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ISTRUZIONE
RICERCA

ITINERIS

D4.5.2: Definition of the customizations necessary for the instrumentation and the aircraft to make the instrumentation airborne.

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1. INTRODUCTION

This deliverable is prepared in the context of the ITINERIS project, within the Work Package 4 (Atmosphere) that deals with the integration of Research Infrastructures working in the atmospheric domain through synergistic approaches and cross boundaries developments.

The activity aims to enhance the country's participation in the EUFAR (EUropean Facilities for Airborne Research) consortium, an international non-profit association that coordinates the operation of European instrumented aircraft and exploits the skills of environmental and geo-sciences experts in airborne measurements. Italy, with the CNR (Consiglio Nazionale delle Ricerche) and the OGS (Istituto di Oceanografia e Geofisica Sperimentale), participates in this network of infrastructures with airborne scientific instrumentation and aircraft. To strengthen this participation, through this project we will acquire scientific instrumentations that can be mounted on piloted aircraft. Given the general aims of the WP in which this activity is inserted, this instrumentation will be usable for the in-situ characterization of atmospheric particulate, on airborne platforms.

During the project, the instrumentation is going to be acquired and customized for avionic use. Moreover, feasibility studies for its implementation on the aircraft will be carried out. The mechanical interfaces for assembly inside the cockpit and possibly on the fuselage of the aircraft will be studied, electrical consumption and thermal conditioning will be sized, and the particulate collection lines will be defined.

This deliverable, in the frame of the WP4.5 activities, summarizes the progress report on acquisition of airborne instrumentation and the customizations necessary for the purchased instrumentation and for the aircraft to make possible airborne measurements with these instruments.

2. SCIENTIFIC RELEVANCE OF AIRBORN OBSERVATIONS IN THE MEDITERRANEAN AREAS

One of the key factors influencing climate dynamics is the presence of aerosols, tiny particles suspended in the atmosphere that originate from both natural sources (such as desert dust and sea spray) and anthropogenic activities (such as industrial emissions and biomass burning). Aerosols play a dual role in climate change: they can scatter and absorb sunlight, directly influencing the Earth's radiative balance, and they also affect cloud formation and properties, indirectly modifying precipitation patterns.

2.1 ITALY IN THE CONTEXT OF MEDITERRANEAN WARMING AND AEROSOL ANOMALIES

The wider Mediterranean region is recognized as one of the global hotspots for climate change (Tuel and Eltahir, 2020). As outlined in the First Mediterranean Assessment Report prepared by the Mediterranean Experts on Climate and Environmental Change (MedECC, 2020), the atmospheric temperature in the Mediterranean Basin is already 1.5 °C higher than the preindustrial period (1860-1890), which represents a 35% greater increase compared to the global atmospheric change. Because of the escalating temperatures, aerosol sources might undergo severe alteration due to the intensification of Mediterranean atmospheric anomalies such as desertification, forest fires, vegetative stress, marine eutrophication and heat waves (MedECC, 2020). Due to the emission reduction policies, the level of anthropogenic aerosol is expected to further decrease in the Mediterranean region (Myhre et al., 2013). Differently, the frequency of dust outbreaks (Gobbi et al., 2019) will increase with the desertification process (MedECC, 2020), while tropospheric drying will intensify the severity of forest fires, which already dominate local air quality (Pace et al., 2005). Sea eutrophication will modify the timing of plankton blooms (MedECC, 2020), causing an unknown impact on the emission of marine biogenic aerosol (Freney et al., 2021). Finally, increasing heat stress on land vegetation (MedECC, 2020) might explain the intensification of extreme pollen events (Cariñanos et al., 2022).

2.2 VERTICAL EXTENT OF THE ANOMALIES

These anomalies interest N the entire troposphere, with different influences on the various atmospheric layers. Mineral dust plumes are usually transported in the high and mid troposphere from the Saharan region (Bakr Merdji et al., 2023). Due to pyrocumulonimbus convection and self-lofting, biomass burning aerosol may reach the tropopause (Ohneiser et al., 2023) The influence of anthropogenic and biogenic (land and marine) emissions may extend from few hundred meters in winter (low troposphere) to a few kilometers in summer (mid-high troposphere) due to atmospheric dynamic and convection (Kotthaus et al., 2023). Considering the sparse and static observations (Laj et al., 2020) of the Southern Mediterranean aerosol, any prevision on aerosol Mediterranean anomalies remains extremely uncertain (MedECC, 2020).

2.3 CNR EXPERIENCE AND GAPS

ISAC-CNR has an extensive expertise in aerosol science and manages several atmospheric observatories spread over the Italian territory. As an example, the continuous aerosol and trace gas observations performed at Cimone station (Cristofanelli et al., 2018) make it possible to differentiate the influence of dust, pollution and stratospheric events (Brattich et al., 2020) quantify extreme dust events (Brattich et al., 2015), speciate biomass burning aerosols (Paglione et al., 2014) and identify the origin of ice nucleating particles (Rinaldi et al., 2017). None the less, the vertical distribution of aerosol particles and their impact on the climate and humate health remains largely unknown on the mediterranean region. Considering Italy, most of the knowledge on the aerosol vertical distribution is derived from remote observations (e.g. Di Lorio et al., 2009; Perrone et al., 2014) while few studies were based on in situ measurement observation from balloon-borne (Ferrero et al., 2014), zeppelin-borne (Rosati et al., 2016) aircraft-borne (Mallet et al., 2016) platforms. Since 1994, one of the European Research infrastructures, the In-Service Aircraft for a Global Observing System (IAGOS, Petzold et al., 2015) occasionally visited Italian airports, without providing recurring measurements.

