FGM

September 24, 2020

1 Read data from .mat and plot FGM (mooring mean)

[1]:
```
# %matplotlib notebook
%matplotlib inline
import numpy as np
import pandas as pd
import xarray as xr
import scipy as sp
import matplotlib.pyplot as plt
import scipy.io as sio
import io
import gsw

from scipy import integrate
from matplotlib import cm
```

[2]:
```
# load time-mean mooring data
mdirec='/Users/tantanmeow/Desktop/WORK/2018-2019/Jesse/sp-tg/';

data0 = sio.loadmat(mdirec+'data/mooring_averages.mat',squeeze_me =␣
 ↪True,struct_as_record = False)
type(data0)
dict.keys(data0)
```

[2]:
```
dict_keys(['__header__', '__version__', '__globals__', 'M5', 'P1', 'P3', 'P4',
'T1', 'T2', 'T4', 'T5', 'T6', 'T7', 'T8', 'T9', 'T10', 'T11', 'T12'])
```

[3]:
```
# load FGM outputs from a .mat dataset
data_name = 'TG_SI_mean_ex1.mat'
data = sio.loadmat(mdirec + 'codes/' + data_name,squeeze_me =␣
 ↪True,struct_as_record = False)
type(data)
dict.keys(data)
```

[3]:
```
dict_keys(['__header__', '__version__', '__globals__', 'B', 'CI', 'CL', 'CR',
'GR', 'II', 'K', 'KFGM', 'L', 'N2', 'Ri', 'V', 'Vz', 'Vzz', 'W', 'botz', 'site',
'zw'])
```

[4]:

```
# Growth rate, imaginary phase speed, real phase speed, numbers of␣
↪zero-crossing, wave vector of the FGM
# GR = xr.DataArray(data['GR'], coords={"site": data['site'], "0-crossings":␣
↪("site",data['II'])}, dims=["site"])
GR = xr.DataArray(data['GR'], coords={"site": data['site']}, dims=["site"],␣
↪attrs={'longname': '$\sigma$: $hr^{-1}$'})
CI = xr.DataArray(data['CI'], coords={"site": data['site']}, dims=["site"])
CR = xr.DataArray(data['CR'], coords={"site": data['site']}, dims=["site"])
II = xr.DataArray(data['II'], coords={"site": data['site']}, dims=["site"],␣
↪attrs={'longname': '0-crossings'})
KFGM = xr.DataArray(data['KFGM'], coords={"site": data['site'], "vector": ['k'␣
↪, 'l']}, dims=["site" , "vector"])

# profiles
B = xr.DataArray(data['B'], coords={"z":data['zw'], "site": data['site']},␣
↪dims=["z" , "site"])
N2 = xr.DataArray(data['N2'], coords={"z":data['zw'], "site": data['site']},␣
↪dims=["z" , "site"])
Ri = xr.DataArray(data['Ri'], coords={"z":data['zw'], "site": data['site']},␣
↪dims=["z" , "site"])
V = xr.DataArray(data['V'], coords={"z":data['zw'], "site": data['site']},␣
↪dims=["z" , "site"])
Vz = xr.DataArray(data['Vz'], coords={"z":data['zw'], "site": data['site']},␣
↪dims=["z" , "site"])
Vzz = xr.DataArray(data['Vzz'], coords={"z":data['zw'], "site": data['site']},␣
↪dims=["z" , "site"])

botz = xr.DataArray(data['botz'], coords={"site": data['site']}, dims=["site"])

# FGM in terms of w
W = xr.DataArray(data['W'], coords={"z":data['zw'], "site": data['site']},␣
↪dims=["z" , "site"])
# critical levels
CL = xr.DataArray(data['CL'], coords={"site": data['site'], "n": np.
↪arange(10)}, dims=["site" , "n"])

FGM_mean = xr.Dataset({'GR': (['site'], 2*np.pi/GR/3600),
                       'CI': (['site'], CI),
                       'CR': (['site'], CR),
                       'II': (['site'], II),
                       'K': (['site','vector'], KFGM),
                       'b': (['z', 'site'], B),
                       'N2': (['z', 'site'], N2),
                       'Ri': (['z', 'site'], Ri),
                       'V': (['z', 'site'], V),
                       'Vz': (['z', 'site'], Vz),
```

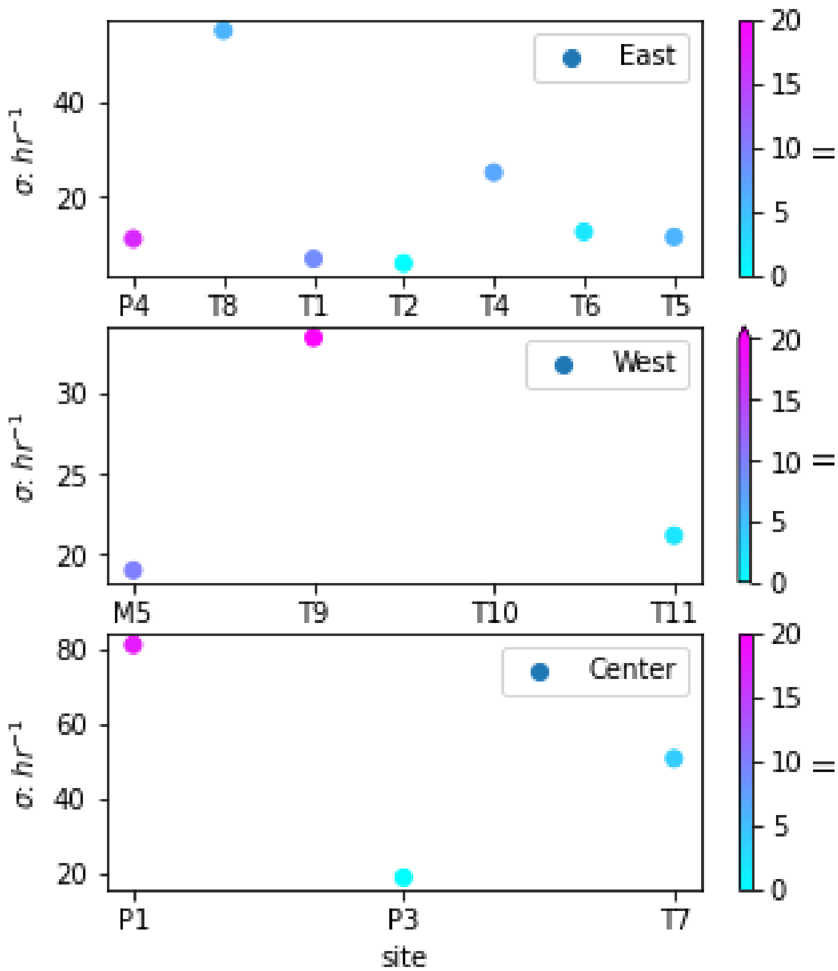
```
                            'Vzz': (['z', 'site'], Vzz),
                            'W': (['z', 'site'], W),
                            'CL': (['site', 'n'], CL),
                            'botz': (['site'], botz)},
                            coords={'site': data['site'],
                                    'z': data['zw'],
                                    'n': np.arange(10)},
                            attrs={'title': 'FGM, mean mooring profiles'})
```

[5]:
```
EB=['P4','T8','T1','T2','T4','T6','T5']
WB=['T12','M5','T9','T10','T11']
OT=['P1','P3','T7']
```

Plot site vs. growth rate, colorbar representing the number of zero-crossings

[6]:
```
fig, ax =  plt.subplots(nrows=3, ncols=1, figsize=(5, 6))
FGM_mean.loc[dict(site=EB)].plot.scatter(x='site', y='GR', hue='II',␣
 ↪marker='o',label='East',
                            ax=ax[0], cmap=cm.cool, vmax=20, vmin=0,␣
 ↪add_guide=True)
ax[0].set_ylabel('$\sigma$: $hr^{-1}$')
ax[0].legend()
FGM_mean.loc[dict(site=WB)].plot.scatter(x='site', y='GR', hue='II',␣
 ↪marker='o',label='West',
                            ax=ax[1], cmap=cm.cool, vmax=20, vmin=0,␣
 ↪add_guide=True)
ax[1].set_ylabel('$\sigma$: $hr^{-1}$')
ax[1].legend()
FGM_mean.loc[dict(site=OT)].plot.scatter(x='site', y='GR', hue='II',␣
 ↪marker='o',label='Center',
                            ax=ax[-1], cmap=cm.cool, vmax=20, vmin=0,␣
 ↪add_guide=True)
ax[-1].set_ylabel('$\sigma$: $hr^{-1}$')
ax[-1].legend()
```

[6]:
```
<matplotlib.legend.Legend at 0x7fe677d37b80>
```

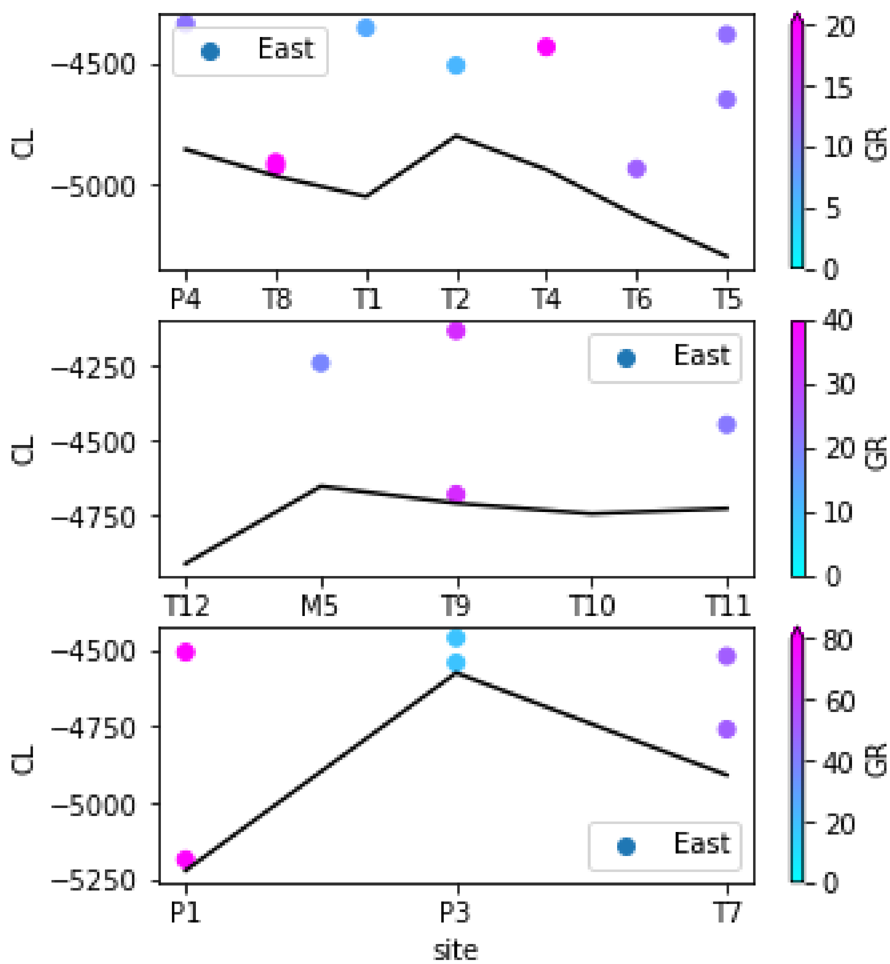


Plot site vs. critical level, colorbar representing the growth rate, black profiles show v

```
[7]: fig, ax =  plt.subplots(nrows=3, ncols=1, figsize=(5, 6))
FGM_mean.loc[dict(site=EB)].plot.scatter(x='site', y='CL', hue='GR',␣
 ↪marker='o',label='East',
                                ax=ax[0], cmap=cm.cool, vmax=20, vmin=0,␣
 ↪add_guide=True)
ax[0].plot(FGM_mean.botz.loc[dict(site=EB)].site, FGM_mean.botz.
 ↪loc[dict(site=EB)].data,c='k')
ax[0].legend()
FGM_mean.loc[dict(site=WB)].plot.scatter(x='site', y='CL', hue='GR',␣
 ↪marker='o',label='East',
                                ax=ax[1], cmap=cm.cool, vmax=40, vmin=0,␣
 ↪add_guide=True)
ax[1].plot(FGM_mean.botz.loc[dict(site=WB)].site, FGM_mean.botz.
 ↪loc[dict(site=WB)].data,c='k')
```

```
ax[1].legend()
FGM_mean.loc[dict(site=OT)].plot.scatter(x='site', y='CL', hue='GR',␣
 ↪marker='o',label='East',
                              ax=ax[-1], cmap=cm.cool, vmax=80, vmin=0,␣
 ↪add_guide=True)
ax[-1].plot(FGM_mean.botz.loc[dict(site=OT)].site, FGM_mean.botz.
 ↪loc[dict(site=OT)].data,c='k')
ax[-1].legend()
```

[7]: <matplotlib.legend.Legend at 0x7fe678a5d970>



2 Read data from .mat and plot FGM (CTD&LADCP snapshot)

Raw profiles (snapshots) have many overturns (especially near sea bottom) and cause violet-shift of the growth rate, suggesting convective instability. As Larry suggested, I sorted the buoyancy profiles to form a stable configuration and made sure $N^2 > 0$ everywhere. I did not process the velocity profiles.

