

# PICARD – Climate

## Review of science objectives and results

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# From the Sun to the Earth climate

- Climate information is already fundamental for society
- Sun is our major source of energy: TSI and SSI compose the Essential Climate Variable (ECV) ensemble required to support Climate Change studies (IPCC)
- A realistic representation of the solar forcing in numerical models is essential to support policy at global and regional scales
- **PICARD-Climate focus on understanding the representation of the Sun as a variable forcing on climate and atmosphere models**
  - *What really needs to be represented: why and how?*

# PICARD-Climate

An international team composed of experts on chemistry-climate modeling, atmospheric measurements and analysis and solar physics was formed within the PICARD mission

France:	Canada:	Switzerland:
<ul style="list-style-type: none"><li>- Alain Hauchecorne, LATMOS</li><li>- Slimane Bekki, LATMOS</li><li>- Gerard Thuillier, LATMOS</li><li>- Chantal Claud, LMD</li><li>- Philippe Keckhut, LATMOS</li><li>- Marion Marchand, LATMOS</li><li>- Sylvaine Turck-Chièze, SAp/IRFU/CEA</li></ul>	<ul style="list-style-type: none"><li>- Stella Melo, EC-CSA</li><li>- Kirill Seminiuk, York U</li><li>- Michel Bourqui, McGill</li><li>- Victor Fomichev, York U</li><li>- Vitali Fioletov, EC</li><li>- Paul Charbonneau, UdeM (TSI and SSI for climate)</li><li>- Ian Short, St-Mary's U (Solar atmosphere - SSI)</li></ul>	<ul style="list-style-type: none"><li>- Eugene Rozanov, PMOD</li><li>- Anna Shapiro, PMOD</li><li>- Alexandre Shapiro, PMOD</li><li>- Tatiana Egorova, PMOD</li><li>- Werner Schmutz, PMOD</li></ul>

Where are we?

# CLIMATE EVOLUTION DURING THE FIRST HALF OF 20<sup>TH</sup> CENTURY

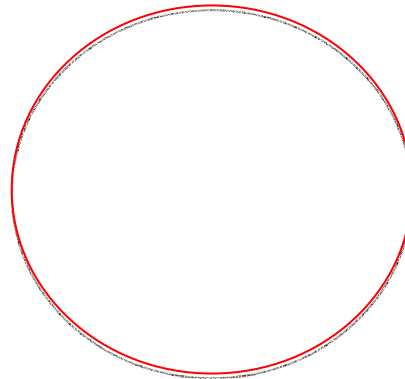
Measurements

Climate models (natural forcing)

Climate models (natural + anthropogenic forcings)

solar forcing?

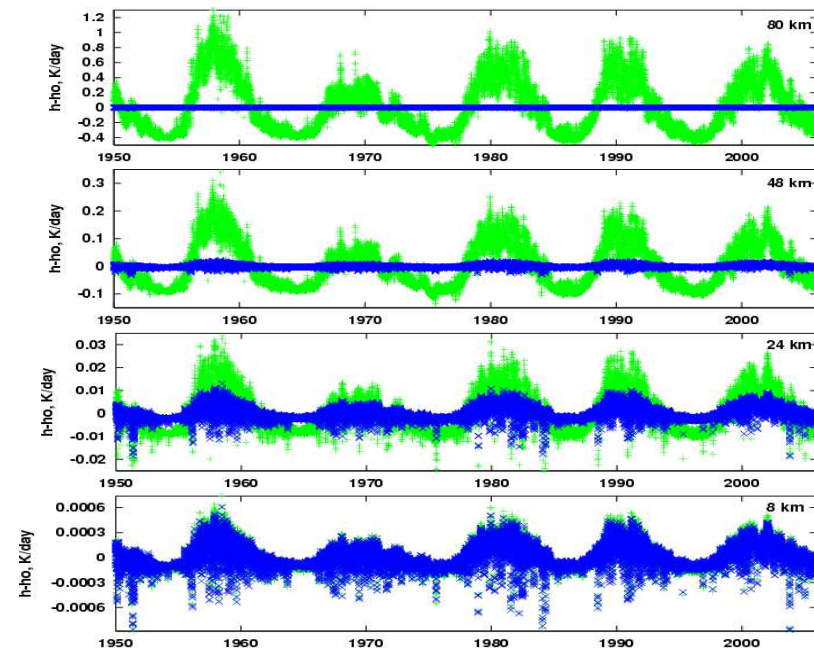
model deficiency?



