Atmospheric chemistry in EC-Earth

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EC-Earth consortium

EC-Earth is an ESM developed by a consortium of ‘smaller’ European countries:

- Netherlands: **KNMI**, IMAU, Utrecht U., VU Amsterdam, **WUR**
- Sweden: **SMHI**, Lund U., Stockholm U.
- Denmark: DMI
- Norway: NMI
- Ireland: Met Éireann, U. College Dublin, ICHEC
- Spain: AEMet, Barcelona SC
- Portugal: IM, U. Lisbon
- Italy: ICTP
- Switzerland: **ETH Zürich**
- Belgium: UC Leuven

- Observer: ECMWF

Latest news is that Météo-France will get involved

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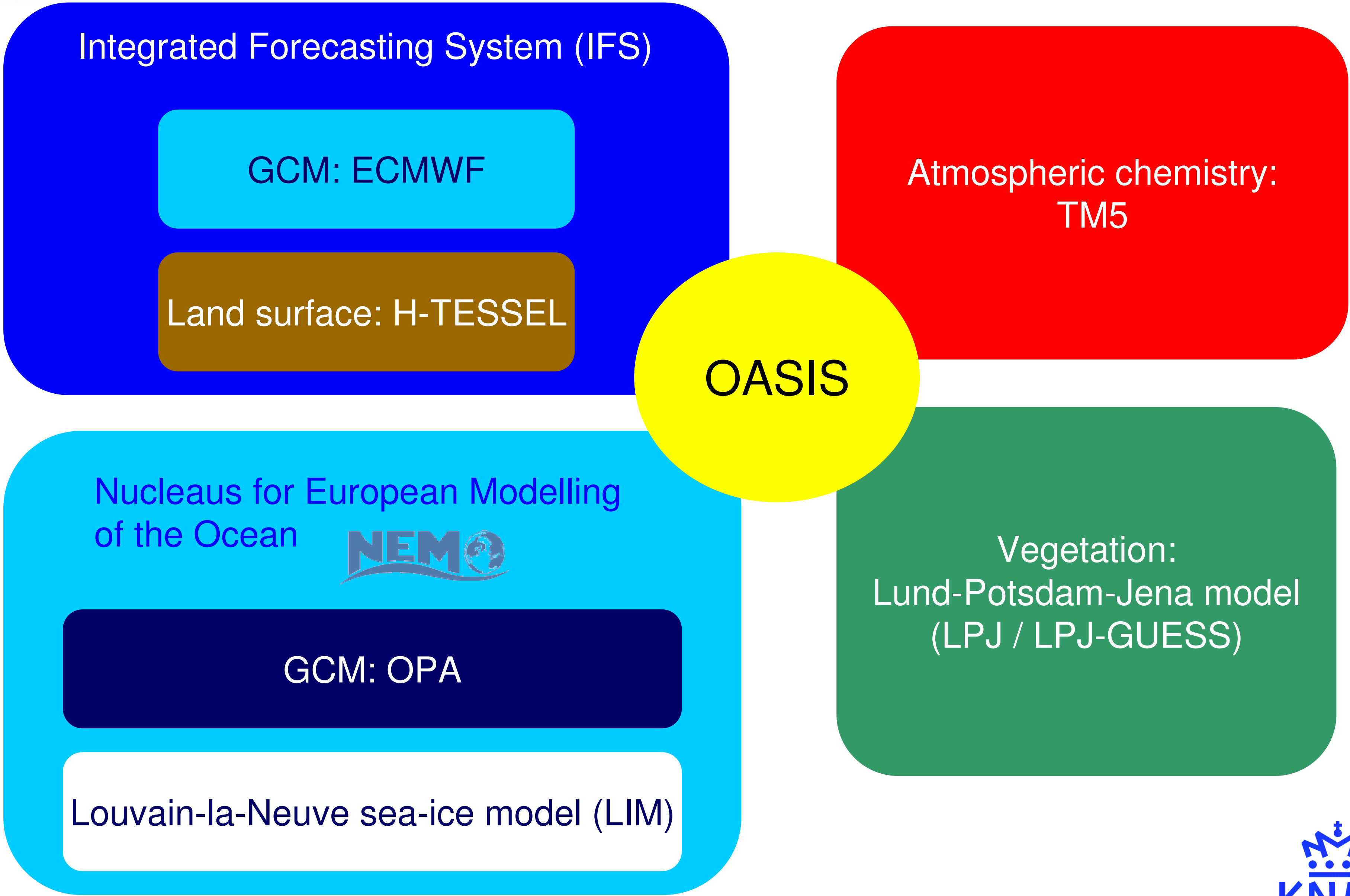
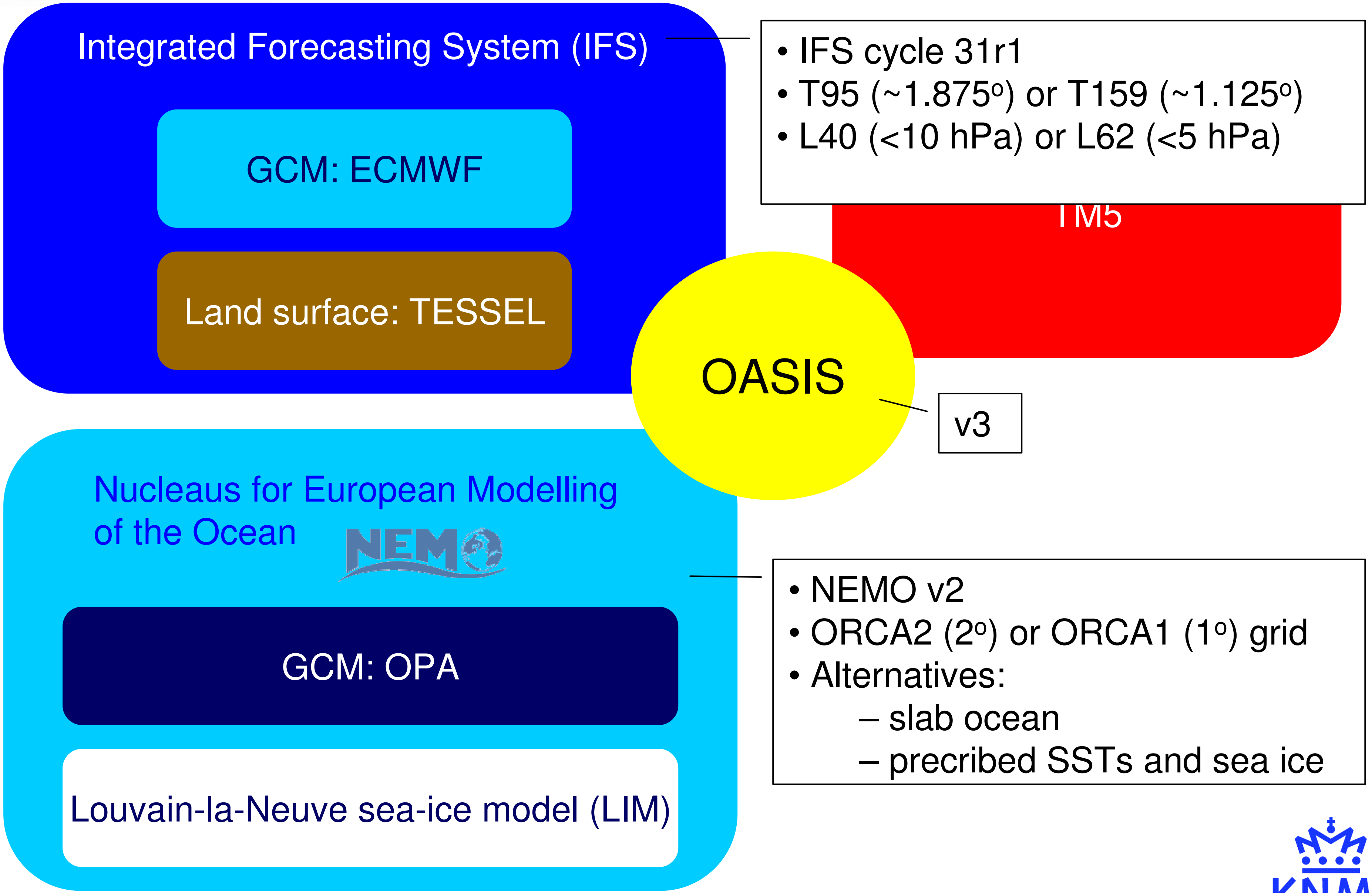
Modules



