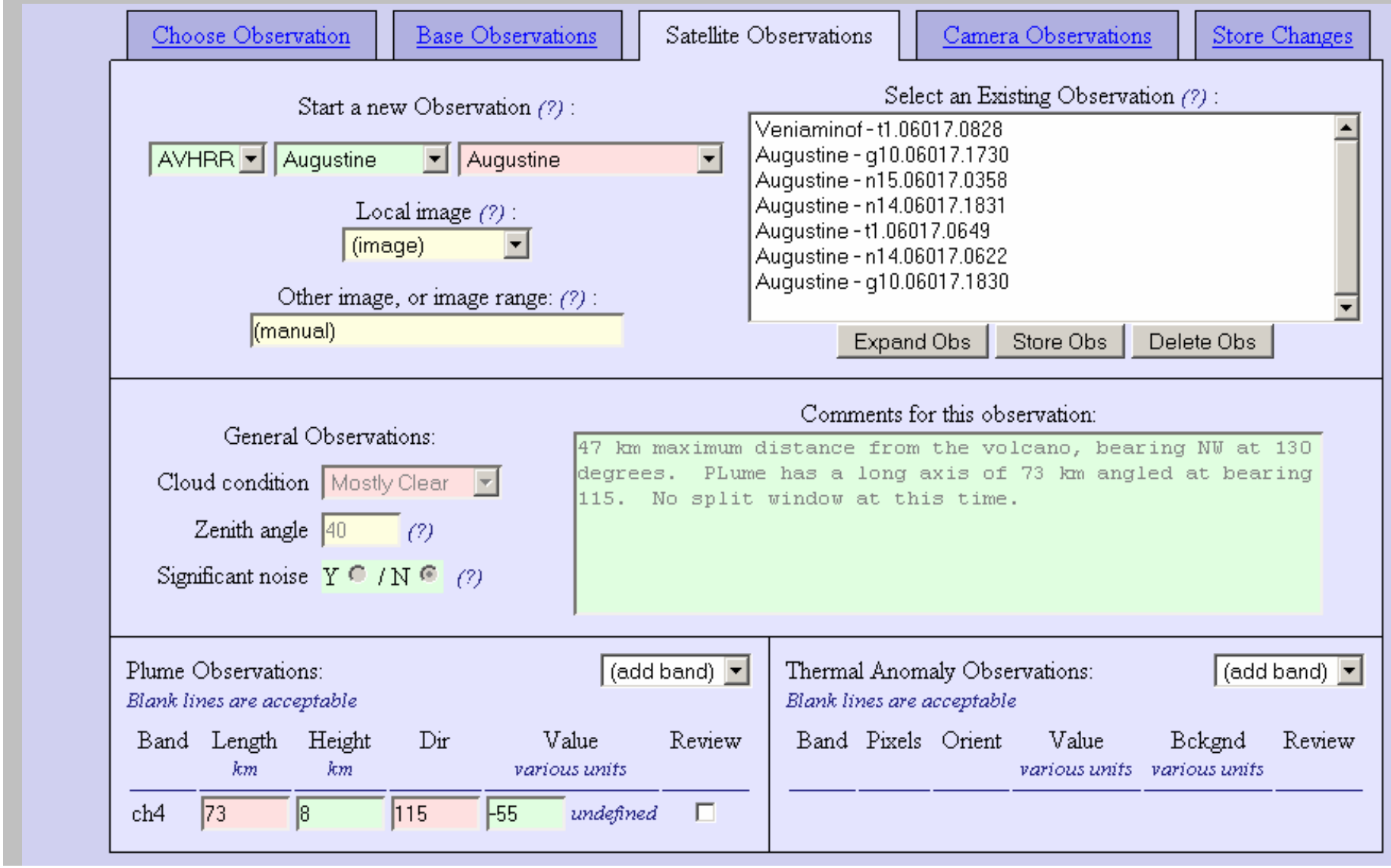
Consistent entry

Automated report

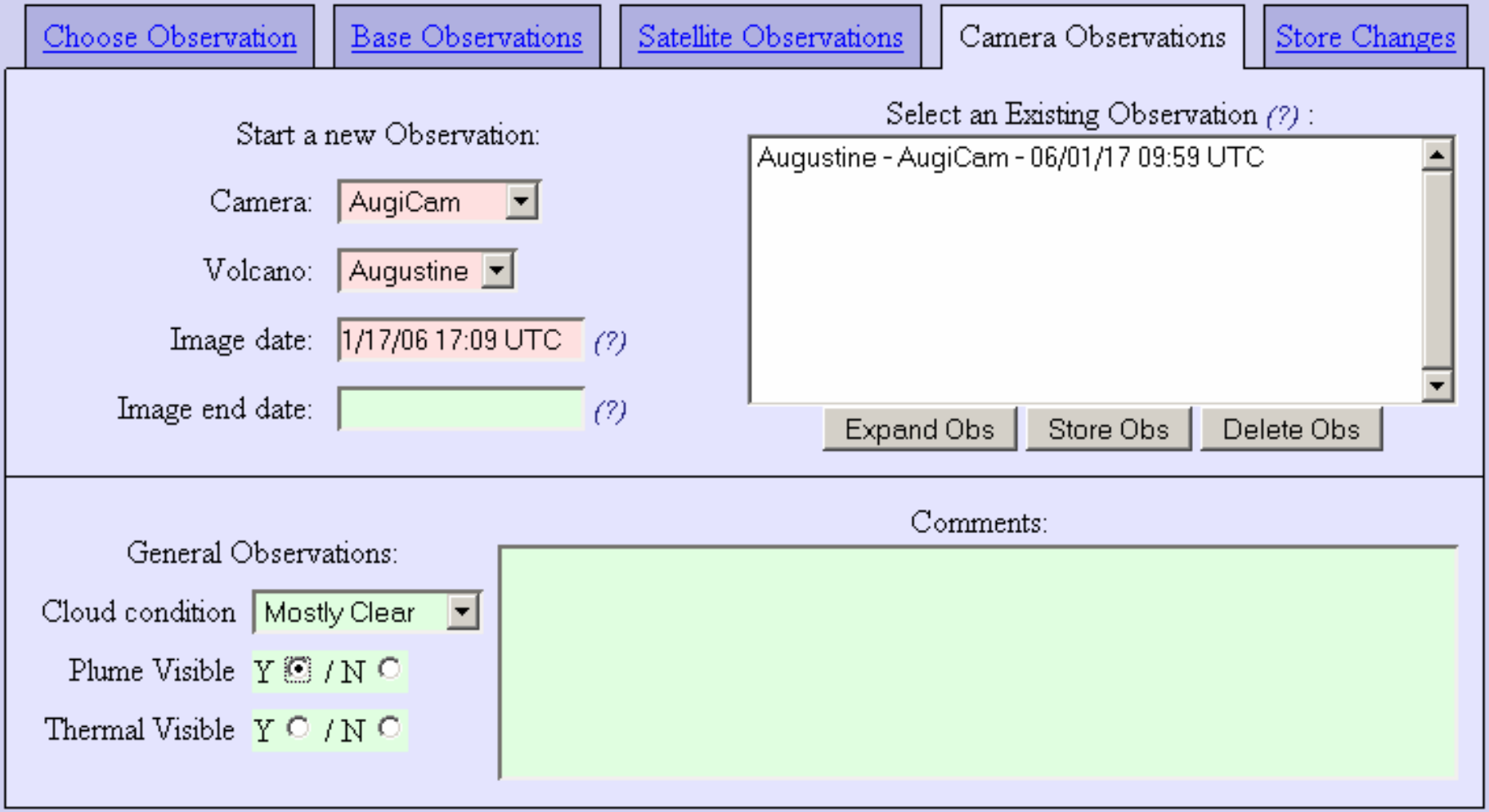
Searchable records



Manual Database Entry: Satellite Observations



Manual Database Entry: Camera Observations



Database Generated Observation Reports

Twice Daily

365 Days/yr

TO: USGS

Information from reports go:

- **NWS**
- **FAA**
- **Others**

AM satellite report for January 17, 2006

SUMMARY:
Plume and thermal anomaly at Augustine, thermal anomaly at Veniaminof

OBSERVATIONS:
Augustine (Red): Mostly clear at volcano
1) Image n14.06017.1831: partly cloudy at volcano, sat zenith angle of 68
- comments: edge pass, plume visible
- ch4 plume: 75km long, heading 130, observed at -47 C, est. 8km high

Martin (Yellow): Mostly clear at volcano

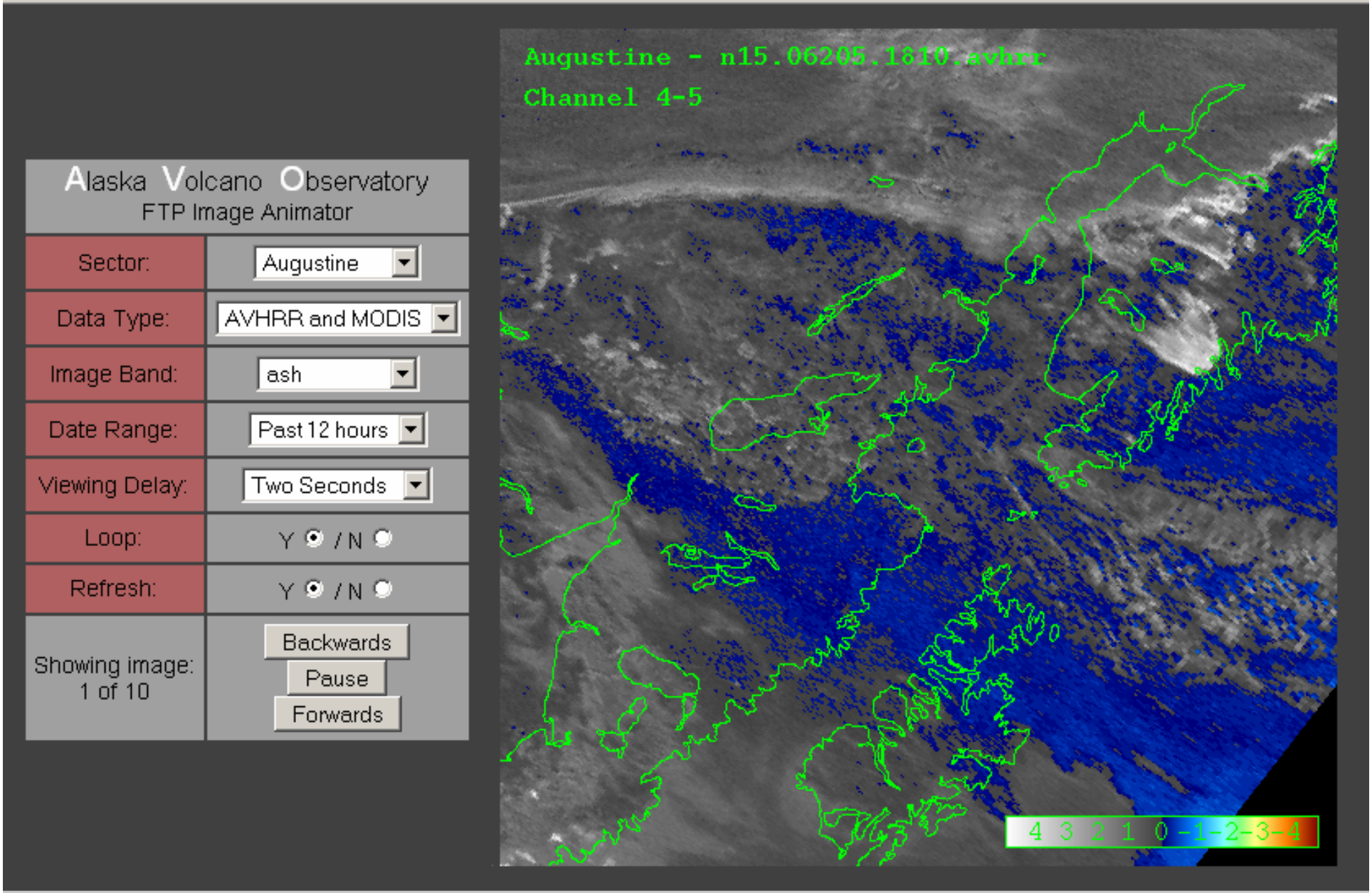
Spurr (Yellow): Partly cloudy at volcano

St. Helens (Orange): Cloudy at volcano

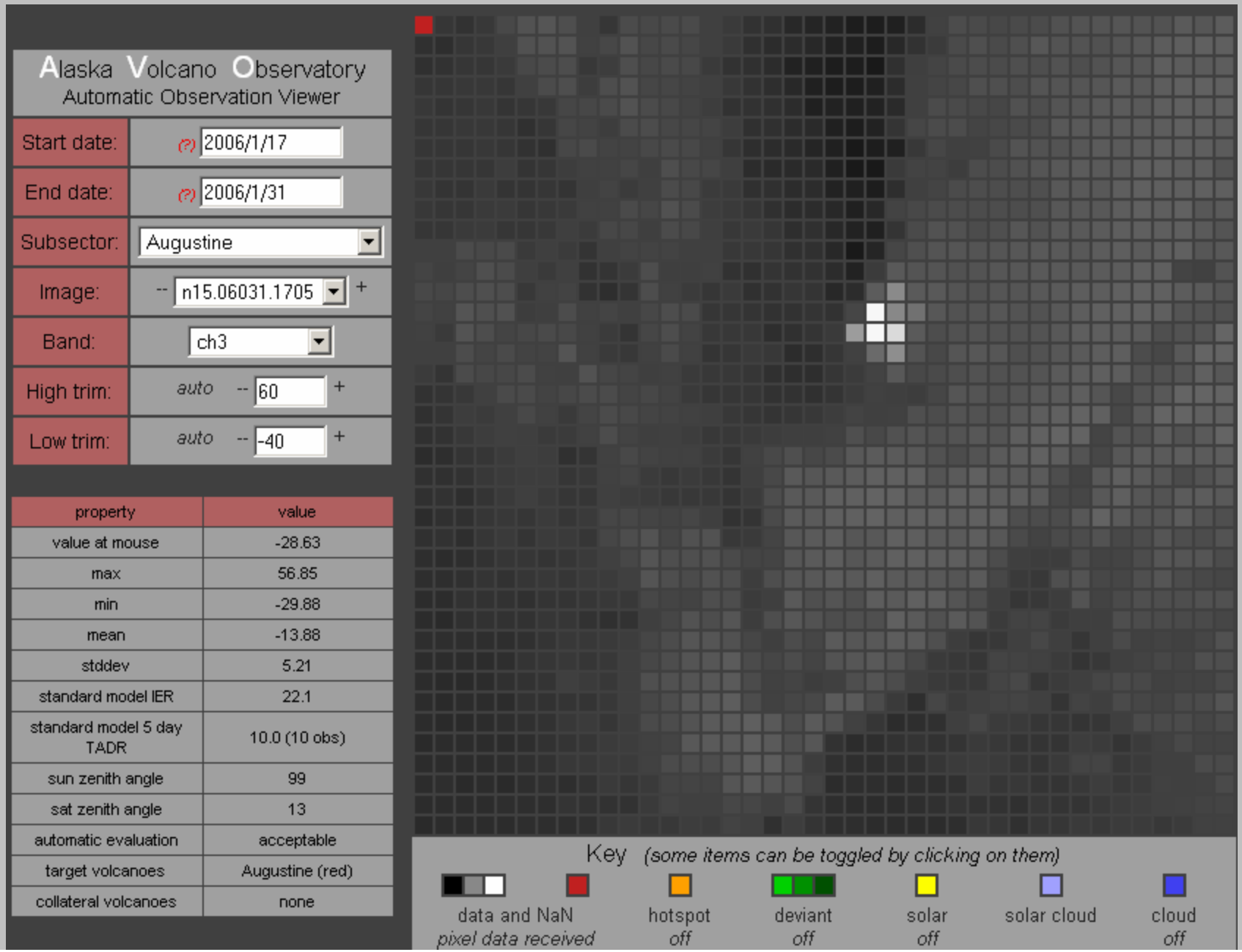
CLOUD CONDITIONS:
Wrangells (Wrangell sector): Mostly Clear
Cook Inlet (Augustine sector): Mostly Clear
Alaska Peninsula (Pavlof sector): Partly Cloudy
Eastern Aleutians (Vsevidof sector): Partly Cloudy

LAST IMAGES VIEWED:
AVHRR: 18:31 UTC
GOES10: 18:30 UTC
MODIS: 18:37 UTC

New Web Tools: Image Animator/sector (512 x 512)



New Web Tools: Auto Observer (40 x 40)



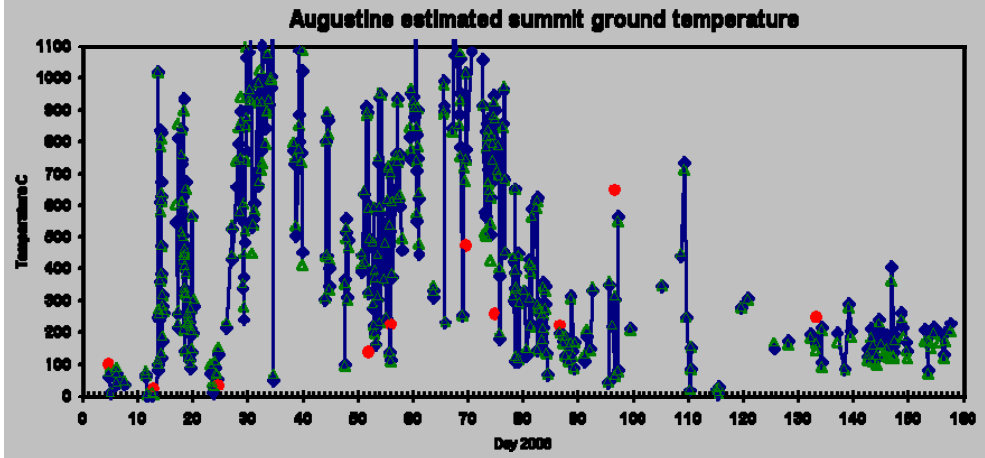
Automated Alerts

2 Types:
Thermal Anomalies – operational
Ash Clouds - underdevelopment

Cell phone text message
Computer voice alert
Automated emil text message

Thermal anomaly detected in n18.06205.1557
Possible volcanoes are Bezymianny
1 pixels 35.31C background 3.09C
sat zen 16
55.98N by 199.41W
http://avo-animate.images.alaska.edu/auto_obs_viewer.phpk

