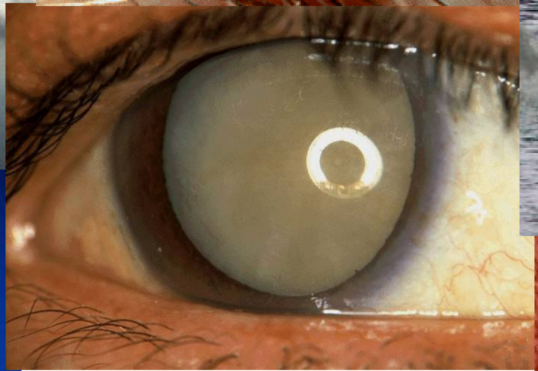
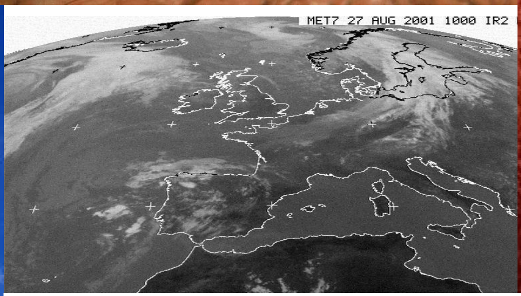
Refining the Impacts: Handling Uncertainty for Adaptation Planning





John Sweeney

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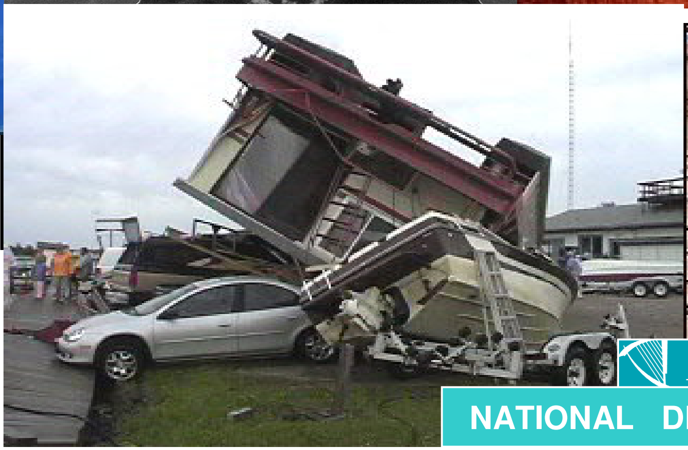


NUI MAYNOOTH
Ollscoil na Éireann Má Nuad

ICARUS
Irish Climate Analysis and Research Units

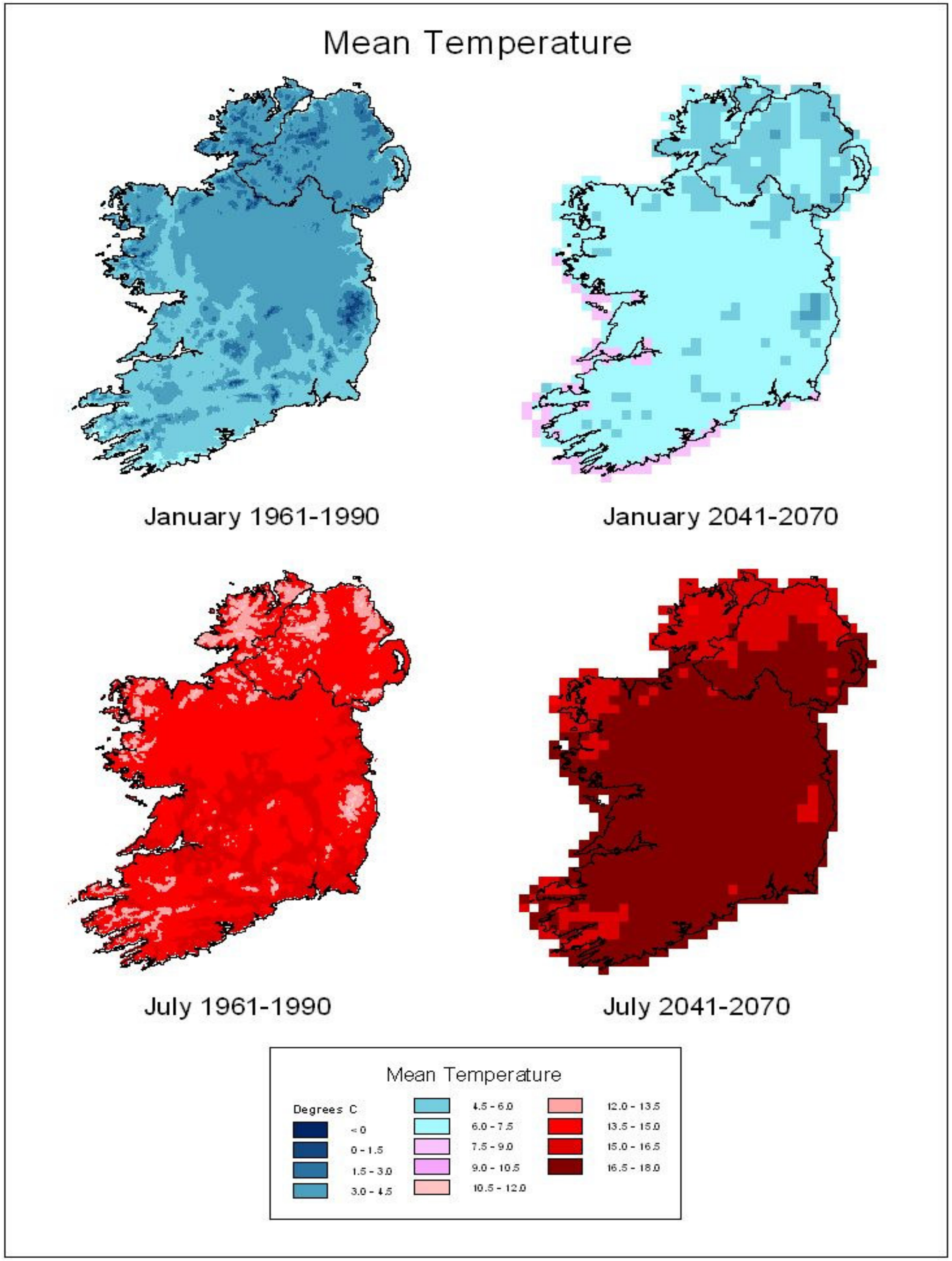
NDP
NATIONAL DEVELOPMENT PLAN

Adaptation has been identified by the Department of the Environment Heritage and Local Government as an important component of Ireland response to climate change (NCCS, 2007). Adaptation planning requires robust analyses of future climate conditions in the context of models. Scenarios for policy need to be based on realistic impact assessments and climate stabilisation for the present century. This process is informed by the EU policies and near term targets.

Where are we with the scientific understanding of climate change in Ireland ?

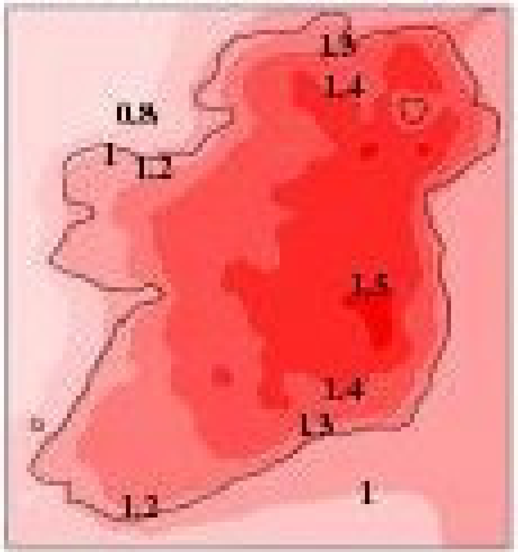
Source: Trenberth (2005)

Mean Temperature Projections using different methodologies show good consistencies

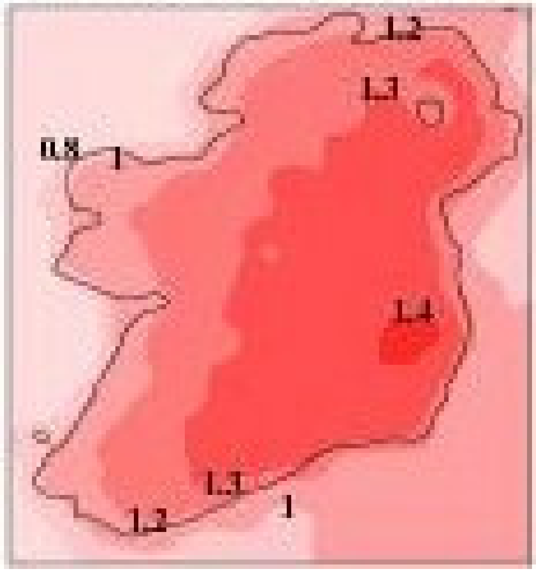


HadCM3+SD (ICARUS)

ECHAM+RCA (C4I)



