Aristotle University
of Thessaloniki

Department of Meteorology
and Climatology

Assessing the performance of RegCM4-chem in the simulation of ozone levels: Summer circulation over Mediterranean and stratospheric intrusion events

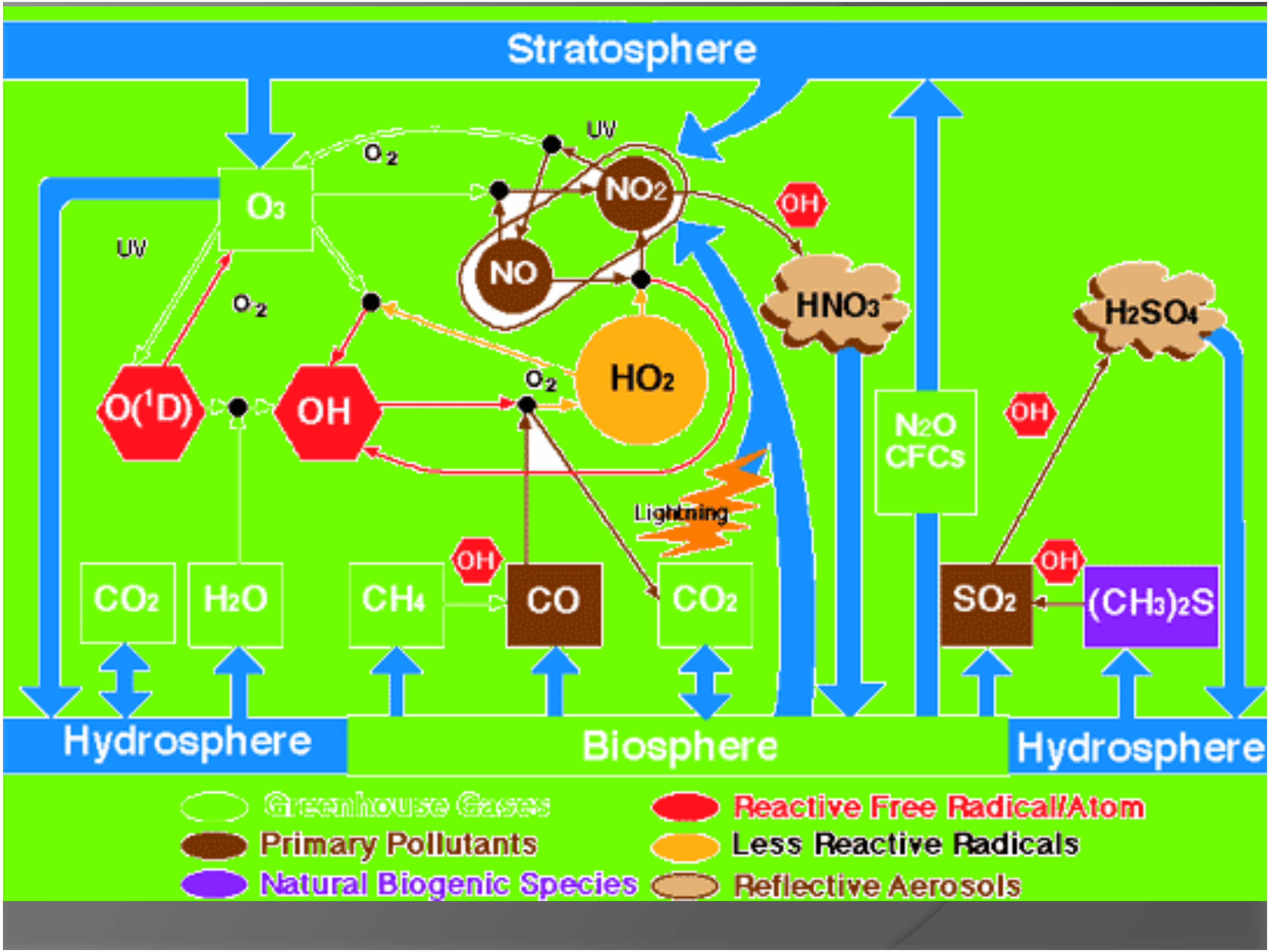
PRODROMOS ZANIS
As. Professor

DEPARTMENT OF METEOROLOGY AND CLIMATOLOGY, ARISTOTLE UNIVERSITY OF THESSALONIKI, GREECE

Acknowledgments

- MY COLLEAGUES: THANOS TSIKERDEKIS, DR. DIMITRIS AKRITIDIS, APOSTOLOS ARAMBATZIS

REQUA – REGIONAL CLIMATE – AIR QUALITY INTERACTIONS MARIE CURIE INTERNATIONAL RESEARCH STAFF EXCHANGE SCHEME (IRSES) ACTIONS



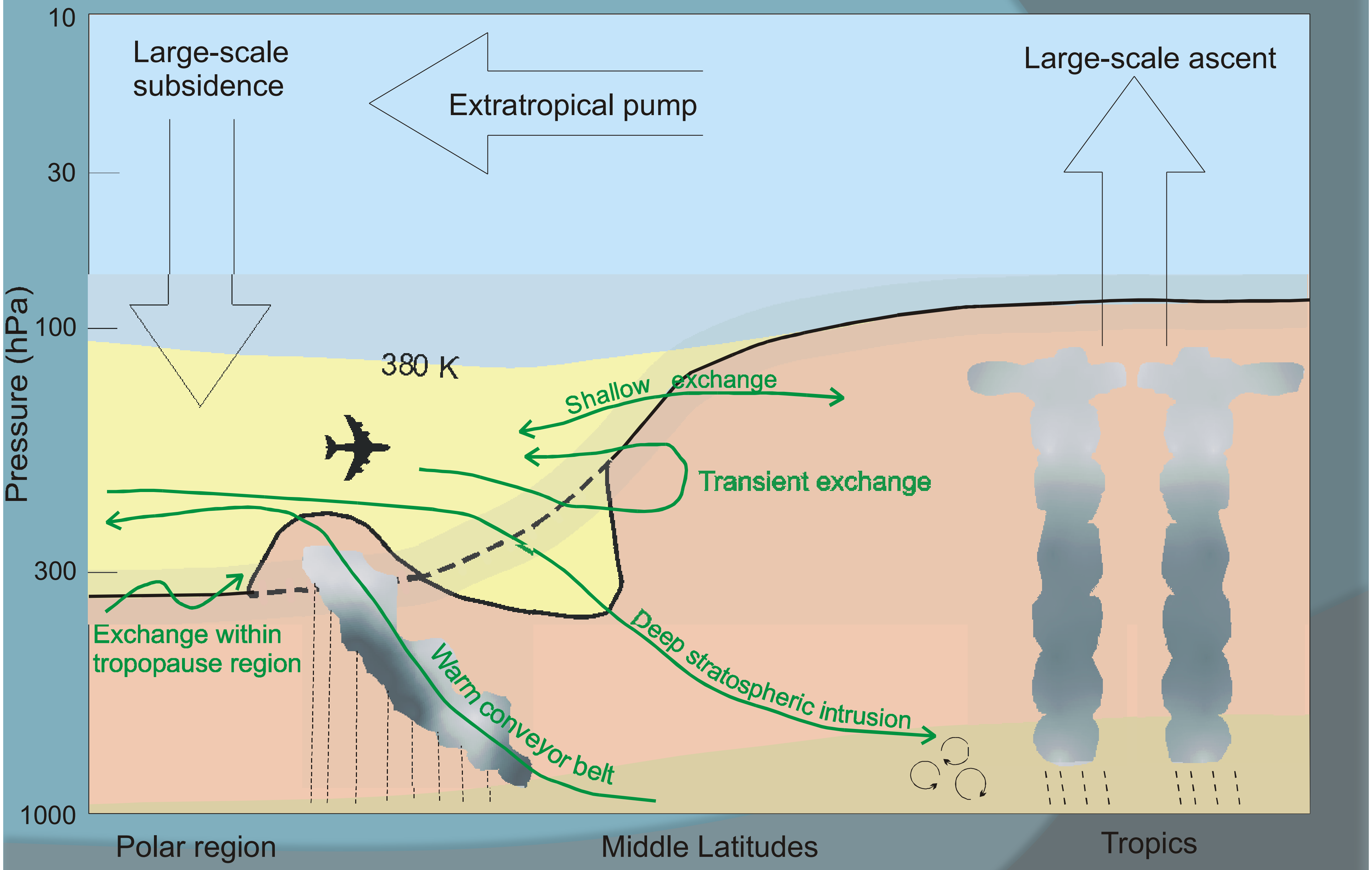
Stratosphere
UV
O2
O3
NO2
OH
UV
O2
NO
HNO3
H2SO4
O2
HO2
O(1D)
OH
O2
N2O
CFCs
OH
Lightning
OH
OH
CO2
H2O
CH4
CO
CO2
SO2
(CH3)2S
Hydrosphere
Biosphere
Hydrosphere
Greenhouse Gases
Reactive Free Radical/Atom
Primary Pollutants
Less Reactive Radicals
Natural Biogenic Species
Reflective Aerosols