New Web Tools: Graphic Analysis of Database



Alaska Volcano Observatory
Graph Tool

Prefab Queries | Basic Queries | Advanced Queries | Bulk Queries

Volcano	Augustine
Volcanoes Targeted	Augustine
Start date	(?) 2006/1/10
End date	(?) 2006/1/31
Platform types	☑ AVHRR - ☐ MODIS
Subsector restrictions (applied to subsector data)	☐ nighttime pass ☐ overhead pass ☐ not noisy
Subsector data series (plot subsector data)	☐ band3 bg mean ☐ band4 bg mean ☐ band5 bg mean ☐ band4m5 min
Hotspot restrictions (applied to hotspot canidates)	☐ band3+band4 > 50 ☐ band3-band4 > 35
Hotspot data series (plot hotspot canidates)	☐ band3 max ☐ band4 max ☐ band5 max
Axis label	none
String for invalid data	NaN
Output format	graph

query

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Chronology

January 11

AVHRR
MODIS
PUFF

January 13-14

AVHRR
MODIS
GOES
PUFF

January 17

AVHRR
MODIS
PUFF

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January 19, 2006

January 11, 2006

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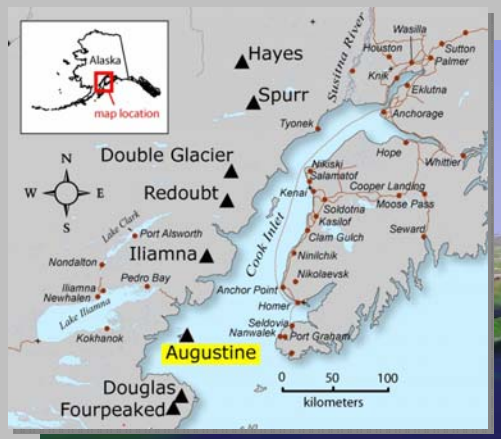
CHRONOLOGY AUGUSTINE LOCATION



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CHRONOLOGY December 12 :: SO_2 Plume

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Chronology

January 11

AVHRR
MODIS
PUFF

January 13-14

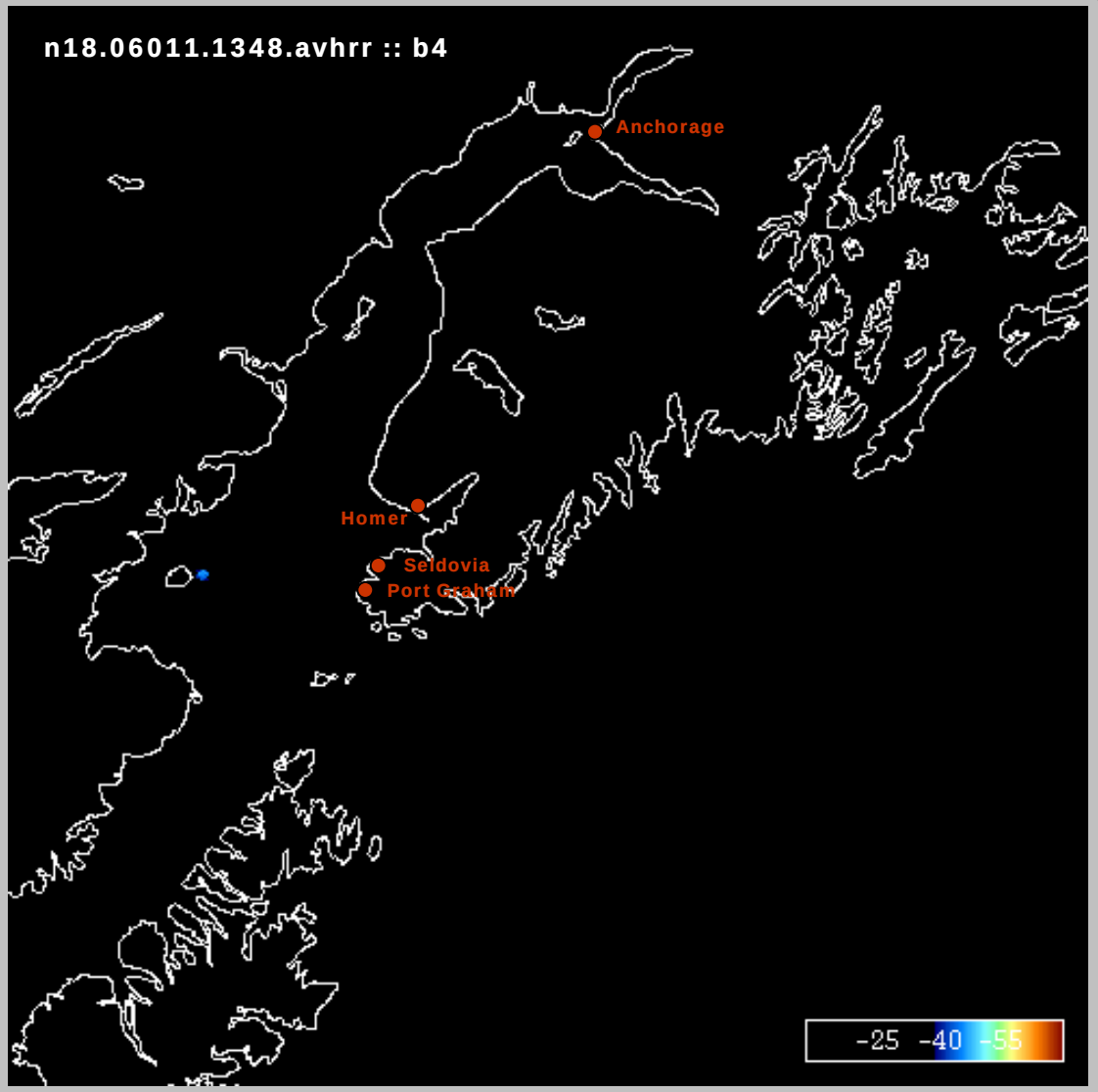
AVHRR
MODIS
GOES
PUFF

January 17

AVHRR
MODIS
PUFF

AVO :: UAF :: GI
January 19, 2006

AVHRR / MODIS :: January 11, 2006



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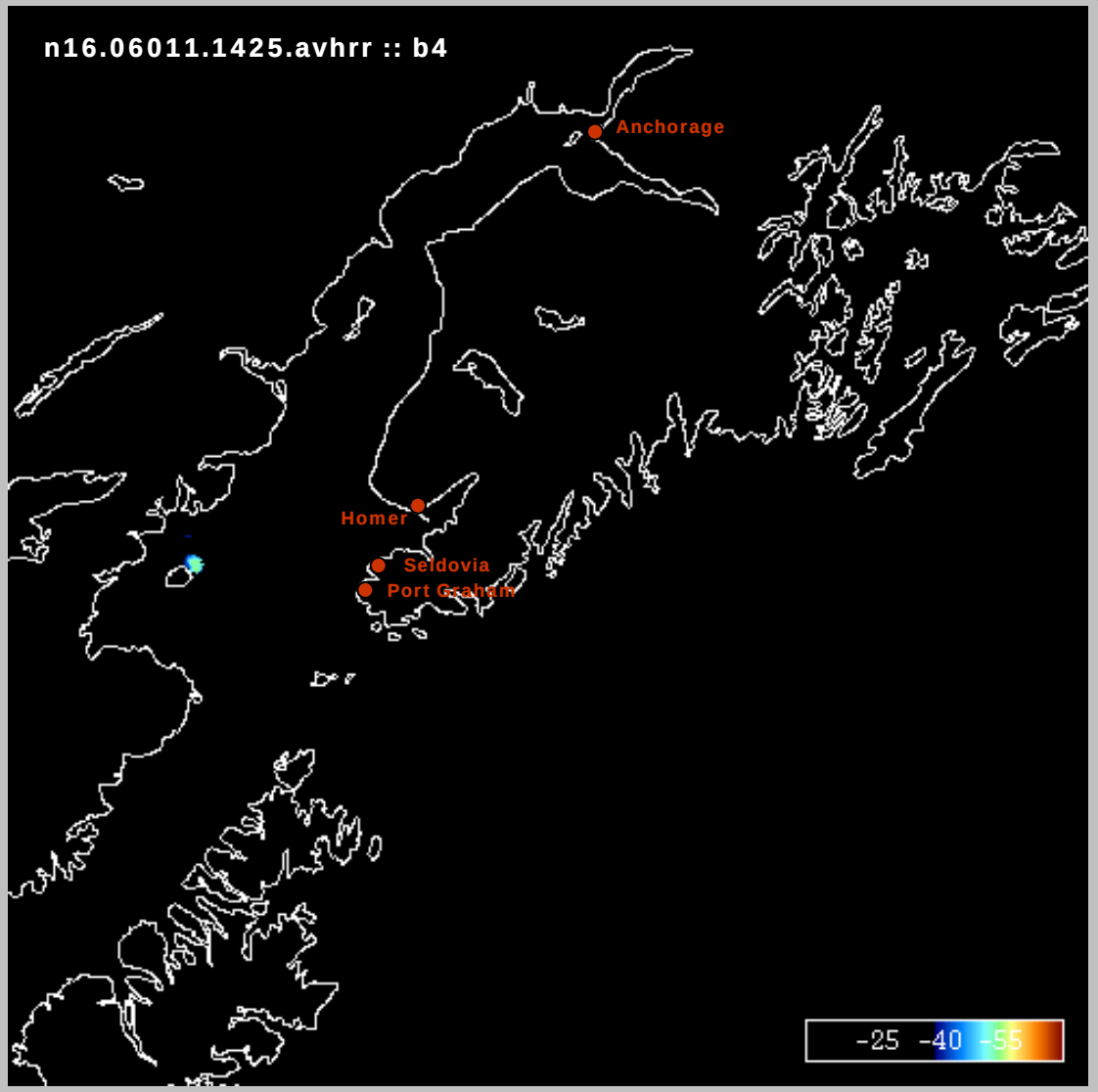

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Chronology

January 11

AVHRR
MODIS
PUFF

January 13-14

AVHRR
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AVHRR
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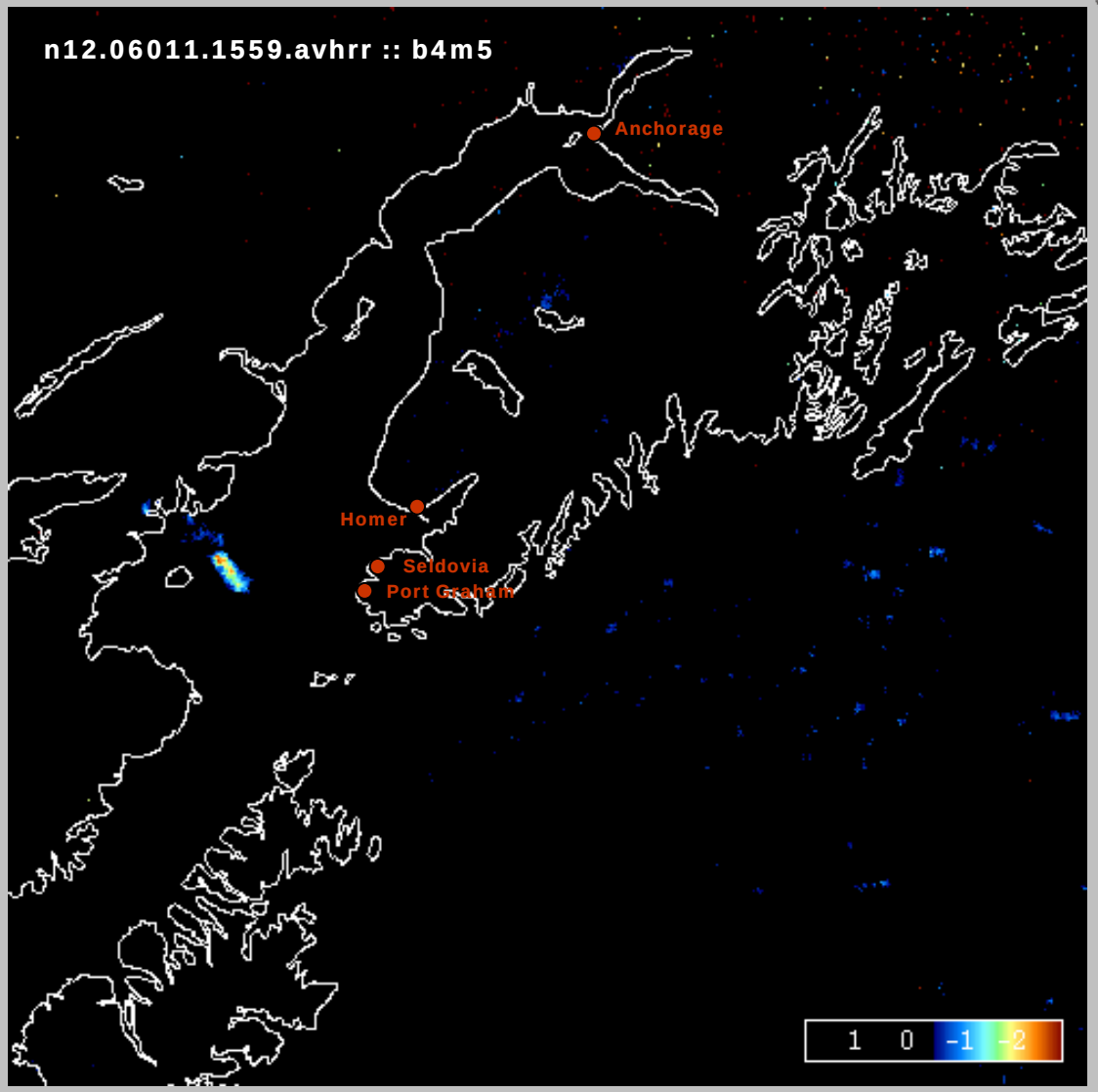
AVO :: UAF :: GI
January 19, 2006

AVHRR / MODIS :: January 11, 2006



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Chronology

January 11

AVHRR
MODIS
PUFF

January 13-14

AVHRR
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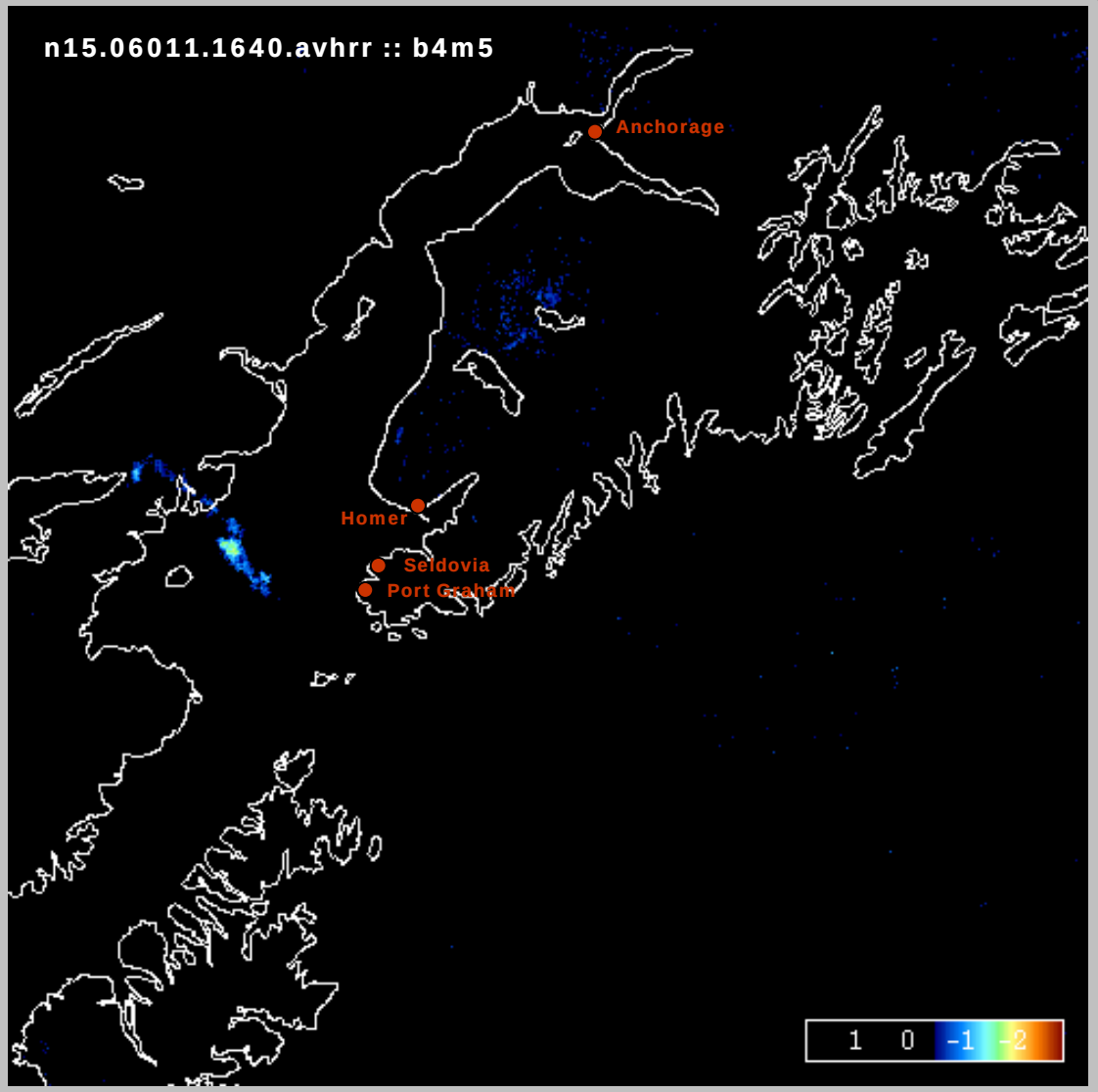
January 19, 2006

