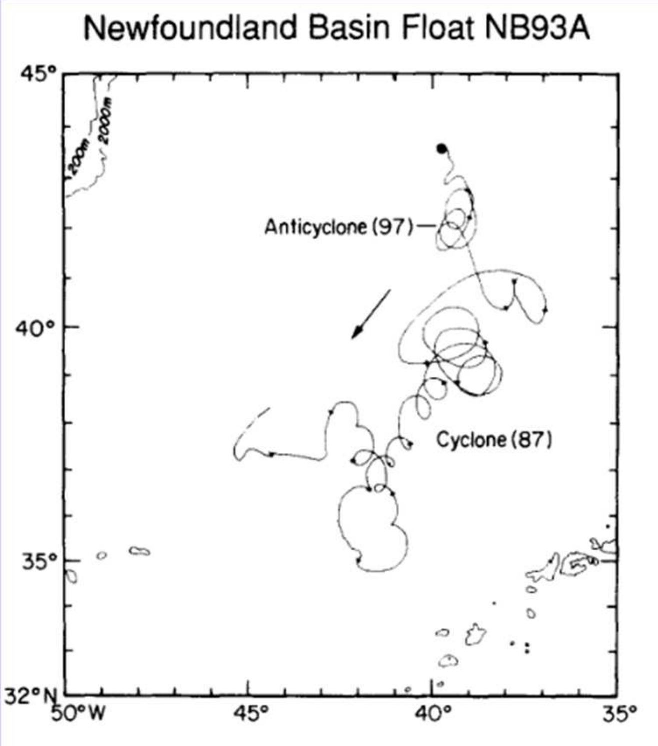
Isolating loopers in drifter trajectories

Rick Lumpkin (NOAA/AOML)



From Richardson (1993):

Each trajectory was visually examined for loops and cusps revealing the characteristic motion of particles in eddies- a rotational velocity around the eddy center, plus its translation … Once a looping float trajectory (looper) was identified, consisting of around two or more consecutive loops in the same direction, …”

Griffa, Lumpkin and Veneziani (2008)

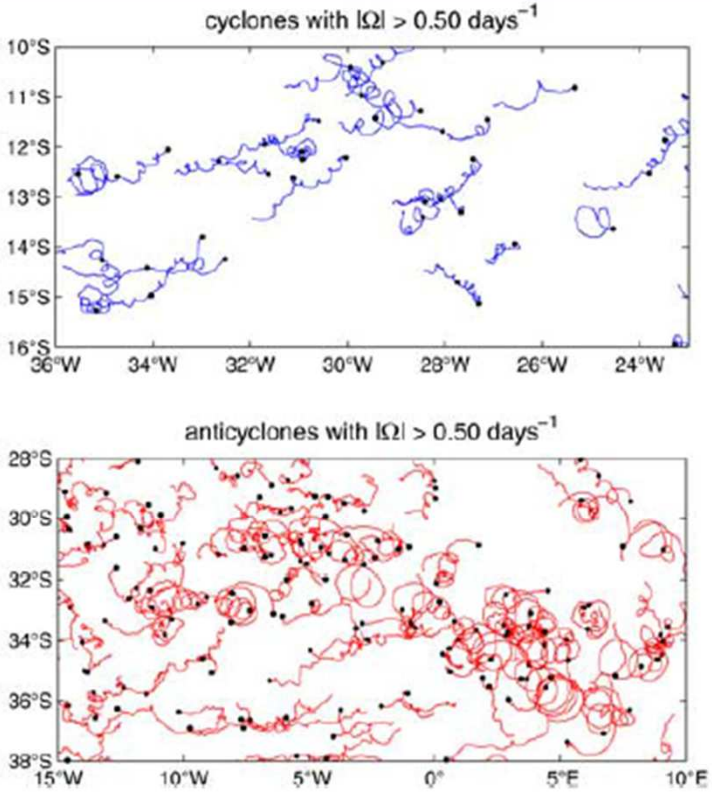


Figure 4. Examples of individual trajectory segments (T_{seg} = 20 days) with defined sense of rotation (spin values $|\Omega| > \Omega_c$) in the South Atlantic Ocean. (top) Cyclones. (bottom) Anticyclones. The black dots indicate the starting location of each trajectory segment.

Automatic detection of loopers in drifter data:

$u' = u_{tot} - \langle U \rangle$ (from climatology).

Drogued and continuous duty cycle only.

Trajectories divided into 20 day non-overlapping segments.

Velocity lowpassed at 1.5 IP to remove inertial oscillations.

Griffa, Lumpkin and Veneziani (2008)

Spin Ω calculated as:

$$\Omega = \frac{< u' \, dv' - v' \, du' >}{2 \, \Delta t \, EKE}$$

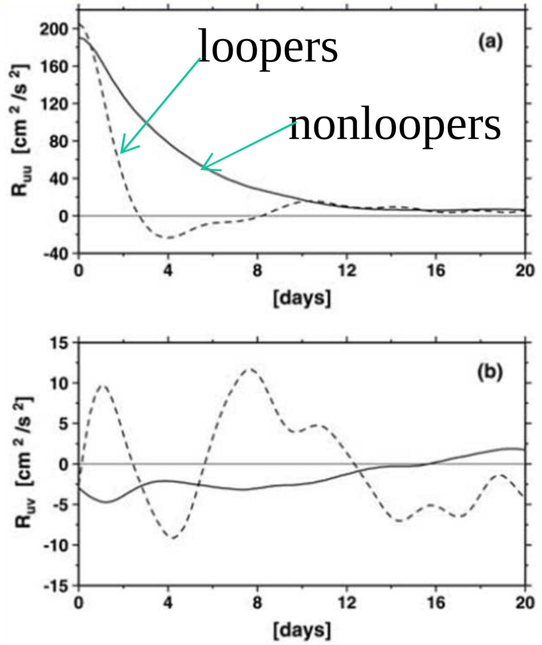
where Δt is the time sampling interval, du' and dv' are the change in u' and v' over that interval, and EKE is the eddy kinetic energy $0.5(u'^2+v'^2)$.

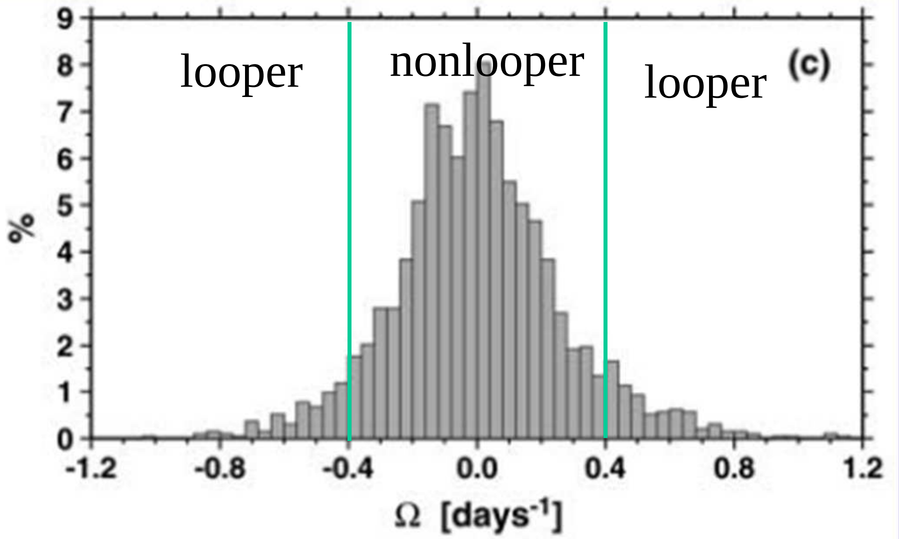
< > is the average over the 20-day trajectory.

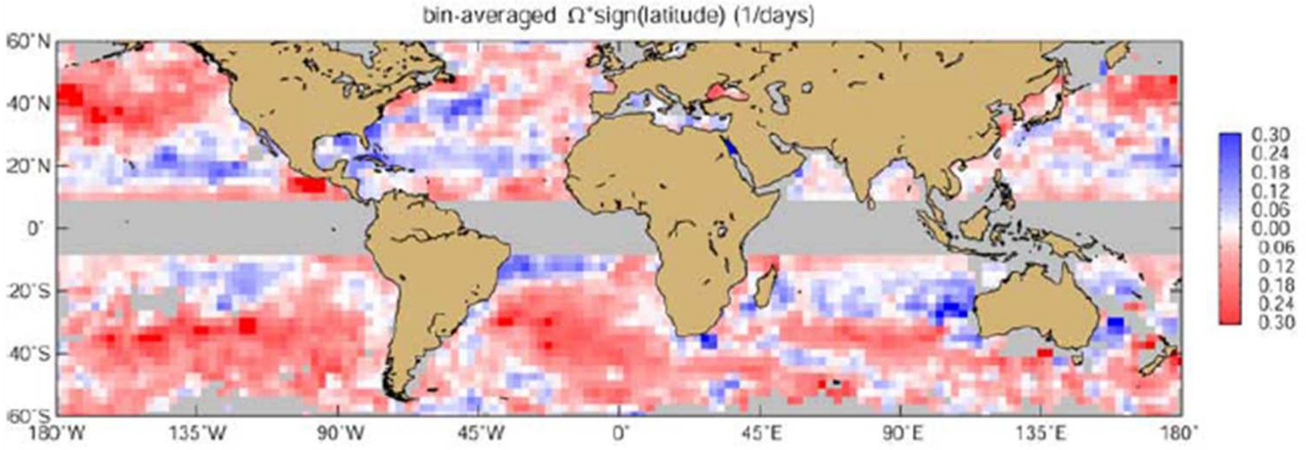
Looper: $|\Omega| > \Omega_c$, determined from examination of specific regions. For the drifter data, $\Omega_c = 0.4$ day^{-1}.

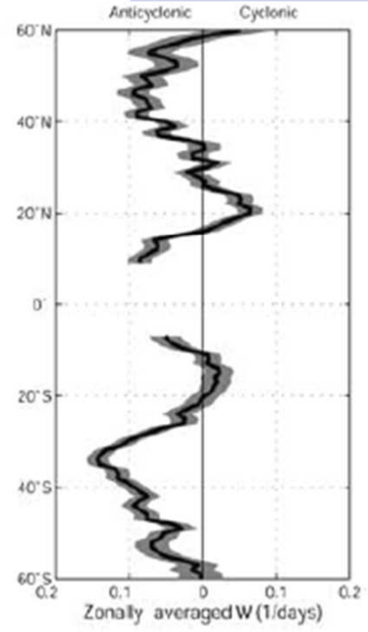
In summary, the methodology is designed to identify trajectory segments with persistent large $|\Omega|$.

