Analysis of meteorological data in the Baltoro area and interaction between western weather patterns and monsoons

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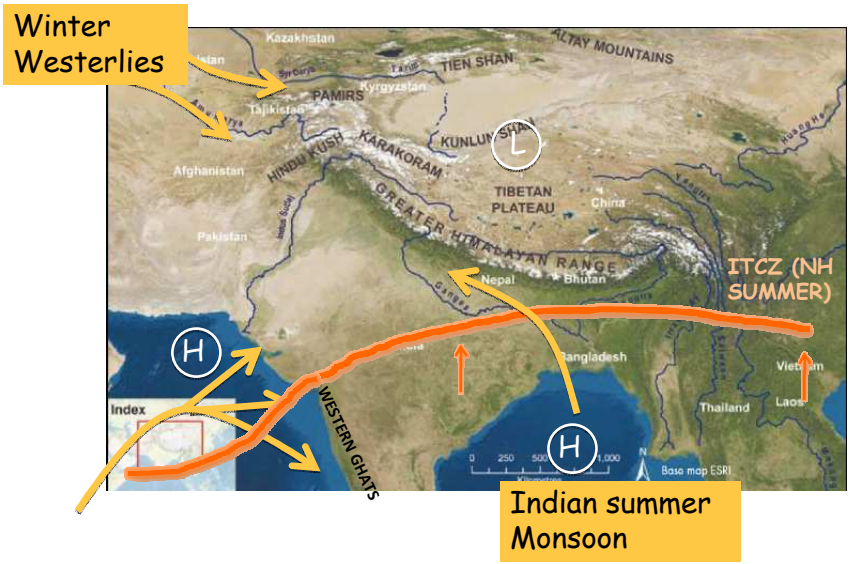
Annual meeting of the SHARE project PAPRIKA-Karakorum

Climate in the Hindu-Kush Karakoram Himalaya (HKKH) and the Indian Subcontinent



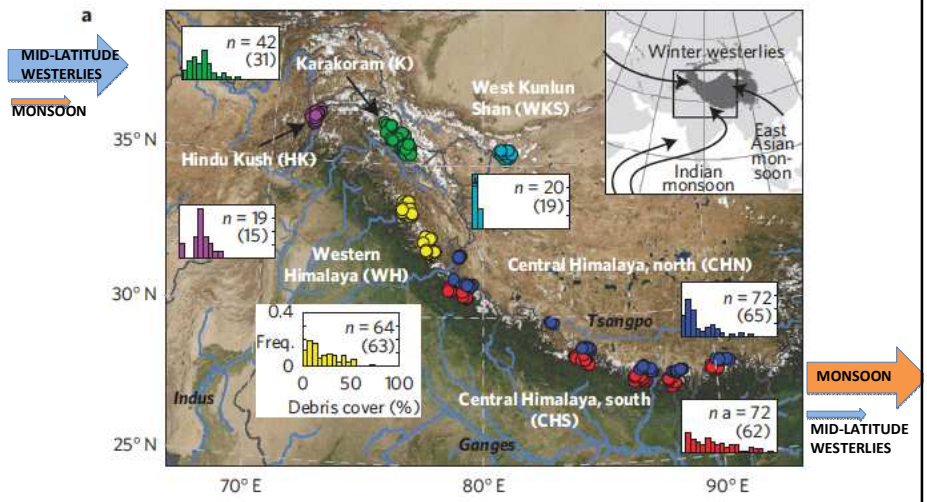
Focus: Hindu-Kush Karakoram

PAPRIKA Karakoram

Evaluate the impact of climate change upon hydrology of the Upper Indus Basin

- Climate of the HKK: semiarid and not dominated by the monsoon. A major contribution to the hydrological regime results from snow and glacier melt.
- Precipitation is concentrated in winter and spring, carried on broad scale westerlies originating from the Mediterranean or Caspian Sea region. Winter precipitation provides the dominant nourishment for the Karakoram glacier systems.
- The pattern of climatic change in Karakoram and Hindu Kush is different from the Greater Himalaya (stable/advancing glaciers vs retreating glaciers)
- Mountainous/heterogeneous regions: Challenge for both observations (few and biased by elevation) and models.

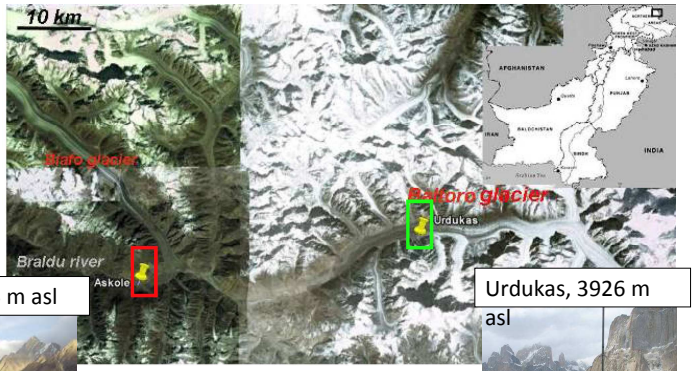
6 geographic regions which differ for Climate and Topography, based on the analysis of 286 mountain glaciers between the HKK and Buthan. From the HKK and across the western Himalaya to the central Himalaya, these regions are characterized by the decreasing influence of the mid-latitude westerlies and increasing influence of the Indian monsoon.



