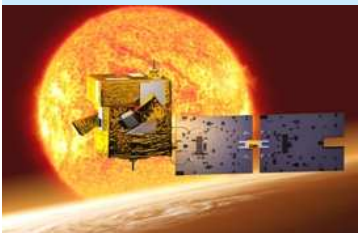


“Solar Variability, Earth’s Climate and Space
Environment” June 1-6, 2008
Bozeman, Montana

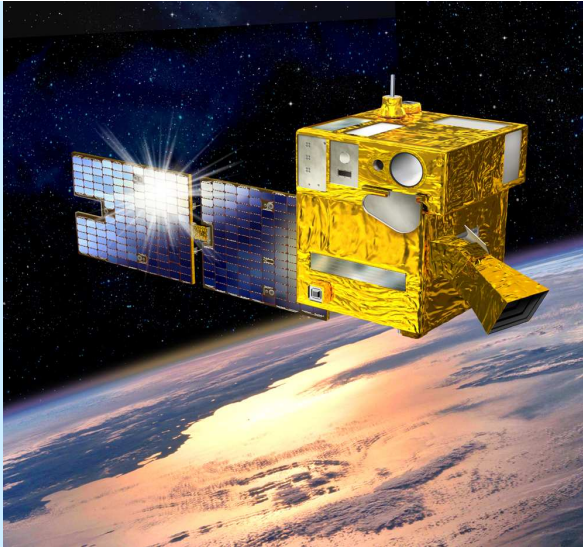
PREMOS/PICARD
LYRA/PROBA2
—
Instruments and Scientific Objectives

Werner Schmutz and
the LYRA + PICARD teams
PMOD/WRC, Switzerland

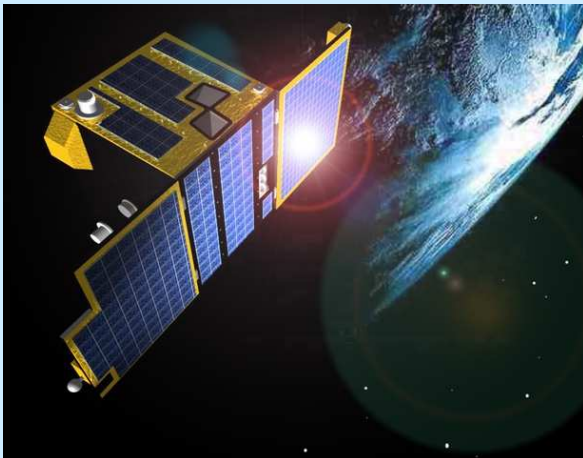


- PREMOS/PICARD
 - Total Solar Irradiance
- Absolute calibration of TSI instruments
- Filter radiometers:
 1. PREMOS/PICARD
 2. LYRA/PROBA2
- Science goal → Nowcasting:
 - Solar influence on the terrestrial middle atmosphere

Launch schedules

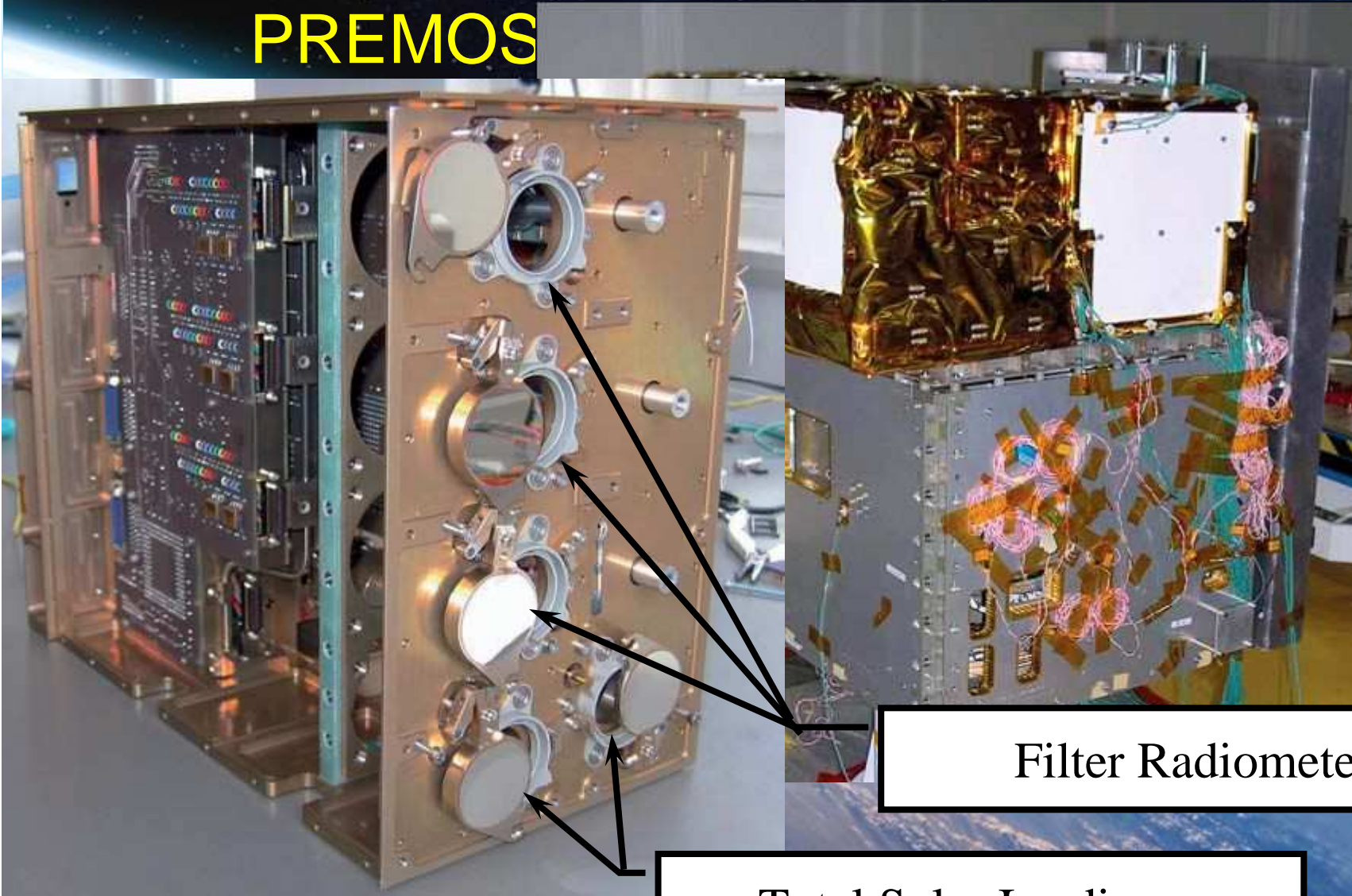


- PICARD
launch mid 2009



- PROBA2
launch end 2008
(probably beginning
of 2009)

