EUMETSAT

An infrared emissivity atlas based on IASI

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EUMETSAT

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Agenda

Motivation

Why another emissivity atlas?

The linear programming (LP) emissivity retrieval approach

Representation of emissivity as a convex combination of emissivity base spectra.

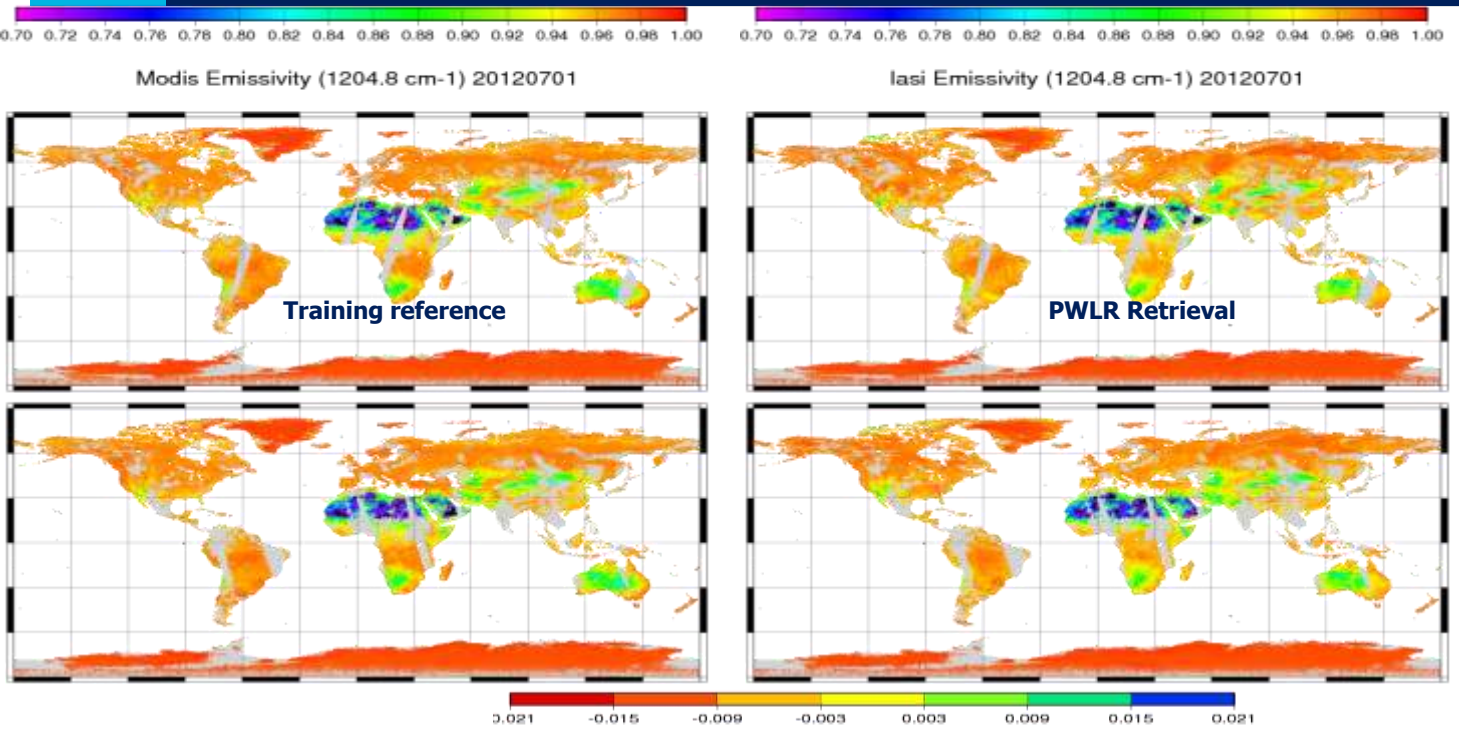
Challenges

Need for very strict cloud screening.

Comparison with Camel

Wrap up (still work in progress)

Piece Wise Linear Regression retrieval of emissivity

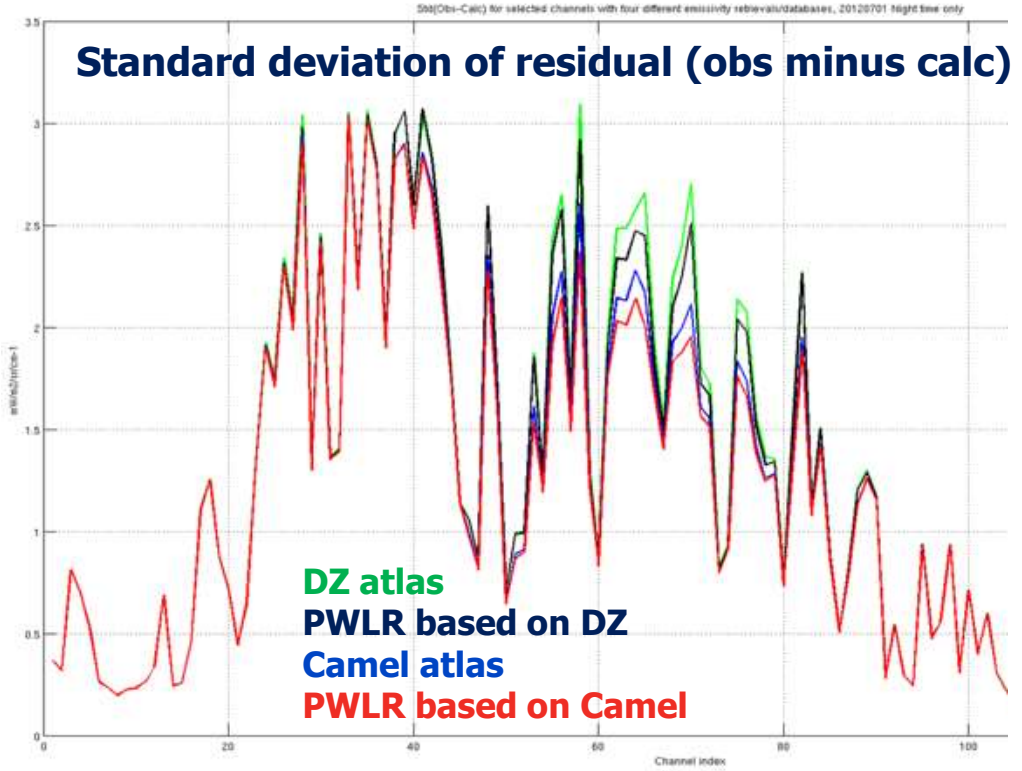


Consistent differences between PWLR retrieval and training atlas day and night

PWLR retrieval trained with Camel atlas:

- Just giving back the atlas? Or is there added value?

