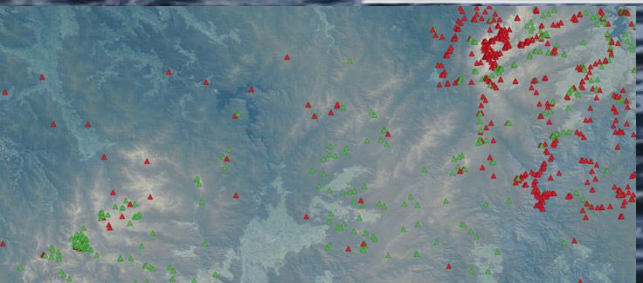
UNSW SYDNEY | Australia's Global University

Core Research Aim

What do we mean by **anomalies?**

climate change using **dynamic predictors** and **anomalies** from their **mean values**

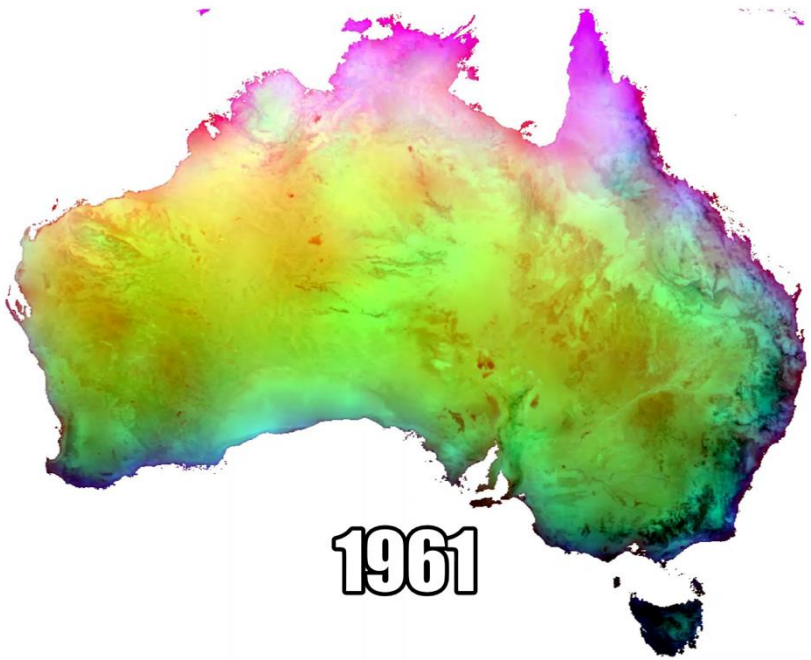


SPATIO-TEMPORAL SPECIES DISTRIBUTION MODELLING

Wasting time…

- Ecologists tend to use **30 year averaged** bioclimatic predictors
- **Mask accelerating** environmental changes – particularly **recent** decades
- It's **difficult** to get predictors at relevant **spatial/temporal scales**

