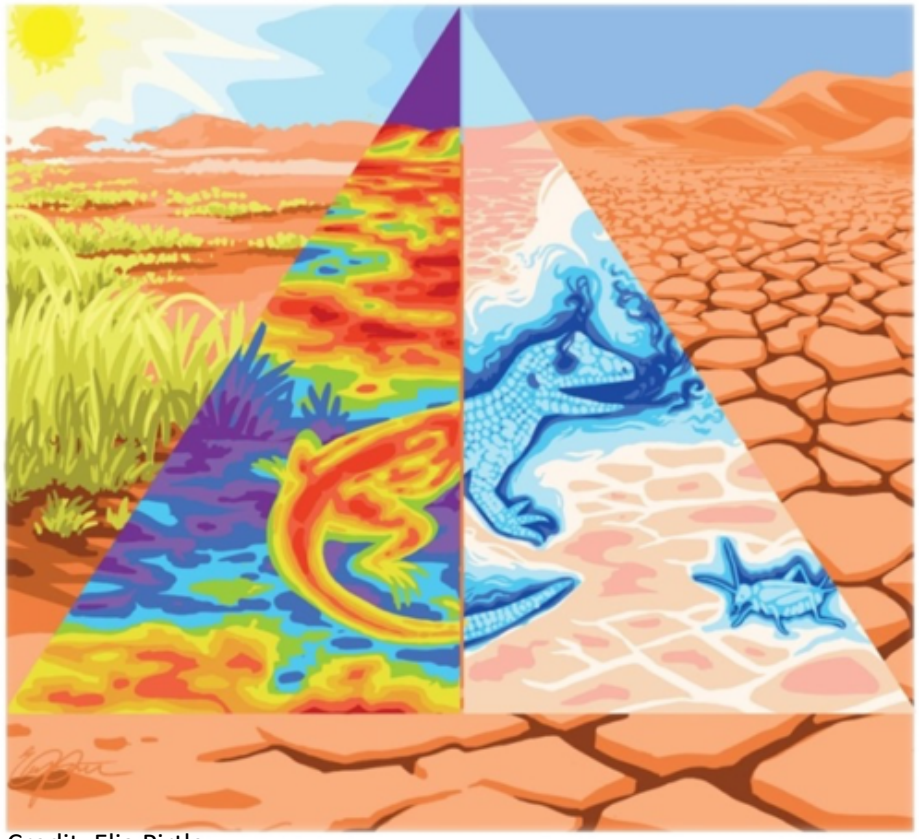
Mechanistic Niche Modelling

Michael Kearney[1] & Lauren Buckley[2]



Credit: Elia Pirtle

School of BioSciences, The University of Melbourne
Department of Biology, The University of Washington

Program

Time	Topic
9:00 -9:15	Introductions
9:15-9:45	What are mechanistic niche models and why do we need them? (MK & LB)
9:45-10:15	Calculating body temperature with TrenchR (LB)
10:15-10:30	Break
10:30-11:15	Intro to microclimate modelling with NicheMapR (MK)
11:15-12:00	Selecting microclimate data (LB & MK)
12:00-13:00	Lunch Break
13:00-13:45	Calculating body/leaf temperature with NicheMapR (MK)
13:45-14:45	Mass budgets with NicheMapR: Dynamic energy budgets (DEB) and water balance (MK)
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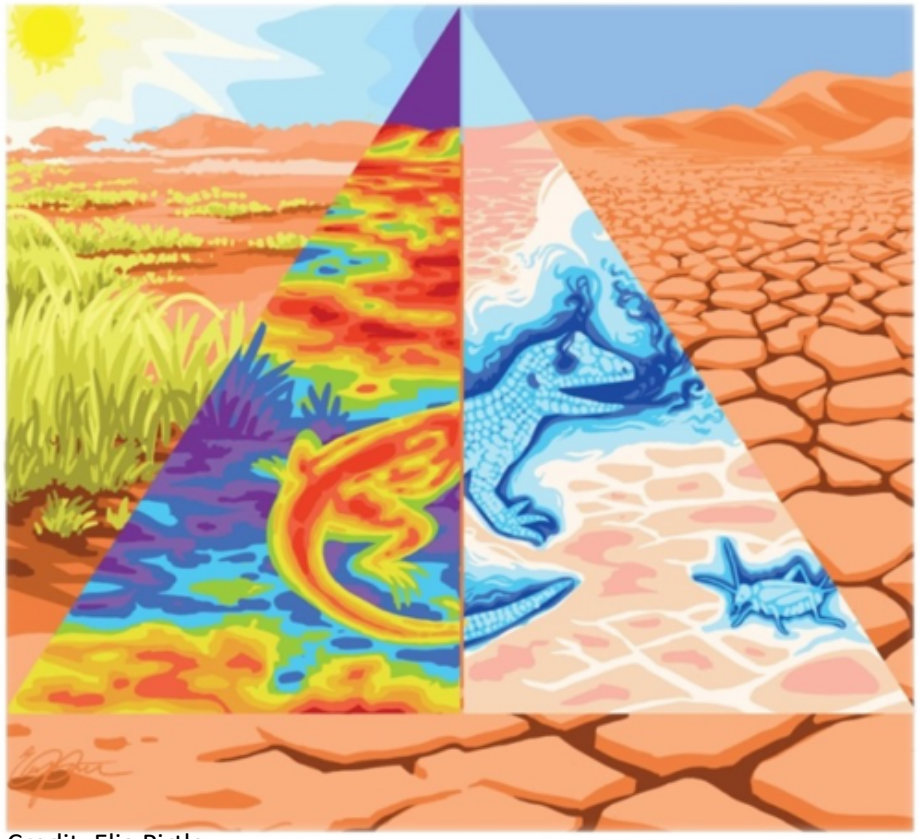
What are Mechanistic Niche Models?



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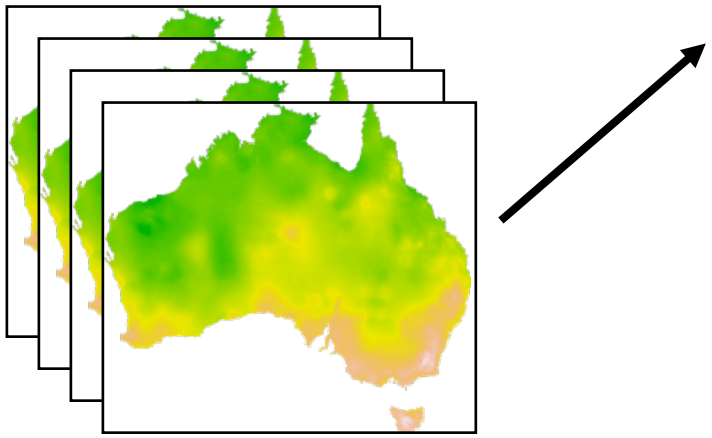
$$Q_{SOLAR} + Q_{IR,in} + J_{O2,MET} + \frac{Q}{J}_{MET} = J_{X,I} + J_{X,G} + J_{X,R} + J_{X,S} + J_{X,P}$$

$$J_{CO2,MET} + J_{N,MET} + J_{H,I} + J_{H,MET} = Q_{IR,out} + Q_{CONV} + J_{H,U} + J_{H,P} + J_{H,S} + \frac{Q}{J}_{EVAP} + Q_{COND} + Q_S$$

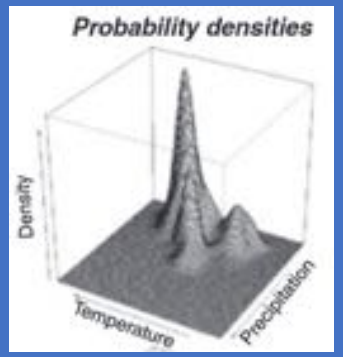
$$C_6H_{12}O_6 + 6\ O_2 \xrightarrow{\text{heat}} 6\ CO_2 + 6\ H_2O$$

Ecological Niche Modelling

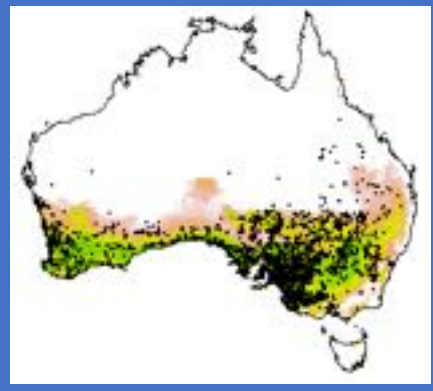


Correlative Model (process implicit)

Maxent model



probability of occurrence



Habitat vs. environment vs. niche

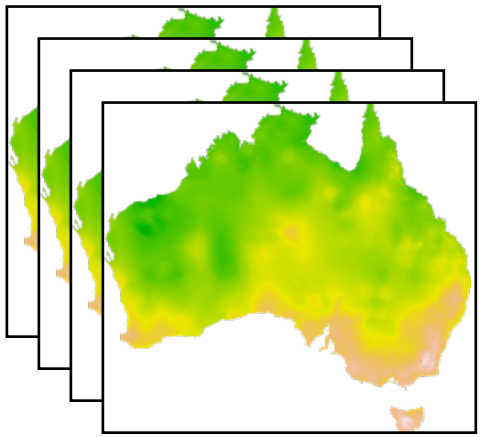
Habitat: a description of a physical place, at a particular scale of space and time, where an organism either actually or potentially lives.

Environment: the biotic and abiotic phenomena surrounding and potentially interacting with an organism.

Niche: a subset of those environmental conditions which affect a particular organism, where the average absolute fitness of individuals in a population is greater than or equal to one.

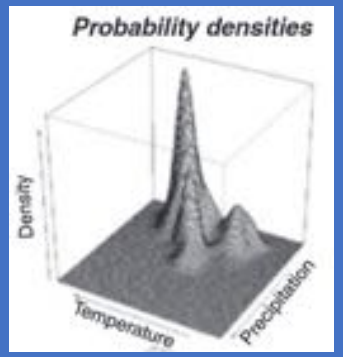
Kearney, M. 2006. Habitat, environment and niche: what are we modelling? — Oikos 115: 186-191.

Ecological Niche Modelling



Correlative Model (process <u>implicit</u>)

Maxent model



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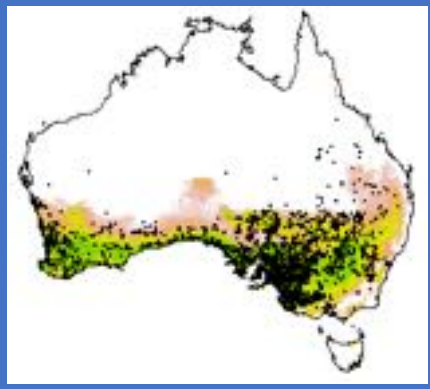
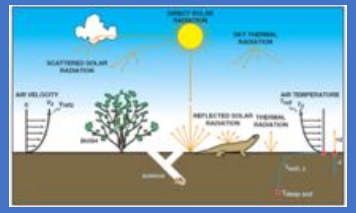
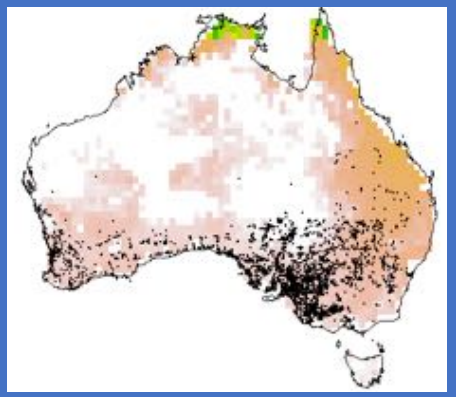


Mechanistic Model (process <u>explicit</u>)

potential reproduction

Thermodynamic Model





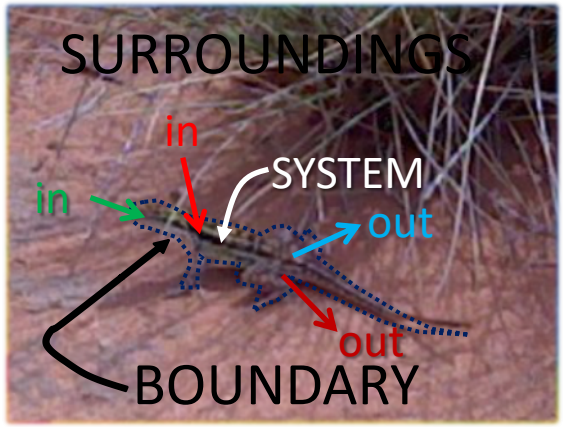
The organism as a thermodynamic system

energy in =

energy out + energy stored

mass in =

mass out + mass stored



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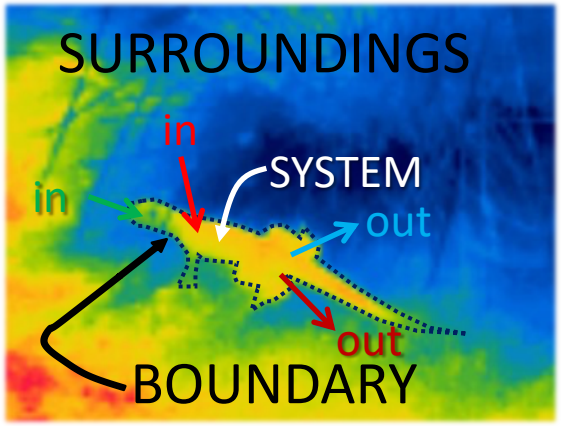
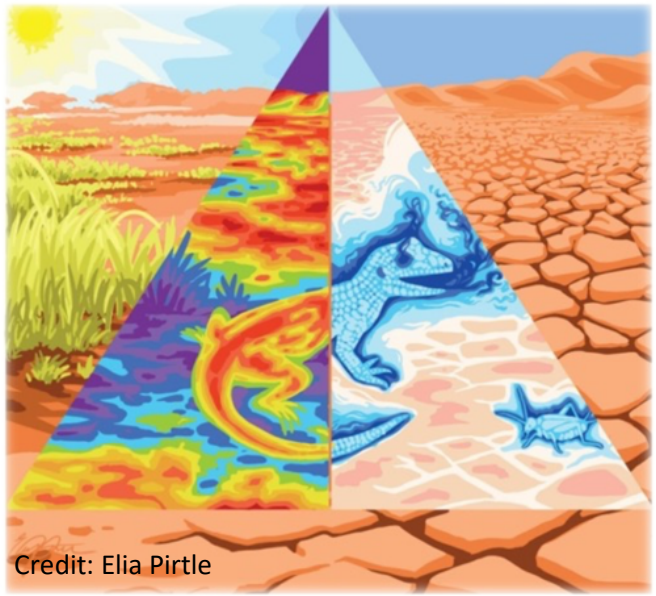
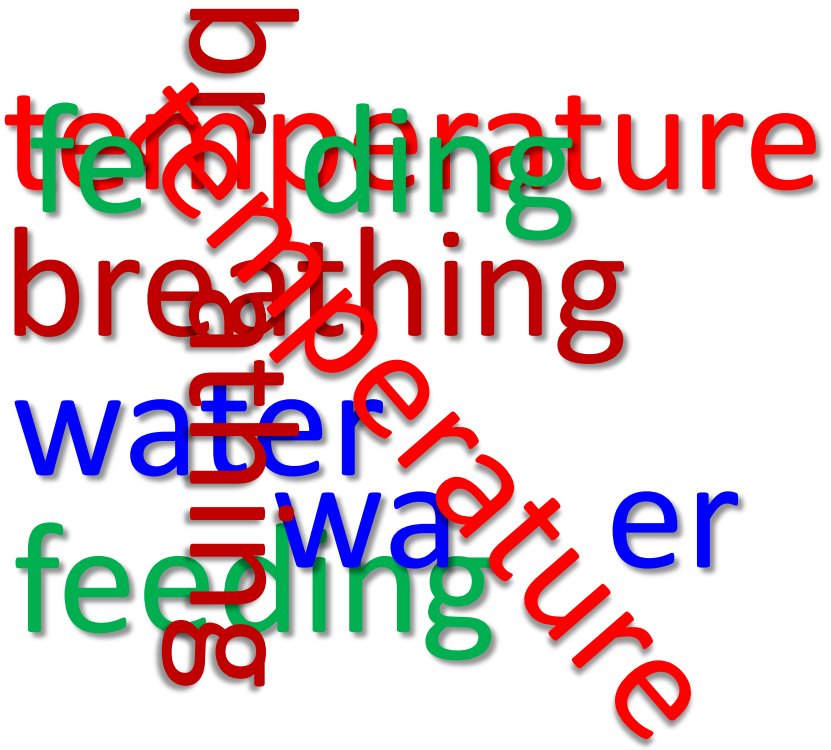



Credit: Elia Pirtle



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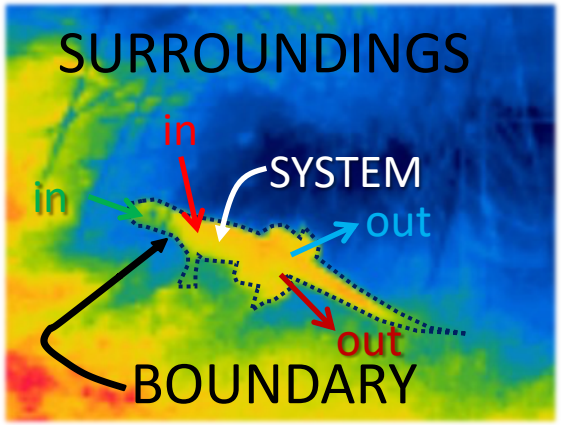
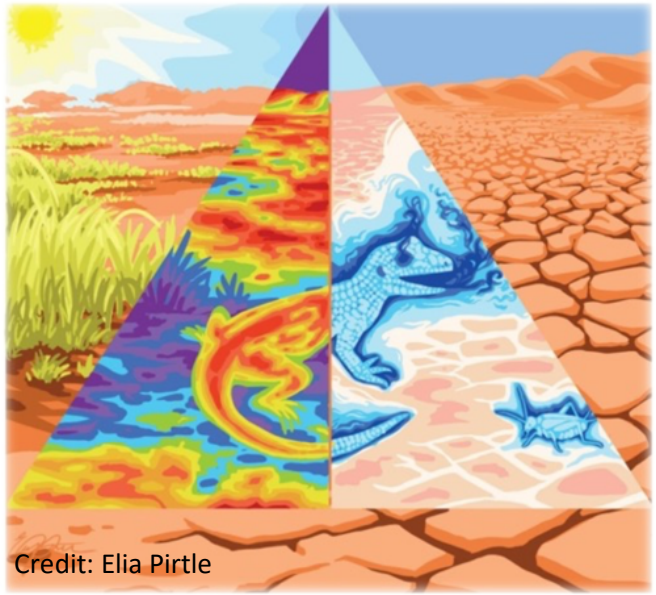



Credit: Elia Pirtle

Q = heat flux J/s
J = mass flux mol/s

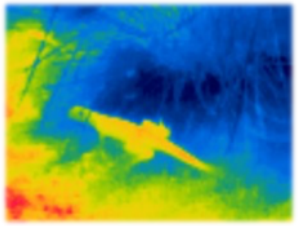
$$Q_{SOLAR} + Q_{IR,in} + J_{O2,MET} + \left(\frac{Q}{J}\right)_{MET} = J_{X,I} + J_{X,G} + J_{X,R} + J_{X,S} + J_{X,P} = Q_{IR,out} + Q_{CONV} + \left(\frac{Q}{J}\right)_{EVAP} + Q_{COND} + Q_S$$

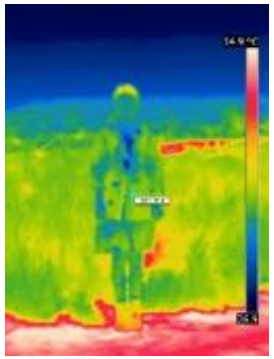
$$J_{CO2,MET} + J_{N,MET} + J_{H,I} + J_{H,MET} = J_{H,U} + J_{H,P} + J_{H,S}$$

heat

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

The Thermodynamic Niche





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heat

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

feeding
temperature
breathing
water

Heat pathways

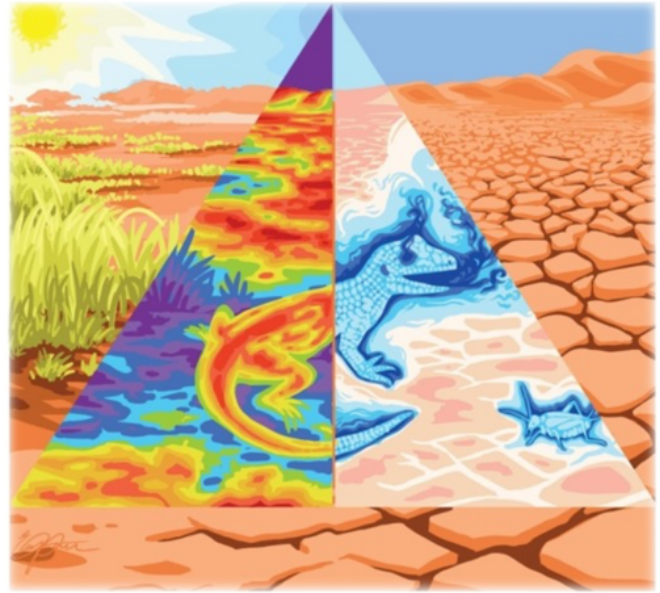
SOLAR = solar radiation
IR = infrared radiation
MET = metabolism
CONV = convection
EVAP = evaporation
COND = conduction

Mass pathways

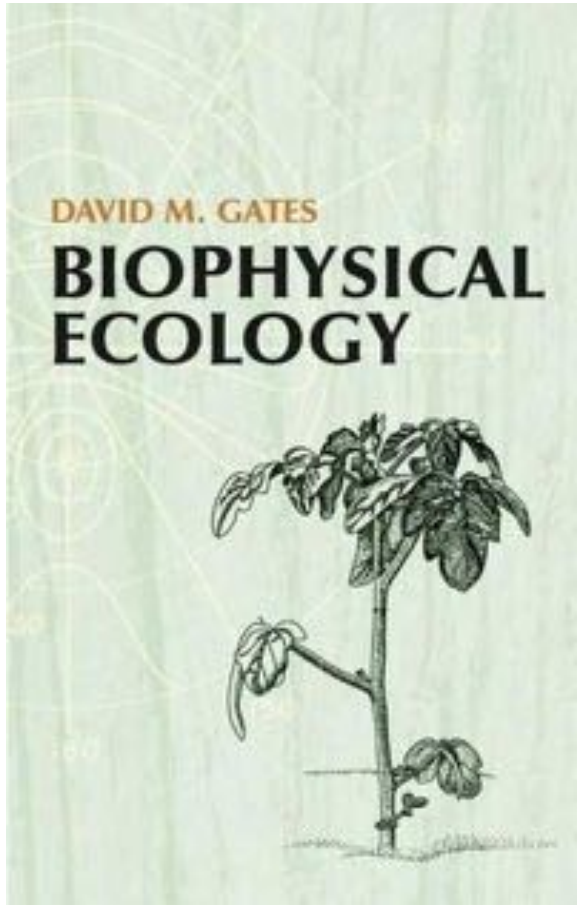
X = food
O2 = oxygen
CO2 = carbon dioxide
N = nitrogenous waste
H = water

