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

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INTRODUCTION

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 - 24, 48, 96 hr
    - Wind & wave analyses - 24, 48, 96 hr
    - Issue warnings, make decisions
- Geostationary Operational Environmental Satellite - R Series (now GOES-16)[4]
  - Compared to the old GOES:
    - 3x spectral resolution
    - 4x spatial resolution
    - 5x faster coverage
  - Comparable to Japanese Meteorological Agency's Himawari-8, used a lot throughout this research

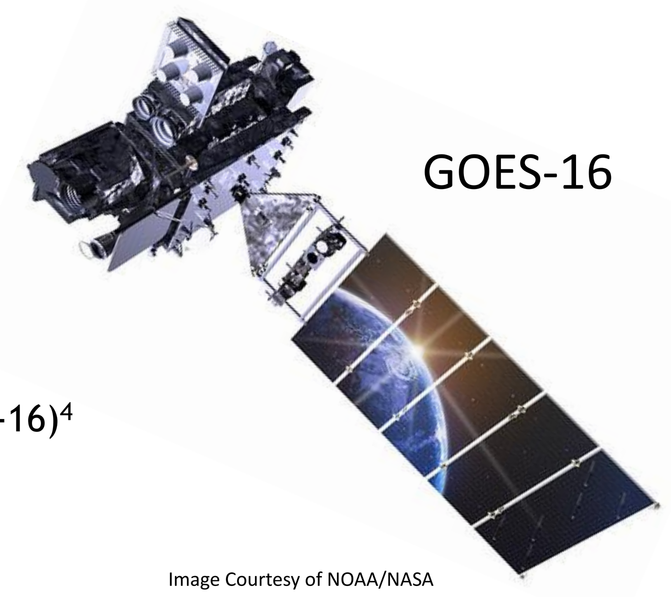

GOES-16

Image Courtesy of NOAA/NASA

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, NUCAPS total column ozone & ozone anomaly
- ➢ ASCAT (A/B) and AMSR-2 wind data

BACKGROUND

Stratospheric Air Intrusions

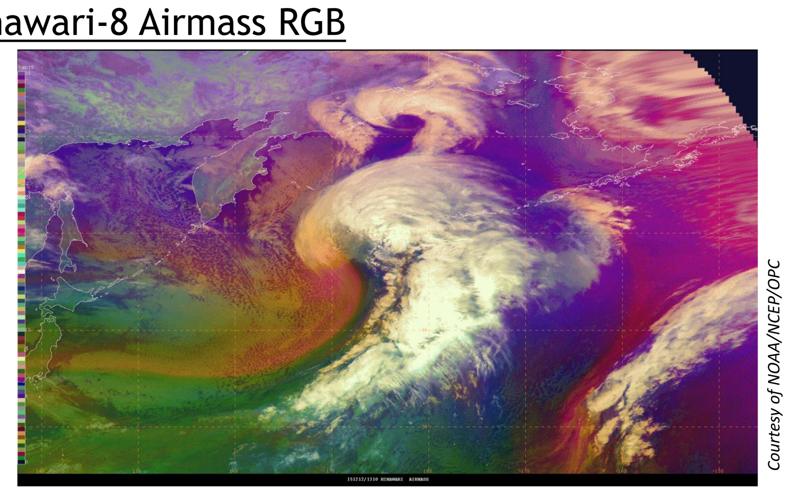
AKA: tropopause folds, stratosphere-troposphere exchange (STE), dry intrusion

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

Troposphere	Stratosphere
Higher humidity	Lower humidity
Lower potential vorticity values	Higher potential vorticity values
Lower ozone	Higher ozone