[8]:
```python
# load FGM outputs from a .mat dataset
data_name = 'TG_SI_snapshot_ex1.mat'
data = sio.loadmat(mdirec + 'codes/' + data_name,squeeze_me =␣
↪True,struct_as_record = False)
type(data)
dict.keys(data)
```

[8]:
```
dict_keys(['__header__', '__version__', '__globals__', 'B', 'CI', 'CL', 'CR',
'GR', 'II', 'K', 'KFGM', 'L', 'LAT', 'LON', 'N2', 'Ri', 'V', 'Vz', 'Vzz', 'W',
'zw'])
```

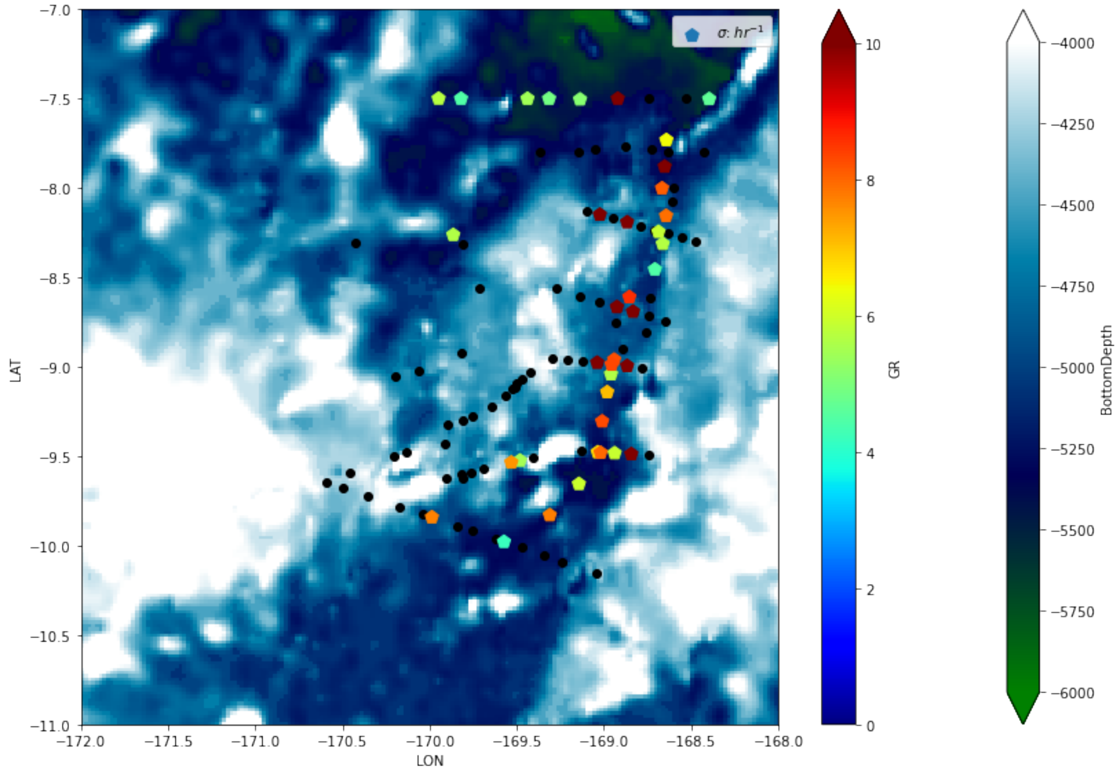
[9]:
```python
# Growth rate, imaginary phase speed, real phase speed, numbers of␣
↪zero-crossing, wave vector of the FGM
# GR = xr.DataArray(data['GR'], coords={"site": data['site'], "0-crossings":␣
↪("site",data['II'])}, dims=["site"])
GR = xr.DataArray(data['GR'], coords={"site": np.arange(len(data['LON']))},␣
↪dims=["site"], attrs={'longname': '$\sigma$: $hr^{-1}$'})
CI = xr.DataArray(data['CI'], coords={"site": np.arange(len(data['LON']))},␣
↪dims=["site"])
CR = xr.DataArray(data['CR'], coords={"site": np.arange(len(data['LON']))},␣
↪dims=["site"])
II = xr.DataArray(data['II'], coords={"site": np.arange(len(data['LON']))},␣
↪dims=["site"], attrs={'longname': '0-crossings'})
KFGM = xr.DataArray(data['KFGM'], coords={"site": np.arange(len(data['LON'])),␣
↪"vector": ['k' , 'l']}, dims=["site" , "vector"])
LON = xr.DataArray(data['LON'], coords={"site": np.arange(len(data['LON']))},␣
↪dims=["site"])
LAT = xr.DataArray(data['LAT'], coords={"site": np.arange(len(data['LON']))},␣
↪dims=["site"])

# profiles
B = xr.DataArray(data['B'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
N2 = xr.DataArray(data['N2'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
Ri = xr.DataArray(data['Ri'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
V = xr.DataArray(data['V'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
Vz = xr.DataArray(data['Vz'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
Vzz = xr.DataArray(data['Vzz'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
```

```
# FGM in terms of w
W = xr.DataArray(data['W'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
# critical levels
CL = xr.DataArray(data['CL'], coords={"site": np.arange(len(data['LON'])), "n":␣
↪np.arange(data['CL'].shape[-1])}, dims=["site" , "n"])

FGM_snapshot = xr.Dataset({'GR': (['site'], 2*np.pi/GR/3600),
                          'CI': (['site'], CI),
                          'CR': (['site'], CR),
                          'II': (['site'], II),
                          'K': (['site','vector'], KFGM),
                          'LON': (['site'], LON),
                          'LAT': (['site'], LAT),
                          'b': (['z', 'site'], B),
                          'N2': (['z', 'site'], N2),
                          'Ri': (['z', 'site'], Ri),
                          'V': (['z', 'site'], V),
                          'Vz': (['z', 'site'], Vz),
                          'Vzz': (['z', 'site'], Vzz),
                          'W': (['z', 'site'], W),
                          'CL': (['site', 'n'], CL)},
                          coords={'site': np.arange(len(data['LON'])),
                                  'z': data['zw'],
                                  'n': np.arange(data['CL'].shape[-1])},
                          attrs={'title': 'FGM, CTD/LADCP profiles'})
```

Plot site vs. growth rate

[10]:
```
topo = xr.open_dataset('/Users/tantanmeow/WORK/larry-data/
↪sp_model_bottom_velocities.nc')
BottomDepth = -topo.BottomDepth
```

[11]:
```
fig, ax =  plt.subplots(nrows=1, ncols=1, figsize=(12, 8))
BottomDepth.plot(ax=ax, xlim=[-172, -168], ylim=[-11, -7], vmax=-4000,␣
↪vmin=-6000, cmap=cm.ocean)
FGM_snapshot.plot.scatter(x='LON', y='LAT',c='k')
FGM_snapshot.plot.scatter(x='LON', y='LAT', hue='GR', marker='p', s=100,␣
↪label='$\sigma$: $hr^{-1}$',
                                 ax=ax, cmap=cm.jet, vmax=10, vmin=0,␣
↪add_guide=True)
ax.legend()
fig.tight_layout()
```



3 Read data from .mat and plot FGM (tow-yo)

[12]:
```
def dataFGM(section):
    import os
    import glob

    towyo_files = np.sort(glob.glob(os.path.join(mdirec + 'codes/TG_SI_TY_' +␣
↪section + "*ex1*")))

    # Growth rate, imaginary phase speed, real phase speed, numbers of␣
↪zero-crossing, wave vector of the FGM
    GRs = np.squeeze(np.concatenate([sio.loadmat(file)["GR"] for file in␣
↪towyo_files] , axis=0))
    CIs = np.squeeze(np.concatenate([sio.loadmat(file)["CI"] for file in␣
↪towyo_files] , axis=0))
    CRs = np.squeeze(np.concatenate([sio.loadmat(file)["CR"] for file in␣
↪towyo_files] , axis=0))
    IIs = np.squeeze(np.concatenate([sio.loadmat(file)["II"] for file in␣
↪towyo_files] , axis=0))
    KFGMs = np.squeeze(np.concatenate([sio.loadmat(file)["KFGM"] for file in␣
↪towyo_files] , axis=0))
```

```
    LONs = np.squeeze(np.concatenate([sio.loadmat(file)["LON"] for file in␣
↪towyo_files] , axis=-1))
    LATs = np.squeeze(np.concatenate([sio.loadmat(file)["LAT"] for file in␣
↪towyo_files] , axis=-1))

    # profiles
    Bs = np.squeeze(np.concatenate([sio.loadmat(file)["B"] for file in␣
↪towyo_files] , axis=-1))
    N2s = np.squeeze(np.concatenate([sio.loadmat(file)["N2"] for file in␣
↪towyo_files] , axis=-1))
    Ris = np.squeeze(np.concatenate([sio.loadmat(file)["Ri"] for file in␣
↪towyo_files] , axis=-1))
    Vs = np.squeeze(np.concatenate([sio.loadmat(file)["V"] for file in␣
↪towyo_files] , axis=-1))
    Vzs = np.squeeze(np.concatenate([sio.loadmat(file)["Vz"] for file in␣
↪towyo_files] , axis=-1))
    Vzzs = np.squeeze(np.concatenate([sio.loadmat(file)["Vzz"] for file in␣
↪towyo_files] , axis=-1))

    # FGM in terms of w
    Ws = np.squeeze(np.concatenate([sio.loadmat(file)["W"] for file in␣
↪towyo_files] , axis=-1))
    # CLs = np.squeeze(np.concatenate([sio.loadmat(file)["CL"] for file in␣
↪towyo_files] , axis=0))

    towyo_files_others = np.sort(glob.glob(os.path.join(mdirec[:-6] +␣
↪'proc_data/TY_' + section + "*")))

    # interface height, bottom height, crtical level
    zw = np.squeeze(sio.loadmat(towyo_files[0])["zw"])
    ideps = np.squeeze(np.concatenate([sio.loadmat(file)["zo"] for file in␣
↪towyo_files_others] , axis=1))
    bdeps = np.squeeze(np.concatenate([sio.loadmat(file)["bdepth"] for file in␣
↪towyo_files_others] , axis=1))
    cdeps = np.zeros(LONs.shape, dtype='f')
    nans = np.isnan(np.nanmax(Ws.real, axis=0))
    cdeps[~nans] = zw[np.int_(np.nanargmax(Ws.real[:,~nans], axis=0))]
    cdeps[nans] = np.nan

    FGM_towyo = xr.Dataset({'GR': (['site'], 2*np.pi/GRs/3600),
                            'CI': (['site'], CIs),
                            'CR': (['site'], CRs),
                            'II': (['site'], IIs),
                            'K': (['site','vector'], KFGMs),
                            'LON': (['site'], LONs),
                            'LAT': (['site'], LATs),
```

```
                                'zo': (['site'], ideps),
                                'bdepth': (['site'], -bdeps),
                                'cdepth': (['site'], cdeps),
                                'iab': (['site'], ideps+bdeps),
                                'cab': (['site'], cdeps+bdeps),
                                'b': (['z', 'site'], Bs),
                                'N2': (['z', 'site'], N2s),
                                'Ri': (['z', 'site'], Ris),
                                'V': (['z', 'site'], Vs),
                                'Vz': (['z', 'site'], Vzs),
                                'Vzz': (['z', 'site'], Vzzs), #
 ↪  'CL': (['site', 'n'], CLs),
                                'W': (['z', 'site'], Ws)},
                                coords={'site': np.arange(len(LONs)),
                                        'z': zw}, #,'n': np.arange(CLs.shape[-1])
                                attrs={'title': 'FGM, tow-yo profiles'})
    return FGM_towyo
```

