Aviation Weather Forecasting With Satellites

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Overview

• Images from geostationary satellites (GOES) can be applied to detect and forecast aviation weather hazards including:
  • Icing
  • Volcanic ash clouds
  • Turbulence
  • Thunderstorm winds
What is a geostationary satellite?

• Located 36,000 km above the earth, the GOES (Geostationary Operational Environmental Satellite) continuously observes the same region (the western hemisphere).

• Why 36,000 km?
GOES Aviation Products

• The GOES aviation forecast products are based on energy measured in different wavelength bands:
  – formulas that add or subtract satellite measured temperatures to show regions of high risk to aircraft.

• Cloud characteristics:
  – Composition
  – Morphology: form and structure and change with time
Electromagnetic Spectrum

The electromagnetic spectrum is divided into several regions based on wavelength. The visible spectrum is highlighted in the center. The regions include:

- Ultraviolet (UV)
- Blue
- Green
- Red
- Infrared (IR)

Other regions include:

- Gamma rays (γ-rays)
- X-rays
- Thermal Infrared
- Microwave
- Near & Mid Infrared
- TV/Radio
## GOES Channels

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength (μm)</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Visible)</td>
<td>0.52-0.77</td>
<td>Cloud detection and identification</td>
</tr>
<tr>
<td>2 (Shortwave IR)</td>
<td>3.76-4.03</td>
<td>Fog identification, water vs. ice clouds</td>
</tr>
<tr>
<td>3 (Water Vapor)</td>
<td>5.77-7.33</td>
<td>Moisture content</td>
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<td>4 (Longwave IR)</td>
<td>10.2-11.2</td>
<td>Cloud top temperature</td>
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<td>5 (Longwave IR)</td>
<td>11.5-12.5</td>
<td>Low-level moisture</td>
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<tr>
<td>6 (Longwave IR)</td>
<td>12.96-13.72</td>
<td>Cloud characteristics</td>
</tr>
</tbody>
</table>

GOES Aviation Products
Quiz

• What is a geostationary satellite?
• What generates energy received by the satellite in the visible band?
• What generates energy received by the satellite in the infrared bands?
• Name 3 weather hazards to aviation.
Aviation Weather

Considerations:

• Aircraft characteristics:
  – Size
  – Design
  – Instruments

• Pilot experience
Aircraft Instruments

- Most aircraft are equipped with a standard set of **flight instruments** which give the pilot information about the aircraft's attitude, airspeed, and altitude.
- **Most aircraft have these six basic flight instruments:**
  - Altimeter
  - Airspeed indicator
  - Magnetic compass
  - Heading indicator
  - Turn and bank indicator
  - Vertical speed indicator
Aircraft Icing

• In-flight icing is the accretion of supercooled liquid water (SLW) on the airframe. This SLW can be in the form of cloud droplets or freezing rain/drizzle.
Aircraft Icing Hazards

• Icing can adversely affect the flight characteristics of an aircraft. Icing can increase drag, decrease lift, and cause control problems.

• Recent icing-related accident: Canadair jet, Montrose, Colorado, 28 November 2004.
  – Six occupants on board: 3 dead, 3 seriously injured
Aircraft Icing

• Weather conditions related to aircraft icing:
  – liquid clouds with temperatures in the 0 to -20 C range
  – large water drop sizes
  – large liquid water content
  – thick, extensive cloud systems resulting in long exposure to icing conditions during flight.
Icing Intensity

- **LIGHT**: The rate of accumulation may create a problem if flight is prolonged in this environment (over one hour).
- **MODERATE**: The rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or diversion is necessary.
- **SEVERE**: The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate diversion is necessary.
Satellite Icing Detection

Decision Tree For GOES-12 Aircraft Icing Image Product

Input GOES CHs 1, 2, 4

- Ch4 IR: 0 > T > -25°C?
  - No: No Icing
  - Yes: Use CH4 IR Data

Cloud Top Temperatures

- CH1 (Vis): B > 40?
  - Day: Liquid Water Clouds?
    - Yes: No Icing
    - No: CH1 B > 166 counts?
      - Yes: CH1 corrected for SZA
        - Yes: Icing Likely
        - No: No Icing
      - No: No Icing
  - Night: (T2 - T4) < -2°C?
    - Yes: No Icing
    - No: No Icing

Gary Elliott
NOAA/NESDIS
Washington, DC
GOES Icing Product
Aircraft Icing Quiz

• What is Icing?
• Why is icing a hazard to aircraft in flight?
• Why is icing important to detect and forecast?
Turbulence

Something Wrong?