2.4 OBJCTIVES AND ROLE WITHIN ITINERIS

For better understanding, quantifying and predicting the climate impacts of Mediterranean aerosol anomalies, installing advanced aerosol measuring instruments on the research aircraft Piper Seneca 3 would allow for high-precision in-situ data collection, enhancing our understanding of aerosol properties and their influence on the Italian and Mediterranean climate system. With this airborne platform we aim to identify and study those atmospheric processes interesting the mid and upper levels of the troposphere, which are poorly understood due to the lack of measurements and unrealistically represented by global climatic models.

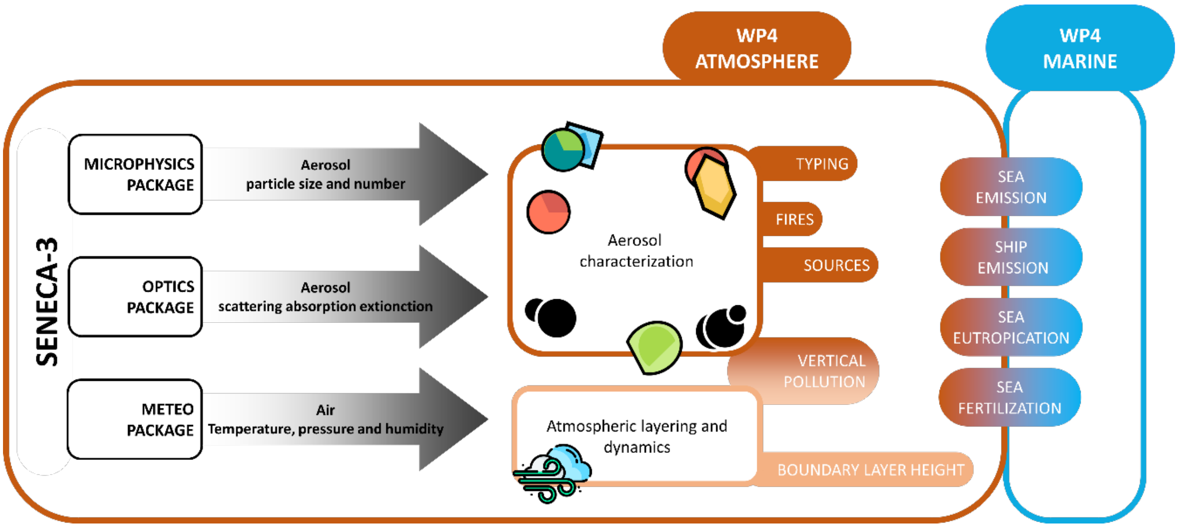

Fig. 1 Connection of the PIPER Seneca 3 activity with ITINERIS WP4-Atmosphere and WP5-Marine.

The platform will serve to connect the various tasks present in the ITINERIS WP4-Atmosphere including the identification and quantification of aerosol properties and the role of atmospheric dynamic on the vertical scale. The research flight will allow to extend the activities of the above-mentioned task on the vertical scale. First it will contribute to type the aerosol (Task 4.11: Aerosol typing), to quantify the vertical and spatial influence of its sources (Task 4.12: Source identification). Last, to trace the impact and evolution of biomass burning events (Task 4.16: Natural and anthropic fires). It will be essential to quantify the impact of the atmospheric dynamic on aerosol concentration (Task 4.14: Impact of boundary layer on aerosol concentration) and validate the retrieval of the boundary layer heigh (Task 4.15: Boundary layer height). Last, to trace the impact and evolution of biomass burning events (Task 4.16: Natural and anthropic fires).

Notably, the activity of the Piper Seneca 3 will help in connecting the ITINERIS WP4-Atmosphere with the WP5-Marine with interdisciplinary study subjects such as marine biogenic emission, sea euthropization and fertilization, ship emission.

3. DESCRIPTION OF THE ACTUAL SENECA III FACILITY

The Piper Seneca III is a twin-engine aircraft used for scientific research by the OGS. Known for its reliability and versatility, the Seneca III has supported various oceanographic studies and environmental monitoring efforts. This aircraft’s design and performance make it a valuable tool for researchers in the field.

Fig. 2 A view of the PIPER Seneca III of the OGS.

The Piper Seneca III has a well-engineered design and operational efficiency. Key specifications are:

Dimensions:

- Wingspan: 11.58 meters
- Length: 8.53 meters
- Height: 2.59 meters

Weight:

- Maximum Takeoff Weight (MTOW): 2,041 kg
- Empty Weight: 1,270 kg

Performance:

- Cruise Speed: 333 km/h
- Maximum Speed: 370 km/h
- Range: 2,220 km
- Service Ceiling: 7,620 meters

Engines:

The aircraft is powered by two Lycoming IO-360 engines, each producing about 200 horsepower. This twin-engine configuration provides not only redundancy but also enhanced performance and stability, essential for research missions (as instance, as a twin engine it has the possibility of flying over urbanized areas).

Avionics:

The cockpit is equipped with modern avionics, including GPS navigation, autopilot systems, and advanced communication tools. These features ensure accurate navigation and efficient data collection, allowing pilots to focus on the scientific objectives during missions.

The OGS aircraft has been employed to collect data on water quality, pollution levels, and the health of marine ecosystems. Researchers use it to monitor changes over time, which is critical for understanding the impact of human activity on the environment. Key missions undertaken by the OGS include collaborative studies with universities and other research institutions. For instance, the aircraft has participated in large-scale projects aimed at mapping underwater topography, assessing the impact of climate change on marine habitats, and studying the distribution of harmful algal blooms.

One among the notable projects involved monitoring the effects of ocean warming on coral reefs. The Seneca III was used to conduct aerial surveys, allowing researchers to collect high-resolution imagery of reef health over time. This data has proven invaluable in understanding how temperature fluctuations affect coral ecosystems.

3.1 CURRENT INSTRUMENTATION

The Piper Seneca III is equipped with a range of advanced instrumentation that enhances its capabilities for scientific research. Some of the key instruments and technologies include:

- Atmospheric Sensors: These sensors measure various atmospheric parameters, such as temperature, humidity, barometric pressure, and wind speed.