DATA & METHODS

Himawari-8 Airmass RGB


Courtesy of NOAA/NCEP/OPC

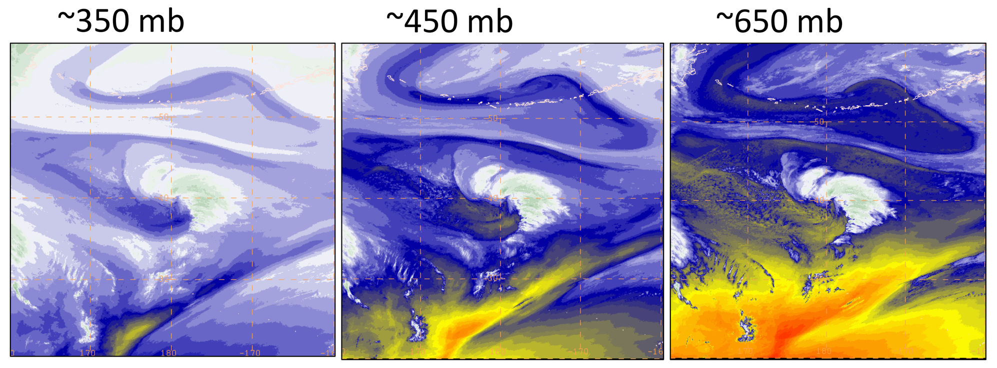
- Each color band represents a wavelength (difference)
- Different wavelengths capture different layers of atmosphere

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

DRY | MOIST

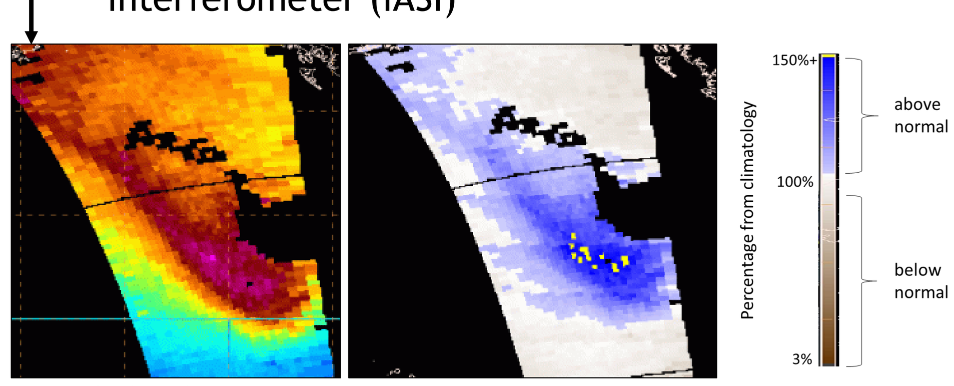
Himawari-8 Water Vapor

- 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

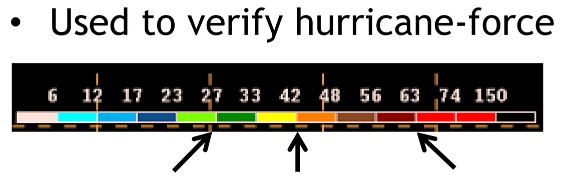
- Used to help quantify Airmass RGB
- Examples of instruments:
  1. Aqua's Atmospheric Infrared Sounder (AIRS)
  2. S-NPP's Cross-track Infrared Sounder/Advanced Technology Microwave Sounder (CrIS/ATMS)
  3. Metop-B's Infrared Atmospheric Sounding Interferometer (IASI)

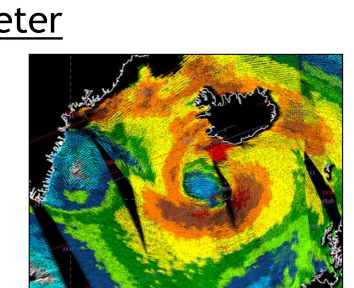


Courtesy of Emily Berndt

Scatterometer & Microwave Radiometer

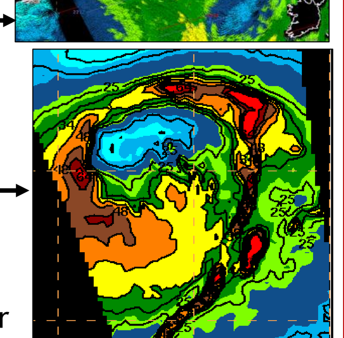
- Used to verify hurricane-force





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

e.g. Advanced SCATterometer (ASCAT A/B)



