Imports

In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
import netCDF4 as nc
import pandas as pd
from scipy import stats
```

Open files and create date lists

In [2]:
```
nino_set = np.zeros((1032,35))
for i in range(2,36):
    if i<10:
        f1 = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ens
emble/CESM_LE/TREFHT/b.e11.B20TRC5CNBDRD.f09_g16.00%s.cam.h0.TREFHT.1920
01-200512.nc" % i)
    elif i>=10:
        f1 = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ens
emble/CESM_LE/TREFHT/b.e11.B20TRC5CNBDRD.f09_g16.0%s.cam.h0.TREFHT.19200
1-200512.nc" % i)
    nino_temp = np.average(np.average(f1.variables["TREFHT"][:,90:101, 1
52:192], axis = 1), axis = 1)-273
    nino_set[:,i-2] = nino_temp
    print(i, end = " ")
    f1.close()
```

```
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
29 30 31 32 33 34 35
```

In [3]:
```
date_1032 = np.linspace(1920,2005,1032)
```

In [4]:
```
nino_ghg_set = np.zeros((1932,20))
for i in range(1,21):
    if i<10:
        f1 = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ens
emble/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xghg.00%s.cam.h
0.TREFHT.192001-200512.nc" % i)
        f2 = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ens
emble/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xghg.00%s.cam.h
0.TREFHT.200601-208012.nc" % i)
    elif i>=10:
        f1 = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ens
emble/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xghg.0%s.cam.h
0.TREFHT.192001-200512.nc" % i)
        f2 = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ens
emble/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xghg.0%s.cam.h
0.TREFHT.200601-208012.nc" % i)
    nino_ghg_temp = np.concatenate( (np.average(np.average(f1.variables[
"TREFHT"][:,90:101, 152:192], axis = 1), axis = 1),
                                     np.average(np.average(f2.variables["T
REFHT"][:,90:101, 152:192], axis = 1), axis = 1)) ) - 273
    nino_ghg_set[:,i-1] = nino_ghg_temp
    print(i, end = " ")
    f1.close()
    f2.close()
```

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
```

In [5]:
```
nino_aer_set = np.zeros((1932,20))
for i in range(1,21):
    if i<10:
        f1 = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ens
emble/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xaer.00%s.cam.h
0.TREFHT.192001-200512.nc" % i)
        f2 = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ens
emble/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xaer.00%s.cam.h
0.TREFHT.200601-208012.nc" % i)
    elif i>=10:
        f1 = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ens
emble/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xaer.0%s.cam.h
0.TREFHT.192001-200512.nc" % i)
        f2 = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ens
emble/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xaer.0%s.cam.h
0.TREFHT.200601-208012.nc" % i)
    nino_aer_temp = np.concatenate( (np.average(np.average(f1.variables[
"TREFHT"][:,90:101, 152:192], axis = 1), axis = 1),
                                     np.average(np.average(f2.variables["T
REFHT"][:,90:101, 152:192], axis = 1), axis = 1)) ) - 273
    nino_aer_set[:,i-1] = nino_aer_temp
    print(i, end = " ")
    f1.close()
    f2.close()
```

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
```

In [6]:
```
date_1932 = np.linspace(1920,2080,1932)
```

In [7]:
```
nino_bmb_set = np.zeros((1320,15))
for i in range(1,16):
    if i<10:
        f = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ense
mble/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xbmb.00%s.cam.h
0.TREFHT.192001-202912.nc" % i)
    elif i>=10:
        f = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ense
mble/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xbmb.0%s.cam.h0.
TREFHT.192001-202912.nc" % i)
    nino_bmb_temp = np.average(np.average(f.variables["TREFHT"][:,90:101
, 152:192], axis = 1), axis = 1)-273
    nino_bmb_set[:,i-1] = nino_bmb_temp
    print(i, end = " ")
    f.close()
```

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
```

