

# North Eurasian GPS Deformation Array

## History and Current State

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### 1. NEDA Operations

- Description and history
- Integration into global network

### 2. NEDA for Geodynamics

- Large-plate tectonics, Eurasia reference frame
- Support for regional projects

Contributed: Tomas Herring, MIT  
Robert King, MIT  
Roland Bürgman, UC Berkley  
Mikhail Kogan, Columbia Univ.

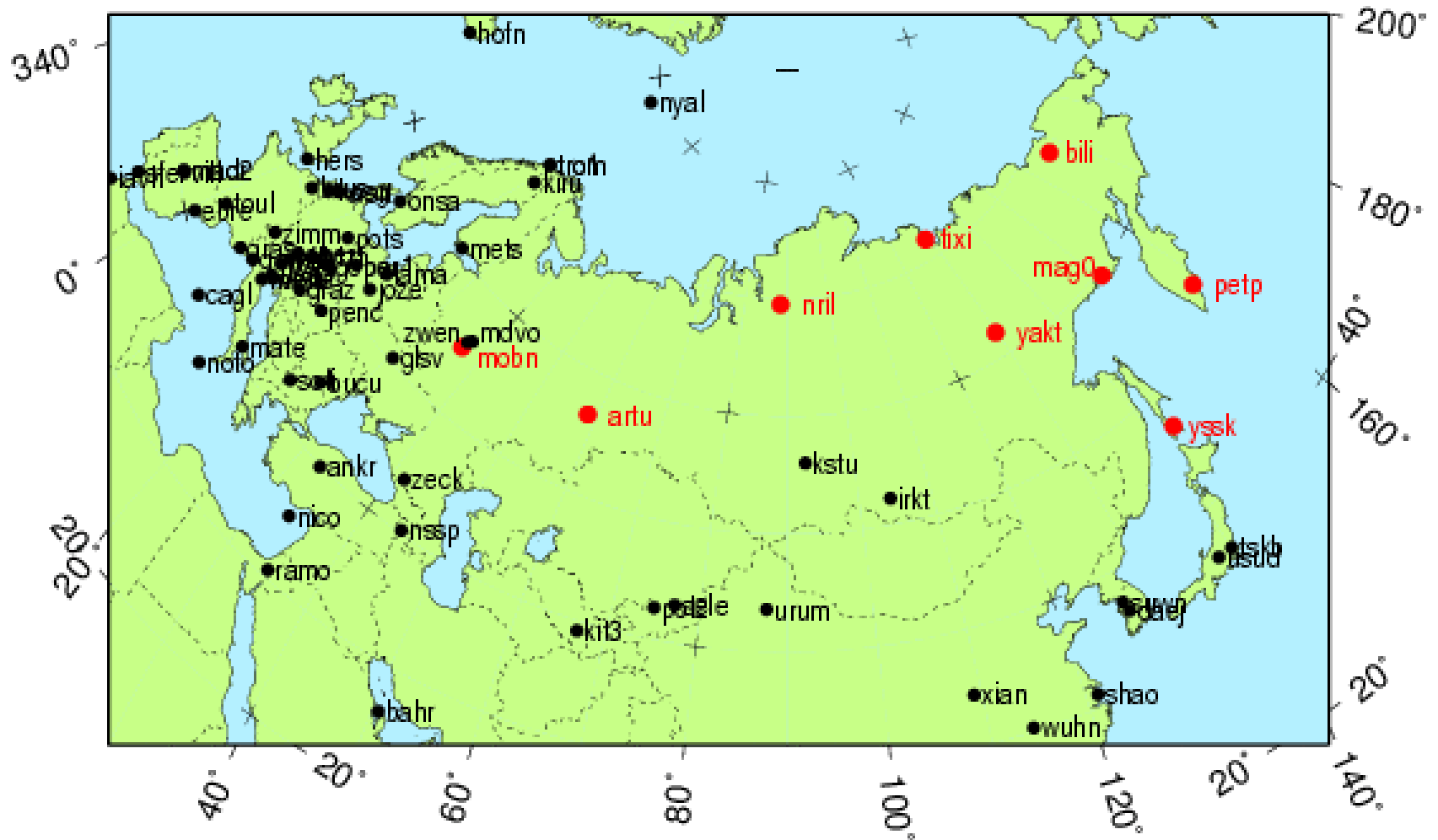


# North Eurasion Deformation Array

## History and achievements

1. NEDA operations
  - Description, map and history
  - Integration into World-Wide network
2. NEDA for Geodynamics
  - Reference frame realization
  - Regional projects support
  - Large-plate tectonics

# NEDA stations



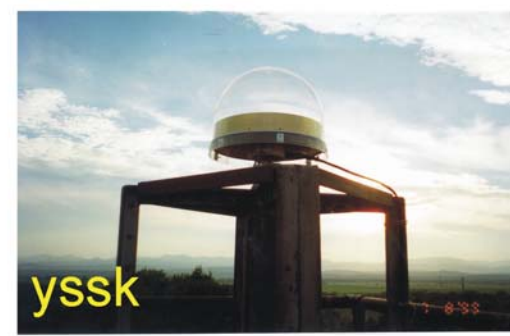
- NEDA stations
- Other IGS stations

RDAAC GS RAS, JPL NASA, MIT, IRIS, LDEO CU

## NEDA History

Station	IGS code	Installation, upgrade	Sampling rate – Transmission mode
Obninsk	MOBN	Dec 18, 2000	1 sec – real time
Arti	ARTU	Aug 6, 1998 July 11, 2002	30 sec – daily 1 sec – real time
Norilsk	NRIL	Sept 17, 2000 July 28, 2001	30 sec – daily 1 sec – real time
Yakutsk	YAKZ, YAKT	Nov 12, 1997 Apr 24, 2000	30 sec – daily 1 sec – real time
Tiksi	TIXI	Oct 8, 1999	30 sec – daily
Magadan	MAG0	Nov 11, 1997	30 sec – daily
Bilibino	BILI	Sept 4, 1999	30 sec – daily
Petropavlovsk- Kamchatsky	PETP, PETS	Nov 12, 1997 Aug 22, 2002	30 sec – daily 1 sec – real time
Yuzhno- Sakhalinsk	YSSK	July 28, 1999	30 sec – daily

