Important
Ce document ne doit pas dépasser 25 pages, dans la mise en page et la typographie fournies par l'ANR. Ce point constitue un critère de recevabilité de la proposition de projet. Les propositions de projet ne satisfaisant pas aux critères de recevabilité ne seront pas évaluées.

Nom et prénom du coordinateur / Coordinator's name	**Camille Risi**		
Acronyme / Acronym	**CONV-ISO**		
Titre de la proposition de projet	Etude des processus convectifs et nuageux associés à la MJO et évaluation de leur représentation dans les modèles de climat en combinant des mesures d'humidité, de nuages et d'isotopes de l'eau		
Proposal title	Studying convective and cloud processes during the MJO and evaluating their representation in climate models by combining humidity, cloud and water isotopic measurements		
Comité d'évaluation / Evaluation committee	SIMI6		
Type de recherche / Type of research	☐ Recherche Fondamentale / Basic Research ~~☐ Recherche Industrielle / Industrial Research~~ ~~☐ Développement Expérimental : Experimental Development~~		
Aide totale demandée / Grant requested	147 660 €	**Durée du projet / Projet duration**	48 months

1. Résume de la proposition de projet / Executive summary

The Madden-Julian Oscillation (MJO) is the dominant mode of intraseasonal variability in the tropical atmosphere. However, for several decades climate models have met difficulties in simulating its properties. The development and propagation of the MJO involves the interaction between convective, cloud, radiative and dynamical processes, whose representation in climate models is subject to uncertainties. The same processes happen to be crucial also in climate change projections.

The goal of this proposal is to understand why some models capture the MJO better than others. What processes are key to simulate the MJO? Although these questions are not new, **the novelty of this proposal is to address these questions by combining humidity and cloud measurements with water vapor isotopic measurements** (HDO/H_2O ratio). Several studies have shown the added value of water isotopic measurements to study convective processes. More specifically for the MJO, a recent study has shown that the water stable isotopic evolution during the MJO provides a complementary information compared to the evolution of meteorological variables.

We will blend and analyze three datasets: (1) the A-train satellite dataset, combining TES isotopic data and CALIPSO and Cloudsat cloud data, with the vertical resolution as the main advantage, (2) the IASI satellite dataset, measuring both isotopic and cloud properties and which can be collocated with the Meghatropiques dataset, with the spatio-temporal coverage as the main advantage, and (3) the isotopic, meteorological and cloud measurements at the Darwin ARM site, with the temporal resolution as the main advantage.

These datasets will be used to evaluate isotopic simulations with the LMDZ general circulation model (GCM). We will compare sensitivity tests to convective and cloud processes to identify critical processes in the MJO simulation. The use of LMDZ is particularly adequate and timely in this context: the new version of LMDZ includes an improved representation of convective processes and exhibits a more realistic MJO variability. We will analyze different model configurations to quantify the relative effects of physical biases and dynamical feedbacks. We will compare LMDZ with an isotopic version of the cloud resolving model Meso-NH to evaluate convective processes in more detail. We will also compare LMDZ with other isotopic GCMs to check the representativity of our results in the context of the diversity of climate models.

The expected outcomes of this project are to :

(1) design a framework to interpret joint humidity, isotopic and cloud distributions in terms of convective processes ;
(2) identify critical processes to simulate properly the MJO and which of these are commonly mis-represented in GCMs ;
(3) suggest parameterization improvement.

2. Contexte, positionnement et objectifs de la proposition / Context, position and objectives of the proposal

2.1. Contexte et enjeux économiques et sociétaux / Context, social and economic issues

The Madden-Julian Oscillation (MJO) is the dominant mode of intraseasonal variability in the tropical atmosphere, with scales from 30 to 60 days (Madden and Julian 1993). Developed in the Indian Ocean, it propagates eastwards and strongly modulates deep convection over the Indian and Western Pacific oceans. It has impacts on onsets and break phases of the Indian and Australian monsoons, on tropical cyclones, on the onset of some El-Nino events, and on North Atlantic variability (Kessler 2001, Wheeler and McBride 2005, Bessafi and Wheeler 2006, Cassou 2008). It is thus a key component of the predictability of weather and climate in tropical regions and beyond.

Projections of future temperature and precipitation changes differ among climate models, mostly due to differences in the representation of tropical convective and cloud processes (IPCC, 2007). In parallel, for several decades, climate models have met difficulties in simulating the MJO (Slingo et al, 1996, Lin et al 2006). The development and propagation of the MJO involves the interaction between various convective, cloud, radiation and dynamical processes. These processes and their interaction happen to be also key in determining the climate sensitivity and the hydrological cycle response to climate change. In the IPSL model for example, changes in the parameterization of convective processes deeply impact both the simulation of the MJO and future projections (Hourdin et al submitted). Therefore, if a model is able to simulate the MJO, and without error compensation, the confidence in its ability to simulate realistic convective and cloud processes in future projections is strengthened. As such, a proper simulation of the MJO has been considered as a « holy grail » of atmospheric modeling for several decades (Raymond 2001, Zhang et al 2005). In this context, **the goal of this project is to contribute to understand the sources of mis-representation of the MJO by climate models and to suggest model improvements**.

2.2. Positionnement du projet / Position of the project

Although significant progress has been made in understanding the processes responsible for the initiation and propagation of the MJO in the last decades (Zhang 2005), accurately simulating it in GCMs has remained a challenge (Slingo et al 1996, Lin et al 2006). For example, among 14 climate models used in the 4^{th} IPCC assessment report, 12 underestimated the MJO variance by more than half. The major difficulty of the MJO is that its development and propagation involve the interaction between many different convective, cloud, radiation and dynamical processes, such as moistening and pre-conditioning of the lower and mid-troposphere by shallow convection (Woolnough et al , 2010), entrainment into convective plumes (Kim et al submitted), rain reevaporation and associated convective downdrafts and cold pools, cloud radiative impact and feedbacks on the large-scale dynamics (Bony et Emanuel, 2005, Zurovac-Jevtic et al 2006), surface fluxes (Woolnough et al 2007). In GCMs, these processes are represented statistically by parameterizations, which strongly differ from model to model.

