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GEMS WP_GHG_8
Estimates of CH_4 sources using existing atmospheric models

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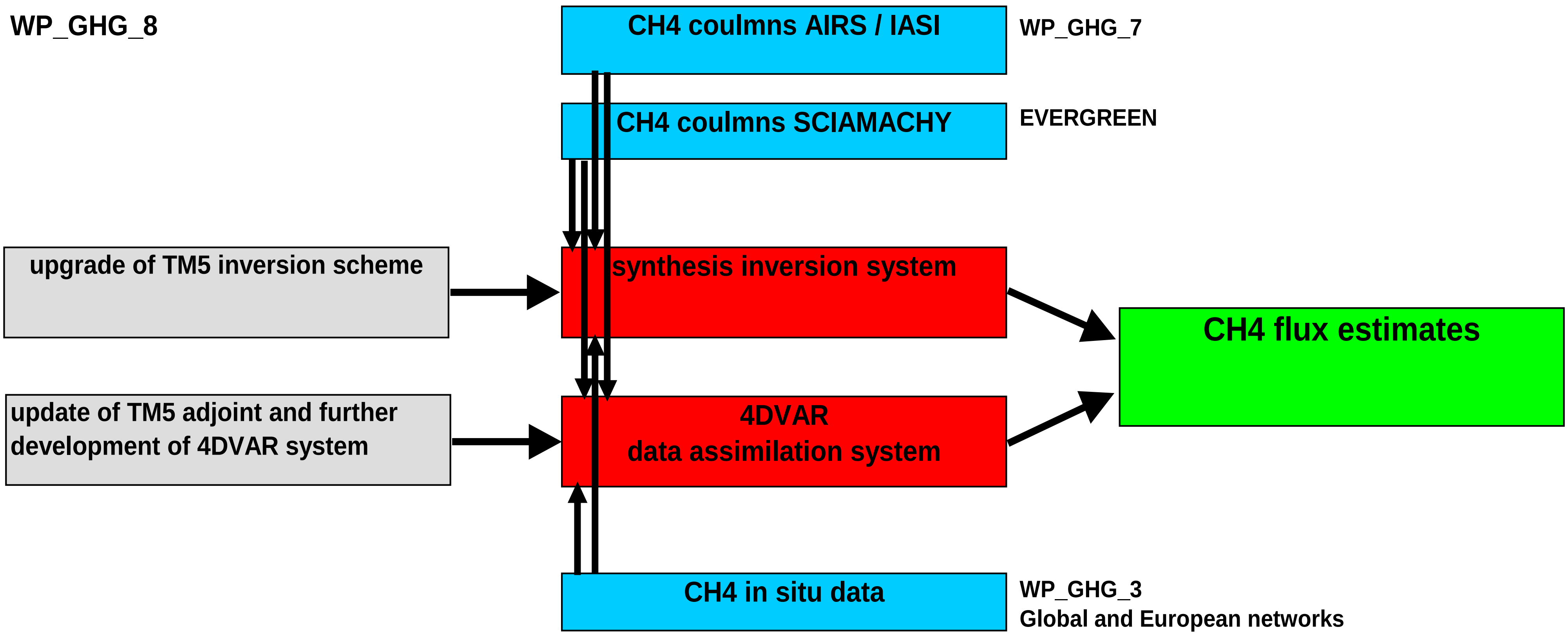


inversion - groundbased monitoring sites / SCIAMACHY

Scenario S1

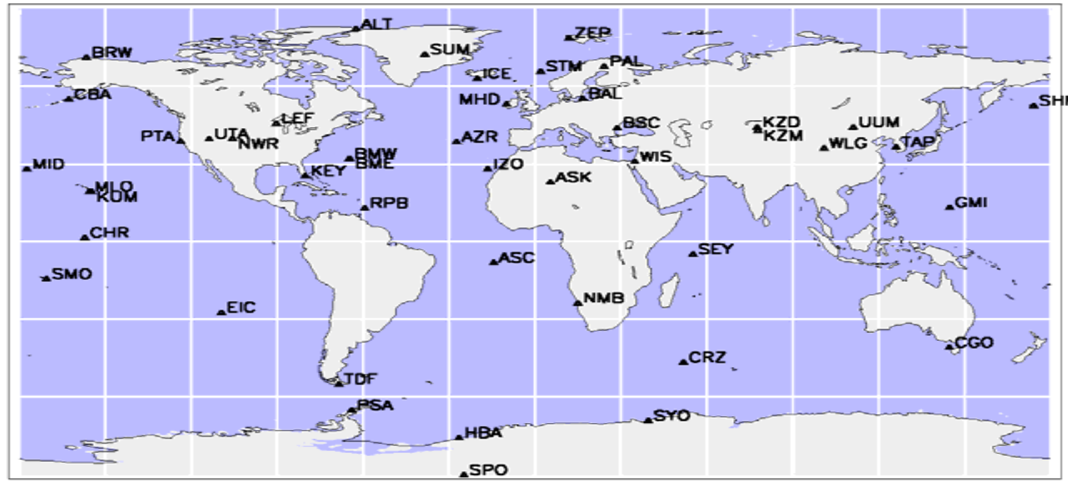
groundbased sites only

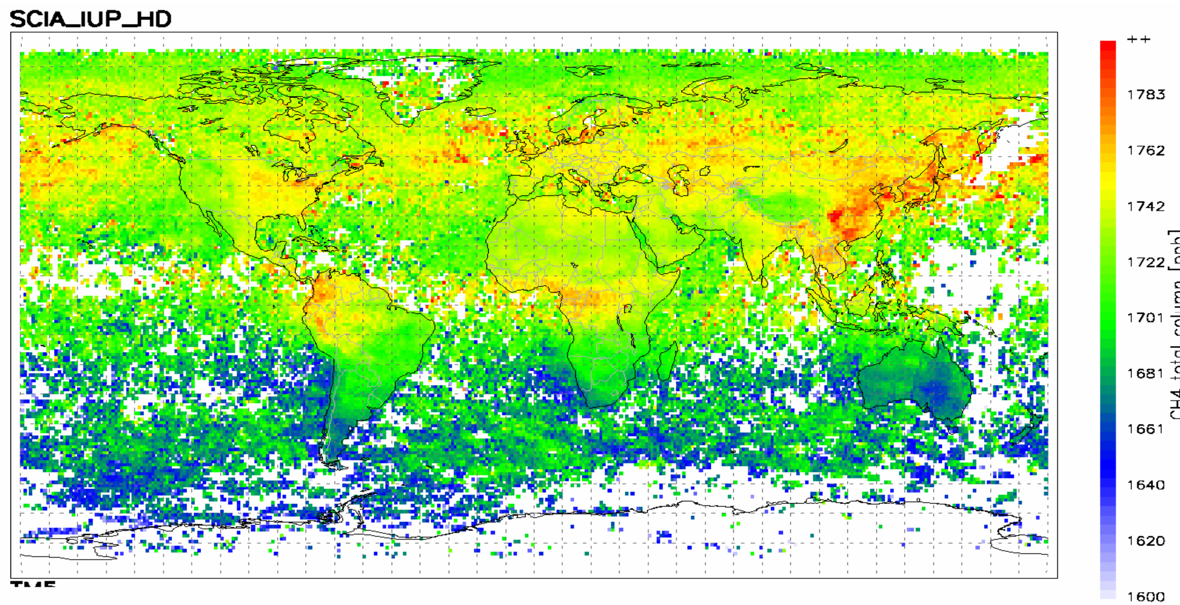
Scenario S2

groundbased sites

+ SCIAMACHY

ground based background monitoring sites (NOAA/CMDL)





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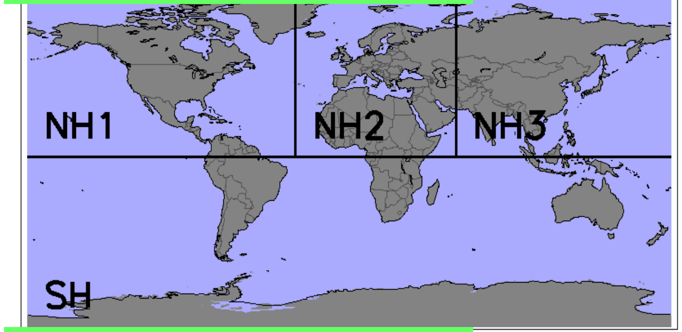
synthesis inversion

synthesis inversion optimizing:

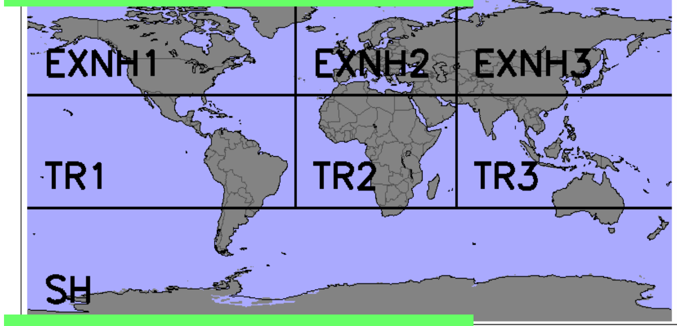
- 11 source categories
- 1-7 global regions
- monthly emissions

coal	IIASA / EDGAR V3.2
oil and gas	IIASA / EDGAR V3.2
enteric fermentation	IIASA / EDGAR V3.2
rice	GISS [Matthews et al., 1991]
biomass burning	[van der Werf et al., 2004]
waste	IIASA / EDGAR V3.2
wetlands	[Kaplan, 2005]
	[Walter et al., 2000]
wild animals	GISS [Fung et al., 1991]
termites	GISS [Fung et al., 1991]
ocean	[Houweling et al., 1999]
soil sink	GISS [Fung et al., 1991]

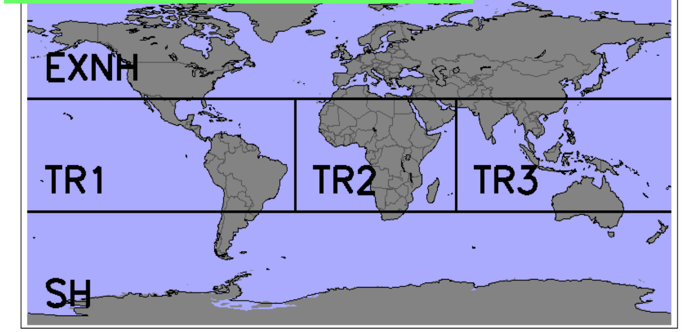
anthrop. sources



wetlands



biomass burning



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TM5 inverse simulations
examples for some monitoring sites

