Helmholtz_decomp

March 30, 2021

[2]:
```
import numpy as np
import netCDF4 as nc
import matplotlib.pyplot as plt
import matplotlib.gridspec as gs
import cmocean.cm as cmo
from matplotlib import rc
#from miracca_functions import psi2uv, zeta, zeta2psi
from lietal import *
import windspharm
from scipy.stats import pearsonr
from scipy.interpolate import interp1d, griddata
import warnings
warnings.filterwarnings('ignore')
```

0.1 We will perform the Helmholtz decomposition using the windspharm package and HYCOM velocity outputs

0.1.1 Loading the outputs and extracting variables

[3]:
```
path = '/media/marianalage/Peanut/Paper_Rossby/'
HYCOM = nc.Dataset(path+'HYCOM_teste_psi_53X.nc4')
HYCOM.variables.keys()
```

[3]:
```
dict_keys(['surf_el', 'time', 'lat', 'lon', 'water_u_bottom', 'water_v_bottom',
'water_u', 'depth', 'water_v'])
```

[4]:
```
lat = HYCOM.variables['lat'][:].data
lon = HYCOM.variables['lon'][:].data

u = HYCOM.variables['water_u'][:].data.squeeze()
u = u[0,:,:] #surface
v = HYCOM.variables['water_v'][:].data.squeeze()
