

# GNSS Products Made in Switzerland

Rolf Dach, Stefan Schaer, Daniel Arnold, Elmar Brockmann, Maciej Kalarus,  
Lars Prange, Pascal Stebler, Adrian Jäggi

*Astronomical Institute, University of Bern, Switzerland*

21<sup>st</sup> Swiss Geoscience Meeting 2023  
17–18. November 2023, Mendrisio, Switzerland

# GNSS Products Made in Switzerland

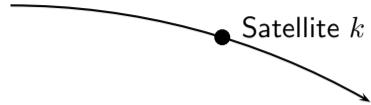
---

IGS: International GNSS Service

CODE: Center for Orbit Determination in Europe

# Introduction: How does GNSS work?

---



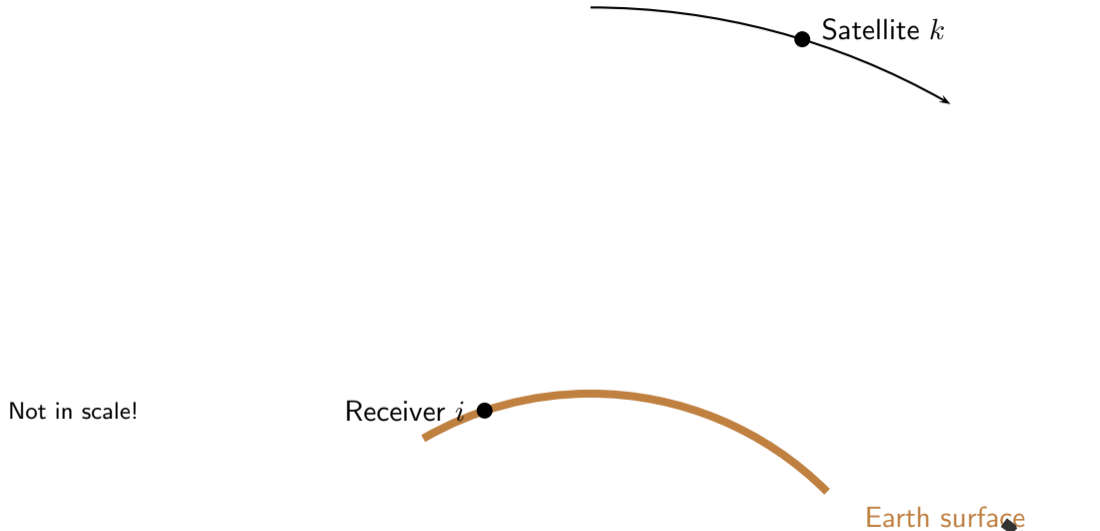
Not in scale!



