Detection of the Inversion Layer over the central North Pacific Ocean using GPS Radio Occultation

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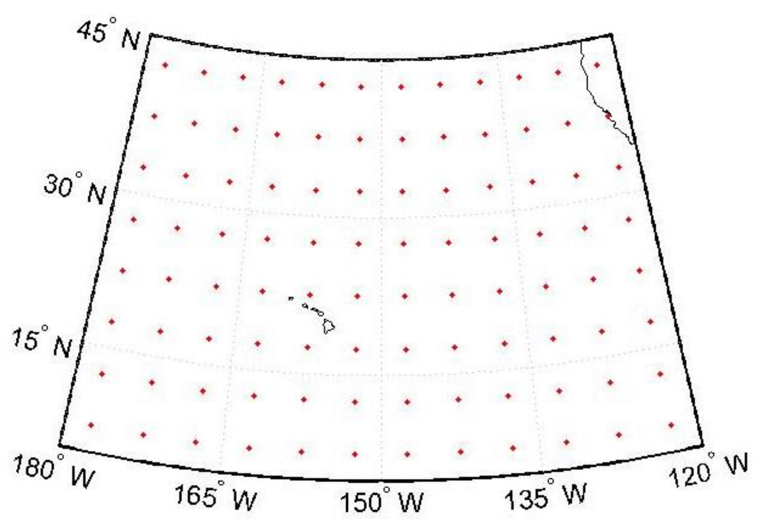
Motivation

- Previous research of the trade wind inversion over the Hawaiian Islands has been restricted spatially and temporally due to limited measurements.
- A 2005 study (Bingaman) used approximately 8,000 radiosonde observations (1999-2004) from Hilo and Lihue to identify the properties and median statistics of the inversion.
- GPS Radio Occultation data provides over 100,000 observations (2007-2012) to estimate the inversion base height over the Hawaiian Island region (5˚N-45˚N, 120˚W-180˚W).
- Radiosonde identified inversion base height was determined using the air temperature profile, GPS RO inversion base height was identified using the refractivity gradient.



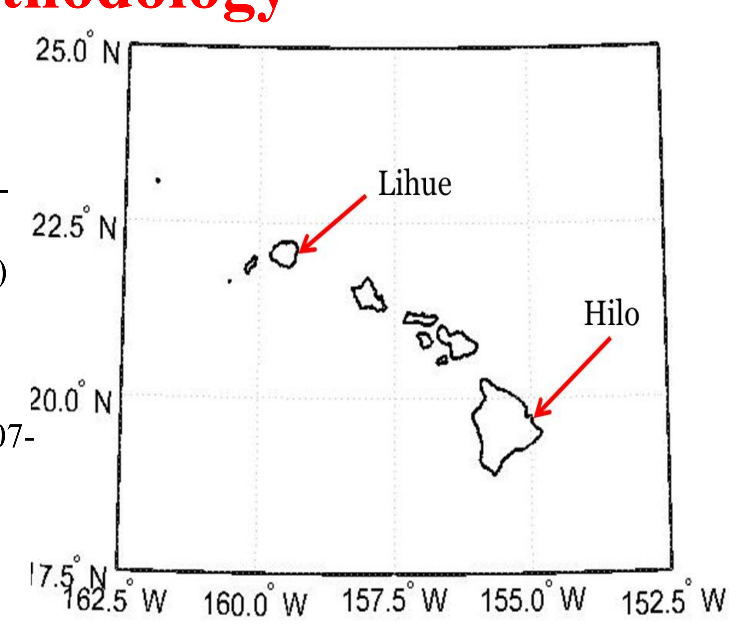
Hawaiian Island region with points representing the center of each 5˚x 5˚ analysis grid point.

