Areal estimates of precipitation and temperature in the Upper Indus Basin

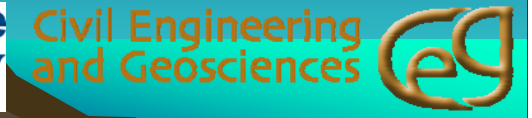
Presentation to workshop on

Water Resources in Developing Countries : Planning & Management in a Climate Change Scenario,

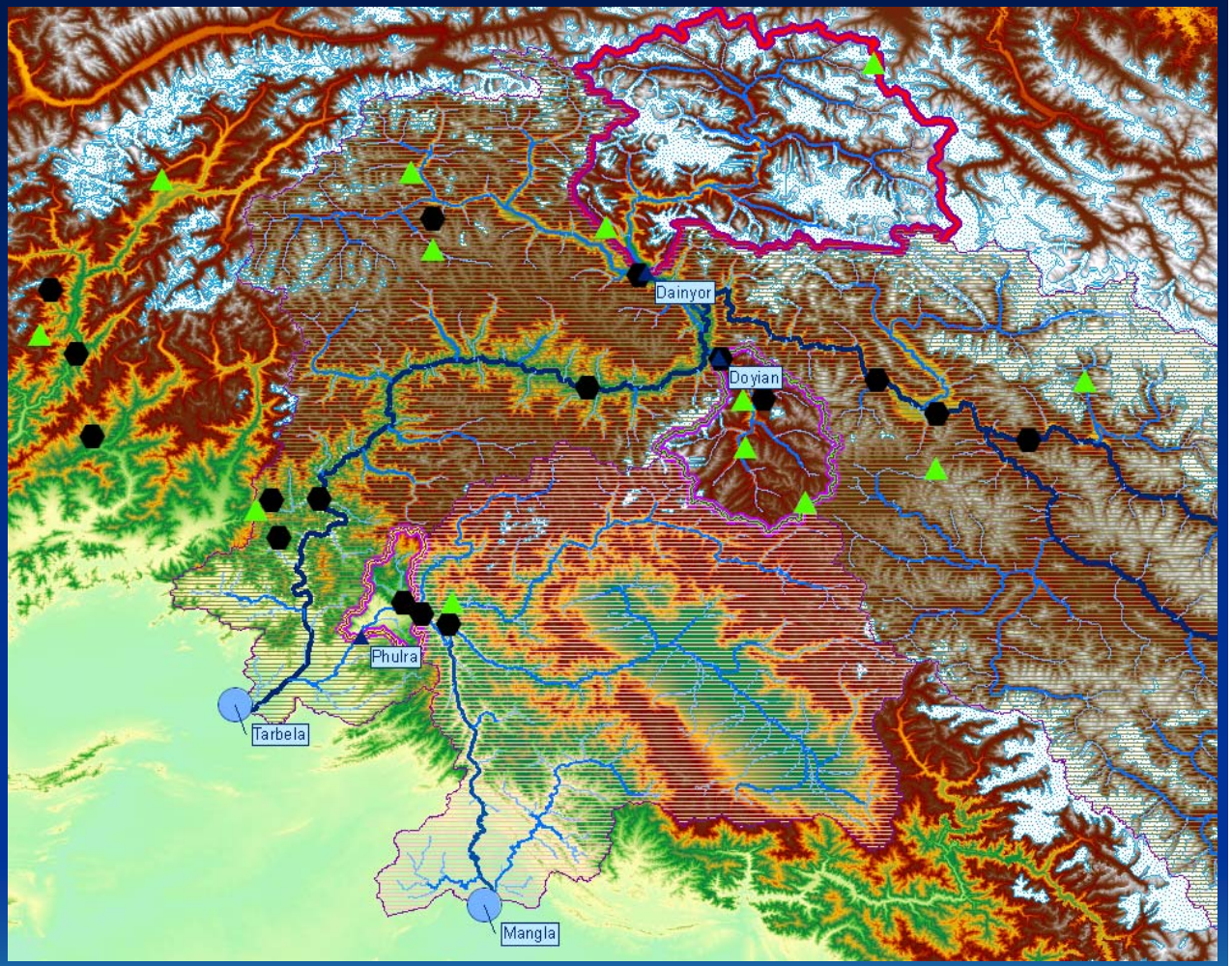
ICTP-Trieste -- 28 April 2009

-- by Nathan Forsythe, Newcastle University

advised by Dr. Hayley Fowler, Prof. Chris Kilsby, Mr. David Archer



Location of the Upper Indus Basin (UIB)



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Reasons for interest in the UIB

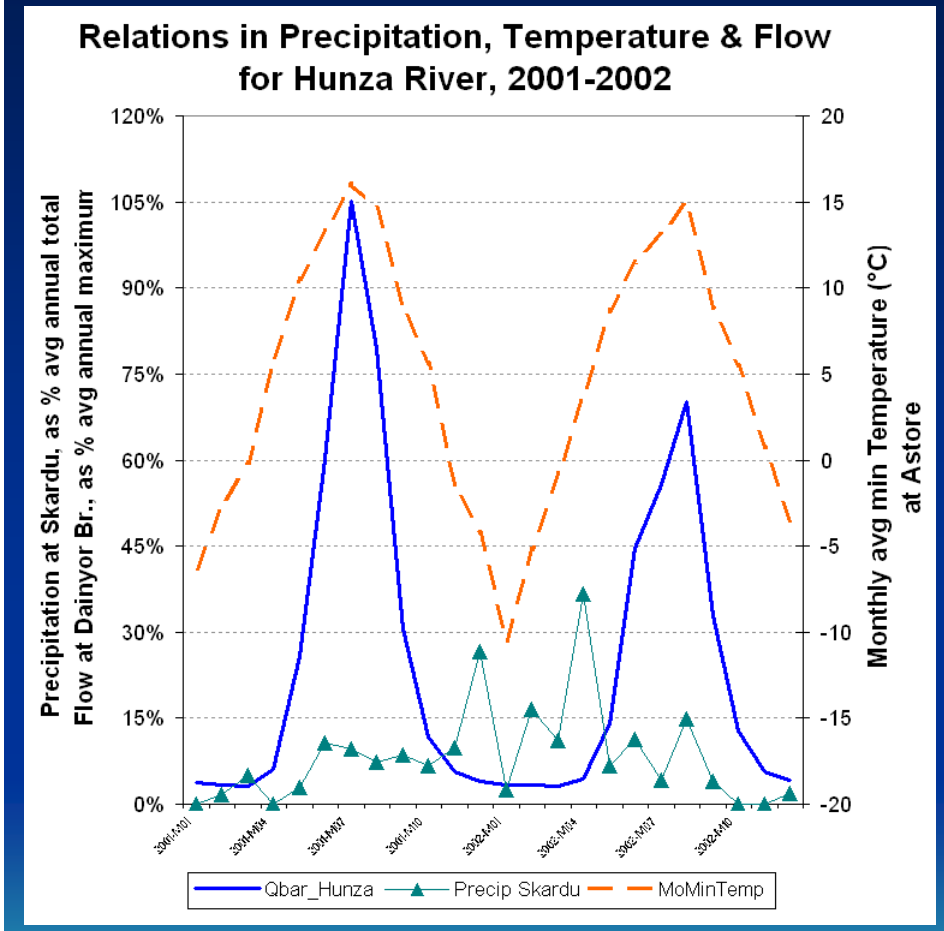
- Convergence of westerly weather influences (Mediterranean, North Atlantic) & tropical systems (Indian Monsoon).
- Hydrological regimes are thus potentially extremely sensitive to climate change.
- Indus River & tributaries dominant elements in Pakistan economy (hydropower, food security and agricultural sector employment).

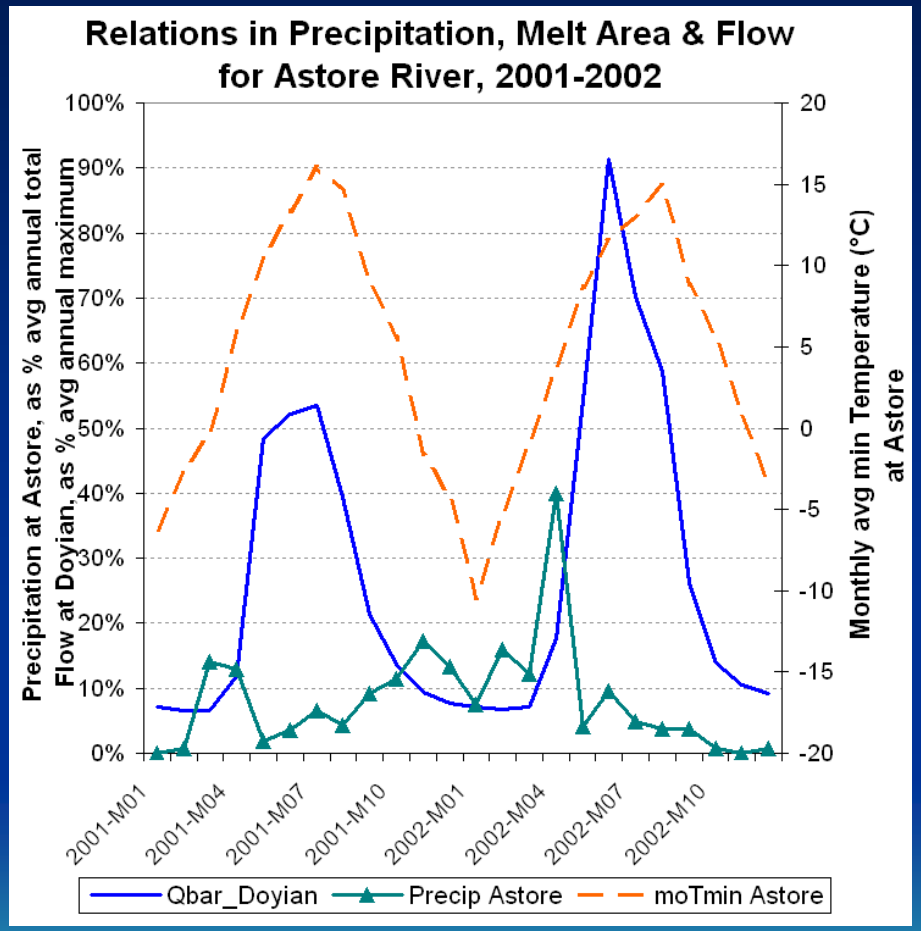
Overview of initial PhD project outline

Plan of work:

1. Exploration of the observed data set.
2. Construction of relationships between large-scale atmospheric patterns and local climate.
3. Construction of a (physically-based) modelling framework.
4. Modelling of future climate change.
5. Assessment of possible responses.