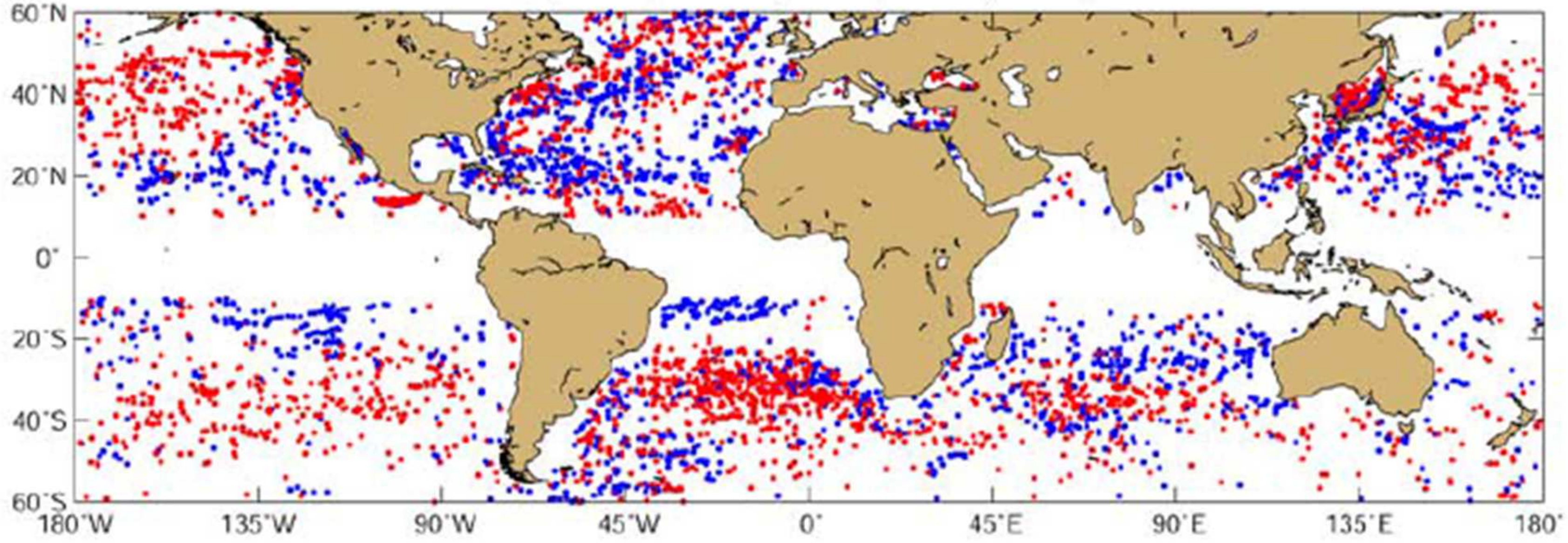
Griffa, Lumpkin and Veneziani (2008)

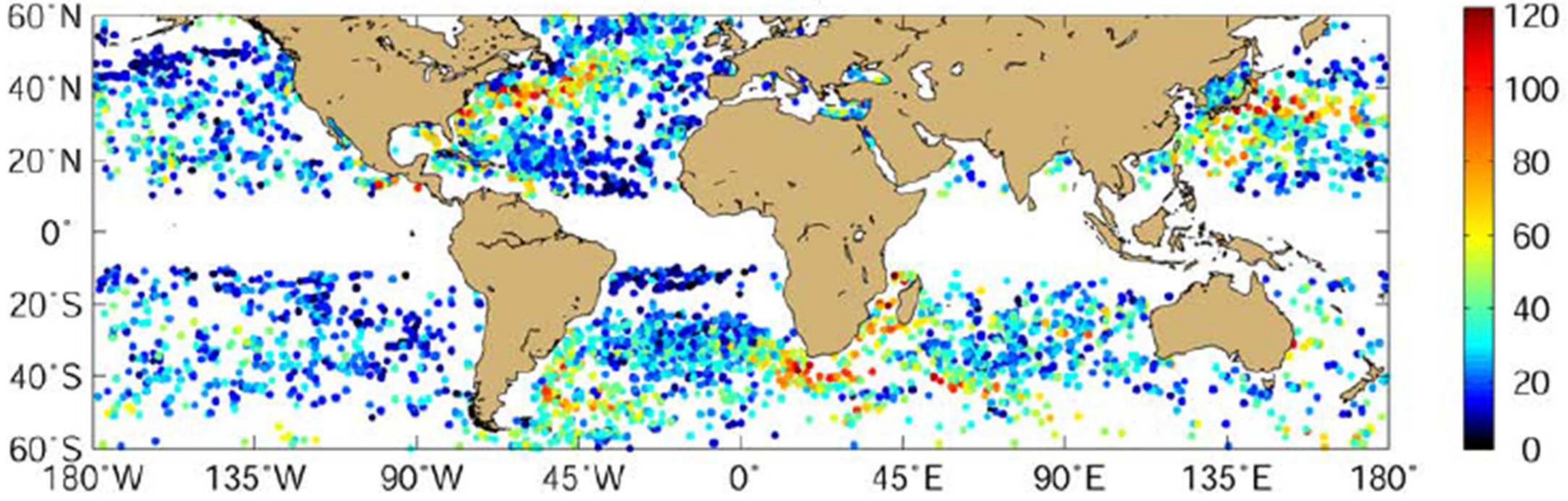









|Ω|>0.50 (red=anticyclones, blue=cyclones)


Radii of loopers with |Ω|>0.5

Weaknesses of Griffa et al. (2008)

- Fixed-length segments (20 days) identified as either looper or nonlooper.
  - Many trajectories exhibit looping during a fraction of the 20 days, but not all 20.
  - Many looping trajectories persist longer than 20 days and are treated as multiple loopers.
- Loopers defined for $|\Omega| > \Omega_c = 0.4$ day^{-1}.
  - This sets upper limit on period. From Griffa et al. (2008): period=$2\pi/|\Omega|$. Any looping trajectory with orbital period greater than ~15.7 days will automatically be "nonlooper".
  - Distribution of looper vs. nonlooper Ω not meaningful.

Goal of this study

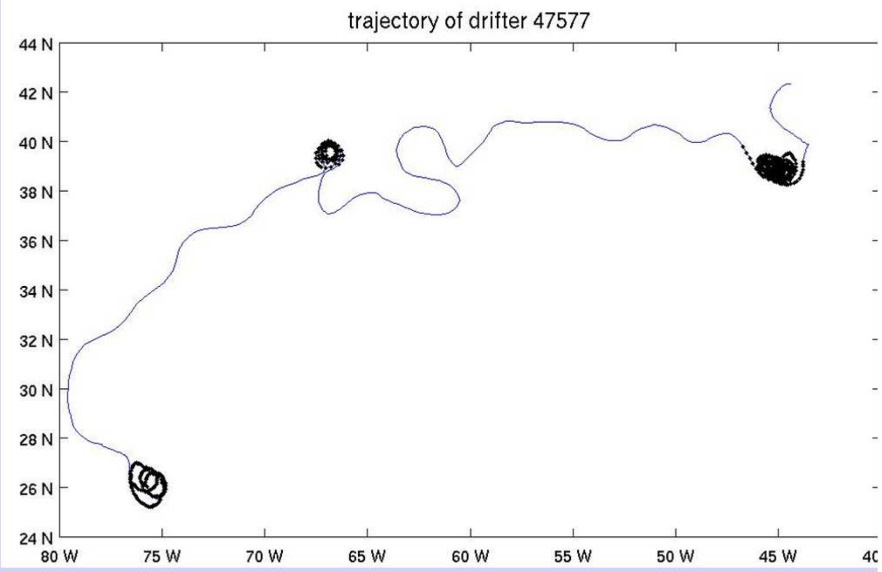
Derive a methodology to identify loopers without the constraint of dividing data into arbitrary 20-day segments and allowing for loops with arbitrarily long periods.

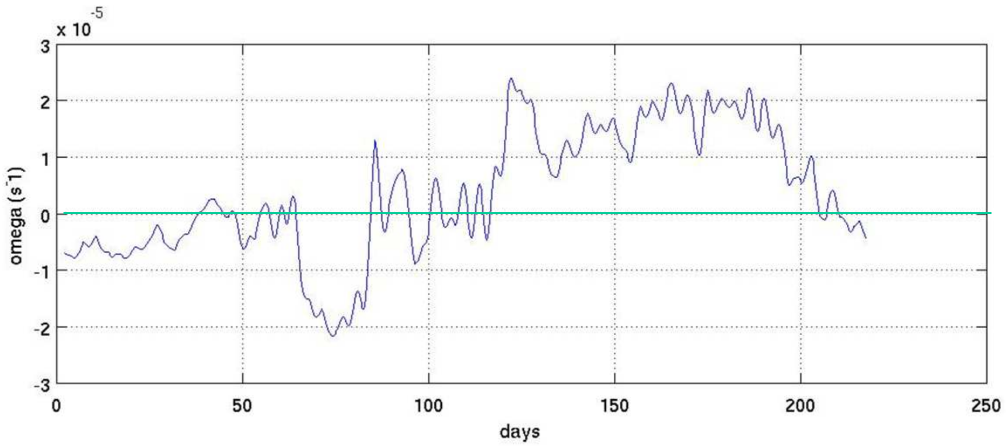
Examine characteristics of loopers vs. nonloopers.

