

Sondáže atmosféry pomocí družic

**Využití mikrovlnného pásma pro
studium teploty v troposféře pomocí
družicových měření**

Měření kryosféry

Milan Šálek

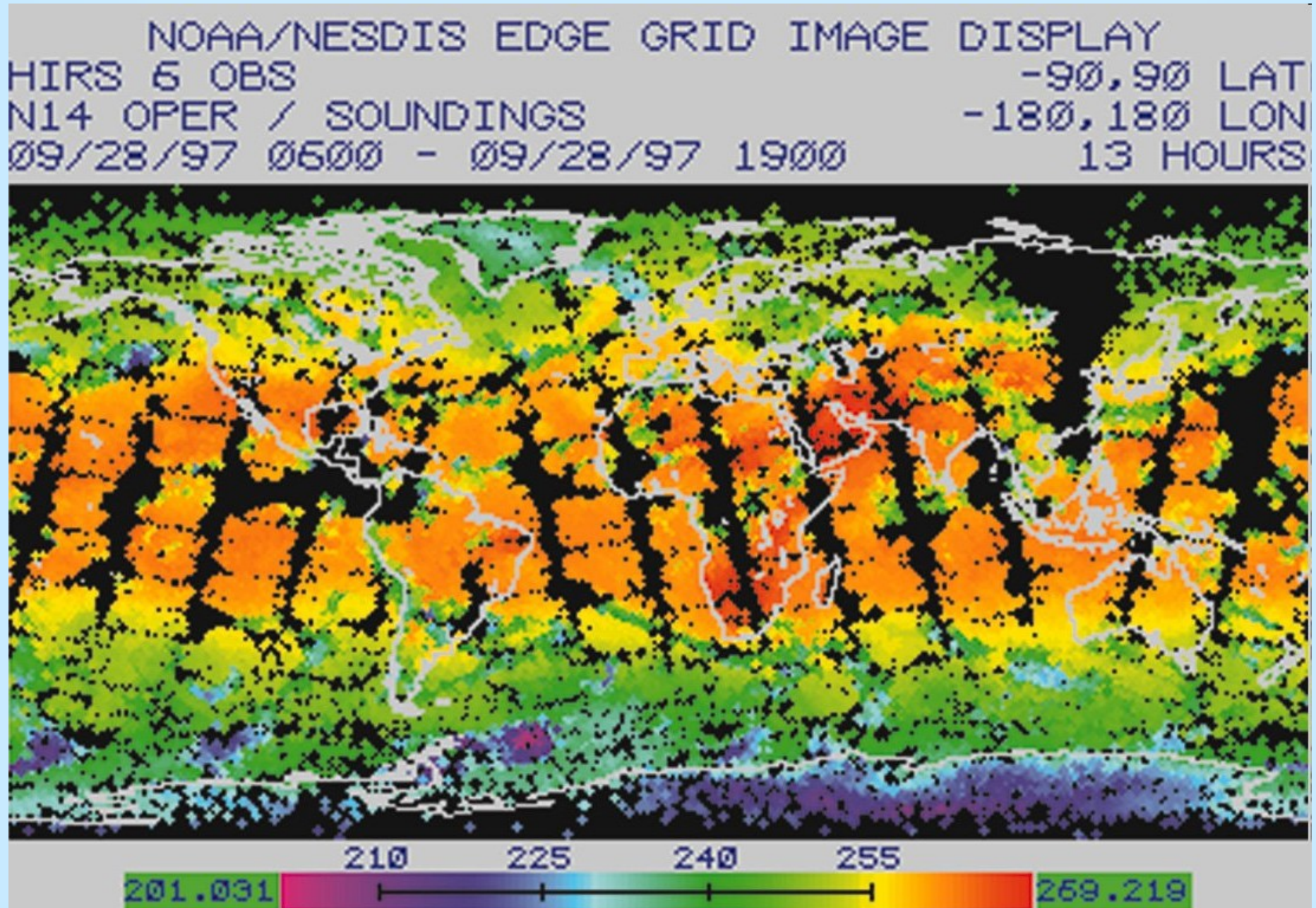
salek@chmi.cz

HIRS

- **HIRS - The High Resolution Infrared Radiation Sounder**
- Radiometr na družicích s polární drahou



Global atmospheric temperature data from HIRS channel 6 on the NOAA 14 satellite.



HIRS

- Poskytuje informace o teplotě v atmosféře v oblastech **bez oblačnosti**

Data od roku 1978 (TIROS-N)

- Field of View (FOV) v nadiru:
 - HIRS/3 (NOAA): 20 km
 - HIRS/4 (Metop, NOAA-N/19,P): 10 km
- 20 spektrálních kanálů

Spektrální kanály

- 1x VIS (0.69 μm)
- 7x NIR (3.7-4.6 μm)
- 20x IR (6.7-15 μm)

HIRS/3 Spectral Characteristics

Channel	Central Wavenumber (cm ⁻¹)	Wavelength (μm)
1	669	14.95
2	680	14.71
3	690	14.49
4	703	14.22
5	716	13.97
6	733	13.64
7	749	13.35
8	900	11.11
9	1,030	9.71
10	802	12.47
11	1,365	7.33
12	1,533	6.52
13	2,188	4.57
14	2,210	4.52
15	2,235	4.47
16	2,245	4.45
17	2,420	4.13
18	2,515	4.00
19	2,660	3.76
20*	14,500	0.690

HIRS

- Klíčová součást TOVS a ATOVS
 - (Advanced) TIROS Operational Vertical Sounding

Základní myšlenky algoritmů výpočtu vertikálních profilů z HIRS, popř. (A)MSU

1. Statistická regrese (předběžný odhad):

- $T_{\text{měřené_profily}} \sim \text{Radiance_profilů}$
 - $T_{\text{měřené profily}}$ – na aerol. stanicích

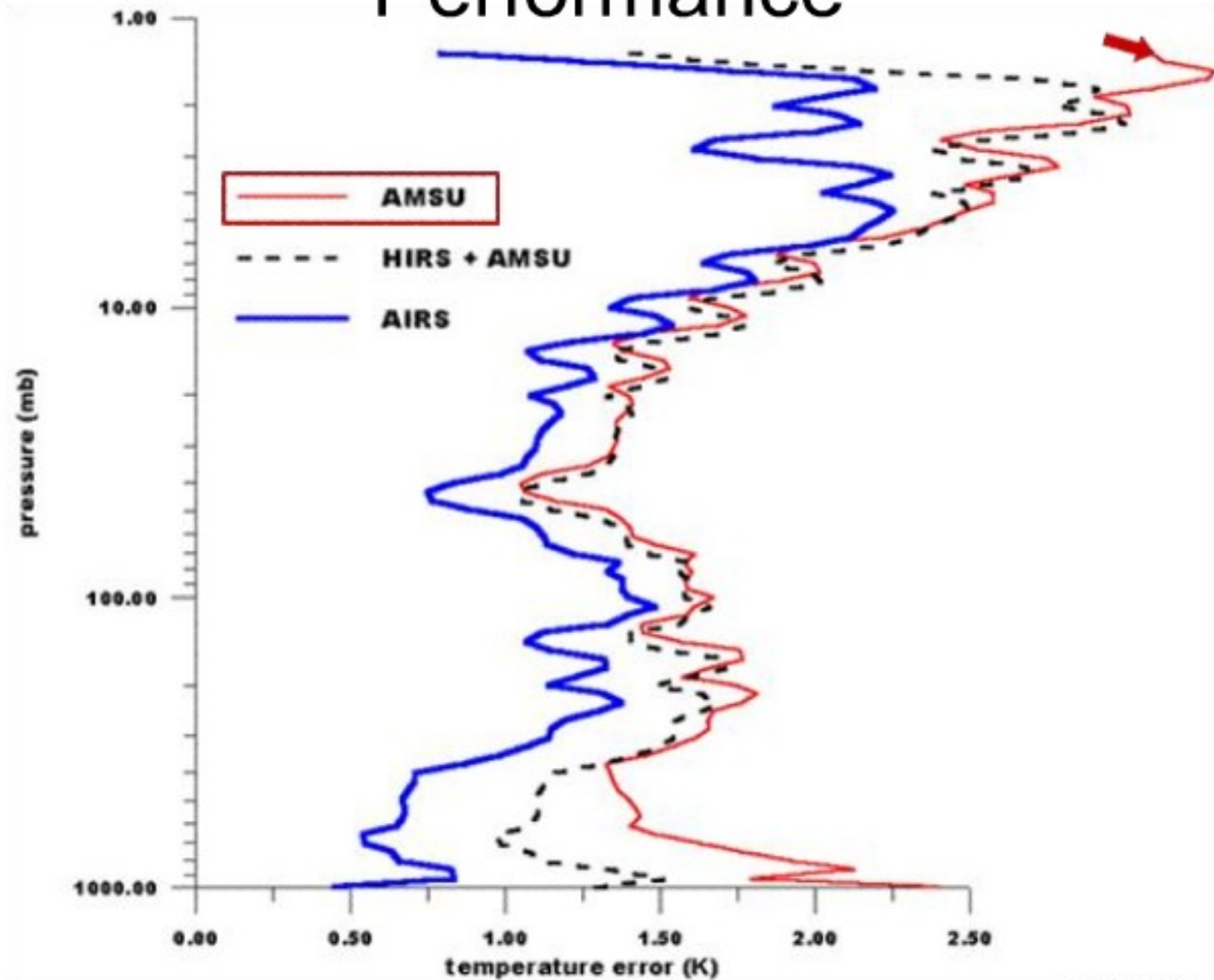
2. Fyzikální algoritmus

- Založený na rovnici přenosu záření (Radiative Transfer Equation, RTE)
- Přibližování regrese (prvotního odhadu) naměřeným hodnotám při splnění podmínek RTE
- využívají se tzv. váhové funkce

NASA, EUMETSAT

- NASA: AIRS: Atmospheric Infrared Sounder
- EUMETSAT: IASI: Infrared Atmospheric Sounding Interferometer
- EUMETSAT: Algorithmus GII „Global Instability Indices“ z MSG

Improvements in Sounding Performance



(Advanced) Microwave Sounding

Unit – MSU, AMSU

- umíst'ované na družicích s polární drahou (NOAA-x, Terra+Aqua)
- rotující zrcadla, kolmo k dráze letu
- MSU:
 - pás 47-48 st. od nadiru
 - elementy v nadiru: 7st (cca 100 km v průměru)
- AMSU: elementy o průměru cca 50 km v nadiru