Allocation

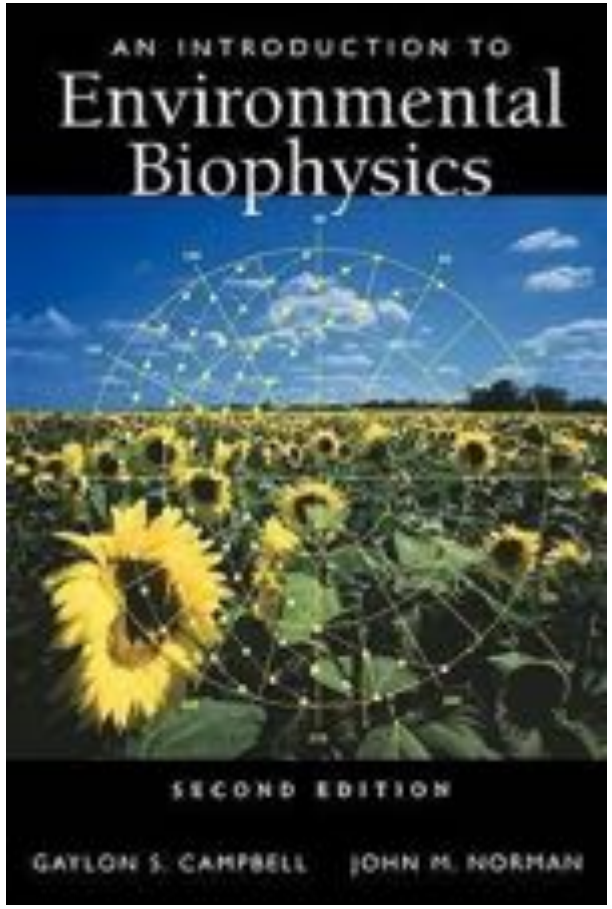
S = stored
I = ingested
G = growth
R = reproduction
P = product (faeces)
U = urinated



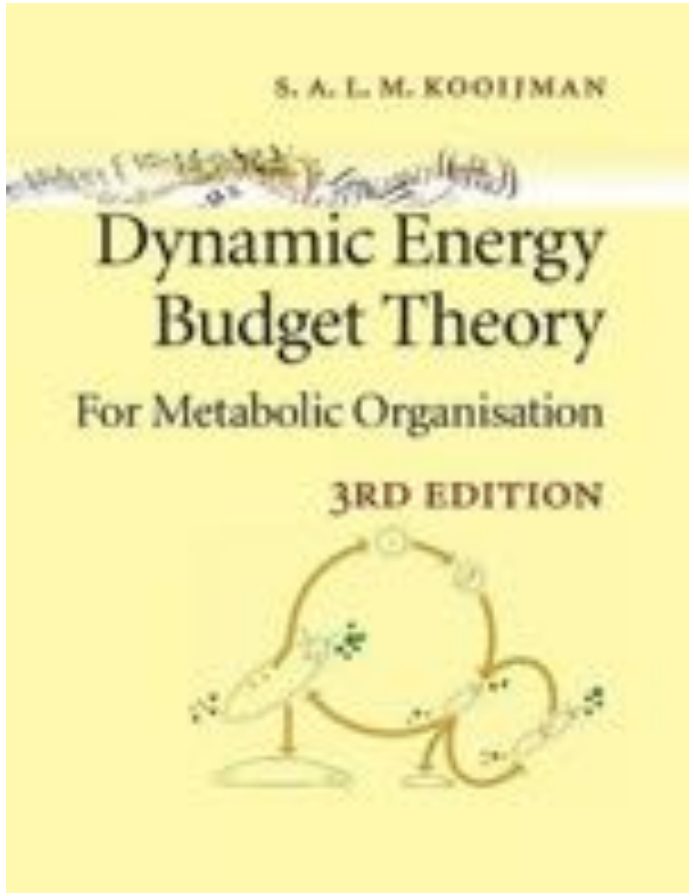
Theory for Mechanistic Niche Modelling



heat and water exchange



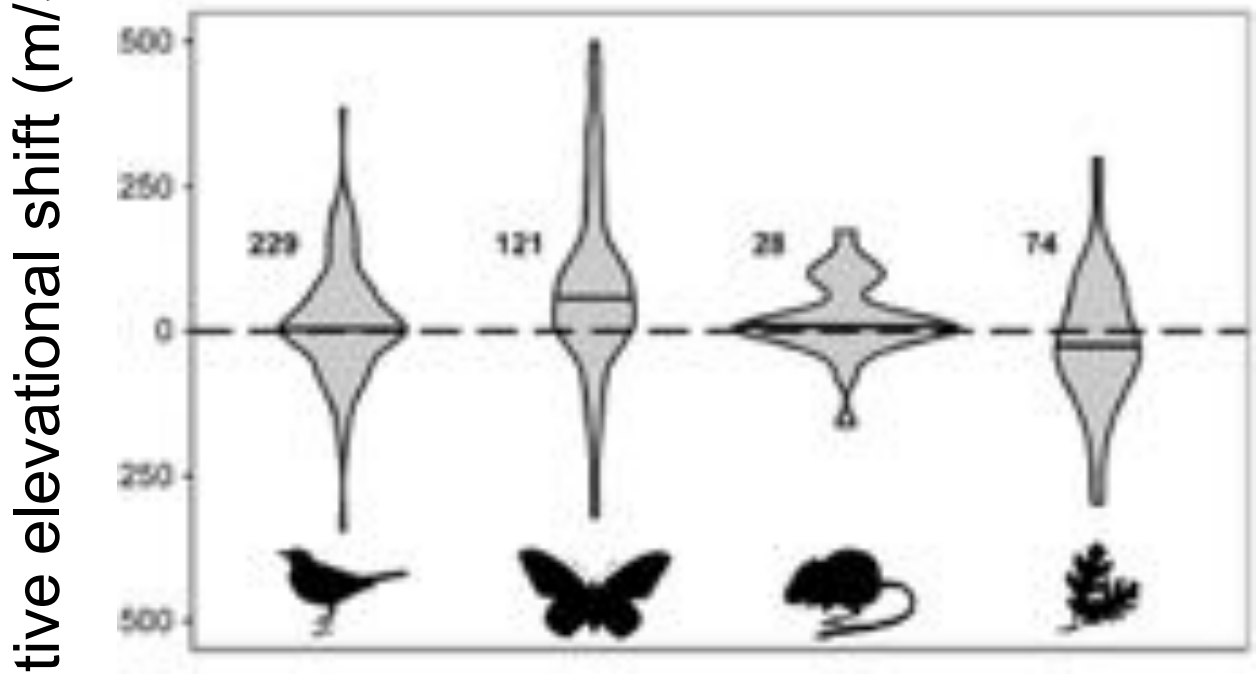
microclimate



metabolism

How can we solve the problem of unpredictability in climate change biology?

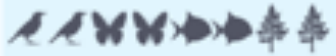
Heterogenous elevation shifts over 20th century in CA



MVZ Grinnell Resurvey
(Rapacciuolo et al. 2014)

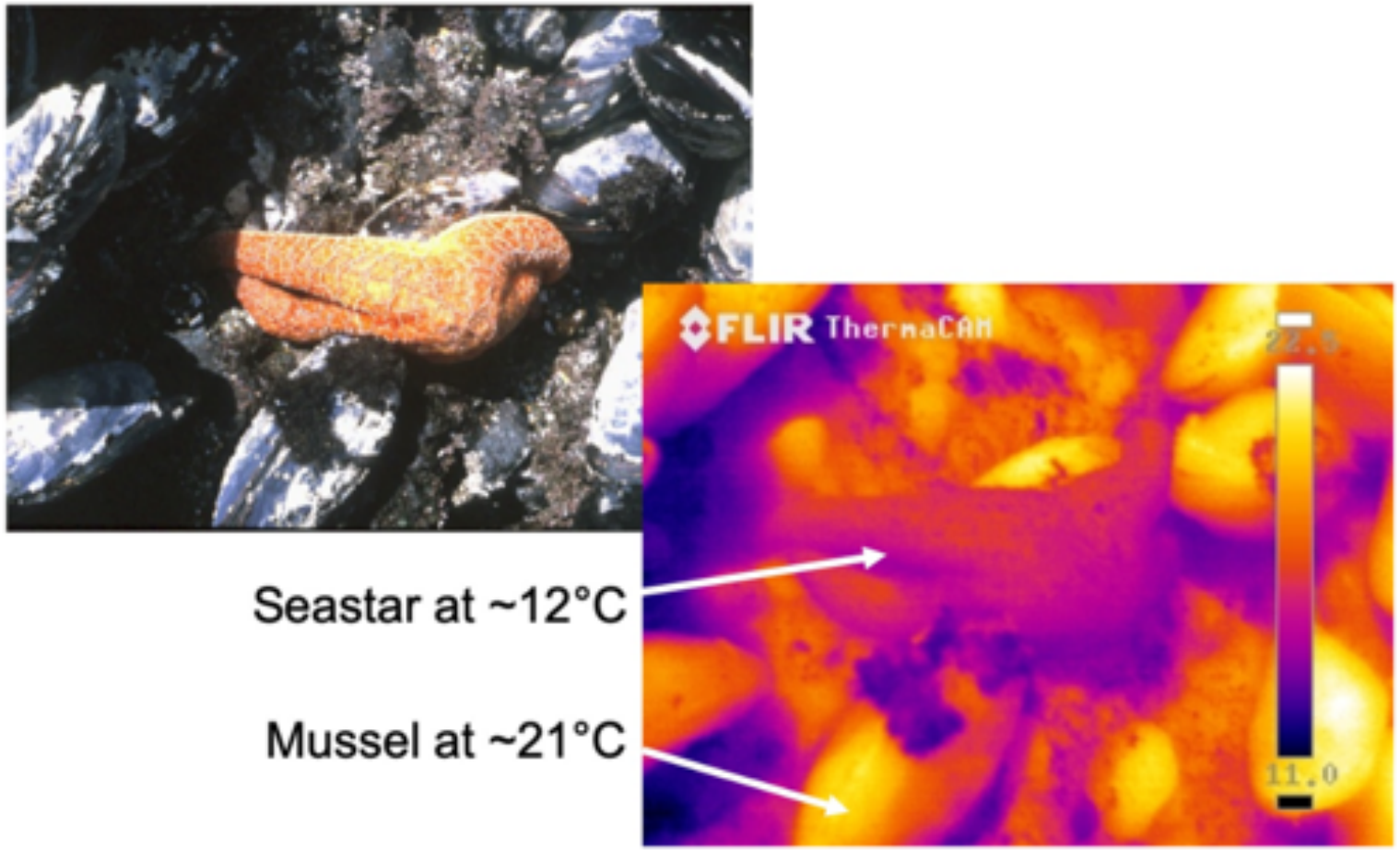
Traits poor predictors of range shifts

- + o

Species traits		Relationship between trait and range shifts		
		Significant, negative	Significant, positive	Not significant
Dispersal ability	Body size (n = 2,098)			
	Migratory strategy (1,249)			
	Movement ability (2,309)			
Reproductive capacity	Fecundity (1,017)			
	Longevity (372)			
Ecological generalization	Diet breadth (2,060)			
	Habitat breadth (2,989)			

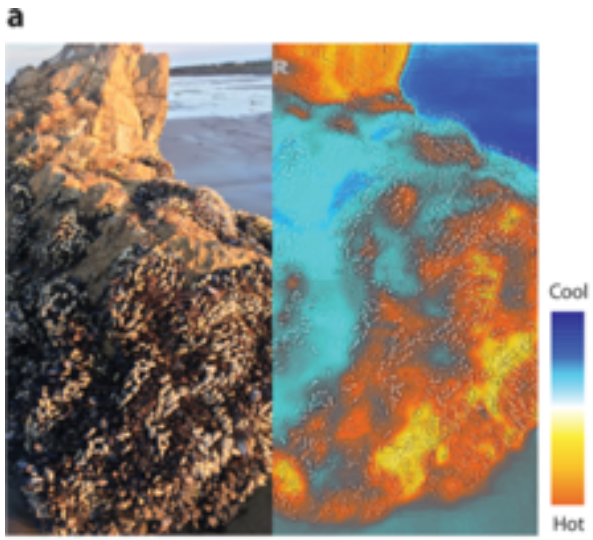
(Beissinger and Riddell 2021 AREE)

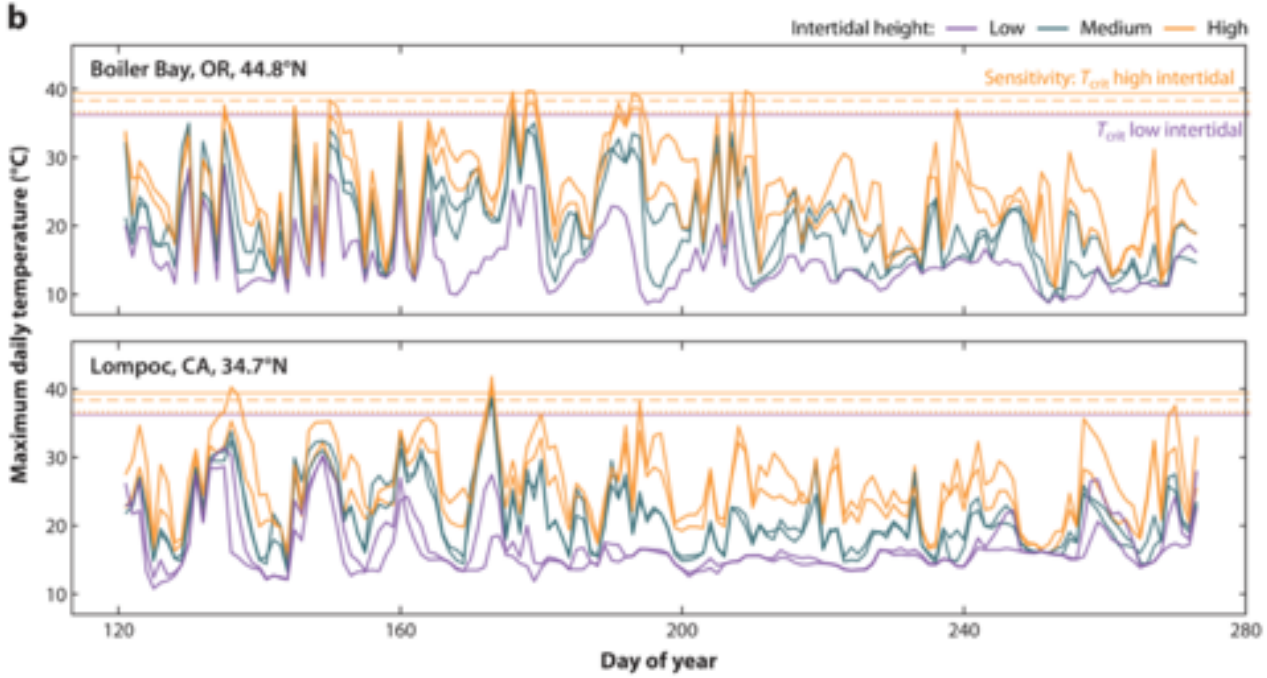
Thinking beyond air temperature to understand how organisms experience climate change



Brian Helmuth

Need to consider both environmental exposure and organismal sensitivity to climate change and variability

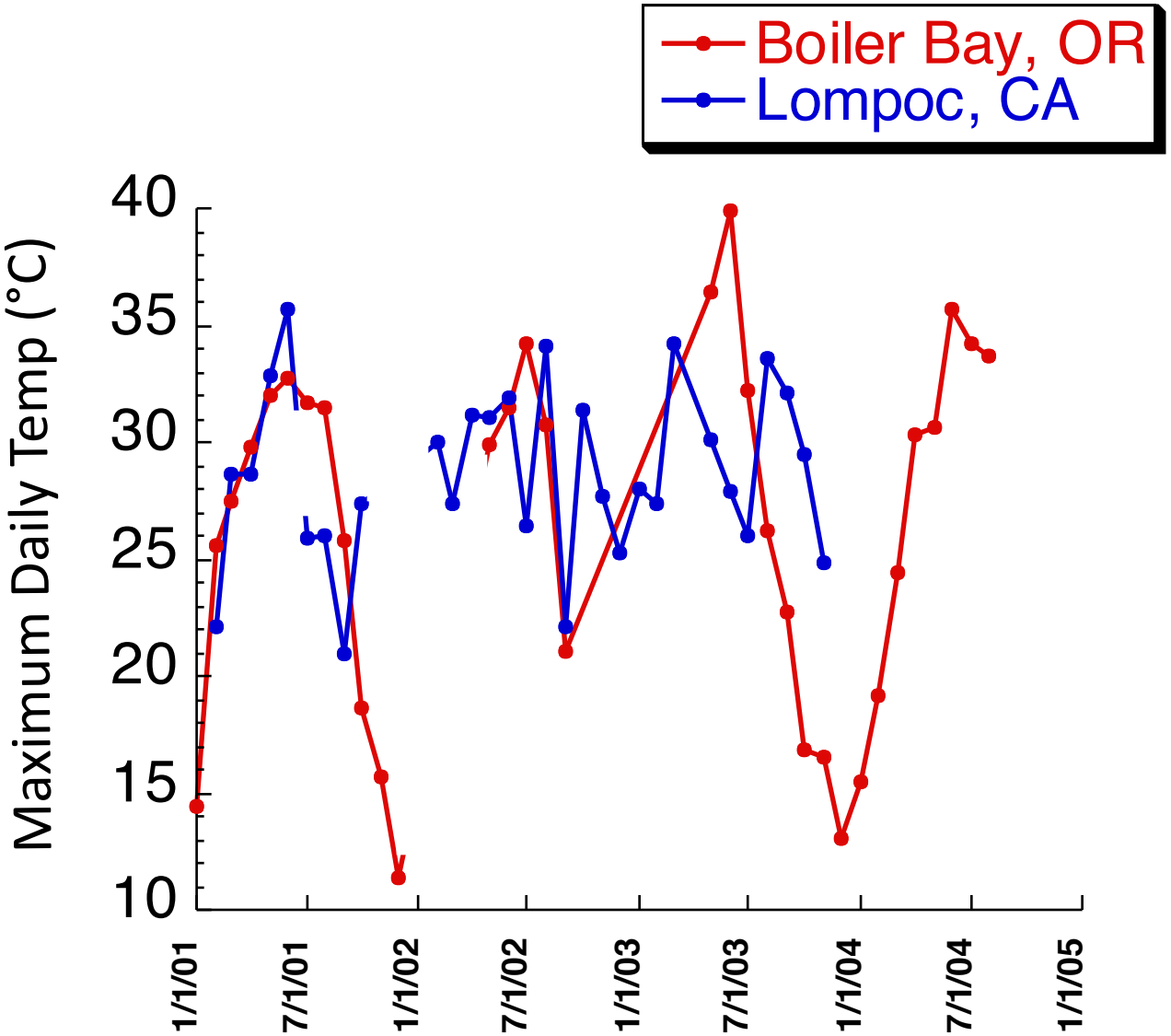




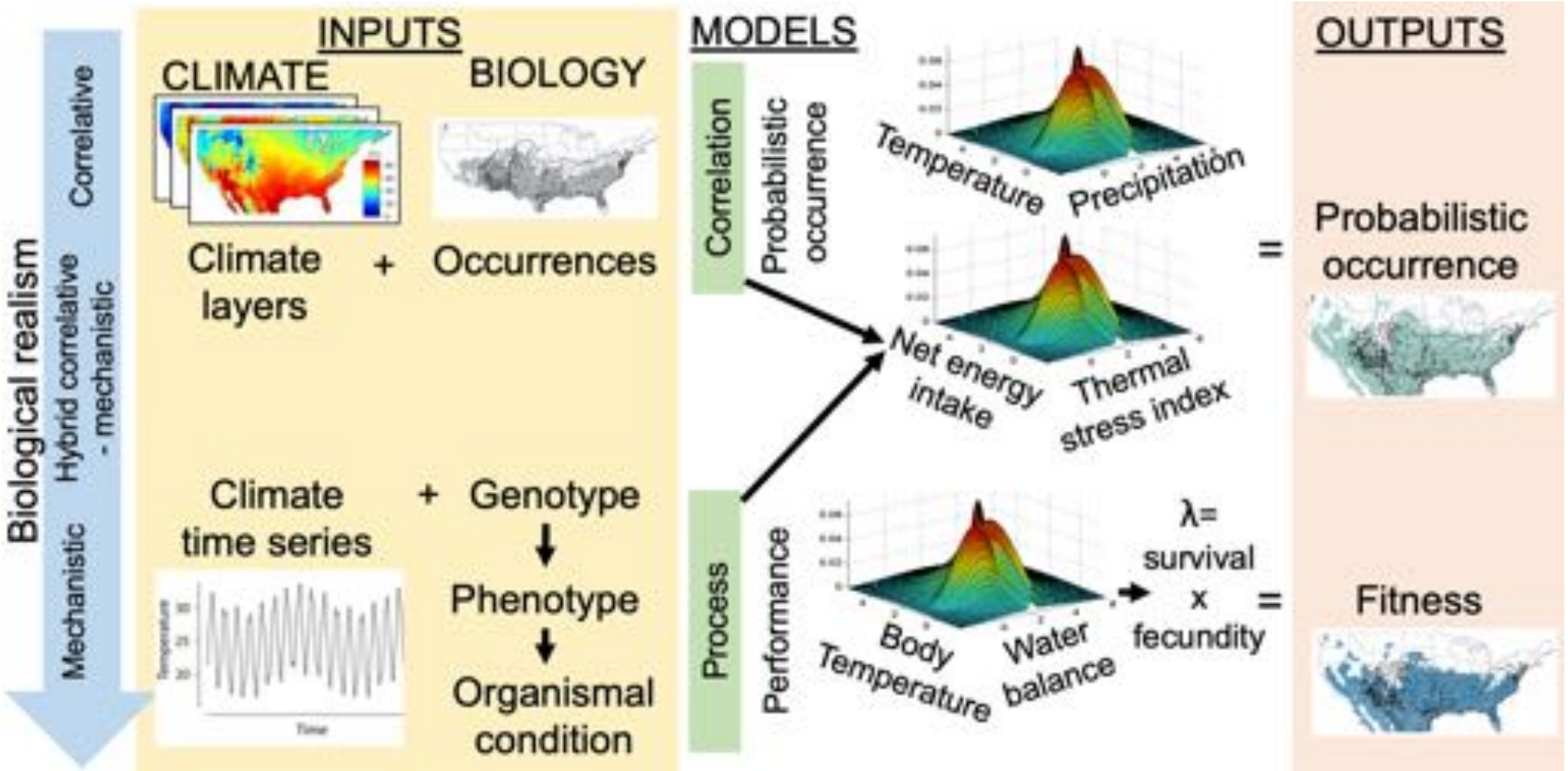
Buckley LB, Kingsolver JG. 2021
Annu. Rev. Ecol. Evol. Syst. 52:563–86

(Buckley and Kingsolver 2021 AREE)

