swarmtoolkit_demo

July 21, 2016

1 Demo

Some examples below are shown to showcase some of the functionality of `swarmtoolkit`.

1) Basic functionality

- Help
- Extract parameter from file(s)
- Modify parameter
- Quick introspection
- Plot parameter(s)
- Unzip file and extract contents

2) FTP-server

- Download file(s) from ftp server and extract contents
- Filter ftp-server vs. interactive selection

3) Delay of parameter

- Shift a parameter wrt. time
- Align two parameters wrt. time

4) Visualization

5) Spherical harmonics

6) Miscellaneous

- Fourier transform
- Read sp3 files
- EFI provisional
- Parameter

1.1 Basic functionality

```
In [1]: %matplotlib inline
        import swarmtoolkit as st
        import numpy as np
        import matplotlib.pyplot as plt
```

1.1.1 Help

```
In [2]: #using the built-in help function:
        #help(st.getCDFparams)
```

```
In [3]: #if using ipython or the jupyter notebook you can also use:
        #st.getCDFlist?
```

```
In [4]: #to find names of functions in the jupyter notebook one can tab(to auto-complete)
        #st. #tab to find avalable functions and submodules
```

```
In [5]: #change this to target your sample data directory
        sample_loc = "sample_files/"

        #cleanup of directory:
        import os
        with open(os.path.join(sample_loc,'sample_files.txt'),'r') as f:
            samplefiles=[line.strip() for line in f]
            for fn in os.listdir(sample_loc):
                if fn not in samplefiles:
                    f_del = os.path.join(sample_loc,fn)
                    if os.path.isfile(f_del):
                        print('Removing {}'.format(f_del))
                        os.remove(f_del)
```

1.1.2 Extract parameter from file(s)

```
In [6]: #check content of directory:
        %ls sample_files/
```

```
IGRF12.shc         SW_OPER_EEFATMS_2F_20150924T010219_20150924T225420_0101.ZIP
sample_files.txt   SW_OPER_EEFATMS_2F_20151101T002034_20151101T221233_0101.DBL
sample_kin.txt     SW_OPER_EEFATMS_2F_20151101T234509_20151102T230946_0101.DBL
sample_rd.txt      SW_PREL_EFIA_LP_1B_20150720T000000_20150720T235959_0103.txt
```

```
In [7]: #a cdf file with the EEF product
        filepath_EEF_1 = os.path.join(sample_loc,'SW_OPER_EEFATMS_2F_20151101T002034_20151101T221233_01
        filepath_EEF_2 = os.path.join(sample_loc,'SW_OPER_EEFATMS_2F_20151101T234509_20151102T230946_01

        #get EEF and timestamp parameter from file
        EEF_1v,EEF_1t,EEF_1lon,EEF_1lat = st.getCDFparams(
            filepath_EEF_1,'EEF','Timestamp','longitude','latitude')
        print('Parameter: {}, units: {}\nValues:\n{}'
              .format(EEF_1v.name,EEF_1v.unit,EEF_1v.values),end='\n\n')
        print('Parameter: {}, units: {}\n(some) Values:\n{}'
              .format(EEF_1t.name,EEF_1t.unit,EEF_1t.values[::3]))
```

```
Parameter: EEF, units: V/m
Values:
[ 0.00075635  0.00079489  0.00089461  0.00053112  0.00052239  0.00046283
  0.00051985  0.00052364  0.0001264   0.00014414  0.00047001  0.0003849
  0.00022549  0.00032556  0.00060109]

Parameter: timestamp, units: ms
(some) Values:
[datetime.datetime(2015, 11, 1, 0, 20, 35)
```

```
 datetime.datetime(2015, 11, 1, 5, 1, 5)
 datetime.datetime(2015, 11, 1, 9, 41, 19)
 datetime.datetime(2015, 11, 1, 14, 25, 30)
 datetime.datetime(2015, 11, 1, 19, 6, 57)]
```

```
In [8]: #Filepaths could also be fetched using:
        filepaths=st.getCDFlist(sample_loc) #get list of cdf files in given path

        #extract data from both files, concatenate output
        EEF_v = st.getCDFparams(filepaths,'EEF')
        print('Parameter: {}, units: {}\nValues:\n{}'
              .format(EEF_v.name,EEF_v.unit,EEF_v.values),end='\n\n')
```

```
Parameter: EEF, units: V/m
Values:
[  7.00498985e-04   9.01116361e-04   7.36308457e-04   4.64592435e-04
   1.30656022e-04   3.22021823e-04   2.45098928e-04   7.35052777e-04
   3.94823967e-04   2.35773796e-04   7.26535923e-05   3.71083663e-04
   3.81770806e-04   4.53130172e-04   6.55204879e-04   4.98714429e-04
   7.56350563e-04   7.94891659e-04   8.94613963e-04   5.31117096e-04
   5.22392922e-04   4.62829641e-04   5.19851551e-04   5.23644858e-04
   1.26398980e-04   1.44138771e-04   4.70008573e-04   3.84904014e-04
   2.25494527e-04   3.25563471e-04   6.01092434e-04]
```

These functions by default do not evaluate zip files unless there are no cdf files available or the keyword argument `includezip=True` is passed. If `getCDFparams` is passed with `cat=False`, values will be a list of `numpy.ndarrays`.

```
In [9]: EEF_v_no_cat,EEF_t_no_cat = st.getCDFparams(filepaths,'EEF','Timestamp',cat=False)
        print(EEF_v_no_cat.values[0],'\n\n',EEF_v_no_cat.values[1])
```

```
[  7.00498985e-04   9.01116361e-04   7.36308457e-04   4.64592435e-04
   1.30656022e-04   3.22021823e-04   2.45098928e-04   7.35052777e-04
   3.94823967e-04   2.35773796e-04   7.26535923e-05   3.71083663e-04
   3.81770806e-04   4.53130172e-04   6.55204879e-04   4.98714429e-04]

 [ 0.00075635  0.00079489  0.00089461  0.00053112  0.00052239  0.00046283
  0.00051985  0.00052364  0.0001264   0.00014414  0.00047001  0.0003849
  0.00022549  0.00032556  0.00060109]
```

1.1.3 Modify parameter

The `values`-attribute is a `numpy.ndarray`, and can thus be freely manipulated.

```
In [10]: from numpy import sqrt,sin,log

         #mathematical operations performed on the EEF array
         derived_value=log(sqrt(sin(1/EEF_v.values)+1.5))**5
         print(derived_value,sum(derived_value))

         #cut of last value:
         EEF_v_no_cat.values[1] = EEF_v_no_cat.values[1][:len(EEF_v_no_cat.values[0])]
         EEF_t_no_cat.values[1] = EEF_t_no_cat.values[1][:len(EEF_t_no_cat.values[0])]
         print(len(EEF_v_no_cat.values[1]))
```

```
[  1.82749839e-02  -1.06637542e-05   1.31339427e-02   8.53674901e-08
   9.31970019e-03   2.00267304e-02   1.28465818e-02   8.95627325e-05
   7.15463630e-03   1.32895036e-03  -1.91147298e-07  -1.38418147e-06
  -4.40133687e-06   1.99759498e-02  -5.05632702e-09   1.03906124e-02
   4.22996807e-03   1.95200880e-02  -6.25422744e-08  -4.37908741e-04
  -5.66711317e-04  -2.45336690e-05   1.33836316e-02   4.44420517e-07
   1.25004456e-02   1.61089665e-02  -1.32752877e-05   4.93340211e-04
  -2.14293773e-03  -9.79609775e-05  -4.11192061e-03] 0.171366663925
15
```

