Outline

- A postmortem of 40 days of rain
- Climatology of Mauna Kea
- The utility of long range lightning data

Recurrent Kona Low in 2006
Kona Lows - Kona Storms

- Kona lows are subtropical cyclones that occur during the cool season in the north central Pacific.
- Upper-level lows cut off from the polar westerlies in winter.
- Kona lows are cold core with the strongest circulation in middle and upper atmosphere.
- Kona lows are relatively long lived storms - often affecting Hawaii for a week or more.
- Erratic track and mesoscale organization of precipitation - makes for forecasting challenges.

Importance of Kona Lows

- Produce significant fraction of annual rainfall for south facing slopes of the Hawaiian Islands.
- Produce a variety weather related hazards
- NWP models generally perform poorly
Kona lows contribute >50% of the heavy rain events on Hawaii Is

Monthly distribution of heavy rain events on the SE slope of Mauna Loa by synoptic type (Kodama and Barnes 1997).

Weather Hazards in Kona Lows

- flash floods
- high winds
- waves and swell
- blizzards at altitude
- severe thunderstorms
  - high winds
  - large hail
  - tornados
Kona Lows hit Mauna Kea during the Winter of 01-02

The highest gust on the right side of the anemometer trace is an amazing 132 mph.

Severe Squall Line

Origin and Intensification

GOES Water Vapor loop  Quickscat Surface Winds

Intensifying Stage
250-mb wind and divergence

Genesis and life cycle explored by Morrison and Businger (W&F 2001) using reanalysis data.
Jet-Streak and Genesis

Intensifying Stage: Vertical Cross Section Height and Temperature Anomalies
Intensifying Stage – Unstable Air

Instability and Rainband Formation
Climatology of Kona Lows

Caruso and Businger (2006) looked at the relationship of upper-levels lows and surface development over the central north Pacific.

When the circulation aloft forms south of 30° N lat. and extends to the surface - it is included in the climatology as a kona low or kona storm.
Climatology of Kona Lows

Monthly Variability

Distribution of Genesis of Upper-Level Lows

All by month
With sfc low
Without sfc low
All by type
TRACKS OF SURFACE LOWS

Mean Life Cycle
Kona Low Climatology

Deepening of Kona lows linked to vorticity advection aloft

Poor NWP of Kona Lows

(Morrison and Businger 2001)
Simulation of a Kona Low

Cherubini, T., S. Businger, C. Velden, and R. Ogasawara, MWR 2006

Mesoscale Model 5 (MM5)

42 h run initialized at 00 UTC 24 February 1997 from NCEP AVN
Run on 16 Fujitsu VPP 700 vector processors
42 vertical levels, top level 10 mb
Four two-way nested domains, 30-s USGS terrain
Mesoscale Model 5 (MM5)

- Grell cumulus parameterization on 27 and 9 km grids
- Parameterization of shallow convection
- Reisner mixed phase resolved-scale moisture physics
- MRF high resolution boundary layer parameterization
- First order turbulence closure scheme
- LW/SW interactions with clouds, water vapor, and surface
- Dry and moist vertical diffusion

MM5 Nested Domains

- Inner domain is 3 km, middle domain is 9 km, and the outer domain is 27 km.
GOES Atmospheric Motion Vectors

Assimilation of Satellite AMV
Kona Low Simulation

With and without data assimilation. Maximum SLP gradient forms north of the low.

Climatological Analysis of Meteorological Observations at the Summit of Mauna Kea
### Data sets

<table>
<thead>
<tr>
<th>variable</th>
<th>CFHT data</th>
<th>UKIRT data</th>
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<tbody>
<tr>
<td></td>
<td>March 1995 - March 2006</td>
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<tr>
<td></td>
<td></td>
<td>Aug 2001 - Dec 2005</td>
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<tr>
<td>dew point</td>
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<td>May 1991 - Sep 2004</td>
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<tr>
<td></td>
<td></td>
<td>May 2005 - Dec 2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May 2005 - Dec 2005</td>
</tr>
</tbody>
</table>

