FGM

September 18, 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 dask.diagnostics import ProgressBar
from scipy import integrate
from matplotlib import cm
```

[2]:
```
# load time-mean mooring data
data0 = sio.loadmat('/Users/tantanmeow/WORK/2018-2019/Jesse/TG/
 ↪mooring_averages_processed.mat',squeeze_me = True,struct_as_record = False)
type(data0)
dict.keys(data0)
```

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

[3]:
```
# build dataset
def dataset_dict(sample_dict, key):
    """build dataarray, coor = 'z'"""
    da_v = xr.DataArray(sample_dict[key].v, coords={"z": sample_dict[key].z,
                                                    "site":key}, dims=["z"])
    da_sigma4 = xr.DataArray(sample_dict[key].sigma4, coords={"z":␣
 ↪sample_dict[key].z,
                                                    "site":key}, dims=["z"])
    da_hab = xr.DataArray(sample_dict[key].hab, coords={"z": sample_dict[key].
 ↪hab,
                                                    "site":key}, dims=["z"])
```

```
    ds = xr.Dataset({"v": (["z"], da_v),
                     "sigma4": (["z"], da_sigma4),
                     "hab": (["z"], da_hab)},
                    coords={"z": (["z"], da_v.z.data),
                            "site":key})

    return ds
```

[4]:
```
# for key in data0.keys():
#     if len(key)<4:
#         eval("key = dataset_dict(data0, key)")
```

[5]:
```
# load FGM outputs from a .mat dataset
data_path = '/Users/tantanmeow/WORK/2018-2019/Jesse/TG/'
data_name = 'TG_SI_mean_ex1.mat'
data = sio.loadmat(data_path + data_name,squeeze_me = True,struct_as_record =␣
 ↪False)
type(data)
dict.keys(data)
```

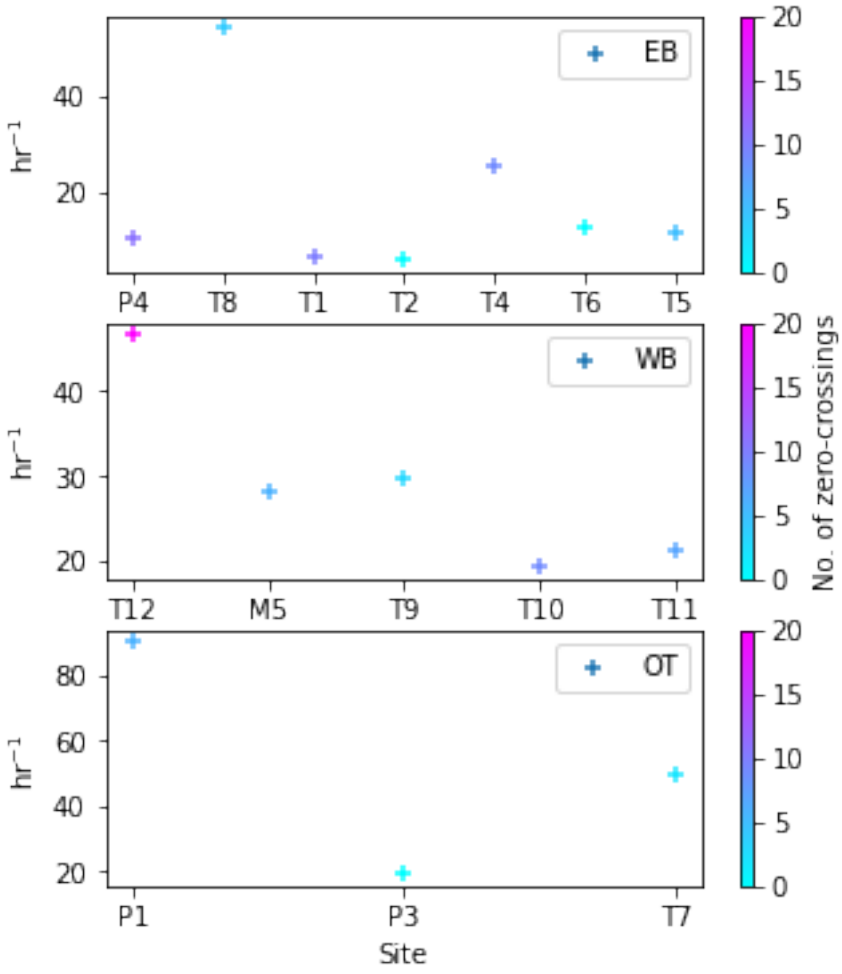
[5]:
```
dict_keys(['__header__', '__version__', '__globals__', 'EB_FGM', 'OT_FGM',
'WB_FGM'])
```

[6]:
```
EB_FGM = data['EB_FGM'] ; WB_FGM = data['WB_FGM'] ; OT_FGM = data['OT_FGM'] ;
```

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

[7]:
```
fig, ax =  plt.subplots(nrows=3, ncols=1, figsize=(5, 6))
# EB
sc = ax[0].scatter(EB_FGM.site, 2*np.pi/EB_FGM.GR/3600, c=EB_FGM.I, marker='+',␣
 ↪vmin=0, vmax=20, cmap=cm.cool, label="EB")
fig.colorbar(sc,label=" ",ax=ax[0])
# ax[0].set_xlabel("Site")
ax[0].set_ylabel("hr$^{-1}$")
ax[0].legend(loc='upper right')
# WB
sc = ax[1].scatter(WB_FGM.site, 2*np.pi/WB_FGM.GR/3600, c=WB_FGM.I, marker='+',␣
 ↪vmin=0, vmax=20, cmap=cm.cool, label="WB")
fig.colorbar(sc,label="No. of zero-crossings",ax=ax[1])
# ax[1].set_xlabel("Site")
ax[1].set_ylabel("hr$^{-1}$")
ax[1].legend(loc='upper right')
# OT
sc = ax[-1].scatter(OT_FGM.site, 2*np.pi/OT_FGM.GR/3600, c=OT_FGM.I,␣
 ↪marker='+', vmin=0, vmax=20, cmap=cm.cool, label="OT")
fig.colorbar(sc,label=" ",ax=ax[-1])
```