1.1.4 Quick introspection

of parameter names One can quickly look at the parameter names of a cdf file (or several files simultaneously):

```
In [11]: st.getCDFparamlist(filepaths)
```

```
INFO
List of parameters for file 'SW_OPER_EEFATMS_2F_20151101T234509_20151102T230946_0101.DBL':
        timestamp
        longitude
        latitude
        EEF
        RelErr
        flags
```

Only one file will be shown for every unique product (based on filename).

of parameter values `param_peek` can be used to get a quick idea of the content within either a parameter in a file or an array. Note that it behaves differently depending on the dimension of the values. This only works if the parameter is represented by floats (eg. not `datetime.datetime` objects)

```
In [12]: #from filename
         st.param_peek(filepath_EEF_1,'EEF')
```

```
INFO        Array of 'EEF',        units: 'V/m'
        shape: (15,)
        max: 0.000895,        min: 0.000126,        mean: 0.000486,        median: 0.000520,        std
        first and last 5 variable(s):
         0:   0.000756
         1:   0.000795
         2:   0.000895
         3:   0.000531
         4:   0.000522
        -5:   0.000470
        -4:   0.000385
        -3:   0.000225
        -2:   0.000326
        -1:   0.000601
        Zeros:     0        Fraction zero values: 0.0
        NaN's:     0        Fraction NaN values:  0.0
        Largest jump over 1 index[along axis=0]:   0.000397
```

```
In [13]: EEF_v_no_cat() #The value array can be accessed also by calling the parameter object
```

```
Out[13]: [array([  7.00498985e-04,   9.01116361e-04,   7.36308457e-04,
                   4.64592435e-04,   1.30656022e-04,   3.22021823e-04,
                   2.45098928e-04,   7.35052777e-04,   3.94823967e-04,
                   2.35773796e-04,   7.26535923e-05,   3.71083663e-04,
                   3.81770806e-04,   4.53130172e-04,   6.55204879e-04,
                   4.98714429e-04]),
          array([ 0.00075635,  0.00079489,  0.00089461,  0.00053112,  0.00052239,
                  0.00046283,  0.00051985,  0.00052364,  0.0001264 ,  0.00014414,
                  0.00047001,  0.0003849 ,  0.00022549,  0.00032556,  0.00060109])]
```

```
In [14]: #15x2 array
         a=np.column_stack((EEF_v_no_cat.values[0][:-1],EEF_v_no_cat.values[1]))
         st.param_peek(a,axis=1)
```

```
INFO        shape: (15, 2)
        1/2        max: 0.000901,        min: 0.000073,        mean: 0.000453,        median: 0.000395,
        2/2        max: 0.000895,        min: 0.000126,        mean: 0.000486,        median: 0.000520,
        Zeros:     0        Fraction zero values: 0.0
        NaN's:     0        Fraction NaN values:  0.0
        Largest jump over 1 index[along axis=1]:   0.000397
```

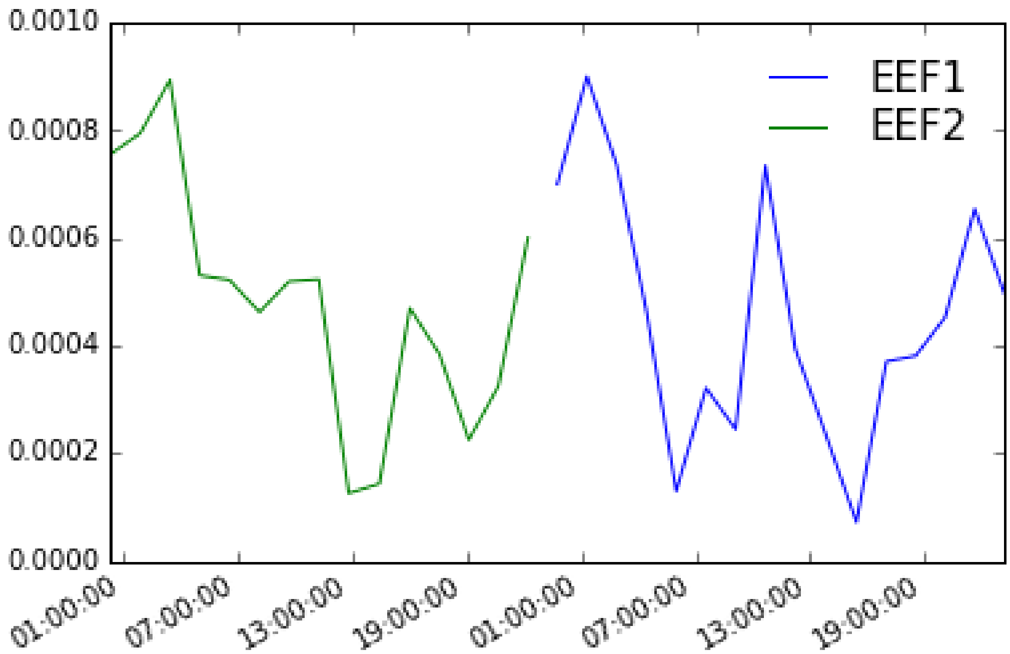
of discontinuities in values

```
In [15]: #find jumps in values:

         #jump larger than difference between 25th and 75 percentile
         jumps_pcnt=st.where_diff(a[:,0])

         #relative difference of 50%
         jumps_rtol=st.where_diff(a[:,0],rtol=0.5)

         #absolute difference
         jumps_atol=st.where_diff(a[:,0],atol=0.0004)

         #abs_tol ∩ rel_tol
         jumps_comb=st.where_diff(a[:,0],atol=0.0004,rtol=0.5)

         print(jumps_pcnt,a[jumps_pcnt,0])
         print(jumps_rtol,a[jumps_rtol,0])
         print(jumps_atol,a[jumps_atol,0])
         print(jumps_comb,a[jumps_comb,0])
```