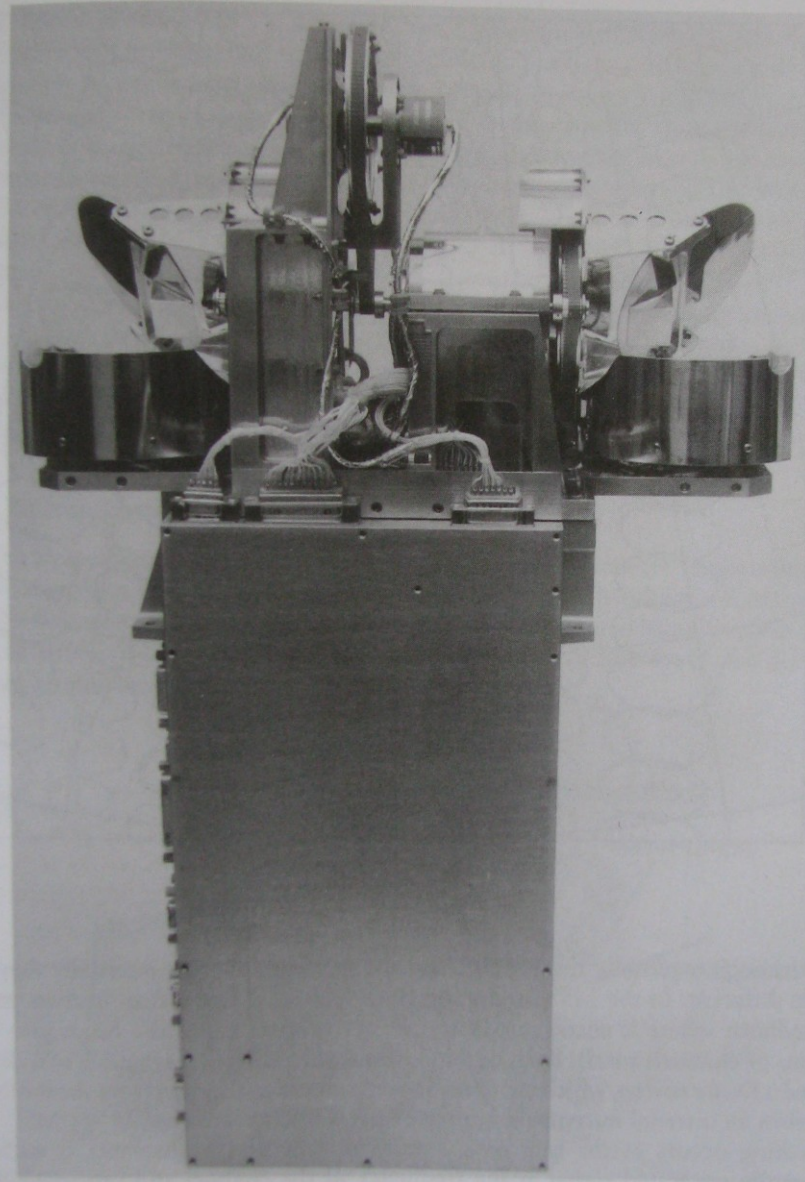


FIGURE 4.9. Photograph of the Microwave Sounding Unit. [Courtesy of James C. Fischer, NOAA/NESDIS.]

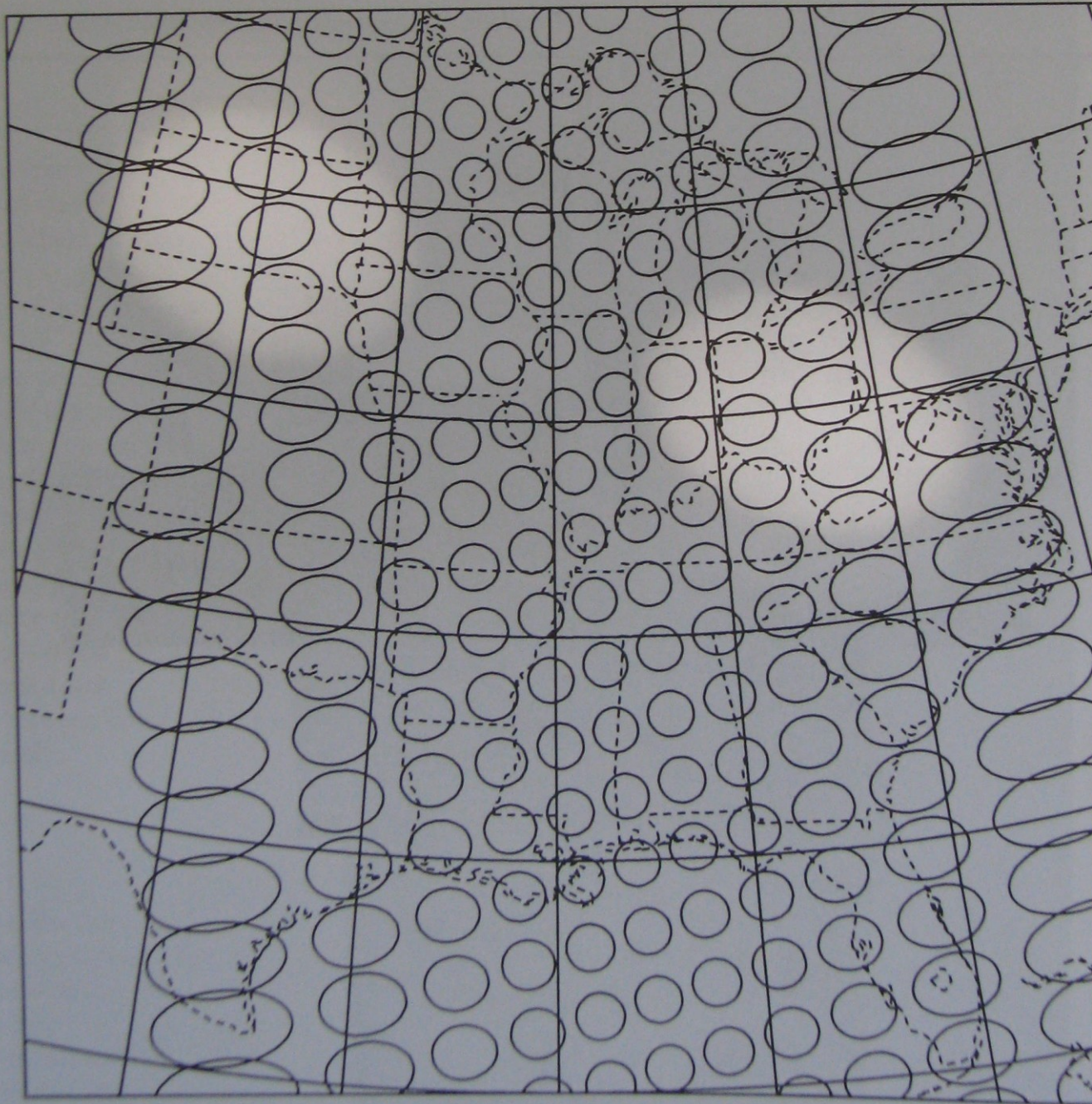


FIGURE 4.10. MSU scan pattern.

ADVANCED MICROWAVE SOUNDING UNIT-A (AMSU-A)

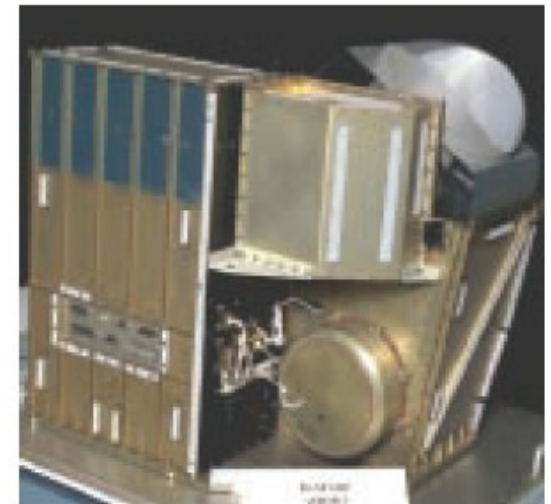
Northrop Grumman Electronic Systems

The AMSU-A measures scene radiance in the microwave spectrum. The data from this instrument is used in conjunction with the HIRS to calculate global atmospheric temperature and humidity profiles from the Earth's surface to the upper stratosphere, approximately a 2-millibar pressure altitude (48 km or 29.8 mi). The data is used to provide precipitation and surface measurements including snow cover, sea ice concentration, and soil moisture.

The AMSU-A is a cross-track scanning total power radiometer. It is divided into two physically separate modules, each of which operates and interfaces with the spacecraft independently. Module A-1 has 13 channels, and Module A-2 has two channels.



