Simulations and forecasts in the UTLS and stratosphere with the chemistry and transport model MOCAGE

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

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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

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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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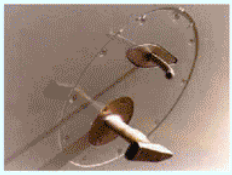
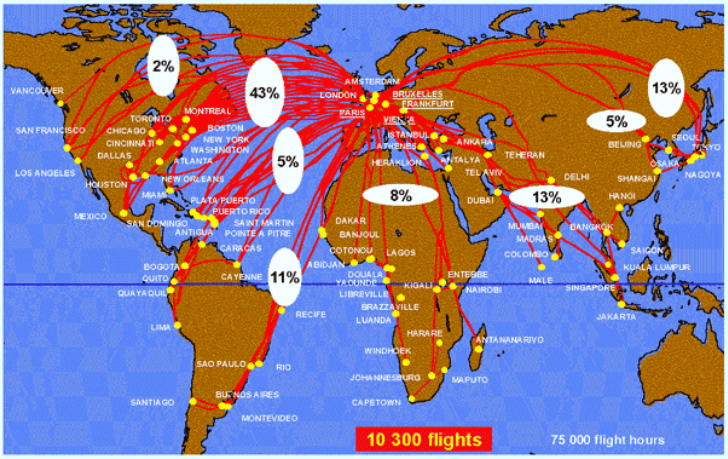
MOZAIC database of the UTLS composition



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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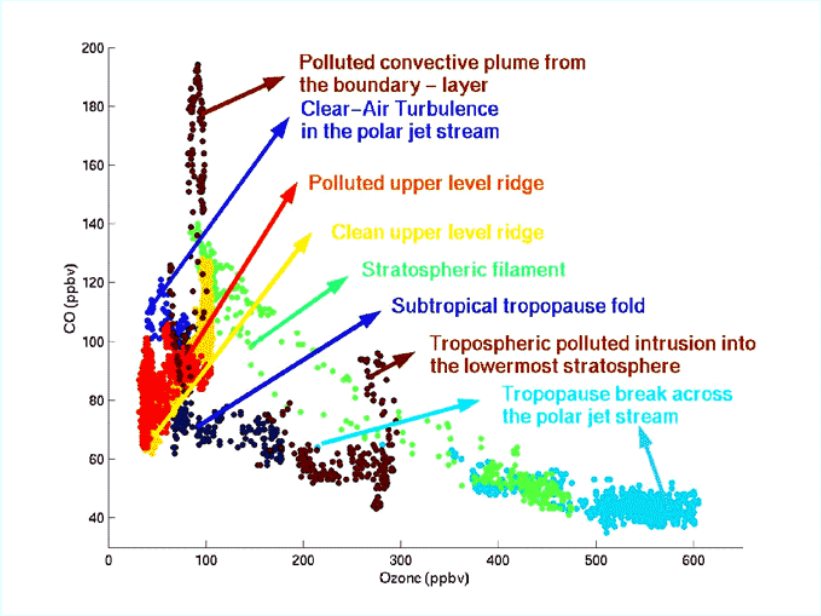

Complexiy of O3/CO sampled by aircrafts
(MOZAIC-III, J.-P. Cammas, Laboratoire d'Aérologie)

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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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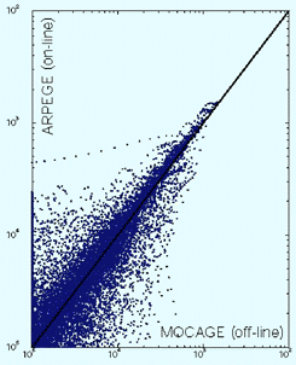
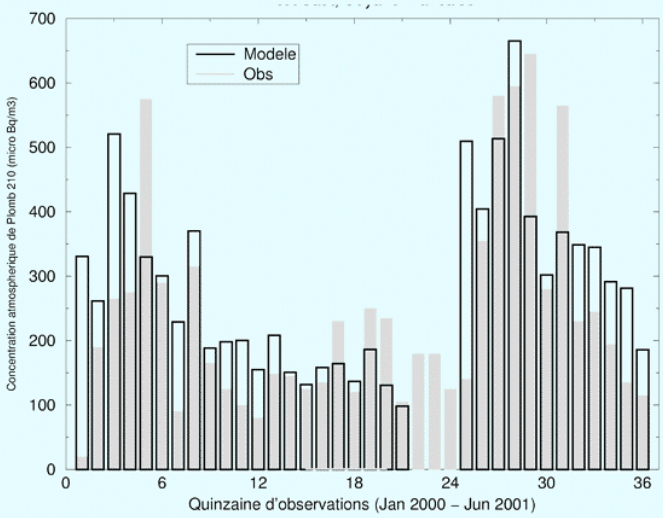
Testing on/off-line

(Josse)



Off-line versus on-line stratiform 3D rainfall



Lead (French Guyana)

