# Towards a comprehensive Global Electric Circuit model: Conductivity and its variability in WACCM model simulations

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Acknowledgements: Ryan Neely, Jeff Thayer, Greg Lucas

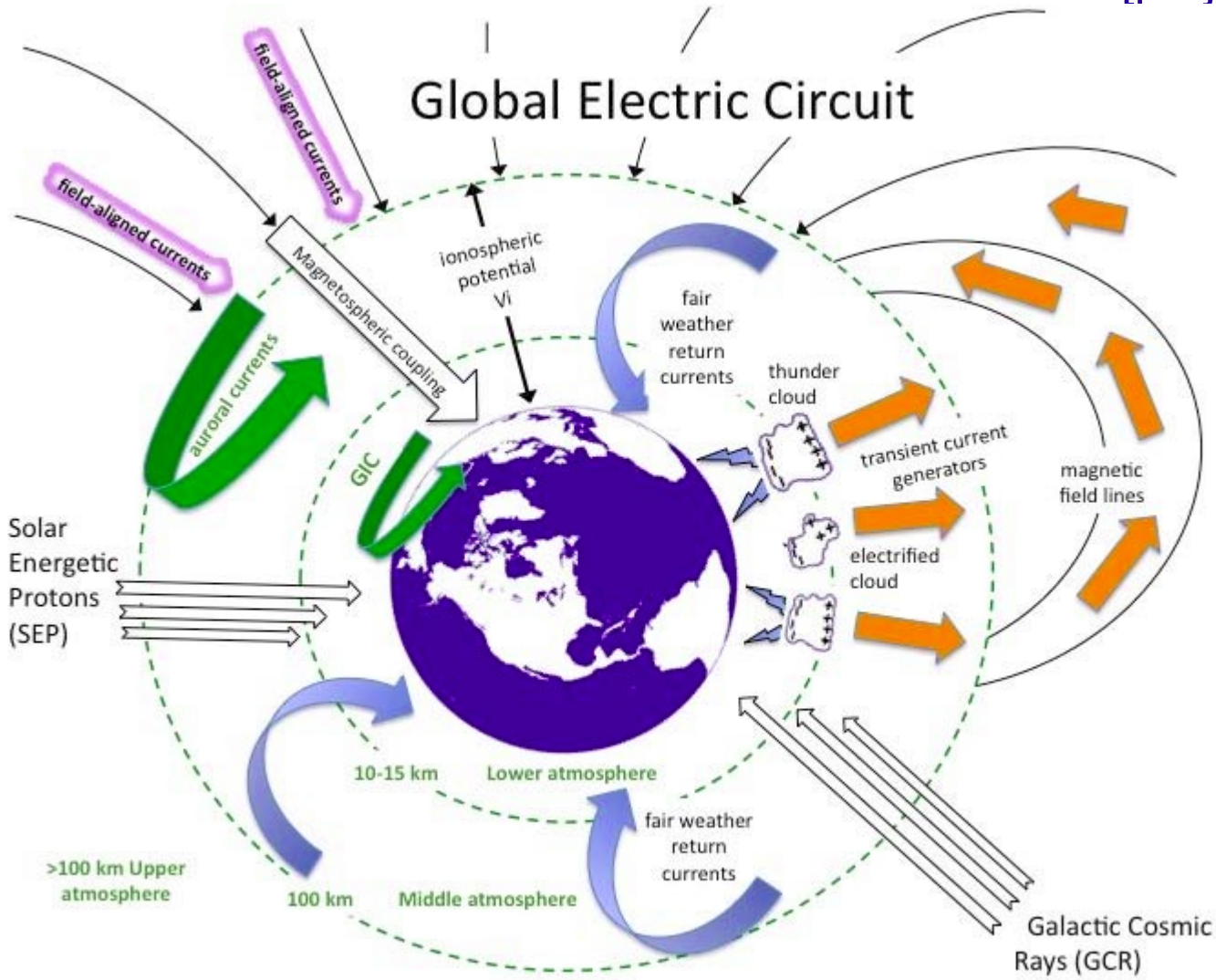
## NSF project: “Electrical Connections and Consequences Within the Earth System”

http://sisko.colorado.edu/FESD



## PI: Jeff Forbes

AIM: *"Understand and quantify the variability of the coupled Earth-atmosphere-geospace system associated with electrical processes driven by external (solar, galactic cosmic ray,...) and internal (e.g. lightning) sources."* [project proposal]




Need: atmospheric resistance, currents, potentials, E-fields,...

