1st WRF-Hydro Workshop, University of Calabria, Rende, Cosenza, 2014-06-11

WRF-Hydro Simulation of the Himalayan Beas River Basin

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Acknowledgements: NORINDIA project and JOINTINDNOR Project

Himalaya region

- ✓ The source of one of the world's largest supplies of fresh water.
- ✓ 800 million people live in the catchments of the Indus, Ganges, and Brahmaputra rivers.
- ✓ Climate change

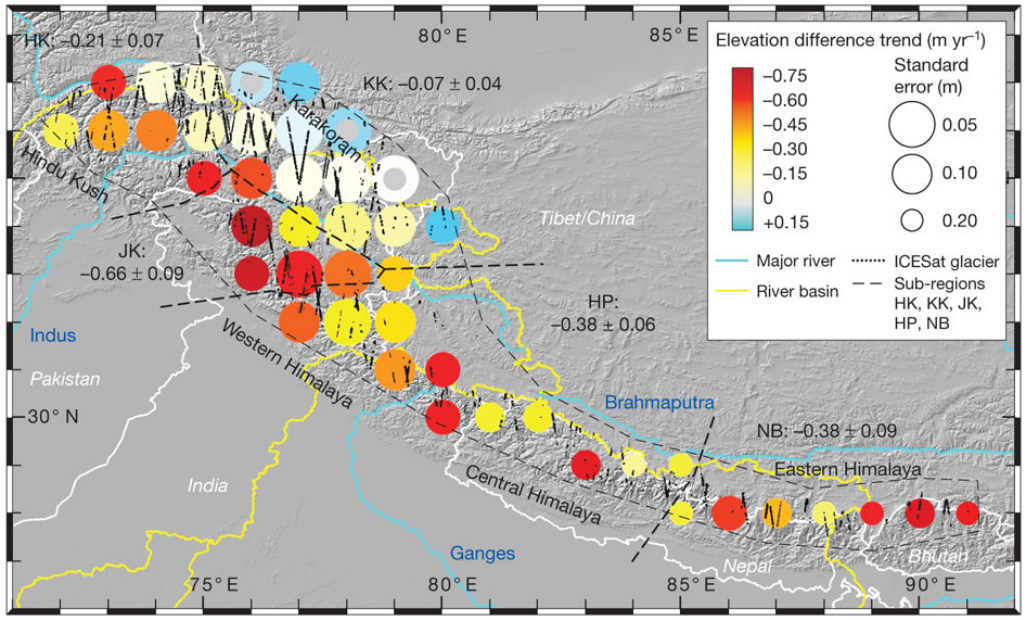
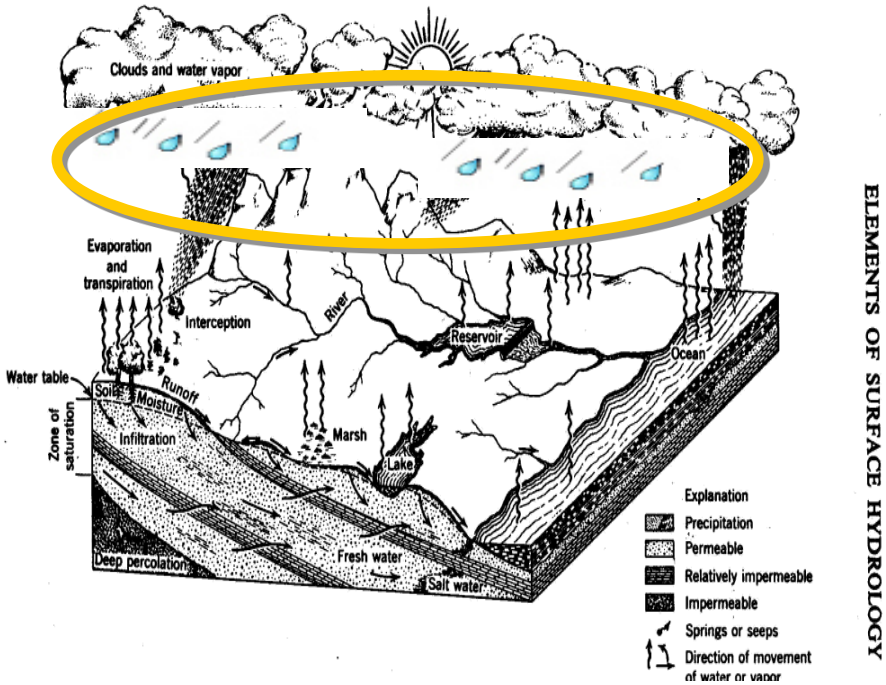


Fig: Study region and trends of elevation differences between ICESat and SRTM over 2003–08.

nature

A Kääb et al. Nature **488**, 495-498 (2012) doi:10.1038/nature11324

Precipitation



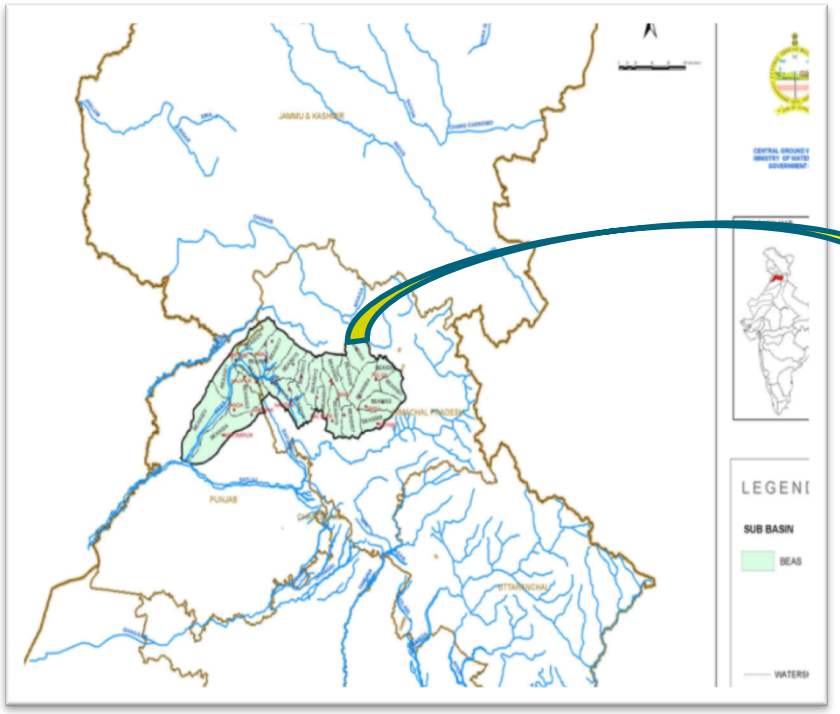
- ✓ Precipitation is crucial in hydrological science!
- ✓ *Himalaya limited in observations*
- ✓ *Influenced by terrain*
- ✓ *Hardly can captured accurately by the gridded dataset*

Numerical weather prediction models (high resolution!)

Objective

- To investigate the WRF capability in producing high-resolution precipitation in Beas river basin;
- To compare two microphysics (MP) schemes;
- To set up WRF-Hydro in Beas river basin and specify if it able to capture accurate precipitation and runoff for long period.

