Lecture 8: Practical training – binary altimeter data

- Satellite altimetry
- Altimetry raw data
- Task 1: Read binary data
- Task 2: Write ASCII files
- (Task 3: Improve reading of binary data)
- Task 4: Plot orbits
- Task 5: Plot orbits over world map
- (Task 6: Improve plotting of orbits over world map)

In cooperation with Dr. Thomas Gruber
thomas.gruber@bv.tum.de

Practical training – satellite altimetry

What is Satellite Altimetry ?

Distance measurements from a satellite to the Earth's surface. It has to be distinguished between radar altimetry and optical instruments. Radar altimetry provides very good results over oceans and to some extent also over ice covered surfaces. With sophisticated processing techniques also over land surfaces distance observations can be processed.

Literature:

- Complete book about altimetry: Satellite Altimetry and Earth Sciences; FuL. L., Cazenave A., Academic Press, 2001
- Introduction and sea level analysis: Diploma Thesis by P. Steigenberger: MATLAB-Toolbox zur TOPEX/POSEIDON Altimeterdatenverarbeitung (Schriftenreihe IAPG, in German). See IAPG Web pages.

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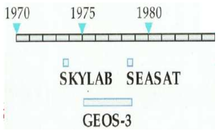
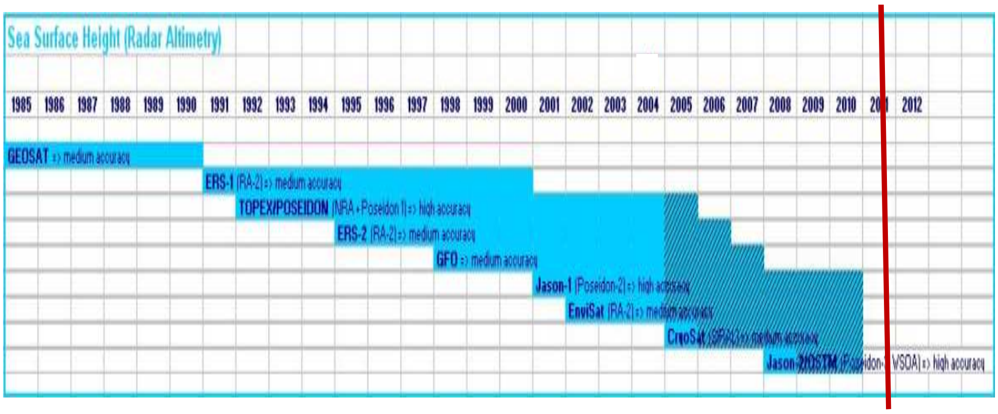
Practical training – satellite altimetry

Satellite missions





See: http://w3.mersea.eu.org/html/remote_sensing/alt_eos.html, Download 2011-12-16

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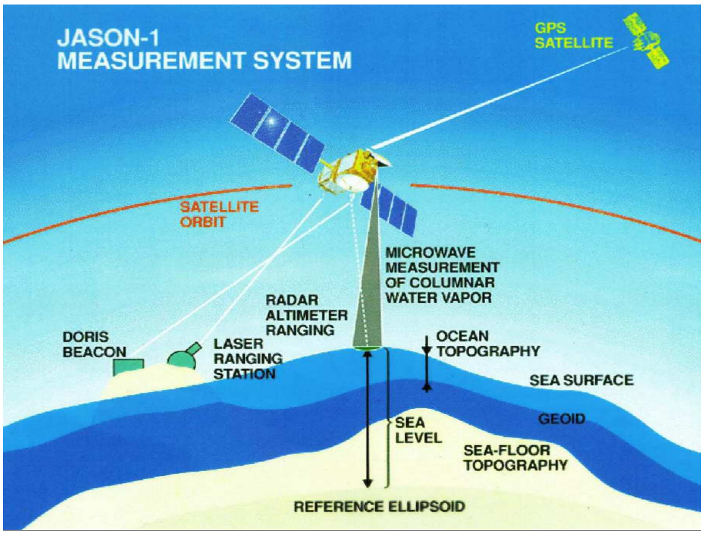
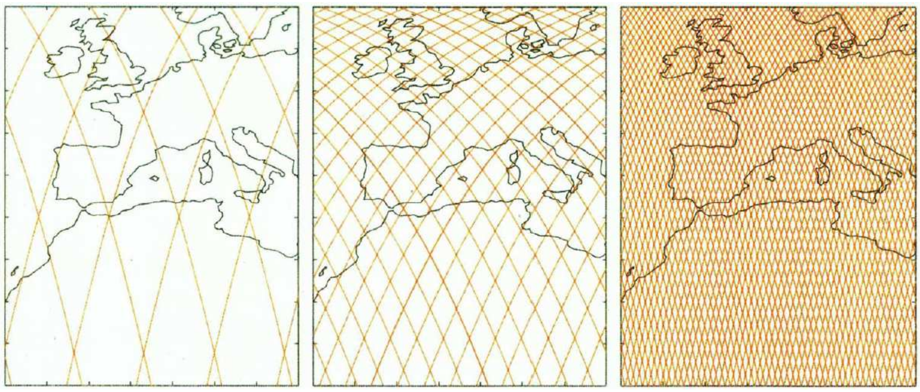
Practical training – satellite altimetry

