Simulations and Forecasts in the UTLS and Stratosphere with the CTM MOCAGE

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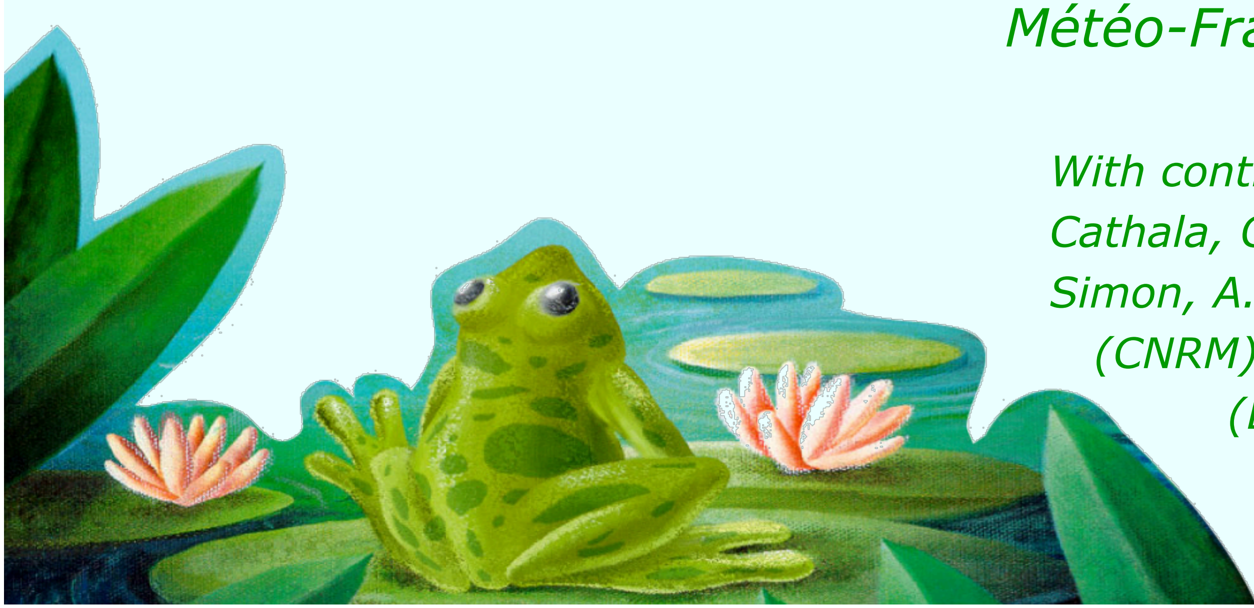
With contributions from : M.-L. Cathala, O. Dessens, B. Josse, P. Simon, A. Peuch and J. Pailleux (CNRM) ; J.-P. Cammas (Laboratoire d'Aérologie)



Overview

- From Cariolle parameterization to the 3D Chemistry and Transport Model of the troposphere and stratosphere MOCAGE
- Model overview ; the off-line / on-line « dilemna » ; evaluation of simulations in the stratosphere and UTLS
- On-going work on chemical data assimilation

Chemistry modeling at MF

Cariolle and Déqué ~1986	Linearized « climatological » stratospheric ozone chemical sources and sinks
MOBIDIC 2D « climatological » model of atmospheric chemistry in the stratosphere of the stratosphere	Teyssèdre et al. ~1992
Lefèvre et al. ~1993	REPROBUS 3D CTM of the stratosphere ; homogeneous and PSC heterogeneous chemistry (collaboration with NCAR)
PSC / « cold » tracer refinement to represent ozone hole chemistry in the C&D framework	Simon ~1999
Peuch et al. ~2001	Multiscale MOCAGE 3D CTM of the troposphere and stratosphere ; includes REPROBUS as well as tropospheric dynamics and chemistry

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Motivations for MOCAGE

- In addition to long-lived species and **stratospheric** ozone, forcings due to tropospheric ozone (and related compounds) and aerosols are associated with high incertitudes and continental-scale patterns (IPCC, 2001)
- **UTLS** for itself : no longer be treated as a lower boundary for a stratospheric model or as a boundary for a tropospheric model
- Cross-influence of **ST and T** : intrusions ; convection ; PBL chemistry ; rain-out and wash-out…
- New fields : « **chemical weather** » forecasts ; chemical **data assimilation** (ST and T)

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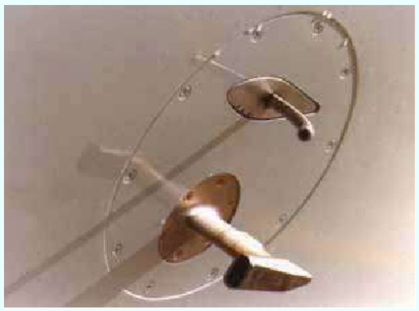
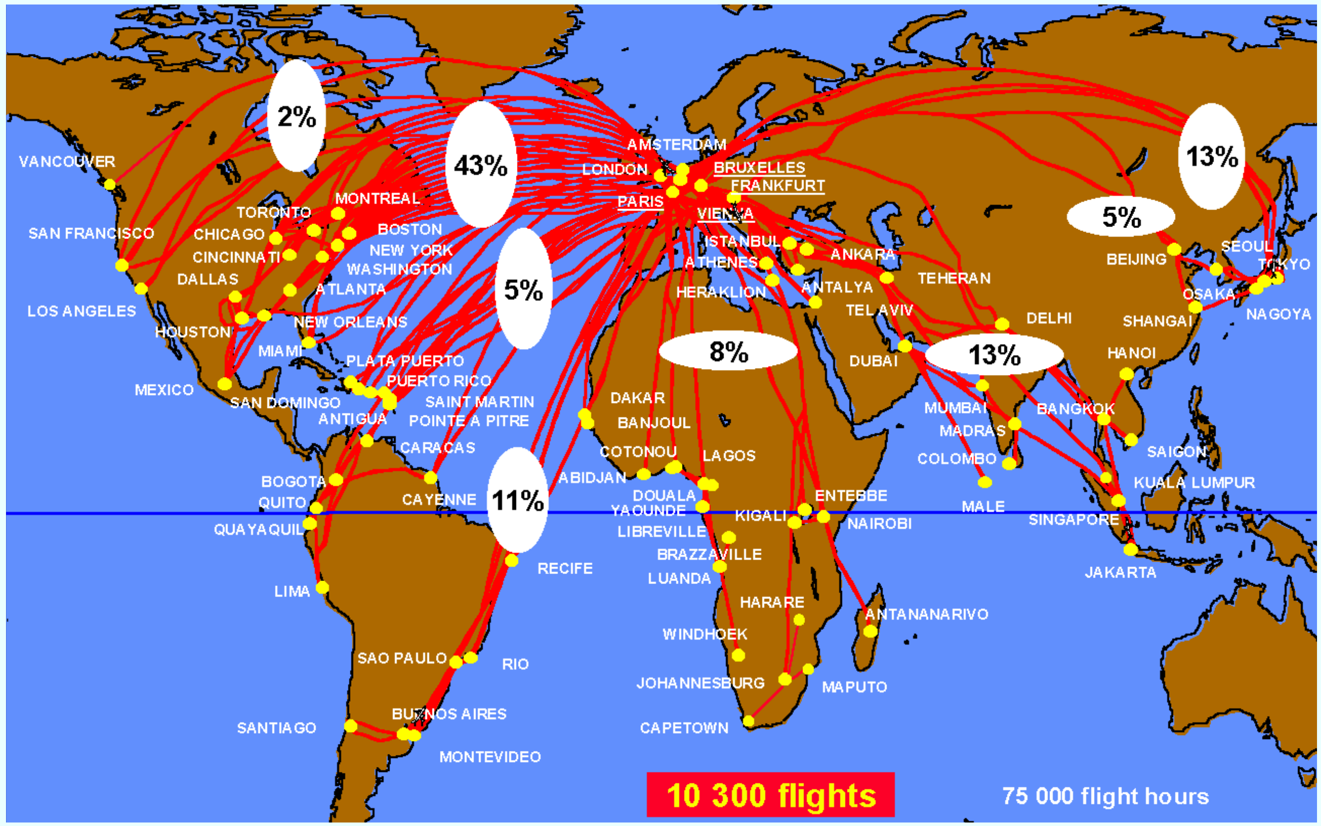
MOZAIC database of the UTLS composition



An average of 5 to 10 daily transcontinental flights



EU project (third phase) : a almost 10 year dataset for UTLS water vapour , ozone, and now carbon monoxyde and nitrogen oxydes. Coordination : J.-P.Cammas (Laboratoire d'Aérologie). *http://www.aero.obs-mip.fr/mozaic*

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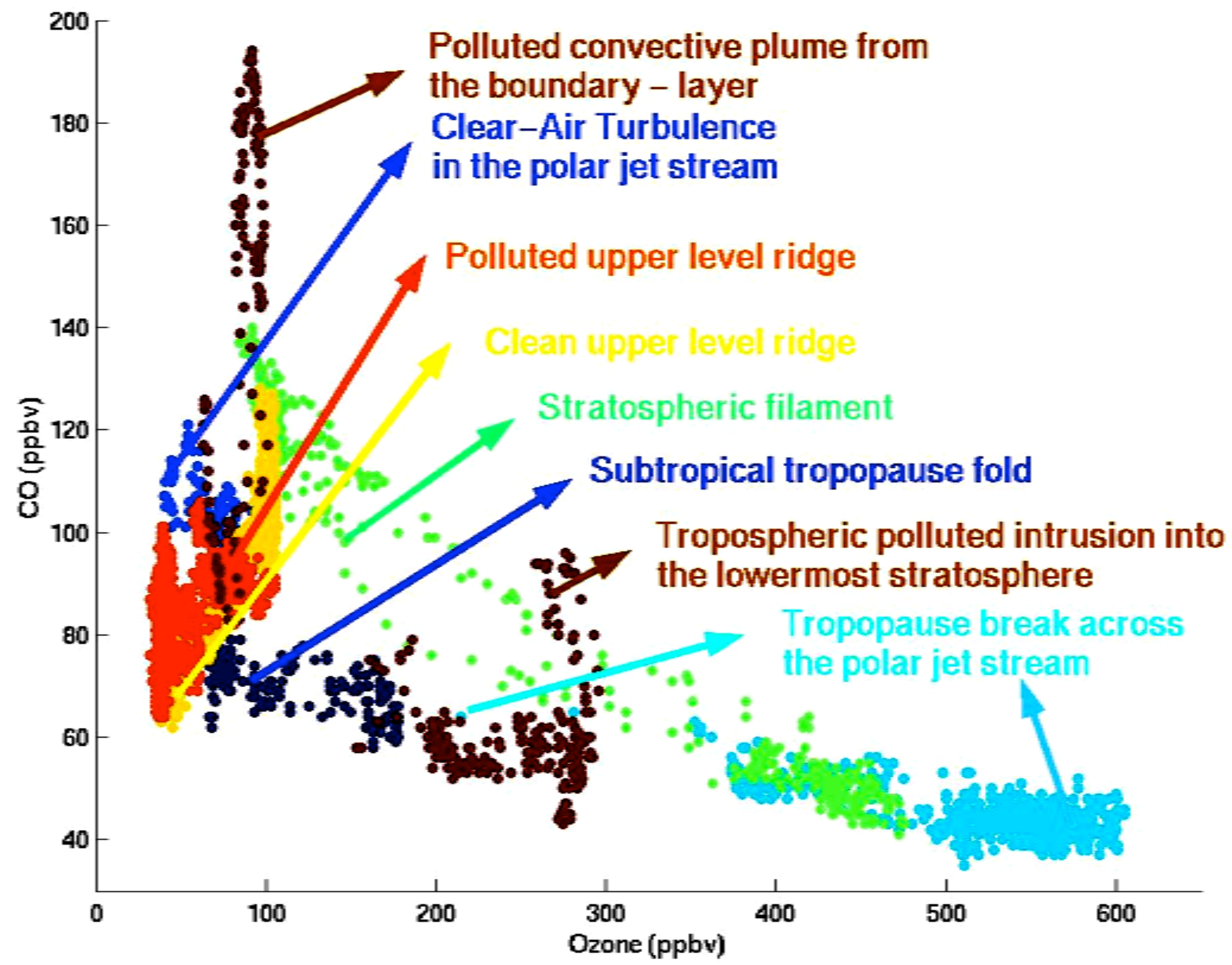

Complexiy of O3/CO sampled by aircrafts

(MOZAIC-III, J.-P. Cammas, Laboratoire d'Aérologie)

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Chemistry in or out of the NWPM?

