Evaluating how and why drifters die

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27th Data Buoy Cooperation Panel

Scientific and Technical Workshop

26 September 2011

Geneva, Switzerland

Motivation

Global drifter array of ~1250 drifters requires deployment of ~1000 drifters per year. When planning these deployments, it's valuable to have an accurate assessment of where drifters are likely to die.

Evaluating manufacturers: if a large number of drifters die after being deployed in a region, is that anomalous? Also, when calculating mean lifetime as a function of manufacturer, we want to exclude drifters that ran aground or were picked up.

Improve scientific use in Lagrangian simulations: regions where drifters run aground indicate where surface-following particles are also likely to run aground. Example: marine debris simulations.

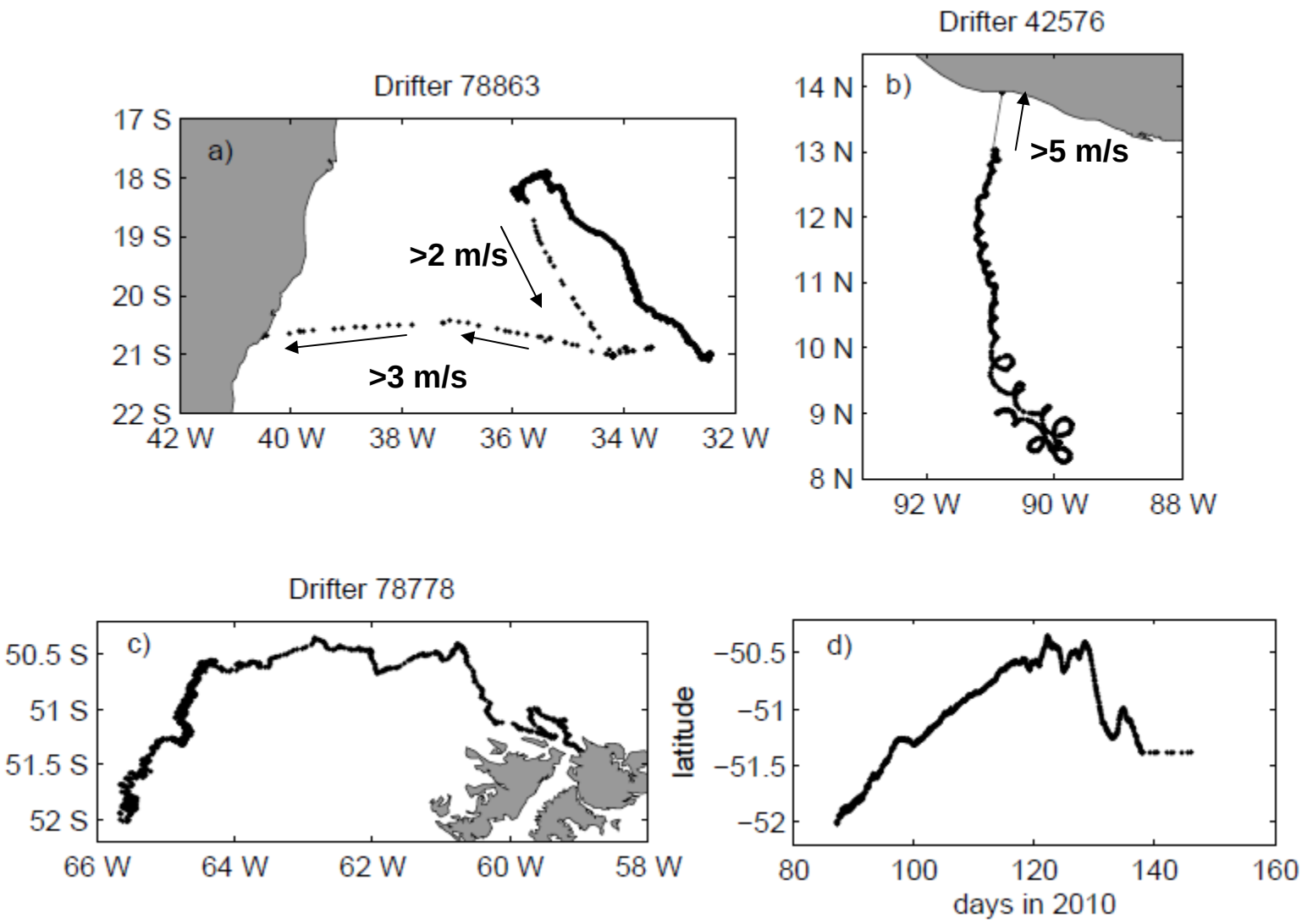
Why drifters die
(according to DAC metadata)

Through June 30, 2010: 14,554 drifters, 1427 still alive.

