Precipitation in the Karakorum and Himalaya from observations and global climate model simulations

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ISAC-CNR, Turin, Italy

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Orographic Precipitation and Climate Change Workshop
Circulation patterns in the Hindu-Kush Karakoram Himalaya (HKKH) and the Indian Subcontinent

Winter Westerlies

Indian summer Monsoon

ITCZ (NH SUMMER)
Precipitation datasets

**Satellite**

TRMM (Tropical Rainfall Measuring Mission)
1998-2007
3B42 product
3-Hour
0.25 x 0.25 ° (30x30 km) from 50°S-50°N.

**In-situ gridded**

APHRODITE (Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources)
1951-2007
APHRO_MA (Monsoon Asia) _V1003R1 product
Daily precipitation datasets derived from rain gauges
0.25 x 0.25 ° in the domain 60°E-150°E, 15°S-55°N

**Merged Satellite + in-situ**

Global Precipitation Climatology Project (GPCP) NOAA
1979-2010
Version V2.2
Monthly means of precipitation derived from satellite and gauge measurements.
2.5°x2.5° from 88.75°S-88.75°N and 1.25°E-358.75°E

**Global Precipitation Climatology Centre (GPCC)**
1901-2009
Gauge-based gridded monthly precipitation data sets
0.5° x 0.5°

**Climate Research Unit (CRU)**
1901-2009
TS 3.10 product precipitation
Monthly
0.5° x 0.5°

**Reanalyses**

ERA-Interim 1979-present, Daily, 1.5°x1.5°
ERA40: 1957-2002, Daily, 1.5°x1.5°
Model: EC-Earth

http://ecearth.knmi.nl/  EC-Earth web site
http://www.to.isac.cnr.it/ecearth/  EC-Earth@ISAC-CNR

EC-EARTH components

- Atmosphere GCM: IFS
- Land: IFS H-tessel
- Vegetation: LPJ
- Atmospheric Chemistry and aerosols: TM5
- Ocean GCM: NEMO
- Sea-ice: LIM2/3
- Marine ecosystem: PISCES

European Community Earth System Model

- 23 Research institutions from 10 different European countries
- ISAC is member of the consortium
- Coordinating institution: KNMI

We have performed at ISAC

- 1 Historical run (1850-2005)
- 3 scenario runs (2006-2100): RCP4.5, RCP8.5, RCP2.6
Precipitation datasets

In-situ gridded

These datasets interpolate grid point values from the nearest few available stations. In areas with sparse station coverage, this represents a significant element of uncertainty.

Summer precipitation (JJAS), Multiannual average 1998-2007

GPCC - raw

GPCC

CRU

Aphrodite
Summer precipitation (JJAS), Multiannual average 1998-2007

GPCP

ERA-Int

TRMM

GPCC

CRU

Aphrodite
Winter precipitation (DJFMA), Multiannual average 1998-2007

GPCP

ERA-Int

TRMM

GPCC

CRU

Aphrodite

mm/day
Winter precipitation (DJFMA), Multiannual average (1998-2007) and standard deviation.

Summer precipitation (JJAS), Multiannual average (1998-2007) and standard deviation.

Winter precipitation (DJFMA), Multiannual average (1998-2007) and standard deviation.
Summer precipitation (JJAS), Multiannual average 1998-2007

Winter precipitation (DJFMA), Multiannual average 1998-2007
Precipitation seasonality in the HKK and Himalaya

- Askole
- Urdukas

EvK2-CNR stations installed in the proximity of the Baltoro Glacier, which is being monitored in the framework of the project SHARE-Paprika-Karakorum

1 to 7: Automatic Weather stations located in Northern Pakistan managed by the Water and Power Development Authority (WAPDA)

Work in progress, in collaboration with Dr. Adnan Tahir
In-situ stations at Askole and Urdukas, Baltoro

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Height of the sensor (m)</th>
<th>Askole data availability (%)</th>
<th>Urdukas data availability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>mm</td>
<td>1.5</td>
<td>59</td>
<td>30</td>
</tr>
<tr>
<td>Air Temperature</td>
<td>°C</td>
<td>2</td>
<td>88</td>
<td>66</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>%</td>
<td>2</td>
<td>88</td>
<td>66</td>
</tr>
<tr>
<td>Air pressure</td>
<td>hPa</td>
<td>2</td>
<td>85</td>
<td>66</td>
</tr>
<tr>
<td>Downward short wave radiation</td>
<td>Wm(^{-2})</td>
<td>2</td>
<td>88</td>
<td>66</td>
</tr>
<tr>
<td>Wind speed</td>
<td>ms(^{-1})</td>
<td>5</td>
<td>84</td>
<td>60</td>
</tr>
<tr>
<td>Wind direction</td>
<td>°</td>
<td>5</td>
<td>78</td>
<td>59</td>
</tr>
</tbody>
</table>