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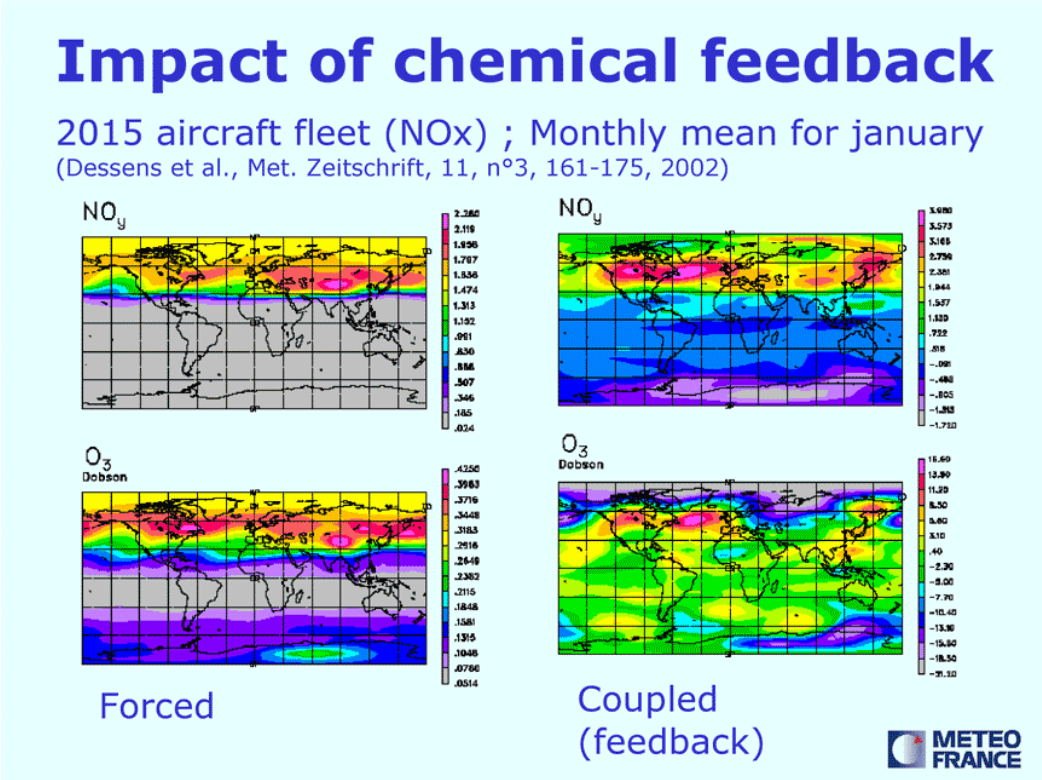
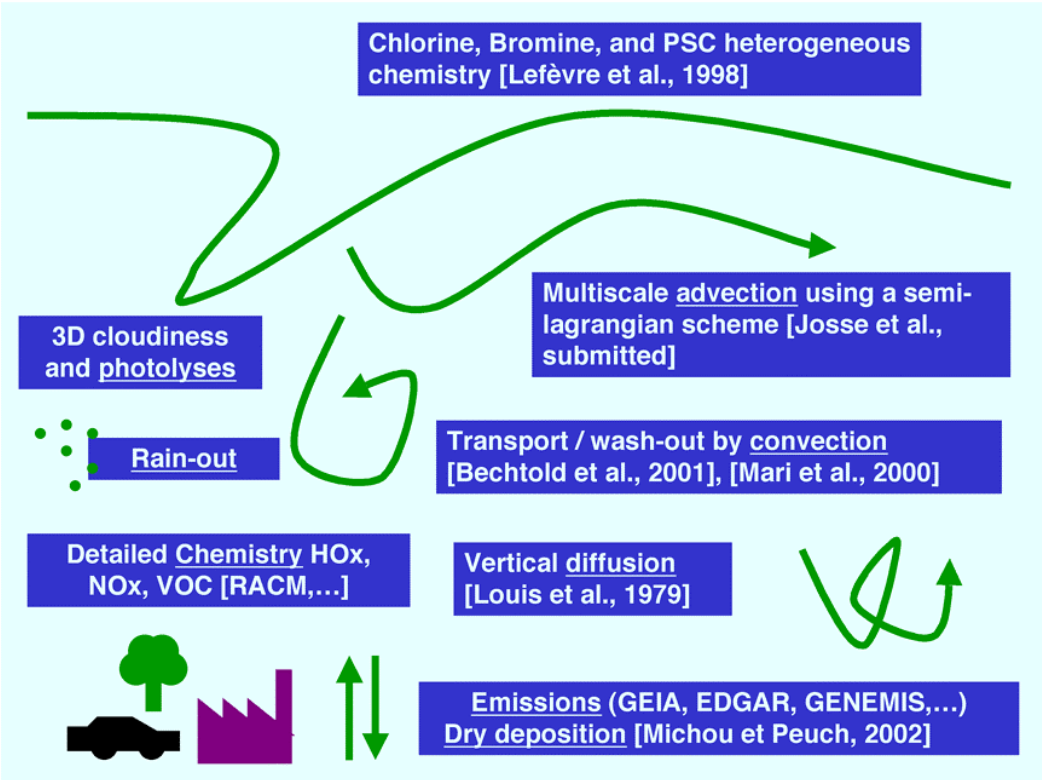
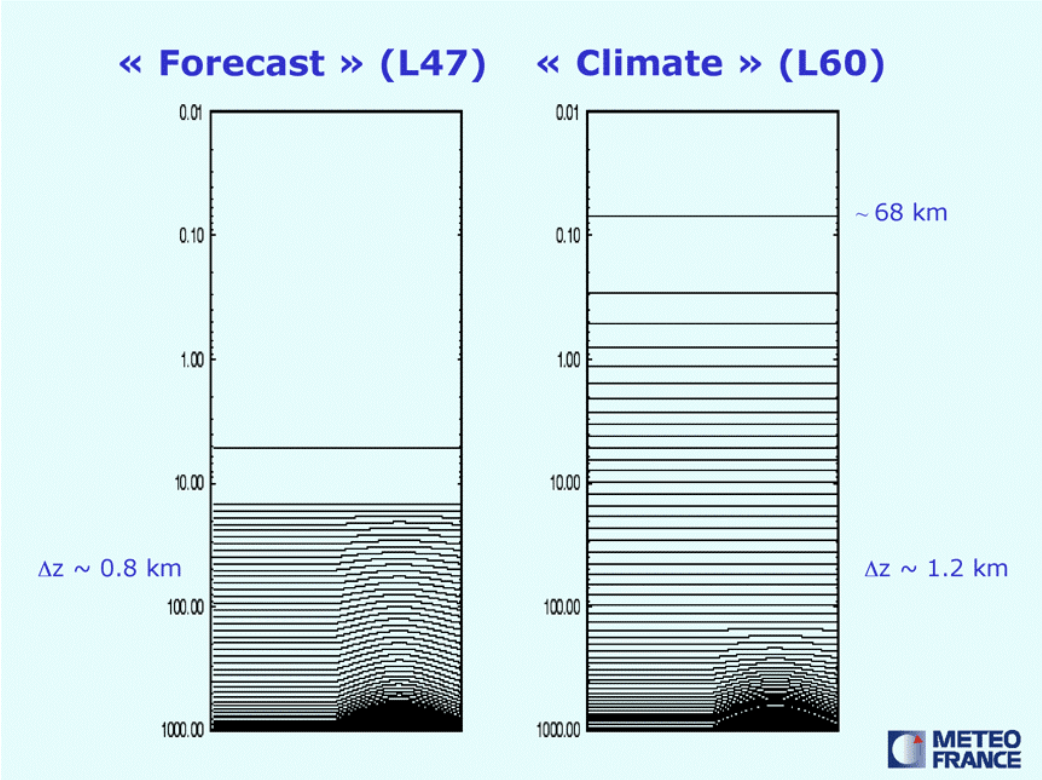

