divand_example

October 30, 2017

1 Example for DIVAnd with automatic data download

- Notebook to create a gridded climatology from in situ observation using DIVAnd (data interpolating variational analysis, n-dimension, doi:10.5194/gmd-7-225-2014)
- Runs on a OpenStack cluster at CINECA (EuDAT) using the storage from B2DROP
- SeaDataCloud will use notebook to create climatologies which will also serve as a complete documentation show the products have been generate
- SeaDataNet will provide a dedicated machine-to-machine interface during the SeaDataCloud project
- As a proof of concept, we use the World Ocean Database as example for bulk access remote data

The path list LOAD_PATH should include the folder containing the module `WorldOceanDatabase`.

```
push!(LOAD_PATH, "path/to/module")
```

where `path/to/module` of the folder containing `WorldOceanDatabase.jl`

For the bathymetry data see instructions at https://github.com/gher-ulg/divand.jl/#example-data. Installation instructions of `divand.jl` are available here https://github.com/gher-ulg/divand.jl.

```
In [30]: # here the module is in the current working directory
         push!(LOAD_PATH, pwd());
```

1.1 Load julia modules

```
In [31]: using PyPlot
         import WorldOceanDatabase
         import divand
         using Interact
```

User parameters for the analysis are first defined

```
In [ ]: # resolution
        dx = dy = 0.25   # medium size test
        #dx = dy = 1.    # small test
```

```
# vectors defining the longitude and latitudes grids
# Here longitude and latitude correspond to the Mediterranean Sea
lonr = -7:dx:37
latr = 30:dy:46

# depth levels
depthr = [0.,10.,20.]

# time range of the in-situ data
timerange = [Date(2016,1,1),Date(2016,12,31)]

# months for the climatology (January, February,...)
timer = [1.,2.,3.]
```

```
In [32]: # Name of the variable
         varname = "Temperature"

         # Email for downloading the data
         email = "a.barth@ulg.ac.be"

         # path to save the results (will be created if necessary)
         basedir = expanduser("~/Downloads/WOD/Med-2016")

         # bathymetry
         bathname = joinpath(dirname(@__FILE__),"../Data/divand-example-data/Global/Bathymetry/g

         # bathymetry is a global data set
         isglobal = true

         # error variance of the observations (normalized by the error variance of the backgroun
         epsilon2 = 0.1;
```

Size of the space-time domain and the correlation length in all spatial dimensions and the temporal dimension. The vertical correlation length increases with depth.

```
In [33]: # size of the domain
         sz = (length(lonr),length(latr),length(depthr),length(timer))

         # horizontal correlation length in meters
         lenx = fill(300_000.,sz) # m
         leny = fill(300_000.,sz) # m


         # vertical correlation length in meters
         # correlation increases at depth
         lenz = Array{Float64}(sz)
         for n = 1:sz[4]
             for k = 1:sz[3]
```

```
            for j = 1:sz[2]
                for i = 1:sz[1]
                    lenz[i,j,k,n] = 10 + depthr[k]/5
                end
            end
        end
    end

    # correlation time-scale in month
    lent = fill(1.,sz); # month
```

1.2 Data download

- World Ocean Database: example for bulk access data by simulating a web-user
- SeaDataNet: will provide a dedicated machine-to-machine interface during the SeaDataCloud project

Comment next line (or skip this cell) if the data has already been downloaded

```
In [34]: #WorldOceanDatabase.download(lonr,latr,timerange,varname,email,basedir)
```