AVHRR / MODIS :: January 11, 2006



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January 19, 2006

January 13-14, 2006

AUGUSTINE 2006

Chronology

January 11

AVHRR
MODIS
PUFF

January 13-14

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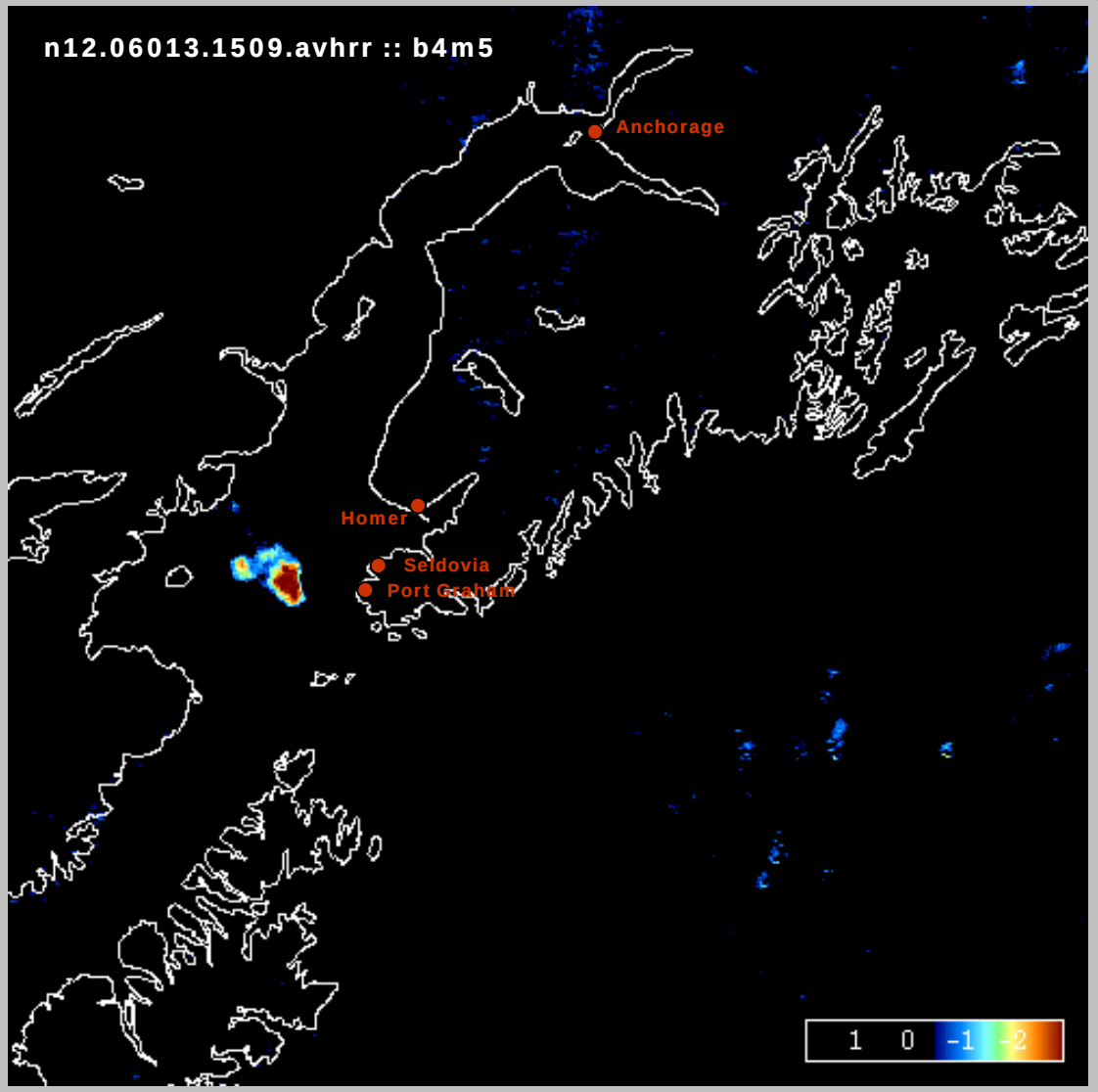
AVO :: UAF :: GI
January 19, 2006

AVHRR / MODIS :: January 13-14, 2006



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PUFF

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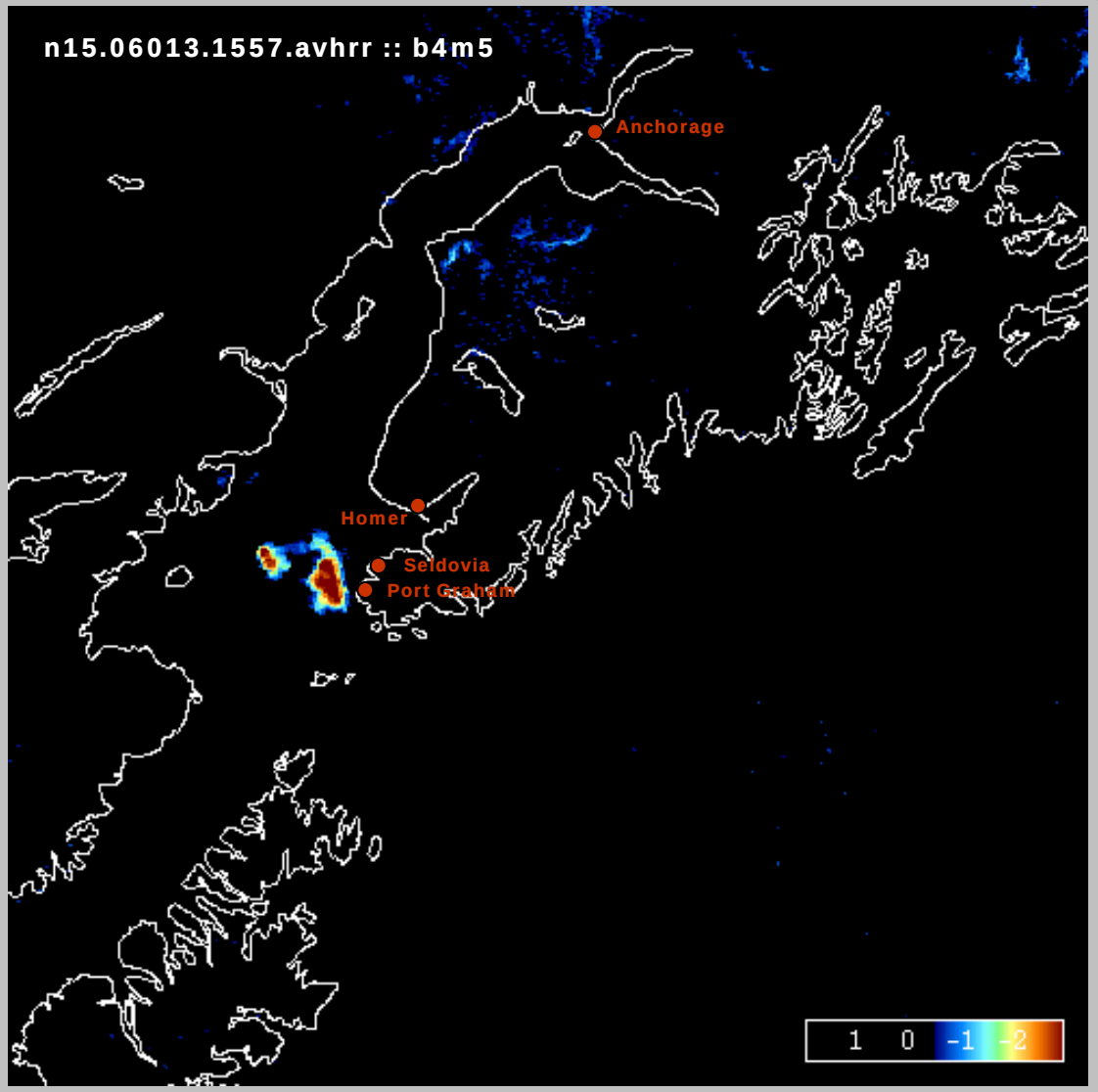
AVO :: UAF :: GI
January 19, 2006

AVHRR / MODIS :: January 13-14, 2006



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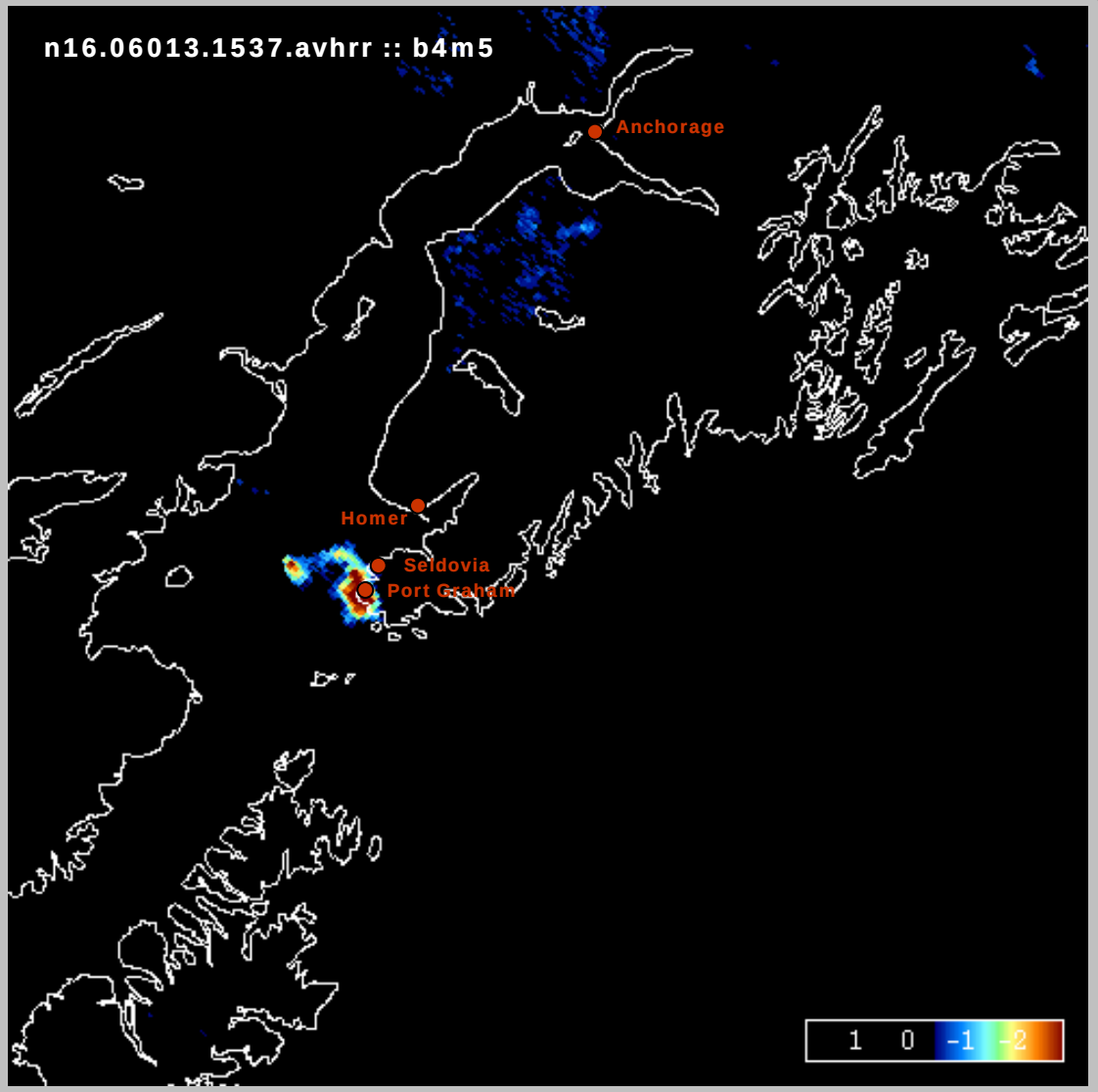
AVHRR / MODIS :: January 13-14, 2006



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January 19, 2006

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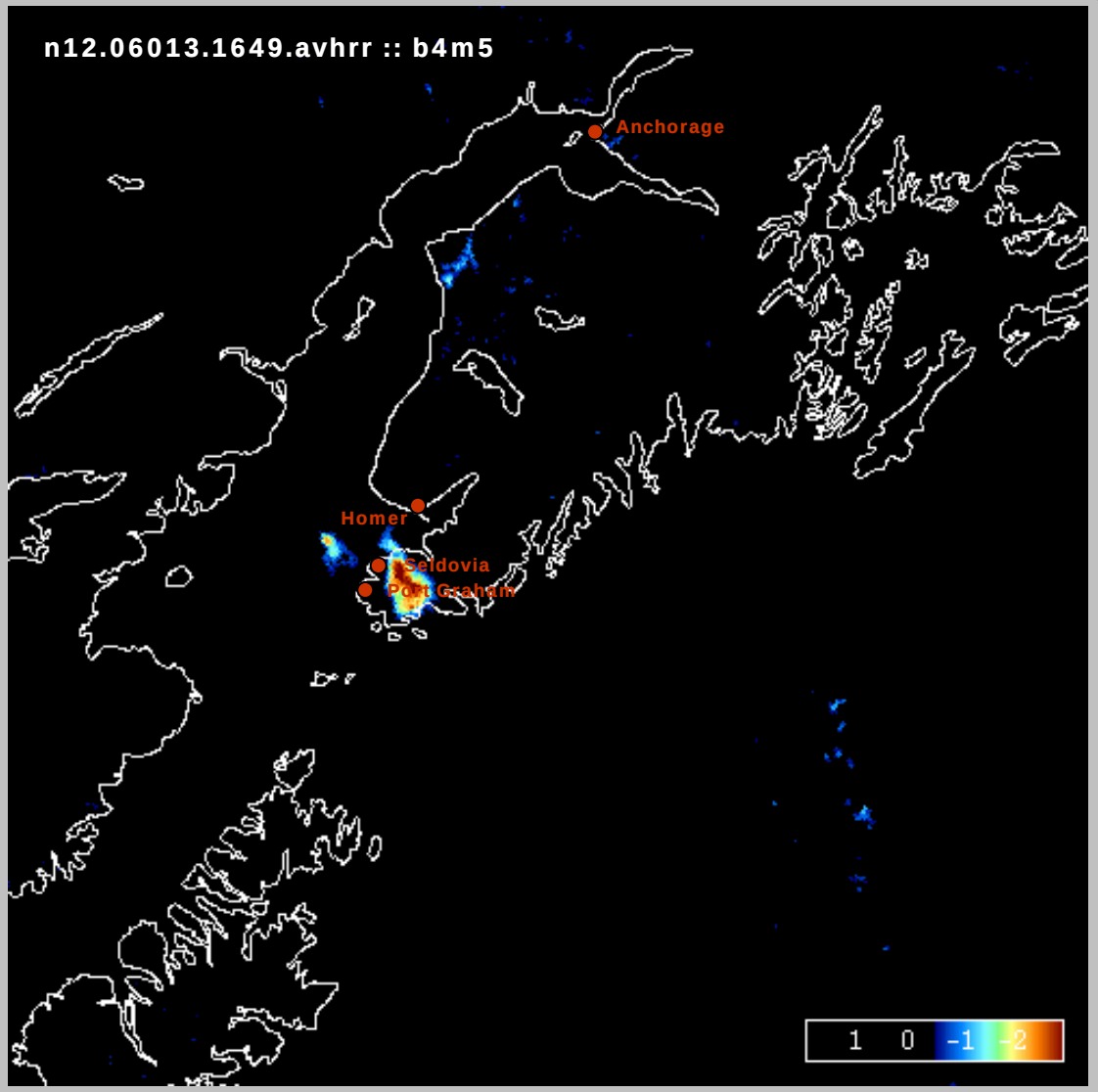

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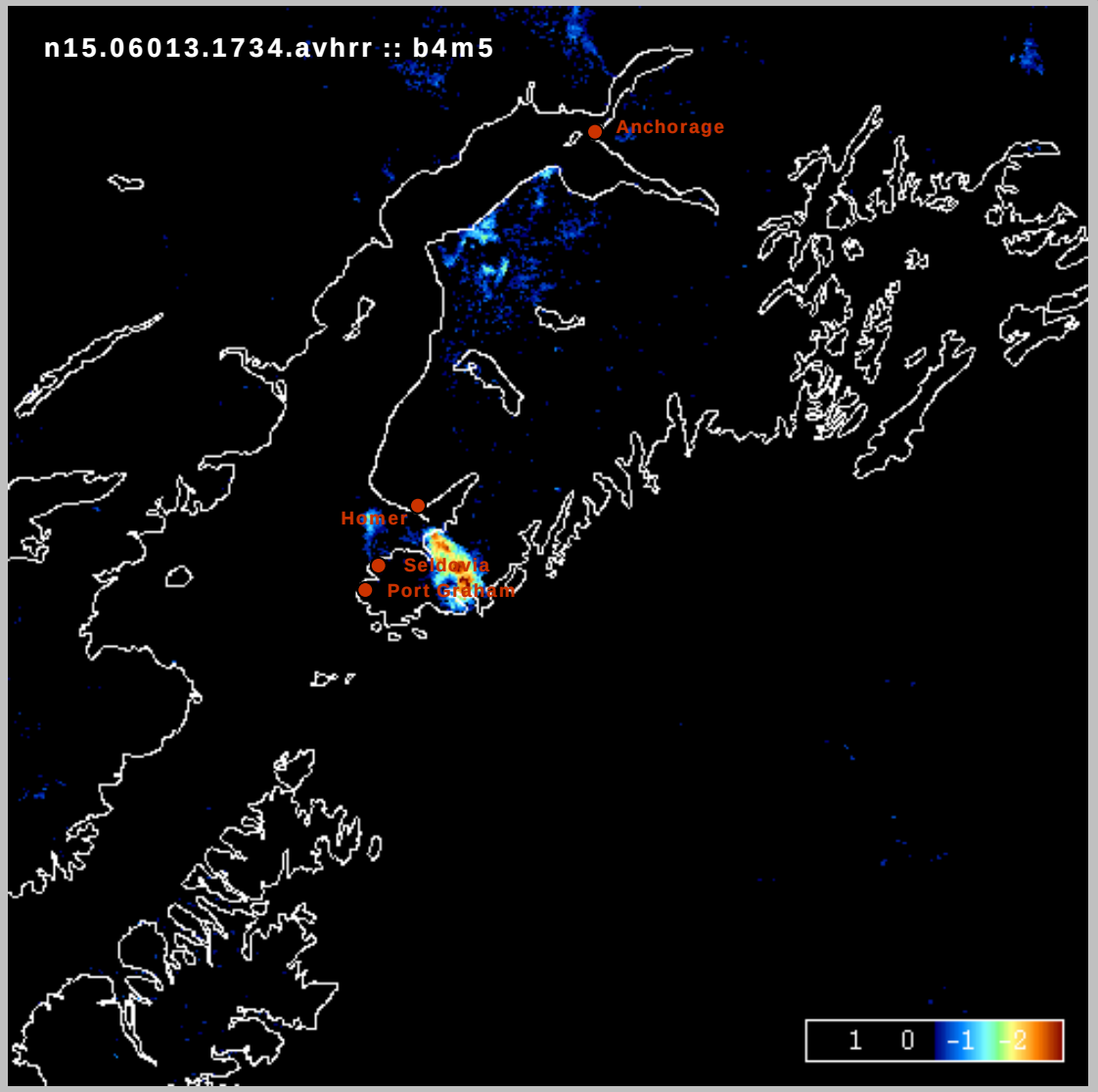
AVHRR / MODIS :: January 13-14, 2006



