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Investigation of General Aviation Accidents in Hawai'i from 2003–2022

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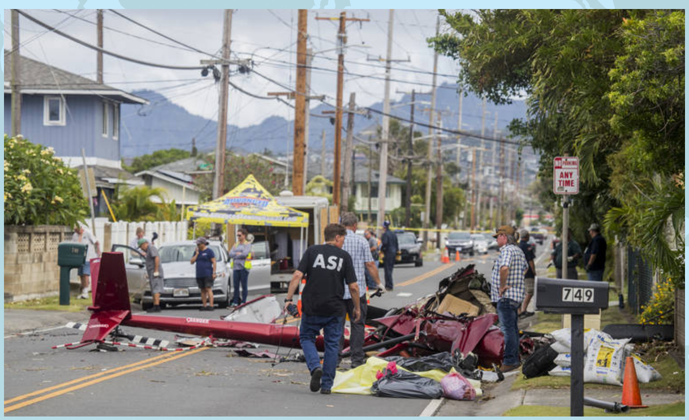
Motivation – What is Going On?

NTSB has investigated 187 airplane and helicopter accidents in Hawaii since 2003, many of which were fatal. Weather is listed as the cause or contributing factor in more than half of the fatal accidents.



Wreckage of a fatal helicopter crash on Oneawa Street near Nowela Place in Kailua on April 30, 2019.
Source: staradvertiser.com

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Causes of All Accidents

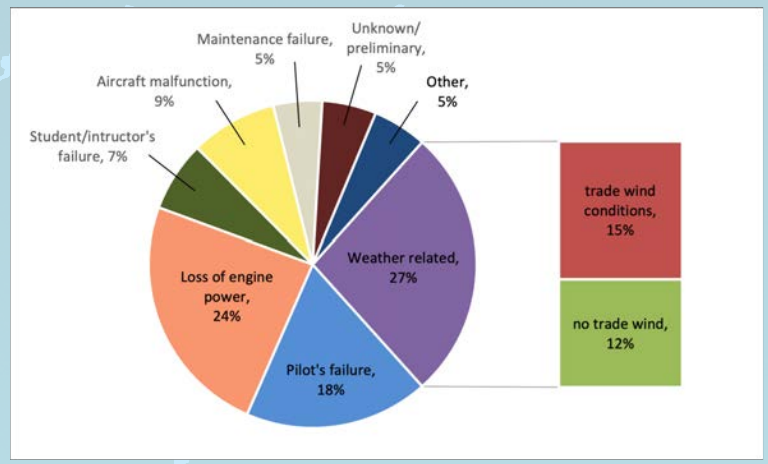

Fig. 1: Accident causes in percent (2003 – 2022). About 27 % of all accidents have a weather-related cause. During 56 % of these weather-related cases are trade winds were present. That means that in total 15% of all accidents are weather related and occurred under trade wind conditions.

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Total Number of Accidents

Total numbers 2003 – 2022:

81 helicopter accidents

106 fixed-wing accidents

187 total aviation accidents!

Weather related accidents 2003 – 2022:

20 helicopter, of which **14** occurred under trade wind conditions

30 fixed-wing, of which **14** occurred under trade wind conditions

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Fatal General Aviation Accidents

35 fatal aviation accidents from 2003 – 2022 (Hawaii)

18 fatal weather related accidents, of which **12** occurred under trade wind conditions

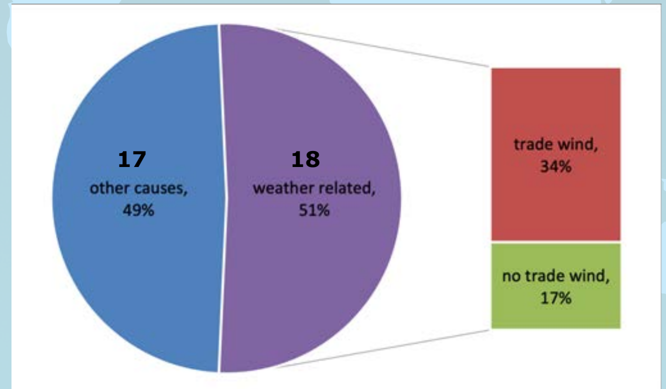

Fig. 2: Hawaii's fatal aviation accidents from 2003 - 2022 in percent. 51% of fatal accidents had weather listed as a cause or contributing factor. Trade winds were prevailing during 2/3 of these accidents.