Therefore, the overarching set of questions of this proposal is : **what are the reasons for the difficulty of models to simulate the MJO ? What makes some models better than others ? Is it at the cost of error compensations ? What key processes need to be properly represented ?**

To address these questions, several approaches have proven valuable in the past :

(1) Sensitivity tests and model inter-comparisons: by comparing the ability of several models or model versions to simulate the MJO and by relating it to the representation of processes in each simulation, some sources of model errors can be identified (e.g. Inness et al 2001, Woolnough et al 2010, Kim et al submitted,b)

(2) Hierarchy of model configurations : Using simplified configurations (e.g. 1D) or configurations in which feedbacks are disabled, critical processes can be nailed down. By comparing model biases in 3D or 1D simulations in which the large-scale dynamics is imposed or inter-active, the relative role of physical errors and dynamical feedbacks can be quantified (Petch et al 2007, Boyle et al 2008, Kim et al submitted).

(3) Cloud resolving (CRM) simulations : provided such simulations are validated against data, they offer a realistic framework in which convective-scale processes can be analyzed in detail (e.g. Grabowski and Moncrieff 2011, 2002).

Despite significant progress achieved thanks to these approaches, some limitations remain. For example, similar profiles of «traditional» variables (humidity, temperature, cloud properties) can hide differences in mass fluxes and water budgets. Besides, the main goal of parameterization is to represent the effect of convective and cloud processes on the large-scale. The relevant scale at which a GCM should be evaluated is thus the scale of a grid box (~50-500km). But «traditional» variables at these scales might lose significant information about processes at the convective and cloud scales (5km-50m). Therefore, additional variables that are complementary to «traditional» variables, and that retain information about convective processes at small scales, are highly needed.

Based on several studies in recent years to which I have actively contributed, the water isotopic composition (HDO/H_2O ratio) can provide such a variable. Due to fractionation during phase changes, water isotopes record the history of phase changes undergone by air parcels (fig 1). Lower-tropospheric water composition is particularly sensitive to rain evaporation (Worden et al, 2007, Risi et al 2010b, Field et al 2011) and associated downdrafts (Risi et al 2010b), to the degree of organization of convection (Lawrence et al, 2004). Mid and upper-tropospheric water composition reflects evaporation of condensate detrained from convective towers (Moyen et al, 1996, Webster et al, 2005).

Therefore, the goal of this project is to combine for the first time humidity, cloud and water isotopic measurements to better understand convective and cloud processes during the MJO and the cause of their mis-representation in models.

The above-mentionned approaches that have already led to significant progress (sensitivity tests, inter-model comparisons, hierarchy of model configurations, CRMs) will be applied in this project, but revisited with isotopes.

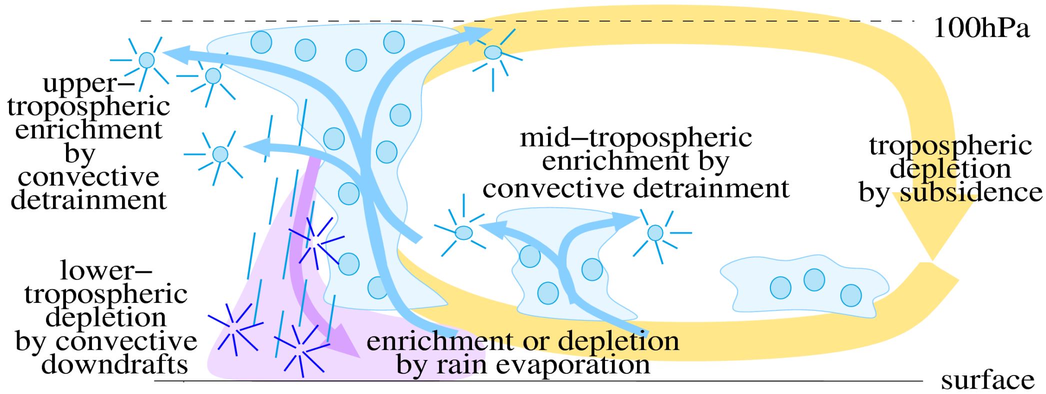

Figure 1 : Convective and cloud processes affecting the isotopic composition (Risi and Bony 2011).

This project is very timely for 2 reasons :

- **New isotopic datasets** that give unprecedented vertical resolution (the new TES satellite dataset : Worden et al submitted), unprecedented spatio-temporal coverage (the IASI satellite dataset : Herbin et al 2008, Schneider and Hase 2011) and unprecedented temporal resolution (ground-based remote sensing dataset, Risi et al submitted,a) are just starting to be retrieved and to become publicly available. This project will be among the first to exploit them, thanks to various international collaborations.
- The **new version of LMDZ** that is used for CMIP5 has just been released and its behavior is just starting to be scrutinized at LMD. This version includes an improved representation of shallow and deep convection, of cold pools and of their coupling (Rio et al 2009, Grandpeix et al 2010). This enables us to perform a variety of new sensitivity tests to the model physics. Moreover, this version exhibits a more realistic MJO variability compared to the previous version. We will thus use this model as a « laboratory » to test the effect of different representation of convective and cloud processes. The implementation of isotopes in this new version is just being finalized.

The isotopic version of LMDZ, which I had developed as part of my PhD, is one of the isotopic models that have been the most thoroughly evaluated against a wide variety of isotopic datasets (in-situ, ground-based and satellite remote-sensing), in many different regions (global, tropical, mountainous and polar regions), in different configurations (low-resolution or zoomed, free or nudged) and for different applications (present-day and paleo-climates) (Risi et al 2010a, Risi et al 2010c, Gao et al in press, Vimeux et al 2011, Steen-Larsen et al 2011, Masson-Delmotte et al 2011, Sime et al submitted, Risi et al submitted a, Risi et al submitted b, Lee et al submitted, Eagle et al in prep).

