# Insect diapause is sensitive to climate variability

A meta-analysis

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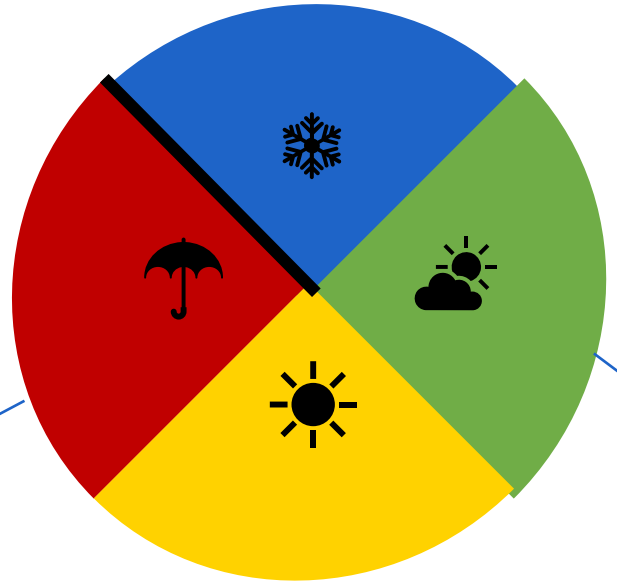
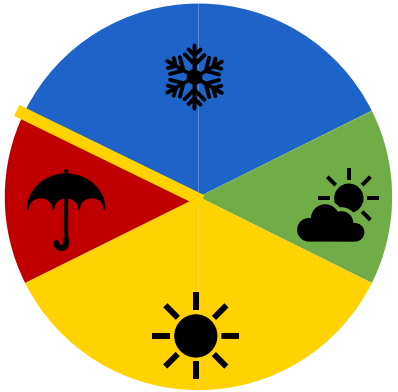
# Climate change

- Climate changes
- Species need to adapt (phenology shifts)
- Frost kills arthropods, so winter phenology is particularly important for them

# Coping with phenological change

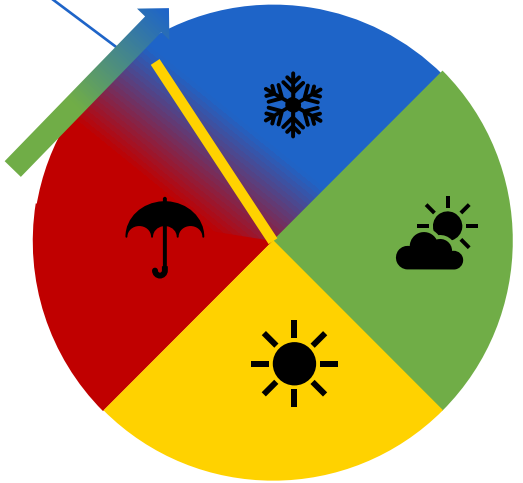


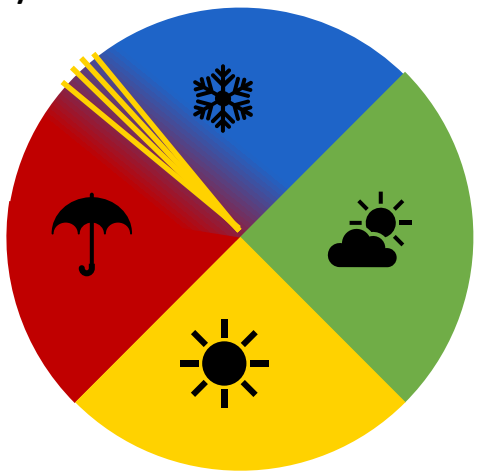
Changes in
Mean winter onset:



**Change your Mean timing**

Changes in
winter Variability:



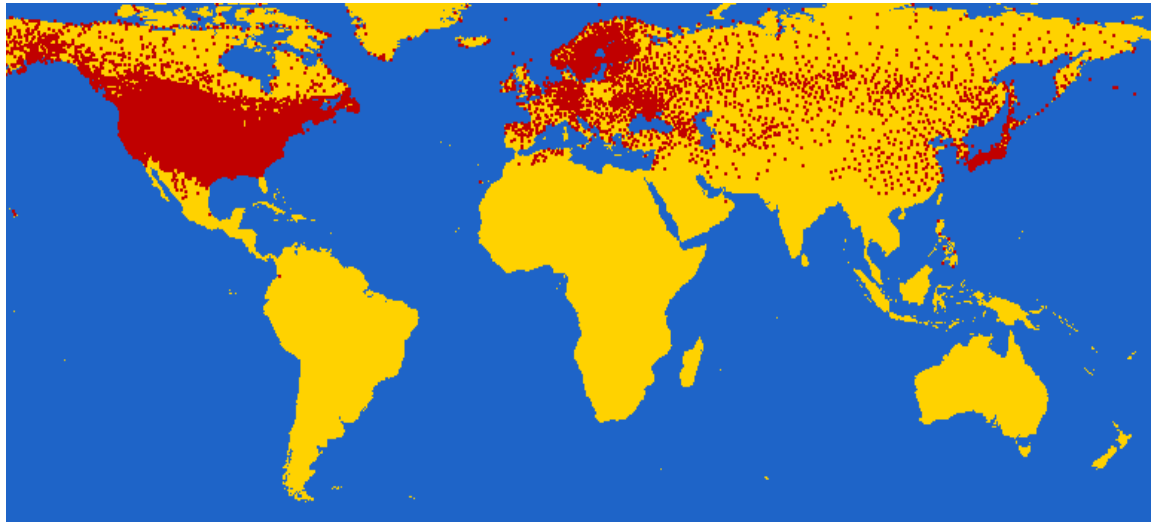


**Rely on plasticity** **OR** **Hedge your bets**
(depending on winter predictability)

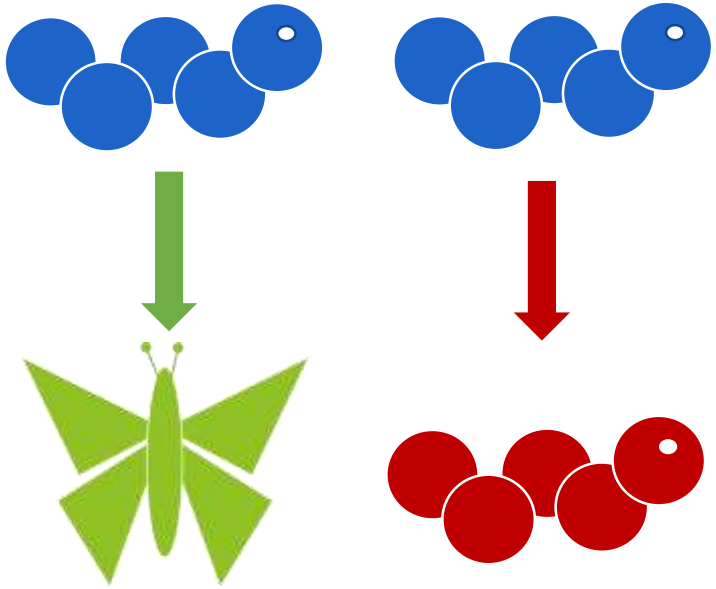
**Do insects have both strategies at disposal?**

# Approach

- Meta-analysis: Populations along latitudinal gradients
  - Mean winter onset, variability, precictability: GHCN-Daily
  - Mean timing, bet-hedging, plasticity : lab studies



Each pixel is a climate station with daily temperature recordings for ~20-50 years

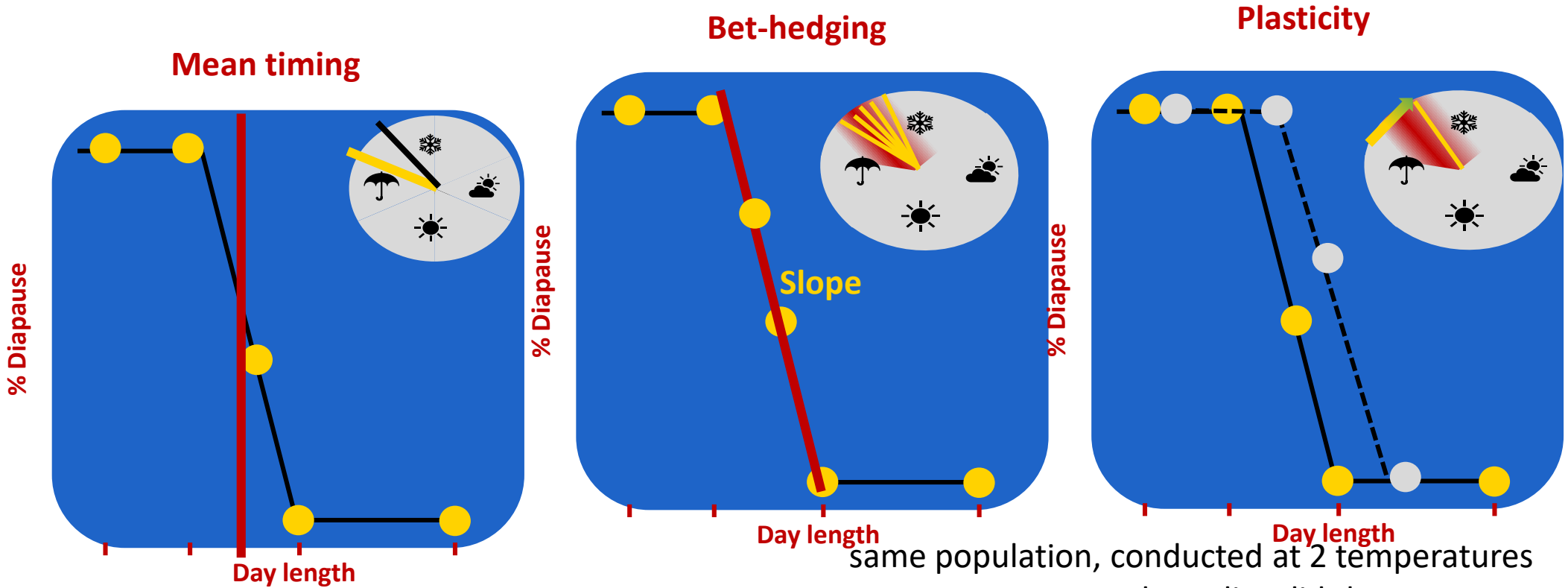


Individuals from multiple populations were put into various day lengths to test for diapause induction

# Methods 1: studies

Hypotheses:
CDL ~ mean winter onset
Slope ~ Variability * predictability

- Photoperiodic response curves for multiple pops (with differing climatic background), derived from lab studies
- Displayed here for 1 hypothetical population