Microwave Radiometer
- Measures microwave signal response for only wind speed

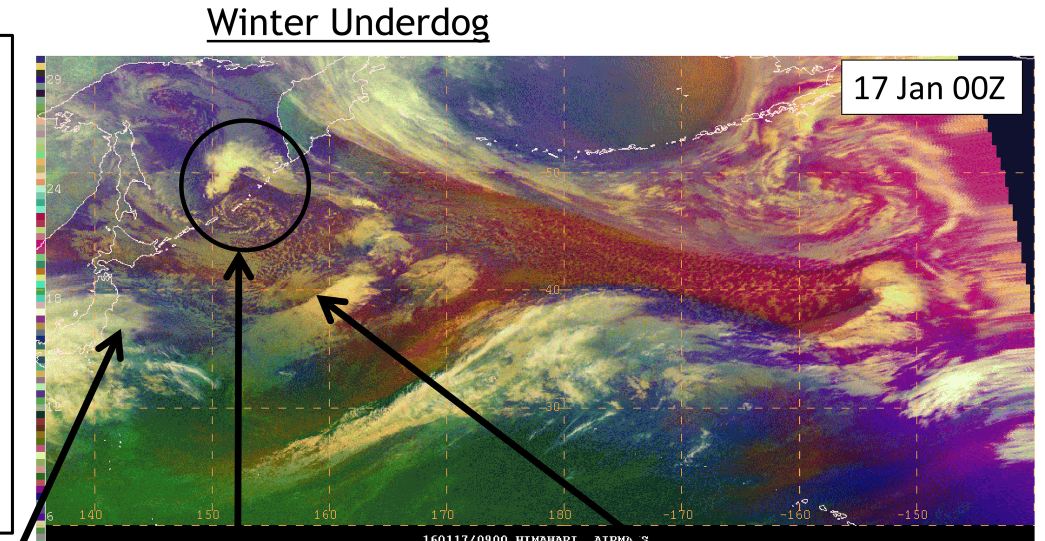
e.g. Advanced Microwave Scanning Radiometer (AMSR-2)

CASE STUDY ANALYSIS

Name/Identifier	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
Winter 'Underdog'	January 17-19, 2016	• Developed rapidly despite small size • Hard to distinguish its early features
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

Winter Underdog

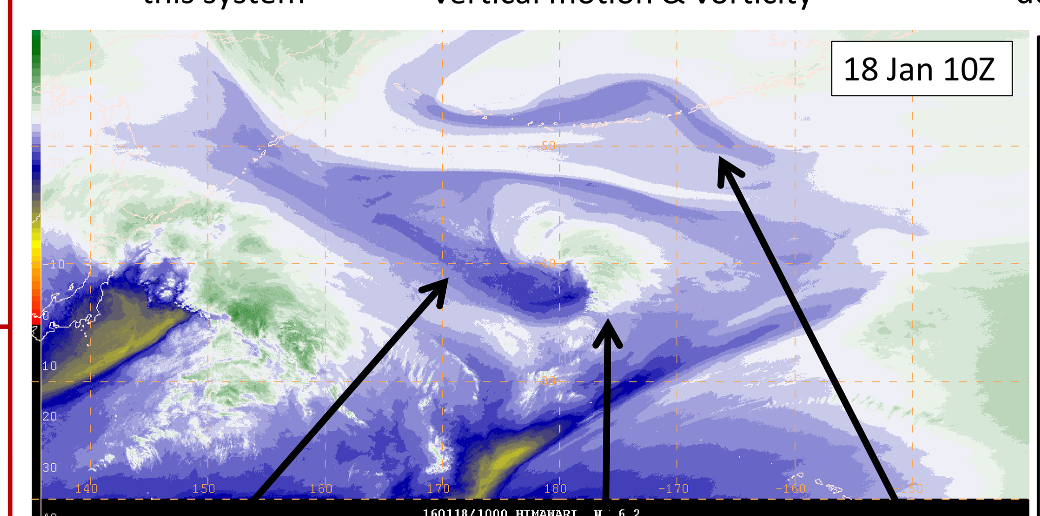
Early features
- PV streamer
- Baroclinic leaf supplying latent heat
- Piece of vorticity absorbed by streamer