# Why SSI?

## Radiative forcing analysis

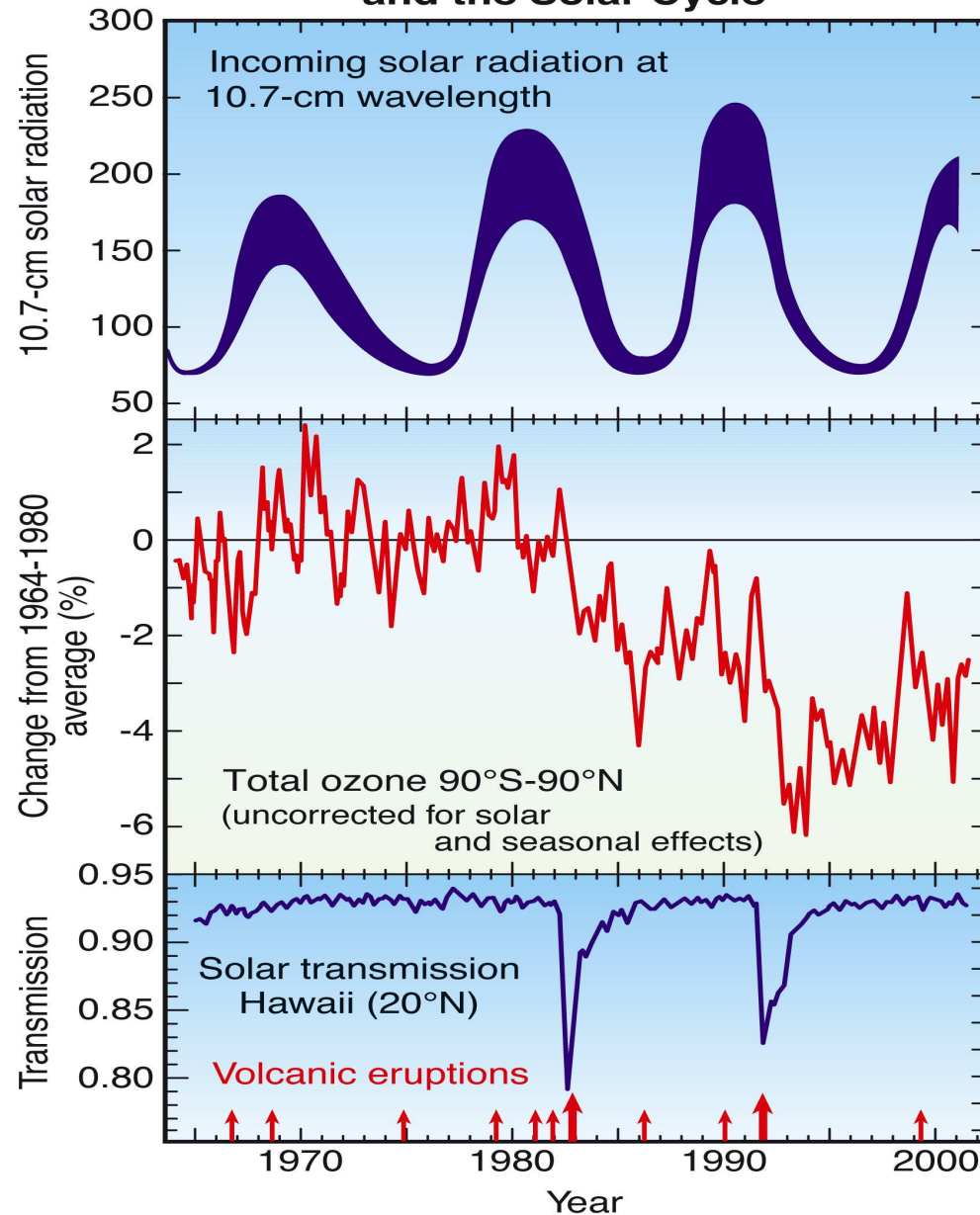
- In order to properly account for variable solar forcing in numerical chemistry-climate models we need time series of the Total Solar Irradiance (TSI) and Spectral Solar Irradiance over different time scales.
- Recent numerical model experiments together with satellite measurements demonstrate the need of represent the forcing by EEP as well.



***Semeniuk et al, Atmos. Chem. Phys., 11, 5045–5077, 2011***

# STRONG LINKS BETWEEN SOLAR VARIABILITY, OZONE AND MIDDLE ATMOSPHERE CLIMATE

## Global Ozone, Volcanic Eruptions, and the Solar Cycle



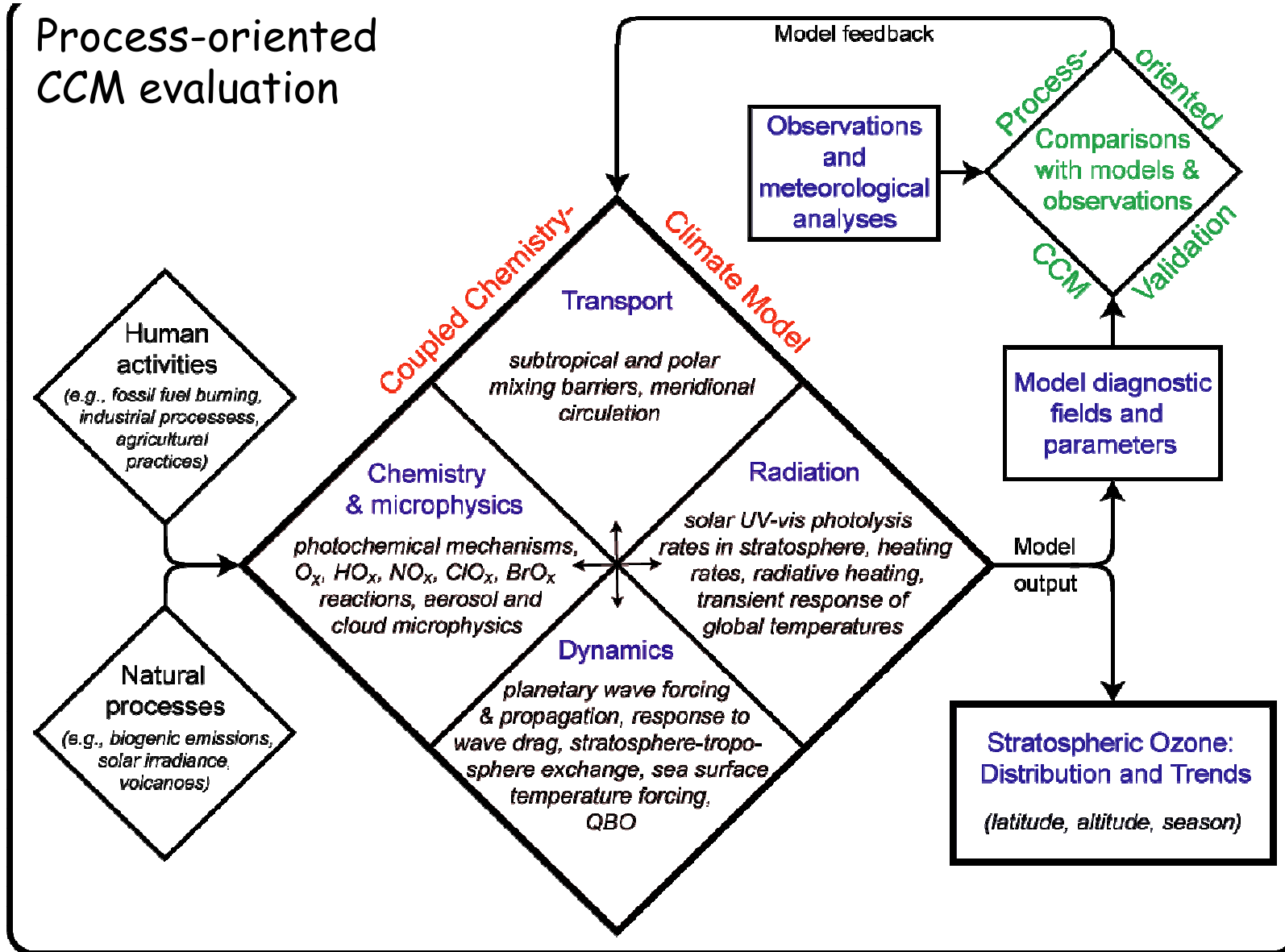
->  $J_{O_2} = f(\text{UV})$   
(source of  $O_3$ )