General principles



Practical training – satellite altimetry

Spatial coverage altimetry



Ground tracks of ERS-1 (3 days repeat), Topex-Poseidon (10 days repeat) and ERS-2 (35 days repeat cyle)

Practical training – satellite altimetry

Correction terms (only for completeness)

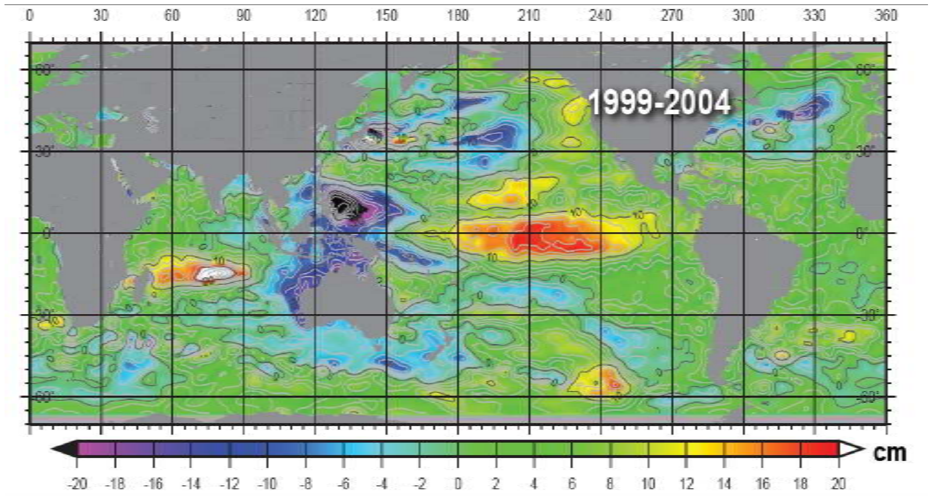
- Travel time correction dry troposphere
- Travel time correction wet troposphere
- Ionosphere
- Sea state bias
- Ocean tides
- Solid earth tides
- Pole tides
- Inverse barometer effect
- Instrumental corrections

Orbit determination

One of the most important quantities for processing the altimeter data is the radial orbit accuracy. The orbit nowadays is determined nearly continuously from microwave tracking systems on board of the satellites. Using these data the radial orbit accuracy could be improved down to a few cm. In case of insufficient observations the accuracy is between 5 and 8 cm depending on the orbit height. Main error source still is the not sufficient knowledge of the Earth’s gravity field as the main force acting on the satellite.

Practical training – satellite altimetry

One of the possible results … long term sea level changes



See: Bosch, Wolfgang: On the Combination of gravity and altimetry (possible applications of ACES), http:// *www.iapg.bv.tum.de/mediadb/15009/15010/04_ACES-bosch-05-2008.pdf*

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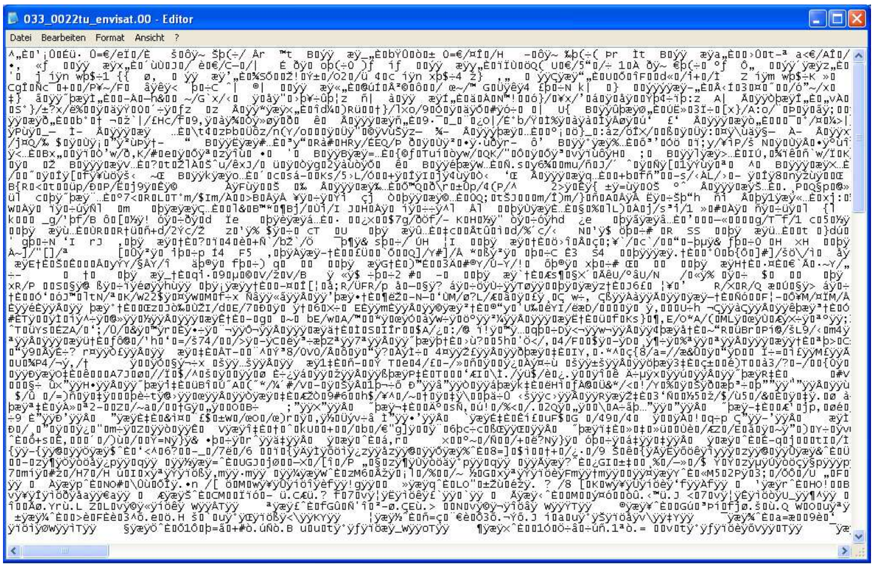
Practical training – altimetry raw data

RMP-Format



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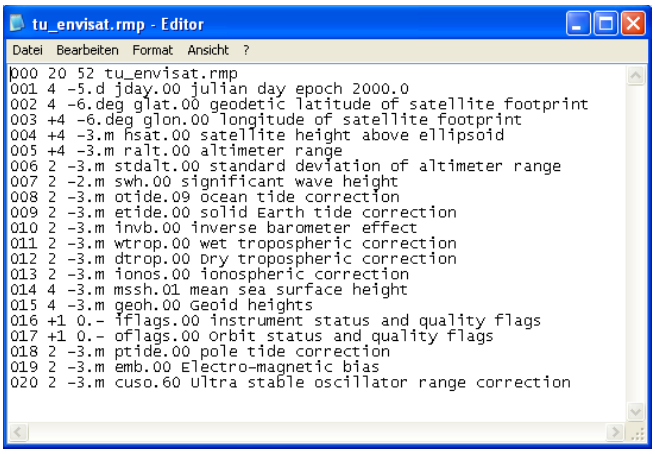
Practical training – altimetry raw data