Study area - Beas



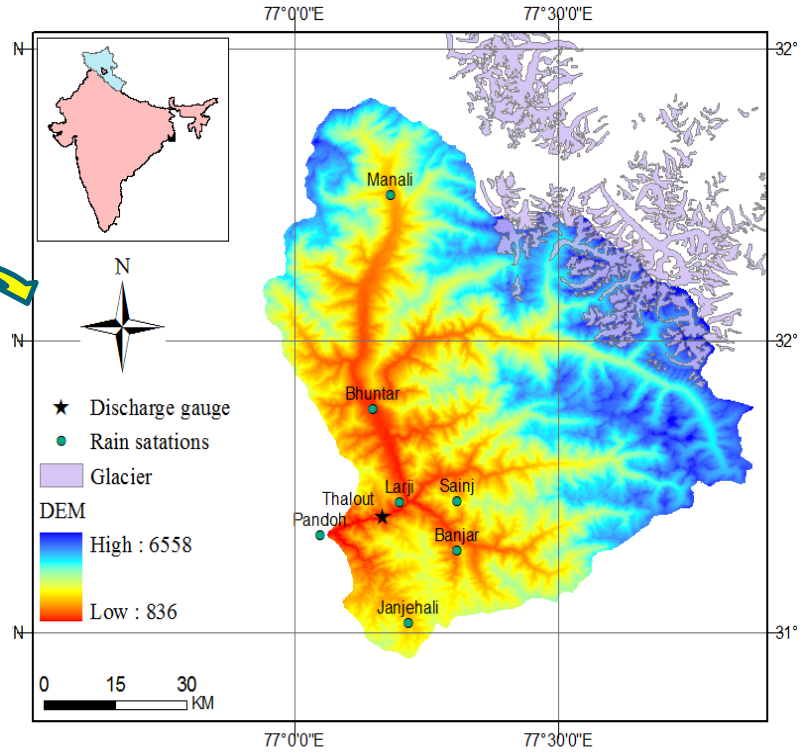


Fig: Beas basin (http://www.nih.ernet.in/rbis/basin%2 0maps/Indus/beas.htm)

Fig : Beas sub-basin up to Pandoh

Data

- Precipitation comparison:
  - TRMM 3B42 (1998-2009)
  - Seven gauge rainfall data (1996-2006)

- WRF-hydro DATA:
  - Forcing data: 6 hourly ERA-Interim (1996-2001)
  - DEM: HydroSHED (3-arc second)
  - Daily discharge of Thalout (1996-2001)

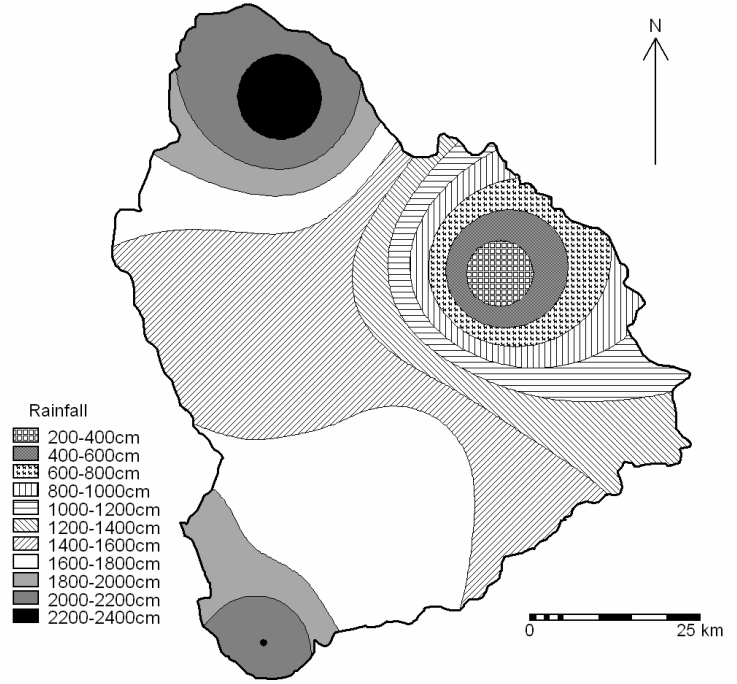


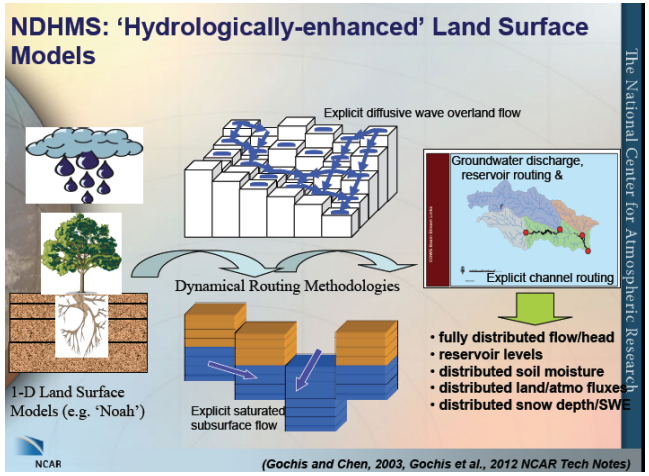
Fig. Cumulative rainfall of 1990–2004 (from Vijay Kumar et al., 2010)

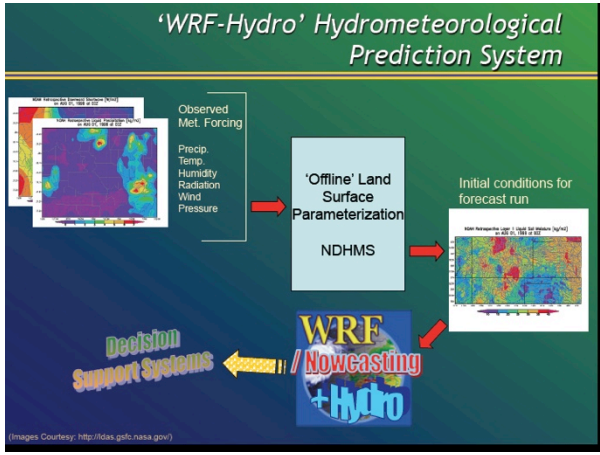
Method

- WRF-ARW 3.5.1 experiments of two Microphysics schemes;
- WRF-Hydro v2.0 offline run for discharge calibration;
- Forcing precipitation assessments by TRMM and gauge rainfall;
- Comparison of two MPs in precipitation downscaling by gauge rainfall (including spatial and temporal variability, statistic distributions).
- The runoff assessment by Nash-Sutcliffe efficiency (NS), absolute value of the volume error (VE) and daily hydrograph.

WRF-hydro

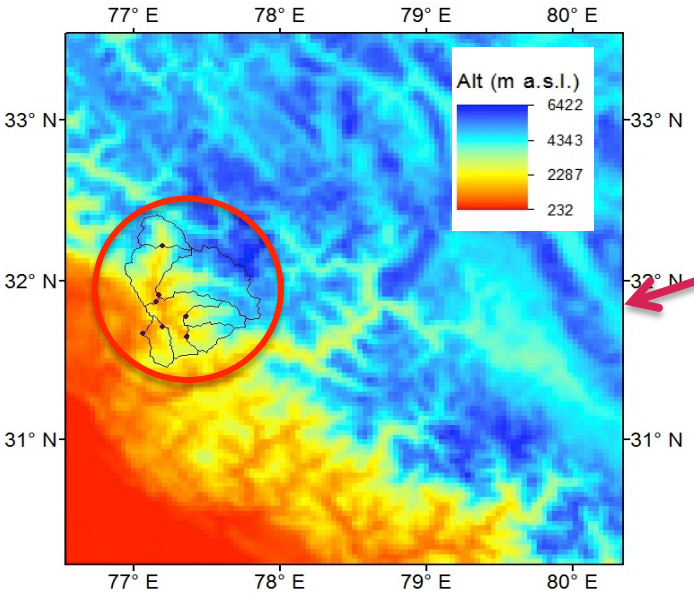
- WRF: Weather Research and Forecasting Model
- NDHMS: the NCAR Distributed hydrological Modeling System (Noah based)
- WRF-hydro : NDHMS coupling with WRF