-> long term trend  
in chlorine loading  
(destruction term)

-> heterogeneous  
chemistry  
(destruction term)

## CHEMISTRY CLIMATE MODELLING

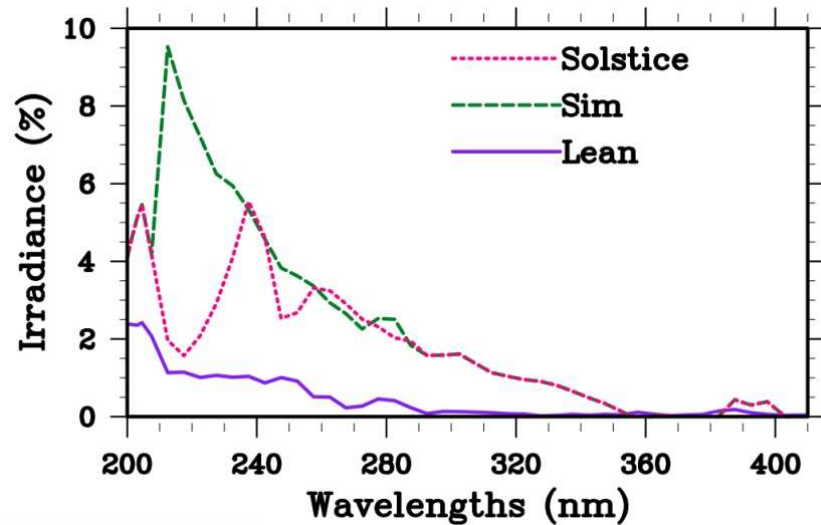
### Process-oriented CCM evaluation



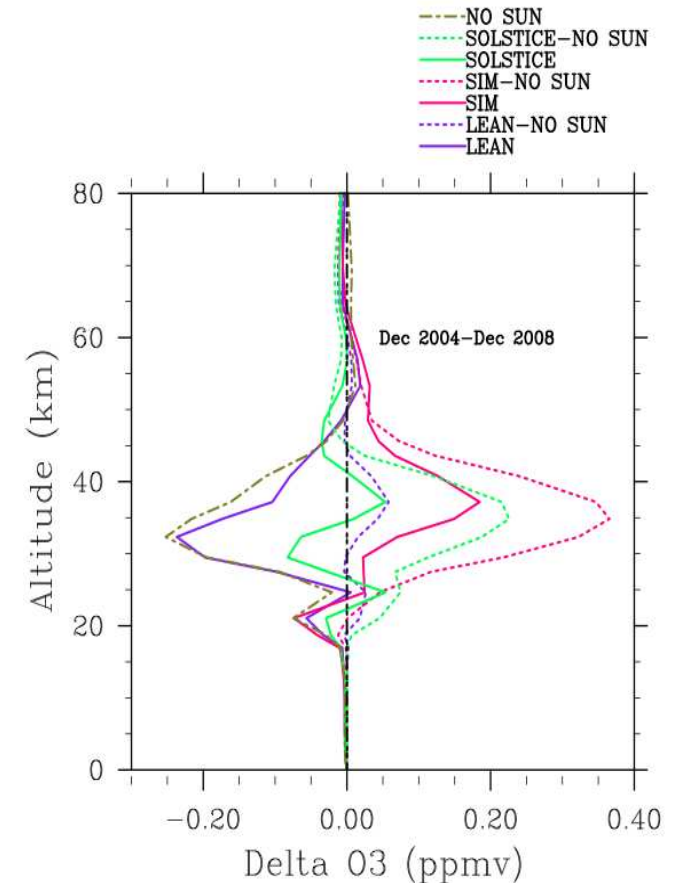


# Which SSI series to use?

## Sensitivity analysis using SOCOL



Difference between Decembers 2004 and 2008, which correspond to the similar QBO phases. The largest response in the stratosphere can be obtained with the SIM data set. The smallest responses are found for Lean et al., 2005 data set.



Pure solar signature obtained by subtracting the reference run from the experiment with the given forcing.

