# From ACRANEB to ACRANEB2 (radiation developments during the Prague years)

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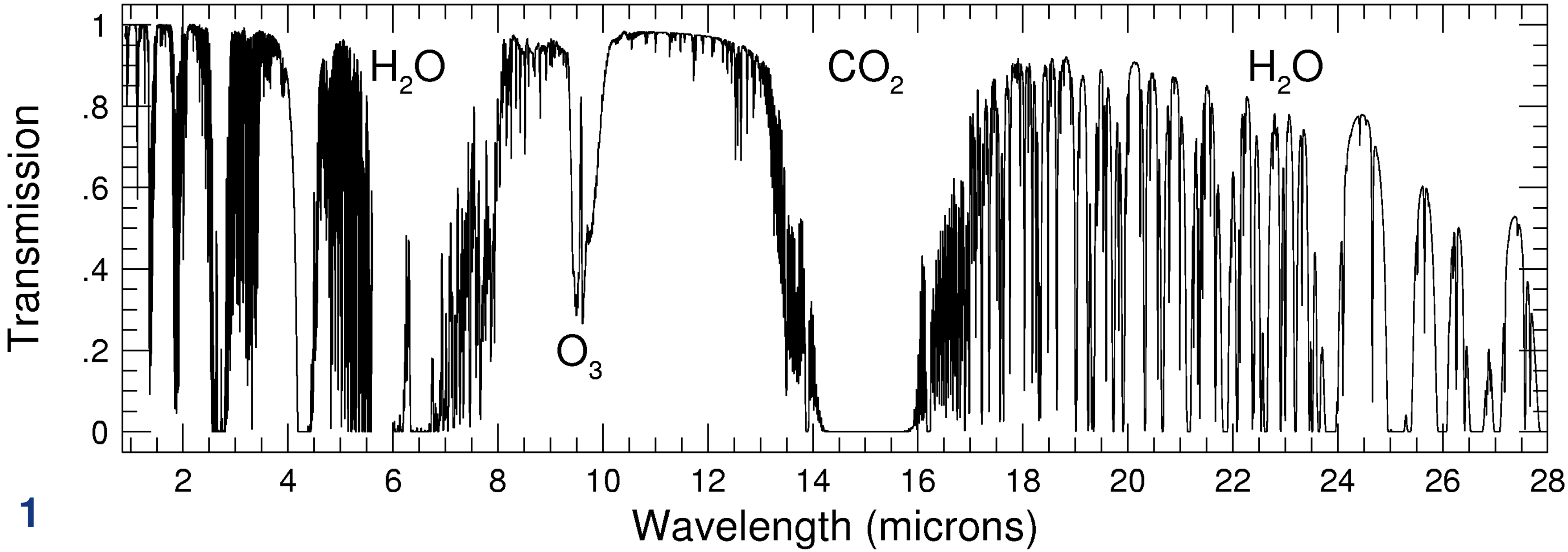
# Prologue

- radiation was Jean-François' beloved subject, accompanying all four decades of his NWP career
- this talk will cover only the last decade leading to ACRANEB2 scheme (it is the period that I witnessed and had honour to contribute)
- ACRANEB2 story started soon after relocation of Jean-François to Prague (September 2003)
- during the years, Jean-François was able to attract a number of people for collaboration on ACRANEB2 developments:

| | |
|---|---|
| Pierre Bénard | Radmila Brožková |
| Neva Pristov | Peter Kuma |
| Alena Trojáková | Haliima Okodel Achom |
| Ján Mašek | Olivier Giot |
| Tomáš Kráľ | Daan Degrauwe |

- it was always adventure to be exposed to Jean-François' exceptional vision, deep knowledge, original ideas, and neverending passion to push the things forward

# Radiative transfer challenges

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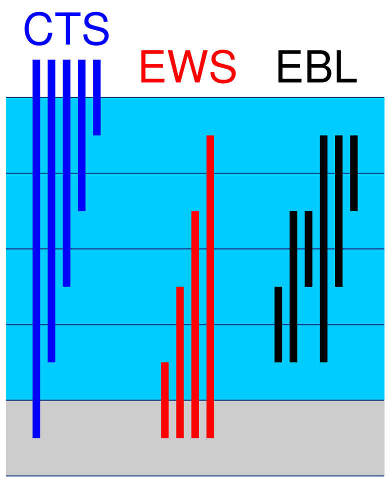


