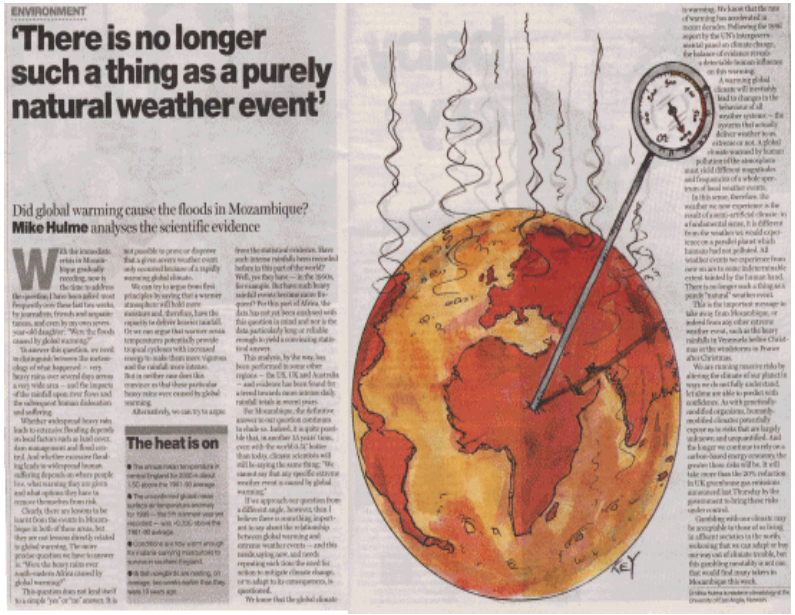
Climate change in the British uplands, a view from the Highlands: Can policy response live with science uncertainty ?

John Coll

ERI

UHI Millennium Institute

True??



ENVIRONMENT

'There is no longer such a thing as a purely natural weather event'

Did global warming cause the floods in Mozambique? **Mike Hulme** analyses the scientific evidence

The heat is on

Tyndall Centre for Climate Change Research

UEA NORWICH

The Tyndall Centre comprises nine UK research institutions. It is funded by three Research Councils - NERC, EPSRC and ESRC - and also receives some support from the DTI

- CO_2 levels increased from 280ppm > 370ppm in last 200 years
- Methane levels x 2 in last 100 years
- Linked to human activities; energy generation, transport & agriculture
- Average global surface temperature (T°) has risen by 0.6°C in last 140 years

=> Scientific Consensus = Qualified ~Yes

Presentation outline….

Introduction

- Focus = temperature changes ($\Delta T°C$); brief overview of precipitation changes
- Trends; different time-scales and spatial resolutions
- Global Climate Models (GCMs) & Regional Climate Models (RCMs)
- The Hadley Centre Regional Climate Model (HadRM3) & 'Highland' representation

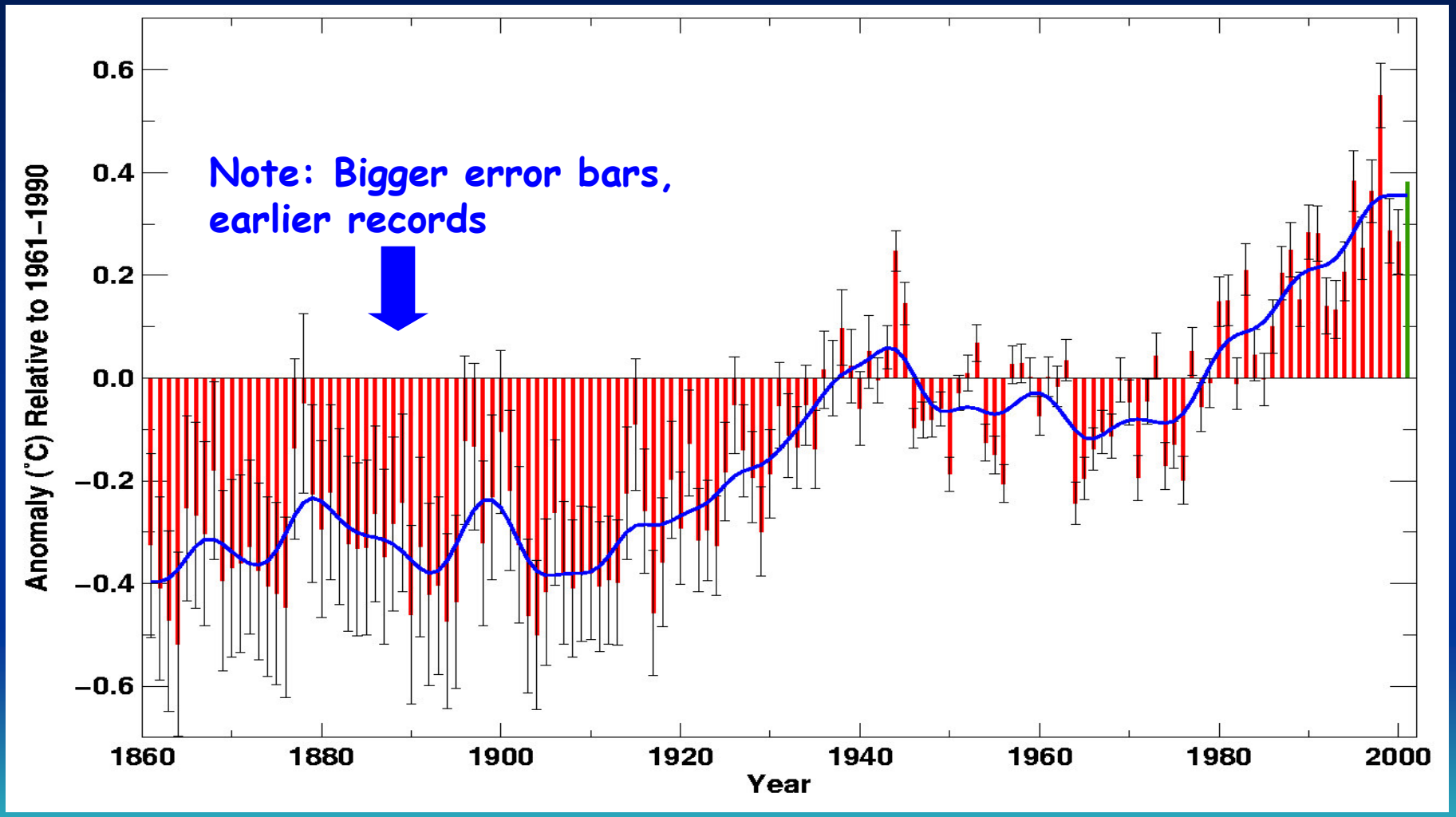
Selected results (own work)

1. Evaluating HadRM3 utilising T° lapse-rate models
2. Refining T° lapse-rate models - projecting future $\Delta T°C$ uphill

Conclusions

- Implications for uplands
- Uncertainty….

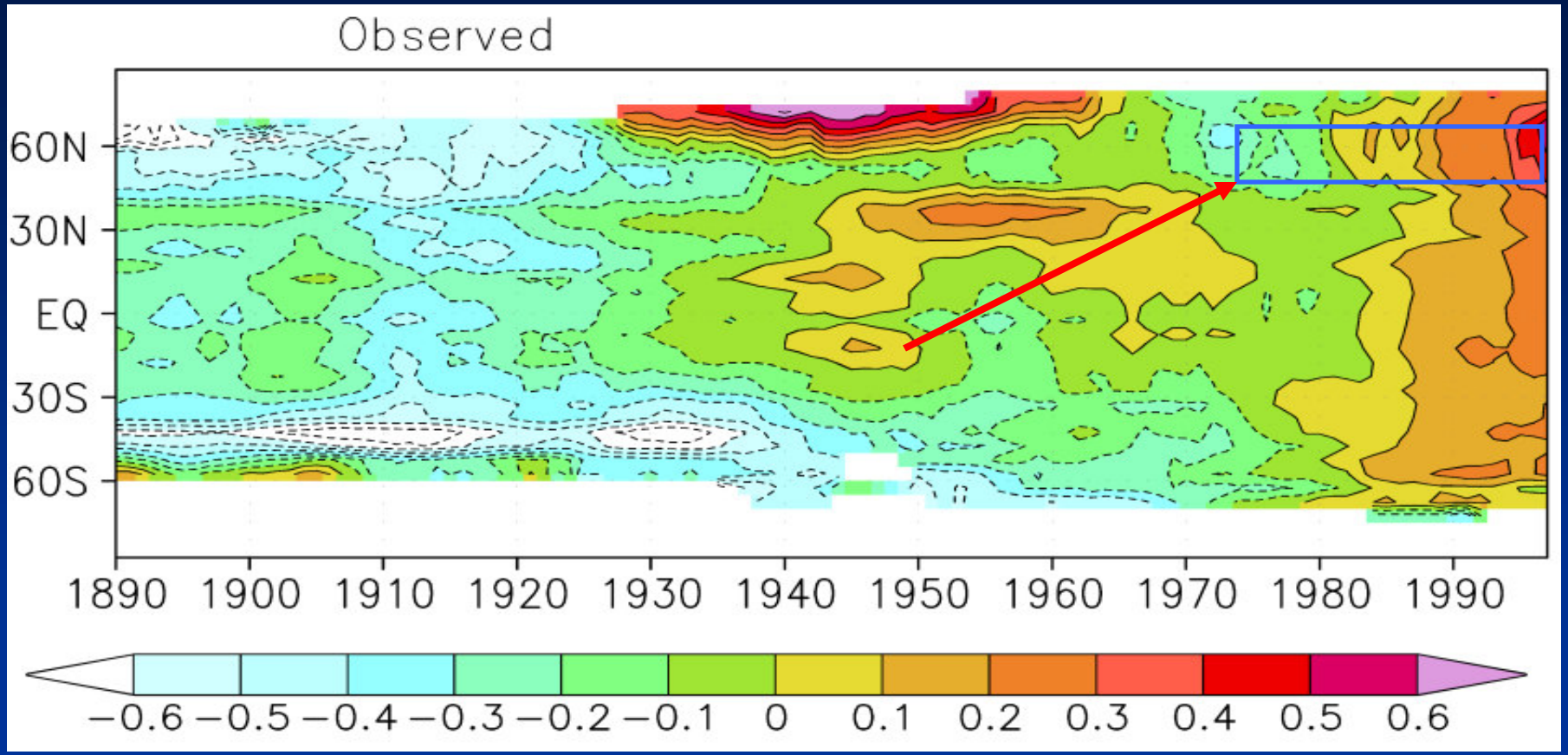
Variations in global temperature and uncertainties; 1861-2001 (land, air and sea surface T°)



=> Two main episodes of warming

Source: Dickson, 2003

A different perspective….

