Systematic Scatterometer Wind Errors Near Coastal Mountains

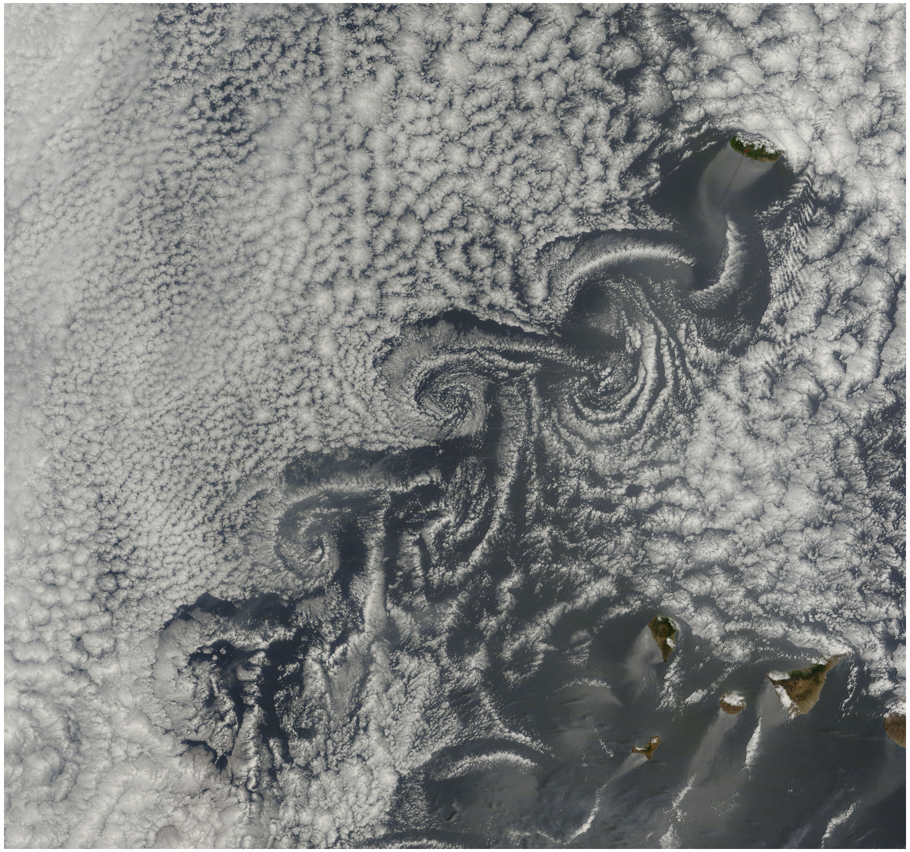
Thomas Kilpatrick
Shang-Ping Xie
Hiroki Tokinaga
David Long
Nolan Hutchings

SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

BYU

KYUSHU UNIVERSITY

NASA



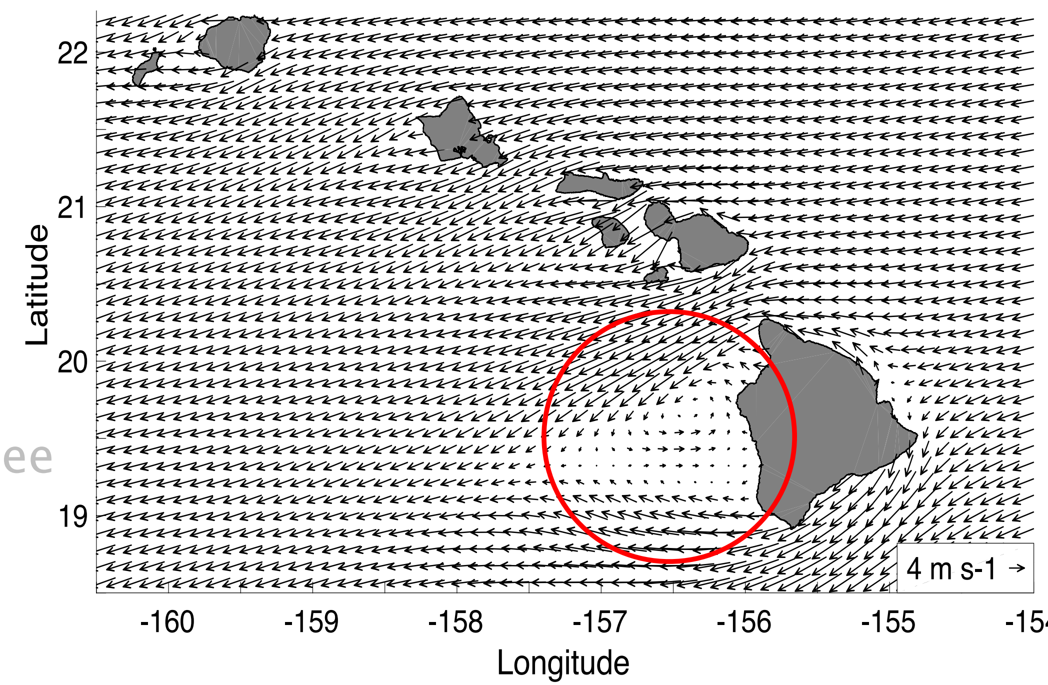
Von Karman vortex near Canary Islands (image: NASA)

Introduction

The observation of narrow orographic wind jets is one of the primary scientific contributions of scatterometer observations, as coastal ocean circulation is sensitive to these winds (Xie et al. 2001, Chelton et al. 2004),

Scatterometer wind retrievals in the coastal zone are challenging due to land contamination effects, questionable assumptions that underlie the GMF, and *ambiguity selection*.

Here we identify systematic errors in QuikSCAT wind retrievals near Hawaii's Big Island and southern California, where coastal mountains force small-scale wind features.

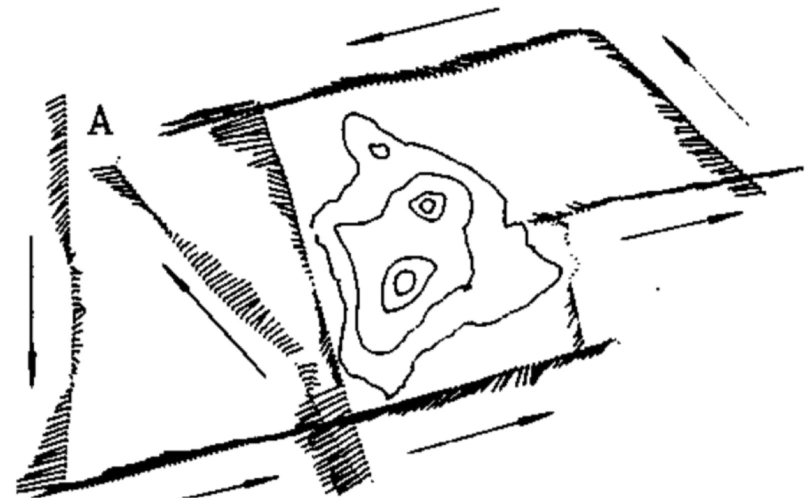


HRCM WRF model wind climatology (JJA 2001) shows westerly "reverse flow" in the lee of Hawaii's Big Island.