- Remote Sensing Equipment: The aircraft may be outfitted with remote sensing technologies, including airborne laser scanner (RIEGL VQ-480II, RIEGL LMS-Q560 and APPLANIX AP50 IMU) and panchromatic multispectral cameras (PHASE ONE iMX-RS150F, SPECIM Aisa Eagle 1K, NEC Thermo Tracer TS9260). These tools allow researchers to collect detailed data on surface features, vegetation cover and water quality.

- GPS and Navigation Tools: Advanced GPS systems provide precise location tracking, which is critical for accurate data collection and mapping synchronized position, attitude navigation iMAR FSAS IMU GNSS NOVATEL ProPakV3.

In addition to these tools, the aircraft's design allows for the customization of its instrumentation based on specific research needs. This flexibility means that the Seneca III can be adapted to support a wide range of scientific inquiries. In fact, the aircraft often participates in joint studies with universities and research organizations, enhancing the breadth of scientific inquiry.

The Piper Seneca III is thus an important asset for the OGS, made available to CNR in the frame of ITINERIS project. Its specifications and instrumentation make it a practical choice for scientific research related to marine and atmospheric studies. As research needs evolve, the Seneca III remains a capable platform for collecting valuable data and supporting various environmental monitoring efforts.

4. UPGRADE OF SENECA III FOR AEROSOL OBSERVATION CAPACITY

The Operating Unit (OU) responsible for the activity 4.5 is CNR-ISAC-BO (Istituto di Scienze dell'Atmosfera e del Clima). CNR-ISAC has selected a set of detectors dedicated to the study of optical and microphysical properties of atmospheric aerosols, as well as the associated meteorological conditions.

The choice of the atmospheric instrumentation considers the main recommendation of the ACTRIS Research Infrastructure for the aerosol in-situ component, as well as the specificity of airborne measurements. It is designed to operate efficiently within the specific limits and conditions of an aircraft owned by the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), specifically the PA-34 twin-engine Seneca III turbocharged aircraft.

The scientific interest is aimed to measure the complete characterization of aerosol properties, such as:

- Aerosol scattering and backscattering coefficient
- Aerosol absorption coefficient
- Black carbon concentration
- Aerosol size distribution
- Aerosol number concentration
- Meteorological parameters

The chosen set of variables is adaptable to a variety of research scenarios enhancing our ability to monitor and understand aerosol processes contributing to better environmental management and policymaking.

4.1 TECHNICAL DESCRIPTION OF INSTRUMENTATION

4.1.1 SAMPLING SYSTEM

The aircraft's airborne sampling system must be designed to capture aerosol particles across a wide size range while maintaining accurate measurements of particle concentration and properties. A key component is the aerosol inlet, which introduces ambient air into the onboard instruments. Due to altitude-related changes in pressure, temperature, and velocity, sampling biases can alter aerosol properties. Given the wide speed range of the aircraft, the inlet must ensure isokinetic sampling, where particles are drawn in at the same velocity as the airflow, minimizing losses and distortions in both concentration and size distribution measurements. Additionally, the inlet should prevent particle fragmentation or coagulation, ensuring accurate data for identifying aerosol sources, anomalies, and interactions with radiation and clouds.

For this purpose, the Brechtel 1200 Isokinetic Aerosol Inlet system was selected, the contract is signed, and it will be delivered by the end of 2024. The system is shown in Figure 3 and includes:

- ISO-1200 inlet: isokinetic sampling of aerosol particles
- ISO-1200 electronic chassis: inlet control system
- ISO-90 bend: transport of aerosol particles
- ISO-SP025/05: distribution of aerosol particles to the measuring instruments

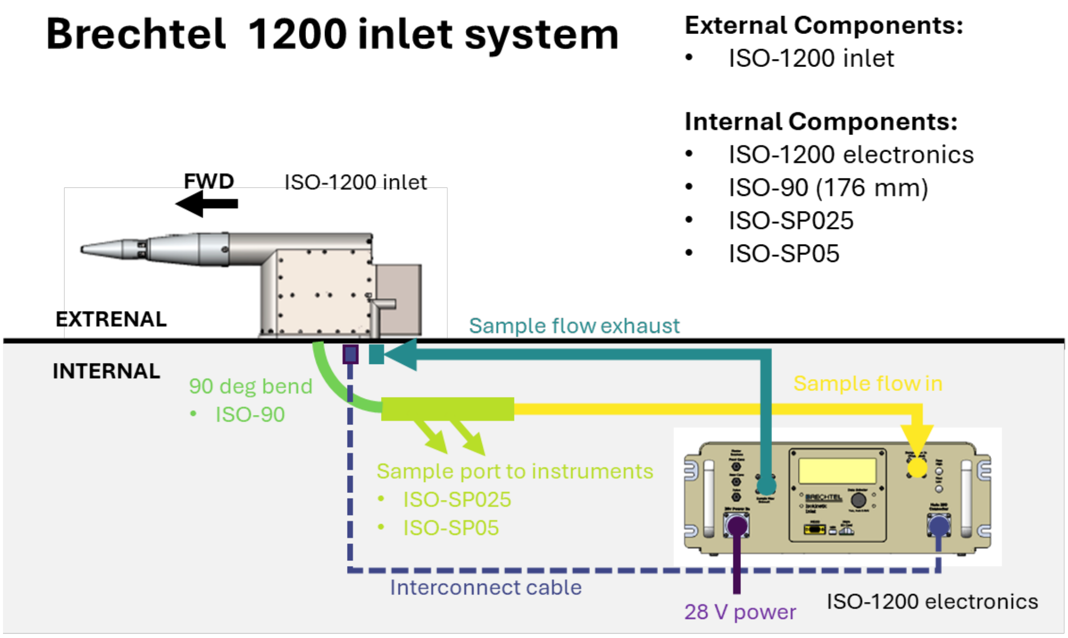

Fig. 3 Brechtel 1200 inlet system.