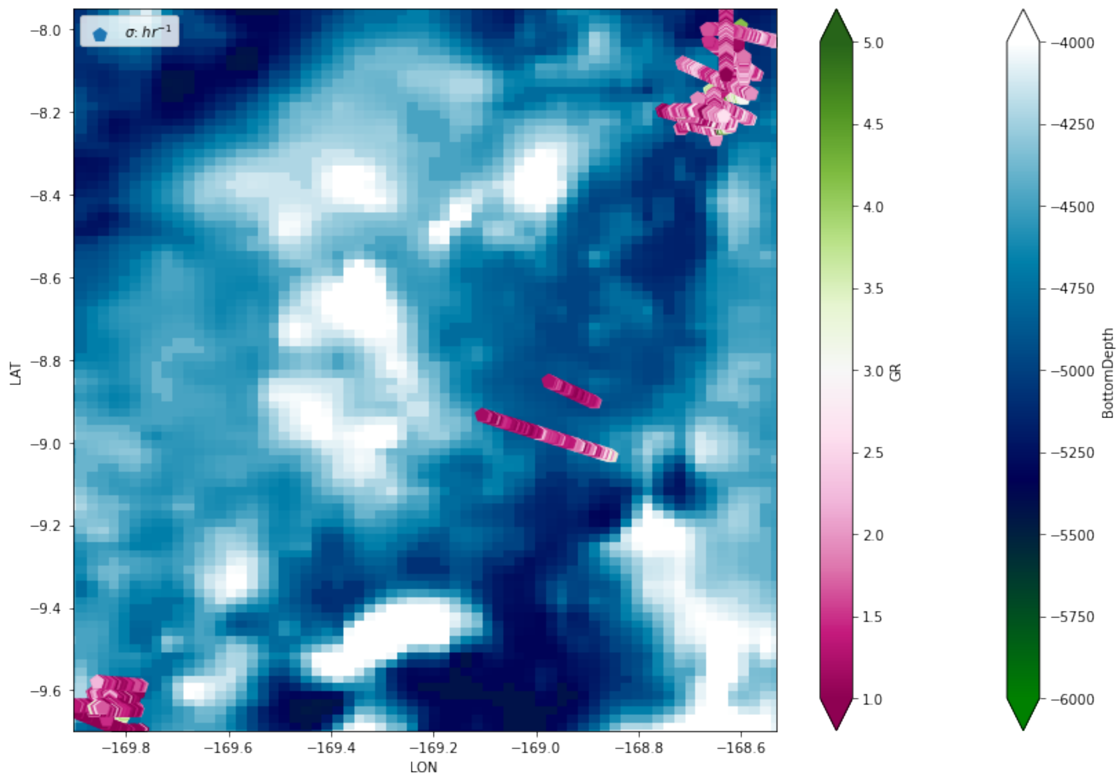
[13]:
```
mdirec='/Users/tantanmeow/Desktop/WORK/2018-2019/Jesse/sp-tg/'
FGM_towyo = dataFGM("P")
FGM_towyo_P2 = dataFGM("P2")
FGM_towyo_P4 = dataFGM("P4")
FGM_towyo_P5 = dataFGM("P5")
```

```
<ipython-input-12-8b7321b496c5>:35: RuntimeWarning: All-NaN slice encountered
  nans = np.isnan(np.nanmax(Ws.real, axis=0))
```

3.1 1. Plot site vs. growth rate

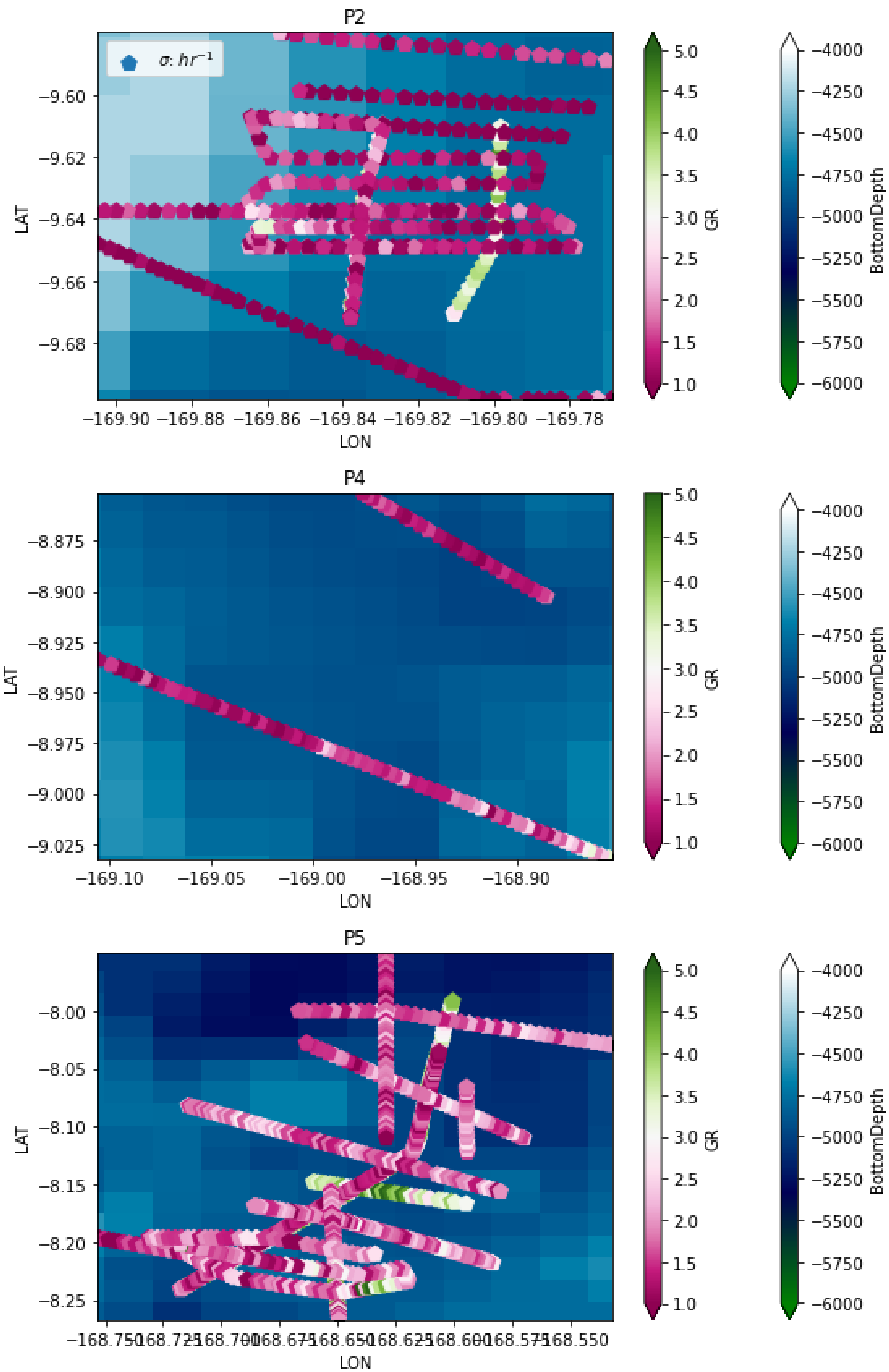
[14]:
```
topo = xr.open_dataset('/Users/tantanmeow/WORK/larry-data/
 ↪sp_model_bottom_velocities.nc')
BottomDepth = -topo.BottomDepth
```

[15]:
```
fig, ax =  plt.subplots(nrows=1, ncols=1, figsize=(12, 8))
BottomDepth.plot(ax=ax, xlim=[FGM_towyo.LON.min(), FGM_towyo.LON.max()],
 ↪ylim=[FGM_towyo.LAT.min(), FGM_towyo.LAT.max()], vmax=-4000, vmin=-6000,
 ↪cmap=cm.ocean)
FGM_towyo.plot.scatter(x='LON', y='LAT', c='k', ax=ax)
FGM_towyo.plot.scatter(x='LON', y='LAT', hue='GR', marker='p', s=100,
 ↪label='$\sigma$: $hr^{-1}$',
                             ax=ax, cmap=cm.PiYG, vmax=5, vmin=1,
 ↪add_guide=True)
ax.legend()
fig.tight_layout()
```



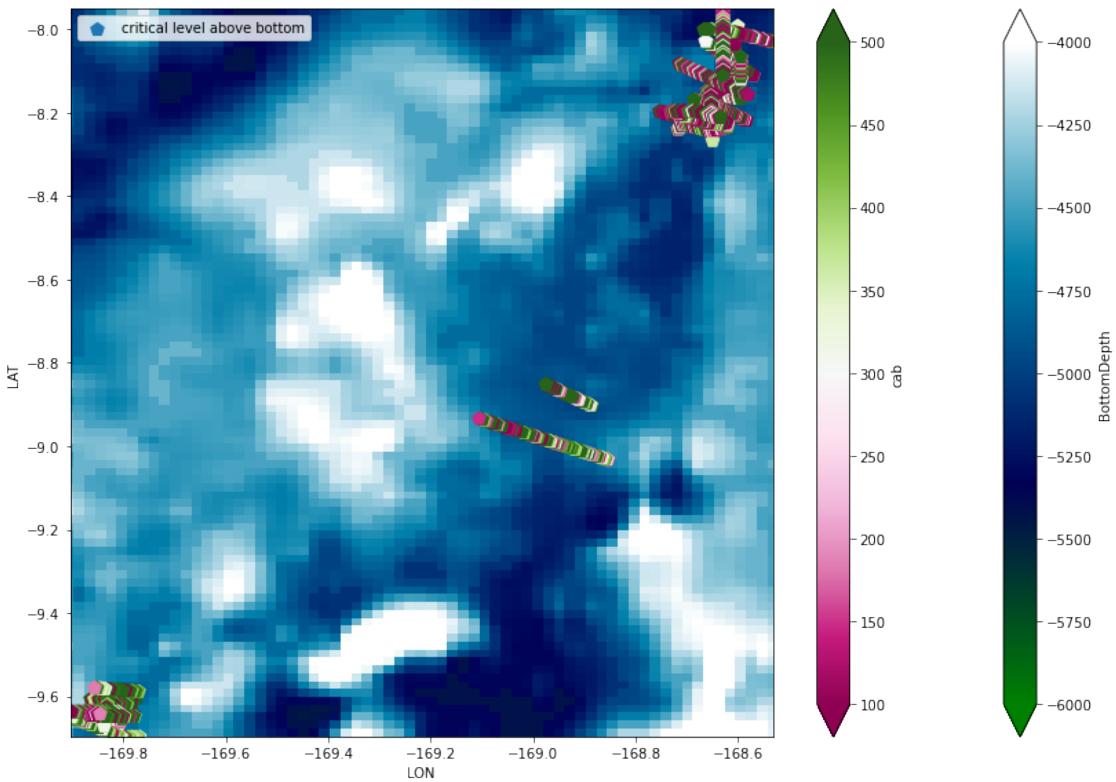
[16]:
```
fig, ax =  plt.subplots(nrows=3, ncols=1, figsize=(8, 12))

BottomDepth.plot(ax=ax[0], xlim=[FGM_towyo_P2.LON.min(), FGM_towyo_P2.LON.
 ↪max()], ylim=[FGM_towyo_P2.LAT.min(), FGM_towyo_P2.LAT.max()], vmax=-4000,␣
 ↪vmin=-6000, cmap=cm.ocean)
FGM_towyo_P2.plot.scatter(x='LON', y='LAT', c='k', ax=ax[0])
FGM_towyo_P2.plot.scatter(x='LON', y='LAT', hue='GR', marker='p', s=100,␣
 ↪label='$\sigma$: $hr^{-1}$',
                          cmap=cm.PiYG, vmax=5, vmin=1, add_guide=True,␣
 ↪ax=ax[0])
ax[0].legend()
ax[0].set_title('P2')

BottomDepth.plot(ax=ax[1], xlim=[FGM_towyo_P4.LON.min(), FGM_towyo_P4.LON.
 ↪max()], ylim=[FGM_towyo_P4.LAT.min(), FGM_towyo_P4.LAT.max()], vmax=-4000,␣
 ↪vmin=-6000, cmap=cm.ocean)
FGM_towyo_P4.plot.scatter(x='LON', y='LAT', c='k', ax=ax[1])
FGM_towyo_P4.plot.scatter(x='LON', y='LAT', hue='GR', marker='p', s=100,␣
 ↪label='$\sigma$: $hr^{-1}$',
                          cmap=cm.PiYG, vmax=5, vmin=1, add_guide=True,␣
 ↪ax=ax[1])
ax[1].set_title('P4')
```