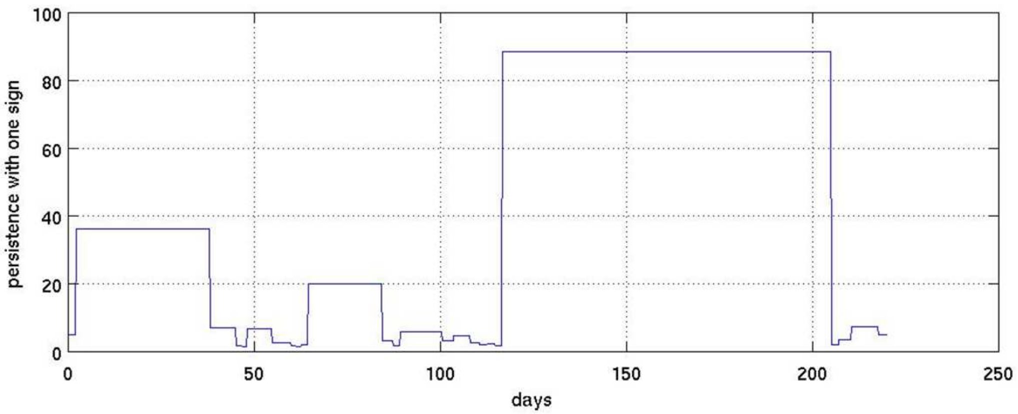
New methodology:

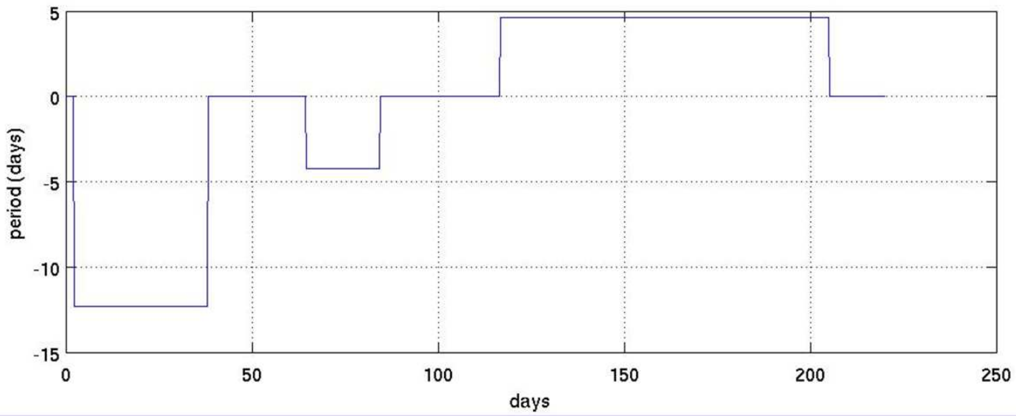
1. remove mean velocity, lowpass at 1.5 IP.
2. Calculate Ω over a running 2 day window.
3. Divide into segments each time value of Ω crosses zero. Duration of segment = “Persistence”.
4. For each segment, calculate period from median Ω.
5. Define as “looper” if persistence > 2 period.

