SAWS AQ Modeling and Forecasting

Air Quality Assessment, Forecasting and Integrated Services

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PREFIA, Nairobi, Kenya

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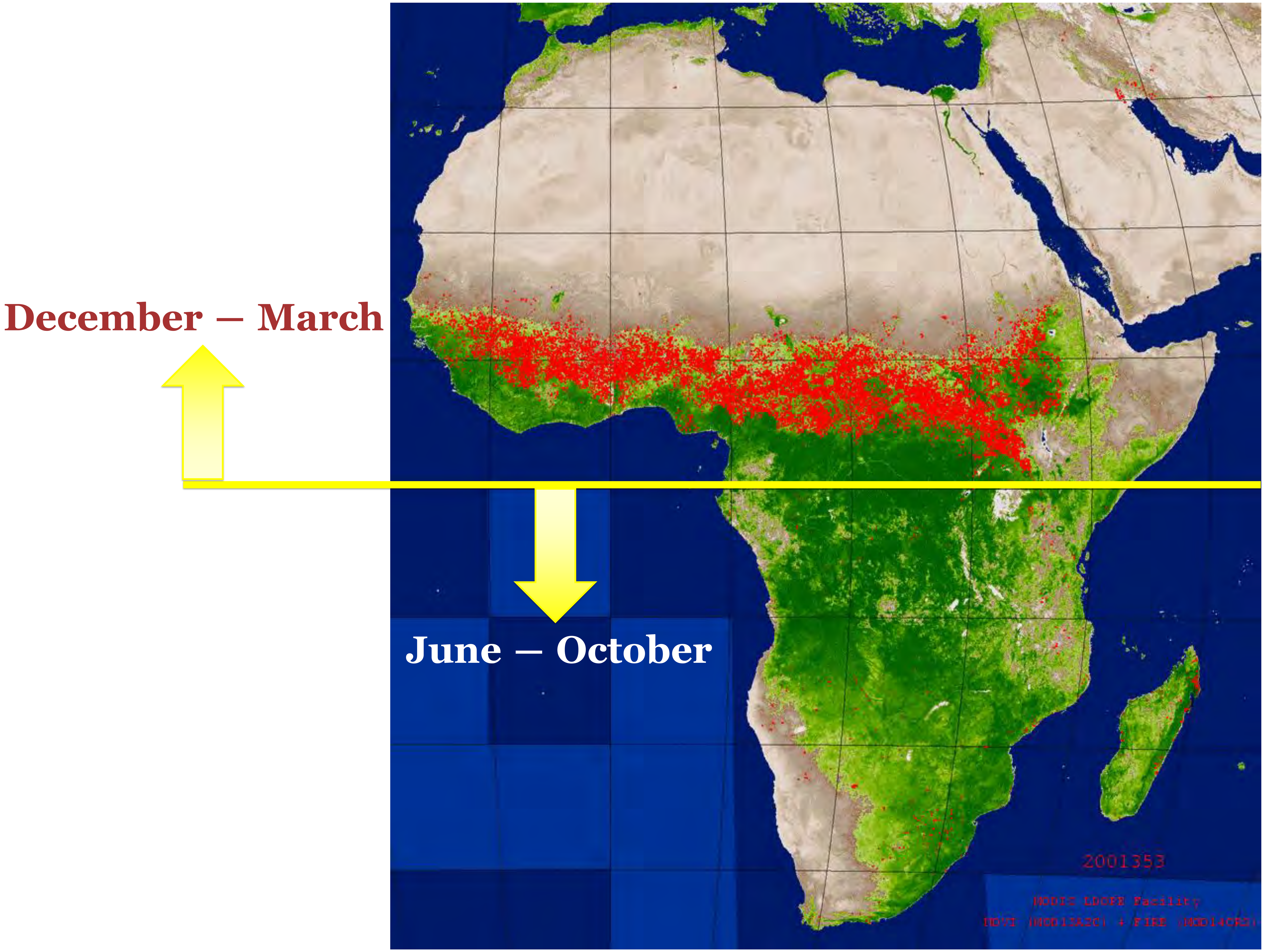
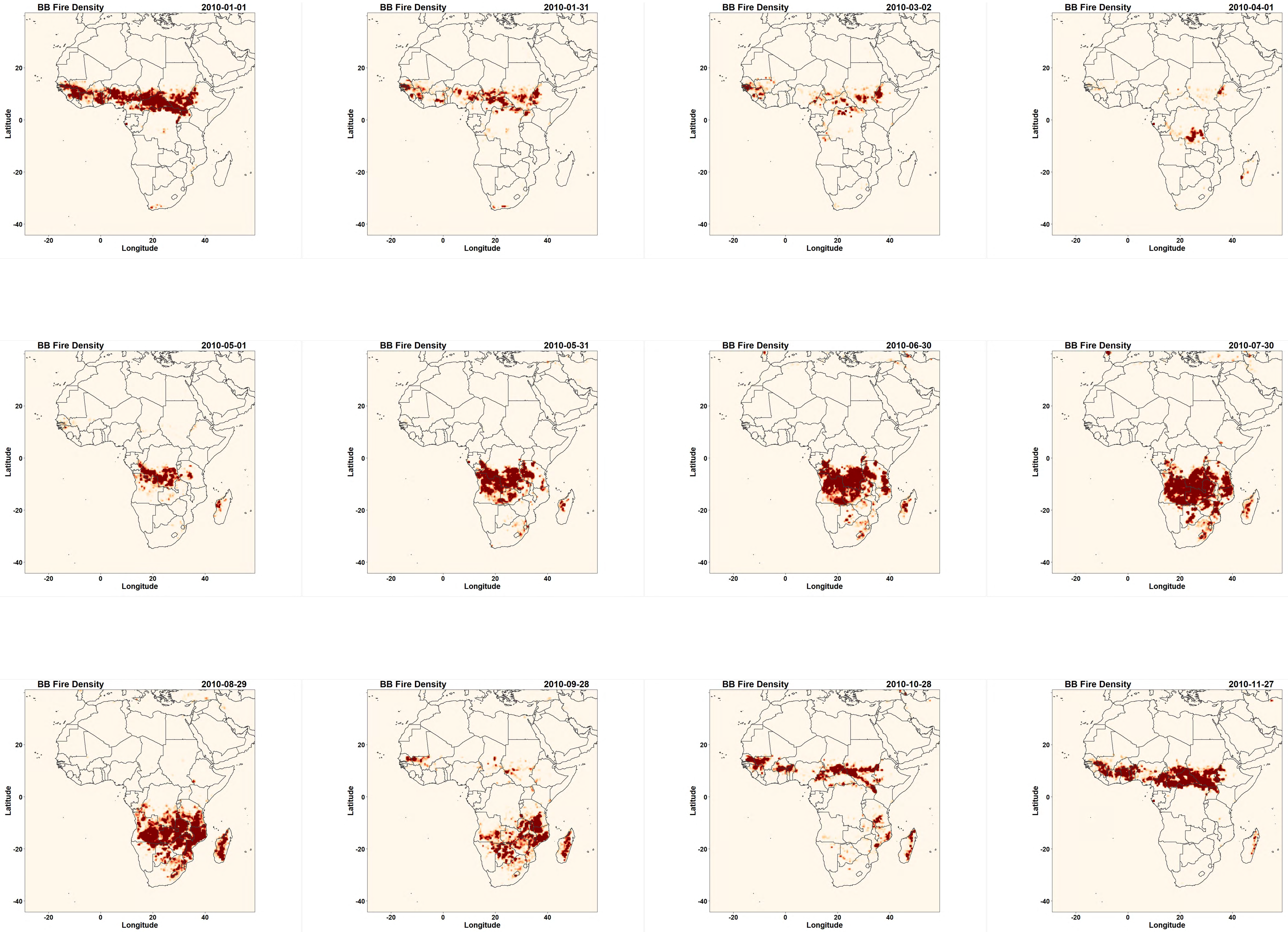
South African
Weather Service

Background: Main Sources Air pollution Africa



South African Weather Service

Background: Main Sources Air pollution Africa



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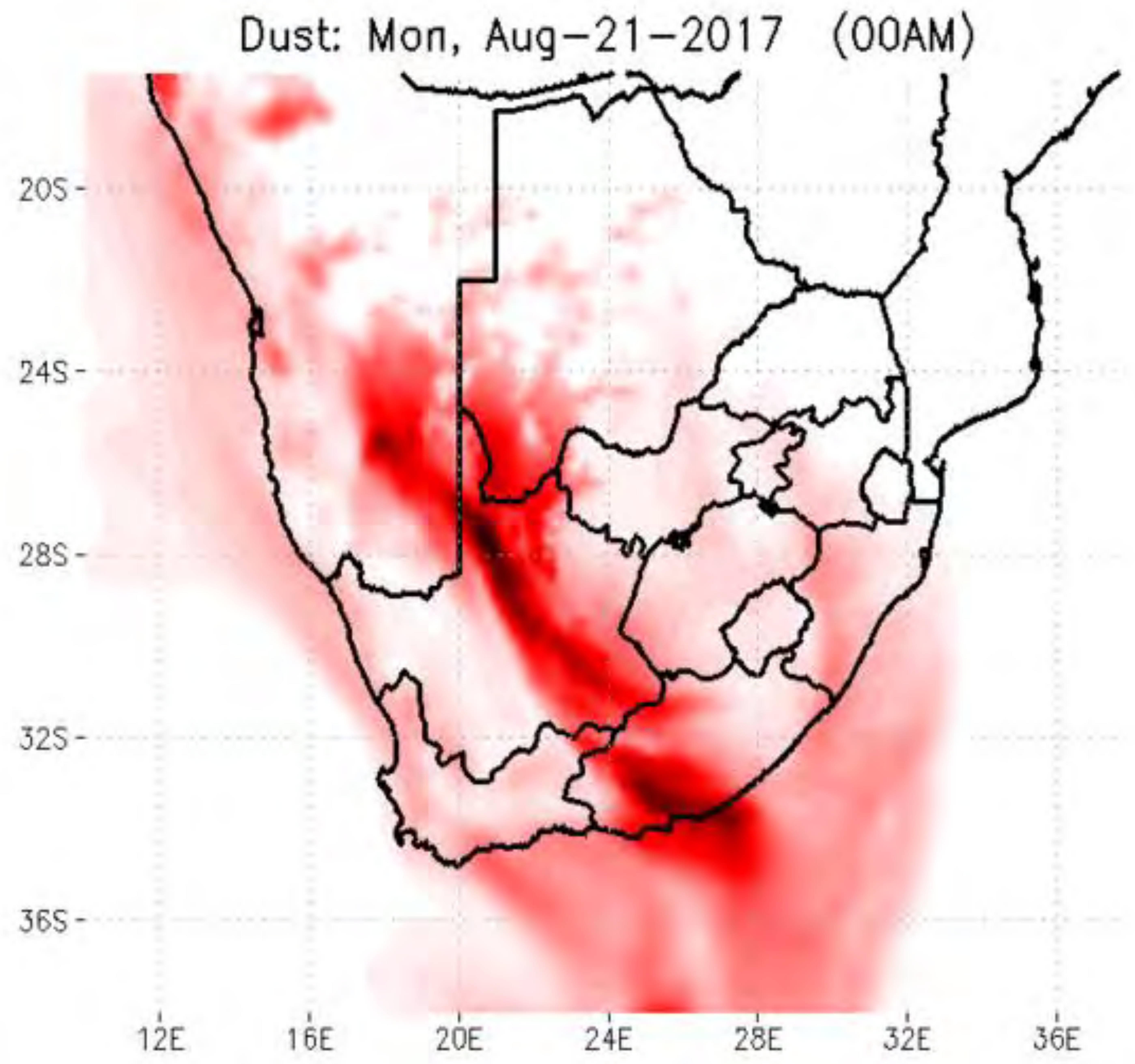
Background: Main Sources Air pollution Africa



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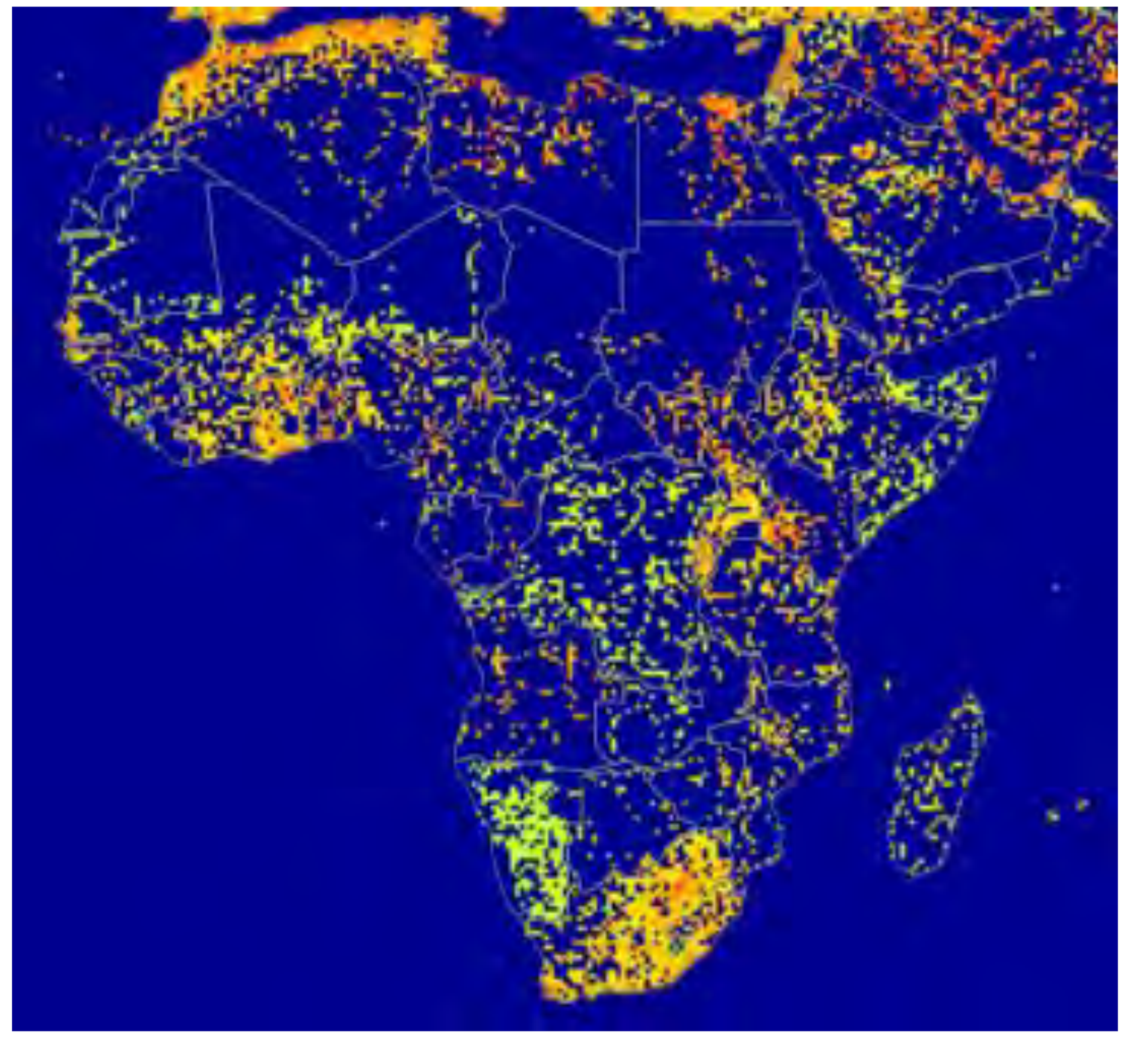
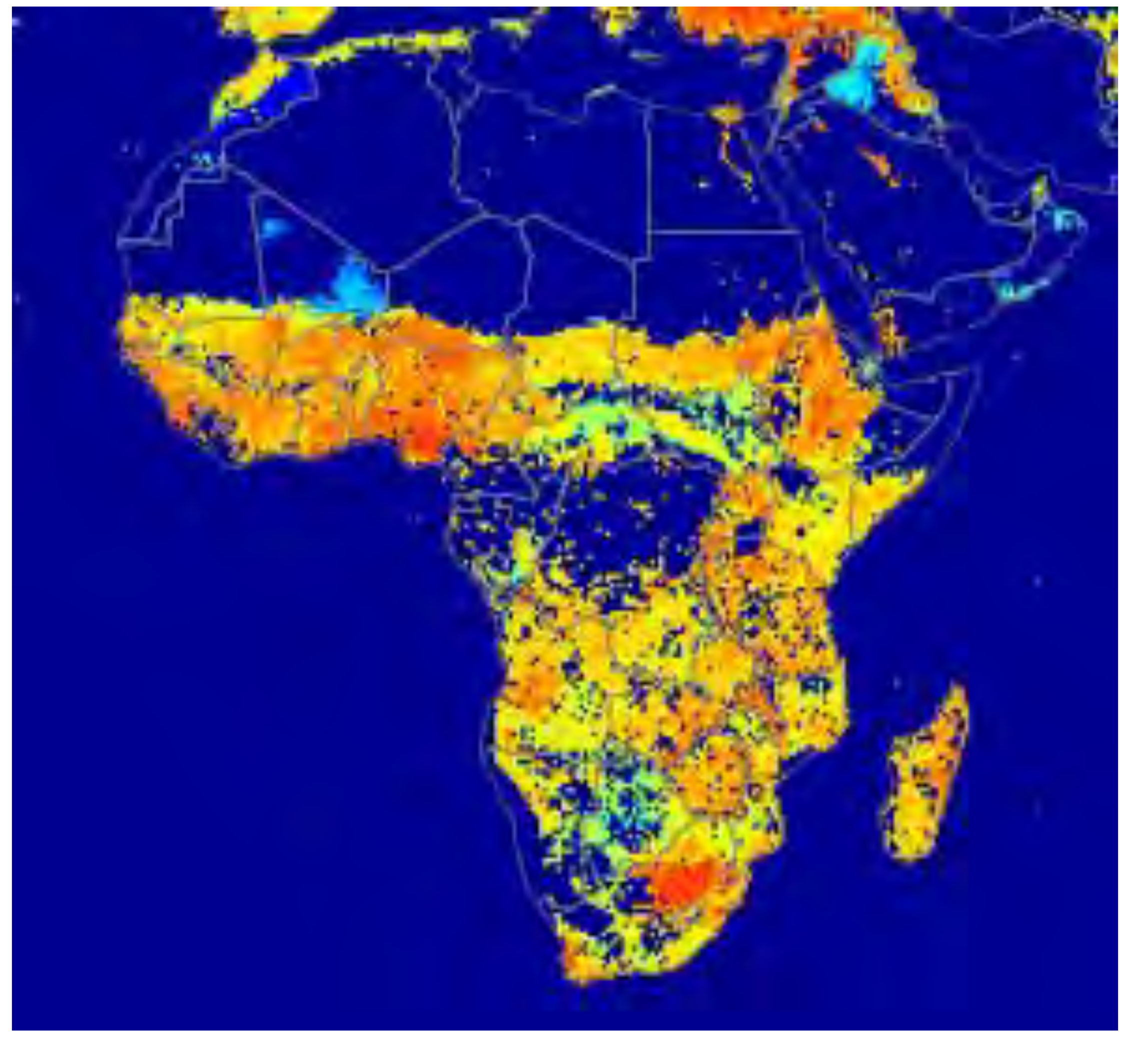
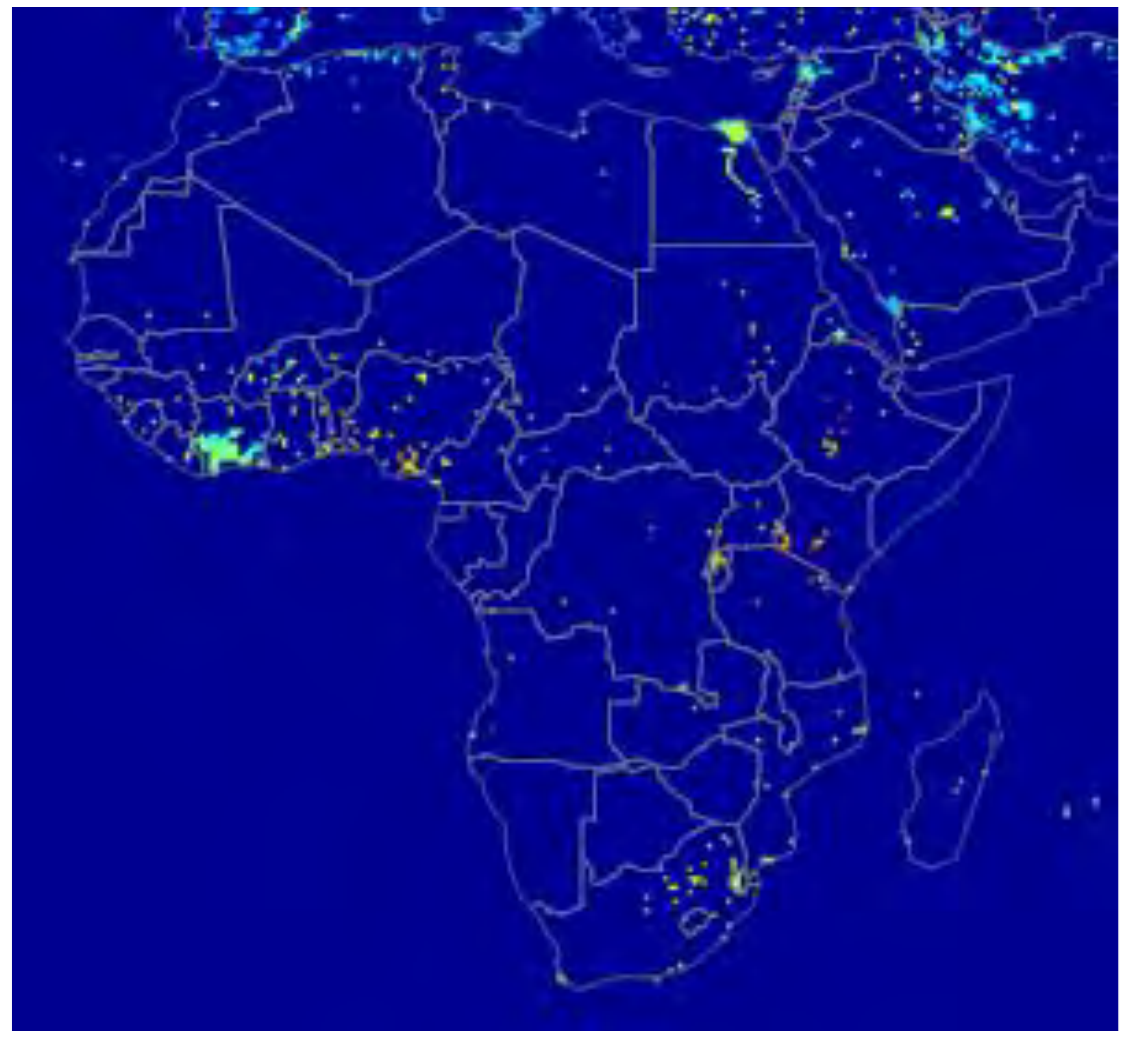
Background: Main Sources Air pollution Africa

EDGARv4.3.2 Anthropogenic


Road transportation

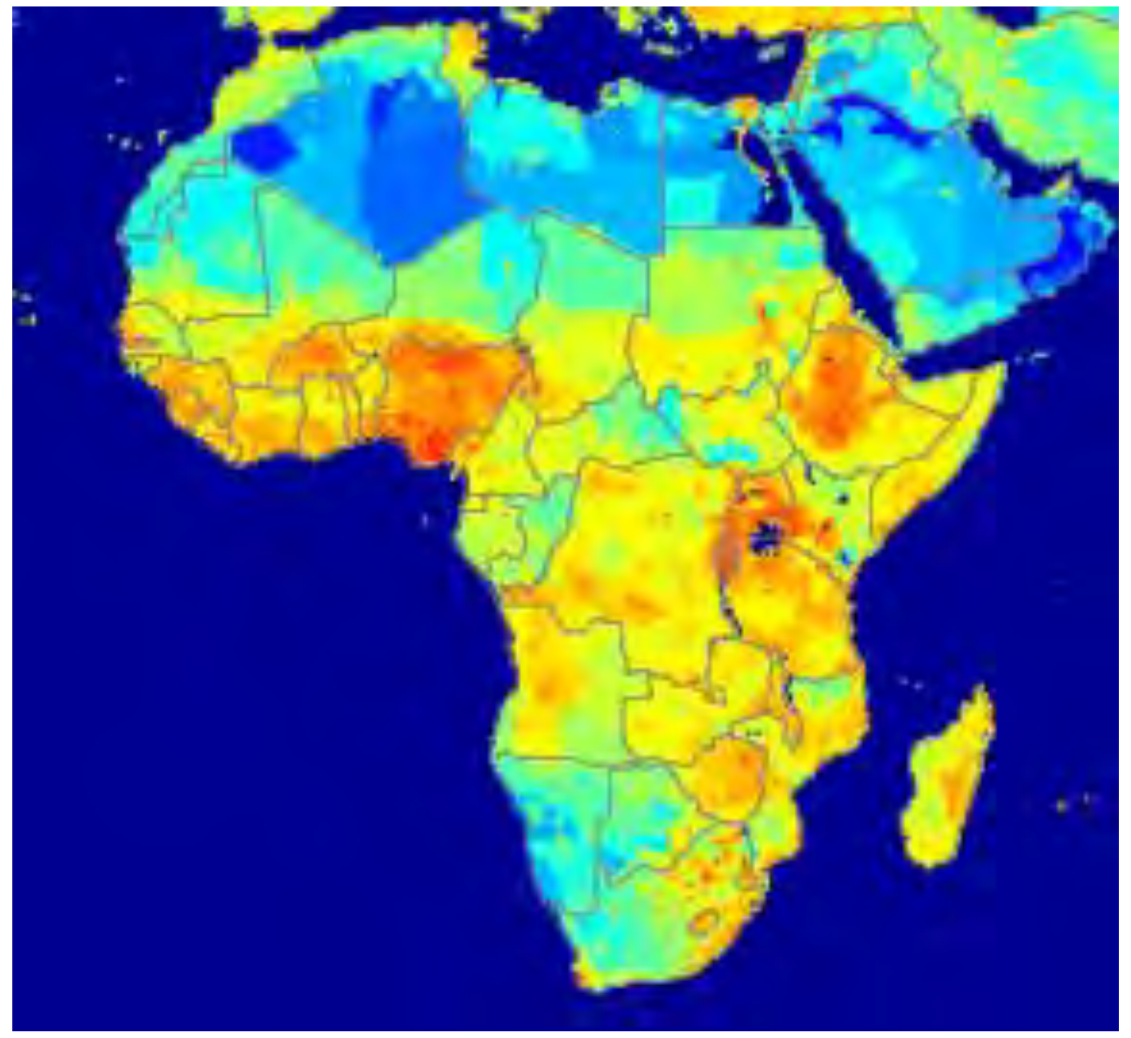

Agricultural waste burning


Oil refineries and Transformation


Energy industry


Combustion in manufacturing


Fuel exploitation


Residential and other sectors

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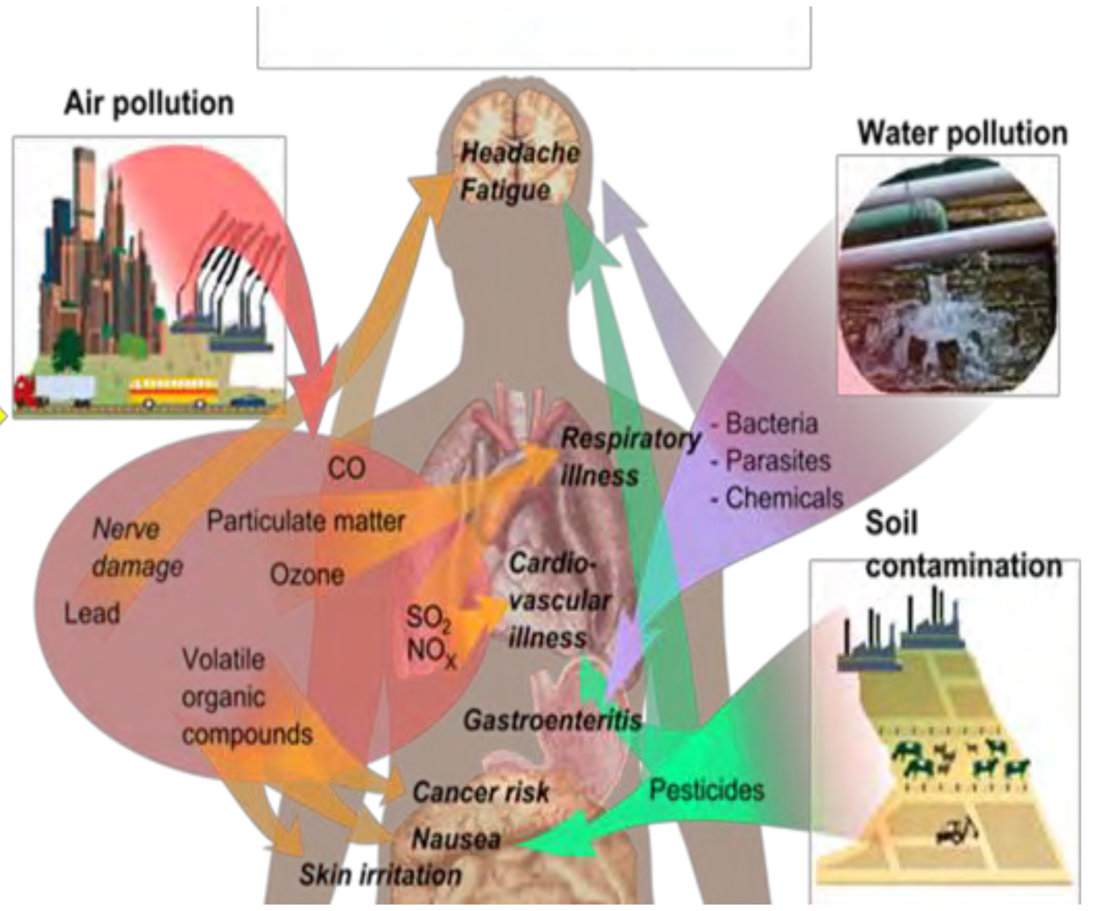
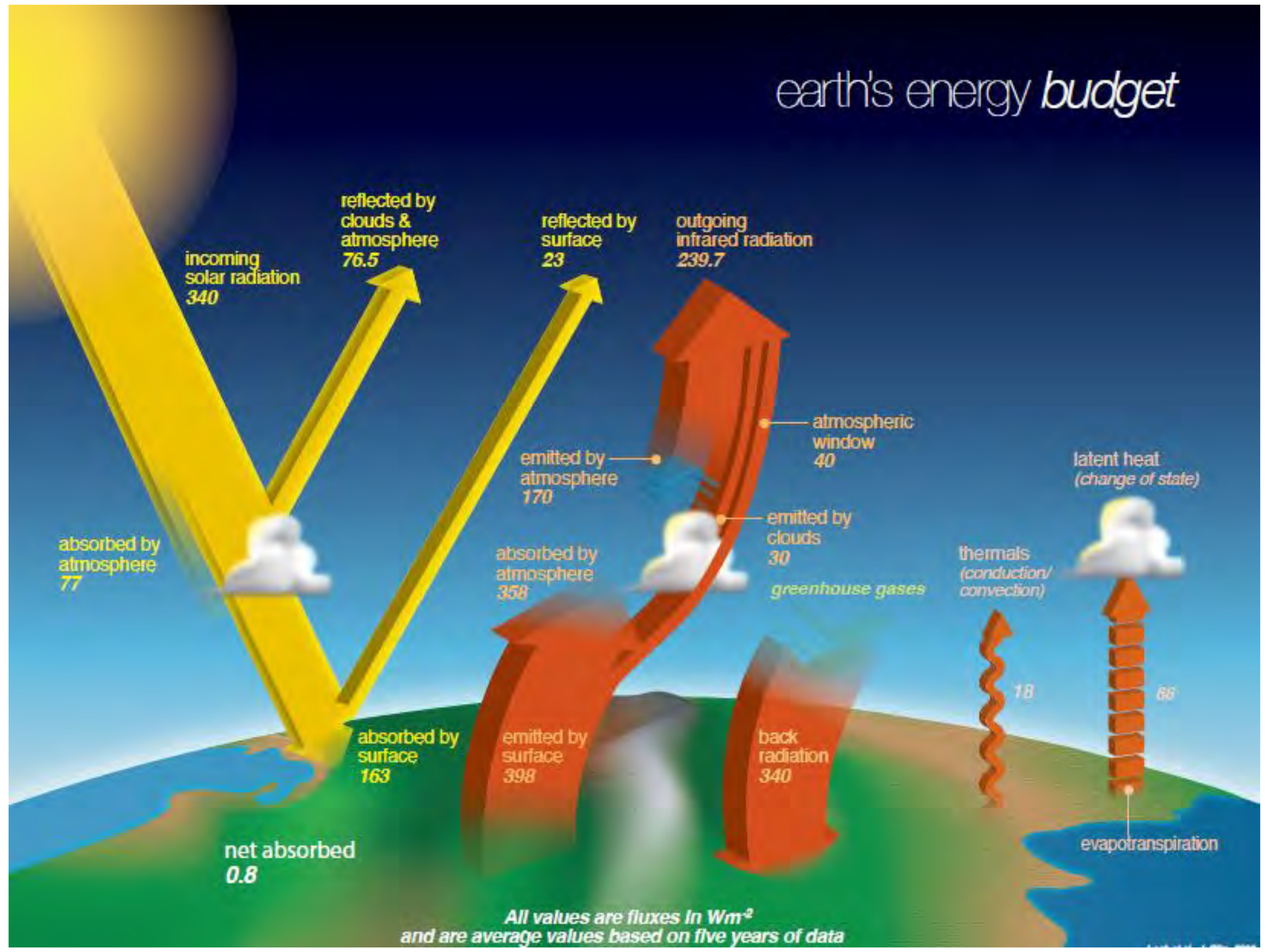
Background: Air pollution impacts

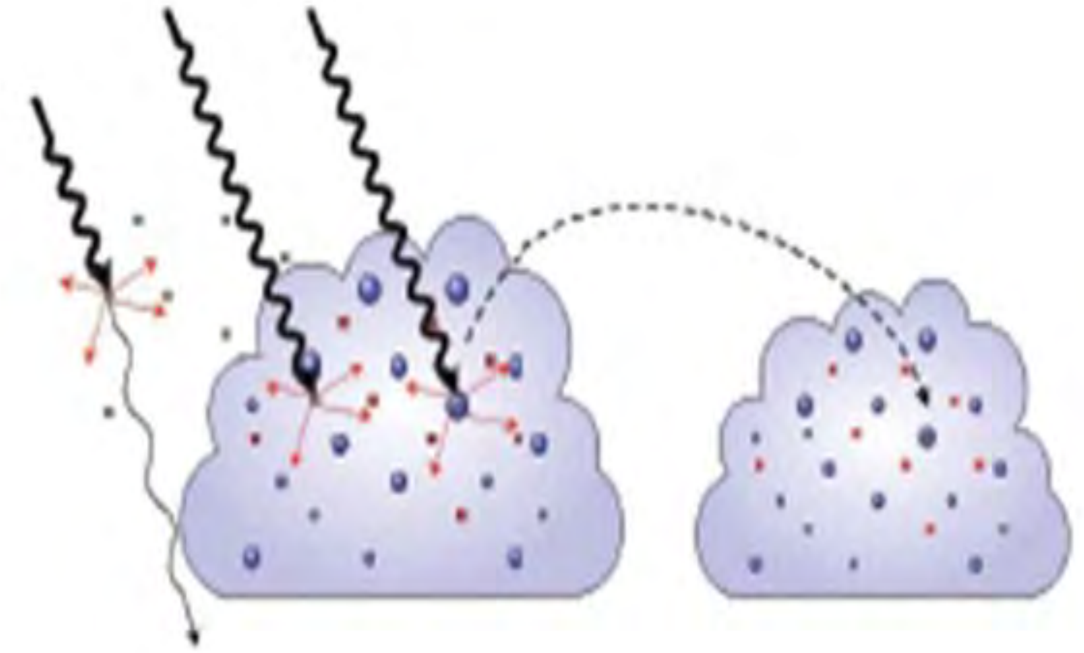
- Health

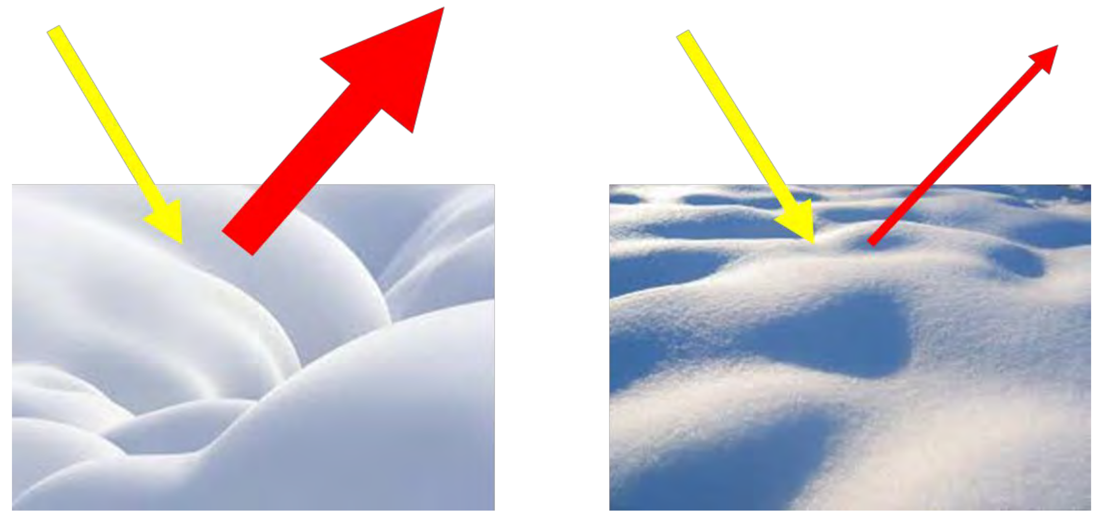


- Radiative transfer

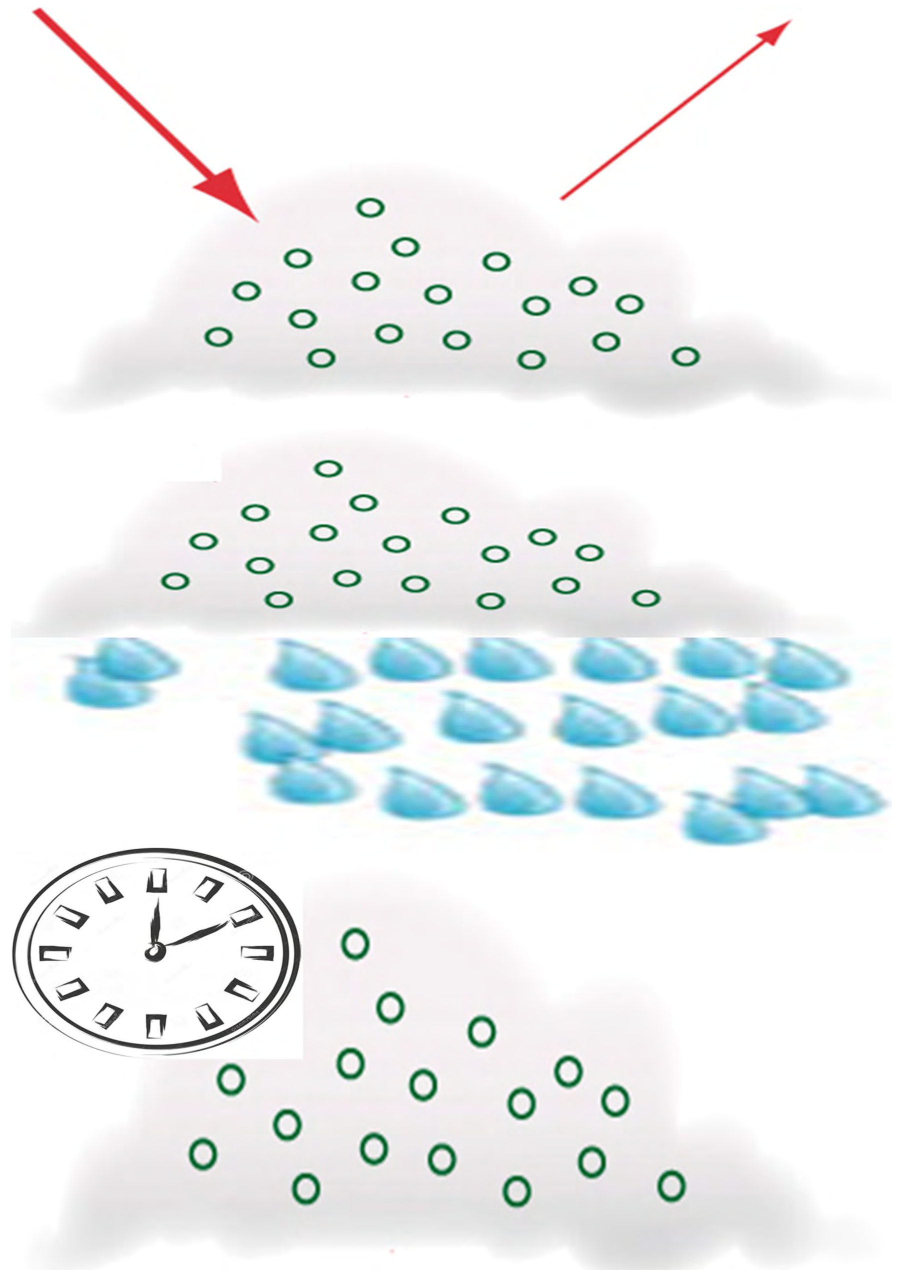


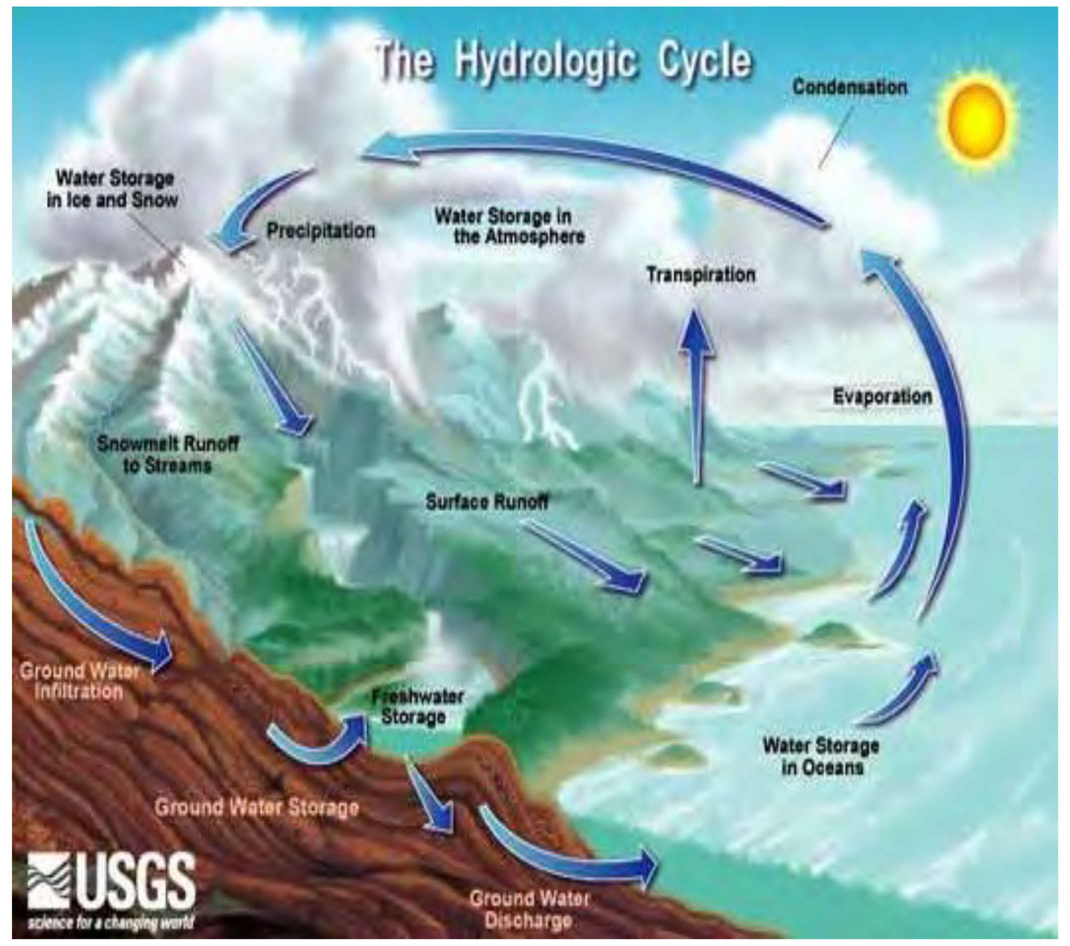
- Semi-direct Effect





- Indirect Effect





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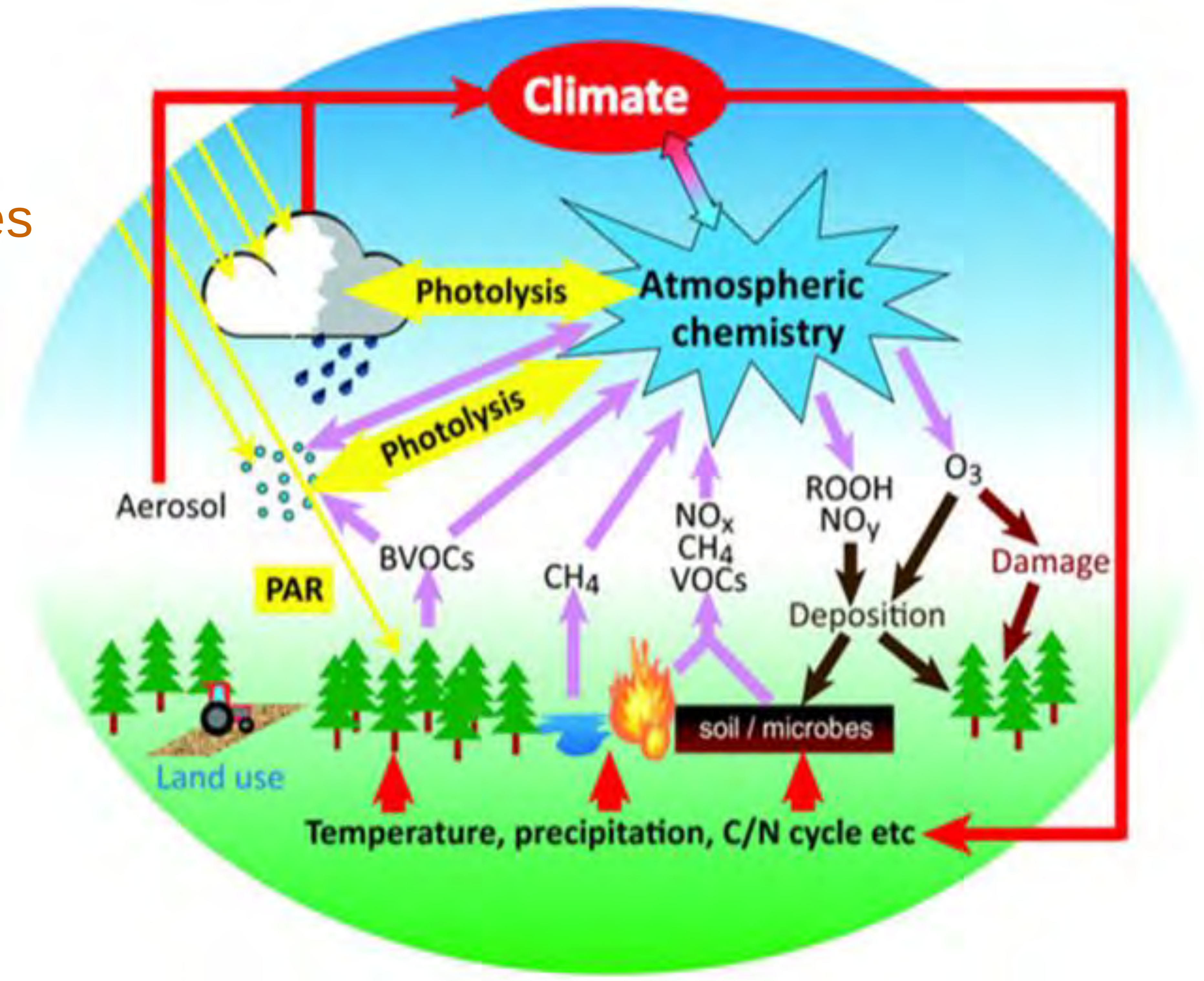
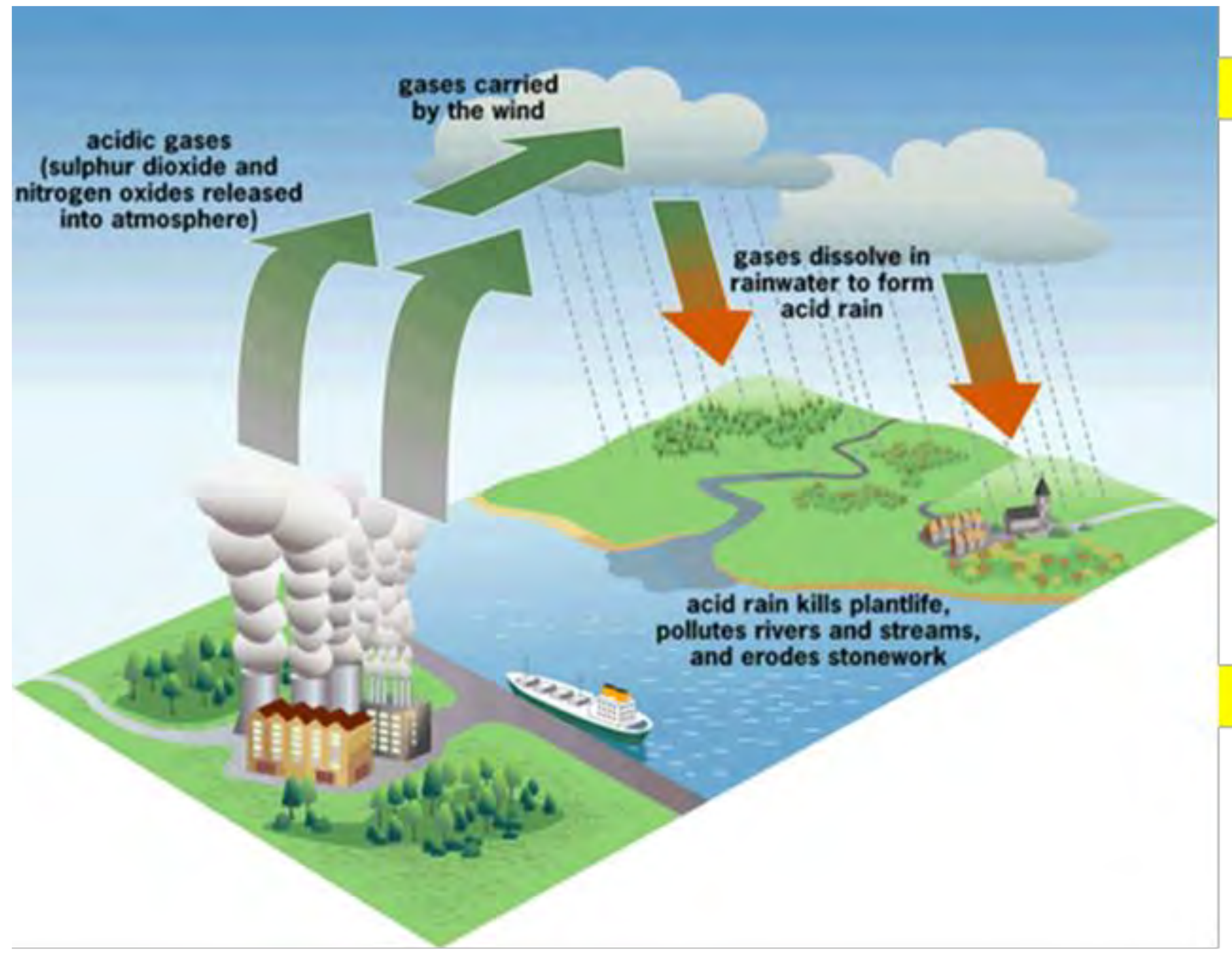
Background: Air pollution impacts

- ❑ Earth atmosphere chemical processes



- ❑ Agricultural production



Changes the pH of soil and surface-atmosphere chemical exchanges

Agro-economic, food security, socio-economic.....

Ozone

Sulfur dioxide

Fluoride

Ammonia

Cement-dust

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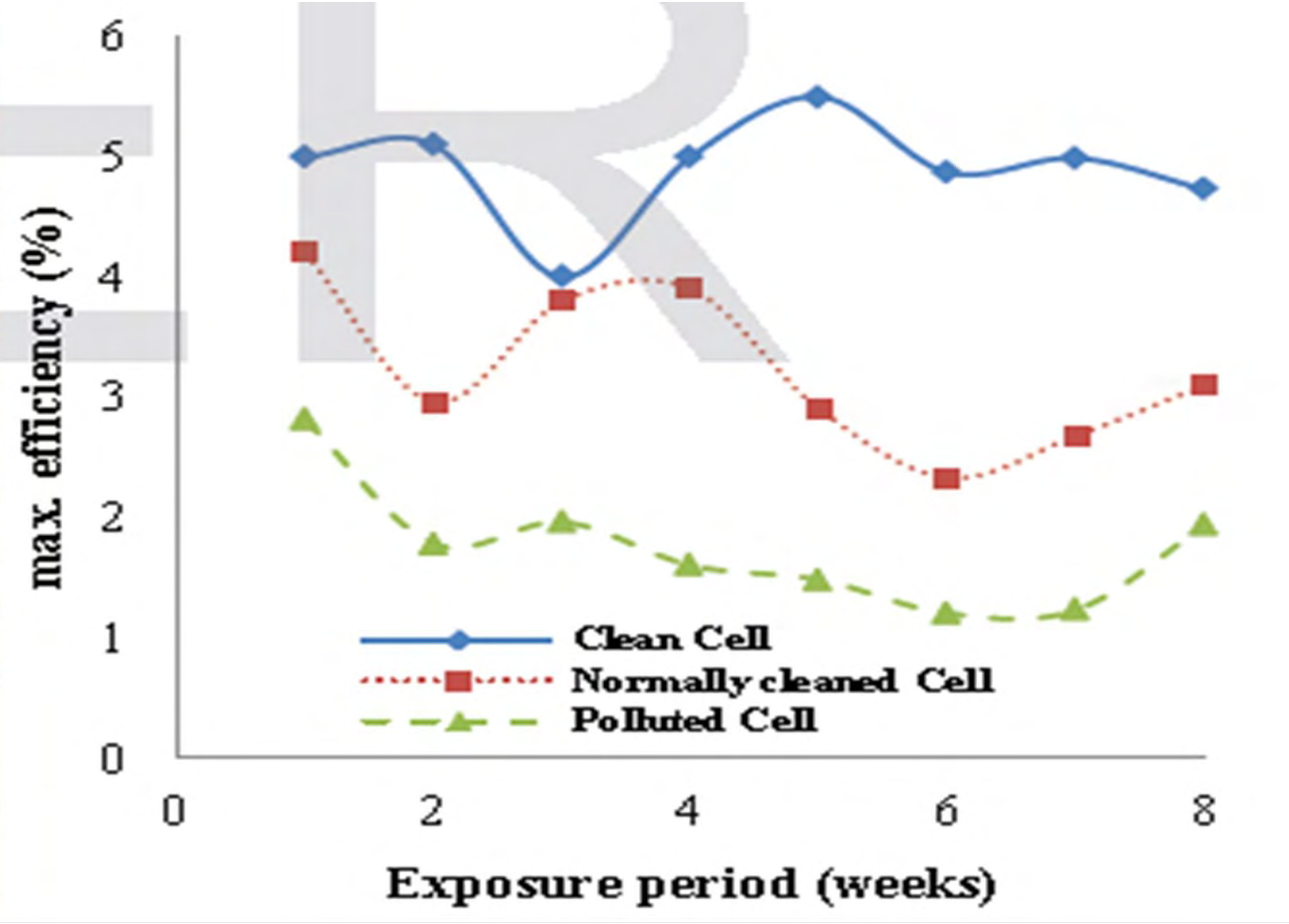
Background: Air pollution impacts

- Energy efficiency



- Built Environment

In 1944

After 58 years of acid rain exposure

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Background: Air Pollution Measurements and Modelling

Ground-based observations

✓ Provide detailed and more accurate information about air pollutant physico-chemical and optical properties

✓ Vital for satellite and model validation

✓ Laboratory studies of air pollutant formation and evolution processes are crucial for representing aerosols in models

X Confined in temporal and/or spatial coverage

Space-borne observations

✓ Provide air pollutant concentration, physico-optical properties with better temporal and spatial coverage

X There exist accuracy limitation

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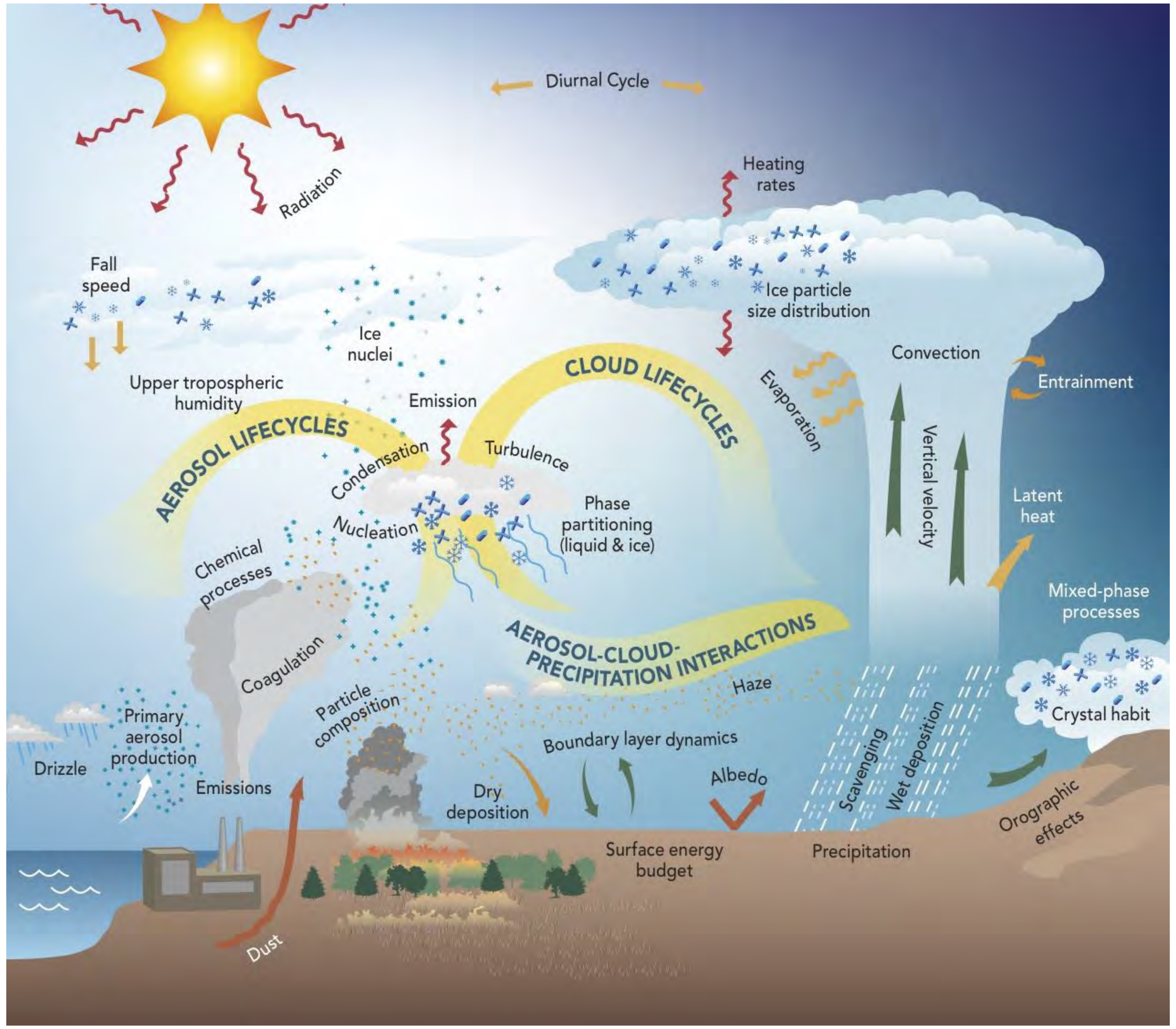
Background: Air Pollution Measurements and Modelling

Interactively coupled climate-chemistry model

4-D [space (V and H) and time resolved] information:

- Primarily air pollutant emission
- Secondary air pollutant formation
- Mass distribution, optical and physico-chemical properties
- Transport and physico-chemical transformation
- Removal process
- Essential to fill spatio-temporally resolving gaps of field measurements and composition identification limitations of satellite observations
- It is important in situations difficult to observe by measurements



- Provide phenomenal information about various climatic and environmental effects of air pollutants
- It is crucial tools for estimating past and projecting their future distribution and climatic/environmental roles

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Regionally optimized climate–chemistry coupled modeling system

- which can provide air quality forecast and alerts, as well as air quality related forecast products to the general public and air quality management bodies

- Interlinked modeling systems, such as epidemiological, Agro., energy and environment – in order to generate new sectorial/public products that assist the public as well as decision makers in making scientifically informed resource management strategies and policies

- scientific research on multiphase and diversified impacts of air pollution on: Earth climate system, environment and natural balance of the ecosystem

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- Research
- Operational
- Services

SAWS-AQ

Research activities in developing

optimal parametrization

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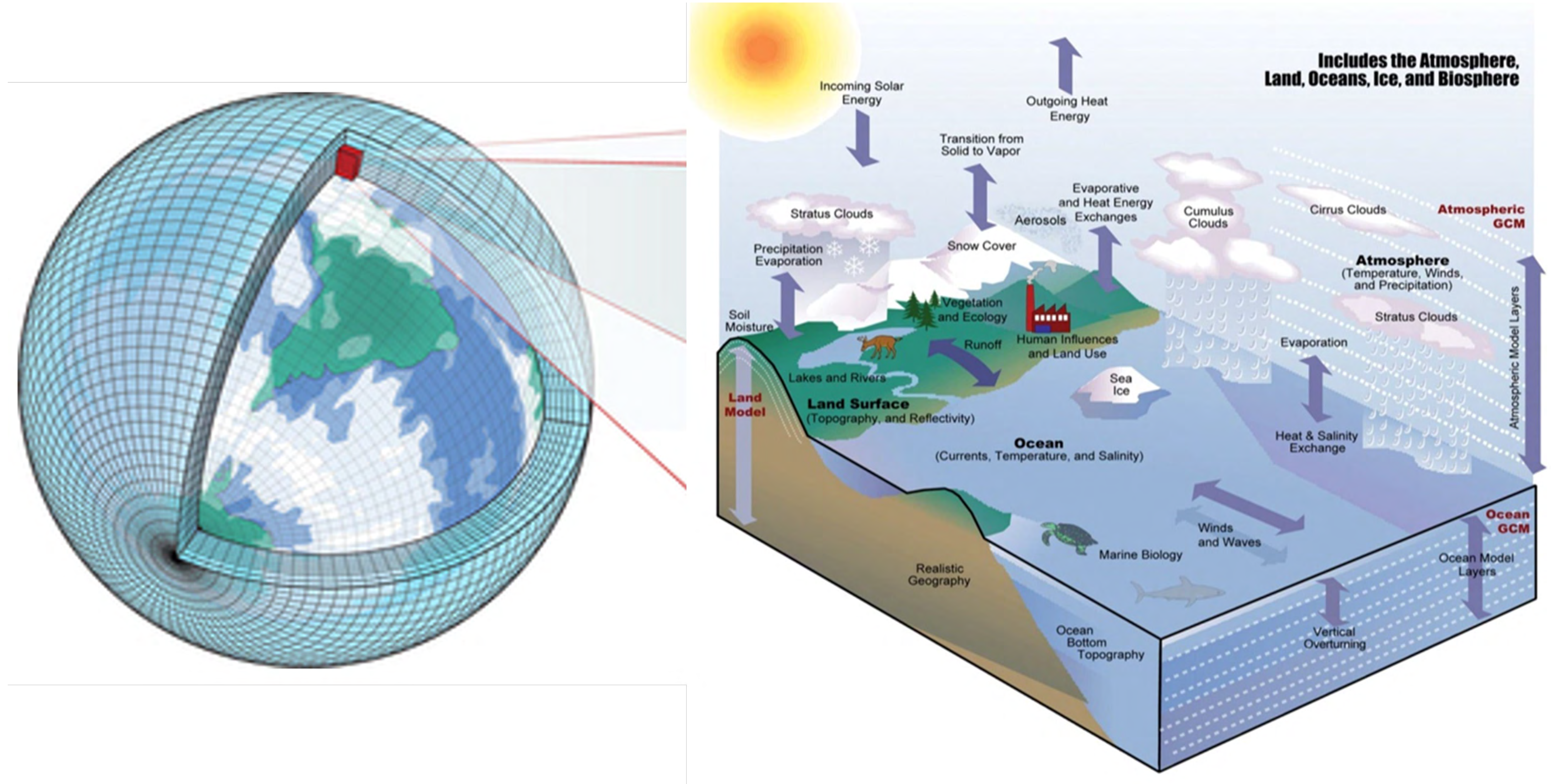

- **Dynamical core:** MM5 hydrostatic & non-hydrostatic
- **Radiation:** CCM3.6, RRTM
- **Cumulus Convection:** Grell (1993) with Frits. & Chapp., Kuo (1977), Emanuel (1991), Tiedtke (1996)
- **Boundary Layer:** Holtslag (1990), UW PBL (Bretherton and McCaa, 2004)
- **Land Surface:** BATS, CLM4.5
- **Moisture scheme:** Explicit moisture (SUBEX; Pal et al., 2000)/Tompkins
- **Large-Scale Clouds & Precipitation:** SUBEX (Pal et al., 2000)
- **Ocean Fluxes:** Zeng et al. (1998), BATS1e Monin-Obukhov, Coare bulk flux algorithm

- **Anthrop. & BB:** Solmon et al. (2006), Qian et al. (2001)
- **Dust–4 & Dust–12 bins:** Zakey et al. (2006), Kok et al. (2011)
- **Sea Salt–2 bins:** Zakey et al. (2008)
- **Gas-Phase Chemistry:** Shalaby et al. (2012)

$$\frac{\partial \chi^{i}}{\partial t} = \underbrace{-\overline{V}.\nabla \xi^{i}_{ADV} + F^{i}_{HTD} + F^{i}_{VTD} + T^{i}_{C}}_{\text{Transportation}} + \underbrace{S^{i}}_{\text{Primary emissions}} \underbrace{- R^{i}_{W,ls} - R^{i}_{W,C} - D^{i}_{d}}_{\text{Dry and Wet dep.}} + \sum \underbrace{(Q^{i}_{p} - Q^{i}_{l})}_{\text{Physico–chem. transformations}}$$

Gas-phase chemistry: CBM-Z

Solver: Radical balance method

Photolysis rates: Tropospheric Ultraviolet-Visible Model with cloud cover

Dry deposition of gaseous species: Stomata and non-stomata multiple resistance model with aerodynamic, quasi-laminar layer and the uptake surface resistance for vegetation, soil, water, snow, ice,…..

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Terrain

Global terrestrial data: Land surface properties, such as land-use category, soil texture, roughness, soil moisture,.....

Domain with land surface properties, such as land-use category, soil texture, roughness, soil moisture,.....

Initial and Lateral Boundary conditions (ICBC)

Meteorological ICBC: GCM reanalysis/forecast; such as ECMWF, EIN15, NNRP1,.....

Surface Pressure

Geopotential

Relative Humidity

Air Temperature

Wind Velocity

Sea Surface Temperature (SST)

to feed the model with reanalysis/forecast ocean temperature

Chemical ICBC

GCTM reanalysis/forecast, such as MOZART CTM, CAM

O3, H2O2, NO, NO2, N2O5, HNO3, SO2, SO4, CH4, HCHO, CO, C2H6, CH3CHO, PAN, C4H10, Xylene, Isoprene, NH3,.....

Emissions

Global (such as CAM, GFAS, GFED, EDGAR,.....) and Local

SO2, CH4, CO, NH3, NOx, OC, BC, acids, alcohols,.....

Pre-processing

Model

Dynamical cores: Hydrostatic and non-hydrostatic

Thermodynamical modules

Air-sea flux schemes

Radiation schemes

Land surface schemes

Planetary boundary layer schemes

Large-scale precipitation schemes

Ocean flux parametrization

Multiple cumulus convection schemes

Mass flux cumulus cloud schemes

Interactively coupled 2D lake mode;

Explicit moisture schemes

Aerosol schemes

Gas-phase chemistryschemes,.....

Simulation

Outputs: *.nc

Analysis and visualization

NCO, NCL, R, CDO, GrADS,.....

Post-processing

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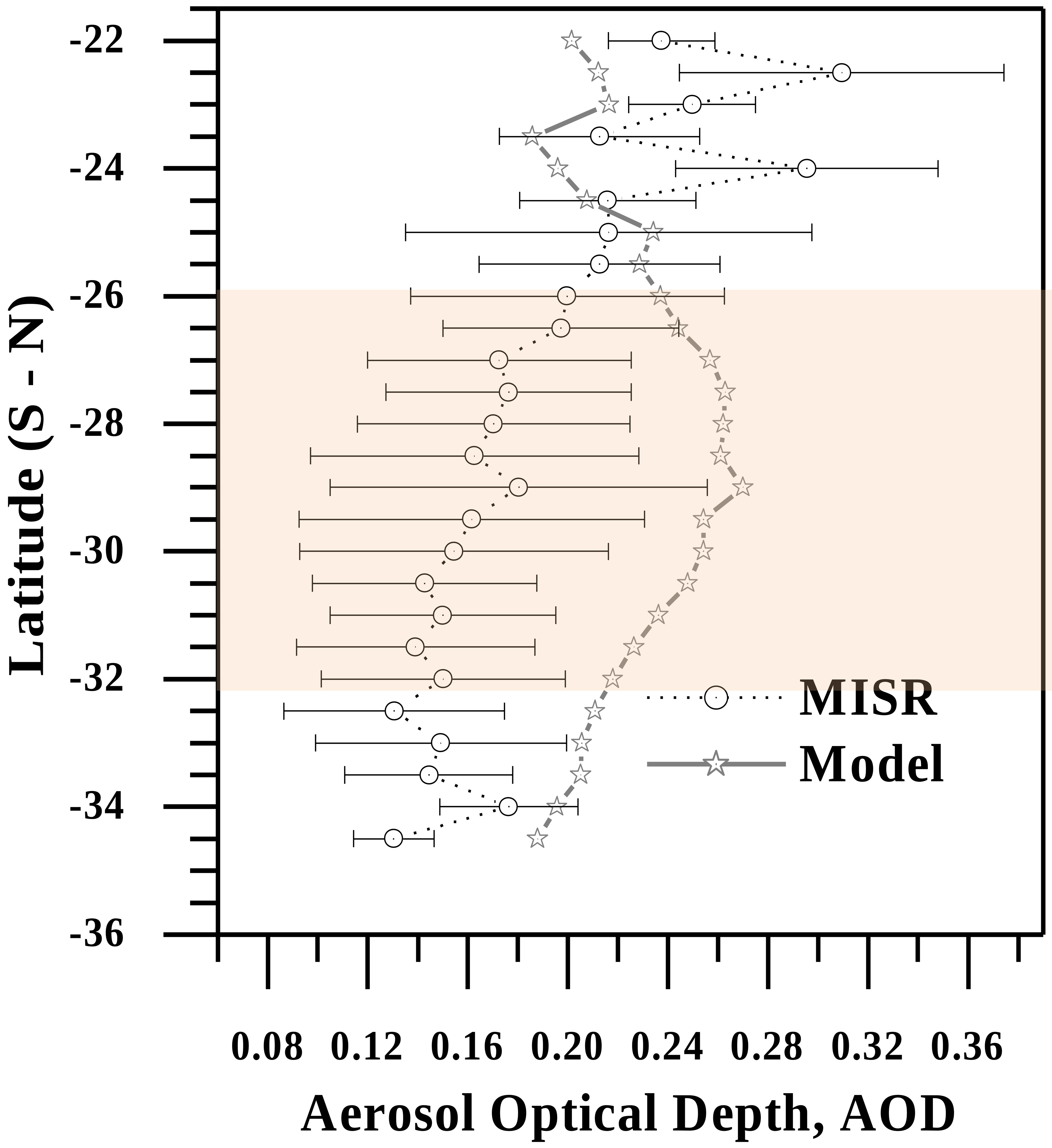

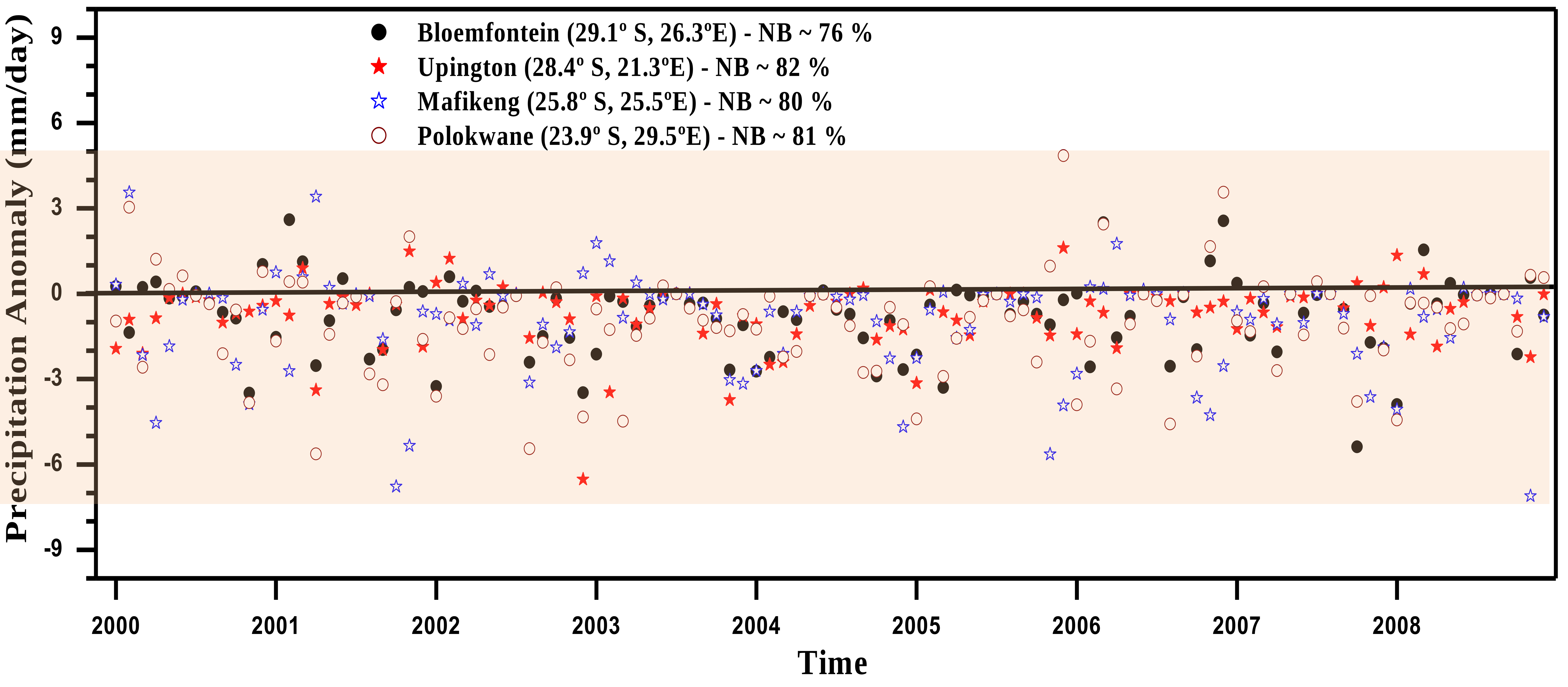

Precipitation

Wet Deposition

Soil Moisture (in turn dust production)

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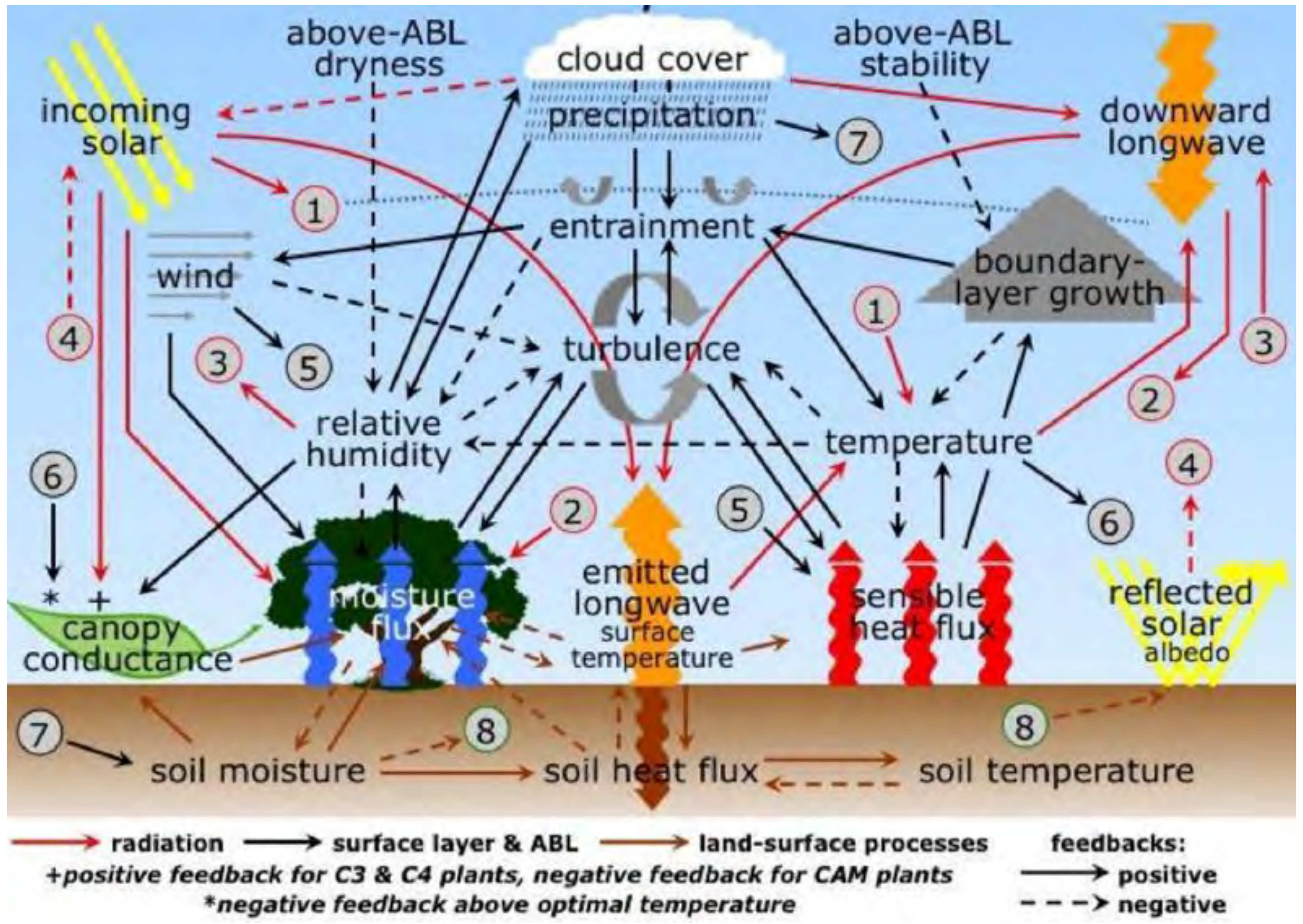
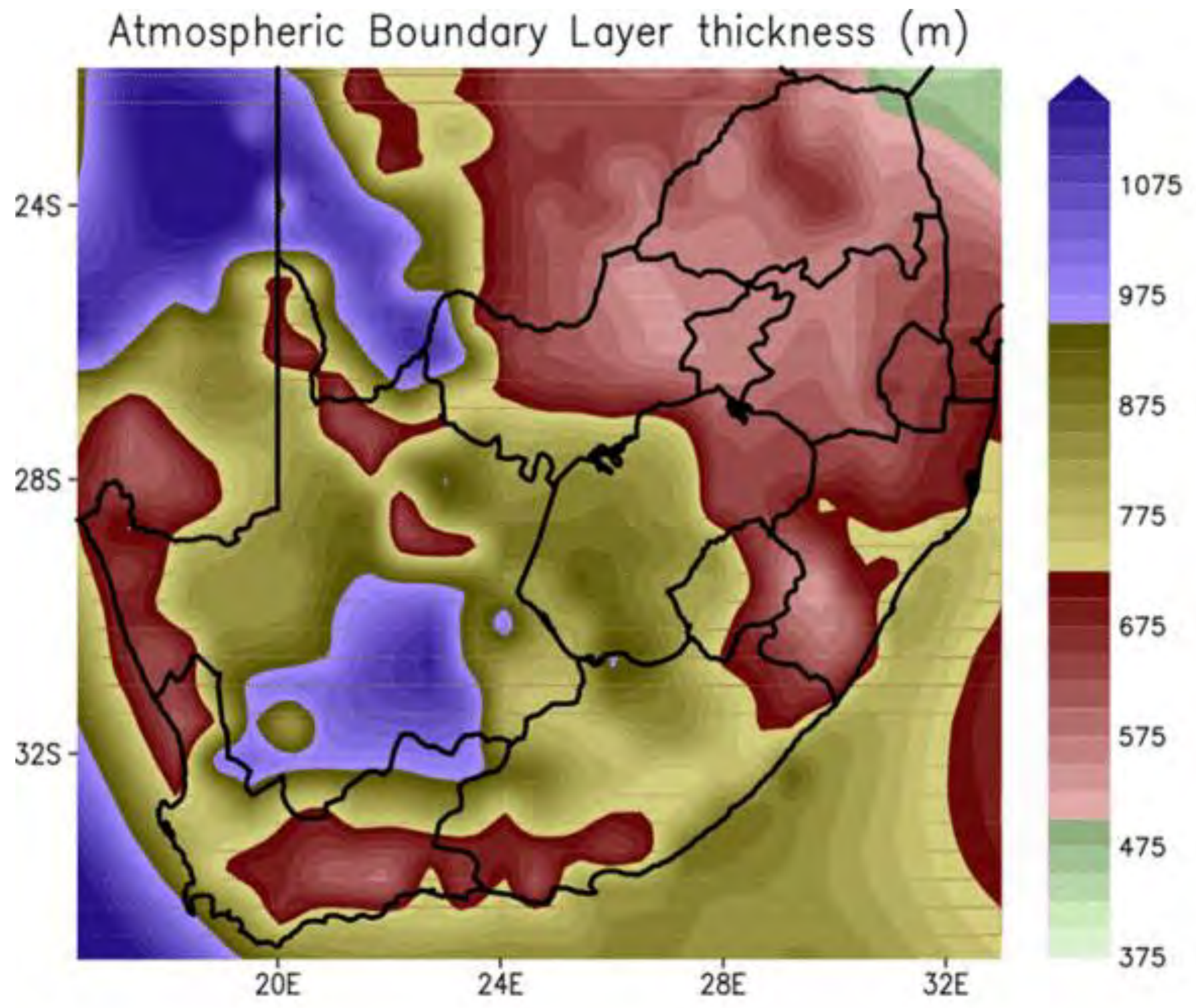
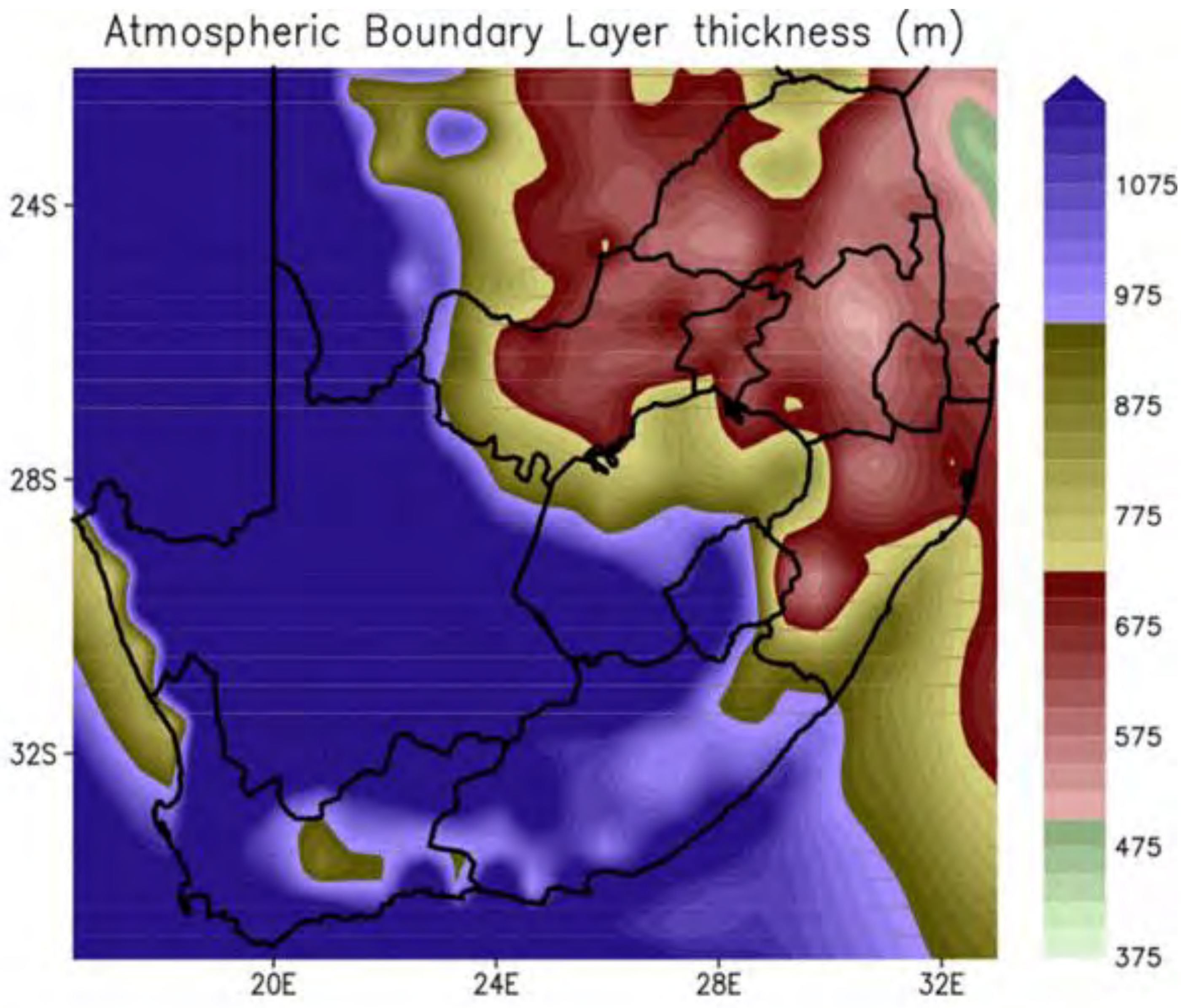
❑ Land–Atmosphere interactions



BATS



CLM



❑ Biosphere-Atmosphere Transfer Scheme(BATS)

❑ Community Land Model (CLM4.5)

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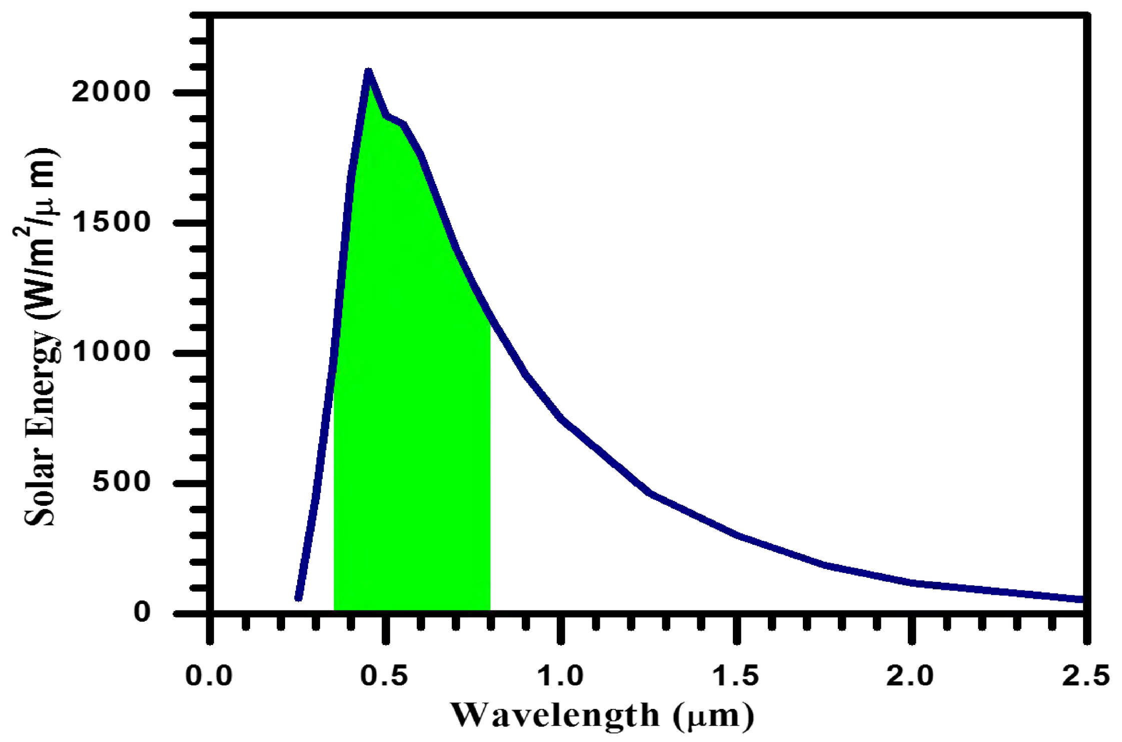
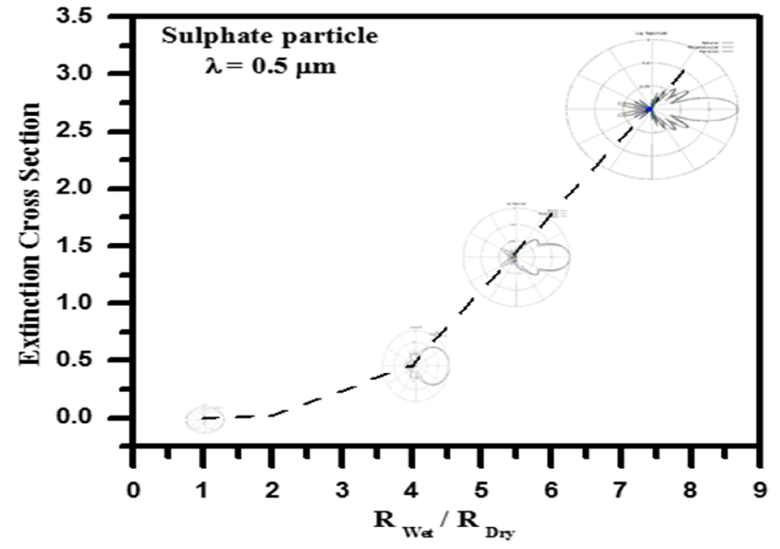
❑ Radiative transfer

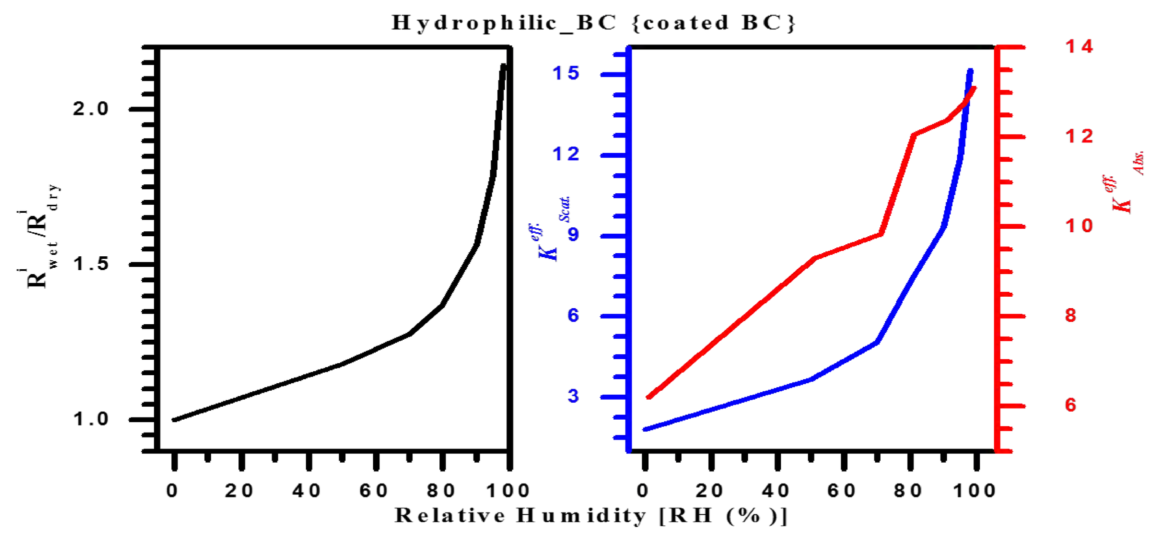
200-245nm	245-265nm	265-275nm	275-285nm	285-295nm	295-305nm	305-350nm	350-640nm	640-700nm	>700

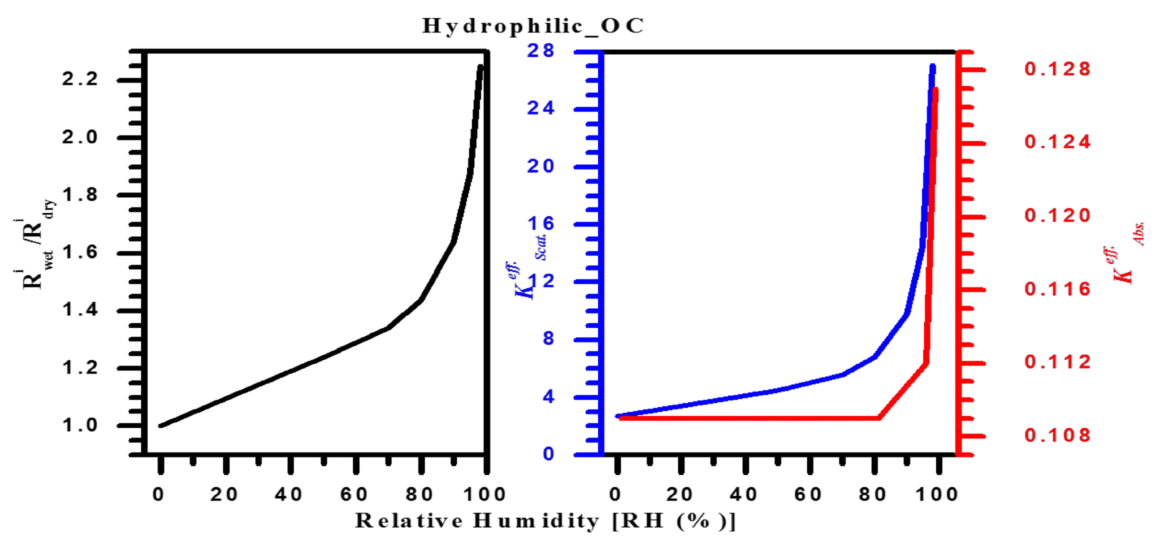
$$\tau^i_{Ext.} = \tau^i_{Scat.} + \tau^i_{Abs.} = [\underbrace{\frac{3Q^i_s}{4\rho^i r^i_e}}_{K^i_{S,\lambda}} + \underbrace{\frac{3Q^i_a}{4\rho^i r^i_e}}_{K^i_{a,\lambda}}]M_i = \frac{3M_i}{4\rho^i r^i_e}\left\{\frac{2}{x_i^2}\sum_{n=1}^{\infty}(2n+1)\left(|a_n|^2+|b_n|^2\right)+\frac{1}{x_i^2}\left[\sum_{n=1}^{\infty}(2n+1)(-1)^n(a_n-b_n)\right]^2\right\}$$

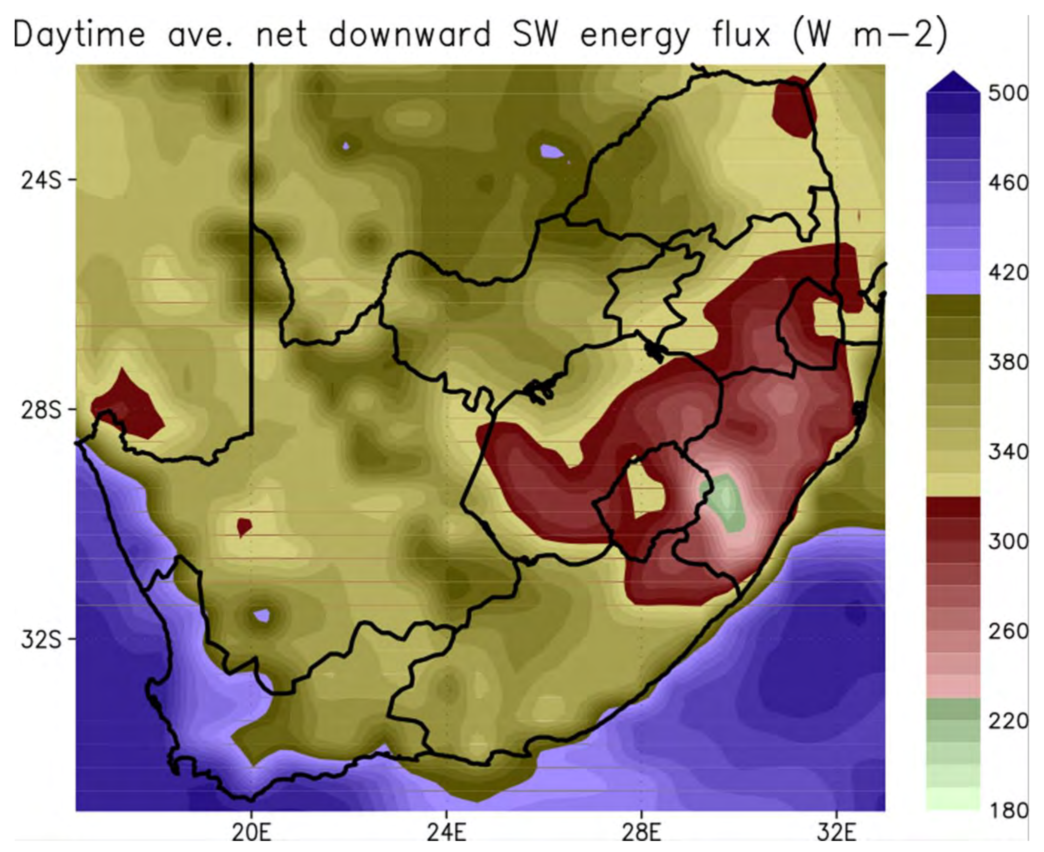
$$K^i_{S(a)\,eff_{VIS}} = \frac{\sum_{VIS}[\int_0^\infty \alpha^i_{S(a)}(r^i, m^i_\lambda, \lambda) n^i(r)\,dr]\, I_0(\lambda)\,\lambda\, d\lambda}{\sum_{VIS}[\int_0^\infty \rho^i(r)\, V^i(r)\, n^i(r)\,dr]\, I_0(\lambda)\, d\lambda}$$

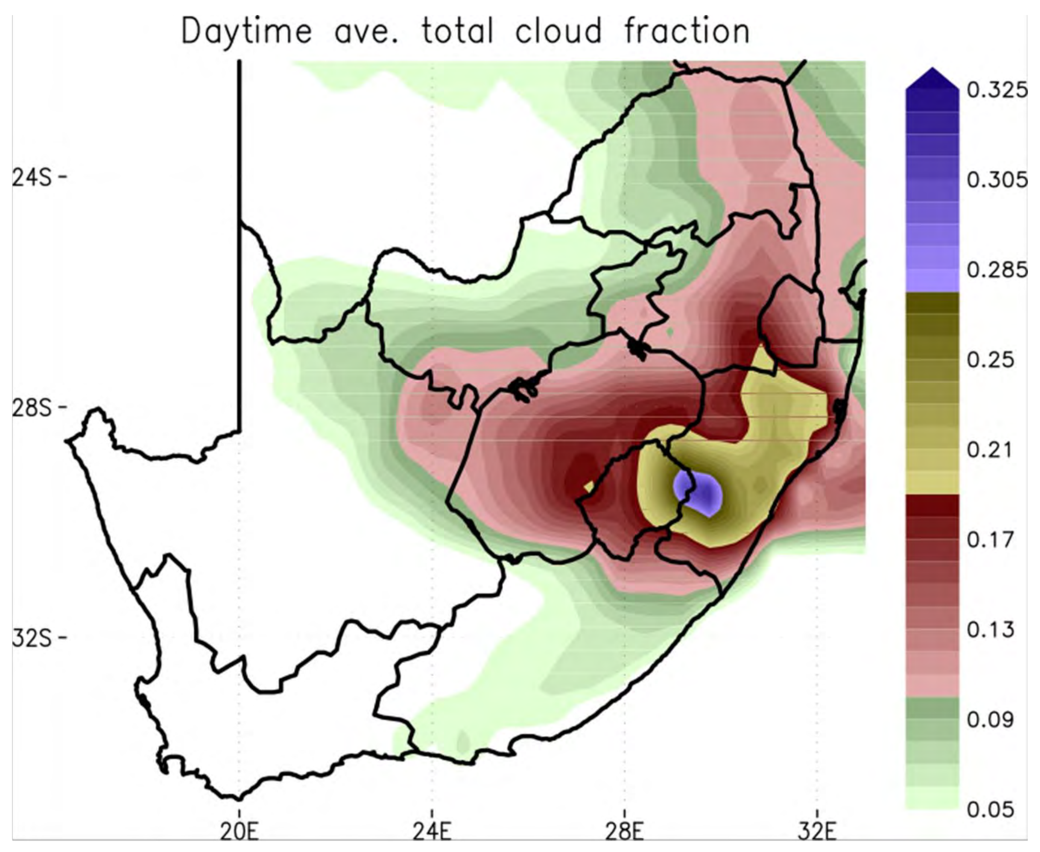


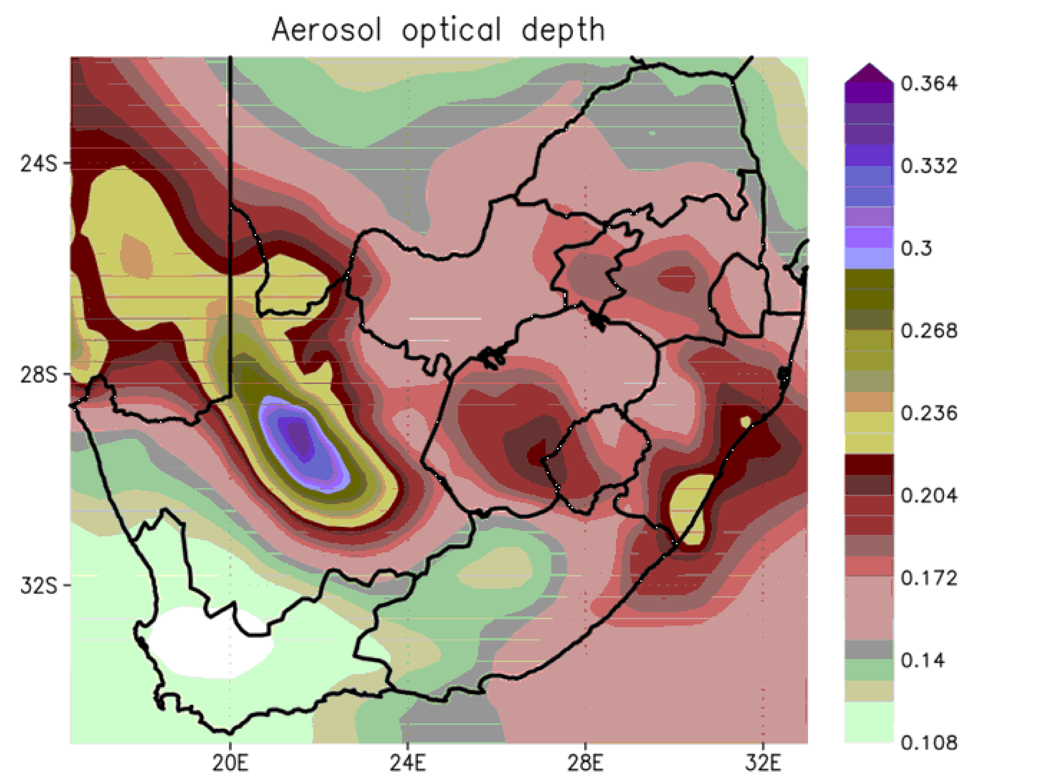












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Mineral Dust

- Diameter size: 2-300 µm
- Main material: sand, silt, clay
- Includes essential trace metals such as Fe
- Consists of insoluble and soluble fractions

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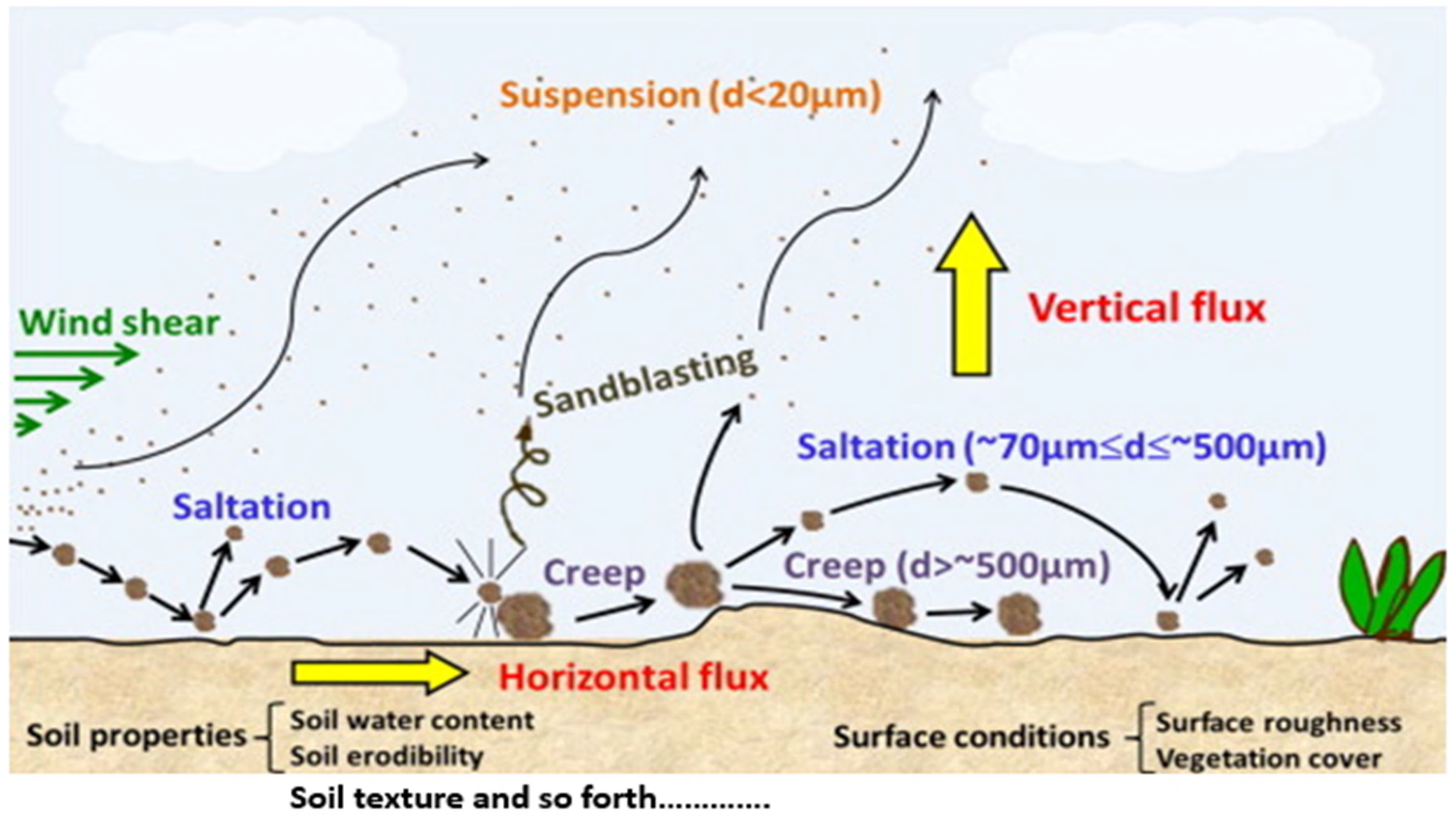
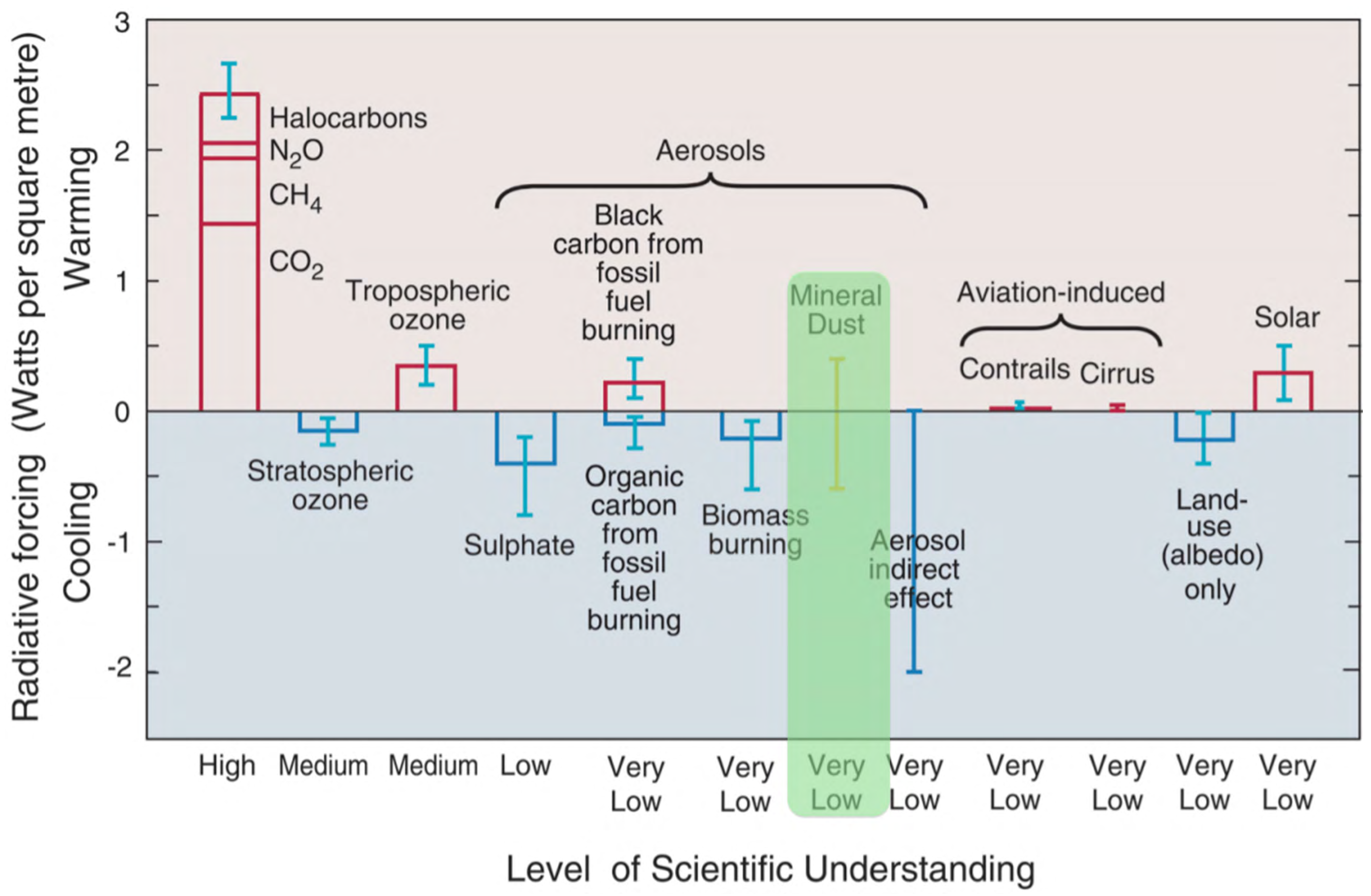
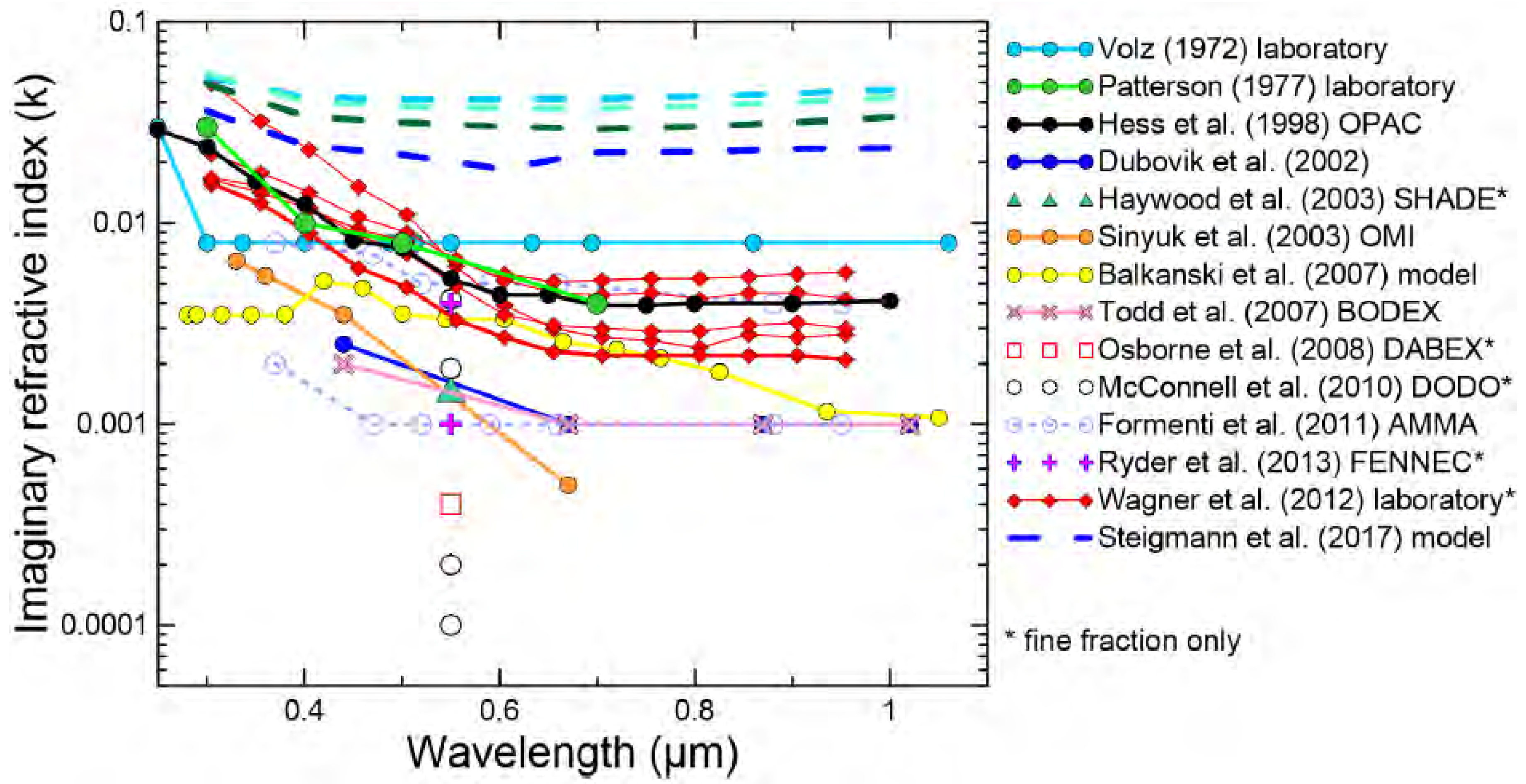
❑ Natural dust emission module regional localization



$$\varepsilon', \varepsilon'' \, [n_r(\lambda, \varepsilon'), n_i(\lambda, \varepsilon')] \Rightarrow \omega_\lambda(x, n), \tau_\lambda(x, n), g_\lambda(x, n)$$





❑ *Climate models and remote sensing retrievals* use spatially invariant *generic* mineral *dust emission coefficients* and *optical properties* such as complex refractive index

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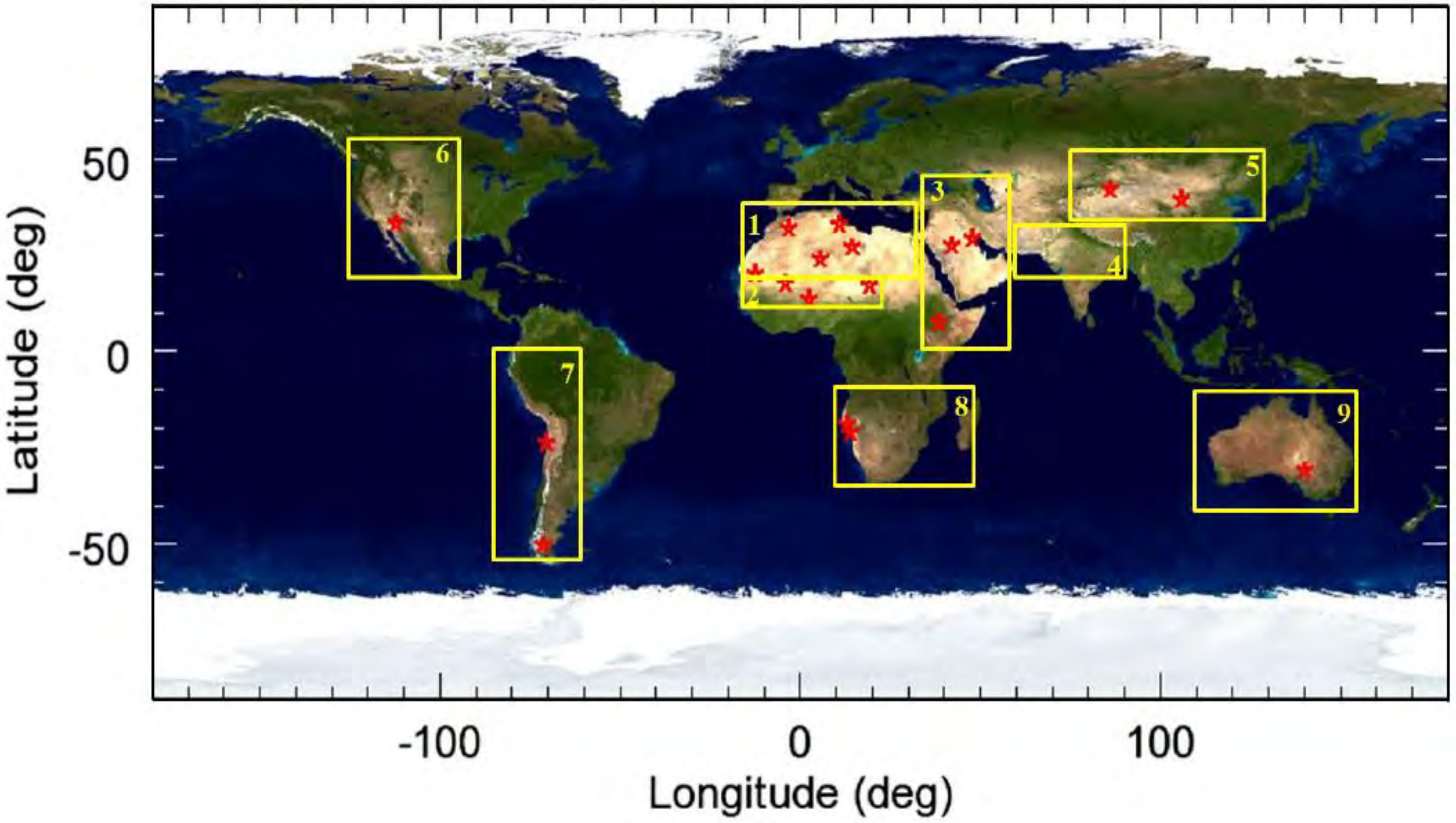
Natural dust emission module regional localization

LISA (Laboratoire Interuniversitaire des Systemes Atmospheriques) and other collaborating institutions

- ❑ Field observations and *in-situ* measurements of dust
  - ► UV/visible/IR optical properties
  - ► Soil mineralogy,
  - ► Size distribution
  - ► Atmospheric ageing



Di Biagio et al. (2017); Caponi et al. (2017)

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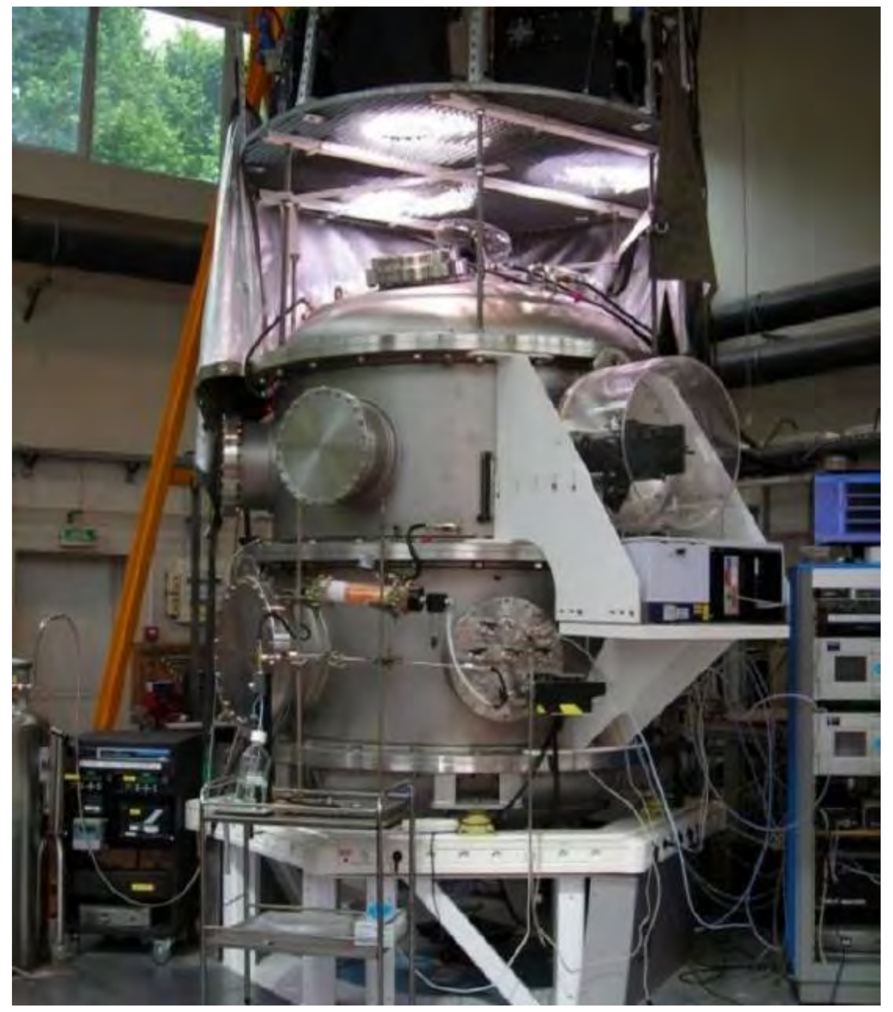
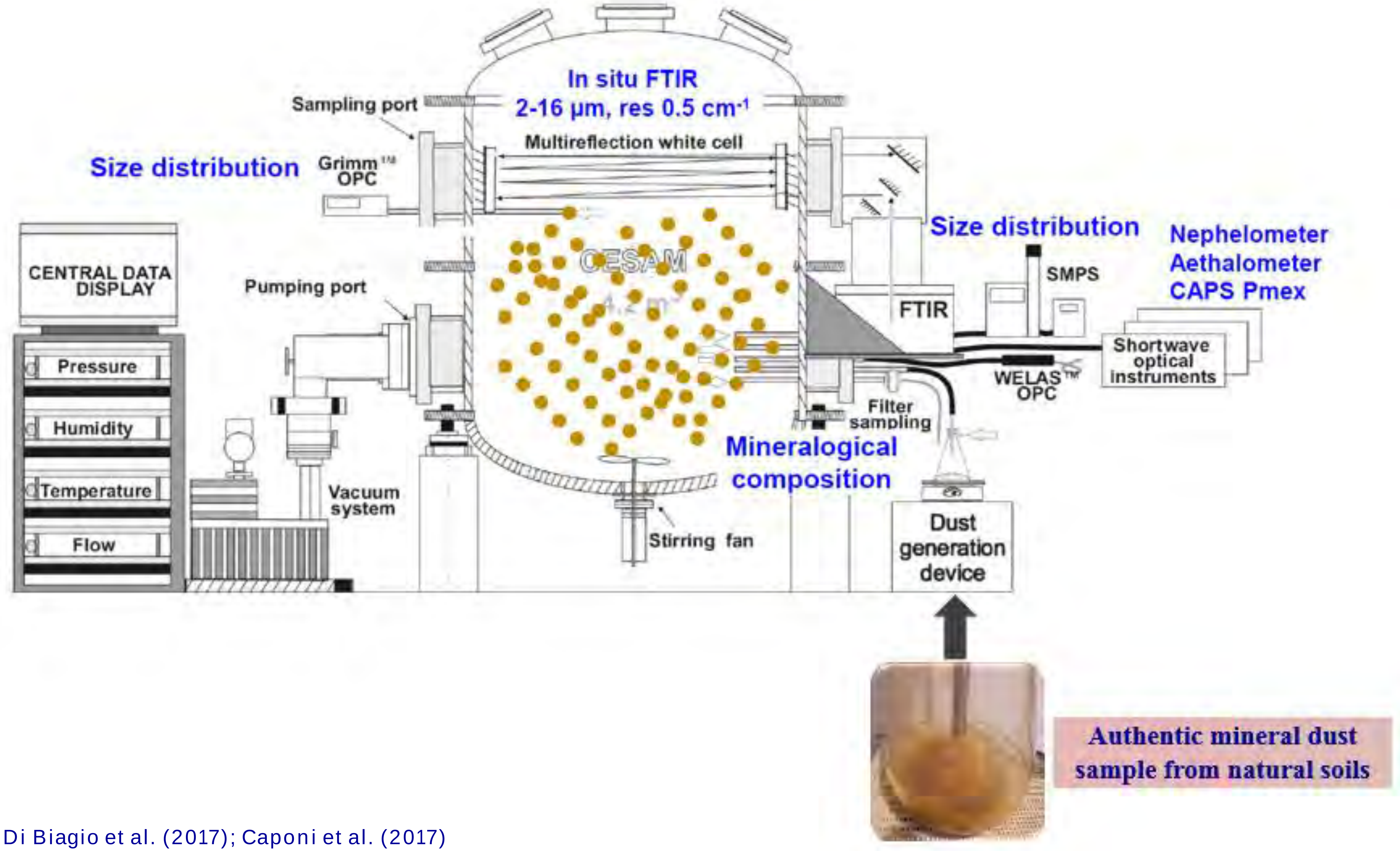
CESAM simulation chamber





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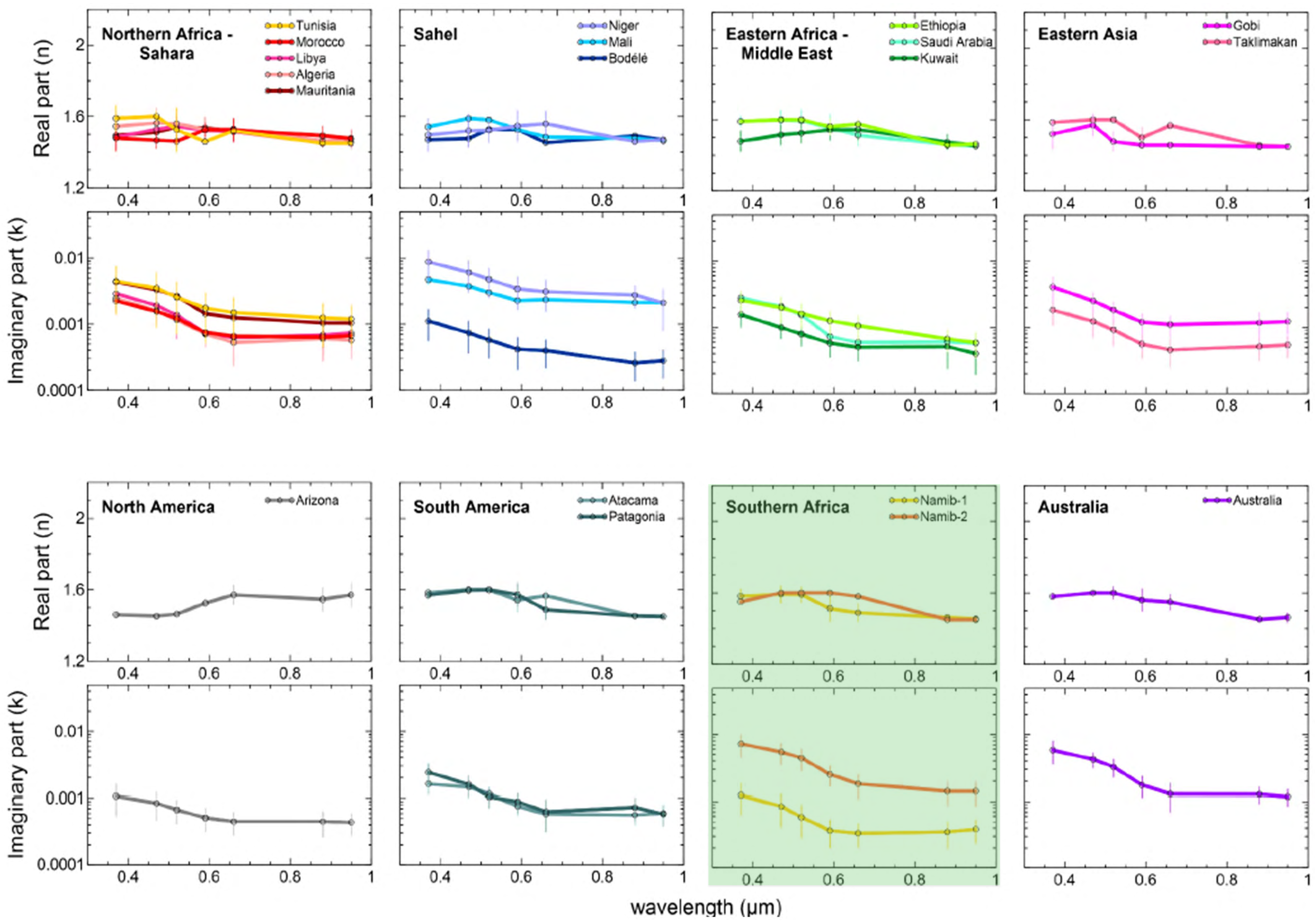
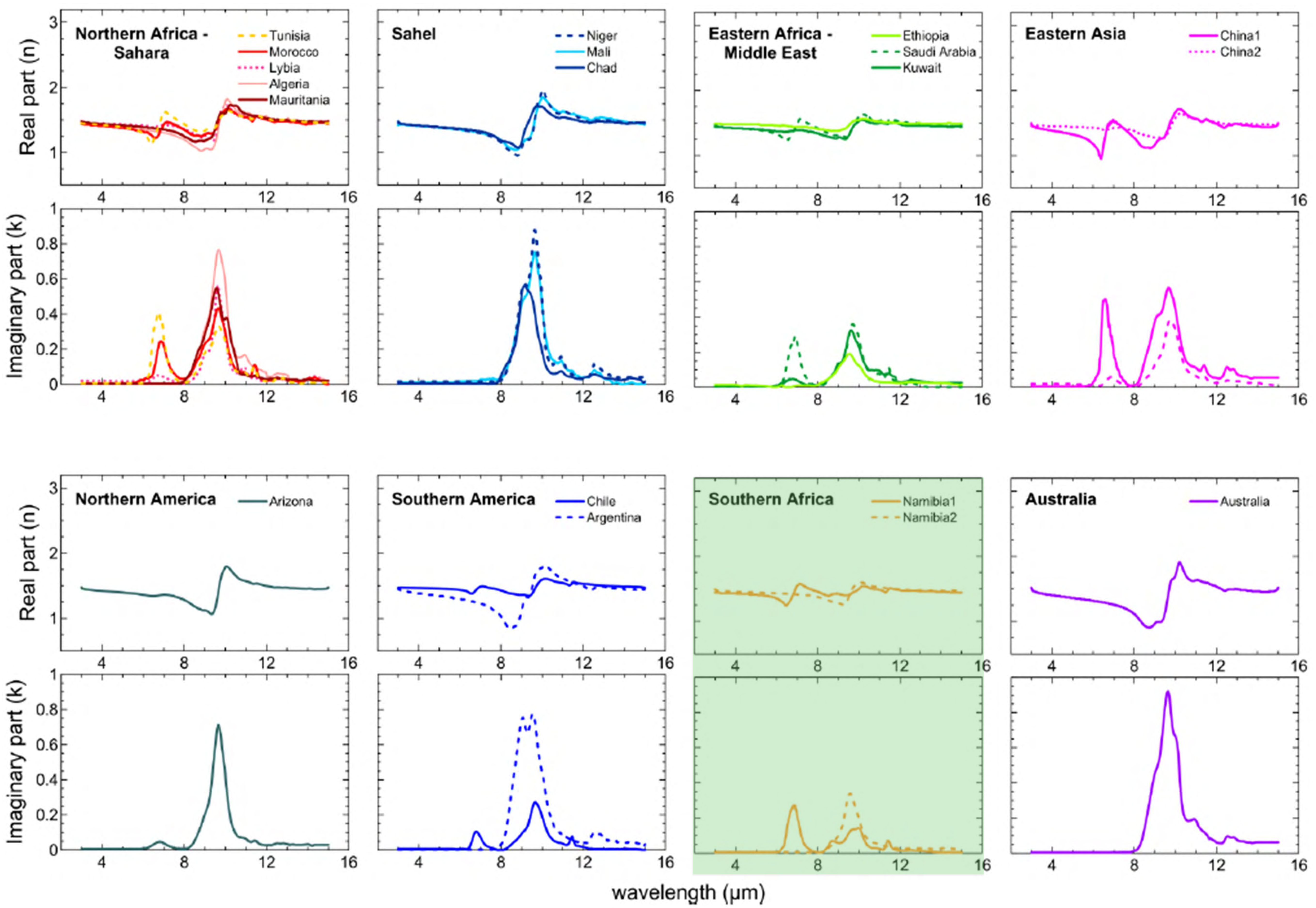
Dust SW refractive index



Dust LW refractive index



Di Biagio et al. (2017)

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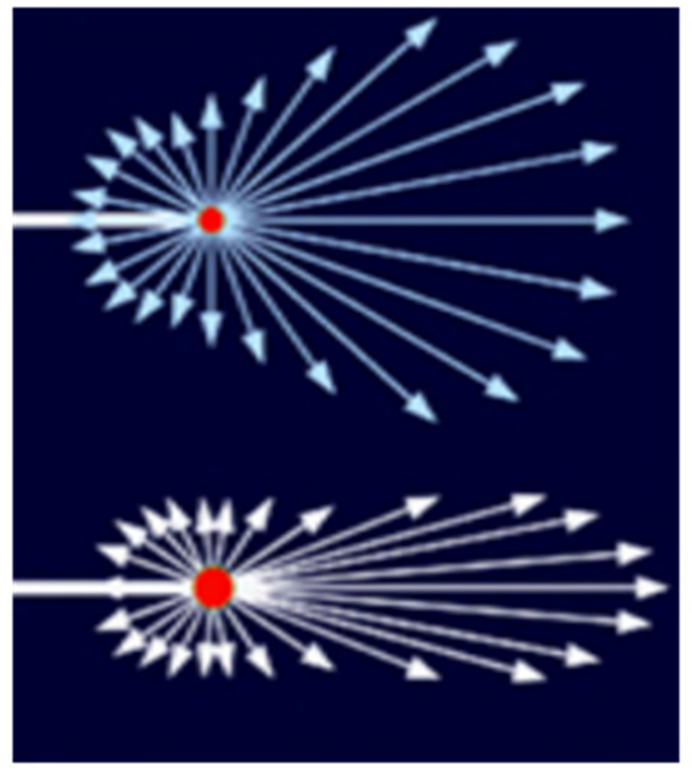
❑ Natural dust emission module regional localization

$$m_r(\tilde{v}) = \left(\frac{\sqrt{\epsilon'(\tilde{v})^2 + \epsilon''(\tilde{v})^2} + \epsilon'(\tilde{v})}{2}\right)^{\frac{1}{2}} \qquad m_i(\tilde{v}) = \left(\frac{\sqrt{\epsilon'(\tilde{v})^2 - \epsilon''(\tilde{v})^2} + \epsilon'(\tilde{v})}{2}\right)^{\frac{1}{2}}$$

where ϵ' and ϵ'' are the real and imaginary part of the dielectric constant

Mie scattering

$r \sim (or >) \ \lambda_i$



$$Q_e = Q_s + Q_a$$

where $\chi = ka = \frac{2\pi r}{\lambda}$ is the size parameter:

$$a_n = \frac{\psi_n(\chi)\psi'_n(m\chi) - m\psi'_n(\chi)\psi_n(m\chi)}{\xi_n(\chi)\psi'_n(m\chi) - m\xi'_n(\chi)\psi_n(m\chi)}$$

$$b_n = \frac{m\psi_n(\chi)\psi'_n(m\chi) - \psi'_n(\chi)\psi_n(m\chi)}{m\xi_n(\chi)\psi'_n(m\chi) - m\xi'_n(\chi)\psi_n(m\chi)}$$

The far-field solution of Mie scattering ($z >> kr^2, k = 2\pi/\lambda$)(Bohren and Huffman, 1983):

$$Q_e = \frac{\sigma_e}{\pi r^2} = \frac{2}{\chi^2}\sum_{n=1}^{\infty}(2n+1)\ Re(a_n + b_n)$$

$$Q_s = \frac{\sigma_s}{\pi r^2} = \frac{2}{\chi^2}\sum_{n=1}^{\infty}(2n+1)\left(|a_n|^2 + |b_n|^2\right)$$

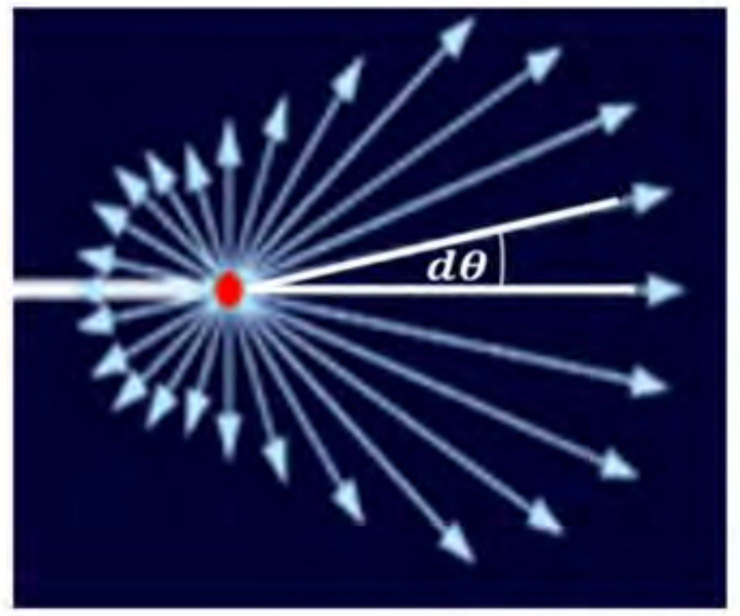
$$Q_a = Q_e - Q_s = \frac{1}{\chi^2}\left[\sum_{n=1}^{\infty}(2n+1)(-1)^n(a_n - b_n)\right]^2$$

❑ optical depth

$$\alpha_{ext} = \int_{r_{min}}^{r_{max}} \pi r^2 Q_e \left(\frac{dN(r)}{dr}\right) dr \quad \text{(unit m}^{-1}\text{)} \qquad \tau_{\lambda(m,\chi,n(r))} = \int_0^{\infty} \alpha_{ext,\lambda} dz$$

❑ Phase function

$$1 = \frac{1}{2}\int_0^{\pi} P_\lambda(\chi, m, \theta)\sin(\theta)d\theta \qquad g_\lambda = \frac{1}{2}\int_0^{\pi} P_\lambda(\chi, m, \theta)\cos(\theta)\sin(\theta)d\theta$$



g_λ : -1 back scattering; θ_s = 180°

0 the scattering is isotropic

+1 forward direction: θ_s = 0°

❑ Single scattering albedo

$$\omega_\lambda = \frac{Q_{scat}^{\lambda}}{Q_{ext}^{\lambda}} = \frac{\tau_{scat}^{\lambda}}{\tau_{ext}^{\lambda}}$$

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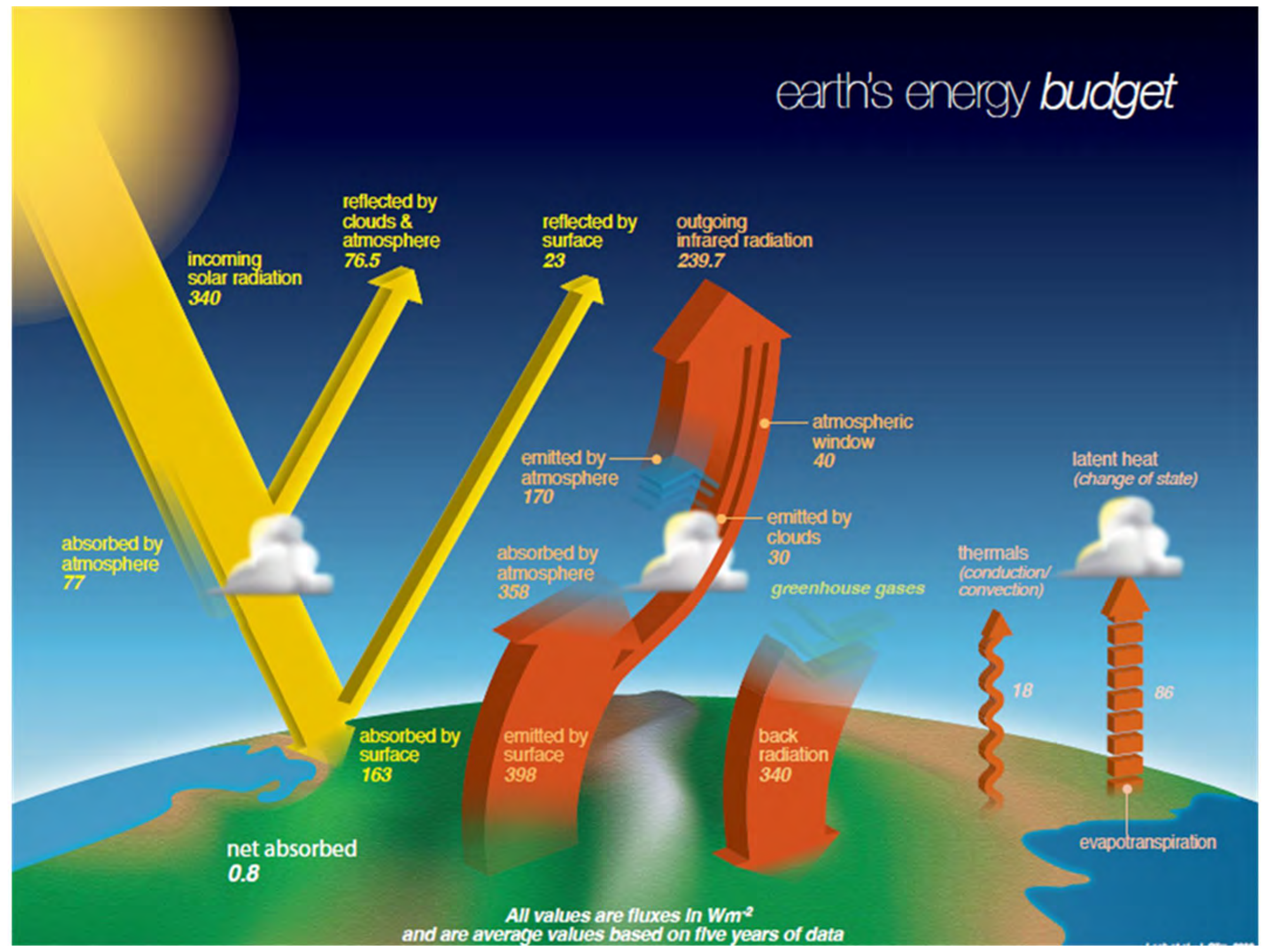
❑ Natural dust emission module regional localization



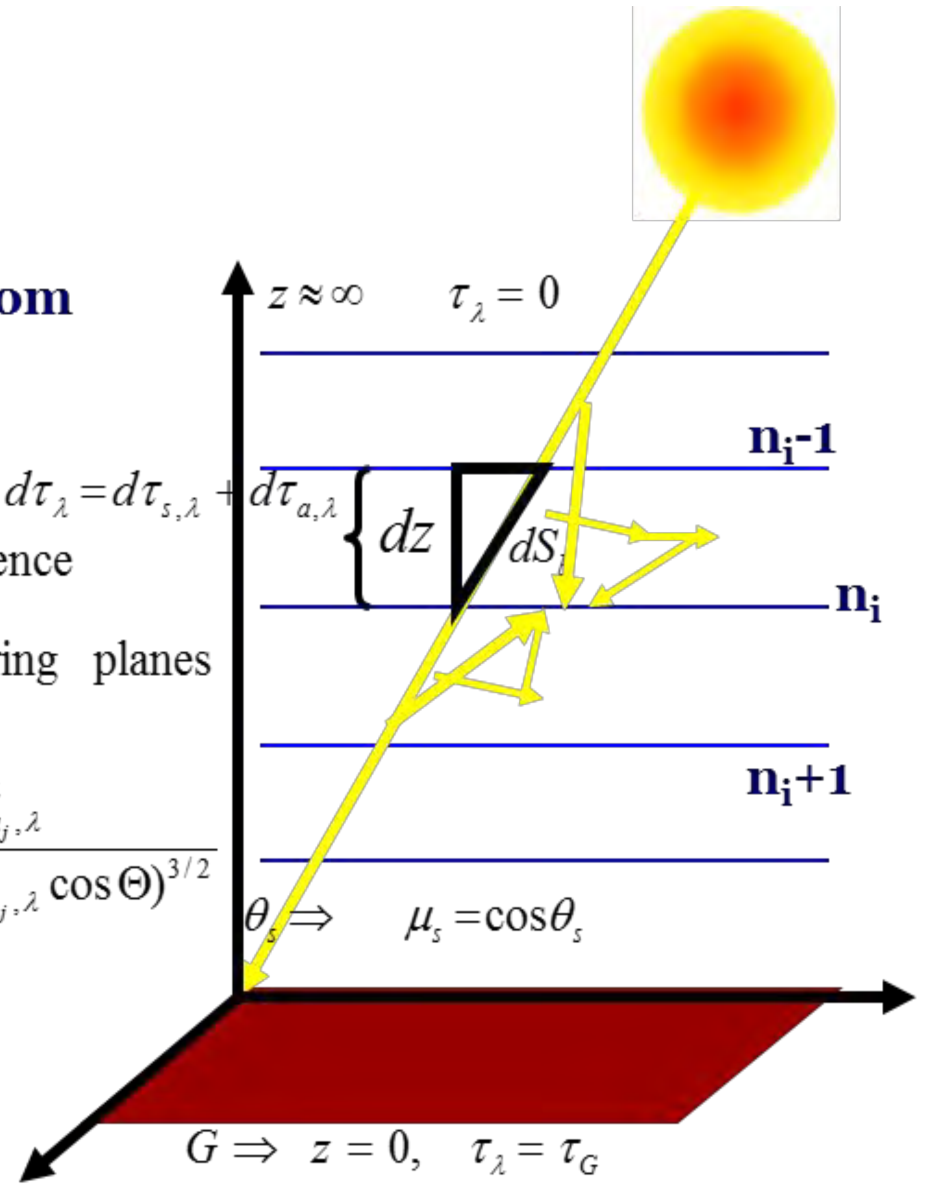
Case 1 and Case 2

❑ **The SW (UV and VIS): downward from layer n_i-1 and upward from layer n_i + 1 in to layer n_i**

$d\tau_\lambda = d\tau_{s,\lambda} + d\tau_{a,\lambda}$

Rayleigh (gas) scattering: $P_{s,g,\lambda}(\Theta) = \frac{3}{4}(1+\cos^2\Theta)$, *where* Θ is the angular difference b/n μ - μ' and ϕ - ϕ' scattering planes

Aerosol particles Henyey–Greenstein function: $P_{s,a,\lambda}(\Theta) = \frac{1-g^2_{a_j,\lambda}}{(1+g^2_{a_j,\lambda} - 2g_{a_j,\lambda}\cos\Theta)^{3/2}}$



$$\sum_k \left(\frac{\omega_{s,k,\lambda}}{4\pi}\int_0^{2\pi}\int_{-1}^{1} I_{\lambda,\mu',\phi'} P_{s,k,\lambda,\mu,\mu',\phi,\phi'}\, d\mu'\, d\phi'\right)$$

$$\approx \begin{cases} \sum_k \frac{\omega_{s,k,\lambda}(1+g_{k,\lambda})}{2} I_\lambda \uparrow + \frac{\omega_{s,k,\lambda}(1-g_{k,\lambda})}{2} I_\lambda \downarrow & \text{upward} \\ \sum_k \frac{\omega_{s,k,\lambda}(1+g_{k,\lambda})}{2} I_\lambda \downarrow + \frac{\omega_{s,k,\lambda}(1-g_{k,\lambda})}{2} I_\lambda \uparrow & \text{downward} \end{cases} \quad \Bigg| \; P_{s,k,\lambda,\mu,-\mu_s,\phi,\phi_s} \approx 1 \pm 3 g_{k,\lambda}\,\mu\,\mu_s$$

$$-\mu\frac{dI_\lambda\downarrow}{d\tau_\lambda} = I_\lambda\downarrow - \sum_k \frac{\omega_{s,k,\lambda}(1+g_{k,\lambda})}{2} I_\lambda\downarrow + \frac{\omega_{s,k,\lambda}(1-g_{k,\lambda})}{2} I_\lambda\uparrow - \sum_k \frac{\omega_{s,k,\lambda}}{4\pi} F_{s,\lambda}\, e^{-\tau_\lambda/\mu_s}(1+3g_{k,\lambda}\,\mu\,\mu_s)$$

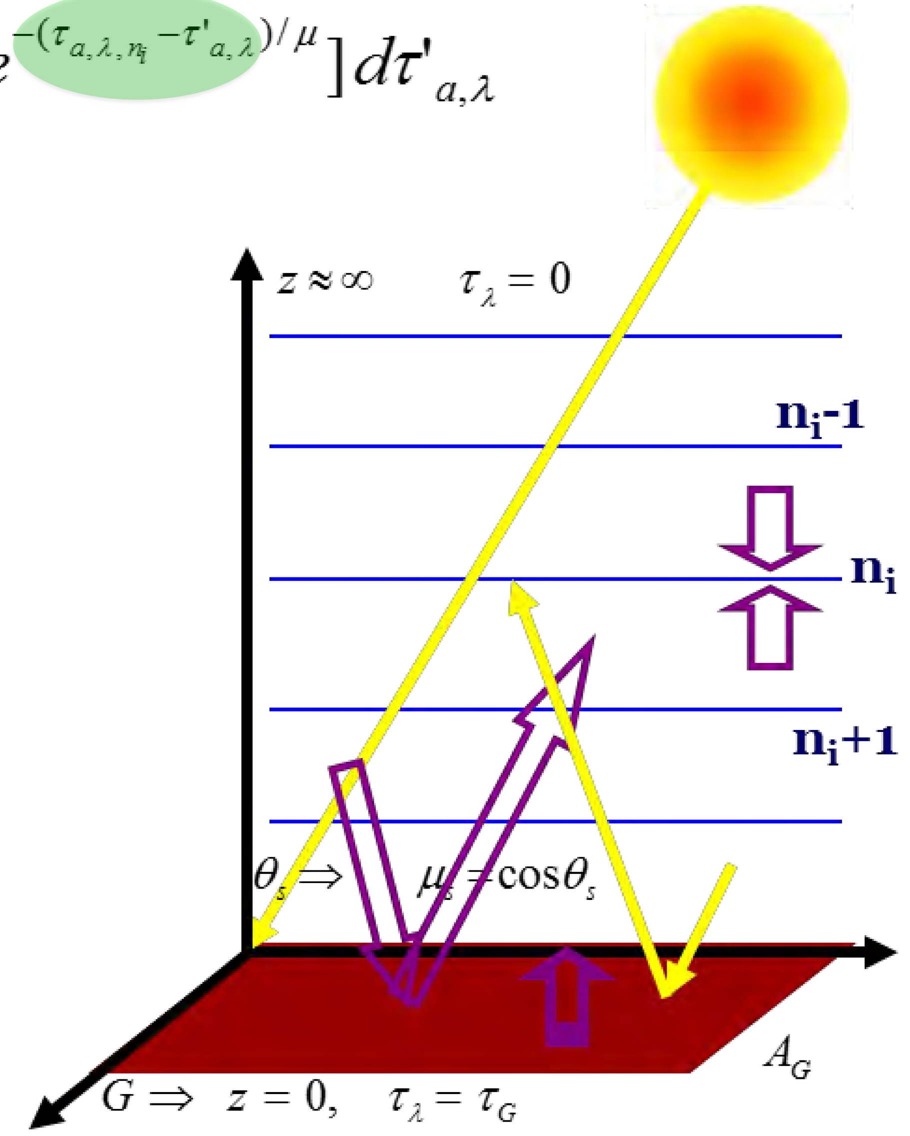
$$\mu\frac{dI_\lambda\uparrow}{d\tau_\lambda} = I_\lambda\uparrow - \sum_k \frac{\omega_{s,k,\lambda}(1+g_{k,\lambda})}{2} I_\lambda\uparrow + \frac{\omega_{s,k,\lambda}(1-g_{k,\lambda})}{2} I_\lambda\downarrow - \sum_k \frac{\omega_{s,k,\lambda}}{4\pi} F_{s,\lambda}\, e^{-\tau_\lambda/\mu_s}(1-3g_{k,\lambda}\,\mu\,\mu_s)$$

Case 3 and Case 4

❑ **The NIF and thermally emitted-LW: downward from layer n_i-1 and upward from lower layers**

$$I_{\lambda,-\mu,\phi}(\tau_{a,\lambda,n_i}) = I_{\lambda,-\mu,\phi}(\tau_{a,\lambda,n_{i-1}})\, e^{-(\tau_{a,\lambda,n_i} - \tau_{a,\lambda,n_{i-1}})/\mu} + \frac{1}{\mu}\int_{\tau_{a,\lambda,n_{i-1}}}^{\tau_{a,\lambda,n_i}} [B_{\lambda,T(\tau'_{a,\lambda})}\, e^{-(\tau_{a,\lambda,n_i} - \tau'_{a,\lambda})/\mu}]\, d\tau'_{a,\lambda}$$

$$I_{\lambda,\mu,\phi}(\tau_{a,\lambda}) = A_{G,\lambda}[I_{\lambda,\mu,\phi}(\tau_{a,\lambda,G})\, e^{(\tau_{a,\lambda,n_i} - \tau_{a,\lambda,G})/\mu} - \frac{1}{\mu}\int_{\tau_{a,\lambda,G}}^{\tau_{a,\lambda,n_i}} (B_{\lambda,T(\tau'_{a,\lambda})}\, e^{(\tau_{a,\lambda,n_i} - \tau'_{a,\lambda})/\mu})\, d\tau'_{a,\lambda}] - \frac{1}{\mu}\int_{\tau_{a,\lambda,G,n_j}}^{\tau_{a,\lambda,n_i}} [B_{\lambda,T(\tau'_{a,\lambda})}\, e^{\tau_{a,\lambda,n_i} - \tau'_{a,\lambda})/\mu}]\, d\tau'_{a,\lambda}$$



Case 5 and Case 6

❑ **Surface reflected SW radiation and surface emitted-LW**

$$F_{G,\lambda}\uparrow = \int_0^{\frac{\pi}{2}} \frac{\boxed{A_G(\lambda,\mu',\varphi}\,)}{\mu'} \int_0^{\tau_G} [I_\lambda\downarrow - \sum_k \frac{\omega_{s,k,\lambda}(1+g_{k,\lambda})}{2} I_\lambda\downarrow + \frac{\omega_{s,k,\lambda}(1-g_{k,\lambda})}{2} I_\lambda\uparrow - \sum_k \frac{\omega_{s,k,\lambda}}{4\pi} F_{s,\lambda}\, e^{-\tau'_\lambda/\mu_s}(1+3g_{k,\lambda}\,\mu\,\mu_s)]\, d\tau'_\lambda\, d\mu'$$

$\varepsilon\pi B_{\lambda,T_s}$, *where* $\varepsilon = 1 - A_G$

Direct effect (RF = $F_{net,a}$ − $F_{net,n}$) ⇒ Cool/Warm the surface and atmosphere

SAWS AQ Research

- Natural dust emission module regional localization

$$f(w) = 1 \text{ for } w < w_r$$

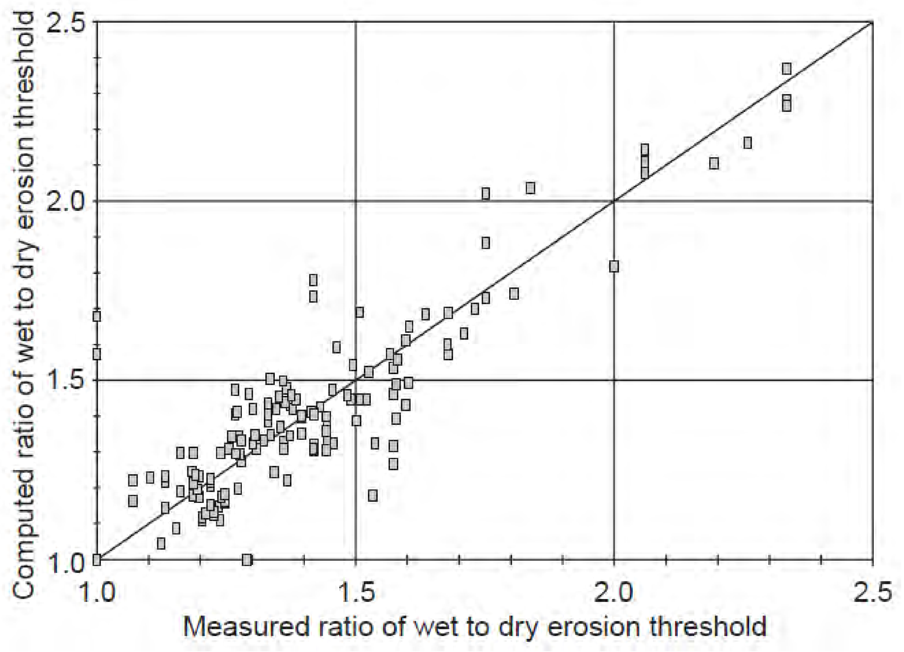
$$f(w) = \sqrt{1 + a(w - w_r)^b} \text{ for } w > w_r$$

$f(w)$: threshold friction velocity
W: volumetric soil moisture
a and b: constants
Wr: threshold soil moisture

The a, b, and w_r Values in Soil Moisture Correction for Different Soil Types

	Sand	Loamy Sand	Sandy Loam	Loam	Silt Loam	Sandy Clay Loam	Clay Loam	Silty Clay Loam	Sandy Clay	Silty Clay	Clay	Heavy Clay
a	21.19	30.0	44.87	17.79	21.79	25.79	29.86	27.50	25.20	22.90	20.47	20.47
b	0.68	0.90	0.85	0.61	0.67	0.74	0.80	0.75	0.70	0.65	0.59	0.54
w_r	0.005	0.01	0.037	0.049	0.059	0.075	0.095	0.110	0.125	0.140	0.156	0.171

Kang et al. (2011); Gherboudj et al. (2016)



Dust

Fine	Accumulation	Coarse	Giant
(0.01–1.0μm)	(1.0–2.5μm)	(2.5–5.0μm)	(5.0–20.0μm)

$$\frac{\partial \xi^{Dust_i}}{\partial t} = -\tilde{\nabla}.\,\nabla\xi^{Dust_i} + B_H^{Dust_i} + B_V^{Dust_i} + T_C^{Dust_i} + E^{Dust_i} - R_{W,ls}^{Dust_i} - R_{W,C}^{Dust_i} - D_d^{Dust_i} + \sum\left(\eta_p^{Dust_i} - \eta_l^{Dust_i}\right)$$

Solmon et al., 2006 **Zakey et al., 2006** **Solmon et al., 2006**

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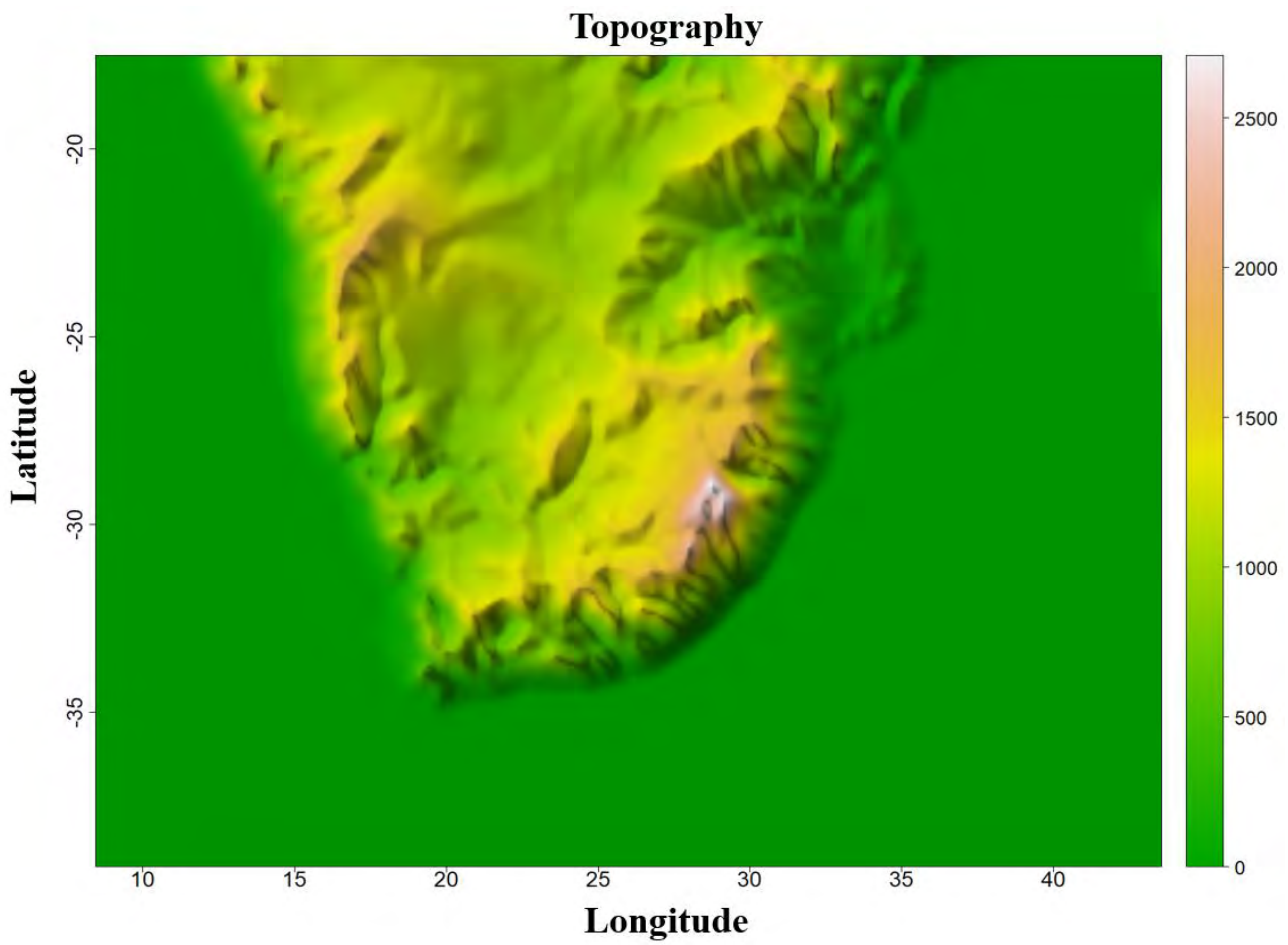
- Southern Africa Domain



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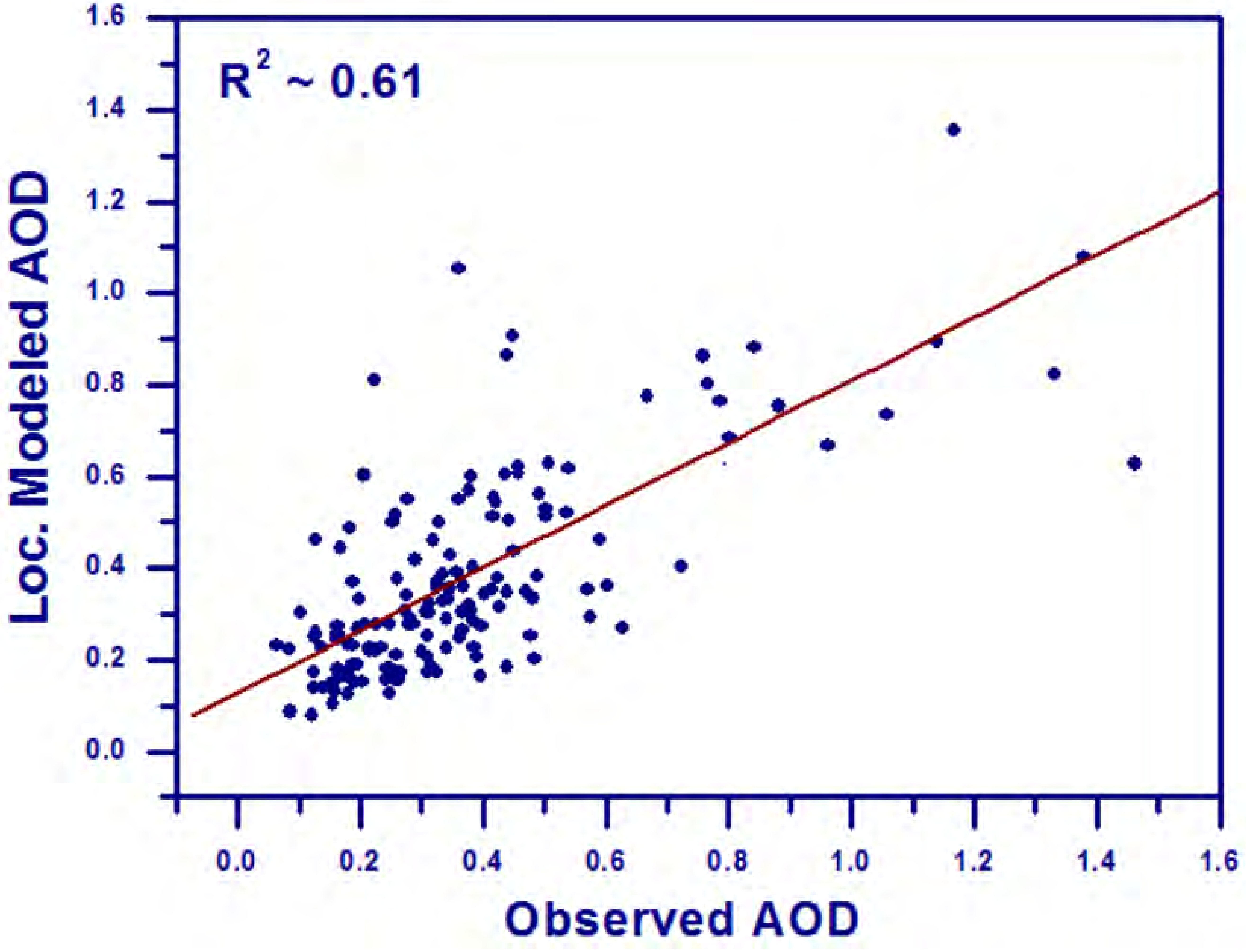
SAWS AQ Research

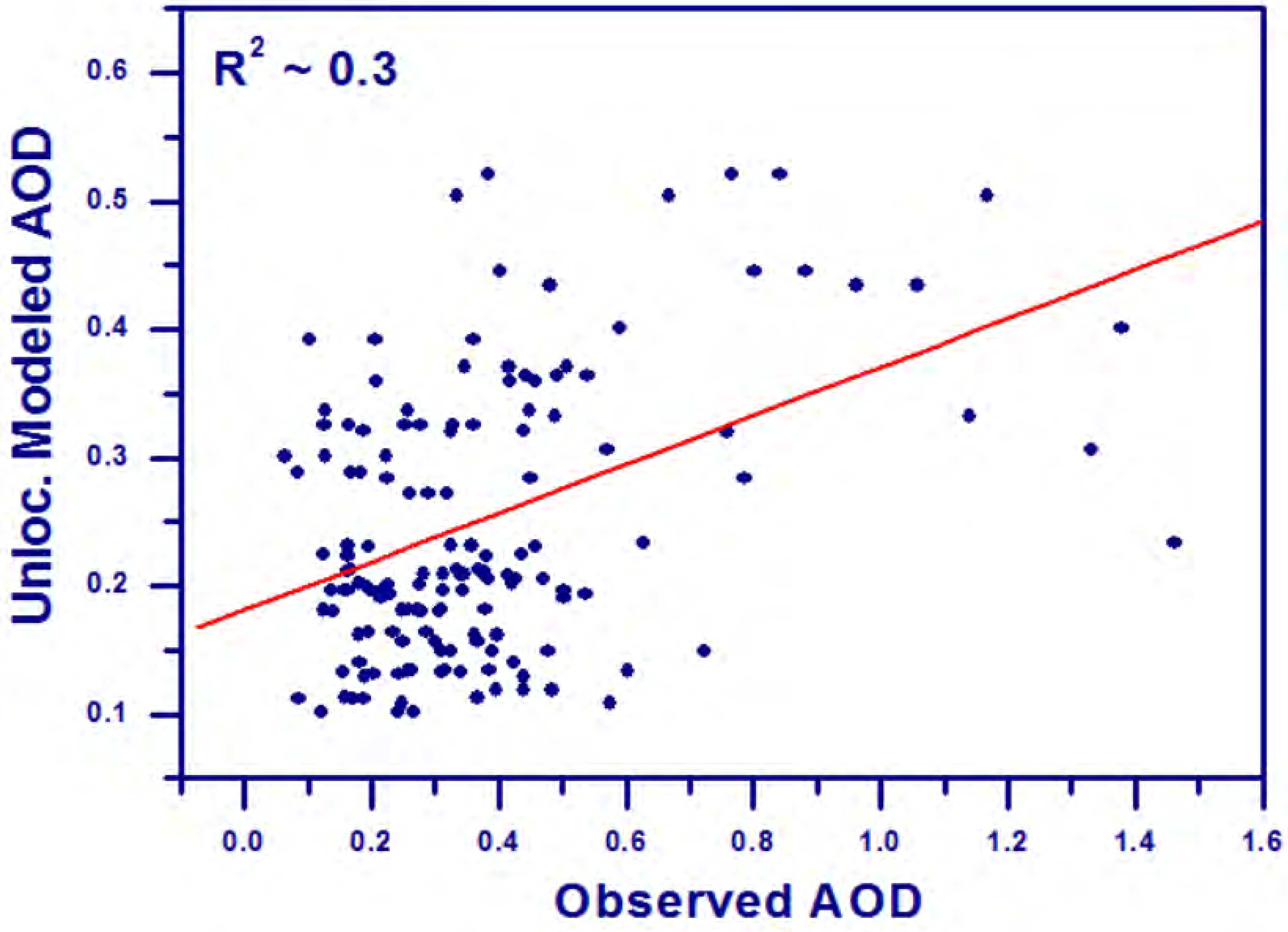
- Natural dust emission module regional localization

South African Weather Service

SAWS AQ Research

- RCM-Chem evaluation





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- RCM-Chem evaluation

Within the Sd. of AERONET and ± 25% of MISR

Temporal correlation ~ 0.6

- uncertainties associated with emissions
- bias in simulated meteorological fields
- biases that propagate from interpolation scheme

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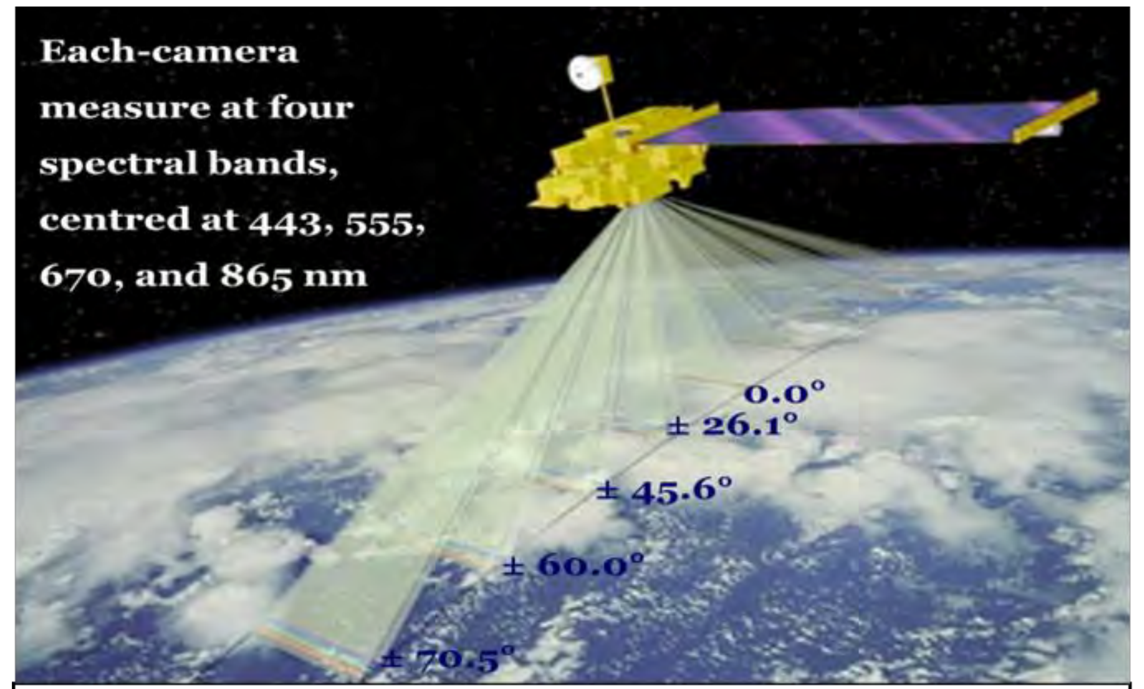
RCM-Chem evaluation



$$\tau_e(r,\lambda,m,n(r)) = \int_0^\infty \pi r^2 Q_{ext}(r,\lambda,m)\, n(r)\, dr$$

Under the framework of Mie theory and Non-linear inversion scheme:

$$\tau_e(r,\lambda,m,n(r)) = \sum_{j=1}^{q} \int_{r_j}^{r_{j+1}} \pi r^2 Q_{ext}(r,\lambda,m) h(r) f(r) dr$$

$$\tau_e(r,\lambda,m,n(r)) = Af(r) + \varepsilon$$

where $A = \int \pi r^2 Q_{ext}(r,\lambda,m)\, h(r) dr$ **and** ε **is an error which arises due to deviation between the** $\tau_e(r,\lambda,m,n(r))$ **and** $\left(\tau_e(r,\lambda,m,n(r)) = \sum A_{ij} f_i\right)$

$$f_{n+1} - f_n = \left(A^T A + \gamma H\right)^{-1} A^T \left(\tau_{measured} - \tau_{simulated}\right)$$

$$\chi^2 = \sum_{i=1}^{n} \left(\tau_{measured}(\lambda_i) - \tau_{simulated}(\lambda_i)\right)^2$$

Columnar weighted

$$n(r) = \frac{2\pi r^2 dN(r)}{dr}$$

and

$$m_{eff}$$

In conjunction with Mie theory

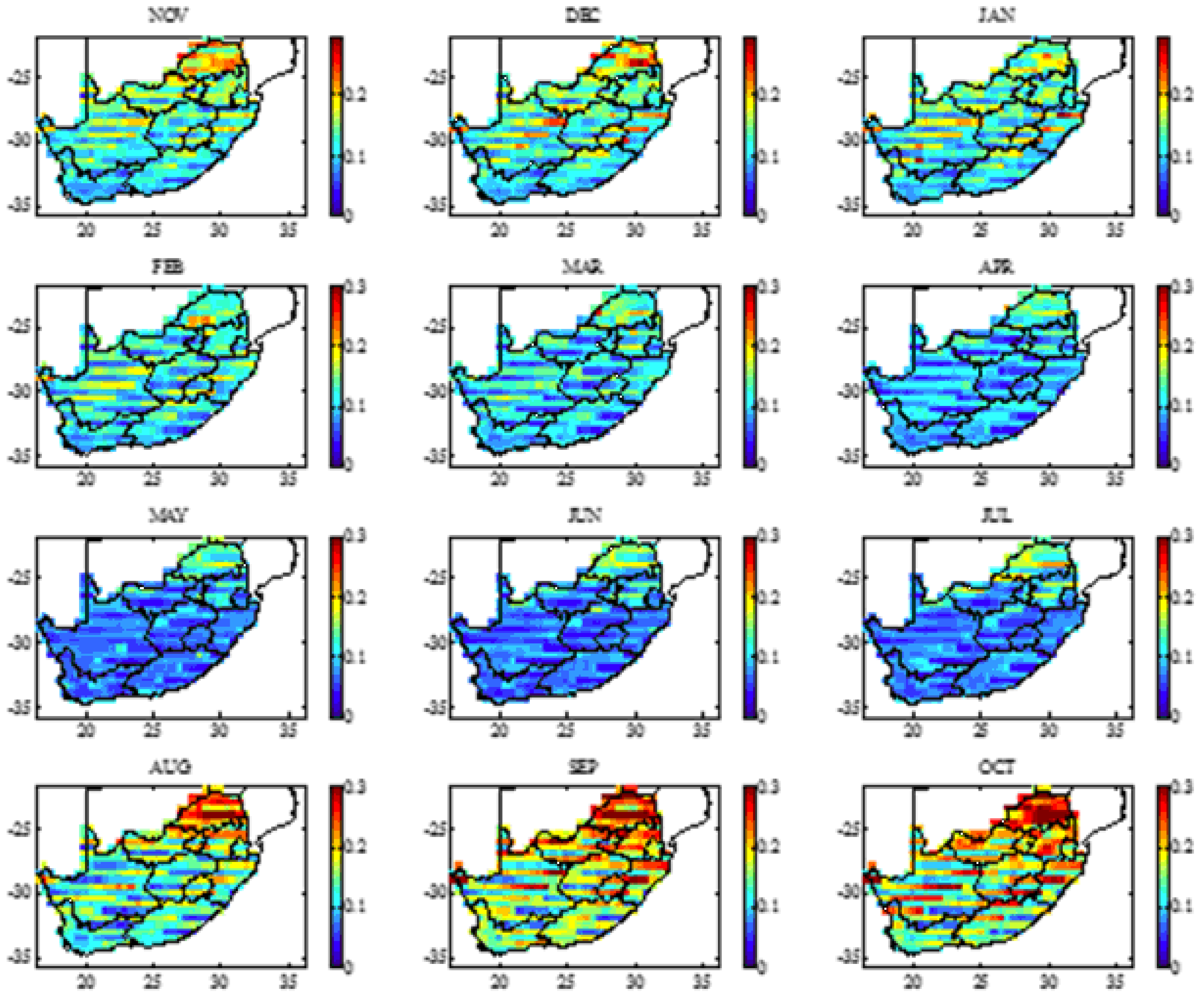
$$\tau_{s(\lambda)} \quad \tau_{a(\lambda)} \quad \omega_{(\lambda)}$$

$$\tau_{e(555\,\mathrm{nm})} \quad \tau_{a(555\,\mathrm{nm})} \quad \omega_{(555\,\mathrm{nm})}$$

$$\frac{\partial Q_{ext}(\lambda,r)}{\partial \lambda} \Rightarrow \alpha_{(443-670)nm} \quad \alpha_{(670-865)nm}$$

$$\alpha' = \frac{d\alpha}{d\ln\lambda} = -\left(\frac{2}{\ln\lambda_{i+1} - \ln\lambda_{i-1}}\right)\left[\frac{\ln\tau_{i+1} - \ln\tau_i}{\ln\lambda_{i+1} - \ln\lambda_i} - \frac{\ln\tau_i - \ln\tau_{i-1}}{\ln\lambda_i - \ln\lambda_{i-1}}\right]$$

$$\tau_{ext\,(555\,\mathrm{nm})}$$



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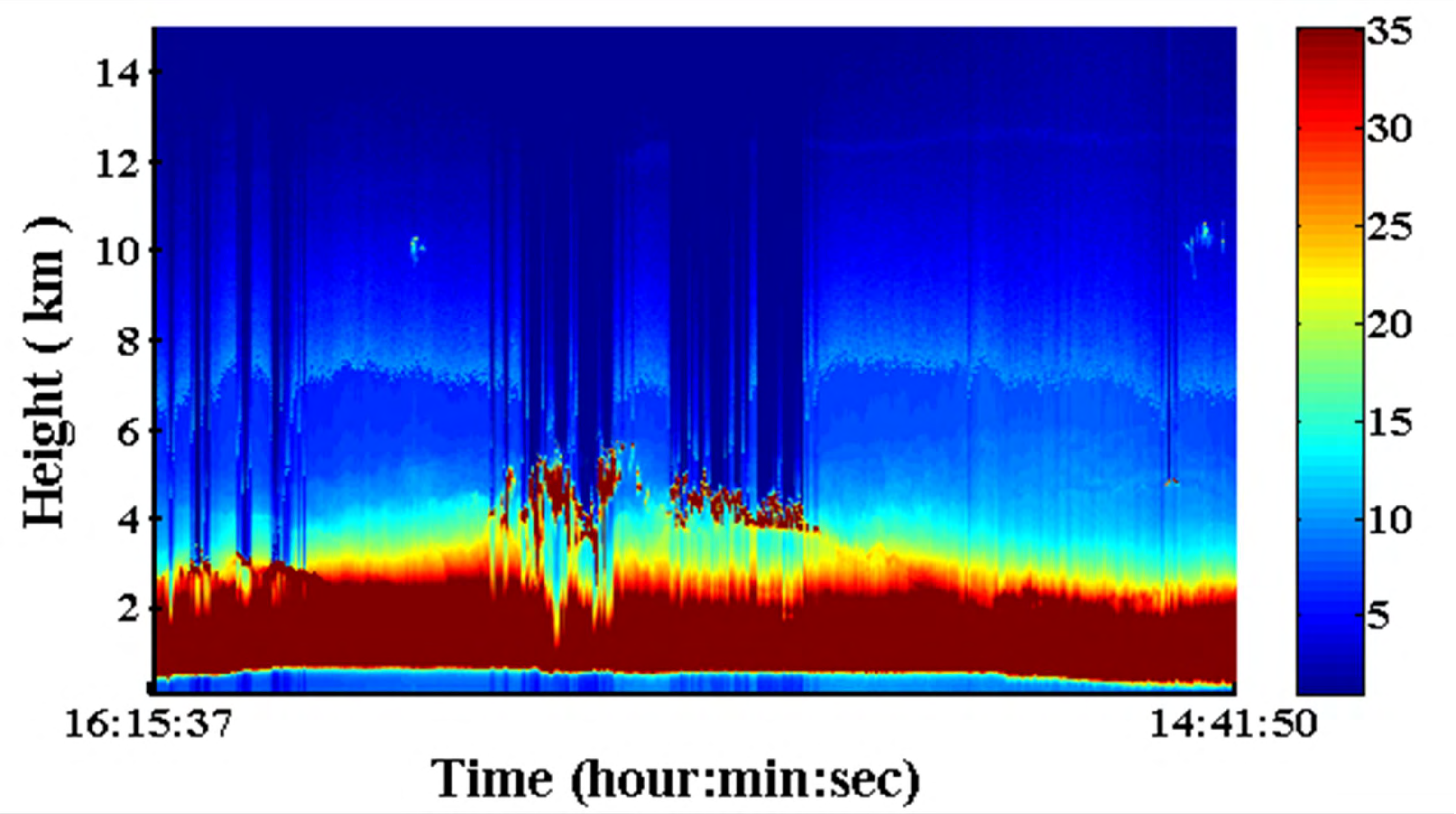
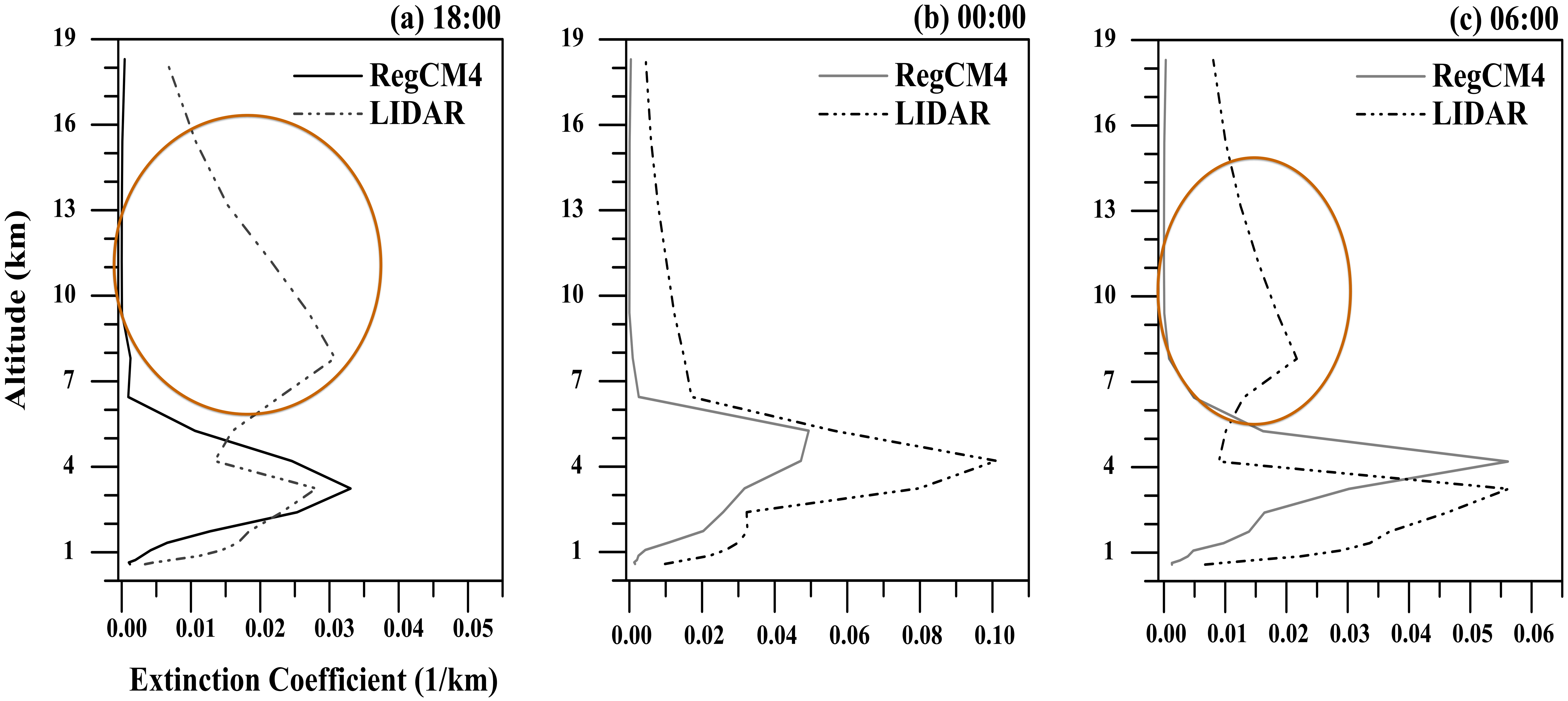
SAWS AQ Modeling and Forecasting

- RCM-Chem evaluation





Air mass trajectory analysis of Tesfaye et al. 2010 shows that > 6 km there exist a large contribution of long-range transportation processes .

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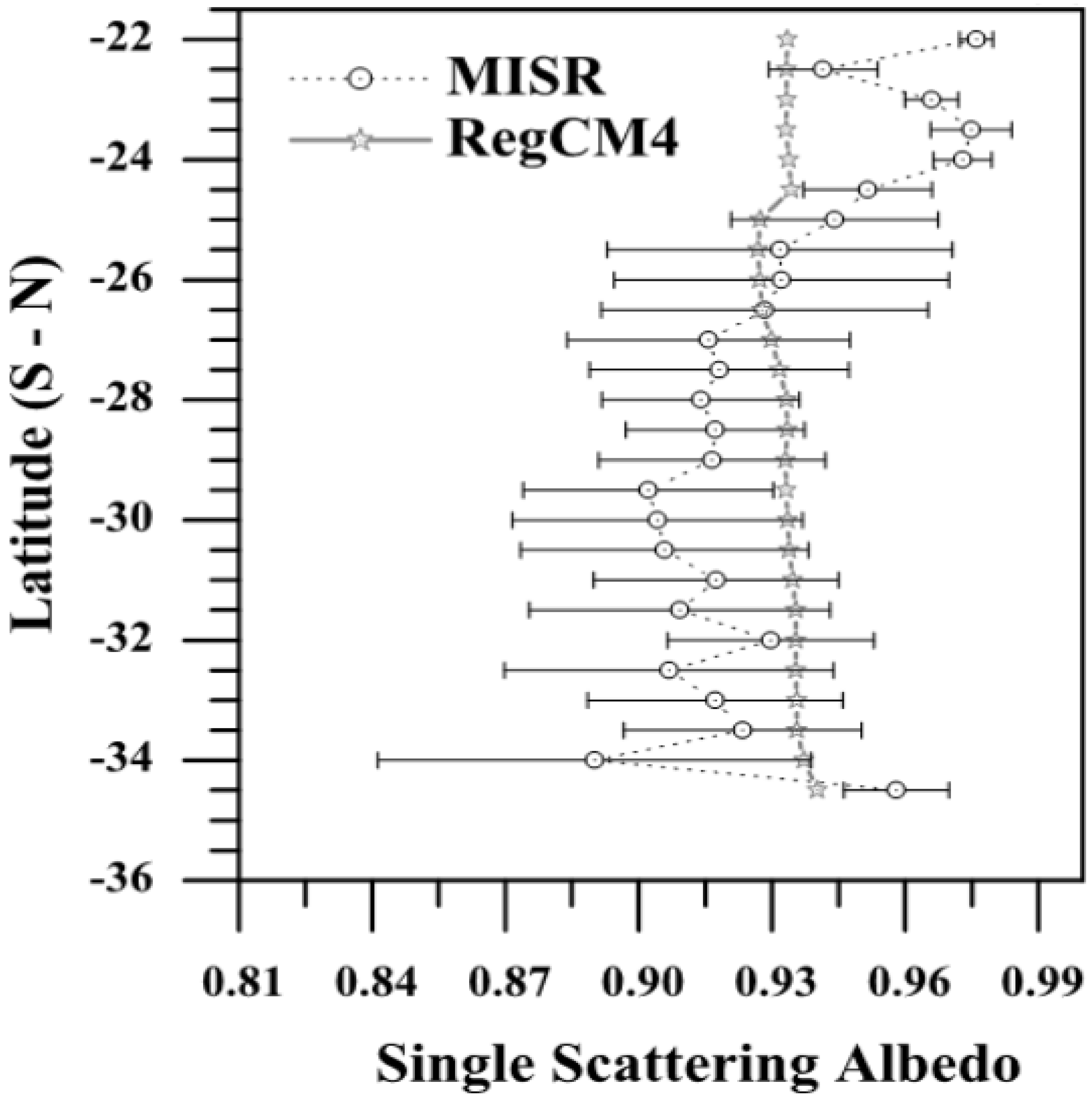
SAWS AQ Research

- RCM-Chem evaluation



SAFARI-2000

SSA	Reference	SSA	Reference
0.87 – 0.99	Formenti et al., 2003	0.84 - 0.90	Eck et al., 2003
0.80 - 0.94	Haywood et al. 2003	0.72 - 0.90	Bergstrom et al., 2003
0.81- 0.93	Magi et al., 2003	0.81-0.91	Kuzmanoski et al., 2007
0.84 - 0.90	Abel et al., 2003	0.73 – 0.96	RCM-Chem

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SAWS AQ Research

- RCM-Chem evaluation

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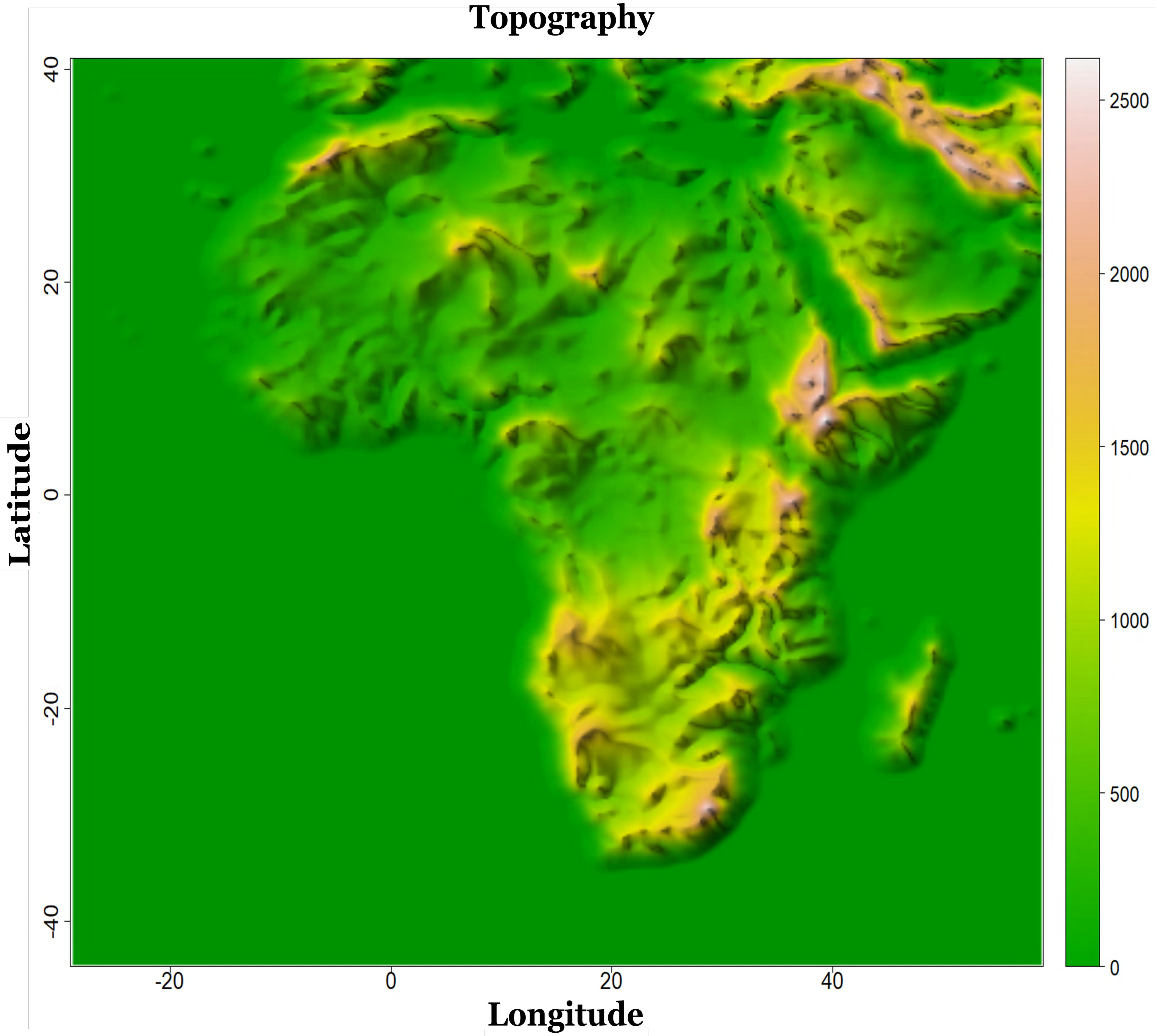
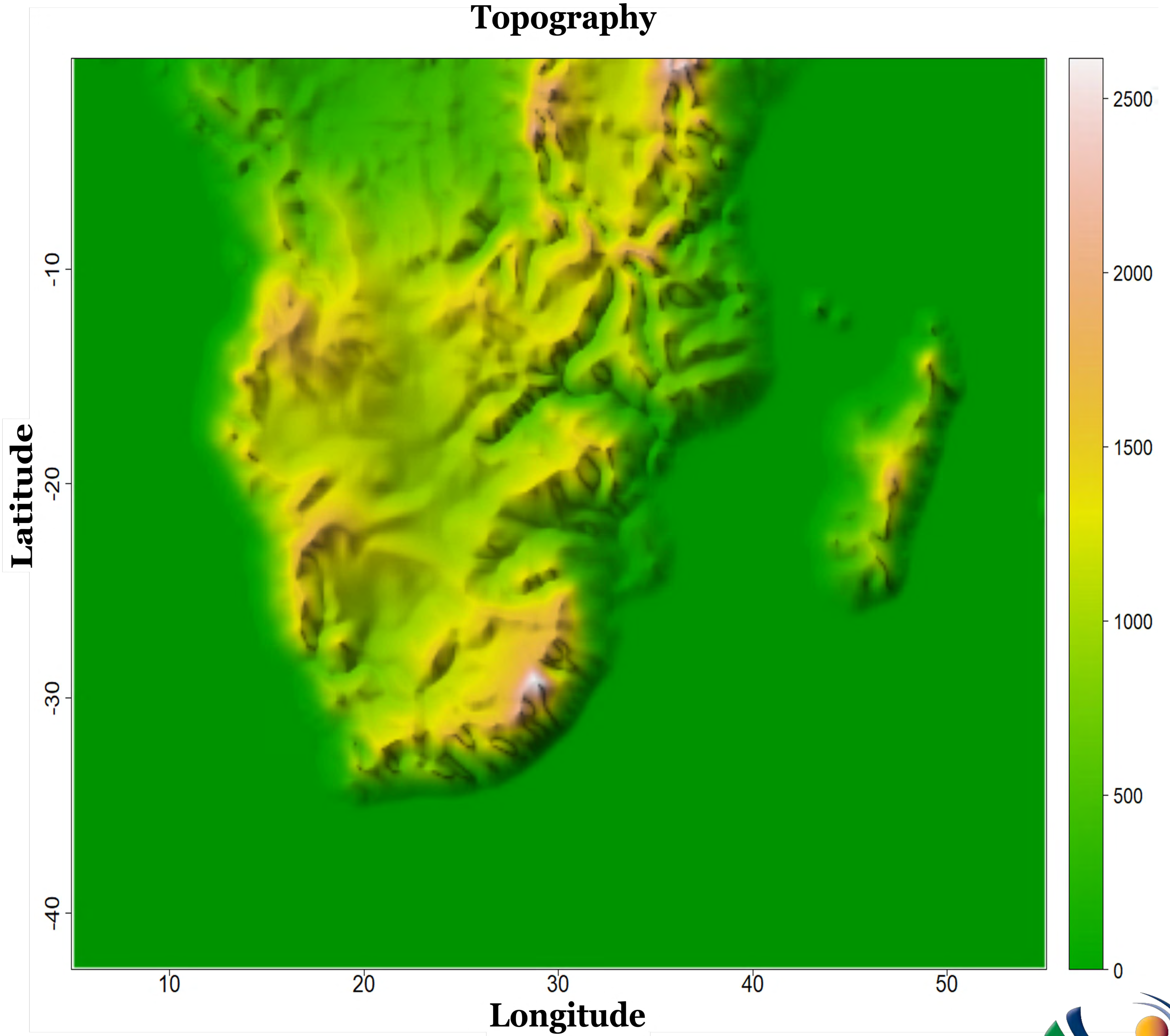
SAWS AQ Research

❑ Simulation Domains

Africa



Southern Africa



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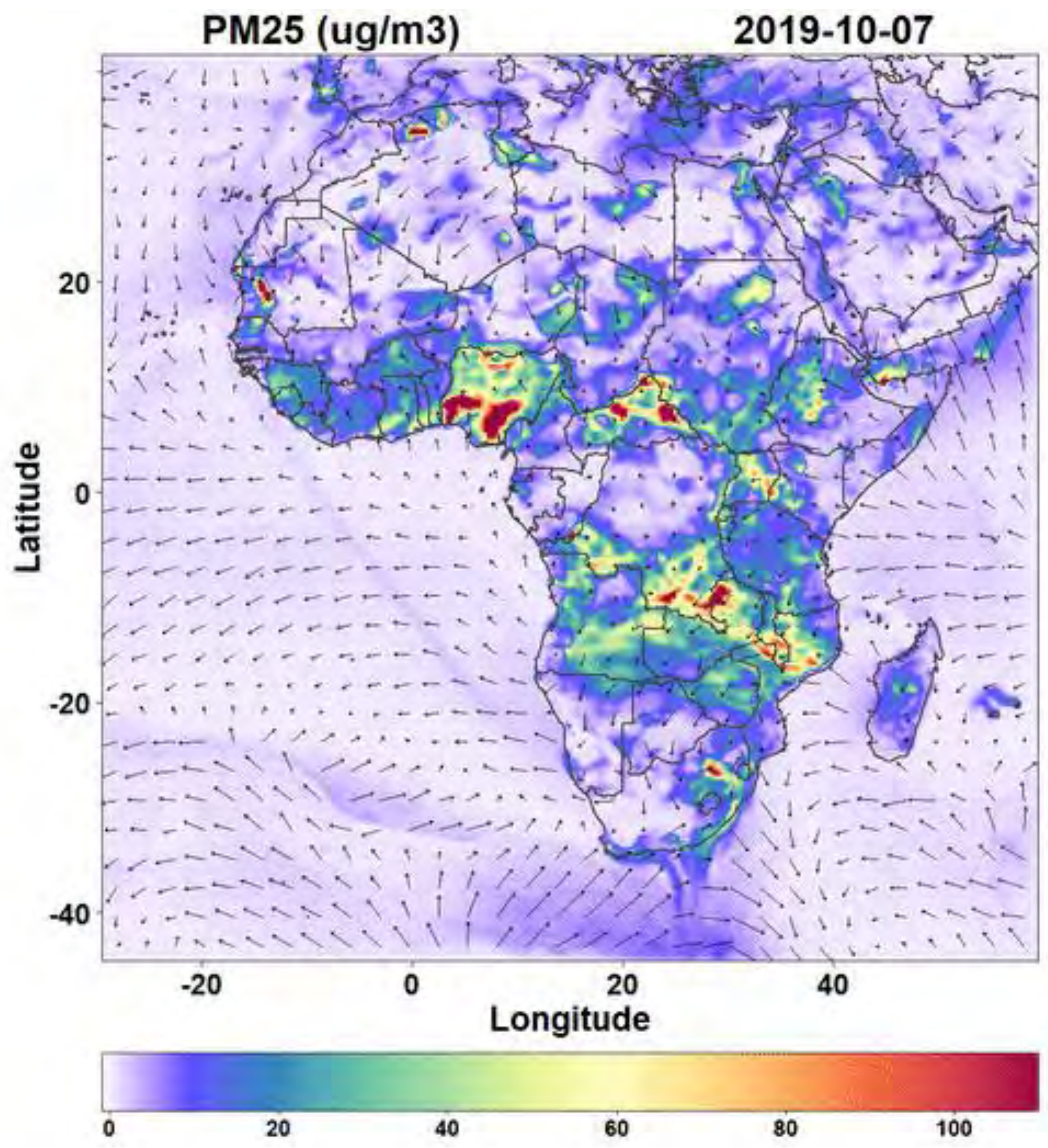
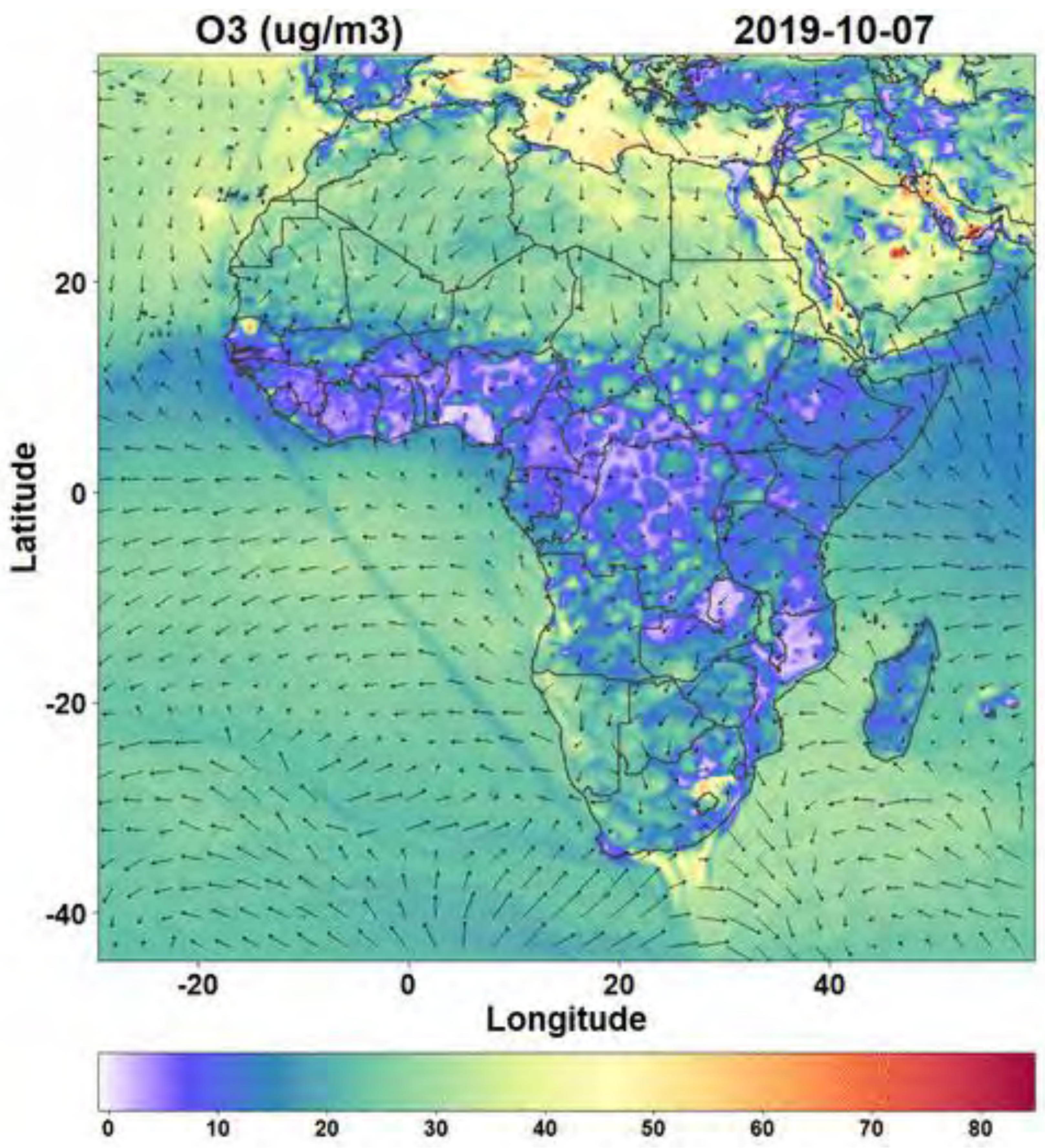
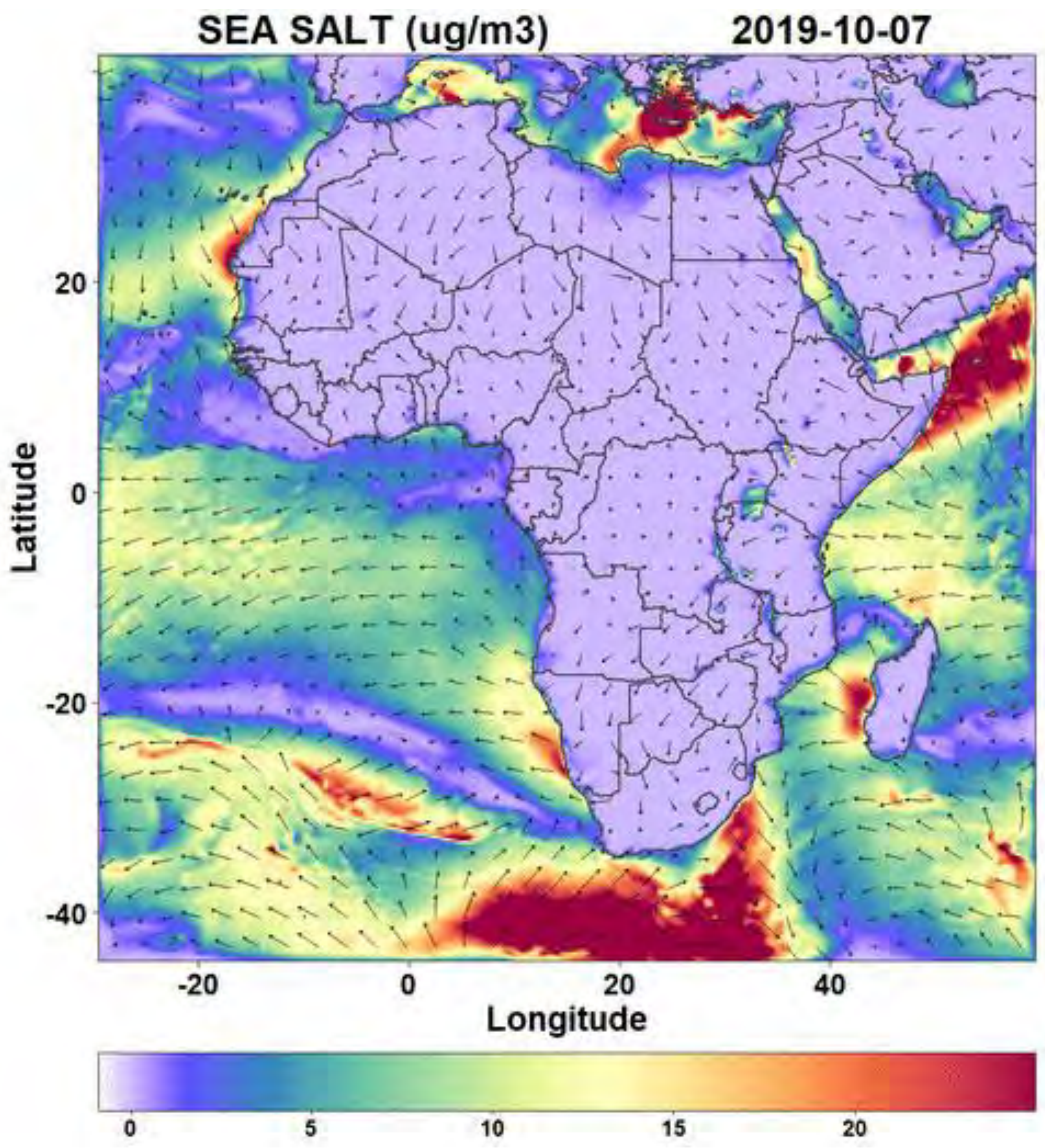
SAWS AQ Research

- AQF: 7 – 9 October







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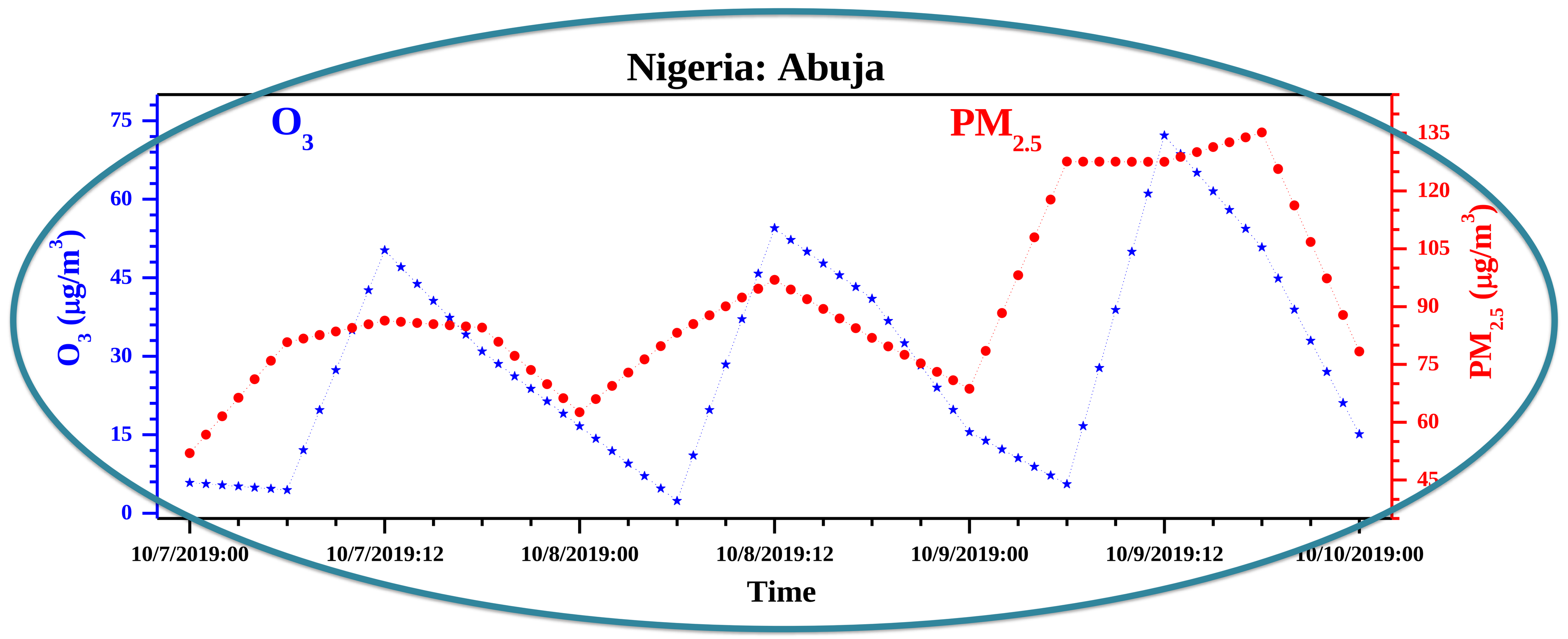
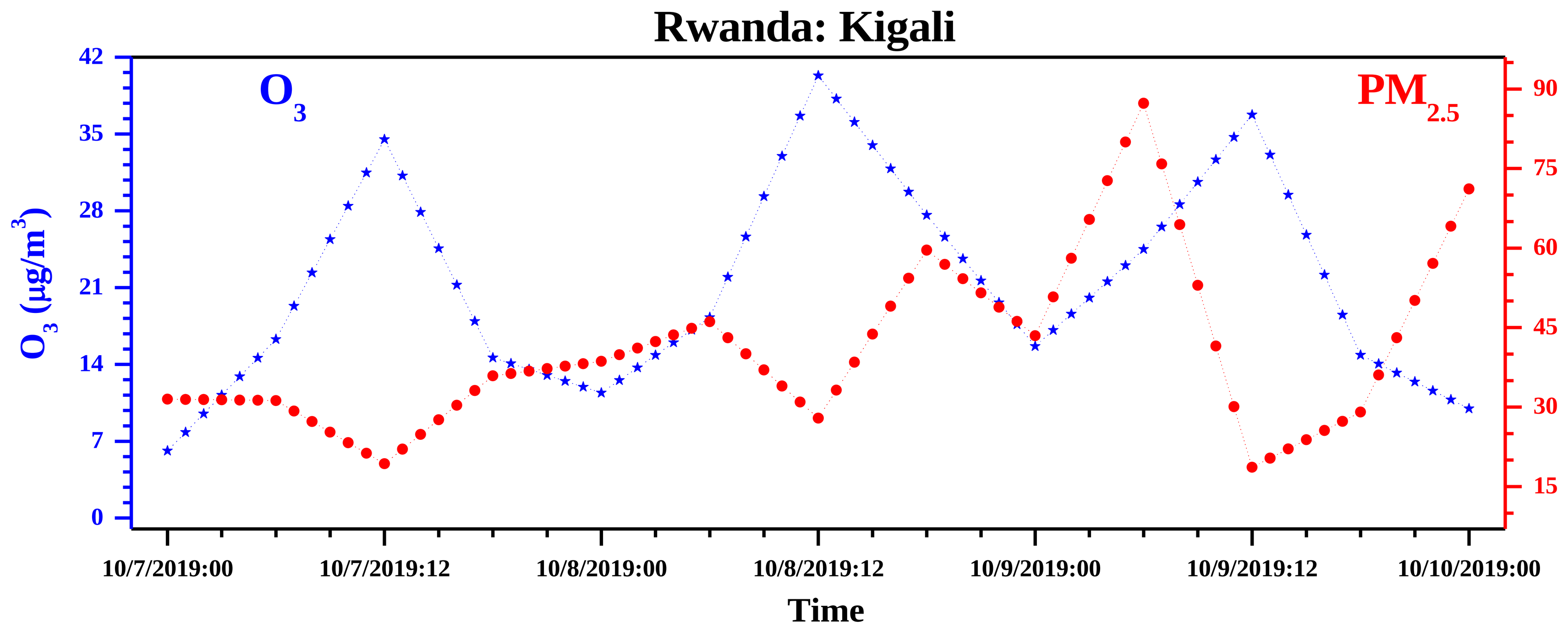
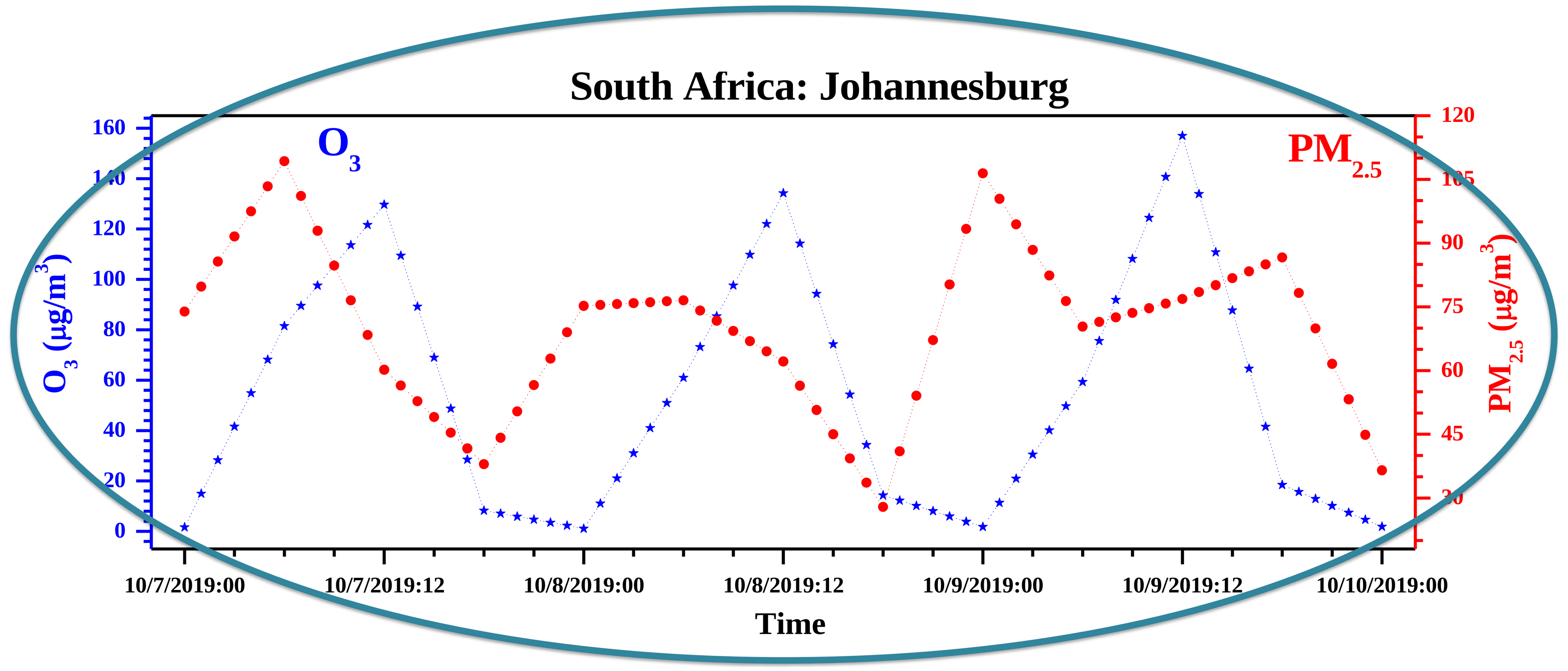
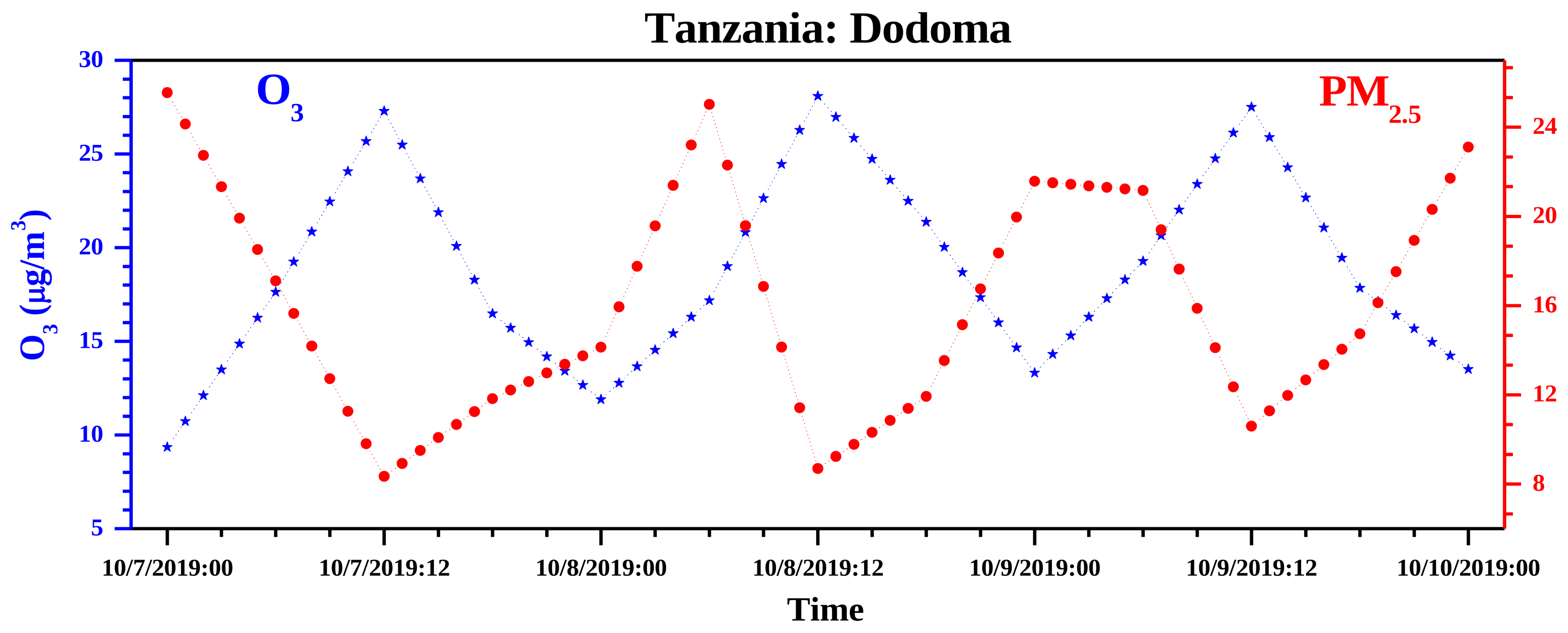
SAWS AQ Research

- AQF: 7 – 9 October



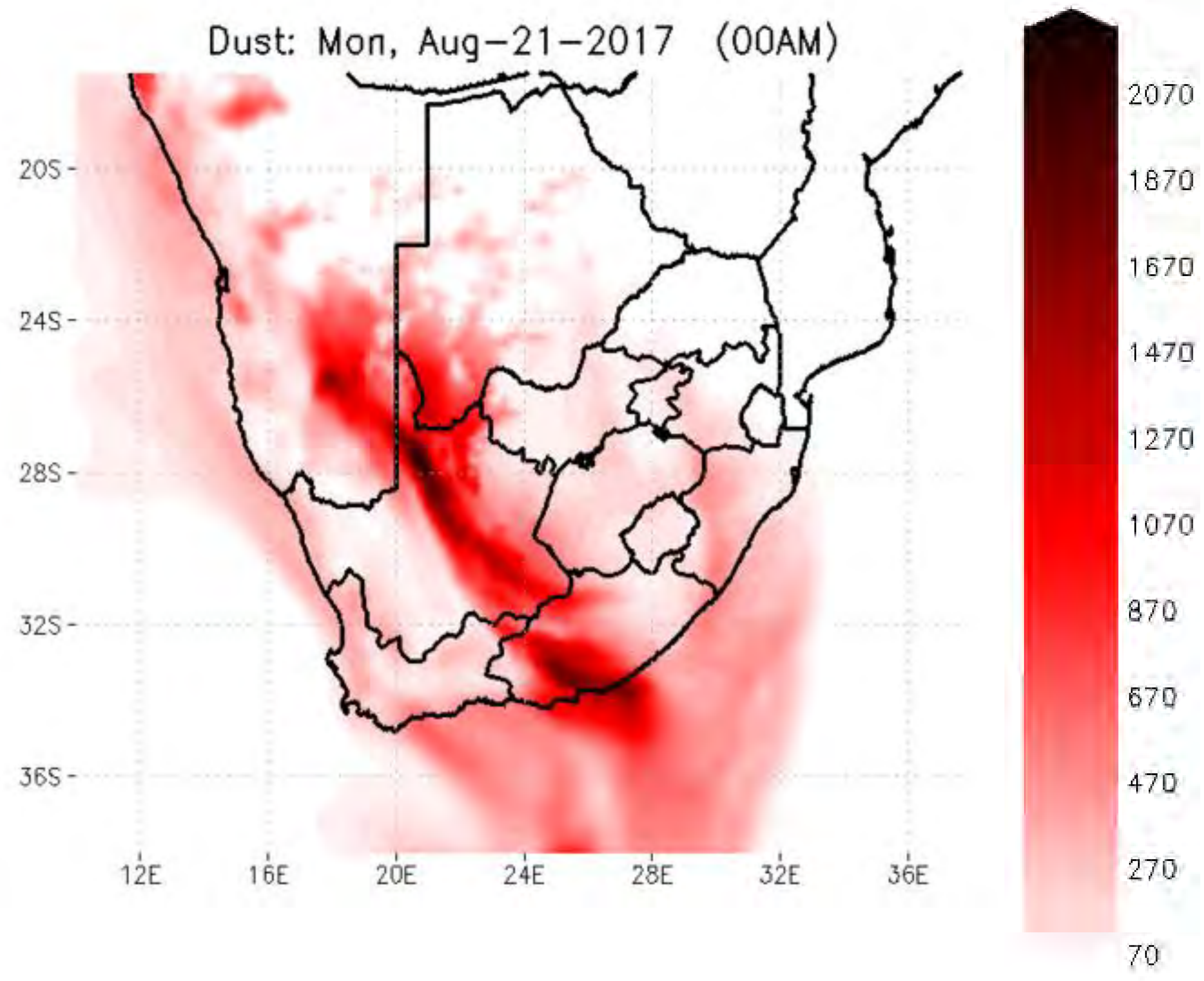


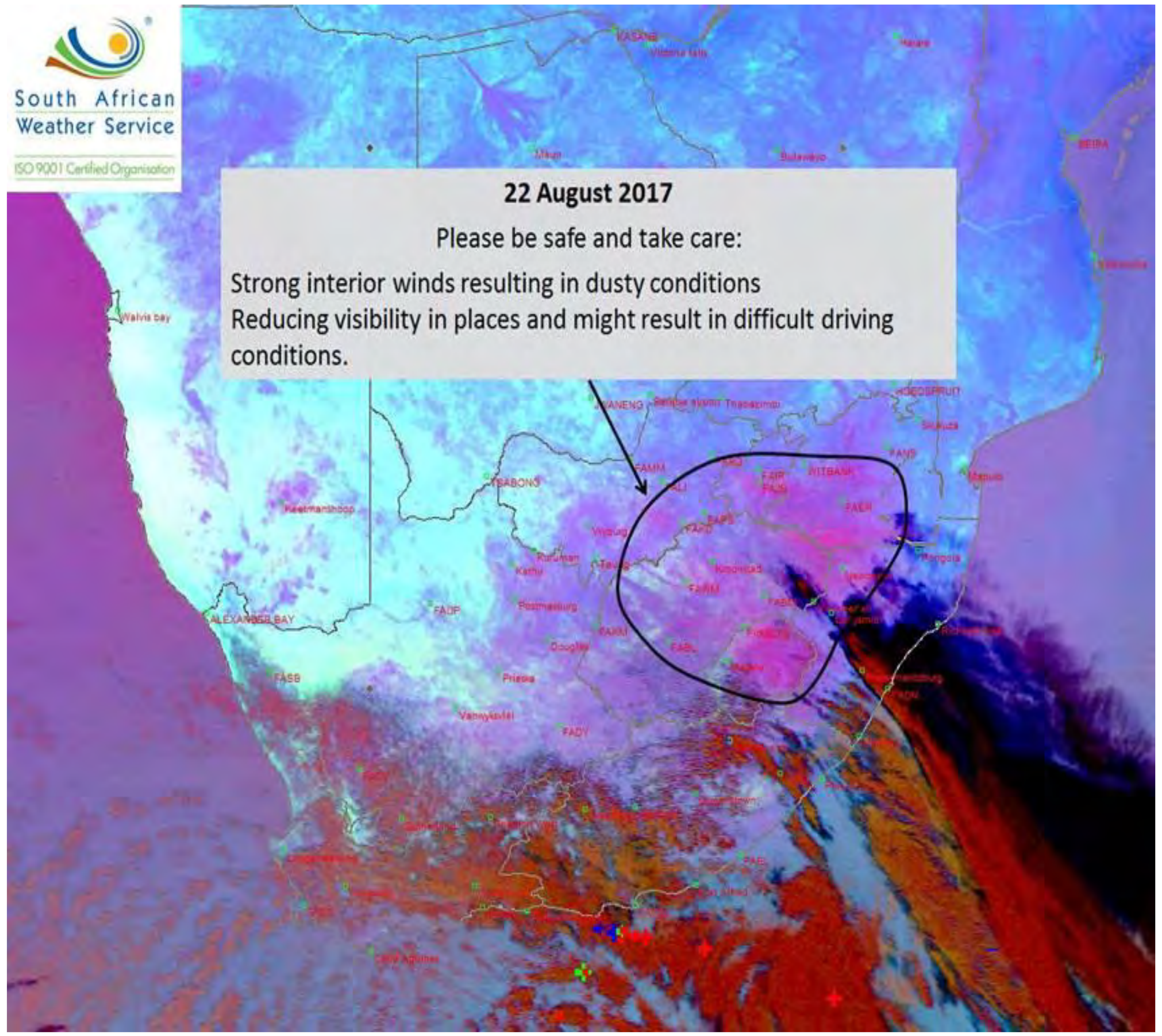




SAWS AQ Modeling and Forecasting

- Africa domain: Dust storm forecast





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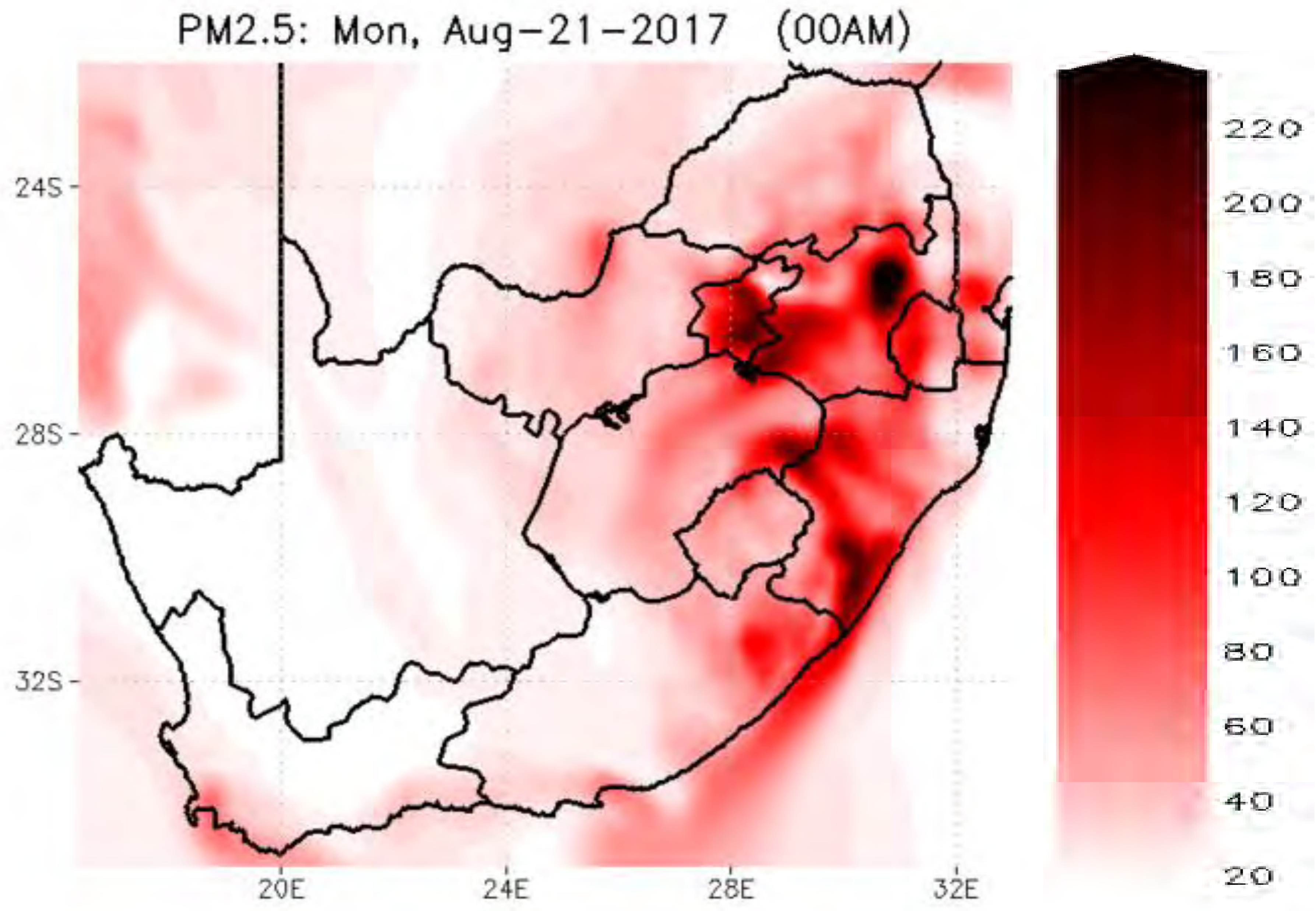
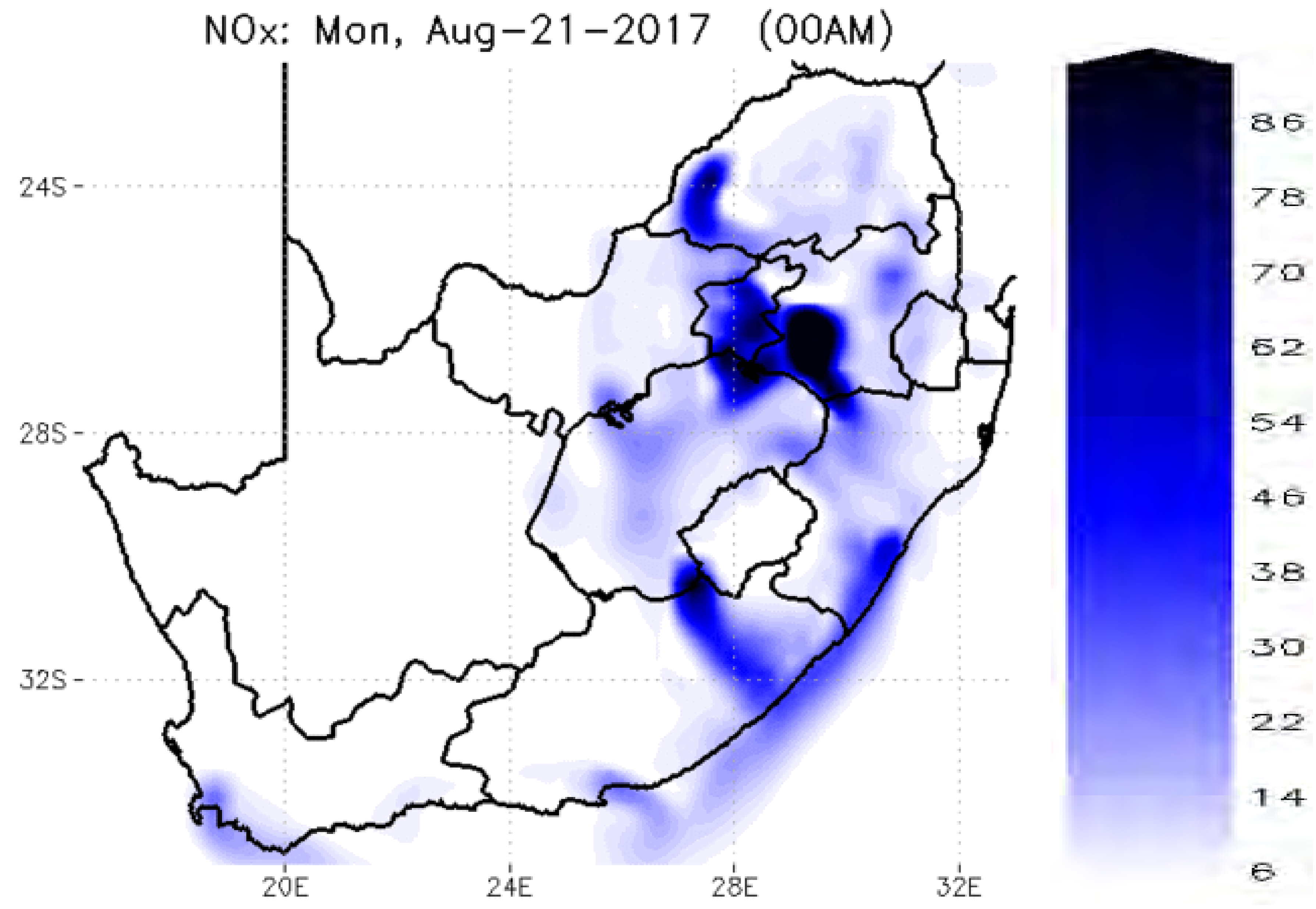
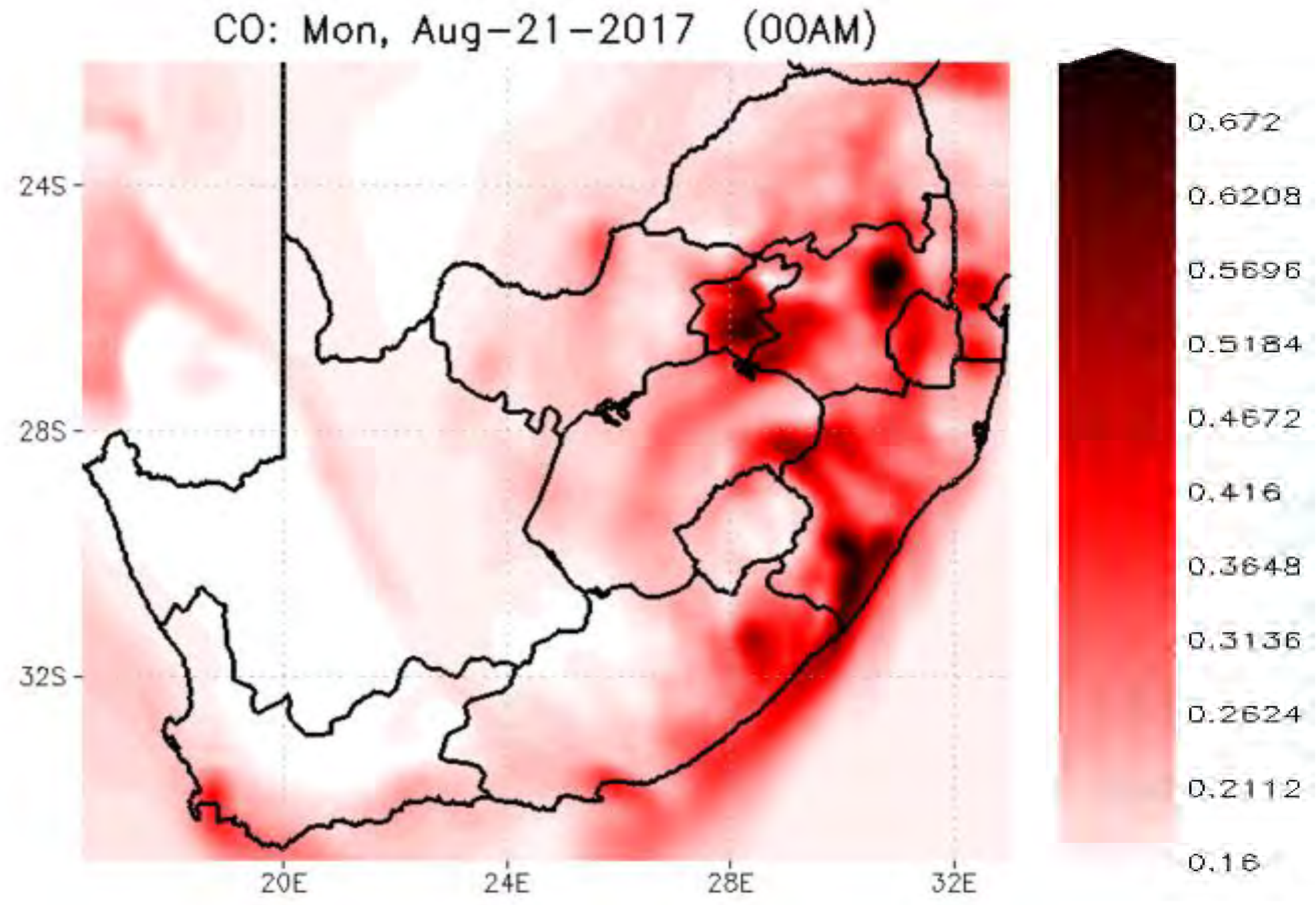
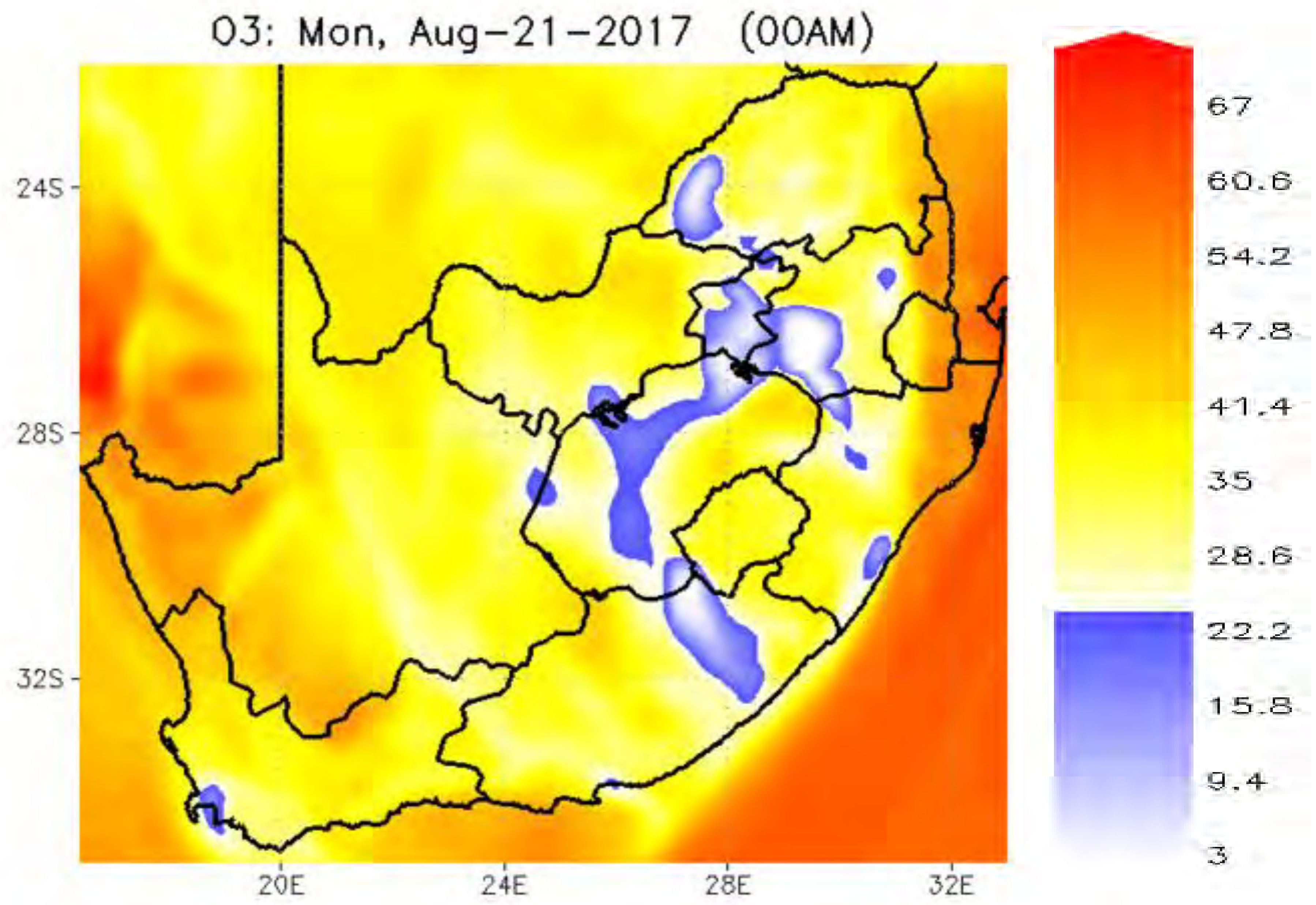
SAWS AQ Modeling and Forecasting

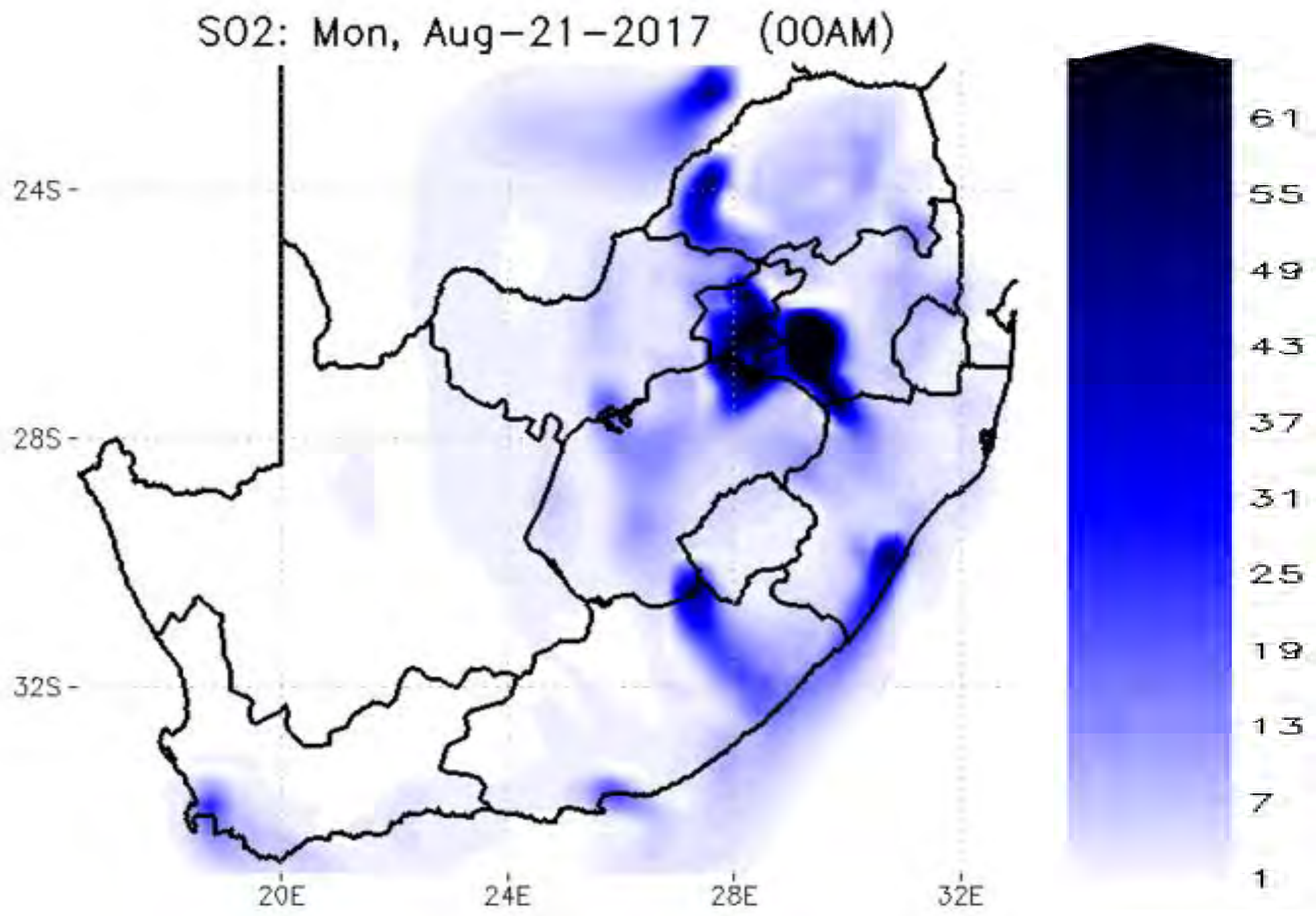
- Africa domain: Air quality forecast











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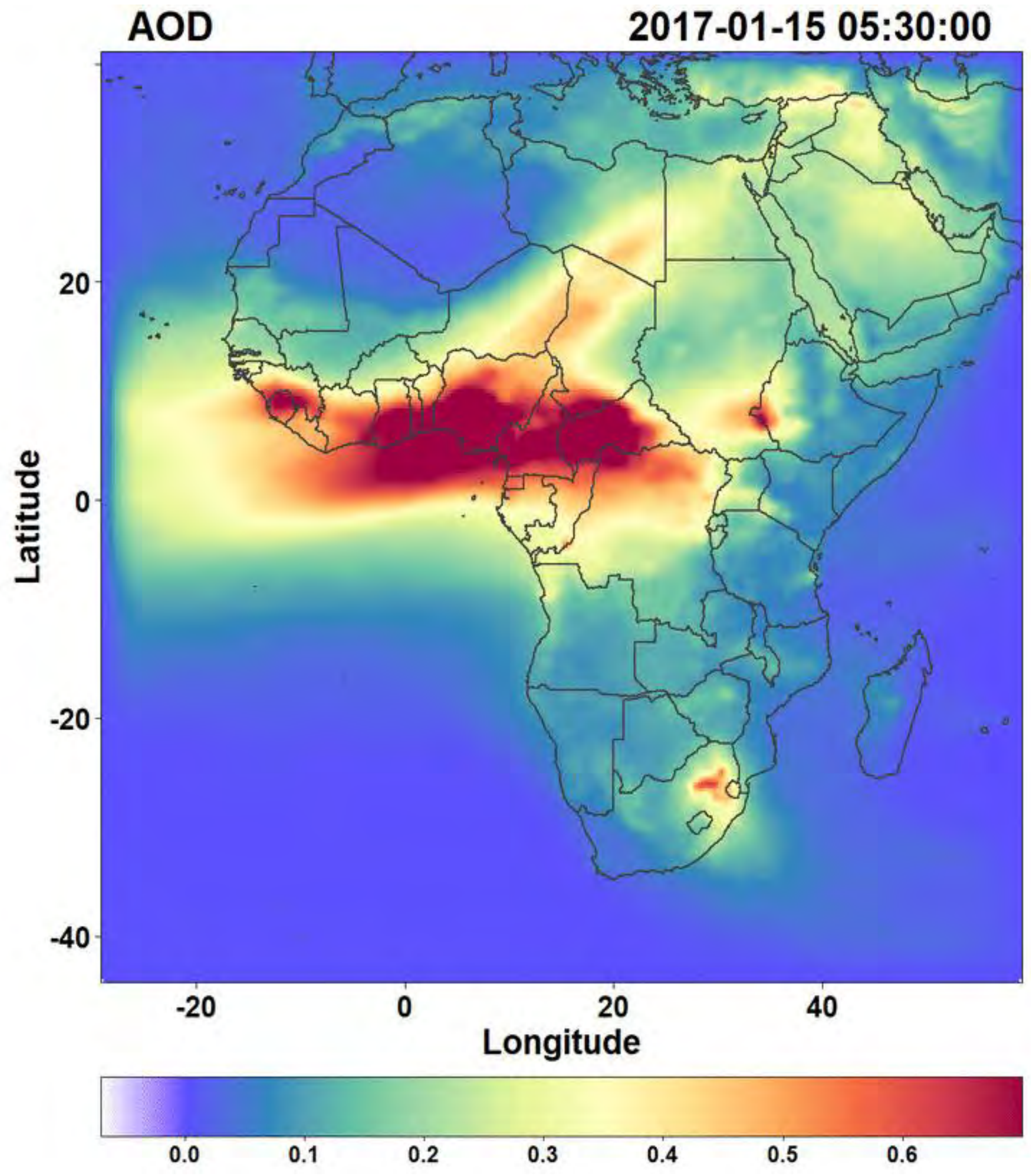
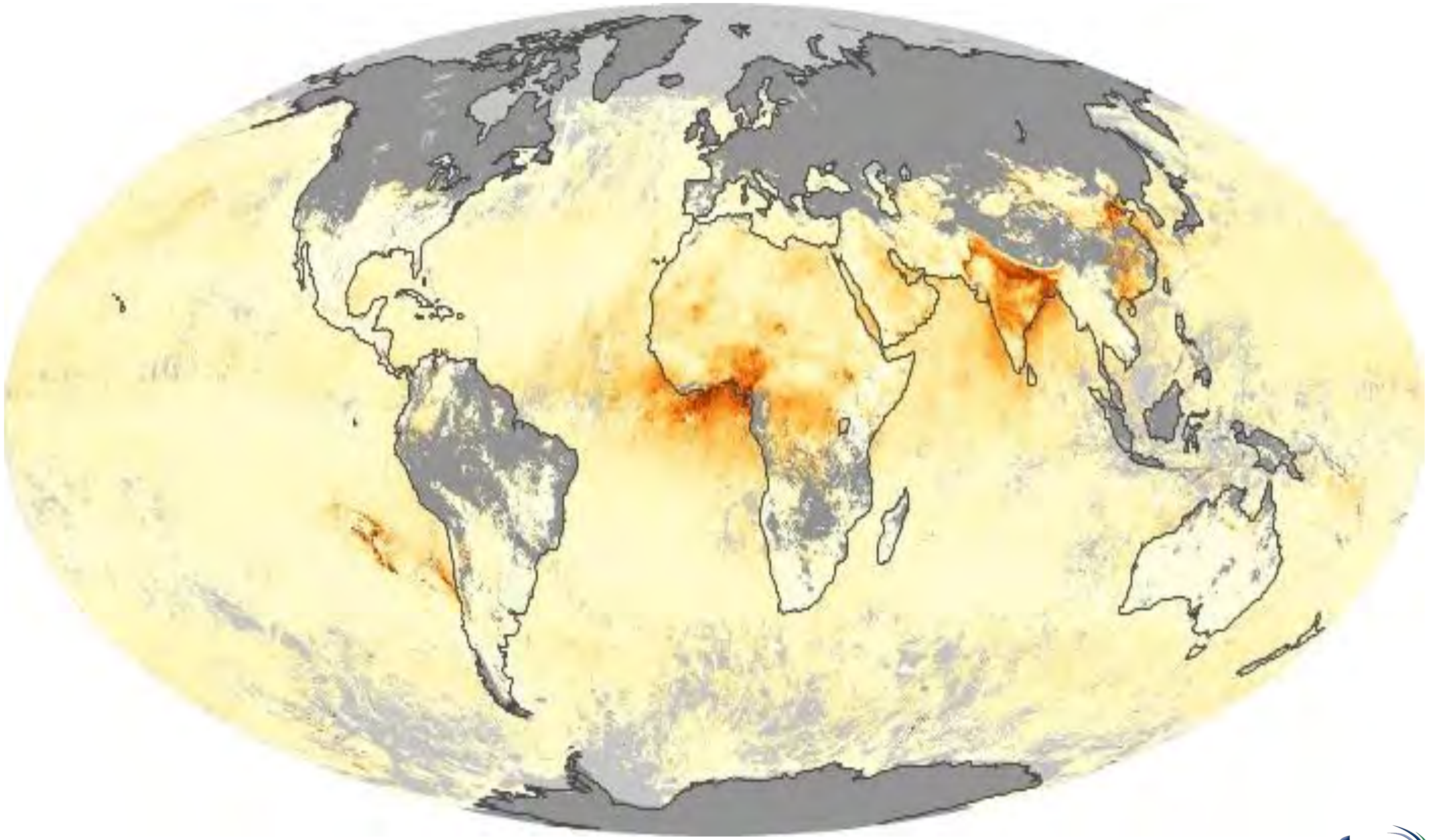
SAWS AQ Research

❑ Simulation Outputs



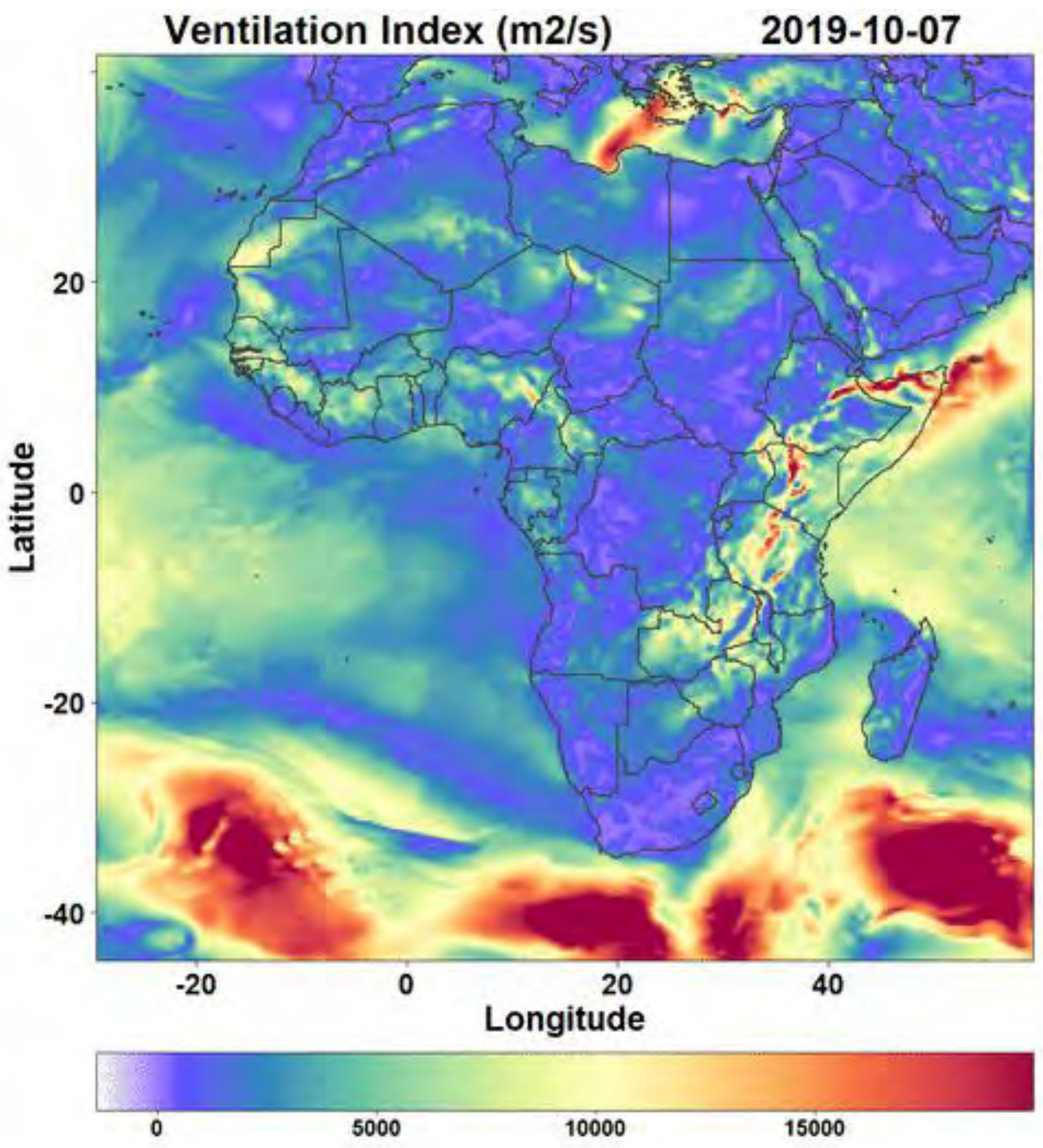
MODIS AOD



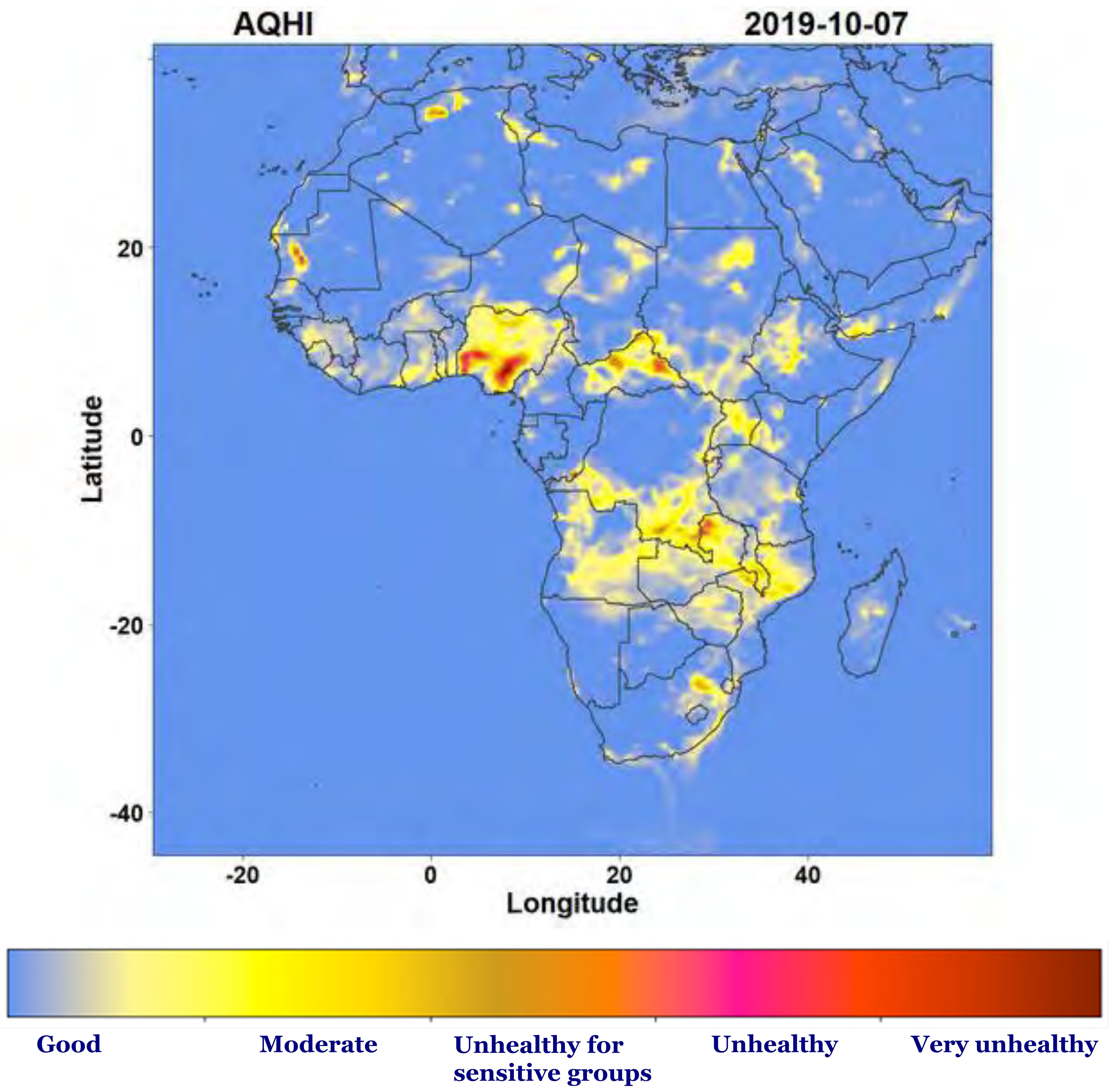
South African

SAWS AQ Research

- AQF: 7 – 9 October



	VI (m2/s)
Excellent	>22500
Very Good	15000 - 22499
Good	9000 - 14999
Fair	6000 - 8999
Poor	<6000



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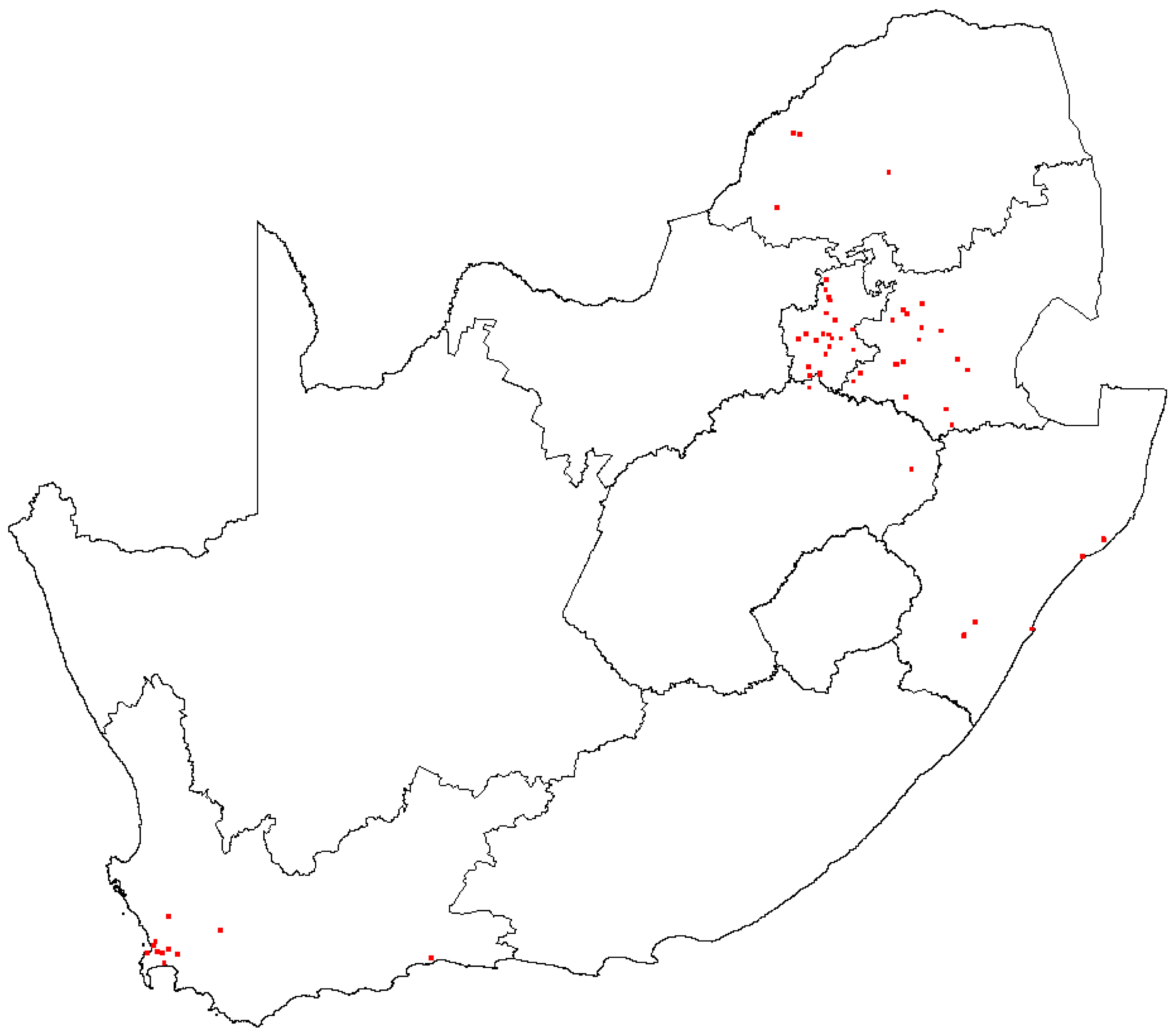
Services

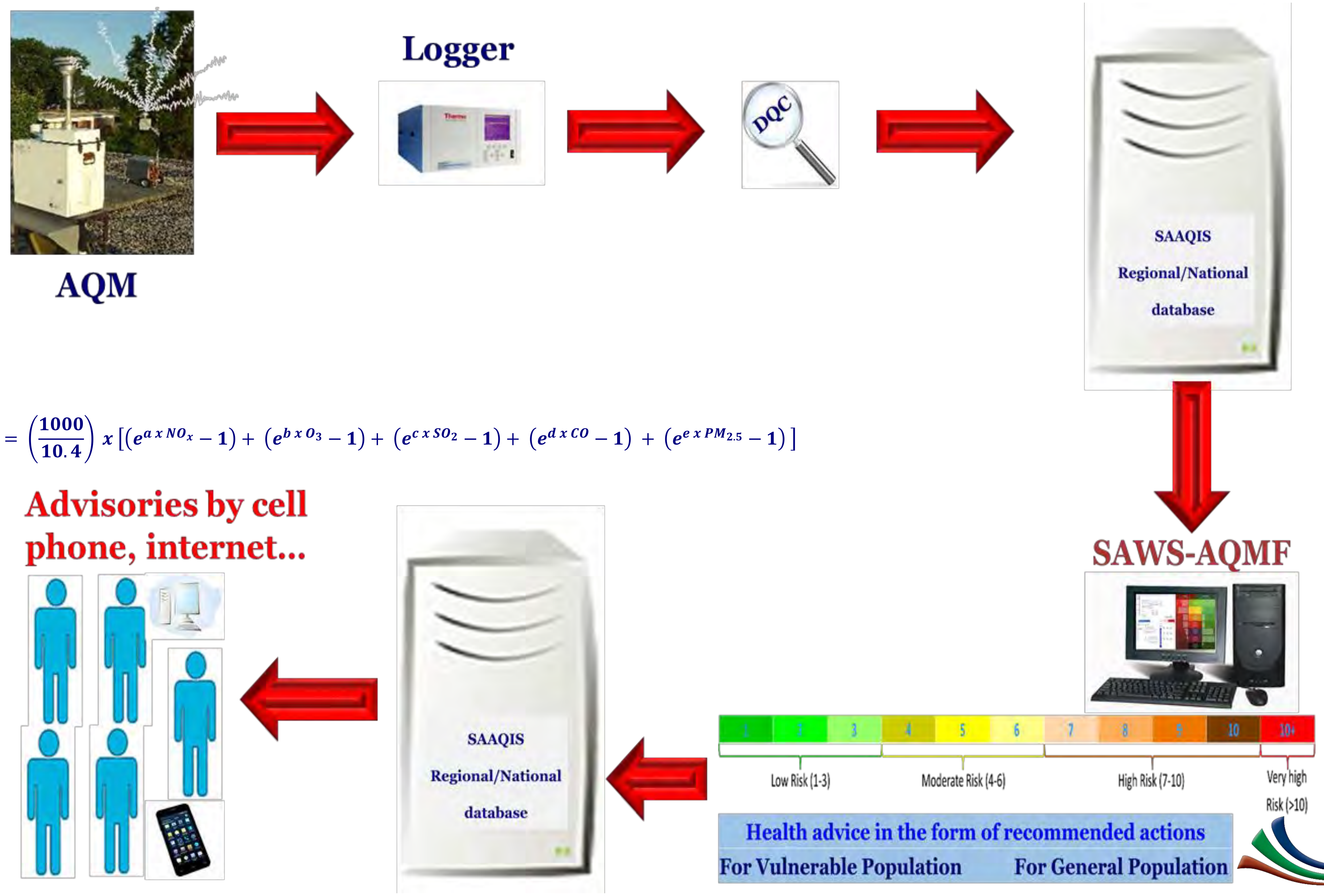
SAWS AQ Research

❑ Services

South African Air Quality Information Systems (SAAQIS)

Centralized air quality information*: DEA & SAWS*





$$AQHI = \left(\frac{1000}{10.4}\right) x\left[\left(e^{a\,x\,NO_x}-1\right)+\left(e^{b\,x\,O_3}-1\right)+\left(e^{c\,x\,SO_2}-1\right)+\left(e^{d\,x\,CO}-1\right)+\left(e^{e\,x\,PM_{2.5}}-1\right)\right]$$

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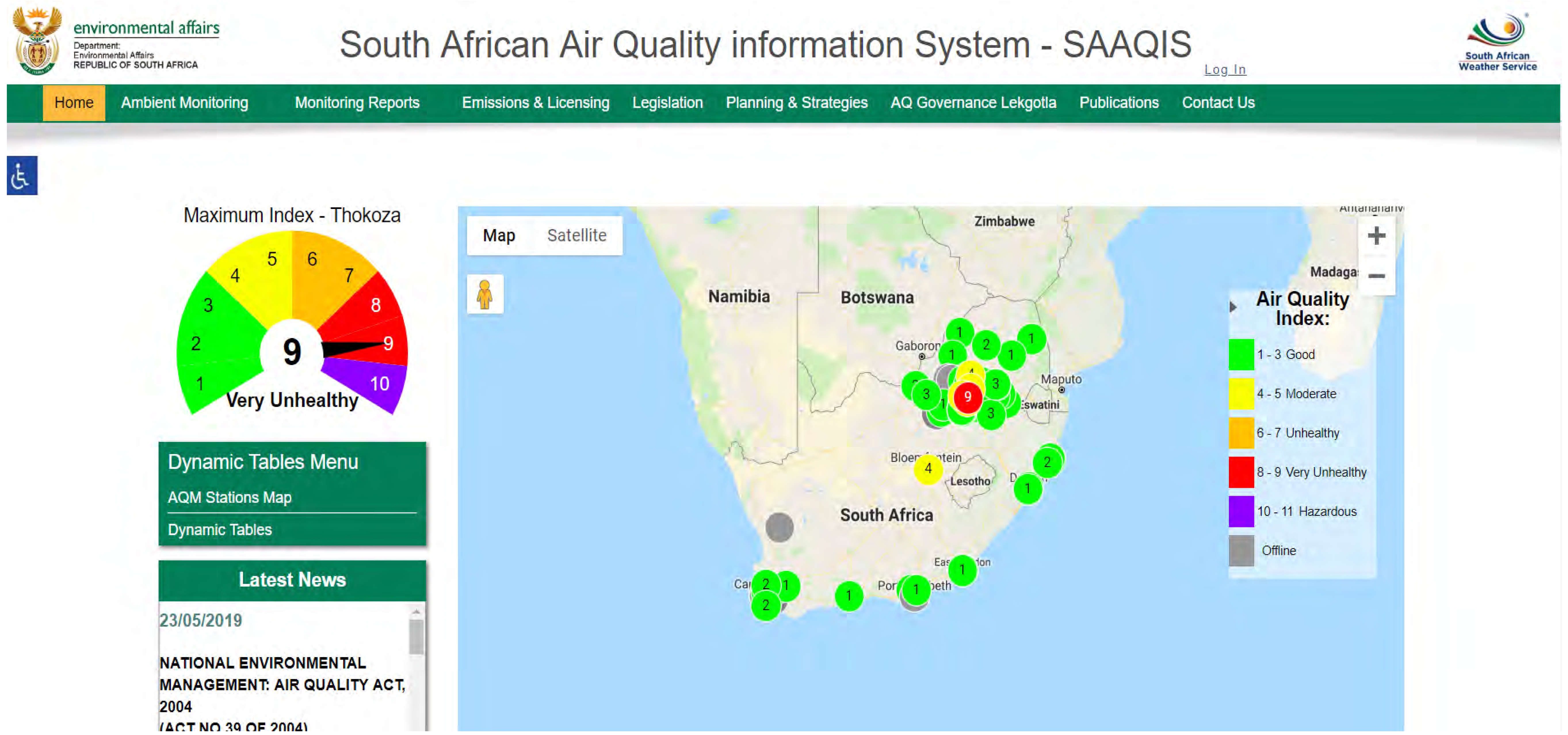
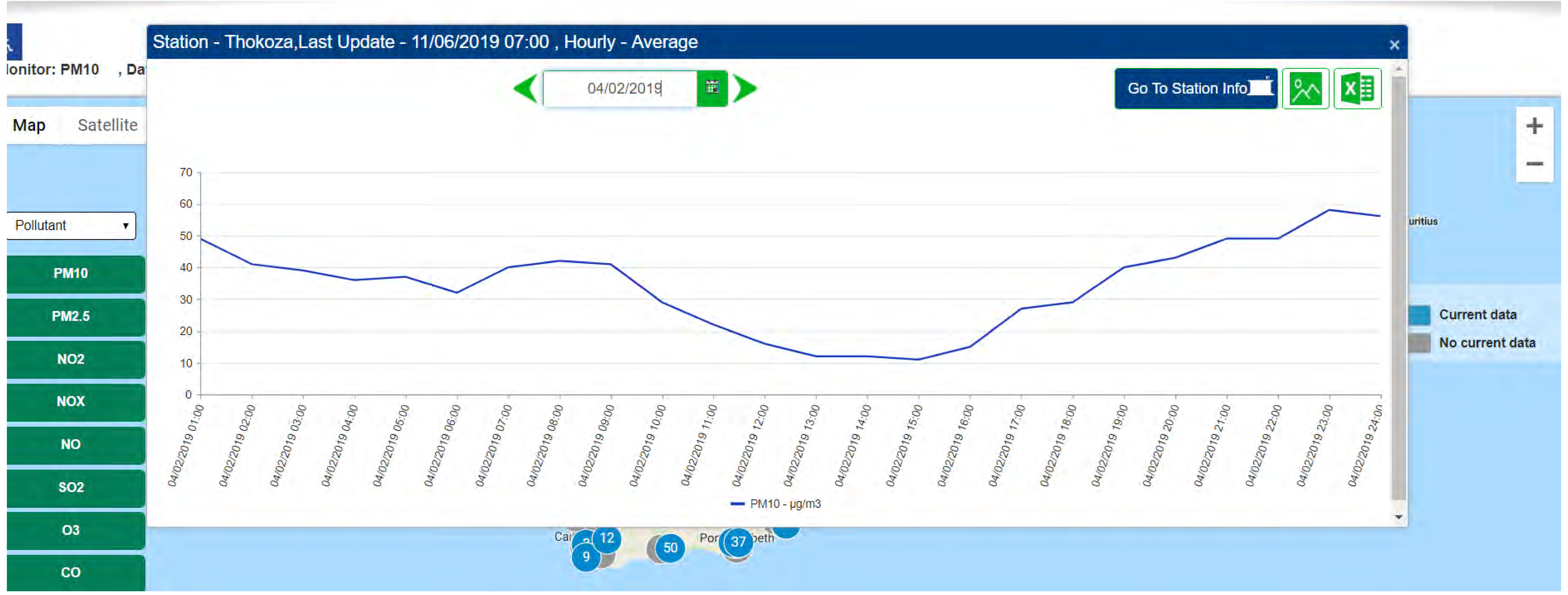
SAWS AQ Research

❑ Services





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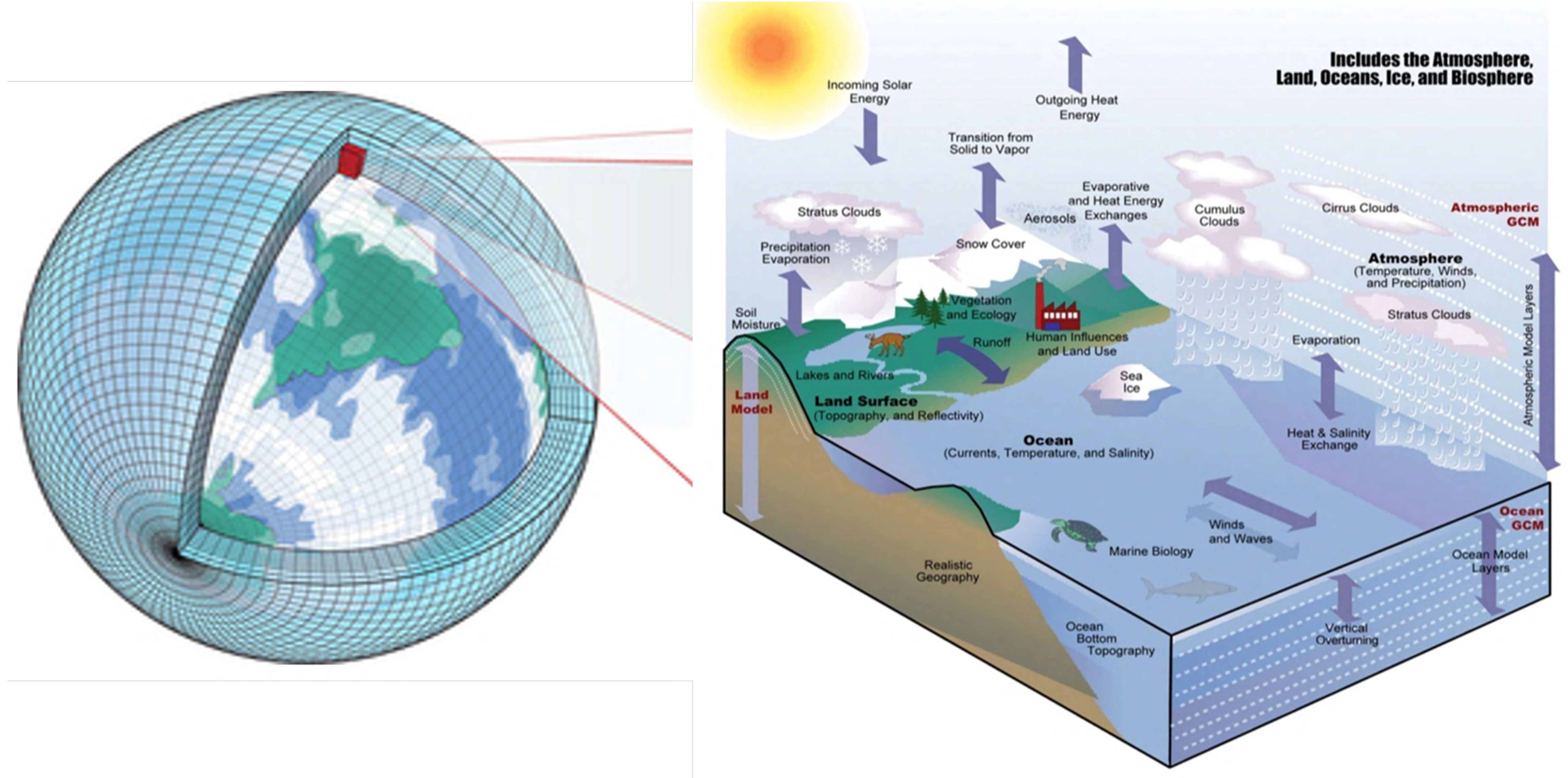
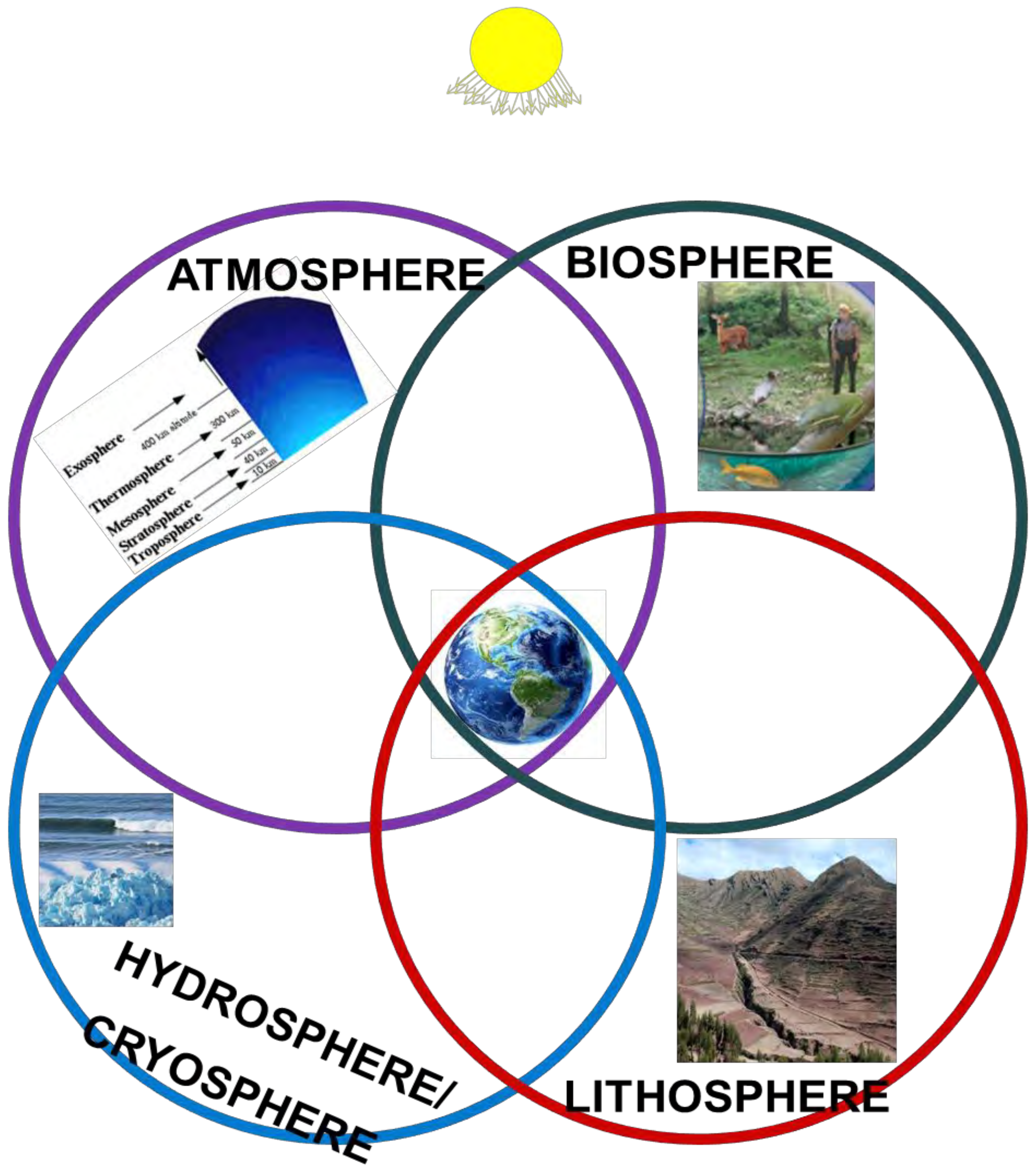
SAWS AQ Research

- Services

$$\frac{\partial \chi^i}{\partial t} = \underbrace{-\overline{V}.\nabla \xi^i_{ADV} + F^i_{HTD} + F^i_{VTD} + T^i_C}_{\text{Transportation}} + \underbrace{S^i}_{\text{Primary emissions}} \underbrace{- R^i_{W,ls} - R^i_{W,C} - D^i_d}_{\text{Dry and Wet dep.}} + \underbrace{\sum (Q^i_p - Q^i_l)}_{\text{Physico-chem. transformations}}$$





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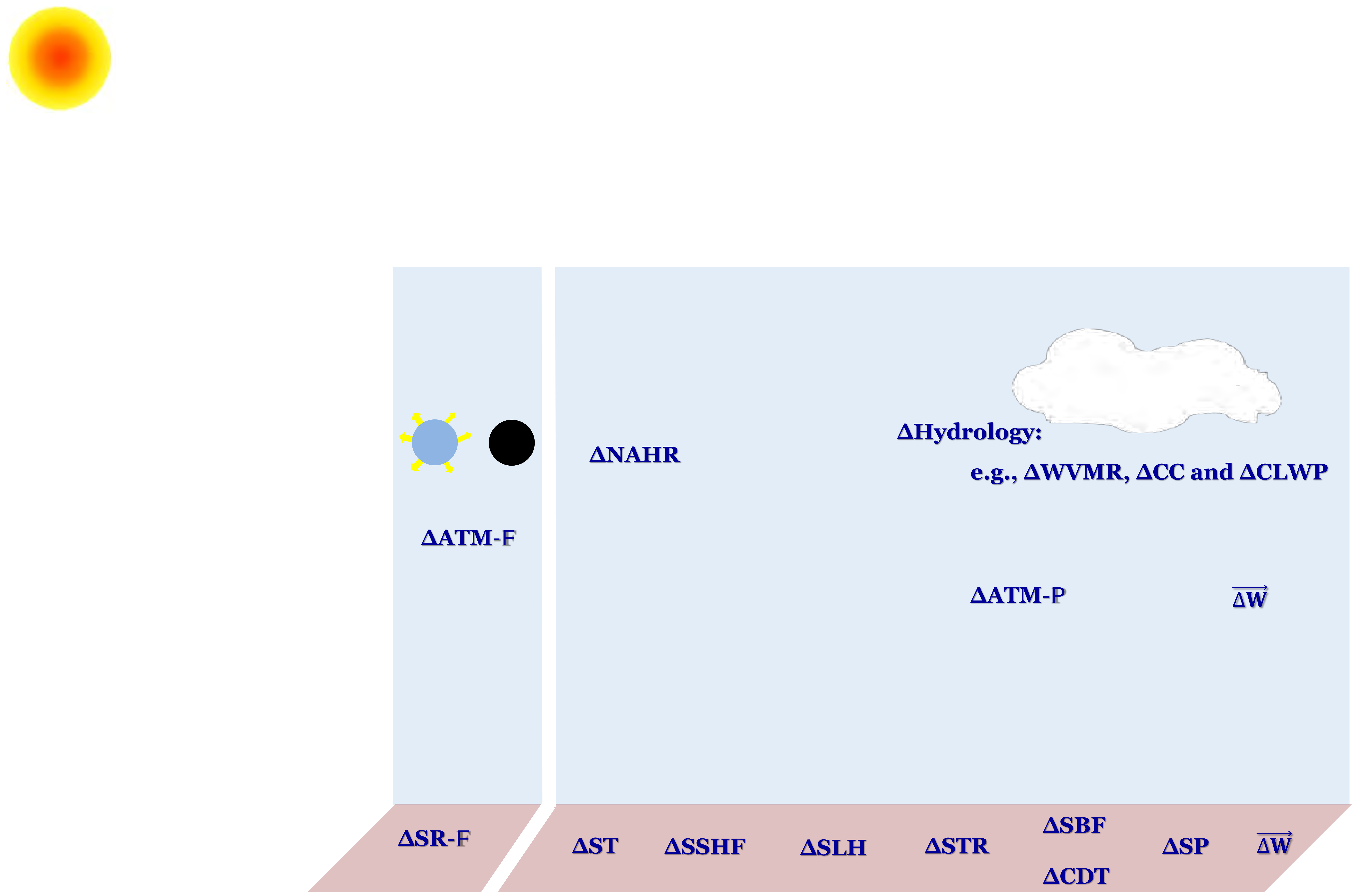

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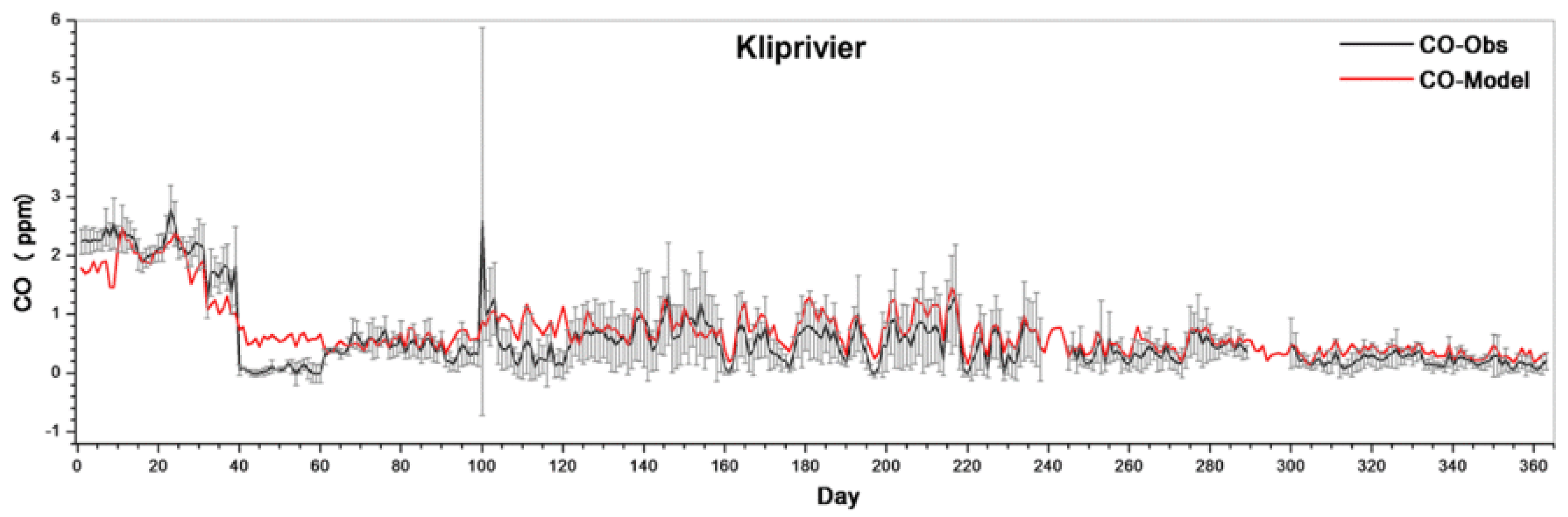


- Services: National Burden of Disease

  Quantile

$$MB = \frac{1}{n}\sum_{i=1}^{n}(M_i - O_i),$$

$$ME = \frac{1}{n}\sum_{i=1}^{n}|M_i - O_i|,$$

$$NMB = \frac{\sum_{i=1}^{n}(M_i - O_i)}{\sum_{i=1}^{n}O_i} \times 100\%,$$

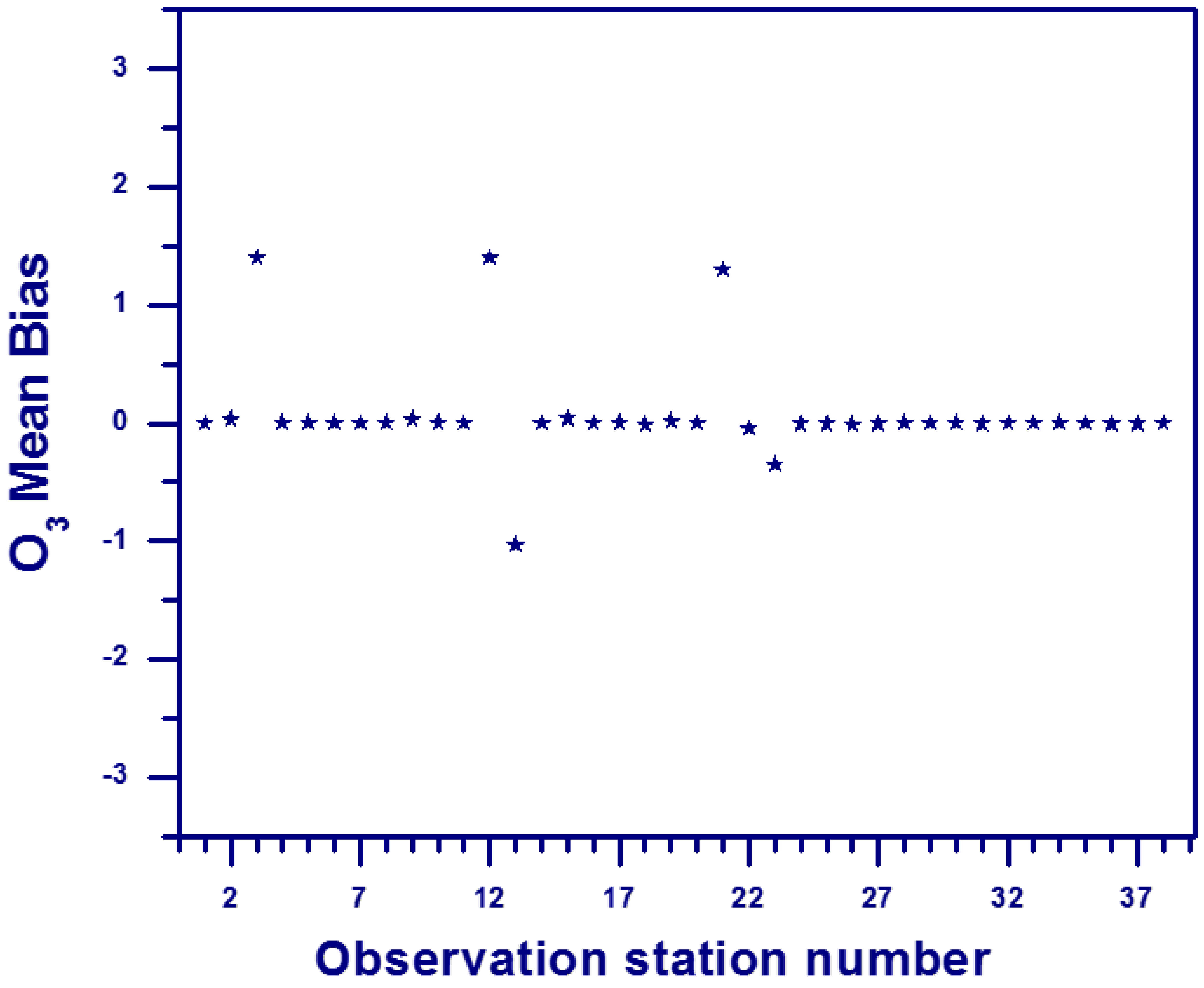
$$NME = \frac{\sum_{i=1}^{n}|M_i - O_i|}{\sum_{i=1}^{n}O_i} \times 100\%,$$

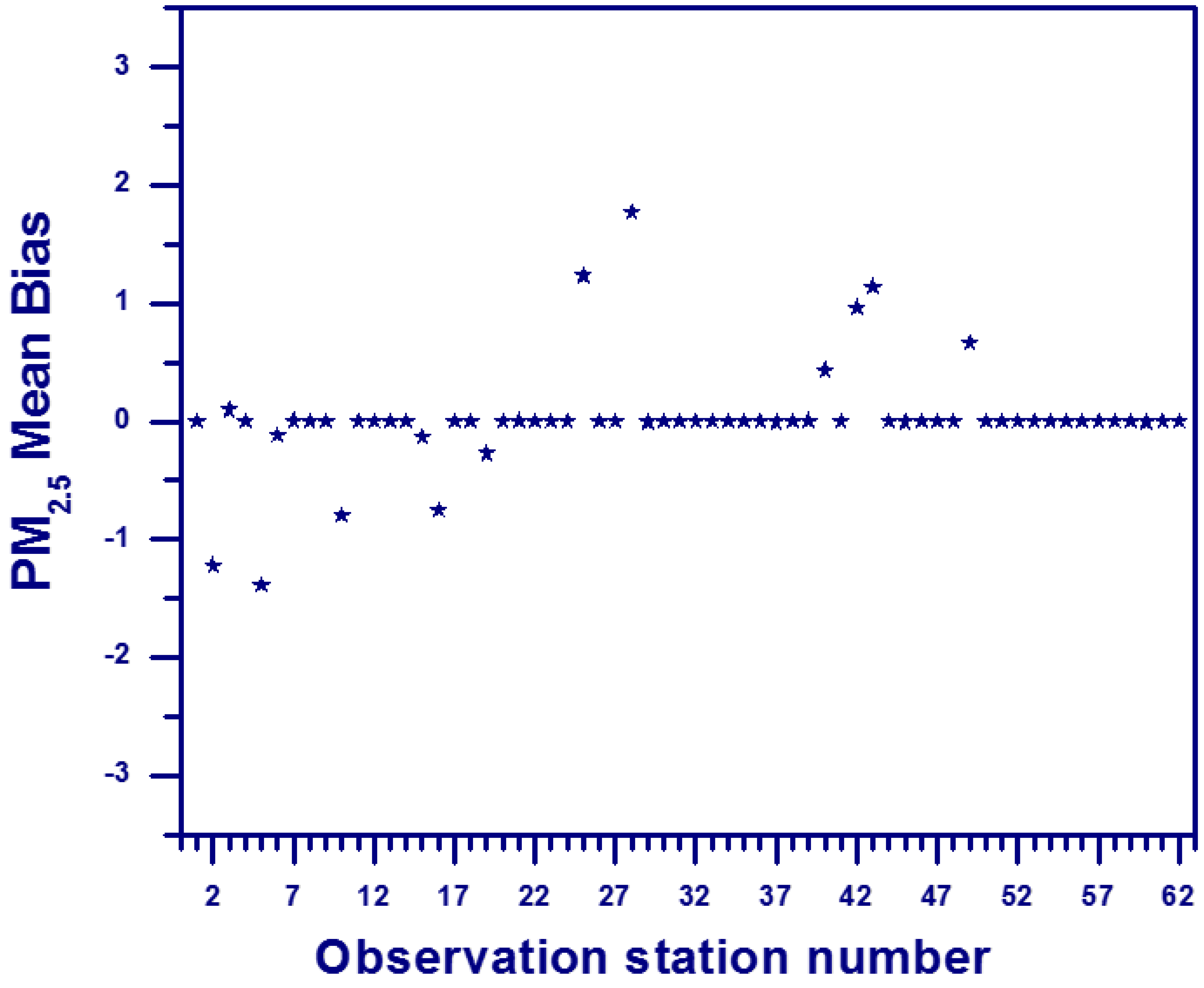
$$MFB = \frac{1}{n}\sum_{i=1}^{n}\frac{2(M_i - O_i)}{M_i + O_i} \times 100\%,$$

$$MFE = \frac{1}{n}\sum_{i=1}^{n}\frac{2|M_i - O_i|}{M_i + O_i} \times 100\%,$$

$$MR = \frac{1}{n}\sum_{i=1}^{n}\frac{M_i}{O_i},$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(M_i - O_i)^2}{n}},$$





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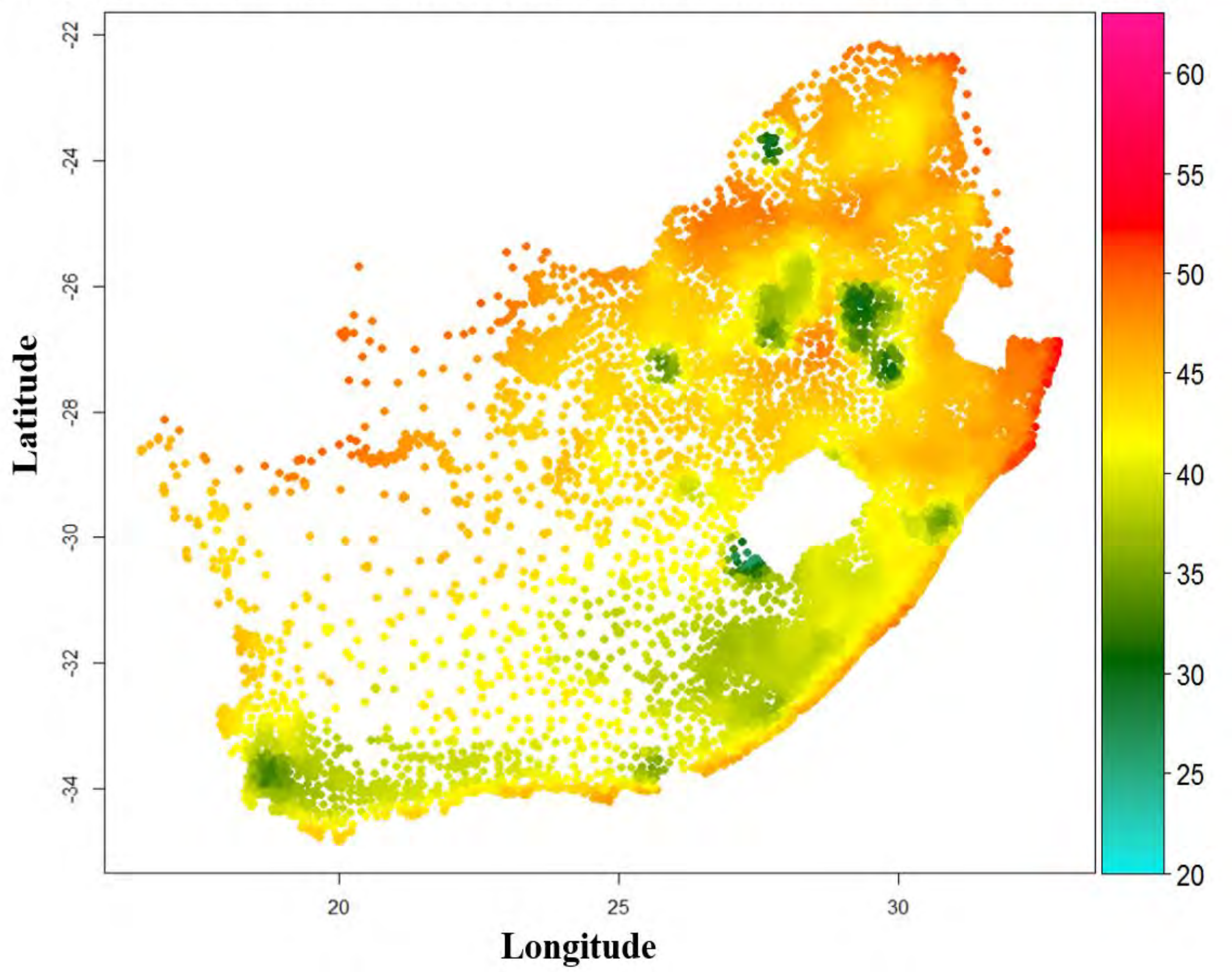
SAWS AQ Research

❑ Services: National Burden of Disease

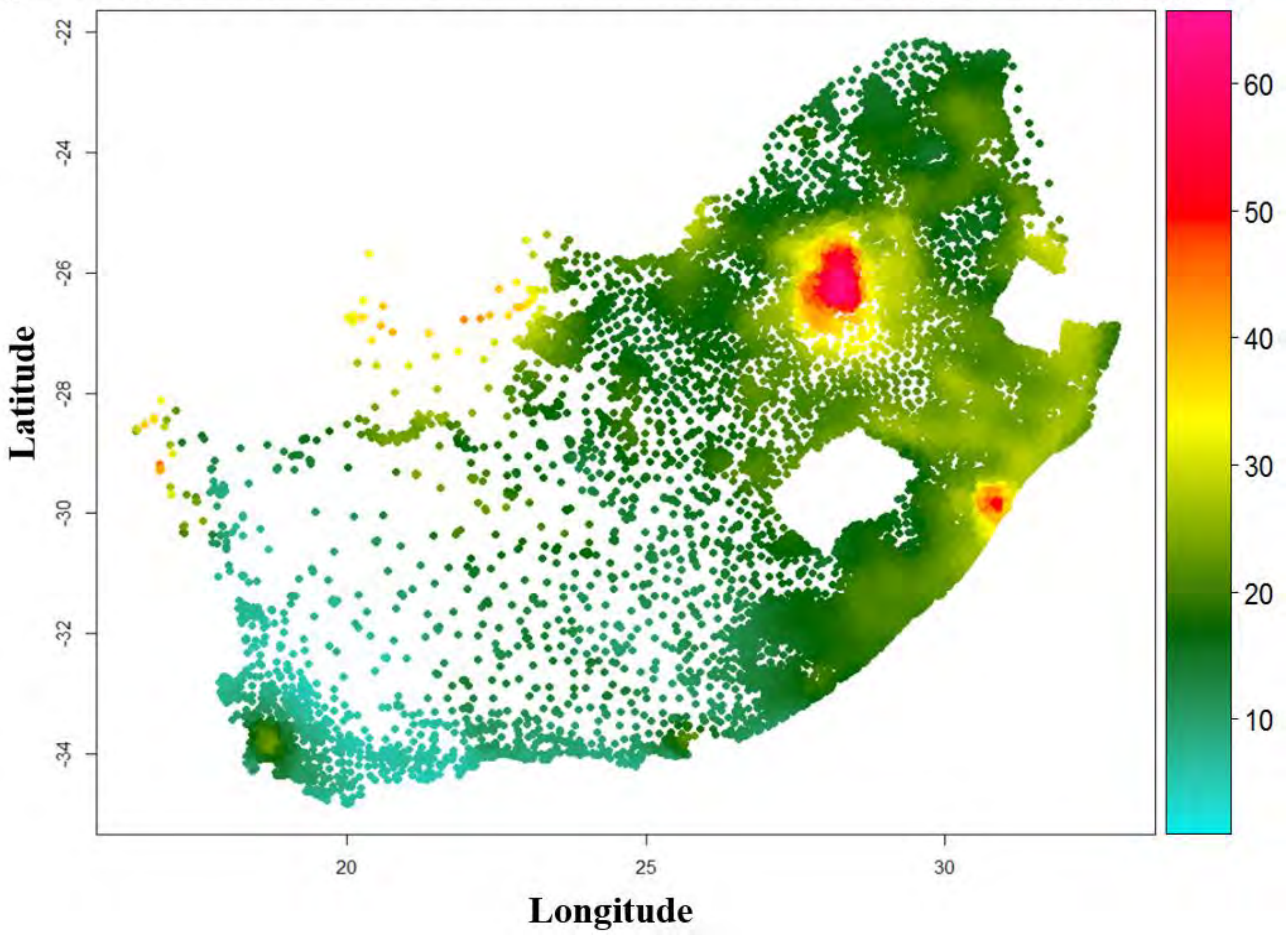
New SA national polygon distribution

- ► 90721 population polygons
- ► Area weighted centroid matrix: > 98.7% transformation accuracy

Polygonal mapped (at the centre of the polygon) - annual mean of 8hr running maximum - O3



Polygon mapped annual mean PM2.5 at the centre of each SA population polygons



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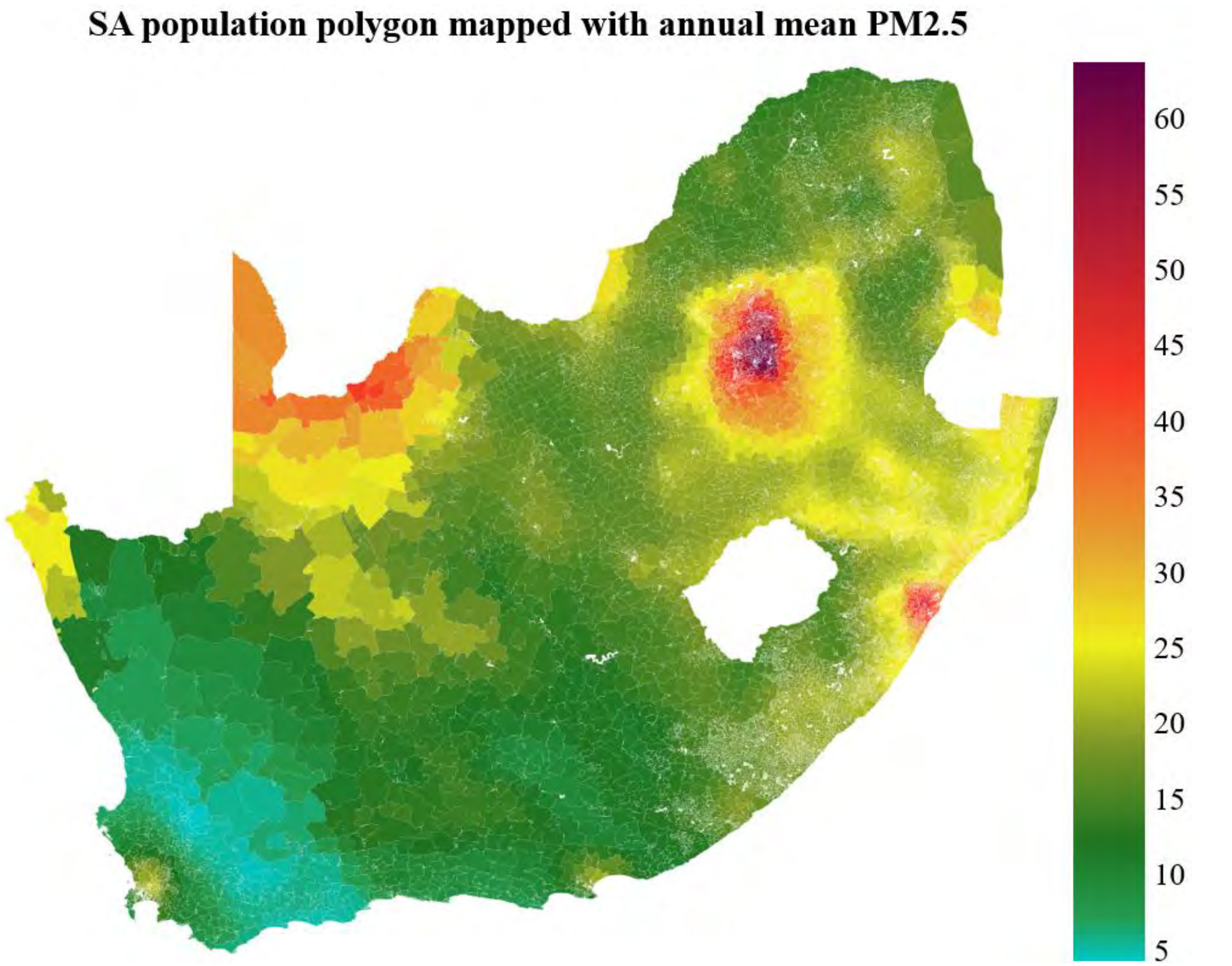
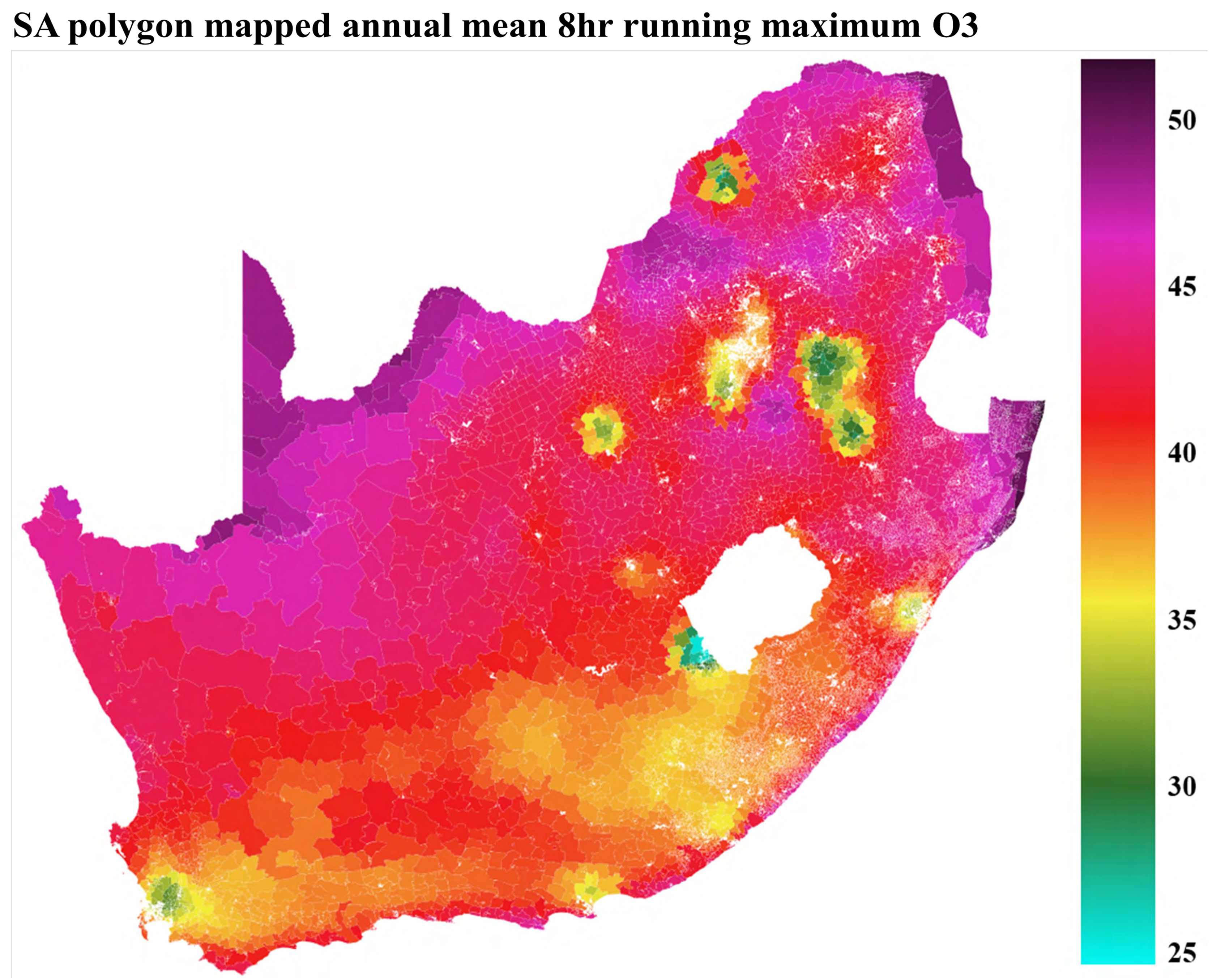
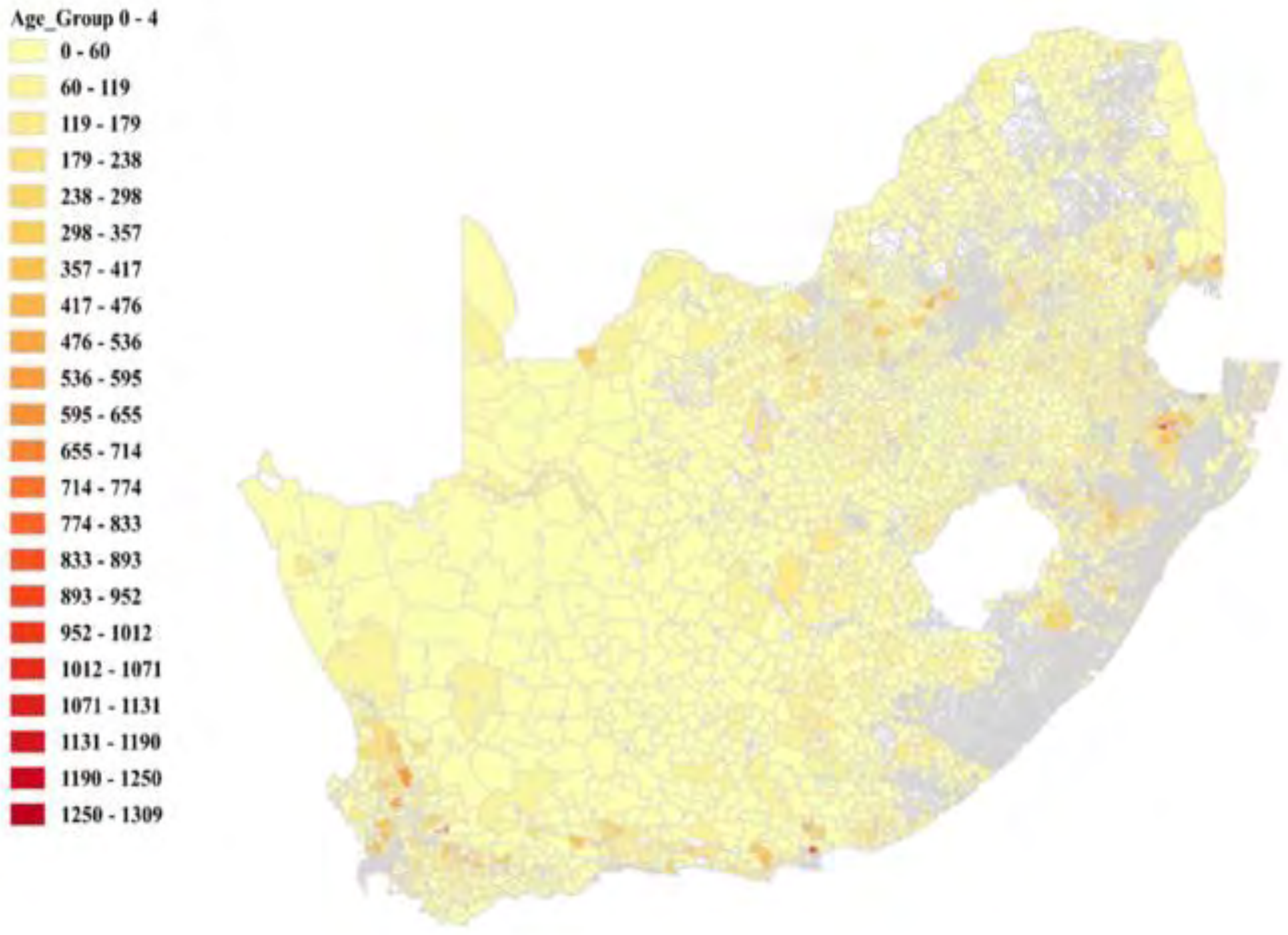
SAWS AQ Research

- Services: National Burden of Disease







$$IER(z) = \begin{cases} 1, \ldots\ldots\ldots\ldots z < z_{cf} \\ 1 + \alpha \times (1 - e^{-\beta(z - z_{cf})^{\delta}}) \ldots\ldots z \geq z_{zf} \end{cases}$$

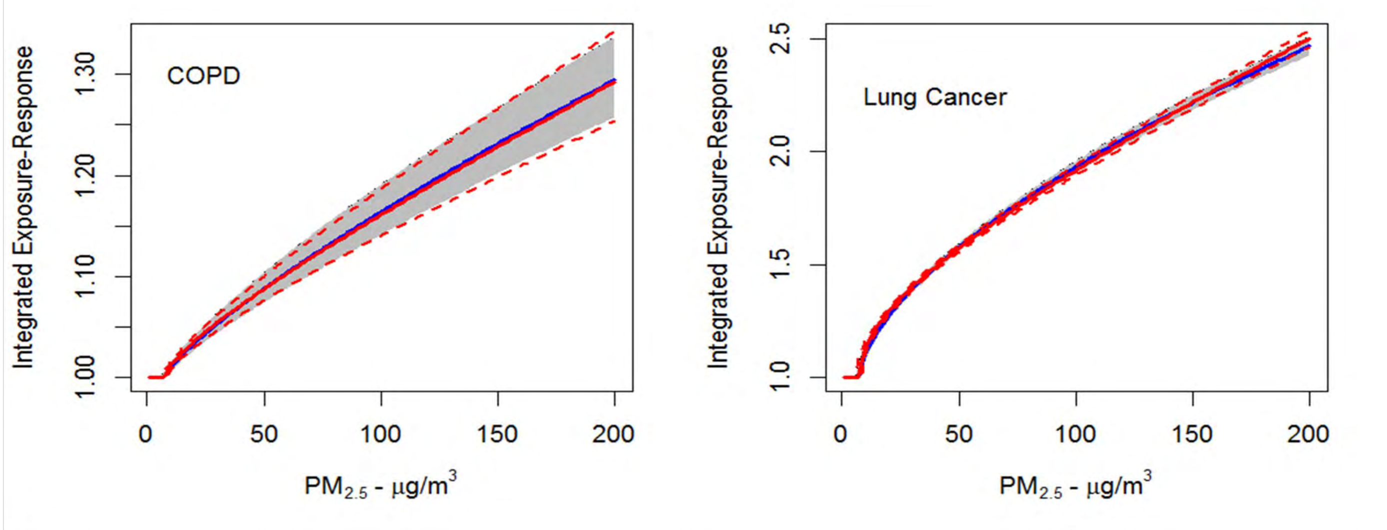
$$R_{\delta}(z|\theta) = \begin{cases} 1, \ldots\ldots\ldots\ldots z < z_{cf} \\ 1 + \theta \times (z - z_{cf})^{\delta} \ldots\ldots z \geq z_{zf} \end{cases}$$