<u>Position of the project with respect to other submitted ANR projects</u>

- Tropical convection is a strong axis of research at LMD. CDFr (J-P Duvel) also revolves around the MJO, but exploiting the data from the CINDY-DYNAMO (CD) field campaign. The novelty and originality of our project is to use water isotopic measurements. Here, isotopic measurements are applied for specific questions related to the MJO, but the understanding acquired on the isotopes-convection relationship will be useful for a much wider range of science questions beyond the MJO. The two projects are also very distinct regarding the goals : diagnose model biases in CONV-ISO, understand processes in nature in CDFr. We expect that these complementary activities will benefit from each other. In this proposal we do not emphasize CD due to its lack of dedicated isotopic observations, but we hope to benefit from the knowledge acquired during this campaign.
- CONVECTRO (B. Legras) intends to investigate the role of convection on troposphere-stratosphere exchanges, including water isotopic aspects. This issue is not part of our proposal, but our results will be of interest for their activities, in particular the prospect of constraining convective detrainment from water isotopic measurements using the TES data. The application of our isotopic research for their purpose is part of the MANGO LEFE project.
- ISOTROPIC (F. Vimeux) intends to use isotopic-based reconstruction of past precipitation to assess the credibility of future precipitation projections. ISOTROPIC will use LMDZ-iso simulations but for a totally different purpose.

2.3. ÉTAT DE L'ART / STATE OF THE ART

In the past few years, advances in isotopic observations and modeling have led to a better understanding of what controls the isotopic composition of water vapor (fig 1) and have shown a potential of isotopic measurements to better evaluate convective parameterizations (Risi et al 2008, Lee et al 2009). More specifically in the context of the MJO, several studies, to which I have collaborated, have shown the added value of water isotopic measurements :

(1) Analyzing the isotopic signature of the MJO in the old TES dataset, in in-situ surface data, and in the MIROC GCM, Kurita et al (in press) have shown that the active phase of the MJO was associated with isotopic depletion, mainly due to unsaturated downdfrats in convective systems.

(2) Analyzing MJO composites of humidity and isotopic composition in the old TES dataset, Berkelhammer et al (submitted) have shown that he isotopic composition and humidity behave differently during an MJO cycle (fig 2). Isotopic observation could thus discriminate between different moistening processes and thus provide valuable complementary information. Besides, preliminary comparison with 3 GCMs, including LMDZ, show that the isotopic evolution during the MJO is model-dependent.

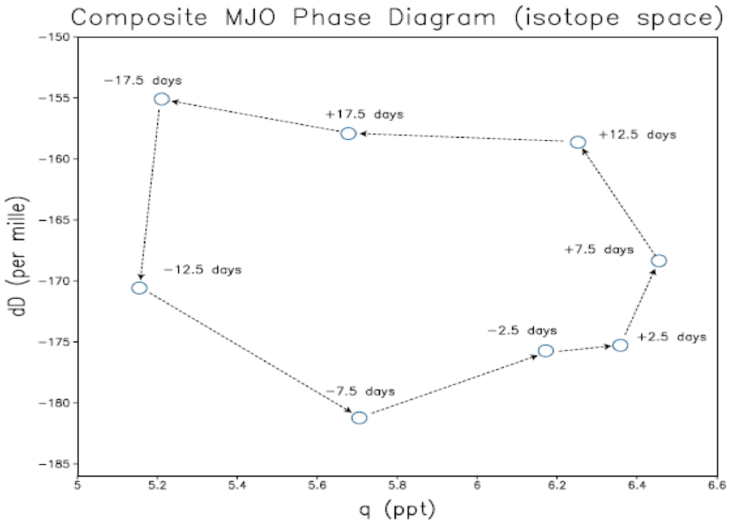

Figure 2 : Complementarity between humidity and isotopic composition during a composite MJO cycle. During the initiation phase (-17.5 to -7.5 days), the water vapor gets more depleted while humidity remains constant, suggesting a change in the water budget that could not be detected in humidity measurements alone. This could be due to a shift from moistening by evaporation to moistening by large-scale convergence. Similarly, just after the peak in MJO activity (-2.5 to +12.5 days), the water vapor gets more enriched while humidity remains constant.

These studies have convinced us of the potential of water vapor isotopic measurements to better evaluate convective processes during the MJO. This proposal intends to build upon these studies and go much further :

(1) the use of new datasets with improved vertical resolution (new TES data, Worden et al submitted), spatial coverage (IASI) or temporal resolution (TCCON site).
(2) The collocation of humidity/isotopic datasets with cloud datasets (TES /Calipso/Cloudsat).
(3) The use of a hierarchy of model configurations to better understand sources of model mis-match.
(4) Our approach strongly oriented towards parameterization evaluation and improvement, due to our strong links with the LMDZ parameterization development team.

Using these new datasets and approaches, we aim at making progress in answering several specific science questions, motivated by the current gaps in MJO knowledge and by our idea of the potential of water vapor isotopes :

(1) It has been shown that when convection is more difficult to trigger or depends more strongly on tropospheric humidity, MJO variance is increased and convection organizes itself at larger scales, in better agreement with observations (Kim et al submitted,a, Bony et Emanuel 2005). In models, this can be done in several ways : increased entrainment, increased contribution of large-scale precipitation (Kim et al submitted,a), increased rain reevaporation (Bony et Emanuel 2005),

dependence on humidity convergence in the convective closure (Lin et al 2006). What potential sources of improvement are the most realistic in terms of processes ? The potential of isotopes to answer these questions is based on the sensitivity of isotopes to the contribution of large-scale precipitation (Risi et al submitted,b) and to rain reevaporation (Risi et al 2008a).

(2) It has been shown that convection-cloud-radiation feedbacks play a key role in the MJO and can slow down its propagation speed, in better agreement with observations (Bony et Emanuel 2005). These feedbacks depend on convective detrainment, microphysical processes in large-scale clouds, and radiative properties of clouds. Which part of this feedback is mis-represented and needs improvement ? The potential of isotopes to answer these questions is based on the sensitivity of isotopes to convective detrainment and large-scale cloud microphysics (Risi et al 2008, submitted,b).

(3) When shallow convection moistens the lower-mid troposphere during suppressed phases of the MJO, the active phase is better represented (Woolnough et al 2007). This moistening can be improved by improving the representation of mass fluxes in the shallow convection scheme (Hourdin et al submitted), of precipitation efficiency or of the melt layer (Inness et al 2001). What sources of improvement are the most critical and realistic ? The potential of isotopes to answer these questions is based on the expected sensitivity to shallow convective detrainment.