Climate & flow regimes in the UIB





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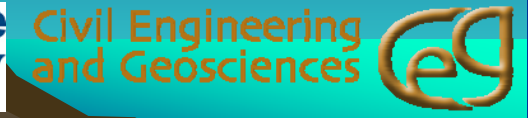
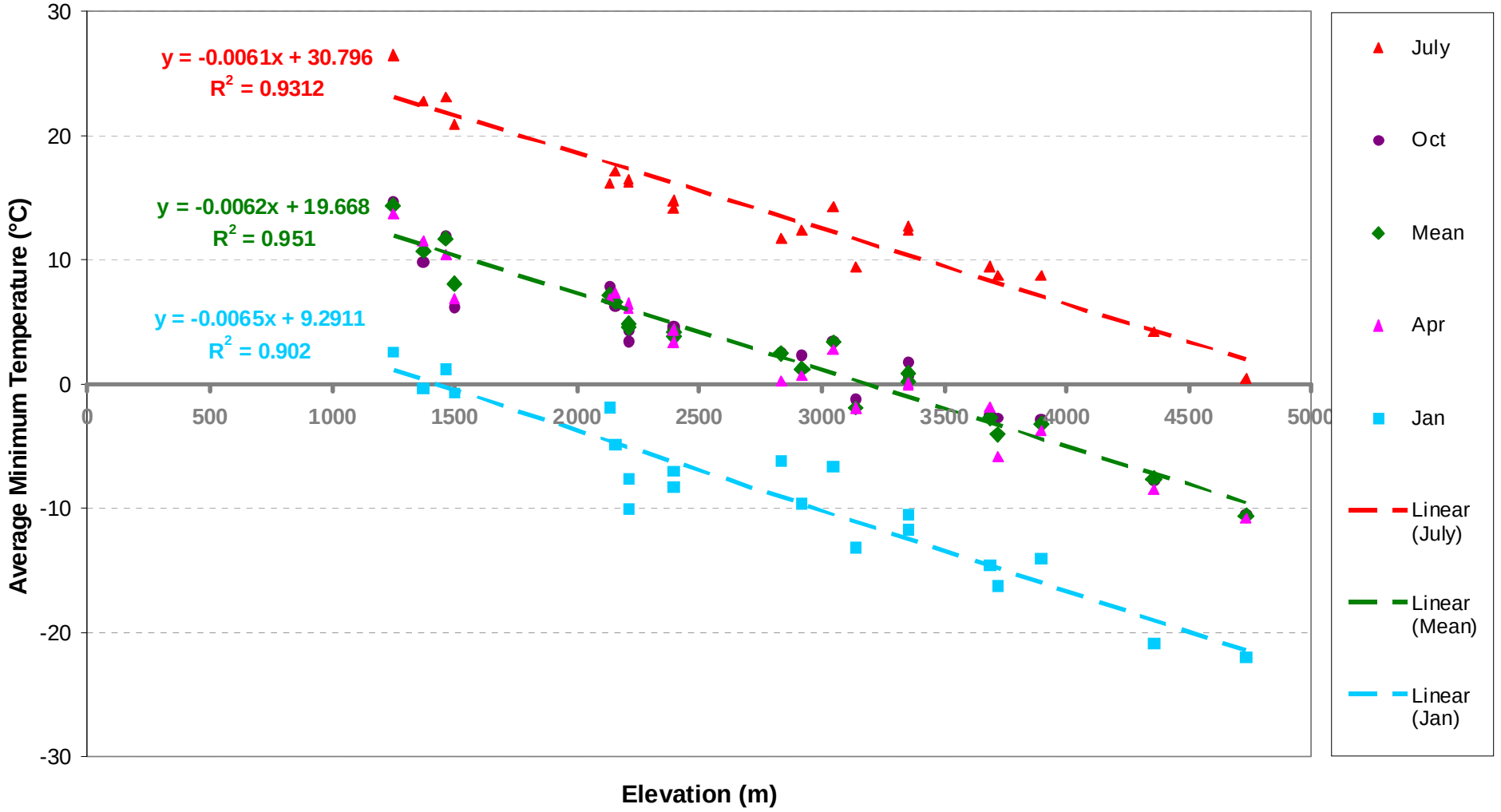
Initial work on areal transformations of temperature as forecasting input / predictor



Lapse rate derivation from Minimum Temperatures, select stations 1994 - 1997/98 & 2001 - 2005



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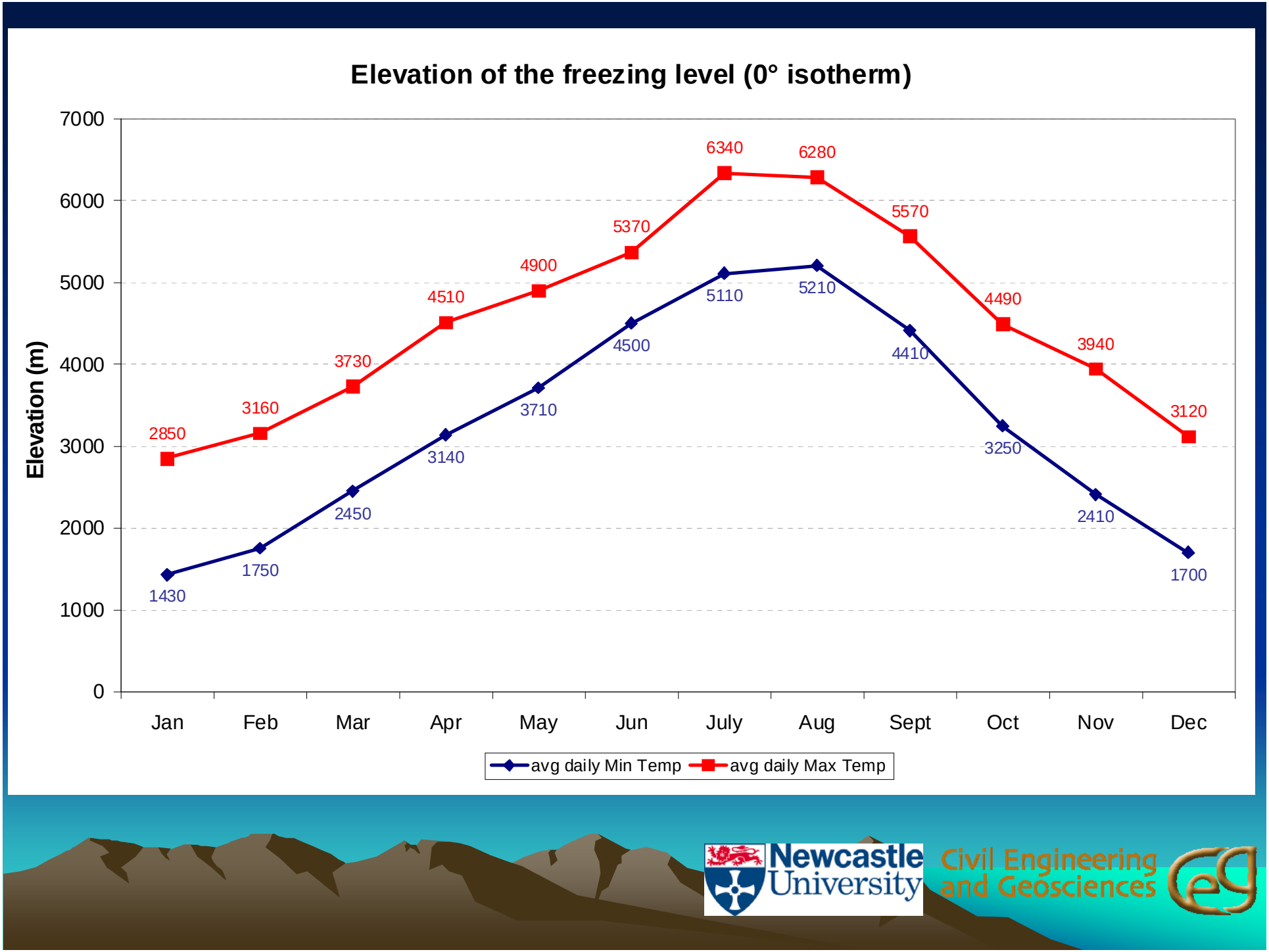
Elevation of the freezing level (0° isotherm)
Elevation (m)
7000
6000
5000
4000
3000
2000
1000
0
Jan
Feb
Mar
Apr
May
Jun
July
Aug
Sept
Oct
Nov
Dec
2850
3160
3730
4510
4900
5370
6340
6280
5570
4490
3940
3120
1430
1750
2450
3140
3710
4500
5110
5210
4410
3250
2410
1700
avg daily Min Temp
avg daily Max Temp
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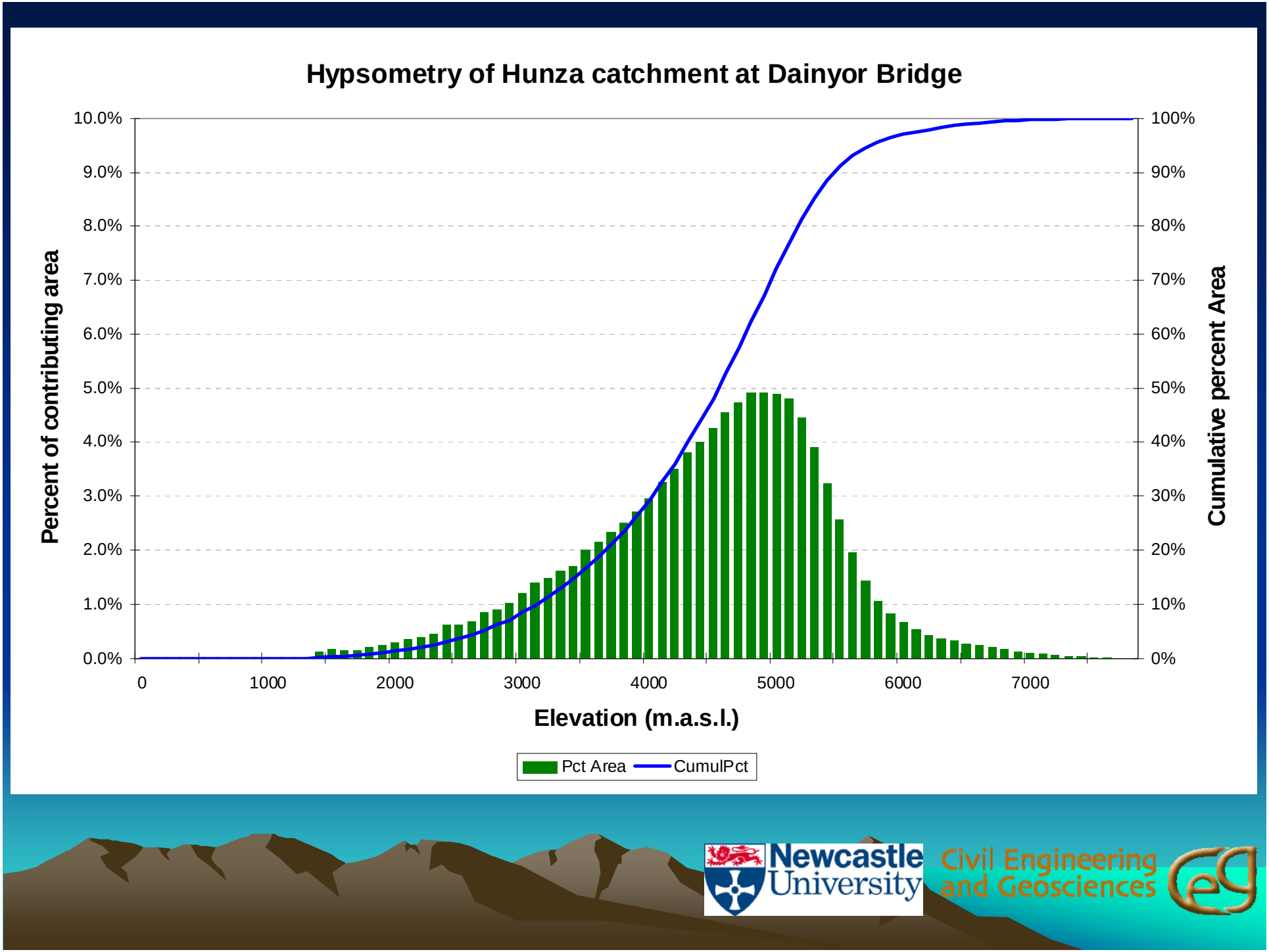
Hypsometry of Hunza catchment at Dainyor Bridge
Percent of contributing area
Cumulative percent Area
10.0%
9.0%
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1000
2000
3000
4000
5000
6000
7000
Elevation (m.a.s.l.)
Pct Area
CumulPct
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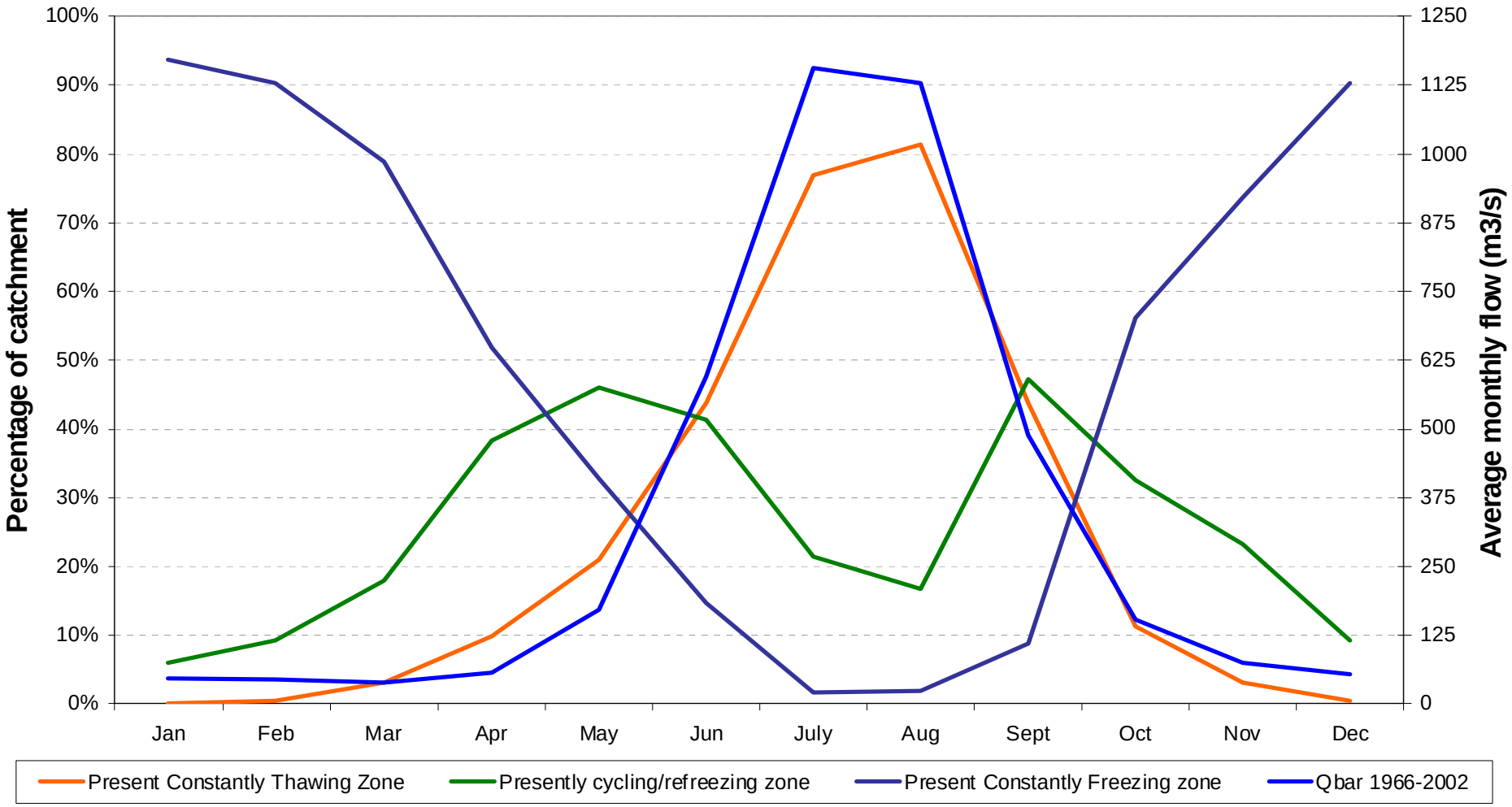
Variation in percent coverage of different temperature zones for Hunza river at Dainyor Bridge



