GP_tas

November 28, 2024

[1]:
```
# imports
import numpy as np
import xarray as xr
import pandas as pd
import matplotlib.pyplot as plt
import cartopy.crs as ccrs
from esem import gp_model
from eofs.xarray import Eof
from utils import *
import gpflow
```

```
2024-11-22 05:56:39.406626: I tensorflow/core/util/port.cc:153] oneDNN custom
operations are on. You may see slightly different numerical results due to
floating-point round-off errors from different computation orders. To turn them
off, set the environment variable `TF_ENABLE_ONEDNN_OPTS=0`.
2024-11-22 05:56:39.436588: E
external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:477] Unable to register
cuFFT factory: Attempting to register factory for plugin cuFFT when one has
already been registered
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
E0000 00:00:1732280199.474419   12989 cuda_dnn.cc:8310] Unable to register cuDNN
factory: Attempting to register factory for plugin cuDNN when one has already
been registered
E0000 00:00:1732280199.484498   12989 cuda_blas.cc:1418] Unable to register
cuBLAS factory: Attempting to register factory for plugin cuBLAS when one has
already been registered
2024-11-22 05:56:39.521904: I tensorflow/core/platform/cpu_feature_guard.cc:210]
This TensorFlow binary is optimized to use available CPU instructions in
performance-critical operations.
To enable the following instructions: AVX2 AVX512F AVX512_VNNI FMA, in other
operations, rebuild TensorFlow with the appropriate compiler flags.
```

[2]:
```
# list of experiment data used for training

train_files= ['ssp126', 'ssp370', 'ssp585', 'historical', 'hist-GHG',␣
 ↪'hist-aer']
```

0.0.1 prepare data

[3]:
```
# get data
Xtrain, eof_solvers = get_Xtrain(train_files)
Ytrain_tas = get_Ytrain(train_files)['tas'].values.reshape(-1, 96*144)

Xtest = get_Xtest('ssp245', eof_solvers)
Ytest = xr.open_dataset('../test/outputs_ssp245.nc').compute()
tas_truth = Ytest['tas'].mean('member')
```

[4]:
```
# drop rows including nans
train_nan_mask = Xtrain.isna().any(axis=1).values
Xtrain = Xtrain.dropna(axis=0, how='any')
Ytrain_tas = Ytrain_tas[~train_nan_mask]
assert Xtrain.shape[0]==Ytrain_tas.shape[0]

test_nan_mask = Xtest.isna().any(axis=1).values
Xtest = Xtest.dropna(axis=0, how='any')
tas_truth = tas_truth[~test_nan_mask]
```

[5]:
```
# Standardize predictor fields requiring standardization (non-EOFs)
train_CO2_mean, train_CO2_std = Xtrain['CO2'].mean(), Xtrain['CO2'].std()
train_CH4_mean, train_CH4_std = Xtrain['CH4'].mean(), Xtrain['CH4'].std()

Xtrain['CO2'] = (Xtrain['CO2'] - train_CO2_mean) / train_CO2_std
Xtrain['CH4'] = (Xtrain['CH4'] - train_CH4_mean) / train_CH4_std

Xtest['CO2'] = (Xtest['CO2'] - train_CO2_mean) / train_CO2_std
Xtest['CH4'] = (Xtest['CH4'] - train_CH4_mean) / train_CH4_std
```

[6]:
```
# Standardize predictand fields
train_tas_mean, train_tas_std = Ytrain_tas.mean(), Ytrain_tas.std()
Ytrain_tas = (Ytrain_tas - train_tas_mean) / train_tas_std
```

0.0.2 Model

[7]:
```
kernel_CO2 = gpflow.kernels.Matern32(active_dims=[0]) # active_dims specifies␣
 ↪which dimension the kernel is applied to
kernel_CH4 = gpflow.kernels.Matern32(active_dims=[1])

kernel_BC = gpflow.kernels.Matern32(lengthscales=5 * [1.], active_dims=[2, 3,␣
 ↪4, 5, 6])
kernel_SO2 = gpflow.kernels.Matern32(lengthscales=5 * [1.], active_dims=[7, 8,␣
 ↪9, 10, 11])

kernel = kernel_CO2 + kernel_CH4 + kernel_BC + kernel_SO2
```

```
2024-11-22 05:56:50.740753: E
external/local_xla/xla/stream_executor/cuda/cuda_driver.cc:152] failed call to
cuInit: INTERNAL: CUDA error: Failed call to cuInit: CUDA_ERROR_NO_DEVICE: no
CUDA-capable device is detected
```

[8]:
```
np.random.seed(5)

"""
In Gaussian Processes, a mean function represents the "prior mean" or the␣
 ↪expected value
of the function at any input point before observing any data.
"""
mean = gpflow.mean_functions.Constant()

model = gpflow.models.GPR(data=(Xtrain.astype(np.float64), # cast to float64␣
 ↪because gpflow requires numerical stability
                                Ytrain_tas.astype(np.float64)),
                          kernel = kernel,
                          mean_function = mean)
```