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Goal of this Project

The overarching goal is to assemble weather data associated with general aviation accidents and then apply machine learning to create a tool to help reduce the number of accidents that are caused by weather in Hawaii.

The initial focus is on accidents during seemingly "benign" trade wind conditions.

Image 2: A sunny trade wind day on O'ahu.

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Literature Overview

- During recent decades there has been a long-term reduction in weather-related aviation accidents in the United States. [1,2]
- However, weather is still the cause or a contributing factor in 20-30% of all aviation accidents in the US [2-5] causing nearly 100 fatalities/year. [1]
- Wind is the most prevalent cause or contributing factor of weather related accidents [1,2], low ceiling is found to be the deadliest weather hazard. [1,3]
- Within the contiguous United States mountainous locations are considered to be the most hazardous for general aviation operations. [1]

[1] Fultz & Ashley, 2016, [2] FFA, 2010, [3] Capobianco & Lee, 2001, [4] NASA, 1999, [5] Kulesa, 2003

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Data Sets

1) NTSB (National Transportation Safety Board) **Reports:** date, time and place of the accident, probable cause and wind data from closest station. Weather related = anytime weather is mentioned as the probable cause or contributing factor (e.g. turbulence, wind, rain, severe weather conditions).

2) ASOS surface wind data: hourly data.

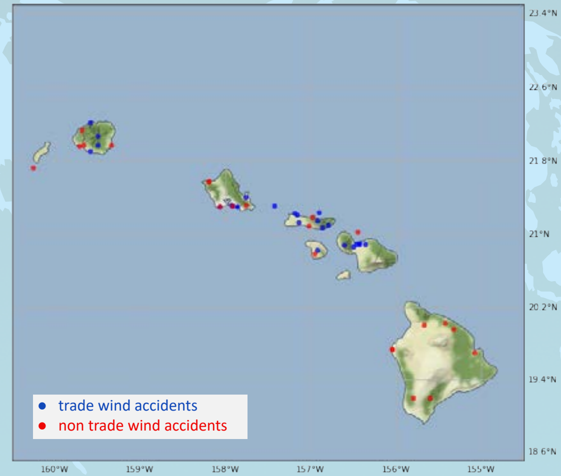
3) NEXRAD (NOAA Next Generation Radar)**:** level 2 and 3 radar data, reflectivity, doppler wind velocity and spectrum width.

4) Satellite: GOES-West & MODIS, large scale weather conditions, open or closed cell convection, fronts and shearlines.

5) Surface analyses: average strength of high surface pressure to the north of Hawaii, SLP gradient for each case, the latter is used to calculate the geostrophic wind.

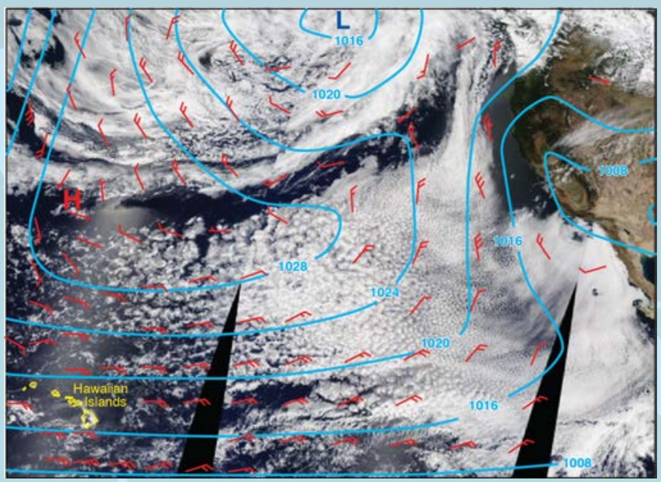
6) Līhu`e and Hilo soundings: trade wind inversion height, maximum wind speed below the inversion, composite (average) wind profile, wind shear, and stability.

Map of Wx Related Accident Sites



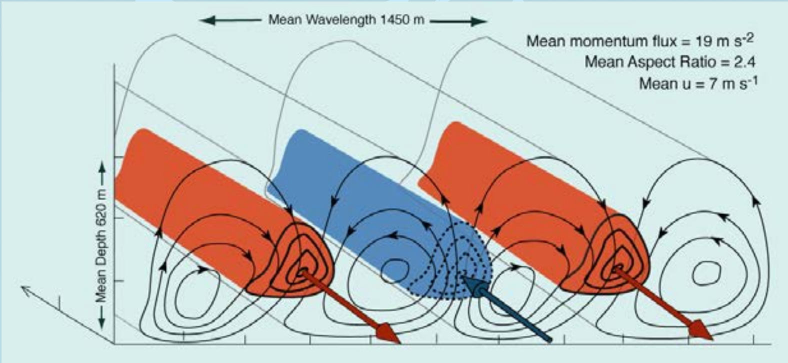
Map showing all weather-related accidents sites from 2003 – 2022. The approximate places of the crashes are marked with blue dots for trade wind cases and red dots for mark non trade wind cases.