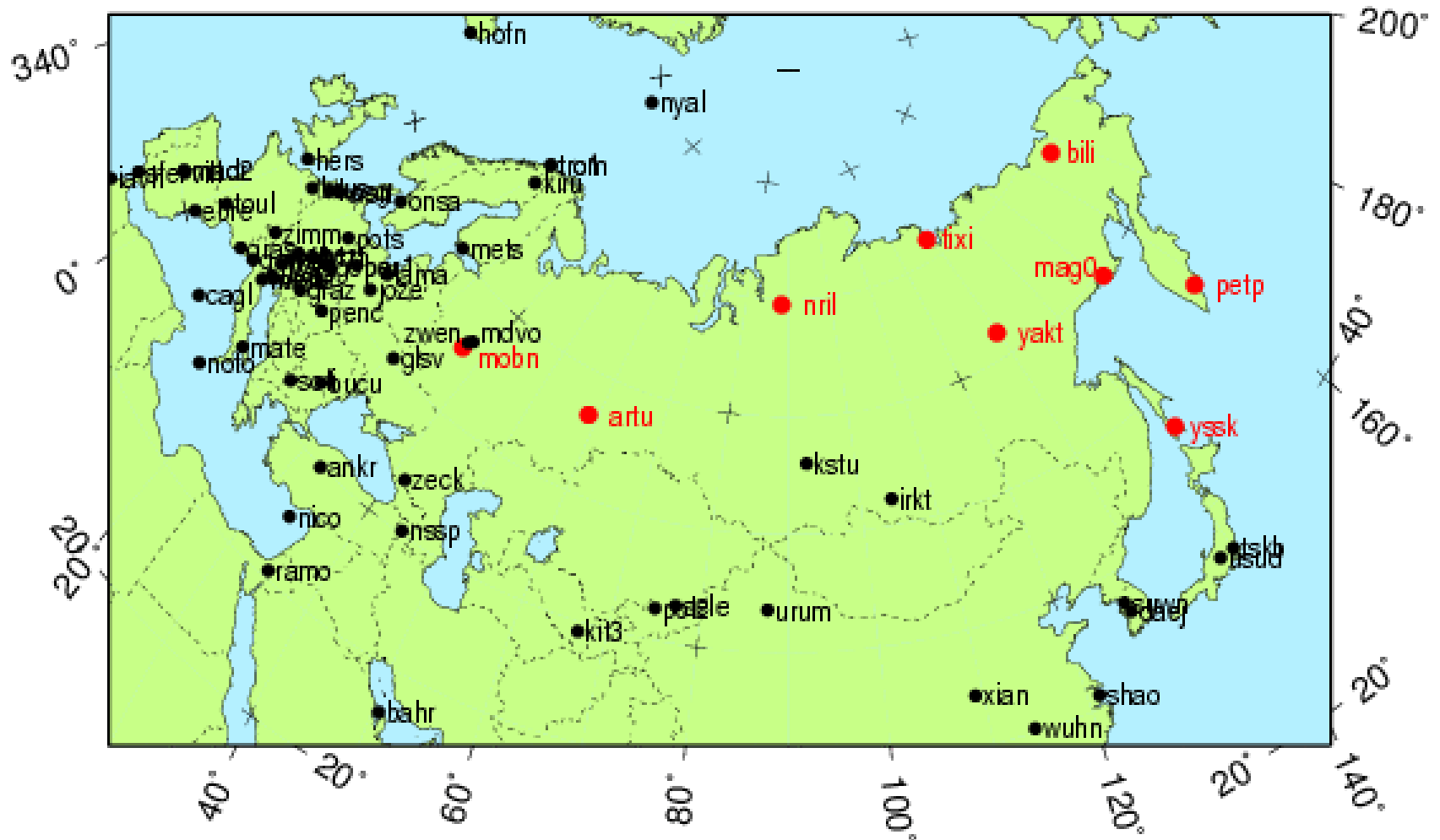
# NEDA GPS Monumentation



# NEDA GPS Monumentation

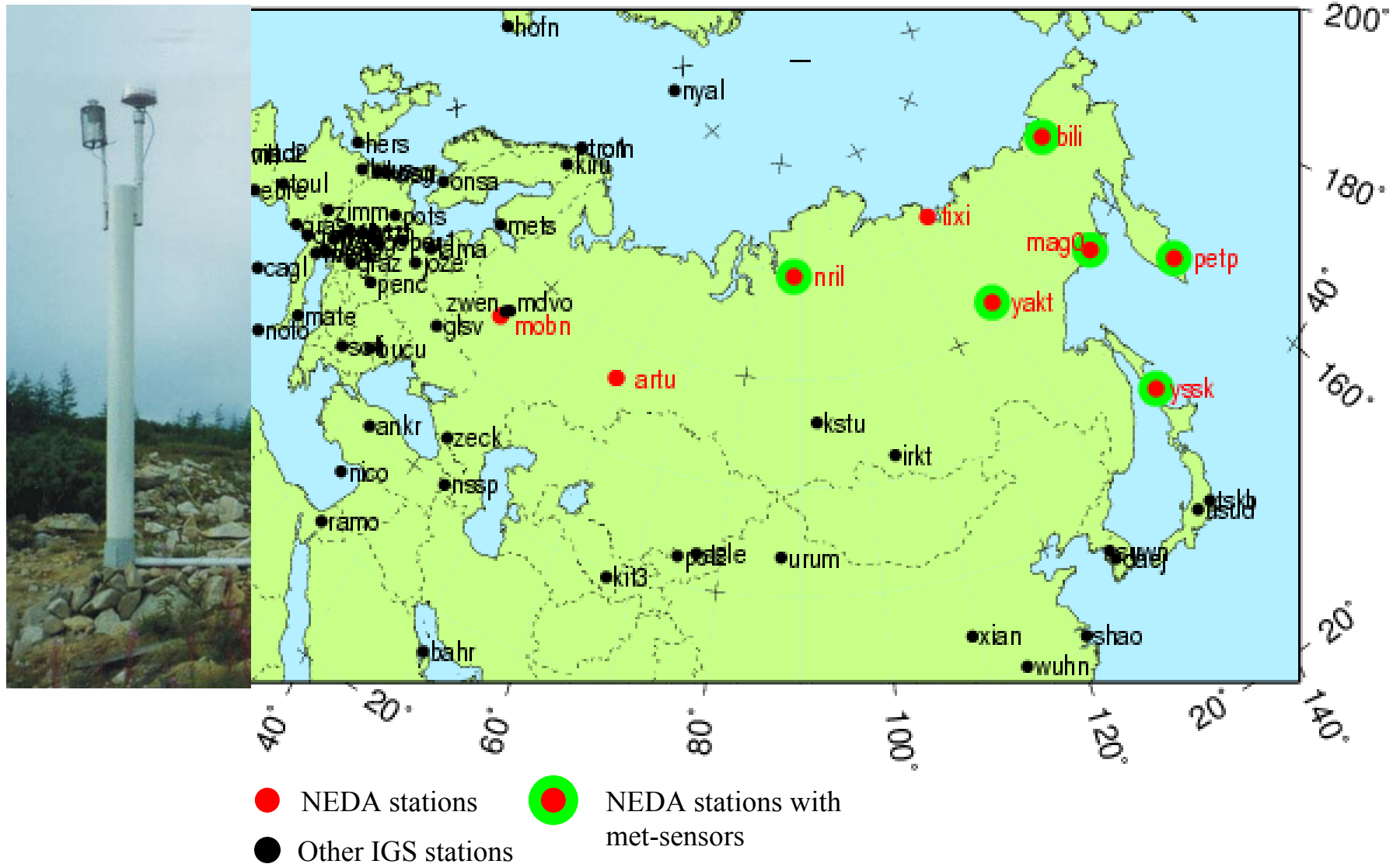


## NEDA stations



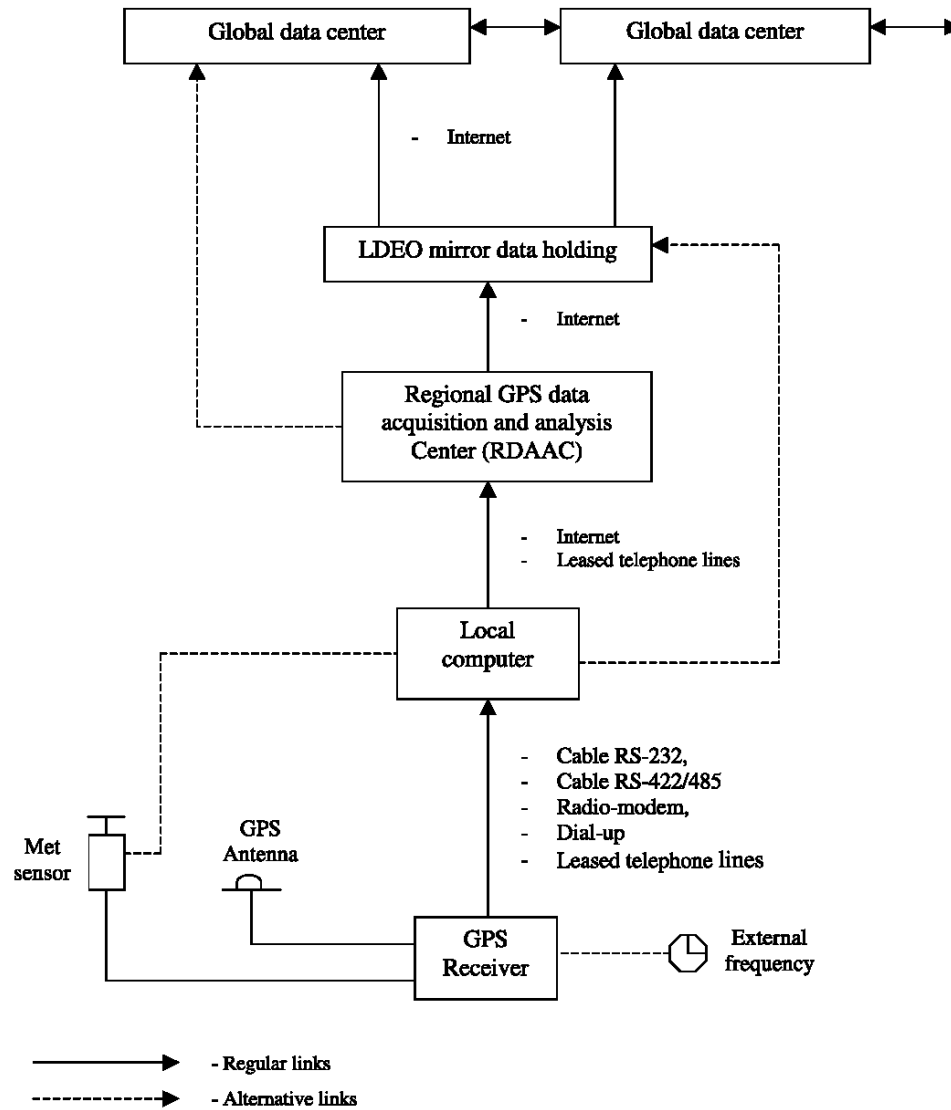
- NEDA stations
- Other IGS stations

# NEDA stations





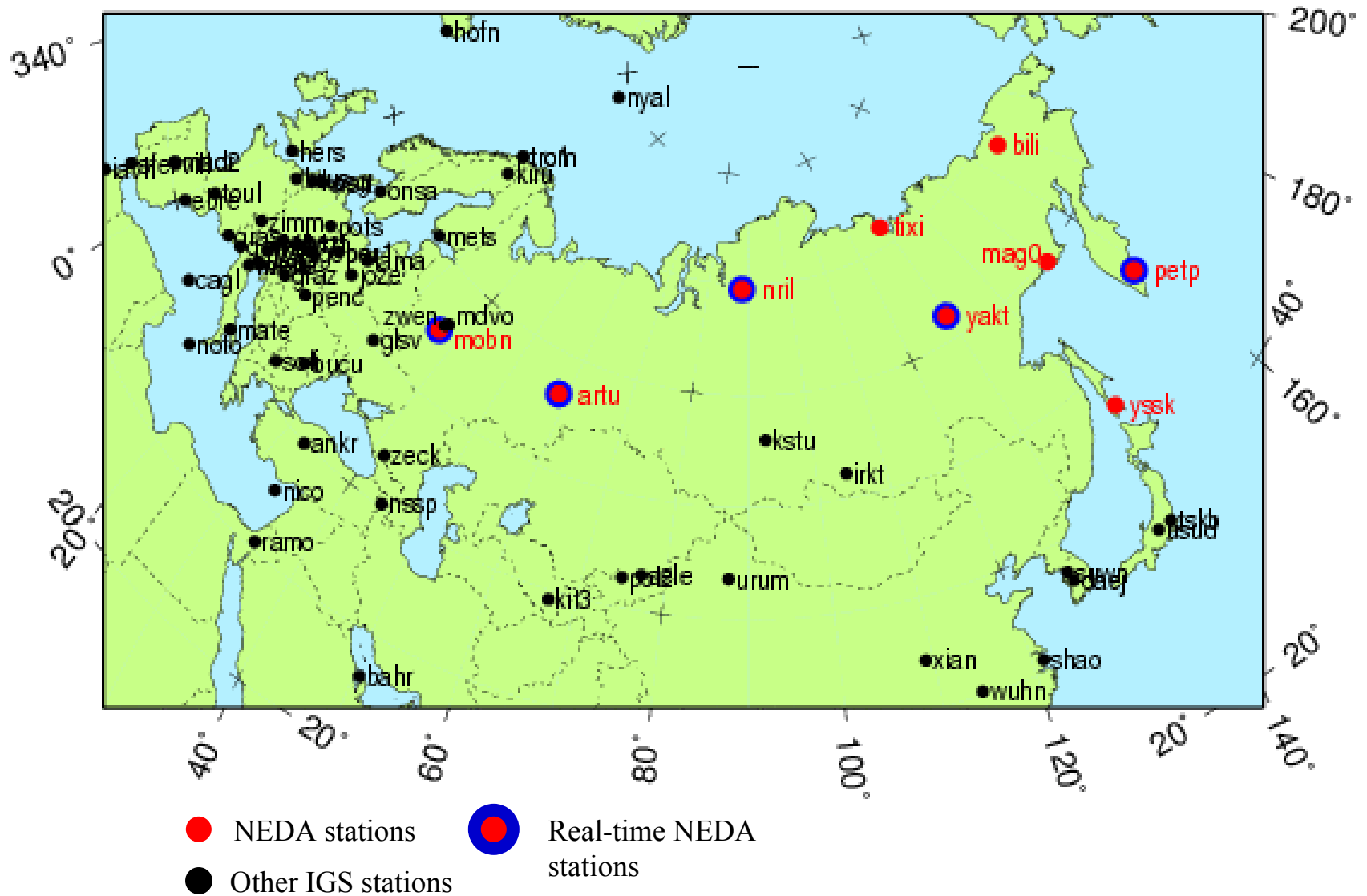
## Data Flow over NEDA Network



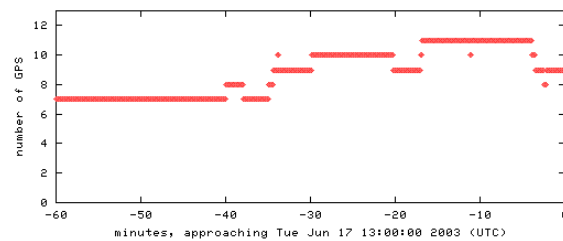
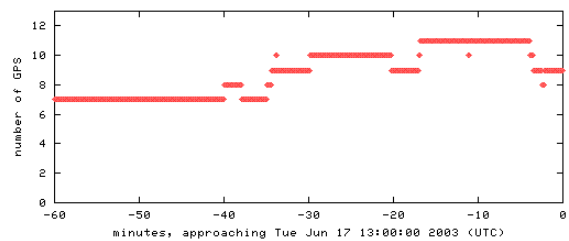
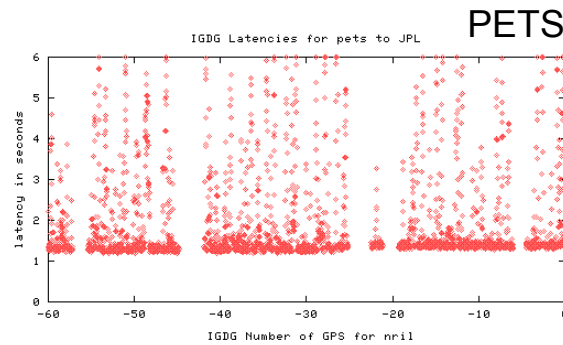
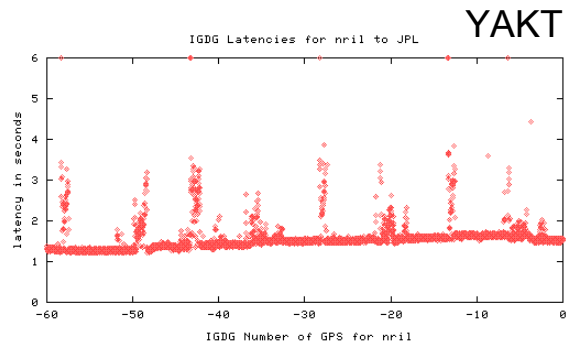
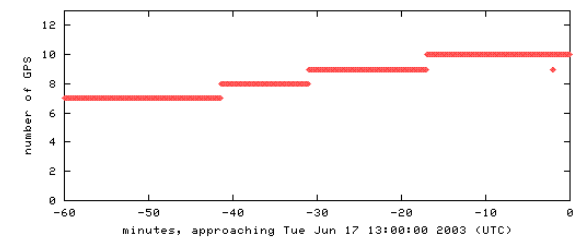
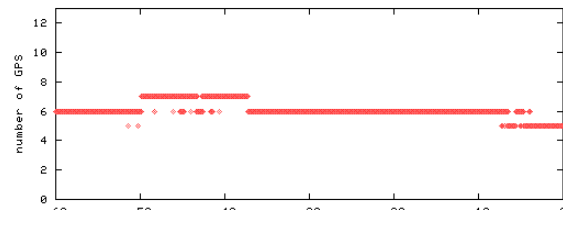
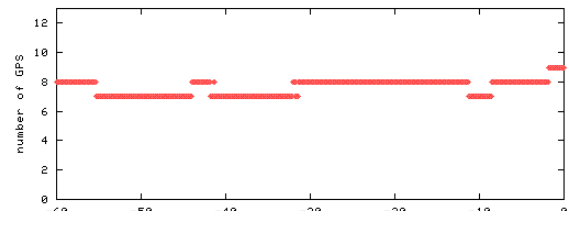
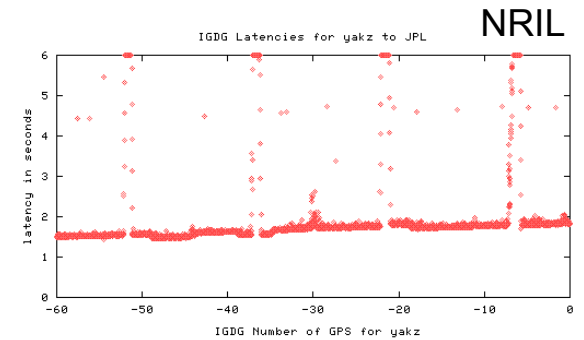
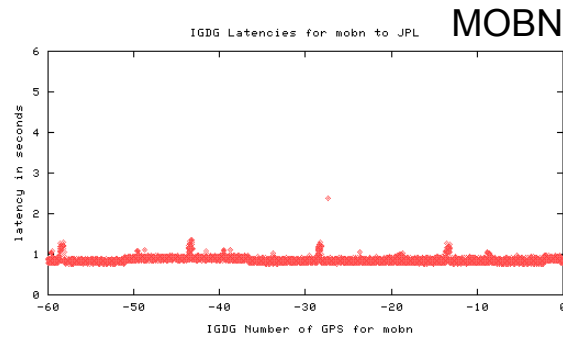
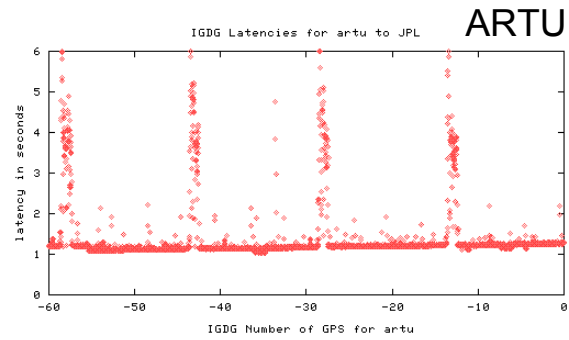
## NEDA History

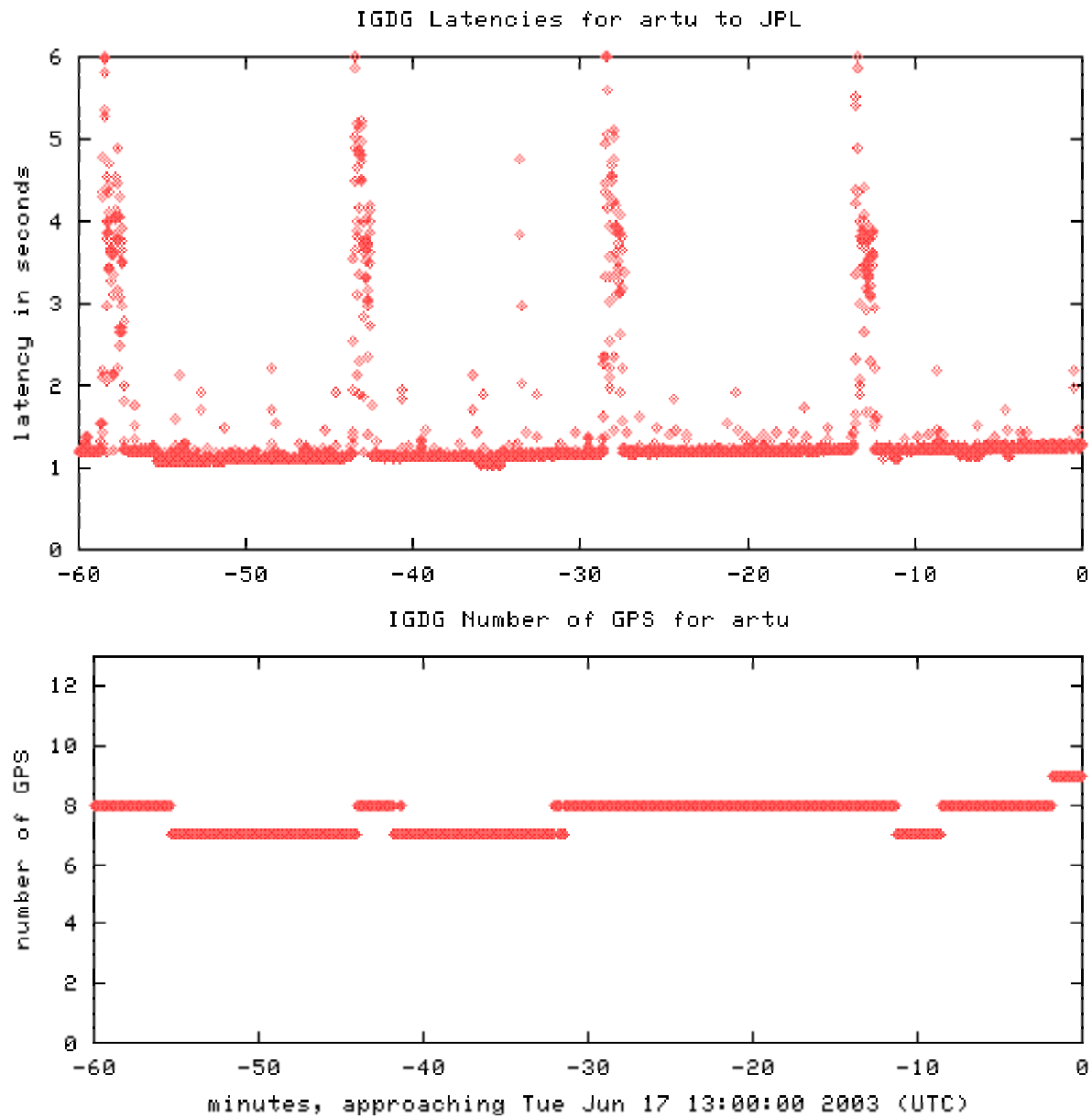
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# NEDA stations