PREMOS PICARD



Filter Radiometers

Total Solar Irradiance

PREMOS/PICARD characteristics

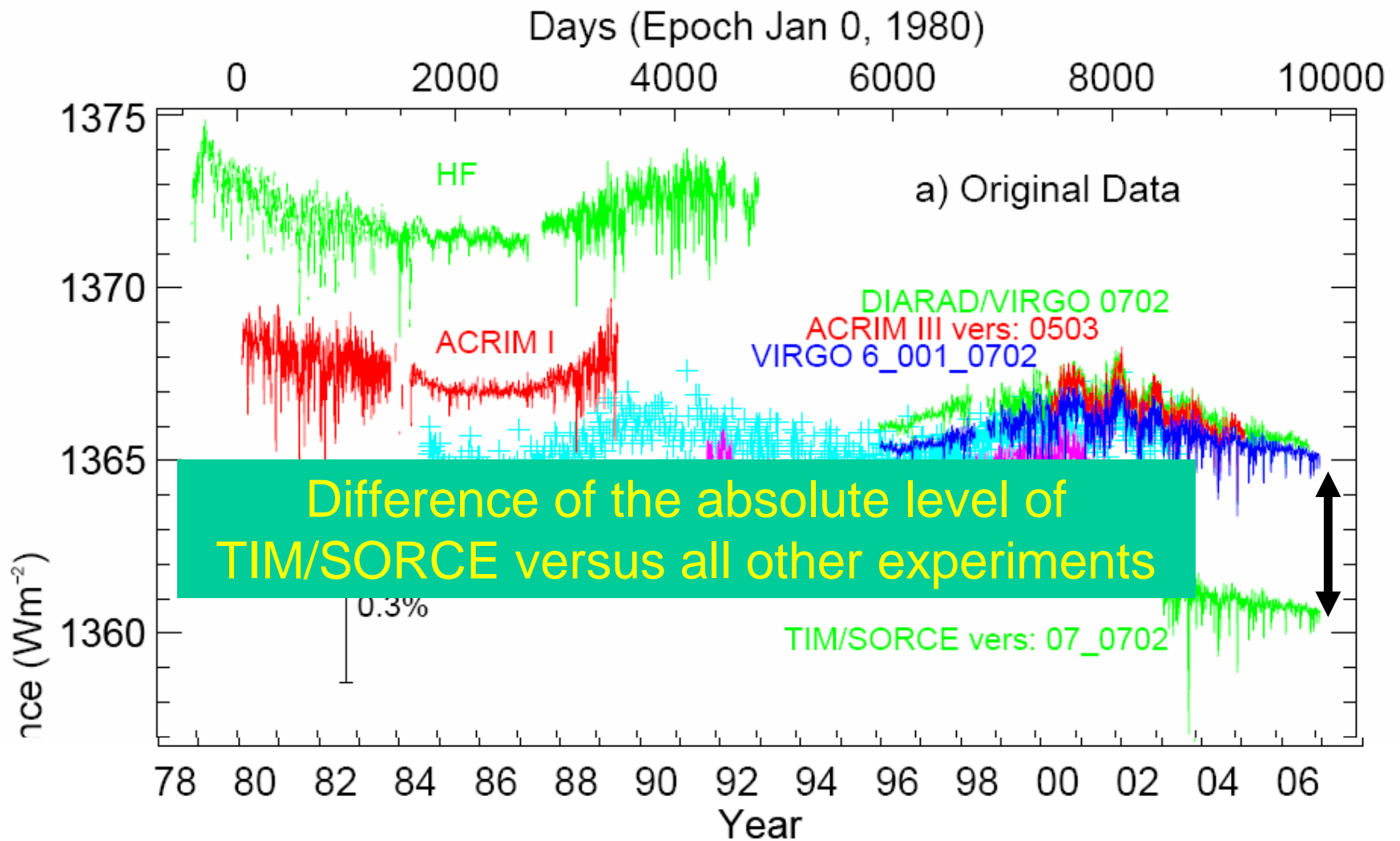


- MASS: 11 kg
- Overall Dimensions:
270 x 327 x 160 mm
- Power Requirement
13W nominal
- Data Rate
3.6 MB/day



- PREMOS-TSI:
 - 2 absolute radiometers
 - internal evaluation of sensitivity changes
- PICARD TSI:
2 TSI experiments as on VIRGO/SOHO
- Anticipated accuracy:
 - absolute accuracy to SI: $\pm 0.1\%$ = $\pm 1 \text{ W/m}^2$
calibration against cryogenic radiometer at NPL
 - relative accuracy $\pm 30 \text{ ppm}$
 - long term stability 5 ppm/year
- PREMOS filter radiometers: ... see below

PREMOS & SOVAP on PICARD: → new calibrated TSI experiments



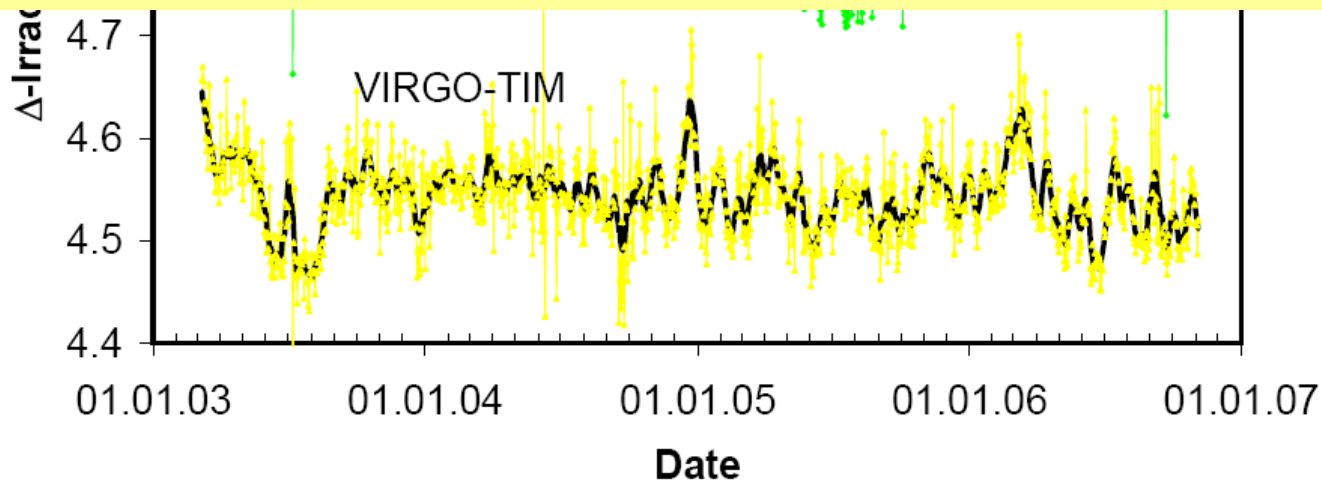
Empirical TSI accuracy

Difference between active absolute radiometers 2003 – 2006

$$\langle \text{VIRGO-TIM} \rangle = 4.54 \pm 0.03 \text{ W/m}^2$$

→ corresponds to ± 30 ppm !

trend 20 ppm in 4 years $\square < 5$ ppm/year !!



TSI absolute accuracy

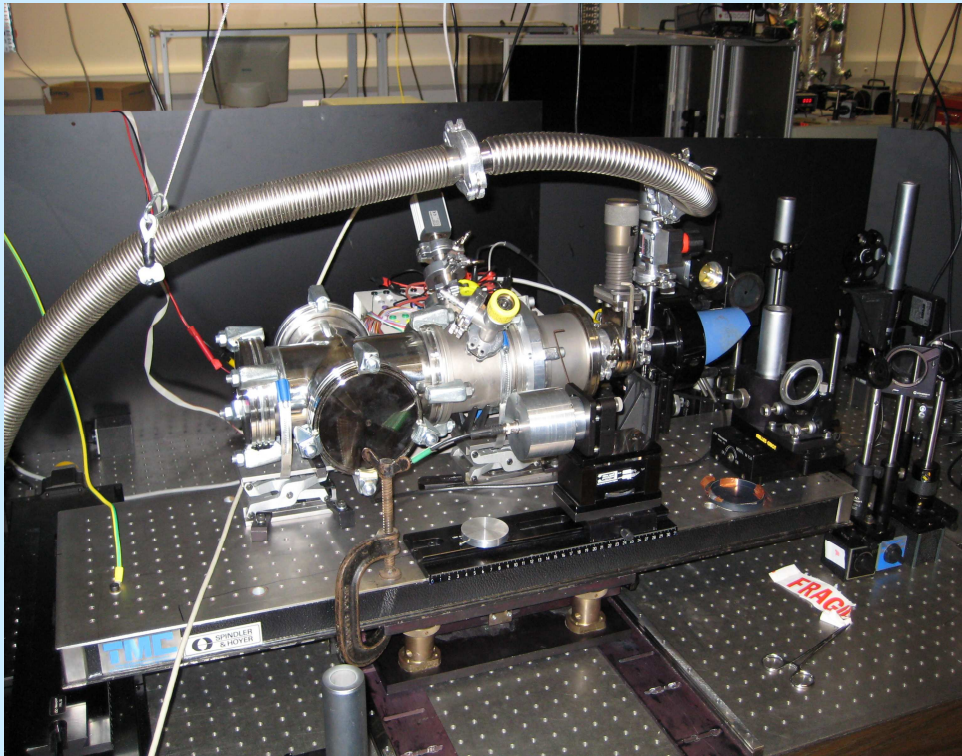


- All TSI experiments are absolutely characterized ...
- VIRGO and SOVIM are traceable ...!
- ... to the World Radiometric Reference, the primary irradiance standard

but ...