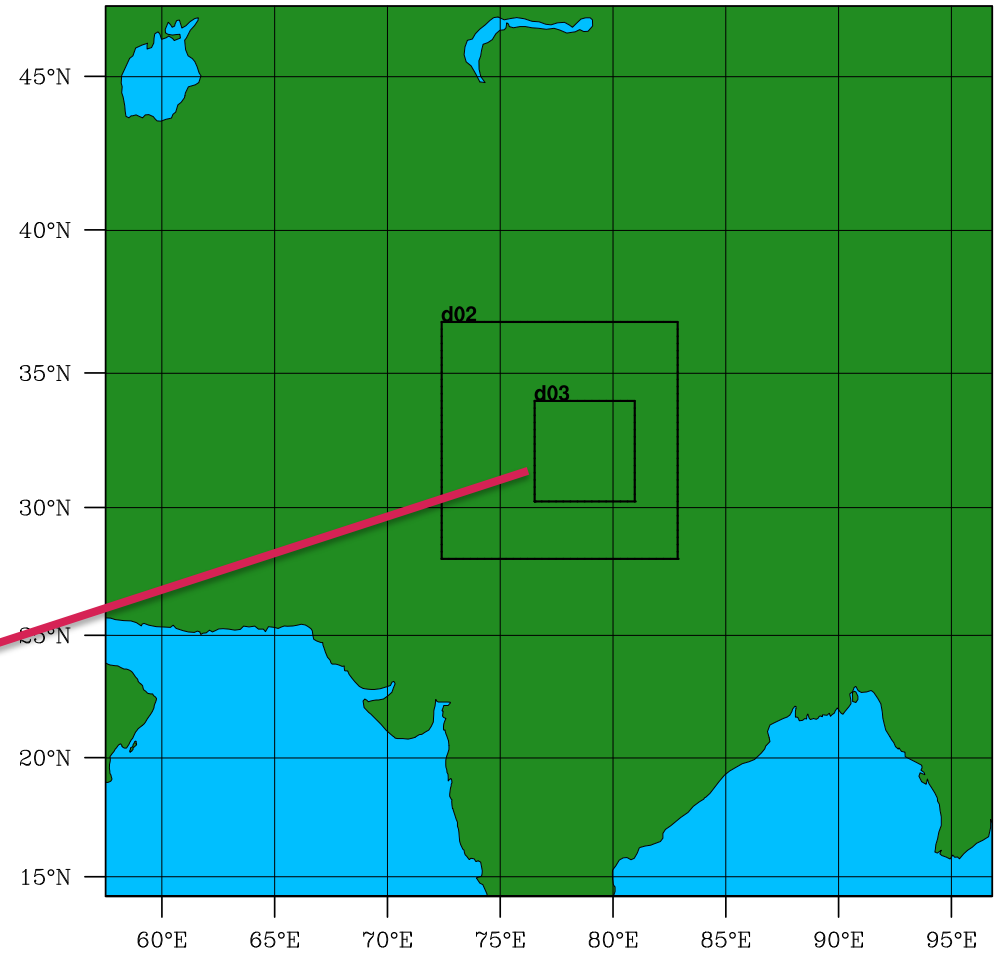




WRF-Hydro Domain design

- ERA-Interim 6 hourly
- 27km: 125*125
- 9km: 100*100
- 3km: 118*118
- Routing subgrid: 300m

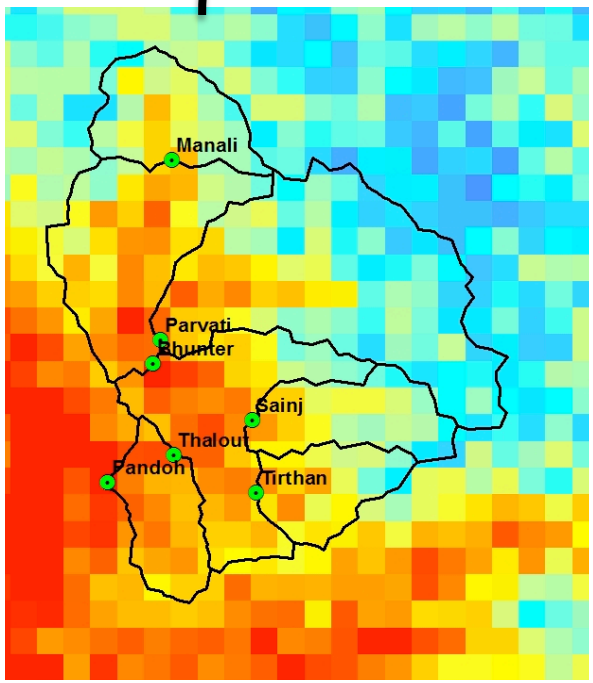




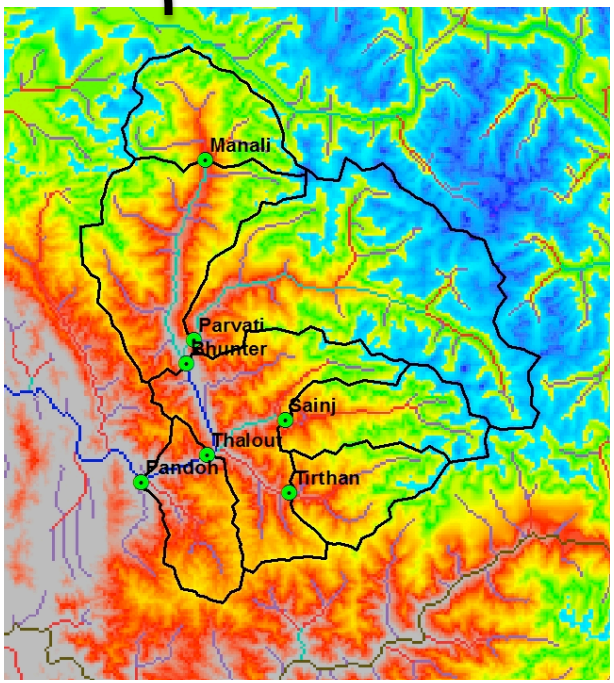
WRF-Hydro

1. Multi-scale aggregation/ disaggregation

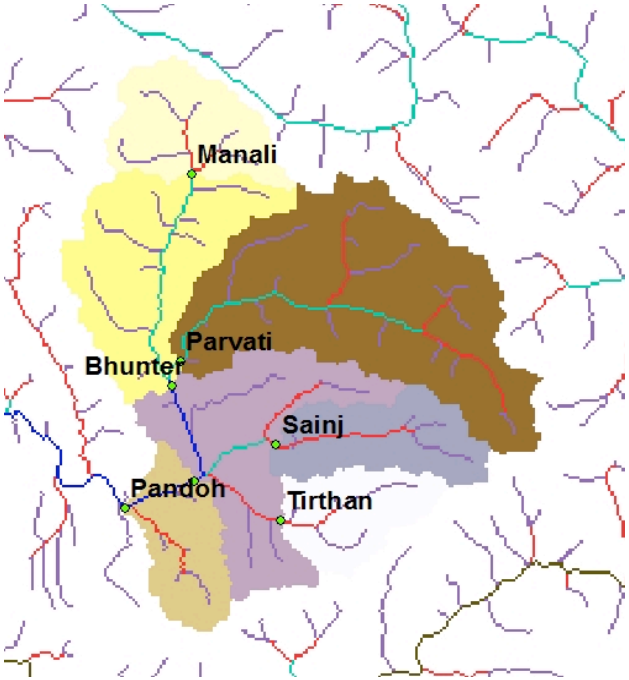
2. High resolution hydro terrain grids



Noah LSM grid (3 km)



Routing grid (300 m)



Routing channels (300 m)