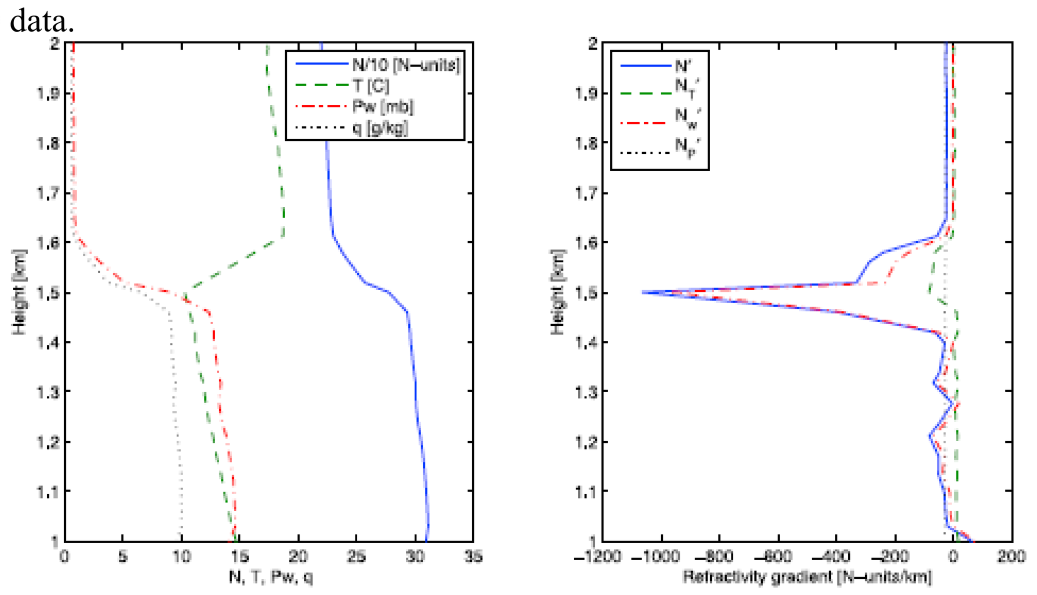
Grid Size (40° x 60° Domain)	Number of Individual Grids	Observations Over the Domain (Seasonal Average)	Average Number of Observations per Grid Box
1˚x 1˚	2400	34713	14
2.5˚ x 2.5˚	384	34713	90
5˚ x 5˚	96	34713	361
5˚ x 10˚	48	34713	723

Seasonal average observations over the analysis region and corresponding average number of COSMIC observations (2007-2012) for each grid size.

Data and Methodology

- Radiosonde observations :
  - Hilo (PHTO) – 19.72˚N, 155.05˚W
  - Lihue (PHLI) – 21.99˚N, 159.34˚W
  - Approximately 1,800 observations per season (1999-2004).
  - Inversion base:: increase in sensible temperature (T) and/or decrease in θ_e (Bingaman, 2005).
- COSMIC GPS RO observations:
  - Hawaiian region: 5˚N-45˚N, 120˚W-180˚W
  - Approximately 34,000 observations per season (2007-2012).
  - Inversion base: height of minimum refractivity gradient value (< -50 N-units km^{-1}) between 500 m-3500 m.
  - Six point moving average was used for smoothing of GPS RO data.