Integrated Forecasting System (IFS)
GCM: ECMWF
Land surface: H-TESSEL
Atmospheric chemistry:
TM5
OASIS
Nucleaus for European Modelling
of the Ocean
NEMO
GCM: OPA
Louvain-la-Neuve sea-ice model (LIM)
Vegetation:
Lund-Potsdam-Jena model
(LPJ / LPJ-GUESS)

Current version (v1)



Science questions

- How will climate change affect future atmospheric composition and air quality (ozone, aerosols)?

Example: future climate impacts on ozone

- Conditions for ozone smog in the Netherlands worst in summer on warm, sunny days with weak easterly or southerly winds:
  - Bad ventilation boundary layer (stagnation)
  - Inflow of pollution from Germany or Belgium
- Production of ozone:
  - increases at higher temperatures
  - is possibly affected by changes in clouds
  - and changes in tropospheric circulation patterns

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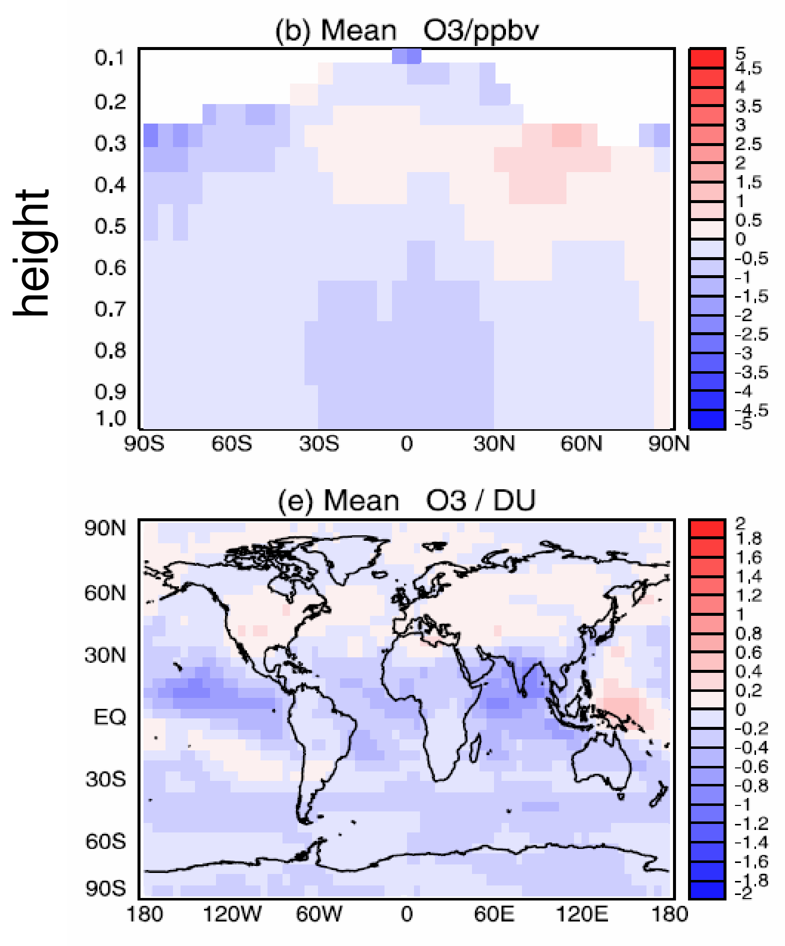
Example: future climate impacts on ozone