RMP-Format Description File



tu_envisat.rmp - Editor

```
000 20 52 tu_envisat.rmp
001 4 -5.d jday.00 julian day epoch 2000.0
002 4 -6.deg glat.00 geodetic latitude of satellite footprint
003 +4 -6.deg glon.00 longitude of satellite footprint
004 +4 -3.m hsat.00 satellite height above ellipsoid
005 +4 -3.m ralt.00 altimeter range
006 2 -3.m stdalt.00 standard deviation of altimeter range
007 2 -2.m swh.00 significant wave height
008 2 -3.m otide.09 ocean tide correction
009 2 -3.m etide.00 solid Earth tide correction
010 2 -3.m invb.00 inverse barometer effect
011 2 -3.m wtrop.00 wet tropospheric correction
012 2 -3.m dtrop.00 Dry tropospheric correction
013 2 -3.m ionos.00 ionospheric correction
014 4 -3.m mssh.01 mean sea surface height
015 4 -3.m geoh.00 Geoid heights
016 +1 0.- iflags.00 instrument status and quality flags
017 +1 0.- oflags.00 orbit status and quality flags
018 2 -3.m ptide.00 pole tide correction
019 2 -3.m emb.00 Electro-magnetic bias
020 2 -3.m cuso.60 Ultra stable oscillator range correction
```

Practical training – altimetry raw data

RMP-Format Description File

tu_envisat.rmp - Editor

Datei Bearbeiten Format Ansicht ?

```
000 20 52 tu_envisat.rmp
001 4 -5.d jday.00 julian day epoch 2000.0
002 4 -6.deg glat.00 geodetic latitude of satellite footprint
003 +4 -6.deg glon.00 longitude of satellite footprint
004 +4 -3.m hsat.00 satellite height above ellipsoid
005 +4 -3.m ralt.00 altimeter range
006 2 -3.m stdalt.00 standard deviation of altimeter range
007 2 -2.m swh.00 significant wave height
008 2 -3.m otide.09 ocean tide correction
009 2 -3.m etide.00 solid Earth tide correction
010 2 -3.m invb.00 inverse barometer effect
011 2 -3.m wtrop.00 wet tropospheric correction
012 2 -3.m dtrop.00 Dry tropospheric correction
013 2 -3.m ionos.00 ionospheric correction
014 4 -3.m mssh.01 mean sea surface height
015 4 -3.m geoh.00 Geoid heights
016 +1 0.- iflags.00 instrument status and quality flags
017 +1 0.- oflags.00 orbit status and quality flags
018 2 -3.m ptide.00 pole tide correction
019 2 -3.m emb.00 Electro-magnetic bias
020 2 -3.m cuso.60 Ultra stable oscillator range correction
```

20 parameters

In sum
52 Bytes

Description File Line **000** (Header)

20 =
Number of described parameters per record

52 =
Total number of bytes per data record

tu_envisat.rmp =
Satellite name

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Practical training – altimetry raw data

RMP-Format Description File

tu_envisat.rmp - Editor

Datei Bearbeiten Format Ansicht ?

```
000 20 52 tu_envisat.rmp
001 4 -5.d jday.00 julian day epoch 2000.0
002 4 -6.deg glat.00 geodetic latitude of satellite footprint
003 +4 -6.deg glon.00 longitude of satellite footprint
004 +4 -3.m hsat.00 satellite height above ellipsoid
005 +4 -3.m ralt.00 altimeter range
006 2 -3.m stdalt.00 standard deviation of altimeter range
007 2 -2.m swh.00 significant wave height
008 2 -3.m otide.09 ocean tide correction
009 2 -3.m etide.00 solid Earth tide correction
010 2 -3.m invb.00 inverse barometer effect
011 2 -3.m wtrop.00 wet tropospheric correction
012 2 -3.m dtrop.00 Dry tropospheric correction
013 2 -3.m ionos.00 ionospheric correction
014 4 -3.m mssh.01 mean sea surface height
015 4 -3.m geoh.00 Geoid heights
016 +1 0.- iflags.00 instrument status and quality flags
017 +1 0.- oflags.00 orbit status and quality flags
018 2 -3.m ptide.00 pole tide correction
019 2 -3.m emb.00 Electro-magnetic bias
020 2 -3.m cuso.60 Ultra stable oscillator range correction
```

Description File Line **001** (First parameter)

4 =
Number of signed integer bytes used for parameter (int32)