Identifying Relevant Wx Patterns



Stratus off the coast of California changes to closed cell convection which transforms to open cell convention near Hawaii. This transition occurs as the marine boundary layer deepens as a result of sea-surface fluxes and entrainment and mixing from above.

Friction Induced Marine Boundary Layer Rolls



Schematic depicting marine boundary layer (MBL) rolls produced by inflection point instability in wind profiles transverse to the rolls. Rolls are common during enhanced trade winds and in the inflow layers of cyclones. Rolls are oriented in the direction of the mean wind over the depth of the rolls. They enhance surface fluxes and increase turbulence.

Breaking Down Vertical Motion

In relation to orography and environment, the vertical motion can be broken down into two parts

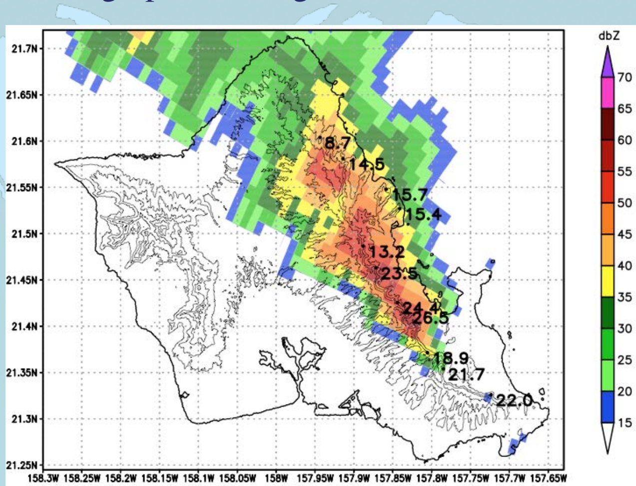
- w_{env} is the environmental vertical motion
- w_{oro} is the orographic lifting

The equation for total vertical motion is

$w = w_{env} + w_{oro}$

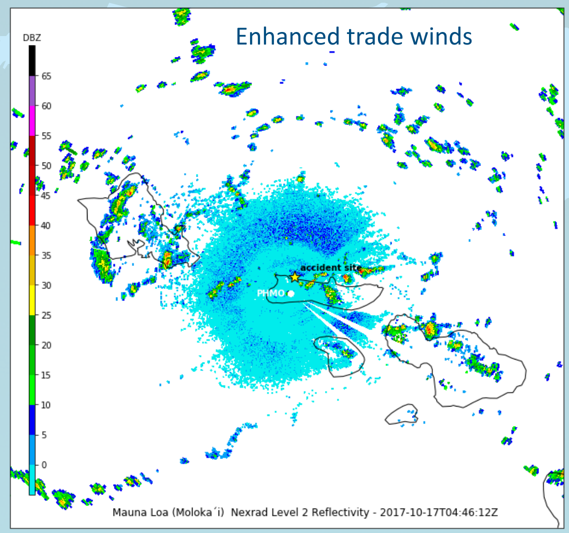
$$w_{oro} = \frac{dh(x,y)}{dt} = \frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} + v\frac{\partial h}{\partial y} + w\frac{\partial h}{\partial z} = u\frac{\partial h}{\partial x} + v\frac{\partial h}{\partial y} = \vec{v}\cdot\nabla h$$

Orographic Lifting and Severe Weather



Orographic Vertical Velocity and Radar Reflectivity on 9 March 2012.