- Destruction of ozone (over tropical oceans) increases at higher humidity
- Influx from stratosphere increases due to enhanced Brewer-Dobson circulation
- Natural emissions change:
  - CH_4
  - biogenic NMVOC, e.g.
    isoprene: ↑ T and ↓ CO_2
  - Soil and lightning NO_x
  - Wildfires

effects largely unknown

Changes in trop. O_3 due to climate change in 2030

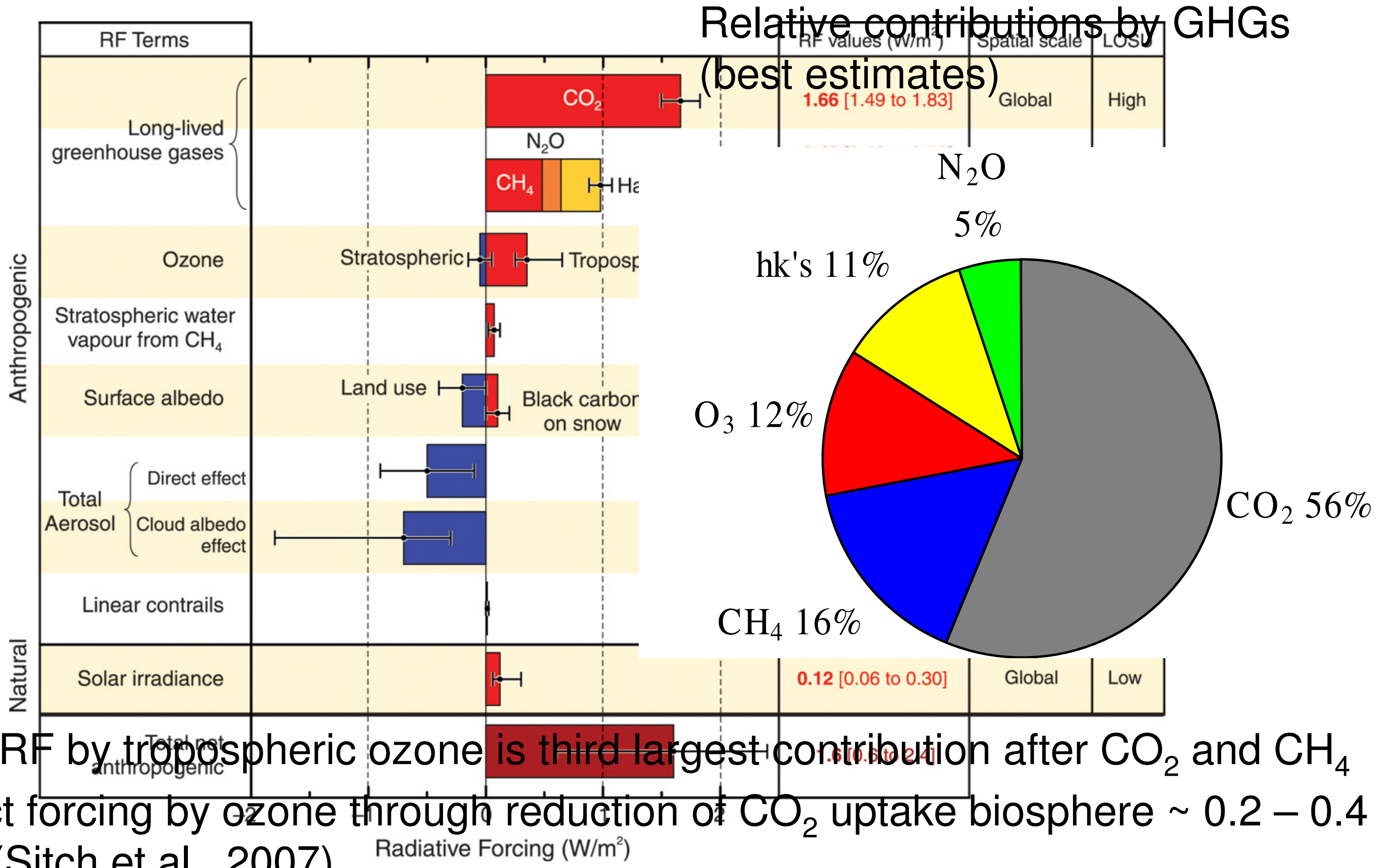


(Stevenson et al., 2006)

Science questions

- How will climate change affect future atmospheric composition and air quality (ozone, aerosols)?
- <u>How will changes in ozone and aerosol concentrations affect the global and regional climate?</u>

