WCRP
World Climate
Research Programme

WCRP EPESC – LEADER Science Meeting

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Aerosol Transport and Polar Climate Anomalies: Heatwave Amplification, Snow-Albedo Feedback, and Cryosphere Vulnerability

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WORLD METEOROLOGICAL ORGANIZATION

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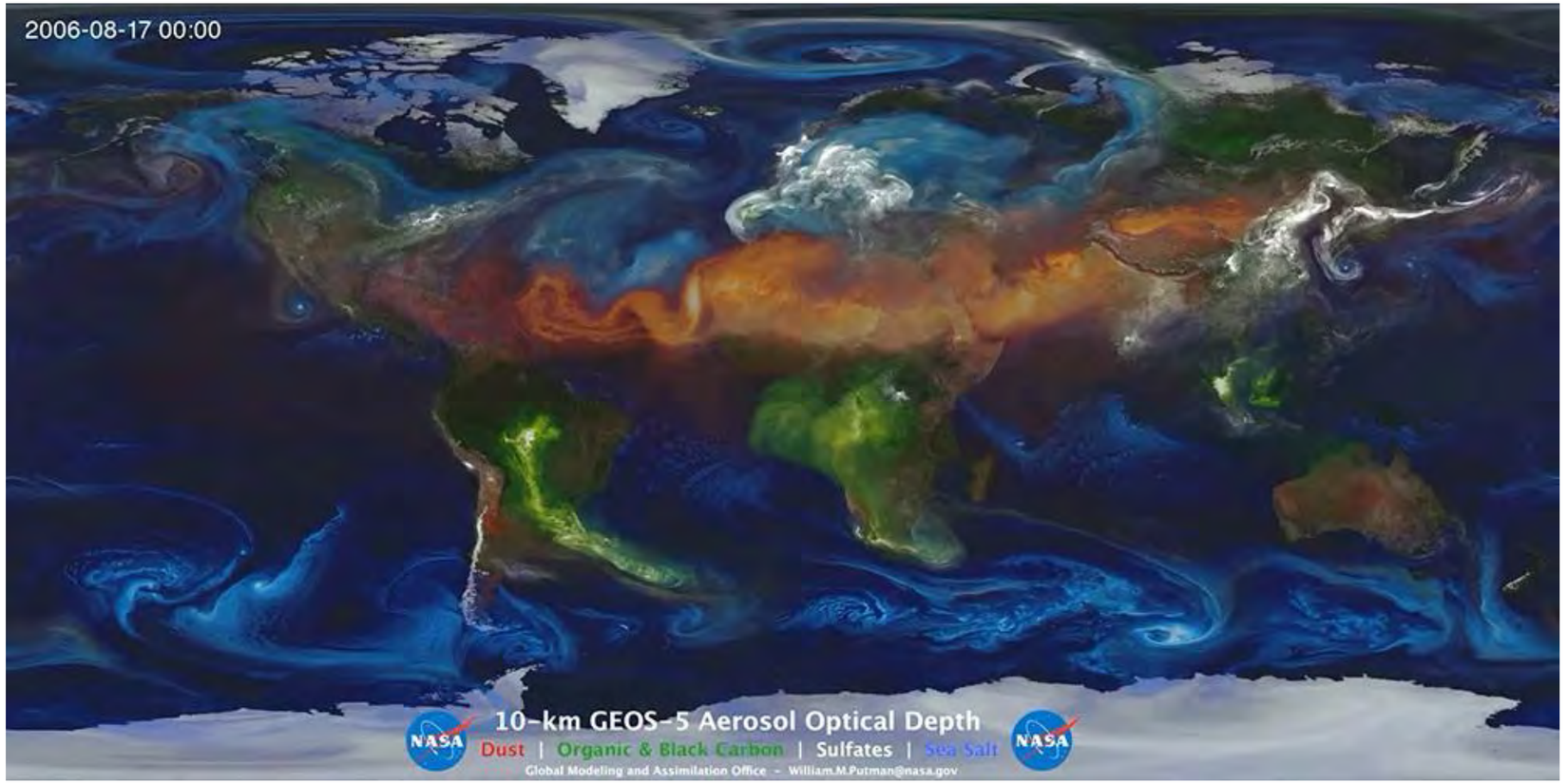
Intergovernmental Oceanographic Commission

International Science Council

Background & Motivation



White represents small particles from industries and burning crops, while red represents larger particles like dust.

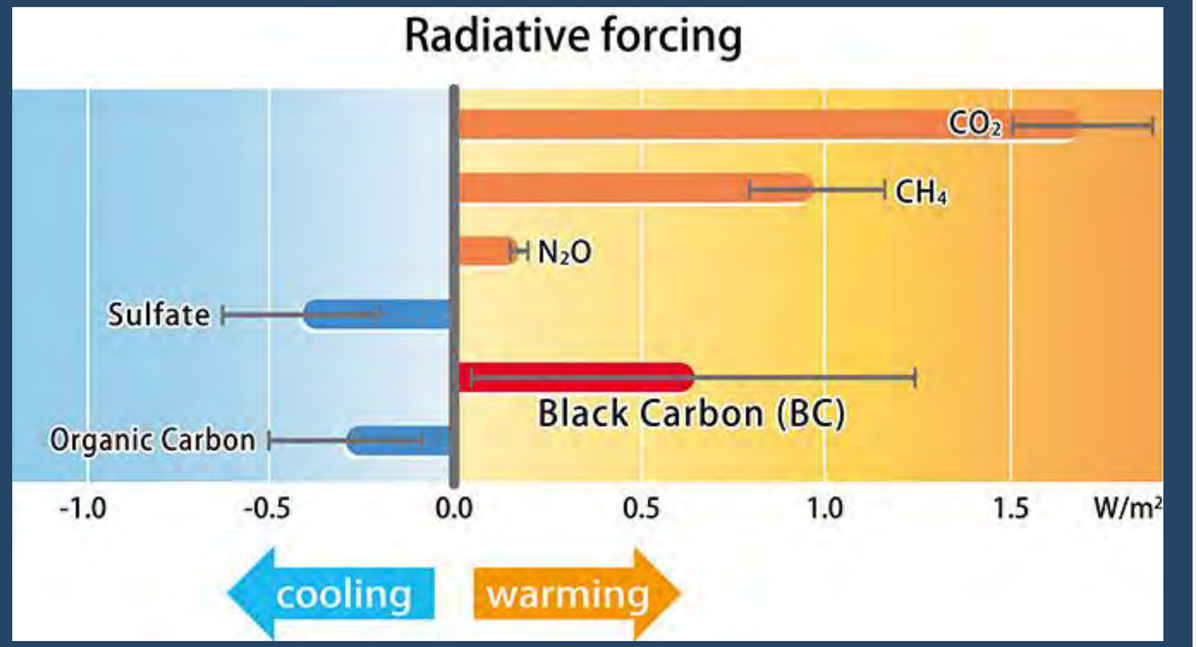


Fig: Radiative Forcing by various agents
Source: https://www.jamstec.go.jp/e/20160220/

INTRODUCTION

- **Aerosols: Tiny particles, Big Impact ; 0.002μm to 100μm**
- **Black sooty component of carbonaceous aerosols. 0.3μm**
- **By incomplete combustion.**
- **Directly absorbs solar radiation, direct radiative forcing.**
- **Reducing the surface albedo, indirect radiative forcing.**
- **Serve as Cloud Condensation Nuclei (CCN)**

INTRODUCTION

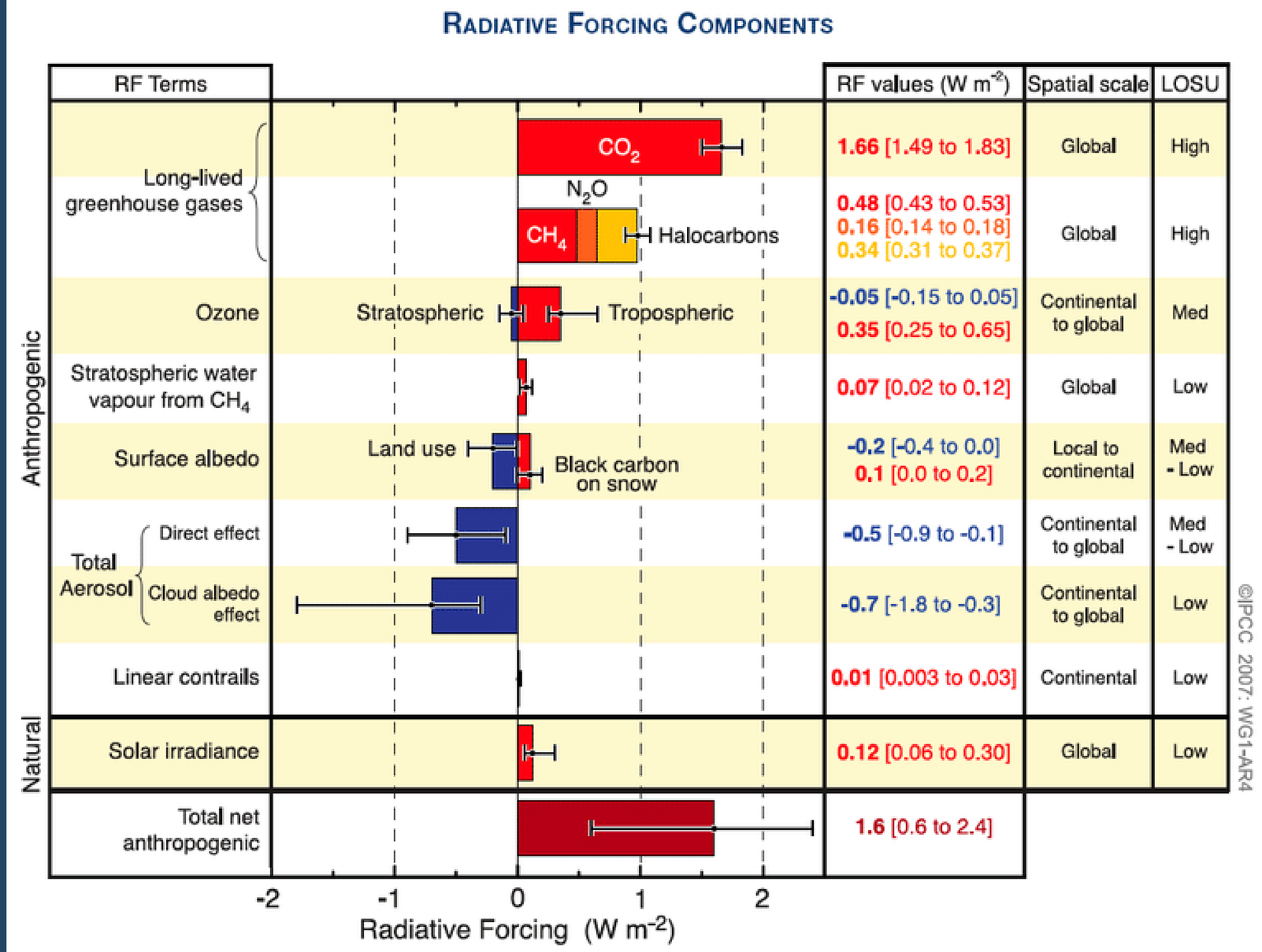
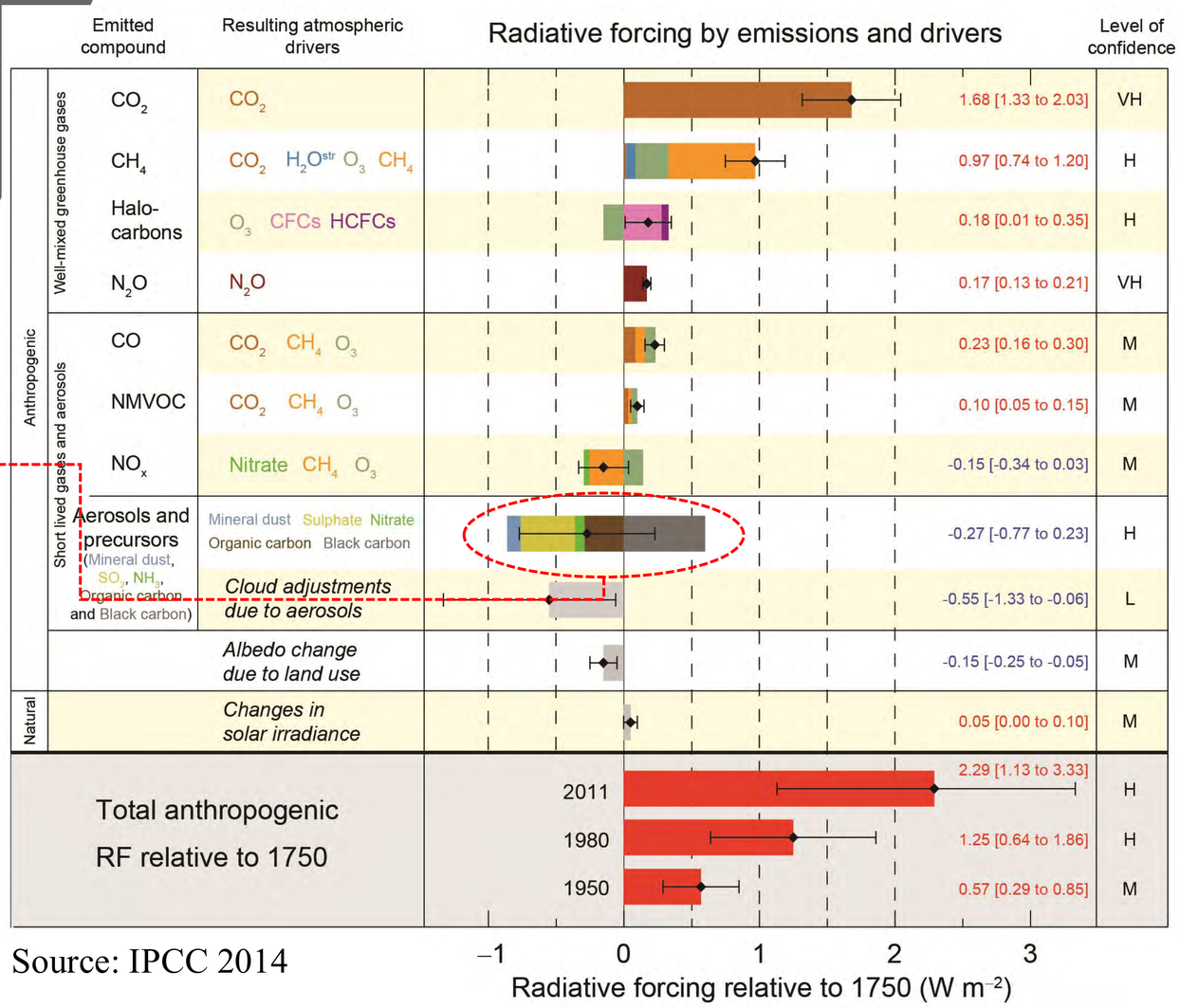


Fig: Radiative Forcing components
Source: IPCC

Different components causing radiative forcing

Aerosol & Radiative Forcing

High uncertainty in aerosol related RF



Source: IPCC 2014

Size Distribution of Aerosols

- Nucleation : <10 nm
- Aitken : 10 to 100 nm
- Accumulation : 100 to 1000 nm
- Coarse : >1000 nm

Particle Formation

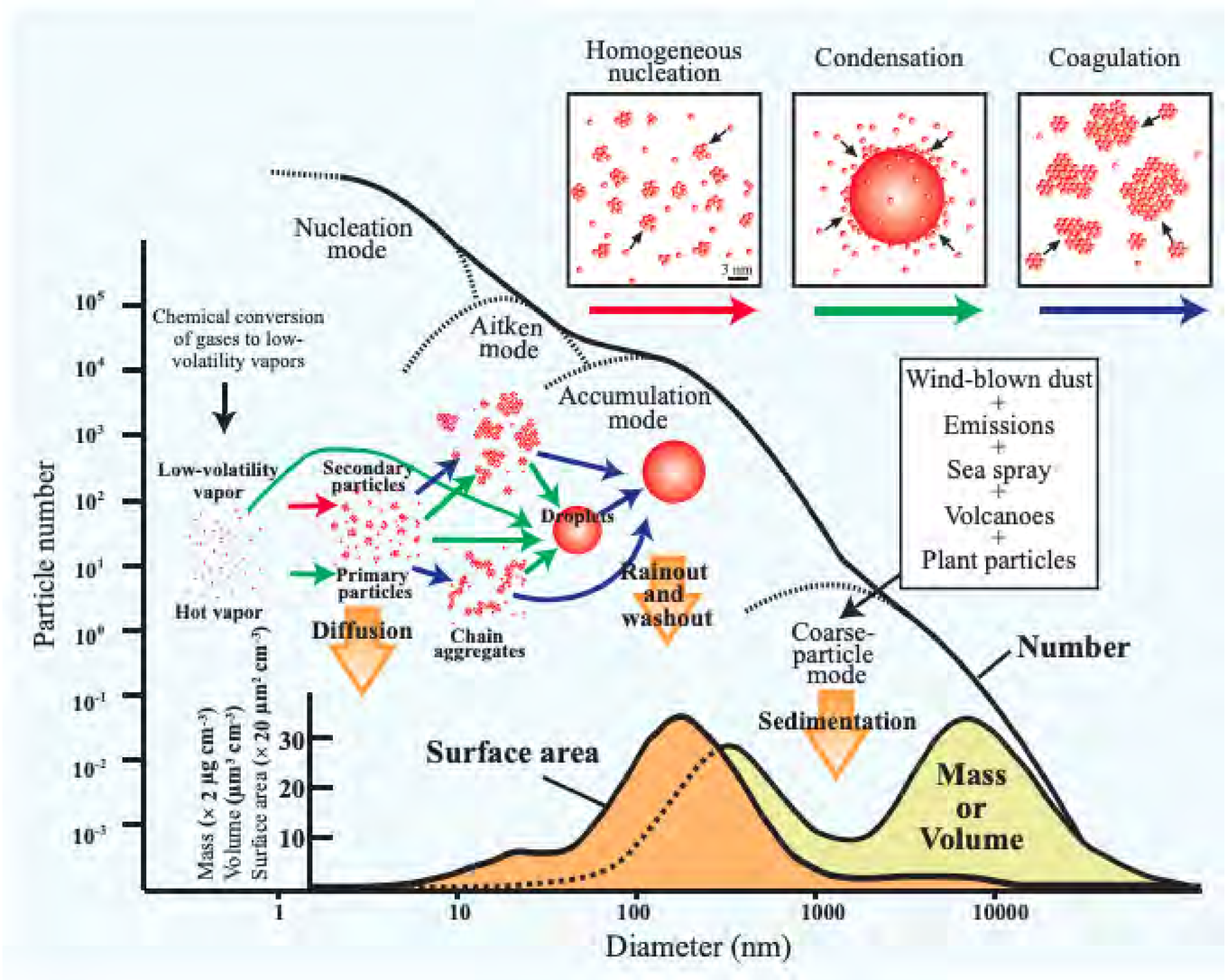
- Mechanical Disintegration
- Gas-to-Particle Conversion

Particle Growth

- Homogenous Nucleation
- Condensation
- Coagulation

Particle Removal

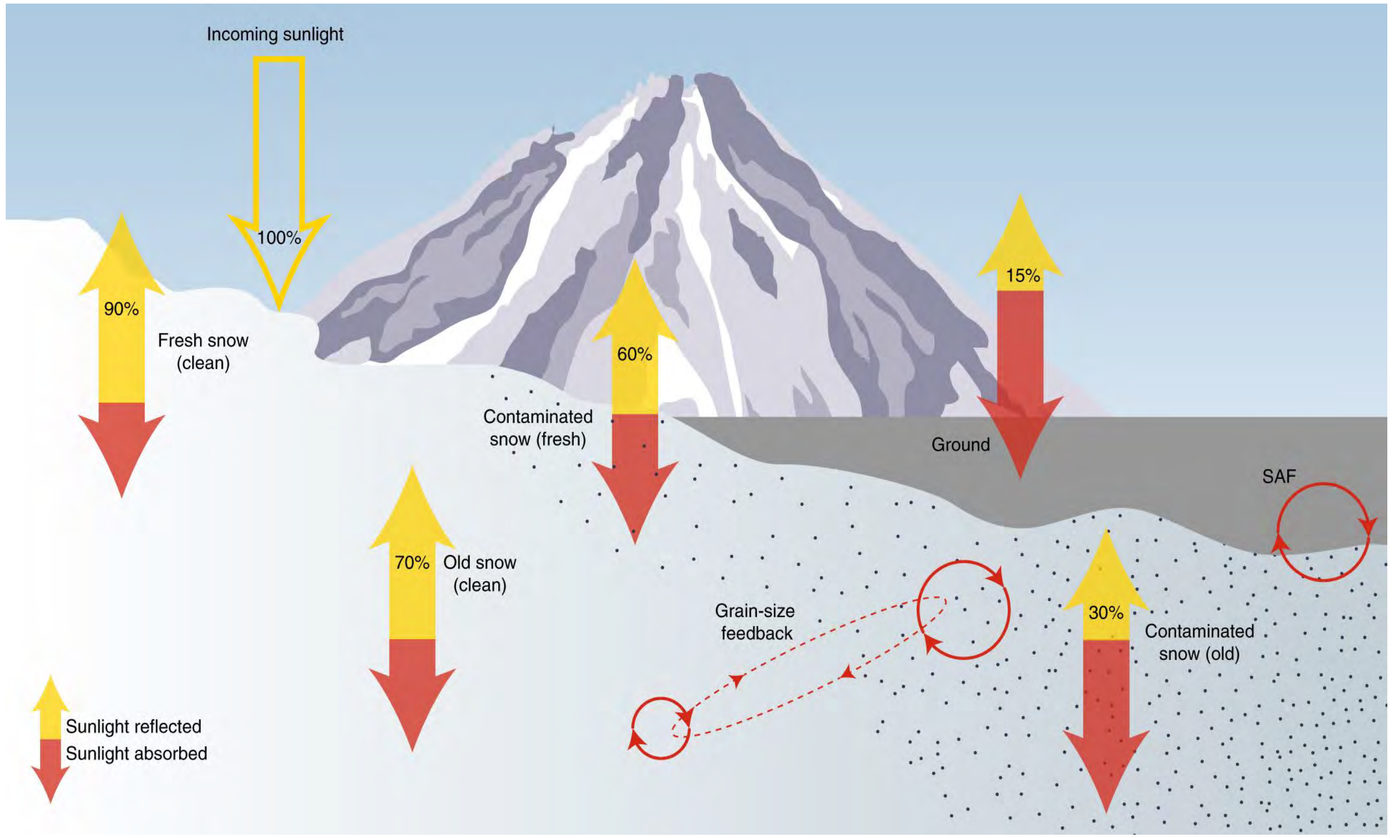
- Diffusion
- Precipitation
- Sedimentation