Critical Day Length = day length with 50% induction

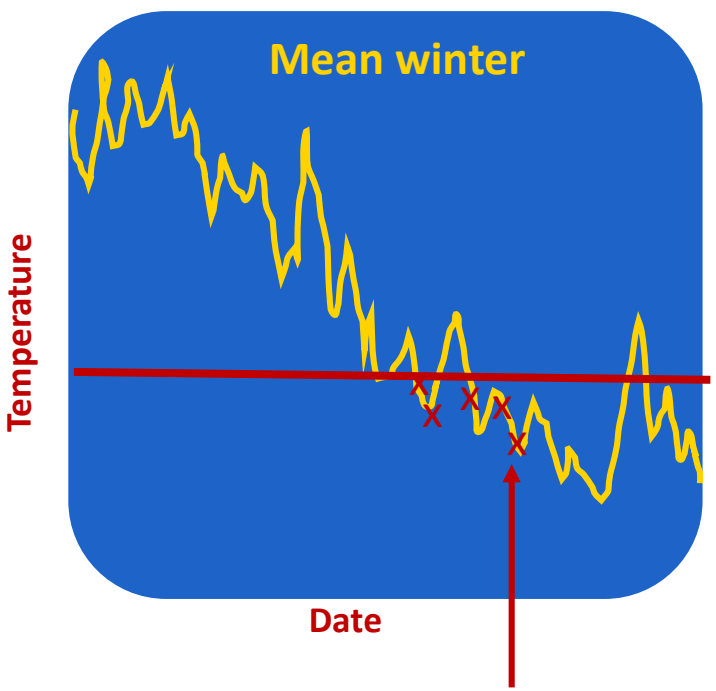
same population, conducted at 2 temperatures
Not enough studies did that
But plasticity can also be inferred by lack of bet-hedging

# Methods 1: Studies

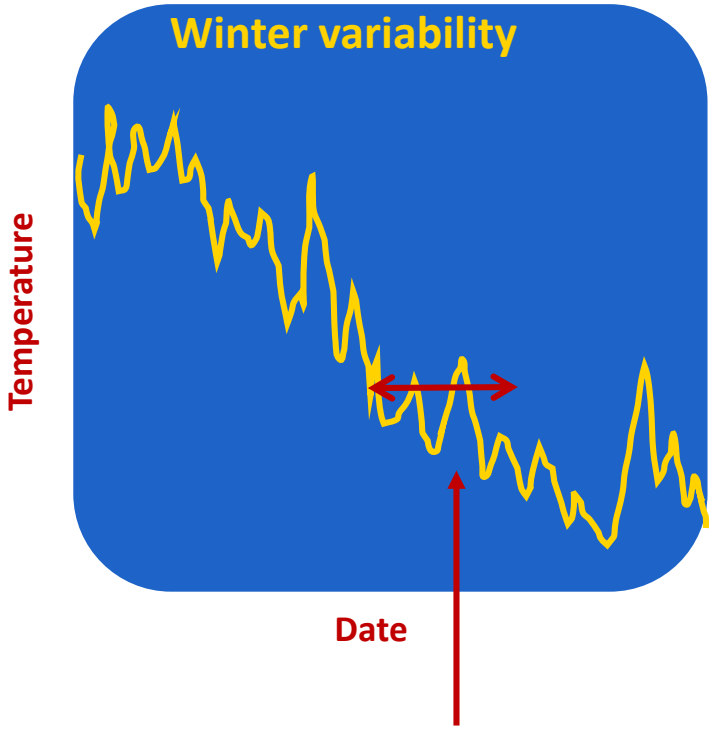
- Eligibility criteria:
  - 3+ pops
  - 4+ points
  - 2+ points on sloped part

- Dose response curve analysis, extract CDL and slope + S.E.