The Brechtel 1200 inlet system has been tested in several airborne measurements and it is a reliable and scientifically sound choice for airborne aerosol sampling, respecting the fundamental technical requirement of isokinetic sampling. Other key Features of the Brechtel 1200 Isokinetic Aerosol Inlet are:

i) Size Range: the Brechtel 1200 can sample particles with diameters ranging from ultrafine (less than 10 nm) to coarse modes (up to several microns), ensuring comprehensive capture of aerosol populations.
ii) Low Particle Loss: due to its isokinetic nature, the inlet experiences minimal losses for particles in both the submicron and supermicron size ranges.
iii) Durability and Versatility: the Brechtel 1200 inlet is robust and suitable for harsh operational environments encountered during high-altitude flights or under turbulent conditions.

These capabilities are crucial to the investigation of aerosol vertical variability in the frame of the WP4's scientific objectives.

4.1.2 MICROPHYSICS PACKAGE

The aerosol microphysical characterization package is designed to provide detailed measurements of the physical properties of atmospheric aerosols including the particle number size distribution and total number concentration.

Technical description

To capture a comprehensive view of aerosol sizes and microphysical properties, four complementary instruments have been selected

The water-Based Condensation Particle Counters (WCPCs) model 3789 (TSI) deliver accurate concentrations of particles while making use of safe, eco-friendly and easily available distilled water. The CPC grows particles in a supersaturated environment, causing them to condense on a fluid (typically butanol or water), providing the total number concentration of aerosol particles between 2 nm and 3 µm.

The Fast Mobility Particle Sizer (FMPS) TSI model 3091 measures the size distribution of submicron particles from 5.6 nm to 560 nm with 1 Hz time resolution. The instrument classifies particles based on their electrical mobility.

The TSI APS model 3321 (Aerodynamic Particle Sizer) uses the time-of-flight technology to measure the number size distribution of aerosol particles having an aerodynamic diameter of 0.5-20 µm. This instrument is under the whitelist of the ACTRIS RI recommended instrument, especially in the range 800nm-20µm.

The aerosol optical counter (OPC) TOPAS LAP-323 is an optical instrument for measuring aerosol size distribution, capable of covering a wide range of particle sizes from 0.2 to 40 µm. It uses laser light scattering to classify particles based on the amount of reflected light.

Application

Overall, the microphysical package will allow to measure all the particles sampled and transmitted by the IOS-1200 inlet (Figure 4). Differentiating submicron from ultramicron particles, such as fine-mode pollution from coarse mineral dust, is crucial for identifying sources (natural from anthropogenic) and understanding processes related to particle aging, including mixing and cloud interactions. These observations complement the optical instruments. While coarse particles strongly affect sunlight absorption and scattering, altering radiation, the most absorbing aerosols (like soot) are found in submicron particles.

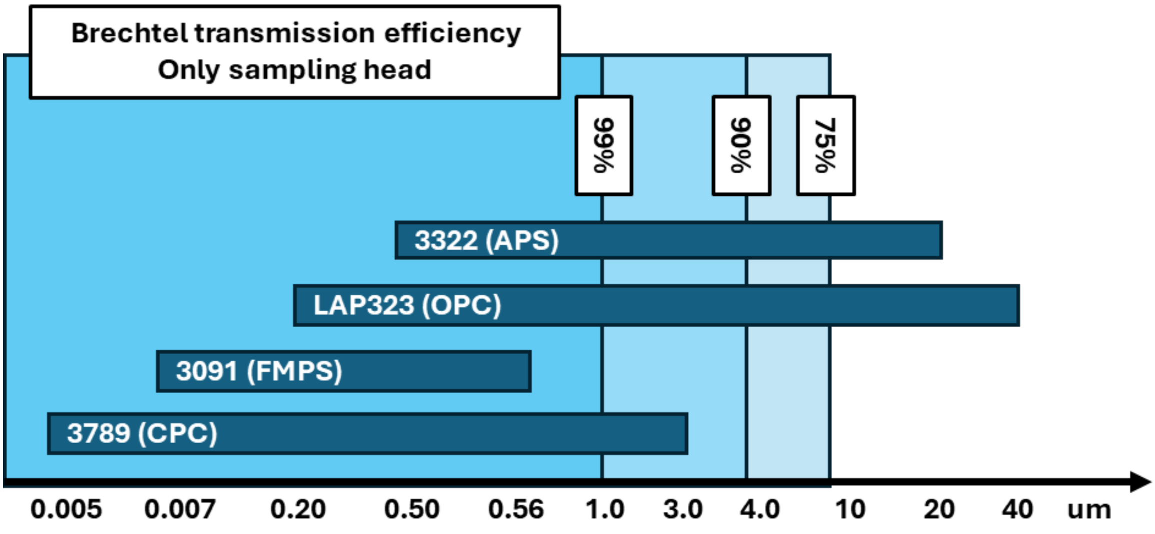

Fig. 4 Inet system transmission efficiency and diameter detection range of the microphysical package

4.1.3 OPTICAL PACKAGE

The aerosol optical characterization package is designed to measure key optical properties of aerosols, which are essential for understanding their impact on radiative forcing, visibility, and air quality. The package includes two complementary instruments, determining the scattering (total + back) and absorption coefficients, providing a comprehensive view of aerosol optical properties across different particle types and sizes.

Technical description

The Aethalometer is a widely used instrument for measuring black carbon (BC) in the atmosphere, operating by measuring light absorption by aerosol particles on a filter. It provides real-time data on BC concentration, a key factor in climate and health due to its role in absorbing sunlight and reducing albedo when deposited on snow and ice. The Magee Scientific Aethalometer AE33, recommended by the ACTRIS Research Infrastructure, draws air through a filter and measures light attenuation at multiple wavelengths (370–950 nm). It includes a real-time algorithm that adjusts for filter loading, ensuring accurate measurements. The Nephelometer measures aerosol scattering and backscattering coefficients, providing key data on aerosol concentration, size, and radiative properties. This information is crucial for understanding how aerosols influence climate by warming or cooling the atmosphere. The Aurora 3000 Nephelometer measures total scattering and backscattering at three wavelengths (450 nm, 525 nm, 635 nm), allowing for detailed analysis of a wide range of aerosol types and sizes. Scattering aerosols, like sulfates and organic particles, reflect sunlight, exerting a cooling effect on the climate.