In [8]:
```
nino_lulc_set = np.zeros((1320,5))
for i in range(1,6):
    f = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ensembl
e/CESM1.1.LE_SF/TREFHT/b.e11.B20TRLENS_RCP85.f09_g16.xlulc.00%s.cam.h0.T
REFHT.192001-202912.nc" % i)
    nino_lulc_temp = np.average(np.average(f.variables["TREFHT"][:,90:10
1, 152:192], axis = 1), axis = 1)-273
    nino_lulc_set[:,i-1] = nino_lulc_temp
    print(i, end = " ")
    f.close()
```

```
1 2 3 4 5
```

In [9]:
```
date_1320 = np.linspace(1920,2029,1320)
```

In [10]:
```
nino_fo3_set = np.zeros((612,10))
for i in range(0,10):
    f = nc.Dataset("/Volumes/Extreme SSD/science_research/large_ensembl
e/CESM1.1.LE_SF/TREFHT/b.e11.B20LE_fixedO3_00%s.cam.h0.TREFHT.195501-200
512.nc" % i)
    nino_fo3_temp = np.average(np.average(f.variables["TREFHT"][:,90:101
, 152:192], axis = 1), axis = 1)-273
    nino_fo3_set[:,i] = nino_fo3_temp
    print(i, end = " ")
    f.close()
```

```
0 1 2 3 4 5 6 7 8 9
```

In [11]:
```
date_612 = np.linspace(1955,2005,612)
```

Calculate centered rolling 20-year variance

In [12]:
```
nino_var_set = np.zeros((1032,35))
for i in range(len(nino_set[0,:])):
    nino_var_temp = pd.DataFrame(nino_set[:,i]).rolling(240, center = Tr
ue).var().to_numpy()[:,0]
    nino_var_set[:,i] = nino_var_temp
```

In [13]:
```
nino_ghg_var_set = np.zeros((1932,20))
for i in range(20):
    nino_ghg_var_temp = pd.DataFrame(nino_ghg_set[:,i]).rolling(240, cen
ter = True).var().to_numpy()[:,0]
    nino_ghg_var_set[:,i] = nino_ghg_var_temp
```

In [14]:
```
nino_aer_var_set = np.zeros((1932,20))
for i in range(20):
    nino_aer_var_temp = pd.DataFrame(nino_aer_set[:,i]).rolling(240, cen
ter = True).var().to_numpy()[:,0]
    nino_aer_var_set[:,i] = nino_aer_var_temp
```

In [15]:
```
nino_bmb_var_set = np.zeros((1320,15))
for i in range(15):
    nino_bmb_var_temp = pd.DataFrame(nino_bmb_set[:,i]).rolling(240, cen
ter = True).var().to_numpy()[:,0]
    nino_bmb_var_set[:,i] = nino_bmb_var_temp
```

In [16]:
```
nino_lulc_var_set = np.zeros((1320,5))
for i in range(5):
    nino_lulc_var_temp = pd.DataFrame(nino_lulc_set[:,i]).rolling(240, c
enter = True).var().to_numpy()[:,0]
    nino_lulc_var_set[:,i] = nino_lulc_var_temp
```

In [17]:
```
nino_fo3_var_set = np.zeros((612,10))
for i in range(10):
    nino_fo3_var_temp = pd.DataFrame(nino_fo3_set[:,i]).rolling(240, cen
ter = True).var().to_numpy()[:,0]
    nino_fo3_var_set[:,i] = nino_fo3_var_temp
```

In [18]:
```
nino_var_se = stats.sem(nino_var_set, axis = 1)
nino_var_mean = np.mean(nino_var_set, axis = 1)
```

In [19]:
```
nino_ghg_var_se = stats.sem(nino_ghg_var_set, axis = 1)
nino_ghg_var_mean = np.mean(nino_ghg_var_set, axis = 1)
```