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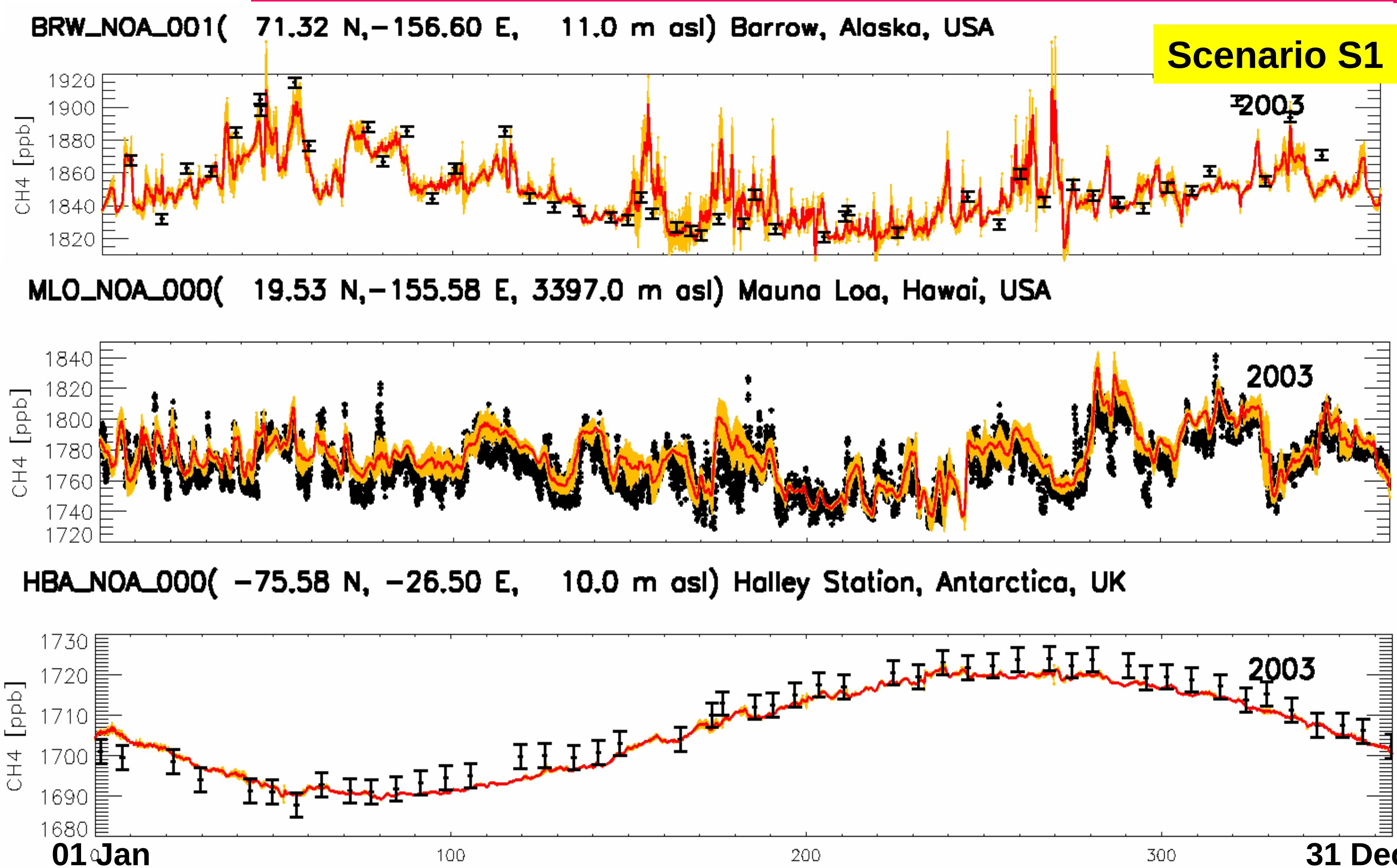
obs
TM5

Scenario S1



simulation of global CH_4 consistent with surface monitoring sites (background sites)

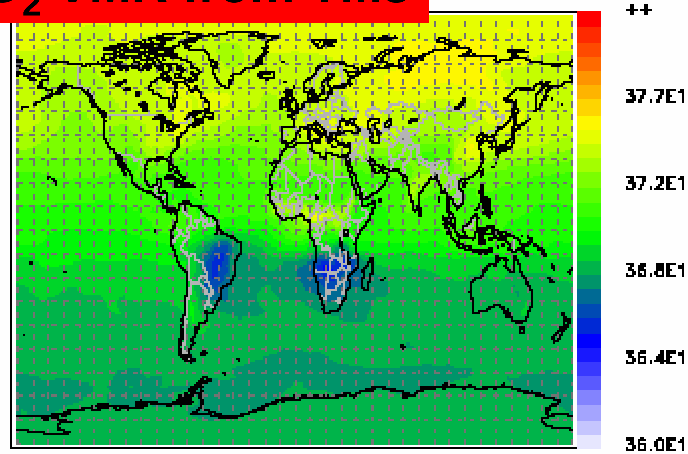
data processing

(1) SCIAMACHY data: CO_2 normalisation

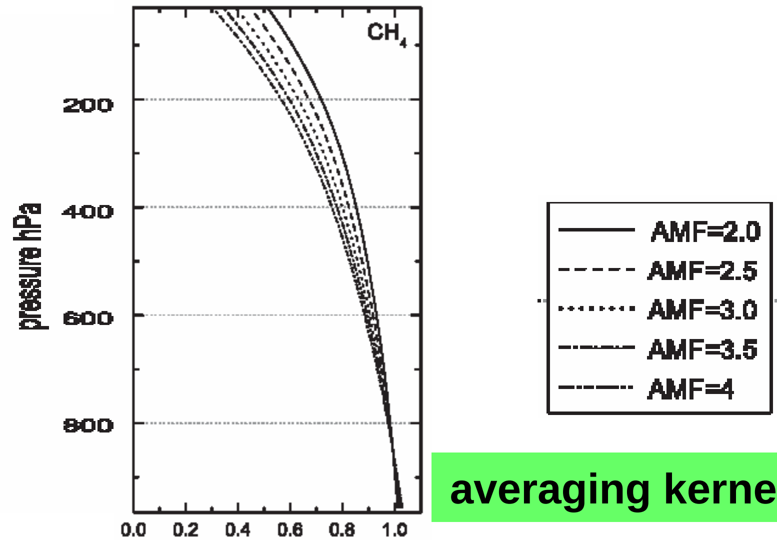
$$\overline{VMR}(\mathrm{CH_4}) = \frac{V_{\mathrm{meas}}(\mathrm{CH_4})}{V_{\mathrm{meas}}(\mathrm{CO_2})} \cdot \overline{VMR}(\mathrm{CO_2})$$

column averaged CH_4 mixing ratio [ppb]

CO_2 VMR from TM3



(2) modelled VMRs: apply AKs



averaging kernel

[Frankenberg et al., 2005]

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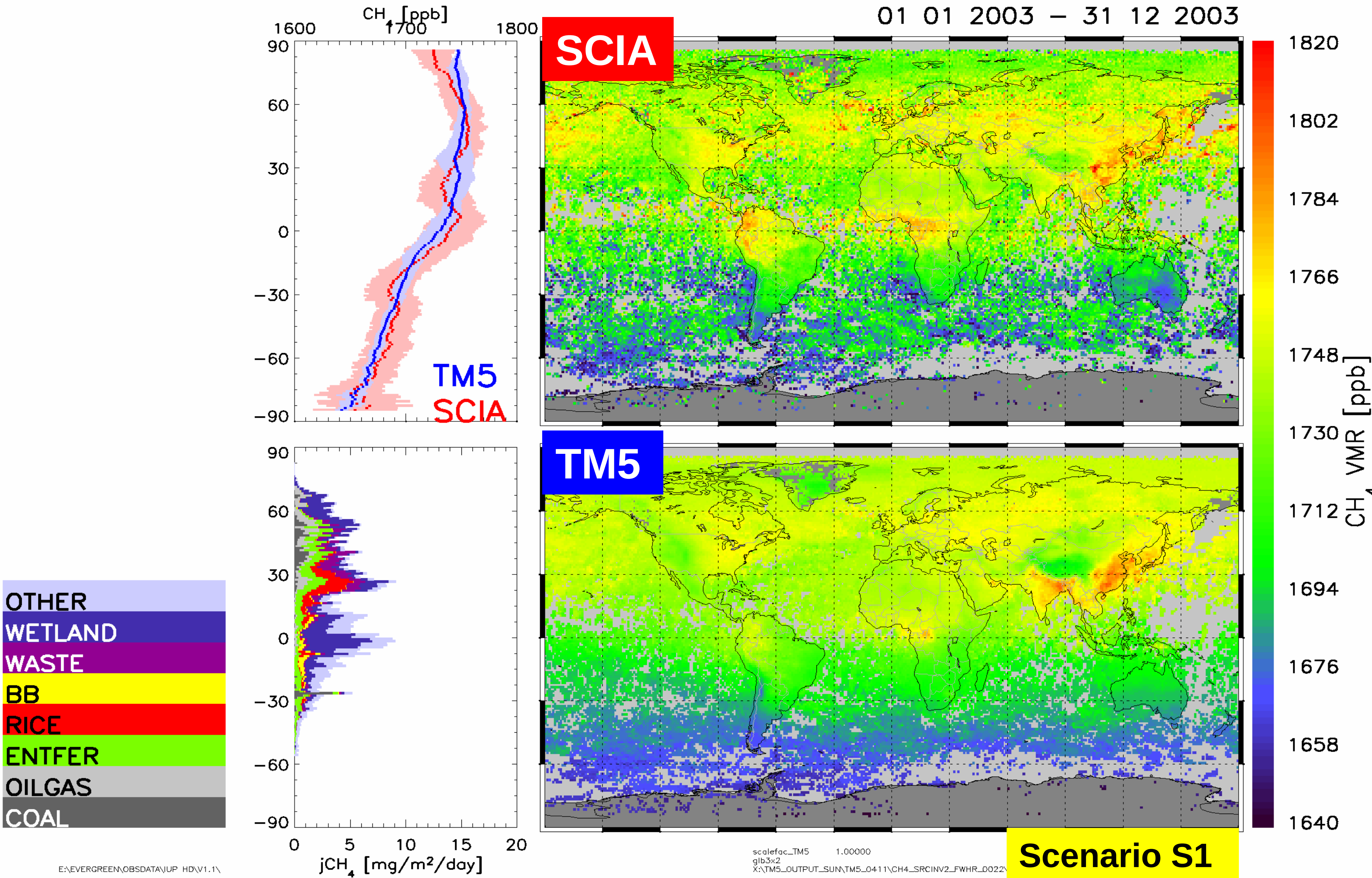
SCIAMACHY vs. TM5 - 01-12/2003