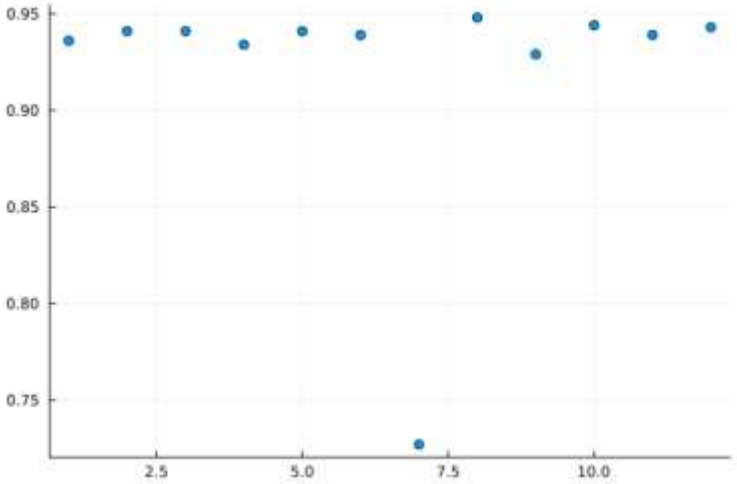
Analysis of obs – calc for different sources of emissivity sources shows that the PWLR retrieval can improve upon the atlas



Camel V3 atlas

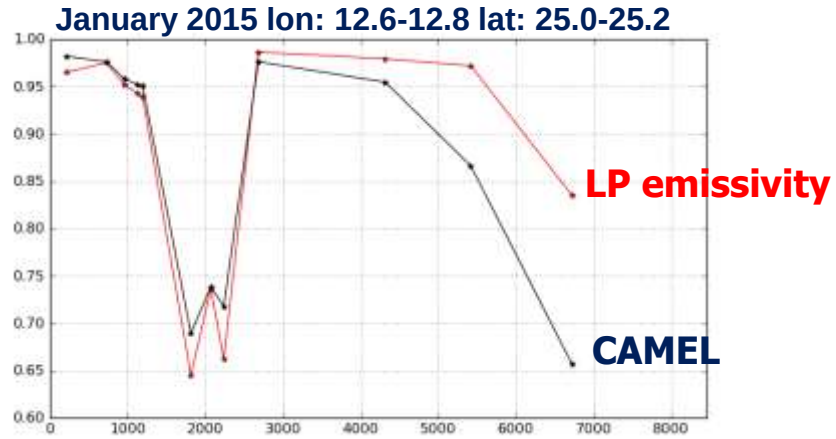
- Integrated in RTTOV. Based on Modis and Aster. Provides emissivity on 13 wavenumbers. PC expansion to emissivity spectra (698-2778 cm^{-1}).

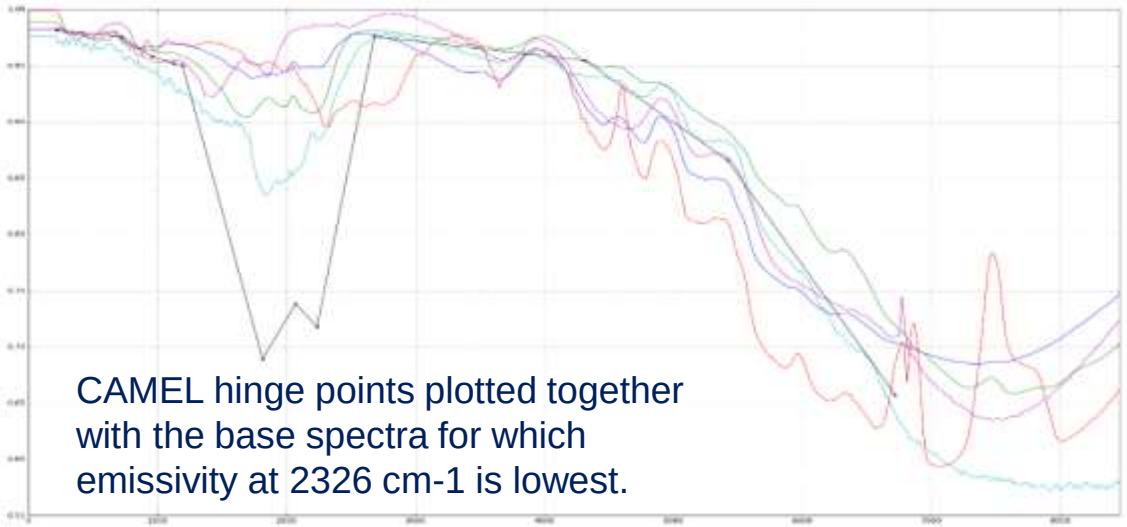
Occasional unrealistic values



Camel V3. Emissivity at 925.93cm^{-1} each month of 2023
Longitude: 37.45, Latitude = 32.7

PC representation allows for unphysical emissivity spectra



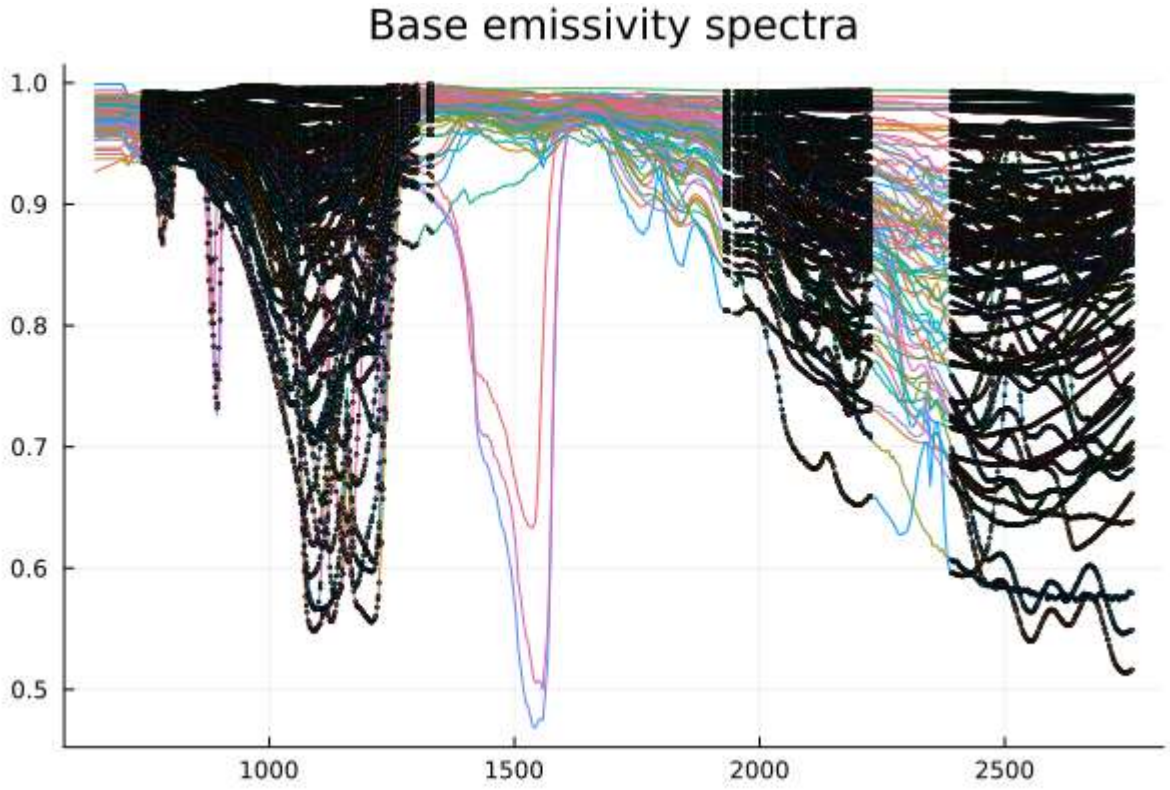


CAMEL hinge points plotted together with the base spectra for which emissivity at 2326 cm-1 is lowest.