v = v[0,:,:] #surface

ssh = HYCOM.variables['surf_el'][:].data.squeeze()
```

Calculating the geostrophic ψ, derived from HYCOM's SSH:

[5]:
```
# Geostrophic Psi and velocities
om = (2*np.pi)/(24*60*60)
f0 = (2.*om*np.sin(lat.mean()*(np.pi/180.)))

Psi_ssh = ssh*9.8/f0

ln,lt = np.meshgrid(lon,lat)
u_g,v_g = psi2uv(ln,lt,Psi_ssh)
```

Plotting ψ and velocities:

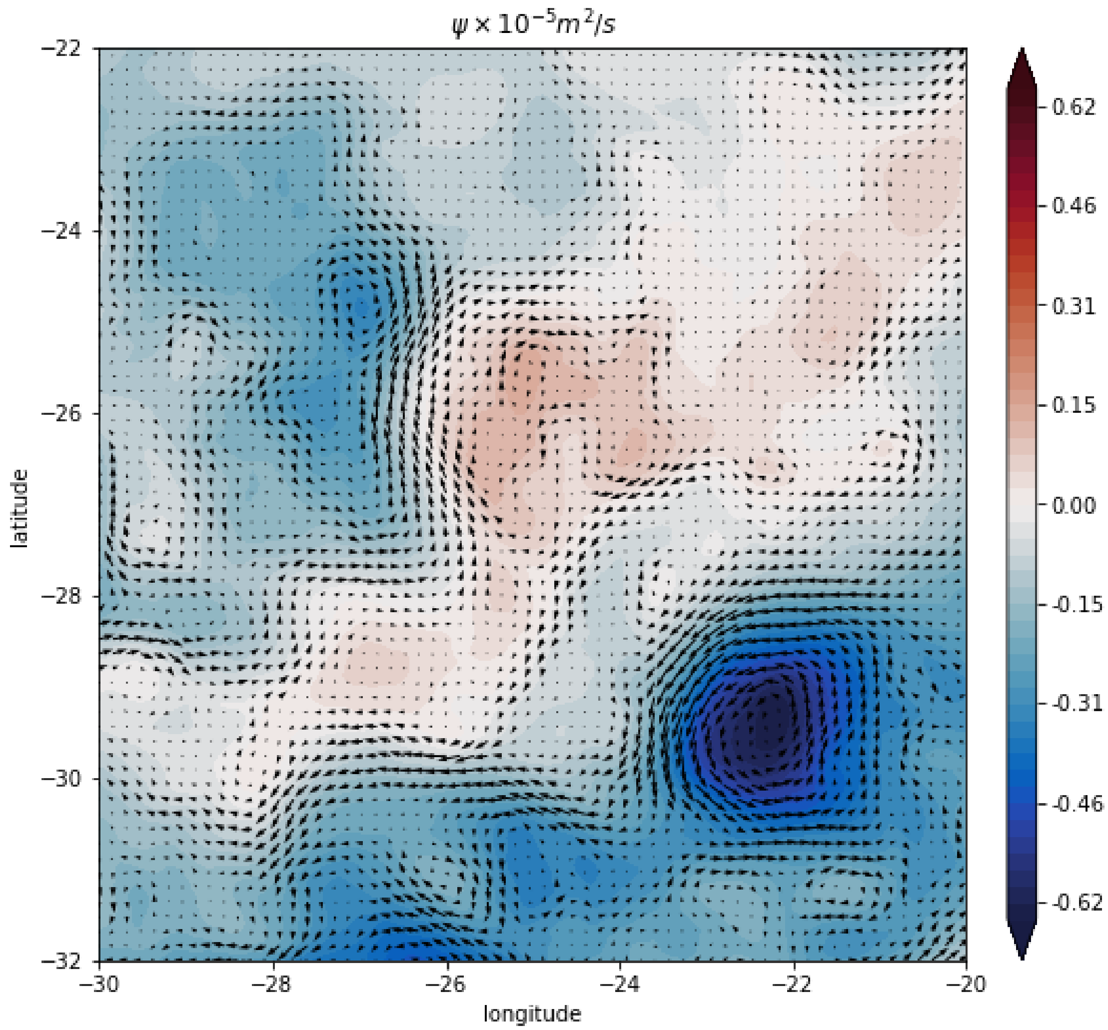
[6]:
```
vmin = np.min(Psi_ssh*1e-5)
vmax = -vmin
levels = np.linspace(vmin,vmax,51)
cmap=cmo.balance

step=2

grd = gs.GridSpec(25,27)
fig1 = plt.figure(figsize=(8,8))

ax1 = fig1.add_subplot(grd[:,:25])
ax2 = fig1.add_subplot(grd[:,26:])
cf = ax1.contourf(ln,lt,Psi_ssh*1e-5,vmin=vmin,
                  vmax=vmax,levels=levels,cmap=cmap,extend='both')
cbar = plt.colorbar(cf,cax=ax2,format='%.2f')
ax1.quiver(ln[::step,::step],lt[::step,::step],
           u_g[::step,::step],v_g[::step,::step],color='k',lw=2)
ax1.set_xlabel('longitude')
ax1.set_ylabel('latitude')
ax1.set_title(r'$\psi \times 10^{-5} m^2/s$')
```

