Compare velocity values from Bioshifts v1 and v3

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Contents

Setup

```
library(data.table)
library(dplyr)
library(ggplot2)
library(tidyverse)
library(terra)
```

```r
library(RColorBrewer)
library(VoCC1)

# set computer
# computer = "muse"
#
# if(computer == "muse"){
#     setwd("/storage/simple/projects/t_cesab/brunno/Exposure-SDM")
#
#     work_dir <- getwd()
#     here::i_am("R/7_velocity/2_compare_velocity_v3_v1.R")
# } else {
#   work_dir <- here::here(work_dir)
# }

# source settings
source(here::here("R/settings.R"))

# Global continental lines
globe_lines <- vect(rnaturalearth::ne_countries(scale = "small"))
globe_lines <- terra::aggregate(globe_lines)
```

Load in v3 velocities

```r
SAs <- list.files(here::here("Data/Velocity_SA"))
SAs <- gsub(".csv","",SAs)
SA_got <- list.files(here::here("Data/Velocity_SA"), full.names = TRUE)
SA_got <- lapply(1:length(SA_got), function(i) {
  tmp <- read.csv(SA_got[i])
  tmp$ID = SAs[i]
  tmp
})
SA_got <- rbindlist(SA_got, fill = TRUE)

SA_got <- SA_got %>%
  dplyr::select(c(v.lat.median.mat,baseline.mat,trend.mean.mat,v.ele.median.mat,baseline.sst,trend.mean

SA_got$ECO <- ifelse(is.na(SA_got$v.lat.median.sst), "T", "M")

SA_got <- SA_got %>%
  mutate(vel_v3 = ifelse(ECO == "T", v.lat.median.mat, v.lat.median.sst),
         baseline.temp_v3 = ifelse(ECO == "T", baseline.mat, baseline.sst),
         Trend = ifelse(ECO == "T", trend.mean.mat, trend.mean.sst)) %>%
  dplyr::select(ECO, vel_v3, Trend, ID, baseline.temp_v3)


SA_got$vel_v3 <- SA_got$vel_v3 * -1
```

Load in Bioshifts v1

```
Bioshifts_DB <- read.csv(here::here("Data/Bioshifts/biov1_fixednames.csv"))

# Filter Polygons in Study areas v3
Bioshifts_DB <- Bioshifts_DB[Bioshifts_DB$ID %in% unique(SA_got$ID),]

# convert everything to km/year
Bioshifts_DB <- Bioshifts_DB %>%
  mutate(
    Type = case_when(
      Type=="HOR" ~ "LAT",
      TRUE ~ as.character(Type)),
    # Standardize shift measures to km/year
    SHIFT = case_when(
      UNIT == "m/year" ~ SHIFT/1000,
      UNIT == "km/year" ~ SHIFT,
      TRUE ~ NA_real_))
```

Merge v1 to v3

```
Bioshifts_vel <- merge(Bioshifts_DB %>%
                         filter(Type %in% c("LAT","ELE")) %>%
                         mutate(vel_v1 = ifelse(Type == "LAT", v.lat.mean, v.ele.mean),
                                baseline.temp_v1 = baseline.temp,
                                trend_v1 = trend.mean) %>%
                         dplyr::select(ID, vel_v1, Type, ECO, SHIFT, baseline.temp_v1, trend_v1),
                       SA_got  %>%
                         dplyr::select(ID, vel_v3, ECO, baseline.temp_v3, Trend) %>%
                         mutate(trend_v3 = Trend) %>%
                         dplyr::select(-Trend),
                       by = c("ID","ECO"))
head(Bioshifts_vel)
```

```
##      ID ECO   vel_v1 Type         SHIFT baseline.temp_v1   trend_v1      vel_v3
## 1 A1_P1   T 13.12588  ELE  0.0017446810          6.69444 0.06809625 -0.03162462
## 2 A1_P1   T 13.12588  ELE -0.0014042550          6.69444 0.06809625 -0.03162462
## 3 A1_P1   T 13.12588  ELE -0.0006382979          6.69444 0.06809625 -0.03162462
## 4 A1_P1   T 13.12588  ELE -0.0032340430          6.69444 0.06809625 -0.03162462
## 5 A1_P1   T 13.12588  ELE -0.0029787230          6.69444 0.06809625 -0.03162462
## 6 A1_P1   T 13.12588  ELE  0.0026808510          6.69444 0.06809625 -0.03162462
##   baseline.temp_v3   trend_v3
## 1         6.697018 0.06028566
## 2         6.697018 0.06028566
## 3         6.697018 0.06028566
## 4         6.697018 0.06028566
## 5         6.697018 0.06028566
## 6         6.697018 0.06028566
```

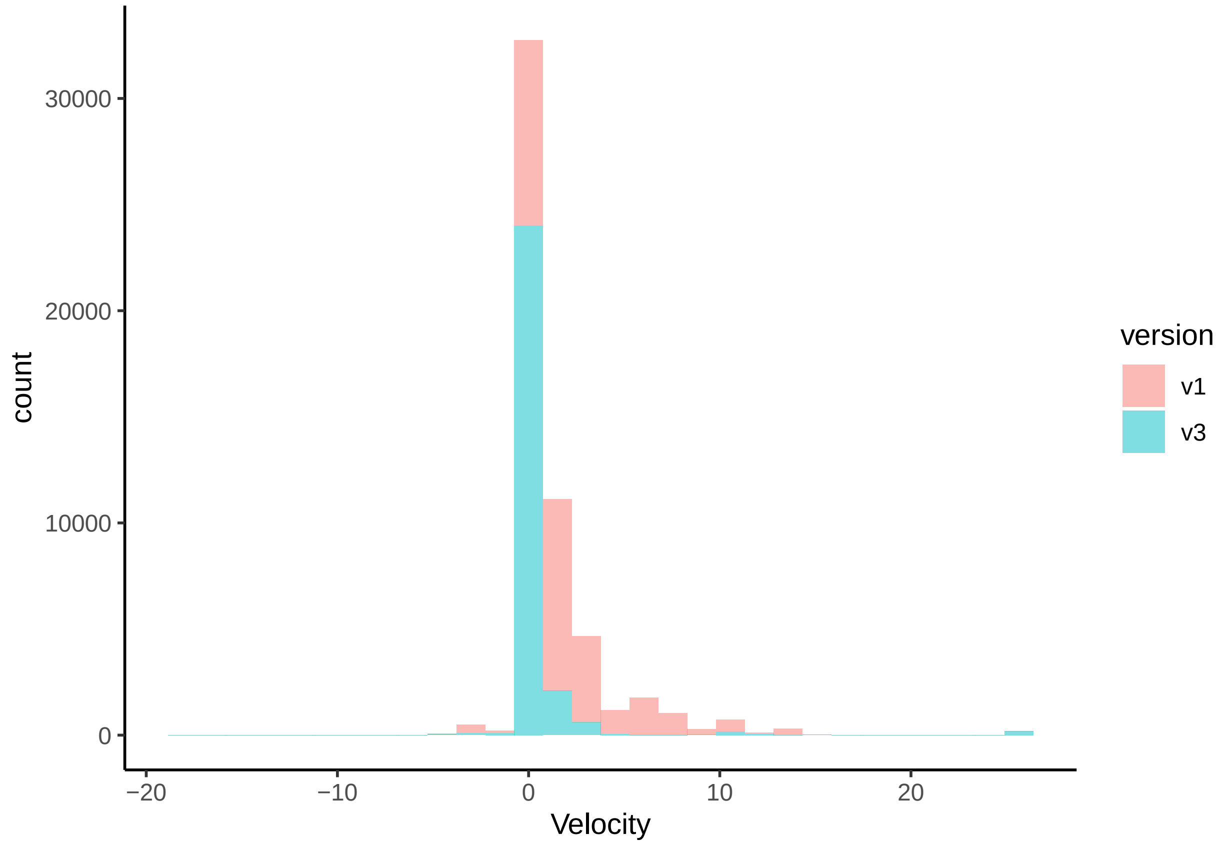
Compare

Density plots of velocities

```r
v1 <- Bioshifts_vel[,c("ID","Type","ECO","vel_v1","baseline.temp_v1","SHIFT")]
v3 <- Bioshifts_vel[,c("ID","Type","ECO","vel_v3","baseline.temp_v3","SHIFT")]

v1$baseline.temp <- v1$baseline.temp_v1
v1$vel <- v1$vel_v1
v1$version = "v1"

v3$baseline.temp <- v3$baseline.temp_v3
v3$vel <- v3$vel_v3
v3$version = "v3"

tmp <- rbind(v1[,c("ID","Type","ECO","vel","baseline.temp","SHIFT","version")],
             v3[,c("ID","Type","ECO","vel","baseline.temp","SHIFT","version")])

# All values
ggplot(tmp, aes(x = vel, fill = version))+
  geom_histogram(alpha = .5)+
  theme_classic()+
  labs(x = "Velocity")
```