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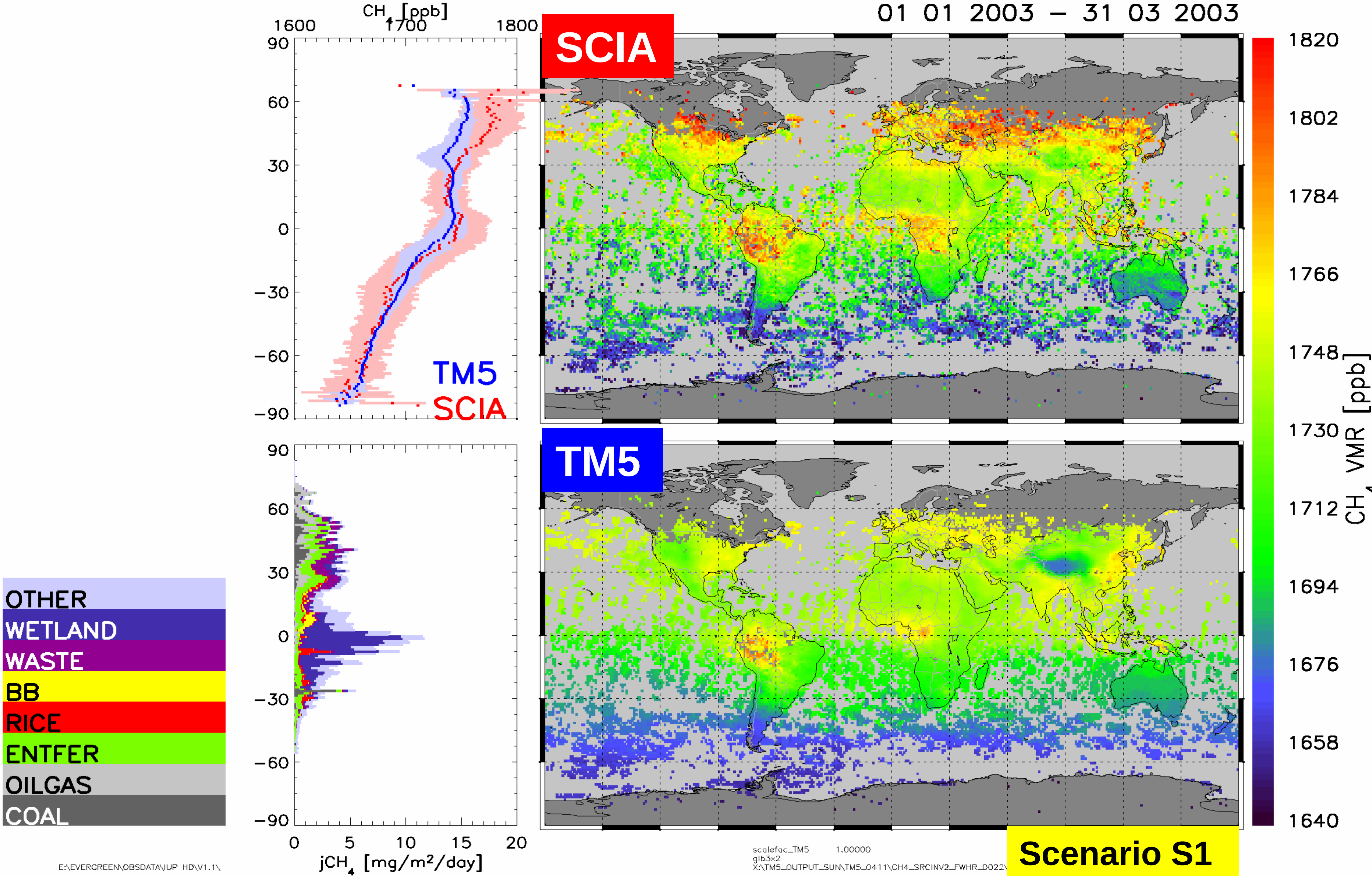
SCIAMACHY vs. TM5 01-03 / 2003



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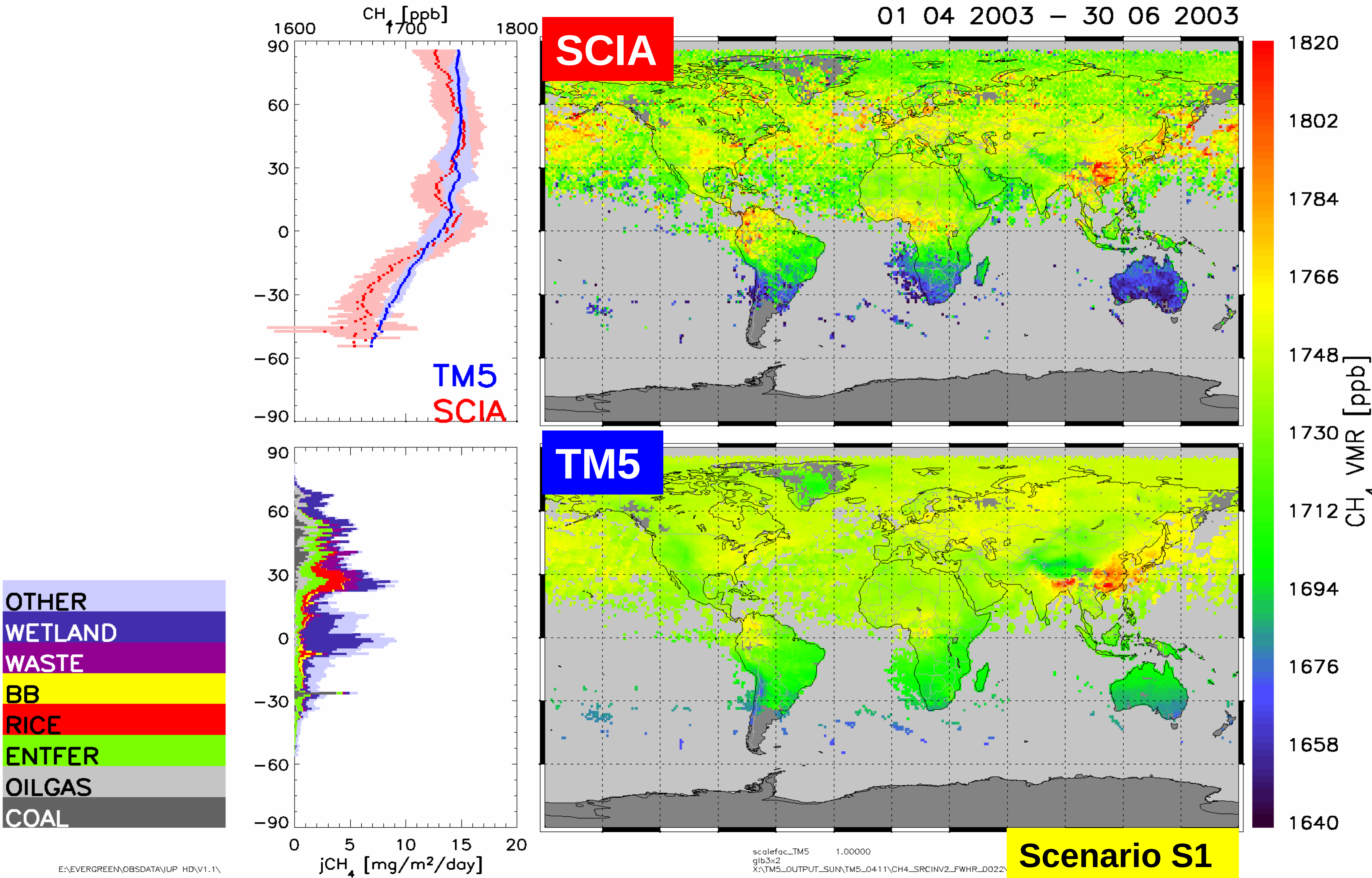
SCIAMACHY vs. TM5 04-06 / 2003



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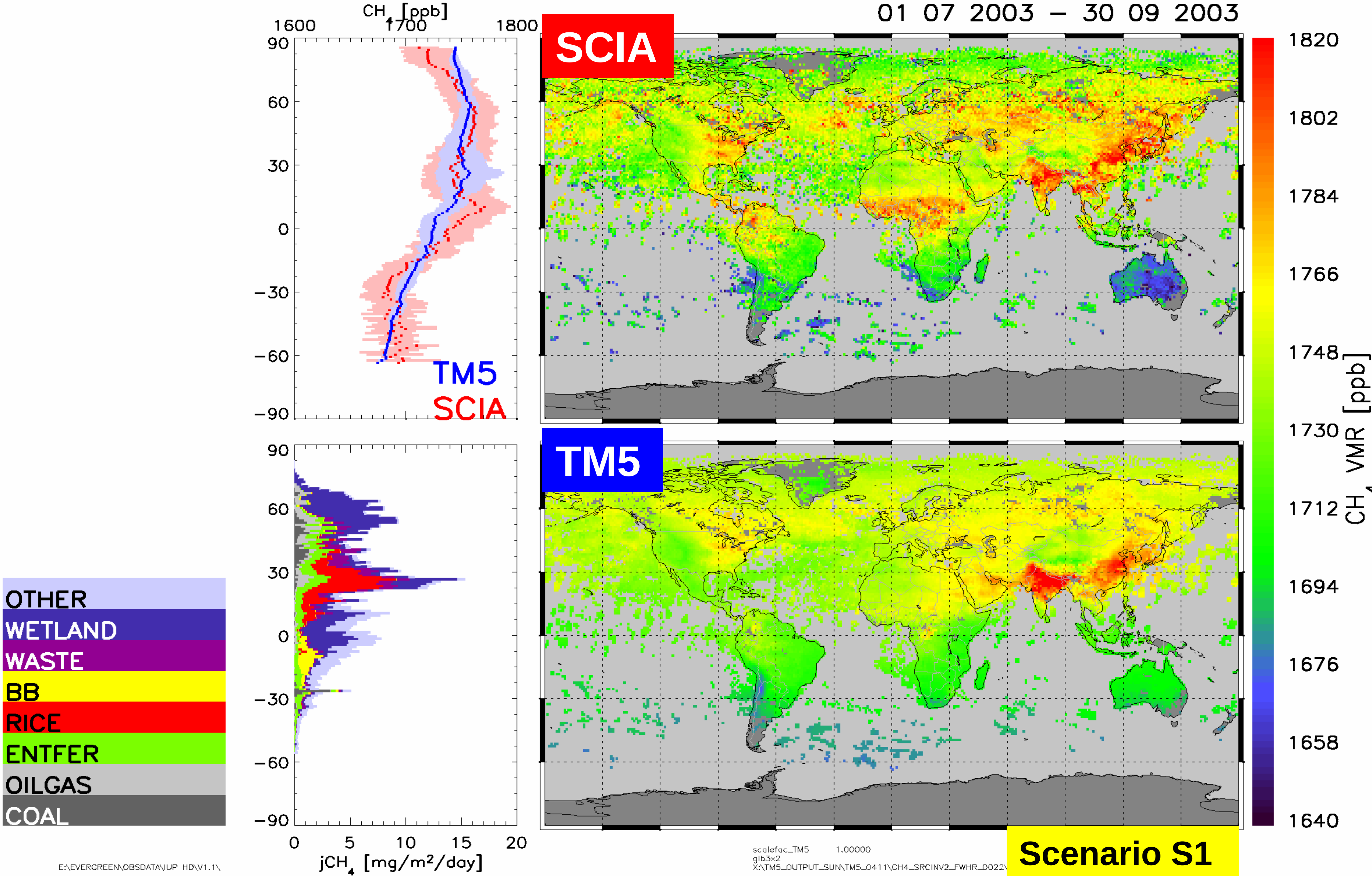
SCIAMACHY vs. TM5 07-09 / 2003



