Temperature Profile Classification - 2 Class system - r3

GMM classification of Southern Ocean Argo float temperature profile data. This notebook uses a previously created model, PCA and sample data.

Choices for data

In [1]:

```
#Experiment data for analysis
dataVariableId = 'thetao'
dataExperimentId = 'historical'
dataSourceId = 'UKESM1-0-LL'
dataInstitutionId = 'MOHC'
approvedIds = ["r1i1p1f2", "r2i1p1f2", "r3i1p1f2"] #insert start of approved member_ids

#File imports
maskName = "OceanMaskVolcello"
modelName = "GMM_UK_2Class_R3"

#Data definitions
startDate = '1980-01'
endDate = '2009-12'
timeRange = slice(startDate, endDate)
levSel = slice(0, 2000) #Selected levels to be investigated
maxLat = -30 #Selected latitude to be investigated
```

Libaries and Modules

Importing the necessary libaries and modules for the notebook.

In [2]:

```
#Import cell
import calendar
import cartopy.crs as ccrs
import cartopy.feature as cfeature
import dask.dataframe as dd
import fsspec
import matplotlib.dates as mdates
import matplotlib as mpl ###
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
import matplotlib.ticker as ticker
import xarray as xr
import zarr

from dask import config
from dask import delayed
from joblib import dump, load
from matplotlib.pyplot import cm
from sklearn import mixture
from sklearn.decomposition import PCA
from sklearn import preprocessing
from scipy import signal
```

```
config.set(**{'array.slicing.split_large_chunks': True})
print("Imports complete")
```

```
Imports complete
```

Importing data sets

Importing the data for the models.

Import sample data set and corresponding time/geo data

In [3]:

```
importName = modelName + "_Meta_Full"
sampleMetaDFL = pd.read_csv(importName)
sampleMetaDFL = sampleMetaDFL.drop(columns=["Unnamed: 0"])
sampleMetaDFL["time"] = pd.to_datetime(sampleMetaDFL["time"])
print("Labeled sample meta data loaded from "+ importName +" and stored in sampleMetaDFL.
sampleMetaDFL.head()
```

```
Labeled sample meta data loaded from GMM_UK_2Class_R3_Meta_Full and stored in sampleMetaDF
L. 7989840 samples loaded.
```

Out[3]:

	lat	lon	time	labelSorted	max posterior prob	classUncertainty
0	-66.111520	73.5	1980-01-01	0	1.0	6.179905e-09
1	-65.703316	73.5	1980-01-01	0	1.0	2.966161e-10
2	-65.288570	73.5	1980-01-01	0	1.0	5.715428e-11
3	-64.867195	73.5	1980-01-01	0	1.0	3.317879e-11
4	-64.439100	73.5	1980-01-01	0	1.0	3.679457e-11

In [4]:

```
#Meta data date processing cell
globalStartDate = sampleMetaDFL["time"][0]
globalDateInc = sampleMetaDFL["time"].unique()[1] - globalStartDate
globalEndDateIn = sampleMetaDFL["time"].iloc[-1]
globalEndDateOut = globalEndDateIn + globalDateInc

globalStartDateStr = str(globalStartDate)[:7]
globalEndDateInStr = str(globalEndDateIn)[:7]
globalEndDateOutStr = str(globalEndDateOut)[:7]
print("Sample meta data dates manipulated and stored in globalStartDate etc.")
```

```
Sample meta data dates manipulated and stored in globalStartDate etc.
```

Loading ocean Masks

In [5]:

```
#Ocean mask import cell
maskFile = xr.open_dataset(maskName)
oceanMask = maskFile.to_array()
maskFile = xr.open_dataset("OceanMaskUKESM1")
oceanMask2 = maskFile.to_array()
print("Mask Loaded and stored in oceanMask and oceanMask2 (volcello and UKESM).")
```

```
Mask Loaded and stored in oceanMask and oceanMask2 (volcello and UKESM).
```

Unpacking ocean masks

In [6]:
```
#Mask unpacking cell
geoRange = oceanMask #copying mask
geoRange = geoRange.rename({"variable":"cleanMe"}) #Dimension removal
geoRange = geoRange.sel(cleanMe = geoRange.cleanMe.values[0]) #Dimension removal
geoRange = geoRange.reset_coords("cleanMe", drop=True) #Dimension removal
geoRangeS = geoRange.stack(ij =("i", "j")) #Stacking
geoRangeFilt = geoRangeS.dropna("ij")
print("Ocean mask unpacked into geoRangeFilt.")

geoRange2 = oceanMask2 #copying mask
geoRange2S = geoRange2.stack(ij =("i", "j")) #Stacking
geoRangeFilt2 = geoRange2S.dropna("ij")
print("UKESM Ocean mask unpacked into geoRangeFilt2.")
```

```
Ocean mask unpacked into geoRangeFilt.
UKESM Ocean mask unpacked into geoRangeFilt2.
```

Date Calculations

In [7]:
```
#Date calculation cell
startDateNp = np.datetime64(startDate, 'M')
endDateNp = np.datetime64(endDate, 'M')
timeDiff = endDateNp - startDateNp
timeDiff = timeDiff.astype(int) + 1
print("Calculated date range.")
```

```
Calculated date range.
```

Calculation functions

Functions:

- pickRand - Takes in data frame and returns sampled data frame with a randomly selected number of rows from the input data frame, controled by the second input variable to the function.
- storeMeta - Returns a np array containing the latitude and longitude data for an input xarray and associated ij.
- loadModel - loadeds and returns GMM model named in input.
- saveModel - saves input GMM model to provided name, if no name provided default is GMMGenerated.

In [8]:
```
#Calculation functions cell
def butter_lowpass(data,cut,order=4,sample_freq=1) :
    nyq = 0.5*sample_freq
    pass_freq =1./cut/nyq
    sos=signal.butter(order, pass_freq, 'low', output='sos')
    filt=signal.sosfiltfilt(sos,data)
    return filt

def pickRand(dataArray, sampleFactor):
    '''Returns a sample of the input array, size of sampled array is based on sampleFactor
    arrLen = len(dataArray)
    if sampleFactor > 1:
        sampleSize = int(sampleFactor)
    elif sampleFactor > 0:
        sampleSize = int(sampleFactor*arrLen)
    else:
        return 1

    filtArr = np.zeros(arrLen, dtype=bool) # empty mask
```

```
    sampleId = np.random.choice(arrLen, sampleSize, False) # np array of randomly generate
    for i in sampleId:
        filtArr[i] = True # populating mask
    return dataArray[filtArr] # applies mask


def pickRandMask(maskLen, maskQuantity, sampleFactor):
    '''Returns a linear mask for the input dimensions, size of mask is based on sampleFact
    if sampleFactor > 1:
        sampleSize = int(sampleFactor)
    elif sampleFactor > 0:
        sampleSize = int(sampleFactor*maskLen)
    else:
        return 1

    globalArr = np.empty(shape=(0), dtype=bool)
    for i in range(maskQuantity):
        filtArr = np.zeros(maskLen, dtype=bool) # empty mask
        sampleId = np.random.choice(maskLen, sampleSize, False) # np array of randomly gen
        for j in sampleId:
            filtArr[j] = True # populating mask
        globalArr = np.append(globalArr, filtArr)
    return globalArr


def storeMeta(dataArray):
    '''Returns a np array containing the latitude and longitude data for the input xarray
    storeLen = len(dataArray["lat"]) # assumes each lat has a corresponding lon
    storage = np.empty(shape=(0,storeLen))
    storage = np.append(storage, [dataArray["lat"].values], axis = 0)
    storage = np.append(storage, [dataArray["lon"].values], axis = 0)
    #storage = np.append(storage, [dataArray["time"].values], axis = 0)
    #storage = np.append(storage, [dataArray["ij"].values], axis = 0)
    return storage


def loadModel(modelName:str):
    '''Loades the input GMM model named in the functions input. Returns loaded model.'''
    means = np.load(modelName + '_means.npy')
    covar = np.load(modelName + '_covariances.npy')
    GMModel = mixture.GaussianMixture(n_components = len(means), covariance_type='full')
    GMModel.precisions_cholesky_ = np.linalg.cholesky(np.linalg.inv(covar))
    GMModel.weights_ = np.load(modelName + '_weights.npy')
    GMModel.means_ = means
    GMModel.covariances_ = covar
    return GMModel


def saveModel(GMModel, modelName = "GMMGenerated"):
    '''Saves the input GMM model's weights, means and covariances. Assigns input name if p
    GMModel_name = str(modelName)
    np.save(modelName + '_weights', GMModel.weights_, allow_pickle=False)
    np.save(modelName + '_means', GMModel.means_, allow_pickle=False)
    np.save(modelName + '_covariances', GMModel.covariances_, allow_pickle=False)
    return 0

print("Calculation functions defined.")
```

```
Calculation functions defined.
```

Plotting functions

Functions:

- locationPlotGroup - plots location and classification of data points for an input numpy array.
- locationPlotGroupDF - plots location and classification of data points for an input data frame.
- locationPlotGroupDFMonthly - plots location and classification of data points for an input data frame in monthly subplots.
- locationPlotTime - plots locations of an input data array on a map with a colour scale for time.
- locationPlotUncertaintyDF - plots uncertainty in classification on a location plot.

In [9]:

```
#Plotting functions Cell
#sampleDepthAxis = dfESMLatLevT["lev"]
decadeColours = ["green", "yellow", "red"]
timeList = sampleMetaDFL["time"].unique()

def locationPlotGroup(metaDataArray, size, plotNo):
    '''Plots locations of numpy arrays with group colour scheme'''
    plt.figure(plotNo, figsize=size)
    ax = plt.axes(projection=ccrs.SouthPolarStereo())
    ax.add_feature(cfeature.OCEAN)
    ax.add_feature(cfeature.COASTLINE)
    ax.coastlines()
    ax.gridlines()
    im = ax.scatter(metaDataArray[1], metaDataArray[0], transform=ccrs.PlateCarree(), c =
    cb = plt.colorbar(im)
    plt.plot(np.arange(0,361,1),np.ones(361)*-29.5, transform=ccrs.PlateCarree(), color="
    plt.title("Grouped Sample Locations ("+str(len(metaDataArray[0]))+")")


def locationPlotGroupDFTime(dataFrame, title, size, plotNo):
    '''Plots locations of data frame points with group colour scheme'''
    plt.figure(plotNo, figsize=size)
    ax = plt.axes(projection=ccrs.SouthPolarStereo())
    ax.add_feature(cfeature.OCEAN)
    ax.add_feature(cfeature.COASTLINE)
    ax.coastlines()
    ax.gridlines()
    im = ax.scatter(dataFrame["lon"], dataFrame["lat"], transform=ccrs.PlateCarree(), c =
    cb = plt.colorbar(im)
    loc = mdates.AutoDateLocator()
    cb.ax.yaxis.set_major_locator(loc)
    cb.ax.yaxis.set_major_formatter(mdates.ConciseDateFormatter(loc))
    plt.plot(np.arange(0,361,1),np.ones(361)*-29.5, transform=ccrs.PlateCarree(), color="
    plt.title(str(title))


def locationPlotGroupDFLab(dataFrame, title, size, plotNo):
    '''Plots locations of data frame points with group colour scheme'''
    plt.figure(plotNo, figsize=size)
    ax = plt.axes(projection=ccrs.SouthPolarStereo())
    ax.add_feature(cfeature.OCEAN)
    ax.add_feature(cfeature.COASTLINE)
    ax.coastlines()
    ax.gridlines()
    im = ax.scatter(dataFrame["lon"], dataFrame["lat"], transform=ccrs.PlateCarree(), c =
    cb = plt.colorbar(im)
    plt.plot(np.arange(0,361,1),np.ones(361)*-29.5, transform=ccrs.PlateCarree(), color="
    plt.title(str(title))


def locationPlotGroupDFMonthly(dataFrame, title, plotNo):
    '''Plots locations of dataframe points by monthly subplot with group colour scheme'''
    fig = plt.figure(plotNo, figsize=(30,42))
    plt.title(str(title))
    for i in range(1, 13):
        #timeData = dataFrame.where(dataFrame["time"].dt.month==i) #normal dt info
```

```python
        timeData = dataFrame.where(dataFrame["time"] ==i) #groupby dt info
        ax = plt.subplot(4, 3, i, projection=ccrs.SouthPolarStereo())
        ax.add_feature(cfeature.OCEAN)
        ax.add_feature(cfeature.COASTLINE)
        ax.coastlines()
        ax.gridlines()
        im = ax.scatter(timeData["lon"], timeData["lat"], transform=ccrs.PlateCarree(), c
        plt.plot(np.arange(0,361,1),np.ones(361)*-29.5, transform=ccrs.PlateCarree(), colo
        plt.title(calendar.month_abbr[i])
    plt.subplots_adjust(wspace=0, hspace=0.05)
    cb_ax = fig.add_axes([0.27, 0.1, 0.5, 0.02])
    cbar = fig.colorbar(im, cax=cb_ax, orientation="horizontal")


def locationPlotTime(dataArray, size, plotNo):
    '''Plots locations of numpy arrays with date colour scheme'''
    plt.figure(plotNo, figsize=size)
    ax = plt.axes(projection=ccrs.SouthPolarStereo())
    ax.add_feature(cfeature.OCEAN)
    ax.add_feature(cfeature.COASTLINE)
    ax.coastlines()
    ax.gridlines()
    im = ax.scatter(dataArray[1], dataArray[0], transform=ccrs.PlateCarree(), c= mdates.da
    cb = plt.colorbar(im)
    loc = mdates.AutoDateLocator()
    cb.ax.yaxis.set_major_locator(loc)
    cb.ax.yaxis.set_major_formatter(mdates.ConciseDateFormatter(loc))
    plt.plot(np.arange(0,361,1),np.ones(361)*-29.5, transform=ccrs.PlateCarree(), color="
    plt.title("Sample Locations ("+str(len(dataArray[0]))+")")


def locationPlotUncertaintyDF(dataFrame, title, size, plotNo):
    '''Plots input data array classification uncertainties'''
    plt.figure(plotNo, figsize=size)
    ax = plt.axes(projection=ccrs.SouthPolarStereo())
    ax.add_feature(cfeature.OCEAN)
    ax.add_feature(cfeature.COASTLINE)
    ax.coastlines()
    ax.gridlines()
    im = ax.scatter(dataFrame["lon"], dataFrame["lat"], transform=ccrs.PlateCarree(), c =
    cb = plt.colorbar(im)
    plt.plot(np.arange(0,361,1),np.ones(361)*-29.5, transform=ccrs.PlateCarree(), color="
    plt.title(str(title))


def locationPlotUncertaintyDFMonthly(dataFrame, title, plotNo):
    '''Plots locations of dataframe points by monthly subplot with group colour scheme'''
    fig = plt.figure(plotNo, figsize=(30,42))
    plt.title(str(title))
    for i in range(1, 13):
        #timeData = dataFrame.where(dataFrame["time"].dt.month==i) #normal dt info
        timeData = dataFrame.where(dataFrame["time"] ==i) #groupby dt info
        ax = plt.subplot(4, 3, i, projection=ccrs.SouthPolarStereo())
        ax.add_feature(cfeature.OCEAN)
        ax.add_feature(cfeature.COASTLINE)
        ax.coastlines()
        ax.gridlines()
        im = ax.scatter(timeData["lon"], timeData["lat"], transform=ccrs.PlateCarree(), c
        #cb = plt.colorbar(im, fraction=0.046, pad=0.04)
        plt.plot(np.arange(0,361,1),np.ones(361)*-29.5, transform=ccrs.PlateCarree(), colo
        plt.title(calendar.month_abbr[i])
    plt.subplots_adjust(wspace=0, hspace=0.05)
    cb_ax = fig.add_axes([0.27, 0.1, 0.5, 0.02])
    cbar = fig.colorbar(im, cax=cb_ax, orientation="horizontal")
```

```
def locationPlotXr(dataArray, size, plotNo):
    '''Plots locations of numpy arrays with date colour scheme'''
    plt.figure(plotNo, figsize=size)
    ax = plt.axes(projection=ccrs.SouthPolarStereo())
    ax.add_feature(cfeature.OCEAN)
    ax.add_feature(cfeature.COASTLINE)
    ax.coastlines()
    ax.gridlines()
    im = ax.scatter(dataArray["lon"], dataArray["lat"], transform=ccrs.PlateCarree())
    plt.plot(np.arange(0,361,1),np.ones(361)*-29.5, transform=ccrs.PlateCarree(), color="B
    plt.title("Sample Locations ("+str(len(dataArray["lat"]))+")")


def locationUncertaintyMean(decadeMeanList, decadeStdList, uncertaintyThreshold, figSize,
    '''Plots mean latitude for classification uncertainty with +- 1 std'''
    plt.figure(plotNo, figsize=figSize)
    ax = plt.axes(projection=ccrs.SouthPolarStereo())
    ax.add_feature(cfeature.OCEAN)
    ax.add_feature(cfeature.COASTLINE)
    ax.coastlines()
    ax.gridlines()
    for i in range(len(decades)):
        ax.plot(decadeMeanList[i].index, decadeMeanList[i]["lat"], transform=ccrs.PlateCar
        ax.plot(decadeMeanList[i].index, decadeMeanList[i]["lat"] + decadeStdList[i]["lat"
        ax.plot(decadeMeanList[i].index, decadeMeanList[i]["lat"] - decadeStdList[i]["lat"

    ax.plot(np.arange(0,361,1),np.ones(361)*-29.5, transform=ccrs.PlateCarree(), color="Bl
    plt.title("Classification Uncertainty above "+str(uncertaintyThreshold)+" Mean Latituc
    plt.legend()


def timeSingleLatMean(meanLatArr, lineStyle , arrThreshold, arrSmoothFact, plotNo):
    plt.figure(plotNo, figsize=(20,10))
    plt.plot(timeList, meanLatArr, lw=1, ls=lineStyle ,label="Thresh_"+str(arrThreshold)+"
    plt.xlabel("Date")
    plt.ylabel("Singular Mean Latitude")
    plt.title("Classification Uncertainty Mean Latitude over time")
    plt.legend()
    #plt.gca().invert_yaxis()


print("Plotting functions defined.")
```

