Identifying stratospheric air intrusions and associated hurricane-force wind events over the north Pacific Ocean

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BACKGROUND

Motivation

- Ocean data is sparse
  - Reliance on satellite imagery for marine forecasting
- Ocean Prediction Center (OPC) – "mariner's weather lifeline"
  - Responsible for:
    - Pacific, Atlantic, Pacific Alaska surface analyses/forecasts – 24, 48, 96 hr
    - Wind & wave analyses/forecasts – 24, 48, 96 hr
    - Warning Services & Decision Support
- Geostationary Operational Environmental Satellite – R Series (now GOES-16)[4] comparable to Japanese Meteorological Agency's Himawari-8

Stratospheric Air Intrusions

AKA: tropopause folds, stratosphere-troposphere exchange (STE), dry intrusion

- Exchanges of air between stratosphere and troposphere
  - Differences in humidity, ozone levels, and potential vorticity
- Importance to weather systems[1,3]
  - +PV anomaly changes vertical distribution of potential temperature & vorticity
  - Promotes rapid cyclogenesis

Research Question: How can integrating satellite data imagery and derived products help forecasters improve prognosis of rapid cyclogenesis and hurricane-force wind events?

Phase I – Identifying stratospheric air intrusions

- Water Vapor – 6.2, 6.9, 7.3 µm channels
- Airmass RGB Product
- AIRS, IASI, ATMS/CrIS total column ozone & ozone anomaly
- ASCAT (A/B) and AMSR-2 wind data

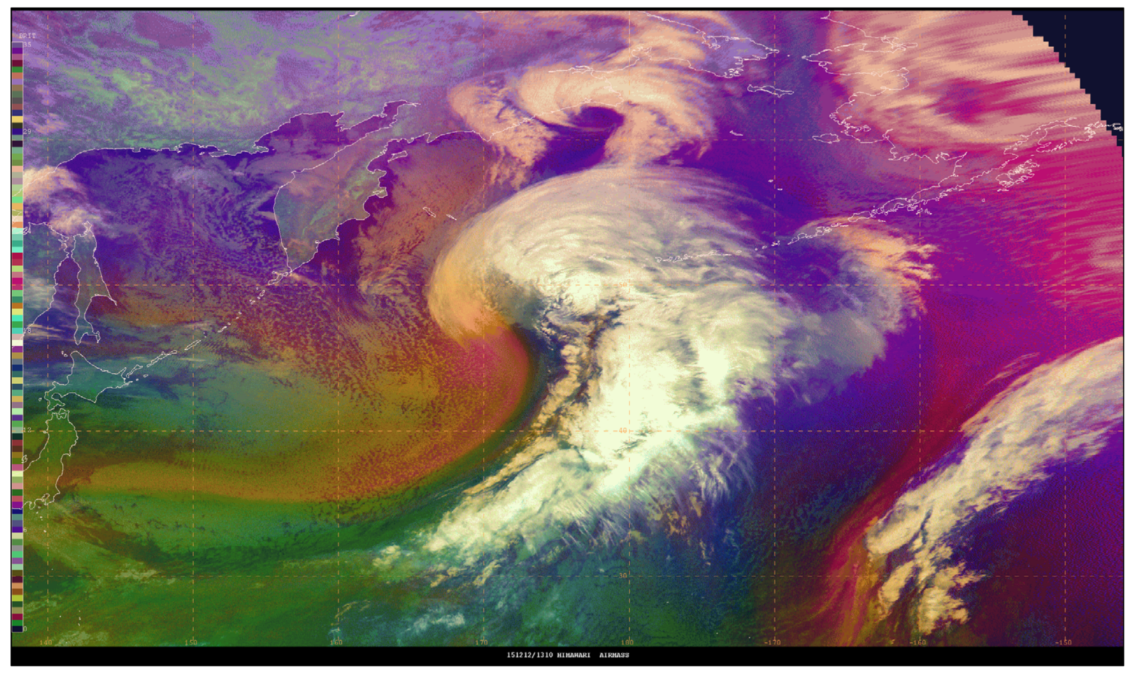
DATA & METHODS

Himawari-8 Airmass RGB

- Each color band represents a wavelength (difference)
- Different wavelengths capture different layers of atmosphere