On–line

Chemical parameterisations within the NWPM

+ : full consistency of the system, chemical feedbacks at every timestep,potential use of all 3D distributions

- : nudging for past periods, « hitch-hiking», more time and memory consuming than the dynamical part (model design)

Semi-Online

Over a coupling timestep :

• the NWPM provides a limited number of dynamical variables to a CTM

• the CTM provides a limited number of chemical 2D or 3D distributions to the NWPM

+ : flexibility, allows chemical feedbacks

- : consistency over the coupling time, recomputations of non-archived variables

Off–line

A stand-alone « Chemistry and Transport Model », reading archived dynamical forcings

+ : self-dependent, sensitivity and real-case studies

- : no chemical feedbacks, consistency between transport in the CTM and the forcings

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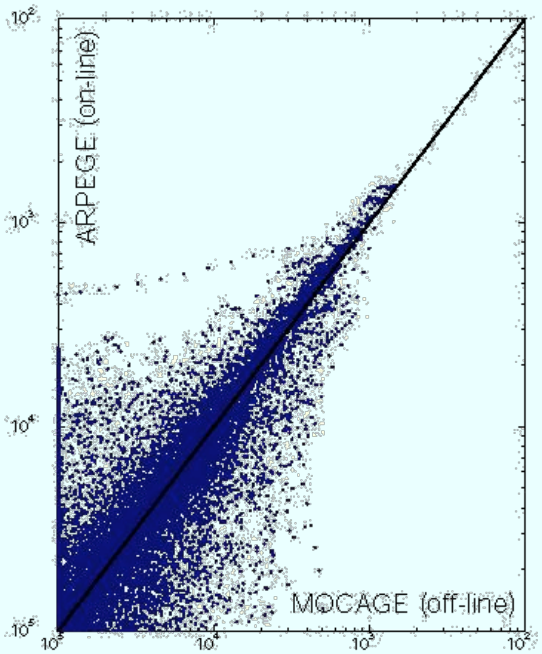
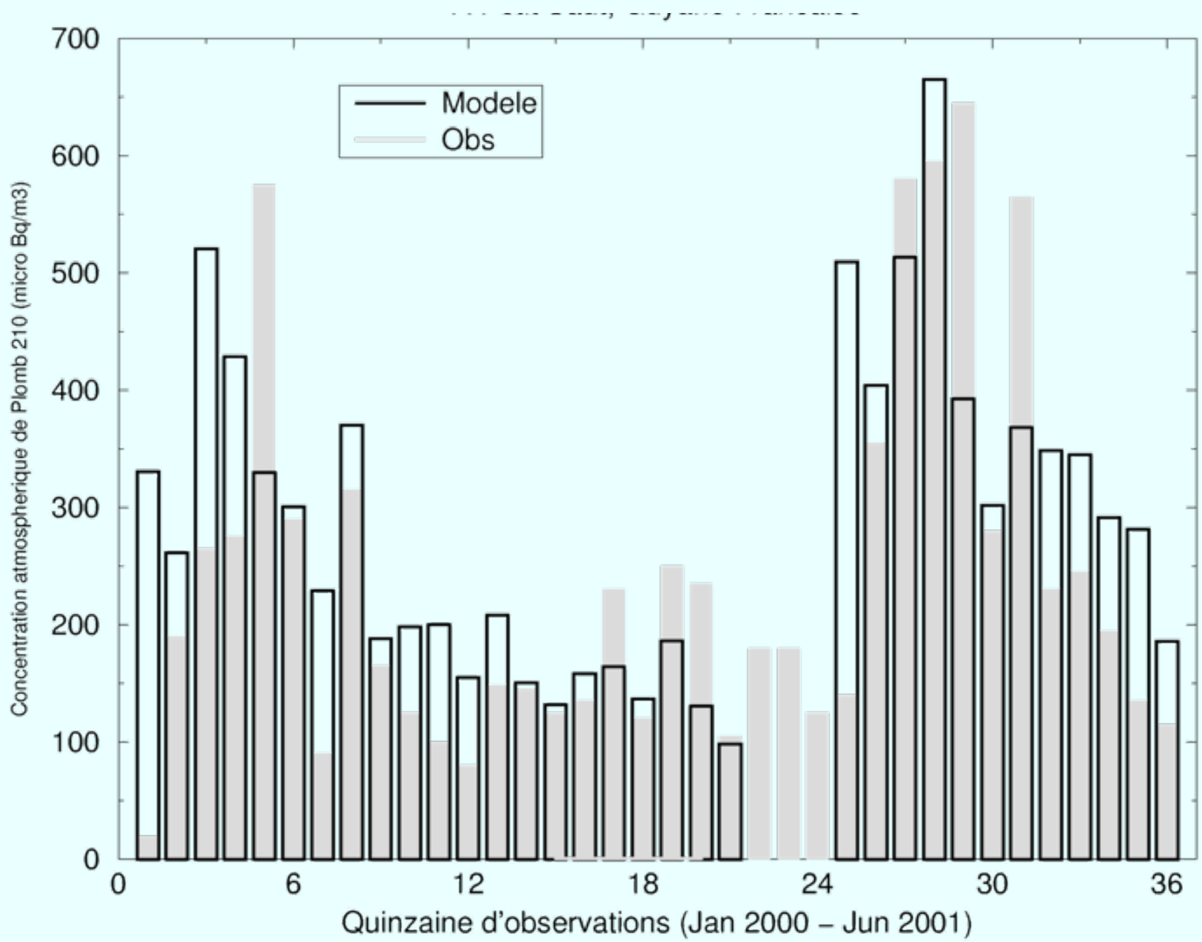
Testing on/off-line

(Josse)



Off-line versus
on-line stratiform
3D rainfall

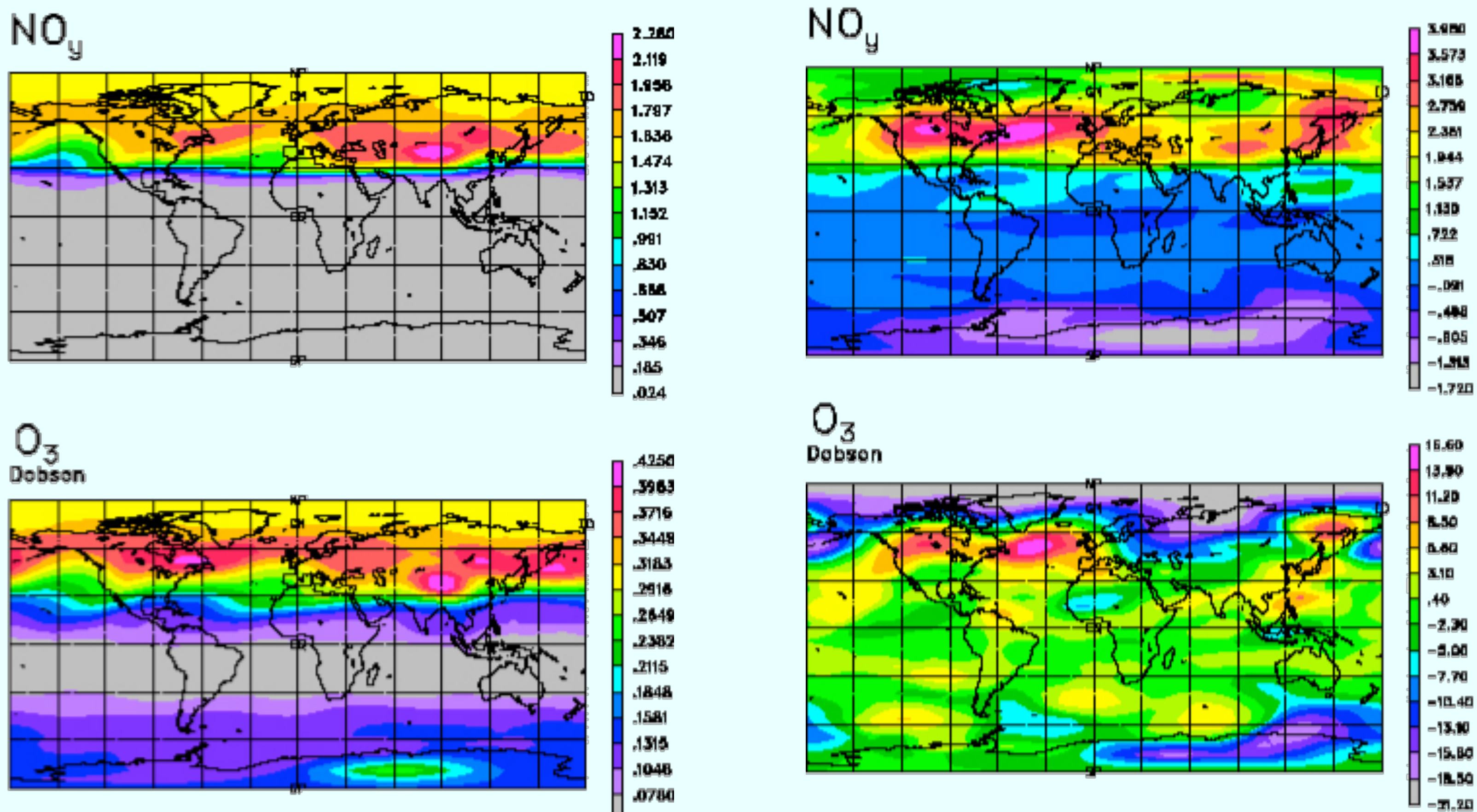


Lead (French Guyana)

Impact of chemical feedback

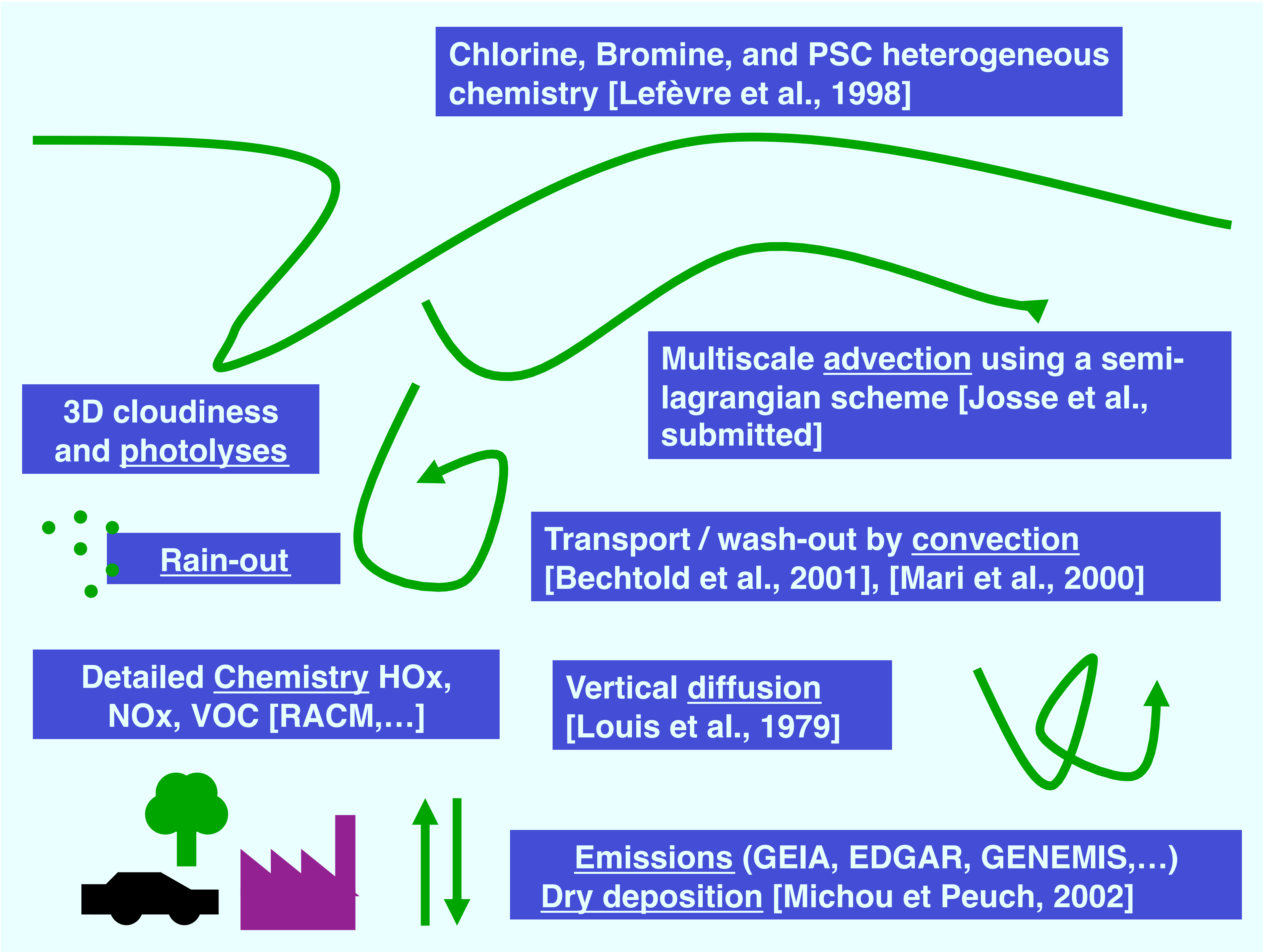
2015 aircraft fleet (NOx) ; Monthly mean for january