Impact of chemical feedback
2015 aircraft fleet (NOx) ; Monthly mean for january
(Dessens et al., Met. Zeitschrift, 11, n°3, 161-175, 2002)
NOy
O3
Dobson
Forced
Coupled
(feedback)
METEO FRANCE


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)
0.01
0.10
1.00
10.00
100.00
1000.00
Δz ~ 0.8 km
~ 68 km
Δz ~ 1.2 km
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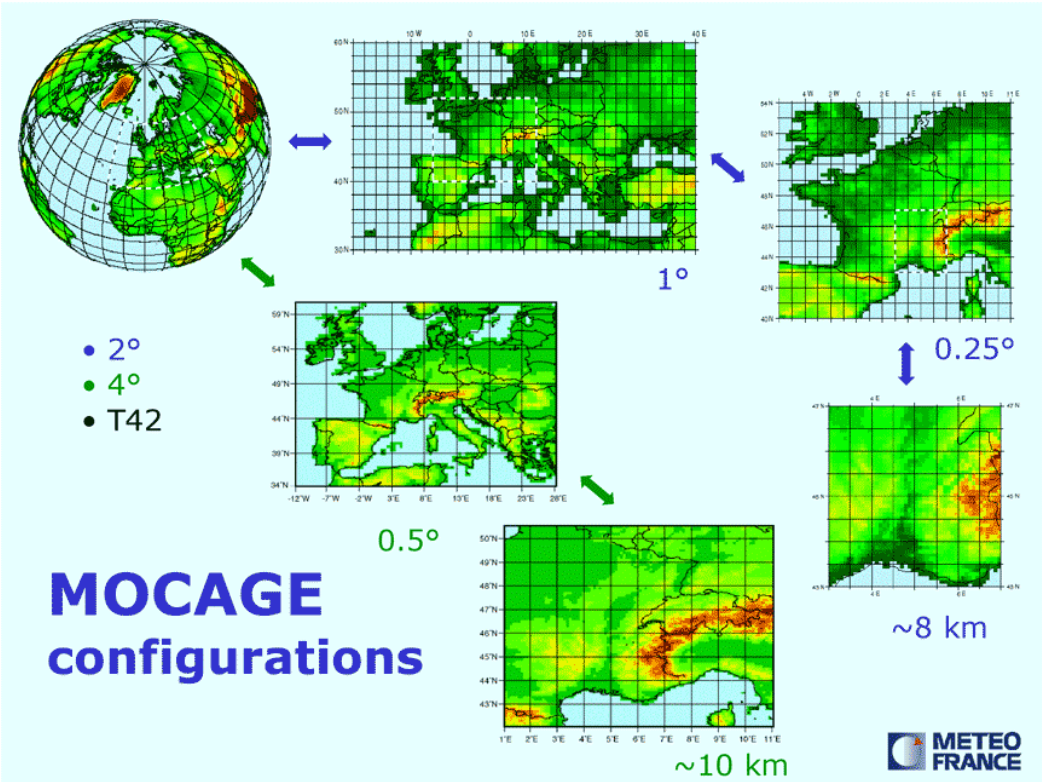
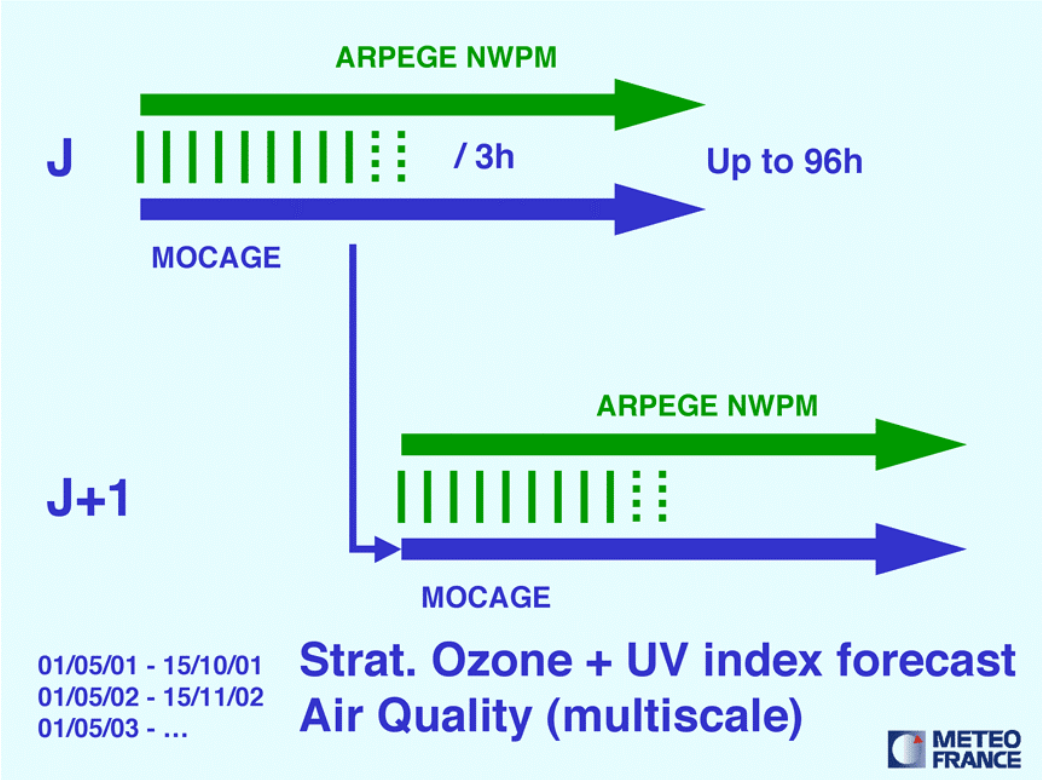
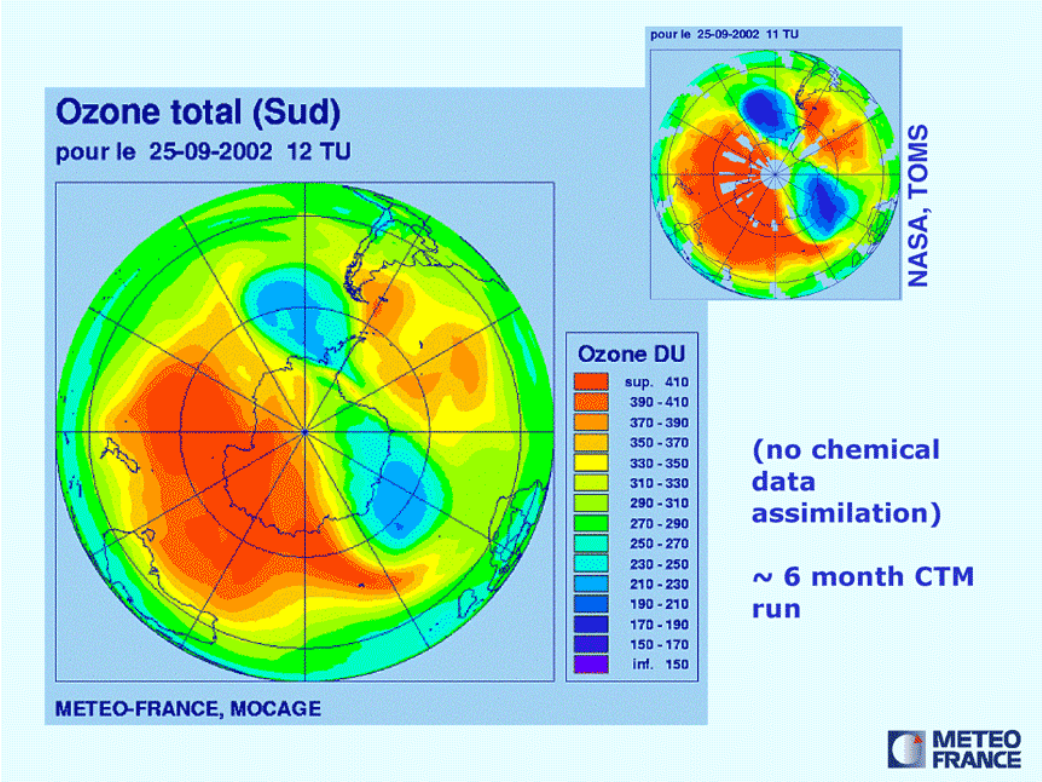

