

**FORMULARIO DE PROYECTOS DE
INTERCAMBIO REGULAR
ECOS-CONICYT 2003**

ECOS : Comité Francés de Evaluación-Orientación de la Cooperación Científica con Chile.
(Presentar en **DRI-CONICYT**, con los documentos anexos que se solicitan, a más tardar el **31 de Marzo del 2003**)

Título del Proyecto :

Impactos de aerosoles naturales y antrópicos en los estratocúmulos costa afuera de Chile / Impact des aérosols naturels et anthropiques sur les champs de stratocumulus au large du Chili

Palabras claves (4 máximo): Aerosoles, estratocúmulos, clima, modelación

Campo disciplinario (poner una cruz)

☐

Ciencias Humanas y Sociales

☐

Ciencias de la Salud

☒

Ciencias de la Tierra y del Universo

☐

Ciencias Exactas

☐

Ciencias de la Vida

Establecimiento principal al que pertenece el Investigador Responsable

En Francia

Laboratorio (o equipo): Laboratoire d'Optique Atmosphérique (UMR 8518)

Nombre del Director : Didier Tanré

En Chile

Laboratorio (o equipo): Centro de Modelamiento Matemático, Universidad de Chile (UMR 2071)

Nombre del Director : Rafael Correa

Responsables del Proyecto

En Francia Nombre: _____ Olivier BOUCHER _____

Teléfono: 03 20 43 62 30

Fax: 3 20 43 43 42

E-mail: : boucher@loa.univ-lille1.fr

En Chile Nombre: _____ Laura GALLARDO KLENNER _____

Teléfono: 56-2-6784882

Fax: 56-2-6889705

E-mail: lgallard@dim.uchile.cl

Lista de los investigadores que participan en el Proyecto, indicando la institución a la que pertenecen. Los investigadores participantes deben formar parte de la planta de las instituciones patrocinantes.

En Francia:

- Olivier Boucher, chargé de recherche 1^{ère} classe, CNRS
- Marie Doutriaux-Boucher, Maître de conférence, Université des Sciences et Technologies de Lille
- Bruno Sportisse, Ecole Nationale des Ponts et Chaussées, chercheur associé
- Hervé Le Treut, Directeur de recherche, 1^{ère} classe, Laboratoire de Météorologie Dynamique du CNRS, chercheur

En Chile

- Laura Gallardo Klenner, Investigador Asociado, Centro de Modelamiento Matemático (Profesor Adjunto, Departamento de Geofísica de la Universidad de Chile)
- José Rutllant Costa , Profesor Asociado, Departamento de Geofísica de la Universidad de Chile

5. Descripción del Proyecto de Intercambio Regular ECOS-CONICYT.

Esta descripción debe incluir los siguientes aspectos:

- a. Breve fundamentación conceptual y teórica (máx. 3 páginas).

La capa más persistente de estratos en el mundo se encuentra bajo la Alta del Pacífico costa afuera de Chile y Perú. Esta capa nubosa tiene un gran impacto sobre las circulaciones regional y global (e.g., Hartmann et al, 1992). En esta región, existen grandes emisiones de azufre oxidado, tanto de origen antrópico, asociadas principalmente a la fundición de cobre (Lefhon et al, 1999), y a procesos naturales, principalmente emisiones biogénicas a lo largo de la Corriente de Humboldt, y quizás también emisiones volcánicas (e.g., Scholes et al, 2003; Andres & Kasgnoc, 1998). A pesar de la relevancia de estos procesos para el clima regional y global, nuestra comprensión cuantitativa y nuestras habilidades predictivas para evaluar potenciales futuros cambios son escasas.

En suma, dadas las grandes emisiones de azufre oxidado que ocurren en Chile central y norte, la circulación y los patrones nubosos del área y los efectos que los aerosoles de azufre pueden tener sobre las nubes, se inició en 2002 una colaboración para evaluar la distribución regional de azufre oxidado y sus efectos radiativos sobre Chile central y norte. Aquí proponemos una colaboración que busca una mejor comprensión de las interacciones entre aerosoles, nubes y clima y proveer herramientas para evaluar y predecir a través de modelación global y regional. De la misma forma queremos fortalecer los lazos con otras actividades de investigación, particularmente el sensoramiento remoto de aerosoles y nubes y la modelación de la dinámica de la capa límite marina del Pacífico Sur Oriental.

- b. Principales objetivos e hipótesis (máx. 1 página).

Objetivos

- Mejor aquilatar la distribución regional de azufre oxidado, tanto de origen antrópico como natural, y evaluar su impacto potencial sobre las propiedades de la capa de nubes estratiformes que prevalecen sobre el mar y bajo la Alta del Pacífico.
- Fortalecer los lazos con otras actividades de investigación y comunidades científicas, especialmente aquellas que trabajan en sensoramiento remoto de nubes y aerosoles en Francia y modelación dinámica de las interacciones océano-atmósfera en Chile

Hipótesis

Suponemos que las actividades de investigación de nuestros grupos ganarán en cuanto a profundidad y perspectiva a través de la complementación de nuestras competencias en modelación climática global y de dispersión regional. Además, suponemos que los modelos atmosféricos pueden proveer estimaciones de la distribución de azufre oxidado emitido a través de procesos bióticos y abióticos y sus impactos subsecuentes sobre el balance radiativo y que la verosimilitud de estas simulaciones puede ser mejorada.

c. Metodología (máx. 2 páginas).

Metodología

- La distribución de azufre oxidado (SO_x) y sus efectos radiativos podrían ser evaluados a través de simulaciones complementarias:
 - Campos de SO_x de alta resolución (0.1°) serán estimados usando el modelo *Multiscale Atmospheric Transport and Chemistry* (MATCH, Robertson et al, 1999), ya implementado en Chile. Este modelo ha sido aplicado para evaluar la dispersión de azufre y arsénico de fuentes mineras en Chile central y norte (Gidhagen et al, 2002; Gallardo et al, 2002; Olivares et al., 2002; Huneus et al, 2003). El modelo sería alimentado con salidas pseudo-climatológicas de un modelo numérico del tiempo, el modelo *High Resolution Limited Area Model* (HIRLAM, Udén et al, 2002) y salidas, para situaciones específicas, provistas por el modelo de pronóstico de la Dirección Meteorológica de Chile en el contexto de investigación en curso en el CMM (FONDECYT 1030809). De esta manera se evaluará la dispersión e influencia de distintas fuentes de azufre oxidado, a saber emisiones biogénicas desde el mar (Dimteilsulfuro, DMS), fuentes industriales (fundiciones de cobre y ciudades), emisiones volcánicas, etc.
 - Se usará el modelode circulación general LMD-ZT (Cosme et al, 2002) para estudiar la dispersión de azufre oxidado y para calcular los forzamientos radiativos asociados. Comparando las simulaciones regionales y globales exploraremos la sensibilidad respecto a la resolución.
 - Las simulaciones proveerían estimaciones del forzamiento directo e indirecto del azufre oxidado. Los forzamientos así calculados serían evaluados comparando valores simulados y observados. Exploraremos en conjunto la asimilación de datos satelitales sobre esta región del mundo que muestra una enorme falta de observaciones y donde fuertes señales podrían ser detectadas desde sensores remotos, dando una oportunidad de validar los algoritmos de recuperación de información (Este es el tema de la tesis doctoral de Nicolás Huneus a desarrollarse en LOA). En general, buscamos ponderar y acotar de mejor manera la dispersión de azufre oxidado sobre el Pacífico sur oriental.
 - Sobre la base de datos observacionales provistos por proyectos complementarios (e.g., Rutllant et al, 2003; FONDECYT 1020833) esperamos mejorar las parametrizaciones de nubosidad estratiforme los modelos aplicados.

Además del trabajo de modelación, talleres y simposios serán organizados en conjunción con las misiones científicas. También se promoverán estadias cortas (1 a 3 meses) de estudiantes de postgrado. Esperamos establecer tesis co-guiadas para estudiantes de Ciencias Atmosféricas, Matemática e Informática.

Referencias

- Andres RJ, Kasgnoc AD (1998) A time-averaged inventory of subaerial volcanic sulfur emissions. *Journal of Geophysical Research* 103: 25,251-25,261.
- Cosme, E., C. Genthon, P. Martinerie, O. Boucher, and M. Pham, Sulfur cycle at high-southern latitudes in the LMD-ZT General Circulation Model, *Journal of Geophysical Research*, 107(D23), 4690, doi:10.1029/2002JD002149, 2002.
- Gallardo, L., Olivares, G., Langner, J. and Aarhus, B., 2002: Coastal lows and sulfur air pollution in Central Chile. *Atmos. Env.* 36/23 pp. 3829-3841
- Hartmann, D., 1994. Global physical climatology. Academic Press, 411 pp..
- Huneus, N., L. Gallardo, J. Rutllant, and O. Boucher, Dispersion of sulphur aerosols off the coast of Northern Chile: An exploratory study, *Simposio de Cambio Global: hacia una vision sistémica*, Puntas Arenas, Chile, 23-25 Enero.
- Lefohn A.S., Husar J.D., and Husar R.B. (1999). Estimating Historical Anthropogenic Global Sulfur Emission Patterns for the Period 1850-1990. *Atmos. Environ.*, 33,21, 3435-3444.
- Robertson, L., Langner, J., and Engardt, M. 1999. An Eulerian limited-area atmospheric transport model. *J. Appl.Met.* 38, 190-210.
- Rutllant J., Fuenzalida H., Aceituno P., Montecinos A., Sanchez R., Salinas H., Inzunza J. y Zuleta R., 2002, Climate dynamics along the arid northern coast of Chile; The 1997-1998 *DICLIMA* experiment. Submitted to *Journal of Geophysical Research*.
- Scholes et al, 2003. Biosphere-Atmosphere Interactions (Ch. 2). In "The Changing Atmosphere: An Integration and Synthesis of a Decade of Tropospheric Chemistry Research". Brasseur et al (Eds.). Springer-Verlag (ISBN: 3-540-

c. Resultados esperados al término del intercambio

- Mayor capacidad de investigación, herramientas y un espectro científico más amplio para nuestros grupos de investigación.
- Publicaciones comunes y definición de proyectos cooperativos mayores e involucrando a otros grupos de investigación.
- Capacitación y formación a través de tesis e intercambio de estudiantes.
- Talleres y simposios.

d. Relación entre el proyecto de intercambio ECOS-CONICYT y el Proyecto Marco de las partes

En Chile, en el Centro de Modelamiento Matemático, estamos desarrollando proyectos sobre:

- *Stratosphere-Troposphere Exchange (STE) processes and their impact on the ozone balance in the subtropics of the Southern Hemisphere: A multi-scale integrated study based at Cerro Tololo (30°S, 70°W, 2200 m.a.s.l)* (FONDECYT 1030809, 2003-2006).

En este proyecto, modelos meteorológicos serán usados para producir campos meteorológicos tridimensionales regionales y de mesoescala que serán usados para correr un modelo Euleriano de transporte para simular la intrusión y subsecuente dispersión de una traza tipo ozono, sujeta a fotólisis y deposición seca. Las simulaciones serán evaluadas contra observaciones in situ y remotas de ozono, vapor de agua y otras trazas relevantes de intercambio entre estratósfera y tropósfera. Tales campos y datos estarán disponibles para estudiar interacciones entre aerosoles, nubes y clima como se propone aquí.