(Dessens et al., Met. Zeitschrift, 11, n°3, 161-175, 2002)



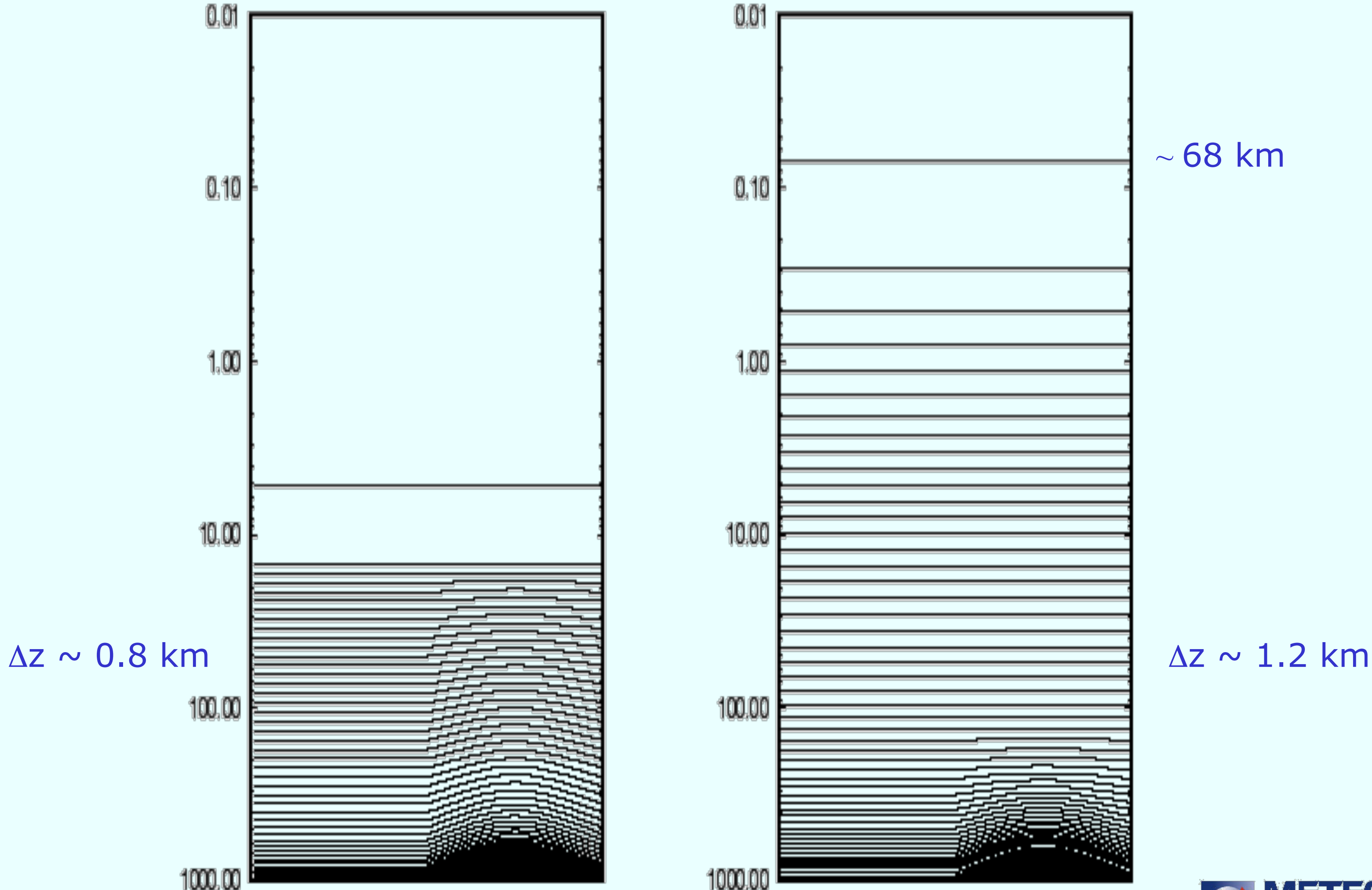
Forced

Coupled
(feedback)



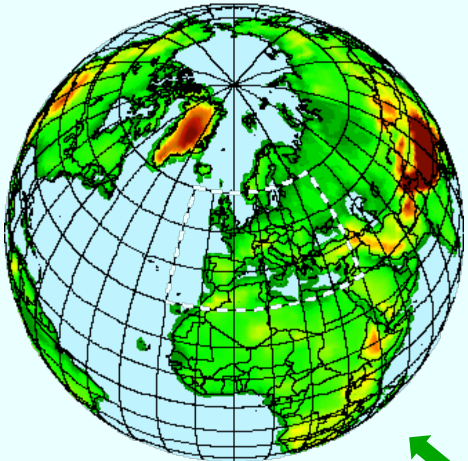
Chlorine, Bromine, and PSC heterogeneous chemistry [Lefèvre et al., 1998]
Multiscale advection using a semi-lagrangian scheme [Josse et al., submitted]
3D cloudiness and photolyses
Rain-out
Transport / wash-out by convection [Bechtold et al., 2001], [Mari et al., 2000]
Detailed Chemistry HOx, NOx, VOC [RACM,…]
Vertical diffusion [Louis et al., 1979]
Emissions (GEIA, EDGAR, GENEMIS,…)
Dry deposition [Michou et Peuch, 2002]

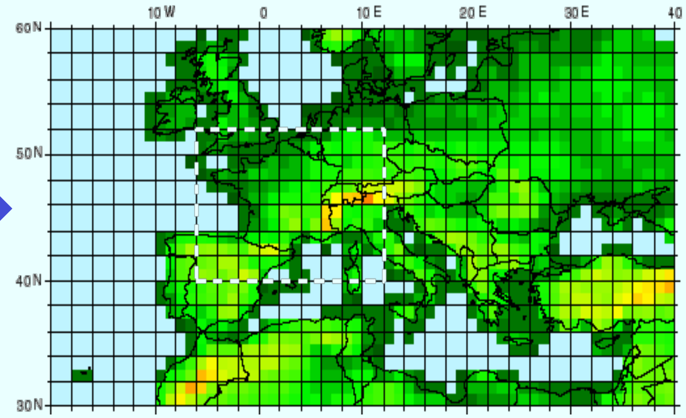
« Forecast » (L47)   « Climate » (L60)