Askole, 3015 m asl

Urdukas, 3926 m asl

October 2005

June 2004
In-situ, Askole and Urdukas, Baltoro
Precipitation: critical points

- precipitation data at the two AWS are largely biased by altitude
- rain gauges are much lower in altitude than the zones of maximum precipitation
- missing data during almost all winter months at both stations
- the seasonality of precipitation cannot be distinguished
Precipitation seasonality in the HKK and Himalaya - observations
In the HKK there is more variability from decade to decade in winter compared to summer.
Time series of precipitation from the different data sets (1901-2009)

OBSERVATIONS
Time series of precipitation from the different data sets (1901-2009)

OBSERVATIONS and ensemble EC-Earth
EC-Earth ensemble (8 members) over the Himalaya

Significant increasing trend during summer in the Himalaya
EC-Earth ensemble (8 members) over the Himalaya

Himalaya box rcp45 JJAS

Member @ ISAC

Prec. [mm/day]

Himalaya box rcp85 JJAS

Member @ ISAC

Prec. [mm/day]

Himalaya box – RCP 4.5 – JJAS

precipitation [mm/day]

Himalaya box – RCP 8.5 – JJAS

precipitation [mm/day]
EC-Earth ensemble (8 members) over the Himalaya
EC-Earth ensemble (8 members) over the Karakoram

Weak increasing trend during winter in the HKK in both scenarios
Concluding remarks

- It is not appropriate to treat the HKK and Himalaya as a single region. They differ in climate, especially in sources and types of precipitation.

- Improvement in the monitoring of mountainous areas would require additional gauges going into the analysis and/or gauge analysis techniques using terrain information to “adjust” the gauges that are available.

- Synergy of surface-based and satellite-based observations/estimates; model data.

- EC-Earth model shows increase in precipitation extremes during summer in the Himalaya and weak increasing trend in winter precipitation over the Karakoram; more variability in wintertime than summertime precipitation.

- Future exploration: dynamics of western weather patterns and interaction between mid-latitude westerlies and the monsoon circulation.

- Modeling chain: GCM, Dynamical and stochastic downscaling.
Due to the lack of data, it is not possible to assess the seasonality of rainfall at these two sites. The multiannual mean summer (JJA) mean precipitation is 3.61 mm/day and 2.53 mm/day at Urdukas and Askole, respectively. The value of March and April averaged precipitation at Urdukas is 0.2 mm/day and for January to April averaged precipitation at Askole is 1.23 mm/day.

The lack of correlation between temperature and relative humidity (the correlation coefficient is -0.47 at Askole and -0.2 at Urdukas) is consistent with the expected non monsoonal behaviour at the AWS site.

2.2 Meteorological observations from the WAPDA network

The WAPDA stations considered in this study are listed in Table 2 along with their elevation, latitude and longitude, the recorded maximum and minimum temperature and the maximum precipitation registered along the whole measurement period and some precipitation and temperature statistics. In particular, the table shows the annual, summer (JJAS) and winter (DJFMA) average of precipitation (<P>), precipitation intensity (Pint), wet days percentage (% wet days) and temperature (<T>) at each station, evaluated over the whole measurement period.

The percentage of wet days at each station is calculated assuming a precipitation threshold of 1 mm/day, and the precipitation intensity is defined as the mean precipitation over only wet days.