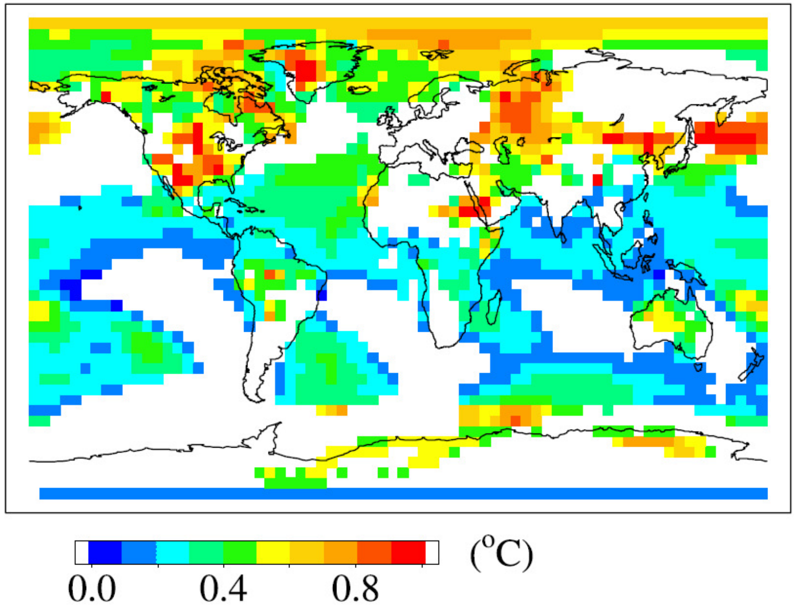
AR4 radiative forcings



- Direct RF by tropospheric ozone is third largest contribution after CO_2 and CH_4
- Indirect forcing by ozone through reduction of CO_2 uptake biosphere ~ 0.2 – 0.4 W/m² (Sitch et al., 2007)

Example: warming by tropospheric ozone

- ~ 2x faster on NH than on SH
- Especially strong contribution in:
  - Arctic in winter en spring (~ 0.4 – 0.5 °C)
  - some polluted NH regions in summer (locally > 0.5 °C)
- In Western Europe nearly everywhere < 0.3 °C



JJA surface warming by O_3 increases since the preindustrial

(Shindell et al., 2006; Mickley et al., 2004)

Scientific questions

- How will climate change affect future atmospheric composition and air quality (ozone, aerosols)?
- How will changes in ozone and aerosol concentrations affect the global and regional climate?
- <u>How will air quality measures affect global and regional climate change over the coming decades?</u>

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TM5 in EC-Earth

- First phase (AR5 decadal runs):
  - Tropospheric chemistry with modal aerosol scheme and linearized stratospheric ozone chemistry
  - Natural emissions parameterized; CH_4 concentrations prescribed at the surface
  - Radiative forcing based on simulated O_3, CH_4, and aerosols

- Second phase (beyond AR5):
  - Stratospheric-tropospheric chemistry
  - Improved stratospheric water vapor source from oxidation of simulated methane (and hydrogen)
  - CH_4 emissions from wetlands parameterized
  - Radiative forcing based on simulated N_2O and halocarbon species (CFC-11, CFC-12, CFC-113, CCl_4, etc.) as well

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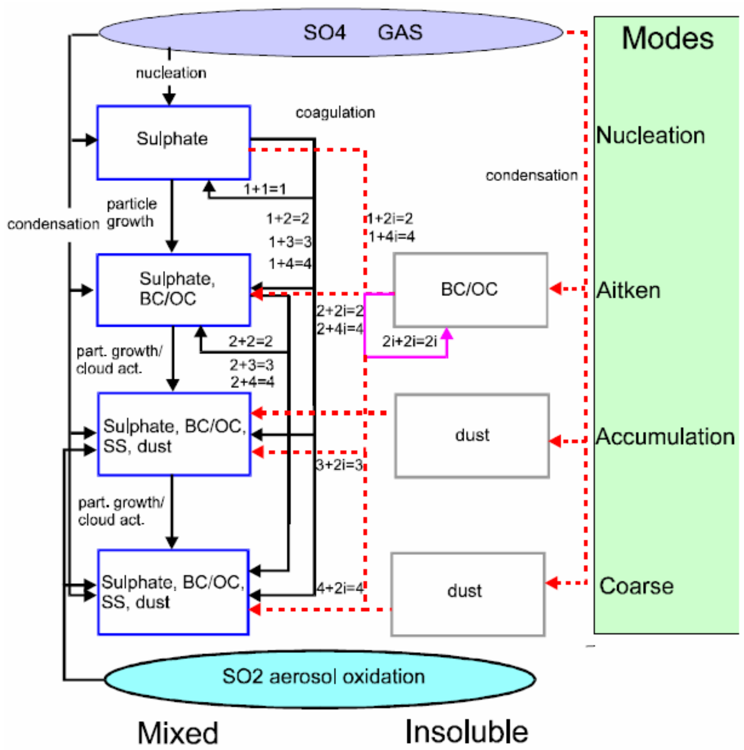
Developments in TM5

- TM5 has recently been extended with:
  - The M7 aerosol scheme

- 2 externally mixed populations:
  - Internally mixed water-soluble particles
  - Insoluble particles
- Each mode described by total particle number and mass of each compound; average particle radius derived
- 25 tracers in total