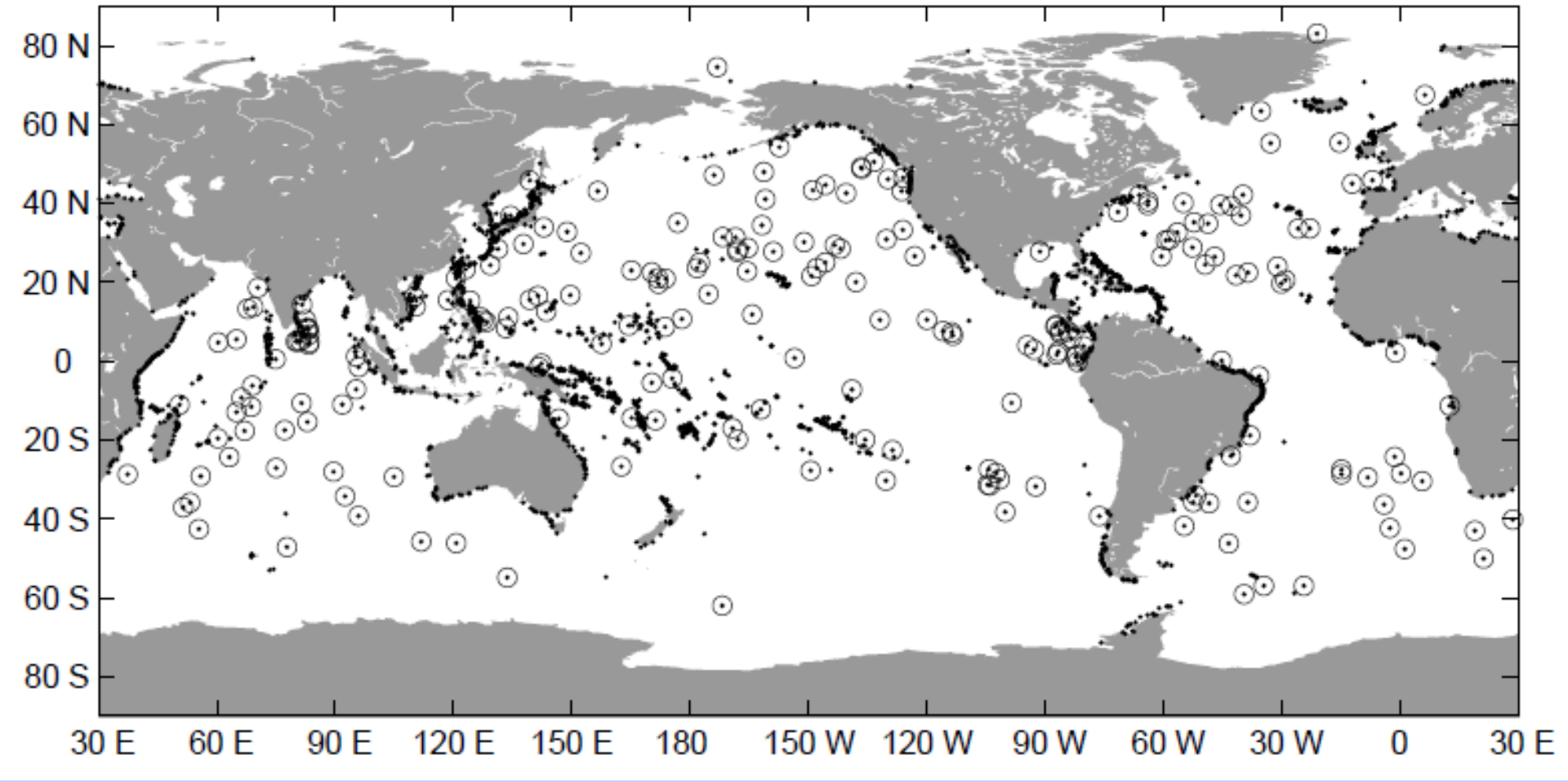
Ran aground:	3049 (23.2%)
Picked up:	888 (6.8%)
Quit transmitting:	8972 (68.3%)
Unreliable transmissions at end of trajectory:	86 (0.7%)
Bad battery voltage:	37 (0.3%)
Placed in inactive status while still transmitting:	95 (0.7%)

→ Most drifters die via “Quit Transmitting”.