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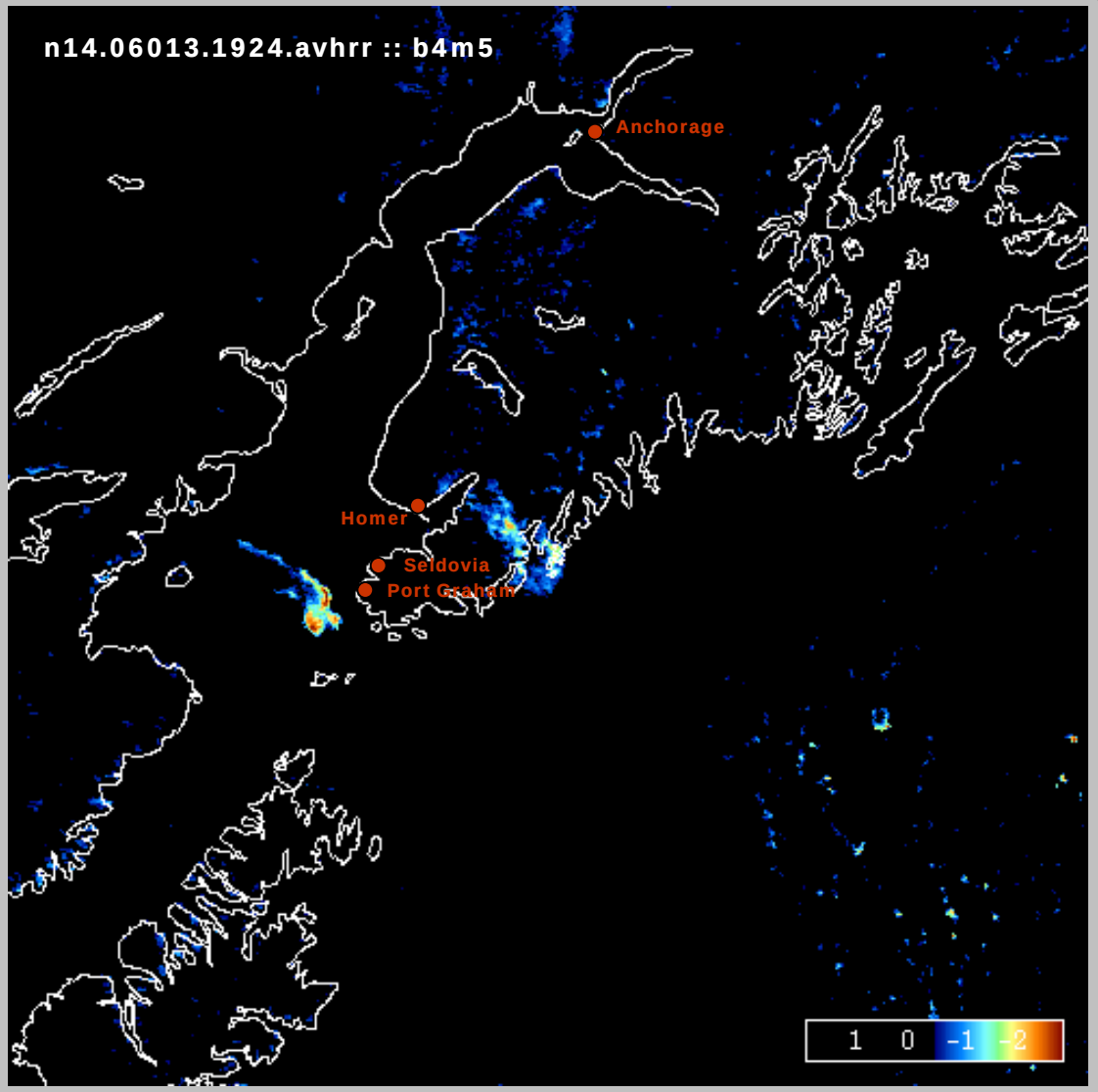
AVHRR / MODIS :: January 13-14, 2006



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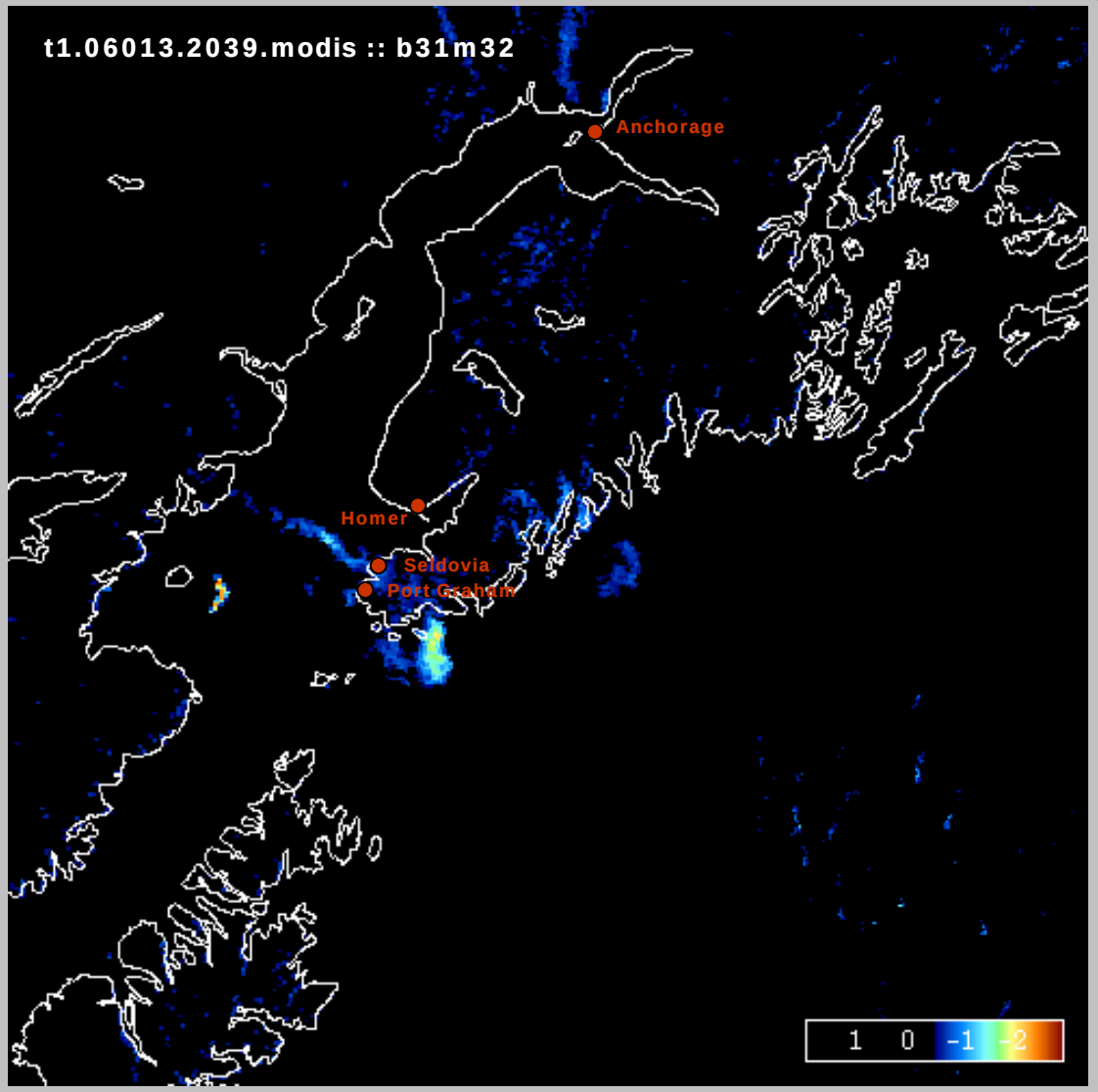
AVHRR/MODIS :: January 13-14, 2006



AUGUSTINE 2006

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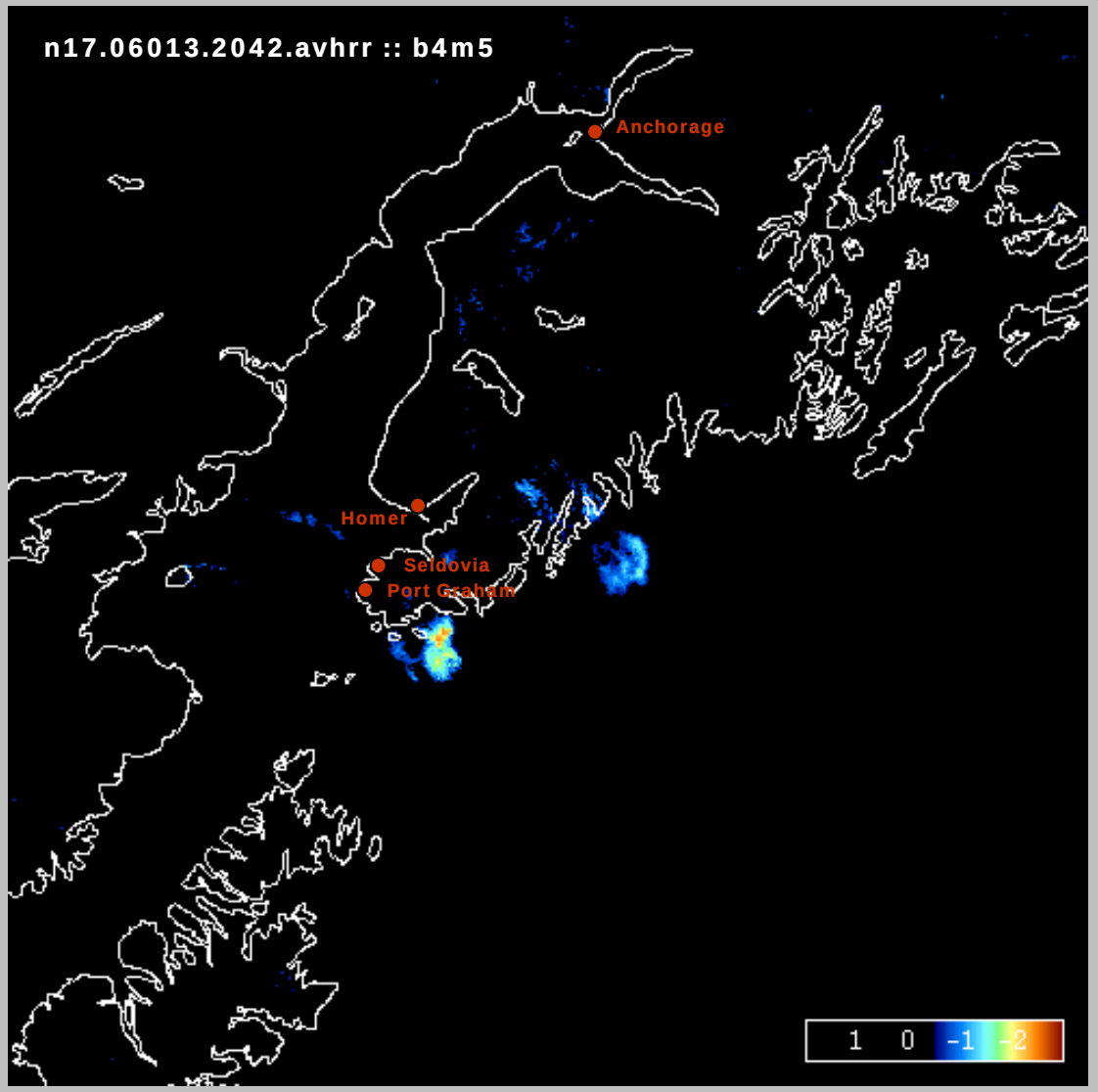
AVHRR/MODIS :: January 13-14, 2006



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AVO :: UAF :: GI
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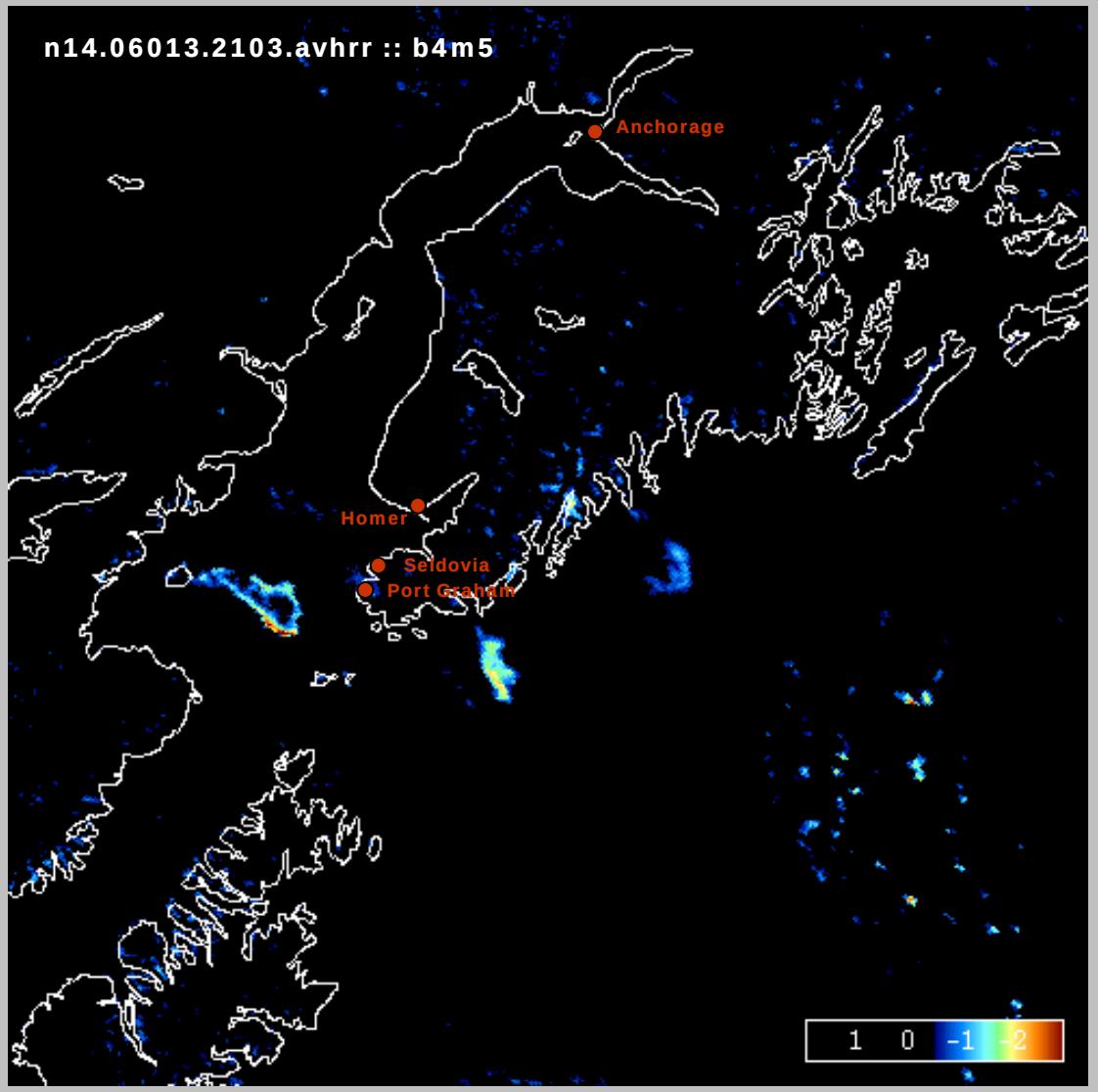

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January 19, 2006

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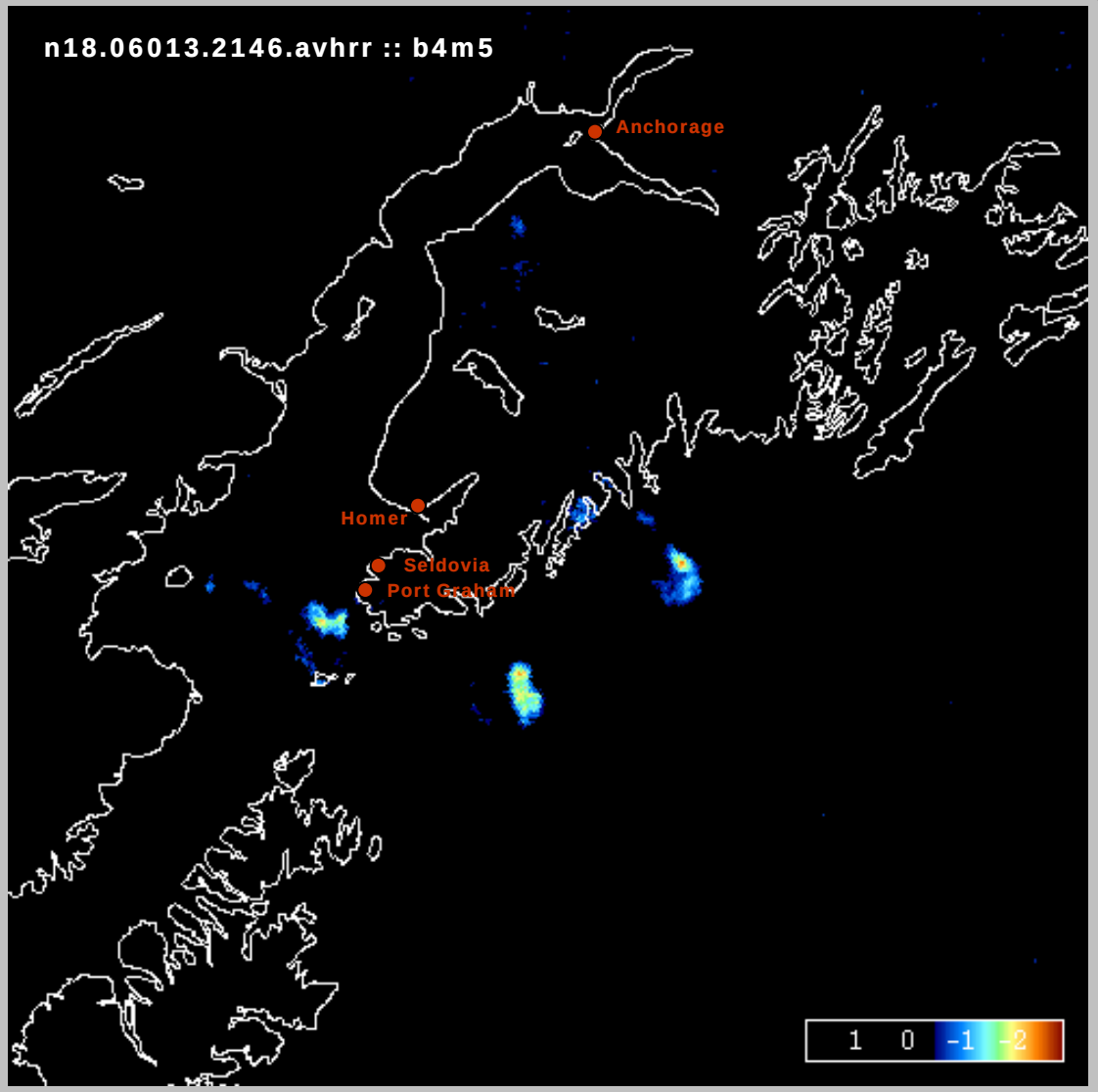