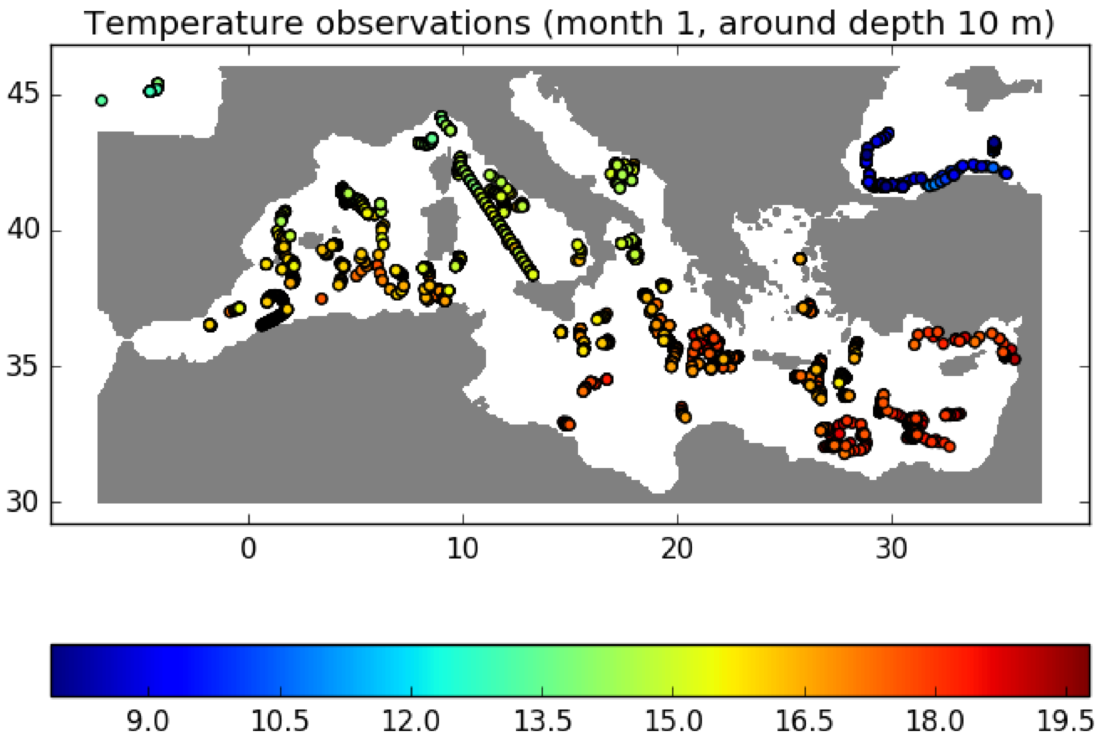
Load the data into memory and perform (potentially) an additional subsetting

```
In [35]: # load all data under basedir as a double-precision floating point variable
         val,lon,lat,depth,time,ids = WorldOceanDatabase.load(Float64,basedir,varname)

         # additional sub-setting and discard bogus negative temperatures
         sel = ((val .> 0 )
                .& (minimum(depthr) .<= depth .<= maximum(depthr))
                .& (minimum(timer) .<= Dates.month.(time) .<= maximum(timer)))

         val = val[sel]
         lon = lon[sel]
         lat = lat[sel]
         depth = depth[sel]
         time = time[sel]
         ids = ids[sel];
```

1.3 Plot the data

```
In [ ]: # contour for plots
        cxi,cyi,mask0 = divand.load_mask(bathname,isglobal,minimum(lonr),maximum(lonr),1/60,mini

        # plot observations
        plotmonth = 1
        plotdepth = 10

        title("Temperature observations (month $(plotmonth), around depth $(plotdepth) m)")
        # around means here +/-5 meters
        selection = (abs.(depth - plotdepth) .<= 5) .& (Dates.month.(time) .== plotmonth);

        contourf(cxi,cyi,mask0',levels  = [0.,0.5],colors = [[.5,.5,.5]])
        scatter(lon[selection],lat[selection],20,val[selection],cmap = "jet")
        colorbar(orientation="horizontal")
```

```
In [36]: # sets the correct aspect ratio
         gca()[:set_aspect](1/cos(mean(latr) * pi/180))
```



Setup the domain using the bathymetry from the file `bathname`.

```
In [37]: # define the geo-temporal domain
         # mask indicates wether a grid point is land or sea (based on the bathymetry)
         # pm,pn,po,pp: correspond to the resolution of grid in space and time
         # xi,yi,zi,ti: the location of the grid cells as 4D-arrays
         mask,(pm,pn,po,pp),(xi,yi,zi,ti) = divand.domain(bathname,isglobal,lonr,latr,depthr,tim

         # size of the domain
         @show size(mask)

         # convert time to month
         time2 = Dates.month.(time)

         # average over longitude and latitude for the background estimate
```

```
        toaverage=[true,true,false,false]

        # compute the background and the anomalies
        @time fmb,vaa = divand.divand_averaged_bg(mask,(pm,pn,po,pp),(xi,yi,zi,ti),(lon,lat,dep

        # perform the analysis
        @time fi,erri=divand.divandgo(mask,(pm,pn,po,pp),(xi,yi,zi,ti),(lon,lat,depth,time2),va

        # add the background
        fanalysis = fi + fmb

        # verify the range (excluding land points)
        @show extrema(fanalysis[mask])
```

```
size(mask) = (177, 65, 3, 3)
size(mask) = (177, 65, 3, 3)
(extrema(vaanalyzed), sum(sm.obsout), extrema(faanom)) = ((14.586604339536294, 16.37581708818916
  0.755234 seconds (860.09 k allocations: 77.192 MiB, 2.95% gc time)
csteps = [1, 1, 1, 1]
problemsize = 1872.0
epsilon = 5.858252779857413
stepsize = [301, 209, 2, 3]
(size(mask), size(windowlist)) = ((177, 65, 3, 3), (1,))
size(windowpoints[1]) = (177,)


WARNING: Test window [1, 1, 1, 1] [177, 65, 3, 3] [1, 1, 1, 1] [177, 65, 3, 3] [1, 1, 1, 1] [177


 2.245147 seconds (1.04 M allocations: 353.604 MiB, 3.93% gc time)
(al, dot(fgs - fs, fgs - fs) / dot(fs, fs), dot(al * fgs - fs, al * fgs - fs) / dot(fs, fs)) = (
  0.284200 seconds (599 allocations: 78.699 MiB, 4.74% gc time)
(al, dot(fgs - fs, fgs - fs) / dot(fs, fs), dot(al * fgs - fs, al * fgs - fs) / dot(fs, fs)) = (
 27.302466 seconds (60.72 M allocations: 8.804 GiB, 20.36% gc time)
extrema(fanalysis[mask]) = (5.575920276366297, 22.586288072296597)
```

```
Out[37]: (5.575920276366297, 22.586288072296597)
```

