

Icelandic transformations and PROJ

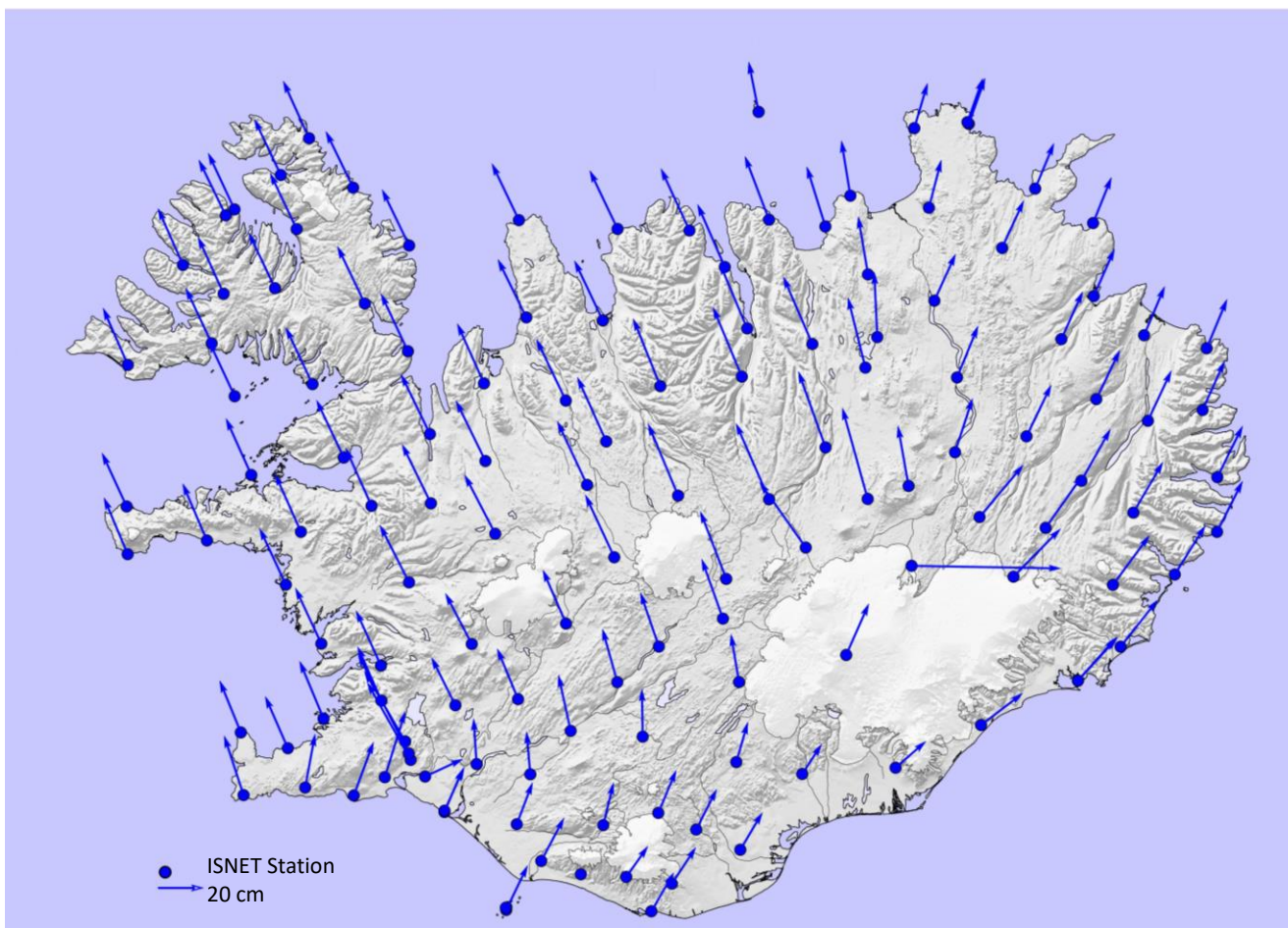