- Hyperspectral Infrared Emissivity Atlas is needed
- Current de facto standard atlas (Camel V3) has some weaknesses
- Hyperspectral data might help determine the emissivity spectral shape

Low dimensional representation of emissivity

Convex combination: linear combination where all coefficients are non-negative and sum to 1



Configuration

- 87 base emissivity spectra from ASTER spectral library (the ones used for Camel PCs)
- 589 surface sensitive channels (rejecting channels if the emissivity Jacobian is less than 0.6 times the simulated radiance)

Simultaneous retrieval of ts and e by fitting radiances

In each clear sky pixel take:

- y the (noise filtered) measured radiances
- x an estimate of the state (obtained without radiance fitting)
- r^x the simulated radiances F(x) obtained by applying a forward model F to x
- K^{ts} the Jacobian wrt surface skin temperature
- K^e the Jacobian wrt emissivity

Want corrections Δts and Δe to ts and e from x such that $r = r^x + K^{ts}\Delta ts + K^e\Delta e$ is close to y

For fixed Δts we can match y by setting $\Delta e = (r^x + K^{ts}\Delta ts - y)_i / K^e_i$

Need regularization by restricting the feasible space of e+Δe

PC representation:

$e+\Delta e = e_m + E_e\mathbf{p}$

Convex combination representation:

$e+\Delta e = E_b\boldsymbol{\lambda}$ with $\boldsymbol{\lambda}\geq 0$ and $\sum\boldsymbol{\lambda} = 1$

Minimize $\sum|r-y|$

Subject to

$r = r^x + K^{ts}\Delta ts + K^e E_b (\boldsymbol{\lambda}-\lambda_0)$

$\sum\boldsymbol{\lambda} = 1$

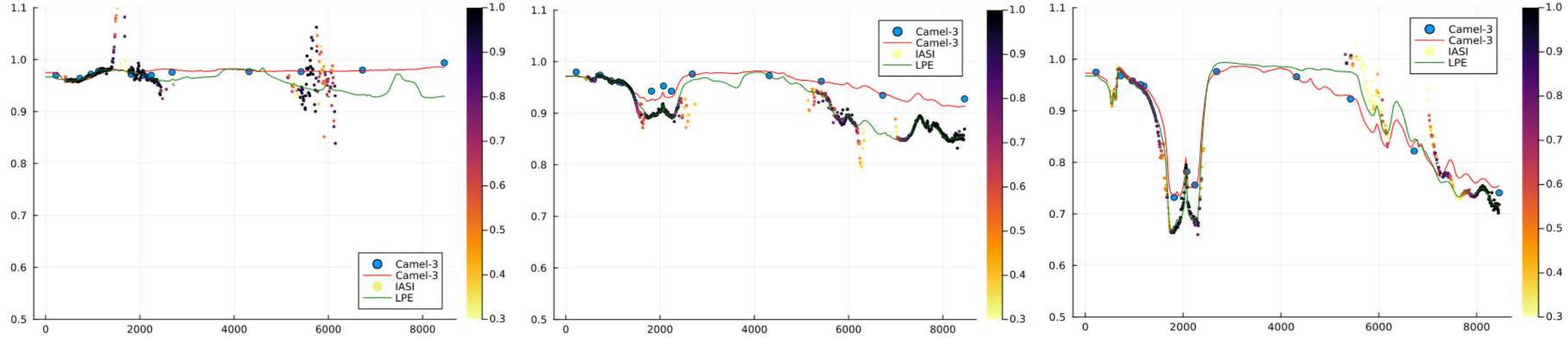
$\boldsymbol{\lambda}\geq 0$

Easy to state and solve in C++ (FLOPC++) or Julia (JuMP)

Can be formulated as a linear program (LP) with objective function min $\sum|r-y|$

Three selected (nighttime) cases

Each dot shows individual channel emissivity retrieval to fit measurement (with fixed Δts)
The colour indicates value of K^e_i/r^x_i (surface sensitivity)



- Only nighttime shortwave radiances are reliably simulated
- Big impact of noise for shortwave in cold scenes
- Aerosols / ozone / CO
- Strict cloud screening needed

PWLR V7 (commercial break)

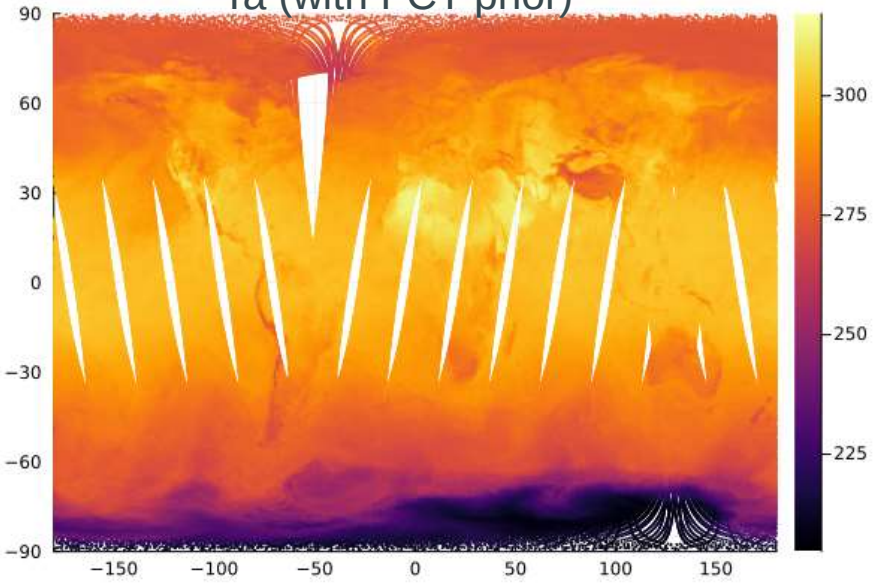
Good quality profiles are needed

- Which have not been obtained by fitting the measurements

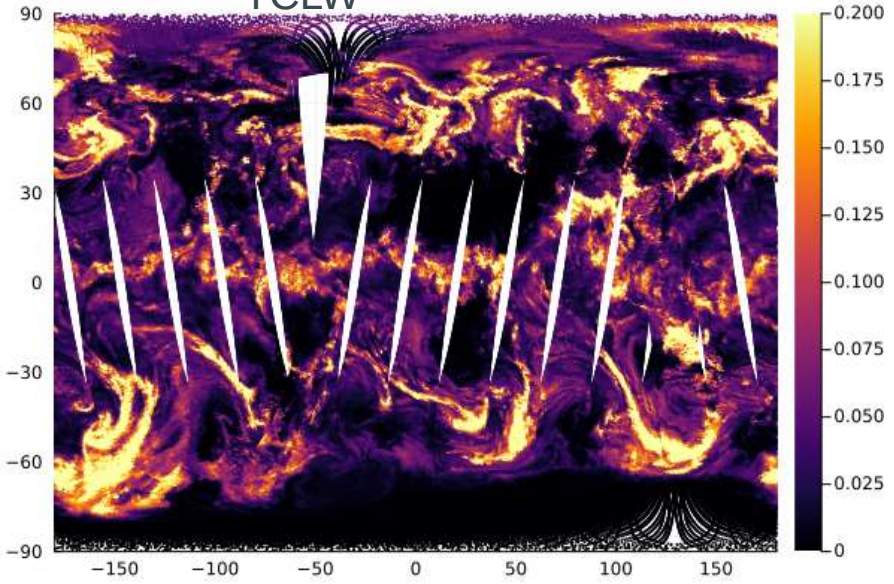
IASI L2 V7 processor (PWLR):