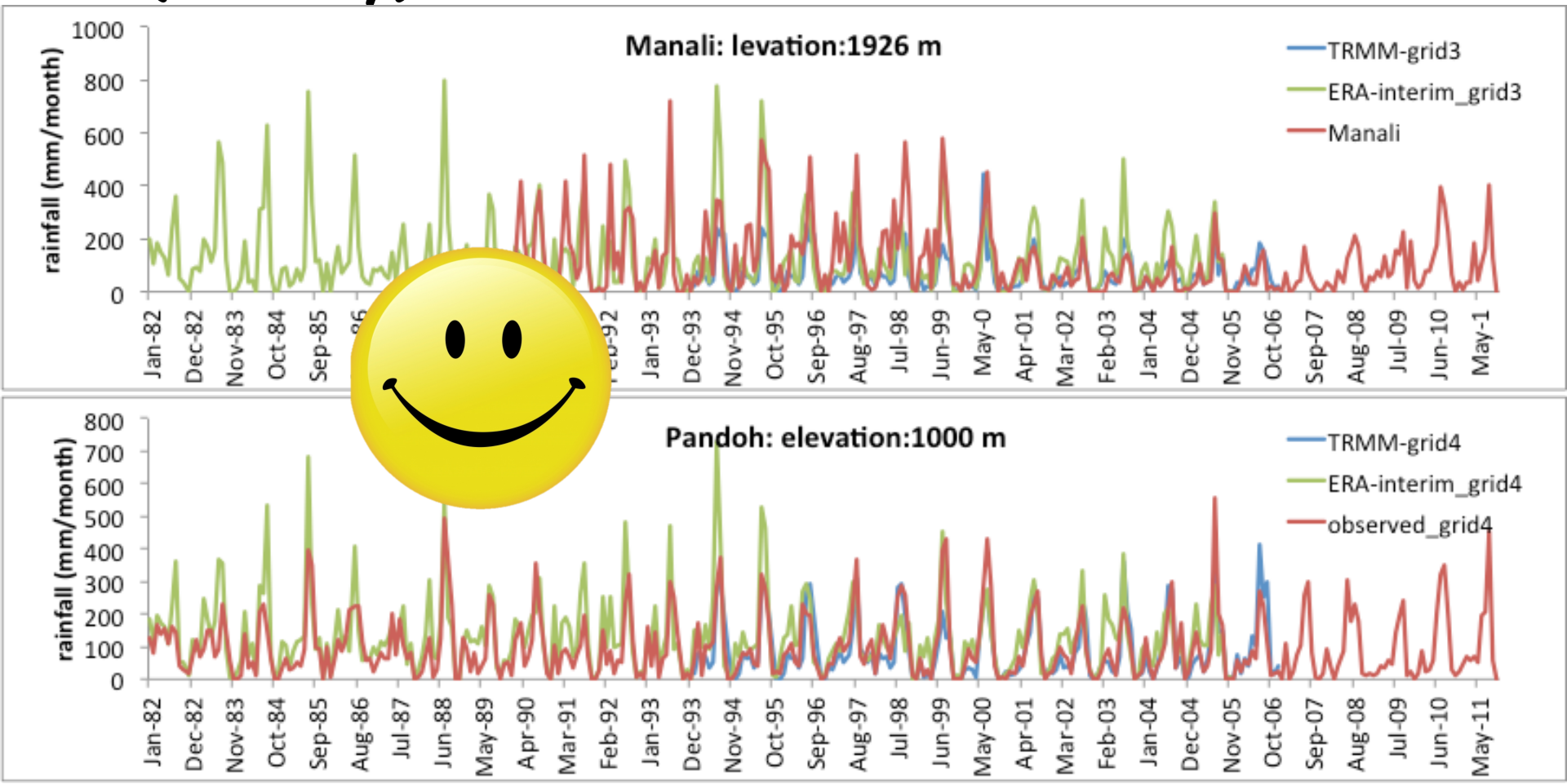
Experiments design

TABLE I DESIGN OF WRF EXPERIMENT

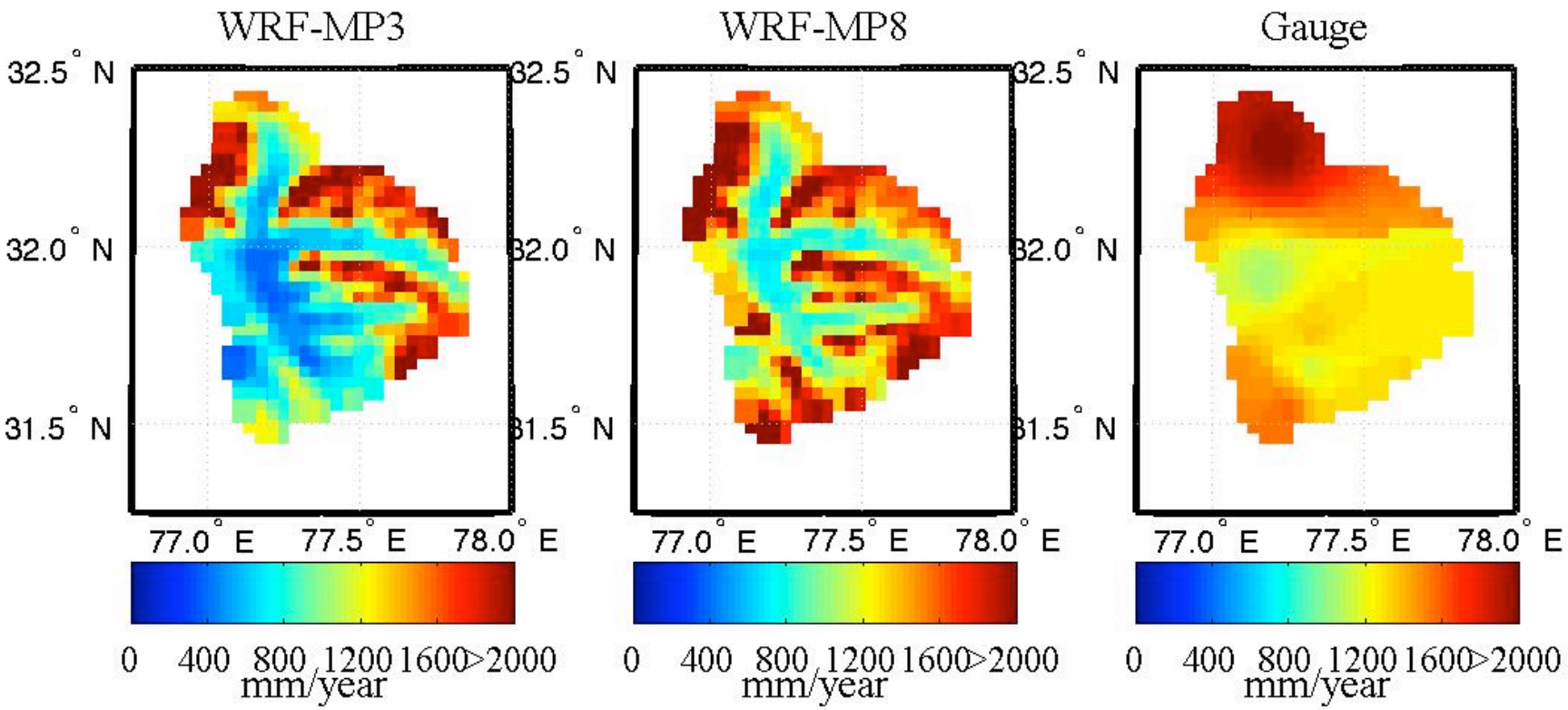
Name	Physical MP schemes
CU (1)	Kain–Fritsch Scheme*
MP (3)	simple 3- class scheme
MP (8)	Thompson Scheme
LS (1)	Unified Noah Land Surface Model
PBL (1)	Yonsei Univeristy scheme
LW (1)	RRTM scheme
SW (1)	Dudhia scheme
Boundary	ECMWF ERA-Interim reanalysis data

- ✓ A standard set-up was used with 40 vertical layers
- ✓ The model time-step was around 8 s in the small domain
- ✓ The simulation was run from 1996 to 2001 and the first year of 1996 is for initialization.
- ✓ The sea-surface temperature (SST) was updated (sst_skin=1) by forcing data.

