# Complementarity Of Measurements And Models To Reproduce Earth Radiation Belt Dynamics

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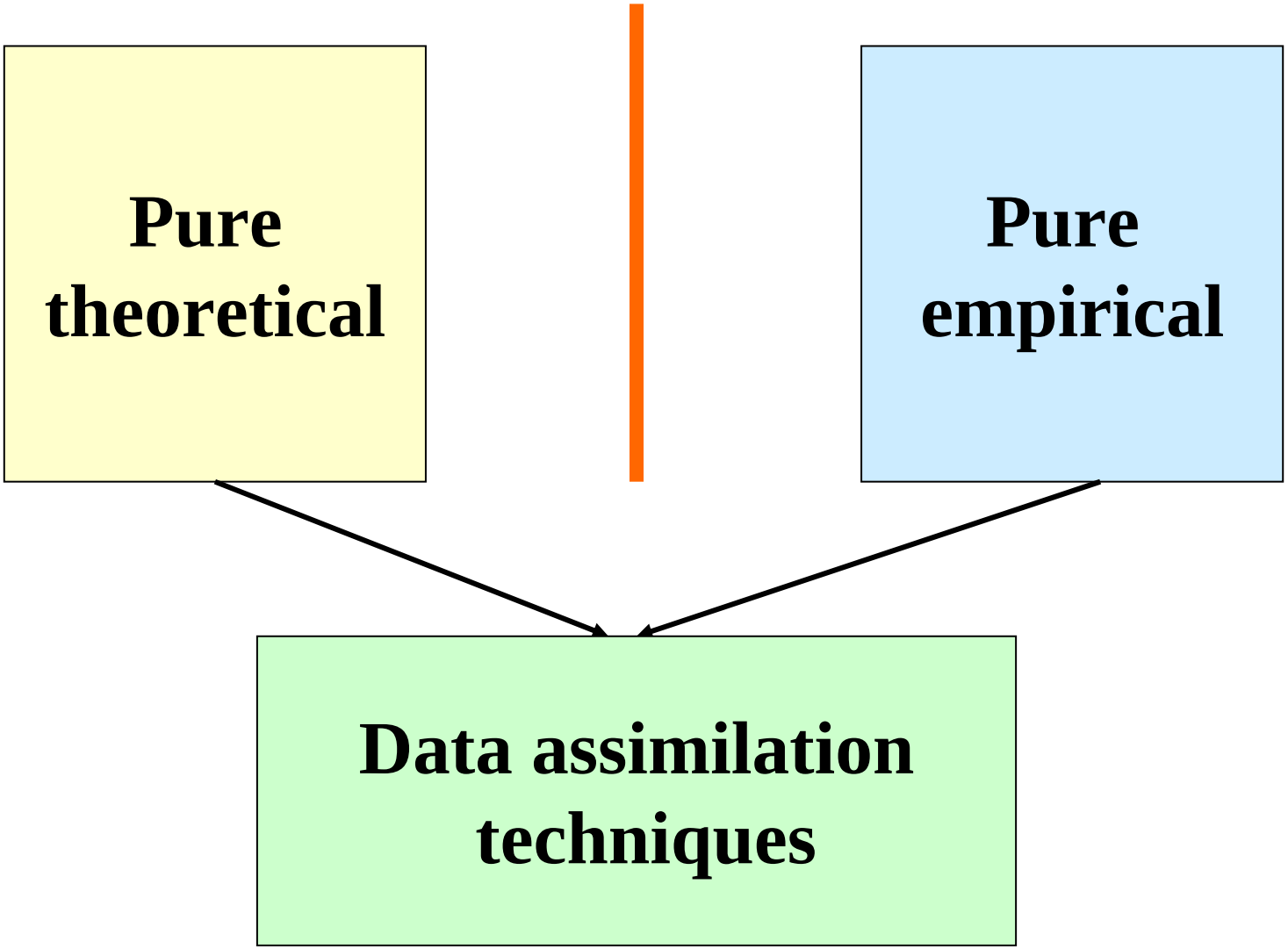
# Outline

- Introduction
- Pure physical approach
- Pure Empirical approach
- Data assimilation
- Conclusions