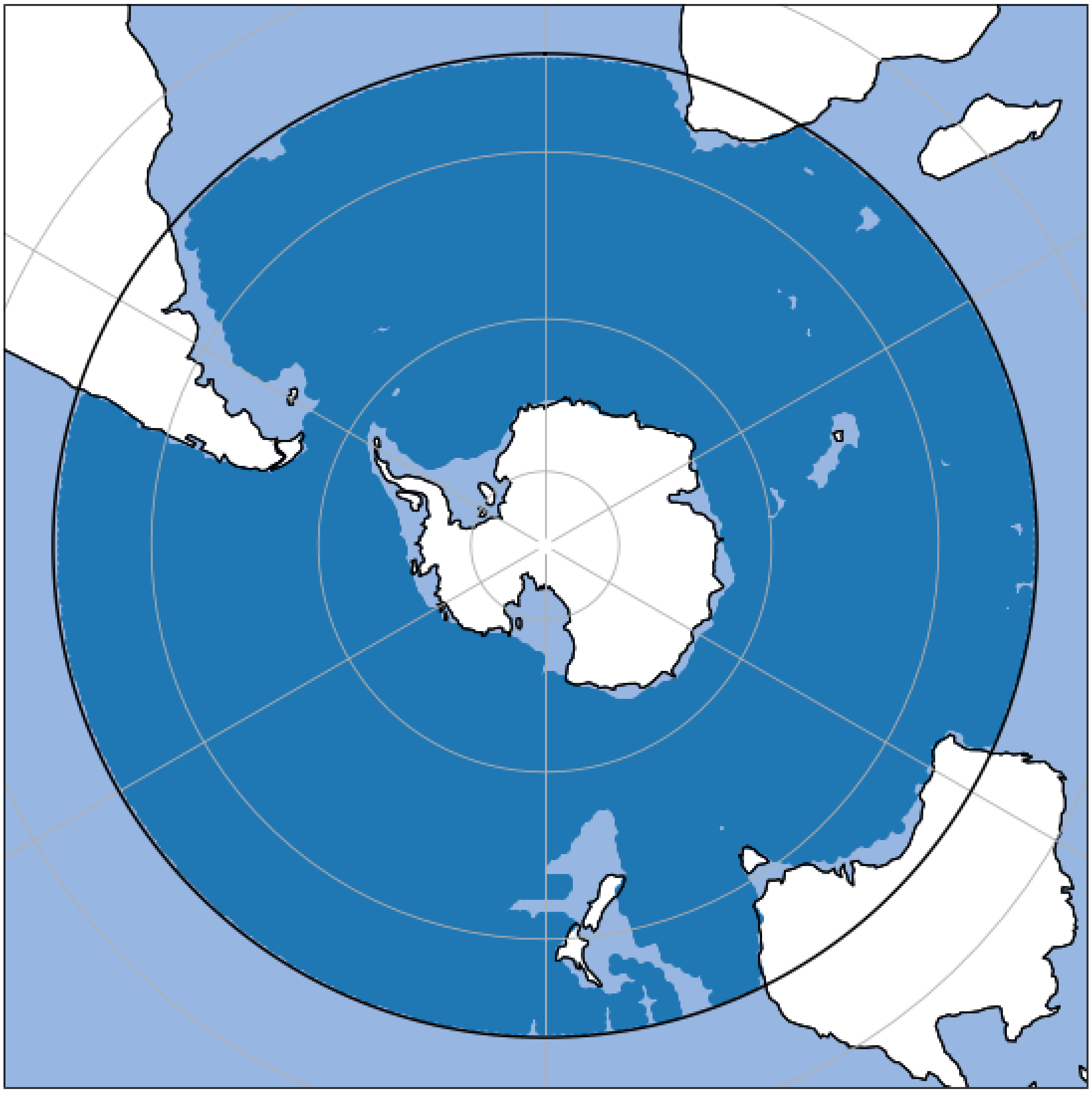
```
Plotting functions defined.
```

Plotting Ocean Mask

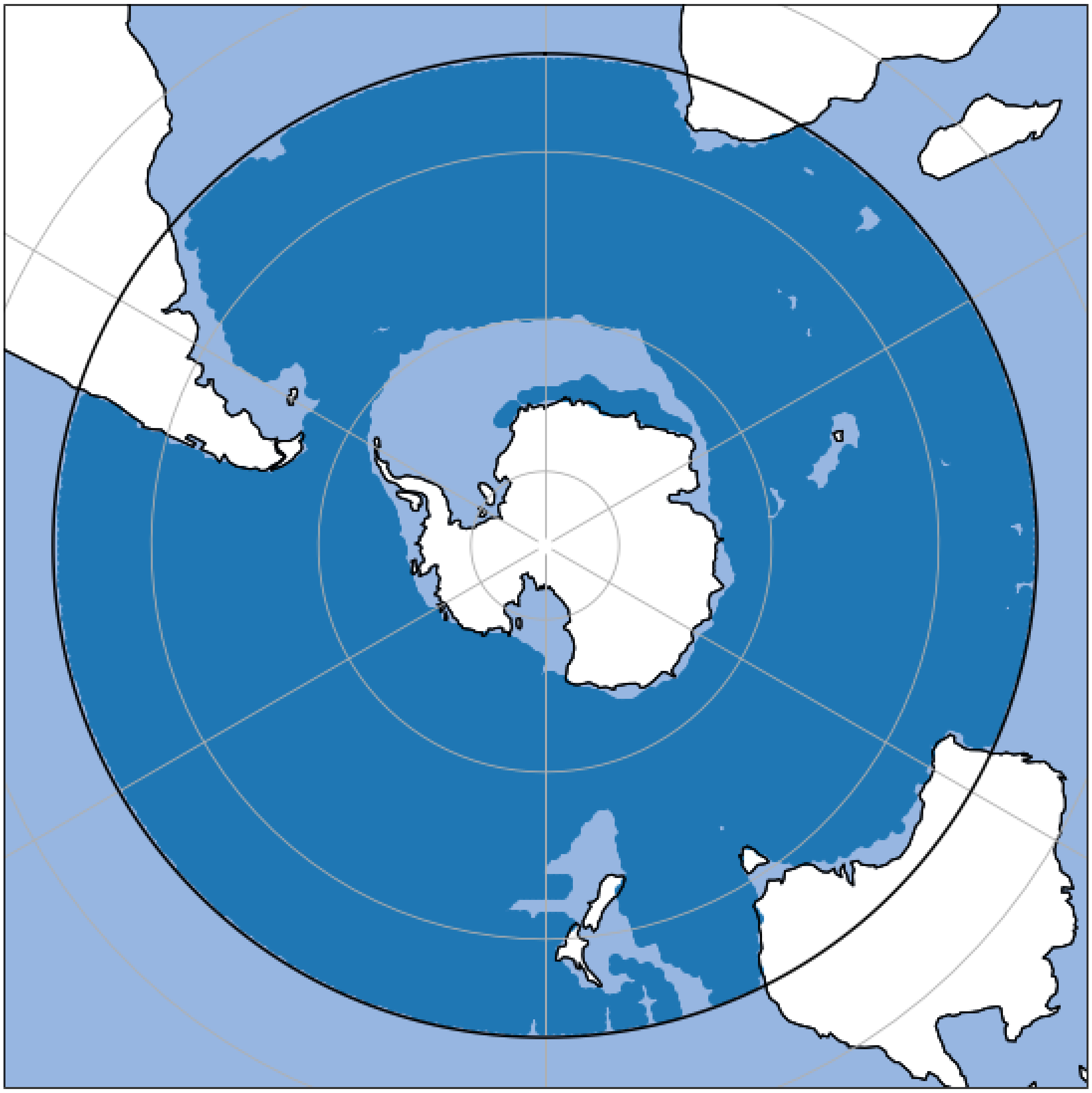
In [10]:

```
#Mask plotting cell
locationPlotXr(geoRangeFilt, (10,10), 1) #OceanMaskVolcello
locationPlotXr(geoRangeFilt2, (10,10), 2) #OceanMaskUKESM1
plt.show()
```

Sample Locations (22194)



Sample Locations (19548)



Anomalies

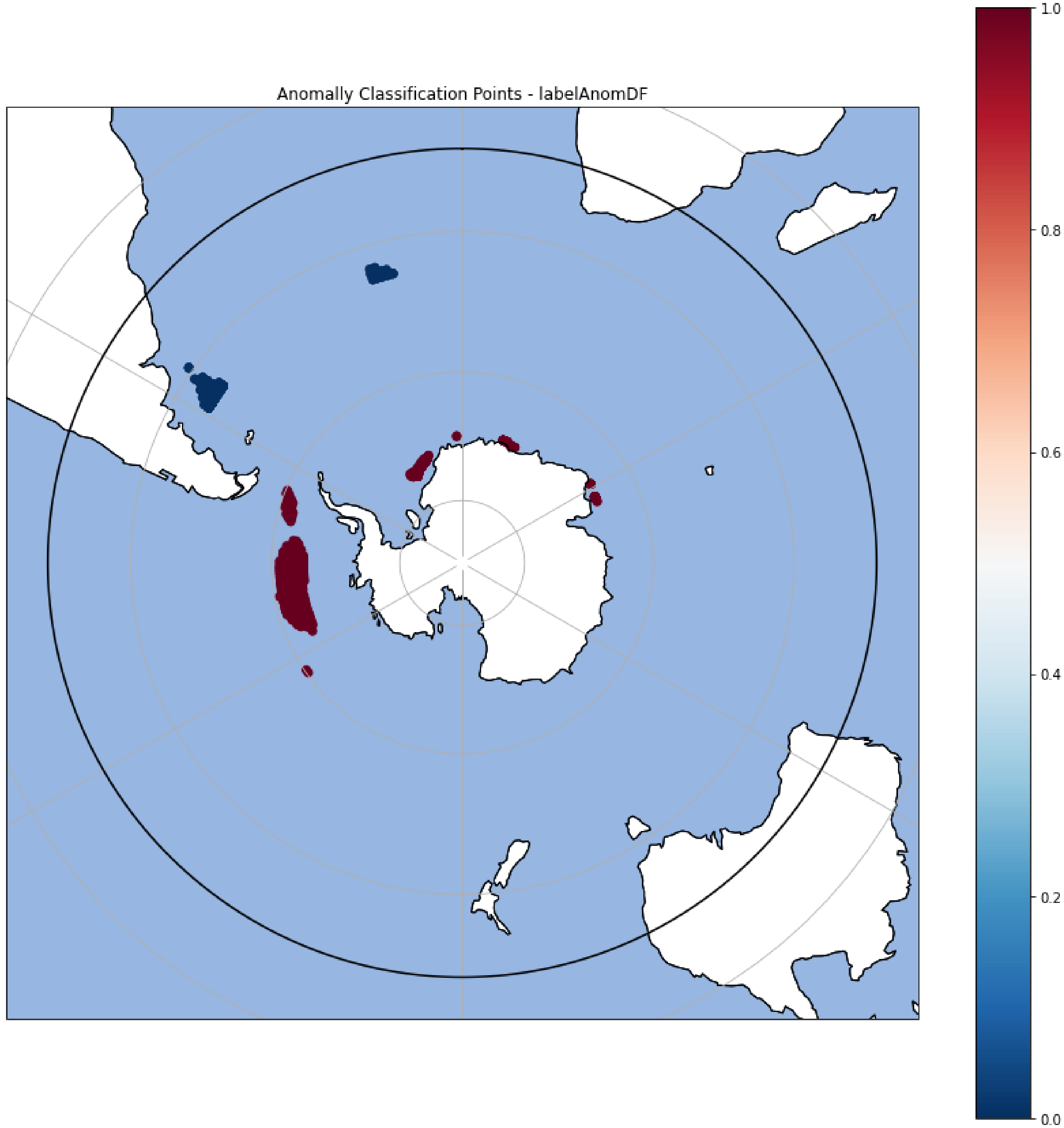
In [11]:
```
#Initial anomalous data point df creation cell
labelAnomDF = sampleMetaDFL[np.logical_or(np.logical_and(sampleMetaDFL["lat"]<-60, sampleM
print("Class 0 above -45 and Class 1 below -60 lat. Stored in labelAnomDF. "+str(len(label
```

```
Class 0 above -45 and Class 1 below -60 lat. Stored in labelAnomDF. 2160 anomalous points
detected.
```