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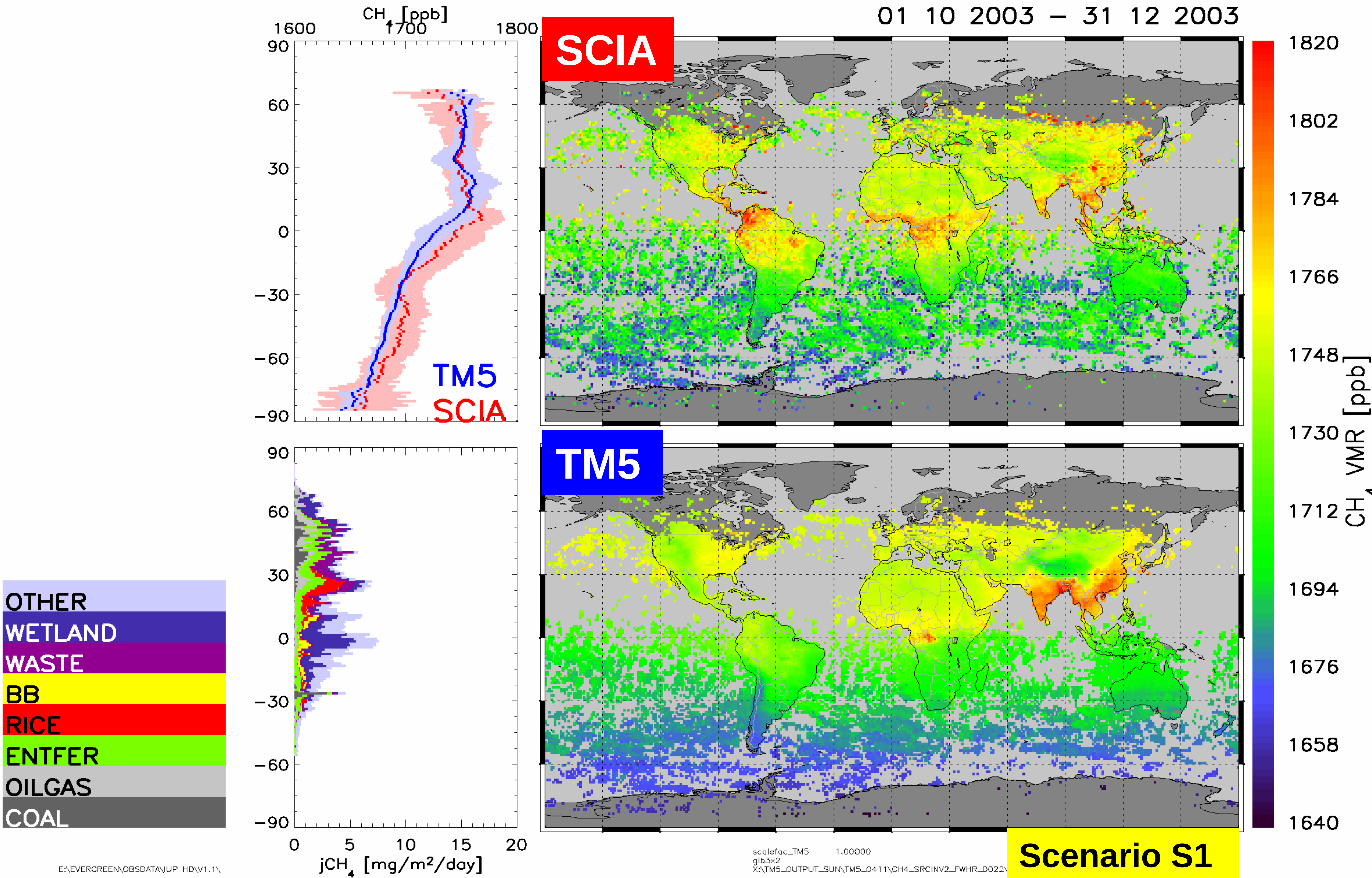
SCIAMACHY vs. TM5 10-12 / 2003



SCIAMACHY vs. TM5 over remote areas

Scenario S1 (groundbased observations only):

- annual mean: latitudinal average SCIAMACHY vs. TM5 relatively consistent

- however: small latitudinal bias depending on season (0 - ~30 ppb)

Reasons for this offset ?

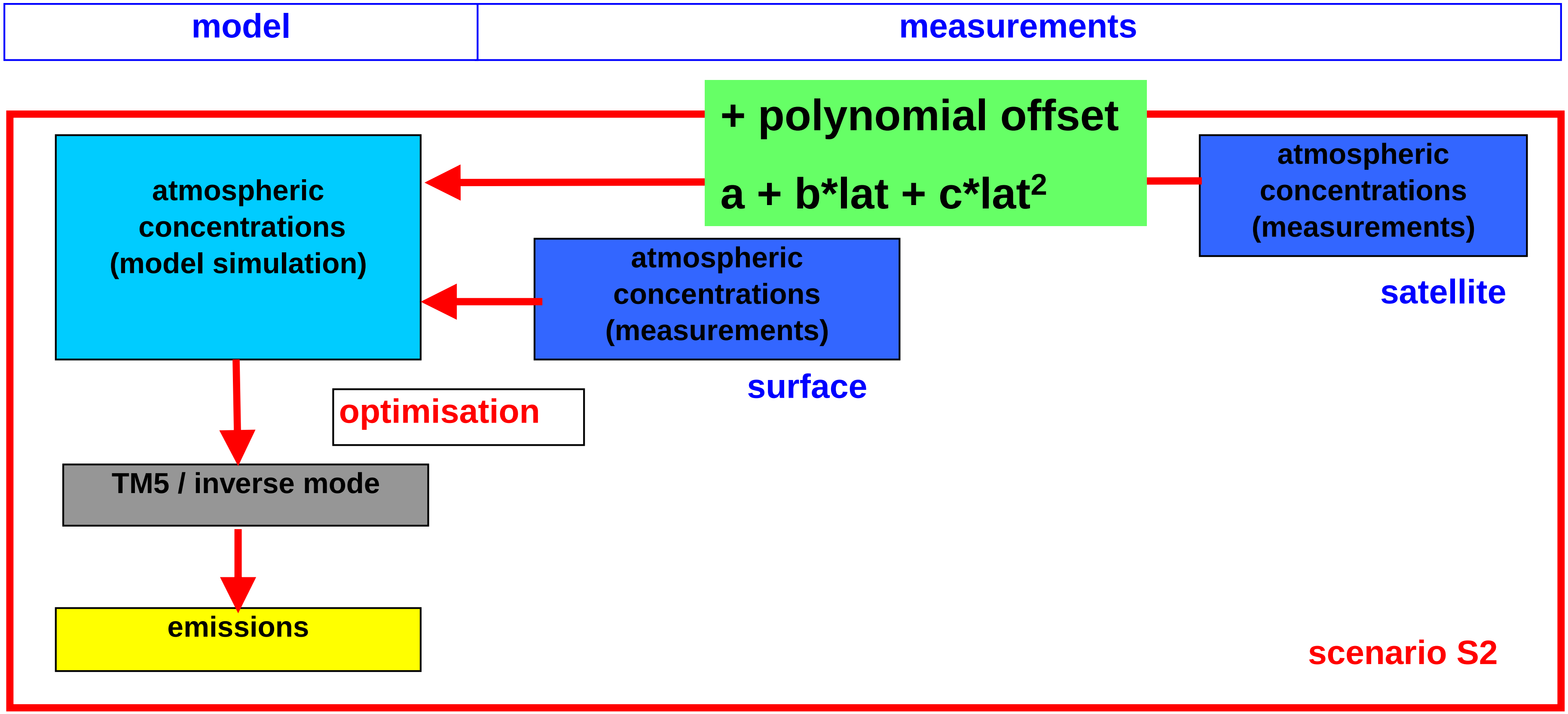
- model errors stratosphere ? comparison with HALOE data (<100 hPa): differences not sufficient to explain offset SCIA-TM5

- model errors, distribution in the middle / upper troposphere ? Probably very small, in particular in well-mixed SH

- small dependence of retrievals on SZA ?

bias (0 - ~30 ppb) < enhancement over large scale sources (~50–100 ppb)

scenario S2


model
measurements
+ polynomial offset
a + b*lat + c*lat²
atmospheric concentrations (model simulation)
atmospheric concentrations (measurements)
atmospheric concentrations (measurements)
satellite
surface
optimisation
TM5 / inverse mode
emissions
scenario S2

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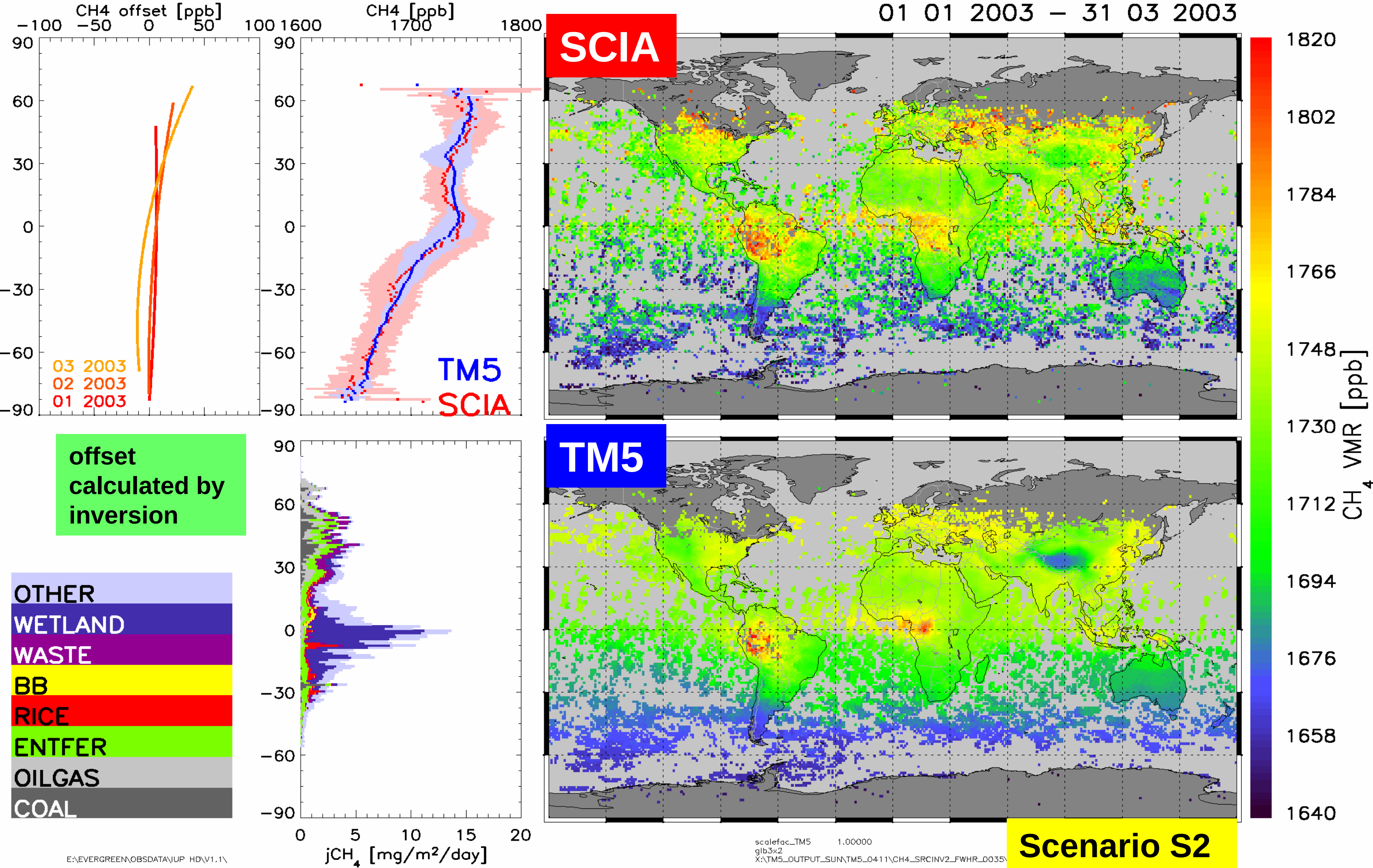
SCIAMACHY vs. TM5 01-03 / 2003