Range of global CTM estimates for the O3 budget

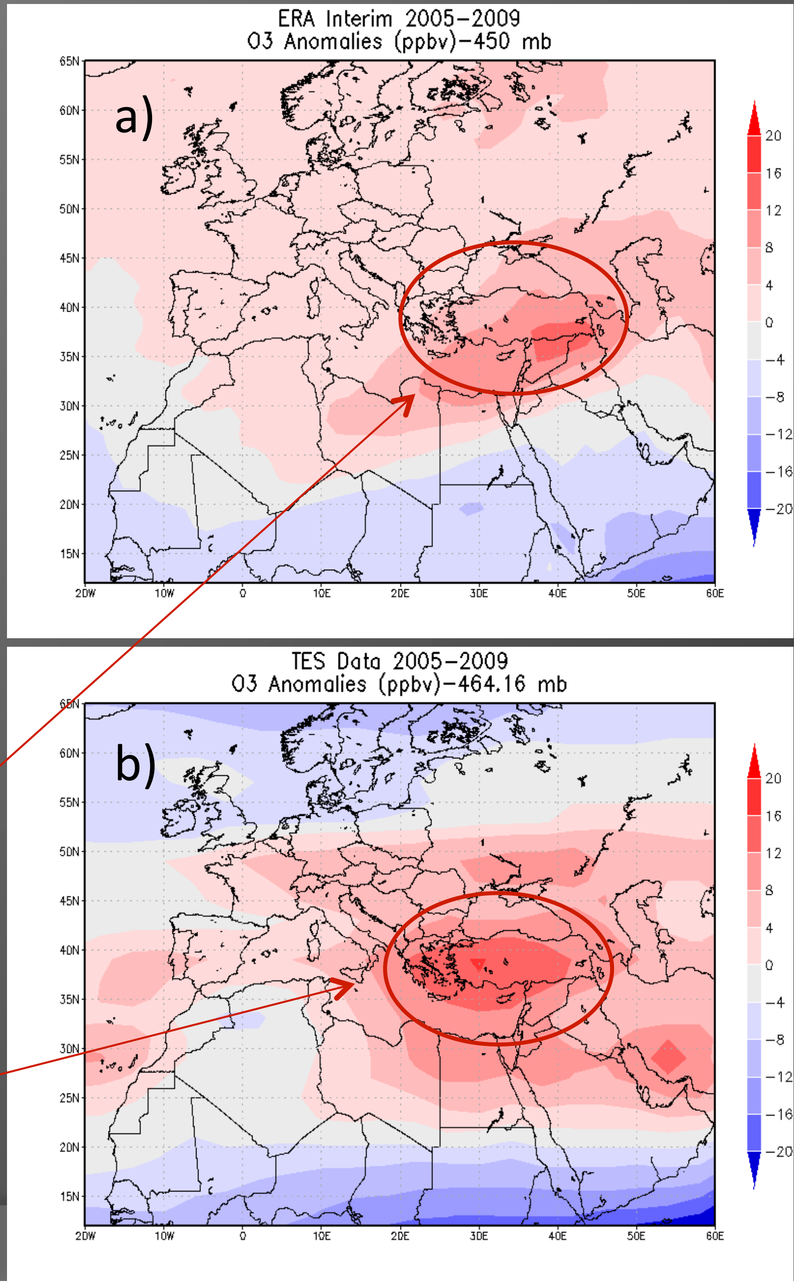
Strat-trop exchange	300 - 1100 Tg/yr
Photochemical prod.	3000 - 5000 Tg/yr
Photochemical dest.	2500 - 4300 Tg/yr
Net chemistry	-500 +600 Tg/yr
Deposition	500 - 1200 Tg/yr
Tropospheric burden	280 - 400 Tg

von Kuhlmann et al., J. Geophys. Res., 2003.

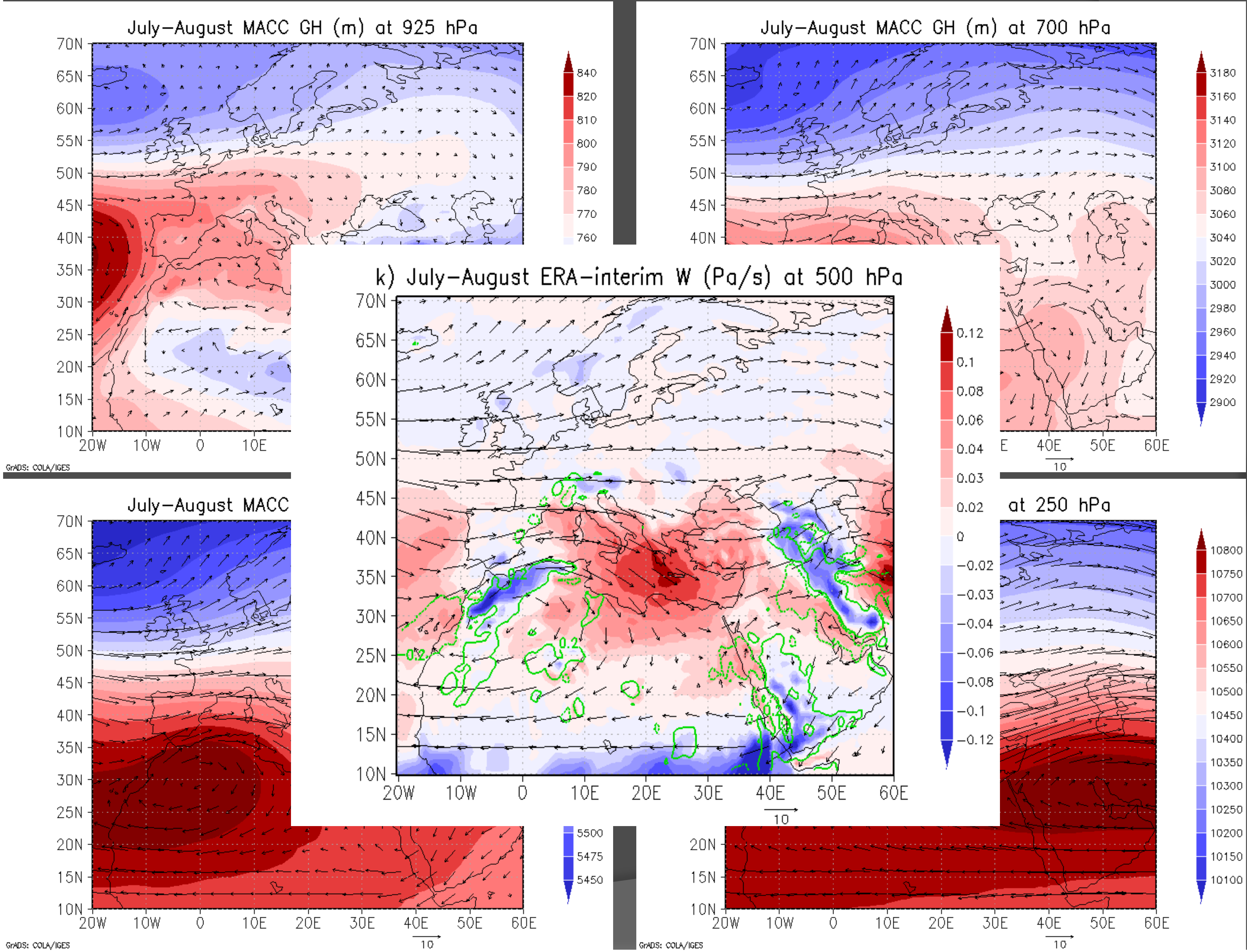
Global aspect of STE (Stohl et al., JGR, 2003)



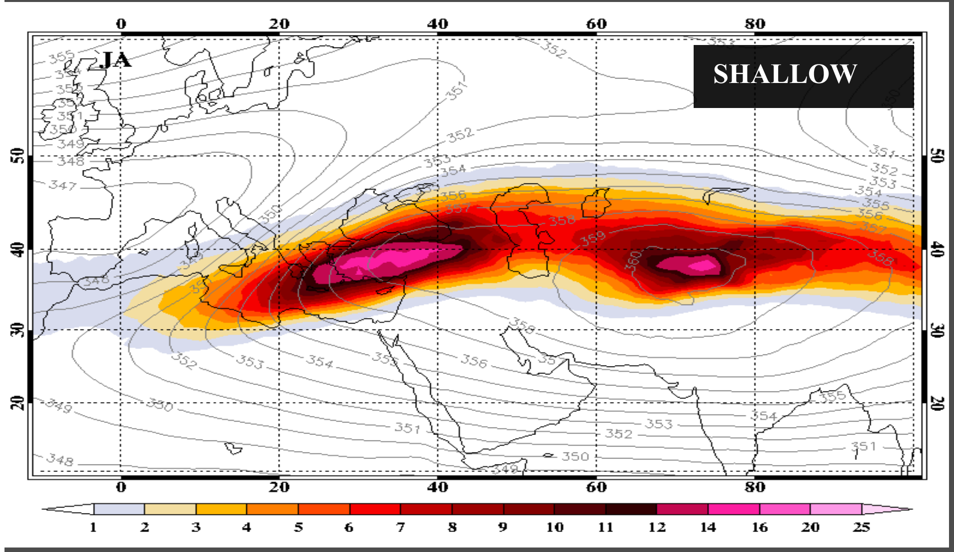
ERA-interim vs TES O_3 in July-August (2005-2009)
Zanis et al., ACP, 2014

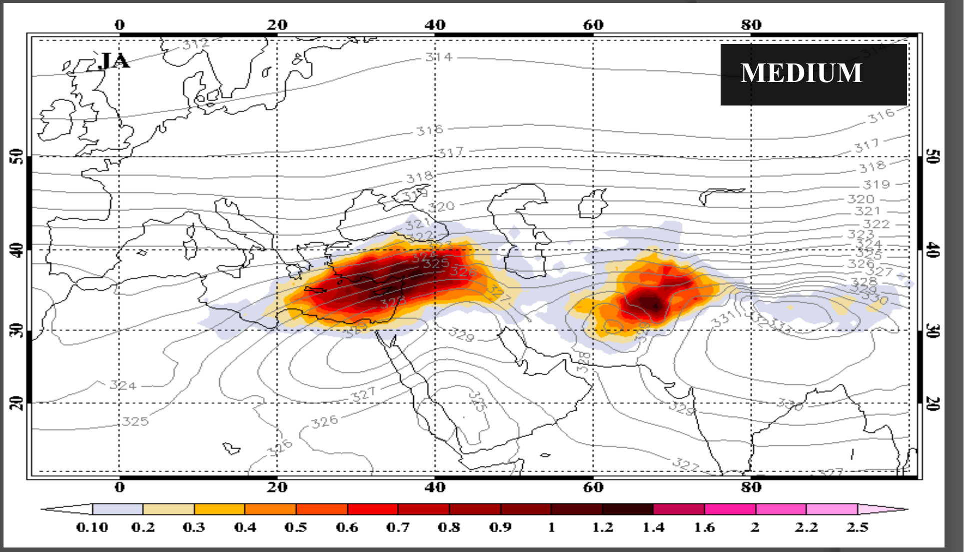


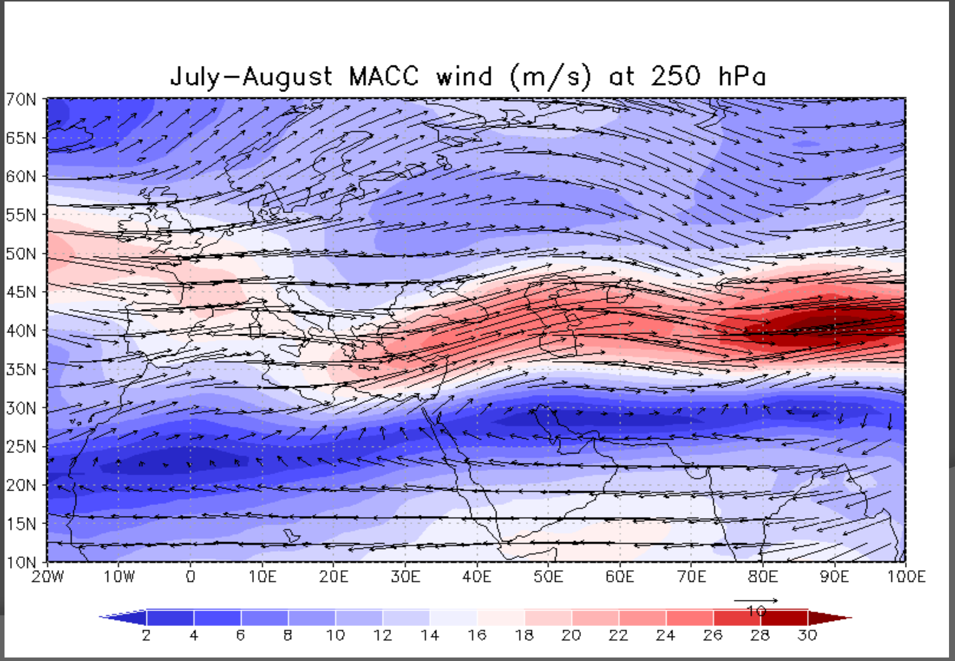
The EMME summer circulation



July – August Tropopause folds (Tyrlis et al., JGR, 2014)