Conditions vary significantly along the S-E to N-W transect of the Himalayan-Karakoram and Hindu-Kush mountain ranges

Scherler, D., Bookhagen, B., Strecker, m. R.: Spatially variable response of Himalayan glaciers to climate change affected by debris cover, Nature Geoscience Volume: 4, Pages: 156–159 Year published: (2011) DOI: doi:10.1038/ngeo1068

Meteo-climatic measurements in the Baltoro Glacier, Northern Pakistan

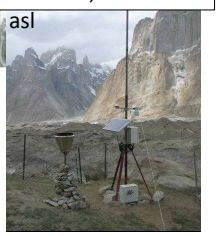


Askole, 3015 m asl

since October 2005

- Air temperature
- Air pressure
- Relative humidity
- Incoming SW radiation
- Wind direction & intensity
- Total precipitation

Urdukas, 3926 m asl



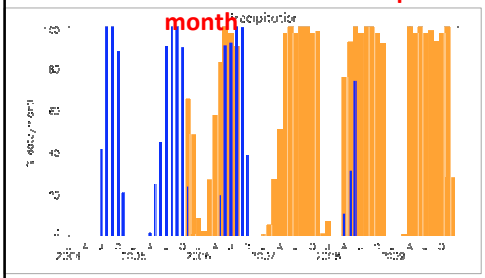
since June 2004

Meteo-climatic measurements in the Baltoro Glacier, Northern Pakistan

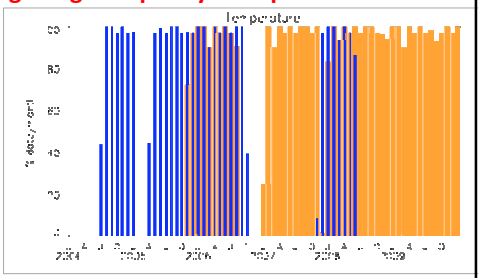
Experimental set up and percentage of good quality data availability

Variable	Instrument	Akole da (%)	Urdukas da (%)
Precipitation at 1.5 m	DQA035 Lsi-Lastem	59	30
Air temperature at 2 m	DMA570 Lsi-Lastem	88	66
Relative Humidity at 2m	DMA570 Lsi-Lastem	88	66
Air pressure at 2m	CX115P Lsi-Lastem	85	66
Incoming short wave radiation at 2 m	CM3 Kipp&Zonen	88	66
Wind speed at 5 m	DNA022 Lsi-Lastem	84	60
Wind direction at 5 m	DNA022 Lsi-Lastem	78	59

DATA AVAILABILITY: percentage of good quality data per month

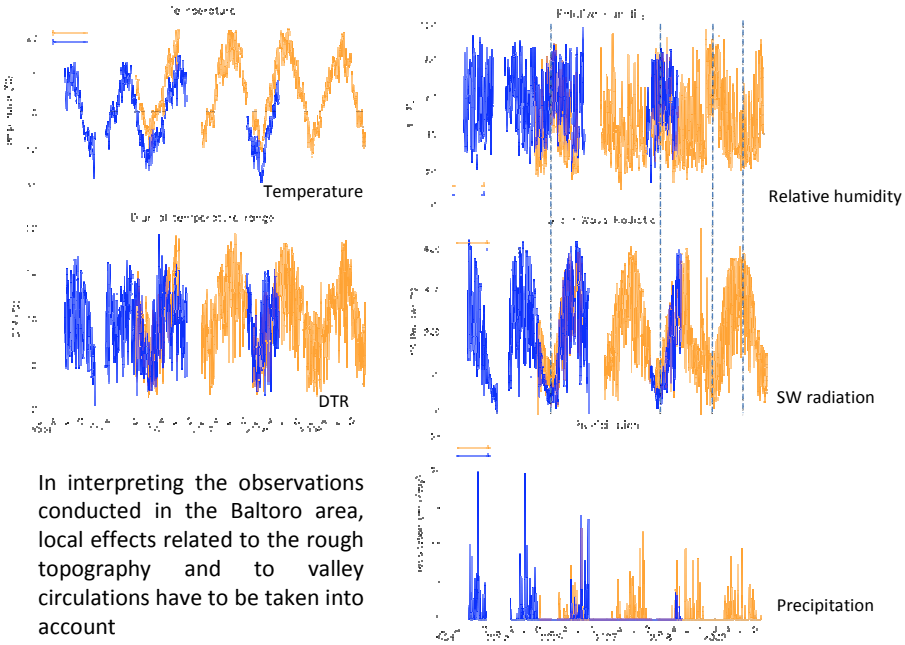


PRECIPITATION



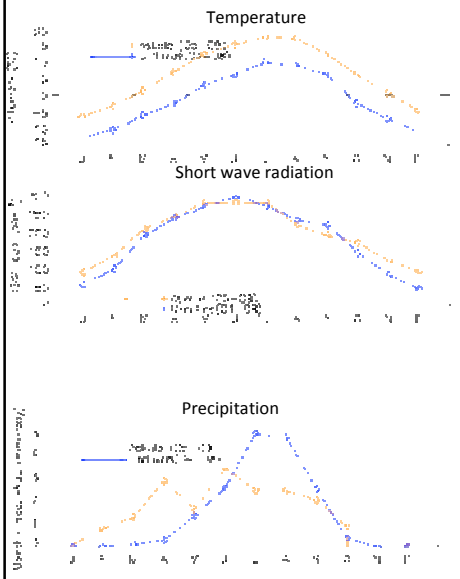
TEMPERATURE

Time series @ Askole and Urdukas

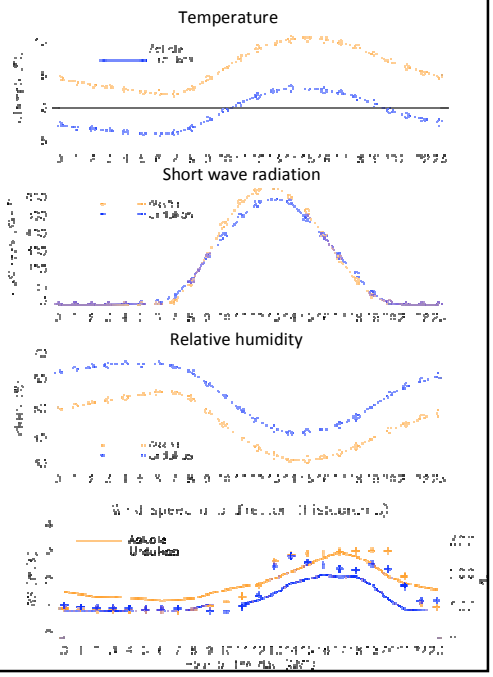


In interpreting the observations conducted in the Baltoro area, local effects related to the rough topography and to valley circulations have to be taken into account

