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ASSESSING SIGNIFICANCE
OF GLOBAL CHANGE IN
LOCAL CLIMATE TIME SERIES

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Motivation

- Local Climate Analysis Tool (LCAT) introduced in July 2013, enables studies of climate change impacts at the local level.
- LCAT provides access to local and regional data and analysis methods recommended by NOAA subject matter experts for application at the local level.
- LCAT users require uncertainty and significance of parameters estimated from short and imperfect time series.
What is LCAT?

LCAT uses principles of Artificial Intelligence to connect humans with computing capability to apply data and scientific techniques.

**How is the temperature in my town changing?**

**Should we expect floods during La Niña events?**

**How severe is the drought in my region this year?**

**Which climate model performs best in my region?**

**What are the projections for climate in my region?**

- **Data:** Homogenized station maximum temperature
  **Analysis:** best practices for trend; rate of change
  **Output:** statistics, plots, metadata

- **Data:** Homogenized precipitation and river flow
  **Analysis:** composites, risk assessment
  **Output:** statistics, plots, metadata

- **Data:** Drought indices
  **Analysis:** time series analysis
  **Output:** statistics, plots, metadata

- **Data:** Reanalysis and GCM fields
  **Analysis:** downscaling, sensitivity tests
  **Output:** statistics, plots, metadata

- **Data:** GCM outputs
  **Analysis:** downscaling
  **Output:** statistics, plots, metadata
LCAT trend-fitting techniques

- **Hinge**: best fit linear trend for 1976-present anchored on the best fit linear trend for 1925-1975

- **Optimal Climate Normal (OCN)**: 10-year (temperature) or 15-year (precipitation) moving average

- **Exponentially Weighted Moving Average (EWMA)**: heavier weight on last optimal period, for temperature:

  \[
  \Delta_{\text{year}} = \left( \frac{2}{N + 1} \right) \left( T_{\text{ST,year}} - T_{\text{CD,year}} \right) + \left( 1 - \frac{2}{N + 1} \right) \Delta_{\text{year-1}}, \text{ where } N = 10 \text{ years}
  \]

  \[
  a_{i,\text{adj}} = a_i + (\Delta_{\text{year}} - \Delta_{\text{mean for 1971-2000}})
  \]

- **Optimal variation of OCN** – under development

- **Ensemble**: provides average and spread due to methods

- **Significance of each method is measured by Root Mean Square Error (RMSE)** – the smaller the error the better fit
## LCAT trend-fitting techniques

<table>
<thead>
<tr>
<th>Trend</th>
<th>Use appropriately</th>
<th>Question answered</th>
<th>Correct interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hinge</td>
<td>Best used for temperature and temperature-derived variables such as Degree Days</td>
<td>What is current climate change?</td>
<td>The slope is the measure of the warming or cooling rate</td>
</tr>
<tr>
<td>OCN</td>
<td>Can be used for any variable</td>
<td>What is the change in the climate normal?</td>
<td>Indicator of how the mean value is changing; mean does not indicate the most likely value to occur</td>
</tr>
<tr>
<td>EWMA</td>
<td>Can be used for any variable</td>
<td>What is the change in the most recent climate normal period?</td>
<td>Indicator of how the mean value is changing; mean does not indicate the most likely value to occur</td>
</tr>
</tbody>
</table>
Rate of Climate Change

Rate of change (ROC) in climate time series is the slope of the hinge or the linear regression line fit to the trend-line.

1925-2014 Jan-Feb-Mar Average Temperature
CD NV04 (Extreme Southern Nevada)

Hinge | OCN-15 | EWMA-15
--- | --- | ---
2.82°F/30 years | 1.59°F/30 years | 1.41°F/30 years
Rate of Climate Change

- Analyzing present climate change, to obtain the most robust result (unimpaired by temporary variations and questionable record coverage) LCAT uses 1940 for beginning year.