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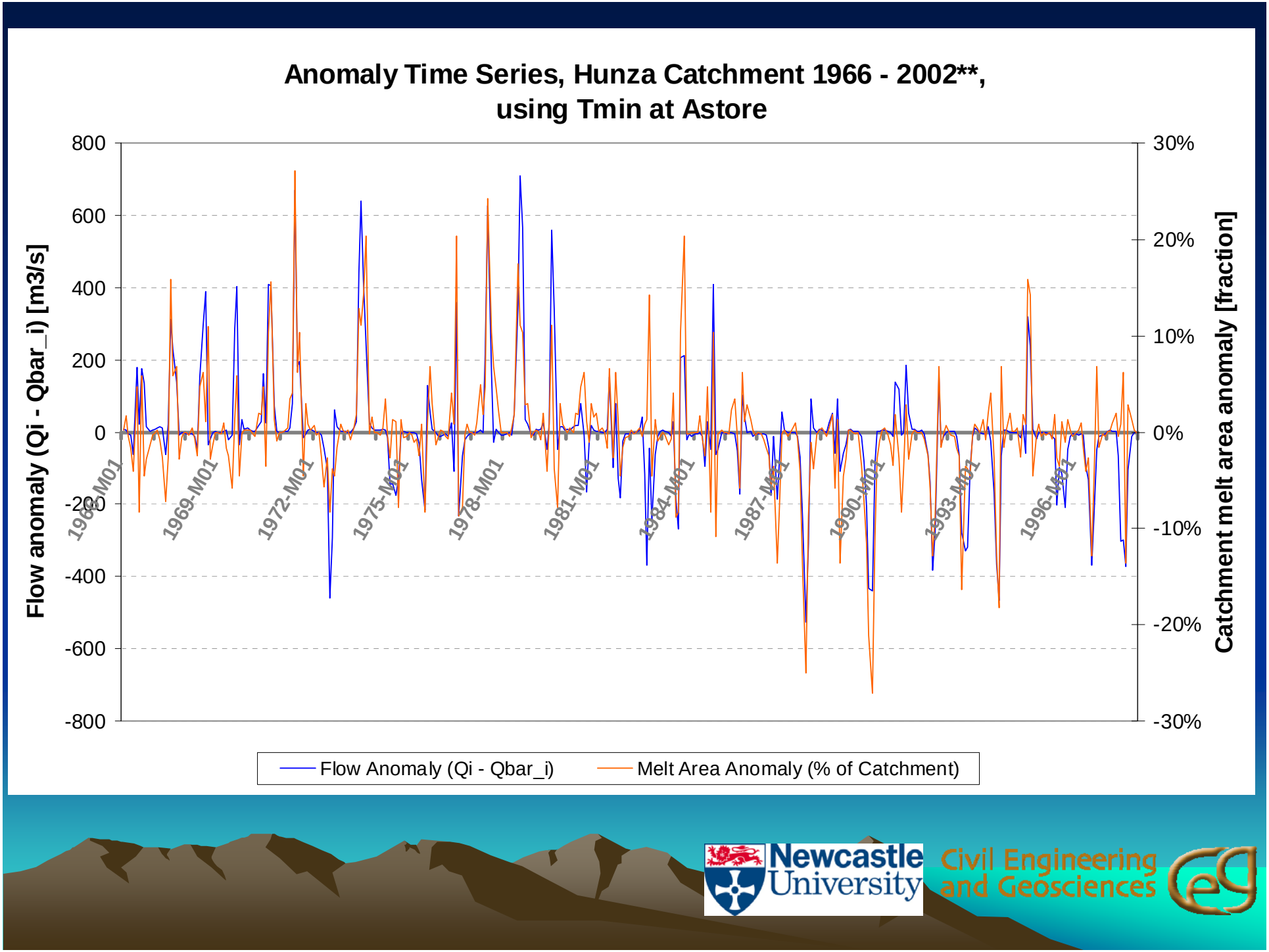
Anomaly Time Series, Hunza Catchment 1966 - 2002**,
using Tmin at Astore
Flow anomaly (Qi - Qbar_i) [m3/s]
Catchment melt area anomaly [fraction]
800
600
400
200
0
-200
-400
-600
-800
30%
20%
10%
0%
-10%
-20%
-30%
1968-M01
1969-M01
1972-M01
1975-M01
1978-M01
1981-M01
1984-M01
1987-M01
1990-M01
1993-M01
1996-M01
Flow Anomaly (Qi - Qbar_i)
Melt Area Anomaly (% of Catchment)
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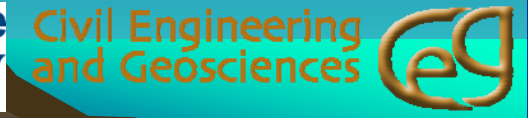
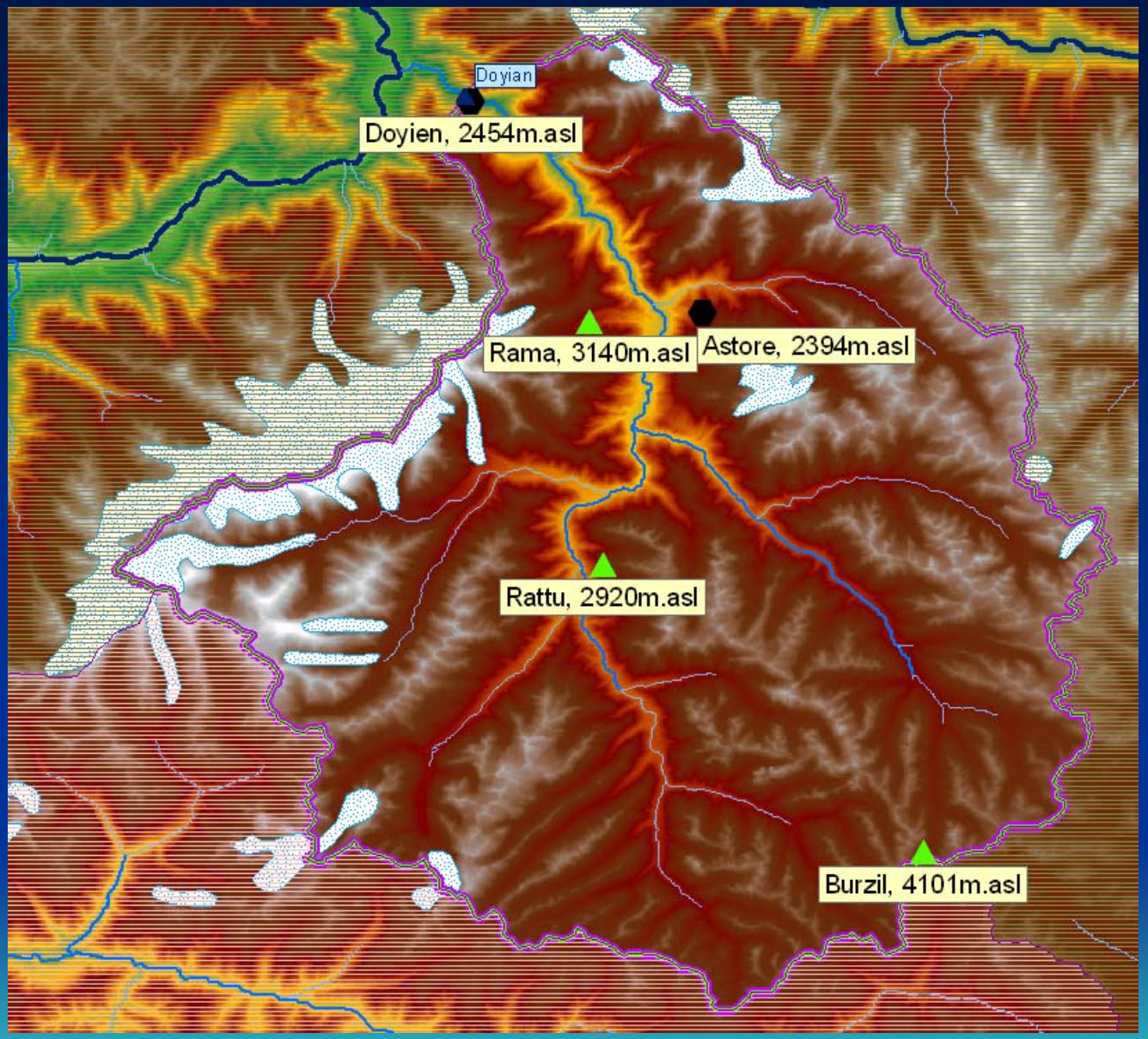
Further work on area representation of catchment melt/energy conditions