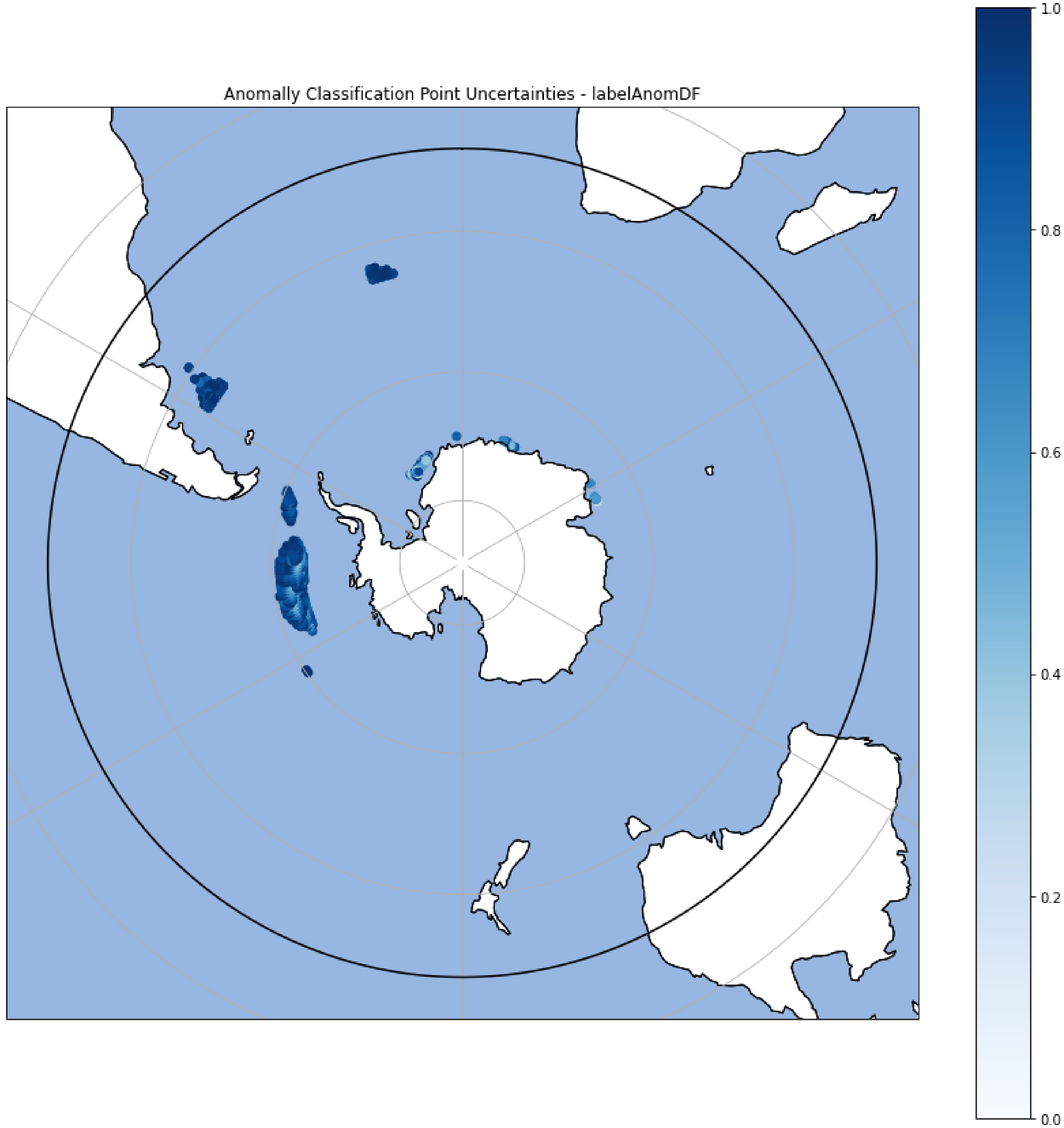
In [12]:
```
#High confidence anomalous data point df creation cell
labelAnomConDF = labelAnomDF[labelAnomDF["classUncertainty"]<0.25]
print("High Classification Confidence DF of labelAnomDF (<0.25). "+str(len(labelAnomConDF)
```

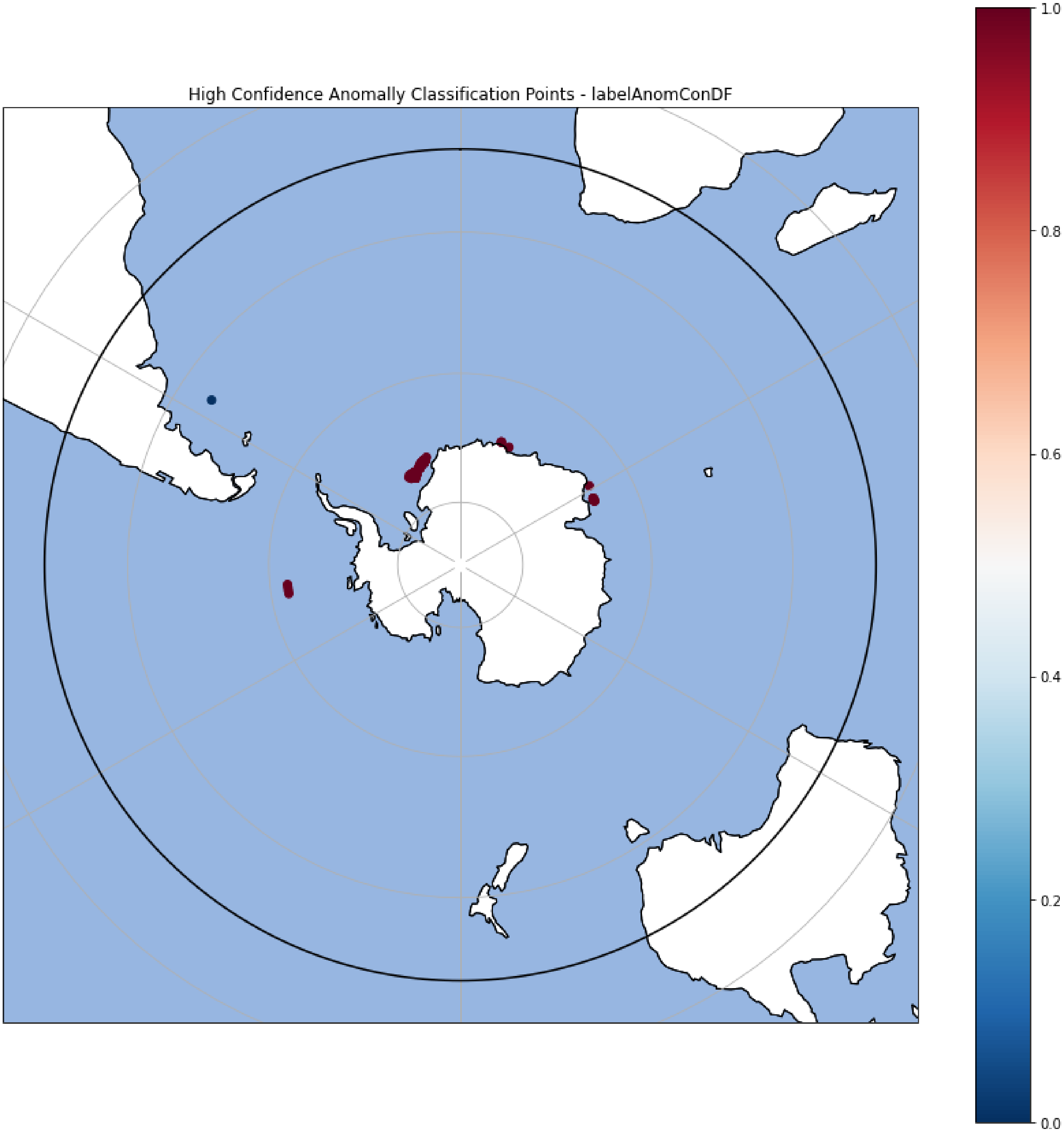
```
High Classification Confidence DF of labelAnomDF (<0.25). 300 anomalous points detected.
```

In [13]:
```
locationPlotGroupDFLab(labelAnomDF, "Anomally Classification Points - labelAnomDF", (15,15
locationPlotUncertaintyDF(labelAnomDF, "Anomally Classification Point Uncertainties - labe
locationPlotGroupDFLab(labelAnomConDF, "High Confidence Anomally Classification Points - I
plt.show()
```



Anomally Classification Points - labelAnomDF
1.0
0.8
0.6
0.4
0.2
0.0


Anomally Classification Point Uncertainties - labelAnomDF
1.0
0.8
0.6
0.4
0.2
0.0

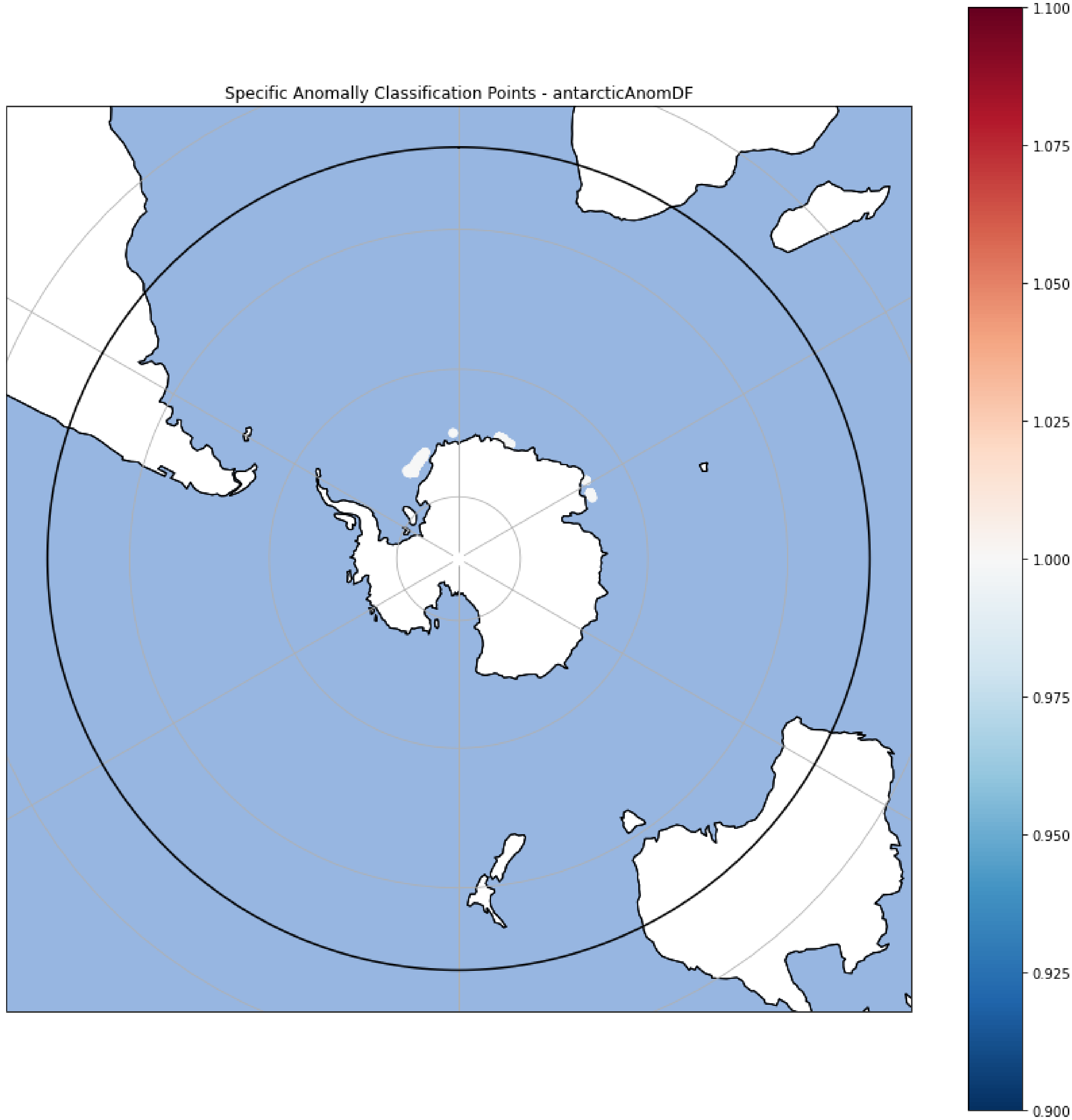


Antarctic Anomalous Classifications

In [14]:

```
antarcticAnomDF = sampleMetaDFL[np.logical_and(np.logical_and(sampleMetaDFL["labelSorted"]
locationPlotGroupDFLab(antarcticAnomDF, "Specific Anomally Classification Points - antarct
print(str(len(antarcticAnomDF))+" anomalous samples found. (Lat<-65, Lon<70, Lon>-60)")
plt.show()
```

```
702 anomalous samples found. (Lat<-65, Lon<70, Lon>-60)
```

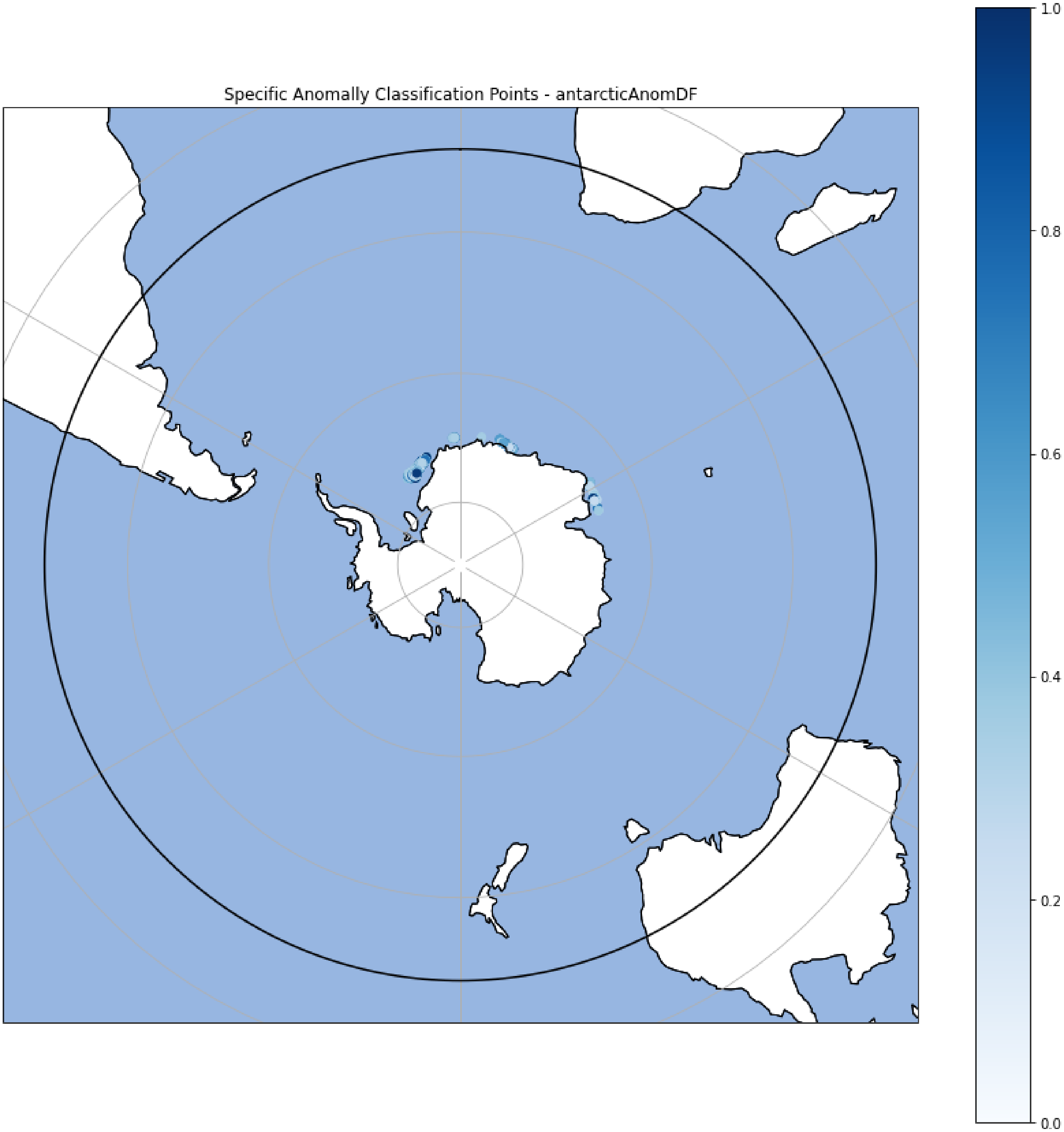


Antarctic Anomalous Classification Uncertainty

In [15]:

```
antarcticUncertDF = sampleMetaDFL[np.logical_and(np.logical_and(sampleMetaDFL["classUncert
locationPlotUncertaintyDF(antarcticUncertDF, "Specific Anomally Classification Points - ar
print(str(len(antarcticUncertDF))+" anomalous samples found. (Lat<-65, Lon<70, Lon>-60)")
plt.show()
```

```
1215 anomalous samples found. (Lat<-65, Lon<70, Lon>-60)
```