### Behavior of the Variables

- Pressure
- Temperature
- Wind speed and direction
- Relative humidity
- Dew point (UKIRT)
Pressure: Monthly Means

\[ A_1 = 1.6 \text{ hPa} \]
\[ A_2 = 0.24 \text{ hPa} \]
\[ \alpha = 11.58 \text{ hPa} \]
\[ P_{\text{max}} = 616.19 \text{ hPa} \]
\[ P_{\text{min}} = 613.34 \text{ hPa} \]
\[ P_{\text{med}} = 615.08 \text{ hPa} \]
\[ \Delta P = 3.35 \text{ hPa} \]
Pressure: Daily Mean

Pressure: Semi-Diurnal Cycle

\[ T = 12 \text{ h} \]
\[ \max_1 = 10 \text{ h} \]
\[ \max_2 = 22 \text{ h} \]
\[ \min_1 = 4 \text{ h} \]
\[ \min_2 = 16 \text{ h} \]

\[ A_1 \text{ (Aug)} = 2.01 \text{ hPa} \]
\[ A_1 \text{ (Feb)} = 2.21 \text{ hPa} \]
\[ A_2 \text{ (Aug)} = 0.9 \text{ hPa} \]
\[ A_2 \text{ (Feb)} = 1.4 \text{ hPa} \]
Temperature: Monthly Means

Temperature: Annual cycle

$A_1 = 2.22 \, ^\circ C$

$A_2 = 0.26 \, ^\circ C$

$\omega = 1.62 \, ^\circ C$

$T_{max} = 4.47 \, ^\circ C$

$T_{min} = -0.28 \, ^\circ C$

$T_{med} = 2.21 \, ^\circ C$

$\Delta T = 4.75 \, ^\circ C$
Temperature: Daily Mean

Temperature: Diurnal Cycle

\[ T = 24 \text{ h} \]
\[ \text{max} = 13 \text{ h} \]
\[ \text{min} = 5 \text{ h} \]
\[ A (\text{Sep}) = 4.46 ^\circ C \]
\[ A (\text{Feb}) = 3.52 ^\circ C \]
Wind Speed: Monthly Mean

\[ A_1 = 1.72 \text{ m/s} \]
\[ A_2 = 0.81 \text{ m/s} \]
\[ \sigma = 1.49 \text{ m/s} \]
\[ w_{s_{\text{max}}} = 10.182 \text{ m/s} \]
\[ w_{s_{\text{min}}} = 4.68 \text{ m/s} \]
\[ w_{s_{\text{mean}}} = 6.82 \text{ m/s} \]
\[ \Delta w_s = 5.5 \text{ m/s} \]

Wind Speed: Daily Mean
Wind Speed: Diurnal Cycle

- max (Feb) = 7 h
- max (Aug) = 10 h
- min (Feb) = 15 h
- min (Aug) = 16 h
- A (Feb) < 1 m/s
- A₁ (Aug) < 1 m/s

Annual Wind Rose

- NE - SE: 50 %
- Strong winds: 10 %
- E: 18 %
- Strong winds: 4 %
- NW - SW: 30 %
- Strong winds: 11 %
- W: 12 %
- Strong winds: 6 %
January Wind Rose

NE - SE: 22 %
Strong winds: 8 %
E: 11 %
Strong winds: 5 %

NW - SW: 51 %
Strong winds: 29 %
W: 27 %
Strong winds: 16 %

May Wind Rose

NE - SE: 47 %
Strong winds: 6 %
E: 19 %
Strong winds: < 5 %

NW - SW: 35 %
Strong winds: 13 %
W: 17 %
Strong winds: 9 %
September Wind Rose

- NE - SE: 53 %
- Strong winds: < 5 %
- E: 19 %
- Strong winds: < 3 %

- NW - SW: 25 %
- Strong winds: < 5 %
- W: 8 %
- Strong winds: < 3 %

Relative Humidity: Monthly Mean

- $\alpha = 3.09 \%$
- $RH_{max} = 41.41 \%$
- $RH_{min} = 30.45 \%$
- $RH_{mean} = 36.08 \%$
- $\Delta RH = 10.96 \%$
Relative Humidity: Daily Mean