[9]:
```
# define optimizer
optimizer = gpflow.optimizers.Scipy()

# train
optimizer.minimize(model.training_loss,
                   variables=model.trainable_variables,
                   options=dict(disp=True, maxiter=1000))
```

```
RUNNING THE L-BFGS-B CODE

           * * *

Machine precision = 2.220D-16
 N =           18     M =           10

At X0         0 variables are exactly at the bounds

At iterate    0    f=  1.13217D+07    |proj g|=  2.67230D+06
 This problem is unconstrained.

At iterate    1    f=  4.82303D+06    |proj g|=  1.26698D+06

At iterate    2    f=  4.48292D+06    |proj g|=  2.01988D+05

At iterate    3    f=  4.43305D+06    |proj g|=  1.95157D+05

At iterate    4    f=  3.96845D+06    |proj g|=  8.74004D+05
```

```
At iterate    5    f=  3.66381D+06    |proj g|=  5.16420D+05

At iterate    6    f=  3.56577D+06    |proj g|=  3.42930D+04

At iterate    7    f=  3.55850D+06    |proj g|=  4.04827D+04

At iterate    8    f=  3.55670D+06    |proj g|=  2.25590D+04

At iterate    9    f=  3.55307D+06    |proj g|=  2.53873D+04

At iterate   10    f=  3.54807D+06    |proj g|=  7.91032D+04

At iterate   11    f=  3.54114D+06    |proj g|=  1.08116D+05

At iterate   12    f=  3.53402D+06    |proj g|=  7.39213D+04

At iterate   13    f=  3.53133D+06    |proj g|=  1.06670D+04

At iterate   14    f=  3.53081D+06    |proj g|=  1.03119D+04

At iterate   15    f=  3.53043D+06    |proj g|=  2.44562D+04

At iterate   16    f=  3.52925D+06    |proj g|=  4.77052D+04

At iterate   17    f=  3.52740D+06    |proj g|=  6.42461D+04

At iterate   18    f=  3.52274D+06    |proj g|=  7.89284D+04

At iterate   19    f=  3.51562D+06    |proj g|=  5.90551D+04

At iterate   20    f=  3.49964D+06    |proj g|=  1.00151D+05

At iterate   21    f=  3.49167D+06    |proj g|=  2.46462D+04

At iterate   22    f=  3.48730D+06    |proj g|=  1.24805D+04

At iterate   23    f=  3.48331D+06    |proj g|=  2.85831D+04

At iterate   24    f=  3.47876D+06    |proj g|=  1.04796D+05

At iterate   25    f=  3.47163D+06    |proj g|=  3.04667D+04

At iterate   26    f=  3.46415D+06    |proj g|=  5.28998D+04

At iterate   27    f=  3.46020D+06    |proj g|=  4.34784D+04

At iterate   28    f=  3.44501D+06    |proj g|=  9.51115D+04
```

```
At iterate   29    f=  3.42971D+06    |proj g|=  2.40140D+05

At iterate   30    f=  3.40605D+06    |proj g|=  1.14705D+05

At iterate   31    f=  3.38744D+06    |proj g|=  5.02413D+04

At iterate   32    f=  3.37918D+06    |proj g|=  3.95833D+04

At iterate   33    f=  3.37638D+06    |proj g|=  3.19371D+04

At iterate   34    f=  3.36912D+06    |proj g|=  1.50318D+04

At iterate   35    f=  3.36255D+06    |proj g|=  3.78830D+04

At iterate   36    f=  3.36221D+06    |proj g|=  4.07795D+04

At iterate   37    f=  3.36021D+06    |proj g|=  2.84120D+04

At iterate   38    f=  3.35941D+06    |proj g|=  2.37755D+04

At iterate   39    f=  3.35863D+06    |proj g|=  6.27852D+03

At iterate   40    f=  3.35768D+06    |proj g|=  5.66888D+03

At iterate   41    f=  3.35673D+06    |proj g|=  7.91474D+04

At iterate   42    f=  3.35531D+06    |proj g|=  2.93686D+04

At iterate   43    f=  3.35394D+06    |proj g|=  8.65880D+03

At iterate   44    f=  3.35033D+06    |proj g|=  5.12905D+04

At iterate   45    f=  3.34617D+06    |proj g|=  6.43522D+04

At iterate   46    f=  3.34360D+06    |proj g|=  4.63634D+04

At iterate   47    f=  3.34296D+06    |proj g|=  1.85511D+04

At iterate   48    f=  3.34226D+06    |proj g|=  9.95568D+03

At iterate   49    f=  3.34160D+06    |proj g|=  1.16067D+04

At iterate   50    f=  3.34072D+06    |proj g|=  4.23515D+04

At iterate   51    f=  3.33972D+06    |proj g|=  3.94585D+04

At iterate   52    f=  3.33918D+06    |proj g|=  1.62003D+04
```

```
At iterate   53    f=  3.33844D+06    |proj g|=  1.21809D+04

At iterate   54    f=  3.33783D+06    |proj g|=  3.69220D+04

At iterate   55    f=  3.33741D+06    |proj g|=  7.91862D+03

At iterate   56    f=  3.33734D+06    |proj g|=  3.90081D+03

At iterate   57    f=  3.33725D+06    |proj g|=  6.20453D+03

At iterate   58    f=  3.33711D+06    |proj g|=  9.96080D+03

At iterate   59    f=  3.33692D+06    |proj g|=  9.23463D+03

At iterate   60    f=  3.33680D+06    |proj g|=  4.59800D+03

At iterate   61    f=  3.33669D+06    |proj g|=  2.10052D+03

At iterate   62    f=  3.33646D+06    |proj g|=  1.74887D+04

At iterate   63    f=  3.33635D+06    |proj g|=  1.16636D+04

At iterate   64    f=  3.33598D+06    |proj g|=  1.51387D+04

At iterate   65    f=  3.33576D+06    |proj g|=  2.28469D+04

At iterate   66    f=  3.33514D+06    |proj g|=  1.81558D+04

At iterate   67    f=  3.33450D+06    |proj g|=  2.29715D+04

At iterate   68    f=  3.33374D+06    |proj g|=  1.44320D+04

At iterate   69    f=  3.33295D+06    |proj g|=  7.31874D+03

At iterate   70    f=  3.33257D+06    |proj g|=  3.36230D+03

At iterate   71    f=  3.33207D+06    |proj g|=  3.45544D+03

At iterate   72    f=  3.33153D+06    |proj g|=  1.63860D+04

At iterate   73    f=  3.33098D+06    |proj g|=  1.08228D+04

At iterate   74    f=  3.33054D+06    |proj g|=  3.46484D+04

At iterate   75    f=  3.33018D+06    |proj g|=  1.87449D+04

At iterate   76    f=  3.33001D+06    |proj g|=  7.50881D+03
```

```
At iterate   77    f=  3.32979D+06    |proj g|=  2.80490D+03

At iterate   78    f=  3.32959D+06    |proj g|=  9.38419D+03

At iterate   79    f=  3.32950D+06    |proj g|=  9.02028D+03

At iterate   80    f=  3.32897D+06    |proj g|=  4.44488D+03

At iterate   81    f=  3.32857D+06    |proj g|=  2.38136D+03

At iterate   82    f=  3.32813D+06    |proj g|=  3.05543D+03

At iterate   83    f=  3.32799D+06    |proj g|=  6.00414D+03

At iterate   84    f=  3.32787D+06    |proj g|=  3.10520D+03

At iterate   85    f=  3.32777D+06    |proj g|=  1.33270D+03

At iterate   86    f=  3.32772D+06    |proj g|=  1.42600D+04

At iterate   87    f=  3.32757D+06    |proj g|=  5.08993D+03

At iterate   88    f=  3.32737D+06    |proj g|=  2.67747D+03

At iterate   89    f=  3.32720D+06    |proj g|=  4.23206D+03

At iterate   90    f=  3.32707D+06    |proj g|=  1.21001D+04

At iterate   91    f=  3.32698D+06    |proj g|=  3.86567D+03

At iterate   92    f=  3.32694D+06    |proj g|=  2.41970D+03

At iterate   93    f=  3.32686D+06    |proj g|=  1.76758D+03

At iterate   94    f=  3.32666D+06    |proj g|=  3.34677D+03

At iterate   95    f=  3.32646D+06    |proj g|=  7.37406D+03

At iterate   96    f=  3.32606D+06    |proj g|=  3.98647D+03

At iterate   97    f=  3.32556D+06    |proj g|=  2.02875D+04

At iterate   98    f=  3.32545D+06    |proj g|=  1.80286D+03

At iterate   99    f=  3.32543D+06    |proj g|=  1.68135D+03

At iterate  100    f=  3.32537D+06    |proj g|=  1.18608D+03
```

```
At iterate  101    f=  3.32526D+06    |proj g|=  4.65420D+03

At iterate  102    f=  3.32523D+06    |proj g|=  1.21041D+03

At iterate  103    f=  3.32521D+06    |proj g|=  9.92304D+02

At iterate  104    f=  3.32512D+06    |proj g|=  1.53304D+03

At iterate  105    f=  3.32500D+06    |proj g|=  1.83076D+03

At iterate  106    f=  3.32489D+06    |proj g|=  3.02406D+03

At iterate  107    f=  3.32475D+06    |proj g|=  5.61759D+03

At iterate  108    f=  3.32467D+06    |proj g|=  4.40405D+03

At iterate  109    f=  3.32464D+06    |proj g|=  6.25461D+03

At iterate  110    f=  3.32459D+06    |proj g|=  3.42202D+03

At iterate  111    f=  3.32453D+06    |proj g|=  2.34755D+03

At iterate  112    f=  3.32448D+06    |proj g|=  2.68780D+03

At iterate  113    f=  3.32434D+06    |proj g|=  1.07797D+04

At iterate  114    f=  3.32415D+06    |proj g|=  6.30981D+03

At iterate  115    f=  3.32397D+06    |proj g|=  7.67708D+03

At iterate  116    f=  3.32387D+06    |proj g|=  1.33196D+04

At iterate  117    f=  3.32373D+06    |proj g|=  3.01839D+03

At iterate  118    f=  3.32370D+06    |proj g|=  6.84407D+02

At iterate  119    f=  3.32369D+06    |proj g|=  1.15541D+03

At iterate  120    f=  3.32369D+06    |proj g|=  1.87815D+03

At iterate  121    f=  3.32369D+06    |proj g|=  7.19926D+02

At iterate  122    f=  3.32368D+06    |proj g|=  7.32770D+02

At iterate  123    f=  3.32367D+06    |proj g|=  7.11818D+02

At iterate  124    f=  3.32365D+06    |proj g|=  5.86931D+02
```

```
At iterate  125    f=  3.32364D+06    |proj g|=  3.25160D+03

At iterate  126    f=  3.32361D+06    |proj g|=  1.19100D+03

At iterate  127    f=  3.32358D+06    |proj g|=  8.66725D+02

At iterate  128    f=  3.32355D+06    |proj g|=  2.61690D+03

At iterate  129    f=  3.32352D+06    |proj g|=  6.00188D+03

At iterate  130    f=  3.32345D+06    |proj g|=  1.56897D+03

At iterate  131    f=  3.32335D+06    |proj g|=  8.96093D+03

At iterate  132    f=  3.32334D+06    |proj g|=  1.88338D+03

At iterate  133    f=  3.32332D+06    |proj g|=  1.26723D+03

At iterate  134    f=  3.32330D+06    |proj g|=  2.74692D+03

At iterate  135    f=  3.32327D+06    |proj g|=  2.17953D+03

At iterate  136    f=  3.32322D+06    |proj g|=  1.36984D+03

At iterate  137    f=  3.32317D+06    |proj g|=  2.00095D+03

At iterate  138    f=  3.32308D+06    |proj g|=  2.66260D+03

At iterate  139    f=  3.32289D+06    |proj g|=  6.16072D+03

At iterate  140    f=  3.32272D+06    |proj g|=  6.08054D+03

At iterate  141    f=  3.32270D+06    |proj g|=  1.35864D+04

At iterate  142    f=  3.32251D+06    |proj g|=  7.42808D+03

At iterate  143    f=  3.32249D+06    |proj g|=  3.72501D+03

At iterate  144    f=  3.32242D+06    |proj g|=  5.27134D+03

At iterate  145    f=  3.32227D+06    |proj g|=  4.74938D+03

At iterate  146    f=  3.32210D+06    |proj g|=  5.17582D+03

At iterate  147    f=  3.32192D+06    |proj g|=  5.37540D+03

At iterate  148    f=  3.32170D+06    |proj g|=  3.70009D+03
```

```
At iterate  149    f=  3.32149D+06    |proj g|=  3.29349D+03

At iterate  150    f=  3.32148D+06    |proj g|=  2.67211D+03

