

GEOGRAPHY, AND ADAPTATION

Peter Ralph

University of Oregon
Biology & Mathematics

Evolution! Austin, June 18, 2016

collaborators

THE MOJAVE DESERT TORTOISE: *Gopherus agassizii*



THE MOJAVE DESERT TORTOISE:



THE MOJAVE DESERT TORTOISE:

World's Largest Solar Plant Opens

Gabriela Quirós, KQED Science | February 13, 2014 | 0 Comments

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The Ivanpah solar project in the Mojave Desert, the largest solar farm in the world. (Lauren Sommer/KQED)

The largest solar plant in the world officially starts generating electricity on Thursday. The Ivanpah solar farm, in California's Mojave Desert about 40 miles south of Las Vegas, will produce enough electricity to power 140,000 homes per year.

THE MOJAVE DESERT TORTOISE:

Endangered tortoises delay Mojave Desert solar plant

APRIL 28, 2011 | 12:18 PM



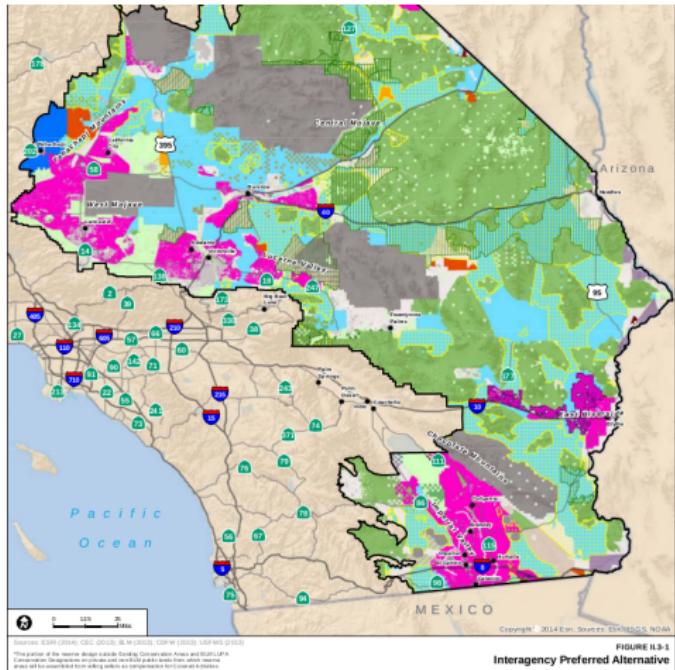
The Obama administration has halted the building of two-thirds of a massive solar project in San Bernardino's Mojave Desert as a new federal assessment found that more than 600 endangered desert tortoises would die as a result of construction.

The U.S. Bureau of Land Management assessment this week disputed the estimate by BrightSource Energy, developer of the 392 MW solar thermal plant, that only 38 of the reptiles would be disturbed by construction at the 5.6-square mile Ivanpah Valley site near Primm, Nev. [corrected: an earlier version of this post said 5.6 acres]

Questions concerning the California tortoises highlight the friction between wilderness conservation and the quest for cleaner power. Many environmentalists contend it would be preferable to subsidize smaller solar arrays on commercial and residential rooftops, or on industrial acreage, than offer government loan guarantees to large complexes on wildlands that require transmission lines to transport the electricity to urban areas.

THE QUESTION

How will changes
to the landscape
change gene flow?



DATA COLLECTION

Thanks to **lots of hard work**,
we have

- ▶ 83 GIS layers at 30m – Jannet Vu (UCLA)
- ▶ tissue samples – Dick Tracy, Chava Weitzman (UNR), Fran Sandmeier (U. Lindenwood)
- ▶ 270 tortoises: whole-genome sequences, average **1x coverage**, $> 10^{12}$ bp – Evan McCartney-Melstad (UCLA)

layer name	Layer Category	Layer Description
imperv_30	anthropogenic	percent impervious surfaces
road_30	anthropogenic	euclidean distance to nearest road
agp_250	biotic	annual growth potential
grass_herb_30	biotic	grassland/herbaceous cover
shrub_30	biotic	shrub cover
m2_08_precip	climate	avg. precip (Aug)
m2_ann_precip	climate	avg. annual precip
m2_anntmax	climate	avg. annual max temp
m2_anntmean	climate	avg. annual mean temp
m2_anntmin	climate	avg. annual min temp
win_precip	climate	avg. winter precip
avg_rough_30	landscape	average surface roughness
aspect_30	landscape	direction of slope face
barren_30	landscape	percent barren land
dem_30	landscape	elevation
eastness_30	landscape	degree to which slope faces east
lat_gcs_30	landscape	latitude
lon_gcs_30	landscape	longitude
northness_30	landscape	degree to which slope faces north
slope_30	landscape	inclination of landscape in degrees
surarea_30	landscape	surface area of a grid cell
bd_ss2_st_30	soils	bulk soil density
bdrock_ss2_st	soils	depth to bedrock
pr_ss2_st	soils	percent rocks
		TOTAL

