A case study on the aerosol-meteorology feedback for Europe with WRF/Chem

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Definitions

- **Direct effect**
  - → **aerosol effect on solar radiation**
- **Semi direct effect**
  - → **changes in (surface) temperature, boundary layer and subsequent effect on radiation, convection, cloudiness, ...**
- **First indirect effect**
  - → **Changed radiation properties of clouds due to different CCN numbers**
- **Second indirect effect**
  - → **Changes in cloud lifetime, precipitation ...**

Motivation

Another simulation of direct and indirect aerosol effect? Why?

- **Feedback to meteorology for a longer episode, temporal development**
- **Investigation for Europe**
- **No particularly high aerosol loads**

AQMEII Air Quality Model Evaluation Initiative: WRF/Chem simulations with and without aerosol direct/indirect effects with nudging for meteorology
→ almost no difference between the two runs except for cloud water

Model Setup

- **Model: WRF/Chem 3.3 (April 2011)**
- **RADM2 gas phase chemistry**
- **MADE/SORGAM modal aerosol module**
  - Nucleation mode < 0.1µm;
    accumulation mode 0.1-2 µm; coarse mode >2 µm
- **Hourly AQMEII 'standard' emissions from TNO**
  Biogenic emissions Guenther et al., 1994
  GOCART sea salt emissions (Ginoux et al., 2001)
- **June - July 2006, Europe Δx=22.5 km**
- **For this case study: Continuous run, no FDDA → Free development of semi-direct effects possible**

Model runs

BASE	**Baseline case; no aerosol feedback**
RFB	**Direct aerosol-radiative effect (and semi direct effect)**
RFBC	**Direct aerosol-radiative effect plus indirect aerosol effect (+ semi-direct effects and second indirect effect)**
RFBC2	**Same as RFBC, but for much higher boundary values for aerosol than for RFBC**