# Model infrastructure

Aerosol dataset*

Other datasets

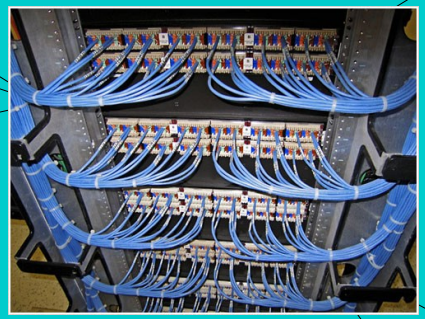
CESM/WACCM

CARMA Aerosol module

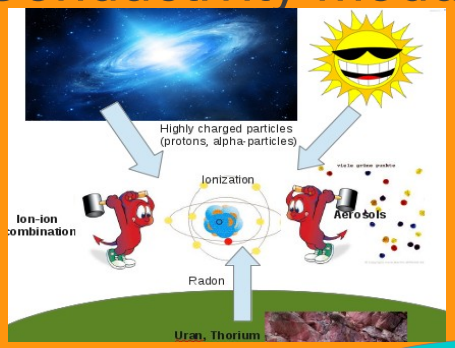
WACCM atmosphere

MOZART chemistry

...



Conductivity module




Source current parametrization (RAL)

Potential solver (CISL)

Science

*kindly provided by Ryan Neely, (CARMA runs, SOA, ...)

# Drivers of ionization / conductivity

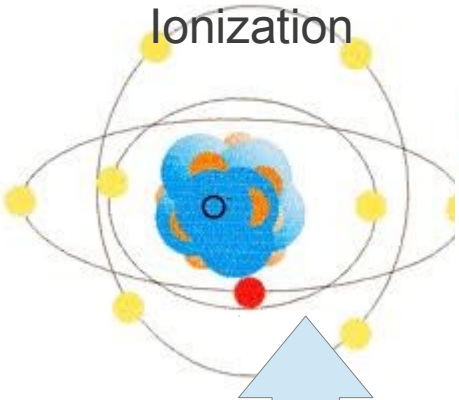
Galactic cosmic rays

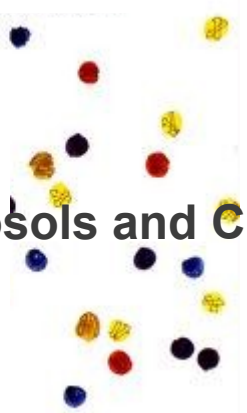
Solar energetic particles

**Highly charged particles**

Ionization

**Ion-ion recombination**





**Aerosols and Clouds**

Radon and ionizing radiation

**Uran, Thorium**

# Calculating ion concentration and conductivity

- steady state from ion production *q* and loss through ion-ion recombination α and ion-aerosol attachment β (*S* = number concentration of particle of type i)

$$q = \alpha n^2 + \sum \beta_i S_i n$$

- Conductivity **σ** requires **ion concentration *n*** and **ion mobilities *μ*** (*e* is electron charge):

$$\sigma = e \cdot \mu \cdot \left( \sqrt{4 \alpha q + \left( \sum \beta S \right)^2} \right) / (2 \alpha)$$

- Clouds lower conductivity locally by factor ~1/60

# The conductivity module

- Many of the conductivity equation input parameters depend on temperature, geopot. height, total cloud fraction, deep convective fraction, solar proton ionization rate, land/ice fraction, … → required input from WACCM
- Contributes $^{222}$Radon tracer
- No feedback (“diagnostic module”)
- Also runs as a column model (“hand-made”, only a few preprocessor directives) and “offline mode” (input data from existing run)