Don’t waste time…

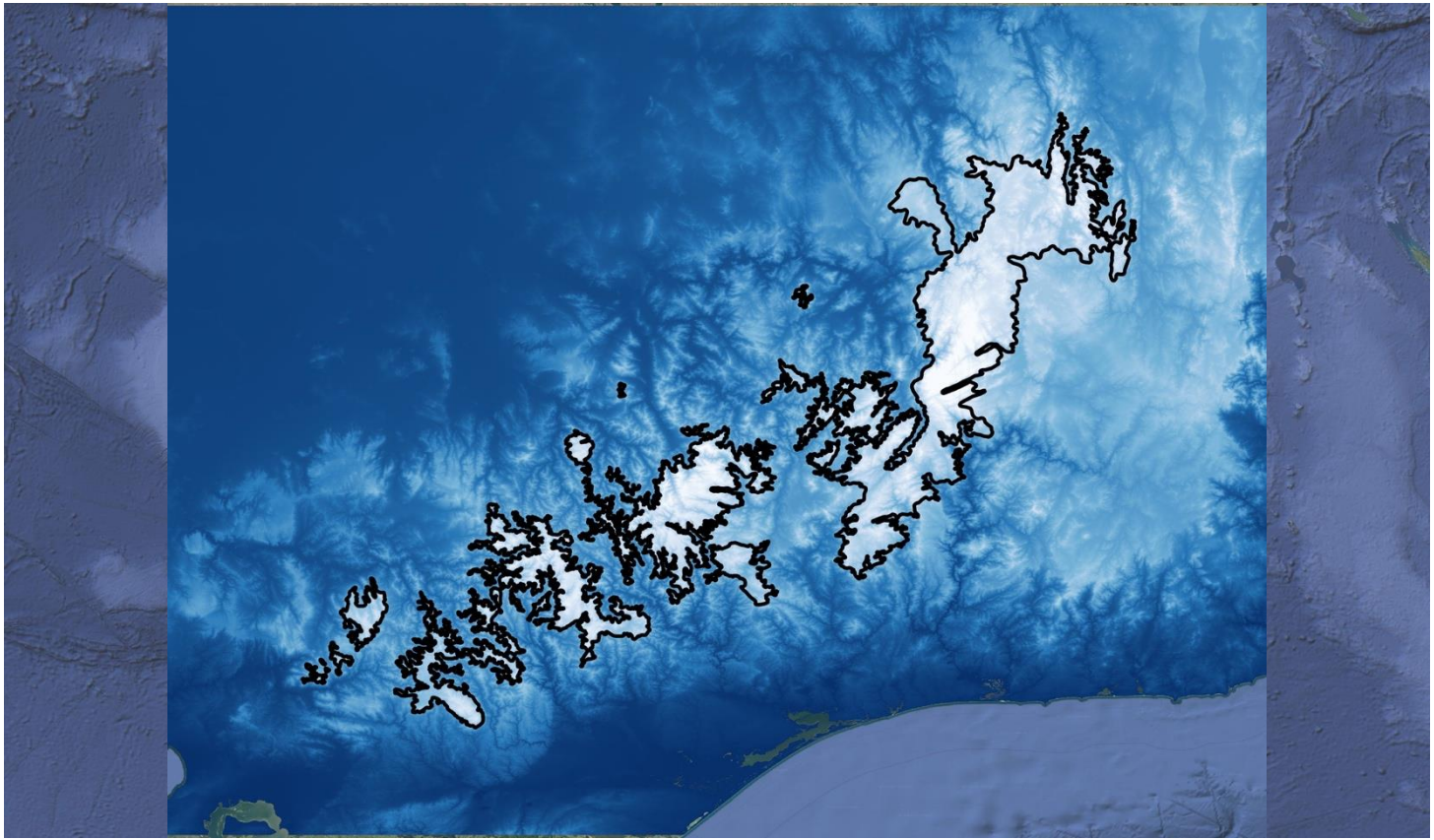


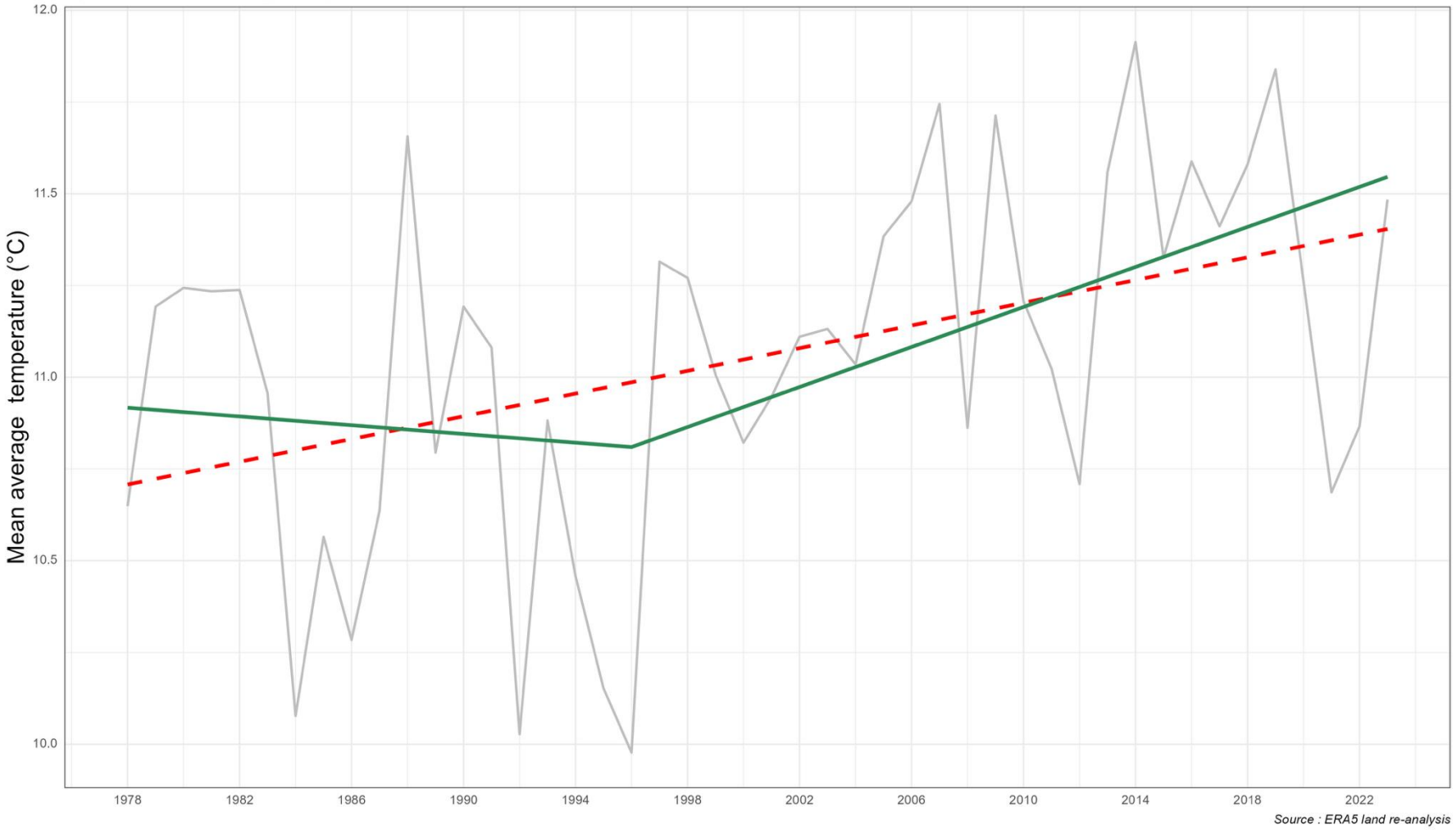
- Overall – **it’s a challenge** that requires non-trivial technical knowledge and **a lot of time**
- BUT – if we want to look for species **responses to climate change**
- While basically treating the climate as **temporally static**
- It’s **not going to work**…

Alpine summits

- Form a **natural laboratory** for ecological research on climate **change impacts**
- Remote areas less impacted by human **population pressures** and **land use activity**
- Species under stress can migrate to **higher elevations** or into habitats that were previously **too cold**

Area of Interest is ~ 85 300 km^2 over 46 years




Mean temperature 1978 to 2023
Spatial mean of average temperature across AUA
Mean average temperature (°C)
12.0
11.5
11.0
10.5
10.0
1978
1982
1986
1990
1994
1998
2002
2006
2010
2014
2018
2022
Source : ERA5 land re-analysis