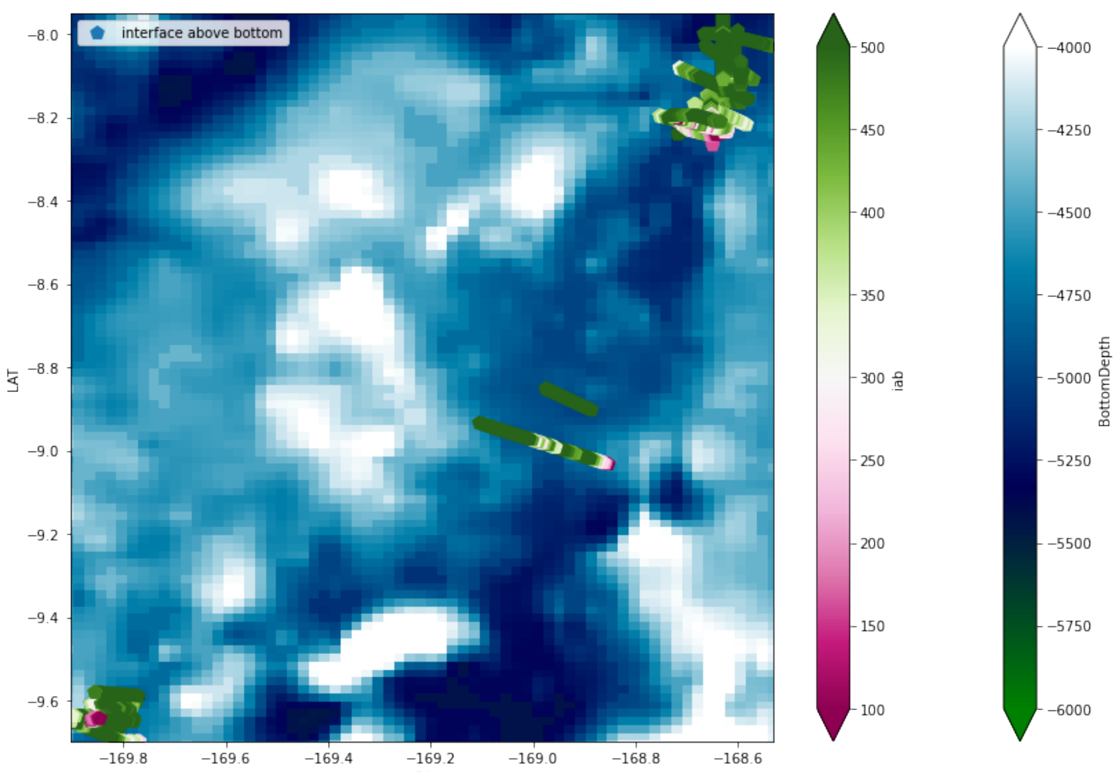
```
BottomDepth.plot(ax=ax[-1], xlim=[FGM_towyo_P5.LON.min(), FGM_towyo_P5.LON.
↪max()], ylim=[FGM_towyo_P5.LAT.min(), FGM_towyo_P5.LAT.max()], vmax=-4000,␣
↪vmin=-6000, cmap=cm.ocean)
FGM_towyo_P5.plot.scatter(x='LON', y='LAT', c='k', ax=ax[-1])
FGM_towyo_P5.plot.scatter(x='LON', y='LAT', hue='GR', marker='p', s=100,␣
↪label='$\sigma$: $hr^{-1}$',
                          cmap=cm.PiYG, vmax=5, vmin=1, add_guide=True,␣
↪ax=ax[-1])
ax[-1].set_title('P5')

fig.tight_layout()
```


P2
σ: hr⁻¹
LAT
−9.60
−9.62
−9.64
−9.66
−9.68
−169.90 −169.88 −169.86 −169.84 −169.82 −169.80 −169.78
LON
GR
5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
BottomDepth
−4000 −4250 −4500 −4750 −5000 −5250 −5500 −5750 −6000
P4
LAT
−8.875
−8.900
−8.925
−8.950
−8.975
−9.000
−9.025
−169.10 −169.05 −169.00 −168.95 −168.90
LON
GR
5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
BottomDepth
−4000 −4250 −4500 −4750 −5000 −5250 −5500 −5750 −6000
P5
LAT
−8.00
−8.05
−8.10
−8.15
−8.20
−8.25
−168.750 −168.725 −168.700 −168.675 −168.650 −168.625 −168.600 −168.575 −168.550
LON
GR
5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
BottomDepth
−4000 −4250 −4500 −4750 −5000 −5250 −5500 −5750 −6000

3.2 2. Plot site vs. critical level above bottom

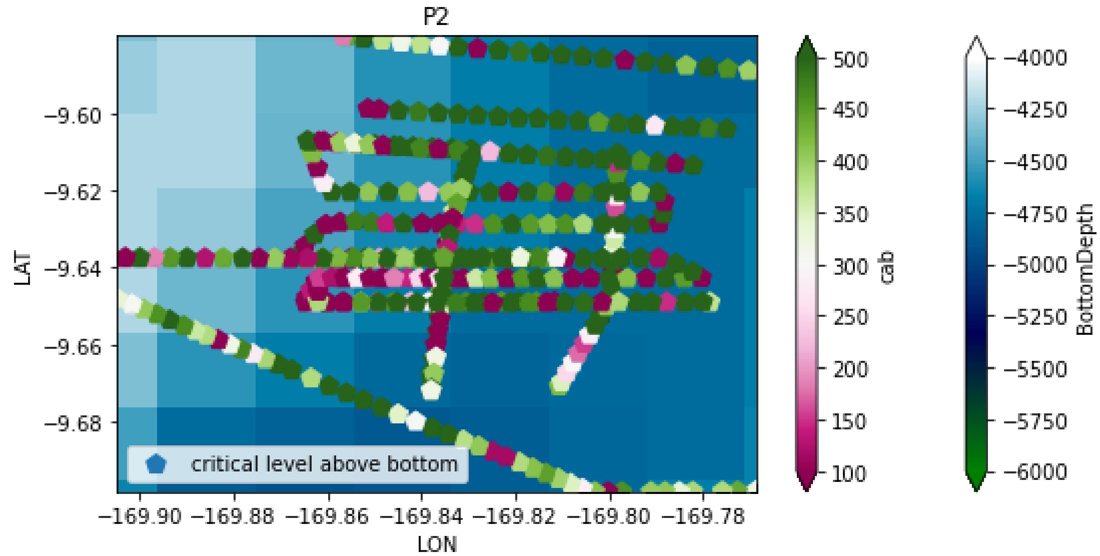
[17]:
```
fig, ax =  plt.subplots(nrows=2, ncols=1, figsize=(12, 16))
BottomDepth.plot(ax=ax[0], xlim=[FGM_towyo.LON.min(), FGM_towyo.LON.max()],␣
 ↪ylim=[FGM_towyo.LAT.min(), FGM_towyo.LAT.max()], vmax=-4000, vmin=-6000,␣
 ↪cmap=cm.ocean)
FGM_towyo.plot.scatter(x='LON', y='LAT', c='k', ax=ax[0])
FGM_towyo.plot.scatter(x='LON', y='LAT', hue='cab', marker='p', s=100,␣
 ↪label='critical level above bottom',
                             ax=ax[0], cmap=cm.PiYG, vmax=500, vmin=100,␣
 ↪add_guide=True)
ax[0].legend()

BottomDepth.plot(ax=ax[1], xlim=[FGM_towyo.LON.min(), FGM_towyo.LON.max()],␣
 ↪ylim=[FGM_towyo.LAT.min(), FGM_towyo.LAT.max()], vmax=-4000, vmin=-6000,␣
 ↪cmap=cm.ocean)
FGM_towyo.plot.scatter(x='LON', y='LAT', c='k', ax=ax[1])
FGM_towyo.plot.scatter(x='LON', y='LAT', hue='iab', marker='p', s=100,␣
 ↪label='interface above bottom',
                             ax=ax[1], cmap=cm.PiYG, vmax=500, vmin=100,␣
 ↪add_guide=True)
ax[1].legend()

fig.tight_layout()
```