Example: The new radon constituent

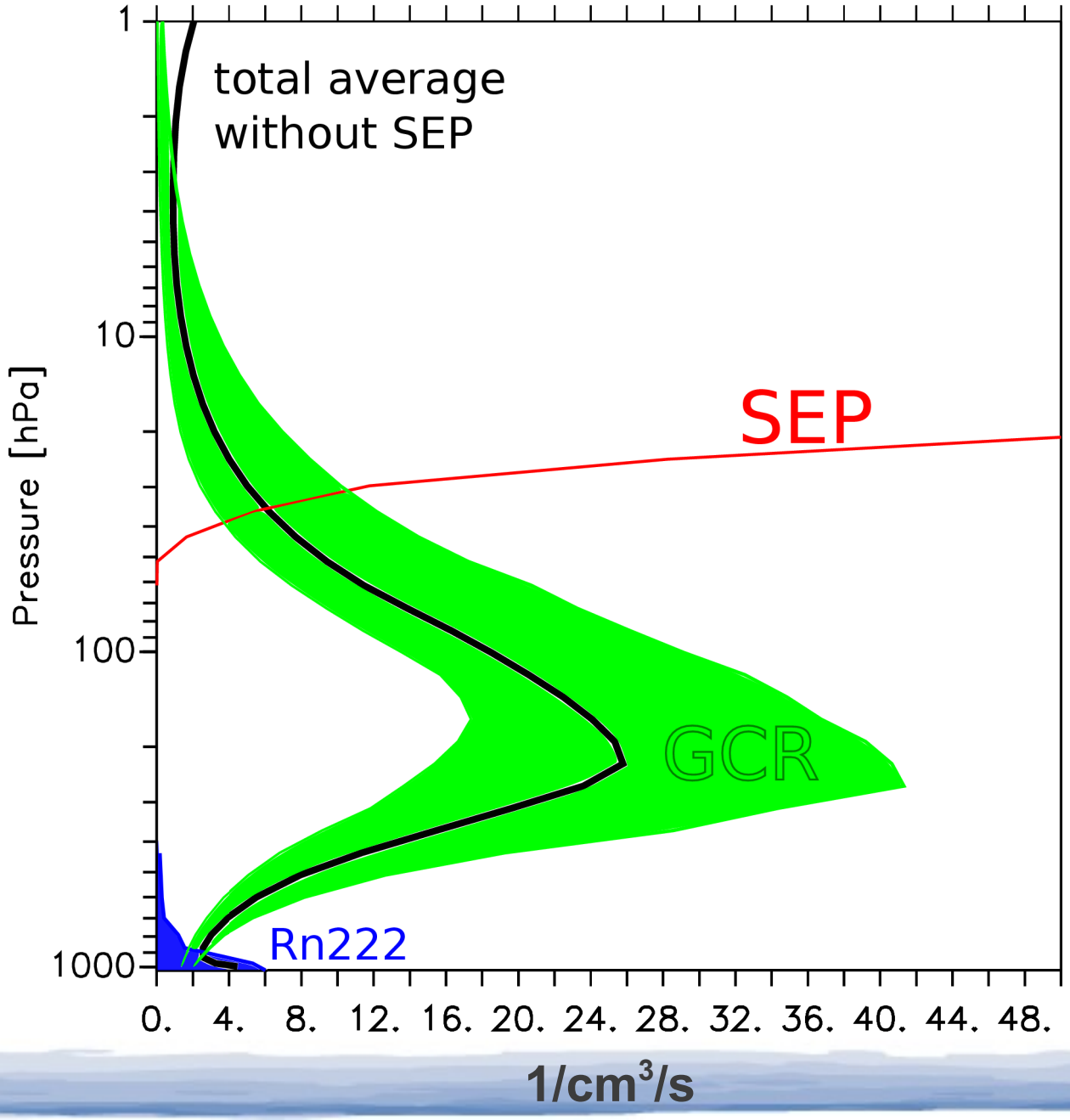
# What's inside?