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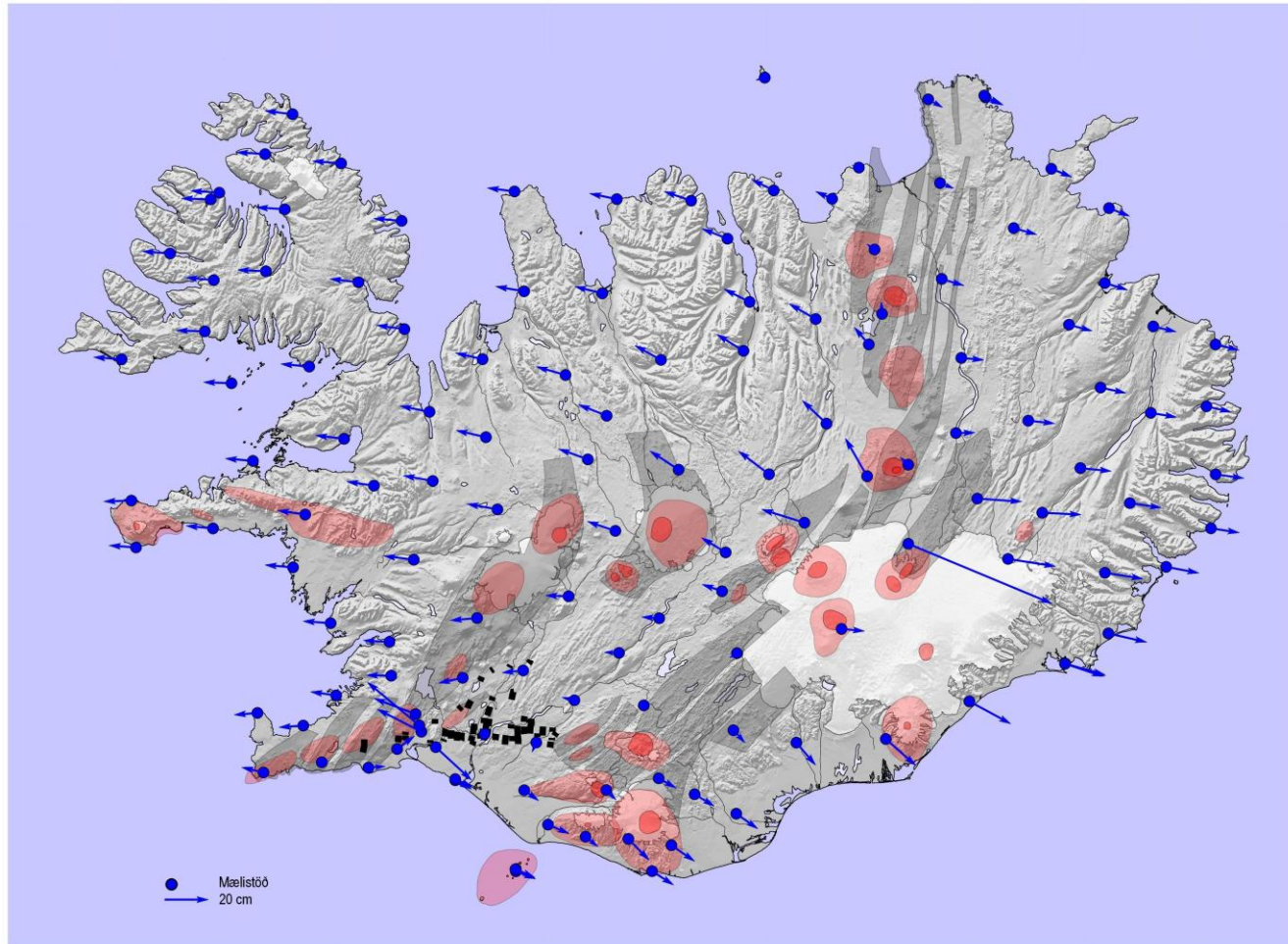
Introduction