Two mountains on Hawaii's Big Island force lee vortices and reverse flow during trade wind conditions

Aircraft observations clearly show two lee vortices and westerly "reverse flow" on the west side of Hawaii's Big Island, extending ~100 km from shore (Nickerson and Dias 1981).

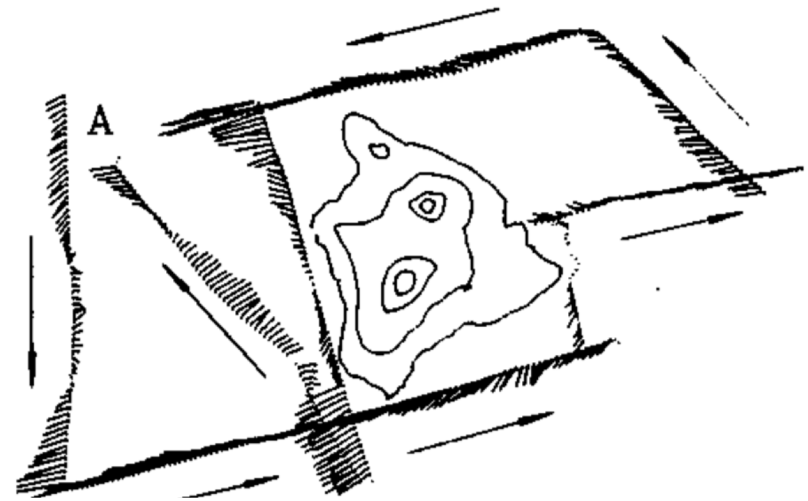
Smith and Grubisic (1993) describe the dynamics of the wake, which is due to the steady trade winds impinging on Mauna Kea and Mauna Loa.



Winds at 450 m, 24 July 1990
(Smith and Grubisic 1993)

Two mountains on Hawaii's Big Island force lee vortices and reverse flow during trade wind conditions

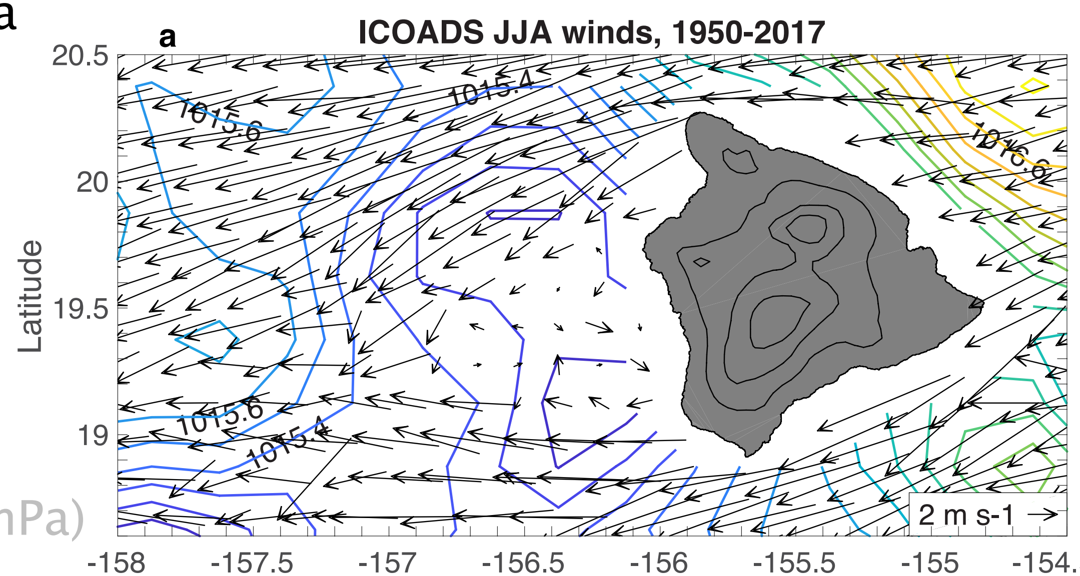
Aircraft observations clearly show two lee vortices and westerly "reverse flow" on the west side of Hawaii's Big Island, extending ~100 km from shore (Nickerson and Dias 1981).



Winds at 450 m, 24 July 1990
(Smith and Grubisic 1993)

Smith and Grubisic (1993) describe the dynamics of the wake, which is due to the steady trade winds impinging on Mauna Kea and Mauna Loa.

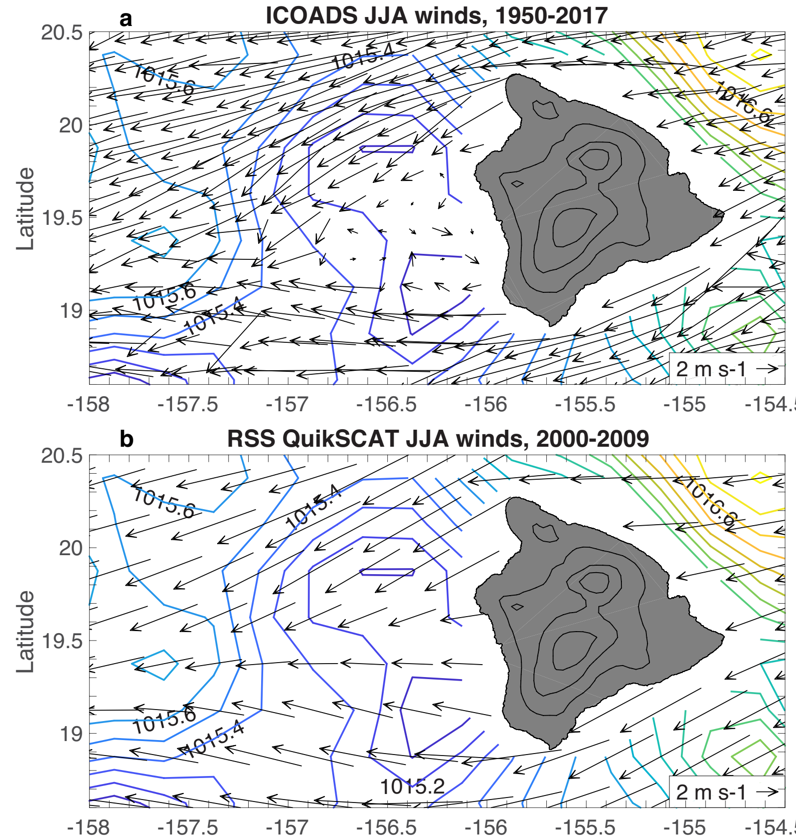
ICOADS JJA climatology of ship observations also shows reverse flow in the Big Island wake.