- $^{222}$Rn is widely applied for the evaluation of the atmospheric transport characteristics (also useful in CESM for other types of studies)
- Decay:

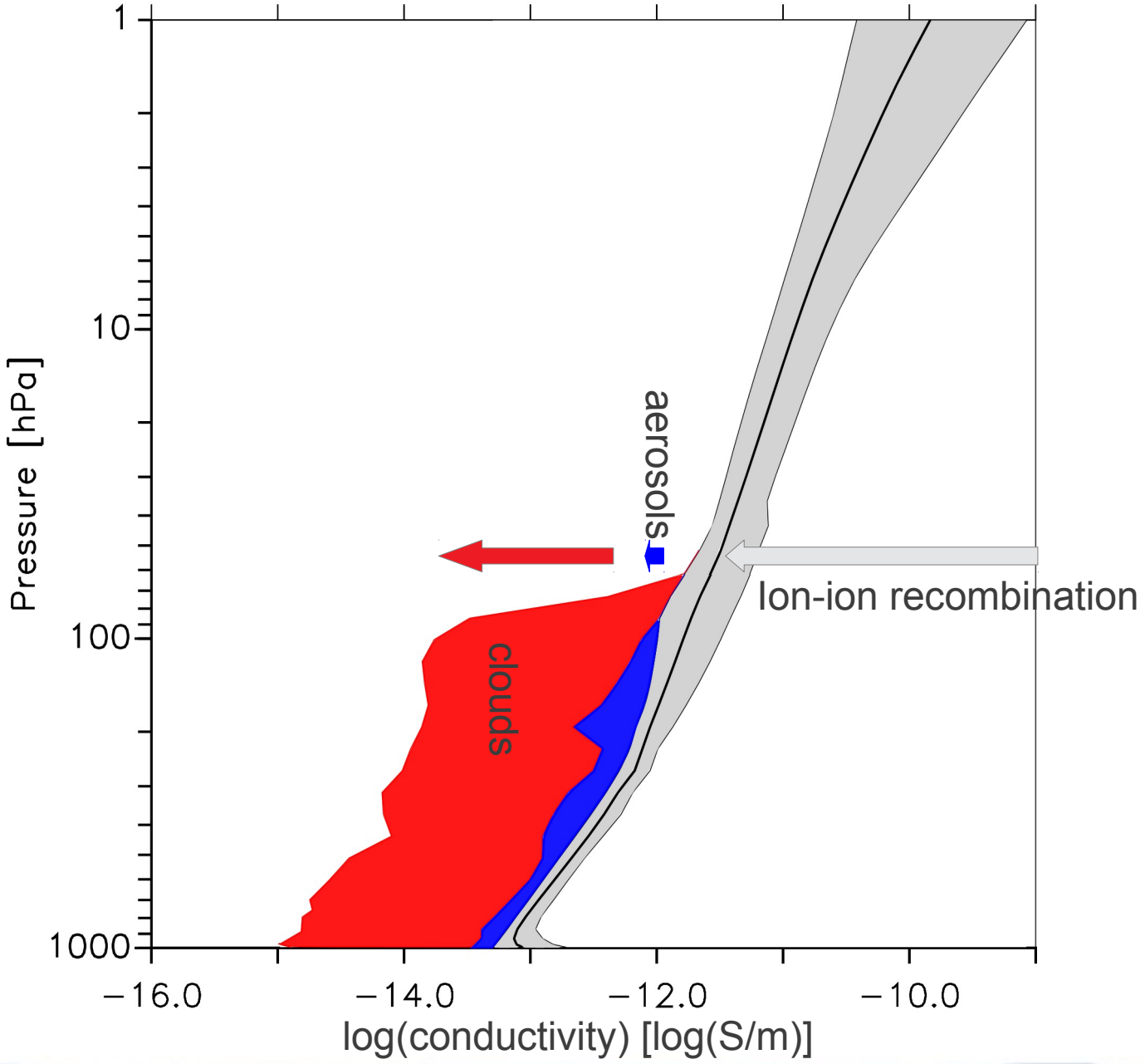
$$\begin{aligned} {}^{222}_{86}\mathrm{Rn} &\xrightarrow[\alpha]{3.8\mathrm{d}} {}^{218}_{84}\mathrm{Po} \xrightarrow[\alpha]{3\mathrm{min}} {}^{214}_{82}\mathrm{Pb} \\ &\xrightarrow[\beta]{27\mathrm{min}} {}^{214}_{83}\mathrm{Bi} \xrightarrow[\beta]{20\mathrm{min}} {}^{214}_{84}\mathrm{Po} \\ &\xrightarrow[\alpha]{180\mu s} {}^{210}_{82}\mathrm{Pb} \end{aligned}$$