Vignati et al., JGR, 2004

Developments in TM5

- TM5 has recently been extended with:
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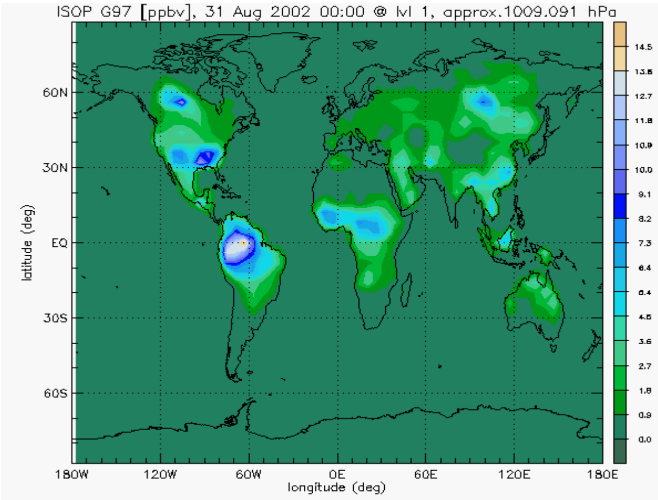
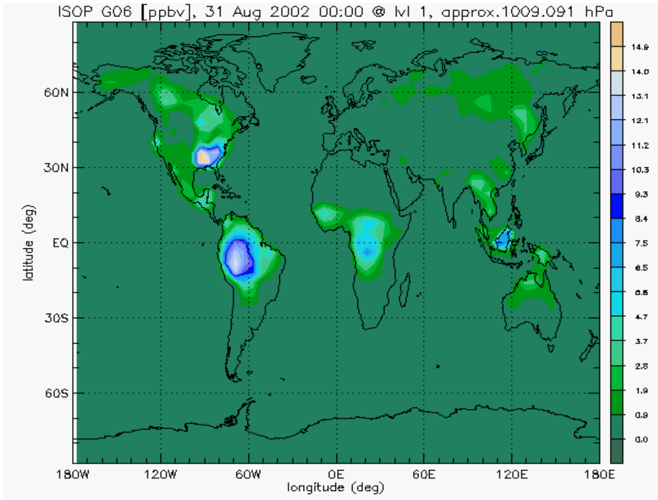
  - Online emission routine for isoprene (MEGAN) and terpenes



Guenther et al., 1997:
~500 Tg/yr



MEGAN:
~450 Tg/yr

Courtesy M. Karl

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Developments in TM5

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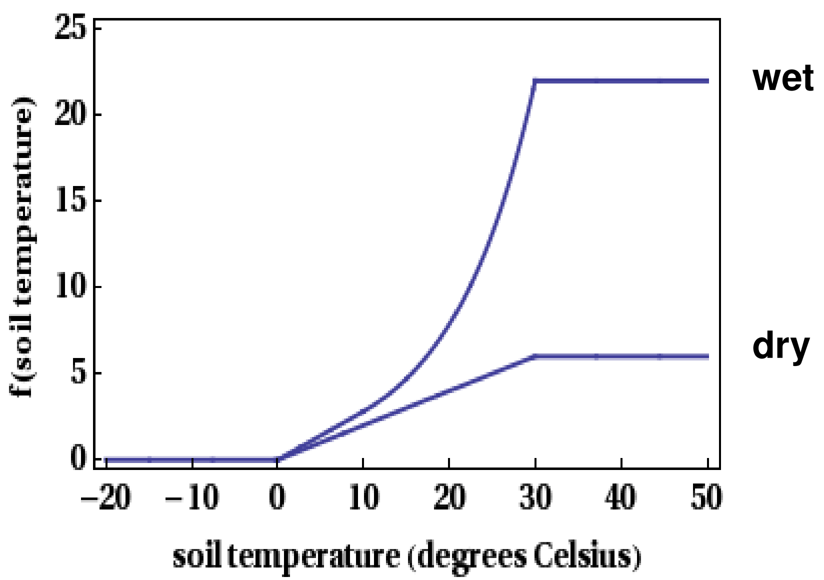
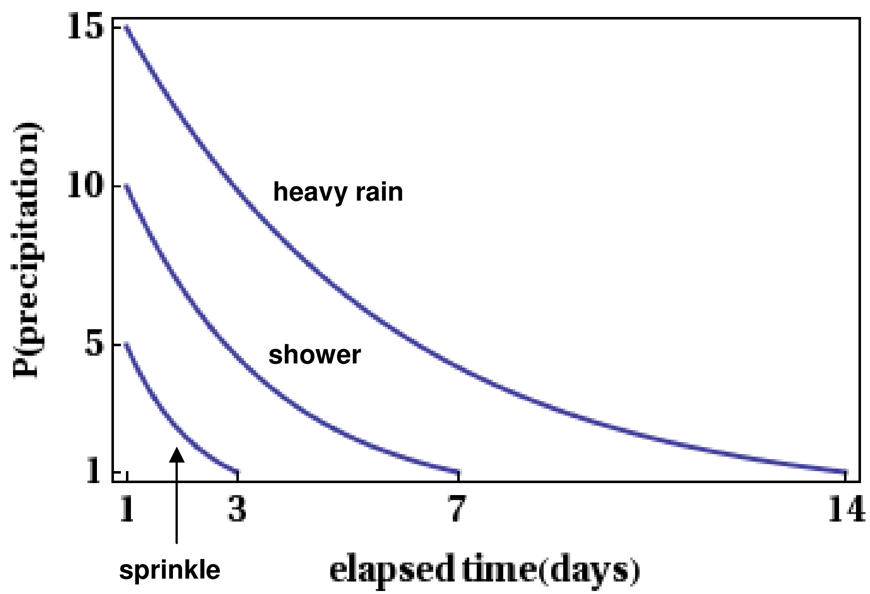
  - Online emission routine for soil NO_x (Yienger and Levy, 1995)

