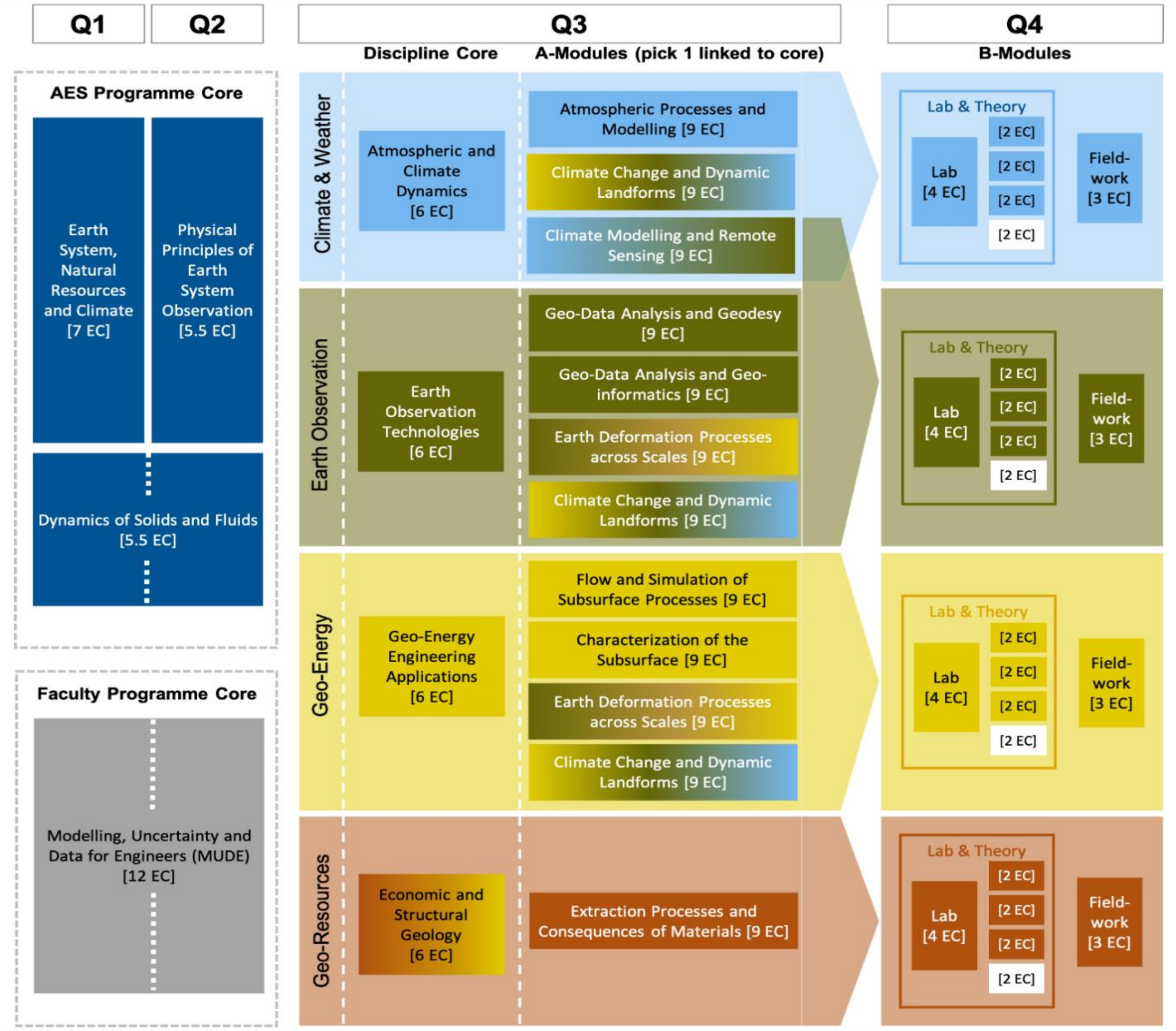
MSC APPLIED EARTH SCIENCES YEAR 1 : DISCIPLINE CLIMATE & WEATHER MODULE DESCRIPTIONS