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MODIS
PUFF

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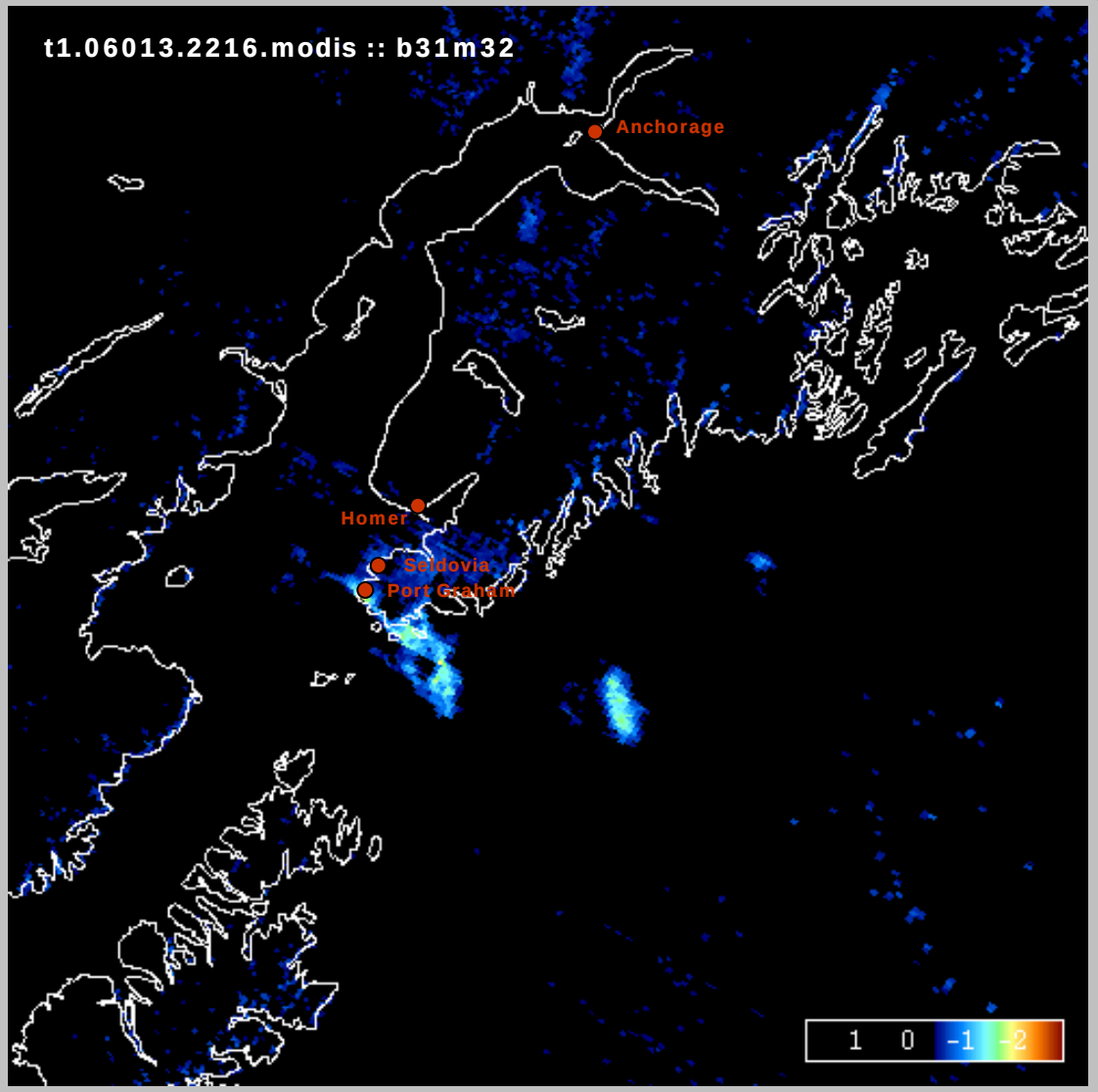

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AVHRR
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AVO :: UAF :: GI
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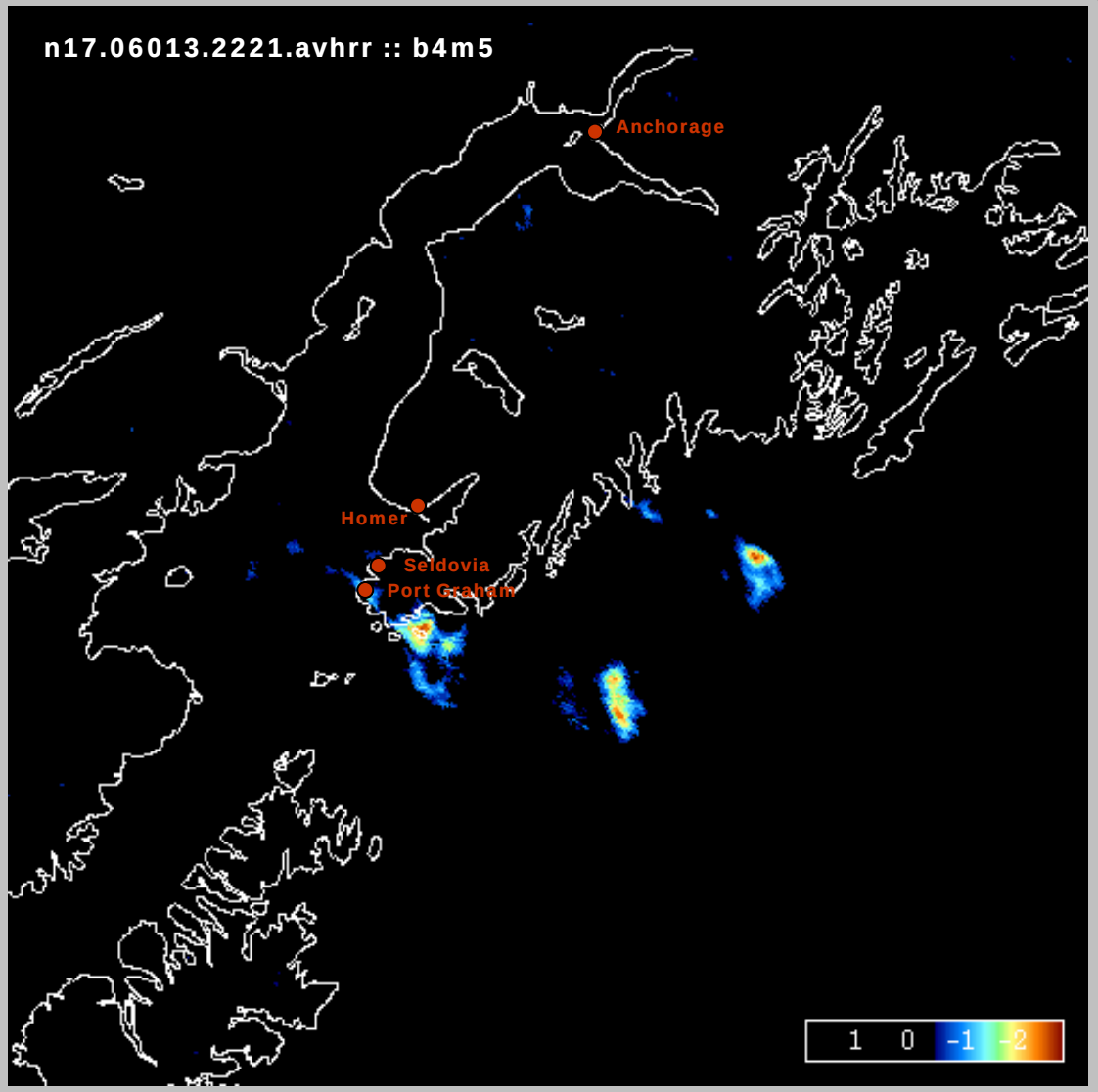

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January 19, 2006

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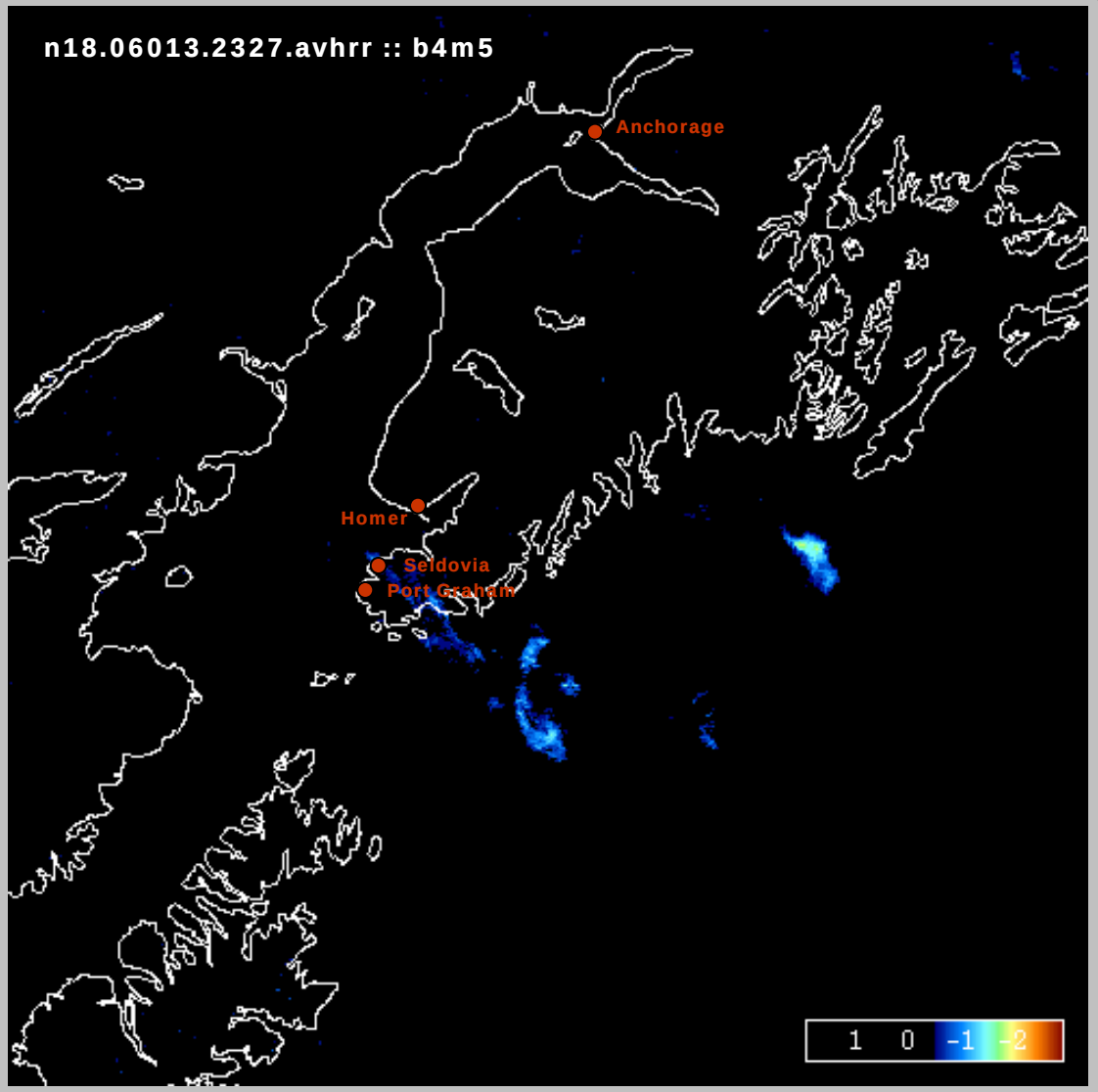

AUGUSTINE 2006

Chronology

January 11

AVHRR
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PUFF

January 13-14

AVHRR
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PUFF

January 17

AVHRR
MODIS
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AVO :: UAF :: GI
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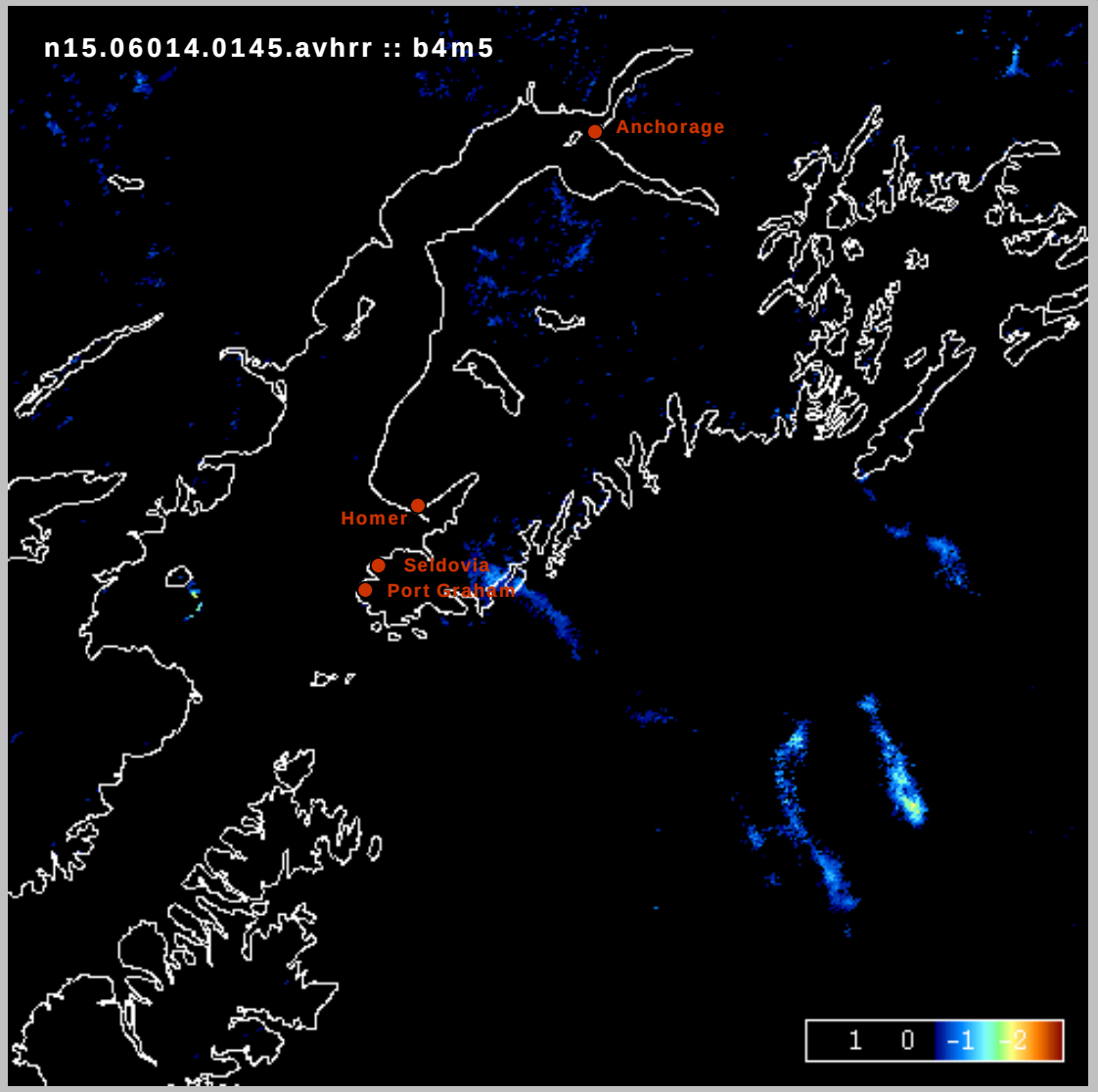
AVHRR / MODIS :: January 13-14, 2006



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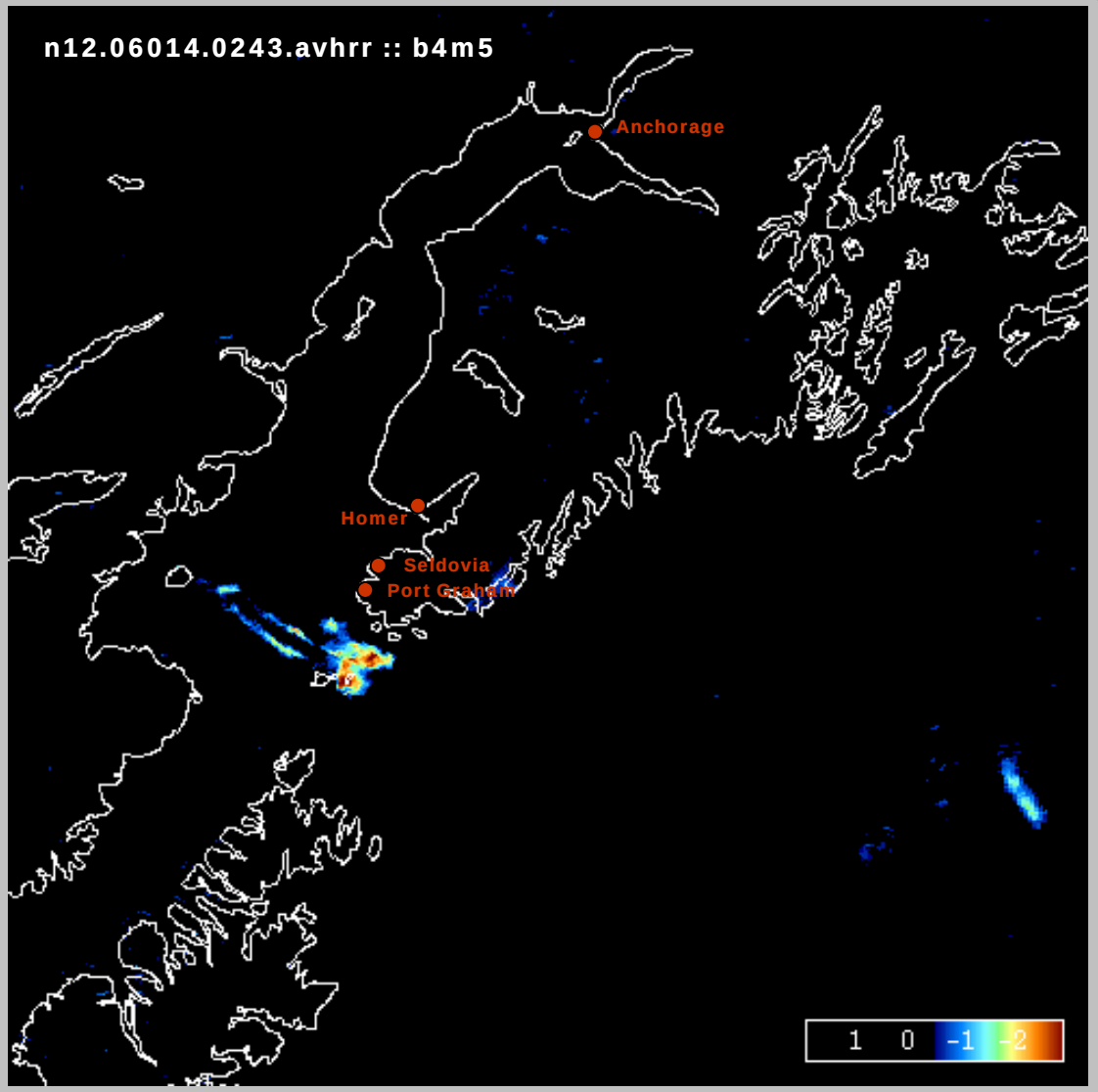