-5.d =
Used number of decimal places (5 => calculate integer value * 10^-5) and unit d for „days"

jday.00 =
Shortcut of parameter

julian day epoch 2000.0 =
Description of parameter

Practical training – altimetry raw data

RMP-Format Description File

tu_envisat.rmp - Editor

Datei Bearbeiten Format Ansicht ?

```
000 20 52 tu_envisat.rmp
001 4 -5.d jday.00 julian day epoch 2000.0
002 4 -6.deg glat.00 geodetic latitude of satellite footprint
003 +4 -6.deg glon.00 longitude of satellite footprint
004 +4 -3.m hsat.00 satellite height above ellipsoid
005 +4 -3.m ralt.00 altimeter range
006 2 -3.m stdalt.00 standard deviation of altimeter range
007 2 -2.m swh.00 significant wave height
008 2 -3.m otide.09 ocean tide correction
009 2 -3.m etide.00 solid Earth tide correction
010 2 -3.m invb.00 inverse barometer effect
011 2 -3.m wtrop.00 wet tropospheric correction
012 2 -3.m dtrop.00 Dry tropospheric correction
013 2 -3.m ionos.00 ionospheric correction
014 4 -3.m mssh.01 mean sea surface height
015 4 -3.m geoh.00 Geoid heights
016 +1 0.- iflags.00 instrument status and quality flags
017 +1 0.- oflags.00 orbit status and quality flags
018 2 -3.m ptide.00 pole tide correction
019 2 -3.m emb.00 Electro-magnetic bias
020 2 -3.m cuso.60 Ultra stable oscillator range correction
```

<u>Description File Line **003** (Third parameter)</u>

+4 =
Number of unsigned integer bytes used for parameter (uint32)

-6.deg =
Used number of decimal places (6 => calculate integer value * 10^-6) and unit deg for „degree“

glon.00 =
Shortcut of parameter

Longitude of satellite footprint =
Description of parameter

Practical training – altimetry raw data

RMP-Format Description File

tu_envisat.rmp - Editor

Datei Bearbeiten Format Ansicht ?

```
000 20 52 tu_envisat.rmp
001 4 -5.d jday.00 julian day epoch 2000.0
002 4 -6.deg glat.00 geodetic latitude of satellite footprint
003 +4 -6.deg glon.00 longitude of satellite footprint
004 +4 -3.m hsat.00 satellite height above ellipsoid
005 +4 -3.m ralt.00 altimeter range
006 2 -3.m stdalt.00 standard deviation of altimeter range
007 2 -2.m swh.00 significant wave height
008 2 -3.m otide.09 ocean tide correction
009 2 -3.m etide.00 solid Earth tide correction
010 2 -3.m invb.00 inverse barometer effect
011 2 -3.m wtrop.00 wet tropospheric correction
012 2 -3.m dtrop.00 Dry tropospheric correction
013 2 -3.m ionos.00 ionospheric correction
014 4 -3.m mssh.01 mean sea surface height
015 4 -3.m geoh.00 Geoid heights
016 +1 0.- iflags.00 instrument status and quality flags
017 +1 0.- oflags.00 orbit status and quality flags
018 2 -3.m ptide.00 pole tide correction
019 2 -3.m emb.00 Electro-magnetic bias
020 2 -3.m cuso.60 Ultra stable oscillator range correction
```

<u>Description File Line **016** (Sixteenth parameter)</u>

+1 =
Number of unsigned integer bytes used for parameter (uint8)

0.- =
Used number of decimal places (0 => use as it is) and no unit

iflags.00 =
Shortcut of parameter

Instrument status and quality flags =
Description of parameter

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In cooperation with Dr. Thomas Gruber
thomas.gruber@bv.tum.de

Practical training – Task 1: Read binary data

Read in binary data

```
FileID = fopen('033_0022tu_envisat.00','r'); % Open the binary file for reading with file ID
[Value,Count] = fread(FileID,1,'int32');     % Scan the data into the vector/scalar "Value"
fclose(FileID);                              % Close the file
```

MATLAB	C or Fortran	Interpretation	
'schar'	'signed char'	Signed character; 8 bits	
'uchar'	'unsigned char'	Unsigned character; 8 bits	
'int8'	'integer*1'	Integer; 8 bits	1 byte signed (description: 1)
'int16'	'integer*2'	Integer; 16 bits	2 bytes signed (description: 2)
'int32'	'integer*4'	Integer; 32 bits	4 bytes signed (description: 4)
'int64'	'integer*8'	Integer; 64 bits	
'uint8'	'integer*1'	Unsigned integer; 8 bits	1 byte unsigned (description: +1)
'uint16'	'integer*2'	Unsigned integer; 16 bits	2 bytes unsigned (description: +2)
'uint32'	'integer*4'	Unsigned integer; 32 bits	4 bytes unsigned (description: +4)
'uint64'	'integer*8'	Unsigned integer; 64 bits	
'float32'	'real*4'	Floating-point; 32 bits	
'float64'	'real*8'	Floating-point; 64 bits	
'double'	'real*8'	Floating-point; 64 bits	

Practical training – Task 1: Read binary data

Read in binary data e.g.

```
001 4 -5.d jday.00 julian day epoch 2000.0
002 4 -6.deg glat.00 geodetic latitude of satellite footprint
```

```
% Open the binary file for reading with file ID
FileID = fopen('033_0022tu_envisat.00','r');

% Scan the data of the first parameter into a vector/scalar
[Value,Count] = fread(FileID,1,'int32');
% Calculate floating point
Value = Value / 100000;
% Create parameter shortcut
Shortcut = 'jday.00';
% Create parameter description
Description = 'julian day epoch 2000.0';
% Save value in record
Record(1) = Value;

% Scan the data of the second parameter
[Value,Count] = fread(FileID,1,'int32');
...

% Close the file
fclose(FileID);
```