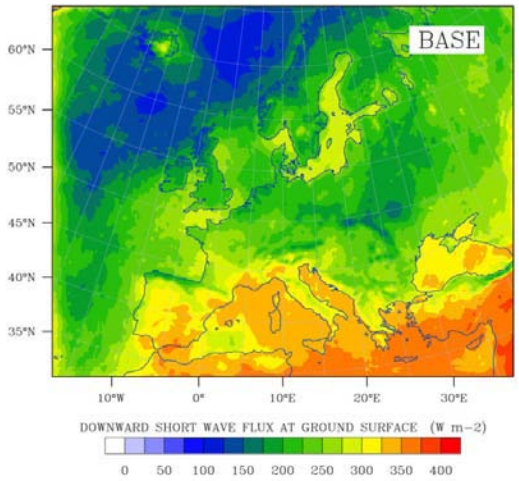
Solar Radiation

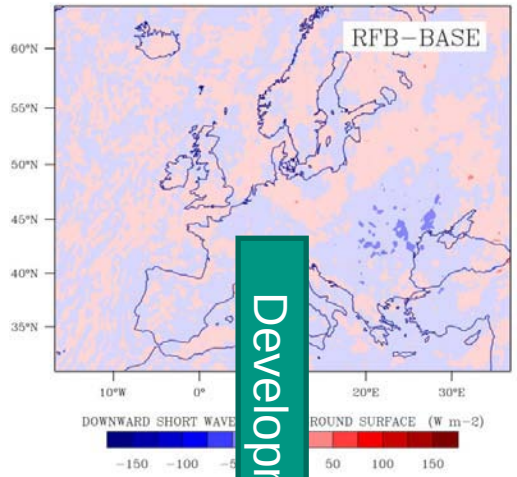
Karlsruhe Institute of Technology

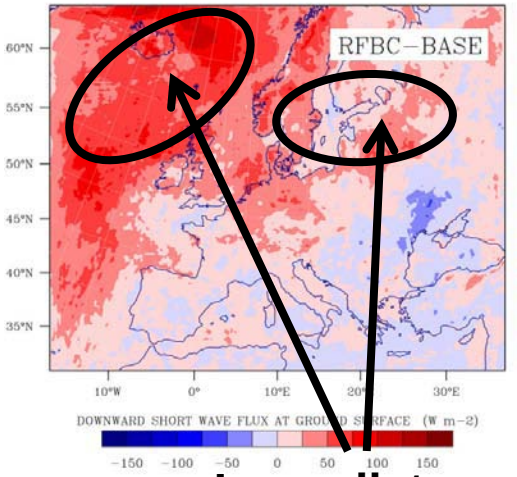
June

July

No aerosol effect	Direct & semi direct	+ indirect effect
BASE	RFB−BASE	RFBC−BASE

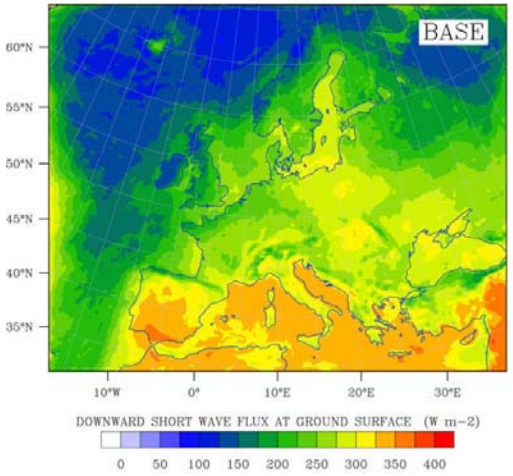


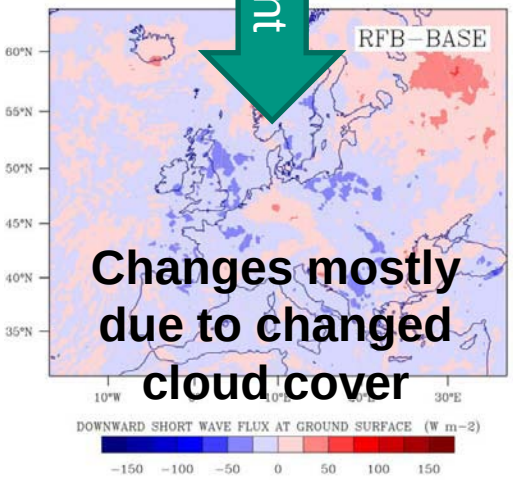




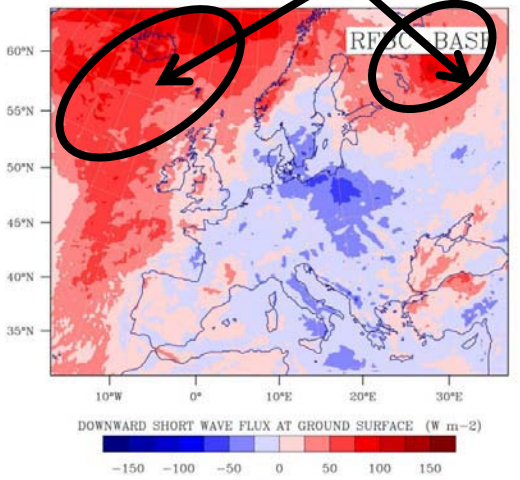
Development

Immediate





Changes mostly due to changed cloud cover



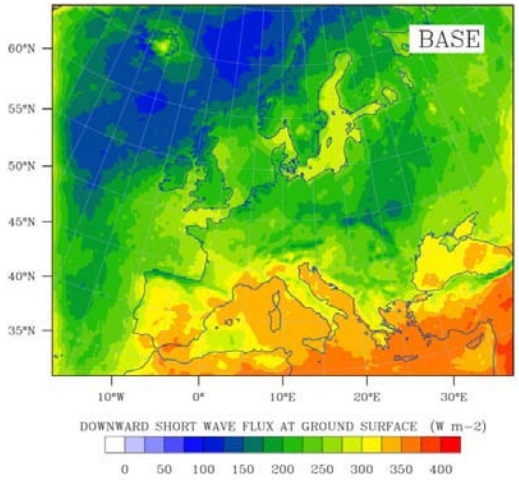