```
ax[-1].set_xlabel("Site")
ax[-1].set_ylabel("hr$^{-1}$")
ax[-1].legend(loc='upper right')

fig.savefig(data_path+data_name[:-4]+'_gr.png', dpi=300)
```



[8]:
```
# plot insets
def plot_insets(key, var, loc, xlim, ylim, ax):
    """plot insets, key = sites, variable = v (1) or n2 (2)"""
    self = ax.inset_axes(loc, transform=None, facecolor='none', frameon=False,␣
 ↪sharey=None)
    self.set_yticks([]) , self.set_ylim(ylim) #, axin1.grid(True)
    self.set_xlim(xlim) , self.set_xticklabels([])
    self.tick_params(top=True, bottom=False, labeltop=True, labelbottom=False)
    if var == 1:
        self.plot([0, 0], [data0[key].z[0], data0[key].z[-1]],'.5')
```

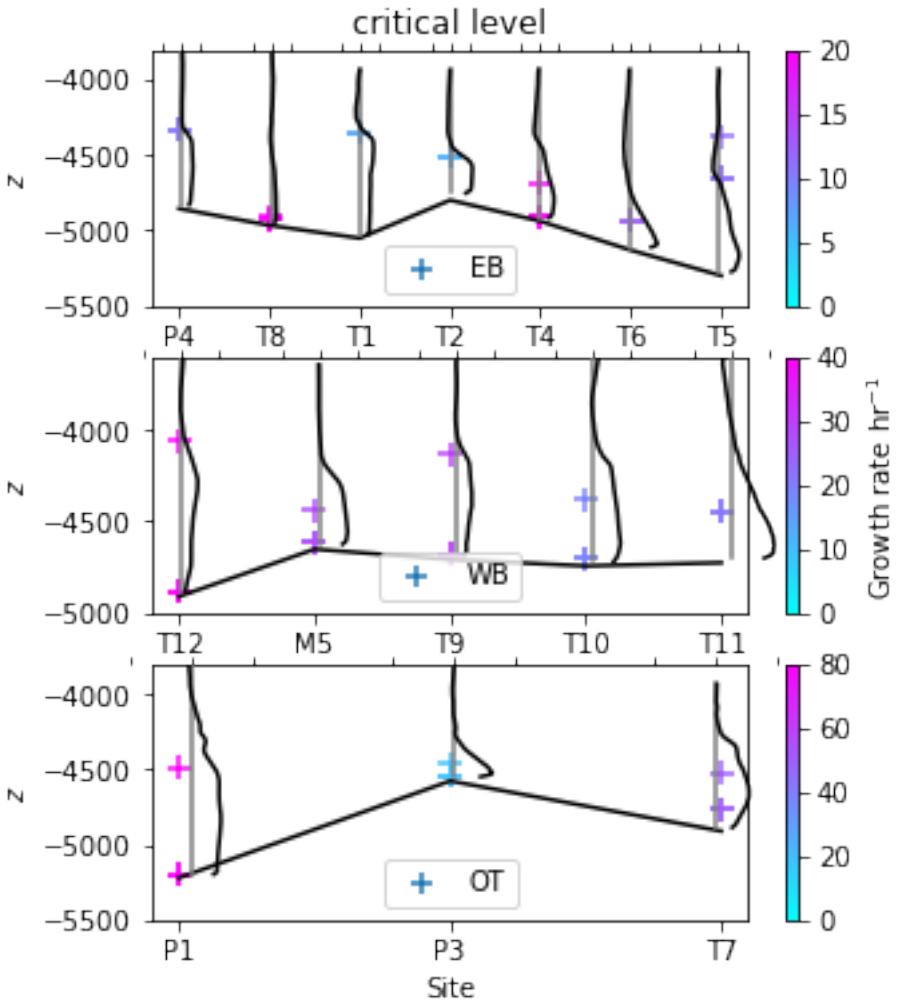
```
        self.plot(data0[key].v, data0[key].z,'k')
    if var == 2:
        self.plot(np.log10(data0[key].n2), data0[key].zz,'k')
```

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

[18]:
```
fig, ax =  plt.subplots(nrows=3, ncols=1, figsize=(5, 6))
# EB
for i in range(len(EB_FGM.site)):
    plot_insets(EB_FGM.site[i], 1, [0+.15*i, 0, 0.1, 1], [-.4, .4],␣
 ↪[-5500,-3800], ax[0])
ax[0].plot(EB_FGM.site, EB_FGM.bz,'k')
sc = ax[0].scatter(EB_FGM.site, EB_FGM.CL[:,0], c=2*np.pi/EB_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=20, cmap=cm.cool, label="EB")