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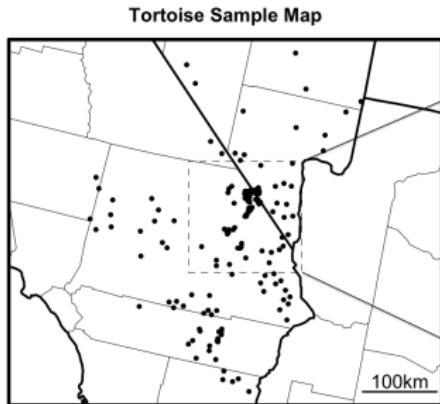
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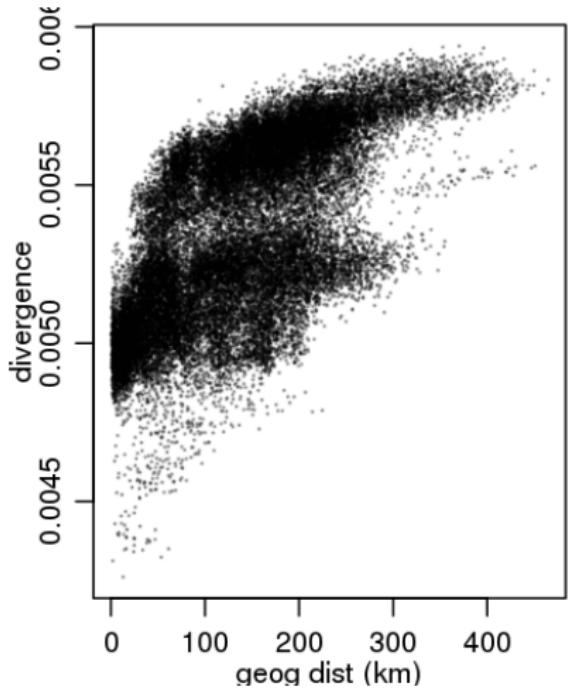
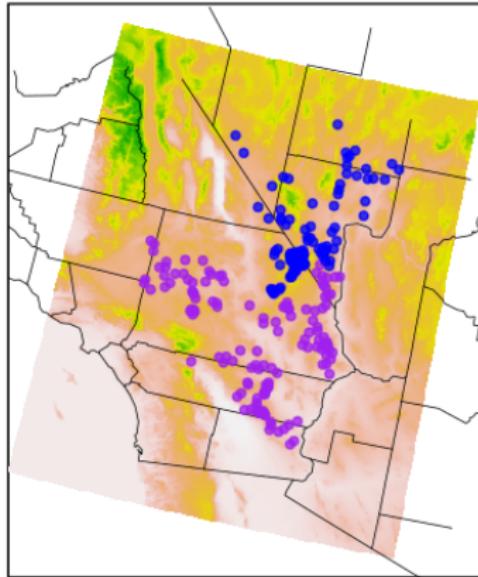
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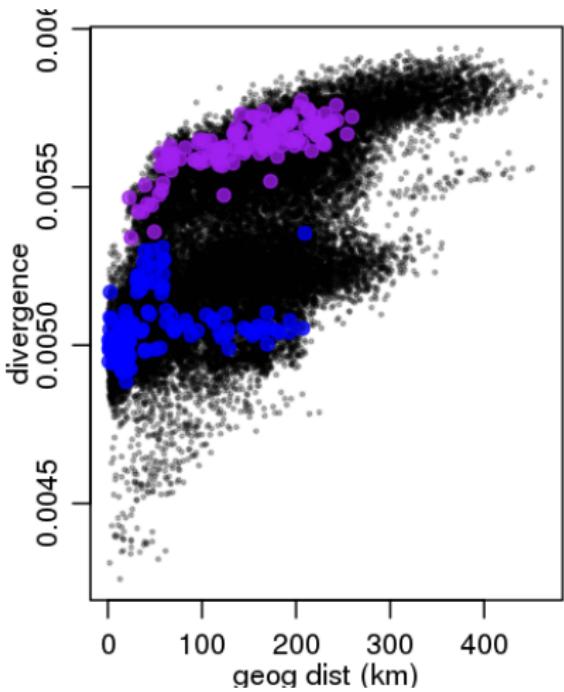
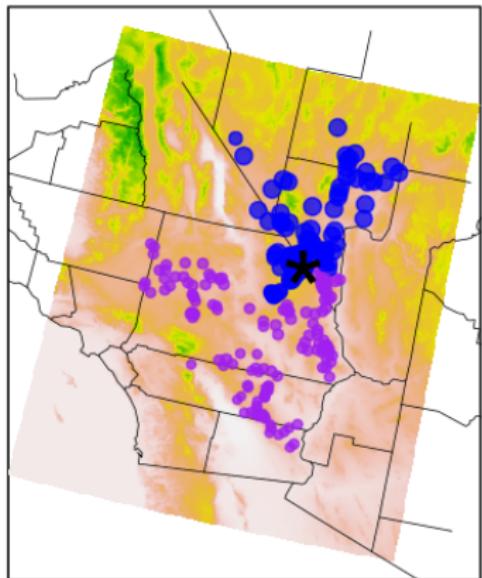