In [20]:
```
nino_aer_var_se = stats.sem(nino_aer_var_set, axis = 1)
nino_aer_var_mean = np.mean(nino_aer_var_set, axis = 1)
```

In [21]:
```
nino_bmb_var_se = stats.sem(nino_bmb_var_set, axis = 1)
nino_bmb_var_mean = np.mean(nino_bmb_var_set, axis = 1)
```

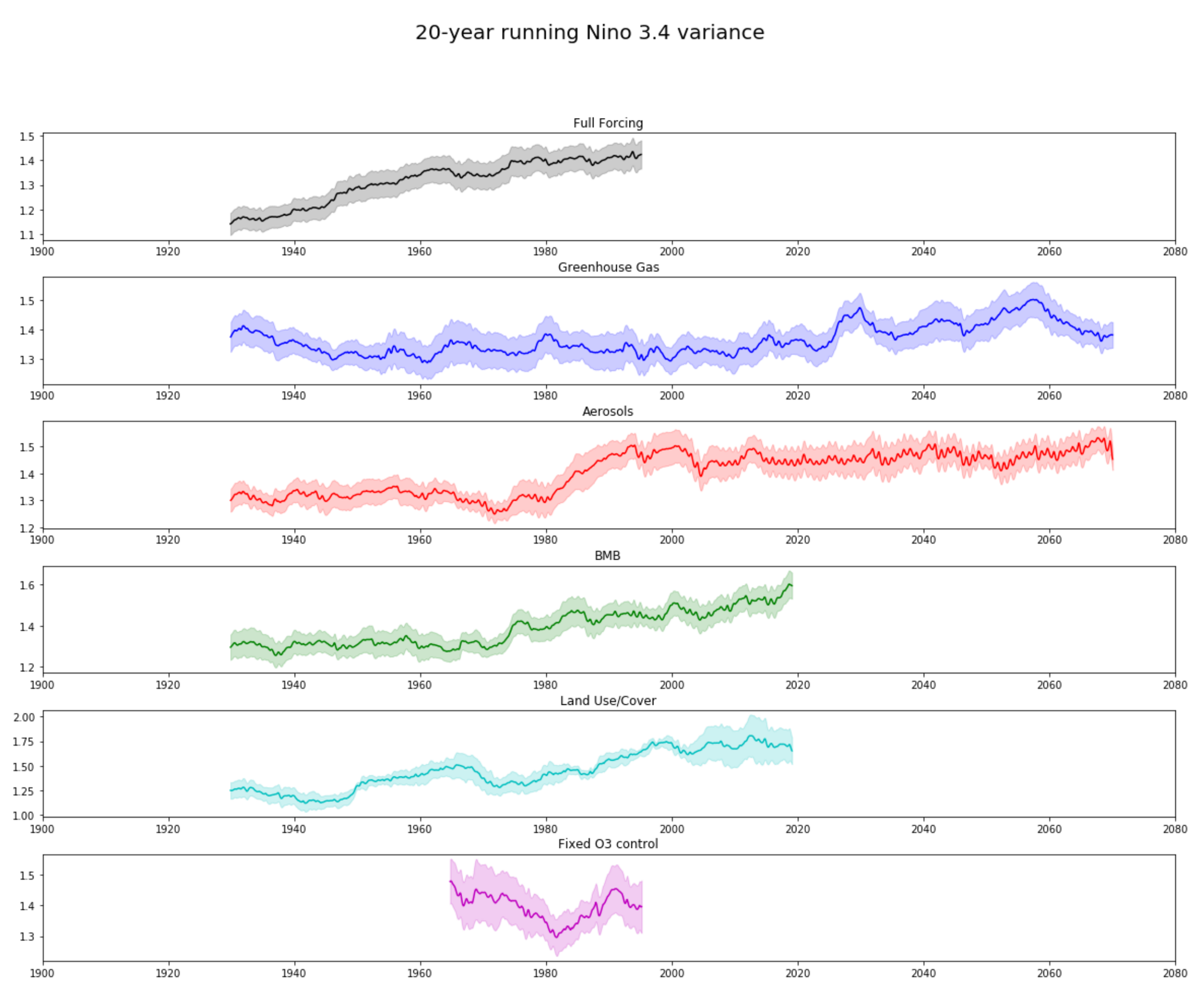
In [22]:
```
nino_lulc_var_se = stats.sem(nino_lulc_var_set, axis = 1)
nino_lulc_var_mean = np.mean(nino_lulc_var_set, axis = 1)
```