Annual cycles



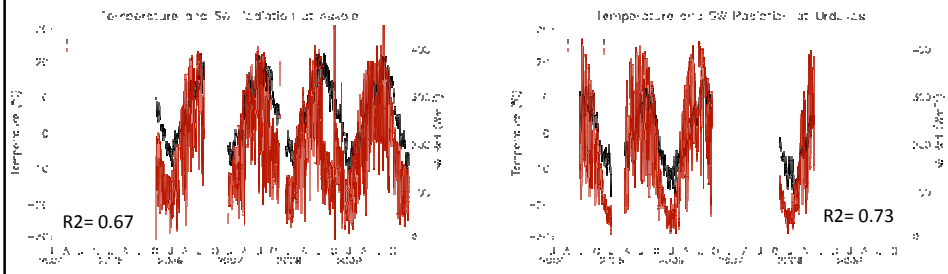
Diurnal cycles



Other analyses performed

- o Correlations between pairs of variable at one stations
- o Correlation between the same variable measured at the two stations
- o Rainfall PDF
- o Rainfall power spectra

Temperature – SW rad



Precipitation and wind-related variables are often locally constrained and display much lower spatial coherence than temperature and pressure

Precipitation data sets

o **TRMM (Tropical Rainfall Measuring Mission)**
Product: 3B42: 3-Hour 0.25 x 0.25 °(30x30 km) from 50°S-50°N. Low spatial, high temporal resolution. 1998-2008

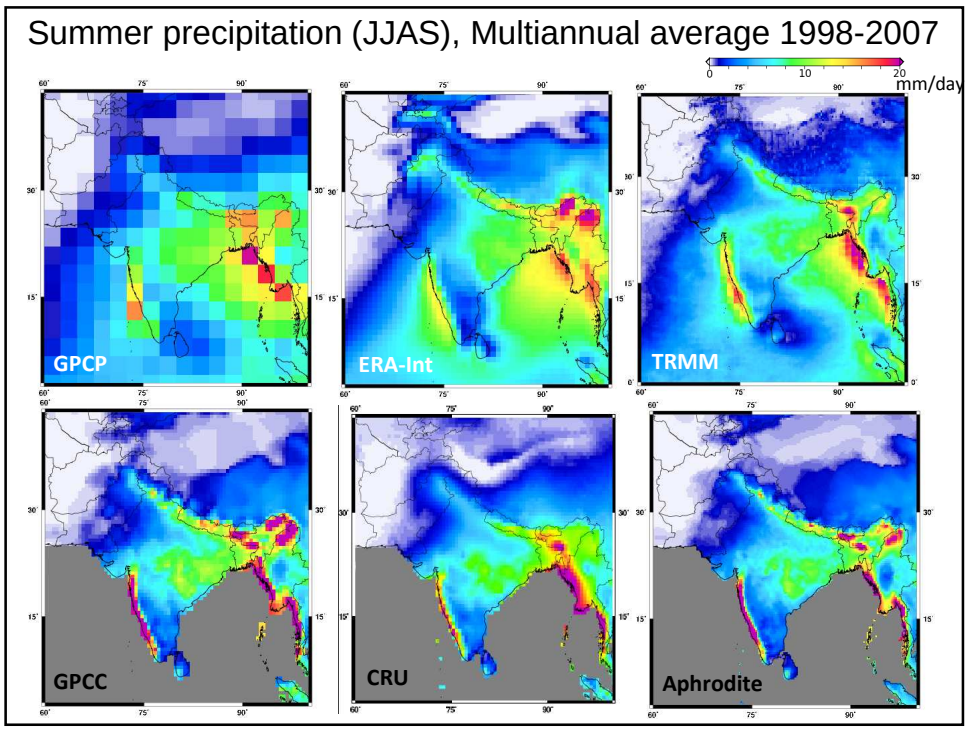
o **APHRODITE (Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources)**
Product: APHRO_MA (Monsoon Asia) _V1003R1. Daily precipitation datasets derived from rain gauge observations with high-resolution grids (Hour 0.25 x 0.25 °) for Asia (domain: 60°E-150°E, 15°S-55°N). 1951-2007

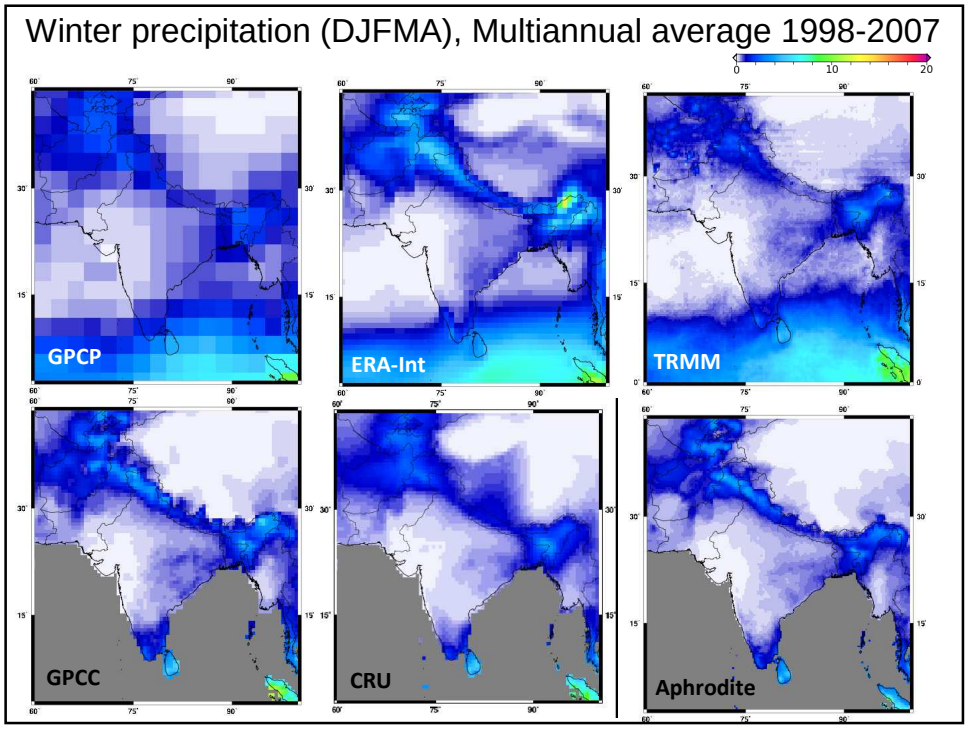
o **Global Precipitation Climatology Centre (GPCC)**
Gauge-based gridded monthly precipitation data sets for the global land surface, spatial resolutions 0.5°x 0.5°. 1901-2009

o **Climate Research Unit (CRU)**: TS 3.10 precipitation monthly data available from 1901 to 2009

o **Global Precipitation Climatology Project (GPCP) NOAA**
Version V2.2 of monthly means of precipitation derived from satellite and gauge measurements. Data are supplied into 2.5°x2.5° globa l grids from 88.75°S - 88.75°N and 1.25°E - 358.75°E. From 1979 to present.