PAIRWISE DIVERGENCE



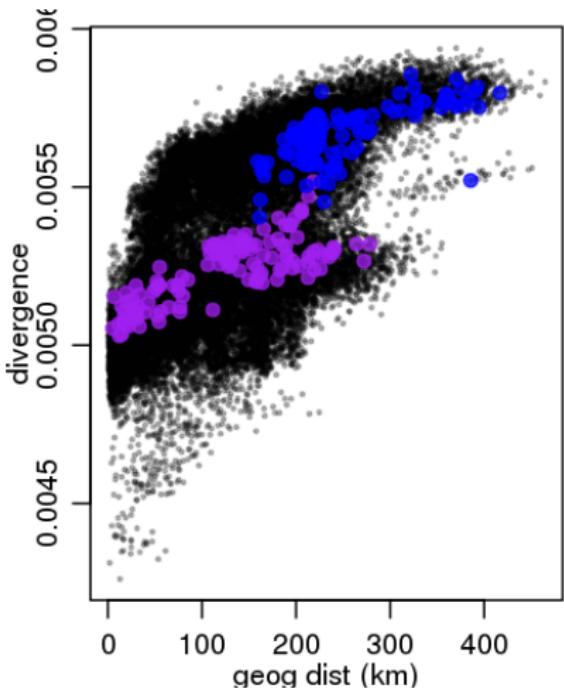
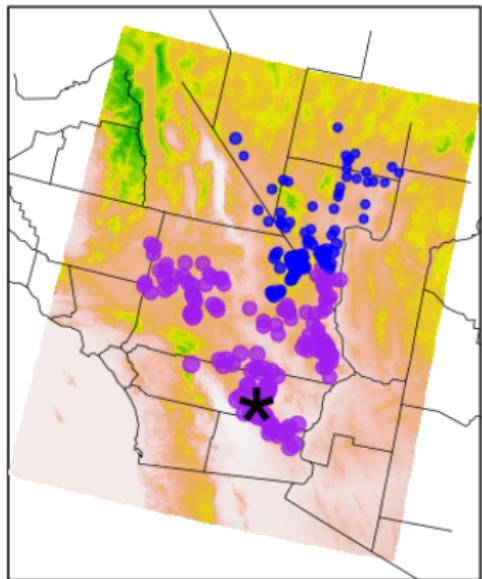
divergence = (mean density of nucleotide differences)