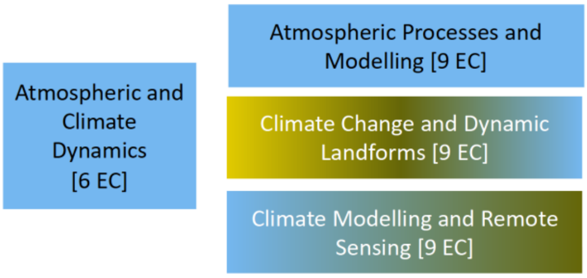
The programme starts with a common core where you gain a solid foundation in earth science, physics, and modelling & data skills. Thereafter you develop your own path, and specialise in specific topics:

- you select one of four defined disciplines: Climate & Weather, Earth Observation, Geo-Energy, and Geo-Resources.
- you choose a mix of modules and electives, developing in-depth knowledge within the discipline or complementing your interests with electives from other disciplines.
- You gain hands on experience by applying theory learned to current engineering case studies from governmental institutes and companies.

This document presents an overview of the curriculum and module descriptions specifically for Discipline Climate and Weather in year 1 of the programme.



CLIMATE AND WEATHER: DISCIPLINE CORE AND A-MODULES



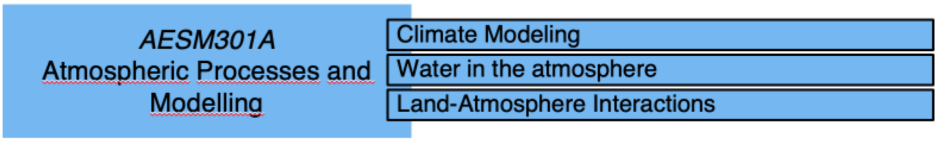
ATMOSPHERIC AND CLIMATE DYNAMICS (DISCIPLINE CORE)

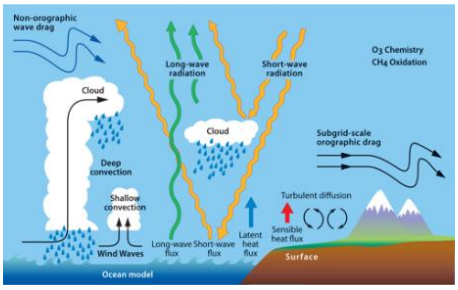
This discipline core module provides you with a deeper physical understanding to comprehend and study the complex atmospheric flows that define climate and weather. The module is organized into seven themes: Planetary Circulation, Baroclinic Instability and Planetary Waves, Tropical Dynamics, Planetary Boundary Layer, Coupled Surface-Atmosphere Dynamics, From Simplified Theoretical Models to General Circulation Models, and Grand Challenges in Weather and Climate Prediction.

Throughout the core module, observations and laboratory experiments serve as a starting point to describe the complex flows in our atmosphere. Building on knowledge gained during the Applied Earth Science's core programme modules, you learn to apply/use the laws of fluid dynamics, thermodynamics and radiation to explain what you observe.

Parallel to the discipline core module, you follow one of three A modules which allow you to deepen or complement your focus on Climate & Weather.

ATMOSPHERIC PROCESSES AND MODELLING (A-MODULE)



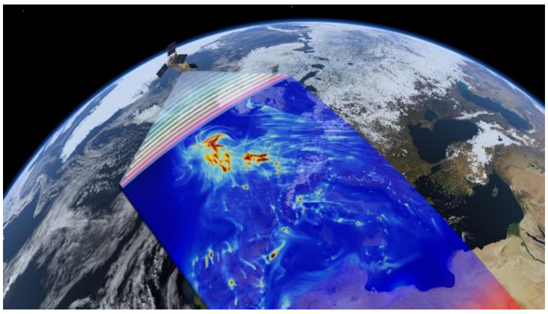


This module explores and solidifies your knowledge in applied meteorology, such as wind and solar energy prediction or climate impacts on land use, and in the design, analysis and assessment of weather and climate models. It focuses on the smaller-scale atmospheric processes, processes that play a key role in climate and that have a strong impact on daily life: winds, clouds and radiation, storms and precipitation. The module does this by focusing on three units. In the first two, you will deepen your process-knowledge and analytical thinking skills in the field of land-atmosphere interactions and convection & clouds, covering atmospheric processes strongly linked to turbulence and radiative transfer across all scales that are not explicitly represented in general circulation models. The third unit you focus on climate modelling and prediction. In this unit you gain hands-on experience in the use and application of state-of-the-art general circulation models, as well as in the assessment of the uncertainties in current climate projections.

While using observations, you will focus on how to analytically and numerically model these processes. How are these small-scale processes coupled to large-scale circulations? Why are their formulations in general circulation models particularly important for climate prediction and assessing uncertainties.

CLIMATE MODELLING & REMOTE SENSING (A-MODULE) - SHARED WITH EARTH OBSERVATION

AESM308A Climate Modeling and Remote Sensing	
	Climate Modeling
	Earth Observation Technologies



This module is shared across the Climate & Weather and Earth Observation disciplines. This is reflected in the module's two units: Climate modelling and Earth Observation Technologies. By following this module, you will learn how remote sensing and climate modelling have a certain type of synergy which helps you understand, predict, and model a wide range of present-day climate system processes. This enables you to study and analyse processes related to the cryosphere, terrestrial water cycle, oceans, and/or the interactions between these components. You will not only gain a physical understanding of the processes, but also the skills needed to use and assess ground-based and space-borne observations, and coupled global models. As part of the module, you will create a preliminary design for an observation mission/campaign, giving you valuable hands-on experience and a deeper understanding of tradeoffs/compromises you will have to make when working in the field with certain techniques.

CLIMATE CHANGE AND DYNAMIC LANDFORMS (A-MODULE) - SHARED WITH EO & GE

AESM309A Climate Change and Dynamic Landforms	
	Climate Modeling
	Geo-Informatics
	Surface Morphodynamics and sedimentation

This module is designed for students interested in studying how climate change affects the natural environment and how this can be analysed using geospatial data. The module is shared between the disciplines Climate&Weather, Earth Observation and Geo-Energy.

The module is split into 3 different units (Climate Modeling, Geo-Informatics, and Surface Morphodynamics and Sedimentation) where you will cover topics such as climate modelling and underlying concepts of numerical and computational models that predict past and future climate dynamics. You will also learn about the interaction between climate change and the solid Earth, using rivers and deltas as natural case studies. Additionally, the module includes a hands-on component where you'll learn how to deliver remote sensing products that can be used in geophysical studies. By the end of the module, you'll have a better understanding of how the natural environment is impacted by climate change and how to use modeling and observations to study these impacts over time.

CLIMATE AND WEATHER: B-MODULES

The B-modules for all disciplines comprises a Theory & Lab component (12 EC) and a fieldwork (3 EC).

The lab has a central place in the module, triggering the inquiries and as the place where the students apply the theory they learn in the theory units to a challenge related to monitoring and/or prediction of climate impacts or geohazards, energy transition, or responsible resource extraction (depending on the discipline). The student (team) selects a topic related to the challenge within a predefined theme that they will work on during the Lab. They collect analyse and interpret data to address or solve their posed topic.

Next to the lab project, students follow 4 theory units. One is compulsory per discipline (indicated with 'C' in table below). In addition, students need to choose 2 units from their own discipline. The available options are indicated in the table below per discipline.

Discipline	Theory components (color indicates with discipline offers it)	B-CW	B-EO	B-GE	B-GR
C&W	Climate data analysis	C	E	E	
	Remote sensing of precipitation	E	E		
	Multi-sensor cloud and atmospheric observations	E	E		
	Cryosphere dynamics	E	E		
	Sea level change and extremes	E	E	E	
EO	Time series analysis	E	C	E	
	GNSS	E	E		
	(In)SAR	E	E	E	
	Optical remote sensing	E	E	E	E
GE	Induced seismicity		E	C	
	Geophysical prospecting		E	E	E
	Production science and technology	E		E	
	Geological interpretation of geophysical data		E	E	
GR	Exploration tools and methods			E	C
	Advanced resource modelling			E	C
GR + EO	Geostatistical data analysis		E	E	C

C	compulsory
E	elective

During the fieldwork, students will work in teams to define an objective related to their discipline. Students start with a project planning phase (0.5EC), in which they receive instruction, and they design a measurement experiment or a fieldwork campaign, which will be reviewed. In a second phase they will implement the measurements, collect data and process the data (1.5EC). Thereafter they will analyse and interpret the data, present their findings, and provide recommendations for future work or answer questions in different formats (1EC).