Solar Radiation

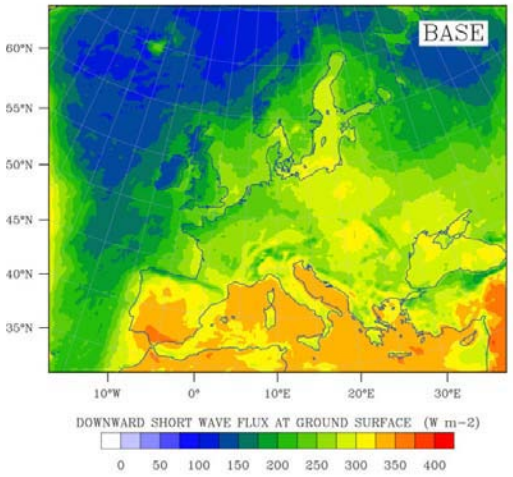
Karlsruhe Institute of Technology

June

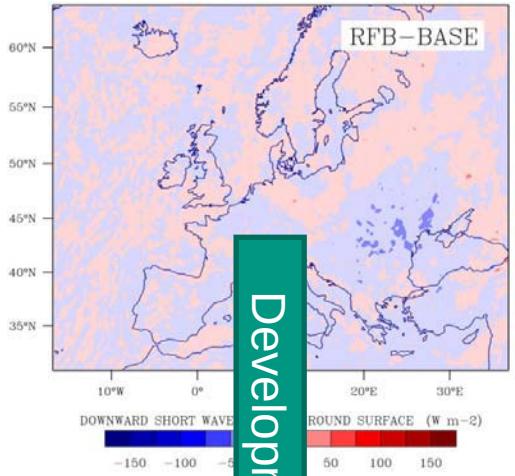
July

No aerosol effect

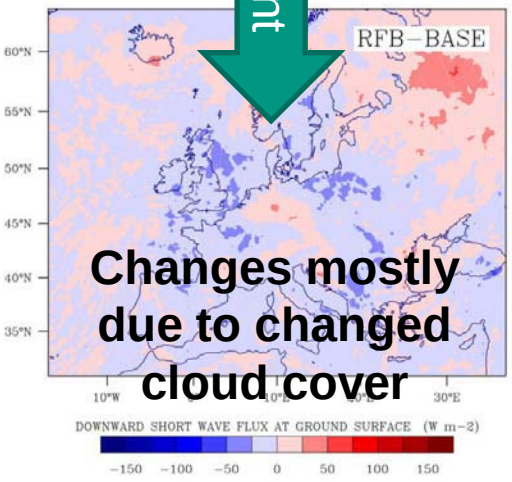




Direct & semi direct

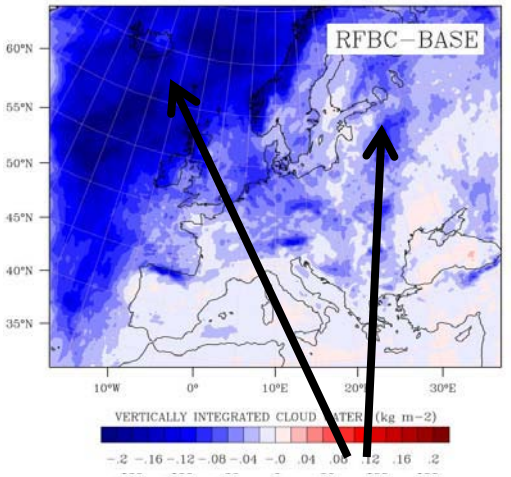


Development

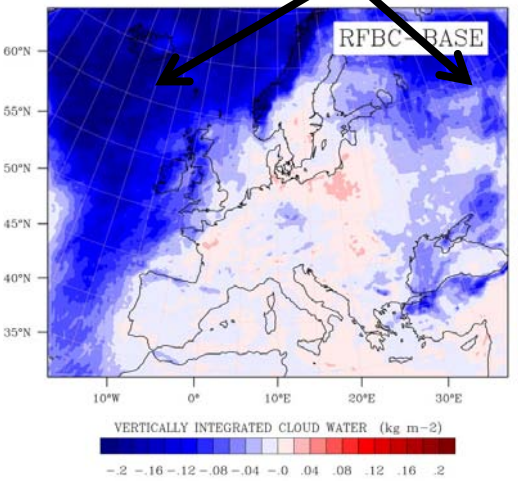


Changes mostly due to changed cloud cover

Effect on cloud water



Immediate

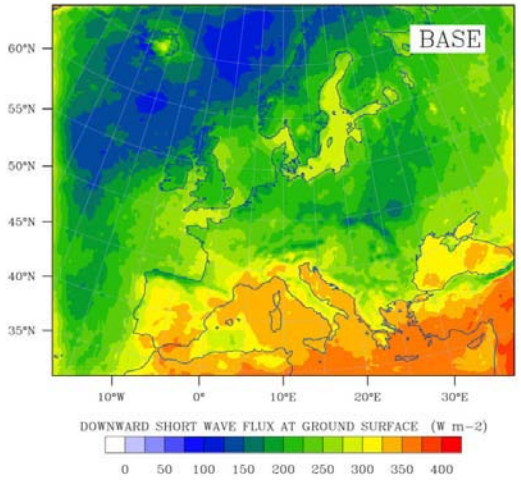


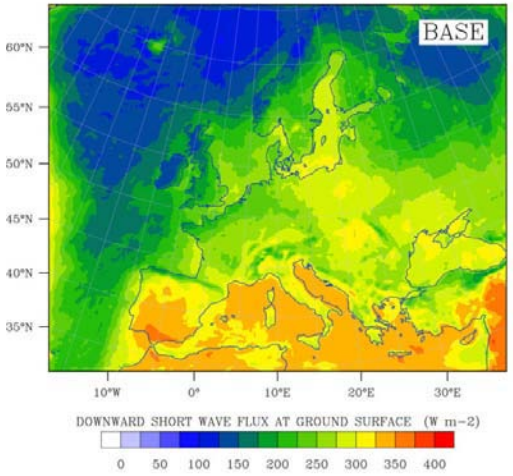