**The model is sensitive to the choice of SSI**

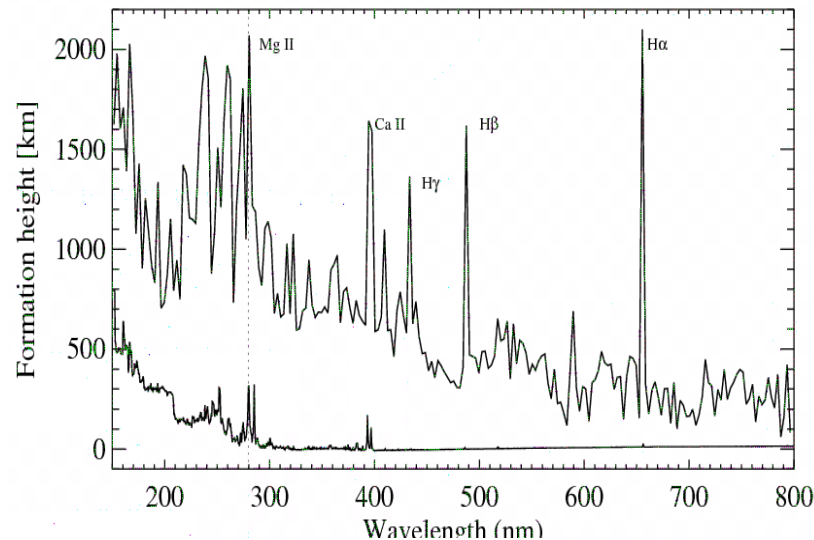
# Working towards generation of reliable and consistent SSI and TSI series for models: past, present and future

- Reconstruction of SSI based on MG II index: past and present;
- Comparing existent SSI series from measurements with reconstructions: towards understanding what drives the variability and its wavelength dependency;
- Modeling TSI and SSI from physical principles: towards minimizing the need of proxies. Ultimately enable future predictions;
- **TSI and SSI series NEED to be CONSISTENT with each other.**

# Reconstruction of SSI based on MGII index

G. Thuillier et al, The Solar Spectral Irradiance as a Function of the Mg II Index for Atmosphere and Climate Modelling, 2011, Solar Physics

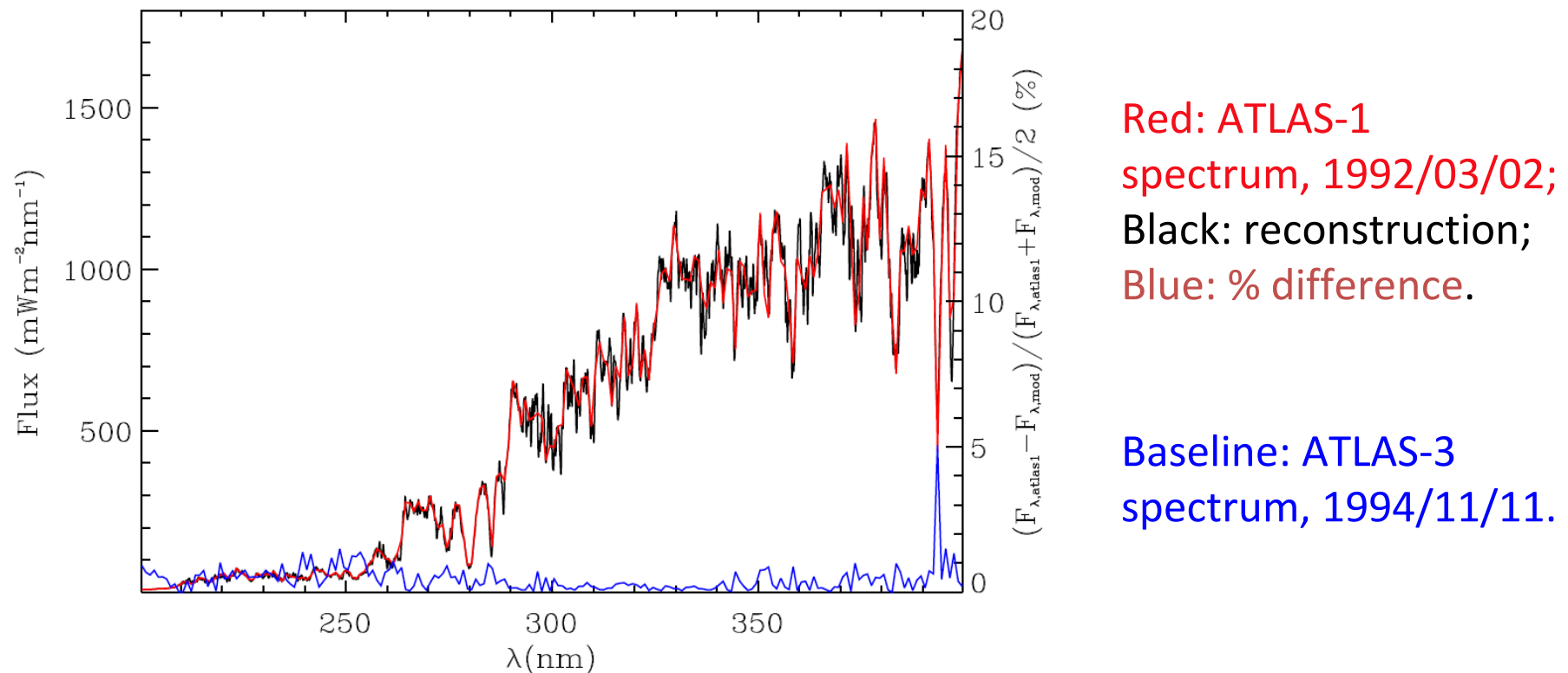
- The proxy model to reconstruct the spectral range above 170 nm is based on comparisons between Mg II index and irradiance changes as measured by the SBUV instruments onboard *Nimbus 7* and NOAA satellites (DeLand and Cebula, 1993).
- Below 170 nm, a second proxy model, developed from the SOLSTICE data onboard UARS, is used (Woods *et al.*, 2000). The solar variability can thus be estimated down to the Ly  $\alpha$  line.



**Figure 2:** The formation height in the core of the strongest lines (upper curve) and a minimal formation height in a 0.5 nm interval (lower curve), which comes close to what could be called pseudo continuum.

# Spectral solar irradiance modelling

Fragmentation+erosion model for emerging active regions, coupled to a 3-component model: quiet sun + sunspots + « faculae »; calibrated on 1991-2001 UARS/SOLSTICE (Bolduc et al. 2011, SolP, soon to be submitted); validated against ATLAS spectra.