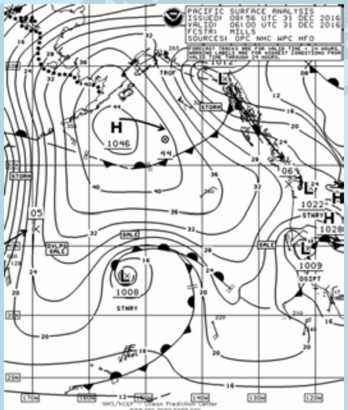
Open-Cell Convection is Non-Steady State



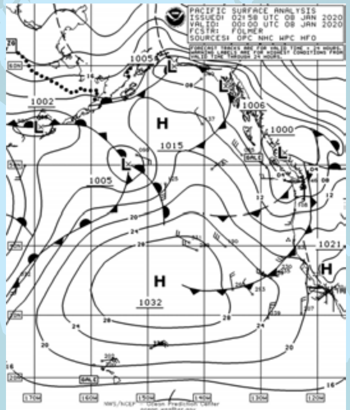
Radar reflectivity animation for 17 October 2017, using NEXRAD level 2 data. Radar station and accident site are highlighted.

Analyses for Two Cases

Shear Line Case



Enhanced Trade Wind Case

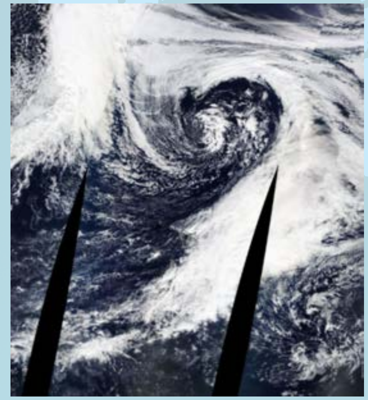


Sea-level pressure analyses (every 4 mb) for 0060 UTC on 31 December 2016 (left) and 0000 UTC on 08 January 2020 (right). Hawaii is visible at the lower left of each map. High pressure area can usually be found north/northeast of Hawaii. Average strength of the high is 1029,83 hPa.

Satellite Views

Satellite view consistent with surface analyses (e.g. shear lines/fronts clearly visible in satellite images). Open cell convection was present during most cases.

Shear Line Case



Enhanced Trade Wind Case

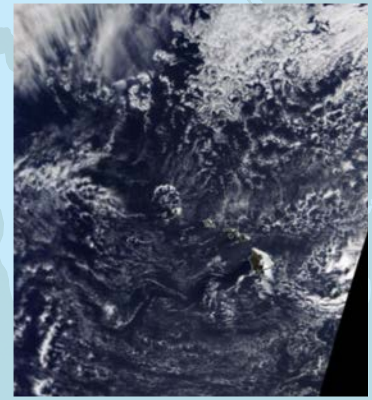
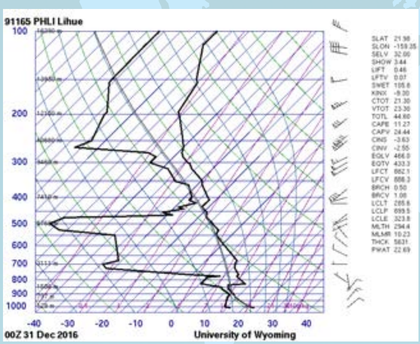


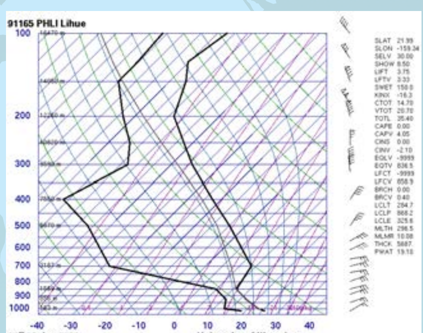
Figure 11a,b: MODIS true color satellite images valid for 31 December 2016 (left, shearline case) and 07 January 2020 (right, enhanced trade wind case) showing Hawaii and surrounding Pacific.

Soundings

Shear Line Case

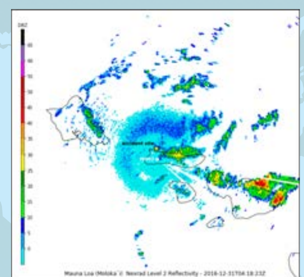


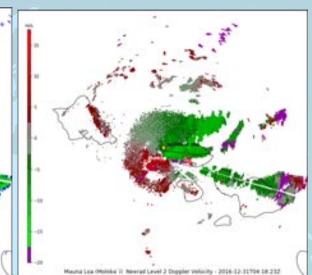
Enhanced Trade Wind Case

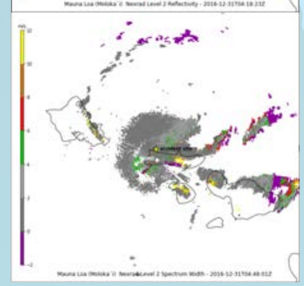


Radiosonde Skew-T profile for 0000 UTC on 31 December 2016 and 0000 UTC on 08 January 2020 for Lihue, HI. Both profiles show temperature (heavy black line to the right) and dew-point temperature (heavy black line to the left). Winds with height are plotted on the right with the usual convention. Additional sounding parameters can be found next to the winds.