- Iceland's position on the boundaries of the Eurasian- and North-American plates makes it challenging to maintain precise national reference frames
- The National Land Survey of Iceland is currently introducing two new reference frames
 - ISN2016 a semi dynamic frame
 - ISN_DRF a dynamic frame
- Coordinate transformations and conversions are a vital part of this
- One part of this to renew our transformation service

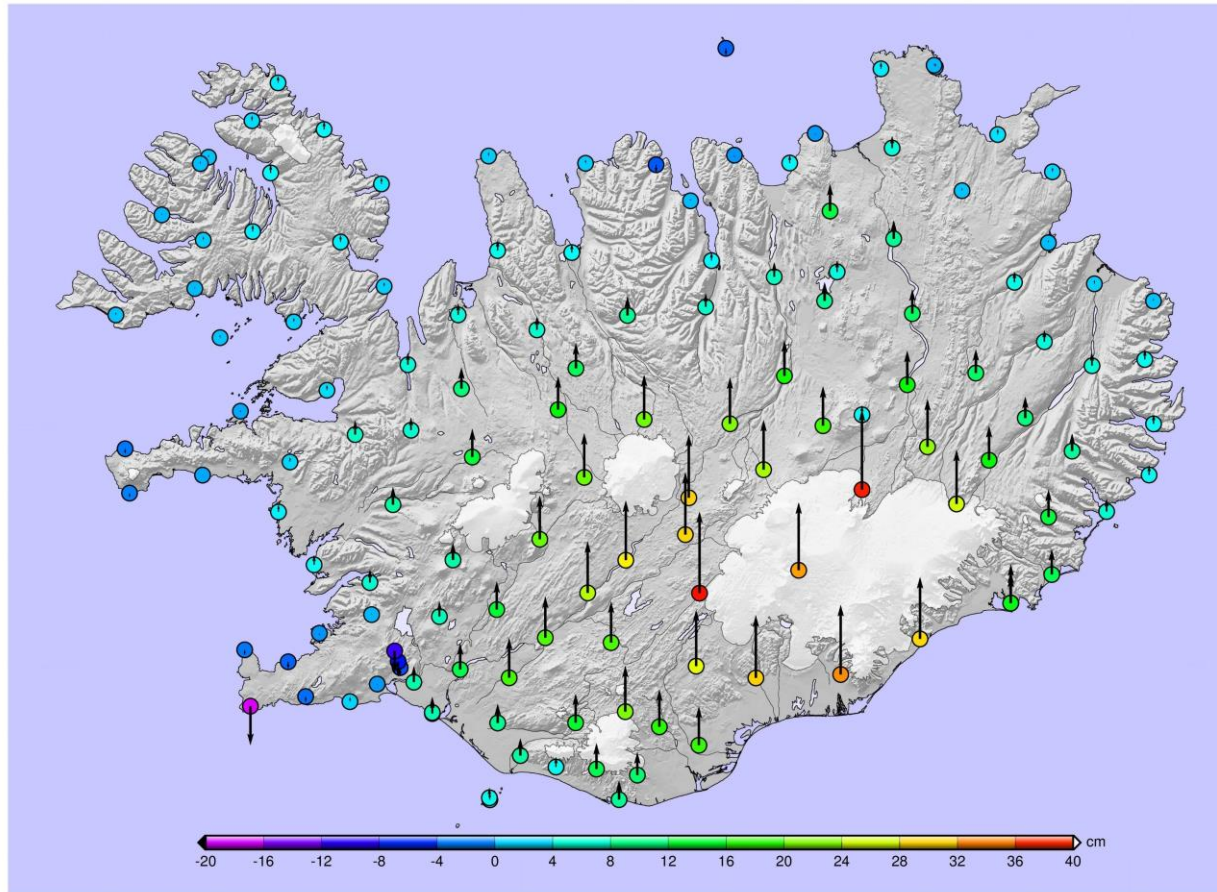
ISN2016 vs. ISN2004 horizontal difference



ISN2016 vs. ISN2004 horizontal deformation



ISN2016 vs. ISN2004 vertical difference



Coordinate systems in Iceland

- We have had 6 official coordinate systems in Iceland since 1900
- One official vertical reference system ISH2004