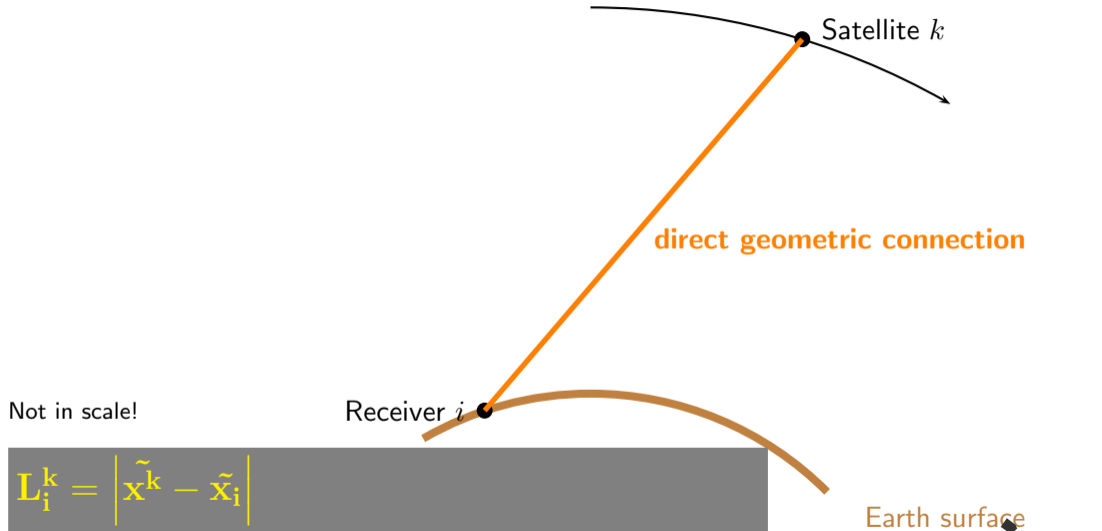
Earth surface

# Introduction: How does GNSS work?

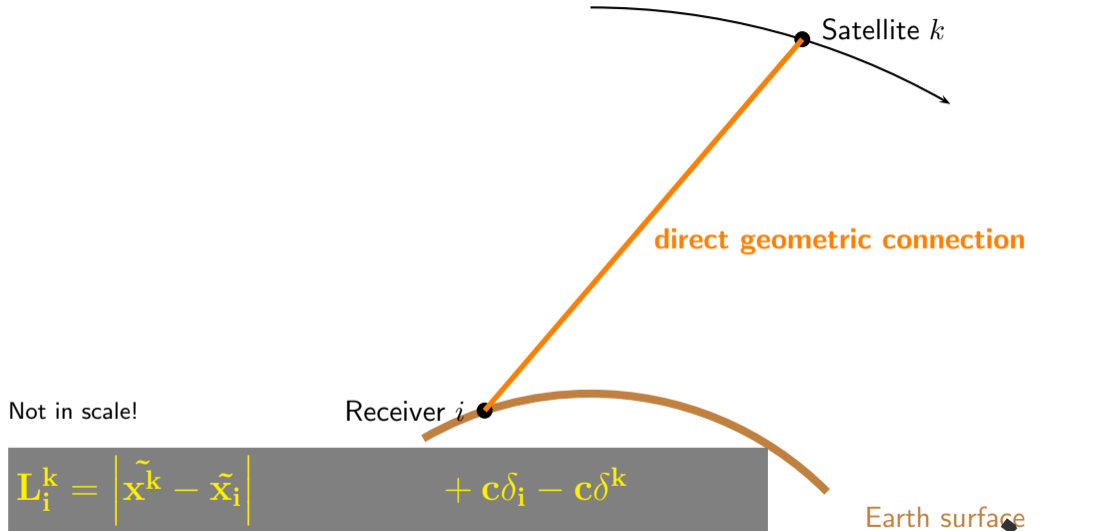
---



# Introduction: How does GNSS work?



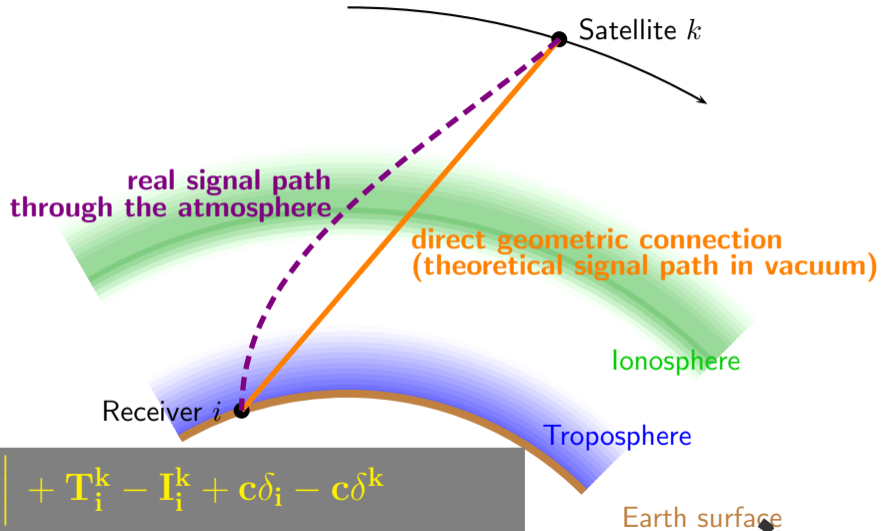
# Introduction: How does GNSS work?



$$L_i^k = \left| \tilde{\mathbf{x}}^k - \tilde{\mathbf{x}}_i \right| + c\delta_i - c\delta^k$$