Latent heat energy from this system

Mid-level circulation= vertical motion & vorticity

Intrusion and cloud development begin



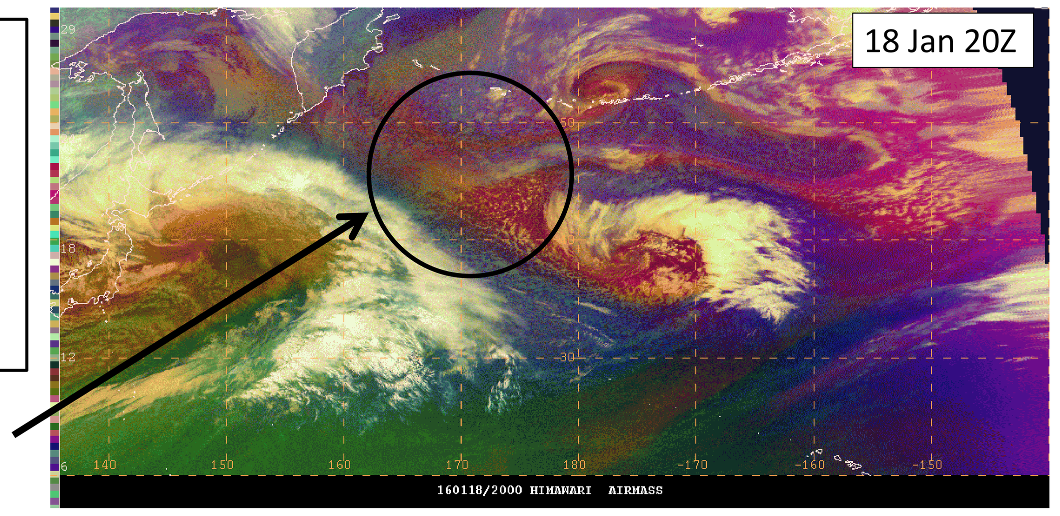
Stream of dry air still feeding system

Comma cloud develops

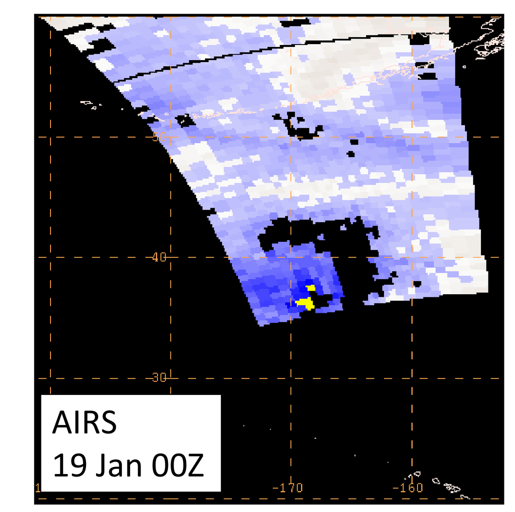
Vortex lobe

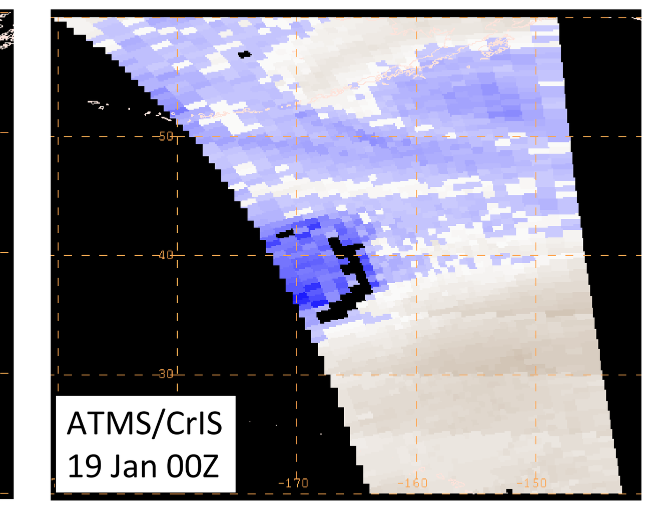
Rapid Development
- Small comma cloud
- Clear dry belt
- Vortex lobe north of system that threatens