Thermal stress deviates from expected latitudinal gradient



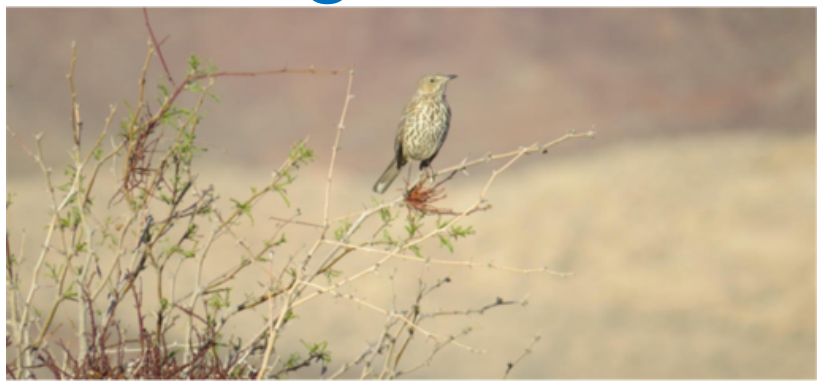
(Helmuth et al. 2002 Science)



(Buckley et al. 2023 PLoS Climate)

Mechanisms driving climate change responses

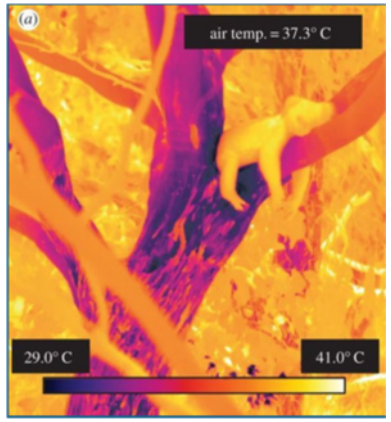
Increased butterfly thermal opportunity offsets survival impacts of thermal extremes
(Buckley and Kingsolver 2019)



Desert mammals fare better than birds due to capacity to buffer thermal extremes
(Riddell et al. 2021)

Pika behavioral buffering of extremes reduces habitat loss
(Mathewson et al. 2017)

Longer lizard reproductive season offsets early life stage survival impacts of thermal extremes
(Levy et al. 2016)



Koala distributions limited by water stress associated with heatwaves and rainfall timing
(Briscoe et al. 2016)

(Buckley et al. 2023 PLoS Climate)

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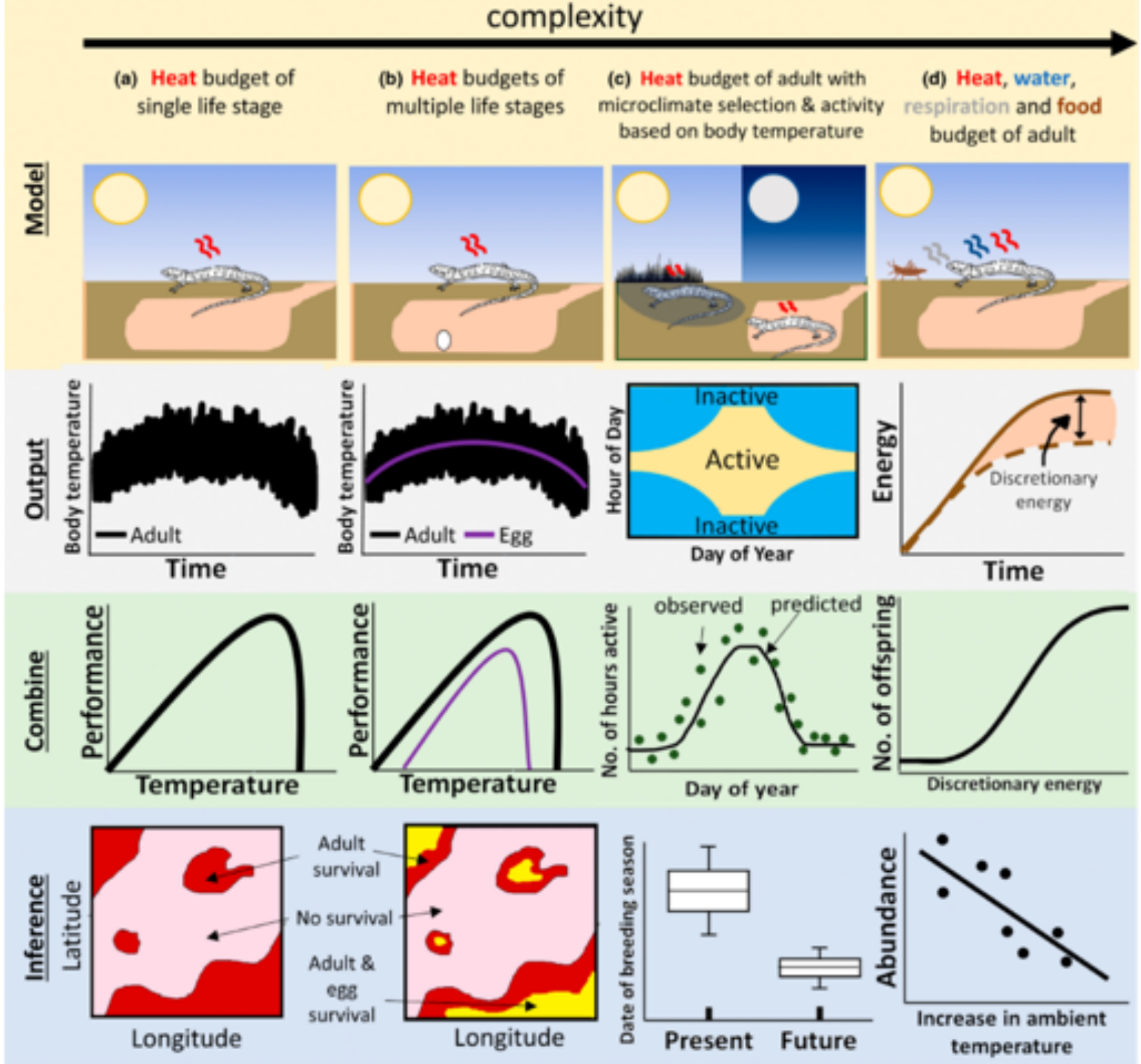
Global Change Biology WILEY

REVIEW

Mechanistic forecasts of species responses to climate change: The promise of biophysical ecology

Natalie J. Briscoe[1] | Shane D. Morris[2] | Paul D. Mathewson[3] | Lauren B. Buckley[4] | Marko Jusup[5] | Ofir Levy[6] | Ilya M. D. Maclean[7] | Sylvain Pincebourde[8] | Eric A. Riddell[9] | Jessica A. Roberts[2] | Rafael Schouten[10] | Michael W. Sears[11] | Michael Ray Kearney[2]


complexity
(a) Heat budget of single life stage
(b) Heat budgets of multiple life stages
(c) Heat budget of adult with microclimate selection & activity based on body temperature
(d) Heat, water, respiration and food budget of adult
Model
Output
Body temperature
Adult
Time
Body temperature
Adult
Egg
Time
Hour of Day
Inactive
Active
Inactive
Day of Year
Energy
Discretionary energy
Time
Combine
Performance
Temperature
Performance
Temperature
No. of hours active
observed
predicted
Day of year
No. of offspring
Discretionary energy
Inference
Latitude
Longitude
Adult survival
No survival
Adult & egg survival
Longitude
Date of breeding season
Present
Future
Abundance
Increase in ambient temperature

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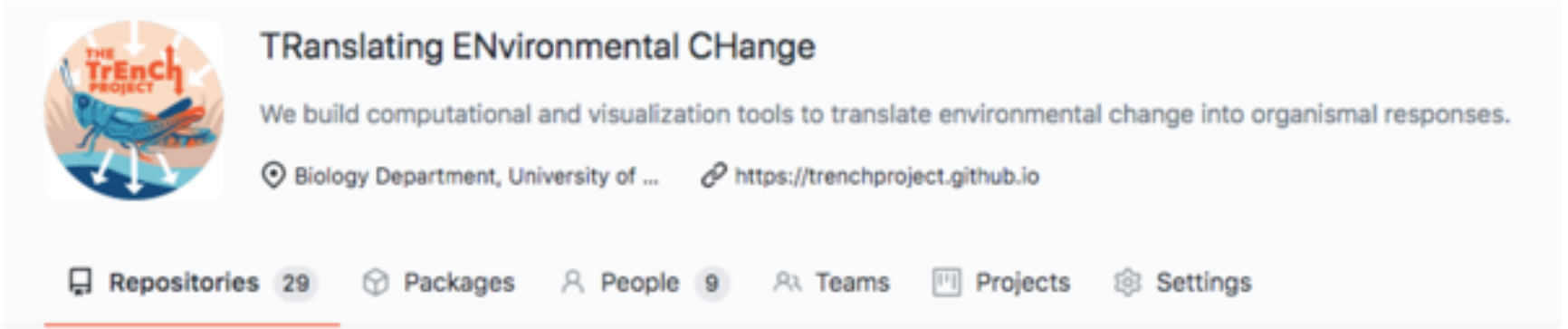
Tools for Translating Environmental Change into organismal responses

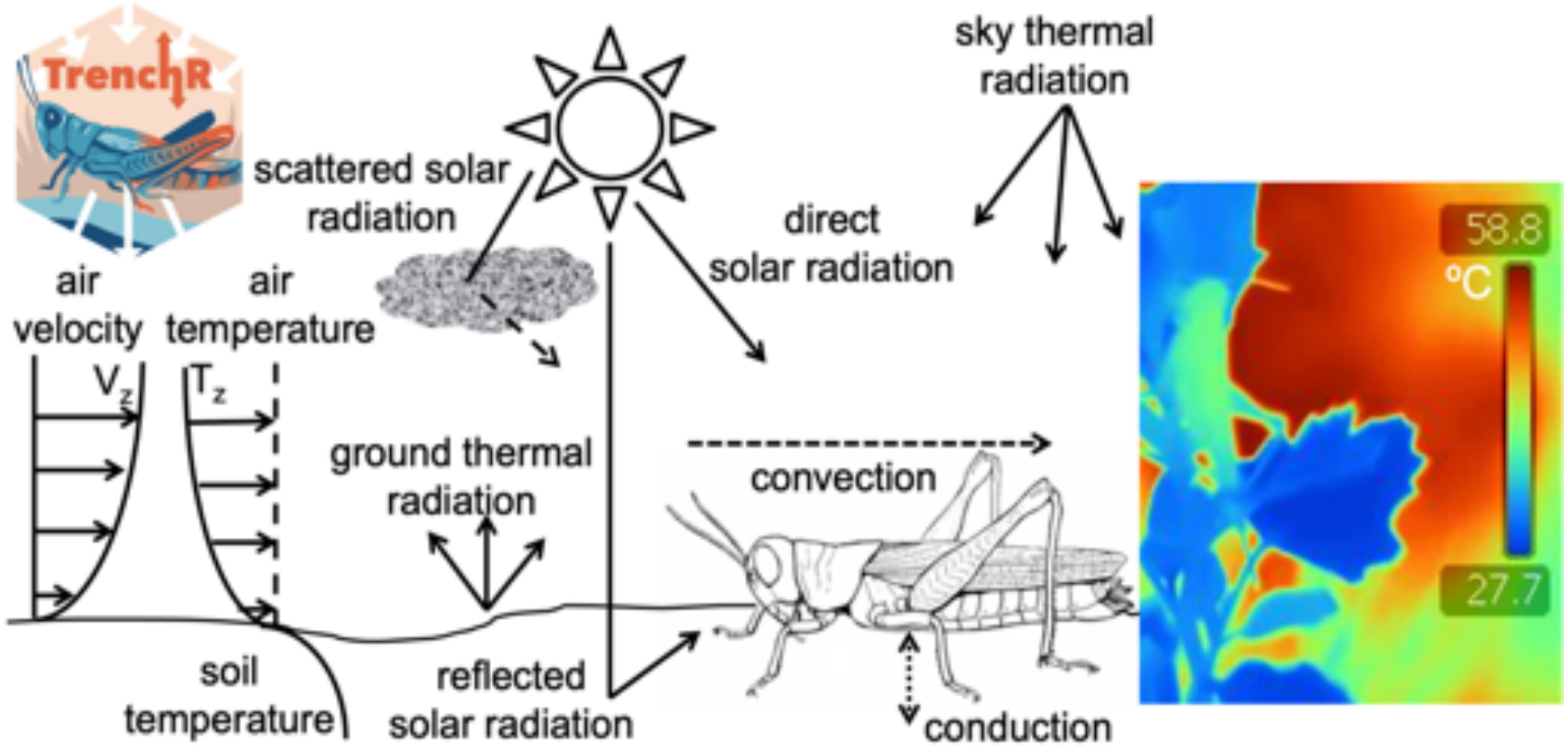
trenchproject.com



TrenchR

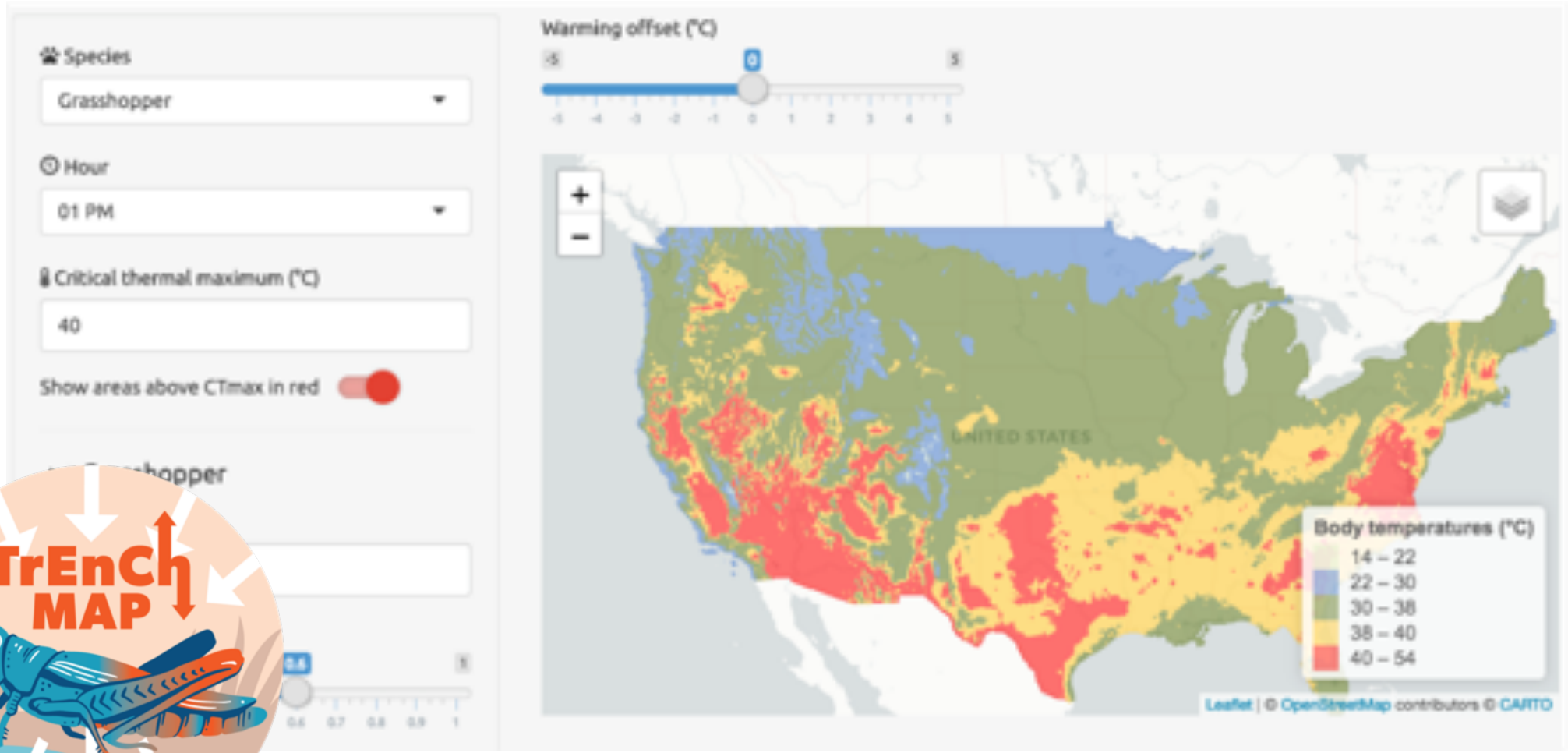
R package for modular and accessible

microclimate and biophysical modelling



TrEnCh Map:

interfaces for examining thermal stress



Education modules for researchers

bookdown.org/huckley/Physical_Processes_In_Ecosystems/

Apps Bookmarks Online LaTeX Equ... UW Libraries - Off... CSV to Markdown... Pakillo/Rpackages... UW Biology facult... Flights mhw_stressviz/To...

Physical Processes in Ecosystems

Foreward

1 Calculus-Integration

2 Calculus-Differentiation

3 Dimensional Methods

4 Foundations of Physical Theory

5 Thermodynamics Intro

6 Thermodynamic Applications

7 Heat Transfer

8 Light and Sound

9 The Climate Space Concept

10 Operative Temperature

11 Transpiration and Leaf Temperature

12 Heat Balance of a Sheep

13 Soil Heat Flow

14 Turbulence and Fluid Flow

15 Appendix 1. Working with microclim

16 Appendix 2. Mapping climate space

17 List of Symbols

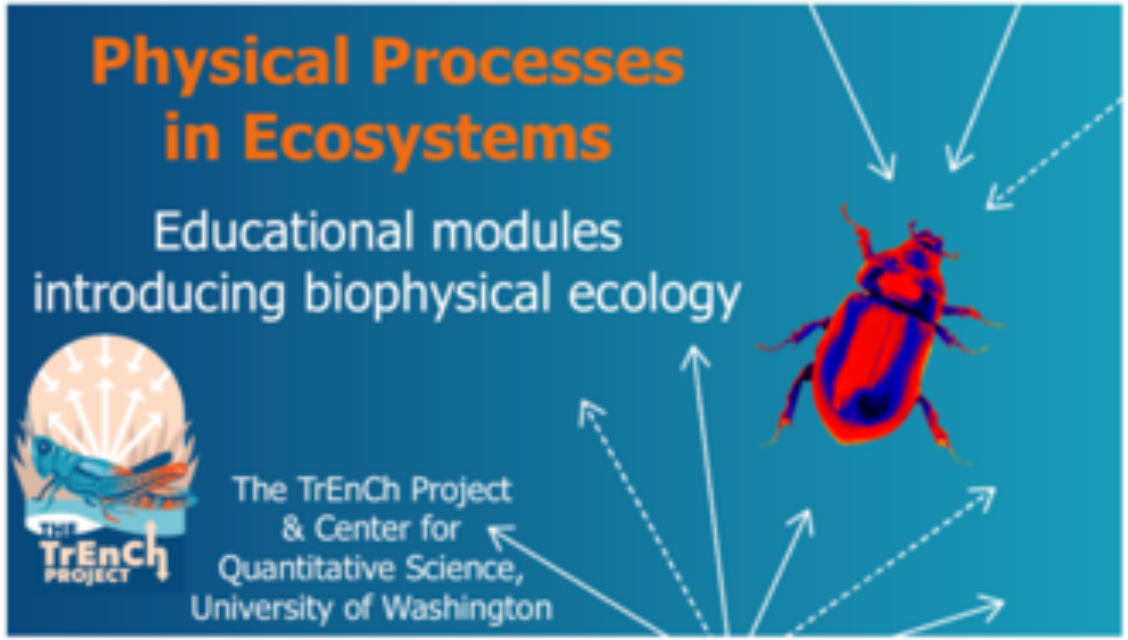
Published with bookdown

Physical Processes in Ecosystems

University of Washington Center for Quantitative Science, Updated by the TrEnCh Project