1°
0.25°
• 2°
• 4°
• T42
0.5°
~8 km
~10 km
MOCAGE
configurations
METEO FRANCE

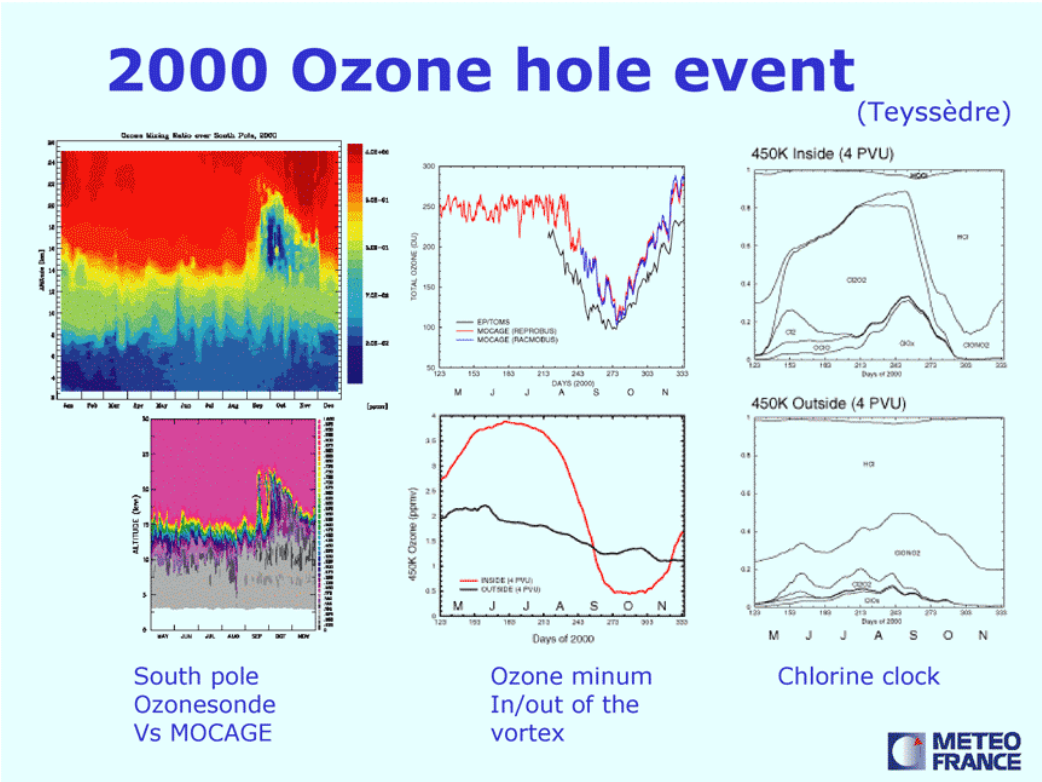


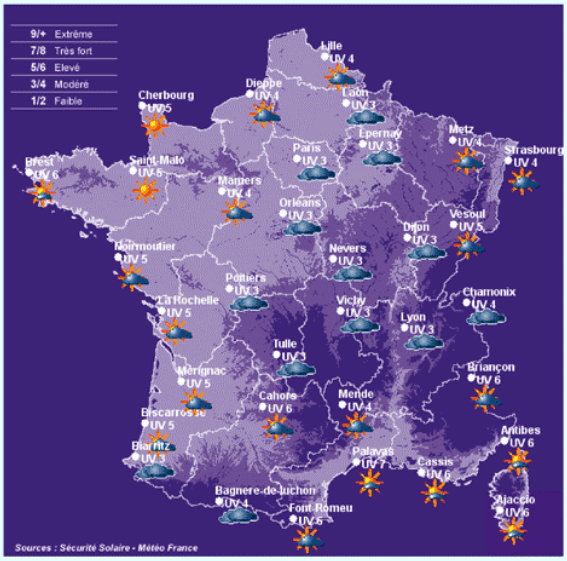
Chemistry within MOCAGE

- 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]