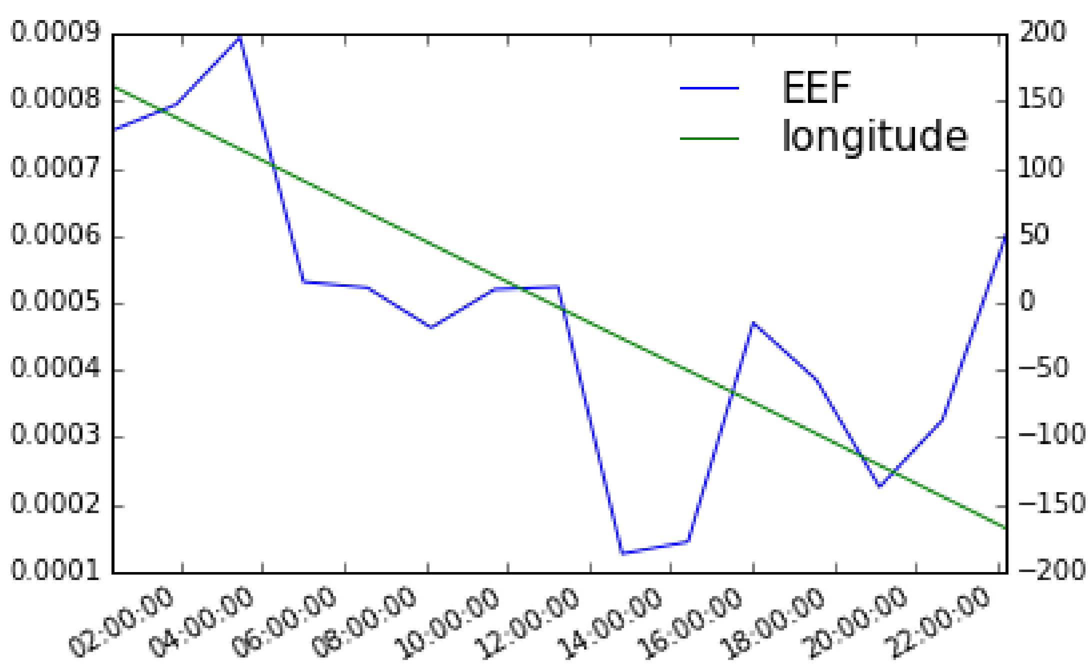
```
(array([7]),) [[ 0.00073505]]
(array([ 3,  4,  5,  7,  8,  9, 10, 11]),) [[  4.64592435e-04   1.30656022e-04   3.22021823e-04   7.3505
    3.94823967e-04   2.35773796e-04   7.26535923e-05   3.71083663e-04]]
(array([7]),) [[ 0.00073505]]
(array([7]),) [[ 0.00073505]]
```

1.1.5 Plot parameter(s)

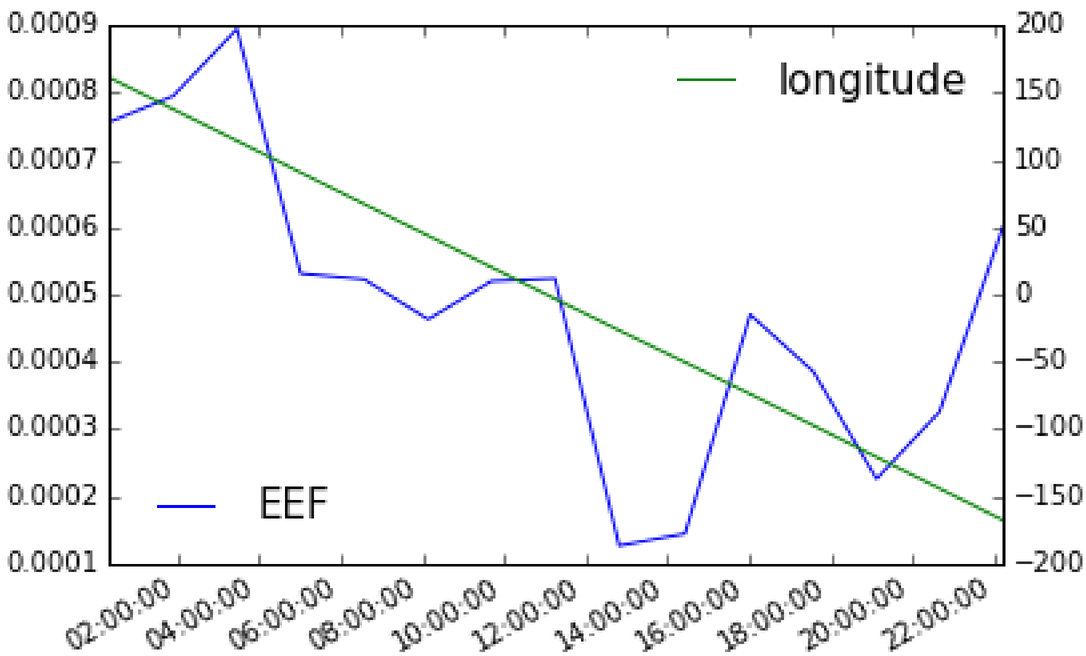
```
In [16]: fig,ax=st.plot(EEF_t_no_cat.values[0],EEF_v_no_cat.values[0],
                                    EEF_t_no_cat.values[1],EEF_v_no_cat.values[1],
                                    legends=[EEF_1v.name+'1',EEF_1v.name+'2'])
```



In [17]:
```
#plot EEF(t) and longitude(t) with own unique y-axis
fig,ax1=st.plot(EEF_1t.values,EEF_1v.values,
                                legends=[EEF_1v.name],lhide=True)
ax2=st.plot_twinx(EEF_1t.values,EEF_1lon.values,ax=ax1,
                             legends=[EEF_1lon.name])
```



```
In [18]: #plot EEF(t) and longitude(t) with own unique y-axis and legend position:
         fig,ax1=st.plot(EEF_1t.values,EEF_1v.values,
                                     legends=[EEF_1v.name,'a'],lloc='lower left')
         ax2=st.plot_twinx(EEF_1t.values,EEF_1lon.values,ax=ax1,
                                  legends=[EEF_1lon.name],lall=False)
```



1.1.6 Unzip file and extract contents

To unzip a cdf file and extract parameter from file, simply use the same syntax as for a normal file. Additionally, one can store the cdf temporarily by specifying `temp=True`:

```
In [19]: #include zipfile in search for cdf files- unzip it in temporary storage,
         #then filter files based on satelite and within time range based on filename
         filepaths_w_zip=st.getCDFlist(sample_loc,includezip=True,temp=True,
                                            sat='A',start_t='20150901',end_t='20151001')
```

```
In [20]: filepaths_w_zip
```

```
Out[20]: ['/tmp/swtools_99thpjbk/SW_OPER_EEFATMS_2F_20150924T010219_20150924T225420_0101.DBL']
```

```
In [21]: EEF_zip=st.getCDFparams(
             os.path.join(sample_loc,'SW_OPER_EEFATMS_2F_20150924T010219_20150924T225420_0101.ZIP'),
             'EEF',temp=True)
```

1.2 FTP-server

1.2.1 Download file(s) from ftp server and extract contents

Extracting from ftp server follows same syntax. output location is by default the current working directory, by may be specified. `filter_param` will ensure that only folders where the parameter is presumed to be will be checked (as of `swarmtoolkit 1.0.2` only main `MAG`, `EFI`, `IBI`, `FAC`, `TEC` and `EEF` products are supported for filtering, and only for the dissemination server `swarm-diss.eo.esa.int`):

NOTE: If experiencing difficulties connecting to the dissemination server from a secure ESA network, the problem may be resolved by adding `use_passive_mode=False` and possibly also temporarily deactivating your firewall.