[6]:
```
Text(0.5, 1.0, '$\\psi \\times 10^{-5} m^2/s$')
```



0.1.2 Windspharm requires the fields to be lat x lon x other dimensions, so uncomment the following lines if your data is other than lat x lon x dim

[7]:
```
#u, info = windspharm.tools.prep_data(u, 'xy')
#v, _ = windspharm.tools.prep_data(v, 'xy')
```

0.1.3 Windspharm also requires that latitude is north-to-south instead of south-to-north oriented. And you may change your variables as well

[8]:
```
lat, u, v = windspharm.tools.order_latdim(lat, u, v)

ln,lt = np.meshgrid(lon,lat)
```

[9]:
```
V = windspharm.standard.VectorWind(u, v) # it is already a regular grid
```

[10]:
```
# Obtaining the variables of interest
# Helmholtz decomposition

wpsi, wphi = V.sfvp()
uchi, vchi, upsi, vpsi = V.helmholtz()
```

0.1.4 And voilà!

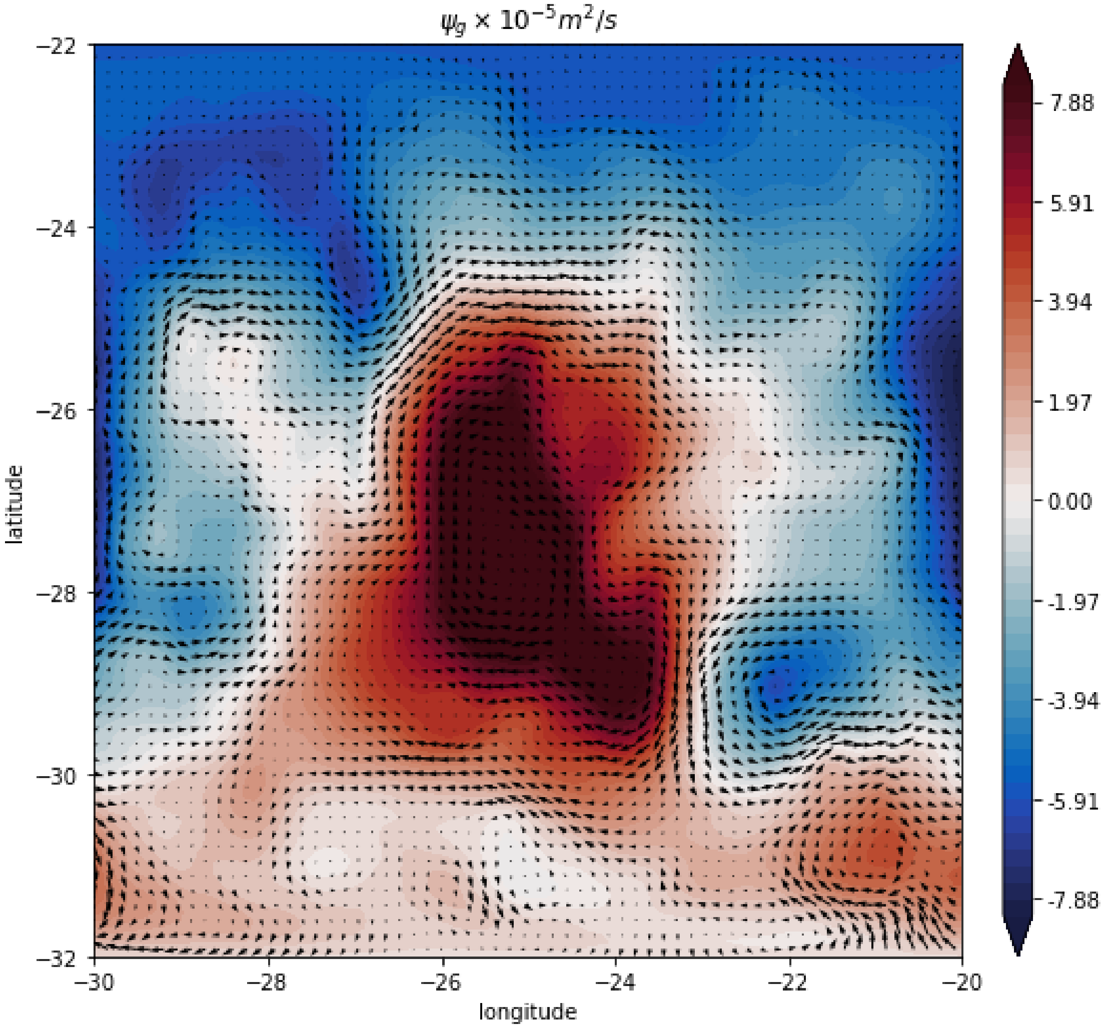
Plotting the geostrophic ψ_g (non-divergent) and the velocities:

[11]:
```
step=2
vmin = np.min(wpsi*1e-5)
vmax = -vmin
levels = np.linspace(vmin,vmax,51)
cmap=cmo.balance

grd = gs.GridSpec(25,27)
fig1 = plt.figure(figsize=(8,8))

ax1 = fig1.add_subplot(grd[:,:25])
ax2 = fig1.add_subplot(grd[:,26:])
cf = ax1.contourf(lon,lat,wpsi*1e-5,vmin=vmin,
                  vmax=vmax,levels=levels,cmap=cmap,extend='both')
cbar = plt.colorbar(cf,cax=ax2,format='%.2f')
ax1.quiver(ln[::step,::step],lt[::step,::step],
           upsi[::step,::step],vpsi[::step,::step],color='k',lw=2)
ax1.set_xlabel('longitude')
ax1.set_ylabel('latitude')
ax1.set_title(r'$\psi_g \times 10^{-5} m^2/s$')
```

[11]:
```
Text(0.5, 1.0, '$\\psi_g \\times 10^{-5} m^2/s$')
```



Plotting the ϕ (non-rotational) and the velocities:

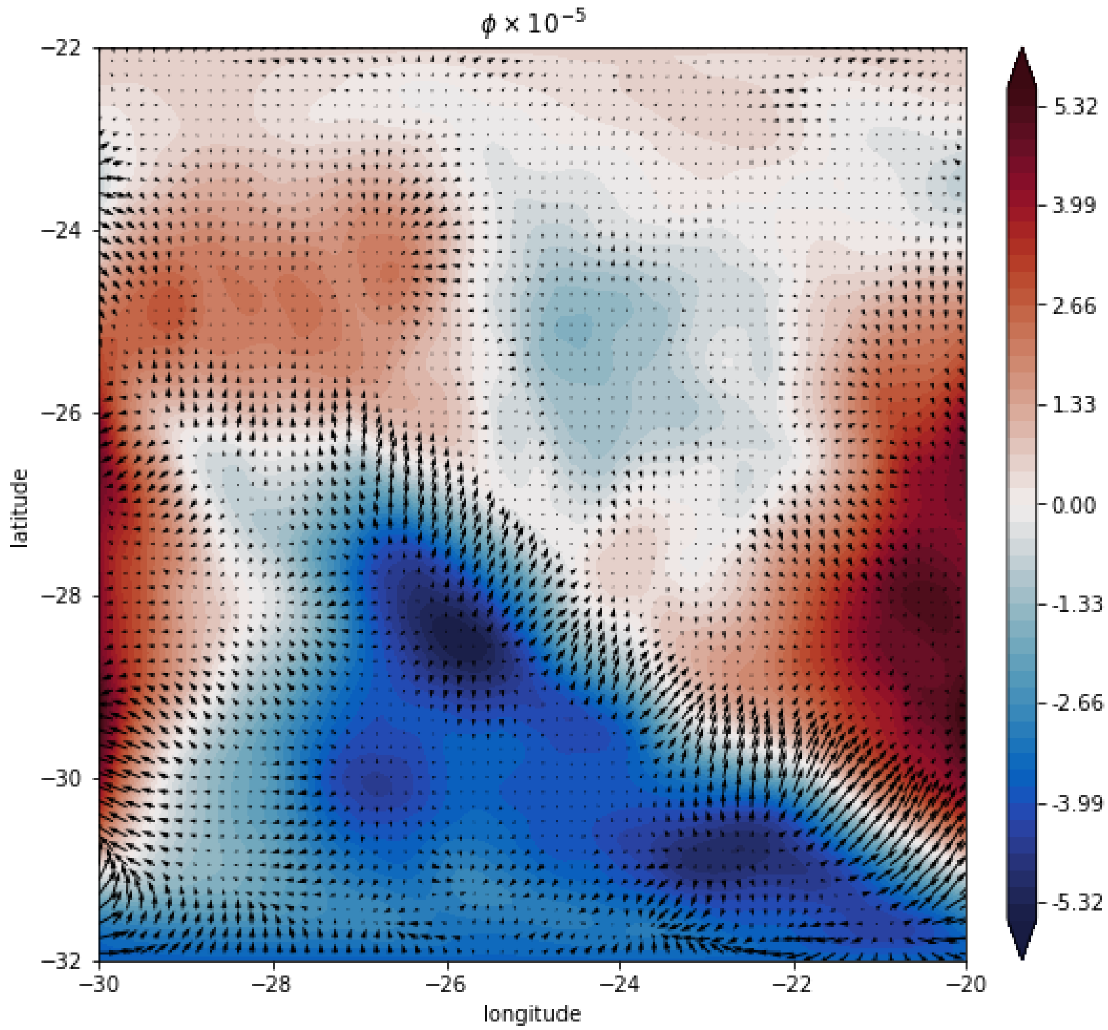
[12]:
```
vmin = np.min(wphi*1e-5)
vmax = -vmin
levels = np.linspace(vmin,vmax,51)

grd = gs.GridSpec(25,27)
fig1 = plt.figure(figsize=(8,8))

ax1 = fig1.add_subplot(grd[:,:25])
ax2 = fig1.add_subplot(grd[:,26:])
cf = ax1.contourf(lon,lat,wphi*1e-5,vmin=vmin,
                  vmax=vmax,levels=levels,cmap=cmap,extend='both')
cbar = plt.colorbar(cf,cax=ax2,format='%.2f')
ax1.quiver(ln[::step,::step],lt[::step,::step],
```

```
            uchi[::step,::step],vchi[::step,::step],color='k',lw=2)
ax1.set_xlabel('longitude')
ax1.set_ylabel('latitude')
ax1.set_title(r'$\phi \times 10^{-5}$')
```

[12]: Text(0.5, 1.0, '$\\phi \\times 10^{-5}$')



Let's compare the velocities!