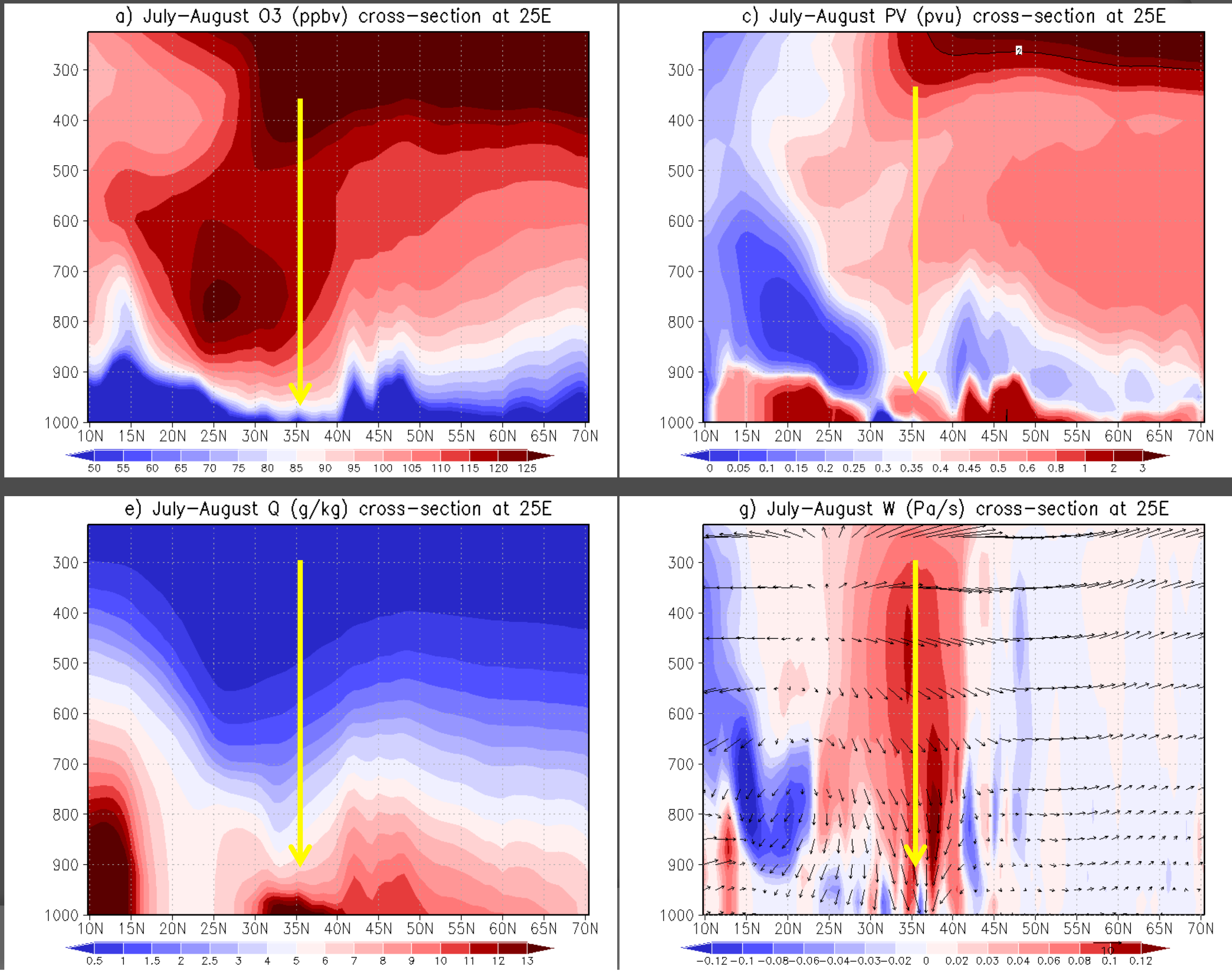






ERA-interim latitude –altitude cross sections at 25 E of O_3, PV, SH and W in July-August (1998-2009)

Zanis et al., ACP, 2014



RegCM4 configuration

- Dynamic core (Grell et al., 1994)
- Radiative scheme: NCAR CCM3 (Kiehl et al., 1996)
  or RRTM (Iacono et al., 2008)
- Convective Precipitation Schemes: Modified-Kuo scheme (Anthes, 1977) or Grell scheme (Grell, 1993) or MIT-Emanuel scheme (Emanuel, 1991) or Tiedke scheme
  Tiedke and Emanuel schemes offer a more detailed treatment of convective transport than the simple mixing hypothesis used with the other schemes.
- Surface model: BATS (Dickinson et al., 1993)
  or CLM (Oleson et al., 2008)
- Planetary Boundary Layer Scheme: Holtslag PBL (Holtslag et al., 1990) or UW Turbulence Closure Model (Grenier and Bretherton, 2001)
- Large-Scale Precipitation Scheme: SUBEX (Sundqvist et al., 1989)
- Initial and Boundary Conditions: meteorology ERA-interim, GTOPO30 Terrain and GLCC Landuse datasets, SSTs ERA-interim

Coupled aerosols and gases in RegCM4

- **Gas phase chemistry: CBMZ scheme with 35 species**

- **Natural aerosols**
  - **Dust aerosols: 4 dust bins (Zakey et al., 2006)**
    (12 dust bins under development)
  - **Sea salt aerosols: 2 sea salt bins (Zakey et al., 2008)**

- **Anthropogenic aerosols (Solmon et al., 2006)**

$SO_2 \Leftrightarrow SO_4^{--}$

BC (soot) → Hydrophilic ⇕ Hydrophobic

6 Tracers

OC_T (primary + secondary) → Hydrophilic ⇕ Hydrophobic

- **Emissions: CMIP5 RCP anthropogenic emissions 1990-2010**
- **Chemical BCs: CAM+EC-EARTH for aerosols, MOZART CTM climatology 2000-2007 for gases, Monthly**

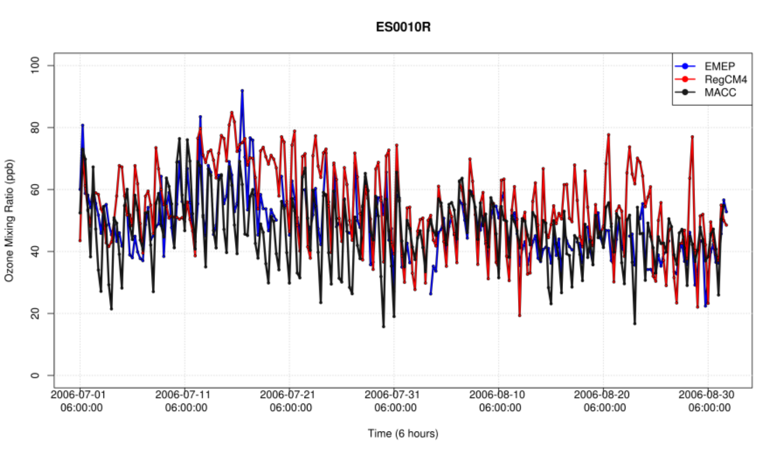
Aerosols and gases in RegCM4

- **General approach** ⟺ Tracer model / RegCM4

$$\frac{\partial \chi}{\partial t} = -\overline{V} \cdot \nabla \chi + F_H + F_V + T_{CUM} + S_\chi - R_{w,ls} - R_{w,cum} - D_{dep} + \sum Q_p - Q_l$$

Transport | Primary Emissions | Removal terms | Physico – chemical transformations

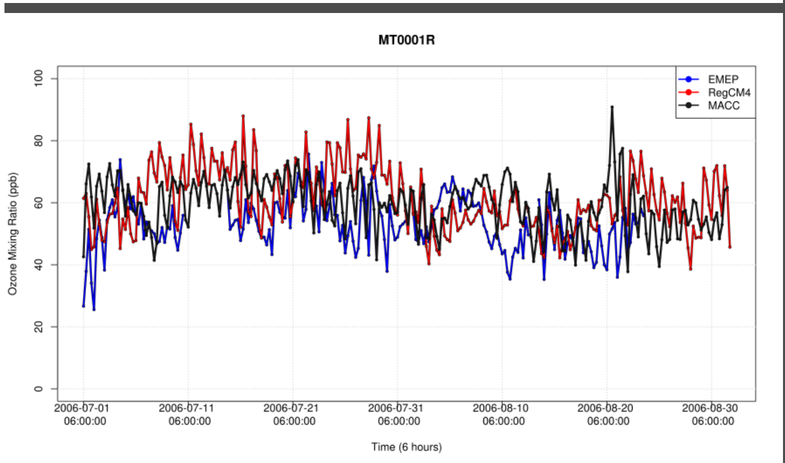
Strongly dependent on the nature of the tracer



EMEP:48.5±10.7 ppbv (7.5±8.7)
RegCM4: 54.6±13.5 ppbv (11.1±10.1)
MACC: 46.8±11.2 ppbv (13.01±7.7)