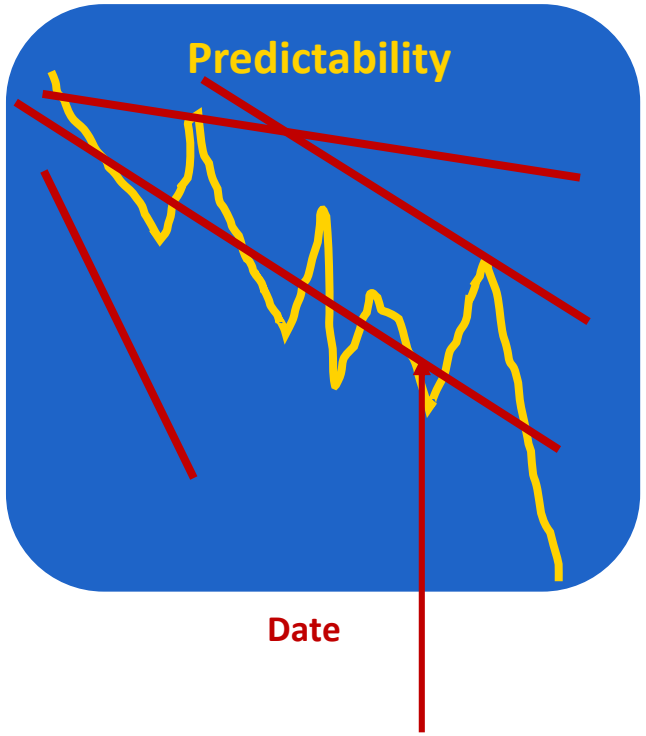
# Methods 2: Climate




Winter onset




Between-years standard deviation



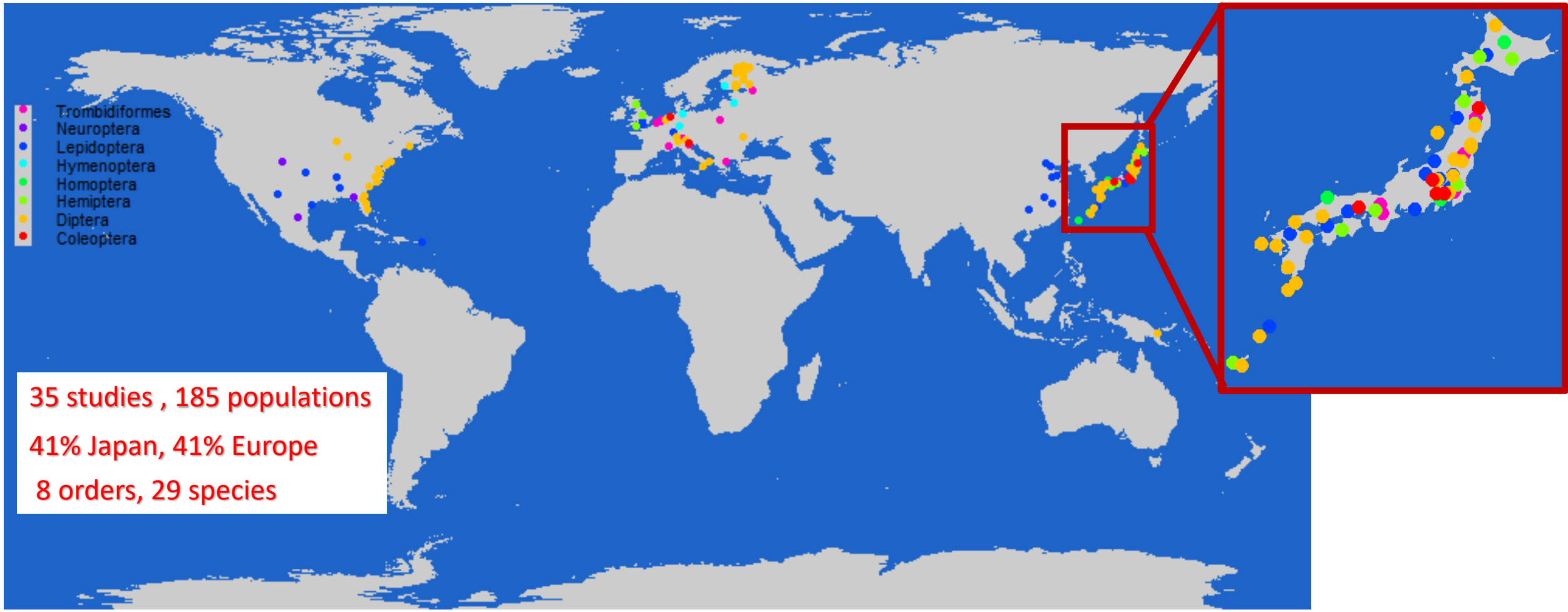

Between-years sd of these slopes