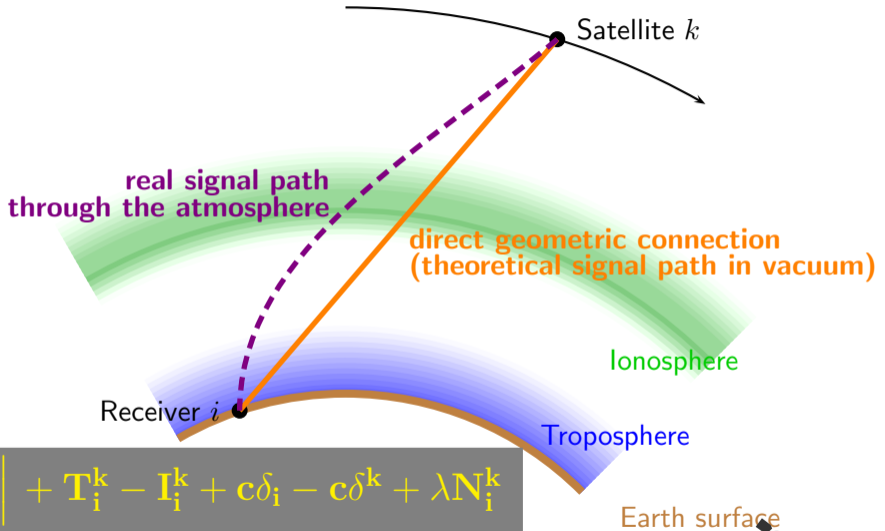
Earth surface

# Introduction: How does GNSS work?



$$L_i^k = \left| \tilde{\mathbf{x}}^k - \tilde{\mathbf{x}}_i \right| + T_i^k - I_i^k + c\delta_i - c\delta^k$$

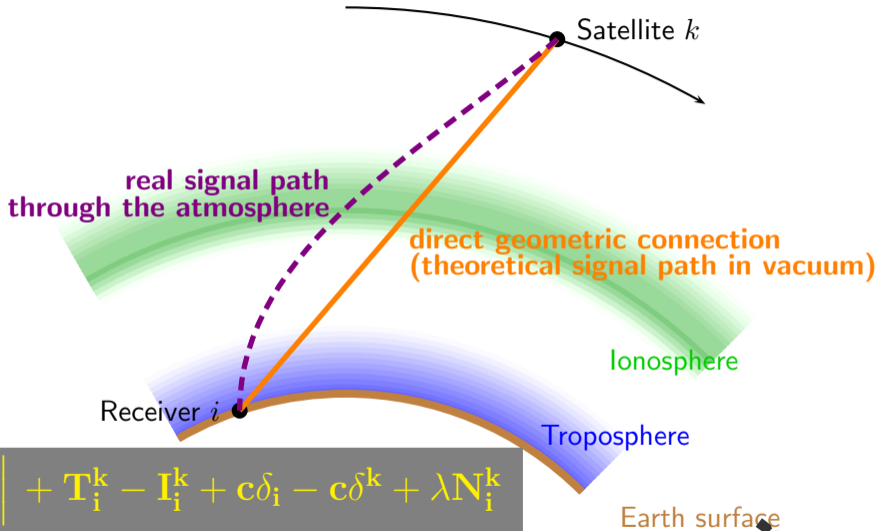
# Introduction: How does GNSS work?



$$L_i^k = \left| \tilde{\mathbf{x}}^k - \tilde{\mathbf{x}}_i \right| + T_i^k - I_i^k + c\delta_i - c\delta^k + \lambda N_i^k$$