WSR-88D Radar for Shearline Case

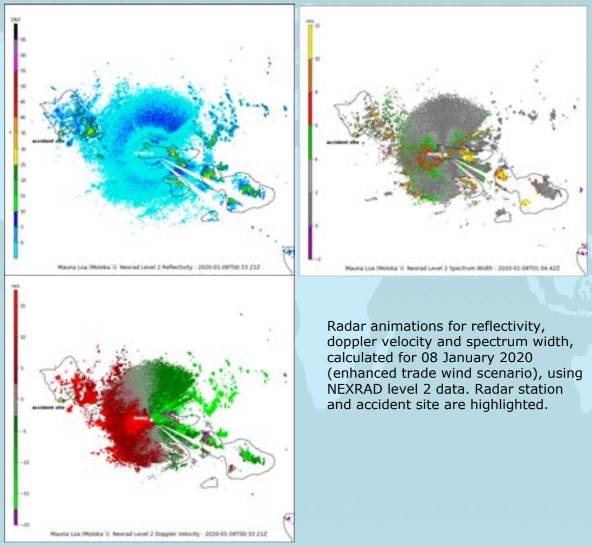






Radar animations for reflectivity, doppler velocity and spectrum width, calculated for 31 December 2016 (shearline scenario), using NEXRAD level 2 data. Radar station and accident site are highlighted.

WSR-88D Radar for Enhanced Trades



Radar animations for reflectivity, doppler velocity and spectrum width, calculated for 08 January 2020 (enhanced trade wind scenario), using NEXRAD level 2 data. Radar station and accident site are highlighted.

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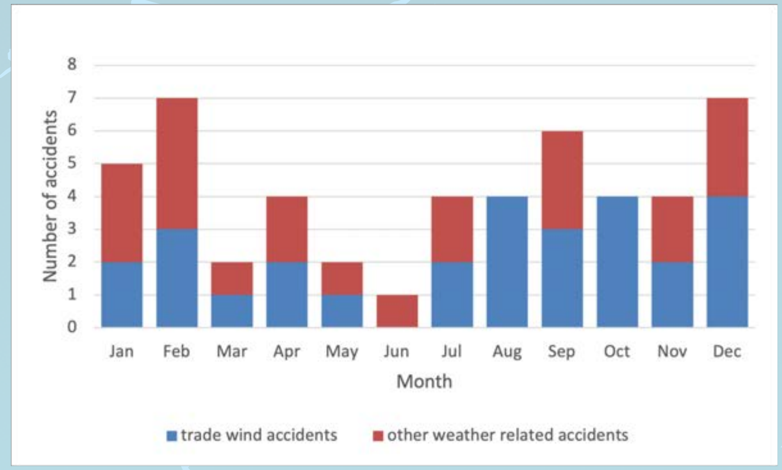
Annual Distribution



Histogram showing monthly average distributions of all weather-related aviation accidents over Hawaii from 2003 – 2022.

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Trade Wind Inversion Height

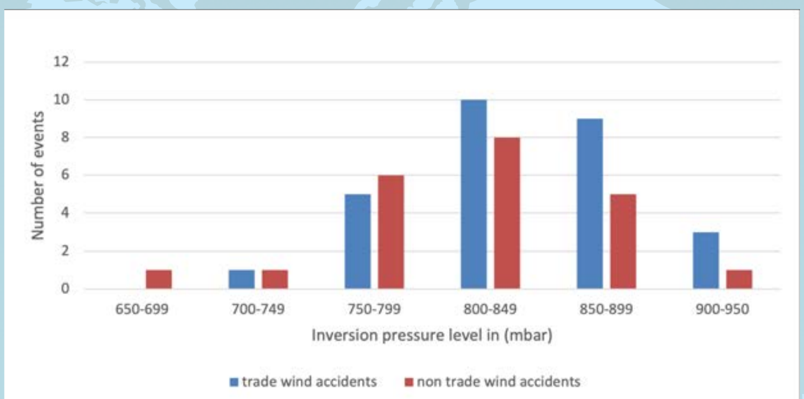

Fig. 5: Histogram showing the inversion heights of the trade wind accident cases (blue bars) in comparison to the non trade wind cases (red bars) from 2003 to 2022. Data was taken from Lihue and Hilo soundings. The majority of the cases show an inversion height between 800 & 850 mbar.