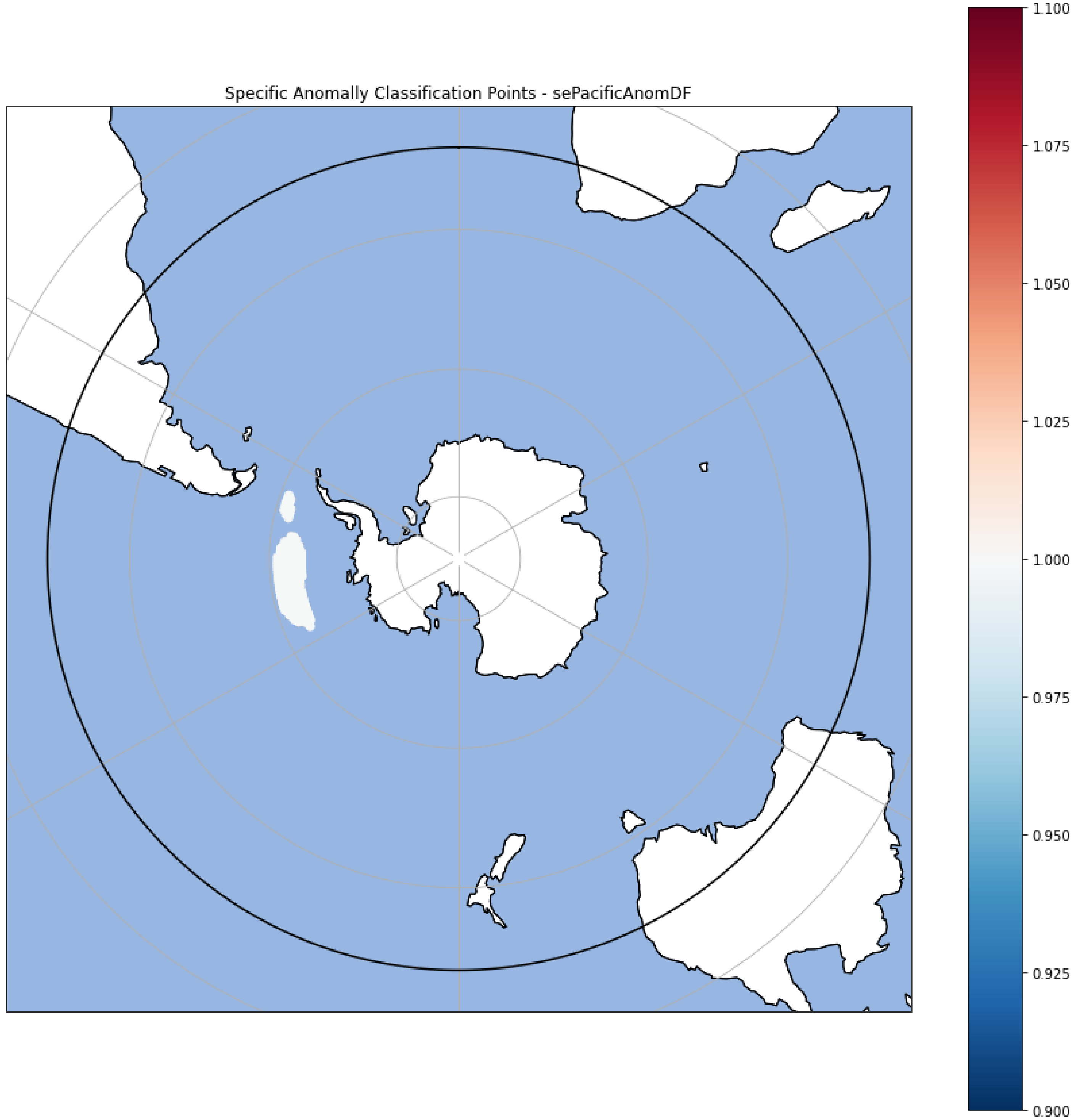


South-East Pacific Classifications

In [16]:

```
sePacificAnomDF = sampleMetaDFL[np.logical_and(np.logical_and(sampleMetaDFL["labelSorted"]
locationPlotGroupDFLab(sePacificAnomDF, "Specific Anomally Classification Points - sePaci
print(str(len(sePacificAnomDF))+" anomalous samples found. (Lat<-61, Lon<-60, Lon>-140)")
plt.show()
```

```
714 anomalous samples found. (Lat<-61, Lon<-60, Lon>-140)
```



In [17]:

```
print("South-East Pacific Anomaly Count (Lat<-61, Lon<-60, Lon>-140)")
sePacificAnomDF.groupby("time")["labelSorted"].value_counts()
```

Out[17]:

```
South-East Pacific Anomaly Count (Lat<-61, Lon<-60, Lon>-140)
time        labelSorted
1981-02-01  1              16
1986-10-01  1              26
1986-11-01  1              30
1986-12-01  1               8
1989-09-01  1              76
1989-10-01  1             110
1989-11-01  1             120
1989-12-01  1              96
1990-01-01  1              51
1990-02-01  1              34
2001-02-01  1               3
2003-09-01  1              25
```

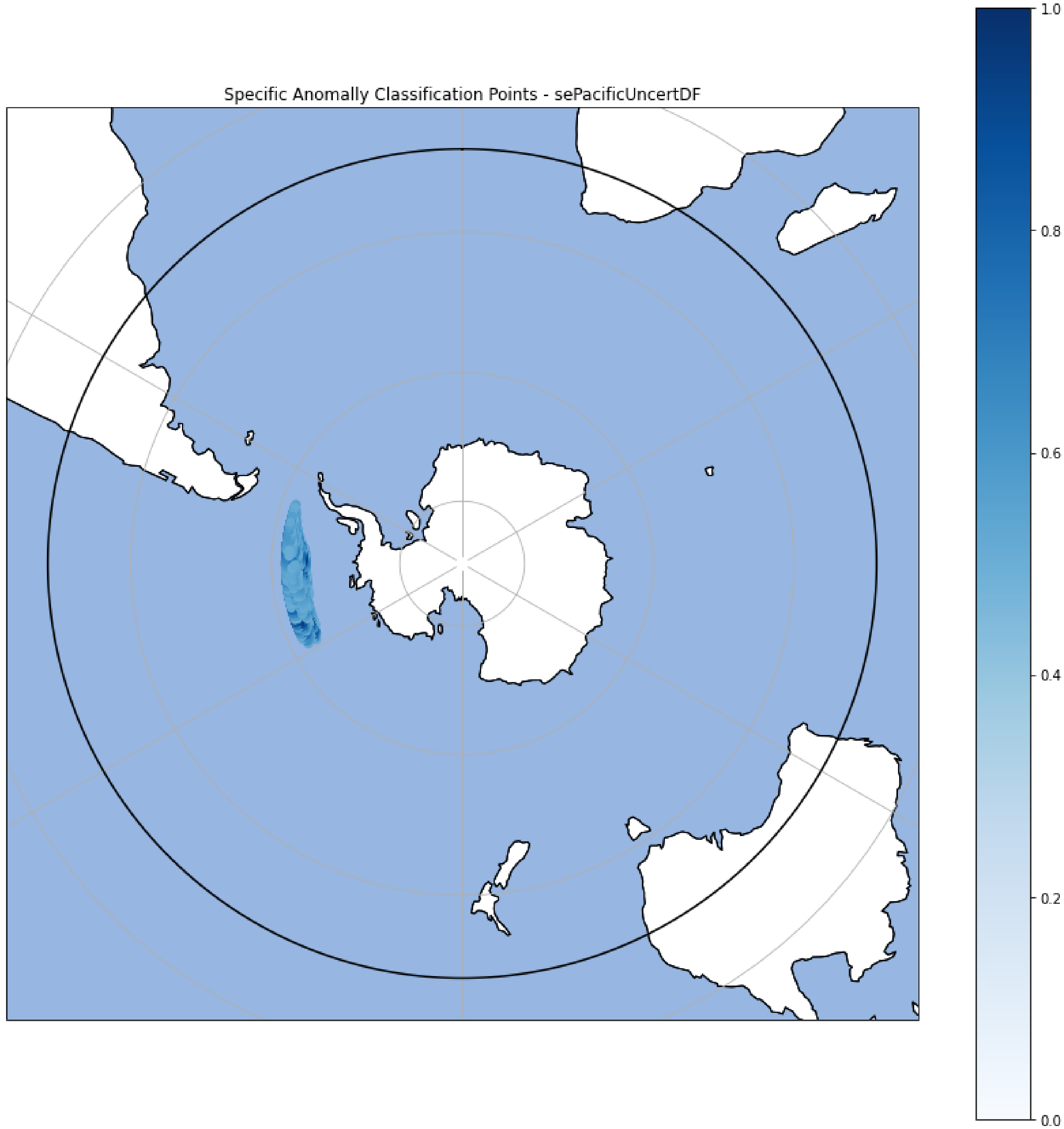
```
2003-10-01  1             53
2003-11-01  1             56
2003-12-01  1             10
Name: labelSorted, dtype: int64
```

South-East Pacific Classification Uncertainties

In [18]:

```
sePacificUncertDF = sampleMetaDFL[np.logical_and(np.logical_and(sampleMetaDFL["classUncert
locationPlotUncertaintyDF(sePacificUncertDF, "Specific Anomally Classification Points - se
print(str(len(sePacificUncertDF))+" anomalous samples found. (Lat<-62, Lon<-60, Lon>-140)'
plt.show()
```

```
3988 anomalous samples found. (Lat<-62, Lon<-60, Lon>-140)
```



In [19]:

```
i = 0
sePacificUncertStack = sePacificUncertDF.groupby("time")["time"].value_counts()
```

```python
print("South-East Pacific Uncertainty Count (Lat<-62, Lon<-60, Lon>-140)")
print("Time\t\t", "Count")
for x in sePacificUncertStack:
    strIndex = str(sePacificUncertStack.index[i])
    print(strIndex[12:22]+"\t", x)
    i +=1
```

```
South-East Pacific Uncertainty Count (Lat<-62, Lon<-60, Lon>-140)
Time            Count
1980-01-01      120
1980-02-01      91
1980-03-01      25
1980-09-01      44
1980-10-01      60
1980-11-01      23
1980-12-01      12
1981-01-01      77
1981-02-01      109
1981-03-01      59
1985-10-01      4
1986-09-01      40
1986-10-01      82
1986-11-01      96
1986-12-01      71
1987-01-01      75
1987-02-01      76
1987-03-01      60
1987-04-01      30
1987-05-01      2
1987-08-01      9
1987-09-01      59
1987-10-01      46
1987-11-01      3
1989-08-01      92
1989-09-01      146
1989-10-01      159
1989-11-01      143
1989-12-01      137
1990-01-01      117
1990-02-01      98
1990-03-01      79
1990-04-01      60
1990-05-01      49
1990-06-01      35
1990-07-01      34
1990-08-01      24
1990-09-01      23
1994-02-01      23
1997-01-01      13
1997-02-01      85
1997-03-01      20
2000-09-01      76
2000-10-01      81
2000-11-01      56
2000-12-01      51
2001-01-01      107
2001-02-01      112
2001-03-01      86
2001-04-01      34
2003-09-01      150
2003-10-01      166
2003-11-01      137
2003-12-01      100
2004-01-01      75
2004-02-01      62
```

```
2004-03-01       24
2006-09-01       15
2006-10-01       26
2006-11-01       18
2007-02-01       2
```

Data Readjustment

In [20]:

```
preAdLen = len(sampleMetaDFL)
if True:
    sampleMetaDFL = pd.concat([sampleMetaDFL, antarcticAnomDF, antarcticAnomDF]).drop_dupl
    print("Removing antarcticAnomDF.")
    sampleMetaDFL = pd.concat([sampleMetaDFL, antarcticUncertDF, antarcticUncertDF]).drop_
    print("Removing antarcticUncertDF.")
    sampleMetaDFL = pd.concat([sampleMetaDFL, sePacificAnomDF, sePacificAnomDF]).drop_dupl
    print("Removing sePacificAnomDF.")
    sampleMetaDFL = pd.concat([sampleMetaDFL, sePacificUncertDF, sePacificUncertDF]).drop_
    print("Removing sePacificUncertDF.\n")

postAdLen = len(sampleMetaDFL)
lenDiff = preAdLen - postAdLen
print("SampleMetaDFL adjusted from "+str(preAdLen)+" to "+str(postAdLen)+". "+str(lenDiff)
```

```
Removing antarcticAnomDF.
Removing antarcticUncertDF.
Removing sePacificAnomDF.
Removing sePacificUncertDF.

SampleMetaDFL adjusted from 7989840 to 7984129. 5711 samples dropped.
```

In [21]:

```
print("Last data point in set (expected 2009-12):")
sampleMetaDFL.iloc[-1]
```

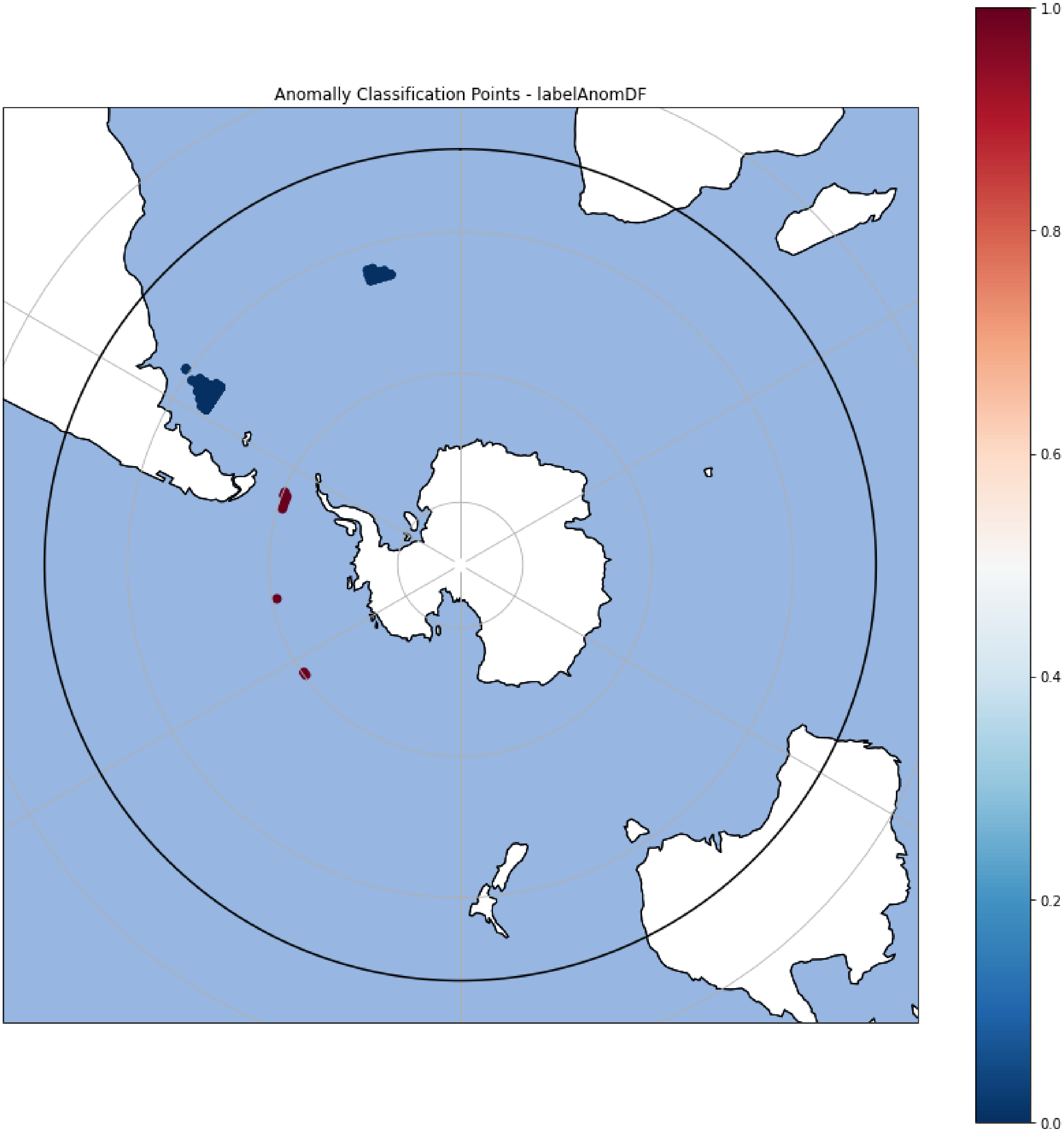
Out[21]:

```
Last data point in set (expected 2009-12):
lat                              -30.455408
lon                               72.500000
time                    2009-12-01 00:00:00
labelSorted                               1
max posterior prob                 1.000000
classUncertainty                   0.000000
Name: 7989839, dtype: object
```