Climate variable anomalies

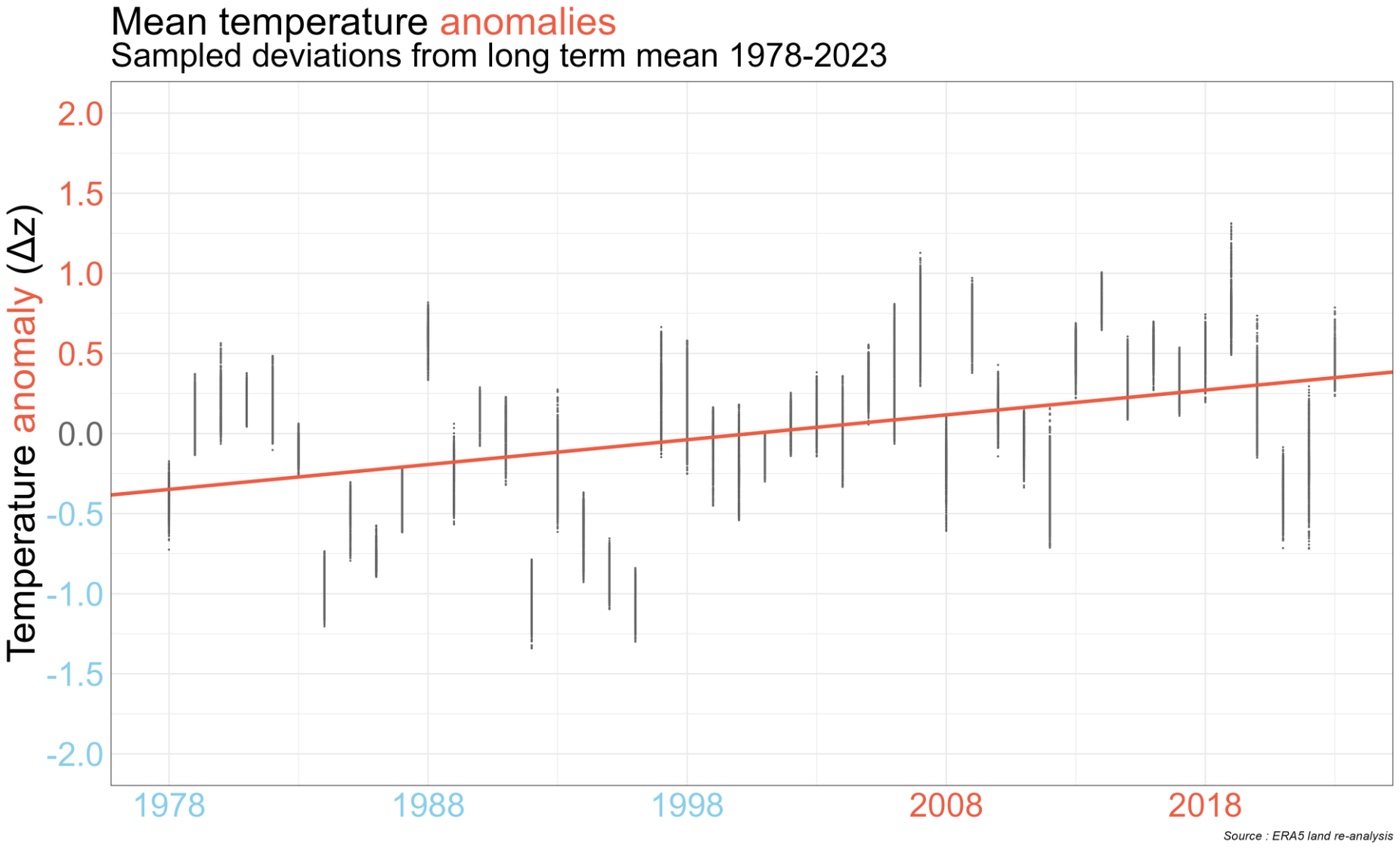
- We want covariates that capture long term **climate changes**
- Let z_{ij} be the temperature at location i at time j and define the **anomaly** as

$$\Delta z_{ij} = z_{ij} - \overline{z_i}$$

where

$$\overline{z_i} = \frac{1}{T} \sum_{j=1}^{T} z_{ij}$$

is the mean temperature at location i over the temporal window


Mean temperature anomalies
Sampled deviations from long term mean 1978-2023
Temperature anomaly (Δz)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
1978
1988
1998
2008
2018
Source : ERA5 land re-analysis

CLIMATE VARIABLES

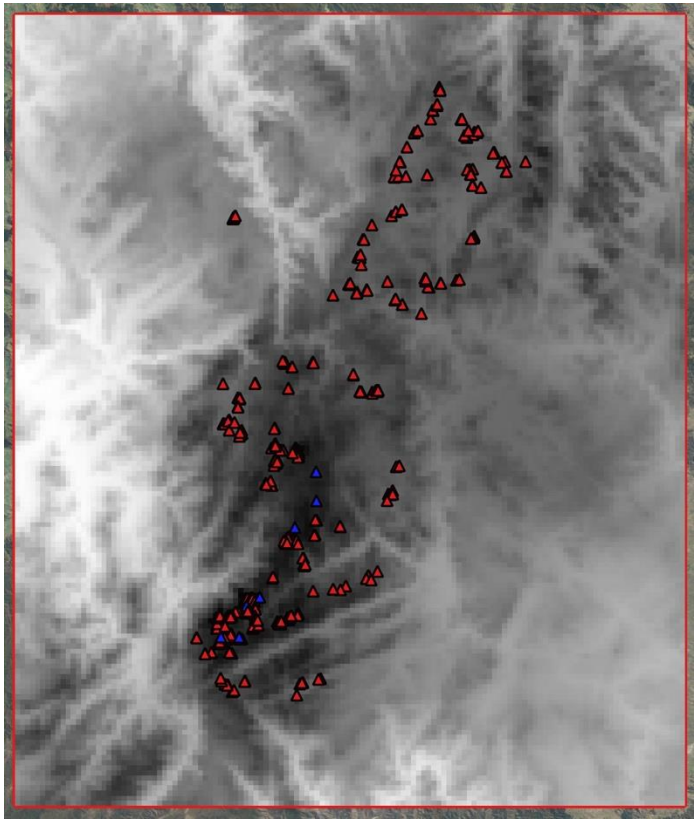
Finding predictors

- The **ERA5** (31 km) and **ERA5-land** (9 km) reanalysis products from ECMWF are currently **best of breed**