At iterate  151    f=  3.32136D+06    |proj g|=  1.22176D+03

At iterate  152    f=  3.32132D+06    |proj g|=  1.10777D+03

At iterate  153    f=  3.32129D+06    |proj g|=  2.57933D+03

At iterate  154    f=  3.32128D+06    |proj g|=  5.37792D+03

At iterate  155    f=  3.32124D+06    |proj g|=  3.20188D+03

At iterate  156    f=  3.32119D+06    |proj g|=  1.18095D+03

At iterate  157    f=  3.32113D+06    |proj g|=  1.63833D+03

At iterate  158    f=  3.32103D+06    |proj g|=  2.26825D+03

At iterate  159    f=  3.32092D+06    |proj g|=  3.30564D+03

At iterate  160    f=  3.32083D+06    |proj g|=  3.21916D+03

At iterate  161    f=  3.32073D+06    |proj g|=  2.50760D+03

At iterate  162    f=  3.32068D+06    |proj g|=  8.71262D+02

At iterate  163    f=  3.32064D+06    |proj g|=  7.28799D+02

At iterate  164    f=  3.32063D+06    |proj g|=  4.83549D+02

At iterate  165    f=  3.32063D+06    |proj g|=  2.98676D+03

At iterate  166    f=  3.32062D+06    |proj g|=  1.99952D+03

At iterate  167    f=  3.32061D+06    |proj g|=  6.25608D+02

At iterate  168    f=  3.32060D+06    |proj g|=  6.51833D+02

At iterate  169    f=  3.32059D+06    |proj g|=  6.38540D+02

At iterate  170    f=  3.32059D+06    |proj g|=  1.07091D+03

At iterate  171    f=  3.32058D+06    |proj g|=  1.27919D+03

At iterate  172    f=  3.32057D+06    |proj g|=  7.67874D+02
```

```
At iterate  173    f=  3.32057D+06    |proj g|=  3.73295D+02

At iterate  174    f=  3.32055D+06    |proj g|=  3.17291D+02

At iterate  175    f=  3.32054D+06    |proj g|=  8.97018D+02

At iterate  176    f=  3.32054D+06    |proj g|=  2.24342D+03

At iterate  177    f=  3.32053D+06    |proj g|=  2.24195D+02

At iterate  178    f=  3.32052D+06    |proj g|=  2.48936D+02

At iterate  179    f=  3.32052D+06    |proj g|=  1.37371D+03

At iterate  180    f=  3.32052D+06    |proj g|=  8.72965D+02

At iterate  181    f=  3.32051D+06    |proj g|=  5.20548D+02

At iterate  182    f=  3.32050D+06    |proj g|=  6.67732D+02

At iterate  183    f=  3.32050D+06    |proj g|=  3.84871D+02

At iterate  184    f=  3.32050D+06    |proj g|=  6.85237D+02

At iterate  185    f=  3.32049D+06    |proj g|=  7.07558D+02

At iterate  186    f=  3.32049D+06    |proj g|=  1.20166D+03

At iterate  187    f=  3.32048D+06    |proj g|=  1.19243D+03

At iterate  188    f=  3.32048D+06    |proj g|=  3.03753D+03

At iterate  189    f=  3.32048D+06    |proj g|=  2.15288D+03

At iterate  190    f=  3.32047D+06    |proj g|=  2.50623D+03

At iterate  191    f=  3.32046D+06    |proj g|=  1.11328D+03

At iterate  192    f=  3.32046D+06    |proj g|=  8.28892D+02

At iterate  193    f=  3.32045D+06    |proj g|=  1.44770D+03

At iterate  194    f=  3.32044D+06    |proj g|=  1.11224D+03

At iterate  195    f=  3.32044D+06    |proj g|=  8.68629D+02

At iterate  196    f=  3.32042D+06    |proj g|=  6.74491D+02
```

```
At iterate  197    f=  3.32041D+06    |proj g|=  3.68214D+03

At iterate  198    f=  3.32040D+06    |proj g|=  1.80949D+03

At iterate  199    f=  3.32039D+06    |proj g|=  5.91429D+02

At iterate  200    f=  3.32039D+06    |proj g|=  1.03848D+03

At iterate  201    f=  3.32039D+06    |proj g|=  9.23820D+02

At iterate  202    f=  3.32039D+06    |proj g|=  1.94186D+03

At iterate  203    f=  3.32038D+06    |proj g|=  1.97667D+03

At iterate  204    f=  3.32036D+06    |proj g|=  4.70923D+02

At iterate  205    f=  3.32035D+06    |proj g|=  6.12270D+02

At iterate  206    f=  3.32034D+06    |proj g|=  1.42709D+03

At iterate  207    f=  3.32032D+06    |proj g|=  1.28774D+03

At iterate  208    f=  3.32032D+06    |proj g|=  2.55568D+03

At iterate  209    f=  3.32031D+06    |proj g|=  9.94888D+02

At iterate  210    f=  3.32031D+06    |proj g|=  3.10989D+02

At iterate  211    f=  3.32031D+06    |proj g|=  5.06497D+02

At iterate  212    f=  3.32030D+06    |proj g|=  1.82109D+03

At iterate  213    f=  3.32030D+06    |proj g|=  6.40317D+02

At iterate  214    f=  3.32030D+06    |proj g|=  2.07974D+03

At iterate  215    f=  3.32029D+06    |proj g|=  1.03301D+03

At iterate  216    f=  3.32029D+06    |proj g|=  9.66147D+02

At iterate  217    f=  3.32029D+06    |proj g|=  1.40000D+03

At iterate  218    f=  3.32028D+06    |proj g|=  1.37257D+03

At iterate  219    f=  3.32028D+06    |proj g|=  9.85662D+02

At iterate  220    f=  3.32027D+06    |proj g|=  2.97499D+03
```

```
At iterate  221    f=  3.32027D+06    |proj g|=  1.14360D+03

At iterate  222    f=  3.32027D+06    |proj g|=  2.89611D+02

At iterate  223    f=  3.32027D+06    |proj g|=  5.52158D+02

At iterate  224    f=  3.32027D+06    |proj g|=  1.16281D+03

At iterate  225    f=  3.32026D+06    |proj g|=  2.42002D+02

At iterate  226    f=  3.32026D+06    |proj g|=  1.00361D+03

At iterate  227    f=  3.32026D+06    |proj g|=  1.25899D+02

At iterate  228    f=  3.32026D+06    |proj g|=  1.82802D+02

At iterate  229    f=  3.32026D+06    |proj g|=  6.59440D+02

At iterate  230    f=  3.32026D+06    |proj g|=  1.05080D+03

At iterate  231    f=  3.32026D+06    |proj g|=  1.19963D+03

At iterate  232    f=  3.32026D+06    |proj g|=  1.25875D+03

At iterate  233    f=  3.32026D+06    |proj g|=  3.59096D+02

At iterate  234    f=  3.32026D+06    |proj g|=  3.99531D+02

At iterate  235    f=  3.32026D+06    |proj g|=  3.77417D+02

At iterate  236    f=  3.32025D+06    |proj g|=  6.58201D+02

At iterate  237    f=  3.32025D+06    |proj g|=  3.42496D+02

At iterate  238    f=  3.32025D+06    |proj g|=  1.85631D+03

At iterate  239    f=  3.32025D+06    |proj g|=  1.84665D+02

At iterate  240    f=  3.32025D+06    |proj g|=  4.46624D+02

At iterate  241    f=  3.32025D+06    |proj g|=  6.70266D+02

At iterate  242    f=  3.32025D+06    |proj g|=  3.14934D+02

At iterate  243    f=  3.32024D+06    |proj g|=  4.20348D+02

At iterate  244    f=  3.32024D+06    |proj g|=  1.81041D+02
```

```
At iterate  245    f=  3.32024D+06    |proj g|=  4.80522D+02

At iterate  246    f=  3.32024D+06    |proj g|=  7.63756D+02

At iterate  247    f=  3.32024D+06    |proj g|=  8.33176D+02

At iterate  248    f=  3.32024D+06    |proj g|=  1.61596D+03

At iterate  249    f=  3.32024D+06    |proj g|=  7.82822D+02

At iterate  250    f=  3.32024D+06    |proj g|=  4.13953D+02

At iterate  251    f=  3.32024D+06    |proj g|=  8.13435D+02

At iterate  252    f=  3.32023D+06    |proj g|=  1.39714D+03

At iterate  253    f=  3.32023D+06    |proj g|=  1.67329D+03

At iterate  254    f=  3.32023D+06    |proj g|=  5.91579D+02

At iterate  255    f=  3.32023D+06    |proj g|=  1.52678D+03

At iterate  256    f=  3.32022D+06    |proj g|=  4.64391D+02

At iterate  257    f=  3.32022D+06    |proj g|=  5.61829D+02

At iterate  258    f=  3.32022D+06    |proj g|=  1.00885D+03

At iterate  259    f=  3.32022D+06    |proj g|=  1.05526D+03

At iterate  260    f=  3.32021D+06    |proj g|=  1.42996D+03

At iterate  261    f=  3.32021D+06    |proj g|=  1.04590D+03

At iterate  262    f=  3.32021D+06    |proj g|=  8.02864D+02

At iterate  263    f=  3.32020D+06    |proj g|=  4.71190D+02

At iterate  264    f=  3.32018D+06    |proj g|=  5.27105D+02

At iterate  265    f=  3.32018D+06    |proj g|=  1.74094D+03

At iterate  266    f=  3.32018D+06    |proj g|=  5.77452D+02

At iterate  267    f=  3.32018D+06    |proj g|=  2.09240D+02

At iterate  268    f=  3.32018D+06    |proj g|=  2.12436D+02
```

```
At iterate  269    f=  3.32018D+06    |proj g|=  8.06423D+02

At iterate  270    f=  3.32018D+06    |proj g|=  6.95611D+02

At iterate  271    f=  3.32017D+06    |proj g|=  3.35806D+02

At iterate  272    f=  3.32017D+06    |proj g|=  3.37070D+02

At iterate  273    f=  3.32017D+06    |proj g|=  3.21437D+02

At iterate  274    f=  3.32017D+06    |proj g|=  1.09088D+03

At iterate  275    f=  3.32017D+06    |proj g|=  7.56629D+02

At iterate  276    f=  3.32017D+06    |proj g|=  3.06197D+02

At iterate  277    f=  3.32017D+06    |proj g|=  4.06942D+02

At iterate  278    f=  3.32016D+06    |proj g|=  1.51104D+03

At iterate  279    f=  3.32016D+06    |proj g|=  1.04971D+03

At iterate  280    f=  3.32016D+06    |proj g|=  8.34104D+02

At iterate  281    f=  3.32016D+06    |proj g|=  4.36879D+02

At iterate  282    f=  3.32016D+06    |proj g|=  1.44524D+03

At iterate  283    f=  3.32016D+06    |proj g|=  5.42701D+02

At iterate  284    f=  3.32016D+06    |proj g|=  3.38521D+02

At iterate  285    f=  3.32015D+06    |proj g|=  4.78219D+02

At iterate  286    f=  3.32015D+06    |proj g|=  5.55935D+02

At iterate  287    f=  3.32015D+06    |proj g|=  1.44386D+03

At iterate  288    f=  3.32015D+06    |proj g|=  7.69593D+02

At iterate  289    f=  3.32015D+06    |proj g|=  3.93815D+02

At iterate  290    f=  3.32014D+06    |proj g|=  3.60980D+02

At iterate  291    f=  3.32014D+06    |proj g|=  2.75132D+03

At iterate  292    f=  3.32013D+06    |proj g|=  4.52668D+02
```

```
At iterate  293    f=  3.32013D+06    |proj g|=  8.39073D+02

At iterate  294    f=  3.32013D+06    |proj g|=  3.17446D+02

At iterate  295    f=  3.32013D+06    |proj g|=  1.32698D+03

At iterate  296    f=  3.32012D+06    |proj g|=  9.40575D+02

At iterate  297    f=  3.32012D+06    |proj g|=  8.90978D+02

At iterate  298    f=  3.32011D+06    |proj g|=  1.03223D+03

At iterate  299    f=  3.32011D+06    |proj g|=  7.92454D+02

At iterate  300    f=  3.32011D+06    |proj g|=  6.78662D+02

At iterate  301    f=  3.32010D+06    |proj g|=  2.54462D+03

At iterate  302    f=  3.32010D+06    |proj g|=  1.84643D+03

At iterate  303    f=  3.32009D+06    |proj g|=  6.38383D+02

At iterate  304    f=  3.32009D+06    |proj g|=  6.56189D+02

At iterate  305    f=  3.32009D+06    |proj g|=  5.77115D+02

At iterate  306    f=  3.32009D+06    |proj g|=  1.23029D+03

At iterate  307    f=  3.32009D+06    |proj g|=  6.07935D+02

At iterate  308    f=  3.32009D+06    |proj g|=  1.35925D+02