SLP contours overlaid (CI=0.1 hPa)

The problem: Orographic wind features are absent in QuikSCAT observations

RSS QuikSCAT v4 0.25° wind climatology (JJA, 2000–2009) shows a deceleration of the trade winds, *but no wind reversal.*



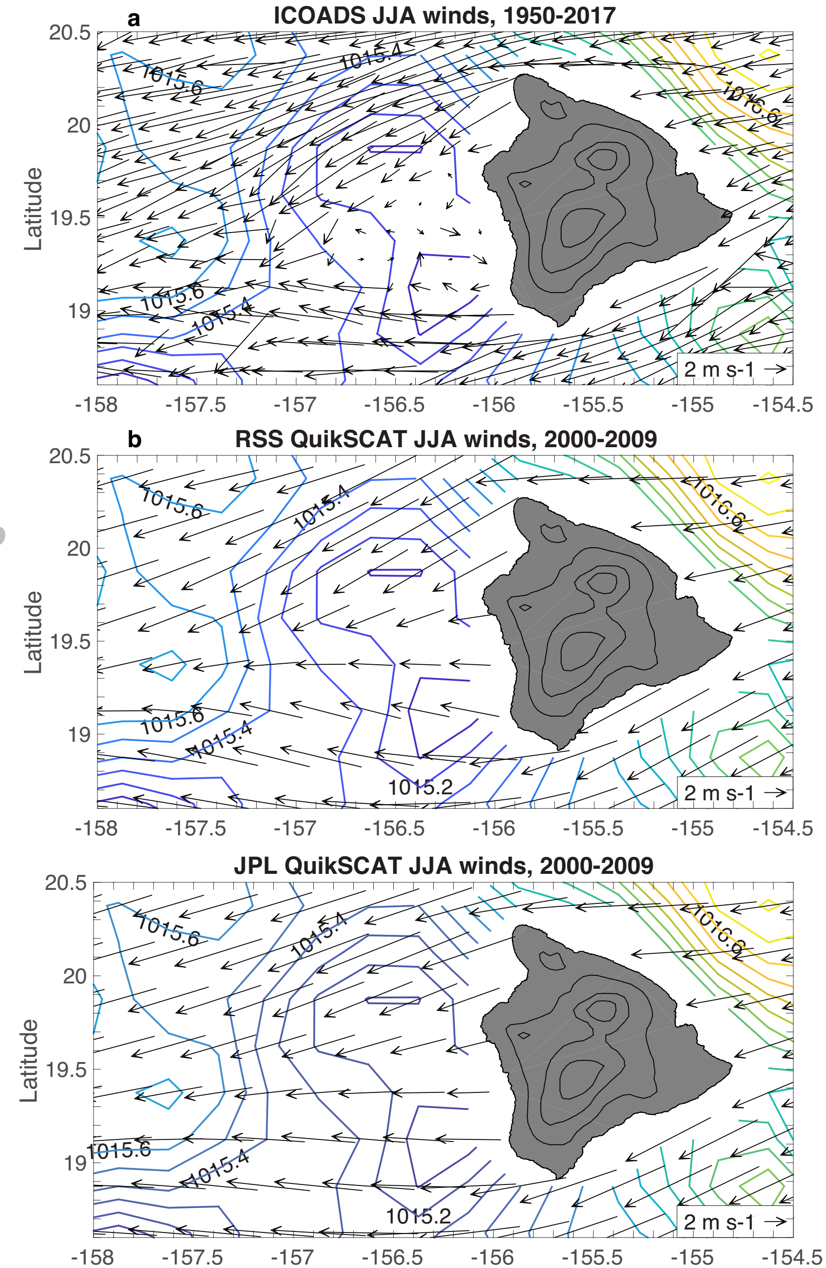
Colored contours = ICOADS SLP climatology (CI=0.1 hPa). Black contours = Big Island elevation (CI=1000m).

The problem: Orographic wind features are absent in QuikSCAT observations

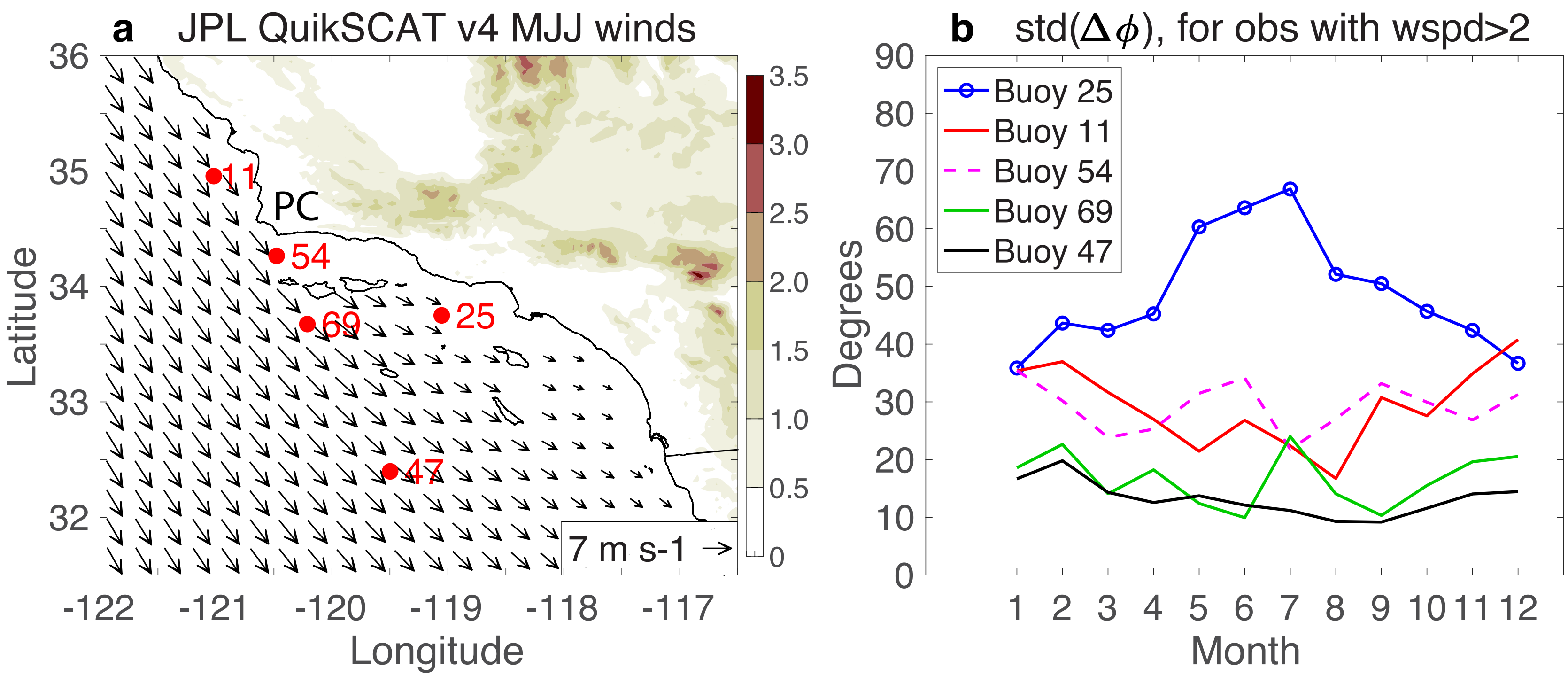
RSS QuikSCAT v4 0.25° wind climatology (JJA, 2000–2009) shows a deceleration of the trade winds, *but no wind reversal.*

Colored contours = ICOADS SLP climatology (CI=0.1 hPa). Black contours = Big Island elevation (CI=1000m).

The wind reversal is also absent in JPL v4 QuikSCAT winds, plotted here at 0.25°.