(4) The lack of convective organization at the large-scale in models can be due to the mis-representation (or lack of representation) of unsaturated downdrafts (Lin et al 2006) and associated cold pools. What are the effects of these components on the boundary layer (drying or moistening ?) and on the maintenance of convection (stabilization, or amplification by gusts?) The potential of isotopes to answer these questions is based on the sensitivity to unsaturated downdrafts (Risi et al 2008a, 2010b,c) and to the degree of organization of convection (Lawrence et al 2004, Risi et al 2008b)

For each of these questions, **the comparison of model simulations with observed joint humidity, isotopic and cloud distributions should allow us to discriminate between different hypotheses more clearly than with conventional measurements alone**.

We are aware that ocean-atmosphere interactions play a significant role in the MJO. However, biases in the MJO simulation in atmosphere-ocean coupled models are already present in atmosphere-only simulations (Waliser et al 1999). Therefore, here **we focus on purely atmospheric processes as a first and critical step**.

2.4. Objectifs et caractère ambitieux/novateur du projet / Objectives, originality and novelty of the project

The simulation of the MJO has been considered has a « holy grail » for several decades (Raymond et al 2001, Zhang et al 2005). Water isotopic observations provide an additional, complementary constrain of model simulations that will allow us to diagnose model shortcomings that could not be detected using humidity and cloud measurements only.

This project is very novel in its combination of science questions (convective processes) and tools (isotopic measurements) to address them. Water stable isotopes have been used for paleo-climate for several decades, but its use to evaluate atmospheric processes in climate models is very new and is something that I had contributed to initiate as part of my PhD.

At the international scale, this project will be a first in several ways :

1. first use of some new datasets for model evaluation (e.g. IASI, which will allow us to document the spatial distribution of isotopes around cloud systems for the first time).
2. first collocation of isotopic data with cloud data and evaluation of both isotopes and clouds using a model-to-satellite approach. This will help to identify model biases that could not be detected by neither isotopes only nor clouds only.
3. First investigation of the isotopic signal in the MJO through a hierarchy of model configuration. This powerful approach, which has already proven successful in understanding model biases for several non-isotopic variables, will help us exploit the potential of water isotopes that I have contributed to evidence, but that has been under-exploited so far.

3. Programme scientifique et technique, organisation du projet / Scientific and technical programme, Project organisation

3.1. Programme scientifique et structuration du projet / Scientific programme, project structure

The proposal is partitioned into 3 tasks (fig 3), each expressed as a science question. The hypothesis underlying this partition is that biases of GCMs in the representation of the MJO stem from biases in the representation of convective and cloud processes for a given dynamical regime, which are then amplified by dynamical/radiative feedbacks.

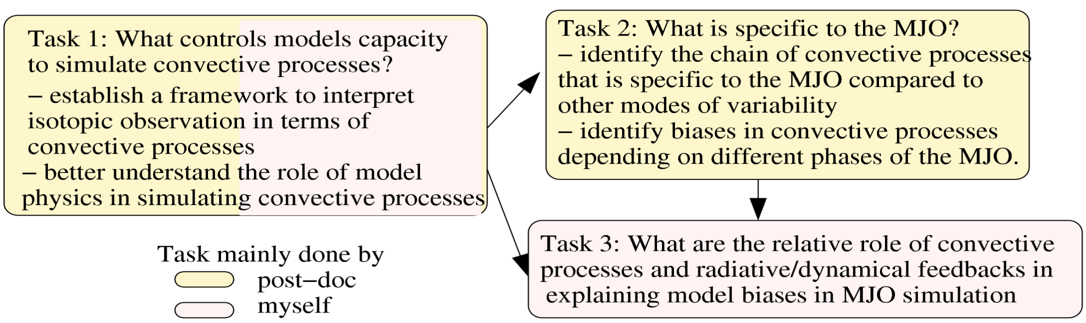

Figure 3 : Organization into 3 tasks.

Task 1 : What controls the capacity of the model to represent the large-scale organization of convection and the role of convection on its environment?
To address this question, we will establish a framework to interpret the joint humidity/isotopic/cloud observations in terms of convective processes, and we will design diagnostics based on these observations to detect and understand biases in GCMs. At this stage, we will focus on the representation of physical processes for a given dynamical regime, using simulations with constrained large-scale circulation. This task is the basis for the following tasks which will focus more specifically on the MJO.

Task 2 : What processes make the MJO specific compared to other modes of intra-seasonal variability ?
What chain of convective processes is specific to the MJO ? What model biases appear more specifically during the MJO ? during which phase ? To answer these questions, the model-data methodology and interpretative framework developed in task 1 will be combined with a composite analysis of the MJO.
Task 3 : What are the relative roles of the representation of different convective processes and of radiative/dynamical feedbacks in explaining model biases in the MJO simulation?
To quantify these relative roles, we will compare the behavior of the model in a hierarchy of model configurations. Results will be interpreted in the light of the understanding acquired in tasks 1 and 2. The expected outcome from this task is to suggest model improvements.

3.2. Management du projet / Project management

The core work will be shared between a post-doc and myself (fig 3 and 4). The coordination will be straightforward. I will focus on tasks for which I have already done significant preliminary work (tasks 1a and 3). The post-doc will focus on the organization of convection using the IASI dataset (task 1b) and on identifying features specific to the MJO (task 2). The post-doc and I should write two papers each (fig 4, table 3).

All the tasks will be done in collaboration with data, convection and modeling experts (section 5.1).

3.3. Description des travaux par tâche / Description by task

3.3.1 Tâche 1 / Task 1 : What controls the capacity of the model to represent the large-scale organization of convection and its role on its environment ?

This task is divided into 2 sub-tasks based on 2 science questions, which can each be best answered using different datasets. Table 2 describes each dataset and how we plan to process and exploit it.

Task 1a : What controls the capacity of the model to represent the moistening role of convection on its environment ?

This question is best answered using the **A-train datasets**, because it provides vertical profiles of both isotopes (new TES dataset : Worden et al 2011) and cloud properties (CALIPSO and Cloudsat : e.g. Martins et al 2011) with good vertical resolution. Isotopic retrievals are available in clear-sky and partially clouded environment, allowing us to study the role of convection on its environment.

First, we will gather the different A-train datasets (TES, CALIPSO, Cloudsat) and collocate them. We will finalize the model-to-satellite approach to compare model outputs and data : we need to calculate what the remote-sensing instrument would measure if it was flying in an atmosphere similar to that of the model, taking into account both spatio-temporal sampling and instrument sensitivity. For TES, this approach is already mastered (Risi et al submitted,a). For CALIPSO and Cloudsat, this is already included in LMDZ as part of the COSP package (Konsta et al submitted, Bodas-Salcedo et al 2011). Significant upstream work has already been done on gathering and processing these datasets.