- ML trained with real IASI and collocated ECMWF profiles
- Profiles at 137 model layers
- TCLW and TCIW added
- T and W profiles with FCT prior information on fine scale vertical structures in the null space added in **addition** to the usual forecast free profiles
- 4.5 TB/year (per satellite)

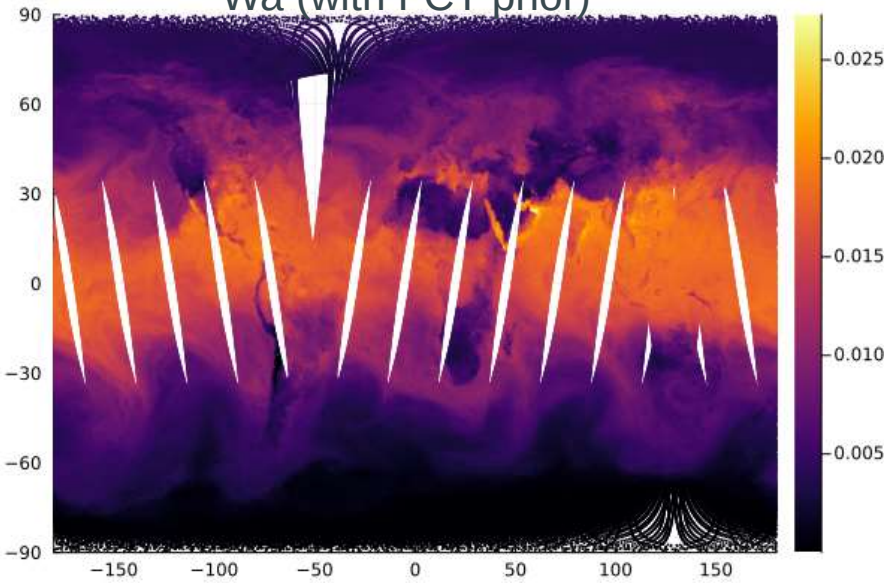
Ta (with FCT prior)



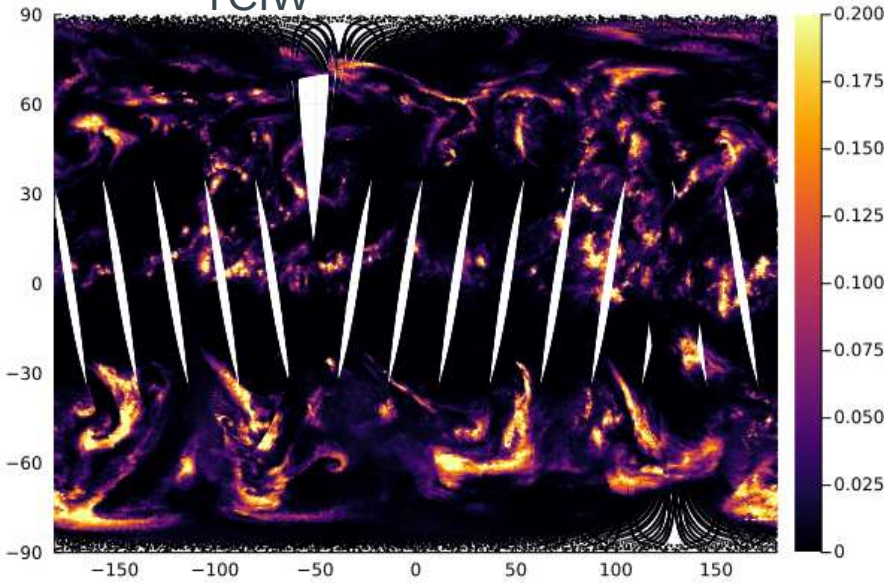
TCLW



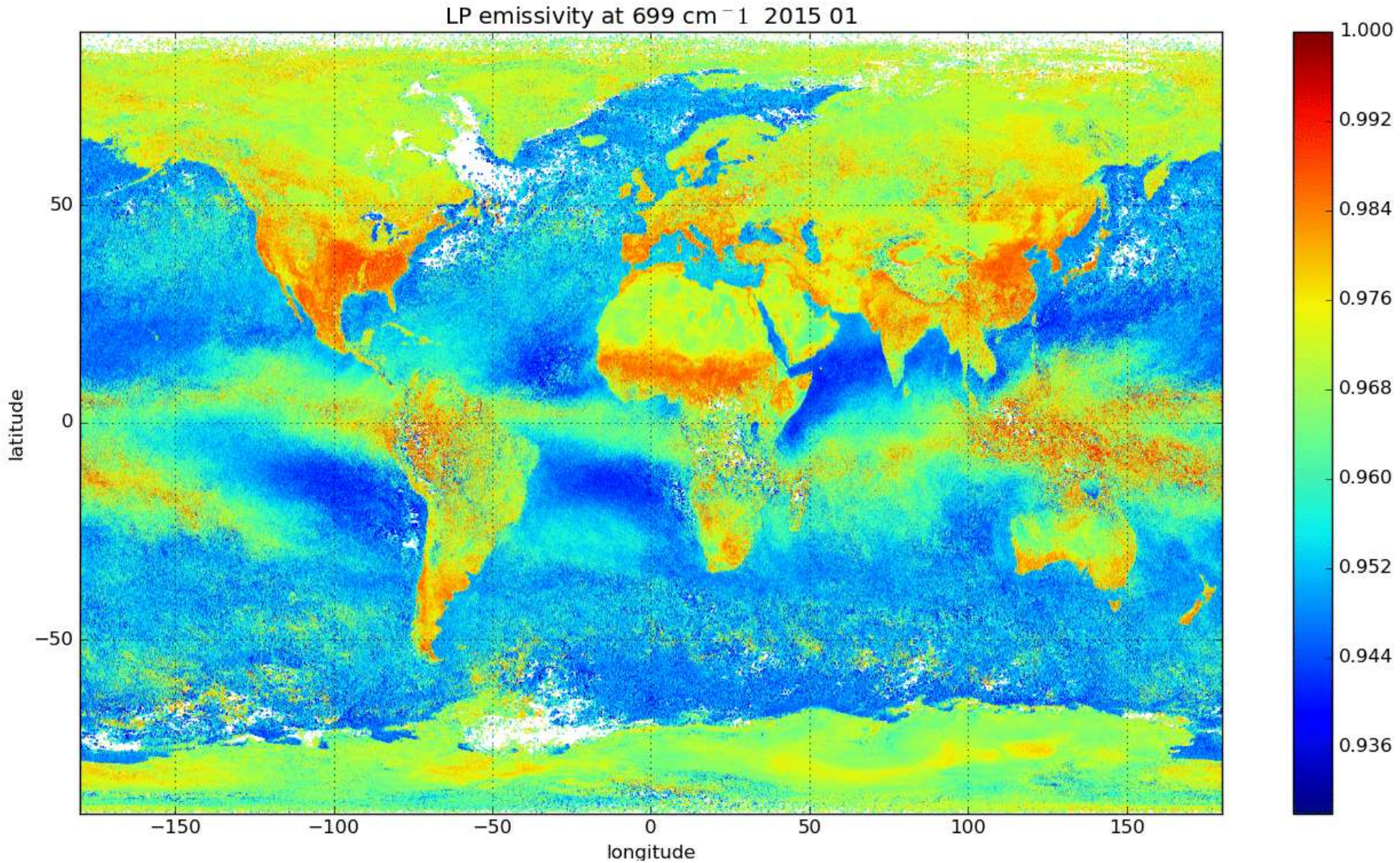
Wa (with FCT prior)