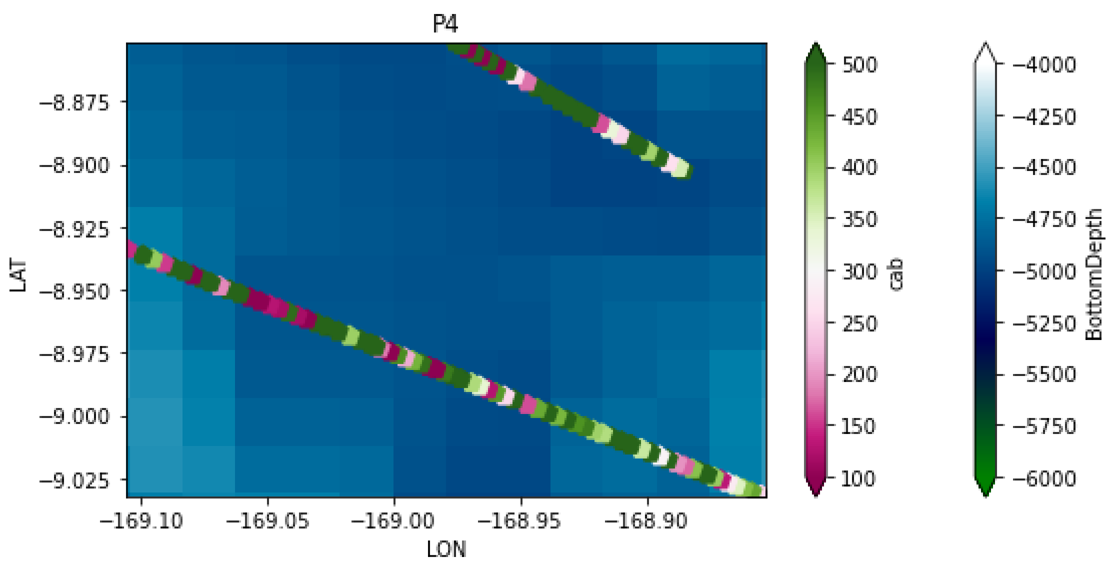

critical level above bottom
LAT
LON
cab
BottomDepth

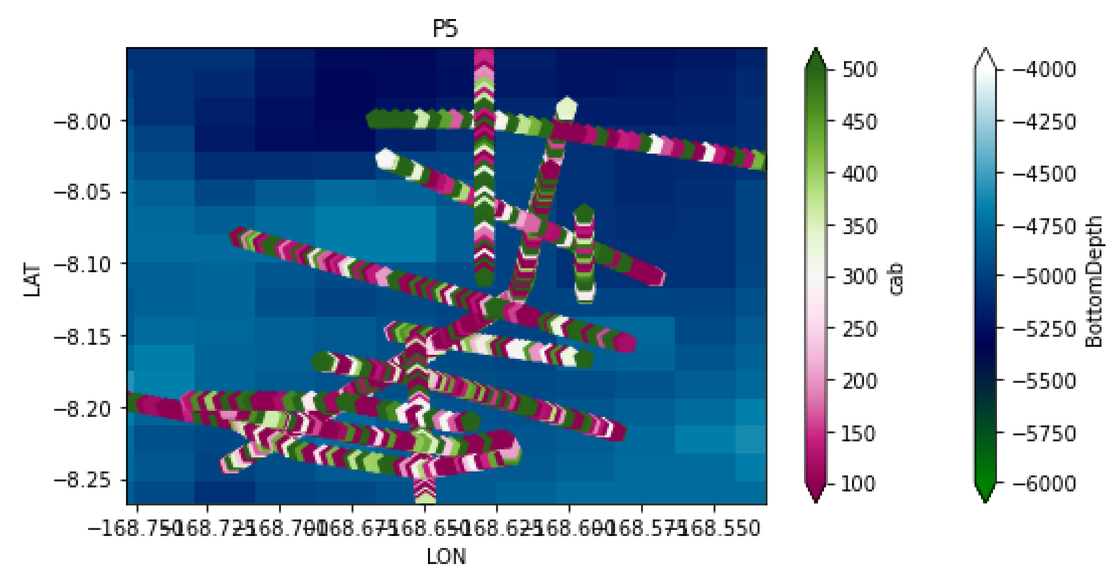

interface above bottom
LAT
LON
iab
BottomDepth

[18]:
```
fig, ax =  plt.subplots(nrows=3, ncols=1, figsize=(8, 12))

BottomDepth.plot(ax=ax[0], xlim=[FGM_towyo_P2.LON.min(), FGM_towyo_P2.LON.
 ↪max()], ylim=[FGM_towyo_P2.LAT.min(), FGM_towyo_P2.LAT.max()], vmax=-4000,␣
 ↪vmin=-6000, cmap=cm.ocean)
FGM_towyo_P2.plot.scatter(x='LON', y='LAT', c='k', ax=ax[0])
FGM_towyo_P2.plot.scatter(x='LON', y='LAT', hue='cab', marker='p', s=100,␣
 ↪label='critical level above bottom',
                          cmap=cm.PiYG, vmax=500, vmin=100, add_guide=True,␣
 ↪ax=ax[0])
ax[0].legend()
ax[0].set_title('P2')

BottomDepth.plot(ax=ax[1], xlim=[FGM_towyo_P4.LON.min(), FGM_towyo_P4.LON.
 ↪max()], ylim=[FGM_towyo_P4.LAT.min(), FGM_towyo_P4.LAT.max()], vmax=-4000,␣
 ↪vmin=-6000, cmap=cm.ocean)
FGM_towyo_P4.plot.scatter(x='LON', y='LAT', c='k', ax=ax[1])
FGM_towyo_P4.plot.scatter(x='LON', y='LAT', hue='cab', marker='p', s=100,␣
 ↪label='critical level above bottom',
                          cmap=cm.PiYG, vmax=500, vmin=100, add_guide=True,␣
 ↪ax=ax[1])
ax[1].set_title('P4')
BottomDepth.plot(ax=ax[-1], xlim=[FGM_towyo_P5.LON.min(), FGM_towyo_P5.LON.
 ↪max()], ylim=[FGM_towyo_P5.LAT.min(), FGM_towyo_P5.LAT.max()], vmax=-4000,␣
 ↪vmin=-6000, cmap=cm.ocean)
FGM_towyo_P5.plot.scatter(x='LON', y='LAT', c='k', ax=ax[-1])
FGM_towyo_P5.plot.scatter(x='LON', y='LAT', hue='cab', marker='p', s=100,␣
 ↪label='critical level above bottom',
                          cmap=cm.PiYG, vmax=500, vmin=100, add_guide=True,␣
 ↪ax=ax[-1])
ax[-1].set_title('P5')

fig.tight_layout()
```

```
<ipython-input-18-c8255bacf86d>:21: UserWarning: Creating legend with loc="best"
can be slow with large amounts of data.
  fig.tight_layout()
```

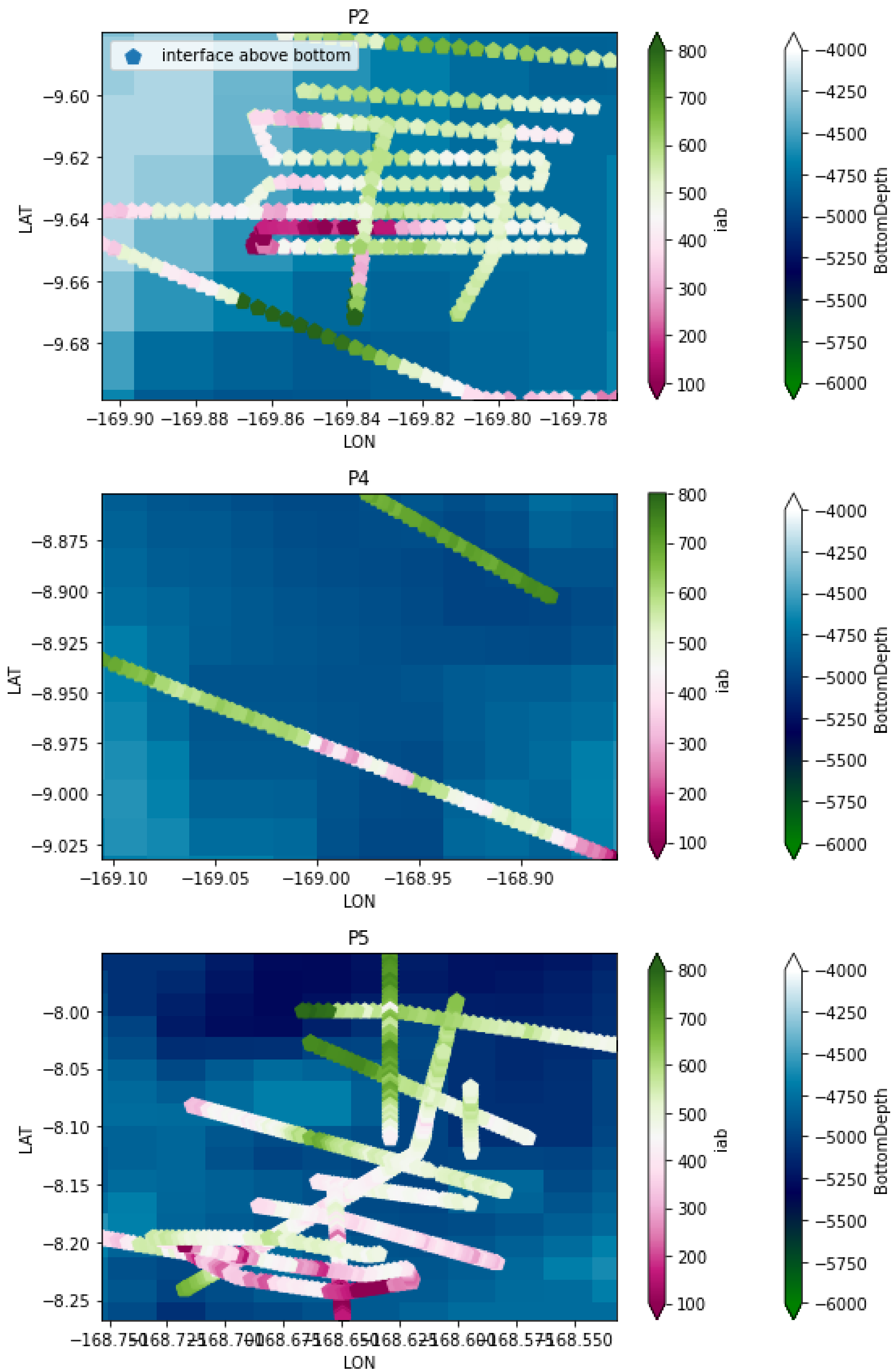

P2
LAT
−9.60
−9.62
−9.64
−9.66
−9.68
critical level above bottom
−169.90 −169.88 −169.86 −169.84 −169.82 −169.80 −169.78
LON
500
450
400
350
300
250
200
150
100
cab
−4000
−4250
−4500
−4750
−5000
−5250
−5500
−5750
−6000
BottomDepth


P4
LAT
−8.875
−8.900
−8.925
−8.950
−8.975
−9.000
−9.025
−169.10 −169.05 −169.00 −168.95 −168.90
LON
500
450
400
350
300
250
200
150
100
cab
−4000
−4250
−4500
−4750
−5000
−5250
−5500
−5750
−6000
BottomDepth


P5
LAT
−8.00
−8.05
−8.10
−8.15
−8.20
−8.25
LON
500
450
400
350
300
250
200
150
100
cab
−4000
−4250
−4500
−4750
−5000
−5250
−5500
−5750
−6000
BottomDepth

[19]:

```
fig, ax =  plt.subplots(nrows=3, ncols=1, figsize=(8, 12))

BottomDepth.plot(ax=ax[0], xlim=[FGM_towyo_P2.LON.min(), FGM_towyo_P2.LON.
 ↪max()], ylim=[FGM_towyo_P2.LAT.min(), FGM_towyo_P2.LAT.max()], vmax=-4000,␣
 ↪vmin=-6000, cmap=cm.ocean)
FGM_towyo_P2.plot.scatter(x='LON', y='LAT', c='k', ax=ax[0])
FGM_towyo_P2.plot.scatter(x='LON', y='LAT', hue='iab', marker='p', s=100,␣
 ↪label='interface above bottom',
                          cmap=cm.PiYG, vmax=800, vmin=100, add_guide=True,␣
 ↪ax=ax[0])
ax[0].legend()
ax[0].set_title('P2')

BottomDepth.plot(ax=ax[1], xlim=[FGM_towyo_P4.LON.min(), FGM_towyo_P4.LON.
 ↪max()], ylim=[FGM_towyo_P4.LAT.min(), FGM_towyo_P4.LAT.max()], vmax=-4000,␣
 ↪vmin=-6000, cmap=cm.ocean)
FGM_towyo_P4.plot.scatter(x='LON', y='LAT', c='k', ax=ax[1])
FGM_towyo_P4.plot.scatter(x='LON', y='LAT', hue='iab', marker='p', s=100,␣
 ↪label='interface above bottom',
                          cmap=cm.PiYG, vmax=800, vmin=100, add_guide=True,␣
 ↪ax=ax[1])
ax[1].set_title('P4')
BottomDepth.plot(ax=ax[-1], xlim=[FGM_towyo_P5.LON.min(), FGM_towyo_P5.LON.
 ↪max()], ylim=[FGM_towyo_P5.LAT.min(), FGM_towyo_P5.LAT.max()], vmax=-4000,␣
 ↪vmin=-6000, cmap=cm.ocean)
FGM_towyo_P5.plot.scatter(x='LON', y='LAT', c='k', ax=ax[-1])
FGM_towyo_P5.plot.scatter(x='LON', y='LAT', hue='iab', marker='p', s=100,␣
 ↪label='interface above bottom',
                          cmap=cm.PiYG, vmax=800, vmin=100, add_guide=True,␣
 ↪ax=ax[-1])
ax[-1].set_title('P5')

fig.tight_layout()
```