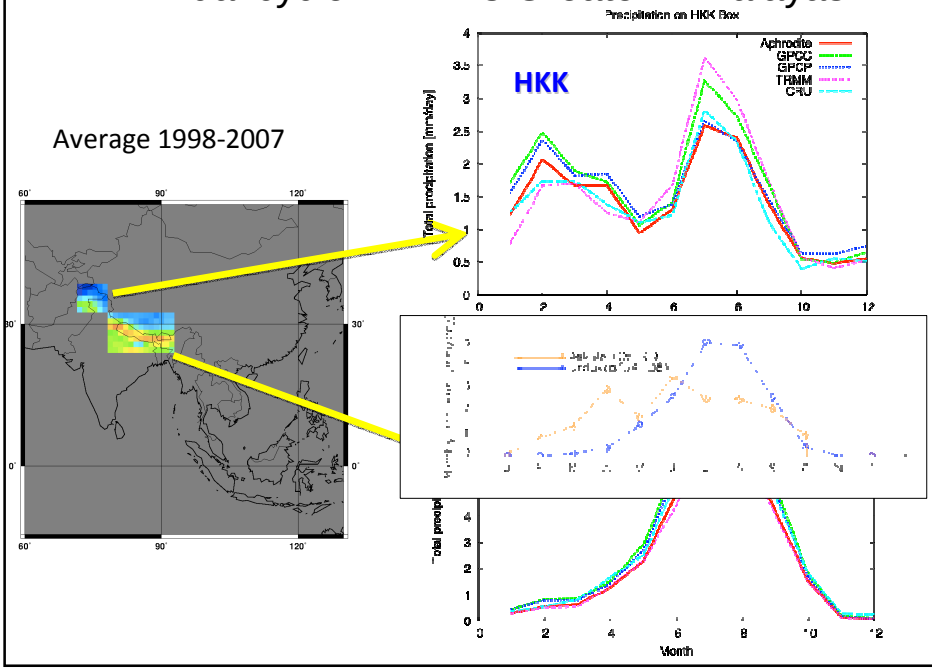
o **ERA-40, ERA-Interim**

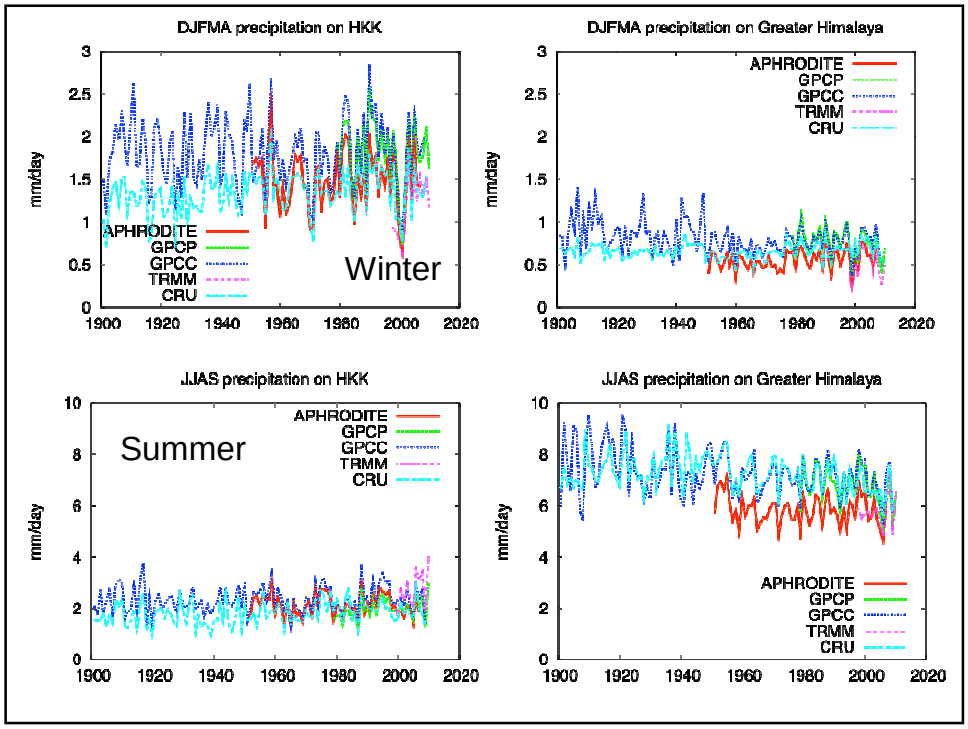

Summer precipitation (JJAS), Multiannual average 1998-2007
0
10
20
mm/day
GPCP
ERA-Int
TRMM
GPCC
CRU
Aphrodite


Winter precipitation (DJFMA), Multiannual average 1998-2007
0
10
20
GPCP
ERA-Int
TRMM
GPCC
CRU
Aphrodite