Flux = $A_{w/d}$ (biome) x f x P





Developments in TM5

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  - The Cariolle scheme (Jos de Laat)

$$\frac{d\chi}{dt} = S_0 + \left.\frac{\partial S}{\partial \chi}\right|_0 (\chi - \chi_0) + \left.\frac{\partial S}{\partial T}\right|_0 (T - T_0) + \left.\frac{\partial S}{\partial \Phi}\right|_0 (\Phi - \Phi_0)$$

O_3 mixing ratio

O_3 overhead column density

Developments in TM5

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  - Online emission routine for isoprene (MEGAN) and terpenes
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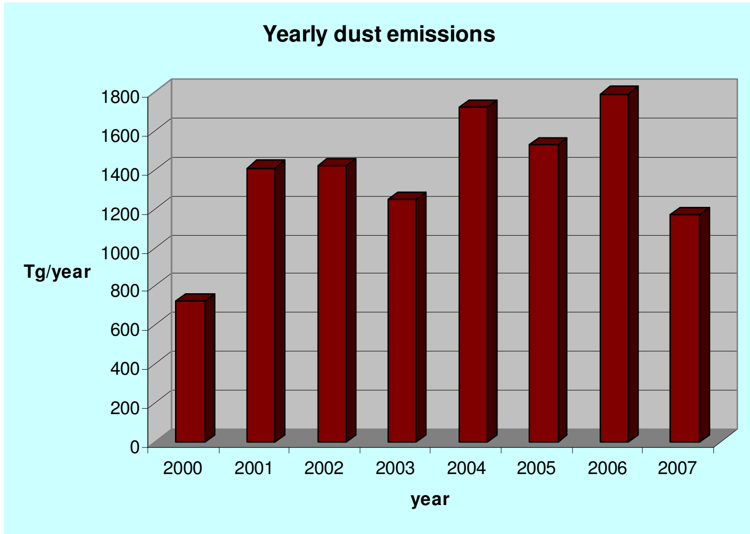
- Plan for next year:
  - Online emission routine for dust



Courtesy E. Vignati (JRC)

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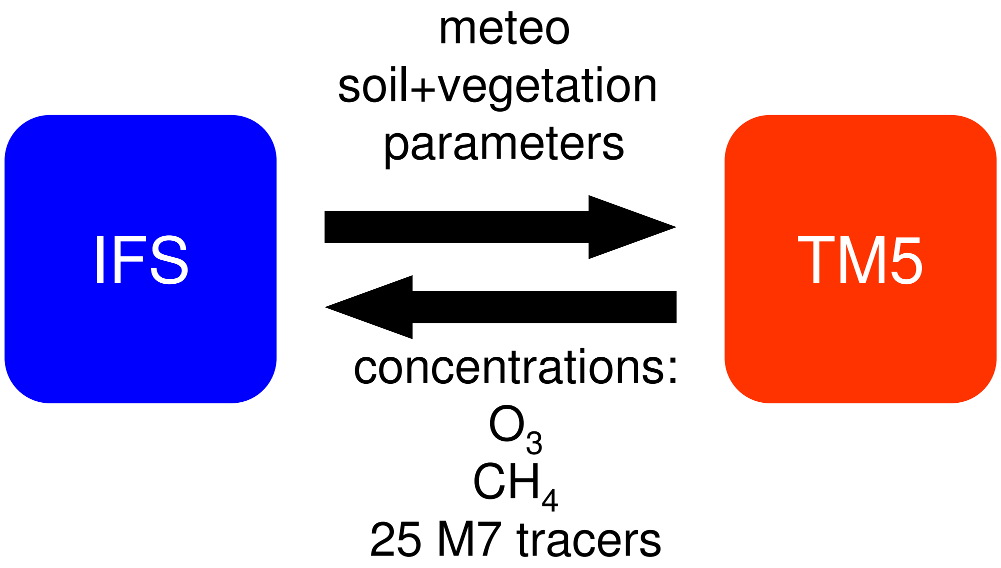
TM5-OASIS3-IFS coupling