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Maximum Wind Speed Below Inversion

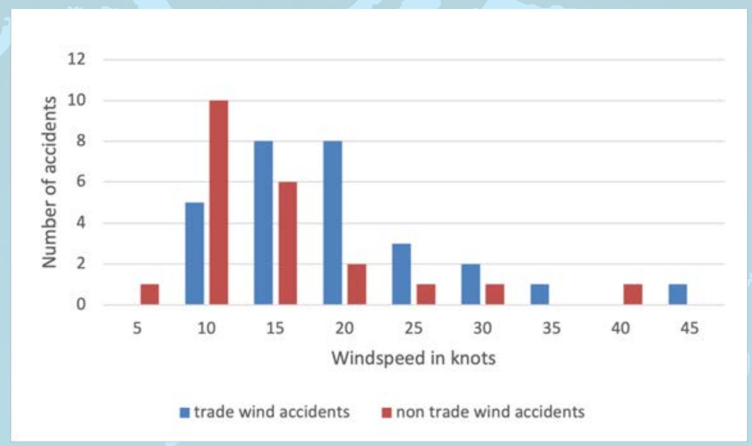

Fig. 6: Histogram showing the maximum wind speeds observed below the trade wind inversion from 2003 to 2022. Data were taken from Lihue and Hilo soundings.

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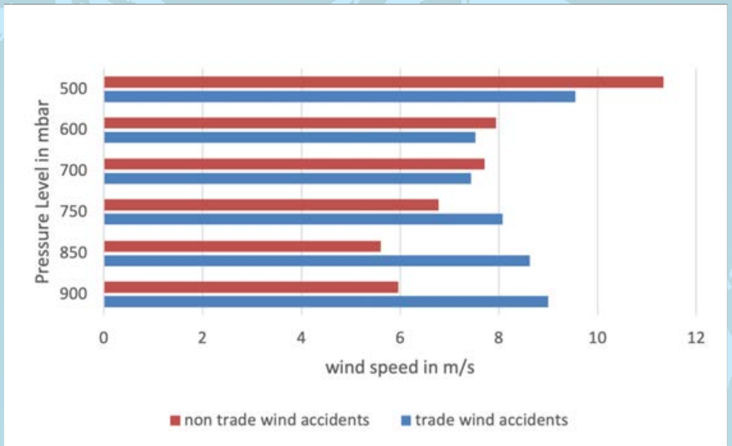
Composite Wind Profile



Composite wind profile at time of the accidents. Data taken from Lihue and Hilo soundings.

Comparing Surface Winds

Trade wind accidents

Non trade wind accidents Results

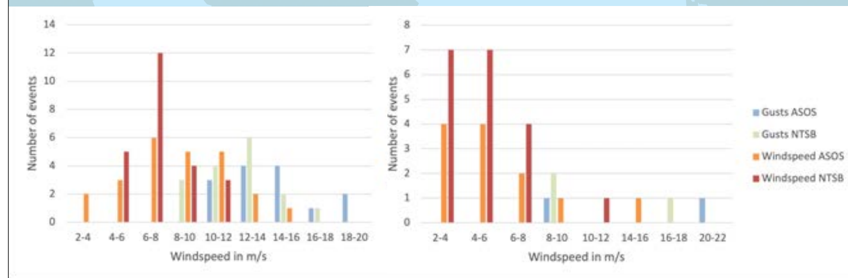


Fig. 8,9: Histograms comparing ASOS and NTSB wind observations for trade wind cases (Figure 8) and non trade wind cases (Figure 9). ASOS data includes the years 2005 – 2022, NTSB data available for 2003 – 2022. For some cases, both ASOS and NTSB data are missing.

Summary

Accidents, during which trade winds were prevalent, can be divided into two scenarios:

1. Shearline is present
2. Enhanced trade winds

- Surface winds are stronger for trade wind cases

All weather-related accidents:

- Most occurred on Molokai, in the Kahului area and Honolulu. No trade wind cases on Big Island
- More accidents during the winter months
- For the majority of the weather-related accident cases a trade wind inversion height between 800 and 850 mbar and surface winds around 6-8 m/s was observed

Next steps

- Document the synoptic and mesoscale weather patterns associated with non trade wind cases.
- Create a tool that can be used by pilots and aviation schools to reduce the number of weather-related accidents in the future!


Questions?