Then we will exploit these datasets to evaluate the representation of profiles of convective moistening by different processes :

(1) shallow and deep convection , with a specific focus on the transition between the two which is usually hard to handle for models. The effect of convective closure, entrainment and detrainment formulation and precipitation efficiency will be more particularly tested (collaboration with C. Rio).

(2) rainfall reevaporation, which can play a significant role in the moisture-convection feedbacks (Bony et Emanuel 2005). Rain reevaporation also drives unsaturated downdrafts and cold pools, with a strong impact on boundary layer properties (Grandpeix et al 2010).

<u>Task 1b : What controls the capacity of the model to represent the large-scale organization of convection ?</u>

This question is best answered using the **IASI dataset**, with the advantage of unprecedented spatio-temporal coverage for isotopes.
Two retrieval algorithms currently exist for isotopes :

(1) at ULB (J-L Lacour and C. Clerbaux, unpublished): the feasibility of their retrieval method has been proved on several sites including the tropical site of Darwin.

(2) at KIT (M. Schneider, Schneider and Hase 2011).

These retrievals use different methods and wavelengths and are sensitive to different heights. We will thus use both to extract the robust features. Both of these products are clear-sky, allowing us to study the role of convection on its environment. Due to high computational cost of isotopic retrievals, we will restrict the analysis to the equatorial Indian and Western Pacific regions where the MJO activity is the strongest : 65°E-155°E, 15°S-10°N, and to only two years (March 2010-March 2012). This region includes the Darwin Atmospheric Radiation Measurement (ARM) site and the Gan ARM mobile facility that is deployed from

September 2011 to March 2012. ARM sites have the advantage of concentrating a large number of meteorological and atmospheric measurements. Besides, two field campaigns investigating convection and the MJO have focused on these sites : TWP-ice in Darwin (2006, before the launch of IASI) and CINDY-DYNAMO (2011-2012).

The model-to-satellite approach still needs to be developed for IASI-ULB, but has already been developed for IASI-KIT. The isotopic data will be combined with cloud properties retrieved from IASI following the approach of Stubenrauch et al 1999,2010 (collaboration with C. Stubenrauch and R. Armante). The model- to-satellite approach for similar retrievals has already been developed (Hendricks et al 2010). In addition, some collocation will be possible with some precipitation, humidity, cloud and radiation products from the Meghatropiques satellite (collaboration with G. Sèze). The Meghatropiques data will add value to our study, but the study could proceed even if technical problems delay its use.

Then, we will exploit this dataset to evaluate :
(1) the spatial distribution of isotopic composition around convective systems. This will allow us to better characterize the fast and direct effect of convection on its environment.
(2) the degree of organization of convection at the large-scale and its impact on large-scale environmental properties, following a method recently developed at LMD (Tobin et al submitted). We expect the isotopic composition to be more depleted around the more organized convective systems (Lawrence et al 2004, Risi et al 2010b). The effect of the parameterization of downdrafts, rain reevaporation and cold pools will be more particularly tested (collaboration with C. Rio, S. Bony, J-Y. Grandpeix).

Dataset	IASI	A-train	Darwin ARM site
Humidity and water isotopes	IASI	TES	TCCON+in-situ
Altitude of isotopic sensitivity	Full profiles (IASI-KIT) and 3-6km (IASI-ULB)	900 to 400hPa	total column water (TCCON) + at 9m (in-situ)
Region of available isotopic data	65°E-155°E, 15°S-10°N	global	Darwin
Time period for isotopic data	March 2010-March 2012	Since 2004	Since 2004 (TCCON), since 2010 (in-situ)
Collocated cloud properties	IASI + collocation with Meghatropiques	Cloud profiles from Cloudsat and CALIPSO	ARM data +additional data during TWP-ice campaign

Spatio-temporal coverage and resolution for isotopic data	Twice a day everywhere, but averaging needed	Every 13 days in a typical 2.5x3.75 LMDZ grid box.	Every few seconds-minutes, very smooth at daily scale
Main advantage	Spatio-temporal coverage	Vertical resolution	Temporal resolution
Science questions best answered using this dataset	Organization of convection, spatial distribution of isotopes	Profiles of convective moistening by convective detrainment and by rain evaporation	Specificity of MJO compared to other modes of variability
Model-to-satellite approach	To be developed for IASI-ULB, already developed for IASI-KIT	Already developed for TES, already incuded in LMDZ for CALIPSO and Cloudsat (COSP)	Already developed for TCCON, straightforward for in-situ data
Contacts	M. Schneider, K. Clerbaux, C. Stubenrauch, G. Sèze	J. Worden, S. Bony, H. Chepfer	N. Deutscher, S. Parkes

Table 1 : The 3 datasets used to combine humidity, water isotopes and cloud measurements.

Common approach for tasks 1a and 1b :

Model analysis will allow us to better understand physical processes at play in each model simulation, and to **establish the link between these physical processes and the signature in humidity/isotopes/clouds**. The model-to-satellite approach will allow us to compare model simulations to observations, and thus to discriminate between simulations based on their agreement with observations. Therefore, we will be able to discriminate between the different physical processes embedded in the simulations, and thus **identify the causes of model biases**.

The set of sensitivity tests will be performed with LMDZ with winds nudged by reanalyses winds. This allows the model to capture the real weather variability, and thus compare directly to observations. It also allows us to **focus on the representation of physical processes for a given large-scale circulation regime**, eliminating much of the dynamical feedbacks. Our sensitivity tests will focus on :

(1) the difference between the previous and new physical package of LMDZ, by activating one by one each new parameterization.

(2) Physical parameters that are known to strongly impact the representation of convective, cloud or water vapor transport processes (Risi et al in revision,b, Hourdin et al submitted).

We will compare LMDZ with other isotopic GCMs : MIROC (collaboration with N. Kurita), GSM (collaboration with K. Yoshimura), HadAM (collaboration with L. Sime), GISS (collaboration with R. Field). This will allow us to check whether our sensitivity tests are representative of the range of behavior of GCMs. These GCMs have very distinct isotopic behaviors (Risi et al submitted a,b).