Example

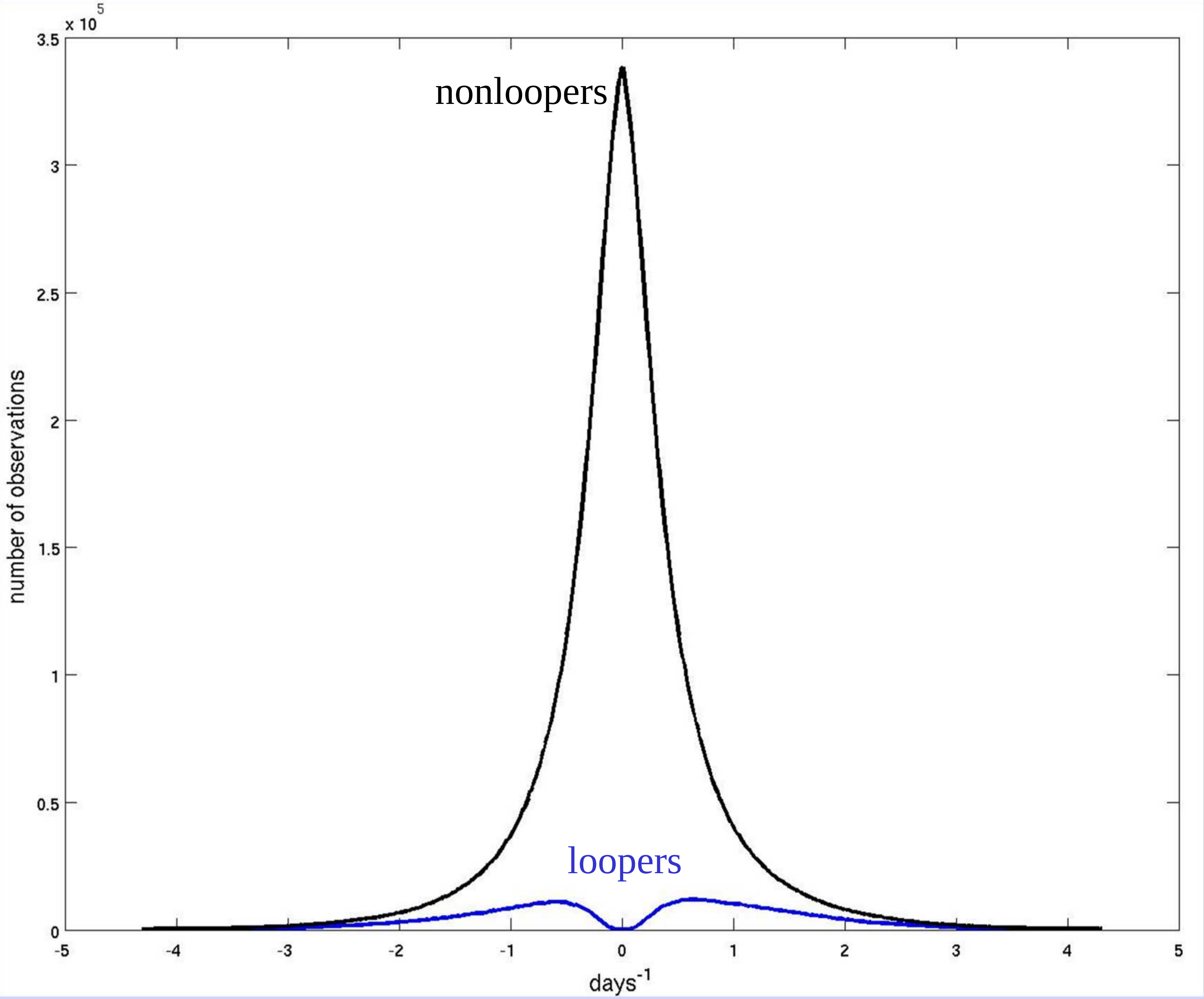

trajectory of drifter 47577



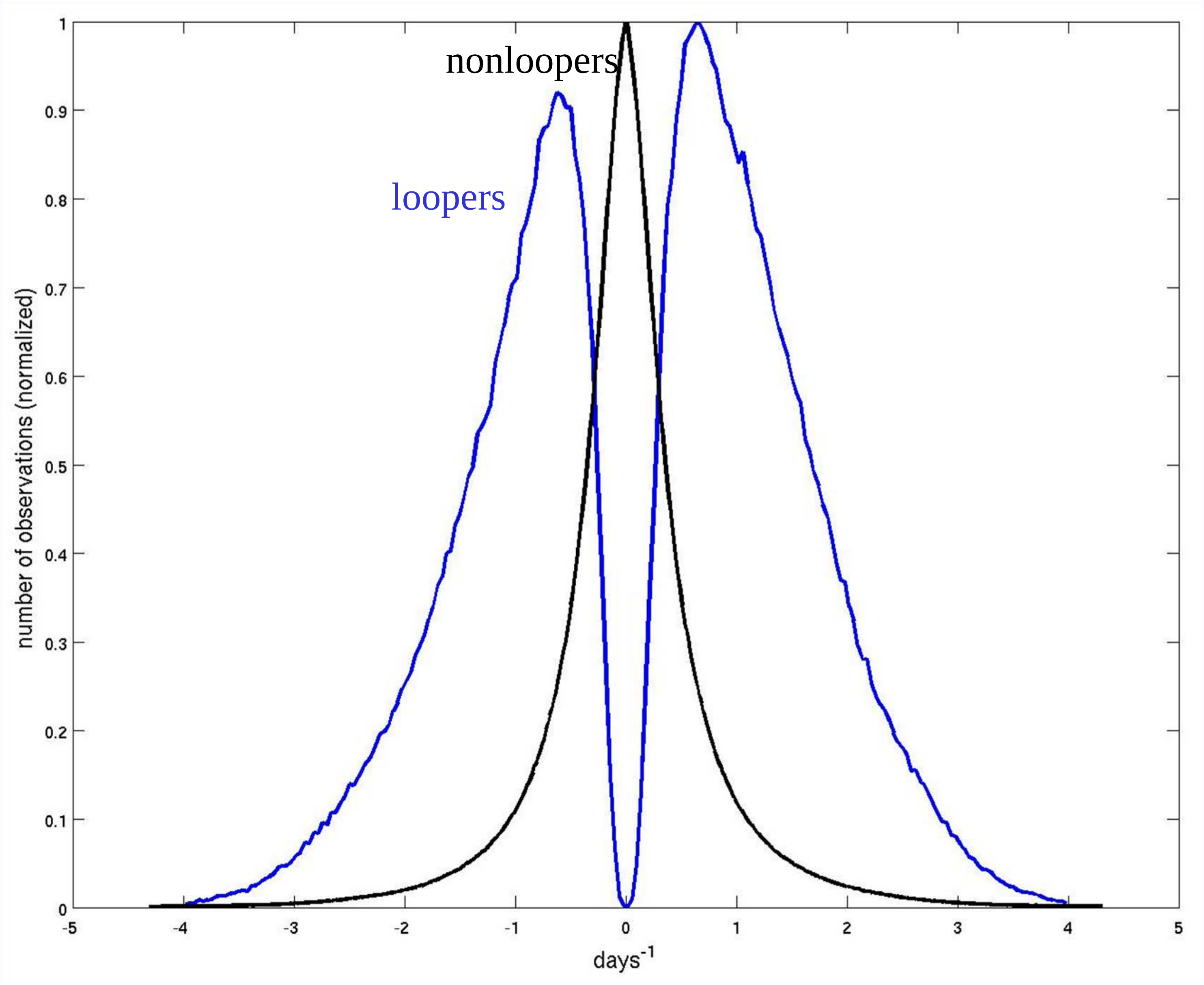




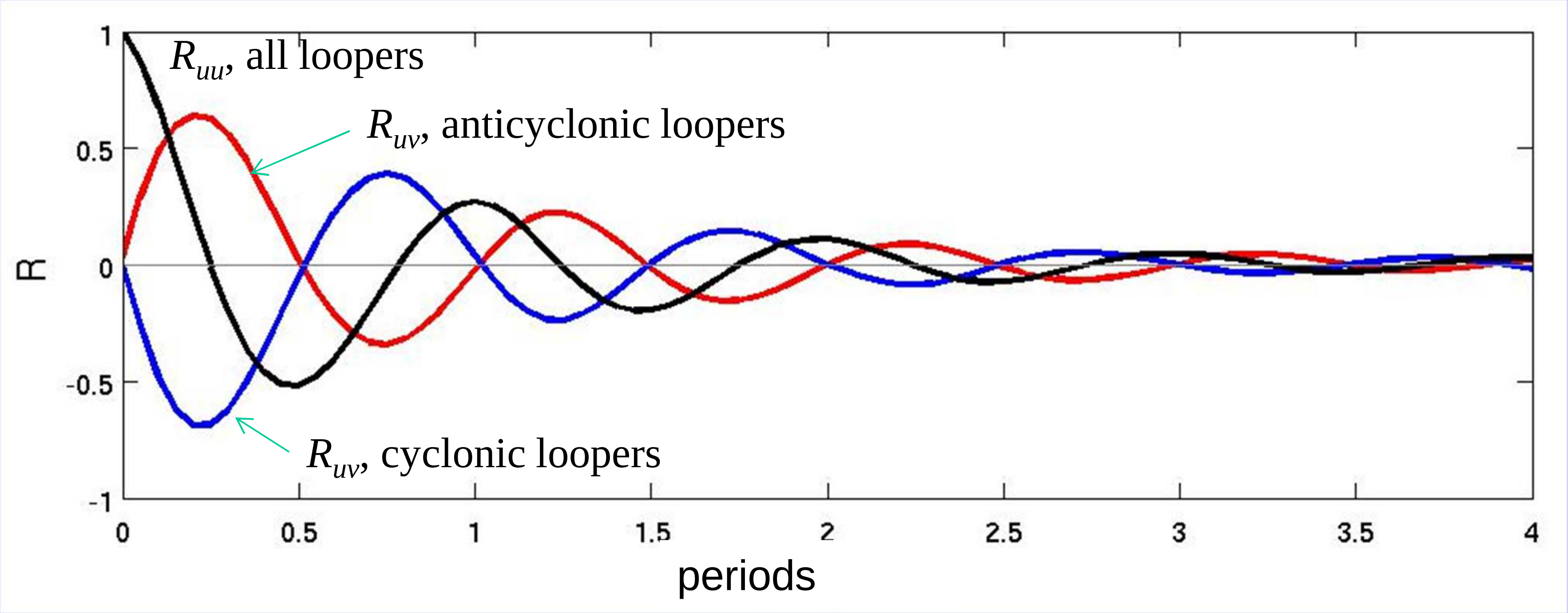
Distribution of spin for loopers vs. nonloopers



Distribution of spin for loopers vs. nonloopers



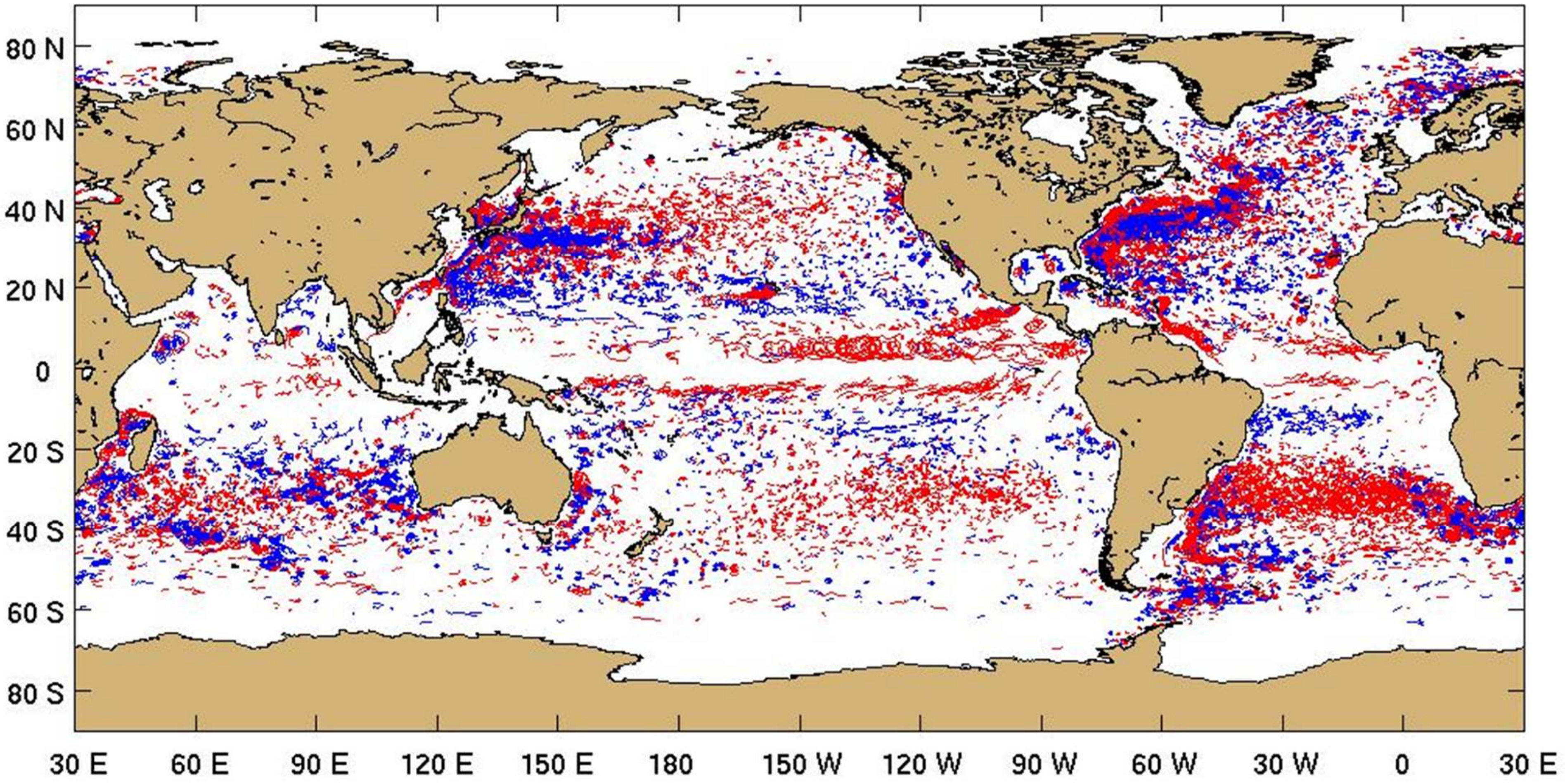
Mean normalized velocity auto/crosscorrelations of loopers



E-folding scale (Lagrangian integral time scale) is approximately one period.

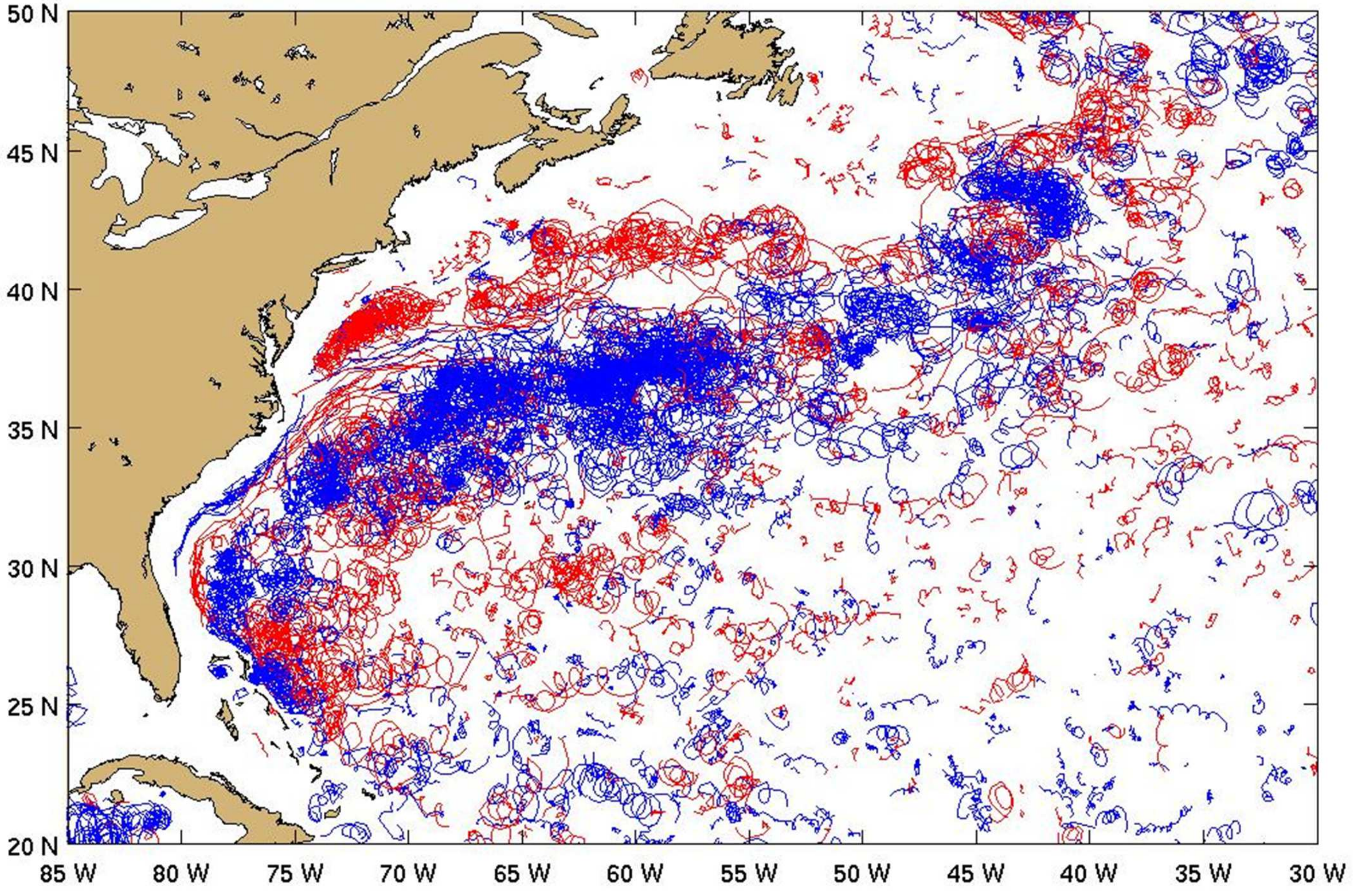
Distribution of loopers

4% of all trajectories (567.7 drifter-years) are loopers.