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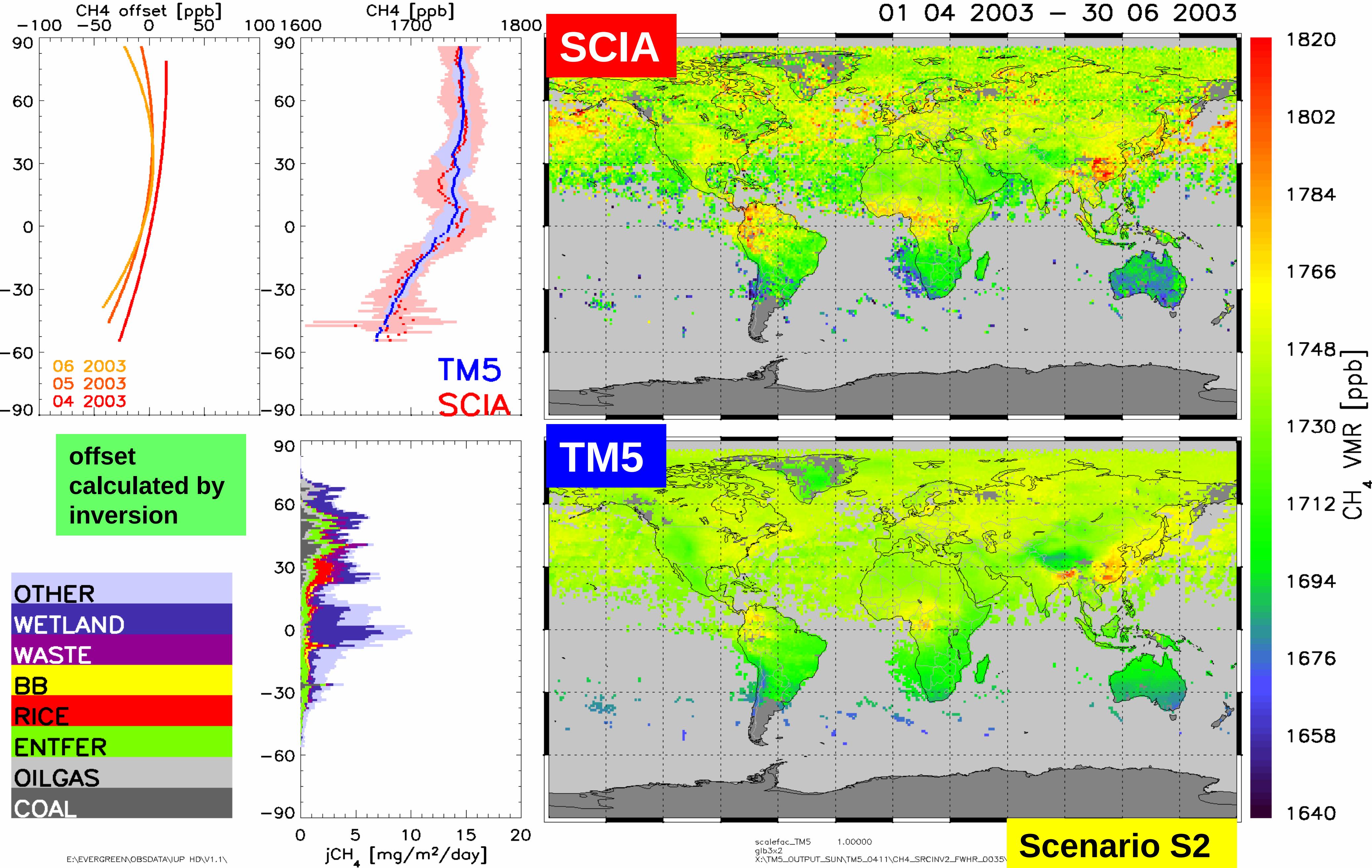
SCIAMACHY vs. TM5 04-06 / 2003



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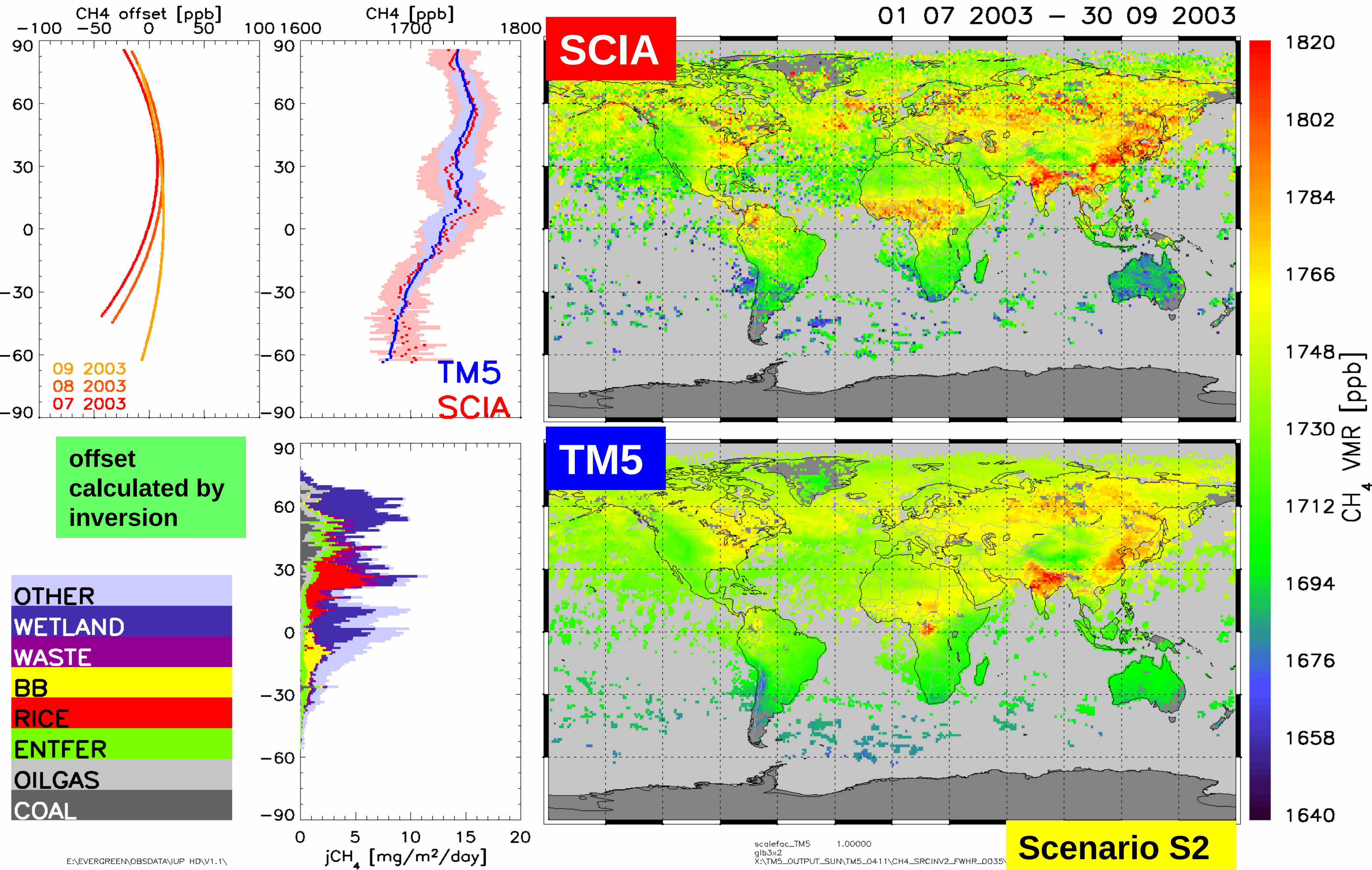
SCIAMACHY vs. TM5 07-09 / 2003



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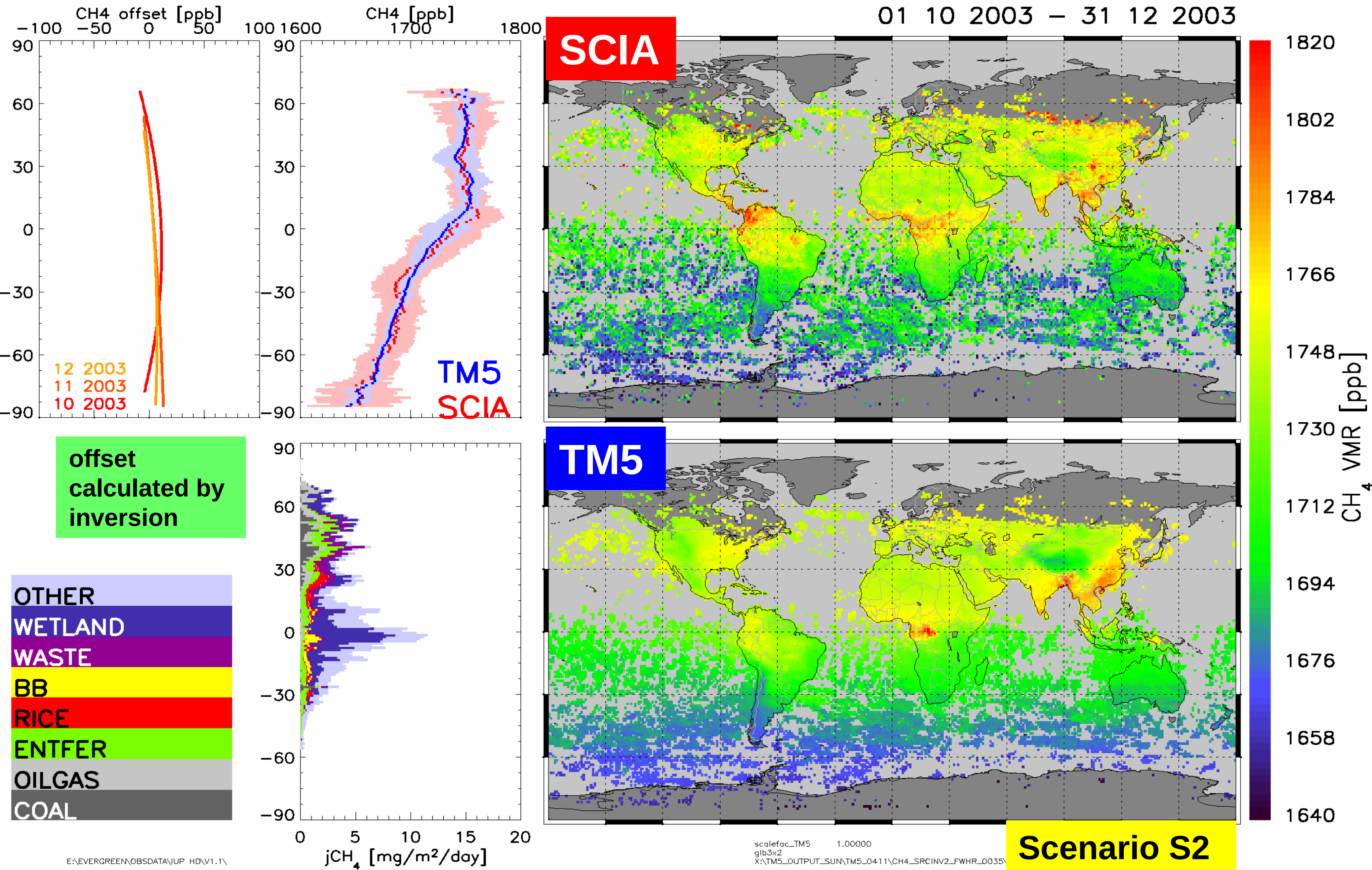
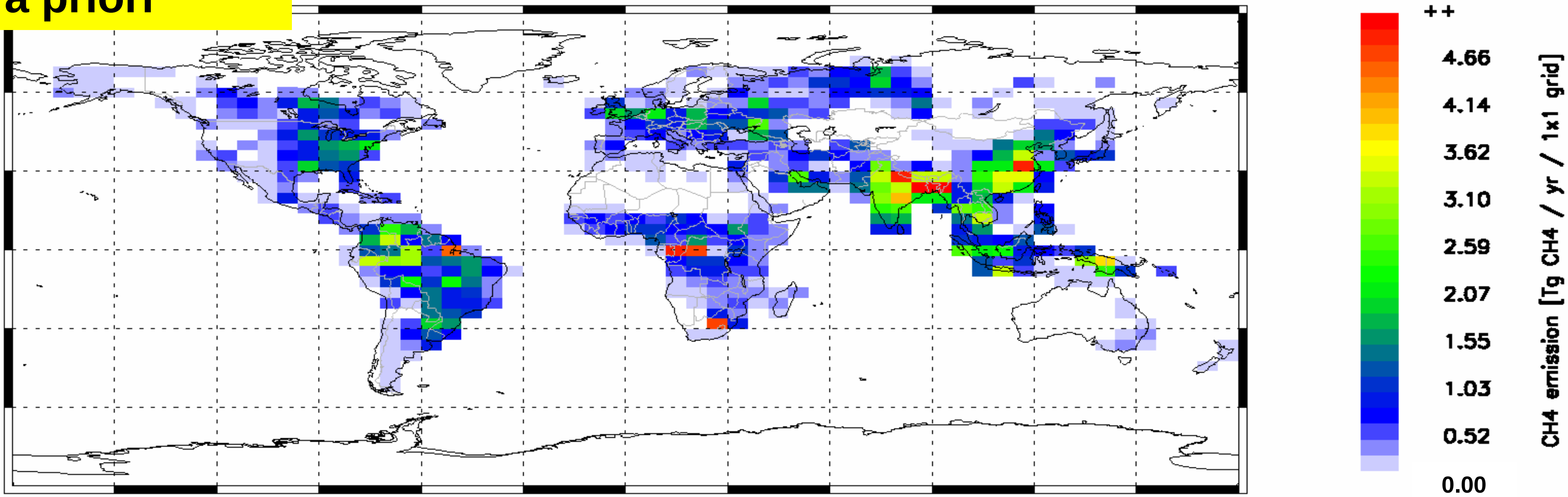
SCIAMACHY vs. TM5 10-12 / 2003