METEO FRANCE

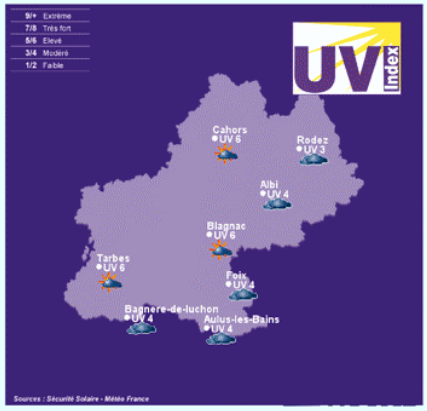

Ozone total (Sud)
pour le 25-09-2002 12 TU
METEO-FRANCE, MOCAGE
pour le 25-09-2002 11 TU
NASA, TOMS
Ozone DU
sup. 410
390 - 410
370 - 390
350 - 370
330 - 350
310 - 330
290 - 310
270 - 290
250 - 270
230 - 250
210 - 230
190 - 210
170 - 190
150 - 170
inf. 150
(no chemical data assimilation)
~ 6 month CTM run
METEO FRANCE


2000 Ozone hole event
(Teyssèdre)
450K Inside (4 PVU)
450K Outside (4 PVU)
Days of 2000
South pole Ozonesonde Vs MOCAGE
Ozone minum In/out of the vortex
Chlorine clock
METEO FRANCE



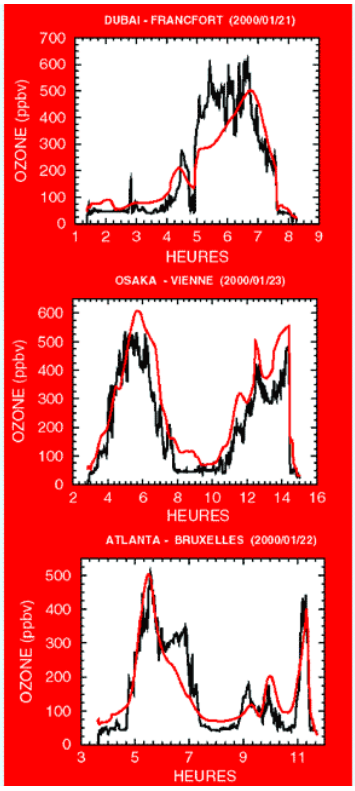
UV index forecast (with clouds)

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

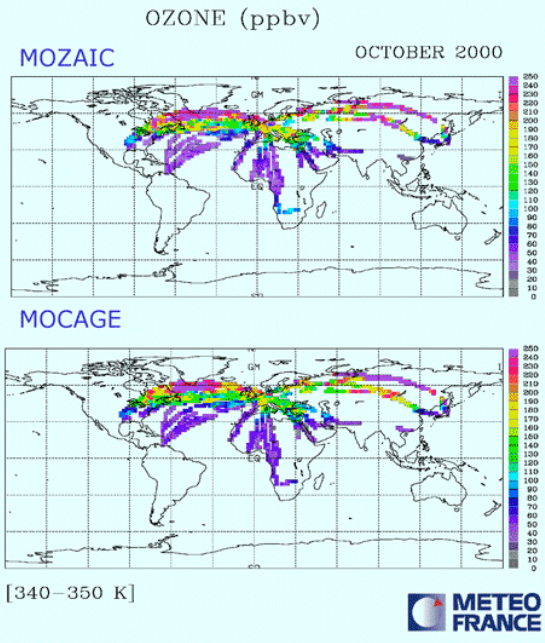


A posteriori check of NWP cloudiness
Phenomenological correction in case of mismatch

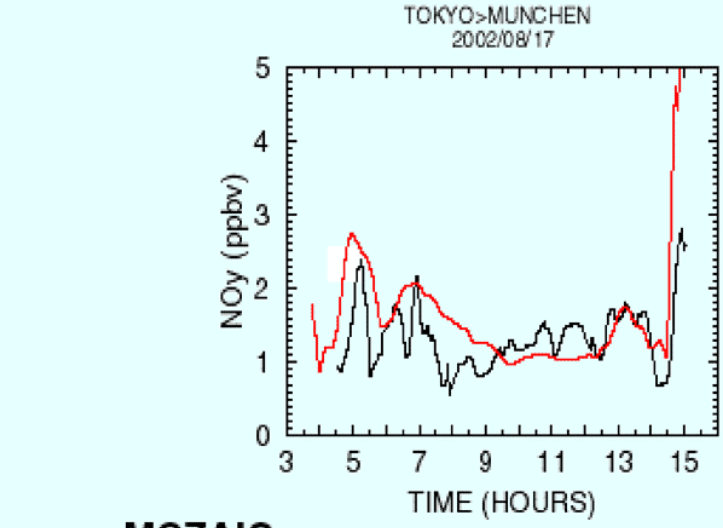
OBSERVATIONS MOZAIC
SIMULATIONS MOCAGE



UTLS ozone : MOCAGE vs MOZAIC



UTLS NO_y : MOCAGE vs MOZAIC



MOZAIC
MOCAGE

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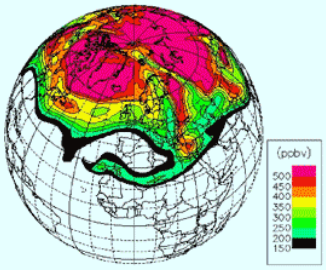
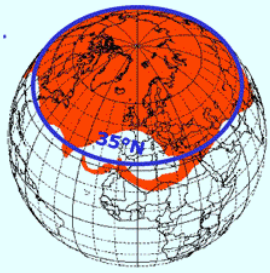
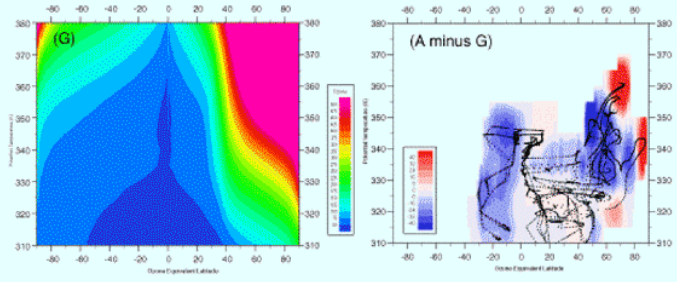
Flux-following coordinate system (Cathala et al., Tellus, 2003)