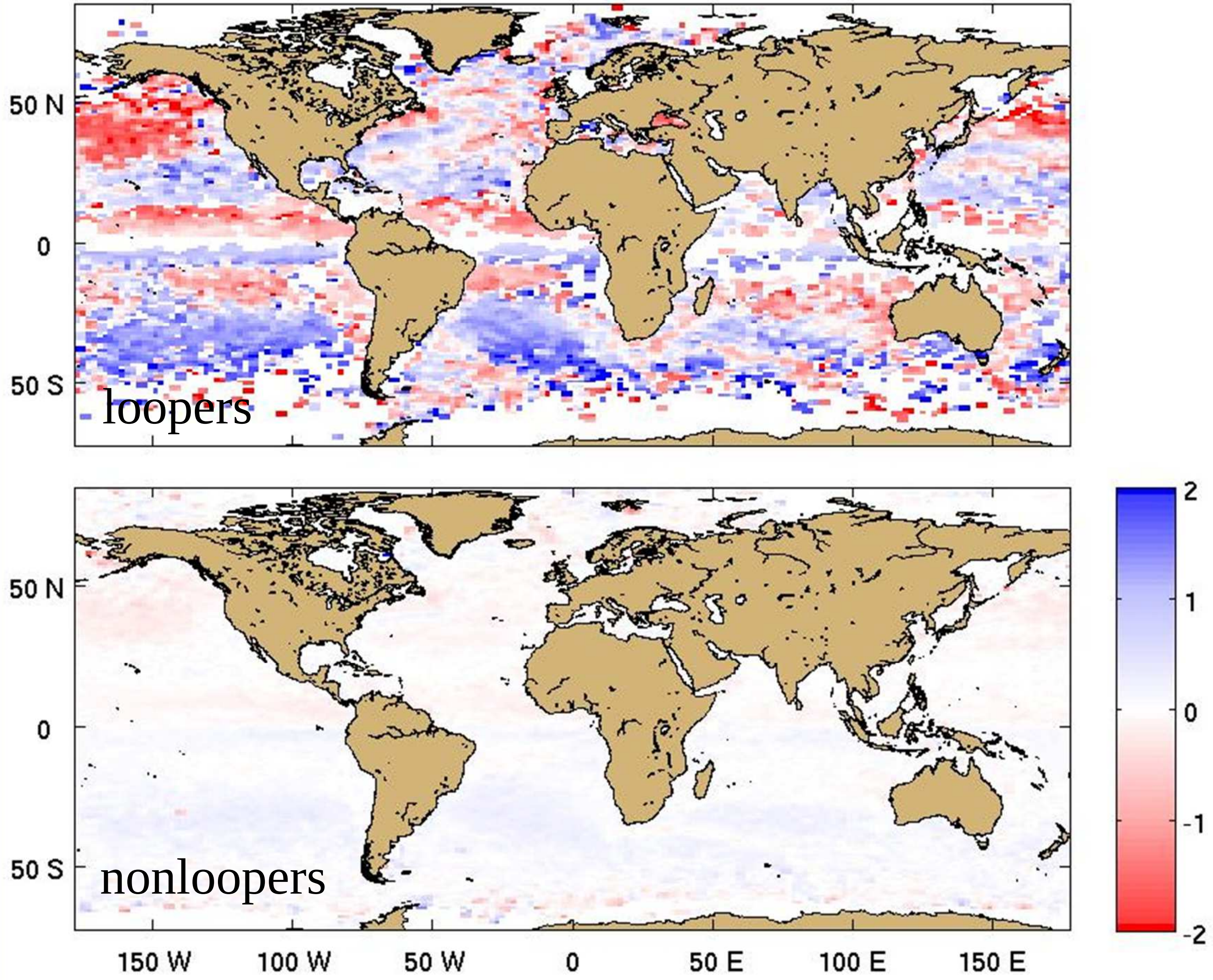


Cyclones: 46% of loopers.
Anticyclones: 54%.

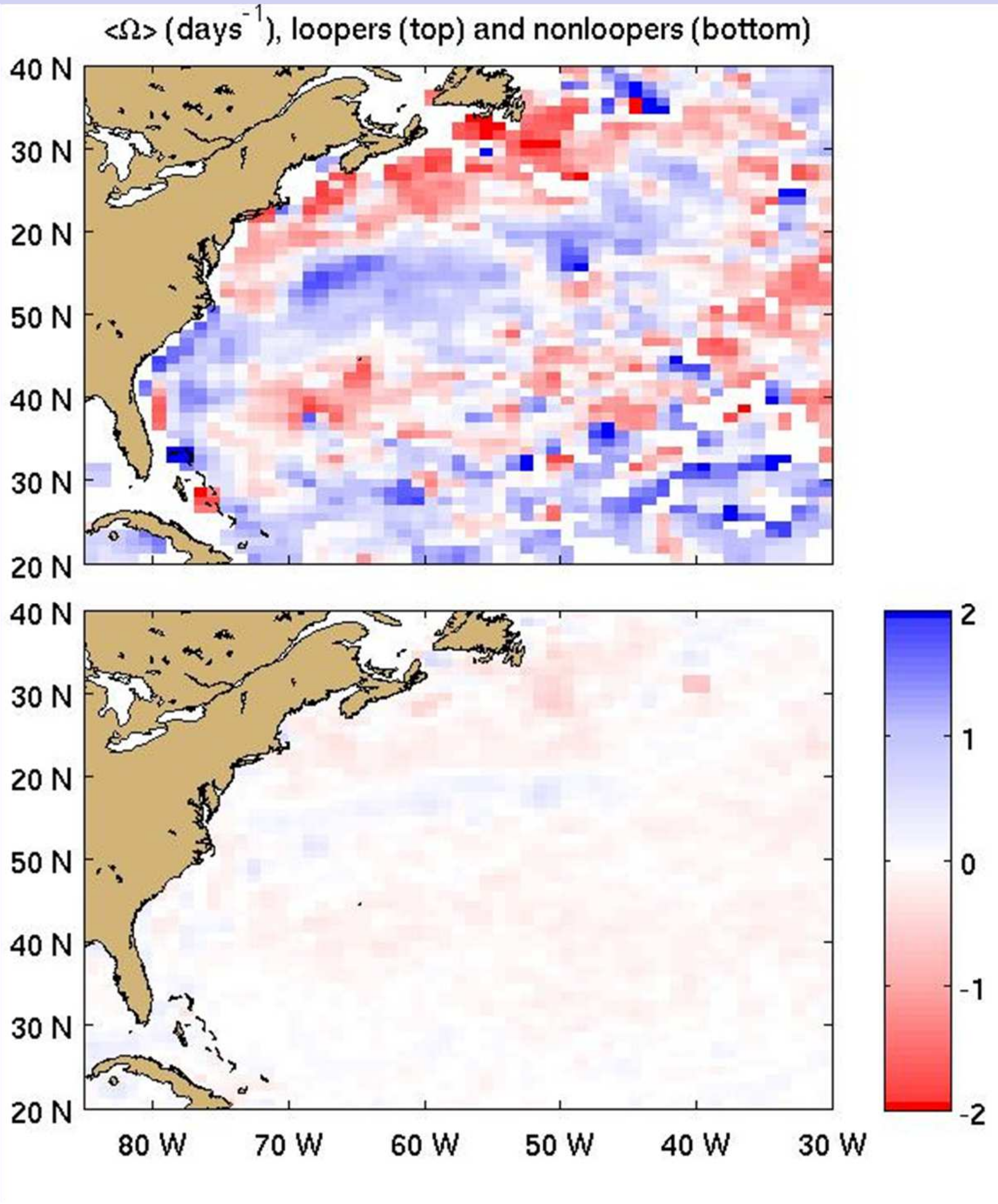
Distribution of loopers



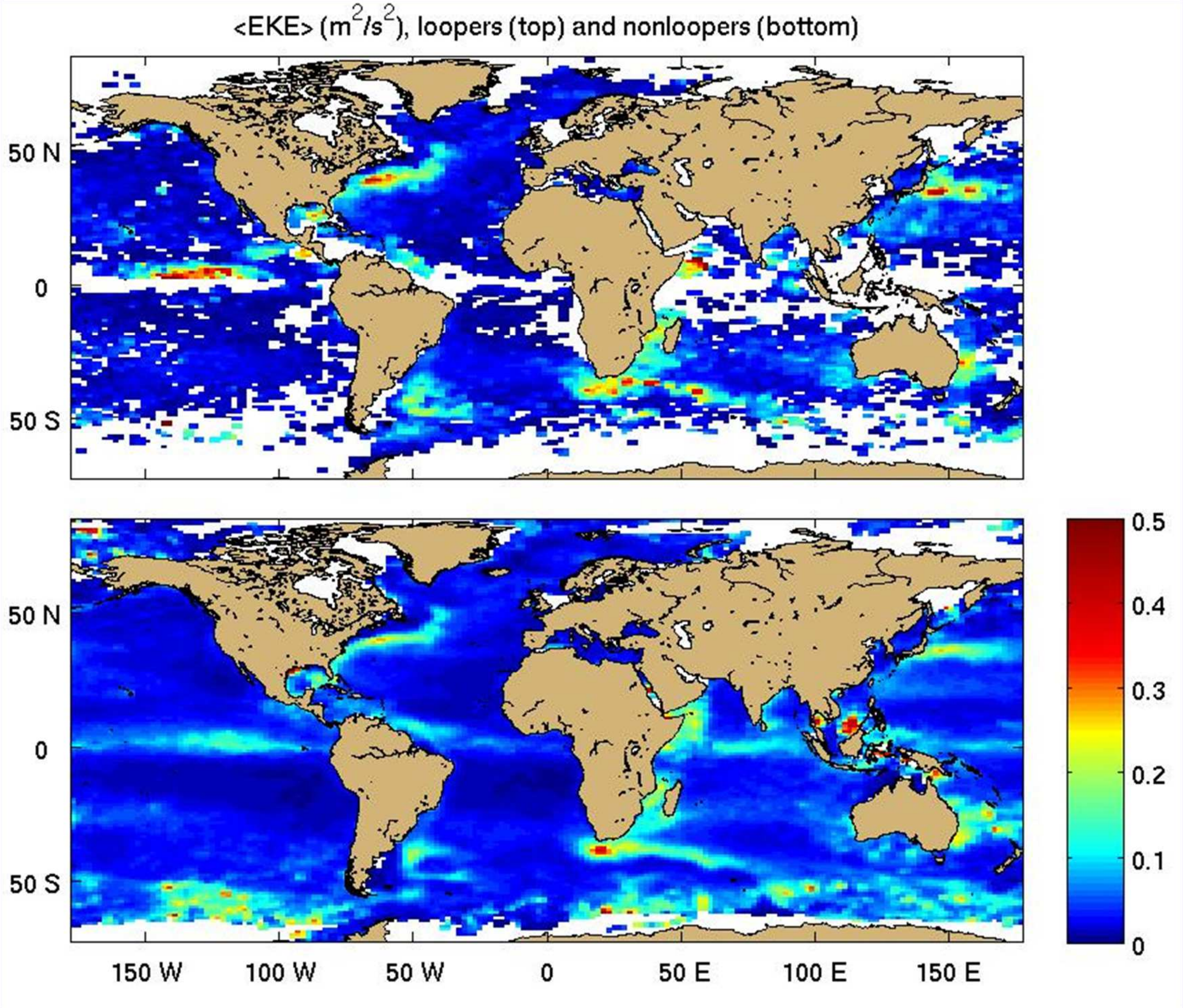
Mean spin Ω (days^{-1})