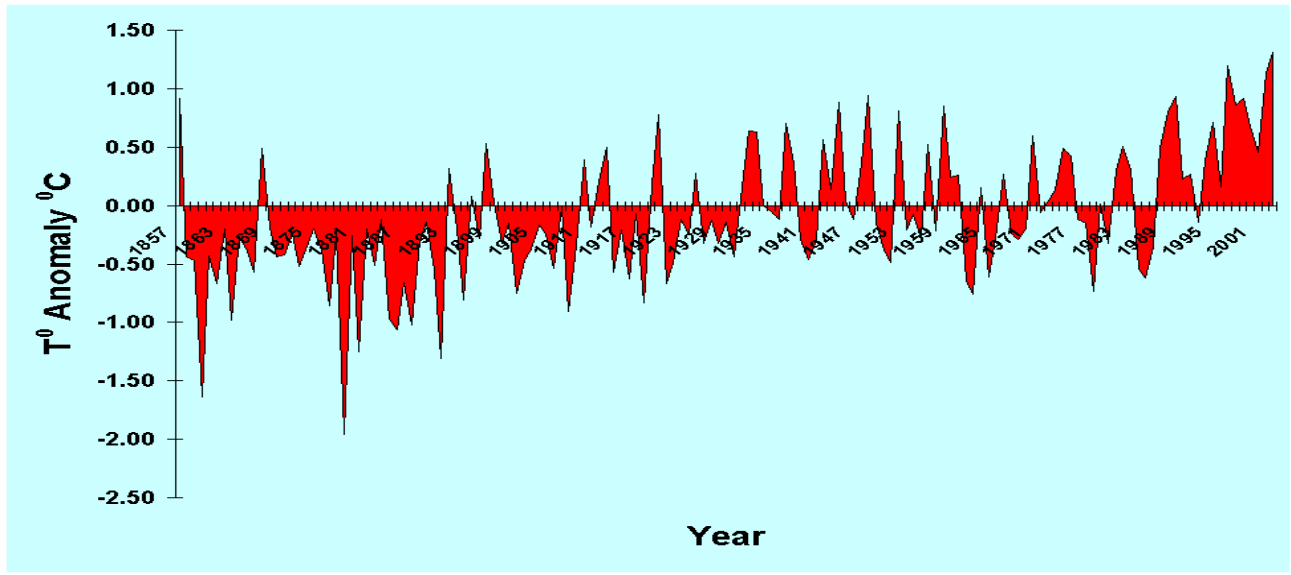


Air temperature plot with latitude and time, two clear conclusions:

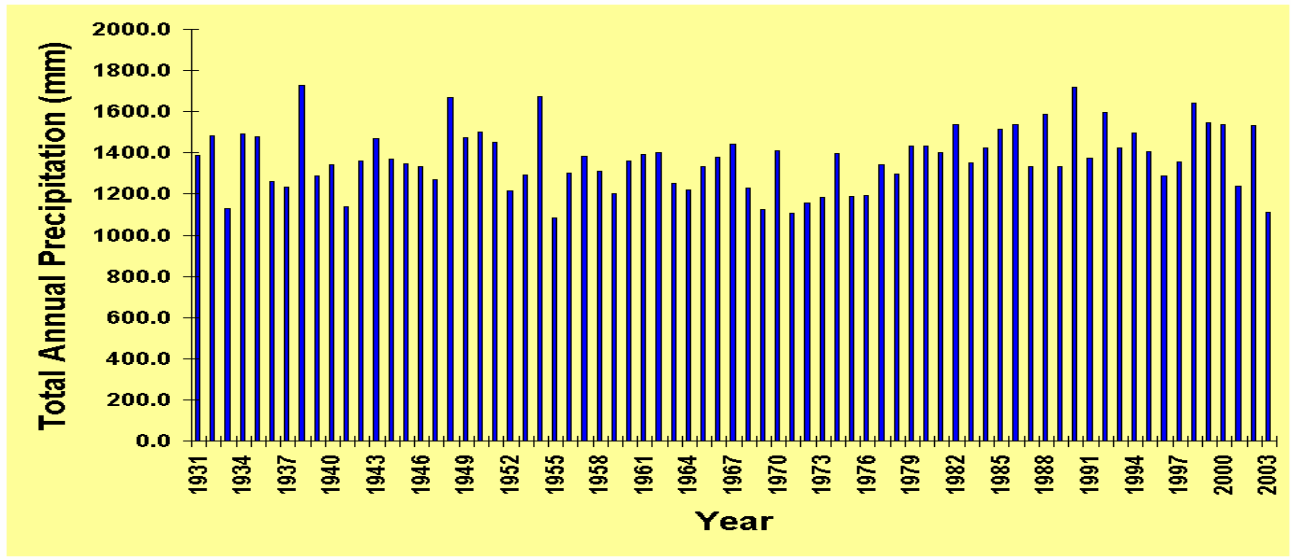
1. World is warmer: Including 2002, all ten of the warmest years since records began in 1861 after 1990; (Jones and Moberg, 2003).
2. Last two decades - distribution of warming global.

Figure source: Morison, 2003

What about Scottish T° & precipitation trends?



RankedYear	Mean Annual T°
2003	9.18
1997	9.07
2002	9.00
1949	8.81
1990	8.80
1999	8.79
1857	8.79
1945	8.75
1998	8.73
1959	8.72



Ranked Year	Total (mm)
1938	1726.6
1990	1720.4
1954	1675.7
1948	1669.9
1998	1641.7
1992	1597.5
1988	1586.4
1999	1545.2
1982	1537.1
1986	1536.4

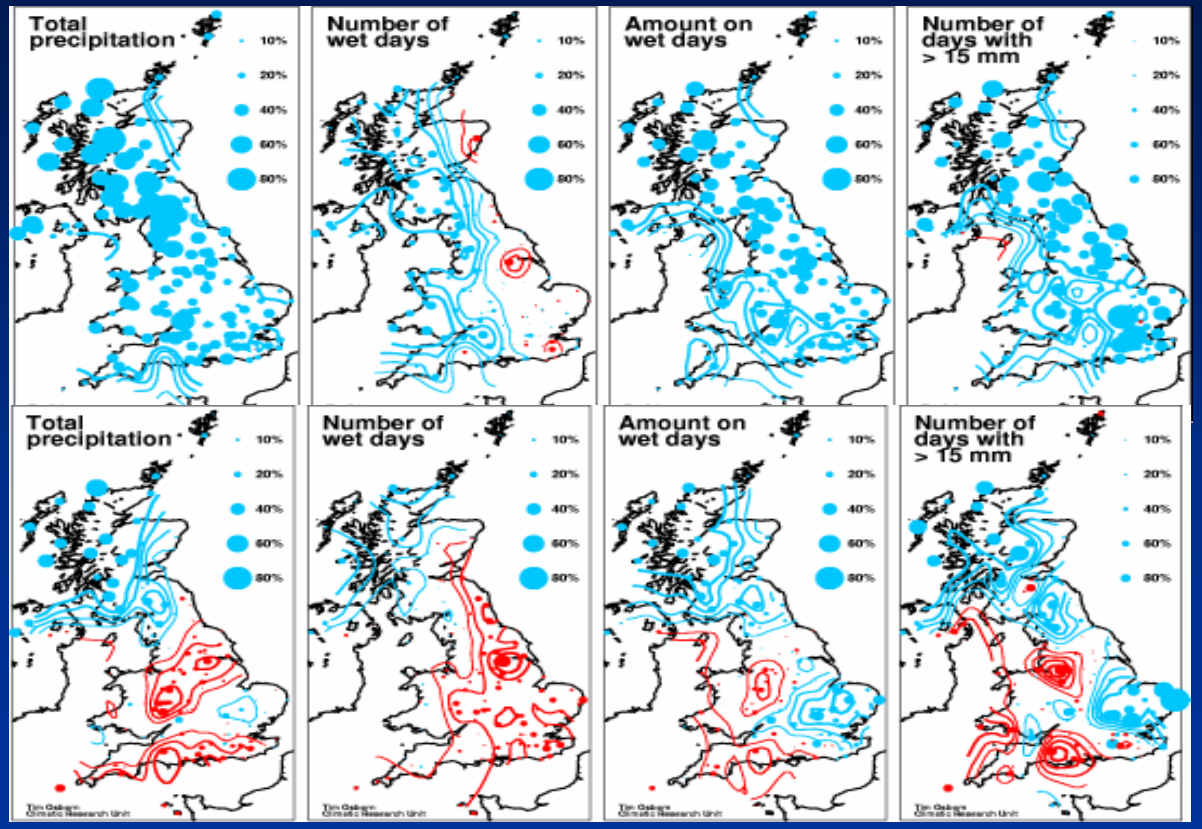
Data source: CRU Gridded 55° - 60° North