CLIMATE & WEATHER – THEORY COMPONENTS

Climate Data Analysis

- *Basic concepts and fundamentals:*
    i. review of most common distributions of climate variables, length/time scales;
    ii. common pitfalls and misuse of statistical analysis in climate research;
    iii. commonly used non-parametric alternatives for parametric regression, hypothesis testing, etc.;
    iv. Origin of auto-/serial correlation in climate data and impact on confidence intervals, bootstrapping, etc.

- *Hypothesis testing of climate data:* field significance tests (e.g., Livezey-Chen, FDR methods, one/two-way ANOVA.

- *Analysis of climate model output*: climate sensitivity, detection and attribution.

- *Spectral analysis of climate data*: cross-spectra, wavenumber-frequency analysis, wavelet power spectra.

- *Empirical orthogonal function analysis*: EOF analysis theory, links to SVD, application to point data & field data, sampling variance of eigenvalues and eigenvectors, selection rules, degenerate multiplets, test for significance of EOF loadings vs noise, rotated EOFs, joint analysis of multiple fields.

- *Statistical forecasts and ensemble forecasts & forecast verification (categorical and quantitative), extreme value analysis*

Sea Level Change and Floods

- *Drivers of sea level change*: steric changes, ocean dynamics, freshwater fluxes, global and regional sea level budgets.
- *Sea level projections*: process-based and semi-empirical, global and regional models.
- *Coastal sea level change and solid Earth deformation*: coastal currents, wind and atmospheric pressure effects, river outflow, vertical land motion, glacial isostatic adjustment.
- *Tides and sea level records*: origin and propagation of tides, the geological and the instrumental sea level records (proxies, systems and networks).
- *Dutch sea level change and the AMOC*: available observations, detection of accelerations, the KNMI scenarios, the role of the Atlantic Meridional Overturning Circulation.
- *Sea level reconstructions*: global and regional past sea level change from tide gauge observations.
- *Storm surges and floods*: causes, frequency and intensity from records and models, operational forecasting, coastal topography and flood risk.
- *Tsunamis*: origin (Earthquakes, landslides), open-ocean propagation, coastal amplification, early warning systems.

Cryosphere Dynamics

- *Surface mass balance of glaciers and ice sheets:* contribution of radiative and sensible heat fluxes to melt, precipitation over ice sheets, meltwater refreezing.
- *Ice sheet flow*: stresses acting on a glacier, Glen's flow law, the Shallow Ice Approximation, Higher Order Approximations to flow
- *Remote sensing of ice/snow properties*: overview of RS ice/snow variables that can be measured using RS (albedo, melt, grain size, extent, ...)
- *Remote sensing of ice dynamics:* overview on monitoring mass balance (altimetry, gravimetry, input/output based on velocity data)
- *Ice sheet modelling*: main equations, types of models, boundary conditions
- *Climate modelling for ice sheets*: state of the art in regional and global climate modelling with application to the polar regions
- *Past ice sheets*: ice sheet evolution through glacial and interglacial periods
- *Contemporary mass budget of ice sheets*: reconstructions from gravimetry/altimetry and the input/output method
- *Projections of ice sheet change*: state-of-the-art, major certainties and uncertainties, challenges, effect of climate mitigation on ice sheet melt, comparison of scenarios
- *Sea-ice:* main processes, observation, modelling

Remote Sensing of Precipitation

This theory component aims at providing state-of-the art knowledge on multi-frequency remote sensing of precipitation. Focus is given on retrieval techniques of precipitation microphysics and precipitation dynamics from weather radar and micro-rain radar, and the validation of radar retrievals using in-situ rain measurements (disdrometers):

- Scanning and profiling weather/cloud radars: interpretation of radar reflectivity, polarimetric, Doppler and Doppler power spectra measurements.
- Identification and removal of non-hydrometeor data (clutter)
- Disentanglement of scattering and propagation variables in cloud radar measurements of rain, spectral polarimetry methodology. Attenuation estimation and correction.
- Retrieval techniques for estimates of rainfall, raindrop size distribution and wind.

Multi-Sensor Cloud and Atmospheric Observation

This unit targets synergetic use of various sensors used at conventional atmospheric and cloud observations that are key to retrieve vertical profiles of atmospheric temperature, water vapor and cloud micro- and macroscopic properties. Topics covered include:

- Microwave radiometry for temperature and humidity profiles
- Cloud remote sensing by lidar
- Cloud remote sensing by radar
- Synergetic cloud retrievals from radar, lidar and microwave radiometers