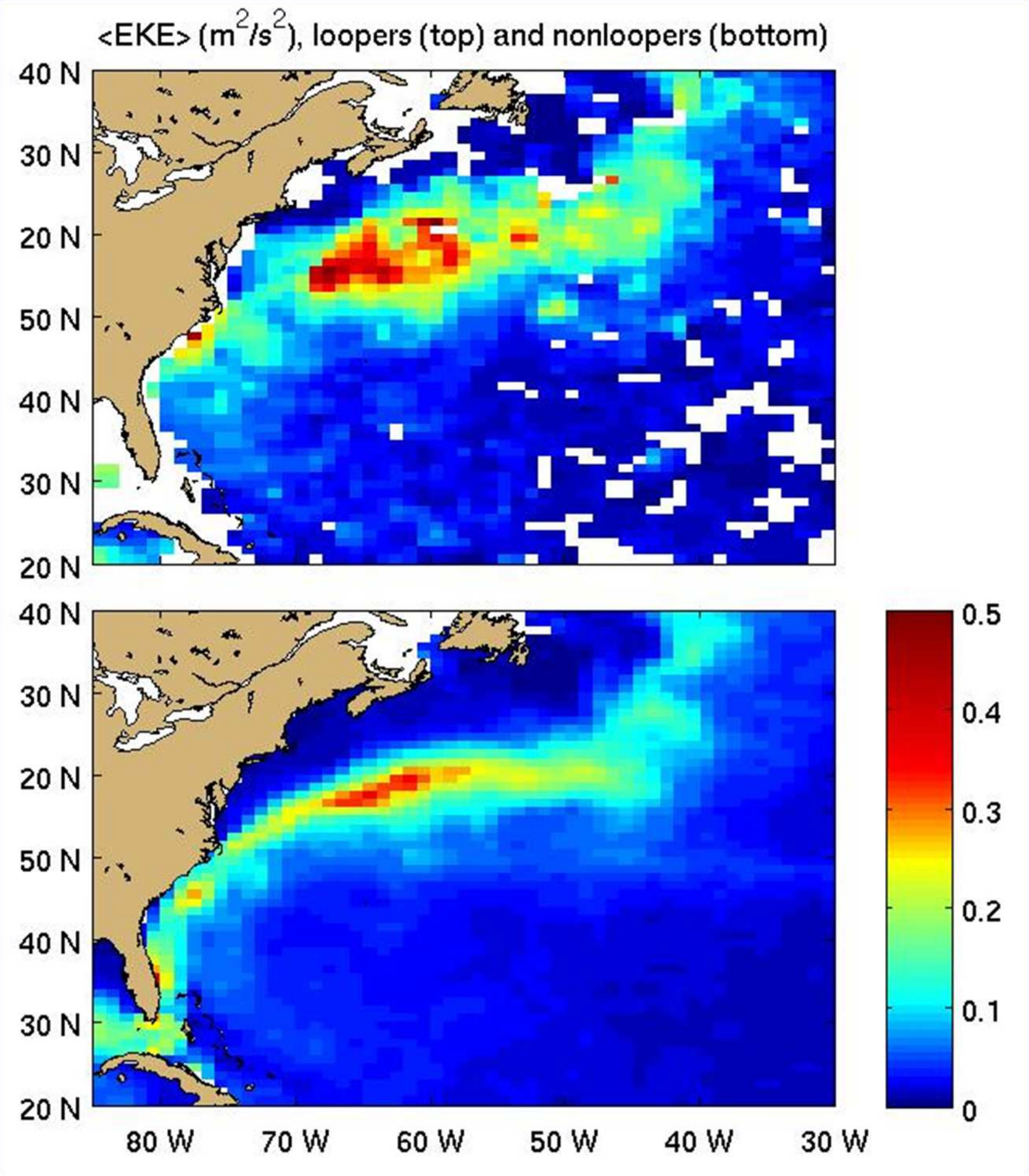
Mean spin Ω (days^{-1})



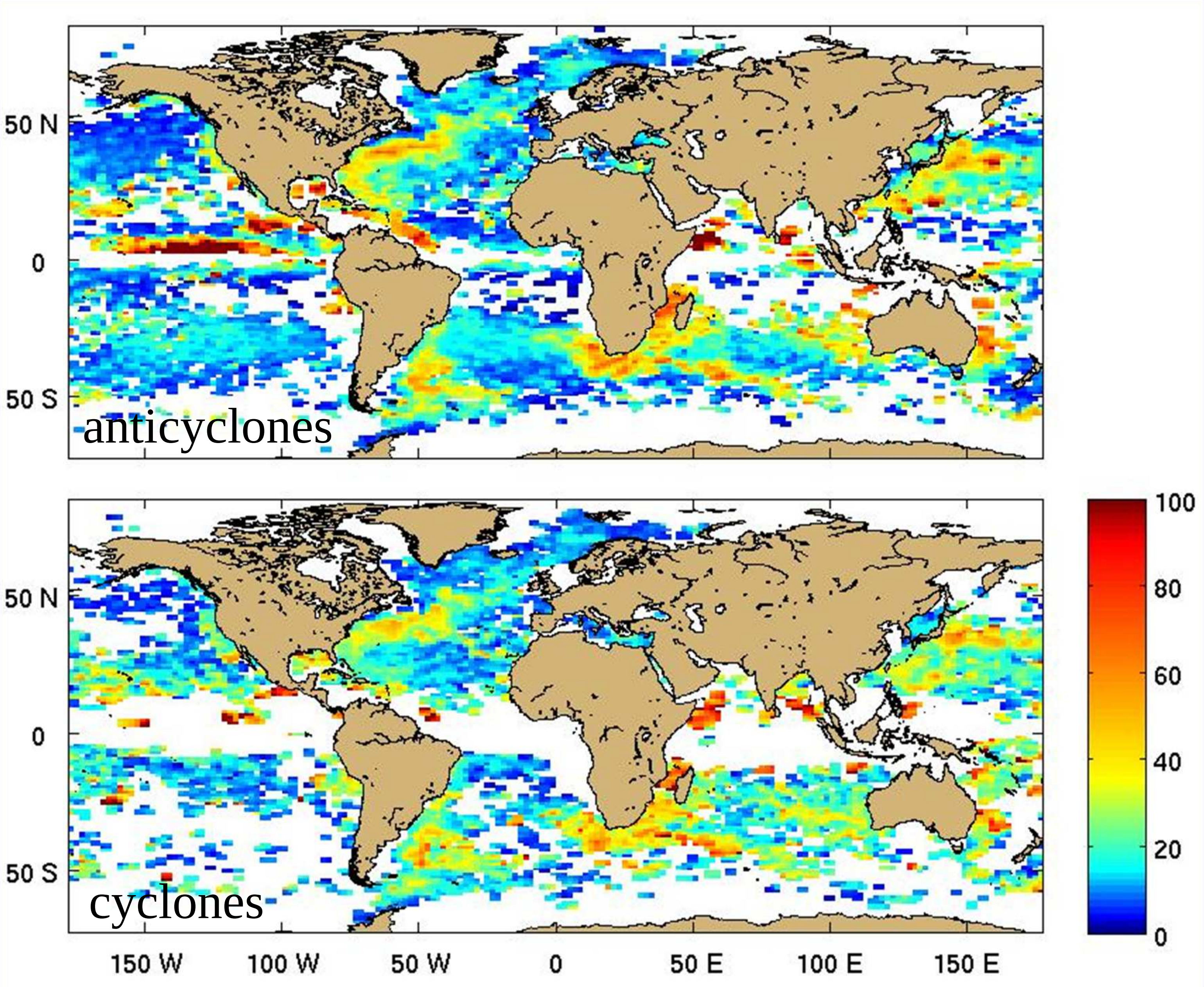
Mean EKE


<EKE> (m²/s²), loopers (top) and nonloopers (bottom)
50 N
0
50 S
50 N
0
50 S
150 W
100 W
50 W
0
50 E
100 E
150 E
0.5
0.4
0.3
0.2
0.1
0

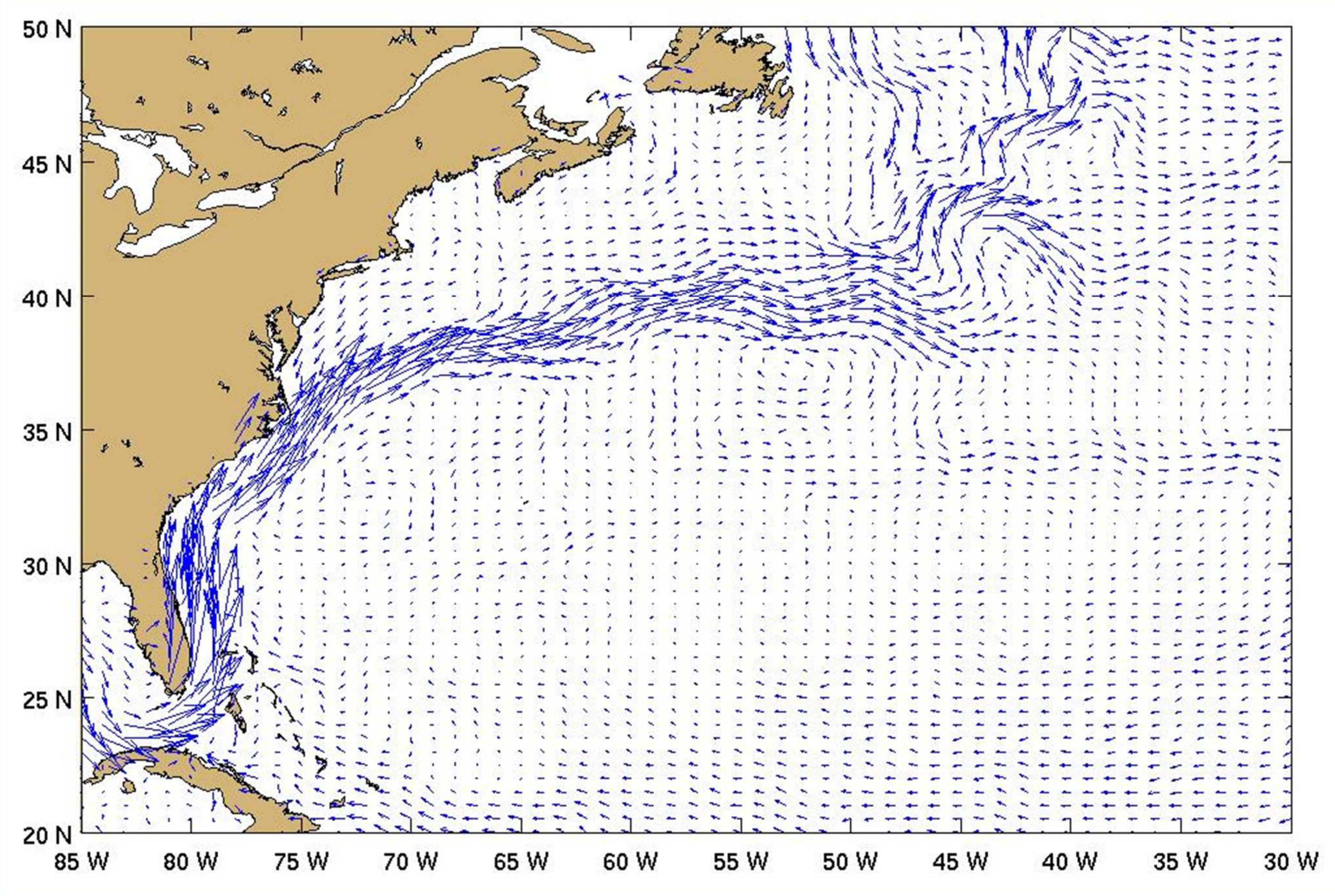
Mean EKE


<EKE> (m^2/s^2), loopers (top) and nonloopers (bottom)
40 N
30 N
20 N
50 N
40 N
30 N
20 N
40 N
30 N
20 N
50 N
40 N
30 N
20 N
80 W
70 W
60 W
50 W
40 W
30 W
0.5
0.4
0.3
0.2
0.1
0