for i in range(len(EB_FGM.CL[0,:])):
    ax[0].scatter(EB_FGM.site, EB_FGM.CL[:,i], c=2*np.pi/EB_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=20, cmap=cm.cool)
fig.colorbar(sc,label=" ",ax=ax[0])
ax[0].set_title("critical level")
# ax[0].set_xlabel("Site")
ax[0].set_ylabel("$z$")
# ax[0].set_ylim([-5500,-4200])
ax[0].set_ylim([-5500,-3800])
ax[0].legend(loc='lower center')

# WB
for i in range(len(WB_FGM.site)):
    plot_insets(WB_FGM.site[i], 1, [-.05+.23*i, 0, 0.2, 1], [-.4, .4],␣
 ↪[-5000,-3600], ax[1])
ax[1].plot(WB_FGM.site, WB_FGM.bz,'k')
sc = ax[1].scatter(WB_FGM.site, WB_FGM.CL[:,0], c=2*np.pi/WB_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=40, cmap=cm.cool, label="WB")
for i in range(len(WB_FGM.CL[0,:])):
    ax[1].scatter(WB_FGM.site, WB_FGM.CL[:,i], c=2*np.pi/WB_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=40, cmap=cm.cool)
fig.colorbar(sc,label="Growth rate hr$^{-1}$",ax=ax[1])
# ax[1].set_xlabel("Site")
ax[1].set_ylabel("$z$")
# ax[1].set_ylim([-5000,-4000])
ax[1].set_ylim([-5000,-3600])
ax[1].legend(loc='lower center')

# OT
for i in range(len(OT_FGM.site)):
    plot_insets(OT_FGM.site[i], 1, [-.1+.44*i, 0, 0.33, 1], [-.4, .4],␣
 ↪[-5500,-3800], ax[-1])
ax[-1].plot(OT_FGM.site, OT_FGM.bz,'k')
```