Datums	Ellipsoid	Reference Frame	Map Projections
Reykjavik 1900	Danish		LCC 1SP
Hjörsey55	Hayford		LCC 1SP, UTM 3 zones, GK 4 zones
ISN93	GRS80	ITRF93	LCC 2SP, UTM 3 zones
ISN2004	GRS80	IGb00	LCC 2SP
ISN2016	GRS80	IGS14	LCC 2SP
ISN_DRF	GRS80	Current ITRF/IGS	LCC 2SP

What do we need in our transformation service

- Classic coordinate conversion
- Transformation
- Deformation models
- Geoid models
- Time depended coordinates
- PROJ v5.0.0 and onwards provides all this features
- Obvious choice for us

PROJ work in Iceland

- We have created an init file containing most definitions for coordinate conversion and transformations in Iceland
- IS.txt
- Then construct pipelines

Geoid and transformation grids

- **#**Transformation Grids

```
# geoid
```

```
<ISH2004> +proj=vgridshift +grids=icegeoid_2011.gtx
```

```
#deformation grids
```

```
<ISN93_04h> +proj=hgridshift +grids=ISN93_04.ct2
```

```
<ISN93_04v> +proj=vgridshift +grids=ISN93_04.gtx +vunits=m
```

```
<ISN93_16h> +proj=hgridshift +grids=ISN93_16.gsb/ct2
```

```
<ISN93_16v> +proj=vgridshift +grids=ISN93_16.gtx +vunits=m
```

```
<ISN04_16h> +proj=hgridshift +grids=ISN04_16.gsb/ct2
```

```
<ISN04_16v> +proj=vgridshift +grids=ISN04_16.gtx +vunits=m
```

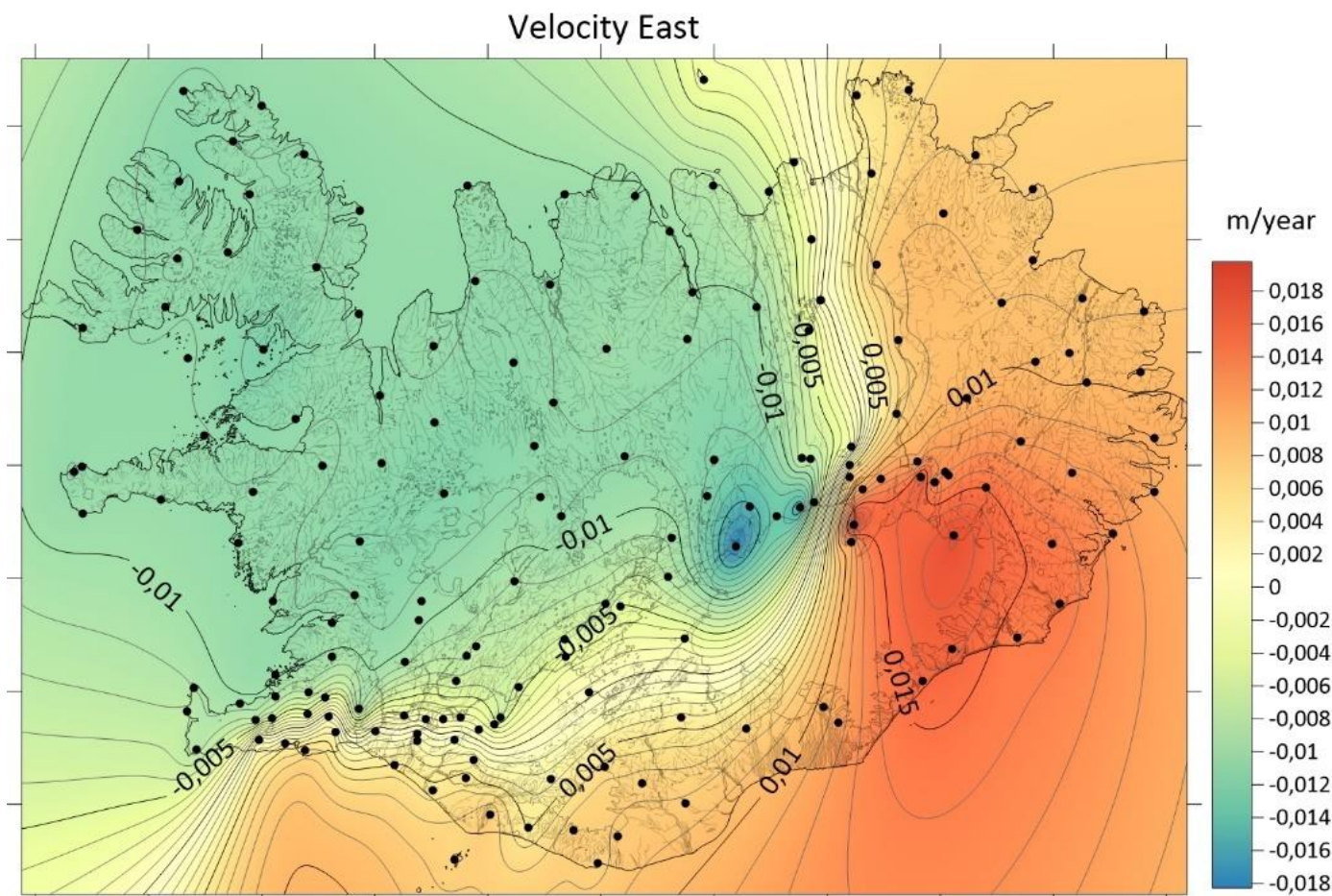
```
# kinematic datum shifting/dynamic transformation
```

```
<KIN_SHIFT> +xy_grids=ISN_vel_beta.ct2 +z_grids=ISN_vel_beta.gtx
```