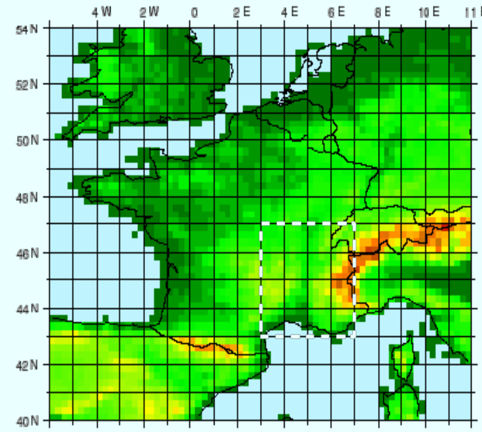
MOCAGE configurations

- 2°
- 4°
- T42

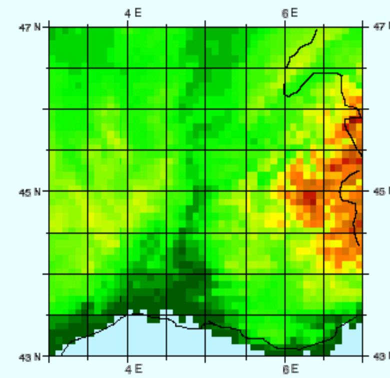




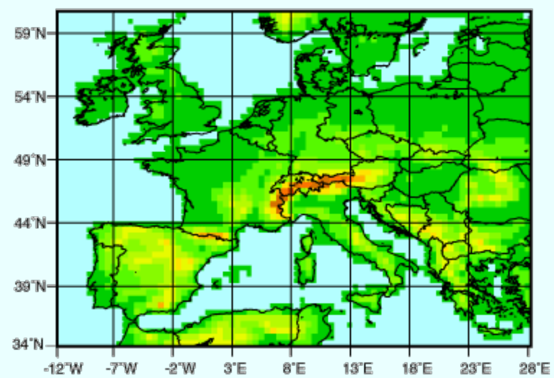
1°



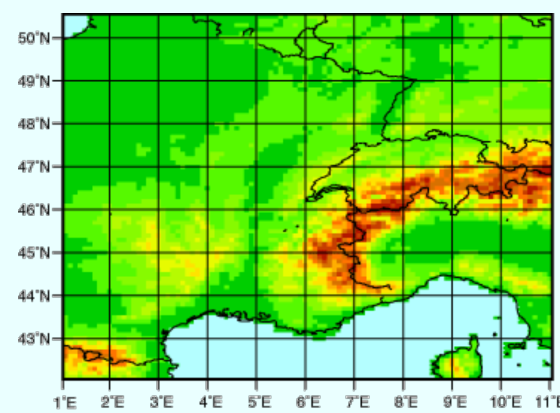
0.25°



~8 km



0.5°



~10 km

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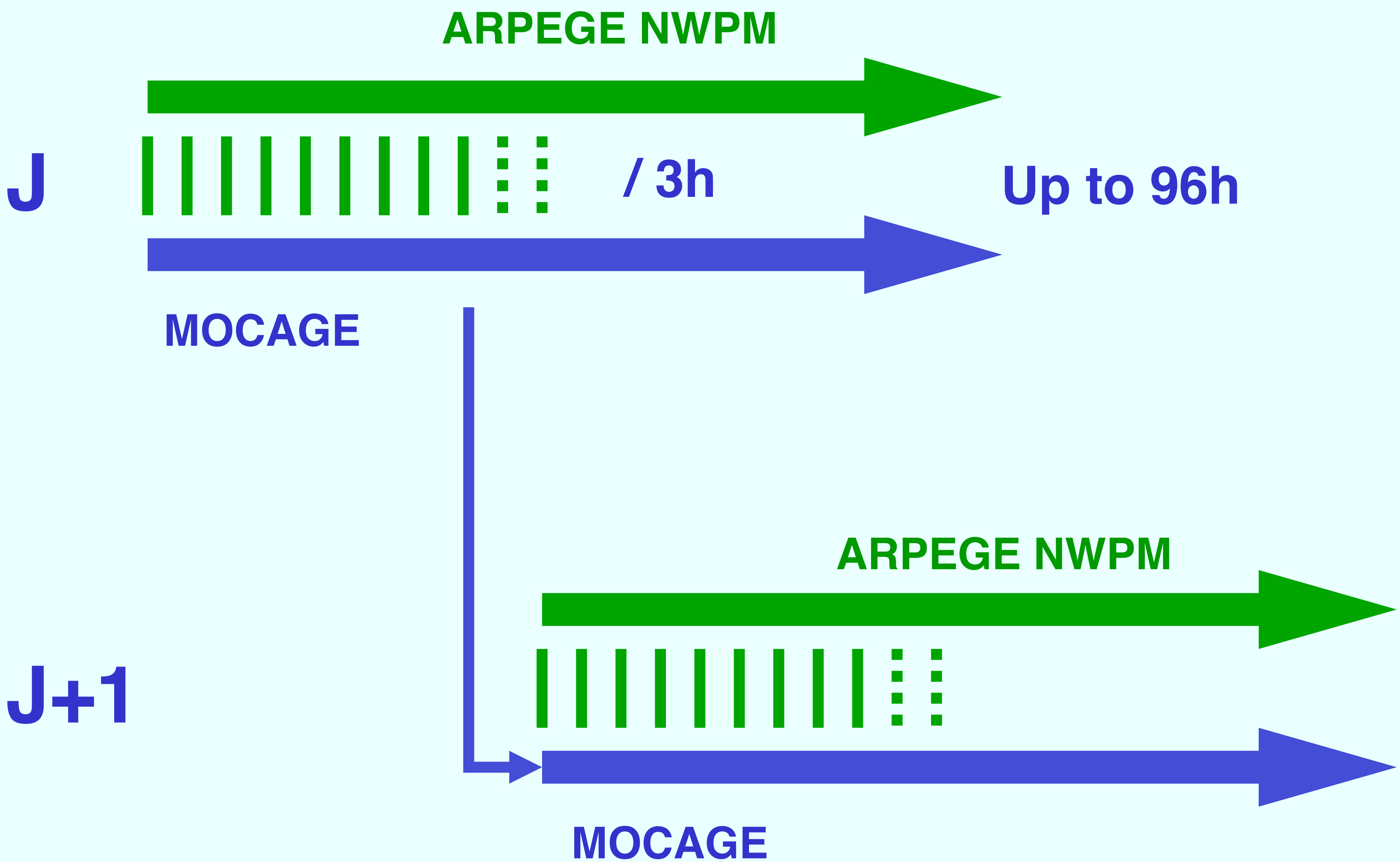

01/05/01 - 15/10/01
01/05/02 - 15/11/02
01/05/03 - …

Strat. Ozone + UV index forecast
Air Quality (multiscale)

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Chemistry within MOCAGE

- Automatic scheme (prod./loss, jacobian) coding from an ASCII description file and a master database (coefficients),…

- Tabulation of photolyses (TUV4.0) for clear-sky conditions (sza, model ozone column, altitude, surface albedo), modified on-line according to 3D cloudiness.

- Over 10 options for chemical scheme depending on application, generally merging a detailed stratospheric chemistry and tropospheric schemes.

- CWF : 118 species, ~270 reactions ; merging of REPROBUS [Lefèvre et al., 1994] and RACM [Stockwell et al., 1998]

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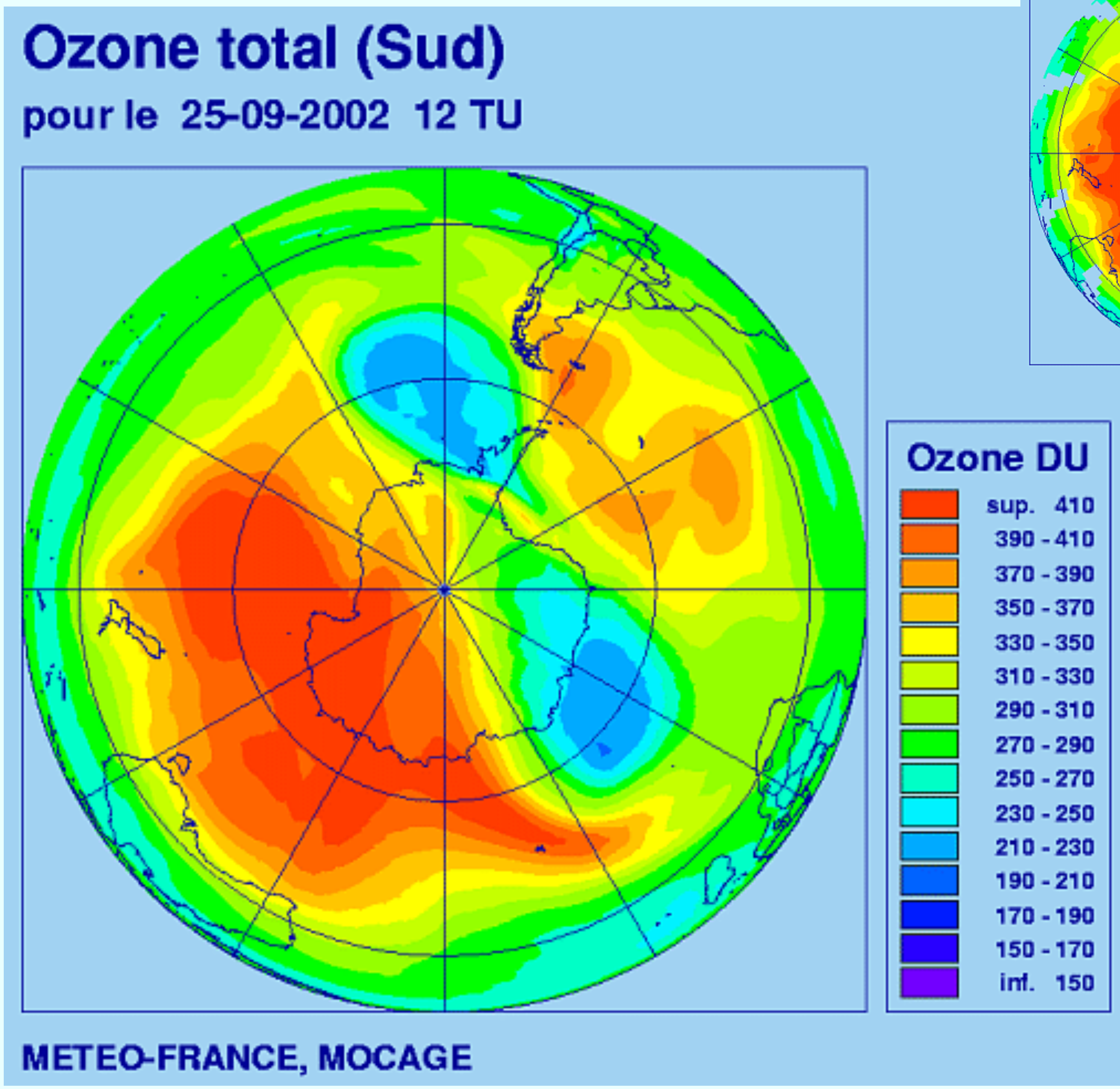

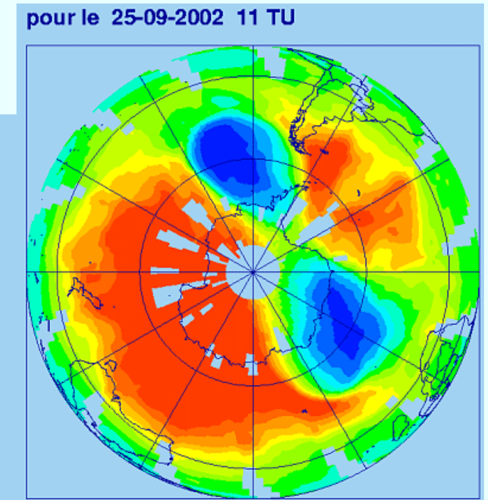

NASA, TOMS

(no chemical data assimilation)

~ 6 month CTM run

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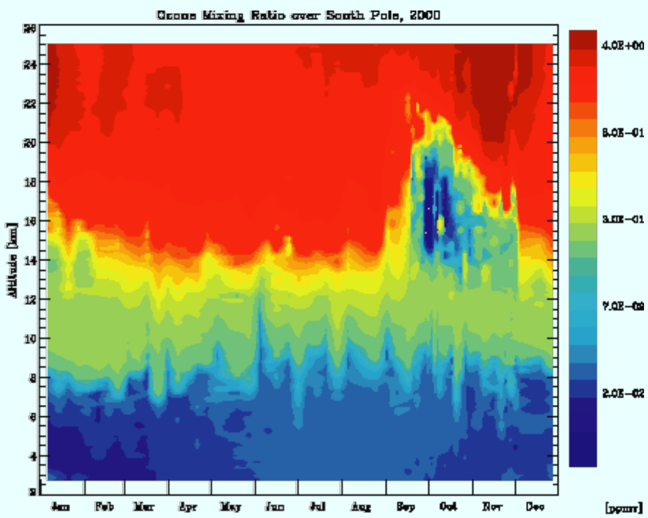
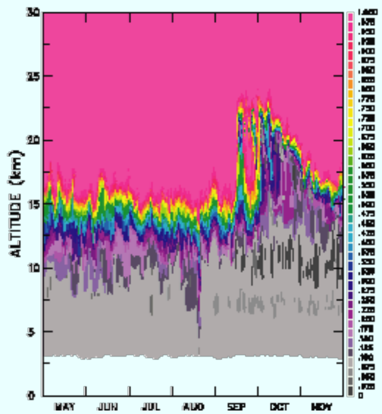
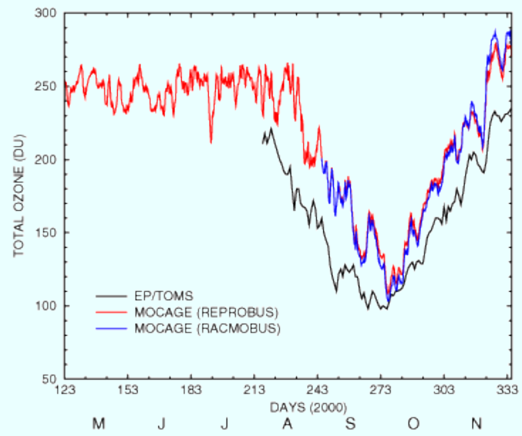
2000 Ozone hole event

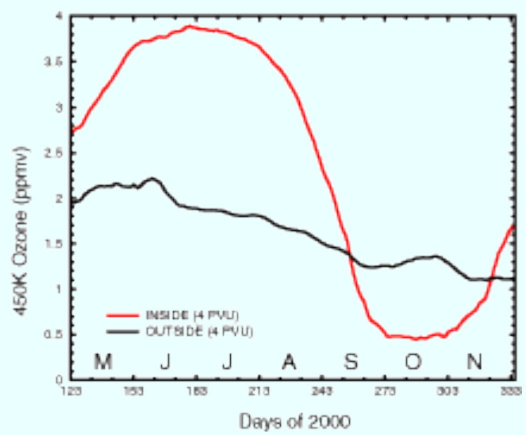
(Teyssèdre)