```
sc = ax[-1].scatter(OT_FGM.site, OT_FGM.CL[:,0], c=2*np.pi/OT_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=80, cmap=cm.cool, label="OT")
for i in range(len(OT_FGM.CL[0,:])):
    ax[-1].scatter(OT_FGM.site, OT_FGM.CL[:,i], c=2*np.pi/OT_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=80, cmap=cm.cool)
fig.colorbar(sc,label=" ",ax=ax[-1])
ax[-1].set_xlabel("Site")
ax[-1].set_ylabel("$z$")
# ax[-1].set_ylim([-5500,-4200])
ax[-1].set_ylim([-5500,-3800])
ax[-1].legend(loc='lower center')

# fig.savefig(data_path+data_name[:-4]+'_cl_v.png', dpi=300)
```

[18]: <matplotlib.legend.Legend at 0x7fc6b4233ad0>



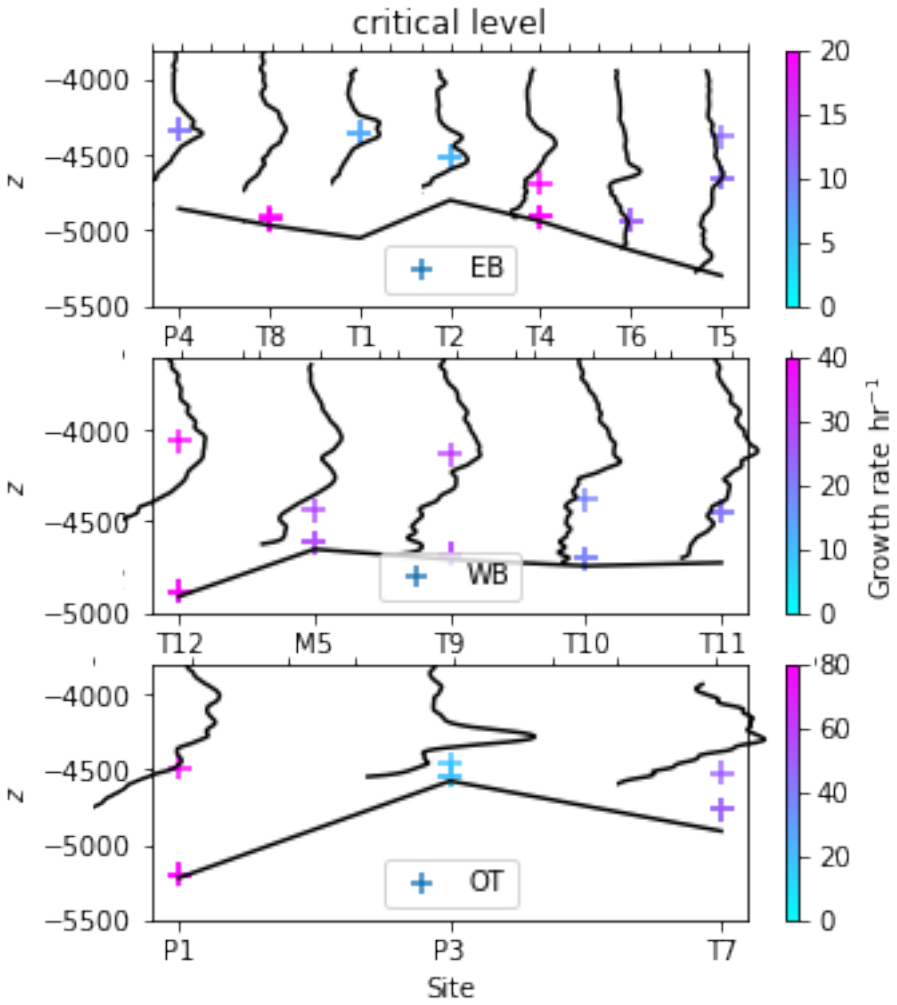
Plot site vs. critical level, colorbar representing the growth rate, black profiles show N^2

[19]:
```
fig, ax =  plt.subplots(nrows=3, ncols=1, figsize=(5, 6))
# EB
for i in range(len(EB_FGM.site)):
    plot_insets(EB_FGM.site[i], 2, [0+.15*i, 0, 0.1, 1], [-7, -5],␣
 ↪[-5500,-3800], ax[0])
ax[0].plot(EB_FGM.site, EB_FGM.bz,'k')
sc = ax[0].scatter(EB_FGM.site, EB_FGM.CL[:,0], c=2*np.pi/EB_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=20, cmap=cm.cool, label="EB")
for i in range(len(EB_FGM.CL[0,:])):
    ax[0].scatter(EB_FGM.site, EB_FGM.CL[:,i], c=2*np.pi/EB_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=20, cmap=cm.cool)
fig.colorbar(sc,label=" ",ax=ax[0])
ax[0].set_title("critical level")
# ax[0].set_xlabel("Site")
ax[0].set_ylabel("$z$")
# ax[0].set_ylim([-5500,-4200])
ax[0].set_ylim([-5500,-3800])
ax[0].legend(loc='lower center')