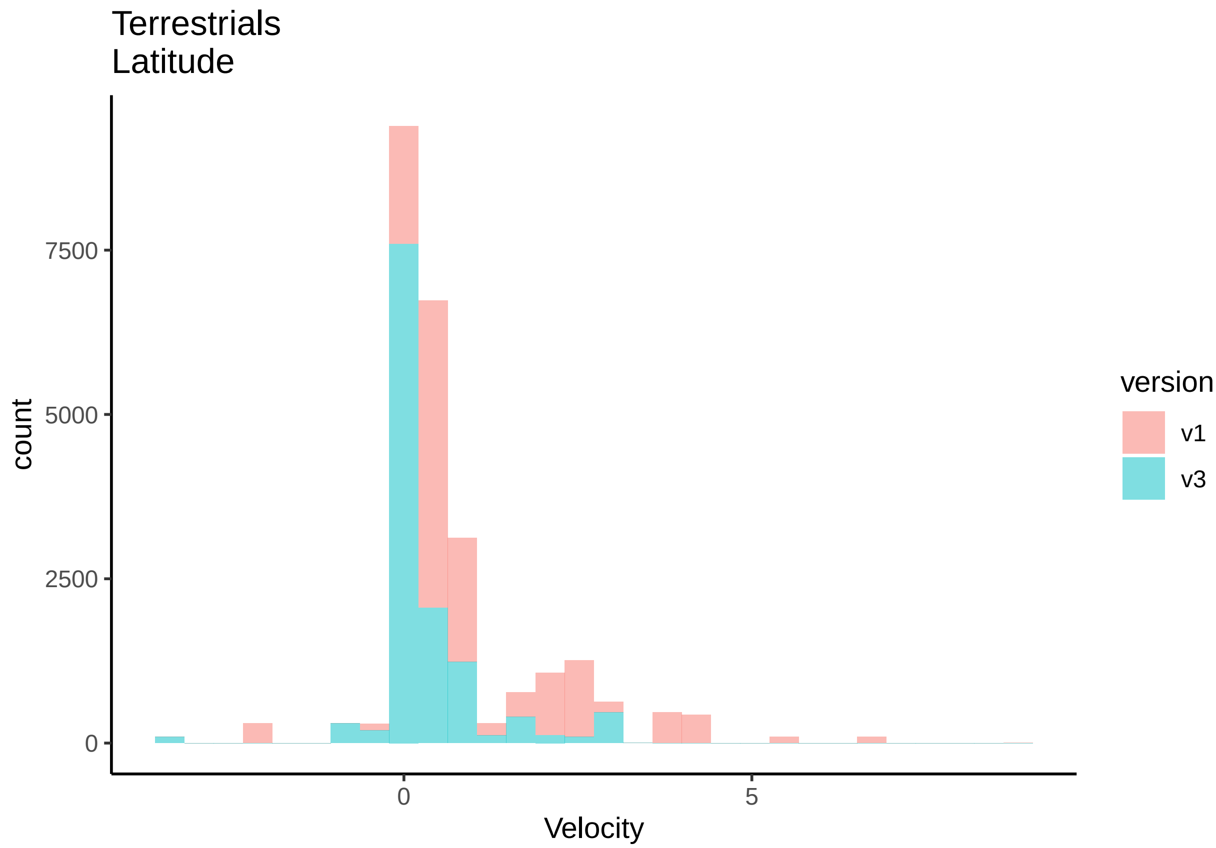
```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

```
## Warning: Removed 34 rows containing non-finite values (`stat_bin()`).
```




```
## Terrestrials
### Latitude
ggplot(tmp %>% filter(ECO=="T",
                      Type == "LAT"),
       aes(x = vel, fill = version))+
  ggtitle("Terrestrials\nLatitude")+
  geom_histogram(alpha = .5)+
  theme_classic()+
  labs(x = "Velocity")
```

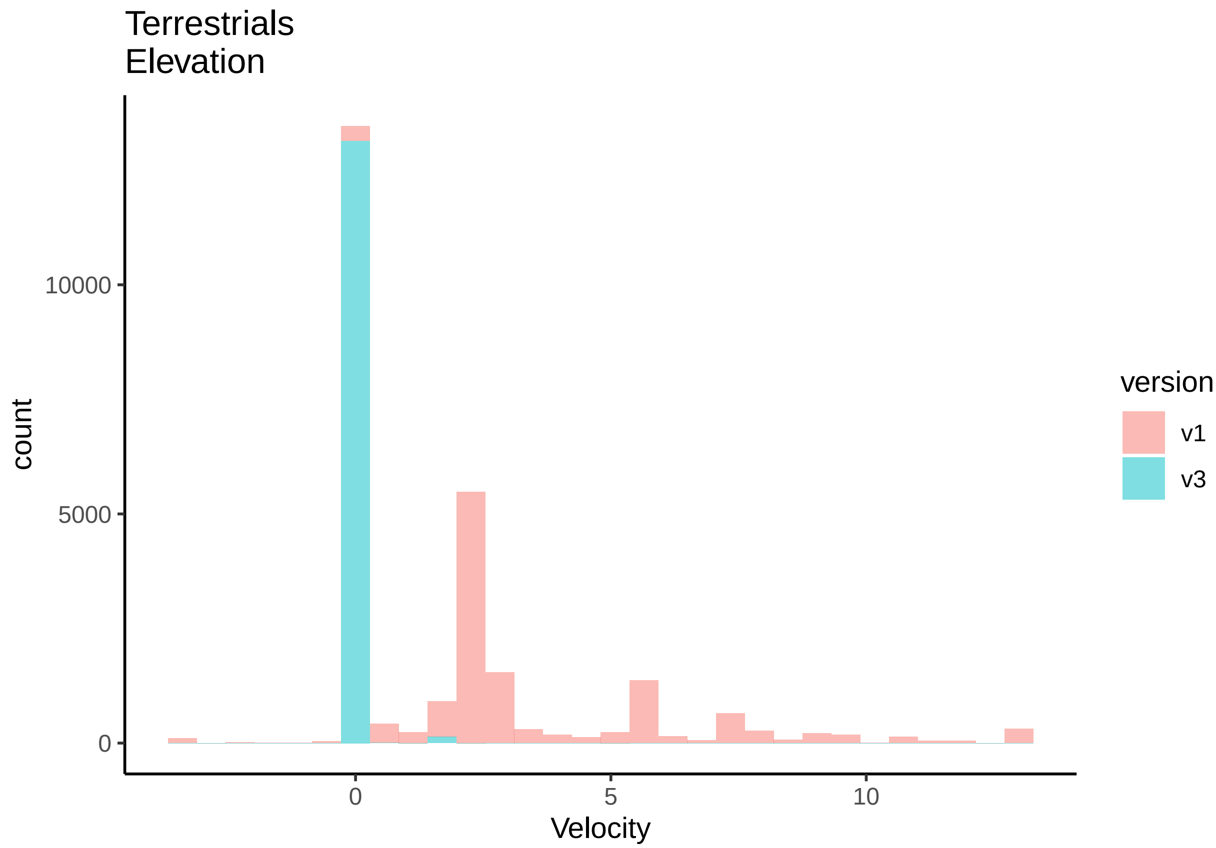
```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```




```r
### Elevation
ggplot(tmp %>% filter(ECO=="T",
                      Type == "ELE"),
       aes(x = vel, fill = version))+
  ggtitle("Terrestrials\nElevation")+
  geom_histogram(alpha = .5)+
  theme_classic()+
  labs(x = "Velocity")
```

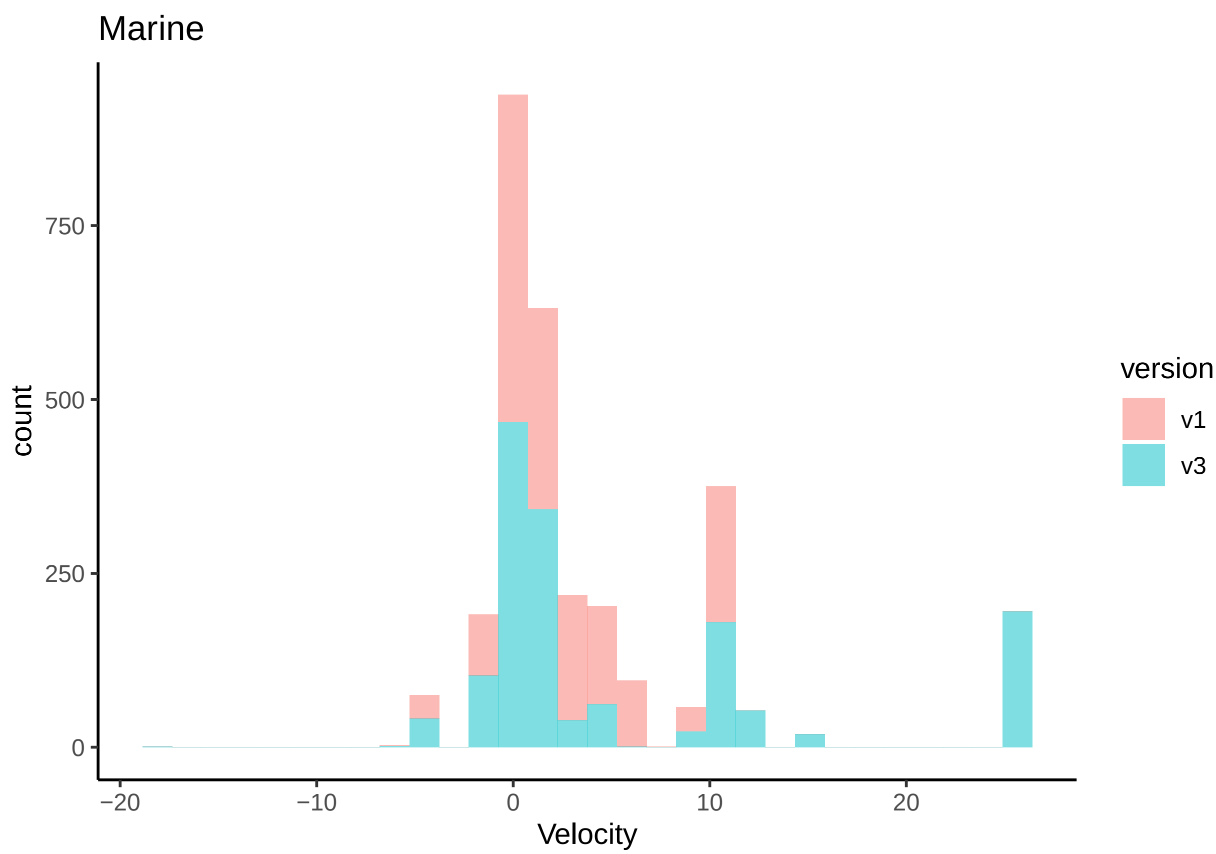
```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