Winter onset = 10$^{th}$ day with mean temperature below 5°

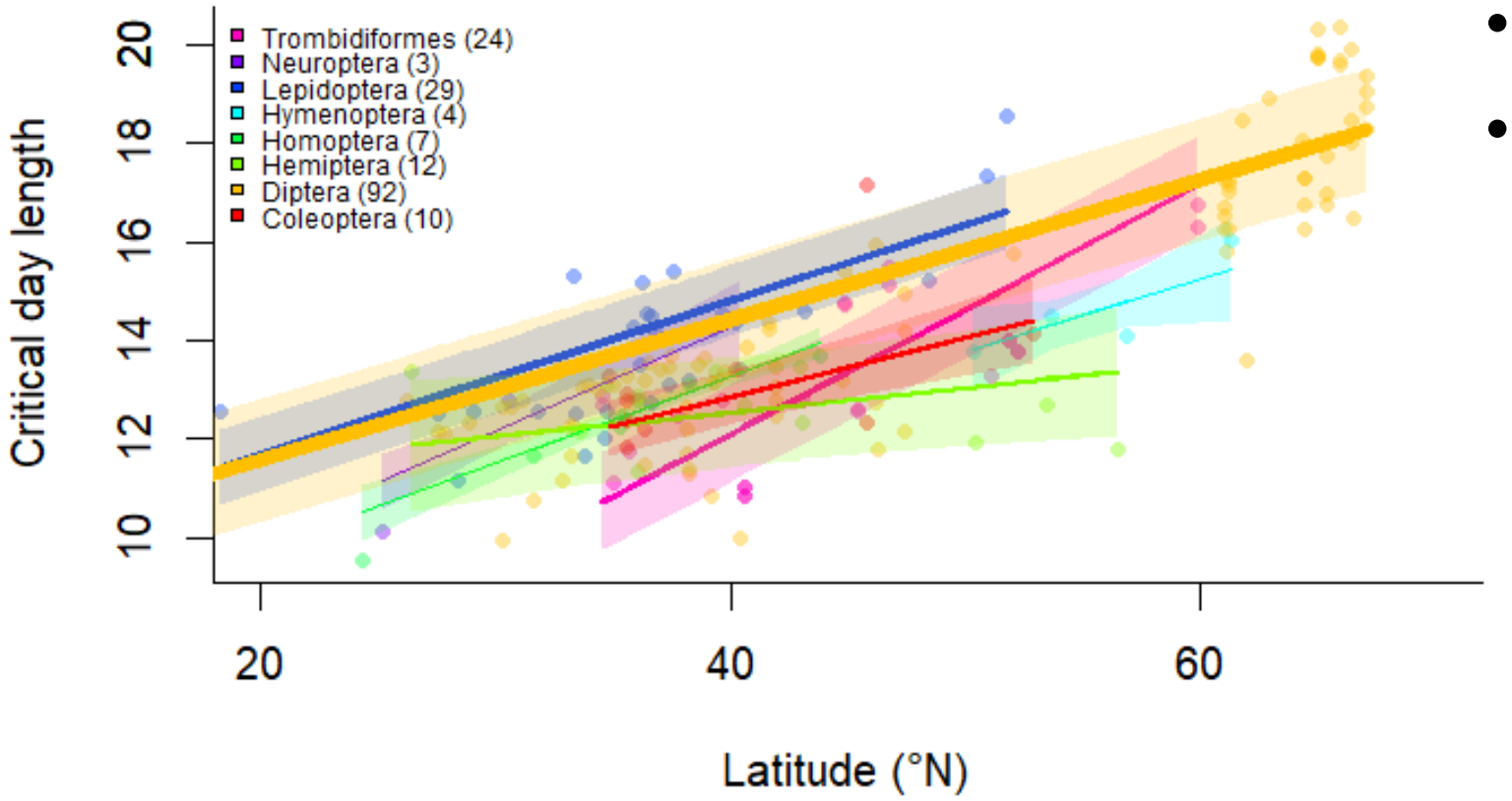
Predictability = standard deviation in slopes, along 30 days before winter onset of each year