Application

First, the real-time capabilities of both instruments allow for high-resolution data collection, which is crucial for airborne studies where aerosol properties can change rapidly with altitude and location. The AE33 data will be beneficial to identify biomass burning plumes and differentiate to fossil fuel burning and to assess the vertical and horizontal extent of a) wildfires in the context of aridification processes occurring across Italy and b) anthropogenic pollution on European pollution hotspot such as the Po-Valley. The Aurora 3000 will be used to map the correlation between pollution and visibility but also to validate backscattering data retrieved from ground-based and satellite-based sensing of backscattering coefficient.

The combination of the Aethalometer AE33 and the Aurora 3000 Nephelometer provides a powerful suite for studying aerosol optical properties. This dual approach is essential for determining the aerosol extinction coeffcient and the single scattering albedo (SSA), which is a critical parameter in climate models for assessing aerosol radiative effects. Moreover, both instruments operate across multiple wavelengths, enabling differentiation between various aerosol types, such as black carbon, brown carbon, sulphates, and organics. By calculating the Ångström exponent of absorption (AAE) and scattering SAE, we can optically speciate different aerosol types (Cappa et al., 2016;Fig. *5*). This optical speciation is complementary to the microphysical/size characterization.

This is particularly important for understanding the vertical distribution of aerosols, their interaction with clouds, and their role in atmospheric processes like radiative transfer and precipitation formation.

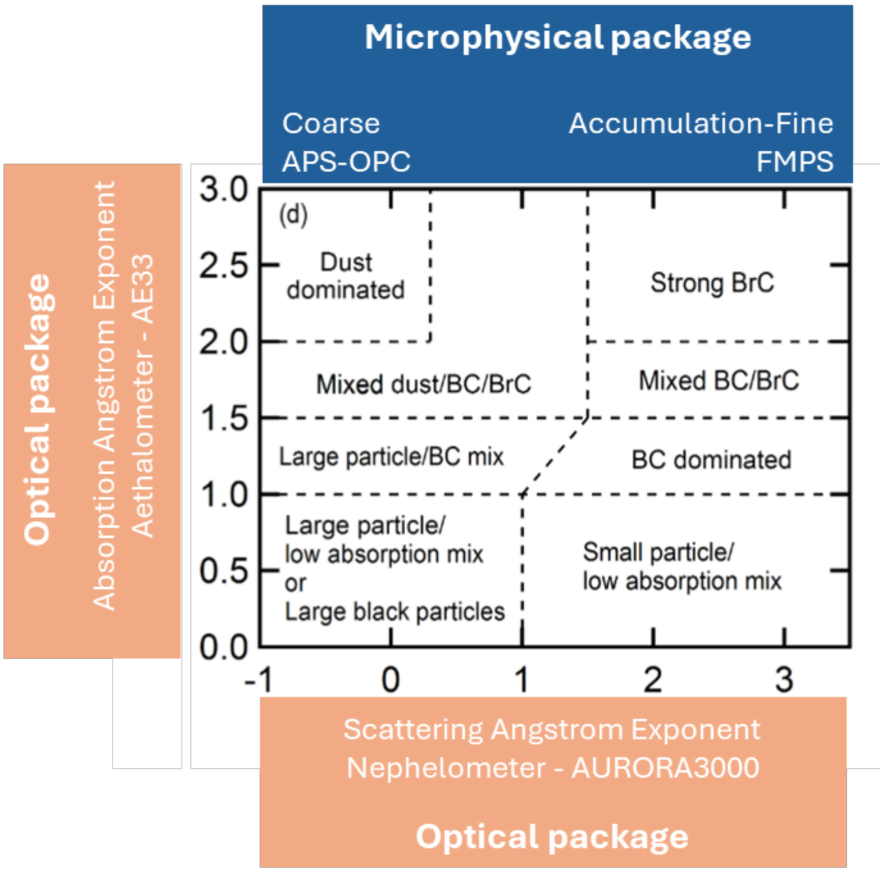

Fig. 5 Classification of aerosol based on microphysical and optical properties.

4.1.4 METEOROLOGICAL PACKAGE

The meteorological packaged is required to provide the basic meteorological parameters including temperature, pressure, humidity and wind speed, which are essential to derive the vertical structure of the atmospheric layers.

Technical description

The meteorological package is composed of the Aventech Aircraft Integrated Meteorological Measurement System (AIMMS-30), an advanced instrument designed for high-accuracy in-flight measurements of atmospheric conditions. AIMMS-30 integrates multiple sensors into a compact system capable of capturing real-time data on key meteorological parameters, including air temperature, pressure, humidity, wind speed, wind direction, and turbulence.

AIMMS-30 features precise sensors to measure static and dynamic pressure, which are necessary for accurate altitude determination and flight data analysis. The air temperature sensor, housed in an aerodynamic probe, provides accurate readings of ambient air temperature, corrected for the aircraft's movement through the atmosphere. The system includes a hygrometer for measuring relative humidity, an essential parameter for understanding cloud formation, atmospheric moisture content, and precipitation processes. AIMMS-30 utilizes a five-port air motion probe for measuring 3D wind vectors. This system accounts for the aircraft's motion, making it possible to accurately measure both horizontal and vertical wind components. These data are critical for understanding airflow patterns, turbulence, and convection within atmospheric layers.

Application

Temperature gradients, moisture distribution, and wind shear will be crucial to study convective systems, boundary layer dynamics, and entrainment or dilution of pollution (Fig. *6*).

The system can provide high-frequency measurements of gusts and eddies, allowing for the identification and characterization of turbulent regions in the atmosphere. This capability is particularly important in understanding energy exchange processes and the dynamics of weather systems. The unique 3D wind analysis will help in understanding the transport of aerosols and gases in the atmosphere, as well as the energy exchanges that drive atmospheric circulation.

The AIMMS-30's turbulence measurement capability is particularly valuable for studying atmospheric boundary layers and cloud microphysics. Turbulence plays a significant role in mixing atmospheric constituents, influencing cloud formation, and affecting energy exchanges between the surface and the atmosphere. For cloud research, turbulence data help in understanding the formation and dissipation of clouds, as well as the initiation of convection. This is especially important in studies related to aerosol-cloud interactions, where turbulent mixing affects particle distribution and cloud dynamics.

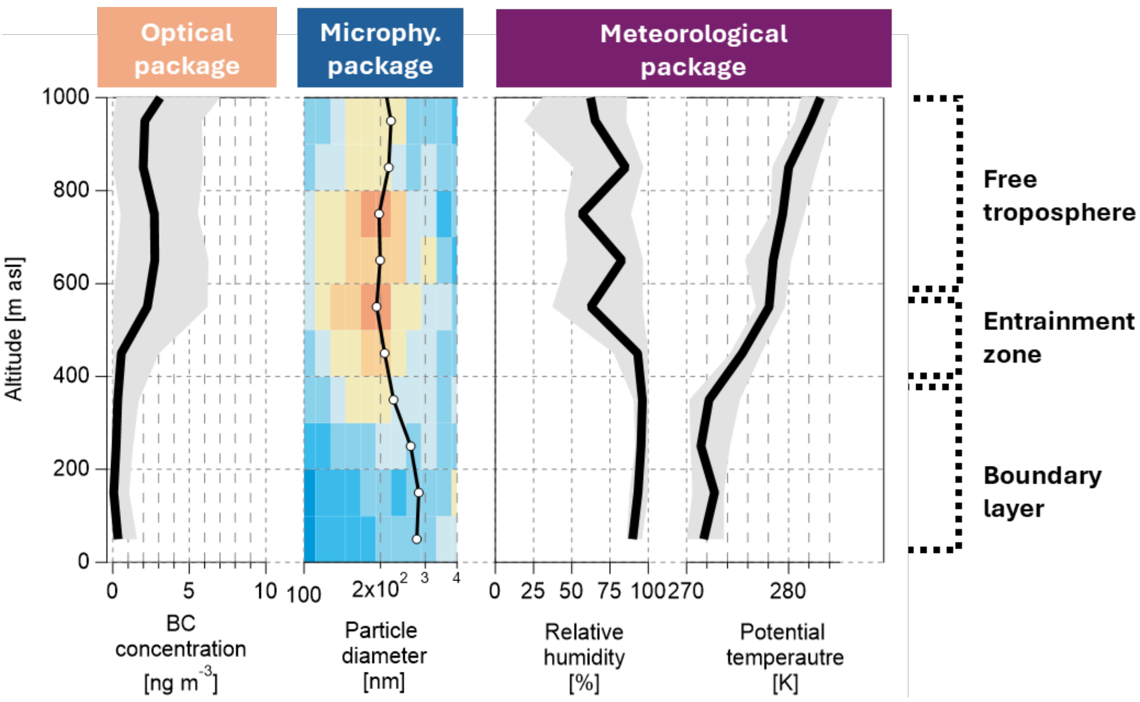

Fig. 6 Example of vertical profile of aerosol and meteorological properties. As function of atmospheric stratification

4.2 DESCRIPTION OF POWER SUPPLY

This report details the electrical requirements for installing aerosol measurement instruments on a Piper Seneca III aircraft for the ITINERIS project and includes: electrical load and installation feature.

Electrical load:

Five instruments require Volts Alternating Current (VAC): Fast Mobility Particle Sizer, Condensation Particle Counter, Topas Laser Aerosol Spectrometer, Aerodynamic Particle Sizer, Aethalometer AE33. The total VAC load is estimated to be 625.4 W. Four instruments require Volts Direct Current (VDC): Brechtel Isokinetic Inlet System, Meteorological Measurement System, AURORA 3000, Data Logger. The total VDC load is estimated to be 540.2 W.

Electrical Provision:

A DC-DC step-up converter (P/N LS03-05002-800, 800W) has been installed with Change P34P001-00, connected to a wall-mounted receptacle (P/N D38999/20WE6SN) in the cabin compartment. The electrical provision installed with Change P34P001-00 is adequate for the installation of the above equipment. Since some equipment requires AC, an inverter (minimum 700W) will be installed, possibly P/N LS03-06356 700W, in the nose compartment near the bus bar.

Protection and Power Distribution:

A circuit breaker will be installed to protect the electrical circuit, located in the nose compartment near the breaker protecting the DC-DC step-up. A selector switch may be installed in the passenger cabin to control the power to different equipment configurations. A wall-mount socket will be installed in the cabin compartment to power the AC equipment.

Installation Standards:

All wiring design and installation are developed according to AC 43.13-1B. Most components are either Mil-STD or compliant with DO160.

Table 1 Operating voltage and power of scientific instrumentation.