```
## Warning: Removed 34 rows containing non-finite values (`stat_bin()`).
```




```
## Marine
ggplot(tmp %>% filter(ECO=="M"),
       aes(x = vel, fill = version))+
  ggtitle("Marine")+
  geom_histogram(alpha = .5)+
  theme_classic()+
  labs(x = "Velocity")
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

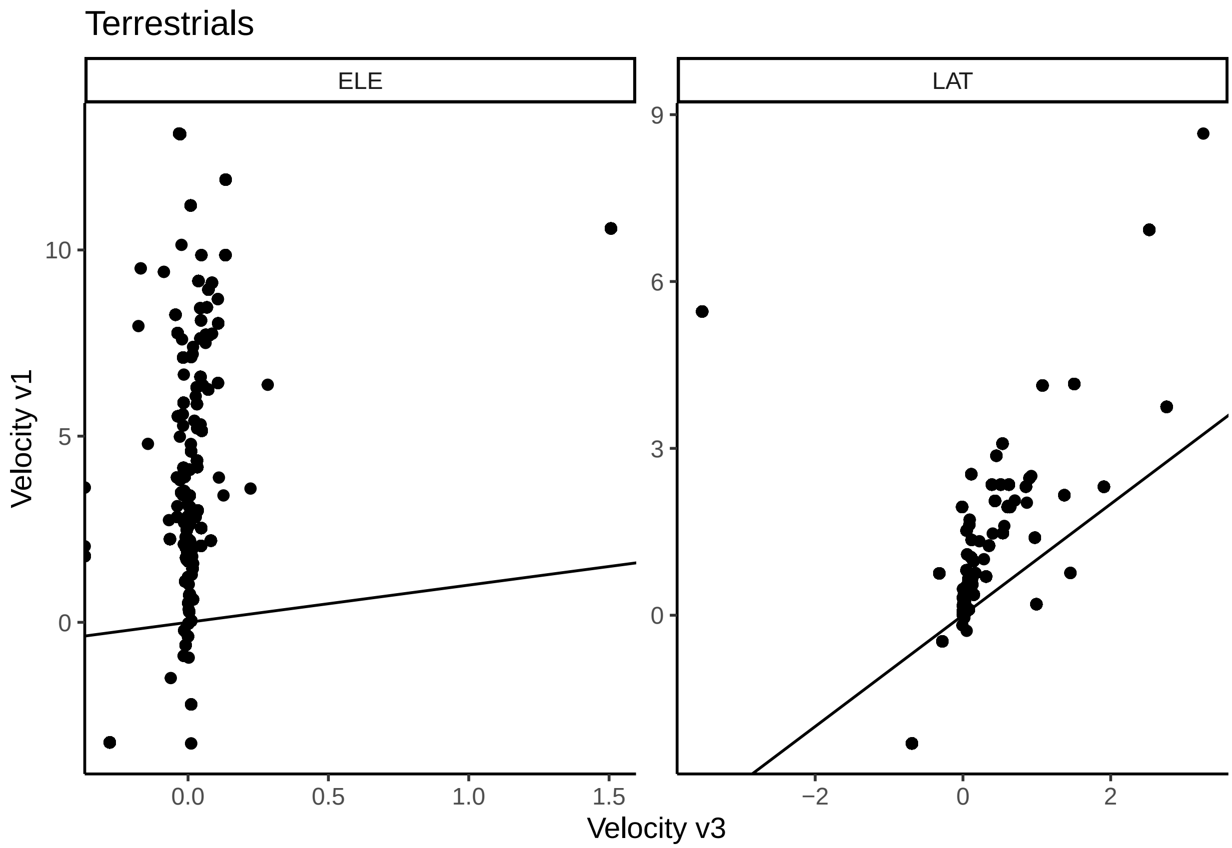


V3 velocity values are mainly negative (towards the tropics).

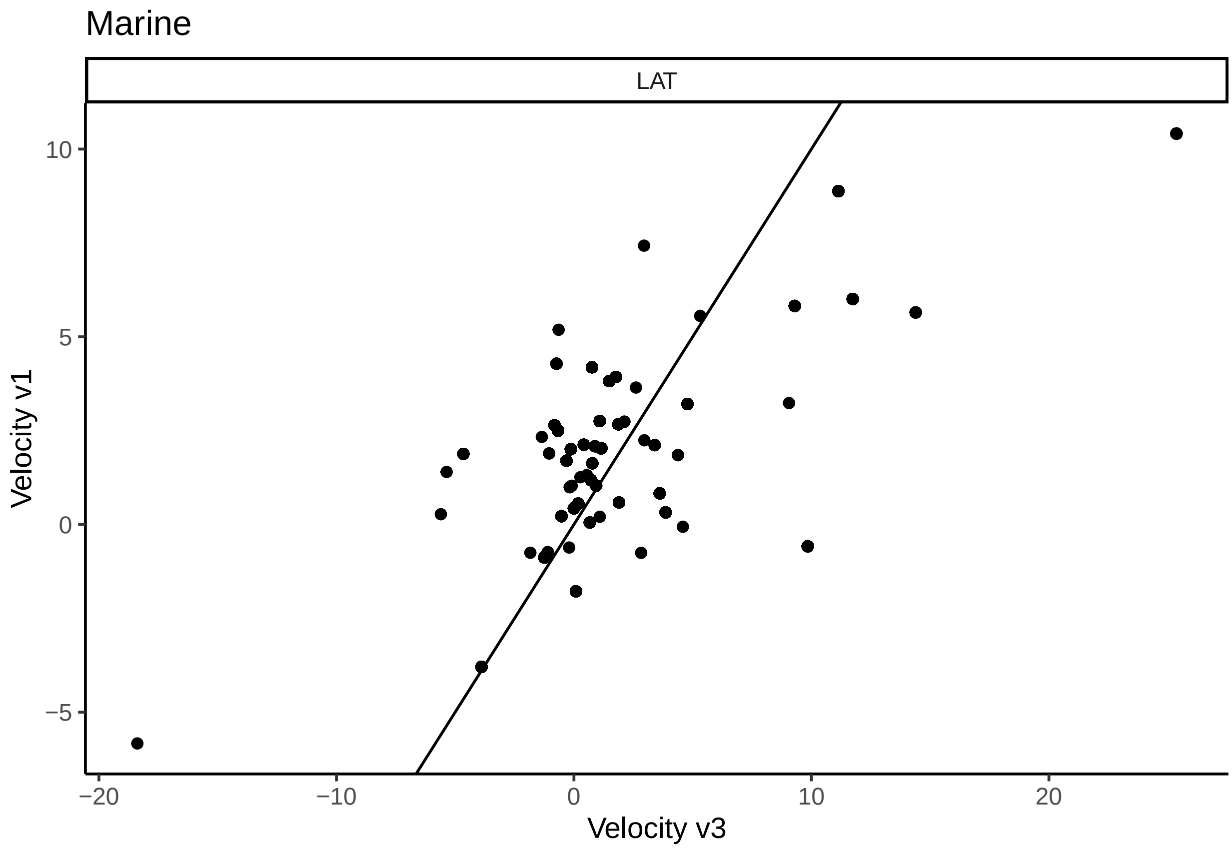
Velocity scatter plots

```
# Terrestrial
ggplot(Bioshifts_vel %>% filter(ECO == "T"),
       aes(x = vel_v3, y = vel_v1)) +
  ggtitle("Terrestrials") +
  geom_point()+
  theme_classic()+
  facet_wrap(.~Type, scales = "free") +
  labs(x = "Velocity v3", y = "Velocity v1")+
  geom_abline(slope = 1, intercept = 0)
```

```
## Warning: Removed 1 rows containing missing values (`geom_point()`).
```