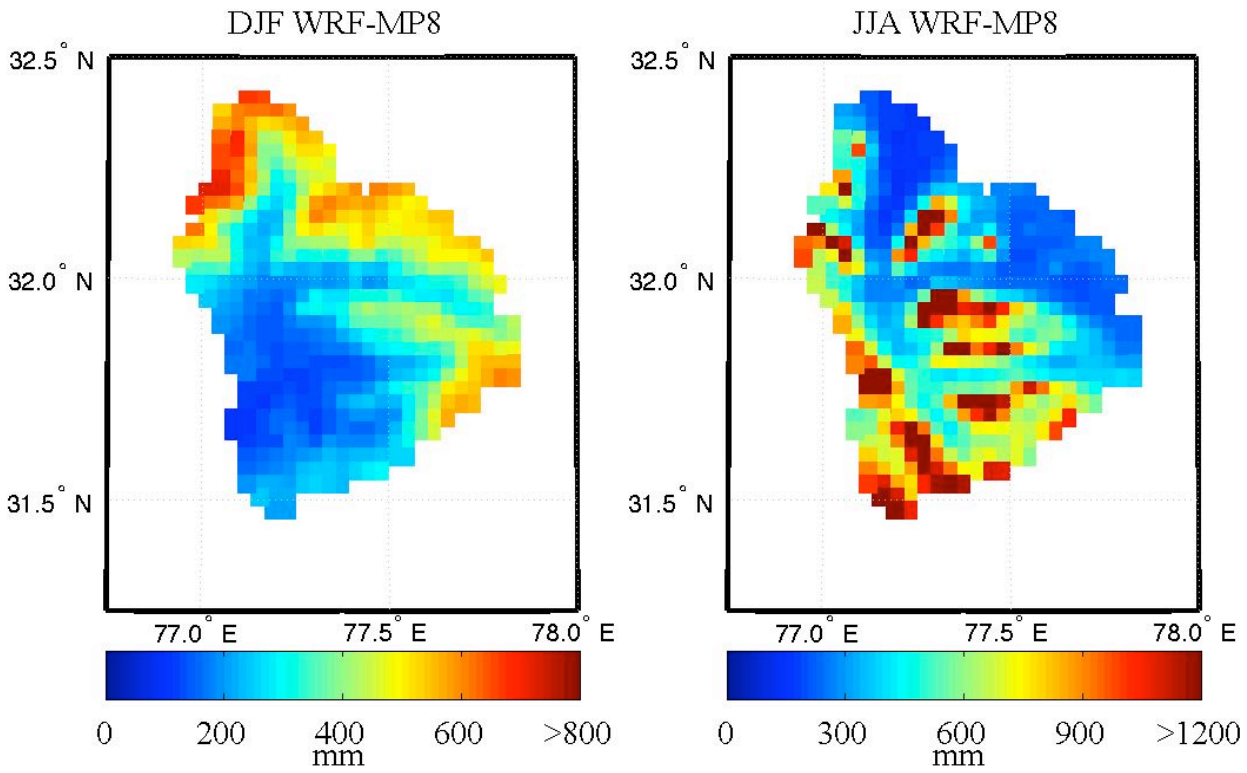
Forcing precipitation assessment (monthly)



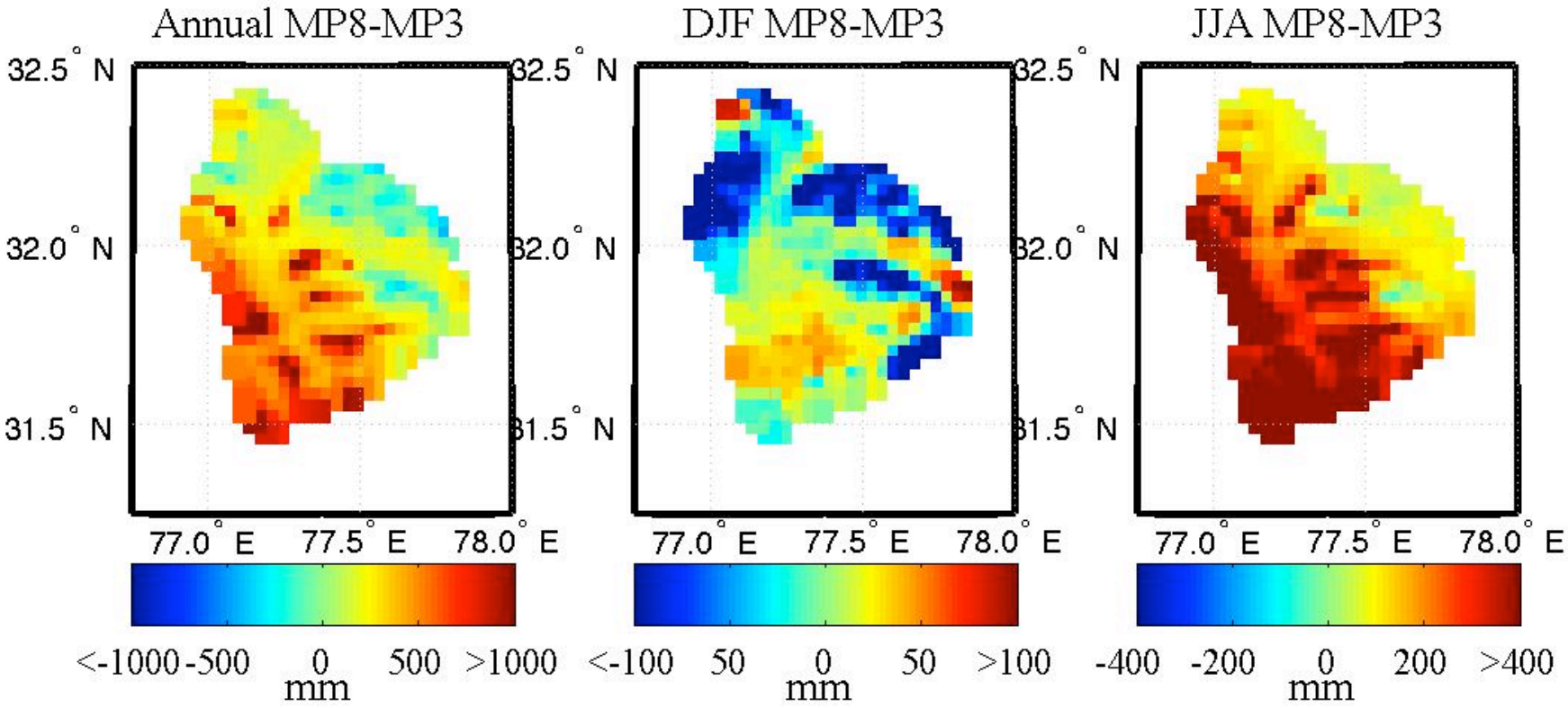
Spatial variability: Annual precipitation (1997-2001)



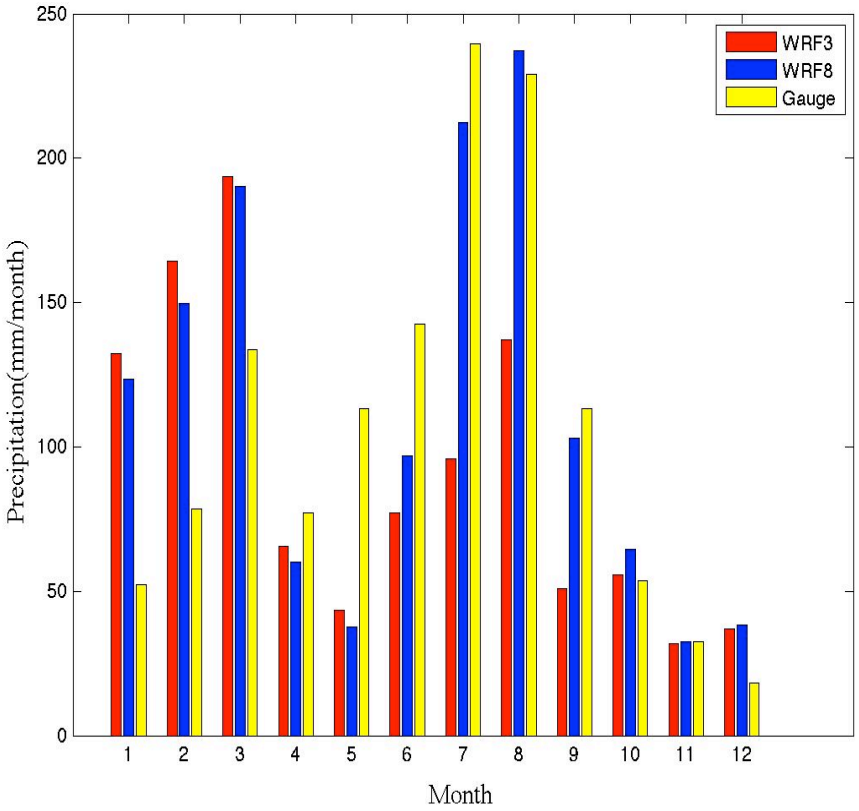
Spatial variability: Seasonal precipitation of WRF-MP8 (1997-2001)