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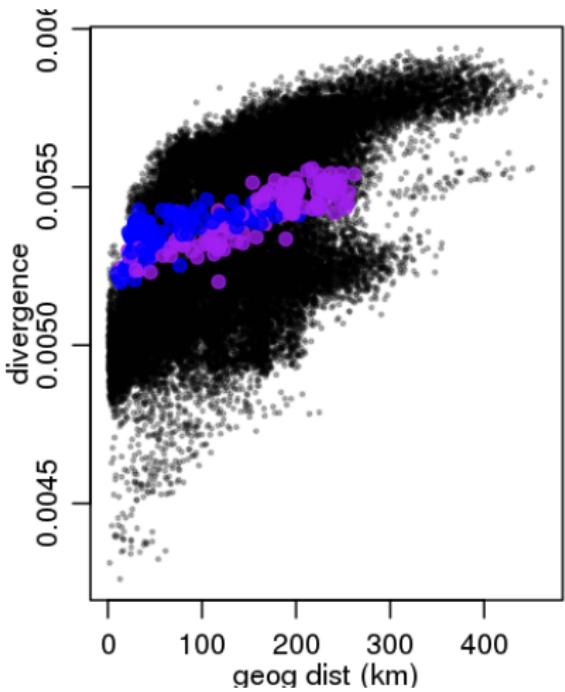
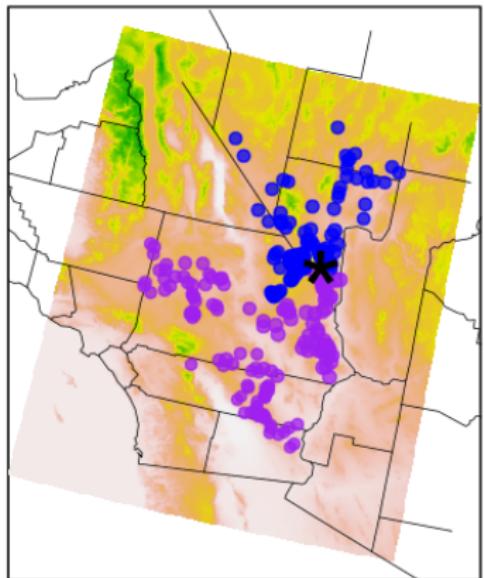
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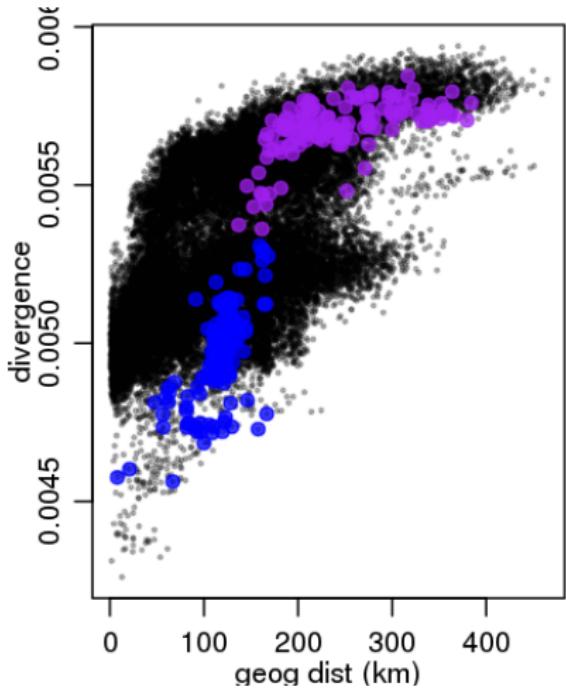
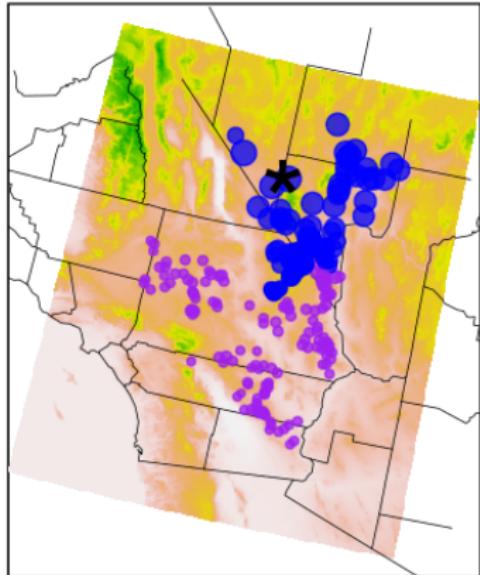
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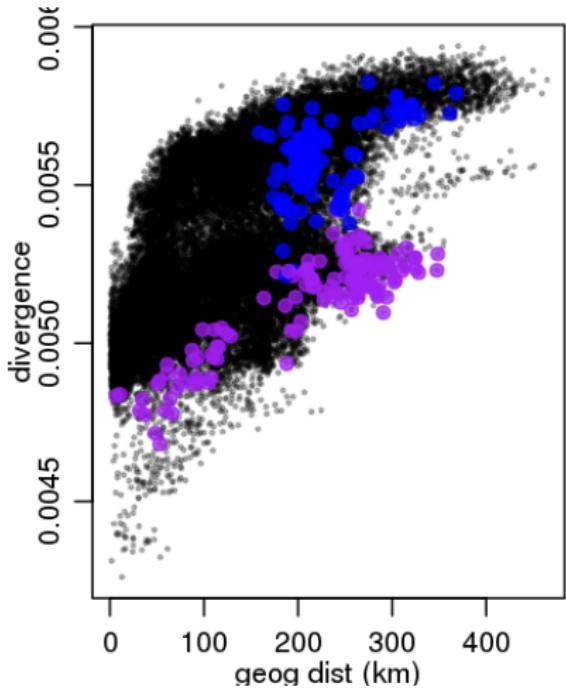
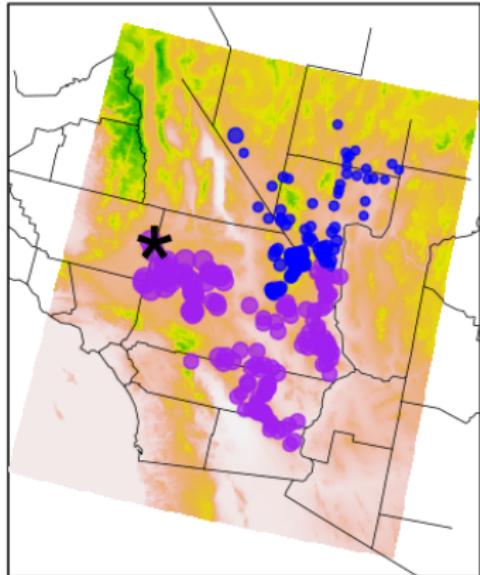
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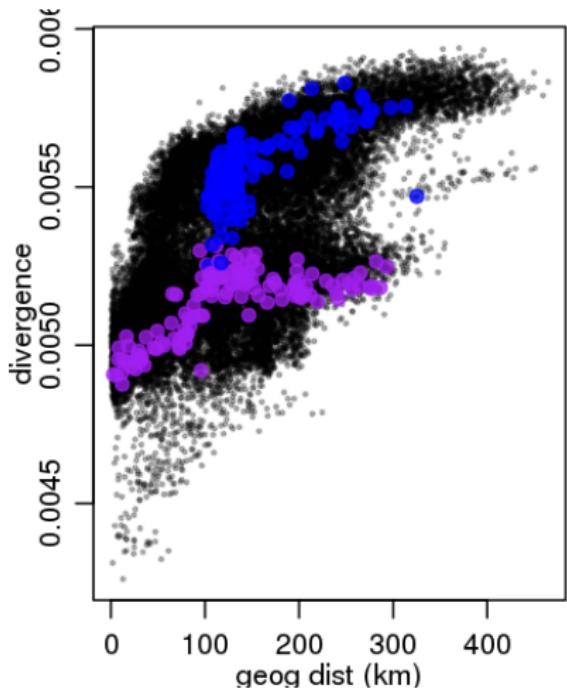