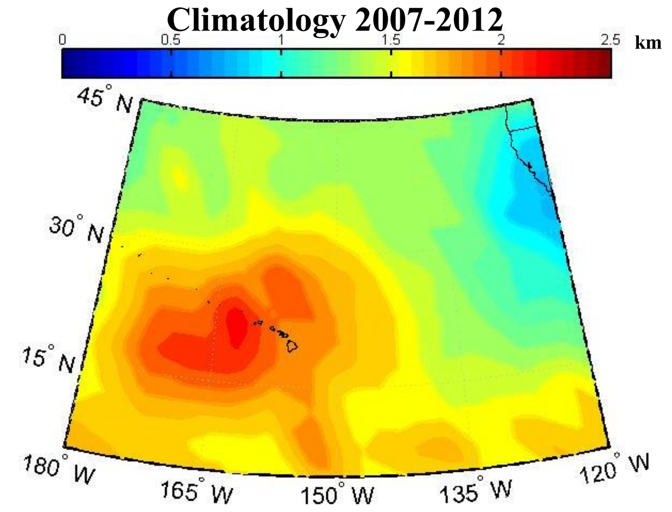




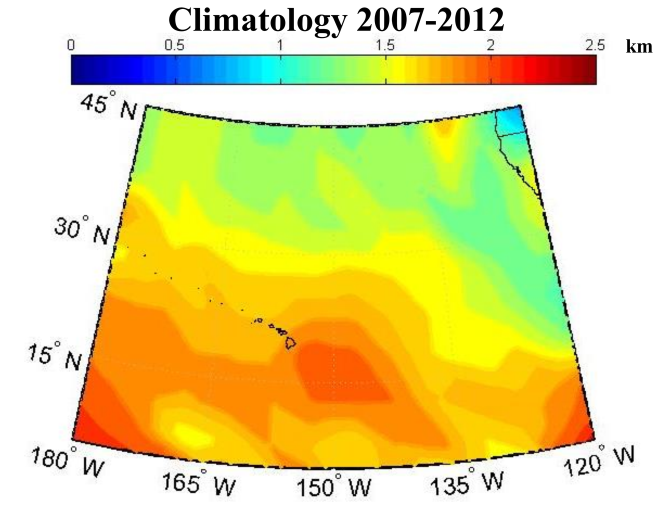
Left - Vertical profiles of refractivity in N-units (blue solid), temperature in ˚C (green dashed), water vapor partial pressure in hPa (red dashed), and mixing ratio in g kg^{-1} (purple dotted). Right – Vertical profiles of refractivity gradient equation components (N'-blue solid), temperature (N_T' – green dashed), water vapor pressure (N_W' – red dashed), and mixing ratio (N_P' – purple dotted). From Ao et al. 2012

GPS RO Observation of Inversion Base Height (km)

