Expansion of the Tropical Belts and Poleward Migration of the Storm Tracks Shown by Variations in Surface-Observed Cloud Cover

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Surface Observed Clouds

- Clouds observed from ships or from weather stations by the human eye
- Observers trained to quantify cloud amount, level, and type

Station 94826, Cape Nelson Lighthouse, VIC, Australia
Clouds from Synoptic Reports

- Reported levels: Low, middle, and high
- At each level, 9 possible cloud types – 27 individual types

<table>
<thead>
<tr>
<th>POSITION</th>
<th>WIND</th>
<th>TEMPERATURE</th>
<th>PRESSURE</th>
<th>PRESSURE CHANGE</th>
<th>WEATHER</th>
<th>CLOUDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 2</td>
<td>Group 3</td>
<td>Group 4</td>
<td>Group 5</td>
<td>Group 6</td>
<td>Group 7</td>
<td>Group 8</td>
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<td>621</td>
<td>3</td>
<td>0854</td>
<td>4</td>
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</table>
Clouds from Synoptic Reports

- Amounts are reported for total and lowest cloud cover in oktas (1/8’s)
- Reports taken every 3-6 hours
Weather Stations

- 5388 Weather stations available in database
EECRA

- Cloud reports are stored from ships and weather stations in the “Extended Edited Cloud Reports Archive”:
  - 1971-2009 over land
    - Current source: Integrated Surface Dataset (ISD)
  - 1954-2008 over the ocean
    - Source: International Comprehensive Ocean-Atmosphere Dataset (ICOADS)
Gridded and Station Averages

- Individual observations are averaged on monthly, seasonal, yearly, and all-time timescales
- 27 reported cloud types aggregated into 9 cloud groups and 1 total cloud cover value
  - 5 low (Fog, Stratus, Stratocumulus, Cumulus, Cumulonimbus)
  - 3 middle (Altostratus, Altocumulus, Nimbostratus)
  - 1 high cloud type
- Available on a grid or for individual stations
Cloud Atlases from the EECRA

- Maps and Data are available online
- Long-term and monthly/seasonal averages

- Land and Ocean available separately
  - Land: 1971 to 2009
  - Ocean: 1954 to 2008
Applications for Surface Observed Clouds

- Longer cloud record than any satellite cloud climatology
- Can be used for trend analysis, provided users exercise adequate quality control
- Use stations with complete record, AND adequate #’s of observations per year
Declining #’s of Observations

- Surface cloud observations are being phased out in favor of automated systems
- US and Canada ceased making human-made observations in the mid 1990’s
“Premium” Stations for this Analysis

- Stations with a complete record before 1994
- We do our analysis with this shortened set, and...
“Premium” Stations for this Analysis

- Stations with a complete record 1971-2009
- We do a separate analysis with this longer set (primarily shown)
Creating an Area Average with Surface Obs

Station Anomaly Time Series

Average of Stations within Grid Box

% Cloud Cover Anomaly

Average of Boxes within Region

Year

Trends in the Zonal Distribution

- Total cloud cover versus latitude
- Maxima and minima determine zone boundaries
- Is this distribution changing?
Trends in the Zonal Distribution

- For each zone
  - Determine the ‘center of mass’ in each seasonal distribution
  - For each year: [seasonal center] – [long-term seasonal center]
  - Show each seasonal anomaly, determine trend
Testing Variability using ENSO

December, January, February

Percent Cloud Cover vs Latitude

Latitudes -80 to 80
Percent Cloud Cover 0 to 100

ENSO Index < 1 (Blue)
ENSO Index > 1 (Red)
Testing Variability using ENSO

- ENSO causes the Hadley cell to retract equatorward.
- Anomalies in dry zone and storm track centers correlate significantly with ENSO index (dry zones shown).
- Variation in these centers is not likely random, but related to climate changes.
- What do trends look like?

![Graph showing correlation between ENSO index and dry zone anomalies.](image)

- Northern Dry Zone Winter: $r = -0.75$
- Southern Dry Zone Winter: $r = 0.50$
Multidecadal Trends in Centers

- Tracking the deviation from climatological average latitude for the center of each zone
- Suggests that both storm tracks are significantly displaced poleward, dry zones move an insignificant amount poleward
Including Ocean Data

- Ocean data lies on a coarser 10x10° grid, and is prone to an unidentified bias causing a spurious long-term trend.
- Inclusion of ocean data appears to diminish storm track and tropical displacement, but enhance dry zone displacement.
Conclusions

• Surface observations can be used to show trends in the zonal distribution of cloud cover — Provided adequate quality control is exercised

• Displacement in dry zones and storm tracks correlates significantly with the ENSO index

• Trends in the distribution over land suggest poleward displacement of the storm tracks

• Inclusion of ocean data suggests a diminished displacement in storm tracks, but an enhanced displacement of the dry zones
Acknowledgements

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