In [22]:

```
labelAnomDF = sampleMetaDFL[np.logical_or(np.logical_and(sampleMetaDFL["lat"]<-60, sampleM
print("Class 0 above -45 and Class 1 below -60 lat. Stored in labelAnomDF. "+str(len(label
locationPlotGroupDFLab(labelAnomDF, "Anomally Classification Points - labelAnomDF", (15,15
```

```
Class 0 above -45 and Class 1 below -60 lat. Stored in labelAnomDF. 744 anomalous points d
etected.
```



In [23]:

```
antarcticAnomDF = sampleMetaDFL[np.logical_and(np.logical_and(sampleMetaDFL["labelSorted"]
antarcticLen = len(antarcticAnomDF)
if antarcticLen:
    locationPlotGroupDFLab(antarcticAnomDF, "Specific Anomally Classification Points - ant
print(str(antarcticLen)+" Antarctic anomalous samples found (Lat<-65, Lon<70, Lon>-60.")
plt.show()
```

```
0 Antarctic anomalous samples found (Lat<-65, Lon<70, Lon>-60.
```

Average location information

In [24]:

```
#Average classification per location cell
averageGeoG = sampleMetaDFL.groupby(["lat", "lon"])
averageGeo = averageGeoG.mean(["lat", "lon"])
```

```
averageGeo = averageGeo.reset_index()
print("Average location information calculated and stored in averageGeo.")
```

```
Average location information calculated and stored in averageGeo.
```

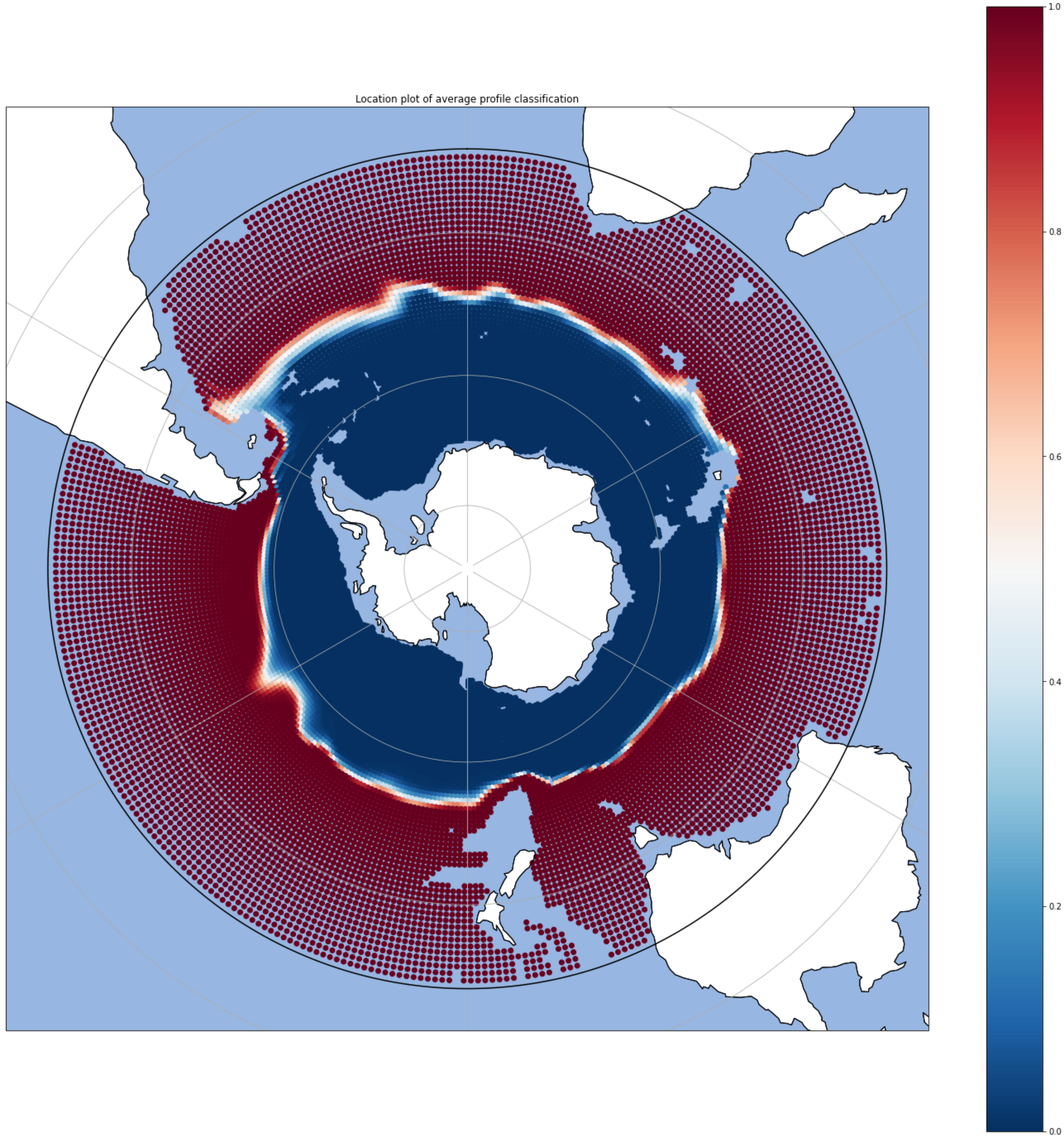
In [25]:

```
#Average classification per location and month cell
averageMonthGeoG = sampleMetaDFL.groupby([sampleMetaDFL.time.dt.month, "lat", "lon"])
averageMonthGeo = averageMonthGeoG.mean(["lat", "lon"])
averageMonthGeo = averageMonthGeo.reset_index()
print("Average monthly location information calculated and stored in averageMonthGeo.")
```

```
Average monthly location information calculated and stored in averageMonthGeo.
```

In [26]:

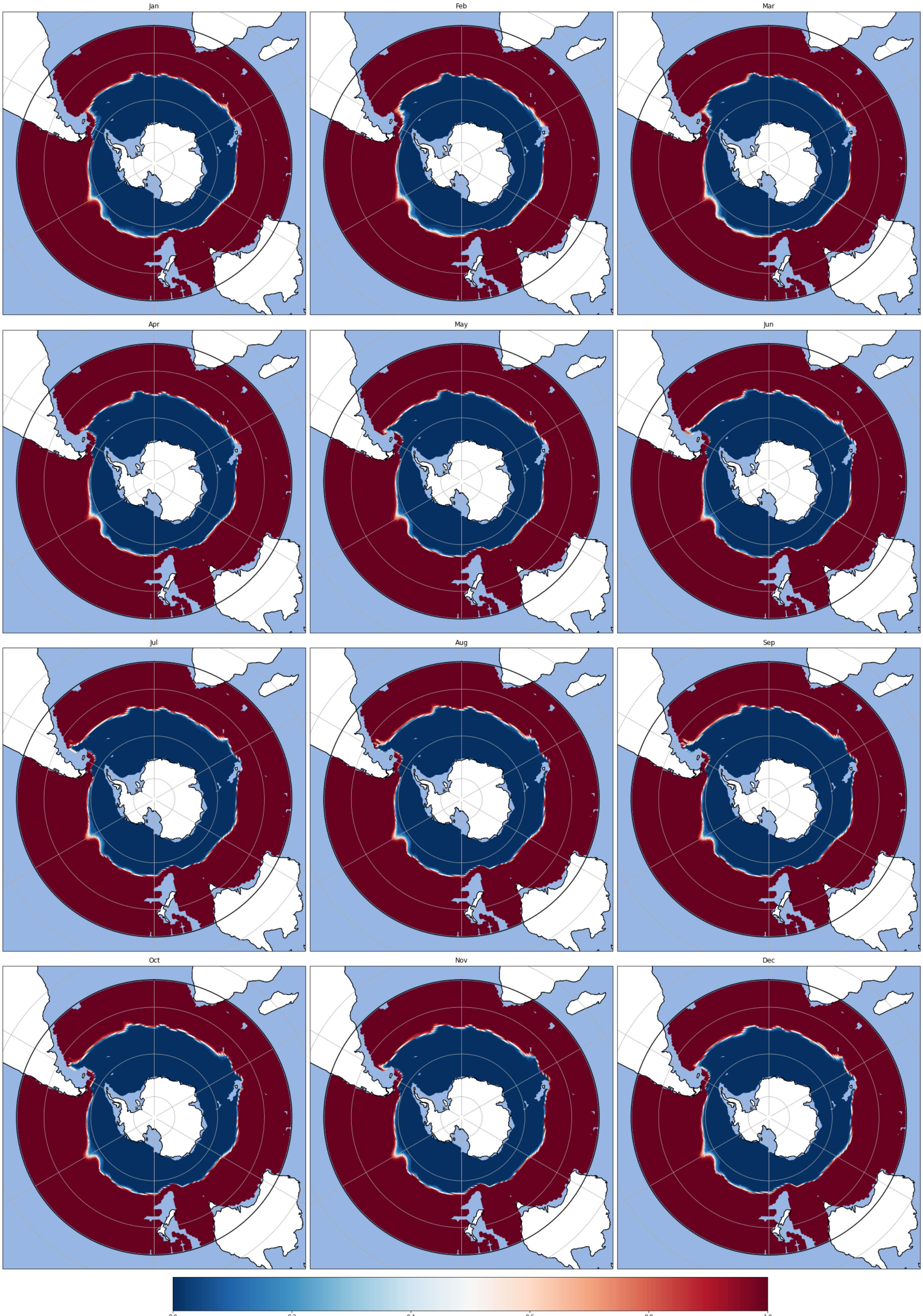
```
#Average classification location plot cell
locationPlotGroupDFLab(averageGeo, "Location plot of average profile classification", (25,
plt.show()
```



In [27]:

```
locationPlotGroupDFMonthly(averageMonthGeo, "Monthly summaries for training data set", 1)
print("Average Classifications, grouped by month.")
plt.show()
```

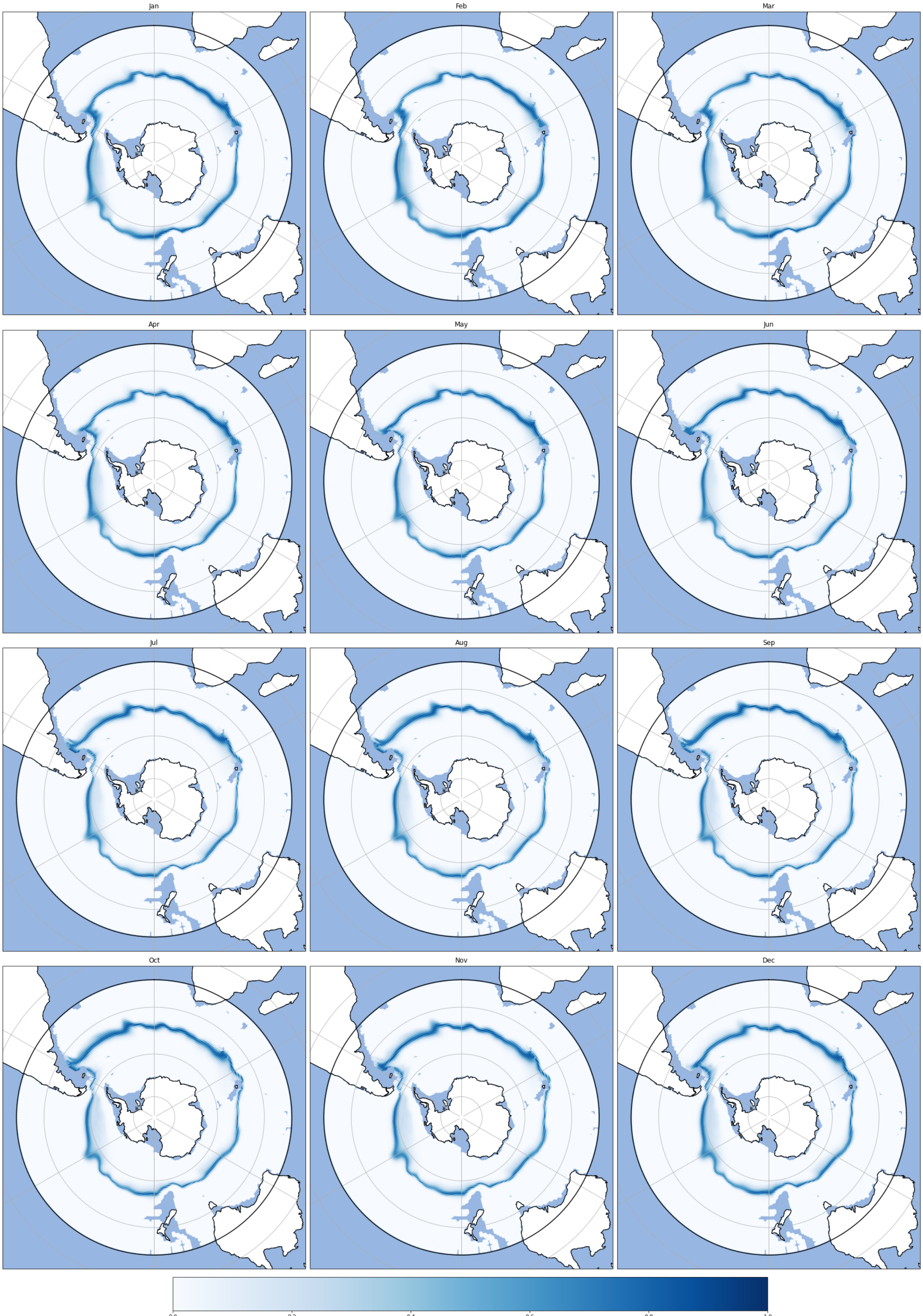
Average Classifications, grouped by month.