# Introduction



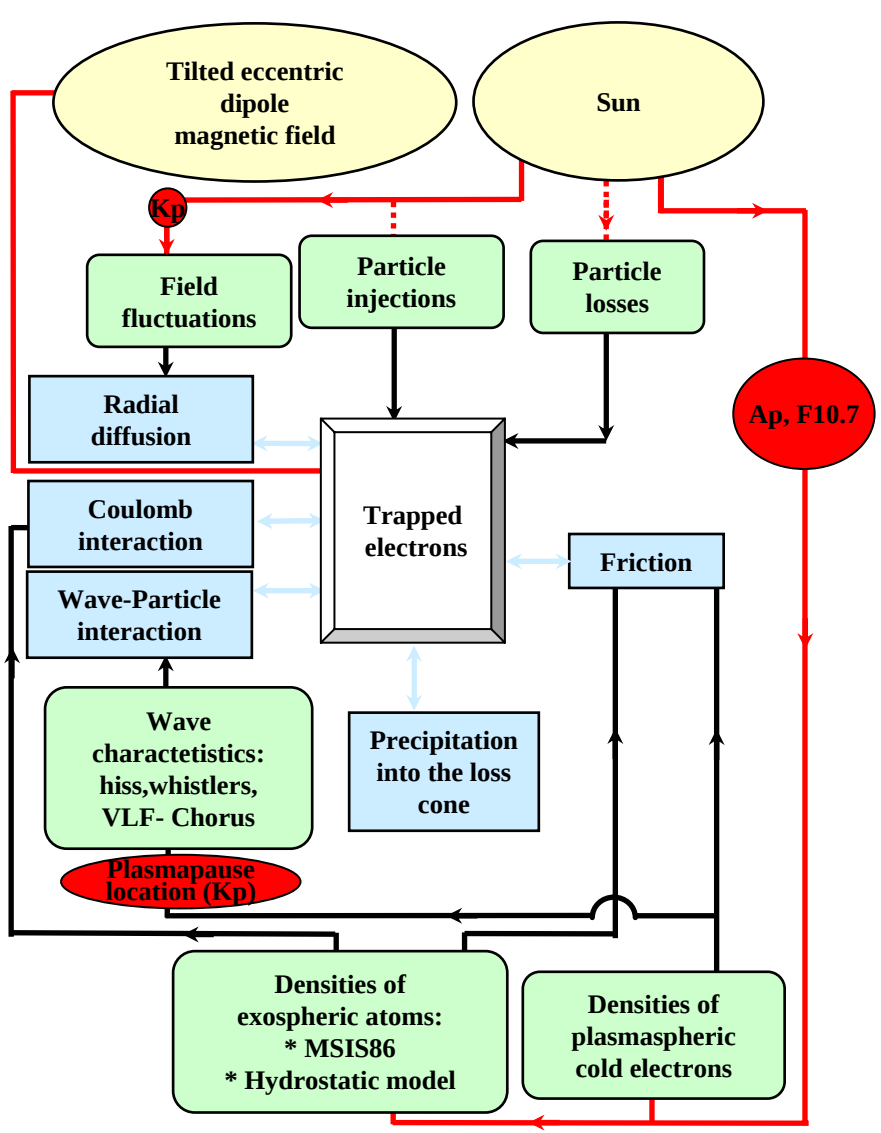
# Pure theoretical approach

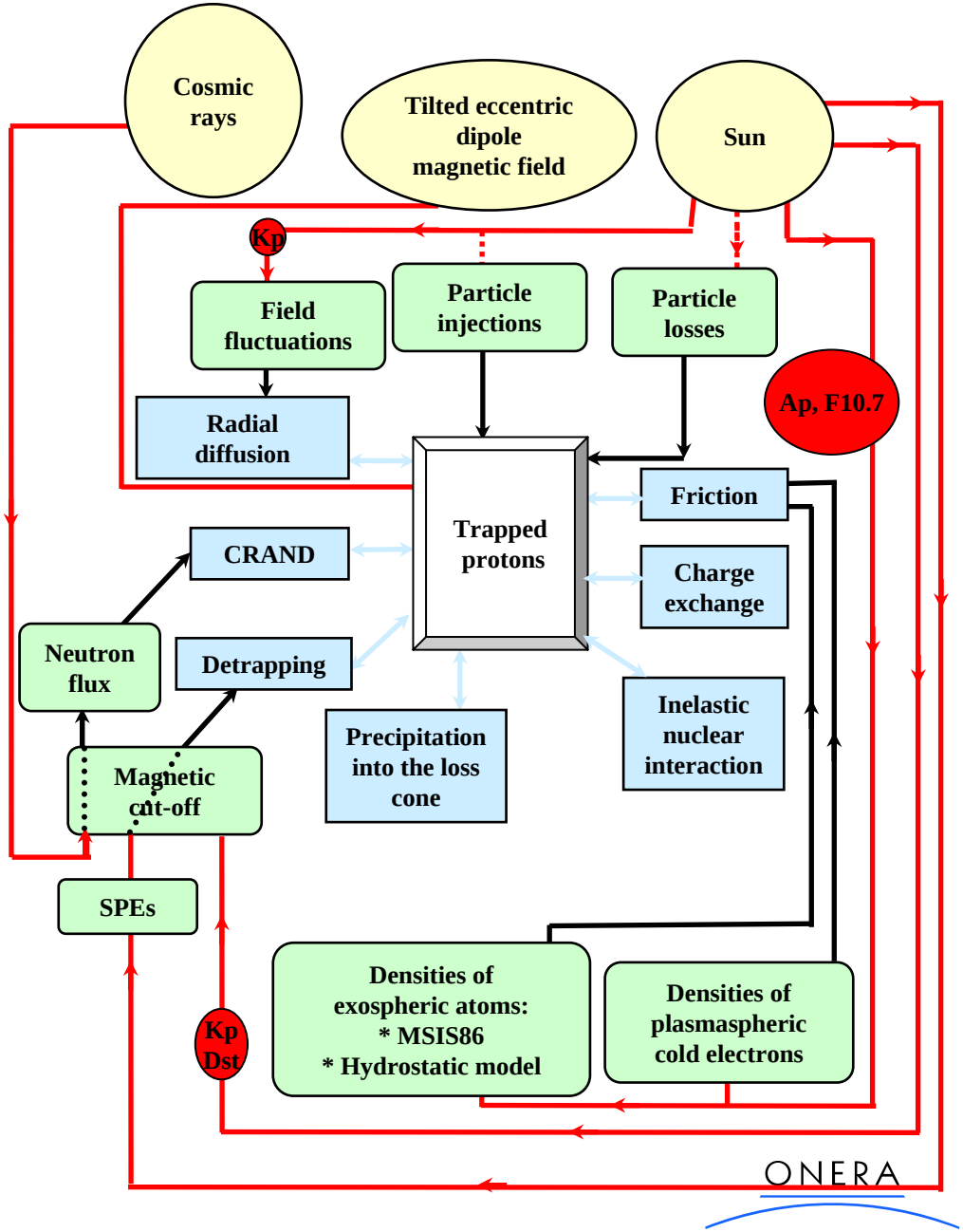
Boltzmann equation to describe distribution functions (6D+ time):

$$df/dt = \partial f/\partial t + d\mathbf{J}/dt\, \partial f/\partial \mathbf{J} + d\boldsymbol{\varphi}/dt\, \partial f/\partial \boldsymbol{\varphi}$$

To simplify the problem it is reduced under some assumptions to 3D + time.