Red	6.2 µm minus 7.3 µm, representing moisture between 300-700 mb
Green	9.6 µm minus 10.3 µm, representing thermal response & tropopause height
Blue	6.2 µm inverted, representing moisture between 200-400 mb

DRY MOIST

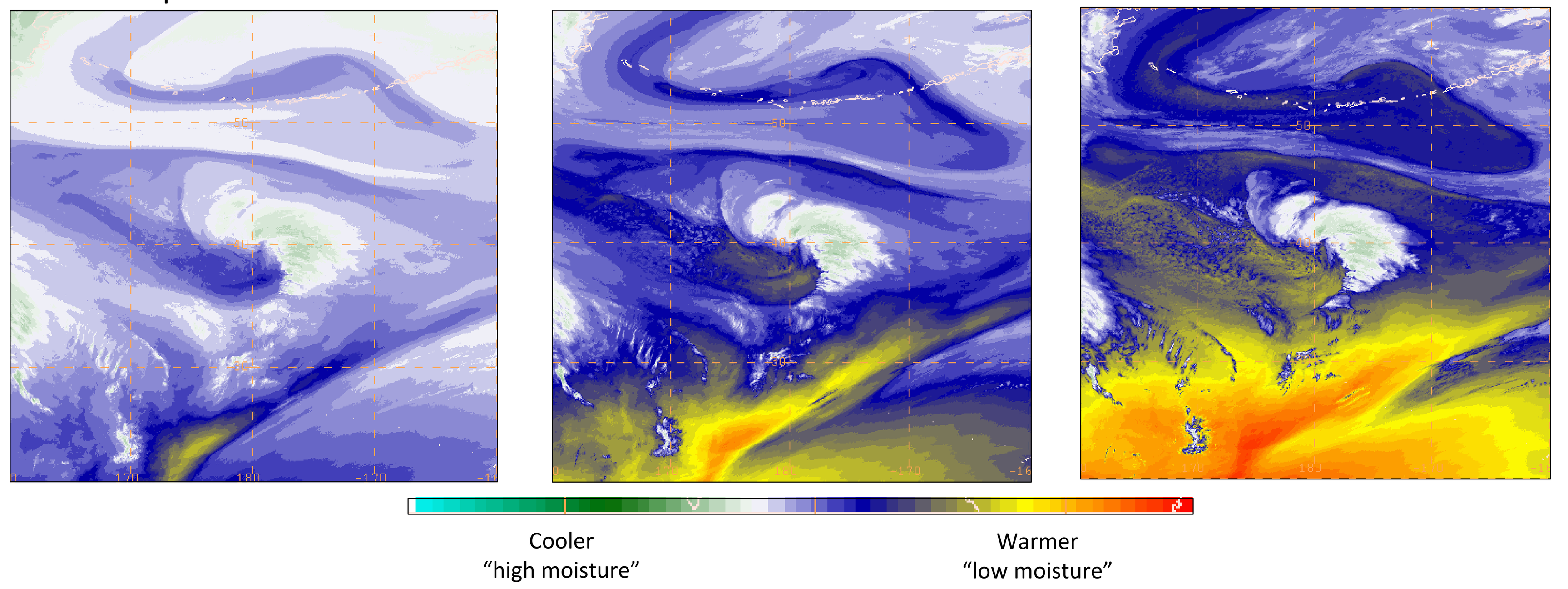


Himawari-8 Water Vapor

Upper-layer
- 6.2 µm channel
- Peak response at ~350 mb

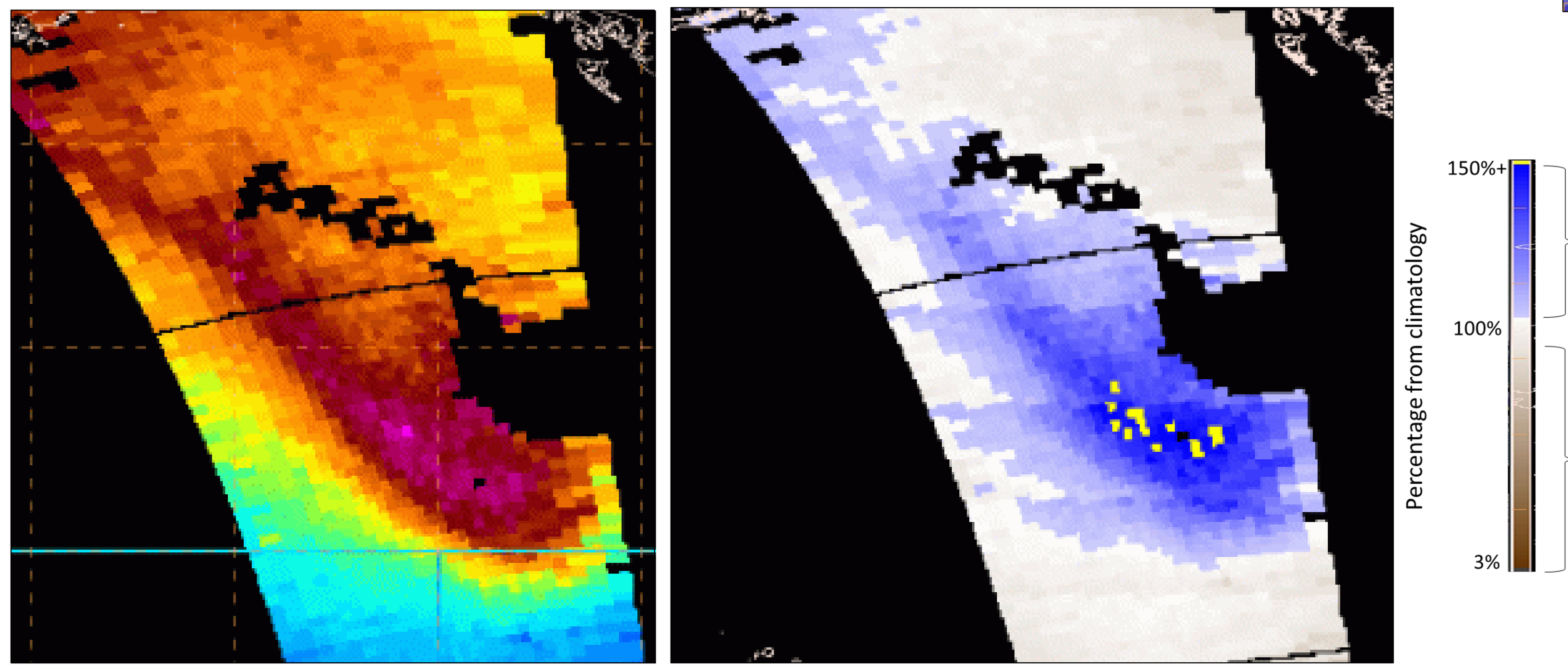
Middle-layer
- 6.9 µm channel
- Peak response at ~450 mb

Lower-layer
- 7.3 µm channel
- Peak response at ~650 mb



Total Column Ozone & Ozone Anomaly

- Used to help quantify Airmass RGB
- Examples of instruments:
  1. Aqua's Atmospheric Infrared Sounder (AIRS)
  2. S-NPP's Cross-track Infrared Sounder/Advanced Technology Microwave Sounder (CrIS/ATMS)
  3. Metop-B's Infrared Atmospheric Sounding Interferometer (IASI)