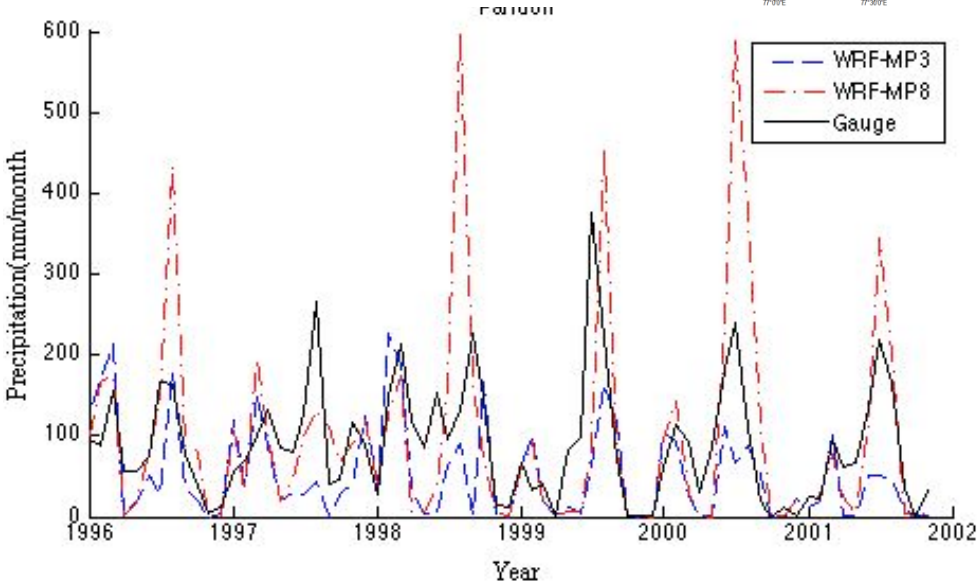
Spatial difference of two WRF-MPs (1997-2001)



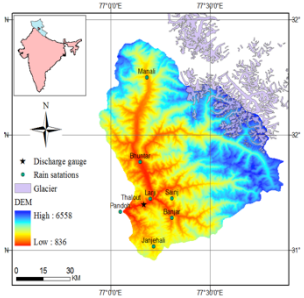
Temporal differences: Monthly precipitation (1997-2001)



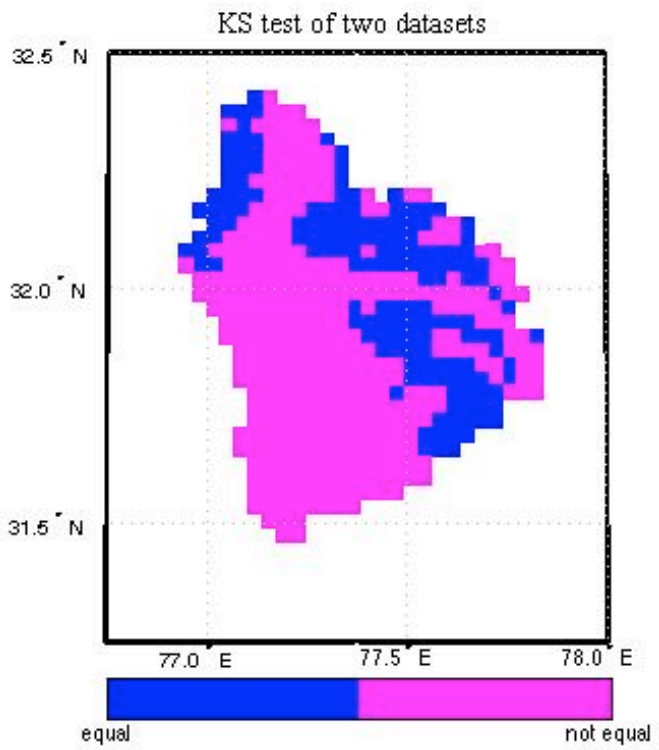
Monthly mean precipitation of Beas

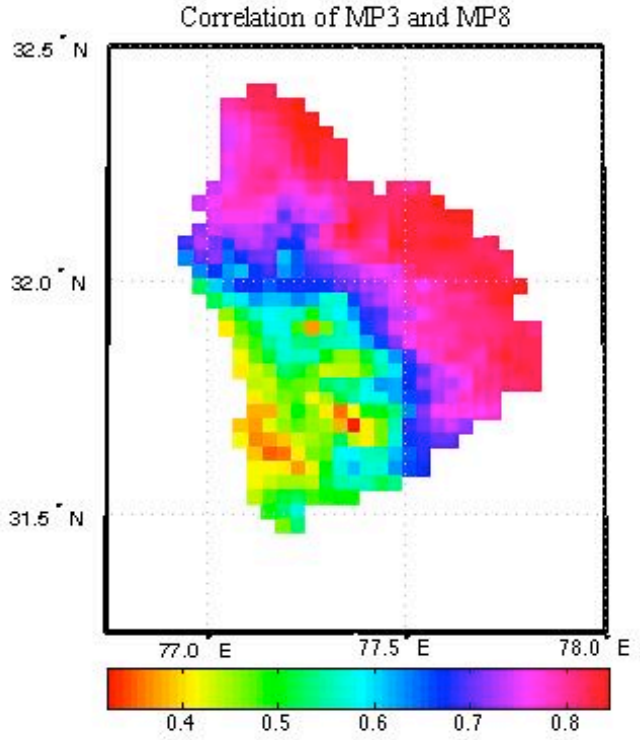


Monthly precipitation of Beas



Statistic analysis: KS and correlations





KS test and correlation of daily precipitation between MP3 and MP8.

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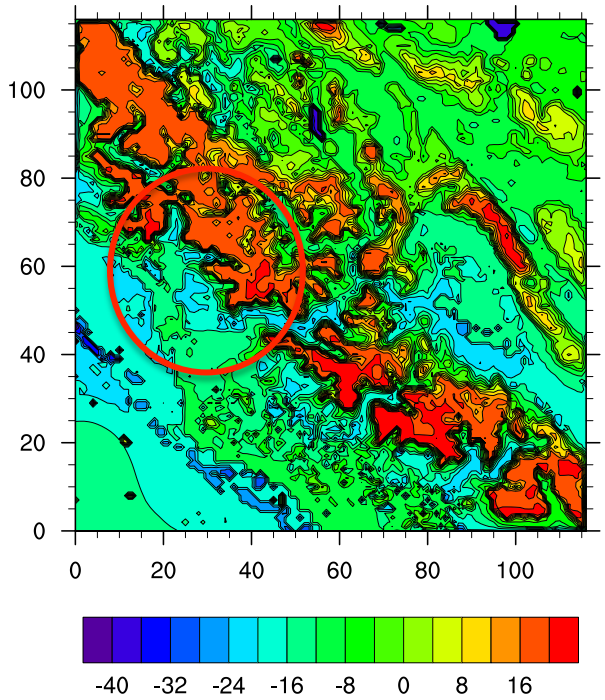
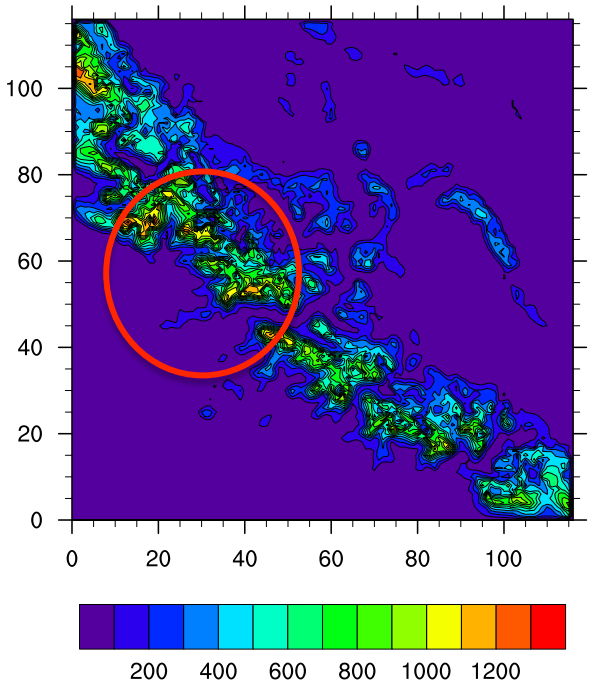
WRF-hydro/MP3 Domain3: annual mean (mm)