- Irradiance primary standard is the
 - World Radiometric Reference (WRR) maintained at the World Radiation Center Davos
 - ... which is operated in air !
 - air-to-vacuum correction is needed, which introduces a large uncertainty term

Vacuum calibration at NPL



- PREMOS TSI instruments are calibrated in power against cryogenic NPL primary standard.

New: PREMOS will be the first vacuum calibrated space radiometer

Fehlmann et al. in preparation

Power comparisons

- Cryogenic primary standards for
→ power
exist; but ...
- ... in this case power-to-irradiance characterization
is required
- power-to-irradiance accuracy of PREMOS has not
been finalized (work in progress)
→ PREMOS irradiance accuracy is not yet known

Future TSI experiments

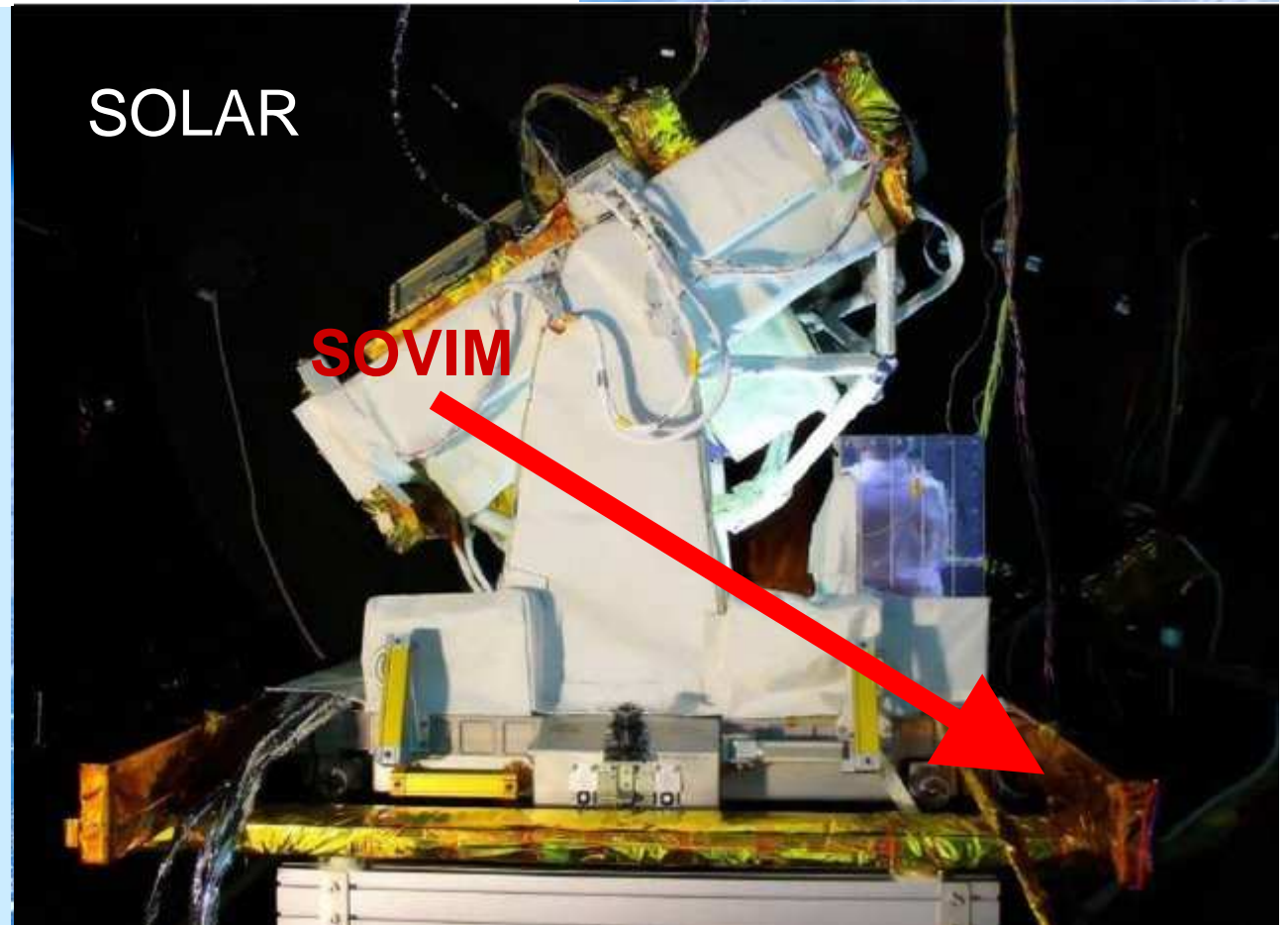
- GLORY (no launch date ?)
- SOVIM/ISS (launch February 2008)
first observations still being evaluated
- PREMOS+SOVAP /PICARD (launch 2009)
- RAD/KuaFu-A the only future TSI experiment
presently being considered by ESA
(launch 2015 ??)

STS 122 Atlantis to the ISS



SOVIM, a PMOD/WRC experiment on SOLAR, a platform on COLUMBUS on the ISS.

Launch with space shuttle Atlantis February 7, 2008.