Courtesy of Emily Berndt

Scatterometer & Microwave Radiometer

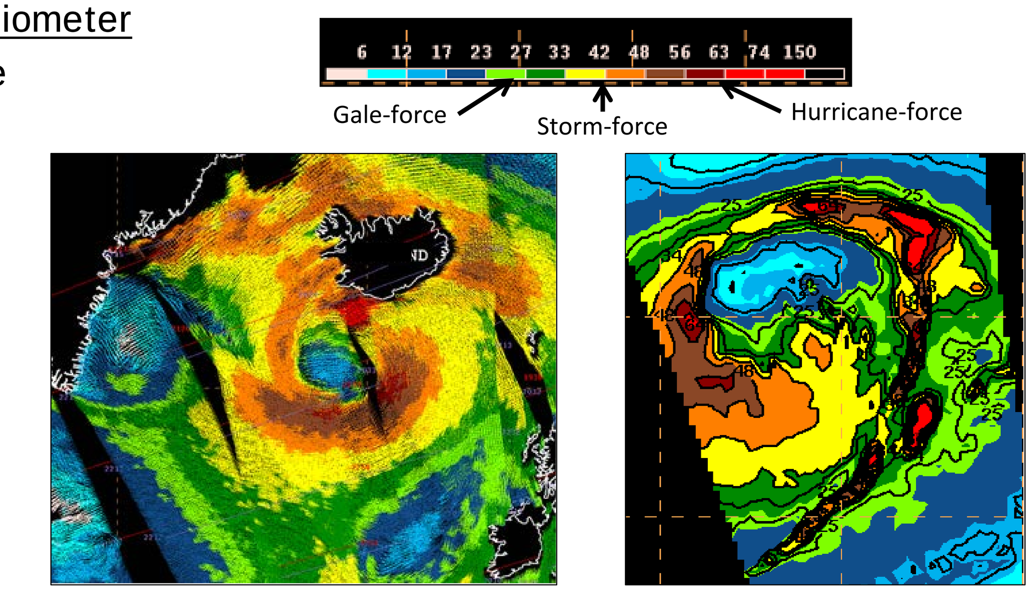
- Used to verify hurricane-force

Scatterometer
- Measures backscatter of radar signal for wind speed & direction

e.g. Advanced SCATterometer (A/B)

Microwave Radiometer
- Measures microwave signal response for only wind speed

e.g. Advanced Microwave Scanning Radiometer (AMSR-2)