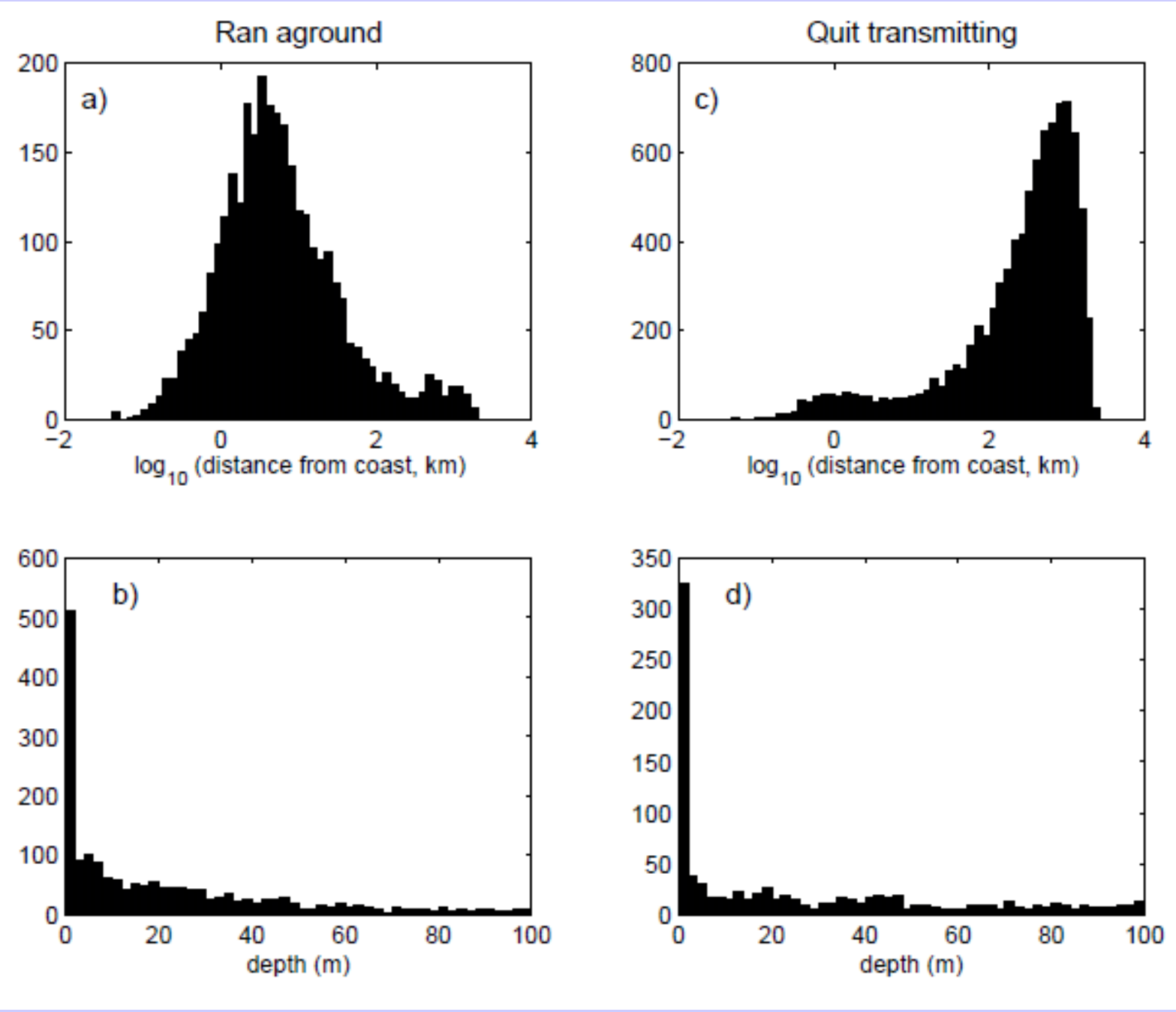
Examples of ran aground / picked up



Location of ran agrounds



3049 total drifters “ran aground”. Circles: 222 locations which are in >100m deep water, >100 km from nearest coast.


Ran aground
a)
200
150
100
50
0
−2
0
2
4
log10 (distance from coast, km)
Quit transmitting
c)
800
600
400
200
0
−2
0
2
4
log10 (distance from coast, km)
b)
600
500
400
300
200
100
0
0
20
40
60
80
100
depth (m)
d)
350
300
250
200
150
100
50
0
0
20
40
60
80
100
depth (m)

Spurious “ran agrounds”

222 drifters listed as “ran aground” in DAC database were in water >100m deep, >100 km from coast. Unlikely that these ran aground.

These have been individually reassessed by the DAC. Some appeared to cease motion for a while, perhaps due to being trapped in a small vortex or entering a very quiescent location. Others (high latitude) may have become temporarily frozen in ice. Many were simply errors and clearly never ran aground. In many cases, additional data were recovered.

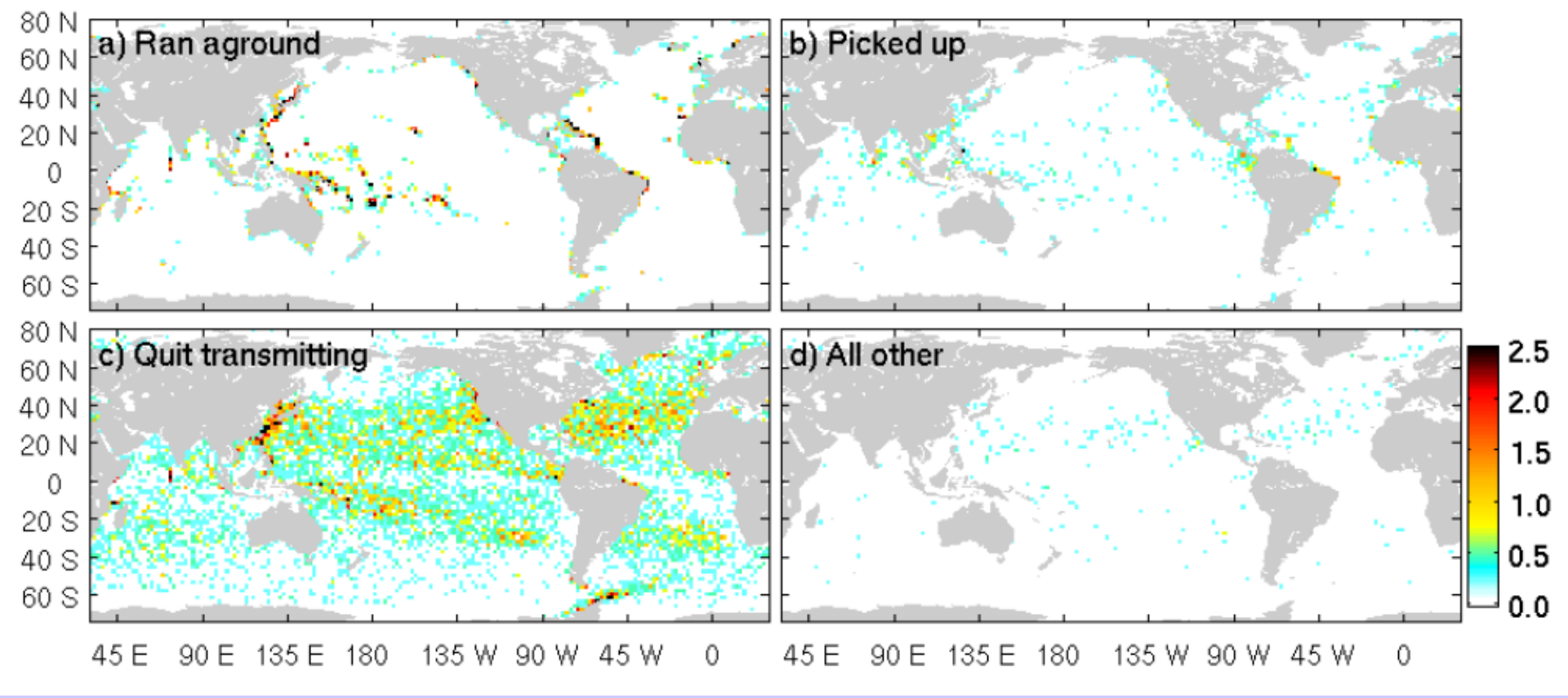
Reassessment:

160 (72%) “Quit transmitting

57 (26%) “Picked up”