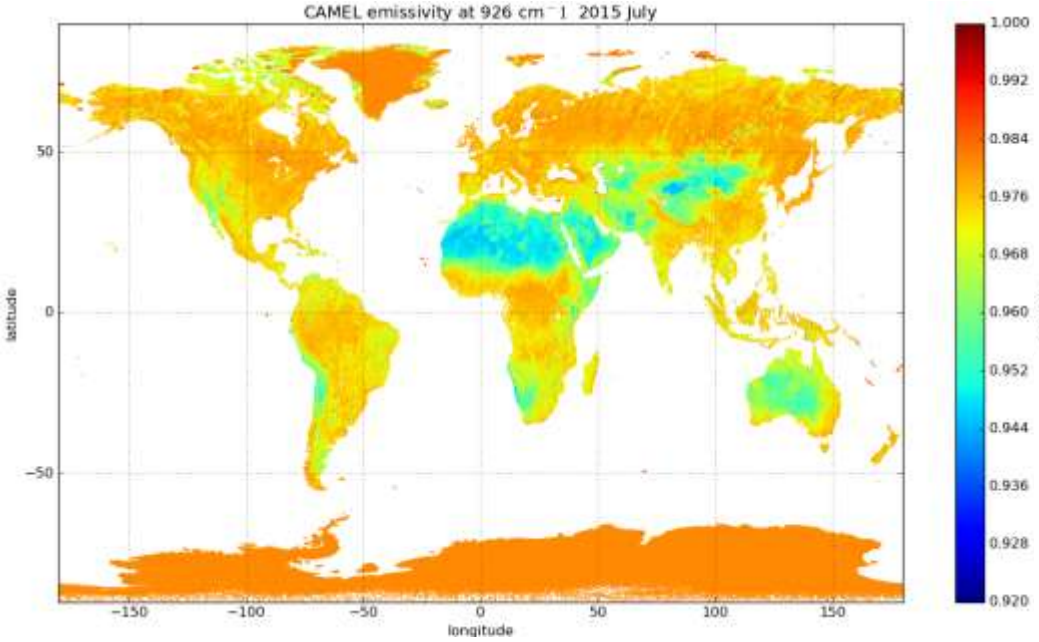
TCIW

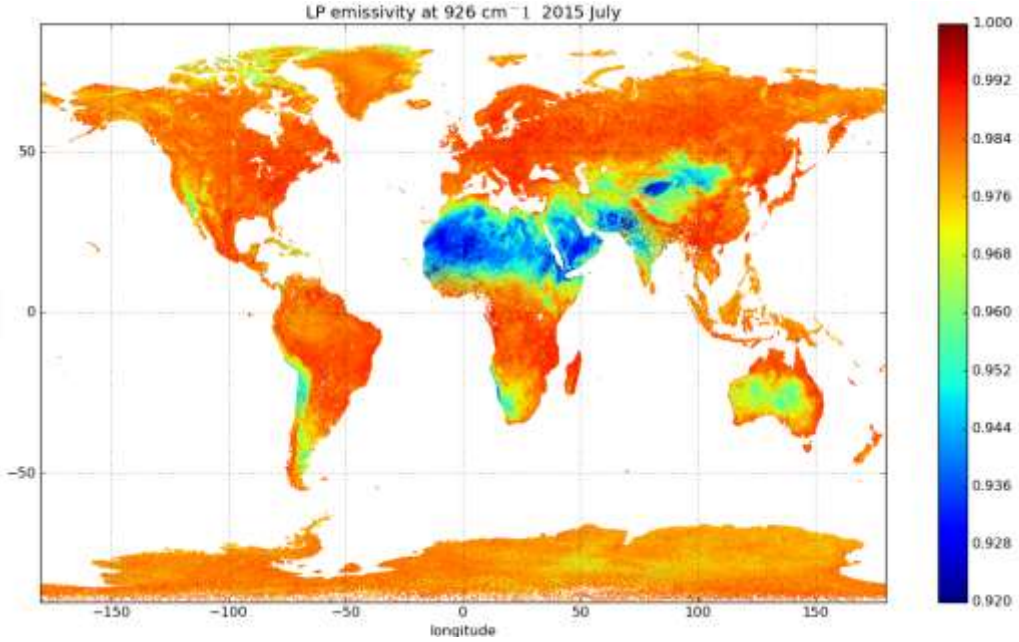


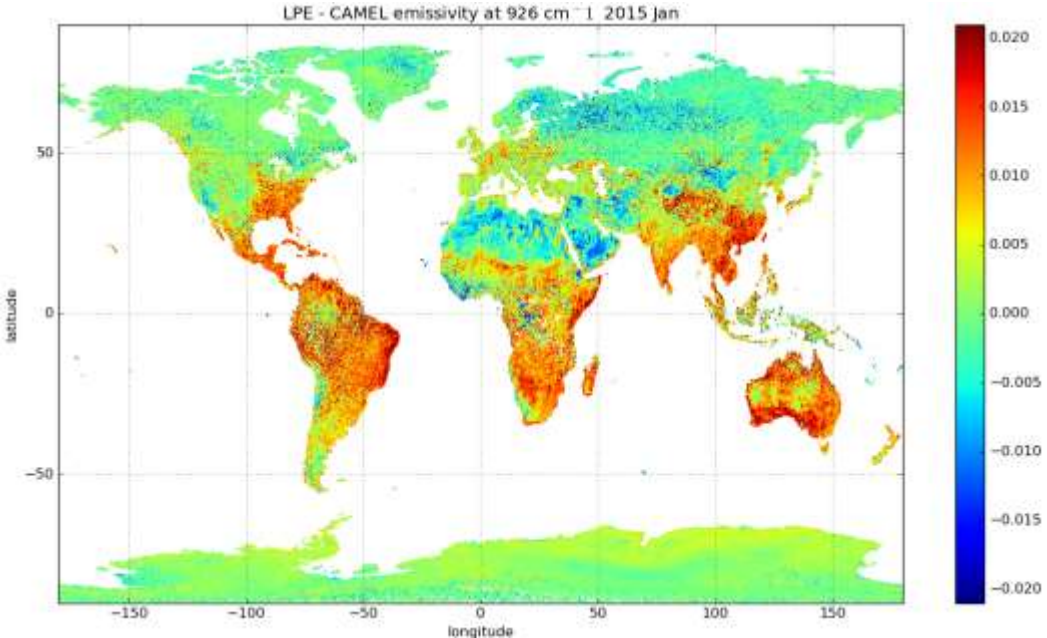
(Insufficient) cloud filtering

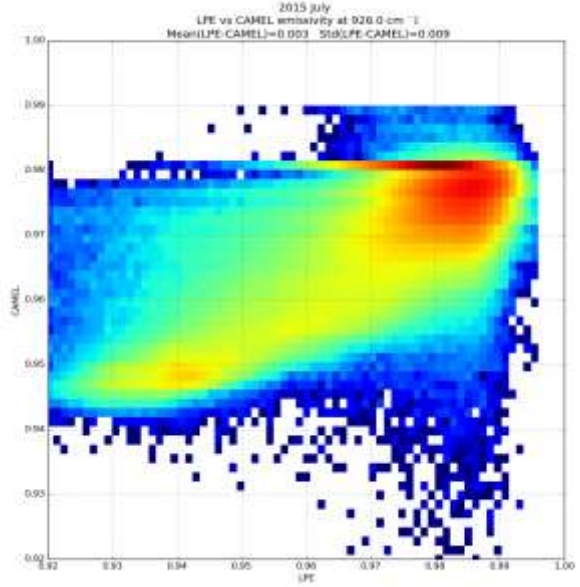


Comparison at 926 cm^{-1}

