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Environmental Consequences of asteroid impacts by General Circulation Model (GCM) simulations

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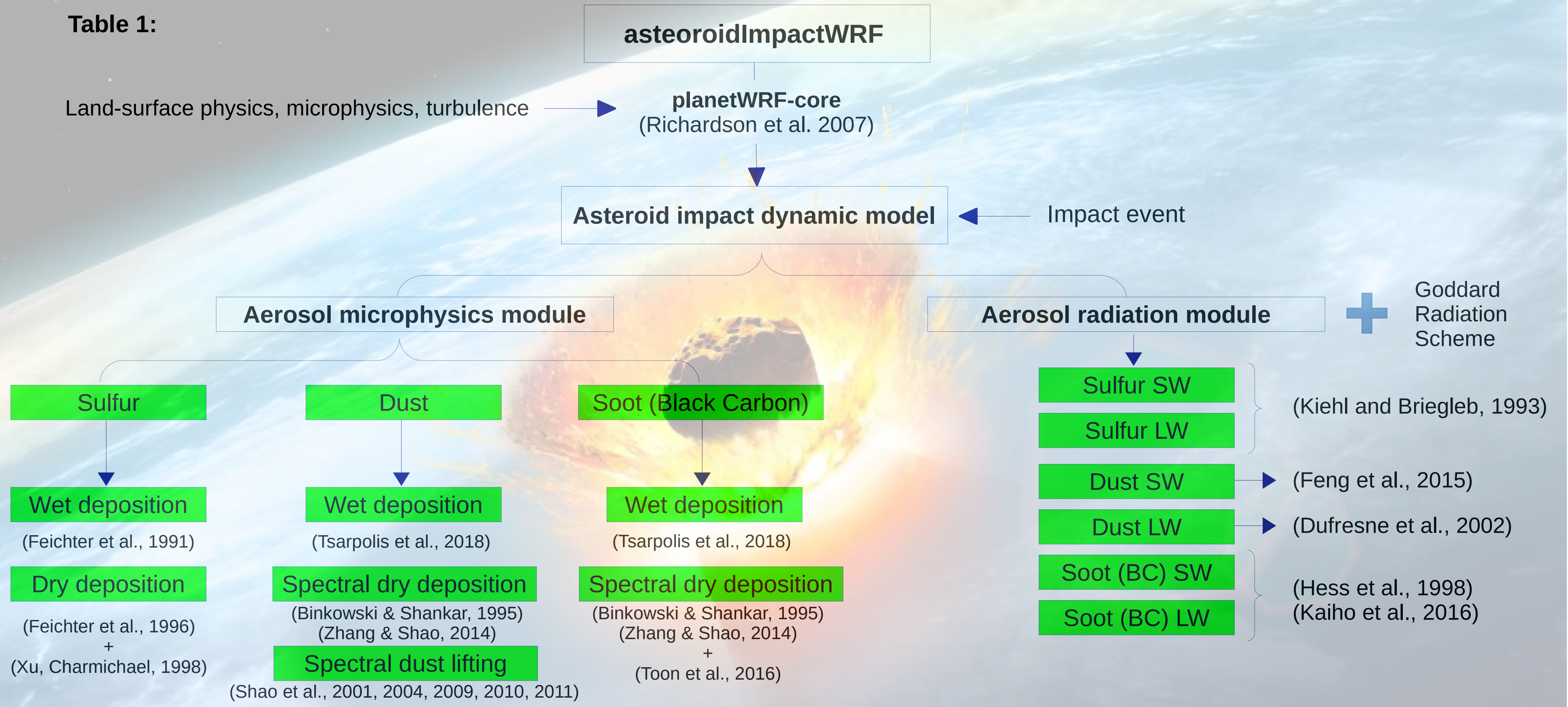
1- Motivation & Methodology

asteroidImpactWRF: to simulate the climatic response of small and large impactors

Table 1:



GCM set-up

- The horizontal grid spacing is 5° through the zonal and meridional directions, having 21 vertical eta layers.
- Goddard radiation model [Chou and Suarez, 1999, Chou et al., 2001] is used for the shorthwave and longwave radiative transfer.
- The aerosol (dust, sulfur, soot) microphysics (lifting, dry/wet deposition) and radiation is modeled as given in Table 1.
- Boundary-layer turbulence is modeled by the Bougeault–Lacarrere Scheme (BouLac) [Bougeault and Lacarrere, 1989].
- For the parameterization of microphysical processes, double-moment 6–class microphysics scheme is used [Lim and Hong, 2010].
- 5–layer thermal diffusion scheme is utilized for land-surface physics [Dudhia, 1996], the surface layer is modeled by the revised MM5 scheme [Jiménez et al., 2012].
- For the ocean model, one-dimensional ocean mixed layer model (OMLM) is used [Pollard et al., 1973].

1- Methodology

Aerosol injection scenarios -based on Toon et al. (1997, 2016)-

Description of GCM experiments: Impact scenarios

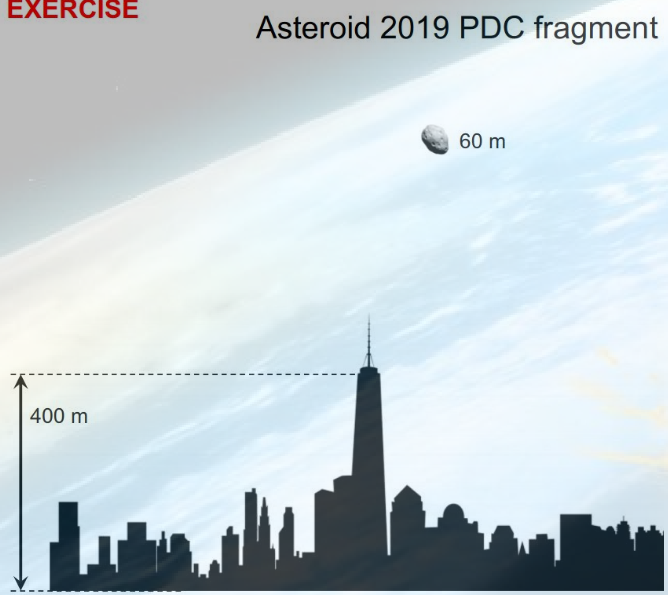
- In the current study, we perform 2 impact scenarios based on 2 different aerosol types (dust and sulfur), depending on 3 different impactor sizes (i.e. diameter) ranging between:
  - 100 m (similar to hypothetical PDC2019 impactor)
  - 1 km
  - 10 km (corresponding to a similar size of Chicxulub impactor)
- The center location of impact event is set to be New York city (∼ 40.7°N, 74.0°W), based upon the hypothetical asteroid impact scenario from PDC2019.
- GCM simulations are performed for the present Earth's climate conditions taking the globally-averaged atmospheric CO_2 concentration to be nearly 416 parts per million (ppm).
- Time integration for each simulation is carried out for 5 years where the first 3-years are removed out (initial spin-up).

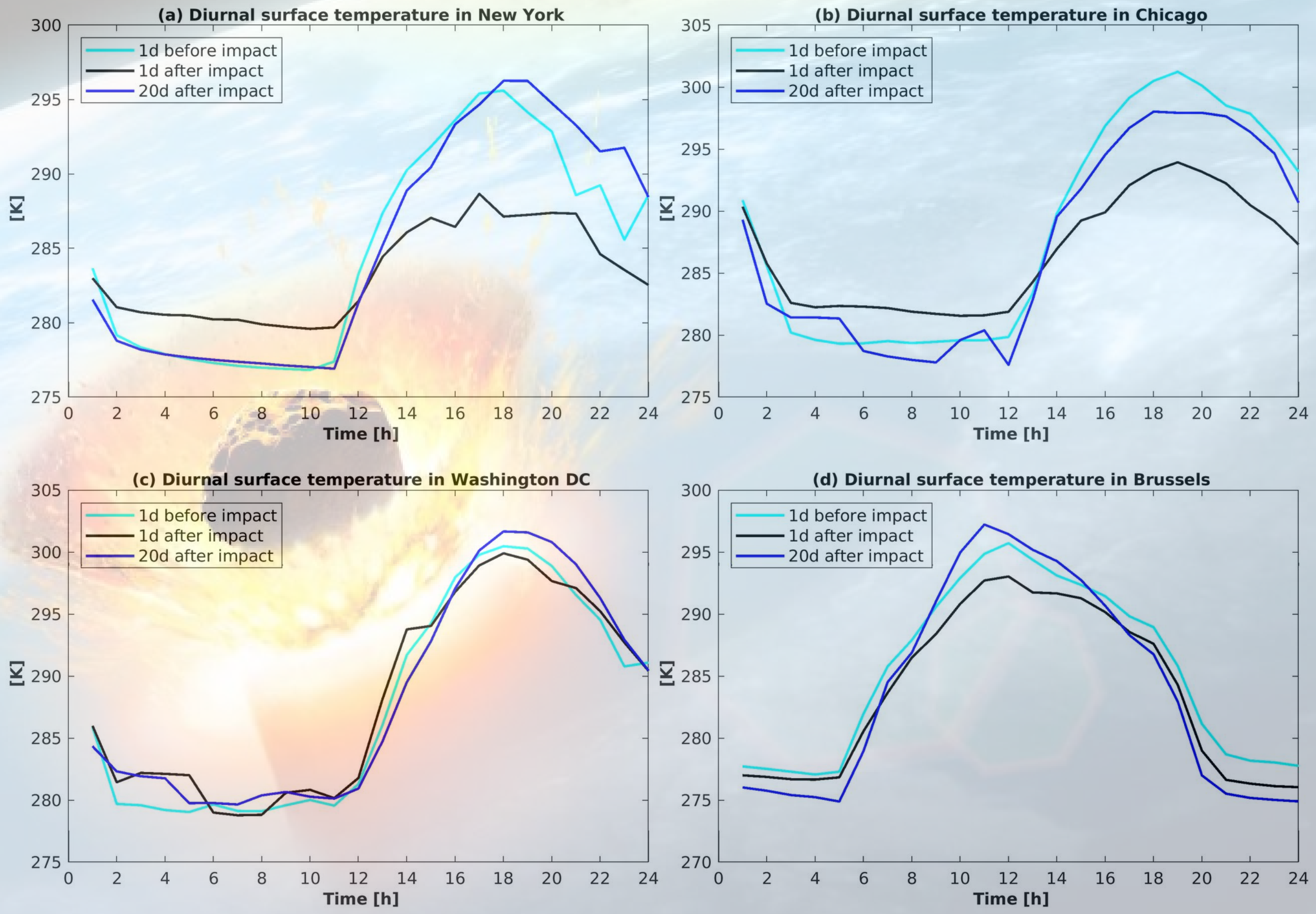
GCM Experiment	Impactor Dia. $[km]$	Impact Energy $[Mt]$	Injected Aerosol Mass $[g]$
Dust-pdc2019	0.1	68	$1.4x10^{12}$
Dust-1km	1	6800	$1.4x10^{15}$
Dust-chicxulub	10	$6.8x10^{7}$	$2.3x10^{18}$
Sulfur-pdc2019	0.1	68	$9.9x10^{10}$
Sulfur-1km	1	6800	$4.4x10^{13}$
Sulfur-chicxulub	10	$6.8x10^{7}$	$9.0x10^{16}$

2- Results: Dust injection

Diurnal surface temperature before and after impact - GCM experiment: Dust-PDC2019

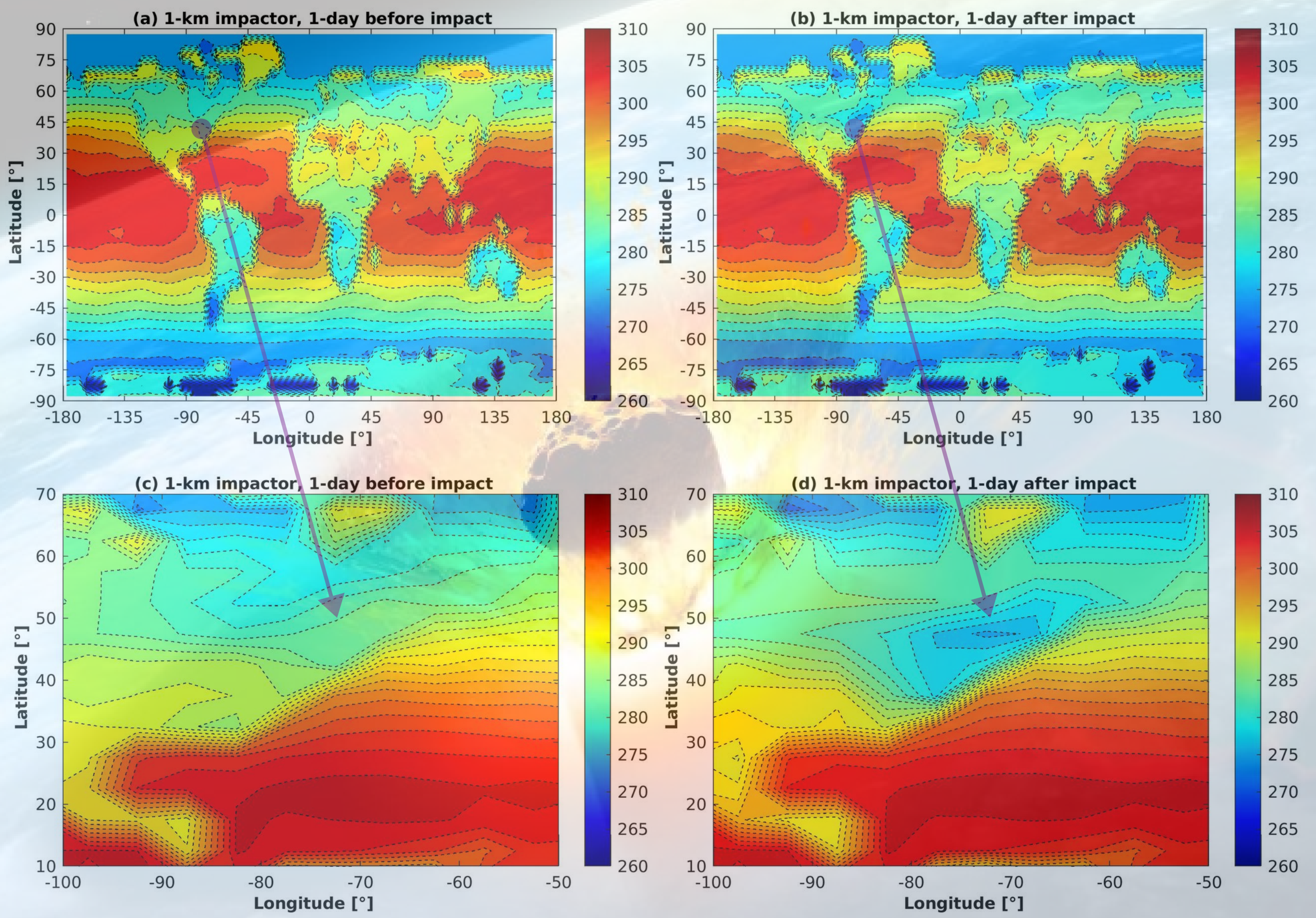
EXERCISE





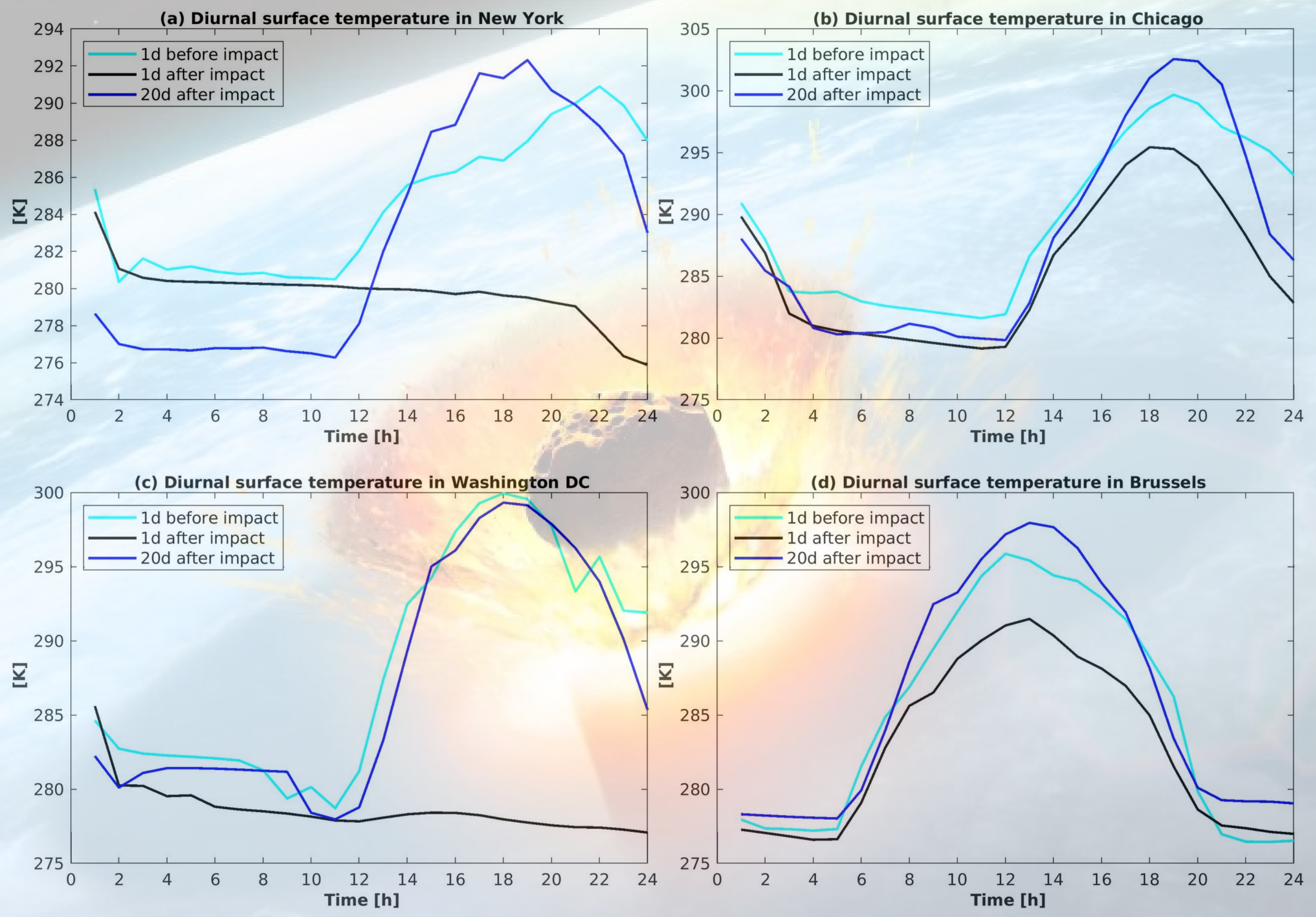
2- Results: Dust injection

Daily mean surface temperature before and after impact - GCM experiment: Dust-1km



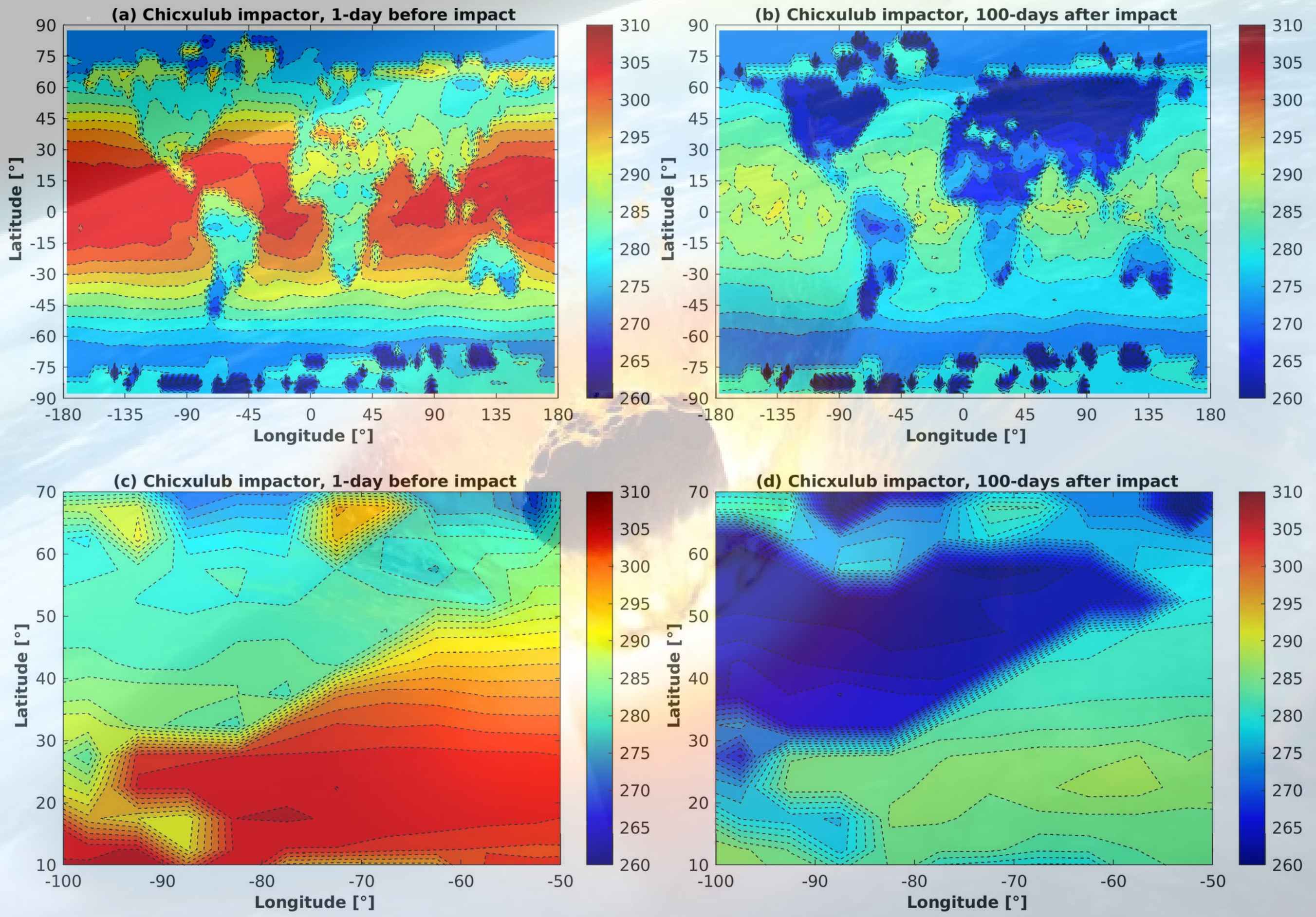
2- Results: Dust injection

Diurnal surface temperature before and after impact - GCM experiment: Dust-1km



2- Results: Dust injection

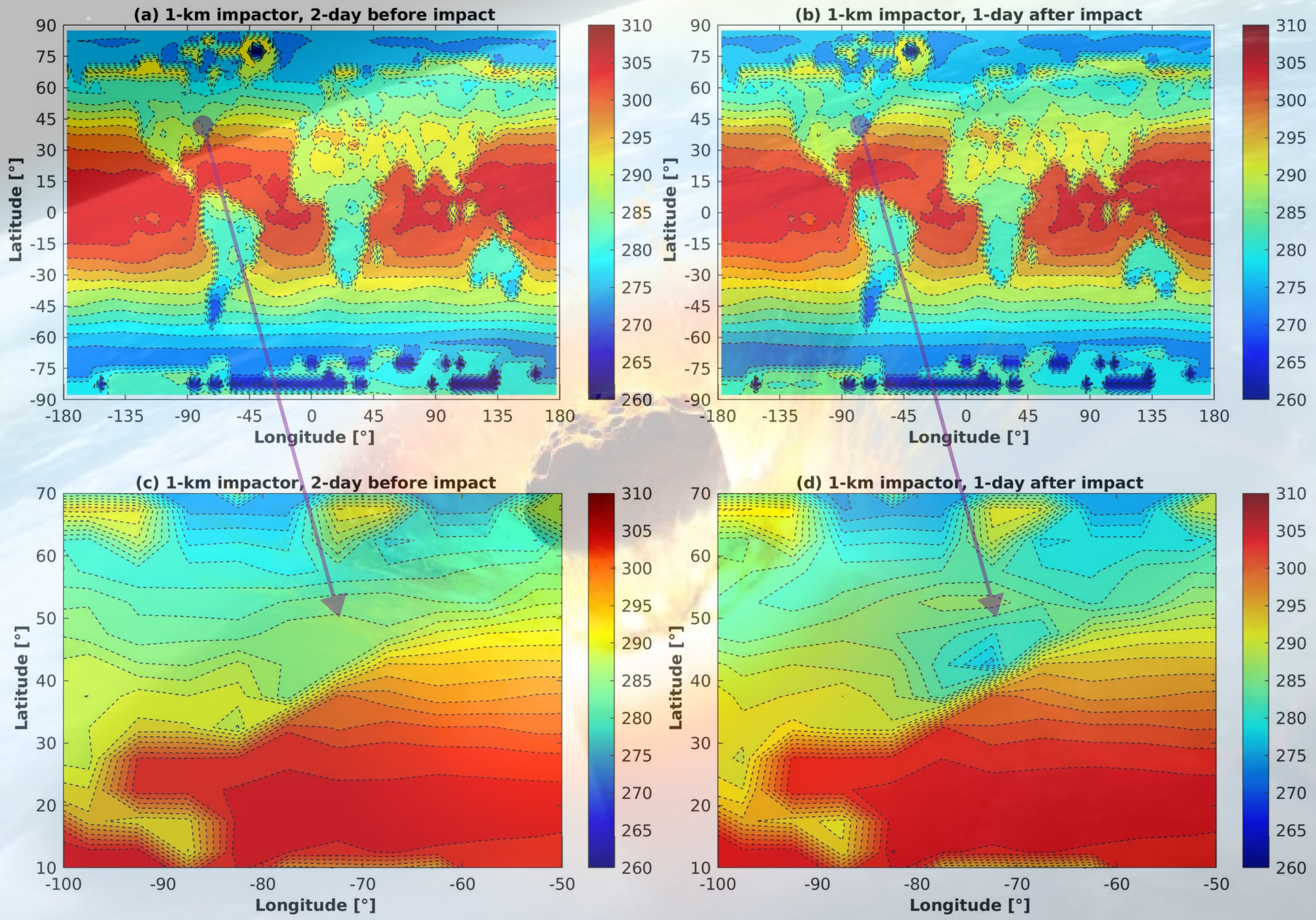
Daily mean surface temperature before and after impact - GCM experiment: Dust-Chicxulub