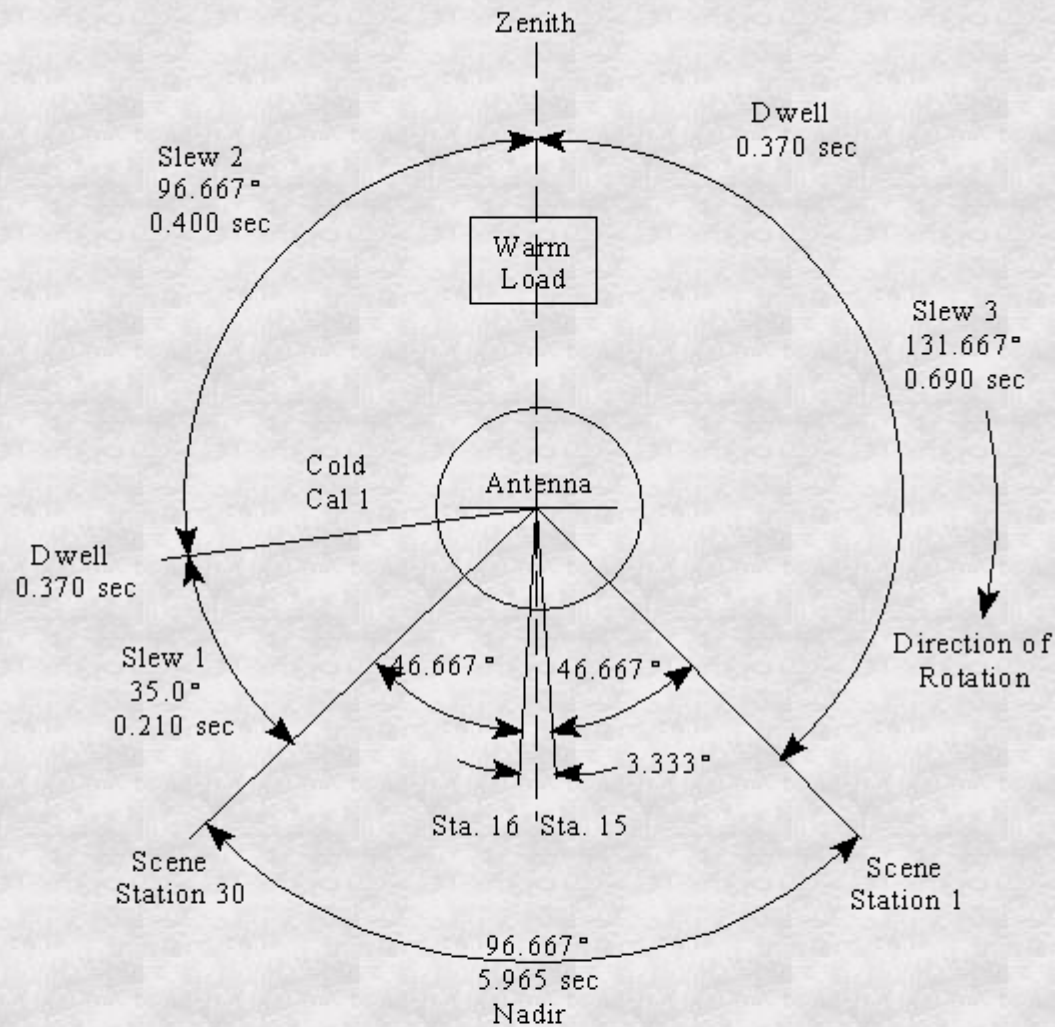
AMSU-A1



AMSU-A2

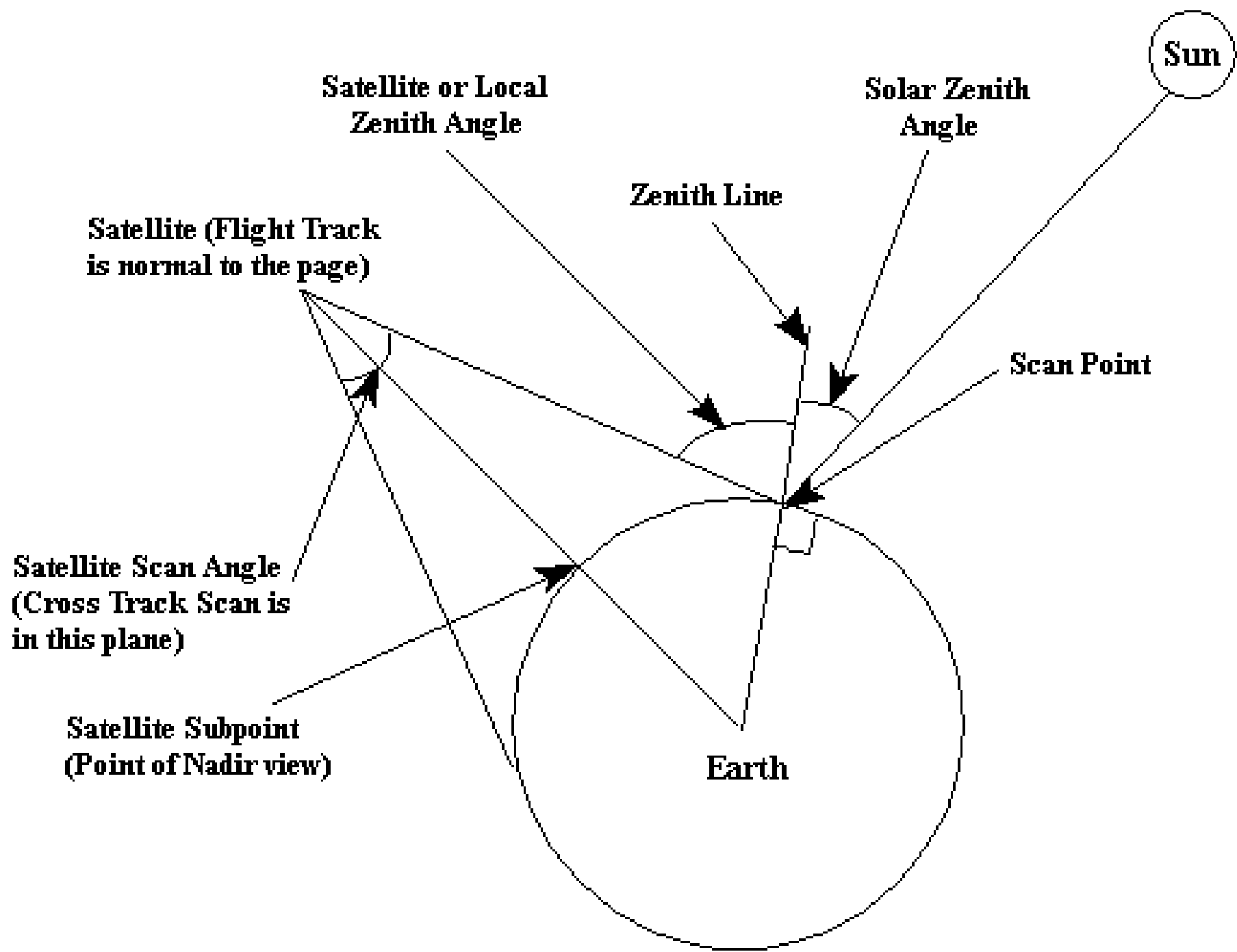
The instrument has an IFOV of 3.3° at the half-power points, providing a nominal spatial resolution at nadir of 48 km (29.8 mi). The antenna provides a cross-track scan, scanning $\pm 48.3^\circ$ from nadir with a total of 30 Earth fields of view per scan line. The instrument completes one scan every 8 seconds.

Figure J.3-1. AMSU-A scanning characteristics.



- Step Scan
 - 30 scene stations
 - Cold and Warm Cal Stations
 - 8 sec period
- Identical Profile for A1 and A2
- Antenna drives
- Synchronized every 8 seconds

- Integration Time
 - A1: 165 msec
 - A2: 158 msec
- Three additional cold cal positions: -1.67°, -3.33° and -6.66° from Cold Cal 1
- Cold Cal Station selected by Ground Command



AMSU-A Channel Characteristics

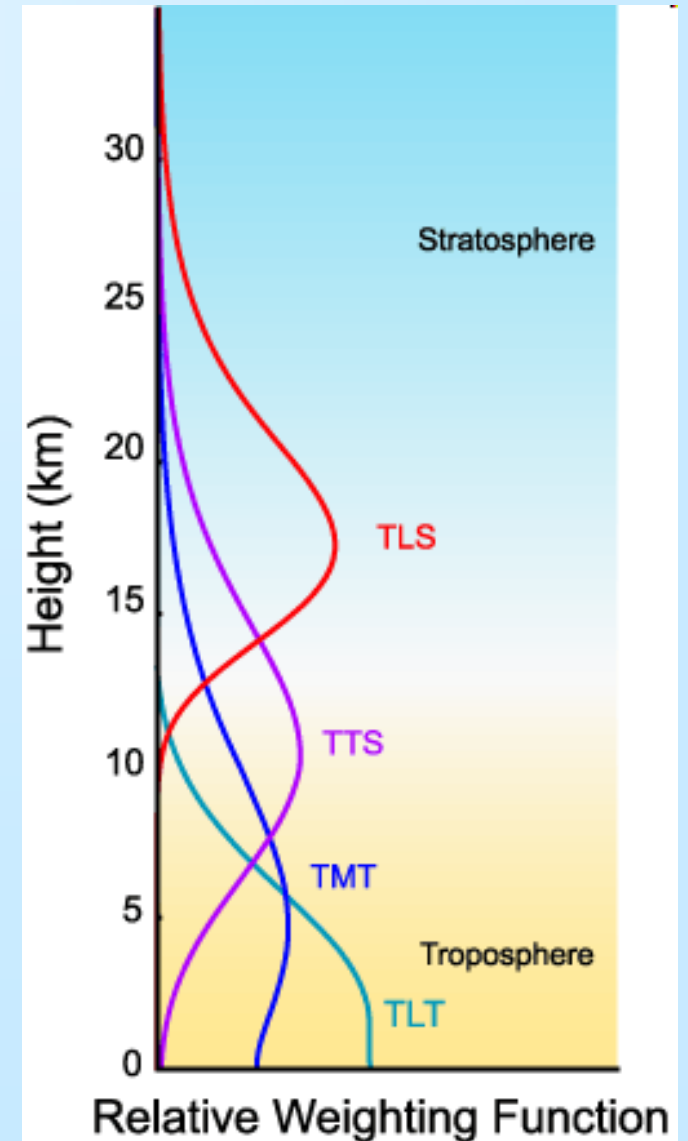
Ch. No.	Center Frequency	No. of Pass Bands	Bandwidth (MHz) (spec)	Center Frequency Stability (MHz)	Temperature Sensitivity (K) $NE\Delta T^*$ (spec)	Calibration Accuracy (K) (spec)	Angle θ_p
1	23,800 MHz	1	270	10	0.30	2.0	V
2	31,400 MHz	1	180	10	0.30	2.0	V
3	50,300 MHz	1	180	10	0.40	1.5	V
4	52,800 MHz	1	400	5	0.25	1.5	V
5	53,596 MHz ± 115 MHz	2	170	5	0.25	1.5	H
6	54,400 MHz	1	400	5	0.25	1.5	H
7	54,940 MHz	1	400	5	0.25	1.5	V
8	55,500 MHz	1	330	10	0.25	1.5	H
9	57,290.344 MHz = f_{LO}	1	330	0.5	0.25	1.5	H
10	$f_{LO} \pm 217$ MHz	2	78	0.5	0.40	1.5	H
11	$f_{LO} \pm 322.2 \pm 48$ MHz	4	36	1.2	0.40	1.5	H
12	$f_{LO} \pm 322.2 \pm 22$ MHz	4	16	1.2	0.60	1.5	H
13	$f_{LO} \pm 322.2 \pm 10$ MHz	4	8	0.5	0.80	1.5	H
14	$f_{LO} \pm 322.2 \pm 4.5$ MHz	4	3	0.5	1.20	1.5	H
15	89.0 GHz	1	<6,000	50	0.50	2.0	V

* $NE\Delta T$ —Noise Equivalent Temperature Difference

Vlnové délky

Výpočet teplot v jednotlivých atmosférických vrstvách

Váhové funkce podle příslušných vlnových délek



Spektrální kanály pro výpočet teploty v atmosféře

TLT =Temperature Lower Troposphere	MSU 2 and AMSU 5
TMT =Temperature Middle Troposphere	MSU 2 and AMSU 5
TTS = Temperature Troposphere / Stratosphere	MSU 3 and AMSU 7
TLS =Temperature Lower Stratosphere	MSU 4 and AMSU 9

MSU1: 50.30 GHz

MSU2: 53.74 GHz

MSU3: 54.96 GHz

MSU4: 57.95 GHz

Princip výpočtu TLT: Od radiační teploty (BT) kanálu 2 (v nadiru) se odečte BT kanálu 3. Navíc se používají lineární kombinace různých úhlů pohledu