RegCM4 vs EMEP

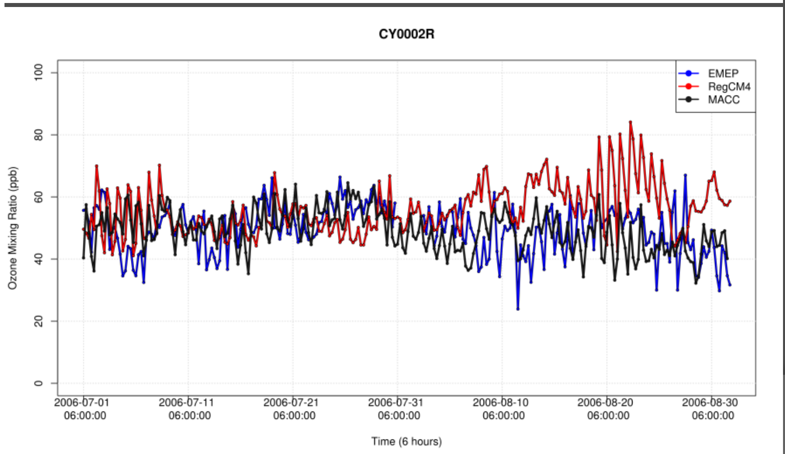
station	MNMB	FGE	R_pearson	R_kendall	R_spearman
NA	NA	NA	NA	NA	NA
CY0002R	0.1198661	0.2011239	-0.07981961	-0.10908776	-0.1589474
MT0001R	0.1092806	0.1632304	0.15579007	0.09973275	0.1458601
ES0010R	0.1030609	0.1841180	0.62204969	0.44167285	0.6177033



EMEP:53.1±8.5 ppbv (6.9±9.6)
RegCM4: 61.4±10.2 ppbv (6.8±8.3)
MACC: 59.0±8.3 ppbv (10.9±8.3)

MACC vs EMEP

station	MNMB	FGE	R_pearson	R_kendall	R_spearman
NA	NA	NA	NA	NA	NA
CY0002R	-0.007529419	0.1403639	0.2668352	0.1852476	0.2761057
MT0001R	0.108038279	0.1472634	0.2154920	0.1237321	0.1821624
ES0010R	-0.038350721	0.1636885	0.6145095	0.4398387	0.6189754



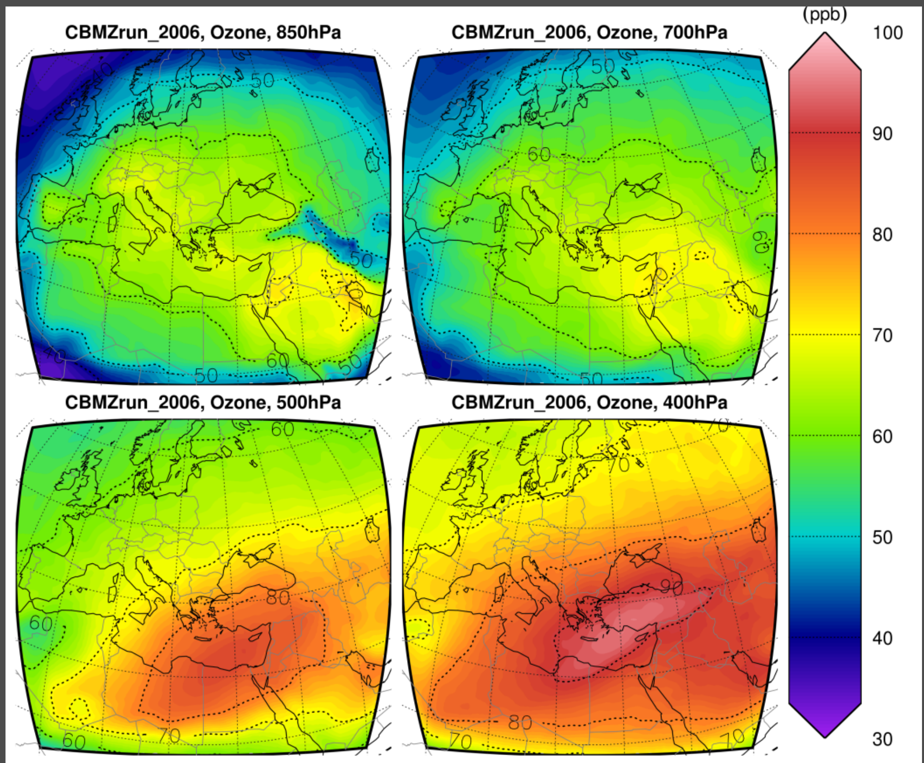
EMEP:49.5±7.9 ppbv (5.3±7.3)
RegCM4: 56.0±8.2 ppbv (7.1±8.1)
MACC: 49.0±6.7 ppbv (9.1±6.4)

MACC vs RegCM4

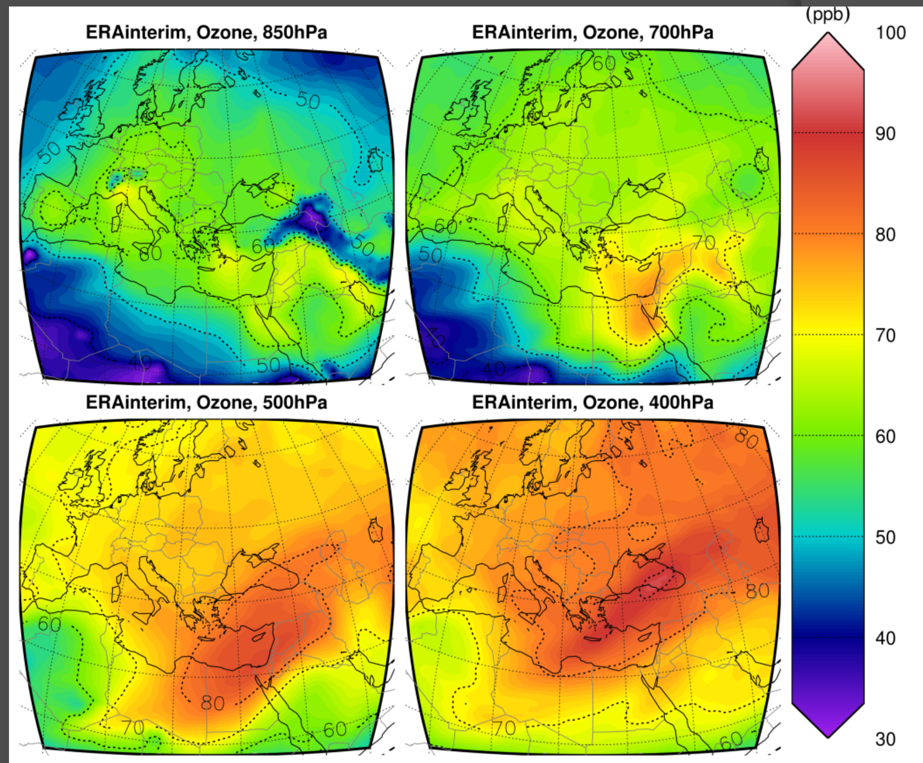
station	MNMB	FGE	R_pearson	R_kendall	R_spearman
NA	NA	NA	NA	NA	NA
CY0002R	0.1299424	0.1845895	0.07220929	0.03293754	0.0492898
MT0001R	0.0250364	0.1478077	0.32910952	0.22904011	0.3375845
ES0010R	0.1472801	0.2431120	0.47612681	0.35625147	0.5152837