Solar Radiation

June

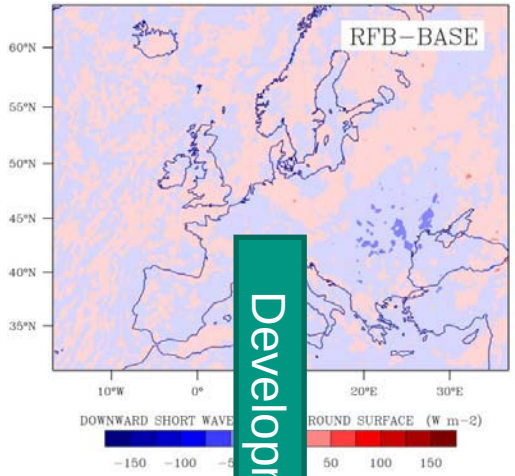
July

No aerosol effect

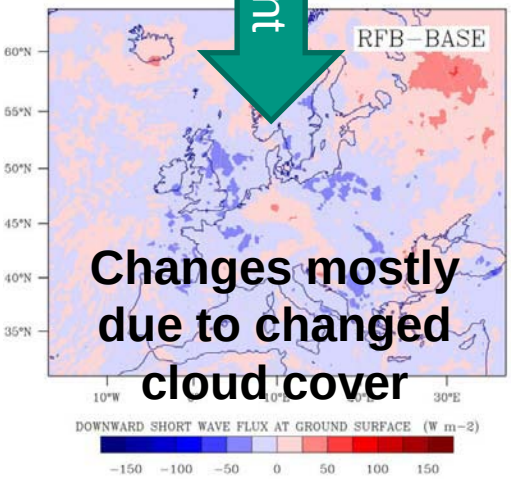




Direct & semi direct

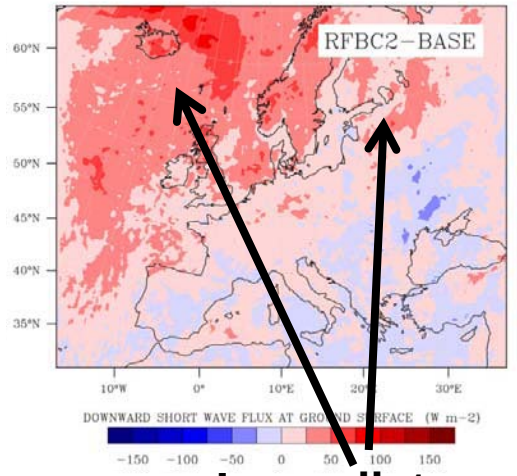


Development



Changes mostly due to changed cloud cover

higher aerosol BC



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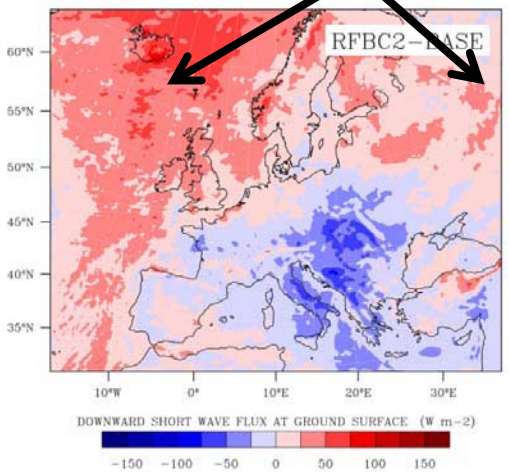
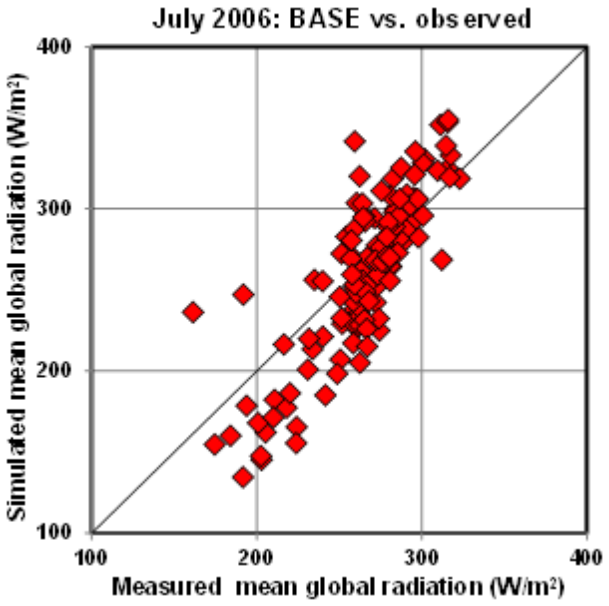
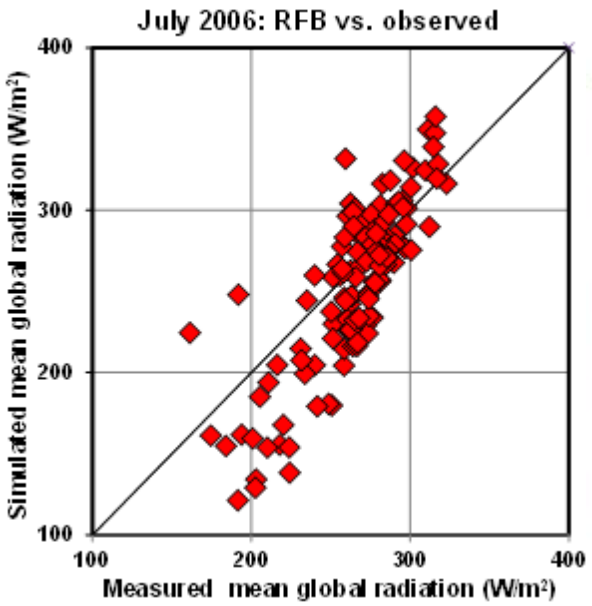
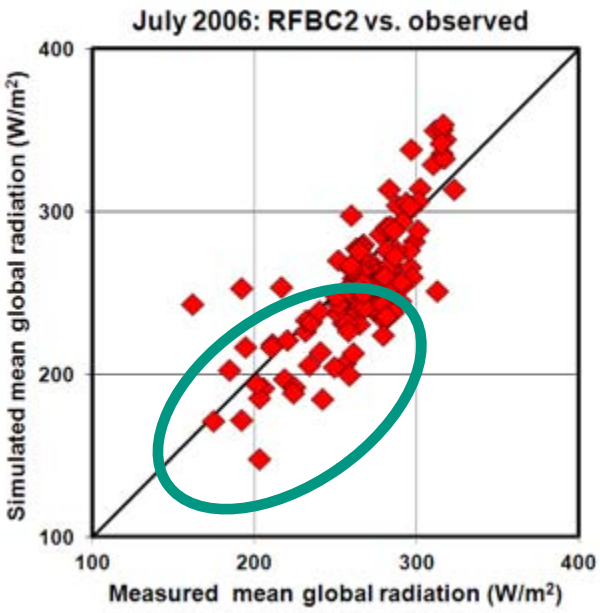


