
KTH
VETENSKAP
OCH KONST
FLOW
LINNÉ FLOW CENTRE

CONTENTS

ABOUT THIS DOCUMENT

Linné FLOW Centre management

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Print: Åtta45, Järfälla, 2018

STARTING POINT AND CHALLENGES

The grand challenges for a sustainable society will involve highly increased efforts in the general areas of environmental and energy research. FLOW is well positioned to contribute to important subareas.

The Linné FLOW Centre at KTH is one of 20 original centres of excellence set up by the Swedish Research Council (VR), as the result of a highly competitive process with international evaluation.

A BLUEPRINT FOR FUTURE FLOW RESEARCH

The role of the Linné FLOW Centre has been to bring together and coordinate the fundamental fluid-dynamics research performed by the partners. It has enabled a strengthening of key areas as well as spearheading into new developing areas.

The application for FLOW was entitled **A blueprint for future flow research** and the vision was summarised in the first sentence of the application abstract: "This proposal aims at utilising new computational possibilities, hand-in-hand with new key physical experiments, to outline a blueprint for future flow research." FLOW has successfully followed the path outlined in the original application although the impact and importance of FLOW have become much larger than could have been anticipated at the time of the application.

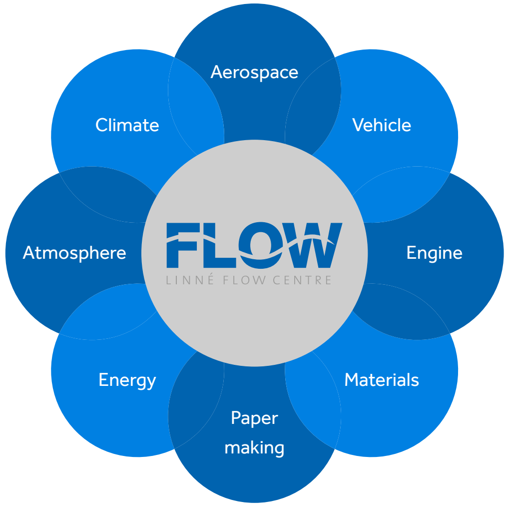
CHALLENGES

FLOW contributes to a number of important areas related to the grand challenges for a sustainable society. Examples are green transport, energy conversion processes (combustion, wind-energy and a number of other topics), climate-modelling-related research, environmental flows and similar.

INTERDISCIPLINARY

One of the most striking features of FLOW is that strong research groups in all three areas of experimental, computational and theoretical fluid mechanics are interacting. The fact that FLOW contains all the three pillars of scientific discovery, and that the centre has been instrumental for collaboration between these groups, is possibly its greatest achievement.

FLOW has enabled KTH researchers simultaneously to attain a globally leading position in fluid dynamics and pursue a number of intensive collaborations with applied research groups, increasing the scientific quality and advancing the deployment of the basic research results from FLOW. As part of its remit for research excellence, FLOW has also educated a large number of PhD students and provided important career progression for young researchers. The international recognition of FLOW is evident from its high scientific visibility and awards received.



The FLOW environment connects several areas of research and innovation that will be instrumental in addressing future challenges.

VISION, OBJECTIVES AND TOOLS

The ambitious vision pursued by FLOW has led to international acclaim in the field of fluid mechanics.

VISION

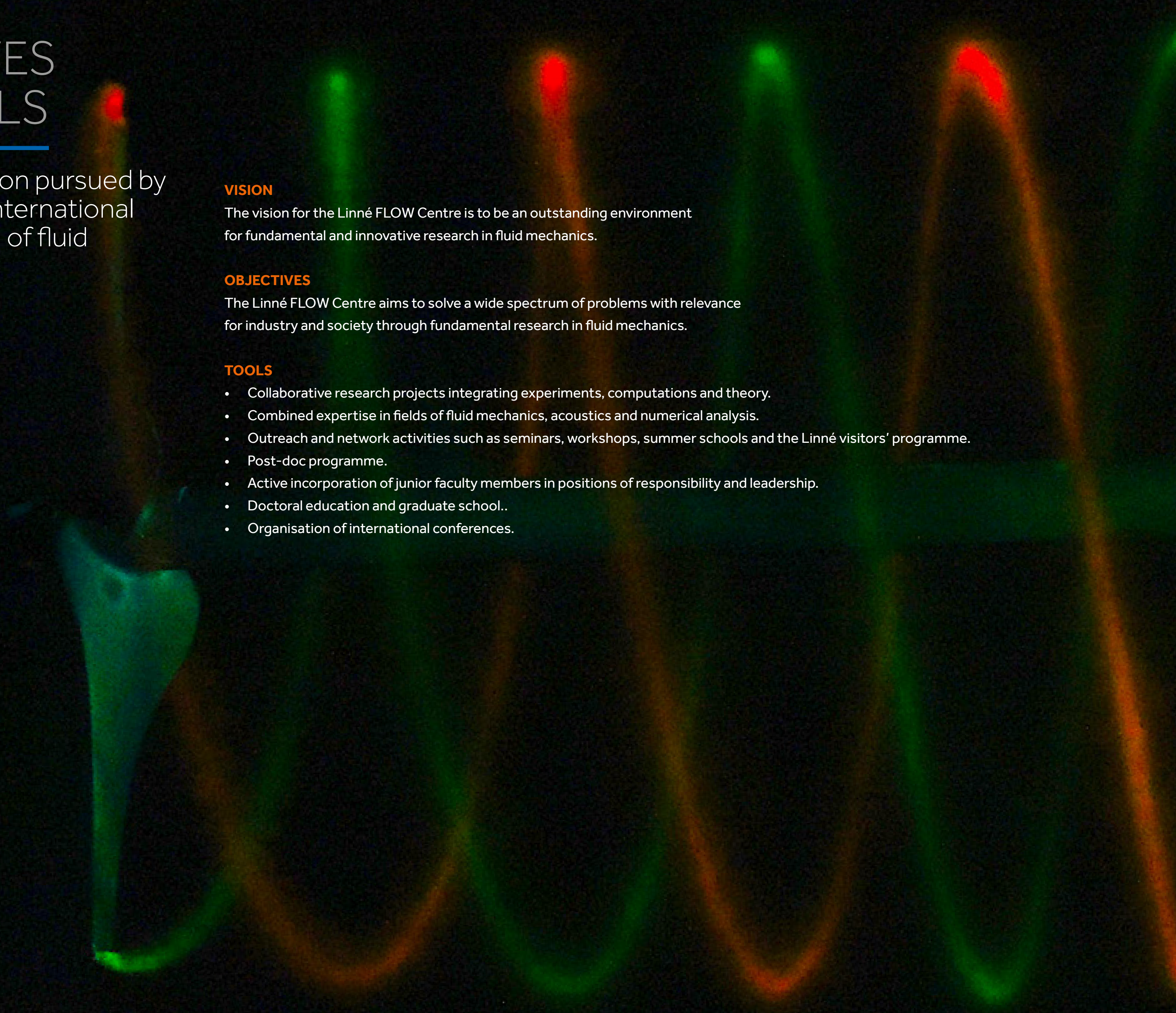
The vision for the Linné FLOW Centre is to be an outstanding environment for fundamental and innovative research in fluid mechanics.

OBJECTIVES

The Linné FLOW Centre aims to solve a wide spectrum of problems with relevance for industry and society through fundamental research in fluid mechanics.

TOOLS

- Collaborative research projects integrating experiments, computations and theory.
- Combined expertise in fields of fluid mechanics, acoustics and numerical analysis.
- Outreach and network activities such as seminars, workshops, summer schools and the Linné visitors' programme.
- Post-doc programme.
- Active incorporation of junior faculty members in positions of responsibility and leadership.
- Doctoral education and graduate school..
- Organisation of international conferences.



RESOURCES

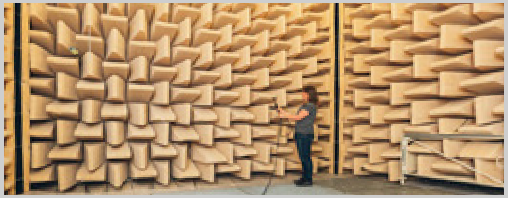
The research in FLOW is possible with access to world-class resources for experiments and simulations.

INFRASTRUCTURE

FLUID PHYSICS LABORATORY

fluidphyslab.kth.se

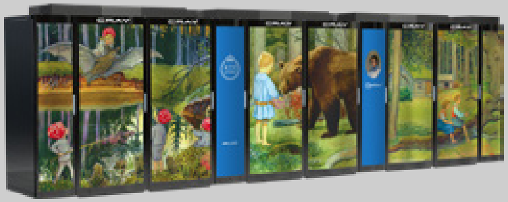
The Fluid Physics Laboratory has several high quality flow facilities as well as top of the line measurement equipment. Experimental work comprises studies into stability, transition and turbulence in boundary-layer flows, fibre-suspension flows related to paper manufacturing and compressible flow. The Minimum-Turbulence-Level (MTL) wind tunnel, which was inaugurated in 1990, due to its extreme low-disturbance flow, has proven to be a world-class resource for advanced transition and stability as well as turbulence research.



MWL

ave.kth.se/avd/mwl/mwl

The Marcus Wallenberg Laboratory for Sound and Vibration Research (MWL) is the largest university centre in northern Europe for experimental work related to sound and vibration problems. Here all types of measurements can be performed ranging from standard measurements of sound power or sound absorption to modal analysis and characterisation of mufflers, vibration mounts and materials. MWL also has an aero-acoustic test rig and a large experience in investigations of fluid machinery noise.

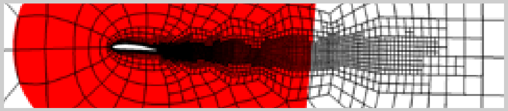


SNIC

snic.se

FLOW has access to the various super-computer resources managed by the Swedish National Infrastructure for Computing (SNIC). FLOW researchers are among the largest users of these computing resources. Since 2015, FLOW has had access to petascale computing resources.

SOFTWARE



NEK5000

nek5000.mcs.anl.gov

FLOW is among the main developers of the Nek5000 code which is one of the top softwares for highly accurate massively-parallel simulations of flow in complex geometries. Our contribution to automatic refinement of computational grids decreases the computational time significantly.

EVALUATION

Anyone can emphasise their own strengths. A more objective and humble approach is to quote external assessments. Here are some excerpts from the mid-term evaluation report.

THE EVALUATION

In 2012, the mid-term evaluation of all Linnaeus environments and doctoral programmes was performed. FLOW was among those 16 (of originally 20) centres that received continuous support.

NATIONAL AND INTERNATIONAL COLLABORATIONS

FLOW collaborates with the KTH Center for Gas Exchange, which deals with different problems of time-dependent gas flows, in particular, as related to internal combustion engines. Problems of cellulose processing are addressed by FLOW with the KTH/Chalmers Center for Wood Science. On a national level, FLOW collaborates with the E-Science activity involving also Stockholm University, the Karolinska Institutet, and Linköping University. FLOW cooperates with Stockholm University through the BBC Centre on the subject of climate research. FLOW and groups from Chalmers and Lund University created CeCOST, which is focused on combustion. Several high-Reynolds-number- related cooperative research activities have been established around FLOW involving U.S. and European institutions.

THE PANEL'S CONCLUSIONS AND RECOMMENDATIONS FOR IMPROVEMENTS

The FLOW Center has achieved a remarkable level of international visibility by building upon excellent research output from within its core area of numerical and experimental simulation and analysis of transitional and turbulent flows. It has been able to maintain and even extend the already impressive research output over the reporting period. For the final funding period the challenge will be to reach out to new and emerging fields in modeling of complex flows, and to further strengthen links with application areas in order to create a solid foundation for transitioning into a self sustaining state after 2016.

The E Panel feels positively about the scientific environment created by FLOW. The Center should have a bright future if the recommendations detailed below are implemented in a timely fashion:

- Exploit the existence of advanced numerical models by utilizing expertise in numerical mathematics to create new application codes.
- Foster the creation of innovative ideas via sponsorship of project-oriented internal workshops that include doctoral students.
- Stimulate high-risk/high-payoff projects through appropriate allocation of funds.

DYNAMICS CREATED

The FLOW Center has been instrumental in establishing the E-Science funding at KTH, emphasizing the significance of methodological advances and numerical simulation in several topical areas. Strategic networks were established between FLOW and the Wallenberg Wood Science Center, and in the fields of biotechnology, wind power, and combustion engines. FLOW is also part of the newly created Center for Experimental Mechanics* at KTH. Scientific outreach to industry is less characterized by direct industry funding, than by participation in industry-led consortia. This indicates that the gap is closing between fundamental research at FLOW and applications. The evolution from purely basic to include applied outcomes is noticeable when comparing the simple modeling in the original core- research program to their more recent, complex, applications-driven efforts, and the movement toward emerging areas.

*Odqvist Laboratory for Experimental Mechanics at KTH

FUTURE POTENTIAL

The future potential of FLOW lies in the scientific excellence of the PIs and in their ability to attract excellent graduate students to create a pool of young researchers that have the potential of becoming future research leaders. The long-term prospects of FLOW also depend, however, on the ability of the PIs to identify, support and exploit emerging new fields.

ACTIVITY

FLOW has been one of the single most important efforts for enhancing the scientific progress across large sectors of KTH research.

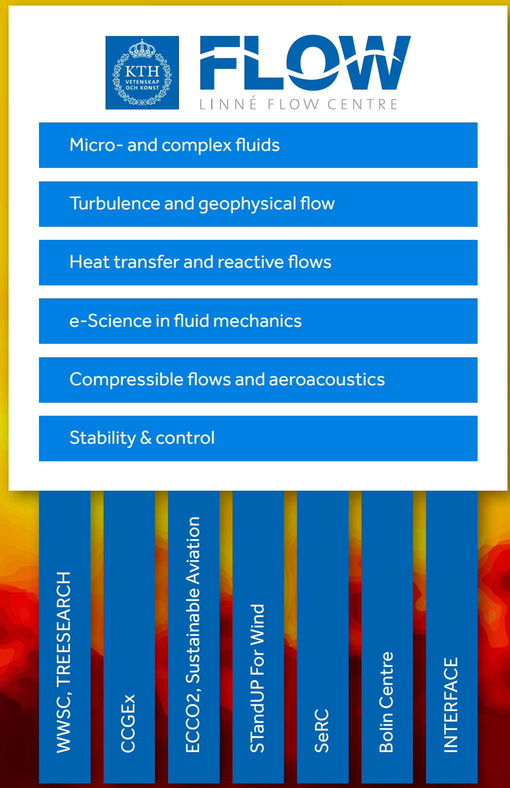
RESEARCH AREAS

At the current stage FLOW has six different priority research areas:

- Stability and control
- Turbulence and geophysical flows
- Micro- and complex fluids
- Compressible flows and aeroacoustics
- Heat transfer and reactive flow
- e-Science in fluid mechanics

EXAMPLES OF RESEARCH ACTIVITIES

- From optimisation and control theory to laminar flow control on aircraft wings
- From transient growth theory to modelling of laminar-turbulent transition in turbomachinery flows
- From modern turbulence simulations and experiments to accurate and efficient models of turbulent flow
- Multiscale modelling of flow phenomena at interfaces involving phase change, surface tension- and thermo-capillary effects
- Experiments and numerical simulations of fibre and particle suspensions in complex fluids
- Compressible flows and aeroacoustics associated with propulsion systems
- Sound generation and scattering in ducts with applications to low Mach number flows
- Biofluids - circulatory and respiratory flows
- Development of accurate and innovative numerical methods



FLOW researchers are involved in a number of other national research and competence centres.

CONNECTIONS AND COLLABORATIONS

From a general point of view, the most important impact of FLOW has been to function not only as a cohesive force between groups within the fluid dynamics area but equally important as a bridge to the numerous application areas stretching from complex flows in forest industry over wind power and combustion-engine design to nanofluidics in biotech equipment.

Connections and collaborations – KTH

The FLOW Centre consists of research groups from three departments at KTH: **Mechanics**, **Aeronautical & Vehicle Engineering** and **Mathematics**. The research is performed within different areas. FLOW collaborates with the following research centres, partly or wholly hosted at KTH:

- The **CCGEx** – Competence Center for Gas Exchange, focussing on time-dependent gas flows in internal combustion engines.
- The **Wallenberg Wood Science Center**, addressing cellulose processing.

FLOW has boosted the fluid mechanics research at KTH in several ways. It has given the young researchers possibility to expand their activities in fields that did not belong to its traditional area. It facilitated collaboration between different disciplines, and it created a strong and attractive environment which has helped to increase the external funding.

Among the prestigious fundings one can mention two **ERC Starting Independent Researcher** grants, one **ERC advanced grant**, **Foundation for Strategic Research** (SSF) and **Wallenberg Academy Fellows**.

Connections and collaborations – nationally

On a national level, FLOW collaborates with various academia and centres:

- **SeRC**, performing e-science reserach, together with Stockholm University, Karolinska Institutet, and Linköping University.
- **Bolin Centre**, performing climate research, together with Stockholm University.
- **CeCOST**, performing combustion-related research, together with Chalmers and Lund University.
- **STandUP for Wind** centre for advanced research on wind-power related aspects, together with Uppsala University and KTH.

Connections and collaborations – internationally

The organisation of international conferences and the establishment of international collaboration networks has been prominent features of FLOW's research environment and have significantly added to the international renown of KTH.

Besides the PhD programme and regularly organised summer schools, FLOW has successfully hosted a number of international conferences and workshops – for example the **7th IUTAM Symposium on Laminar-Turbulent Transition**, **16th AIAA/CEAS Aeroacoustics Conference**, **European Turbulence Conference ETC16**, NORDITA research programmes **Turbulent Boundary Layers & Turbulent Combustion**, and **Stability & Transition**.

FLOW has also been instrumental in the establishment of several EU projects in which KTH is a partner, including several where KTH had the coordinator role.

FLOW researchers have also been very active in **PRACE** (Partnership for Advanced Computing in Europe), securing a number of Tier-0 and Tier-1 computer-time grants amounting to more than 250 million core hours on the largest computers in Europe.

Connections and collaborations – industry

FLOW has been closely collaborating with industries in a wide range of sectors. Some examples are within aeronautics (**Saab**, **GKN**), automotive (**Scania**), railway (**Bombardier**) and food processing (**Tetra Pak**). The collaborations address both understanding of fundamental physical processes and technical solutions.

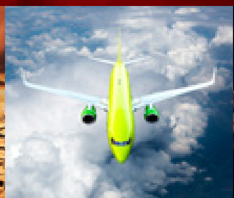
Connections and collaborations – society

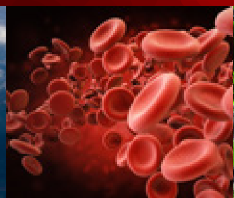
FLOW has been a key element in forming the e-science (e-science.se) agenda for Sweden and a driver for the development of the necessary high-performance computing infrastructure.

FLOW researchers established the **Centre for Sustainable Aviation** (kth.se/en/sci/centra/hallbarluftfart) and contributed to build **Centre for ECO2 Vehicle Design** (kth.se/en/sci/centra/eco2), the **Swedish Aeronautical Research Center** (sarc.center) and **Treesearch** (wwsc.se/treesearch).

In our **showcases** on the following pages, we will tell you about **FLOW impact on ...**


... climate modelling, ...


... green mobility, ...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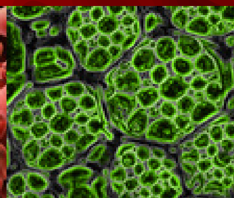

... materials processing, ...

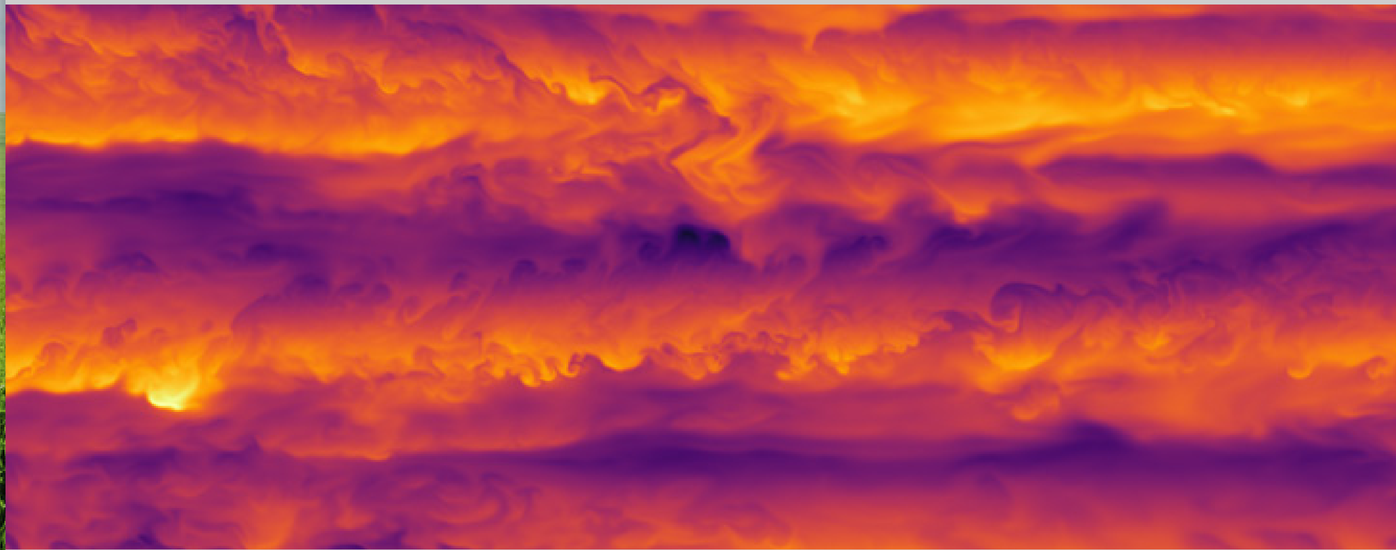

... and renewable energy.

FLOW
LINNÉ FLOW CENTRE
IMPACT

... ON CLIMATE MODELLING

REAL-LIFE PROBLEM

The climate on Earth is determined by processes on a vast range of scales; from hundreds of kilometers to micro scales. Many key climate processes cannot be resolved on the necessarily coarse numerical grid of global climate models used to study climate change and the effects of greenhouse gas emissions.



FLOW SOLUTION

These processes need to be modelled. Research by the FLOW community lays the groundwork for those essential subgrid-scale models and we also develop new advanced models for climate processes.

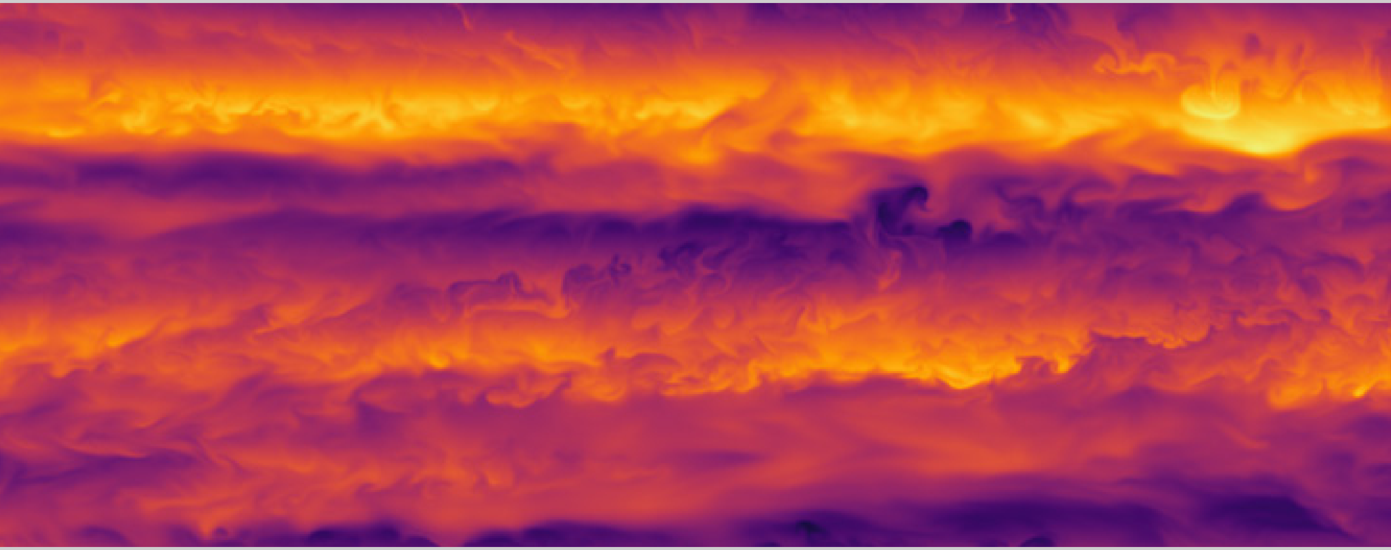
At the small scales, we have made an important contribution to the understanding of how turbulence in clouds affects the growth of water droplets and helps to produce rain through the use of detailed direct numerical simulations. This work led to a theoretical breakthrough published in Physical Review Letters 2015.

On a larger scale, our theoretical and numerical work led to completely new insights into the dynamics of stratified flows, as found in the atmosphere and oceans. Vertical motions are strongly damped when a flow is strongly stratified as the result of a density gradient, but our research has made clear that the dynamics stays essentially three-dimensional. This research provided an explanation for a number of puzzling observations in the atmosphere and the oceans. Our numerical and theoretical research in the mixing of stratified flows also helps to provide an answer to the question how fast heat is and us to capture much more of the underlying physics, as is exemplified by the good agreement with observations. This work also aims to develop better atmospheric boundary conditions and near-surface treatment in order to make climate projections more reliable.

COLLABORATION

FLOW is active in the **Bolin Centre** through which national and international collaboration have evolved.

Direct numerical simulation of a strongly stratified flow with density layers.



salt is transported in the oceans, thus contributing to the modelling of ocean circulations.

Another key aspect in climate models is the atmospheric boundary layer since this determines the heat exchange between the Earth's surface and the atmosphere and the transport of water vapour. The dynamics of the turbulent atmospheric boundary layer is highly complex and notoriously difficult to model. Most of the existing models are therefore of an empirical nature. We are developing a new model for the atmospheric boundary layer using a novel much more rigorous approach. This enables

FLOW PROFILE

- ○ Stability and control
- ● Turbulence and geophysical flows
- ○ Micro- and complex fluids
- ○ Compressible flows and aeroacoustics
- ○ Heat transfer and reactive flow
- ● e-Science in fluid mechanics

FLOW LINNÉ FLOW CENTRE IMPACT

… ON GREEN MOBILITY

REAL-LIFE PROBLEM

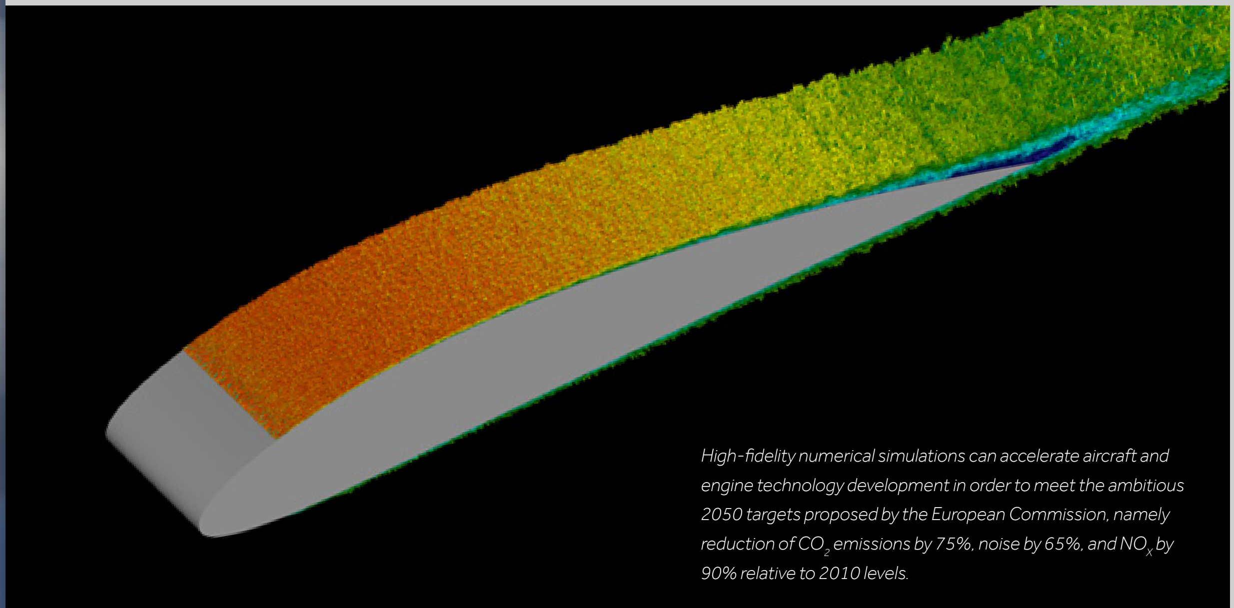
Transport of goods and people around the globe is an unavoidable ingredient of a globalised world. Increasing land-, sea-, and airborne transport stands for a significant amount of emission and noise pollution. A great part of the energy spend in the transport sector, roughly half, is used to overcome the resistance caused by the turbulent flow close to the surface of the vehicles. Therefore, the knowledge of flow close to these surfaces is essential for improved performance through optimal shape or passive/active flow control. Increased efficiency of the engines is also of great importance in creating a sustainable transport system.

FLOW SOLUTION

Our large-scale accurate and detailed numerical simulations of simple and complex flow cases have contributed to the understanding of details of relevant flow phenomena such as separation and laminar-turbulent transition. These simulations together with highly advanced experimental investigations, for example flow around wings, provide highly demanded knowledge required for design of low-drag/low-emission aircraft wings.

The European Commission proposed for 2050 to reduce aircraft noise by 65% relative to 2010 levels. The largest noise disturbances for aircraft engines are linked with jet noise. However, to reach the proposed targets, it is essential to address the relative importance of other noise sources, for instance direct and indirect combustion noise.

High-fidelity tools for computational aeroacoustics are extensively used to identify the mechanisms for noise generation in high-temperature turbulent flows, environments such as those encountered in jet engines.



High-fidelity numerical simulations can accelerate aircraft and engine technology development in order to meet the ambitious 2050 targets proposed by the European Commission, namely reduction of CO_2 emissions by 75%, noise by 65%, and NO_x by 90% relative to 2010 levels.

Tests at KTH show that trucks could reduce fuel consumption by up to 5 percent by using plasma actuators to cut wind resistance.

The gained knowledge enables new avenues for designing noise-suppression technologies for more silent and efficient engines.

Experimental and numerical investigations of modern flow-control approaches with application to flow around trucks and wing surfaces contribute to the development of efficient control devices which could lower drag through different mechanisms. An example is the application of plasma actuator for suppression of the flow separation around trucks, studied in close collaboration with Scania.

The long-term efforts such as research on quieter engines and short-time solutions like flight-path optimisation are other examples of topics through which FLOW research contributes to a sustainable transport system.

COLLABORATION

FLOW is involved in coordinating research towards a greener transport system through involvement – for example in the **Centre for Sustainable Aviation** and the **Swedish Aeronautic Research Center** – and through collaboration with industries – for instance **Bombardier**, **GKN**, **Saab**, **Scania** and **Volvo**.

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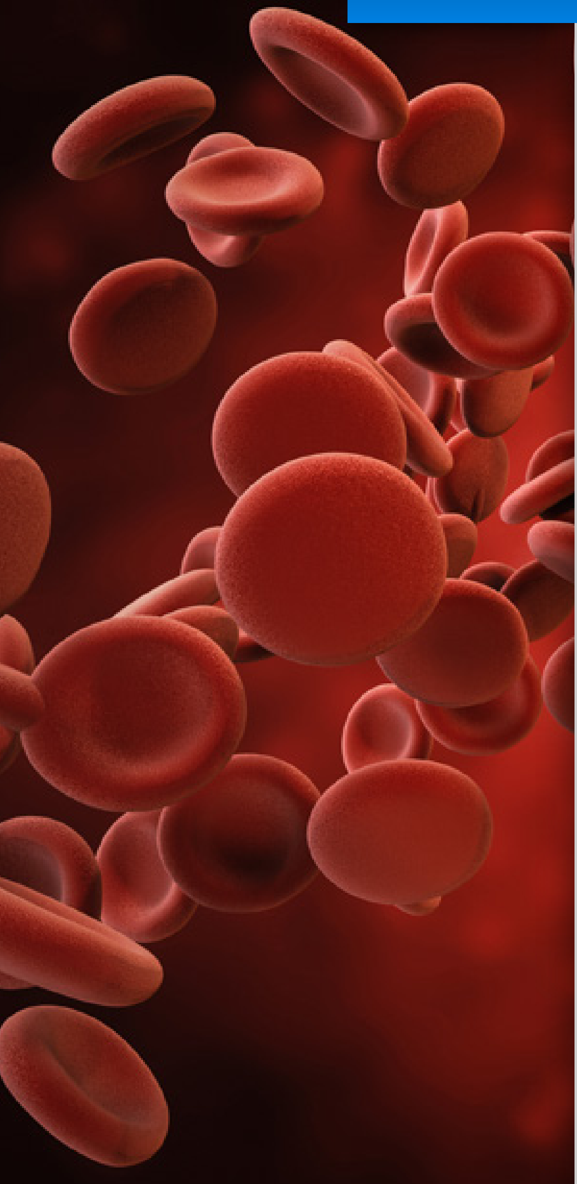
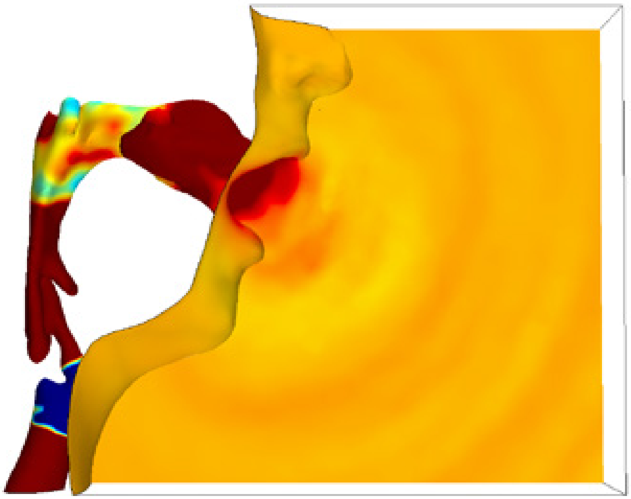
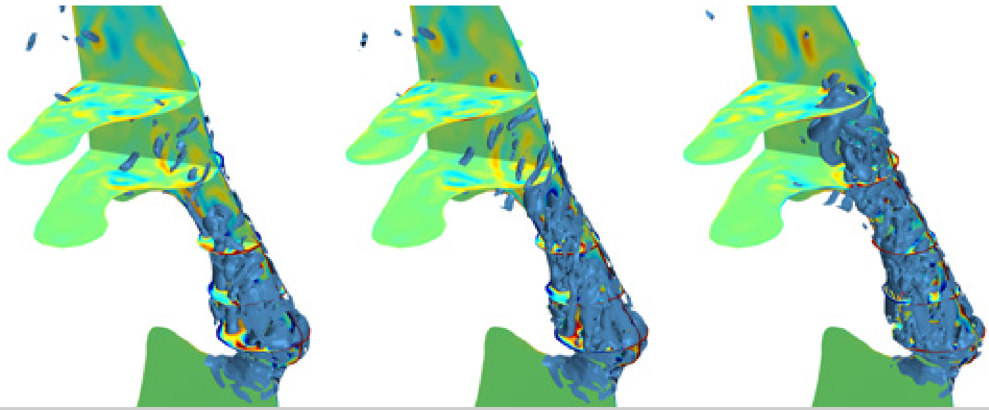


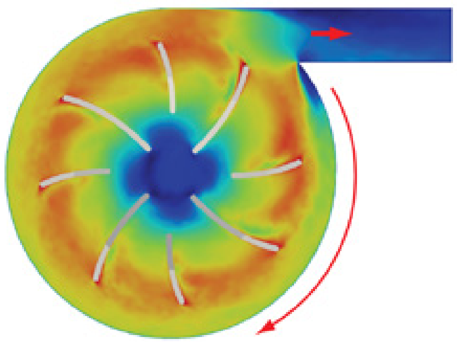
... ON HEALTH

REAL-LIFE PROBLEM
Most common diseases affecting large populations are often hemodynamics-related, including cardiovascular diseases and stroke. Cardiovascular diseases in particular constitute the number-one cause of death in the industrialised Western countries; yet the underlying causes and the mechanisms behind the pathological processes remain unknown. Furthermore, there is a considerable economic strain put on welfare states to finance therapy and surgery. Similarly, the manifestation and/or treatment of diseases in lungs and kidneys are also closely related to fluid flows.

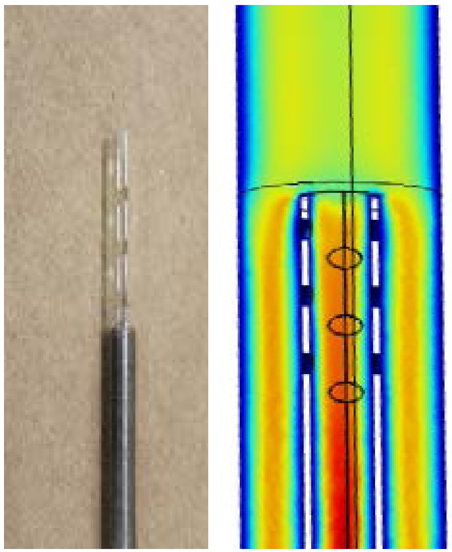


Speech process simulation using MRI-based geometries. The flow structures in the vocal tract region are shown at three stages.





Numerical simulation of a centrifugal blood pump.



Simulated flow in a cannula with multiple wholes placed in a vessel under steady flow conditions.

FLOW SOLUTION

An analysis of the flow inside biological systems based on medical imaging data of subjects in healthy and diseased state helps to understand the causes and underlying processes of these diseases.

Also, linking clinical observations with numerical as well as experimental basic fluid dynamical investigations can provide knowledge regarding grafts, implants and artificial components such as extracorporeal blood pumps and cannulae.

Moreover, data about the flow can be used in order to predict the risk for thrombus formation or hemolysis, enabling the development of improved therapy procedures. In the area of airway flows and speech, fluid dynamics and aeroacoustics simulations, validated by experiments, facilitates studies of physical flow mechanisms that are difficult to observe with any diagnostic tool.

COLLABORATION

This research is carried out in close collaboration with specialist in areas such as radiology, cardiology, intensive care, nephrology and ENT (ear, nose and throat).

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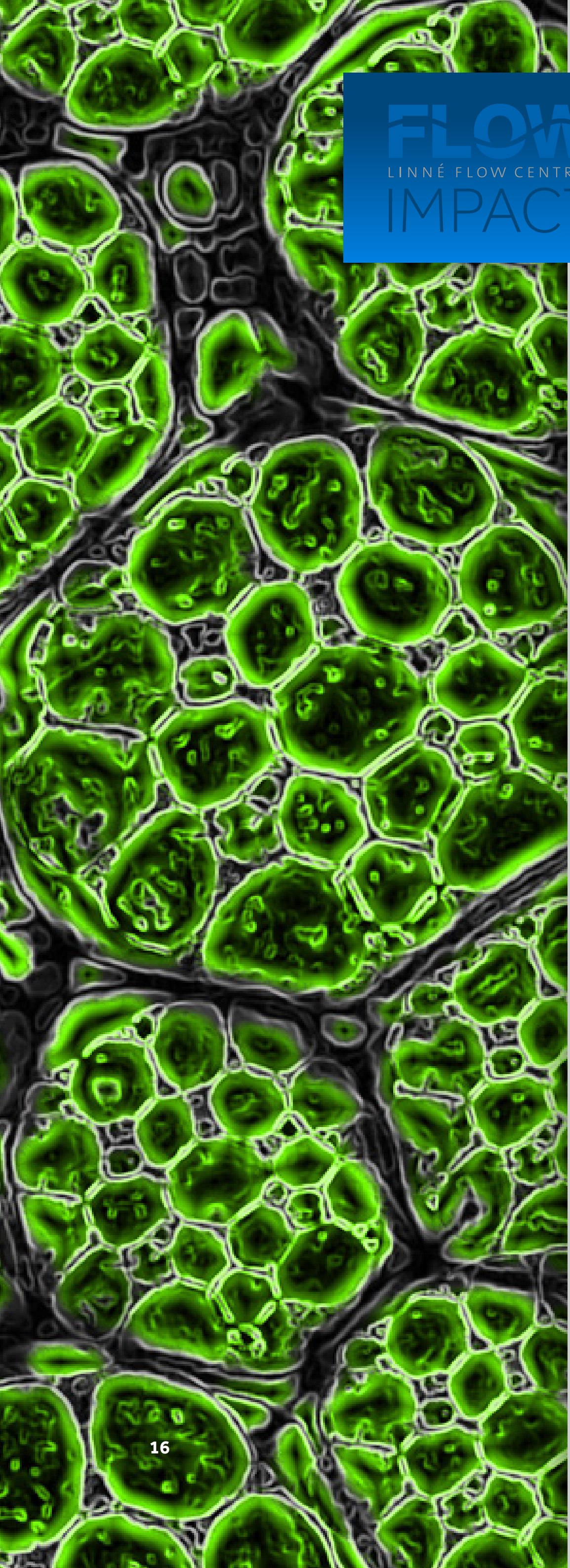


... ON MATERIALS PROCESSING

REAL-LIFE PROBLEM

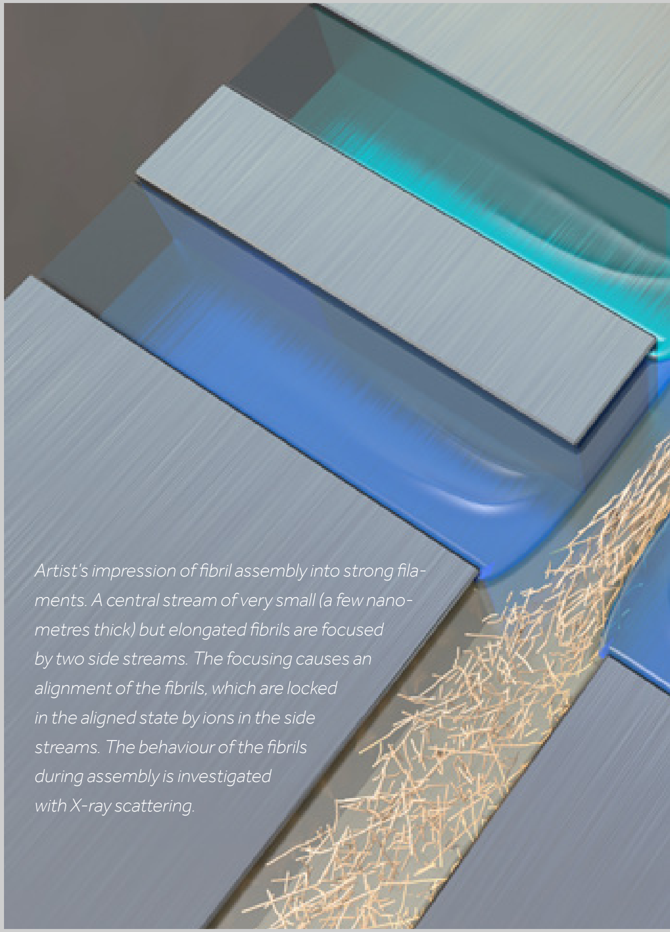
Advanced biocompatible functional materials are needed to develop sustainable solutions to our challenges when it comes to health, water purification and energy storage. In order to achieve this, processes that allow assembly of materials with a controllable structure on all scales, from molecular scales via nano-, micro- and millimeter scales all the way up to the final size, must be developed. FLOW researchers take part in multiple efforts making this possible.

FLOW SOLUTION

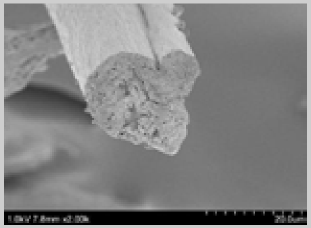
A result from collaboration between FLOW's Complex Fluids group and Wallenberg Wood Science Center is a patented technology that can be used to assemble cellulose nanofibrils obtained from trees into the strongest biomaterial reported to date. The key to this achievement has been fundamental understanding of how elongated particles behave in different flows. At FLOW, such knowledge is developed by combining theoretical, numerical and experimental tools.

This approach has been applied to a number of situations that are critical for the development of future materials. In addition to elongated particles in flows mentioned above, droplets in flows and wetting on surfaces can be mentioned. The latter two are key mechanisms in processes such as painting, powder production and additive manufacturing.

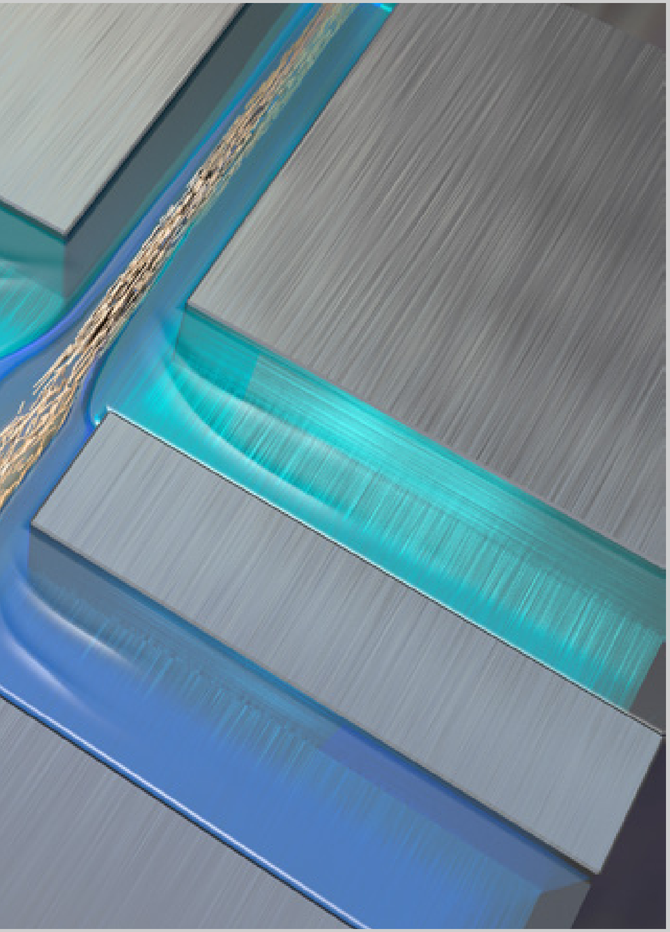
These flow cases have something in common: they are governed by multiple physical phenomena. Fluid dynamics is coupled with free surface dynamics (surface tension), the behaviour of a liquid front on a surface (wetting) or the behaviour of particles in the flow (suspension dynamics). Theoretical investigations of the fundamental physics involved together with advanced and novel numerical methods have made it possible to



Artist's impression of fibril assembly into strong filaments. A central stream of very small (a few nanometres thick) but elongated fibrils are focused by two side streams. The focusing causes an alignment of the fibrils, which are locked in the aligned state by ions in the side streams. The behaviour of the fibrils during assembly is investigated with X-ray scattering.

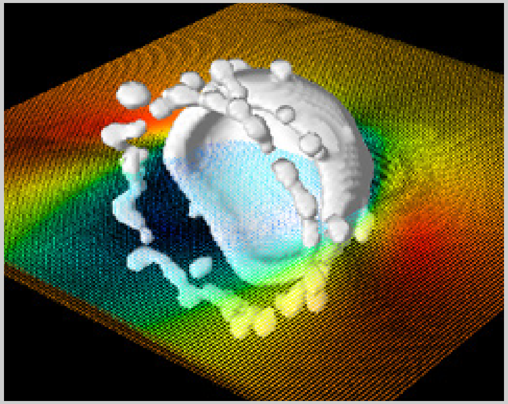


Scanning-electron-microscopy image of the resulting filament. The diameter of the filament is approximately 12 μm.



develop numerical tools for these complex flow situations.

On the experimental side, a challenge has been that either the time- or length scales are very short or small, respectively. In order to study phenomena as fast as 0.01 milliseconds and as small as a few nanometres, access to state-of-the-art experimental facilities such as high-speed cameras in the 100-kHz range and synchrotron X-ray sources has been instrumental.



Numerical simulation of a droplet breaking up in a gas. The gas flow tears off smaller droplet from the main drop. Simulations like this give new insights into applications such as powder manufacturing and painting.

COLLABORATION

The FLOW research on assembly of novel biomaterials is performed as a part of the **Wallenberg Wood Science Center**. A close collaboration with **Deutsche Elektronen Synkrotron** (DESY) in Hamburg has been established and gives access to advanced characterisation techniques. Other recent collaborators are **RISE** and **Holmen**.

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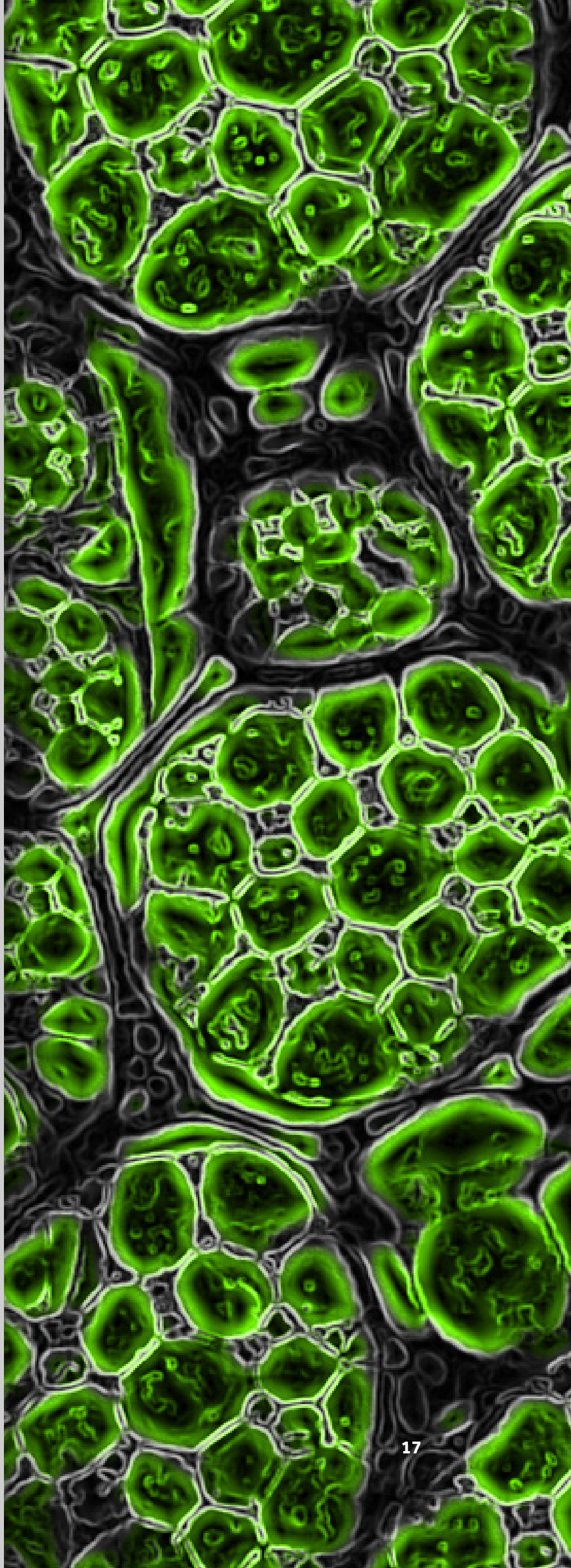


... ON RENEWABLE ENERGY

REAL-LIFE PROBLEM

The worldwide energy demand is a challenge that must be solved to ensure a sustainable future. In the last 30 years, there has been a continuous growth of wind energy worldwide since wind turbines produce energy almost without an environmental impact, using the wind as the source to extract energy from. However, wind energy is more challenging than other energy sources during the planning, design and operation of a power plant. Indeed, many countries have undertaken significant research, pushed by the industrial need, to develop new tools and to understand more about wind turbines and wind farms placed over simple and complex terrains.

THE FLOW SOLUTION

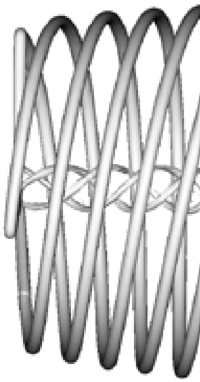
There are three main ingredients characterising a wind-energy project, all of them actively studied at FLOW:

The wind resource

Since the power generated by a turbine scales with the cube of the wind speed, it is of paramount importance to assess as best as possible the wind resource, at least from a statistical point of view. Several experimental campaigns in wind-tunnel settings and in the atmosphere have been conducted to increase the understanding of the wind aerodynamics over complex terrains with particular focus on forested areas.

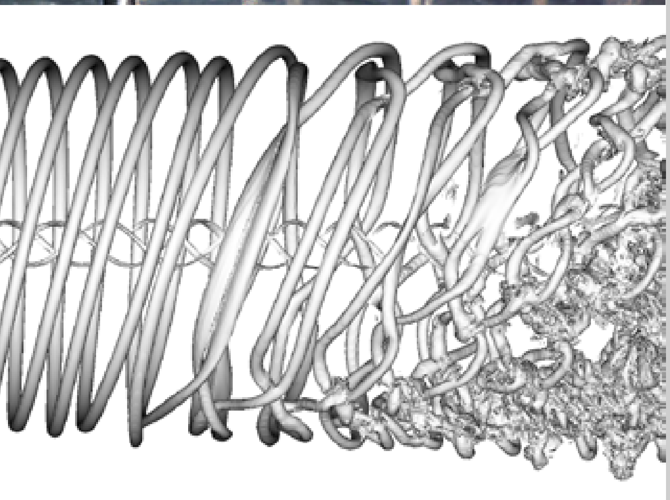
The aerodynamics of the wind turbine

Currently, wind turbines are often still designed according to theories developed in the last century. However, the understanding of the wake downstream of a wind turbine is still far from complete. The helical tip-vortex structure released by the rotor blades has been the focus of several wind-tunnel, numerical and theoretical investigations at FLOW. After a distance corresponding to several rotor diameters downstream, the ordered wake



Simulations of the breakdown of the tip-vortex structure (visualised using vorticity magnitude) under sheared inflow when perturbed harmonically at the blade tips.

An example of an inline wind farm in the MTL wind tunnel at KTH. 150 turbines were involved in the measurement campaign.



pattern is lost due to non-linear interactions of the vortex structures. The wake breakdown mechanism has been analysed in detail, including effects of sheared inflow and yaw misalignment. The accuracy of numerical simulations is a key ingredient to providing reliable data, and to this end, several graduate projects have been actively developing new high-order simulation tools.

The wind-farm aerodynamics

Coupled with the previous point, when multiple turbines are present, it is possible that some turbines operate in the wake of previous ones, with a decreased power production of the wind farm. It is still unclear how to model accurately interacting wakes: while industry is still using very crude approaches based on prescribed wake superposition, FLOW is performing large-eddy simulations and wind-tunnel experiments to provide quantitative or at least qualitative observations. A recent experiment performed at KTH involved a large number of turbines to understand the physics of the energy transfer taking place over a long wind farm. In collaboration with Vattenfall, several experiments have been performed to assess how multiple turbines with different arrangements provide an effect upstream of the farm.

COLLABORATION

The activities within FLOW in the area of wind power are performed as a part of the **STandUP for Wind** centre, a close collaboration with Uppsala University, Campus Gotland and Technical University of Denmark (DTU).

FLOW PROFILE

- ● Stability and control
- ● Turbulence and geophysical flows
- ○ Micro- and complex fluids
- ● Compressible flows and aeroacoustics
- ○ Heat transfer and reactive flow
- ● e-Science in fluid mechanics

EDUCATION

Meet five of our alumni with their testimonies about research life at FLOW.

GRADUATE SCHOOL

A FLOW graduate school was started in January 2008 with five-year funding of 1.5 million SEK/year from the Swedish Research Council. Although formally separate, it was decided from the start of the graduate school to align it with FLOW as a fully integrated activity and with the same governance management structure. Activities of the graduate school continued even after its original period through FLOW funding.

INTERVIEW:

JOHAN MALM, PHD STUDENT

Current position: AI/ML algorithm developer at Imagimob

To me, the FLOW research environment was an environment with a lot of resources, knowledge and drive. It required much of you as a student, but you got very much back.

My doctoral studies at the Linné FLOW Centre are the most important of all studies I have had in my life. Most importantly, I have learned how to run and plan a research project, which has been extremely valuable in all jobs I have had so far, even though the topic has often not been fluid mechanics.

At FLOW, I always had the feeling of being backed up financially. Going to conferences, taking courses, making trips to start collaborations were never a problem.

INTERVIEW:

ONOFRIO SEMERARO, PHD STUDENT

Current position: Researcher at LIMSI

My experience at the FLOW has been very international. The centre is literally a research hub, thanks to the numerous internal and external collaborations, the possibility at participating at local/international research programmes and world-leading conferences. FLOW allows people to perform cutting-edge research, also thanks to the availability of high-level computer facilities allowing very large-scale computations.

My time at FLOW has been very productive. My doctoral studies are probably among the strongest assets that have helped me for getting this research appointment. I have acquired numerous abilities that have helped me in shaping some of the applications I did in the past years (mainly for academic positions).

At FLOW, I learned that a research group and the academic world are places of discussion, exchanges, and sharing of knowledge. I mistakenly assumed that that these aspects are obvious in any research environment, but my post-doctoral experiences have shown that they were rather unique to the FLOW environment. I will consider as a personal success if I will be able to introduce/implement/share this attitude in my future positions and environments.

POST-DOC PROGRAMME

From the start, it has been an ambition to increase the amount of research conducted by the post-docs and we succeeded to make FLOW an attractive centre for incoming post-docs. Totally 55 post-doctoral researchers have been active at different research groups within FLOW in 2007–2017. Of these 55, twelve positions have been funded through FLOW core funding and the rest through other additional funding.

INTERVIEW :

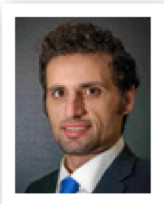
SEYED MOHAMMAD HOSSEINI, PHD STUDENT

Current position: Data scientist at Electrolux

The FLOW research environment is generally a good environment providing supplements such as literature, funding for attending conferences, and a network of researchers. Additionally, the centre provides a good opportunity for collaborations between different groups.

I enjoyed my time at FLOW a lot, especially during the events organised by the centre. It was however sometimes hard to distinguish between the centre and KTH Mechanics. The FLOW centre is well known within the fluid mechanics community; it could be a great opportunity if more outside guests would attend possible conferences by the centre.

The best part of being at FLOW was the support and the network provided by the centre.



INTERVIEW:

ELLINOR APPELQUIST, PHD STUDENT

Current position: Researcher at Alfa Laval

FLOW's many connections to other universities and researchers contributed to a high-level research environment. The connections made it possible to be on top of your research by attending the best conferences and discussing your research with the right people.

The fact that many PhD students started at the same time was an advantage when you needed a push forward, either to discuss your research, application procedures to conferences, or which courses to take.

Without FLOW, I wouldn't have secured my PhD position because it was funded by FLOW and because my fluid-dynamics experience prior to my PhD project was in another field. Also, when I finished my studies, I had many future career opportunities to choose from – definitely thanks to FLOW.

There were many good things about FLOW, but one of the best things was that it forced you to get out of your office to communicate with others (FLOW annual conference and FLOW beer). This created an environment where people knew each other, and where you experienced research that could be far from your own field but still interesting for you.

INTERVIEW:

EKATERINA EZHOVA, POST-DOC

Current position: Researcher at University of Helsinki

FLOW's financial support of selected projects suggested by applicants was a great idea. It brought to the department new people with different backgrounds. For me it was an excellent chance to get experience on a new method – numerical simulations – and to see my area of research from a different perspective. It was a chance to start as an independent researcher and ultimately to get the feeling that I can do it. I had three first-author papers in a prestigious oceanographic journal in my less than two years at FLOW.

At FLOW I learned about the importance of collaboration. Nothing is impossible, one just has to contact the right person. The network of people at FLOW is extremely wide – and extremely useful. Also, the computational resources are really impressive.

During my FLOW period I took several courses which I thought would be useful – not only at KTH, but at Stockholm University and at the University of Helsinki.

My FLOW experience helps me to better understand the outcome of numerical models, to estimate what models can capture and what they can not. This is valuable knowledge in Earth sciences where numerical modelling plays a very important role.

FACTS, FIGURES AND GRAPHS

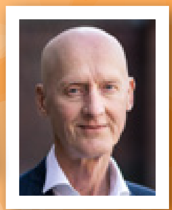
FLOW's development over the years is best expressed in terms of objective indicators.

BASICS

- Official kick-off: January 2007.
- Number of faculty & researchers: 41
- Total number of PhD students: 87
- Total number of postdocs: 55

DIRECTORS THROUGH THE YEARS

2006–2010: Dan Henningson

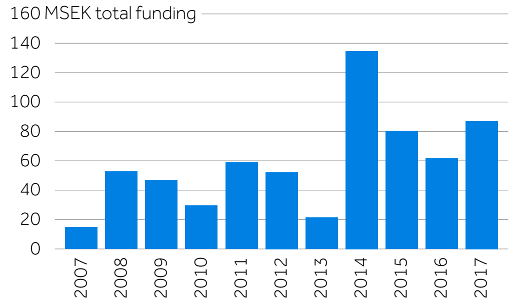


2010–2014: Arne Johansson

2014–present: Philipp Schlatter

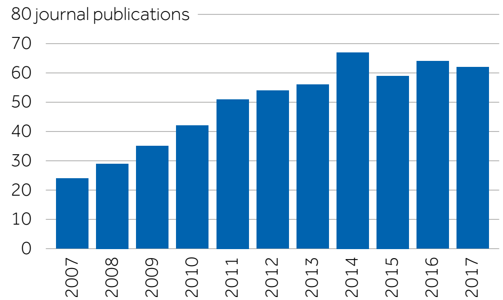
FINANCING

From July 2006 to June 2016, FLOW has received funding from VR (5 MSEK per year) and KTH (1 MSEK per year). This has been only a small part of the total funding to FLOW researchers, indicating the strong synergy effects of FLOW.



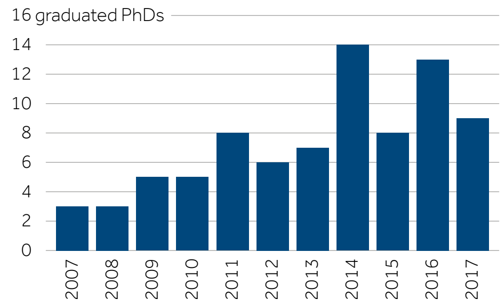
PUBLICATIONS

The experiments and simulations performed in our facilities have generated a large number of high-quality scientific journal papers and doctoral theses. The large number of publications in high-ranked journals is a proof of FLOW's success. Many of these publications are results of research in new areas and new interdisciplinary collaborations promoted by FLOW.



GRADUATIONS

An important measure for FLOW, in addition to publications, is the graduation of large number of high-quality PhD students in the general area of fluid mechanics.



EXCEPTIONAL ACHIEVEMENTS AND AWARDS

FLOW researchers have received three **ERC awards**, two **KAW Academy Fellows**, an **SSF Future Research Leader**, an **Outstanding Young Researcher** award and an **Alexander Humboldt Prize**.

FLOW IN THE FUTURE

Building on our success ...

NEW METHODS AND TECHNOLOGY ...

The development of faster and more efficient computing resources, better measurement systems and advances in modelling of different flow phenomena open for a range of new applications and research topics in a not so far future. Based on the wide competence of FLOW, our research will be influential in field of the fluid mechanics.

... WILL BRING A REVOLUTION

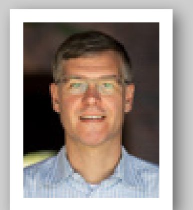
Our capability and competence in high-fidelity simulations of complex flows and novel ways of optimisation will help to revolutionise computer-aided prediction and design in areas as diverse as cars, trains, ships or aircraft and biomedical applications (patient-specific computational fluid dynamics). With our improved models of turbulent flows we will contribute to more accurate climate and weather prediction.

Our comprehensive computational multi-physics-based approach will enhance the understanding of physics of the blood- and airflow in the human body, which will enable us to develop technics that will improve the quality of life of patients with airway- and heart disorders. The developed tool shall enable the determination and understanding of disease pathophysiology, its severity, and the risks for flow-induced obstruction at pre and post-treatment.

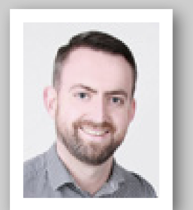
Our advances in modelling and simulations of micro fluidics, wetting process and phase change on micro and nano-patterned surfaces will help produce new coating materials reducing friction drag and thereby energy consumption. The potential of using flow-induced micro- and nanostructures in assembly of novel biomaterials with different functions is tremendous. Our increased understanding of boiling and heat transfer over complex hydrophilic and hydrophobic surfaces will result in production of novel and improved energy-conversion processes, for instance waste-heat recovery.

THE NEXT-GENERATION FLOW FACULTY

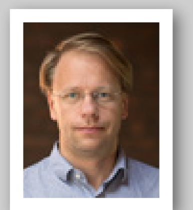
During the last ten years a number of young faculty members has been recruited who with their enthusiasm and fresh ideas will lead FLOW into the future.



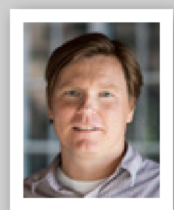
Christophe Duwig



Ciarán O'Reilly

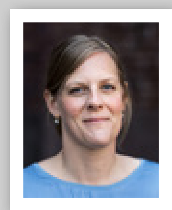


Fredrik Lundell

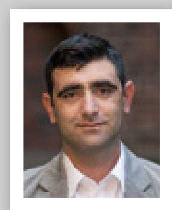


Jens Fransson

Luca Brandt

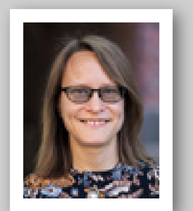


Lisa Prahl Wittberg

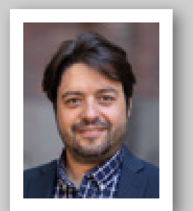


Michael Liverts

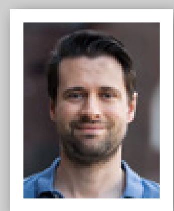
Mihai Mihaescu



Outi Tammisola



Philipp Schlatter



Ricardo Vinuesa

Sara Zahedi

Shervin Bagheri

Susann Boij

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