- 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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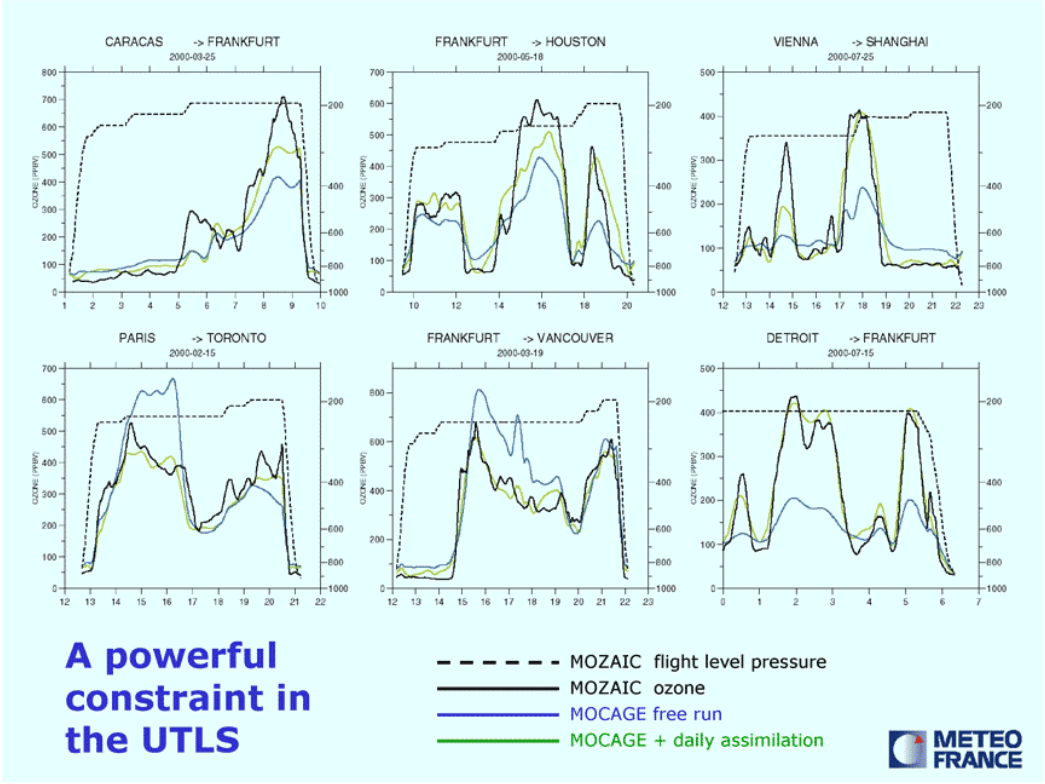
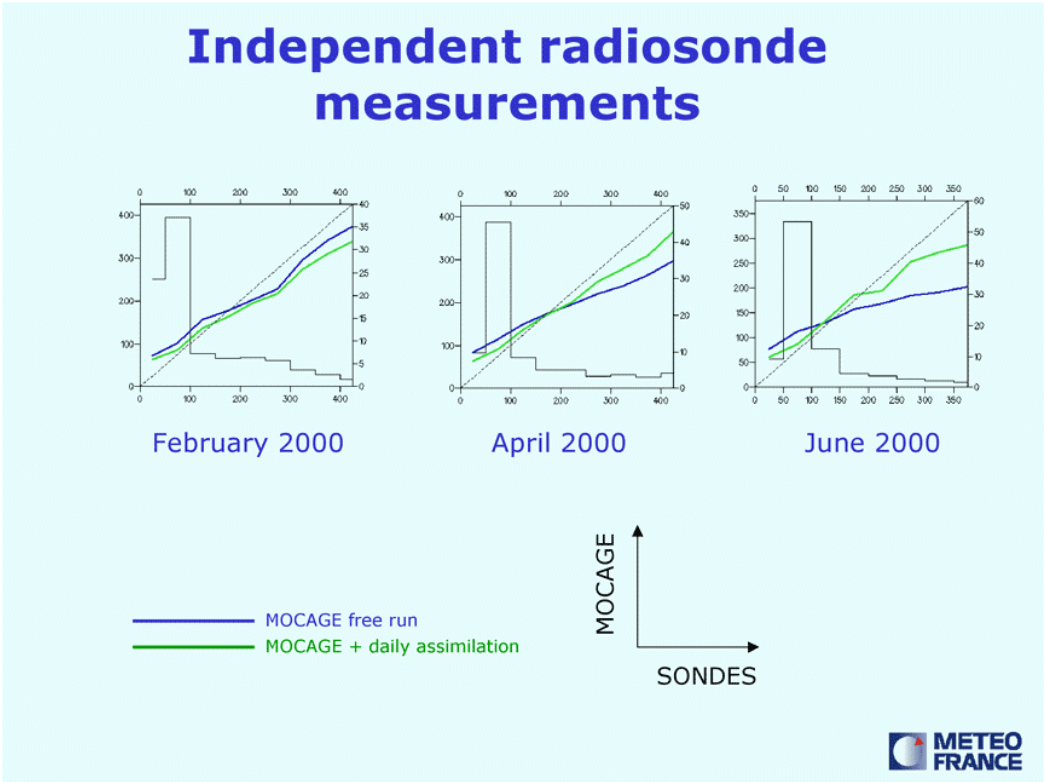
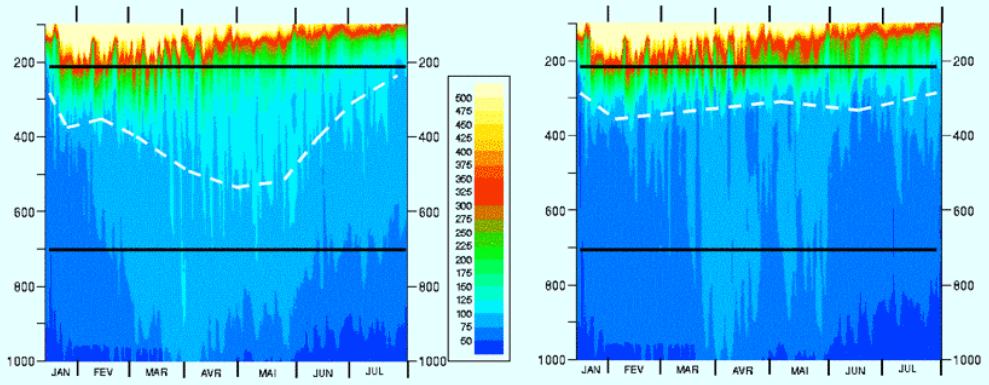