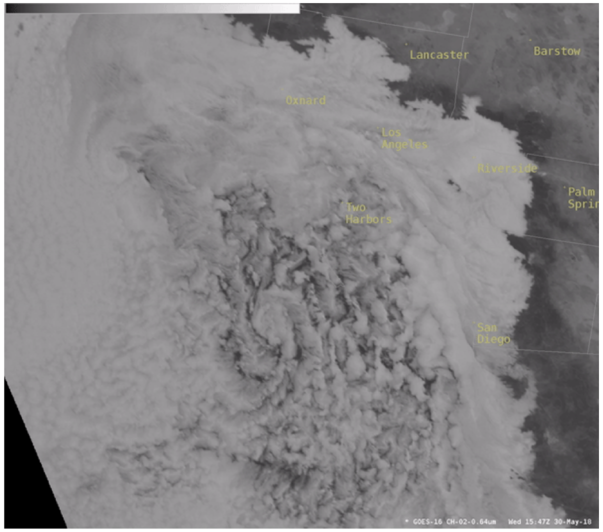
The problem: Orographic wind features are absent in QuikSCAT observations



PC = Pt. Conception
Color = elevation (km)

- In the Southern California Bight, JPL QuikSCAT wind direction errors ($\Delta\phi$, relative to buoy) exceed 60° during the spring season.
- Why are the QuikSCAT errors so large at buoy 25 relative to other locations, and why do they peak during the late spring?

Huge wind direction errors in the Southern California Bight are associated with Catalina Eddy events

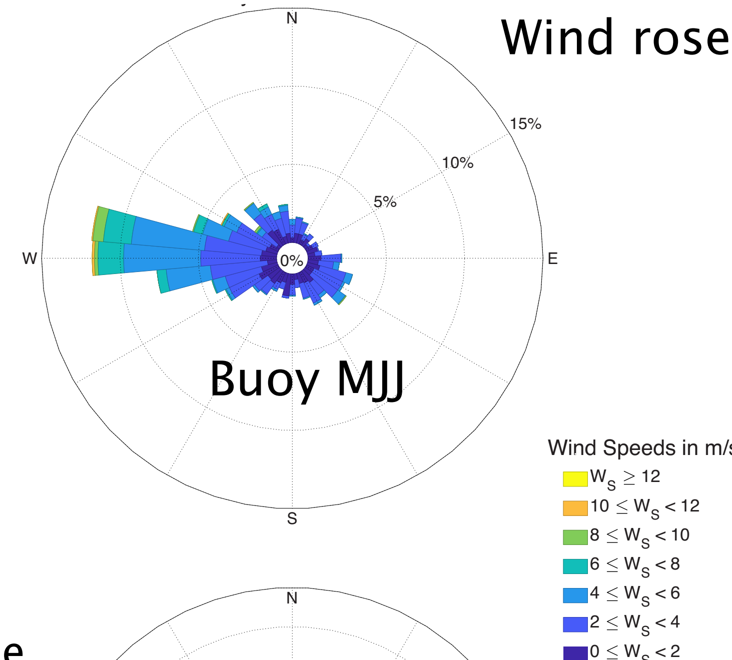


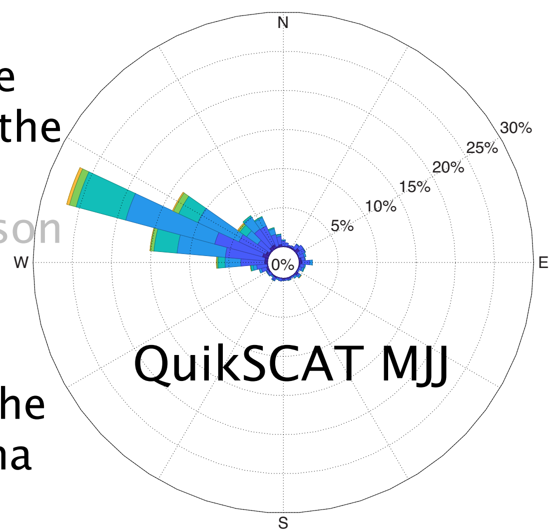
GOES-16 cloud imagery, 30 May 2018 *(NWS San Diego)*

The Catalina Eddy is a mesoscale cyclonic feature that appears in the Southern California Bight, often during the spring upwelling season *(e.g., Bosart 1983)*.

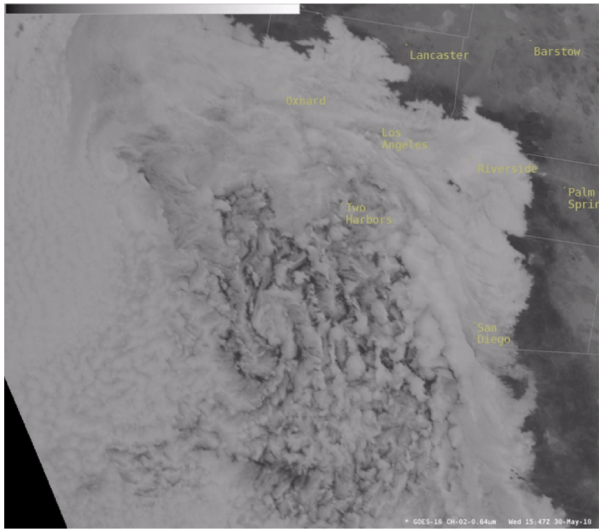
Large QuikSCAT wind errors in the bight are associated with Catalina Eddy events.