O3 fields in RegCM4 and MACC reanalysis for summer 2006

RegCM4-Chem
JJA 2006



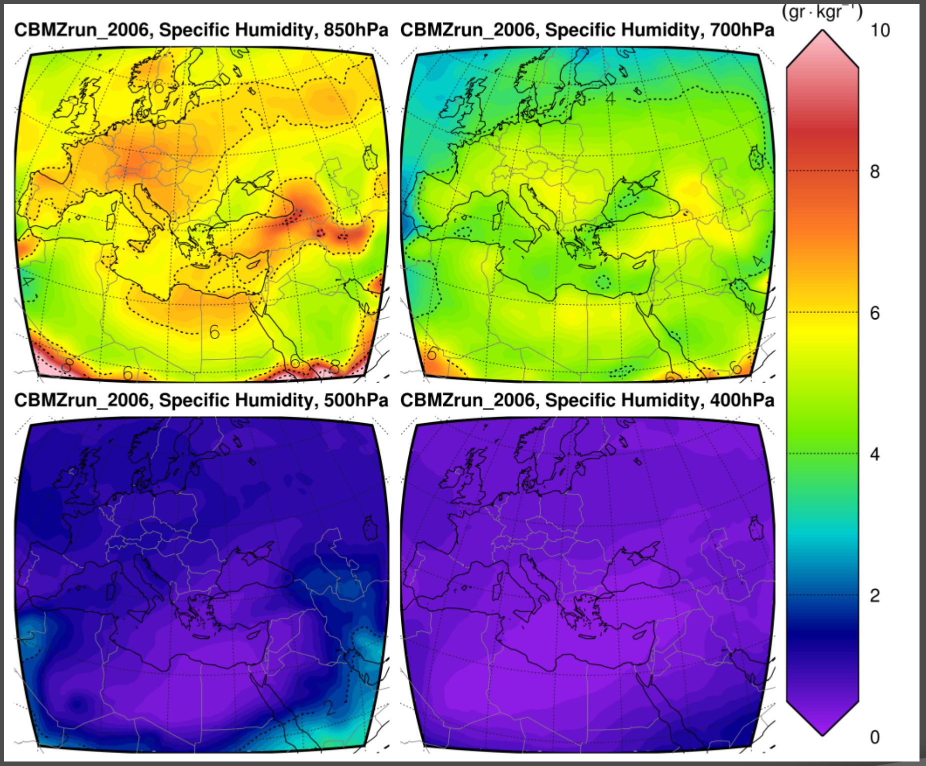
MACC reanalysis
JJA 2006

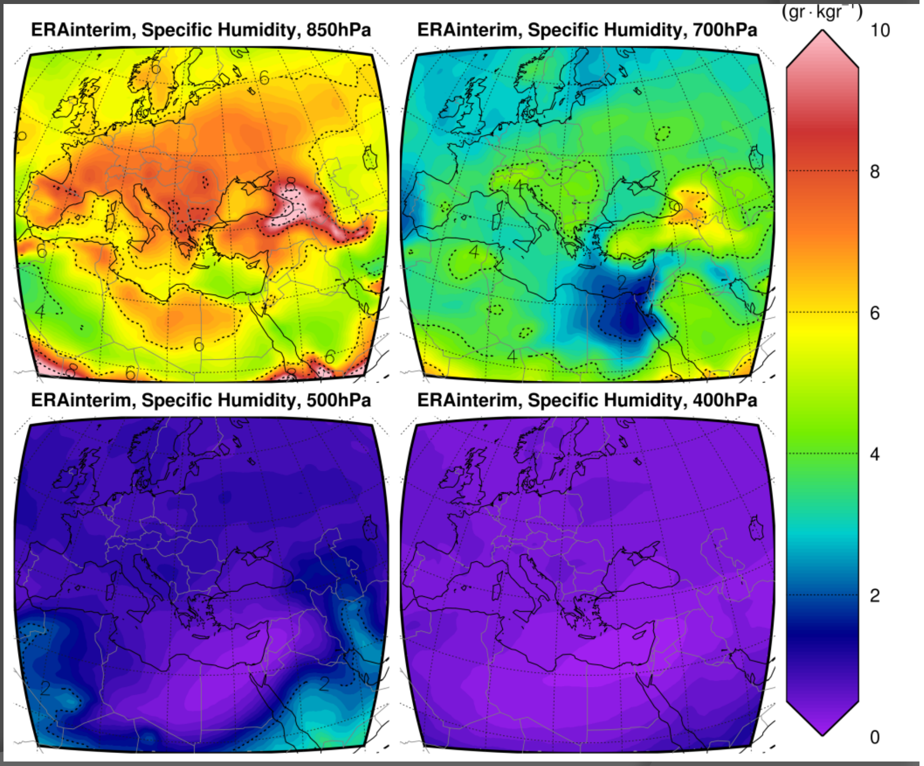


SH fields in RegCM4 and MACC reanalysis for summer 2006

RegCM4-Chem
JJA 2006

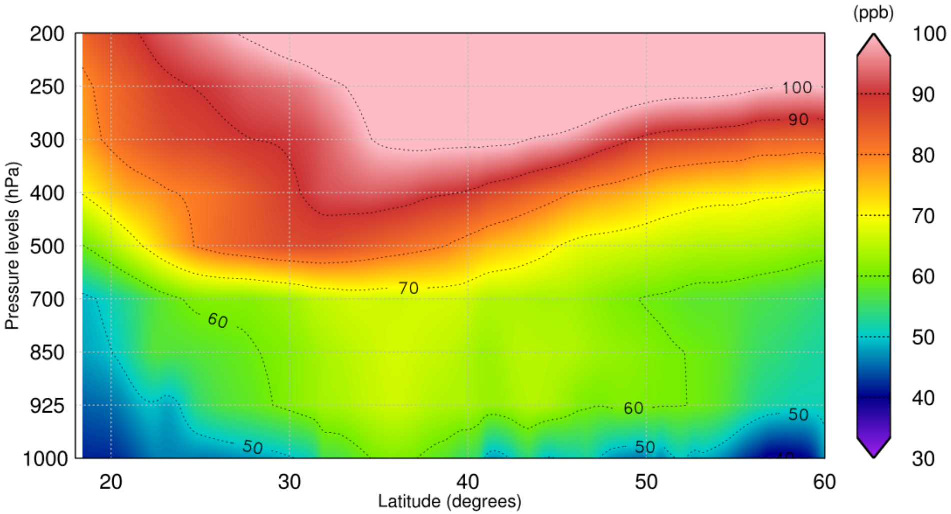
MACC reanalysis
JJA 2006

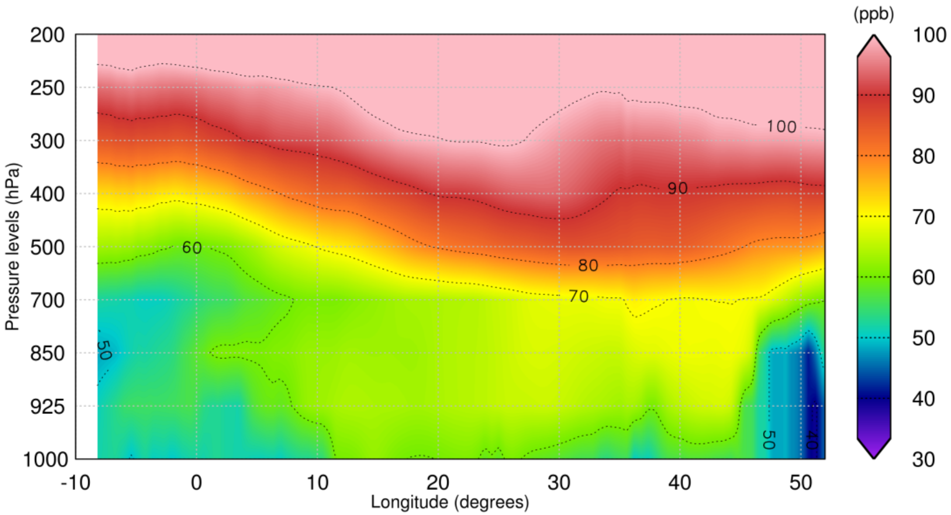




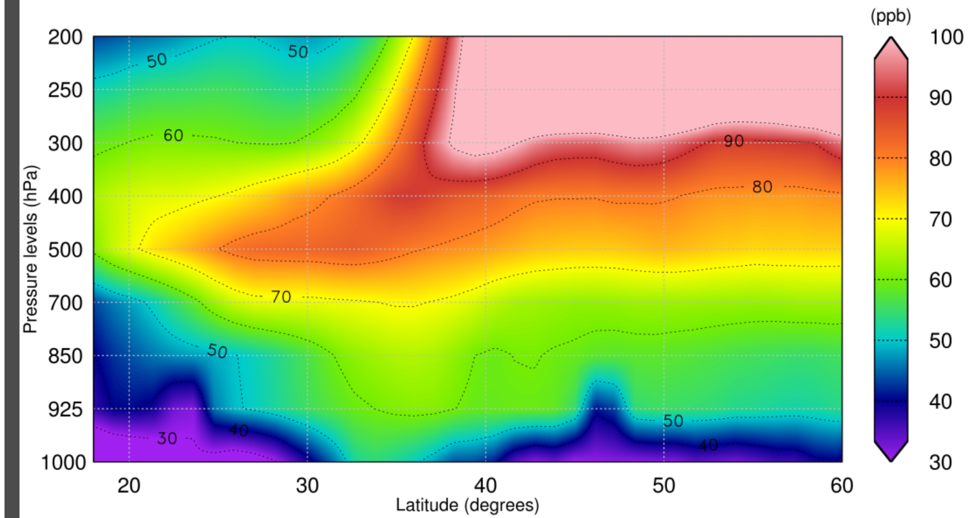
Ozone cross sections in RegCM4 and MACC reanalysis