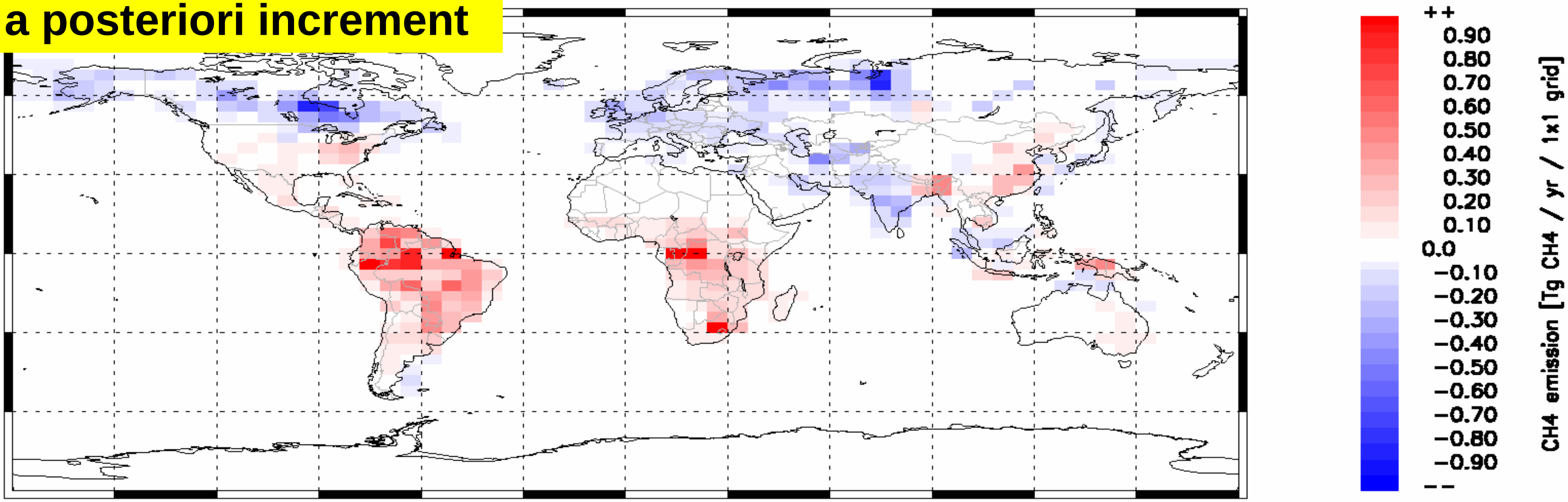


a priori emissions / a posteriori increment (S1)

a priori

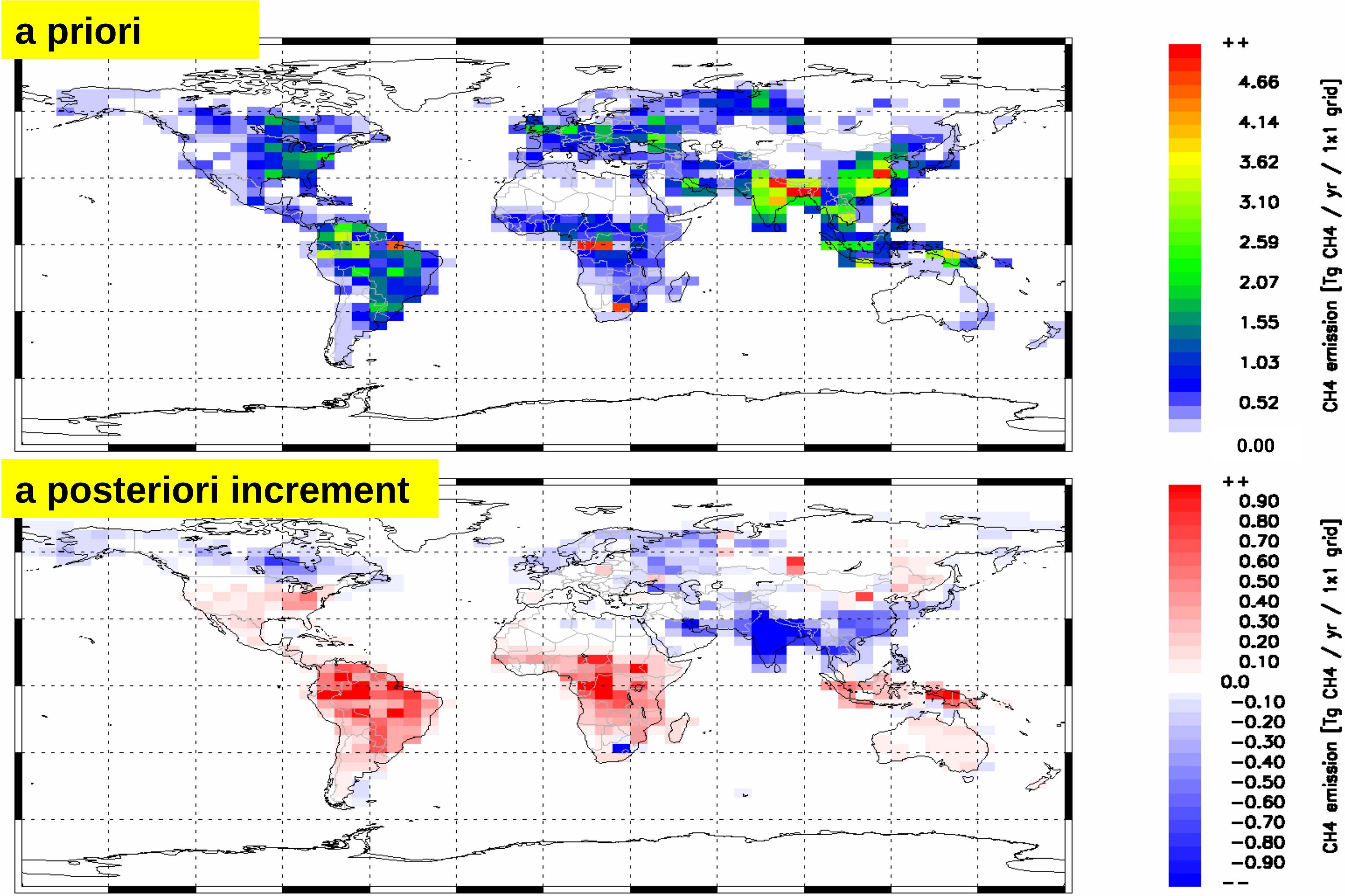


a posteriori increment



Scenario S1

a priori emissions / a posteriori increment (S2)



Scenario S2

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Conclusions (coupled inversion)

Scenario S2 (groundbased + SCIAMACHY observations):

- **polynomial offset (here applied: $a + b*lat + c*lat^2$) significantly improves agreement between SCIAMACHY and TM5; similar agreement cannot be achieved by optimizing emissions only (without polynomial offset); Reasons for this offset ?**

- **Inversion S2 suggests higher tropical emission**

- **Emissions from rice paddies in India and South East Asia relatively well constrained by the SCIAMACHY data; slightly reduced by the inversion**

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4DVAR inversion using synthetic observations (European zoom 1x1)

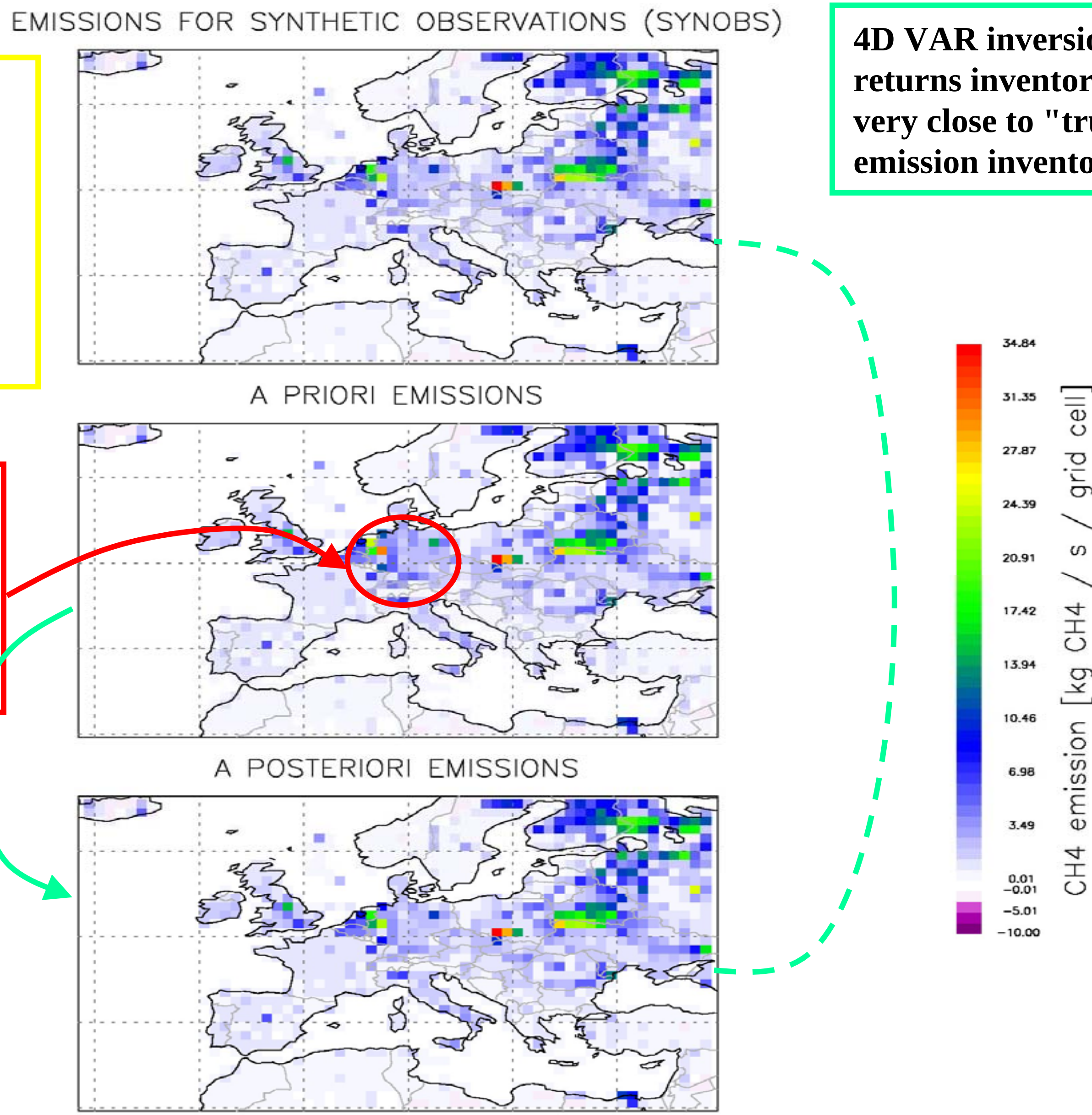
emission inventory used to create synthetic observations