January 2021-2060



July 2021-2060

Confidence in Mean Temperature Change Projections is Robust

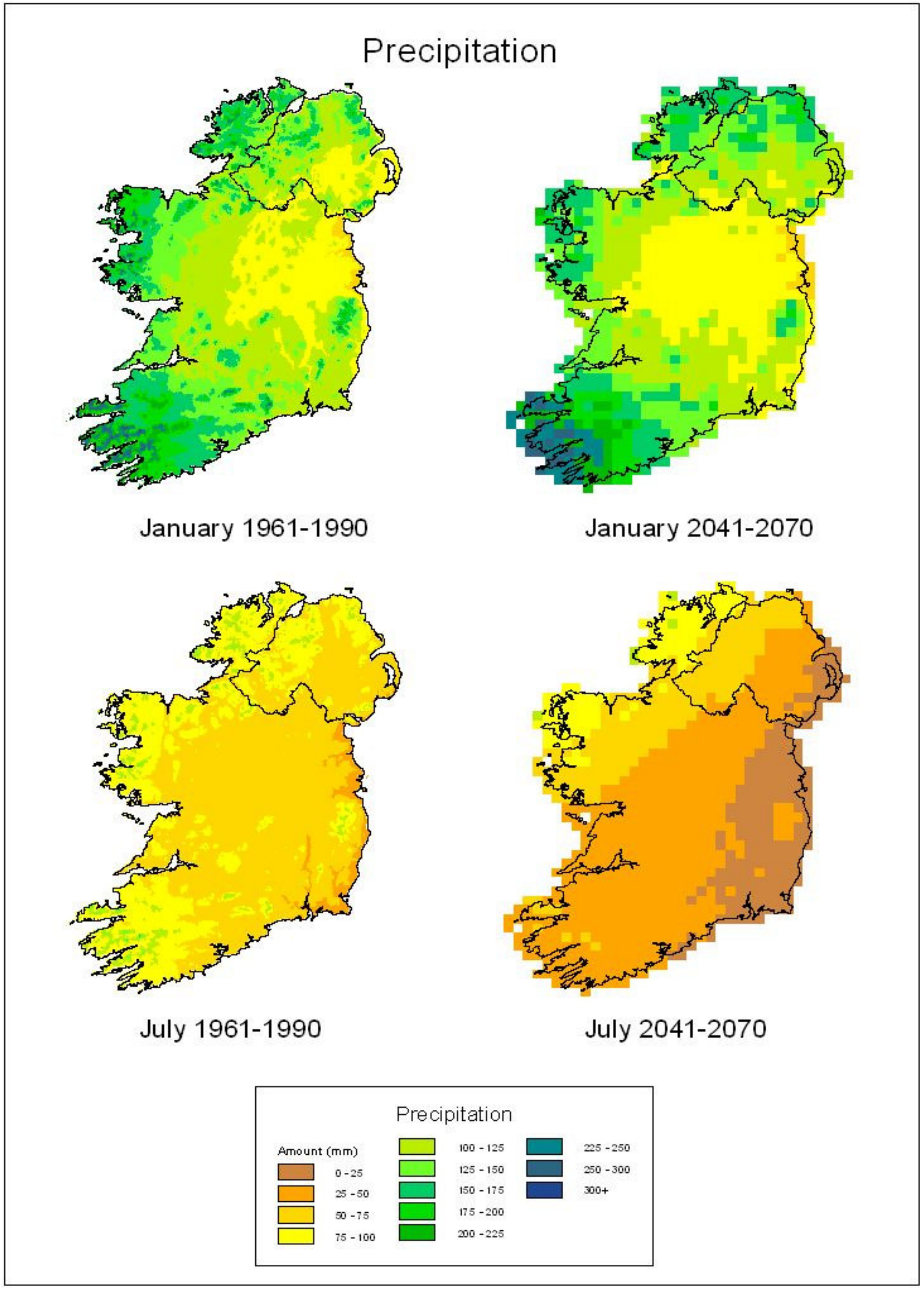
- Warming relative to the 1961-90 period of 1.5^{o}C by mid century and 3-4^{o}C by end century
- Summers warming slightly more than winters
- Regional warming greatest away from coastal areas, especially Atlantic coasts.
- Current decadal warming of 0.42^{o}C/decade unlikely to be continued, but overall warming trend in Ireland likely to correspond closely to the global figure.

Uncertainties in Temperature Projections

- Different scenario models give slightly different regional patterns
- Extremes of temperature have as yet not been well tied down

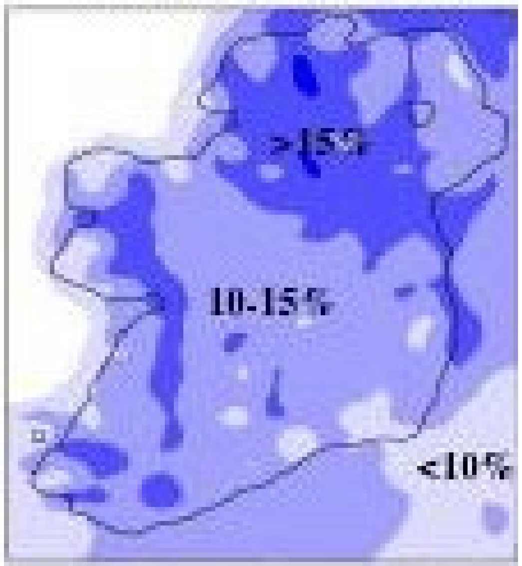
- These problems can best be tackled by a diversity of approaches, multiple model runs strongly grounded in observational data and understanding of how the Irish climate works

Precipitation Projections exhibit greater uncertainties, especially regionally

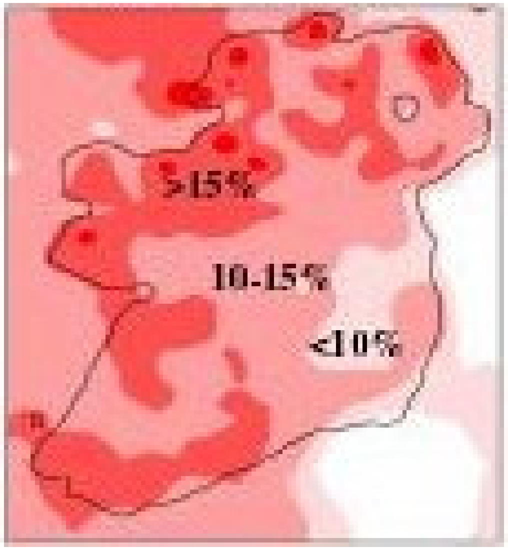


HadCM3+SD (ICARUS)

ECHAM+RCA (C4I)



January 2021-2060



July 2021-2060

Confidence in Mean Precipitation Change Projections is lower

- Winters will become wetter throughout Ireland by approximately 10-15% by mid century
- Summers will become drier by approximately 10-25% by mid century
- Regional modelling does not identify a marked spatial trend, though Statistical Downscaling suggests a pronounced NW-SE trend, especially in summer.

Uncertainties in Precipitation Projections

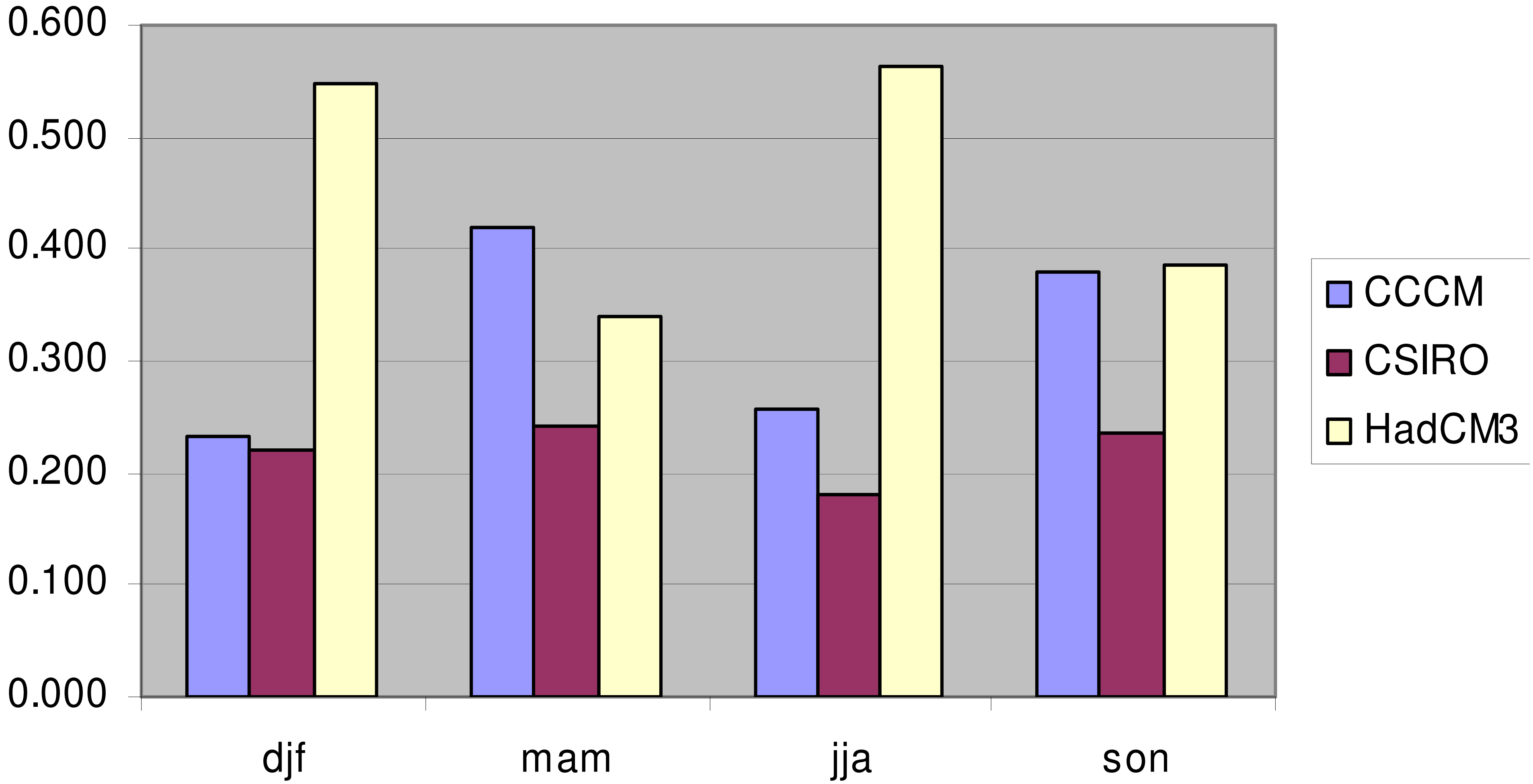
- Different global climate models give substantially different seasonal regional patterns across Ireland. These in turn produce uncertainties in Irish regional climate model outputs.
- Extremes of rainfall are likely to become more pronounced, requiring higher resolution temporal and spatial research

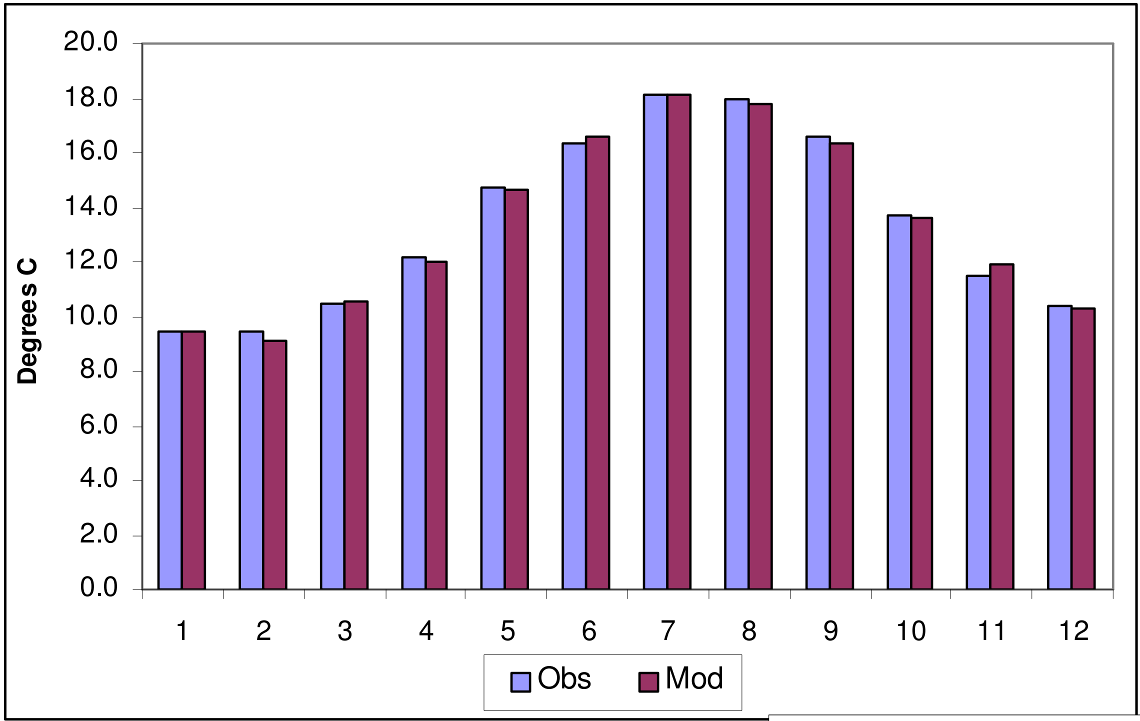
Global Climate Models used in daily statistical downscaling for Irish synoptic stations

