In [23]:
```
# Turning on inline plots -- just for use in ipython notebooks.
%pylab inline
```

```
Welcome to pylab, a matplotlib-based Python environment [backend: module://IPython.zmq.pylab.backend_inline].
For more information, type 'help(pylab)'.
```

In [24]:
```
# Import the necessary packages
import netCDF4 as netCDF
import tracpy
import matplotlib.pyplot as plt
```

Particle Tracking for Drug Washups along the Texas-Louisiana Shelf

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Numerical drifter simulations were run offline using model output from the TX-LA continental shelf model. In these simulations, drifters were started near the washup/found location of 39 different drug packages (an additional package was found near Florida, outside of the model domain). 12 drifter simulations were started over the 2 days prior to the day each package was found (every four hours) and 1000 drifters were run for each simulation. Not all drifters were used in analysis, but sensitivity to the drifters used was examined by trying a few different configurations to check that results remained about the same. Drifters were run backward in time for seven days for each simulation.

Many drifters are used, and many start times for drifter simulations, in an attempt to represent a spread of possible behavior. A single drifter will not represent the movement of the actual package due to the many uncertainties and models involved, but the idea is to capture the range of possible behavior given the conditions.

In [25]:
```
# Set the location of the model output and read in the grid information
loc = 'http://barataria.tamu.edu:8080/thredds/dodsC/NcML/txla_nesting6.nc'
grid = tracpy.inout.readgrid(loc)
```

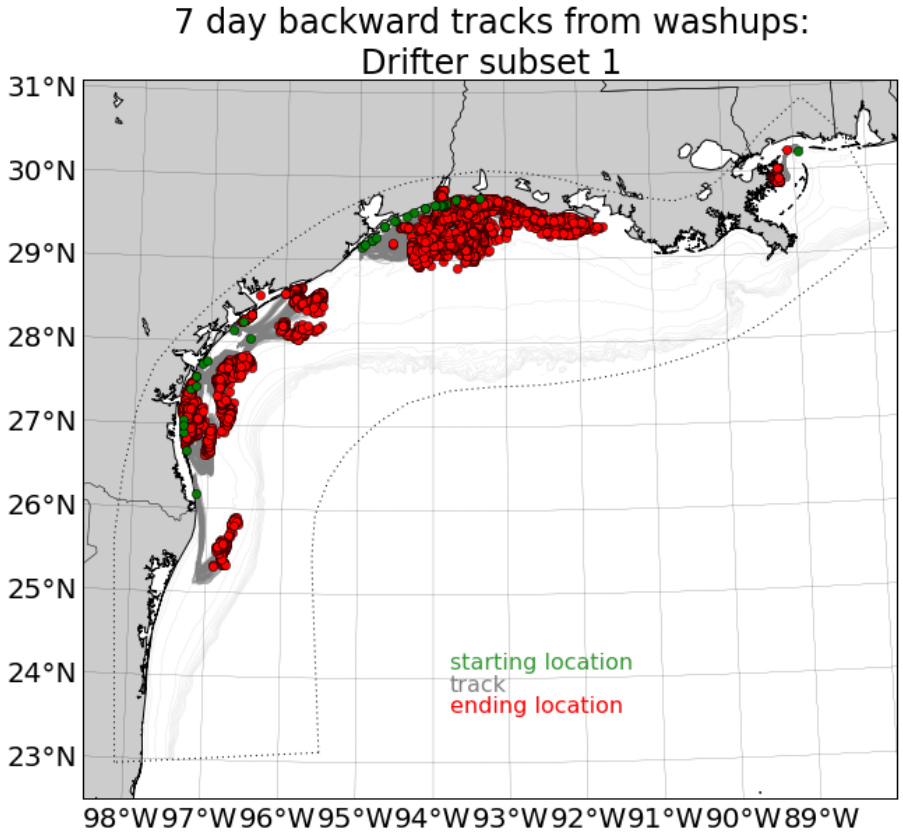
In [26]:
```
# There is a lot of drifter information available. Take two different subsets as a small test to make sure we get about the same results.
fmod1 = '*T1*'; dstart = 50*4; # files T12, T16 (x2)
fmod2 = '*T?0*'; dstart = 50*4; # files T00, T20 (x2)
d1 = netCDF.MFDataset('tracks/' + fmod1, aggdim='ntrac')
# only want 50 of 1000 drifters from each of the 12 files (4 files) for each simulation
dd = 1000/50
# Save out the lat/lon pairs for drifter tracks for the two subsets
lonp1 = d1.variables['lonp'][::dd,:]
latp1 = d1.variables['latp'][::dd,:]
d1.close()
d2 = netCDF.MFDataset('tracks/' + fmod2, aggdim='ntrac')
lonp2 = d2.variables['lonp'][::dd,:]
latp2 = d2.variables['latp'][::dd,:]
d2.close()
```