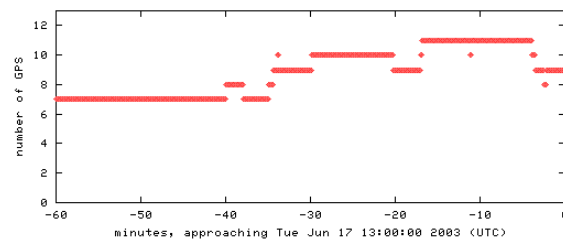
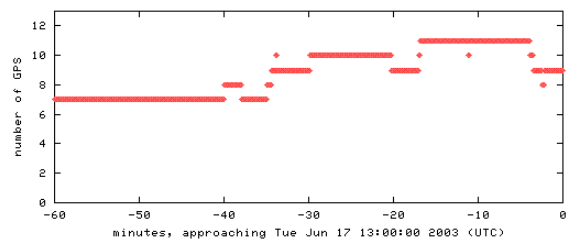
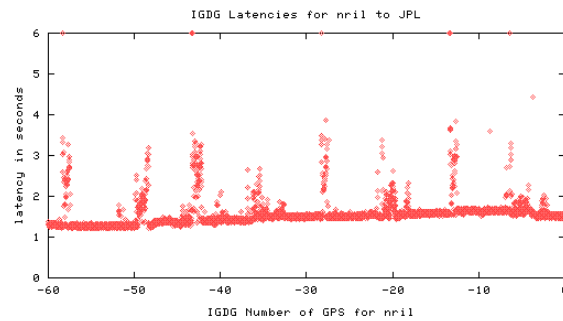
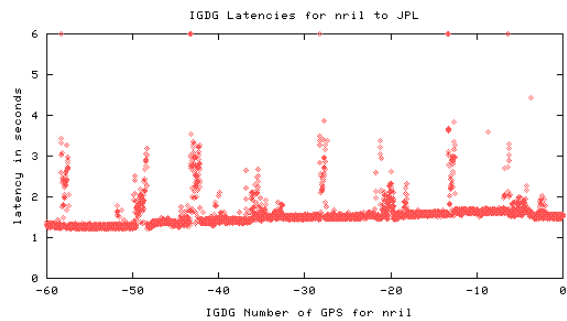
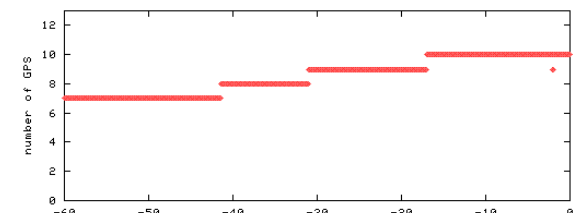
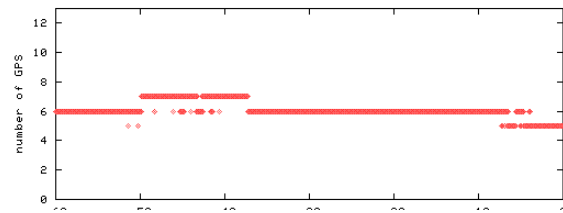
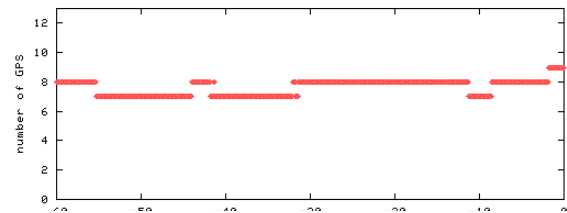
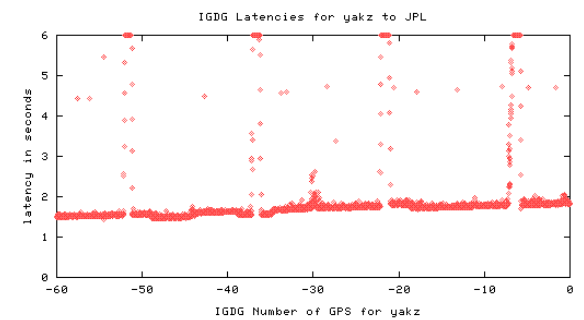
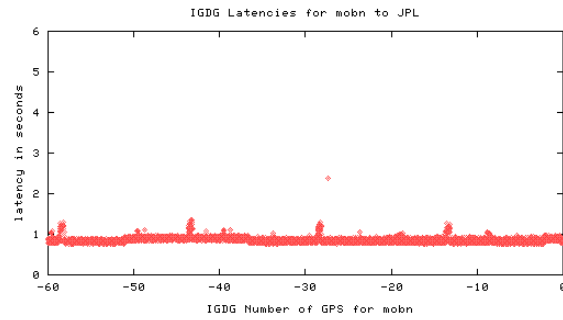
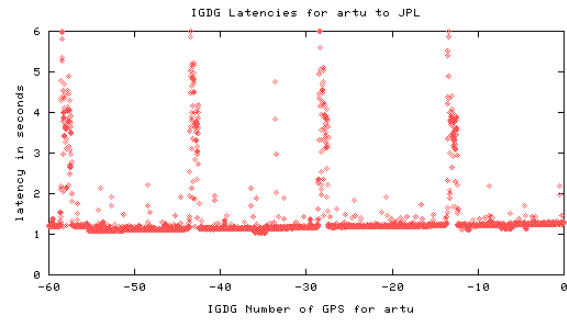