Wind roses

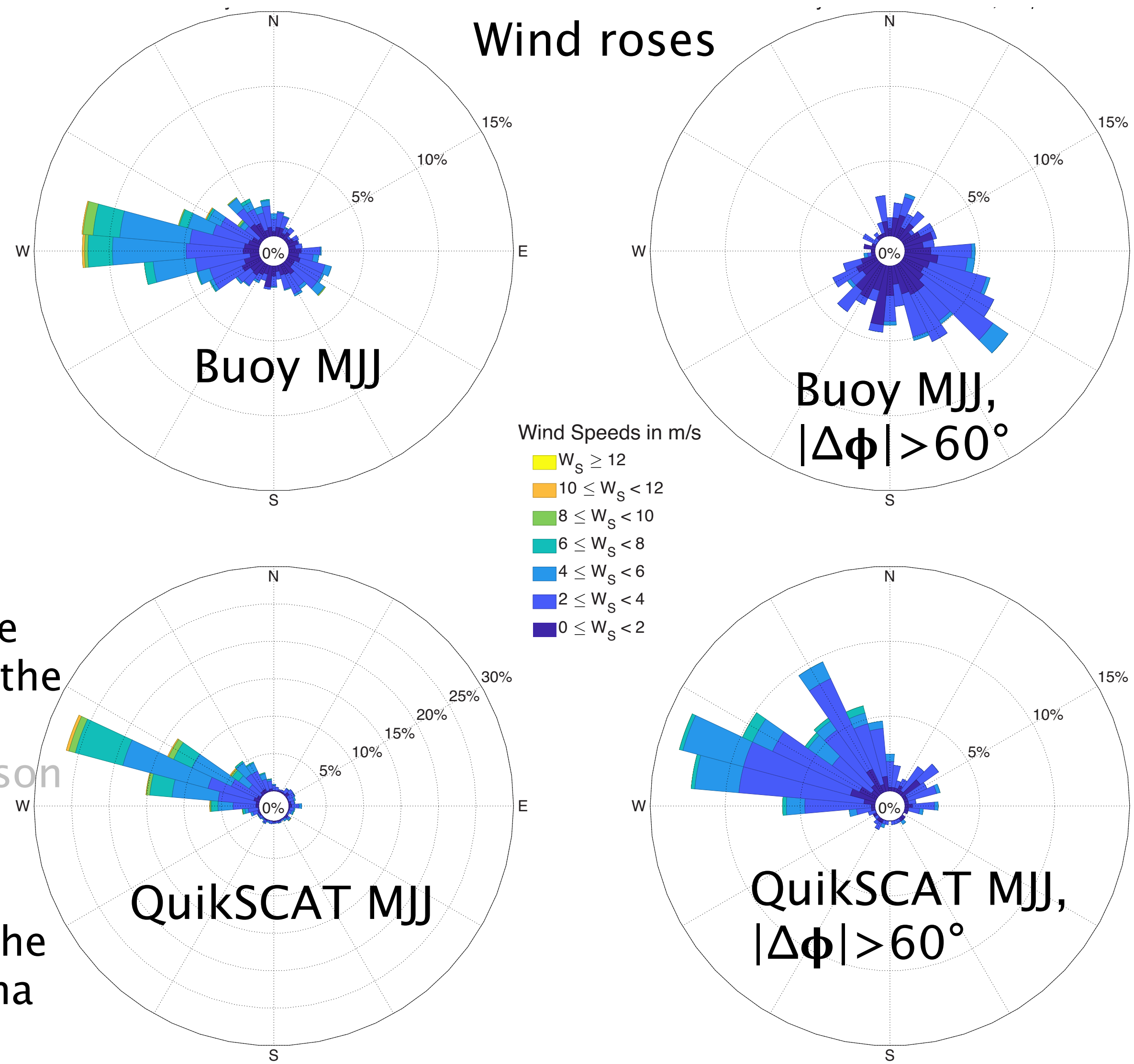




Huge wind direction errors in the Southern California Bight are associated with Catalina Eddy events



GOES-16 cloud imagery,
30 May 2018 *(NWS San Diego)*



The Catalina Eddy is a mesoscale cyclonic feature that appears in the Southern California Bight, often during the spring upwelling season *(e.g., Bosart 1983)*.

Large QuikSCAT wind errors in the bight are associated with Catalina Eddy events.

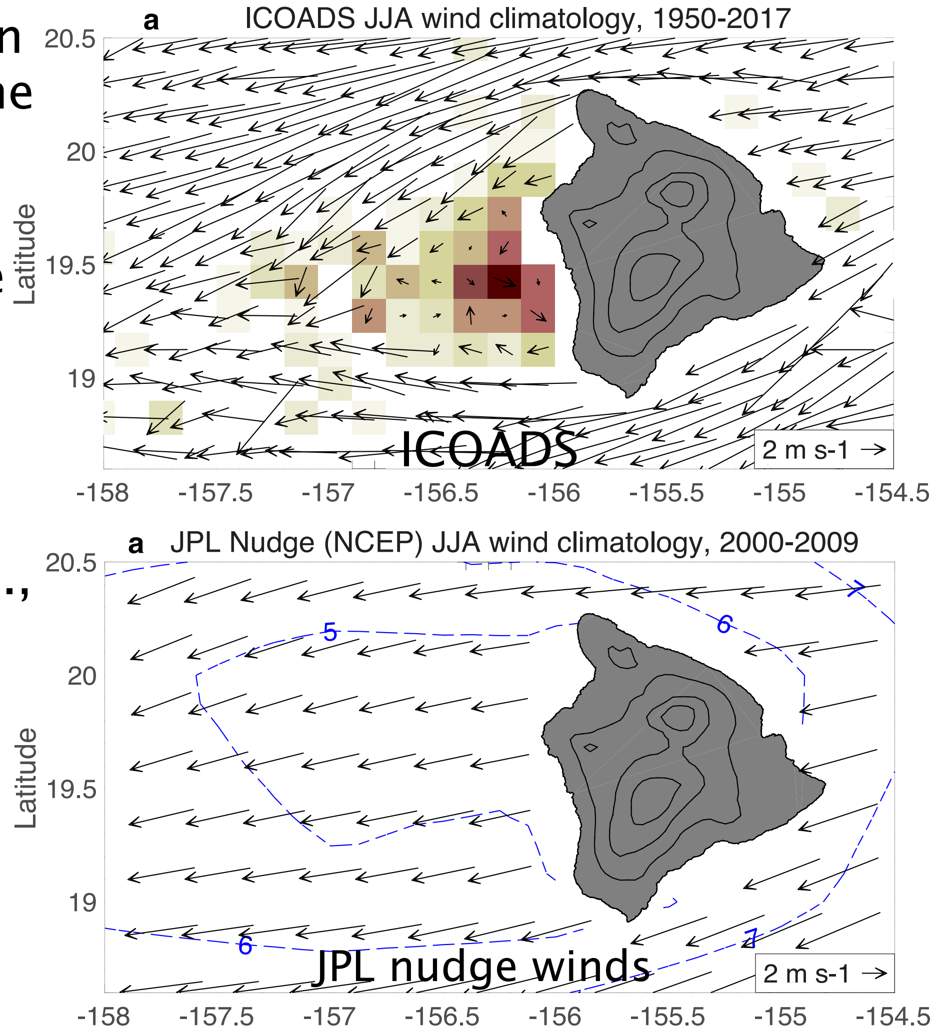
Other mesoscale features such as von Karman vortices are likely absent in QuikSCAT observations

This von Karman vortex in the lee of Guadalupe Island is visible in GOES-16 cloud imagery, 13 May 2019.

(image: instagram.com/noaasatellites)

There are several steps of scatterometer wind processing where these errors may be introduced

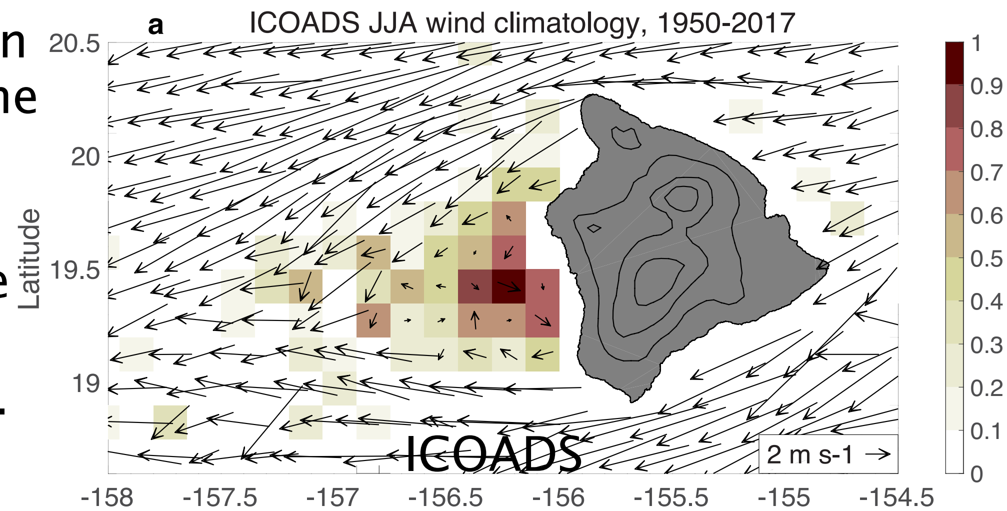
- Initial ambiguity selection relies on the “nudge” wind field; JPL uses the ~2.5° NCEP analysis.
- The ”median filter” step applies a spatial low-pass filter (7x7) to the wind field, and the spatial scales are not adapted for coastal winds.
- Some of the assumptions that underlie the GMF may be questionable in coastal zones, e.g., long-fetch assumption.