Source: Peter R. Buseck & Kouji Adachi 2008

Aerosol Snow Interaction

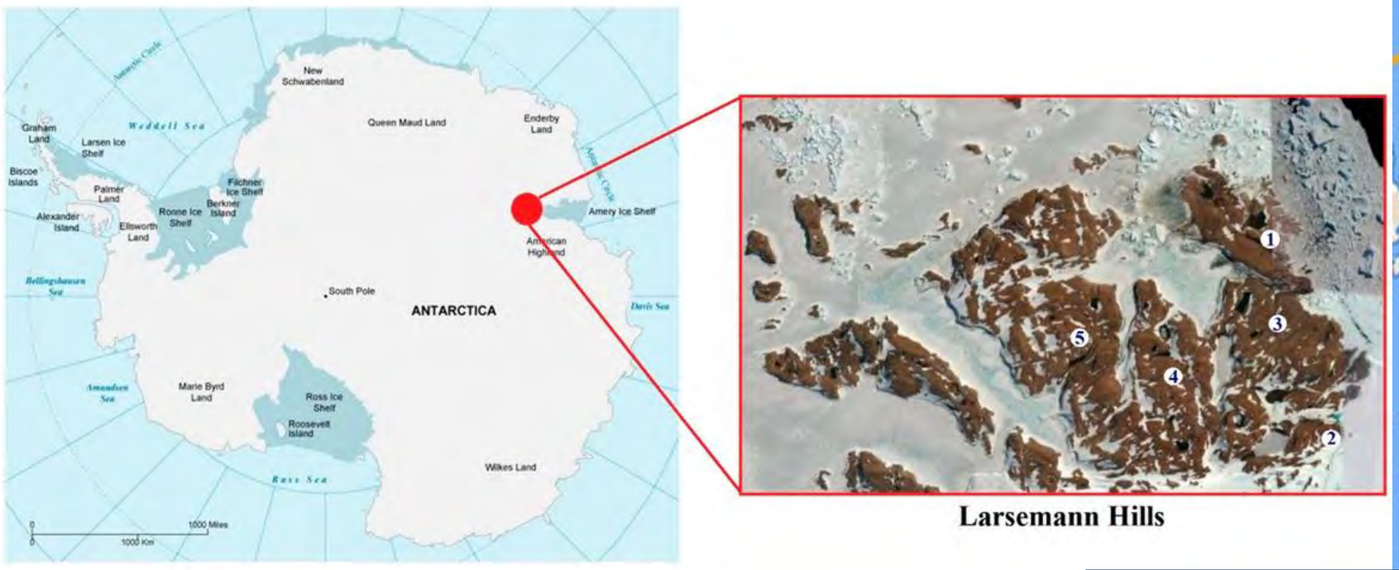
- In the diagram the arrows represent how the absorption (red) and reflection (yellow) of incoming sunlight change with LAP content and snow age, which represents snow grain size.
- The direct impact of LAPs (surface darkening) enhances snow grain growth, effectively aging it faster, which further lowers snow albedo (grain-size feedback).
- Combined, these two processes enhance melt, and as the subsequent retreat of snow cover accelerates, darker underlying surfaces (ice or ground) are exposed earlier, lowering landscape-scale albedo (SAF).



Source: Skiles et al., 2018

STUDY AREA

- **Indian Research Station – Bharati 69°24.41’S & 76°11.71’E.**
- **Larsemann Hills, Prydz Bay, Antarctica.**
- **Scientifically and logistically significant coastal hills.**



Larsemann Hills

Fig: Bharati Station *Source: Mukunda M Gogoi et al., 2013*

AGATA
ANTARCTIC GEOSPACE AND ATMOSPHERE RESEARCH

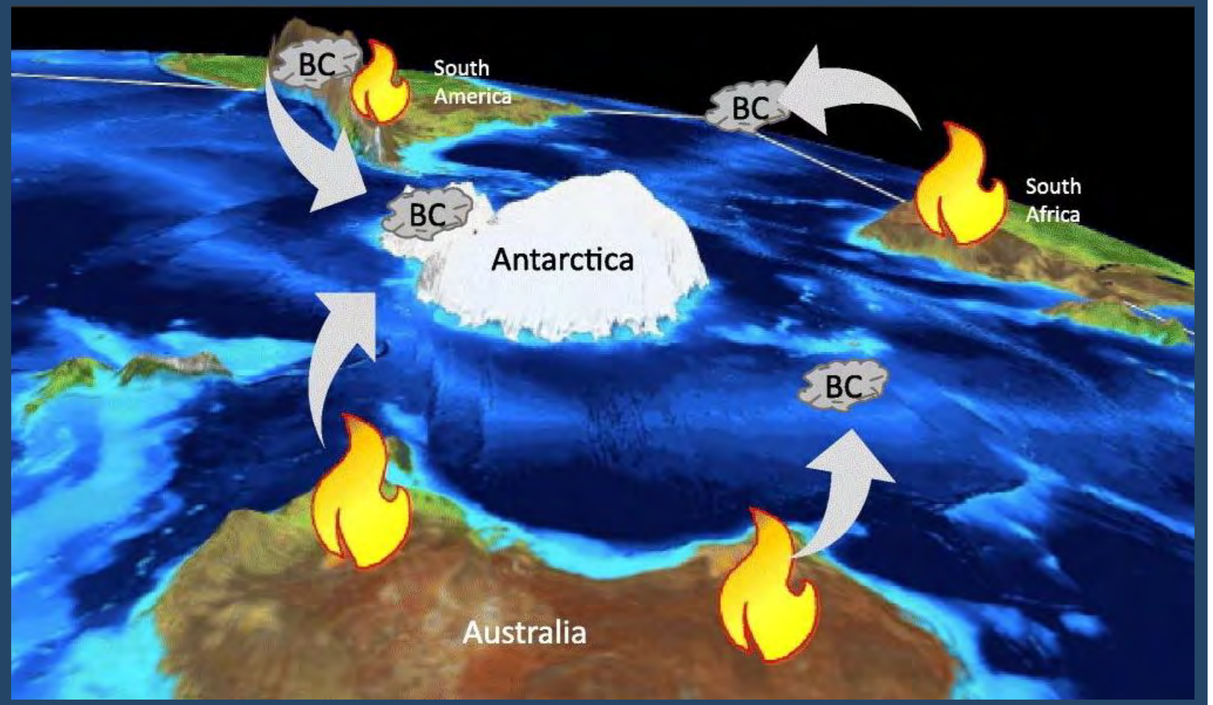


Fig: Illustration of BC around Antarctica
Source: https://ars.els-cdn.com/content/

OBJECTIVES

- **To study the seasonal variations and factors affecting the concentration levels of Black Carbon.**

- **To understand the potential sources of higher levels of Black Carbon.**

METHODOLOGY

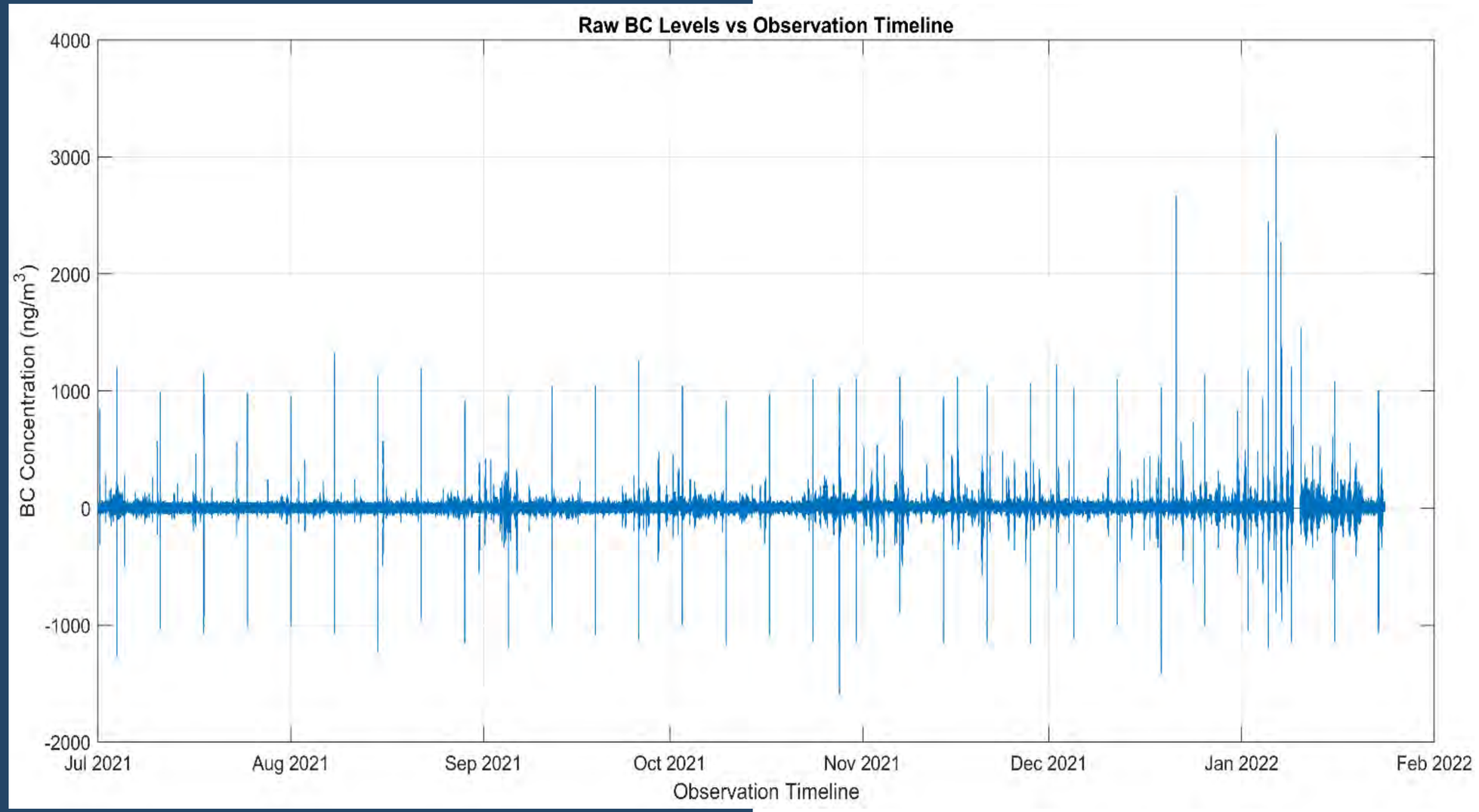


Fig: Raw Black Carbon data plotted against the Observation Timescale

METHODOLOGY

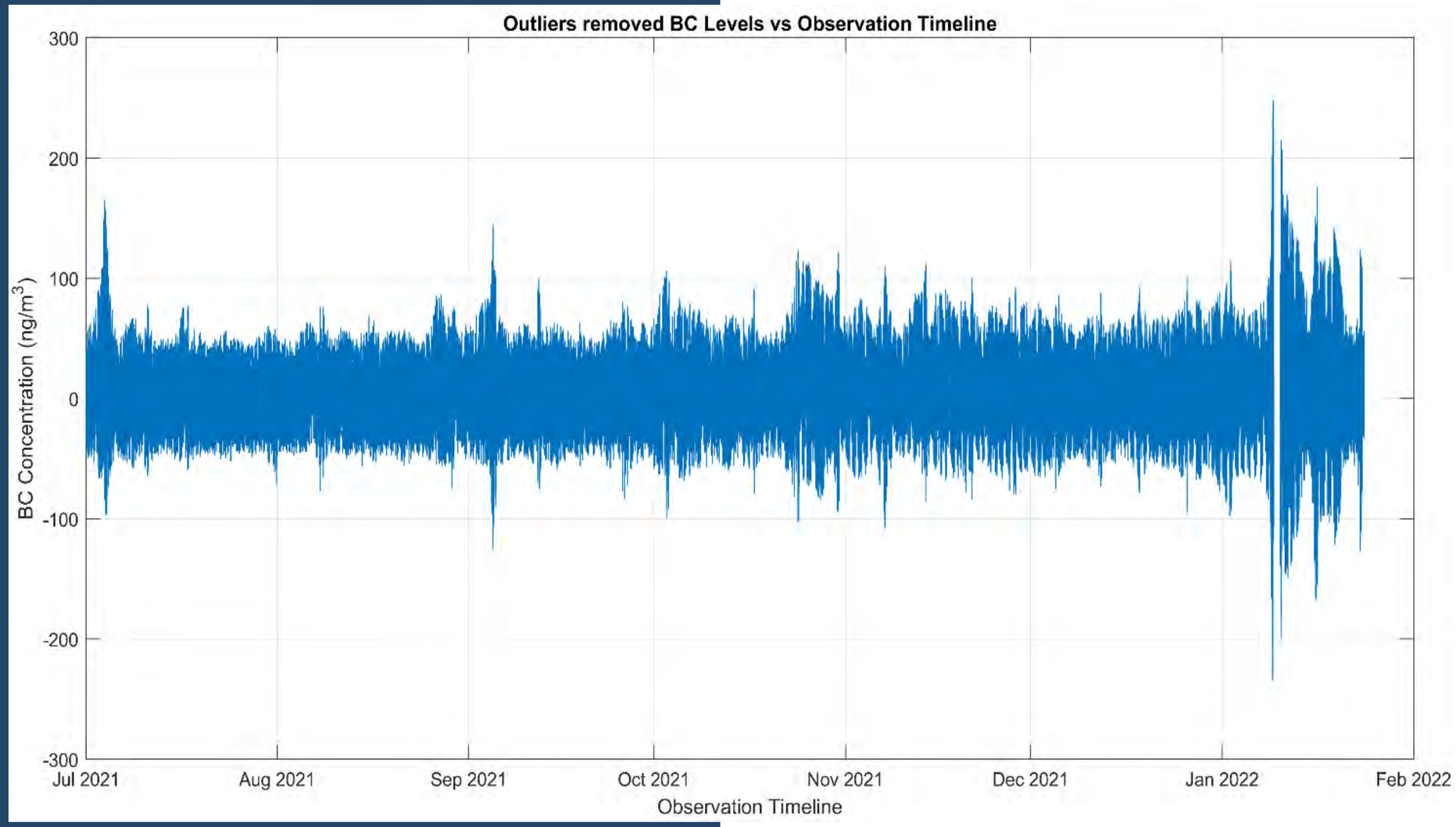


Fig: BC concentration after removal of outliers

ANALYSIS

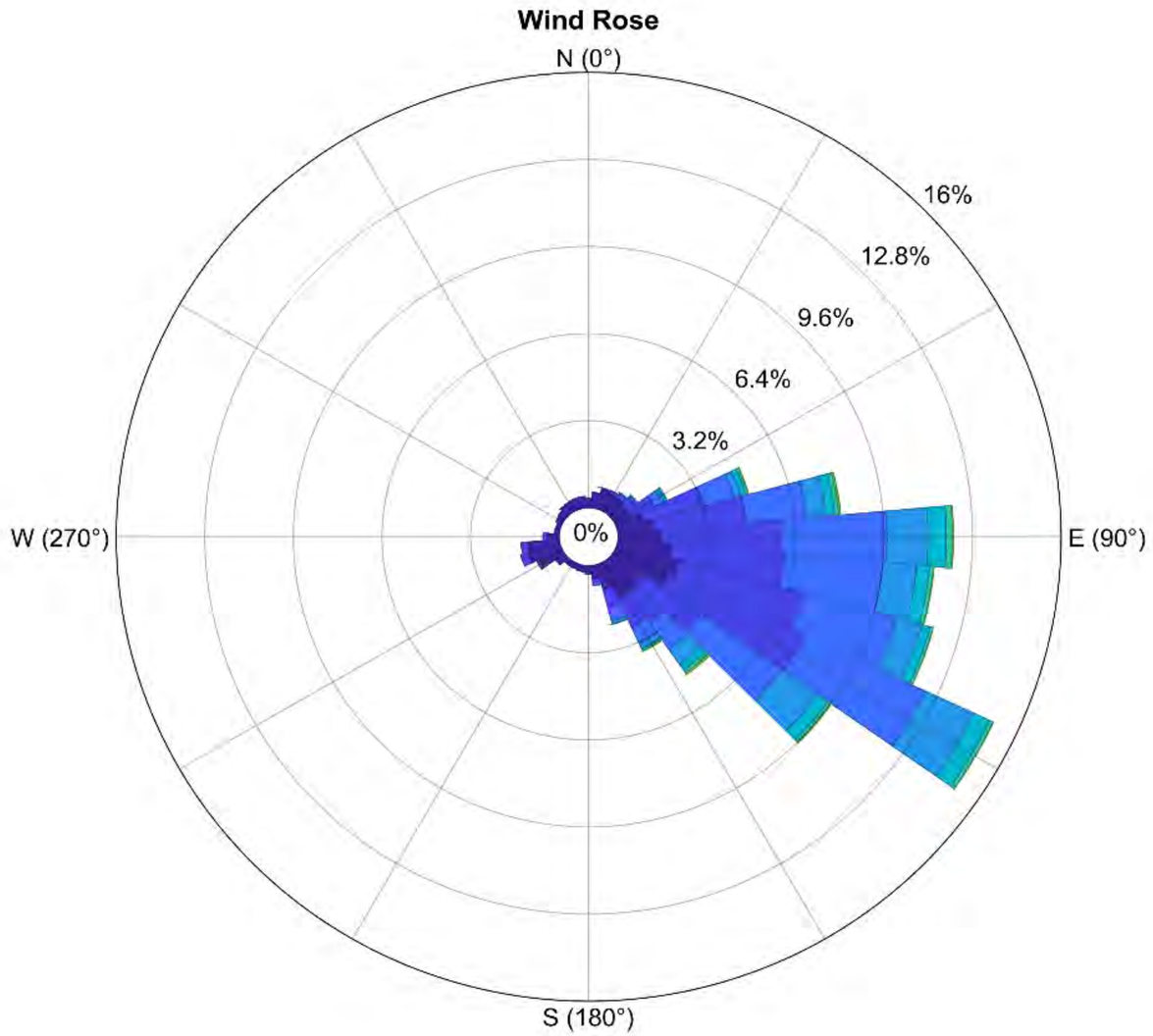


Fig: Wind Rose plot of Winds at Bharati Observatory

ANALYSIS

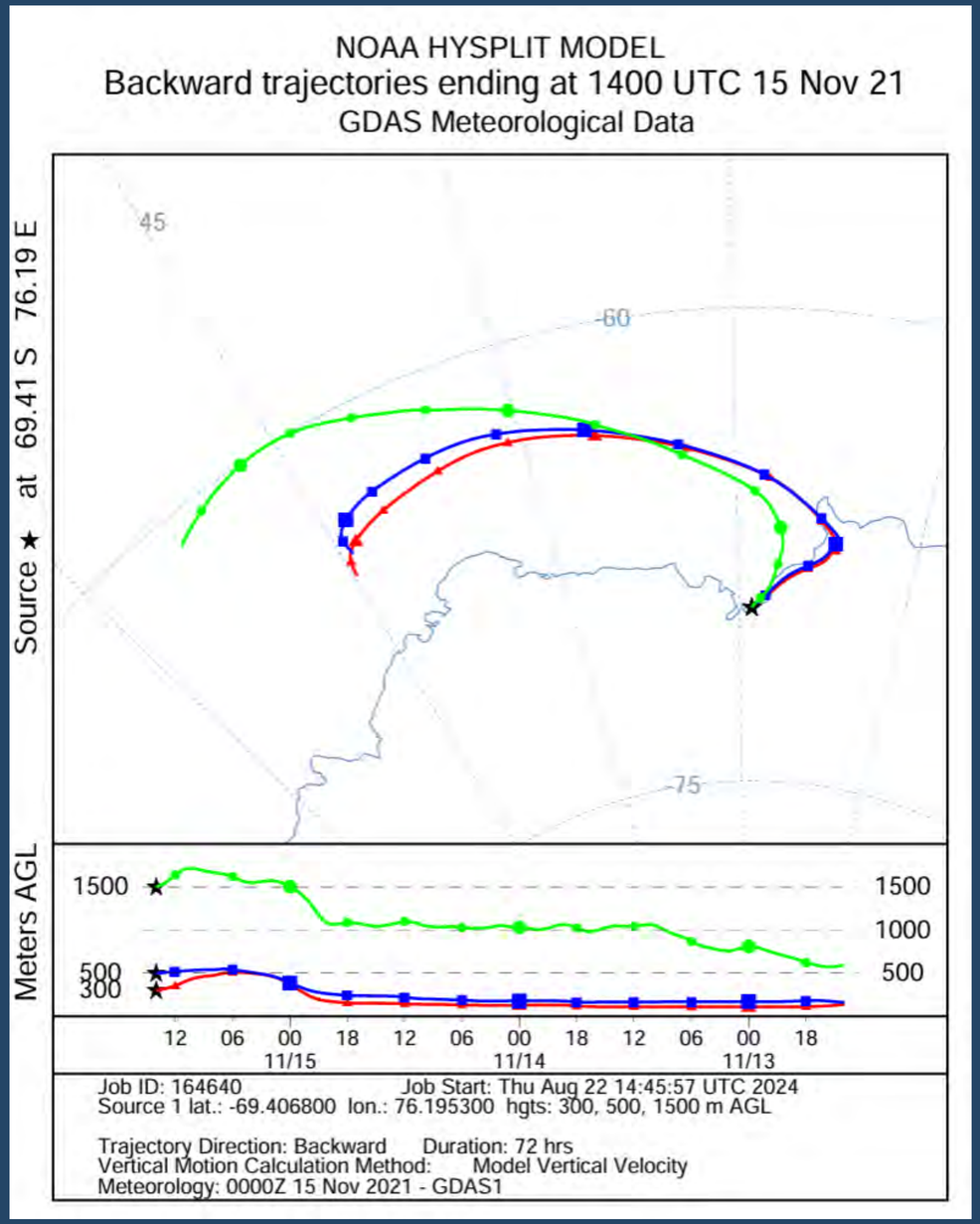
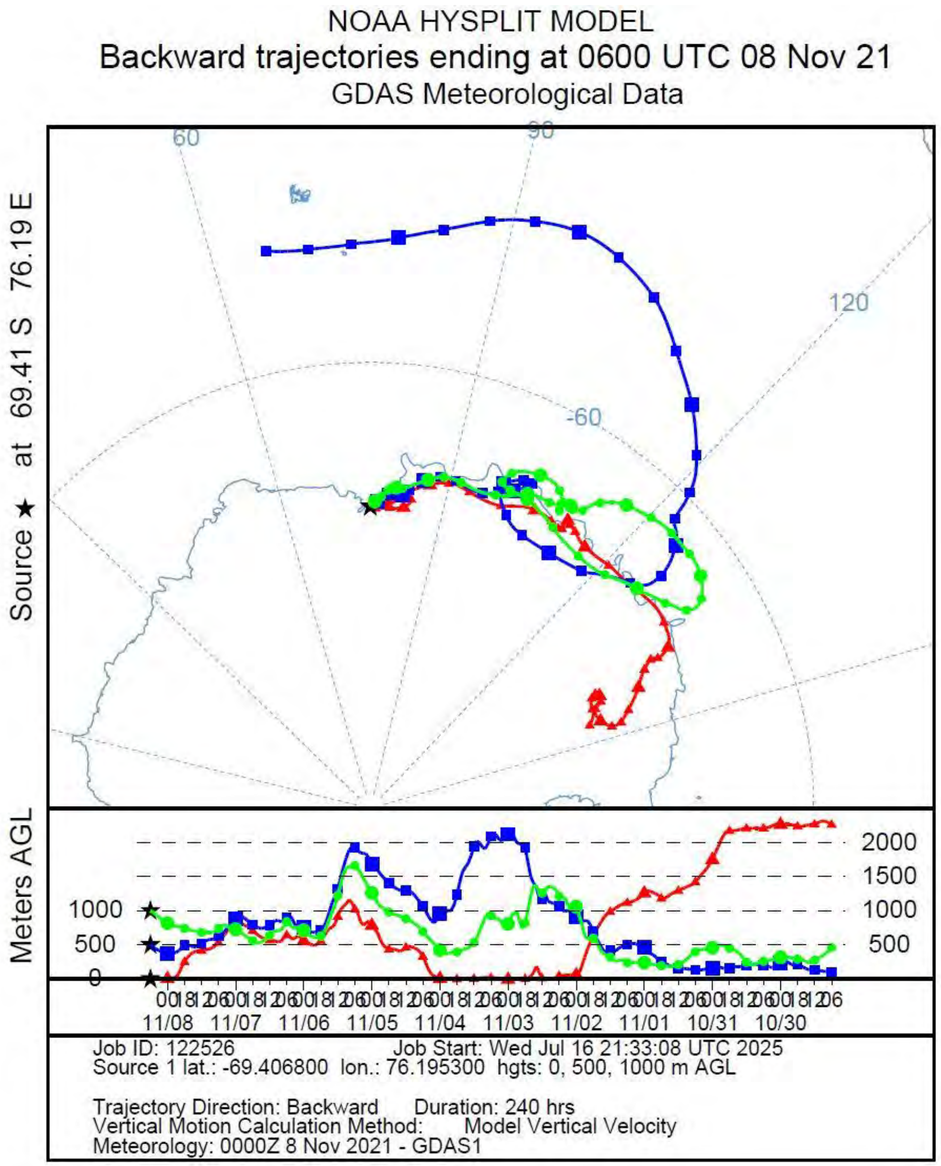


Fig: Back Trajectory by HYSPLIT at Bharati Observatory



ANALYSIS

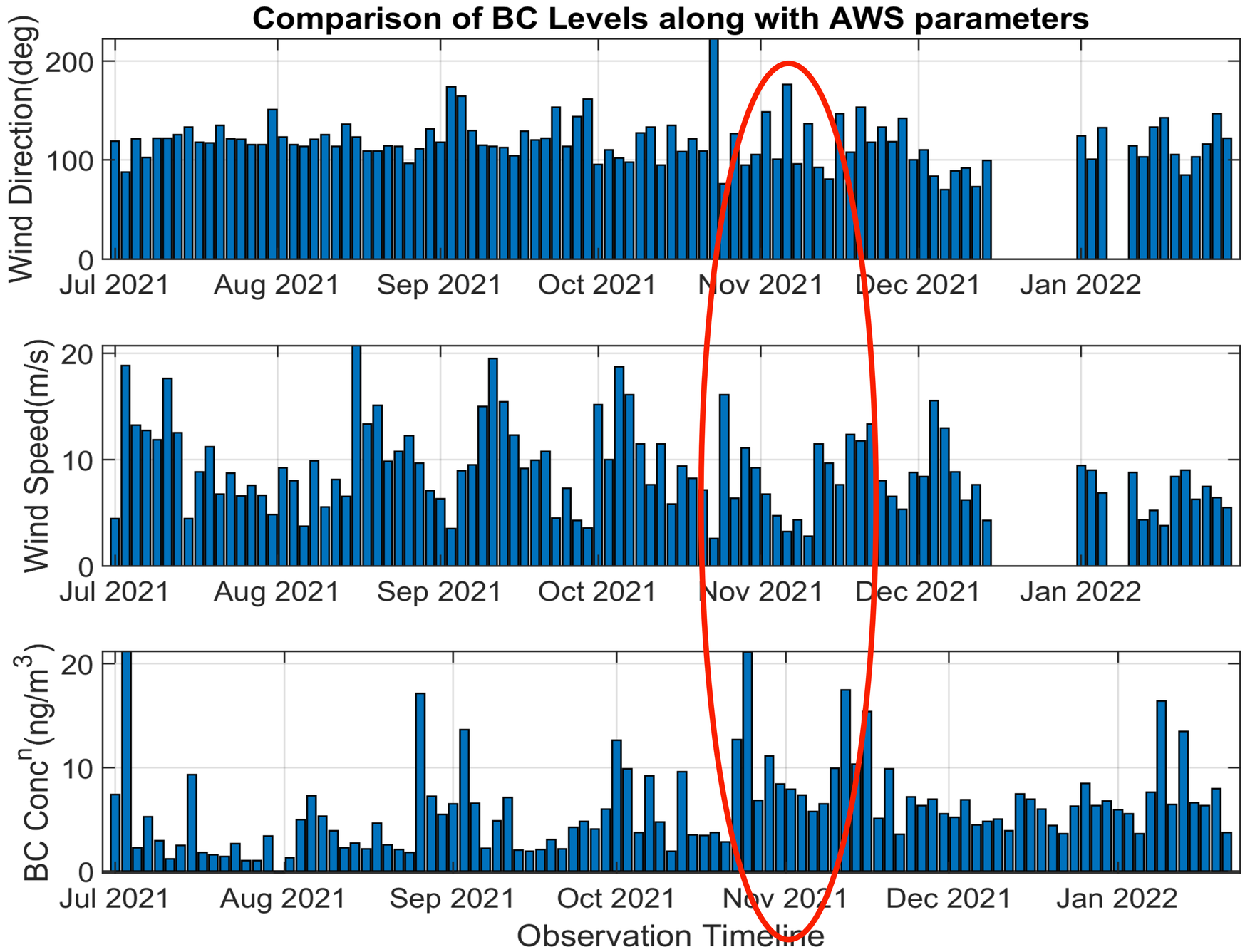


Fig: Raised BC level with Met parameters

ANALYSIS

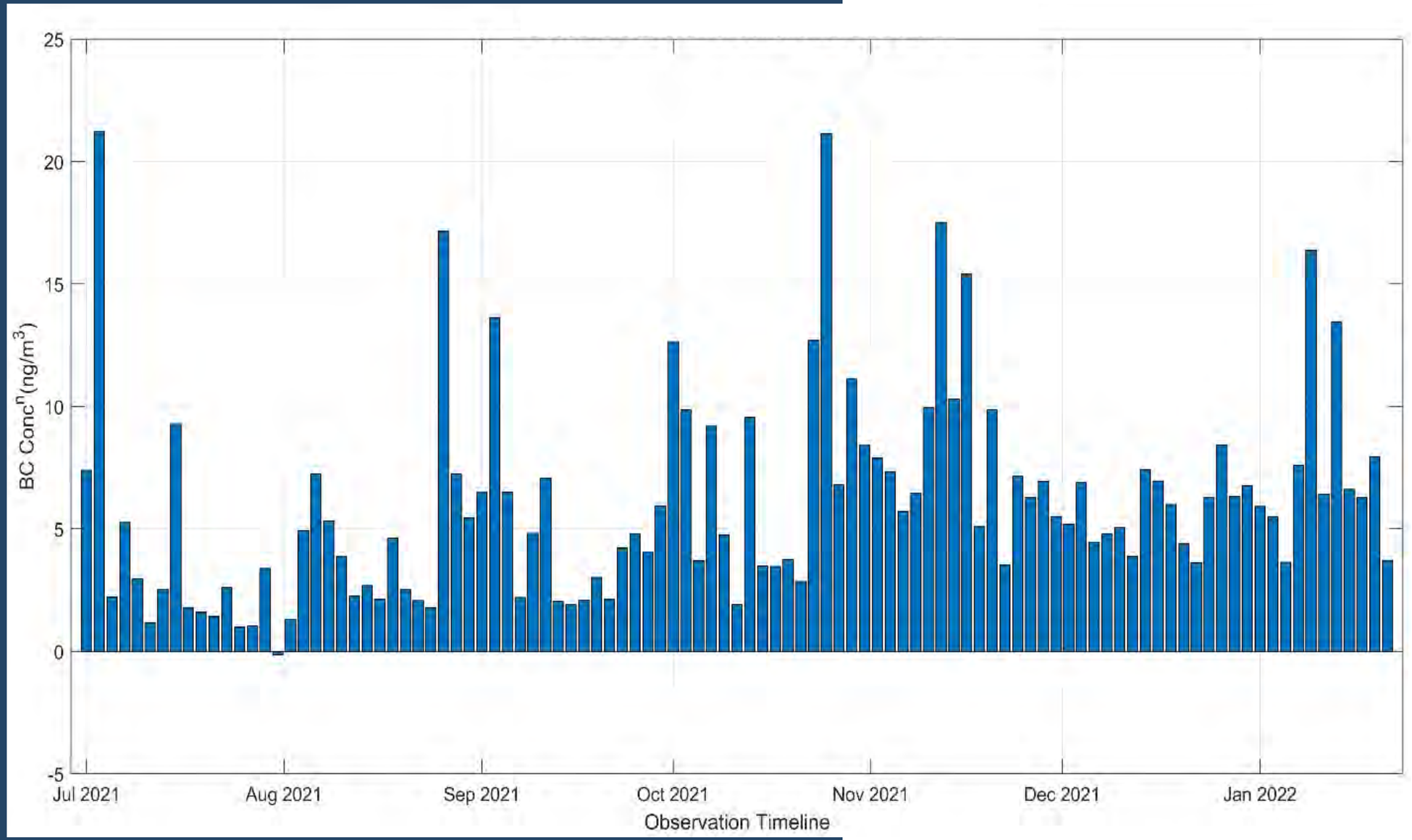


Fig: Seasonal shift of BC concentration

Increasing trend towards austral summer.

ANALYSIS

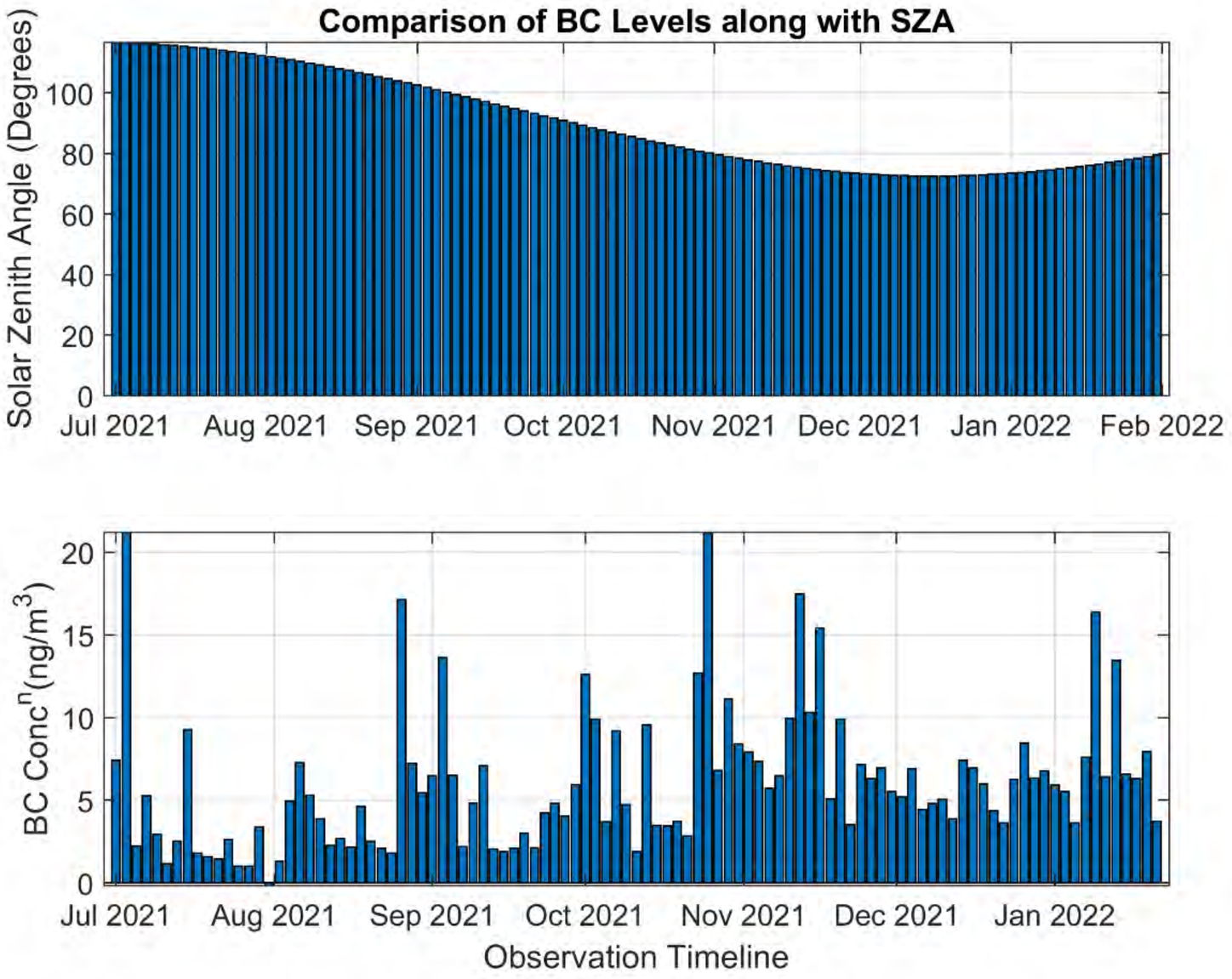
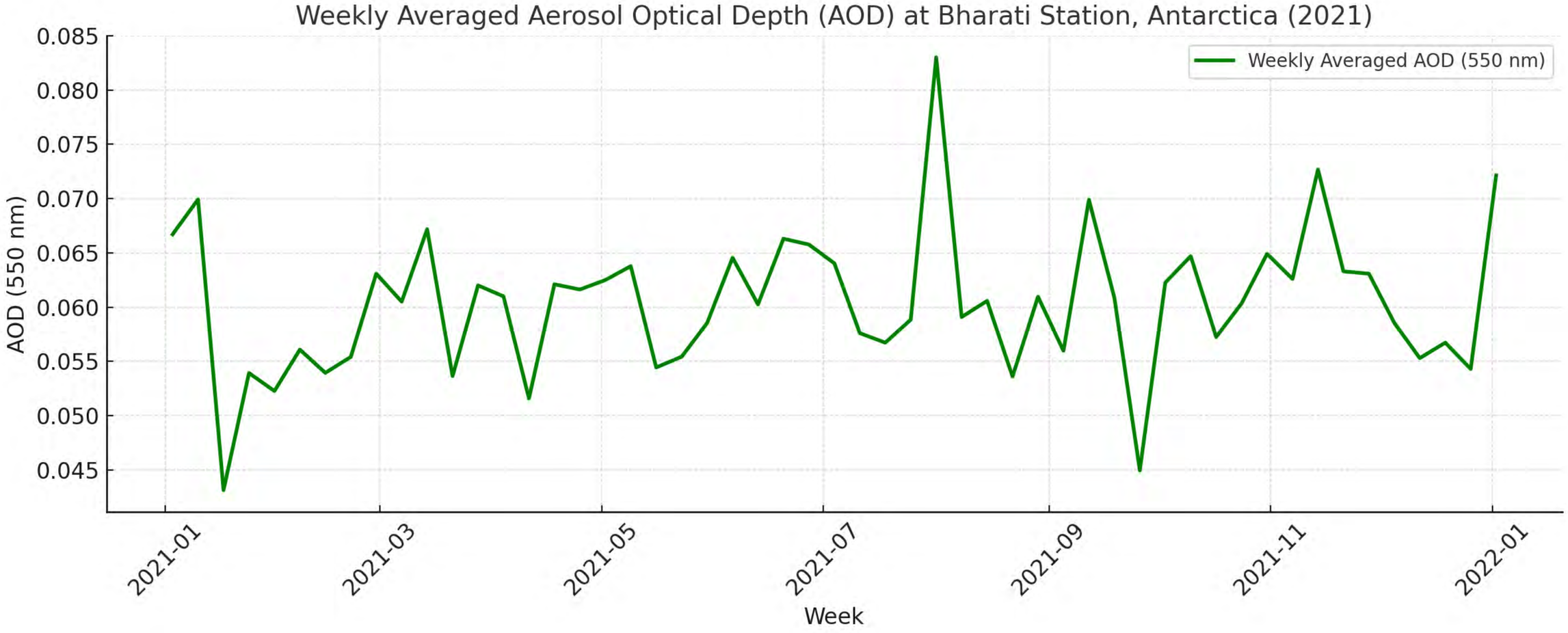
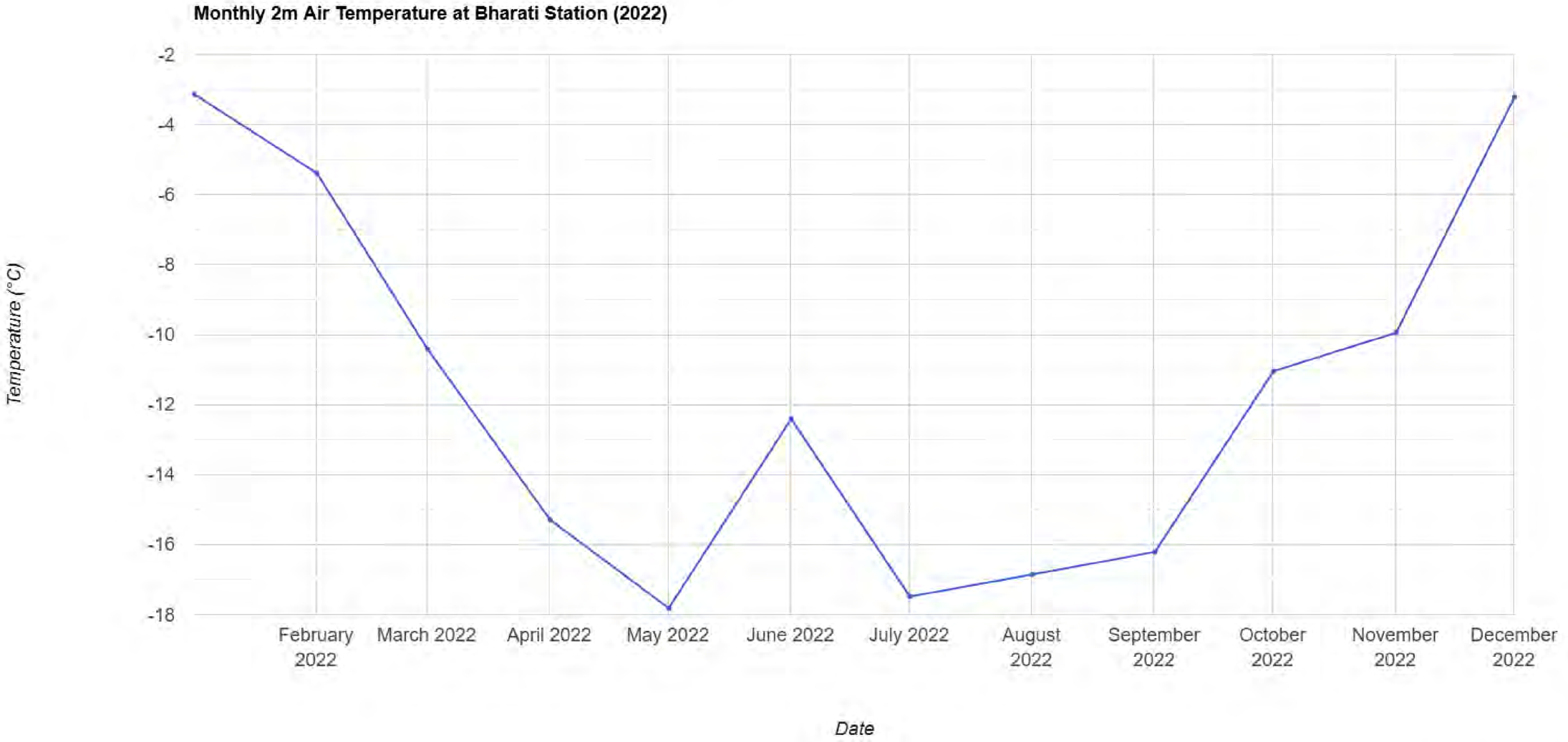


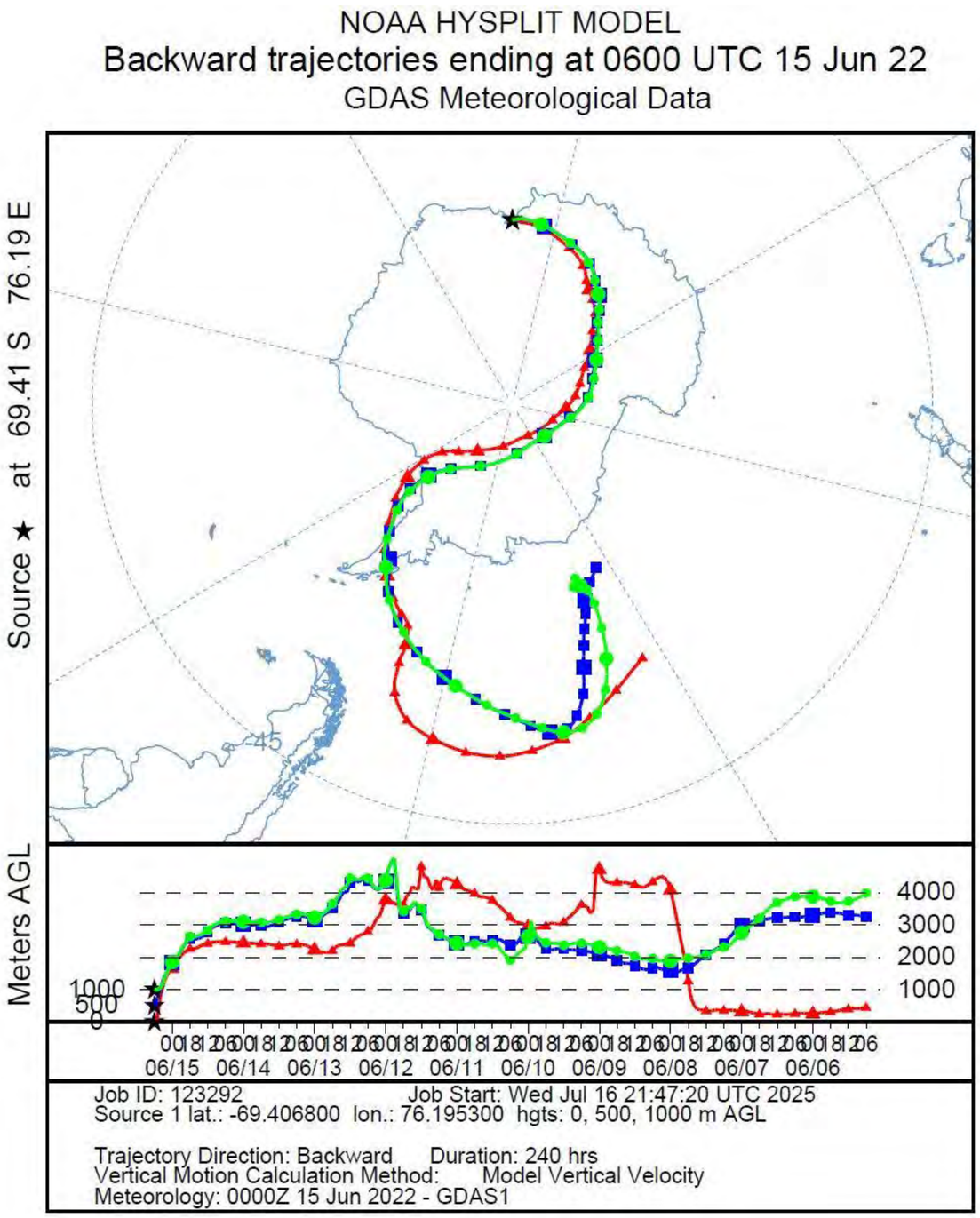
Fig: Simultaneous plotting of BC and SZA

Investigation with Solar Zenith Angle

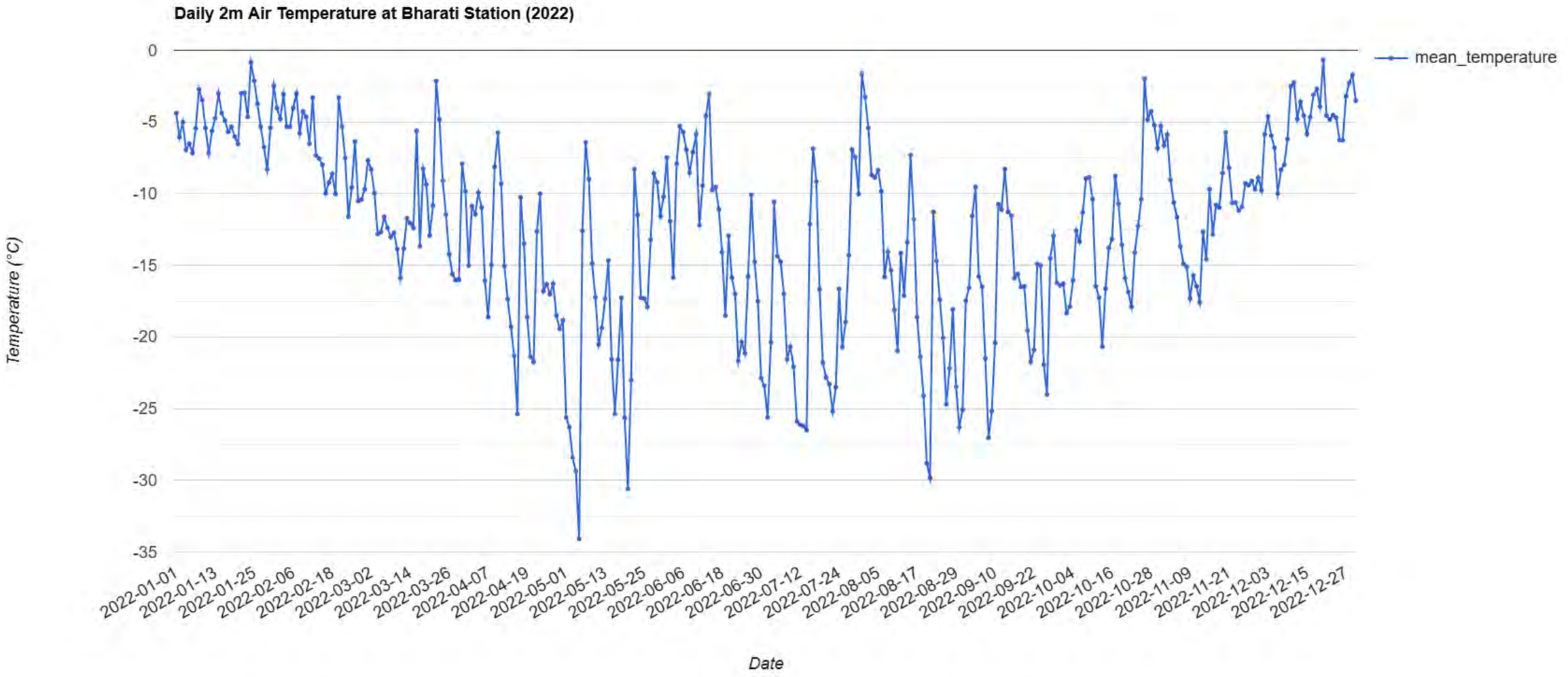
- Lower towards Austral Summer
- Less slanting
- Higher BC Concentration
- However, no direct correlation in diurnal variation.


Weekly Averaged Aerosol Optical Depth (AOD) at Bharati Station, Antarctica (2021)
Weekly Averaged AOD (550 nm)
AOD (550 nm)
0.085
0.080
0.075
0.070
0.065
0.060
0.055
0.050
0.045
2021-01
2021-03
2021-05
2021-07
2021-09
2021-11
2022-01
Week

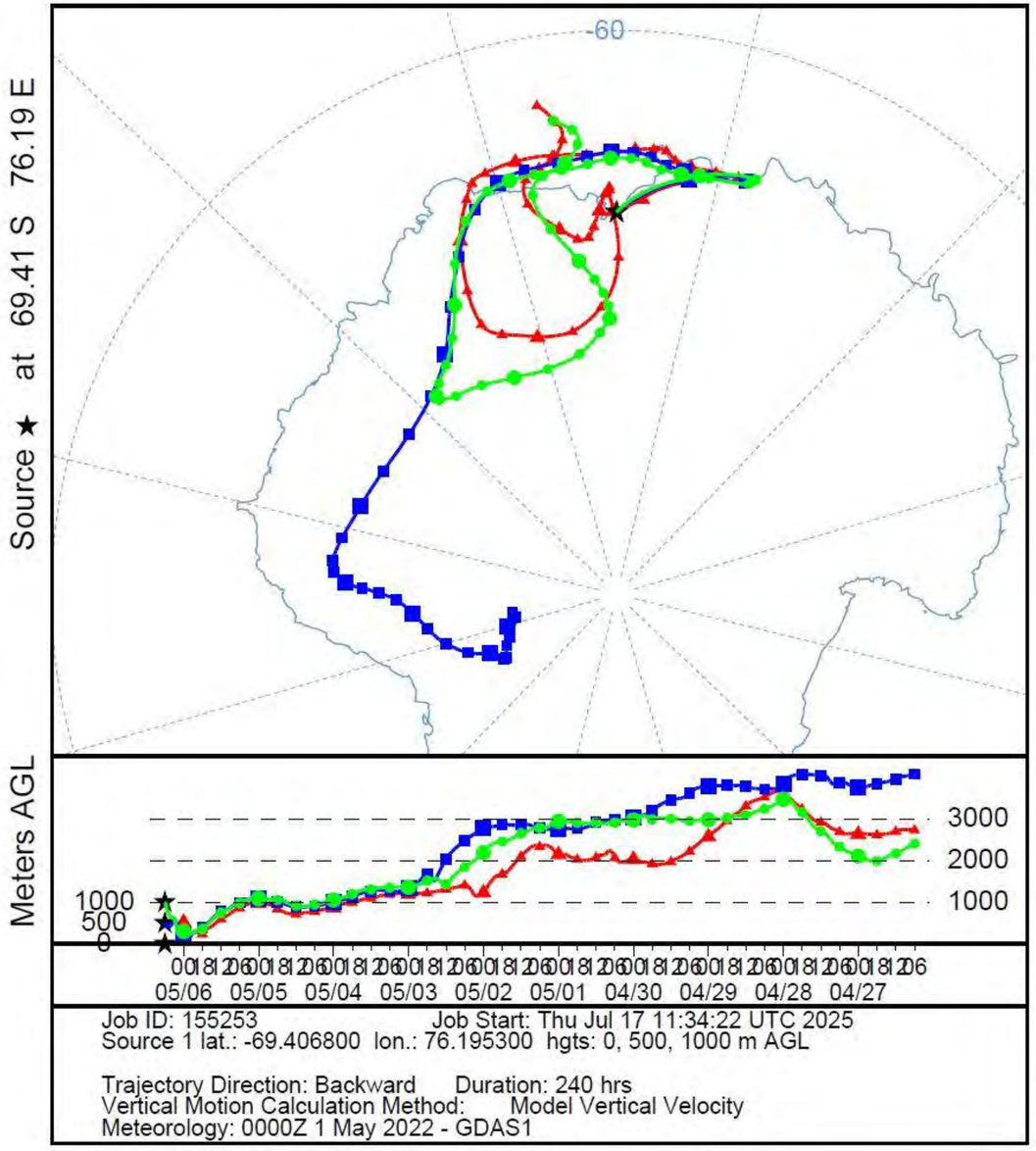

Monthly 2m Air Temperature at Bharati Station (2022)
Temperature (°C)
-2
-4
-6
-8
-10
-12
-14
-16
-18
February 2022
March 2022
April 2022
May 2022
June 2022
July 2022
August 2022
September 2022
October 2022
November 2022
December 2022
Date



Back Trajectory Shows on June 15th, 2022 air parcel was from In-land Antarctica.


Daily 2m Air Temperature at Bharati Station (2022)
mean_temperature
Temperature (°C)
0
-5
-10
-15
-20
-25
-30
-35
2022-01-01
2022-01-13
2022-01-25
2022-02-06
2022-02-18
2022-03-02
2022-03-14
2022-03-26
2022-04-07
2022-04-19
2022-05-01
2022-05-13
2022-05-25
2022-06-06
2022-06-18
2022-06-30
2022-07-12
2022-07-24
2022-08-05
2022-08-17
2022-08-29
2022-09-10
2022-09-22
2022-10-04
2022-10-16
2022-10-28
2022-11-09
2022-11-21
2022-12-03
2022-12-15
2022-12-27
Date