- Flux from surface: external monthly database (Schery and Wasiolek, 1998)
- Differential equation for tendency solved analytically (see Joeckel et al., 2010)

# Ionization rate

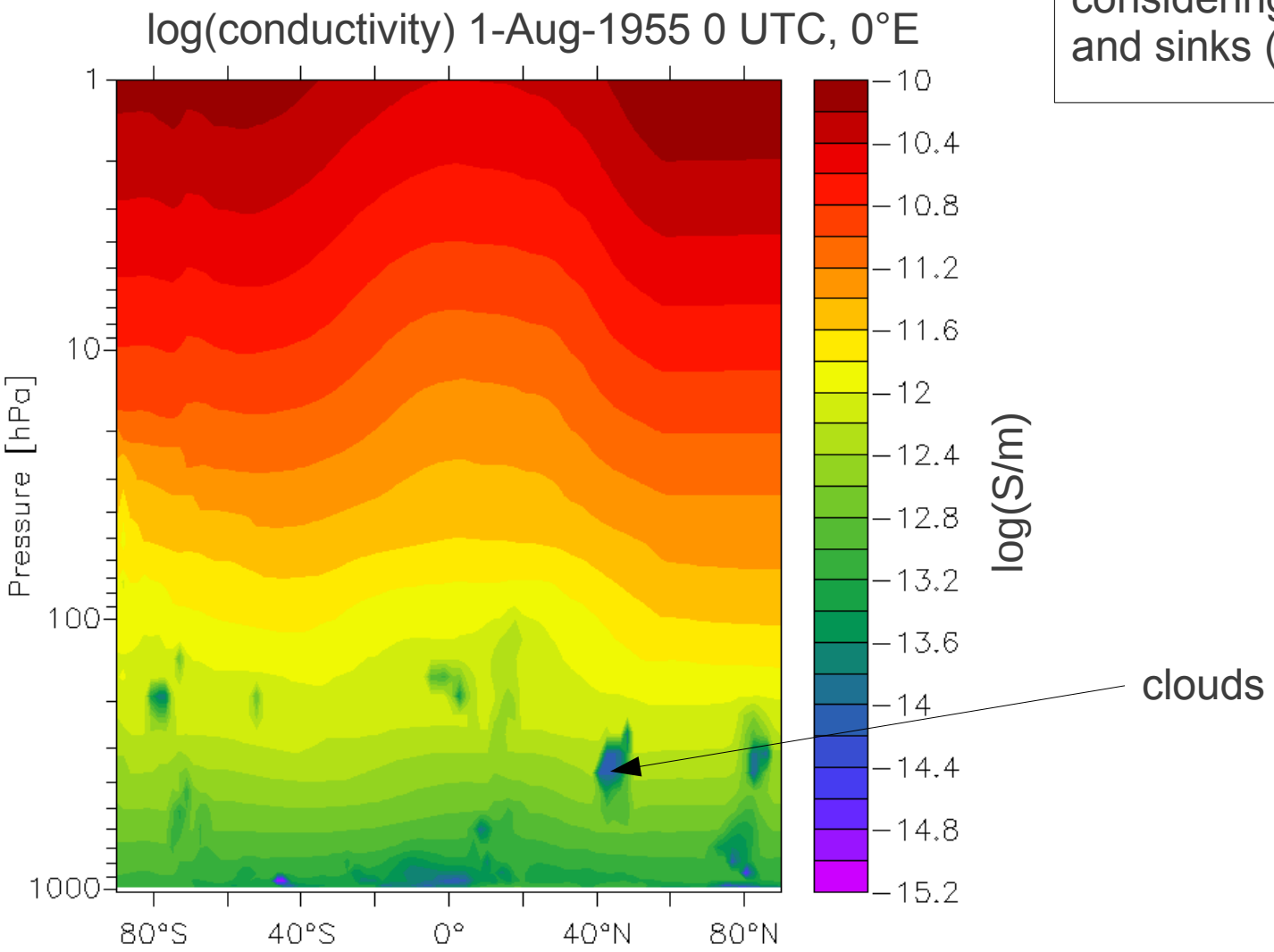


# Local effects of aerosols and clouds

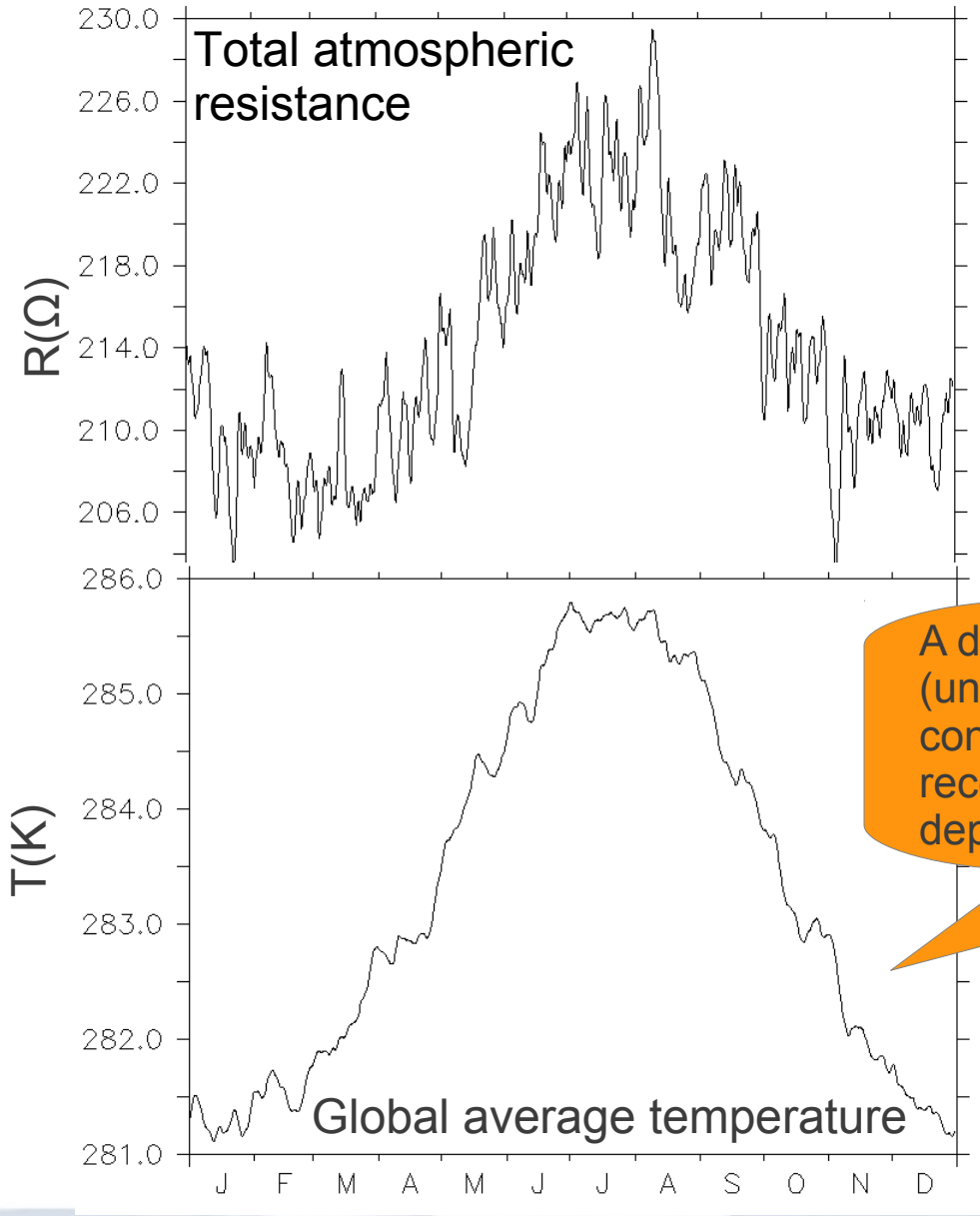


# Conductivity

considering all sources and sinks (no SEP event)



# A bit of science ...




A detailed analysis shows that this (unexpected) temperature-dependency is controlled by complex ion-ion recombination-rate and mobility temperature dependencies.