Annual cycle: HKK vs Greater Himalayas

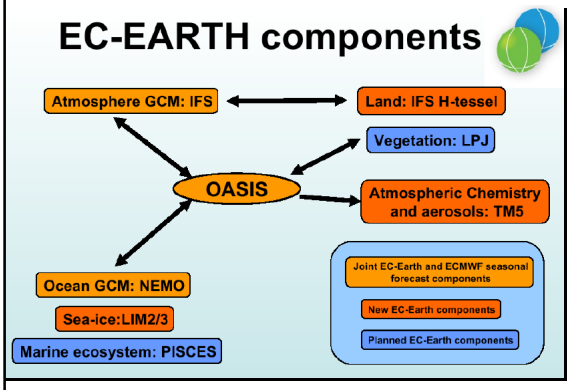
Average 1998-2007





Interaction between western weather pattern and monsoon circulation in the HKK

Observations and one Earth system model data

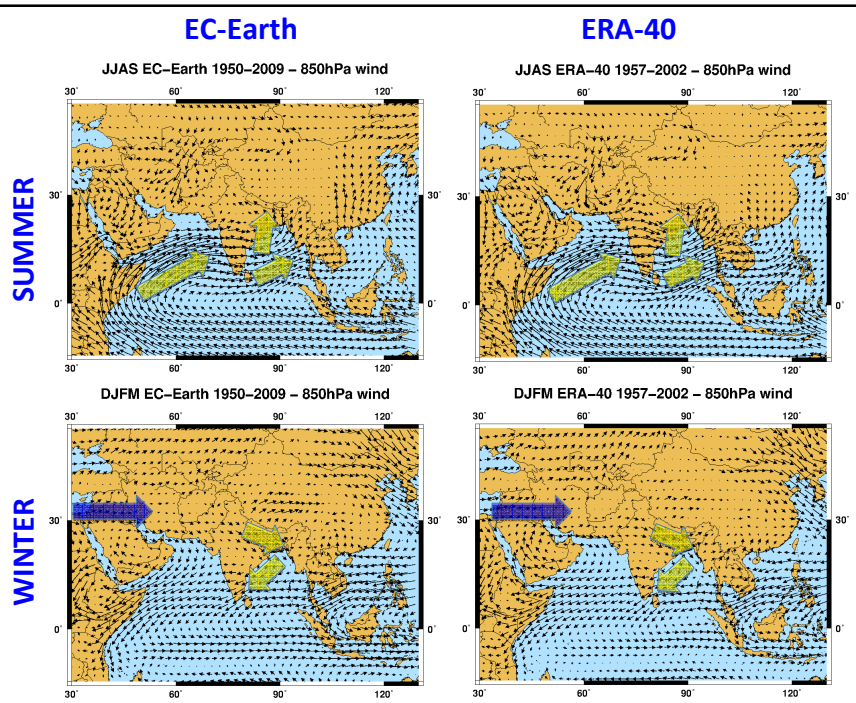


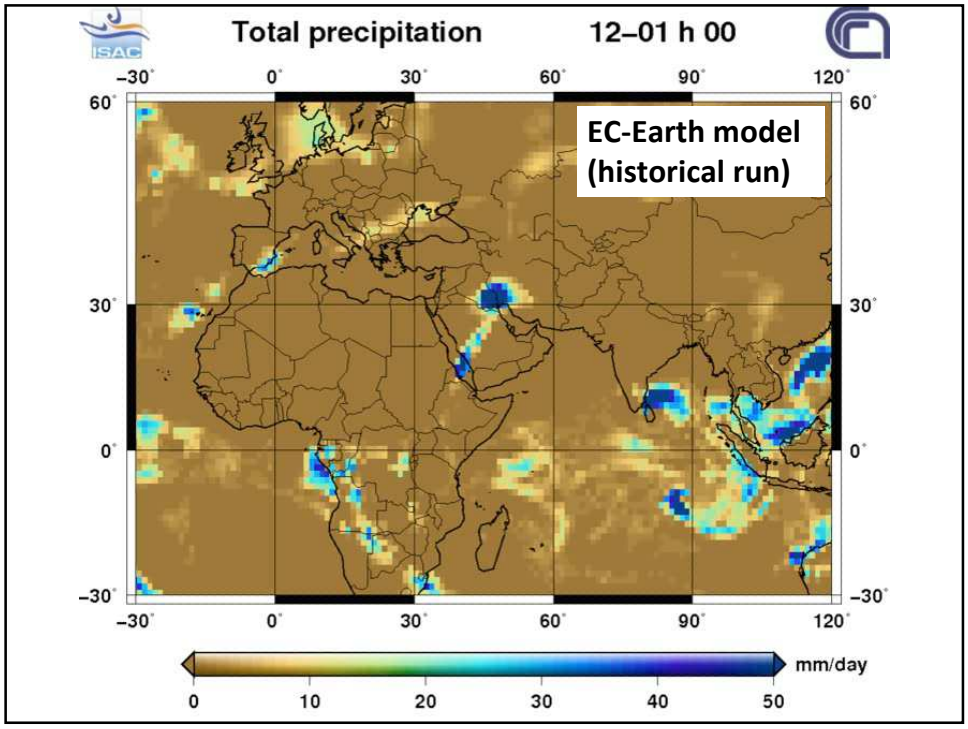
Community model

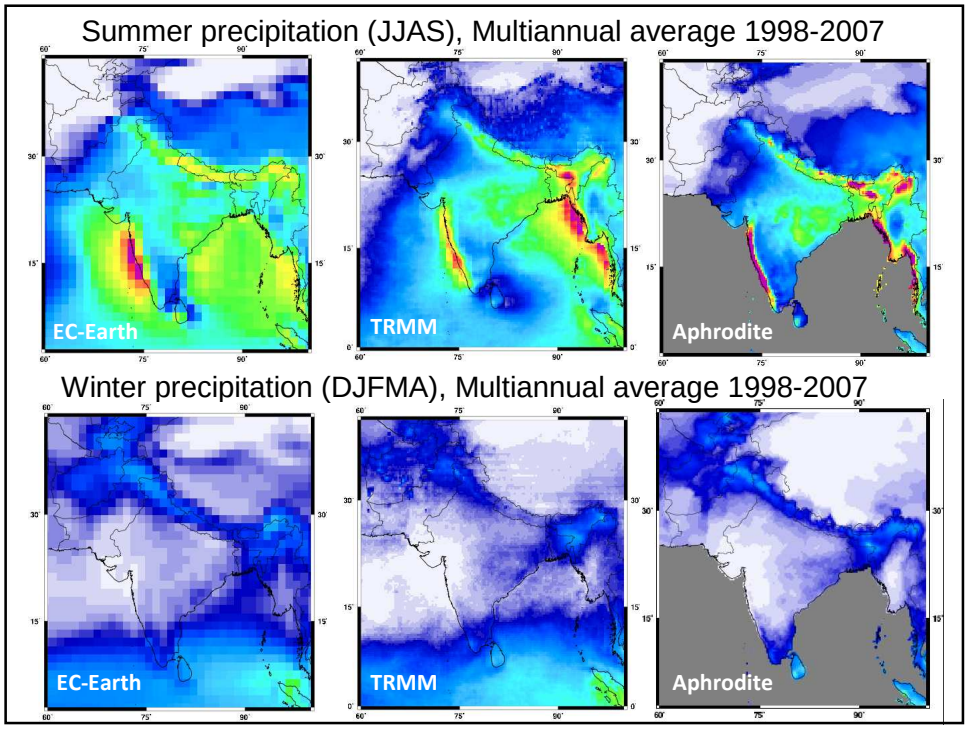
- 22 Research institutions from 10 different european countries
- Origin: ECMWF
- Coordinating institution: KNMI