- *Application and Development of Inverse Modeling techniques to air quality monitoring network design* (INRIA-CONICYT, 2002-2003).

El objetivo general de este proyecto es ensamblar las partes de un eje de investigación duradero y proyectos comunes en modelación inversa aplicada a problemas de contaminación atmosférica a escalas local y regional, con especial énfasis en el diseño de redes de monitoreo para evaluar los impactos de la industria minera en la densamente poblada y expansiva región urbana de Chile central. El creciente número de observaciones de trazas químicas y aerosoles, tanto in situ como remotas, acarrea la posibilidad de aplicar técnicas de asimilación de datos y modelación inversa para mejorar la prestación de los modelos tridimensionales de transporte y química (3-D CTMs), de manera de determinar la intensidad y ubicación de fuentes emisoras, optimizar el diseño de redes de monitoreo, evaluar los errores y sensibilidades de modelos, etc. De tal manera que esta colaboración se vería favorecida por el trabajo aquí propuesto.

En Chile, en el Departamento de Geofísica de la Universidad de Chile:

- Se están realizando estudios para mejorar la comprensión de los procesos dinámicos tras la existencia y persistencia de las capas de estratocúmulos en el Pacífico Sur Oriental, su interacción con los sistemas meteorológicos (incluyendo la convección profunda), los ciclos estacionales y la variabilidad climática interanual sobre América del Sur y su retroalimentación con el océano

subyacente (FONDECYT, 1020833). Este estudio incluye una recopilación de observaciones in situ que pueden usarse para validar resultados de modelos. Otros estudios se han enfocado a los regímenes de circulación que explican la aridez extrema del desierto de Atacama y su influencia sobre la surgencia de aguas frías y ricas en nutrientes (e.g., Rutllant et al, 2002). Estos patrones de circulación son cruciales para determinar los potenciales flujos de especies azufradas de origen biótico y la dispersión costa afuera del azufre oxidado. Un estudio exploratorio por Huneus et al (2003) sugiere que el transporte de azufre oxidado antrópico tendría lugar episódicamente en conexión con la ocurrencia de bajas costeras.

- e. Formulación teórica, objetivos específicos y lista de participantes (no incluir CVs) involucrados en el Proyecto Marco (adjunte documento si lo considera necesario).

VER ANEXO

6. Colaboración entre las Partes (chilenas y francesas)

Antecedentes previos donde se incluya:

- a. Publicaciones co-firmadas.

Gallardo, L., Boucher, O., and Huneus, N., 2002: Potential impacts of Sulfur Aerosols Off the Coast of Central and Northern Chile: A preliminary Assessment. 10th Scientific Conference of the International Association of Meteorology of Atmospheric Sciences (IAMAS) Commission for Atmospheric Chemistry and Global Pollution (CACGP)", and "7th Scientific Conference of the International Global Atmospheric Chemistry Project (IGAC)" "*ATMOSPHERIC CHEMISTRY WITHIN THE EARTH SYSTEM: FROM REGIONAL POLLUTION TO GLOBAL CLIMATE CHANGE*", 18-25 September, 2002, Crete, Greece.

Huneus, N., Gallardo, L., Rutllant, J., and Boucher, O., 2003. Dispersion of sulfur aerosols off the coast of Northern Chile: an exploratory study. Simposio de Cambio Global: Hacia una visión Sistémica, Punta Arenas, 2003.

Huneus, N., Gallardo, L., Rutllant, J., and Boucher, O., 2003. Modeling anthropogenic sulfate aerosol off the Chilean coast. Manuscript in preparation.

- b. Proyectos conjuntos.

Ninguno sobre una base formal

- c. Co-dirección de tesis.

La tesis de MSc en Ciencias Atmosféricas de Nicolás Huneus, "*Dispersión de azufre oxidado en el norte de Chile*" ha sido oficialmente co-guiada por Laura Gallardo y José Rutllant pero este trabajo ha sido seguido de cerca por Olivier Boucher. La tesis doctoral de Nicolás se iniciará oficialmente en Septiembre de 2003 bajo la tutela de Olivier Boucher ("*Assimilation variationnelle d'observations satellitaires dans un modèle atmosphérique d'aérosols*", Université des Sciences et Technologies de Lille).

d. Otros que considere oportuno

Los investigadores principales de esta colaboración se conocieron a principios de los 1990 en el Departamento de Meteorología de la Universidad de Estocolmo en Suecia cuando cursaban sus doctorados. Desde entonces se han mantenido en contacto y han visitado sus respectivos laboratorios. Además, participan en *International Global Atmospheric Chemistry* (IGAC) que es un subproyecto de *International Geosphere-Biosphere Programme* (IGBP).

7. Fuentes de financiamiento para las actividades a realizar durante el Proyecto de Intercambio Regular.

Dado que Ecos solo financia los intercambios, se espera que, cuando corresponda, las partes especifiquen las fuentes de financiamiento para aquellas actividades (ej. viajes a terreno, reactivos, fungibles, etc.) que sean necesarias para el cumplimiento de los objetivos propuestos en el proyecto ECOS-CONICYT.

Fuentes	Montos	Período de vigencia
FONDAP Matemáticas Aplicadas	600.000.000 \$ (anual)	2000-2007
FONDECYT 1030809	86.627.000 \$	2003-2006

Recursos ECOS-CONICYT solicitados para el primer año:

- Número de misiones (Chile/Francia) para investigadores de alto nivel, especificando nombre de los beneficiarios (se dará prioridad a investigadores jóvenes) y beneficios solicitados. Se debe indicar, además, la duración (15 días mínimo), fechas y las actividades específicas a realizar durante las misiones.

Dos misiones en 2004:

- o Visita de Laura Gallardo a LOA en Enero de 2004 por 20 días. El objetivo es sintetizar la información y los resultados obtenidos hasta entonces. Además, en esta estadía se discutirá acerca del tipo de datos de aerosoles que se pretende asimilar en el modelo climático y eventualmente en el modelo regional.
- o José Rutllant visitará LOA y LMD en Paris en Junio de 2004 por 15 días. El objetivo es familiarizarse con las parametrizaciones de estratocúmulos empleadas en el modelo climático y comparar con los datos sobre estratocúmulos recogidos durante la realización de proyectos complementarios.

- Número de misiones (Francia/Chile) para investigadores de alto nivel, especificando el nombre de los beneficiarios (se dará prioridad a investigadores jóvenes) y beneficios solicitados. Se debe indicar, además, la duración (15 días mínimo), fechas de los intercambios (i.e. meses) y las actividades específicas a realizar durante las misiones.

No se contemplan misiones durante el primer año sino que para el segundo

- Número de estadías de perfeccionamiento o post-doctorales para estudiantes chilenos en Francia, adjuntando, además, el curriculum vitae del candidato y breve programa de trabajo. Se debe

especificar si el postulante cuenta con financiamiento en Chile (FONDECYT u otros).

- Número de estadías de perfeccionamiento o post-doctorales para estudiantes franceses en Chile, anexando curriculum vitae del candidato y breve programa de trabajo.
- Becas de doctorado en co-tutela previstas en la totalidad del proyecto (1 o 2 estadías por un máximo de 18 meses) . Anexar curriculum vitae del candidato y breve programa de trabajo.

(Nota: Es indispensable completar formulario de becas adjunto)

8. Información complementaria (marcar el que corresponda) :

- Este Proyecto fue presentado en totalidad o en parte a otro organismo (indicar los recursos eventualmente obtenidos) :

Organismo

Recursos Obtenidos

- Este Proyecto no fue sometido total o parcialmente a ningún otro organismo.

No

PROGRAMA DE COOPERACION ECOS-CONICYT

Fecha :

Nombre y firma del responsable chileno del Proyecto :

Nombre y firma del responsable de la Unidad de Investigación a la cual pertenece el responsable del Proyecto:

¡Error! Marcador no definido.

IMPORTANTE

Adjuntar obligatoriamente el CV de cada investigador chileno y francés beneficiarios de las misiones solicitadas, de acuerdo al formato adjunto.

CONICYT: Departamento de Relaciones Internacionales - DRI
Bernarda Morín #545 piso 3, Providencia, Santiago
Teléfono:(56-2)3654428-3654425, Fax:(56-2)2741897

**POSTULACIONES A BECAS DE DOCTORADO EN CO-TUTELA
PROGRAMA ECOS/CONICYT**

Ruego a Ud. adjuntar la siguiente información, en relación a su postulante

- Curriculum Vitae
- Area de especialidad a la que postula:
- Nombre del programa de Doctorado:
- Programa acreditado en CONICYT SI ____ NO ____
- Año de inicio
- Título de la Tesis
- Tutor de la tesis en Chile
- Tutor de la tesis en Francia
- Universidad en Francia
- Dominio del idioma Francés: Excelente ☐ Aceptable ☐ Regular ☐

NOTA

1. Respecto a las postulaciones para becas de co-tutela Chile-Francia es fundamental el conocimiento del idioma francés. La Embajada de Francia considera la oferta de un curso previo de preparación en el idioma francés.
2. La beca de co-tutela no contempla financiamiento para la familia del becario.

CURRICULUM VITAE

1. PERSONAL INFORMATION

Name : Laura E. G. Gallardo Klenner
Born : Santiago de Chile, February 27th 1962
Nationality : Chilean
Address : Blanco Encalada 2120, piso 7, Santiago, Chile
Possition : Associated researcher, Part time teacher

2. STUDIES

- B.Sc. Physics 1986, Department of Physics, Faculty of Physical and Mathematical Sciences, University of Chile
- M.Sc. Chemical Meteorology, 1993, Department of Meteorology, Stockholm University
- Ph.D. Chemical Meteorology, 1996, Department of Meteorology, Stockholm University

3. ACADEMIC APPOINTMENTS

- PhD student (teaching and research), Stockholm University (1991-1996)
- Part-time teacher, Geophysics Department, University of Chile (1998-)
- Associate researcher, Center for Mathematical Modeling, University of Chile (2001-)

4. OTHER APPOINTMENTS

- 1986-1987 Research assistant, Department of Geophysics, University of Chile
- 1997-2001 Scientific Advisor for the Chilean Environmental Agency (Comisión Nacional del Medio Ambiente, CONAMA).