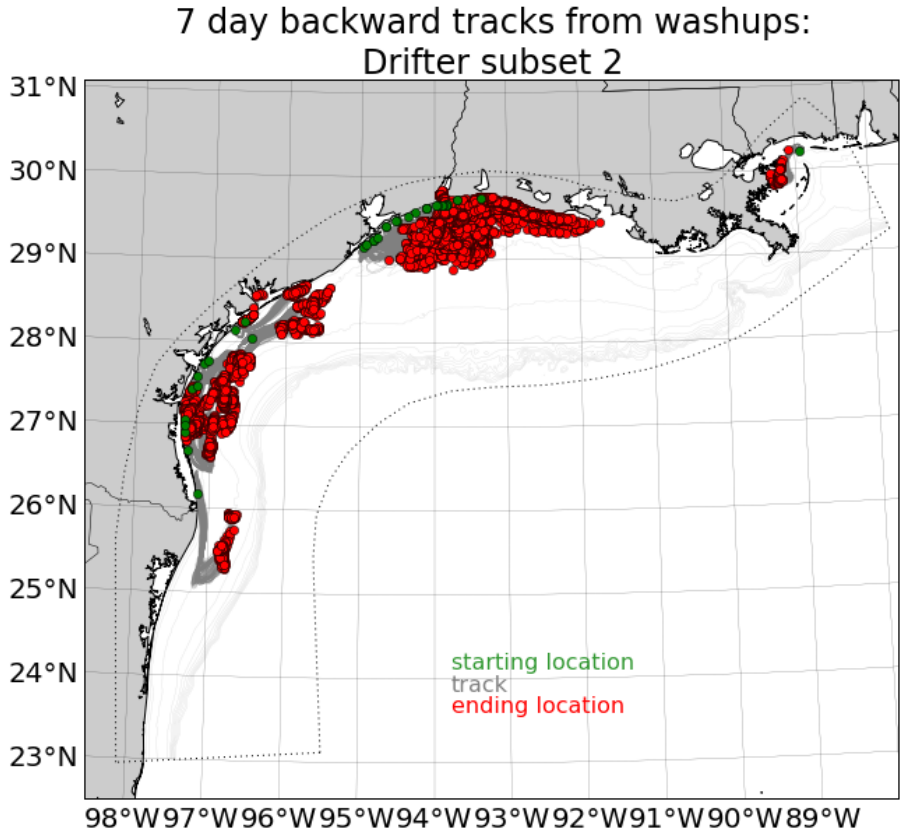
Overall Tracks

After reading in information from an aggregation of simulations, tracks from two subsets of the drifters are plotted below for comparison. From near the washup locations (green), numerical drifters were stepped backward in time for 7 days. Their paths are shown in grey lines and their final locations after 7 days are shown as red circles. Most packages were found north of the Texas-Mexico border, along the Corpus Christi/Padre Island area, or along the Texas-Louisiana border (Galveston and east). For the amount of time that most of the packages are suspected to have been at sea, it is unlikely that the packages came from the middle of the Gulf of Mexico.