# Real-time data flow

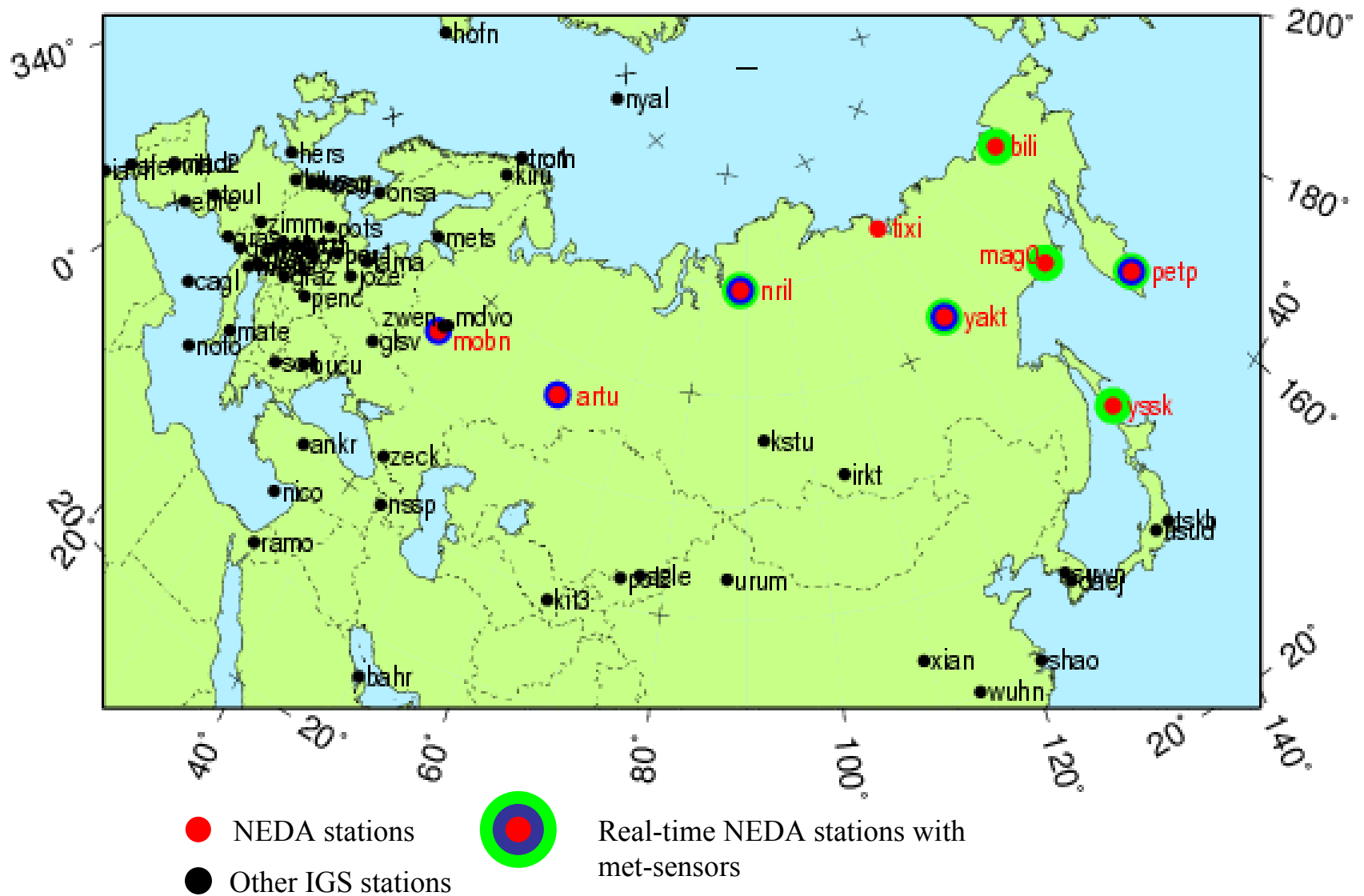




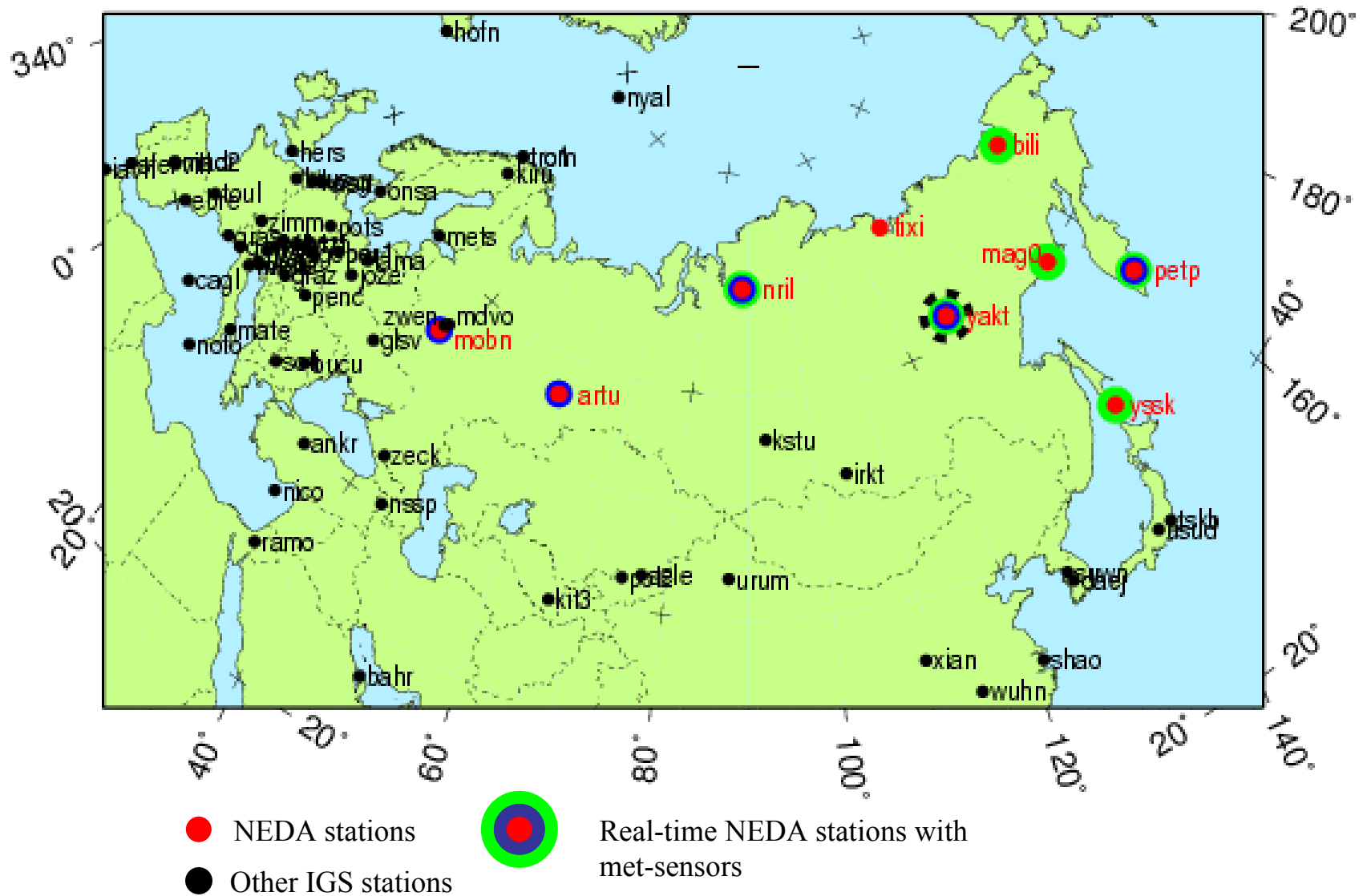
# Real-time data flow



# NEDA stations

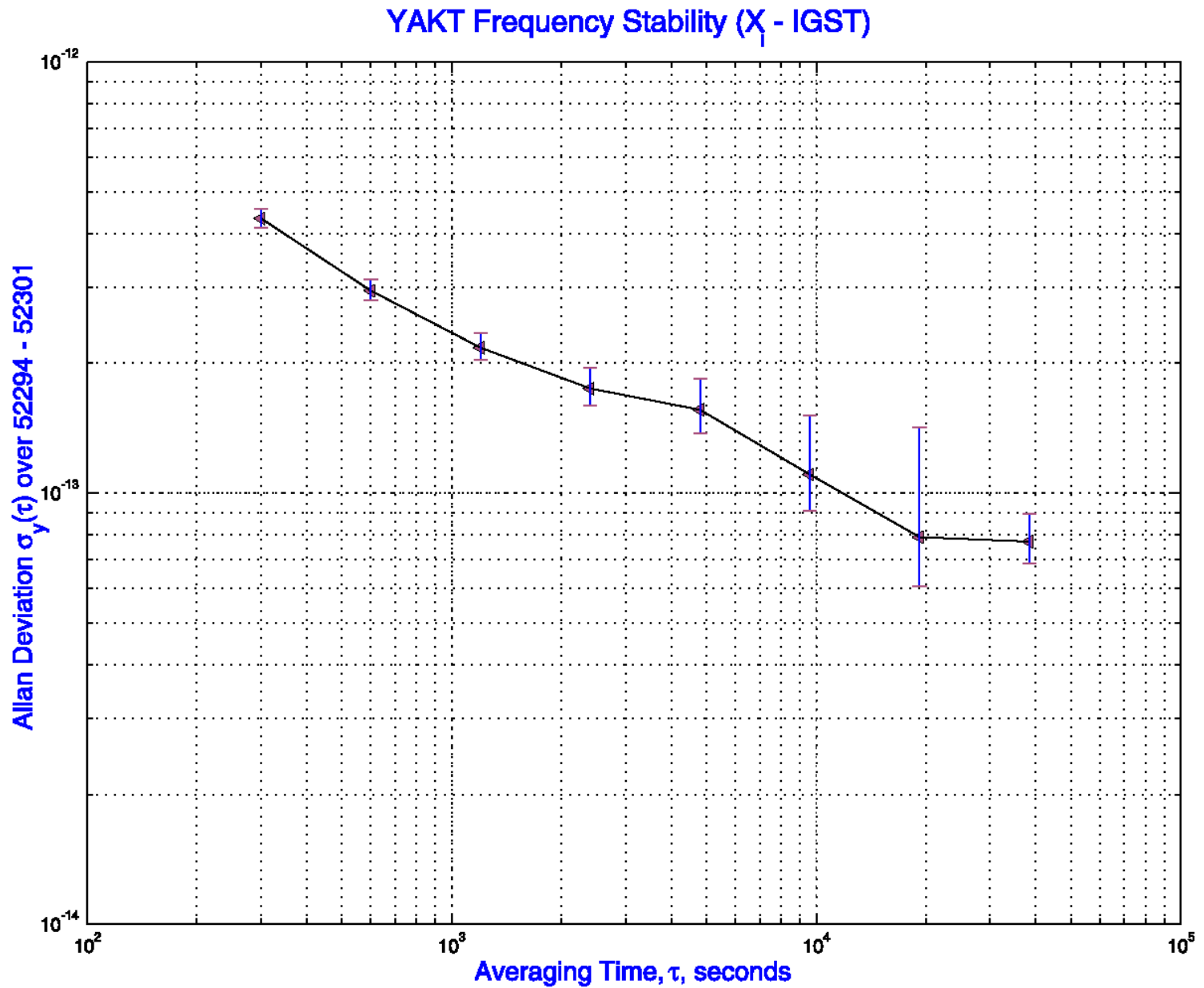


# NEDA stations

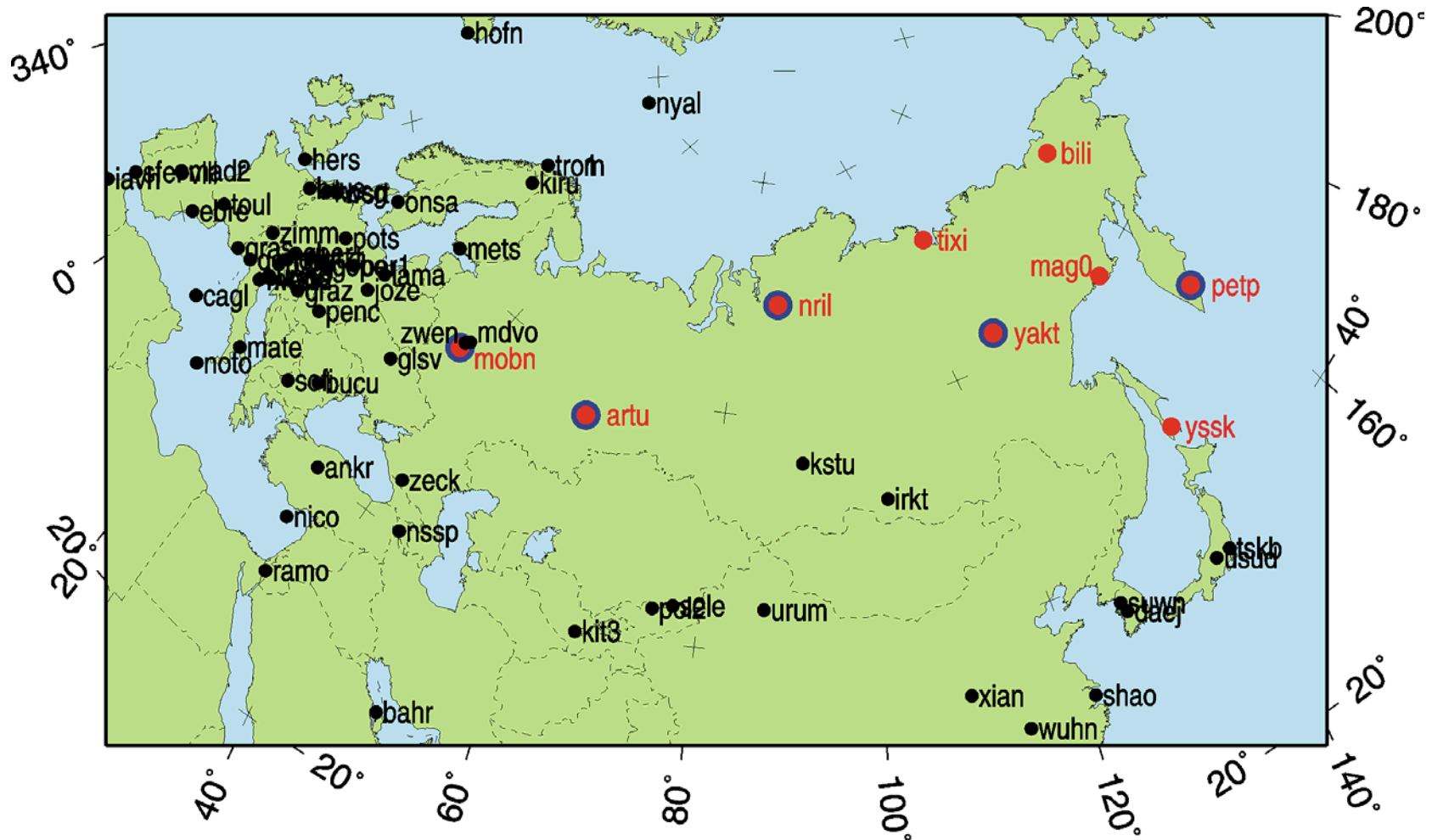




# Cesium Frequency at YAKT

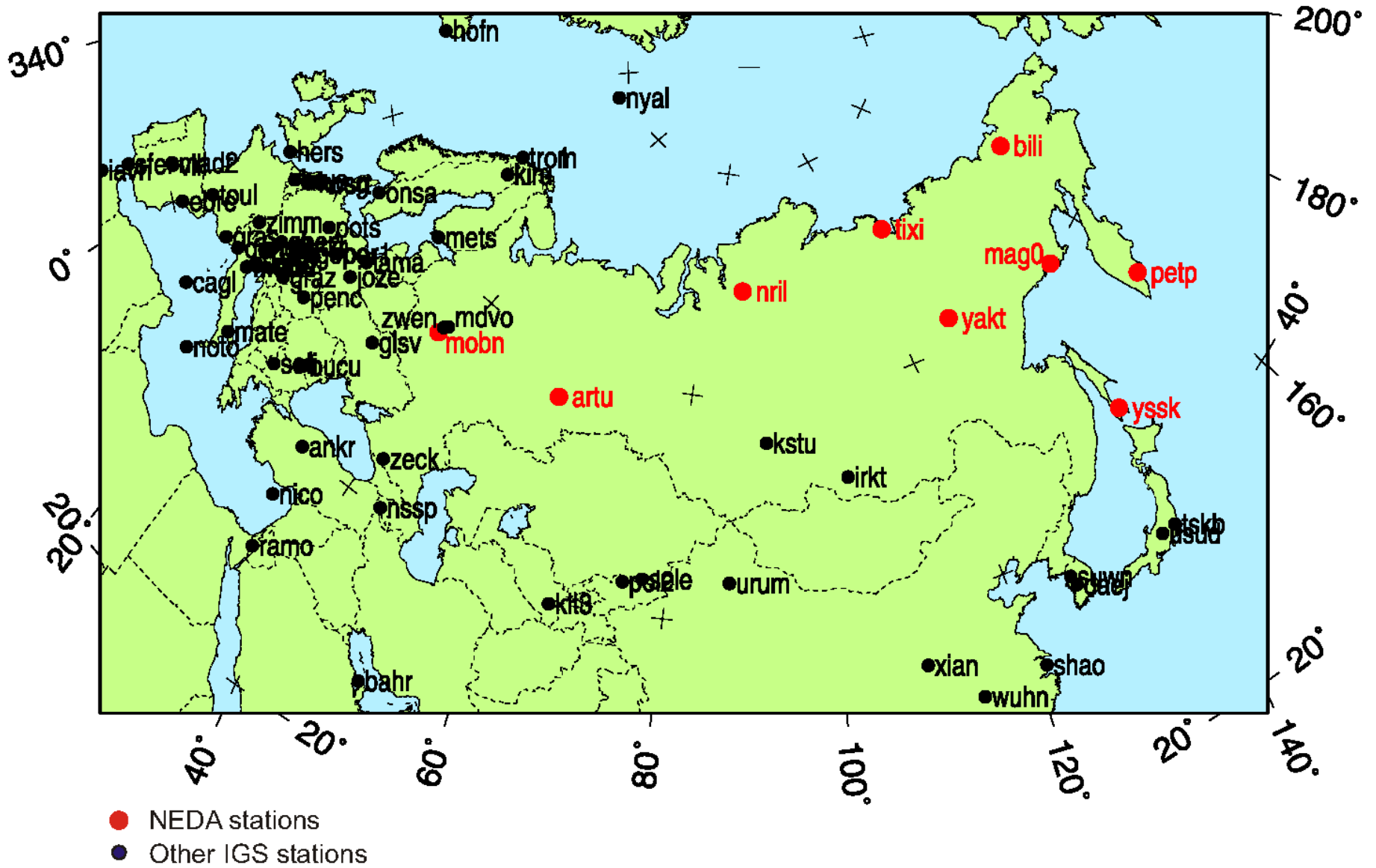


# NEDA stations map



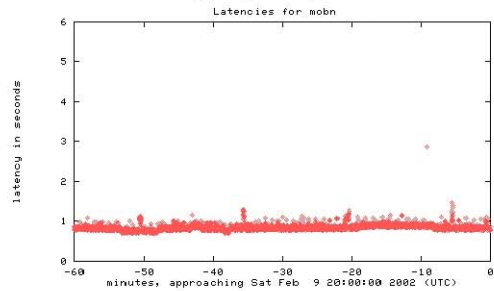
- NEDA stations
- NEDA real-time stations
- Other IGS stations

# NEDA GPS Network

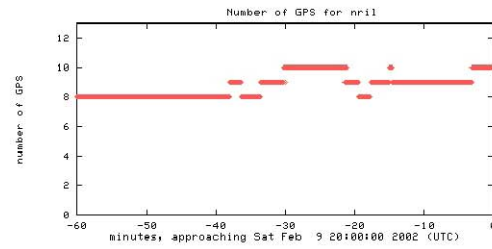
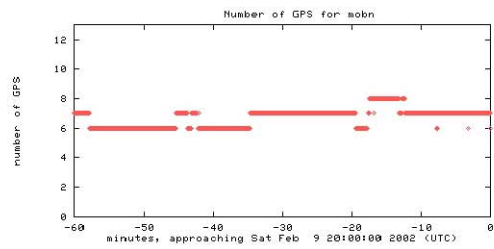
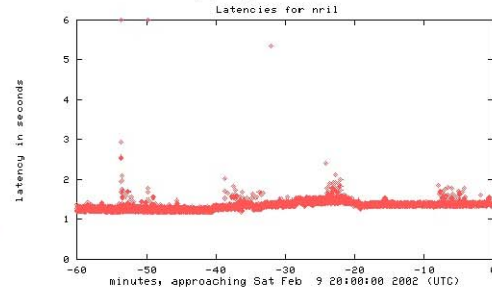


# Real Time Data Flow

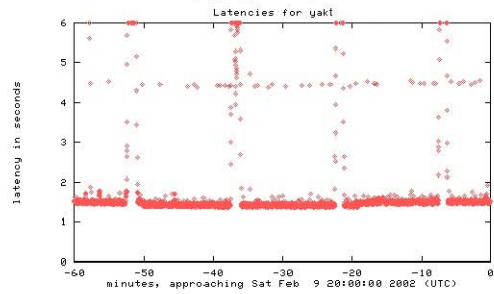
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Sat Feb 9 20:00:00 2002 UTC  
This page is updated every 30 minutes



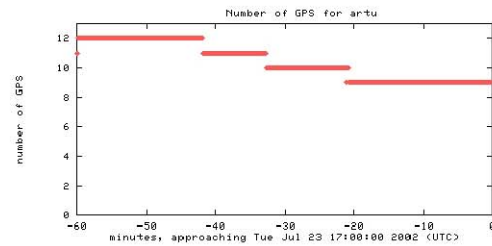
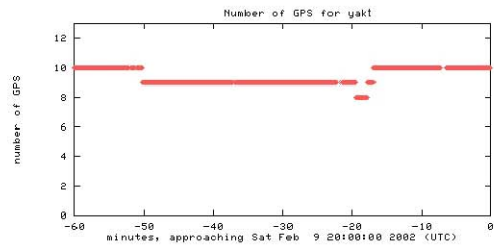
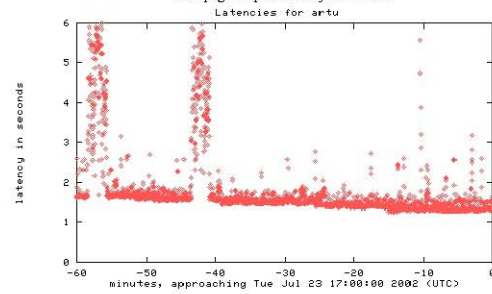
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Sat Feb 9 20:00:00 2002 UTC  
This page is updated every 30 minutes



**Yakutsk, Russia (yakt)**  
Sat Feb 9 20:00:00 2002 UTC  
This page is updated every 30 minutes



**Arti, Russia (artu)**  
Tue Jul 23 17:00:00 2002 UTC  
This page is updated every 30 minutes



# IGS LEO Station Network



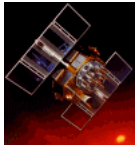
GMT Mar 5 13:46:07 2001

◆ 1s, 15m station, ready

◆ 1s, 15m station, planned

● 30s, 1h station, ready

● 30s, 1h station, planned

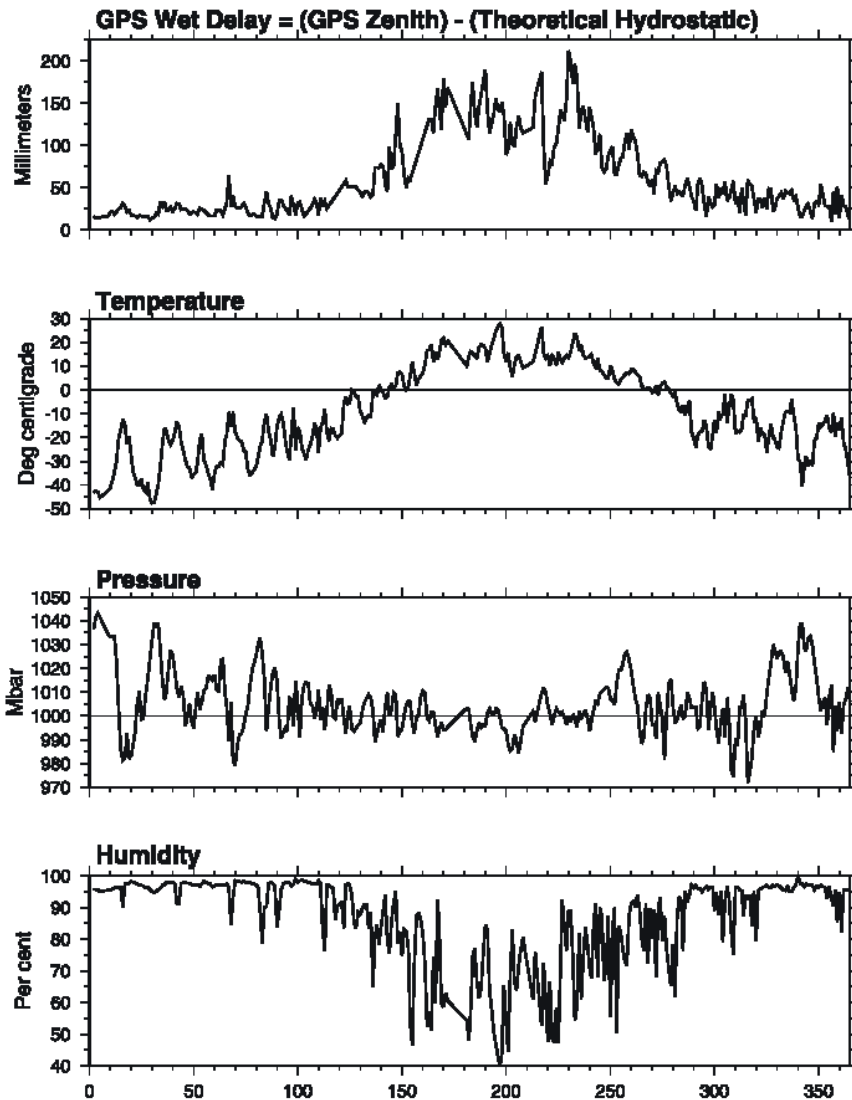


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# GPS Water Vapor Climatology