- For Hunza, at least 40% of variation in anomalies from seasonal (monthly) averages remains to be explained (quantifiably traced)

- Planned analysis approach :
  - Consideration of proxy variables for albedo variation (eg number of days with precipitation)
  - Analyses of relationship between cloud cover and flow variability

Initial work on areal transformations of precipitation as forecasting input / predictor





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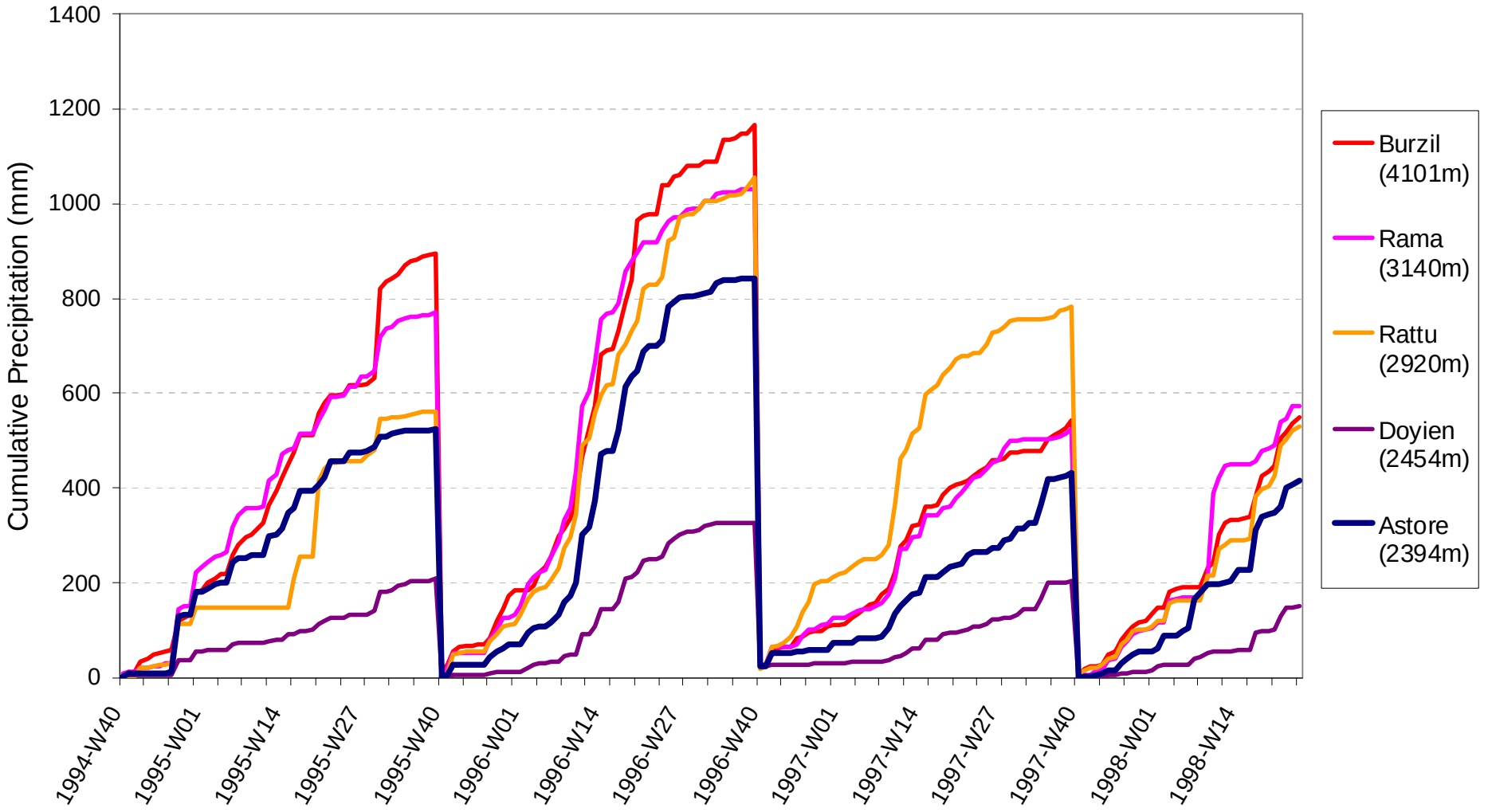
Cumulative Annual Precipitation in the Astore catchment



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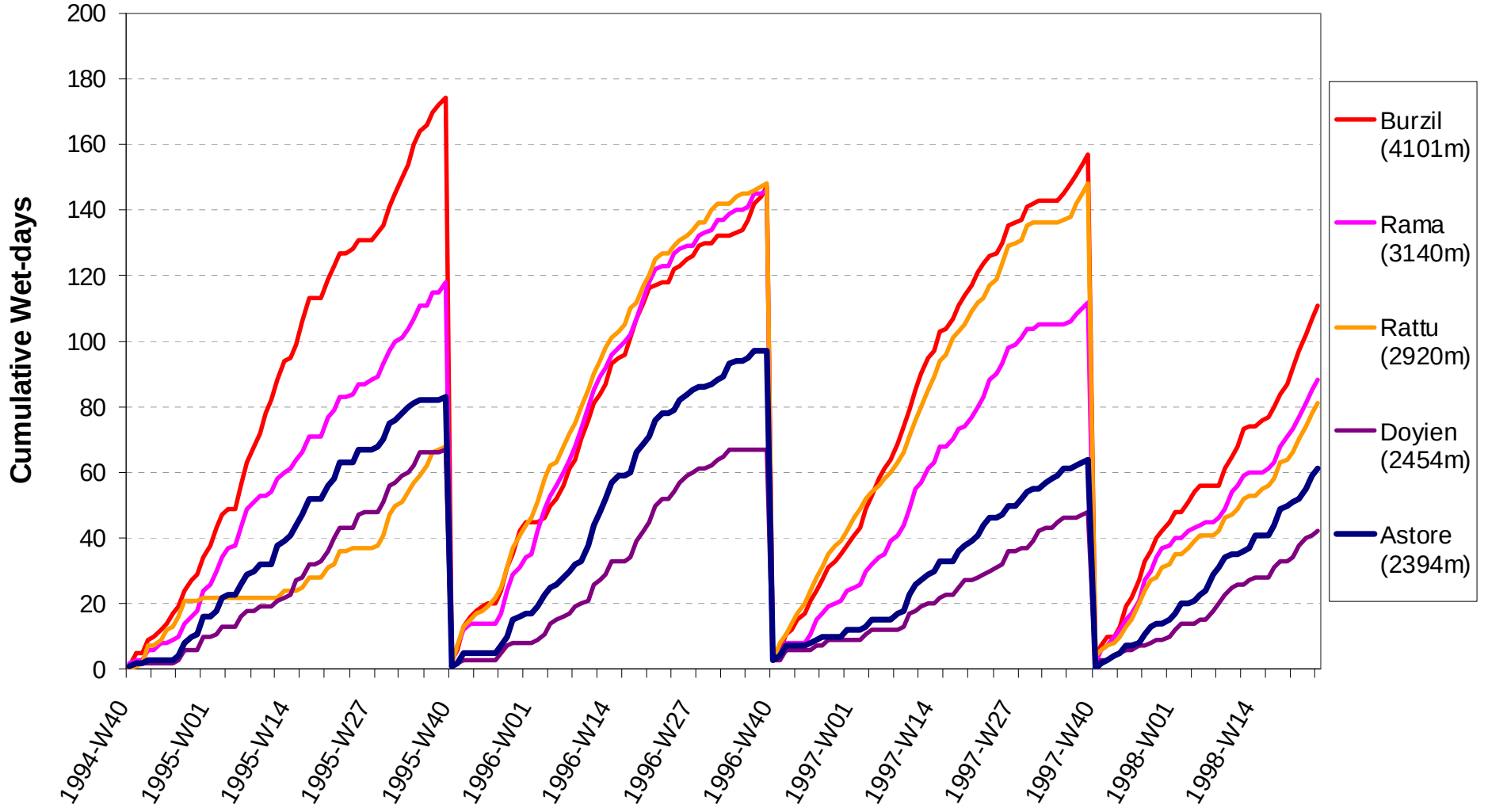
Cumulative Annual Wetdays in the Astore catchment