In [28]:

```
locationPlotUncertaintyDFMonthly(averageMonthGeo, "Monthly uncertainty", 1)
print("Average Uncertainty in classifications, grouped by month.")
plt.show()
```

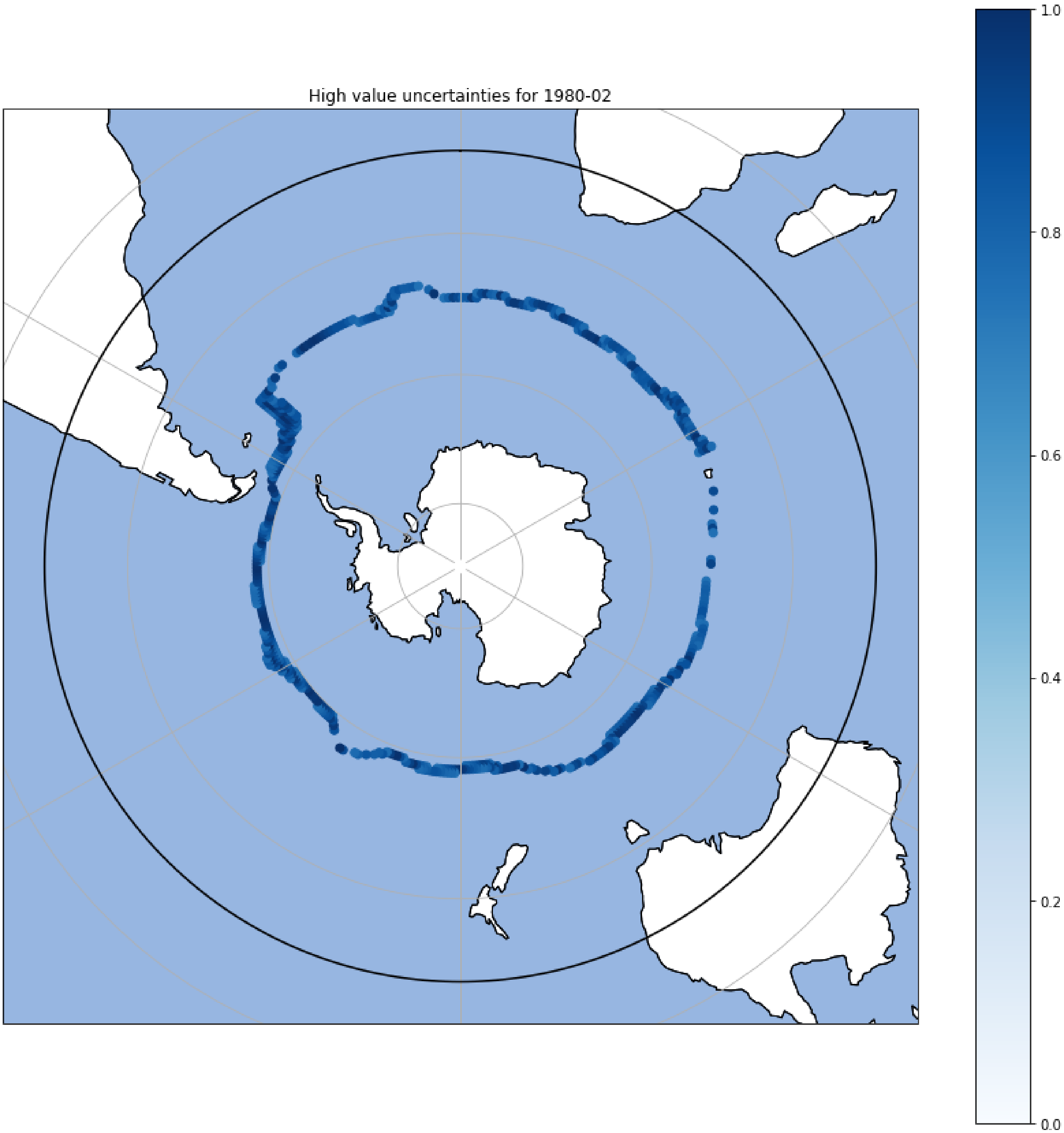
```
Average Uncertainty in classifications, grouped by month.
```


Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0.0
0.2
0.4
0.6
0.8
1.0

Single Month Properities

In [29]:

```
testTime = "1980-02"
uncertaintyDFL = sampleMetaDFL[sampleMetaDFL["classUncertainty"] > 0.75]
monthlyData = uncertaintyDFL[uncertaintyDFL["time"]=="1980-02"]#["lon"].unique()
locationPlotUncertaintyDF(monthlyData, "High value uncertainties for "+testTime, (15,15),
plt.show()
print("Single Month data identified and plotted and stored in monthlyData. "+str(len(montł
```




```
Single Month data identified and plotted and stored in monthlyData. 534 high classificatio
n uncertainty points identified.
```

Mean Singular Latitudes over time

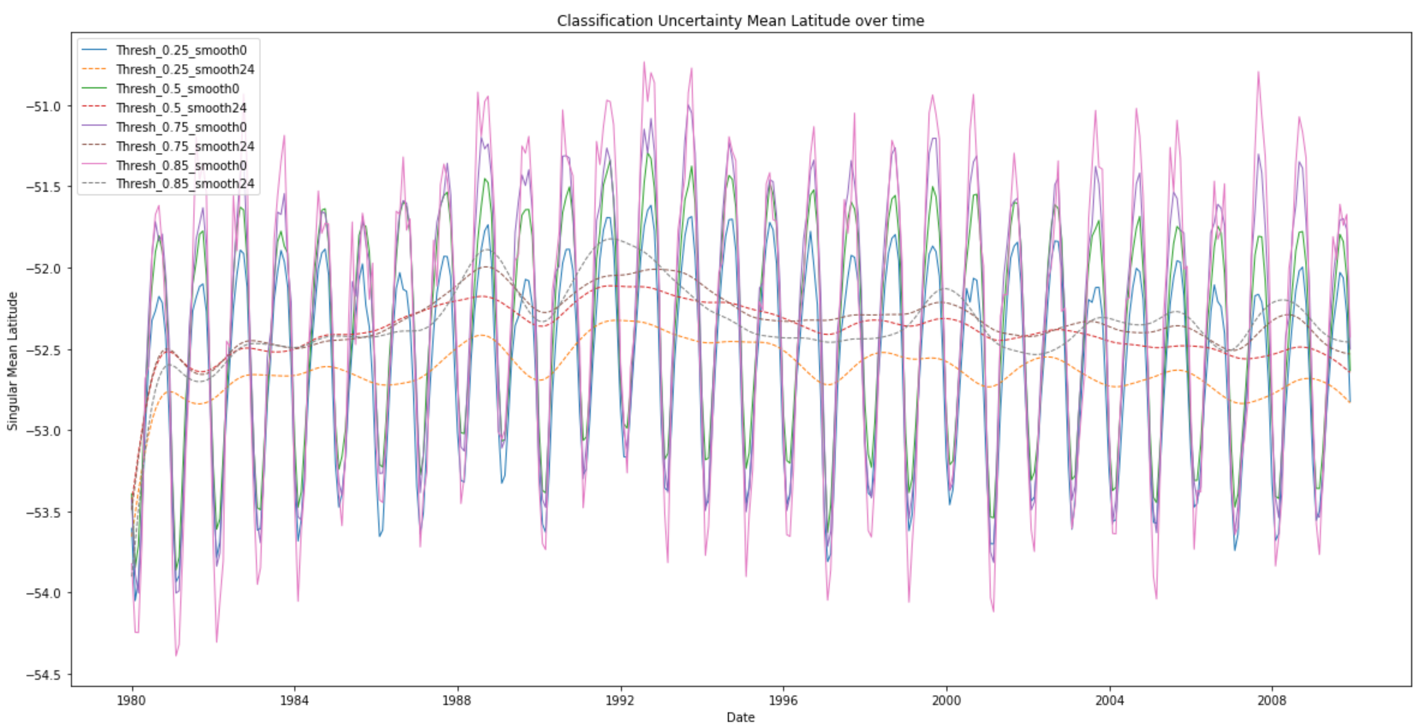
In [30]:

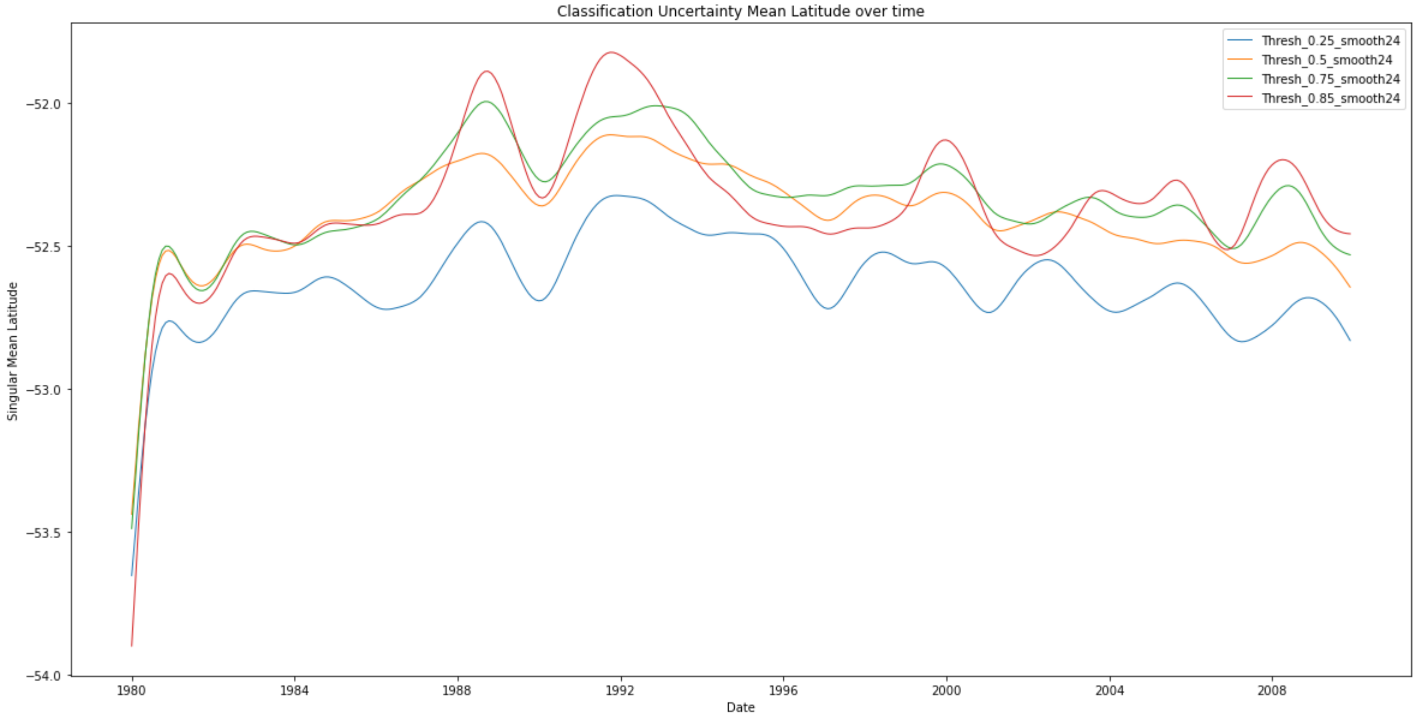
```
thresholds = [0.25, 0.50, 0.75, 0.85]
smoothFactor1 = 24
smoothFactor2 = 120
monthlyLatMMList = []
monthlyLatMMS1List = []
monthlyLatMMS2List = []

for i in range(len(thresholds)):
    uncertaintyDFL = sampleMetaDFL[sampleMetaDFL["classUncertainty"] > thresholds[i]]

    uncertaintyDFLLonTimeG = uncertaintyDFL.groupby(["lon","time"])
    uncertaintyDFLLonM = uncertaintyDFLLonTimeG.mean("lon")
    uncertaintyDFLLonM = uncertaintyDFLLonM.reorder_levels(['time', 'lon']).sort_index()
    uncertaintyDFLLonMTimeG = uncertaintyDFLLonM.groupby("time")

    monthlyLatMMList.append(uncertaintyDFLLonMTimeG.mean()[["lat"]])
    monthlyLatMMS1List.append(butter_lowpass(monthlyLatMMList[i]["lat"], smoothFactor1))
    monthlyLatMMS2List.append(butter_lowpass(monthlyLatMMList[i]["lat"], smoothFactor2))
print("Monthly Singular Mean Latitudes calculated, with smoothing.")
```

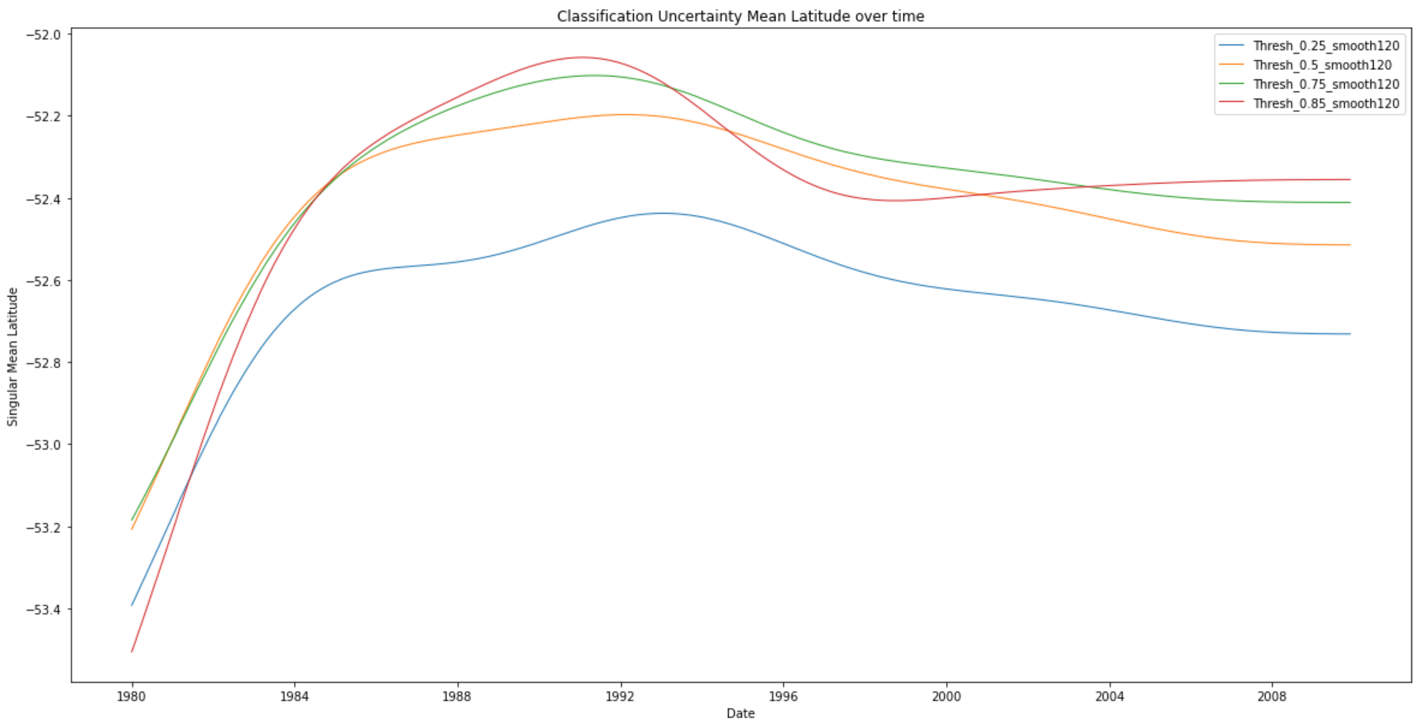
```
Monthly Singular Mean Latitudes calculated, with smoothing.
```

In [31]:

```
for i in range(len(thresholds)):
    timeSingleLatMean(monthlyLatMMList[i], "-", thresholds[i], 0, 1)
    timeSingleLatMean(monthlyLatMMS1List[i], "--", thresholds[i], smoothFactor1, 1)

    timeSingleLatMean(monthlyLatMMS1List[i], "-", thresholds[i], smoothFactor1, 2)
    timeSingleLatMean(monthlyLatMMS2List[i], "-", thresholds[i], smoothFactor2, 3)

for i in range(1, 4):
    plt.figure(i)
    #plt.gca().invert_yaxis()

plt.show()
```