2020-11-23

Foreward

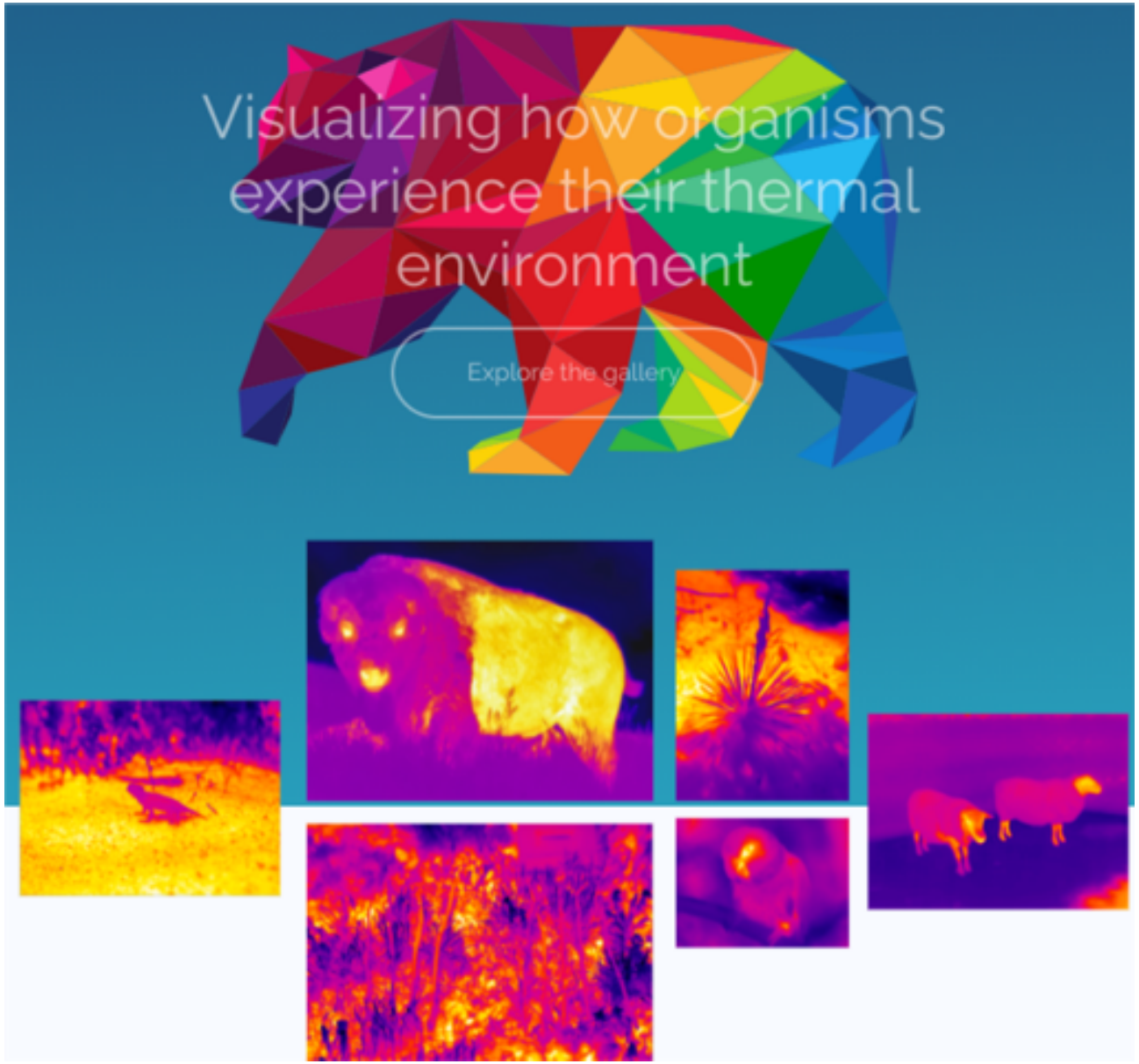


TrEnCh-Ed


TrEnCh-Ed
Welcome! Learn about TrEnCh education


Climate Change

TrEnCh-IR thermal image repository

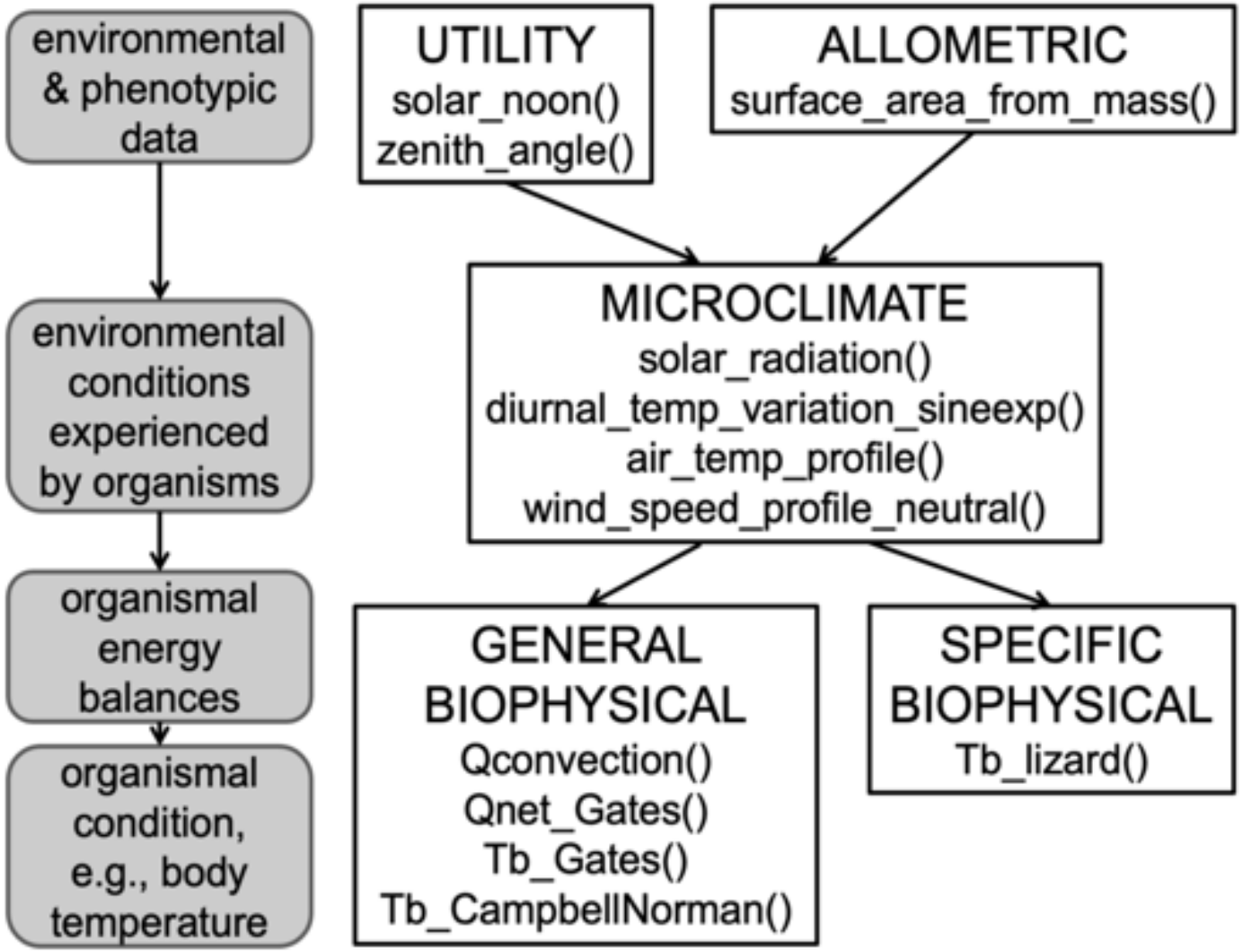


Conversion

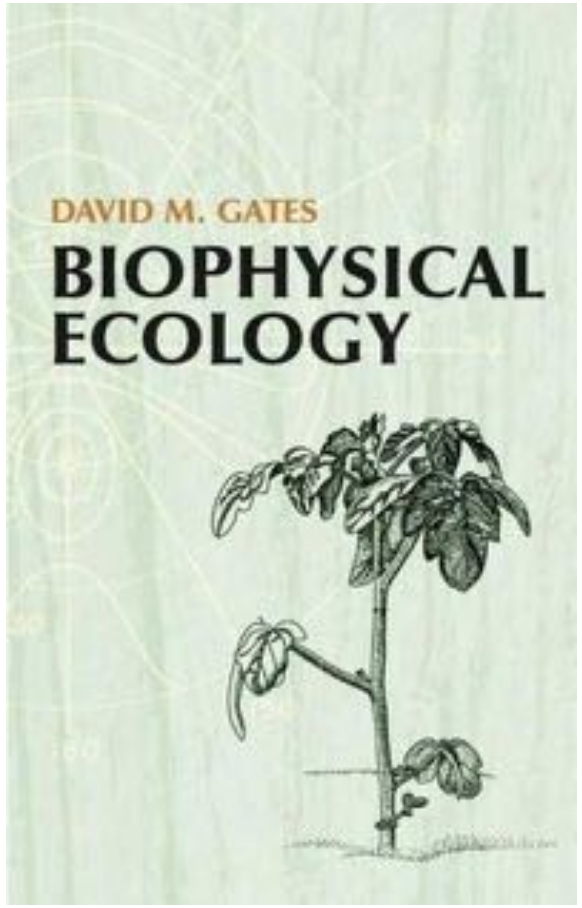
Storage

Education

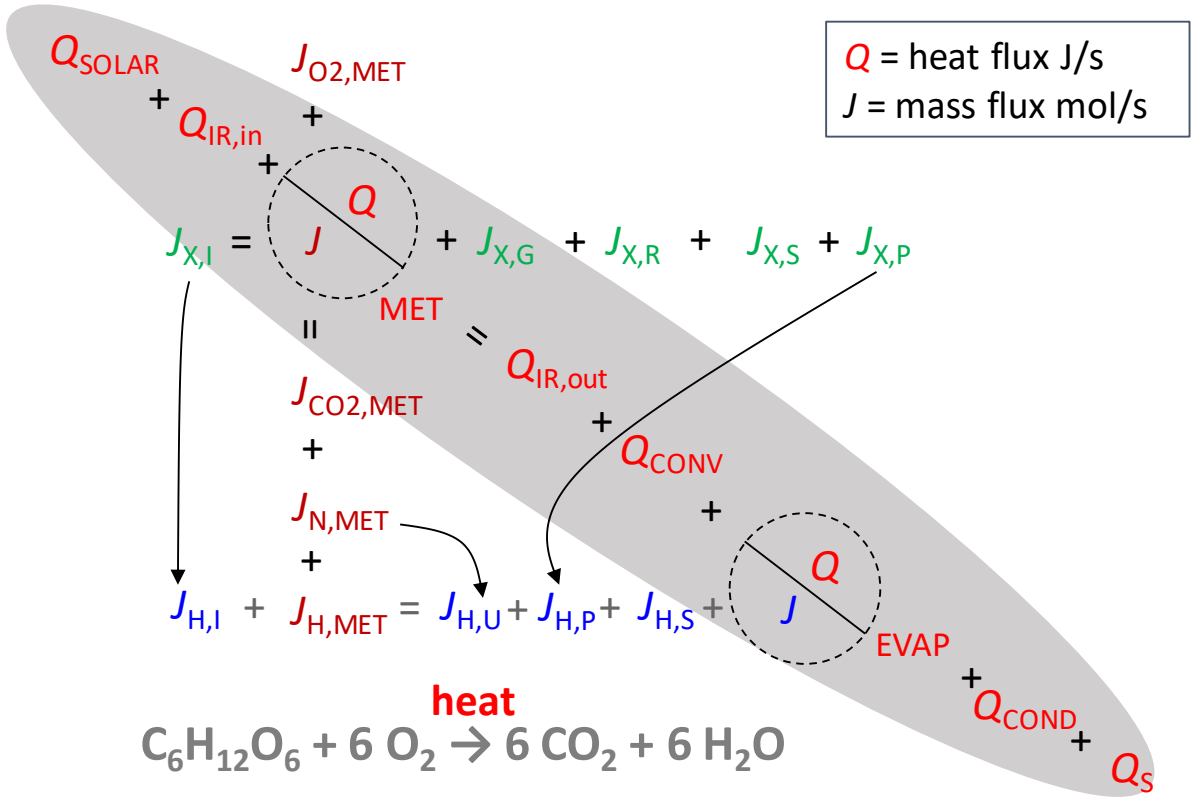

TrenchR


environmental & phenotypic data
environmental conditions experienced by organisms
organismal energy balances
organismal condition, e.g., body temperature
UTILITY
solar_noon()
zenith_angle()
ALLOMETRIC
surface_area_from_mass()
MICROCLIMATE
solar_radiation()
diurnal_temp_variation_sineexp()
air_temp_profile()
wind_speed_profile_neutral()
GENERAL BIOPHYSICAL
Qconvection()
Qnet_Gates()
Tb_Gates()
Tb_CampbellNorman()
SPECIFIC BIOPHYSICAL
Tb_lizard()

Theory for Mechanistic Niche Modelling

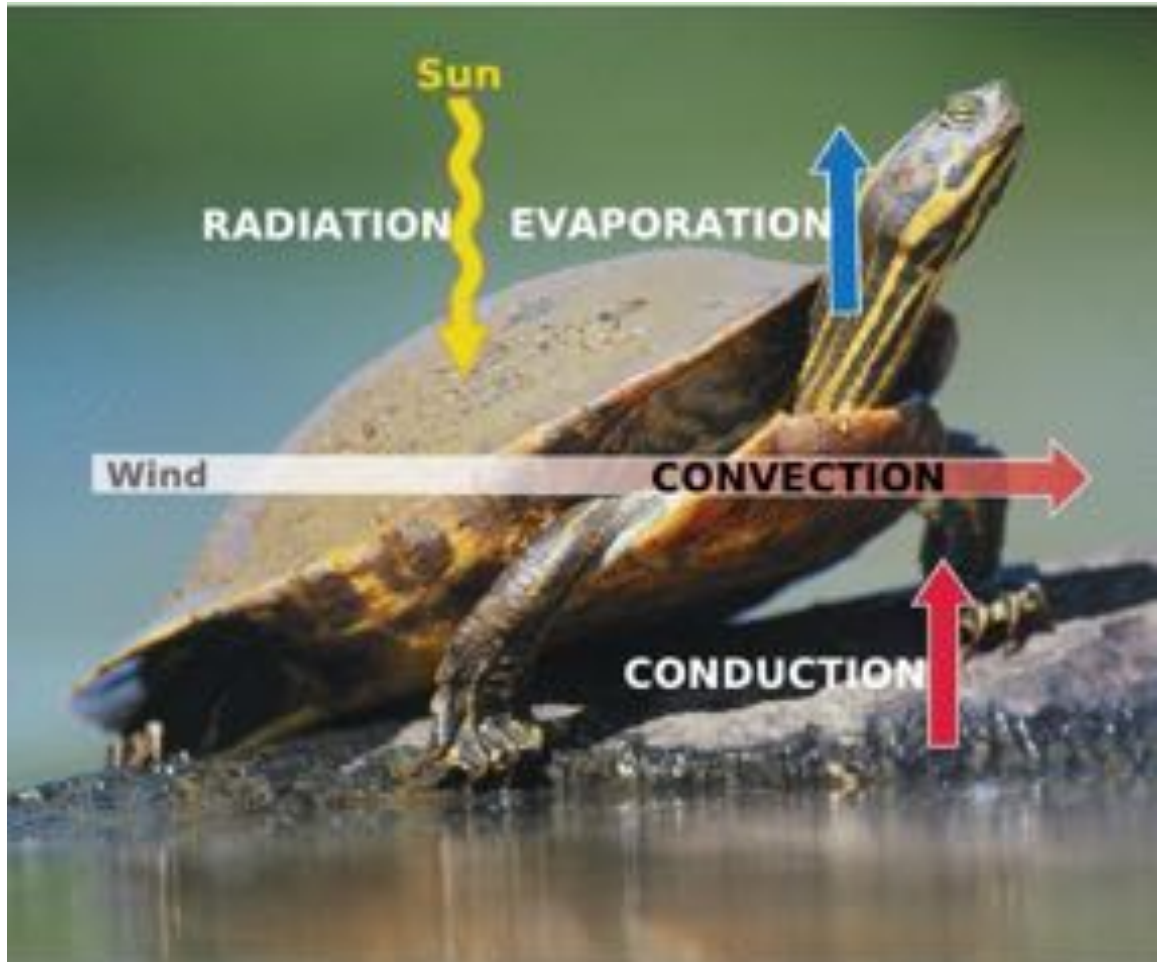


heat and water exchange



Net heat exchange with environment

$$Q_{net} = + Q_{rad} + Q_{met} \pm Q_{cond} \pm Q_{conv} - Q_{evap}$$



Net heat exchange with environment

$$Q_{net} = + Q_{rad} + Q_{met} \pm Q_{cond} \pm Q_{conv} - Q_{evap}$$

If not steady state: $(+Q_{stor} + Q_{work})$

Q_{stor}: Δheat

Q_{work}: Work against environmental gradient

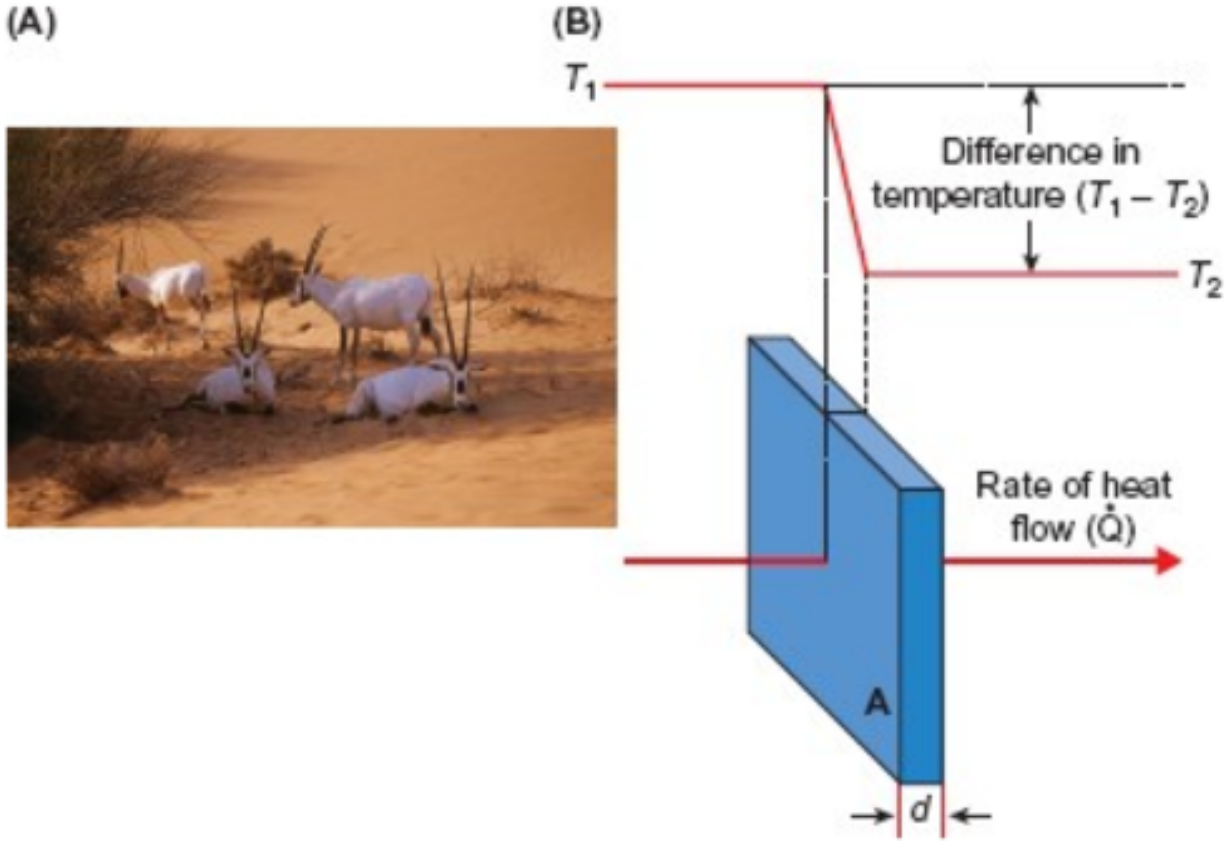
Organism core vs surface temperature

$$T_b - T_a = (T_b - T_s) + (T_s - T_a)$$

T_s: T organism surface; T_b: T body

Diffusion

Movement from high to low concentration.



Plus diffusion coefficient

(Butler et al. Animal Physiology)

Radiation

A heat transfer between two substances that are not in contact.

Thermal radiation from (body) surface

$$Q_{rad} = \varepsilon \sigma A T^4$$

Thermal radiation between organism and enclosed environment

$$Q_{rad} = \varepsilon \sigma A (T_s^4 - T^4)$$

A: Surface area

T: Temperature, s= surface

ε: Emissivity (proportion radiated)

σ: Stefan-Boltzmann constant

Conduction

A heat transfer involving two objects in physical contact with each other.

$$Q_{cond} = -kA\frac{(T_2 - T_1)}{(X_2 - X_1)}$$

Temperature gradient

Separation, e.g., thickness of animal skin

A: Surface area

T: Temperature

k: thermal conductivity

X: position

Convection

A heat transfer between a solid and a liquid or a gas.

$$Q_{conv} = h_c A(T_s - T_a)$$

A: Surface area

h_c: convective coefficient

T_s: organism surface temperature

T_a: ambient temperature

Convection

A heat transfer between a solid and a liquid or a gas.

$$Q_{conv} = h_c A(T_s - T_a)$$

h_c depends on type of convection:

- within boundary layer (stagnant air)
- free convection driven by density differential
- forced by wind or current

Important factors:

- fluid velocity, viscosity, density
- organism dimensions

Evaporation

A loss of heat due to liquid water phase changing into gaseous water.

$$Q_{evap} = h_d A(\rho_o - \rho_a)$$

A: Surface area

h_d: mass transfer coefficient

ρ_o : Saturated water vapor density

ρ_a : water vapor density of airmass

Rmd example

https://github.com/trenchproject/ESA_MechModelWorkshop/TrenchR_TeExample.Rmd

Program

Time	Topic
9:00 -9:15	Introductions
9:15-9:45	What are mechanistic niche models and why do we need them? (MK & LB)
9:45-10:15	Calculating body temperature with TrenchR (LB)
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10:30-11:15	Intro to microclimate modelling with NicheMapR (MK)
11:15-12:00	Selecting microclimate data (LB & MK)
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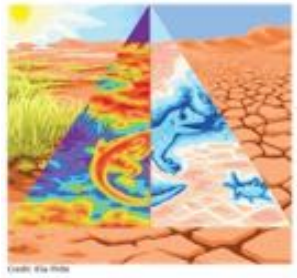
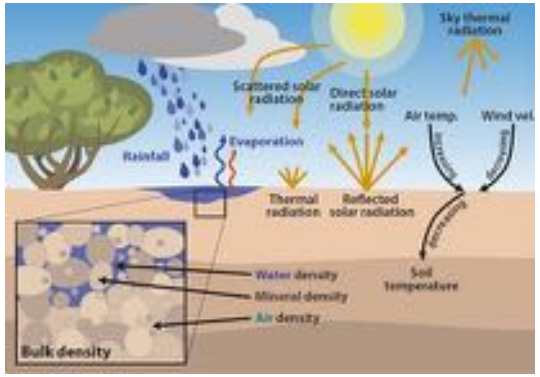
15:00-16:00	Q&A on mechanistic niche modelling (LB & MK)



NicheMapR

microclimate model



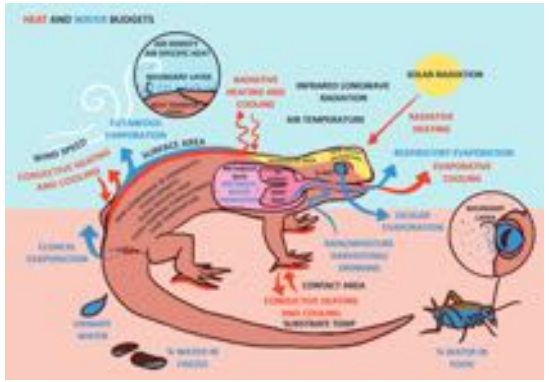
microclimate

plantgro

DRYAIR
WETAIR

micro_global
micro_terra
micro_ncep
micro_era5
micro_aust
micro_usa
micro_uk
micro_nz

ectotherm model

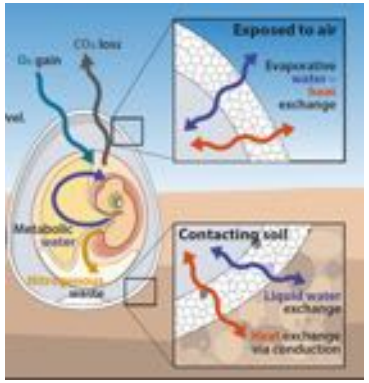


ectotherm

leaf_temperature

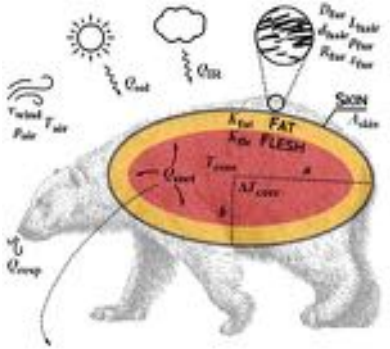
onelump
onelump_var
twolump

egg model



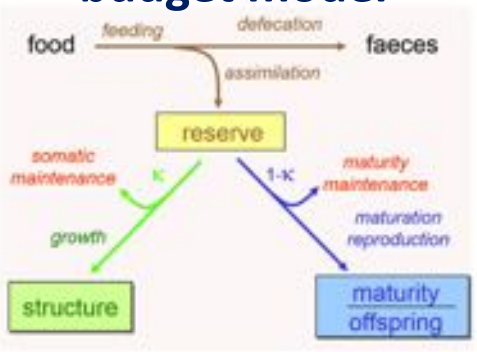
get_p_wet
egg_water

endotherm model



ellipsoid
endoR
endoR_devel

dynamic energy budget model



DEB
DEB_const
DEB_var
DEB_euler

Home Getting Started People Models Help News Related Projects

NicheMapR

Modelling the thermodynamic constraints on life

Twitter

GitHub

NicheMapR: Software suite for microclimate and mechanistic niche modelling in the R programming environment.