In [27]:
```
# Make overall plots of numerical drifter tracks, as viewed over the entire Texas-Louisiana shelf
```

In [27]:
```
# Make overall plots of numerical drifter tracks, as viewed over the entire Texas-Louisiana shelf
name = 'all_packages_' + fmod1 + '_' + fmod2
# Set up and do the plots
fig = figure(figsize=(23,16))
ax1 = fig.add_subplot(1,2,1)
tracpy.plotting.tracks(lonp1, latp1, name, grid=grid, fig=fig, ax=ax1, Title='7 day backward tracks from washups:\nDrifter subset 1')
ax2 = fig.add_subplot(1,2,2)
tracpy.plotting.tracks(lonp2, latp2, name, grid=grid, fig=fig, ax=ax2, Title='7 day backward tracks from washups:\nDrifter subset 2')
# Plot initial location
x01, y01 = grid['basemap'](lonp1[0:-1:dstart,0], latp1[0:-1:dstart,0])
x02, y02 = grid['basemap'](lonp2[0:-1:dstart,0], latp2[0:-1:dstart,0])
ax1.plot(x01, y01, 'go')
ax2.plot(x02, y02, 'go')
grid['basemap'].drawstates(ax=ax1); grid['basemap'].drawcountries(ax=ax1)
grid['basemap'].drawstates(ax=ax2); grid['basemap'].drawcountries(ax=ax2)
# Resave file
savefig('figures/' + name + 'tracks.png', bbox_inches='tight')
```



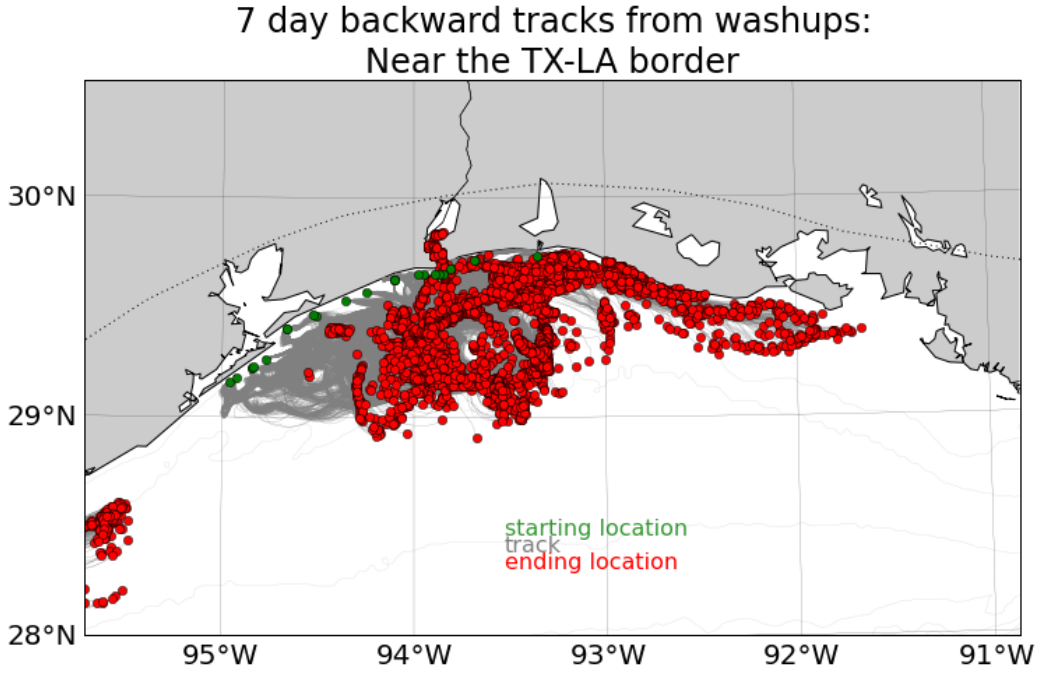


Magnified near the Texas-Louisiana Border

One subset of the drifter tracks are shown below, magnified near the Texas-Louisiana border. It is not clear that the packages all originated in Louisiana waters, but the drifter simulation indicates that they originated in that direction. Given the number of variables and the amount of uncertainty involved in this (including, most obviously, the lack of certainty in the washup location and timing), a general result is the best that can be done at this point.