http://ecearth.knmi.nl/ EC-Earth web site

http://www.to.isac.cnr.it/ecearth/ @ISAC-CNR



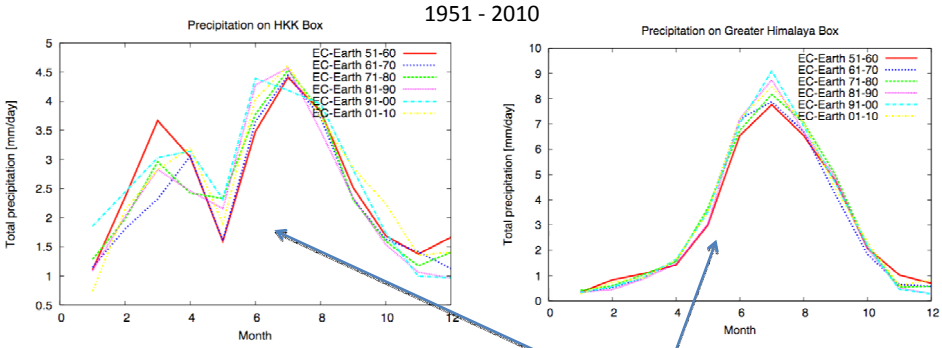

Total precipitation
12–01 h 00
EC-Earth model
(historical run)
mm/day
0
10
20
30
40
50


Summer precipitation (JJAS), Multiannual average 1998-2007
EC-Earth
TRMM
Aphrodite
Winter precipitation (DJFMA), Multiannual average 1998-2007
EC-Earth
TRMM
Aphrodite

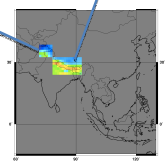
Annual cycle from one earth system model data: EC-Earth

6 different decades of the EC-Earth model historical run
(The model attempts to reproduce the properties of real climate in a statistical sense, there is no exact agreement with observations in any particular year)

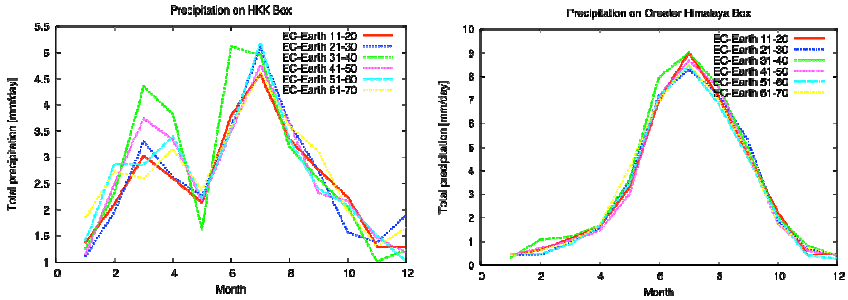
1951 - 2010



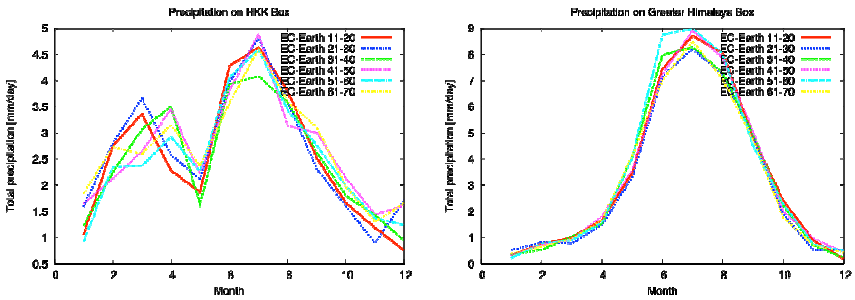
There is much more variability of the EC-Earth response
- in the HKK than main Himalaya region
- during winter/spring than during summer in the HKK



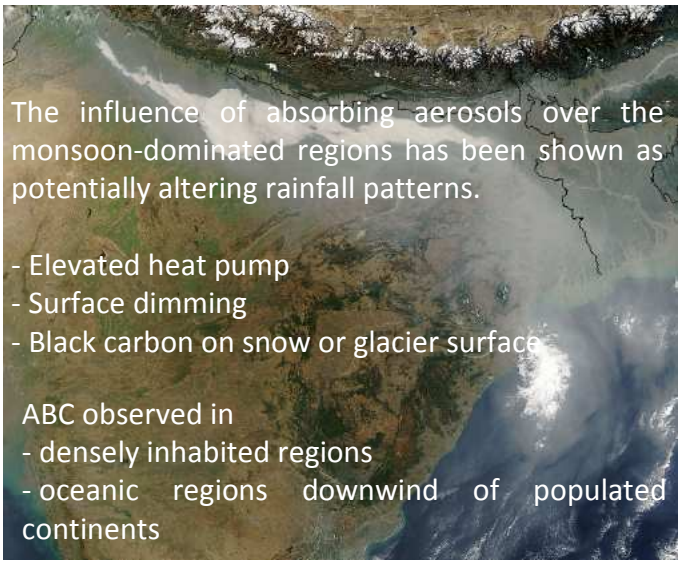
Scenario RCP 4.5 – 2011-2070



Scenario RCP 8.5 – 2011-2070



Aerosol-induced changes in rainfall patterns



TERRA-MODIS true color image depicting a high concentration of aerosols over Northern India on December 17, 2004.