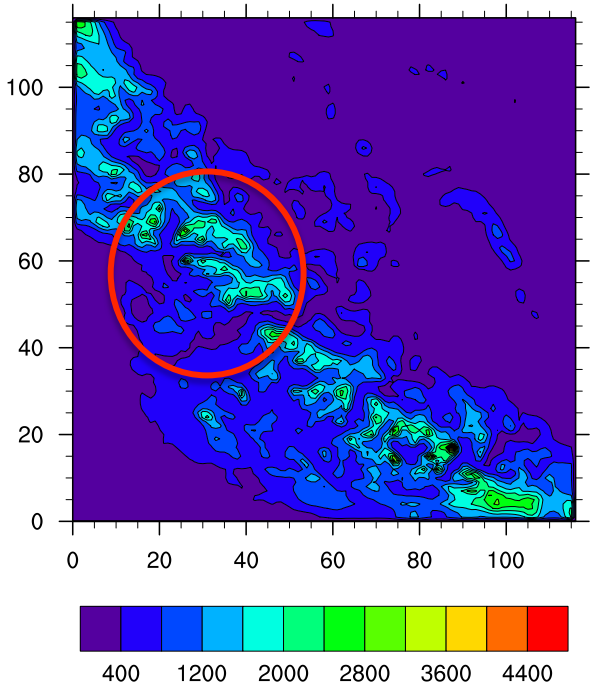
Soil moisture

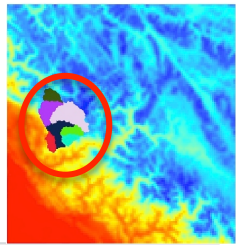


Snowmelt



Precipitation





Aera: 354*354 km

Time: 1996-2001

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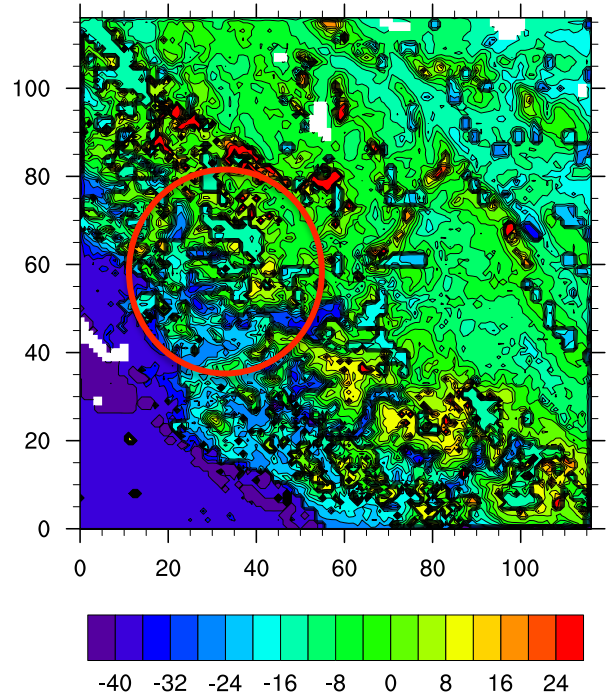
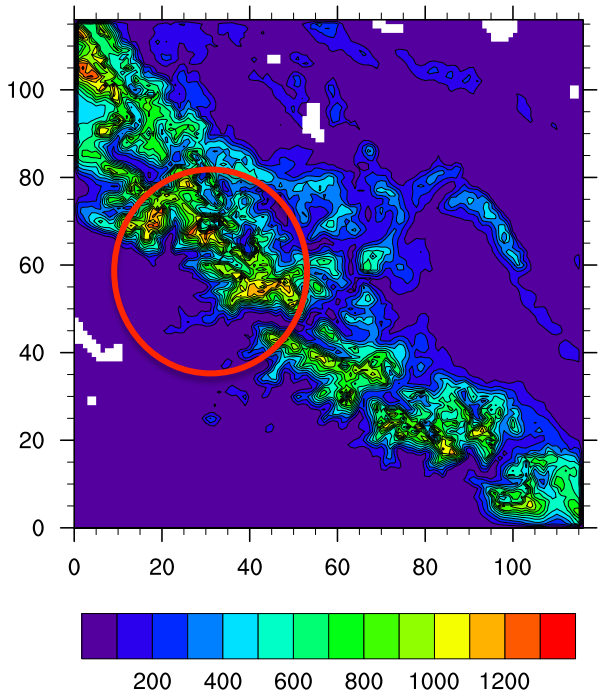
WRF-hydro/MP8 Domain3: annual mean (mm)