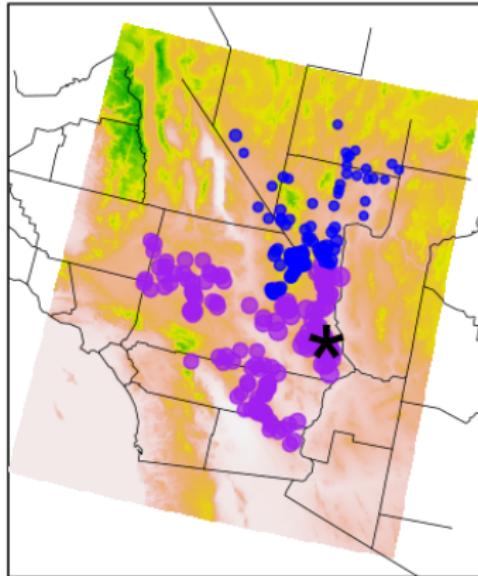
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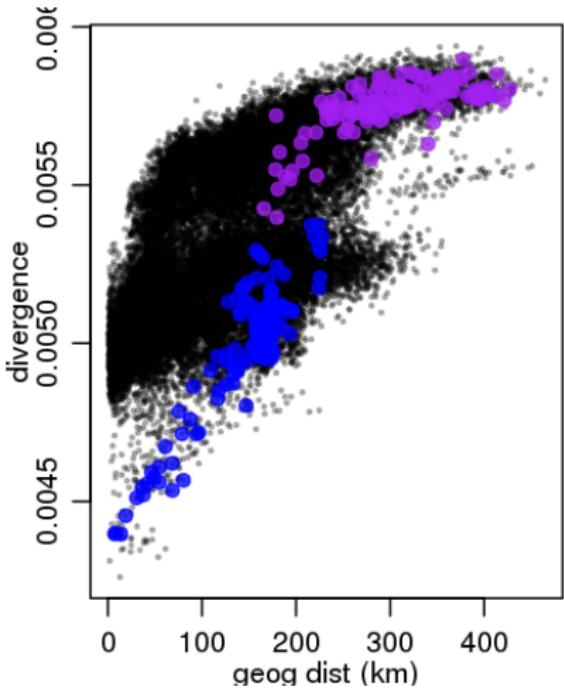
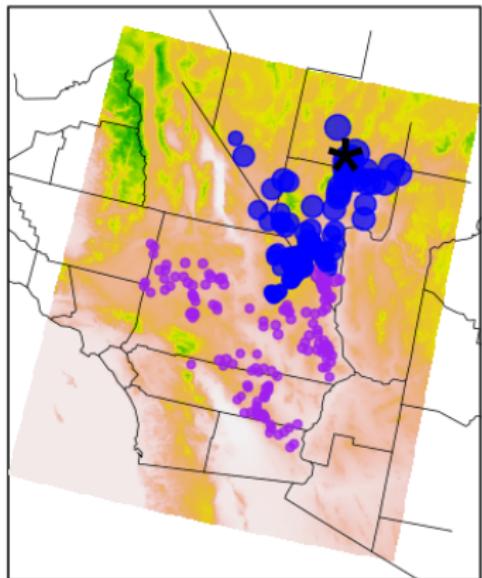
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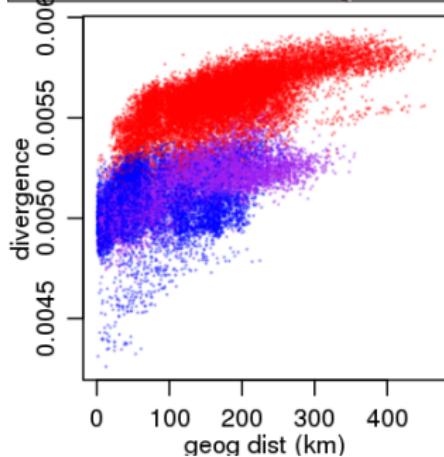
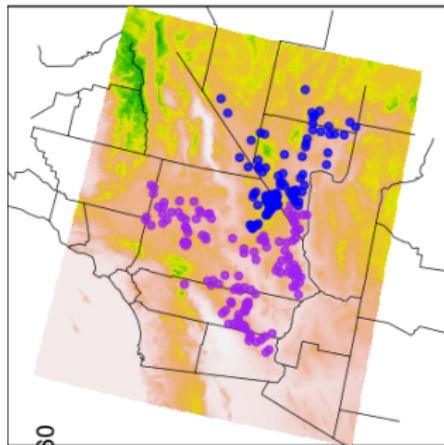
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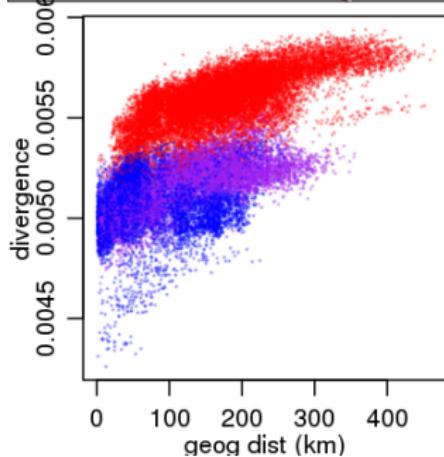
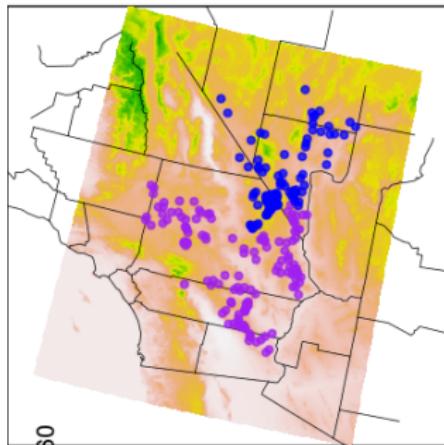
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DESCRIPTIVE STATISTICS