Overview

NicheMapR is a suite of programs for the R environment that compute fundamental physical and chemical constraints on living things. It aims at asking the general question: *Can an organism complete its life cycle in a particular place and time, without overheating, desiccating or starving?*

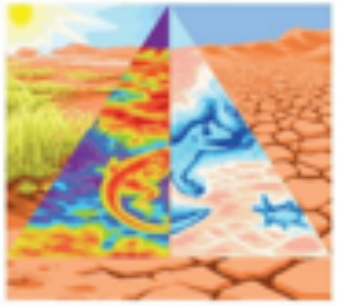
In other words, starting with the functional traits of an organism, the programs can be used to determine the environmental sequence experienced by an organism in a particular habitat and assess whether this sequence is inside, or outside, of its niche.

https://mrke.github.io/

https://camel.science.unimelb.edu.au/biological-forecasting-and-hindcasting-tools/

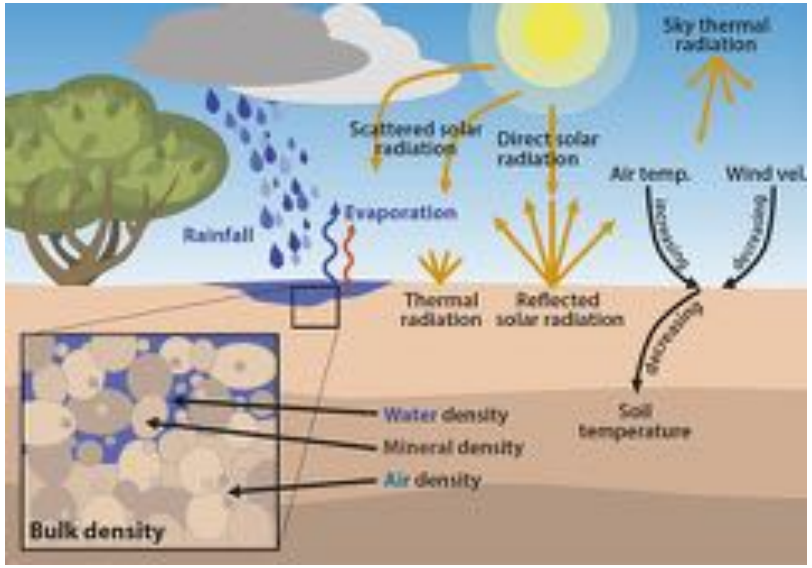
Biological Forecasting and Hindcasting Tools

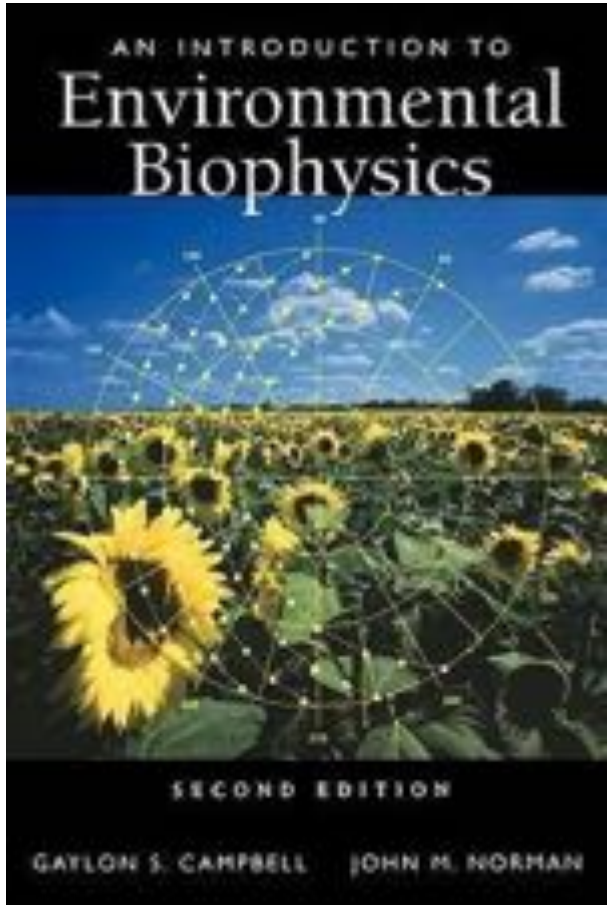
Quick Links

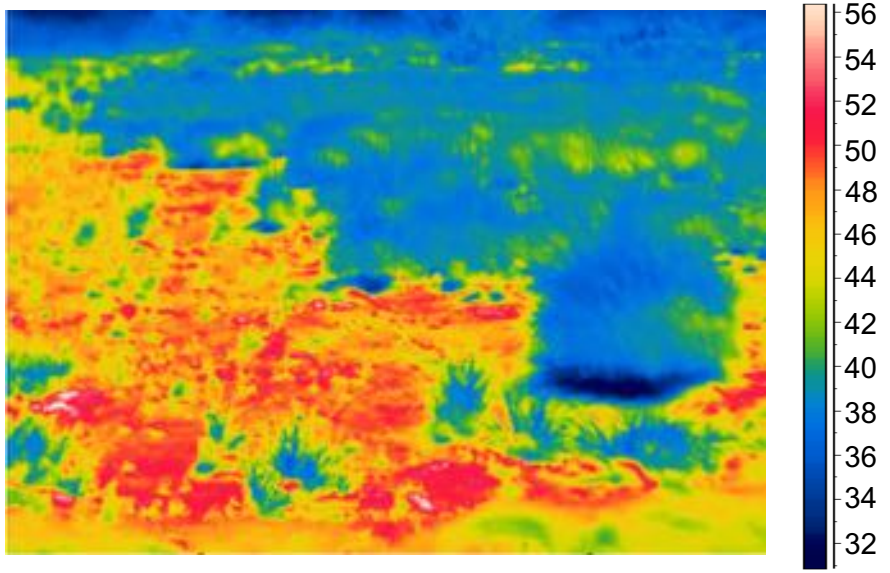


1. Global Soil Microclimate Calculator (typical day in each month)
2. Global Soil Microclimate Hindcaster (historical back to 1949)
3. Global Ectotherm Calculator (typical day in each month)
4. Global Transient Ectotherm Calculator (typical day in each month, accounts for thermal mass)
5. Global Ectotherm Hindcaster (historical back to 1949)
6. Australian Soil Microclimate Hindcaster (historical back to 1911)
7. Australian Ectotherm Hindcaster (historical back to 1911)
8. Australian Ectotherm Forecaster (next three days)
9. USA Soil Microclimate Hindcaster (historical from yesterday back to 1980)
10. USA Ectotherm Hindcaster (historical from yesterday back to 1980)
11. Dynamic Energy Budget model (simulate energy budgets under constant food and temperature)
12. Dynamic Energy Budget model in the sea (simulate energy budgets as a function of sea surface temperature)
13. Leaf Temperature and Transpiration Hindcaster (historical back to 1949)

Microclimate



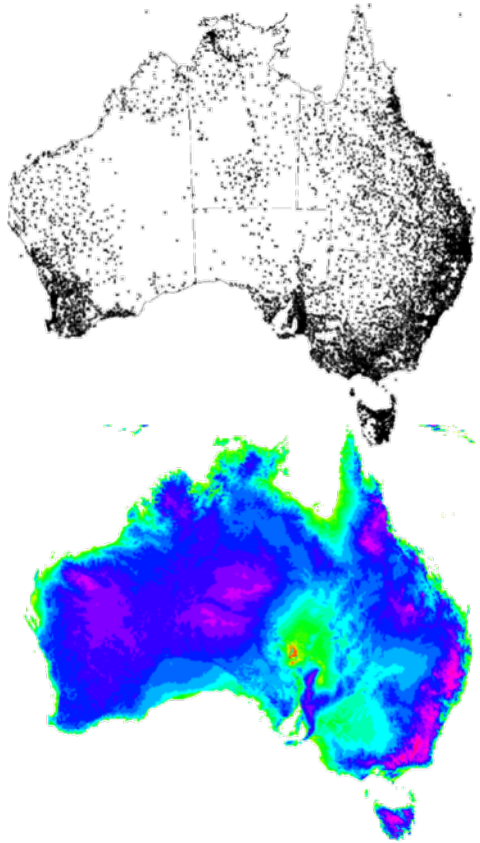




microclimate

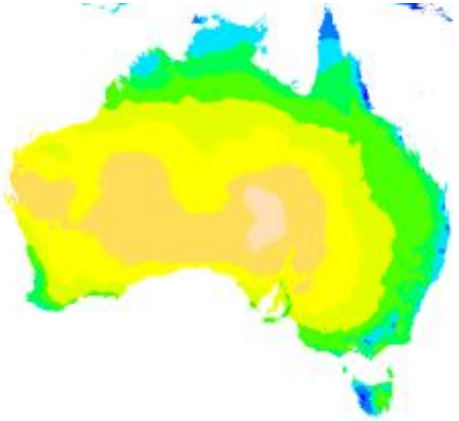
Microclimate

rainfall observations



thin-plate smoothing splines (Wabah and Wendelberger, 1980)

mean annual rainfall

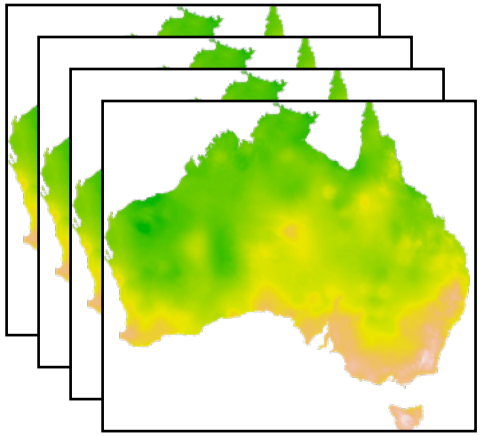


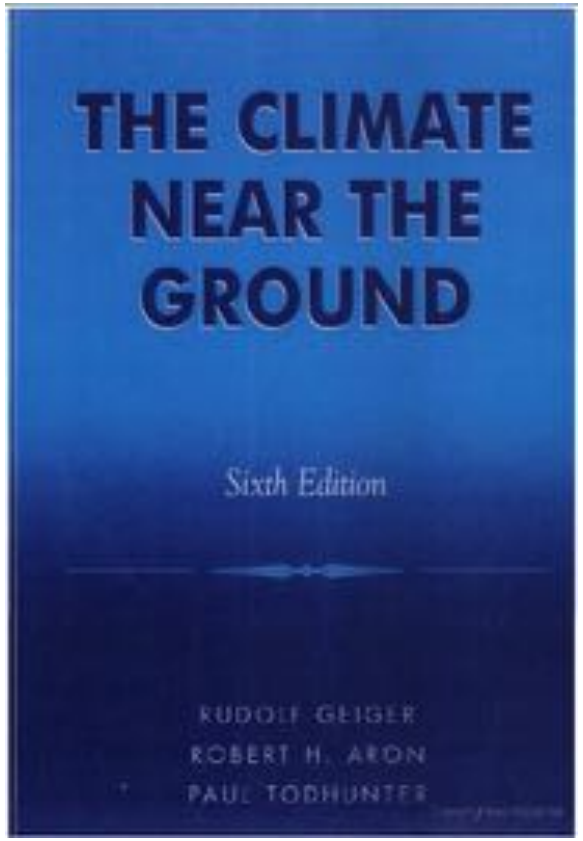
digital elevation model (DEM)

Mike Hutchinson

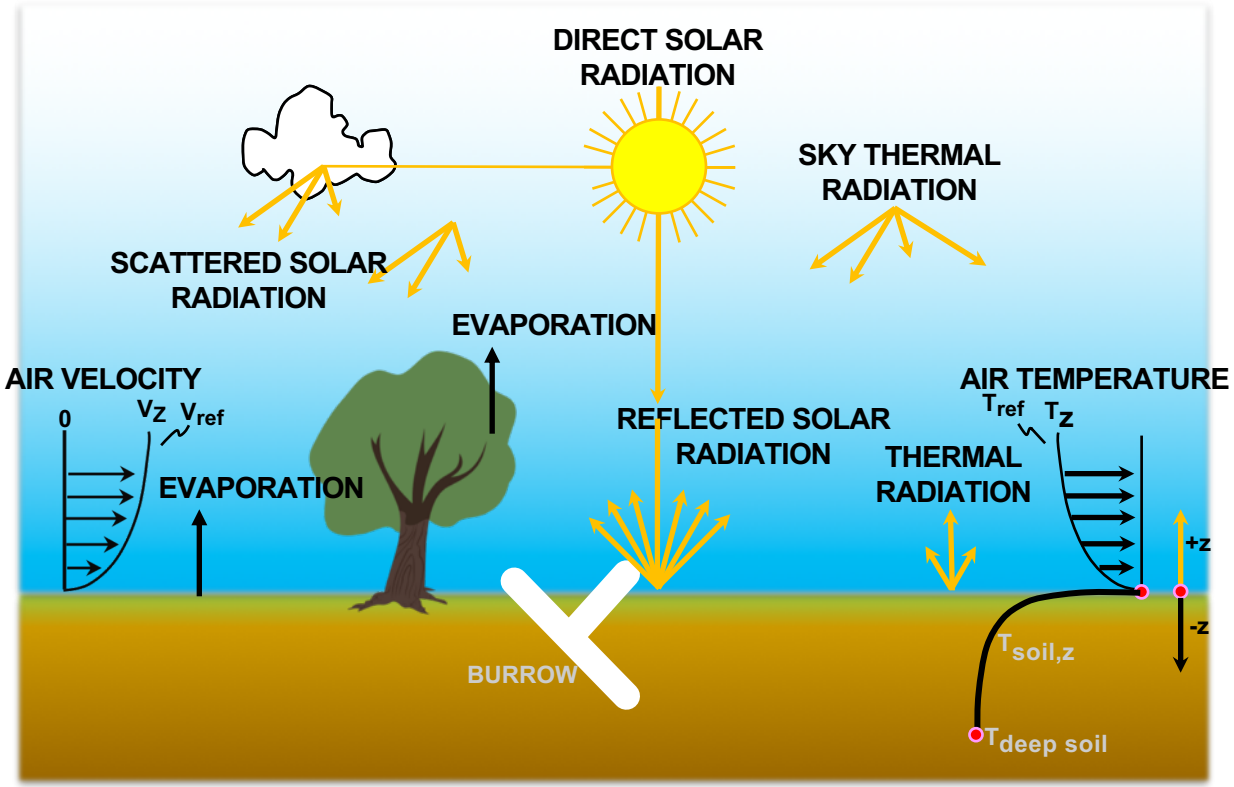
Hutchinson, M. F., & Bischof, R. J. (1983). A new method for estimating the spatial distribution of mean seasonal and annual rainfall applied to the Hunter Valley, New South Wales. *Australian Meteorological Magazine, Bremerhaven, PANGAEA*, *31*(3), 179–184. https://doi.org/10013/epic.37358.d001

Microclimate





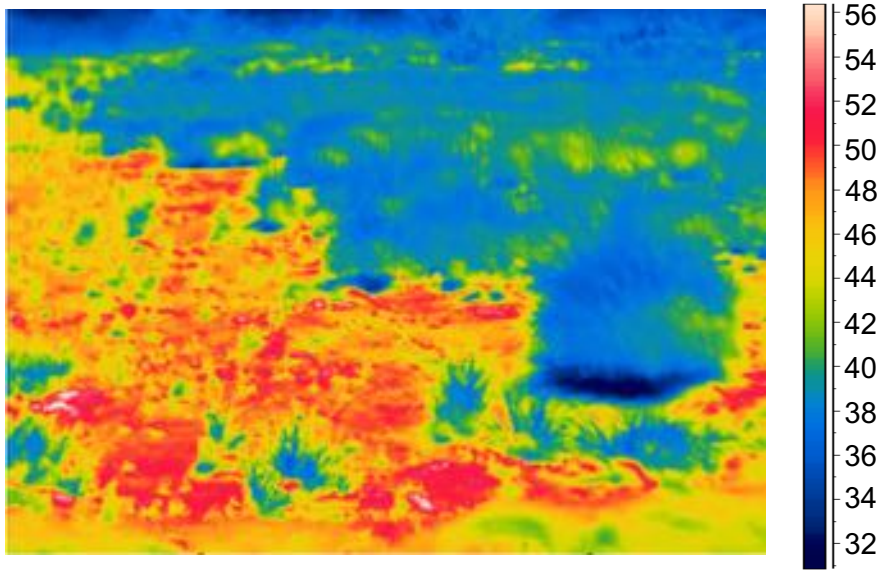
Microclimate

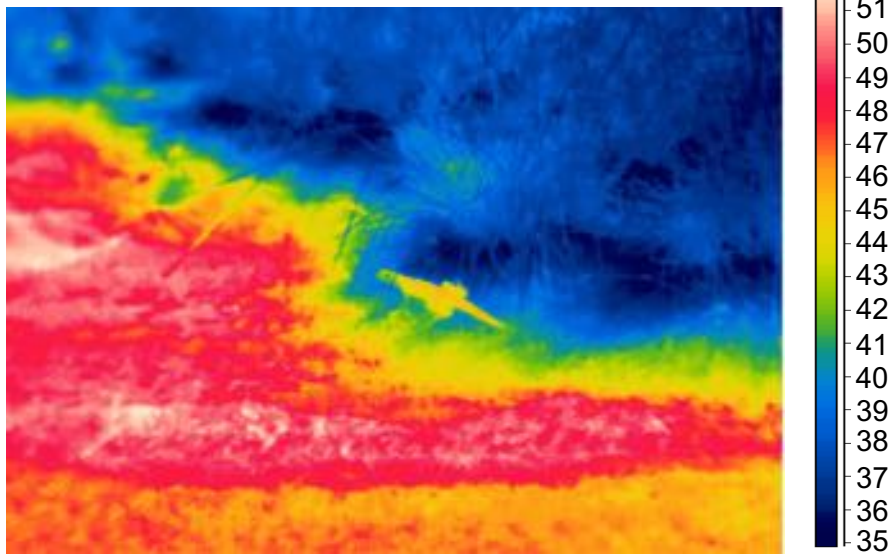


(Heat) Energy Balance of the Ground

Solar (gained) + Infra-red (gained) = Infra-red (lost) + Convection (gained/lost) + Conduction (gained/lost) + Evaporation (gained/lost)

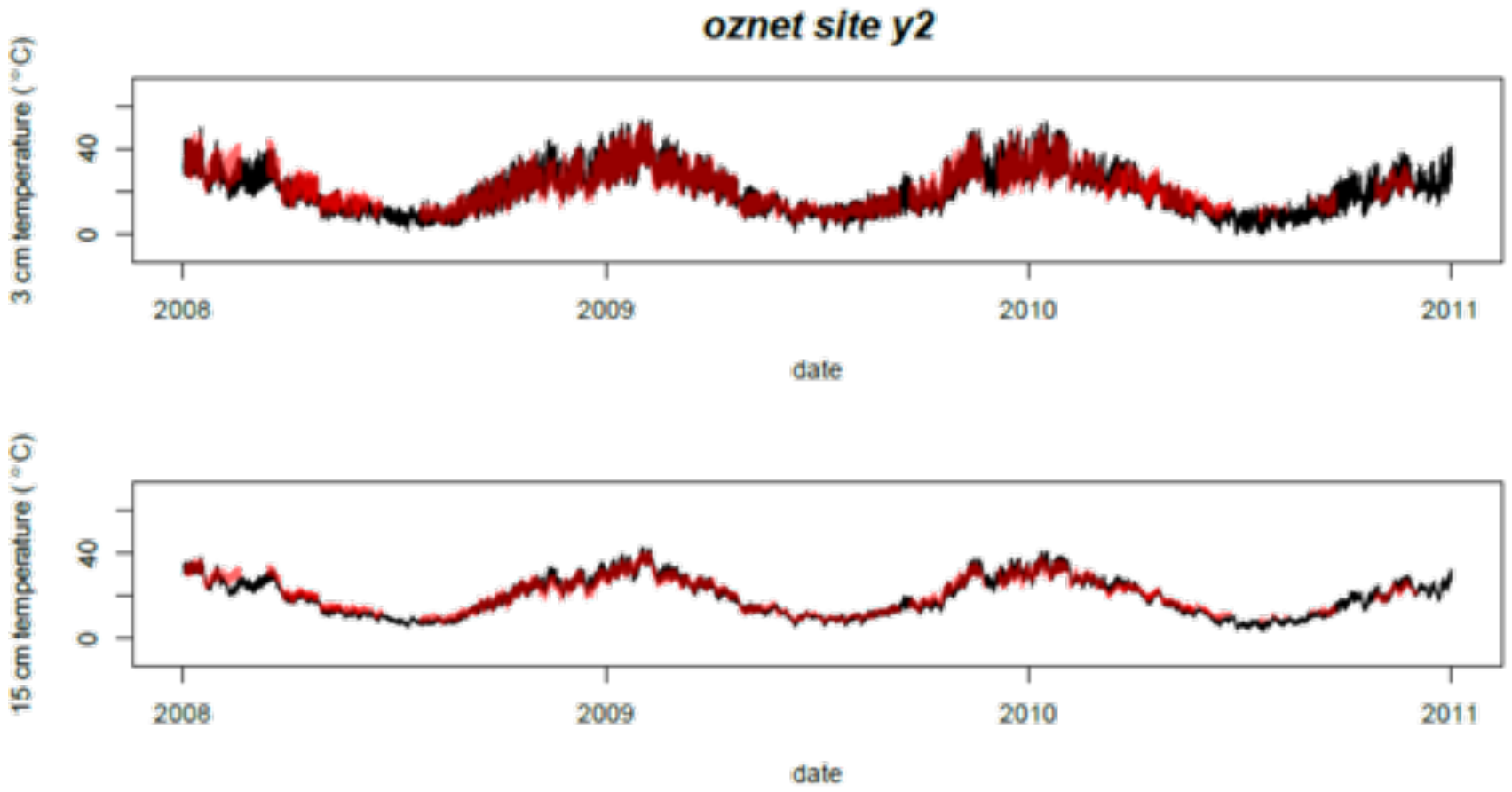
Microclimate



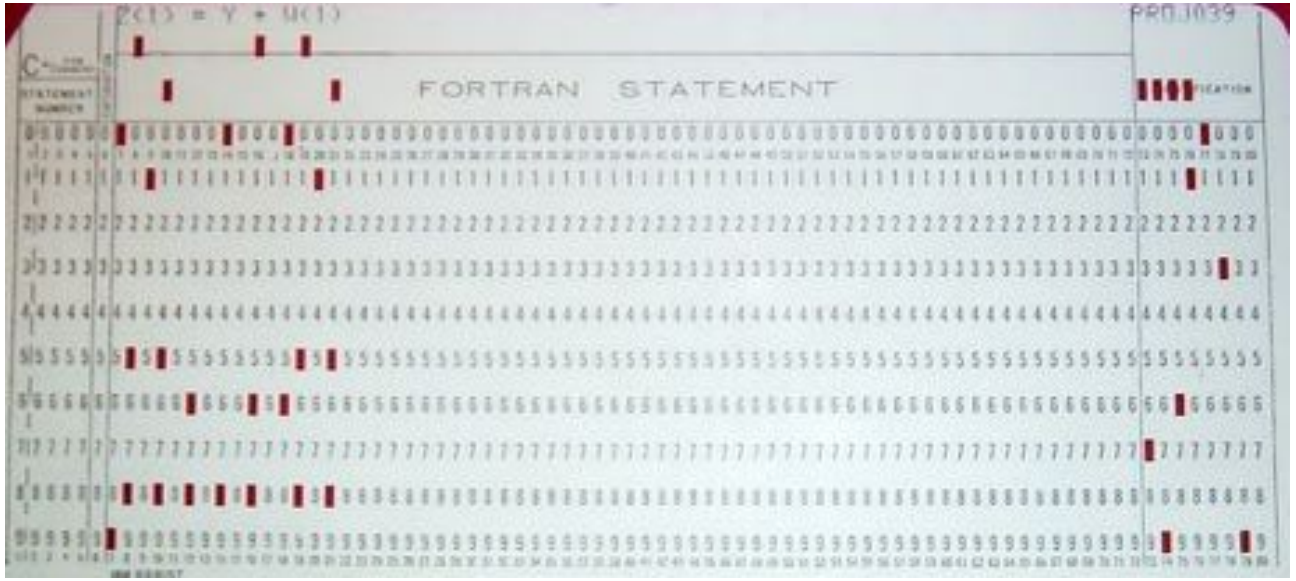


micro_ncep function

Downscaled 250 km resolution 6-hourly gridded data (NCEP)