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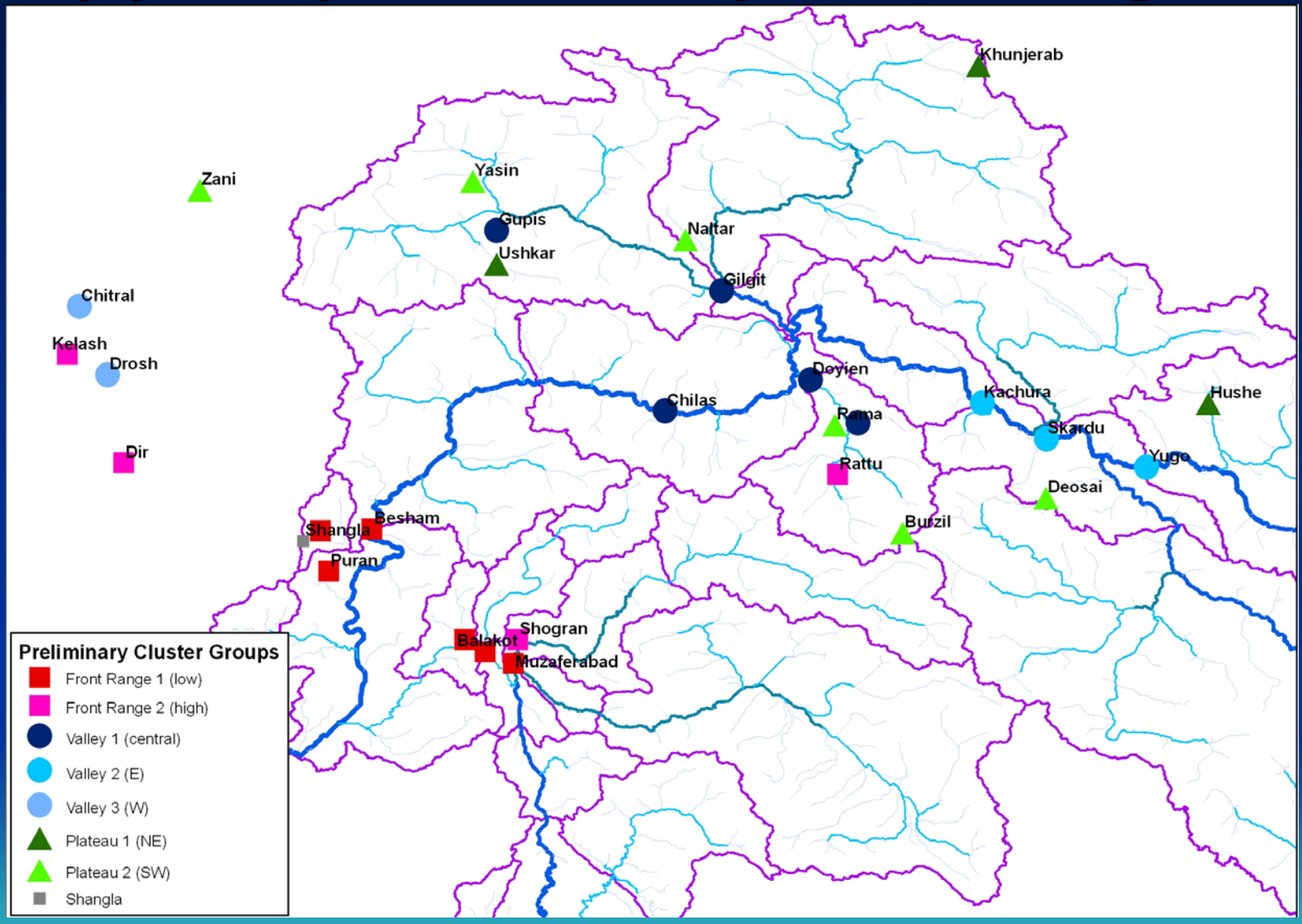
Mapped preliminary cluster groups



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Further work on areal representation of catchment precipitation distribution

- Analysis approach :
  - Literature review for comparison of potential physically-based interpolation techniques
  - Pursuit of regime classification by cluster analysis once adequate AWS record has been acquired

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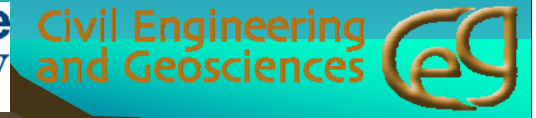
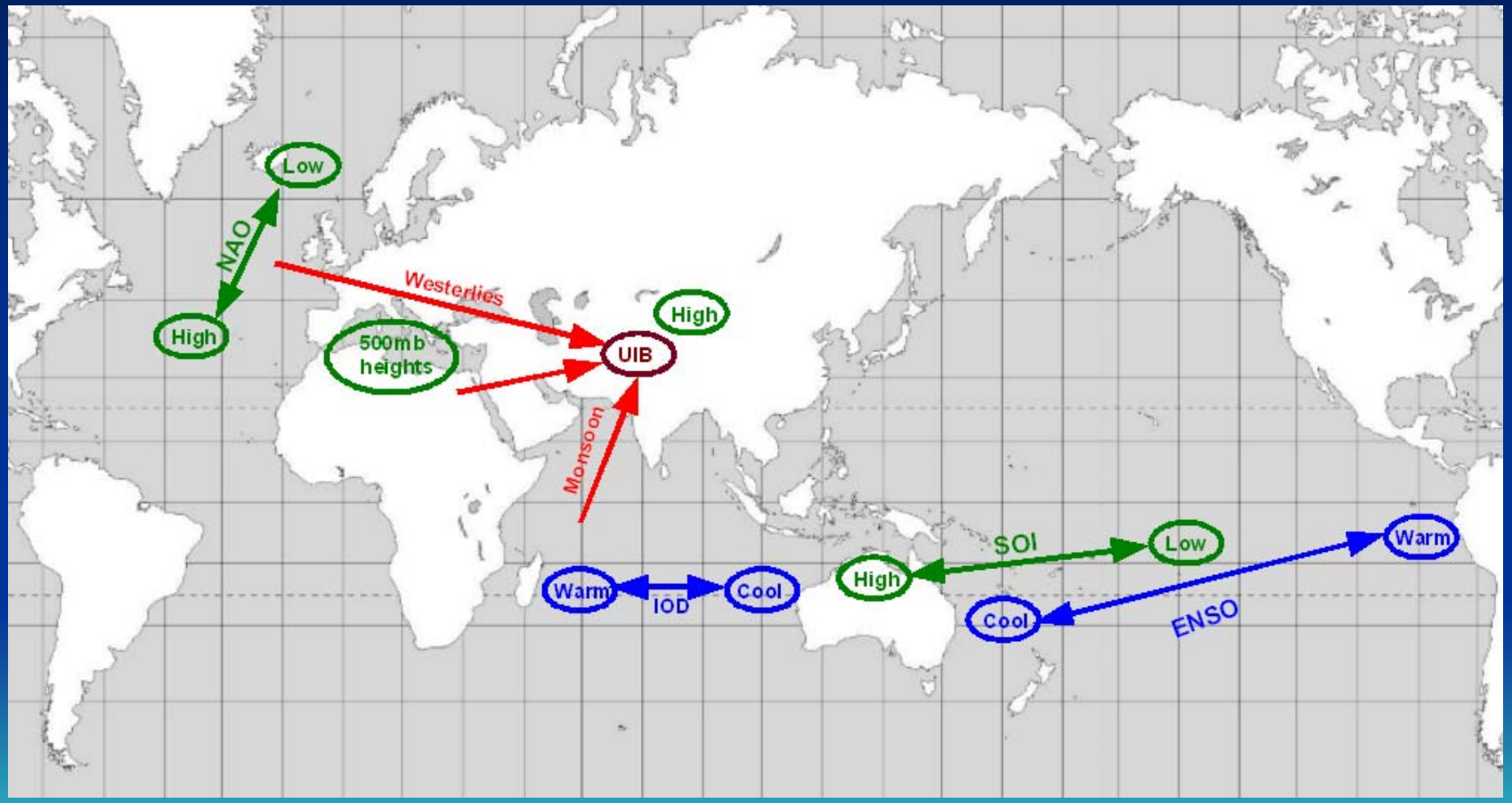
Further work on forecasting of anomalies in concurrent-effect predictors

(eg energy inputs, albedo variation, etc)



Anomaly forecasting by relationships between large-scale atmospheric patterns and local climate

Global circulation phenomena thought to affect UIB climate :



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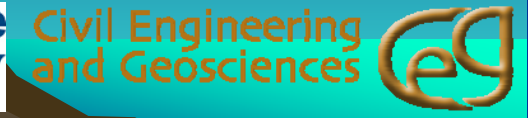
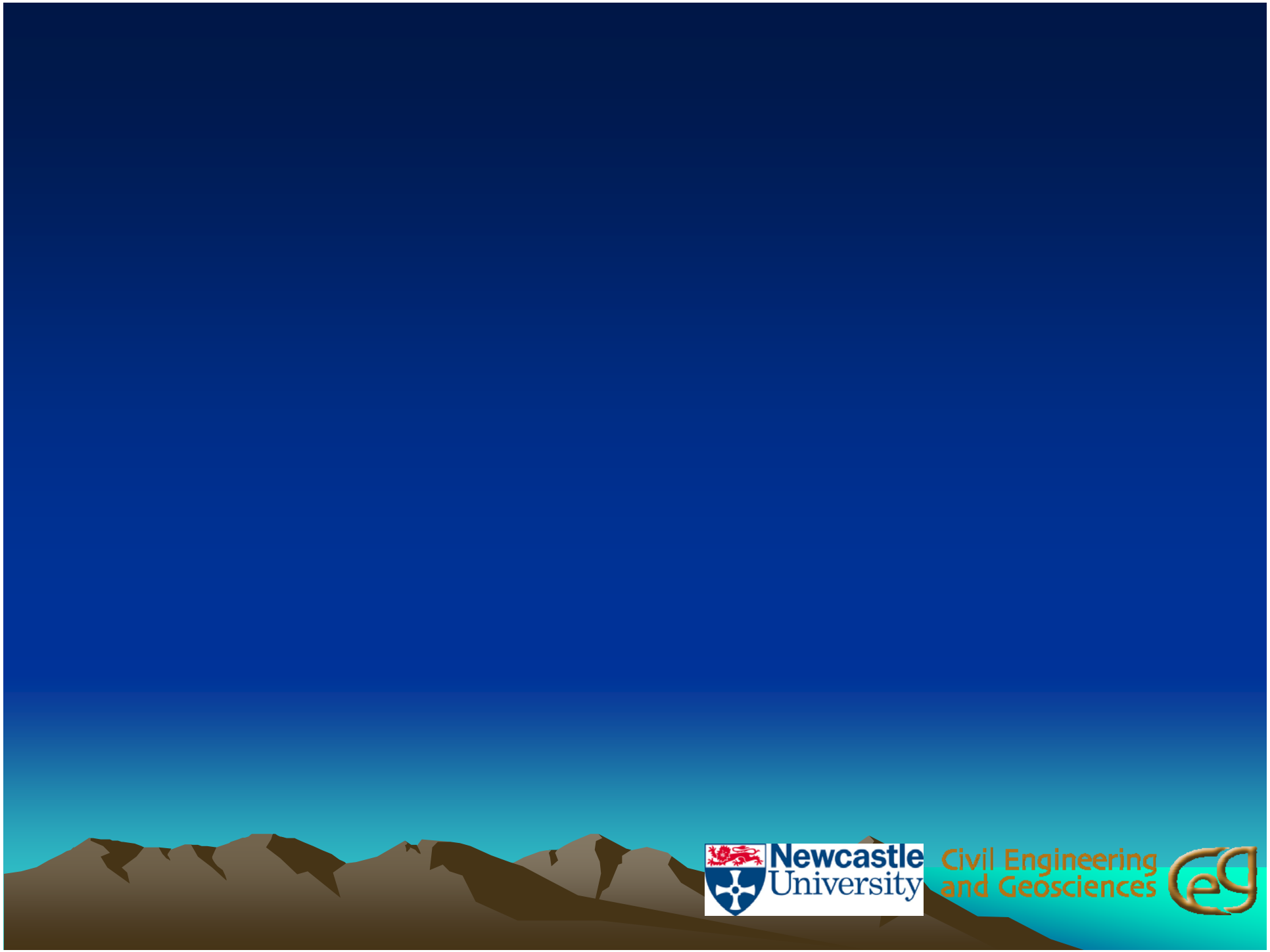
Thank you for your time.