ISS February 2008

pmod wrc

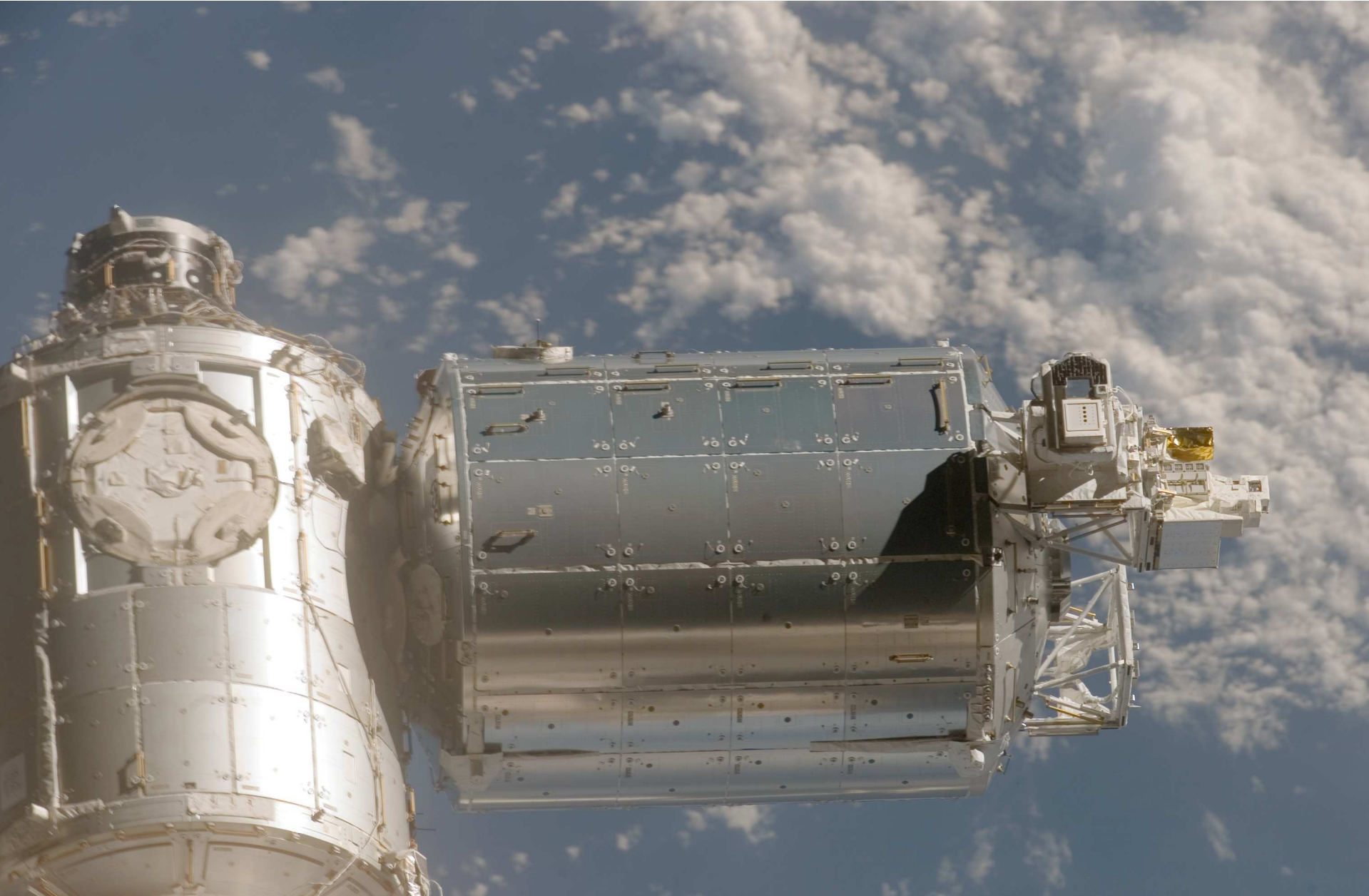


Columbus

pmod wrc



SOLAR on Columbus



SOVIM/SOLAR

pmod wrc



Total Solar Irradiance observations between 2006 and 2012



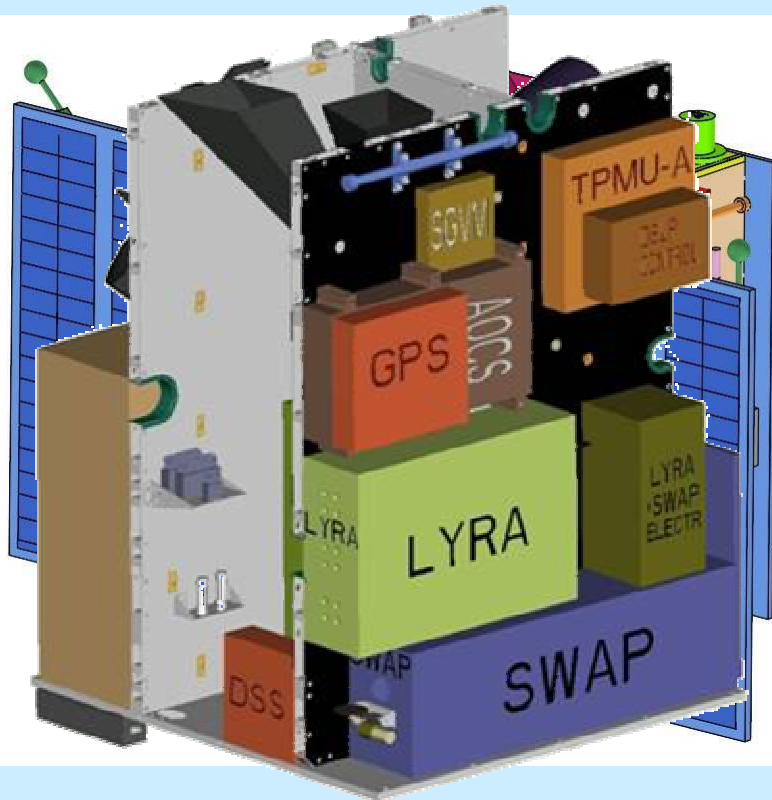
| | | | |
|---|----------|-----------------|----------------------|
| ACRIM III | 2000 - ? | | |
| VIRGO/SOHO | 1996 - | 2007 - | 2009 + ? |
| TIM/SORCE (GLORY) | 2003 - | 2008 - | 2012 |
| SOVIM/ISS | | 2008 - 2009 - ? | |
| PREMOS-TSI/ PICARD | | 2009 - | 2011 (2013) |
| SOVAP/PICARD | | | |
| KuaFu-A | | | 2015(?) |
| TSI-instrumentation comprising: | | | |
| SIM = Solar Irradiance Monitor (CN) | | | |
| DOR = Davos Observatory Radiometer (CH) | | | |

Conclusions TSI

- Long-term relative TSI reconstruction is probably reliable to $\pm 0.1 \text{ W/m}^2$ (0.01% , 100 ppm)
- With PICARD and SORCE the TSI observations are most likely continues and overlapping until about 2012 +
- So far nothing approved beyond 2012
- more than 1 TSI experiment in space at any time is mandatory!

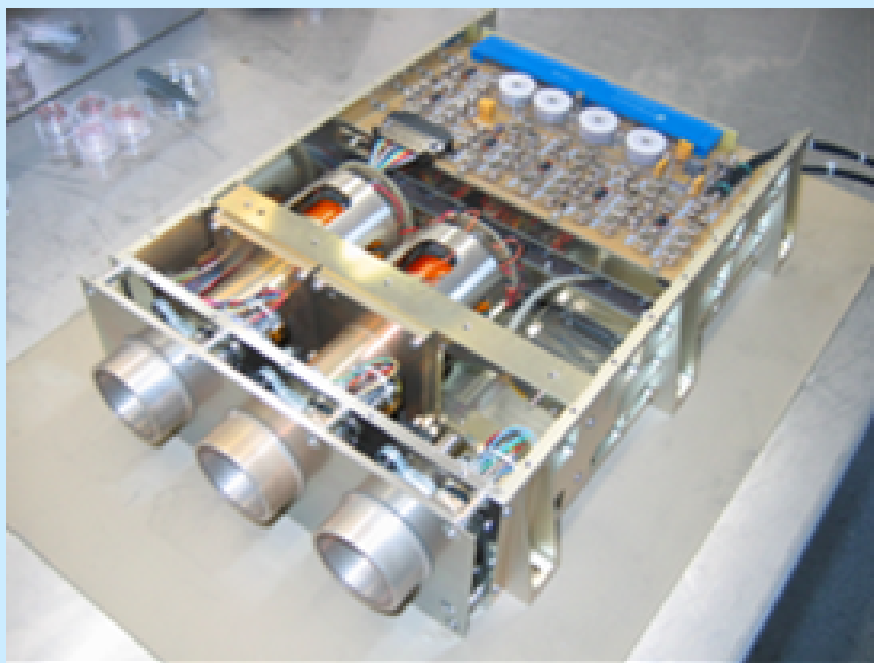
PROBA 2

2 solar instruments



- **LYRA**
 - UV radiometer
 - PI: JF Hochedez
 - PMOD/WRC built hardware
 - LYRA.oma.be
- **SWAP**
 - EUV imager at 17.5 nm
 - PIs: D Berghmans & JM Defise
 - SWAP.oma.be

LYRA (FM March 2006)



BESSY synchrotron
calibration at PTB



LYRA integration on PROBA2 5.3.2007

pmod wrc



6.6.2008

Filter radiometers:

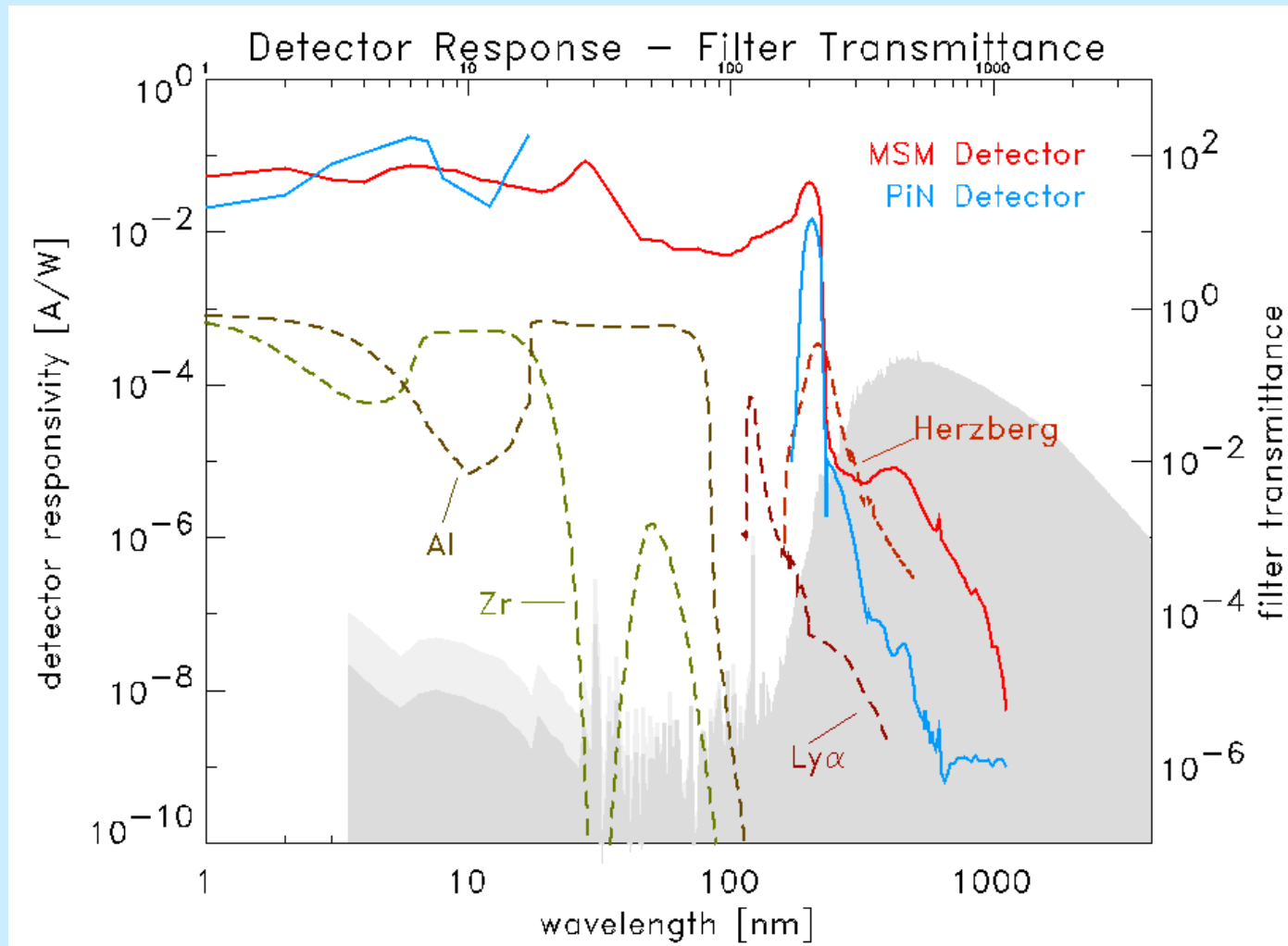
cadence:

- 50 Hz

channels (2 of each):

- 30 nm (Zr-filter)
- 70 nm (Al-filter)
- 121 nm Ly α
- 210 nm O₃ Herzberg band

LYRA filters



Slide: J.F. Hochedez (ROB)

Filter radiometers:

cadence:

- 10 Hz in one channel (selectable)
- all others: 1 min

channels (2 of each):

- 210 nm (25 nm) Herzberg O₃ band
- 215 nm (7 nm) Herzberg O₃ band
- 266 nm (20 nm) Hartley O₃ band
- 535.75 nm (0.6 nm) identical filters as on SODISM/PICARD
- 607.16 nm (0.9 nm) “
- 782.30 nm (1.7 nm) “

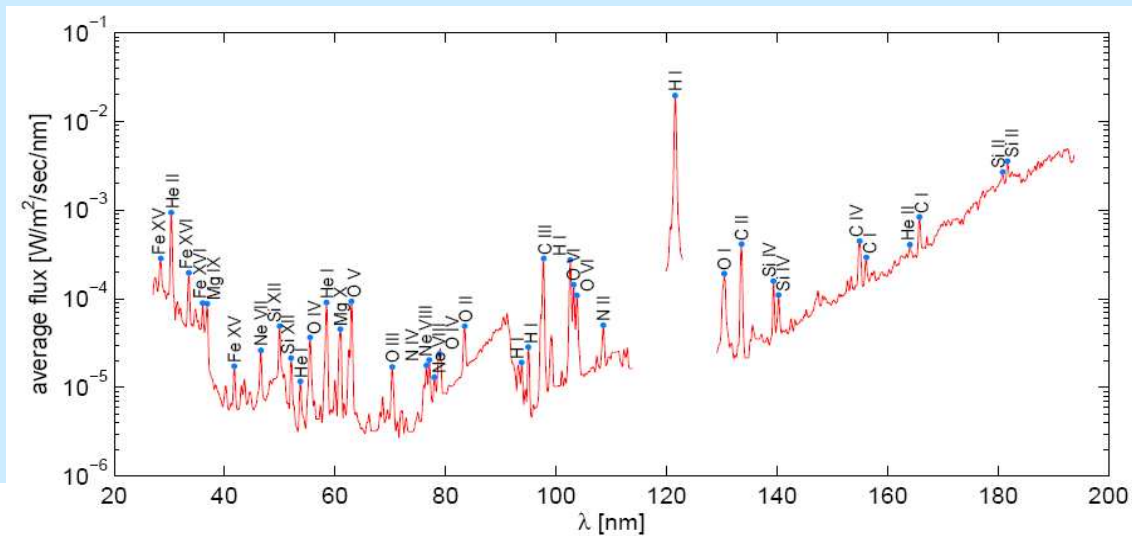
Filter Radiometers

LYRA/PROBA2 (launch November 2008 ?)