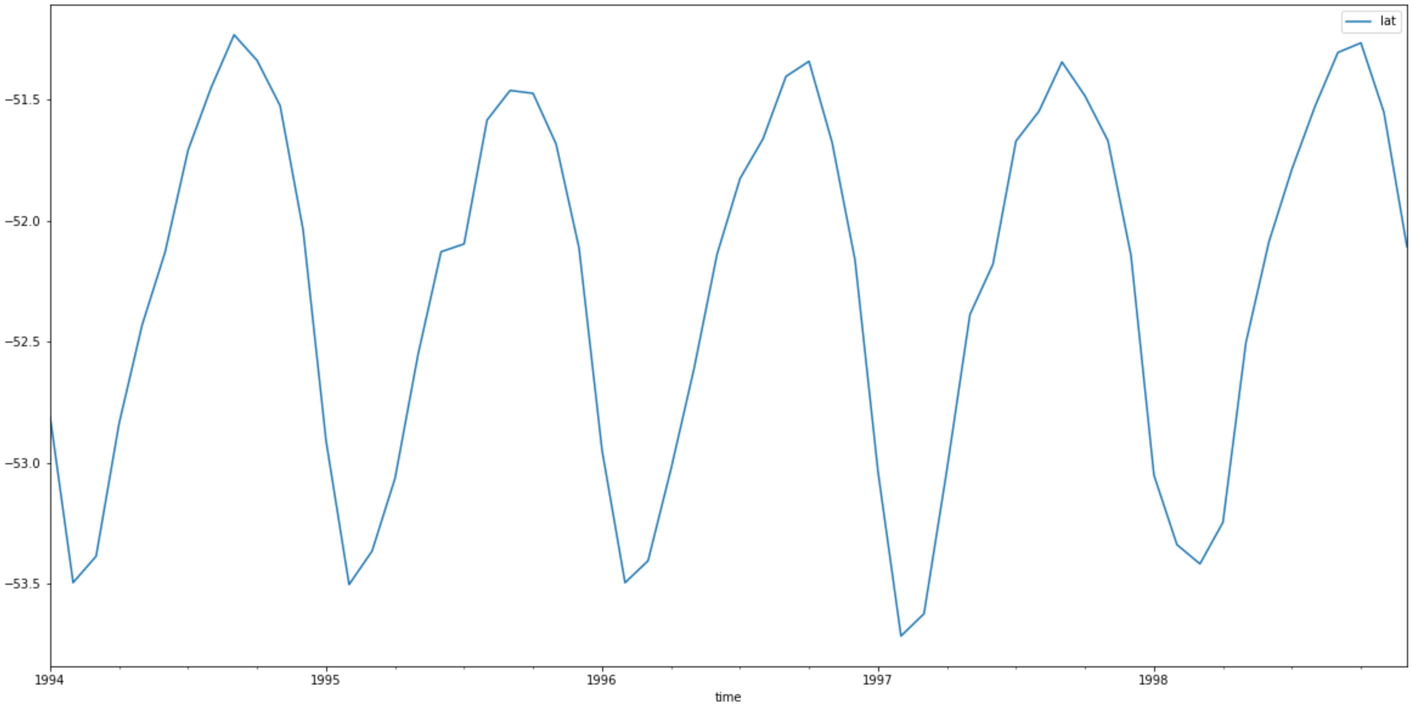


1997 Dip investigation

In [32]:

```
timeRange = np.arange(np.datetime64("1994-01",'M'), np.datetime64("1999-01", 'M'), np.time
breakDown = monthlyLatMMList[2]
timeRangeDF = breakDown[breakDown.index.isin(timeRange)]
timeRangeDF.plot(figsize=(20,10))
print("Single Lat mean value for 1994 to 1998")
plt.show()
```

```
Single Lat mean value for 1994 to 1998
```



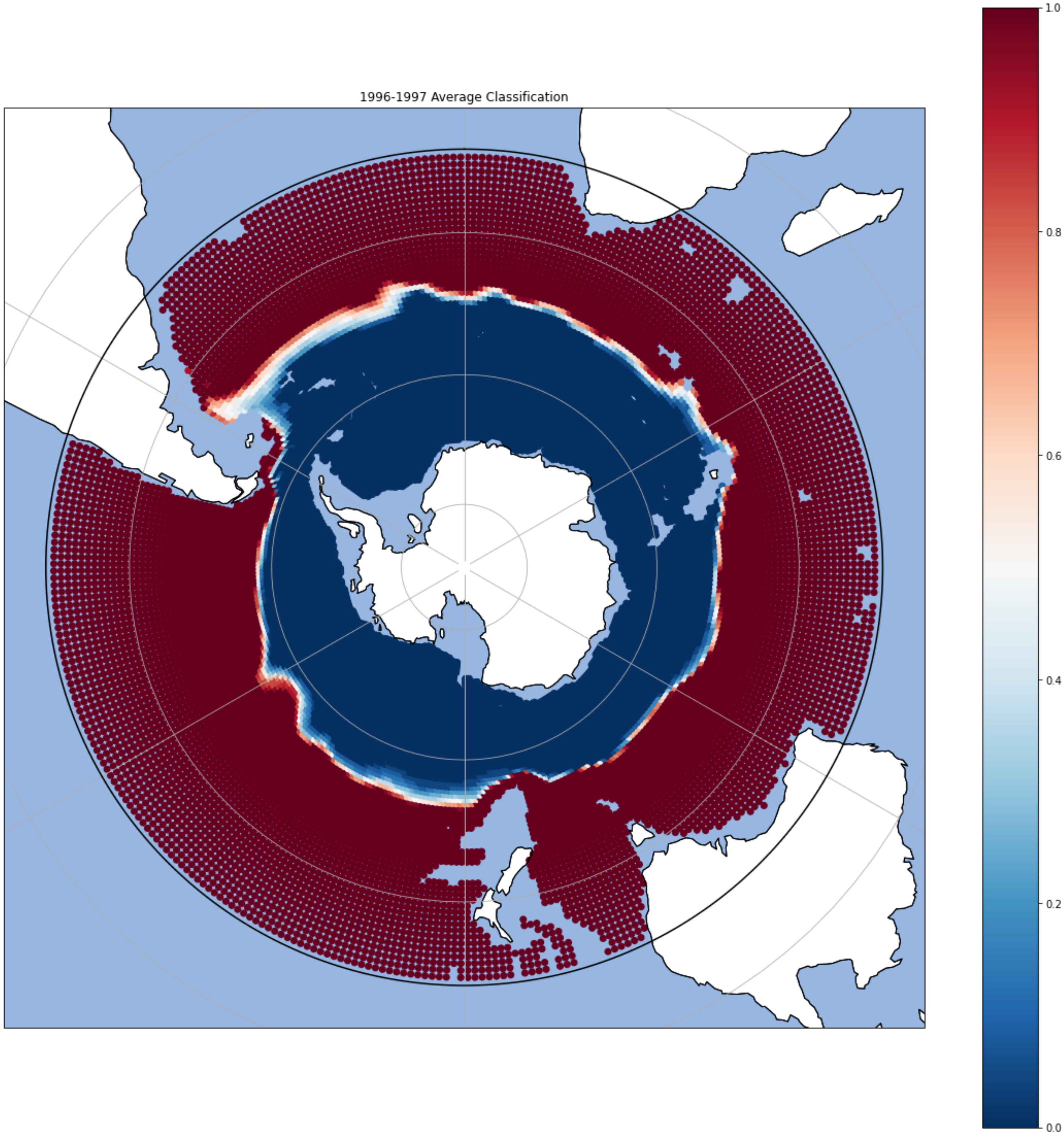
In [33]:

```
timeRangeClose = np.arange(np.datetime64("1996-01",'M'), np.datetime64("1998-01", 'M'), np
timeRangeCloseDF = sampleMetaDFL[sampleMetaDFL["time"].isin(timeRangeClose)]
avgGeoTimeRangeCloseDFG = timeRangeCloseDF.groupby(["lat", "lon"])
avgGeoTimeRangeCloseDF = avgGeoTimeRangeCloseDFG.mean(["lat", "lon"])
avgGeoTimeRangeCloseDF = avgGeoTimeRangeCloseDF.reset_index()
print("Average classification information calculated for 1996 - 1997, stored in avgGeoTime
```

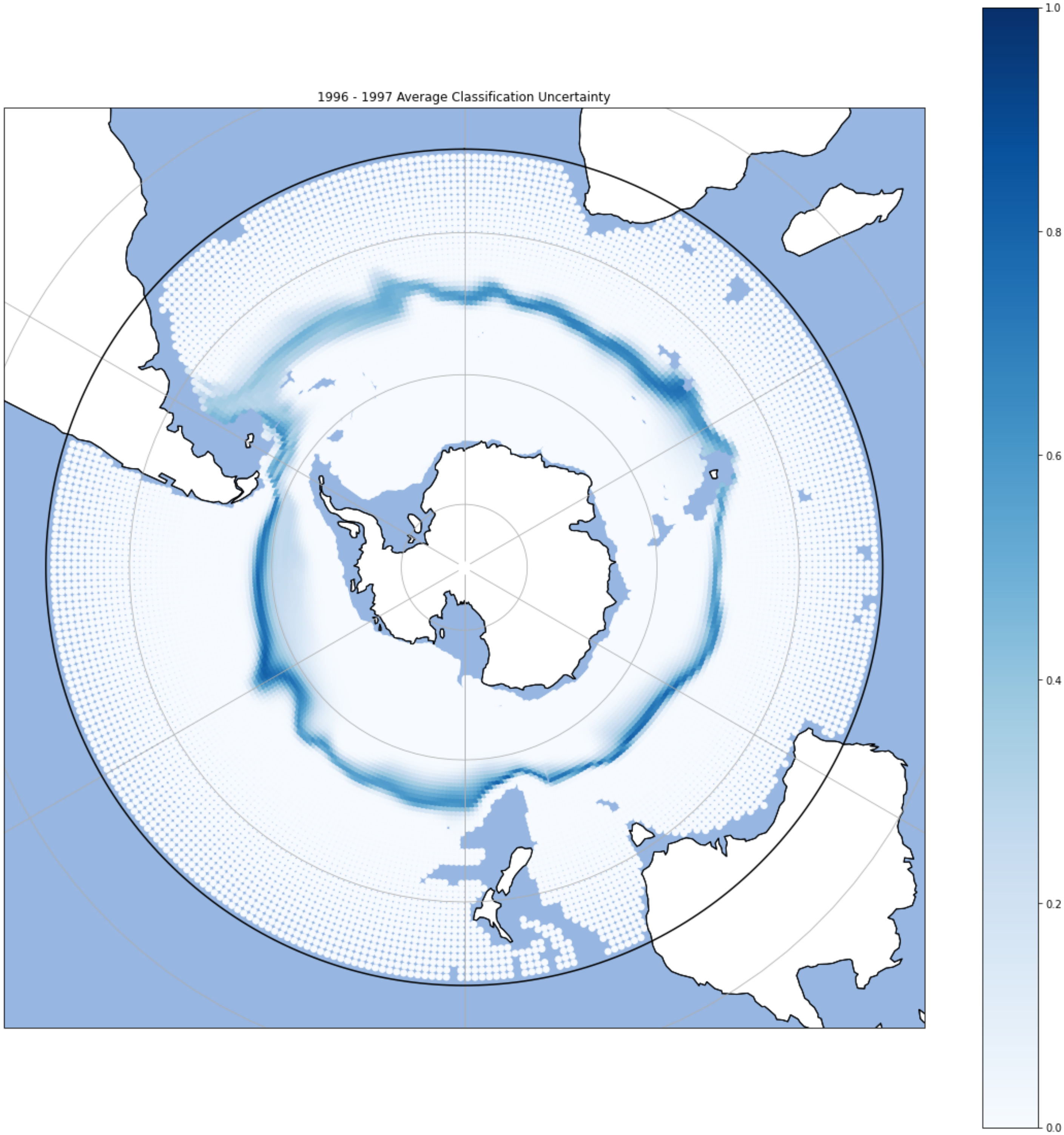
```
Average classification information calculated for 1996 - 1997, stored in avgGeoTimeRangeCl
oseDF.
```

In [34]:

```
locationPlotGroupDFLab(avgGeoTimeRangeCloseDF, "1996-1997 Average Classification", (20,20)
locationPlotUncertaintyDF(avgGeoTimeRangeCloseDF, "1996 - 1997 Average Classification Unce
plt.show()
```



1996-1997 Average Classification
1.0
0.8
0.6
0.4
0.2
0.0



Decadal investigation

In [35]:
```
decades = ["1980", "1990", "2000"]
decade80 = np.arange(np.datetime64("1980", 'M'), np.datetime64("1990", 'M'), np.timedelta6
decade90 = np.arange(np.datetime64("1990", 'M'), np.datetime64("2000", 'M'), np.timedelta6
decade00 = np.arange(np.datetime64("2000", 'M'), np.datetime64("2010", 'M'), np.timedelta6
decadeList = [decade80, decade90, decade00]
print("Decade lists created and stored in decade80, decade90 and decade00.")
```

```
Decade lists created and stored in decade80, decade90 and decade00.
```

In [36]:
```
sampleMetaDFDecList = [sampleMetaDFL[sampleMetaDFL["time"].isin(decade80)], sampleMetaDFL
print("Decade split performed and stored in sampleMetaDFDecList.")
```

Decade split performed and stored in sampleMetaDFDecList.

In [37]:

```
decDFIThreshList = []
decDFIThreshLatMList = []
decDFIThreshLatSList = []
threshold = 0.75

for i in range(len(decades)):
    decDF = sampleMetaDFDecList[i]
    decDFIThresh = decDF[decDF["classUncertainty"] > threshold]
    decDFIThreshList.append(decDFIThresh)

    decDFIThreshLonG = decDFIThresh.groupby("lon")
    decDFIThreshLatMList.append(decDFIThreshLonG.mean()[["lat"]])
    decDFIThreshLatSList.append(decDFIThreshLonG.std()[["lat"]])
print("Decadal class uncertainty latitude means calculted and stored in decDFIThreshLatMLi
```

Decadal class uncertainty latitude means calculted and stored in decDFIThreshLatMList. Sta
ndard deviations are stored in decDFIThreshLatSList.

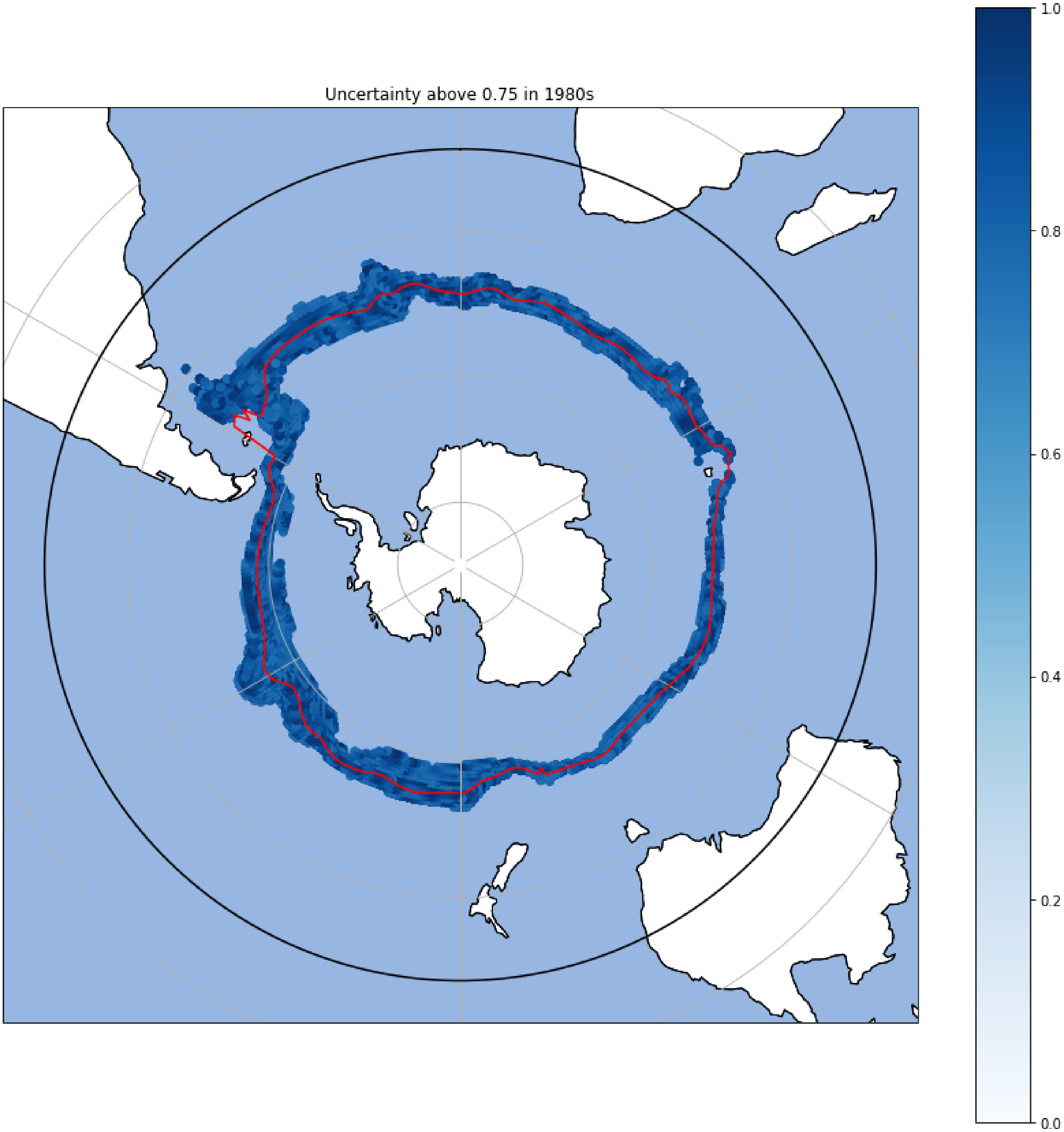
In [38]:

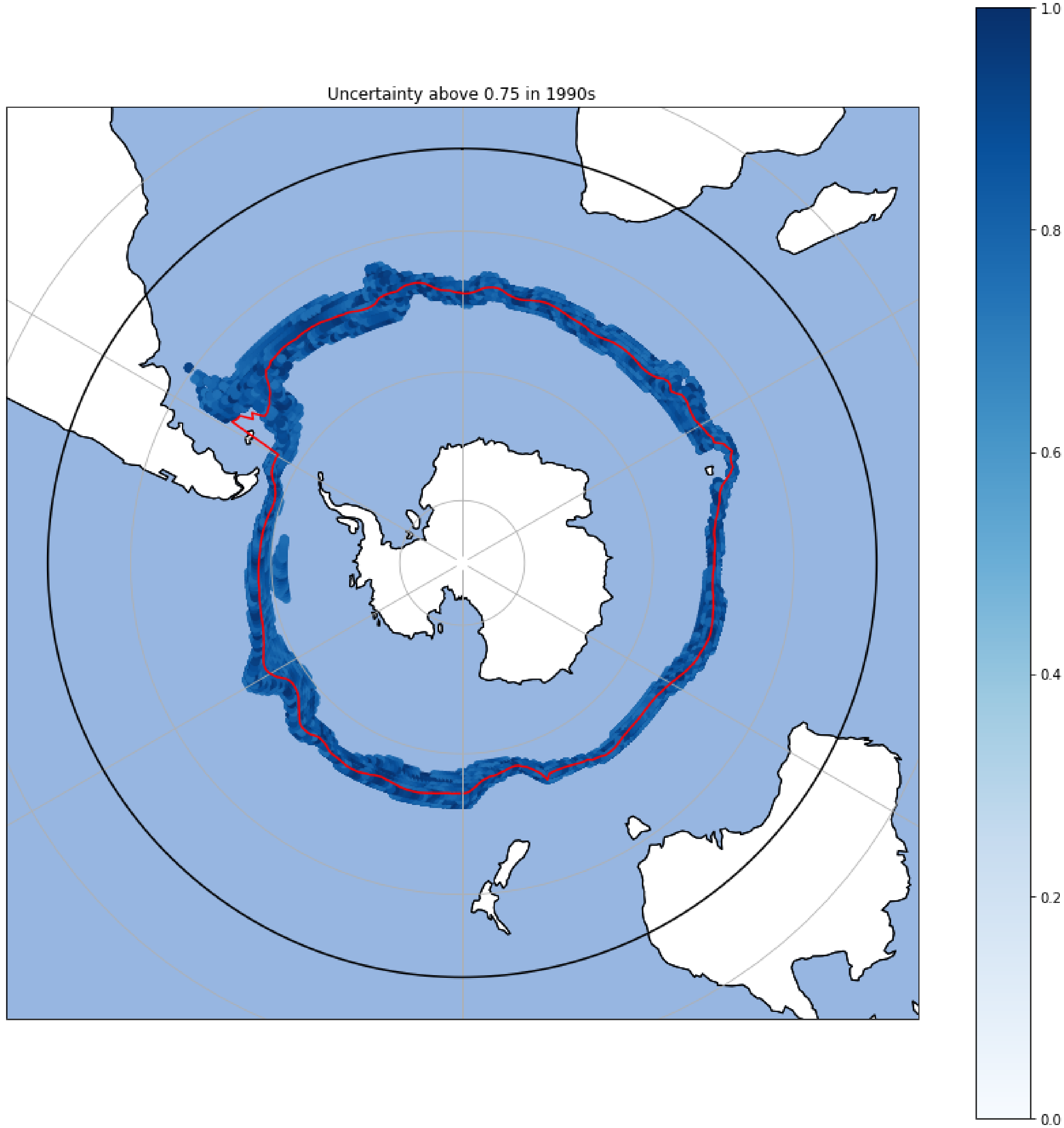
```
decDFIThreshLatMMListDecade = []
decDFIThreshLatMMListYearly = []
for i in range(len(decDFIThreshLatMList)):
    decDFIThreshLatMMListDecade.append(decDFIThreshLatMList[i]["lat"].mean()) #Decadal Mea

    yearlyLatMeans = monthlyLatMMList[2]
    decadeSet = yearlyLatMeans[yearlyLatMeans.index.isin(decadeList[i])]
    decDFIThreshLatMMListYearly.append(decadeSet["lat"].mean()) #Yearly Mean from previous

    print("For "+str(decades[i])+" the singular mean latitude for a threshold of "+str(thr
print("Decade singular mean latitude values calculated.")
```

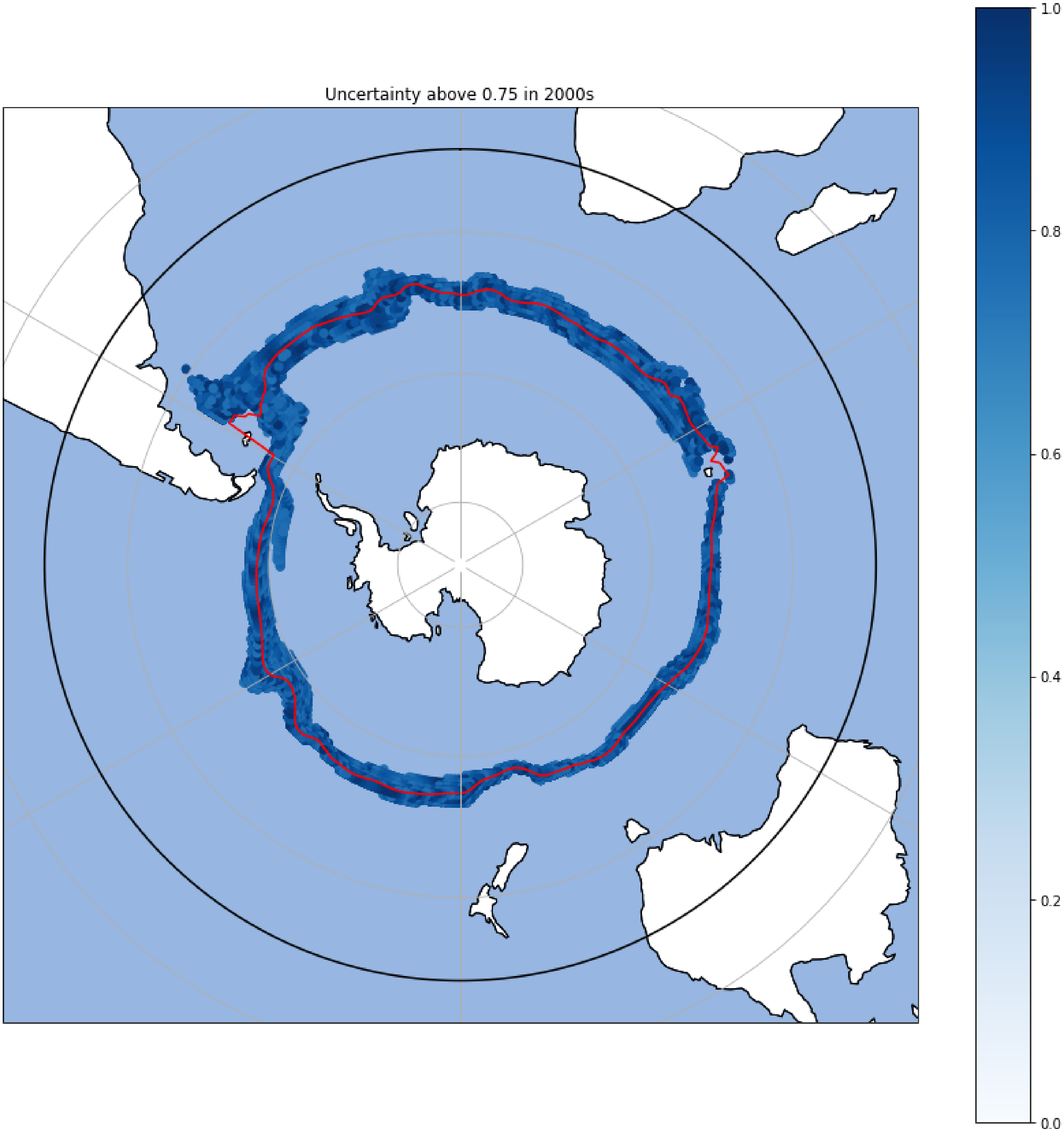
For 1980 the singular mean latitude for a threshold of 0.75 was -52.37 via decade and -52.
39 via yearly.
For 1990 the singular mean latitude for a threshold of 0.75 was -52.17 via decade and -52.
2 via yearly.
For 2000 the singular mean latitude for a threshold of 0.75 was -52.39 via decade and -52.
39 via yearly.
Decade singular mean latitude values calculated.

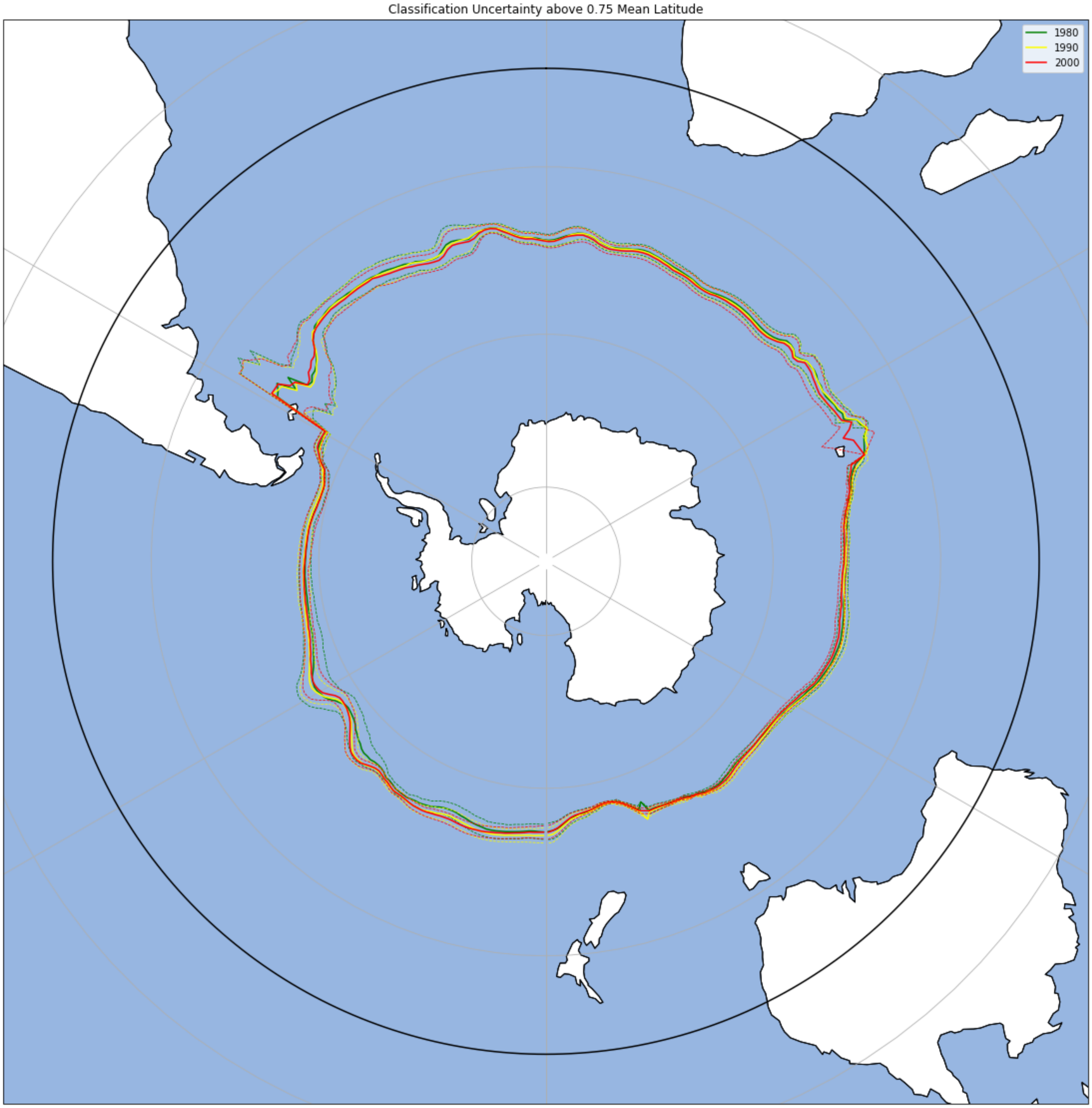
In [39]:

```
for i in range(len(decades)):
    locationPlotUncertaintyDF(decDFIThreshList[i], "Uncertainty above "+str(threshold)+" i
    plt.plot(decDFIThreshLatMList[i].index, decDFIThreshLatMList[i]["lat"], transform=ccrs

locationUncertaintyMean(decDFIThreshLatMList, decDFIThreshLatSList, threshold, (20,20), 4)
plt.show()
```


Uncertainty above 0.75 in 1980s
1.0
0.8
0.6
0.4
0.2
0.0


Uncertainty above 0.75 in 1990s
1.0
0.8
0.6
0.4
0.2
0.0


Uncertainty above 0.75 in 2000s
1.0
0.8
0.6
0.4
0.2
0.0



Exporting Monthly Latitude Means

In [40]:
```
exportName = modelName + "_LatMeans"
np.save(exportName, monthlyLatMMList)
print("Monthly Latitude means (monthlyLatMMList) exported to "+exportName+".")
```

```
Monthly Latitude means (monthlyLatMMList) exported to GMM_UK_2Class_R3_LatMeans.
```

In [41]:
```
importName = exportName+".npy"
monthlyLatMMListReload = np.load(importName)
print("Monthly Latitude means reloaded into monthlyLatMMListReload from "+importName+".")
```

```
Monthly Latitude means reloaded into monthlyLatMMListReload from GMM_UK_2Class_R3_LatMean
s.npy.
```

In [42]:
```
print("Reloaded monthly latitude means.")
monthlyLatMMList
```

```
Reloaded monthly latitude means.
```

Out[42]:
```
[                  lat
 time
 1980-01-01 -53.605186
 1980-02-01 -54.048988
 1980-03-01 -53.923532
 1980-04-01 -53.540696
 1980-05-01 -52.997968
 ...               ...
 2009-08-01 -52.200197
 2009-09-01 -52.031156
 2009-10-01 -52.064855
 2009-11-01 -52.285808
 2009-12-01 -52.824674

 [360 rows x 1 columns],
                  lat
 time
 1980-01-01 -53.392420
 1980-02-01 -53.846527
 1980-03-01 -53.710886
 1980-04-01 -53.288604
 1980-05-01 -52.802768
 ...               ...
 2009-08-01 -52.003570
 2009-09-01 -51.796976
 2009-10-01 -51.841820
 2009-11-01 -52.057901
 2009-12-01 -52.634595

 [360 rows x 1 columns],
                  lat
 time
 1980-01-01 -53.429640
 1980-02-01 -53.887248
 1980-03-01 -54.002583
 1980-04-01 -53.490542
 1980-05-01 -52.782657
 ...               ...
 2009-08-01 -51.884481
 2009-09-01 -51.709261
 2009-10-01 -51.700797
 2009-11-01 -51.766722
 2009-12-01 -52.502595

 [360 rows x 1 columns],
                  lat
 time
 1980-01-01 -53.822148
 1980-02-01 -54.243302
 1980-03-01 -54.245425
 1980-04-01 -53.692926
 1980-05-01 -52.683200
 ...               ...
 2009-08-01 -51.953098
 2009-09-01 -51.612260
 2009-10-01 -51.741910
 2009-11-01 -51.674509
 2009-12-01 -52.429019

 [360 rows x 1 columns]]
```

End of Notebook