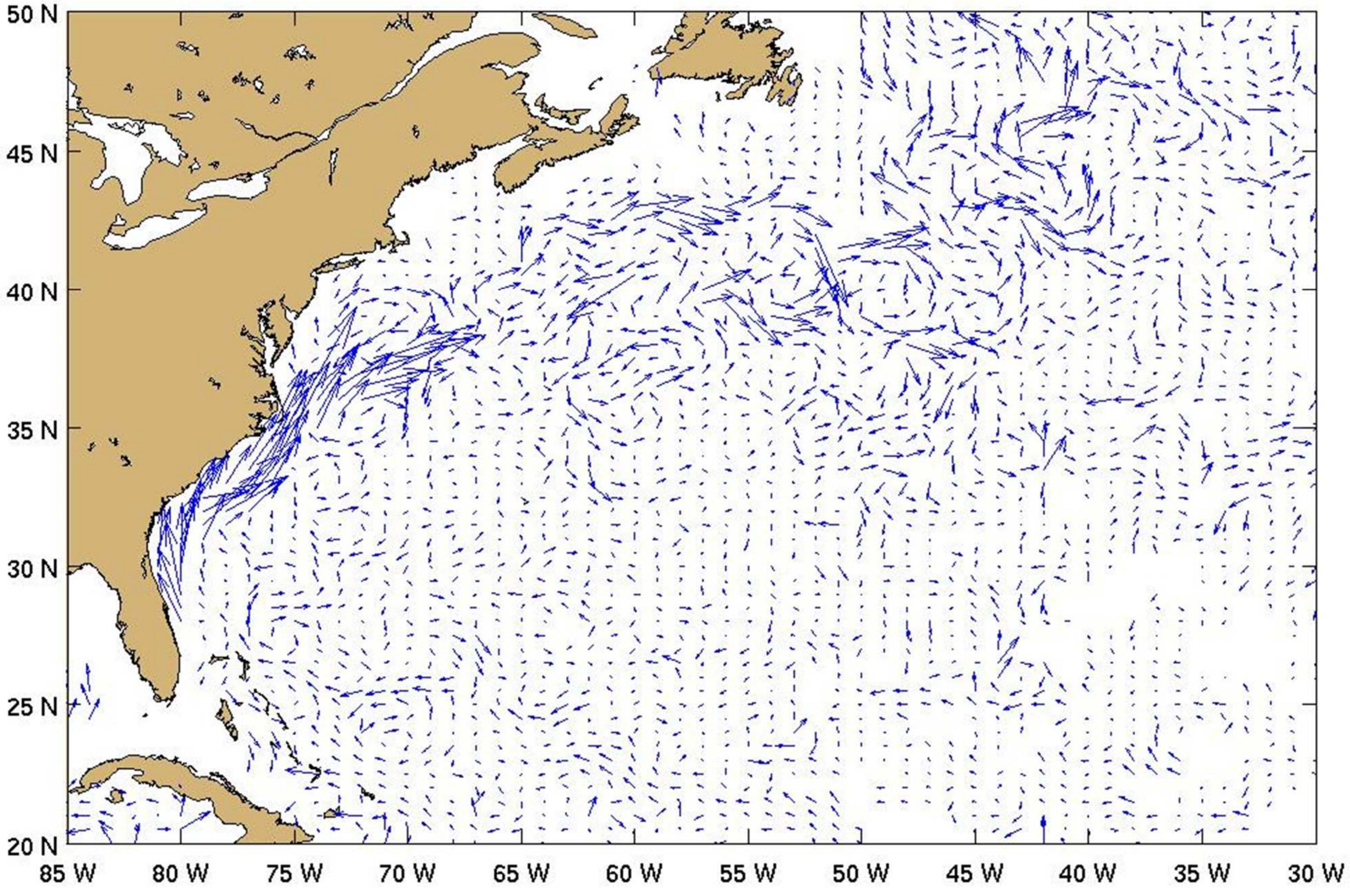
Mean radius of loops (km)



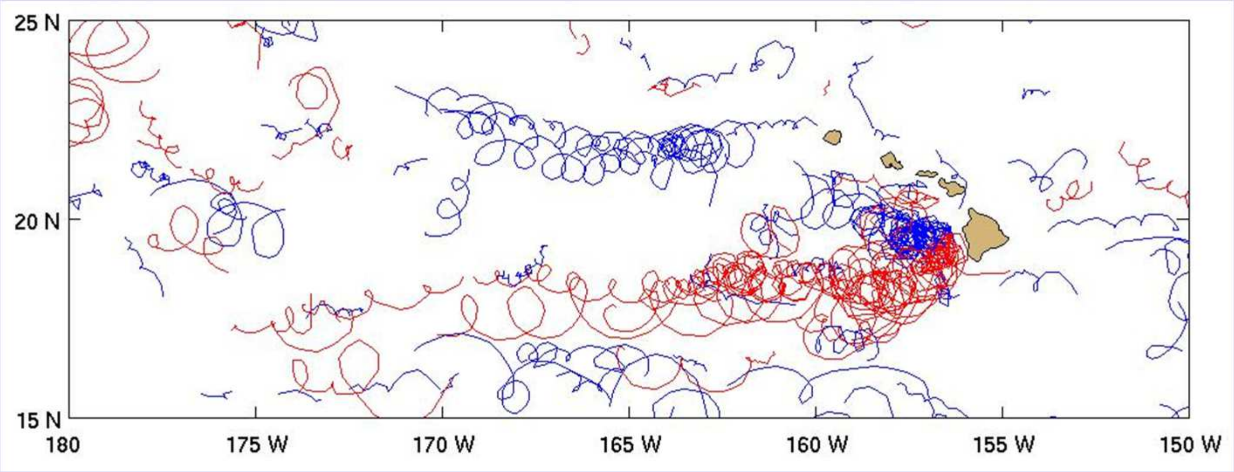
Mean speed (nonloopers)



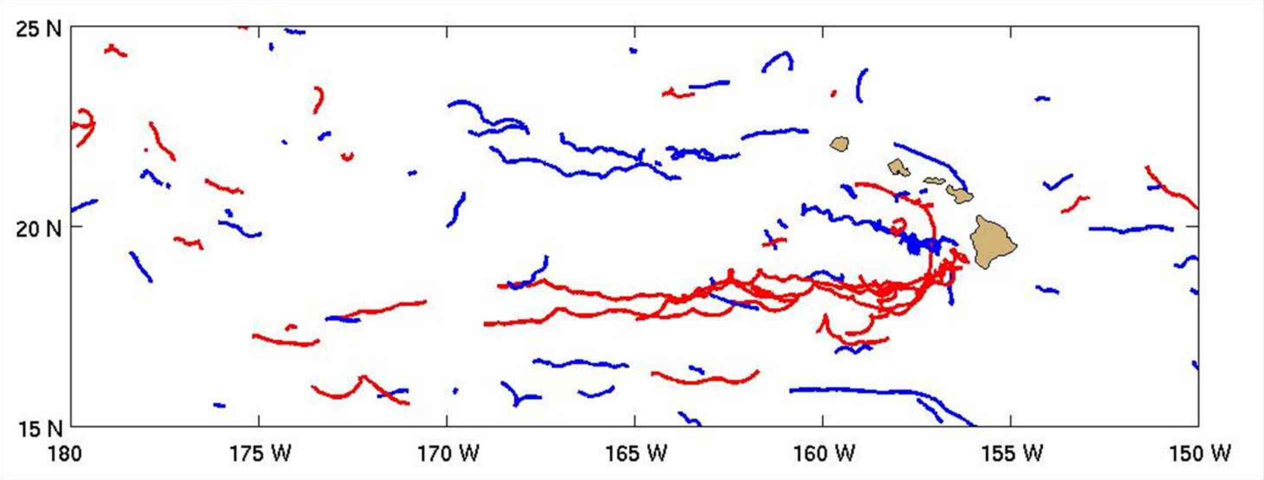
Mean speed (loopers)