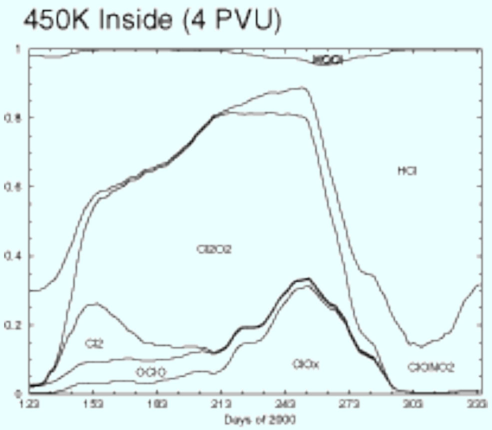


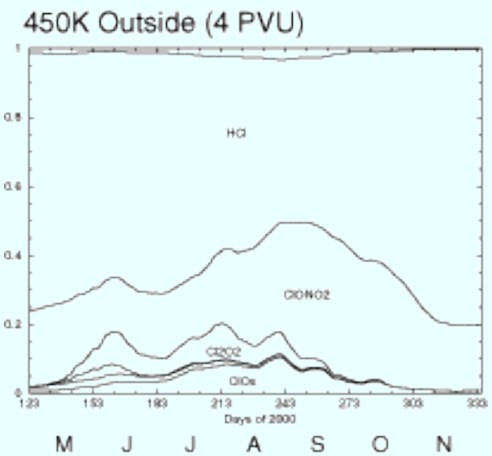
South pole
Ozonesonde
Vs MOCAGE





Ozone minum
In/out of the
vortex





Chlorine clock

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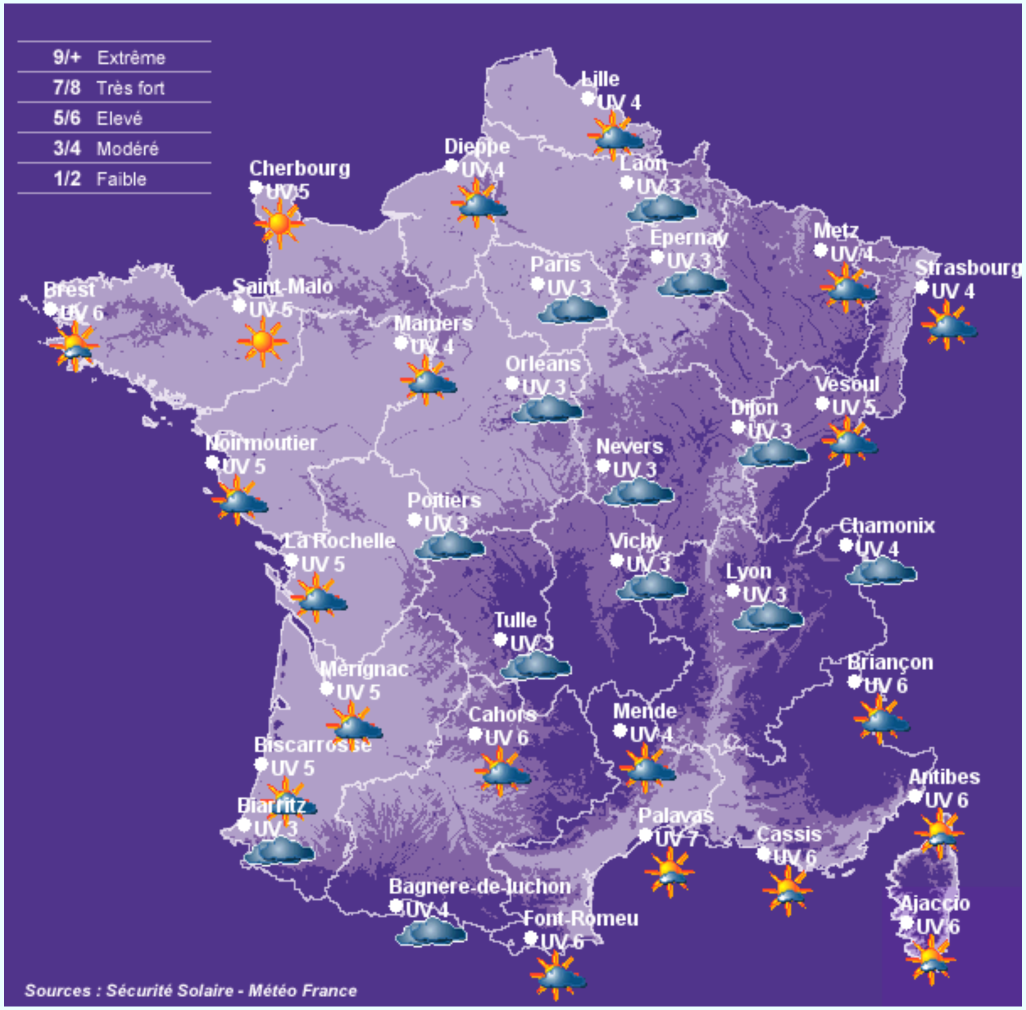
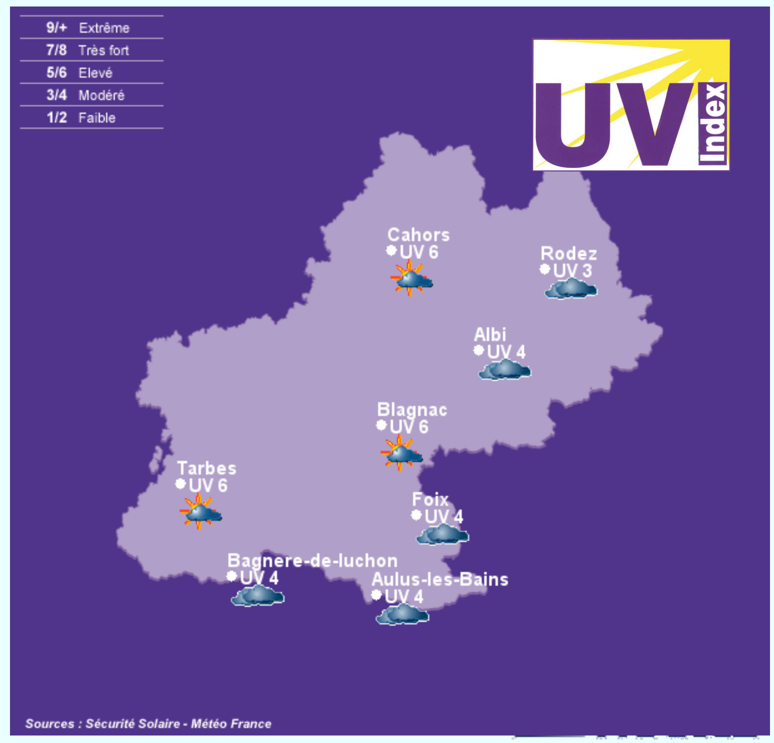
UV index forecast (with clouds)

(28/08/02)
http://www.meteo.fr
http://www.infosoleil.com

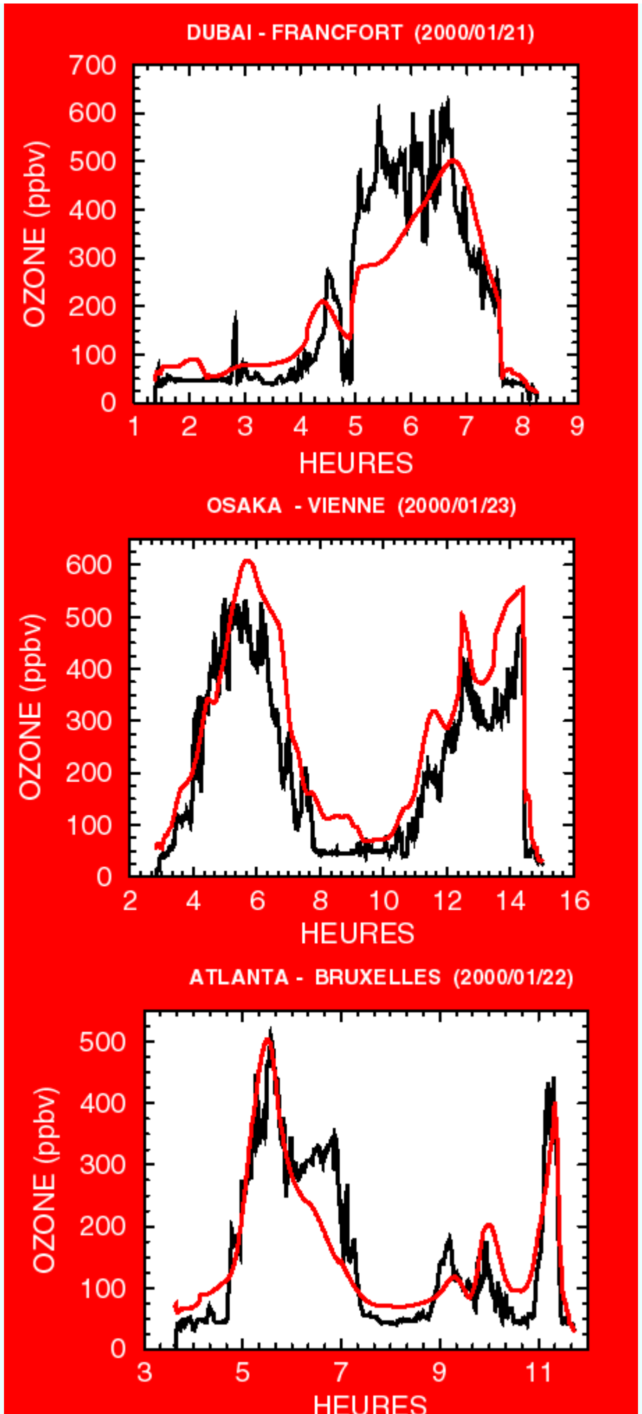




A posteriori check of NWP cloudiness
Phenomenological correction in case of mismatch

UTLS ozone : MOCAGE vs MOZAIC

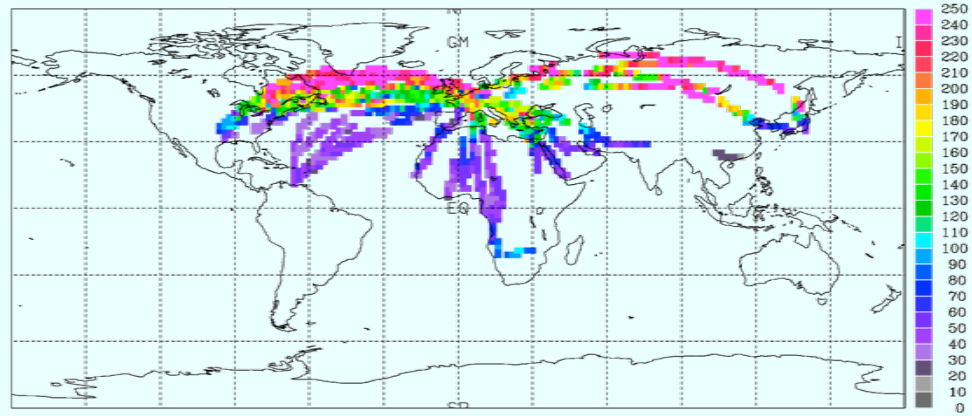
OBSERVATIONS MOZAIC
SIMULATIONS MOCAGE



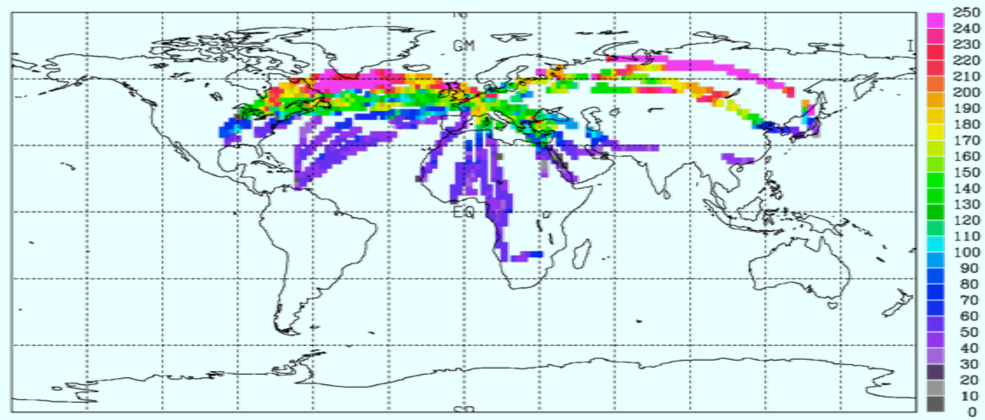
OZONE (ppbv)

MOZAIC

OCTOBER 2000



MOCAGE



[340–350 K]