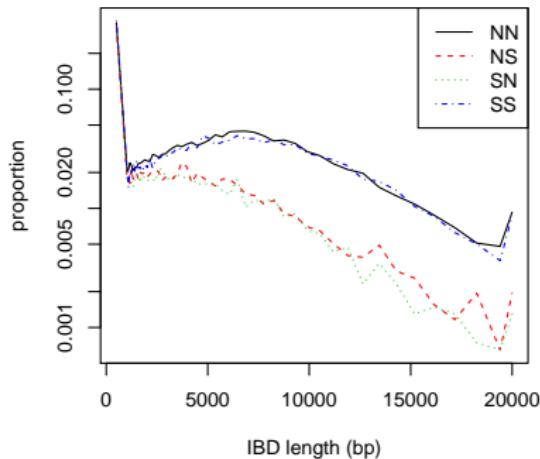
- ▶ Sequencing error < .001 (from mitochondria)
- ▶ Mean time to most recent common ancestor:
≈ 100,000 generations
(calibrated to painted turtle)
- ▶ Additional separation across north/south break:
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- ▶ Similar demography in north and south?

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FOLLOWING A LINEAGE



A **single lineage** back through time:

- ▶ jump rate is mean age of parent at birth
- ▶ tends to move towards regions that produce more offspring

LINEAGE MOVEMENT

Recall that we have **landscape variables**, e.g.,

$$g_1(x) = (\text{elevation at } x)$$

$$g_2(x) = (\text{scrub cover at } x)$$

⋮

and define

jump rate at x : $u(x) = 1 / \left(1 + \exp \left(- \sum_{k=1}^n \alpha_k g_k(x) \right) \right)$

habitat quality at x : $\rho(x) = e^\gamma / \left(1 + \exp \left(- \sum_{k=1}^n \beta_k g_k(x) \right) \right)$

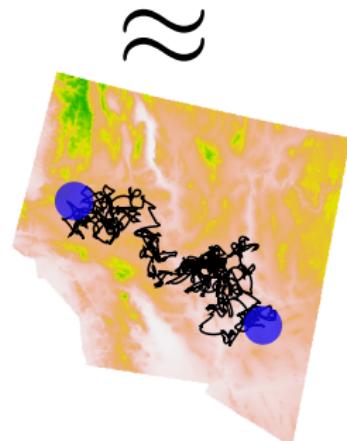
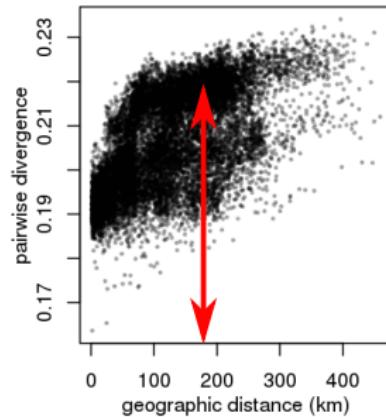
Then choose α , β , and γ so that

$$dX_t = \rho(X_t) \nabla u(X_t) dt + \sqrt{\rho(X_t) u(X_t)} dB_t$$

fits the data.

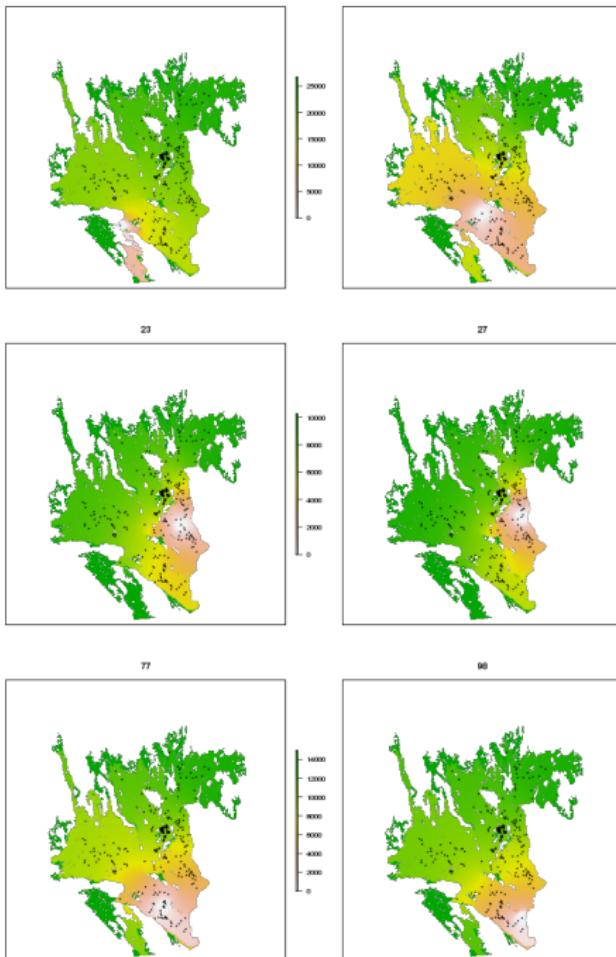
THE REST OF THE METHOD

- ▶ Sequence divergence
≈ mean hitting times of a lineage
- ▶ fit parameters by solving PDE
- ▶ Results: quantitative comparison of different development scenarios.



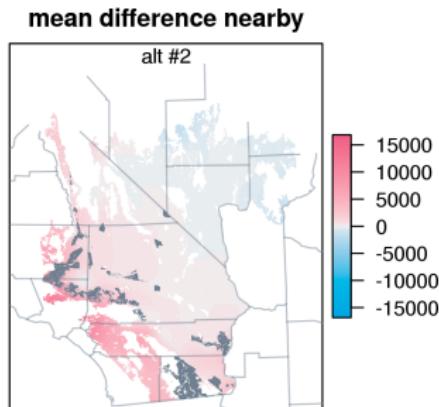
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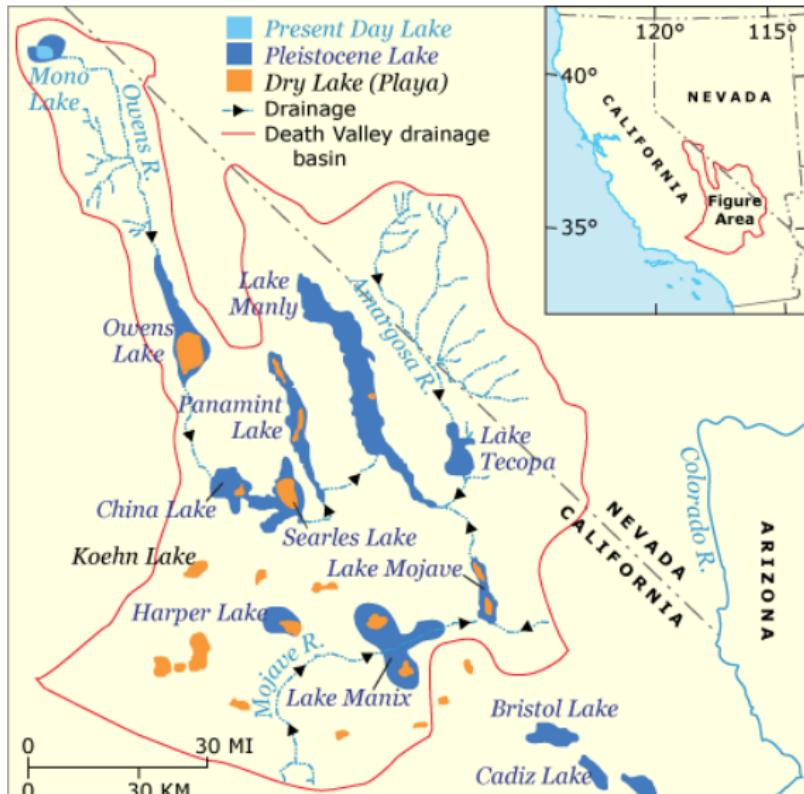