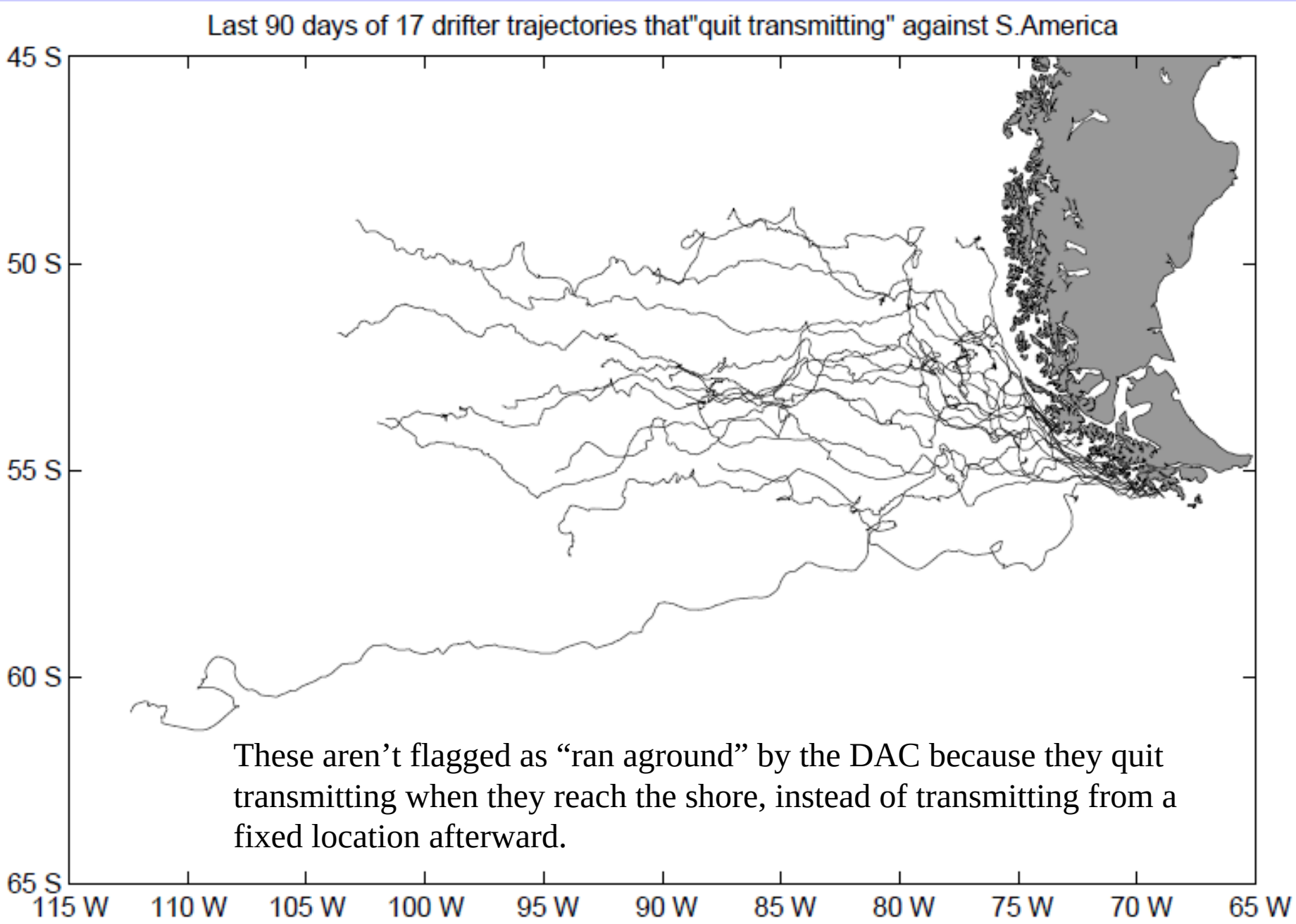
2 (1%) “Ran aground” (but later)

Spatial distribution of deaths
(deaths / square degree)



Values summed in 2°×2°bins

Problem: coastlines “glowing” in Quit Transmitting map.



These aren't flagged as "ran aground" by the DAC because they quit transmitting when they reach the shore, instead of transmitting from a fixed location afterward.

Reassessing “Quit Transmitting”

It’s problematic that many drifters “quit transmitting” because they likely ran aground or were picked up. We would like to distinguish these from drifters which quit transmitting due to internal reasons such as battery failure, leaking hulls, etc.

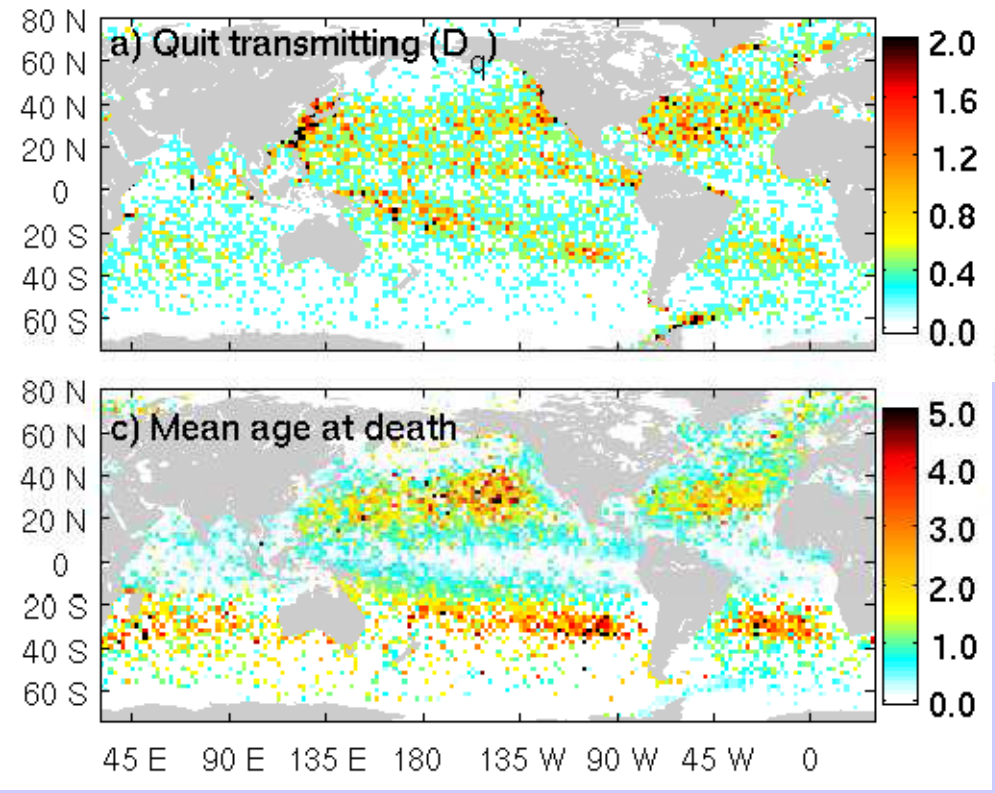
If D is the total number of drifters that have died in a 2°×2° box,