UK winter & spring precipitation trends 1961-1995

Winter

Spring

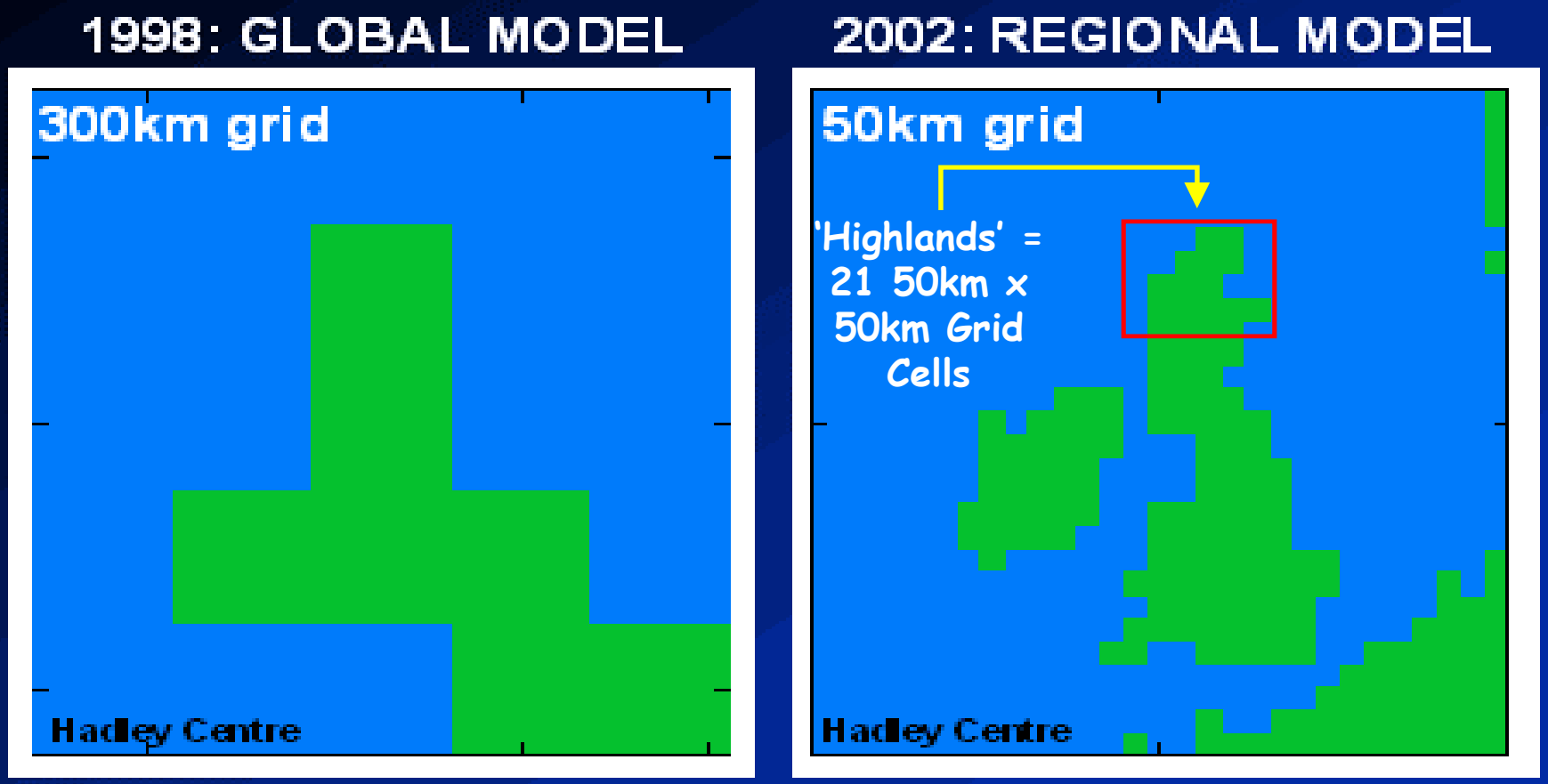
(Blue = increase; Red = decrease)



=> <u>Intensity</u> of rainfall events is changing; e.g. in east of Scotland the 50 year autumn & winter extreme event 1961-90 an 8 year event during the 1990s (Fowler and Kilsby, 2003)

Figure source: CRU 2001

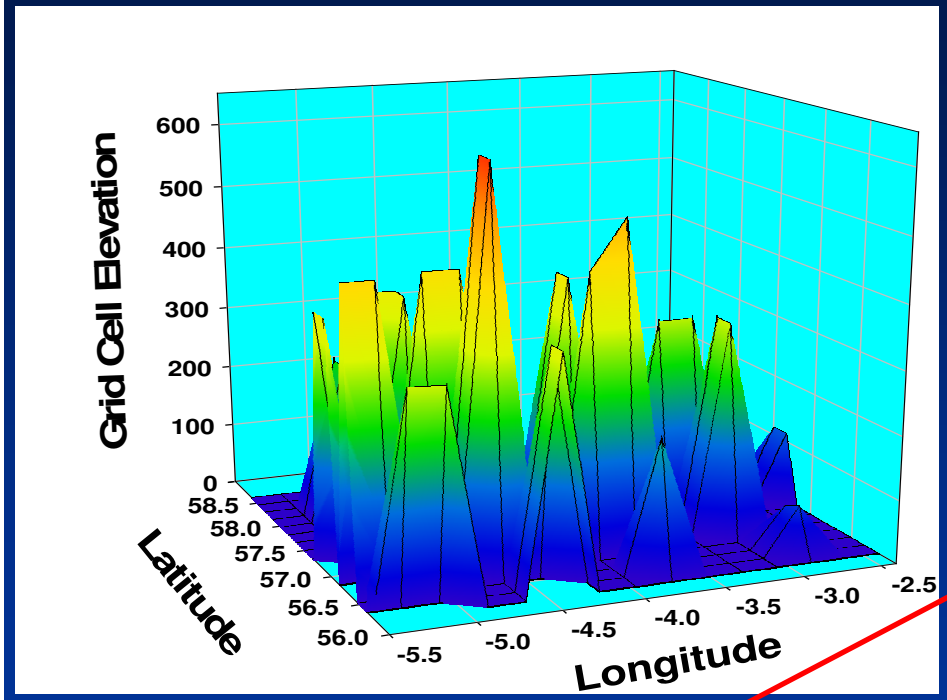
Spatial resolution of climate models



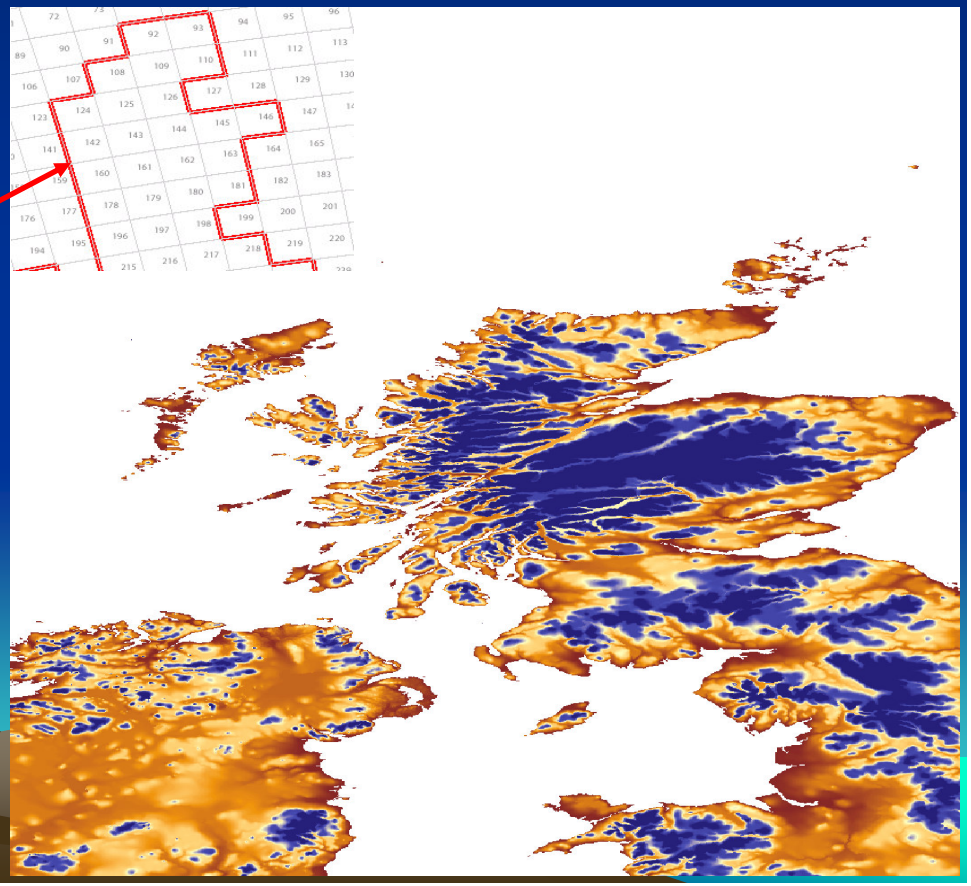
=> UKCIP98 = 300km grid Global Climate Model [GCM] whereas

UKCIP02 = 50km grid nested Regional Climate Model [RCM]

Relief Representation: HadRM3 and the Highlands



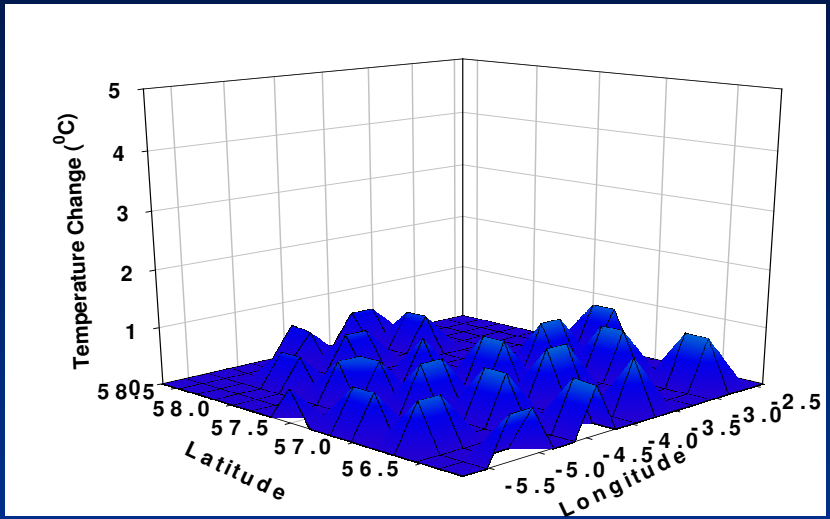
- Complex juxtaposition of land and sea in the west poorly captured
- The real altitudinal range is <0m > ~1300m