In [28]:
```
# Read in a small grid to for a magnified plot
smallgrid = tracpy.inout.readgrid(loc, llcrnrlon=-95.7, llcrnrlat=28.0, urcrnrlat=30.5, urcrnrlon=-90.8)
```

In [29]:
```
name = 'all_packages_zoomed_TX-LA' + fmod1
# Do plot
tracpy.plotting.tracks(lonp1, latp1, name, grid=smallgrid, Title='7 day backward tracks from washups:\nNear the TX-LA border')
# Plot initial location
x0, y0 = smallgrid['basemap'](lonp1[0:-1:dstart,0], latp1[0:-1:dstart,0])
plot(x0, y0, 'go')
smallgrid['basemap'].drawstates()
# Resave file
savefig('figures/' + name + 'tracks.png', bbox_inches='tight')
```



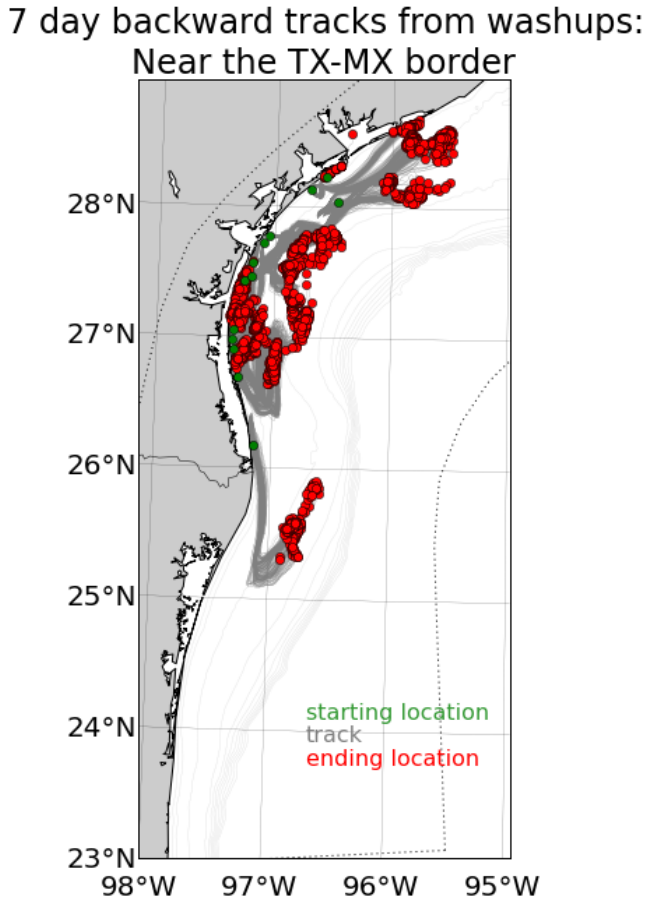
Magnified near the Texas-Mexico border

Some drifter tracks are again shown below, this time magnified near the Texas-Mexico border. Most packages found along the southern Texas coastline probably did not originate in Mexico, with the possible except of a package found near South Padre Island, which is very close to the border with Mexico.