Alternative calculation: “Color of noise” as Vasseur & Yodzis (2003), autocorrelation structure in temperature data

# Results: Data



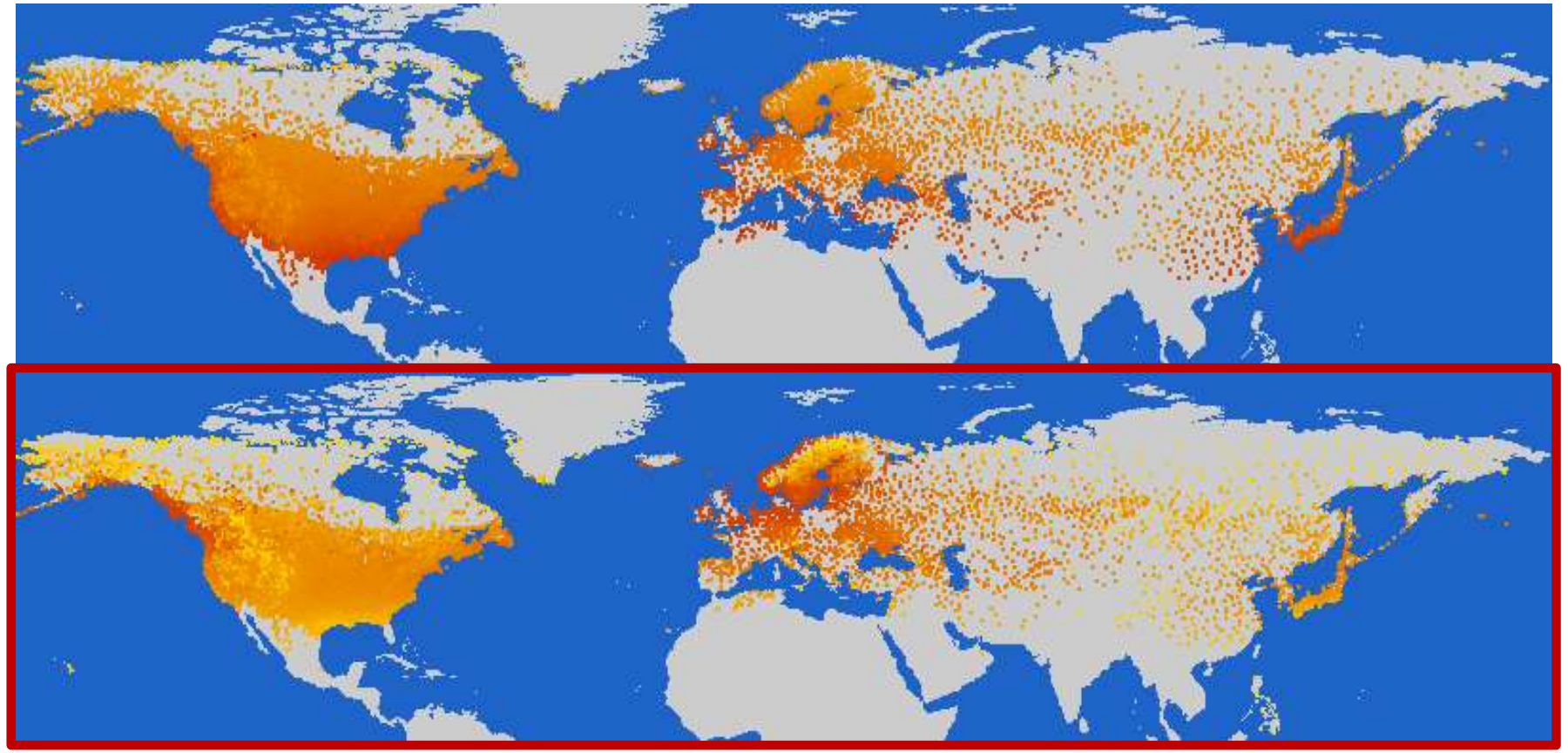
# Results: Mean timing




- CDL shifts by 55 min / 5 °N
- $R^2 = 0.35$

$I^2$:
Order: 35%
Genus: 49%
Study: 15%

# Results: Mean winter onset

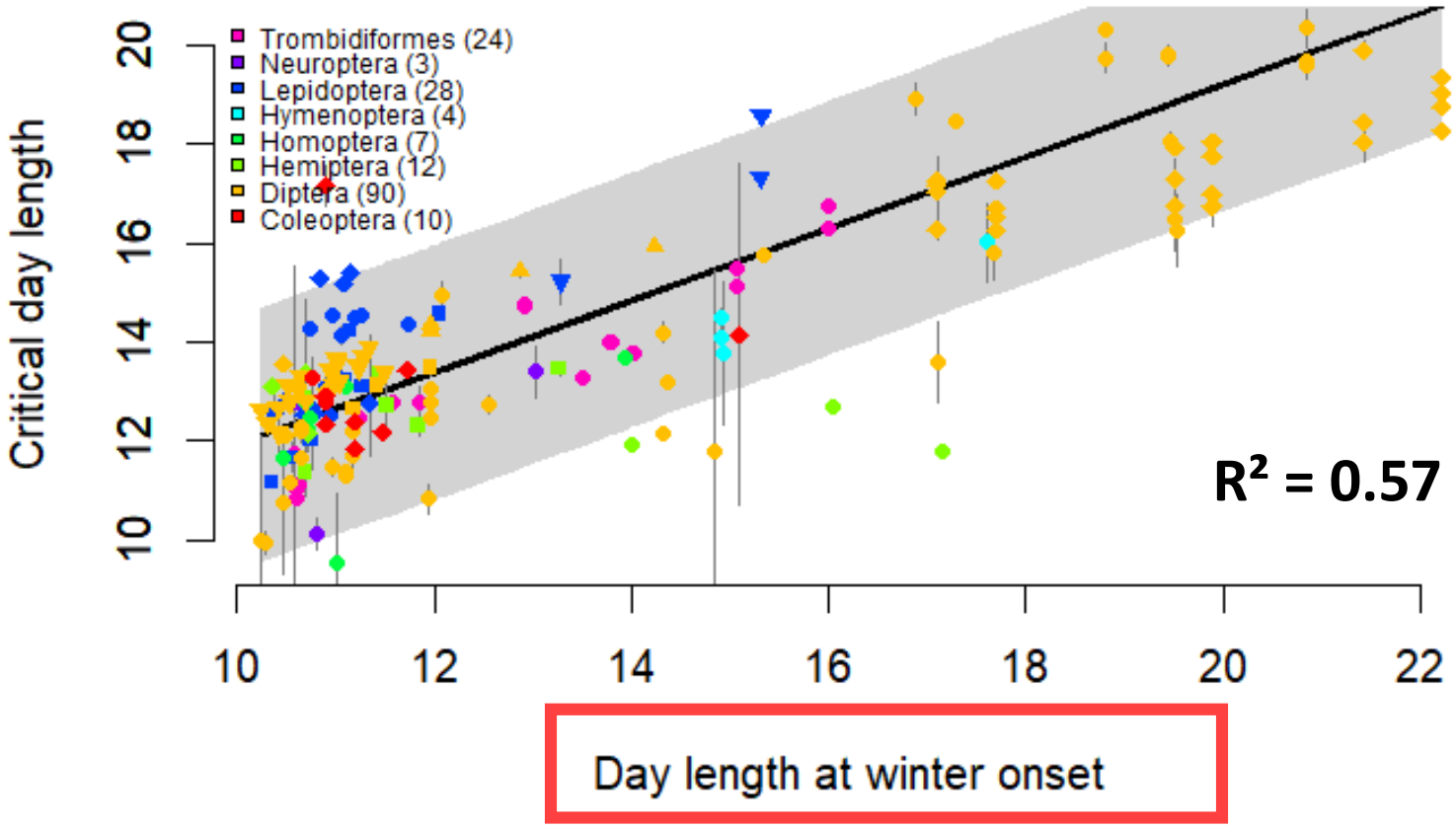


Julian day of winter onset

Day length at winter onset

- Winter onset depends on latitude and altitude
- But insects don’t know days, needs to be converted into day length