- HadCM3 UK
- CGCM2 Canada
- CSIRO Mark 2 Australia

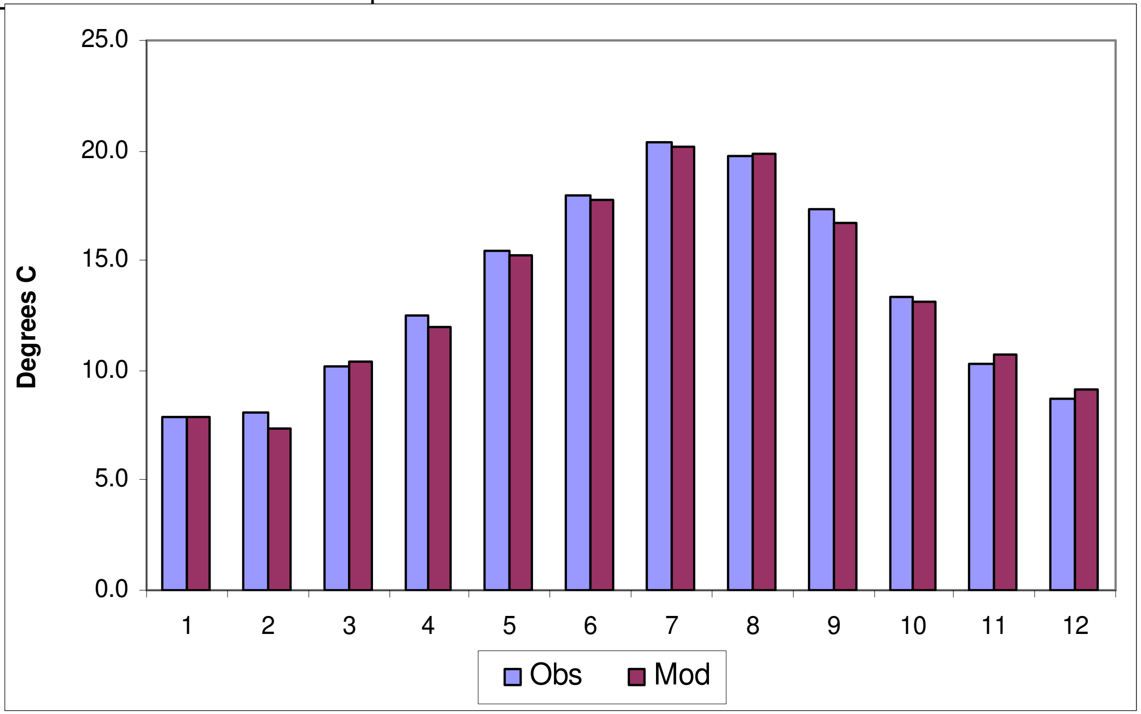
- A2 and B2 SRES Emissions Scenarios

Seasonal weights derived from the CPI score for each of the GCMs to produce the weighted ensemble mean





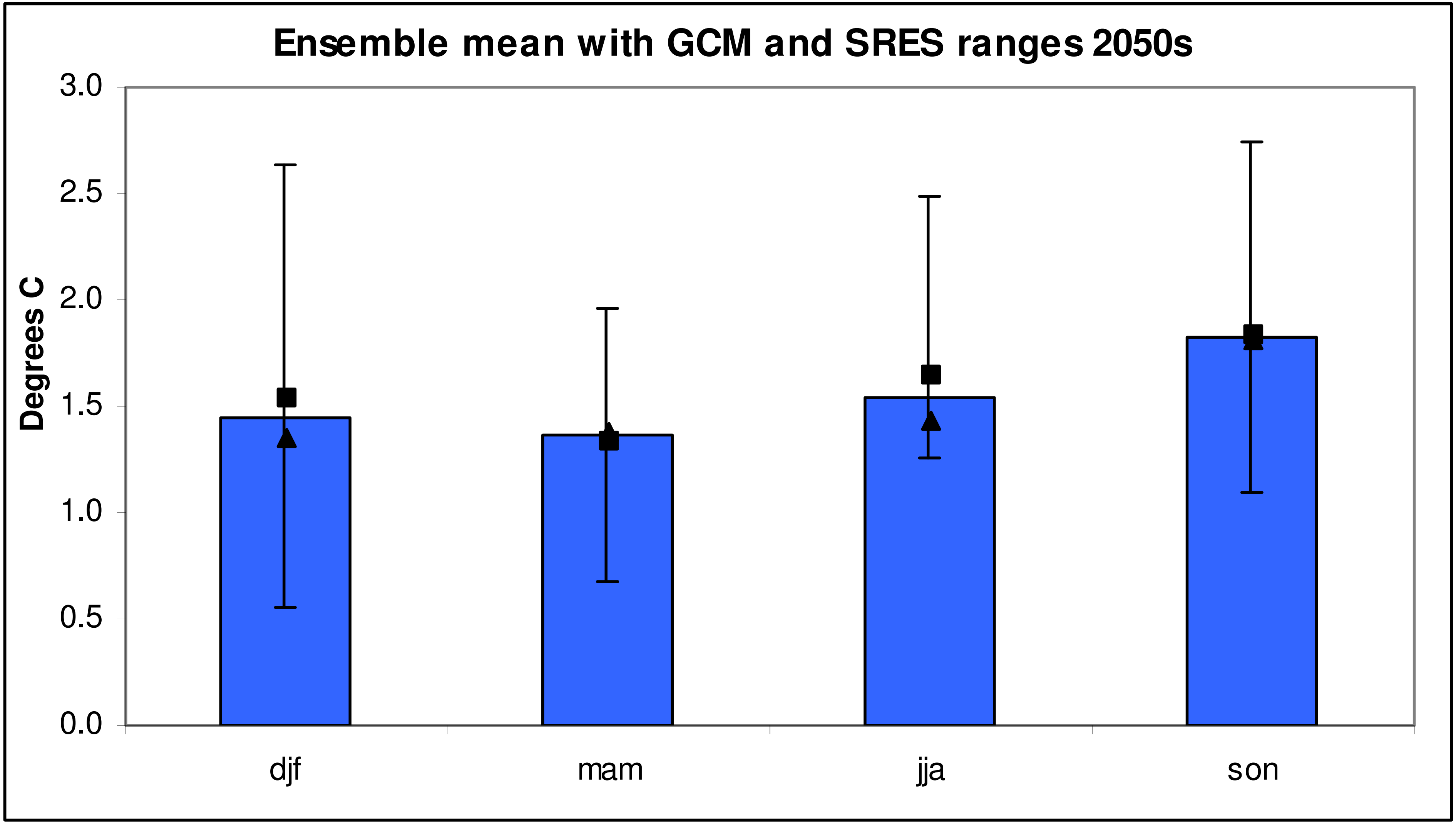
Comparison of observed and modelled maximum temperatures from Valentia, for the independent verification period 1979-1993.



Comparison of observed and modelled maximum temperatures from Kilkenny, for the independent verification period 1979-1993.

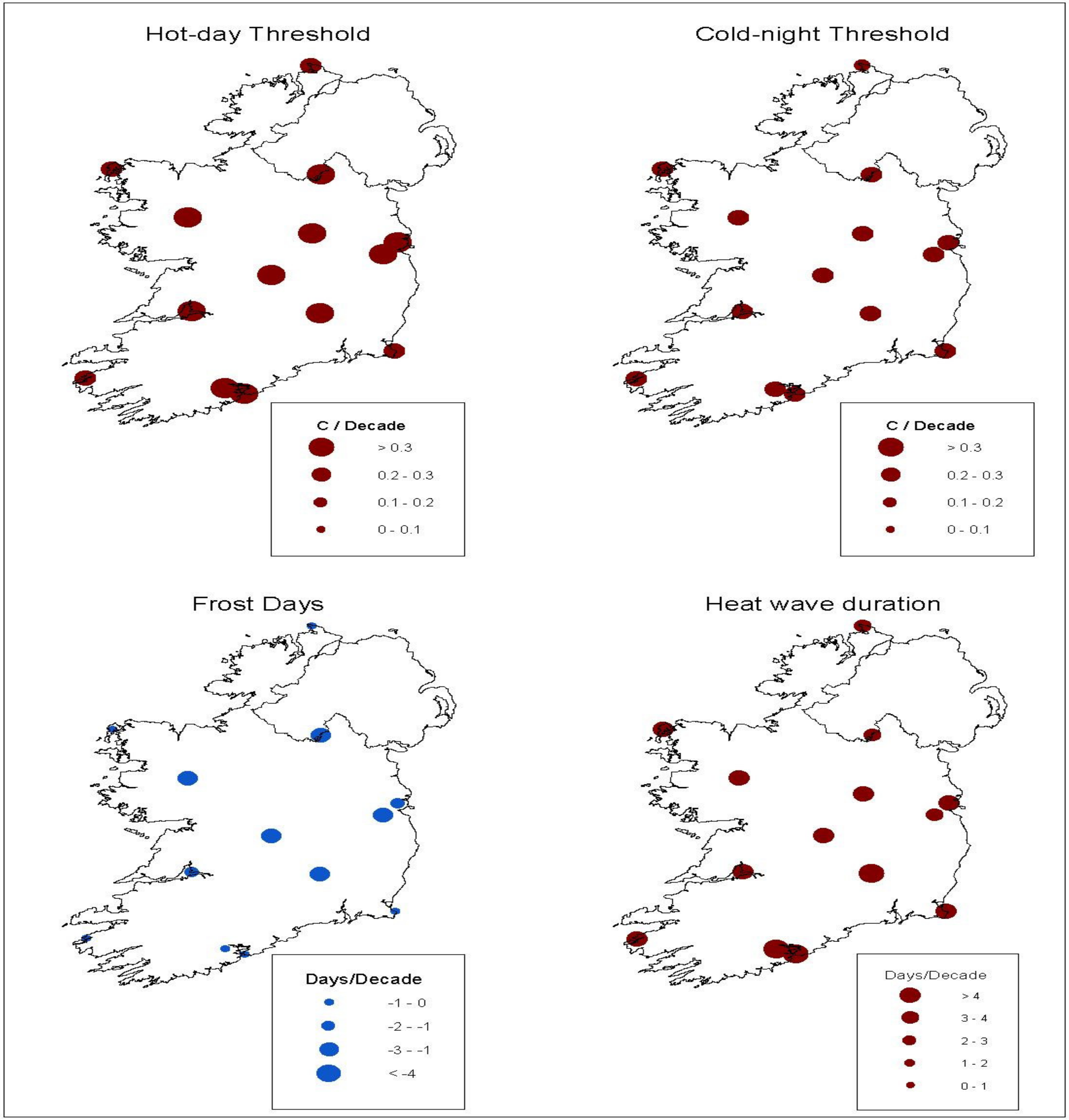
Ensemble mean temperature for the 2050s produced from the weighted ensemble of all GCMs and emissions scenarios (bars). Upper and lower ranges (lines) are the results from the individual GCMs and emissions scenarios.