CARACAS -> FRANKFURT
2000-03-25
FRANKFURT -> HOUSTON
2000-05-18
VIENNA -> SHANGHAI
2000-07-25
PARIS -> TORONTO
2000-02-15
FRANKFURT -> VANCOUVER
2000-03-19
DETROIT -> FRANKFURT
2000-07-15
A powerful constraint in the UTLS
MOZAIC flight level pressure
MOZAIC ozone
MOCAGE free run
MOCAGE + daily assimilation
METEO FRANCE


Independent radiosonde measurements
February 2000
April 2000
June 2000
MOCAGE free run
MOCAGE + daily assimilation
MOCAGE
SONDES
METEO FRANCE

Free Run vs Assimilation run

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



free run assimilation

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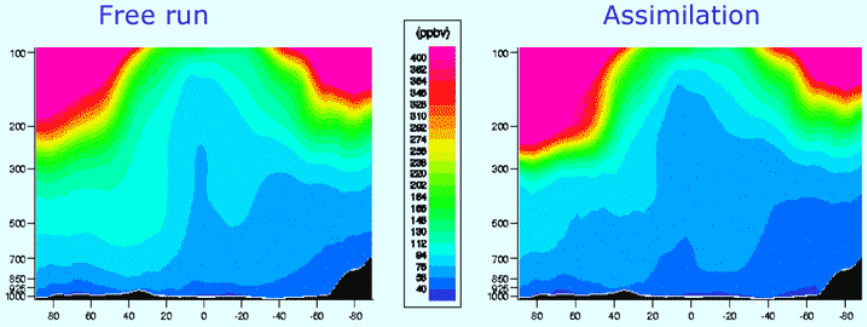
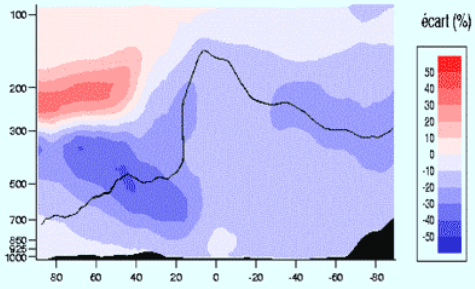
June 2000 zonal mean