Conclusions, ideas and next steps

o 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 and in glacier behaviour and dynamics

o Dynamics of western weather patterns:
- impact on winter precipitation in the HKK
- relationship with monsoon rainfall

o Synergy of surface-satellite observations/estimates

o Role of aerosol in shaping regional climate change over South Asia; concomitant role of GHGs warming (model data are also needed)

o EC-Earth model: one possible tool to explore these mechanisms (historical run and scenarios)

o Teleconnections of regional climate with large-scale circulation patterns

o Stochastic downscaling of precipitation for studies of climate change impacts on precipitation extremes and water availability

Outline

- Climate in the Hindu-Kush Karakoram Himalaya (HKKH) and the Indian Subcontinent: monsoon and and western weather patterns

- Meteorological data in the Baltoro glacier region. Preliminary analysis

- Broad scale characterization of precipitation amounts and distribution: satellite and gridded in-situ data sets

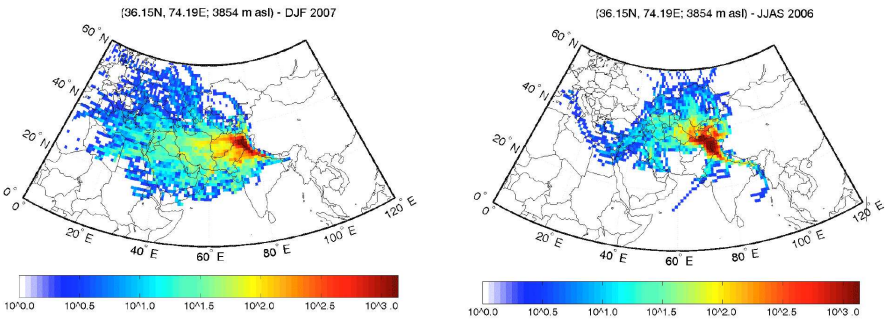
- Precipitation climatology in the HKK: summer and winter regimes