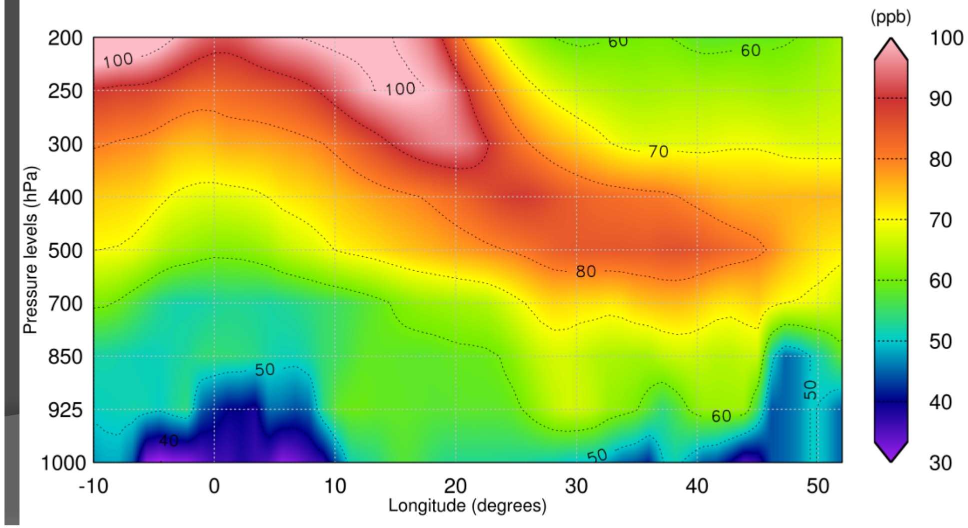
RegCM4-Chem
JJA 2006





MACC reanalysis
JJA 2006

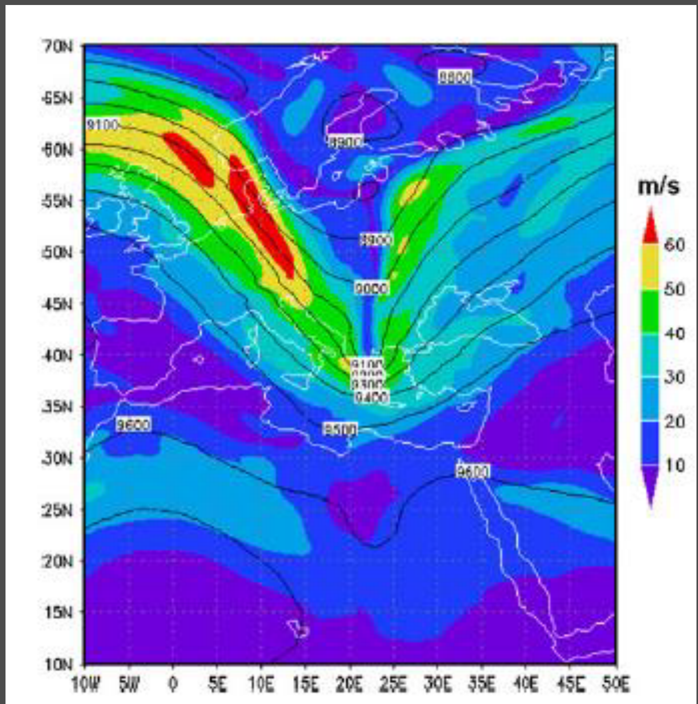




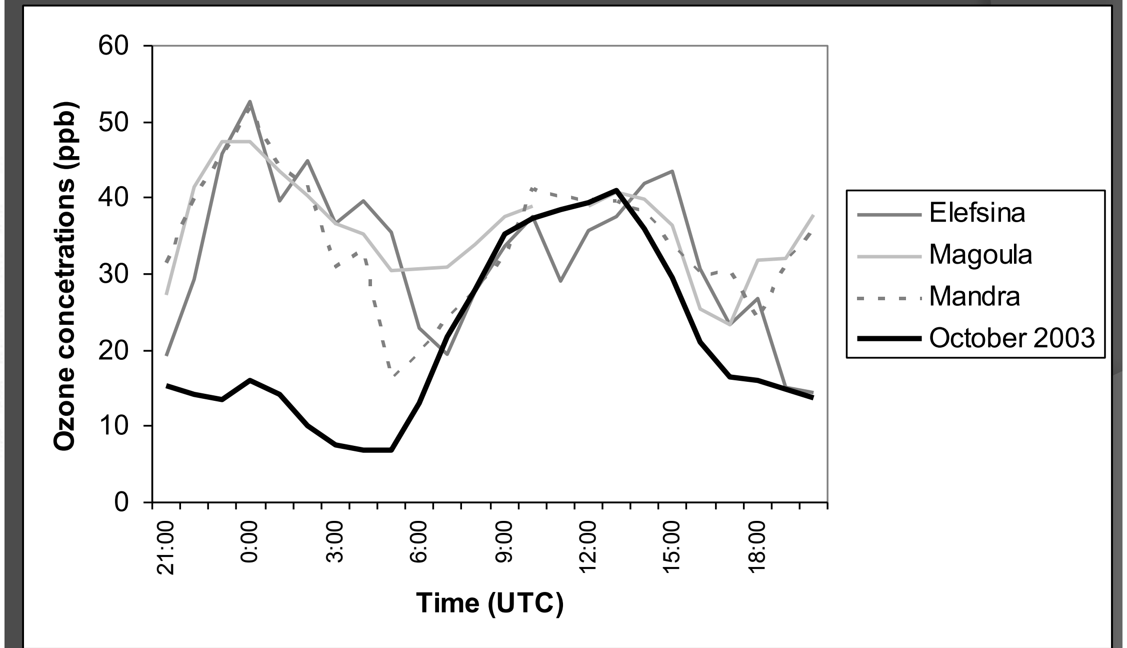
Key remarks 1

- There is enhanced ozone over Eastern Mediterranean and Middle East (EMME) which is a robust feature, propagating down to lower free tropospheric levels.
- This is linked the downward transport from the UTLS region associated with the enhanced subsidence and TP folds that dominates the summertime EMME circulation.
- RegCM4-chem simulations capture the ozone pool pattern over EMME.
- Discrepancies in upper troposphere between RegCM4 and MACC could be linked to differences in top chemical boundary conditions.

A deep stratospheric intrusion event down to earth's surface of the megacity of Athens - 9 October 2003 (Akritidis et al., MAP, 2010)

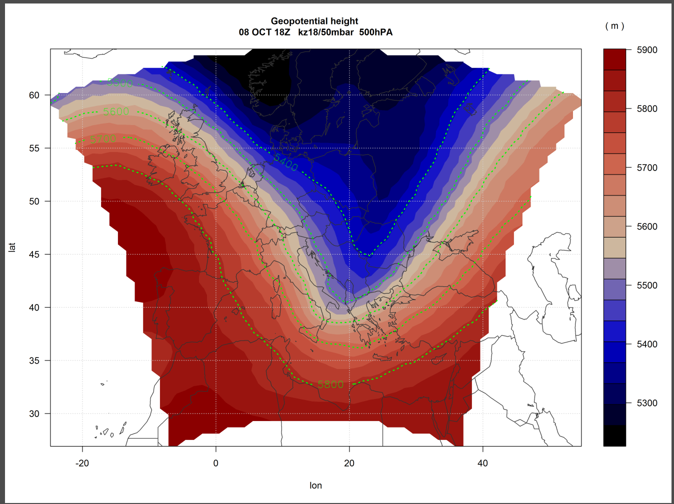


ECMWF

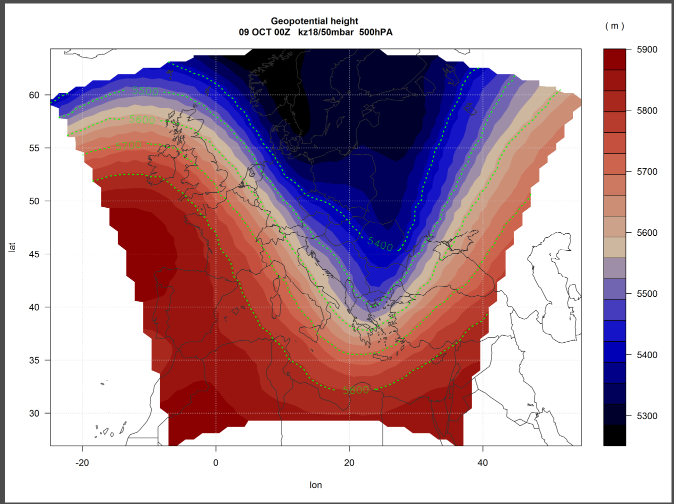


Near surface O_3 measurements

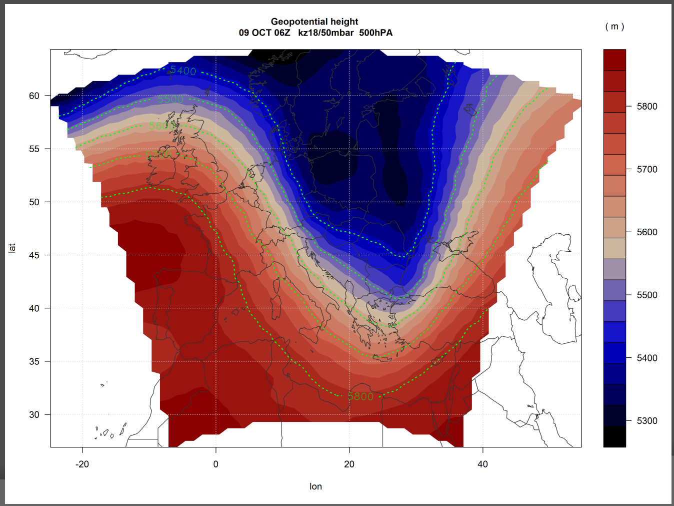
RegCM4 – Geopotential Height at 500 hPa
8-9 October 2003



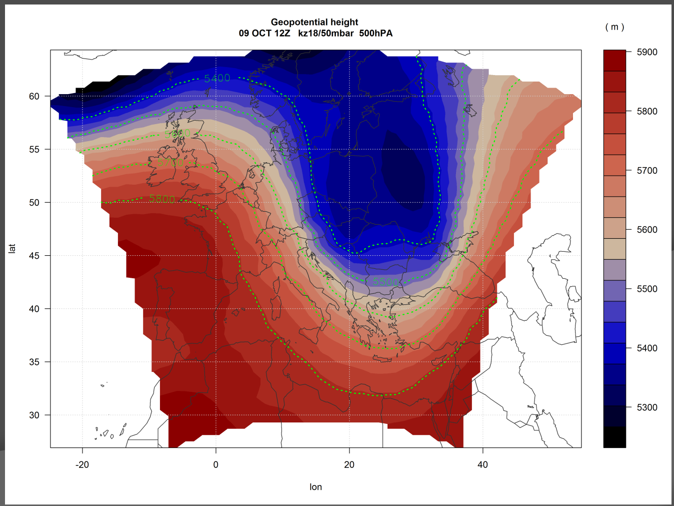
(a) 18 Z - 8 October



(b) 00 Z - 9 October

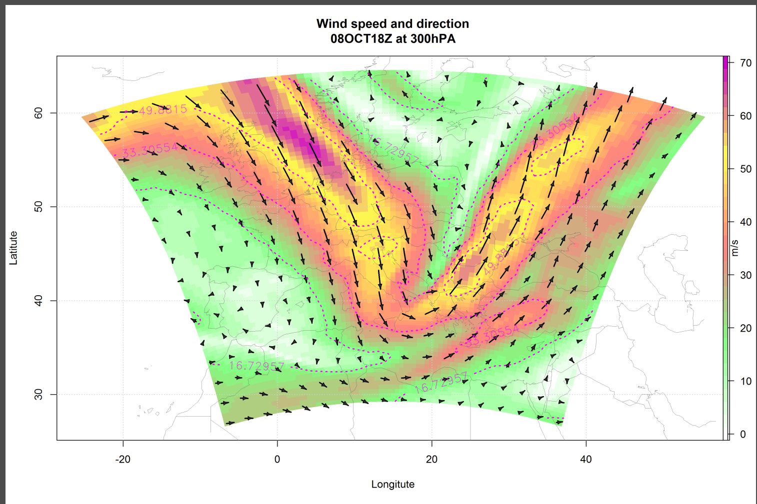


(c) 06 Z - 9 October

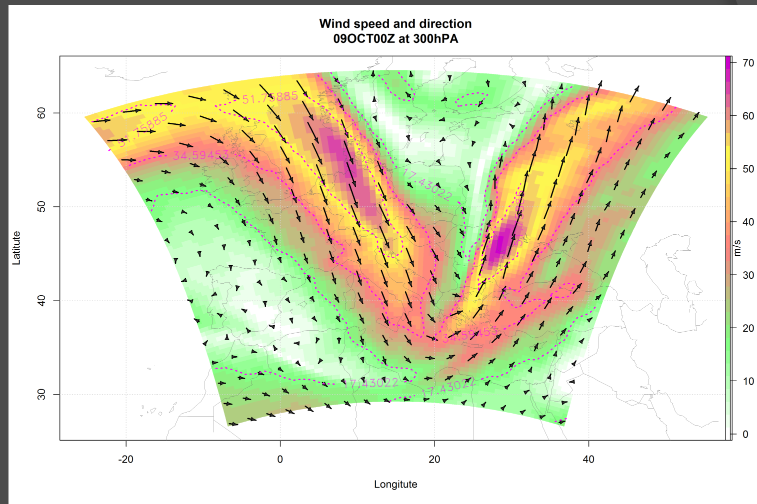


(d) 12 Z - 9 October

RegCM4 – Wind Speed at 300 hPa 8-9 October 2003



(a) 18 Z - 8 October



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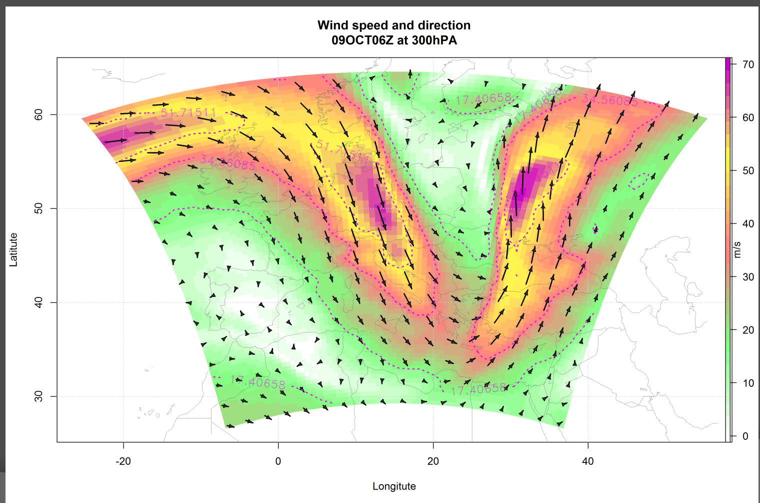