History of the microclimate model

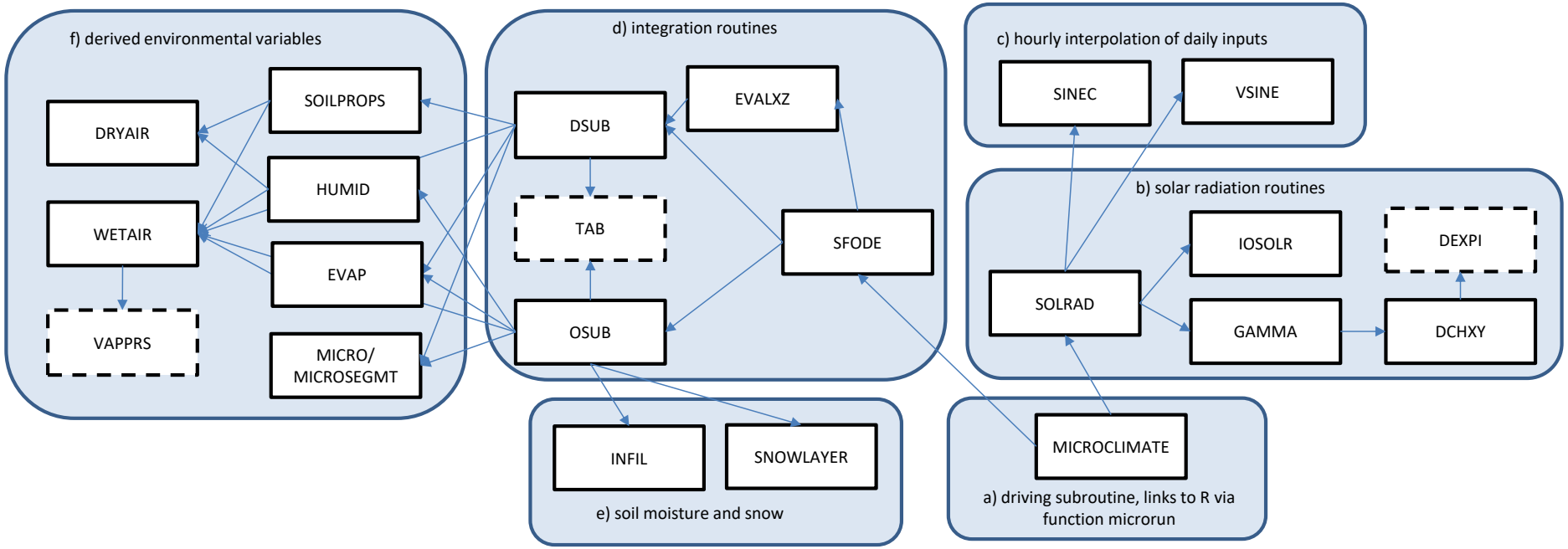


Niche Mapper → NicheMapR

Porter, W. P., J. W. Mitchell, W. A. Beckman, and C. B. DeWitt. 1973. Behavioral implications of mechanistic ecology - Thermal and behavioral modeling of desert ectotherms and their microenvironment. Oecologia 13:1–54.

Microclimate Program Structure

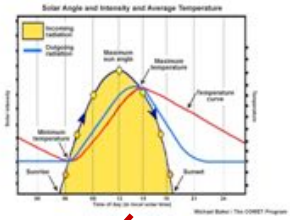
Niche Mapper → NicheMapR



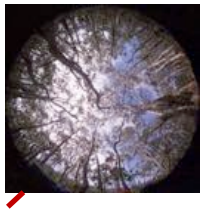
Microclimate Program Structure

soil properties

diurnal cycles



shade



f) derived environmental variables

SOILPROPS

DRYAIR

HUMID

WETAIR

EVAP

VAPPRS

MICRO/
MICROSEGMT

d) integration routines

EVALXZ

DSUB

TAB

SFODE

OSUB

c) hourly interpolation of daily inputs

SINEC

VSINE

b) solar radiation routines

IOSOLR

DEXPI

SOLRAD

GAMMA

DCHXY

INFIL

SNOWLAYER

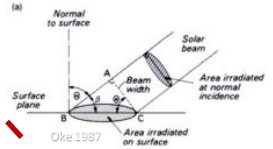
e) soil moisture and snow

MICROCLIMATE

a) driving subroutine, links to R via function microrun

vertical air temp &
wind speed profiles

solar radiation

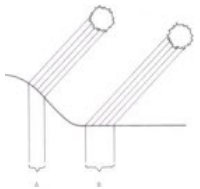


soil moisture

snow

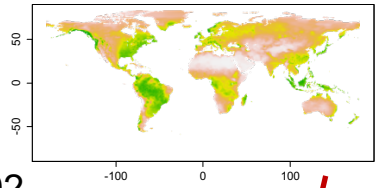
weather

terrain

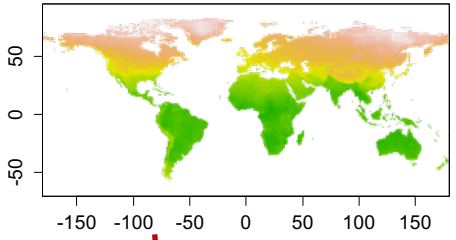


NicheMapR

CPC soil moisture



New et al. 2002



a) Call to Fortran

Fortran microclimate model library

microrun.R

c) User arguments

User Input (location, terrain, shade, soil type, …)

d) Climate and soil data sets

CampNormTbl9_1

soil.mon.ltm.v2.nc

global_climate.nc

e) Global Aerosol Data Set

rungads

GADS Tables

Fortran GADS library

b) micro_global.R

f) output

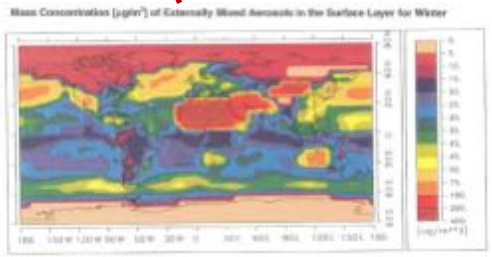
metout

soil

soilmoist

soilpot

humid



Koepke et al 1997

Biological Forecasting and Hindcasting Tools

Global Soil Microclimate Calculator

RUN MODEL

load parameters

Browse... No file selected

latitude

-25.34

longitude

131.04

height, cm

1

month to plot:

January

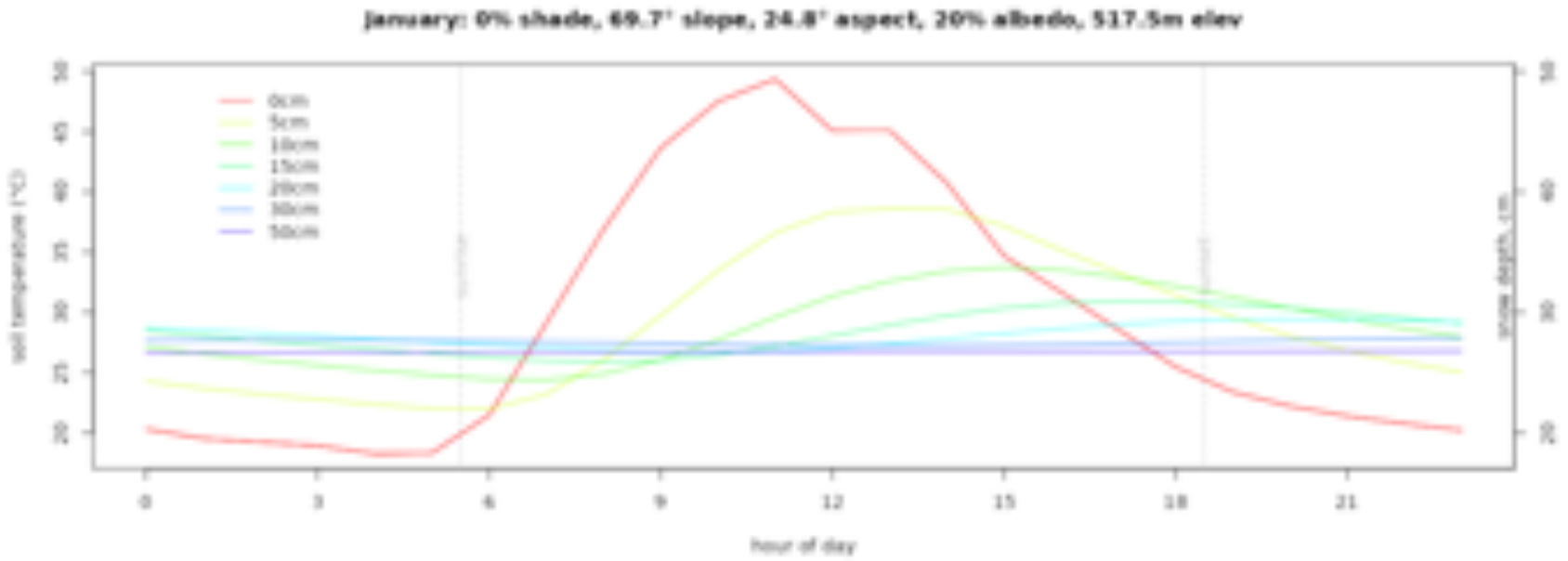
depths to plot:

0cm 2.5cm 5cm 10cm 15cm 20cm 30cm 50cm 100cm 200cm

°C offset

0

Video instructions These calculations are made using the microclimate model of NicheMapR driven by the New et al. 2002 1960-1990 global climate grids. See also microclim. Send feedback or issues to m.kearney@unimelb.edu.au. Photo credit: Nicole Kearney



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15:00-16:00	Q&A on mechanistic niche modelling (LB & MK)

TrEnCh Project Microclimate Selection Tool

Overview

Most ecological analyses and forecasts use weather station data or coarse interpolated, gridded temperature data. Yet, these products often poorly capture the microclimates experienced by organisms that live near the surface and respond to fine scale spatial and temporal environmental variation. Historic and projected future environmental data derived from spatial interpoation or dynamic modelling better capture the microclimate relevant to organisms and ecosystems. This site is designed to help you select microclimate datasets for projects characterizing responses to spatial and temporal environmental variability.

We temporally and spatially compare several related types of environmental data to weather station observations, which we assume reflect actual environmental conditions. We focus on datasets that offer (near) hourly data. Although several datasets are global, regional datasets are focused on the United States. We start by examining **environmental forcing data**, generated by spatial interpolation or dynamic modelling, which afford high spatial and temporal resolution but tend to be at a reference height (1-2m) above where most organisms reside. These environmental forcing data can then be processed using microclimate models, which characterise the processes of heat transport through air and soil to estimate vertical temperature and wind profiles. We use both detailed NicheMapR microclimate models and simple TrenchR vertical profile models to scale conditions from sensor to organism height. We include data both that we have processes using **microclimate algorithms** and that is pre-computed and stored as a **microclimate dataset**.

For weather station observations, we focus on three weather stations in Colorado, Oregon, and Hawaii that were chosen to represented different climate regimes and ecosystems, as well as examining weather stations across the United States in the US Climate Reference Network (USCRN). We examine environmental data from 2017, a recent year for which data is available from all datasets. We evaluate the data for both summer (month of July) and winter (month of January) conditions. We focus on environmental variables that are needed to estimate body temperatures of organisms using microclamte and biophysical modelling.

Tabs in this application allow you to interactively filter datasets based on your data needs, to temporally compare monthly timeseries, to spatially compare microclimate datasets to weather station observations, and to compare the body temperature estimates produced by the microclimate datasets. Once you select a dataset, the TrEnCh Project Microclimate Data Users' Guide provides intructions for accessing and processing the data.

This app compares the following datasets.

Weather Station Observations

- USCRN - US Climate Reference Network
- SCAN - Soil Climate Analysis Network
- NOAA NCDC - NOAA National Climatic Data Center

Environmental Forcing Data

- ERA5-Land - Reanalysis
- GLDAS - Global Land Data Assimilation System
- gridMET - Interpolated meteorology
- NEW01 - CRU CL v. 2.0, Climate Research Unit Mean monthly climatology
- NCEP - NCEP/NCAR Reanalysis 1

Microclimate Algorithms

- NicheMapR - micro_era5, micro_usa, micro_global, and micro_ncep functions forced with ERA-5, gridMET, NEW01, and NCEP data, respectively
- Microclima - used by micro_ncep function
- TrenchR - air_temp_profile_neutral() for scaling from reference to organismal height

Microclimate Datasets

- microclimUS - gridMET data preprocessed using NicheMapR
- microclim - NCEP data preprocessed using NicheMapR

Weather Station Observations

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- SCAN - Soil Climate Analysis Network
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Microclimate Datasets

- microclimUS - gridMET data preprocessed using NicheMapR
- microclim - NCEP data preprocessed using NicheMapR

Microclimate models in R

Model	Emphasis	Physical explicitness	Reference
NicheMapR	realism, time-series	high	10.1111/ecog.02360 https://github.com/mrke/
microclima	speed, grids	low	10.1111/2041-210X.13093 https://github.com/ilyamaclean/
microclimf	speed, grids	med	in progress https://github.com/ilyamaclean/
microclimc	within-canopy	high	10.1016/j.ecolmodel.2021.109567 https://github.com/ilyamaclean/
TrEnChR	education	low	in review https://github.com/trenchproject/

Data selection | Temporal comparison | Spatial comparison | Operative temperature comparison

Area of interest
- (•) US
- ( ) Outside of US

Beginning of temporal coverage: 2017

End of temporal coverage: 2017

Temporal resolution
- [x] Monthly
- [x] Daily
- [x] 6-hourly
- [x] 3-hourly
- [x] Hourly
- [x] Other

Variables of interest: Select variables

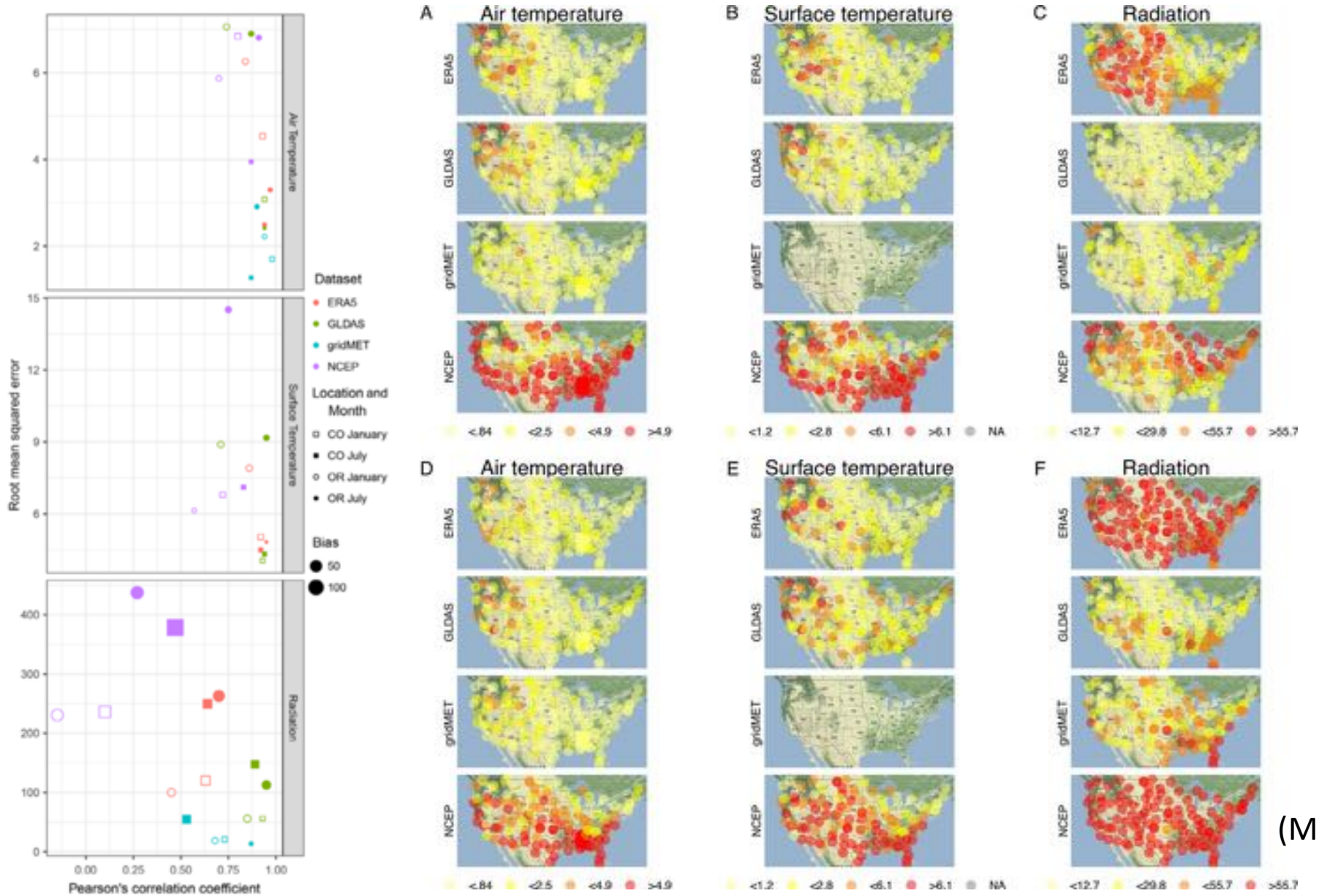
Suitable datasets

Show 10 entries

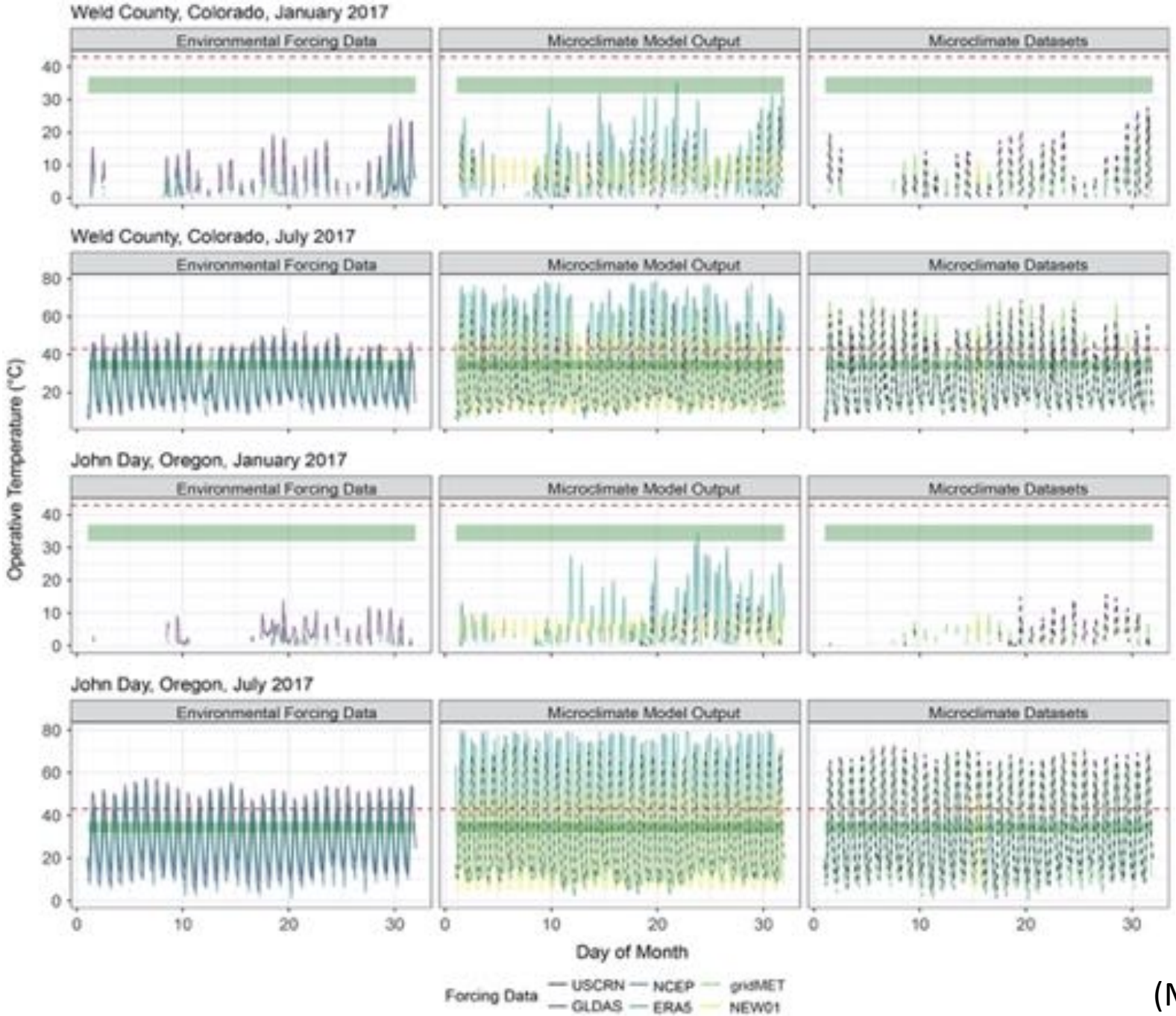
Search:

	Dataset	Temporal coverage	Temporal resolution	Spatial coverage	Spatial resolution	Air temp	Surface temp	Soil temp	Radiation	Wind speed	Precipitation	Humidity	Soil moist	Snow depth
1	SCAN	1991-2021	Hourly	US	Stations	✔	✖	✔	✔	✔	✔	✔	✔	✖
2	USCRN	2000-2021	Sub-hourly, Hourly, Daily	US	Stations	✔	✔	✔	✔	✔	✔	✔	✔	✖
3	ERA5	1981-2021	Hourly	Global	0.1° x 0.1°	✔	✔	✔	✔	✔	✔	✖	✖	✔
4	GLDAS	2000-2021	3-hourly	Global	0.25° x 0.25°	✔	✔	✔	✔	✔	✔	✔	✔	✔
5	GRIDMET	1979-2021	Daily	US	0.04° x 0.04°	✔	✖	✖	✔	✔	✔	✖	✖	✖
6	NEWD1	Infinite	Monthly	Global	10' x 10'	✔	✖	✖	✖	✔	✔	✔	✖	✖
7	NCEP	1948-2021	6-hourly	Global	2.5° x 2.5°	✔	✔	✔	✔	✔	✔	✖	✔	✖
8	microSimUS	1979-2017	Hourly	US	0.6° x 0.6°	✔	✔	✔	✔	✔	✖	✔	✔	✔
9	microSim	Infinite	One day each month	Global	0.17° x 0.17°	✔	✔	✔	✔	✔	✖	✔	✖	✖