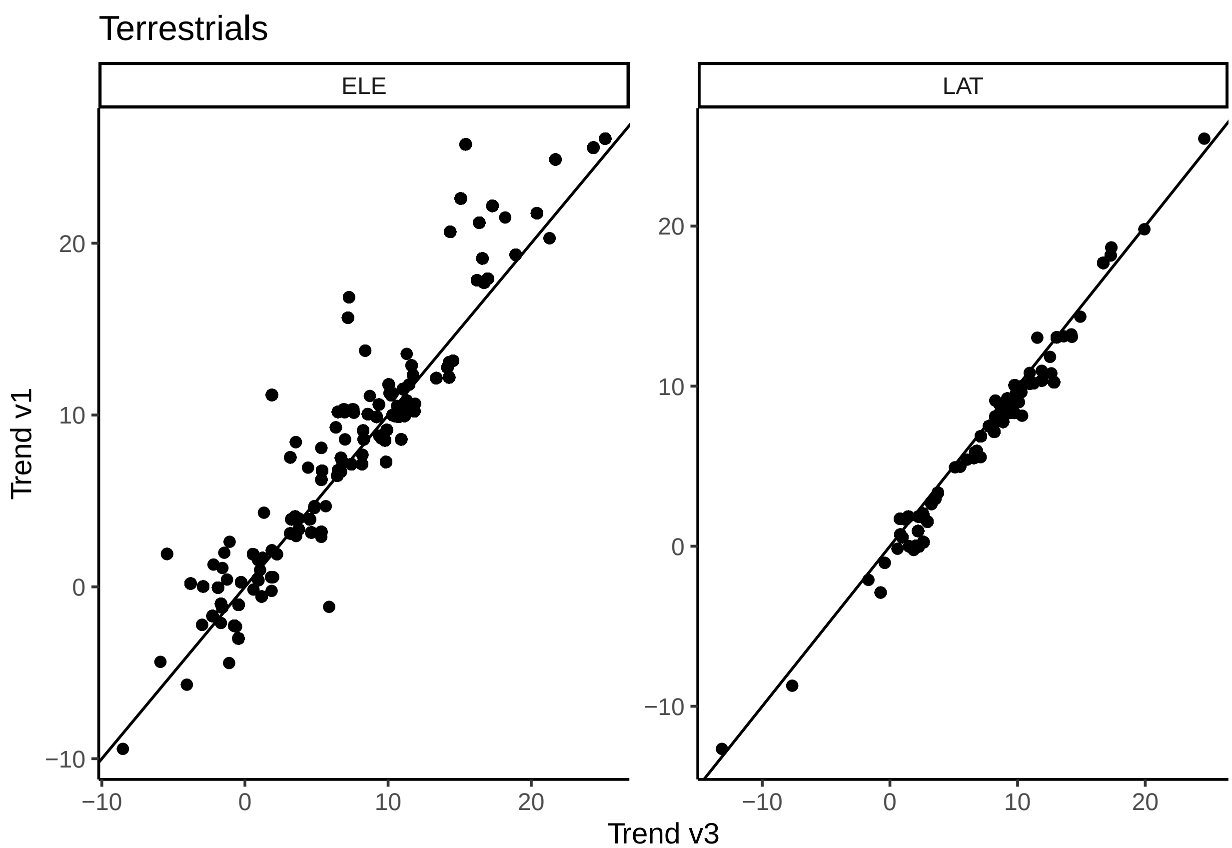

```r
# Marine
ggplot(Bioshifts_vel %>% filter(ECO == "M"),
       aes(x = vel_v3, y = vel_v1)) +
  ggtitle("Marine") +
  geom_point()+
  theme_classic()+
  facet_wrap(.~Type, scales = "free") +
  labs(x = "Velocity v3", y = "Velocity v1")+
  geom_abline(slope = 1, intercept = 0)
```



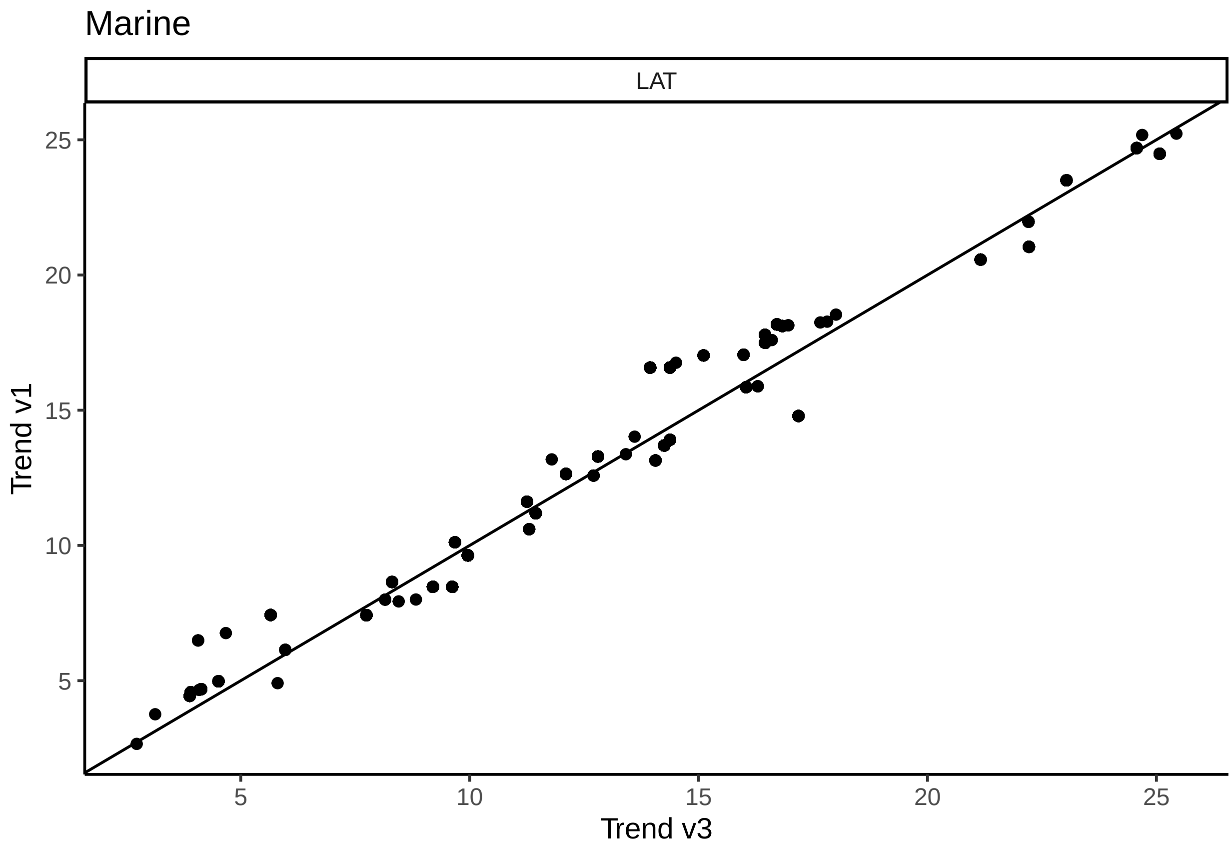
Velocity values from v3 and v1 are highly decoupled, and tend to be negatively correlated to each other.

Baseline temperature

```
# Terrestrial
ggplot(Bioshifts_vel %>% filter(ECO == "T"),
       aes(x = baseline.temp_v3, y = baseline.temp_v1)) +
  ggtitle("Terrestrials") +
  geom_point()+
  theme_classic()+
  facet_wrap(.~Type, scales = "free") +
  labs(x = "Trend v3", y = "Trend v1")+
  geom_abline(slope = 1, intercept = 0)
```

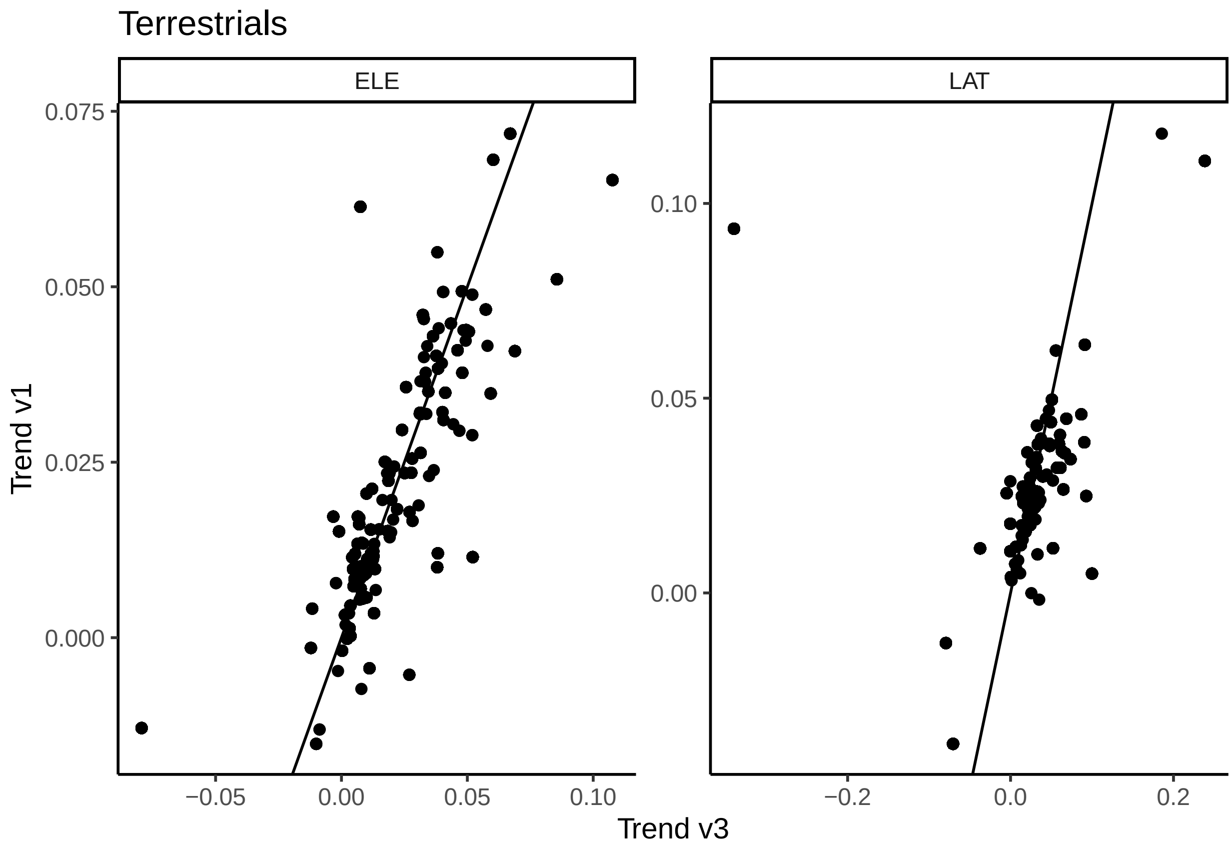



```r
# Marine
ggplot(Bioshifts_vel %>% filter(ECO == "M"),
       aes(x = baseline.temp_v3, y = baseline.temp_v1)) +
  ggtitle("Marine") +
  geom_point()+
  theme_classic()+
  facet_wrap(.~Type, scales = "free") +
  labs(x = "Trend v3", y = "Trend v1")+
  geom_abline(slope = 1, intercept = 0)
```