5. AWARDS

6. ACTIVE RESEARCH GRANTS.

YEAR		TITLE	FUNDING AGENCY
Starting	Ending		
2003	2006	<i>Stratosphere-Troposphere Exchange processes and their impact on the ozone balance in the subtropics of the Southern Hemisphere: A multi-scale integrated study based at Cerro Tololo (30°S, 70°W, 2200 m.a.s.l) (FONDECYT 1030809, 2003-2006).</i>	CONICYT
2002	2003	<i>Application and development of inverse modeling techniques to air quality monitoring network design</i>	CONICYT/Chile-INRIA/France
2002	2003	DIULS 020-2-03 <i>Influencia de fenómenos meteorológicos sobre la dispersión de contaminantes atmosféricos en la Región de Coquimbo</i>	Dirección de Investigación Universidad de La Serena

7. RESEARCH GRANTS OBTAINED UNDER COMPETITIVE BASIS (last 5 years)

- CONICYT-FONDECYT 1030809, 2003-2006 (Principal Investigator): *Stratosphere-Troposphere Exchange processes and their impact on the ozone balance in the subtropics of the Southern Hemisphere: A multi-scale integrated study based at Cerro Tololo (30°S, 70°W, 2200 m.a.s.l)*
- CONICYT-INRIA, 2002-2003 (Principal Investigator): *Application and development of inverse modeling techniques to air quality monitoring network design*
- CONICYT-BMBF, 1999-2-196, 2000-2001 (Co-investigator): *Un sistema de información ambiental sobre contaminación atmosférica*
- CONICYT-BMBF, CHL 007/98ENV, 1999-2-196, 1999-2001 (Co-investigator): The influence of meteorological phenomena on trace gas concentrations at Cerro Tololo

NB. CONICYT: Chilean Research Council; **INRIA:** French Institute for research on Informatics and automatization; **BMBF:** German Federal Ministry for Research and Education

8. SCIENTIFIC PUBLICATIONS

8.1. ISI publications

Authors, Year and Title	Journal
Rodhe, H., Langner, J., Gallardo, L. , and Kjellström, E., 1995: Global scale transport of acidifying pollutants.	<i>Water, Air and Soil Pollut.</i> , 85:37-50.
Gallardo, L. and Cooray, V., 1996: Could cloud-to-cloud discharges be as effective as cloud-to-ground discharges in producing NO _x ?	<i>Tellus B</i> , 641-651.
Lee, D., Köhler, I., Grobler, E., Rohrer, F., Sausen, R., Gallardo, L. , Olivier, J. and Dentener, F., 1996: Estimations of global NO _x emissions and their uncertainties.	<i>Atmos. Env.</i> , 31, 12, 1735-1749.
Gallardo, L. and Rodhe, H., 1997: Oxidized nitrogen in the remote Pacific: the role of electrical discharges over the oceans.	<i>Atmos. Chem.</i> , 26, 147-168.
Ryaboshapko, A., Gallardo, L. , Kjellström, E., Gromov, S., Paramonov, S., Afonogenova, O. and Rodhe, H., 1998: Balances of oxidized sulfur and nitrogen over the former Soviet Union territory.	<i>Atmos. Env.</i> , 32, 647-658.
Bergan, T., Gallardo, L. and Rodhe, H., 1999: Mercury in the global troposphere: a three-dimensional model study.	<i>Atmos. Env.</i> 33, 1575-1585.
Gallardo, L. , Carrasco, J. and Olivares, G., 2000: An analysis of ozone measurements at Cerro Tololo (70°W, 30°S, 2200 m.a.s.l.) in Chile.	<i>Tellus B</i> , 52, 50-59.
Kalthoff, N., Bischoff-Gauß, I., Fiebig-Wittmaack, M., Fiedler, F., Thürauf, J., Novoa, E., Pizarro, C., Castillo, R. Gallardo, L. , Rondanelli, R., 2002: Mesoscale Wind Regimes in Chile at 30 °S.	<i>J. Appl. Meteo.</i> , 953-970.
Gallardo, L. , Olivares, G., Langner, J. and Aarhus, B., 2002: Coastal lows and sulfur air pollution in Central Chile.	<i>Atmos. Env.</i> 36, 23, 3829-3841
Olivares, G., Gallardo, L. , Langner, J. and Aarhus, B., 2002: Regional dispersion of oxidized sulfur in Central Chile.	<i>Atmos. Env.</i> 36, 23, 3819-3828
Rondanelli, R., Gallardo, L. , Garreaud, R., 2002: Tropospheric ozone changes at Cerro Tololo (30°S, 70°W, 2200 m) in connection with cut-off lows.	<i>J. Geophys. Res.</i> , 10.1029/2001JD001334, 03 December 2002.

8.2. Non-ISI publications

Authors, Year and Title	Publication
Gallardo, L. , Rodhe, H. and Crutzen, P., 1993: Evaluation of a global 3-D model of the tropospheric odd nitrogen cycle.	Licenciat thesis. Department of Meteorology, Stockholm University, 55 pp.
Gallardo, L. and Rodhe, H., 1995: <i>Evaluation of a global 3-D model of tropospheric oxidized nitrogen</i> .	Report CM-85, International Meteorological Institute in Stockholm, Department of Meteorology, Stockholm University.
Gallardo, L. , Kjellström, E. and Feichter, J. 1995: <i>Representation of the global emission of oxidized nitrogen by lightning discharges in large-scale models</i> . Report	CM-87, International Meteorological Institute in Stockholm, Department of Meteorology, Stockholm University.
Gallardo, L. , Olivares, G., Aguayo, A., Langner, J., Aarhus, B., Gidhagen, L., 2000. “ <i>Regional Dispersion of Oxidized Sulfur over Central Chile Using the HIRLAM – MATCH System</i> ”. Strengthening of the Air Quality Information System (Working area 2): Application of a regional-scale model over the central part of Chile.	Final report. National Commission for the Environment [www.conama.cl]

8.3. BOOKS - CHAPTERS

Authors and title	Publication
Sausen, R., Hov, Ø., Johnson, C., Kelde, H., Köhler, I., Kraabøl, A., Ramarosan, R., Rohrer, F., Stordal, F., Strand, A., van Velthoven, P., Wauben, W., Lee, D., Gallardo, L. , Gardner, R., and Grobler, E., 1995: The impact of NO _x emissions from aircraft upon the atmosphere at flight altitudes 8-15 km (AERONOX). Sub-project 3, Global Atmosphere Model Simulations.	Commission of European Communities, Brussels.
Gallardo, L. , 1996: Oxidized nitrogen in the troposphere: the role of lightning. Filosofie Doctor thesis. Department of Meteorology, Stockholm University	Akademityck AB, Edsbruk, Sweden, 172 pp.
Gallardo, L. , 2003. Trazas atmosféricas y su modelación. Capítulo 7, en Morales et al (Eds).	Centro Nacional del Medio Ambiente
Matus, P., Farías, F. y Gallardo, L. , 2003. Política pública ambiental.	Organización Panamericana de la Salud (OPS).

8.4. EDITOR OF BOOKS-PROCEEDINGS-OTHERS

Authors and title	Publication

9. GRADUATE ACTIVITIES

9.1. MEMBER OF THESIS COMMITTEES

9.2. STUDENTS SUPERVISED

Gustavo Olivares "*Dispersión de azufre oxidado en Chile central*", M.Sc. Thesis Chemical Engineering, University of Chile. Defended with honors October 2001. Now PhD student at the Dept. of Meteorology, Stockholm University (MISU).

Roberto Rondanelli, "*Caracterización sinóptica de la estación de Cerro Tololo y análisis de las observaciones de ozono*", M.Sc. Atmospheric Sciences, University of Chile. Co-guided by Dr. René Garreaud, Geophysics Dept. U. of Chile. Defended with honors December 2001. Now PhD student at the Massachusetts Institute of Technology (MIT)

Nicolás Huneeus, "*Dispersión de azufre oxidado en el norte de Chile*" M.Sc. Atmospheric Sciences, University of Chile. Co-guided by Dr. José Rutllant, Geophysics Dept. U. of Chile. To be defended in early 2003. He will start a PhD training at Lille University in April 2003.

Cristian Bustos, "*Revisión de la aplicación de modelos gaussianos a la evaluación de impactos de fuentes puntuales sobre la calidad del aire*" M.Sc. Thesis Environmental Management and Planning, University of Chile. Initiated in March 2001. To be defended in early 2003.

Henry Quiroz, "*Modelación inversa y su aplicación a la determinación de fuentes y optimización de redes de monitoreo*". M.Sc. Atmospheric Sciences, University of Chile. Initiated November 2001. He will start a PhD training at Ecole National de Ponts et Chaussées in October 2003.

Rafael Valdés, "*Análisis de sondeos de ozono troposférico realizados en Isla de Pascua (1996-2002): tendencias y representatividad*". Atmospheric Chemistry degree, University of Chile. Initiated October 2002.

10. POSTDOCTORAL TRAINEES

11. OTHER ACTIVITIES RELEVANT TO THE PROPOSAL

Laura Gallardo has been elected as a member of the Scientific Committee of the International Global Atmospheric Chemistry (IGAC) for the period 2003-2006. At the Department of Geophysics, University of Chile, she teaches a course on atmospheric chemistry models and another on global change. At the Department of Mathematical Engineering she teaches on inverse modeling.

Olivier Boucher
Laboratoire d'Optique Atmosphérique
Université de Lille-1
59655 Villeneuve d'Ascq Cedex
Tél (bureau) : 03 20 43 62 30
Mél: boucher@loa.univ-lille1.fr
Marié, 32 ans, 2 enfants.
Nationalité française.

Docteur en sciences de l'atmosphère
Ancien élève de l'Ecole Normale Supérieure
Chercheur au CNRS, habilité
Bilingue français-anglais
Notion d'espagnol



Expériences professionnelles

Octobre 1999 – Septembre 2001: Détaché à l'institut Max Planck de chimie à Mayence (Allemagne).

Depuis octobre 1996 : Chercheur au CNRS affecté au Laboratoire d'Optique Atmosphérique de l'Université de Lille.

Septembre 1992 à septembre 1996 : Doctorant et chercheur au Laboratoire de Météorologie Dynamique du CNRS (Paris) et au département de météorologie de l'Université de Stockholm (Suède).

Responsabilités professionnelles

Investigateur de plusieurs instruments et missions spatiales (POLDER-2 et CALIPSO).

Participant ou coordonnateur de plusieurs projets de recherche nationaux et internationaux.

Coordonnateur du projet européen DAEDALUS et la partie "aérosol" du projet européen intégré GEMS.

Expert pour de nombreuses institutions dont le CNES, le CNRS, le FNRS (Belgique), le NERC (Grande-Bretagne), et journaux scientifiques.

Editeur thématique de la revue *Annales Geophysicae* (lower atmosphere and climate) depuis 09/02.

Editeur associé du journal *La Météorologie* de la Société Météorologique de France.

Formation, diplômes et prix

Octobre 2000 : Médaille de Bronze du CNRS.

Septembre 1996 : Prix Prud'homme de la Société Météorologique de France.

Décembre 1995 : Docteur ès sciences de l'université Pierre et Marie Curie, Paris.

Juin 1991 : Maîtrise de mathématiques appliquées de l'Université Pierre et Marie Curie, Paris.

Ancien élève de l'Ecole Normale Supérieure de Paris. Agrégé de mathématiques.

Informatique et langues

Connaissances des systèmes d'exploitation UNIX, LINUX, WINDOWS, des langages de programmation Fortran, C et OpenMP, des logiciels graphiques GrADS, Ferret, IDL et PV-WAVE, de LaTeX, Microsoft Office et Microsoft Project.

Bilingue français-anglais.

Connaissances en allemand, suédois et espagnol.

PRODUCTION SCIENTIFIQUE DE OLIVIER BOUCHER (5 dernières années)

Une grande partie des publications est consultable à partir du site <http://www-loa.univ-lille1.fr/~boucher>

1. Revues à comité de lecture

Boucher, O., On Aerosol direct shortwave forcing and the Henyey-Greenstein phase function, *Journal of the Atmospheric Sciences*, 55, 128–134, 1998.

Boucher, O., M. Pham, and R. Sadourny, General circulation model simulations of Indian summer monsoon with increasing levels of sulphate aerosols, *Annales Geophysicæ*, 16, 346–352, 1998.

Boucher, O., S. E. Schwartz, T. P. Ackerman, T. L. Anderson, B. Bergstrom, B. Bonnel, P. Chylek, A. Dahlback, Y. Fouquart, Q. Fu, R. N. Halthore, J. Haywood, T. Iversen, S. Kato, S. Kinne, A. Kirkevåg, E. Knapp, A. Lacis, I. Laszlo, M. I. Mishchenko, S. Nemesure, V. Ramaswamy, D. Roberts, P. Russell, M. Schlesinger, G. L. Stephens, R. Wagener, M. Wang, J. Wong, and F. Yang, Intercomparison of models representing shortwave radiative forcing by sulfate aerosols, *Journal of Geophysical Research*, 103, 16979–16998, 1998.

Boucher, O., Aircraft can increase cirrus cloudiness, *Nature*, 397, 30–31, 1999.

Boucher, O., and D. Tanré, Estimation of the aerosol perturbation to the Earth's radiative budget over oceans using POLDER satellite aerosol retrievals, *Geophysical Research Letters*, 27, 1103–1106, 2000.

Boucher, O., and J. M. Haywood, On summing the components of radiative forcing of climate change, *Climate Dynamics*, 18, 297–302, 2001.

Boucher, O., and M. Pham, History of the sulfate aerosol radiative forcings, *Geophysical Research Letters*, 29(9), 1308, doi:10.1029/2001GL014048, 2002.

Boucher, O., C. Moulin, S. Belviso, O. Aumont, L. Bopp, E. Cosme, R. von Kuhlmann, M. G. Lawrence, M. Pham, M. S. Reddy, and C. Venkataraman, DMS atmospheric concentrations and sulphate aerosol indirect radiative forcing: a sensitivity study to the DMS source representation and oxidation, *Atmospheric Chemistry and Physics*, 3, 49–65, 2003.

Claquin, T., M. Schulz, Y. Balkanski, and O. Boucher, Uncertainties in modelling radiative forcing by mineral dust, *Tellus*, 50B, 491–505, 1998.

Cosme, E., C. Genthon, P. Martinerie, O. Boucher, and M. Pham, Sulfur cycle at high-southern latitudes in the LMD-ZT General Circulation Model, *Journal of Geophysical Research*, 107(D23), 4690, doi:10.1029/2002JD002149, 2002.

Formenti, P., O. Boucher, T. Reiner, D. Sprung, M. O. Andreae, M. Wendisch, H. Wex, D. Krinkred, M. Tzourtziou, A. Vasaras, and C. Zerefos, The STAAARTE-MED 1998 airborne measurements over the Aegean Sea: II. Aerosol scattering and absorption, and radiative calculations, *Journal of Geophysical Research*, 107(D21), 4451, doi:10.1029/2001JD001536, 2002.

Guyon, P., O. Boucher, B. Graham, J. Beck, O. L. Mayol-Bracero, P. Artaxo, W. Maenhaut, and M. O. Andreae, Refractive index of aerosol particles over the Amazon Tropical forest during LBA-EUSTACH 1999, *Journal of Aerosol Science*, sous presse, 2003.

Kaufman, Y. J., D. Tanré, and O. Boucher, A satellite view of aerosols in the climate system, *Nature*, 419, 215-223, 2002.

Haywood, J. M., and O. Boucher, Estimates of the direct and indirect radiative forcing due to tropospheric aerosols: A review, *Reviews of Geophysics*, 38, 513-543, 2000.

Le Treut, H., M. Forichon, O. Boucher, and Z.-X. Li, Sulfate aerosol indirect effect and CO₂ greenhouse forcing: equilibrium response of the LMD GCM and associated cloud feedbacks, *Journal of Climate*, 11, 1673-1684, 1998.

Ibis. Revues à comité de lecture (articles soumis)

Anderson, T. L., R. J. Charlson, S. E. Schwartz, R. Knutti, O. Boucher, H. Rodhe, and J. Heintzenberg, Forbidden magnitudes of aerosol forcing, *Science*, soumis, 2003.

Bellouin, N., O. Boucher, D. Tanré, and O. Dubovik, Estimation of aerosol absorption over the oceans from POLDER and AERONET data, *Geophysical Research Letters*, soumis, 2003.

Bellouin, N., and O. Boucher, Refinements and assumptions in estimating the aerosol radiative forcing, *Journal of Quantitative Spectroscopy and Radiative Transfer*, en préparation, 2003.

Bopp, L., O. Boucher, O. Aumont, S. Belviso, J.-L. Dufresne, M. Pham, and P. Monfray, Will marine dimethylsulphide emissions alleviate global warming?, *Canadian Journal of Fisheries and Aquatic Sciences*, soumis, 2002.

Boucher, O., G. Myhre, and A. Myhre, Direct influence of irrigation on atmospheric water vapour and climate, *Climate Dynamics*, soumis, 2003.

Generoso, S., F.-M. Bréon, Y. Balkanski, O. Boucher, and M. Schulz, Improving the seasonal cycle and interannual variations of biomass burning aerosol sources, *Atmospheric Chemistry and Physics*, soumis, 2003.

Guyon, P., B. Graham, J. Beck, O. Boucher, E. Gerasopoulos, O. L. Mayol-Bracero, G. C. Roberts, P. Artaxo, and M. O. Andreae, Physical properties and concentration of aerosol particles over the Amazon tropical forest during background and biomass burning conditions, *Atmospheric Chemistry and Physics*, soumis, 2003.

Menon, S., O. Boucher, P. Davison, A. Del Genio, J. Feichter, S. Ghan, U. Lohmann, X. Liu, J. Penner, J. Quaas, D. Roberts, Evaluating cloud-aerosol process parameterizations with a single column model and ACE-2 Cloudy Column observations, *Journal of Geophysical Research*, soumis, 2003.

Quaas, J., O. Boucher, J.-L. Dufresne, and H. Le Treut, Aerosol-cloud-radiation interactions in the LMDZT GCM and their impact on the simulated 20th century climate, xxx, en préparation, 2003.

Trentmann, J., B. Früh, O. Boucher, T. Trautmann, and M. O. Andreae, Three-dimensional solar radiation effects in a biomass burning plume: Implications for photochemistry and remote sensing, *Journal of Geophysical Research*, soumis, 2003.

2. Conférences invitées dans des congrès

Boucher, O., The use of models and measurements to resolve the indirect effect of aerosols, Part I. The history of the indirect aerosol effect, *Proceedings of the ALPS'99 International Conference*, Méribel, France, 18-22 January 1999, pp. Aerosols/O/02/1-2, 1999.

Boucher, O., J.-C. Buriez, I. Chiapello, P. Goloub, Y. J. Kaufman, J. Riedi, and G. Sèze, The use of models and measurements to resolve the indirect effect of aerosols, Part II. Detection of the indirect effect of aerosols by POLDER, *Proceedings of the ALPS'99 International Conference*, Méribel, France, 18-22 January 1999, pp. Aerosols/O/02/3-4, 1999.

Boucher, O., N. Bellouin, M.S. Reddy, P. Guyon, and J. Trentmann, Direct radiative forcing of aerosols, *Abstracts*, pp. 37, *8th Scientific Assembly of IAMAS*, Innsbruck, July 2001.

Boucher, O., Climatic effects of aerosols, *Simposio Cambio Climatico, Cienca de Cambio Climatico en Chile*, Santiago du Chili, 3-5 décembre 2001.

Boucher, O., Aerosol radiative forcing and related feedbacks: How do we reduce the uncertainties, *IGACActivities*, n° 26, pp. 8-12, May 2002. (conférence invitée à l'IGAC Planning Meeting, Stockholm, 27-30 January 2002)

Boucher, O., Indirect radiative forcing by tropospheric aerosols and aircraft emissions, *Radiative Forcing of Climate Change*, *Royal Meteorological Society*, Londres, 20 février 2002.

Boucher, O., Integrating aerosols data into policy relevant information, *Second conference of the GMES forum*, ESA-ESTEC, Noordwijk, Pays-Bas, 14-16 janvier 2003.

Boucher, O., Aerosols and radiative forcing of climate, invited talk, *Gordon Research Conference on 'Solar Radiation and Climate'*, juillet 2003.

Kaufman, Y., L. Remer, D. Tanré, O. Boucher, M. Chin, O. Dubovik, and B. Holben, New results from space and field observations on the aerosol direct and indirect radiative forcing, *Fall AGU meeting*, San Francisco, December 2002.

3. Proceedings à comité de lecture

4. Publications dans des revues sans comité

Boucher, O., C. Moulin, S. Belviso, O. Aumont, L. Bopp, E. Cosme, R. von Kuhlmann, M. G. Lawrence, M. Pham, M. S. Reddy, and C. Venkataraman, Sensitivity study of DMS atmospheric concentrations and

sulphate aerosol indirect radiative forcing to the DMS source representation and oxidation, *Atmospheric Chemistry and Physics Discussions*, 2, 1181-1216, disponible en ligne sur www.atm-chem-phys.org, 2002.

Generoso, S., F.-M. Bréon, Y. Balkanski, O. Boucher, and M. Schulz, Improving the seasonal cycle and interannual variations of biomass burning aerosol sources, *Atmospheric Chemistry and Physics Discussions*, disponible en ligne sur www.atm-chem-phys.org, 2003.

Guyon, P., B. Graham, J. Beck, O. Boucher, E. Gerasopoulos, O. L. Mayol-Bracero, G. C. Roberts, P. Artaxo, and M. O. Andreae, Physical properties and concentration of aerosol particles over the Amazon tropical forest during background and biomass burning conditions, *Atmospheric Chemistry and Physics Discussions*, 3, 1367-1414, disponible en ligne sur www.atm-chem-phys.org, 2003.

5. Communication à des congrès, symposium

Bellouin, N., O. Boucher, and D. Tanré, Direct use of clear-sky POLDER radiances to retrieve the aerosol flux perturbation over the oceans, *Abstracts*, pp. 38-39, *8th Scientific Assembly of IAMAS*, Innsbruck, July 2001.

Bellouin, N., O. Boucher, and D. Tanré, Direct use of clear-sky POLDER radiances to retrieve the shortwave aerosol radiative perturbation over the ocean, *21st Annual Conference of the American Association for Aerosol Research*, Charlotte, North Carolina, October 7-11, 2002.

Bopp, L., O. Boucher, O. Aumont, S. Belviso, C. Moulin, M. Pham, and P. Monfray, Towards an assesment of the DMS-aerosol-climate feedback, *Third International Symposium on Biological and Environmental Chemistry of DMS(P) and related compounds*, Rimouski, Canada, 26-28 Septembre 2002.

Bopp, L., O. Boucher, O. Aumont, S. Belviso, J.-L. Dufresne, M. Pham, and P. Monfray, Will marine DMS emissions amplify or alleviate global warming? - A model study, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Boucher, M., J. Quaas, O. Boucher, and J.-L. Dufresne, Testing and developing cloud parameters in the LMDZ GCM by using POLDER and METEOSAT satellite data, session CL5, Observing climate change and variability from space: achievements and challenges, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Boucher, O., Is there any observable increase in cirrus cloud due to aviation during 1982–1991?, *European Geophysical Society General Assembly, Annales Geophysicæ*, Supplement II to Volume 16, pp. C765 / Supplement III to Volume 16, pp. C953, Nice, avril 1998.