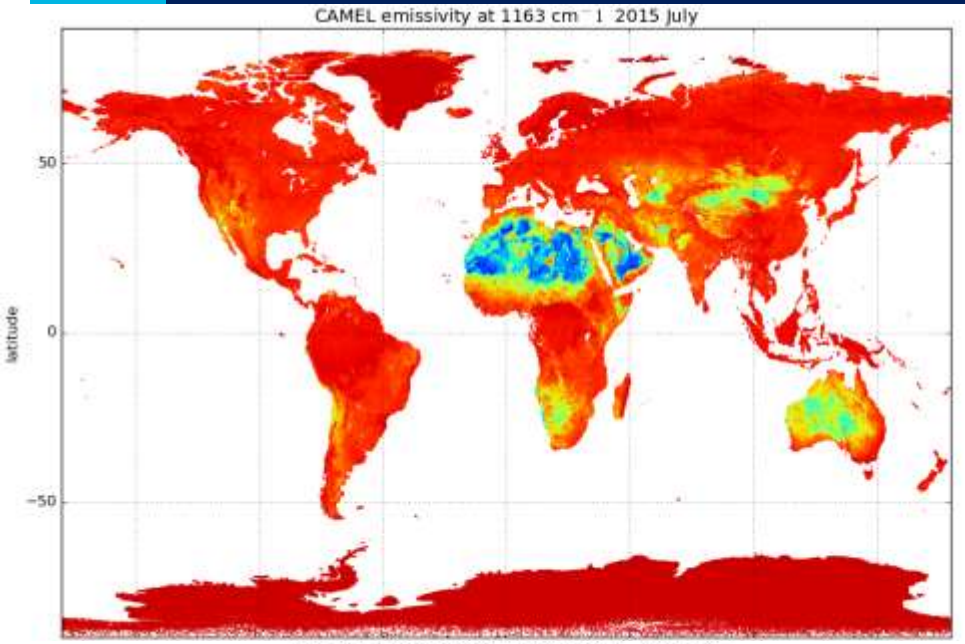


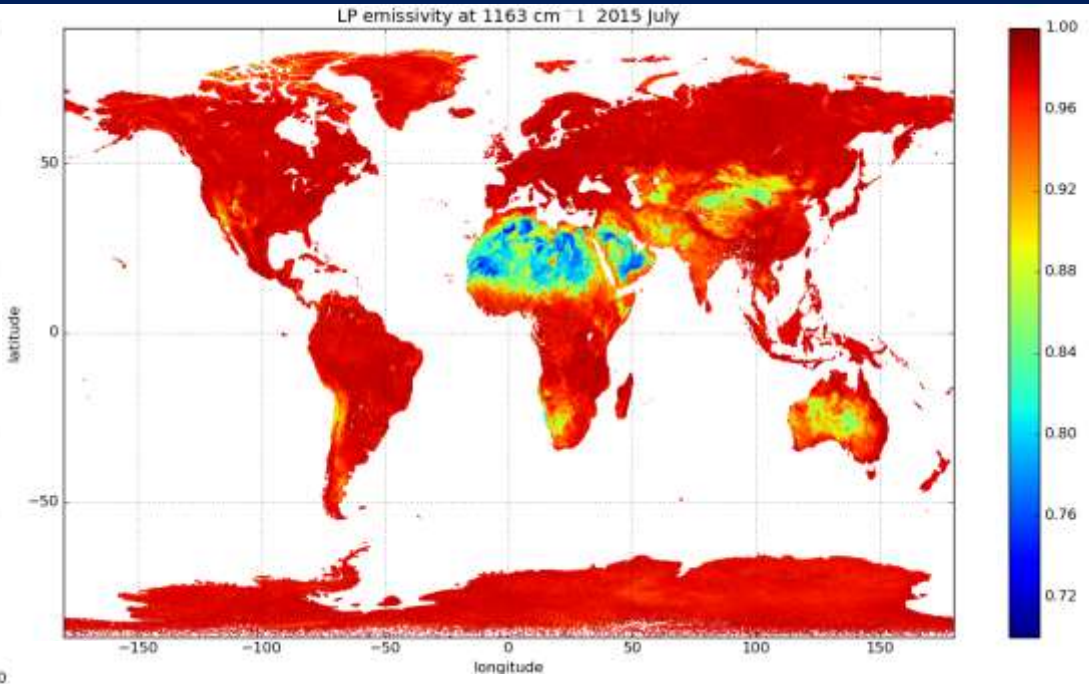


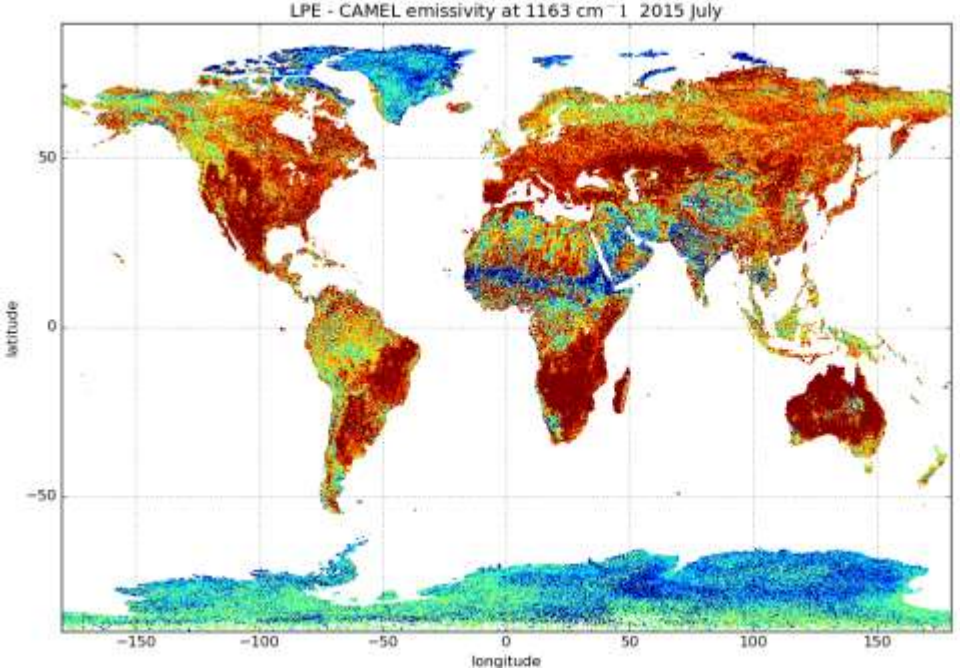


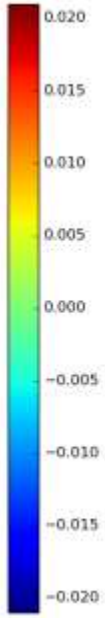


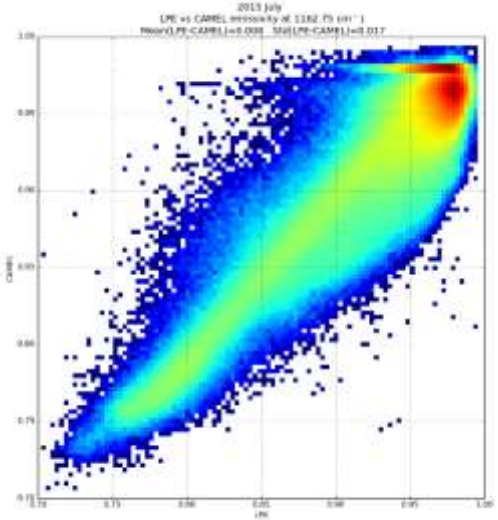