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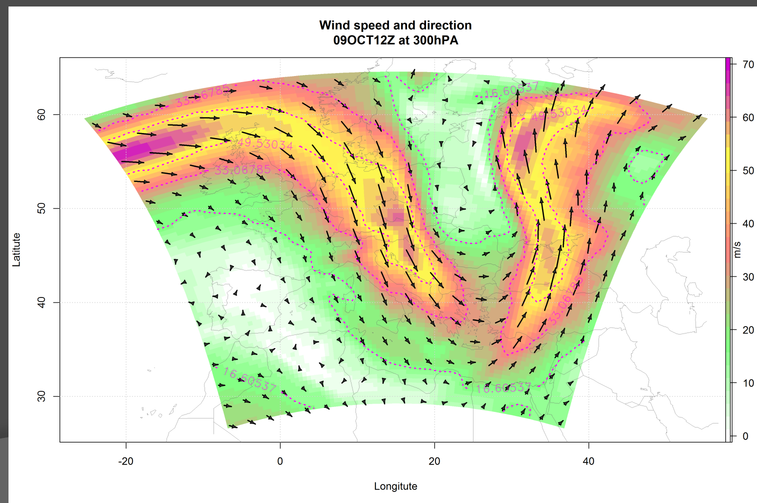
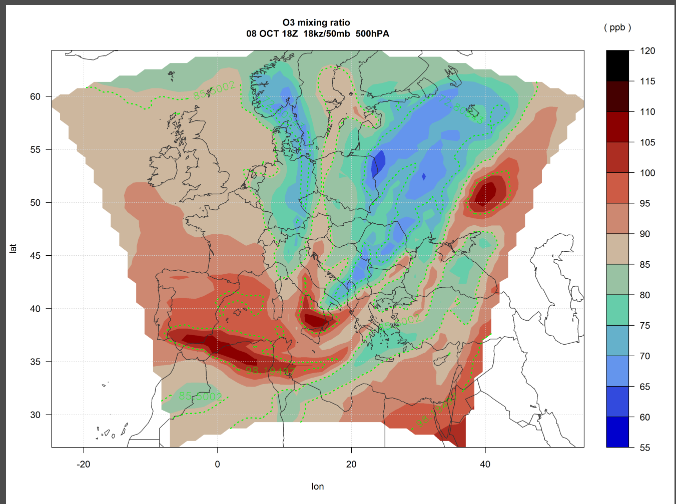


(d) 12 Z - 9 October

RegCM4 – Ozone at 500 hPa
8-9 October 2003



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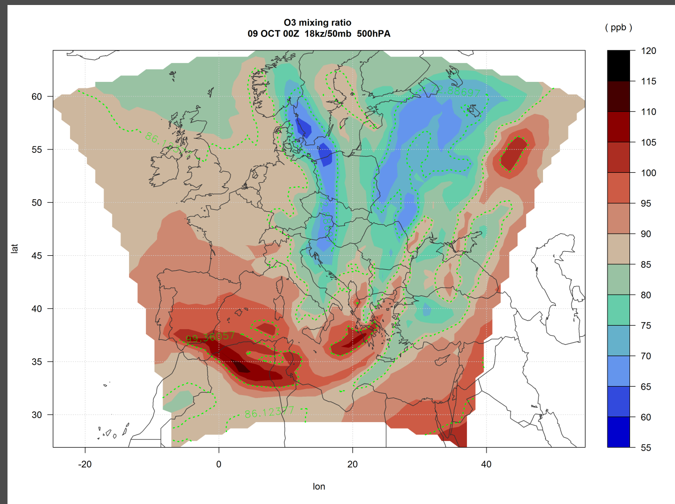

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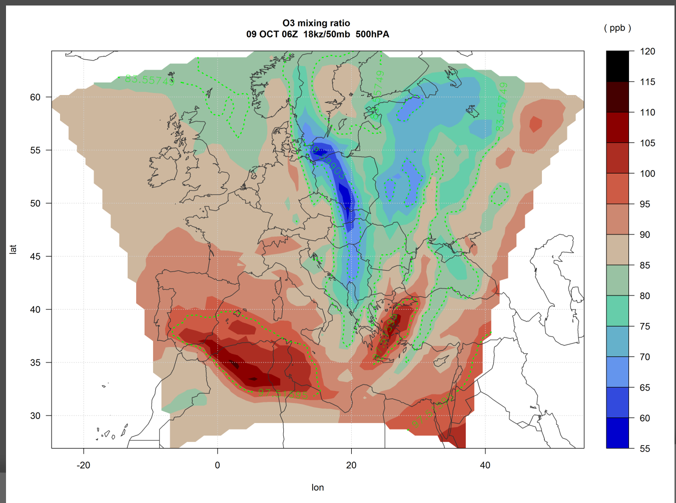

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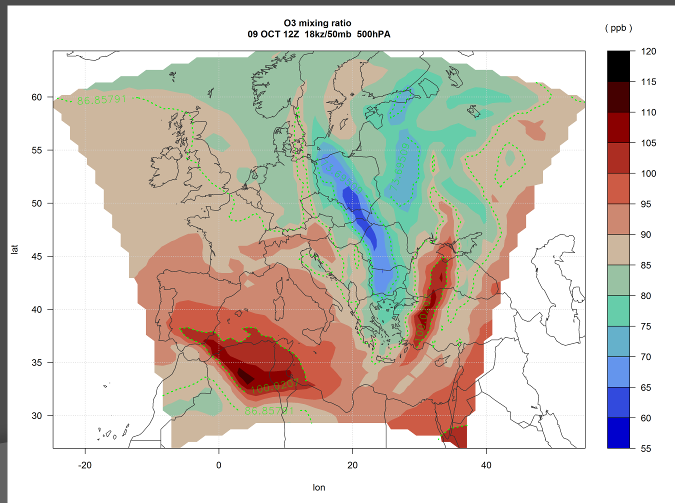
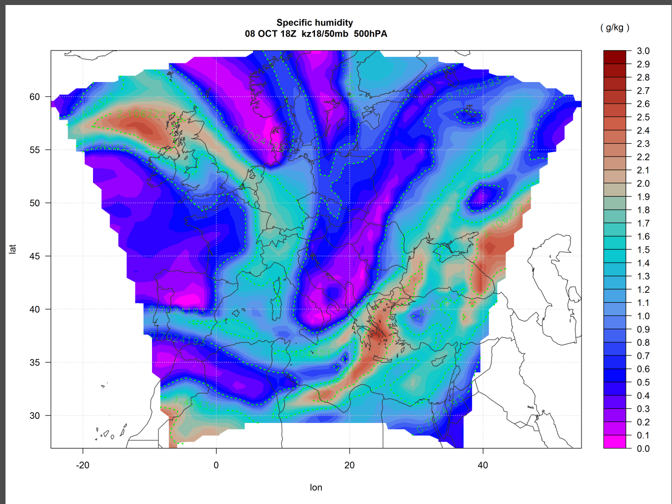
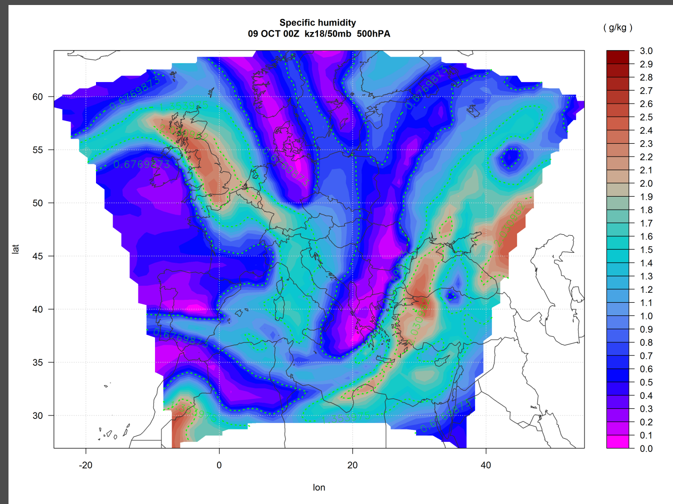


(d) 12 Z - 9 October

RegCM4 – Specific Humidity at 500 hPa
8-9 October 2003



(a) 18 Z - 8 October



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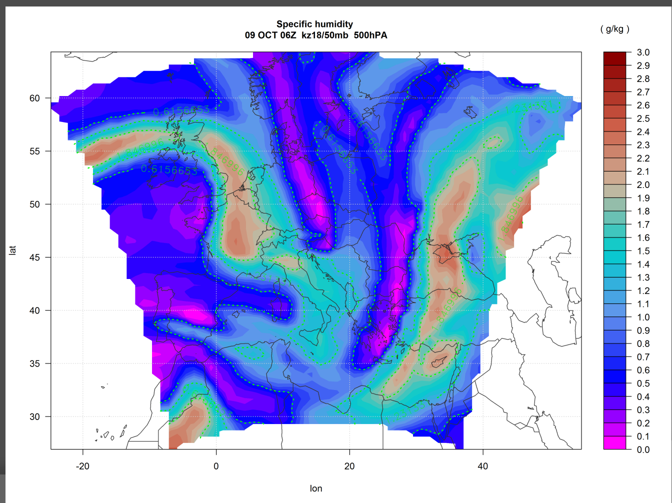