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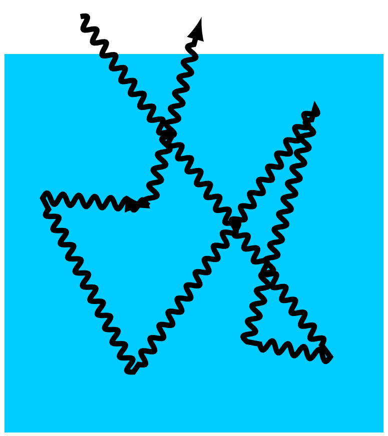

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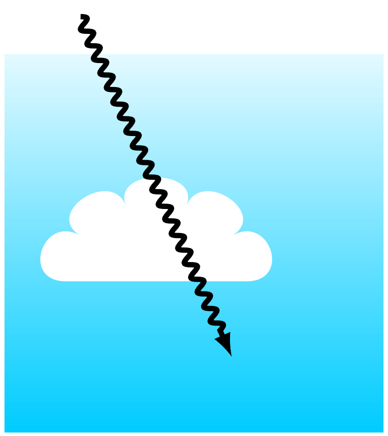

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# Some NWP answers

| problem | | relevance SW | relevance LW | NWP solutions |
|---|---|---|---|---|
| **1** | spectral integration | • | • | reordering of $k$-values, broadband approach |
| **2** | number of exchanges | | • | quasi-monochromatic calculations, NER decomposition with bracketing |
| **3** | multiple scattering | • | ∘ | delta-two-stream approximation |
| **4** | inhomogeneous optical paths | • | • | adding method with either correlated assumption or scaling approximation |

SW – ShortWave
LW – LongWave
CKD – Correlated $k$-Distribution
NER – Net Exchanged Rate

CKD specific choices (mainstream approach)
NER specific choices (offered alternative)