Your questions and comments are most welcome !

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Analyses of Temperature data

- Derivation of lapse rates
- Calculation of monthly position of freezing level (0° isotherm) for Tmin & Tmax
  - Monthly equations for regional daily Tmin & Tmax by altitude/elevation
- Extrapolation using hypsometry data, on a subcatchment basis, to determine % area experiencing different water-phase states
- Comparison of estimated melt area (Tmin>0°C) to observed flow on monthly basis

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Analyses of Precipitation data

Analysis approach :

- Identification of orographic and wind-orientation (windward or leeward) effects within coherent rainfall regime groups

- Exploration of relationships between regime groups for simplified estimation and forecasting

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Further work on forecasting anomalies of predictors concurrent with melt-runoff processes

- Correlation analyses of published phenomena indices (eg SOI, IOD) at various time-lags with temperature and precipitation anomalies in UIB
- Development of linear regression models for anomalies
- Development of weather typing combining local observations with gridded dataset of atmospheric variables

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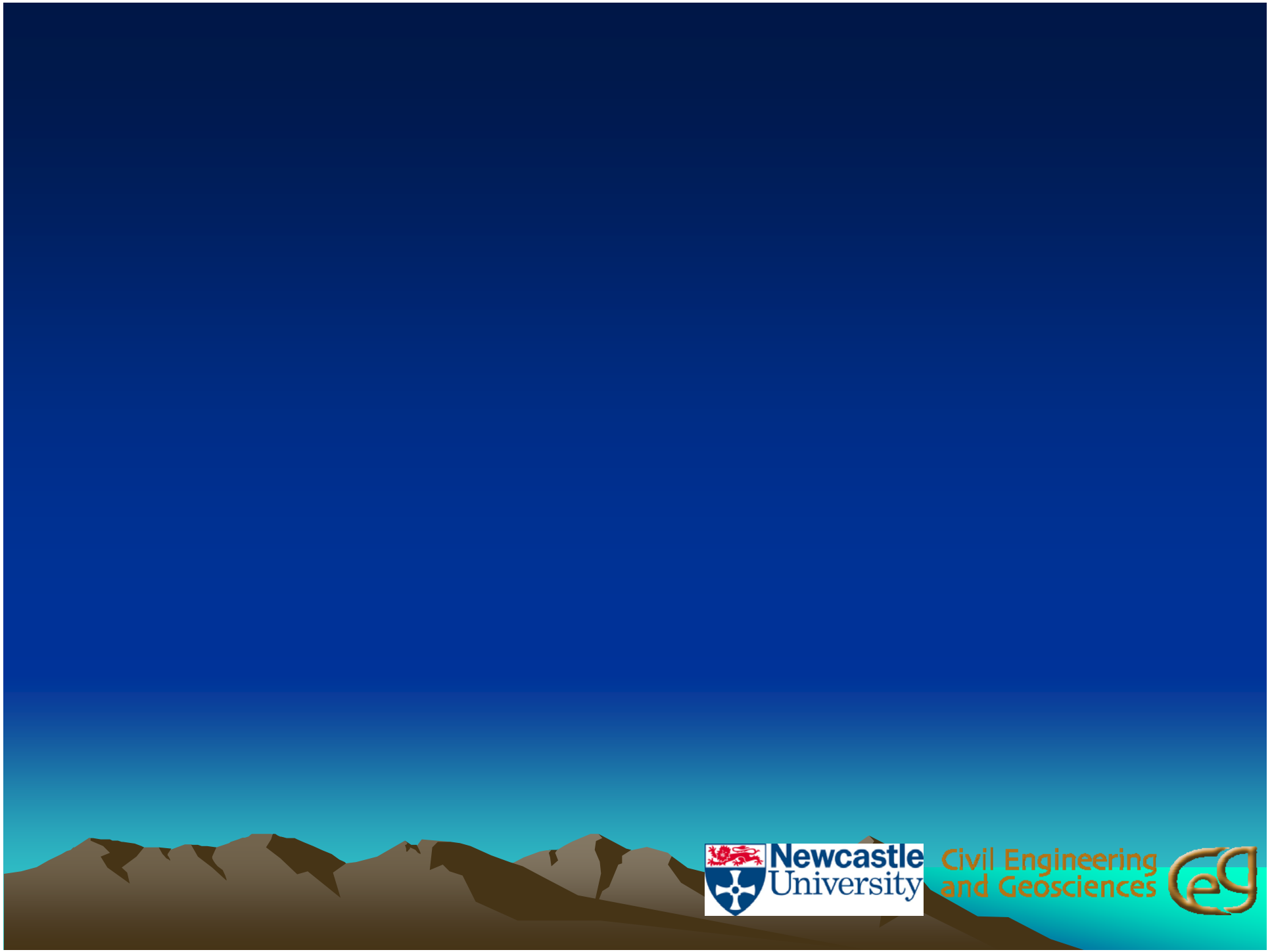
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Project context & status

NSF

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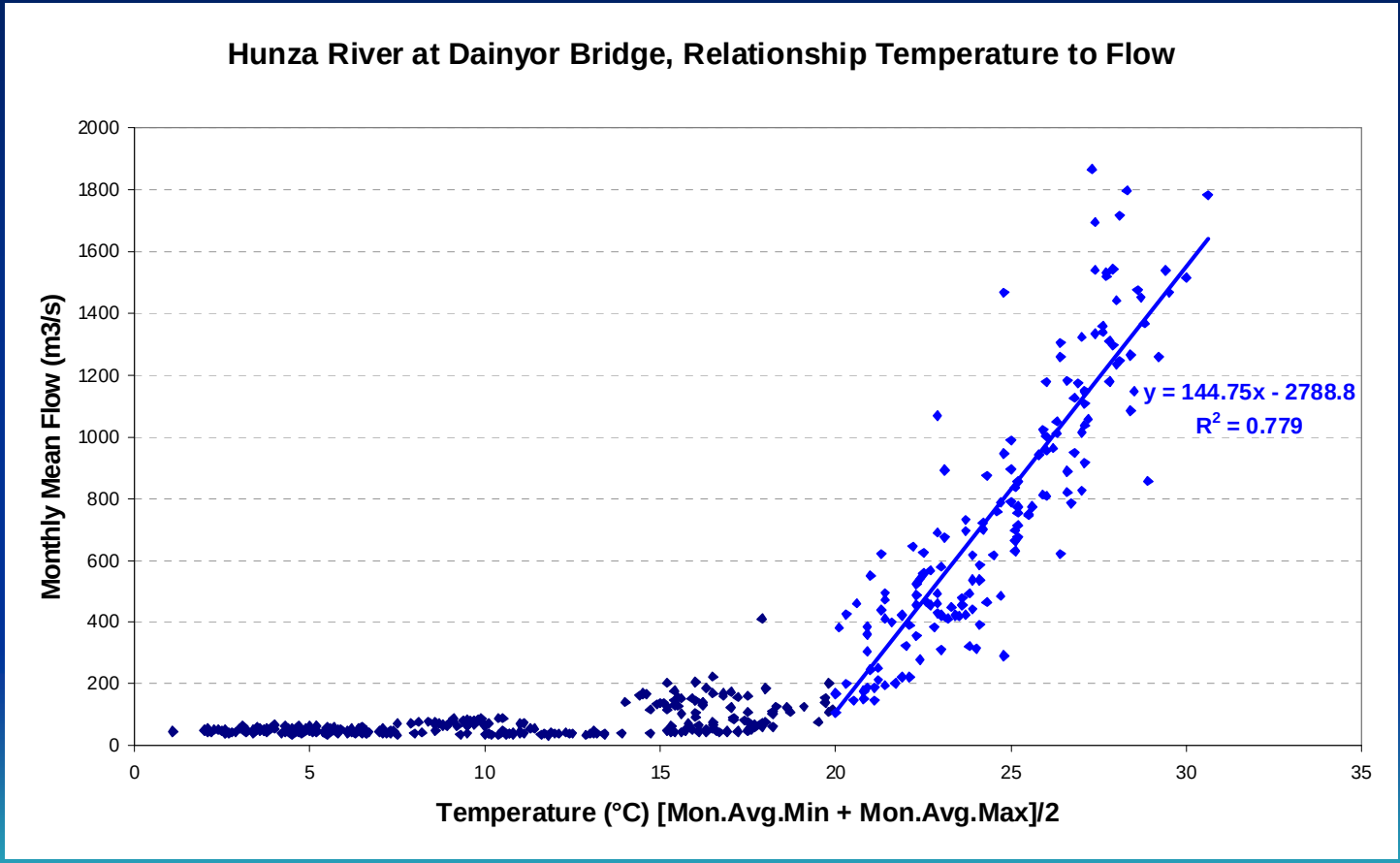
Objective of this analysis :

develop linear predictors of flow derived from local observations.



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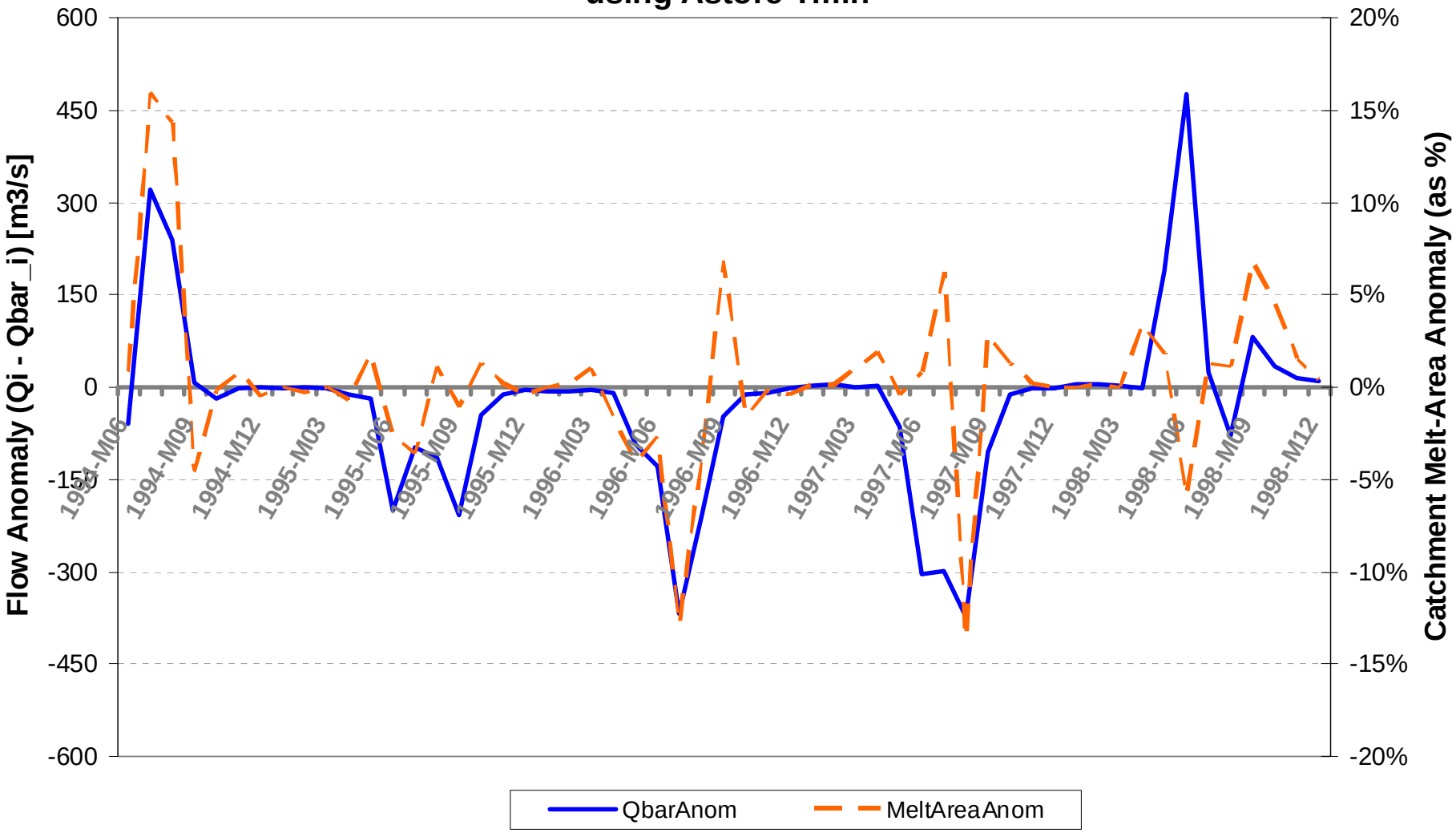

