On the statistical significance of climatic trends estimated from GRUAN tropospheric time series

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Overview

Climate norms 30 years → GNSS time series question of time
Overview

- TIGA: Tide Gauge Benchmark Monitoring
- Reprocessing of data, 1995–2015
  - 750 sites
  - 371 > 10 years
On the statistical significance of climatic trends estimated from GPS tropospheric time series

GRUAN GPS stations

April 25, 2018
GRUAN GPS stations

Reprocessed GPS data

Years

2011–2017

Idb0  ldrz  nya2  pots  soda  utqi
Workflow

Data processing

Data evaluation

Data homogenization

Seasonal adjustment

Trend estimation
PWV at NyAlesund

RS data from M. Maturilli
PWV at NyAlesund

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April 25, 2018
PWV at NyAlesund

PWV at the site Ny-Alesund

PWV at the site Ny-Alesund 2011-2016

On the statistical significance of climatic trends estimated from GPS tropospheric time series

April 25, 2018
Table: PWV at NyAlesund

<table>
<thead>
<tr>
<th></th>
<th>GNSS-RS</th>
<th>ERAI-RS</th>
<th>ERAI-GNSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All data</td>
<td>Outlier removed</td>
<td>All data</td>
</tr>
<tr>
<td>Bias</td>
<td>0.06</td>
<td>-0.26</td>
<td>-0.12</td>
</tr>
<tr>
<td>STD</td>
<td>1.67</td>
<td>1.11</td>
<td>1.18</td>
</tr>
</tbody>
</table>
PWV at NyAlesund

ERAI vs. RS

ERAI vs. GPS

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Overview

RS data from M. Sommer
Trend Estimation

Important are:

- the time span of the time series
- the presence of gaps (the start and the end of the time series)
- the presence of noise, its magnitude compared to the expected trend
- the autocorrelation in the time series
- homogeneity
Trend Estimation

- **Data Homogeneity** → prerequisite for detecting climatic trends

- Inconsistencies in time series:
  - change processing setup → avoidable by Reprocessing, One model setup for the whole time window
  - change hardware or software of GNSS stations → not avoidable!
  → Homogeneity check

- Singular spectrum analysis
Trend Estimation

- Trend
- Seasonal
- Irregular

\[ Y = T + S + N \]
\[ T = a + bt \]

\[ \sigma_b = \frac{\sigma_N}{\sqrt{\sum (t-\bar{t})^2}} \cdot \sqrt{\frac{1 + r}{1 - r}} \]

1-lag autocorrelation

When \( |b|/ \sigma_b > 2 \), confidence >95% \( \rightarrow \) significant
Results: Radiosonde data Ny-Ålesund

Significant ✓

Trend=0.23 mm/decade with 95.9% confidence

Significant ✓

Trend=1.24 K/decade with 98.3% confidence
Results: Radiosonde data Ny-Ålesund

6.97% increase in PWV per a degree Celsius increase in temperature → Agreement to Clausius-Clapeyron equation
Results: Radiosonde data Lindenberg

Trend = 0.59 mm/decade with 97.4% confidence

24 years

Significant ✓
Trend Estimation

- Trend
- Seasonal
- Irregular

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\( r \) 1-lag autocorrelation

\( \sigma_b \) standard error

\( \sigma_N \) magnitude

Required data size

For a trend magnitude \( b_o \) and 90% confidence level

\[ n_{req} = \left[ 3.3 \frac{\sqrt{12}}{\sqrt{365.25}} \frac{\sigma_N}{|b_o|} \sqrt{\frac{1 + r}{1 - r}} \right]^{2/3} \]

- Higher \( r \), \( \sigma_N \)
- Smaller \( b_o \)
  → longer dataset is required
### Required Length of PWV time series

**Required length to detect a PWV trend of 0.4 mm/decade**

<table>
<thead>
<tr>
<th>Station</th>
<th>( \sigma_N )</th>
<th>( #\text{years} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDB0</td>
<td>3.84</td>
<td>12</td>
</tr>
<tr>
<td>POTS</td>
<td>3.81</td>
<td>12</td>
</tr>
<tr>
<td>NYA2</td>
<td>4.97</td>
<td>14</td>
</tr>
</tbody>
</table>
## Required Length of temperature time series

### Required length to detect a T trend of 1 K/decade

<table>
<thead>
<tr>
<th>Location</th>
<th>$\sigma_N$</th>
<th>#years</th>
<th>T</th>
<th>PWV</th>
<th>T</th>
<th>PWV</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDB0</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>NYA2</td>
<td>4.97</td>
<td>14</td>
<td>2.94</td>
<td>16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary

- PWV trend estimation using
  - GPS
  - Radiosonde
  - ERA-Interim

- The trends are statistically significant for adequately long time series

- Time series longer than 15 years are required to estimate significant trends


Alshawaf et al., 2018: On the statistical significance of climatic trends estimated from GPS tropospheric time series, JGR, submitted.
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Thank you!