max (Aug) = 15 h
min (Aug) = 6 h
A (Aug) = 11.13 %
A (Dec) = 5.19 %
Dew point: Monthly Mean

\[ \sigma = 2.11 \, ^\circ C \]

\[ T_{d_{max}} = -12.89 \, ^\circ C \]

\[ T_{d_{min}} = -18.42 \, ^\circ C \]

\[ T_{med} = -15.56 \, ^\circ C \]

\[ \Delta T = 5.53 \, ^\circ C \]

Dew point: Daily Mean
Dew point: Diurnal Cycle

- max (Feb) = 15 h
- max (Aug) = 15 h
- min (Feb) = 5 h
- min (Aug) = 5 h
- A (Feb) = 6.62 °C
- A (Aug) = 9.24 °C

Snowfall Proxies

To estimate snowfall events at Mauna Kea (in the absence of data) a proxy was constructed as follows:

Proxy: Conditions:

- PW > 4 mm and T < 0 °C for at least 4 hours
Snowfall Proxy Results

March: 6 possible events
September: 0 possible events
Total number of days: 28

El Niño vs La Niña

\[ P = 613.64 \text{ hPa} \]
\[ P_{\text{EN}} = 615.32 \text{ hPa} \]
\[ P_{\text{LN}} = 613.74 \text{ hPa} \]
\[ \Delta_{\text{EN}} = 1.69 \text{ hPa} \]
\[ \Delta_{\text{LN}} = 0.1 \text{ hPa} \]
El Niño vs La Niña

Temperature

\[ T = 0.33 \, ^\circ C \]
\[ T_{EN} = 2.79 \, ^\circ C \]
\[ T_{LN} = -0.65 \, ^\circ C \]
\[ \Delta_{EL} = 2.46 \, ^\circ C \]
\[ \Delta_{LN} = -0.98 \, ^\circ C \]

El Niño vs La Niña

Wind Speed

\[ ws = 8.67 \, m/s \]
\[ ws_{EN} = 6.55 \, m/s \]
\[ ws_{LN} = 8.98 \, m/s \]
\[ \Delta_{EL} = -2.12 \, m/s \]
\[ \Delta_{LN} = 0.3 \, m/s \]
El Niño vs La Niña

Relative Humidity

RH = 36.98 %
RH\textsubscript{EN} = 18.36 %
RH\textsubscript{LN} = 33.23 %
\Delta\textsubscript{EL} = - 18.59 %
\Delta\textsubscript{LN} = - 3.71 %

Dew Point

Td = - 17.88 °C
Td\textsubscript{EN} = - 24.46 °C
Td\textsubscript{LN} = - 17.36 °C
\Delta\textsubscript{EL} = - 6.6 °C
\Delta\textsubscript{LN} = 0.52 °C
El Nino Wind Rose

- NE - SE: 23 %
- Strong winds: < 5 %
- E: 8 %
- Strong winds: < 3 %
- NW - SW: 50 %
- Strong winds: 16 %
- W: 26 %
- Strong winds: 10 %

La Nina Wind Rose

- NE - SE: 61 %
- Strong winds: 25 %
- E: 20 %
- Strong winds: 8 %
- NW - SW: 19 %
- Strong winds: 9 %
- W: 8 %
- Strong winds: < 3 %
Climatology

NE - SE: 37 %
Strong winds: 12 %
E: 13 %
Strong winds: 5 %
NW - SW: 48 %
Strong winds: 20 %
W: 19 %
Strong winds: 10 %

The Utility of Long-Range Lightning Networks
PacNet Sensor Sites

Currently 4 sensors installed at Dutch Harbor, Lihue, Kona and Kwajalein. Sensors in North-America and Japan contribute.

Synoptic View

Like GOES, long-range lightning data provide a synoptic view over data-sparse oceans.
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Synoptic View

Histogram of monthly mean lightning strikes.

Questions?

Acknowledgements
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