P2
interface above bottom
LAT
LON
iab
BottomDepth
P4
LAT
LON
iab
BottomDepth
P5
LAT
LON
iab
BottomDepth

[20]:

```python
# a closer look at a repeated along-path section, (P5 2012 vs 2014)
fig, ax =  plt.subplots(nrows=3, ncols=2, figsize=(12, 16))

sc = ax[0,0].scatter(FGM_towyo_P5.LON[136:254], FGM_towyo_P5.LAT[136:254],␣
↪c=FGM_towyo_P5.GR[136:254], marker='o',vmax=4, vmin=0, cmap=cm.PiYG,␣
↪label='P5 2014')
ax[0,0].scatter(FGM_towyo_P5.LON[0:100], FGM_towyo_P5.LAT[0:100],␣
↪c=FGM_towyo_P5.GR[0:100], marker='+',vmax=4, vmin=0, cmap=cm.PiYG, label='P5␣
↪2012')
ax[0,0].set_xlabel('lon'); ax[0,0].set_ylabel('lat'); ax[0,0].legend()
fig.colorbar(sc,label=" ",ax=ax[0,0])

ax[0,1].plot(FGM_towyo_P5.LAT[136:254], FGM_towyo_P5.bdepth[136:254], 'r-',␣
↪label='sea bottom')
ax[0,1].plot(FGM_towyo_P5.LAT[136:254], FGM_towyo_P5.zo[136:254], 'r--',␣
↪label='interface')
ax[0,1].plot(FGM_towyo_P5.LAT[136:254], FGM_towyo_P5.cdepth[136:254], 'r.',␣
↪label='critical level')
ax[0,1].plot(FGM_towyo_P5.LAT[0:100], FGM_towyo_P5.bdepth[0:100], 'g-')
ax[0,1].plot(FGM_towyo_P5.LAT[0:100], FGM_towyo_P5.zo[0:100], 'g--')
ax[0,1].plot(FGM_towyo_P5.LAT[0:100], FGM_towyo_P5.cdepth[0:100], 'g.')
ax[0,1].set_xlabel('lat'); ax[0,1].set_ylabel('z'); ax[0,1].legend()

ax[1,0].hist(FGM_towyo_P5.GR[136:254], facecolor='r', alpha=0.5, label='P5␣
↪2014')
ax[1,0].hist(FGM_towyo_P5.GR[0:100], facecolor='g', alpha=0.5, label='P5 2012')
ax[1,0].set_xlabel('lon'); ax[1,0].set_ylabel('GR'); ax[1,0].legend()

# ax[1,1].hist(FGM_towyo_P5.cdepth[136:254], facecolor='r', alpha=0.5,␣
↪label='P5 2014')
# ax[1,1].hist(FGM_towyo_P5.cdepth[0:100], facecolor='g', alpha=0.5, label='P5␣
↪2012')
# ax[1,1].set_xlabel('critical level heigth'); ax[1,1].legend()
wl = 2*np.pi/np.sqrt(FGM_towyo_P5.K[:,0]**2 + FGM_towyo_P5.K[:,1]**2)
ax[1,1].hist(wl[136:254], facecolor='r', alpha=0.5, label='P5 2014')
ax[1,1].hist(wl[0:100], facecolor='g', alpha=0.5, label='P5 2012')
ax[1,1].set_xlabel('wavelength'); ax[1,1].legend()

ax[-1,0].hist(FGM_towyo_P5.cab[136:254], facecolor='r', alpha=0.5, label='P5␣
↪2014')
ax[-1,0].hist(FGM_towyo_P5.cab[0:100], facecolor='g', alpha=0.5, label='P5␣
↪2012')
ax[-1,0].set_xlabel('critical level above bottom'); ax[-1,0].legend()
```

```
ax[-1,1].hist(FGM_towyo_P5.cab[136:254]-FGM_towyo_P5.iab[136:254], facecolor='r', alpha=0.5, label='P5 2014')
ax[-1,1].hist(FGM_towyo_P5.cab[0:100]-FGM_towyo_P5.iab[0:100], facecolor='g', alpha=0.5, label='P5 2012')
ax[-1,1].set_xlabel('critical level below interface'); ax[-1,1].legend()

fig.tight_layout()
```

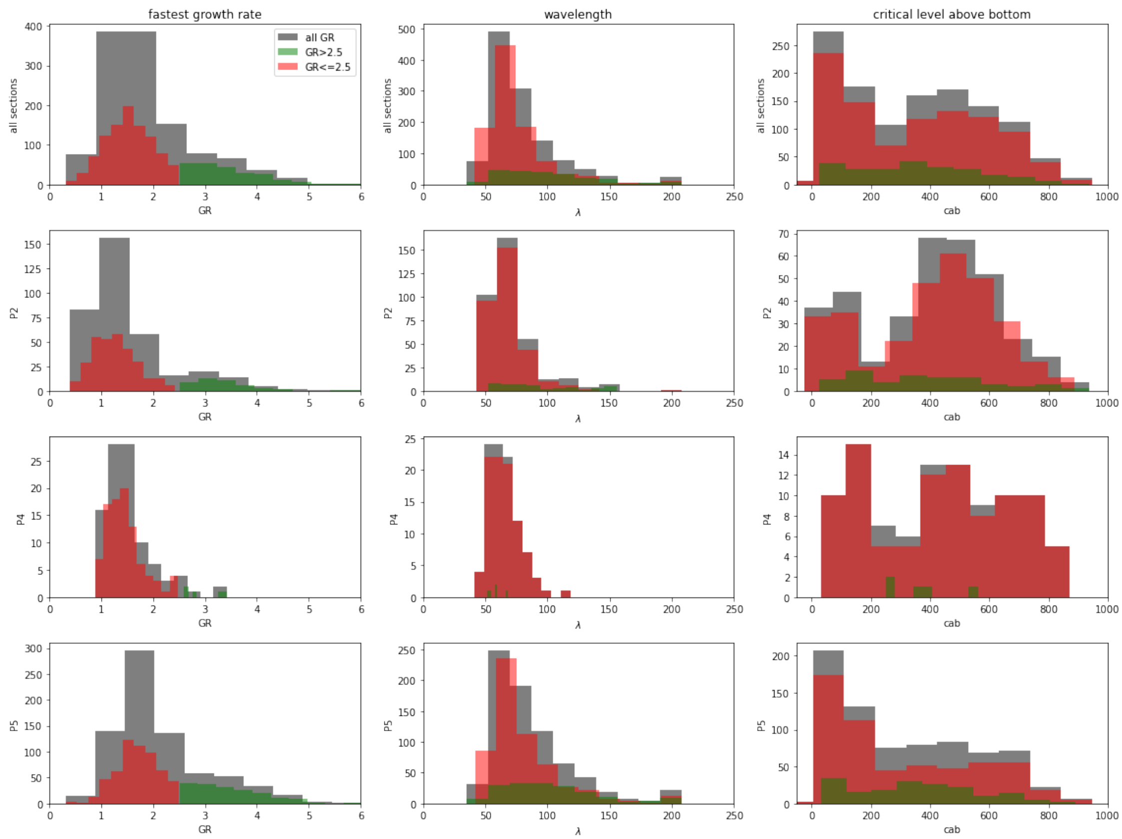

P5 2014
P5 2012
lat
lon
sea bottom
interface
critical level
z
GR
wavelength
critical level above bottom
critical level below interface