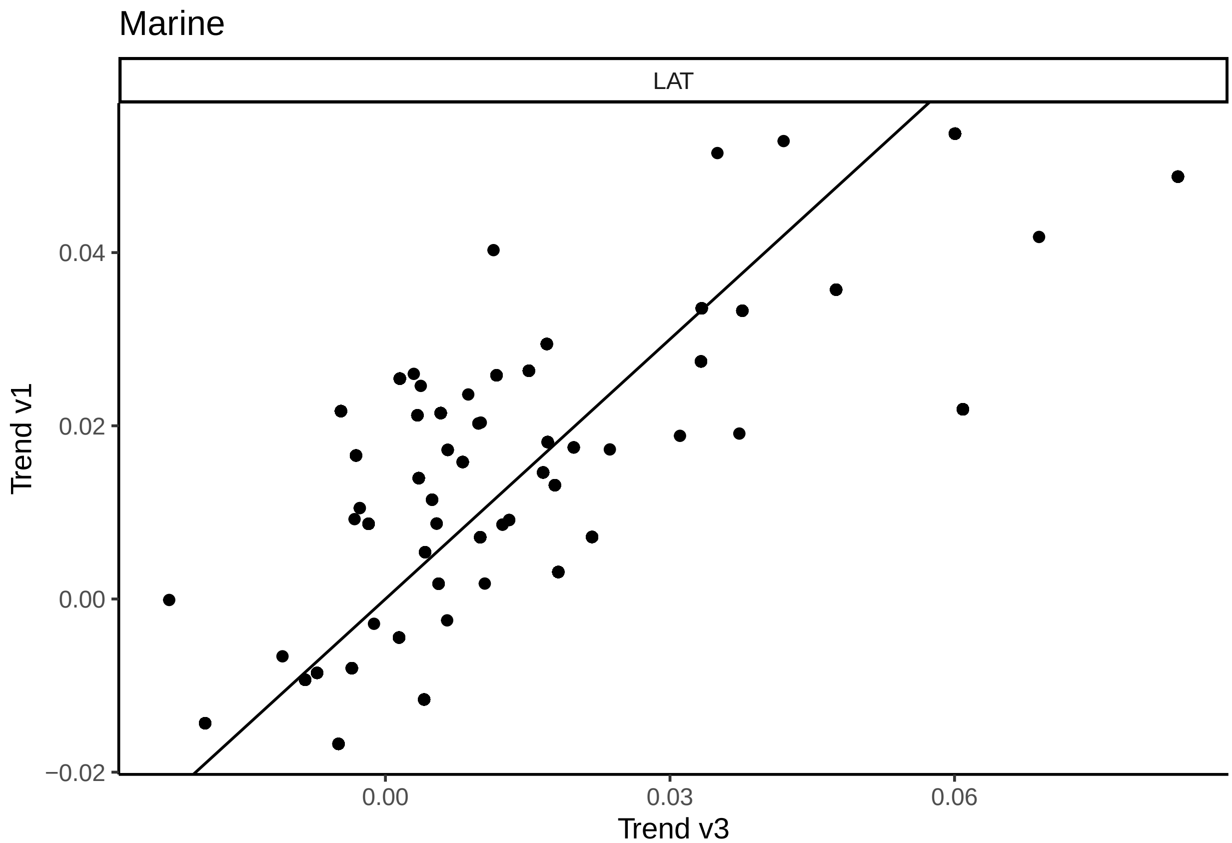


Trend

```
# Terrestrial
ggplot(Bioshifts_vel %>% filter(ECO == "T"),
       aes(x = trend_v3, y = trend_v1)) +
  ggtitle("Terrestrials") +
  geom_point()+
  theme_classic()+
  facet_wrap(.~Type, scales = "free") +
  labs(x = "Trend v3", y = "Trend v1") +
  geom_abline(slope = 1, intercept = 0)
```




```r
# Marine
ggplot(Bioshifts_vel %>% filter(ECO == "M"),
       aes(x = trend_v3, y = trend_v1)) +
  ggtitle("Marine") +
  geom_point()+
  theme_classic()+
  facet_wrap(.~Type, scales = "free") +
  labs(x = "Trend v3", y = "Trend v1") +
  geom_abline(slope = 1, intercept = 0)
```

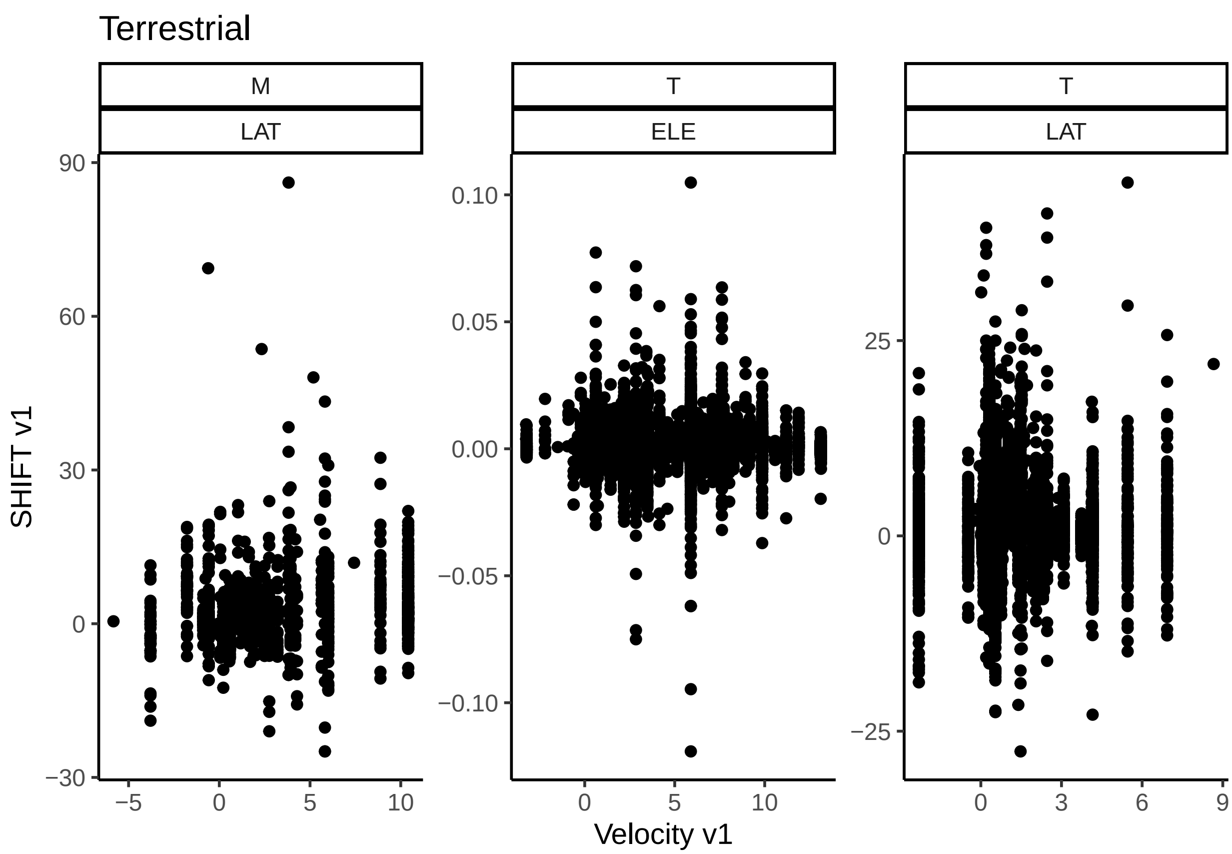


When comparing trend values between v1 and v3, they seem to be correlated. This means that the decoupling in velocity values between v1 and v3 comes from differences in the way the spatial gradient is calculated.