# Pure theoretical approach

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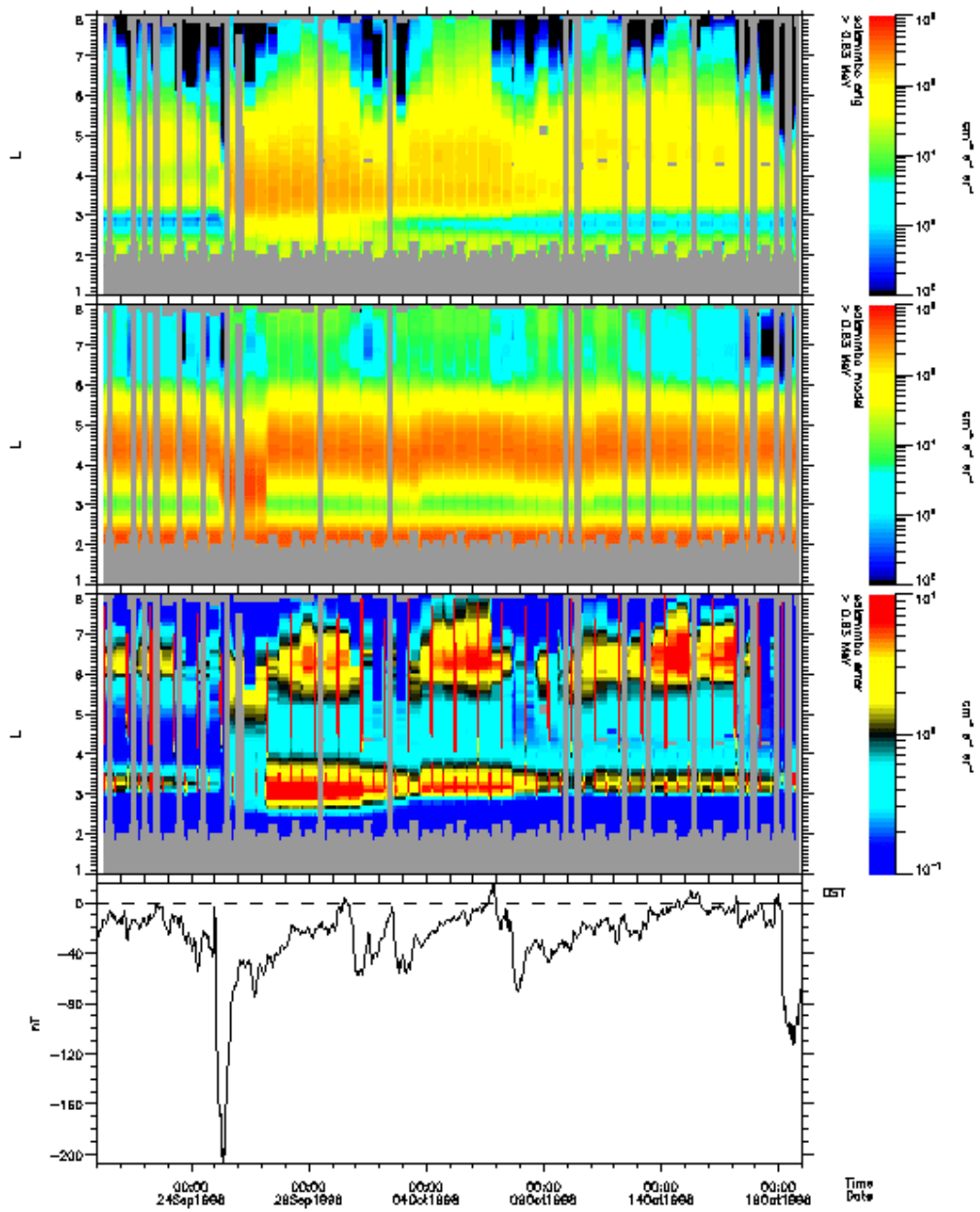
# Pure theoretical approach

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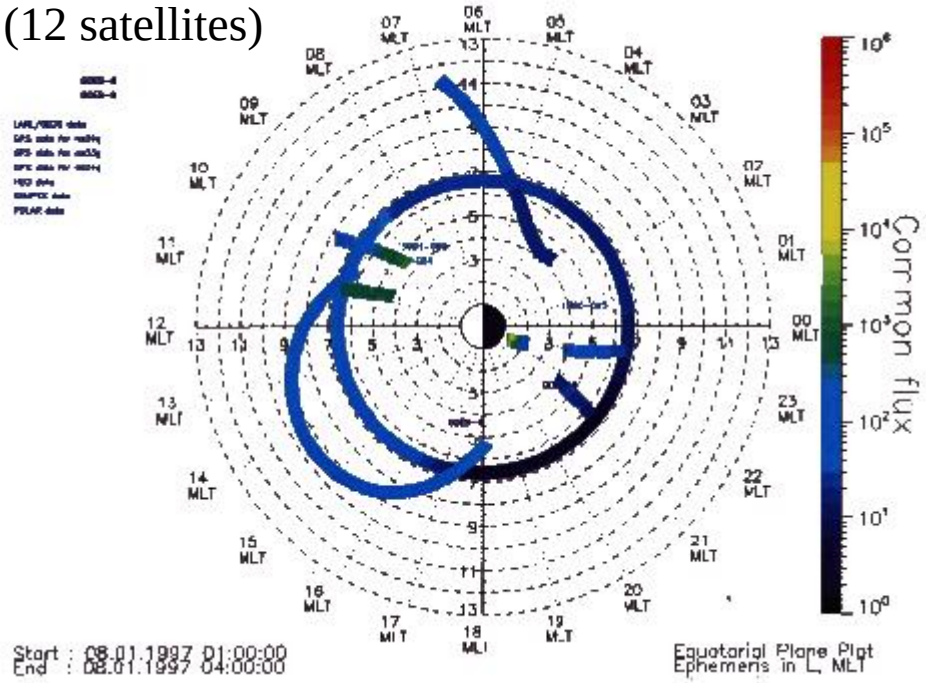
# Pure theoretical approach

Limitations:

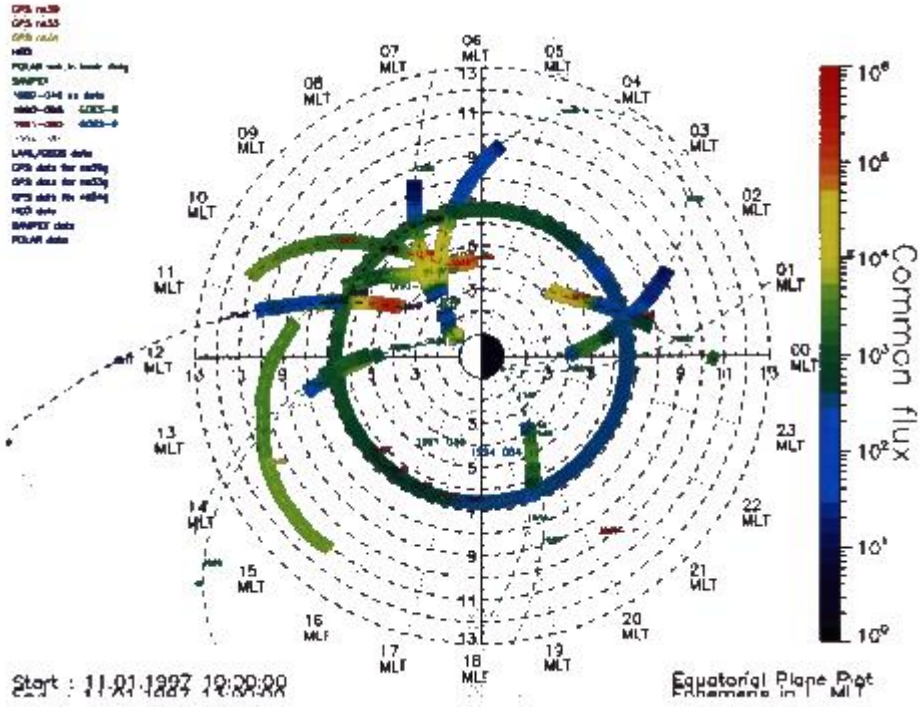
- Physical processes included into the model (complete set or not)
- Mathematical description of physics (detailled or not)
- Parameterisation of physical processes (according to magnetic activity)
- Mapping from geographic to « magnetic » coordinates.

# Pure empirical approach

(12 satellites)




(12 satellites)




From Reeves et al. EOS, 79, December 15, 1998

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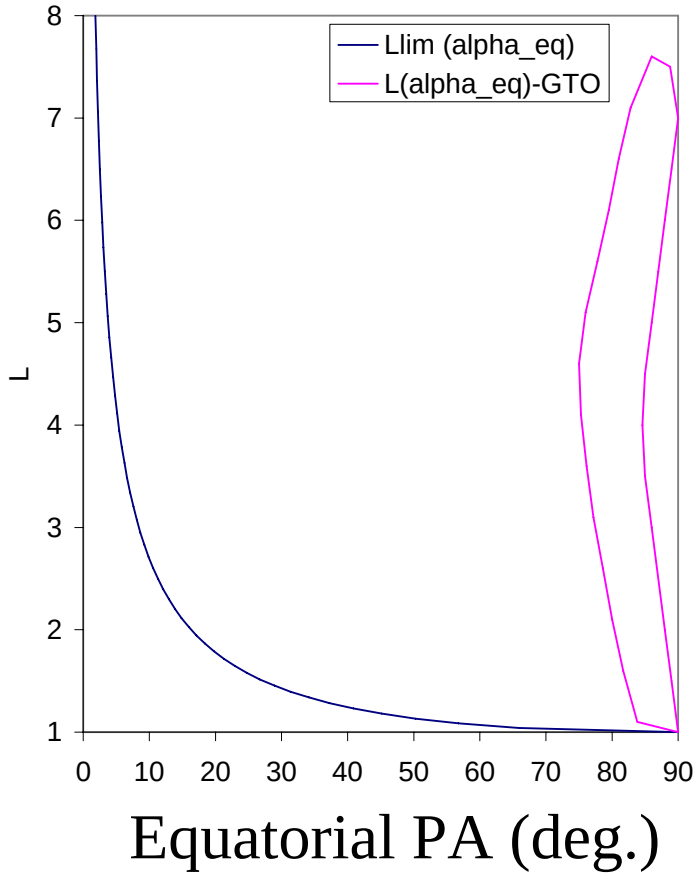
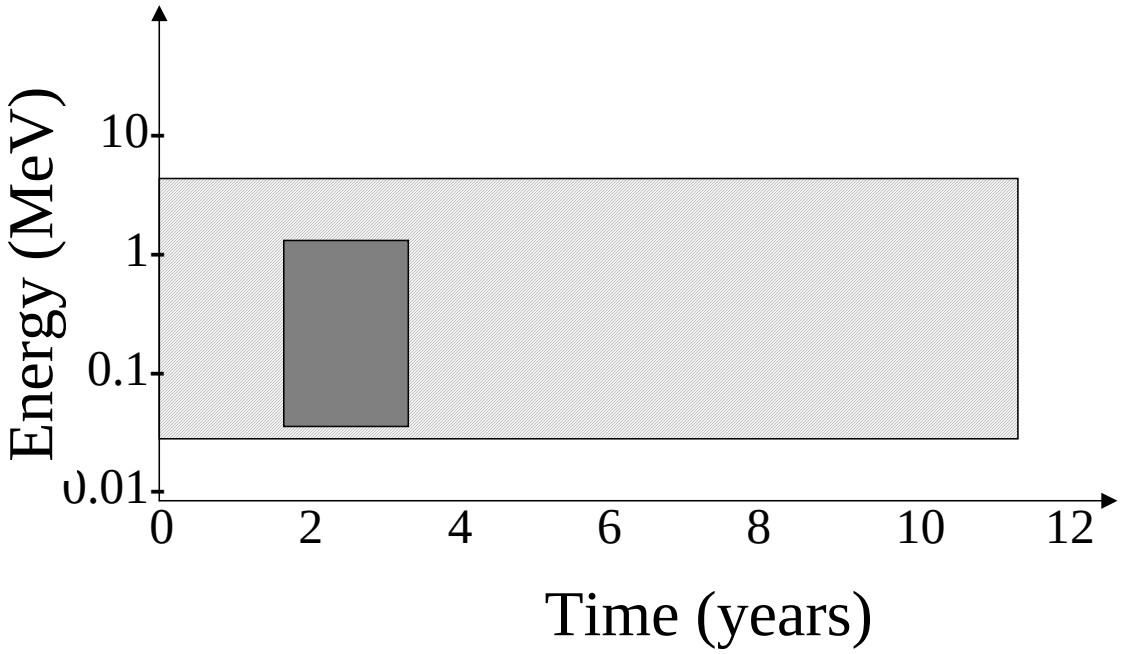
# Pure empirical approach

