Cloud Changes from Land Stations Worldwide 1971-2009

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May 2012

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Surface-Observed Clouds

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

Station 94826, Cape Nelson Lighthouse, VIC, Australia

Photograph by dmmaus via flickr
Clouds from Synoptic Reports

- Reported Levels: Low, middle, and high
- At each level, 9 possible cloud types – 27 individual types
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 chosen worldwide.
EECRA

- Cloud reports are stored from ships and weather stations in the 'Extended Edited Cloud Reports Archive':
  
  - 1971-2009 over land (updated this year)
    - New source data: “Integrated Surface Dataset (ISD)”
  
  - 1954-2008 over the ocean
    - Source: “International Comprehensive Ocean-Atmosphere Dataset (ICOADS)”
EECRA

- Project began in 1980
  - Carole Hahn, Steve Warren, and Julius London made cloud climatology Atlases
- Database has been updated twice (1996 and 2009)
Cloud Atlases from the EECRA

- First Atlases made in the early 1980's
- Data through 1981

For land and ocean separate
Cloud Atlases from the EECRA

- Maps and raw data are available for contouring

- Now available online: www.atmos.../CloudMap
EECRA

- EECRA contains cloud type data as well as other environmental data
  - Cloud base height
  - Present weather
  - 'Illuminance' is determined by solar and lunar altitude and lunar phase
    - Adequate light is equivalent to a half-moon at zenith
    - ~38% of night observations are acceptable
- Environmental data is used to enhance the report
  - Precipitating cloud types are determined
  - Adequately illuminated reports are flagged
  - Observations with inconsistencies are removed
Monthly & Seasonal Averages

- 27 cloud types are grouped into 9 classes “types”
  - 5 low (fog, stratocumulus, stratus, cumulus, cumulonimbus)
  - 3 middle (altostratus, altocumulus, nimbostratus)
  - 1 high cloud (cirriform)
  - Also total cloud cover and clear skies frequency

- Grouping of types was required due to subtle differences in reporting between countries
  - National boundaries were apparent
Monthly & Seasonal Averages

- Files contain:
  - Average frequency of occurrence (f)
  - Amount when present (awp)
  - Amount \( (f \times awp) \)

- Stations are included in our analyses:
  - For trends:
    - 75 obs/season, 25 years, spanning 30 yrs
  - For averages / correlation with other data:
    - 50 obs/season, 15 seasons, spanning 15 yrs
Station Changes Worldwide

- Number of stations in decline
  - New source data has incompatibilities
- No longer includes US, Canada, New Zealand after 1996
  - Switch to 'ASOS' makes cloud obs incompatible
- Geographic area represented has declined less
Station Distribution Over Time

- Stations in the US, Canada, and New Zealand mostly gone

- Most regions have seen some thinning, but much of the land-area is still represented
Weighted Regional Averages

Station Anomaly Time Series

Average of Stations within Grid Box

Average of Boxes within Region

Year
Quality Control: Time Series Analysis

- Good time series with small, steady cloud trend

![Galati, Romania, JJA](chart1.png)

- Questionable time series in the Arctic, step at 1986

![Byron Bay, NT, Canada, JJA](chart2.png)
Spurious Time Series

- Nearby station (166 km away) matches until step at 1986
- Plot trends on a map to search for other bad time series in the region
  - Possible explanation?
Spurious Time Series

Trends of Total Cloud Cover; June, July, August Over Canada & Alaska
Distant Early Warning Line

- Radar & weather stations created to detect soviet missiles or bombers over the Arctic

- In 1986 they were instructed only to report 'significant weather'
  - Clouds were only reported when it was stormy
  - Trends are caused by this change, nearby stations unaffected

- These stations are rejected from our dataset
Time Series in Russia

- Smooth time series suggest trends in Ns & Cb

- Two prior publications have shown this separately
Questionable Trends

Cumulonimbus Trends over North Asia, DJF
Suspicious Ns / Cb tradeoff

- Cb and Ns show enormous changes not 'corroborated' by changes in other types
  - Seen at over 100 Russian stations
  - Steps seen in different years at different stations
- These suspicious stations were removed from our averages, and all subsequent figures
Global Cloud Cover Changes

- Calculated as shown above, using weighted averages
- Total cloud cover appears to be relatively steady
- Ocean trend may be based on spurious ship observations
Global Land Trends in Cloud Types

- Small changes taking place
- Slight tendency for cumulus and stratocumulus to overtake stratus
- Most change is due to decreases at middle and high levels

