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Land Surface Albedo Climatology Using MODIS Satellite Data and Its Changes with Climate

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1 Background

- ❑ **Key Role**: Albedo influences energy exchange by reflecting sunlight and affecting surface temperature, evaporation, and heat exchange.
- ❑ **Traditional Approach**: Categorized surface types with intrinsic albedo values but limited in capturing surface diversity. Difficult to capture the full complexity of mixed land surface and topographic effect.
- ❑ **Previous Study**: Developed a climatological land surface albedo dataset version 1 (Koo et al., 2017) using 16 years of MODIS data, validated with CERES observations.
- ❑ **Recent Updates**: Applied improved data processing to 2021–2023 satellite data, producing a new dataset version 2 reflecting climate and land use changes.

2 Data and Parametrization

- MCD43C2 BRDF/Albedo Model Snow-Free Quality
- Climate Modeling Grid (CMG) resolution : 0.05 deg
- White-sky(diffuse radiation) and black-sky (beam radiation) parametrization
- Weighting parameters for the Ross Thick Li Sparse Reciprocal BRDF model
- Visible and near-infrared broadbands

$$\alpha_{bs}(\Theta,\lambda) = f_{iso}(\lambda)(g_{0iso} + g_{1iso}\Theta^2 + g_{2iso}\Theta^3) + f_{vol}(\lambda)(g_{0vol} + g_{1vol}\Theta^2 + g_{2vol}\Theta^3) + f_{geo}(\lambda)(g_{0geo} + g_{1geo}\Theta^2 + g_{2geo}\Theta^3)$$

$$\alpha_{ws}(\lambda) = f_{iso}(\lambda)g_{iso} + f_{vol}(\lambda)g_{vol} + f_{geo}(\lambda)g_{geo}$$

Term	iso	vol	geo
g0	1.0	-0.007574	-1.284909
g1	0.0	-0.070987	-0.166314
g2	0.0	0.307588	0.041840
g	1.0	0.189184	-1.377622

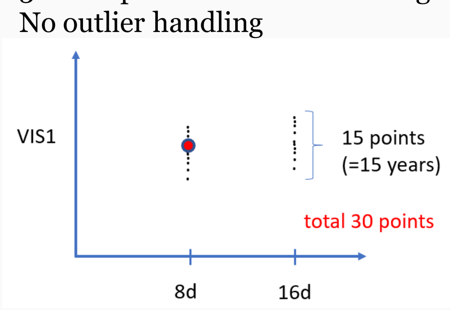
3 Methods

Step 1 : Data Compilation

- Extract 6 variables *fiso_vis, fvol_vis, fgeo_vis, fiso_nir, fvol_nir, fgeo_nir*
- Longitude and latitude dimension : (7200,3600)
- Make every 16-day (23 times series of a your) climatological data

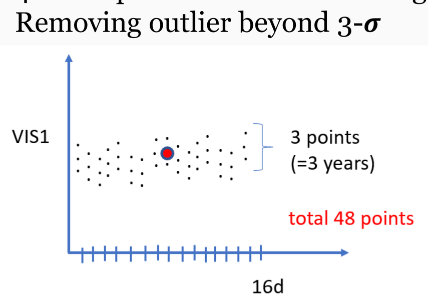
Version 1

- Every 8-day data from **Feb 2000** to **May 2015**
- 795 HDF format files
- 30 data points for one climatological value
- No outlier handling



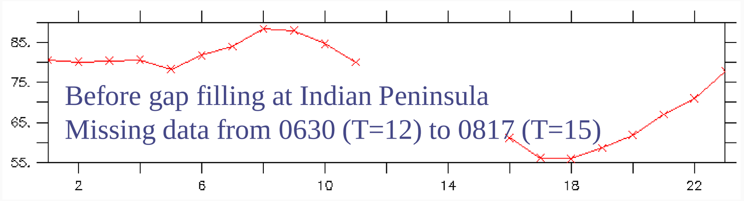
Version 2

- Daily data from **Jan 2021** to **Dec 2023** :
- 1095 files HDF format files
- 48 data points for one climatological value
- Removing outlier beyond 3-σ