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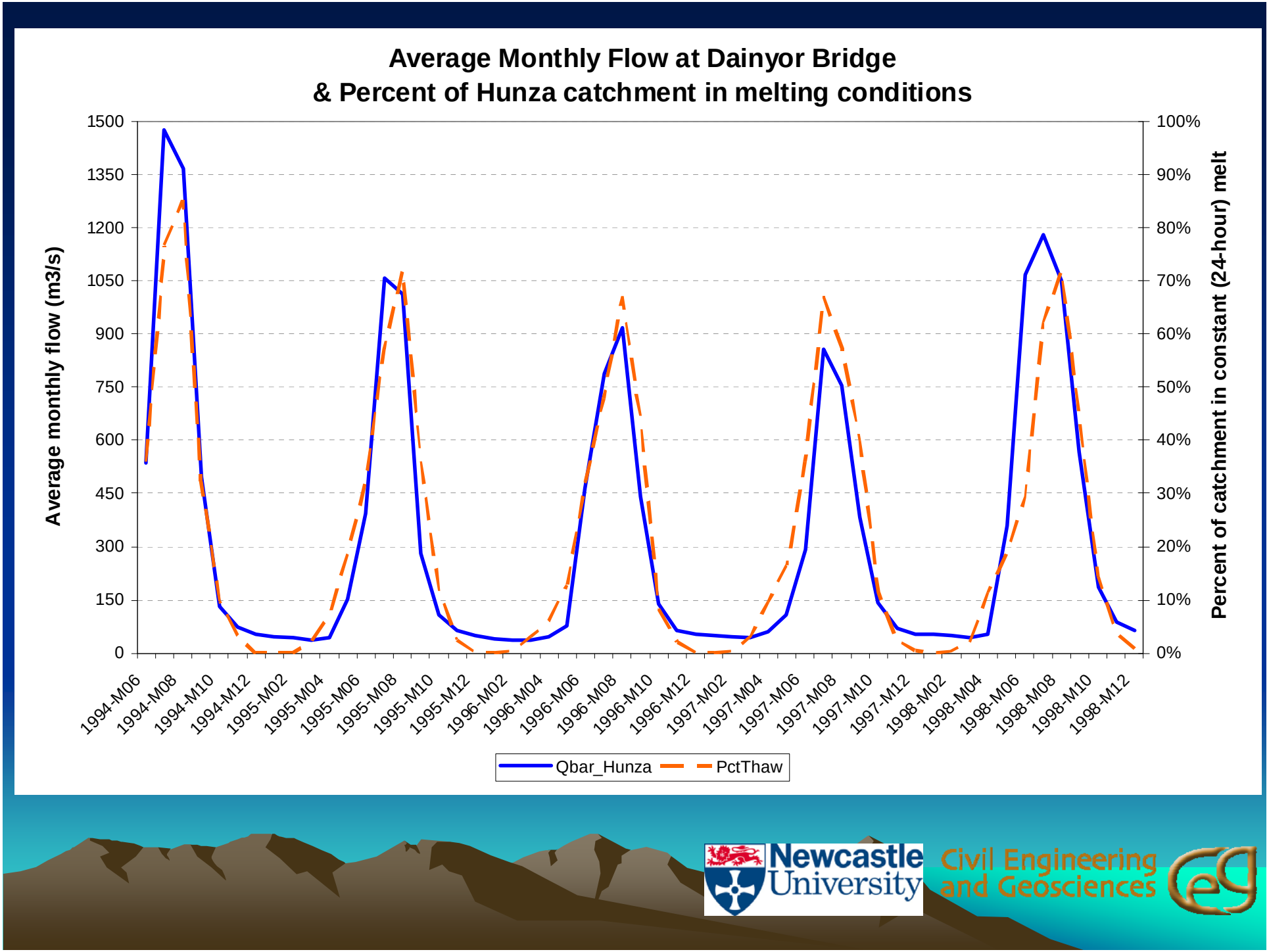
Average Monthly Flow at Dainyor Bridge
& Percent of Hunza catchment in melting conditions
Average monthly flow (m3/s)
Percent of catchment in constant (24-hour) melt
1500
1350
1200
1050
900
750
600
450
300
150
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1994-M06
1994-M08
1994-M10
1994-M12
1995-M02
1995-M04
1995-M06
1995-M08
1995-M10
1995-M12
1996-M02
1996-M04
1996-M06
1996-M08
1996-M10
1996-M12
1997-M02
1997-M04
1997-M06
1997-M08
1997-M10
1997-M12
1998-M02
1998-M04
1998-M06
1998-M08
1998-M10
1998-M12
Qbar_Hunza
PctThaw
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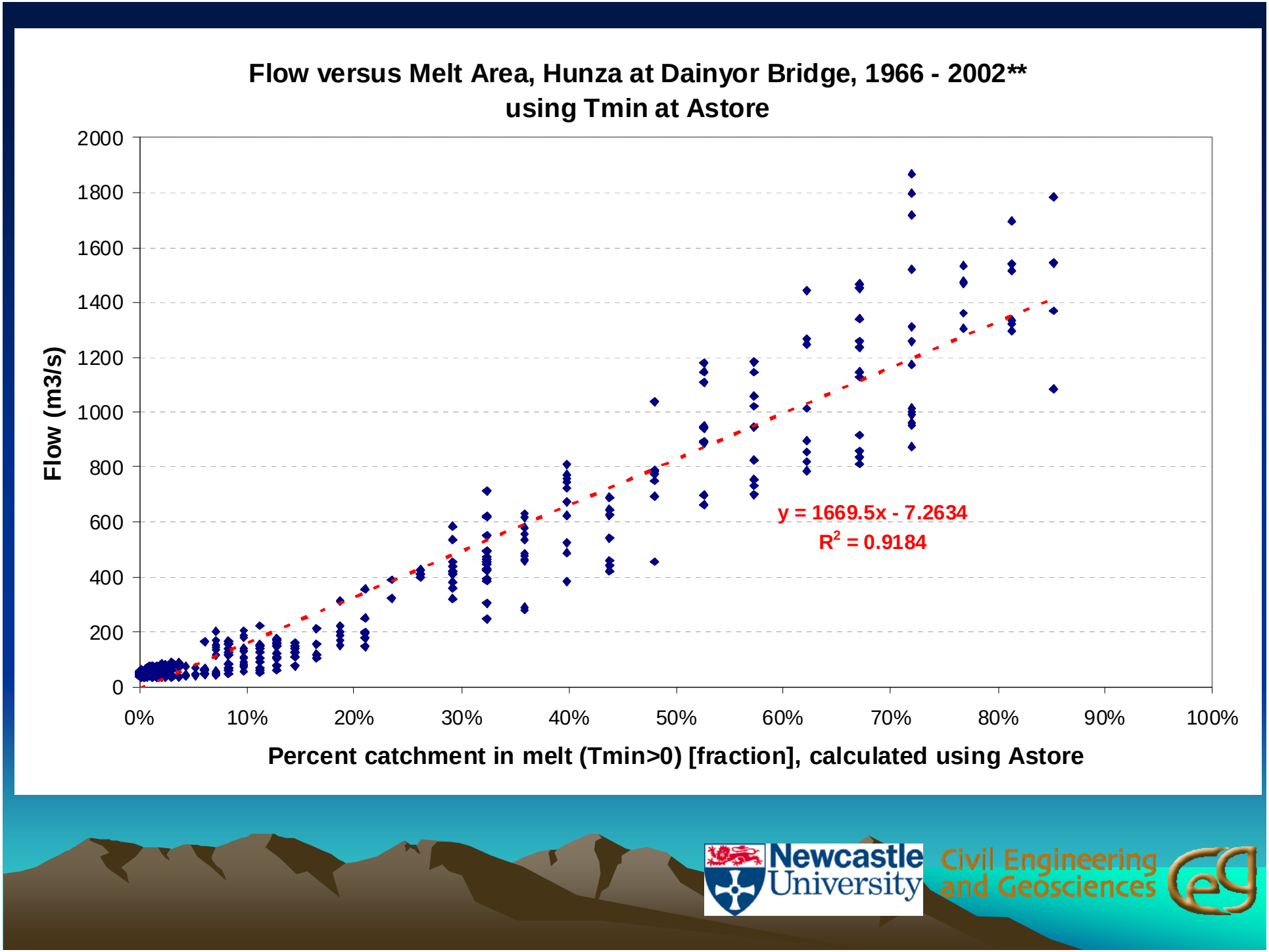
Flow versus Melt Area, Hunza at Dainyor Bridge, 1966 - 2002**
using Tmin at Astore
Flow (m3/s)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
y = 1669.5x - 7.2634
R2 = 0.9184
Percent catchment in melt (Tmin>0) [fraction], calculated using Astore
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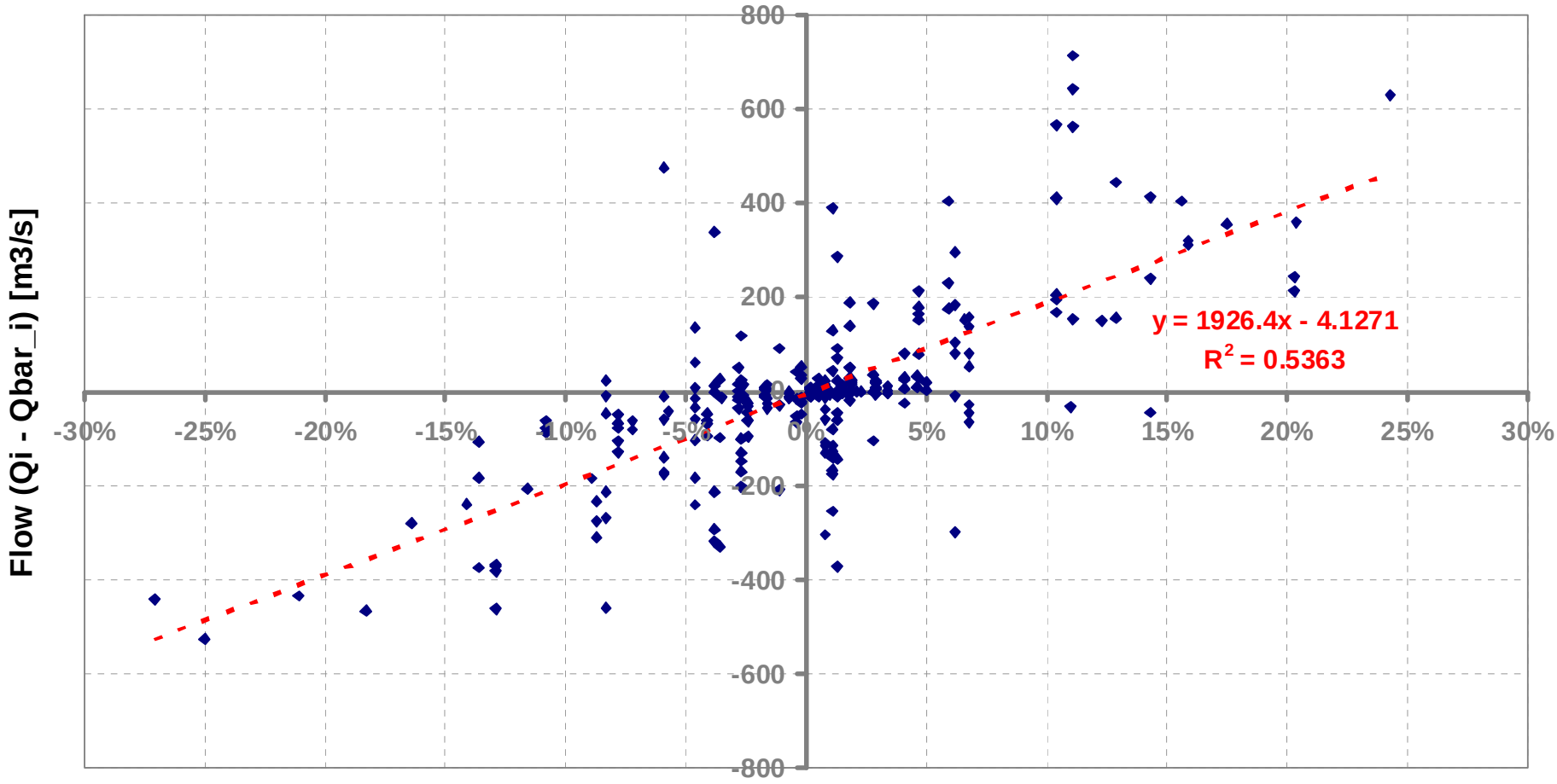
Anomaly comparison : Flow versus Melt Area, Hunza at Dainyor Bridge, 1966 - 2002**, melt season only (area > 2%)