Comparison at 1163 cm^{-1}



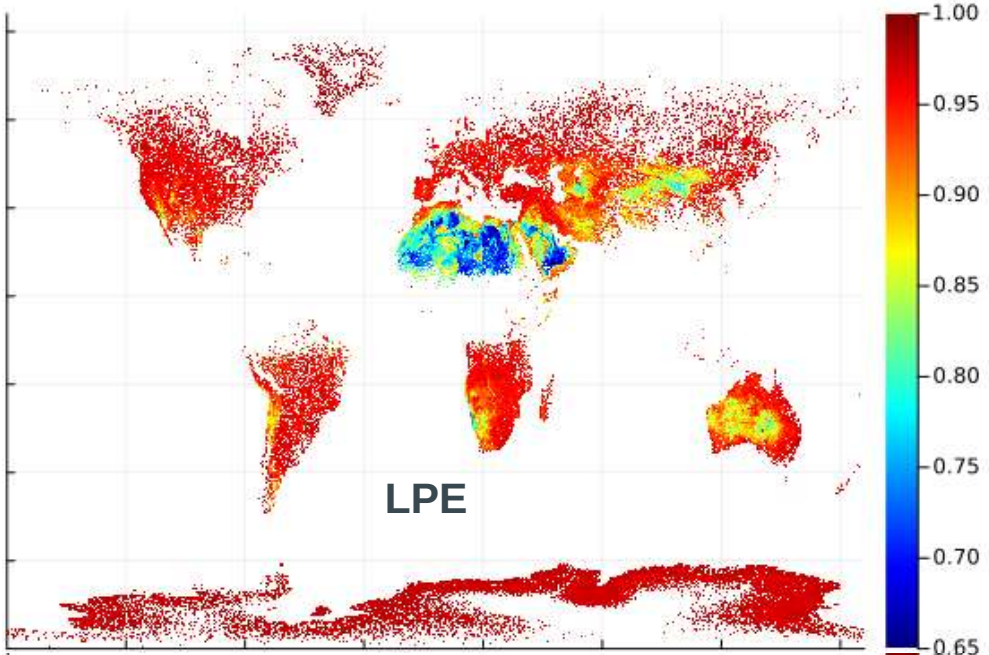


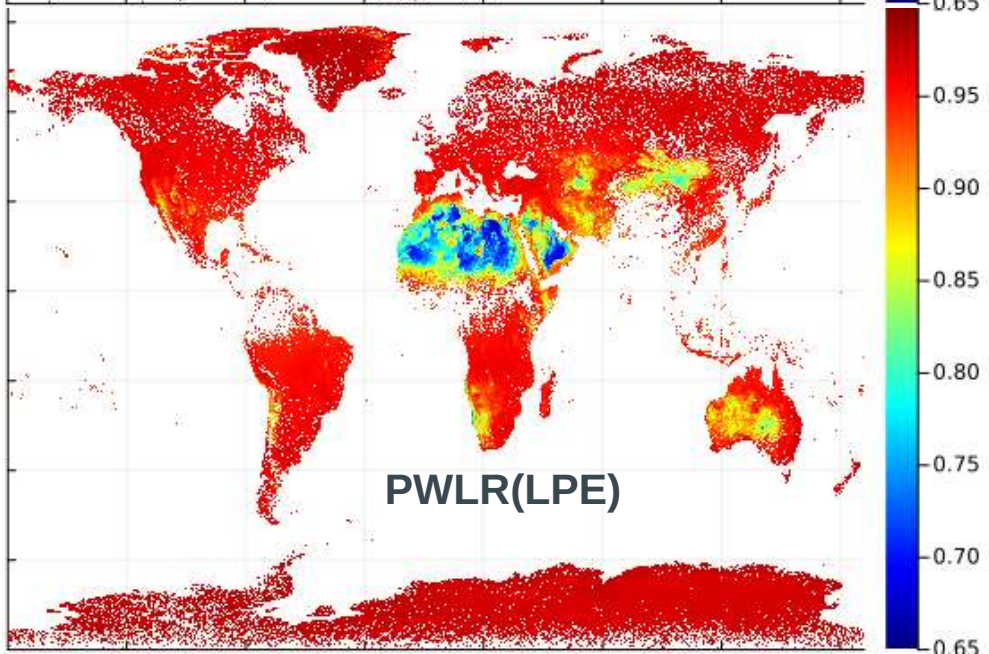






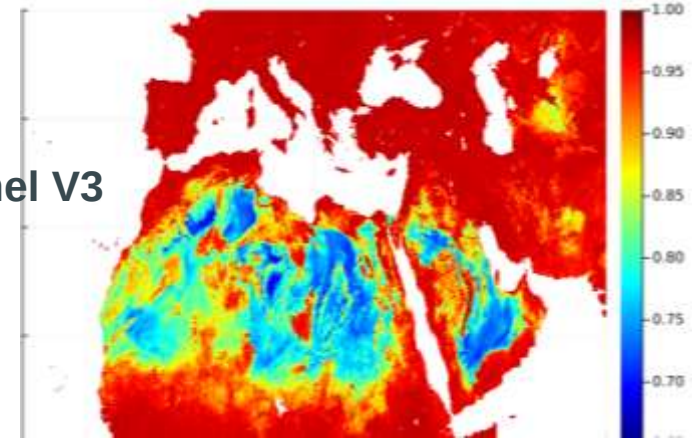
First month of new atlas, fresh from the computer…





