Relating Electrified Cloud Properties to Wilson Currents: An Oceanic and Continental Case Study

SOARS Protégé: Sarah Al-Momar
Research Mentors: Wiebke Deierling and Christina Kalb
Writing and Communications Mentor: Kimberly Kosmenko
Community Mentor: Carol Park
Peer Mentor: Logan Dawson
The Global Electric Circuit (GEC)

- Ionospheric potential of 250 kV
- The potential difference creates a variable fair weather current
- Thunderstorms and ESCs produce Wilson currents
- Wilson currents contribute to maintaining the potential difference

FESD: ECCWES
Cloud Electrification and Thunderstorm Charge Distribution

- Carnegie curve and diurnal thunderstorm variations
- Cloud electrification mechanisms:
  - Non-inductive charging
  - Collisions between graupel and ice crystals, in the presence of supercooled water
  - Gravitational size sorting creates main charge regions

Mach et al. 2011

Saunders 1993
The Cases

Oceanic Storm (multicell) - A

Continental Storm (single cell) - B

Continental Storm (single cell) - C
Data

- Wilson Current Estimates
  - ER-2 aircraft with electric field mills and conductivity probe; Mach et al. (2009-2011)

- EDOP X-Band Radar
  - Updraft volume, maximum updraft velocity, maximum reflectivity, echo top height, storm evolution

- KAMX NEXRAD
  - Echo top height, maximum reflectivity, storm evolution

- Precipitation Ice Mass in kg

- Ice Water Path (IWP) in g/m²
NEXRAD vs. EDOP
Maximum Reflectivity
Oceanic Case Only

- Change in Wilson current with storm evolution
- Correlation coefficient $r = 0.63$
Ice Water Path above -10ºC
Oceanic Case Only

- Strong correlation with lightning activity and IWP found by Petersen et al. (2005)
- Correlation coefficient $r = 0.81$
Precipitation Ice Mass above -10°C
Oceanic Case Only

- Strong correlation between total lightning and precipitation ice mass (Deierling et al. 2008)
- Correlation coefficient $r = 0.46$
EDOP Measurements

EDOP Reflectivity

EDOP Updraft Velocity

EDOP Updraft Volume with $w>5\text{m/s}$

Max. Updraft Velocity
Maximum Updraft above -5°C
Oceanic Case Only

- Strong updrafts support the development of large hydrometeors
- Correlation coefficient $r = 0.70$
Updraft Volume with $w > 5 \text{ m/s}$ above $-5^\circ\text{C}$

- Both peaks are well aligned
- Correlation coefficient $r = 0.74$
NEXRAD – IWP above -10°C level for all storms
EDOP – Updraft volume above -5°C for all storms

![Graph showing updraft volume for storms with Wilson Current (A)]
Wilson Current Relationships

- Investigating oceanic and continental storms
- Varies with storm evolution
- Wilson currents relate well to max. reflectivity, IWP, precip ice mass, max. updraft, and updraft volume
- Differences in conduction current due to storm type difference (Single cell vs Multicells)
- Much more data, especially from continental storms, is needed to draw any robust conclusions
- Look for differences in storm type and regime

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NEXRAD - Oceanic Case Only

Correlation Coefficient

\[ r = -0.28 \]
# Wilson Current Correlations

## EDOP

<table>
<thead>
<tr>
<th>Metric</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>IWP -10°C</td>
<td>0.767543</td>
</tr>
<tr>
<td>Precip Ice Mass -10°C</td>
<td>0.675552185</td>
</tr>
<tr>
<td>Max Updraft 0°C</td>
<td>0.695023819</td>
</tr>
<tr>
<td>Max Updraft -5°C</td>
<td>0.69968696</td>
</tr>
<tr>
<td>Max Updraft -10°C</td>
<td>0.701876275</td>
</tr>
<tr>
<td>Max Reflectivity</td>
<td>0.7467564</td>
</tr>
<tr>
<td>Updraft Volume 0°C</td>
<td>0.675060866</td>
</tr>
<tr>
<td>Updraft Volume -5°C</td>
<td>0.743271675</td>
</tr>
<tr>
<td>Updraft Volume -10°C</td>
<td>0.70099782</td>
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</tbody>
</table>

## NEXRAD

<table>
<thead>
<tr>
<th>Metric</th>
<th>Correlation Coefficient</th>
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</thead>
<tbody>
<tr>
<td>IWP -10°C</td>
<td>0.81329</td>
</tr>
<tr>
<td>Precip Ice Mass -10°C</td>
<td>0.459780322</td>
</tr>
<tr>
<td>Max Reflectivity</td>
<td>0.631745</td>
</tr>
<tr>
<td>Cloud Top</td>
<td>-0.27966</td>
</tr>
</tbody>
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Oceanic Storm A