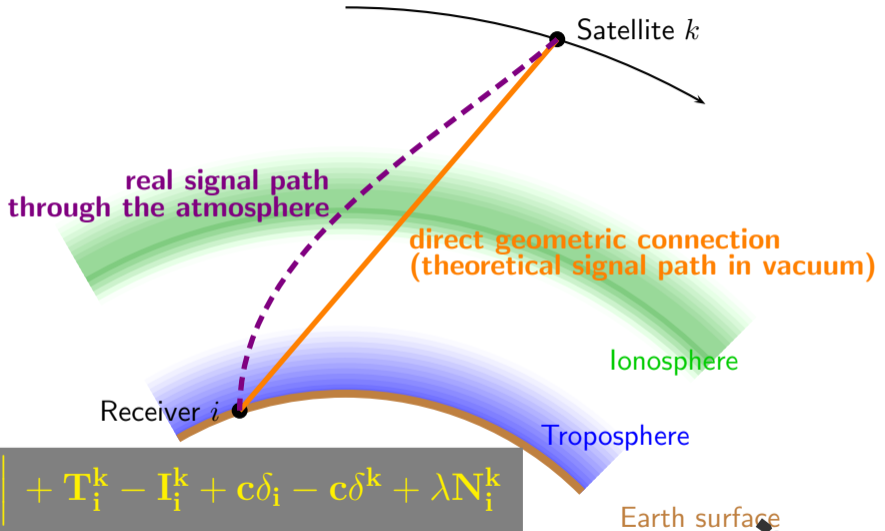


# Introduction: How does GNSS work?



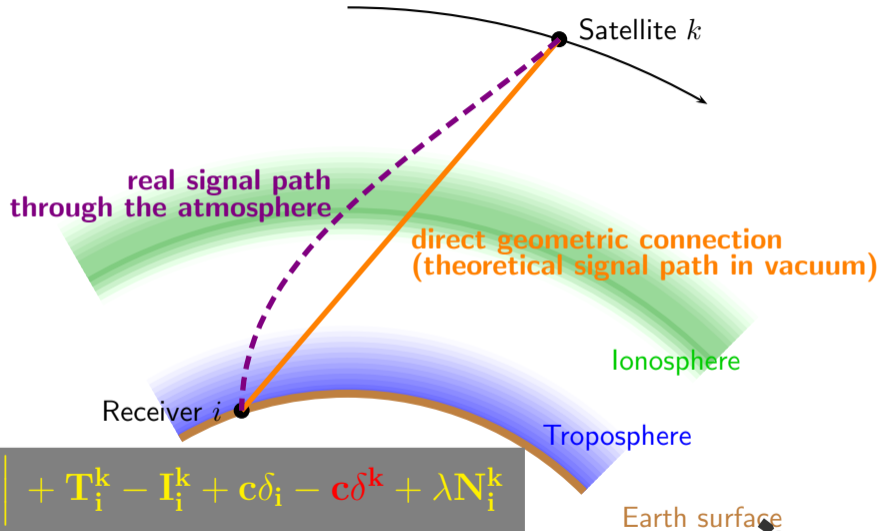
$$L_i^k = \left| \tilde{\mathbf{x}}^k - \tilde{\mathbf{x}}_i \right| + T_i^k - I_i^k + c\delta_i - c\delta^k + \lambda N_i^k$$

# Introduction: How does GNSS work?



$$L_i^k = \left| \tilde{\mathbf{x}}^k - \tilde{\mathbf{x}}_i \right| + T_i^k - I_i^k + c\delta_i - c\delta^k + \lambda N_i^k$$

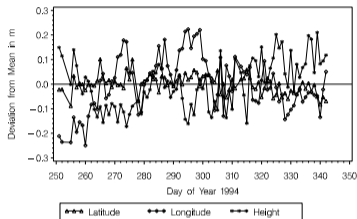
# Introduction: How does GNSS work?



$$L_i^k = \left| \tilde{\mathbf{x}}^k - \tilde{\mathbf{x}}_i \right| + T_i^k - I_i^k + c\delta_i - c\delta^k + \lambda N_i^k$$

# IGS: Motivation

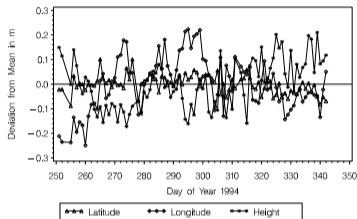
Daily Repeatabilities of Latitude, Longitude, Height of the Baseline Onsala—Graz (from 8.9.94 – 8.12.94) Using Broadcast Orbits



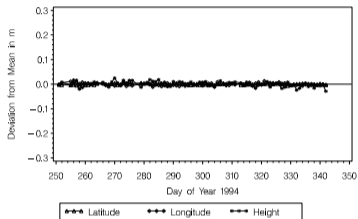
- Repeatability (north, east, up) when processing 90 days of GPS observations at Graz (Austria) and Onsala (Sweden) (1200 km baseline) with broadcast orbits

# IGS: Motivation

Daily Repeatabilities of Latitude, Longitude, Height of the Baseline Onsala–Graz (from 8.9.94 – 8.12.94) Using Broadcast Orbits



Daily Repeatabilities of Latitude, Longitude, Height of the Baseline Onsala–Graz (from 8.9.94 – 8.12.94) Using IGS Orbits



- Repeatability (north, east, up) when processing 90 days of GPS observations at Graz (Austria) and Onsala (Sweden) (1200 km baseline) with broadcast orbits (left) and with IGS orbits (right).
- Towards the end of the 1980ties it was recognized that the error of the broadcast orbit was the accuracy limiting factor.