SLOW AND STEADY

Best-fit model uses only the shape of the range (**flat!**),
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WHAT'S NEXT

- ▶ Use haplotype sharing to fit models of lineage movement,
 - ▶ including time-inhomogeneous models.

Putting it all together,

- ▶ spatially explicit models
- ▶ of explicit regulatory networks
- ▶ adapting to heterogeneous selective pressures.

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Thanks!

Evan McCartney-Melstad



Graham Coop



Brad Shaffer



Gideon Bradburd

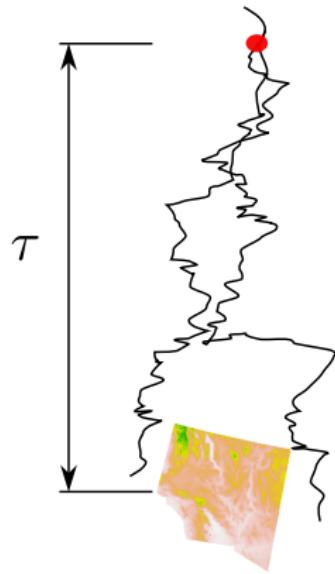
Jannet Vu

Data: POPRES // Fran Sandmeier,
Chava Weitzman, Dick Tracy

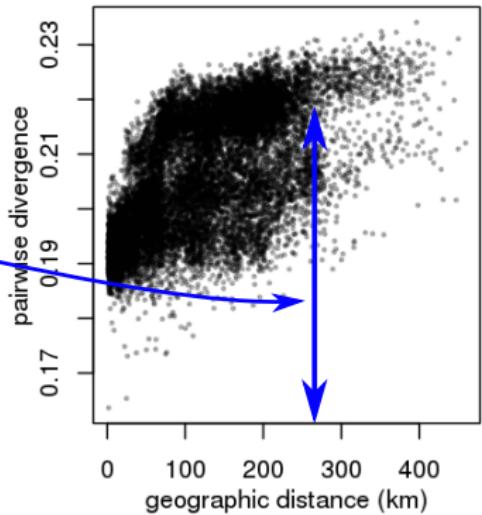
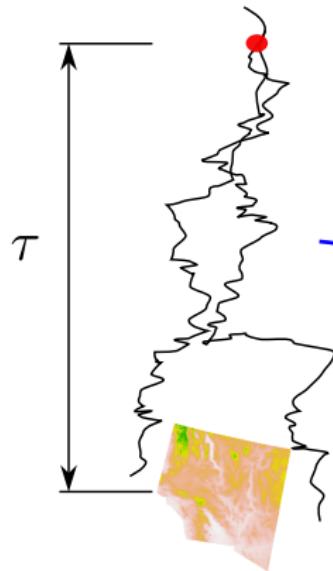
Funding:

NSF: ABI // Sloan Foundation

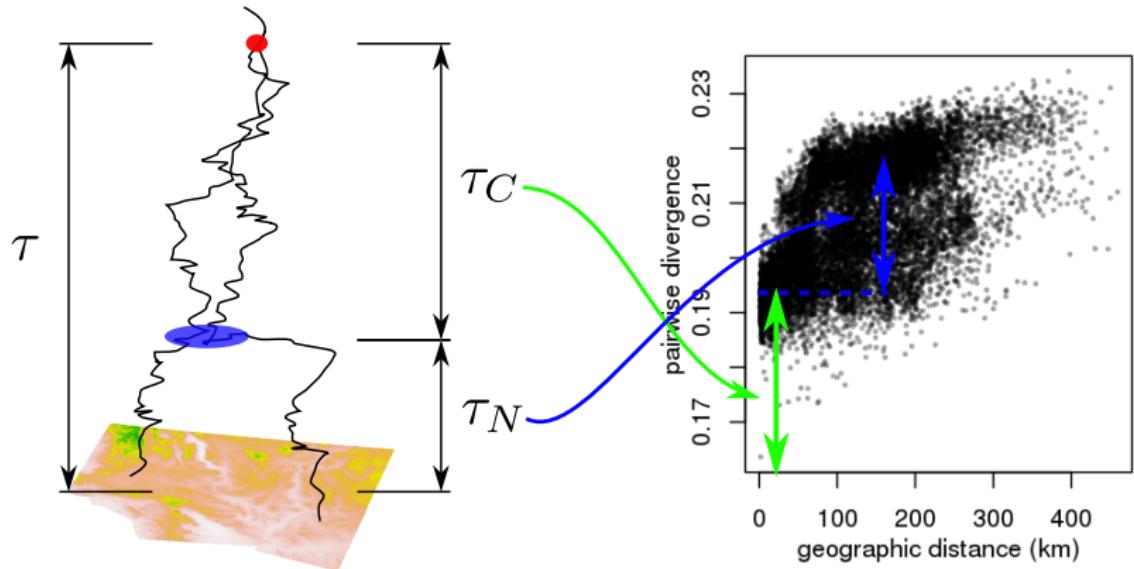
PAIRWISE DIVERGENCE AND HITTING TIMES



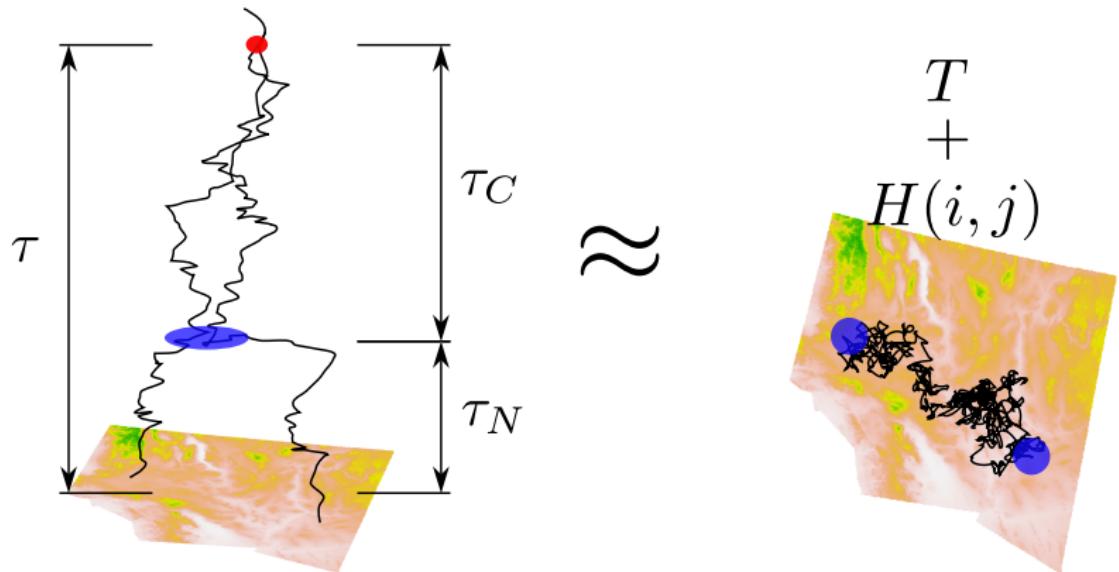
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A MORE TRACTABLE PROBLEM

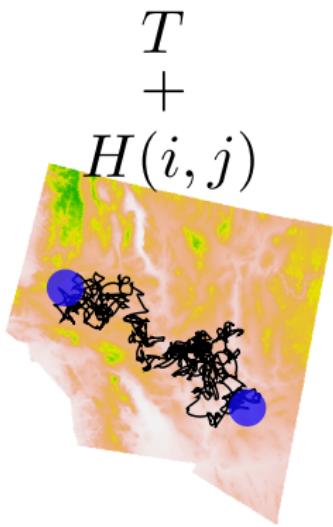


Replace τ_N by commute time
(a.k.a. **resistance distance**, McRae et al)

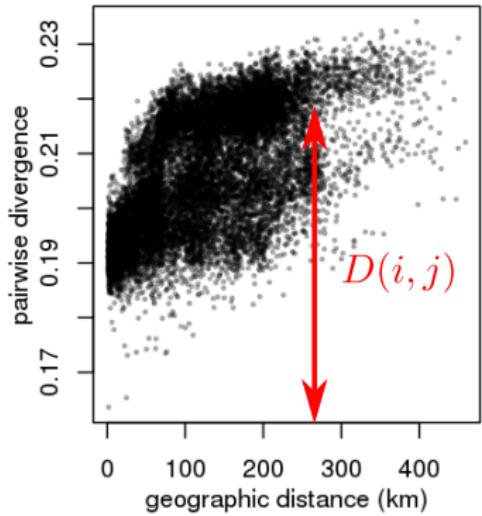
$$N(i, j) = \mathbb{E}[(\text{time to get near } j \text{ started from } i)]$$

$$H(i, j) \approx \frac{N(i, j) + N(j, i)}{2}.$$

A MORE TRACTABLE PROBLEM



??



Find parameters α, β, γ, T to minimize

$$\sum_{ij} |D(i, j) - T - H(i, j)|^2$$

FITTING HITTING TIMES

Parameters α, β, γ determine u and ρ :

$$Gf(x) := \rho(x) \nabla \cdot (u(x) \nabla f(x)).$$

Then

$$h_A(x) := \mathbb{E}[\text{ time for } X_t \text{ to hit } A \text{ from } x],$$

solves

$$Gh_A(x) = -1 \quad \text{for } x \notin A$$

$$h_A(x) = 0 \quad \text{for } x \in A$$

Keywords: multigrid methods for elliptic PDE.

... and we can get derivatives by solving the same sort of equation:

$$G(\partial_\alpha h_A(x)) = -(\partial_\alpha G)h_A(x)$$

$$G(\partial_\alpha^2 h_A(x)) = -(\partial_\alpha^2 G)h_A(x) - 2(\partial_\alpha G)(\partial_\alpha h_A(x))$$

... and use a **trust region algorithm** to optimize.