3.3.2 Tâche 2 / Task 2 : What processes make the MJO specific compared to other modes of intra-seasonal variations ?

Among tropical modes of variability, the MJO is the one models have the most trouble to capture (Lin et al 2006). What makes the MJO so difficult to simulate ? More specifically :

(1) what chain of convective processes is specific to the MJO compared to other modes such as Kelvin waves or synoptic scale disturbances ?
(2) What model biases appear more specifically in the context of the MJO ?
(3) What are the phases of the MJO at which model biases appear ?

To answer these questions, we will make **composites of MJO events** following the method of Berkelammer et al (submitted), to document the different phases of the MJO. Composites of other modes of variability will also be computed for comparison. Both the A-train and IASI datasets prepared in task 1 will be used. In addition, we will use the Darwin ARM site dataset, including the total column isotopic composition from the TCCON ground-based remote-sensing instrument, surface air isotopic in-situ measurements and ARM cloud and surface meteorology measurements. These datasets have the advantage of a high temporal resolution (table 1), allowing us to document more smoothly individual MJO events. The model-to-observations approach has already been developed for the TCCON data (Risi et al submitted a).

Again, we will analyze simulations with LMDZ nudged by reanalyses winds. This ensures that the large-scale circulation associated with the MJO events and the other modes of tropical variability are captured by the model. We will make use of the knowledge acquired in task 1 to link physical processes with the observable signature in humidity/isotopes/clouds. Comparison with other isotopic GCMs will allow us to check the representativity of our sensitivity tests.

3.3.3 Tâche 3/ Task 3 : What are the relative roles of the representation of different convective processes and radiative/dynamical feedbacks in explaining model biases in the MJO simulation?

In task 1 and 2 we identify model biases associated with the model physics when the large-scale circulation is nudged towards reanalyses. What is the consequence of these biases when the simulation is free-running, i.e. run in a climate mode without nudging ? The goal of task 3 is to quantify and understand the relative roles of physical processes and radiative and dynamical feedbacks in explaining model biases in the MJO simulation.

To do so, we will compare the sensitivity tests in a hierarchy of model configurations. Comparison between 1D and 3D simulations will allow us to identify local versus 3D effects (e.g. Influence of air mass origin on the isotopic composition). Comparison between prescribed and interactive dynamics will allow to isolate dynamical feedbacks. Comparison between prescribed and interactive radiation will allow us to isolate radiative feedbacks. Besides, single-column simulations offers a much simpler framework in which the model behavior can be analyzed in more detail. To compare free-running simulation outputs with observations, the methodology developed by Field et al (in prep) for TES will be adapted to all datasets.

<u>Task 3a : case study at the Darwin ARM site.</u>

In task 3a, this approach will be tested at the **Darwin ARM site as a case study** for which a high density of observation is available, especially during the **TWP-ice campaign** (May et al 2007). Meteorological observations were sufficient during this campaign to build forcings for cloud resolving models (CRMs, Varble et al 2011) and single column models (SCMs).

1. A series of sensitivity tests will be performed with the **1D configuration of LMDZ** (Rio et al submitted, collaboration with C. Rio). Coordinated 1D simulations with the MIROC (collaboration with N. Kurita) and GISS (collaboration with C. Rio and R. Field) GCMs will also be possible.
2. CRM simulations could provide a reference for evaluating 1D simulations regarding variables that are not directly observable. An isotopic version of the **Meso-NH CRM** is currently under validation by J-P Pinty. The TWP-ice simulation performed as part of a CRM inter-comparison study (Varble et al 2011) will be redone with isotopic diagnostics. This would be the first time that SCM and CRM are being compare for water water isotopes. Physical and isotopic properties in updrafts, downdrafts and cold pools simulated explicitly by the CRM will be diagnosed (Couvreux et al 2010, collaboration with C. Rio) and compared with those parameterized in LMDZ-1D. This will greatly enhance our capacity to understand the physical processes at small spatial scales controlling the isotopic composition. However, if any technical problems delay the use of the CRM simulation, this will not prevent this task from achieving significant progress.

<u>Task 3b : Generalization over the Indian Ocean and Western Pacific regions</u>

Once we have mastered the approach for the Darwin case study, this approach will be generalized to the Indian and Western Pacific ocean regions over which the MJO strongly modulates deep convection. We will use the A-train and IASI datasets to better evaluate the vertical and spatial structures of the simulated MJO in the different simulations. Single column case studies will be constructed based on MJO composites elaborated in task 2. The Indian Ocean, where the MJO develops, and the Western Pacific, where the MJO propagates, will be contrasted. The different physical processes responsible for poor MJO simulation will be identified, and the associated convective/radiative/dynamical feedbacks will be disentangled and quantified.

The expected outcome of this task is to suggest model improvements to improve the simulation of the MJO.

3.4. CALENDRIER DES TÂCHES, LIVRABLES ET JALONS / TASKS SCHEDULE, DELIVERABLES AND MILESTONES

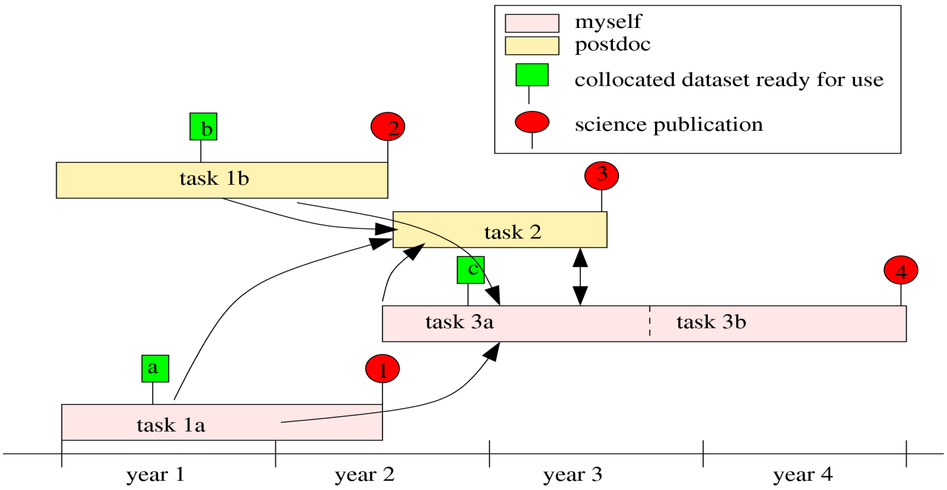

Figure 4 : Task schedule. The numbering of science publications and technical accomplishment correspond to deliverables listed in table 2.