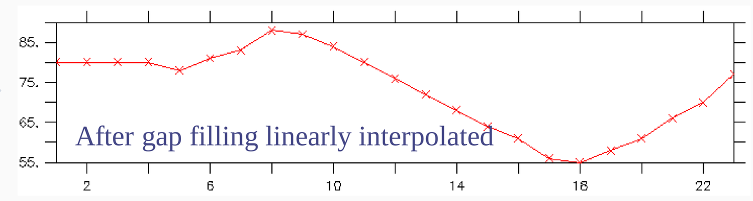


Step 2 : Gap Filling

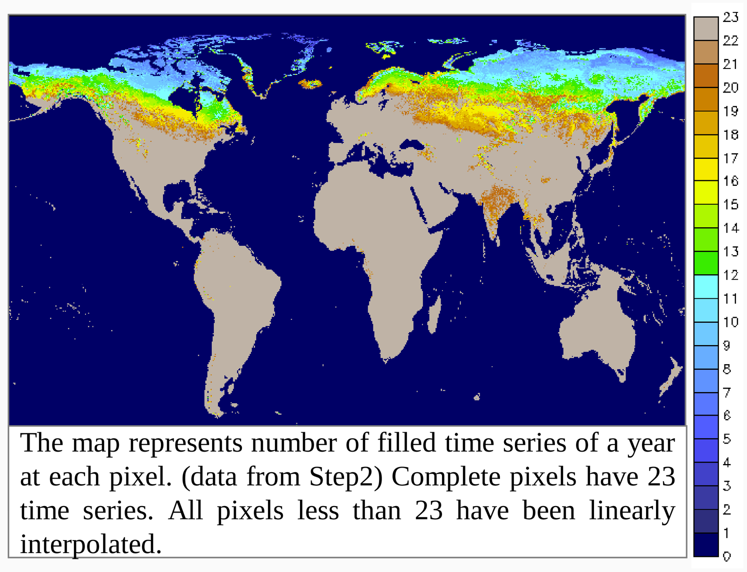
- Gap filling : Missing data treatment (C. Schaaf et al.)
- Missing data points are filled linearly with data from other 16-day retrievals
- Winter : due to snow at high-latitude Northern Hemisphere
- Summer : due to cloud during Monsson in the Indian peninsula



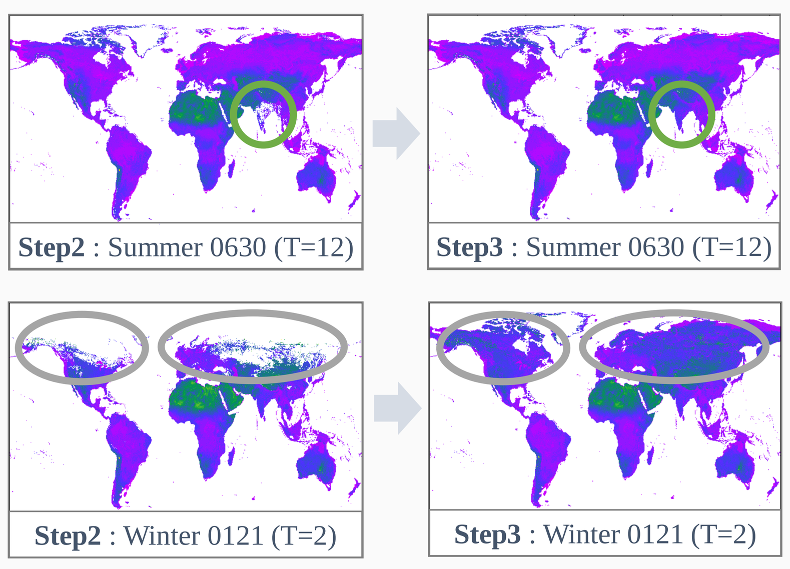
23 time series of a year



23 time series of a year



The map represents number of filled time series of a year at each pixel. (data from Step2) Complete pixels have 23 time series. All pixels less than 23 have been linearly interpolated.



Step 3 : Interpolation

- Horizontal : Latitude Longitude grid ➔ Cubed Sphere grid (for the KIM model)
- Temporal : During model run, temporal linear interpolation between the two nearest time points at every radiation call (hour)
- Read 6 variables (cubed sphere grid dimension and 23 times series) → Compute 4 type albedo (beam/diffuse or VIS/NIR) →Radiation main solver

4 Result

Albedo Changes

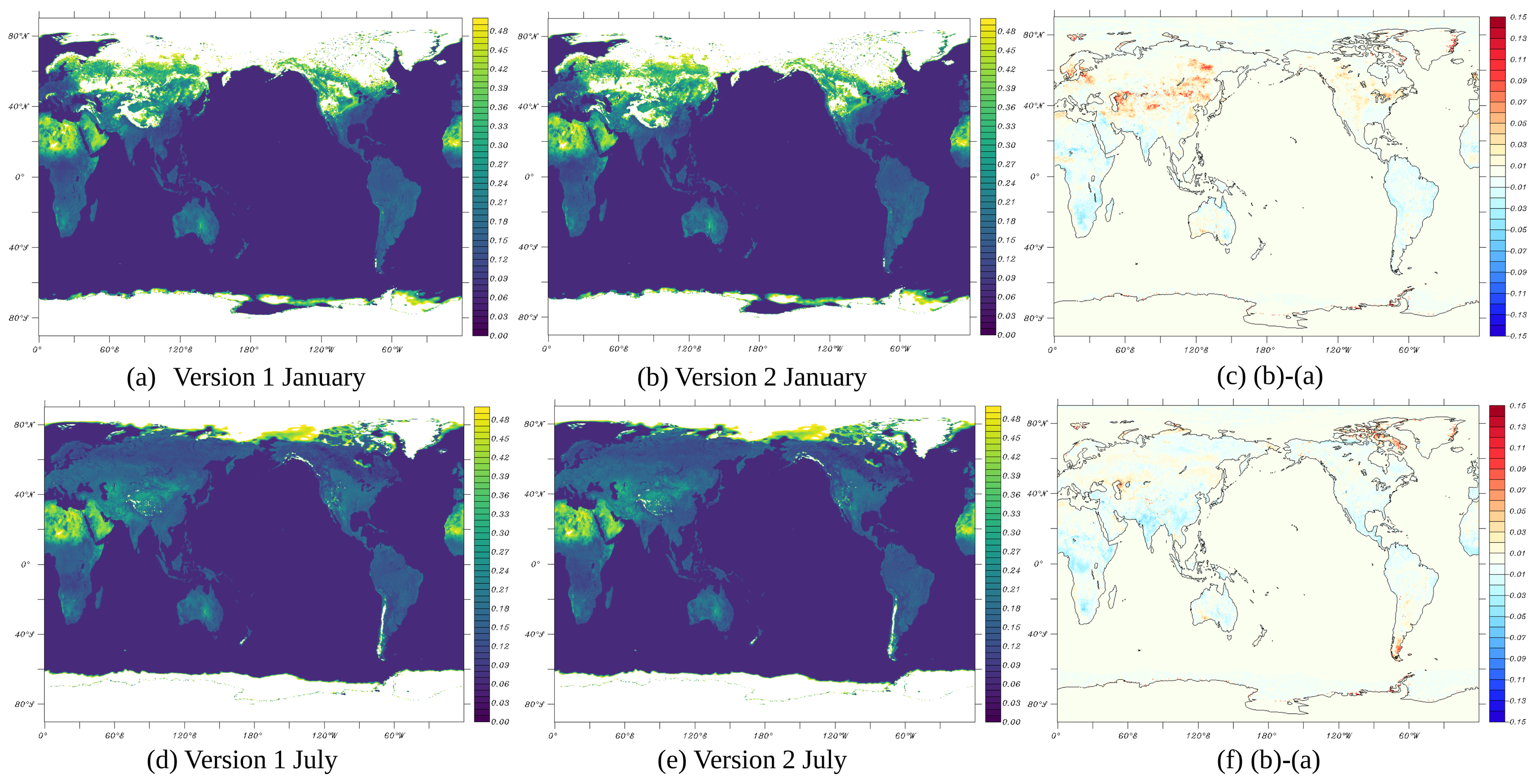


Figure 1. Composite (VIS+NIR) diffuse radiation surface albedo computed in the KIM model

- Version 1 : **2000 - 2015**
- Version 2 : **2021 - 2023**
- Albedo in January :
  - **(+)** Central Asia-Mongolia : Zud (extreme snowfall and cold wave) events are becoming more frequent and intense
  - **(-)** Southern Africa : increased wildfires
- Albedo in July :
  - **(-)** Indian Peninsula and Southern China : Changes in soil moisture and vegetation
  - **(-)** Middle Africa : Central African Forestry Initiative (CAFI)
- The changes in surface albedo over the past decade have been mainly attributed to the increase in extreme weather events due to climate and land use changes.

Seasonal Forecast Effect

- Seasonal forecast sensitivity experiments for JJA and DJF conducted to investigate the impact of surface albedo
- 1 – 5 May 2022 (5 ens) IC for JJA, 1-5 Nov 2021 (5 ens) for DJF
- CTL : version 1 MODIS surface albedo
- EXP : version2 MODIS surface albedo