Rapid Development
- RGB Airmass really shows the stream of dry, high PV air
- Vortex lobe's streamers intersecting with original streamer
- Comma cloud getting brighter

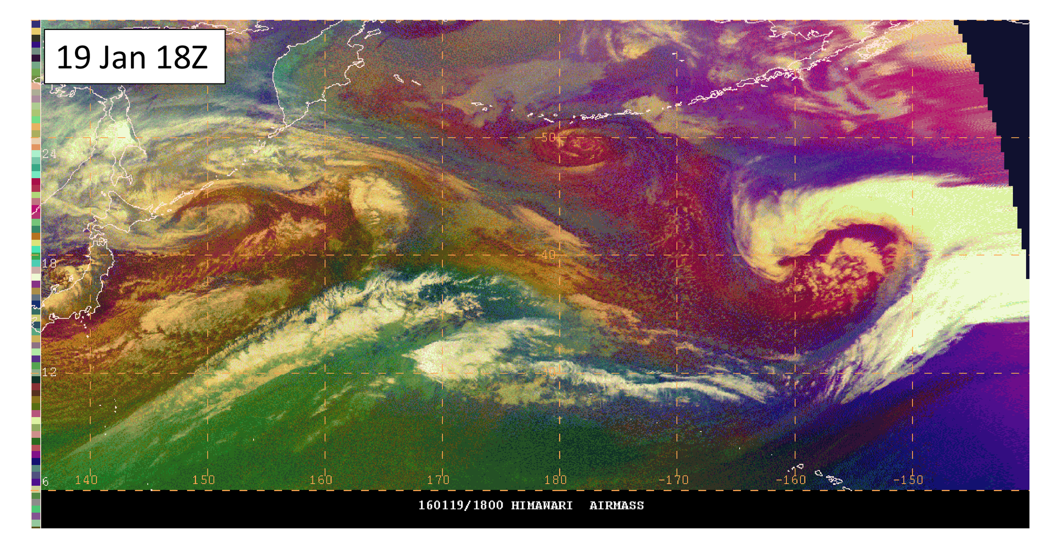


Intersection of dry air from multiple systems

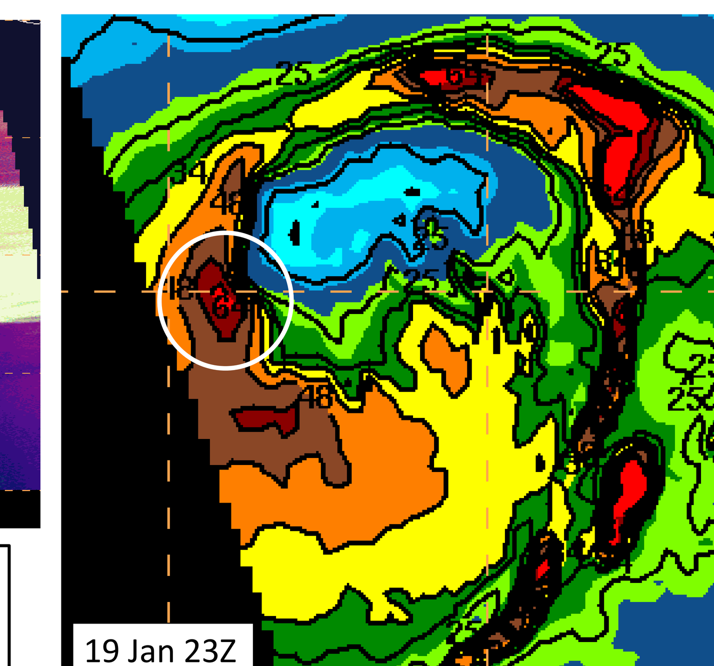




Rapid Development
- Anomalous ozone becoming more condensed
- AIRS and ATMS/CrIS relatively agree
- AIRS suggesting 150%+ climatology
- Know system must be rapidly intensifying