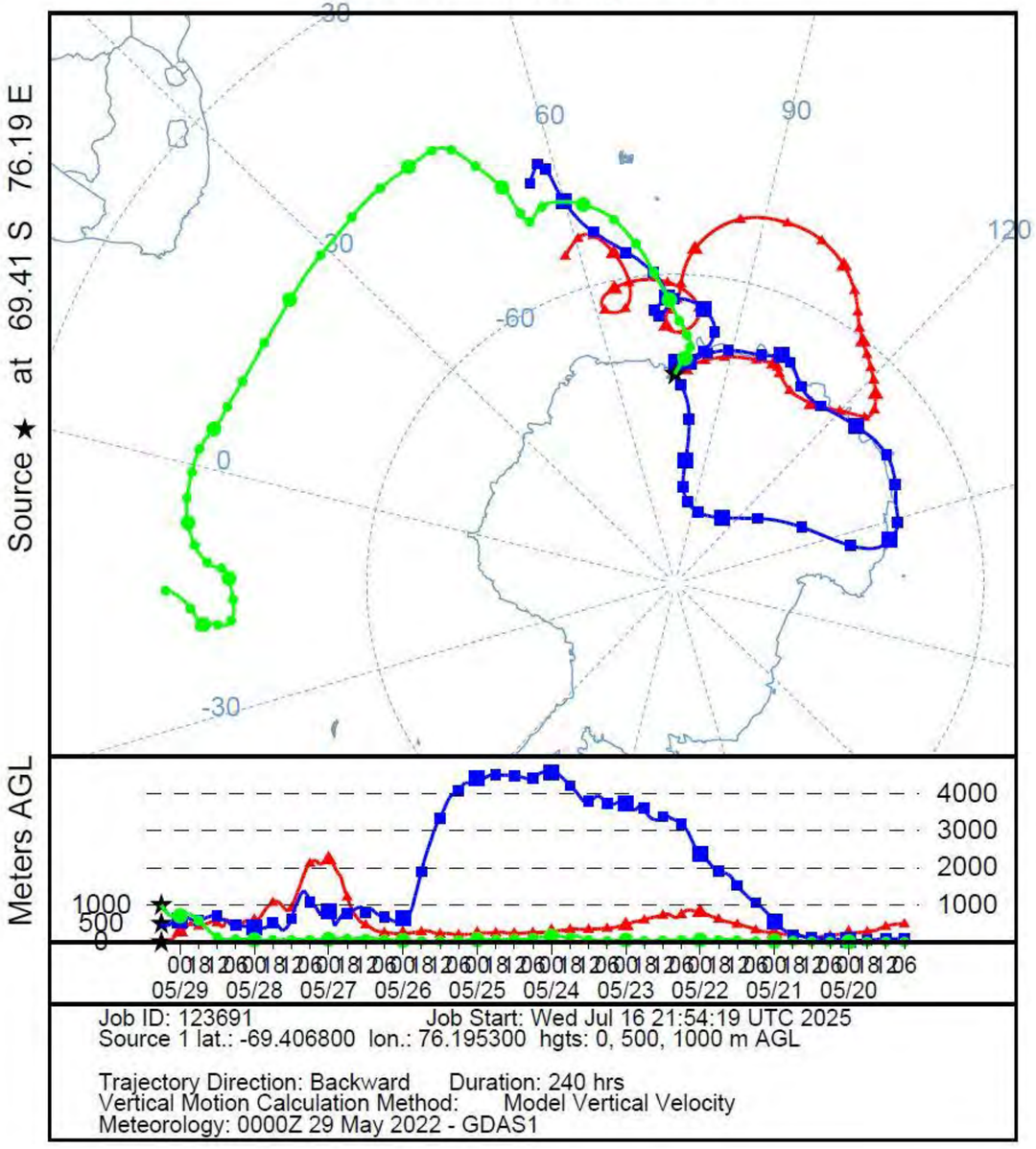
NOAA HYSPLIT MODEL
Backward trajectories ending at 0600 UTC 06 May 22
GDAS Meteorological Data



Job ID: 155253 Job Start: Thu Jul 17 11:34:22 UTC 2025
Source 1 lat.: -69.406800 lon.: 76.195300 hgts: 0, 500, 1000 m AGL

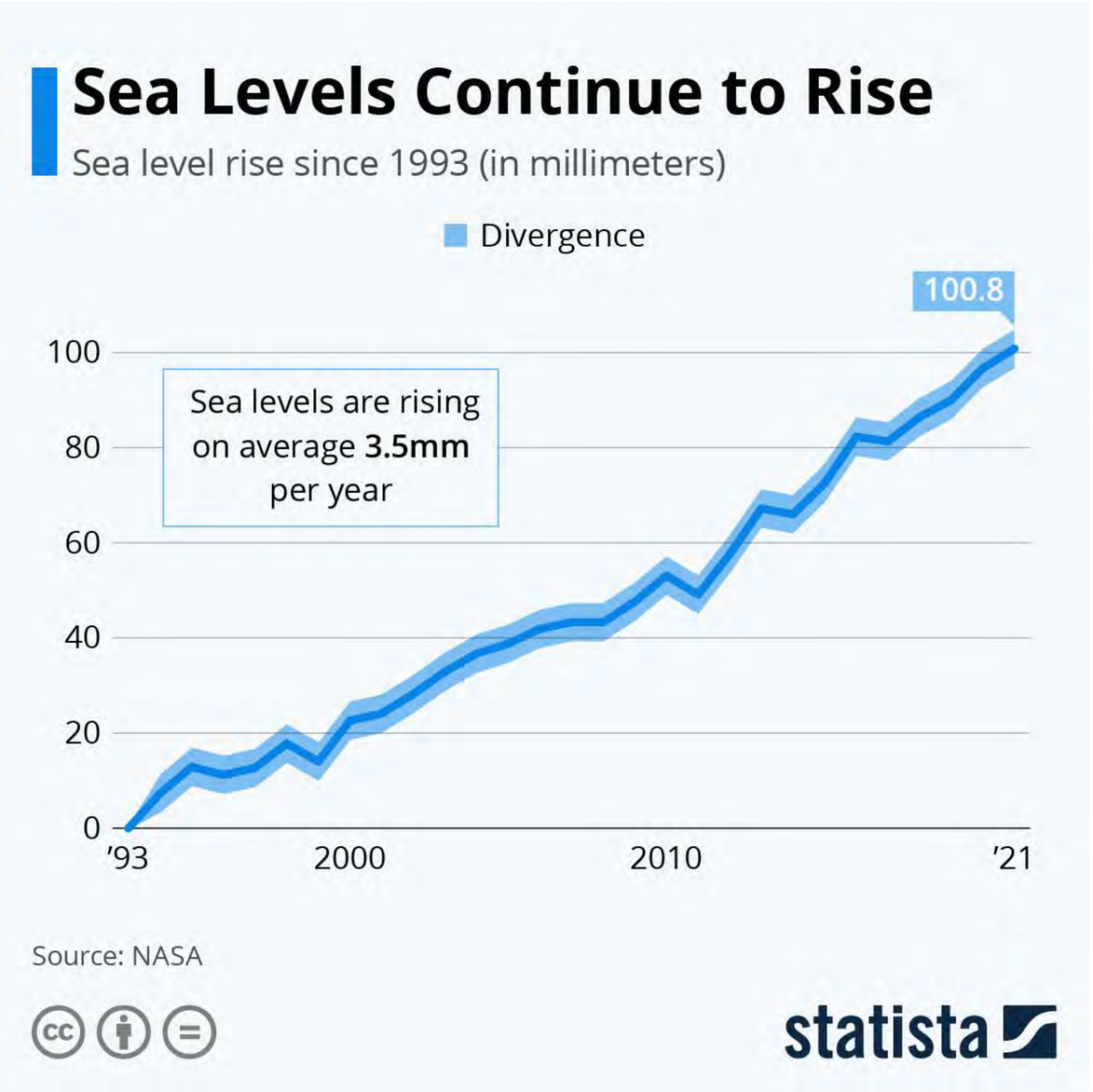
Trajectory Direction: Backward Duration: 240 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 1 May 2022 - GDAS1

NOAA HYSPLIT MODEL
Backward trajectories ending at 0600 UTC 29 May 22
GDAS Meteorological Data

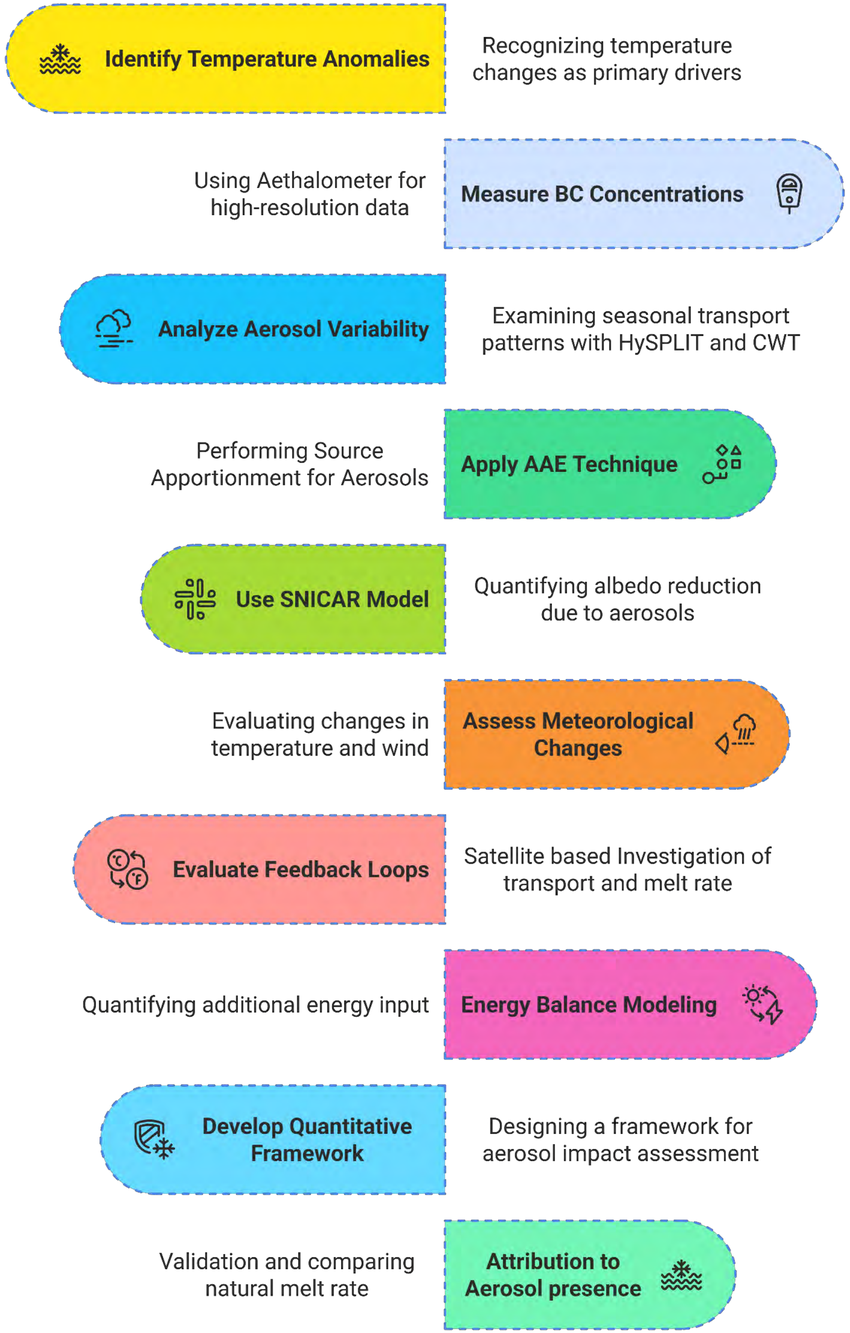


Job ID: 123691 Job Start: Wed Jul 16 21:54:19 UTC 2025
Source 1 lat.: -69.406800 lon.: 76.195300 hgts: 0, 500, 1000 m AGL

Trajectory Direction: Backward Duration: 240 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 29 May 2022 - GDAS1



2023–2024 saw a **spike in sea level rise**, driven partly by El Niño and record ocean heat content—~9.4 cm rise since 1993



How would I go about it all?

CONCLUSION

- Aerosols attribution still needs to be done with higher correlation.
- General circulation in southern hemisphere facilitates it [Karoly et al., 1999]
- Meteorological parameters showed relatively less impact.
- Local transport which happens to be regional dispersion from sources like anthropogenic activities [Diehl et al., 2012] etc. in close proximity.
- Diurnal Variation because of activities.
- The negative meridional flow transport burning particles from tropical to middle latitudes. When cyclonic systems cross Drake Passage, tAntarctica Peninsula [Pereira et.al 2006].
- Katabatic winds. from polar plateau area towards sea, causes dryness and diminished precipitation [Grazioli et al., 2017].

Thank You! GRACIAS!