In [30]:
```
# Read in a small grid to for a magnified plot
```

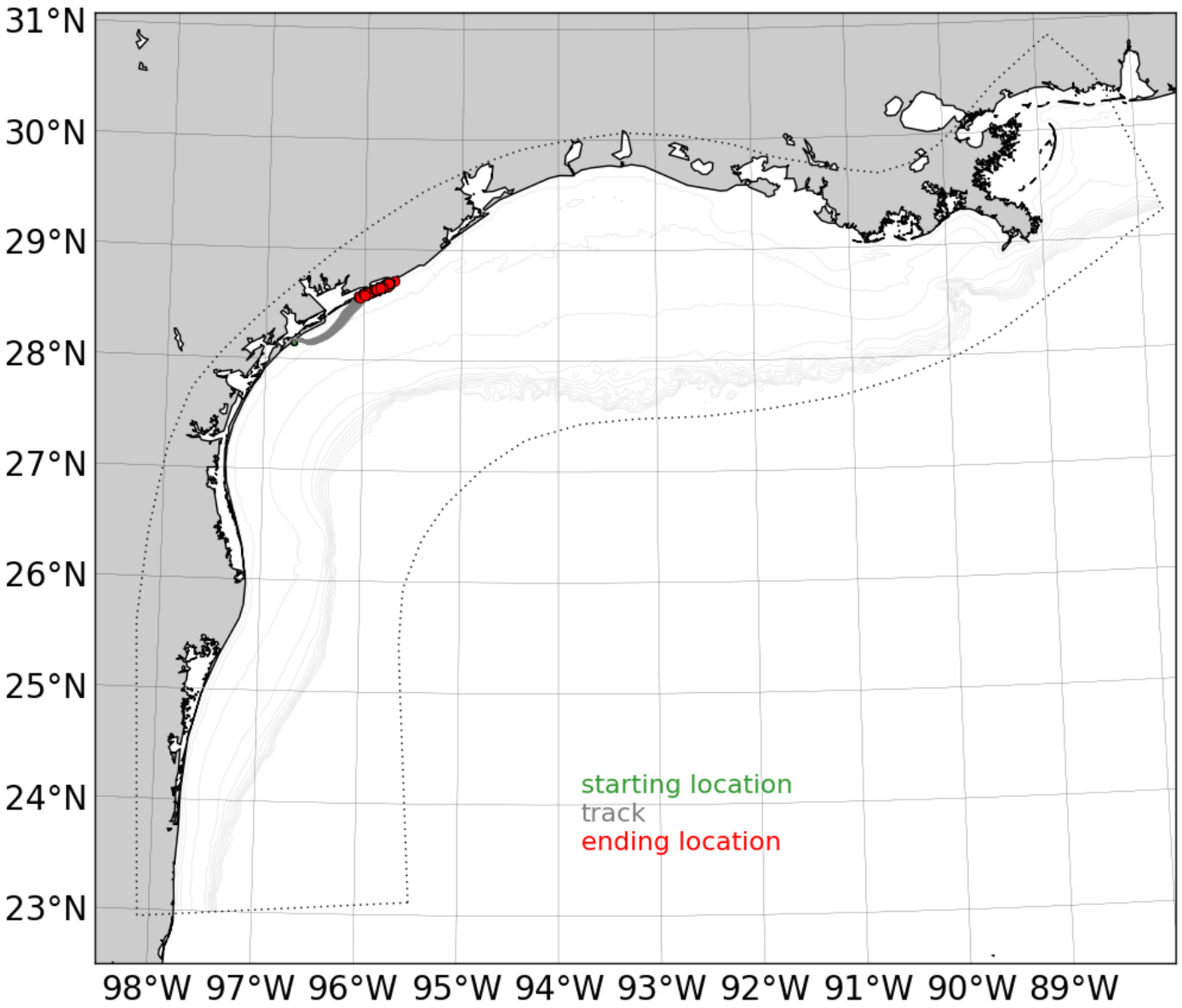
```
smallgrid2 = tracpy.inout.readgrid(loc, llcrnrlon=-98, llcrnrlat=23, urcrnrlat=29, urcrnrlon=-95)
```

In [31]:
```
name = 'all_packages_zoomed_TX-MX' + fmod1
tracpy.plotting.tracks(lonp1, latp1, name, grid=smallgrid2, Title='7 day backward tracks from washups:\nNear the TX-MX border')
# Plot initial location
x0, y0 = smallgrid2['basemap'](lonp1[0:-1:dstart,0], latp1[0:-1:dstart,0])
plot(x0, y0, 'go')
smallgrid2['basemap'].drawcountries()
# Resave file
savefig('figures/' + name + 'tracks.png', bbox_inches='tight')
```



Plots for individual drifter simulations

Note that plots of tracks from each individual simulation are available. Here is an example:



Summary

More drug packages than usual have been washing up onshore in the Gulf of Mexico this year, mostly along the Texas and Louisiana coastline. We are employing numerical particle tracking to learn more about typical patterns

in relation to the packages and the probable paths they took before being found. Pertinent findings include:

- Packages do not appear to be typically be originating in the middle of the Gulf of Mexico
- Packages also do not appear to be originating in Mexico directly, with the possible exception of a package found near the border at South Padre Island
- It is not clear from this initial work if packages are originating in just one state (Texas or Louisiana), but the simulated drifters that end up in Texas near the Louisiana border do tend to have traveled from the east

Other questions

From correspondence, a few questions were put forth. At least one lingering question is:

- What is the relationship of the washup locations with shipping lanes and anchorage areas?