# Possibilities for the future …

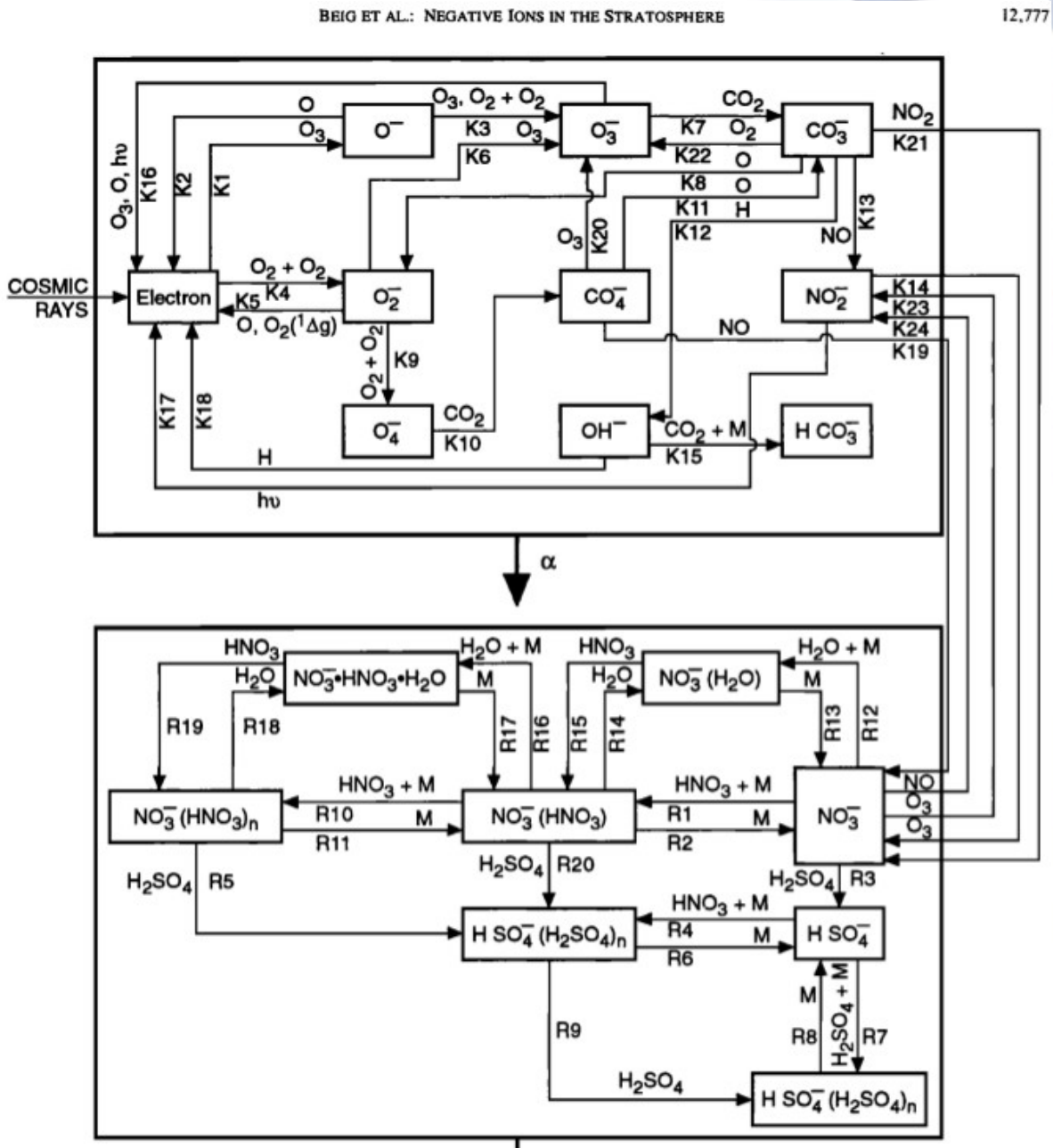
(please discuss with me!)

- Ion chemistry in the stratosphere (and even troposphere?): can we do that with MOZART?
- Global galactic cosmic rays: better parametrization or input data? e.g. NAIRAS (Nowcast of Atmospheric Ionizing Radiation) ionization rates?
- A separate CVS branch for the project?

# Ion chemistry

Brasseur (2005):

"Theoretical studies of both positive and negative ions are hampered by the lack of laboratory data regarding some of the relevant rate constants."




From Beig et al. (1993)