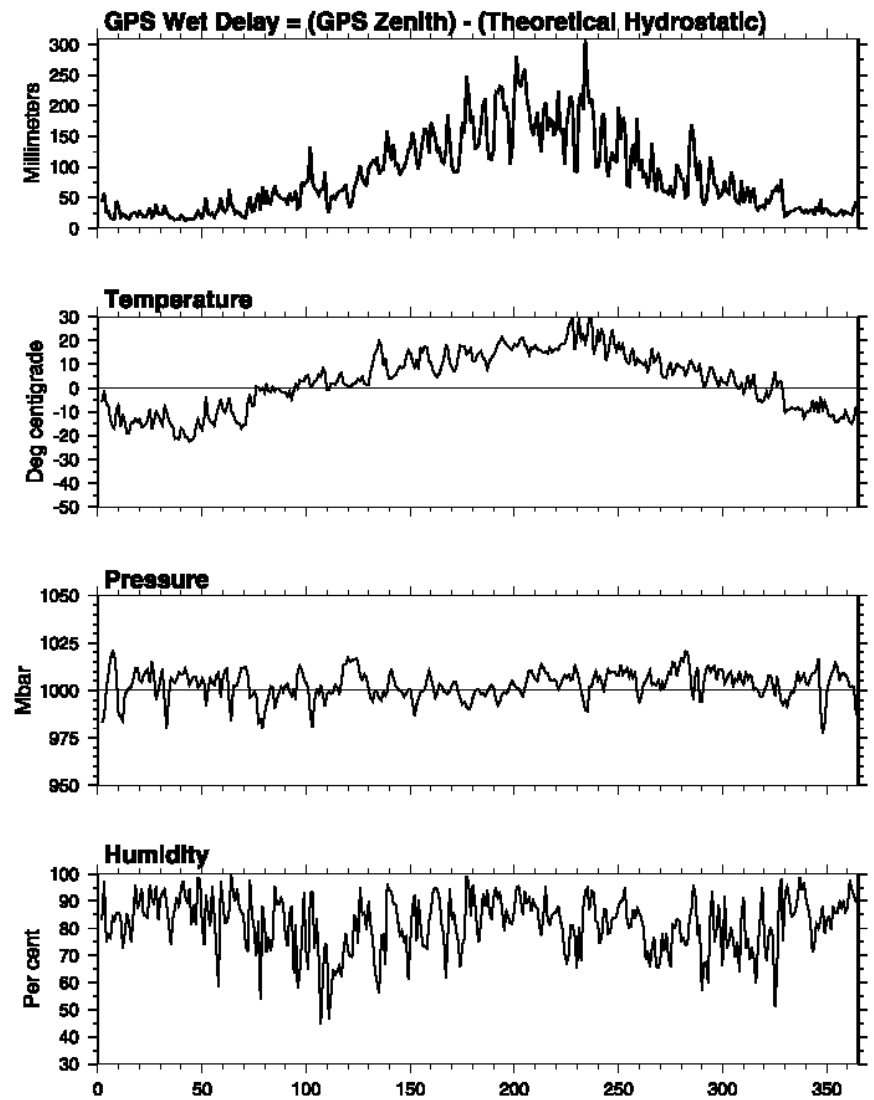
## Norilsk 2001: GPS Meteorology

Lat: 69.4N  
Lon: 88.4E

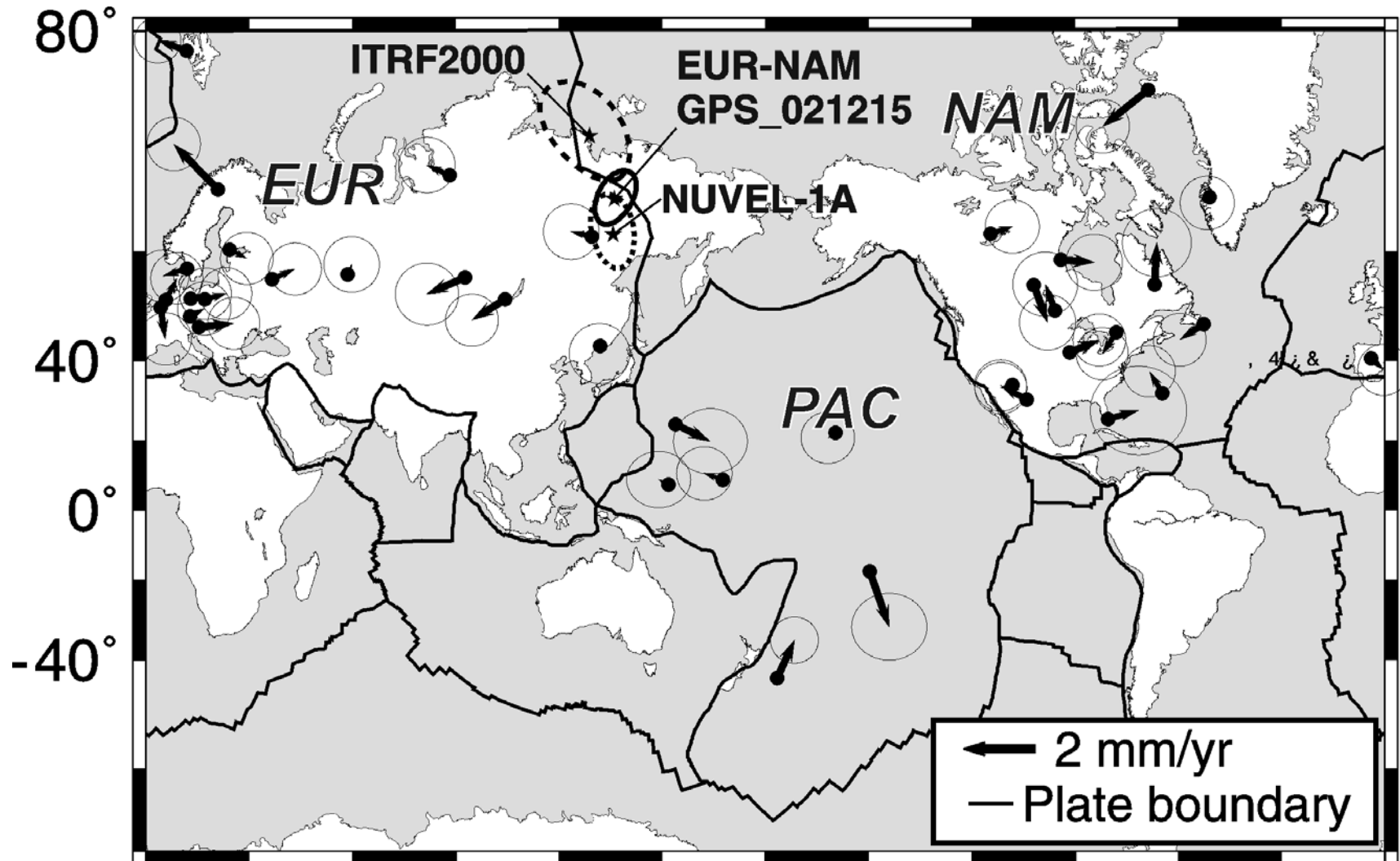


## Yuzhno-Sakhalinsk 2001: GPS Meteorology

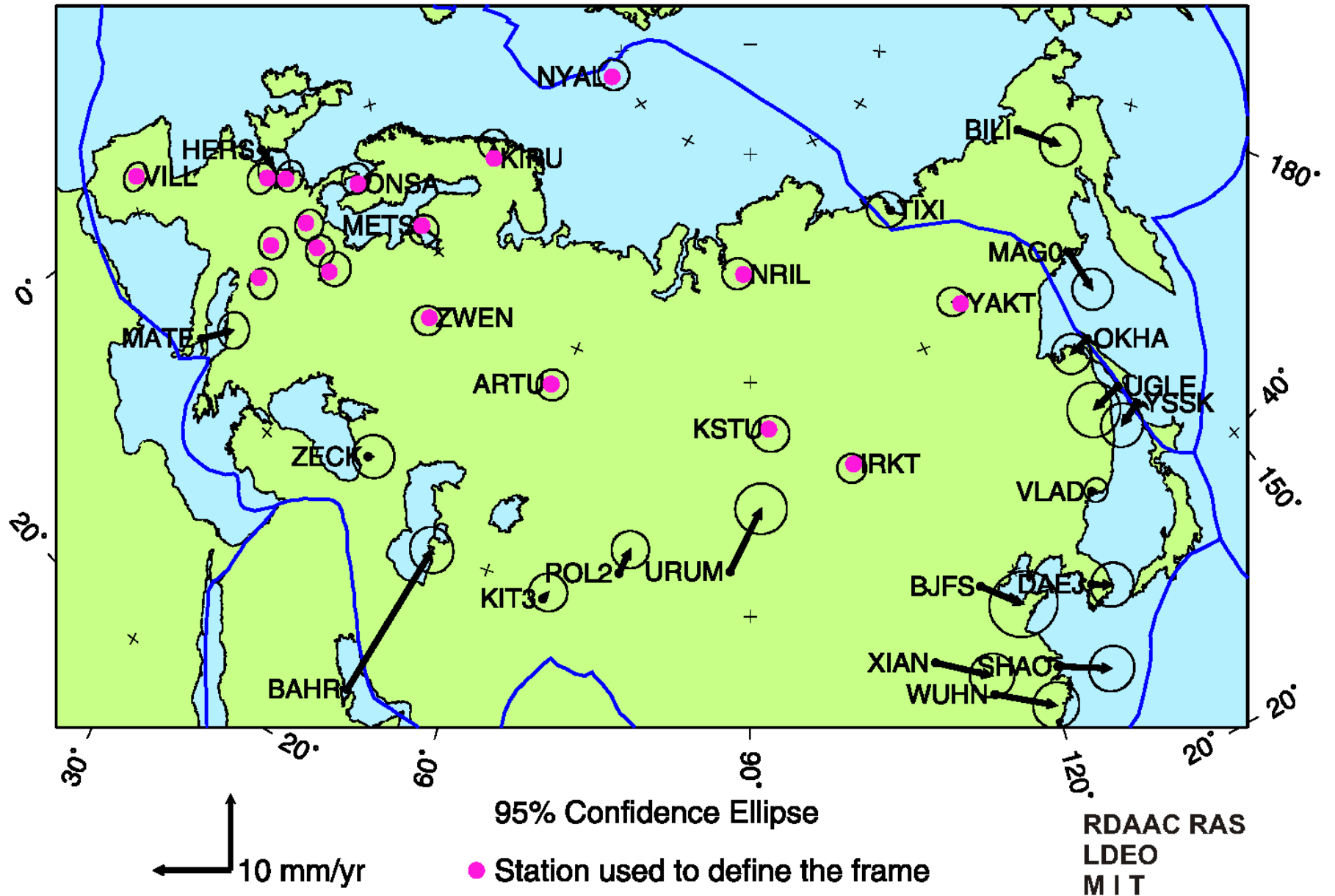
Lat: 47.0N  
Lon: 142.7E



## NUVEL-1A plate boundaries

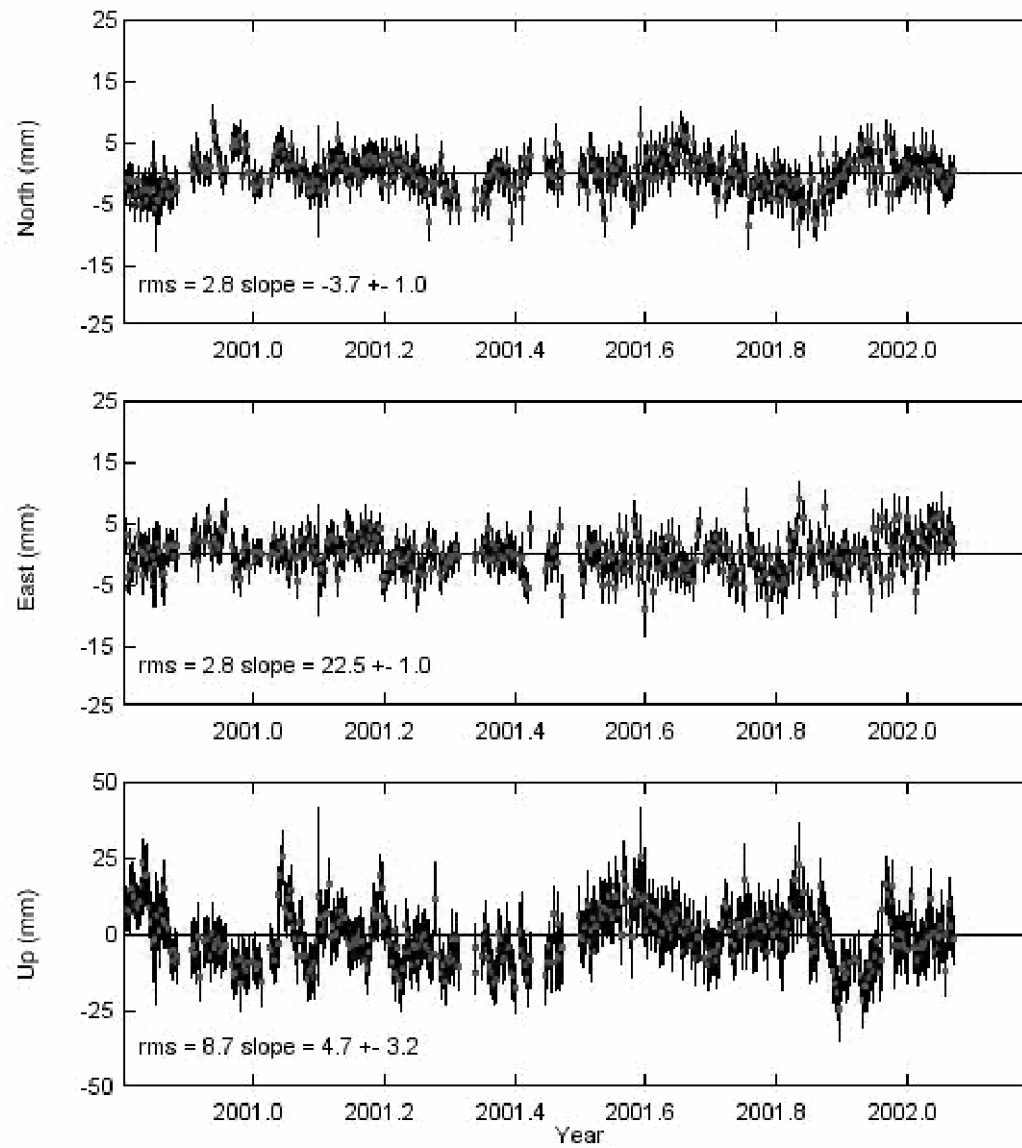


# GPS Velocities in Eurasian Frame





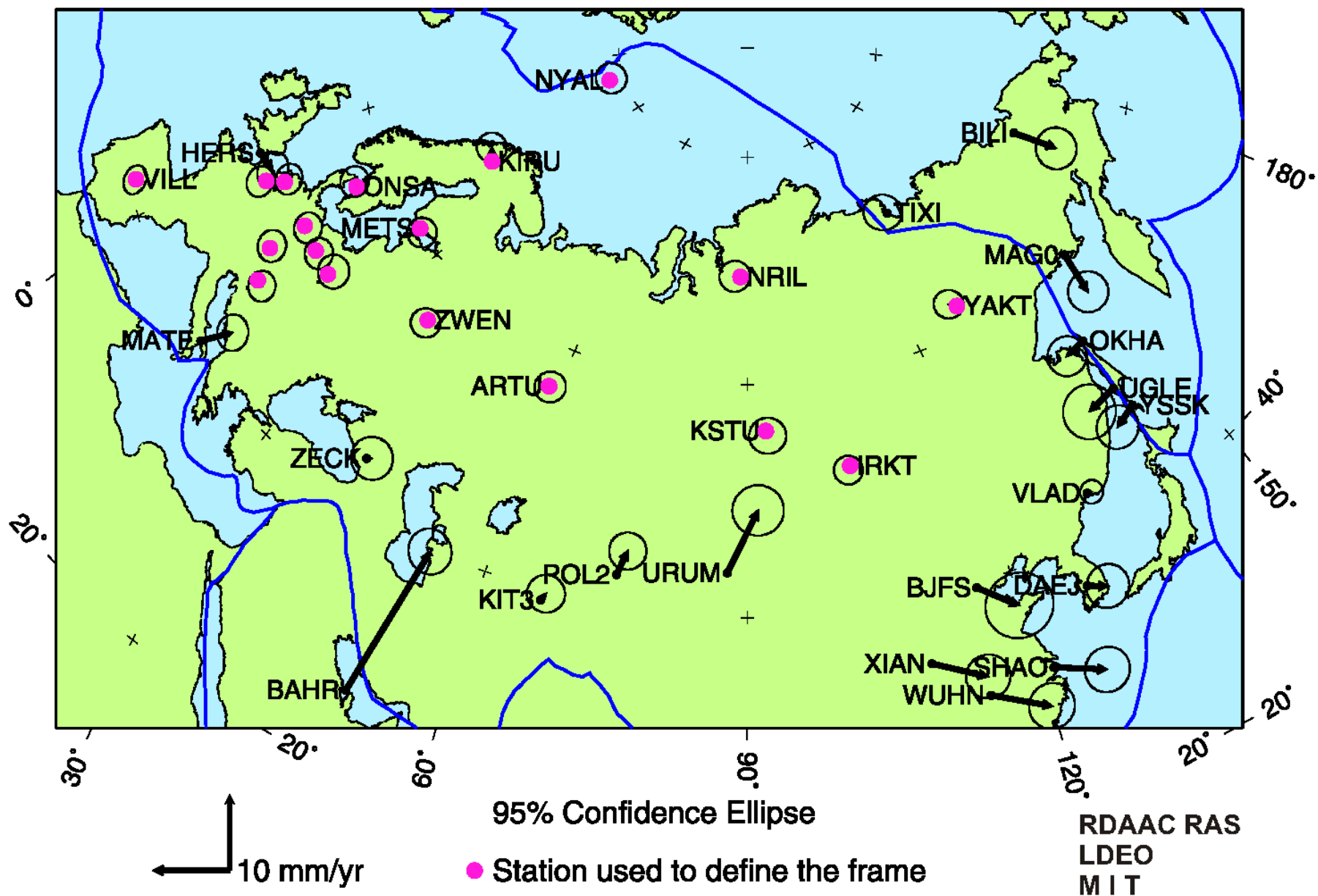
## NRIL Position Time Series

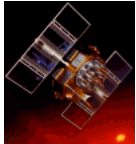


# Plate definition stability

Plate	Station	Long.	Lat.	Ve	Vn	$\sigma$ Ve	$\sigma$ Vn	Correl.	Obs. period.
EUR	ARTU	58.56	56.43	0.0	0.3	0.8	0.8	0.000	1996.6-2002.7
EUR	BOR1	17.07	52.28	0.7	0.2	0.8	0.8	0.000	1995.6-2002.7
EUR	BRUS	4.36	50.80	0.3	-0.9	0.8	0.8	0.000	1995.6-2002.7
EUR	GRAZ	15.49	47.07	1.0	0.2	0.8	0.8	-0.001	1995.6-2002.7
EUR	IRKT	104.32	52.22	-1.0	-0.6	0.8	0.8	-0.002	1995.7-2002.7
EUR	KIRU	20.97	67.86	-1.4	1.1	0.8	0.8	0.000	1995.6-2002.7
EUR	KOSG	5.81	52.18	0.5	0.6	0.8	0.8	0.000	1995.6-2002.7
EUR	KSTU	92.79	55.99	-1.3	-0.3	0.9	0.9	0.000	1997.7-2002.7
EUR	METS	24.40	60.22	0.5	-0.4	0.8	0.8	0.000	1995.6-2002.7
EUR	NRIL	88.36	69.36	-0.7	0.2	0.9	0.9	0.000	1996.6-2002.7
EUR	NYAL	11.86	78.93	-0.7	-0.1	0.6	0.6	0.001	1995.6-2002.7
EUR	ONSA	11.93	57.40	-0.4	-0.3	0.8	0.8	0.000	1995.6-2002.7
EUR	POTS	13.07	52.38	0.4	0.1	0.8	0.8	-0.001	1995.6-2002.7
EUR	VILL	356.05	40.44	0.6	-0.1	0.8	0.7	0.000	1995.6-2002.7
EUR	VLAD	131.93	43.20	0.1	-0.3	0.9	0.9	0.000	1996.2-2001.5
EUR	WTZR	12.88	49.14	0.7	0.3	0.8	0.8	0.000	1996.2-2002.7
EUR	YAKT	129.68	62.03	-0.6	0.2	0.8	0.8	-0.001	1996.6-2002.7
EUR	ZWEN	36.76	55.70	0.6	0.2	0.8	0.8	0.000	1995.6-2002.7
NAM	ALGO	281.93	45.96	-0.5	-0.8	0.8	0.8	0.000	1995.6-2002.7
NAM	BRMU	295.30	32.37	-0.5	0.8	0.8	0.7	0.000	1995.6-2002.7
NAM	CHUR	265.91	58.76	1.0	-0.3	0.8	0.8	0.001	1996.5-2002.7
NAM	DUBO	264.13	50.26	0.0	0.7	0.9	0.9	0.001	1996.9-2002.7
NAM	FLIN	258.02	54.73	0.3	-1.2	0.8	0.8	0.001	1996.5-2002.7
NAM	KELY	309.05	66.99	-0.4	-0.3	0.8	0.8	0.000	1995.7-2002.7
NAM	MDO1	255.99	30.68	-0.5	0.5	0.8	0.7	0.002	1995.6-2002.7
NAM	NLIB	268.42	41.77	0.8	0.2	0.8	0.8	0.001	1995.6-2002.7
NAM	PIE1	251.88	34.30	-0.2	0.0	0.8	0.7	0.002	1995.6-2002.7
NAM	RCM5	279.62	25.61	0.1	0.0	1.6	1.5	-0.004	1995.6-1998.8