# WB
for i in range(len(WB_FGM.site)):
    plot_insets(WB_FGM.site[i], 2, [-.05+.23*i, 0, 0.2, 1], [-7, -5],␣
 ↪[-5000,-3600], ax[1])
ax[1].plot(WB_FGM.site, WB_FGM.bz,'k')
sc = ax[1].scatter(WB_FGM.site, WB_FGM.CL[:,0], c=2*np.pi/WB_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=40, cmap=cm.cool, label="WB")
for i in range(len(WB_FGM.CL[0,:])):
    ax[1].scatter(WB_FGM.site, WB_FGM.CL[:,i], c=2*np.pi/WB_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=40, cmap=cm.cool)
fig.colorbar(sc,label="Growth rate hr$^{-1}$",ax=ax[1])
# ax[1].set_xlabel("Site")
ax[1].set_ylabel("$z$")
ax[1].set_ylim([-5000,-3600])
# ax[1].set_ylim([-5000,-4000])
ax[1].legend(loc='lower center')

# OT
for i in range(len(OT_FGM.site)):
    plot_insets(OT_FGM.site[i], 2, [-.1+.44*i, 0, 0.33, 1], [-7, -5],␣
 ↪[-5500,-3800], ax[-1])
ax[-1].plot(OT_FGM.site, OT_FGM.bz,'k')
sc = ax[-1].scatter(OT_FGM.site, OT_FGM.CL[:,0], c=2*np.pi/OT_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=80, cmap=cm.cool, label="OT")
for i in range(len(OT_FGM.CL[0,:])):
```

```
    ax[-1].scatter(OT_FGM.site, OT_FGM.CL[:,i], c=2*np.pi/OT_FGM.GR/3600,␣
 ↪marker='+', s=80, vmin=0, vmax=80, cmap=cm.cool)
fig.colorbar(sc,label=" ",ax=ax[-1])
ax[-1].set_xlabel("Site")
ax[-1].set_ylabel("$z$")
# ax[-1].set_ylim([-5500,-4200])
ax[-1].set_ylim([-5500,-3800])
ax[-1].legend(loc='lower center')