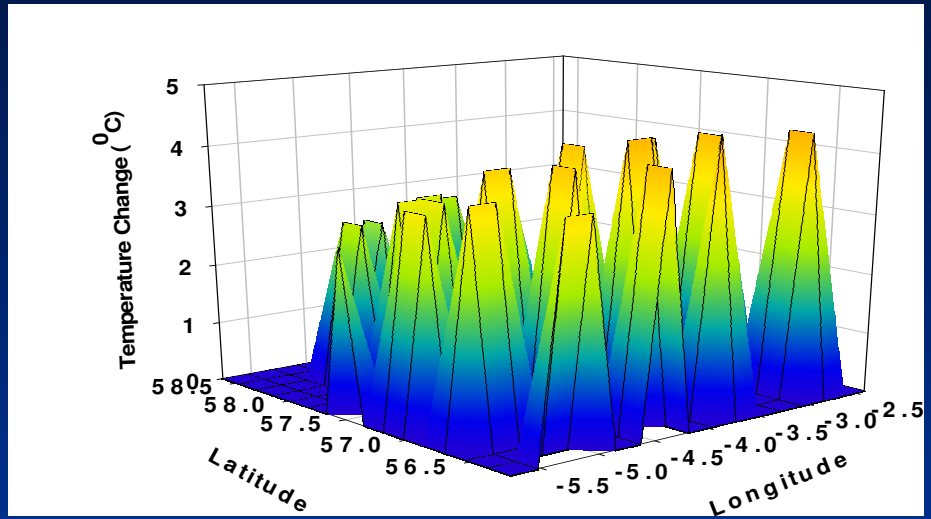
- HadRM3 truncates 'land' west and east
- Western & northern isles not treated as land
- HadRM3 grid elevations range from 77.14m > 618.85m

What sort of changes to T° does HadRM3 project?

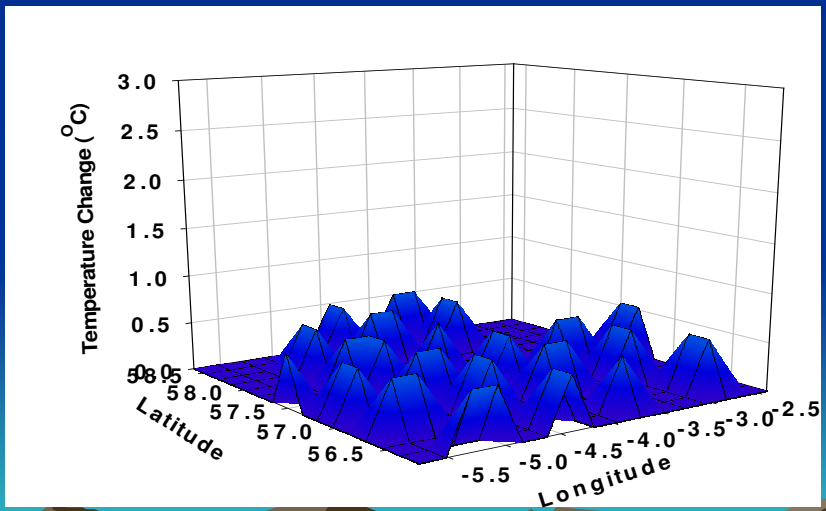
2020s Low Summer T_{max}



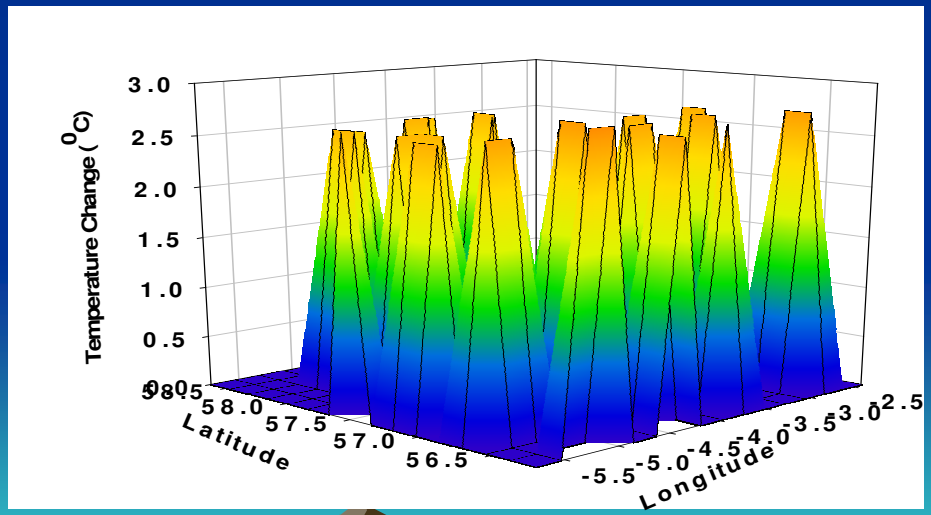
2080s High Summer T_{max}



2020s Low Winter T_{min}



2080s High Winter T_{min}



N

S

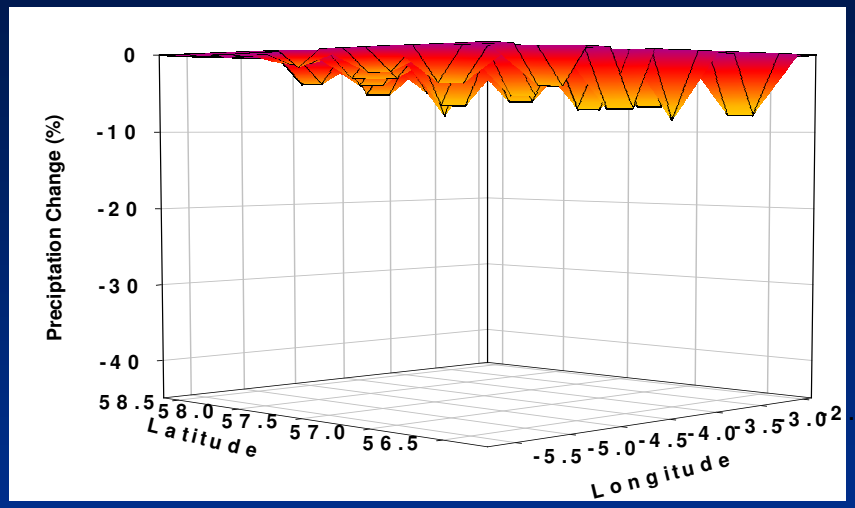
W

E

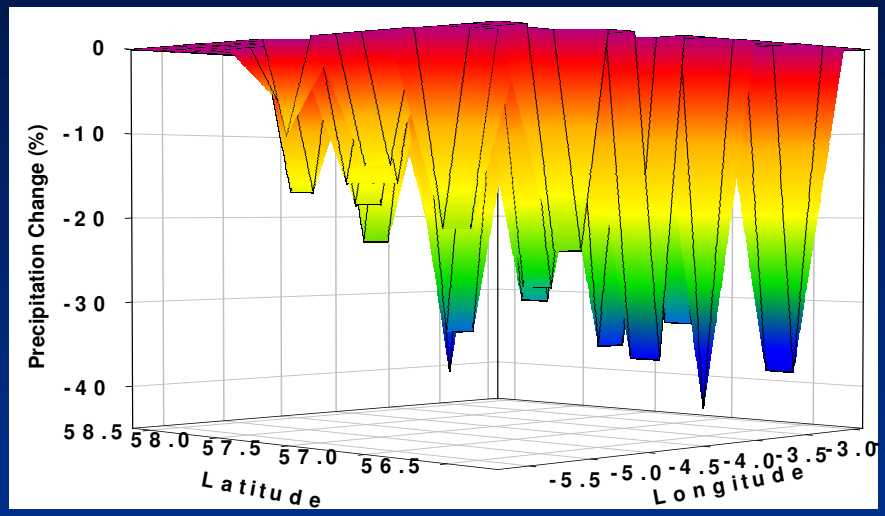
=> Summers >>> Continental: Winters >>> Oceanic

What sort of changes to Precip does HadRM3 project?

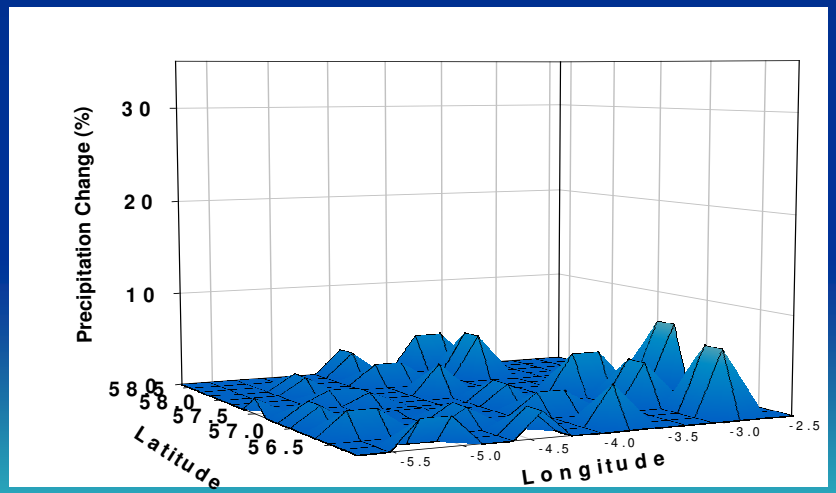
2020s Low Summer Δ%



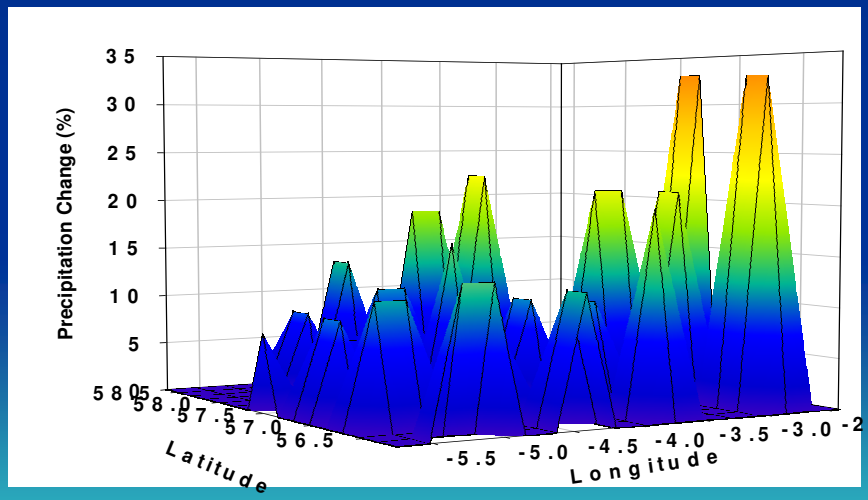
2080s High Summer Δ%



2020s Low Winter Δ%



2080s High Winter Δ%



N

S

W

E

=> Summers >>> Continental: Winters >>> Oceanic

Summary so far…..