Spatial and temporal comparison

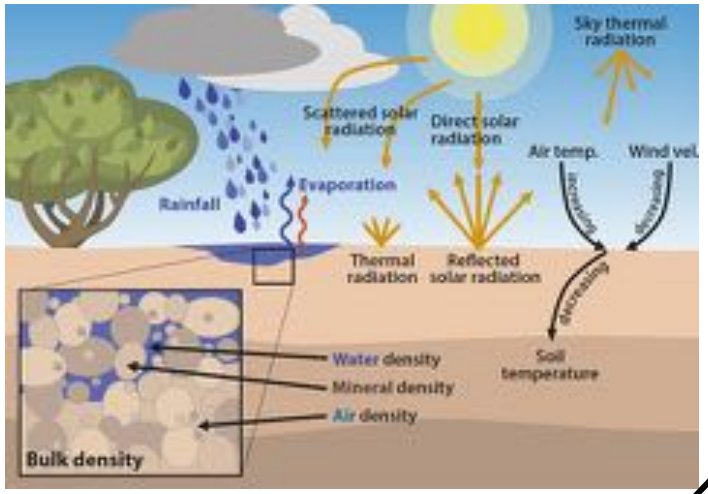


(Meyer et al. 2023 Ecosphere)



(Meyer et al. 2023 Ecosphere)

micro_x functions



micro_global
micro_terra
micro_ncep
micro_era5
micro_aust
micro_usa
micro_uk
micro_nz

New et al. (2002). A high-resolution data set of surface climate over global land areas. *Climate Research*, *21*(1), 1–25. https://doi.org/10.3354/cr021001

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Hersbach et al. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, *146*(730), 1999–2049. https://doi.org/10.1002/qj.3803

Jones et al. *Australian Meteorological and Oceanographic Journal*, *58*(04), 233–248. https://doi.org/10.22499/2.5804.003

Abatzoglou, J. T. (2013). Development of gridded surface meteorological data for ecological applications and modelling. *International Journal of Climatology*, *33*(1), 121–131. https://doi.org/10.1002/joc.3413

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Tait et al. (2012). An assessment of the accuracy of interpolated daily rainfall for New Zealand. *Journal of Hydrology (New Zealand)*, *51*(1), 25–44. JSTOR.

micro_ncep (and micro_era5) function

Download climate-forcing data using package RNCEP

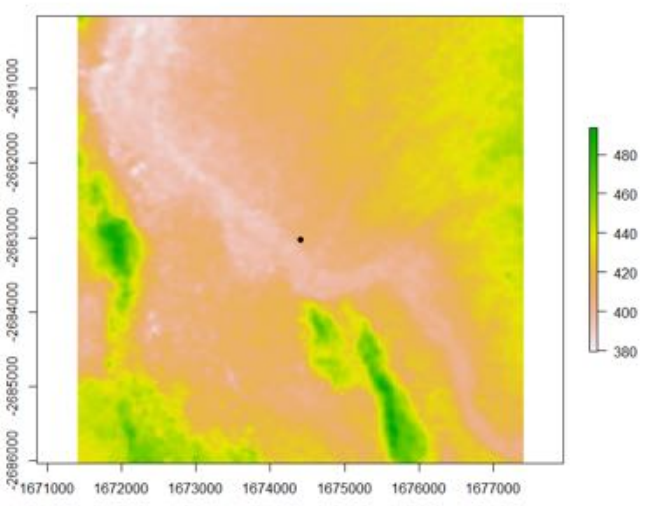
Methods in Ecology and Evolution

Methods in Ecology and Evolution 2012, **3**, 65–70 doi: 10.1111/j.2041-210X.2011.00138.x

APPLICATION

RNCEP: global weather and climate data at your fingertips

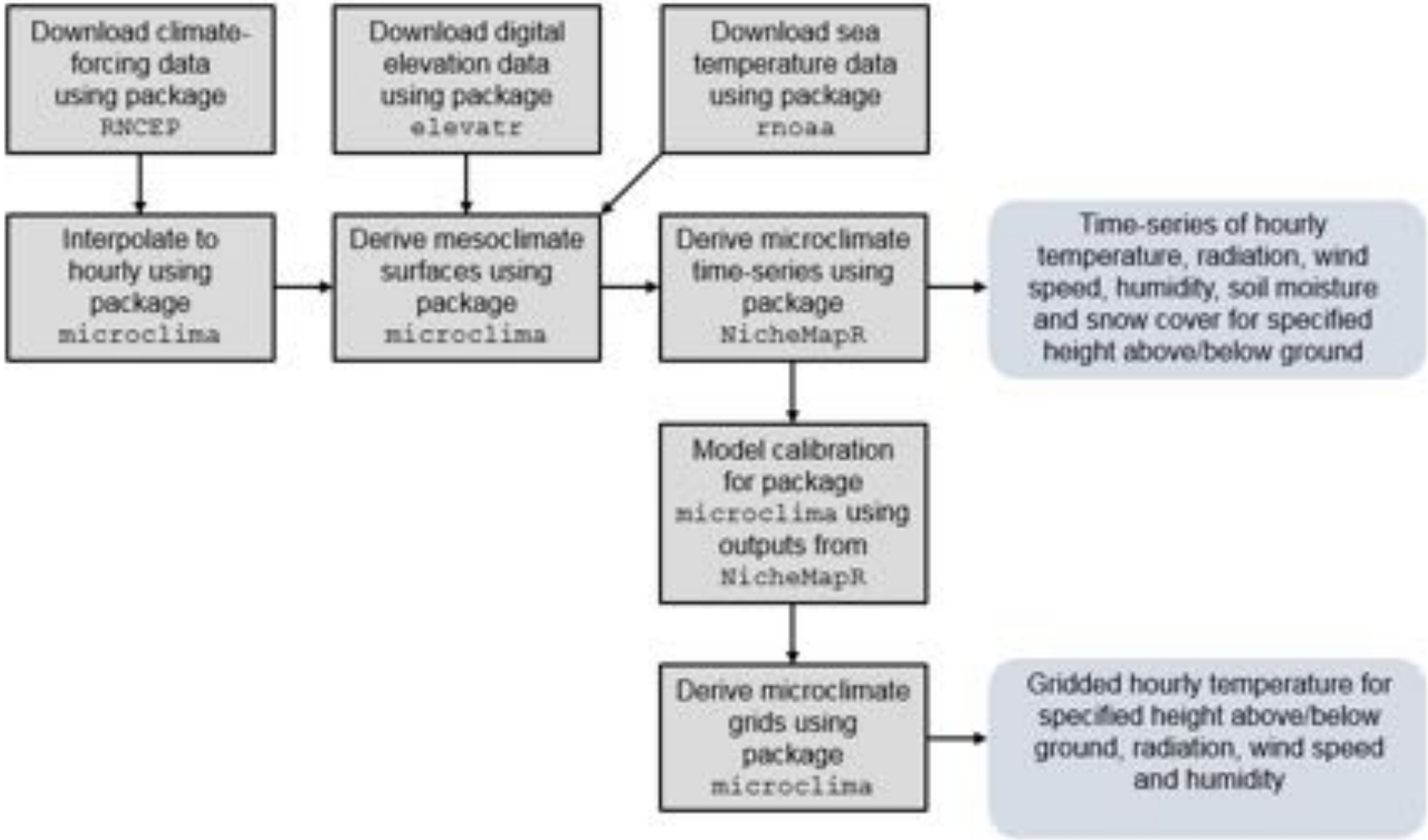
Michael U. Kemp*, E. Emiel van Loon, Judy Shamoun-Baranes and Willem Bouten



Maclean, Mosedale & Bennie (2019). Microclima: An r package for modelling meso- and microclimate. *Methods in Ecology and Evolution*, *10*(2), 280–290. https://doi.org/10.1111/2041-210X.13093

Kearney et al. (2020). A method for computing hourly, historical, terrain-corrected microclimate anywhere on earth. *Methods in Ecology and Evolution*, *11*(1), 38–43. https://doi.org/10.1111/2041-210X.13330

micro_ncep (and micro_era5) function



micro_era5 function

Methods in Ecology and Evolution | BRITISH ECOLOGICAL SOCIETY

APPLICATION

mcera5: Driving microclimate models with ERA5 global gridded climate data

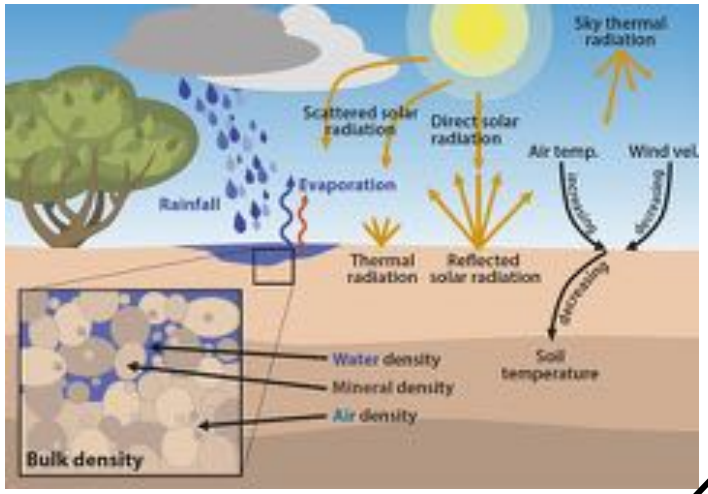
David H. Klinges ✉ James P. Duffy. Michael R. Kearney. Ilya M. D. Maclean

First published: 26 April 2022 | https://doi.org/10.1111/2041-210X.13877

Abstract

1. Microclimate models predict temperature and other meteorological variables at scales relevant to individual organisms. The broad application of microclimate models requires gridded macroclimatic variables as input. However, the spatial and temporal resolution of such inputs can be a limiting factor on the accuracy of microclimate predictions. Due to its fine resolution and accuracy, the ERA5 reanalysis dataset is emerging as the favoured resource for global historical weather and climate data and has great potential for aiding microclimate modelling.

microclimate gridded data



micro_global
micro_terra
micro_ncep
micro_era5
micro_aust
micro_usa
micro_uk
micro_nz

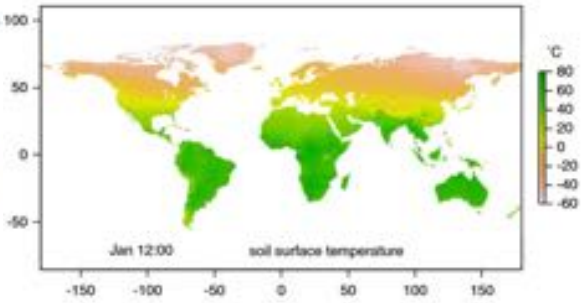
SCIENTIFIC DATA

OPEN

SUBJECT CATEGORIES
- Ecophysiology
- Plant ecology
- Biogeography
- Bioenergetics

microclim: Global estimates of hourly microclimate based on long-term monthly climate averages

Michael R. Kearney[1], Andrew P. Isaac[2] and Warren P. Porter[3]

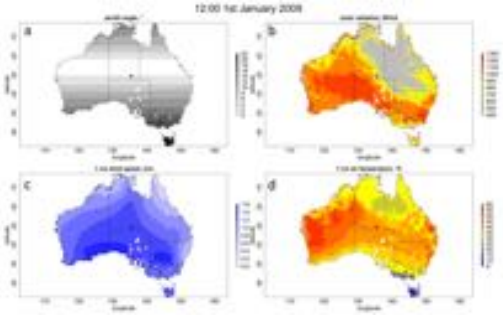


Austral ECOLOGY A Journal of ecology in the Southern Hemisphere

Austral Ecology (2019) **44**, 534–544

MicroclimOz – A microclimate data set for Australia, with example applications

MICHAEL R. KEARNEY*
School of BioSciences, The University of Melbourne, Parkville, Victoria 3010, Australia (Email: mrke@unimelb.edu.au)



Ecology, 100(11), 2019, e02829
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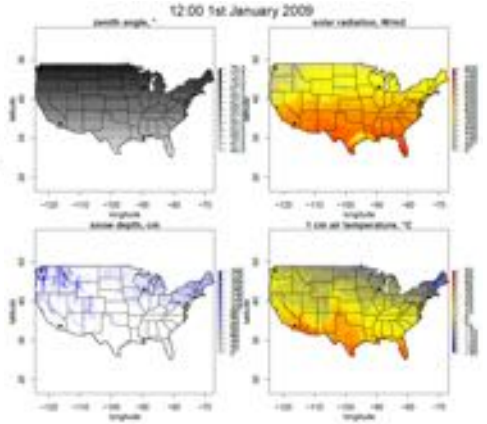
microclimUS: hourly estimates of historical microclimates for the United States of America with example applications

MICHAEL R. KEARNEY[1]

School of BioSciences, The University of Melbourne, Melbourne, Victoria 3010 Australia

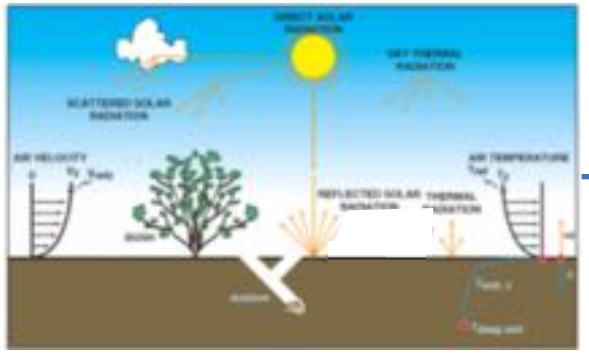
Citation: Kearney, M. R. 2019. microclimUS: hourly estimates of historical microclimates for the United States of America with example applications. Ecology 100(11):e02829. 10.1002/ecy.2829



Program

Time	Topic
9:00 -9:15	Introductions
9:15-9:45	What are mechanistic niche models and why do we need them? (MK & LB)
9:45-10:15	Calculating body temperature with TrenchR (LB)
10:15-10:30	Break
10:30-11:15	Intro to microclimate modelling with NicheMapR (MK)
11:15-12:00	Selecting microclimate data (LB & MK)
12:00-13:00	Lunch Break
13:00-13:45	Calculating body/leaf temperature with NicheMapR (MK)
13:45-14:45	Mass budgets with NicheMapR: Dynamic energy budgets (DEB) and water balance (MK)
14:45-15:00	Break
15:00-16:00	Q&A on mechanistic niche modelling (LB & MK)

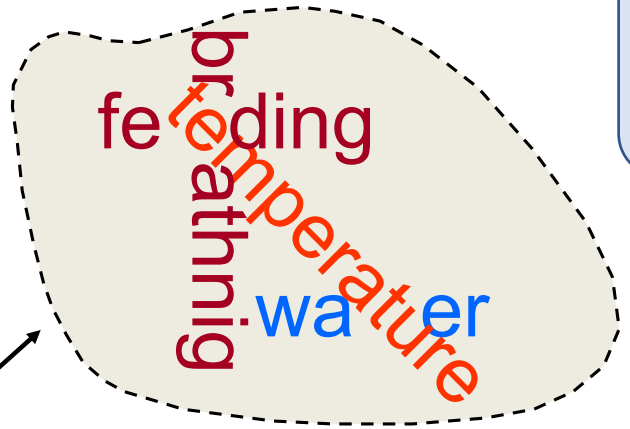
The Heat and Water Budget Model



output

- metout
- soil
- soilmoist
- soilpot
- humid

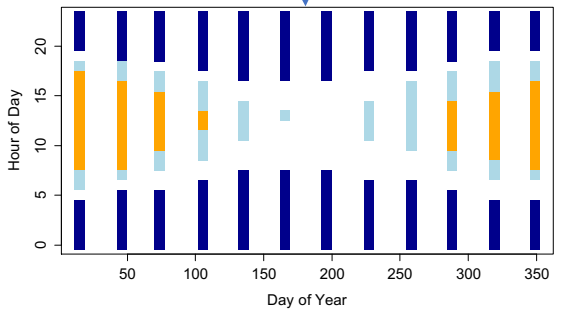
SURROUNDINGS



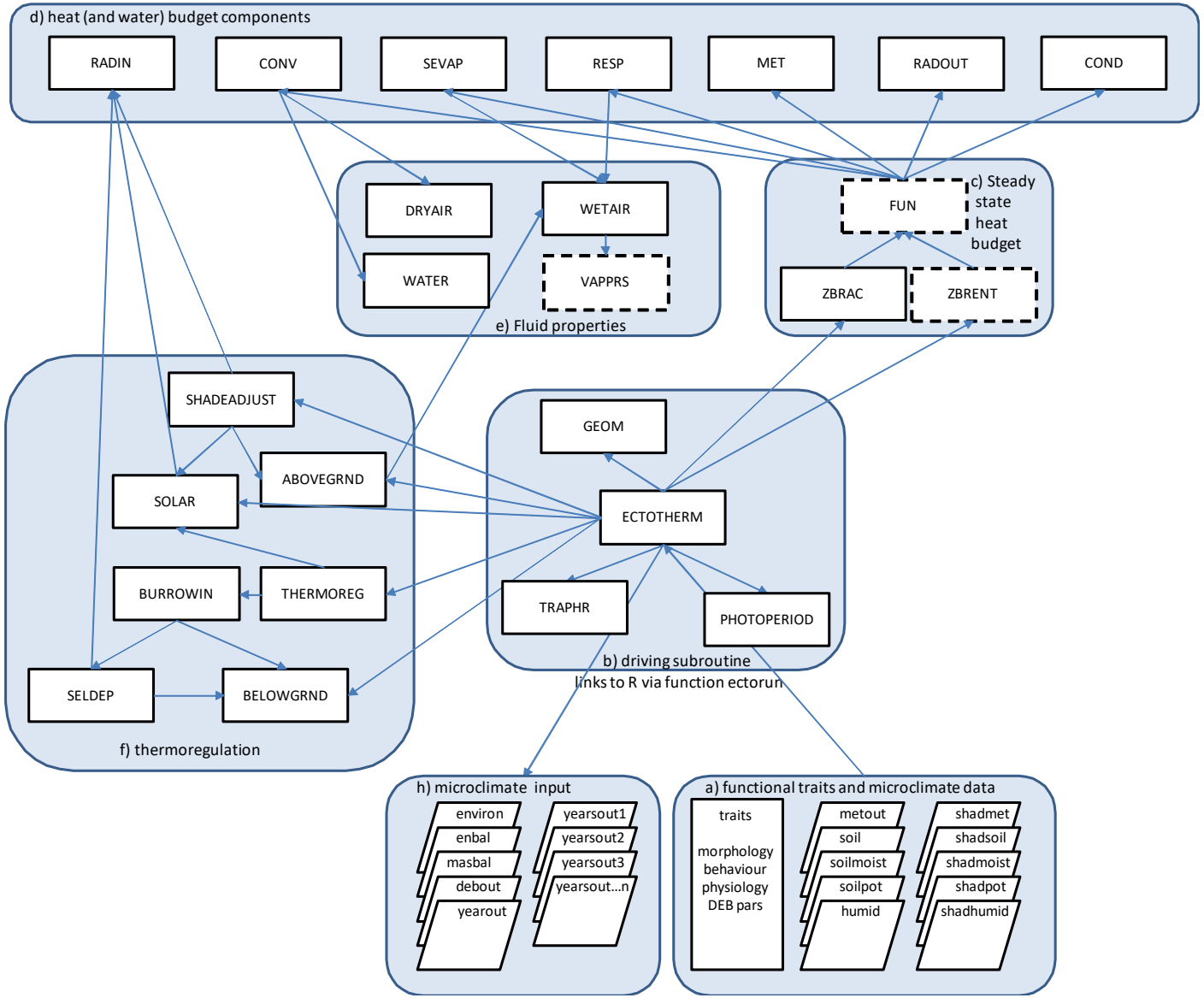
BOUNDARY

ectotherm.R

- environ
- enbal
- masbal

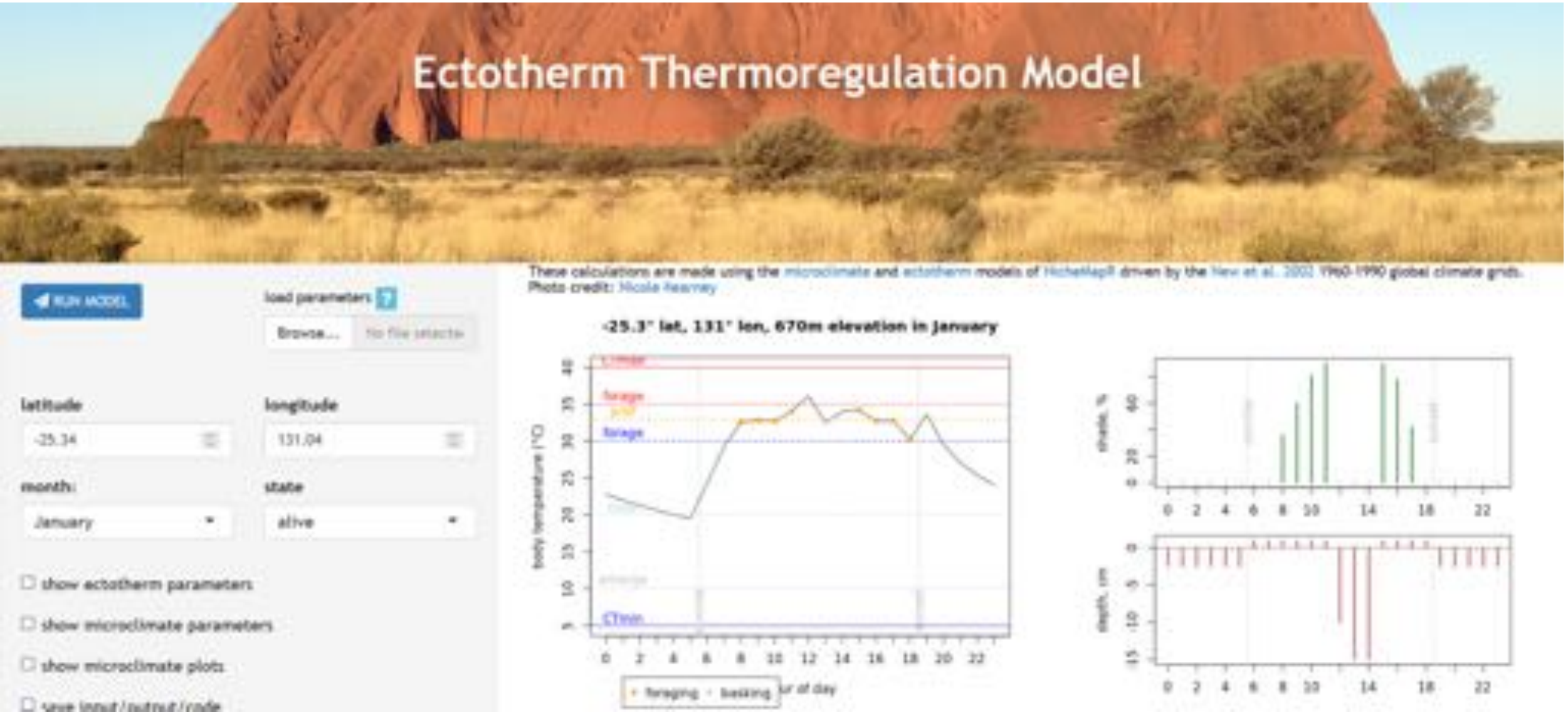


The Heat and Water Budget Model



shiny apps for NicheMapR

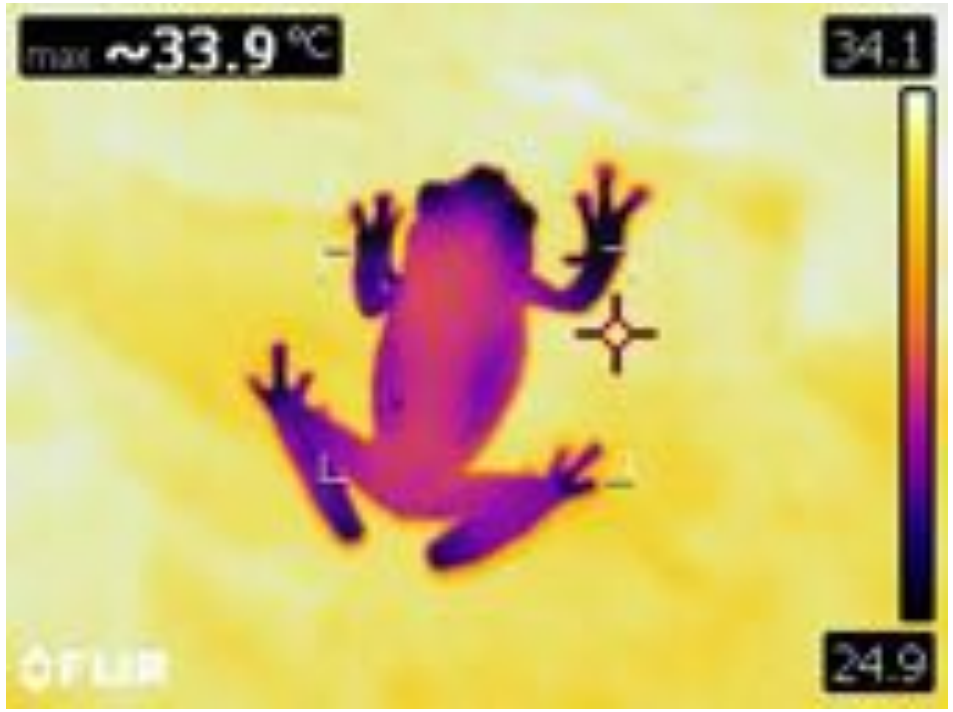
http://bioforecasts.science.unimelb.edu.au/app_direct/ectotherm/