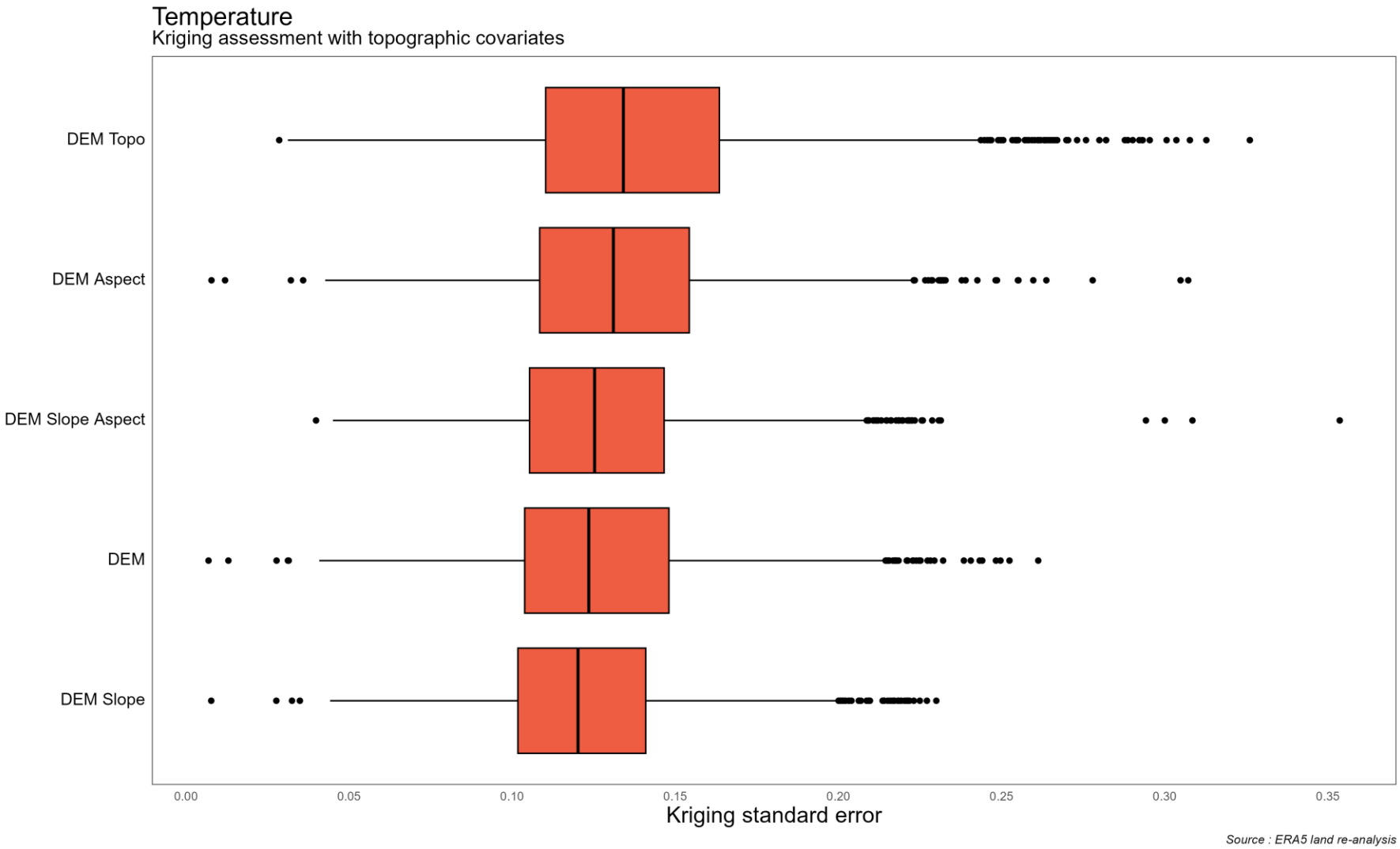
- About **80 variables** (precipitation, solar radiation, total snowfall, soil moisture…)

- Available at **hourly resolutions** back to **1950**

One resolution to rule them all



- 9km cell resolution often **too big**
- So **downscale** with **relevant physics** (**topography** for temperature)
- Covariates for downscaling chosen using **validation** (1/3 cells in random **hold-out sample**)


Temperature
Kriging assessment with topographic covariates
DEM Topo
DEM Aspect
DEM Slope Aspect
DEM
DEM Slope
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Kriging standard error
Source : ERA5 land re-analysis

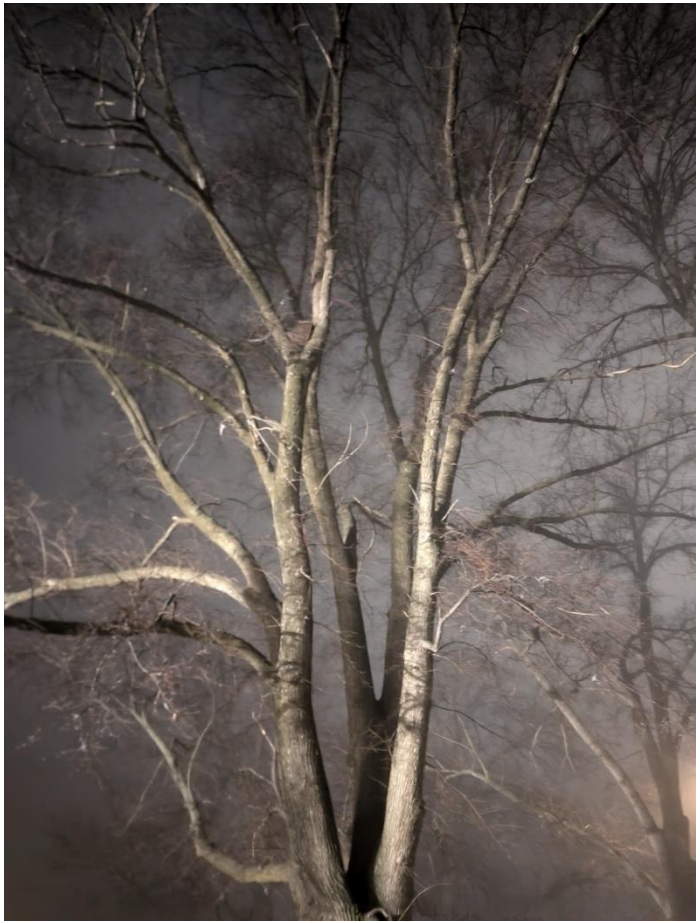
SPECIES ACQUISITION

Building species datasets (finding XYTs…)

- Acquiring **presence-absence** observations over large areas and long time periods turns out to be ***really* hard…**
- Many sources, **many formats**
- Usually **absences** have to be **inferred**