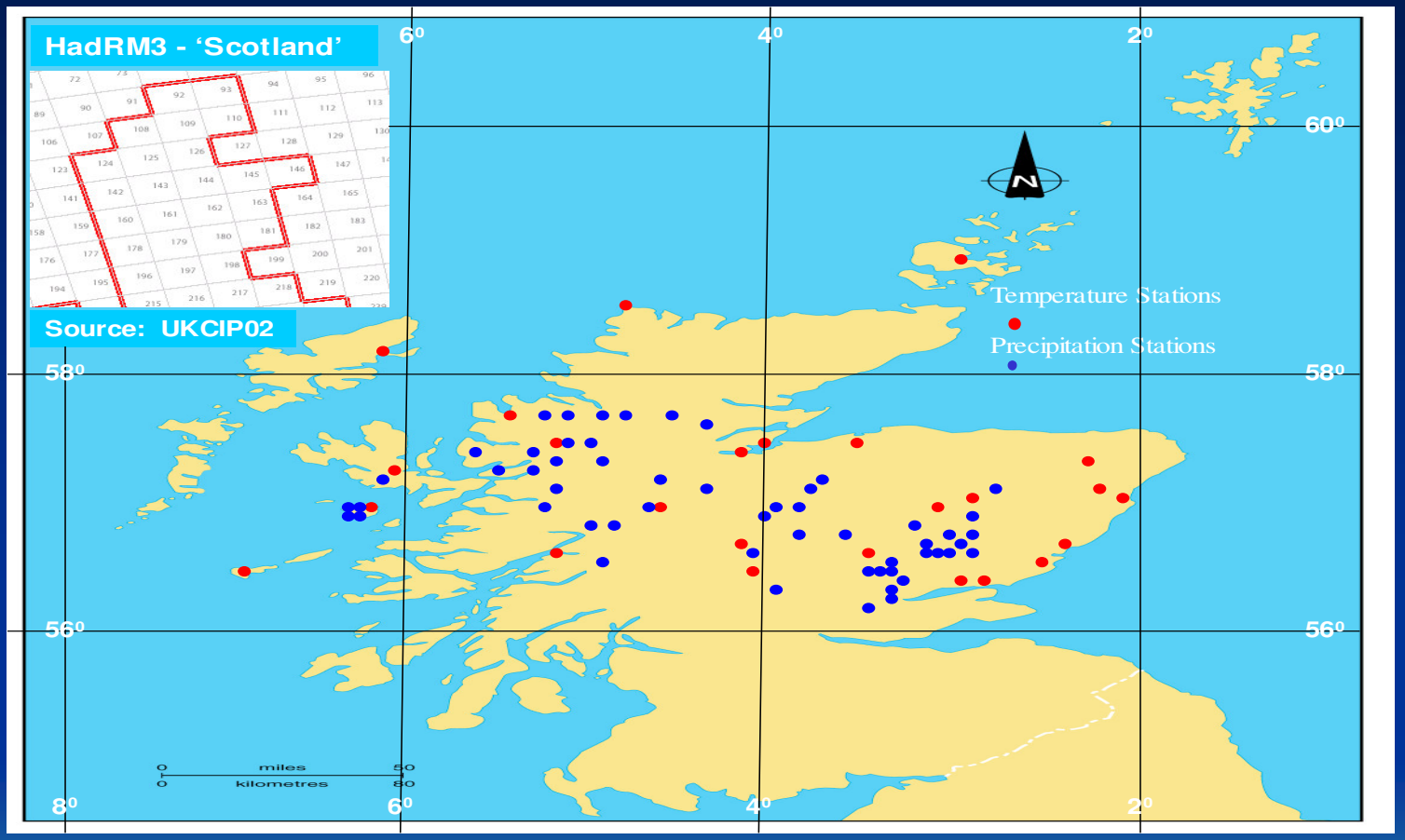
1. Recent warming = unusual; 2003 hottest year on global & Scottish instrumental record
2. Outputs from GCMs/RCMs - trends set to amplify => greater warming as the century progresses
3. Incidence of extreme events set to increase; e.g. summer heat-waves, seasonal rainfall events

But….

- Do climate models work in the Highlands?
- What about our mountains - can we project climate model outputs uphill?
- Future socio-economic trajectories and Greenhouse Gas Emissions (GHGs)? Can we anticipate them realistically & do we believe the scenarios?

So, some of my own work….

Referencing stations to HadRM3 grids - evaluating HadRM3 1961-1990 baseline simulation



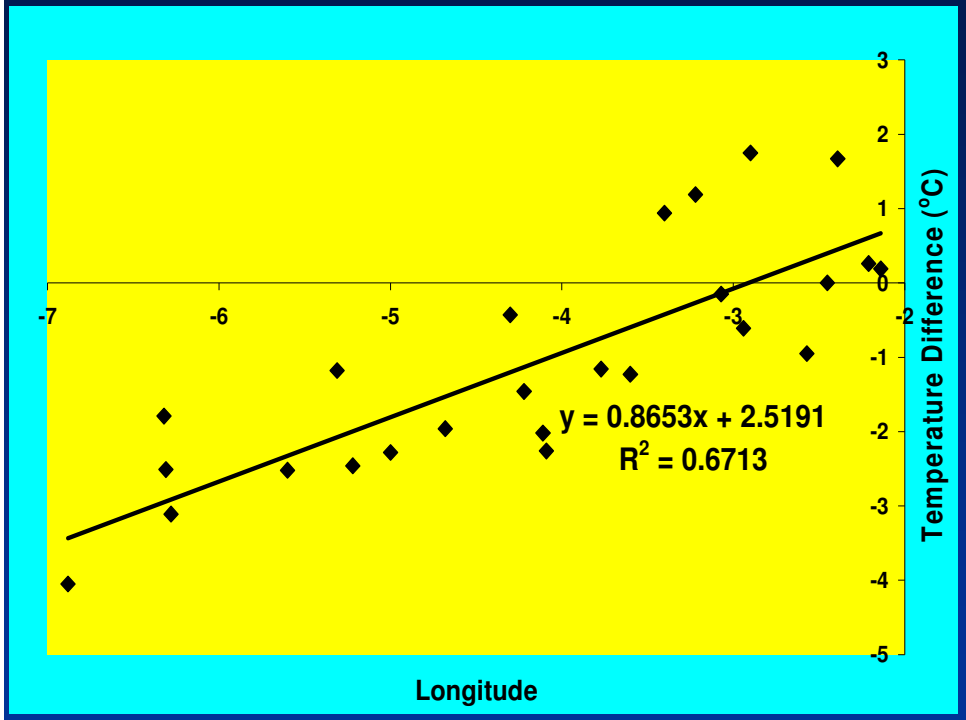
Note; lack of spatial cover - observed data >>> Sutherland & Caithness

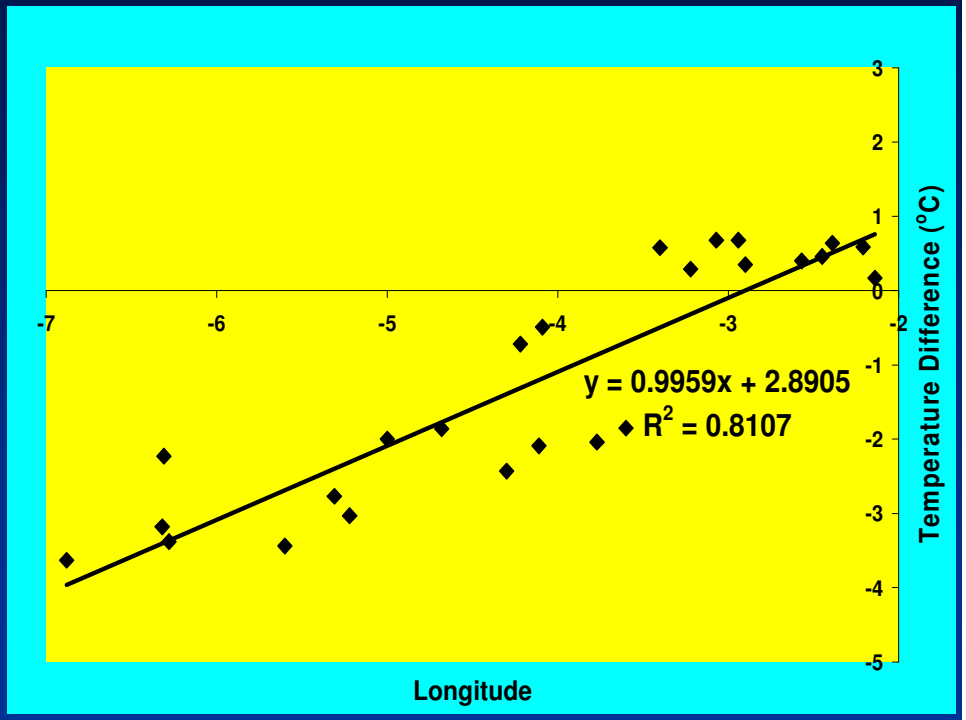
Highlands = data sparse!