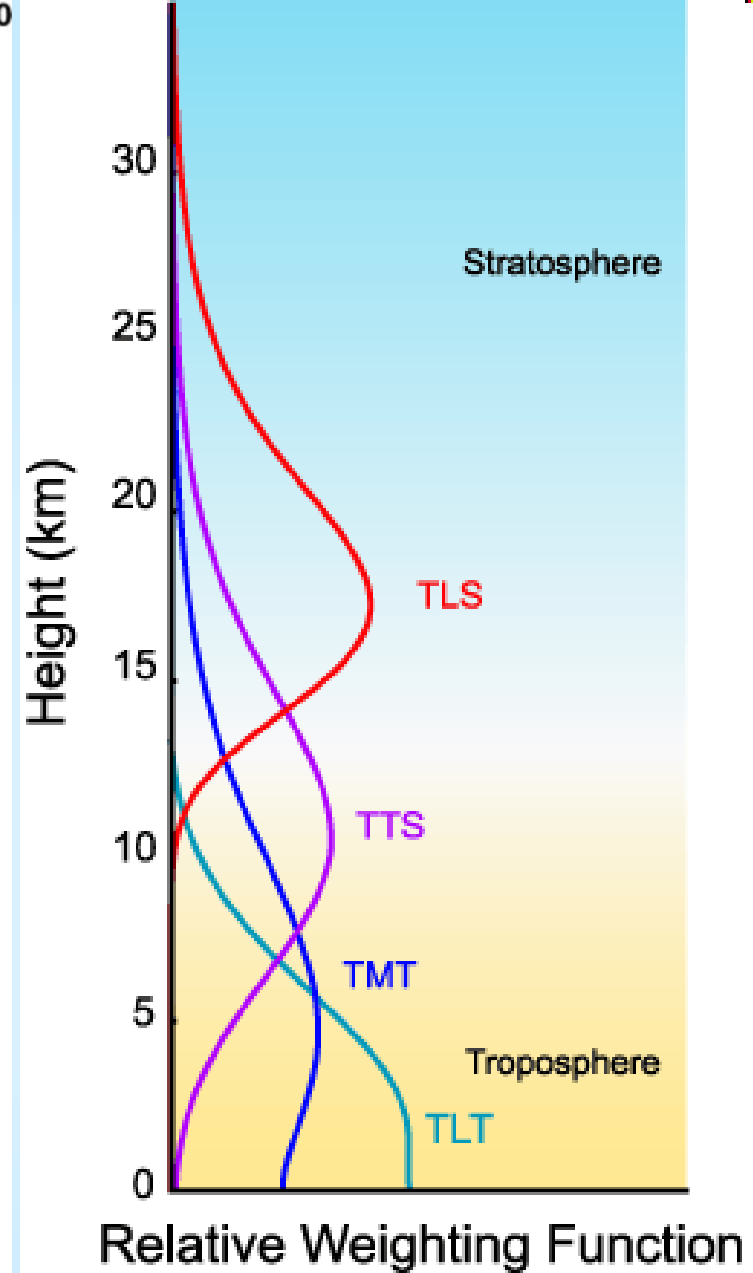
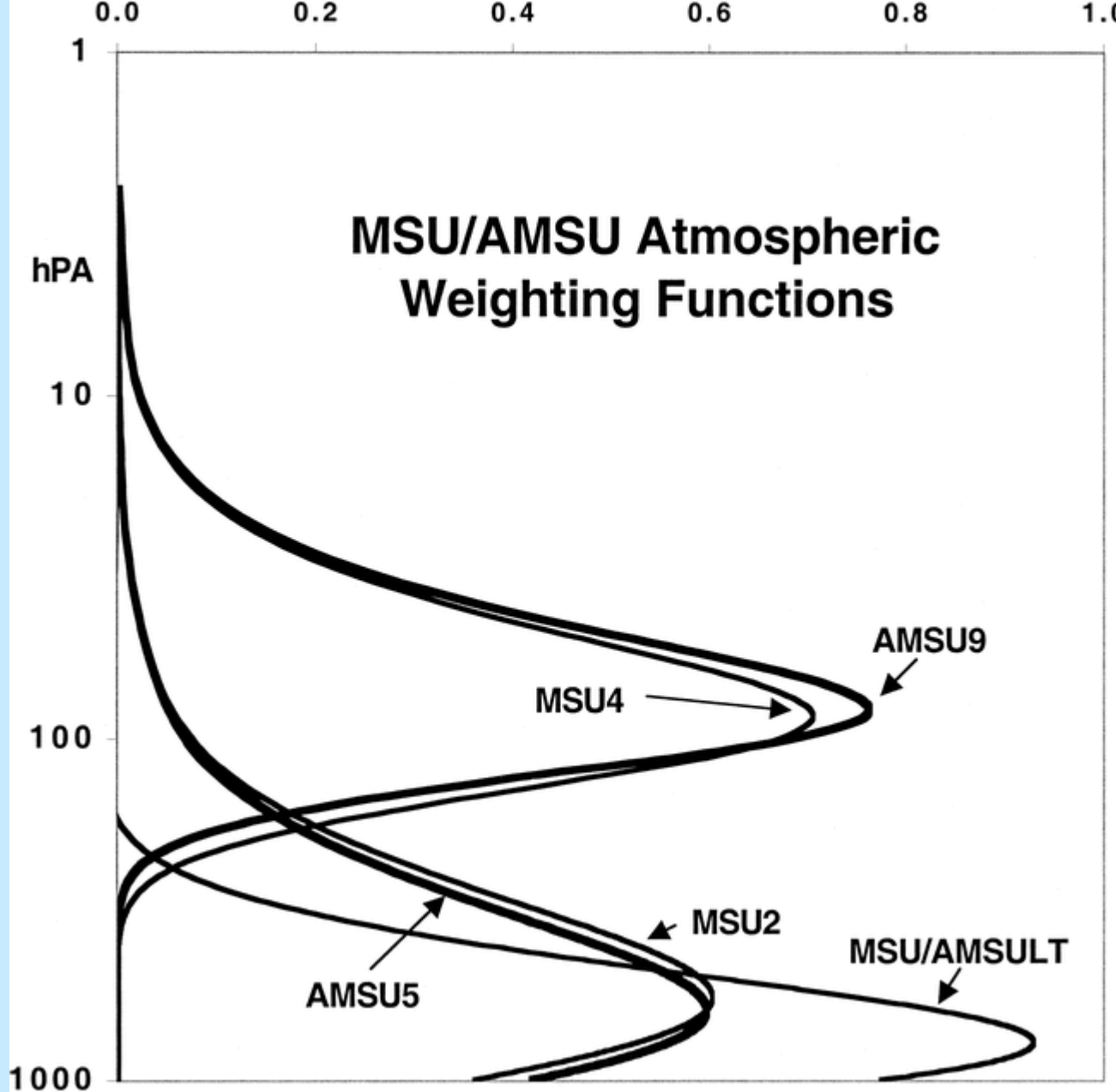
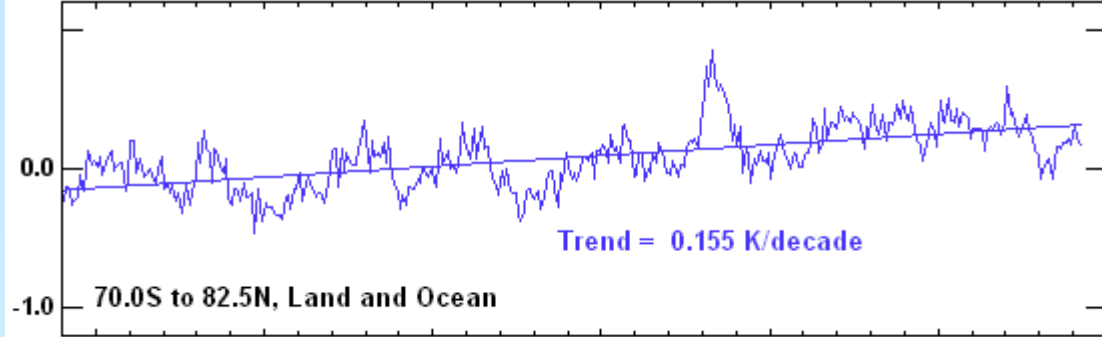


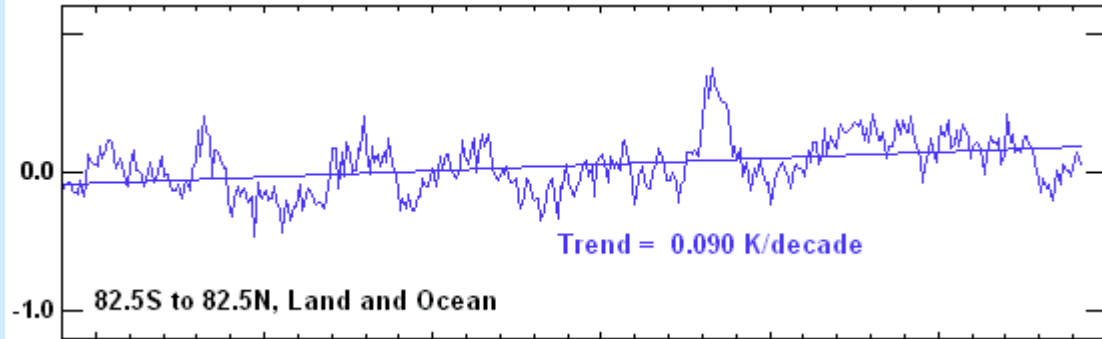
Fig. 1. Static atmospheric weighting function profile for the MSU and AMSU products. Not shown is the surface contribution factors, which for land (ocean) for TLT are 0.20 (0.10) and for TMT are 0.10 (0.05) of the total weighted profile. The land surface contribution increases for higher surface altitudes

Poslední výsledky

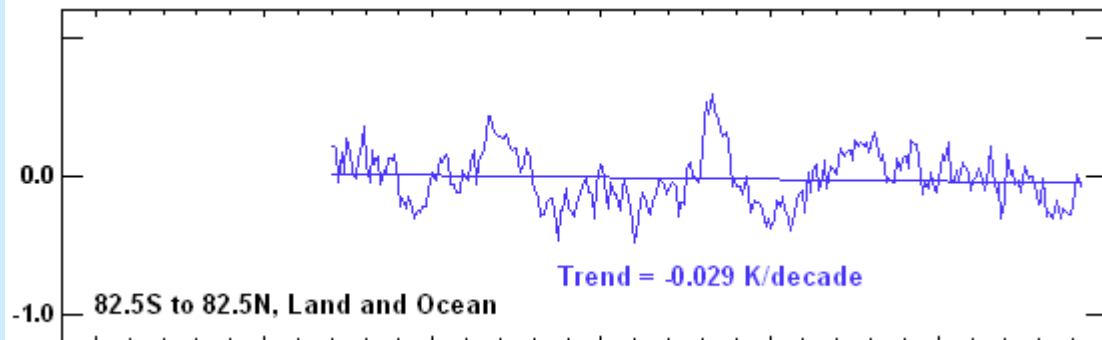
Global Brightness Temperature Anomaly (K)