At iterate  309    f=  3.32008D+06    |proj g|=  1.78410D+02

At iterate  310    f=  3.32008D+06    |proj g|=  9.76694D+01

At iterate  311    f=  3.32008D+06    |proj g|=  5.31003D+02

At iterate  312    f=  3.32008D+06    |proj g|=  3.06272D+02

At iterate  313    f=  3.32008D+06    |proj g|=  2.01279D+02

At iterate  314    f=  3.32008D+06    |proj g|=  1.38564D+02

At iterate  315    f=  3.32008D+06    |proj g|=  5.67137D+02

At iterate  316    f=  3.32008D+06    |proj g|=  2.32764D+02
```

```
At iterate  317    f=  3.32008D+06    |proj g|=  9.96167D+02

At iterate  318    f=  3.32008D+06    |proj g|=  4.50250D+02

At iterate  319    f=  3.32007D+06    |proj g|=  1.62280D+02

At iterate  320    f=  3.32007D+06    |proj g|=  8.55309D+02

At iterate  321    f=  3.32007D+06    |proj g|=  1.31680D+03

At iterate  322    f=  3.32007D+06    |proj g|=  1.25650D+03

At iterate  323    f=  3.32007D+06    |proj g|=  1.16712D+03

At iterate  324    f=  3.32007D+06    |proj g|=  5.46593D+02

At iterate  325    f=  3.32007D+06    |proj g|=  8.53124D+02

At iterate  326    f=  3.32007D+06    |proj g|=  1.60282D+03

At iterate  327    f=  3.32006D+06    |proj g|=  1.52860D+03

At iterate  328    f=  3.32006D+06    |proj g|=  3.05268D+03

At iterate  329    f=  3.32006D+06    |proj g|=  1.76873D+03

At iterate  330    f=  3.32006D+06    |proj g|=  2.04502D+02

At iterate  331    f=  3.32006D+06    |proj g|=  5.19036D+02

At iterate  332    f=  3.32006D+06    |proj g|=  6.03692D+02

At iterate  333    f=  3.32006D+06    |proj g|=  8.43529D+02

At iterate  334    f=  3.32005D+06    |proj g|=  5.63841D+02

At iterate  335    f=  3.32005D+06    |proj g|=  4.04368D+02

At iterate  336    f=  3.32004D+06    |proj g|=  5.67799D+02

At iterate  337    f=  3.32004D+06    |proj g|=  8.18813D+02

At iterate  338    f=  3.32003D+06    |proj g|=  9.93747D+02

At iterate  339    f=  3.32003D+06    |proj g|=  1.47531D+03

At iterate  340    f=  3.32002D+06    |proj g|=  5.42863D+02
```

```
At iterate  341    f=  3.32001D+06    |proj g|=  1.46123D+03

At iterate  342    f=  3.32001D+06    |proj g|=  2.44757D+03

At iterate  343    f=  3.32001D+06    |proj g|=  3.83917D+02

At iterate  344    f=  3.32001D+06    |proj g|=  2.29432D+02

At iterate  345    f=  3.32001D+06    |proj g|=  1.19323D+03

At iterate  346    f=  3.32001D+06    |proj g|=  1.41348D+03

At iterate  347    f=  3.32000D+06    |proj g|=  2.05154D+03

At iterate  348    f=  3.31999D+06    |proj g|=  1.80111D+03

At iterate  349    f=  3.31999D+06    |proj g|=  1.03000D+03

At iterate  350    f=  3.31998D+06    |proj g|=  3.09558D+03

At iterate  351    f=  3.31998D+06    |proj g|=  1.05370D+03

At iterate  352    f=  3.31997D+06    |proj g|=  5.92657D+02

At iterate  353    f=  3.31997D+06    |proj g|=  1.38781D+03

At iterate  354    f=  3.31996D+06    |proj g|=  1.68897D+03

At iterate  355    f=  3.31996D+06    |proj g|=  3.57266D+03

At iterate  356    f=  3.31996D+06    |proj g|=  2.09146D+03

At iterate  357    f=  3.31995D+06    |proj g|=  5.02979D+02

At iterate  358    f=  3.31995D+06    |proj g|=  7.45695D+02

At iterate  359    f=  3.31995D+06    |proj g|=  1.46760D+03

At iterate  360    f=  3.31995D+06    |proj g|=  1.92086D+03

At iterate  361    f=  3.31994D+06    |proj g|=  7.31151D+02

At iterate  362    f=  3.31993D+06    |proj g|=  1.13938D+03

At iterate  363    f=  3.31992D+06    |proj g|=  1.77591D+03

At iterate  364    f=  3.31990D+06    |proj g|=  2.87874D+03
```

```
At iterate  365    f=  3.31986D+06    |proj g|=  5.15885D+03

At iterate  366    f=  3.31985D+06    |proj g|=  2.46322D+03

At iterate  367    f=  3.31984D+06    |proj g|=  9.64401D+02

At iterate  368    f=  3.31982D+06    |proj g|=  1.81984D+03

At iterate  369    f=  3.31982D+06    |proj g|=  2.45280D+03

At iterate  370    f=  3.31981D+06    |proj g|=  3.54118D+02

At iterate  371    f=  3.31981D+06    |proj g|=  9.45988D+02

At iterate  372    f=  3.31981D+06    |proj g|=  1.79074D+03

At iterate  373    f=  3.31980D+06    |proj g|=  2.04113D+03

At iterate  374    f=  3.31980D+06    |proj g|=  3.71463D+03

At iterate  375    f=  3.31980D+06    |proj g|=  7.52387D+02

At iterate  376    f=  3.31979D+06    |proj g|=  2.53455D+02

At iterate  377    f=  3.31979D+06    |proj g|=  1.30123D+02

At iterate  378    f=  3.31979D+06    |proj g|=  6.43816D+02

At iterate  379    f=  3.31979D+06    |proj g|=  6.17176D+02

At iterate  380    f=  3.31979D+06    |proj g|=  2.06700D+02

At iterate  381    f=  3.31979D+06    |proj g|=  9.53777D+02

At iterate  382    f=  3.31979D+06    |proj g|=  2.62534D+02

At iterate  383    f=  3.31979D+06    |proj g|=  2.48726D+02

At iterate  384    f=  3.31979D+06    |proj g|=  4.17982D+02

At iterate  385    f=  3.31978D+06    |proj g|=  5.75256D+02

At iterate  386    f=  3.31977D+06    |proj g|=  6.36606D+02

At iterate  387    f=  3.31977D+06    |proj g|=  1.14848D+03

At iterate  388    f=  3.31977D+06    |proj g|=  3.43484D+02
```

```
At iterate  389    f=  3.31977D+06    |proj g|=  2.33382D+02

At iterate  390    f=  3.31977D+06    |proj g|=  3.12978D+02

At iterate  391    f=  3.31977D+06    |proj g|=  1.97528D+02

At iterate  392    f=  3.31976D+06    |proj g|=  3.79911D+02

At iterate  393    f=  3.31976D+06    |proj g|=  1.90745D+02

At iterate  394    f=  3.31976D+06    |proj g|=  1.54364D+02

At iterate  395    f=  3.31976D+06    |proj g|=  3.34807D+02

At iterate  396    f=  3.31976D+06    |proj g|=  4.75088D+02

At iterate  397    f=  3.31976D+06    |proj g|=  3.35083D+02

At iterate  398    f=  3.31975D+06    |proj g|=  3.39424D+02

At iterate  399    f=  3.31974D+06    |proj g|=  3.55121D+02

At iterate  400    f=  3.31974D+06    |proj g|=  2.24068D+03

At iterate  401    f=  3.31973D+06    |proj g|=  9.83912D+02

At iterate  402    f=  3.31972D+06    |proj g|=  2.26467D+03

At iterate  403    f=  3.31972D+06    |proj g|=  1.04044D+03

At iterate  404    f=  3.31972D+06    |proj g|=  7.82403D+02

At iterate  405    f=  3.31971D+06    |proj g|=  6.38286D+02

At iterate  406    f=  3.31971D+06    |proj g|=  2.57552D+02

At iterate  407    f=  3.31970D+06    |proj g|=  9.10290D+02

At iterate  408    f=  3.31970D+06    |proj g|=  4.46920D+02

At iterate  409    f=  3.31970D+06    |proj g|=  1.12517D+03

At iterate  410    f=  3.31969D+06    |proj g|=  1.25538D+03

At iterate  411    f=  3.31968D+06    |proj g|=  1.56312D+03

At iterate  412    f=  3.31968D+06    |proj g|=  6.05775D+02
```

```
At iterate  413    f=  3.31968D+06    |proj g|=  2.88224D+02

At iterate  414    f=  3.31968D+06    |proj g|=  6.56371D+02

At iterate  415    f=  3.31968D+06    |proj g|=  1.82166D+02

At iterate  416    f=  3.31968D+06    |proj g|=  1.76696D+02

At iterate  417    f=  3.31968D+06    |proj g|=  3.69473D+02

At iterate  418    f=  3.31968D+06    |proj g|=  6.21657D+02

At iterate  419    f=  3.31967D+06    |proj g|=  1.08484D+03

At iterate  420    f=  3.31966D+06    |proj g|=  1.28503D+03

At iterate  421    f=  3.31966D+06    |proj g|=  2.12960D+03

At iterate  422    f=  3.31965D+06    |proj g|=  1.33446D+03

At iterate  423    f=  3.31964D+06    |proj g|=  2.11369D+03

At iterate  424    f=  3.31964D+06    |proj g|=  7.15294D+02

At iterate  425    f=  3.31964D+06    |proj g|=  4.47819D+02

At iterate  426    f=  3.31964D+06    |proj g|=  4.02155D+02

At iterate  427    f=  3.31964D+06    |proj g|=  1.66243D+03

At iterate  428    f=  3.31964D+06    |proj g|=  3.71430D+02

At iterate  429    f=  3.31963D+06    |proj g|=  5.78022D+02

At iterate  430    f=  3.31963D+06    |proj g|=  7.34639D+02

At iterate  431    f=  3.31963D+06    |proj g|=  7.61470D+02

At iterate  432    f=  3.31962D+06    |proj g|=  9.02095D+02

At iterate  433    f=  3.31961D+06    |proj g|=  1.22162D+03

At iterate  434    f=  3.31960D+06    |proj g|=  7.90302D+02

At iterate  435    f=  3.31959D+06    |proj g|=  3.04806D+03

At iterate  436    f=  3.31958D+06    |proj g|=  5.35699D+02
```

```
At iterate  437    f=  3.31958D+06    |proj g|=  2.60775D+02

At iterate  438    f=  3.31958D+06    |proj g|=  2.26587D+02

At iterate  439    f=  3.31958D+06    |proj g|=  9.78442D+02

At iterate  440    f=  3.31958D+06    |proj g|=  3.91049D+02

At iterate  441    f=  3.31958D+06    |proj g|=  2.94567D+02

At iterate  442    f=  3.31957D+06    |proj g|=  2.28022D+02

At iterate  443    f=  3.31957D+06    |proj g|=  1.89784D+02

At iterate  444    f=  3.31957D+06    |proj g|=  2.72002D+02

At iterate  445    f=  3.31957D+06    |proj g|=  8.14949D+02

At iterate  446    f=  3.31957D+06    |proj g|=  2.08774D+02

At iterate  447    f=  3.31957D+06    |proj g|=  2.42839D+02

At iterate  448    f=  3.31957D+06    |proj g|=  9.25391D+02

At iterate  449    f=  3.31957D+06    |proj g|=  7.23163D+02

At iterate  450    f=  3.31957D+06    |proj g|=  4.25740D+02

At iterate  451    f=  3.31957D+06    |proj g|=  3.13475D+02

At iterate  452    f=  3.31957D+06    |proj g|=  1.10331D+03

At iterate  453    f=  3.31957D+06    |proj g|=  2.07912D+02

At iterate  454    f=  3.31956D+06    |proj g|=  1.22535D+02

At iterate  455    f=  3.31956D+06    |proj g|=  3.99010D+02

At iterate  456    f=  3.31956D+06    |proj g|=  6.20208D+02

At iterate  457    f=  3.31956D+06    |proj g|=  5.53825D+02

At iterate  458    f=  3.31956D+06    |proj g|=  1.01078D+03

At iterate  459    f=  3.31956D+06    |proj g|=  3.22489D+02

At iterate  460    f=  3.31956D+06    |proj g|=  3.26070D+02
```

```
At iterate  461    f=  3.31956D+06    |proj g|=  8.99348D+02

At iterate  462    f=  3.31956D+06    |proj g|=  1.39967D+03

At iterate  463    f=  3.31956D+06    |proj g|=  1.15814D+03

At iterate  464    f=  3.31956D+06    |proj g|=  3.79073D+02

At iterate  465    f=  3.31955D+06    |proj g|=  2.10886D+02

At iterate  466    f=  3.31955D+06    |proj g|=  8.49951D+02