JJA Trade Wind Inversion Base Height (km) Climatology 2007-2012

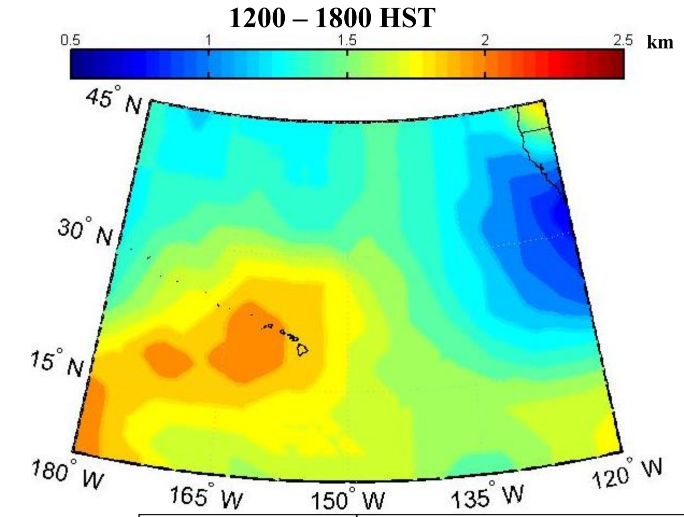


DJF Trade Wind Inversion Base Height (km) Climatology 2007-2012

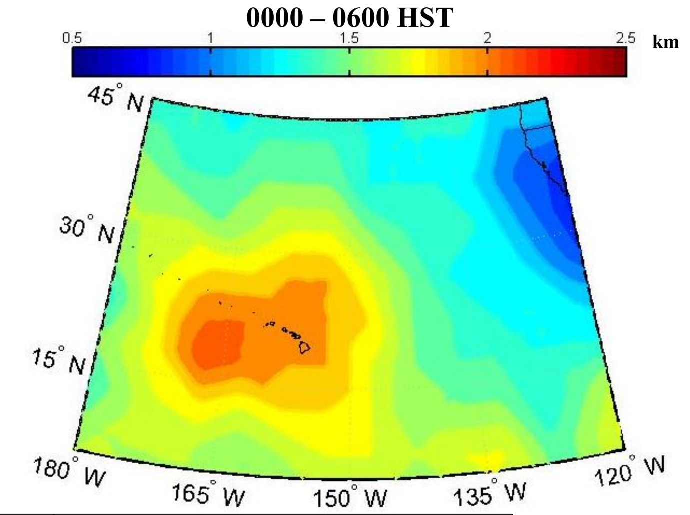


	Hilo, Hawaii – z_i (km)		Lihue, Kauai – z_i (km)	
	Radiosonde	Satellite	Radiosonde	Satellite
JJA	2.15	1.85±0.55	1.95	2.05±0.65
DJF	2.05	1.85±0.45	1.75	1.75±0.55

JJA (Day-time) Inversion Base Height Climatology (km) 1200 – 1800 HST



JJA (Night-time) Inversion Base Height Climatology (km) 0000 – 0600 HST

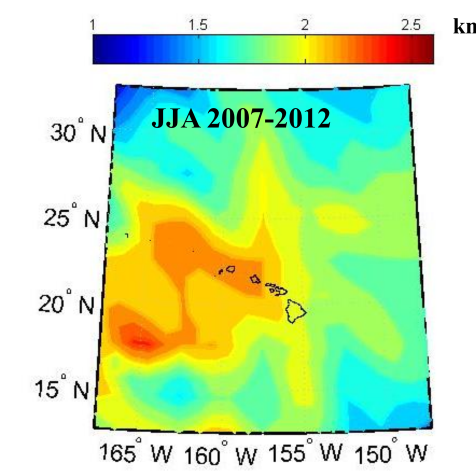


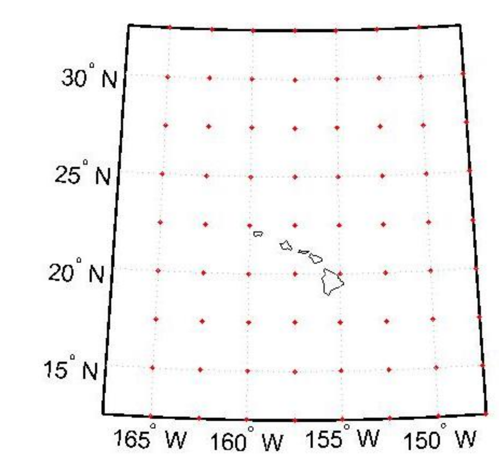
	Hilo, Hawaii – z_i (km)		Lihue, Kauai – z_i (km)	
	Radiosonde	Satellite	Radiosonde	Satellite
Day	2.15	1.85±0.65	1.85	1.95±0.65
Night	2.15	1.95±0.65	1.95	1.95±0.65

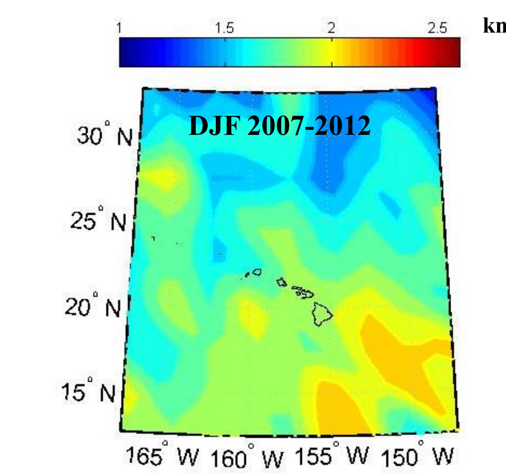
- Trade wind days defined as any period when northeasterly surface flow is not interrupted or aided by a disturbance (based on 6 hour surface pressure analysis NCEP-FNL).
- Inversion base height estimated from GPS RO were consistently lower than radiosonde observations
  - Height difference at Hilo (300-400m) most likely caused by the local terrain effects of Mauna Loa which is directly upstream of the sounding site (Garrett 1980).
  - Height difference at Lihue (100-200m) is not subject to the same terrain effects and results in a closer comparison
- The different inversion base identification techniques could also contribute to discrepancies between radiosonde and GPS RO estimation techniques.