Let assume a 3D space + t divided into 2 sub-space ($L^*$,$\alpha_{eq}$) and (E,t)

$1<L^*<8$ - $0< \alpha_{eq} <90°$ - $50\ keV <E<7MeV$ - $1<t<11$ years

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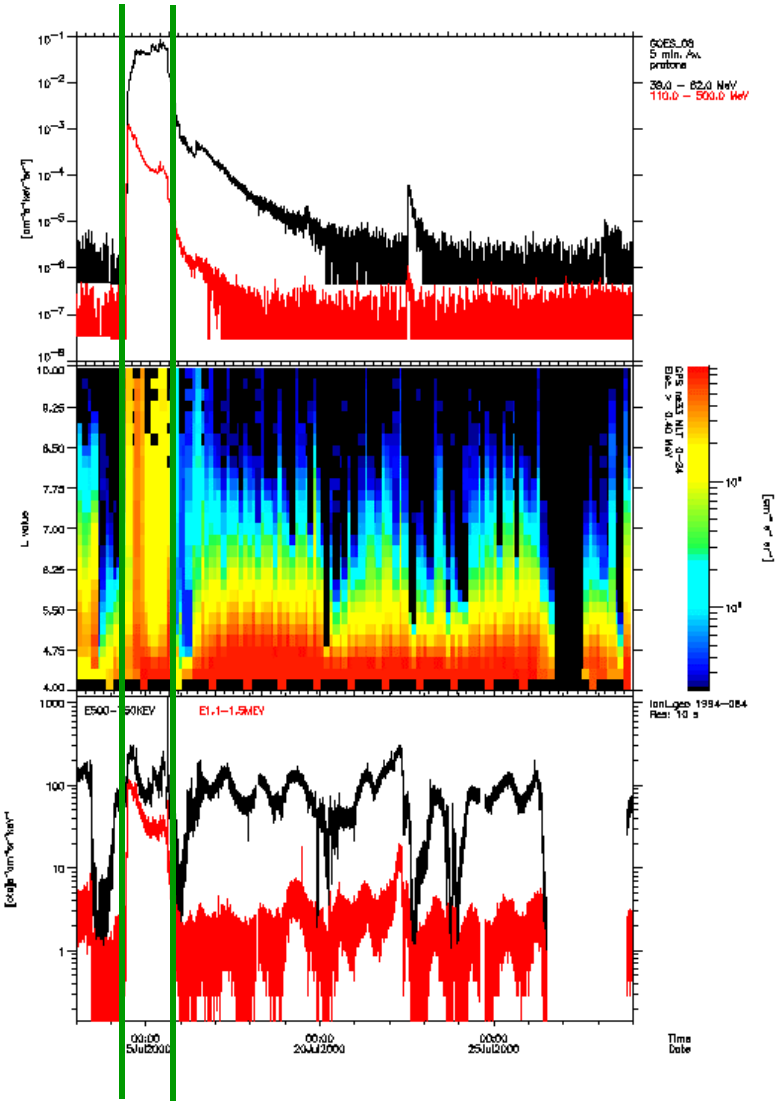
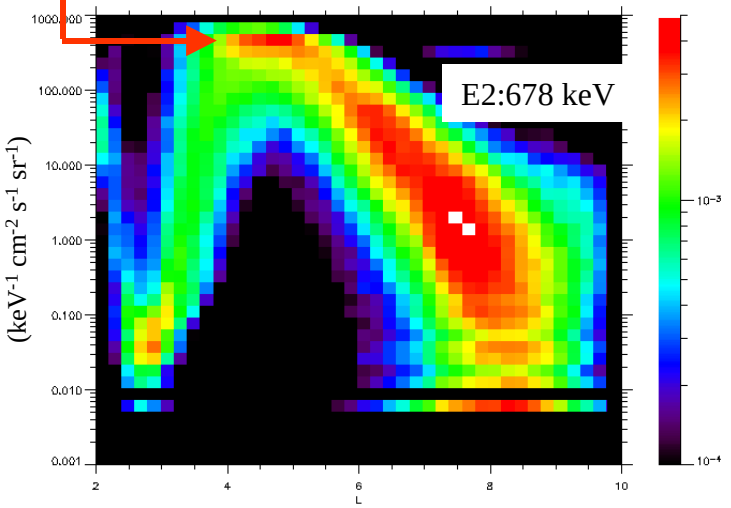
# Pure empirical approach