At iterate  467    f=  3.31955D+06    |proj g|=  6.02483D+02

At iterate  468    f=  3.31955D+06    |proj g|=  2.44808D+02

At iterate  469    f=  3.31955D+06    |proj g|=  1.91967D+02

At iterate  470    f=  3.31955D+06    |proj g|=  6.44345D+02

At iterate  471    f=  3.31955D+06    |proj g|=  9.83868D+02

At iterate  472    f=  3.31955D+06    |proj g|=  1.67064D+02

At iterate  473    f=  3.31955D+06    |proj g|=  3.28633D+02

At iterate  474    f=  3.31955D+06    |proj g|=  1.69190D+02

At iterate  475    f=  3.31955D+06    |proj g|=  8.54381D+01

At iterate  476    f=  3.31955D+06    |proj g|=  5.68069D+02

At iterate  477    f=  3.31955D+06    |proj g|=  9.13618D+02

At iterate  478    f=  3.31955D+06    |proj g|=  1.97460D+03

At iterate  479    f=  3.31955D+06    |proj g|=  1.23225D+03

At iterate  480    f=  3.31954D+06    |proj g|=  6.11302D+02

At iterate  481    f=  3.31954D+06    |proj g|=  3.50895D+02

At iterate  482    f=  3.31954D+06    |proj g|=  1.26369D+03

At iterate  483    f=  3.31954D+06    |proj g|=  1.48971D+03

At iterate  484    f=  3.31954D+06    |proj g|=  2.08376D+03
```

```
At iterate  485    f=  3.31954D+06    |proj g|=  6.28327D+02

At iterate  486    f=  3.31954D+06    |proj g|=  3.53502D+02

At iterate  487    f=  3.31954D+06    |proj g|=  1.67805D+02

At iterate  488    f=  3.31954D+06    |proj g|=  1.81958D+02

At iterate  489    f=  3.31954D+06    |proj g|=  5.37339D+02

At iterate  490    f=  3.31954D+06    |proj g|=  1.86177D+02

At iterate  491    f=  3.31954D+06    |proj g|=  2.96811D+02

At iterate  492    f=  3.31953D+06    |proj g|=  1.99310D+02

At iterate  493    f=  3.31953D+06    |proj g|=  8.80573D+02

At iterate  494    f=  3.31953D+06    |proj g|=  6.06816D+02

At iterate  495    f=  3.31953D+06    |proj g|=  1.62813D+02

At iterate  496    f=  3.31953D+06    |proj g|=  2.09375D+02

At iterate  497    f=  3.31953D+06    |proj g|=  2.49058D+02

At iterate  498    f=  3.31953D+06    |proj g|=  3.98003D+02

At iterate  499    f=  3.31953D+06    |proj g|=  2.92726D+02

At iterate  500    f=  3.31953D+06    |proj g|=  2.93543D+02

At iterate  501    f=  3.31953D+06    |proj g|=  1.19236D+03

At iterate  502    f=  3.31952D+06    |proj g|=  1.47344D+03

At iterate  503    f=  3.31952D+06    |proj g|=  9.41373D+02

At iterate  504    f=  3.31951D+06    |proj g|=  2.74236D+03

At iterate  505    f=  3.31951D+06    |proj g|=  4.95826D+02

At iterate  506    f=  3.31951D+06    |proj g|=  2.56448D+02

At iterate  507    f=  3.31951D+06    |proj g|=  4.25104D+02

At iterate  508    f=  3.31951D+06    |proj g|=  4.22666D+02
```

```
At iterate  509    f=  3.31951D+06    |proj g|=  7.76312D+02

At iterate  510    f=  3.31951D+06    |proj g|=  4.84289D+02

At iterate  511    f=  3.31951D+06    |proj g|=  1.85554D+02

At iterate  512    f=  3.31951D+06    |proj g|=  5.11393D+02

At iterate  513    f=  3.31951D+06    |proj g|=  7.39681D+02

At iterate  514    f=  3.31950D+06    |proj g|=  6.85950D+02

At iterate  515    f=  3.31950D+06    |proj g|=  1.33930D+03

At iterate  516    f=  3.31950D+06    |proj g|=  2.96693D+02

At iterate  517    f=  3.31950D+06    |proj g|=  1.72378D+02

At iterate  518    f=  3.31950D+06    |proj g|=  4.59263D+02

At iterate  519    f=  3.31950D+06    |proj g|=  3.49558D+02

At iterate  520    f=  3.31950D+06    |proj g|=  1.61235D+02

At iterate  521    f=  3.31950D+06    |proj g|=  1.64533D+02

At iterate  522    f=  3.31950D+06    |proj g|=  1.77960D+02

At iterate  523    f=  3.31950D+06    |proj g|=  3.71965D+02

At iterate  524    f=  3.31950D+06    |proj g|=  4.90506D+02

At iterate  525    f=  3.31950D+06    |proj g|=  2.28333D+02

At iterate  526    f=  3.31950D+06    |proj g|=  2.57169D+02

At iterate  527    f=  3.31950D+06    |proj g|=  4.77430D+02

At iterate  528    f=  3.31950D+06    |proj g|=  5.98017D+01

At iterate  529    f=  3.31950D+06    |proj g|=  7.44428D+01

At iterate  530    f=  3.31950D+06    |proj g|=  1.69727D+02

At iterate  531    f=  3.31950D+06    |proj g|=  6.04314D+01

At iterate  532    f=  3.31950D+06    |proj g|=  7.91873D+01
```

```
At iterate  533    f=  3.31950D+06    |proj g|=  1.19652D+02

At iterate  534    f=  3.31950D+06    |proj g|=  1.36320D+02

At iterate  535    f=  3.31950D+06    |proj g|=  6.50999D+02

At iterate  536    f=  3.31950D+06    |proj g|=  2.30638D+02

At iterate  537    f=  3.31949D+06    |proj g|=  2.58545D+02

At iterate  538    f=  3.31949D+06    |proj g|=  4.52900D+02

At iterate  539    f=  3.31949D+06    |proj g|=  6.25188D+02

At iterate  540    f=  3.31949D+06    |proj g|=  2.96485D+02

At iterate  541    f=  3.31949D+06    |proj g|=  2.70815D+02

At iterate  542    f=  3.31949D+06    |proj g|=  2.32458D+02

At iterate  543    f=  3.31949D+06    |proj g|=  1.70916D+02

At iterate  544    f=  3.31949D+06    |proj g|=  9.96445D+01

At iterate  545    f=  3.31949D+06    |proj g|=  1.17747D+02

At iterate  546    f=  3.31949D+06    |proj g|=  3.89529D+02

At iterate  547    f=  3.31949D+06    |proj g|=  1.98612D+02

At iterate  548    f=  3.31949D+06    |proj g|=  9.07318D+01

At iterate  549    f=  3.31949D+06    |proj g|=  1.08751D+02

At iterate  550    f=  3.31949D+06    |proj g|=  1.41674D+02

At iterate  551    f=  3.31949D+06    |proj g|=  1.69695D+02

At iterate  552    f=  3.31949D+06    |proj g|=  9.06256D+01

At iterate  553    f=  3.31949D+06    |proj g|=  2.79329D+01

At iterate  554    f=  3.31949D+06    |proj g|=  5.01606D+01

At iterate  555    f=  3.31949D+06    |proj g|=  1.16204D+02

At iterate  556    f=  3.31949D+06    |proj g|=  8.72684D+01
```

```
At iterate  557    f=  3.31949D+06    |proj g|=  2.81912D+02

At iterate  558    f=  3.31949D+06    |proj g|=  1.62811D+02

At iterate  559    f=  3.31949D+06    |proj g|=  8.03339D+01

At iterate  560    f=  3.31949D+06    |proj g|=  1.20303D+02

At iterate  561    f=  3.31949D+06    |proj g|=  2.26707D+02

At iterate  562    f=  3.31949D+06    |proj g|=  2.46018D+02

At iterate  563    f=  3.31949D+06    |proj g|=  1.81319D+02

At iterate  564    f=  3.31949D+06    |proj g|=  4.78194D+01

At iterate  565    f=  3.31949D+06    |proj g|=  2.23011D+02

At iterate  566    f=  3.31949D+06    |proj g|=  3.29735D+02

At iterate  567    f=  3.31949D+06    |proj g|=  3.82783D+02

At iterate  568    f=  3.31949D+06    |proj g|=  1.66541D+02

At iterate  569    f=  3.31949D+06    |proj g|=  4.22831D+02

At iterate  570    f=  3.31948D+06    |proj g|=  1.32205D+02

At iterate  571    f=  3.31948D+06    |proj g|=  1.87625D+02

At iterate  572    f=  3.31948D+06    |proj g|=  6.90834D+02

At iterate  573    f=  3.31948D+06    |proj g|=  1.59967D+02

At iterate  574    f=  3.31948D+06    |proj g|=  7.92517D+02

At iterate  575    f=  3.31948D+06    |proj g|=  1.41197D+02

At iterate  576    f=  3.31948D+06    |proj g|=  2.92029D+02

At iterate  577    f=  3.31948D+06    |proj g|=  3.96355D+02

At iterate  578    f=  3.31948D+06    |proj g|=  1.59415D+02

At iterate  579    f=  3.31948D+06    |proj g|=  6.79831D+02

At iterate  580    f=  3.31948D+06    |proj g|=  3.63981D+02
```

```
At iterate  581    f=  3.31948D+06    |proj g|=  3.52401D+02

At iterate  582    f=  3.31948D+06    |proj g|=  2.81099D+02

At iterate  583    f=  3.31948D+06    |proj g|=  2.01597D+02

At iterate  584    f=  3.31948D+06    |proj g|=  2.18134D+02

At iterate  585    f=  3.31948D+06    |proj g|=  1.36814D+02

At iterate  586    f=  3.31948D+06    |proj g|=  4.17624D+02

At iterate  587    f=  3.31948D+06    |proj g|=  1.74163D+02

At iterate  588    f=  3.31948D+06    |proj g|=  1.10000D+02

At iterate  589    f=  3.31948D+06    |proj g|=  1.77004D+02

At iterate  590    f=  3.31948D+06    |proj g|=  2.08708D+02

At iterate  591    f=  3.31948D+06    |proj g|=  3.69998D+02

At iterate  592    f=  3.31948D+06    |proj g|=  1.97892D+02

At iterate  593    f=  3.31948D+06    |proj g|=  1.59334D+02

At iterate  594    f=  3.31948D+06    |proj g|=  9.05386D+01

At iterate  595    f=  3.31948D+06    |proj g|=  1.12638D+02

At iterate  596    f=  3.31947D+06    |proj g|=  1.92629D+02

At iterate  597    f=  3.31947D+06    |proj g|=  6.88404D+02

At iterate  598    f=  3.31947D+06    |proj g|=  5.73929D+02

At iterate  599    f=  3.31947D+06    |proj g|=  3.50224D+02

At iterate  600    f=  3.31947D+06    |proj g|=  3.39360D+02

At iterate  601    f=  3.31947D+06    |proj g|=  4.69085D+02

At iterate  602    f=  3.31946D+06    |proj g|=  3.09880D+02

At iterate  603    f=  3.31946D+06    |proj g|=  2.14559D+03

At iterate  604    f=  3.31946D+06    |proj g|=  3.32738D+02
```

```
At iterate  605    f=  3.31946D+06    |proj g|=  2.78008D+02

At iterate  606    f=  3.31945D+06    |proj g|=  5.74326D+02

At iterate  607    f=  3.31945D+06    |proj g|=  3.42976D+02

At iterate  608    f=  3.31945D+06    |proj g|=  9.65300D+02

At iterate  609    f=  3.31945D+06    |proj g|=  5.43418D+02

At iterate  610    f=  3.31945D+06    |proj g|=  3.32227D+02

At iterate  611    f=  3.31945D+06    |proj g|=  1.87925D+02

At iterate  612    f=  3.31945D+06    |proj g|=  2.22143D+02

At iterate  613    f=  3.31945D+06    |proj g|=  1.27624D+02

At iterate  614    f=  3.31945D+06    |proj g|=  2.13615D+02

At iterate  615    f=  3.31945D+06    |proj g|=  7.00925D+01

At iterate  616    f=  3.31945D+06    |proj g|=  1.29809D+02

At iterate  617    f=  3.31945D+06    |proj g|=  5.90809D+01

At iterate  618    f=  3.31945D+06    |proj g|=  1.41399D+02

At iterate  619    f=  3.31945D+06    |proj g|=  2.01619D+02

At iterate  620    f=  3.31945D+06    |proj g|=  2.34367D+02

At iterate  621    f=  3.31945D+06    |proj g|=  1.88746D+02

At iterate  622    f=  3.31945D+06    |proj g|=  1.53967D+02

At iterate  623    f=  3.31945D+06    |proj g|=  1.12956D+02

At iterate  624    f=  3.31944D+06    |proj g|=  1.19101D+02

At iterate  625    f=  3.31944D+06    |proj g|=  3.34699D+02