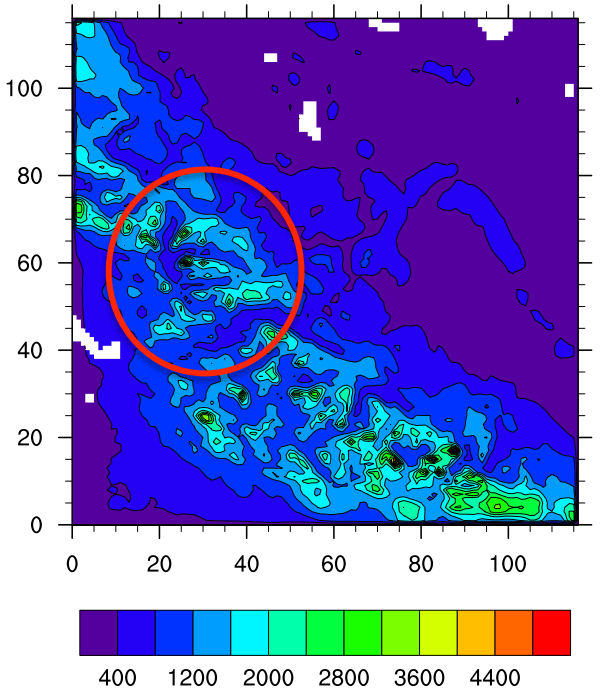
Soil moisture

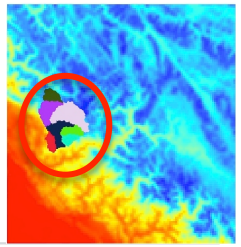


Snowmelt



Precipitation





Aera: 354*354 km

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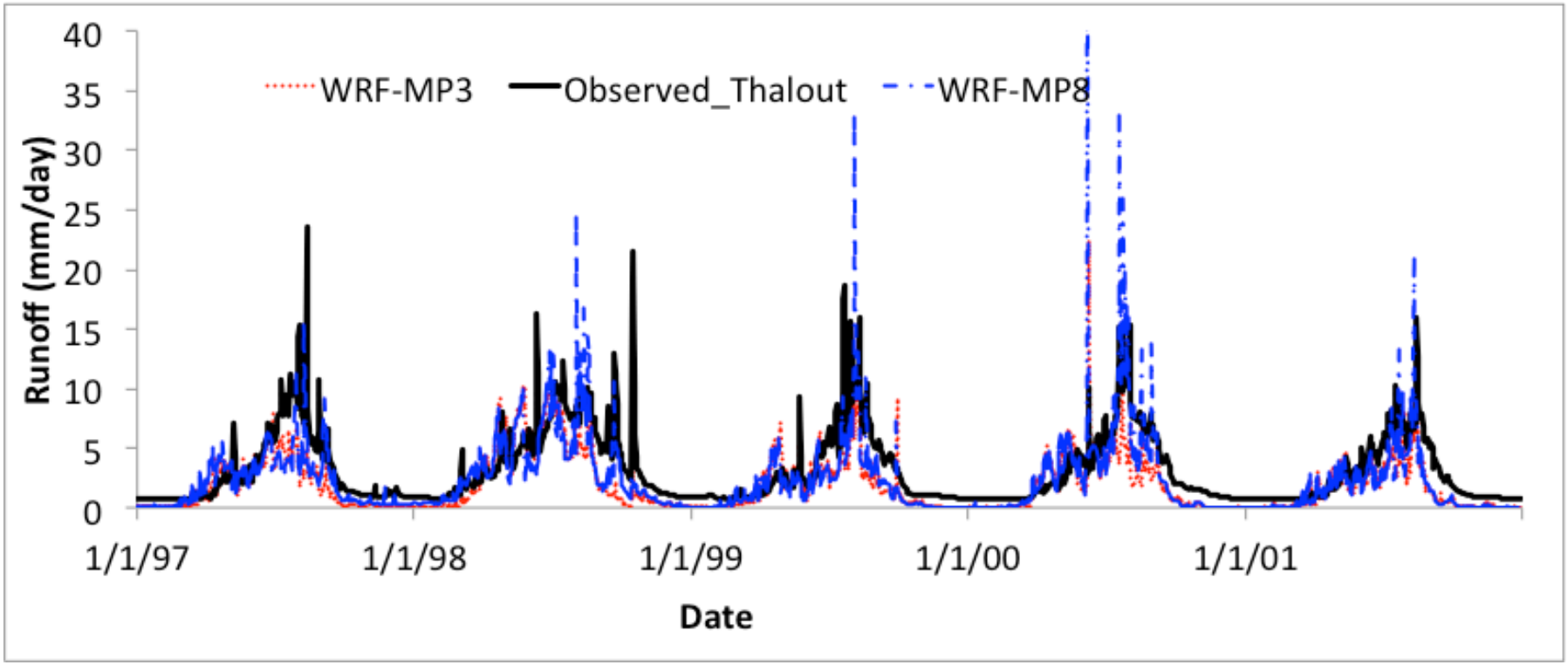
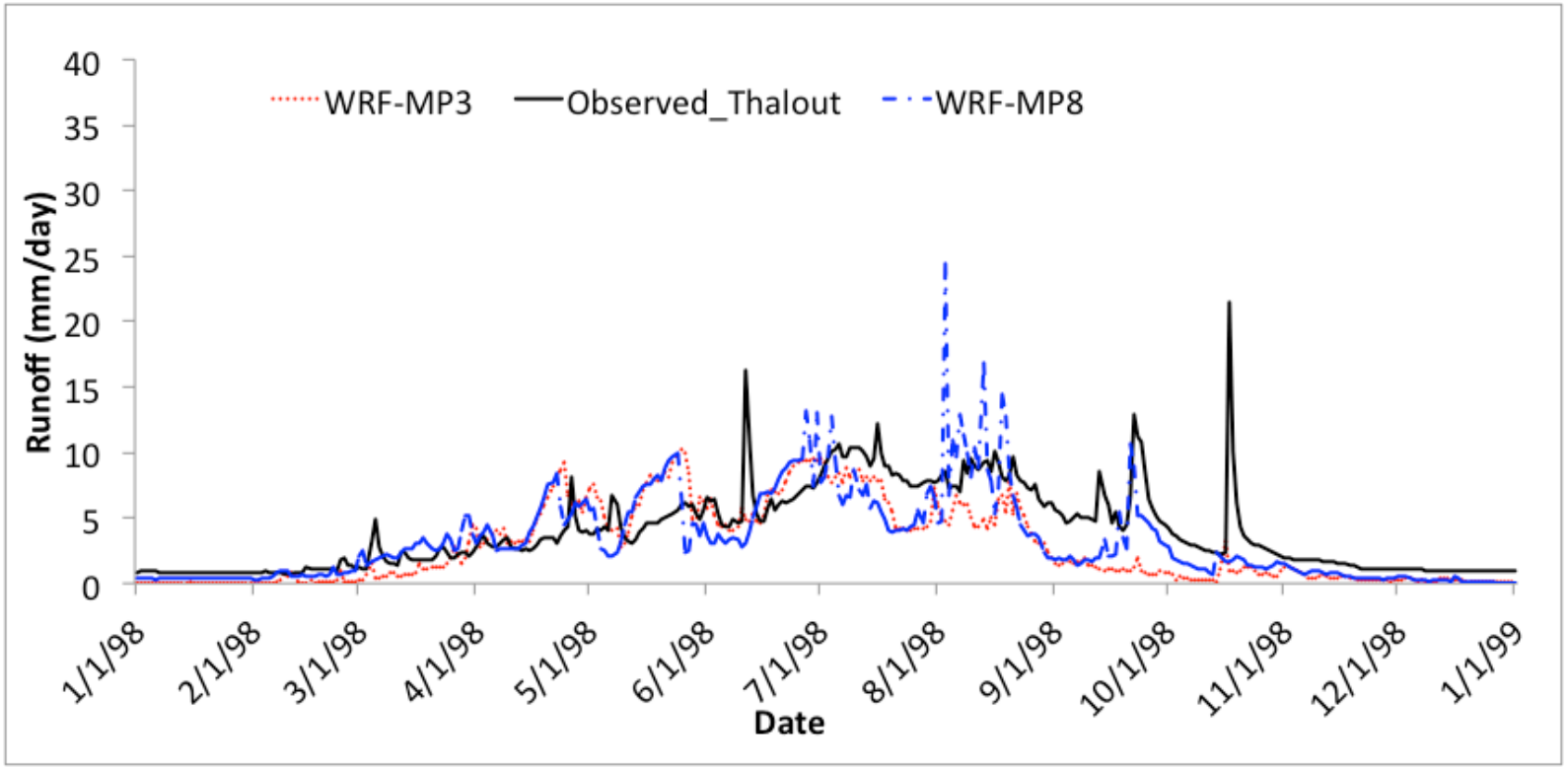
RUNOFF (without routing)



WRF-Hydro/MP3: monthly NS efficiency = 0.47 VE = 38%
WRF-Hydro/MP8: monthly NS efficiency = 0.68 VE = 24%

1998 RUNOFF (without routing)



WRF-Hydro/MP3: monthly NS efficiency = 0.47 VE = 38%
WRF-Hydro/MP8: monthly NS efficiency = 0.68 VE = 24%

Summary

- **Spatial variability**:
  - ✓ highly related to the topography in Beas;
  - ✓ In winter, precipitation of MP8 is smaller than MP3, especially in mountain area;
  - ✓ In summer, precipitation of MP8 is much larger than MP3 over 400 mm/year, especially over downstream area;
- **Temporal variability:**
  - ✓ The monthly variability have been captured fairly well by 3km WRF simulations, although the precipitation from WRF-MP3 is under-estimated while WRF-MP8 is over-estimated (especially in summer);
  - ✓ MP8 is more closer to Gauge rainfall than MP3;
- **Statistic analysis:** the daily precipitation distributions (6years) of two MPs is hardly the same, only some grids in mountain area; the correlation between two MPs daily precipitations is increasing with the elevation increasing.
- **Water cycle elements**: more precipitation and snowmelt from MP8 than MP3, while soil water increased more from MP3 than MP8, especially in mountain area mainly results from higher precipitation.
- **The 6 yrs runoff:** MP8 has 0.68 NS and 24% absolute volume error which is better than MP3.

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Thank you !

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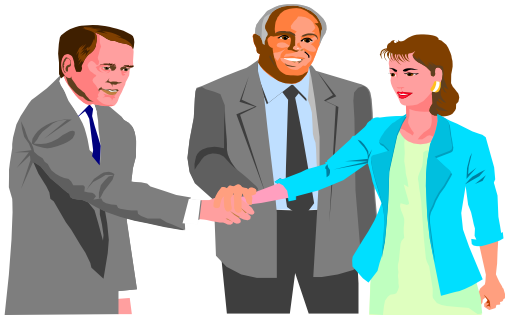

Acknowledgements:
Dr. Stefan Sobolowski (Uni Research AS, Bergen, Norway)
Dr. Wei Yu (NCAR, Boulder, USA)
Prof. Chongy-Yu Xu (University of Oslo, Oslo, Norway)
Prof. Sharad K. Jain (National Institute of Hydrology, Roorkee, India)