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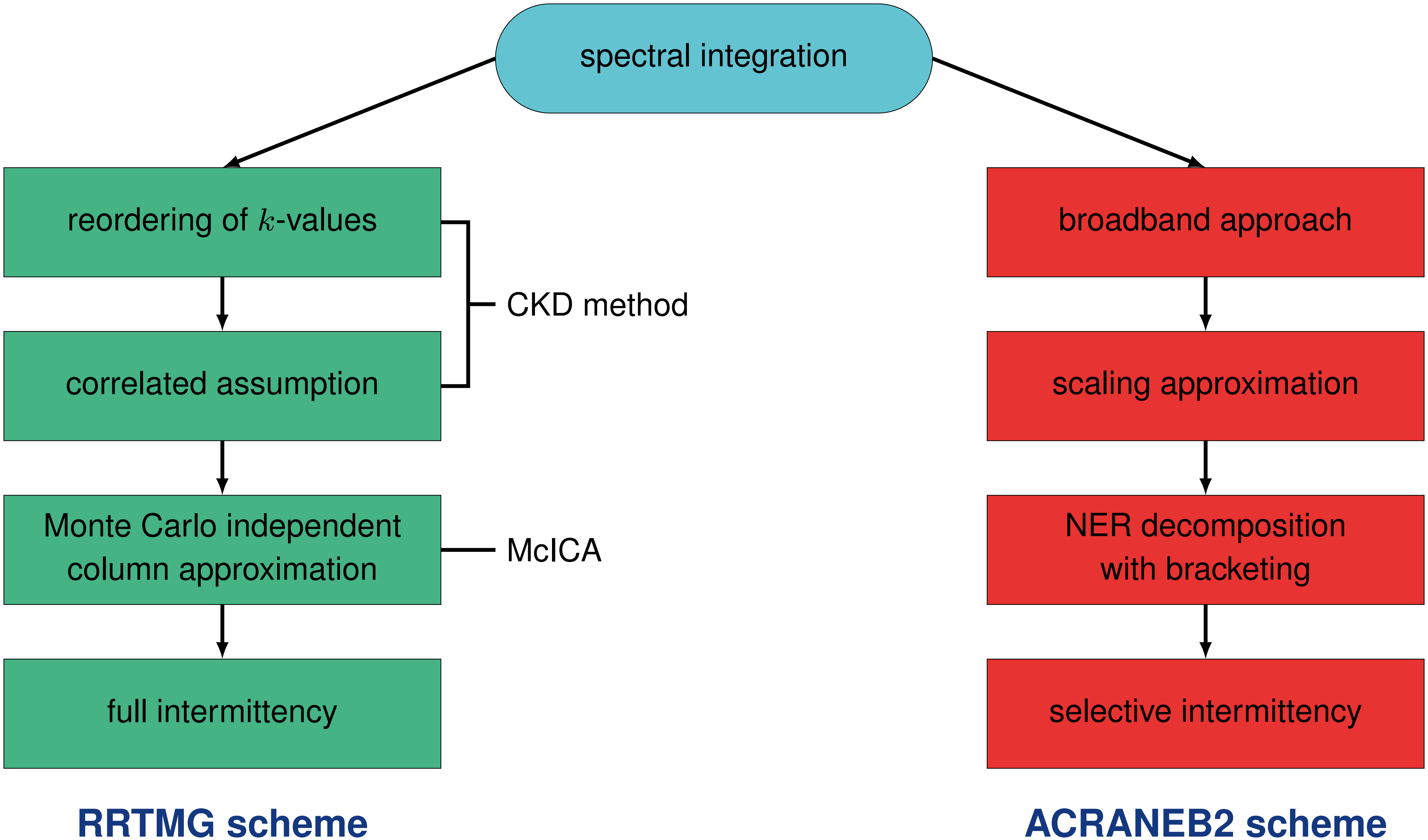
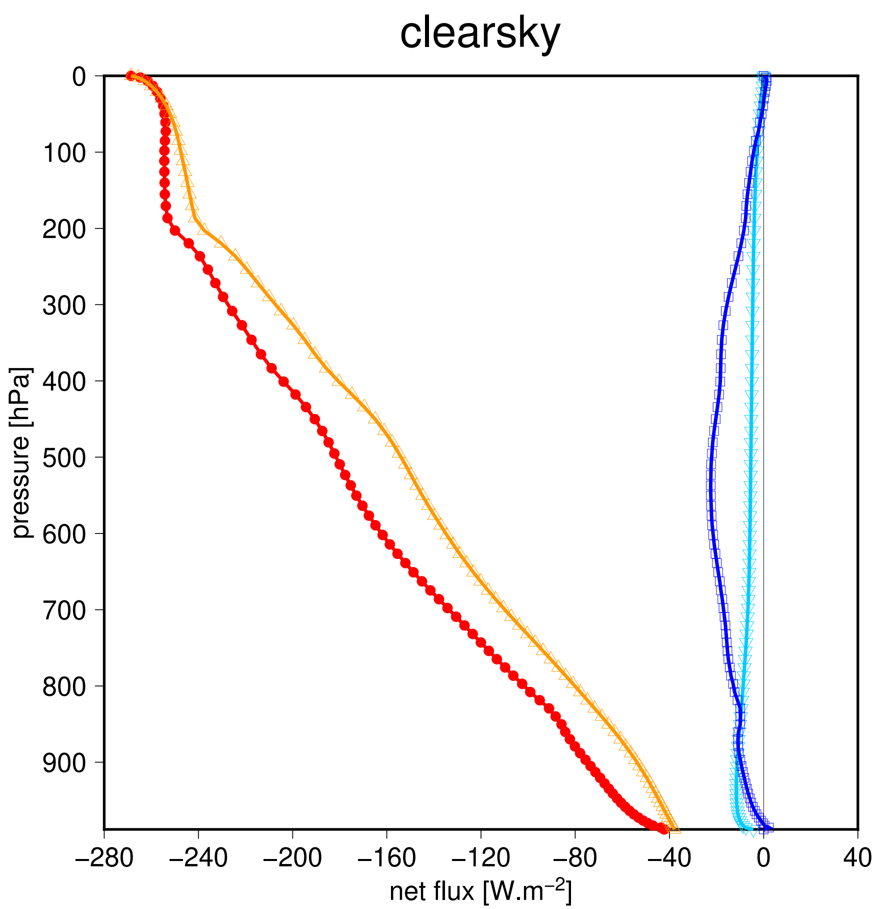
# Key choice