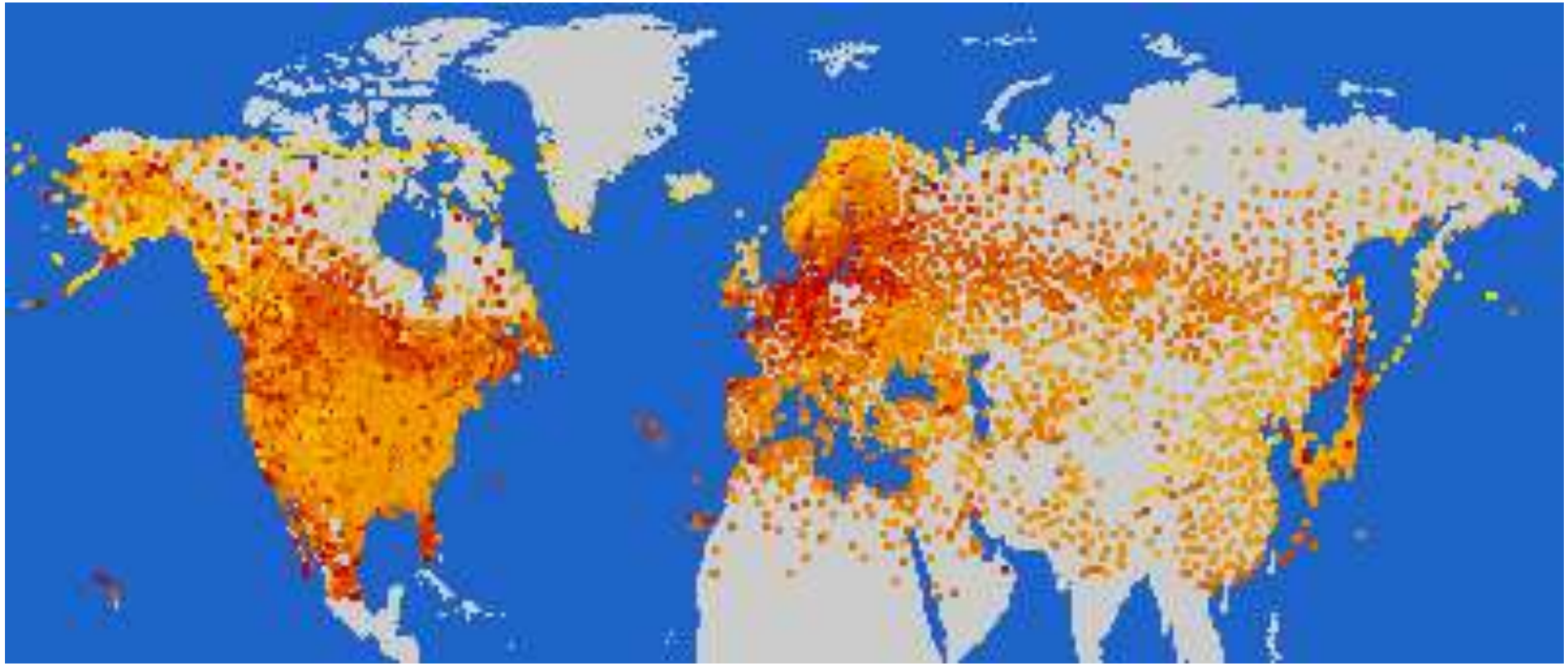
# Results: mean winter vs. mean timing




- Insects adapt their mean timing to changes in winter onset

$I^2$
Order: 24%
Genus: 59%
Study: 15%

# Results : Climate variability



- Winter variability depends on latitude

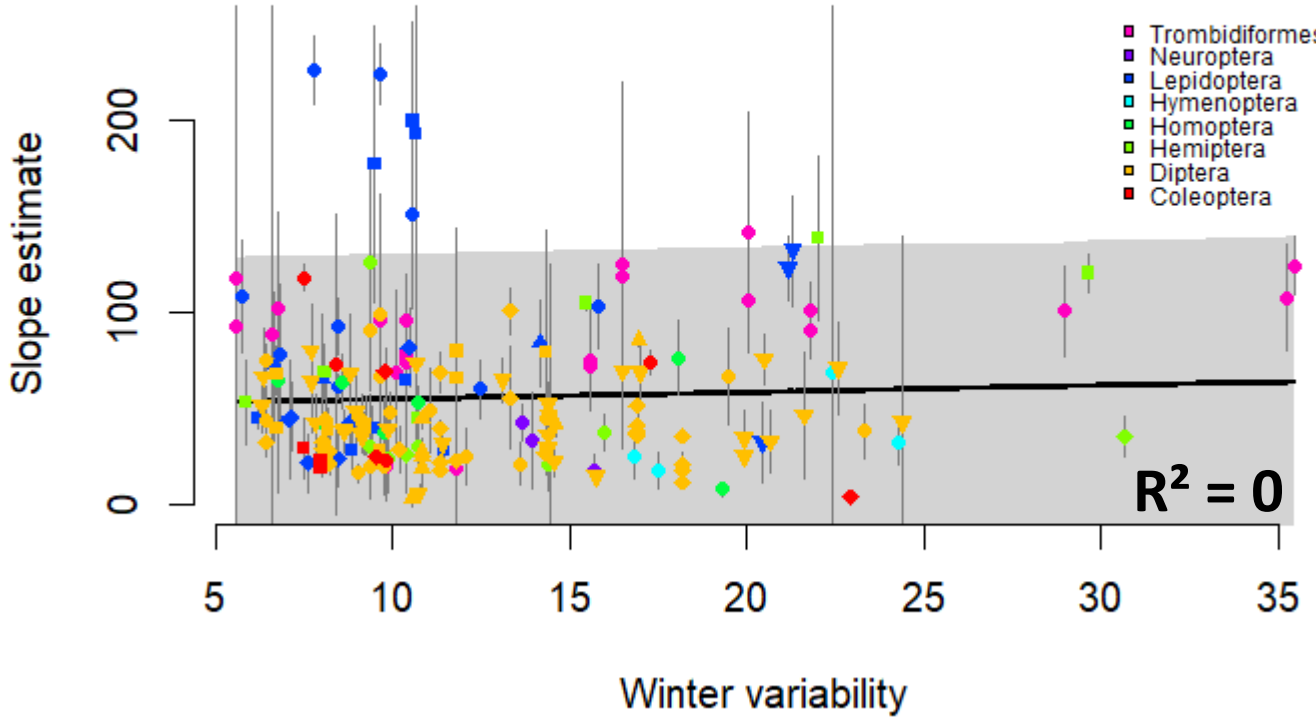
# Results : Climate predictability

Map based on standard deviation in slopes (30 days before winter onset)
= between-years sd in rate of change