## IGS: International GPS Service for Geodesy and Geodynamics

- Planning phase 1989 and 1991 initiated by Ivan I. Mueller,



## IGS: International GPS Service for Geodesy and Geodynamics

- Planning phase 1989 and 1991 initiated by Ivan I. Mueller,
- IGS stations  $\Rightarrow$  data centers  $\Rightarrow$  analysis centers



## IGS: International GPS Service for Geodesy and Geodynamics

- Planning phase 1989 and 1991 initiated by Ivan I. Mueller,
- IGS stations  $\Rightarrow$  data centers  $\Rightarrow$  analysis centers
- First test campaign in Summer 1992





## IGS: International GPS Service for Geodesy and Geodynamics

- Planning phase 1989 and 1991 initiated by Ivan I. Mueller,
- IGS stations  $\Rightarrow$  data centers  $\Rightarrow$  analysis centers
- First test campaign in Summer 1992
- Since 01. January 1994 operational service of the IAG



## IGS: International GPS Service for Geodesy and Geodynamics

- Planning phase 1989 and 1991 initiated by Ivan I. Mueller,
- IGS stations  $\Rightarrow$  data centers  $\Rightarrow$  analysis centers  $\Rightarrow$  product combination
- First test campaign in Summer 1992
- Since 01. January 1994 operational service of the IAG
- Regular comparison and combination of the AC contributions

# IGS: Development

---



- International GPS Service for Geodesy and Geodynamics  
January 1994

# IGS: Development

---



- International GPS Service for Geodesy and Geodynamics  
January 1994
- International GPS Service  
May 1998

# IGS: Development

---



- International GPS Service for Geodesy and Geodynamics  
January 1994
- International GPS Service  
May 1998
- International GNSS Service  
March 2005

# IGS: Development

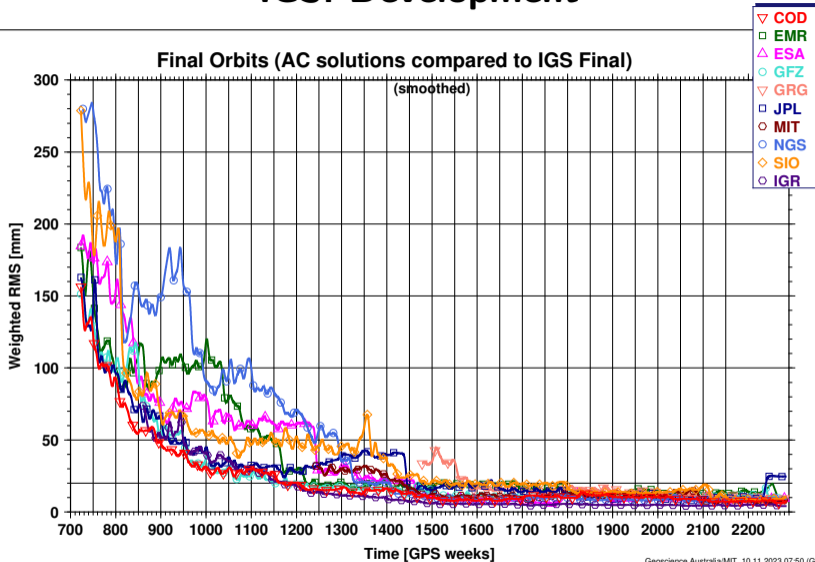
---



IGS INTERNATIONAL  
GNSS SERVICE

- International GPS Service for Geodesy and Geodynamics  
January 1994
- International GPS Service  
May 1998
- International GNSS Service  
March 2005

# IGS: Development



# The CODE Analysis Center

---

- CODE, Center for Orbit Determination in Europe, is one of at present ten Analysis Centers of the IGS. CODE is formed as a joint venture of
  - the Astronomisches Institut, Universität Bern (AIUB),
  - the Bundesamt für Landestopografie (swisstopo),
  - the Bundesamt für Kartographie und Geodäsie (BKG), and
  - the Institut für Astronomische und Physikalische Geodäsie of TU München (IAPG, TUM).