-> "true emissions"

Artificial increase of CH_4 emissions over Germany by 30 %

-> a priori emissions

4D VAR inversion

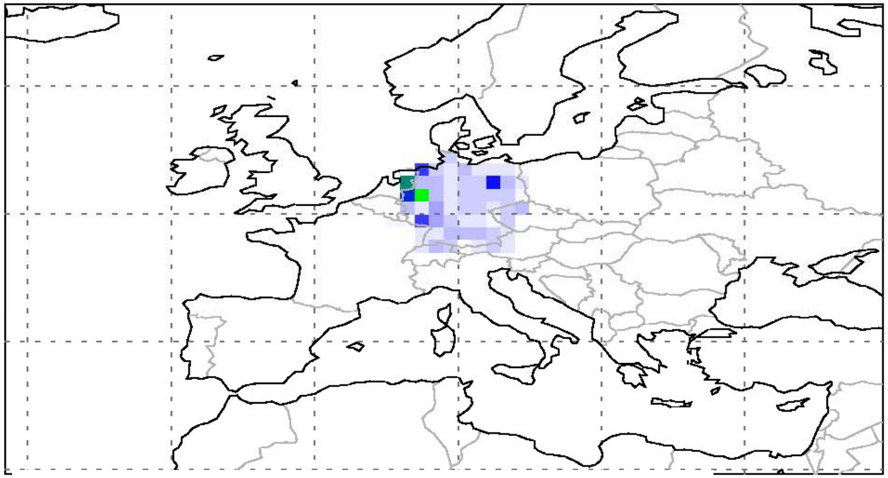


4D VAR inversion returns inventory very close to "true emission inventory'

4DVAR inversion - analysis increments (European zoom 1x1)

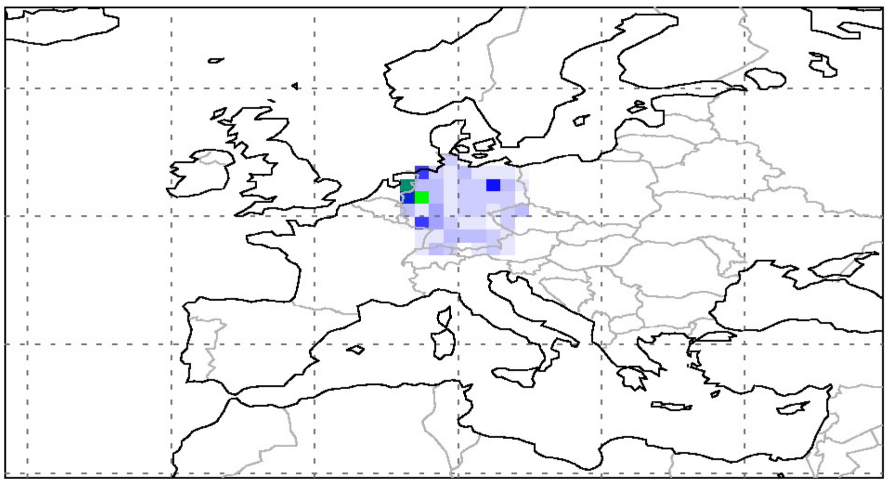
4D VAR inversion

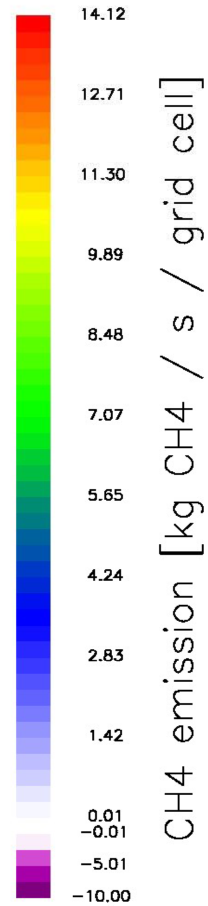
a priori - a posteriori



artificial increase

a priori - SYNOBS





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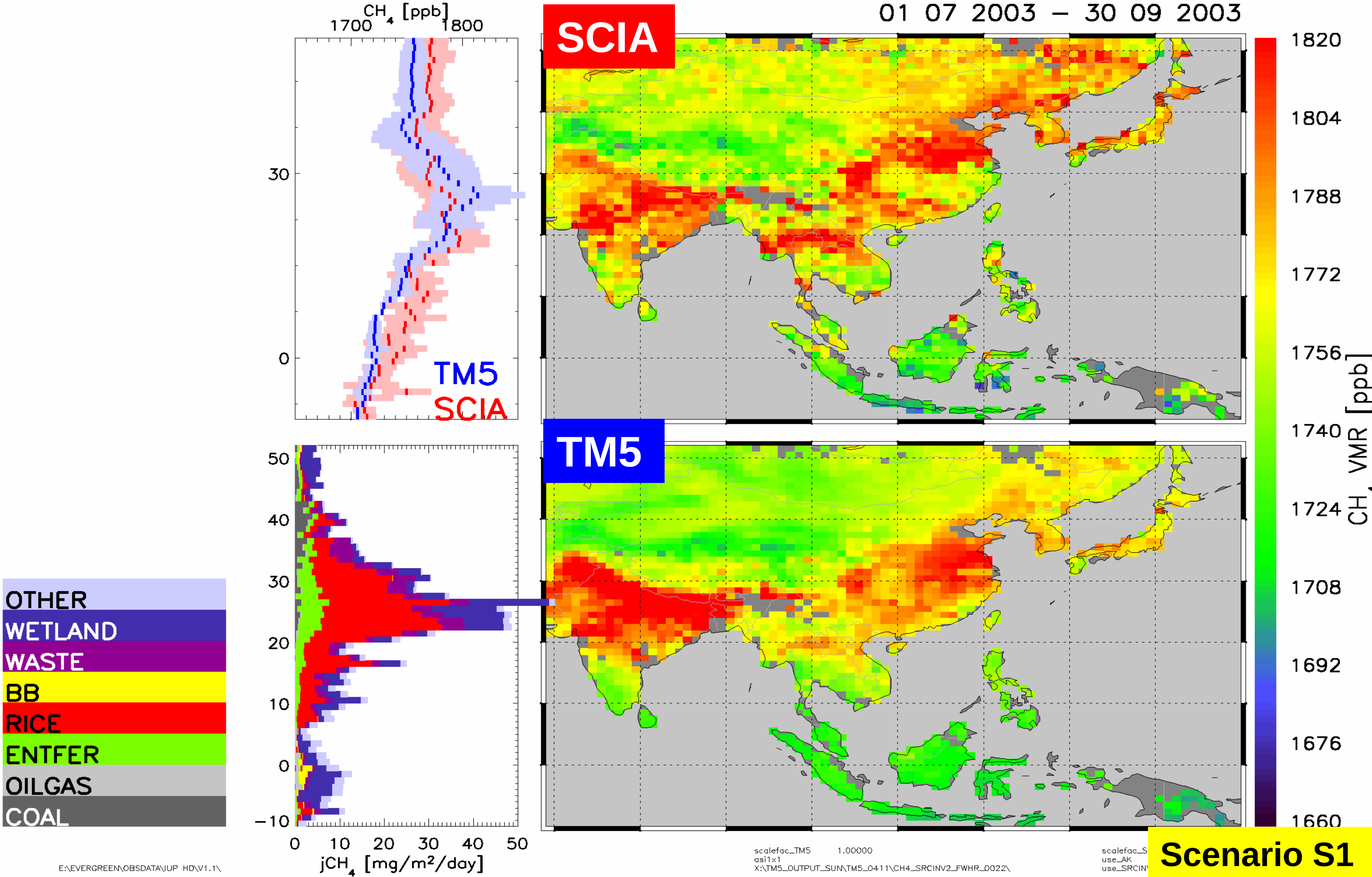
SCIAMACHY vs. TM5 - Asia 07-09 2003



Scenario S1

progress summary (1)

Joint Research Centre

Task 8.1: Upgrade of the existing TM5 inversion scheme (synthesis inversion) to allow processing of satellite data (from WP_GHG_7) and sequential application for quasi-operational inversions.

- implementation sequential inversion (15 months blocks)

- inversion scheme in to include satellite data

- monthly averaging is performed consistently between SCIAMACHY observations and TM5 model simulations

- correct use of averaging kernels of SCIAMACHY retrievals

- CO2 correction based on simulations from the TM3 model (MPI Jena)

- simultaneous use of surface measurements (e.g. from NOAA/CMDL) and SCIAMACHY. Bias correction using a polynomial offset as function of latitude and month. However the underlying reasons for the offset are not yet identified. Potential reasons are systematic retrieval offsets depending on solar zenit angle.

progress summary (2)

Task 8.2: Update of the TM5 adjoint model and further development of 4DVAR data assimilation system

- The TM5 adjoint model has been updated. This has been done by manual coding (matrix transposition). One major advantage of this approach is that the adjoint code is rather fast (almost as fast as forward model).