Ensemble A2 scenario (■) and B2 scenario (▲)




2020s
2050s
2080s
Winter
Spring
Summer
Autumn
Mean temperature change
(Deg. C)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5

Hot Day threshold= 10th hottest day per year



Cold night threshold= 10th coldest night per year

Modelling Precipitation

- Daily precipitation data is rarely, if ever, normally distributed, resulting from a high frequency occurrence of low fall events and a low frequency of high fall events.
- Modelling precipitation requires a two-step procedure:
- First, precipitation <u>occurrence</u> must be modelled.
- Then a model is fitted to precipitation <u>amounts</u> which describes the rainfall distribution for days on which precipitation occurs.

Precipitation Occurrence Model

- For the purposes of the present study, logistic regression, which is a particular type of generalised linear model (GLM), was employed to model wet and dry day sequences of precipitation.

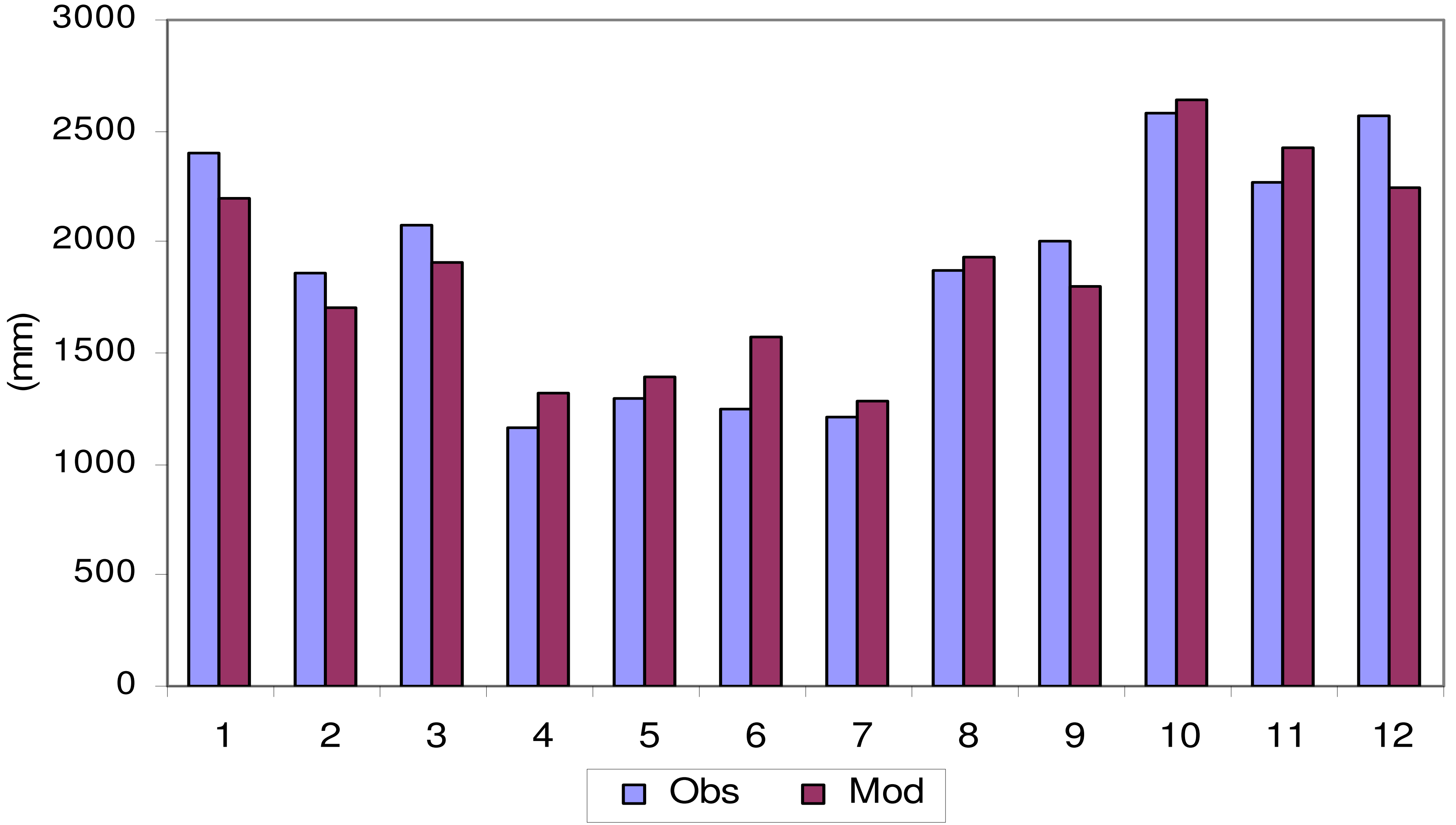
$$\frac{P}{1-P} = e^{B_o + B_1 x_1 + \dots B_{n+1} x_{n+1}}$$

P=probability of an event
x= independent variable
B_0, B_1= coefficients estimated from the data

Precipitation amounts model

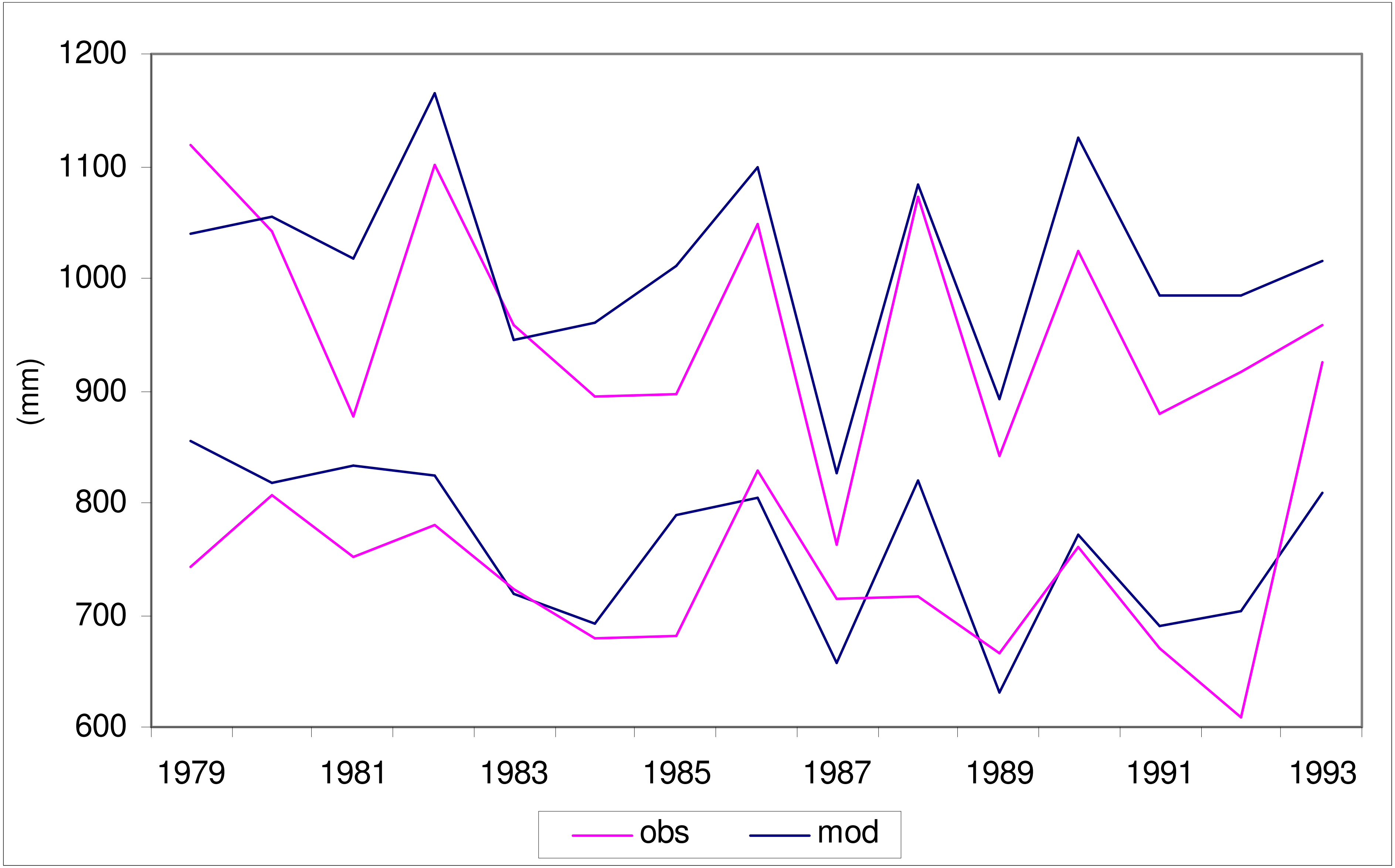
- A Generalised Linear Model (GLM) was employed to model precipitation amounts conditional on a range of atmospheric variables.
- GLMs do not require the dependent variable to be normally distributed.
- GLMs have the added advantage in that they fit probability distributions to the variable being modelled
- Fitting probability distributions, in this manner, should also improve how extreme values in the tails of the distributions are handled within the modelling framework.

Comparison of observed and modelled precipitation from Valentia, a west coast station with high annual receipts, for the independent verification period 1979-1993.