3.3 3. statistics

[21]:
```
fig, ax =  plt.subplots(nrows=4, ncols=3, figsize=(16, 12))
# GR
GRc = 2.5
ax[0,0].hist(FGM_towyo.GR, facecolor='k', alpha=0.5, label='all GR')
ax[0,0].hist(FGM_towyo.GR[FGM_towyo.GR>GRc], facecolor='g', alpha=0.5,␣
 ↪label=['GR>' + str(GRc)])
ax[0,0].hist(FGM_towyo.GR[FGM_towyo.GR<=GRc], facecolor='r', alpha=0.5,␣
 ↪label=['GR<=' + str(GRc)])
ax[0,0].set_xlim([0,6]); ax[0,0].set_title("fastest growth rate"); ax[0,0].
 ↪set_ylabel('all sections'); ax[0,0].set_xlabel('GR'); ax[0,0].legend()

ax[1,0].hist(FGM_towyo_P2.GR, facecolor='k', alpha=0.5, label='all GR')
ax[1,0].hist(FGM_towyo_P2.GR[FGM_towyo_P2.GR>GRc], facecolor='g', alpha=0.5,␣
 ↪label=['GR>' + str(GRc)])
ax[1,0].hist(FGM_towyo_P2.GR[FGM_towyo_P2.GR<=GRc], facecolor='r', alpha=0.5,␣
 ↪label=['GR<=' + str(GRc)])
ax[1,0].set_xlim([0,6]); ax[1,0].set_title(""); ax[1,0].set_ylabel('P2');␣
 ↪ax[1,0].set_xlabel('GR');

ax[2,0].hist(FGM_towyo_P4.GR, facecolor='k', alpha=0.5, label='all GR')
ax[2,0].hist(FGM_towyo_P4.GR[FGM_towyo_P4.GR>GRc], facecolor='g', alpha=0.5,␣
 ↪label=['GR>' + str(GRc)])
ax[2,0].hist(FGM_towyo_P4.GR[FGM_towyo_P4.GR<=GRc], facecolor='r', alpha=0.5,␣
 ↪label=['GR<=' + str(GRc)])
ax[2,0].set_xlim([0,6]); ax[2,0].set_title(""); ax[2,0].set_ylabel('P4');␣
 ↪ax[2,0].set_xlabel('GR');

ax[-1,0].hist(FGM_towyo_P5.GR, facecolor='k', alpha=0.5, label='all GR')
ax[-1,0].hist(FGM_towyo_P5.GR[FGM_towyo_P5.GR>GRc], facecolor='g', alpha=0.5,␣
 ↪label=['GR>' + str(GRc)])
ax[-1,0].hist(FGM_towyo_P5.GR[FGM_towyo_P5.GR<=GRc], facecolor='r', alpha=0.5,␣
 ↪label=['GR<=' + str(GRc)])
ax[-1,0].set_xlim([0,6]); ax[-1,0].set_title(""); ax[-1,0].set_ylabel('P5');␣
 ↪ax[-1,0].set_xlabel('GR');

# wavelength
wl = 2*np.pi/np.sqrt(FGM_towyo.K[:,0]**2 + FGM_towyo.K[:,1]**2)
ax[0,1].hist(wl, facecolor='k', alpha=0.5, label='all GR')
ax[0,1].hist(wl[FGM_towyo.GR<=GRc], facecolor='r', alpha=0.5, label=['GR<=' +␣
 ↪str(GRc)])
ax[0,1].hist(wl[FGM_towyo.GR>GRc], facecolor='g', alpha=0.5, label=['GR>' +␣
 ↪str(GRc)])
ax[0,1].set_xlim([0,250]); ax[0,1].set_title("wavelength"); ax[0,1].
 ↪set_ylabel('all sections'); ax[0,1].set_xlabel('$\lambda$');
```

```
wl = 2*np.pi/np.sqrt(FGM_towyo_P2.K[:,0]**2 + FGM_towyo_P2.K[:,1]**2)
ax[1,1].hist(wl, facecolor='k', alpha=0.5, label='all GR')
ax[1,1].hist(wl[FGM_towyo_P2.GR<=GRc], facecolor='r', alpha=0.5, label=['GR<=' + str(GRc)])
ax[1,1].hist(wl[FGM_towyo_P2.GR>GRc], facecolor='g', alpha=0.5, label=['GR>' + str(GRc)])
ax[1,1].set_xlim([0,250]); ax[1,1].set_title(""); ax[1,1].set_ylabel('P2'); ax[1,1].set_xlabel('$\lambda$');

wl = 2*np.pi/np.sqrt(FGM_towyo_P4.K[:,0]**2 + FGM_towyo_P4.K[:,1]**2)
ax[2,1].hist(wl, facecolor='k', alpha=0.5, label='all GR')
ax[2,1].hist(wl[FGM_towyo_P4.GR<=GRc], facecolor='r', alpha=0.5, label=['GR<=' + str(GRc)])
ax[2,1].hist(wl[FGM_towyo_P4.GR>GRc], facecolor='g', alpha=0.5, label=['GR>' + str(GRc)])
ax[2,1].set_xlim([0,250]); ax[2,1].set_title(""); ax[2,1].set_ylabel('P4'); ax[2,1].set_xlabel('$\lambda$');

wl = 2*np.pi/np.sqrt(FGM_towyo_P5.K[:,0]**2 + FGM_towyo_P5.K[:,1]**2)
ax[-1,1].hist(wl, facecolor='k', alpha=0.5, label='all GR')
ax[-1,1].hist(wl[FGM_towyo_P5.GR<=GRc], facecolor='r', alpha=0.5, label=['GR<=' + str(GRc)])
ax[-1,1].hist(wl[FGM_towyo_P5.GR>GRc], facecolor='g', alpha=0.5, label=['GR>' + str(GRc)])
ax[-1,1].set_xlim([0,250]); ax[-1,1].set_title(""); ax[-1,1].set_ylabel('P5'); ax[-1,1].set_xlabel('$\lambda$');

# critical level above bottom
ax[0,-1].hist(FGM_towyo.cab, facecolor='k', alpha=0.5, label='all GR')
ax[0,-1].hist(FGM_towyo.cab[FGM_towyo.GR<=GRc], facecolor='r', alpha=0.5, label=['GR<=' + str(GRc)])
ax[0,-1].hist(FGM_towyo.cab[FGM_towyo.GR>GRc], facecolor='g', alpha=0.5, label=['GR>' + str(GRc)])
ax[0,-1].set_xlim([-50,1000]); ax[0,-1].set_title("critical level above bottom"); ax[0,-1].set_ylabel('all sections'); ax[0,-1].set_xlabel('cab');

ax[1,-1].hist(FGM_towyo_P2.cab, facecolor='k', alpha=0.5, label='all GR')
ax[1,-1].hist(FGM_towyo_P2.cab[FGM_towyo_P2.GR<=GRc], facecolor='r', alpha=0.5, label=['GR<=' + str(GRc)])
ax[1,-1].hist(FGM_towyo_P2.cab[FGM_towyo_P2.GR>GRc], facecolor='g', alpha=0.5, label=['GR>' + str(GRc)])
ax[1,-1].set_xlim([-50,1000]); ax[1,-1].set_title(""); ax[1,-1].set_ylabel('P2'); ax[1,-1].set_xlabel('cab');

ax[2,-1].hist(FGM_towyo_P4.cab, facecolor='k', alpha=0.5, label='all GR')
```

```
ax[2,-1].hist(FGM_towyo_P4.cab[FGM_towyo_P4.GR<=GRc], facecolor='r', alpha=0.5,␣
↪label=['GR<=' + str(GRc)])
ax[2,-1].hist(FGM_towyo_P4.cab[FGM_towyo_P4.GR>GRc], facecolor='g', alpha=0.5,␣
↪label=['GR>' + str(GRc)])
ax[2,-1].set_xlim([-50,1000]); ax[2,-1].set_title(""); ax[2,-1].
↪set_ylabel('P4'); ax[2,-1].set_xlabel('cab');

ax[-1,-1].hist(FGM_towyo_P5.cab, facecolor='k', alpha=0.5, label='all GR')
ax[-1,-1].hist(FGM_towyo_P5.cab[FGM_towyo_P5.GR<=GRc], facecolor='r', alpha=0.
↪5, label=['GR<=' + str(GRc)])
ax[-1,-1].hist(FGM_towyo_P5.cab[FGM_towyo_P5.GR>GRc], facecolor='g', alpha=0.5,␣
↪label=['GR>' + str(GRc)])
ax[-1,-1].set_xlim([-50,1000]); ax[-1,-1].set_title(""); ax[-1,-1].
↪set_ylabel('P5'); ax[-1,-1].set_xlabel('cab');

fig.tight_layout()
```




```
[22]: def datafromfile(data_name):
          data = sio.loadmat(mdirec + 'codes/' + data_name,squeeze_me =␣
      ↪True,struct_as_record = False)
```

```
    type(data)
    dict.keys(data)

    # Growth rate, imaginary phase speed, real phase speed, numbers of␣
↪zero-crossing, wave vector of the FGM
    GR = xr.DataArray(data['GR'], coords={"site": np.arange(len(data['LON']))},␣
↪dims=["site"], attrs={'longname': '$\sigma$: $hr^{-1}$'})
    CI = xr.DataArray(data['CI'], coords={"site": np.arange(len(data['LON']))},␣
↪dims=["site"])
    CR = xr.DataArray(data['CR'], coords={"site": np.arange(len(data['LON']))},␣
↪dims=["site"])
    II = xr.DataArray(data['II'], coords={"site": np.arange(len(data['LON']))},␣
↪dims=["site"], attrs={'longname': '0-crossings'})
    KFGM = xr.DataArray(data['KFGM'], coords={"site": np.
↪arange(len(data['LON'])), "vector": ['k' , 'l']}, dims=["site" , "vector"])
    LON = xr.DataArray(data['LON'], coords={"site": np.
↪arange(len(data['LON']))}, dims=["site"])
    LAT = xr.DataArray(data['LAT'], coords={"site": np.
↪arange(len(data['LON']))}, dims=["site"])

    # profiles
    B = xr.DataArray(data['B'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
    N2 = xr.DataArray(data['N2'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
    Ri = xr.DataArray(data['Ri'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
    V = xr.DataArray(data['V'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
    Vz = xr.DataArray(data['Vz'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
    Vzz = xr.DataArray(data['Vzz'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])

    # FGM in terms of w
    W = xr.DataArray(data['W'], coords={"z":data['zw'], "site": np.
↪arange(len(data['LON']))}, dims=["z" , "site"])
    # critical levels
    CL = xr.DataArray(data['CL'], coords={"site": np.arange(len(data['LON'])),␣
↪"n": np.arange(data['CL'].shape[-1])}, dims=["site" , "n"])

    # interface height, bottom height
    data0 = sio.loadmat(mdirec[:-7]+'/proc_data/'+data_name[6:-8]+'.
↪mat',squeeze_me = True,struct_as_record = False)
    idep = xr.DataArray(data0['zo'], coords={"site": np.
↪arange(len(data['LON']))}, dims=["site"])
```

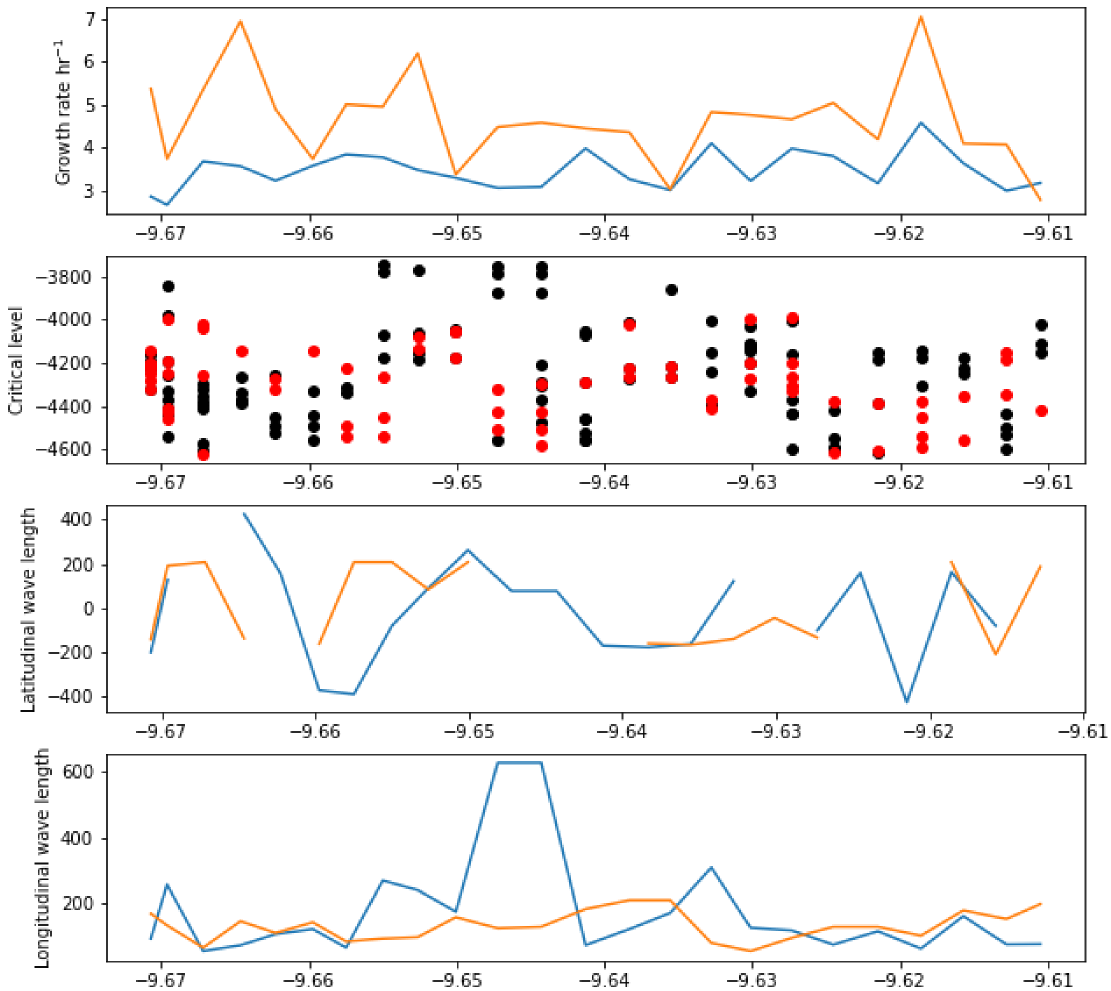
```
    bdep = xr.DataArray(data0['bdepth'], coords={"site": np.
↪arange(len(data['LON']))}, dims=["site"])


    FGM_towyo_ex = xr.Dataset({'GR': (['site'], 2*np.pi/GR/3600),
                             'CI': (['site'], CI),
                             'CR': (['site'], CR),
                             'II': (['site'], II),
                             'K': (['site','vector'], KFGM),
                             'LON': (['site'], LON),
                             'LAT': (['site'], LAT),
                             'zo': (['site'], idep),
                             'bdepth': (['site'], -bdep),
                             'b': (['z', 'site'], B),
                             'N2': (['z', 'site'], N2),
                             'Ri': (['z', 'site'], Ri),
                             'V': (['z', 'site'], V),
                             'Vz': (['z', 'site'], Vz),
                             'Vzz': (['z', 'site'], Vzz),
                             'W': (['z', 'site'], W),
                             'CL': (['site', 'n'], CL)},
                             coords={'site': np.arange(len(data['LON'])),
                                     'z': data['zw'],
                                     'n': np.arange(data['CL'].shape[-1])},
                             attrs={'title': 'FGM, tow-yo profiles, ex_'})
    return FGM_towyo_ex
```