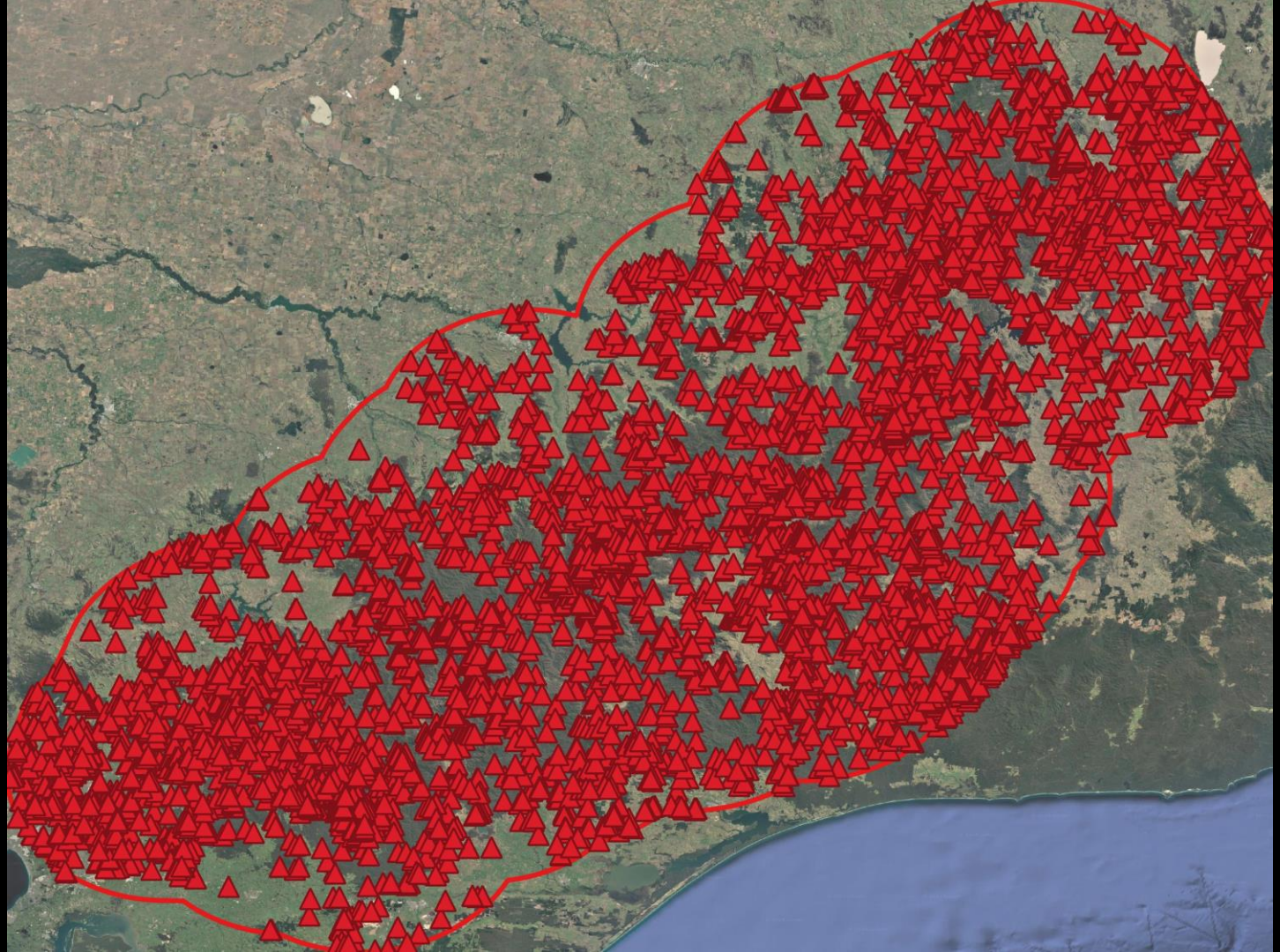
Building species datasets (finding XYTs…)

- We obtained **3.3 million** observations from systematic surveys of **flora** in NSW and Victoria
- Developed a **10-step workflow** (synonyms, taxonomic analysis level, standardisation, filters spatial/temporal clips …)
- Application => **98.5%** data reduction => **focus** on research question



Species selection

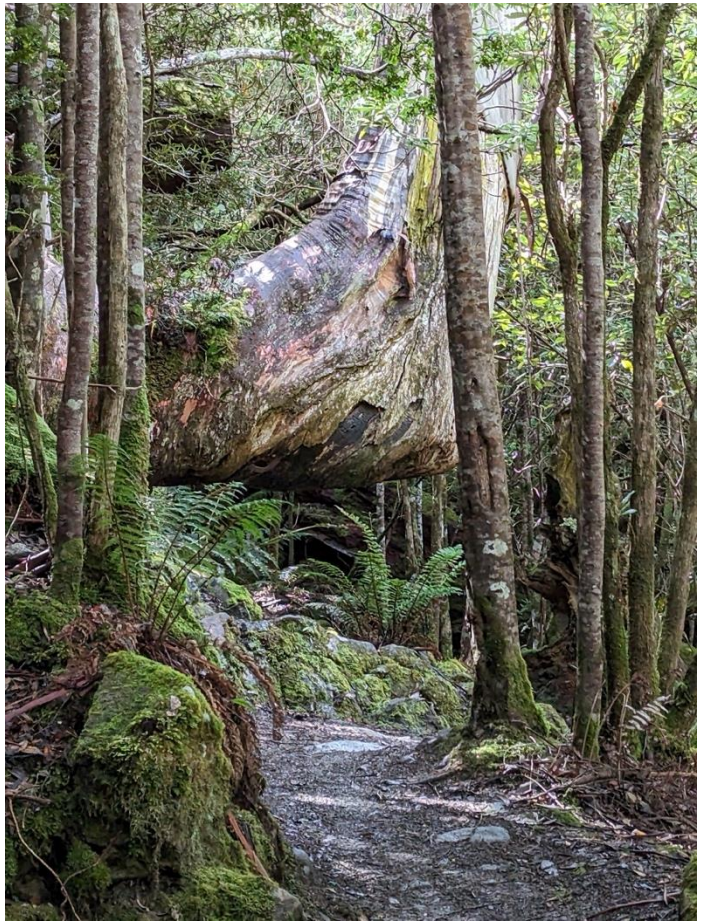
- Presence/absence observations of **Australian native species**
- Temporal window of **at least 30 years**
- Median observation **elevation** of at least **1400m**
- **~120** species datasets and almost **50K** observations over **7300** sites



MODELLING IN SPACE & TIME

Model setup

- GAM regression with a **binomial** response and a **complementary log-log** link
- Temperature/**anomaly** interaction
- non-linear terms : species **response to extremes**



ERA5 anomaly model – main effects

presence

~ aspect (northerness/easterness)