Comparison of observed and modelled precipitation from Dublin Airport, an east coast station with low annual receipts, for the independent verification period 1979-1993

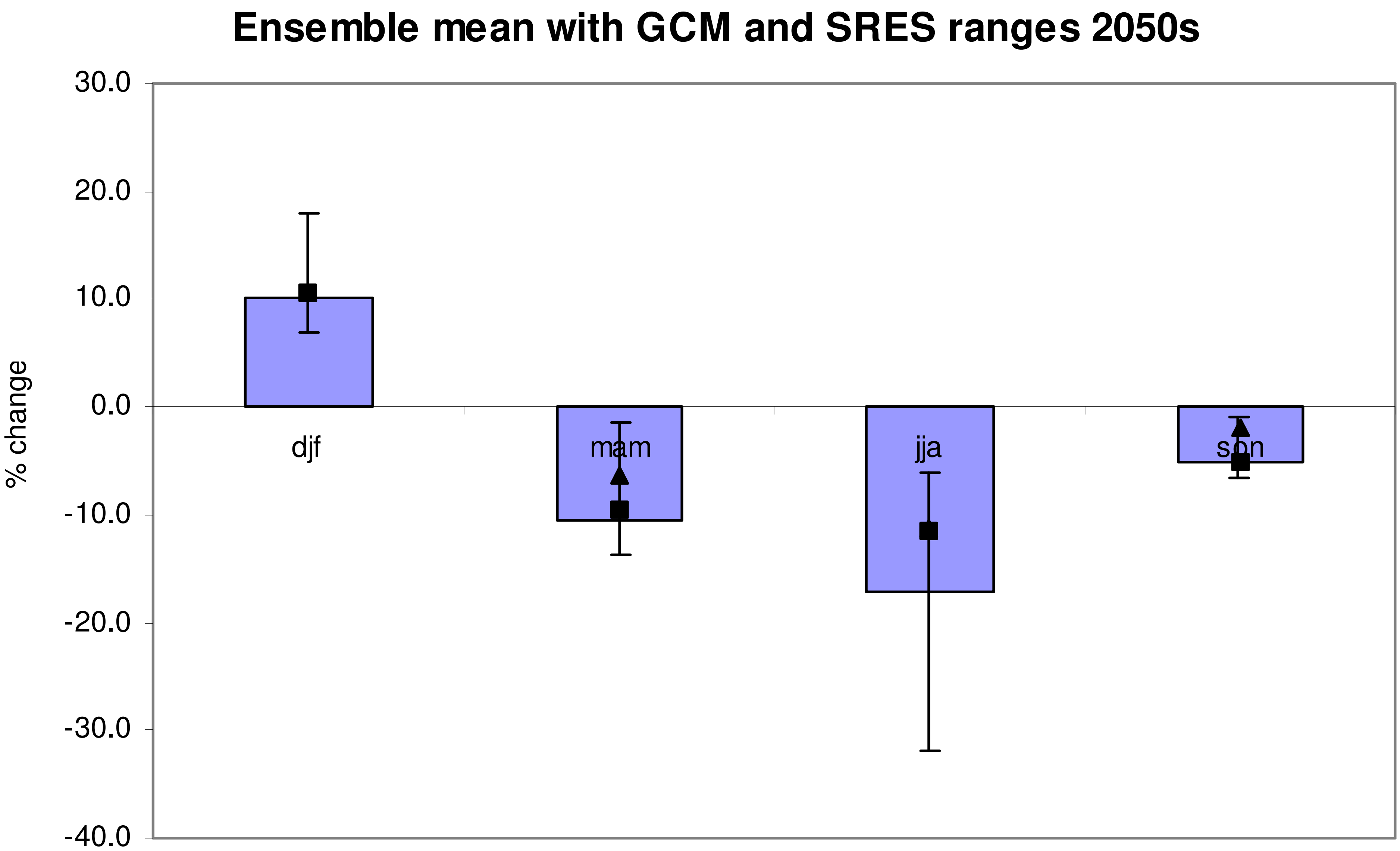
Interannual variability for observed and model precipitation from Shannon Airport, (top) and Casement Aerodrome, (bottom) for the independent verification period 1979-1993

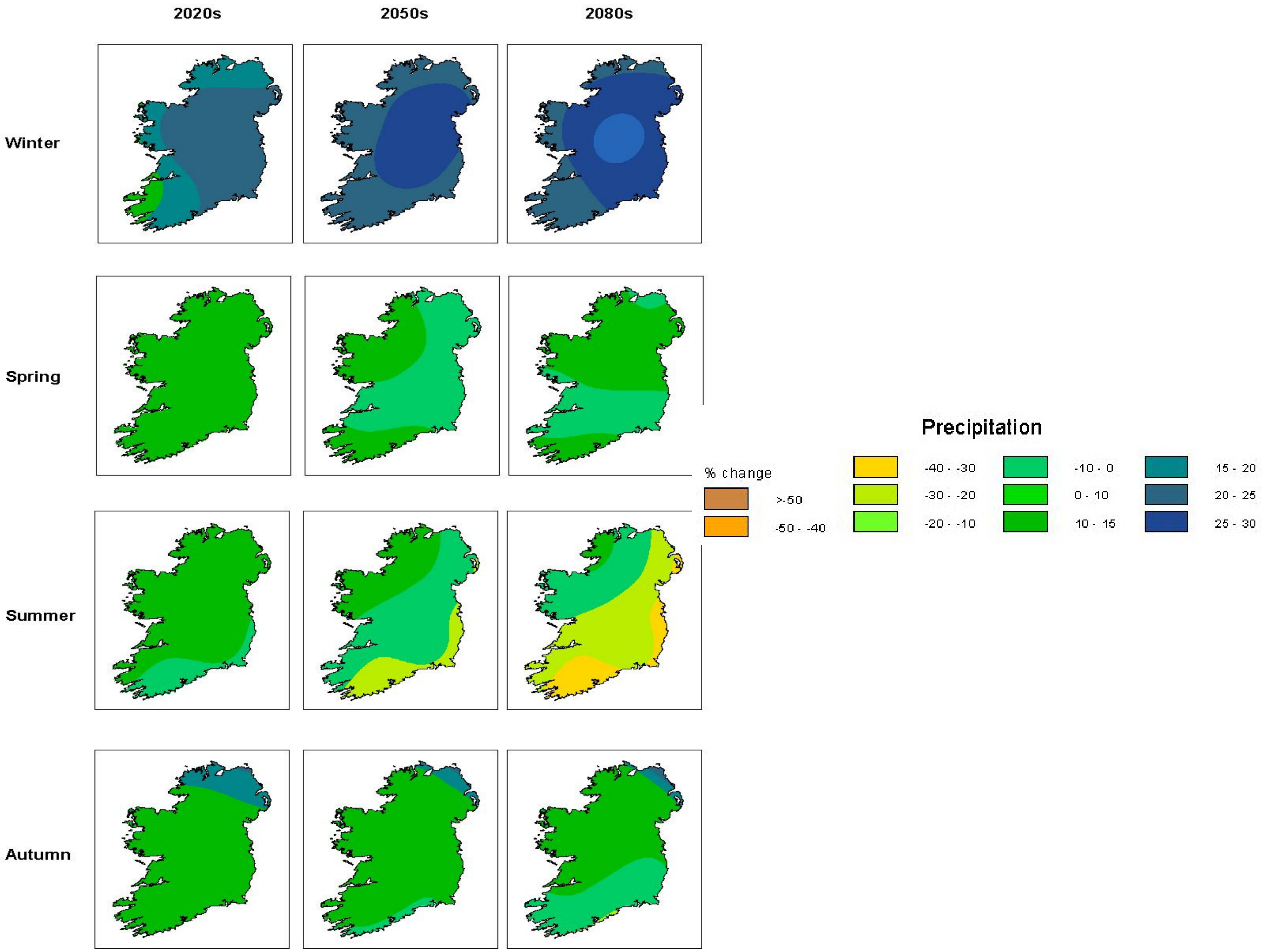


Comparison of mean daily radiation derived from sun hours from Rosslare and modelled radiation for an independent verification period of 1961-1970

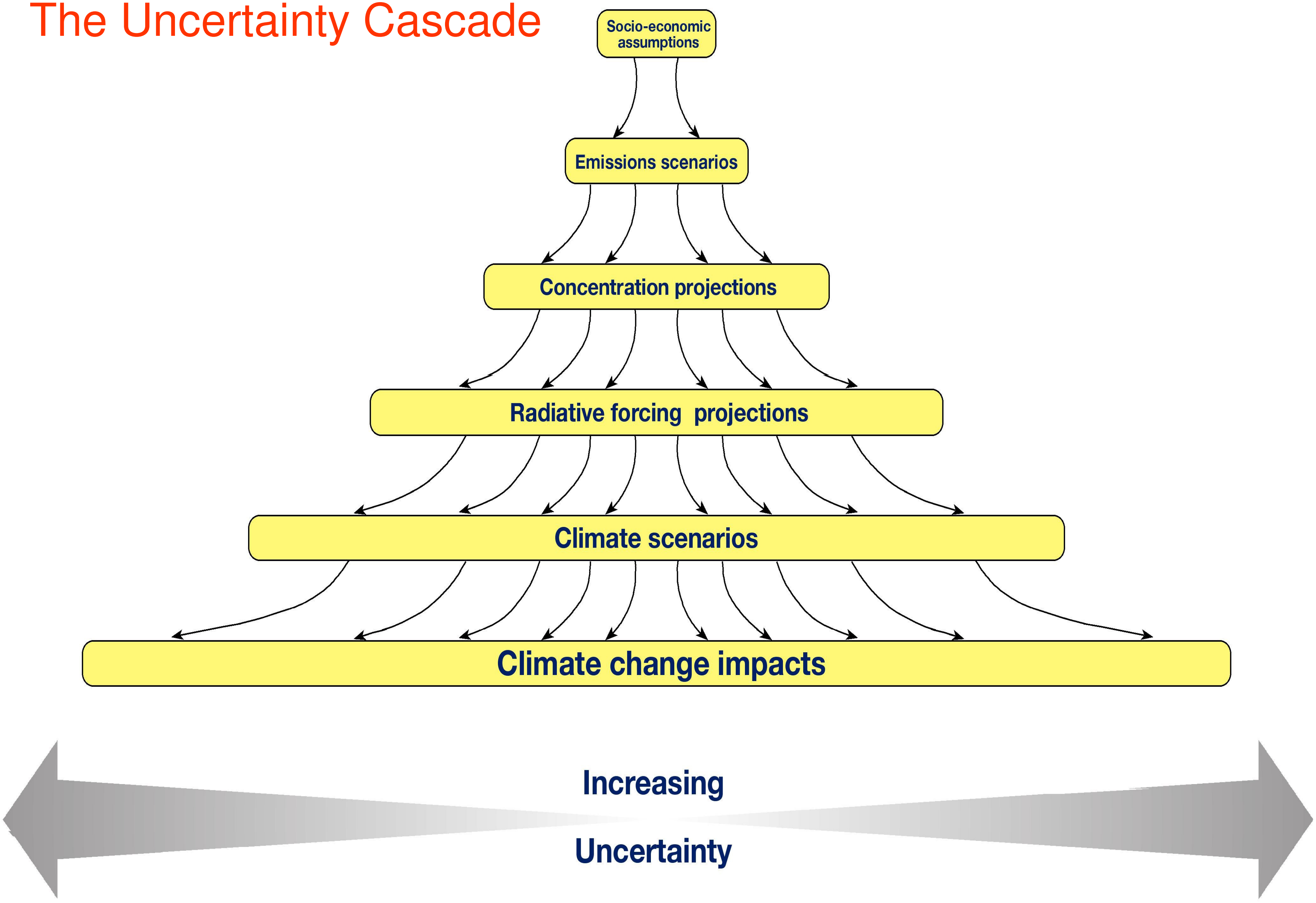
Comparison of observed mean daily potential evapotranspiration from Kilkenny and modelled potential evapotranspiration for an independent verification period of 1991-2000

Ensemble mean precipitation for the 2050s produced from the weighted ensemble of all GCMs and emissions scenarios (bars). Upper and lower ranges (lines) are the results from the individual GCMs and emissions scenarios. Ensemble A2 scenario (■) and B2 scenario (▲).