Practical training – Task 1: Read binary data

Read in binary data

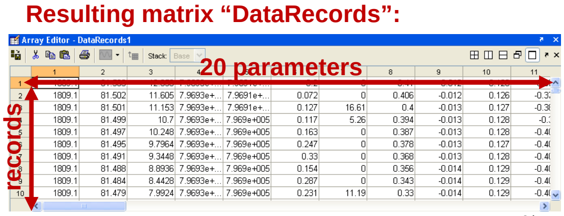
```
function [ColumnShortcuts, ColumnDescriptions, ColumnUnits, DataRecords] =
readrmpenvisat (DirectoryPath, SatelliteName, DataFilesList, DebugFlag)
% Read altimetry data RMP
% Needs DirectoryPath of the data (including description),
%       the satellite name (file name of description),
%       a list of data file names and a
%       DebugFlag which switches output of debug text on (> 0) or off
% Returns ColumShortcuts as shortcut of record parameter description,
%         ColumnDescription with the complete record parameter description,
%         the units of the columns (parameters) and
%         the DataRecords with a matrix of records per line with all
%         parameters

% ***********************************************************************
% Initialize return values
% ***********************************************************************
ColumnShortcuts = [];
ColumnDescriptions = [];
DataRecords = [];
ColumnUnits = [];

...

return;
```

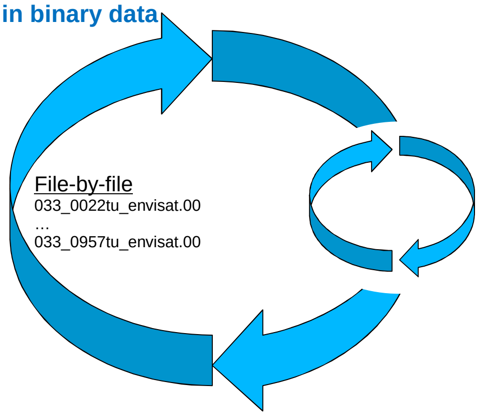
Resulting matrix “DataRecords”:



	1	2	3	4	5	6	7	8	9	10	11
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	1809.1	81.502	11.605	7.9693e+...	7.9691e+...	0.072	0	0.406	-0.012	0.126	-0.3
3	1809.1	81.501	11.153	7.9693e+...	7.9691e+...	0.127	16.61	0.4	-0.013	0.127	-0.3
4	1809.1	81.499	10.7	7.9693e+...	7.969e+005	0.117	5.26	0.394	-0.013	0.128	-0.
5	1809.1	81.497	10.248	7.9693e+...	7.969e+005	0.163	0	0.387	-0.013	0.128	-0.4
6	1809.1	81.495	9.7964	7.9693e+...	7.969e+005	0.247	0	0.378	-0.013	0.127	-0.4
7	1809.1	81.491	9.3448	7.9693e+...	7.969e+005	0.33	0	0.368	-0.013	0.128	-0.4
8	1809.1	81.488	8.8936	7.9693e+...	7.969e+005	0.154	0	0.356	-0.014	0.129	-0.4
9	1809.1	81.484	8.4428	7.9693e+...	7.969e+005	0.287	0	0.343	-0.014	0.129	-0.4
10	1809.1	81.479	7.9924	7.9693e+...	7.969e+005	0.231	11.19	0.33	-0.014	0.129	-0.4

Practical training – Task 1: Read binary data

Read in binary data



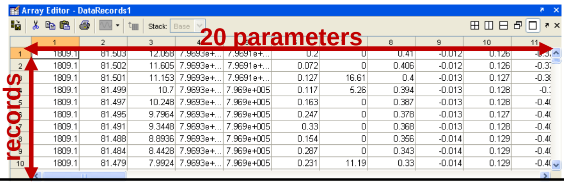
Record-by-record
<int32><int32><Iuint32>…<int16>
<int32><int32><Iuint32>…<int16>
<int32><int32><Iuint32>…<int16>
…
<int32><int32><Iuint32>…<int16>
<end-of-file>

```
while (feof(FID) == 0)

   % Binary reading of parameter
   ...

   % Additional empty line check
   if (feof(FileID) == 1)
      break;
   end;
end;
```

Resulting matrix "DataRecords":



	1	2	3	4	5	6	7	8	9	10	11
1	1809.1	81.503	12.058	7.9693e+...	7.9691e+...	0.2	0	0.41	-0.012	0.126	[illegible]
2	1809.1	81.502	11.605	7.9693e+...	7.9691e+...	0.072	0	0.406	-0.012	0.126	-0.3
3	1809.1	81.501	11.153	7.9693e+...	7.9691e+...	0.127	16.61	0.4	-0.013	0.127	-0.3
4	1809.1	81.499	10.7	7.9693e+...	7.969e+005	0.117	5.26	0.394	-0.013	0.128	-0.
5	1809.1	81.497	10.248	7.9693e+...	7.969e+005	0.163	0	0.387	-0.013	0.128	-0.4
6	1809.1	81.495	9.7964	7.9693e+...	7.969e+005	0.247	0	0.378	-0.013	0.127	-0.4
7	1809.1	81.491	9.3448	7.9693e+...	7.969e+005	0.33	0	0.368	-0.013	0.128	-0.4
8	1809.1	81.488	8.8936	7.9693e+...	7.969e+005	0.154	0	0.356	-0.014	0.129	-0.4
9	1809.1	81.484	8.4428	7.9693e+...	7.969e+005	0.287	0	0.343	-0.014	0.129	-0.4
10	1809.1	81.479	7.9924	7.9693e+...	7.969e+005	0.231	11.19	0.33	-0.014	0.129	-0.4