Item	P/N	Voltage [V]	Power [W]
Fast Mobility Particle Sizer™ Spectrometer	3091	240VAC	250.00
Condensation Particle Counter	3750	240VAC	200.00
Topas Laser Aerosol Spectrometer	LAP 323	110-230 VAC	50.4
Aerodinamic particle sizer	Model 3321	100-240	100
AETHALOMETER	AE33	100-230	25
TOTAL		**VAC**	**625.40**
Brechtel Isokinetic Inlet System	de-ice		887.00
	Model 1200		56
Aircraft Integrated Meteorological Measurement System	AIMMS-30	9-36VDC	4.20
AURORA 3000	AURORA 3000	12VDC	60.00
Data logger	DX-1200	9-48 VDC	420.00
TOTAL		**VDC**	**540.20**

1. **Electrical Load**:
    a. The total AC load is 625.4W, and the total DC load is 540.2W.
    b. A DC-DC step-up converter (800W) and a 700W inverter (for AC equipment) are recommended to support these devices.
2. **Installation Requirements**:
    a. An inverter (700W) will be installed in the nose compartment to convert DC to AC.

b. A breaker and selector switch for controlling different equipment configurations will also be installed, along with a wall-mount socket for AC equipment.

4.2.1 RECOMMENDATION BASED ON THE ACTUAL LAYOUT

Given that the total AC and DC power loads have been clearly calculated (625.4W AC, 540.2W DC), the current electrical system on the Piper Seneca III with the proposed inverter and step-up converter seems adequate to handle these loads. However, to ensure safety and long-term reliability, it's important to:

1. **Verify Inverter Capacity**: The inverter is rated at 700W, but the total AC load is 625.4W. While this is within the inverter's capacity, it's close to the maximum, leaving little headroom for future expansion or unexpected spikes. We will consider using a higher-capacity inverter (e.g., 1000W) for added safety.
2. **Cooling and Ventilation**: WE will ensure that both the inverter and step-up converter are installed in well-ventilated areas, as continuous operation near their capacity may generate heat, potentially leading to failures.
3. **Testing and Validation**: Once installed, comprehensive testing should be performed under full load conditions to validate the system's performance and ensure all components (inverter, breaker, DC-DC converter) function as expected without tripping or overheating.

4.3 PAYLOAD LAYOUT (INLET, METEO PROBE AND RACKS)

This chapter outlines the strategic placement of aerosol measurement instruments inside the Piper Seneca III aircraft, alongside the installation of an aerosol inlet and meteorological probe on the aircraft's exterior. The instruments are thus classified into internal and external payload.

4.3.1 EXTERNAL PAYLOAD

The most significant challenge is determining the optimal location for the external probes, which must be placed in a position that guarantees the highest sampling accuracy and efficiency while minimizing potential interference. The considered instrumentation comprises:

- Brechtel 1200 Isokinetic Aerosol Inlet
- Meterological probe AIMMS-30

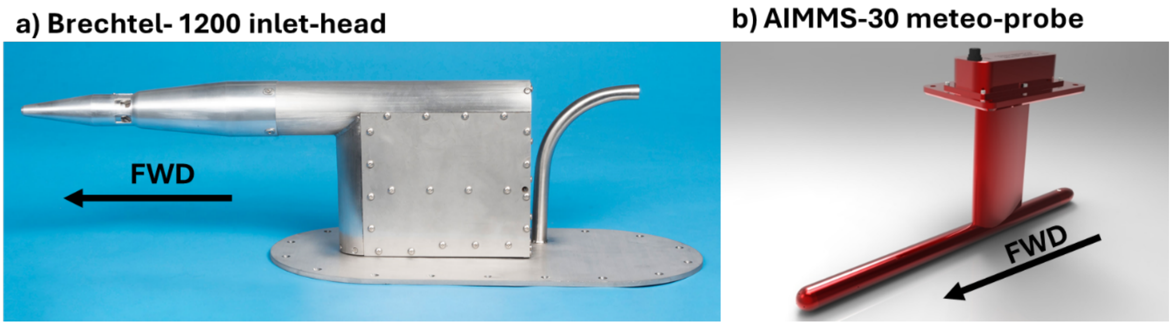

Fig. 7 a) inlet head; b) meteo-probe.

A detailed technical evaluation involving Boggi Avionics, Luxinger, CNR-ISAC-BO, and OGS is ongoing to assess the three potential positions: 1) Nose of the aircraft, 2) Upper part of the fuselage, 3) bottom of the fuselage.

The decision on where to position the external probe is not only critical for the accuracy of external measurements but also directly influences the internal arrangement of the payload. The following factors are paramount in this decision:

Sampling Efficiency:

- The primary goal of the external aerosol inlet is to ensure that the aerosols entering the system are representative of the atmospheric conditions encountered during flight. An inefficient sampling system could lead to significant losses of aerosol particles or bias in the size distribution.
- For instance, a probe positioned on the nose may capture particles more effectively due to the relatively undisturbed air in front of the aircraft, minimizing losses and turbulence-induced inaccuracies. However, this needs to be balanced against structural and aerodynamic constraints.

Contamination from Engines:

- Contamination from the aircraft's engines is a major concern, as exhaust emissions can skew aerosol data, especially for particles in the submicron range. The position of the engines relative to the probe influences the risk of contamination.
- Placing the probe on the upper part of the plane could reduce the risk of contamination, as this location is farther from the engine exhaust paths. On the other hand, a lower placement (e.g., under the fuselage) could expose the probe to greater contamination risks, depending on the aircraft's design and flight dynamics.

Aerosol Transmission Efficiency:

- Once aerosol particles are sampled through the inlet, they need to be efficiently transmitted to the instruments inside the aircraft. The length and configuration of the tubing that connects the inlet to the measurement devices are crucial in maintaining the integrity of the aerosol sample. Long tubing or sharp bends can cause particle loss due to impaction or diffusion.
- The nose and upper fuselage options might allow for shorter and more direct tubing routes to the instruments, improving transmission efficiency. Conversely, a probe placed on the bottom could require more complex tubing arrangements, which might increase losses, particularly for larger or more fragile particles.

4.3.2. INTERNAL PAYLOAD

The internal payload comprises the instruments used to characterize the optical and microphysical properties of the aerosol particles, the control units of the external probes discussed above and the dataloggers needed for data acquisition of both external and internal payload. The payload will be distributed in 3 avionic racks reducing the number of passenger seats to the number of two. These seats will be dedicated to the operators needed to verify the in-flight operation of the instrumentation.