In [22]:
```
url,user,pw='swarm-diss.eo.esa.int/','myuser','mypw'
#get files with parameter 'n'(ie. EFI product) from satellite B,
#within two days after 1.9.2015, download to current directory

#st.getCDFparams(url+'Level1b/','n',user=user,pw=pw,outloc=sample_loc,
#                        filter_param=True,sat='B',start_t='20150901',duration=2)
```

1.2.2 Filter ftp-server vs. interactive selection

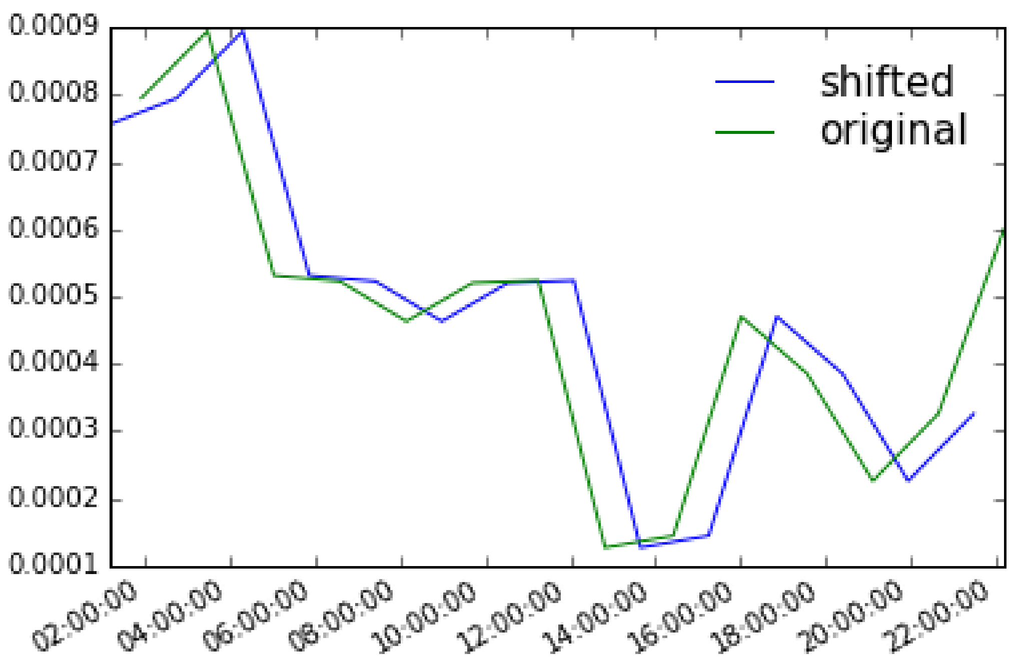
In the above example no interaction is needed, as everything is specified. If not all filters are used, the user can select files/directories interactively:

In [23]:
```
#look for products from satellite B  with parameter 'timestamp'
#st.getCDFparams(url,'Timestamp',user=user,pw=pw,outloc=sample_loc,sat='B')
```

1.3 Delay of parameter

1.3.1 Shift a parameter wrt. time

In [24]:
```
#shift a parameter with respect to itself 10000s(for illustration purposes)
eef1,eef2,eeft1,eeft2=st.shift_param(
    EEF_1v.values,EEF_1v.values,EEF_1t.values,EEF_1t.values,delta_t=3000,k=1)
fig,ax=st.plot(eeft1,eef1,eeft2,eef2,legends=['shifted','original'])
```



It is also possible to make the function shift into a best fit using `auto=True`.

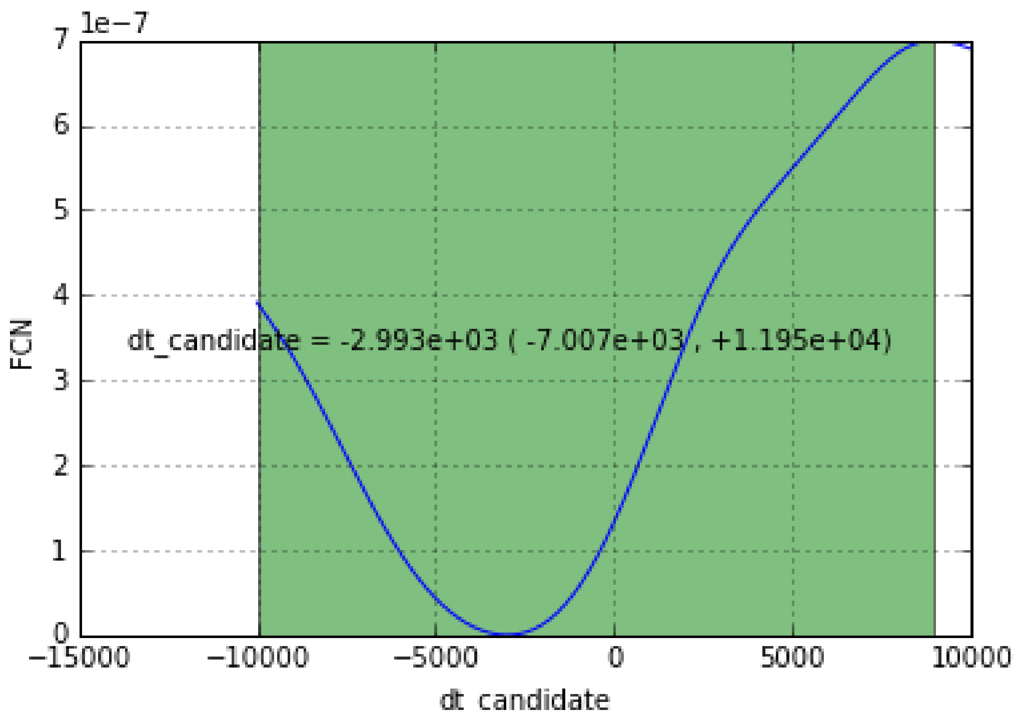
In [25]:
```
#Shift to best fit (which should shift eef1 back to initial position), and
#find the "unknown" shift assumed to be +-10000s from present position.
#'ext=0' due to large errors, so the solver starts to try to extrapolate
#otherwise
eef1_,eef2_,eeft1_,eeft2_=st.shift_param(eef1,eef2,eeft1,eeft2,
                                          dt_lim=[-10000,10000],
                                          auto=True,ext=0)
```

```
INFO        delta_t converged to solution near lower limit, consider rerunning with new limits
INFO        output delta_t: -2908.2535406263496
```

Here due to using very few points(EEF has ~15 values/day) the error is large, and interpolation poor, and a warning is shown; but the original value was approximately regained. More detailed output can be gained from `v=2` and `show=True`:

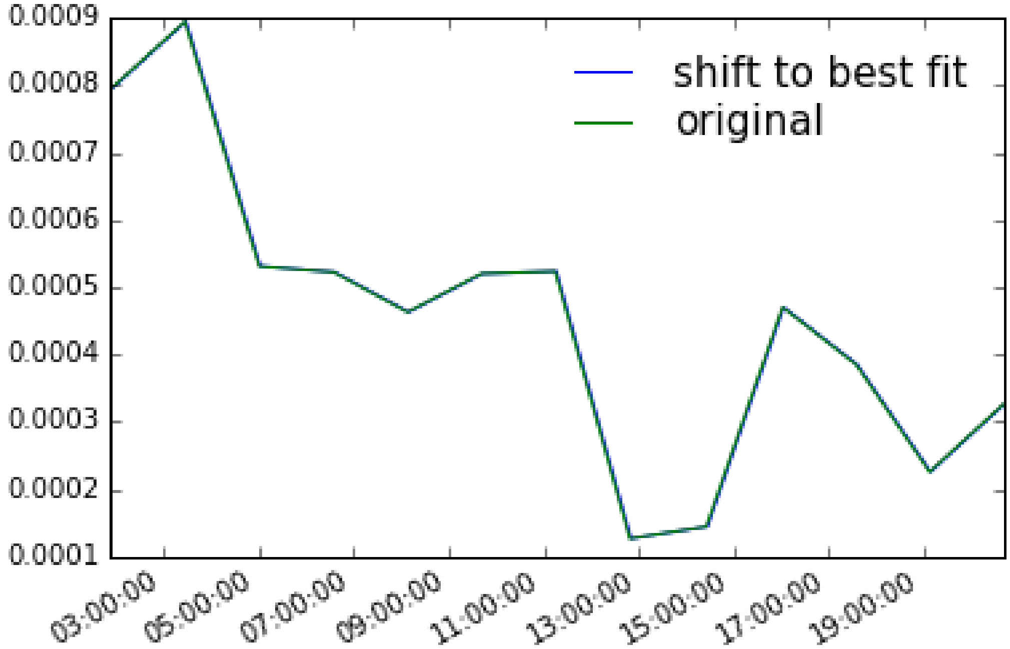
In [26]:
```
eef1_,eef2_,eeft1_,eeft2_=st.shift_param(
    eef1,eef2,eeft1,eeft2,dt_lim=[-10000,10000],
    auto=True,ext=0,v=2,show=True)
```

```
INFO        delta_t converged to solution near lower limit, consider rerunning with new limits
INFO        output delta_t: -2908.2535406263496
```



In [27]:
```
#best fit:
st.plot(eeft1_,eef1_,eeft2_,eef2_,legends=['shift to best fit','original'])
```

Out[27]:
```
(<matplotlib.figure.Figure at 0x7f1ad894ff60>,
 <matplotlib.axes._subplots.AxesSubplot at 0x7f1ad886d6a0>)
```

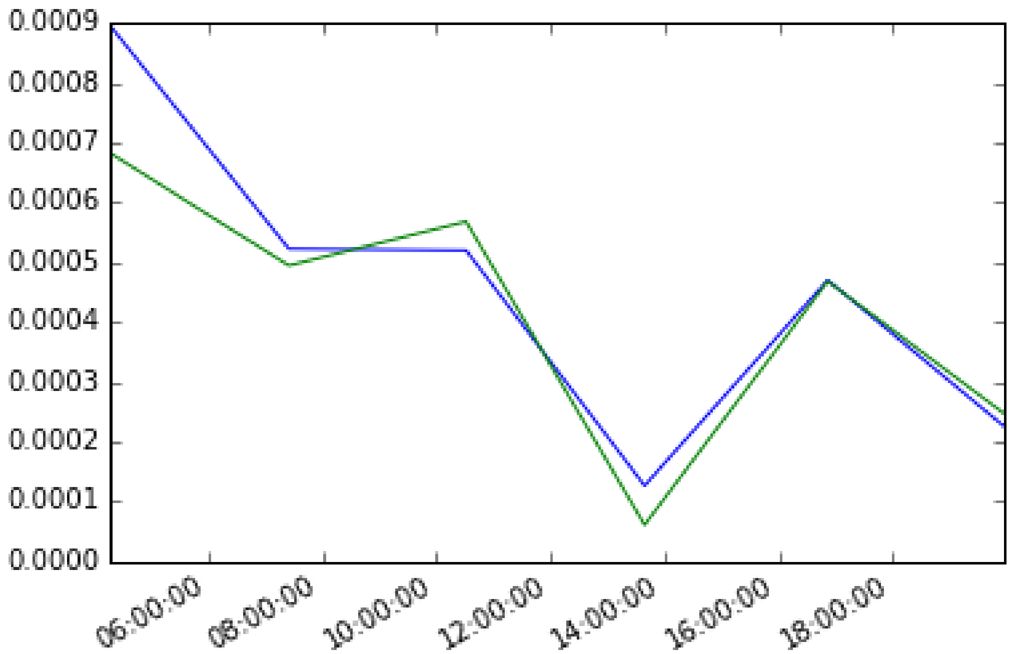


1.3.2 Align two parameters wrt. time

If we want to plot to parameters with different frequencies together(downsample one of them), we can use `align_param`:

In [28]:
```
#plot shifted values, where one has half the frequency of the other:
eef1_a,eef2_a,eeft=st.align_param(eef1[::2],eef2,eeft1[::2],eeft2)
st.plot(eeft,eef1_a,eeft,eef2_a)

#one could use plot_align(eef1[::2],eef2,eeft1[::2],eeft2)
#if not interested in the output values(only the visualization)
```

Out[28]:
```
(<matplotlib.figure.Figure at 0x7f1ad87a6748>,
 <matplotlib.axes._subplots.AxesSubplot at 0x7f1ad8692160>)
```