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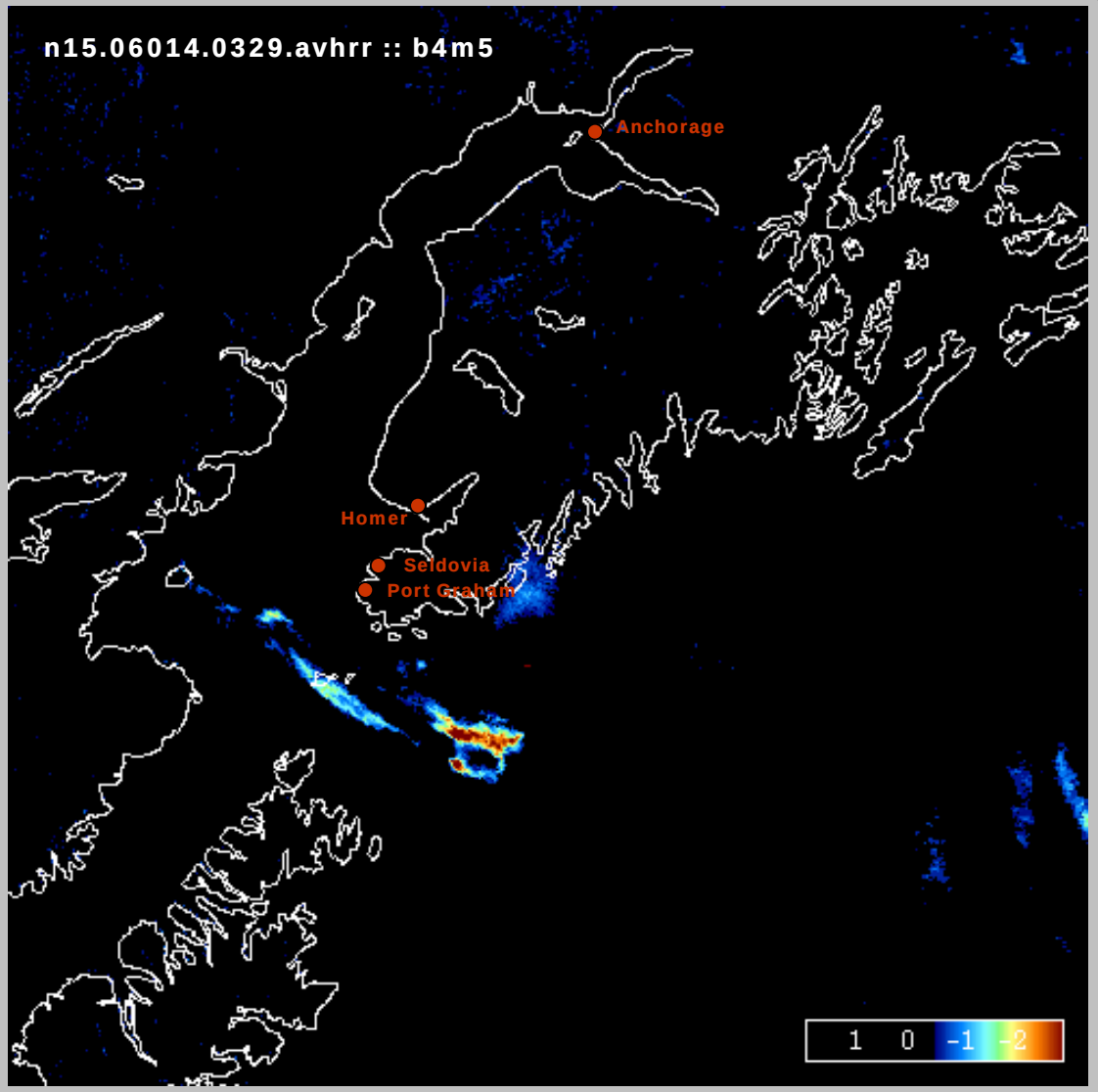

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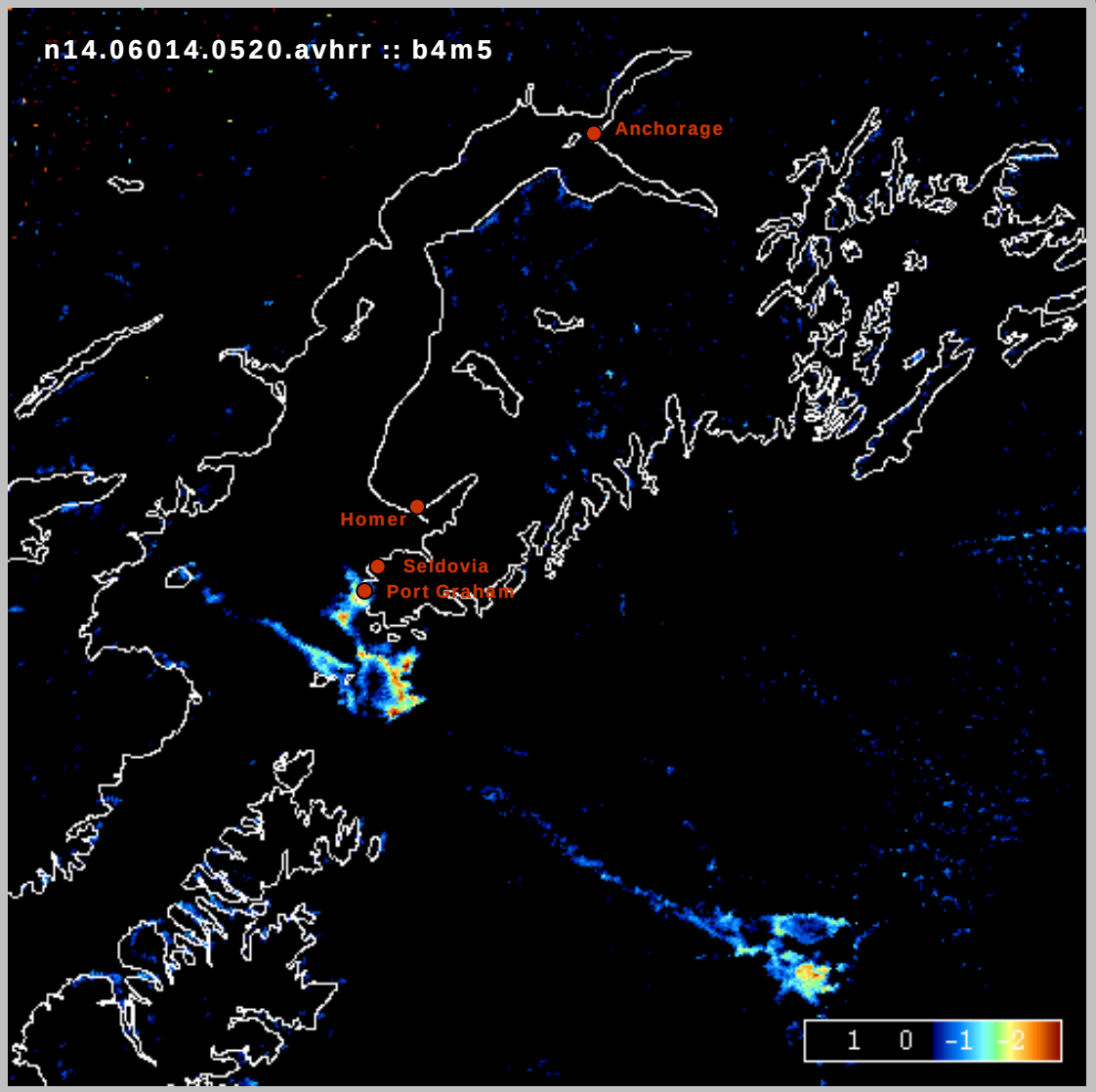

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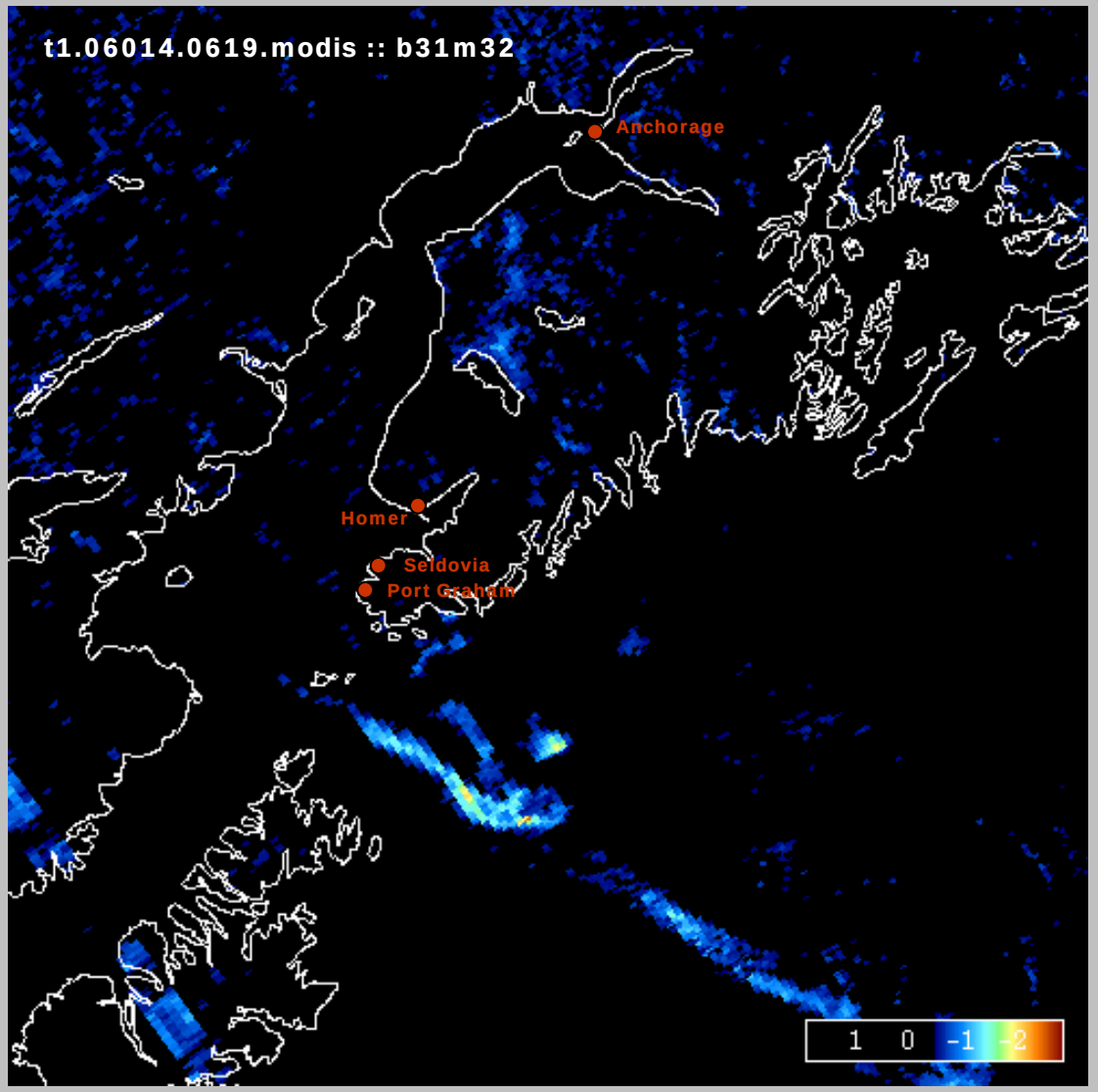

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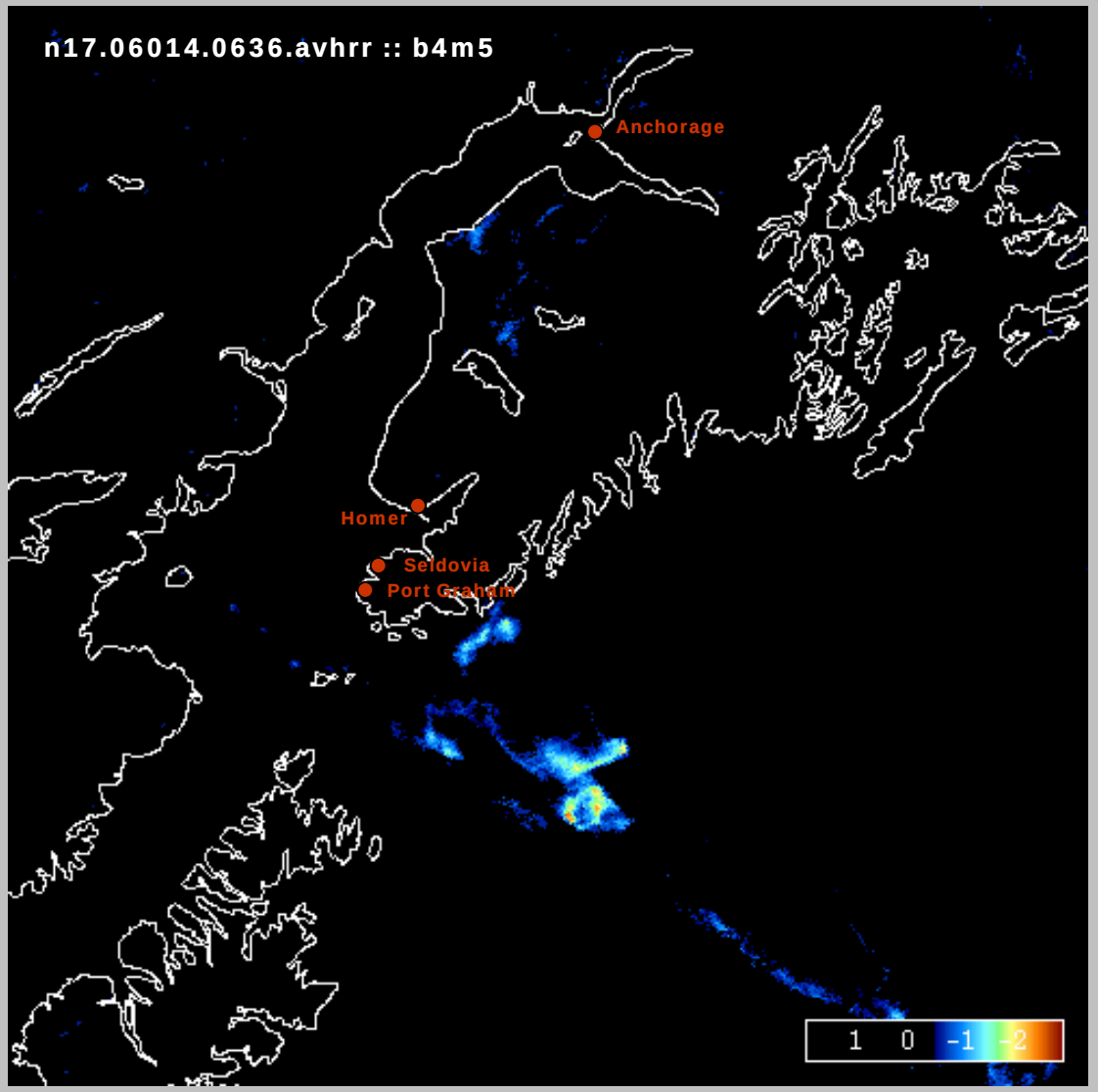

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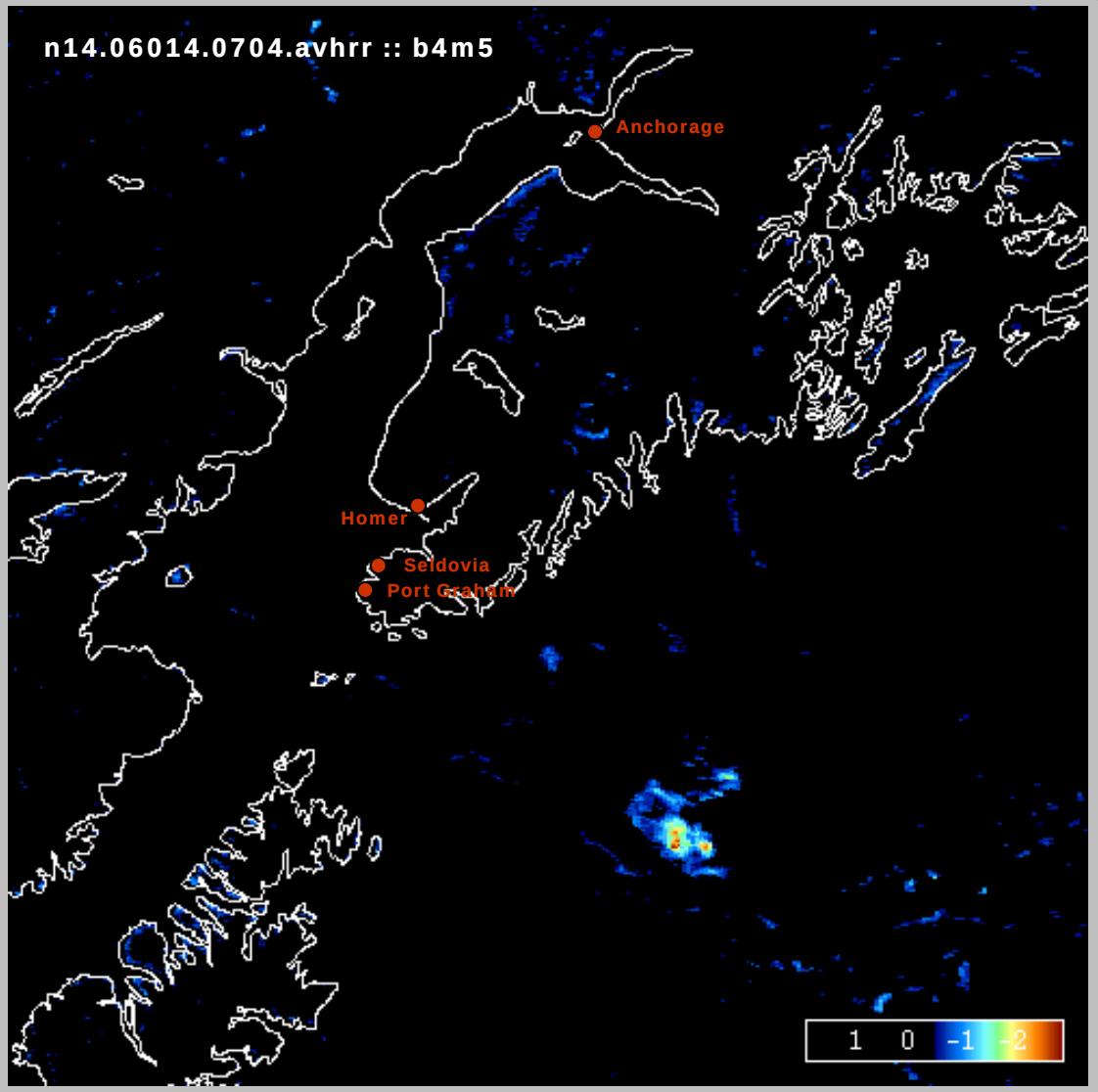