# fig.savefig(data_path+data_name[:-4]+'_cl_n2.png', dpi=300)
```

```
/Users/tantanmeow/anaconda3/lib/python3.7/site-
packages/ipykernel_launcher.py:12: RuntimeWarning: invalid value encountered in
log10
  if sys.path[0] == '':
```

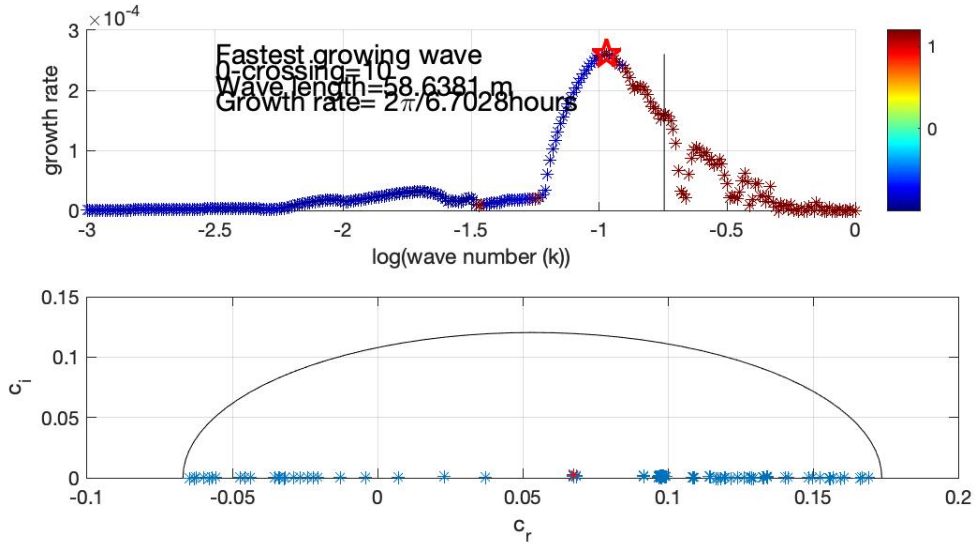
[19]: <matplotlib.legend.Legend at 0x7fc6b4b61690>



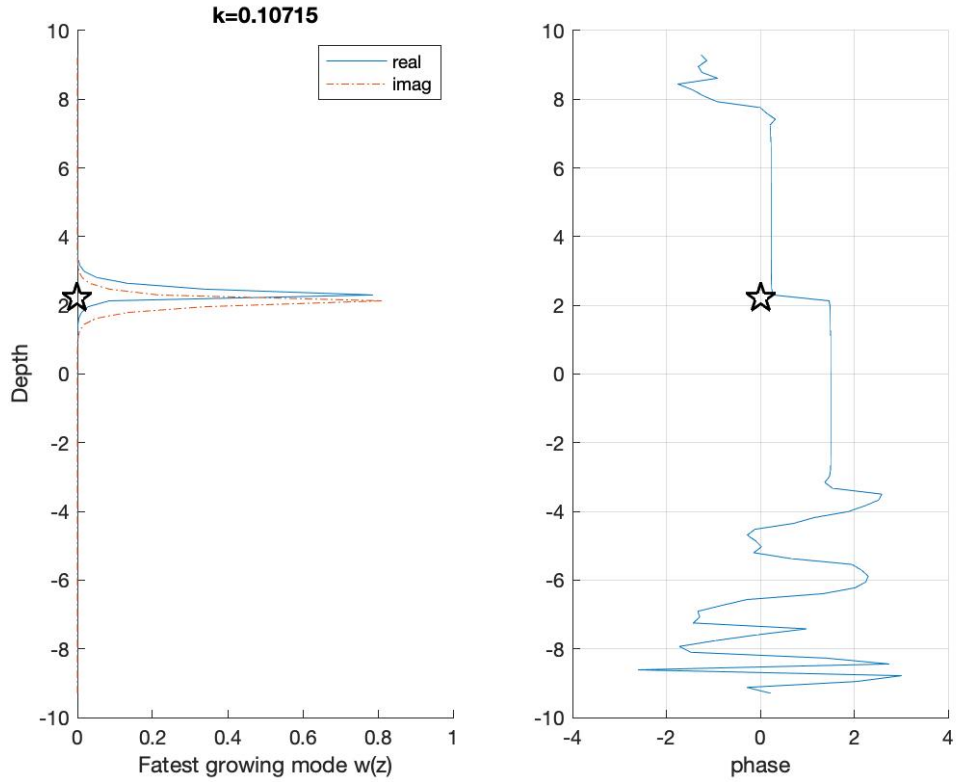
Unstable modes seem to grow very rapidly with critical levels located near the interface of overflow at T1 and T2 (slightly upstream of sill?).

Mooring T1:

Growh rates of the fastest growing mode for different k and the Howard's semicircle:

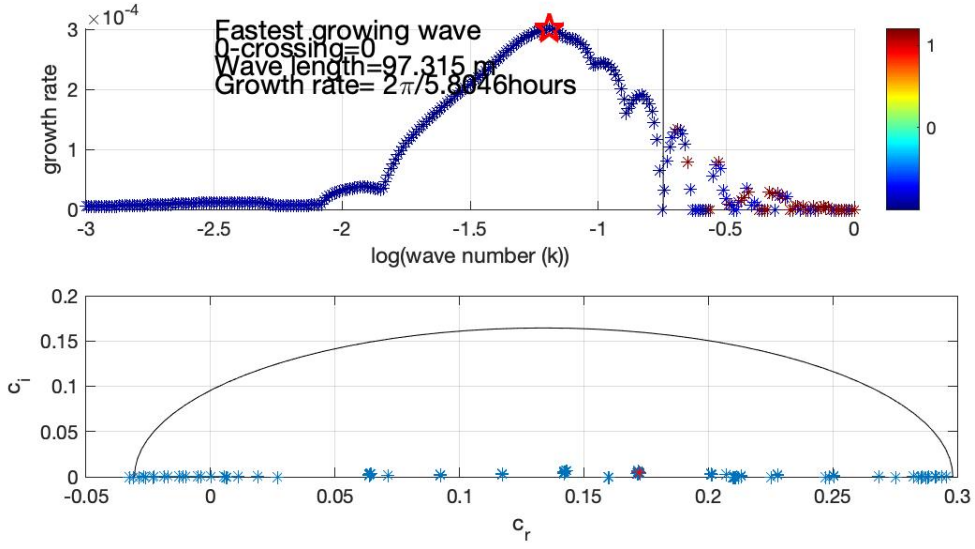