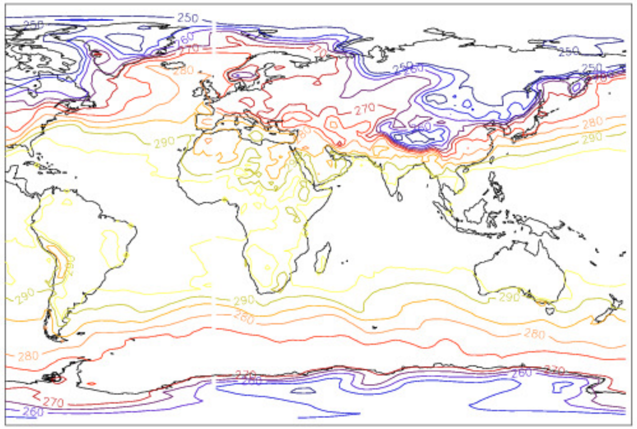
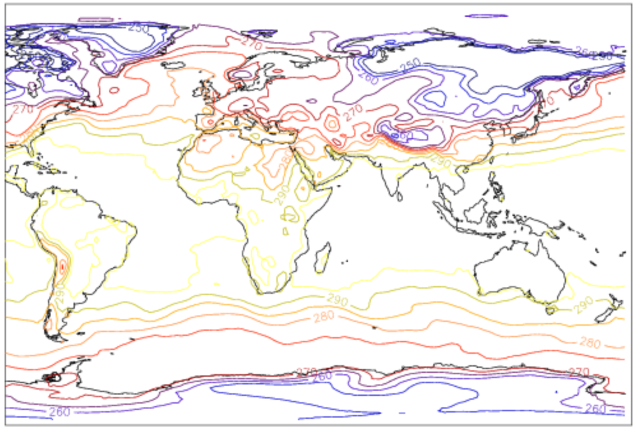
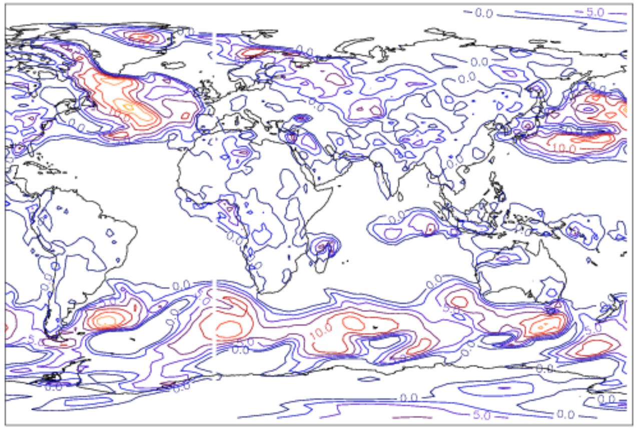
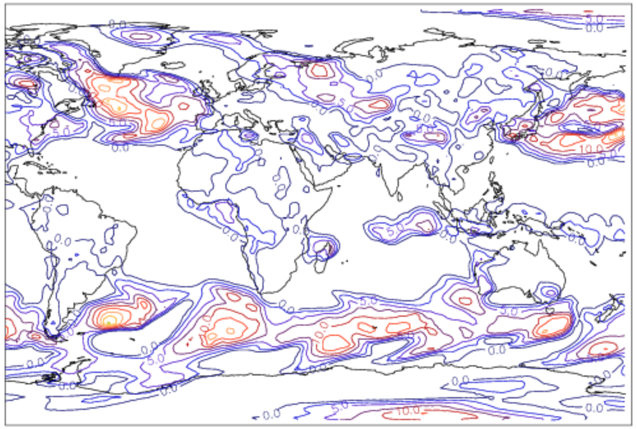


Exchange times will depend on performance;
currently set to 6 hours (both ways)

Status of the coupled system

- OASIS3 coupling TM5 and EC-Earth includes:
  - Online transfer of surface pressure, wind, temperature, humidity, and surface fields

Example: instantaneous fields

	IFS (T95~N48~1.875^o)	TM5 (1^ox1^o)
2-m temperature		
10-m u-wind		

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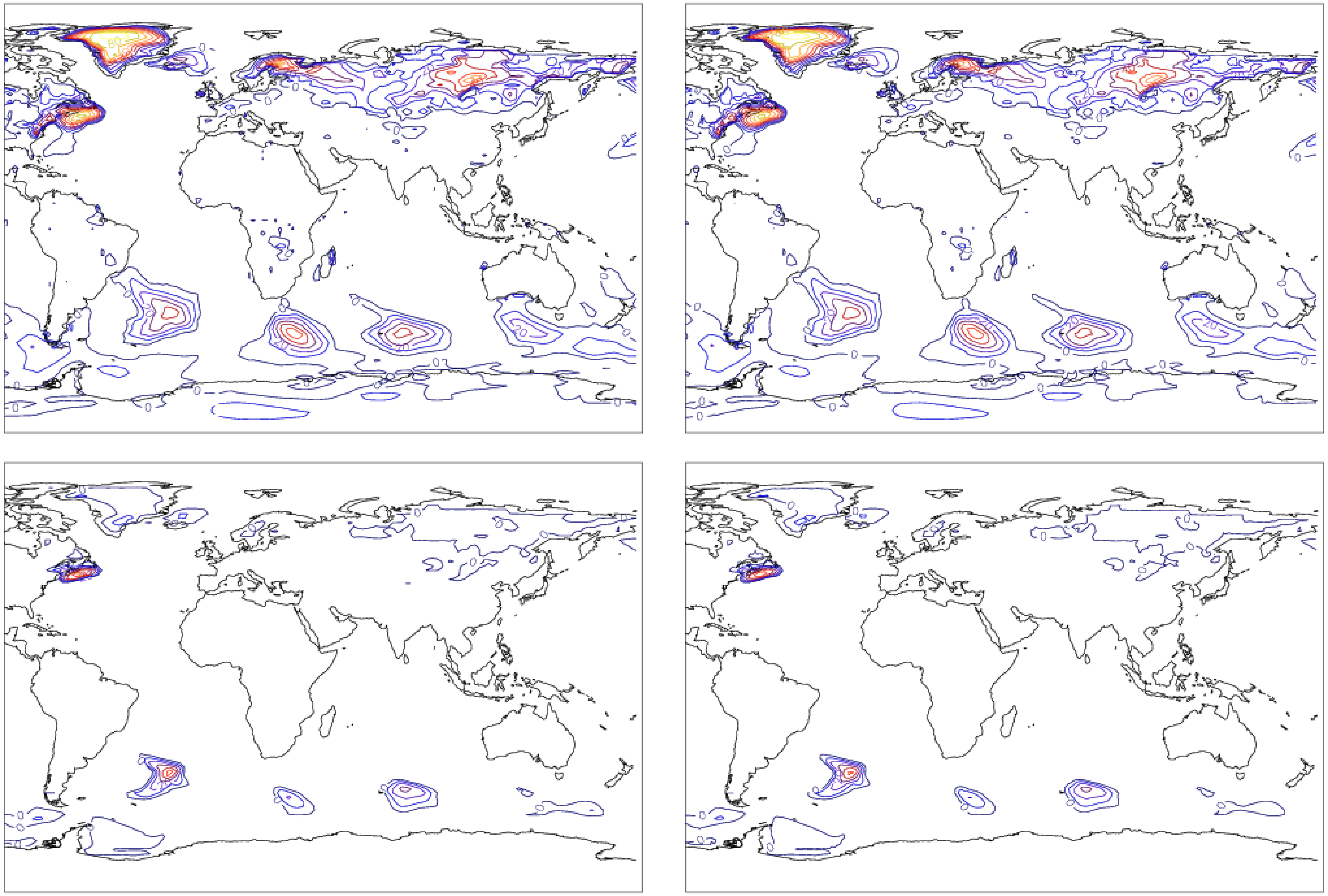
Example: accumulated fields (0-24 hours)