*Bolduc et al., A fast model for the reconstruction of spectral solar irradiance in the near- and mid-ultraviolet Solar Physics, accepted, 2012*

# Understanding the model response

Table 1: Summary of the models to be used in this project with some basic information on each model.

Model	Leading institution	Model levels and altitude range	Particular strength of the model – of interest of this project	Reference
CMAM	University of Toronto, Canada	Surface to about 250 km	Realistic representation of the middle atmosphere. Includes a representation of the lower thermosphere.	deGrandpré, J et al., 2000. Fomichev, et al., 2003.
IGCM-FASTOC	McGill University, Canada	T31 from ground to 0.1hPa	Realistic representation of the stratosphere. Fast chemistry scheme allow for unexpensive and relatively fast long term runs	Bourqui, M.S., et al. 2005.
LMDz-Reprobus	LMD, France	Hybrid sigma pressure. 50 levels from the surface to 0.07hPa (65km)	Includes a detail realistic description of the troposphere with interactive chemistry	Jourdain, L. et al. 2008
SOCOL	Davos/ World Radiation Center (PMOD/WRC), Switzerland	T30 horizontal truncation and 39 vertical levels on a hybrid sigma-pressure coordinate System covering from the surface to 0.01 hPa	Detail ion-chemistry at the middle atmosphere	Egorova, T. et al. 2005

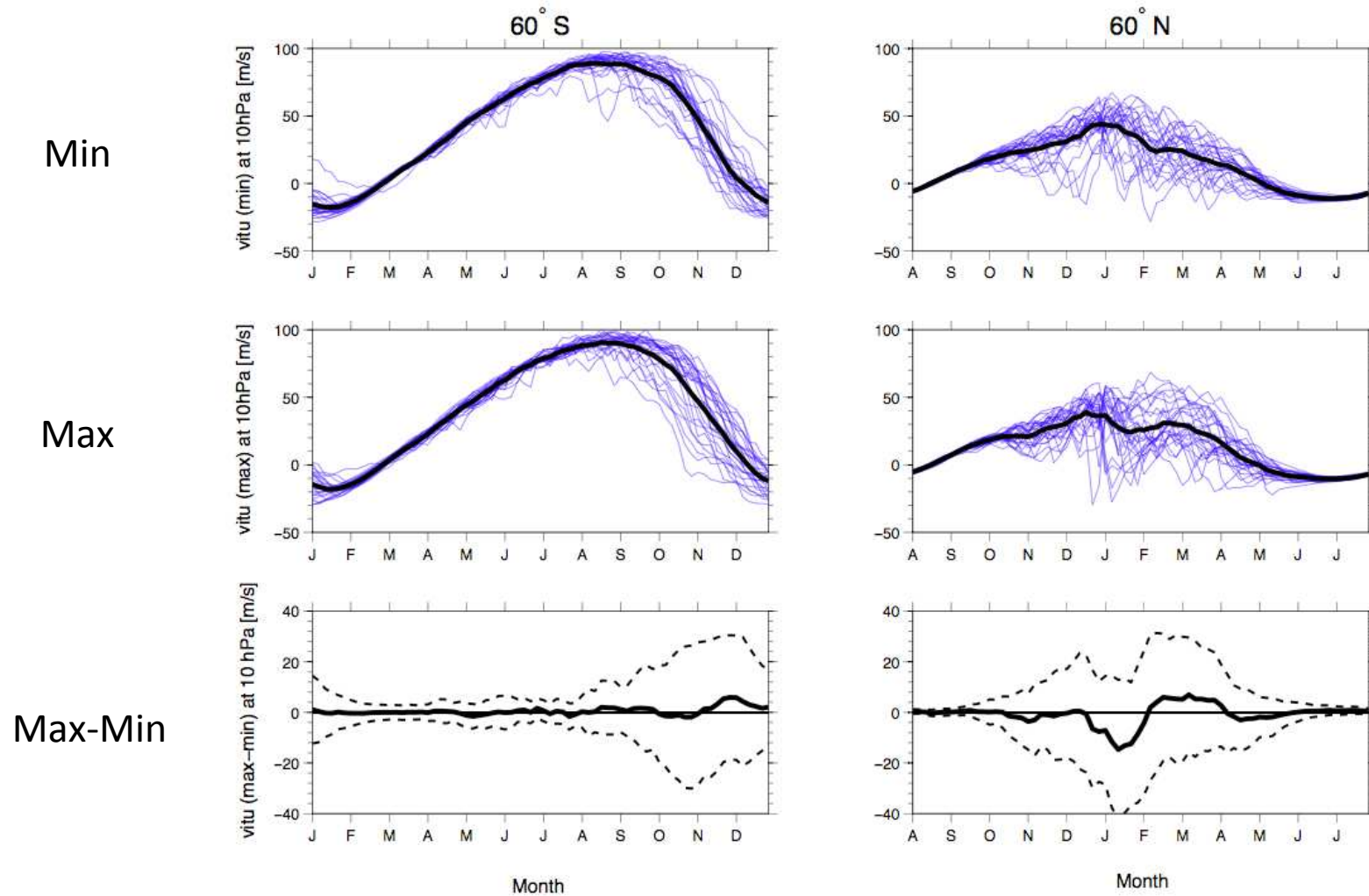
# LMDz-Reprobus

- Domain  $2.5^\circ \times 3.75^\circ$
- 50 Levels from ground to 0.07 hPa (~70 km)
- Radiative feedback O<sub>3</sub>, CH<sub>4</sub>, N<sub>2</sub>O, H<sub>2</sub>O, CFC-11, CFC-12
- Full stratospheric chemistry including heterogeneous reactions and formation of polar stratospheric clouds

Impact of solar UV variability:

- Radiative effect (O<sub>2</sub> and O<sub>3</sub> absorption)
- Photochemistry effect (change in photo-dissociation coefficients)
- 2x 30 years (max/min)
- SST and sea ice concentration forced (AMIP climatology, 1995-2004).