**AIUB**



Bundesamt für  
Kartographie und Geodäsie



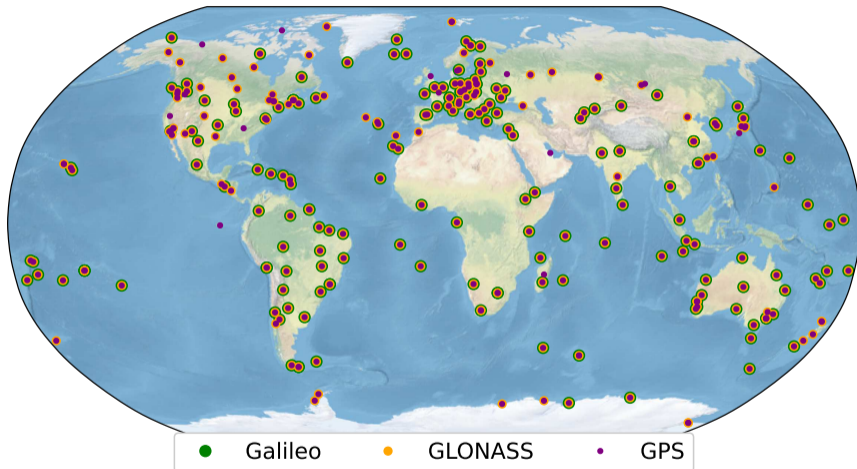
Schweizerische Eidgenossenschaft  
Confédération suisse  
Confederazione Svizzera  
Confederaziun svizra

**TUM**

Technische Universität München

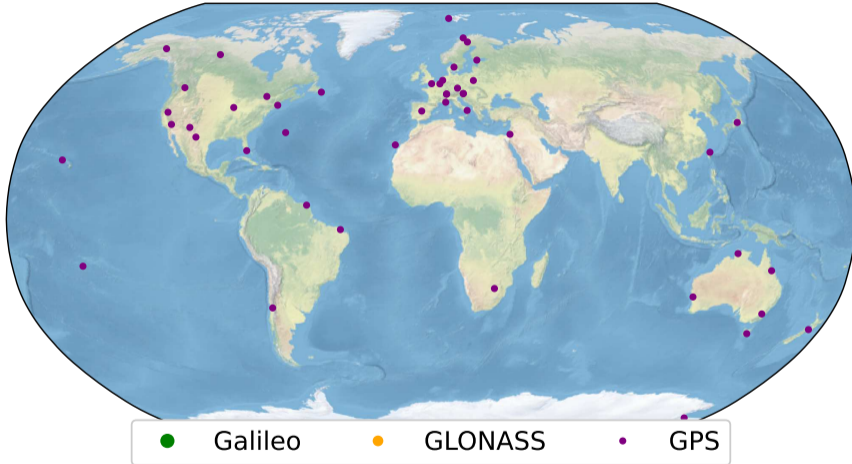


# The CODE Analysis Center



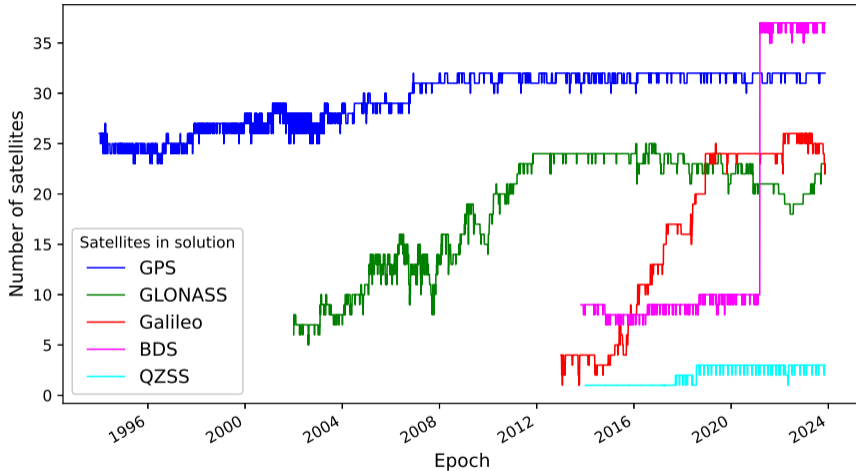
Network of about 250 stations used for the GNSS processing at CODE. Status: November 2023

# The CODE Analysis Center



Network of about 50 stations used for the GNSS processing at CODE. Status: January 1994