Contamination



Saturation

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# Pure empirical approach

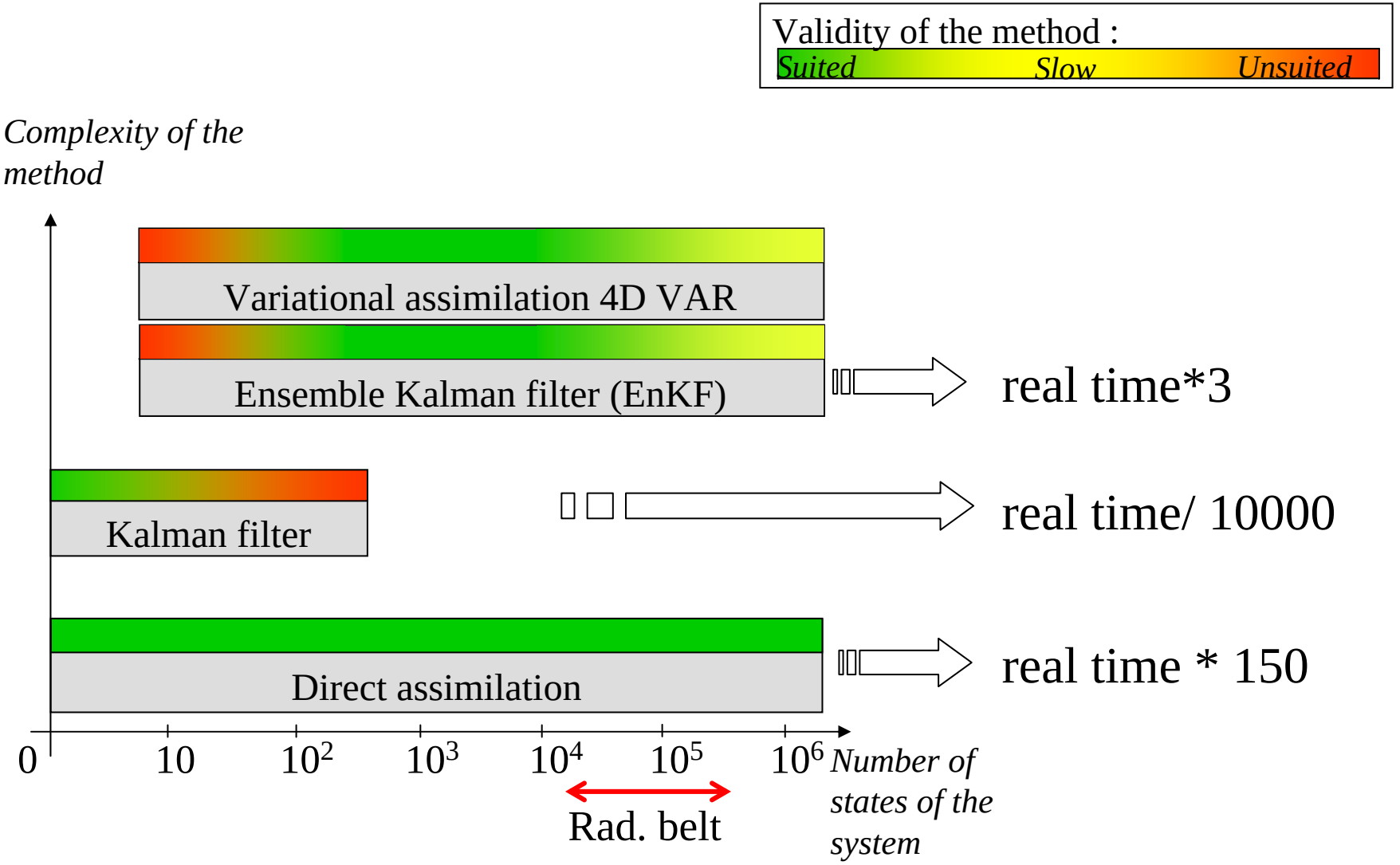
Limitations:

• Instruments are never perfect

• Data must be analized in term of (contamination, saturation, cross-calibration …)

• Mapping from geographic to « magnetic » coordinates

# Data assimilation

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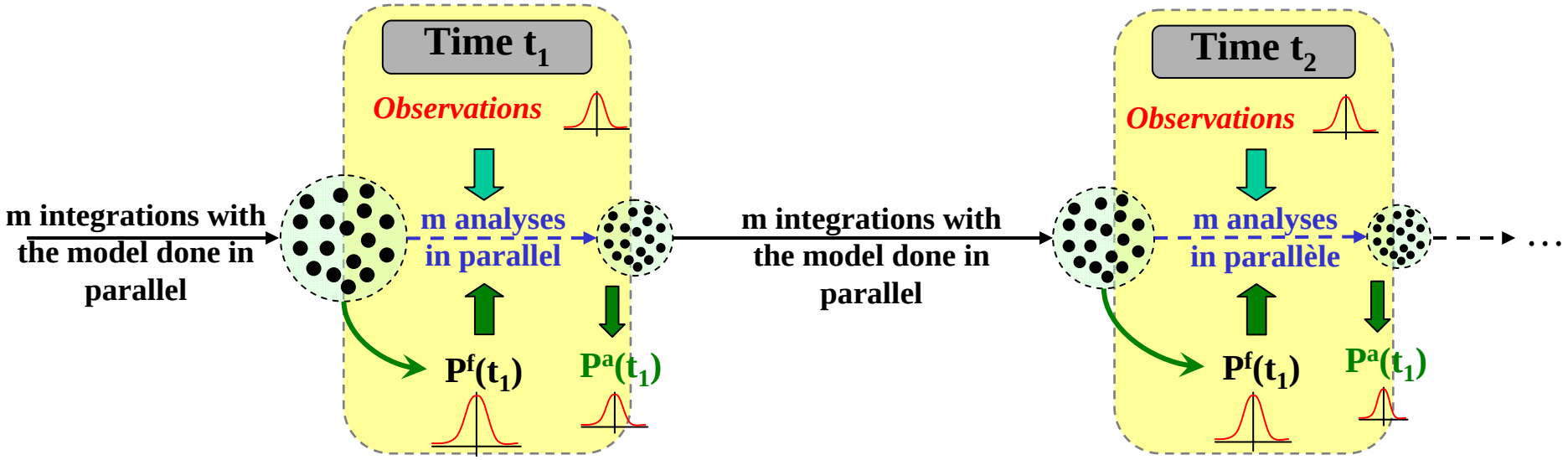
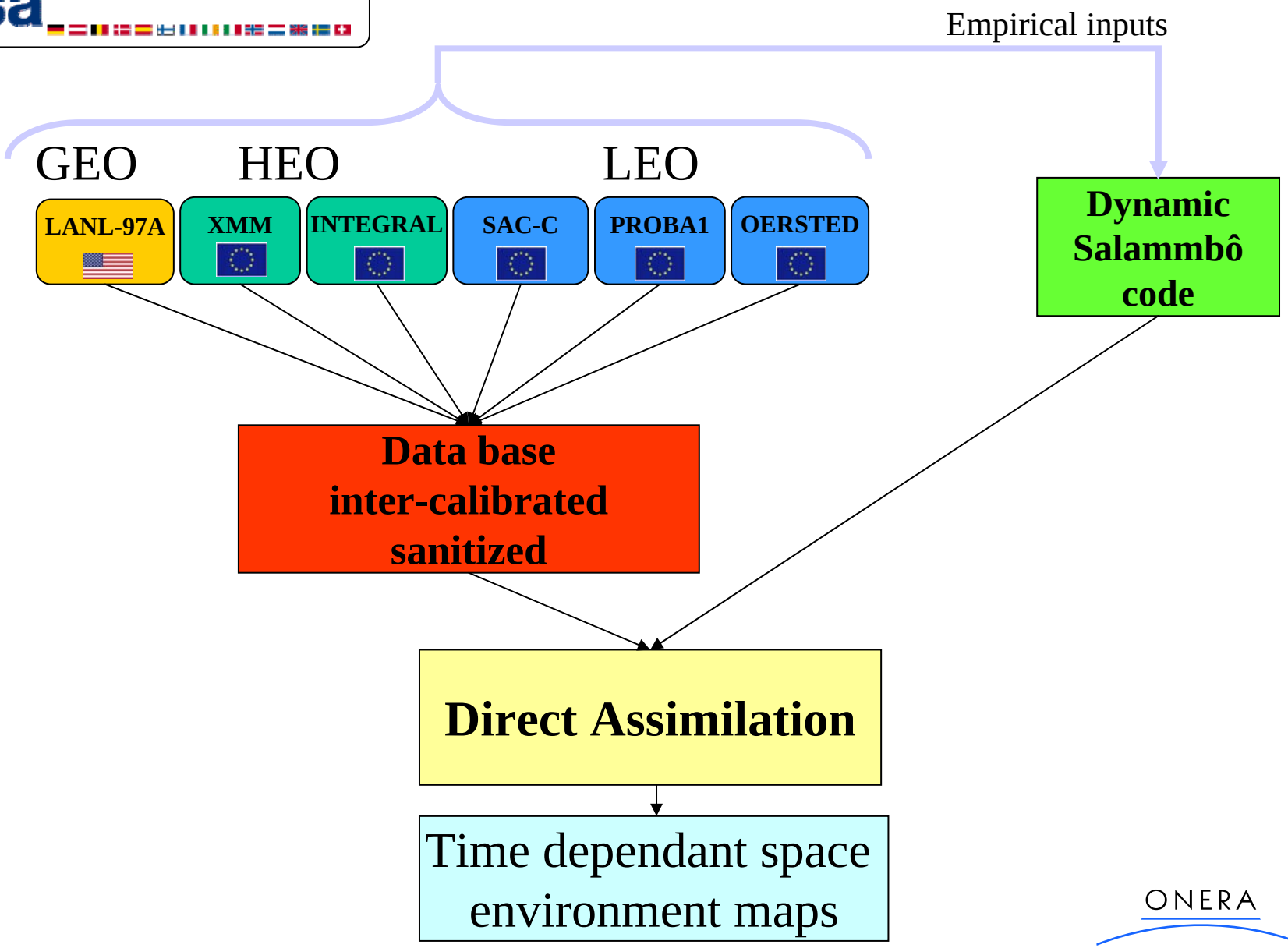
# Data assimilation