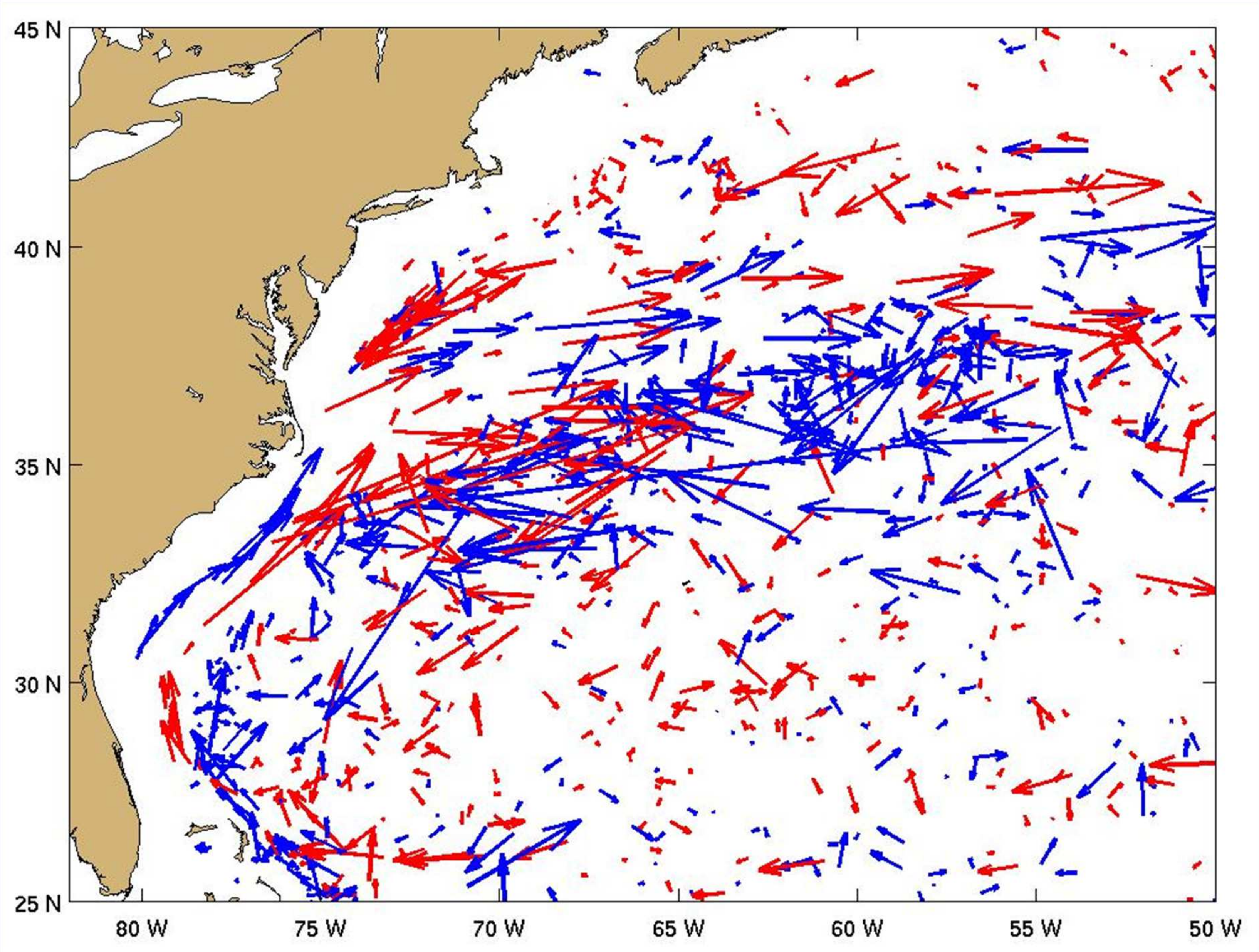
Calculating mean eddy movement



Each looper is a drifter orbiting the center of an eddy. Calculate motion of center by lowpassing trajectory at orbital period (running lowpass with time-varying period).



Eddy displacements in the GS region



Conclusions

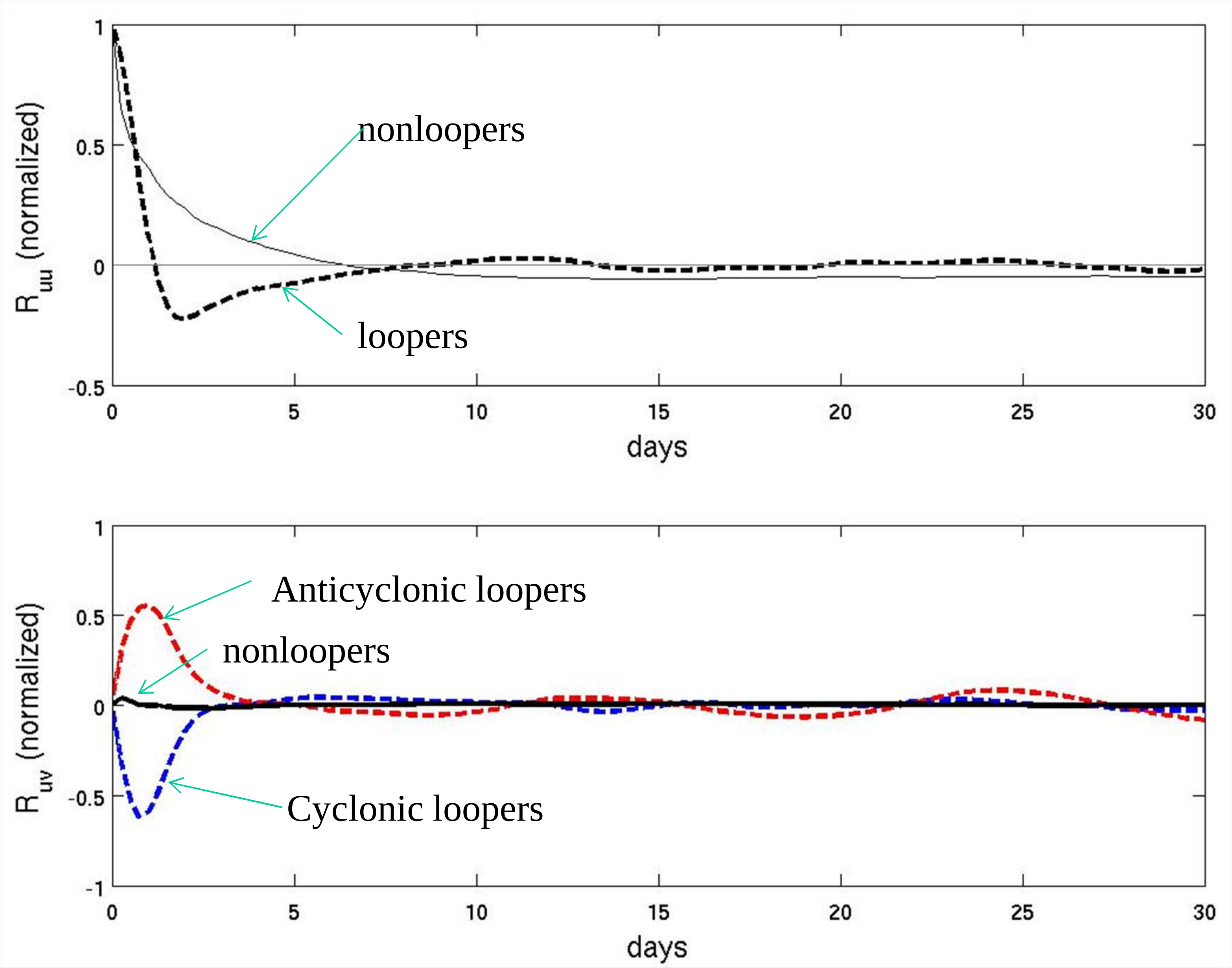
Loopers can be automatically identified in the drifter data without the constraints of Griffa *et al*. (2008) and other prior studies.

Looper characteristics such as persistence, vorticity, orbital period, orbital radius, and eddy propagation pathways can be extracted from these data. Loopers behave differently than nonloopers with respect to basic properties like mean motion.

Higher-order statistics, such as retention rate in cyclones vs. anticyclones, or the potential for biased sampling of Cs vs ACs, can be examined in the data.

Other questions are so far unanswered. E.g.: do we see a comparable number of eddies in altimetry? We might expect the drifters to show more at high latitude (small Rossby radius). True?

Mean velocity auto/crosscorrelation



nonloopers

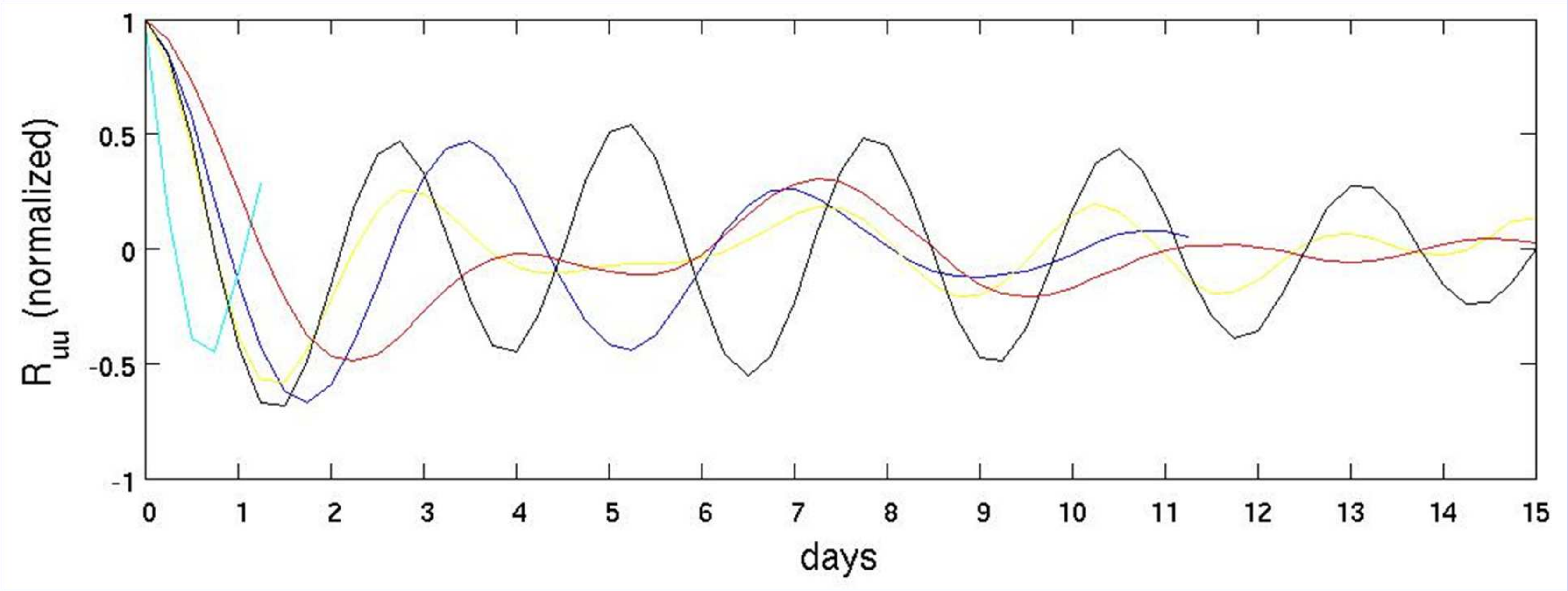
loopers

Anticyclonic loopers

nonloopers

Cyclonic loopers

Example autocorrelations of loopers



Veneziani et al. (2004):

$R_{uu}=R_{vv}=\exp(-t/T_L)\cdot\cos(2\pi t/P)$, $R_{uv}=\exp(-t/T_L)\cdot\sin(2\pi t/P)$

For each looper, period P and Lagrangian integral time scale T_L can be calculated by fitting this to the observations.