Grid formats

- Originally our grids are in Surfer or GravSoft format
- We use GDAL to convert our original grids
- Grids for horizontal deformation in PROJ (hgridshift)
 - NTV2 (*.gsb)
 - Lat, Lon grid
 - Deformation in seconds, west is positive
 - CTable2 (*.ct2)
 - Lat, Lon grid
 - Deformation in radians, west is positive
 - Band_1=Northward deformation, Band_2=Westwards deformation
- Grids for vertical deformation
 - GTX (*.gtx)
 - Values are subtracted
- Grids for kinematic datum shifting
 - xy_grids, CTable2, units mm/year
 - z_grids, gtx, units mm/year and values are added

Kinematic grid (east component)



Projections and datums in use

```
<KIN_LAM> +proj=lcc +lat_1=64.25 +lat_2=65.75 +lat_0=65 +lon_0=-19
+x_0=4700000 +y_0=300000
```

```
<ISN2016_LAM> +proj=lcc +lat_1=64.25 +lat_2=65.75 +lat_0=65 +lon_0=-19
+x_0=2700000 +y_0=300000
```

```
+ellps=GRS80 +units=m +no_defs
```

```
<ISN2004_LAM> +proj=lcc +lat_1=64.25 +lat_2=65.75 +lat_0=65 +lon_0=-19
+x_0=1700000 +y_0=300000
```

```
+ellps=GRS80 +units=m +no_defs
```

```
<ISN93_LAM> +proj=lcc +lat_1=64.25 +lat_2=65.75 +lat_0=65 +lon_0=-19
+x_0=500000 +y_0=500000
```

```
+ellps=GRS80 +units=m +no_defs
```

```
<ISN16_ISH04> +proj=pipeline +step +init=IS.txt:ISN04_16v +step
+init=IS.txt:ISH2004
```

```
<ISN93_ISH04> +proj=pipeline +step +inv +init=IS.txt:ISN93_04v +step
+init=IS.txt:ISH2004
```

Historical datums (examples)