Ensemble Kalman filter



RERMM project
http://plasma.oma.be/mrm/home.html

# Data assimilation

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CRATERRE project

http://wwwe.onecert.fr/craterre/home.html

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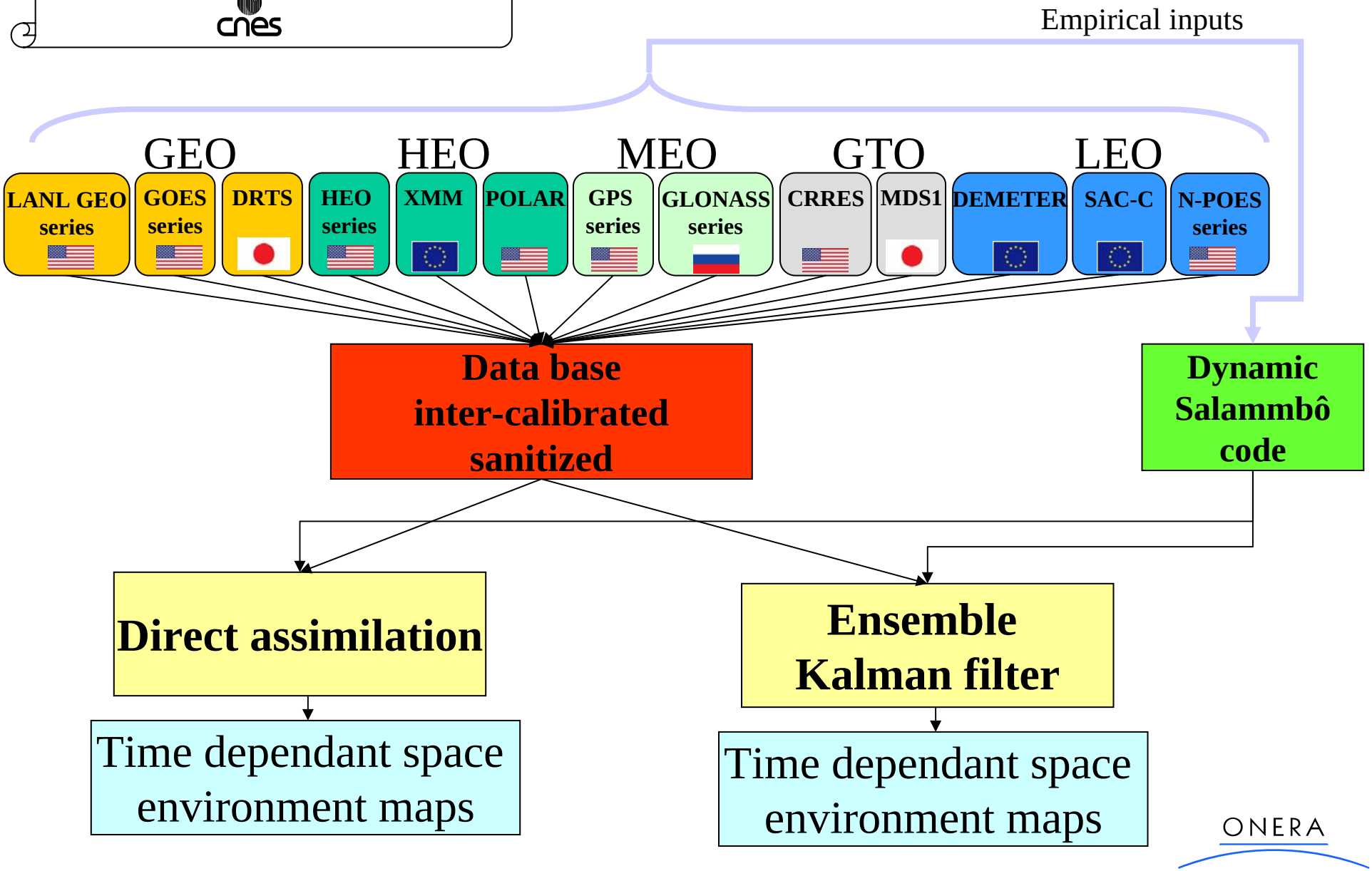
# Data assimilation