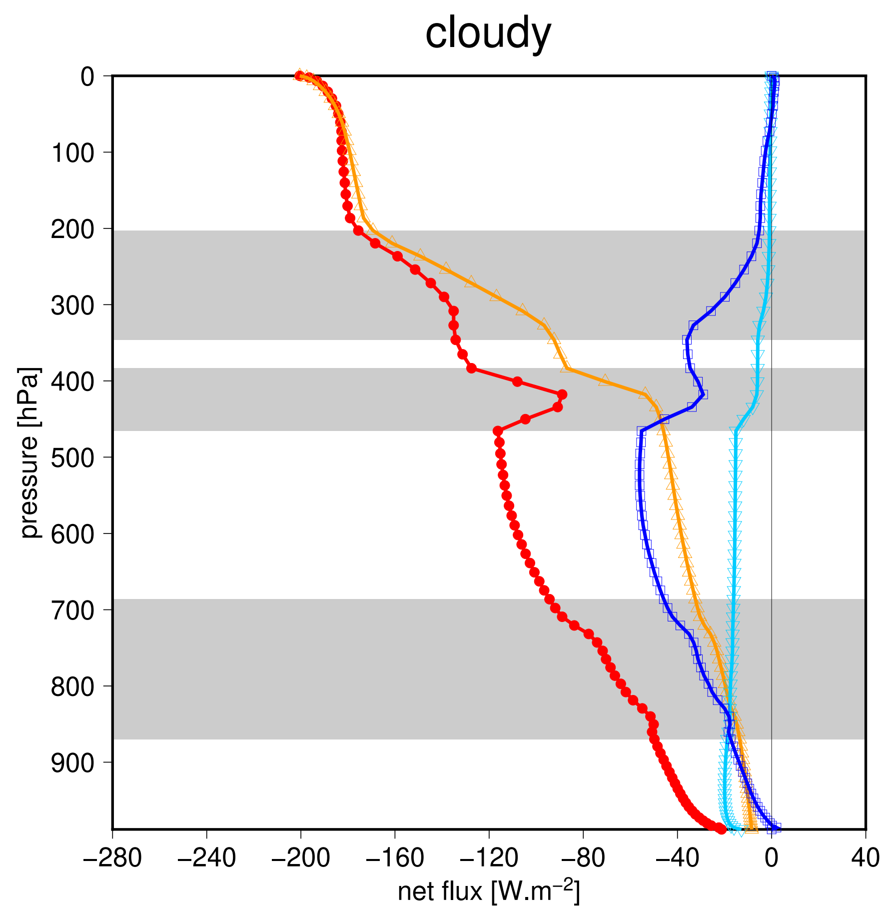

spectral integration
reordering of $k$-values
correlated assumption
CKD method
Monte Carlo independent column approximation
McICA
full intermittency
broadband approach
scaling approximation
NER decomposition with bracketing
selective intermittency
RRTMG scheme
ACRANEB2 scheme

# Radiation concept of Jean-François

- the goals:
  - **full cloud-radiation interaction** (not feasible with CKD method)
  - **sufficient accuracy** for the short range NWP
  - **scalability** (computational cost linear in the number of layers $L$)
- well chosen ingredients crucial for reaching these goals:
  - **single-band approach** in both SW and LW spectra, enabling independent update of gaseous and cloud optical properties alias **selective intermittency**
  - gaseous transmissions evaluated along **idealized optical paths**, then used in a full system with scattering
  - **parameterized spectrally unresolved phenomena**, pushing accuracy of the single-band approach up to its limits
  - LW solver using the **NER decomposition**, plus the **bracketing technique** providing cheap estimate of otherwise costly internal exchanges