=> Observed station network: Rum in the west > Aberdeenshire in the east. Temperature, n = 19 (+6), 5m – 283m. Precipitation, n = 55, 15m – 536m.

=> Matrix at 0.1⁰ resolution (latitude and longitude) references stations to corresponding HadRM3 grid cell

Temperature variation - HadRM3 and observed (Obs)





Autumn T_{min}

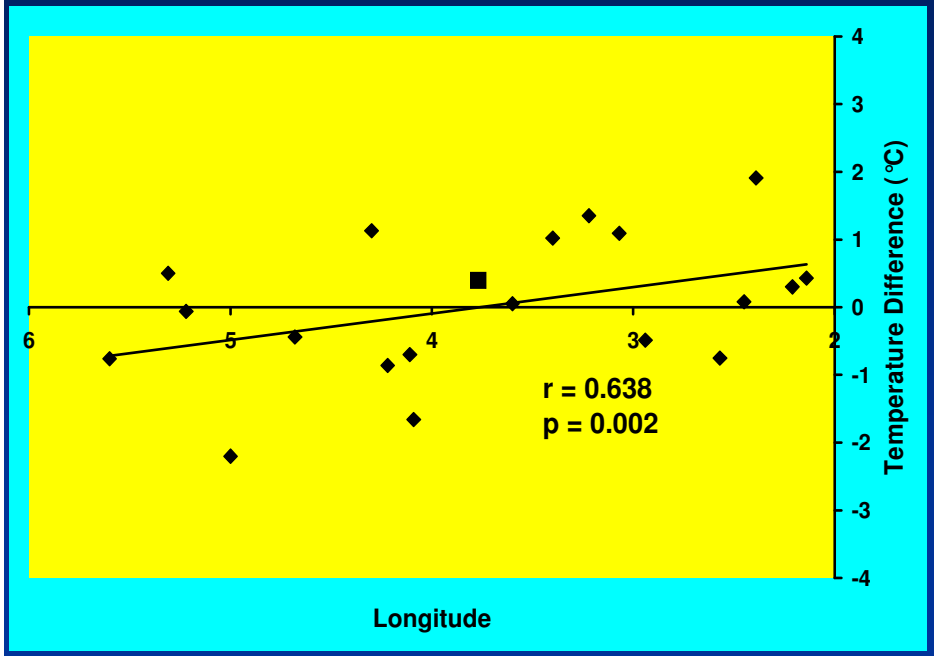
Winter T_{max}

=> Clear west > east gradient in the mismatch of seasonal temperatures. On the face of it HadRM3 is apparently performing best in the Aberdeenshire/Morayshire lowlands.

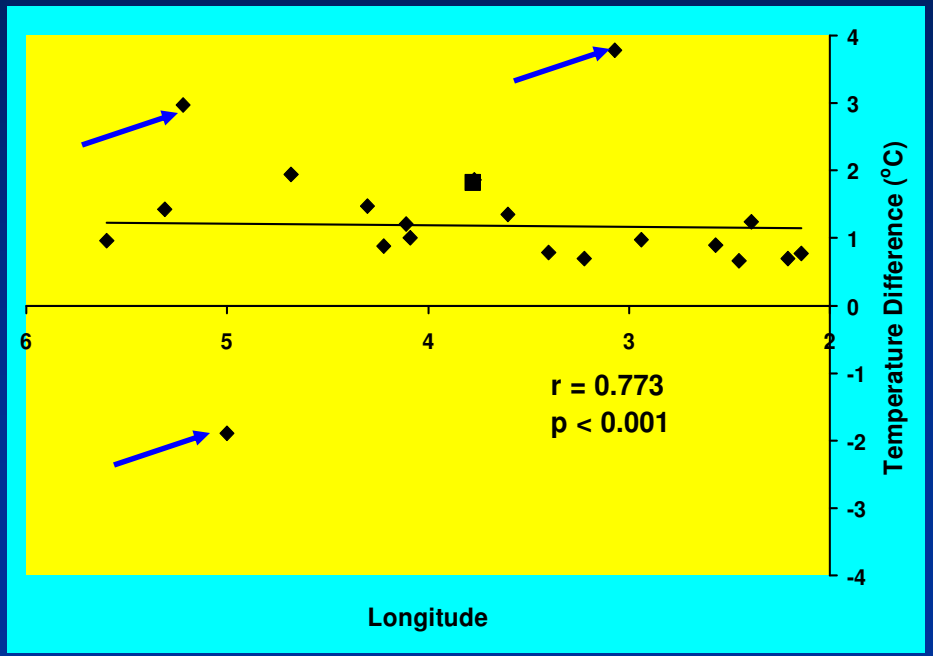
=> The west > east gradient in $\Delta T°C$ HadRM3 vs Obs especially marked for mean winter maxima

ΔT°C - Obs values lapse-rate adjusted > HadRM3 grid cell elevation

Recall from earlier slide Obs station elevations not = HadRM3 grid cell elevations



Autumn T_{min}

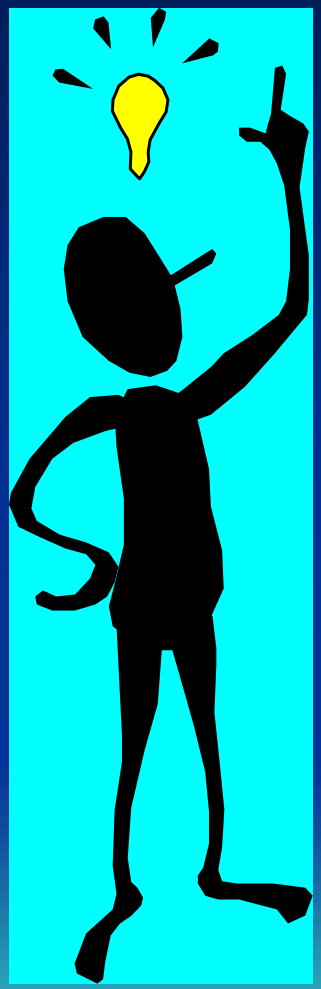


Winter T_{max}

=> Dropping island Obs sites & lapse - adjustment reduces west - east differences considerably, particularly for winter maxima

=> The three outliers (coastal sites) for Winter T_{max} = further investigation

Maritime uplands & community/sector vulnerability….. site-scale assessment tools??



Concerns about e.g.:

- arctic-alpine species at southern range limit
- snow-bed communities
- and what about the ski industry?

Lapse-rate experiments demonstrated,e.g.

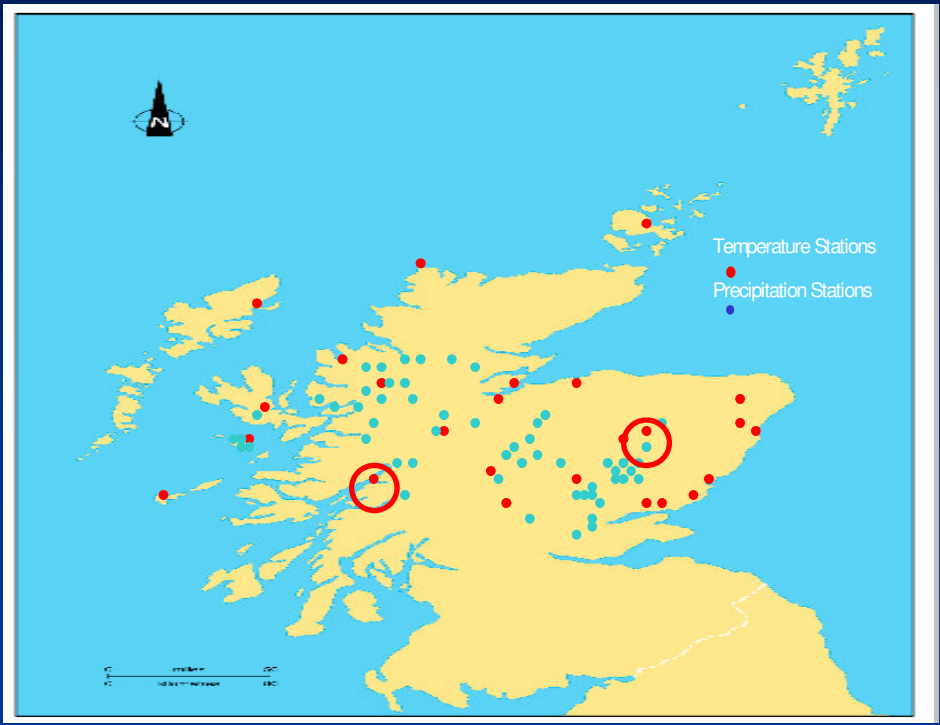
For 1961-1990 can adjust Obs > HadRM3 grid elevations & vice-versa:

=> Extend the approach;

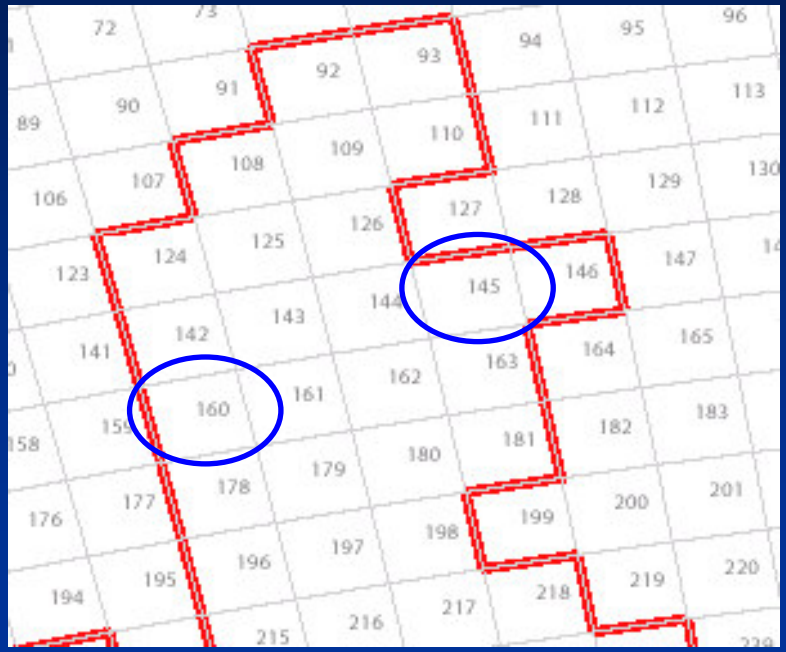
1. By elevation => build a 'Ben Nevis' & 'Beinn Macdhui'
2. By scenario => model future isotherm shifts….