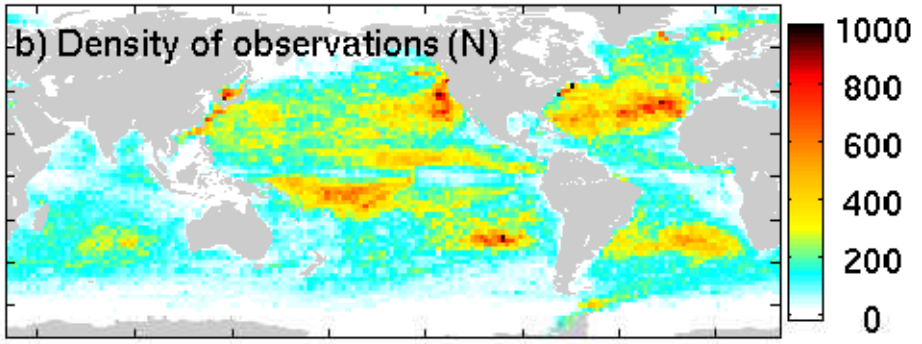
$$D = D_g + D_{pu} + D_q,$$

where D_g is the number of grounded drifters, D_{pu} is the number of picked up drifters, and D_q is the number of drifters which quit.

Let’s first compare D_q to the density of observations N.

Density of observations: calculated from 6h kriged positions in QC data set. Highlights regions of convergence and also of dense deployments.





Away from coastlines, the distributions of D_q and N are very similar.

D_q resembles N more than age: suggests that drifters are dying from internal (location-independent) reasons that are, to lowest order, age-independent.

More observations = more deaths.

Mean age: similar to N, but less affected by inhomogeneous distribution of deployments.

Sorting out why drifters “quit”

Anomalously high values of D_q near coasts are due to drifters that were picked up or ran aground.

Let D_q^* be the number of drifters that have quit due to location-independent and age-independent reasons. Then

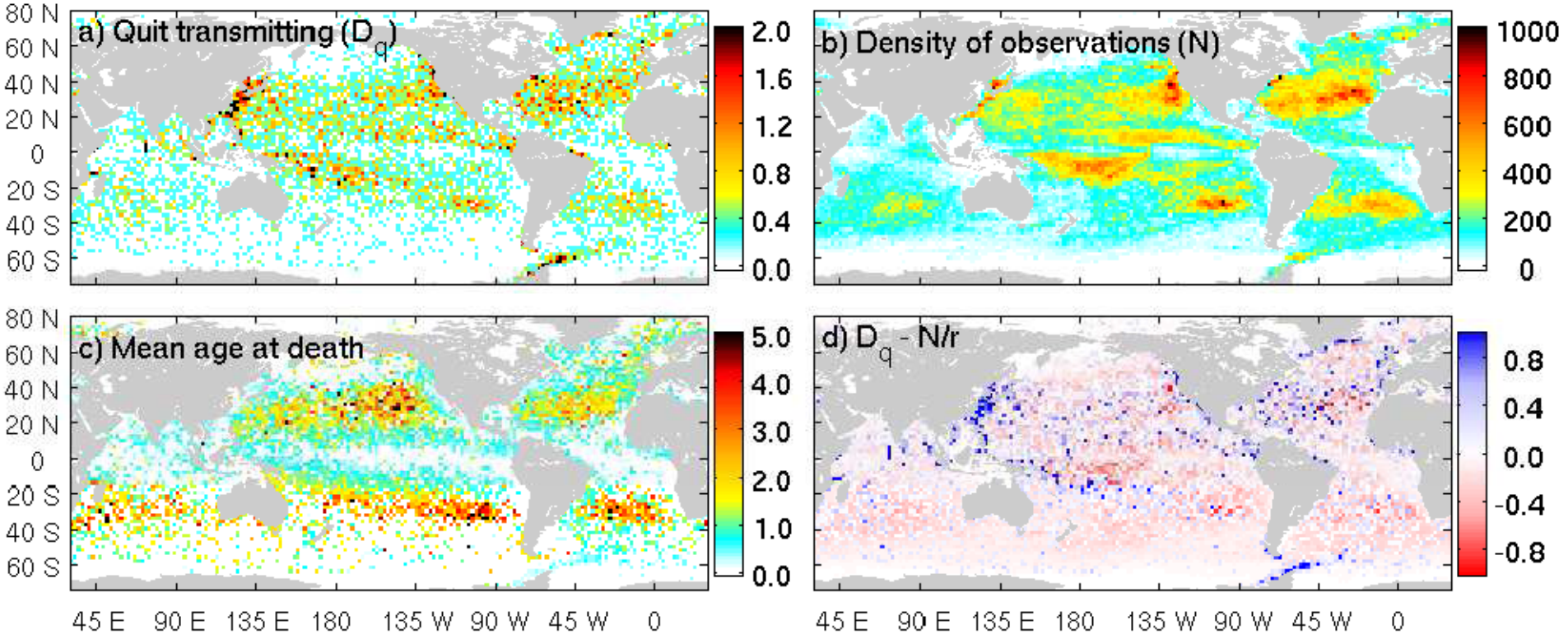
$$D_q^* = N / r,$$

where r is a constant coefficient.