At iterate  626    f=  3.31944D+06    |proj g|=  6.92722D+02

At iterate  627    f=  3.31944D+06    |proj g|=  5.94895D+02

At iterate  628    f=  3.31944D+06    |proj g|=  1.89711D+02
```

```
At iterate  629    f=  3.31944D+06    |proj g|=  1.16775D+02

At iterate  630    f=  3.31944D+06    |proj g|=  1.27508D+02

At iterate  631    f=  3.31944D+06    |proj g|=  1.24923D+02

At iterate  632    f=  3.31944D+06    |proj g|=  6.82027D+02

At iterate  633    f=  3.31944D+06    |proj g|=  3.38114D+02

At iterate  634    f=  3.31944D+06    |proj g|=  1.89434D+02

At iterate  635    f=  3.31943D+06    |proj g|=  3.55436D+02

At iterate  636    f=  3.31943D+06    |proj g|=  5.26172D+02

At iterate  637    f=  3.31942D+06    |proj g|=  2.95665D+03

At iterate  638    f=  3.31942D+06    |proj g|=  6.89749D+02

At iterate  639    f=  3.31941D+06    |proj g|=  1.34402D+03

At iterate  640    f=  3.31941D+06    |proj g|=  3.66016D+02

At iterate  641    f=  3.31940D+06    |proj g|=  2.64830D+02

At iterate  642    f=  3.31940D+06    |proj g|=  4.27014D+02

At iterate  643    f=  3.31940D+06    |proj g|=  9.18406D+02

At iterate  644    f=  3.31940D+06    |proj g|=  2.02179D+03

At iterate  645    f=  3.31939D+06    |proj g|=  5.64082D+02

At iterate  646    f=  3.31939D+06    |proj g|=  4.60390D+02

At iterate  647    f=  3.31939D+06    |proj g|=  4.27121D+02

At iterate  648    f=  3.31939D+06    |proj g|=  9.26192D+02

At iterate  649    f=  3.31939D+06    |proj g|=  1.22226D+02

At iterate  650    f=  3.31939D+06    |proj g|=  8.75056D+01

At iterate  651    f=  3.31939D+06    |proj g|=  1.22939D+02

At iterate  652    f=  3.31939D+06    |proj g|=  4.34739D+02
```

```
At iterate  653    f=  3.31939D+06    |proj g|=  5.34540D+02

At iterate  654    f=  3.31939D+06    |proj g|=  6.47911D+02

At iterate  655    f=  3.31939D+06    |proj g|=  1.10913D+02

At iterate  656    f=  3.31939D+06    |proj g|=  1.32307D+02

At iterate  657    f=  3.31939D+06    |proj g|=  1.48180D+02

At iterate  658    f=  3.31939D+06    |proj g|=  1.58333D+02

At iterate  659    f=  3.31939D+06    |proj g|=  1.69765D+02

At iterate  660    f=  3.31938D+06    |proj g|=  1.23702D+03

At iterate  661    f=  3.31938D+06    |proj g|=  2.04409D+02

At iterate  662    f=  3.31938D+06    |proj g|=  1.13213D+02

At iterate  663    f=  3.31938D+06    |proj g|=  1.51236D+02

At iterate  664    f=  3.31938D+06    |proj g|=  3.24616D+02

At iterate  665    f=  3.31938D+06    |proj g|=  3.18435D+02

At iterate  666    f=  3.31938D+06    |proj g|=  1.68653D+03

At iterate  667    f=  3.31938D+06    |proj g|=  7.80972D+02

At iterate  668    f=  3.31937D+06    |proj g|=  1.31548D+02

At iterate  669    f=  3.31937D+06    |proj g|=  1.09645D+02

At iterate  670    f=  3.31937D+06    |proj g|=  3.17565D+02

At iterate  671    f=  3.31937D+06    |proj g|=  9.56645D+01

At iterate  672    f=  3.31937D+06    |proj g|=  7.19759D+01

At iterate  673    f=  3.31937D+06    |proj g|=  1.40040D+02

At iterate  674    f=  3.31937D+06    |proj g|=  1.61574D+02

At iterate  675    f=  3.31937D+06    |proj g|=  2.20777D+02

At iterate  676    f=  3.31937D+06    |proj g|=  1.85055D+02
```

```
At iterate  677    f=  3.31937D+06    |proj g|=  3.45421D+02

At iterate  678    f=  3.31937D+06    |proj g|=  3.96034D+02

At iterate  679    f=  3.31937D+06    |proj g|=  2.01978D+02

At iterate  680    f=  3.31937D+06    |proj g|=  2.82517D+02

At iterate  681    f=  3.31937D+06    |proj g|=  3.34852D+02

At iterate  682    f=  3.31937D+06    |proj g|=  3.21137D+02

At iterate  683    f=  3.31937D+06    |proj g|=  1.04300D+03

At iterate  684    f=  3.31936D+06    |proj g|=  5.29211D+02

At iterate  685    f=  3.31936D+06    |proj g|=  2.34801D+02

At iterate  686    f=  3.31936D+06    |proj g|=  2.96074D+02

At iterate  687    f=  3.31936D+06    |proj g|=  3.46997D+02

At iterate  688    f=  3.31936D+06    |proj g|=  8.51328D+02

At iterate  689    f=  3.31936D+06    |proj g|=  2.39168D+02

At iterate  690    f=  3.31936D+06    |proj g|=  1.90281D+02

At iterate  691    f=  3.31936D+06    |proj g|=  2.50879D+02

At iterate  692    f=  3.31935D+06    |proj g|=  2.68750D+02

At iterate  693    f=  3.31935D+06    |proj g|=  2.54160D+02

At iterate  694    f=  3.31935D+06    |proj g|=  1.13046D+03

At iterate  695    f=  3.31935D+06    |proj g|=  3.11805D+02

At iterate  696    f=  3.31935D+06    |proj g|=  1.64748D+02

At iterate  697    f=  3.31935D+06    |proj g|=  9.51636D+01

At iterate  698    f=  3.31934D+06    |proj g|=  3.19467D+02

At iterate  699    f=  3.31934D+06    |proj g|=  1.30982D+02

At iterate  700    f=  3.31934D+06    |proj g|=  9.88797D+01
```

```
At iterate  701    f=  3.31934D+06    |proj g|=  5.91572D+02

At iterate  702    f=  3.31934D+06    |proj g|=  4.95987D+02

At iterate  703    f=  3.31934D+06    |proj g|=  2.63421D+02

At iterate  704    f=  3.31934D+06    |proj g|=  2.98645D+02

At iterate  705    f=  3.31934D+06    |proj g|=  7.69370D+02

At iterate  706    f=  3.31933D+06    |proj g|=  5.18876D+02

At iterate  707    f=  3.31933D+06    |proj g|=  1.98752D+03

At iterate  708    f=  3.31933D+06    |proj g|=  5.50461D+02

At iterate  709    f=  3.31933D+06    |proj g|=  1.89621D+02

At iterate  710    f=  3.31933D+06    |proj g|=  2.72715D+02

At iterate  711    f=  3.31933D+06    |proj g|=  2.83118D+02

At iterate  712    f=  3.31933D+06    |proj g|=  7.23407D+02

At iterate  713    f=  3.31933D+06    |proj g|=  4.11565D+02

At iterate  714    f=  3.31933D+06    |proj g|=  1.75018D+02

At iterate  715    f=  3.31933D+06    |proj g|=  1.05484D+02

At iterate  716    f=  3.31933D+06    |proj g|=  8.86180D+01

At iterate  717    f=  3.31933D+06    |proj g|=  1.44665D+02

At iterate  718    f=  3.31933D+06    |proj g|=  2.02276D+02

At iterate  719    f=  3.31933D+06    |proj g|=  5.75648D+02

At iterate  720    f=  3.31933D+06    |proj g|=  2.68281D+02

At iterate  721    f=  3.31933D+06    |proj g|=  1.23795D+02

At iterate  722    f=  3.31933D+06    |proj g|=  2.34085D+02

At iterate  723    f=  3.31933D+06    |proj g|=  3.69200D+02

At iterate  724    f=  3.31932D+06    |proj g|=  1.27943D+03
```

```
At iterate  725    f=  3.31932D+06    |proj g|=  6.89067D+02

At iterate  726    f=  3.31932D+06    |proj g|=  2.14681D+02

At iterate  727    f=  3.31932D+06    |proj g|=  2.60638D+02

At iterate  728    f=  3.31932D+06    |proj g|=  3.50388D+02

At iterate  729    f=  3.31932D+06    |proj g|=  2.30930D+02

At iterate  730    f=  3.31932D+06    |proj g|=  9.01718D+02

At iterate  731    f=  3.31932D+06    |proj g|=  2.22322D+02

At iterate  732    f=  3.31932D+06    |proj g|=  1.40814D+02

At iterate  733    f=  3.31932D+06    |proj g|=  1.31601D+02

At iterate  734    f=  3.31932D+06    |proj g|=  3.60442D+02

At iterate  735    f=  3.31932D+06    |proj g|=  4.77129D+02

At iterate  736    f=  3.31932D+06    |proj g|=  5.67123D+02

At iterate  737    f=  3.31932D+06    |proj g|=  3.60705D+02

At iterate  738    f=  3.31932D+06    |proj g|=  5.87027D+02

At iterate  739    f=  3.31931D+06    |proj g|=  6.21357D+02

At iterate  740    f=  3.31931D+06    |proj g|=  5.50673D+02

At iterate  741    f=  3.31930D+06    |proj g|=  1.05484D+03

At iterate  742    f=  3.31930D+06    |proj g|=  1.79697D+03

At iterate  743    f=  3.31929D+06    |proj g|=  6.72365D+02

At iterate  744    f=  3.31929D+06    |proj g|=  5.15293D+02

At iterate  745    f=  3.31929D+06    |proj g|=  4.77605D+02

At iterate  746    f=  3.31928D+06    |proj g|=  9.12549D+02

At iterate  747    f=  3.31926D+06    |proj g|=  2.22566D+03

At iterate  748    f=  3.31925D+06    |proj g|=  1.24328D+03
```

```
At iterate  749    f=  3.31924D+06    |proj g|=  6.91962D+02

At iterate  750    f=  3.31924D+06    |proj g|=  4.99254D+02

At iterate  751    f=  3.31924D+06    |proj g|=  1.21838D+02

At iterate  752    f=  3.31924D+06    |proj g|=  1.16888D+02

At iterate  753    f=  3.31924D+06    |proj g|=  3.26727D+02

At iterate  754    f=  3.31924D+06    |proj g|=  5.66118D+02

At iterate  755    f=  3.31923D+06    |proj g|=  3.87168D+02

At iterate  756    f=  3.31923D+06    |proj g|=  1.61713D+02

At iterate  757    f=  3.31923D+06    |proj g|=  1.31199D+02

At iterate  758    f=  3.31923D+06    |proj g|=  2.56140D+02

At iterate  759    f=  3.31923D+06    |proj g|=  1.03480D+03

At iterate  760    f=  3.31923D+06    |proj g|=  1.98843D+02

At iterate  761    f=  3.31923D+06    |proj g|=  1.40618D+02

At iterate  762    f=  3.31923D+06    |proj g|=  1.19483D+02

At iterate  763    f=  3.31923D+06    |proj g|=  2.65961D+02

At iterate  764    f=  3.31922D+06    |proj g|=  7.02029D+02

At iterate  765    f=  3.31922D+06    |proj g|=  7.11997D+02

At iterate  766    f=  3.31922D+06    |proj g|=  2.34421D+02

At iterate  767    f=  3.31922D+06    |proj g|=  6.60138D+02

At iterate  768    f=  3.31922D+06    |proj g|=  3.14600D+02

At iterate  769    f=  3.31922D+06    |proj g|=  2.82242D+02

At iterate  770    f=  3.31922D+06    |proj g|=  5.16598D+02

At iterate  771    f=  3.31921D+06    |proj g|=  5.26382D+02

At iterate  772    f=  3.31921D+06    |proj g|=  1.94145D+02
```

```
At iterate  773    f=  3.31921D+06    |proj g|=  3.24117D+02

At iterate  774    f=  3.31921D+06    |proj g|=  9.05633D+02

At iterate  775    f=  3.31921D+06    |proj g|=  8.30834D+02

At iterate  776    f=  3.31921D+06    |proj g|=  5.14224D+02

At iterate  777    f=  3.31921D+06    |proj g|=  2.56637D+03

At iterate  778    f=  3.31920D+06    |proj g|=  5.49288D+02

At iterate  779    f=  3.31920D+06    |proj g|=  3.12229D+02

At iterate  780    f=  3.31920D+06    |proj g|=  4.15016D+02

At iterate  781    f=  3.31920D+06    |proj g|=  4.96081D+02

At iterate  782    f=  3.31920D+06    |proj g|=  9.22869D+02

At iterate  783    f=  3.31920D+06    |proj g|=  5.02997D+02