# Results : Climate predictability


Map based on colour of environmental noise

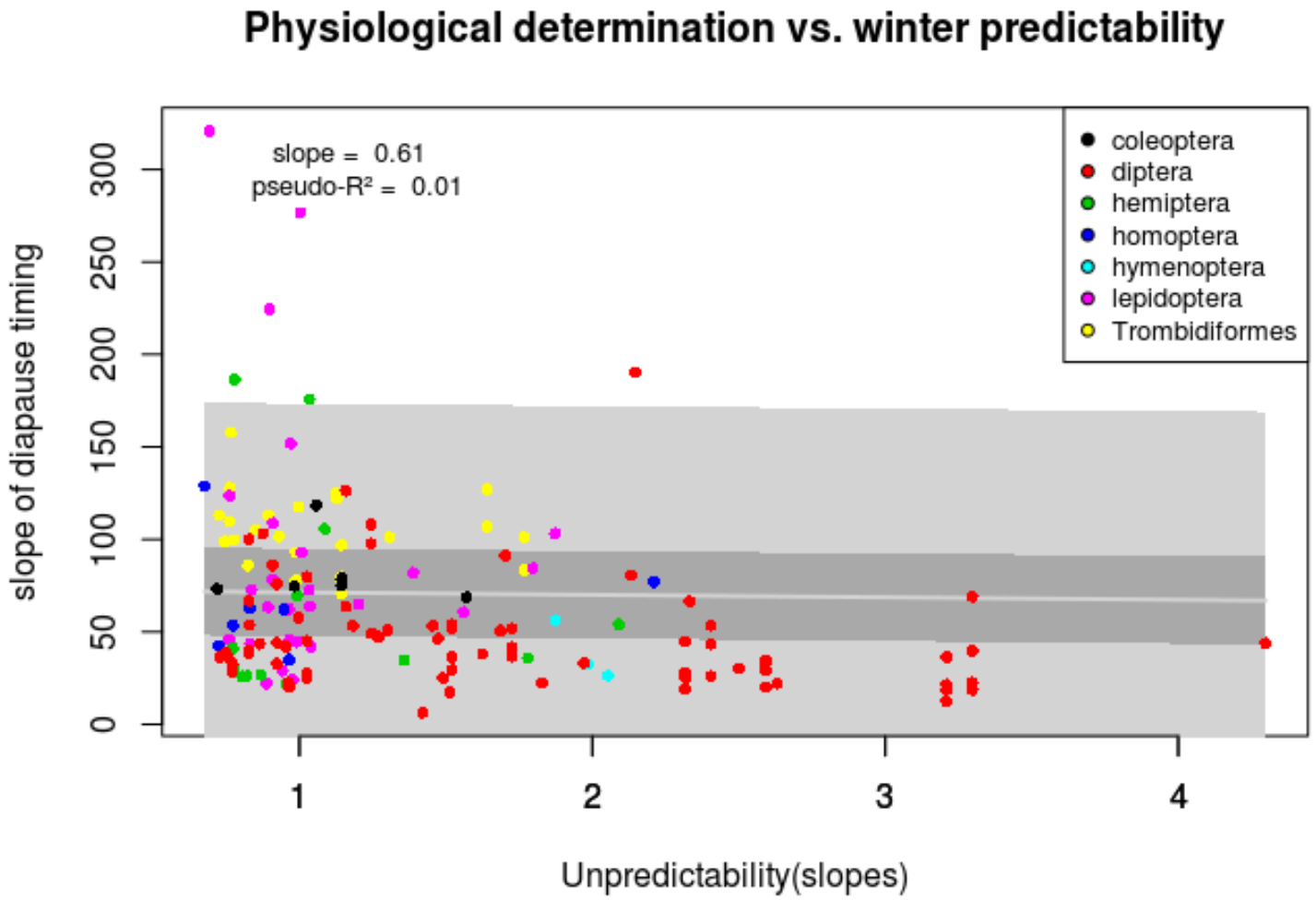
# Results: bet-hedging vs. climate variability




- No correlation of slope with variability → No evidence of bet-hedging

$I^2$
Order: 7%
Genus: 64%
Study: 29%

# Results: bet-hedging vs. climate variability




Results were same for Colour-of-noise approach

# Discussion

- Mean diapause timing: correlates with mean winter onset
  - Diapause unlikely to constrain range/phenology shifts

✓

- Bet-hedging: No correlation with climate variability
  - Changes in climate variability may become **problematic**
  - Conservative bet-hedging (early diapause) is costly
  - There are other ways to hedge one‘s bets (e.g. dispersal)

✗

- Plasticity: unknown
  - More data needed

# Take-home message

Changes in variability are a larger threat than changes in means

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