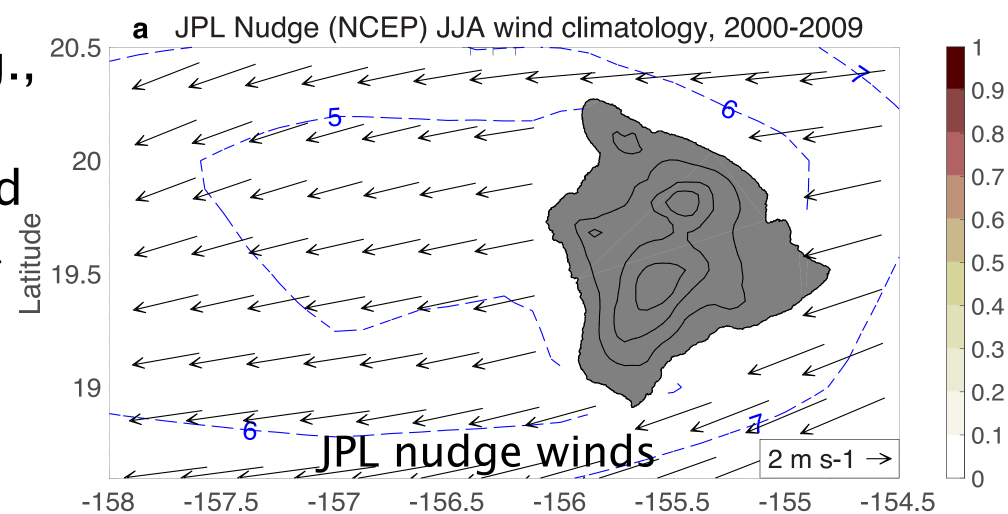


Color = JJA westerly wind occurrence

There are several steps of scatterometer wind processing where these errors may be introduced

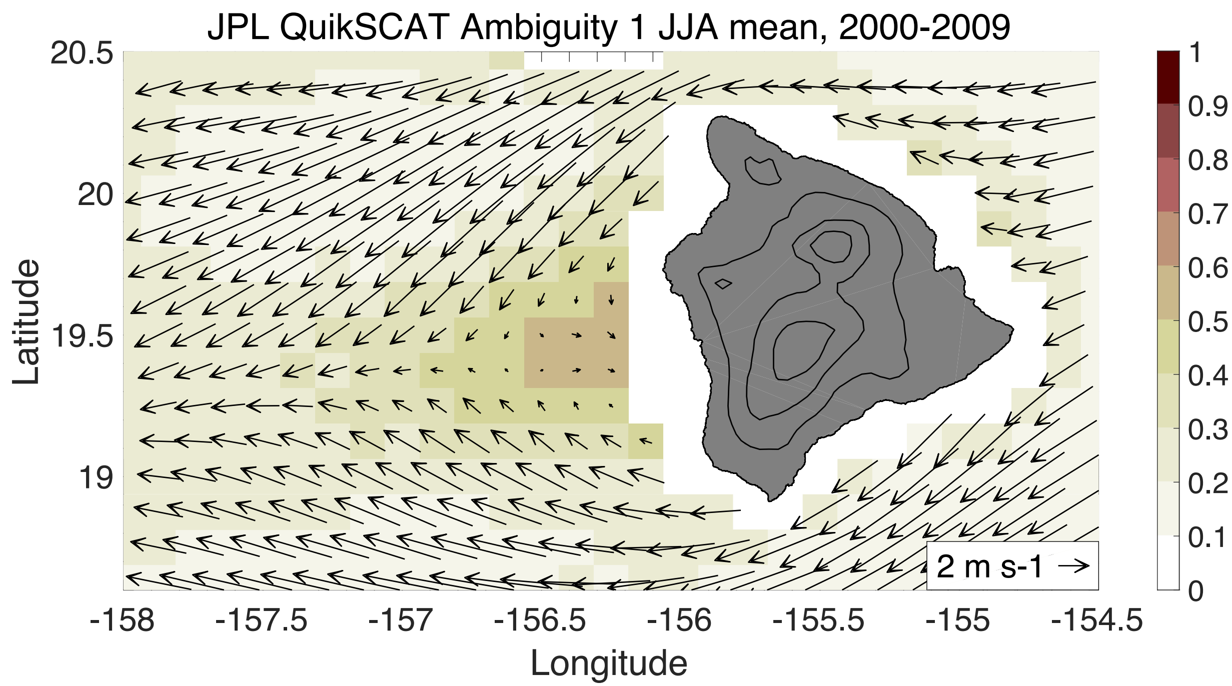
- Initial ambiguity selection relies on the "nudge" wind field; JPL uses the ~2.5° NCEP analysis.
- The "median filter" step applies a spatial low-pass filter (7x7) to the wind field, and the spatial scales are not adapted for coastal winds.
- Some of the assumptions that underlie the GMF may be questionable in coastal zones, e.g., long-fetch assumption.
- Examination of the JPL nudge wind field suggests it is the source of a substantial portion of the QuikSCAT coastal wind errors.





Color = JJA westerly wind occurrence

QuikSCAT processing appears to throw out correct ambiguities in the lee of Big Island



Color = JJA westerly wind occurrence

JJA climatology of JPL QuikSCAT ambiguity 1 actually shows weak westerly winds in the Big Island wake, with 50–60% westerly wind occurrence.

This suggests the processing often throws out the correct (westerly) ambiguity in the Big Island wake because it puts too much faith in the nudge winds.

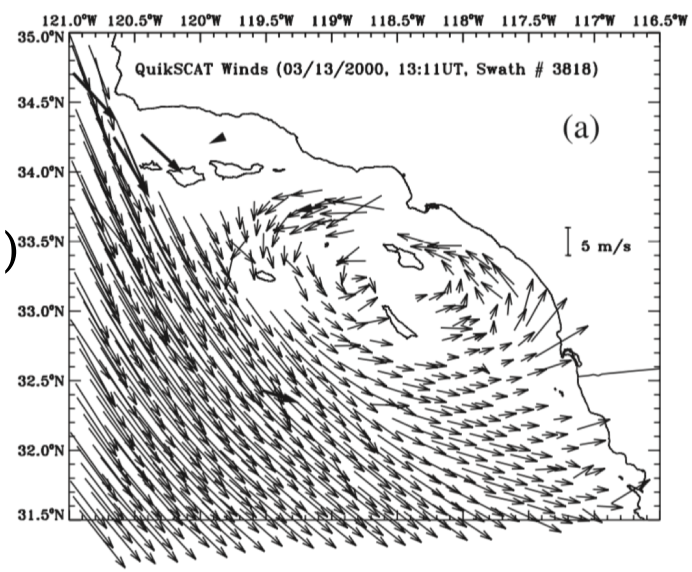
The 50–60% westerly occurrence in the wake is lower than ICOADS, suggesting a problem with the GMF.