Find r in all bins which have $D_{pu} = D_g = 0$ and have >100 drifter days of observations (for a robust value):

$$r = 650 \pm 7 \text{ days.}$$

This is an estimate of the mean lifetime of drifters in the presence of internal failures. For comparison, mean lifetime of all drifters is 384 days, all “quit” drifters is 417 days, and design lifetime goal is 450 days.


a) Quit transmitting (D_q)
b) Density of observations (N)
c) Mean age at death
d) D_q - N/r
80 N
60 N
40 N
20 N
0
20 S
40 S
60 S
45 E
90 E
135 E
180
135 W
90 W
45 W
0
2.0
1.6
1.2
0.8
0.4
0.0
1000
800
600
400
200
0
5.0
4.0
3.0
2.0
1.0
0.0
0.8
0.4
0.0
-0.4
-0.8

***r*=650 days**

A statistical model for “quit transmitting”

Without further data, we can’t individually asses which of the drifters that “quit” near the coast quit due to internal reasons, or due to running aground or being picked up. But we can calculate the odds.

True (unknown) number of run-aground drifters in a bin: D_g^*. By construction, $D_g^* \geq D_g$. Similarly, $D_{pu}^* \geq D_{pu}$. Express as:

$$D_g^* = (1 + x_1)\, D_g, \quad D_{pu}^* = (1 + x_2)\, D_{pu}$$

The background “quit transmitting” drifters can then be estimated as:

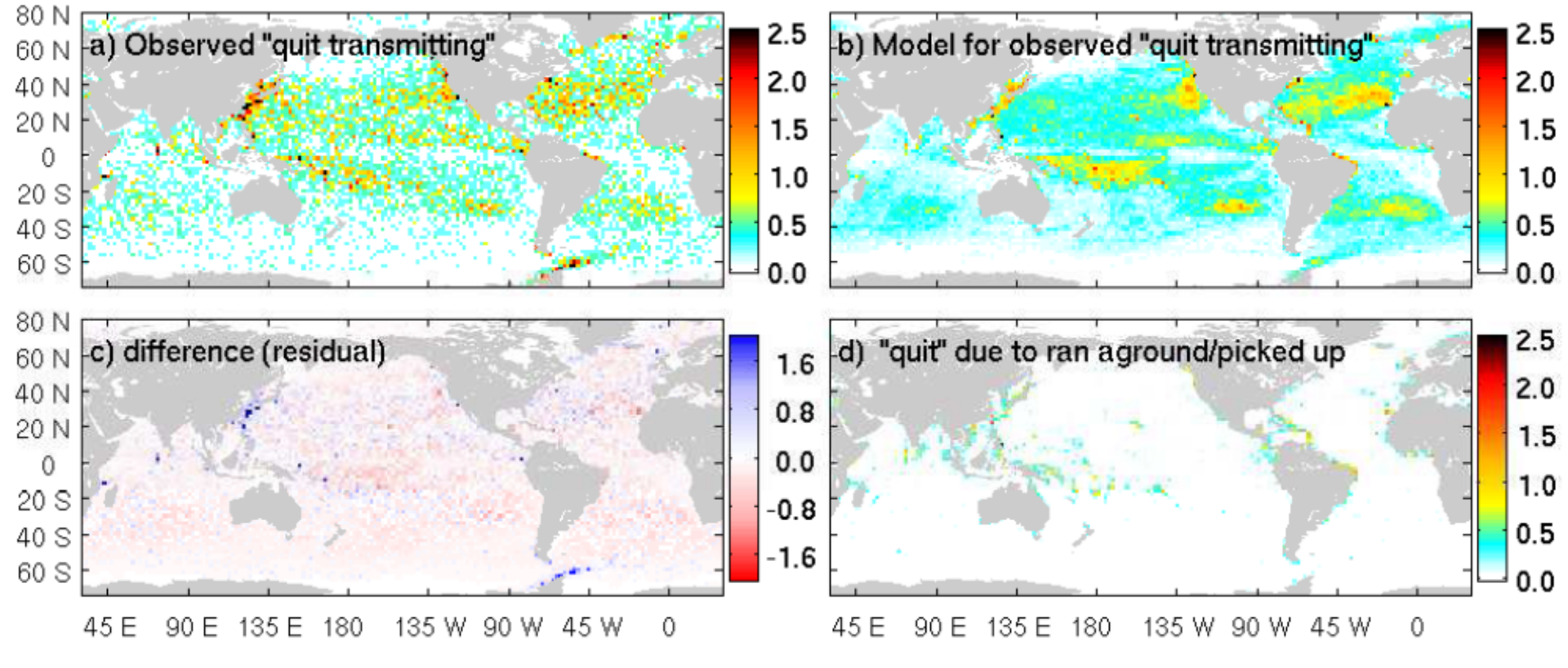
$$D_q^* = N/r \sim D_q - x_1 D_g - x_2 D_{pu},$$

where r=(650±7) days. Solve for x_1, x_2 by minimizing

$$(D_q - x_1\, D_g - x_2\, D_{pu} - N/r)^2$$

in all bins with N>100 observations / square degree (5109 bins).

Solution: x_1=0.241±0.001, x_2= 0.430±0.005.



Conclusions

222 “ran aground” drifters reassessed, most have new cause for death in revised metadata file.

Nearly 70% of drifters die due to “quit transmitting”.

Distribution of “quit transmitting” reflects data density, but is enhanced near coastlines.

Enhanced values can be attributed to drifters which were picked up or ran aground. The odds that a drifter experienced one of these fates can be statistically estimated.

Results indicate that the true number of drifters that have run aground is 24% greater than suggested in the DAC metadata. 43% more were picked up.