Linking station values & HadRM3 grid outputs

Observed station network



HadRM3 - 'Scotland'



(Source: UKCIP02)

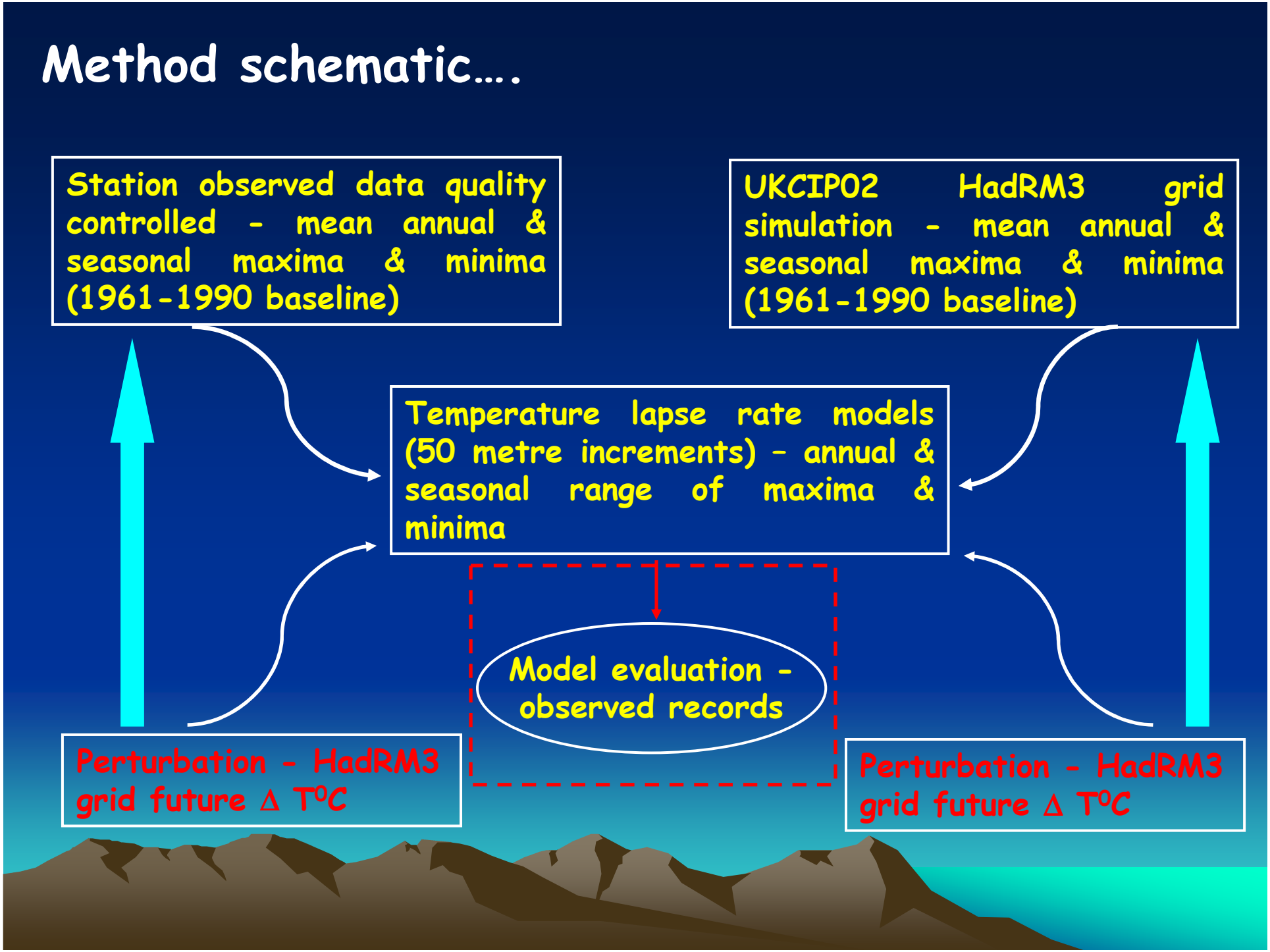
Onich = 15 metres

Balmoral = 283 metres

HadRM3 Grid 160 = 460.54 metres

HadRM3 Grid 145 = 320.72 metres

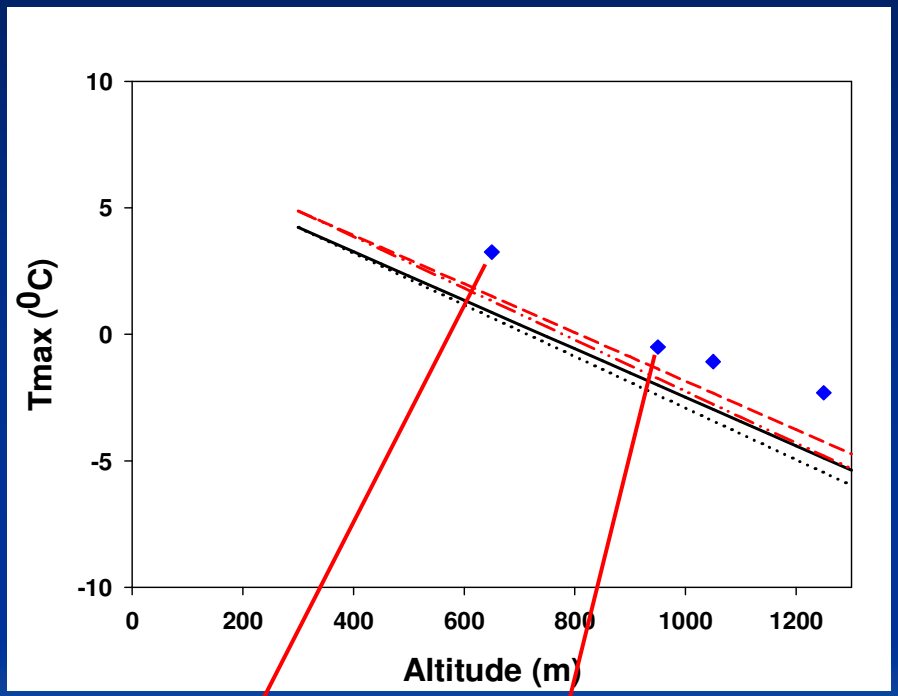
Method schematic….



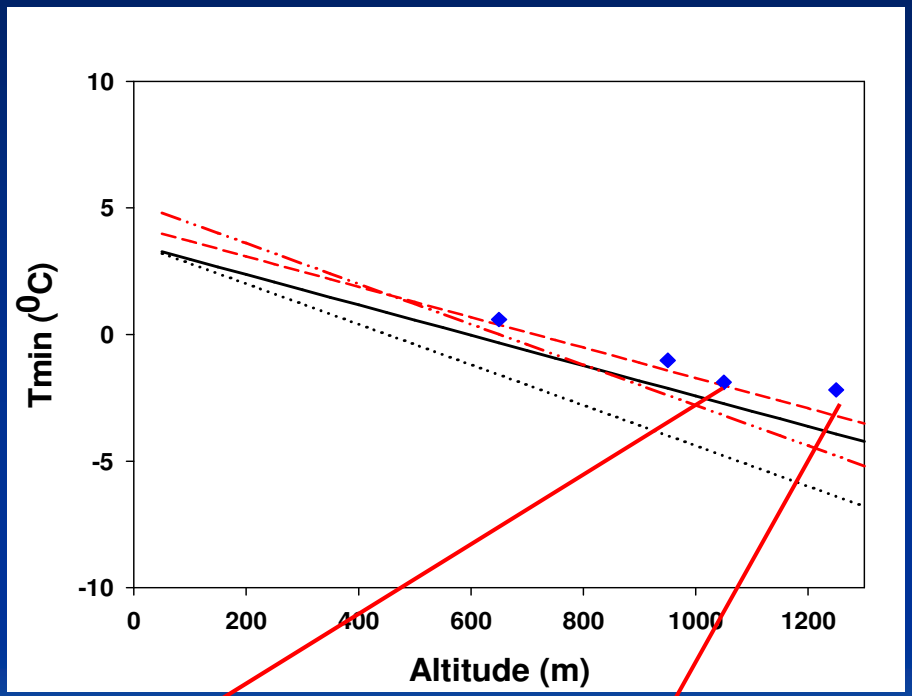
Evaluating models > observed station records

(Note: HadRM3 grid projected values in red, station observed projected values in black)

Winter T_{max} – Balmoral (1961-90)



Spring T_{min} – Onich (1961-90)



Cairngorm Chairlift, 663m (1981-1998)

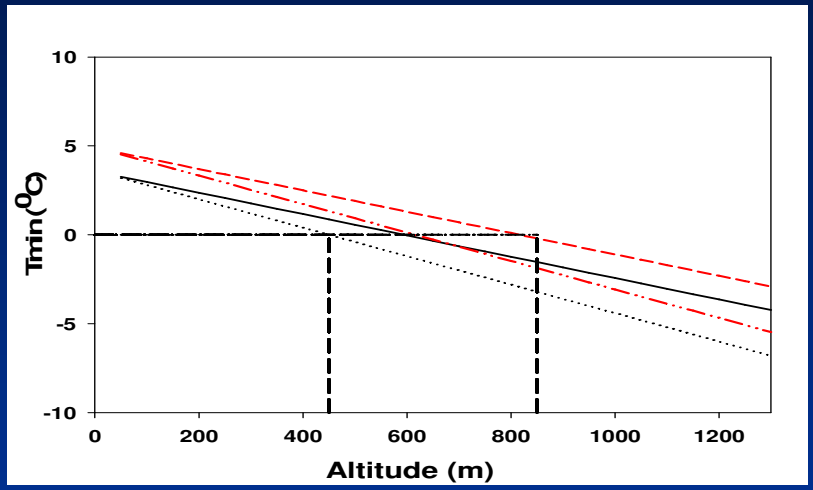
Cairnwell, 933m (1995-1999)