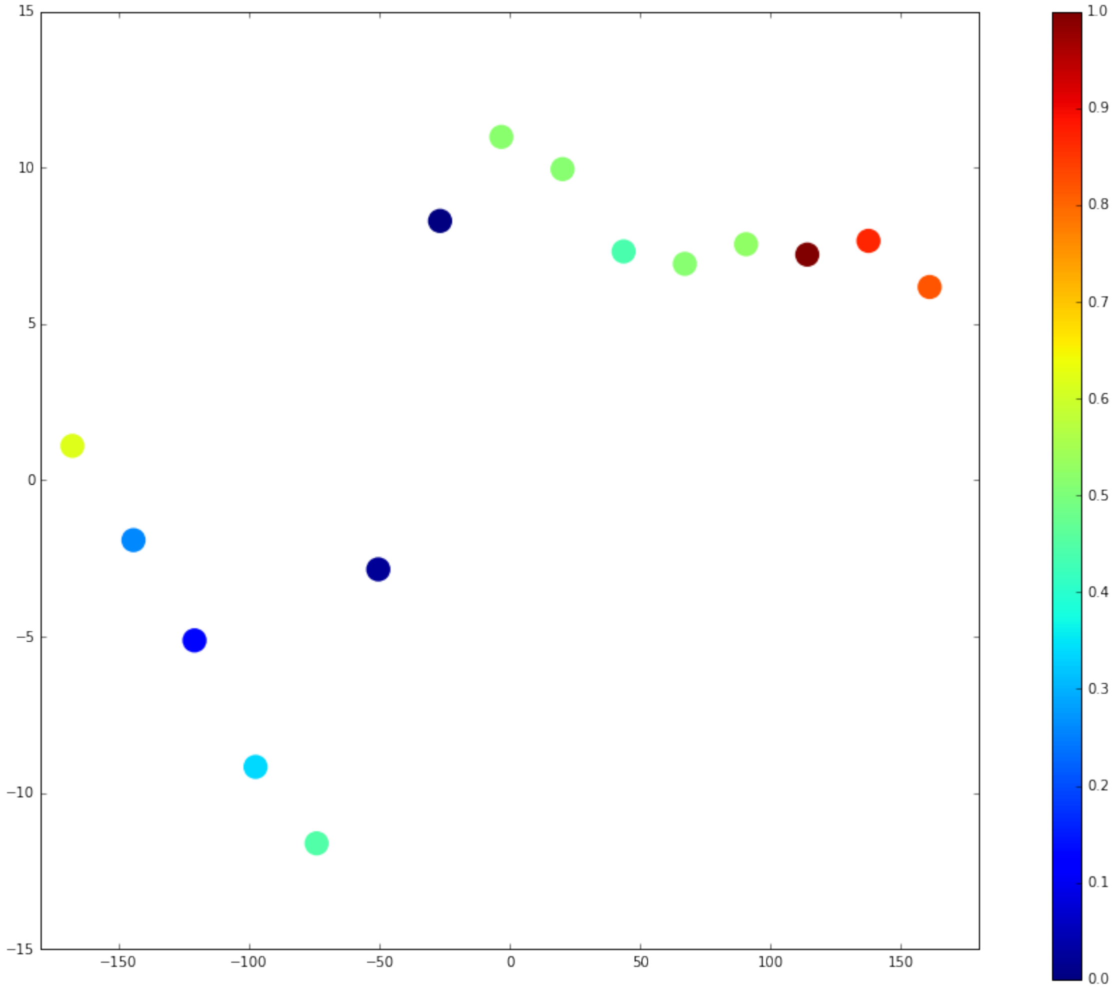


1.4 Visualization

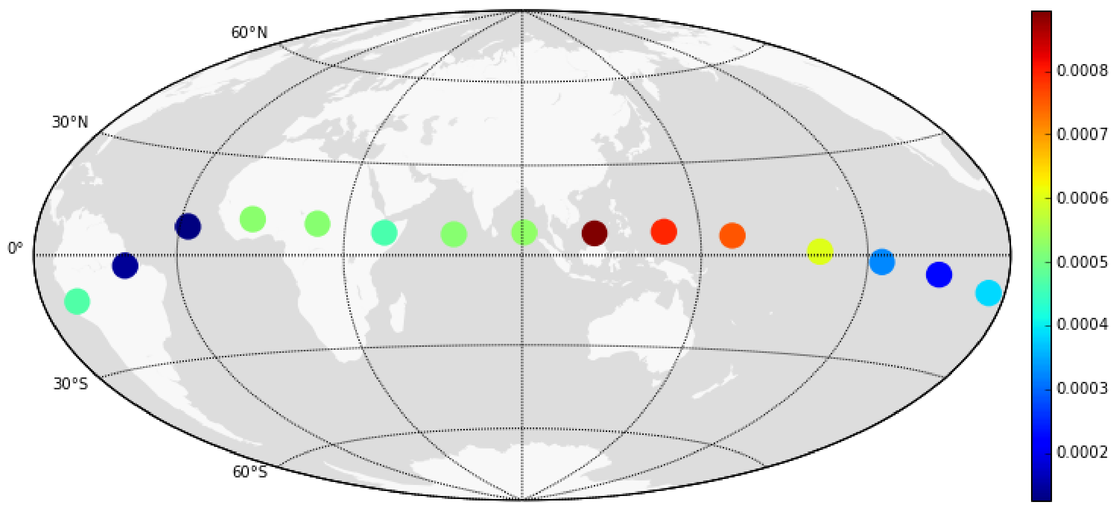
Visualize on the globe

In [29]:
```
#plain scatter plot with no background
fig,ax=st.plot_scatter(EEF_1lon.values,EEF_1lat.values,EEF_1v.values,
                              s=300,figsize=(12,12))
ax.set_xlim([-180,180])
```

Out[29]:
```
(-180, 180)
```



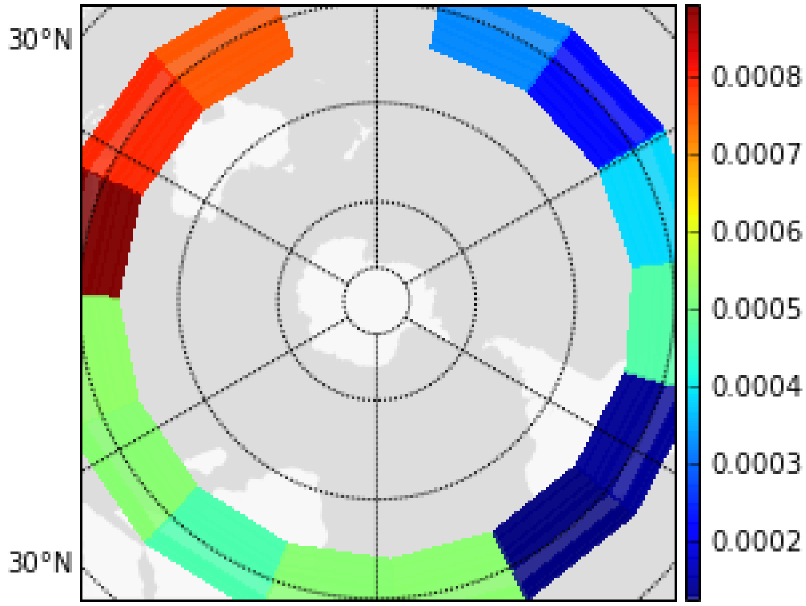

```
In [30]: #scatter on hammer projection centered on longitude=90
         st.plot_geo(EEF_1lat.values,EEF_1lon.values,EEF_1v.values,
                         s=300,projection='hammer',lon_0=90,figsize=(12,12))

Out[30]: (<matplotlib.figure.Figure at 0x7f1b00170320>,
          <mpl_toolkits.basemap.Basemap at 0x7f1ad871aef0>)
```




```
In [31]: #Orthographic projection centered on (50° N,10° E) using dark map,
         #no colorbar and a figure size of 12x12 inches
         st.plot_geo(EEF_1lat.values,EEF_1lon.values,EEF_1v.values,
                     s=1500,lon_0=10,lat_0=50,projection='ortho',
                     dark_map=True,cbar=False,figsize=(12,12))

Out[31]: (<matplotlib.figure.Figure at 0x7f1ad978f898>,
          <mpl_toolkits.basemap.Basemap at 0x7f1ad9784048>)
```