Observation Period	Total Observations	Qualifying Observations	Percentage of total
JJA 2007-2012 Trade Wind Climatology	19,921	11,554	58%
DJF 2007-2012 Trade Wind Climatology	17,357	8,331	48%
JJA (Day-time) Climatology 1200 – 1800 HST	8,274	4,608	56%
JJA (Night-time) Climatology 0000 – 0600 HST	9,023	4,564	51%

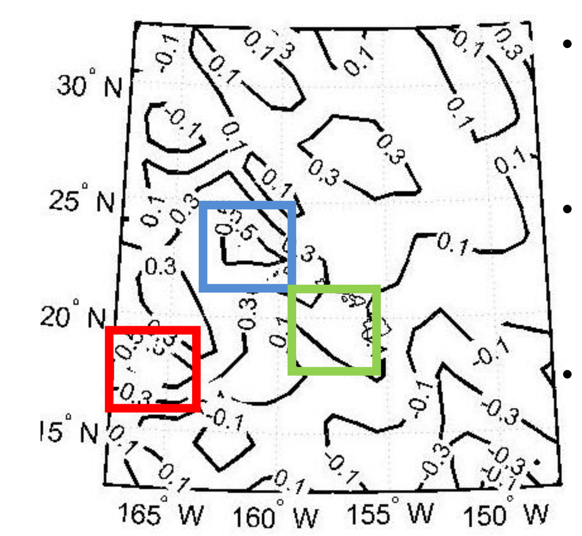
Seasonal Height Comparison







- Observation region enhanced to 2.5˚x2.5˚ grid over the region 12.5˚N-37.5˚N, 147.5˚W-170˚W.
- Difference between JJA and DFJ inversion base heights were calculated.
- Significance testing for three grid boxes
  - Two with the largest difference and one in the immediate wake of the Big Island.



- Red square (17.5˚N, 165˚W)
  - 41 total observations with a z_i difference of 0.5 km.
  - t value of 4.13 is greater than the critical value of 2.02
  - statistically significant at a 95% confidence level
- Blue square (22.5˚N, 162.5˚W)
  - 74 total observations with a z_i difference of 0.5 km.
  - t value of 5.53 is greater than the critical value of 2.00
  - statistically significant z_i at a 95% confidence level.
- Green square (20˚N, 157.5˚W)
  - 47 total observations with a z_i difference of 0.3 km.
  - t value of 2.99, which is greater than the critical value of 2.00
  - statistically significant at a 95% confidence interval.

- In comparison, when surface flow is not restricted to trade wind conditions
  - Observations within the red and blue box locations show a statistically significant difference
  - Observations within the green box do not.
- High median value areas decrease spatially with smaller grid size.
  - Location of high median values are comparable to the larger sample size.
- High median value south of the island chain during DJF season still needs to be investigated.

Conclusions

- A well mixed boundary layer along with the consistent presence of a sharp inversion layer make the Hawaiian Island region an ideal location to use GPS RO refractivity to estimate the inversion base height.
- Inversion base estimates during the JJA season show the high median values in the wake of the island chain with a secondary high value on the windward side.
- GPS RO estimations of the inversion are comparable to observations using radiosonde measurements from Hilo and Lihue.
- The differences in median base height at Hilo (300-400 m) are related to local terrain effects which are not picked up by GPS RO data due to the large grid size.
- Accurate depiction of the inversion base using GPS RO data is subject to the size of the analysis grid, data availability and interpretation of the space between grid points by plotting software.

Acknowledgements

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