NAM	SCH2	293.17	54.83	-0.6	1.2	1.0	1.0	0.000	1997.7-2002.2
NAM	STJO	307.32	47.60	-0.8	-0.3	0.8	0.8	0.001	1995.6-2002.6
NAM	THU1	291.21	76.54	-1.5	-1.3	0.8	0.8	0.000	1995.6-2002.7
NAM	YELL	245.52	62.48	0.7	0.2	0.8	0.8	0.000	1995.6-2002.4
PAC	CHAT	183.43	-43.96	0.5	0.9	0.7	0.7	0.002	1996.0-2002.7
PAC	KOKB	200.34	22.13	0.0	-0.1	0.8	0.8	0.002	1995.6-2002.6
PAC	KWJ1	167.73	8.72	-0.5	0.1	0.8	0.8	-0.002	1996.3-2002.6
PAC	MARC	153.98	24.29	0.9	-0.9	1.0	1.0	-0.004	1995.6-2000.4
PAC	THTI	210.39	-17.58	0.5	-1.2	1.0	1.0	0.007	1998.5-2002.7
PAC	TRUK	151.89	7.45	-0.7	0.6	0.9	0.9	-0.004	1996.0-2002.3

# GPS Velocities in Eurasian Frame



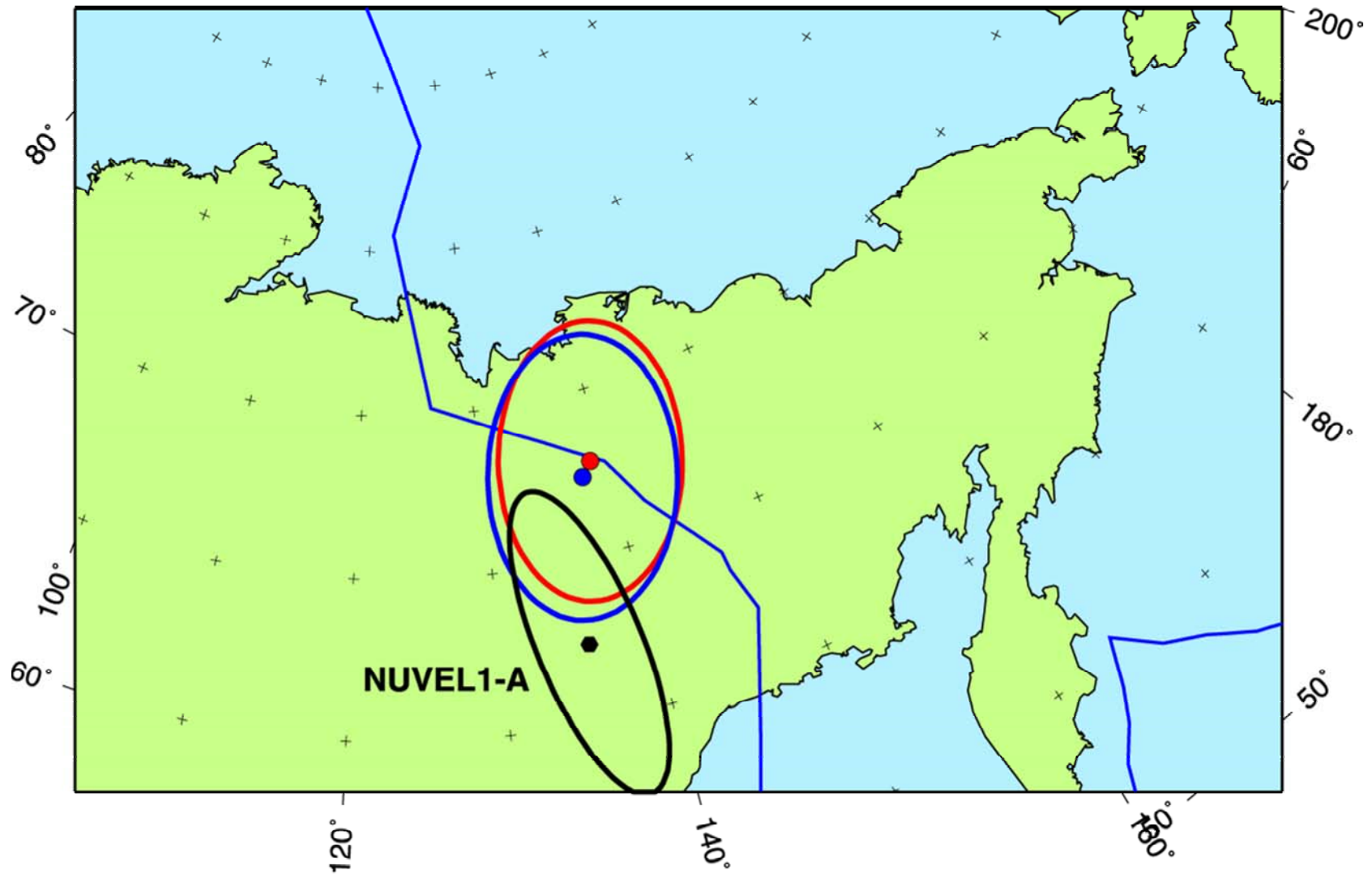


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# Plates definition stability

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EUR	KSTU	92.79	55.99	-1.3	-0.3	0.9	0.9	0.000	1997.7-2002.7
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EUR	VLAD	131.93	43.20	0.1	-0.3	0.9	0.9	0.000	1996.2-2001.5
EUR	WTZR	12.88	49.14	0.7	0.3	0.8	0.8	0.000	1996.2-2002.7
EUR	YAKT	129.68	62.03	-0.6	0.2	0.8	0.8	-0.001	1996.6-2002.7
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NAM	BRMU	295.30	32.37	-0.5	0.8	0.8	0.7	0.000	1995.6-2002.7
NAM	CHUR	265.91	58.76	1.0	-0.3	0.8	0.8	0.001	1996.5-2002.7
NAM	DUBO	264.13	50.26	0.0	0.7	0.9	0.9	0.001	1996.9-2002.7
NAM	FLIN	258.02	54.73	0.3	-1.2	0.8	0.8	0.001	1996.5-2002.7
NAM	KELY	309.05	66.99	-0.4	-0.3	0.8	0.8	0.000	1995.7-2002.7
NAM	MDO1	255.99	30.68	-0.5	0.5	0.8	0.7	0.002	1995.6-2002.7
NAM	NLIB	268.42	41.77	0.8	0.2	0.8	0.8	0.001	1995.6-2002.7
NAM	PIE1	251.88	34.30	-0.2	0.0	0.8	0.7	0.002	1995.6-2002.7
NAM	RCM5	279.62	25.61	0.1	0.0	1.6	1.5	-0.004	1995.6-1998.8
NAM	SCH2	293.17	54.83	-0.6	1.2	1.0	1.0	0.000	1997.7-2002.2
NAM	STJO	307.32	47.60	-0.8	-0.3	0.8	0.8	0.001	1995.6-2002.6
NAM	THU1	291.21	76.54	-1.5	-1.3	0.8	0.8	0.000	1995.6-2002.7
NAM	YELL	245.52	62.48	0.7	0.2	0.8	0.8	0.000	1995.6-2002.4
PAC	CHAT	183.43	-43.96	0.5	0.9	0.7	0.7	0.002	1996.0-2002.7
PAC	KOKB	200.34	22.13	0.0	-0.1	0.8	0.8	0.002	1995.6-2002.6
PAC	KWJ1	167.73	8.72	-0.5	0.1	0.8	0.8	-0.002	1996.3-2002.6
PAC	MARC	153.98	24.29	0.9	-0.9	1.0	1.0	-0.004	1995.6-2000.4
PAC	THTI	210.39	-17.58	0.5	-1.2	1.0	1.0	0.007	1998.5-2002.7
PAC	TRUK	151.89	7.45	-0.7	0.6	0.9	0.9	-0.004	1996.0-2002.3