+ soil.moisture

+ temp.mean + temp.mean.anom

+ **temp.mean:temp.mean.anom**

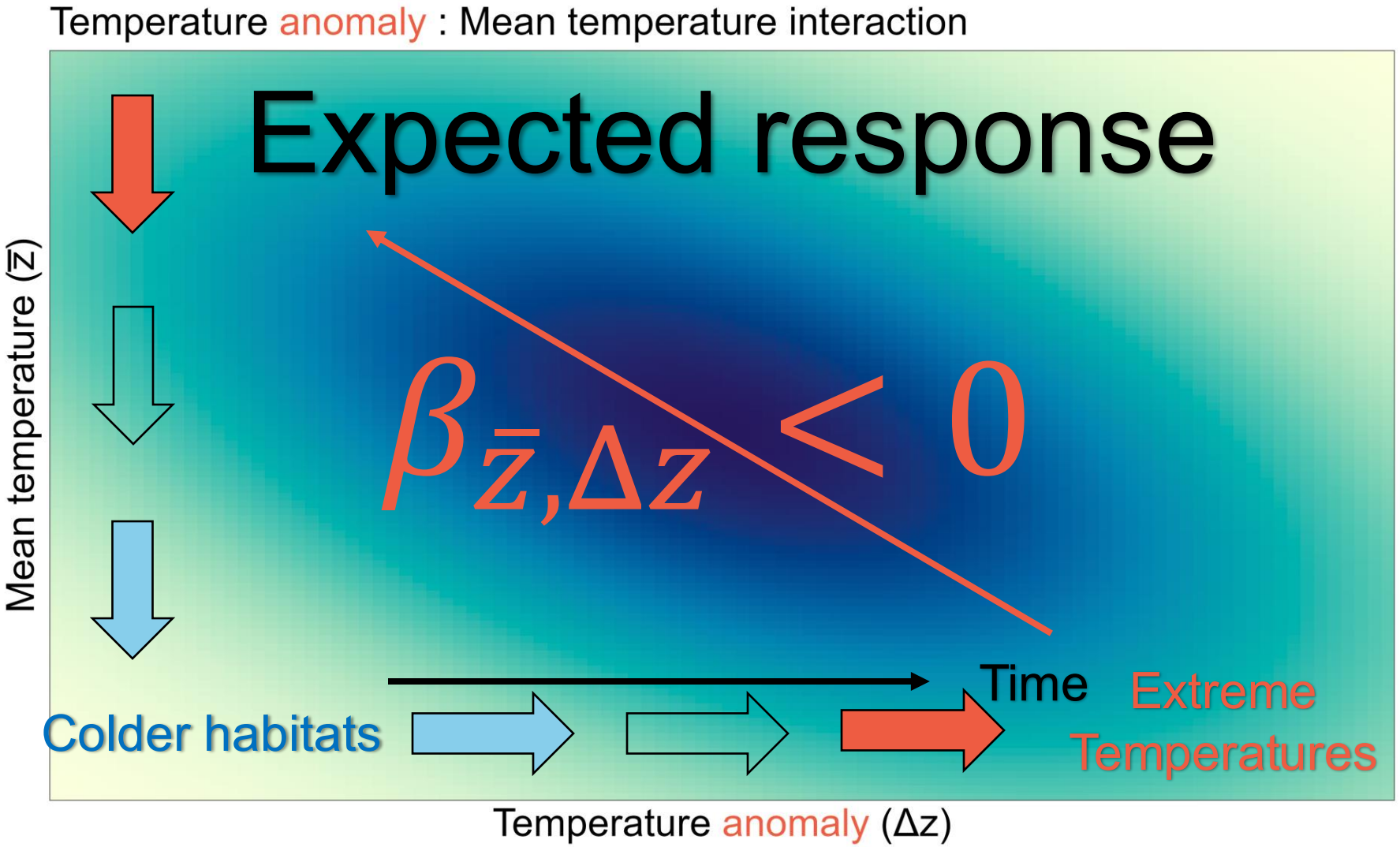
+ <non-linear terms>

+ spatio-temporal **smooth**

ERA5 anomaly model – spatio-temporal smooth

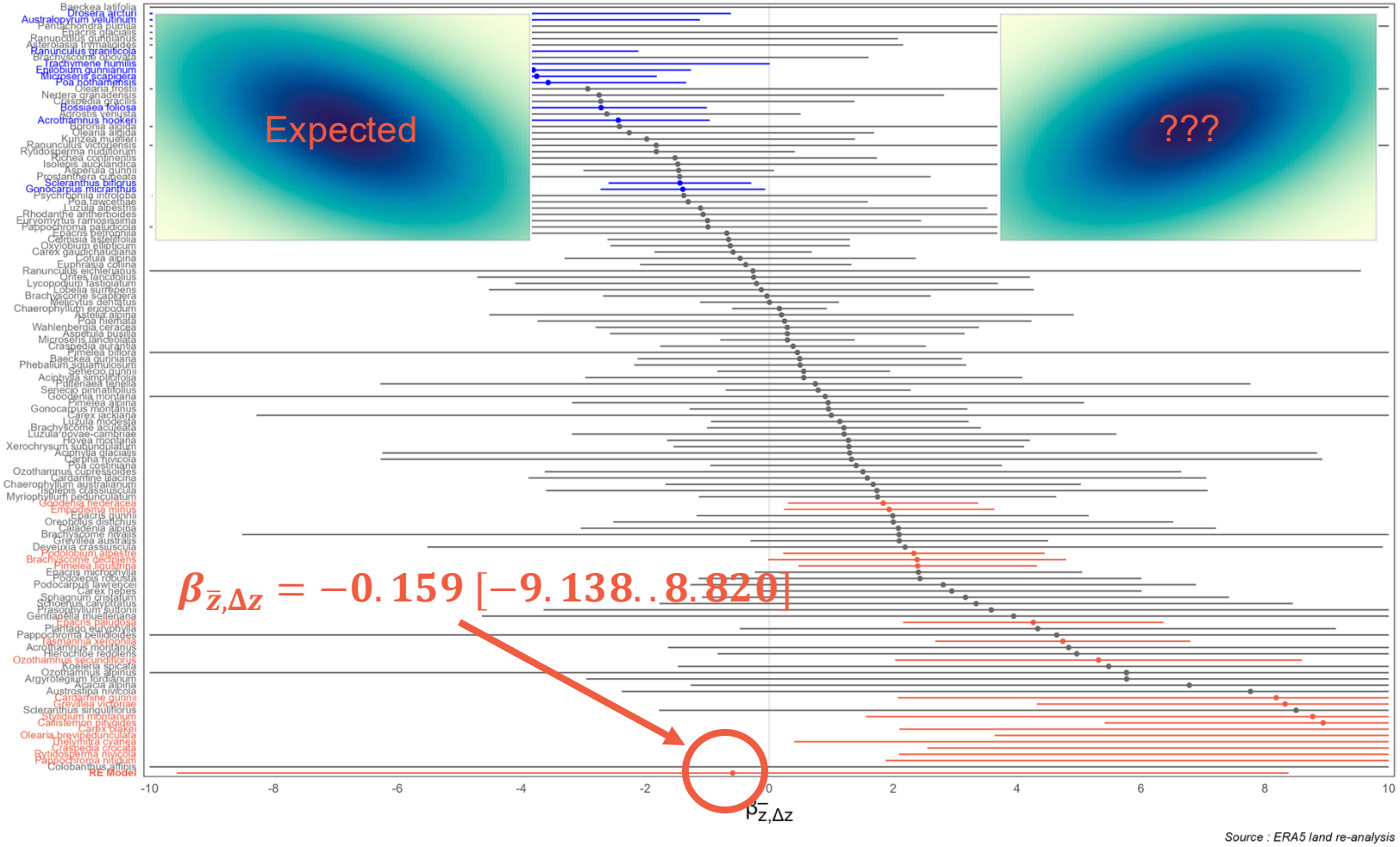
- a **tensor product** of two bases over easting, northing and time
- for spatial, a **gaussian process** basis is applied over 100 knots
- for temporal, a **cubic regression spline** over 5 knots

…ok so *what do we expect here*?