Solar Radiation



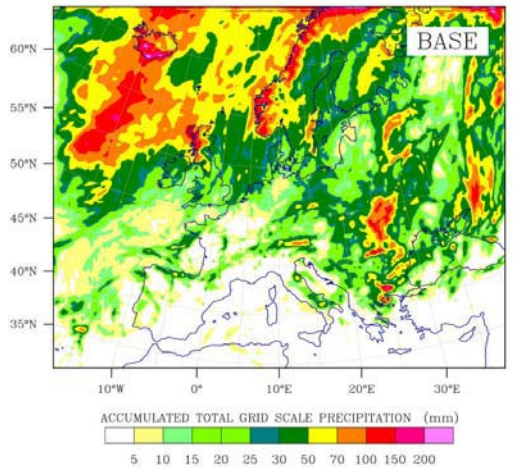
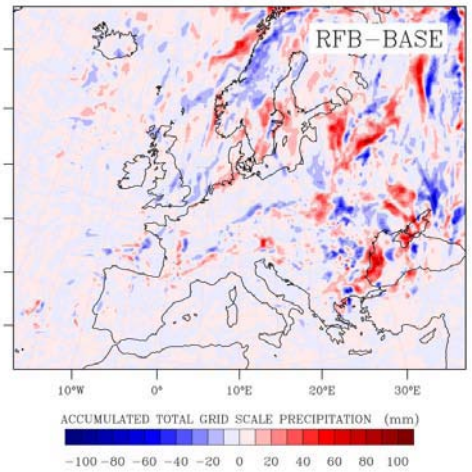
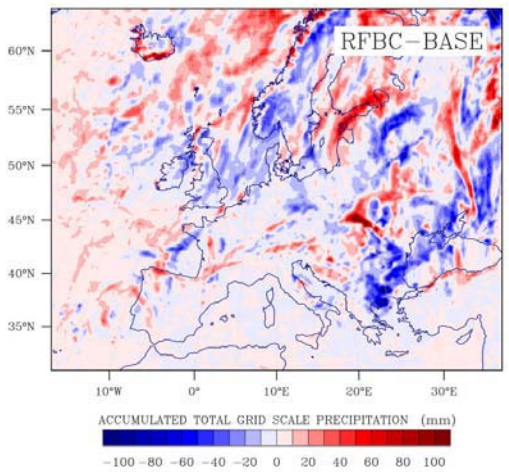
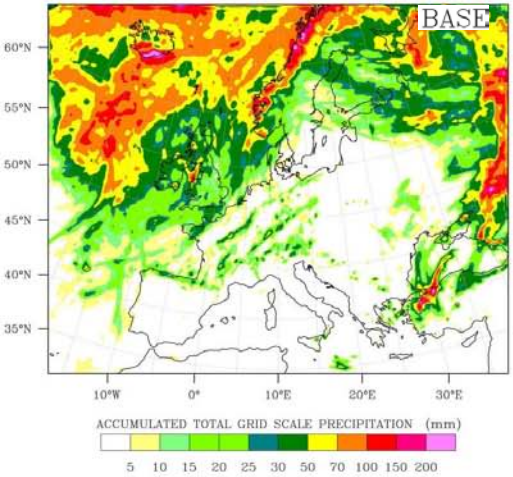
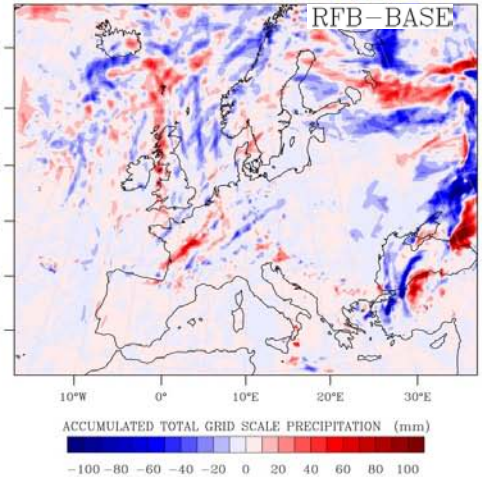
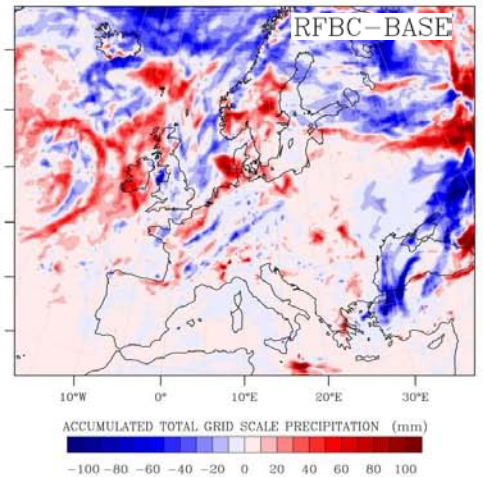




Simulated versus observations published by the WRDC

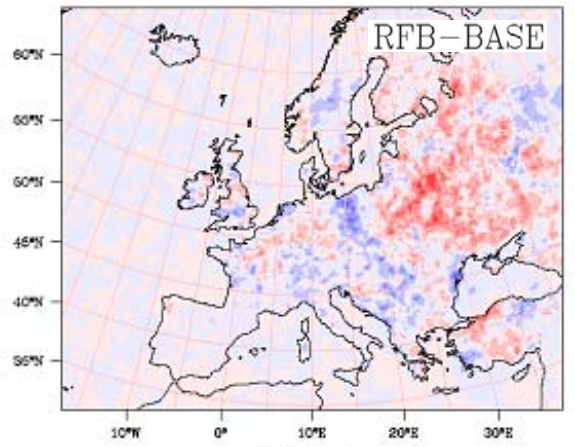
Better agreement particularly for cloudy conditions in Northern Europe