# Euler poles EUR-NAM

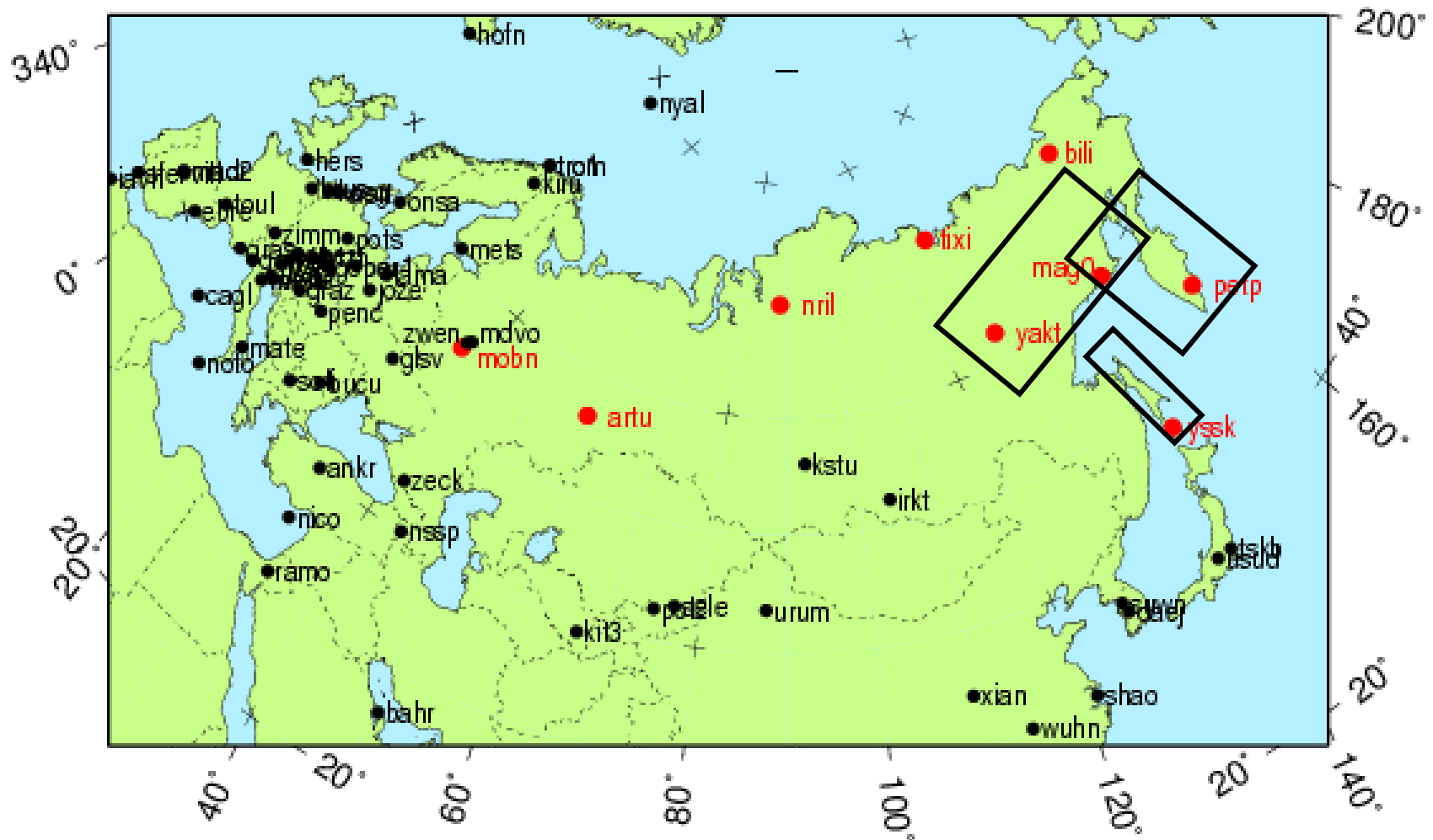


**GPS Poles for Reference Frames:**

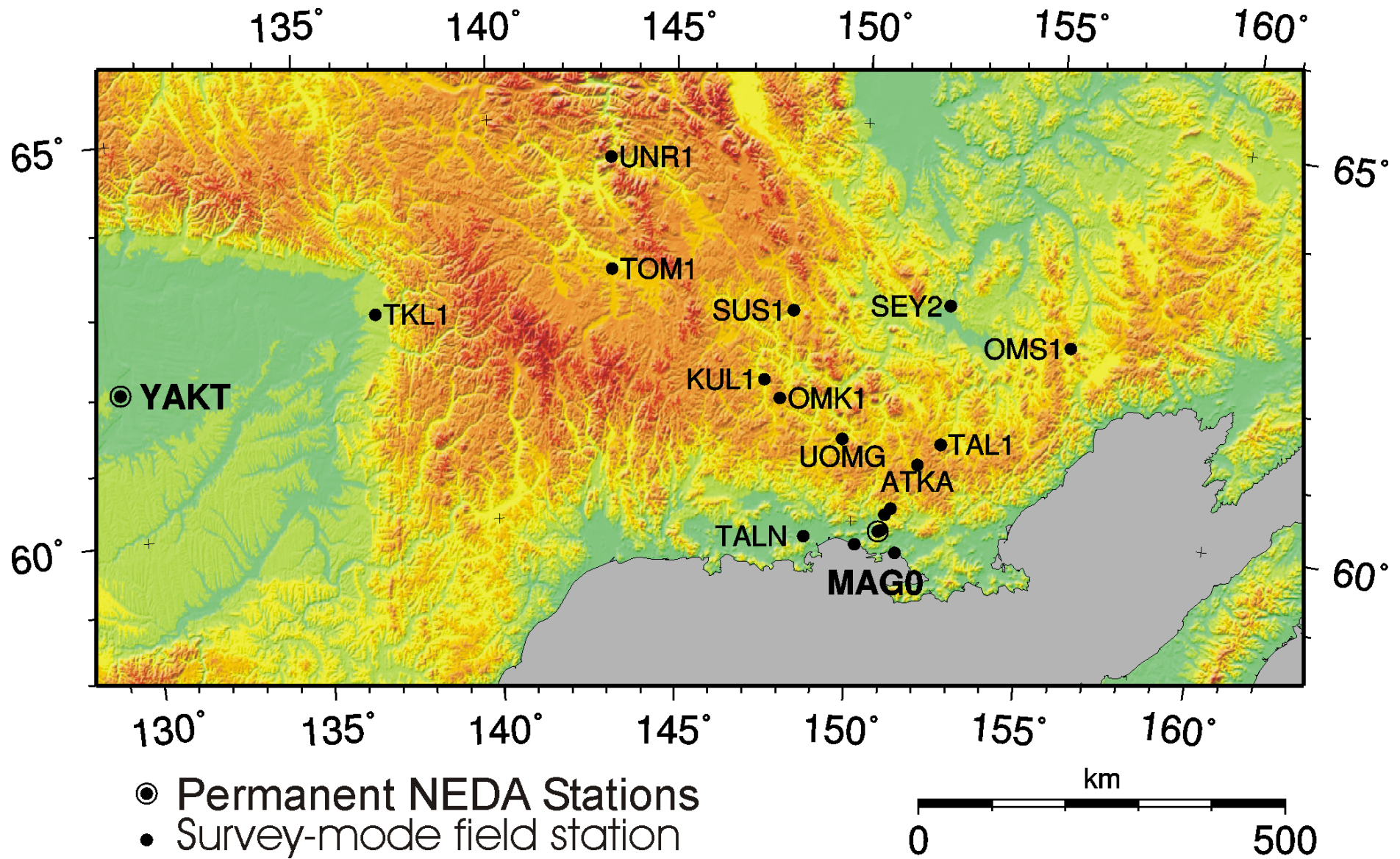
○ Eurasia

○ North America

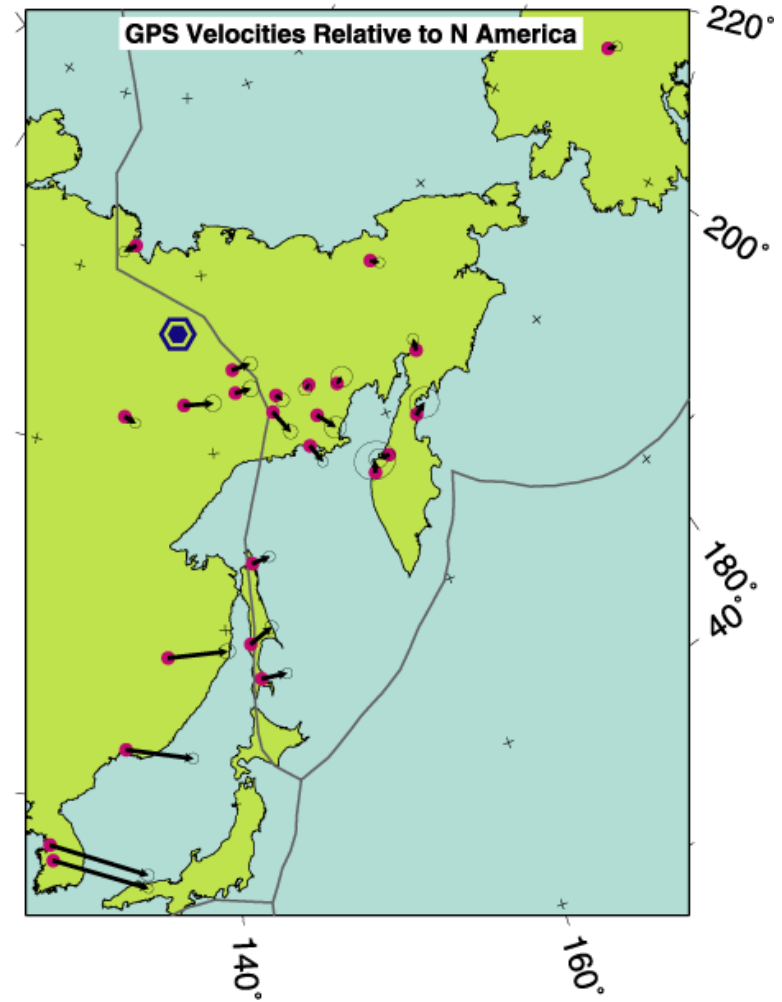
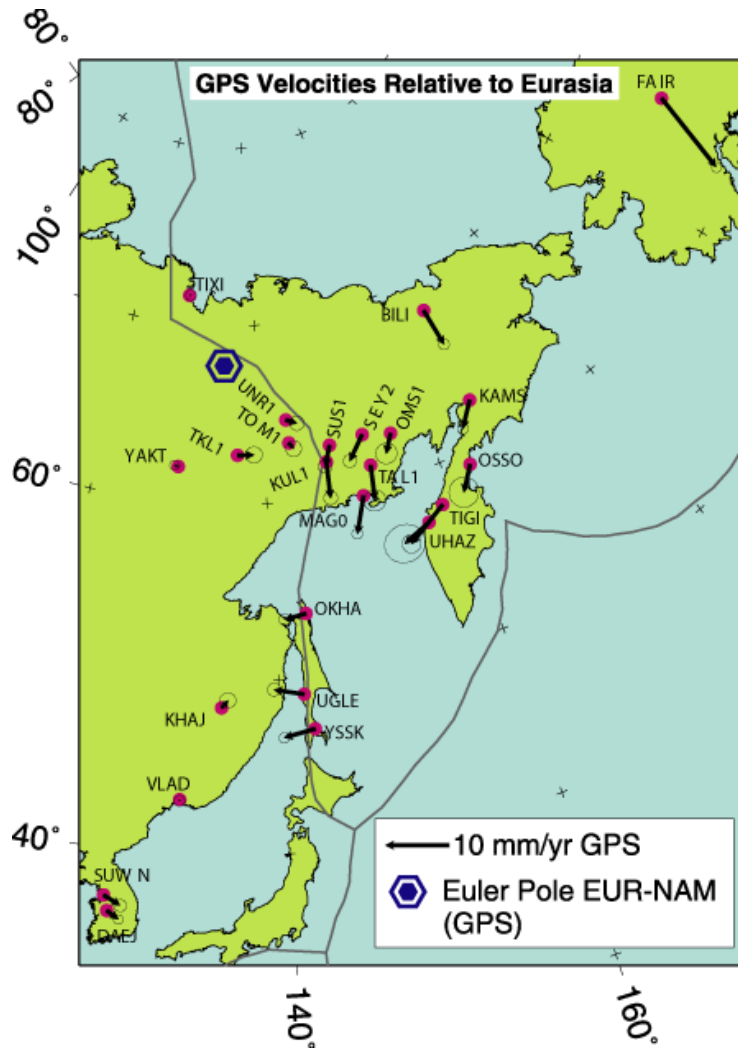
# Regional projects: Cherskiy range, Kamchatka, Sakhalin