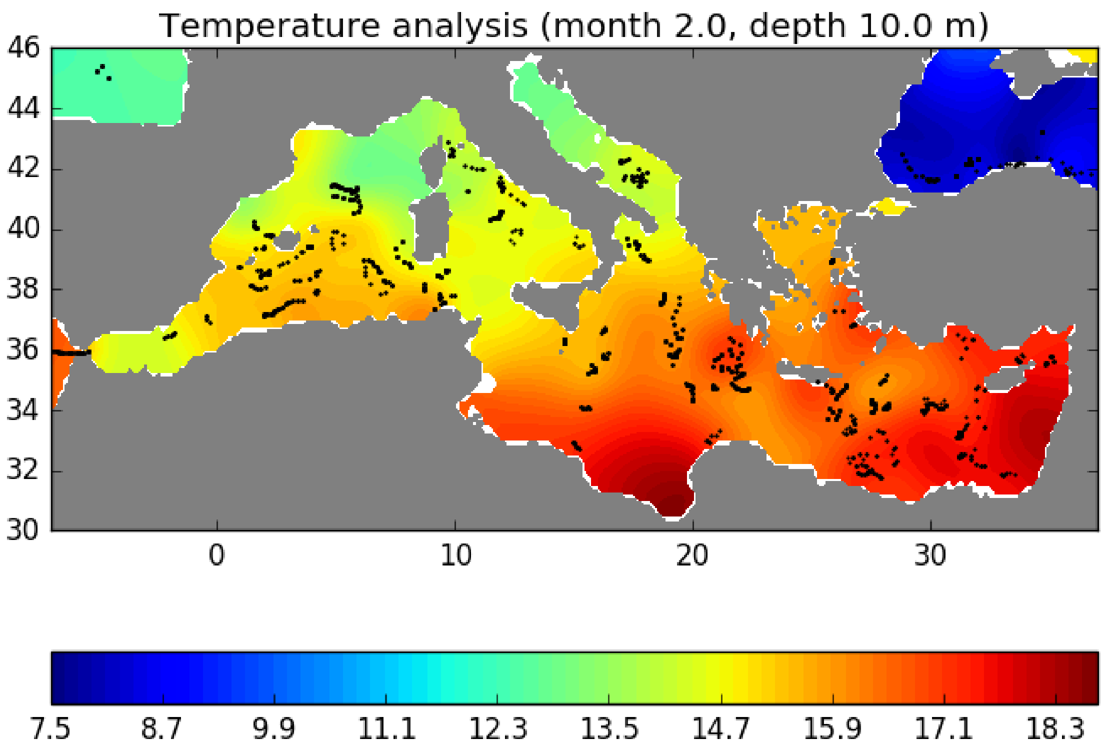
Plot the first depth level and the first time instance (`k` is the depth index and `n` is the time index)

```
In [41]: f = figure()
         @manipulate for k = 1:length(depthr), n = 1:length(timer)
             withfig(f) do
                 title("Temperature analysis (month $(timer[n]), depth $(depthr[k]) m)")
                 contourf(xi[:,:,k,n],yi[:,:,k,n],fanalysis[:,:,k,n],100,cmap="jet")
                 colorbar(orientation="horizontal")

                 # plot land
```

```
                contourf(cxi,cyi,mask0',levels  = [0.,0.5],colors = [[.5,.5,.5]])

                # plot observation location
                selection = (abs.(depth - depthr[k]) .<= 5) .& (Dates.month.(time) .== timer[n]
                plot(lon[selection],lat[selection],"k.",ms=2)

                # sets the correct aspect ratio
                gca()[:set_aspect](1/cos(mean(latr) * pi/180))
            end
        end
```

```
Interact.Options{:SelectionSlider,Int64}(55: "input-19" = 2 Int64 , "k", 2, "2", Interact.Option


Interact.Options{:SelectionSlider,Int64}(57: "input-20" = 2 Int64 , "n", 2, "2", Interact.Option
```

Out[41]:



1.4 Result export

Save the results in a NetCDF

```
In [39]: divand.divand_save("temperature.nc", mask, "temperature", fanalysis);
```

```
filename = "temperature.nc"
```