Conclusions

In each bin, the total number of "quit transmitting" drifters is

$$D_q = N/r + x_1 D_g + x_2 D_{pu},$$

of which $x_1 D_g$ actually ran aground. Thus, the spatially varying field

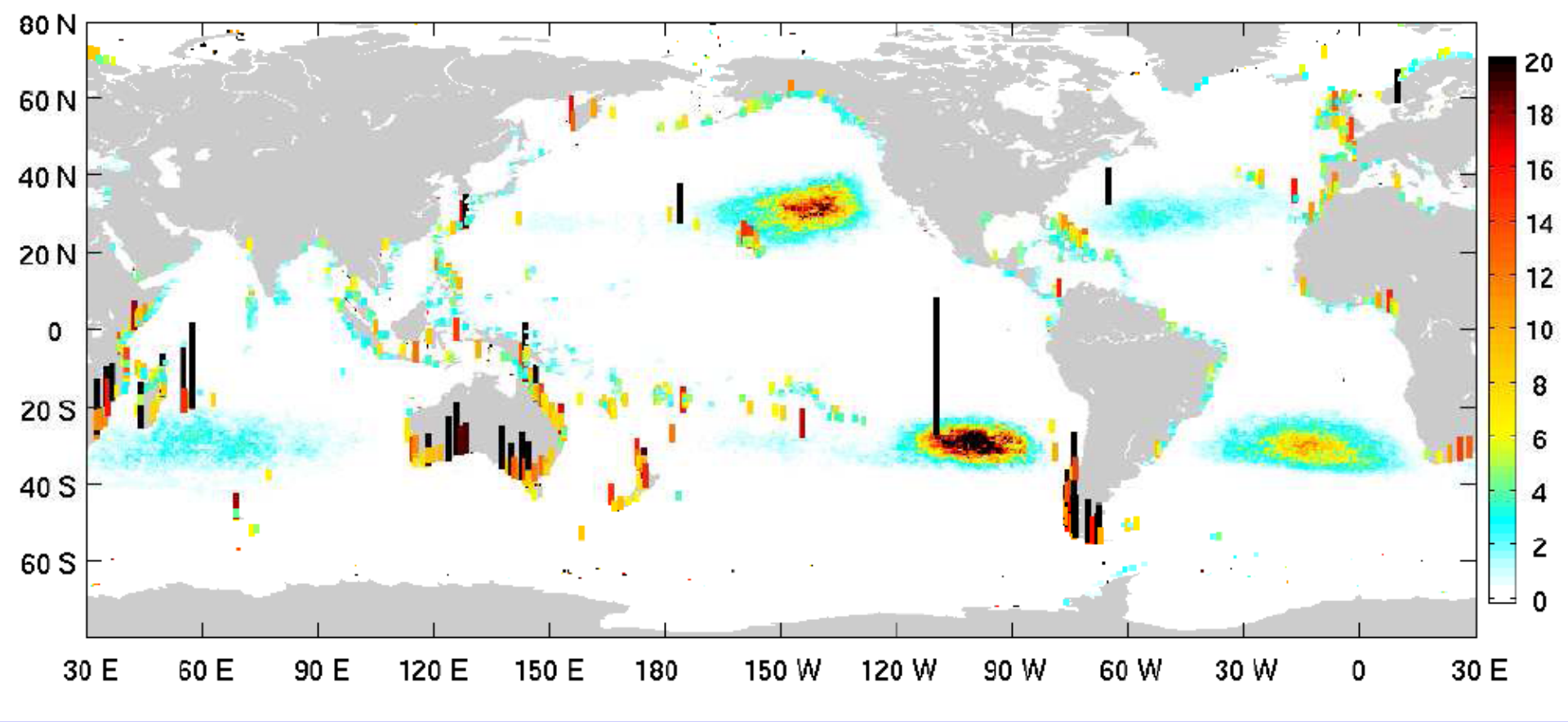
$$\frac{x_1 D_g}{N/r + x_1 D_g + x_2 D_{pu}},$$

interpolated to a "quit" drifter's death location, gives the odds that it actually quit because it ran aground.

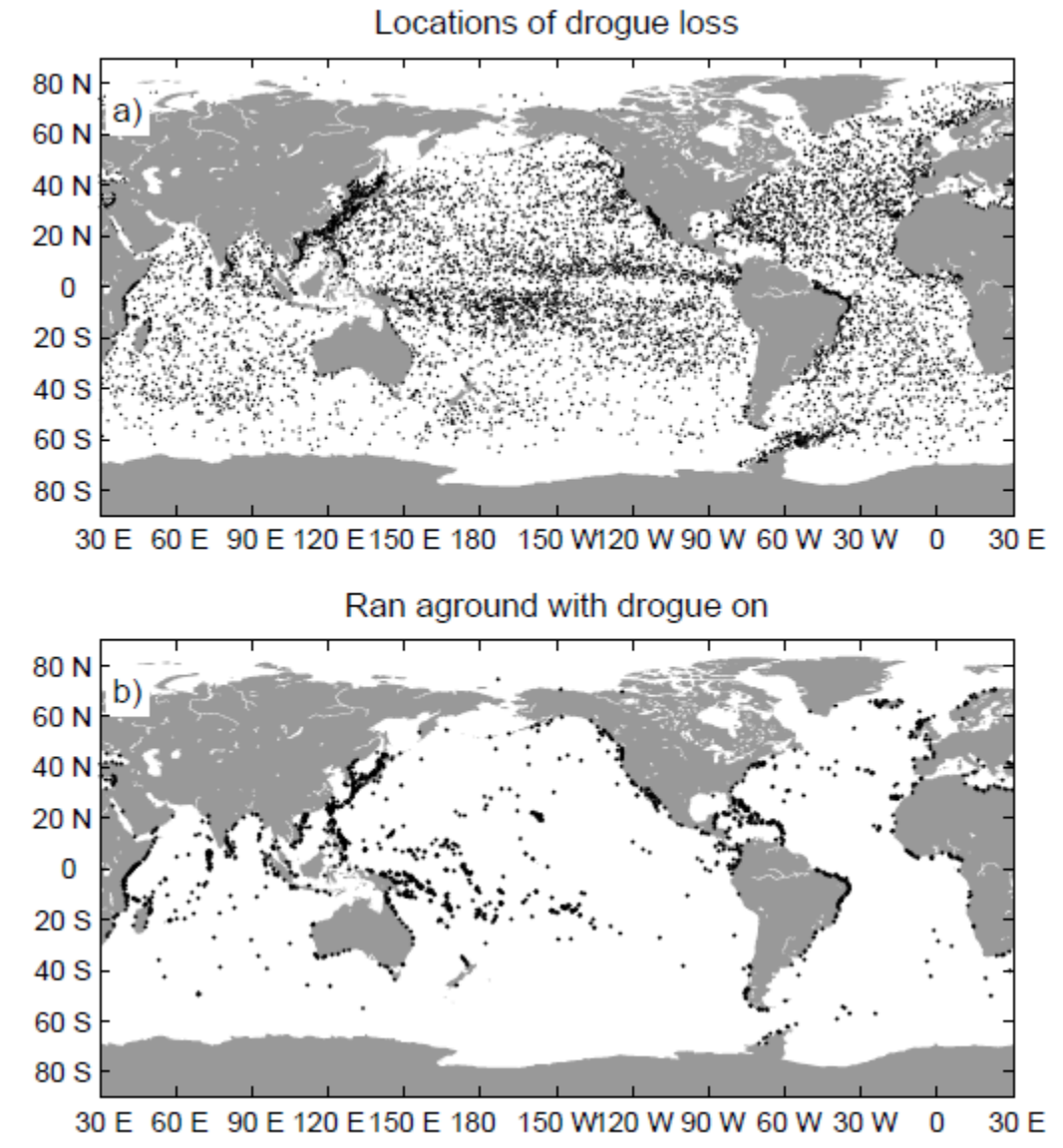
This has been applied to all dead drifters in the DAC metadata, with odds for each available at