# Cherskiy range region

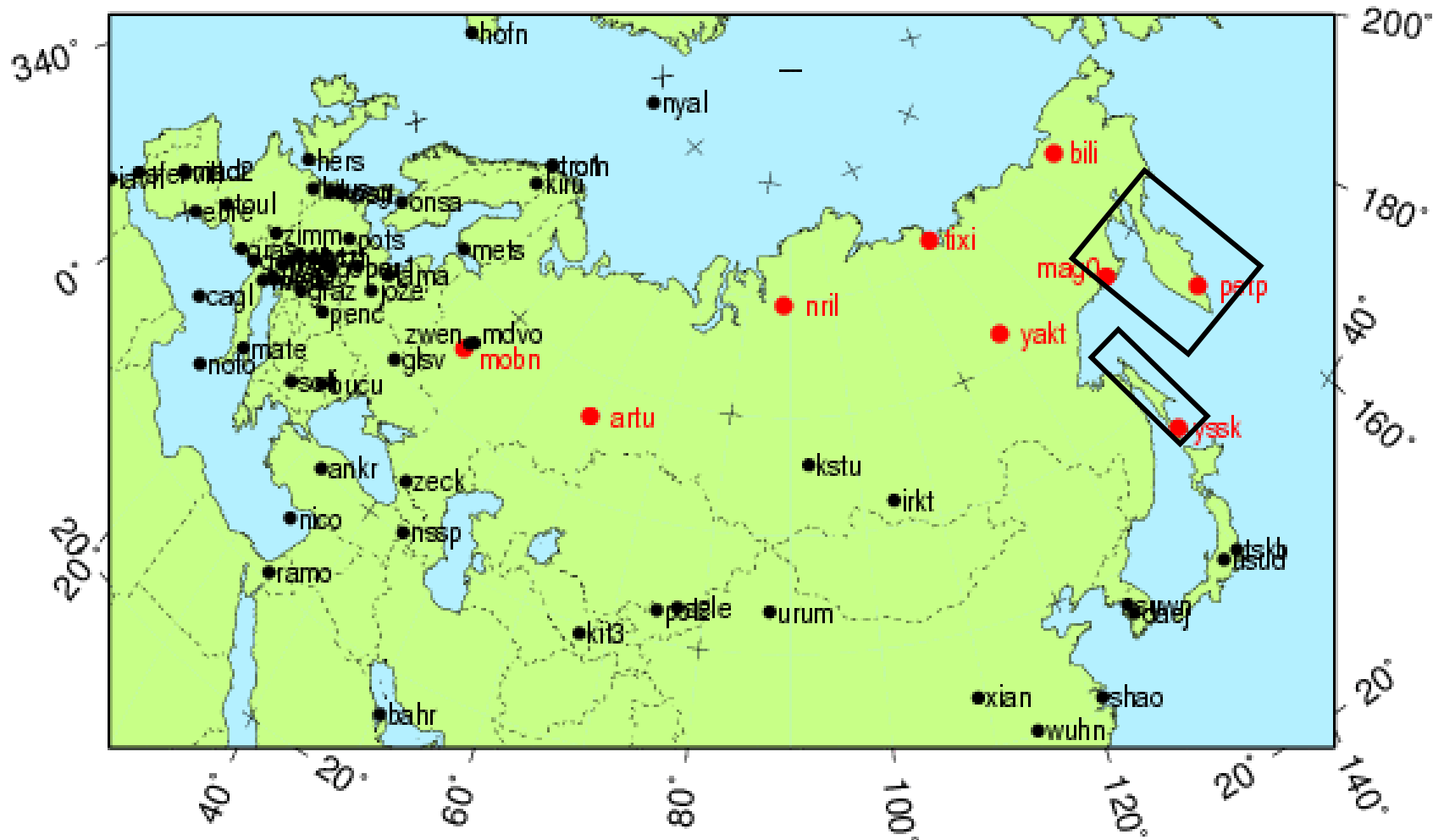


# EUR-NAM plates rotation

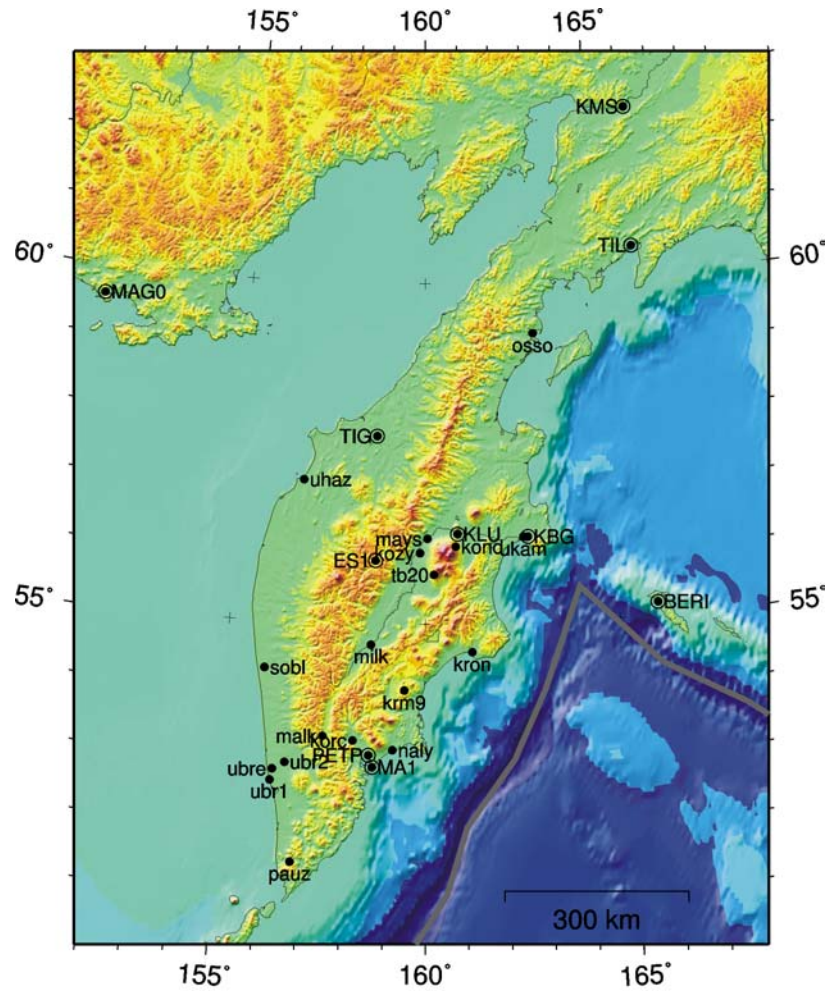




# Regional projects: Kamchatka, Sakhalin

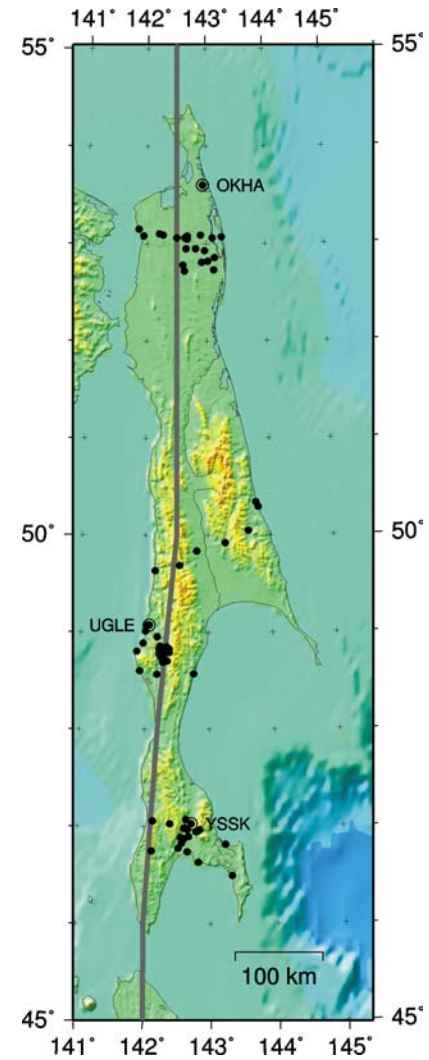


# Kamchatka

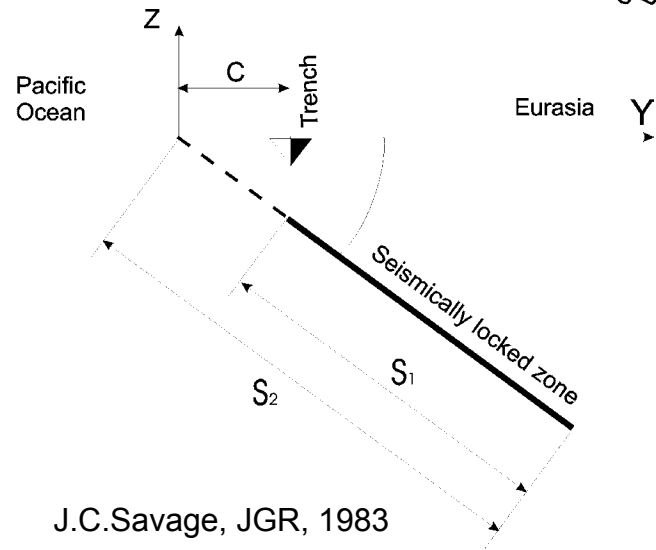
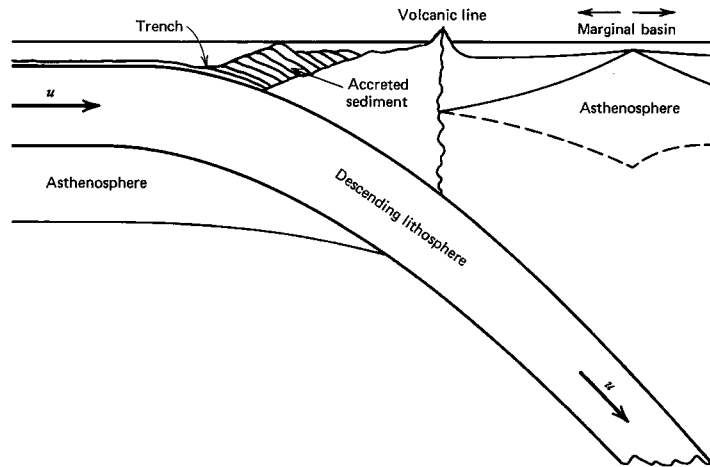


- Plate boundaries (model NUVEL-1A)
- Permanent GPS stations (1996 - 2003)
- Survey-mode field GPS stations (2001 - 2003)

# Sakhalin

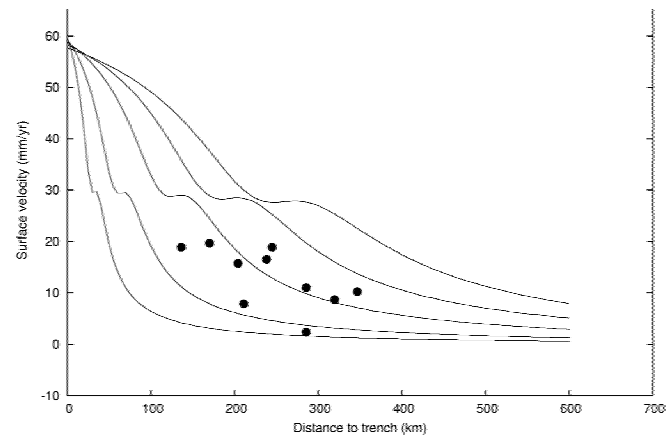
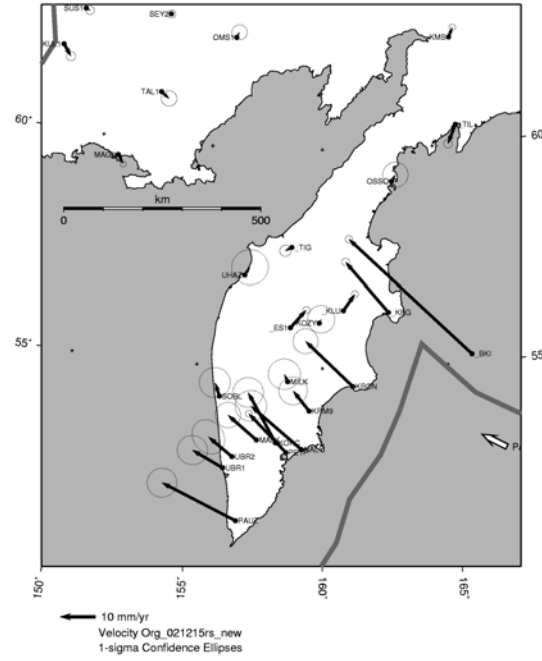


# Kamchatka subduction zone

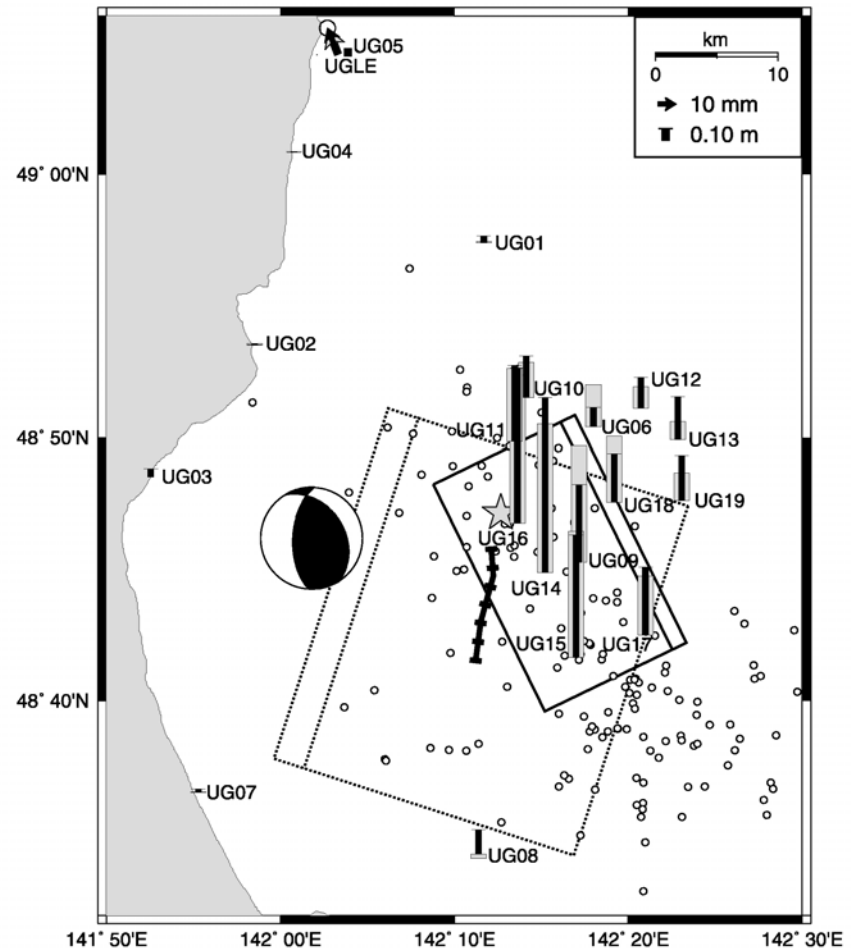
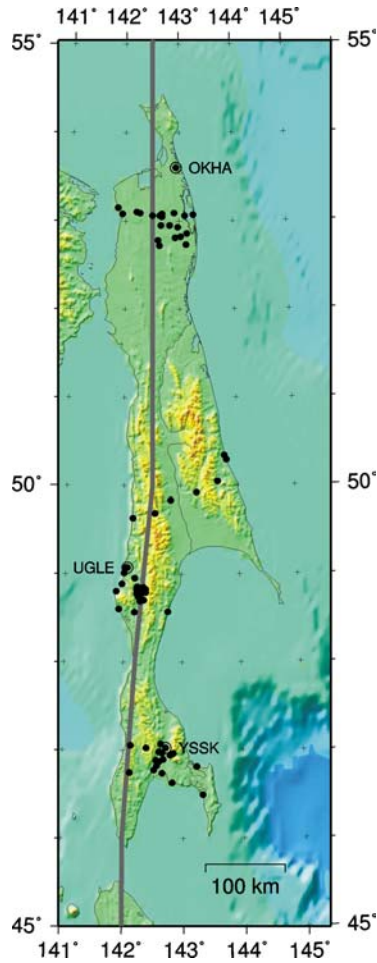


J.C.Savage, JGR, 1983

Reference Frame: North America



# Sakhalin: Ulegorsk earthquake



# Exploring Cherskiy range: GPS equipment ground transportation



# Conclusions

## General Network Tasks:

- Densification of the global GPS network – realization of North Eurasia reference frame
- Improvement of the orbit determination
- Global–scale real-time operations, high-frequency applications

## Applications to Geodynamics :

- Kinematics of three largest tectonic plates (East of Eurasia – boundary geometry, Euler poles)
- Regional seismo-tectonic studies

Contributed: Tomas Herring, MIT  
Robert King, MIT  
Roland Bürgman, UC Berkley  
Mikhail Kogan, Columbia Univ.



## **Conclusion**

Six years of the NEDA GPS network operation and improvement since it was initiated in 1997, contributed significantly to researches in following aspects:

- definition of the Eurasian reference frame;
- orbit definitions over Eurasian continent;
- understanding plate kinematics in the Far East of Eurasia;
- precise real-time navigation;

Last but not least, the long term successful operation of NEDA has been provided by the devoted activity of local operators and computer staff of the Geophysical Service RAS.

## **Conclusion**

Six years of the NEDA GPS network operation and improvement since it was initiated in 1997, contributed significantly to researches in following aspects:

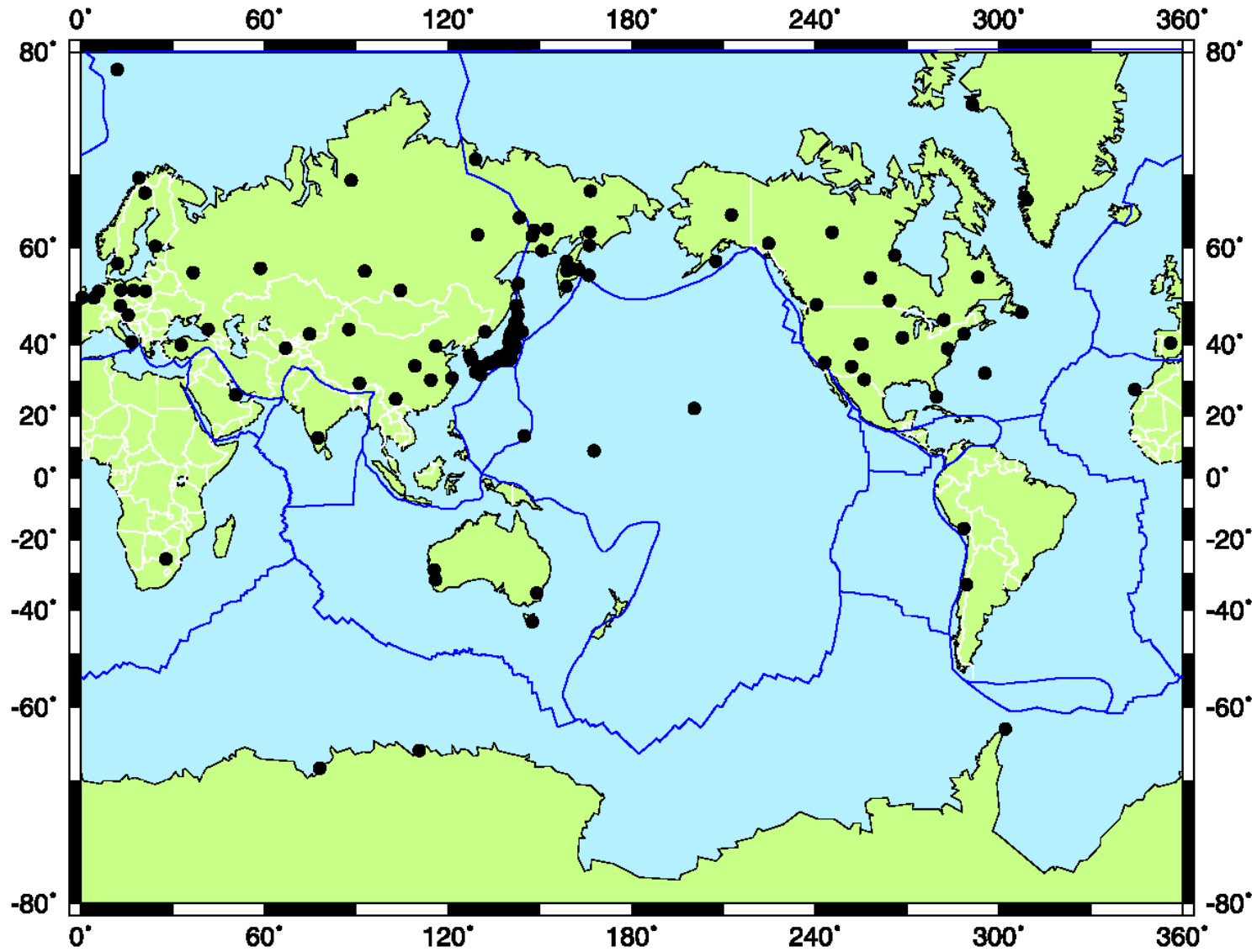
- definition of the Eurasian reference frame;
- fluctuations of the ionosphere on the global scale;
- the water vapor climatology;
- maintaining the international time/frequency standard.

The NEDA network employs the uniform instrumentation with the best signal-to-noise ratio as compared with any other, and computers directly plugged into the internet. The NEDA network is integrated with the RAS/GSN seismic network and its Russian internet segment.

Last but not least, the long term successful operation of NEDA has been provided by the devoted activity of local operators and computer staff of the Geophysical Service RAS.



# GPS Network used in Solution SML-2001 (126 Stations, Aug-1995 through Aug-2001)



— Plate boundaries of NUVEL-1A

**Reference Frames for GPS Solution SML-2001:  
Goodness of Fit**

**Reference frame best fit by rotation and translation (Elevation  
Velocities downweighted by a Factor of 3)**

<b>Reference Frame</b>	<b>Stations</b>	<b>A priori Velocities</b>	<b>Post RMS mm/yr</b>
Eurasia	14 stations in stable regions of Europe and Siberia	0.0	0.7
North America	13 stations in stable North American Plate excluding east Asia	0.0	1.0
Eurasia + North America	27 stations (sum of the above)	EUR: 0.0 NAM: Plate rotation best fit	0.8
ITRF 97	Sum of the above	ITRF 97	0.8
ITRF 96	Sum of the above	ITRF 96	1.2

**Plate rotation vector best fit**

<b>Plate</b>	<b>Stations</b>	<b>WRMS mm/yr</b>	<b>NRMS</b>
Eurasia	14 stations in stable regions of Europe and Siberia	0.5	0.7
North America	13 stations in stable North American Plate excluding east Asia	0.7	0.9
Arctic	3 stations in east Siberia and Alaska	0.9	0.9
Amuria	5 stations of Heki et al. [1999]	1.6	2.7
Okhotsk	5 stations at northern, eastern, and southern boundaries	1.8	2.5