## LMDz-Reprobus solar simulation: zonal wind evolution at 60° (North and South)



Vortex plus persistant en cycle  
solaire max

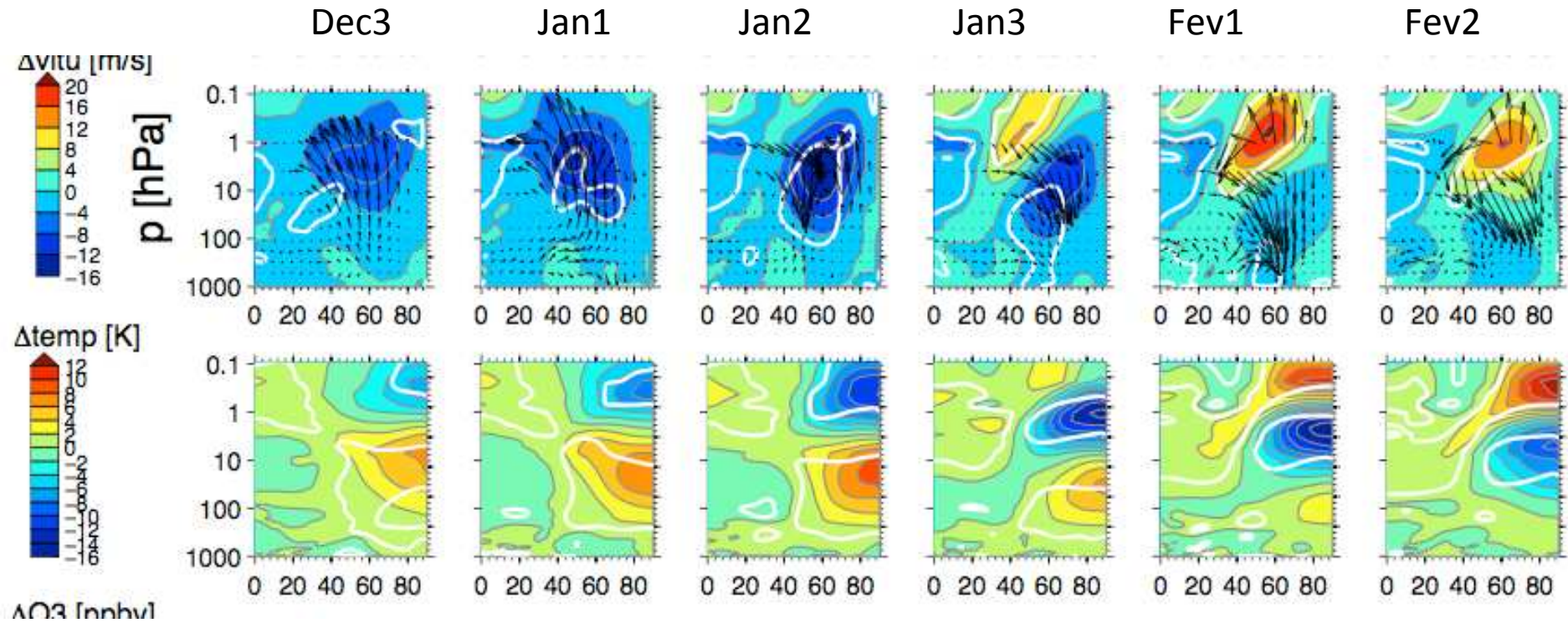
Différences dans le timing des  
SSW

Marchand et al., 2010, soumis



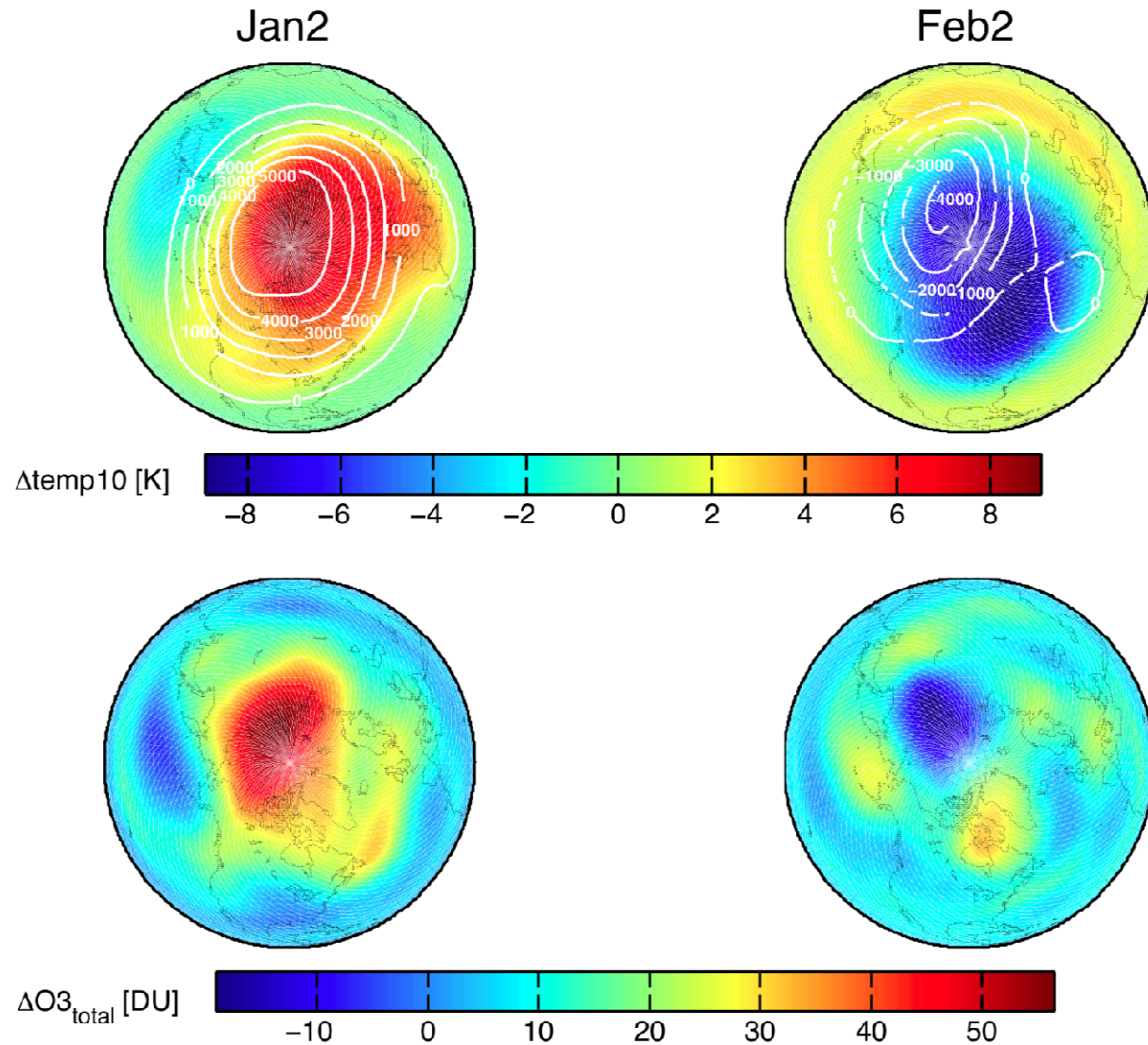
## LMDz-Reprobus solar simulation:

### Max-Min 10-day mean U and EPF, T evolution

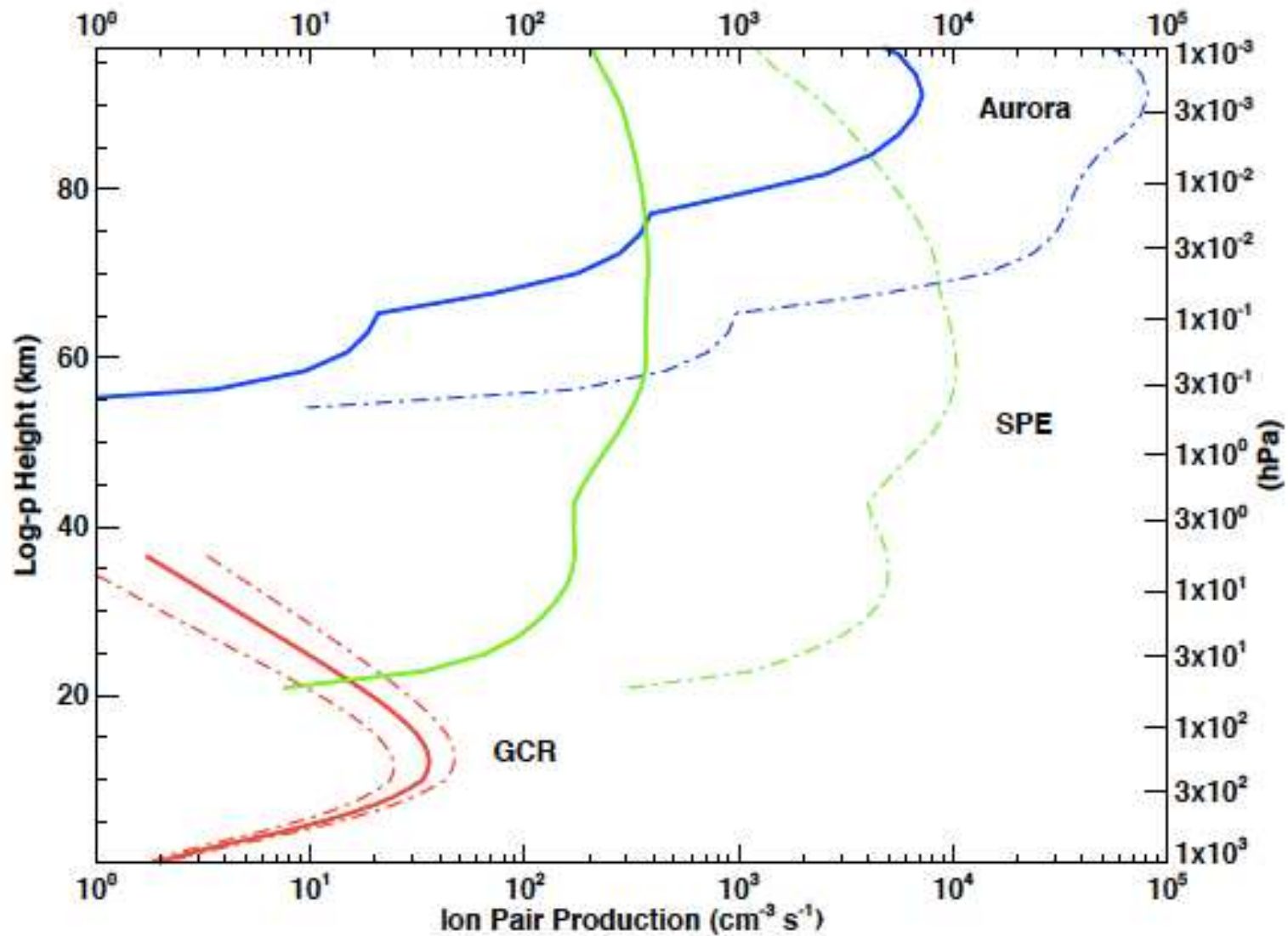




# LMDz-Reprobus: analysis using solar max – solar min scenarios



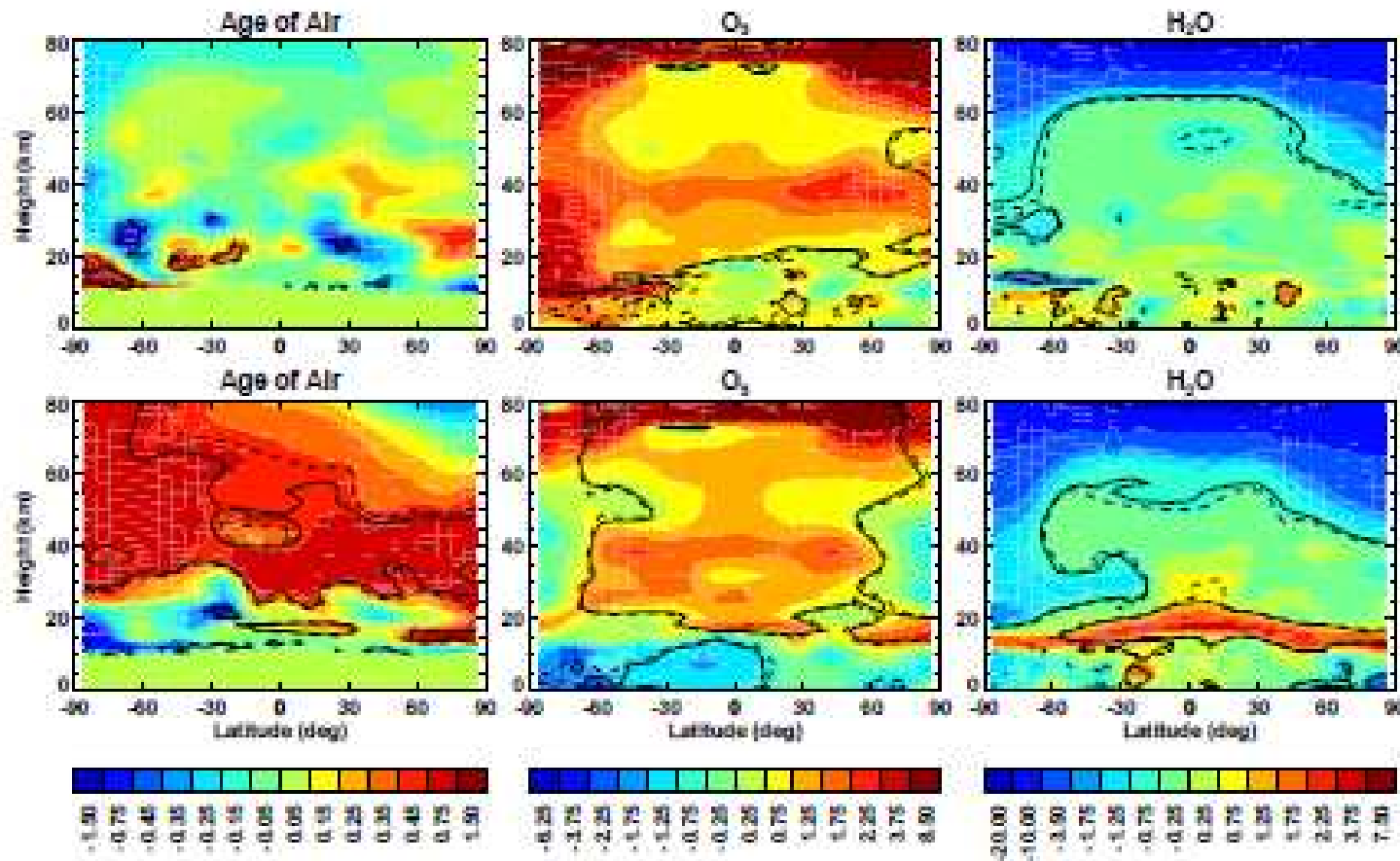
## UNACCOUNTED MECHANISM: IONIZING PARTICLE PRECIPITATION



Not accounted  
for in most  
chemistry-  
climate models

# Transient runs: understanding how variable solar forcing compose effects with energetic particle precipitation

K. Semeniuk et al.: EPP impact on the middle atmosphere, Atmos. Chem. Phys., 11, 5045–5077, 2011



Correlation of  
solar response  
with F10.7:  
variable TSI and  
SSI

Including  
energetic particle  
precipitation

# Summary

- PICARD is a science mission exploiting synergies between model and measurements to advance the knowledge on solar physics and on the solar variable forcing at the Earth's climate.
- Climate model activities within PICARD are producing results:
  - All the chemistry-climate models participating in the project have now representation of solar forcing
  - We produced a SSI variability parameterization for climate model extending from today to -7000 years: increase reliability on simulations and preserve consistency on approach towards the past;
  - Working towards modeling SSI and TSI from physical principles.
- **Within the PICARD project in Canada:**
  - Solar physics and atmosphere/climate model communities working together;
  - Two different chemistry-climate models already have variable solar forcing and EPP representations;
  - Motivated further developments of the Extended CMAM and LMDz to cover also the thermosphere
- **We welcome broadening our team! A PICARD-Climate 3<sup>rd</sup> Workshop is planned for end Summer – early fall 2012!**

# Use of PICARD data and other satellite data for climate modelling

Climate modelling needs the reconstruction of solar variability over periods longer than a single space mission (several decades): TSI, SSI, energetic particles

Satellite data are in general not directly injected in climate model but are used to reconstruct series of solar proxies

PICARD data will be used to reconstruct the solar variability:

- Total solar irradiance (PREMOS, SOVAP)
- Reconstructed spectral irradiance using Mg II and Ca II indexes: relation with contrast in 393 nm SODISM images

Data from other solar space mission are also essential for PICARD climate modelling: i.e. SOLSPEC for Solar Spectral Irradiance