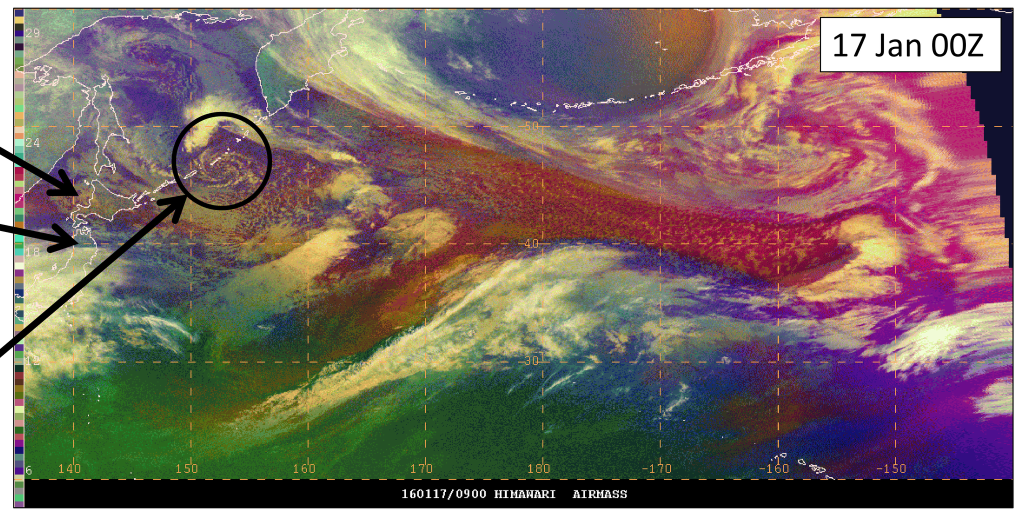
CASE STUDY ANALYSIS

Case: January 17-19, 2016

- Developed rapidly despite small size
- Hard to distinguish its early features

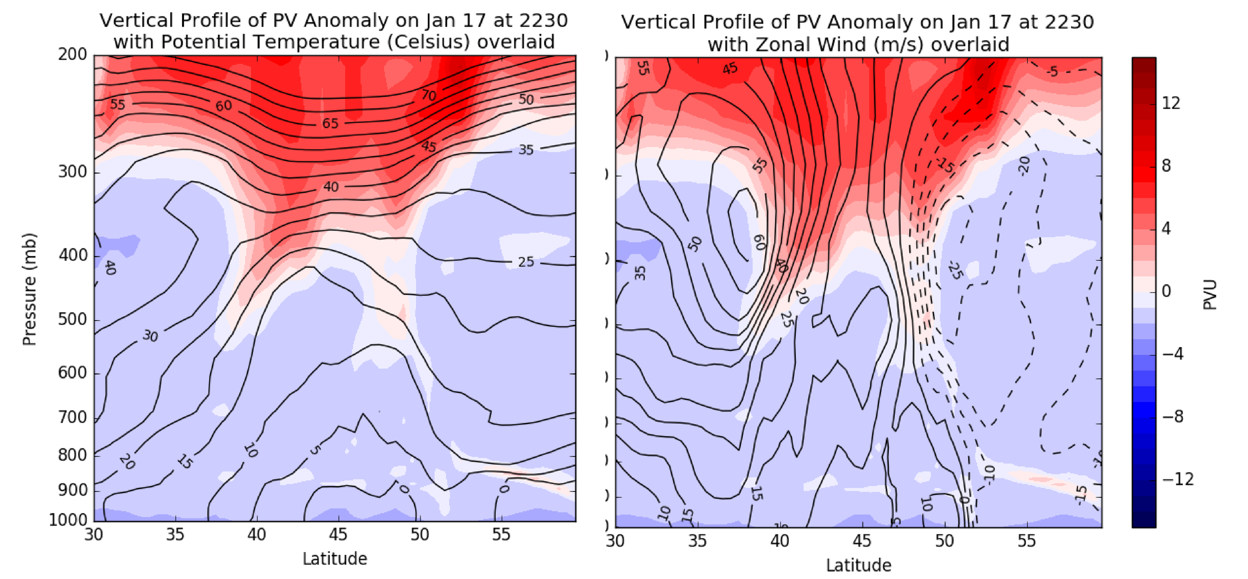
1. Early features

- PV streamer
- Baroclinic leaf supplying latent heat
- Piece of vorticity absorbed by streamer