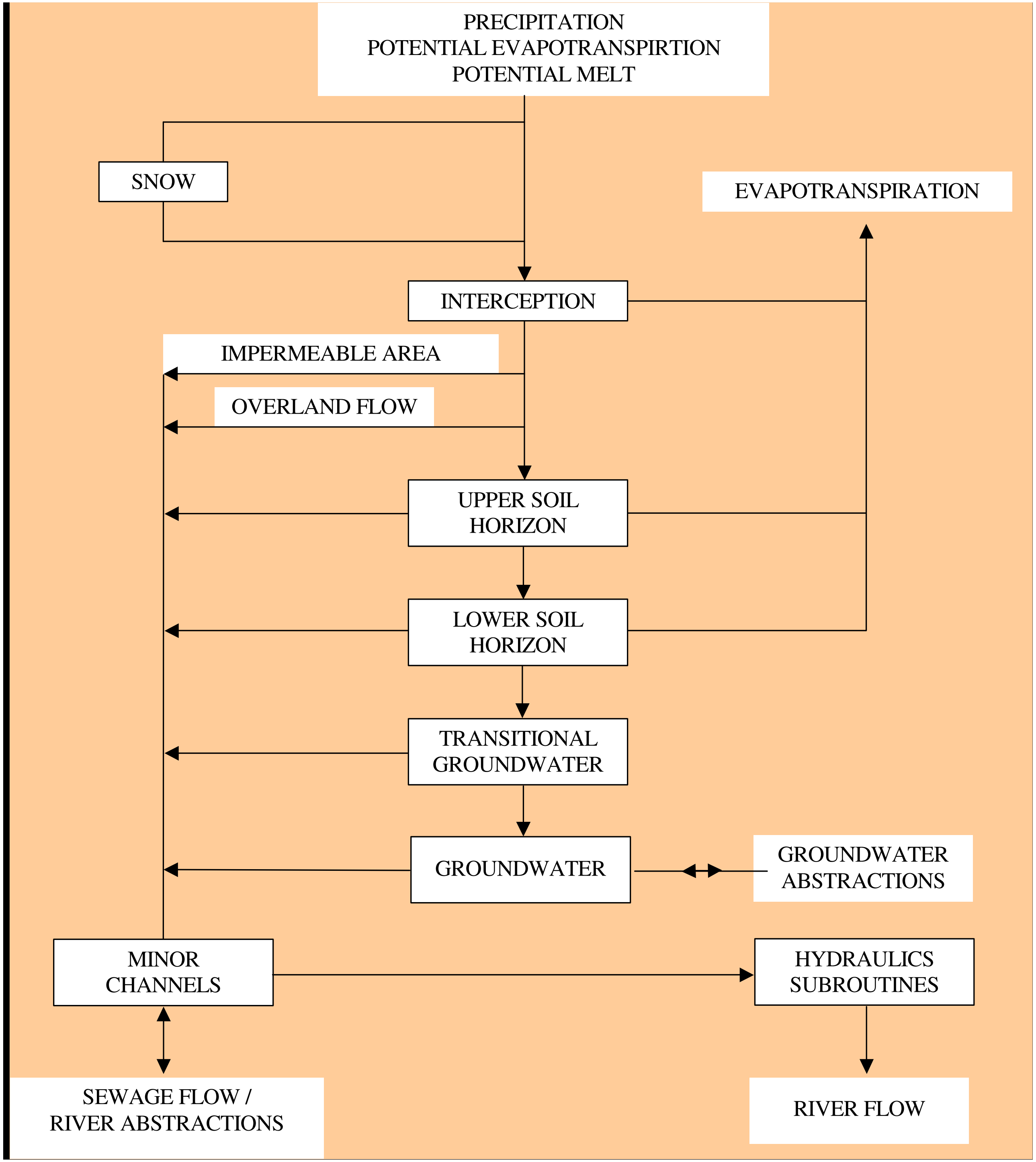



2020s
2050s
2080s
Winter
Spring
Summer
Autumn
Precipitation
% change
>-50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 15
15 - 20
20 - 25
25 - 30