GOES Aviation Products
Turbulence

• Definition:
  – Irregular motion in the atmosphere, can be observed as gusts and lulls in the wind.

• Causes:
  – Vertical wind shear
  – Convection
Causes of Turbulence

Clear-air Turbulence (CAT)

Mountain wave Turbulence (MWT)

In-cloud turbulence

Cloud-induced or Convectively-induced Turbulence (CIT)

Convective boundary Layer turbulence

Low level Terrain-induced Turbulence (LLT)

Turbulence Hazards

• Why is turbulence a hazard to aircraft?
  – **Structural Damage**: Results from encountering severe clear air turbulence. In extreme cases, this can lead to the break up of the aircraft. In even moderate turbulence, damage can occur to fittings within the aircraft especially as a result of collision with unrestrained items of cargo or passenger luggage. Prolonged exposure to turbulence will shorten the fatigue life of the aircraft.
  – **Physical Injury to Crew/Passengers**: Passengers and crew walking around the aircraft cabin can be injured.
  – 1997: United Airlines B747 encountered CAT over the Pacific ocean. Several passengers and crew were severely injured, one death.

• Why is it important to forecast turbulence?
  – Aircraft can avoid regions of severe turbulence.
Jet Stream Turbulence
Low-level Turbulence

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Turbulence Quiz

• What is turbulence?
• What are different types of turbulence?
• Why is turbulence a hazard to aircraft?
• Why is it important to forecast turbulence?
• Where can turbulence occur?
Turbulence Quiz

GOES Aviation Products
Volcanic Ash Hazards

• In addition to damaging the leading edge surfaces of aircraft, ash ingested into jet engines results in loss of performance, and possibly complete shutdown.

From: FAA Aviation Safety Journal Vol. 2 (3)

Mt. Redoubt, AK 1750 UTC 26 March 2009
Taken from Diamond Ridge near Homer, AK
Satellite Volcanic Ash Detection

- Combine information from the shortwave IR (CH 2), with two longwave IR channels (4 and 5).
- Temperature differences in Bands 4 and 5 can help identify areas of volcanic ash due to unique energy properties.
Satellite Volcanic Ash Detection

Anchorage Radar

GOES Volcanic Ash Product

GOES Aviation Products
Satellite Volcanic Ash Detection

GOES Aviation Products
Volcanic Ash Quiz

• Why is volcanic ash a hazard to aircraft in flight?
• Why is volcanic ash important to detect and forecast?
Volcanic Ash Quiz

Alaska Volcano Sector
GOES-West Experimental Volcanic Ash Product (IR CHs 2, 4, 5)

Bering Sea
McKee
Redoubt
Anchorage

GOES Aviation Products
Downburst and Microburst

- Strong downdraft produced by a convective storm (or thunderstorm) that causes **damaging winds** on or near the ground.
- Due to the resulting **intense wind shear**, downbursts are a **hazard to aircraft** in flight, especially during takeoff and landing.
Microburst Hazards
Microburst Hazards

![Diagram of Microburst Hazards]

- **Headwind**: Slows and lifts plane above normal path.
- **Downdraft**: While pilot compensates for headwind by dipping nose, plane enters downdraft.
- **Tailwind**: Dangerously reduces plane’s speed.
- **Normal landing glide path**
  - **Airport runway**
Historic Microburst-Related Airline Disasters

- Eastern 66, New York (JFK), June 1975
- Continental 426, Denver, August 1975
- Pan American 759, New Orleans, July 1982
- Delta 191, Dallas-Ft. Worth (DFW), August 1985
- USAIR, Charlotte (CLT), July 1994
- American Airlines, Little Rock (LIT), June 1999
Microburst Quiz

- What is a downburst/microburst?
- Why are microbursts a hazard to aircraft?
- Why is it important to forecast microbursts?
- Where do microbursts occur?
Microburst Quiz

GOES Aviation Products
GOES Aviation Products

http://www.star.nesdis.noaa.gov/smcd/opdb/aviation/aviation.html
Summary

• Aviation weather requires understanding:
  • Aircraft characteristics
  • Hazards
  • Weather conditions
  • Detection methods
  • Satellite imagery interpretation
    – Identify meteorological features/hazards
Questions?

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