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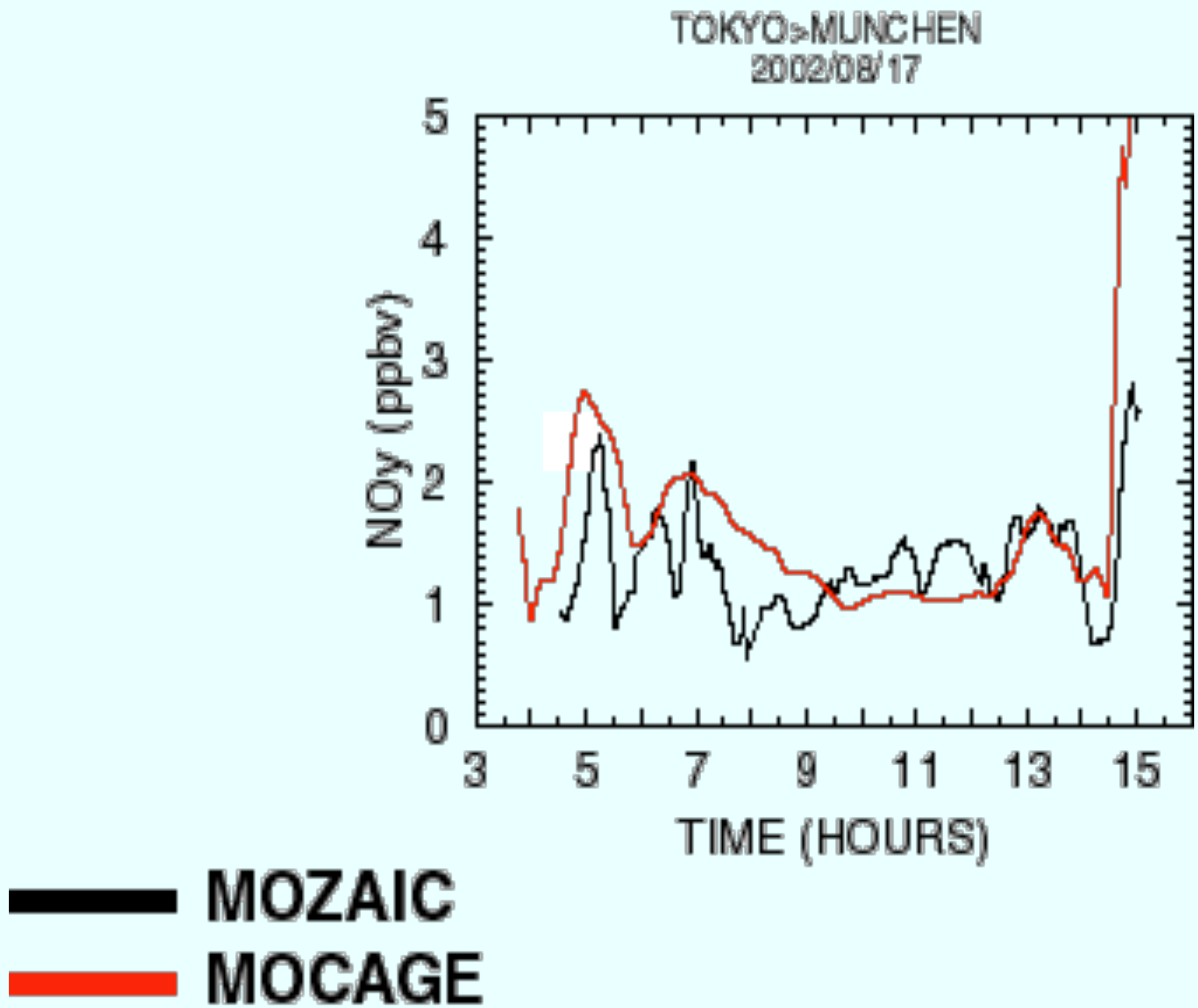
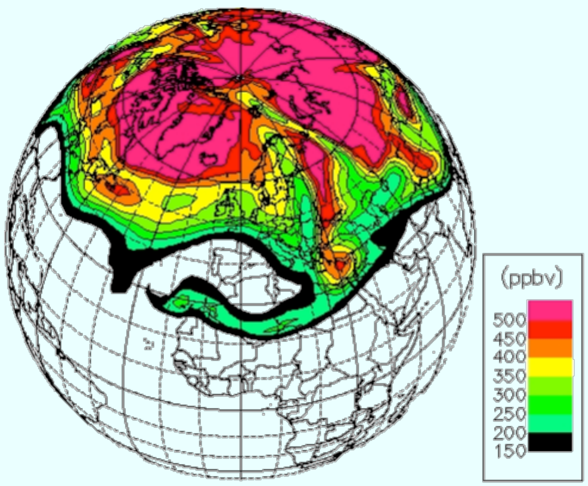
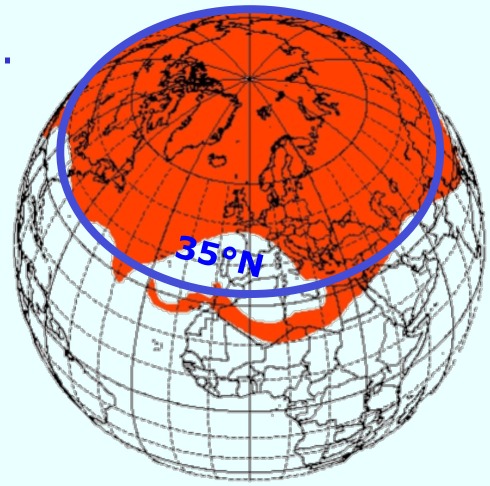
UTLS NO_y : MOCAGE vs MOZAIC

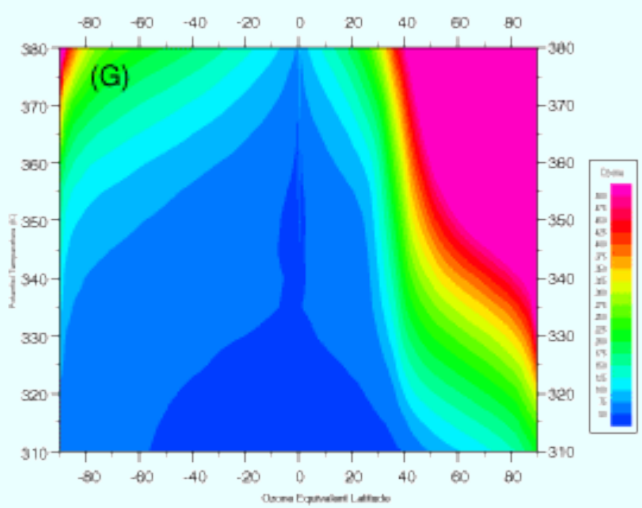


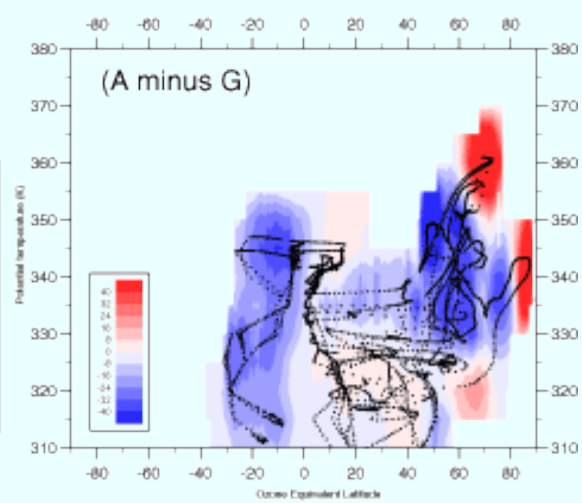
Flux-following coordinate system (Cathala et al., Tellus, 2003)



- Similar to (θ, PVEL), introduced by Lary et al. (1995), but free of « blobby » spurious features.
- for initialization (from zonal climatology) and assimilation (MOZAIC ozone).







- a few aircraft flights can have a global impact in the UTLS

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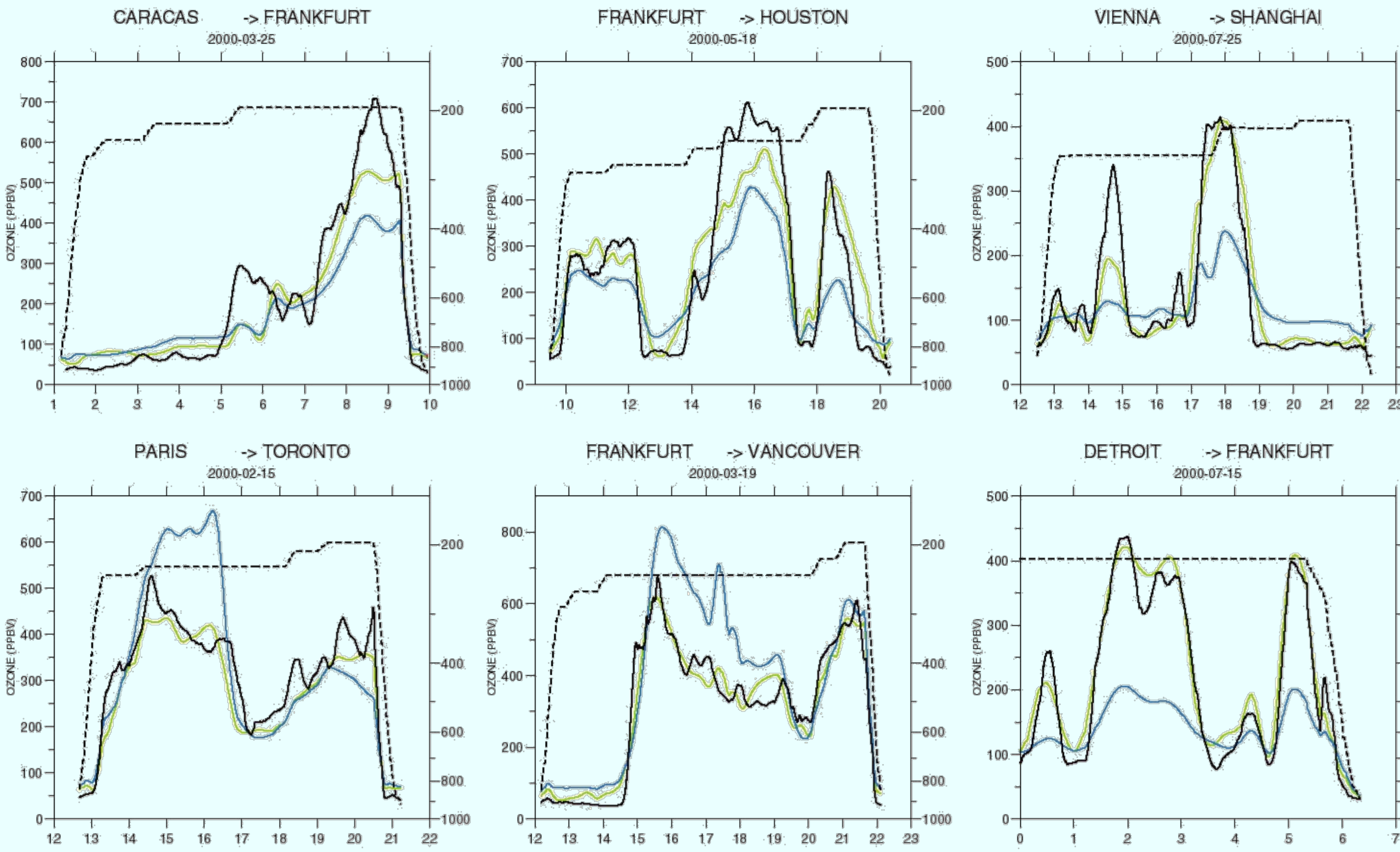
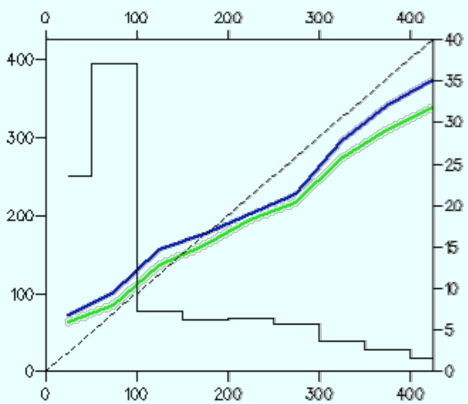


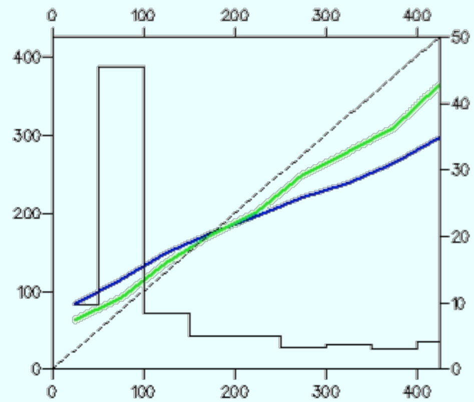
A powerful constraint in the UTLS

MOZAIC flight level pressure
MOZAIC ozone
MOCAGE free run
MOCAGE + daily assimilation