Amplitude and phase (a shift of about 70°) of the fastest growing mode, star represents the critical level:

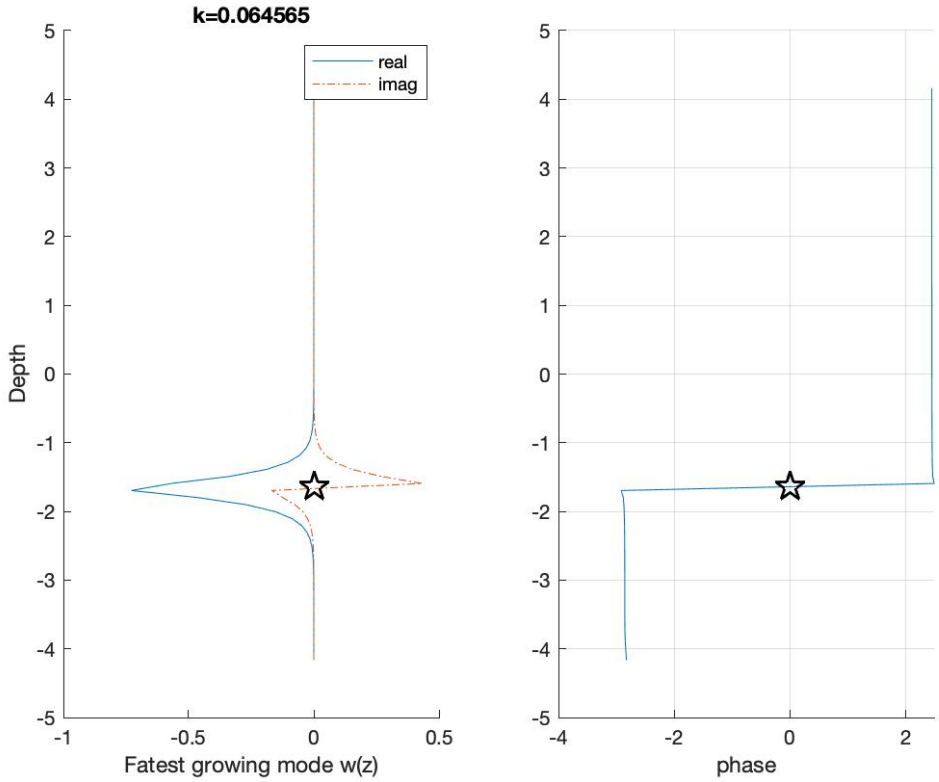


Mooring T2:

Growh rates of the fastest growing mode for different k and the Howard's semicircle:



Amplitude and phase (a shift of about 60°) of the fastest growing mode, star represents the critical level:



2 Read data from .mat and plot FGM (tow-yoo snapshot)

Raw profiles (snapshots) have many overturns and cause violet-shift of the growth rate, suggesting convective instability. I tried to exclude these overturns but found the minimum Ri is typically larger than 1/4...

[15]:
```
6e-4*1000/(2e-5*1.2e+5)
```

[15]:
```
0.24999999999999994
```

[ ]:
```

```