At iterate  784    f=  3.31920D+06    |proj g|=  1.74136D+02

At iterate  785    f=  3.31920D+06    |proj g|=  5.55132D+02

At iterate  786    f=  3.31920D+06    |proj g|=  1.20334D+03

At iterate  787    f=  3.31920D+06    |proj g|=  1.15102D+03

At iterate  788    f=  3.31919D+06    |proj g|=  5.40115D+02

At iterate  789    f=  3.31919D+06    |proj g|=  2.98641D+02

At iterate  790    f=  3.31919D+06    |proj g|=  1.14964D+03

At iterate  791    f=  3.31919D+06    |proj g|=  3.92374D+02

At iterate  792    f=  3.31919D+06    |proj g|=  5.39310D+02

At iterate  793    f=  3.31919D+06    |proj g|=  3.63891D+02

At iterate  794    f=  3.31918D+06    |proj g|=  2.21719D+02

At iterate  795    f=  3.31918D+06    |proj g|=  5.92641D+02

At iterate  796    f=  3.31918D+06    |proj g|=  3.20168D+02
```

```
At iterate  797    f=  3.31918D+06    |proj g|=  1.10850D+03

At iterate  798    f=  3.31918D+06    |proj g|=  3.08764D+02

At iterate  799    f=  3.31918D+06    |proj g|=  2.00652D+02

At iterate  800    f=  3.31918D+06    |proj g|=  2.86059D+02

At iterate  801    f=  3.31917D+06    |proj g|=  6.87028D+02

At iterate  802    f=  3.31917D+06    |proj g|=  3.87538D+02

At iterate  803    f=  3.31917D+06    |proj g|=  2.40840D+02

At iterate  804    f=  3.31917D+06    |proj g|=  1.87335D+02

At iterate  805    f=  3.31917D+06    |proj g|=  3.30153D+02

At iterate  806    f=  3.31917D+06    |proj g|=  5.12714D+02

At iterate  807    f=  3.31916D+06    |proj g|=  5.34072D+02

At iterate  808    f=  3.31916D+06    |proj g|=  2.11650D+03

At iterate  809    f=  3.31916D+06    |proj g|=  7.45072D+02

At iterate  810    f=  3.31915D+06    |proj g|=  3.71844D+02

At iterate  811    f=  3.31915D+06    |proj g|=  6.04585D+02

At iterate  812    f=  3.31915D+06    |proj g|=  1.35593D+03

At iterate  813    f=  3.31914D+06    |proj g|=  5.89231D+02

At iterate  814    f=  3.31914D+06    |proj g|=  3.95146D+02

At iterate  815    f=  3.31914D+06    |proj g|=  6.02170D+02

At iterate  816    f=  3.31914D+06    |proj g|=  7.10437D+02

At iterate  817    f=  3.31913D+06    |proj g|=  4.62972D+02

At iterate  818    f=  3.31913D+06    |proj g|=  4.81696D+02

At iterate  819    f=  3.31913D+06    |proj g|=  5.73457D+02

At iterate  820    f=  3.31913D+06    |proj g|=  1.46620D+02
```

```
At iterate  821    f=  3.31913D+06    |proj g|=  6.19880D+01

At iterate  822    f=  3.31913D+06    |proj g|=  7.81976D+01

At iterate  823    f=  3.31913D+06    |proj g|=  2.76594D+02

At iterate  824    f=  3.31913D+06    |proj g|=  1.58248D+02

At iterate  825    f=  3.31913D+06    |proj g|=  1.47595D+02

At iterate  826    f=  3.31913D+06    |proj g|=  2.93385D+02

At iterate  827    f=  3.31913D+06    |proj g|=  2.76010D+02

At iterate  828    f=  3.31913D+06    |proj g|=  3.40260D+02

At iterate  829    f=  3.31913D+06    |proj g|=  4.77140D+02

At iterate  830    f=  3.31913D+06    |proj g|=  8.14798D+02

At iterate  831    f=  3.31913D+06    |proj g|=  1.11528D+02

At iterate  832    f=  3.31913D+06    |proj g|=  9.41326D+01

At iterate  833    f=  3.31913D+06    |proj g|=  1.61768D+02

At iterate  834    f=  3.31913D+06    |proj g|=  2.73045D+02

At iterate  835    f=  3.31913D+06    |proj g|=  5.45818D+02

At iterate  836    f=  3.31913D+06    |proj g|=  3.18143D+02

At iterate  837    f=  3.31913D+06    |proj g|=  8.83982D+01

At iterate  838    f=  3.31913D+06    |proj g|=  7.69610D+01

At iterate  839    f=  3.31912D+06    |proj g|=  9.60626D+01

At iterate  840    f=  3.31912D+06    |proj g|=  1.69942D+02

At iterate  841    f=  3.31912D+06    |proj g|=  2.21566D+02

At iterate  842    f=  3.31912D+06    |proj g|=  4.44612D+02

At iterate  843    f=  3.31912D+06    |proj g|=  2.75107D+02

At iterate  844    f=  3.31912D+06    |proj g|=  1.21541D+02
```

```
At iterate  845    f=  3.31912D+06    |proj g|=  7.83065D+01

At iterate  846    f=  3.31912D+06    |proj g|=  7.18891D+02

At iterate  847    f=  3.31912D+06    |proj g|=  2.42748D+02

At iterate  848    f=  3.31912D+06    |proj g|=  1.74810D+02

At iterate  849    f=  3.31912D+06    |proj g|=  1.65042D+02

At iterate  850    f=  3.31912D+06    |proj g|=  2.03442D+02

At iterate  851    f=  3.31912D+06    |proj g|=  2.55104D+02

At iterate  852    f=  3.31912D+06    |proj g|=  3.42578D+02

At iterate  853    f=  3.31912D+06    |proj g|=  2.60785D+02

At iterate  854    f=  3.31912D+06    |proj g|=  3.16828D+02

At iterate  855    f=  3.31912D+06    |proj g|=  2.56218D+02

At iterate  856    f=  3.31912D+06    |proj g|=  8.31182D+02

At iterate  857    f=  3.31911D+06    |proj g|=  8.17782D+02

At iterate  858    f=  3.31911D+06    |proj g|=  6.15252D+02

At iterate  859    f=  3.31911D+06    |proj g|=  1.54971D+03

At iterate  860    f=  3.31911D+06    |proj g|=  2.43952D+02

At iterate  861    f=  3.31911D+06    |proj g|=  3.18975D+02

At iterate  862    f=  3.31911D+06    |proj g|=  3.17859D+02

At iterate  863    f=  3.31911D+06    |proj g|=  3.20706D+02

At iterate  864    f=  3.31911D+06    |proj g|=  6.22025D+02

At iterate  865    f=  3.31911D+06    |proj g|=  1.80067D+02

At iterate  866    f=  3.31911D+06    |proj g|=  6.45952D+01

At iterate  867    f=  3.31911D+06    |proj g|=  2.87917D+02

At iterate  868    f=  3.31911D+06    |proj g|=  5.30461D+02
```

```
At iterate  869    f=  3.31911D+06    |proj g|=  6.04567D+02

At iterate  870    f=  3.31911D+06    |proj g|=  9.64722D+02

At iterate  871    f=  3.31911D+06    |proj g|=  1.22740D+03

At iterate  872    f=  3.31911D+06    |proj g|=  1.46226D+02

At iterate  873    f=  3.31911D+06    |proj g|=  1.57864D+02

At iterate  874    f=  3.31911D+06    |proj g|=  2.75157D+02

At iterate  875    f=  3.31911D+06    |proj g|=  2.59307D+02

At iterate  876    f=  3.31911D+06    |proj g|=  6.15425D+02

At iterate  877    f=  3.31911D+06    |proj g|=  2.70282D+02

At iterate  878    f=  3.31911D+06    |proj g|=  1.56720D+02

At iterate  879    f=  3.31911D+06    |proj g|=  1.69526D+02

At iterate  880    f=  3.31910D+06    |proj g|=  2.54487D+02

At iterate  881    f=  3.31910D+06    |proj g|=  2.30417D+02

At iterate  882    f=  3.31910D+06    |proj g|=  1.16515D+02

At iterate  883    f=  3.31910D+06    |proj g|=  4.70084D+02

At iterate  884    f=  3.31910D+06    |proj g|=  7.58089D+01

At iterate  885    f=  3.31910D+06    |proj g|=  5.58111D+01

At iterate  886    f=  3.31910D+06    |proj g|=  9.08541D+01

At iterate  887    f=  3.31910D+06    |proj g|=  2.97205D+01

At iterate  888    f=  3.31910D+06    |proj g|=  9.65048D+01

At iterate  889    f=  3.31910D+06    |proj g|=  2.43105D+02

At iterate  890    f=  3.31910D+06    |proj g|=  2.36057D+02

At iterate  891    f=  3.31910D+06    |proj g|=  2.85040D+02

At iterate  892    f=  3.31910D+06    |proj g|=  2.49033D+02
```

```
At iterate  893    f=  3.31910D+06    |proj g|=  1.41164D+02

At iterate  894    f=  3.31910D+06    |proj g|=  2.95403D+02

At iterate  895    f=  3.31910D+06    |proj g|=  1.51355D+02

At iterate  896    f=  3.31910D+06    |proj g|=  1.10821D+02

At iterate  897    f=  3.31910D+06    |proj g|=  1.17379D+02

At iterate  898    f=  3.31910D+06    |proj g|=  1.45542D+02

At iterate  899    f=  3.31910D+06    |proj g|=  1.62495D+02

At iterate  900    f=  3.31910D+06    |proj g|=  5.85135D+02

At iterate  901    f=  3.31910D+06    |proj g|=  1.54463D+02

At iterate  902    f=  3.31910D+06    |proj g|=  5.24307D+01

At iterate  903    f=  3.31910D+06    |proj g|=  6.95887D+01

At iterate  904    f=  3.31910D+06    |proj g|=  1.13818D+02

At iterate  905    f=  3.31910D+06    |proj g|=  2.17401D+02

At iterate  906    f=  3.31910D+06    |proj g|=  7.53733D+02

At iterate  907    f=  3.31910D+06    |proj g|=  1.45244D+02

At iterate  908    f=  3.31910D+06    |proj g|=  1.58752D+02

At iterate  909    f=  3.31910D+06    |proj g|=  7.90157D+01

At iterate  910    f=  3.31910D+06    |proj g|=  4.03931D+01

At iterate  911    f=  3.31910D+06    |proj g|=  1.75322D+02

At iterate  912    f=  3.31910D+06    |proj g|=  1.55207D+02

At iterate  913    f=  3.31910D+06    |proj g|=  5.23229D+02

At iterate  914    f=  3.31910D+06    |proj g|=  2.77971D+02

At iterate  915    f=  3.31910D+06    |proj g|=  1.09287D+02

At iterate  916    f=  3.31910D+06    |proj g|=  1.08114D+02
```

```
 At iterate  917    f=  3.31910D+06    |proj g|=  8.35741D+01

 At iterate  918    f=  3.31910D+06    |proj g|=  2.64461D+02

 At iterate  919    f=  3.31910D+06    |proj g|=  9.68659D+01

 At iterate  920    f=  3.31910D+06    |proj g|=  4.46530D+01

 At iterate  921    f=  3.31910D+06    |proj g|=  5.68613D+01

 At iterate  922    f=  3.31910D+06    |proj g|=  1.09727D+02

 At iterate  923    f=  3.31910D+06    |proj g|=  1.44247D+02

 At iterate  924    f=  3.31909D+06    |proj g|=  1.45719D+02

 At iterate  925    f=  3.31909D+06    |proj g|=  9.41452D+01

           * * *

 Tit   = total number of iterations
 Tnf   = total number of function evaluations
 Tnint = total number of segments explored during Cauchy searches
 Skip  = number of BFGS updates skipped
 Nact  = number of active bounds at final generalized Cauchy point
 Projg = norm of the final projected gradient
 F     = final function value

           * * *

    N    Tit     Tnf  Tnint  Skip  Nact     Projg        F
   18    925    1059      1     0     0   9.415D+01   3.319D+06
  F =   3319094.8833318558

 CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
```

```
[9]:   message: CONVERGENCE: REL_REDUCTION_OF_F_<=_FACTR*EPSMCH
       success: True
        status: 0
           fun: 3319094.8833318558
             x: [ 9.760e+00  9.214e+00 … -2.529e+00  5.239e-01]
           nit: 925
           jac: [-4.675e+00  1.071e+01 … -2.464e+01  1.849e+01]
          nfev: 1059
          njev: 1059
      hess_inv: <18x18 LbfgsInvHessProduct with dtype=float64>
```