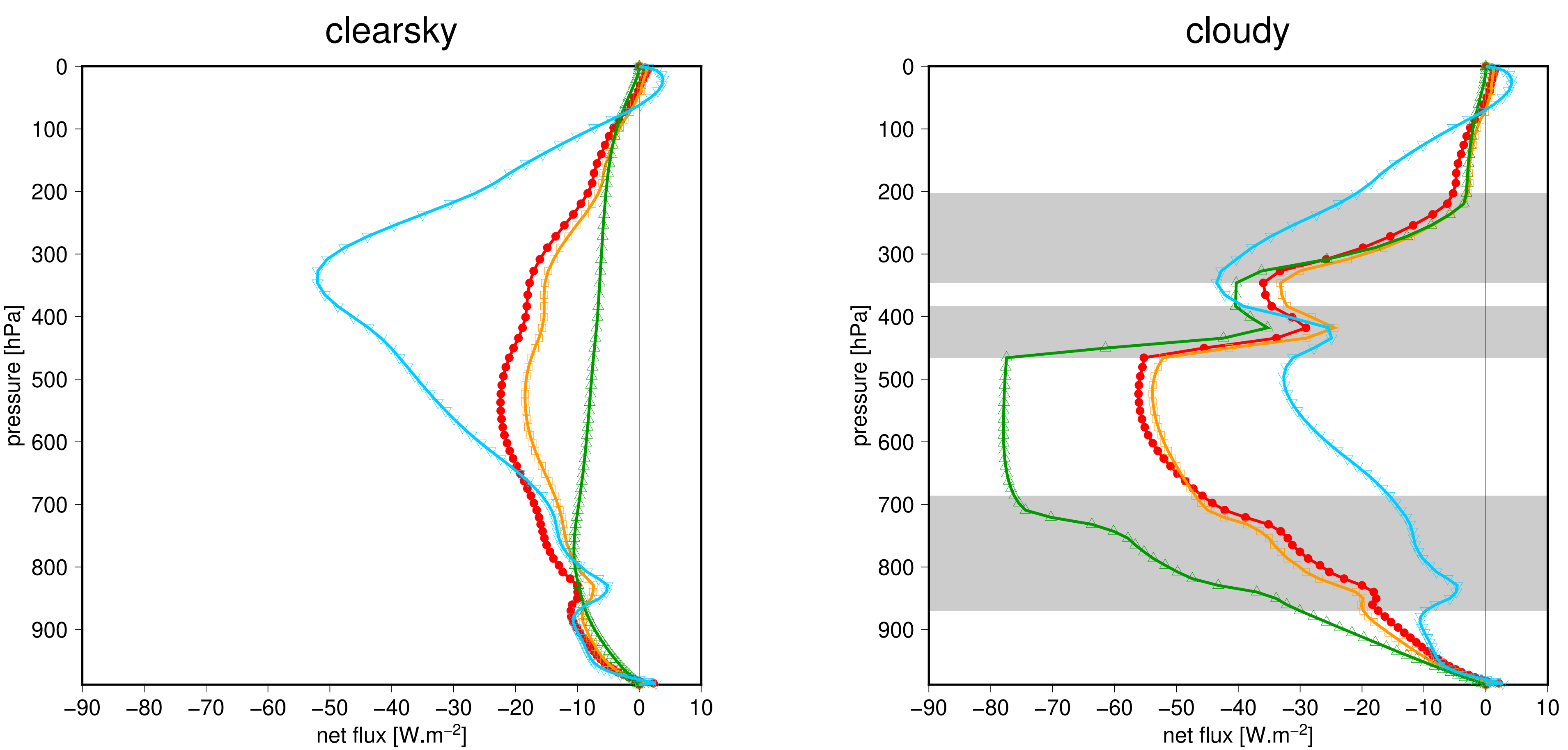
# Cornerstones – NER decomposition of the LW net flux




LW net flux (CTS+EWS+EBL)
CTS – Cooling To Space
EWS – Exchange With Surface
EBL – Exchange Between Layers
cloud layers

# Cornerstones – bracketing of EBL flux




true EBL flux (narrowband reference)
true/interpolated EBL flux (broadband computation)
minimum EBL flux
maximum EBL flux
cloud layers

# Brief story of ACRANEB

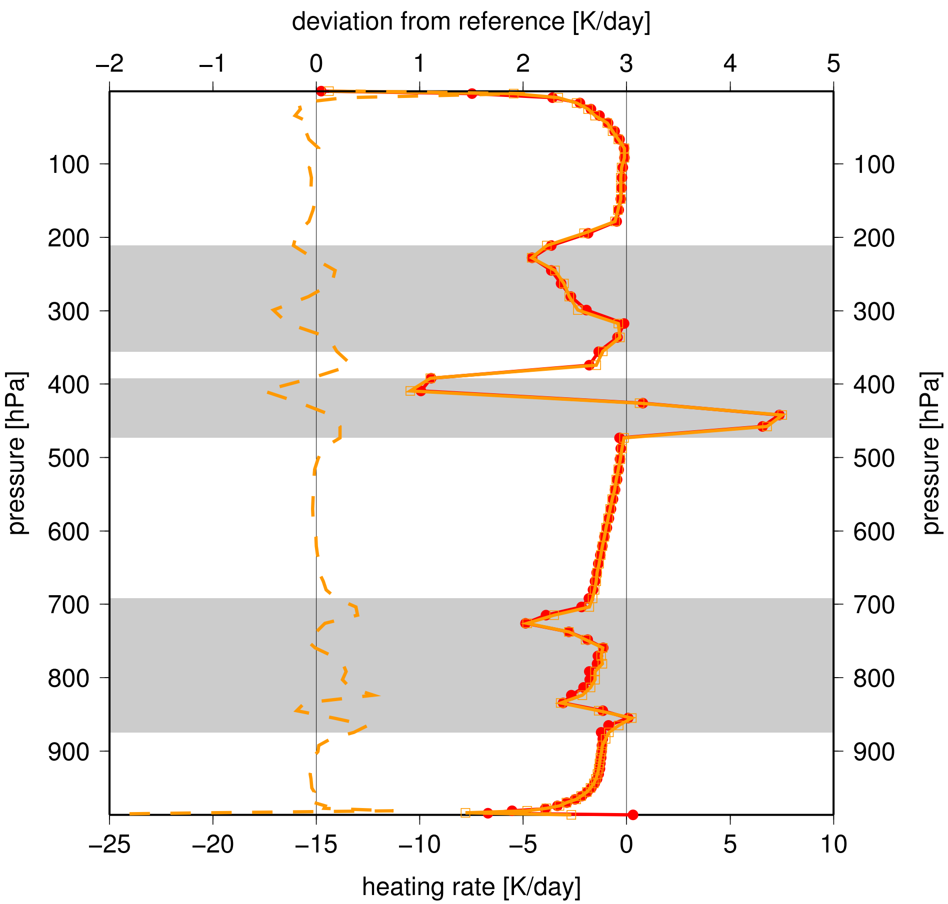
- ACRANEB gaseous transmissions were cheap enough to be evaluated at every model grid-point and time-step $\Rightarrow$ no need of selective intermittency
- overall accuracy was strongly limited by very simple gaseous transmissions and cloud optical properties
- ACRANEB was used operationally in Météo France in 1992–2005, then it was abandoned due to its drawbacks with respect to rising RRTMG scheme
- at a time, ACRANEB was used by all operational ALADIN models
- although ACRANEB developments are frozen since 2013, it is still a valid part of ALARO-0 canonical model configuration
- historically, ACRANEB can be viewed as a **testbed for NWP implementation of the NER decomposition**, breaking the $L^2$ computational barrier

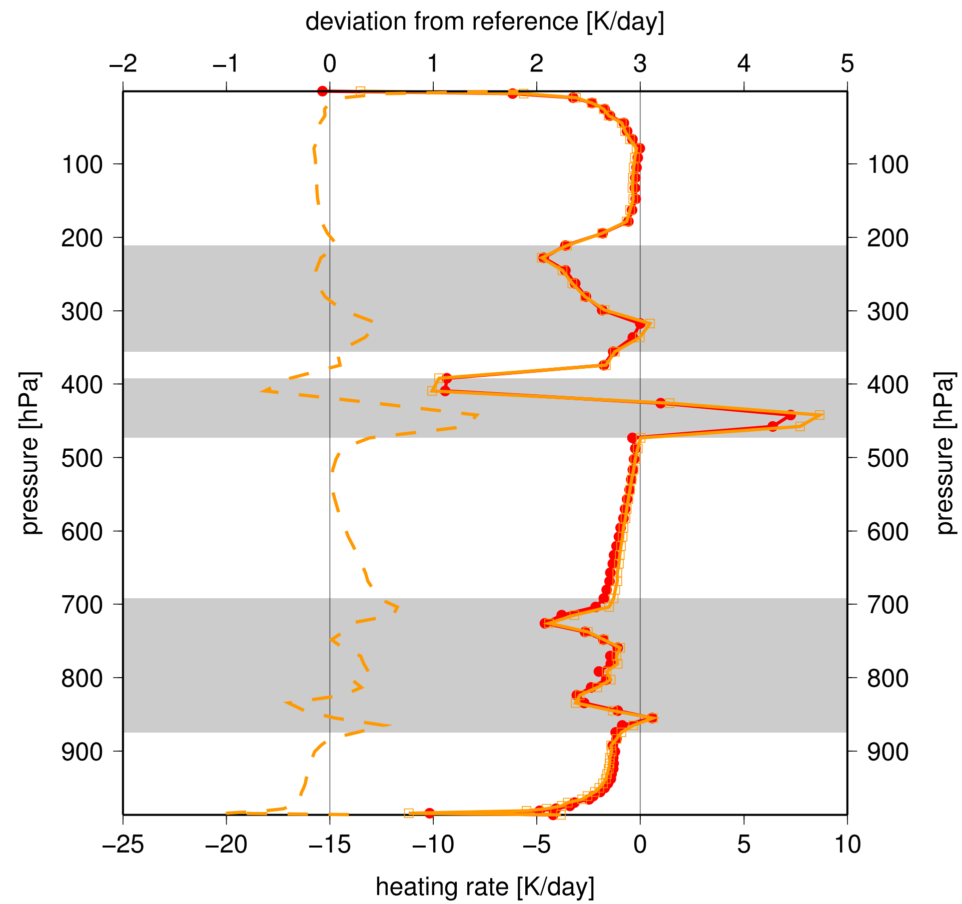
# From ACRANEB to ACRANEB2

- ACRANEB2 developments started in 2005 under ALARO flagship
- **principle:** ACRANEB strategic choices kept, weakest components redeveloped
- proper tools were created, including reference narrowband model and non-linear fitting procedure
- new functional shape of the broadband fits was proposed, respecting desired asymptotic behaviour whenever possible
- fitting references were derived from modern optical datasets
- some previously ignored phenomena were parameterized
- higher cost of more sophisticated gaseous transmissions was fully compensated by their intermittent update
- **radiation scheme competitive to the mainstream approach was obtained,** entering CHMI operations as a part of ALARO-1 prototype in January 2015
- somewhat lower accuracy of ACRANEB2 in a stand-alone mode is counter-balanced by a full cloud-radiation interaction, important for NWP

# Final achievement – stand-alone accuracy

*LW heating rate error with respect to the narrowband reference for single profile:*