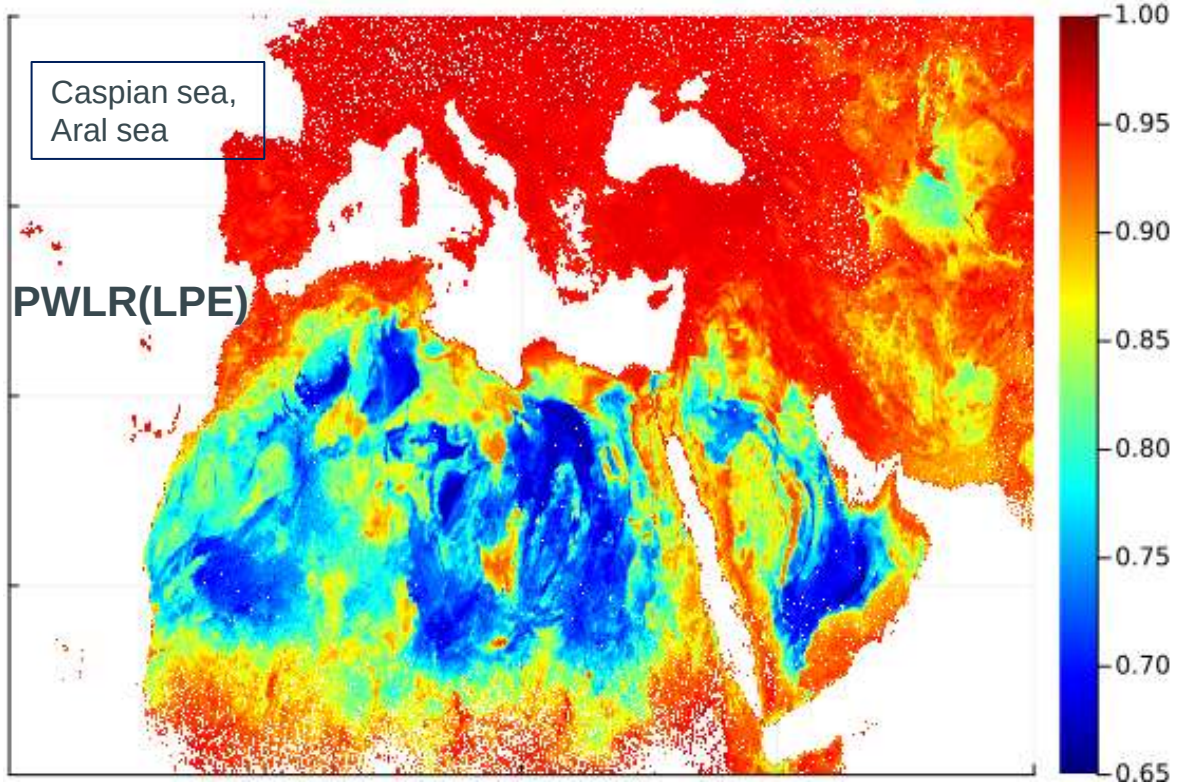
July 2023 at 1099 cm^{-1}

Camel V3

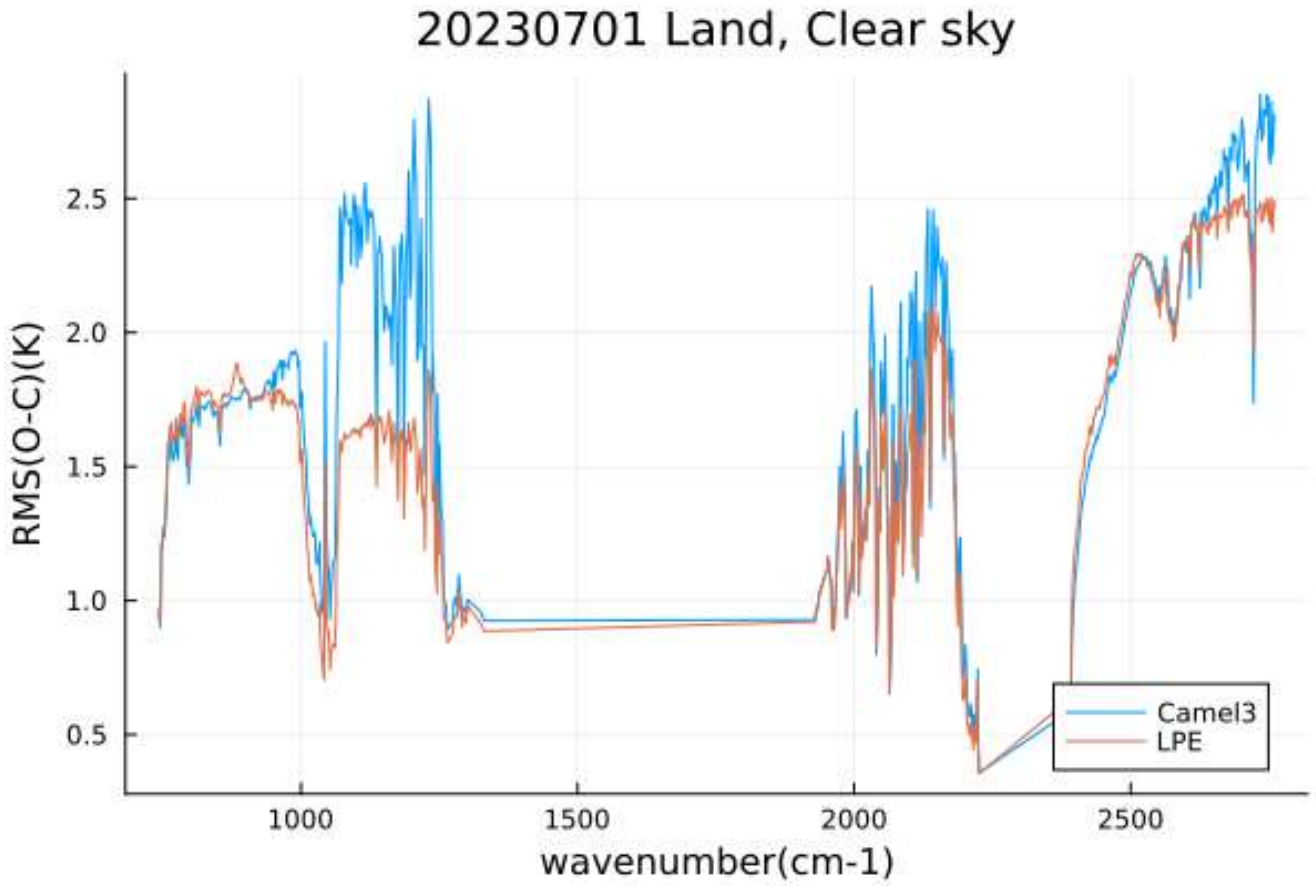


Caspian sea,
Aral sea

PWLR(LPE)



Comparison in radiance space



Wrap up

- Using LP for retrieval is cool – and hopefully beneficial…
- Main purpose of atlas to serve as training data for PWLR, but we also plan to make it publicly available
- Not yet ready for general distribution (one year of M01 V7 profiles and emissivity retrievals done – atlas to be compiled and checked)
- Spatial resolution 0.1 times 0.1 degree or 0.5 times 0.5 (as Camel)?
- Cloud screening trade off?
- Validation?
- Feedback and pilot users are welcome