0.0.3 make prediction

[10]:
```
# predict
standard_posterior_mean, standard_posterior_var = model.predict_y(Xtest.values)␣
 ↪# predicted mean of GP, predicted variance of GP
posterior_mean = standard_posterior_mean * train_tas_std + train_tas_mean #␣
 ↪transform mean prediction to original scale
posterior_stddev = np.sqrt(standard_posterior_var) * train_tas_std # transform␣
 ↪variance prediction to original scale standard deviation
```

[11]:
```
# put output back into xarray format for calculating RMSE/plotting
posterior_tas = np.reshape(posterior_mean, [86, 96, 144])
posterior_tas_stddev = np.reshape(posterior_stddev, [86, 96, 144])

posterior_tas_data = xr.DataArray(posterior_tas, dims=tas_truth.dims,␣
 ↪coords=tas_truth.coords)
posterior_tas_std_data = xr.DataArray(posterior_tas_stddev, dims=tas_truth.
 ↪dims, coords=tas_truth.coords)
```

[12]:
```
# Compute RMSEs
print(f"RMSE at 2050: {get_rmse(tas_truth[35], posterior_tas_data[35])}")
print(f"RMSE at 2100: {get_rmse(tas_truth[85], posterior_tas_data[85])}")
print(f"RMSE 2045-2055: {get_rmse(tas_truth[30:41], posterior_tas_data[30:41]).
 ↪mean()}")
print(f"RMSE 2090-2100: {get_rmse(tas_truth[75:], posterior_tas_data[75:]).
 ↪mean()}")
print(f"RMSE 2050-2100: {get_rmse(tas_truth[35:], posterior_tas_data[35:]).
 ↪mean()}")

# RMSE for average field over last 20 years
print(f"RMSE average last 20y: {get_rmse(tas_truth[-20:].mean(dim='time'),␣
 ↪posterior_tas_data[-20:].mean(dim='time'))}")
```

```
RMSE at 2050: 0.3026616879034685
RMSE at 2100: 0.349660122056607
RMSE 2045-2055: 0.37197303087860867
RMSE 2090-2100: 0.36988188858895676
RMSE 2050-2100: 0.3765012617102069
RMSE average last 20y: 0.19389283978715924
```

[18]:
```
from matplotlib import colors
# plotting predictions
divnorm = colors.TwoSlopeNorm(vmin=-2., vcenter=0., vmax=5)
diffnorm = colors.TwoSlopeNorm(vmin=-2., vcenter=0., vmax=2)

## Temperature
proj = ccrs.PlateCarree()
```

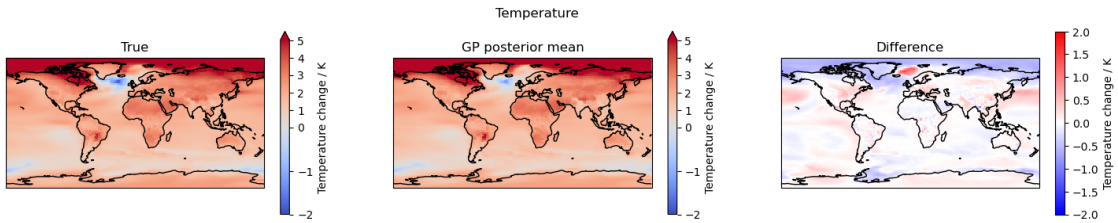
```
fig = plt.figure(figsize=(18, 3))
fig.suptitle('Temperature')

# Test
plt.subplot(131, projection=proj)
tas_truth.sel(time=slice(2050,None)).mean('time').plot(cmap="coolwarm",␣
 ↪norm=divnorm,
                                cbar_kwargs={"label":"Temperature change / K"})
plt.gca().coastlines()
plt.setp(plt.gca(), title='True')

# Emulator
plt.subplot(132, projection=proj)
posterior_tas_data.sel(time=slice(2050,None)).mean('time').
 ↪plot(cmap="coolwarm", norm=divnorm,
                        cbar_kwargs={"label":"Temperature change / K"})
plt.gca().coastlines()
plt.setp(plt.gca(), title='GP posterior mean')

# Difference
difference = tas_truth - posterior_tas_data
plt.subplot(133, projection=proj)
difference.sel(time=slice(2050,None)).mean('time').plot(cmap="bwr",␣
 ↪norm=diffnorm,
                cbar_kwargs={"label":"Temperature change / K"})
plt.gca().coastlines()
plt.setp(plt.gca(), title='Difference')
```

[18]:
```
[Text(0.5, 1.0, 'Difference')]
```



[14]:
```
model
```

[14]:
```
<gpflow.models.gpr.GPR object at 0x154a4419b160>
```

name	class	transform	prior

```
trainable     shape     dtype     value


 GPR.mean_function.c                  Parameter   Identity
True          (1,)      float64   [0.52391237]


 GPR.kernel.kernels[0].variance       Parameter   Softplus
True          ()        float64   9.2137


 GPR.kernel.kernels[0].lengthscales   Parameter   Softplus
True          ()        float64   9.76014


 GPR.kernel.kernels[1].variance       Parameter   Softplus
True          ()        float64   0.0849203733848593


 GPR.kernel.kernels[1].lengthscales   Parameter   Softplus
True          ()        float64   0.7701057103859545


 GPR.kernel.kernels[2].variance       Parameter   Softplus
True          ()        float64   0.05500694522190085


 GPR.kernel.kernels[2].lengthscales   Parameter   Softplus
True          (5,)      float64   [2.91624279e-02, 5.70395500e+01,
6.89007300e+01…
```

```
  GPR.kernel.kernels[3].variance       Parameter   Softplus
True          ()        float64   1.08074
```

```
  GPR.kernel.kernels[3].lengthscales   Parameter   Softplus
True          (5,)      float64   [14.39288, 15.15776, 28.04018…
```

```
  GPR.likelihood.variance              Parameter   Softplus + Shift
True          ()        float64   0.07668340655647475
```

[ ]: