Met Office

NERC SCIENCE OF THE ENVIRONMENT

Joint Weather & Climate Research Programme – a partnership in weather and climate research

Atmospheric Dry Deposition in JULES

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(3) Hadley Centre, UK Met Office

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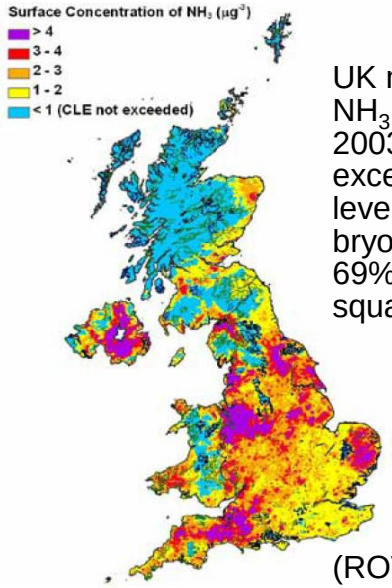
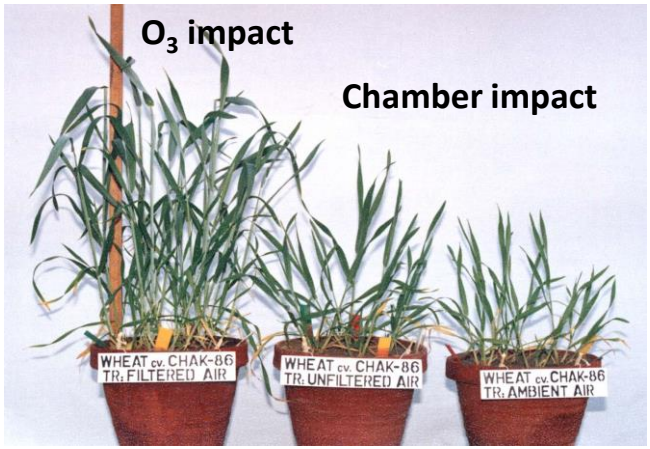
Atmospheric dry deposition

- Important atmospheric process
  - *Governs atmospheric abundance of many compounds (e.g., O_3, H_2O_2, HNO_3, SO_2, NH_3, aerosol, …)*
- Important process for the biosphere
  - *Governs input of key nutrients/oxidants to vegetation*
- Links atmosphere and biosphere
  - *Contributes to climate and Earth system feedbacks*



UK map of modelled NH_3 concentrations for 2003 showing exceedance of critical levels for sensitive bryophyte and lichen in 69% of the 1-km grid squares

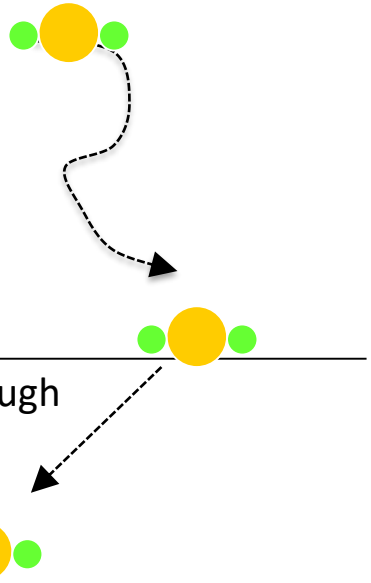
(ROTAP, 2012)



O_3 injury to wheat, Pakistan (courtesy of A. Wahid)

- Policy-relevant implications for air quality, crop yields, etc.
  - *Critical loads for acid deposition and eutrophication*
  - *Ozone exposure and effects on human health and vegetation*
  - *Particulate matter (aerosol) and impact on human health*

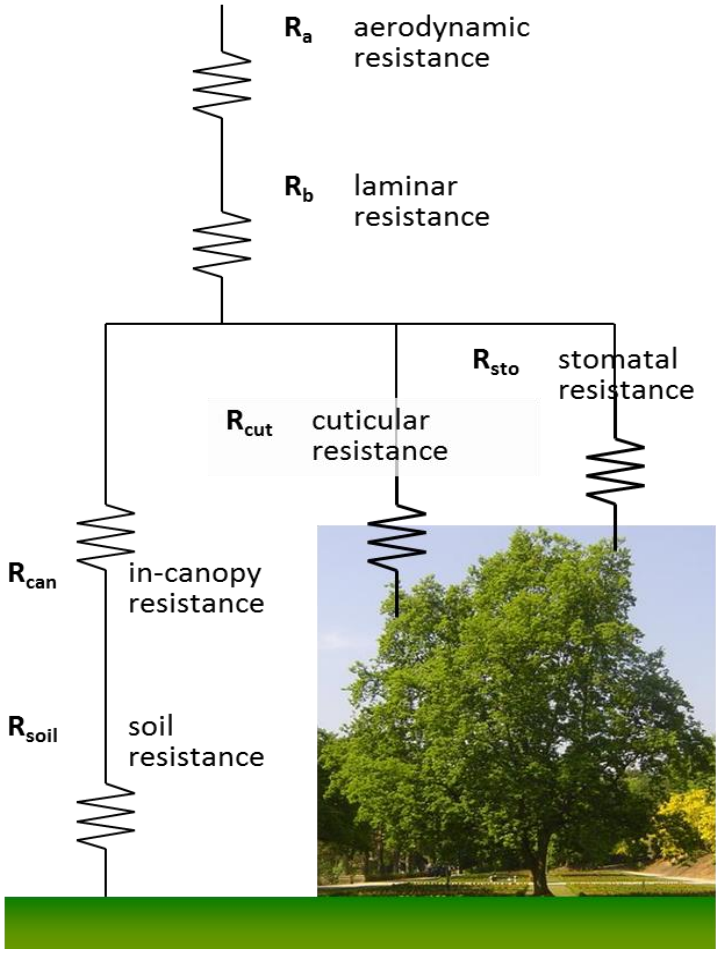
Modelling dry deposition processes



1. **Turbulent transport** through atmosphere

2. **Molecular diffusion** through laminar sub-layer

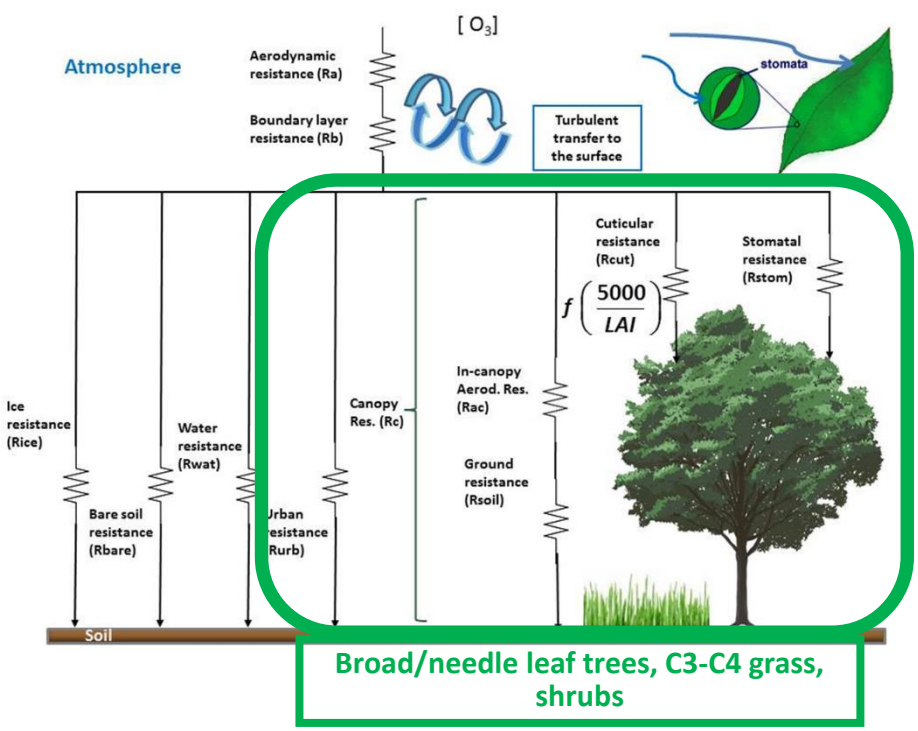
3. **Uptake** on surface by adsorption, followed by dissolution or reaction (depends on surface type: vegetation, soil, water, light, etc.)



- Many atmospheric chemical transport models, including UK chemistry-climate and Earth System models, use a “Wesely-resistance” approach
- Atmospheric dry deposition currently in UKCA

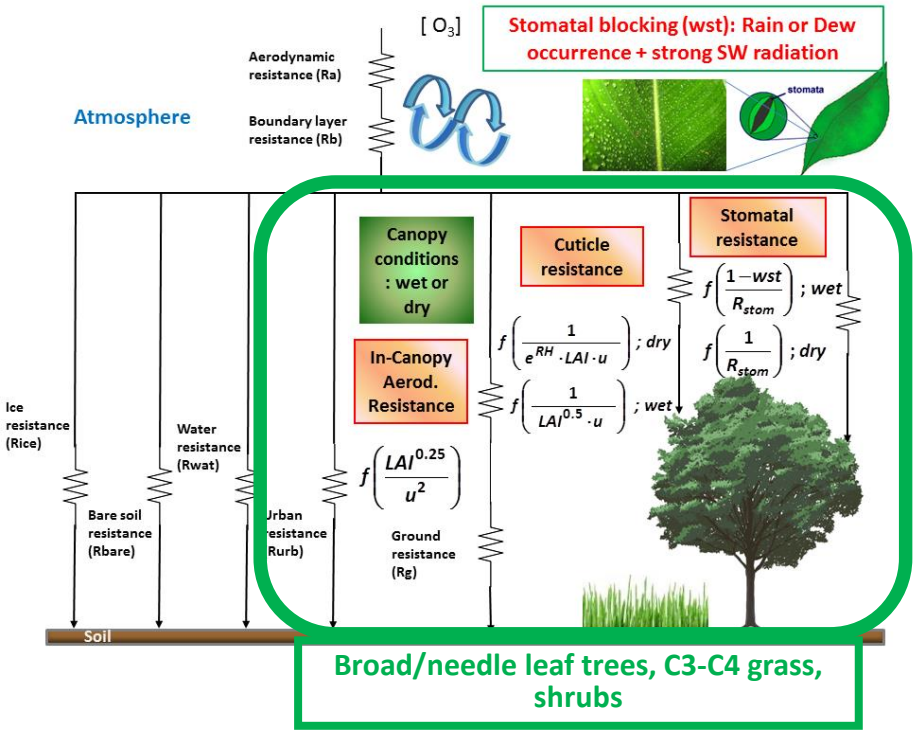
Dry deposition schemes in the UKCA model

Current scheme in UKCA (UKESM)



- Wesely (1989) scheme for gas-phase species
- Deposition of aerosol species based on roughness length and the use of prescribed deposition velocities. Also sedimentation.
- Need to mirror pft order/description used in JULES

HadGEM3 branch
F. Centoni (CEH & U. Edinburgh)



- Implementation of Zhang et al. scheme (Atmos. Chem. Phys. 2003) for O_3
- Allows for stomatal blocking when wet, which reduces stomatal uptake.

Dry Deposition Velocity

$$V_d = \frac{1}{R_a + R_b + R_c}$$

R_a - *Aerodynamic resistance*
R_b – *Qasi laminar layer resistance*
R_c – *Surface resistance*

$$R_c = LAI\ R_s + R_{ns}$$

R_s - *Stomatal resistance*
R_{ns} – *Non stomatal resistance*

Current position

- Code development
  - Deposition I/O in JULES trunk from vn5.5 (Doug Clark)
  - JULES with Atmospheric Deposition (for UKCA 'as is' and flexible tiling):
    https://code.metoffice.gov.uk/trac/jules/browser/main/branches/dev/garryhayman/JULES_vn6.1_atmospheric_deposition
    https://code.metoffice.gov.uk/trac/um/browser/main/branches/dev/garryhayman/vn12.0_JULES_atmospheric_deposition
  - JULES with Atmospheric Deposition (implementing deposition scheme of Zhang et al.):
    https://code.metoffice.gov.uk/trac/jules/browser/main/branches/dev/garryhayman/JULES_vn5.9_atmospheric_deposition_zhang
  - Identified 'bug' in existing UKCA surface resistance routine: parts of code hardwired to 5-pft configuration. Now corrected by Alan Hewitt:
    https://code.metoffice.gov.uk/trac/um/browser/main/branches/dev/alanjhewitt/vn11.1_fix_npft
  - Identified further 'bugs' in existing UKCA deposition routines, reported to ukca_bugs

- Model runs and testing
  - Wesely (1989) Scheme – JULESvn5.9
  - EMEP Surface resistance - JULES vn5.9
  - Zhang et al.,(2003) scheme - JULES vn5.9 and vn6.1

Site-specific runs

- Adapted JULES FLUXNET suite (u-al752) to use JULES Deposition Branch: u-bh191
- Suite upgraded to use JULES vn5.9
- Sourcing and collating driving meteorological, ancillary and deposition-related measurements for model evaluation

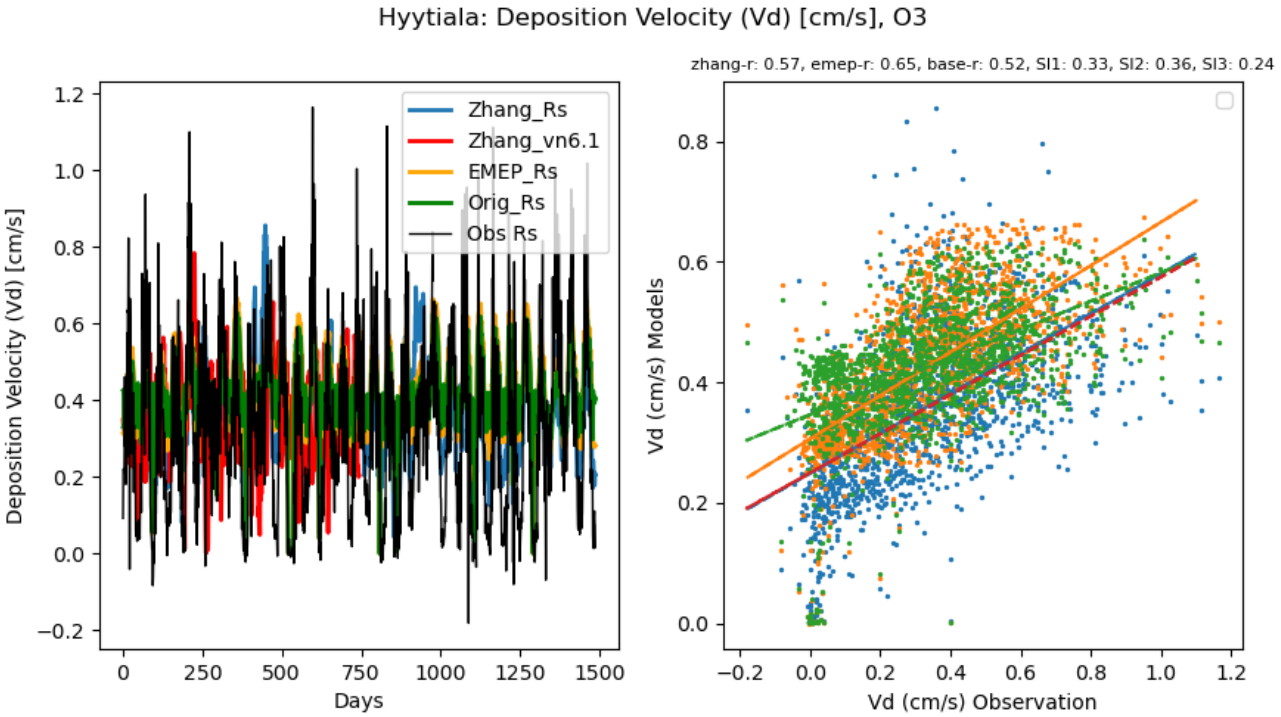
Site	Site biome	Data Availability			Part of JULES FLUXNET Suite
		Met.	Ancillary	Deposition	
Harvard Forest (US)	Deciduous broad-leaf forest	Y	Y	Not Yet	Y
Blodgett Forest (US)	Evergreen needle-leaf forest	Y	Y	Not Yet	Y
Hyytiälä (FI)	Evergreen needle-leaf forest	Y	Y	Y: O_3	Y
Castel Porziano (IT)	Evergreen broad-leaf forest	Y	Y	Y: O_3	Y
Grignon (FR)	Crop	Y	Y	Y: O_3	Y
Oensingen (CH)	Grassland	Y	Y	Y: O_3	Y
Alice Holt (UK)	Broadleaf woodland				
Auchencorth Moss (UK)	Ombrotrophic peatland	Y	Y	Y	
Easter Bush (UK)	Improved grassland	Y	Y	Y	

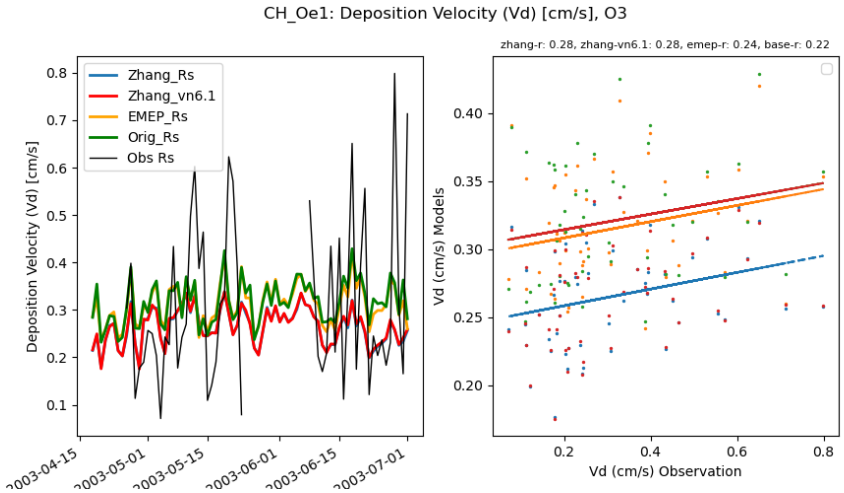
Assistance of Karina Williams, Eddy Comyn-Platt and Carolina Duran Rojas gratefully acknowledged

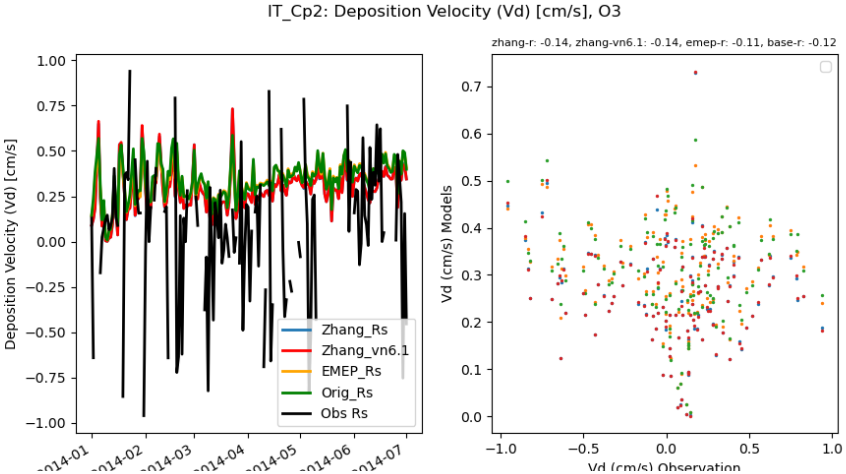
Surface Resistance Values

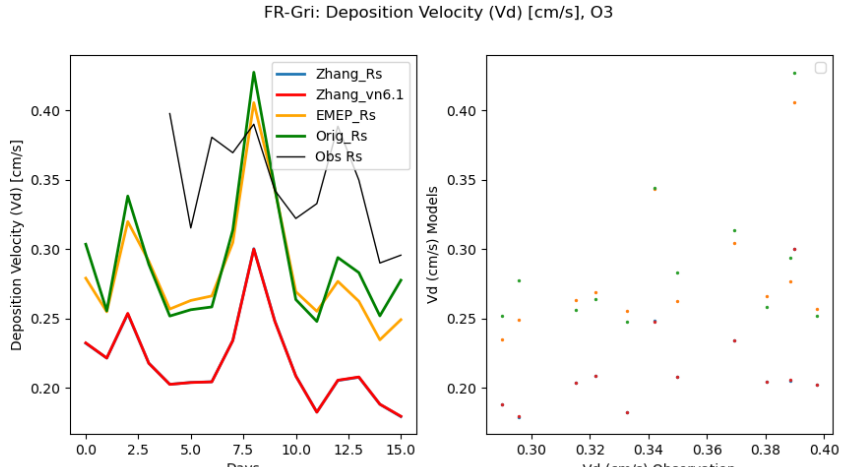
	Wesely	EMEP
R_tundra	800.0	400.0
R_wetsoil	500.0	400.0
BL_Deciduous	285.7	543.2
BL_Evergreen	280.4	278.7
BL_Temperate	307.7	278.7
NL_Deciduous	233.5	543.2
NL_Evergreen	232.6	276.2
C3G	355.0	271.6
Shrub_deciduous	645.0	2000.0

Deposition Velocity

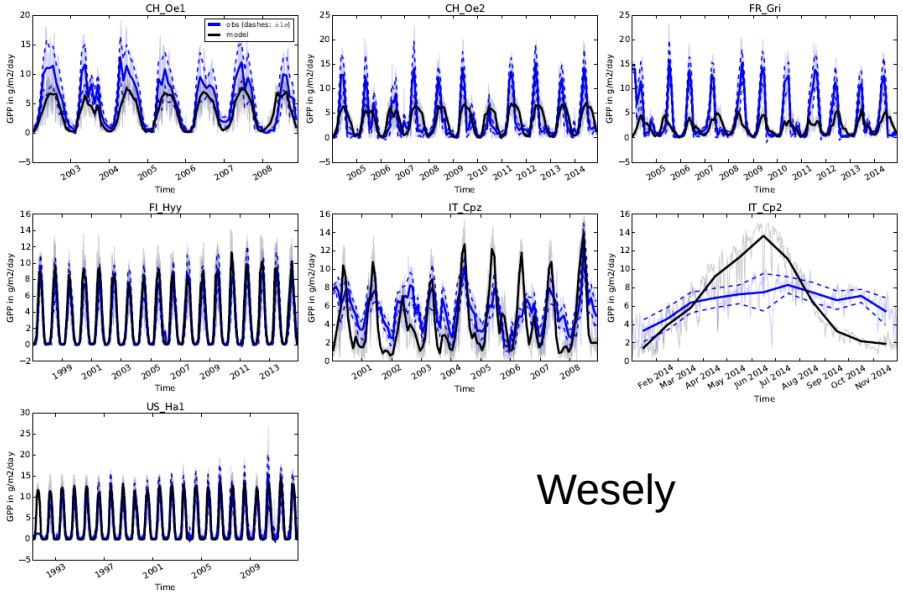




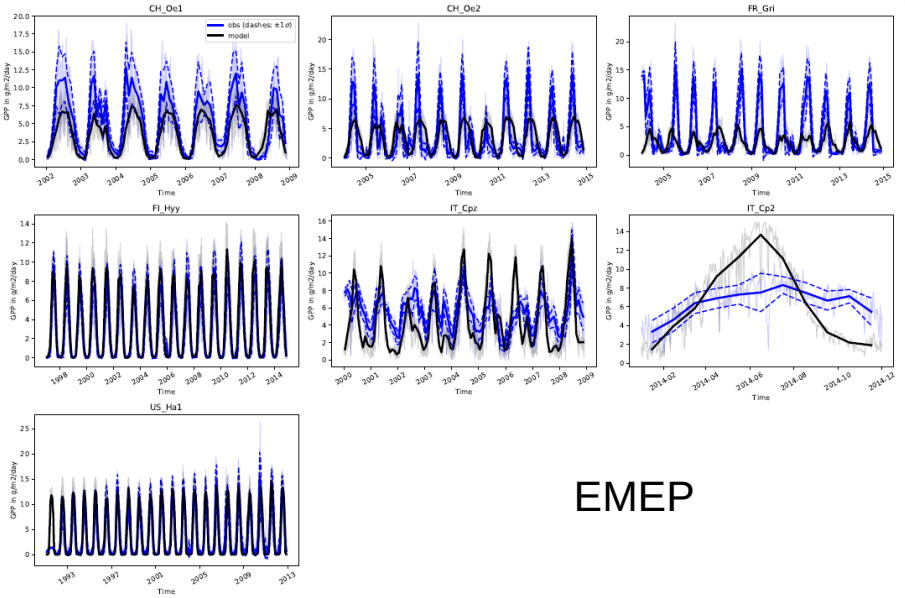




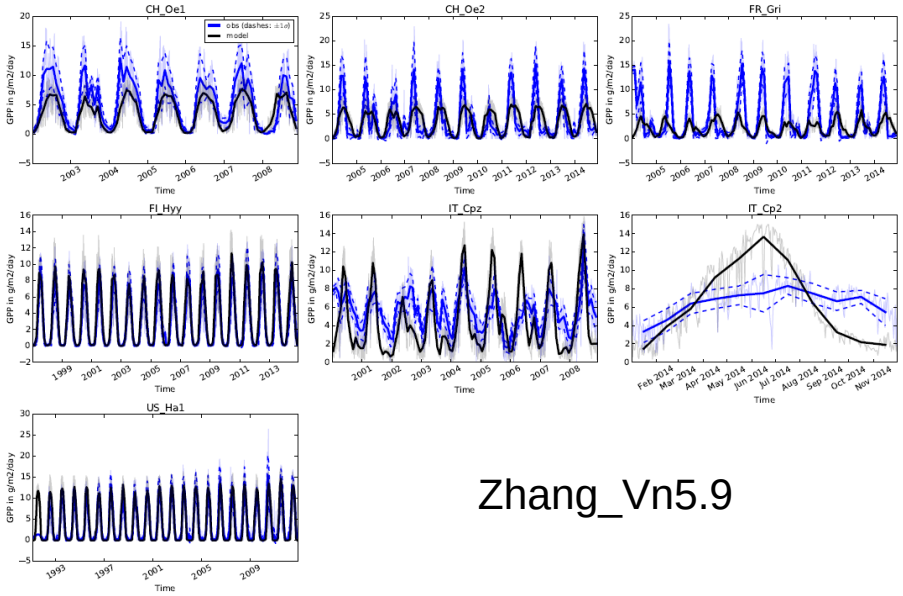
Results: Gross Primary Productivity



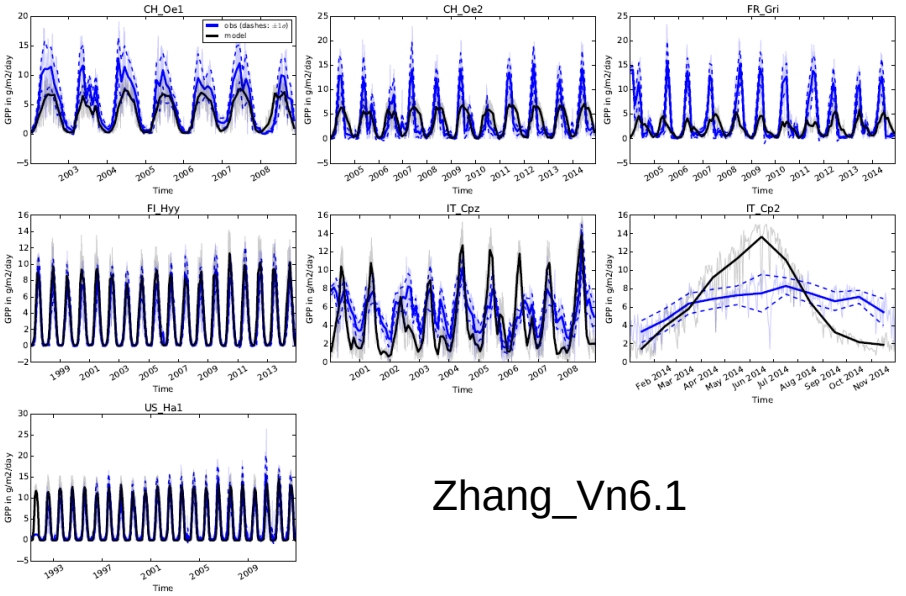
Wesely



EMEP



Zhang_Vn5.9



Zhang_Vn6.1

Dry Deposition in UKESM

- Code into JULES & UM trunks
  - To allow flexible tiling for UKESM applications and to use UM-UKCA with 2 urban surfaces
  - Starting science review
  - Metadata and upgrade marcos
  - Deposition diagnostics & stash
  - Aiming for release after October 2021

Future Requirements

- Consistency between UKCA (Gas and Aerosols) and JULES as more land surface types added
- Deposition to other surfaces, e.g., ocean and cryosphere
- Aerosol Deposition
- Move towards more process-based dry deposition schemes, especially for aerosol species
- Longer-term: Move towards ‘bidirectional surface exchange’ schemes: deposition, (re-) emission and PBL mixing