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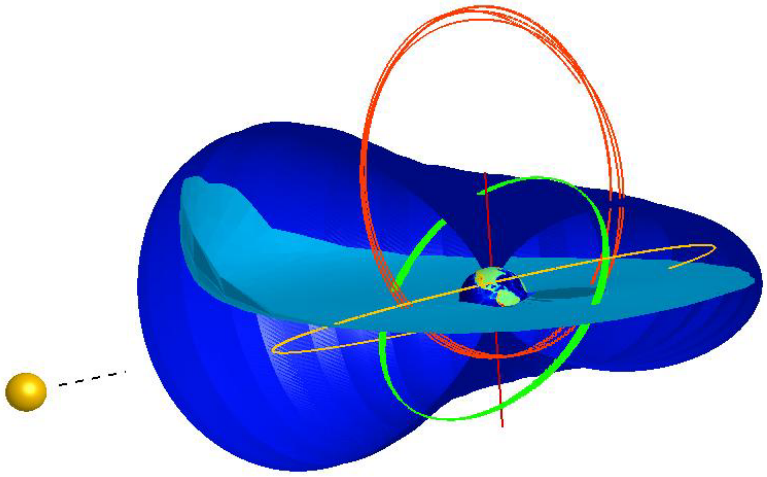
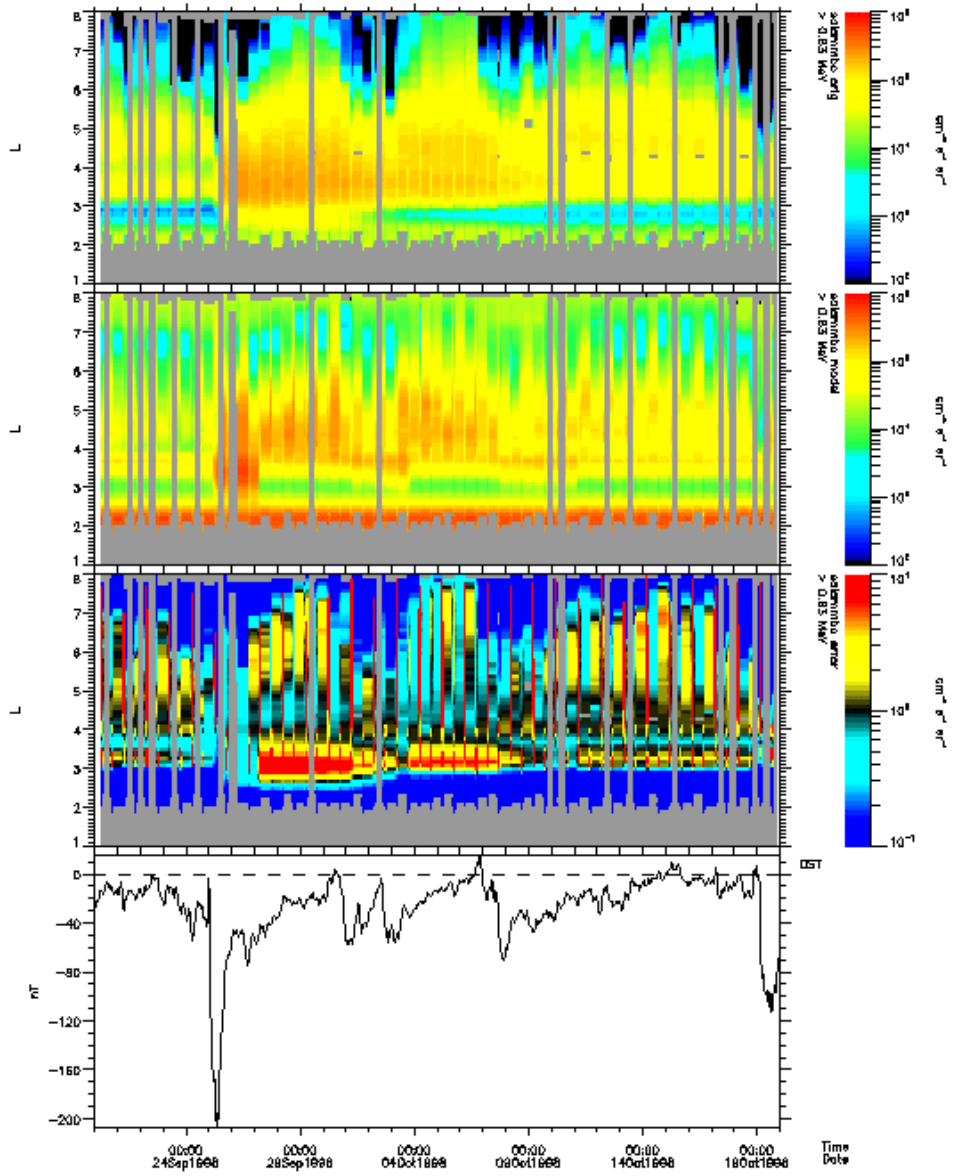
# Data assimilation

Direct assimilation



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# Conclusions

• Reproducing the time variations of electron and proton radiation belts is not an easy task.

•Pure theoretical and empirical approaches have their own intrinsic limitations which might led to many unrealistic local time and radial variations.

•Clearly important progress can be done by combining both approaches.

•The development of data assimilation techniques is very popular nowadays and takes advantages of both models and in-situ data.

•To this end physical models have to be more and more detailed and radiation belt measurements will have to be done at locations where errors in models are the highest.