# CODE GNSS Satellite Orbits



Number of satellites provided by CODE in its final/MGEX orbit

# CODE GNSS Satellite Orbits



GPS Block IIR



GLONASS-M



Galileo IOV



BeiDou3 CAS



GPS Block IIM



GLONASS-K1



Galileo FOC



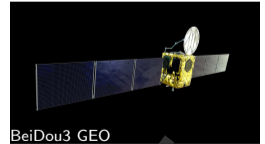
BeiDou3 SECM



GPS Block IIIA



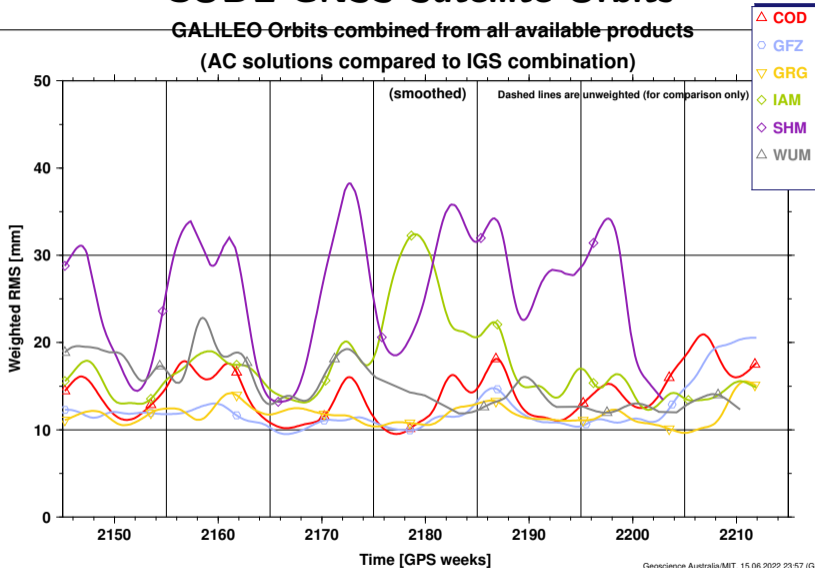
GLONASS-K2



BeiDou3 GEO

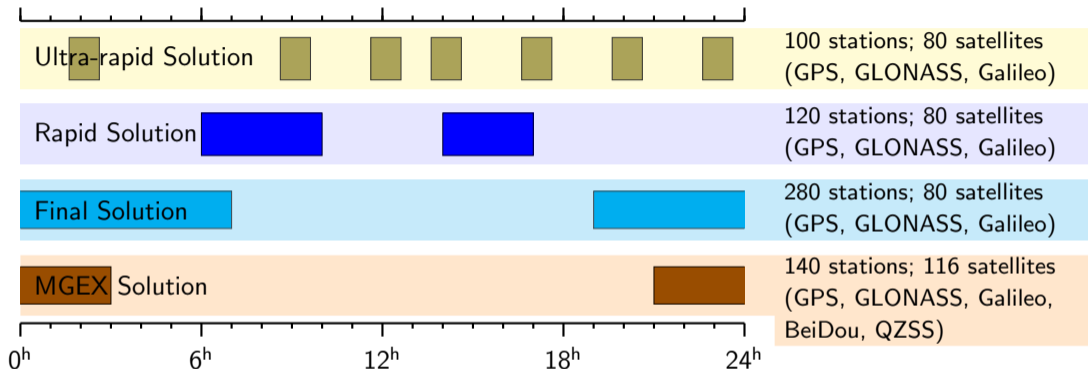
# CODE GNSS Satellite Orbits

GALILEO Orbits combined from all available products  
(AC solutions compared to IGS combination)



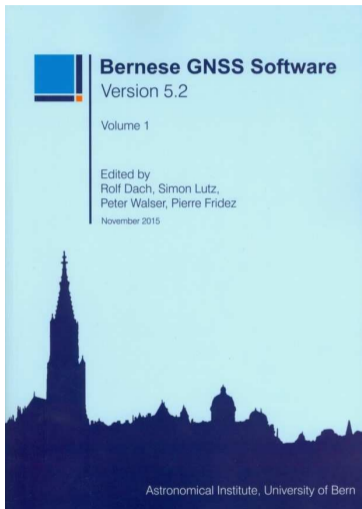
Geoscience Australia/MIT, 15.06.2022 23:57 (GMT)

# CODE Processing for the IGS



IGS-related processes running at CODE analysis center

# The Bernese GNSS Software



All processing at CODE analysis center are based on the **Bernese GNSS Software** package, developed at AIUB.