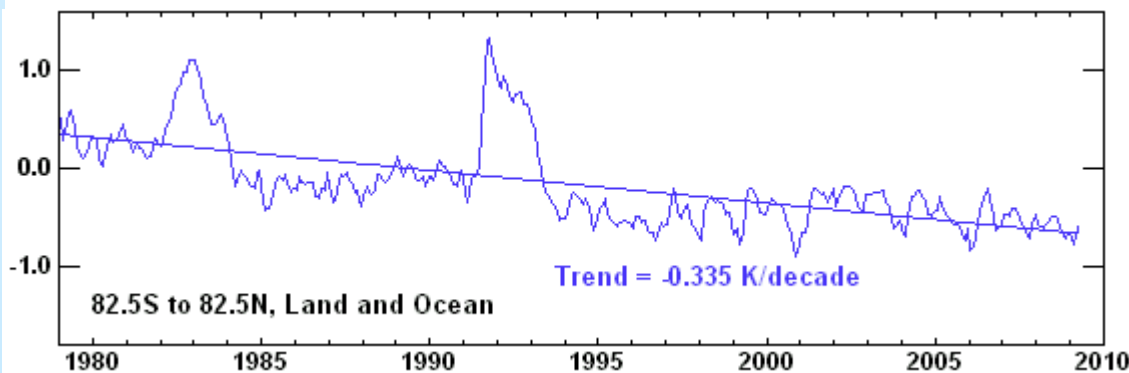
Ch. TLT



Ch. TMT



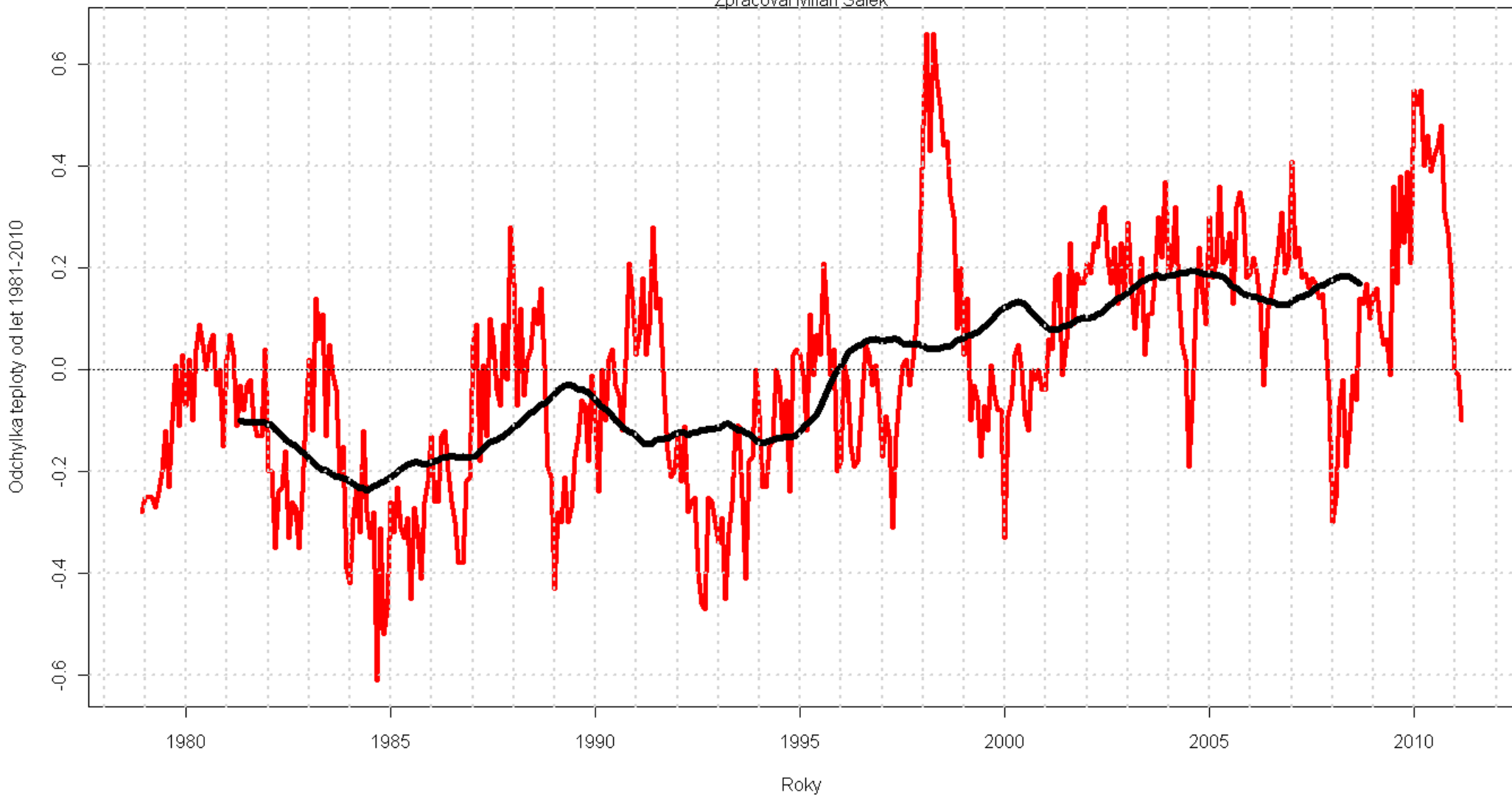
Ch. TTS



Ch. TLS

**Odchylky teploty spodní troposféry od průměru let 1981-2010 z družic NOAA/MSU,
algoritmus UAH, od roku 1979 s 5letým klouzavým průměrem údajů UAH**

Zpracoval Milan Šálek



IPCC, AR4, Ch. 9, p. 675

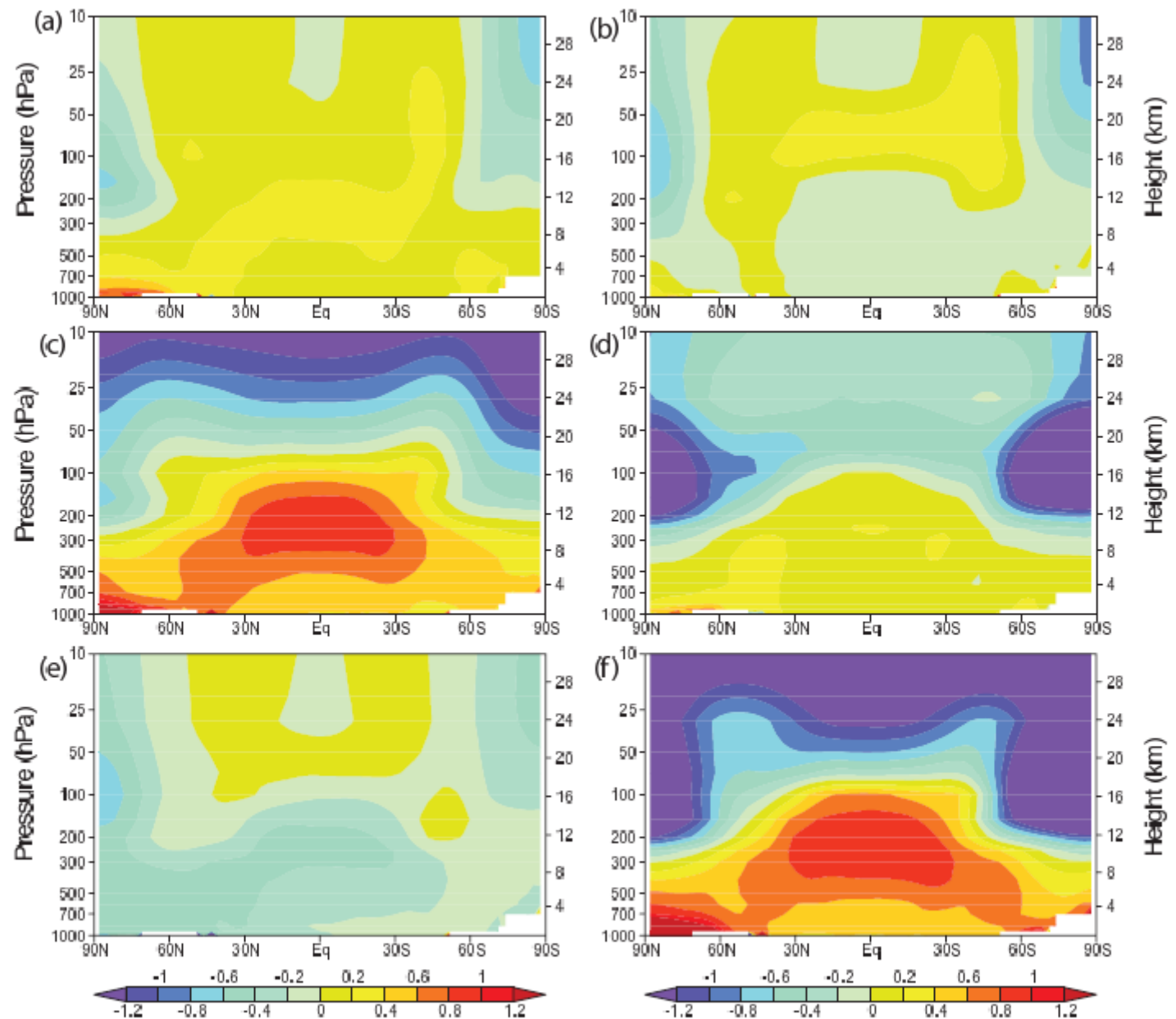
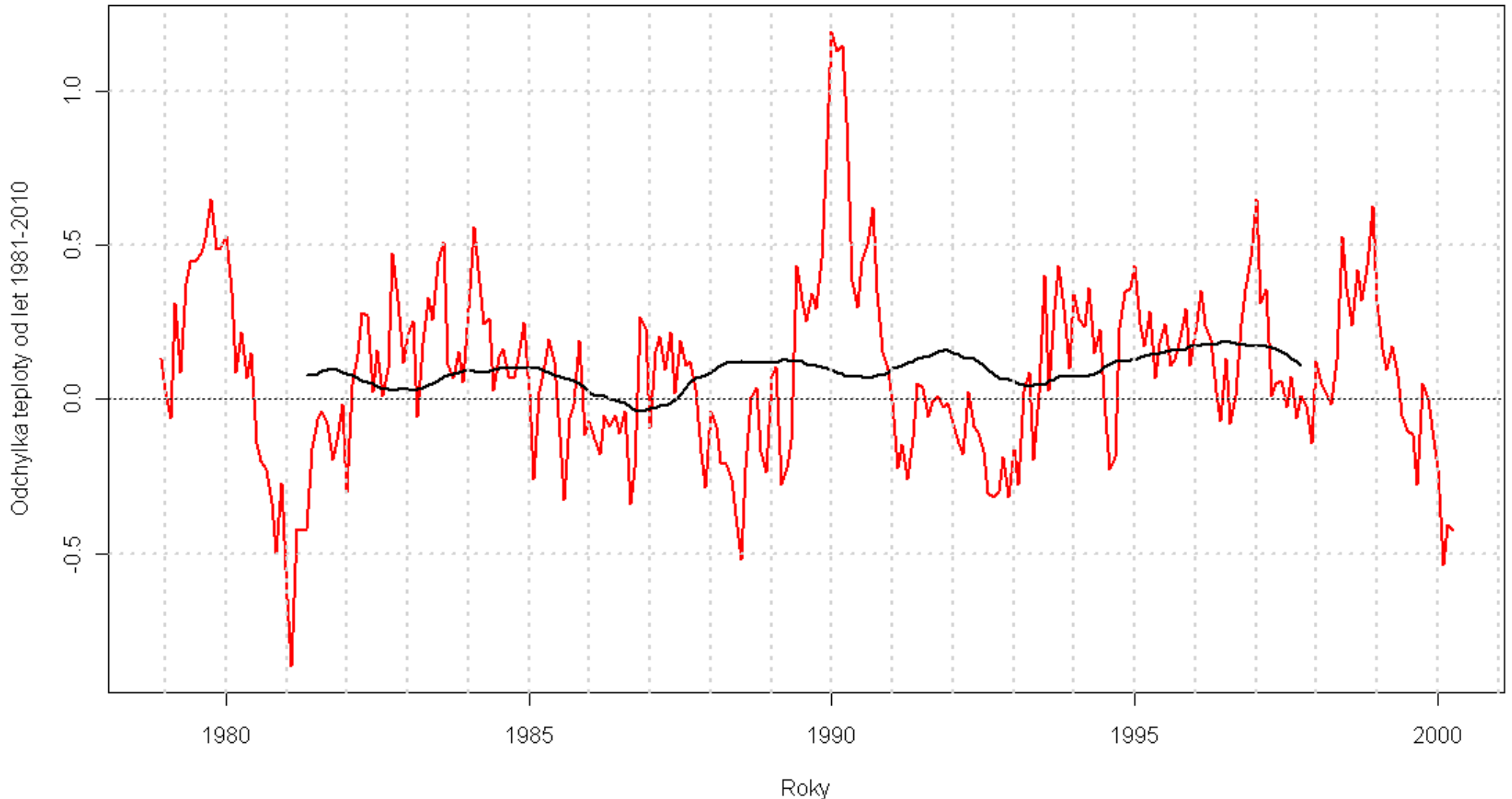


Figure 9.1. Zonal mean atmospheric temperature change from 1890 to 1999 ($^{\circ}\text{C}$ per century) as simulated by the PCM model from (a) solar forcing, (b) volcanoes, (c) well-mixed greenhouse gases, (d) tropospheric and stratospheric ozone changes, (e) direct sulphate aerosol forcing and (f) the sum of all forcings. Plot is from 1,000 hPa to 10 hPa (shown on left scale) and from 0 km to 30 km (shown on right). See Appendix 9.C for additional information. Based on Santer et al. (2003a).