Potential strategies to solve the ambiguity selection problem near coastal mountains

- The first target for improving QuikSCAT winds near coastal mountains is the nudge wind field; higher resolution nudge winds will better represent orographically induced features (see poster by David Long & Nolan Hutchings).
- Using a shorter length scale in the median filter for coastal zones may also help prevent smoothing out real features.
- For persistent wind reversals (e.g., Hawaii), it may be possible to utilize σ_0 observations over several days to aid the ambiguity selection.
- Statistical techniques to determine the wind direction in lee regions from larger-scale flow patterns (see poster by Will Chapman et al.).

Potential strategies to solve the ambiguity selection problem near coastal mountains

- The first target for improving QuikSCAT winds near coastal mountains is the nudge wind field; higher resolution nudge winds will better represent orographically induced features (see poster by David Long & Nolan Hutchings).
- Using a shorter length scale in the median filter for coastal zones may also help prevent smoothing out real features.
- For persistent wind reversals (e.g., Hawaii), it may be possible to utilize σ_0 observations over several days to aid the ambiguity selection.
- Statistical techniques to determine the wind direction in lee regions from larger-scale flow patterns (see poster by Will Chapman et al.).
- Revisit past methodologies? Hu and Liu (2002) apparently detected Catalina Eddy events…



Hu and Liu 2002, GRL

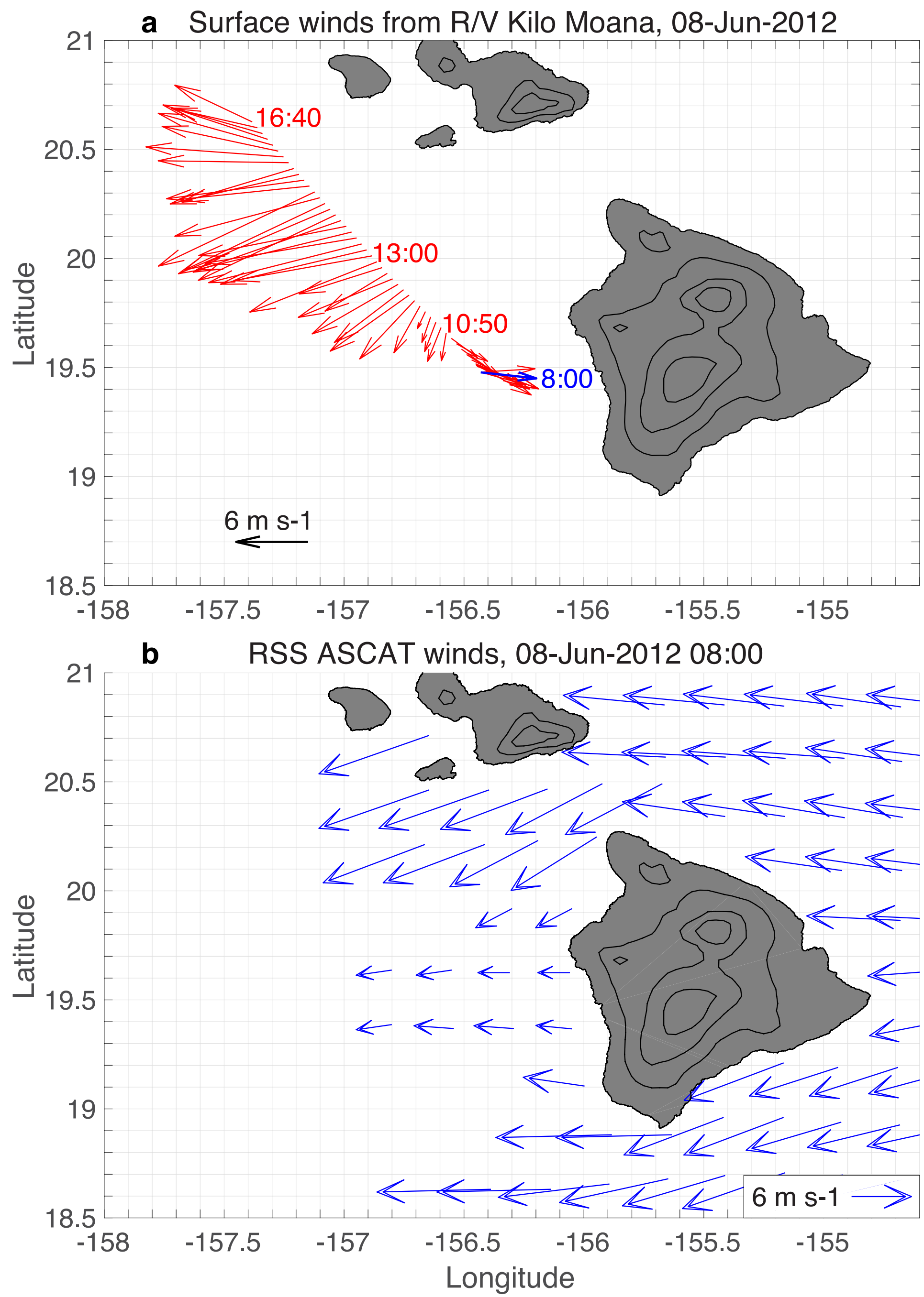
Summary

Orographic wind features near Hawaii’s Big Island and southern California are absent in QuikSCAT and ASCAT observations.

Existing satellite wind datasets therefore likely systematically underestimate orographic wind curls around the world.