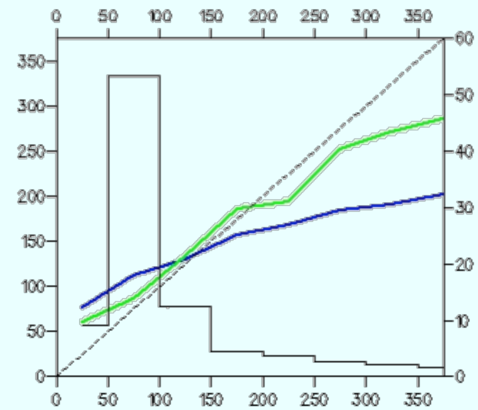
Independent radiosonde measurements



February 2000



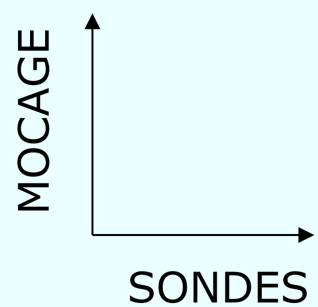
April 2000



June 2000

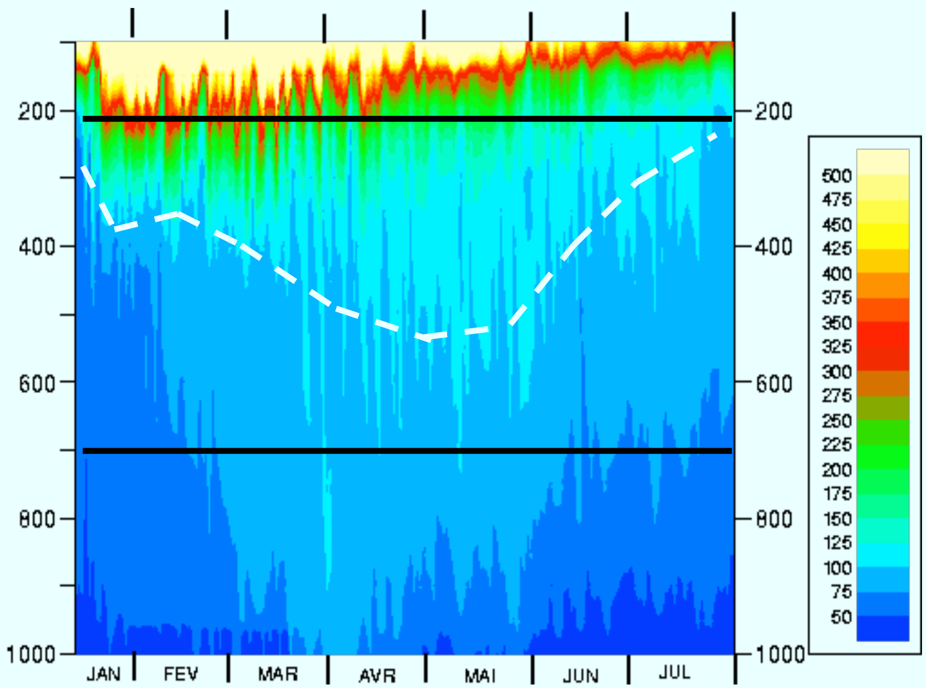
MOCAGE free run

MOCAGE + daily assimilation

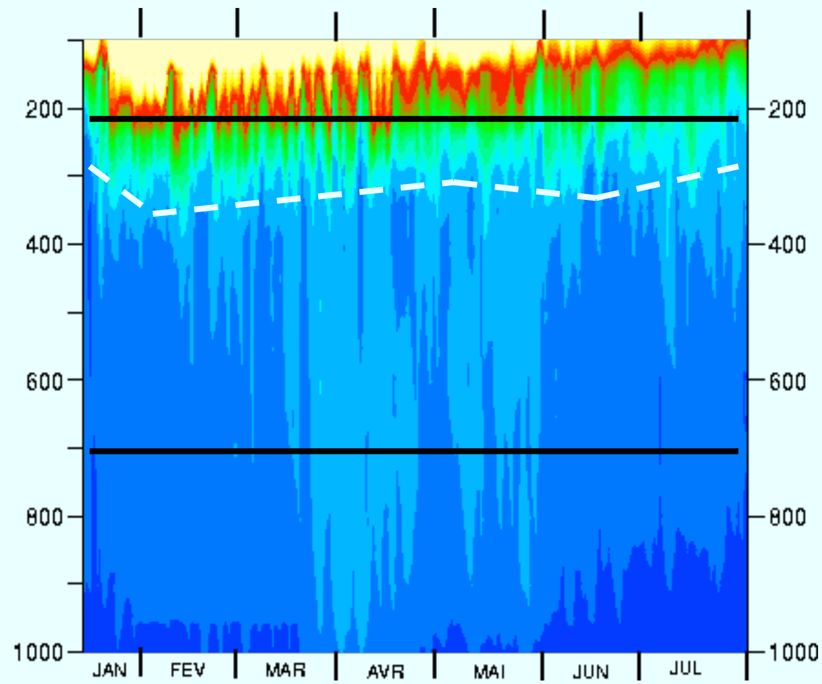


Free Run vs Assimilation run

Mean zonal NH mid-latitudes (20°N-60°N) profiles



free run



assimilation

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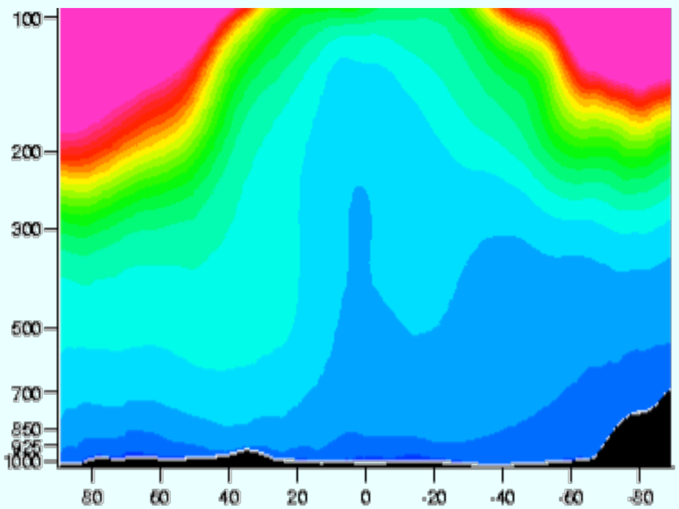
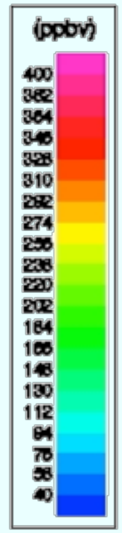
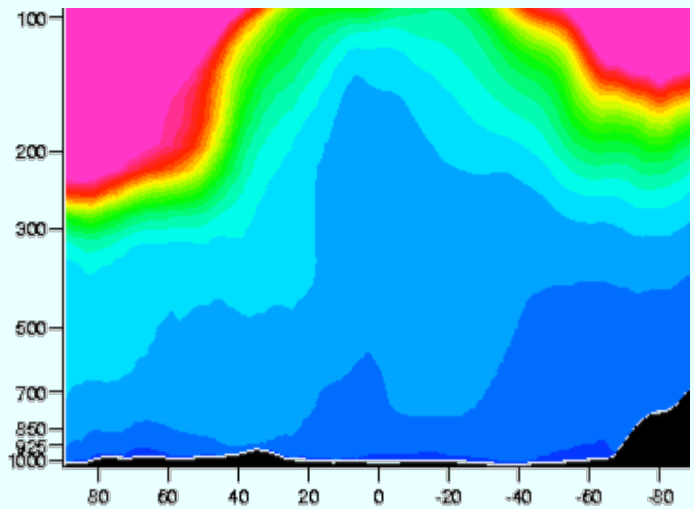
June 2000 zonal mean

Free run

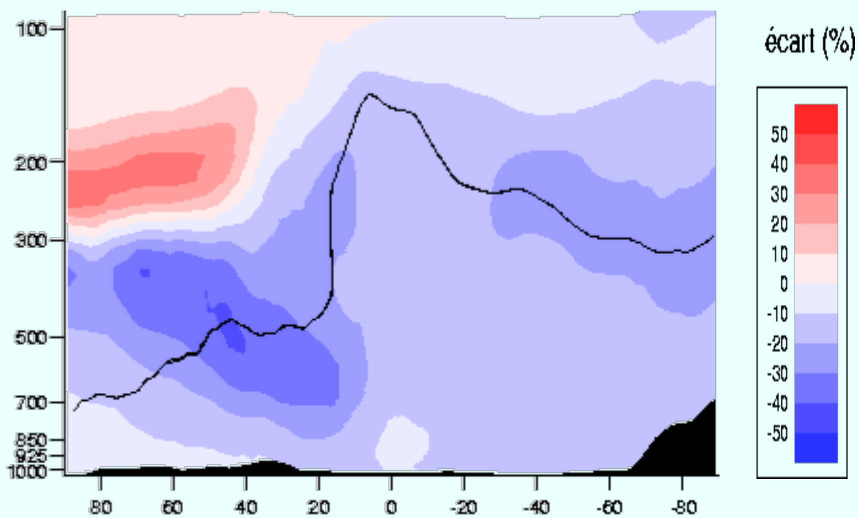




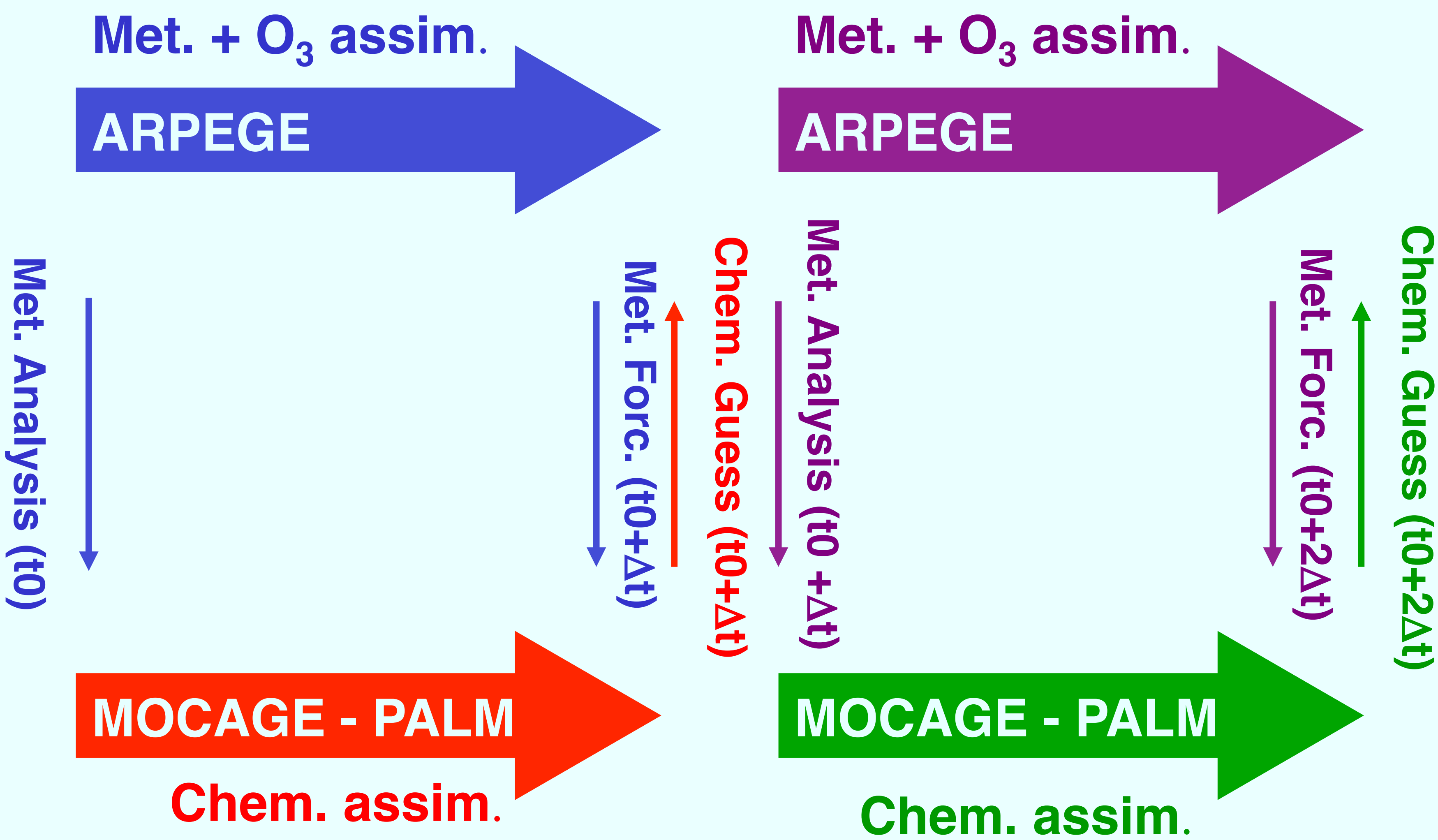
Assimilation



Relative difference (%)



ARPEGE-MOCAGE NWP/CHEM assim.