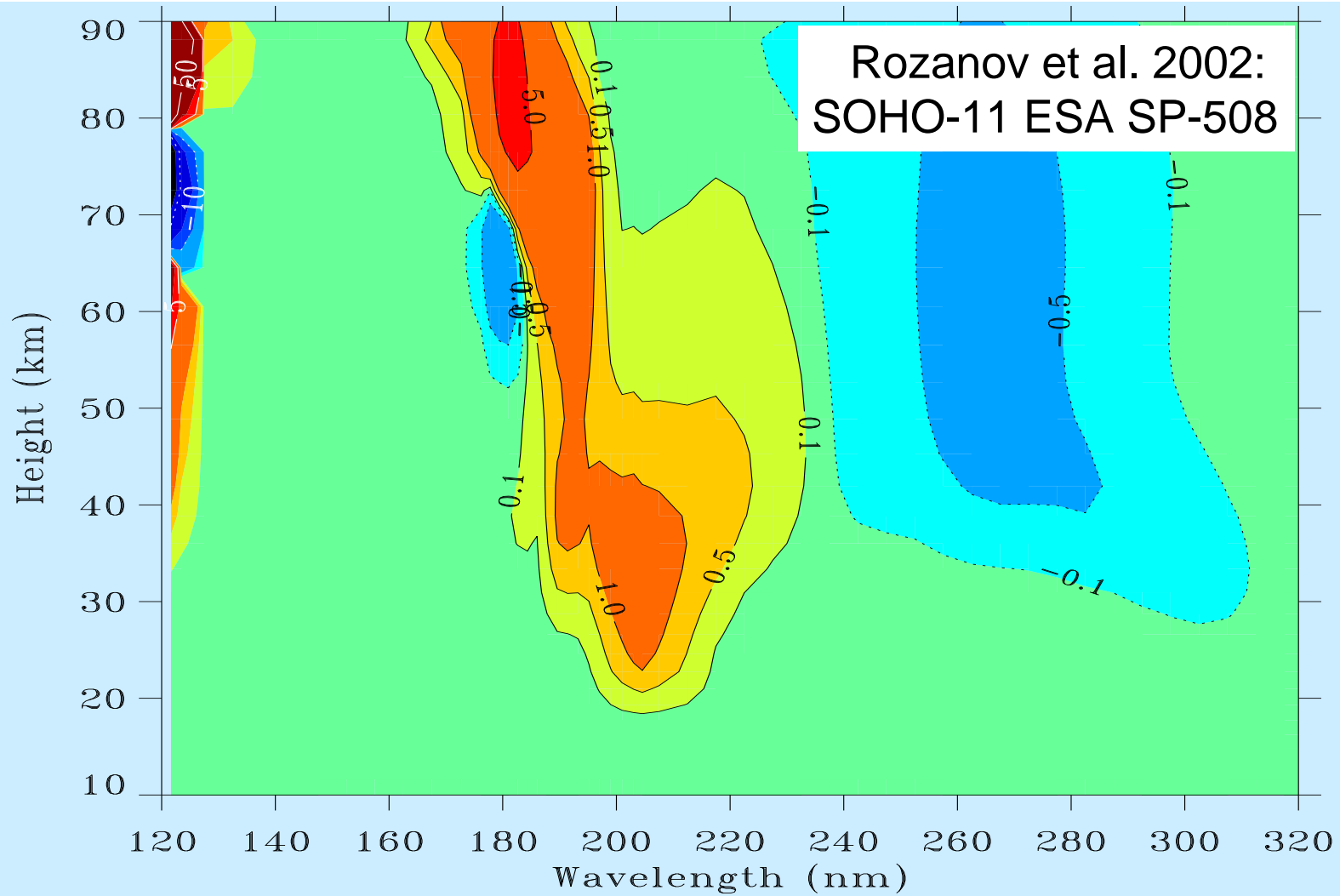
PREMOS-PFR/PICARD (launch 2009)

LYRA: 30 (Zr), 70 (Al), 125, 210 nm

PREMOS: 215, 266, 535, 607, 782 nm



Filter wavelength selection



Ozone mixing ratio changes (%) due to a 10% increase of the spectral solar flux in 1 wavelength bin (1 nm).

- **PREMOS - Total Solar Irradiance**
 - Long term TSI monitoring

- **PREMOS - Filter Radiometer**
 - Support observations of SODISM/PICARD:
→ absolute and relative long-term calibration

- **PREMOS and LYRA - Filter Radiometer**
 - fast cadence observations: 10 Hz and 50 Hz
→ unknown domain!
 - Space climate: influence of UV irradiance on the climate

Hourly/Daily Data from observations by PREMOS, LYRA, SORCE

Nowcast of neutral and ion composition in the mesosphere based on solar irradiance measurements

Radiation spectrum reconstruction 120-680 nm (Egorova et al., 2008, ACP)

Nowcast of anomalies of neutral and charged species with free running CICM SOCOLi

Output validation to improve the model and experimental set-up

Nowcast results available on web every 6 hours

Aim of Nowcast

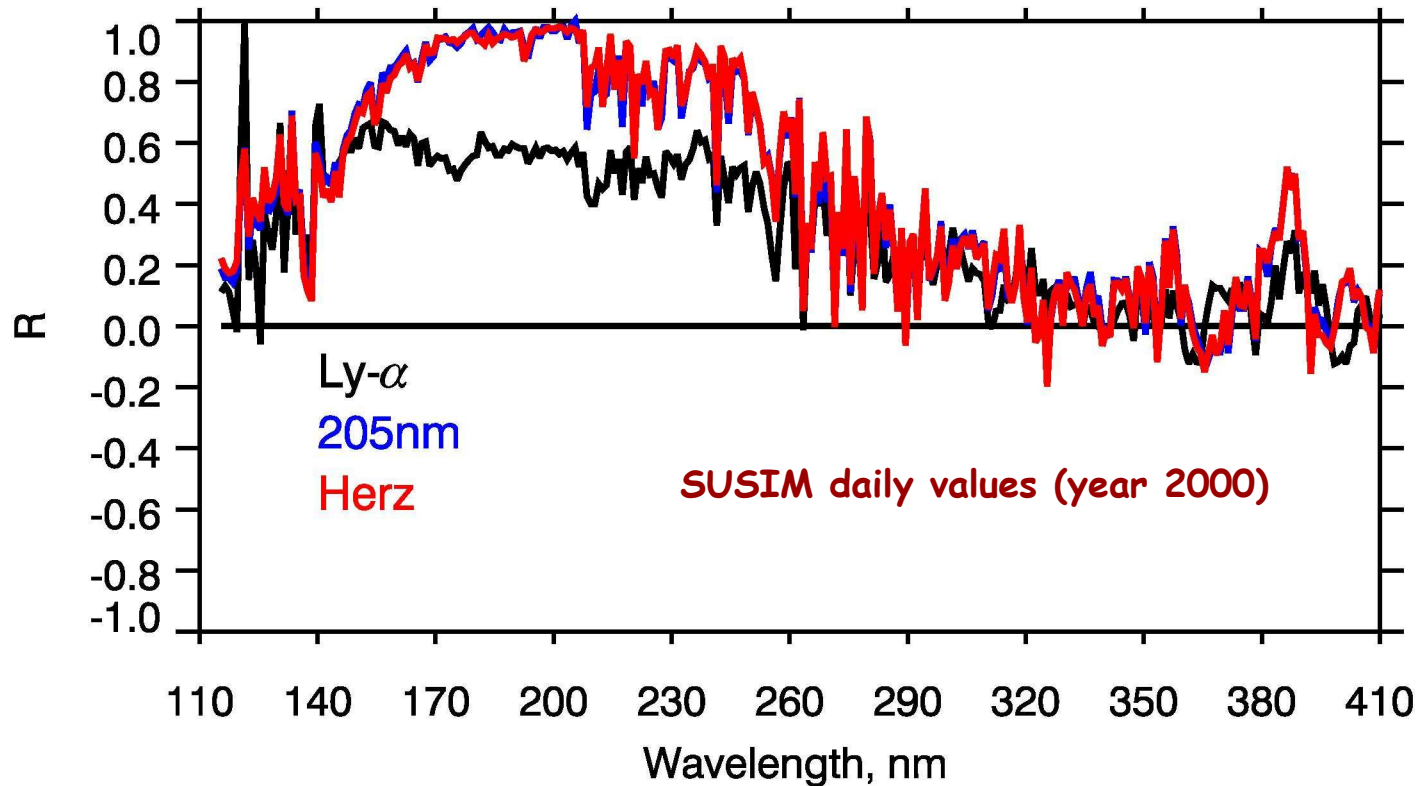


- Find out how well we understand the solar influence on the middle atmosphere;
- Learn how to provide near-real-time operation;
- Space Weather Service is secondary goal but may become interesting if successful !