Boucher, O., J.-C. Buriez, I. Chiapello, P. Goloub, Y. J. Kaufman, J. Riedi, and G. Sèze, Detection of the indirect effect of aerosols by POLDER, *Geophysical Research Abstracts, European Geophysical Society General Assembly*, La Haye, avril 1999.

Boucher, O., and M. Pham, Time history of the sulfur cycle and sulfate radiative forcing, Session ERE.1, *XXVII European Geophysical Society General Assembly*, Nice, avril 2002.

Boucher, O., S. Belviso, E. Cosme, and C. Moulin, Sensitivity of the sulfur cycle and sulfate aerosol indirect effect to the representation of the DMS source, Session ST8, Chemistry-climate interactions, *XXVII European Geophysical Society General Assembly*, Nice, avril 2002.

Cosme, E., C. Genthon, P. Martinerie, O. Boucher, and M. Pham, Simulation of the atmospheric sulfur cycle at mid and high southern latitudes using a general circulation model, *Geophysical Research Abstracts*, Volume 3, available as a CD-ROM from the European Geophysical Society, *European Geophysical Society General Assembly*, Nice, avril 2001.

Cosme, E., C. Genthon, P. Martinerie, O. Boucher, and M. Pham, Dimethylsulfide (DMS) oceanic emissions around Antarctica in LMD-ZT general circulation model, Poster presented at the international workshop *Emission of Chemical Species and Aerosols into the Atmosphere*, Paris, 19-22 June 2001.

Cosme, E., O. Boucher, C. Genthon, P. Martinerie, M. Pham, and J. Sciare, A study of dimethylsulfoxide (DMSO) oxidation with a global sulfur cycle model, Session OA20.02, Tropospheric chemistry and aerosols: Heterogeneous chemistry and modelling, *XXVII European Geophysical Society General Assembly*, Nice, avril 2002.

Cosme, E., C. Genthon, P. Martinerie, O. Boucher, and M. Pham, High-southern latitudes sulfur cycle in an atmospheric general circulation model, *Spring meeting of the American Geophysical Union*, session A52, Washington, 28-31 May 2002.

Formenti, P., O. Boucher, T. Reiner, D. Sprung, M. O. Andreae, M. Wendisch, H. Wex, D. Krindred, M. Tzourtziou, A. Vasaras, and C. Zerefos, The STAAARTE-MED airborne measurements over the Aegean Sea: II. Aerosol scattering, absorption, and radiative calculations, *8th European Symposium on the Physico-Chemical Behaviour of Atmospheric Pollutants*, Torino (Italy), septembre 2001.

Gallardo, L., O. Boucher, and N. Huneus, Potential impacts of sulfur aerosols off the coast of Central and Northern Chile: A preliminary assessment, *7th "International Global Atmospheric Chemistry" Scientific Conference*, Crete, 18-25 September 2002.

Generoso, S., Y. Balkanski, O. Boucher, F.-M. Bréon, and M. Schulz, Comparisons between aerosol data retrievals from the POLDER spaceborne instrument and aerosol output from the LMDz model, *7th "International Global Atmospheric Chemistry" Scientific Conference*, Crete, 18-25 September 2002.

Generoso, S., F.-M. Bréon, Y. Balkanski, O. Boucher, M. Schulz, Improving the seasonal cycle and interannual variations of biomass burning aerosol sources, session AS6.05 The global aerosol system - perspectives from satellite measurements, global chemical transport and climate models, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Hauglustaine, D., M. Schulz, Y. Balkanski, G. Folberth, C. Textor, S. Bauer, L. Jourdain, S. Generoso, and O. Boucher, Interactive chemistry and aerosols in a general circulation model: LMDz-INCA, session AS11.02 SPARC-IGAC Symposium on climate-chemistry interactions, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Huneus, N., L. Gallardo, J. Rutilant, and O. Boucher, Dispersion of sulphur aerosols off the coast of Northern Chile: An exploratory study, *Simposio de Cambio Global: hacia una vision sistematica*, Puntas Arenas, Chili, 23-25 janvier 2003.

Jourdain, L., D. Hauglustaine, F. Hourdin, M.-A. Filiberti, A. Armangaud, O. Boucher, The global distribution of NO_x simulated on-line in the LMDz general circulation model, ST6 Processes and issues in the upper troposphere and lower stratosphere, *Geophysical Research Abstracts*, Volume 2, available as a CD-ROM from the European Geophysical Society, *European Geophysical Society General Assembly*, Nice, avril 2000.

Mercier, P., F. Hourdin, O. Boucher, M. Pham, D. Hauglustaine, and C. Granier, Greenhouse gases in the LMD-Z general circulation model, *Annales Geophysicae*, Supplement II to Volume 16, pp. 742 / Supplement IV to Volume 16, pp. C1120, *European Geophysical Society General Assembly*, Nice, avril 1998.

Pham, M., and O. Boucher, Simulation of the global sulfur cycle in the general circulation model LMDZ, OA2 Anthropogenic climate changes: forcing, impacts, including socio-economic aspects and uncertainties, *Geophysical Research Abstracts*, Volume 2, available as a CD-ROM from the European Geophysical Society, *European Geophysical Society General Assembly*, Nice, avril 2000.

Pham, M., O. Boucher, D. Hauglustaine, and J.-F. Müller, Influence of changes in stratospheric ozone on sulfur chemistry and related climate effects, *Quadriennial Ozone Symposium*, Japon, 2000.

Quaas, J., and O. Boucher, Parameterization of the aerosol indirect effect in the LMDZT GCM, *Abstracts*, pp. 52, *8th Scientific Assembly of IAMAS*, Innsbruck, July 2001.

Quaas, J., O. Boucher, and F.-M. Bréon, Aerosol-cloud interactions in the LMDZ GCM and in POLDER satellite data, session AS6.05 The global aerosol system - perspectives from satellite measurements, global chemical transport and climate models, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Quaas, J., O. Boucher, and H. Le Treut, Development of a liquid- and ice-phase cloud microphysics scheme and application in the LMDZ GCM to investigate aerosol indirect effects, session AS4.05 Aerosol-cloud interactions, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Quaas, J., O. Boucher, J.-L. Dufresne, and H. Le Treut, Mechanisms of anthropogenic climate change in a simulation of the 20th century's climate with the LMDZ GCM with focus on aerosol indirect radiative effects, session CL6, Anthropogenic climate changes: forcing, modelling, detection and impact, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Reddy, M.S., C. Venkataraman, O. Boucher, and M. Pham, A sulphur dioxide and aerosol emissions inventory for India for implementation in the LMD GCM, Poster presented at the international workshop *Emission of Chemical Species and Aerosols into the Atmosphere*, Paris, 19-22 June 2001.

Reddy, M.S., C. Venkataraman, O. Boucher, and M. Pham (2001). A 0.25° x 0.25° SO₂ and aerosol emissions inventory for India and implementation in the LMD GCM during INDOEX-IFP 1999, *A Changing Atmosphere, 8th European Symposium on the Physico-Chemical Behaviour of Atmospheric Pollutants*, Torino (Italy), septembre 2001.

Reddy, M. S., O. Boucher, J.-F. Léon, C. Venkataraman, and M. Pham, Simulation of aerosol transport and radiative effects in LMD-GCM during INDOEX-IFP 1999, Session OA20.02 Tropospheric Chemistry and Aerosols: Heterogeneous Chemistry and Modelling, *Geophysical Research Abstracts*, *European Geophysical Society XXVII General Assembly*, Nice, avril 2002.

Reddy, M. S., O. Boucher, and C. Venkataraman, Seasonal carbonaceous aerosol emissions from open biomass burning in India, *Annual Conference of Indian Aerosol Science and Technology Association*, Thiruvananthapuram, India, September 18-20, 2002.

Reddy, M. S., O. Boucher, C. Venkataraman, and M. Pham, Analysis of regional aerosol transport during INDOEX through GCM modelling, *Annual Conference of Indian Aerosol Science and Technology Association*, Thiruvananthapuram, India, September 18-20, 2002

Reddy, M. S., O. Boucher, C. Venkataraman, J.-F. Léon, and M. Pham, Aerosol transport and radiative effects during north-east winter Indian monsoon, *21st Annual Conference of the American Association for Aerosol Research*, Charlotte, North Carolina, October 7-11, 2002.

Reddy, M. S., and O. Boucher, Carbonaceous aerosol transport and radiative forcing estimates in LMD-Z GCM, session AS6.05, The global aerosol system - perspectives from satellite measurements, global chemical transport and climate models, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Reddy, M. S., O. Boucher, Y. Balkanski, and M. Schulz, Global three-dimensional simulation of multi-component aerosol transport and radiative forcing with GCM, session AS6.05, The global aerosol system - perspectives from satellite measurements, global chemical transport and climate models, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Reddy, M. S., O. Boucher, S. Belviso, O. Aumont, L. Bopp, and P. Monfray, Natural aerosol emissions and fate in the future climate: sea salt and dimethylsulfide, session AS11.02, SPARC-IGAC Symposium on climate-Chemistry Interactions, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Reddy, M. S., C. Venkataraman, and O. Boucher Decadal trends in fossil fuel energy consumption and related air pollutant emissions, session ERE1, Modelling the scientific and socio-economic aspects of anthropogenic changes to the atmosphere, EGS - AGU - EUG Joint Assembly, Nice, France, April 2003.

Sadourny, R., A. Harzallah, O. Boucher, and M. Pham, Indian monsoon variability: Observations and modelling, *Proceedings of INTROMET'97 International Symposium on Asian Monsoon and Pollution over the Monsoon Environment*, 2-5 December 1997, New-Delhi, 1998.

Schulz, M., O. Boucher, Y. Balkanski, M. S. Reddy, and F.-M. Bréon, Use of spaceborne POLDER aerosol index and optical thickness in cloud free regions, *7th "International Global Atmospheric Chemistry" Scientific Conference*, Crete, 18-25 September 2002.

Trentmann, J., B. Frueh, O. Boucher, T. Trautmann, and M. O. Andreae, Three-dimensional solar radiation effects in a biomass plume, OA16. Clouds in radiative and dynamical processes, *Geophysical Research Abstracts, European Geophysical Society XXVII General Assembly*, Nice, avril 2002.

Trentmann, J., M. O. Andreae, O. Boucher, and H.-F. Graf, Investigation of a biomass burning plume: Aerosol absorption and atmospheric chemistry, *Spring meeting of the American Geophysical Union*, session A22, Washington, 28-31 May 2002.

6. Séminaires, workshops

Bellouin, N., et O. Boucher, Etude de l'impact radiatif des aérosols à l'aide de POLDER, *Journée « Fédération de recherche et ELICO », Université du Littoral et Côte d'Opale*, 24 juin 2002.

Boucher, O., et M. Pham, Modélisation du cycle du soufre "en ligne" dans le modèle de circulation générale LMDZ : Premiers résultats et perspectives, Poster présenté au *Colloque de prospective du PNCA*, Clermont-Ferrand, 1-3 Déc. 1999.

Boucher, O., Direct and indirect radiative effects of aerosols, Séminaire à l'*Institut Max Planck de chimie*, Mayence, Allemagne, 30 mars 2000.

Boucher, O., Le cycle du soufre dans LMDZ, journée « chimie-climat » de l'IPSL, février 2001.

Boucher, O., The direct and indirect radiative effects of aerosols, Séminaire au "Centre for Environmental Studies and Engineering", *Indian Institute of Technology, Bombay*, Inde, avril 2001.

Boucher, O., Effets climatiques des aérosols, Séminaire au Laboratoire des Sciences du Climat et de l'Environnement (LSCE), 18 octobre 2001.

Boucher, O., Satellite observations of aerosols, *Workshop "Global Land Ocean Atmosphere Monitoring from Space through Data Assimilation" to prepare a proposal for an Integrated Project in the EU's Framework 6 Programme*, ECMWF, Reading, Grande-Bretagne, May 16-17, 2002.

Boucher, O., Effets radiatifs des aérosols : modélisation et données satellitaires, Séminaire au pôle air du CEREVE, *Ecole Nationale des Ponts et Chaussées*, 4 juin 2002.

Boucher, O., and J. Quaas, The role of present and future satellite observations in assessing the aerosol indirect effects, *Round Table on the Aerosol-Cloud-Radiation Interaction in Boundary Layer Clouds*, Météo-France, Toulouse, 24-27 juin 2002.

Pham, M. et O. Boucher, Modélisation en ligne du cycle du soufre, *Compte-rendus de l'Atelier de Modélisation de l'Atmosphère*, pp. 11-14, CNRM, Toulouse, 30 Nov- 2 Déc. 1999.

Sharma, O. P., O. Boucher, M. Pham, H. C. Upadhyaya, P. Le Van, R. Sadourny, and F. S. Binkowski, Simulation of sulphate aerosol distribution over the INDOEX region with tropospheric chemistry and aerosol dynamics in a global zoom model. *Tropical Environmental Problems Workshop*, Palampur (India), 9-13 octobre 2000.

7. Chapitres dans les ouvrages

Chanin, M.-L., G. Ancellet, O. Boucher, D. Cariolle, S. Godin, D. Hauglustaine, H. Le Treut, Connaissances scientifiques de l'atmosphère, chapitre 3, *Rapport de l'Académie de l'Air et de l'Espace sur l'Aviation*, sous presse, 2003.

Fahey, D. W., U. Schumann, S. Ackerman, P. Artaxo, O. Boucher, M. Y. Danilin, B. Kärcher, P. Minnis, T. Nakajima and O. B. Toon, Aviation-produced aerosols and cloudiness, *Chapter 3, IPCC Special Report on Aviation and the Global Atmosphere*, J. E. Penner, D. H. Lister, D. J. Griggs, D. J. Dokken, and M. McFarland (Eds.), Cambridge University Press, Cambridge, UK, pp. 65-120, 1999.

Ko, M., G. Poulet, D. Blake, O. Boucher, J. Burkholder, M. Chin, T. Cox, C. George, H. Graf, J. Holton, D. Jacob, K. Law, M. Lawrence, P. Midgeley, P. Seakins, D. Shallcross, S. Strahan, D. Wuebbles, Y. Yokoyouchi, Chapter 2. Very short-lived substances, In: *WMO/UNEP Scientific Assessment of Ozone Depletion 2002*, WMO, sous presse, 2002.

Ramaswamy, V., O. Boucher, J. Haigh, D. Hauglustaine, J. Haywood, G. Myhre, T. Nakajima, G.-Y. Shi, and S. Solomon, Radiative forcing of climate change, *chapter 6, IPCC Third Assessment Report*, Cambridge University Press, Cambridge, UK, pp. 349-416, 2001.

La Science au Présent 2001, Une année d'actualité scientifique et technique, Les avions, les cirrus et le climat, pp. 76-77, *Encyclopaedia Universalis*, 2000.

La Science au Présent 2002, Une année d'actualité scientifique et technique, Amincissement de la calotte glaciaire à la périphérie du Groenland, pp. 72-73, *Encyclopaedia Universalis*, 2002.

8. Livres et ouvrages

9. Brevets

10. Logiciels

11. Cours d'écoles d'été

Boucher, O., P. Goloub, and D. Tanré, Remote-Sensing of Aerosols: Principles and Applications, In *Proceedings of the Advanced Study Course on Tropospheric Chemistry and Space Observation*, Riom, 21-31 July 1997, Edited by N. Chaumerliac, G. Mégie, N. Papineau and G. Angeletti, pp. 79-94, European Commission, *Air Pollution Research Report No. 65*, EUR17790, 1998.

Boucher, O., Effets radiatifs direct et indirect des aérosols: Modélisation, cours disponible sous forme d'un CD-ROM, *Ecole d'été Interactions-Aérosol-Nuage-Rayonnement*, La Londe-les-Maures, 16-28 septembre 2001.

Boucher, O., Absorption anormale dans l'atmosphère, conférence du soir, disponible sous forme d'un CD-ROM, *Ecole d'été Interactions-Aérosol-Nuage-Rayonnement*, La Londe-les-Maures, 16-28 septembre 2001.

Boucher, O., Observing and Modelling Aerosol Forcing of Climate, *The Oxford / RAL Spring School in Quantitative Earth Observation*, Cours disponible sous forme d'un rapport relié, Oxford, Grande-Bretagne, 18-28 mars 2002.

Boucher, O., Study of the aerosol direct effect, Conférence donnée au colloque d'été ASP, NCAR, Boulder, Colorado, 8-19 July 2002, disponible sur internet sous la forme d'un fichier audio/vidéo.

Boucher, O., Some considerations on the aerosol indirect effect, Conférence donnée au colloque d'été ASP, NCAR, Boulder, Colorado, 8-19 July 2002, disponible sur internet sous la forme d'un fichier audio/vidéo.

12. Notes internes, rapports d'activité, autres

Bopp, L., O. Boucher, O. Aumont, S. Belviso, J.-L. Dufresne, M. Pham, and P. Monfray, Modifications des émissions marines de DMS à $2\times\text{CO}_2$ et effet radiatif associé, *LMDZ info*, n°3, édité par le Laboratoire de Météorologie Dynamique, Février 2003.

Boucher, O., Is the Observed Trend in Cirrus Occurrence due to Aviation?, *Note Interne du Laboratoire d'Optique Atmosphérique No. 1*, Mai 1998.

Boucher, O., and O. P. Sharma, Aerosols and Indian monsoons, *Annual report 2000/2001 of the CEFIPRA/IFCPAR*, disponible sous forme d'un CD-ROM auprès du CEFIPRA, 2001.

Boucher, O., and O. P. Sharma, Aerosols and Indian monsoons, *Annual report 2001/2002 of the CEFIPRA/IFCPAR*, disponible sous forme d'un CD-ROM auprès du CEFIPRA, 2002.

Boucher, O., et M. Pham, Chimie du soufre, *LMDZ info*, n° 0, édité par le Laboratoire de Météorologie Dynamique, Juillet 2000.

Boucher, O., et M. Pham, Modélisation du cycle du soufre dans LMDZT, *LMDZ info*, n° 1, pp. 19, édité par le Laboratoire de Météorologie Dynamique, Mai 2001.

Boucher, O., et M. Pham, Historique du cycle du soufre, *LMDZ info*, n°2, pp. 14-15, édité par le Laboratoire de Météorologie Dynamique, Juillet 2002.

Boucher, O., C. Moulin, S. Belviso, O. Aumont, L. Bopp, E. Cosme, R. von Kuhlmann, M. G. Lawrence, M. Pham, M. S. Reddy, and C. Venkataraman, Sensibilité des concentrations atmosphériques de DMS à la représentation de la source et de l'oxydation, *LMDZ info*, n°3, édité par le Laboratoire de Météorologie Dynamique, Février 2003.

Boucher, O., M. Pham, and C. Venkataraman, Simulation of the atmospheric sulfur cycle in the Laboratoire de Météorologie Dynamique General Circulation Model. Model description, model evaluation, and global and European budgets, *Note Technique de l'IPSL n° 23*, juillet 2002.

Boucher, O., G. Jennings, et al., CREATE (Creation, use, and delivery of an European aerosol database)-DAEDALUS (Delivery of aerosol products for assimilation and environmental use) work plan, project EVK2-2002-00572, European Commission, August 2002.

Kerridge, B.J., W.J. Reburn, R. Siddans, D.L. Smith, P.D. Watts, T. von Clarmann, G.P. Stiller, A. Linden, S. Kellmann, J.J. Remedios, F. Lama, J.J. Barnett, D. Murtagh, J. Stegman, F. Merino, P. Baron, H. Roscoe, D. Hausamann, M. Birk, F. Schreier, B. Schimpf, M. van Weele, H. Kelder, P. van Velthoven, M. Gauss, I. Isaksen, D. Hauglustaine, C. Clerbaux, and O. Boucher, Definition of Mission Objectives and Observational Requirements for an Atmospheric Chemistry Explorer Mission, *ESA Contract No: 13048/98/NL/GD, Final Report*, available as a CR-ROM from ESA, April 2001.

Reddy, M. S., and O. Boucher, Modélisation des aérosols carbonés dans LMDZT, *LMDZ info*, n°3, édité par le Laboratoire de Météorologie Dynamique, Février 2003.

van Weele, M., P. van Velthoven, H. Kelder, C. Clerbaux, D. Hauglustaine, M. Gauss, I. Isaksen, and O. Boucher, Definition of Observational Requirements for Support to Future Earth Explorer Atmospheric Chemistry and Climate Explorer Mission (ACCEM), ESA contract No: 1-3379/98/NL/GD, 2nd progress report, February 1999.

13. Articles de vulgarisation

Bessemoulin, P. et O. Boucher, Les besoins en observations pour la climatologie, *La Météorologie*, 8^e série, n° 39, pp. 36-42, novembre 2002.

Boucher, O., Traînée de navires, Image du mois, *Pour la Science*, pp. 108–109, février 1998.

Boucher, O., Effets climatiques des aérosols, In *POLDER : la surveillance des aérosols, CNESQUISEPASSE ?*, 94, pp. 13, juillet 1998.

Boucher, O., The trails may increase the cirrus cover over air traffic regions, Interview donné à la BBC, fichier audio disponible sur <http://news.bbc.co.uk/1/hi/sci/tech/249744.stm>, 1999.

Boucher, O., Le ciel se couvre... dans les couloirs aériens, *Pour la Science*, pp. 23, mars 1999.

Boucher, O., Editorial « Expliquer sans trahir », *La Météorologie*, 8^e série, No 25, pp. 3, mars 1999.

Boucher, O., Lu Pour Vous, Les aérosols, Physique et Météorologie par André Renoux et Denis Boulaud, *La Météorologie*, 8^e série, No. 25, 65-66, mars 1999.

Boucher, O., G. Brogniez, V. Giraud, Y. Fouquart et J.-F. Gayet, Aviation, traînée de condensation et climat, *La Météorologie*, 8^e série, No. 26, pp. 14-24, juin 1999.

Boucher, O., Une moisson de résultats pour l'instrument POLDER, *La Météorologie*, 8^e série, No. 27, pp. 31 et 66-67, septembre 1999.

Boucher, O., Découverte d'un nouveau gaz à effet de serre, *La Météorologie*, 8^e série, No. 31, pp. 67, septembre 2000.

Boucher, O., Lu pour Vous, Atmosphères Planétaires : Origine et évolution par Thérèse Encrenaz, *La Météorologie*, 8^e série, No. 32, pp. 60-61, février 2001.

Boucher, O., A sa périphérie la calotte glaciaire du Groenland s'amincit, *La Météorologie*, 8^e série, No. 32, pp. 54, février 2001.