Temperature anomaly : Mean temperature interaction
Expected response
$\beta_{\bar{z},\Delta z} \leq 0$
Mean temperature ($\bar{z}$)
Time
Colder habitats
Extreme Temperatures
Temperature anomaly (Δz)

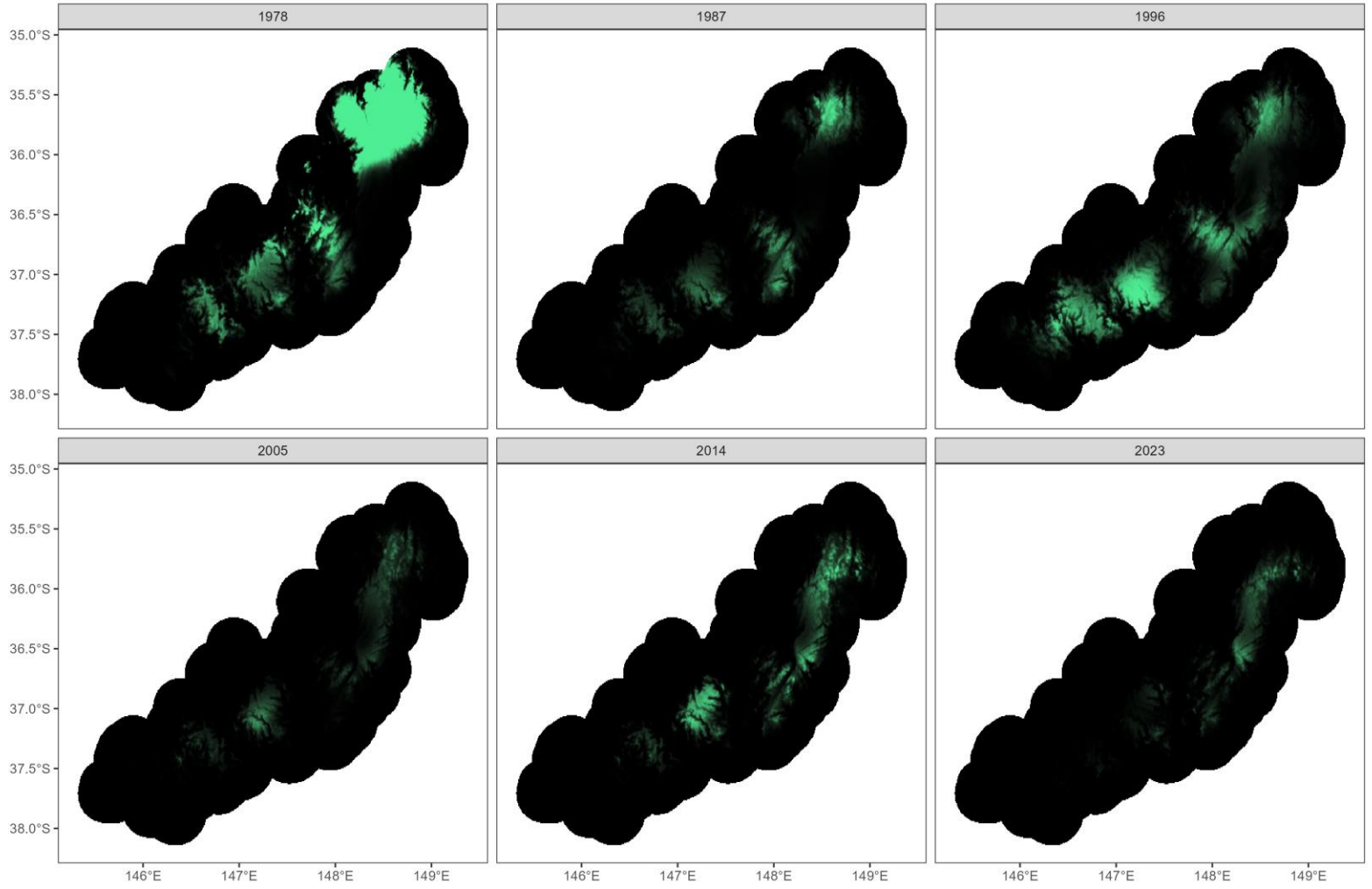
FINDING A CLIMATE CHANGE RESPONSE

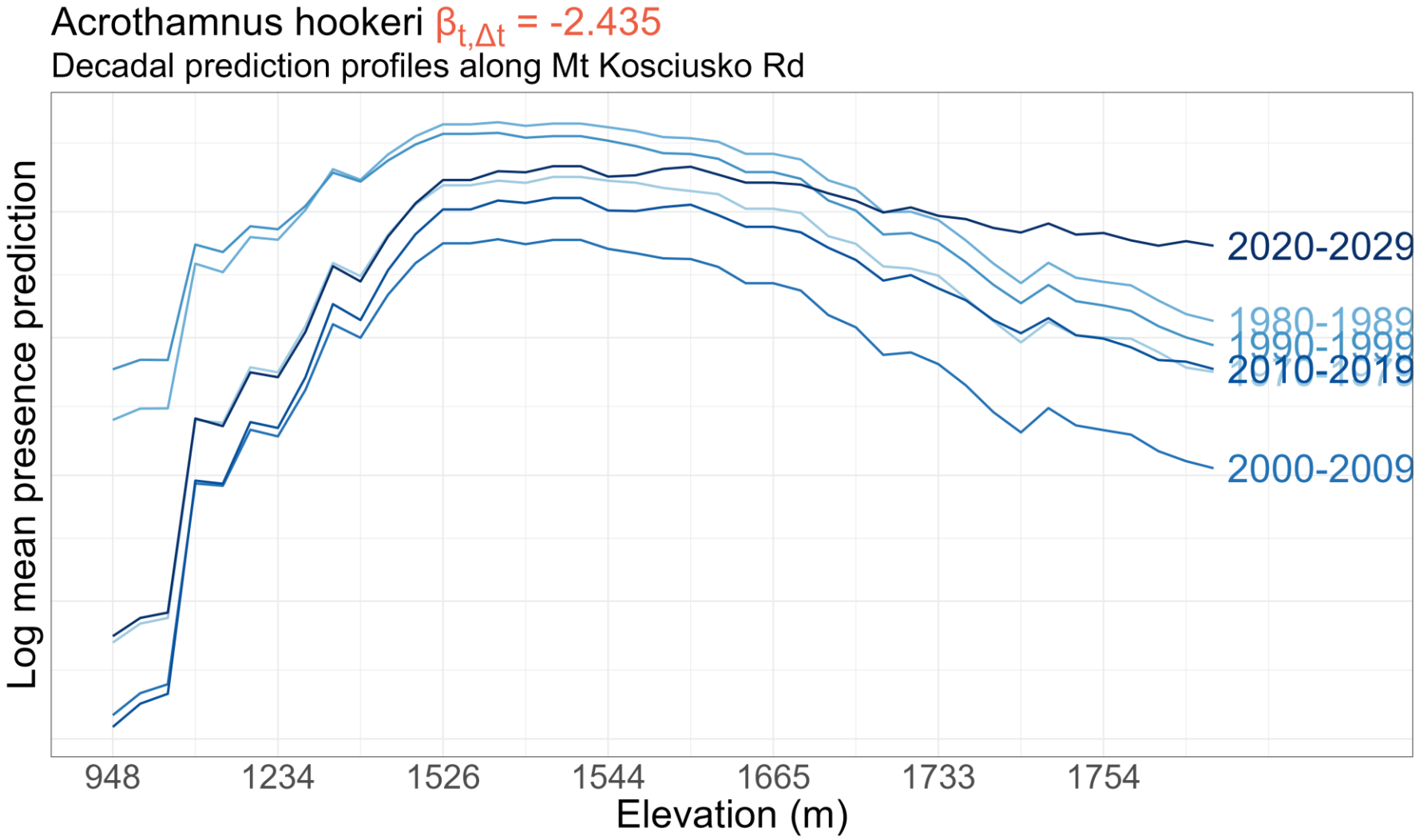
Results Alpine plants appear to be moving to higher **and** lower altitudes