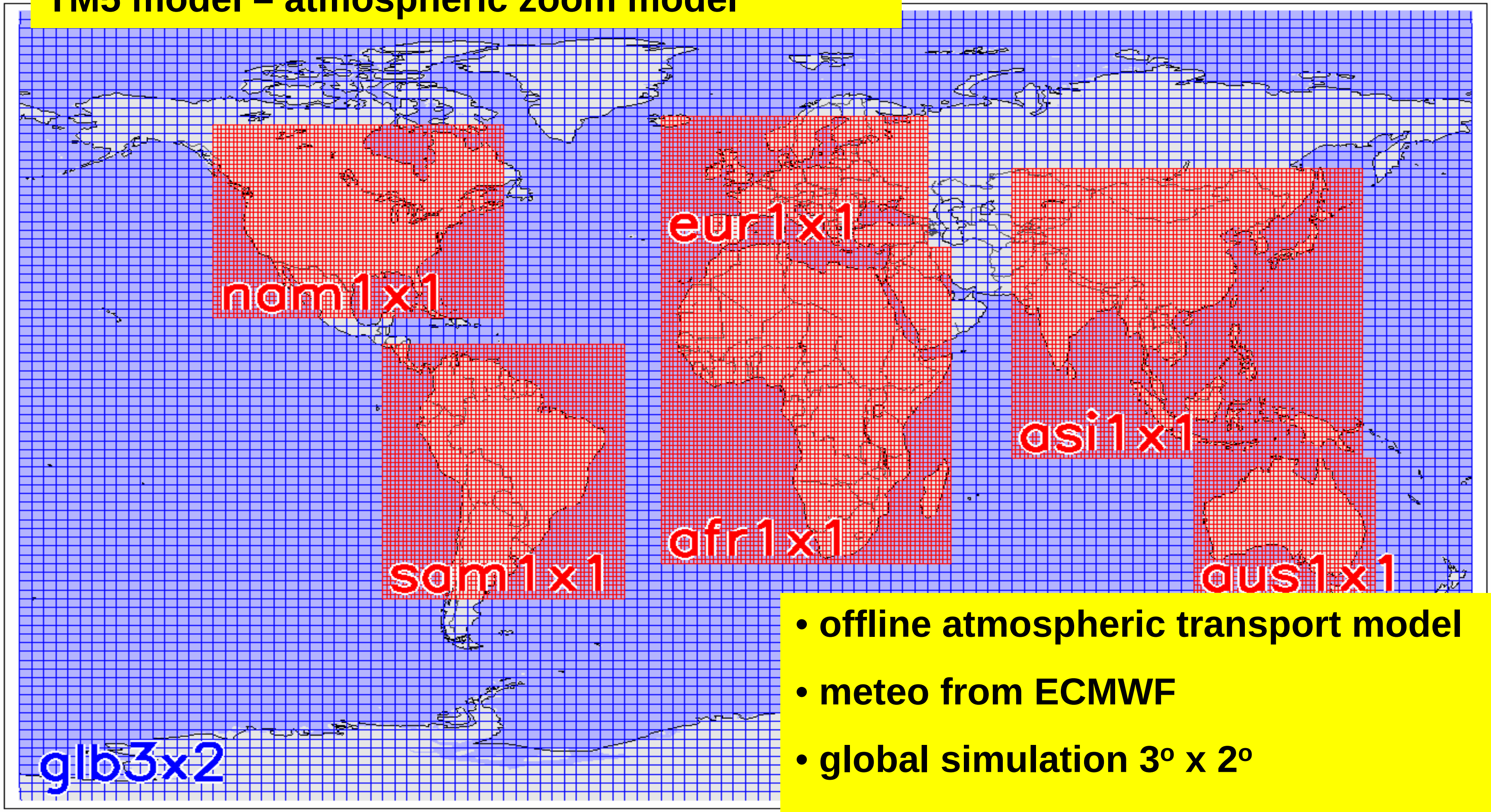
- First tests indicated that the coding is correct. The gradient test showed excellent results (convergence better than 1.0 E-5 for integration time of 4 days).

- A first 4DVAR assimilation system has been assembled based on the new TM5 adjoint model. First test assimilations (short time windows (1 day) with synthetic observations have been performed. These tests demontrated that the system is converging well (within ~30-50 iterations).

Supporting Material

TM5 model

TM5 model – atmospheric zoom model



- **offline atmospheric transport model**
- **meteo from ECMWF**
- **global simulation 3° x 2°**
- **zooming 1° x 1° (North America, South America, Europe, Africa, Asia, Australia)**
- **http://www.phys.uu.nl/~tm5/**
- **[Krol et al., 2005]**

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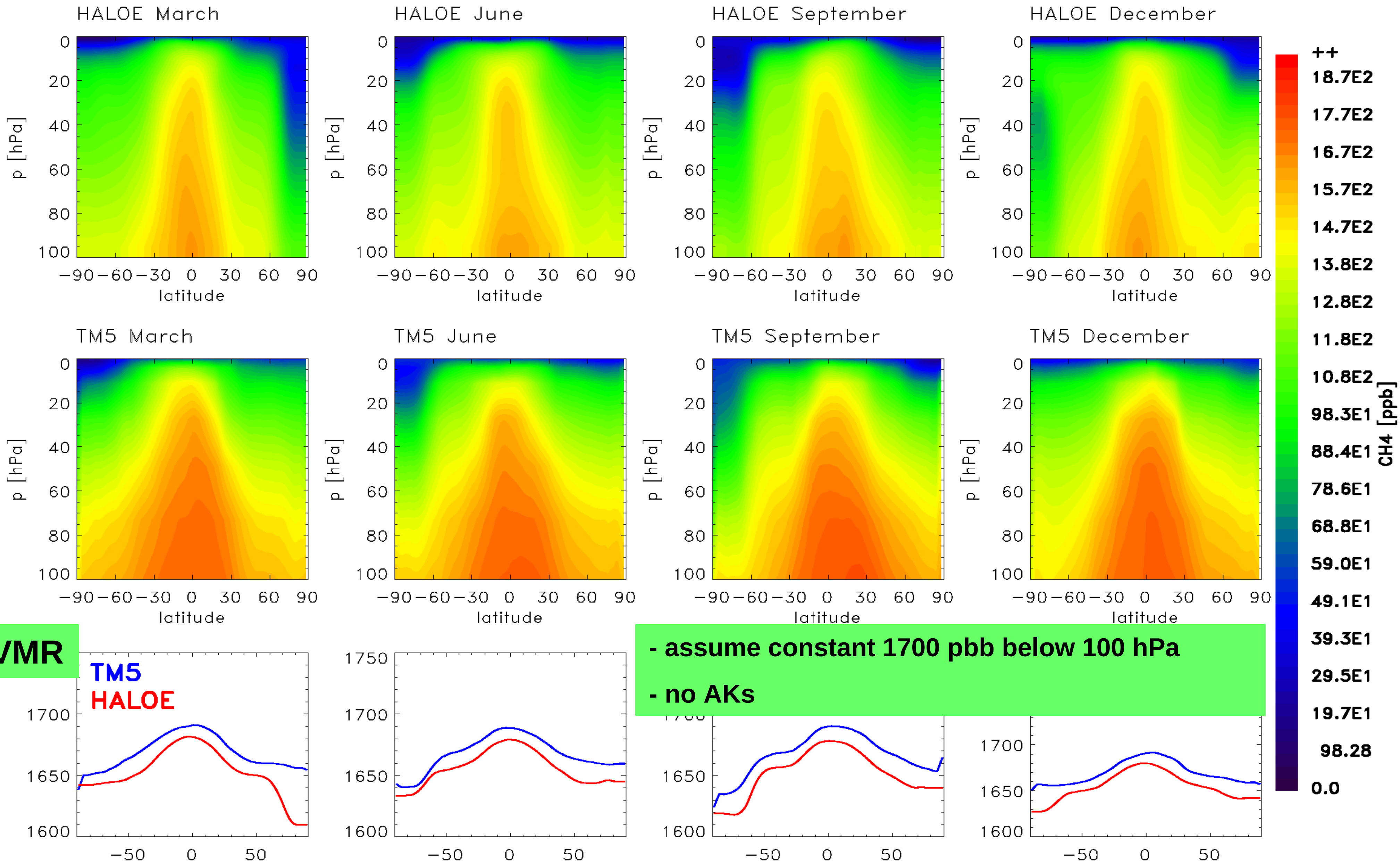
TM5 - HALOE



- assume constant 1700 pbb below 100 hPa
- no AKs

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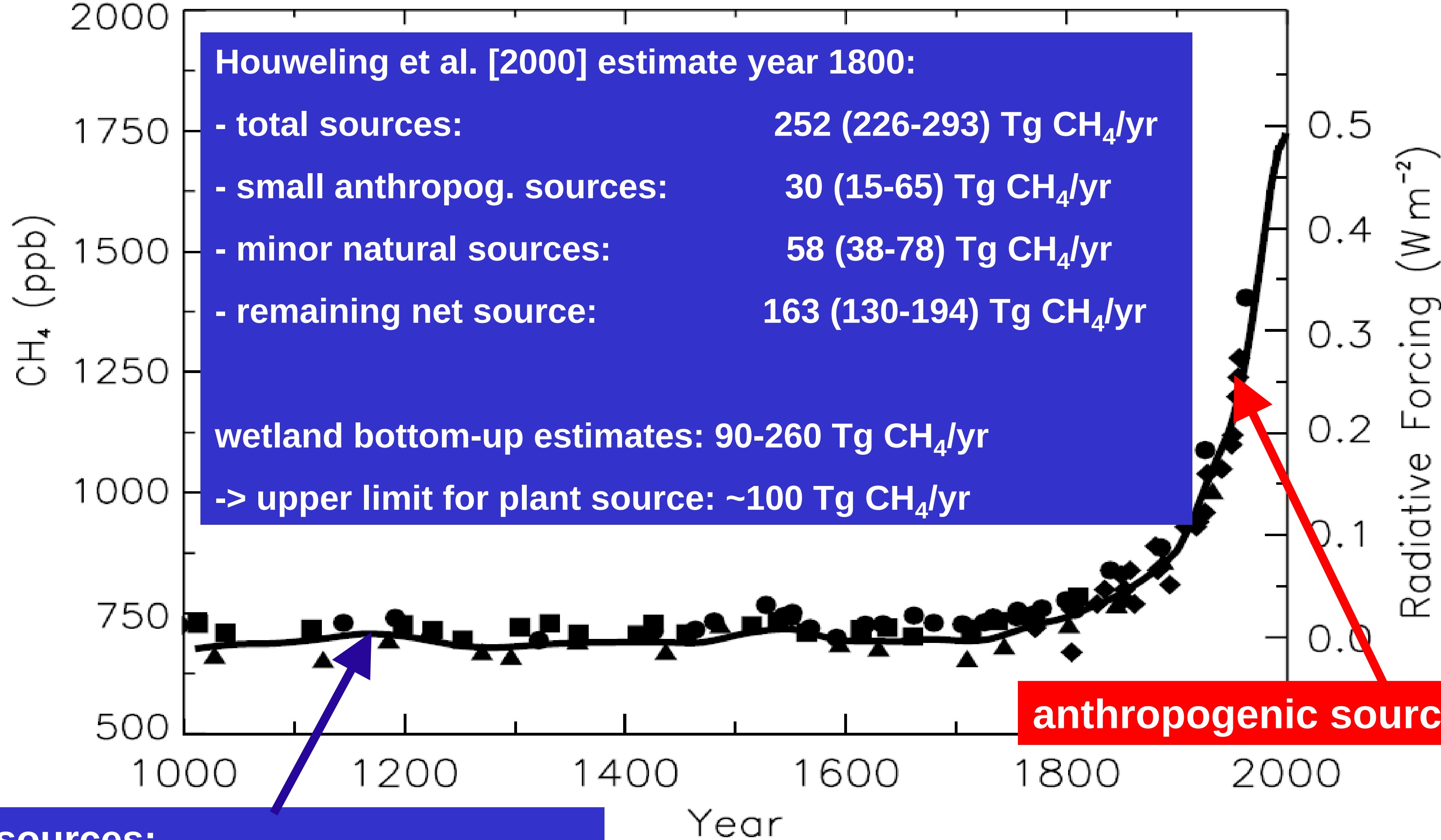
CH_4 emissions from plants ?



Houweling et al. [2000] estimate year 1800:

- total sources:	252 (226-293) Tg CH_4/yr
- small anthropog. sources:	30 (15-65) Tg CH_4/yr
- minor natural sources:	58 (38-78) Tg CH_4/yr
- remaining net source:	163 (130-194) Tg CH_4/yr

wetland bottom-up estimates: 90-260 Tg CH_4/yr

-> upper limit for plant source: ~100 Tg CH_4/yr

anthropogenic sources

Natural sources:

- wetlands
- plants ? [Keppler et al., Nature, 2006]: CH_4 from plants: 62-236 Tg CH_4/yr

- CH_4 sink: OH radicals (photochemistry)
- atmospheric lifetime: ~8 years
- change of CH_4 sink: since ~1750: < 20%