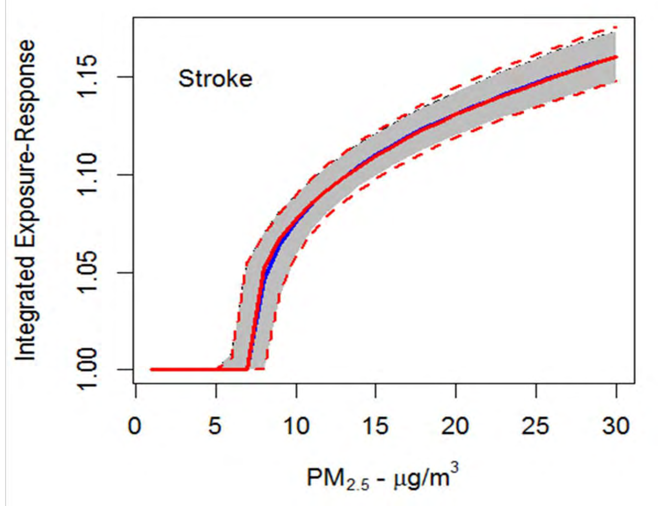
$$R_{\delta}(z|\theta) = \begin{cases} 1, \ldots\ldots\ldots\ldots z < z_{cf} \\ \exp\{\theta \times (z - z_{cf})^{\delta}\} \ldots\ldots z \geq z_{zf} \end{cases}$$

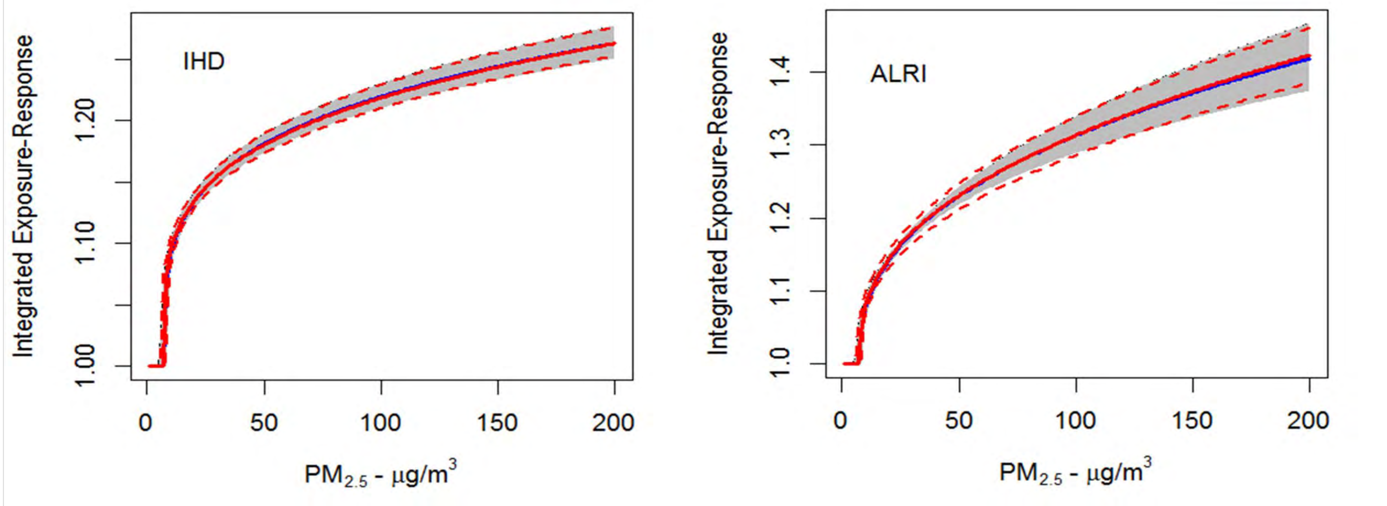
$$\log R_{\delta=\hat{\delta}_M}(z|\theta) = \theta \times (z - z_{cf})_{+}^{\hat{\delta}_M}, \quad \theta \sim N(\hat{\theta}_M, \hat{\sigma}^2), \quad z_{cf} \sim U(5.9, 8.7)$$

$$\hat{\theta}_M^{IHD}(age) = 0.17268 - 0.002037 \times (age - 25)$$

$$\hat{\theta}_M^{Stroke}(age) = 0.14506 - 0.001747 \times (age - 25)$$







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SAWS AQ Research

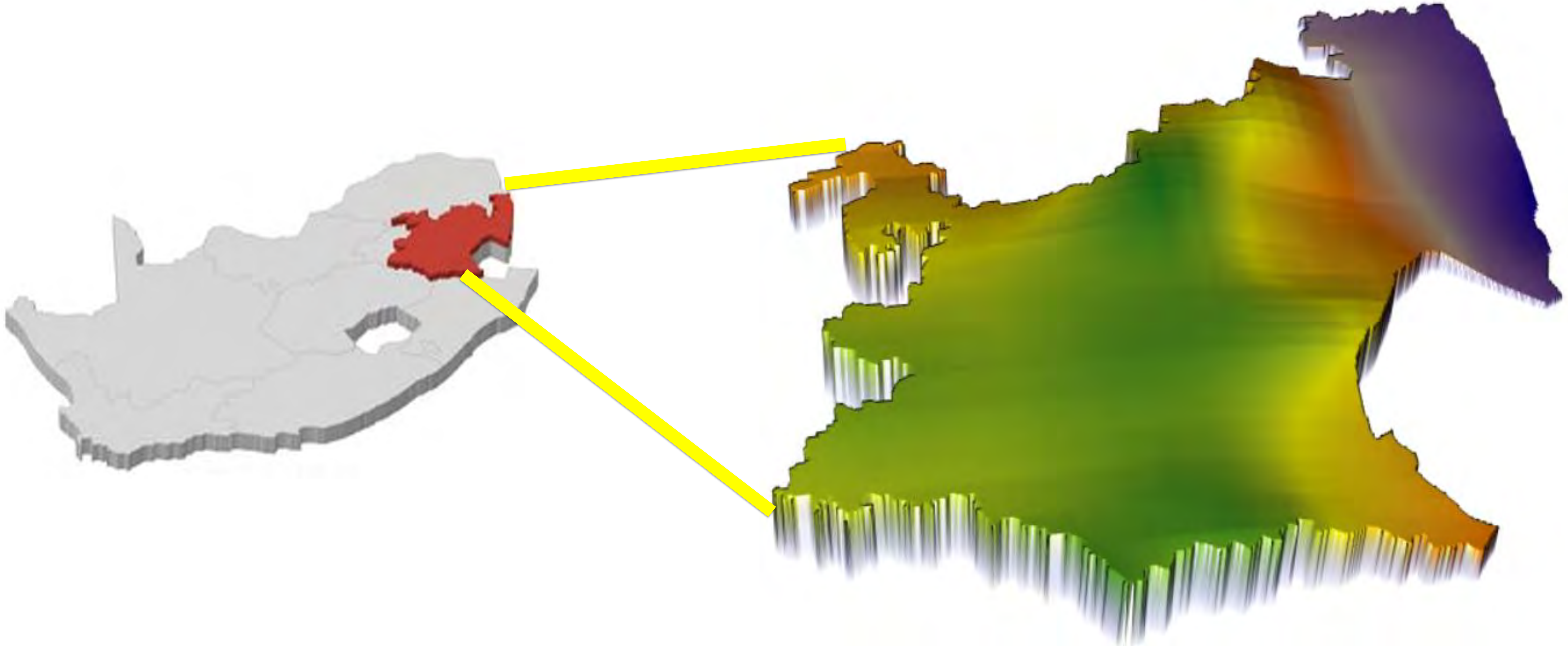
- ❑ Services: Scenario based AQMP

Business-as-usual emissions (i.e., real emission) = A_i

Green emissions (i.e., reduced emission)
- → Small reduction = $A_{i'}$
- → Medium reduction = $A_{i''}$
- → Large reduction = $A_{i'''}$

South Africa main sources of atmospheric Pollutants

Anthropogenic		Natural
Energy	Industries	Desert dust over the west part
Mining	Biomass burning	Ocean spry of the coastal
Agriculture	Transportation	biogenic emissions
Residential	Ships	
Agric. Waste		



- ❑ AQ management and planning
- ❑ Cost benefit analysis
- ❑ Stakeholder engagement

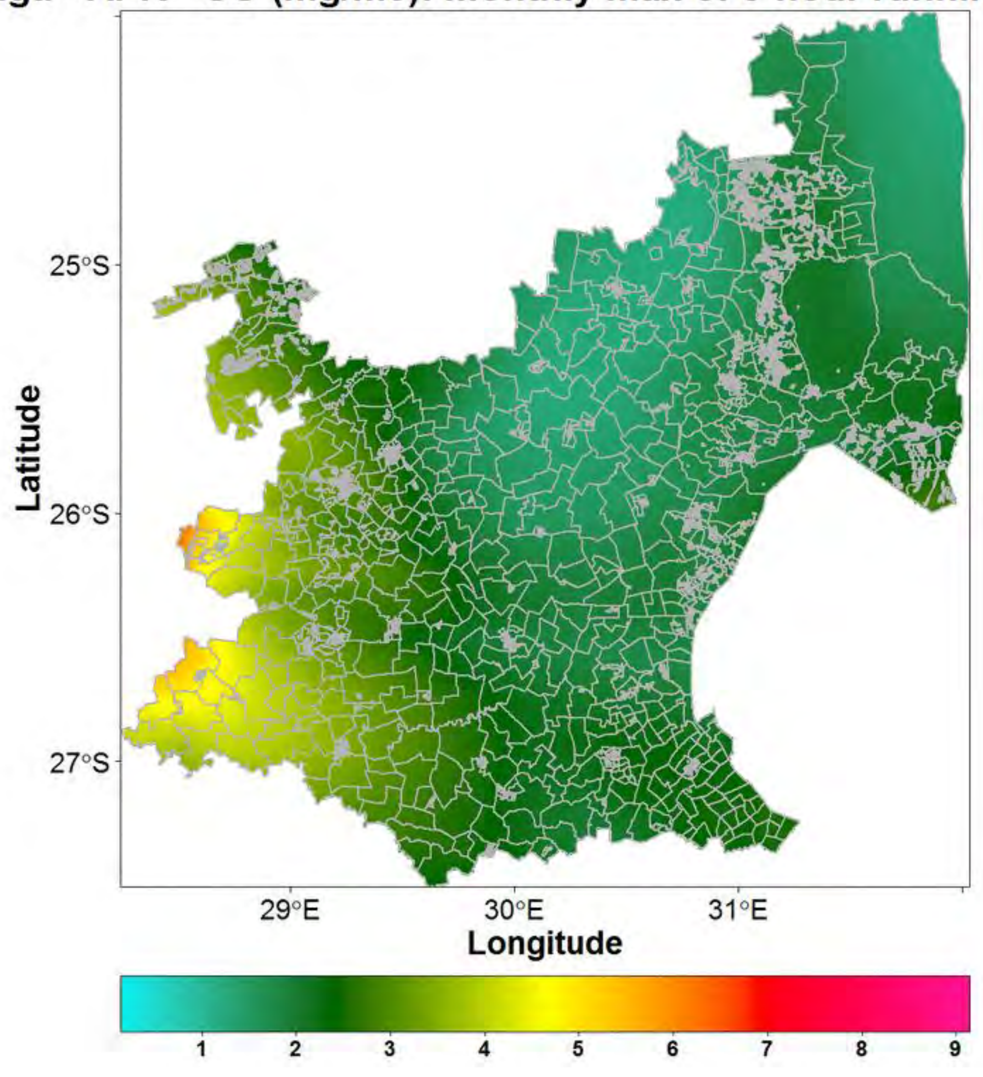
South African Weather Service

SAWS AQ Research

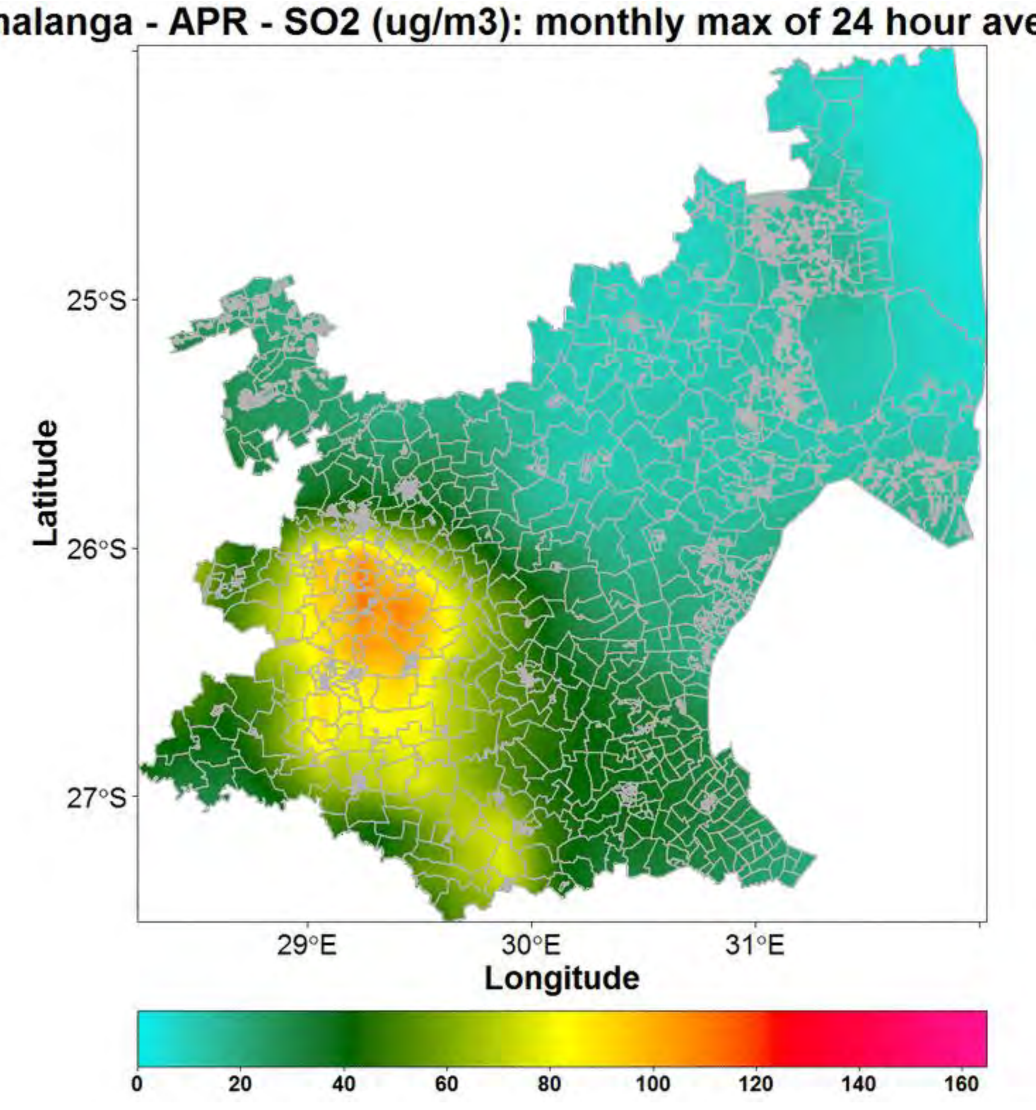
❑ Services: Scenario based AQMP

Status Quo

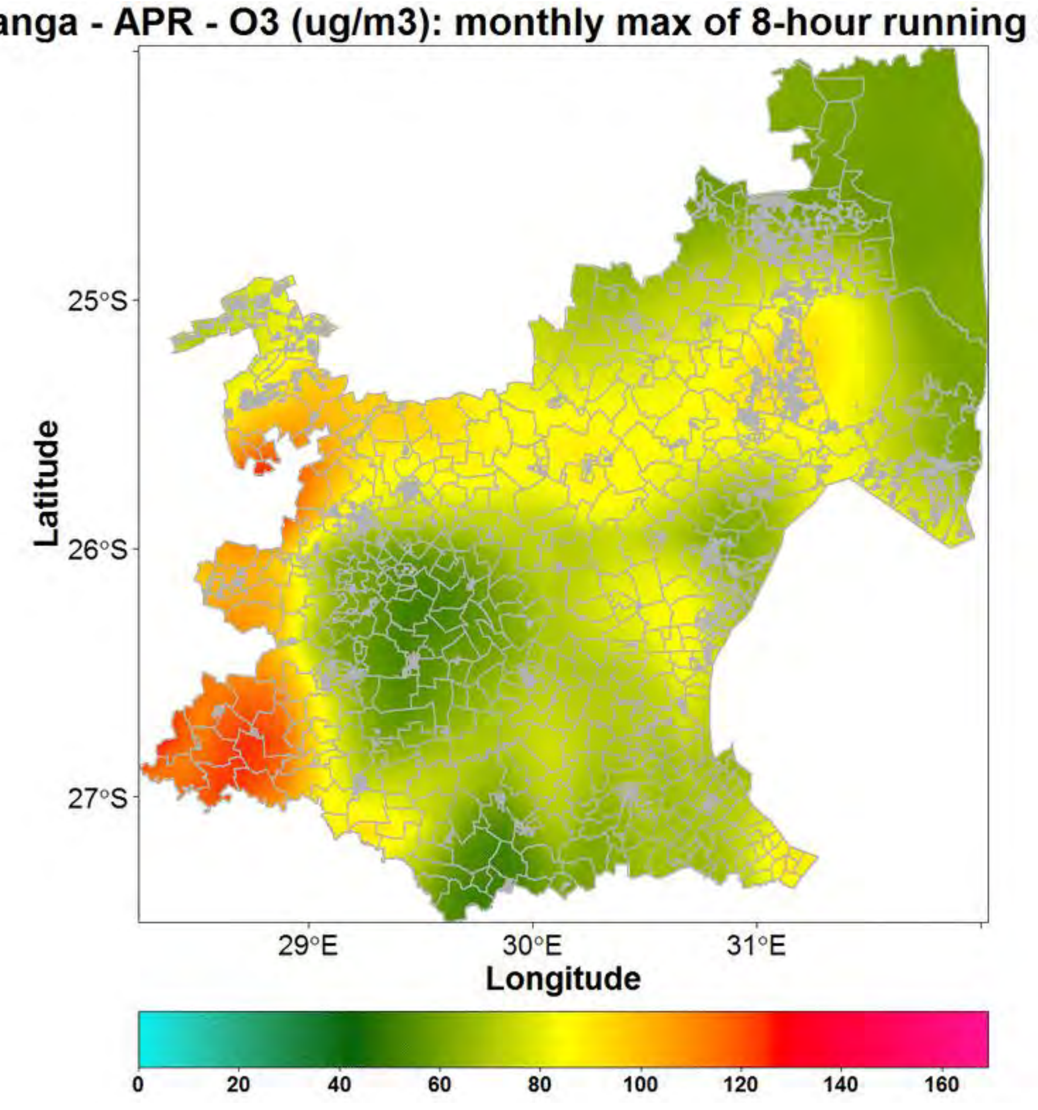
Mpumalanga - APR - CO (mg/m3): monthly max of 8-hour running average



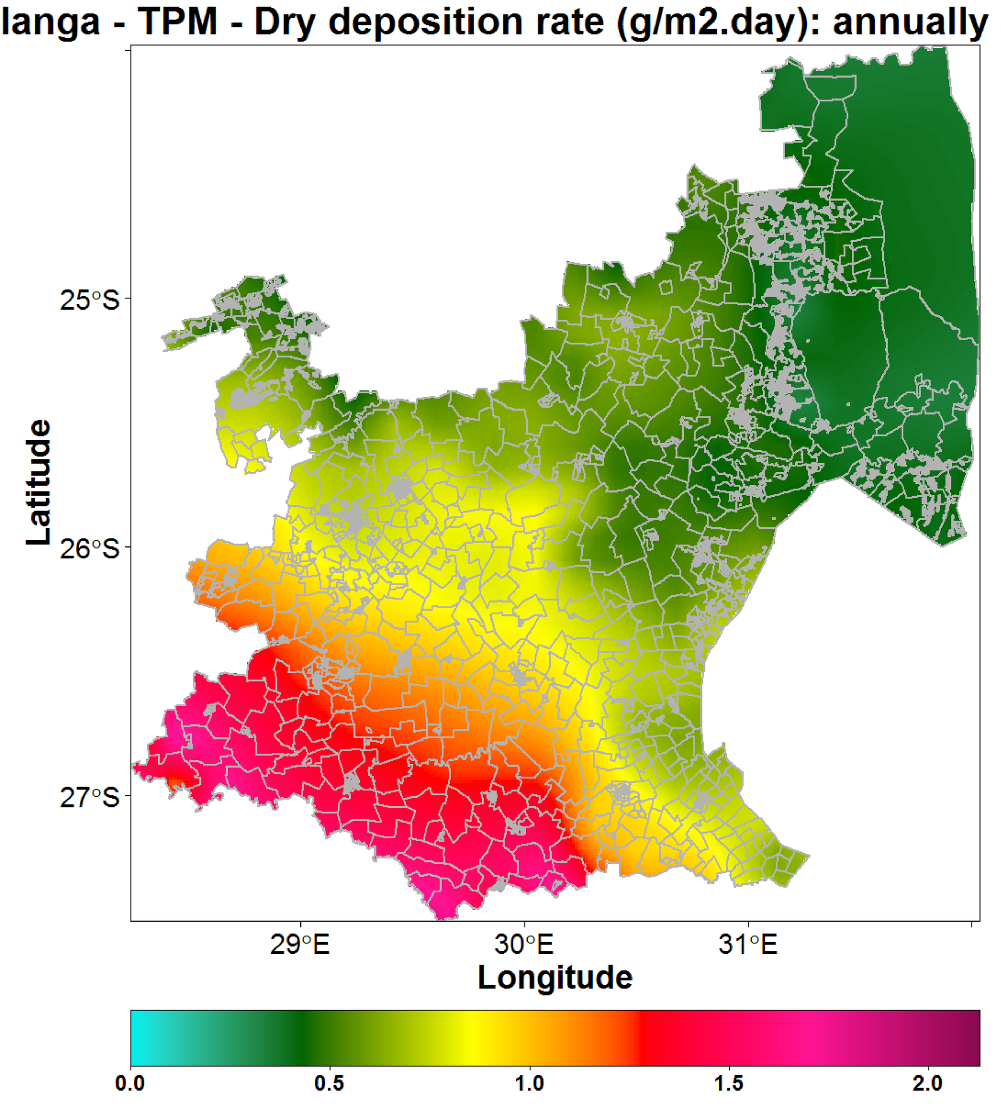
Mpumalanga - APR - SO2 (ug/m3): monthly max of 24 hour average



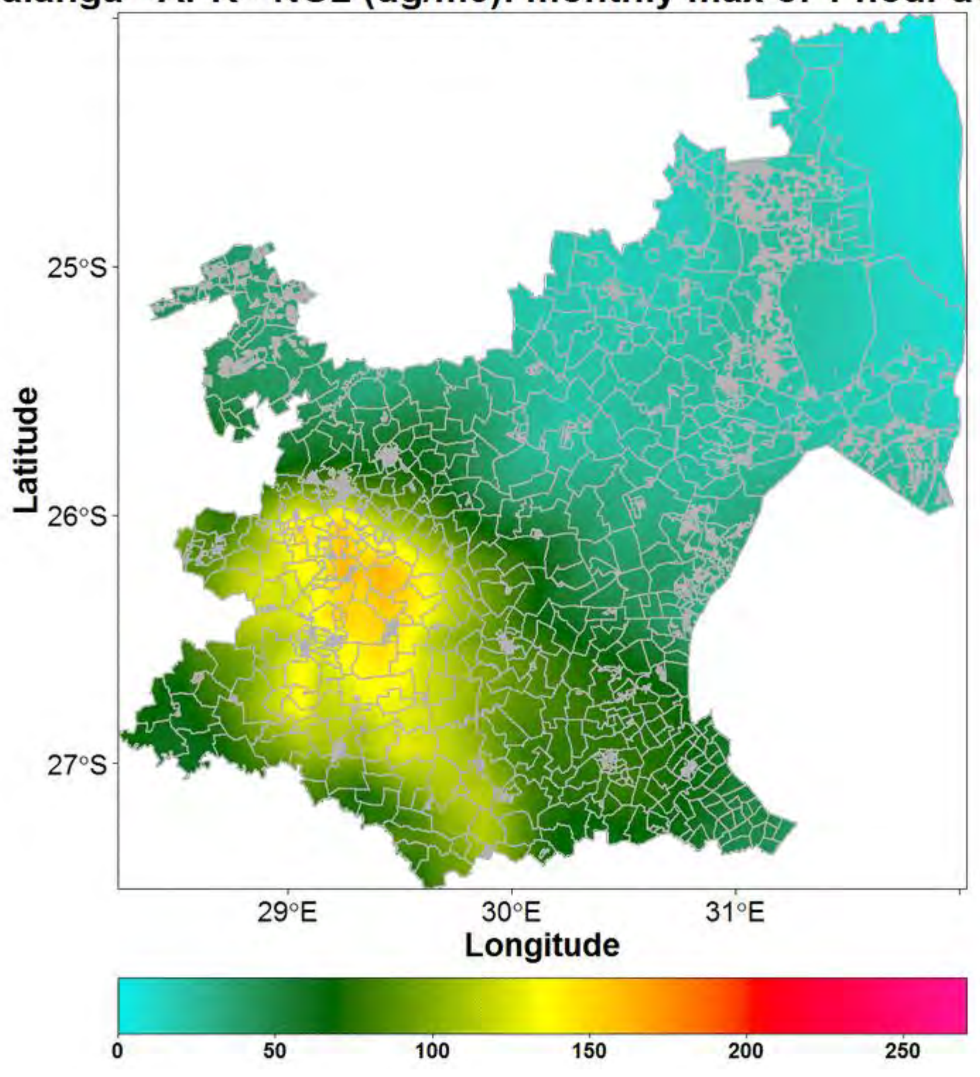
Mpumalanga - APR - O3 (ug/m3): monthly max of 8-hour running average



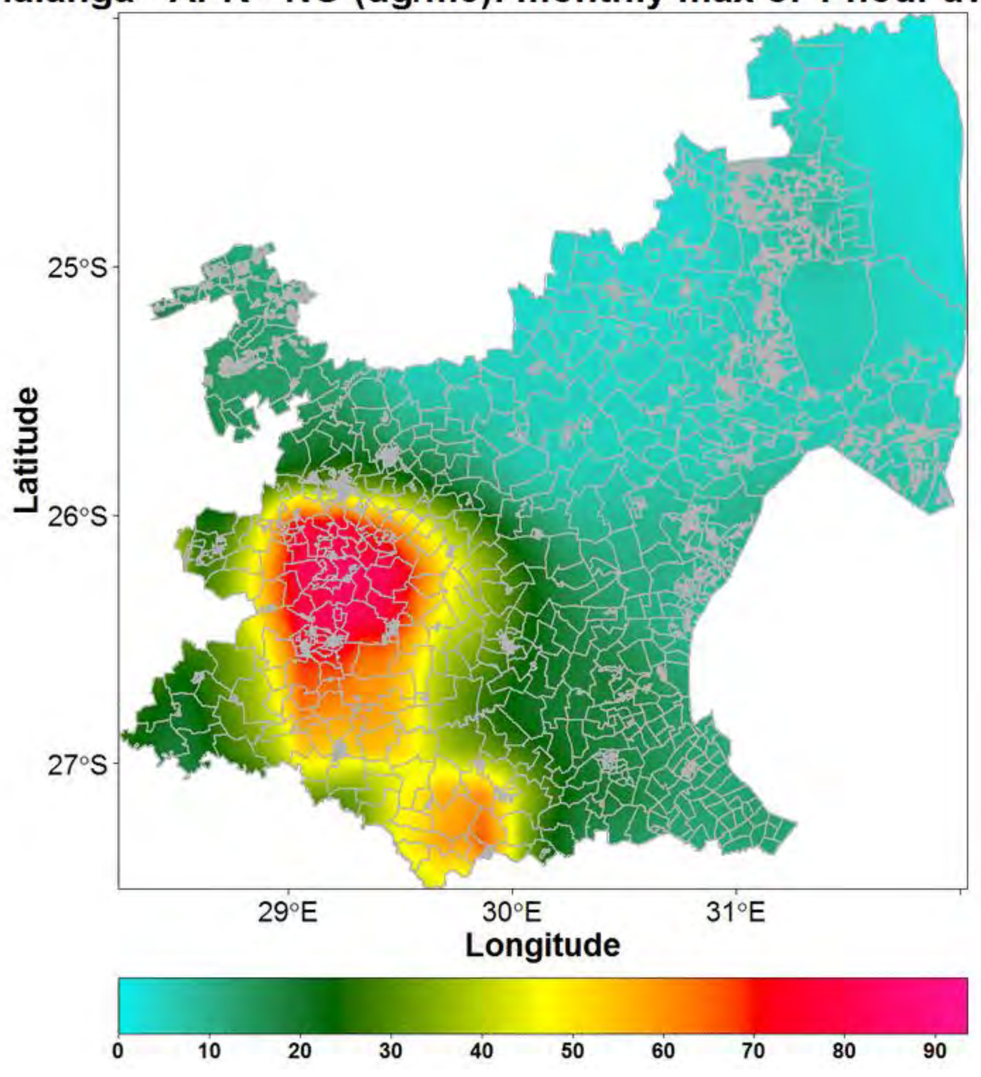
Mpumalanga - TPM - Dry deposition rate (g/m2.day): annually average



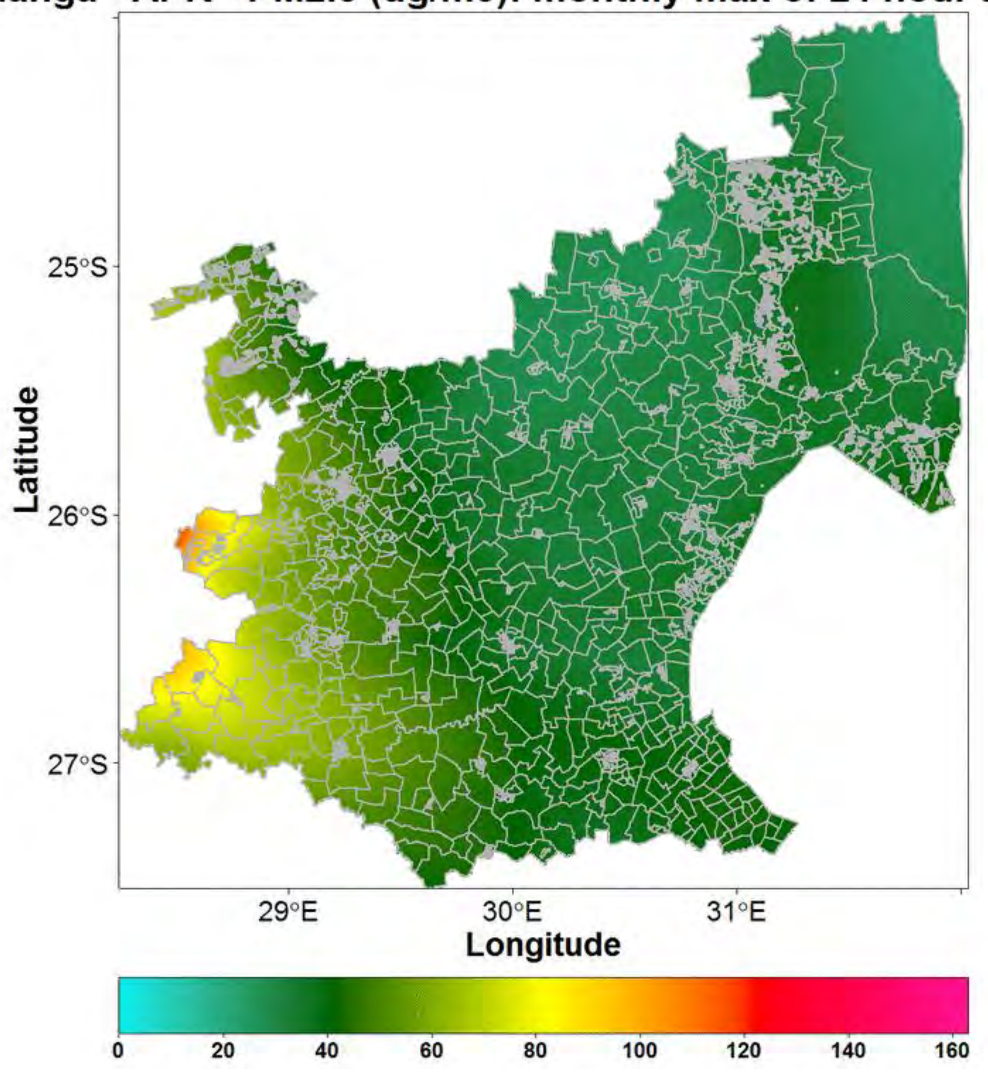
Mpumalanga - APR - NO2 (ug/m3): monthly max of 1 hour average



Mpumalanga - APR - NO (ug/m3): monthly max of 1 hour average



Mpumalanga - APR - PM2.5 (ug/m3): monthly max of 24 hour average



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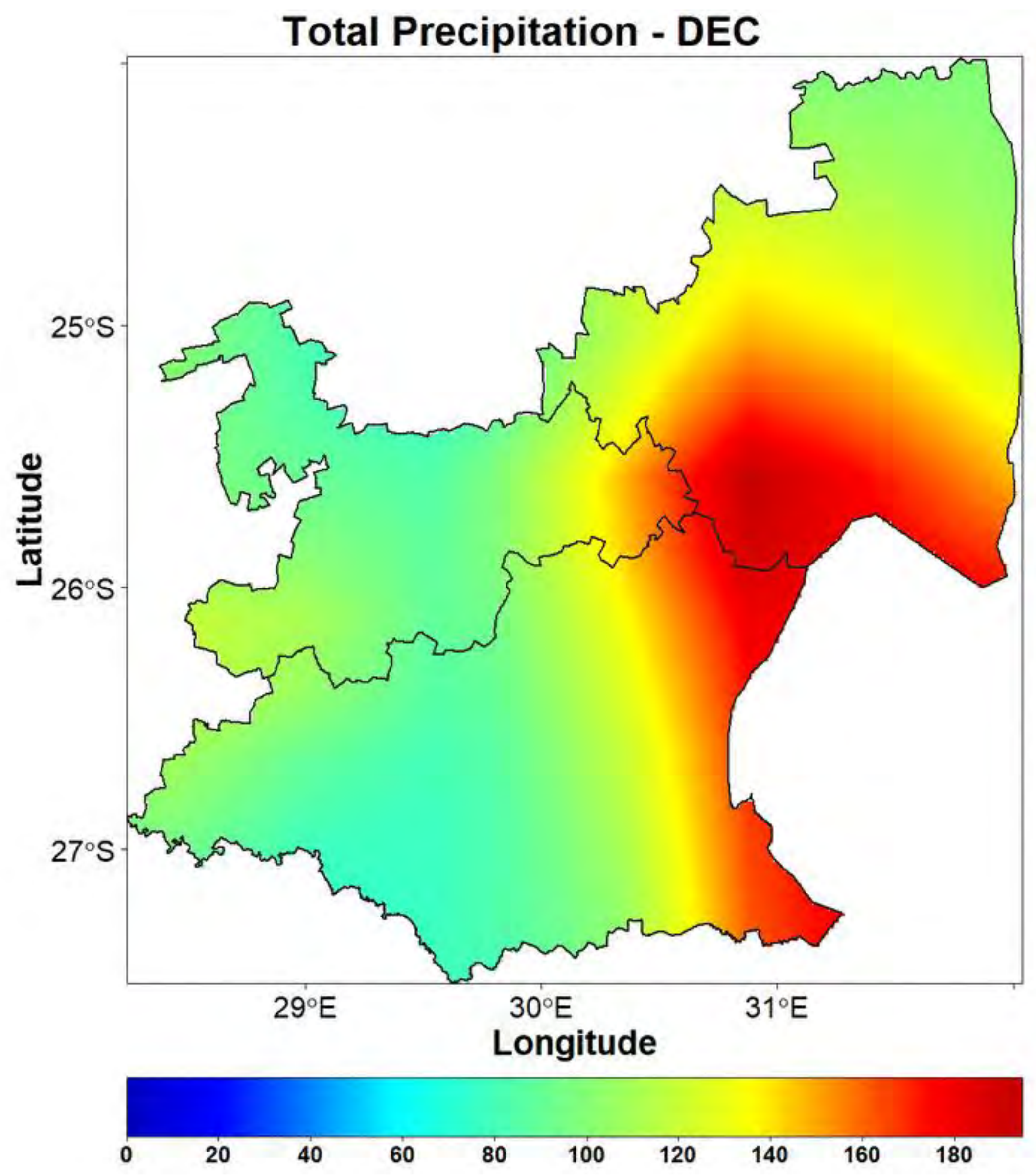
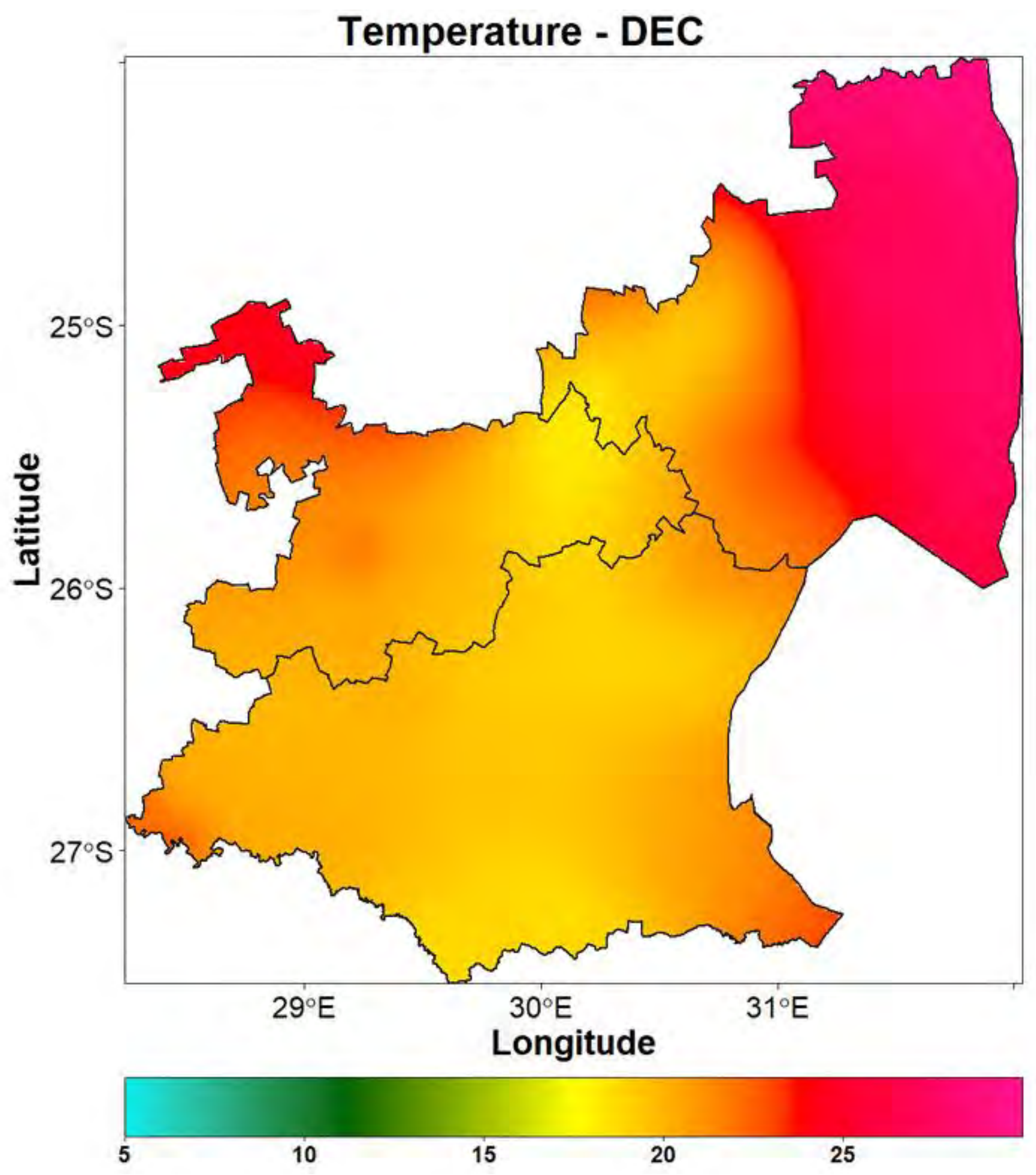
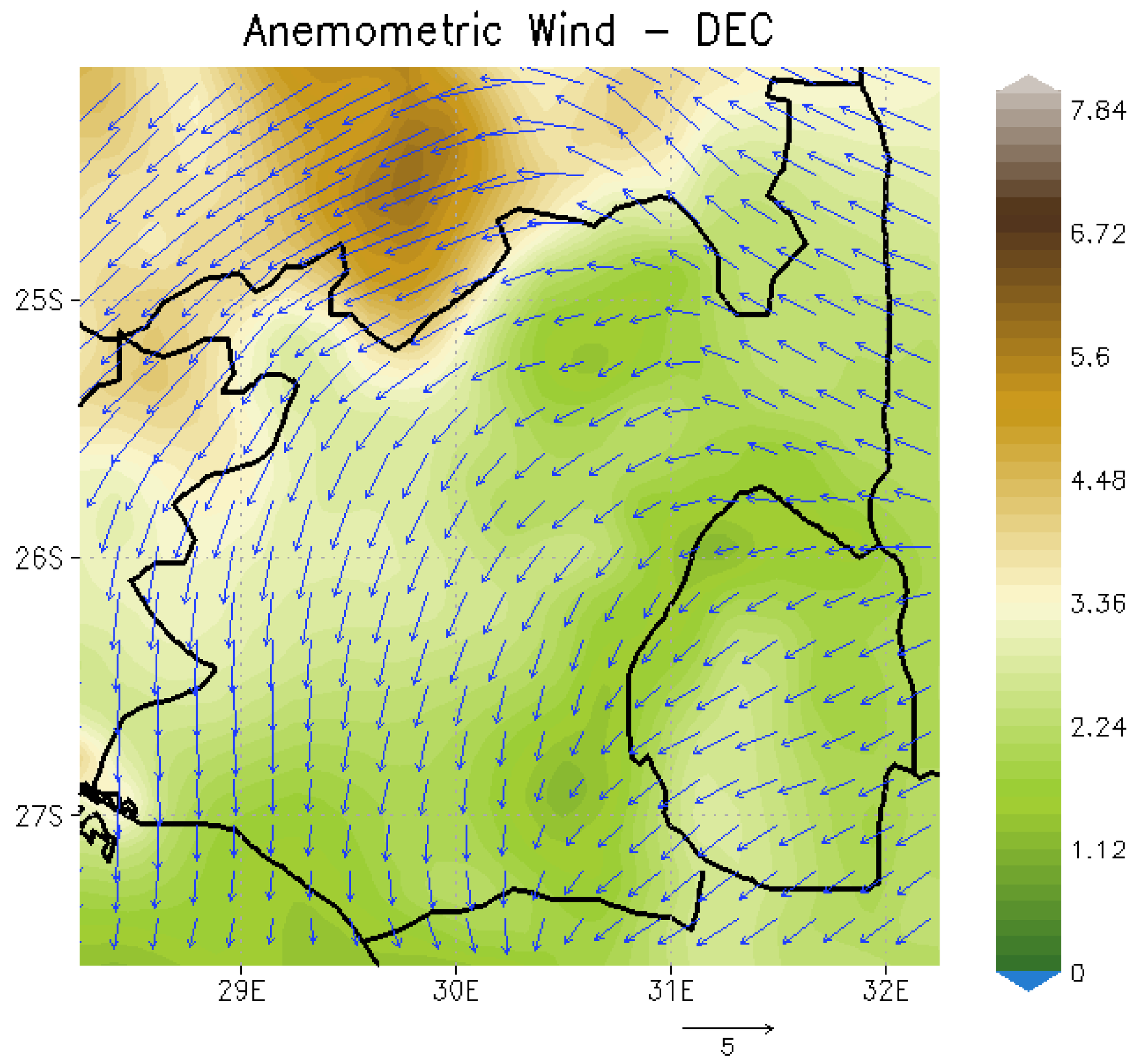
SAWS AQ Research

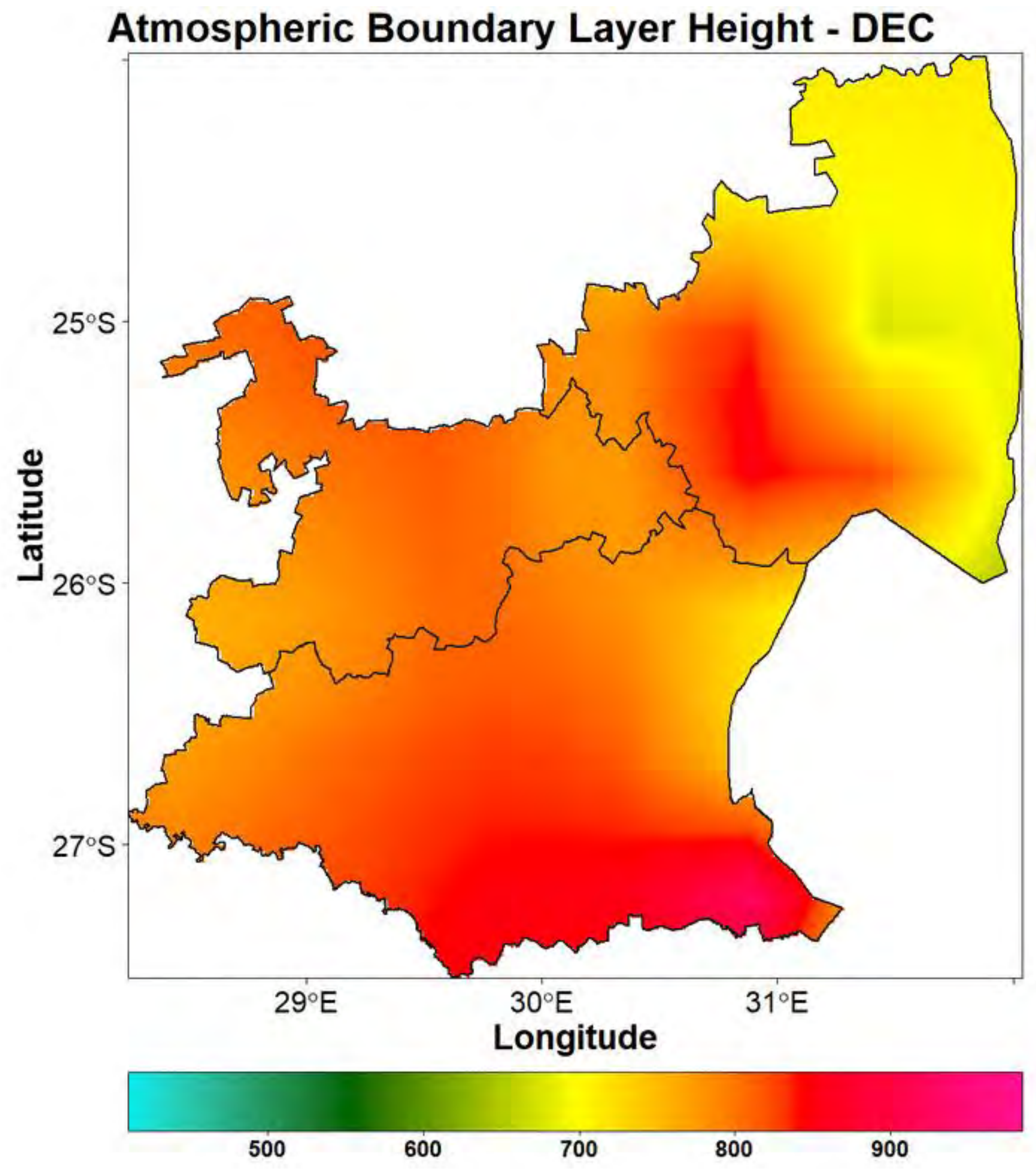
❑ Services: Scenario based AQMP

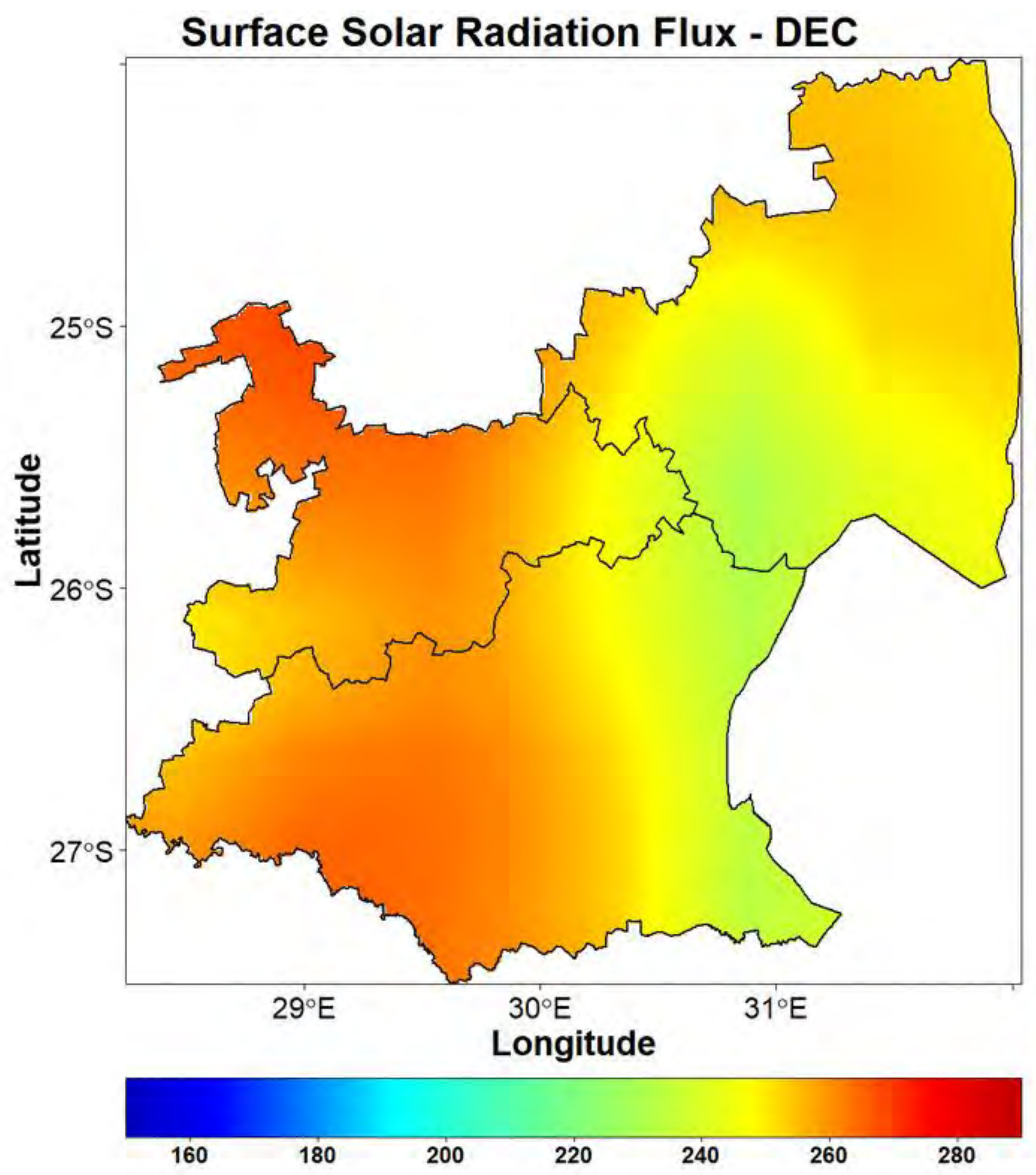
Climatology

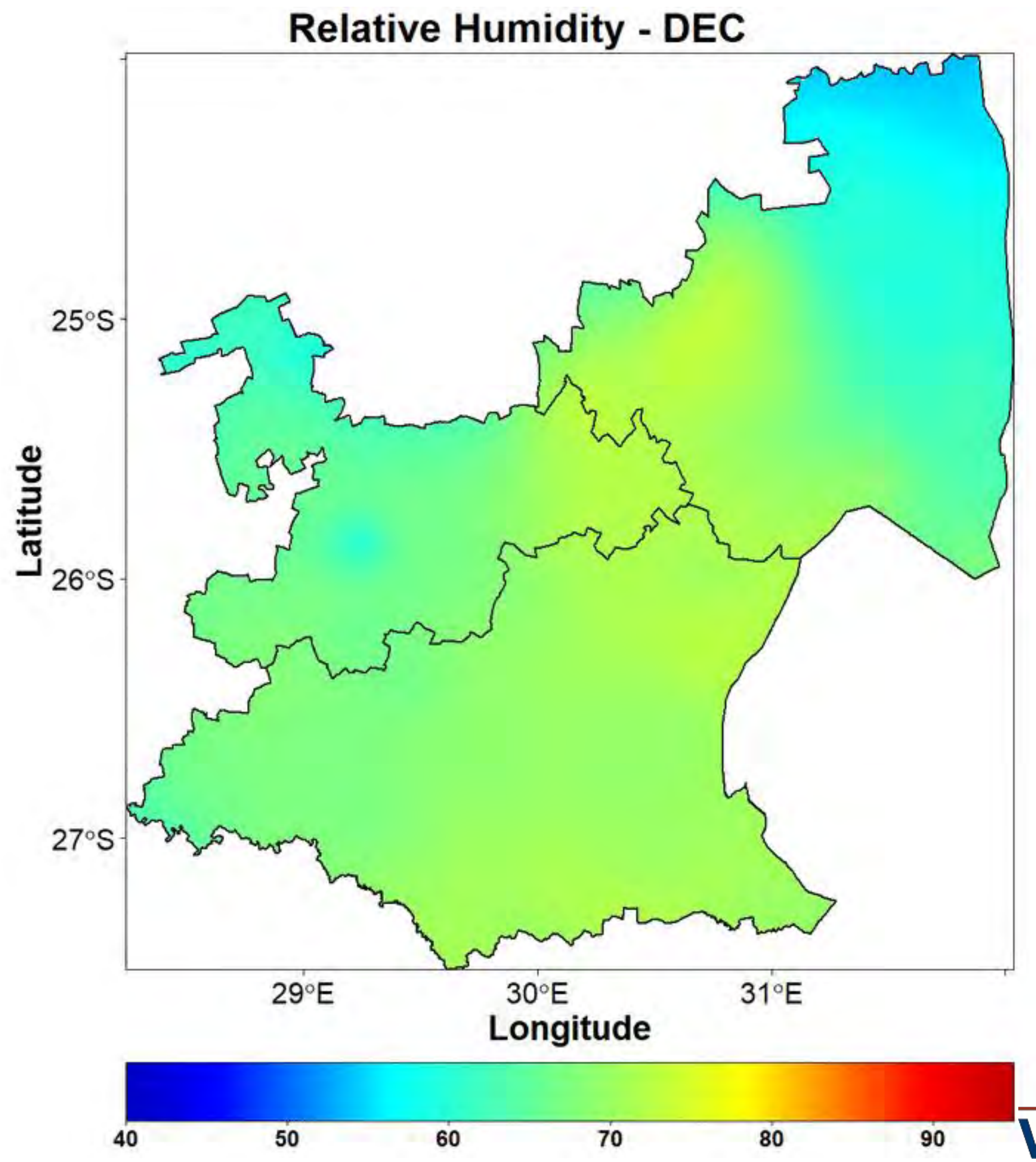












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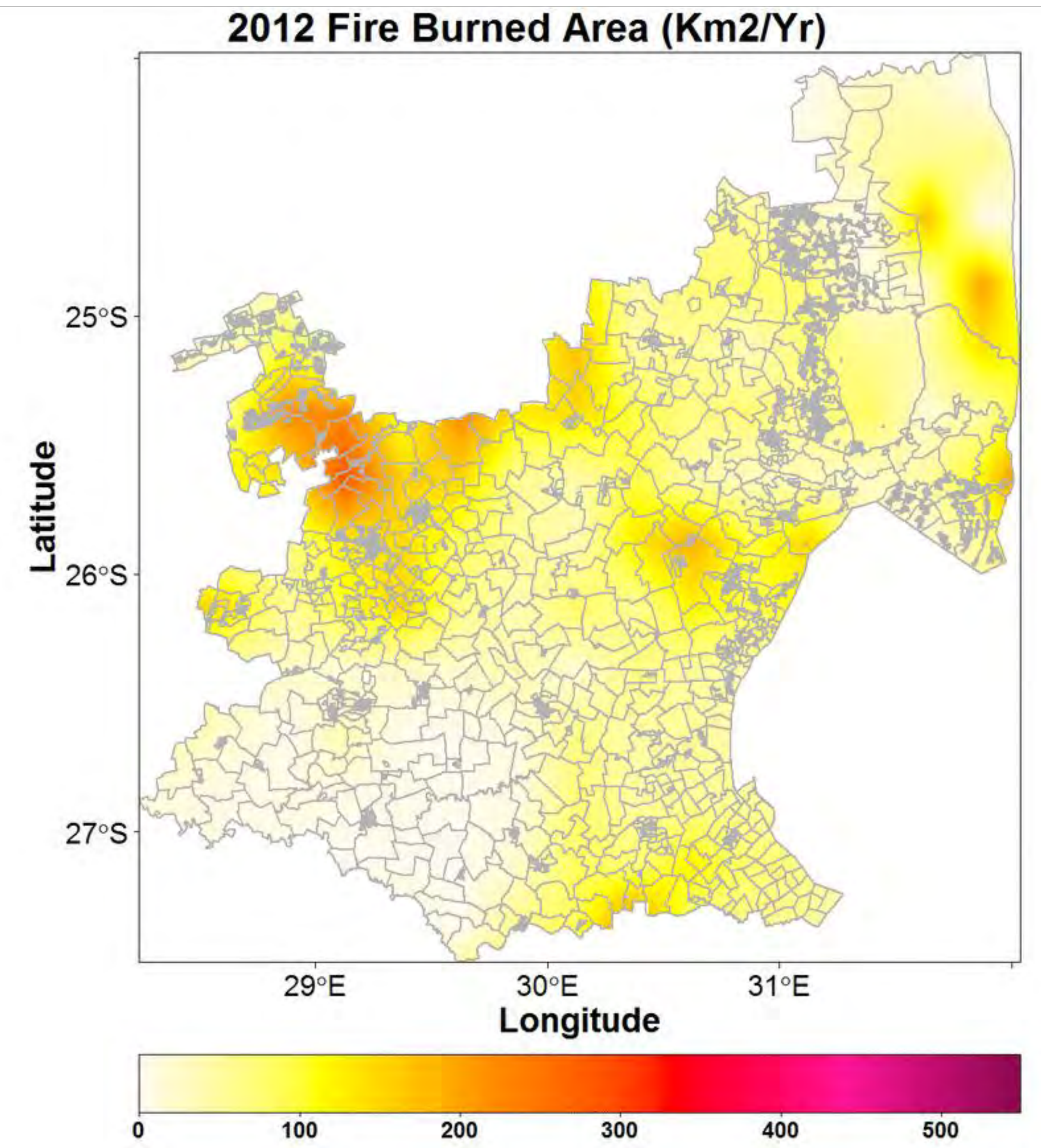
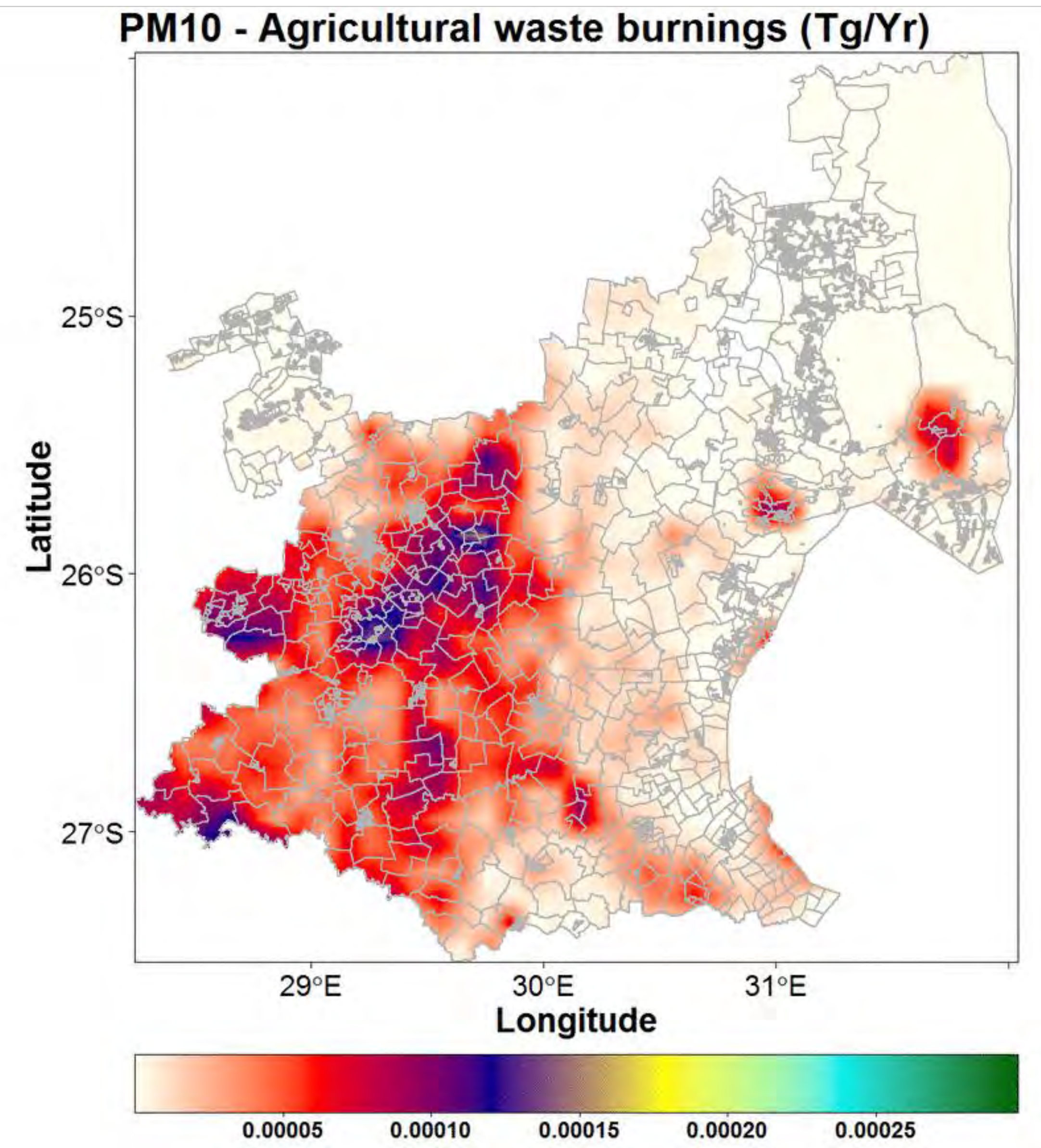
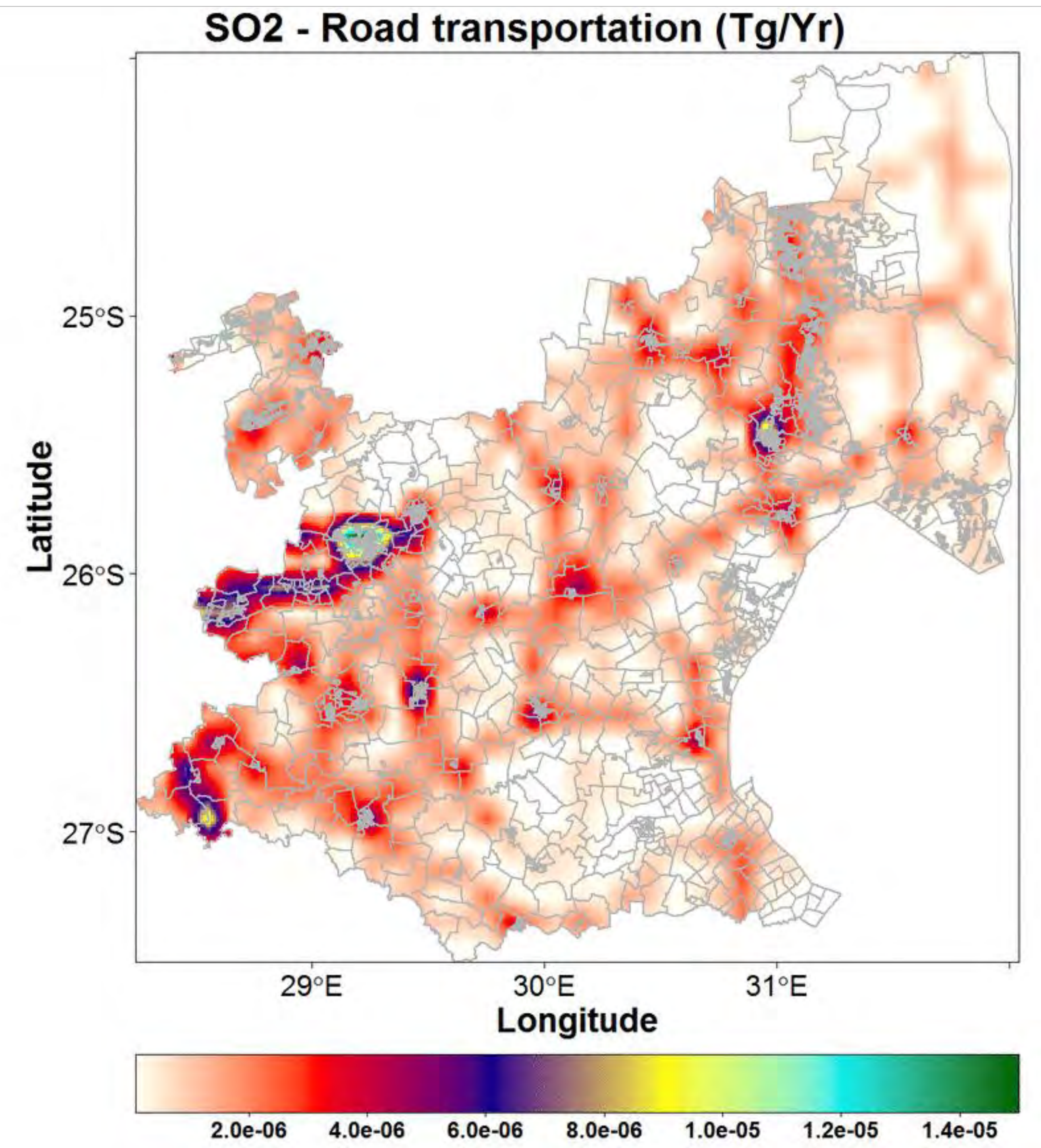
SAWS AQ Research

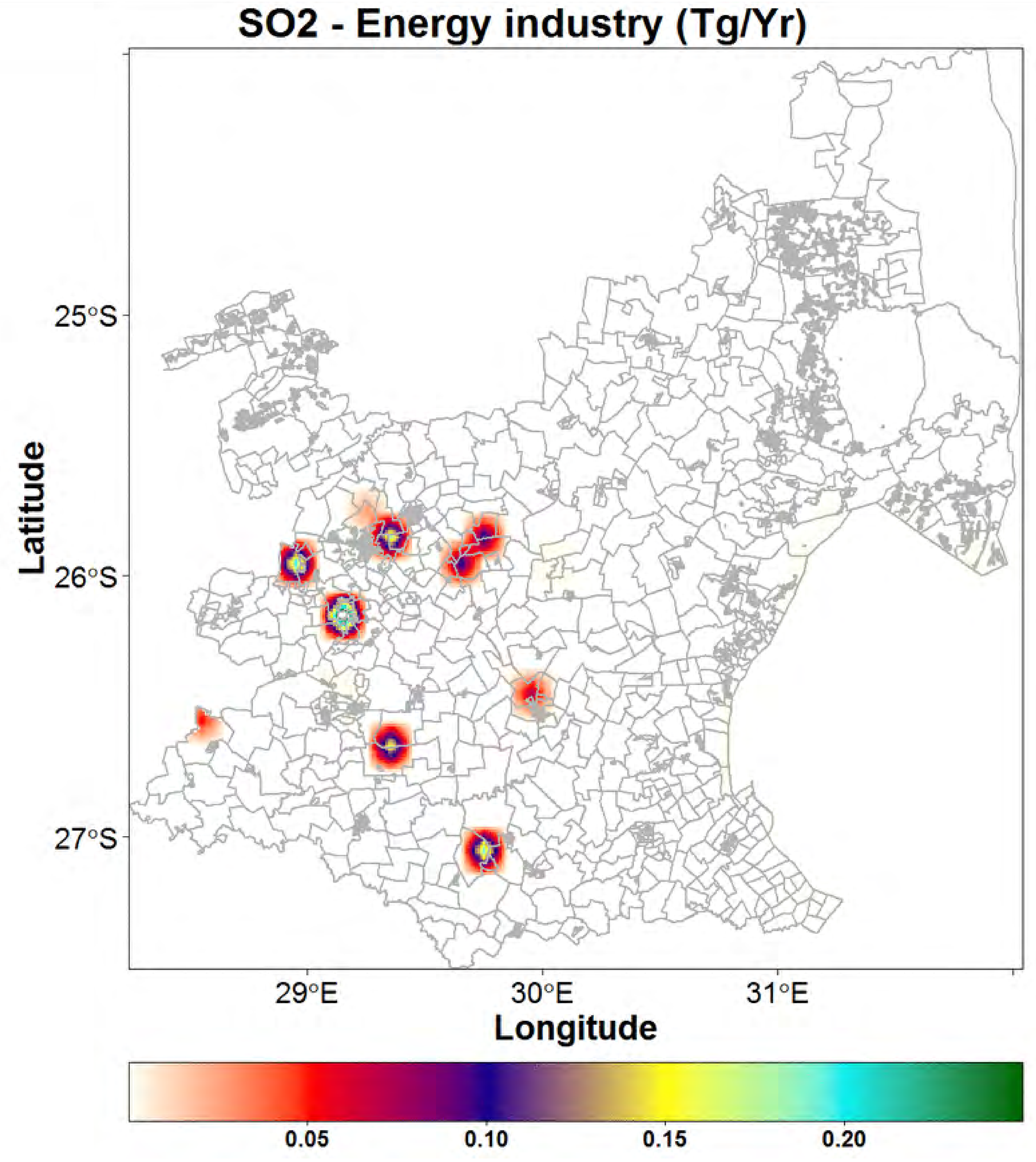
❑ Services: Scenario based AQMP

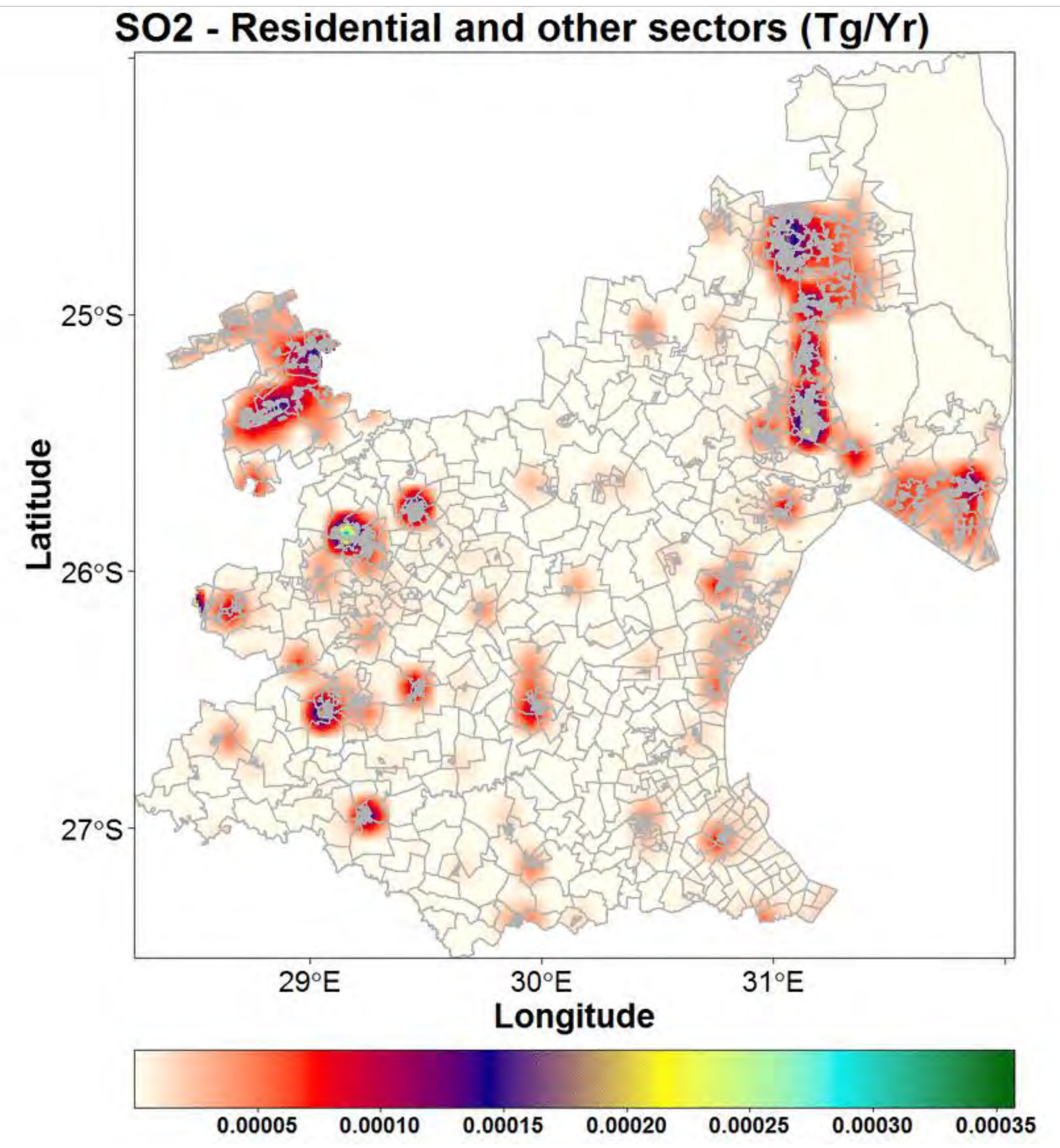
Sectorial emission climatology

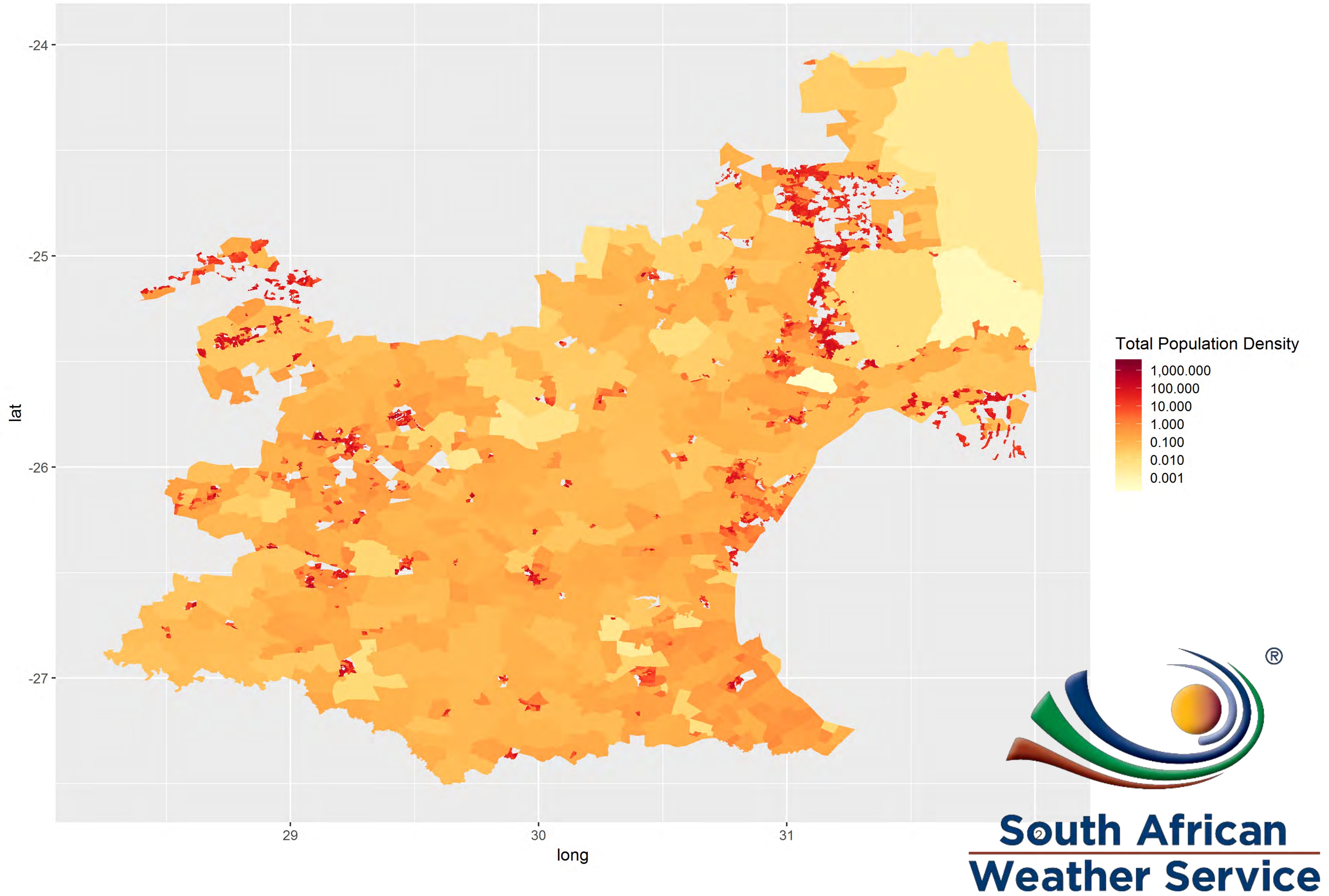












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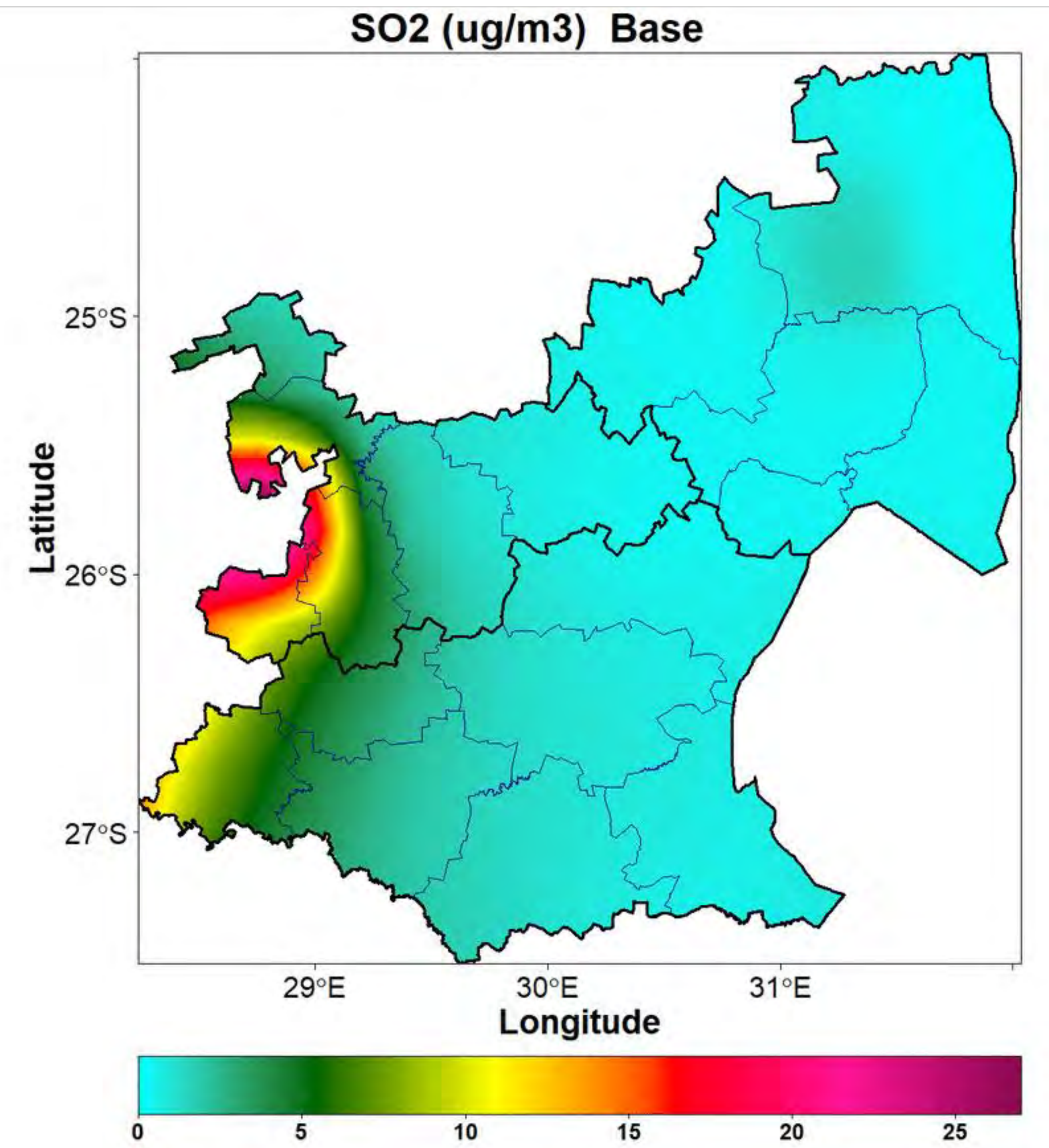
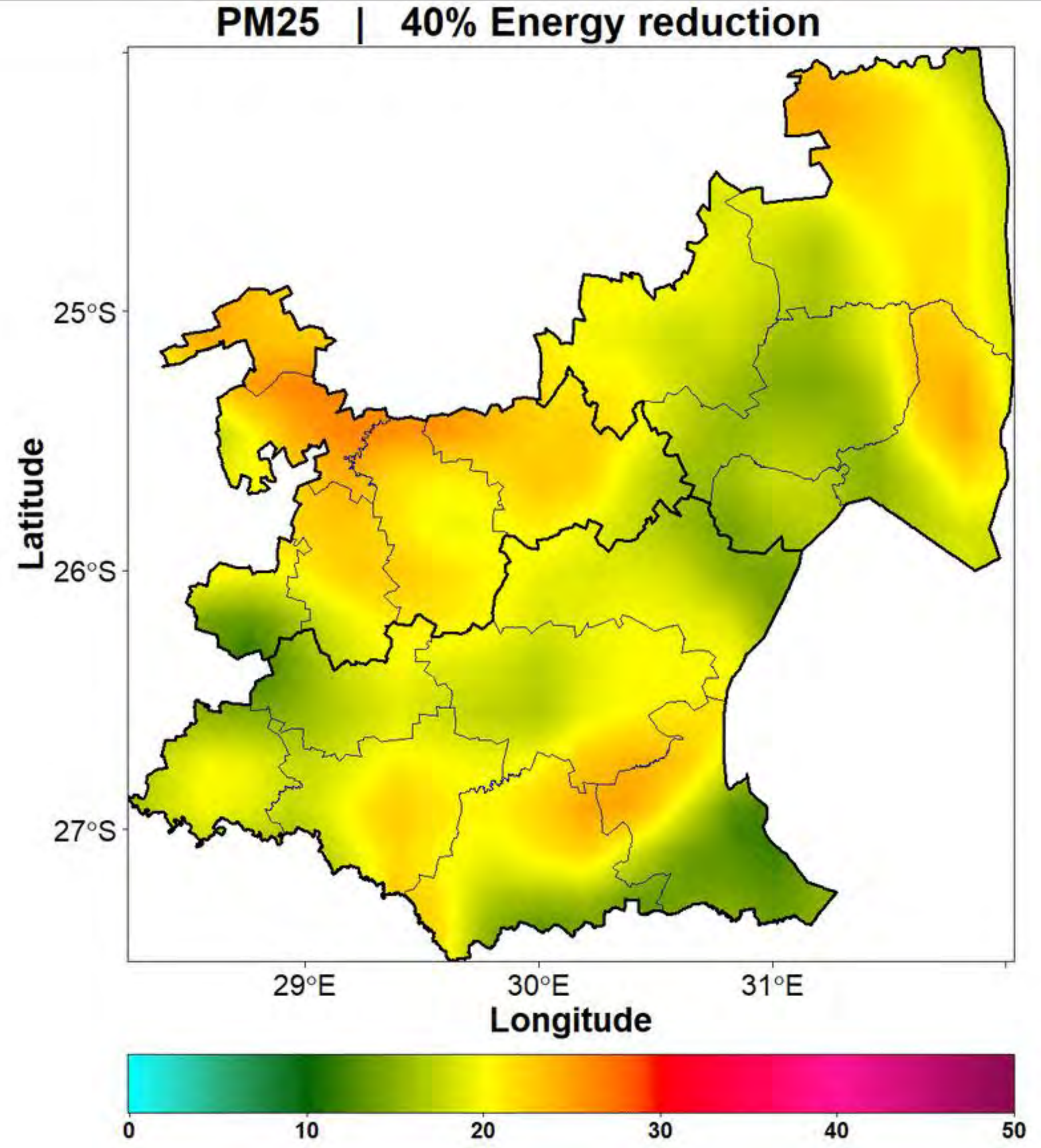
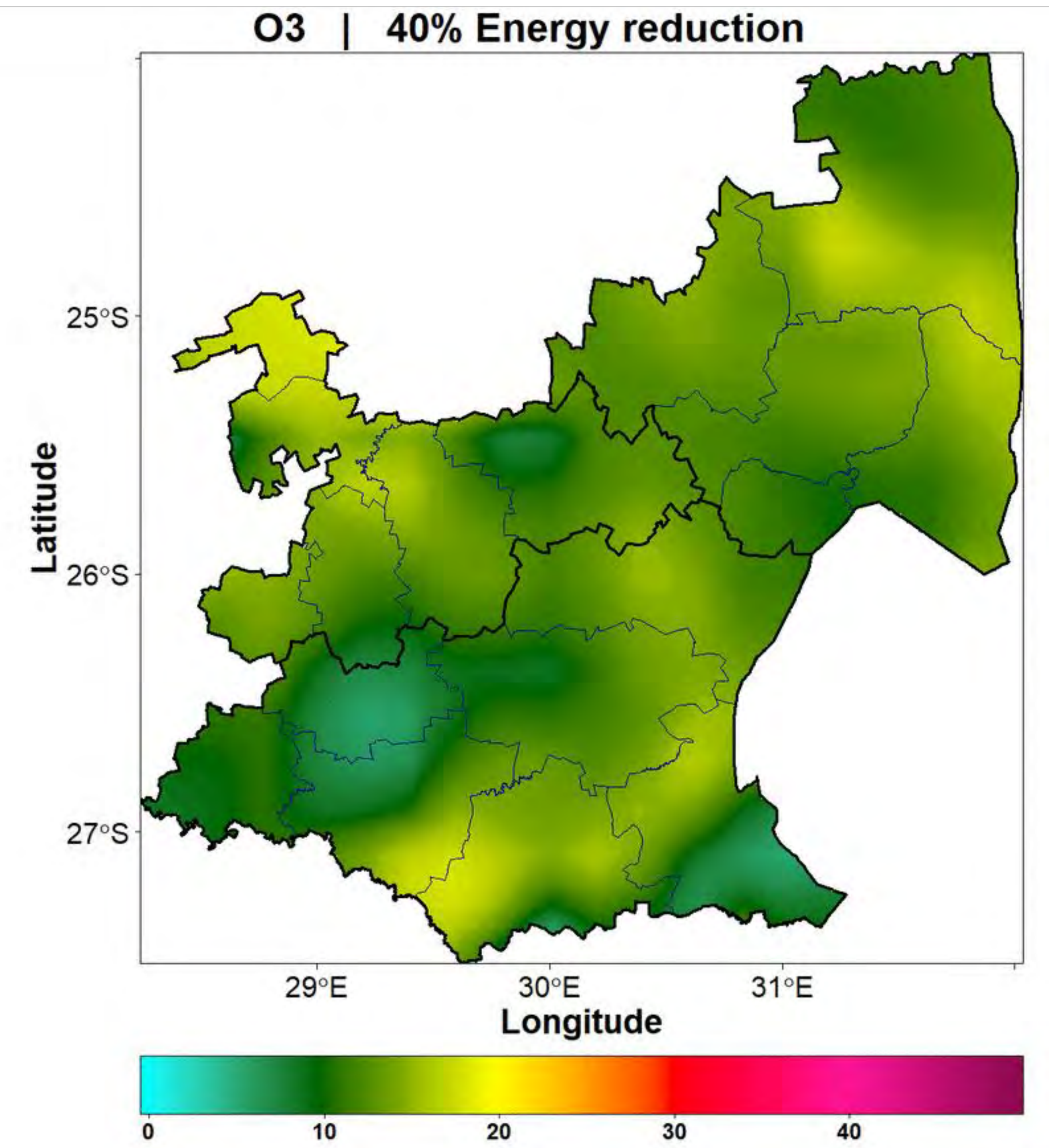
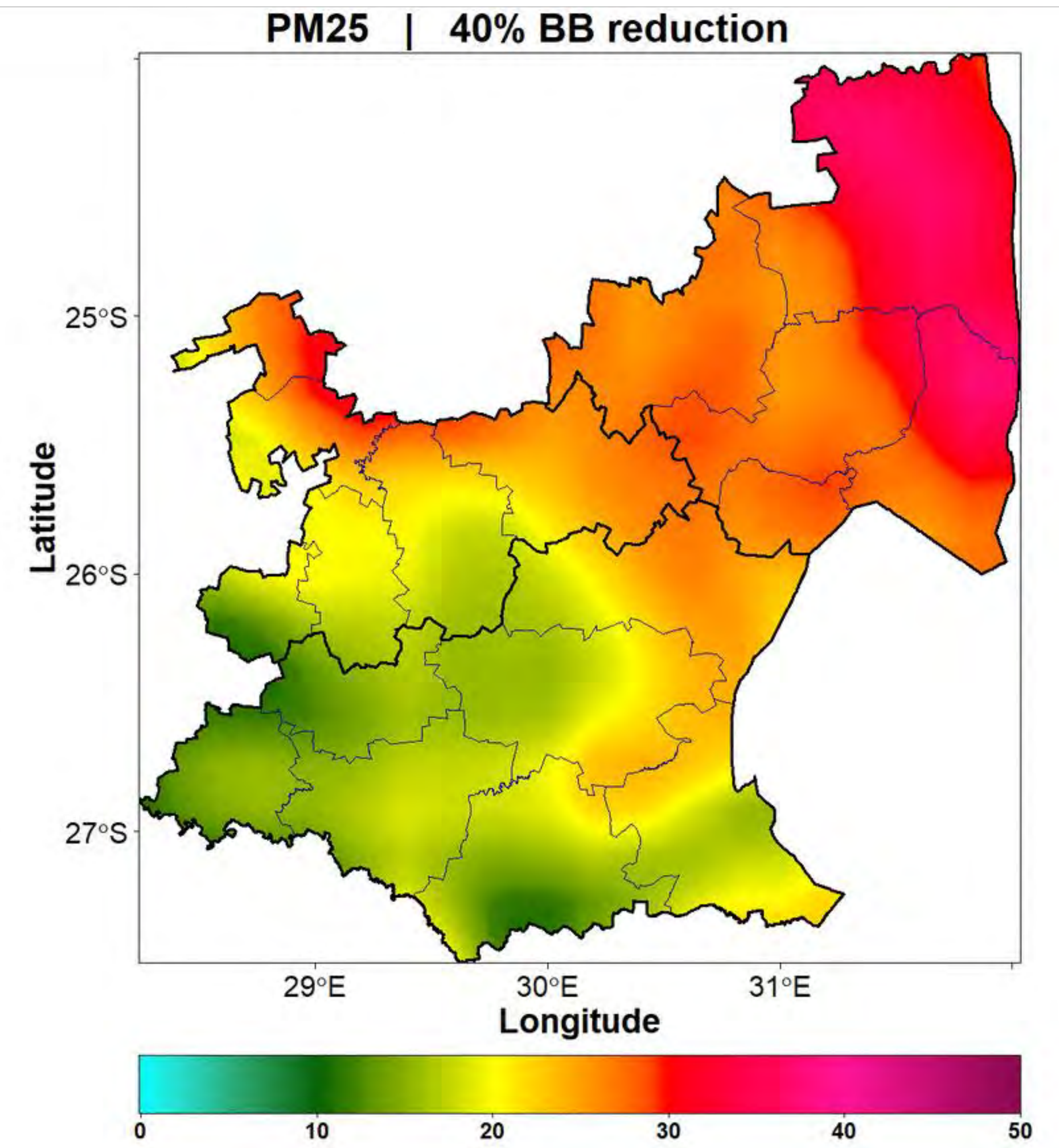
SAWS AQ Modeling and Forecasting

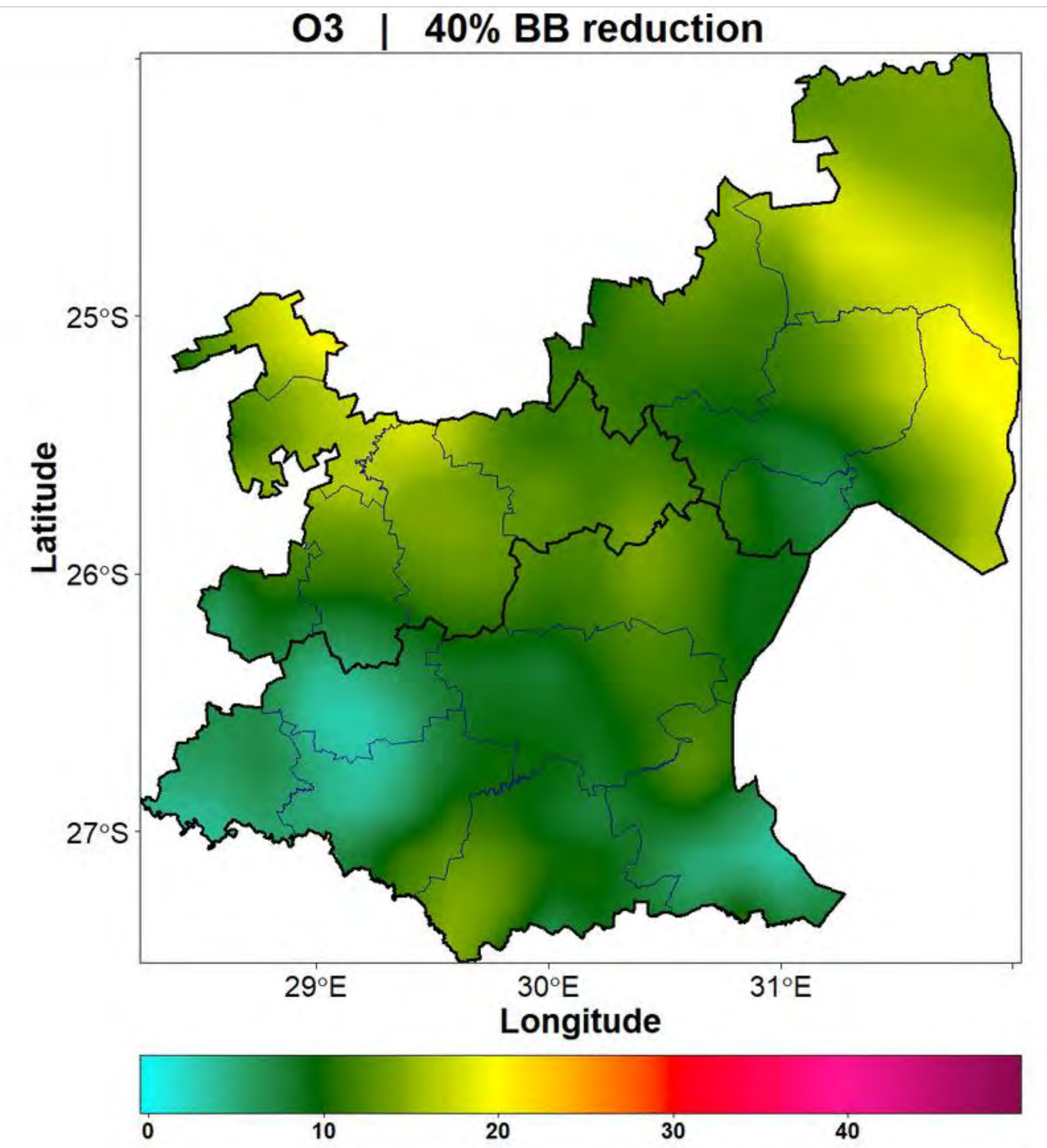
- Services: Scenario based AQMP











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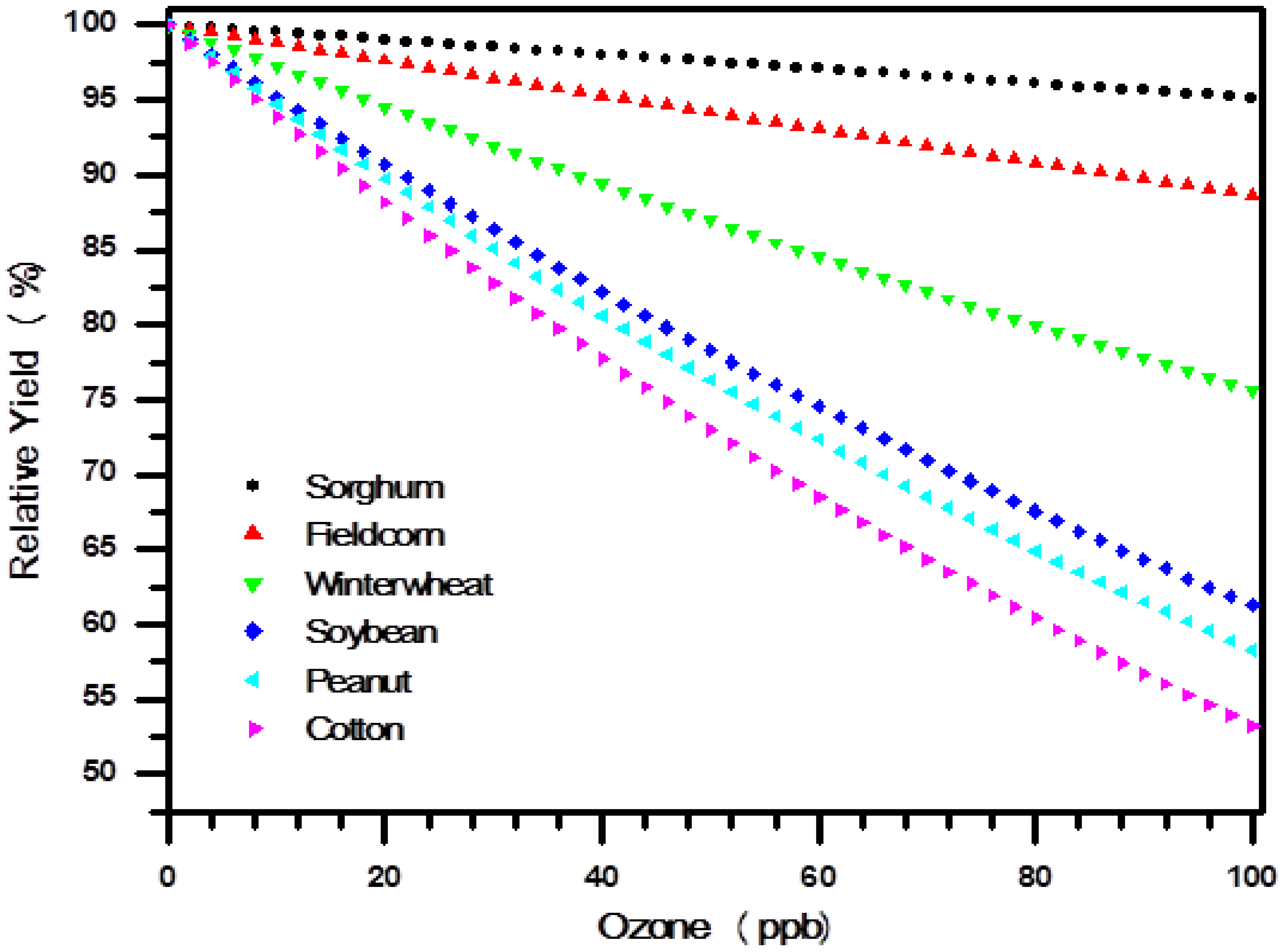
SAWS AQ Research

❑ Services: Air pollutant impact on plant

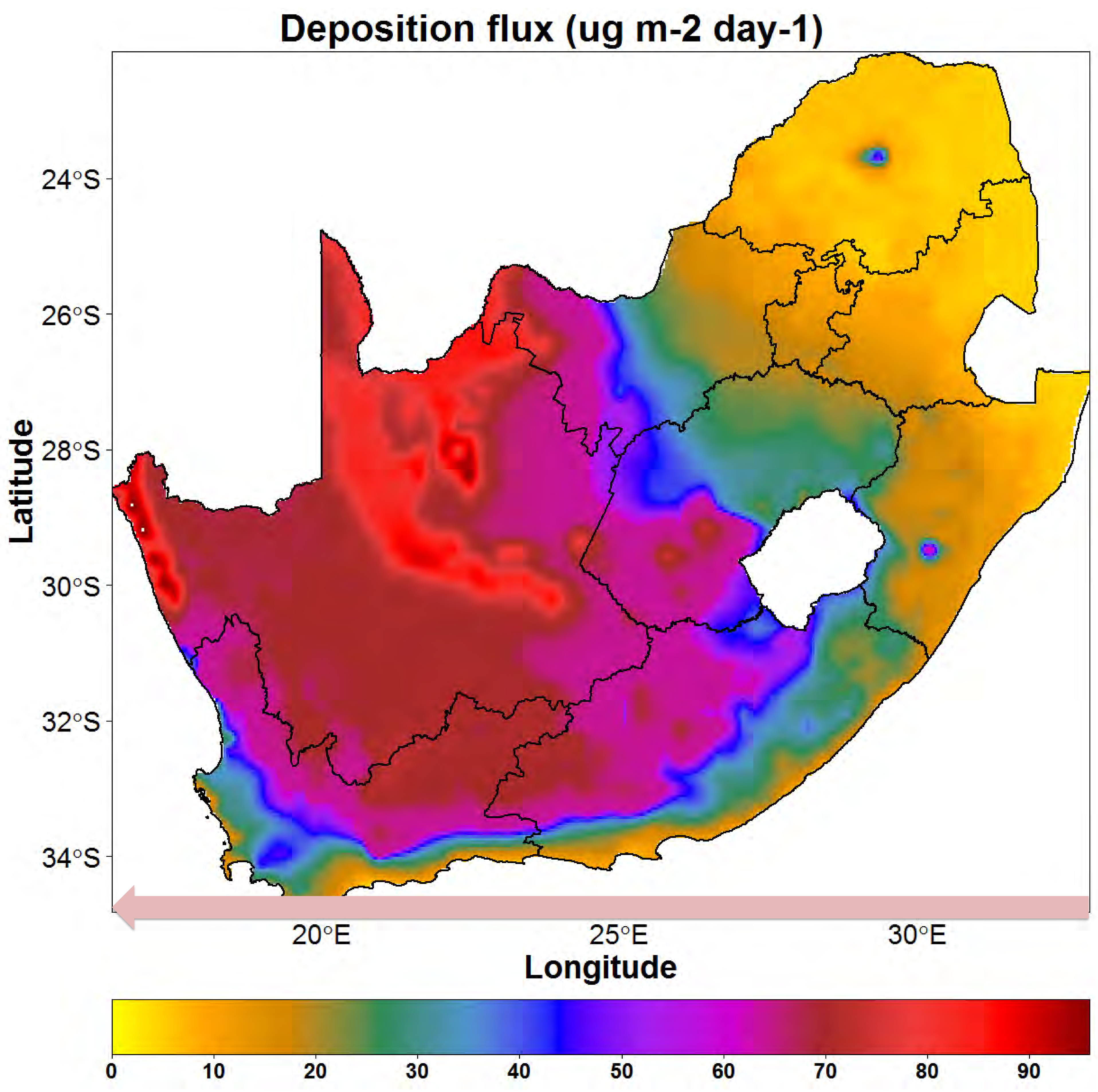
Changes the pH of soil and surface-atmosphere chemical exchanges

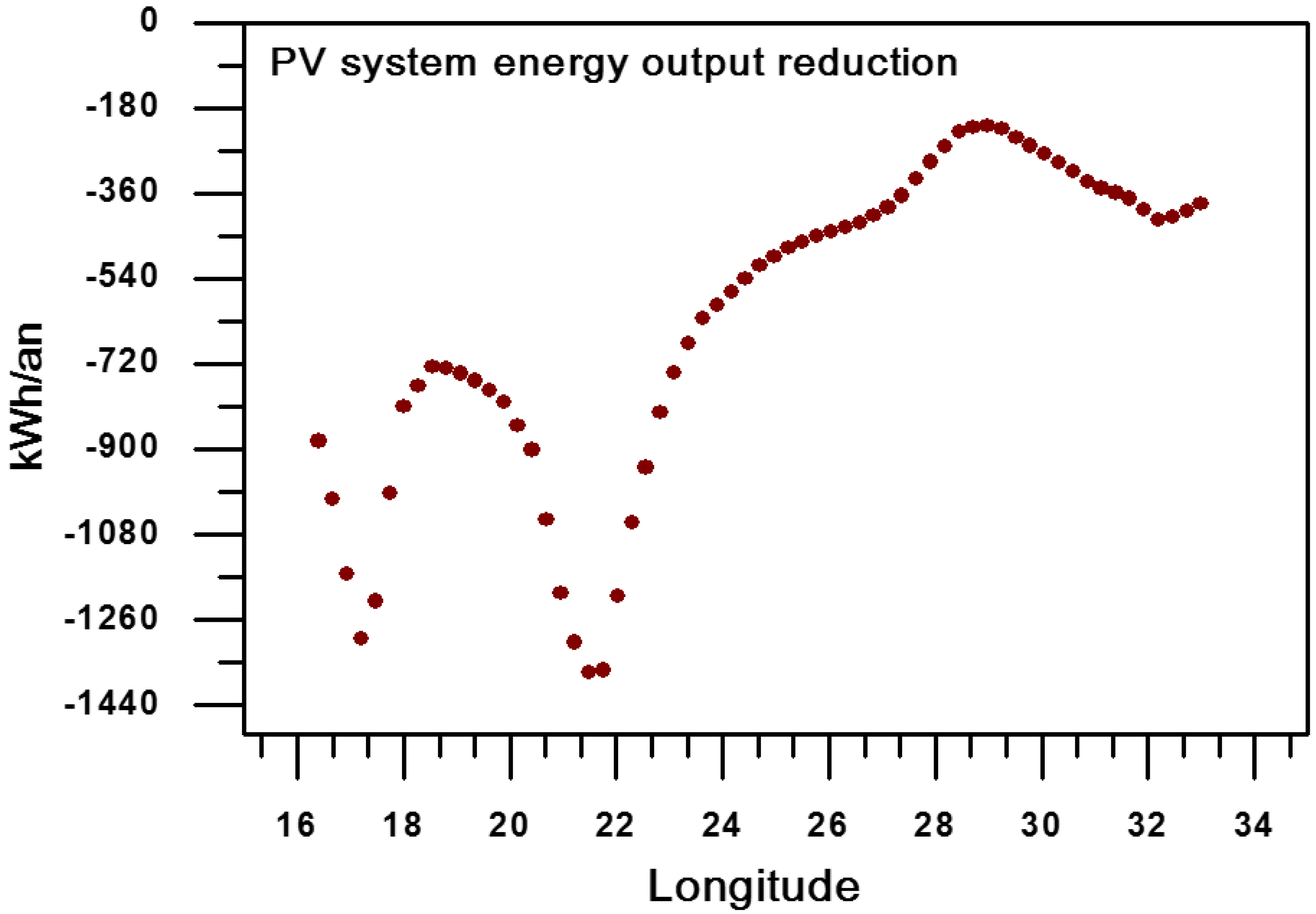
Ozone | Sulfur dioxide | Fluoride | Ammonia | Cement-dust



SAWS AQ Modeling and Forecasting

- Services: PV Energy





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THANK YOU FOR YOUR ATTENTION

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