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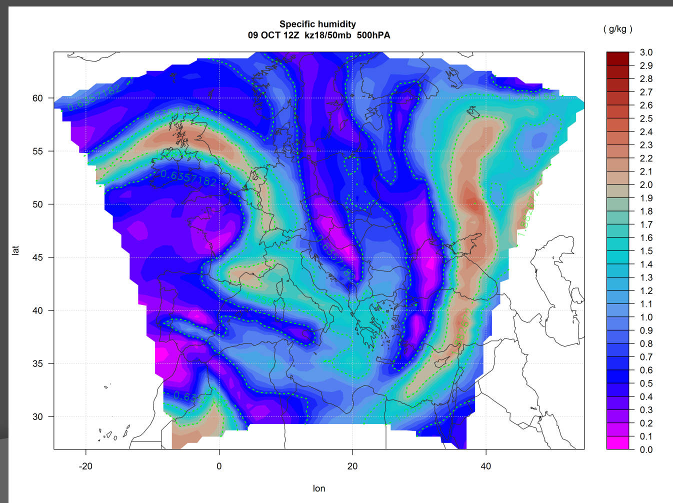
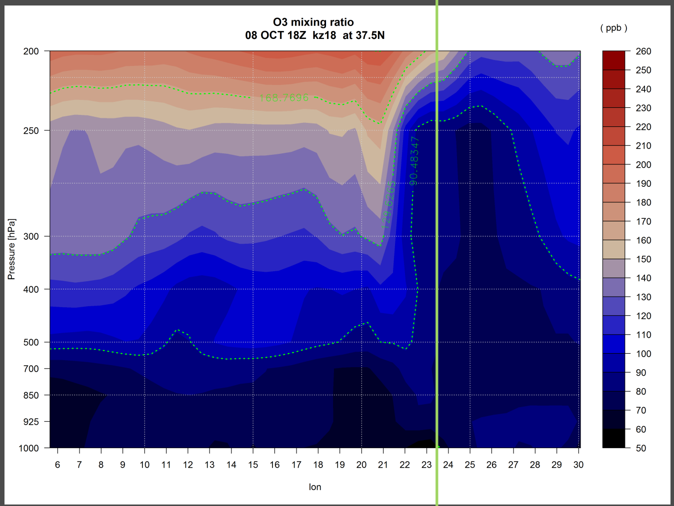
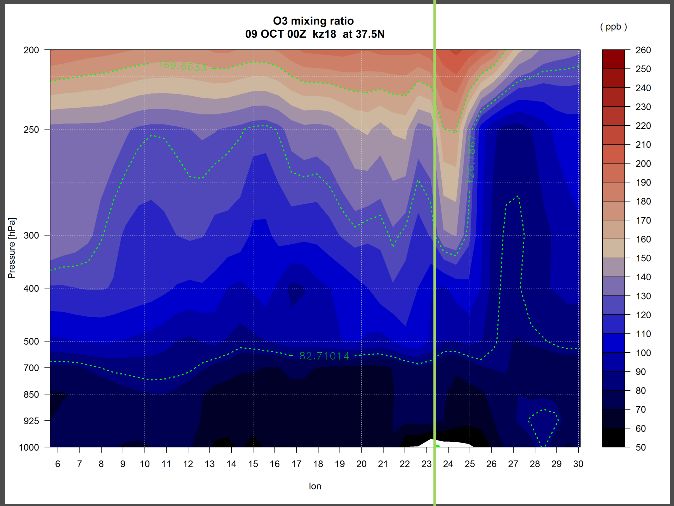


(d) 12 Z - 9 October

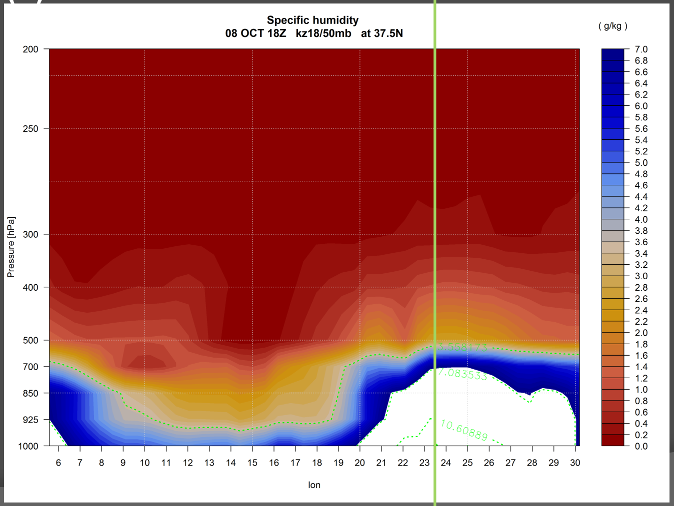
RegCM4 – O3 and SH lon-pres cross sections 8-9 October 2003



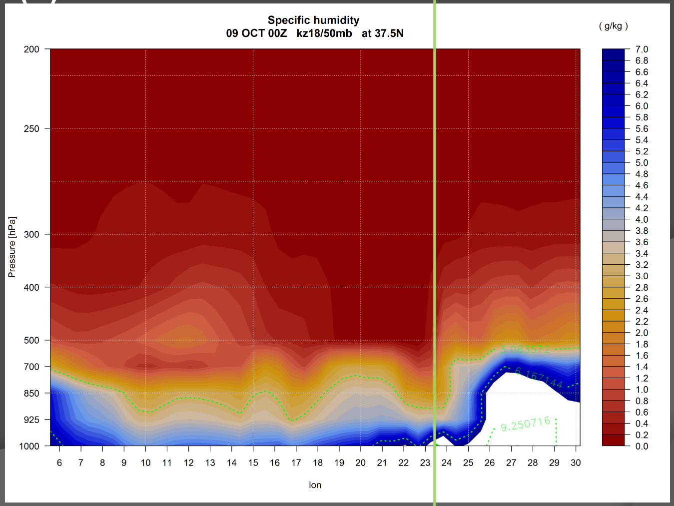
(a) 18 Z - 8 October / O3



(b) 00 Z - 9 October / O3



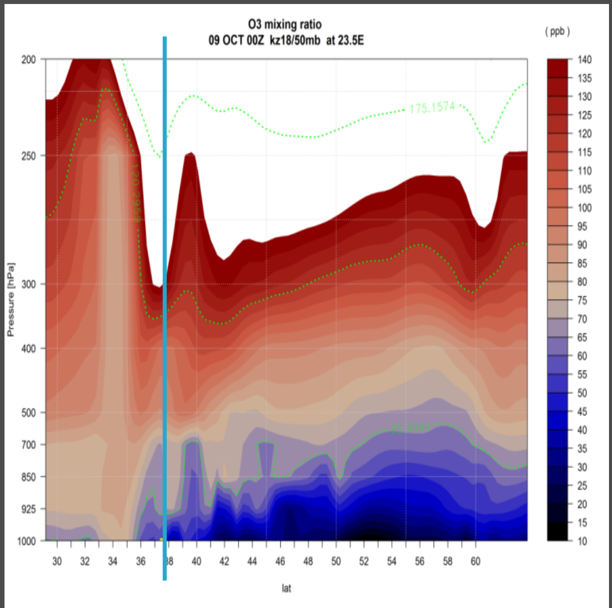
(c) 18 Z - 8 October / SH



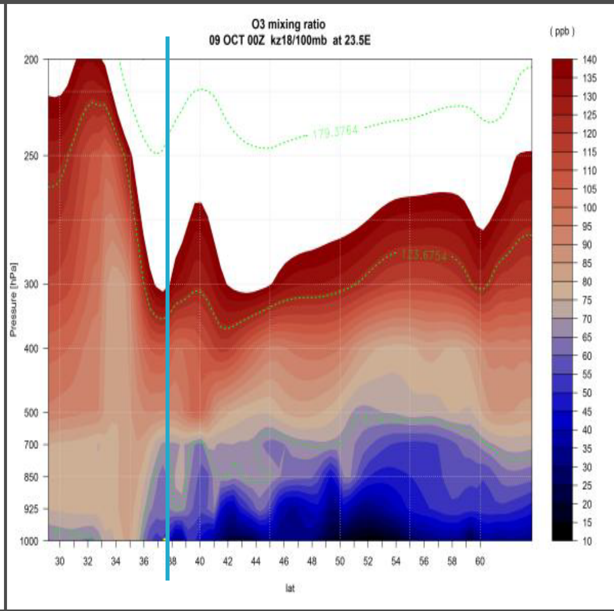
(d) 00 Z - 9 October / SH

RegCM4 – O3 lat-pres cross sections
00 Z - 9 October 2003

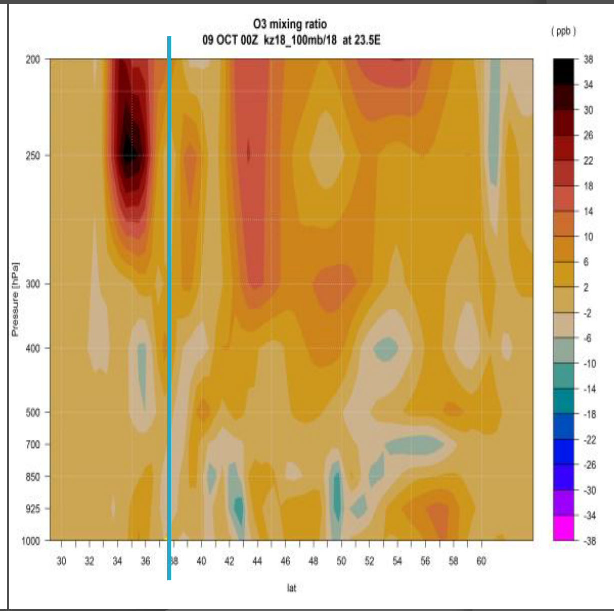
(a) Ptop = 50 mbar



(b) Ptop = 100 mbar



c) differences 100-50



Key remarks 2

- The ability of RegCM4-chem to simulate a deep stratospheric intrusion (9 October 2003) and its impact on tropospheric ozone levels was investigated.
- RegCM4-chem captures adequately the evolution of the event and indicates transport of dry and rich in ozone air masses to lower tropospheric levels.
- Prliminary analysis of the model's sensitivity to the top model level indicated higher ozone around the tropopause fold in the upper tropoposhere in the simulation with the lower top of the atmosphere. No significant impact in lower tropospheric levels.

Department of Meteorology and Climatology
AUTH

Thanks for your attention