Teplota TTS (cca 200-300 hPa), 20 st od rovníku, algoritmus RSS, III/2011

Odchyly teploty horní troposféry a spodní stratosféry v tropech od průměru let 1981-2010 z družic NOAA/MSU, (červeně) a 5letý klouzavý průměr (černě), od roku 1979



Monitoring mořského ledu

- Založen na informacích MSU/AMSU, popř. SSM/I, AMSR-E
 - SSM/I:
 - Defense Meteorological Satellite Program (DMSP)
Special Sensor Microwave/Imager(SSM/I)
 - Advanced Microwave Scanning Radiometer
AMSR-E, družice Aqua (EOS – Earth
observing satellite)

Algoritmus detekce koncentrace mořského ledu

TB1 : AMSU Channel 1
brightness temperature (23.8
GHz)

TB2 : AMSU Channel 2
brightness temperature (31.4
GHz)

TB3 : AMSU Channel 3
brightness temperature (50.3
GHz)

W : scattering parameter
m : cosine of local zenith angle

- **SIce - Sea Ice Concentration**

- Retrieved emissivity at 23.8 GHz (Channel 1) is

$$e = a + b \text{ TB1} + c \text{ TB2} + d \text{ TB3}$$

- where $a = 1.84 - 0.723 m$; $b = -0.00088$; $c = 0.0066 + 0.0029 m$; $d = -0.00926$.

- Emissivity of water is

$$e_{\text{water}} = 0.1824 + 0.9048 m - 0.6221 m^2$$

Emissivity of ice is

$$e_{\text{ice}} = \begin{cases} 0.93, & \text{if } (TB1 - TB2) < 5 \text{ K} \\ 0.87, & \text{if } 5 < (TB1 - TB2) < 10 \text{ K} \\ 0.83, & \text{if } 10 < (TB1 - TB2) \end{cases}$$

Sea ice concentration (%) is computed from

$$s_{\text{ice}} = 100 (e - e_{\text{water}}) / (e_{\text{ice}} - e_{\text{water}})$$

Note:

1. Sea ice concentration is set to be zero in the latitude band from -50° to 50° .
2. A cutoff value of 30% is applied in the sea ice concentration algorithm.

<http://www.star.nesdis.noaa.gov/corp/scsb/mspps/algorithms.html>

Detekce mořského ledu

- Koncentrace mořského ledu – *sea ice concentration* (podíl ledu/vody)
 - problém s vodou na ledu (!)
- Rozsah mořského ledu - *sea ice extent*
 - oblast, kde je koncentrace mořského ledu nejméně 15%
 - pozor na rozlišení (průměr oblasti 50-100 km)
- Plocha mořského ledu - *sea ice area*:
 - (Rozsah(>15%) x koncentrace)

Sea Ice Extent
04/25/2011



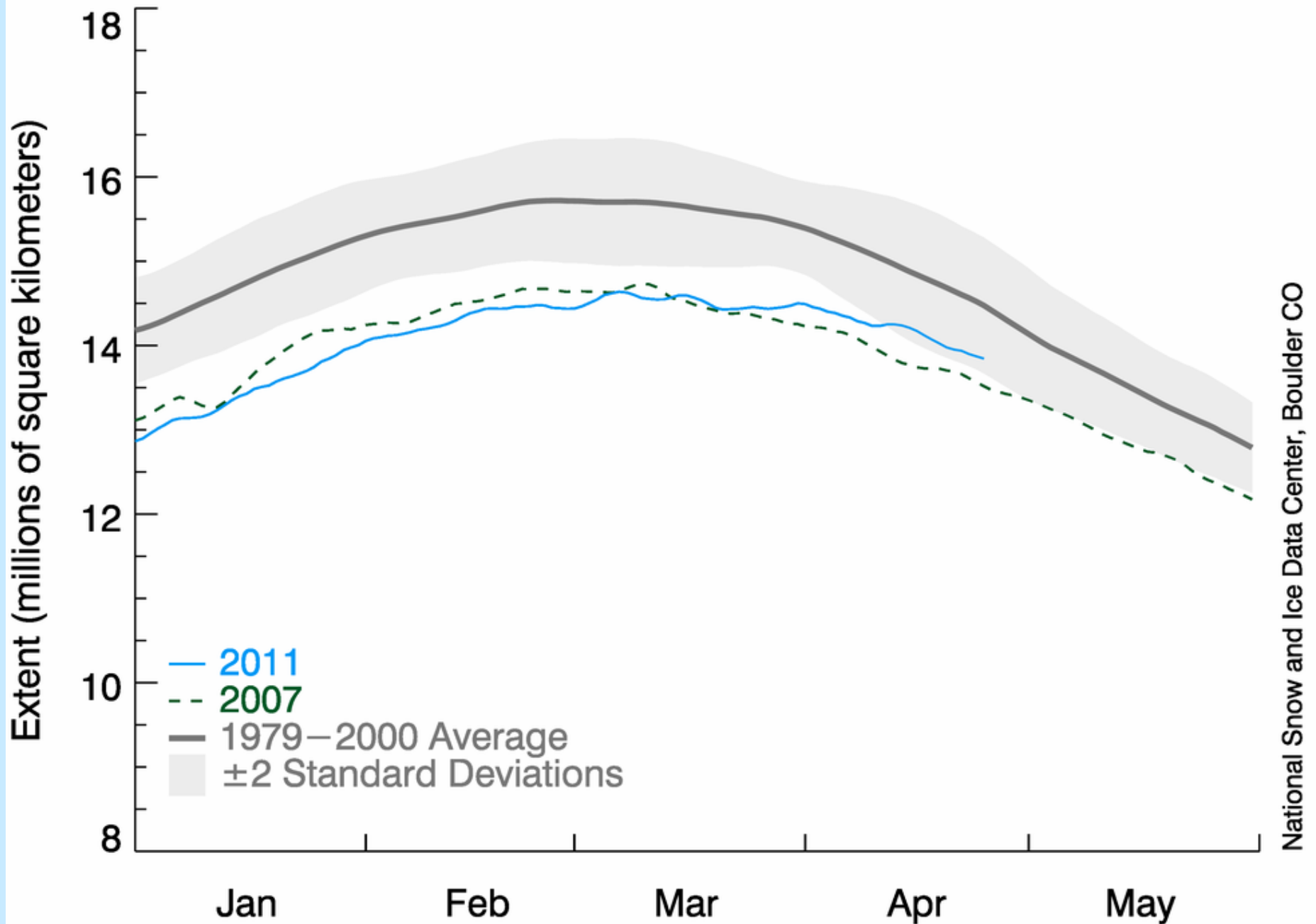
National Snow and Ice Data Center, Boulder, CO

median
1979-2000

http://nsidc.org/data/seaice_index/

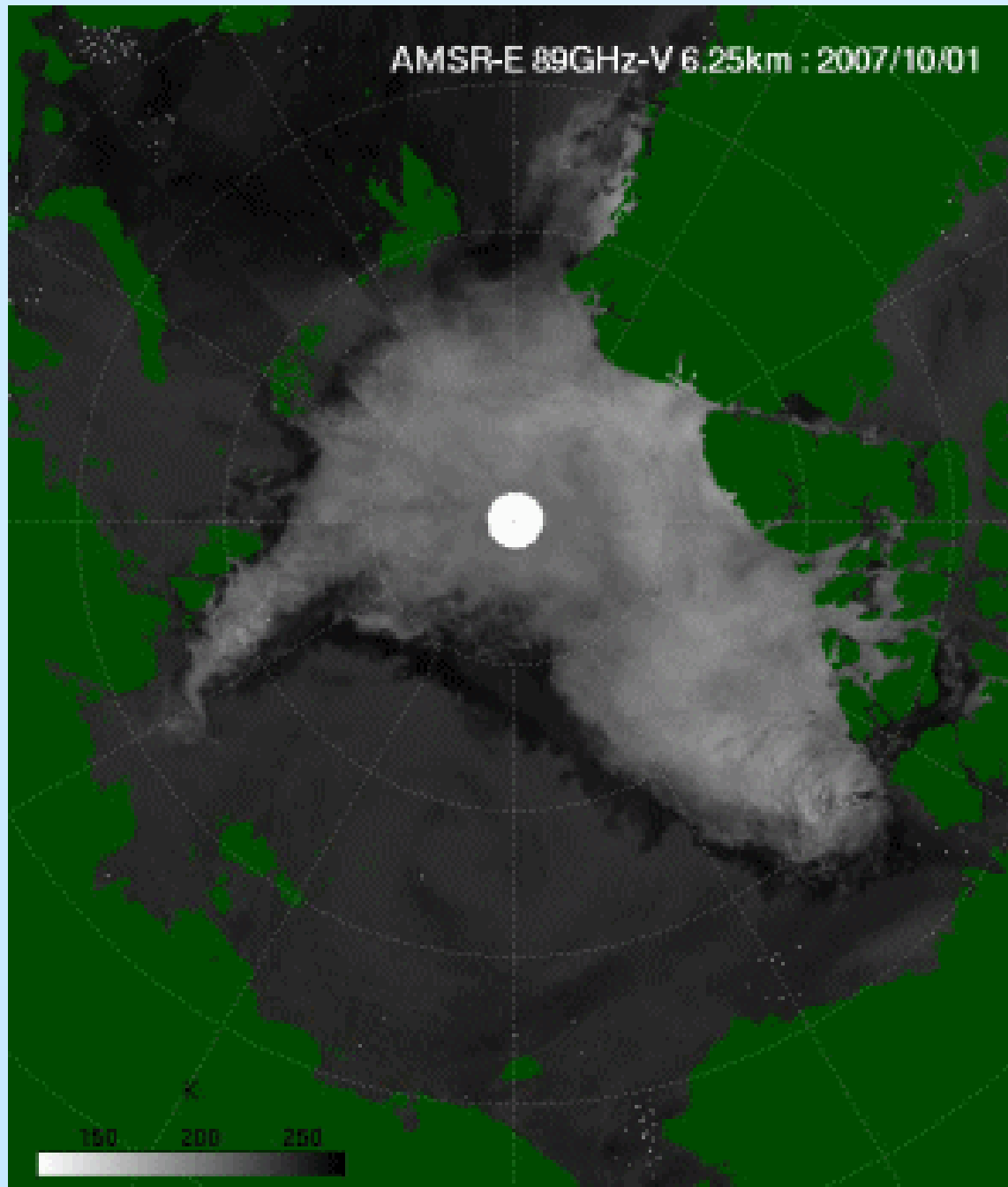
Arctic Sea Ice Extent

(Area of ocean with at least 15% sea ice)