Aonach Mor, 1033m (1992-1999)

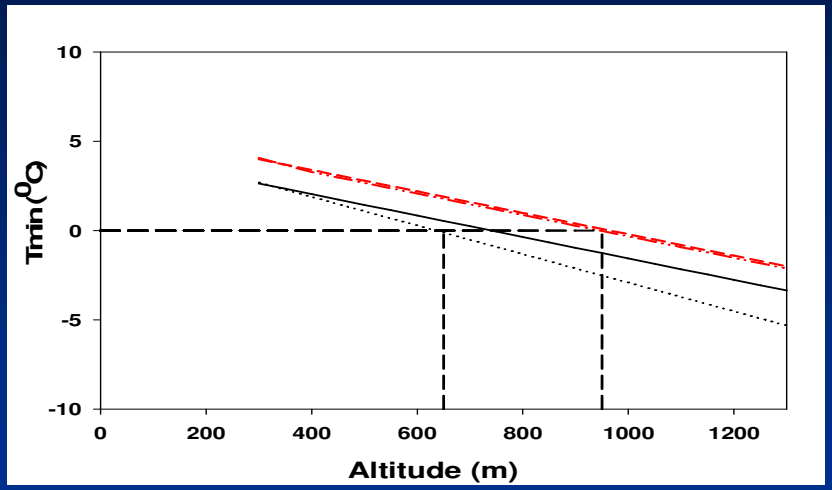
Cairngorm Siesaws, 1245m (1992-1999)

Results 1: 2050s Medium-Low Scenario – mean spring minima

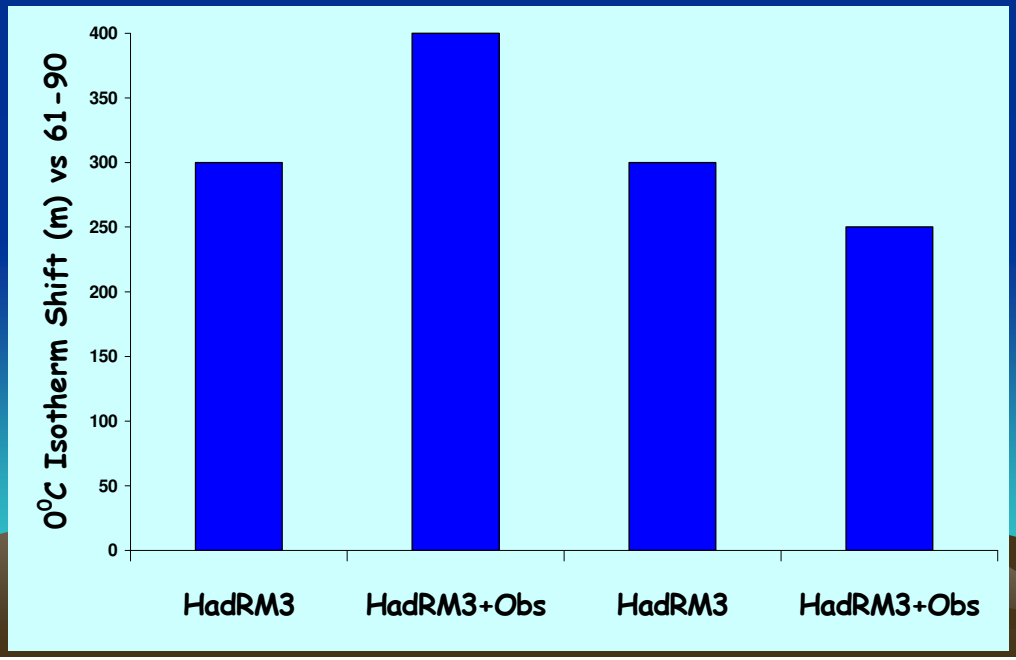
HadRM3 + Onich observed



HadRM3 only, 'Balmoral'



Onich Balmoral

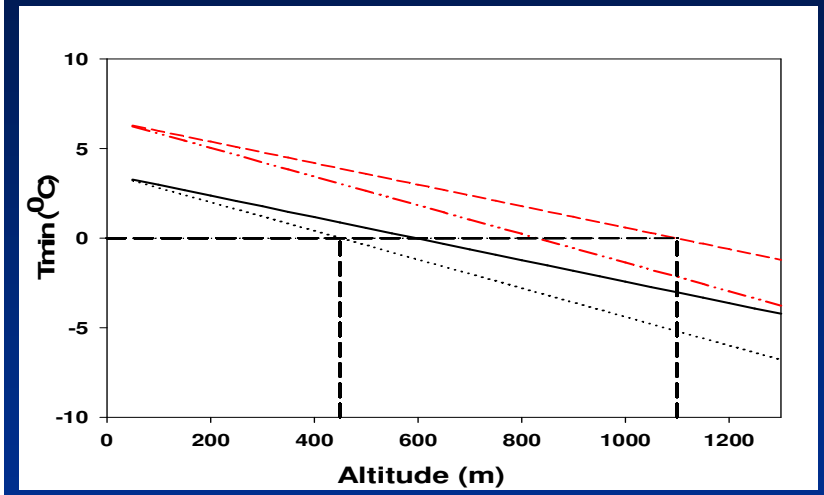


=> Lochaber shift = ~+300-400 metres

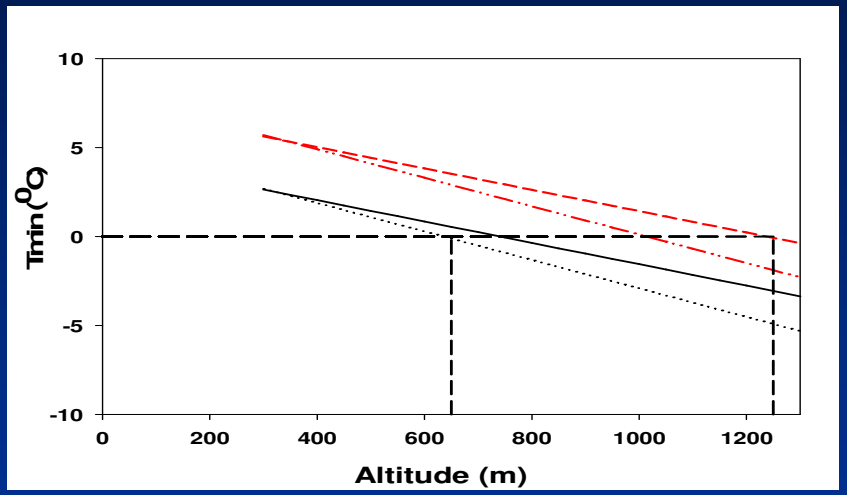
=> Grampian shift = ~+250-300 metres

Results 2: 2080s High Scenario – mean spring minima

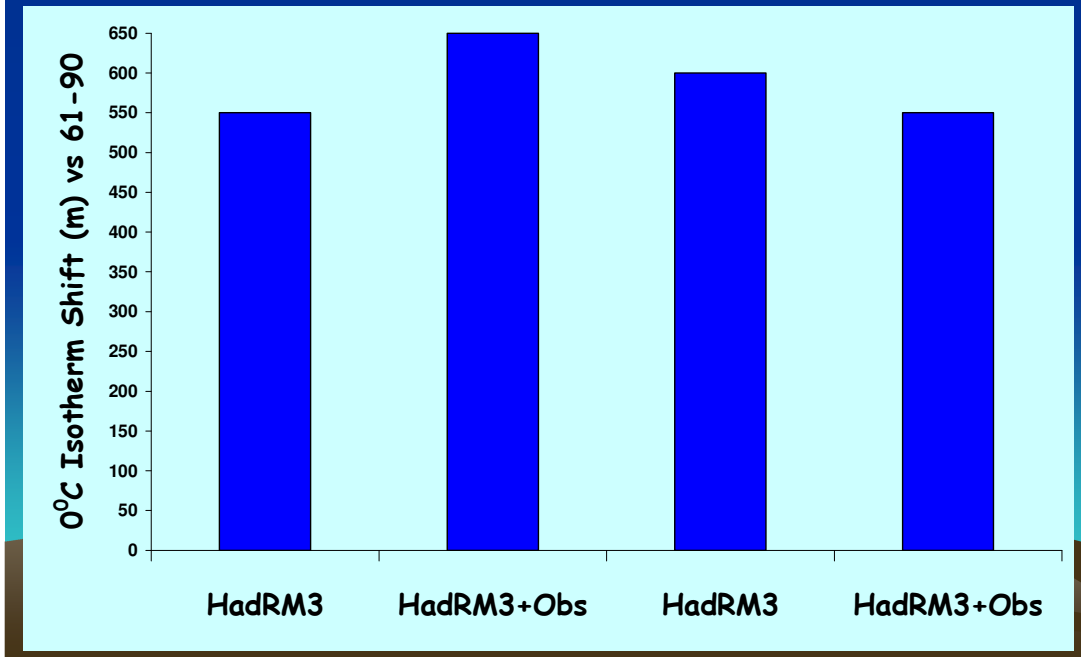
HadRM3 + Onich observed



HadRM3 only, 'Balmoral'



Onich Balmoral



=> Lochaber shift = ~+550-650 metres

=> Grampian shift = ~+550-600 metres

Some conclusions….

=> Substantial technical problems remain with climate model outputs in mountainous regions

=> Methods developed here indicate local-scale workarounds can be found elsewhere in the British Uplands, at least for $\Delta T°C$

=> Implications for uplands likely to be profound, both for conservation and future land-use

=> A rigorous & highly inter-disciplinary research programme is required; both to further understanding & formulate a credible policy response

Uncertainty….