`http://www.aoml.noaa.gov/phod/dac/chance_aground.html`

Lagrangian simulation of floating debris after 10 years of integration



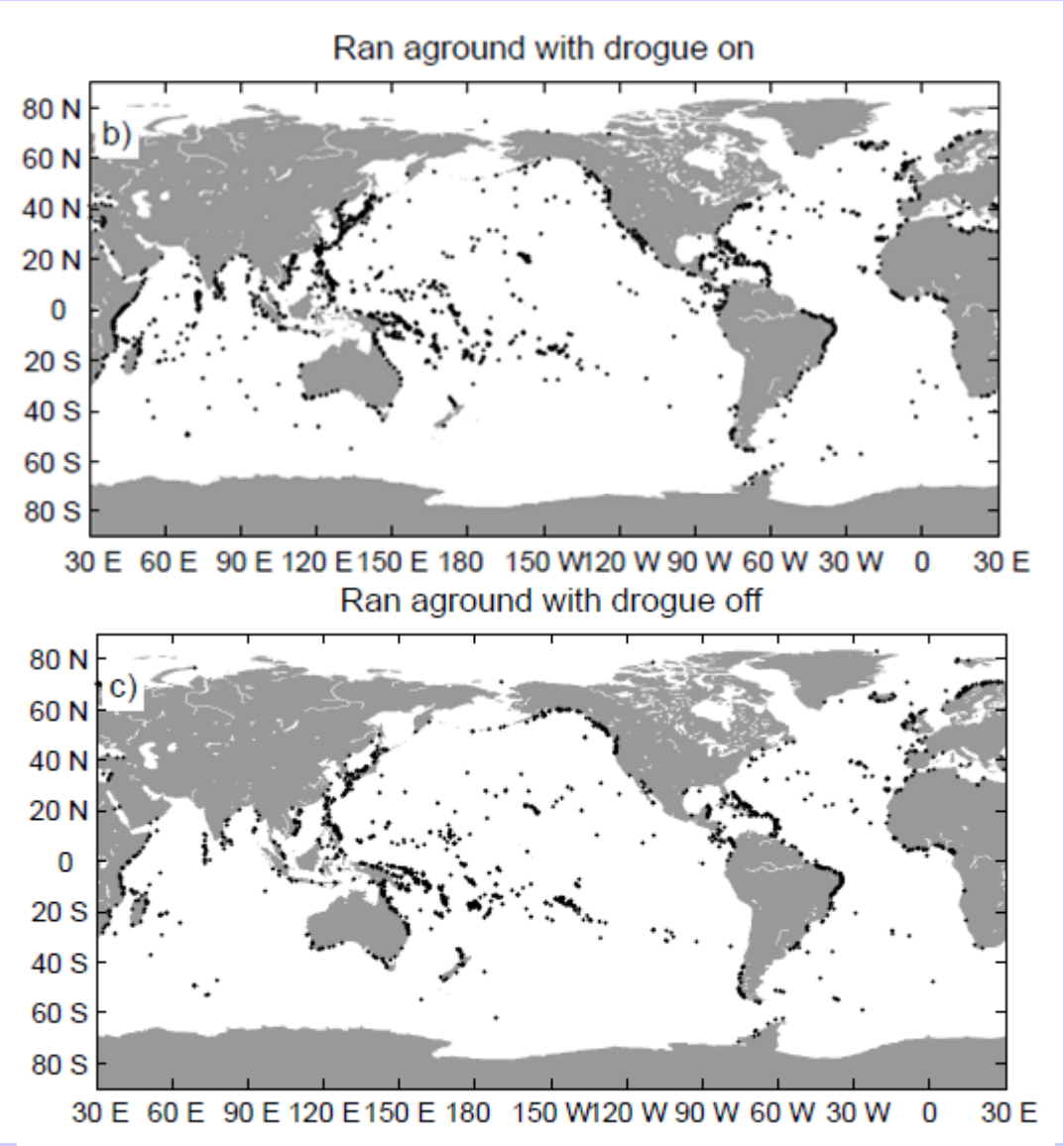
Distribution initially homogeneous. Vertical bars: concentration of material that has grounded, 10× scale of color bar.



5354 drifters

1672 drifters

Drogue loss clusters near coastlines, suggesting that a significant fraction of drogues may be lost in the process of running aground.



1672 drifters

1376 drifters

To lowest order, the location of drifters that ran aground with vs. without drogues is similar.