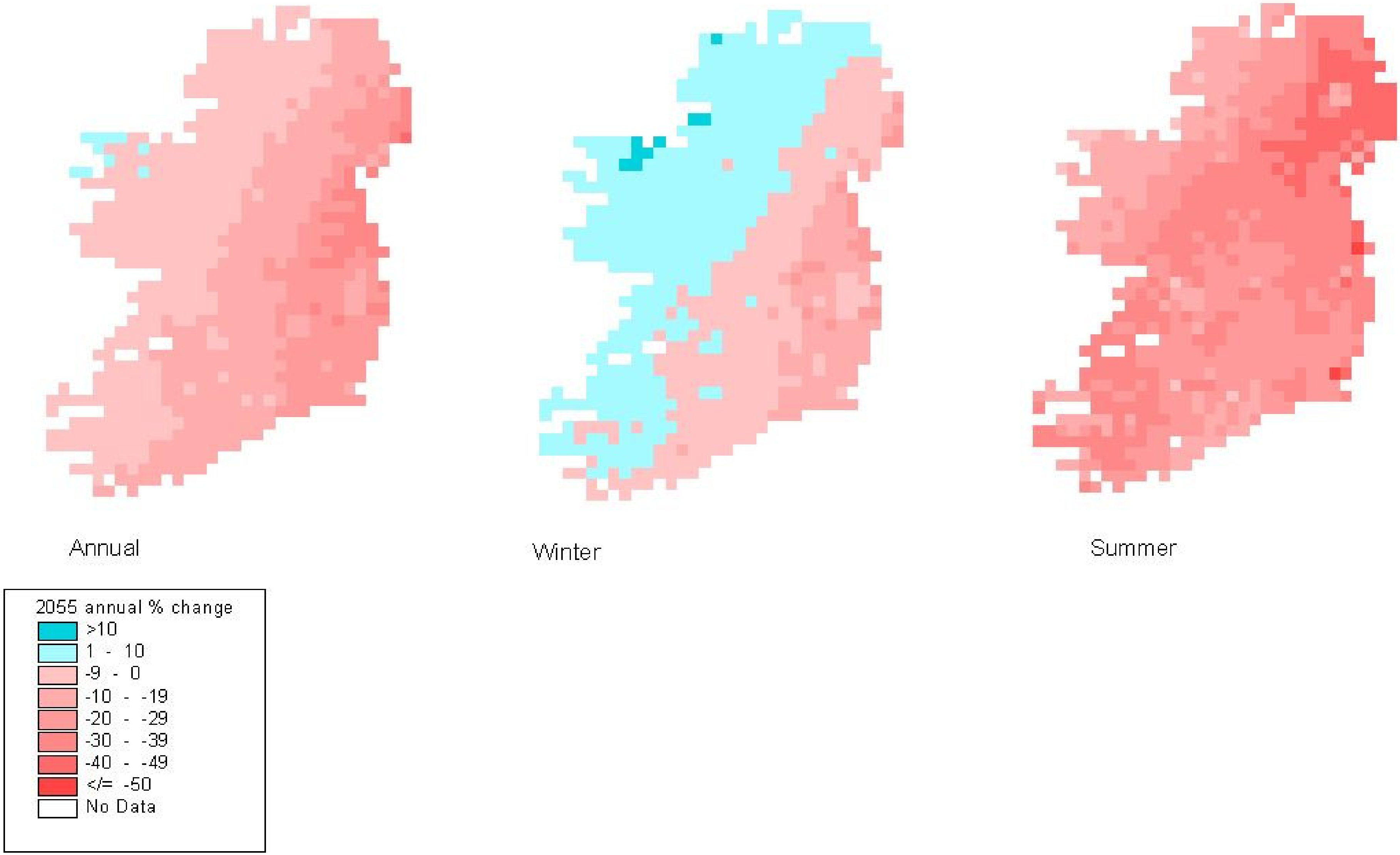
The Uncertainty Cascade



The HYSIM Model - a Conceptual Rainfall-Runoff Model

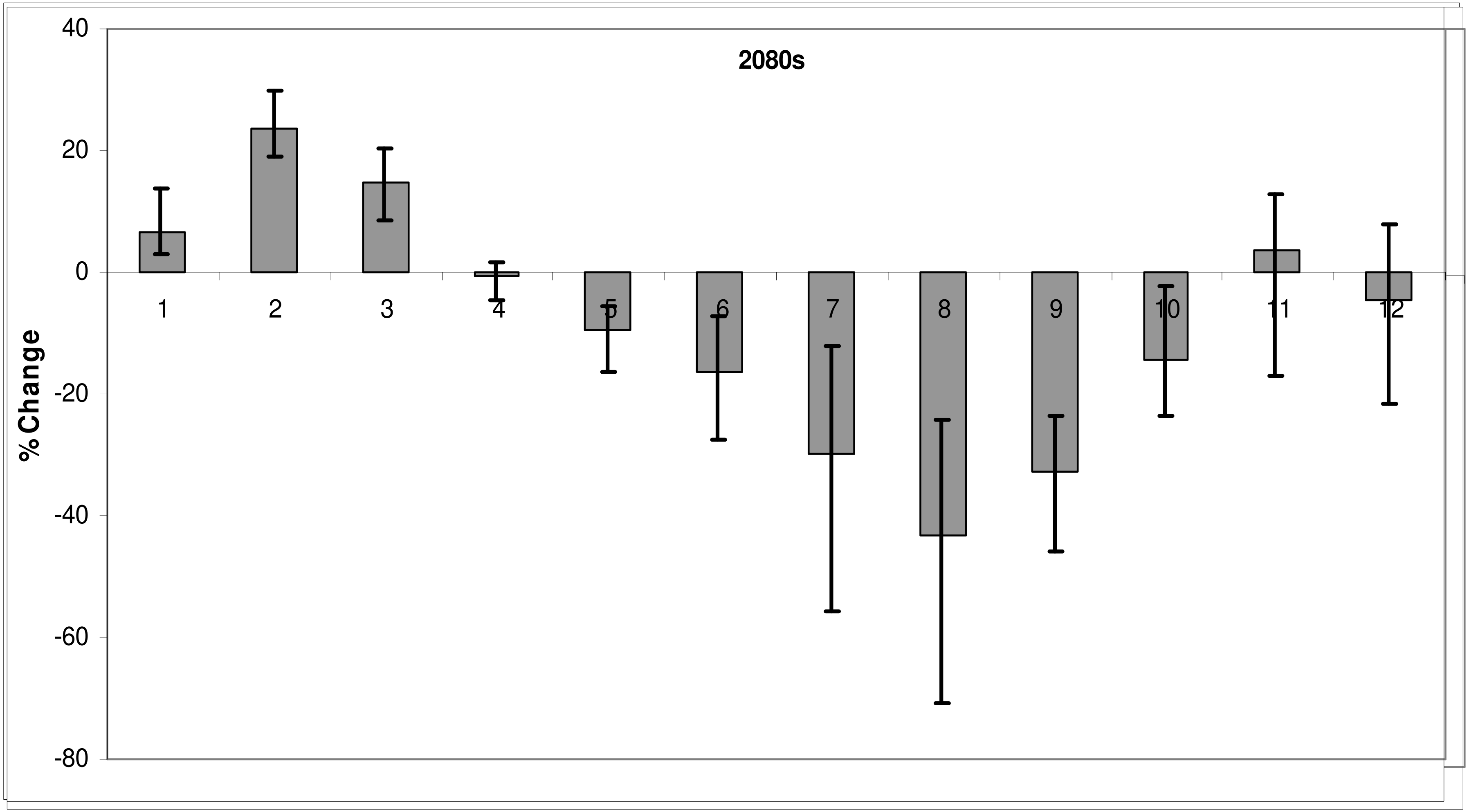


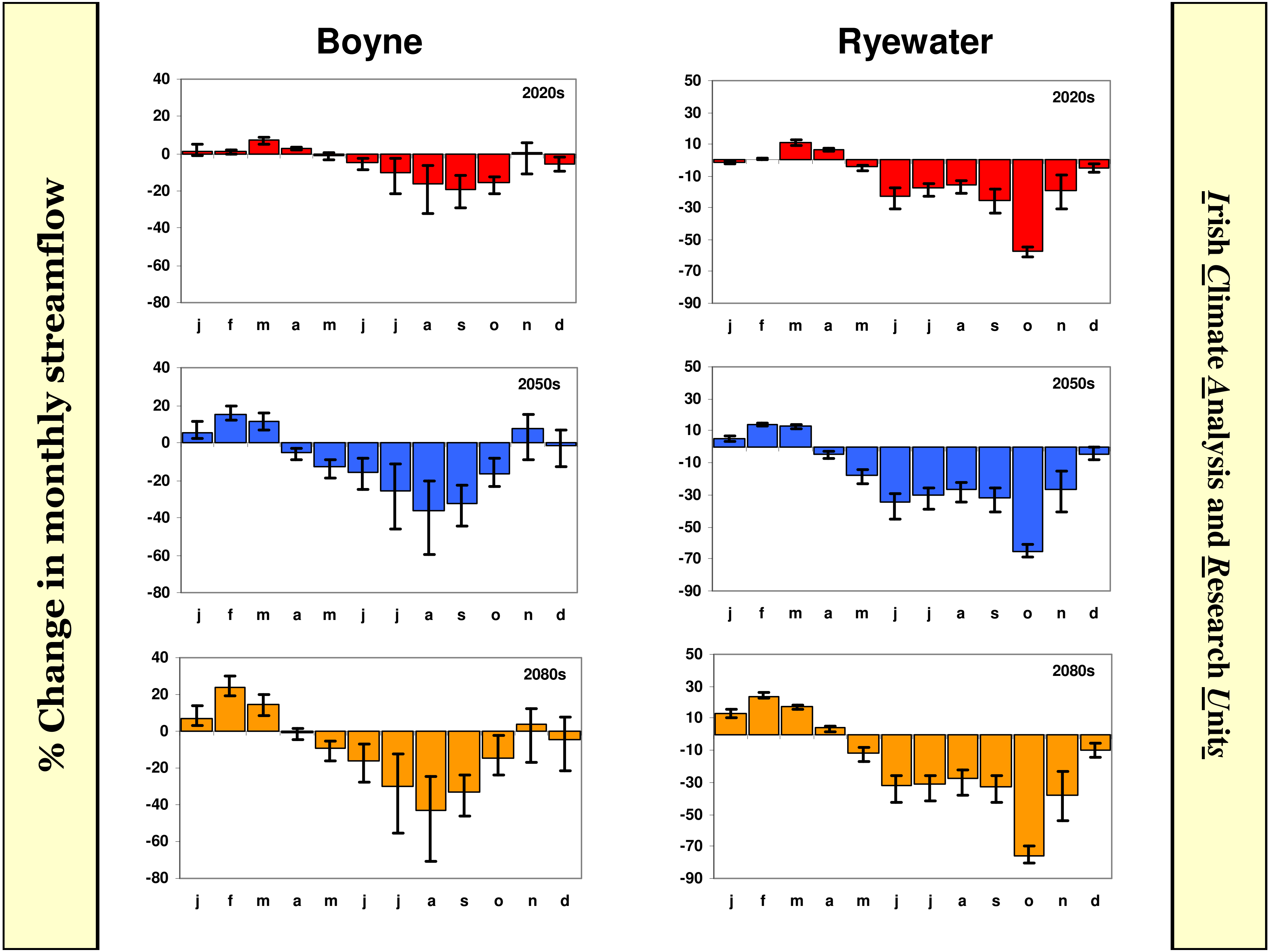
% Change 2041-70



Changes in Runoff as a % of 1961-90 averages

Percent change in simulated monthly **Streamflow** Boyne Mean Ensemble





% Change in monthly streamflow
Boyne
Ryewater
2020s
2050s
2080s
40
20
0
-20
-40
-60
-80
50
30
10
-10
-30
-50
-70
-90
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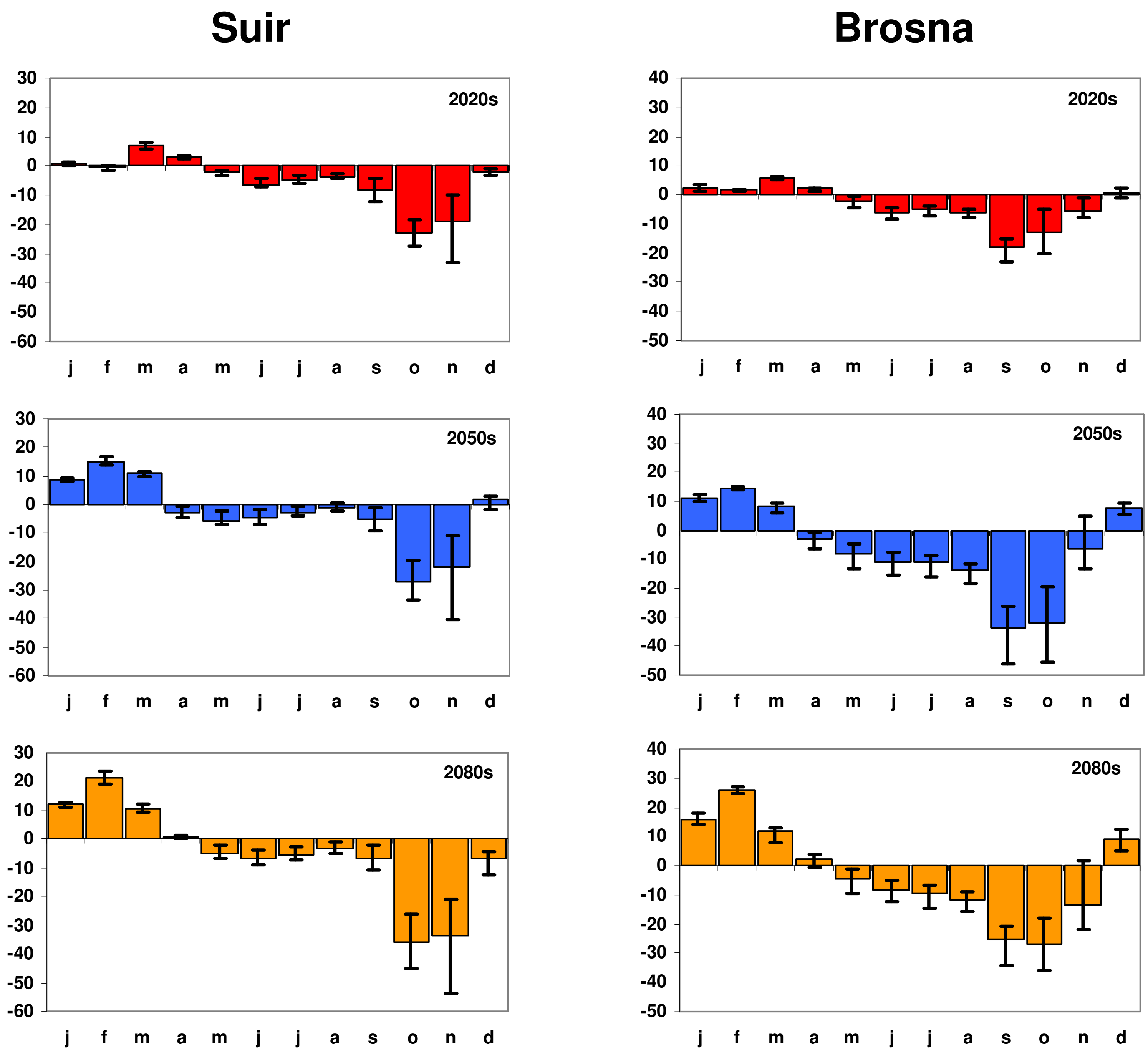
% Change in monthly streamflow