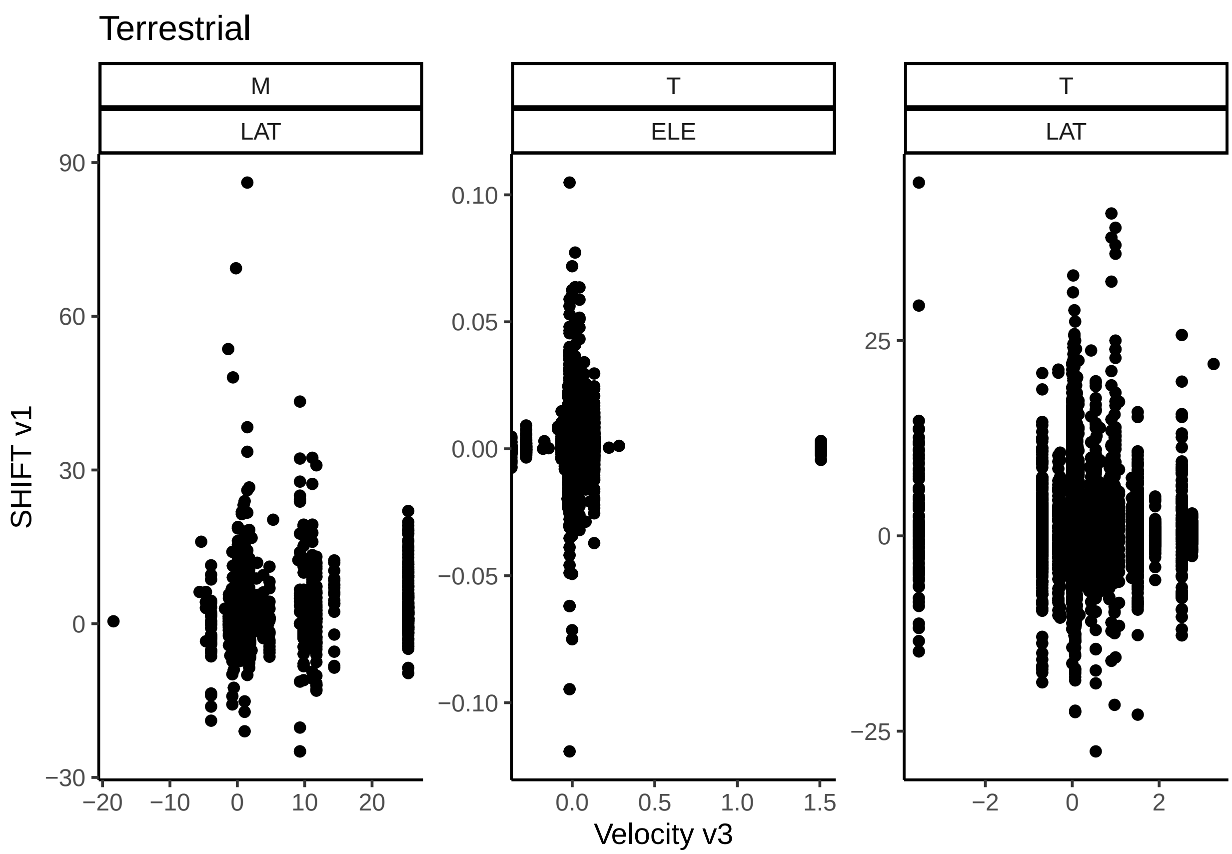
Velocity vs shift

```
# Velocity v1 vs Shift
ggplot(Bioshifts_vel,
       aes(x = vel_v1, y = SHIFT)) +
  ggtitle("Terrestrial") +
  geom_point()+
  theme_classic()+
  facet_wrap(ECO~Type, scales = "free") +
  labs(x = "Velocity v1", y = "SHIFT v1")
```

```
## Warning: Removed 1 rows containing missing values (`geom_point()`).
```




```r
# Velocity v3 vs Shift
ggplot(Bioshifts_vel,
       aes(x = vel_v3, y = SHIFT)) +
  ggtitle("Terrestrial") +
  geom_point()+
  theme_classic()+
  facet_wrap(ECO~Type, scales = "free") +
  labs(x = "Velocity v3", y = "SHIFT v1")
```

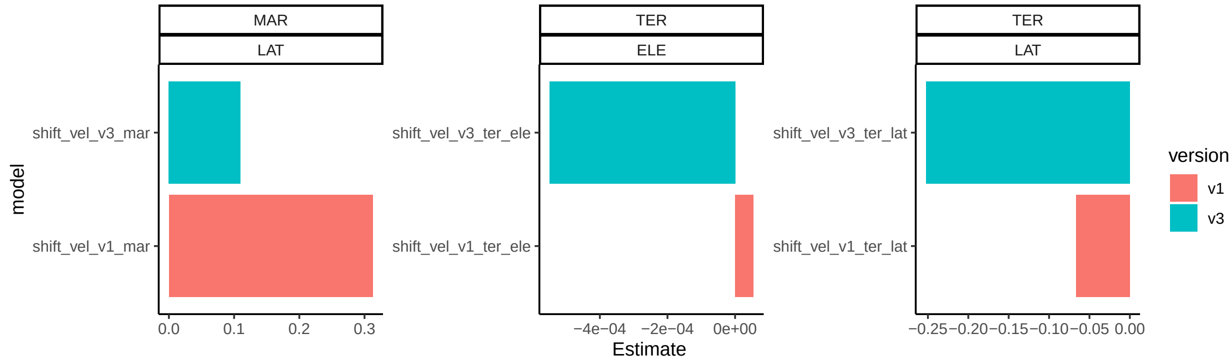


As expected based on the decoupling between velocity values in v1 and v3, the effect of velocity on observed range shift can be quite different depending on version of bioshifts used to extract velocity values.

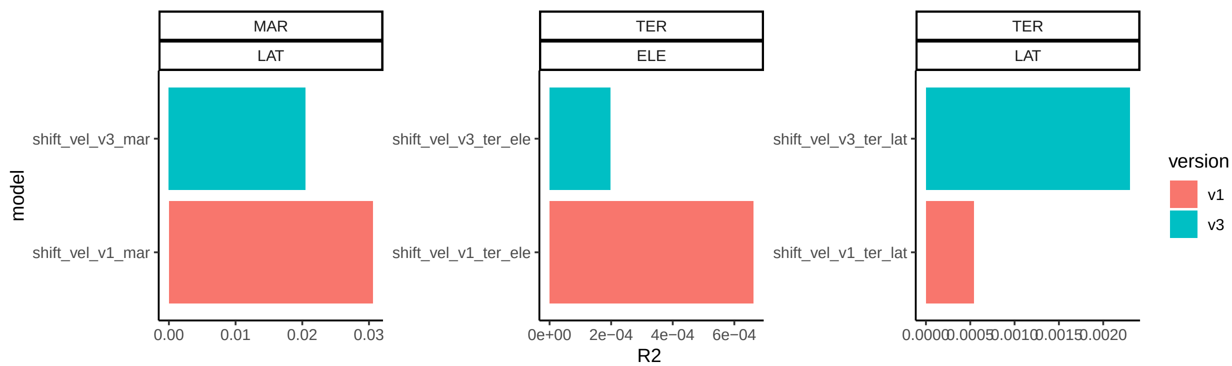
OLS results: Velocity vs Shift

```
# Terrestrial + Lat
shift_vel_v1_ter_lat <- summary(lm(SHIFT~vel_v1,
                                   Bioshifts_vel %>%
                                     filter(ECO=="T" & Type == "LAT")))

shift_vel_v3_ter_lat <- summary(lm(SHIFT~vel_v3,
                                   Bioshifts_vel %>%
                                     filter(ECO=="T" & Type == "LAT")))

# Terrestrial + Ele
shift_vel_v1_ter_ele <- summary(lm(SHIFT~vel_v1,
                                   Bioshifts_vel %>%
                                     filter(ECO=="T" & Type == "ELE")))

shift_vel_v3_ter_ele <- summary(lm(SHIFT~vel_v3,
                                   Bioshifts_vel %>%
                                     filter(ECO=="T" & Type == "ELE" & !is.infinite(vel_v3))))

# Marine
```

```r
shift_vel_v1_mar <- summary(lm(SHIFT~vel_v1,
                               Bioshifts_vel %>%
                                 filter(ECO=="M")))

shift_vel_v3_mar <- summary(lm(SHIFT~vel_v3,
                               Bioshifts_vel %>%
                                 filter(ECO=="M")))

models <- list(
  shift_vel_v1_ter_lat,
  shift_vel_v3_ter_lat,
  shift_vel_v1_ter_ele,
  shift_vel_v3_ter_ele,
  shift_vel_v1_mar,
  shift_vel_v3_mar
)
names(models) <- c("shift_vel_v1_ter_lat",
                   "shift_vel_v3_ter_lat",
                   "shift_vel_v1_ter_ele",
                   "shift_vel_v3_ter_ele",
                   "shift_vel_v1_mar",
                   "shift_vel_v3_mar")

Coeffs <- lapply(models, function(x){
  data.frame(x$coefficients)[2,]
})
Coeffs <- rbindlist(Coeffs)

R2 <- sapply(models, function(x){
  x$r.squared
})

# group all
ols <- data.frame(Coeffs,
                  R2,
                  model = names(models)
)
ols$version = ifelse(grepl("v1",ols$model),"v1","v3")
ols$Type = ifelse(grepl("ele",ols$model),"ELE","LAT")
ols$ECO = ifelse(grepl("ter",ols$model),"TER","MAR")


ggplot(ols, aes(y = model, x = Estimate, fill = version))+
  geom_col()+
  theme_classic() +
  facet_wrap(ECO~Type, scales = "free")
```




```
ggplot(ols, aes(y = model, x = R2, fill = version))+
  geom_col()+
  theme_classic() +
  facet_wrap(ECO~Type, scales = "free")
```



Coefficients tend to be stepper when using velocities v3 relative to v1. However, the coefficient in negative at the marine realm.

In general, I believe that velocities at the landscape scale are not helpful to explain observed range shifts. We might need to work better metrics, perhaps using sdms to apply weights on landscape scale velocity based on suitability. This way, we have a species level, rather than landscape level velocity.

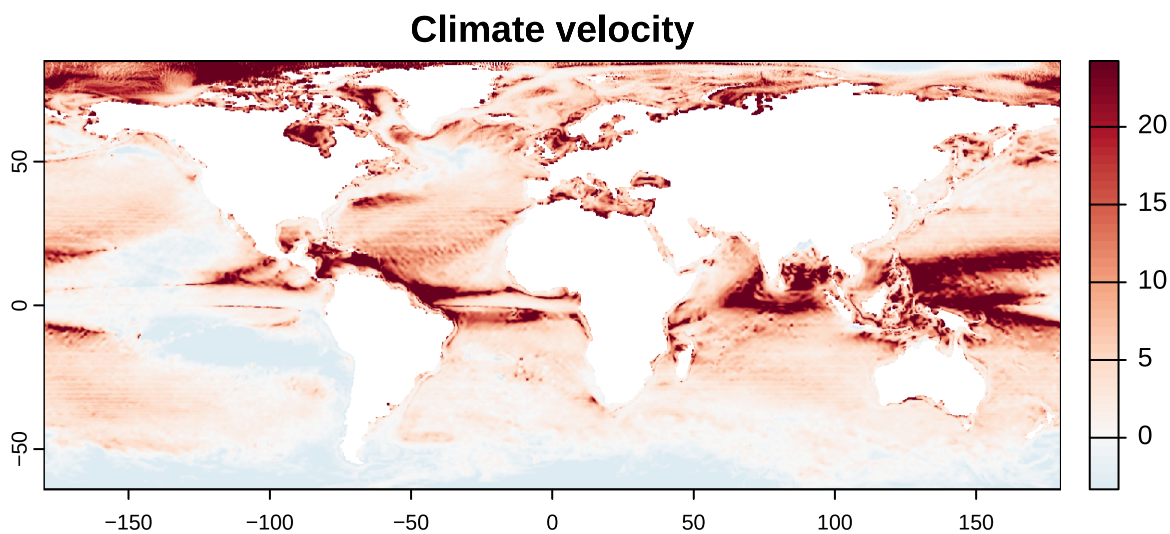
A next step we made was to test if the metric of velocity calculated in Bioshifts v3 matches with velocity patterns shown in previous studies. This is crutial for us to test if we can trust the metric. Therefore, we calculated velocity at global scale at the marine realm and compare with a published global map.