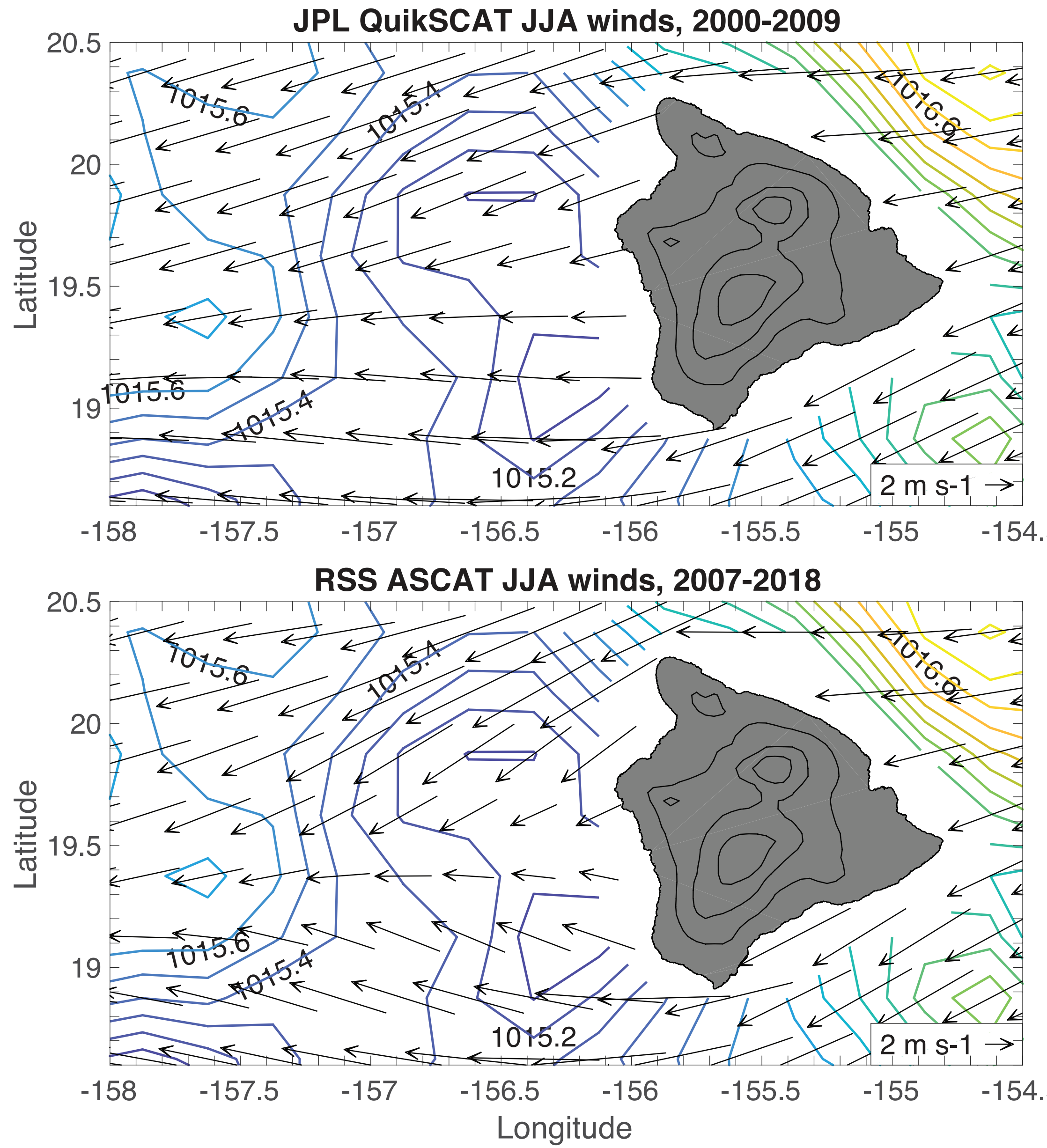
Analyses of nudge wind fields and ambiguities in the JPL QuikSCAT v4 files indicate a substantial part of the errors is due to incorrect ambiguity selection, though inadequacies in the GMF (e.g., long fetch assumption) may also contribute.

Strategies to improve wind retrievals near coastal mountains include utilizing higher resolution nudge winds and utilizing data from different times to select ambiguities. See posters by David Long and Nolan Hutchings; and by Will Chapman, Tom Kilpatrick, and Shang-Ping Xie.

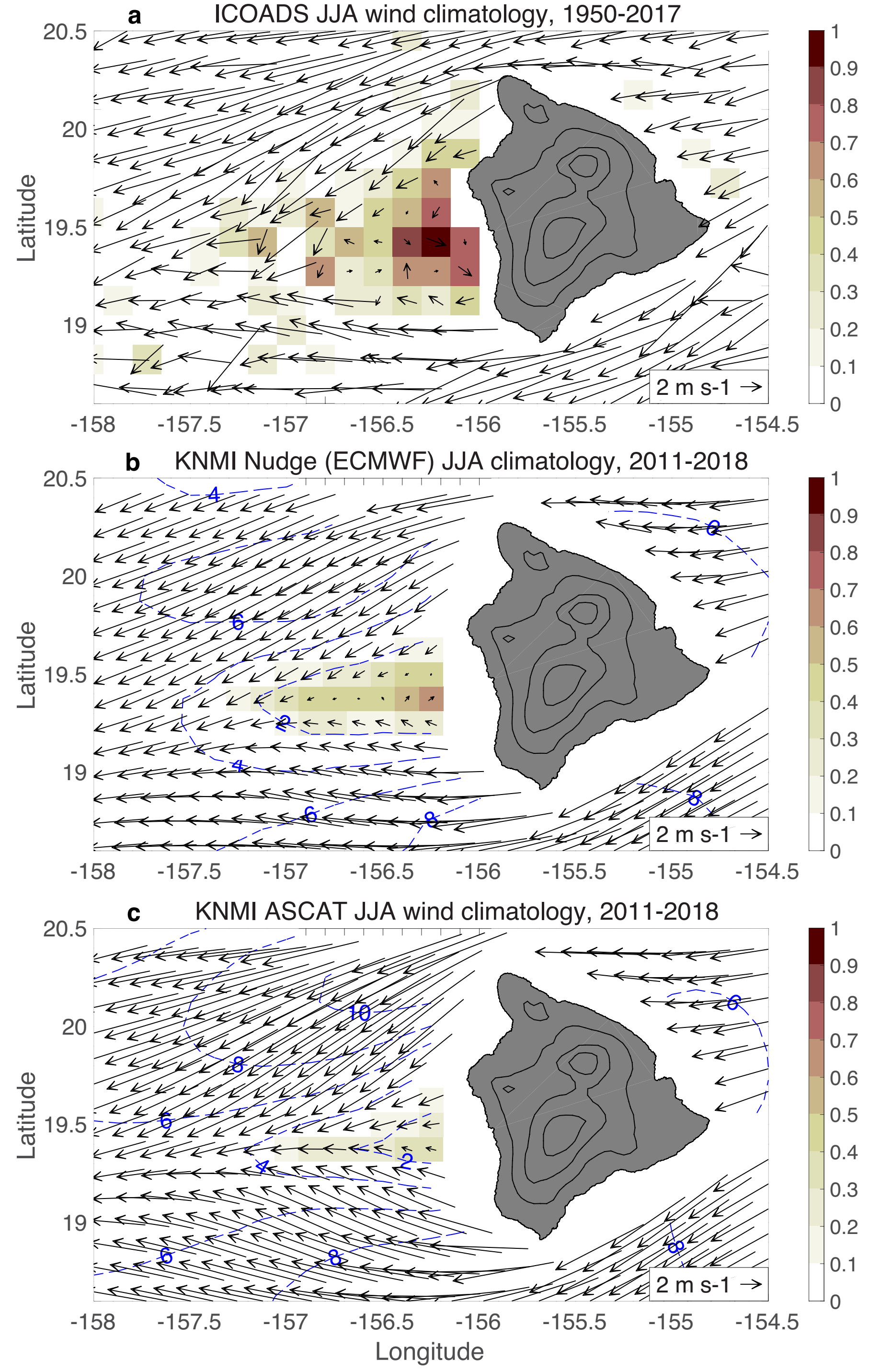


a Surface winds from R/V Kilo Moana, 08-Jun-2012
16:40
13:00
10:50
8:00
6 m s-1
Latitude
21
20.5
20
19.5
19
18.5
-158
-157.5
-157
-156.5
-156
-155.5
-155
b RSS ASCAT winds, 08-Jun-2012 08:00
6 m s-1
Latitude
Longitude

- Reverse flow also absent in RSS ASCAT winds.



- ICOADS vs Nudge vs ASCAT



- 2°N