FD and FG methods seem to have different results

[23]:
```
# FD and FG

FGM_towyo_ex1 = datafromfile('TG_SI_TY_P2_00_2012_ex1.mat')
FGM_towyo_ex2 = datafromfile('TG_SI_TY_P2_00_2012_ex2.mat')

fig, ax =  plt.subplots(nrows=4, ncols=1, figsize=(10, 10))
# 1. GR
ax[0].plot(FGM_towyo_ex1.LAT,FGM_towyo_ex1.GR) #FD
ax[0].plot(FGM_towyo_ex2.LAT,FGM_towyo_ex2.GR) #FG
ax[0].set_ylabel("Growth rate hr$^{-1}$")
# 2. CL
ax[1].plot(FGM_towyo_ex1.LAT,FGM_towyo_ex1.CL,'ko') #FD
ax[1].plot(FGM_towyo_ex2.LAT,FGM_towyo_ex2.CL,'ro') #FG
ax[1].set_ylabel("Critical level")
# 3. K and L
# K
ax[2].plot(FGM_towyo_ex1.LAT,2*np.pi/FGM_towyo_ex1.K[:,0]) #FD
ax[2].plot(FGM_towyo_ex2.LAT,2*np.pi/FGM_towyo_ex2.K[:,0]) #FG
```

```
ax[2].set_ylabel("Latitudinal wave length")
# L
ax[-1].plot(FGM_towyo_ex1.LAT,2*np.pi/FGM_towyo_ex1.K[:,-1]) #FD
ax[-1].plot(FGM_towyo_ex2.LAT,2*np.pi/FGM_towyo_ex2.K[:,-1]) #FG
ax[-1].set_ylabel("Longitudinal wave length")
```

[23]: Text(0, 0.5, 'Longitudinal wave length')

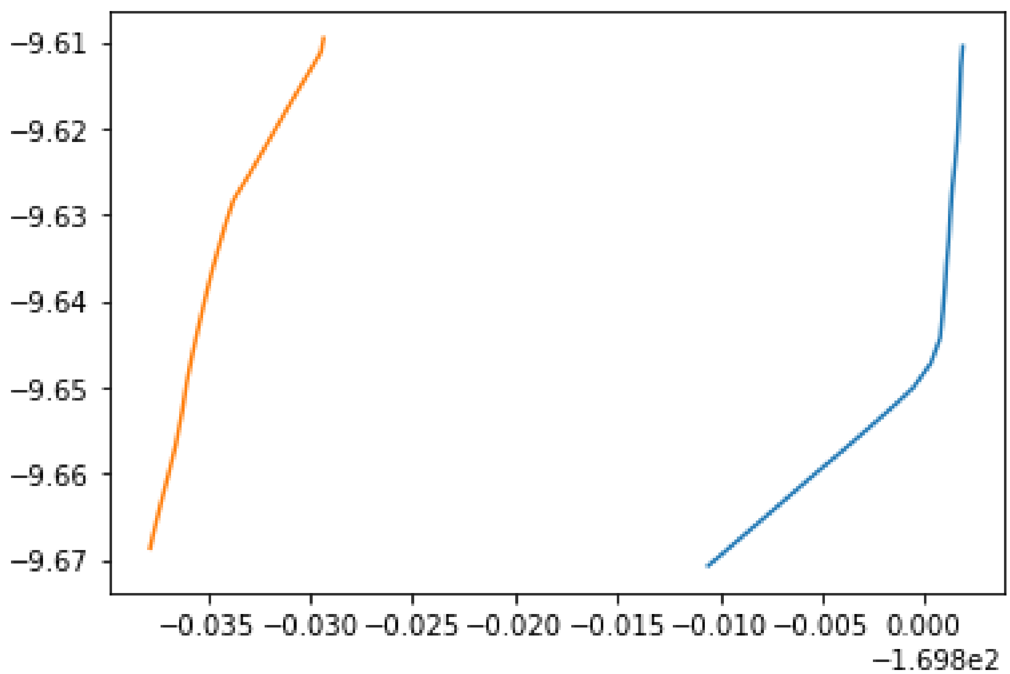


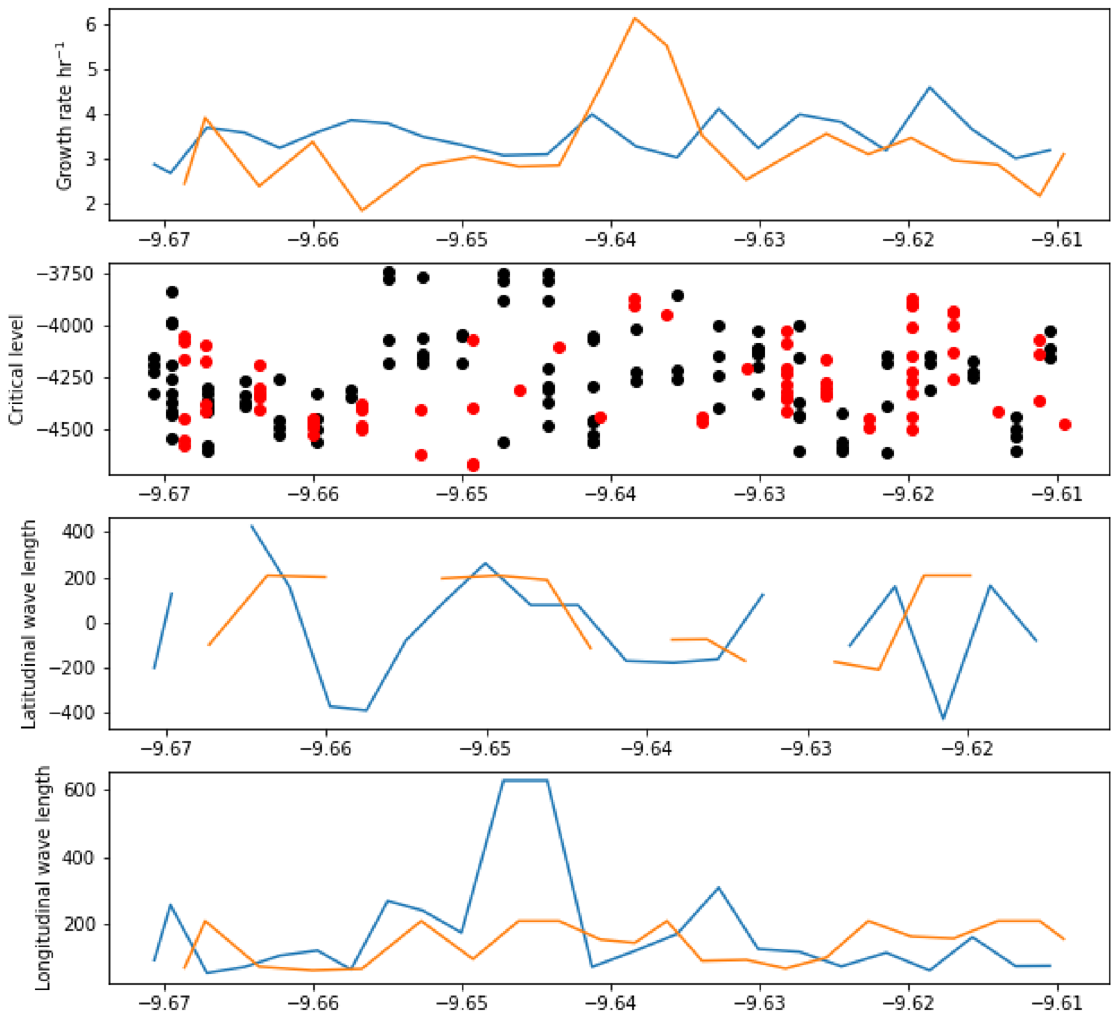
[24]:
```
# another tow-yo section

FGM_towyo_ex = datafromfile('TG_SI_TY_P2_01_2012_ex1.mat')

plt.plot(FGM_towyo_ex1.LON,FGM_towyo_ex1.LAT)
plt.plot(FGM_towyo_ex.LON,FGM_towyo_ex.LAT)

fig, ax =  plt.subplots(nrows=4, ncols=1, figsize=(10, 10))
```

```
# 1. GR
ax[0].plot(FGM_towyo_ex1.LAT,FGM_towyo_ex1.GR)
ax[0].plot(FGM_towyo_ex.LAT,FGM_towyo_ex.GR)
ax[0].set_ylabel("Growth rate hr$^{-1}$")
# 2. CL
ax[1].plot(FGM_towyo_ex1.LAT,FGM_towyo_ex1.CL,'ko')
ax[1].plot(FGM_towyo_ex.LAT,FGM_towyo_ex.CL,'ro')
ax[1].set_ylabel("Critical level")
# 3. K and L
# K
ax[2].plot(FGM_towyo_ex1.LAT,2*np.pi/FGM_towyo_ex1.K[:,0])
ax[2].plot(FGM_towyo_ex.LAT,2*np.pi/FGM_towyo_ex.K[:,0])
ax[2].set_ylabel("Latitudinal wave length")
# L
ax[-1].plot(FGM_towyo_ex1.LAT,2*np.pi/FGM_towyo_ex1.K[:,-1])
ax[-1].plot(FGM_towyo_ex.LAT,2*np.pi/FGM_towyo_ex.K[:,-1])
ax[-1].set_ylabel("Longitudinal wave length")
```

[24]:

```
Text(0, 0.5, 'Longitudinal wave length')
```

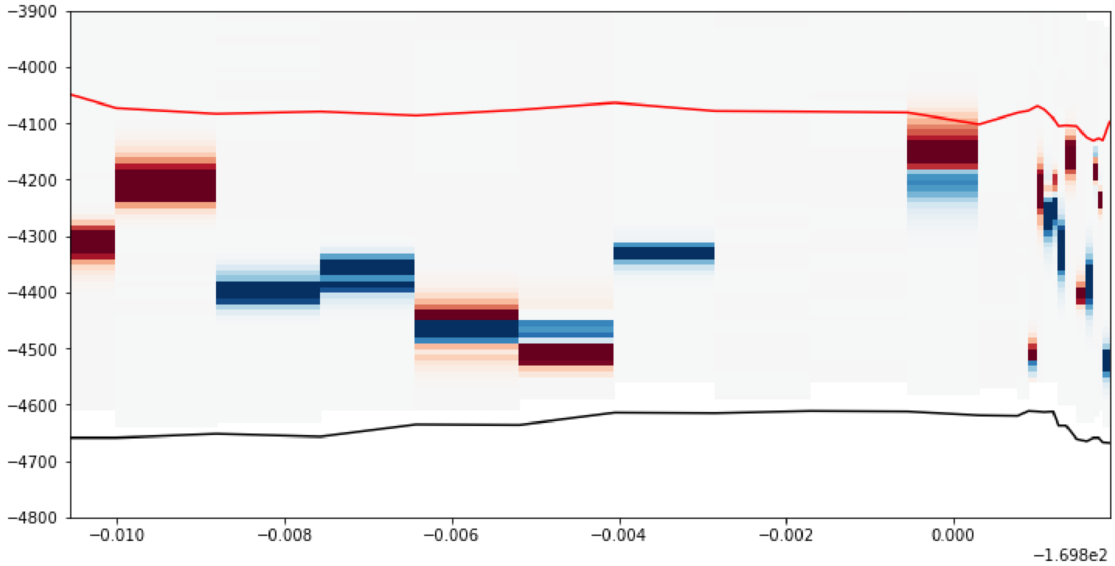




[25]:
```
fig, ax =  plt.subplots(nrows=1, ncols=1, figsize=(12, 6))

ax.pcolor(FGM_towyo_ex1.LON,FGM_towyo_ex1.z,FGM_towyo_ex1.W.real,cmap=cm.
 ↪RdBu,vmin=-.2, vmax=.2)
ax.plot(FGM_towyo_ex1.LON,FGM_towyo_ex1.bdepth,'k')
ax.plot(FGM_towyo_ex1.LON,FGM_towyo_ex1.zo,'r')
ax.set_ylim([-4800,-3900])
```

```
<ipython-input-25-6e1d5eec3edd>:3: MatplotlibDeprecationWarning: shading='flat'
when X and Y have the same dimensions as C is deprecated since 3.3.  Either
specify the corners of the quadrilaterals with X and Y, or pass shading='auto',
'nearest' or 'gouraud', or set rcParams['pcolor.shading'].  This will become an
error two minor releases later.
  ax.pcolor(FGM_towyo_ex1.LON,FGM_towyo_ex1.z,FGM_towyo_ex1.W.real,cmap=cm.RdBu,
vmin=-.2, vmax=.2)
```

[25]: (-4800.0, -3900.0)



[ ]: