INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

# *Team clime*

# *Couplage de la donnée environnementale et des modèles de simulation numérique pour une intégration logicielle*

*Rocquencourt*

THEME NUM

Activity Report

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# 2. Overall Objectives

## 2.1. Overall Objectives

The international political and scientific context is indicating the serious potential risks related to environmental problems, and is also pointing out the role that can be played by models and observation systems for the evaluation and forecasting of these risks. At the political level, agreements such as the Kyoto protocol and European directives on air quality or on major accident hazards involving dangerous substances (Seveso directive) establish objectives for the mitigation of environmental risks. These objectives are supported at a scientific level by international initiatives like the European GMES program (Global Monitoring of Environment and Security), or national programs such as the Air Chemistry program, which will give a long term structure to environmental research. These initiatives emphasize the importance of observational data and also the potential of satellite acquisitions.

The complexity of the environmental phenomena, as well as the operational objectives, necessitate a growing interweaving between physical models, data processing, simulation and database tools.

This situation is met for instance in atmospheric pollution, an environmental domain whose modelling is gaining a widening importance, either at local (air quality), regional (transboundary pollution) or global scale (greenhouse effect). In this domain, modelling systems are used for operational forecast (short or long term), detailed case studies, impact studies for industrial sites, management of different spatial and temporal scales, coupled modelling (e.g. pollution and health, pollution and economy). These scientific subjects strongly require coupling the model with all available data; these data being either of numerical origin (e.g. models outputs), or coming from raw observations (e.g. satellite acquisitions or information measured in situ by an observation network), or obtained by processing and analysis of these observations (e.g. chemical concentrations retrieved by inversion of a radiative transfer model).

The Clime team has been created for studying these questions by joining researchers in data assimilation and modelling from the CEREA laboratory (ENPC, Ecole Nationale des Ponts et Chaussées) and INRIA researchers in environmental data and image processing. The Clime team carries out research in three directions:

- Environmental data processing, notably satellite data, by means of computer vision techniques and by accounting for the physical information on the acquisition process and on the dynamic of the observed phenomena.
- Data and model coupling, by means of data assimilation techniques and related issues (optimization problems, targetting observation, uncertainties propagation, ...).
- Development of integrated chains for data/models/outputs (system architecture, workflows, databases, visualisation, ...).

# 3. Scientific Foundations

## 3.1. Environmental images and data processing

**Keywords:** *change detection*, *image assimilation*, *inverse problem*, *matching*, *monitoring*, *motion*, *remote sensing*, *tracking*.

The overall objective is the extraction of dynamic information from sequences of images -and notably satellite images-, for provision to environmental forecast or monitoring systems. Information extraction must satisfy the following constraints:

- All the available physical information should be accounted for. This concerns the dynamic of the observed phenomena (e.g. evolution law) and the process of image formation (e.g. radiative transfer and sensor model).
- The information is extracted from images in view of data assimilation within a numerical model: the nature of information, as well as the process used to extract it, must therefore be compatible with data assimilation.

The dynamic information to be extracted can be classified into two main groups:

- Dynamic structures: structures moving on image sequences. This is for instance the case of fluid structures in meteorological and oceanic image sequences (clouds, fronts, eddies, filaments). These structures are tracers of the fluid flow, and hence their apparent motion is an information that can be assimilated in an environmental forecast system. The fluid and turbulent nature of the involved flows necessitate the design of specific image processing methodologies for apparent motion estimation, tracking of deformable structures, trajectory estimation, turbulence characterization. The investigations concern the nature of the physical information to be used for dynamic structures extraction. The two following alternative approaches are studied:
  1. establishment of visual description models of images,
  2. use of the physical evolution and transport equations, expressed in the physical model space or in an image space to be defined.
- Parameters: evolution in time of a physical parameter. Environmental models frequently require a physical parameterisation: for instance, chemistry-transport and radiative transfer models require energy budget parameters (emissivity, albedo), agronomical models require vegetation and leaf area indices, hydrological models require the knowledge of evapotranspiration. This research falls in the general framework of inverse problems: a model (either physical or empirical) of image formation is inverted to retrieve parameters of interest. Addressing this problem in the context of image data permits the design of image-based regularisation techniques, where the information coming from neighboring pixels is used to constrain the inversion process. Finally, monitoring the temporal evolution of the retrieved parameter, and being able to characterise and detect normal and abnormal evolution, is a strong requirement of environmental monitoring systems.

The effective use of the extracted information by environmental models arises the general problem of image assimilation. Most of existing approaches are restricted to the assimilation of images, considered as a collection of individual measurements, directly related to state variables. The challenge is the design of methods for assimilating the structured information contained in image data and sequences. This requires tackling the following issues:

- Image processing methodologies for extracting structured information, as previoulsy discussed.
- Definition of mathematical spaces for characterising the structured information. Different levels of abstraction (e.g. a curve can be seen as a collection of points, or as a parameterised curve, or as a level set) must be considered, each carrying a different amount of information.
- Definition of observation operators mapping the model's state space to the image space.
- Definition of a norm, or of a family of norms, in the image space. These norms are used to assess the discrepancy between model's results and image observations.

## 3.2. Data assimilation and inverse modelling

**Keywords:** *data assimilation*, *ensemble forecast*, *inverse modelling*, *network design*.

This activity is one of the present major stake in environmental sciences. It matches up the setting and the use of data assimilation methods, notably variational methods (4D-var). An emerging point lies in uncertainties propagation in models, notably through ensemble prevision methods.

Although modeling is not part of the scientific objectives of the Clime team, we have a complet access to models developed by CEREA (joint ENPC/EDF R&D laboratory): Polair3D (photochemical pollution forecasting at continental and regional scales) and MERCURE (urban scale) for air quality problems. Concerning other modelling domains, the Clime team accesses models through co-operations. For instance, a shallow model of the Black Sea circulation developped at Marine Hydrophysical Institut (MHI, Ukrain), the radiative transfer model LBLRTM developped at Atmospheric Environment Research (AER), *etc*.

The research activities tackle scientific issues such as:

- Which observational network must be set up for performing a better forecast, taking into account additional criteria such as observation cost? What are the optimal location, type and mode of deployment of sensors? How to operate the trajectories of mobile sensors, while the studied phenomenon is evolving in time? This issue is usually referred as 'network design'.
- How to assess the quality of the prediction? How do data quality, missing data, data obtained from sub-optimal locations, affect the forecast? How to better include information on uncertainties (of data, of models) within the data assimilation system?
- Among a family of models (differing by their physical approximations or their discretization parameters), what is the optimal model for a given set of observations?
- How to perform forecast (and a better forecast!) by using several models coming from different institutes, or different parameterizations (corresponding to different physical configurations) of the same model? In both cases we have a set of models and it raises the question: how to assimilate data in this context?

## 3.3. Software chains for environmental applications

**Keywords:** *database*, *system architecture*, *visualisation*, *workflow*.

The objective of the Clime project lies in the participation to the design and realization of software chains for impact assessment and environmental crisis management. Such software chains put together static or dynamic databases, data assimilation systems, forecast models, processing methods for images and environmental data, complex visualization tools, scientific workflows ...

The Clime project is currently building such a system for air pollution modelling: Polyphemus (see Internet page http://www.enpc.fr/cerea/polyphemus ), which architecture is specified to account for the data requirements (e.g. various raw data nature and sources, data preprocessing) and the different usages of an air quality model (e.g. forecast, data assimilation, ensemble runs).

# 4. Application Domains

## 4.1. Panorama

The first and priority application domain is atmospheric chemistry, since this is the research topic of CEREA. We have at our disposal the 3D Eulerian chemistry transport model Polair3D and its adjoint, thus capable of data assimilation. Atmospheric data processing will aim at providing Polair3D with relevant input data.

A second application domain is oceanography. The objective is comparable: providing oceanic circulation models with relevant information, extracted from satellite images. This information is ingested within models using data assimilation techniques. The application domain is getting of crucial interest owing to the numerous satellite sensors providing relevant information on oceanographic modelling.

A third application domain is meteorology, in particular the forecast of extreme events. Problematics concern the identification and extraction, from satellite images, of precursors of extreme events, for further assimilation within conceptual meteorological models.

Finally, Clime carries out applied remote sensing approaches in close cooperation with environmental experts. These studies concern the potential use of satellite data for monitoring agriculture and natural risks: monitoring of land cover changes, assessment of hail damages, soil degradation (deforestation, desertification) and fire plumes. For these studies, an image model of the observed phenomenon is first established, then tracking and change detection techniques are applied in the state space of this model.

## 4.2. Air quality

Air quality modelling implies studying the interactions between meteorology and atmospheric chemistry in the various phases of matter, which leads to the development of highly complex models. The different usages of these models comprise operational forecast, case studies, impact studies, *etc*, with both societal (e.g. public information on pollution forecast) and economical impacts (e.g. impact studies for dangerous industrial sites). A model lacks some appropriate data, notably emissions, for performing an accurate forecast and data assimilation techniques are recognised as crucial for the improvement of forecast's quality. These techniques, and notably the variational ones, are barely surfacing in atmospheric chemistry.

In this context, the Clime team is interested in different problems:

- Definition of second order data assimilation for the design of optimal observation networks. Management of combinations of sensor types and deployment modes. Dynamic management of mobile sensors' trajectories.
- Development of ensemble forecast methods for estimating the quality of the prediction, in relation with the quality of the model and of the observations. Sensitivity analysis with respect to model's parameters so as to identify physical and chemical processes, whose modelling must be improved.
- Development of methodologies for super-ensemble forecast (different models, or different configurations of the same model). Investigation on how super-ensembles must be generated, with how many members and with which constraints?
- How to estimate the source of an accidental release of pollutant, using observations and a dispersion model (from the near-field to the continental scale)? How to optimally predict the evolution of a plume? Hence, how to help people in charge to evaluate risks for the population?
- Assimilation of satellite measurements of troposphere chemistery.

The activities of the Clime team in air quality are supported by the development of the Polyphemus air quality modelling system. This system has a modular design, which makes it easier to manage high level applications such as inverse modelling, data assimilation and ensemble forecast.

## 4.3. Oceanography

The main motivation is to extract, from satellite images, structured (in space and time) information that can be related to the state variables of oceanic circulation models, hence allowing for data assimilation. We are currently investigating the following issues:

- surface motion estimation from Sea Surface Temperature and ocean color measurements, directly related to a state variable (flow velocity),
- trajectories estimation by tracking specific structures in satellite sequences, requiring the use of Lagrangian data assimilation techniques,
- turbulence characterization,
- detection and assimilation of fronts and filaments.

## 4.4. Meteorology

The motivation is to detect and extract structured information from image sequences (geostationnary or polar orbiting), in view of assimilation with circulation model or conceptual models of specific events. This application domain addresses :

- the motion estimation for turbulent fluids (winds);
- the assimilation of satellite images for the forecast of meteorological extreme events. The goal is to devise methods for assimilating structure information extracted from images such as synoptic scale wintertime storms and fronts and the precursors in the upper troposphere; convective clouds producing lightning storms, squall lines and gusts; fog and low-level clouds.

## 4.5. Remote Sensing for natural risks and agricultural monitoring

This area concerns specific case studies on crucial environmental topics, involving strong cooperation with environmental experts and access to multiple data sources (satellite images, ground truth, validation data, models). Currently the Clime team is involved in five activities, which are strongly related from a methodological point of view:

**Soil degradation:** AVHRR and MODIS image sequences are used to assess the changes of land use and land cover in the Pantanal area (Brazil), for monitoring of soil degradation, erosion, deforestation and sustainable agricultural practices.

**Desertification:** the investigations concern the characterisation of long-term time series of vegetation indices (computed from AVHRR or MODIS acquisitions) for the early detection of desertification in Northern Africa and Southern Italy.

**Land cover changes and early classification:** the goal is to assess the potential of SPOT sequences for the detection of land use changes in agricultural areas, and for obtaining an early land use classification with respect to the vegetation cycle.

**Hail damage assessment:** the purpose is to define a method for the detection and quantification, from satellite images, of damages caused by hail to vineyards.

**Fire plume detection:** it aims at the definition of methods for fire plumes detection from multispectral satellite images (NOAA-AVHRR, METEOSAT). The investigation concerns the definition of spatial and temporal constraints for improving the robustness of pixel-based detection methods.

# 5. Software

## 5.1. Polyphemus

**Participants:** Vivien Mallet, Meryem Ahmed de Biasi, Lin Wu, Denis Quélo.

Polyphemus is a modeling system for air quality. As such, it is designed to yield up-to-date simulations in a reliable framework: aerosols, data assimilation, ensemble forecast and daily forecasts. Its completeness allows to deal with many fields: photochemistry, heavy metals, radionuclides, *etc*. It is able to handle simulation from local to continental scale, with several physical models.

It is divided into three main parts:

- libraries that gather data processing tools (SeldonData), physical parameterizations (AtmoData) and postprocessing abilities (AtmoPy);
- programs for physical preprocessing and chemistry-transport models (Polair3D, Castor and Gaussian models);
- drivers on top of the models in order to implement advanced simulation methods such data assimilation algorithms.

Clime is involved in the overall design of the system and in the development of advanced methods in data assimilation and ensemble forecast (through drivers and post-processing). The main achievements in 2006 are:

1. a strong improvement in the models interface,
2. the implementation of optimal interpolation, ensemble Kalman filter, reduced-rank Kalman filter and 4D-Var,
3. the release of Polyphemus 1.0 (http://www.enpc.fr/cerea/polyphemus/).

## 5.2. Jfluid

**Keywords:** *API*, *GUI*, *Java implementation*, *microcanonical multifractal formalism*.

**Participants:** Hussein Yahia, Antonio Turiel [ICM].

**Jfluid** is a set of Java classes for the implementation of the Microcanonical Multifractal Formalism (MMF). **Jfluid** provides an API (Application Programming Interface) and a GUI (Graphical User Interface) for computing in the MMF. Main features are:

- a complete implementation of the MMF,
- a way of deriving various geometric structures associated to the singularity exponents,
- the handling of geophysical data formats,
- a multi-threaded environment of execution for the computation in the MMF, ready for a distributed implementation,
- a complete documentation,
- a server and servlet implementation (under way),
- analysis of dynamics (under way).

# 6. New Results

## 6.1. Robust uncompressible fluid flow estimation using a partition of unity

**Keywords:** *optical flow*, *partition of unity*, *quadtree*, *quasi-interpolation*, *radial basis functions*, *uncompressible fluid motion*, *vector splines*.

**Participants:** Till Isambert, Jean-Paul Berroir, Isabelle Herlin, Christine Graffigne [Université Paris V].

This study is part of a Phd thesis on fluid apparent motion estimation with application to oceanography and meteorology. We estimate sea surface streams using divergence free conservation equation coupled with a second order div-curl regularisation. The problem is solved in a vector splines framework and follows the work of Suter [30]: the vector spline is uniquely defined given a set of control points, defined by local image criteria such as the motion index.

However, the basis functions introduced in Suter's work grow arbitrary large whenever $r \to \infty$, $r$ being the distance to control points, with two consequences: first, evaluation of the solution at a single point depends on the whole set of control points, and second, computation of the coefficients of the solution involves inverting a dense and ill-conditionned matrix. These problems lead to prohibitive computational costs in case of large data sets.

A partition of unity is proposed to circumvent these problems. The idea is to first subdivise the image into smaller regions. The motion is then computed in each small region using vector splines: as the regions are small and contain a small number of control points, the vector spline estimation is numerically stable. Finally, all motion fields, defined in small regions, are merged into a single one defined on the whole domain.

The definition of smaller regions is based on an iterative quadtree subdivision approach: starting from an unique region (the image domain), each region is subdivided if it contains more than a fixed number of control points.

In order to minimize aliasing effects at the limits between regions, the vector splines are computed in balls centered on the quadtree cells, so that the vector splines of adjacent regions intersect. The overall solution is obtained by summing up every vector spline, computed in individual regions, weighted by local coefficients depending on the distance to the centre of the associated quadtree cell.

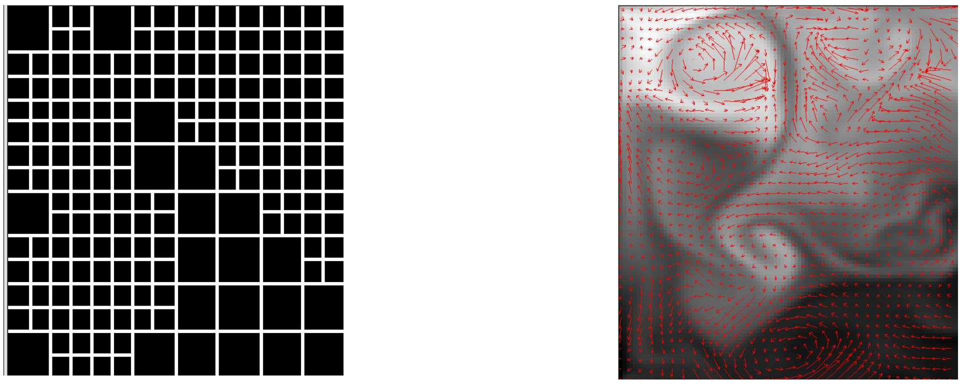

*Figure 1. Left: cells; Right: estimated motion field.*

Figure 1 displays a result from the model on a synthetic oceanographic image sequence: left, a 193 cells quadtree is built from 6085 control points, defined according to local criteria (gradient norm and motion index) in the image. The subdivision is controlled in such a way that each cell contains no more than 200 points. The resulting motion field is displayed on the right side of figure 1.

## 6.2. Multiscale fluid flow estimation using Voronoï centered radial basis functions

**Keywords:** *compact support*, *fluid motion*, *multiscale*, *optical flow*, *radial basis functions*, *turbulence*, *vector splines*.

**Participants:** Till Isambert, Jean-Paul Berroir, Isabelle Herlin, Christine Graffigne [Université Paris V].

Oceanographic (current) and meteorological (winds) fluid flows are characterised by turbulence and hence the presence of structures of different temporal and spatial scales. The vector splines approach to motion estimation is adapted to oceanography (brightness conservation) and meteorology (mass transport equation) and preserves the rotatioanal patterns of the flow owing to its div-curl regularity constraint. But it needs to be formulated in a multiscale framework.

The multiscale approach is tackled by using compactly supported radial basis functions centered at Voronoï points of $X$. The set of Voronoï points $V_X$ defines an irregular grid which is connected to the spatial distribution of the original control points set. We define various scales by applying a *thinning* algorithm [28] to the set $V_X$. The thinning algorithm provides a decomposition of $V_X$ into a nested sequence of subsets in such a way that the points in each subset are distributed as evenly as possible and their spatial density increases smoothly.

At each scale, we solve a least square problem to find coefficients of the solution. The system is large and consists in two terms: a term for the conservation equation and a regularization term which consists in a discretisation of partial differential operators applied to the radial basis functions.

The support of the basis functions are adapted to the grids at each scale and are a function of the “fill distance”, which measures the sparsity of the grid. Since the basis functions are defined on a compact domain, the system is sparse and computing the solution is fast, especially with the use of iterative methods such as conjugate gradient. As a matter of fact, the complexity of the algorithm solely depends on the number of Voronoï centers and not on the number of selected control points used for motion estimation.

Model estimates motion at several levels of details, from global to local, explicitly taking into account the spatial scales related to turbulence. Figure 2 displays an example of motion estimation at two different scales from sea surface temperatures measurements in the Black Sea.

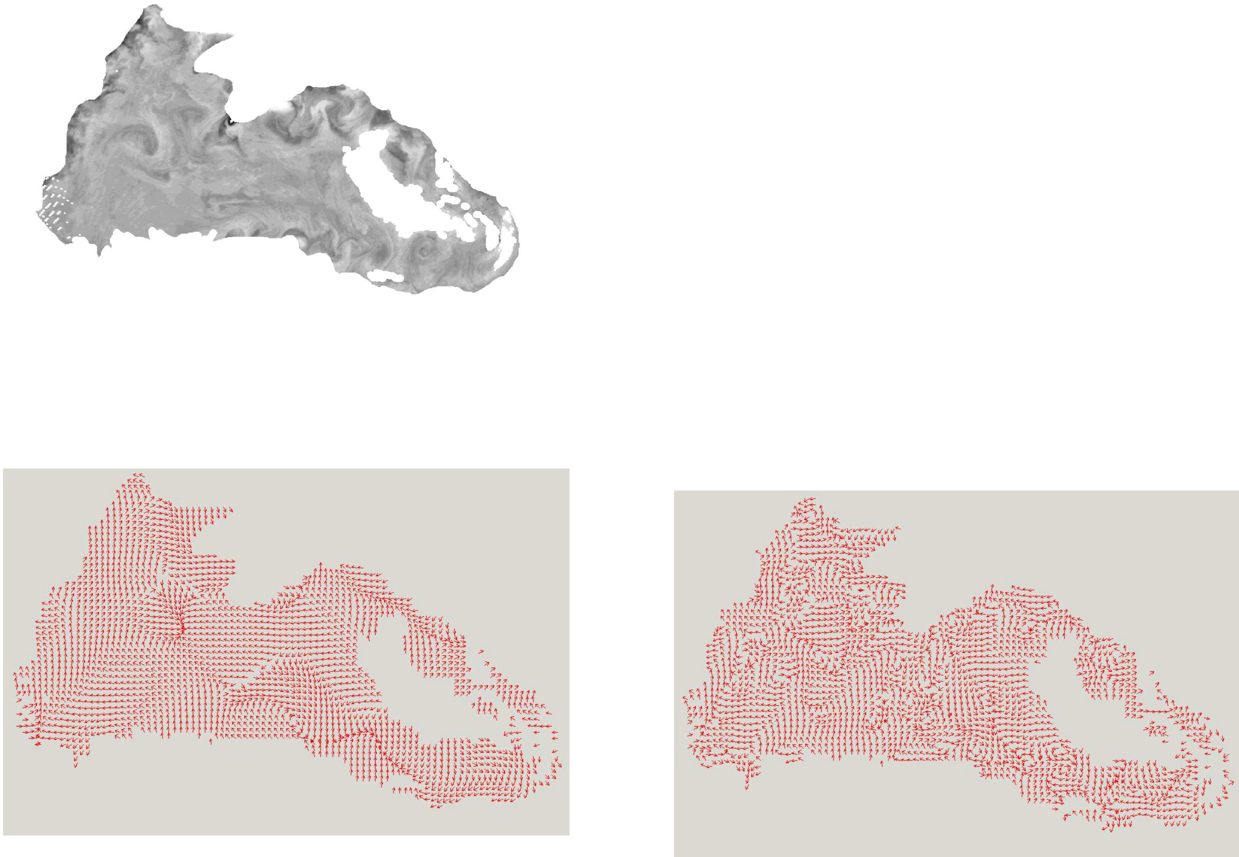

Figure 2. Motion estimation from SST oceanographic images of the Black Sea. Top: one image of the sequence (SST acquired by AVHRR). Bottom: estimated flow fields at two different resolutions; the left one displays global motion and the right one displays local motions.

## 6.3. Desertification monitoring from AVHRR data

**Keywords:** *desertification*, *vegetation index*.

**Participants:** Jean-Paul Berroir, Isabelle Herlin.

The INRIA P3+3 project DESMED has been starting since 2006. It involves the Clime project, CNR in Italy, INSAT in Tunisia, and the Ibn Tofail University in Morocco. The goal of DESMED aims at analyzing long term time-series of vegetation indices acquired by the NOAA-AVHRR sensor, in order to characterize desertification processes occurring in Northern Africa and Southern Italy.

Currently, the achievements of the project are: First, databases have been established for documenting learning sites (Menzel Habib and Jfarra in Tunisia, Salento peninsula in Italy) with classification of Landsat images at different dates, and co-registered time-series of weekly and monthly vegetation indices from 1995 to 2006. Second, definition of a processing chain for characterizing land degradation from NOAA data: this processing chain models time-series of vegetation indices by polynomials, and represents them using a selected set of parameters. The characterization of desertification is then performed in the vector space defined by these parameters. Currently, the work concerns the automatic selection of parameters for distinguishing safe areas and areas undergoing desertification on the basis of pluri-annual time series of vegetation indices.

## 6.4. Estimation of hail damages on vineyards from SPOT images

**Keywords:** *change detection*, *hail damage*, *vegetation*.

**Participants:** Jean-Paul Berroir, Isabelle Herlin.

In the framework of a research contract with the LYNX company, the Clime team analyses the detection and quantification of damages caused to vineyards by hail events. A sequence of SPOT images, acquired before and after the event, is used for detected and measuring changes of vegetation indices and to relate them to production losses. This is an application of great potential interest for insurance companies.

The researches address the following issues:

- Proving the feasibility: changes of vegetation indices are compared at the parcel level to production losses, as estimated by insurance experts, or to objective loss measurements, obtained from harvesting data. The potential of satellite data has been proved, as well as the inaccuracy of insurance expertises.
- Analysing the causes of variability: a sequence of 6 monthly images is used to assess the influence of the observation dates on the loss estimation; the nature of grapes (Chiraz, Sauvignon, etc.) is also addressed on a well documented site.
- Definition of an operational prototype, able to forecast production losses with a limited number of satellite images and without requiring harvesting data nor insurance expertises. The key issue is the ability to forecast the production of a parcel from satellite data. Encouraging results have been obtained by using an adaptation of a yield production model specifically designed for wheat. This model is fed by vegetation information throughout the vegetative period, obtained by fitting a phenological model to the satellite measurements.

## 6.5. Ontological description of a remote sensing processing chain

**Keywords:** *land degradation*, *ontology*.

**Participants:** Jean-Paul Berroir, Isabelle Herlin, Eleni Tomai [FORTH-IACM].

The Clime team is studying the use of ontologies for documenting complex remote sensing processing chains.

A first objective is to provide end-users with a documentation adapted to their level of expertise and corresponding requirements. A first group of users includes scientists in remote sensing or environmental experts or geologist, *etc*. They require a step by step execution of the processing chain, in order to analyse and check intermediate results, change parameterisation, *etc*. On another hand, operational users would prefer a black box with fully automatic execution using sensible default values, *etc*.

A second objective is to take advantage of the applicability and usability of ontologies: ontologies help for adapting a given processing chain to another site and/or another application; they enable to share knowledge between different users/developers of the processing chain: a change in the processing chain is documented and described by the ontology; they provide means to reason about knowledge, e.g. at the highest level on the processing chain, at the lowest levels, on data and site specific issues.

These objectives have been fulfilled by developing a hiearchical ontology, based on a tree structure, for describing a given processing chain: land degradation monitoring from MODIS data, developed in the context of the ENVIAIR project. We hope that this ontology will help adapting this processing chain to other applications, such as desertification monitoring (DESMED P3+3 project).

Current research is geared at the automatic derivation of ontologies, consistent with the available software components.

## 6.6. Plume detection in NOAA AVHRR datasets: use of the Microcanonical Multifractal Formalism

**Keywords:** *fire plume*, *microcanonical multifractal formalism*, *multispectral image*, *natural risk*.

**Participants:** Hussein Yahia, Jacopo Grazzini [FORTH-IACM], Isabelle Herlin, Antonio Turiel [ICM], Nektarios Chrysoulakis [FORTH-IACM].

This work takes place within the framework of the Egide PAI Plumesat. The greek partners have developped a pixel-based method allowing the characterisation of plume pixels in NOAA-AVHRR data. The present work attempts at solving some remaining problems by use of the turbulent spatial information properties contained in the various channels of the NOAA-AVHRR sensor.

The Microcanonical Multifractal Formalism (MMF) is a theoretical and algorithmic framework allowing the derivation of geometric structures in turbulent acquisition datasets; these geometric structures describe the multifractal hierarchy of transition fronts in the context of Fully Developped Turbulence (FDT). We make use of a fundamental property of MMF about reconstructible systems: the derivation of a *synthesized multispectral reduced signal*. We use the assumption that the **MSM** (Most Singular Manifold) computed in the thermal infrared band is directly related to the streamlines of the underlying fluid, so we take this set as the correct reference on the geophysical fluid flow dynamics. Consequently, we want to use the information of the **MSM** in combination with other spectral bands to provide a spatially-based discrimination method for the determination of plumes. We will use the signal gradient of a function of channels $c_2$ (near infrared) and $c_3$ (middle infrared) to enhance the discrimination between plumes and others bodies taking into account temperature and reflectance information. Let $\phi(c_2, c_3)$ be a function of the pixel's grey-level values acquired in spectral bands $c_2$ and $c_3$. We define a synthesized signal **p** by propagating $\phi$'s gradient vectors from the **MSM** computed in channel $c_5$ (thermal channel); that is, we use the MMF reconstruction formula in which the gradient information is replaced by $\phi$'s gradient values $\nabla\phi$:

$$\hat{\mathbf{p}}(\mathbf{f}) = \frac{\sqrt{-1}\mathbf{f} \cdot \widehat{\nabla|_{\mathcal{F}_\infty}\phi}(\mathbf{f})}{||\mathbf{f}||^2} \quad (1)$$

with:

1. $\mathbf{f} = (\mathbf{f}_x, \mathbf{f}_y)$ is the two-dimensionnal frequency vector.
2. The hat symbol $\hat{\mathrm{s}}$ refers to the Fourier transform.
3. $\nabla|_{\mathcal{F}_\infty}\mathrm{s}$ is the signal's gradient restricted to the **MSM**.
4. The dot symbol $\cdot$ in formula (1) refers to vector dot product.

This formula means that the gradient of $\phi$ is diffused from the set of strongest transitions on the thermal infrared channel. Results are presentend in figure 3 in the case of the Genoa acquisition dataset.

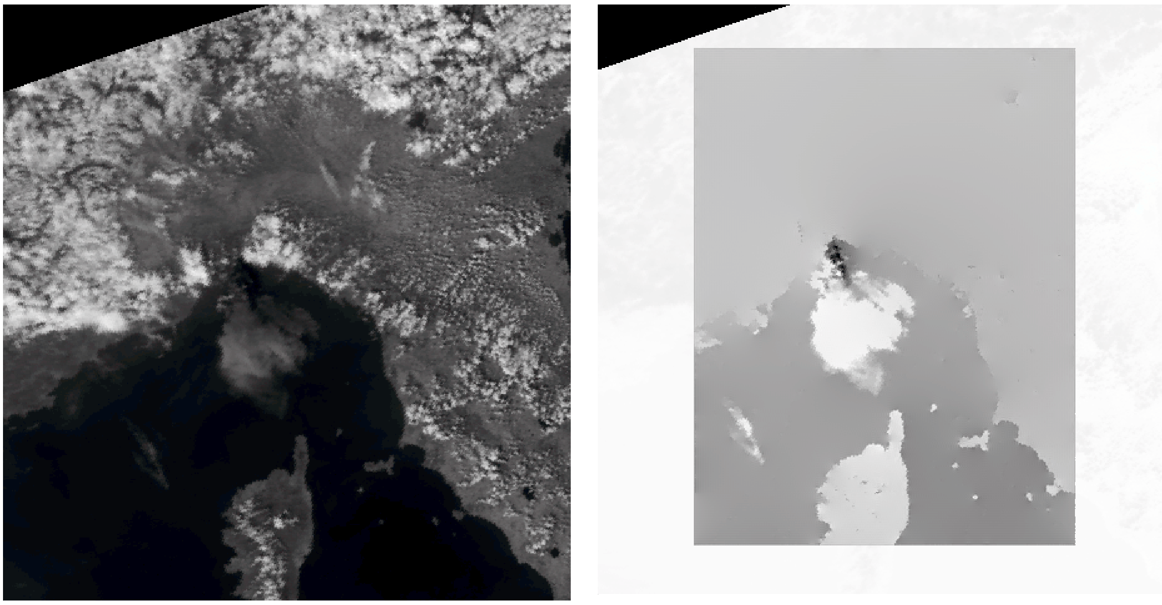

*Figure 3. Left: the original signal, corresponding to the near infrared channel of the NOAA-AVHRR acquisition on Genoa (acquisition date: april, 13, 1991). Right: the resulting multispectral reduced signal displaying the plume.*

## 6.7. Geometric structures in the microcanonical formalism associated to bio/geochimical datasets

**Keywords:** *altimetry*, *chlorophyl concentration*, *geostrophic velocity*, *microcanonical multifractal formalism*, *ocean dynamics*, *sea surface temperature*, *turbulence*.

**Participants:** Hussein Yahia, Véronique Garçon [CNRS-LEGOS].

The subtropical convergence zone is one of the major frontal systems in oceans, and it is the place where specific complex ocean dynamics, algae blooms and upwelling occur. The phenomena are visible on Sea Surface Temperature (SST), cholorophyl alpha (ocean colour) and altmimetry satellite datasets. We begin the study of the ocean dynamics in the subtropical convergence zone using the microcanonical multifractal formalism (MMF), i.e. from the geometric structures associated to singularity exponents derived within the MMF on satellite acquisition datasets. The MMF provides a unified framework for analyzing the dynamics of related events acquired in different oceanographic acquisition datasets. The first phase of the study associated to these data is an experimental phase. We compute the singularity exponents in the different datasets and begin the analysis by studying the Most Singular Manifolds (MSMs) and other geometric structures derived from the singularity exponents. The datasets have different spatial and temporal resolutions. In figure 4 we show the singularity exponents and the MSM associated to a particular altimetric acquisition. In figure 5 we show the singularity exponents associated to the chlorophyl concentration and the SST (Sea Surface Temperature), these oceanographic datasets being available at a finer spatial resolution. The observed similarity between the geometric structures associated to exponents of different datasets show that a similar dynamic is under way in the specified zone. We are now exploiting these results to obtain finer characterizations of the ocean dynamics in the subtropical convergence zone.

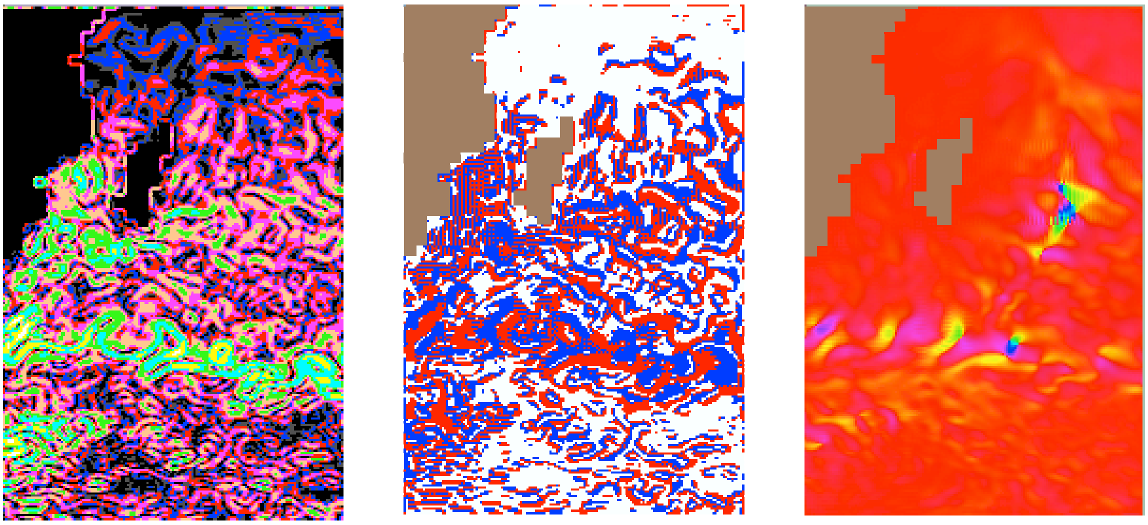

*Figure 4. Left: Singularity exponents associated to a satellite acquisition of the medium sea level (altimetry). The most turbulent area extends from left to right below the middle of the image. Middle: the MSM associated to the exponents. Red and blue pixels correspond to positive and negative orientation of the MSM. Right: phase of the Radon-Nykodim derivative of the multiscale entropy by the signal; the most turbulent areas of the altimetric signal correspond to areas where the color is varying the most.*

## 6.8. Advection of singularity exponents and mesoscale ocean dynamics

**Keywords:** *microcanonical multifractal formalism*, *ocean dynamics*, *turbulence*.

**Participants:** Hussein Yahia, Antonio Turiel [ICM].

A. Turiel has worked recently on the empirical estimation of turbulent diffusivity of a passive scalar with an experimental sequence made at Laboratory for Statistical Physics (ENS Paris). From the results, it is possible to define an effective concept of diffusivity associated to apparent advection's depletion at a given scale of observation. These results open a new way of research for the computation of the multi-scale motion field in ocean dynamics. Indeed, oceanographic turbulent data in the Fully Developped Turbulence regime show that, due to discretization, a passive scalar (like sea surface temperature) does not satisfy the conservation equation at the pixel level. Consequently, we start a study on the multi-scale estimation of the motion field in oceanic dynamics; the method is not based on a conservation hypothesis as it is the case in optical flow methods, but using quantities computed from the singularity exponents.

## 6.9. Limiting behaviour of wavelets and singularity exponents

**Keywords:** *microcanonical multifractal formalism*, *singularity exponents*, *wavelets*.

**Participants:** Hussein Yahia, Antonio Turiel [ICM].

The accurate computation of singularity exponents is a key aspect of the Microcanonical Multifractal Formalism (MMF). The singularity exponents are computed using a wavelet projection of a multifractal measure: the wavelet projection of measure $\mu_{\|\nabla\|}$ at $\mathbf{x} = 0$ and at scale $\mathbf{r}$ in $\mathbb{R}^d$ is given by:

$$T_\Psi \|\nabla s\|(0, \mathbf{r}) = \frac{1}{\mathbf{r^d}} \int_{\mathbf{R^d}} \Psi\left(\frac{\mathbf{y}}{\mathbf{r}}\right) \, \mathrm{d}\mu_{\|\nabla\|}(\mathbf{y}) = \frac{1}{\mathbf{r^d}} \int_{\mathbf{R^d}} \Psi_{\mathbf{r}}(\mathbf{y}) \, \mathrm{d}\mu_{\|\nabla\|}(\mathbf{y}) \quad (2)$$

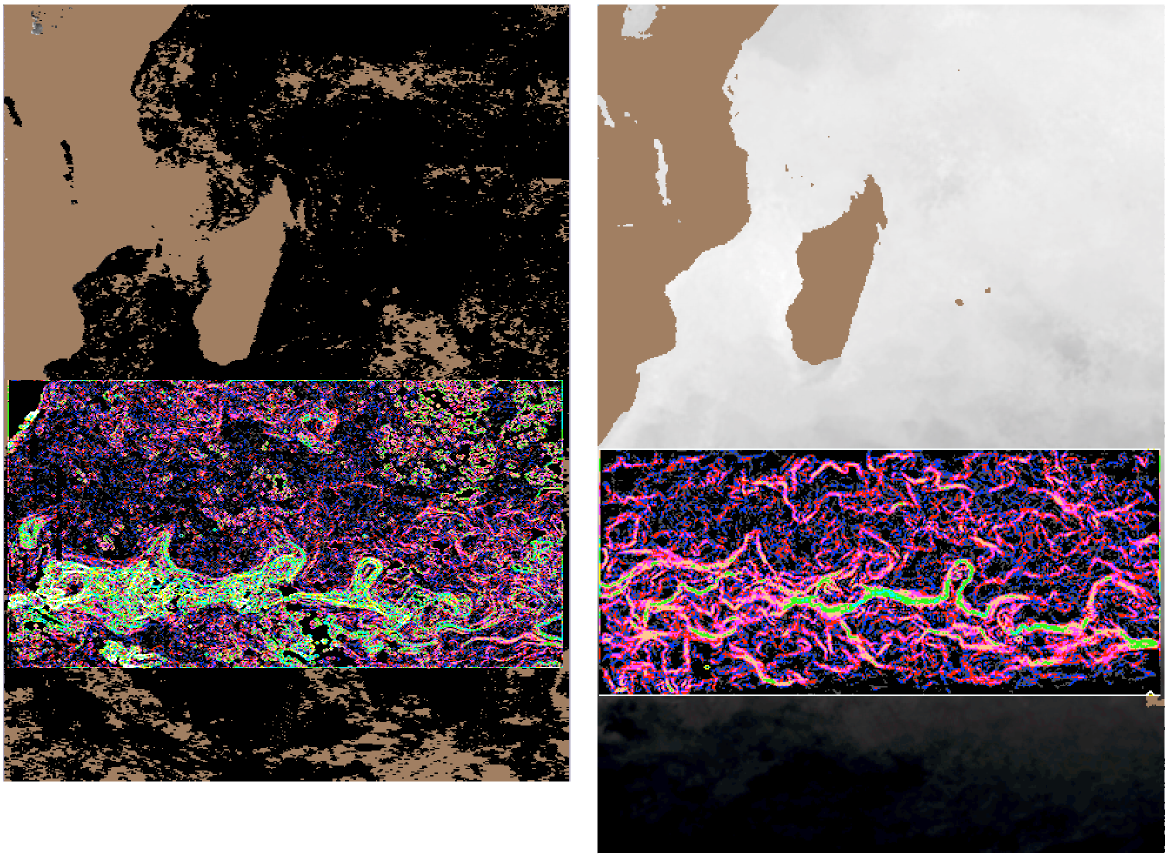

*Figure 5. Left: Singularity exponents associated to a satellite acquisition of the chlorophyl-alpha concentration. The singularity exponents are computed in a rectangular area depicted on the image. Right: singularity exponents associated to a satellite acquisition of the SST (Sea Surface Temperature) on the same zone.*

with wavelet $\Psi$ and

$$\Psi_{\mathbf{r}}(\mathbf{y}) = \Psi\left(\frac{\mathbf{y}}{\mathbf{r}}\right).$$

Therefore, it is important to understand, both qualitatively and quantitatively, the influence of the wavelet $\Psi$ on the computation of the singularity exponent at $\mathbf{x} = 0$.

We study the influence of the wavelet's tail at infinity on the singularity exponent computed at $\mathbf{x} = 0$. Using the Lebesgue density theorem and the analysis of the integral appearing in (2), we obtain that the local behaviour of the wavelet at $\mathbf{x} = 0$ lets the singularity exponent at 0 unchanged when $\mathbf{r} \to 0$, as long as $\Psi(0) \neq 0$, but if the wavelet $\Psi$ decreases towards infinity according to a power law : $\Psi(\mathbf{x}) \sim \|\mathbf{x}\|^{-n_0}$ when $\|\mathbf{x}\| \to \infty$, powers of $n_0$ pop up in the integral which may change the behaviour of $\mu_{\|\nabla\|}$'s singularity exponent at 0, when $\mathbf{r}$ tend towards 0. This qualitative analysis is the first step towards a mathematical understanding of numerical artefacts appearing in the algorithms implementing the wavelet projection. The second step will consist in computing the quantitative dependance of the wavelet's tail on the singularity exponents.

## 6.10. Image data assimilation for oceanography

**Keywords:** *data assimilation*, *motion estimation*, *oceanography*, *remote sensing*.

**Participants:** Etienne Huot, Isabelle Herlin, Gennady Korotaev, François-Xavier Le Dimet [MOISE], Lin Wu, Yan Xu.

The objective of this study is to compute the circulation velocity from a sequence of satellite images of Sea Surface Temperature (SST), in order to assimilate it into an oceanographic circulation model.

It is possible to assess velocities from several images by solving a PDE system (conservation equation, regularity) defined using derivatives of the image computed at every pixels. This is not satisfying in the case of oceanographic observations, since a significant part of the observations of the sea surface is occulted by clouds.

We therefore propose a velocity estimation method with a similar principle as data assimilation: the available image data (not occulted by clouds) constitute observations of SST, to be assimilated within a dedicated *Image Model*, used to describe the evolution of image information. The Image Model implements a simplified version of the transport of temperature by advection and diffusion: the transport is expressed in the 2D image space, source and sink terms being ignored. The state space is defined by the SST and the 2D components of the surface velocity. The latter are assumed constant during the assimilation time window.

Observations of sea surface temperature are assimilated within the Image Model, by minimizing a functional expressing the discrepancy between the modelled and the observed SST, plus an additional second-order div-curl regularization term applied to the retrieved velocity field.

This study is a crucial step towards the formalisation of assimilation techniques for image data. Current research works address the application of this technique to the assimilation of structured image data such as fronts, instead of considering an image as a collection of independent measurements.

## 6.11. Trajectory reconstruction for Lagrangian data assimilation

**Keywords:** *data assimilation*, *lagragian data*, *trajectory estimation*.

**Participants:** Etienne Huot, Dominique Béréziat, Marc Honnorat [MOISE], Jérôme Monnier [MOISE].

This work is performed in cooperation with M. Honnorat and J. Monnier (INRIA team MOISE) in the framework of the ASSIMAGE ACI: an hydrological model based on Saint-Venant equations (state space constituted of water elevation and 2D velocity) is used in a data assimilation framework for flood forecasting.

The practical difficulty lies in access to observation data, especially 2D velocity. We thus applied tracking methodologies on video acquisitions of water flow. This has been performed on the experimental installation of the Fluid Mechanic and Acoustic Laboratory of University of Lyon (LMFA) of river simulation. Trajectories are computed by tracking targets with a maximum correlation matching method. The trajectories are then assimilated in a Lagrangian framework in order to retrieve initial condition and/or parameters in the hydrological model.

## 6.12. Satellite data assimilation for air quality forecast

**Keywords:** *IASI*, *air quality*, *chemistry transport model*, *data assimilation*.

**Participants:** Jean-Paul Berroir, Hervé Boisgontier, Marc Bocquet, Isabelle Herlin, Vivien Mallet, Denis Quélo, Bruno Sportisse.

The latest generation of satellite sensors dedicated to atmospheric chemistry provide chemical measurements of the lowest layers of the troposphere: MOPITT (Measurement Of Pollution In The Troposphere) and OMI (Ozone Monitoring Instrument) are already operational on NASA platforms, whereas the IASI (Infrared Atmospheric Sounding Interferometer) and GOME-2 (Global Experiment Monitoring Experiment-2) have been launched by ESA in October 2006. All these instruments provide tropospheric columns of selected trace gases (ozone, nitrogen oxydes): the vertical integral in the troposphere of the gas concentration.

The objective of this work is to assess the feasibility of assimilating the 0-6km ozone column, to be provided by IASI, within the regional Chemistry-Transport Model Polyphemus, in view of improving air quality forecast at European scale. This study is led in the contexts of the ESA-EumetSat "EPS-MetOp Research Annoucement of Opportunity" (the Clime project being Principal Investigator), and of the TRAQ proposal (TRopospheric composition and Air Quality) for the future ESA tropospheric mission (around 2012), coordinated by KNMI, and comprises two main steps.

The first step is to assess the potential of the 0-6km ozone columns for air quality modelling, i.e. for improving the knowledge of ozone in the atmospheric boundary layer. A Polyphemus simulation for the month of July 2001, extensively validated, serves as reference and allows to conclude that the boundary layer represents a The sensitivity of boundary layer ozone to changes of concentration in the free troposphere is furthermore evaluated to a mean of 25%. This suggests that a better control of free troposphere ozone, to be provided by the satellite instrument, will in turn allow to better control boundary layer ozone.

The second step consists in leading data assimilation experiments. The IASI data not being available yet, a simulation chain has been developed, based on an atmosphere description (Polyphemus concentrations in the 0-5km domain, climatologies above), on the radiative transfer model LBLRTM (AER), on the IASI instrument model (kindly provided by IPSL/SA) and on the IASI operational inversion procedure SA-NN, developed by IPSL/SA. The simulated 0-6km columns have an average 27% error as compared to the reference, which is larger than the expected 20% accuracy of the IASI columns. The simulated data has been assimilated in a perturbated Polyphemus simulation, by means of an Optimal Interpolation procedure. A 5% improvement of boundary layer ozone concentrations has been observed. The next steps will concern the assimilation of the actual IASI data, expected during 2007.

## 6.13. Data Assimilation for Image Processing

**Keywords:** *Tikhonov regularization*, *data assimilation*, *ill-posed problem*, *image processing*.

**Participants:** Dominique Béréziat, Isabelle Herlin.

In the image processing area, most of problematics correspond to ill-posed problems (edge detection, segmentation, optical flow estimation, deblurring, ...). A common method used to solve ill-posedness is to regularize solutions by adding smoothing constraints. For example, Tikhonov like approach proposes to minimise a functional measuring the discrepancy between model and solution and constraining the spatial variations of the solution. It is now well known [29] that the Euler-Lagrange evolution equation associated to this functional corresponds to a diffusion process.

Similar equations are found in the modelling in many physical situations (meteorology, oceanography, air quality, ...), and data assimilation techniques [31] have proven their efficiency for solving them, even when partial and/or indirect observations of state variables are available.

We propose to exploit this property in order to formulate ill-posed image processing problems in a variational data assimilation framework. The research addresses the definition of evolution models for the image information to be retrieved. In a first step this approach is studied for 3D reconstruction from a sequence of 2D observations: we try to reconstruct the evolution of a 3D object from a sequence of 2D image acquisitions. The observations consist of the 2D images, obtained by projection of the 3D space. The evolution model can be as simple as an optical-flow like constraint (transport of grey level over 3D sequence).

## 6.14. Towards comparison studies of sequential and variational data assimilation methods for air quality models

**Keywords:** *Polyphemus*, *air quality models*, *comparison study*, *data assimilation*.

**Participants:** Lin Wu, Vivien Mallet, Marc Bocquet, Bruno Sportisse.

The objective is to evaluate the performance of different data assimilation schemes for atmospheric chemistry-transport models (CTM). Contrary to meteorological models, air quality models are non chaotic and the problem is not the control of the initial conditions but of forcing termes. There are recent applications of variational and sequential data assimilation methods based on atmospheric chemistry-transport models, however, comparison studies of the two approaches in the same experimental setting have never been performed mainly due to technical problematics. The recently developed platform Polyphemus (developed by Clime) makes it possible to overcome these technical difficulties for a data assimilation system.

A typical data assimilation system consists of three components, namely data (observation), model (physics), and assimilation algorithms. We adopted object-oriented techniques, such that the developments of the three components are independent from one another. Most of the classical data assimilation schemes for CTMs have been implemented within Polyphemus for comparison studies. The available sequential schemes are Optimal Interpolation (OI), Ensemble Kalman Filter (EnKF), and Reduced Rank Square RooT Kalman filter (RRSQRT). For the variational approach, we have derived the adjoint model for the underlying CTM Polair3D within Polyphemus using automatic differentiation techniques, and the four-dimensional variational assimilation method (4D-Var) is still under testing and will be available in the near future.

For the first application of the data assimilation system, the simple method OI is employed to assess the impact of assimilating EPS troposphere ozone observations. For advanced assimilation methods, say EnKF, RRSQRT, or 4D-Var, one needs the error specifications for CTMs and/or background (a priori) species concentrations. We approximate the model error by perturbing model input data, such as surface emissions, boundary conditions etc. The preliminary results of EnKF and RRSQRT show that the predictions based on assimilated concentrations approach quickly to reference simulations. This is a strong indication that our approximation of model error is not very realistic, and the assimilation suffers from filter divergence.

In summary, we have implemented both classical sequential and variational assimilation methods within Polyphemus platform, and preliminary results are obtained by perturbation methods. For meaningful results, more investigations are needed on (model and background) error modeling for the atmospheric chemistry-transport models.

## 6.15. IRSN future remote monitoring network for radioactive particles in atmosphere

**Participants:** Marc Bocquet, Rachid Abida, Nikki Vercauteren.

The aim of this study is to give an objective response concerning the setting up of an optimal monitoring network over France. For this, Polair3D model forced by ECMWF analysis was used to generate a database representing all probable scenarios accident over one year. Spatial interpolation methods and simulated annealing algorithm were used to assess monitoring networks capacity to detect and reproduce the accident situations. One month of database was used to perform the first tests on the inference chain. Several computing tools (parallel distributed) were designed to alleviate the task.

## 6.16. Adjoint modelling and sensitivities computations for the Chernobyl accident

**Participants:** Arnaud Anantharaman [ENPC], Romain Roehrig [ENPC], Tej Ghoul [ENPC], Marc Bocquet, Yelva Roustan.

Adjoint modelling and sensitivities computations have benn carried out for the Chernobyl accident. This work has been carried out as a research training period (IMI department of ENPC) for three of the ENPC students (advisor: Marc Bocquet.) This work aimed at building and validating several tools dedicated to sensitivity analysis of activity measurements with respect to many forcing fields, especially sources. A similar work had been carried out in 2004-2005 on the dispersion of mercury [Roustan, Bocquet]. The goal is to demonstrate that such an approach could also be applied on a radionuclide dispersion episode. Most of the work has focused on the computation of adjoint solutions related to wet deposition (the wet scavenging using a Belot or relative humidity parameterization.) In addition to the results obtained for the sensitivity analysis of the Chernobyl accident, this work can be understood as a prelude to inverse modelling of deposited activity.

## 6.17. Inverse modelling-based reconstruction of the Chernobyl source term available for long-range transport

**Participants:** Xavier Davoine, Marc Bocquet.

The reconstruction of the Chernobyl accident source term has been previously carried out using core inventories, but also back and forth confrontations between model simulations and activity concentration or deposited activity measurements. The approach developped in this work is based on inverse modelling techniques. It relies both on the activity concentration measurements and on the adjoint of a chemistry-transport model. The location of the release is assumed to be known, and one is looking for a source term available for long-range transport that depends both on time and altitude. The method relies on the maximum entropy and the mean principle, exploiting source positivity. The inversion results are mainly sensitive to two tuning parameters, a mass scale and the scale of the prior errors in the inversion. To overcome this hardship, we resort to the statistical L-curve method to estimate balanced values for these two parameters. Once this is done, many of the retrieved features of the source are robust within a reasonable range of parameter values. Our results favour the acknowledged three-step scenario, with a strong initial release (26 to 27 April), followed by a weak emission period of four days (28 April - 1 May) and again a release, longer but less intense than the initial one (2 May - 6 May). The retrieved quantities of iodine-131, caesium-134 and caesium-137 that have been released are in good agreement with the latest reported estimations. Yet, a stronger apportionment of the total released activity is ascribed to the first period and less to the third one. Finer chronological details are obtained, such as a sequence of eruptive episodes in the first two days, likely related to the modulation of the boundary layer diurnal cycle. In addition, the first two-day release surges are found to have effectively reached an altitude up to the top of the domain (5000 metres).

## 6.18. High resolution reconstruction of a tracer dispersion event

**Participant:** Marc Bocquet.

In a previous QJRMS two-part paper, new methods to reconstruct the source for an atmospheric tracer at regional scale have been developed. Specifically the Maximum Entropy on the Mean (MEM) method was extended to large (although linear) data assimilation problem. Tests using twin experiments and a limited subset of the data from the European Tracer Experiment [ETEX] were performed. Although temporal reconstruction knowing the location of the source was satisfying, a full 3D reconstruction was still out of reach with real data. In this work, using the MEM method and some of its refinements, a reconstruction using all ETEX-I measurements at a resolution of 1.125° x 1.125° x 1 hour is shown to be possible. This allows for a reconstruction of the full dispersion event. The MEM retrieval of the tracer plume using what is believed to be a good prior is then compared to other priors including Gaussian ones. Eventually, a reconstruction using all data sequentially in time (not all together) is obtained. This helps define what a maximum entropy filter applied to sequential data assimilation of a linear tracer should be able to do, with a view to an efficient emergency response in case of an accidental release of pollutant.

## 6.19. Source reconstruction of an accidental radionuclide release at European scale

**Participants:** Monika Krysta, Marc Bocquet.

Source retrieval is one of the problems that are currently being addressed within a framework of data assimilation for dispersion of radionuclides. Firstly, a series of hypothetical releases have been designed. The accidents have been imagined to take place at one of the European nuclear facilities at a time. The aim of a retrieval is to tell the position of the source and the shape of its temporal profile. The solution is given by a procedure based on the maximum of entropy principle. A couple of new, problem-adapted cost functions have been put forward and their performance tested. The tests have been undertaken with perfect and noisy synthetic measurements, and have been assessed with an objective indicator. In perfect measurement configurations, perfect reconstructions have been obtained for a number of measurements significantly lower than the number of unknowns. Secondly, temporal profile of an accidental release of caesium-137 in Algeciras steel mill has been inverted. The total reconstructed activity falls within an interval given by the official estimations. The profile is narrow which remains in accordance with the information disclosed after the release but is slightly shifted towards the earlier times.

## 6.20. Ensemble forecast

**Participants:** Vivien Mallet, Bruno Sportisse.

A strong limitation of chemistry-transport models lies in the high uncertainties in the physical parameterizations and the input data (meteorological data, emissions, ...). Uncertainties in input fields often range between 20% and 50%. Many physical parameterizations are available to estimate the same fields, which is usually the main source of uncertainties in output concentrations. In this context, a single forecast has little meaning: modern forecasting systems should plan to include ensemble forecasts, that is, simulations from an ensemble of models.

The modeling system Polyphemus has been designed in order to handle ensembles: it hosts several chemistry-transport models and includes many options with regard to the physical formulation of the models. An ensemble of 48 models has been studied to apply ensemble methods to photochemical forecasts (ozone). Methods have been proposed to build a forecast with linear combinations of the models outputs. Significant improvements in forecasts are obtained when the combination weights are optimal in least-square sense over the past (moving learning period).

On top of all models and of several model combinations, machine learning algorithms (sequential aggregation) have proven to improve performances. Unlike other methods, they come with theoretical bounds and are well known for their robustness. This is joint work with Gilles Stoltz (ENS Paris, DMA).

Ensemble forecasts (without combinations) have been tested daily (and for months) for the operational forecasting platform Prév'air (http://www.prevair.org/).

# 7. Contracts and Grants with Industry

## 7.1. LYNX

A research contract is established with the LYNX company currently being under creation. It aims to define a software prototype for the estimation of damages caused to vineyards by hail events.

## 7.2. IRSN

A convention has been established between CEREA and IRSN. This convention notably includes the installation of the Polyphemus software at the technical crisis centre of IRSN. A research contract is furthermore underway concerning network design: its objective is the optimal definition of an aerosol monitoring network for detection and diagnosis in the event of an accident/event in a French or neighbouring nuclear power plant.

## 7.3. INERIS

The Clime team is partner with INERIS (National Institute for Environmental and Industrial Risks) in a joint project devoted to air quality forecast. This includes research topics in data assimilation and ensemble modeling.

# 8. Other Grants and Activities

## 8.1. National initiatives

- The Clime Project is involved in the ASSIMAGE contract (Ministry Grant) since 2003, dealing with image data assimilation, in collaboration with two other INRIA teams (IDOPT and VISTA), CEMAGREF and CNRS.
- Clime is member of the ADDISA contract (Ministry Grant, just starting at the end of 2006), with the INRIA team MOISE, the LEGI, the CNRM/GMAP laboratory of Météo-France and the MIP laboratory of Université Paul Sabathier, Toulouse. This project deals with image assimilation, with application to forecast of extreme meteorological events and marine circulation.
- The Clime team is involved in the ADOQA contract (INRIA Investigation Grant) dealing with advanced data assimilation techniques for air quality forecast: non linear assimilation with particle filtering and assimilation of raw satellite measurements. The ADOQA project also includes the INRIA teams MOISE (Rhône-Alpes) and ASPI (Rennes), and INERIS.
- Clime has a close collaboration with the CETP/IPSL Laboratory particularly in the context of the ADIMO concract granted by University of Versailles - Saint-Quentin in its BQR2006 (Research Quality Bonus) framework. ADIMO aims at the assimilation of image structures within oceanographic models.

## 8.2. European initiatives

- The Clime team is member of the ERCIM working group “Environmental Modelling”. Within this working group, Clime cooperates with FORTH-IACM on remote sensing methodologies, transfer on GIS and definition of ontologies for complex applications.
- H.Yahia is coordinating PAI Plumesat project (Detection and monitoring of accidental fire plumes). The other partner is FORTH in Heraklion (Greece).
- H. Yahia has been a 1 year visiting scientist at the Institute for Marine Sciences (ICM, Barcelona) and he is developping a strong collaboration with ICM and DYNBIO (CNRS, Toulouse) on theoretical advances in ocean dynamics and algorithmic implementation around the Multifractal Microcanonical Formalism (MMF).

- THe Clime team is the principal investigator of an ESA-EumetSat project devoted to the assimilation of troposphere chemical measurements, to be provided by the sensors onboard EPS/MetOp.

## 8.3. International initiatives.

- A research contract, ENVIAIR, was accepted under the framework of the INRIA-CNPq programme, with the State University of Rio de Janeiro, Federal University of Rio de Janeiro and Embrapa Solos. This contract aims at monitoring soil degradation and sustainable agricultural practices in the Taquari basin (Brasil). The Clime team is also involved, as external partner, in the Rio de la Plata project, funded by the Inter American Institute for Global Change Research. The objective is the monitoring of land use changes in the Rio de la Plata basin, a region large as six times the superficy of France.
- The Clime team has strong cooperations with CMM (Chile) and University of Cordoba (Argentina) on establishing air quality forecast systems and data assimilation capacities in Chile and Argentina. This cooperation is currently supported by the research contract ADOQA-Conesud. It was initiated under the France-Conesud programme, with the University of Cordoba (Argentina), the National Centre for Nuclear Energy (Argentina), CMM (Chile) and the Chilean Meteorological Office (Chile). The objective are inverse modelling of air pollution sources by means of sequential data assimilation procedures. Finally, a Stic-AmSud contract has started for the forecast of air quality using data assimilation techniques in South America. This contract involves CMM (Chile), the Chilean weather office (DMC, Chile), the University of Cordoba (Argentina), and the environmental monitoring group of CNEA (Argentina).
- An ECO-NET contract, ADIMO, has started since 2006. This contract is led in cooperation with the MOISE project (INRIA Rhône-Alpes), the Institute for Numerical Analysis in Moscow (Russia), and the Institute of Oceanography in Sevastopol (Ukraine). The objectives of ADIMO concern the assimilation of images within ocean circulation models.
- An INRIA P3+3 Méditerrannée contract, DESMED, has started on the study of desertification in Northern Africa and Southern Italy using long term time series of vegetation indices. This contract involves CNR-ISAC in Italy, INSAT in Tunisia, University Ibn Tofail in Morocco.
- A Stic-Asia contract (MSND, Models and Simulations for Natural Disasters) has started with ESIEE (F), the Chinese Academy of Surveying and Mapping, the Faculty of Engineering Multimedia University of Malaysia, the Faculty of Social Sciences and Humanities (University Kebangsaan), Malaysia, the Malaysian Centre for Remote Sensing. Clime is associated partner of this project and is involved in the detection of precursors of extreme meteorological events.

# 9. Dissemination

## 9.1. Leadership within scientific community.

- Dominique Béréziat is member of the commission of specialists for University Paris 6.
- Isabelle Herlin is member of the commission of specialists for University Paris 12.
- H. Yahia was Ph.D. rewiever of Claire Pottier's thesis which was to be defended on December 22, at CNES, Toulouse.
- The Clime team is strongly involved in the national and European scientific community of satellite data for atmosphere chemistry: the Clime team is member of the ADOMOCA project (PNCA, atmospheric chemistry national programme) on assimilation of satellite atmospheric chemistry missions, is PI of a ESA-EumetSat project for the exploitation of EPS-MetOp data for air quality forecast, and member of the TRAQ proposal for the definition of the future ESA tropospheric missions.

## 9.2. Teaching.

- Air Pollution (ENPC & TPE, TRADD/Renault Master, SGE Master) and atmospheric sciences (ENPC): 150 hours (Marc Bocquet, Vivien Mallet, Bruno Sportisse).
- Computational Physics for Environment (ENSTA/ENPC) and Applied Maths (ENPC): 60 hours (Marc Bocquet, Vivien Mallet, Bruno Sportisse).
- Data Assimilation for Geophysics (ENSTA/ENPC, Master): 35 hours (Marc Bocquet, Vivien Mallet, Bruno Sportisse).
- Multimedia, 21 hours, ISTM (Isabelle Herlin).
- Algorithmics, 50 hours, ISTM and PULV (Isabelle Herlin).
- Programming (C, Java), 50 hours at ISTM and PULV (Jean-Paul Berroir).
- Computer Science (including Computer Vision), 120 hours, Master EDITE de Paris (Dominique Béréziat).

## 9.3. Conference and workshop committees, invited conferences.

- In January 2006, I. Herlin has made a presentation on the image assimilation problematic at Berkeley laboratory.
- On January, 12th, 2006, H. Yahia has made a presentation at ICM (Barcelona, Spain). Title : "Multifractal analysis of geophysical flows: a new model, its implementation and a strategy for its diffusion".
- On October, 11th, 2006, H. Yahia has made a presentation intented at teachers in Mathematics. Title : "Analyse des signaux complexes multiéchelles: une modélisation issue de la physique et son application à des données environnementales". Web site of the lecture: http://www-clime.inria.fr/Acad.

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