**1940-2014 Jan-Feb-Mar Average Temperature**
CD NV04 (Extreme Southern Nevada)

<table>
<thead>
<tr>
<th>Method</th>
<th>Rate of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hinge</td>
<td>2.82°F/30 years</td>
</tr>
<tr>
<td>OCN-15</td>
<td>2.16°F/30 years</td>
</tr>
<tr>
<td>EWMA-15</td>
<td>1.95°F/30 years</td>
</tr>
</tbody>
</table>
Local Rate of Climate Change

http://www.cpc.noaa.gov/trndtext.shtml
Local Rate of Climate Change

Climate Division

Rate of Long-Term Trend Temperature Change (top; °F per decade) & Precipitation Change (bottom; inches per decade) — JFM

Stations

Rate of Change:
- <1.20
- 1.20 to -0.80
- 0.80 to -0.40
- -0.40 to -1.20

Rate of Change:
- <1.20
- 1.20 to -0.80
- 0.80 to -0.40
- -0.40 to -1.20
ROC vs Climatology

- Climatology is currently the main driver of many climate-sensitive decisions

- Incorporating ROC into decision making provides additional information on magnitude of the change

- Understanding confidence of ROC is critical for decision makers

Guidance to users:

- 1961-1990 Climo = 48.6°F
- 1971-2000 Climo = 49.4°F
- 1981-2010 Climo = 50.0°F
- OCN-15 2014 = 50.5°F
- Hinge 2014 = 51.4°F
ROC significance

- **Slope confidence intervals**

\[
\left( \frac{ROC - t\sigma_E}{\sqrt{S_{xx}}}, \frac{ROC + t\sigma_E}{\sqrt{S_{xx}}} \right)
\]

<table>
<thead>
<tr>
<th>Confidence Level</th>
<th>Hinge*ROC=0.094</th>
<th>OCN11 ROC=0.07</th>
<th>OCN15 ROC=0.071</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75%</td>
<td>0.036</td>
<td>0.152</td>
<td>0.003</td>
</tr>
<tr>
<td>90%</td>
<td>-0.016</td>
<td>0.204</td>
<td>-0.055</td>
</tr>
<tr>
<td>95%</td>
<td>-0.048</td>
<td>0.236</td>
<td>-0.091</td>
</tr>
</tbody>
</table>

**Figure:** January-February-March Average Temperature (Degrees F)
Time Series Analysis for NCDC Climate Division ID #NV04

- Data
- Hinge-1975

**75%**
Signal to noise ratio evaluates climate change impacts in comparison to climate variability

The $\beta$ unit is fraction of change over years

Example: if $\beta = 0.05$ (very steep change), it implies that climate change will be as large as climate variability today in 20 years, and double in 40 years
ROC significance

**Current Climate**

ROC = 2.82°F/30 yrs  
β = 0.057  
CV = CC in 17.5 yrs

**Current Normals**

ROC = 2.16°F/30 yrs  
β = 0.038  
CV = CC in 26 yrs

ROC = 1.95°F/30 yrs  
β = 0.033  
CV = CC in 30 yrs
ROC significance

The greater the variability of climate element, the less the climate change impact.

This example:

ROC = -0.9 change in PDI in 30 yrs

β = 0.012

CC=CV in 83 yrs
Trend adjustment in CV studies

- Applies the trend to the historical record such that decisions can be based on the changing climate rather than unadjusted past climate.

- Computed by taking the difference between each individual observation and the trend at each observation point and adding these differences to the very last year of the trend.

\[ \text{Detrend} = \text{Trend}_{\text{last year}} + (\text{Raw Data} - \text{Trend}) \]

- Detrended time series are used for determining climate variability impacts on local climate.

- This approach assumes that variability in the climate data and climate change act independently from each other, thus their effects can be additive.
Trend adjustment in CV studies

- ROC application trend adjustment is critical for assessing impacts of climate events such as ENSO.

### Raw Series

| ONI Probability Distribution [1950-2014] of January-February-March Average Temperature for NCDC Climate Division ID #NV04 |
|---|---|---|
| CNI<=-0.5 | 21.1% | 21.1% | 57.9% |
| Neutral | 26.6% | 32.1% | 39.3% |
| ONI>0.5 | 27.0% | 11.1% | 61.1% |

**Based on 1981-2010 climatological reference period using observations. Bold borders indicate at least 90% statistical significance.**

### Trend Adjusted

| ONI Probability Distribution [1950-2014] of January-February-March Average Temperature for NCDC Climate Division ID #NV04 |
|---|---|---|
| CNI<=-0.5 | 5.3% | 32.1% | 38.2% |
| Neutral | 7.1% | 14.3% | 78.6% |
| ONI>0.5 | 11.1% | 22.2% | 65.7% |

**Based on 1981-2010 climatological reference period using Hinge adjusted data. Bold borders indicate at least 90% statistical significance.**
Summary

- LCAT is a new and evolving climate services tool
- Slope confidence intervals and signal-to-noise ratio are the tools to evaluate the significance of the rate of change
- Understanding the significance of rate of change builds user confidence in making climate-sensitive decisions