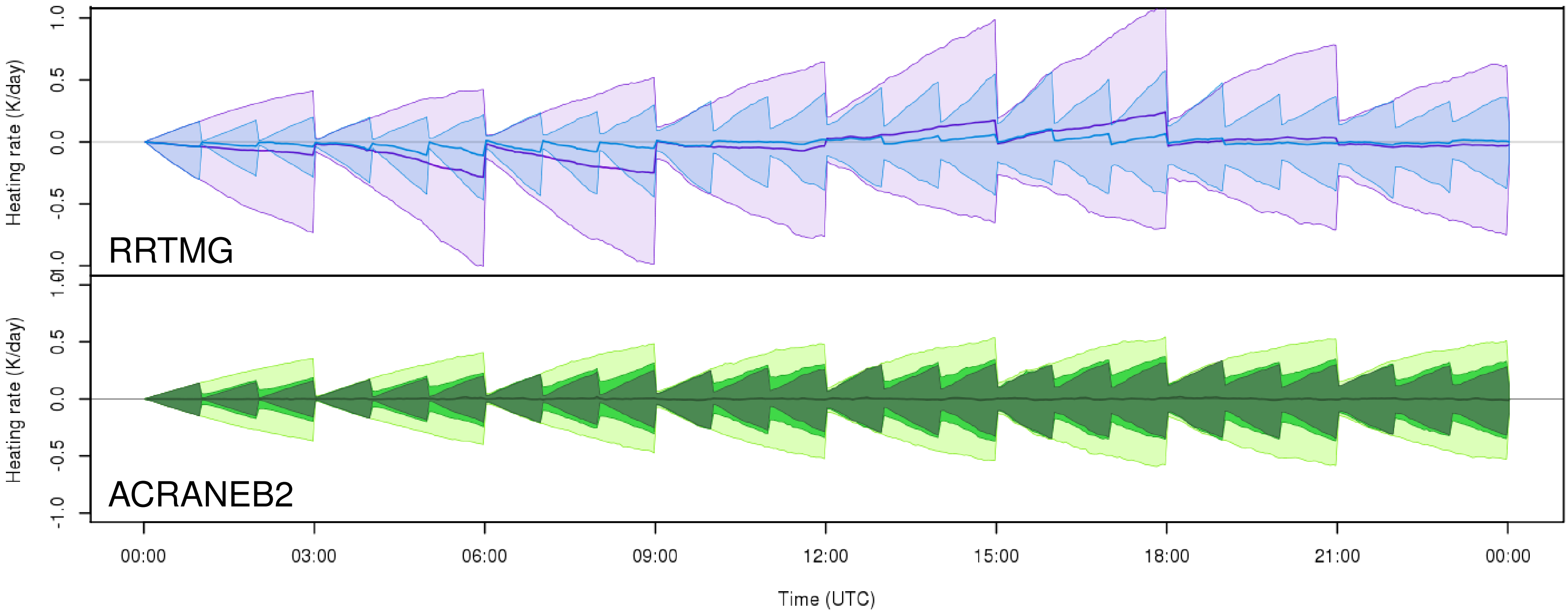




narrowband reference (432 LW intervals)
RRTMG (16 LW intervals, 140 solvings)
cloud layers

narrowband reference (432 LW intervals)
ACRANEB2 (1 LW interval, 8 solvings)

# Final achievement – accuracy of intermittent strategy

*Mean error and 68% confidence interval of tropospheric LW heating rates during 24 hour model integration (reference is non-intermittent run with given scheme):*




RRTMG – **full intermittency** (LW fluxes updated every 1h or 3h)
ACRANEB2 – **selective intermittency** (LW gaseous transmissions and bracketing weights updated every 1h, 1h/3h or 3h)

# Will the story be continued?

- after 10 years of developments, **ACRANEB2 fulfilled original expectations**
- largest errors now arise from imprecise cloud and aerosol inputs, these should be improved with high priority
- some components of radiation scheme itself could still be improved, although with lower priority
- **tough challenge ahead:** 3D radiative effects of clouds become resolved as we move to subkilometric resolutions, but 1D radiation scheme cannot treat them!
- truly 3D radiation solvers are both expensive and incompatible with current columnar design of model physics, necessary for efficient parallelization
- reduced radiation grid is an option, but a bit paradoxical in cloud resolving NWP
- **question to be answered:** does it make sense to fully resolve the clouds in dynamics and microphysics, but not in radiation?

# Epilogue

Working with Jean-François,
we have grown up not in a shadow,
but in a shine of genius!

We miss him a lot.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# Thank you for your attention

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