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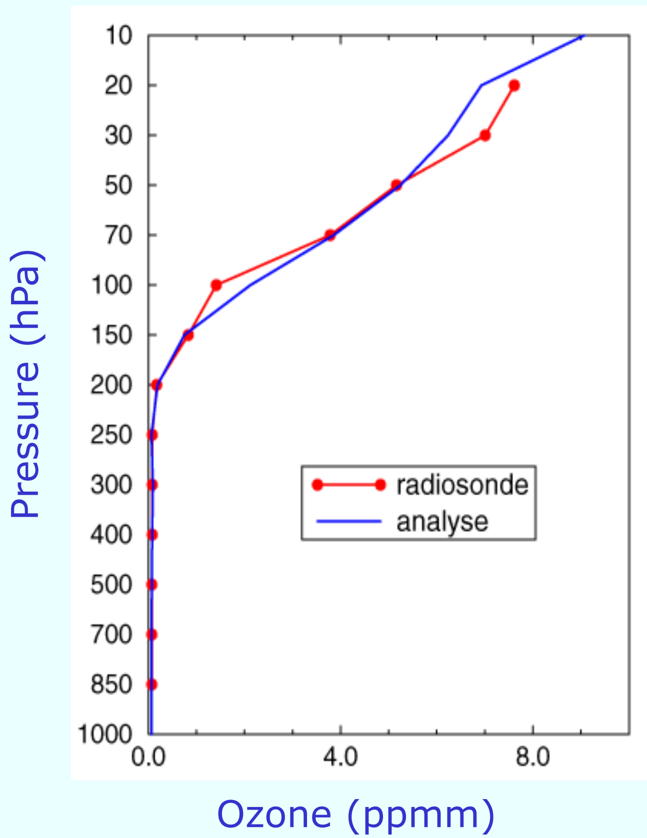
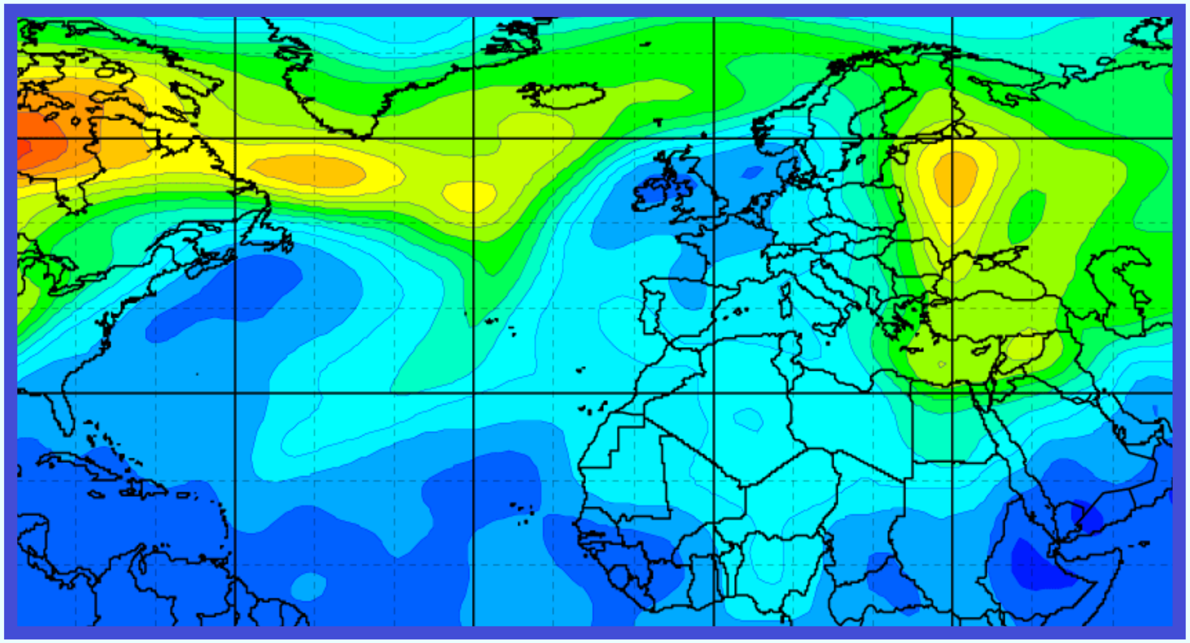
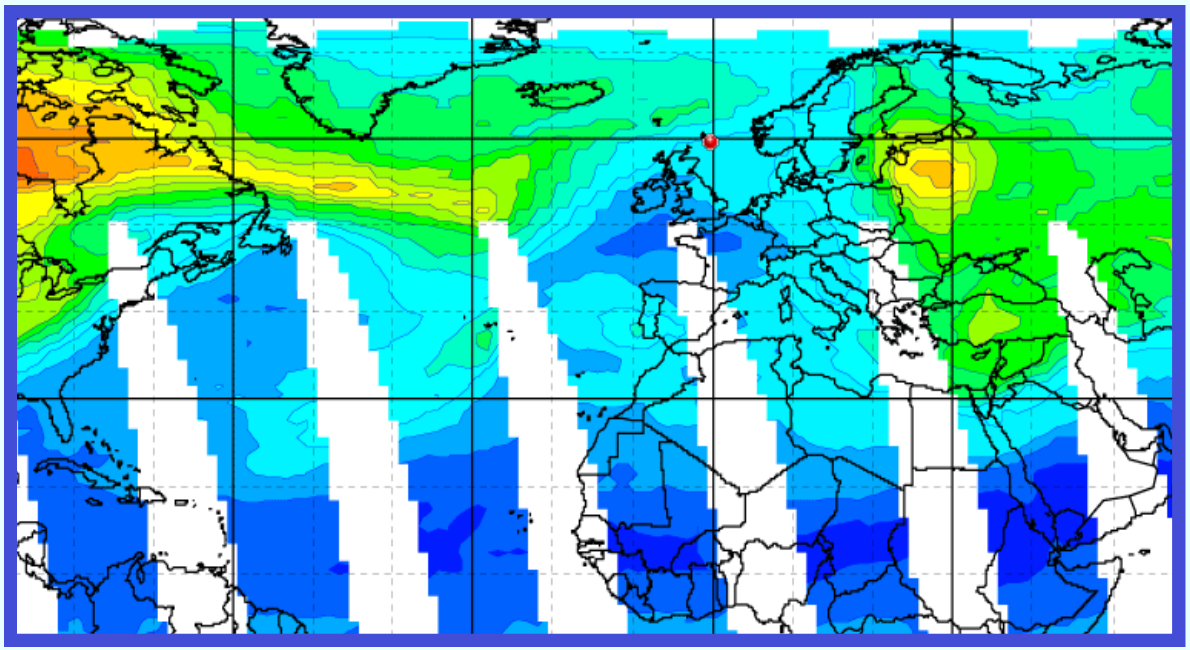
TOVS ozone total columns assimilation in ARPEGE

(Peuch A. et al.)



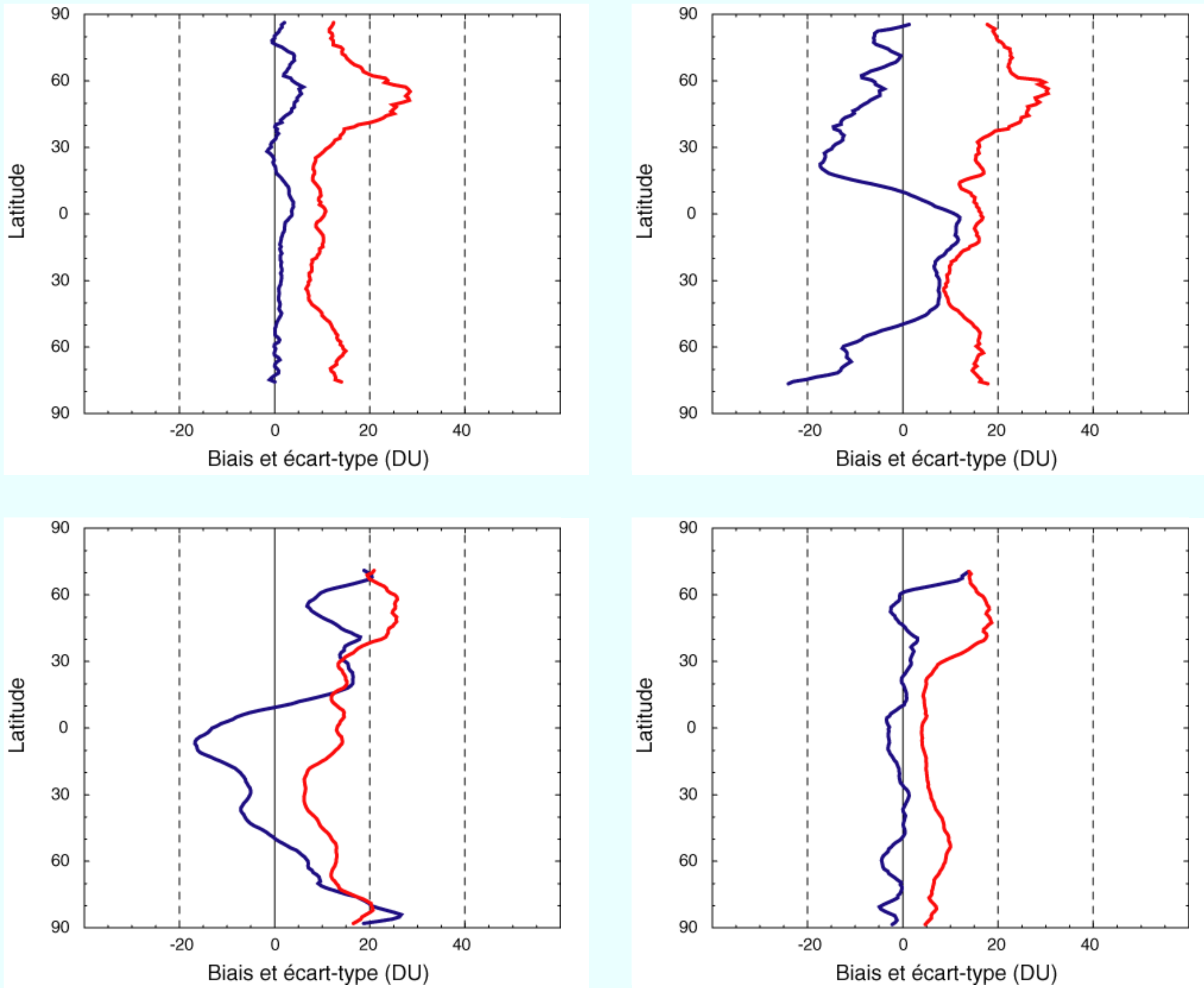




ARPEGE Analyses — ERA-40

TOVS

TOMS



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Conclusions

- The CTM approach (off-line / semi-online) provides a practical and flexible solution for : CWF, data assimilation, climate-chemistry…
- Valuable input from MOZAIC in-situ observations ; assimilation increments reveal model deficiencies
- Open questions on mutual benefits NWP/chemical data assimilation + impact on ratiative transfer in NWP

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