Impact Winter

3- Results: Sulfur injection

Daily mean surface temperature before and after impact - GCM experiment: Sulfur-1km



4. Next step

- GCM grid resolution will be refined: from Δ=5°x5° to Δ=1°x1° resolutions.
- Aerosol microphysics and radiation will be treated via two-moment framework based on Morrison, H., & Gettelman, A. (2008).
- Impact-induced soot (black carbon) emission will be taken into account.
- Surface radiative fluxes and precipitation rates will be investigated in detail following small/large asteroid impact events.

Thank you for your attention.

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References

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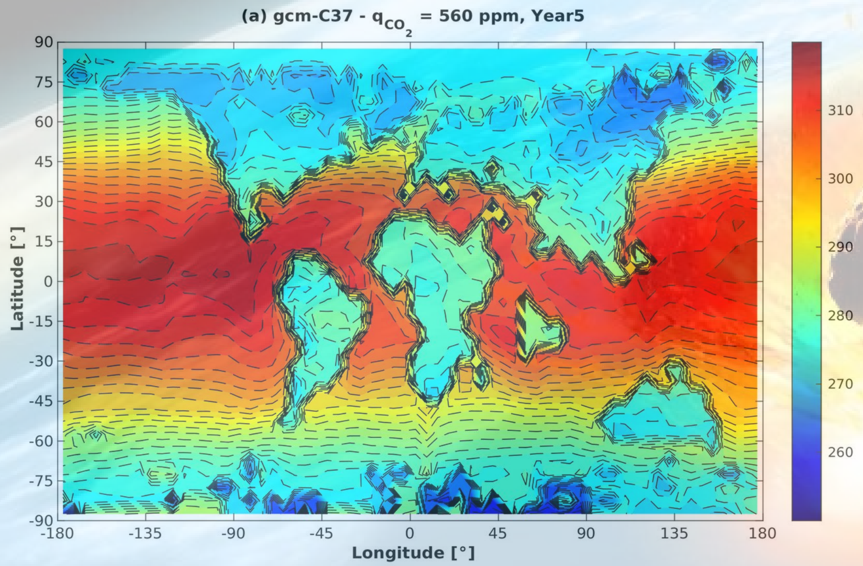
Backup: Methodology

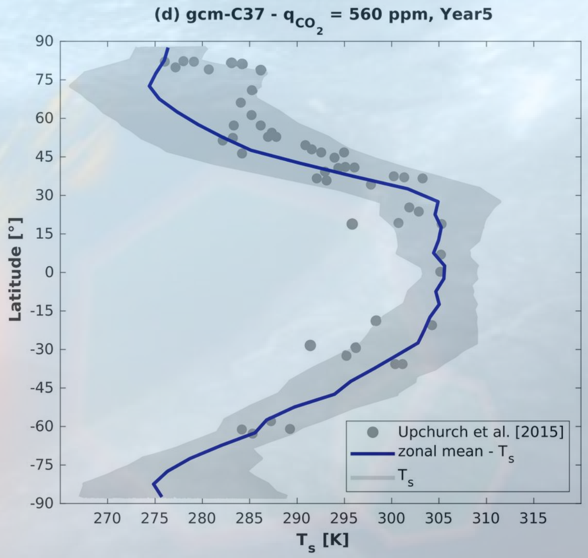
Verification of the model at the latest Cretaceous conditions

asteroidImpactWRF

Land-surface physics, microphysics, turbulence → **planetWRF-core** (Richardson et al. 2007)



Pre-impact surface temperature [K] contours



Min, max and zonally-averaged surface temperature

Upchurch et al. (2015)
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