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In cooperation with Dr. Thomas Gruber
thomas.gruber@bv.tum.de

Practical training – Task 2: Write ASCII

Write binary data in readable ASCII-records file-by-file

```
FileID = fopen('033_0022tu_envisat.00.txt', 'w');      % Open the binary file for writing with file ID
[Count, Errmsg] = fprintf(FileID, '%f', DataRecords(1,1)); % Write floating point value
fclose(FileID);                                        % Close the file
```

Specifier	Description
%c	Single character
%d	Decimal notation (signed)
%e	Exponential notation (using a lowercase e as in 3.1415e+00)
%E	Exponential notation (using an uppercase E as in 3.1415E+00)
%f	Fixed-point notation
%g	The more compact of %e or %f, as defined in [2]. Insignificant zeros do not print.
%G	Same as %g, but using an uppercase E
%i	Decimal notation (signed)
%o	Octal notation (unsigned)
%s	String of characters
%u	Decimal notation (unsigned)
%x	Hexadecimal notation (using lowercase letters a-f)
%X	Hexadecimal notation (using uppercase letters A-F)

Or:
```
save ('-ascii', '-double', '033_0022tu_envisat.00.txt', 'DataRecords');
```


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Practical training – Task 2: Write ASCII

Discuss advantages and disadvantages of binary- and ASCII-files

Usage
File sizes
Platform-dependency
User friendliness
Error stability
…

?

Lecture 8: Practical training – binary altimeter data

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Practical training – Task 3: Improve reading of binary data

Use description file

```
function [ColumnShortcuts, ColumnDescriptions, ColumnUnits, DataRecords] =
readrmp (DirectoryPath, SatelliteName, DataFilesList, DebugFlag)

% Read description file first
% Read file line by line
FileID = fopen(DescriptionFilePath);
Line = fgetl(FileID);
while ischar(Line)
    ...
    % Parse first line to get number of records
    IndexOfWhitespaces = find (isspace(Line));
    % Read number of records
    NumberOfRecordParameter = str2num(Line(IndexOfWhitespaces(1)+1: ...
                                  IndexOfWhitespaces(2)-1));
    ColumnShortcuts = zeros(NumberOfRecordParameter,16);
    ColumnDescriptions = zeros(NumberOfRecordParameter,128);
    ColumnUnits = zeros(NumberOfRecordParameter,3);
    ByteSize = zeros(1,NumberOfRecordParameter);
    ByteSign = ones(1,NumberOfRecordParameter);
    FloatingPointDivisionFactors = zeros(1,NumberOfRecordParameter);
    ...
    % Parse the other lines and retrieve the information
    Line = fgetl(FileID);
end;
...
```

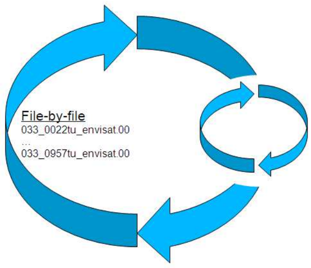
Practical training – Task 3: Improve reading of binary data

Use description file

```
    ...

    % Continue as in the previous task but use the desctription
    % vectors to select the bit size for the binary read
    ...
    % Read in value by value of record
    switch (ByteSize(CurrentNumberOfRecordParameter))
        case (1)
            if (ByteSign(CurrentNumberOfRecordParameter) == 1)
                ReadValue = fread(FileID,1,'int8');
            else
                ReadValue = fread(FileID,1,'uint8');
            end;
        case (2)
            ...
        case (4)
            ...
    end;
    ...

return;
```



Lecture 10: Practical training – binary altimeter data

✓ Satellite altimetry
✓ Altimetry raw data
✓ Task 1: Read binary data
✓ Task 2: Write ASCII files
✓ (Task 3: Improve reading of binary data)
- Task 4: Plot orbits
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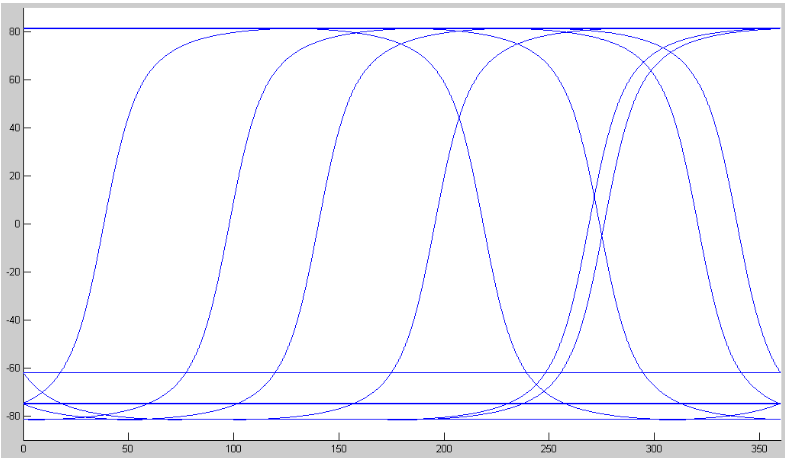
- (Task 6: Improve plotting of orbits over world map)