<table>
<thead>
<tr>
<th>Type</th>
<th>Trend % per Decade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fog</td>
<td>0</td>
</tr>
<tr>
<td>Stratus</td>
<td>-0.3</td>
</tr>
<tr>
<td>Stratocumulus</td>
<td>0.2</td>
</tr>
<tr>
<td>Cumulus</td>
<td>0.1</td>
</tr>
<tr>
<td>Cumulonimbus</td>
<td>0</td>
</tr>
<tr>
<td>Nimbostratus</td>
<td>-0.2</td>
</tr>
<tr>
<td>Altostratus</td>
<td>-0.2</td>
</tr>
<tr>
<td>Altocumulus</td>
<td>0.1</td>
</tr>
<tr>
<td>High (cirriform)</td>
<td>-0.2</td>
</tr>
<tr>
<td>Total cloud cover</td>
<td>-0.4</td>
</tr>
<tr>
<td>Clear sky</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Changing cloud cover by continent

- South America, Australia showing biggest declines
- Other continents show smaller declines
- Interannual Variation appears to stay similar throughout the time series (except N. America)
Cloud Changes by Latitude Zone (Land)

- Total cloud cover versus latitude
  - Maxima and minima determine zone boundaries
- Zones represent
  - Tropics
  - Subtropical deserts
  - Midlatitude jet streams
- Are these zones moving?
Cloud Changes by Latitude Zone (Land)

- For each zone
  - Determine the 'center of mass' in each seasonal distribution
  - For each year: [Seasonal center of mass] – [long-term seasonal mean]
  - Show each seasonal anomaly, determine trend
Testing the Analysis

- El Nino causes the Hadley cell to retract equatorward
  - Northward dry zone-anomalies correlated with ENSO index
- Significant correlation (95%) is shown between ENSO and our 'Center of Mass' anomalies in dry regions (shown) AND jet streams
Cloud Changes by Latitude Zone (Land)

- Clouds in jet stream regions are shifting poleward significantly
  - 80 – 100 km in 39 yrs
- Desert regions also show poleward shifts, but not significant
- Tropical northward shift somewhat mysterious
- Agrees with Fu & Lin
Aerosols and Cloud Types in India

- India has seen dramatic population increases over our period (doubled from 1971 to 2009)
  - 560 million to 1.16 billion
- Also increases in aerosols, which can influence clouds & precipitation
- Mechanisms:
  - Black carbon can stabilize the atmosphere by cooling the surface and heating the atmosphere
  - Aerosols can prolong cloud life with increased CCN, suppressed precipitation
- Recent studies have blamed aerosols for reducing precipitation in the north
Indian Monsoon

JJA, Total Cloud Cover Correlated with the Indian Summer Monsoon

Correlation Coefficient (r)

-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1
Aerosols and the Indian Monsoon

- We would expect less precipitation in NE India given the increased pollution.

- Cloud changes should accompany this decrease:
  - Increased stability should favor stratiform versus cumuliform clouds.
  - Precipitating clouds should decrease, especially cumulonimbus clouds.

- Examine trends in cloud cover by month in Northern and Southern India.

- Indian monsoon index shows a negligible trend.
Aerosols and the Indian Monsoon

- North India matches region used by Bollasina et al. (2011)
  - Used models to show that aerosols can affect the monsoon
  - Area shows declining precipitation June - Sept. 1950-1999
- South India shows a more neutral precipitation trend
Northern India

- Cloud Cover peaks during monsoon
  - Caused by precipitating and cumuliform clouds
- Precipitating clouds decreasing after June
  - Mostly due to Cumulonimbus
- Stratiform clouds are increasing at the expense of cumuliform
- Agrees with predictions
Southern India

- Same peak in cloud cover during monsoon
- Precipitating clouds are increasing
  - Nimbostratus is increasing, cumulonimbus shows no trend
- Stratiform clouds are increasing year-round at the expense of cumuliform
Conclusions I

- A dataset of surface observed cloud cover over land is updated through 2009
  - Spans 39 years 1971 – 2009
- DEW stations have been identified
- Quality control work on station time series has shown spurious trends in Cumulonimbus and Nimbostratus cloud amounts over Russia
  - Conclusions based on these stations may be in doubt
  - Bad stations have been removed from our dataset
Conclusions II

- Cloud cover over land shows a slight decreasing trend globally
  - Steady since 1982
  - Decline is due mostly to middle and high clouds
  - A tendency for cumuliform to replace stratiform low clouds is seen
- Time series show that cloud amounts are steady or slowly decreasing on every continent
  - Especially South America & Australia
Conclusions III

- Cloud distributions associated with the jet streams have moved poleward by 80-100 km
  - Variations seen are likely real, as they correlate significantly with the ENSO index
- Predicted cloud changes are seen in northern India during summer
  - Cumuliform clouds are decreasing, while stratiform clouds are increasing
  - Aerosols could be a cause of drought in this area