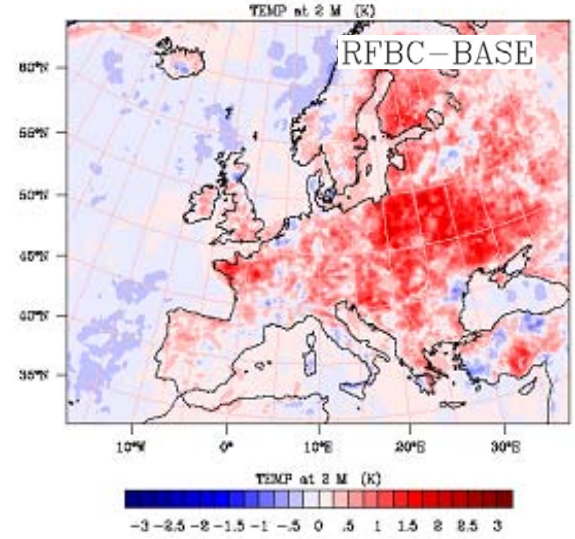
Grid Scale Precipitation

	No aerosol effect	Direct & semi direct	+ indirect effect
June			
July			

Near Surface Temperature

June

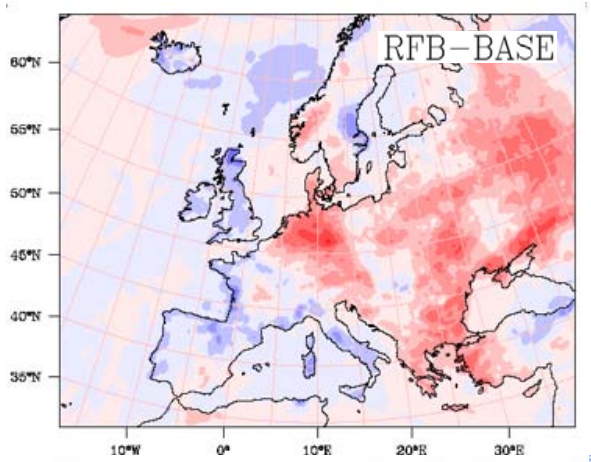


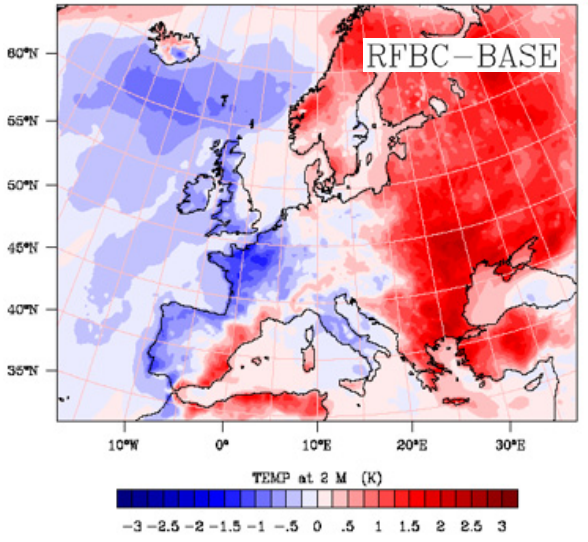


Direct & semi direct

+ Indirect

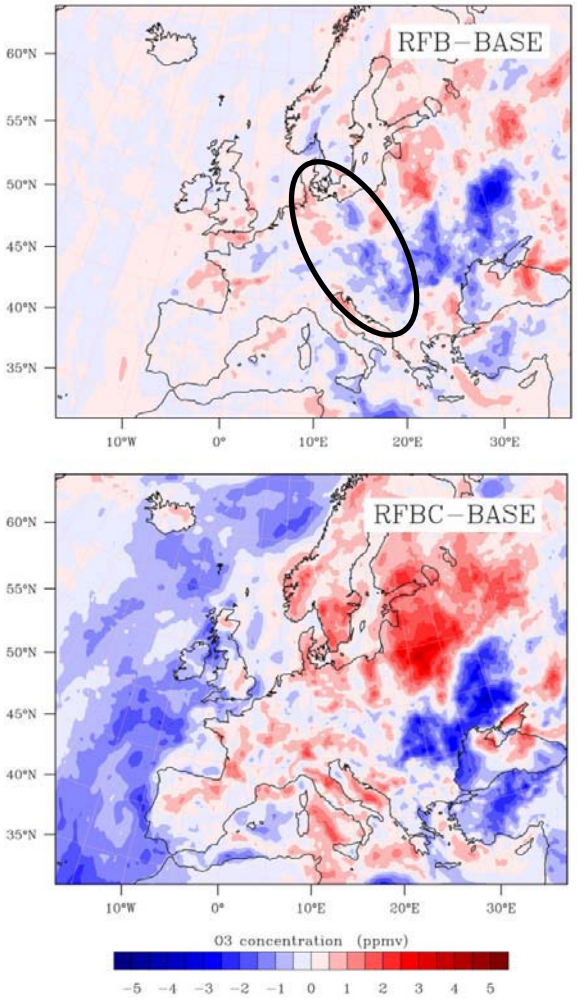
July





Ozone

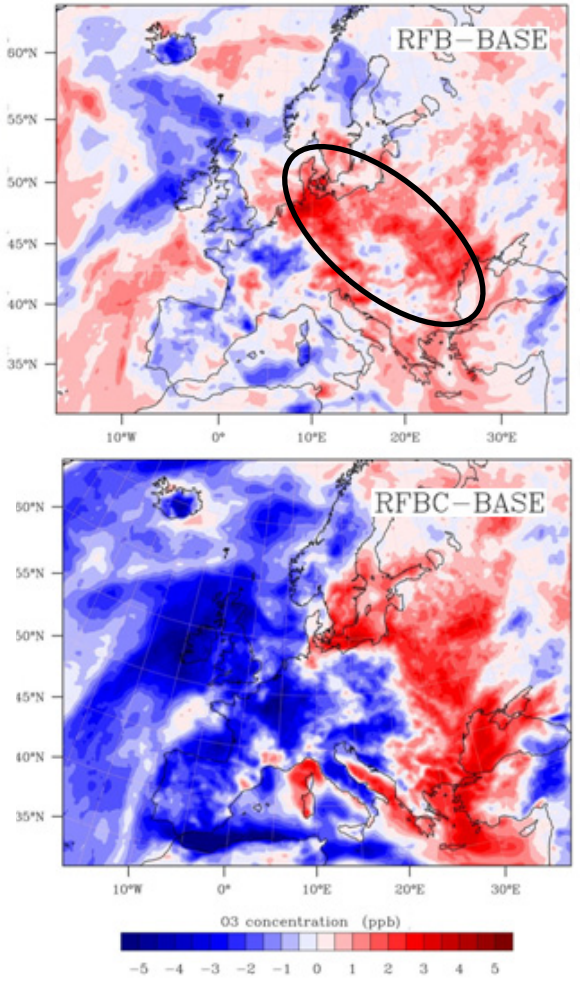
June



Direct & semi direct

+ Indirect

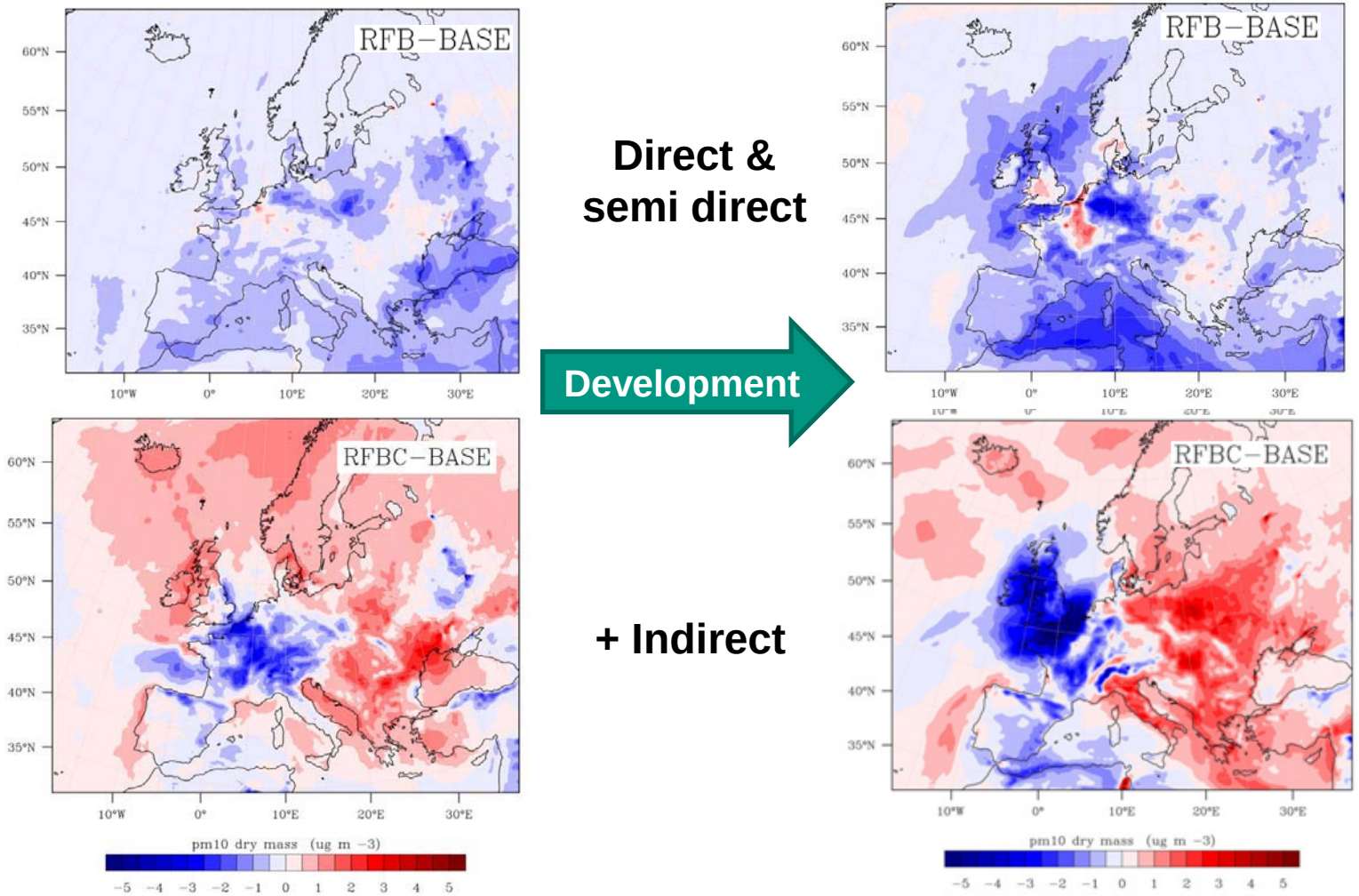
July



PM10

June

July

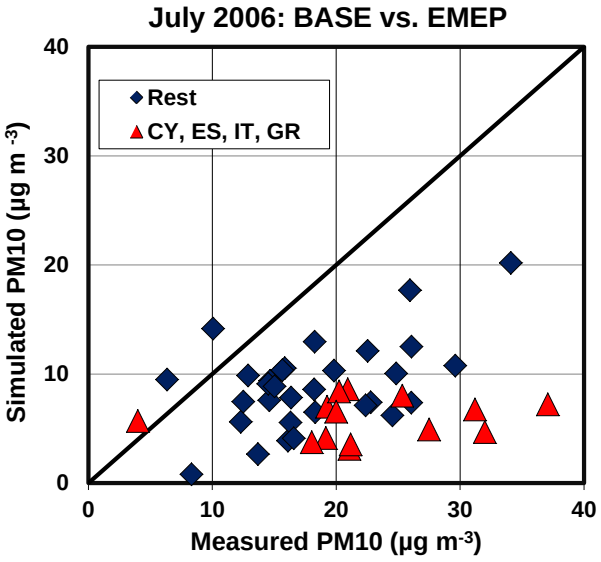


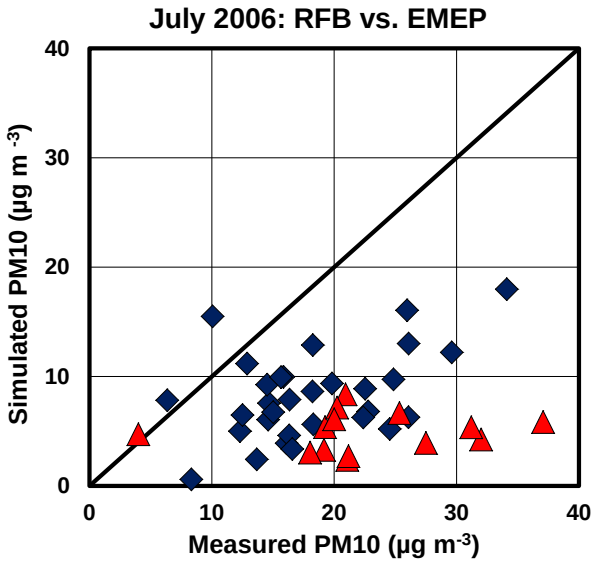
Direct & semi direct

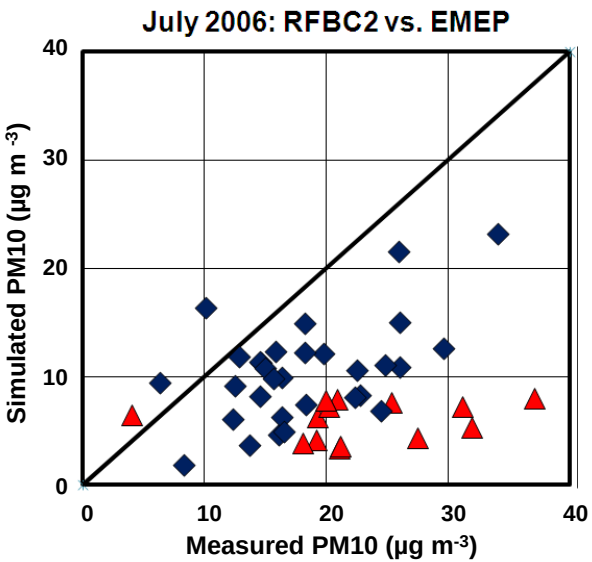
Development

+ Indirect

PM10







Simulated versus observed (EMEP data)