type	date	description	lead	Corresponding tasks
Collocated dataset a	M6	TES/Cloudsat/CALIPSO	C. Risi	1a
Collocated dataset b	M6	IASI isotopes and clouds, Meghatropics	Post-doc	1b
Paper 1	M18	Evaluation of convective moistening profiles using collocated A-train data	C. Risi	1a
Paper 2	M18	Evaluation of convective organization using IASI data	Post-doc	1b
Collocated dataset c	M18	TCCON/ARM dataset	C. Risi	2, 3a
Paper 3	M30	What processes and model biases are specific to the MJO ?	Post-doc	2
Paper 4	M42	Understanding sources of model errors in simulating the MJO through a hierarchy of model configurations.	C. Risi	3

Table 2 : expected delivrables.

4. STRATÉGIE DE VALORISATION, DE PROTECTION ET D'EXPLOITATION DES RÉSULTATS / DISSEMINATION AND EXPLOITATION OF RESULTS. INTELLECTUAL PROPERTY

We plan to publish 4 papers in A-rank journals (fig 4, table 2). We will present our results in international conferences, targeting both the isotopic community, to show a novel use of isotopic measurements, and the convection/modeling communities, to show the added value of isotopic measurements.

As part of this project, 3 collocated datasets will be produced (delivrables a,b,c on table 2, fig 4), which is a significant technical achievement in itself. These datasets will be very useful for the community and we will share them on demand after publication.

As part of this project a set of simulations will be performed with LMDZ. My experience shows that there is a high demand for isotopic simulations from both data and modeling communities. Sharing our simulations has lead and will continue to lead to fruitfull collaborations (e.g. Frankenberg et al in prep, Lee et al submitted, Gao et al 2011, Vimeux et al 2011).

5. DESCRIPTION DE L'EQUIPE / TEAM DESCRIPTION

5.1. DESCRIPTION, ADÉQUATION ET COMPLÉMENTARITÉ DES PARTICIPANTS / PARTNERS DESCRIPTION & RELEVANCE, COMPLEMENTARITY

This projects builds on the expertise that I have aquired in :

(1) isotopic modeling, after having implemented water isotopes in LMDZ4 (Risi et al 2010a) and now LMDZ5,
(2) processing and exploiting isotopic satellite datasets (Risi et al submitted),
(3) developing model-to-satellite approach to model-data comparison,
(4) convective and cloud processes (Risi et al 2008a,b, Risi et al 2010b,c), and their parametrization in the LMDZ model.

This expertise has been acquired from collaborations with colleagues from different communities, and the success of this project will critically depend on the maintenance of such collaborations, with :

(1) data community: C. Clerbaux and J-L Lacour (isotopes from IASI-ULB), M. Schneider (isotopes from IASI-KIT), C. Stubenrauch (clouds from IASI), N. Deutscher (TCCON Darwin), S. Parkes (Darwin), G. Sèze (Meghatropiques), H. Chepfer (CALIPSO).
(2) Convection and parameterisation community : C. Rio (shallow convection, TWP-ice case), J-Y. Grandpeix (deep convection, cold pools), S. Bony (cloud processes).
(3) Isotopic modellingg community : N. Kurita (MIROC), K . Yoshimura (GSM), L. Sime (HadAM), R. Field (GISS).

Most of these fruitful collaborations have already lead to common publications (Risi et al 2010b, Risi et al submitted a,b, Kurita et al in press).

5.2. Qualification du coordinateur du projet / Qualification of the project coordinator

- I have already managed a few master students : co-supervision of 1 student in 2010, supervision of 3 students in 2012.
- I have a wide network of collaboration in in-situ data, remote-sensing and modeling fields. I'm used to deal with many collaborators from different backgrounds, as shown by the number of co-authors on my recent publications (e.g. Risi et al in review a)

5.3. Qualification, rôle et implication des participants / Qualification and contribution of each partner

	Nom / Name	Prénom / First name	Emploi actuel / Position	Discipline / Field of research	Personne .mois* / PM	Rôle/Responsabilité dans la proposition de projet/ Contribution to the proposal 4 lignes max
Coordinateur/responsable	RISI	Camille	CR CNRS, LMD	Isotopes, climate	36pm 75.00%	Coordination Core work on tasks 1a, 3a, 3b
Personnel temporaire	XXX	XXX	Post-doc, LMD	Isotopes, climate	30pm 100.00%	Core work on task 1b and 2
Autres membres français	Stubenrauch	Claudia	DR CNRS, LMD	Remote sensing of clouds	2.4pm 5.00%	Provides IASI cloud data and advice for task 1b
	Pinty	Jen-Pierre	IR1, LA	Meso-scale modeling	2.4pm 5.00%	Provides model outputs and advice for task 3a
	Armante	Raymond	IR1, LMD	Remote sensing of clouds	2.4pm 5.00%	Provides IASI cloud data and advice for task 1b
	Rio	Catherine	CR CNRS, LMD	Convection	4.8pm 10.00%	Provides expertise on LMDZ-1D modelling and on the TWP-ice case in ask 3a
Autres membres français, experts	Clerbaux	Cathy	DR CNRS, LATMOS	Remote-sensing of isotopes	Experte	Provides IASI humidity/isotopic data and advice for task 1b
	Chepfer	Hélène	Professor, UPMC, LMD	Remote sensing of clouds	Experte	Provides CALIPSO-GOPCC dataset and advice for task 1a
	Sèze	Geneviève	DR CNRS, LMD	Remote sensing of clouds	Experte	Provides Meghatropiques data and advice for task 1b
	Grandpeix	Jean-Yves	DR CNRS, LMD	Convection	Expert	Expertise on convection useful for all tasks
	Bony	Sandrine	DR, CNRS, LMD	Climate	Experte	Expertise on tropical meteorology useful for all tasks
Autres membres étrangers	Schneider	Matthias	KIT (Germany)	Remote-sensing of isotopes	2.4pm 5.00%	Provides IASI humidity/isotopic data for task 1b
	Lacour	Jean-Lionel	ULB (Belium)	Remote-sensing of isotopes	2.4pm 5.00%	Provides IASI humidity/isotopic data and advice for task 1b