The external probe's position also dictates the internal distribution of instruments and the 3 racks, as the routing of sample lines and cabling must align with the aircraft's layout. A well-planned configuration is essential to ensure:

- **Minimized sample loss**: Shorter and straighter sample lines are preferable to reduce particle loss, especially for microphysical measurements.
- **Efficient use of space**: Instruments in the optical, microphysical, and meteorological packages must be strategically positioned to make the best use of the limited space inside the aircraft while maintaining operational accessibility.
- **Safety and balance**: The weight distribution of the payload must not compromise the aircraft's balance and flight performance.

In conclusion, the final choice of probe placement will emerge from a balance between optimizing sampling efficiency, minimizing contamination from the engines, and ensuring high transmission efficiency for aerosol particles. This decision will be crucial in determining not only the quality of the external measurements but also the internal configuration of the scientific payload, ensuring that the instruments operate at their peak performance throughout the ITINERIS project.

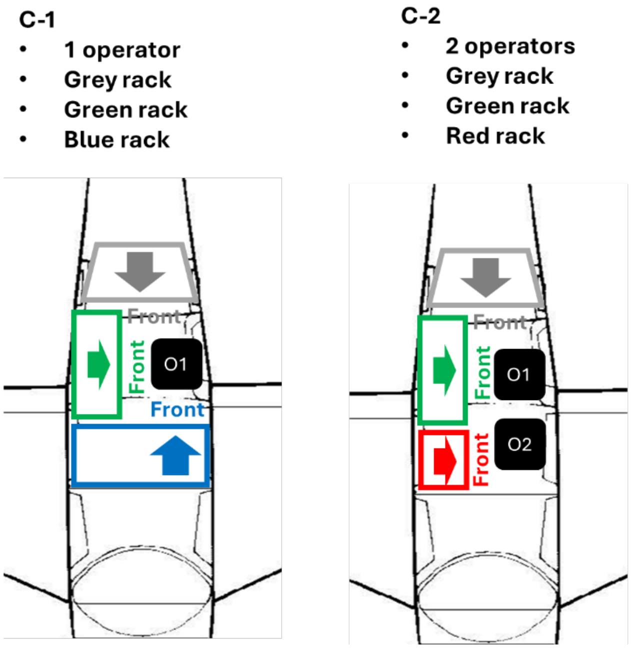

Fig. 8 Different configurations of payload layout.

Depending on the actual space availability, we might be able to choose to operate with 1 or 2 operators. Now we propose 3 different configurations characterized by the presence of 1 operator (C-1) or 2 operators (C-2 and C-2b).

Configuration C-1 is designed to maximise the payload including all the instrumentation from the three packages. On the other end, C-1 also maximise the work of the operator, which might not be recommended for prolonged flights with a complex flying pattern (intense profiling, cloud presence, etc..). On the other end, C-2 maximises the operator presence onboard, with a lead operator, managing the flight pattern and inlet, and an instrument operator mangeing the data acquisition. C-2 reduces the available payload limiting the size distribution coverage excluding the FMPS instrument. C-2b, maximise both the instrumental payload and operator presence. The latter must be verified as function of space availability.

5. RESEARCH COLLABORATION AGREEMENT BETWEEN CNR-ISAC AND OGS

The agreement between CNR-ISAC (Institute of Atmospheric Sciences and Climate of the National Research Council) and OGS (National Institute of Oceanography and Experimental Geophysics) focuses on the installation and use of scientific instrumentation on the Piper Seneca III aircraft, owned by OGS, for atmospheric and environmental observations.

The operation of CNR-ISAC-BO instrumentation on the Piper Seneca III, owned by OGS, has been successfully initiated following the formalization of the Research Collaboration Agreement between ISAC-CNR and OGS. The agreement, now fully signed, was the result of thorough and detailed interactions between the two Institutes. As it follows the main points formalized by the agreement:

- The agreement is valid until October 31, 2025, with automatic extension if the ITINERIS project is prolonged.
- Main Role of CNR-ISAC: CNR-ISAC is responsible for providing scientific instrumentation and overseeing its installation, certification, and use on the aircraft. It also handles coordination with companies for certification and installation procedures, sharing its expertise in airborne measurements and supporting research efforts related to the atmosphere and Earth sciences.

The procurement and customization of the airborne instrumentation for the Piper Seneca III is in process. All necessary steps, including purchase procedures and the definition of the aircraft's airborne customization, were carried out efficiently, while the airworthiness certification and the final installation of the instrumentation on the aircraft have been postponed. The final installation of the instruments on the aircraft and the in-flight certification will need to be deferred to a subsequent round of tenders, and the execution of this final task is likely to extend for a year from the completion of the tender procedures.

This phased approach allowed us to avoid delays while progressing on tasks that could be independently completed. Now, with the Research Collaboration Agreement in place, all collaborative tasks can be fully addressed.

The research collaboration agreement is an attached file to be considered part of this deliverable.

6. CONCLUSIONS

Thanks to the upgrade made available through ITINERIS project the CNR-ISAC-BO OU will deeply implement the observational capacity of a new airborne platform. We plan to install all the new instrumentation for a testing phase in extreme controlled conditions at the NF of Monte Cimone. Monte Cimone offers the unique opportunity in Italy to intercompare the recently ACTRIS labelled instrumentation (aerosol-in-situ component) with the new purchased instrument for airborne measurement.
Meanwhile we are taking care of the customizations, aviation certification and the arrangement of Seneca III to host the instrumentation.
The Seneca III upgraded will be available before the end of project.

The infrastructural strengthening improves the capacity to attract new users though the access programs of ITINERIS. Moreover, this will develop the conditions for harmonising standards, metadata and policies amongst the different RIs, that are very diverse and on different levels of maturity, but face similar challenges in their operations regarding FAIR compliance and Access management.

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