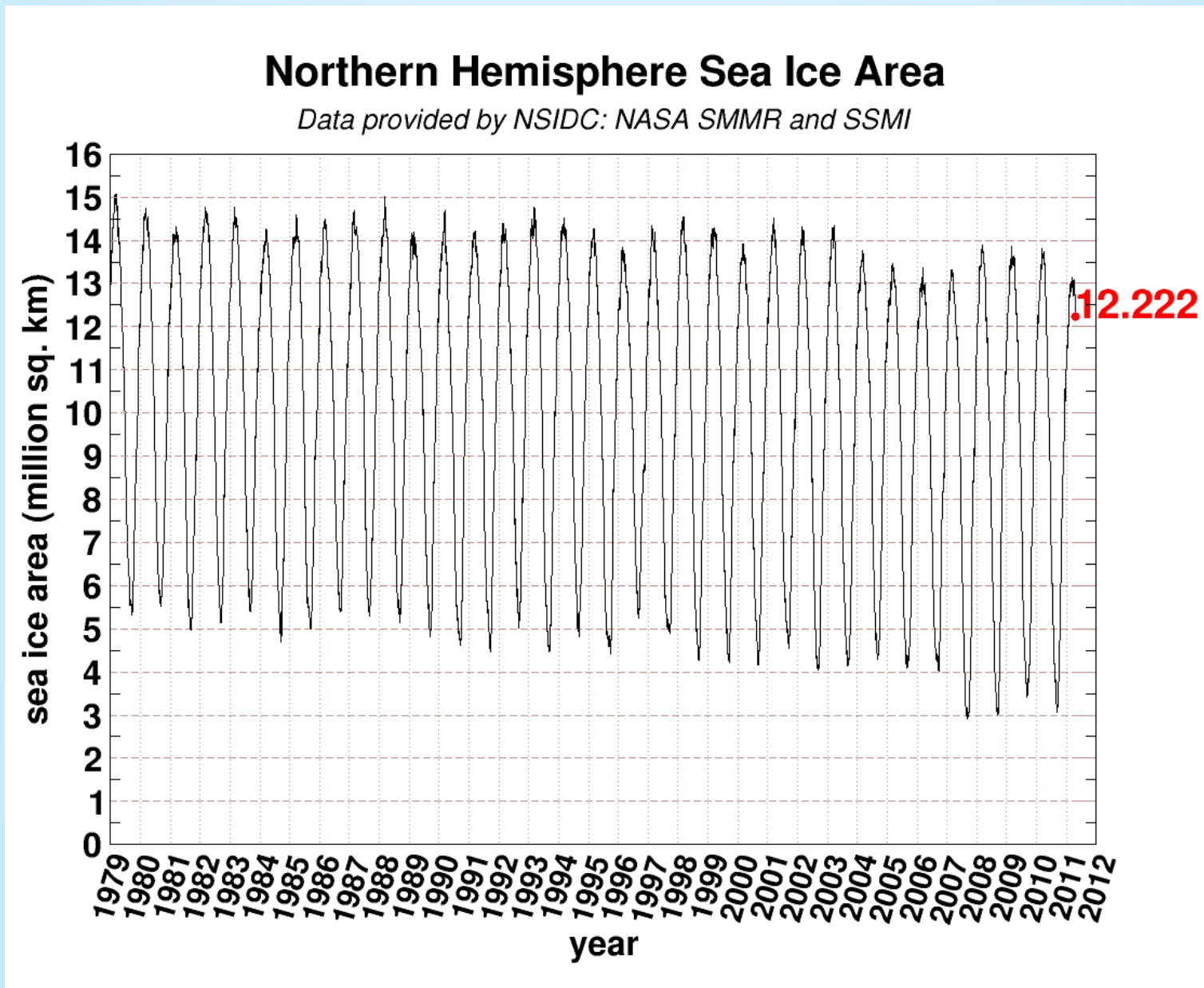
National Snow and Ice Data Center, Boulder CO