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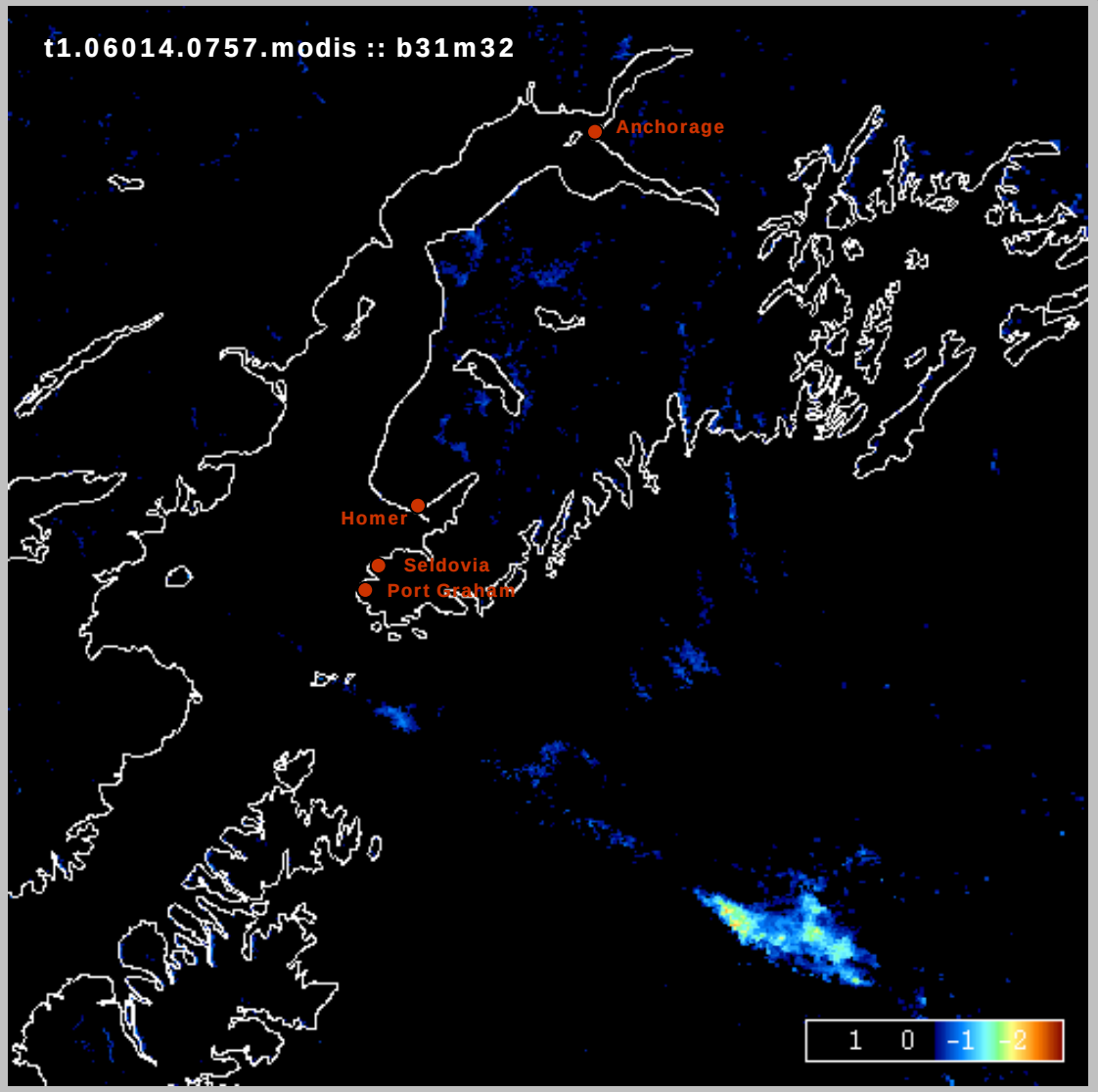

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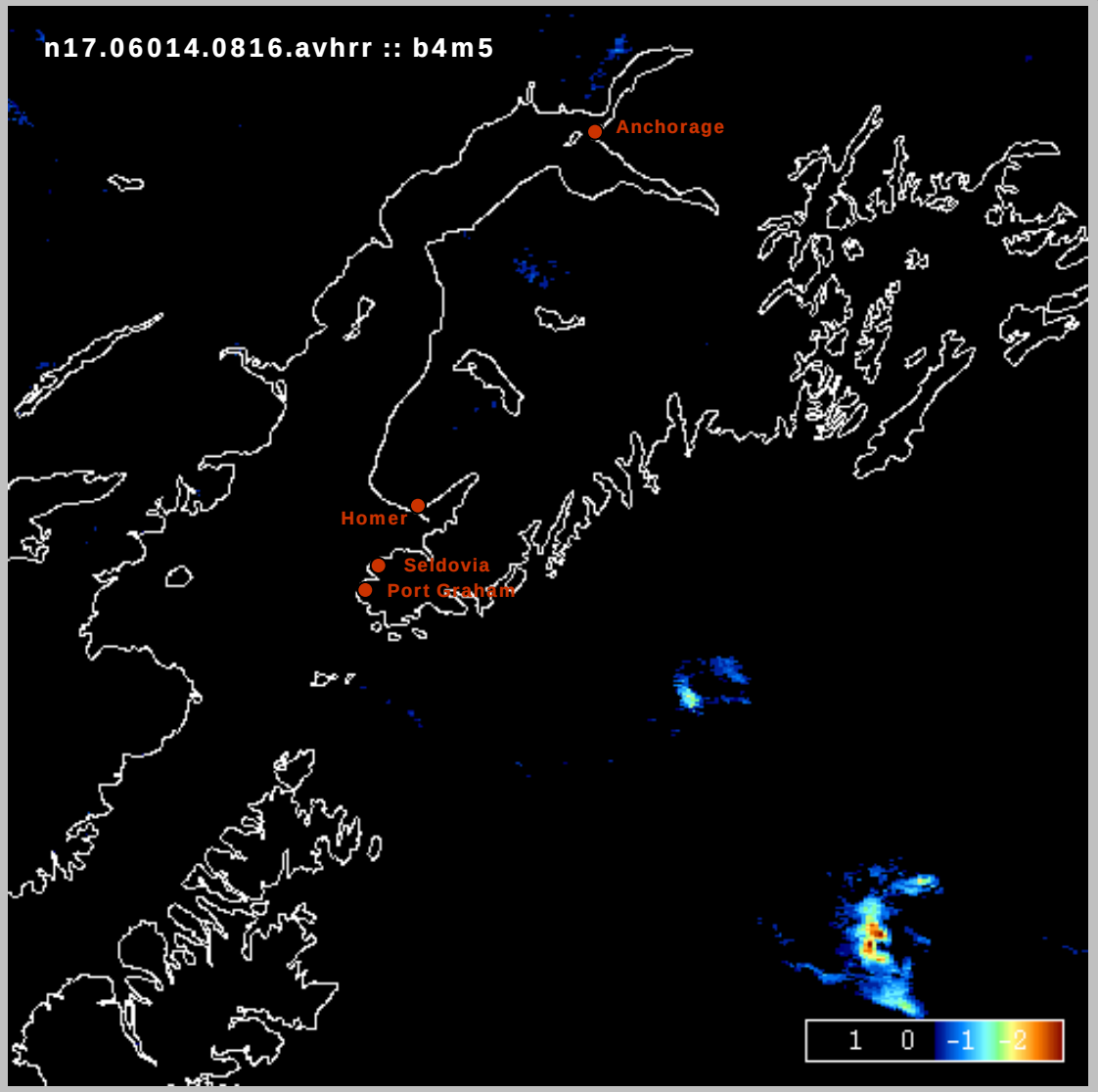
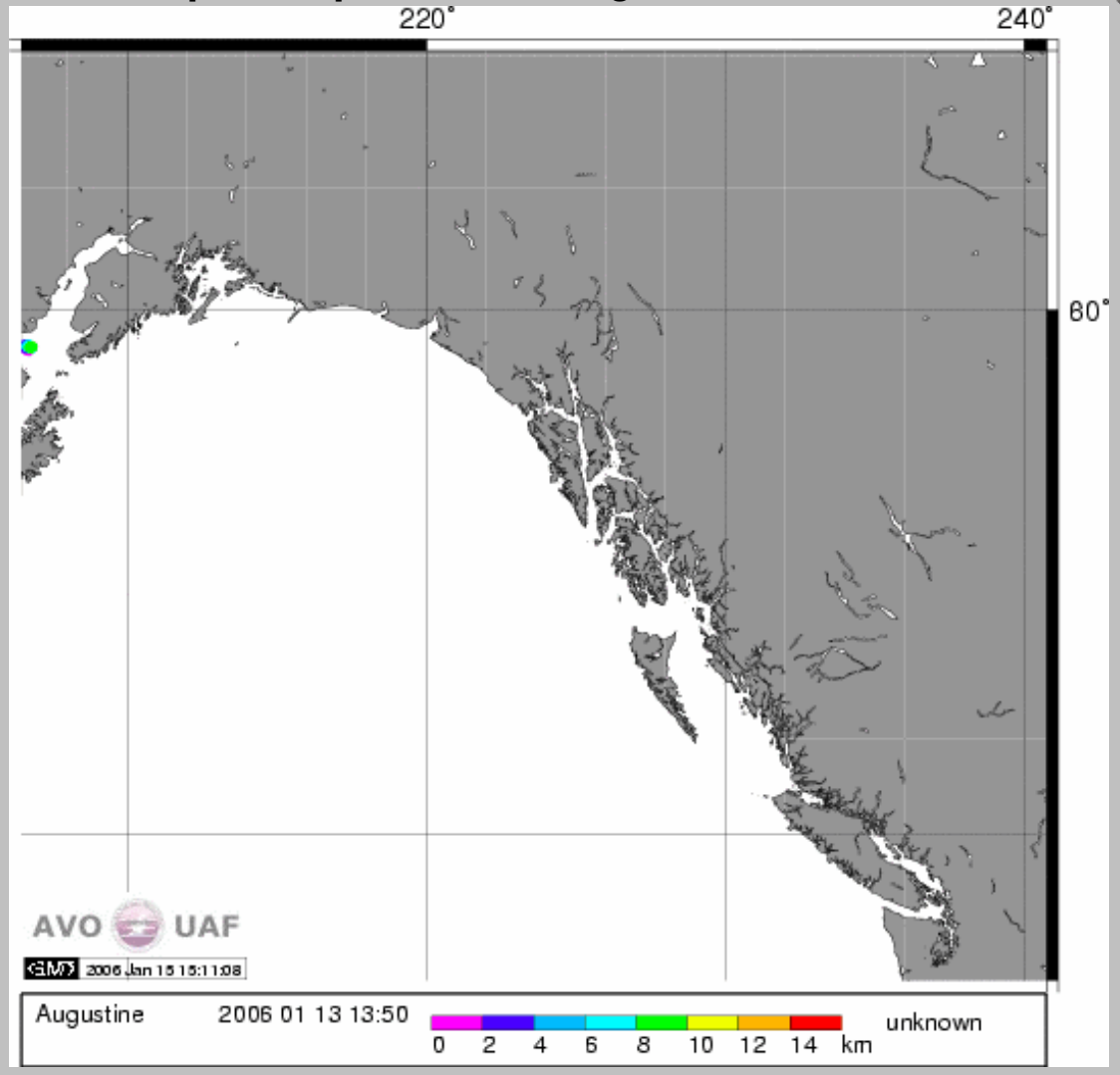


AVO :: UAF :: GI
January 19, 2006

PUFF MODEL :: January 13-14, 2006

New: Multiple Eruption Tracking



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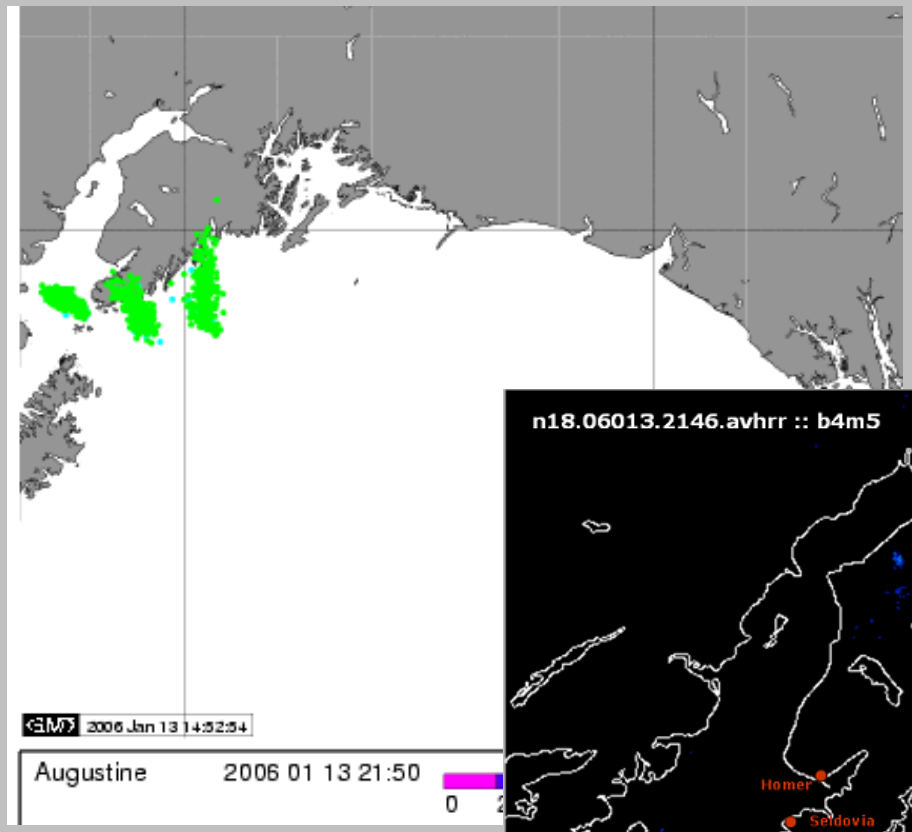
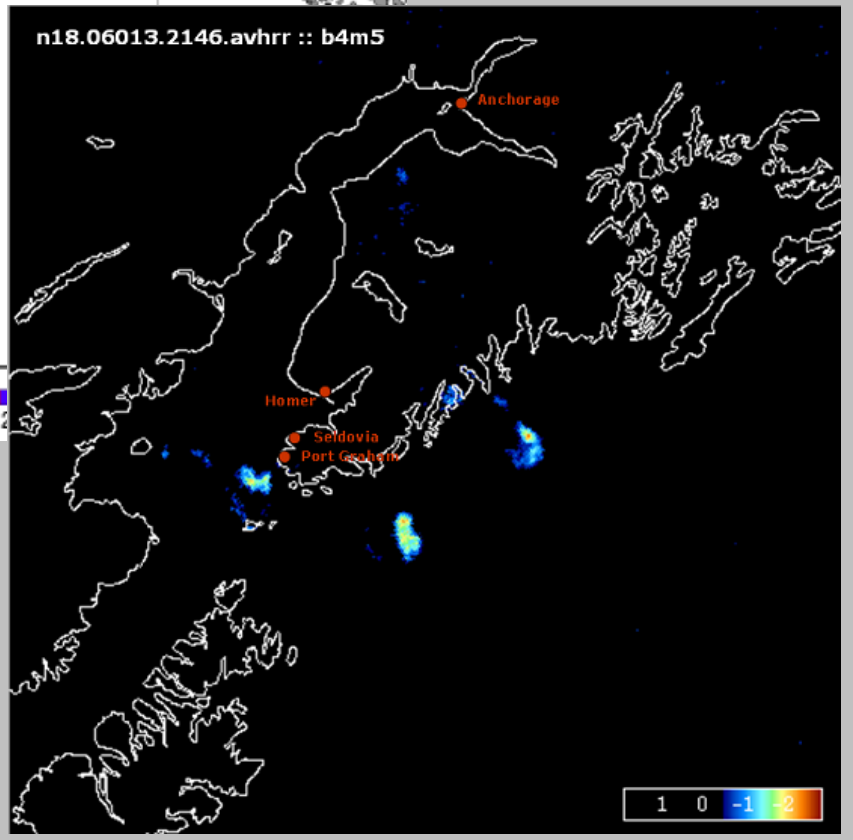


Puff output on Jan 13th 2006, 2150 UTC (8 – 10 km)



AVHRR Ash Signal Jan 13th 2006, 2150 UTC (8 – 10 km)