In [23]:
```
nino_fo3_var_se = stats.sem(nino_fo3_var_set, axis = 1)
nino_fo3_var_mean = np.mean(nino_fo3_var_set, axis = 1)
```

In [24]:
```
nino_var_se_avg = np.nanmean(nino_var_se)
nino_ghg_var_se_avg = np.nanmean(nino_ghg_var_se)
nino_aer_var_se_avg = np.nanmean(nino_aer_var_se)
nino_bmb_var_se_avg = np.nanmean(nino_bmb_var_se)
nino_lulc_var_se_avg = np.nanmean(nino_lulc_var_se)
nino_fo3_var_se_avg = np.nanmean(nino_fo3_var_se)
```

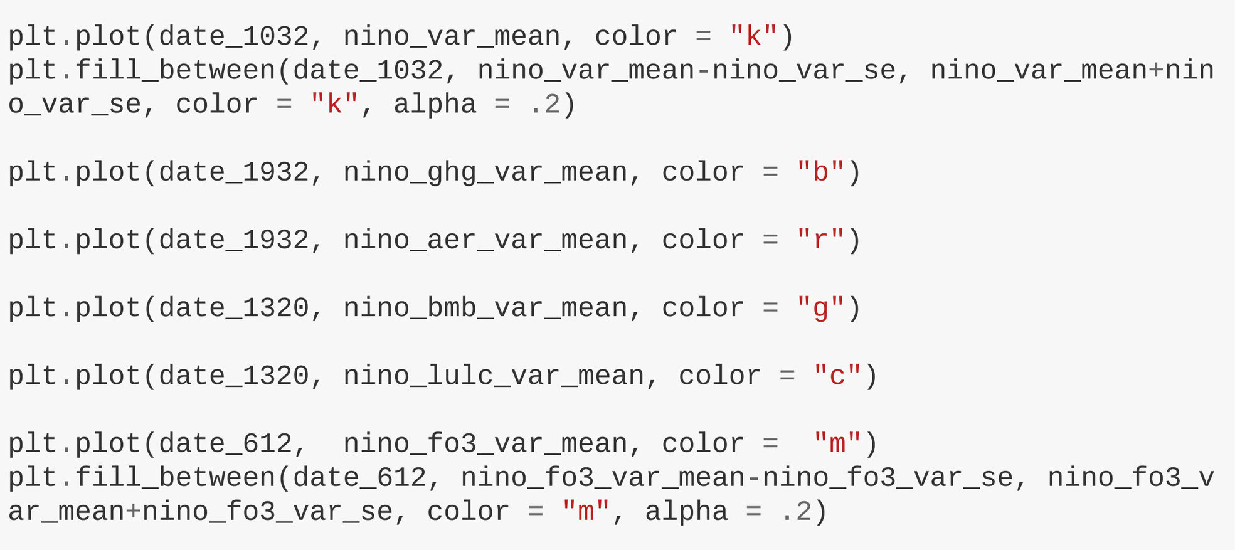
In [93]:
```
plt.figure(figsize = (20,15))
plt.subplots_adjust(hspace = .35)
plt.suptitle("20-year running Nino 3.4 variance", fontsize = 20)

plt.subplot(6,1,1)
plt.plot(date_1032, nino_var_mean, color = "k")
plt.fill_between(date_1032, nino_var_mean-nino_var_se, nino_var_mean+nin
o_var_se, color = "k", alpha = .2)
plt.xlim(1900,2080)
plt.title("Full Forcing")

plt.subplot(6,1,2)
plt.plot(date_1932, nino_ghg_var_mean, color = "b")
plt.fill_between(date_1932, nino_ghg_var_mean-nino_ghg_var_se, nino_ghg_
var_mean+nino_ghg_var_se, color = "b", alpha = .2)
plt.xlim(1900,2080)
plt.title("Greenhouse Gas")

plt.subplot(6,1,3)
plt.plot(date_1932, nino_aer_var_mean, color = "r")
plt.fill_between(date_1932, nino_aer_var_mean-nino_aer_var_se, nino_aer_
var_mean+nino_aer_var_se, color = "r", alpha = .2)
plt.xlim(1900,2080)
plt.title("Aerosols")

plt.subplot(6,1,4)
plt.plot(date_1320, nino_bmb_var_mean, color = "g")
plt.fill_between(date_1320, nino_bmb_var_mean-nino_bmb_var_se, nino_bmb_
var_mean+nino_bmb_var_se, color = "g", alpha = .2)
plt.xlim(1900,2080)
plt.title("BMB")

plt.subplot(6,1,5)
plt.plot(date_1320, nino_lulc_var_mean, color = "c")
plt.fill_between(date_1320, nino_lulc_var_mean-nino_lulc_var_se, nino_lu
lc_var_mean+nino_lulc_var_se, color = "c", alpha = .2)
plt.xlim(1900,2080)
plt.title("Land Use/Cover")

plt.subplot(6,1,6)
plt.plot(date_612,  nino_fo3_var_mean, color =  "m")
plt.fill_between(date_612, nino_fo3_var_mean-nino_fo3_var_se, nino_fo3_v
ar_mean+nino_fo3_var_se, color = "m", alpha = .2)
plt.xlim(1900,2080)
plt.title("Fixed O3 control")
```