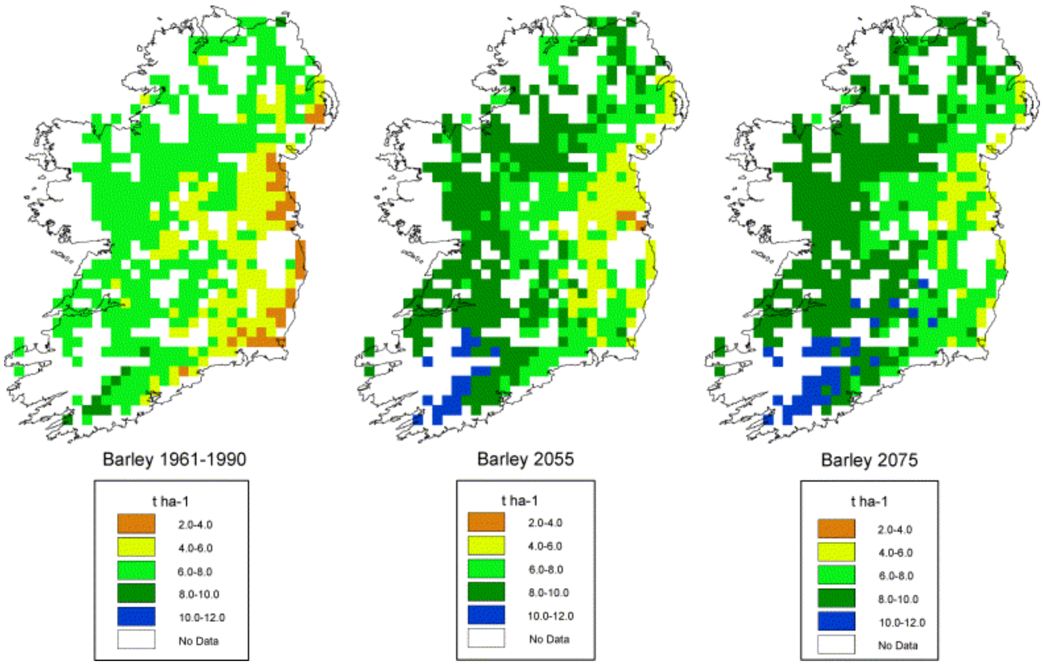
			Barrow	B'water	Boyne	Brosna	Inny	Moy	R'water	Suck	Suir
T2	A_2	20s	1.8	1.8	1.9	2.1	2.5	1.6	1.6	1.5	1.8
		50s	1.6	1.5	1.4	1.5	1.4	1.5	1.4	1.4	1.7
		80s	1.3	1.4	1.2	1.3	1.2	1.3	1.5	1.2	1.5
	B_2	20s	1.8	1.5	1.4	1.8	1.6	1.4	1.4	1.4	1.8
		50s	1.6	1.5	1.4	1.4	1.3	1.4	1.7	1.4	1.8
		80s	1.5	1.5	1.3	1.3	1.3	1.4	1.6	1.4	1.6
T10	A_2	20s	4.8	3.6	7.1	13.9	12.7	4.2	3.4	4.4	4.4
		50s	4.8	4.2	3.4	3.4	4.5	4.4	3.3	4.5	6.9
		80s	3.4	3.4	1.8	2.0	2.0	2.2	4.1	2.1	3.2
	B_2	20s	3.7	2.6	2.3	4.0	4.1	2.2	3.5	2.4	4.1
		50s	4.0	2.6	3.5	3.0	3.5	4.6	5.5	5.5	4.1
		80s	2.9	3.8	2.2	2.1	2.3	3.9	5.4	4.6	2.8
T25	A_2	20s	8.3	5.1	15.1	39.3	26.4	7.7	5.3	8.8	6.5
		50s	10.1	7.3	5.6	4.9	7.5	8.5	5.5	9.7	16.9
		80s	6.7	5.3	2.3	2.8	2.7	3.1	6.9	3.0	4.7
	B_2	20s	5.5	3.2	3.0	5.6	6.6	3.0	6.4	3.5	5.8
		50s	7.7	3.4	6.9	4.5	6.1	10.3	11.0	14.2	5.8
		80s	4.6	6.6	3.2	2.6	3.2	8.2	12.8	13.8	3.7

Changes in the frequency of floods of a given magnitude for each future time period. Results are based on the HADCM3 GCM using both A2 and B2 emissions scenarios.

Impacts of Climate Change on Irish Agriculture

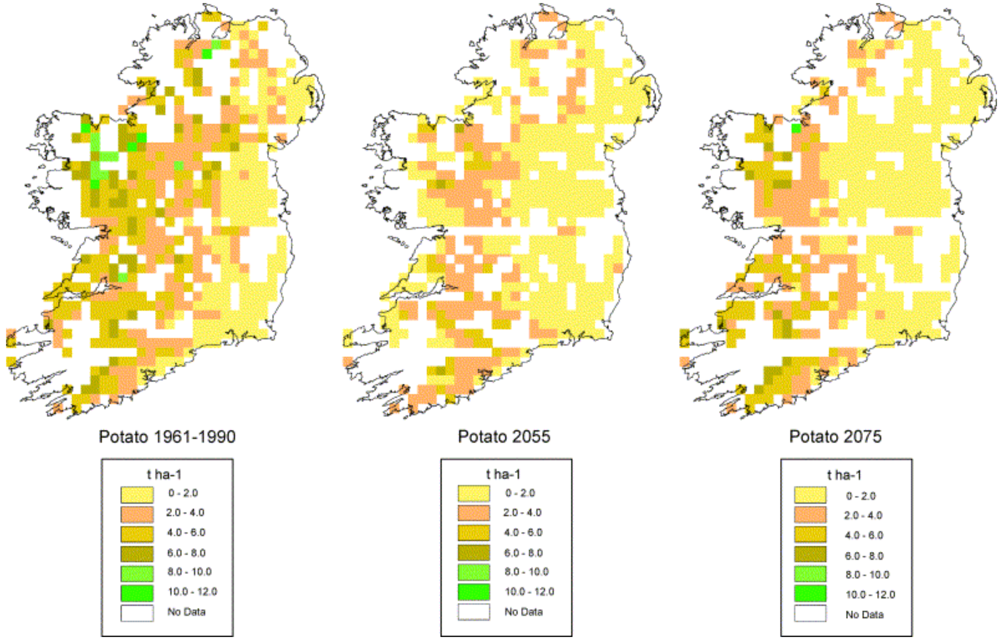
- Drive crop models with high spatial resolution monthly climate scenario data

- Drive farm management systems with low spatial resolution daily climate scenario data



Modelling Assumptions

- Increase in CO_2 to 581ppm by 2055
- Allowance for increased growth rates due to enhanced CO_2 (1.05-1.2 for barley, 1.02-1.08 for potato)
- No pest/disease effects
- No limitations in field access or planting dates
- Dominant soil type at each location used
- Models: Decision Support System for Agricultural Technology Transfer (DSSAT)



Adaptation lessons

- Water stress avoidance will enable reductions in fertiliser use for key crops. Application rates could be halved by 2055. For most areas, barley yields will increase in the medium term, even without irrigation.
- Potato growing areas in Donegal and Cork will only be able to maintain yields in the absence of irrigation by increasing fertiliser inputs to high levels. Wexford and the drier SE appears increasingly unsuited to potato cultivation. Even with 310mm of irrigation in the north Co. Dublin area soil conditions will limit yields considerably.
- Infrastructure to store winter rainfall will be needed in areas of the SE where irrigation is profitable.

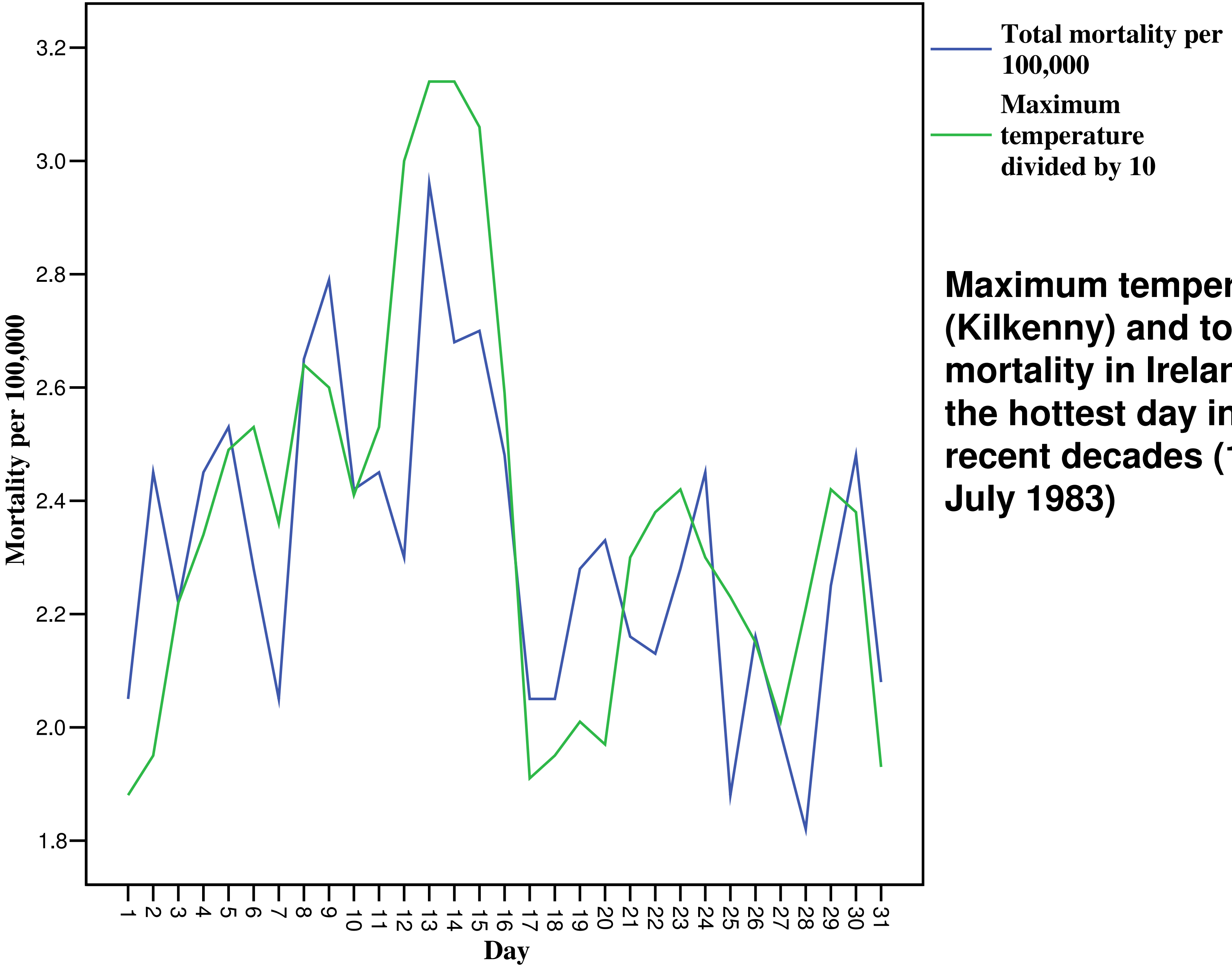
Adaptation lessons

- Summer soil moisture deficits pose the greatest threat for future Irish agricultural production, especially in western parts

- Where water is available and needed, substantial reductions in fertiliser use can be achieved. Water stress avoidance will enable reductions in fertiliser use for key crops. Application rates could be halved by 2055. For most areas, barley yields will increase in the medium term, even without irrigation.
- Where water is unavailable and needed, yields may be partially maintained by increased fertiliser application. Infrastructure to store winter rainfall will be needed in areas of the SE where irrigation is profitable.

Impacts currently being researched by ICARUS and ICARUS-led projects

- Water resources (flooding, drought, supply)
- Agricultural pests/diseases
- Soils/soil degradation
- Human Health
- Biodiversity
- Aquatic ecosystems/salmon survival
- Residential Energy Consumption/Planning



Maximum temperatures (Kilkenny) and total mortality in Ireland on the hottest day in recent decades (13th July 1983)

Modelling Research currently being developed by ICARUS

- Downscaling for biodiversity modelling
- Regional Climate Development (WRF)
- Regional Climate Model-Ocean Model Coupling (WRF-ROMS)
- Regional Model Comparison studies to aid addressing uncertainty

Adaptation Projects Recently Commenced

- Water Resource Management
- Tourism
- Construction
- Biodiversity
- Planning

What do we need for Adaptation Planning?

- Improved spatial and temporal resolution of model scenarios, especially with respect to extremes
- Access to spatial datasets necessary for calibration/verification purposes, especially climate, soils, biodiversity,health,pests, energy demand etc.
- Incorporation of best practice adaptation into national, regional and local decision making in order to provide climate-change-proofed roadmaps for current and future investments.