Compare velocity maps with previously published patterns

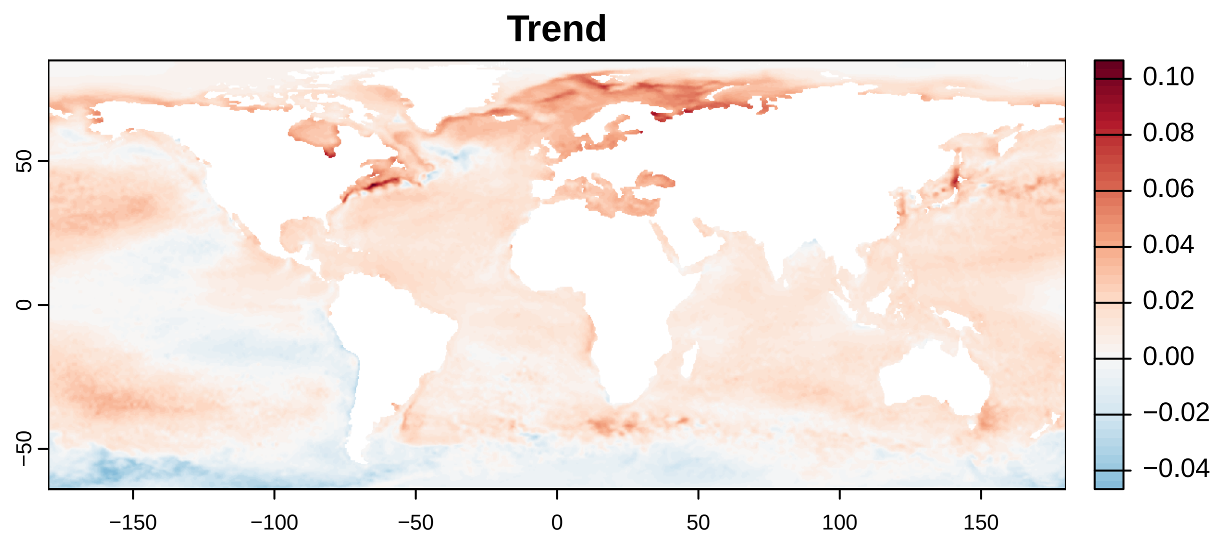
v3 vs Woolway & Maberly 2020 Nat Eco Evo

```
# Velocity
gVel <- terra::rast(here::here("Data/Mar_mean_gVel_1979-2018.tif"))

gVelrange <- range(gVel[],na.rm = TRUE)
the_palette_fc <- leaflet::colorNumeric(
  palette = "RdBu",
```

```r
  domain = c(-max(abs(gVelrange)),max(abs(gVelrange))),
  reverse = TRUE)

the_colors <- the_palette_fc(seq(min(gVelrange), max(gVelrange), length.out = 50))

plot(gVel, col = the_colors, main = "Climate velocity")
```




```r
# Trend
ttrend <- terra::rast(here::here("Data/Mar_mean_trend_1979-2018.tif"))

ttrendrange <- range(ttrend[],na.rm = TRUE)
the_palette_fc <- leaflet::colorNumeric(
  palette = "RdBu",
  domain = c(-max(abs(ttrendrange)),max(abs(ttrendrange))),
  reverse = TRUE)
the_colors <- the_palette_fc(seq(min(ttrendrange), max(ttrendrange), length.out = 50))

plot(ttrend, col = the_colors, main = "Trend")
```

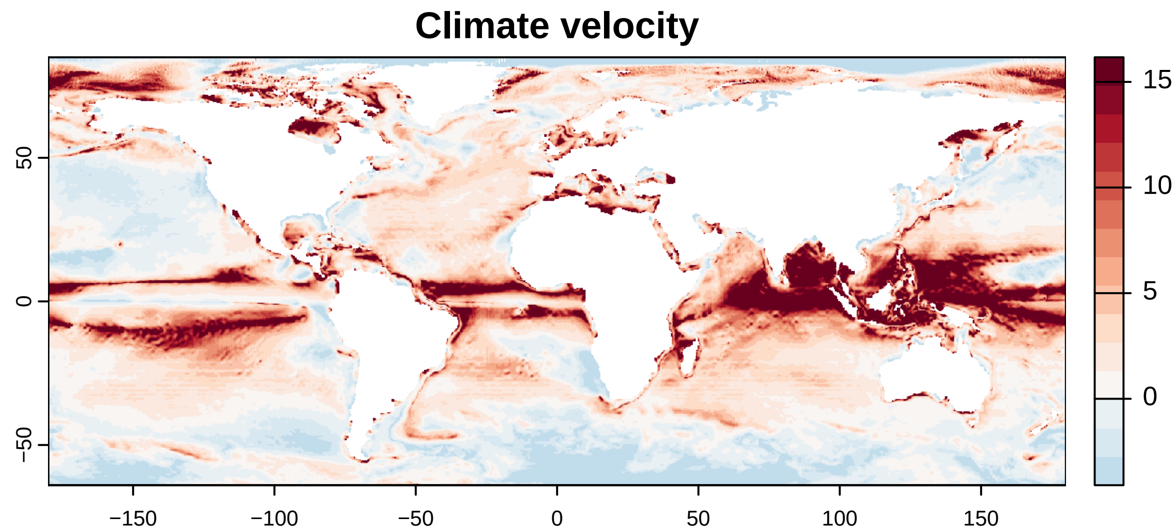



```
# # zoom to mediterranean
# plot(project(crop(gVel,c(-10,40,30,71)),Eckt), col = the_colors)
#
# # zoom to australia
# plot(project(crop(gVel,c(90,180,-30,30)),Eckt), col = the_colors)
```

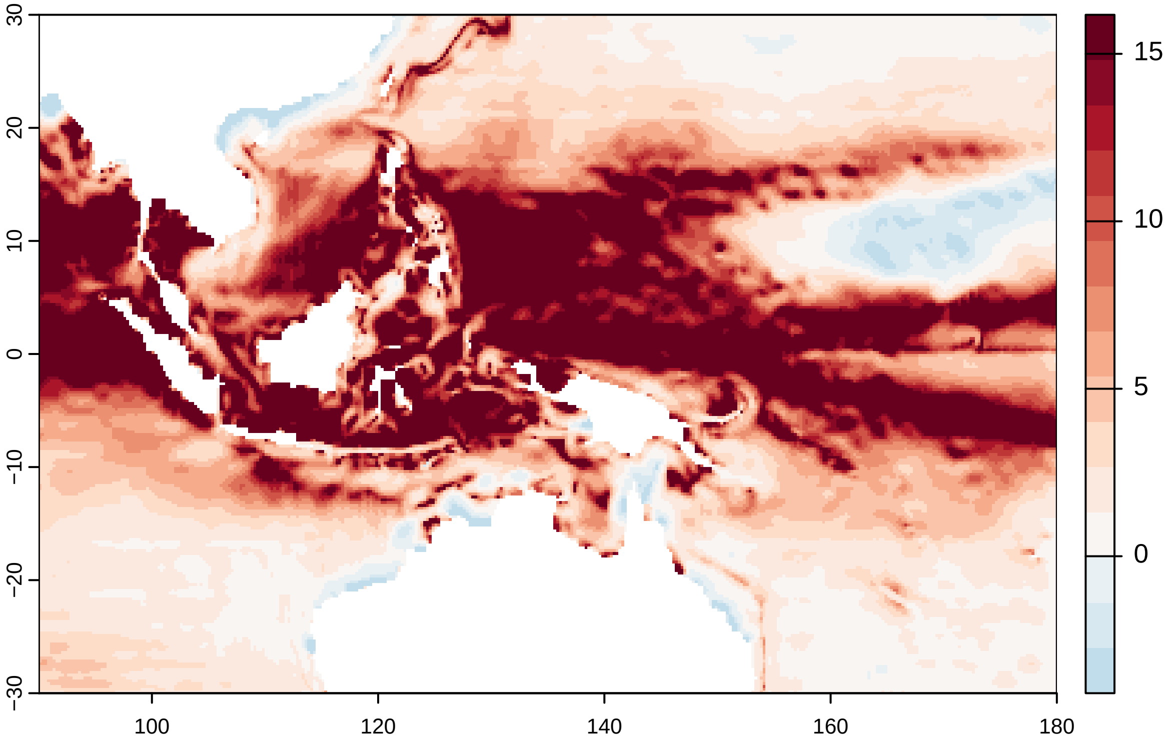
The velocity and trend patterns identified here (using our function based on the VoCC package) are very similar to what has been presented in a previous study (see Fig 2a and c from https://www.nature.com/articles/s41558-020-0889-7).