Boucher, O., Succès de la campagne Shade d'étude des poussières désertiques, *La Météorologie*, 8^e série, No. 32, pp. 55-56, février 2001.

Boucher, O., Le troisième rapport d'évaluation du GIEC, *La Météorologie*, 8^e série, No. 33, pp. 3, mai 2001.

Boucher, O., Les variations du CO₂ atmosphérique dans le passé et leurs mystères, *La Météorologie*, 8^e série, No. 34, pp. 4-5, août 2001.

Boucher, O., Editorial, Météorologie et climatologie, *La Météorologie*, 8^e série, No. 37, pp. 1, mai 2002.

Boucher, O., et B. Tranchant, Depuis l'espace Jason arpente les océans, *La Météorologie*, 8^e série, No. 37, pp. 4, mai 2002.

Boucher, O., Interview donné au Figaro, http://www.revue-politique.com/2_0824.htm, 27 mai 2002.

Boucher, O., I. Chiapello, et E. Cosme, Poussières africaines dans les Alpes, *La Météorologie*, 8^e série, No. 38, pp. 5-6, août 2002.

Boucher, O., Réchauffement climatique : peu de marge de manoeuvre jusqu'en 2050 ?, *La Météorologie*, 8^e série, No. 38, pp. 2, août 2002.

Boucher, O., Envisat et Aqua : deux nouveaux satellites pour l'observation de la Terre, *La Météorologie*, 8^e série, No. 39, pp. 2-3, novembre 2002.

Boucher, O., Tour du monde en montgolfière en solitaire réussi pour "Spirit of Freedom" de Steve Fossett, *La Météorologie*, 8^e série, No. 39, pp. 4, novembre 2002.

Boucher, O., L'Europe, les scientifiques et les experts, rubrique débat, *LMDZ Info*, n° 3, Edité par le Laboratoire de Météorologie Dynamique, Février 2003.

Boucher, O., et B. Crouzille, Pics de consommation d'électricité en janvier, *La Météorologie*, 8^e série, No. 41, pp. ?, mai 2003.

Boucher, M., et O. Boucher, La climatologie satellitaire, *Atmosphériques*, 2003.

Doutriaux-Boucher, M., et O. Boucher, Pluies et nuages sur les océans, Quelques exemples d'études réalisées à partir des observations météorologiques de navires, *Metmar*, 179, 29–32 et page couleur I, deuxième trimestre 1998.

IMPACTS OF NATURAL AND ANTHROPOGENIC AEROSOLS ON THE STRATOCUMULUS DECK OFF CHILE

Laura Gallardo⁽¹⁾ and Olivier Boucher⁽²⁾

(1) Centro de Modelamiento Matemático de la Universidad de Chile, Casilla 170, Correo 3, Santiago, Chile, lgallard@dim.uchile.cl

(2) Laboratoire d'Optique Atmosphérique, CNRS/Université de Lille I, Villeneuve d'Ascq, France, boucher@loa.univ-lille1.fr

The world's most extended and persistent stratus deck around the world is that located under the Pacific high off the coast of Chile and Southern Peru. This cloud deck has a large impact on the regional and global circulations (e.g., Hartmann et al, 1992; Hartmann, 1994). In this region, large emissions of oxidized sulfur occur, both due to anthropogenic processes (Lefhon et al, 1999), mainly copper smelting, and natural processes, mainly biogenic emissions along the Humboldt current system, and perhaps also volcanic emissions (e.g., Scholes et al, 2003; Andres & Kasgnoc, 1998). Despite the relevance of these processes for the regional and global climate, our quantitative understanding and our predictive capabilities to assess potential future changes are scarce.

Altogether, given the large emissions of oxidized sulfur that take place in Northern and Central Chile, the circulation and cloud patterns in the area, and the potential effects of sulfur aerosols on clouds, we started in 2002 a collaboration to assess the regional distribution of oxidized sulfur and its radiative effects over Central and Northern Chile. Here we propose a collaboration intended to better understand the aerosol-cloud-climate interactions and to provide tools for assessing and predicting these effects by means of global and regional scale modeling. Also, we aim at strengthening the links with other research activities, particularly remote sensing of aerosols and clouds and dynamical modeling of the marine boundary layer over the Eastern Pacific.

Introduction

In addition to impacts of oxidized sulfur on human health, various other impacts on climate, clouds and precipitation have been widely recognized by the scientific community (e.g., Twomey, 1974; Charlson et al, 1987; Albrecht, 1989; Charlson et al, 1991; Kiehl and Brigleb, 1993; Boucher and Lohmann, 1995; Nemesure et al, 1995; Jones and Slingo, 1996; Chuang et al, 1997; Haywood and Boucher, 2000; IPCC, 2001; Wilson et al, 2001; Lohmann, 2002). Acidic deposition in connection with sulfate aerosols was pointed out in the early 60's and 70's as a regional issue of concern in Europe and North America. Nowadays, acidic deposition by sulfur and other species has become an issue in developing countries, particularly over Southeast Asia (e.g., Rodhe et al, 1995; Rodhe et al, 2002). The scattering effects of aerosols in general, and of sulfate aerosols in particular, are daily experienced by inhabitants of polluted urban areas all over the world as reflected in hazy conditions and low visibility. On the regional and global scales, it has been shown that the main contributors to the scattering of solar radiation are sulfate and some organic aerosols with a net global average direct forcing of about -0.5 W/m^2 (e.g., IPCC, 2001). The quantification of the impact of sulfate aerosols due to their role as cloud condensation nuclei (CCN) has been more elusive. Nevertheless, anthropogenic sulfate aerosols are thought to make clouds brighter and more long-lived (e.g., Ramanathan et al, 2001).

Chile has a long tradition of exploiting mineral resources, particularly copper. The copper smelters in Chile stand for about 1 % of the ca. 70 TgS/yr oxidized sulfur (SO_x) emitted worldwide. In addition, in the coast of Central and Northern Chile exchanges of biogenic trace species are significant, particularly dimethylsulfide (DMS), which is an important precursor of natural aerosols and cloud condensation

nuclei (CCN). Volcanoes may also be a significant source of aerosols, sulfate aerosols in particular. Finally, Santiago, one of South America's megacities is also a significant source of polluted air, containing both organic and inorganic aerosols that also may affect the properties of clouds.

An outstanding feature of Central and Northern Chile is the persistent stratus clouds off the coast out over the ocean under the Pacific High. This cloud deck has a large impact on the regional and global circulations. Therefore, given the large emissions of oxidized sulfur, both anthropogenic and natural, that take place in Northern and Central Chile, the circulation and cloud patterns in the area, and the potential effects aerosols on clouds, particularly sulfur aerosols, we aim at establishing a long-term collaboration with European researchers to assess the regional distribution of oxidized sulfur and its direct and indirect radiative effects over Central and Northern Chile.

Objectives

Hence, given the large emissions of oxidized sulfur that take place in Northern and Central Chile, the circulation and cloud patterns in the area, and the effects of sulfur aerosols on clouds and precipitation, we find it necessary to provide the basis for a long-term collaboration to quantify these effects. In particular, we aim at establishing the modeling tools require to provide quantifications and scenarios for such impacts. From this, the following objectives are extracted.

- To estimate the distribution of oxidized sulfur, both natural and anthropogenic, over the stratocumulus area over the Eastern Pacific
- To estimate the potential impact on the properties of the persistent stratus deck (direct and indirect effects)
- To estimate the relative importance of natural and anthropogenic sources on the burden and distribution of oxidized sulfur
- To evaluate the sensitivity of the estimates with respect to model resolution with emphasis on relevant weather conditions such as coastal lows and cut-off lows.
- To improve, in close collaboration with other research groups, the accuracy of the simulations by means of assimilation of satellite data.
- To improve, in collaboration with concurrent research the parametrizations of Sc clouds in current models

Participants

- Chile/ Center for Mathematical Modeling (CMM)
 - o Framework project FONDAP de Matemáticas Aplicadas. The CMM is mainly funded as an Excellence Center through the Chilean Research Council (Comisión Nacional de Investigación en Ciencia y Tecnología, CONICYT).
 - o Framework project FONDECYT 1030809, 2003-2006: *Stratosphere-Troposphere Exchange (STE) processes and their impact on the ozone balance in the subtropics of the Southern Hemisphere: A multi-scale integrated study based at Cerro Tololo (30°S, 70°W, 2200 m.a.s.l.)*.
 - Laura Gallardo (Ph.D. Chemical Meteorology), Centro de Modelamiento Matemático
 - Melitta Fiebig (PhD Mathematics), Universidad de La Serena, Centro de Investigaciones Atmosféricas
 - Juan Quintana (MSc/C), Dirección Meteorológica de Chile

- o Framework project CONICYT-INRIA (2002-2003): *Application and Development of Inverse Modeling techniques to air quality monitoring network design*
 - Laura Gallardo (Ph.D. Chemical Meteorology), Centro de Modelamiento Matemático
 - Jaime Ortega (Ph.D. Mathematics), Centro de Modelamiento Matemático
 - Axel Osses (Ph.D. Mathematics), Centro de Modelamiento Matemático
- Chile/ Geophysics Department, University of Chile/DGF_UCH
 - o Framework project FONDECYT 1020833, 2002-2005: *The Stratocumulus cloud deck off the subtropical west coast of South America: High frequency variability.*
 - René Garreaud (Ph.D. Meteorology), Departamento de Geofísica, Universidad de Chile
 - José Rutllant (Ph.D. Meteorology), Departamento de Geofísica, Universidad de Chile
 - Ricardo Muñoz (Ph.D. Meteorology), Departamento de Geofísica, Universidad de Chile
- France/ Laboratoire d'Optique Atmosphérique (UMR 8518)/ LOA. *Financement PNTS et européens, bourse de thèse cofinancée CNES-région Nord-Pas-de-Calais*
- Olivier Boucher, chargé de recherche 1^{ère} classe, CNRS
- Marie Doutriaux-Boucher, Maître de conférence, Université des Sciences et Technologies de Lille
- France/ Ecole Nationale des Ponts et Chaussées : Bruno Sportisse, , chercheur associé
- France/ Laboratoire de Météorologie Dynamique du CNRS, Hervé Le Treut, chercheur

Overall objectives

- To better grasp the regional distribution of oxidized sulfur, both natural and anthropogenic, and to evaluate their potential impact on the properties of the persistent stratus deck over the ocean under the Pacific high
- To strength the links with other research activities and communities particularly those related to remote sensing of aerosols and clouds in France, dynamical modeling of the marine boundary layer over the Eastern Pacific and modeling of ocean-atmospheric interaction in Chile

Hypotheses

We assume that both of our group's research activities will gain in depth and perspective by complementing our expertises un global climate modeling and regional scale dispersion. Further, we assume that available atmospheric models can provide estimates of the atmospheric distribution of oxidized sulfur emitted from biotic and abiotic processes, and their subsequent impacts on the radiative balance, and that the accuracy of these simulations can be improved.

Methodology

The distribution of oxidized sulfur (SO_x) and its radiative effects could be assessed by means complementary model simulations.