Predicting Ectotherm Evaporation

Metabolism (gained) + Solar (gained) + Infra-red (gained) =

Infra-red (lost) + Convection (gained/lost) + Conduction (gained/lost) + Evaporation (lost)



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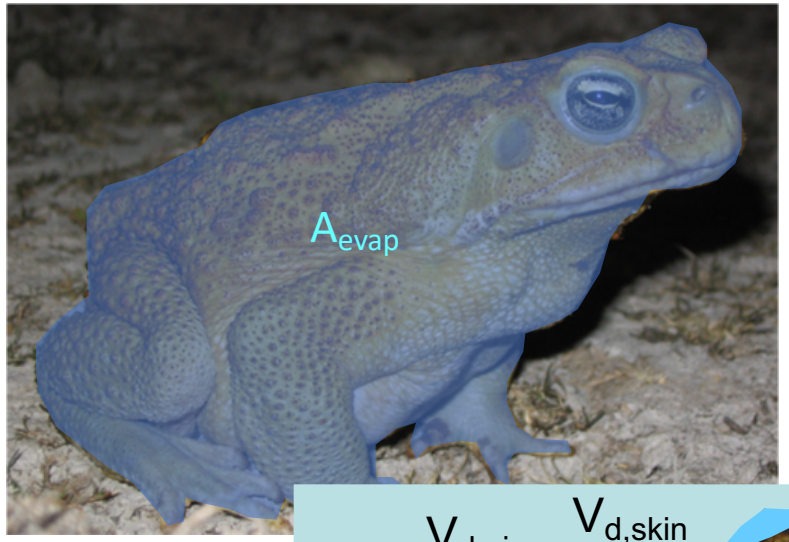


$$Q_{evap,resp} = \lambda(m_{out,resp} - m_{in,resp})$$

2.265 kJ/g

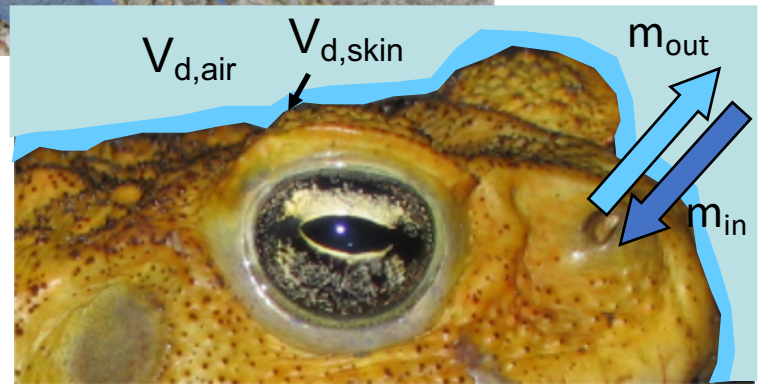
latent heat of vaporisation, J kg^{-1}

area wet, m^2

$$Q_{evap,cut} = A_{evap} h_d (V_{d,skin} - V_{d,air}) \lambda$$

mass transfer coefficient, m s^{-1}

vapor density, kg m^{-3}



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Endotherm Heat Budgets

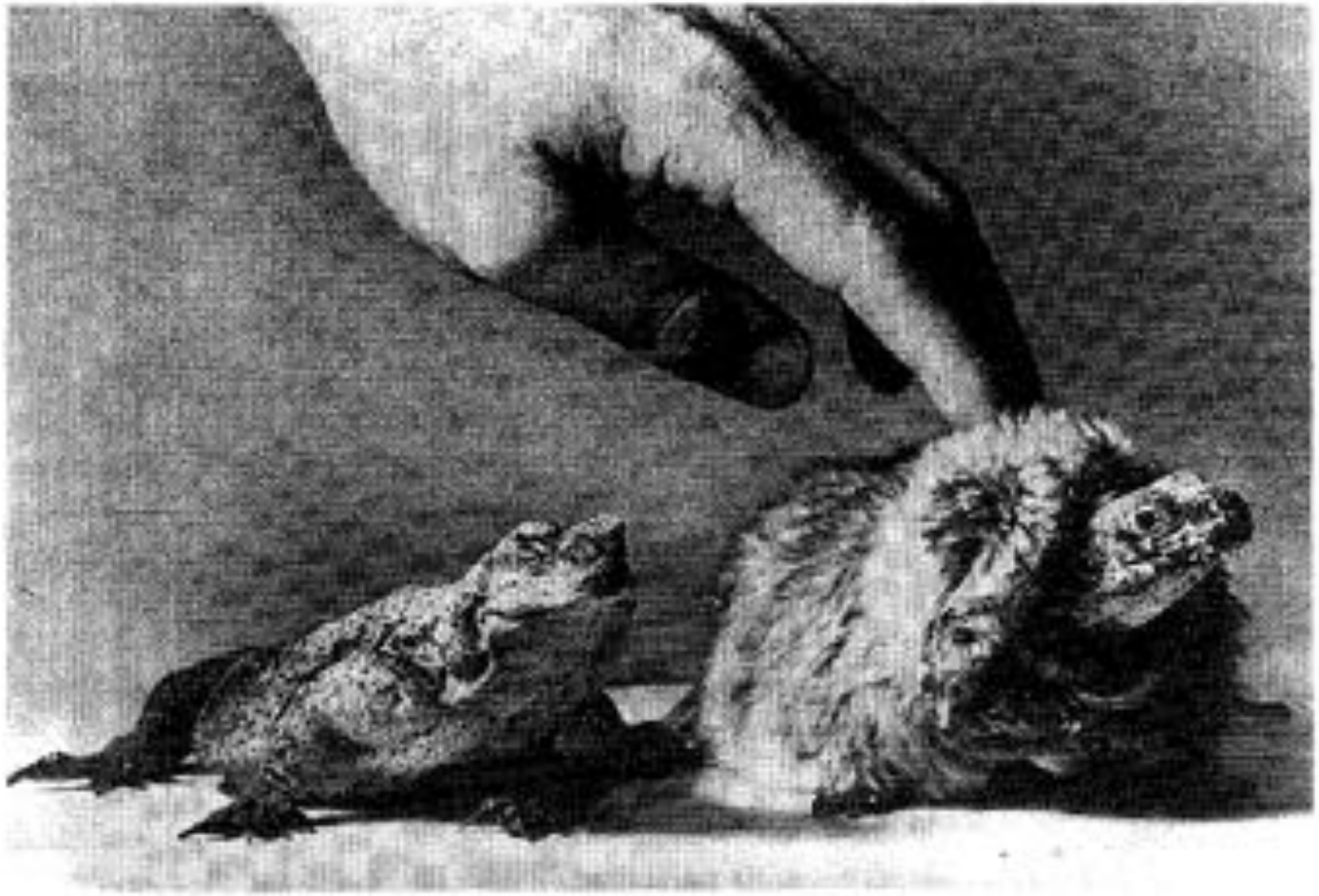
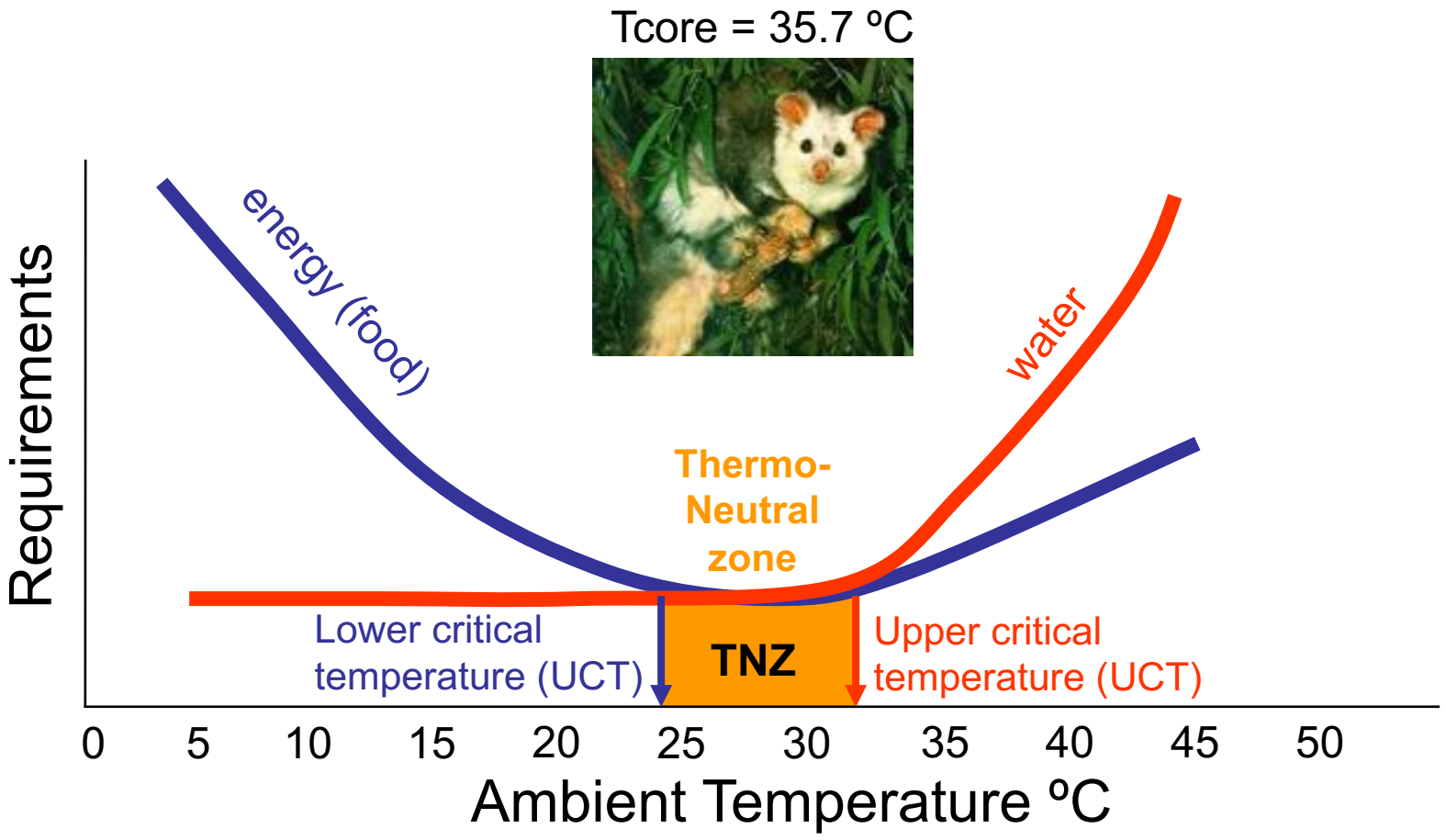
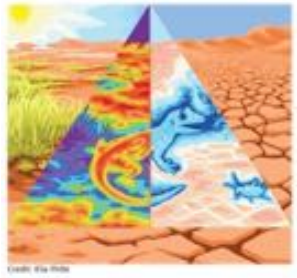


Fig. 1. Unpublished photograph of Raymond Cowles's early work on thermoregulation in reptiles as affected by fur (courtesy of Raymond Huey).

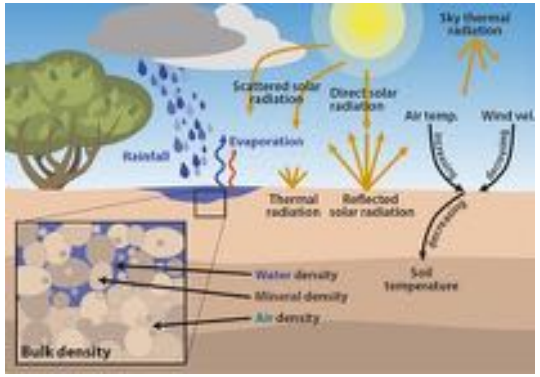
Endotherm Heat Budgets





NicheMapR

microclimate model



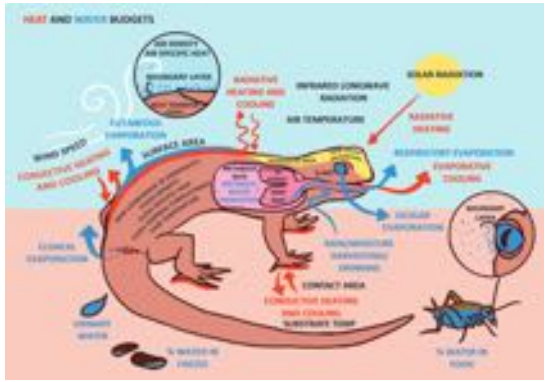
microclimate

plantgro

DRYAIR
WETAIR

micro_global
micro_terra
micro_ncep
micro_era5
micro_aust
micro_usa
micro_uk
micro_nz

ectotherm model

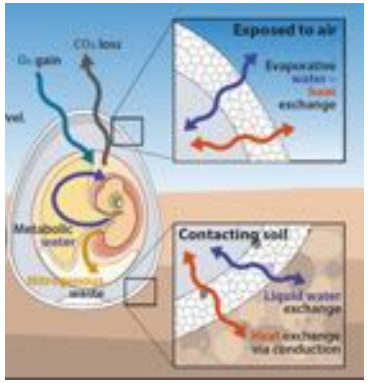


ectotherm

leaf_temperature

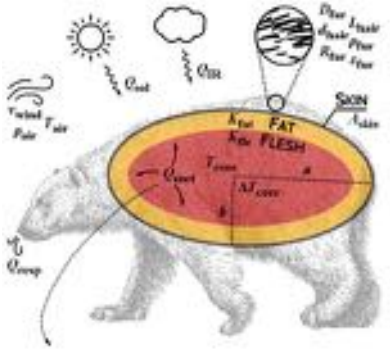
onelump
onelump_var
twolump

egg model



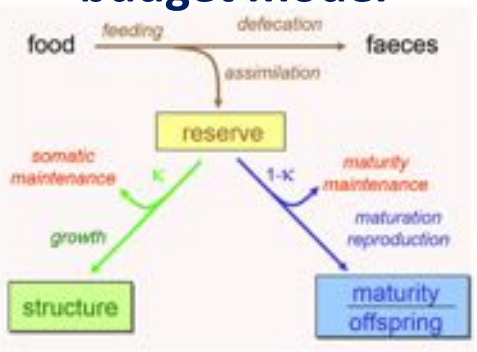
get_p_wet
egg_water

endotherm model

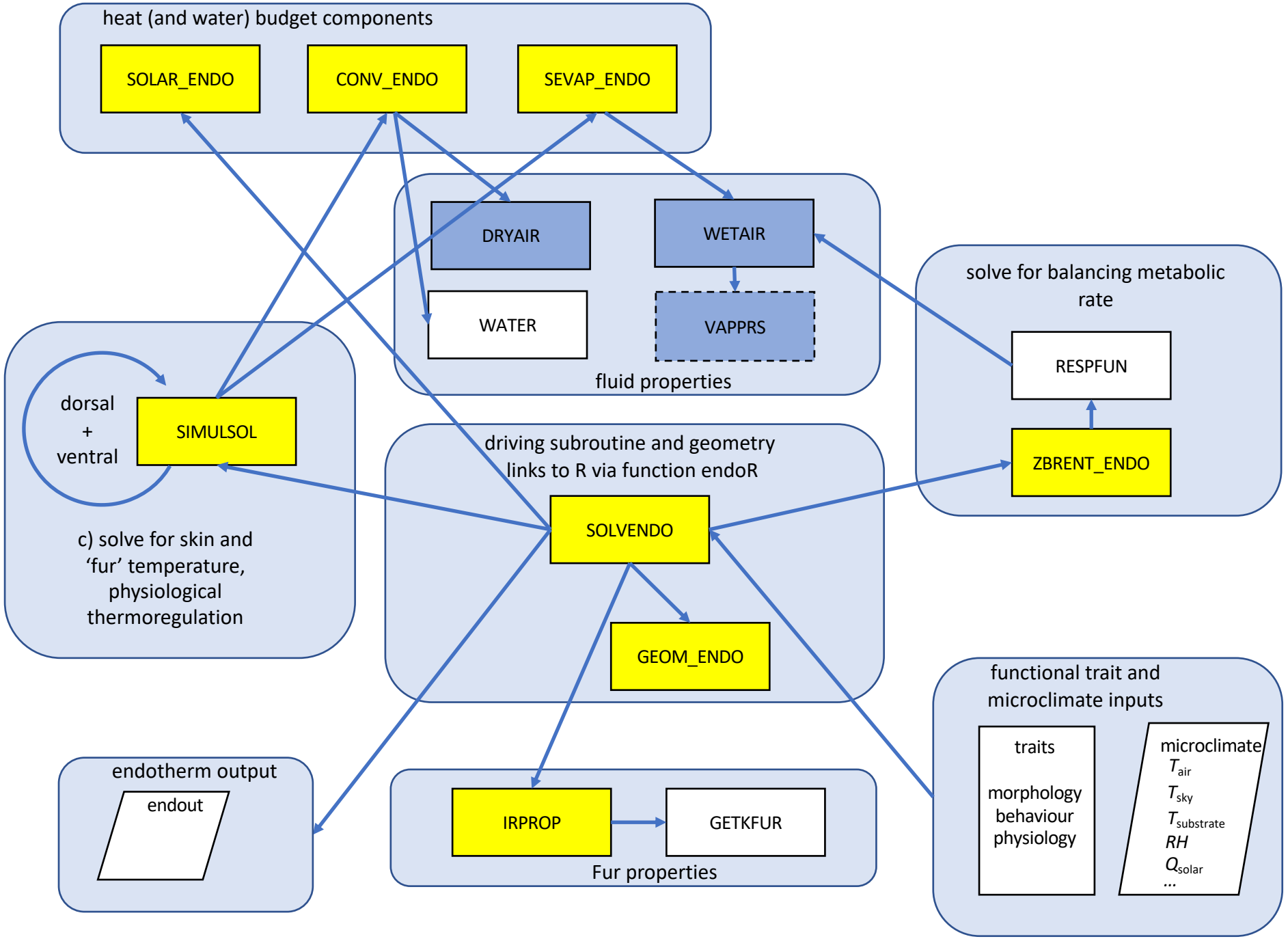


ellipsoid
endoR
endoR_devel

dynamic energy budget model



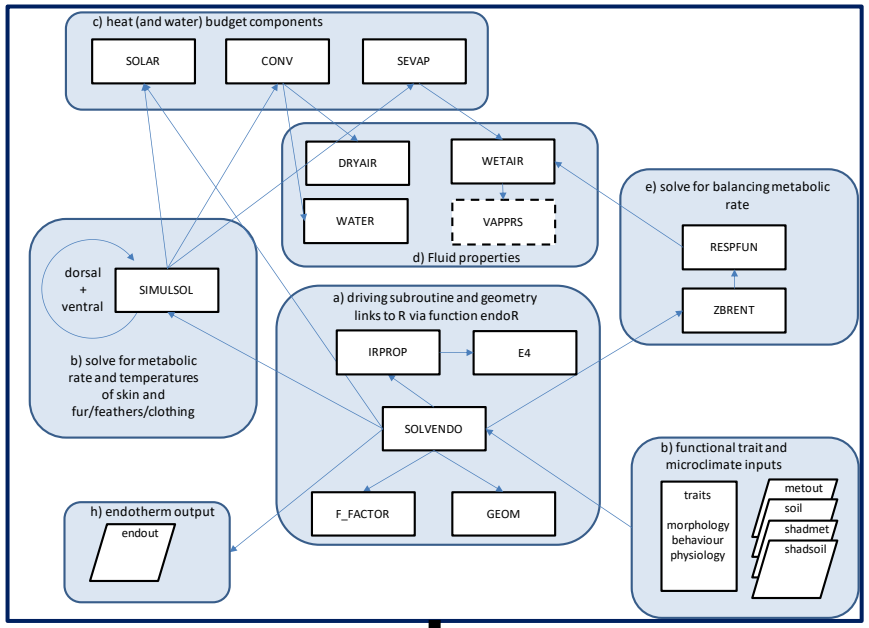
DEB
DEB_const
DEB_var
DEB_euler


heat (and water) budget components
SOLAR_ENDO
CONV_ENDO
SEVAP_ENDO
DRYAIR
WETAIR
WATER
VAPPRS
fluid properties
solve for balancing metabolic rate
RESPFUN
ZBRENT_ENDO
dorsal
+
ventral
SIMULSOL
c) solve for skin and 'fur' temperature, physiological thermoregulation
driving subroutine and geometry links to R via function endoR
SOLVENDO
GEOM_ENDO
functional trait and microclimate inputs
traits
morphology
behaviour
physiology
microclimate
T_{air}
T_{sky}
$T_{substrate}$
RH
Q_{solar}
...
endotherm output
endout
IRPROP
GETKFUR
Fur properties

Thermoregulation Routine

change

shade/depth/height
posture
flesh conductivity
core temperature
panting
skin wetness



>= QBASAL?