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Elevation (m)</td>
<td>4733</td>
<td>3688</td>
<td>3353</td>
<td>3353</td>
<td>3140</td>
<td>2920</td>
<td>2100</td>
</tr>
<tr>
<td>Latitude (°)</td>
<td>36.83</td>
<td>36.73</td>
<td>35.99</td>
<td>36.47</td>
<td>35.43</td>
<td>35.14</td>
<td>36.29</td>
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<tr>
<td>Longitude (°)</td>
<td>75.40</td>
<td>74.62</td>
<td>73.25</td>
<td>73.27</td>
<td>74.79</td>
<td>74.73</td>
<td>74.12</td>
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<tr>
<td>T max (°C)</td>
<td>17.8</td>
<td>30.5</td>
<td>31.4</td>
<td>29.1</td>
<td>28.6</td>
<td>33.1</td>
<td>31</td>
</tr>
<tr>
<td>Tmin (°C)</td>
<td>-30.3</td>
<td>-25</td>
<td>-20.1</td>
<td>-19</td>
<td>-21.1</td>
<td>-19.9</td>
<td>-17.1</td>
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<tr>
<td>Pmax (mm/day)</td>
<td>15</td>
<td>38.5</td>
<td>80.5</td>
<td>35.8</td>
<td>176</td>
<td>104.1</td>
<td>77.5</td>
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<tr>
<td>&lt;P&gt; (mm/day)</td>
<td>0.5</td>
<td>0.6</td>
<td>0.9</td>
<td>0.9</td>
<td>2.3</td>
<td>2</td>
<td>1.9</td>
</tr>
<tr>
<td>P intensity (mm/day)</td>
<td>1.9</td>
<td>2.6</td>
<td>2.8</td>
<td>3.3</td>
<td>6.8</td>
<td>6.5</td>
<td>5.5</td>
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<tr>
<td>% wet days</td>
<td>2</td>
<td>24</td>
<td>30</td>
<td>26</td>
<td>33</td>
<td>30</td>
<td>34</td>
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<tr>
<td>&lt;T&gt; (°C)</td>
<td>-5.3</td>
<td>3.2</td>
<td>6</td>
<td>5</td>
<td>4.4</td>
<td>7.7</td>
<td>6.6</td>
</tr>
<tr>
<td>&lt;P&gt; (mm/day)</td>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
<td>1</td>
<td>1.4</td>
<td>0.7</td>
<td>1.8</td>
</tr>
<tr>
<td>P intensity (mm/day)</td>
<td>2.2</td>
<td>2.6</td>
<td>2.4</td>
<td>3.7</td>
<td>4.4</td>
<td>2.6</td>
<td>5.1</td>
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<tr>
<td>% wet days</td>
<td>13</td>
<td>9</td>
<td>10</td>
<td>9</td>
<td>11</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>&lt;T&gt; (°C)</td>
<td>3.4</td>
<td>8.6</td>
<td>16</td>
<td>15</td>
<td>12.3</td>
<td>16.7</td>
<td>15.2</td>
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<td>0.3</td>
<td>0.6</td>
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<tr>
<td>&lt;T&gt; (°C)</td>
<td>-12.4</td>
<td>-0.9</td>
<td>-2.3</td>
<td>-3</td>
<td>-1.1</td>
<td>0.5</td>
<td>-0.5</td>
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Temperature time series from the different data sets (1901-2009)
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<td><strong>Himalaya</strong></td>
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<td></td>
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</tr>
<tr>
<td>JJAS</td>
<td>0.04 (0.01)</td>
<td></td>
<td></td>
<td>0.01</td>
<td>0.03 (0.01)</td>
</tr>
<tr>
<td>DJFMA</td>
<td>0.06 (0.02)</td>
<td>0.07</td>
<td></td>
<td>0.03</td>
<td>0.05 (0.02)</td>
</tr>
<tr>
<td><strong>HKK</strong></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>JJAS</td>
<td>0.03 (0.02)</td>
<td></td>
<td></td>
<td>0.02</td>
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</tr>
<tr>
<td>DJFMA</td>
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<td></td>
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</tr>
</tbody>
</table>
Inter-decadal variability of precipitation in the EC-Earth scenario runs

Radiative Forcing (anthropogenic & natural)

RCP = Representative Concentration Pathway

![Graph showing Inter-decadal variability of precipitation in the EC-Earth scenario runs](image)

- **RCP4.5 run**
  - 2011–2020
  - 2021–2030
  - 2031–2040
  - 2041–2050
  - 2051–2060
  - 2061–2070
  - 2071–2080
  - 2081–2090
  - 2091–2100

- **RCP8.5 run**
  - 2011–2020
  - 2021–2030
  - 2031–2040
  - 2041–2050
  - 2051–2060
  - 2061–2070
  - 2071–2080
  - 2081–2090
  - 2091–2100

Greater Himalaya
HKK