- High-resolution (0.1°) SO_x fields will be estimated using the off-line Multiscale Atmospheric Transport and Chemistry (MATCH) model (Robertson et al, 1999) already implemented in Chile. It has been applied to assess dispersion of oxidized sulfur and arsenic over Northern and Central Chile (e.g., Gallardo et al, 2002; Huneus et al, 2003). This model would be fed with semi-climatological outputs provided by a three-dimensional numerical weather prediction (NWP) model, the High Resolution Limited Area Model (HIRLAM, Undén et al, 2002) and outputs for specific situations provided by a regional climate model and the NWP model at use the Chilean Weather Office within the framework of ongoing research at the CMM (FONDECYT 1030809).

- The General Circulation model LMD-ZT (Cosme et al, 2002) will be used to study the dispersion of oxidized sulfur and to estimate the corresponding radiative forcings. By comparing the global and regional simulations we will explore the sensitivity of the estimates to model resolution.
- The simulations will provide estimates of the direct and indirect forcing by oxidized sulfur. These forcings will be evaluated by comparing with observations. . We will then jointly explore the assimilation of satellite data to improve the simulations over this area of the world that is in an appalling lack of observations and where strong signals can be detected by remote sensors providing an opportunity for validation of retrieval algorithms. (This is the theme of Nicolás Huneeus PhD work at LOA). In general, we expect to better constrain aerosol transport to Pacific Ocean.
- On the basis of observational data provided from complementary projects (e.g., Rutllant et al, 2003; FONDECYT 1020833) we expect to improve the parameterizations of Sc in the models we apply.

In addition to the modeling work, workshops and symposia will be organized in connection with the visits of the scientists. Also, short-term (1-3 months) stays of graduate students will be promoted. We expect to be able to establish co-guided graduate theses for students in Atmospheric Science, Mathematics and Informatics.

Missions during the first year of the project

France to Chile: None during the first year, the missions should take place during the second year of the cooperation

Chile to France:

- o Laura Gallardo, January 2004, 20 days, Gathering and synthesis of results. Also, learning about the type of aerosol data intended to be assimilated in the climate model and eventually in a regional-scale model.
- o José Rutllant, June 2004, 15 days, Acquaintance with the stratocumulus parameterizations in the model and comparisons with sounding data collected through complementary projects in the Sc area

Results

- Increased research capabilities, tools and a broader scientific spectrum for both research groups
- Common publications and definition of larger scale cooperative projects involving other research groups.
- Capacity building as expressed in theses and student exchanges
- Workshops and symposia

Links with ongoing research

At the CMM we are developing studies on:

- *Stratosphere-Troposphere Exchange (STE) processes and their impact on the ozone balance in the subtropics of the Southern Hemisphere: A multi-scale integrated study based at Cerro Tololo (30°S, 70°W, 2200 m.a.s.l)* (FONDECYT 1030809, 2003-2006).

In this project, meteorological models will be used to produce dynamically interpolated three-dimensional (3-D) regional and meso-scale meteorological fields, which will drive a 3-D Eulerian transport model that will simulate the intrusion and subsequent dispersion of an ozone-like tracer subject to photolysis and dry deposition. The simulations will be evaluated against in situ and

available satellite measurements of ozone, water vapor and other relevant STE tracers. These fields will also be available for studying aerosol-cloud-climate interactions as those proposed here.

- *Application and Development of Inverse Modeling techniques to air quality monitoring network design* (INRIA-CONICYT, 2002-2003).

The overall objective of this project is to bring together the pieces for defining a long-term research axis and a common research project on inverse modeling applied to air pollution problems at the local and regional scale, with particular emphasis on monitoring network design to assess the impacts of the large-scale copper industry over in the densely populated and expanding urban areas of Central Chile. The increasing number of observations of chemical tracers and aerosols, both in-situ and remote (e.g., satellites) brings now the possibility of applying assimilation data and inverse modeling in order to improve the performance of available three-dimensional chemistry transport models (3-D CTMs), to bracket the strength and location of emissions of relevant compounds, to optimize the design monitoring networks, to assess model errors and sensitivities, etc.. So, this collaboration would benefit from and provide support to the work proposed here by.

At the Geophysics Department:

- Studies are being conducted to generate an improved understanding of the dynamical processes involved in the existence and persistence of Southeastern Pacific stratus decks, their interaction with weather systems (including deep convection), the seasonal cycle and interannual climate variations over South America, and their feedback with the underlying ocean (FONDECYT, 1020833). This study includes the compilation of in situ observations that can be of use for validating model results. Other studies have focused on the mesoscale circulation regimes that explain the extreme aridity of the Atacama desert and their influence on the upwelling of cold nutrient-rich waters (e.g., Rutllant et al, 2003). These circulation patterns are crucial for determining the potential fluxes of biogenic sulfur species and the offshore dispersion of anthropogenic sulfur. An exploratory work by Huneeus et al (2003), suggests that the transport of anthropogenic sulfur would occur episodically in connection with the occurrence of coastal lows.

References

- Albrecht, B., 1989. Aerosols, cloud microphysics, and fractional cloudiness. *Science*, 245, 1227-1230.
- Andres RJ, Kasgnoc AD (1998) A time-averaged inventory of subaerial volcanic sulfur emissions. *Journal of Geophysical Research* 103: 25,251-25,261.
- Boucher, O. and U. Lohmann, The sulfate-CCN-cloud albedo effect: A sensitivity study with two general circulation models, *Tellus*, 47B, 281-300, 1995.
- Charlson, R.J., Lovelock, J.E., Andreae, M.O. and Warren, S.G., 1987. Oceanic phytoplankton, atmospheric sulphur, cloud albedo and climate. *Nature*, 326, 655-661.
- Charlson, R. J., Langner, J., Rodhe, H., Leovy, C. B. and Warren, S. G., 1991. Perturbation of the northern hemisphere radiative balance by backscattering from anthropogenic sulfate aerosols. *Tellus* 4B3, 152-163.
- Chuang, C. C., Penner, J. E., Taylor, K. E., Grossman, A. S. and Walton, J. J., 1997. An assessment of the radiative effects of anthropogenic sulfate. *J. Geophys. Res.*, 102, 3761-3778.
- Andres RJ, Kasgnoc AD (1998) A time-averaged inventory of subaerial volcanic sulfur emissions. *Journal of Geophysical Research* 103: 25,251-25,261.
- Cosme, E., C. Genthon, P. Martinerie, O. Boucher, and M. Pham, Sulfur cycle at high-southern latitudes in the LMD-ZT General Circulation Model, *Journal of Geophysical Research*, 107(D23), 4690, doi:10.1029/2002JD002149, 2002.
- Gallardo, L., Olivares, G., Langner, J. and Aarhus, B., 2002: Coastal lows and sulfur air pollution in Central Chile. *Atmos. Env.* 36/23 pp. 3829-3841
- Hartmann, D., Ockert-Bell, M., and Michelsen, M., 1992: The effect of cloud type on earth's energy balance: global analysis. *J. Clim.*, 5, 1281-1304.

- Hartmann, D., 1994. Global physical climatology. Academic Press, 411 pp..
- Haywood, J. and Boucher, O., 2000. Estimates of the direct and indirect radiative forcing due to tropospheric aerosols: A review. *Rev. Geophys.*, 38, 513-543.
- Huneus, N., Gallardo, L., Rutllant, J., and Boucher, O., 2003. Dispersion of sulfur aerosols off the coast of Northern Chile: an exploratory study. *Simposio de Cambio Global: Hacia una visión Sistémica*, Punta Arenas.
- IPCC, 2001: The scientific basis. Summary for policy makers. IPCC WGI Third assessment report (Available from www.ipcc.ch).
- Jones, A. and Slingo, A., 1996. Predicting cloud-droplet effective radius and indirect sulphate aerosol forcing using a general circulation model. *Q. J. R. Meteorol. Soc.*, 122, 1573-1595.
- Kiehl, J. and Briegleb B., 1993: The relative roles of sulfate aerosols and greenhouse gases in climate forcing. *Science* 260, 311-314.
- Lefohn A.S., Husar J.D., and Husar R.B. (1999). Estimating Historical Anthropogenic Global Sulfur Emission Patterns for the Period 1850-1990. *Atmos. Environ.*, 33,21, 3435-3444.
- Lohmann, U., 2002. Possible aerosol effects on ice clouds via contact nucleation. *J. Atmos. Sci.*, 59, 647-656.
- Nemesure, S., Wagener R. and Schwartz, S. E.,1995. Direct shortwave forcing of climate by anthropogenic sulfate aerosol size and composition. *J. Geophys. Res.*, 100, 18739-18754.
- Ramanathan, V., P.J. Crutzen, J. Lelieveld, A.P. Mitra, D. Althausen, J. Anderson, M.O. Andreae, W. Cantrell, G.R. Cass, C.E. Chung, A.D. Clarke, J.A. Coakley, W.D. Collins, W.C. Conant, F. Dulac, J. Heintzenberg, A.J. Heymsfield, B. Holben, S. Howell, J. Hudson, A. Jayaraman, J.T. Kiehl, T.N. Krishnamurti, D. Lubin, G. MacFarquhar, T. Novakov, J.A. Ogren, I.A. Podgorny, K. Prather, K. Priestley, J.M. Prospero, P.K. Quinn, K. Rajeev, P. Rasch, S. Rupert, R. Sadourny, S.K. Satheesh, G.E. Shaw, P. Sheridan and F.P.J. Valero. The Indian Ocean Experiment: An Integrated Analysis of the Climate Forcing and Effects of the Great Indo-Asian Haze. Submitted revisions, *J. Geophys. Res.-Atmos.*, January 2001.
- Robertson, L., Langner, J., and Engardt, M. 1999. An Eulerian limited-area atmospheric transport model. *J. Appl.Met.* 38, 190-210.
- Rodhe, H., Langner, J., Gallardo, L., and Kjellström, E., 1995: Global scale transport of acidifying pollutants. *Water, Air and Soil Pollut.*, 85:37-50.
- Rodhe, H. 1999. Clouds and climate. *Nature*. 401, 223-224.
- Rodhe, H., Dentener, F. and Schulz, M. The Global Distribution of Acidifying Wet Deposition. *Environ. Sci. Technol*, 36 (20), 4382-4388.
- Rutllant J., Fuenzalida H., Aceituno P., Montecinos A., Sanchez R., Salinas H., Inzunza J. y Zuleta R., 2003, Climate dynamics along the arid northern coast of Chile; The 1997-1998 DICLIMA experiment. Submitted to *Journal of Geophysical Research*
- Rutllant J., Fuenzalida H., Aceituno P., Montecinos A., Sanchez R., Salinas H., Inzunza J. y Zuleta R., 2002, Climate dynamics along the arid northern coast of Chile; The 1997-1998 *DICLIMA* experiment. Submitted to *Journal of Geophysical Research*.
- Scholes et al, 2003. Biosphere-Atmosphere Interactions (Ch. 2). In “The Changing Atmosphere: An Integration and Synthesis of a Decade of Tropospheric Chemistry Research”. Brasseur et al (Eds.). Springer-Verlag (ISBN: 3-540-43050-4).
- Twomey, S., 1974. Pollution and the planetary albedo. *Atmos. Environ.* 8, 1251-1256.
- Undén et al, 2002. HIRLAM-5 Scientific documentation. (Available at <http://www.knmi.nl/hirlam/>)
- Wilson J., Cuvelier C. and Raes F., 2001. A modeling study of global mixed aerosol fields. *J. Geophys. Res.*, 106, 34081-34108.