Advanced Microwave Scanning Radiometer - EOS (AMSR-E), družice Aqua

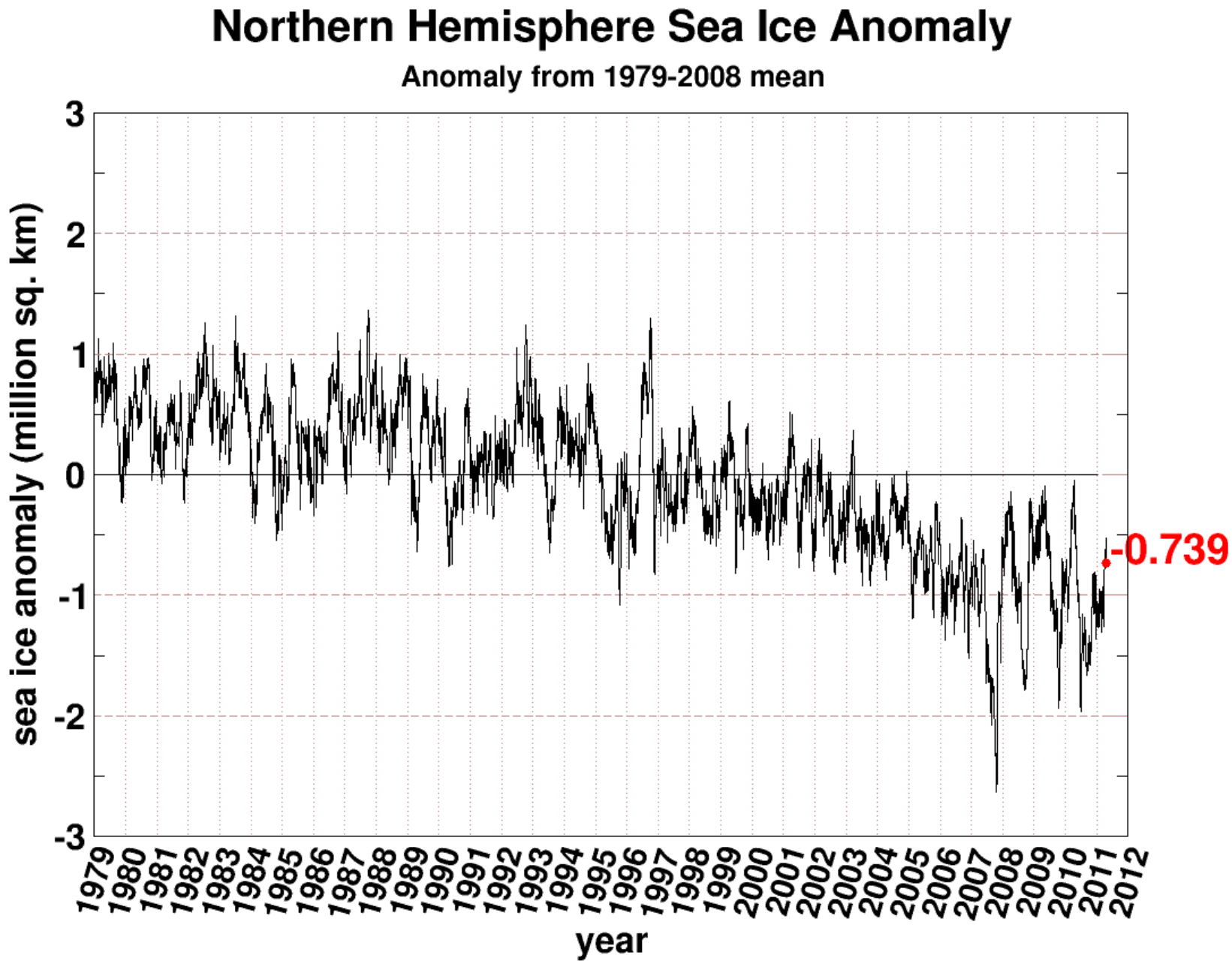


Plocha mořského ledu – Arktida

<http://arctic.atmos.uiuc.edu/cryosphere/>

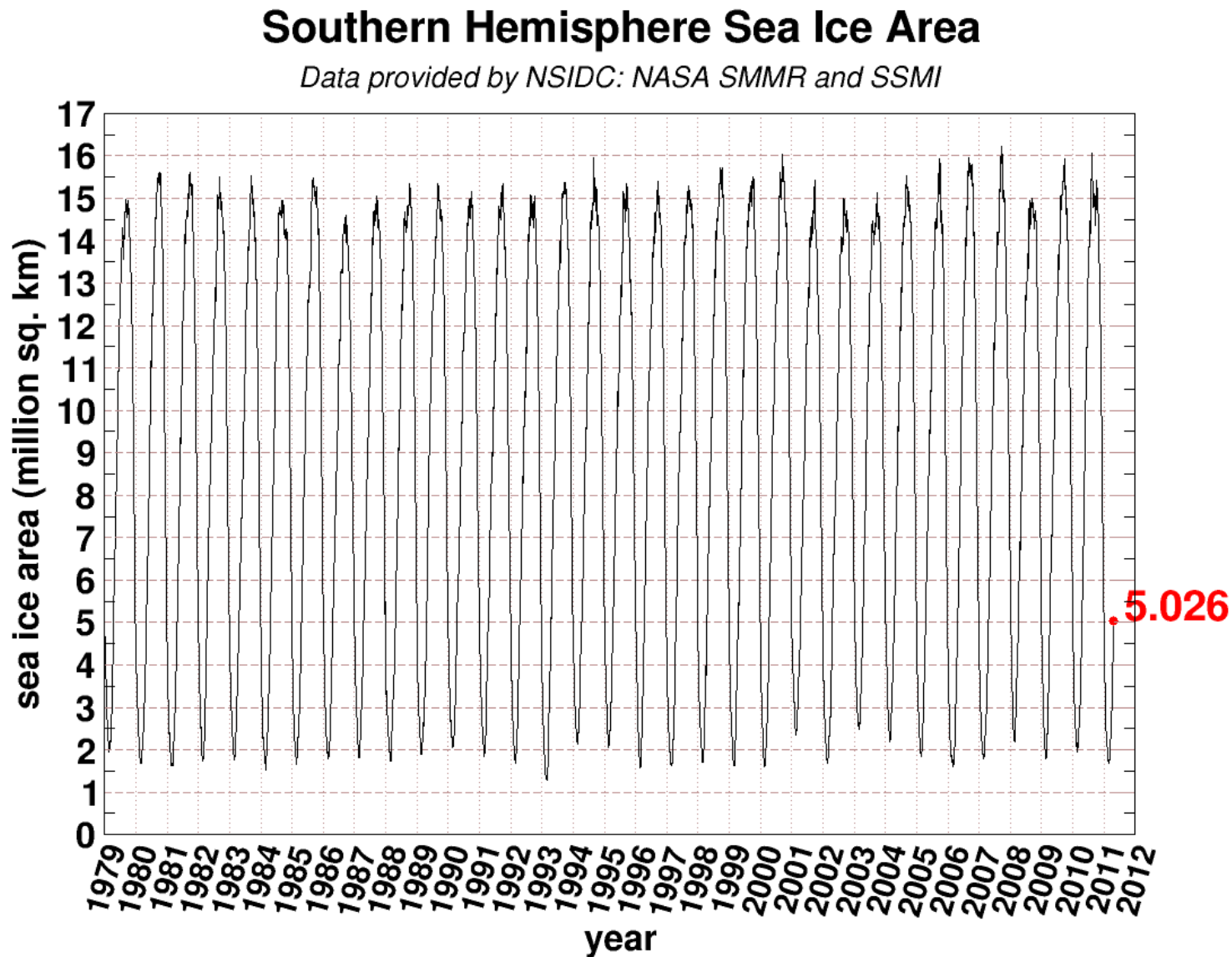


Plocha mořského ledu – Arktida

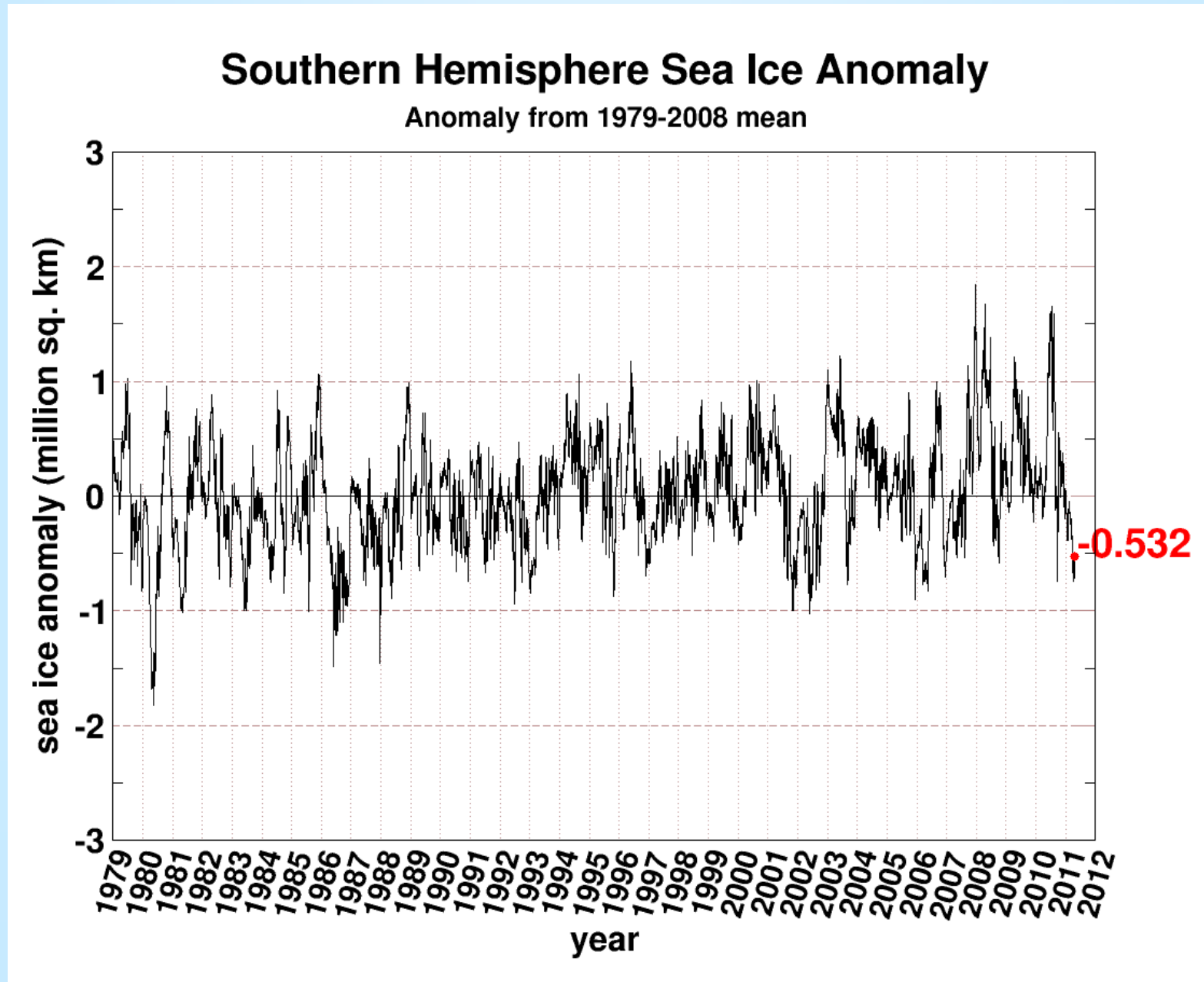


Plocha mořského ledu – Antarktida

<http://arctic.atmos.uiuc.edu/cryosphere/>

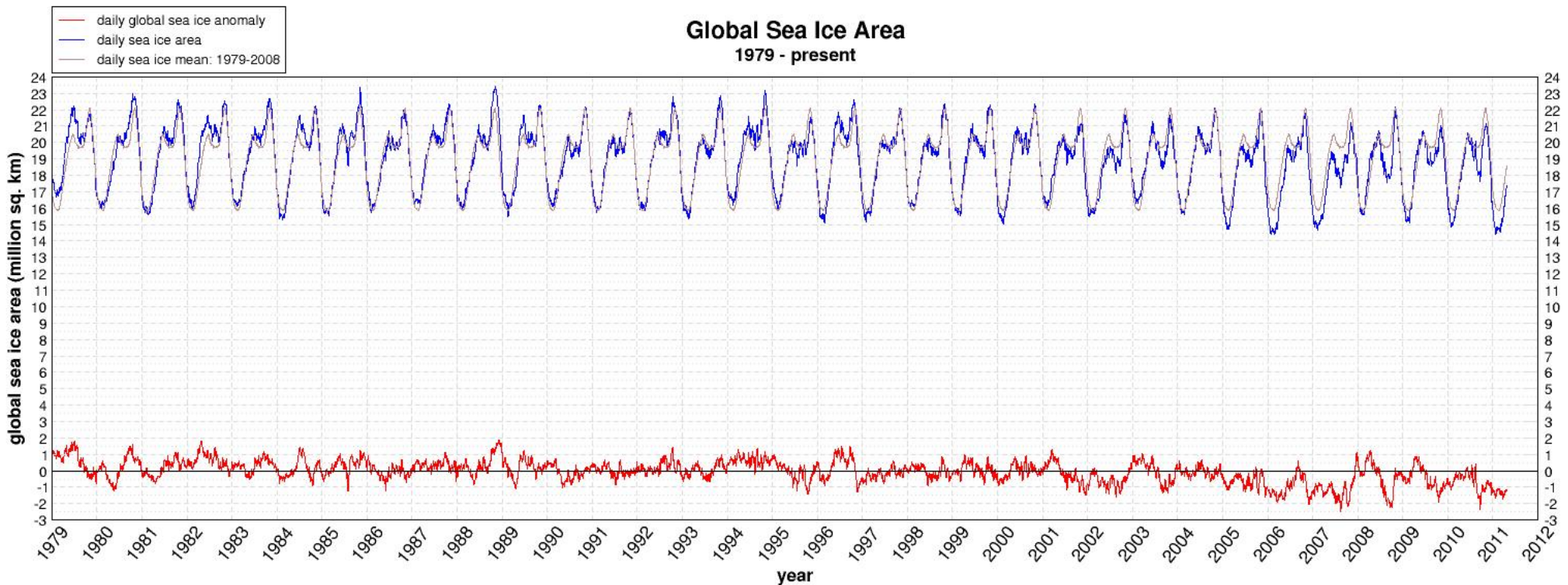


Plocha mořského ledu – Antarktida



Cryosphere today – součet plochy mořského ledu

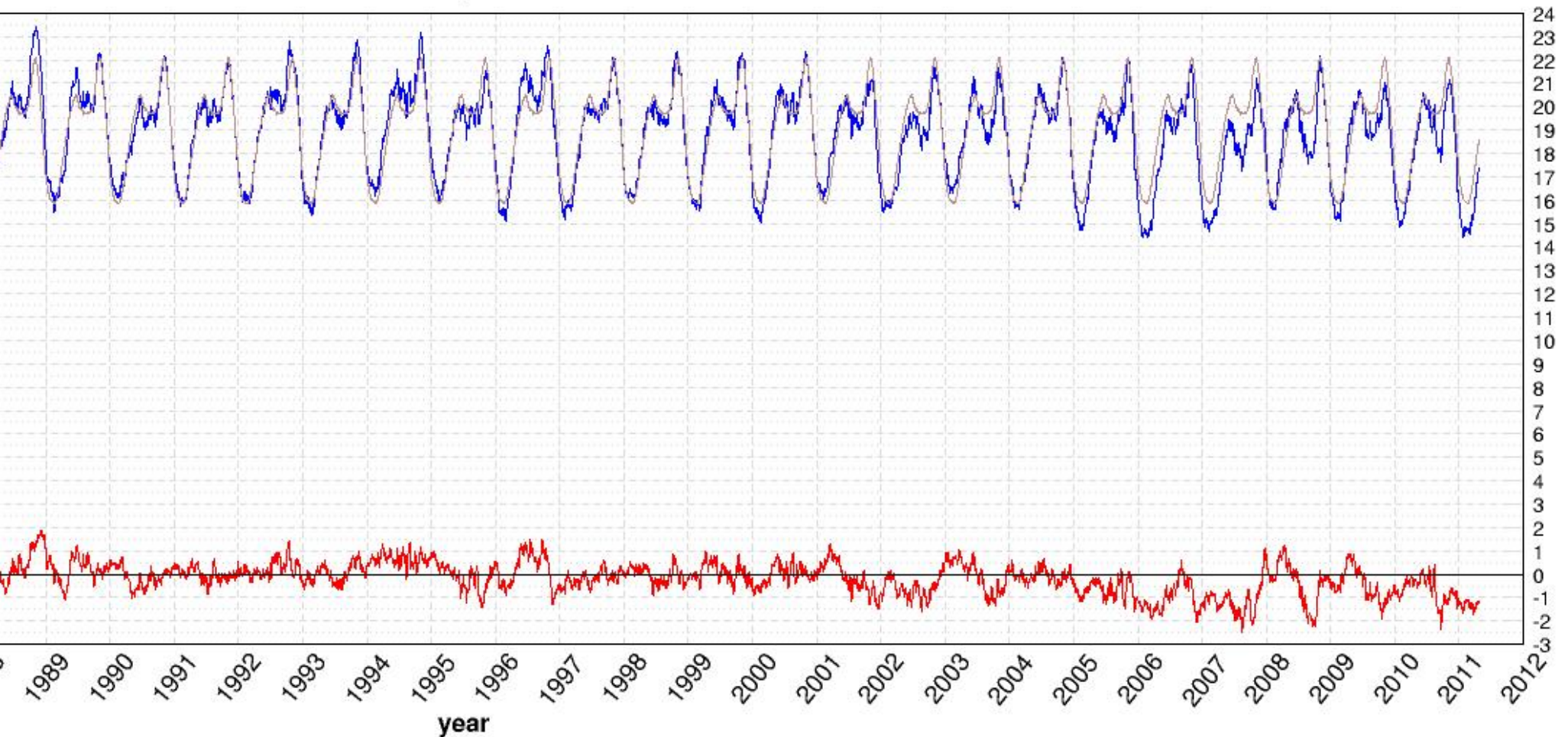
<http://arctic.atmos.uiuc.edu/cryosphere/>



Cryosphere today – součet plochy mořského ledu

<http://arctic.atmos.uiuc.edu/cryosphere/>

Global Sea Ice Area
1979 - present



International Arctic Research Center (IARC)+Japan
Aerospace Exploration Agency (JAXA)

http://www.ijis.iarc.uaf.edu/en/home/seaice_extent.htm