Peak Intensity
- Before peak intensity, cloud head becomes more zonally oriented
- Vortex shedding
- Can spot the dry belt, cold front, occlusion
- Warm seclusion?

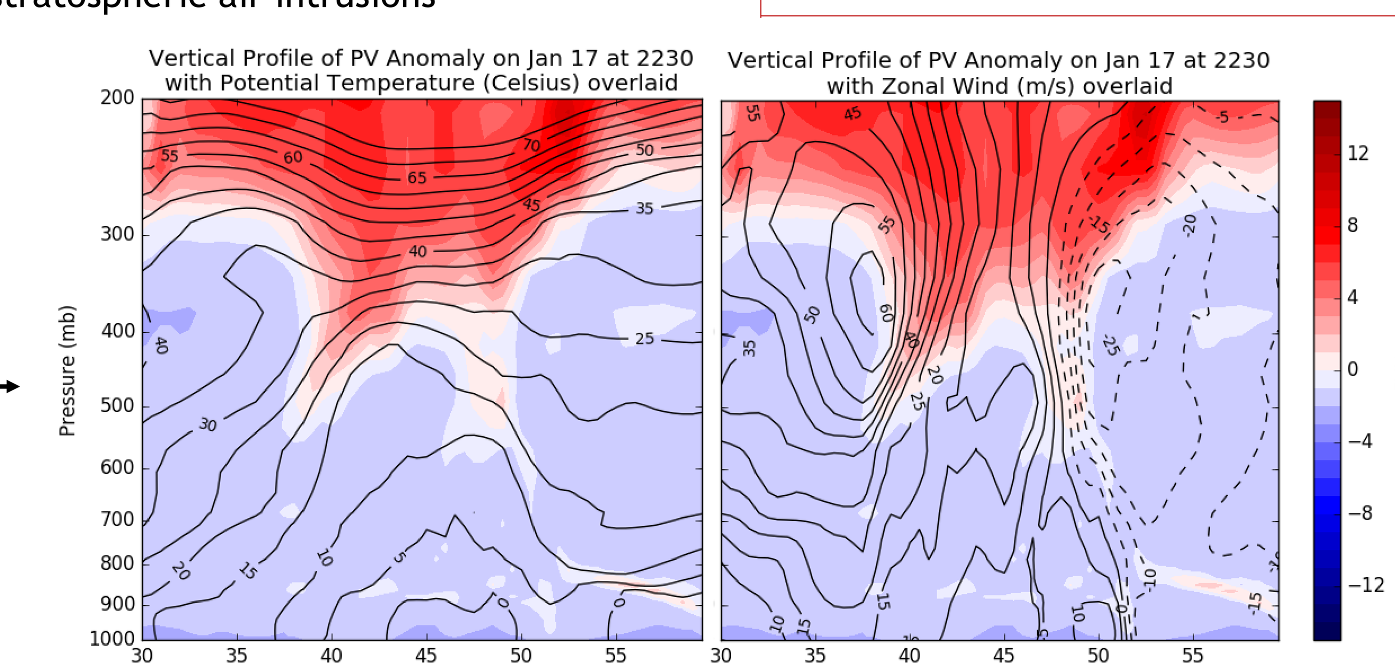


Peak Intensity
- AMSR-2 picks up hurricane-force winds right outside occlusion

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 one single layer of atmosphere at a time
  - Doesn't give information 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
  - Incorporating MERRA-2 global reanalysis model visualization
    - Preview of Jan 17 intrusion →
- 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



Cross-section (170⁰E, 30 ⁰ to 60⁰N) 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

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