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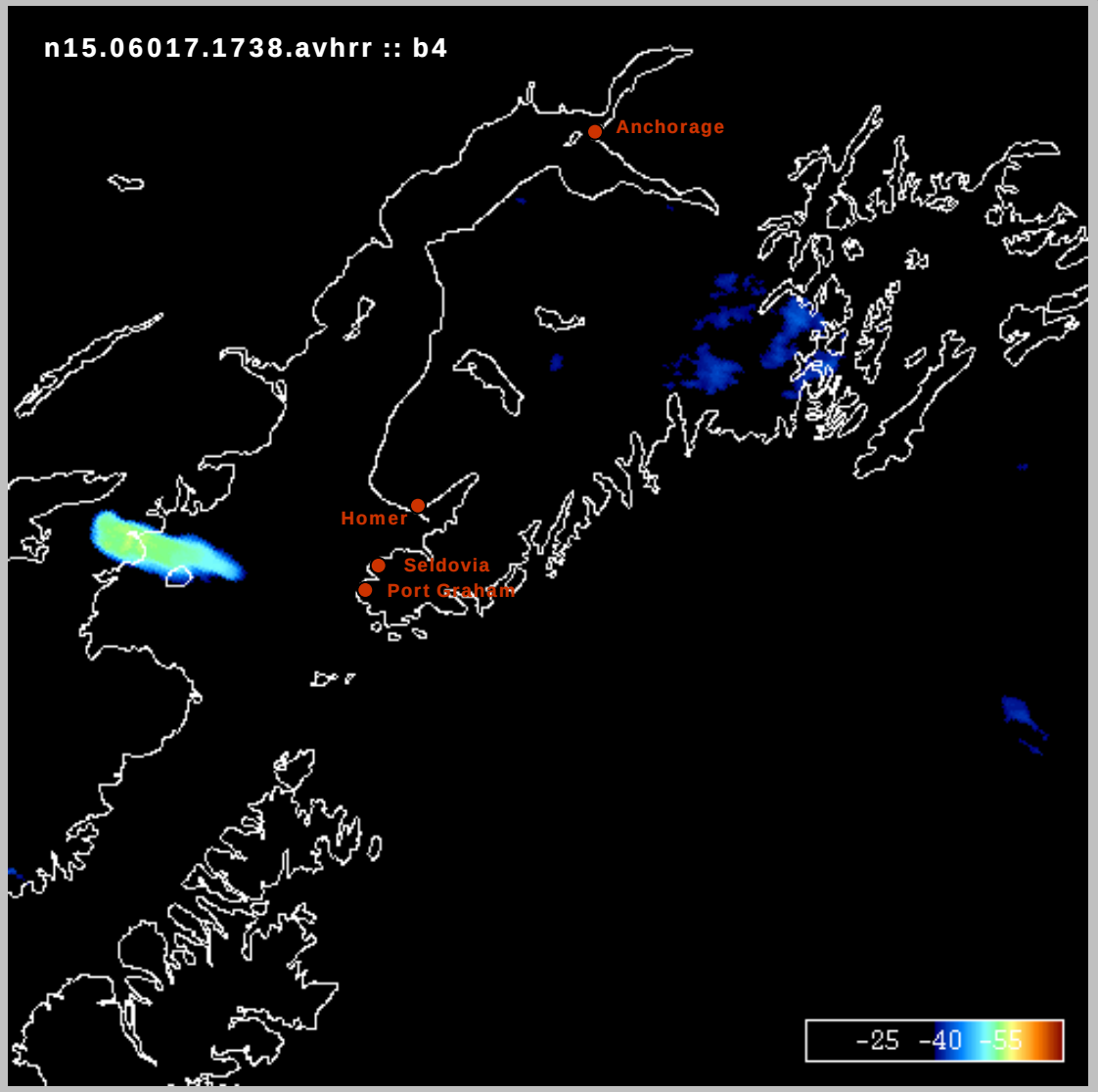
AVHRR/MODIS :: January 17, 2006

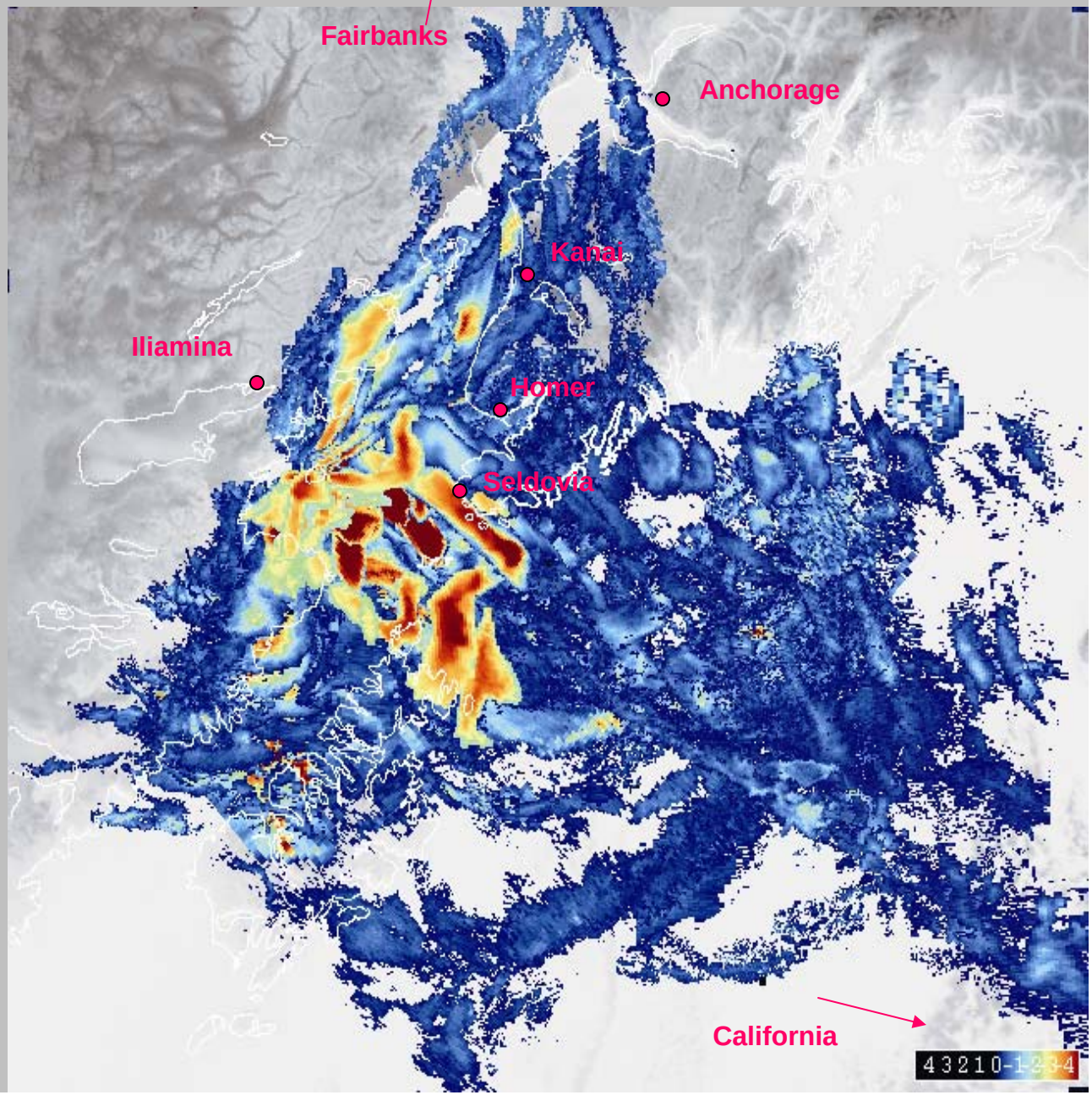


Ash Cloud Composite

Total area affected by ash clouds (split-window)

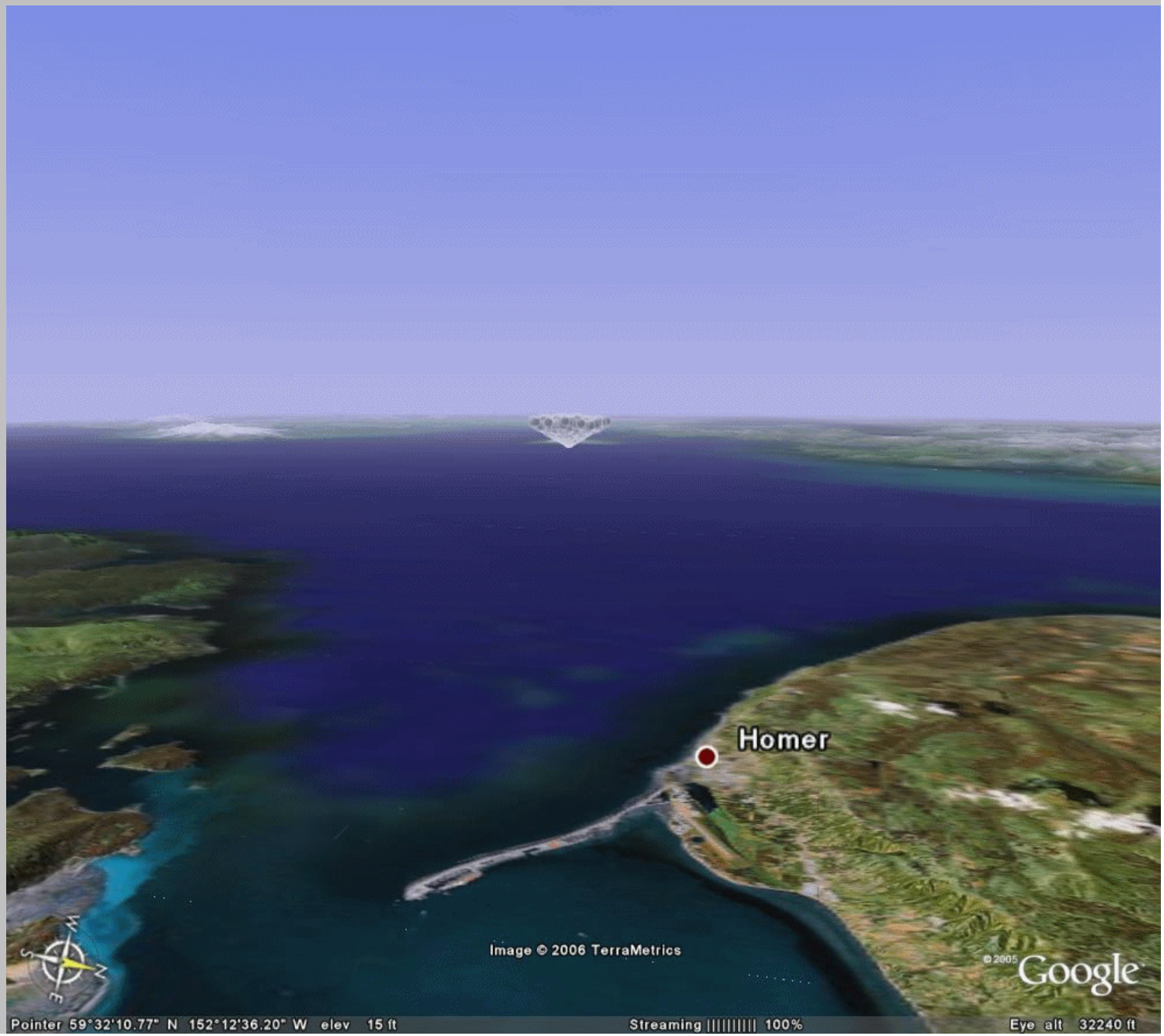
Areas of ashfall

Augustine Eruption 2006



New: 3D Puff, Google Earth

Augustine Eruption 14 Jan. 06



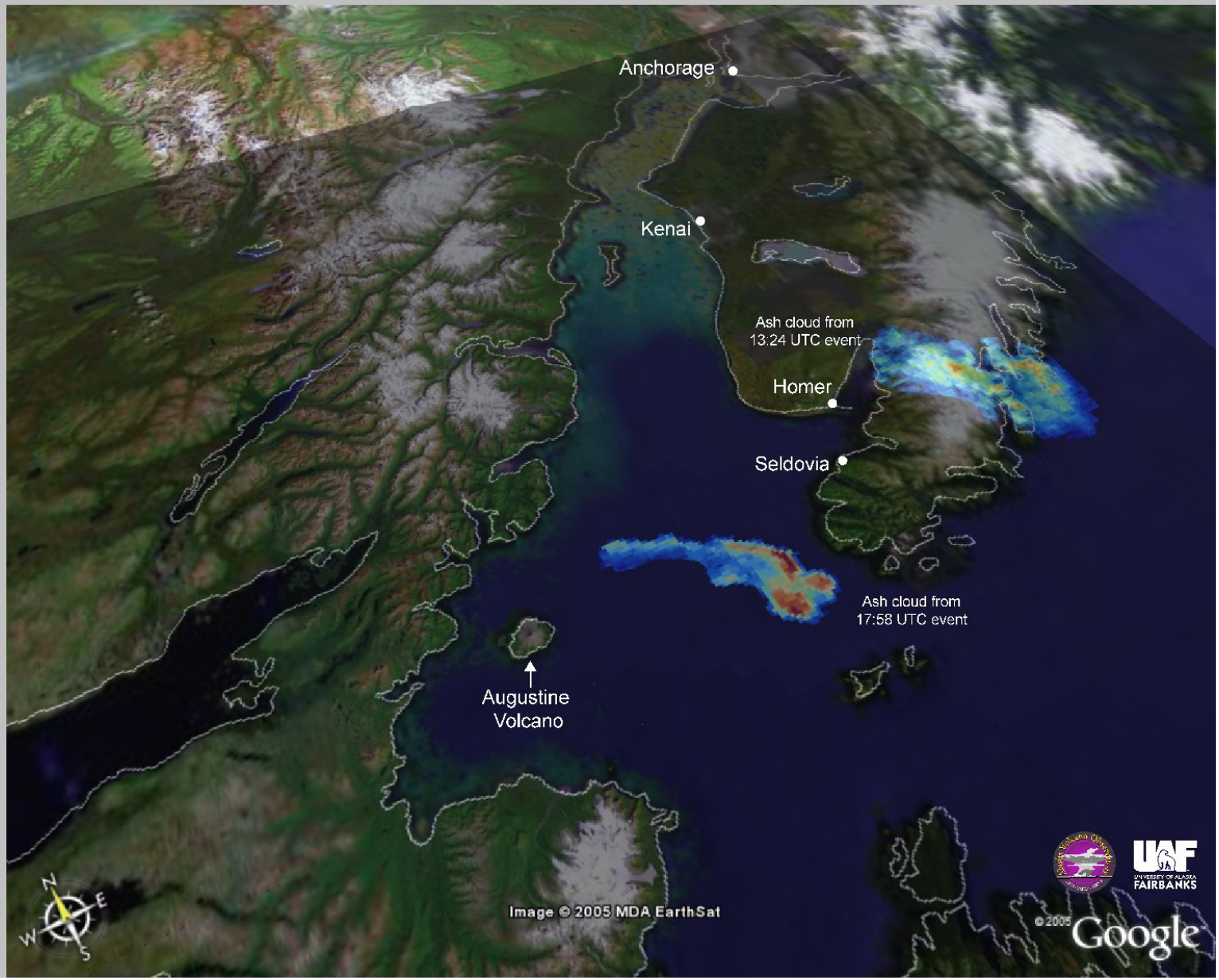
New: Satellite Images in Google Earth

Augustine Ash Clouds, 13 Jan

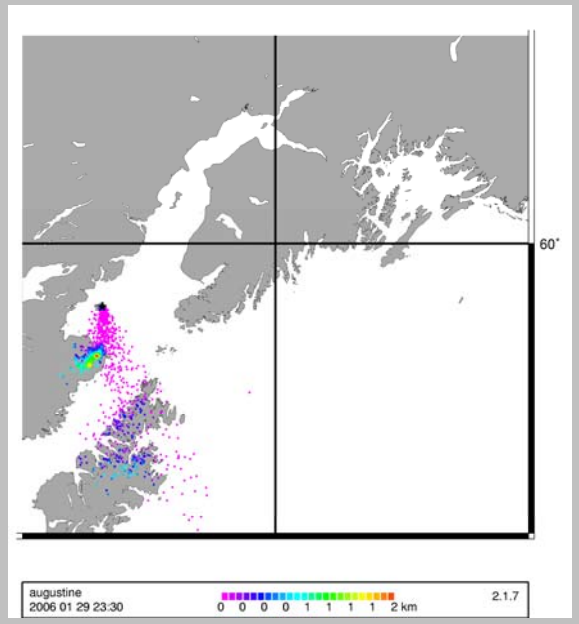
Excellent Geographic Control

Simple interface

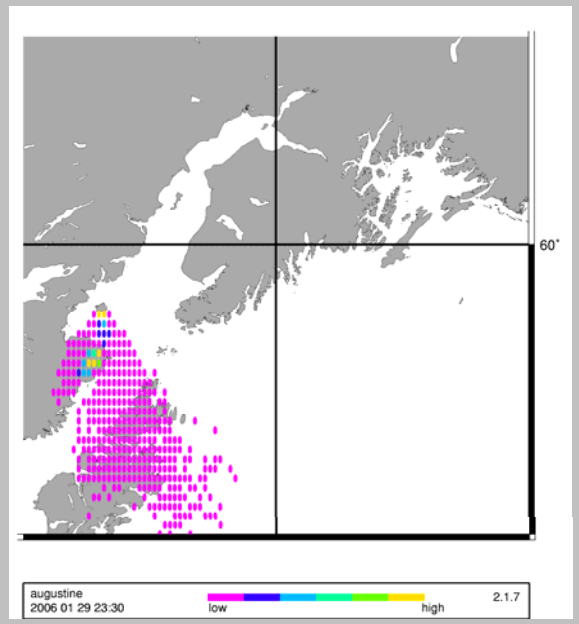
Easy for customers To use and understand



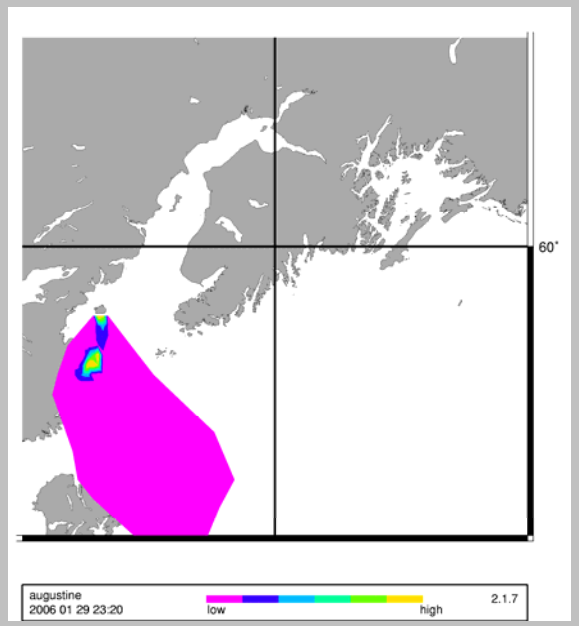
Under development: Ash Fall Mapping



Ash fallout by height



Ash fallout concentration (Points)



Ash fallout concentration (Contours)

Delimas and Future Developments

Automated effusion rates or thermal flux to predict eruptions.

Quantification of ash concentration observed on Satellite data and predicted by models.

Incorporate SO2 detection into monitoring system.

incorporate SAR deformation & amplitude into volcano monitoring program.

Book Publication Date: Summer 2007

Puff Model of 30 yrs of Eruptions

Volcanic Eruptions in North Pacific Region

Puff Volcanic Ash Dispersion Model

Time Series

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