v3 vs Garcia-Molinos et al. 2019 Meth Eco Evo

```
# Velocity
gVel <- terra::rast(here::here("Data/Mar_mean_gVel_1960-2009.tif"))
gVelrange <- range(gVel[],na.rm = TRUE)

the_palette_fc <- leaflet::colorNumeric(
  palette = "RdBu",
  domain = c(-max(abs(gVelrange)),max(abs(gVelrange))),
  reverse = TRUE)

the_colors <- the_palette_fc(seq(min(gVelrange), max(gVelrange), length.out = 15))

plot(gVel, col = the_colors, main = "Climate velocity")
```




```
# # zoom to mediterranean
# plot(project(crop(gVel,c(-10,40,30,71)),Eckt), col = the_colors)
#
# # zoom to australia
plot(crop(gVel,c(90,180,-30,30)), col = the_colors)
```



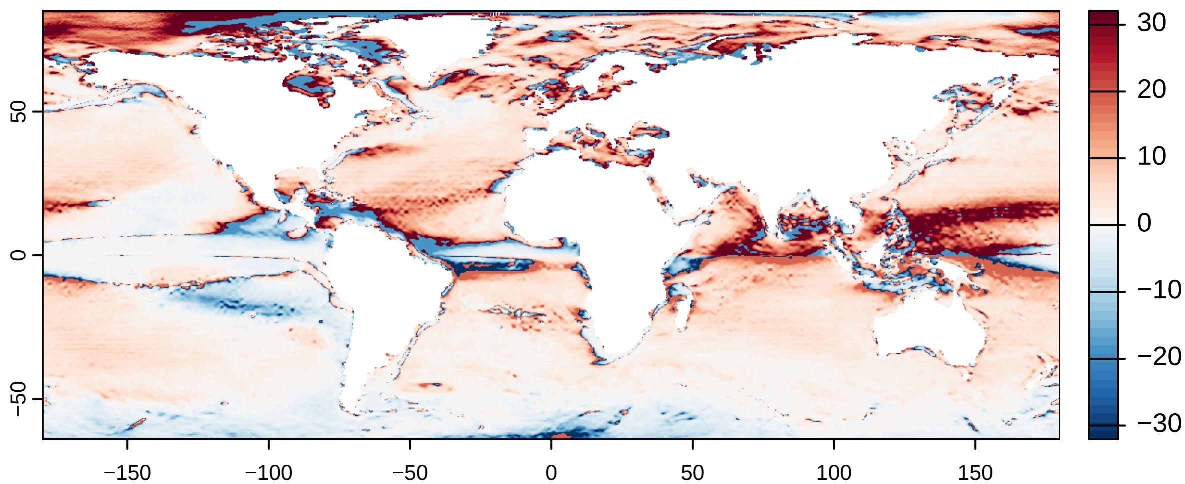
The velocity pattern is very similar to what has been presented in a previous study from Garcia-Molinos et al. 2019 Meth Eco Evo (see Fig 2a and 3a from 10.1111/2041-210X.13295).

Latitude

In order to retrieve a climate velocity across the latitudinal gradient, we calculated the resulting velocity away from the tropics (direction North for study areas at the North hemisphere, and direction South for study areas at the South hemisphere). Note that velocity values become quite different if compared to multidirectional velocity gradient showed above.

```
# Latitude
gVelLat <- terra::rast(here::here("Data/Mar_mean_gVelLat_1979-2018.tif"))
# velocity angles have opposite direction to the spatial climatic gradient if warming and same directio
ind <- cells(gVel > 0)
gVelLat[ind] <- gVelLat[ind]*-1

# SouthCells <- terra::as.data.frame(gVelLat, xy = TRUE, cell = TRUE)
# SouthCells <- SouthCells %>% filter(y<0)
# SouthCells <- SouthCells$cell
# if(length(SouthCells)>0){
#   gVelLat[SouthCells] <- gVelLat[SouthCells] * -1
# }

gVelLatrange <- range(gVelLat[], na.rm = TRUE)
the_palette_fc <- leaflet::colorNumeric(
```

```
  palette = "RdBu",
  domain = c(-max(abs(gVelLatrange)),max(abs(gVelLatrange))),
  reverse = TRUE)
the_colors <- the_palette_fc(seq(min(gVelLatrange), max(gVelLatrange), length.out = 50))

plot(gVelLat, col = the_colors)
```



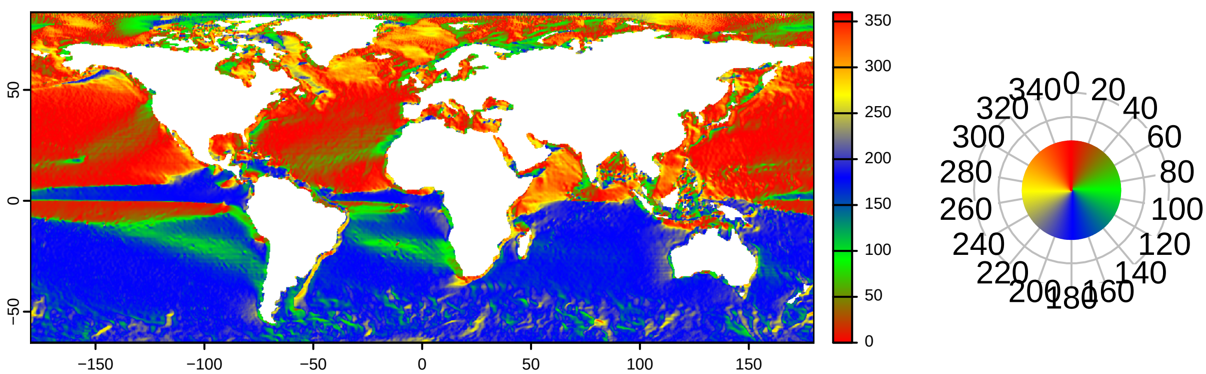
The difference is due to the direction (angle) of the gradient. Take a closer look to the direction of climate change.

Angle

```
SouthCells <- terra::as.data.frame(gVelLat, xy = TRUE, cell = TRUE)
SouthCells <- SouthCells %>% filter(y<0)
SouthCells <- SouthCells$cell

gVelAngle <- terra::rast(here::here("Data/Mar_mean_gVelAngle_1960-2009.tif"))
gVelAngle <- (gVelAngle + 180) %% 360

myramp <- colorRampPalette(colors = c("red","green","blue","yellow","red"))(360)

{
  layout(matrix(c(1,1,1,2), nrow = 1, ncol = 4, byrow=T))
  plot(gVelAngle,
```

```
      col = myramp)
  plotrix::polar.plot(
    start = 90,
    lengths = c(rnorm(360,mean = 1, sd = 0.001)),
    polar.pos = seq(0,360,by=1),
    clockwise = TRUE,
    cex=.01,
    show.grid.labels=0,
    line.col=myramp)
}
```

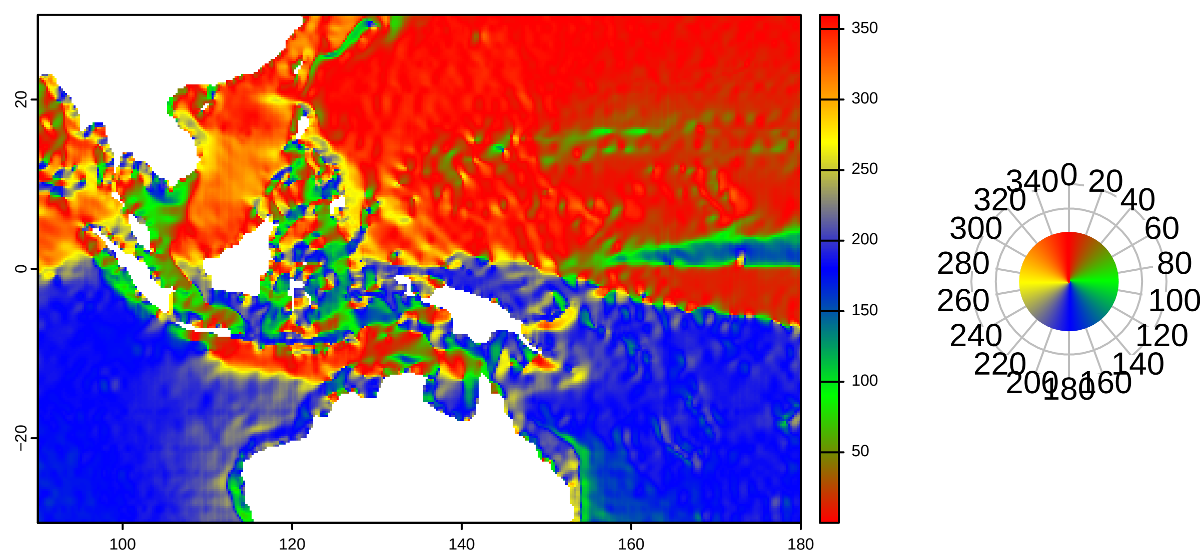
```
## Warning in cos(radial.pos[i, ]) * lengths[i, ]: longer object length is not a
## multiple of shorter object length

## Warning in sin(radial.pos[i, ]) * lengths[i, ]: longer object length is not a
## multiple of shorter object length
```




```
# zoom to australia
{
  layout(matrix(c(1,1,1,2), nrow = 1, ncol = 4, byrow=T))
  plot(crop(gVelAngle,c(90,180,-30,30)), col = myramp)
  plotrix::polar.plot(
    start = 90,
    lengths = c(rnorm(360,mean = 1, sd = 0.001)),
```

```r
    polar.pos = seq(0,360,by=1),
    clockwise = TRUE,
    cex=.01,
    show.grid.labels=0,
    line.col=myramp)
}
```

```
## Warning in cos(radial.pos[i, ]) * lengths[i, ]: longer object length is not a
## multiple of shorter object length

## Warning in cos(radial.pos[i, ]) * lengths[i, ]: longer object length is not a
## multiple of shorter object length
```



The angles are very similar to what has been presented in a previous study from Garcia-Molinos et al. 2019 Meth Eco Evo (see Fig3b from 10.1111/2041-210X.13295).