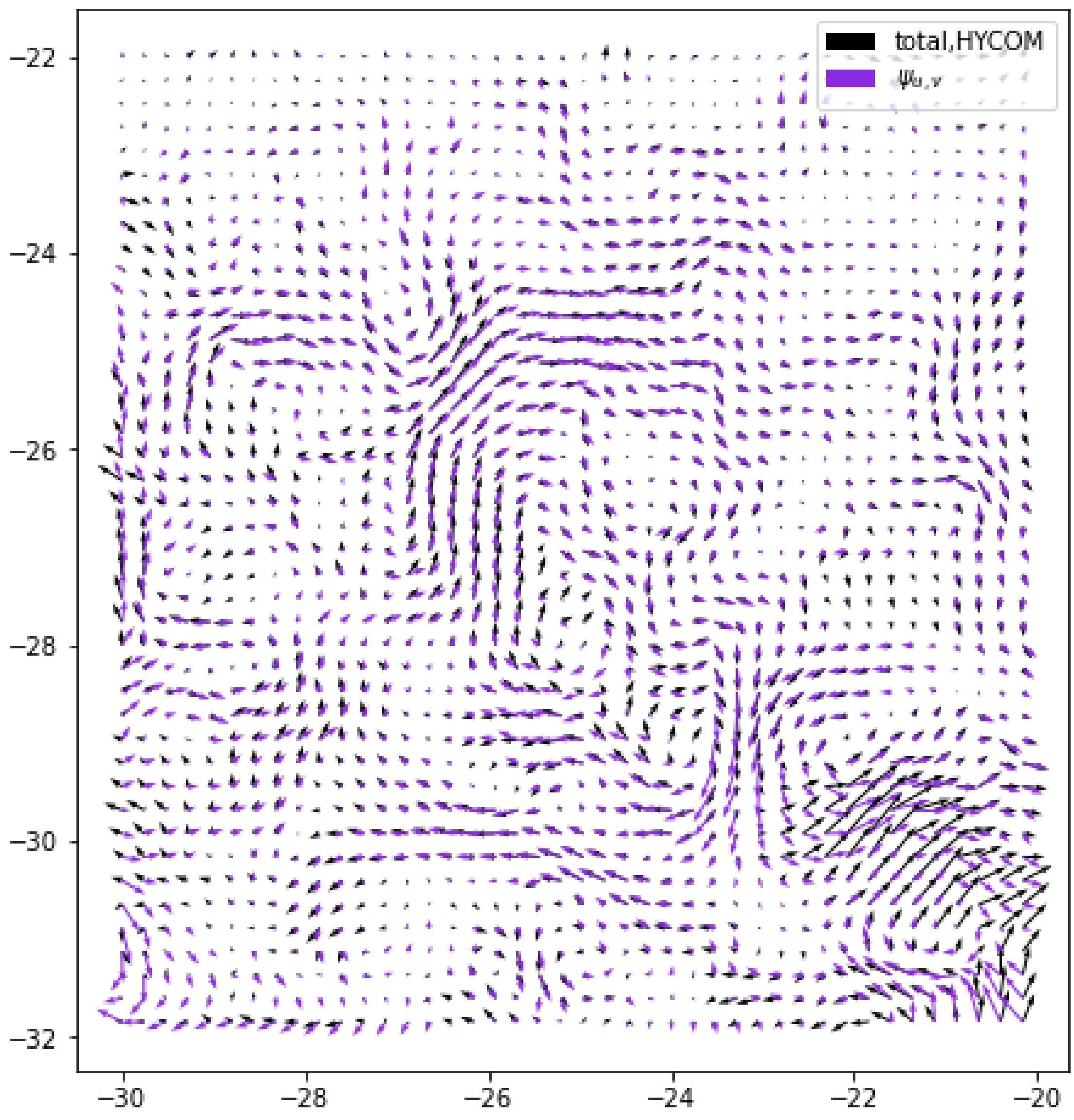
[13]:
```
step = 3

grd = gs.GridSpec(20,22)
fig1 = plt.figure(figsize=(8,8))

ax1 = fig1.add_subplot(grd[:,:20])
```

```
ax1.quiver(ln[::step,::step],lt[::step,::step],
           u[::step,::step],v[::step,::step],
           color='k',lw=2,label='total,HYCOM')
ax1.quiver(ln[::step,::step],lt[::step,::step],
           upsi[::step,::step],vpsi[::step,::step],
           color='#8A2BE2',lw=2,label=r'$\psi_{u,v}$')
#ax1.quiver(ln[::step,::step],lt[::step,::step],
#            uchi[::step,::step],vchi[::step,::step],
#            color='#DC143C',lw=2,label=r'$\phi_{u,v}$')
ax1.legend(loc=0)
```

[13]: <matplotlib.legend.Legend at 0x7fb8aa7e1730>



1 Spatial correlations between Ψ_{ssh} and Ψ_g

[14]:
```
print('Corr = {:.2f}'.format(pearsonr(Psi_ssh.ravel(),wpsi.ravel())[0]),
      ', p-value = {:.2f}'.format(pearsonr(Psi_ssh.ravel(),wpsi.ravel())[1]) )
```

```
Corr = 0.50 , p-value = 0.00
```

Now the velocities…

[15]:
```
print('Corr u = {:.2f}'.format(pearsonr(u.ravel(),upsi.ravel())[0]),
      ', p-value = {:.2f}'.format(pearsonr(u.ravel(),upsi.ravel())[1]) )
```

```
Corr u = 0.84 , p-value = 0.00
```

[16]:
```
print('Corr v = {:.2f}'.format(pearsonr(v.ravel(),vpsi.ravel())[0]),
      ', p-value = {:.2f}'.format(pearsonr(u.ravel(),upsi.ravel())[1]) )
```

```
Corr v = 0.80 , p-value = 0.00
```