In cooperation with Dr. Thomas Gruber
thomas.gruber@bv.tum.de

Practical training – Task 4: Plot data

Plot the passages

```
plot (DataRecords1(:,3)',DataRecords1(:,2)');
...
```



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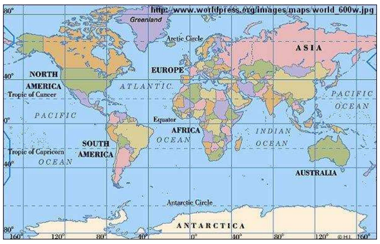
Lecture 8: Practical training – binary altimeter data

- Satellite altimetry
- Altimetry raw data
- Task 1: Read binary data
- Task 2: Write ASCII files
- (Task 3: Improve reading of binary data)
- Task 4: Plot orbits
- Task 5: Plot orbits over world map
- (Task 6: Improve plotting of orbits over world map)

In cooperation with Dr. Thomas Gruber
thomas.gruber@bv.tum.de

Practical training – Task 5: Plot data over world map

Plot the passages

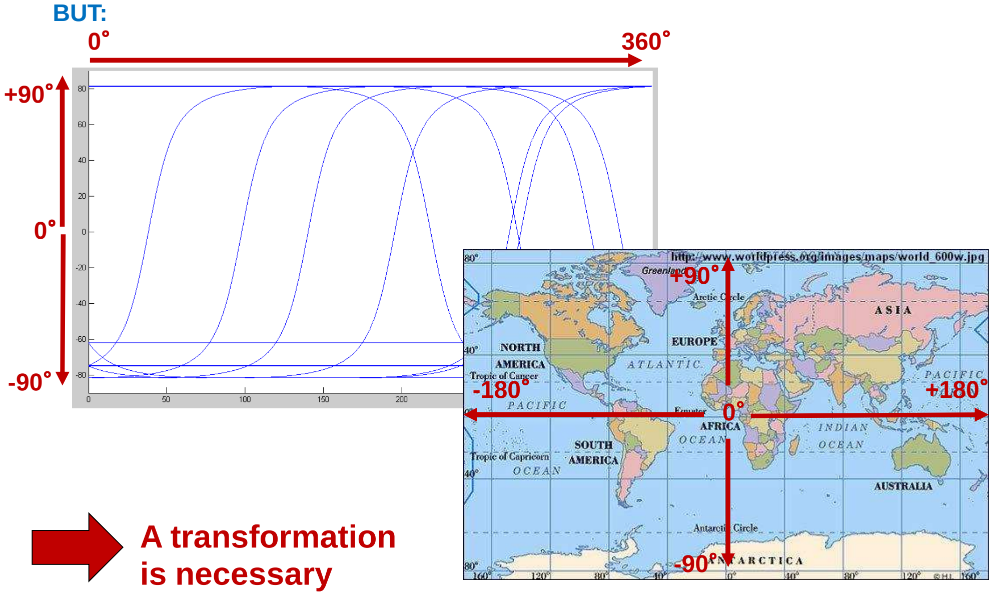



```
figure;
hold on;

% Set background image
BackgroundImageFilePath = [DirectoryPath,'map.jpg'];
BackgroundImage = imread(BackgroundImageFilePath);
imagesc([-180 180], [-86 89], flipdim(BackgroundImage,1));
set(gca,'ydir','normal');
% Plot data
plot (DataRecords1(:,3)',DataRecords1(:,2)', 'r', 'LineWidth', 2);
...
% Set limits for the axis
xlimits = [-180 180];
set(gca,'XLim', xlimits);
ylimits = [-90 90];
set(gca,'YLim', ylimits);
hold off;
```


Practical training – Task 5: Plot data over world map

BUT:

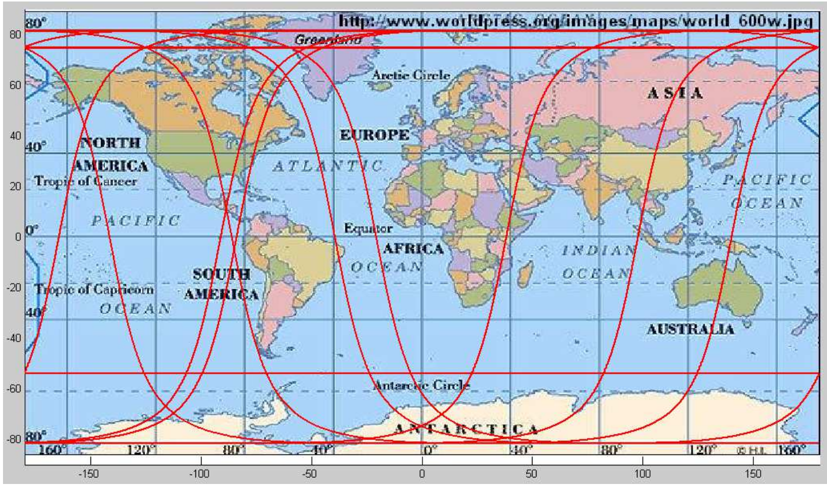


A transformation is necessary

Practical training – Task 5: Plot data over world map

Plot the passages

Result



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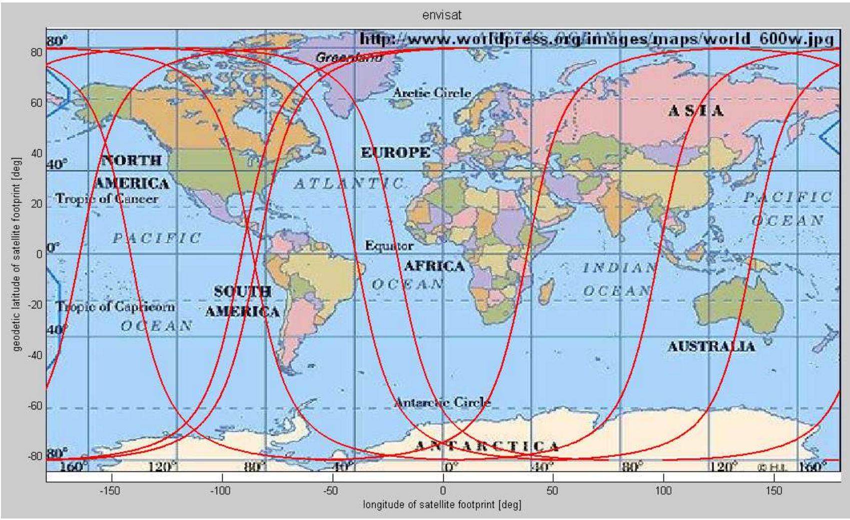
Practical training – Task 6: Improve plotting over world map

Plot the passages

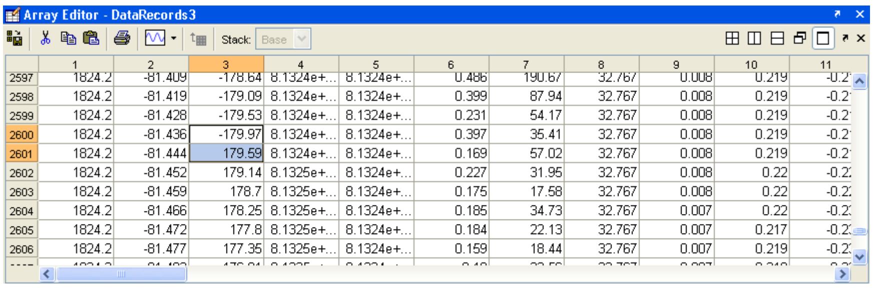
Goal:



Practical training – Task 6: Improve plotting over world map

Hint:

Search for changes in geodetic longitude from 180 deg to -180 deg or from -180 deg to 180 deg after the transformation in the previous task.



	1	2	3	4	5	6	7	8	9	10	11
2597	1824.2	-81.409	-178.64	8.1324e+...	8.1324e+...	0.486	190.67	32.767	0.008	0.219	-0.2
2598	1824.2	-81.419	-179.09	8.1324e+...	8.1324e+...	0.399	87.94	32.767	0.008	0.219	-0.2
2599	1824.2	-81.428	-179.53	8.1324e+...	8.1324e+...	0.231	54.17	32.767	0.008	0.219	-0.2
2600	1824.2	-81.436	-179.97	8.1324e+...	8.1324e+...	0.397	35.41	32.767	0.008	0.219	-0.2
2601	1824.2	-81.444	179.59	8.1324e+...	8.1324e+...	0.169	57.02	32.767	0.008	0.219	-0.2
2602	1824.2	-81.452	179.14	8.1325e+...	8.1324e+...	0.227	31.95	32.767	0.008	0.22	-0.2
2603	1824.2	-81.459	178.7	8.1325e+...	8.1324e+...	0.175	17.58	32.767	0.008	0.22	-0.2
2604	1824.2	-81.466	178.25	8.1325e+...	8.1324e+...	0.185	34.73	32.767	0.007	0.22	-0.2
2605	1824.2	-81.472	177.8	8.1325e+...	8.1324e+...	0.184	22.13	32.767	0.007	0.217	-0.2
2606	1824.2	-81.477	177.35	8.1325e+...	8.1324e+...	0.159	18.44	32.767	0.007	0.219	-0.2

Paint the sections of the orbit yourself using “line”, e.g.

```
line ([X1,X2)],[Y1,Y2], 'Color', 'r', 'LineWidth', 2);
... (for each section)
```

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Matlab project – additional tips

Try to write readable and efficient code:

- Add comments to explain the code
- Use understandable (variable) matrix names
- Structure the code into logical units
- Avoid loops (use "."-operators)
- Initialize matrixes
- Use the advantages of MATLAB matrix operations
- Use the MATLAB standard functions instead of own code
- …

Matlab project

Thank you!