#Historical datums and projections

```
<HJORSEY_LAM> +proj=lcc +lat_1=65 +lat_0=65 +lon_0=-18 +x_0=-500000 +y_0=500000 +ellps=intl +units=m +no_defs +axis=wnu
```

```
<HJ UTM27> +proj=utm +zone=27 +ellps=intl +units=m +k_0=0.9996 +no_defs
```

```
<HJ GK21> +proj=tmerc +ellps=intl +lat_0=0 +lon_0=-21 +x_0=500000 +units=m +k_0=1 +axis=neu +no_defs
```

```
<RE LAM> +proj=lcc +lat_1=65 +lat_0=65 +lon_0=-19.022125 +x_0=0 +y_0=0 +ellps=danish +units=m +no_defs
```

Transformations

```
#Transformations
```

```
<REYK1900_ISN93> +proj=pipeline  
    +step +proj=cart +ellps=danish  
    +step +proj=helmert +inv +ellps=Danish  
    +convention=coordinate_frame  
        +x=556.020 +y=-168.701 +z=942.364  
        +rx=4.145 +ry=-0.269 +rz=-2.279 +s=-3.729  
    +step +proj=cart +inv +ellps=GRS80  
  
<HJORSEY55_ISN93> +proj=pipeline  
    +step +proj=cart +ellps=intl  
    +step +proj=helmert +inv +ellps=intl  
        +x=-73 +y=46 +z=-86  
    +step +proj=cart +inv +ellps=GRS80  
    +step +init=IS:HEY55_ISN93P
```

Gridshift tests

- We have tested all possibilities between the ISN systems on points with “known coordinates”
- We’ve used cct instead of proj
 - Can include height and time
- Not more than few mm differences in some cases

From ISN93 LCC ellipsodal (geodetic) height to ISN2016 LCC ellipsodal (geodetic) height

Point LM0331

```
echo 545293.098 670683.324 75.737 0 |
```

```
cct +proj=pipeline
```

```
+step +inv +init=IS.txt:ISN93_LAM
```

```
+step +init=IS.txt:ISN93_16h
```

```
+step +inv +init=IS.txt:ISN93_16v
```

```
+step +init=IS.txt:ISN2016_LAM --
```

```
output: E=2745292.996 N=470683.759 h=75.618
```

```
ISN2016: E=2745292.998 N=470683.759 h=75.618
```

From ISN2004 LCC ellipsoidal (geodetic) height to ISN2016 LCC MSL height (ISH2004 vertical datum)

```
echo 1745293.042 470683.539 75.653 0 |  
  cct    +proj=pipeline  
  +step  +inv    +init=IS.txt:ISN2004_LAM  
  +step  +init=IS.txt:ISN04_16h  
  +step  +init=IS.txt:ISH2004  
  +step  +init=IS.txt:ISN2016_LAM --  
output: E=2745292.9970 N=470683.7595 MSL=11.6145
```

Kinematic datum shifting

- # from ISN DRF epoch 2017.5 LCC h to ISN_DRF LCC h epoch 2018.5

```
echo 4740331.728      376698.750      134.205 2017.5|
```

```
cct +proj=pipeline
```

```
+step +inv +init=IS.txt:KIN_LAM
```

```
+step +proj=cart +ellps=GRS80
```

```
+step +proj=deformation +dt=1
```

```
+init=IS.txt:KIN_SHIFT
```

```
+step +proj=cart +inv +ellps=GRS80
```

```
+step +init=IS.txt:KIN_LAM
```

```
4740331.7177      376698.7737      134.2083
```

New version of cocodati

- We launched a new version of our transformation service cocodati (**C**oordinate **C**onversion and **D**atum **T**ransformation for **I**celand) in November 2018
- <http://sandmerki.lmi.is/cocodati/>

Further work

- We're working on transformation from Reykjavik local system to ISN2016
 - 4 parameter transformation + gridshift
- Create patches for the 2000 and 2008 earthquakes in south Iceland
 - Kinematic datum shifting + temporal gridshifting
- Add service for vector and raster data in cocodati or separate service
 - GDAL 3.0.0
- Some plans to improve the Hjörsey55 transformation
 - Grid or polynomial

Tank you

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