Out[93]:
```
Text(0.5, 1.0, 'Fixed O3 control')
```



In [95]:
```
plt.figure(figsize = (20,7))
plt.suptitle("20-year running Nino 3.4 variance", fontsize = 20)

plt.plot(date_1032, nino_var_mean, color = "k")
plt.fill_between(date_1032, nino_var_mean-nino_var_se, nino_var_mean+nin
o_var_se, color = "k", alpha = .2)

plt.plot(date_1932, nino_ghg_var_mean, color = "b")

plt.plot(date_1932, nino_aer_var_mean, color = "r")

plt.plot(date_1320, nino_bmb_var_mean, color = "g")

plt.plot(date_1320, nino_lulc_var_mean, color = "c")

plt.plot(date_612,  nino_fo3_var_mean, color =  "m")
plt.fill_between(date_612, nino_fo3_var_mean-nino_fo3_var_se, nino_fo3_v
ar_mean+nino_fo3_var_se, color = "m", alpha = .2)

plt.legend(["Full forcing", "Greenhouse gas", "Aerosols", "BMB", "Land u
se/cover", "Fixed O3 control"])
```

Out[95]:
```
<matplotlib.legend.Legend at 0x12c813550>
```



In [26]:
```
plt.figure(figsize = (10,5))
plt.bar(["full forcing", "greenhouse gasses", "aerosols","bmb", "land us
e/cover", "fixed O3"], [nino_var_se_avg, nino_ghg_var_se_avg, nino_aer_v
ar_se_avg, nino_bmb_var_se_avg, nino_lulc_var_se_avg, nino_fo3_var_se_av
g ], color = ["k", "b", "r", "g", "c", "m"])
plt.title("Average Nino 3.4 variance standard error among ensemble model
s")
plt.ylabel("Standerd error C")
plt.xlabel("Ensemble")
```

Out[26]:
```
Text(0.5, 0, 'Ensemble')
```