**OPSEST 3.1: General Options 1**

TITLE: RNK2SNK\_SYSS+0\_5(FFFF): QIF ambiguity resolution

**OBSERVATION SELECTION**

- Satellite system: ALL
- LI4L2: LI4L2
- Elevation cutoff angle: 10 degrees
- Sampling interval: 30 seconds
- Tolerance for simultaneity: 100 milliseconds
- Special data selection: NO
- Observation window: NO

**OBSERVATION MODELING AND PARAMETER ESTIMATION**

- A priori sigma of unit weight: SPEC.NON-ECL
- Elevation-dependent weighting: 5(SDSEL)
- Type of computed residuals: CODE
- Correlation strategy: NORMALIZED
- BASELINES: BASELINES

**LEO-SPECIFIC SELECTION AND MODELING OPTIONS**

- Elevation cutoff angle: 0 degrees
- Elevation-dependent weighting: NONE

**BPE Server: RNK2SNK.PCF**

Status of RNK2SNK.PCF on 08-Jul-2021 20:07:03

```
Session 102070: running
000 SRIP RES R2S_GEN finished
001 R2S_COP R2S_GEN finished
002 ATXPCV R2S_GEN running <
003 COOVEL R2S_GEN running <
004 COOVEL R2S_GEN running <
005 CRRMERC R2S_GEN waiting
011 RNK_COP R2S_GEN running <
021 OBSNRGAP R2S_GEN waiting
022 OBSNRGAP R2S_GEN waiting
031 IOW_MRG R2S_GEN waiting
099 DUMMY R2S_GEN waiting <
101 POLUPPH R2S_GEN running <
111 OBSNRGAP R2S_GEN running <
112 PRETAB R2S_GEN waiting
113 OBSGNH R2S_GEN waiting
199 DUMMY NO_OPT waiting
201 RNKEMTAP R2S_GEN waiting
202 RNKEMT_H R2S_GEN waiting
211 RNKGRA R2S_GEN waiting
212 OBSNRGAP R2S_GEN waiting
```

# The IGS Family



IGS: Family: 350 institutions from 188 countries



# The IGS Family



IGS: Family: learn more at [www.igs.org](http://www.igs.org)

# The IGS Family



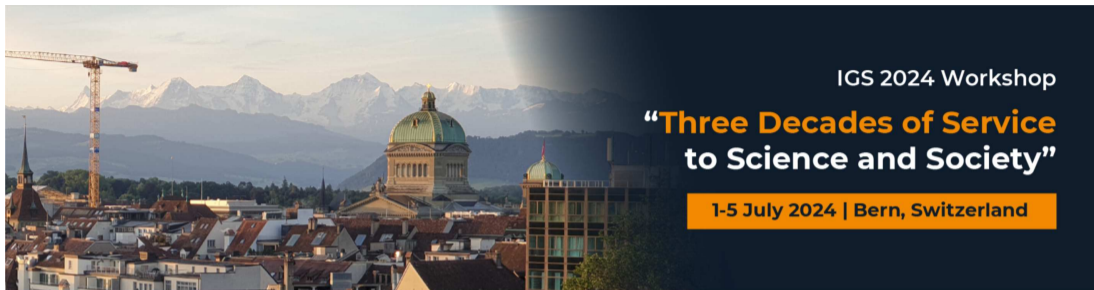
Acknowledge their work by referencing

# The IGS Family



Join the IGS family – we are open

# The IGS Family



IGS 2024 Workshop

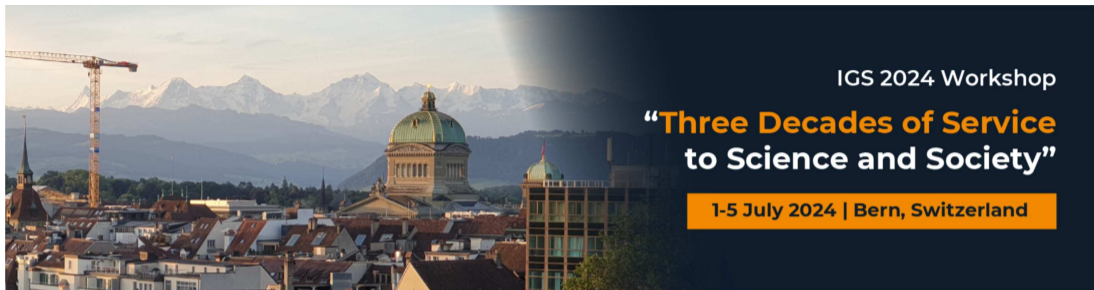
**“Three Decades of Service  
to Science and Society”**

1-5 July 2024 | Bern, Switzerland

## IGS 2024 Workshop

Join the IGS family – we are open

# The IGS Family



## IGS 2024 Workshop

Join the IGS family – we are open

We are looking for supporting staff (contact [rolf.dach@unibe.ch](mailto:rolf.dach@unibe.ch) or your supervisor)

# THANK YOU

---

## for your attention



Publications of the satellite geodesy research group:

<http://www.bernese.unibe.ch/publist>