Simulated versus observed for higher boundary values for PM

Summary of results

- **Semi - direct effects (temperature, boundary layer, clouds) develop already after some days**
- **Semi - direct effects dominate the direct effect**
- **Development of semi direct effects become more dominant with time**
- **Indirect effects results immediately in a lower cloud water content over the North Atlantic; higher precipitation only over parts in the Northern Atlantic**
- **Better agreement with observed radiation for cloudy conditions in clean areas with indirect effect**
- **Up to 10% changes in O_3 and up to 50% change in PM after 2 months**

Conclusions

- **Episode of a specific meteorological situation →Snapshot of investigation**
- **Further investigations are necessary with higher horizontal resolution (cloud resolving resolution)**
- **Indirect effect for convective clouds necessary**
- **Mid- and long term impact of semi-direct effect still needs further investigation → AQMEII Phase 2 (more models with feedback)**
- **Nudging versus development of semi-direct and second indirect effect: What is the right balance?**

Thank you for your attention

Publication
Renate Forkel, Johannes Werhahn, Ayoe Buus Hansen, Stuart McKeen, Steven Peckham, Georg Grell, Peter Suppan (2012): **Effect of aerosol-radiation feedback on regional air quality - A case study with WRF/Chem.** Atmospheric Environment, 45, doi:10.1016/j.atmosenv.2011.10.009 (special issue about the AQMEII initiative)