Reconstructing the UV (1)

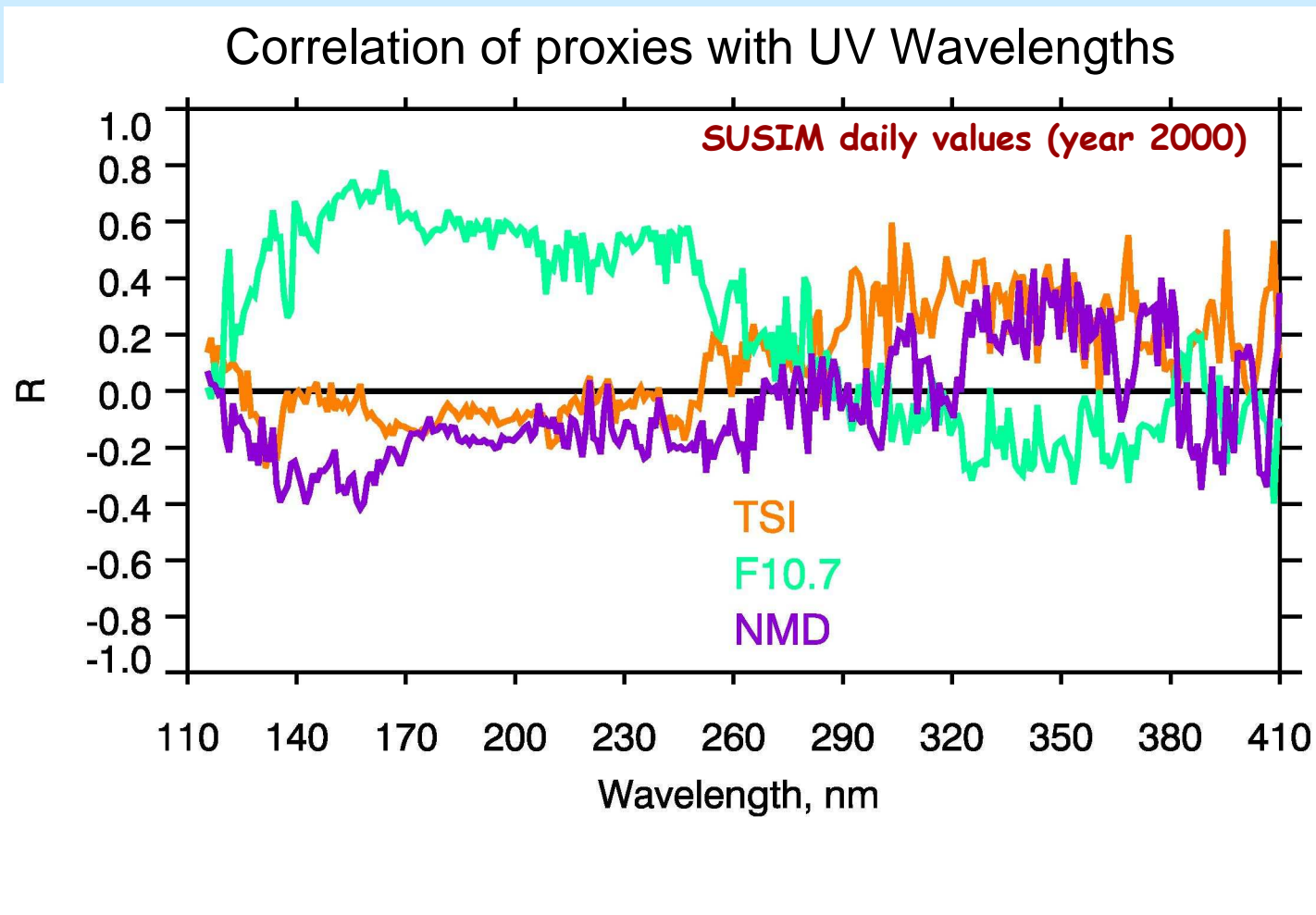
Radiation spectrum reconstruction 120-680 nm (Egorova et al., 2008, ACP)

Correlation of LYRA channels with other wavelengths



Reconstructing the UV (2)

Radiation spectrum reconstruction 120-680 nm (Egorova et al., 2008, ACP)



Ion chemistry in the D-region



Height-scale: 0-90 km; $\Delta Z = \sim 2$ km; time-steps : $\Delta t = 2$ h

Chemistry:

Electron density: e^-

30 positive ions:

O^+ , O_2^+ , O_4^+ , N^+ , NO^+ , N_2^+ , $H_2O_2^+$, H_3O^+ , $O_2^+ \cdot N_2$, $O_2^+ \cdot H_2O$, $H_3O^+ \cdot OH$, $NO^+ \cdot H_2O$,
 $NO^+ \cdot (H_2O)_2$, $NO^+ \cdot (H_2O)_3$, $NO^+ \cdot CO_2$, $NO^+ \cdot N_2$, $NO^+ \cdot H_2O \cdot CO_2$, $NO^+ \cdot H_2O \cdot N_2$,
 $NO^+ \cdot (H_2O)_2 \cdot CO_2$, $NO^+ \cdot (H_2O)_2 \cdot N_2$, $H^+ \cdot (H_2O)_2$, $H^+ \cdot (H_2O)_3$, $H^+ \cdot (H_2O)_4$, $H^+ \cdot (H_2O)_5$,
 $H^+ \cdot (H_2O)_6$, $H^+ \cdot (H_2O)_7$, $H_3O^+ \cdot CO_2$, $H_3O^+ \cdot N_2$, $H^+ \cdot (H_2O)_2 \cdot CO_2$, $H^+ \cdot (H_2O)_2 \cdot N_2$

17 negative ions:

O^- , O_2^- , O_3^- , O_4^- , OH^- , CO_3^- , CO_4^- , NO_2^- , NO_3^- , HCO_3^- , ClO^- , Cl^- ,
 CH_3^- , $O_2^- \cdot H_2O$, $NO_3^- \cdot H_2O$, $CO_3^- \cdot H_2O$

43 neutral species:

O_3 , O^* , O , O_2^* , NO , HO_2 , ClO , NO_2 , OH , NO_3 , N_2O_5 , HNO_3 , $HONO_3$, $ClONO_2$, Cl , N ,
 N^* , H_2O_2 , H , $HOCl$, Cl_2 , Cl_2O_2 , HCl , Br , CH_2O , BrO , HBr , $HOBr$, $BrNO_3$, $BrCl$, CH_3 ,
 CH_3O_2 , CH_3O , HCO , CH_3O_2H , H_2O , $CFC-11$, $CFC-12$, N_2O , CH_4 , CO , H_2 , $CBrF$

~ 200 reactions for ions and ~ 200 neutral gaseous reactions

Ion chemistry in the D-region



Ionization sources:

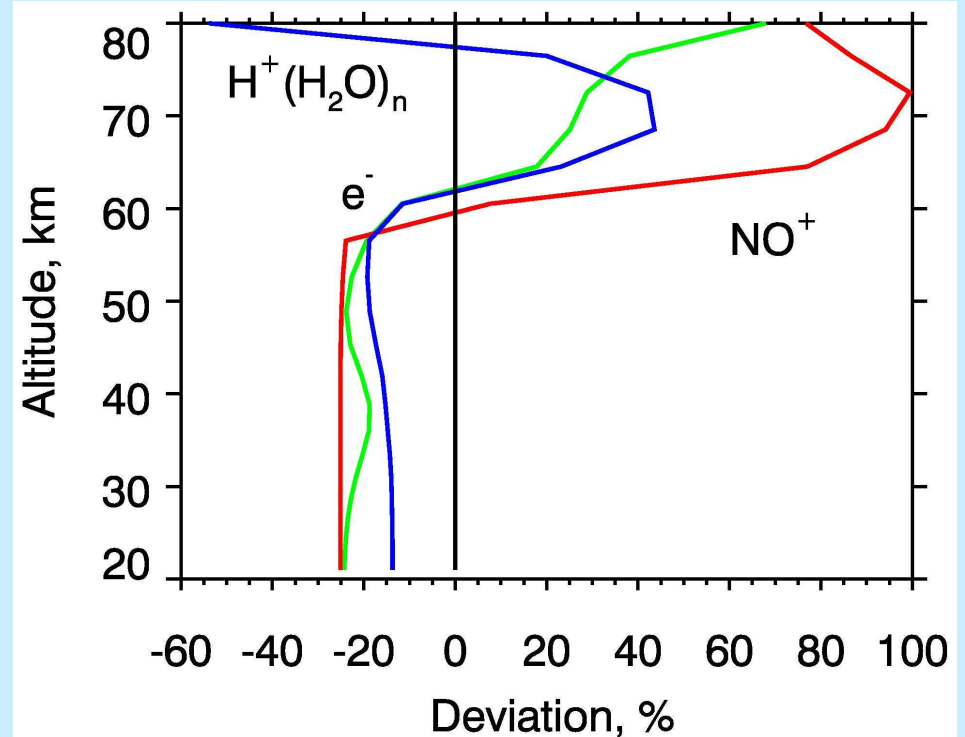
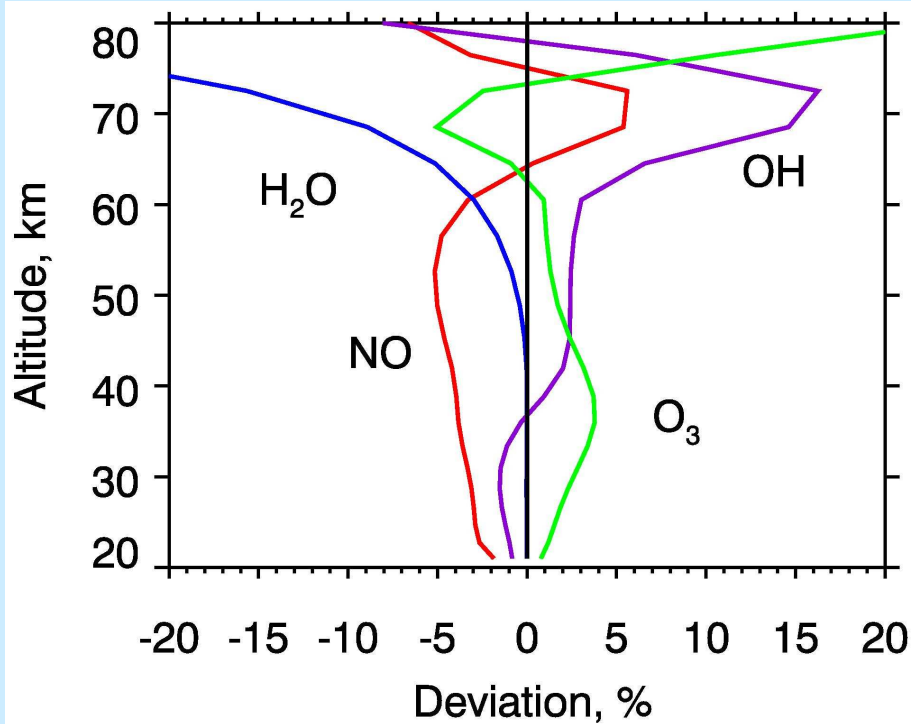
- Ly-alpha (above 65 km)
- Galactic Cosmic Rays(GCR) (below 65 km) (Heaps, 1978)
- Energetic Particles Precipitation (EPP)
- Solar Proton Events (SPE), data base from Jackman (2006)

Radiation:

- spectral region 120-780 nm with 73 spectral intervals
(Rozanov et al., 2002)
- radiation data source for model validation:
daily SUSIM/UARS observations

Validation

Difference of selected neutral and ionized species between solar maximum and minimum at 50° N



Conclusion Nowcasting

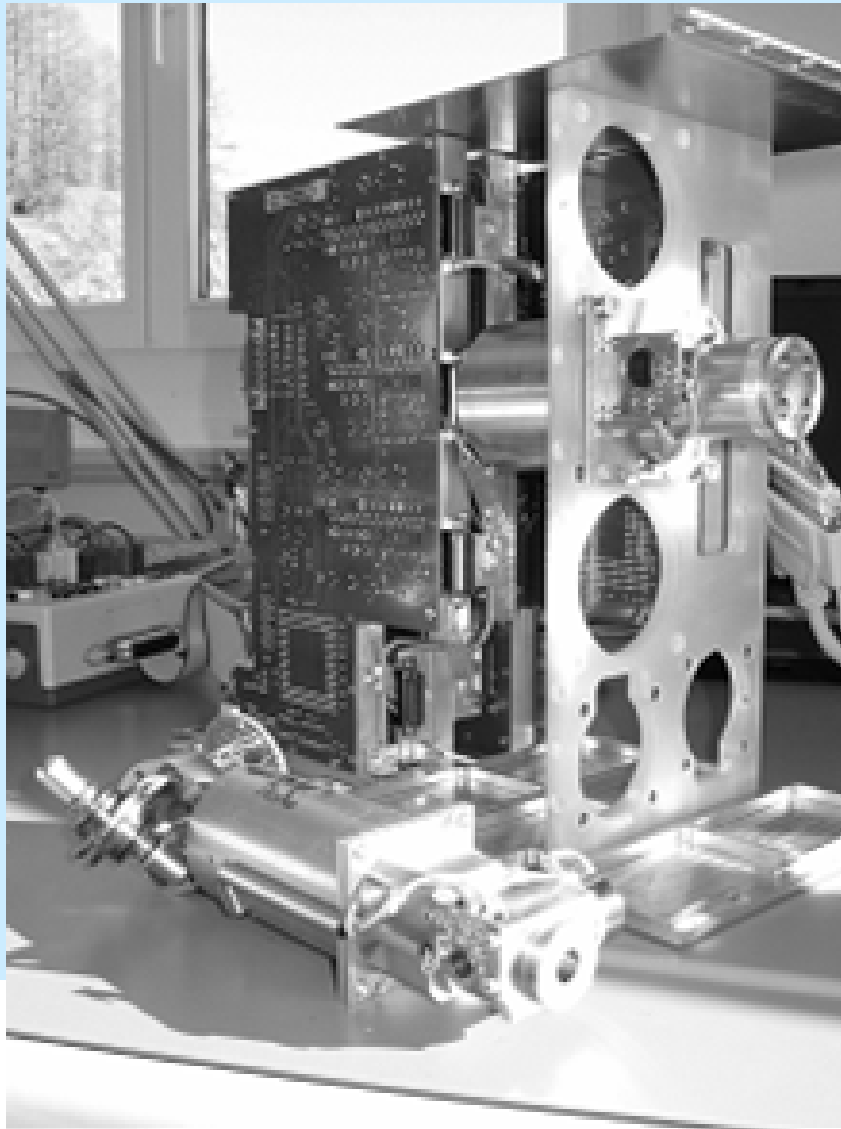


1. Ionospheric model has been developed and validated
2. Ion-ion recombination reactions have been added which improved the model performance
3. Solar Proton Events have been implemented
4. Several experiments have been performed and we have verified that the neutral and ion compositions of the middle atmosphere are sensitive to the solar activity
5. Plans:
 - Continue to compare with available observations and models
 - 3D validation
 - Paper in preparation

- **PREMOS - Total Solar Irradiance**
 - Continue long term TSI monitoring

- **PREMOS - Filter Radiometer**
 - Support of SODISM observations
 - absolute and relative long-term calibration
 - Combine with LYRA/ PROBA2 fast cadence observations
 - Space climate: influence of UV irradiance on the climate

We are looking forward to PICARD science ...



Thank you for
your attention!