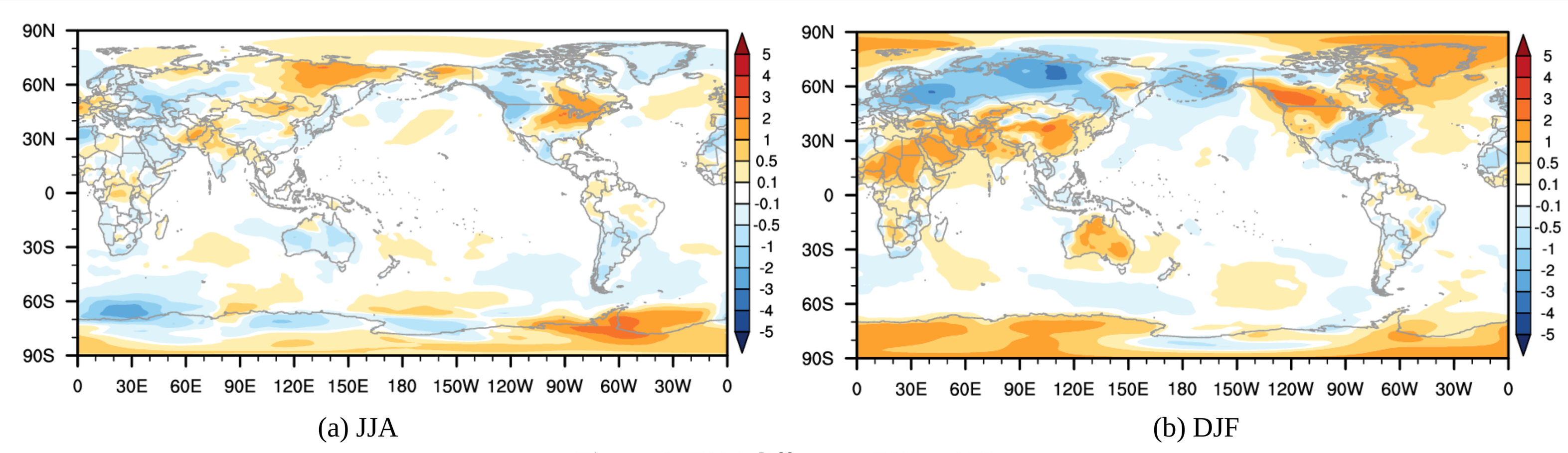


Figure 2. T2M difference EXP - CTL

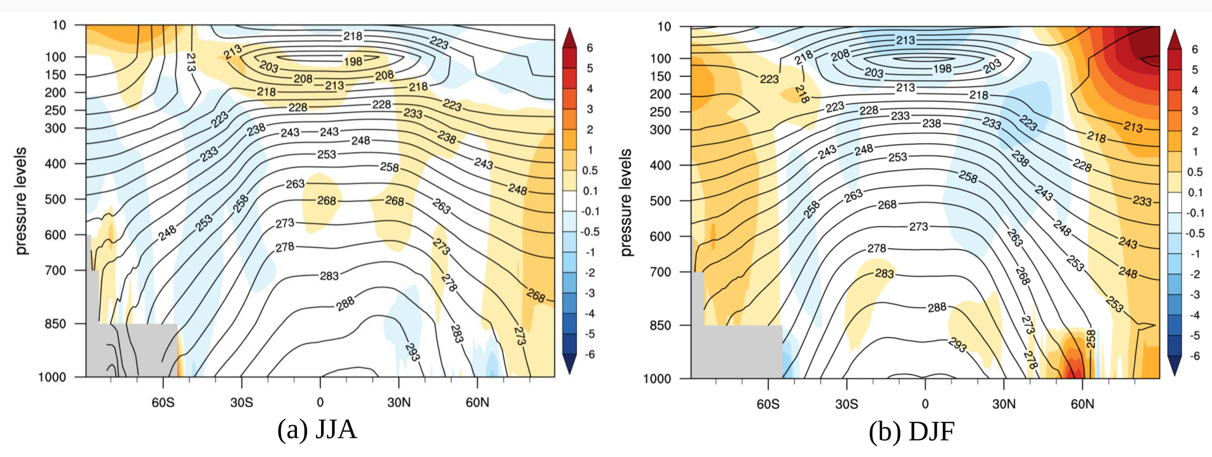


Figure 3. Zonal Mean Temperature difference EXP - CTL

- The impact of the seasonal forecast is more pronounced in DJF than in JJA
- The positive or negative sign of the albedo difference is not directly related to T2M temperature
- The largest difference appears as a temperature increase of over 5K in the Artic region above 100 hPa during the DJF experiment, consistent across all five ensemble members

5 Conclusions

- The surface albedo, derived from MODIS satellite data created in 2015, has been updated to incorporate the latest data from 2021-2023.
- This approach to albedo takes into account the effects of various surface type and complex terrain.
- The new version, though based on a shorter period, was generated using more data and a refined processing method.
- Over the past decade, there has been a decrease in albedo, except in the Central Asia-Mongolia region during boreal winter. This trends reflects the combined effects of climate change and human-driven land use changes.
- The seasonal experiment response to surface albedo changes was more pronounced in DJF than JJA, with a temperature change of 5K in the Artic region above 100 hPa.

ECMWF Annual Seminar 2025 | Bonn, Germany | 7–11 April 2025