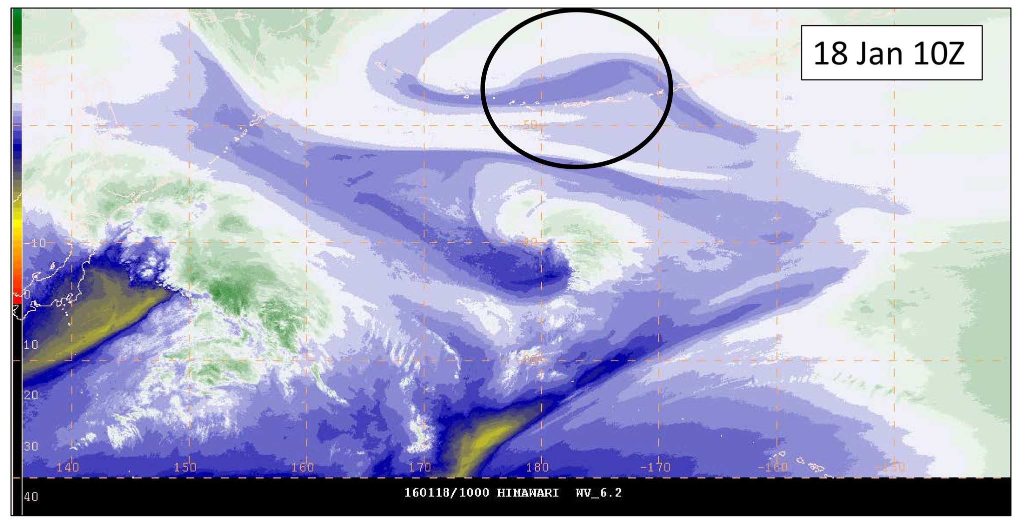


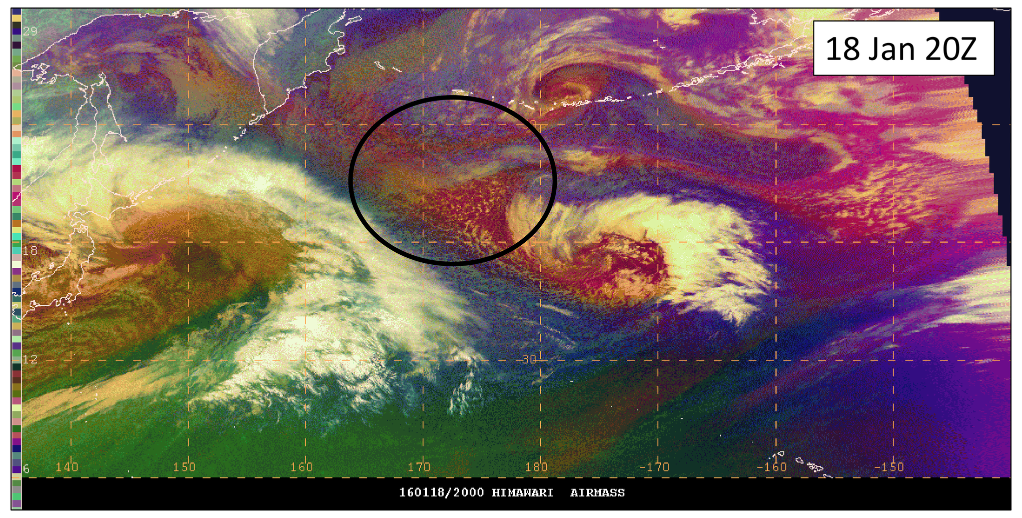
MERRA-2 Global Reanalysis Model Visualization

- Intrusion develops January 17 seen by dip of anomalous PV
- Stable air associated with stratosphere and less-stable air in troposphere
- Counterclockwise rotation around intrusion and max winds at PV gradient



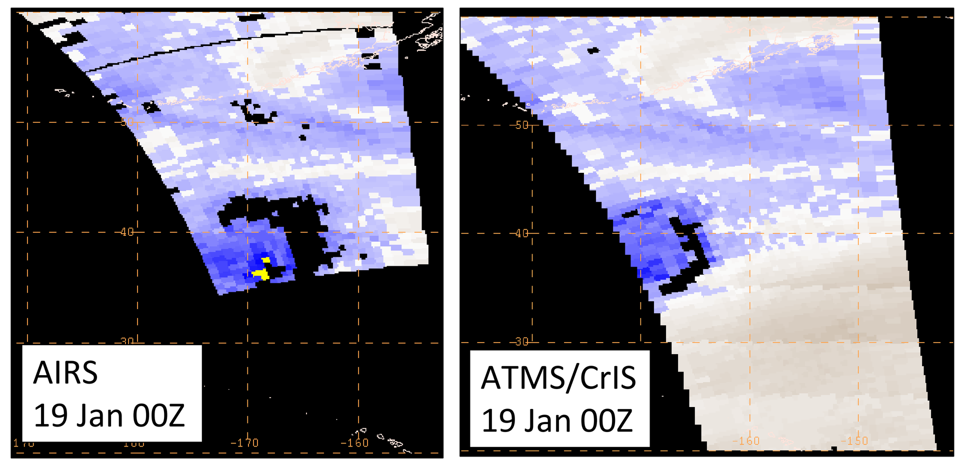
Cross-section (170°E, 30 ° to 60°N) of intrusion for 17 January 2230 UTC with PV anomaly with respect to 2 PVU as dynamical tropopause; (left) overlaid with potential temperature and (right) overlaid with zonal wind