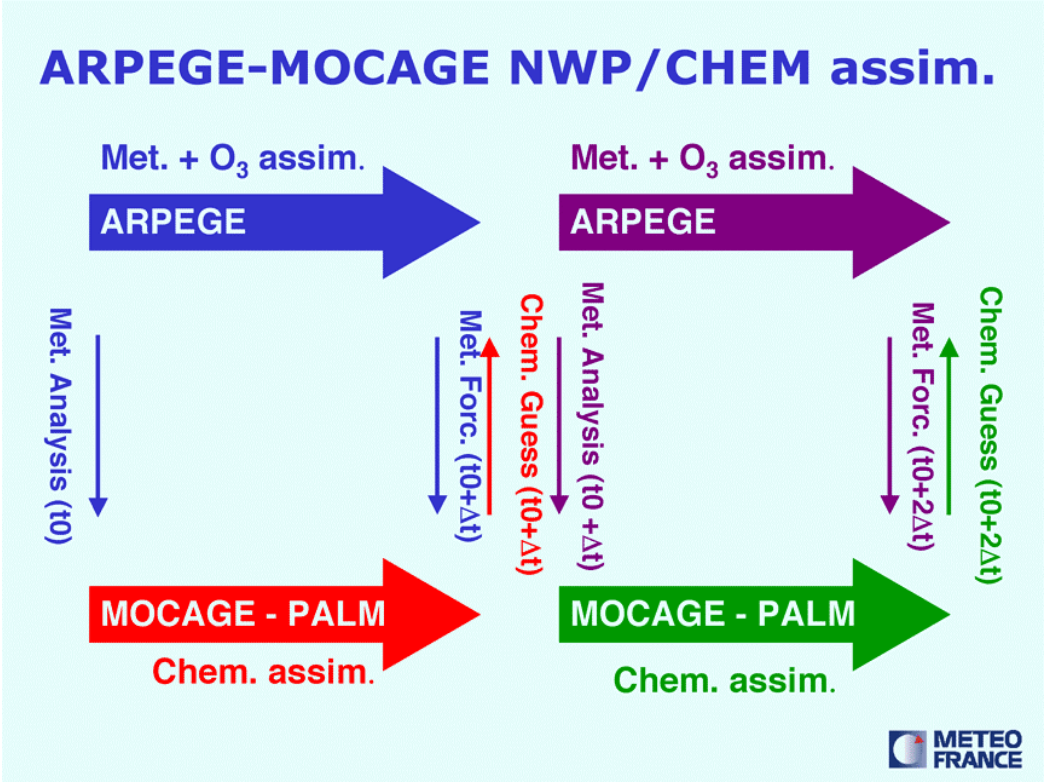
Free run Assimilation

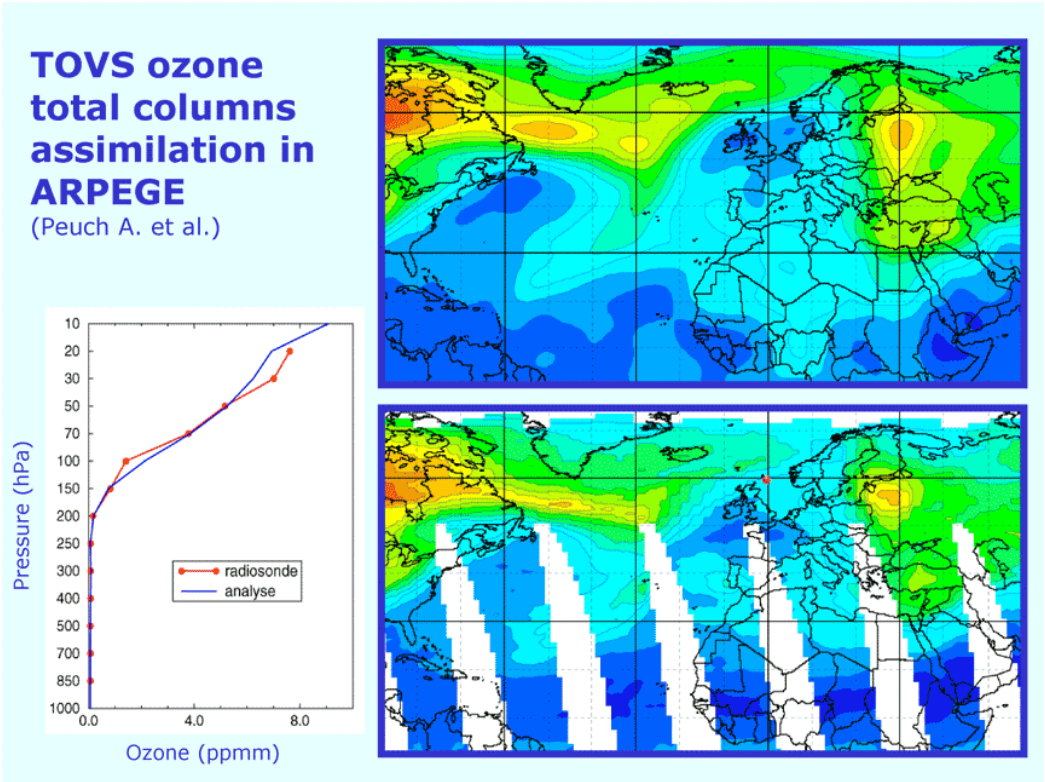


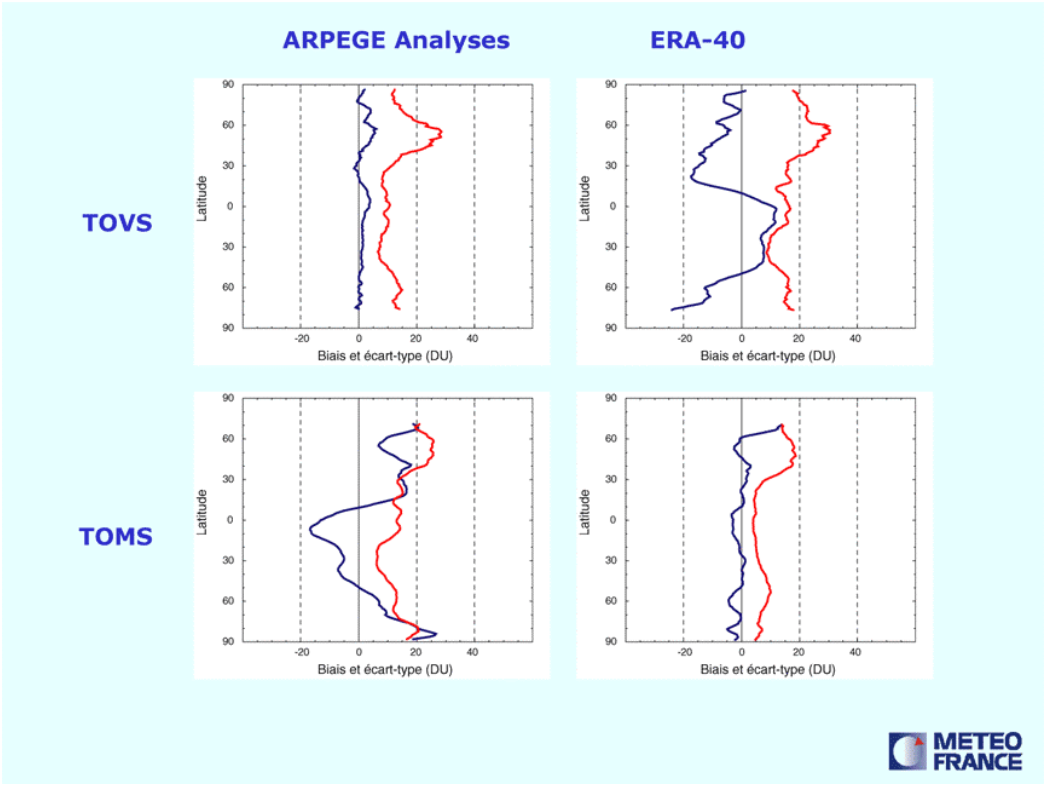
Relative difference (%)



METEO FRANCE


ARPEGE-MOCAGE NWP/CHEM assim.
Met. + O3 assim.
ARPEGE
Met. + O3 assim.
ARPEGE
Met. Analysis (t0)
Met. Forc. (t0+Δt)
Chem. Guess (t0+Δt)
Met. Analysis (t0 +Δt)
Met. Forc. (t0+2Δt)
Chem. Guess (t0+2Δt)
MOCAGE - PALM
Chem. assim.
MOCAGE - PALM
Chem. assim.
METEO FRANCE


TOVS ozone total columns assimilation in ARPEGE
(Peuch A. et al.)
Pressure (hPa)
10
20
30
50
70
100
150
200
250
300
400
500
700
850
1000
0.0
4.0
8.0
radiosonde
analyse
Ozone (ppmm)



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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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