Presence predictions for Acrothamnus hookeri 1978 to 2023

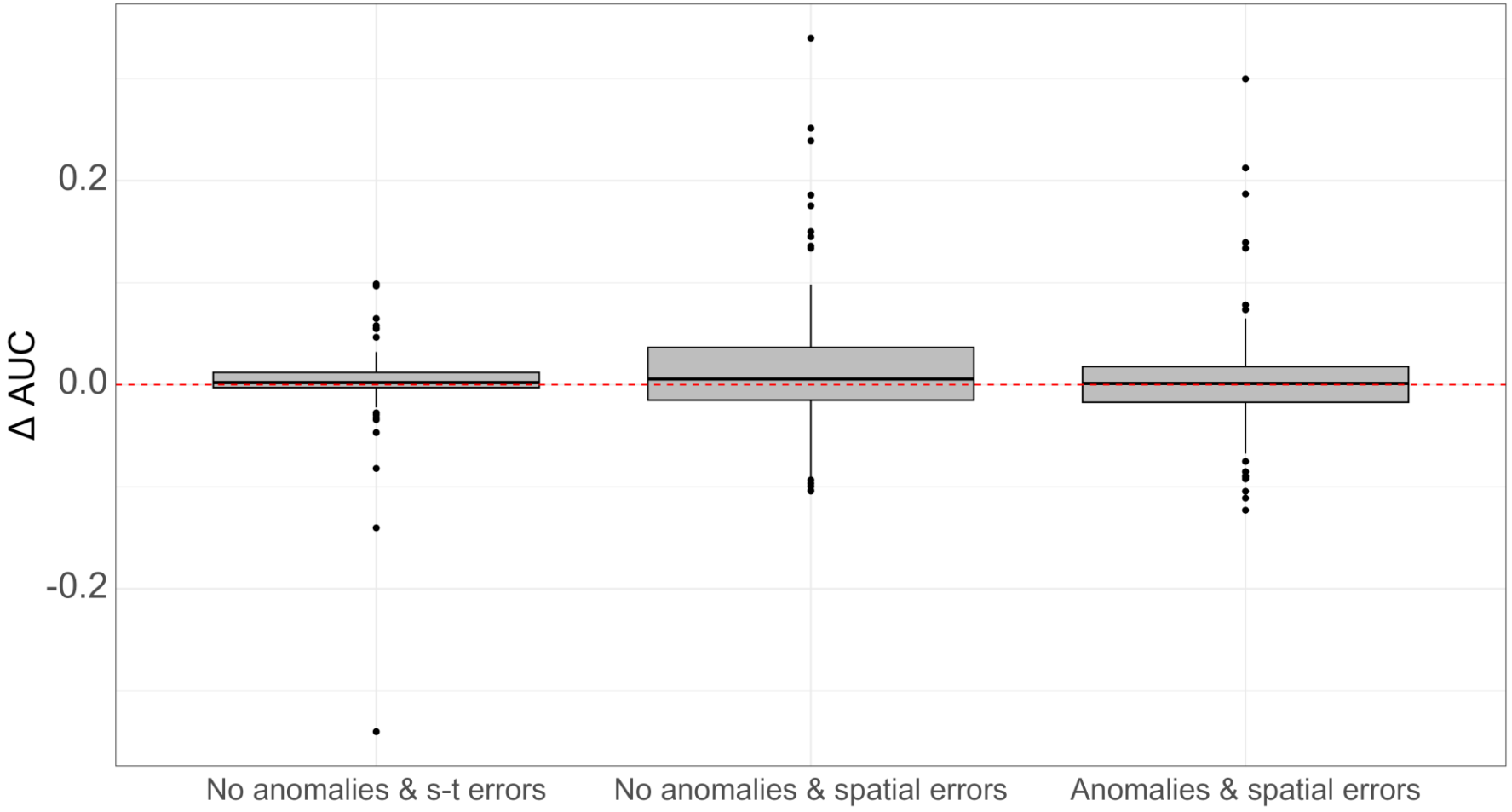
Predictions at 9 year intervals over AUA 25km




Acrothamnus hookeri $\beta_{t,\Delta t}$ = -2.435
Decadal prediction profiles along Mt Kosciusko Rd
Log mean presence prediction
2020-2029
1980-1989
1990-1999
2010-2019
2000-2009
948
1234
1526
1544
1665
1733
1754
Elevation (m)
Source : ERA5 land re-analysis

Predicting species distributions

Change in AUC relative to spatio-temporal anomaly baseline




Trees & GAMs
Anomaly definitions
Climate sources
Temperature variable
Spatial vs Spatio-Temporal
Presence/absence vs Presence only
85 300 km²
46 years
5800 models

Is anything actually going on here?

- Maybe species responses are far more **nuanced** than expected?
- Maybe there is **no spatio-temporal signal** ?

Ockham's Razor…

"Entia non sunt multiplicanda praeter necessitate"

Australian Alpine plants are
not responding
to climate change
as expected

Species responses are complex…

- Our research provides an **entirely new approach**
- Models **must directly link** species responses to climate change
- Which improves their **explanatory** and **predictive** value

Species responses are complex…

- Drive **better research** in **academia**
- Inform **better policy** in **industry**
- And provide better **outcomes for all**


Thank You!