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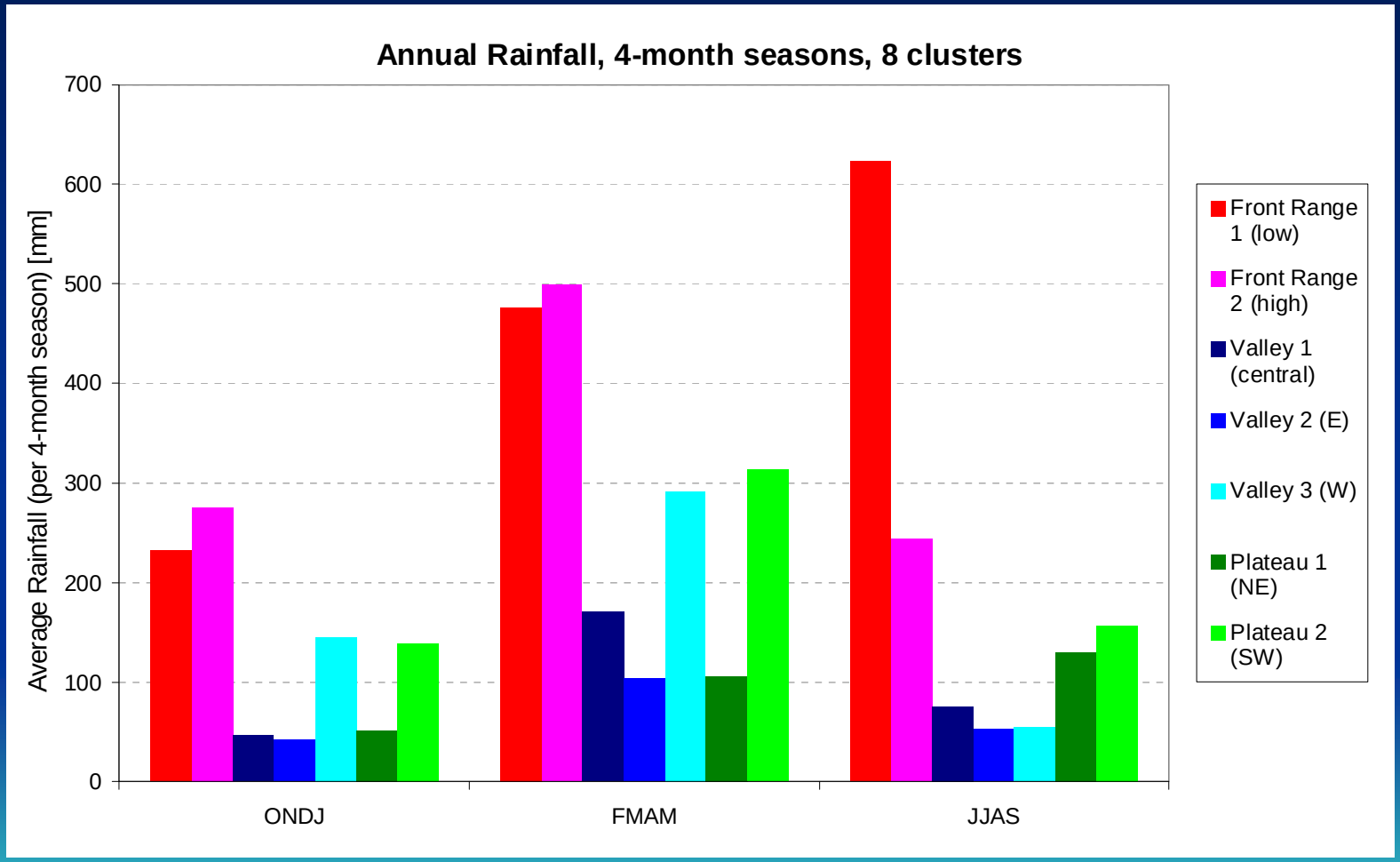
Total precip by 4-month season
(averaged by previous cluster iteration)



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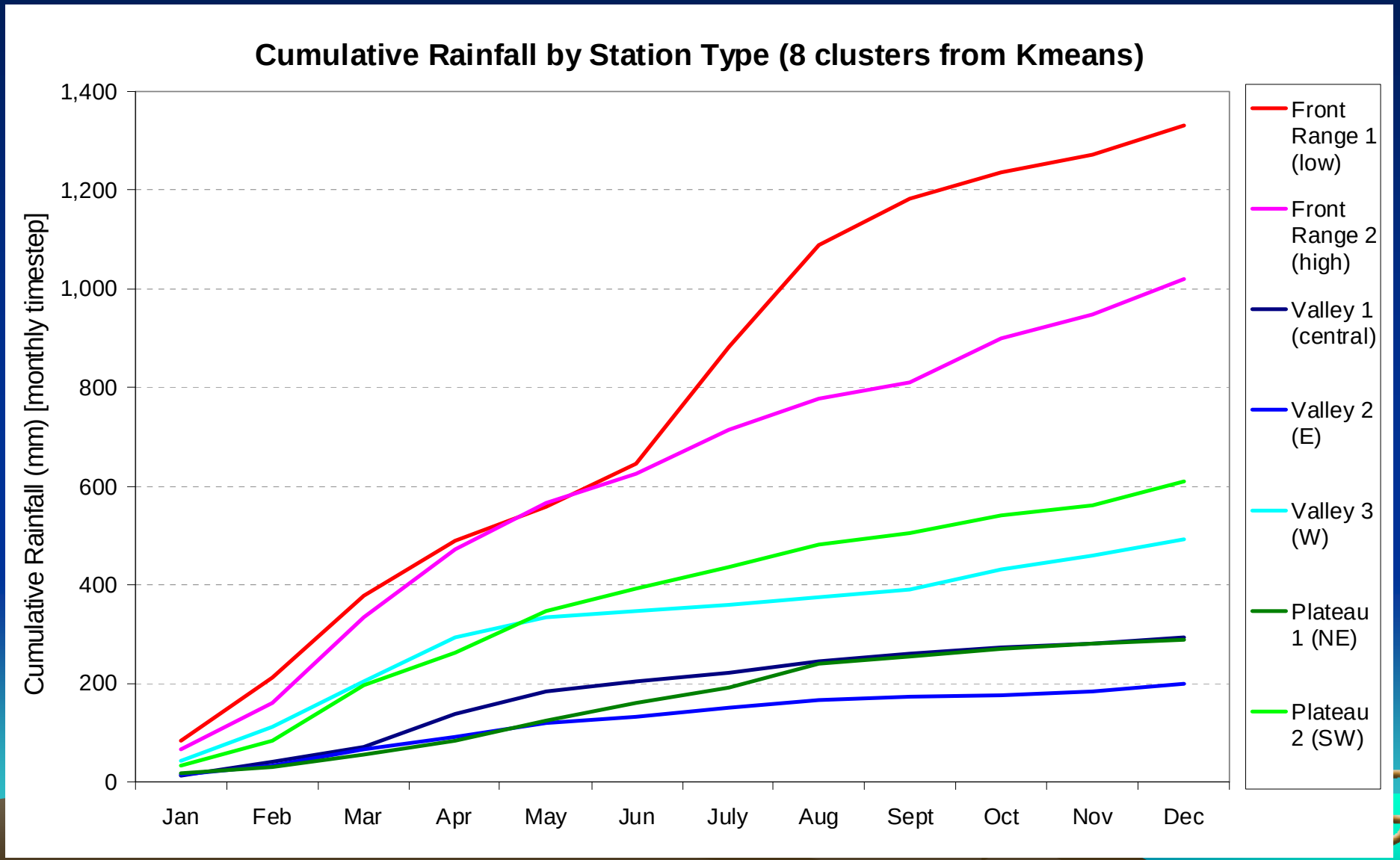
Cumulative precip monthly
(averaged by previous cluster iteration)



Cumulative wetdays monthly
(averaged by previous cluster iteration)