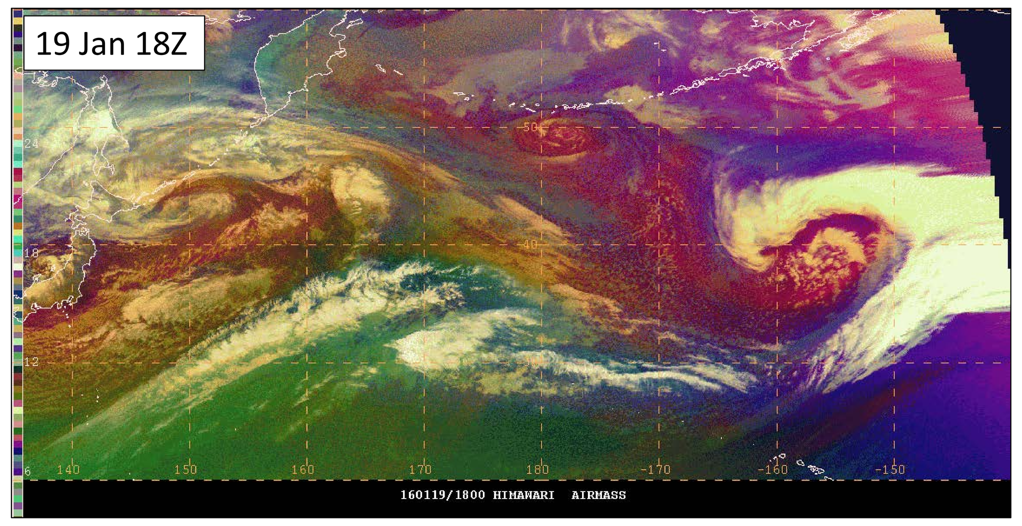
2. Rapid Development

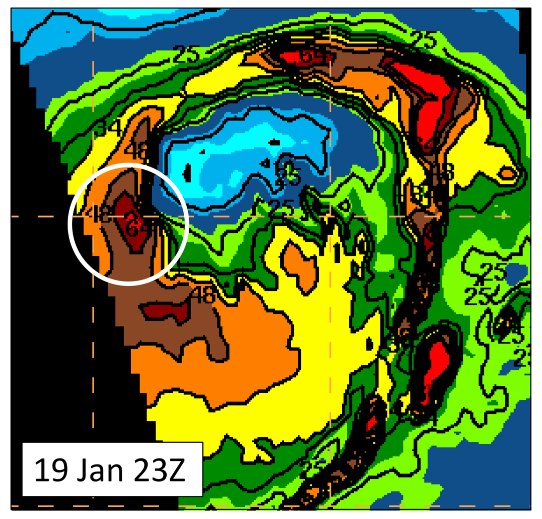
- Small comma cloud that gets brighter
- Clear dry belt using RGB Airmass red colors
- Vortex lobe north of system that threatens, eventually intersecting with original streamer
- Anomalous ozone becoming more condensed
- AIRS suggesting 150%+ climatology



3. Peak Intensity

- Shapiro-Keyser cyclone model features
  - Before peak intensity, cloud head becomes more zonally oriented
  - Vortex shedding
- Can spot the dry belt, cold front, occlusion using RGB Airmass
- Possible warm seclusion in low pressure center
- AMSR-2 picks up hurricane-force winds right outside occlusion





CONCLUSION

Summary

- Stratospheric air intrusions → +PV → Explosive cyclogenesis → Hurricane-force winds
- Single Water Vapor channels supply forecasters with information about jet stream interactions and tropopause folds
  - Can only look at single layer of atmosphere at a time
  - Doesn't give info about if air is from stratosphere
- Potential in Airmass RGB + ozone products to identify stratospheric air intrusions
  - Demonstrated in case studies
  - Experimental for real-time use

Future Work

- Finishing case studies
  - Similar satellite imagery
  - MERRA-2 global reanalysis model visualization
- Build instructional toolkit for OPC and Alaskan Weather Forecast Offices
  - More real-time use
  - Training for RGB Airmass and ozone products as supplementary information about stratospheric air intrusions
  - Apply to GOES-16

Name	Date Range	Reasons for Interest
Bering Sea Bomb	December 10-13, 2015	• One of the strongest (924 mb center) non-tropical storms on record • Large impacts
Spring Transition	April 5-9, 2016	• Late season cyclone • Atypical development
TC Songda Transition	October 12-15, 2016	• Lost most of its tropical features • Atypical extratropical transition & development

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