IFS
(T95~N48~1.875°)

TM5
(1°x1°)

Sensible heat flux

Latent heat flux



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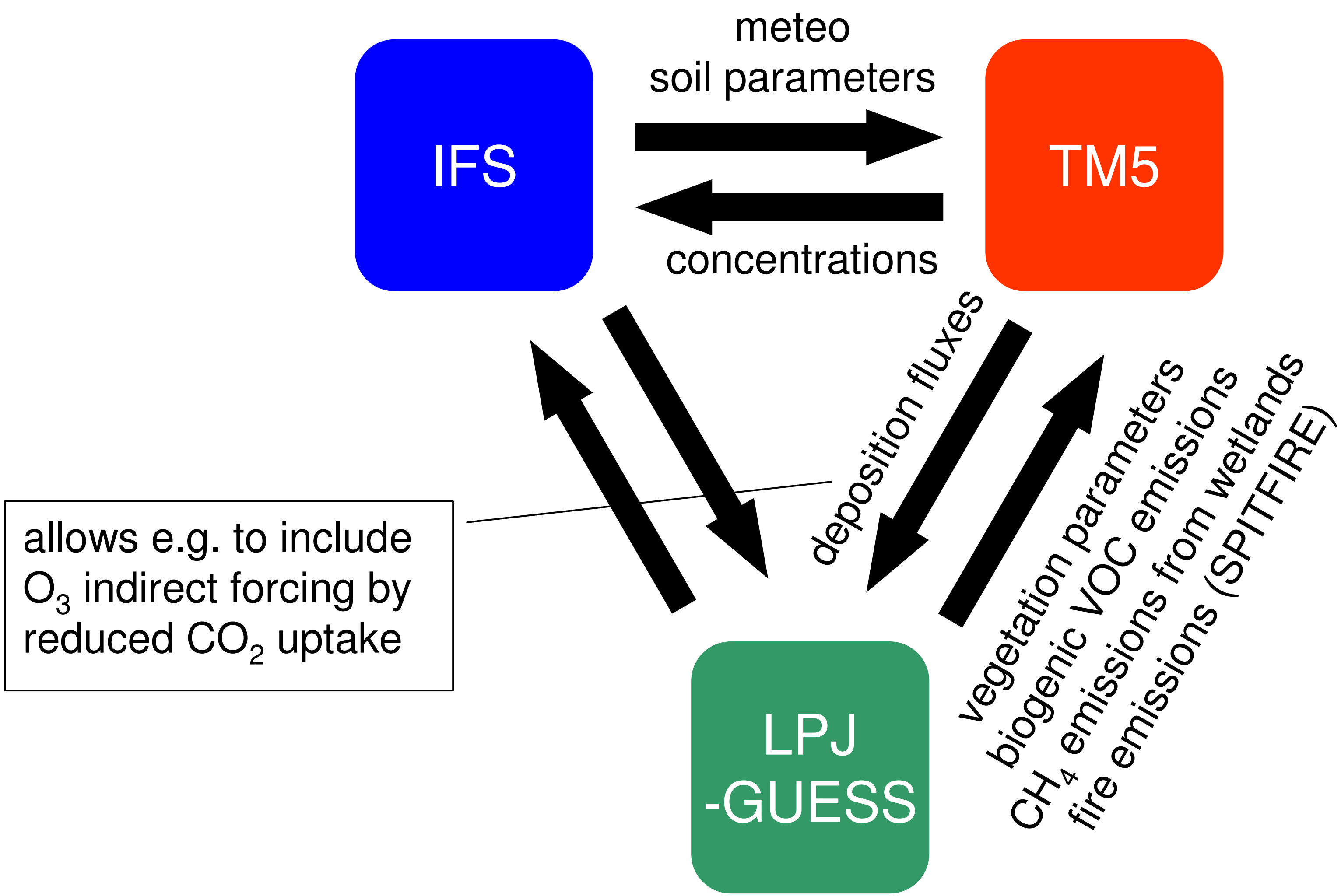
Status of the coupled system

- OASIS3 coupling TM5 and EC-Earth includes:
  - Online transfer of surface pressure, wind, temperature, humidity, and surface fields; clouds and convection to be done
  - Feedback of ozone, methane, 25 aerosol tracers (M7)
- Calculation optical properties M7 aerosols done (SMHI)

Planned for 2009:

- Update to IFS cycle 33r1, which uses new radiation scheme (McRad) and cloud parameterization
- Couple simulated concentrations to McRad
- Implement indirect aerosol effects for M7 aerosols

Plan for coupling with DGVM



Questions ?