In [32]:
```
#need 2d array for colormesh, so here I just stack the EEF values on top of eachother,
#essentially losing the latitude information.
EEF_band=np.column_stack([EEF_1v.values]*15).T
#colormesh on South-Polar Azimuthal Equidistant projection,
#with the equator as bounding latitude
st.plot_geo(EEF_1lat.values,EEF_1lon.values,EEF_band,
                 ptype='colormesh',latlon=True,projection='spaeqd',boundinglat=0)
```

Out[32]:
```
(<matplotlib.figure.Figure at 0x7f1ad8aabbe0>,
 <mpl_toolkits.basemap.Basemap at 0x7f1ad8dd6b38>)
```

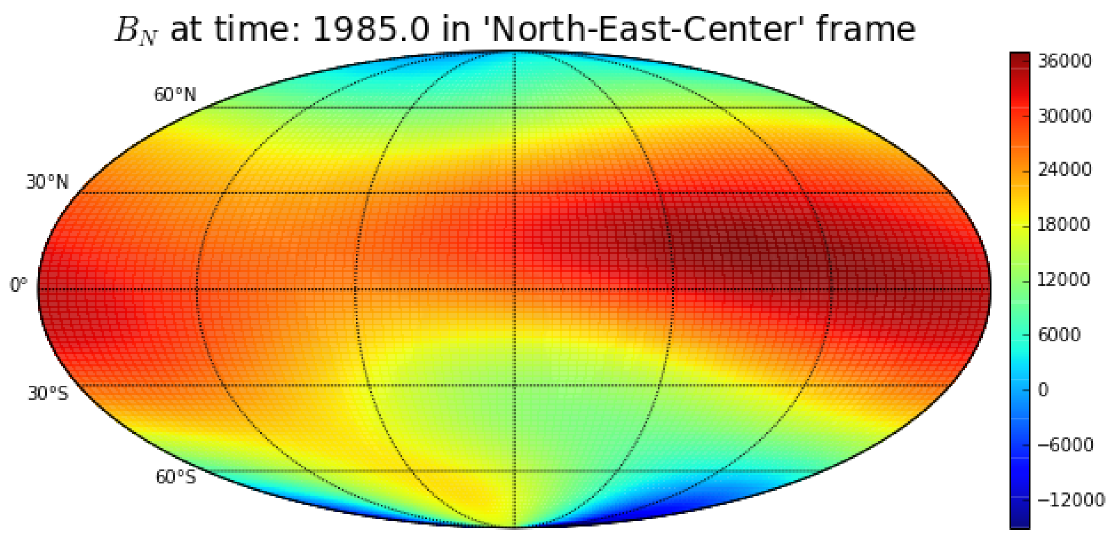


1.5 Spherical harmonics

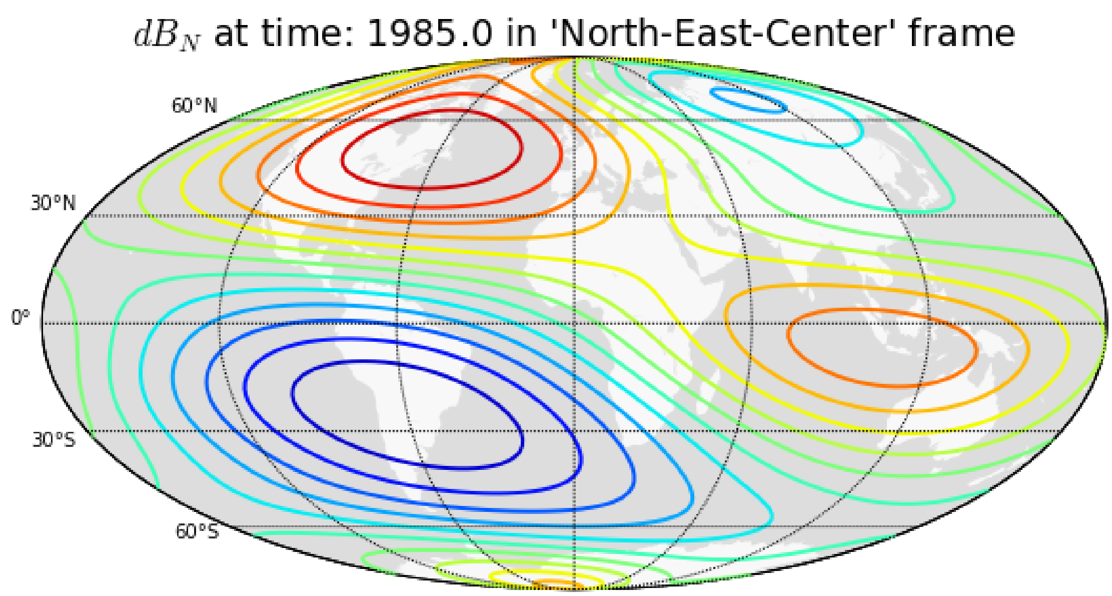
```
In [33]: lon,lat=np.linspace(0,360,101),np.linspace(-90,90,101)
         shc_fn=os.path.join(sample_loc+'IGRF12.shc')
         Bnec=st.get_Bnec(shc_fn,lat,lon,h=100)
         dBnec=st.get_Bnec(shc_fn,lat,lon,h=100,dB=True)
```

```
In [34]: time_idx=17
         dim_idx=0
         print("Number of time values: {}, Dimensions in B(fixed): {},\n"
               .format(*Bnec.shape[:2]) +
               "Number of latitude values: {}, Number of longitude values: {}"
               .format(*Bnec.shape[2:]))
         fig,m=st.plot_geo(lat,lon,Bnec[time_idx][dim_idx],
                                  ptype='colormesh',latlon=True,figsize=(10,10))

         #can read data from shc file using 'read_shc':
         plt.title("$B_{}$ at time: {} in 'North-East-Center' frame"
                   .format('NEC'[dim_idx],st.read_shc(shc_fn)[-1][time_idx]),fontsize=19)
         plt.show()
```

```
Number of time values: 25, Dimensions in B(fixed): 3,
Number of latitude values: 101, Number of longitude values: 101
```




```
In [35]: #same for its derivative
         fig,m=st.plot_geo(lat,lon,dBnec[time_idx][dim_idx],
                           ptype='contour',latlon=True,figsize=(10,10),
                           linewidths=2,cbar=False)
         plt.title("$dB_{}$ at time: {} in 'North-East-Center' frame"
                   .format('NEC'[dim_idx],st.read_shc(shc_fn)[-1][time_idx]),fontsize=19)
         plt.show()
```