- Western weather patterns and monsoons: analysis with model data

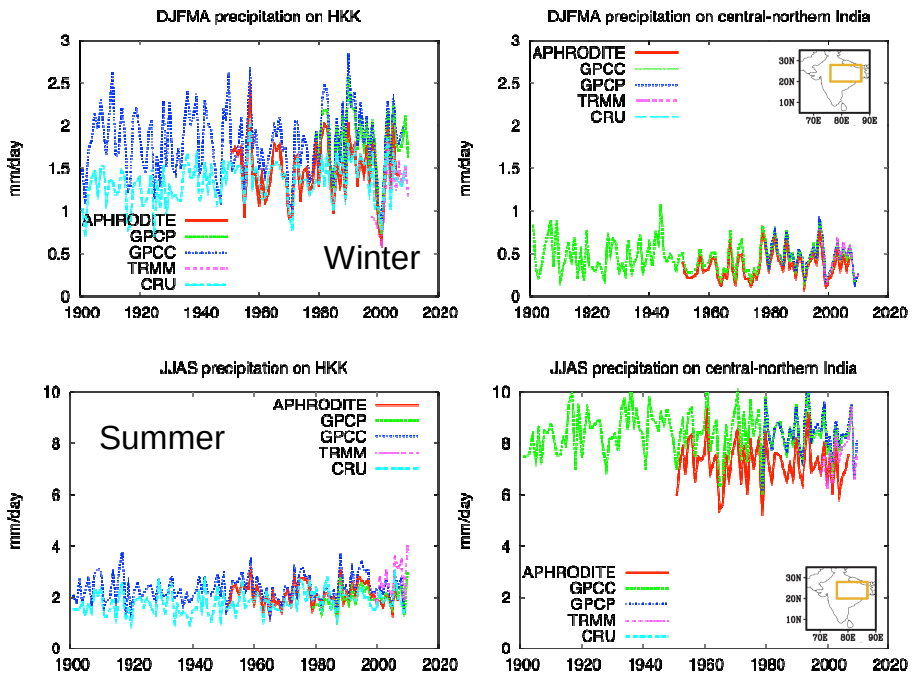
- Conclusions and next steps

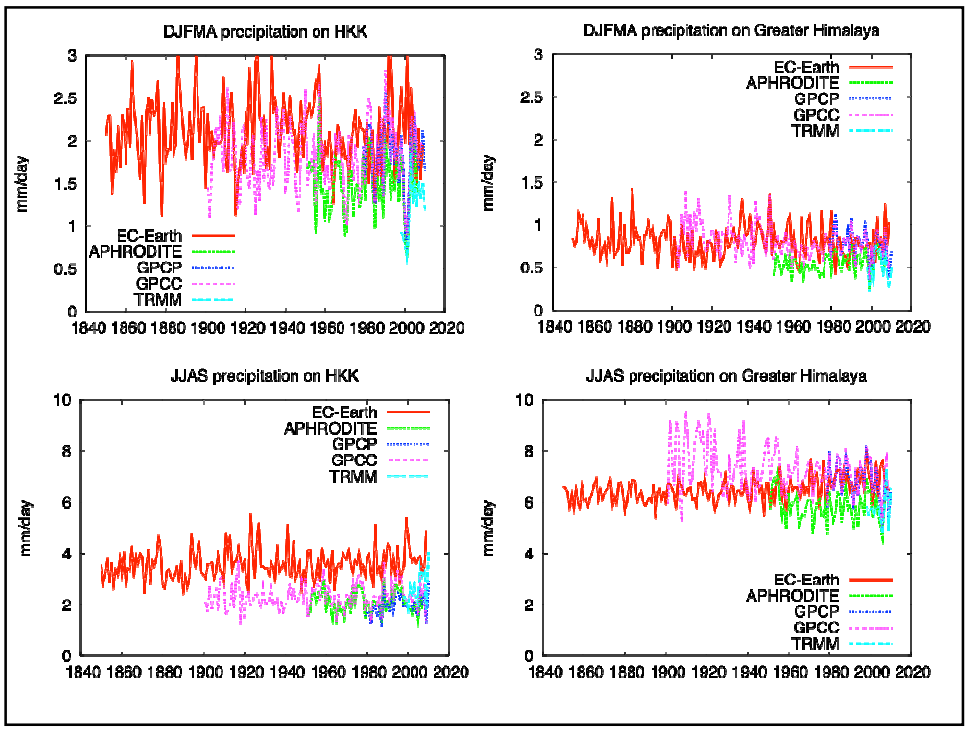
WINTER

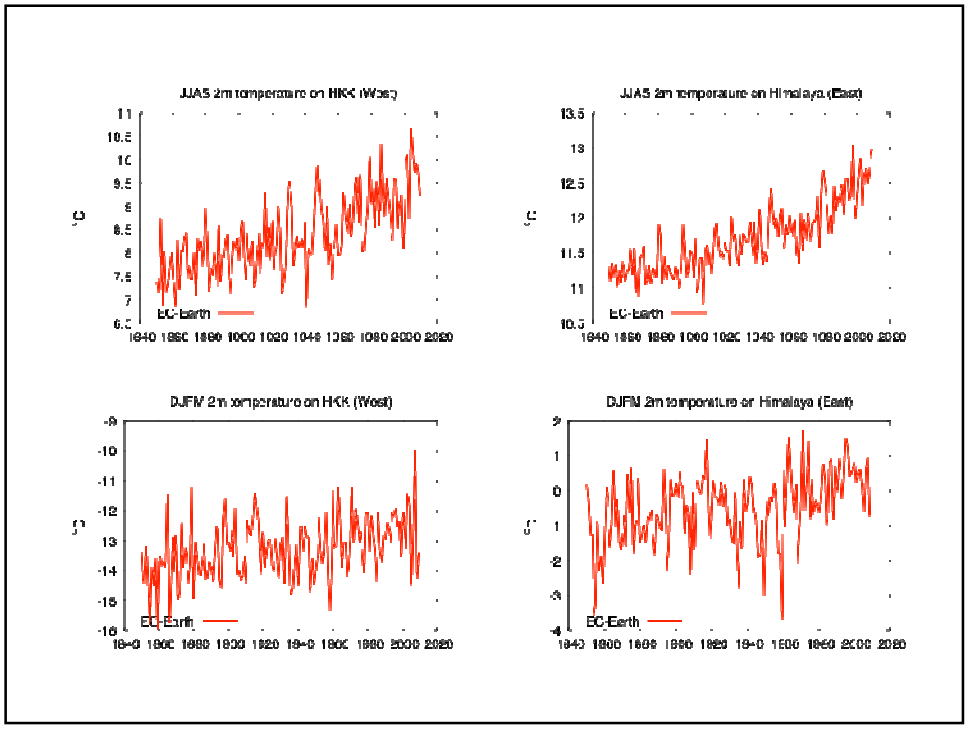
SUMMER

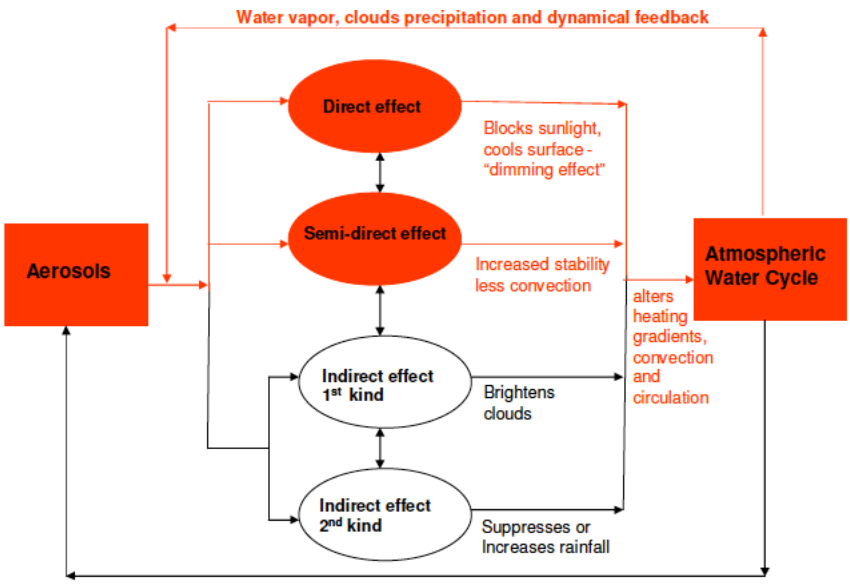


Concentration fields of HYSPLIT backtrajectories ending at one possible site in Northern Pakistan during winter (left) and summer (right) 2007.




DJFMA precipitation on HKK
DJFMA precipitation on Greater Himalaya
JJAS precipitation on HKK
JJAS precipitation on Greater Himalaya
mm/day
EC-Earth
APHRODITE
GPCP
GPCC
TRMM


JJAS 2m temperature on HKK (West)
JJAS 2m temperature on Himalaya (East)
DJFM 2m temperature on HKK (West)
DJFM 2m temperature on Himalaya (East)
EC-Earth



Model analyses are needed to understand the role of aerosols in possibly modifying rainfall patterns in the monsoon-dominated regions: e.g. EC-Earth coupled with TM5

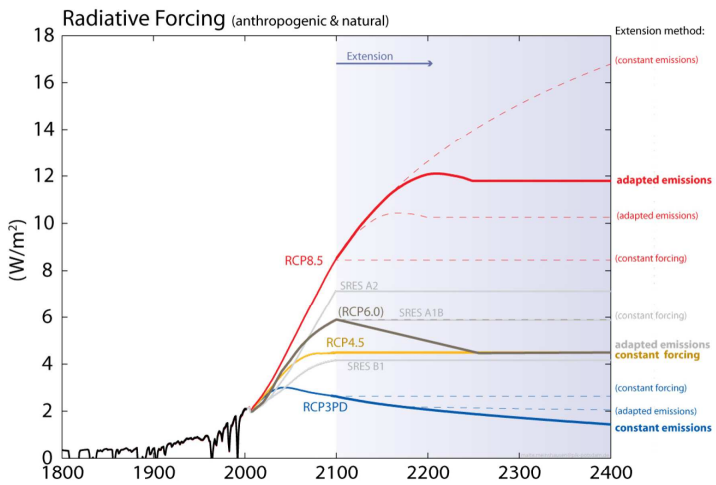


Figure 2: Schematic illustration of radiative forcing in line with a set of extension proposals developed by Detlef van Vuuren, Malte Meinshausen, Steve Smith, and Keywan Riahi. Solid bold lines post-2100 indicate the proposed recommendations by the teleconference participants with dashed lines indicating additional extension possibilities under alternative extension rules. Note that the final RCP6.0 pathway is not yet available and has been approximated here for illustrative purposes.