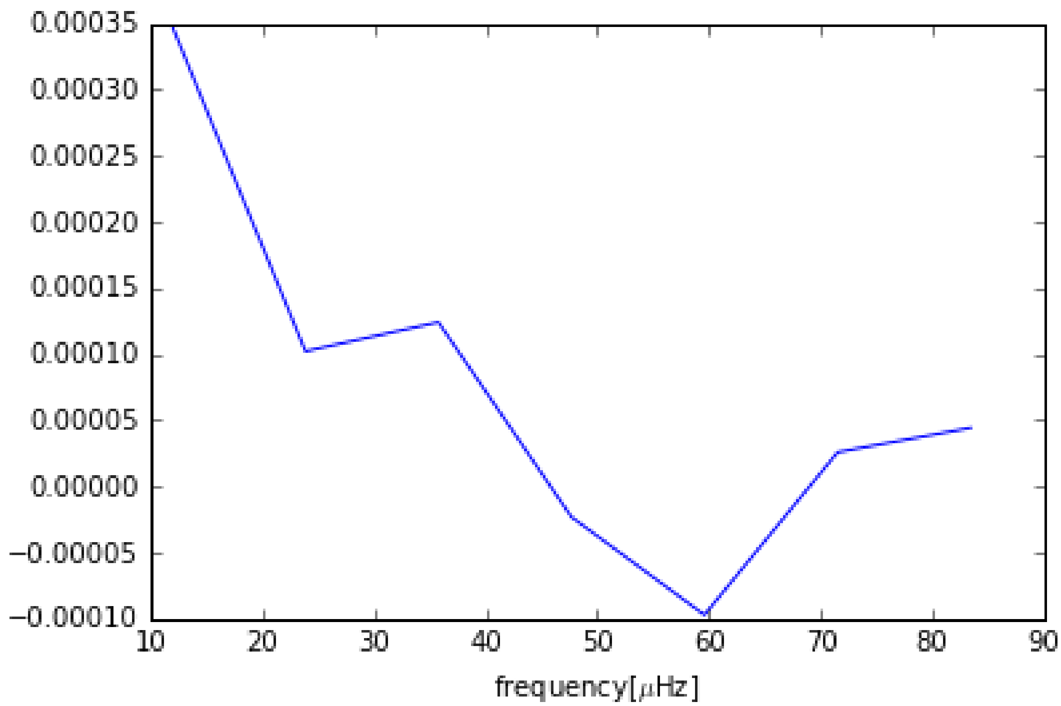


1.6 Miscellaneous

1.6.1 Fourier transform

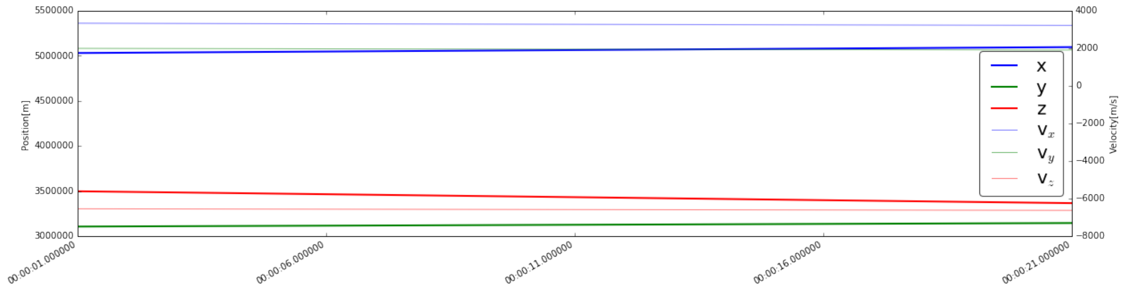
Fourier transforms can be performed on data:

In [36]:
```
#Note that the input should have a fixed frequency
#unitary fourier transform off EEF values
fEEF,EEF_freq=st.fourier_transform(EEF_1v.values,EEF_1t.values,
                                    norm='ortho')
positive_freq=np.where(EEF_freq>0)
fig,ax=st.plot_basic(EEF_freq[positive_freq]*1e6,fEEF[positive_freq])
ax.set_xlabel('frequency[$\mu$Hz]')
plt.show()
```



1.6.2 Read sp3 files

In [37]:
```
#x,y,z,t,header=st.read_sp3('sample_kin.txt',doctype=1)#read kinetic sp3 file
x,y,z,vx,vy,vz,dt,t,header=st.read_sp3(sample_loc+'sample_rd.txt')
fig,ax=st.plot_basic(t,x,t,y,t,z,legends=['x','y','z'],
                     figsize=(20,5),lhide=True,lw=2)
ax2=st.plot_twinx(t,vx,t,vy,t,vz,legends=['v$_x$','v$_y$','v$_z$'],
                  lfontsize=20,lbox=True,alpha=0.5,colors=['b','g','r'])
ax2.set_ylabel('Velocity[m/s]')
ax.set_ylabel('Position[m]')
plt.show()
```



1.6.3 EFI provisional

Read the provisional EFI ascii files

In [38]:
```
#if no parameter specified, a dictionary of all parameters are returned
out=st.read_EFI_prov_txt(
    os.path.join(sample_loc,'SW_PREL_EFIA_LP_1B_20150720T000000_20150720T235959_0103.txt'))
print("Parameters available in provisional ascii file:\n\t"+'\n\t'.join(out.keys()))
print("first 5 values:",out['n'][:5])
```

```
Parameters available in provisional ascii file:
        longitude
        latitude
        radius
        u_sc
        flag
        n
        t_elec
        timestamp
first 5 values: [ 163151.  162957.  163151.  162957.]
```

1.6.4 Parameter

When a parameter is returned from `st.extract_parameter` or `st.getCDFparams`, it is an instance of the `Parameter` class.

In [39]:
```
EEF_1v
```

Out[39]:
```
Parameter EEF V/m
array([ 0.00075635,  0.00079489,  0.00089461,  0.00053112,  0.00052239,
        0.00046283,  0.00051985,  0.00052364,  0.0001264 ,  0.00014414,
        0.00047001,  0.0003849 ,  0.00022549,  0.00032556,  0.00060109])
```

In [40]:
```
#the instance has a `values`,`name` and `unit` attribute.
EEF_1v.values,EEF_1v.name,EEF_1v.unit
```

Out[40]:
```
(array([ 0.00075635,  0.00079489,  0.00089461,  0.00053112,  0.00052239,
         0.00046283,  0.00051985,  0.00052364,  0.0001264 ,  0.00014414,
         0.00047001,  0.0003849 ,  0.00022549,  0.00032556,  0.00060109]),
 'EEF',
 'V/m')
```

In [41]:
```
#values can be accessed directly:
print(EEF_1v[:4])
#calling is shorthand for `.values`:
print(EEF_1v())
```

```
[ 0.00075635  0.00079489  0.00089461  0.00053112]
[ 0.00075635  0.00079489  0.00089461  0.00053112  0.00052239  0.00046283
  0.00051985  0.00052364  0.0001264   0.00014414  0.00047001  0.0003849
  0.00022549  0.00032556  0.00060109]
```