	Kurita	Naoyuki	JAMSTEC (Japan)	Isotopes	2.4pm 5.00%	Provides MIROC model outputs useful for all tasks
Autres membres étrangers, experts	Worden	John	NASA/JPL (USA)	Remote-sensing of isotopes	Expert	Provides TES data for task 1a
	Deutscher	Nicholas	U. Bremen (Germany)	Remote-sensing of isotopes	Expert	Provides TCCON data and advice for tasks 2 and 3a
	Parkes	Stephen	ANSTO (Australia)	In-situ isotopic measurements	Expert	Provides in-situ isotopic data and advice for tasks 2 and 3a
	Sime	Louise	Br. Antarc. Surv. (UK)	Isotopes	Expert	Provides HadAM model outputs useful for all tasks
	Field	Robert	GISS (USA)	Isotopes	Expert	Provides GISS model outputs useful for all tasks
	Yoshimira	Kei	U. Tokyo (Japan)	Isotopes	Expert	Provides GSM model outputs useful for all tasks
	Berkelhammer	Max	U. Colorado (USA)	Isotopes	Expert	Expertise on MJO useful for task 2

* à renseigner par rapport à la durée totale du projet

Table 3 : qualification and contribution of each partner. My biography is in annex.

6. Justification scientifique des moyens demandés / Scientific justification of requested ressources

1. Équipement / Equipment

- 2 laptops for the post-doc and myself : 2500€x2=5000€
- 1 disk space to store the IASI, TES datasets, and the collocated Calipso and Cloudsat data : 500€

2. Personnel / Staff

1 post-doc to take part in the data and model analysis : 3672€/mois x 30 months=110160€
The post-doc should have knowledge in climate dynamics and convection, and skill in processing and analysing large datasets and simulations.

3. Prestation de service externe / Subcontracting

None

4. Missions / Travel

- 6 travels to AGU-like conferences : 6x2500€=15000€
- meeting with collaborators (France, Belgium, Germany) : 10x500€=5000€

5. Dépenses justifiées sur une procédure de facturation interne / Costs justified by internal procedures of invoicing

None

6. Autres dépenses de fonctionnement / Other expenses

- 4 AGU-like Publication fees : 4*3000€=12000€

7. Références bibliographiques / References

7.1. Publications of proposal members

Berkelhammer, M., **Risi**, C, **Kurita**, N, Noone, D. , The moisture source sequence for the Madden-Julian Oscillation as derived from satellite retrievals of HDO, submitted to J. Geophys. Res.

Bony, S. and Emanuel, K. (2005). On the role of moist processes in tropical intraseasonal variability : Cloud-radiation and moisture ?convection feedbacks. J. Atmos. Sci., 62 :2770-2789.

Bony, S and Dufresne, J-L (2005) Marine boundary layer clouds at the heart of tropical cloud feedback uncertainties in climate models. Geophys. Res. Lett. doi:10.1029/2005GL023851

Chepfer, H, **Bony**, S, Winker, D, Chriracio, M, Dufresne, J-L, **Sèze**, G (2008) Use of CALIPSO lidar observations to evaluate the cloudiness simulated by a climate model. Geophys. Res. Lett. 351:L15704.

Couvreux, F, F. Hourdin and C. **Rio** (2010) Resolved Versus Parametrized Boundary-Layer Plumes. Part I: A Parametrization-Oriented Conditional Sampling in Large-Eddy Simulations . Boundary-Layer Meteorology, 134 (3) 441-458

Eagle, R. A., **Risi**, C., Eiler, J. M., Seibt, U., Tripati, A. K . High regional climate sensitivity over continental China inferred from glacial-recent changes in temperature and the hydrologic cycle. In preparation.

Frankenberg, F, **Worden**, J, Lee, J-E., **Risi**, C et al. HDO/H2O retrievals from GOSAT. In preparation.

Field, R, Risi, C. Comparing modeled water vapor amount and isotopic composition against satellite measurements. in prep.

Gao, J, V. Masson-Delmotte, T. Yao, L. Tian, C. Risi, G. Hoffmann (2011). Precipitation water isotopes in the South Tibetan Plateau: observations and modeling, J. Clim. doi: 10.1175/2010JCLI3736.1

Grandpeix, J, Lafore, J-P (2010). A density current parameterization coupled with Emanuel's convection scheme. Part 1 : The models. J. Atmos. Sci. 67:881-897.

Hendricks J., Falb A., **Stubenrauch** C. J., Lohmann U. and Emde C., A Method for comparing properties of cirrus clouds in global climate models with those retrieved from IR sounder satellite observations. *Meteorol. Z.* 19, 577-589 (2010).

Herbin, H., Hurtmans, D., **Clerbaux**, C., Clarisse, L., and Coheur, P.-F. (2009). H216O and HDO measurements with IASI/MetOp. Atmos. Chem. Phys. Discuss., 9 :92679290.

Hourdin, F, Grandpeix, JY, **Rio**, C, **Bony**, S, Jam, A, Cheruy, F, Rochetin, N, Fairhead, L, Idelkadi, A, Musat, I, Dufresne, J-L, Lefebvre, M-P, Lahellec, A, Roerig, R. From LMDZ5A to LMDZ5B : revisiting the parameterizations of clouds and convection in the atmospheric component of the IPSL-CM5 climate model. Submited to Clim. Dyn.

Kurita, N., D. C. Noone, C. **Risi**, G. A. Schmidt, H. Yamada, K. Yoneyama, and (2011), Intraseasonal isotopic variation associated with the Madden-Julian Oscillation,J. Geophys. Res., 116.

Konsta D., H. **Chepfer**, JL Dufresne, 2011: A process oriented description of tropical oceanic clouds for climate model evaluation, based on a statistical analysis of daytime A-train high spatial resolution observations, Climate Dynamics, submitted

Lee, J-E, Fung, I, **Risi**, C, **Worden**, J, Scheepmaker, R, Frankenberg, C. Asian monsoon hydrology investigated with LMDZ GCM and two satellite measurements (TES and SCIAMACHY) of water vapor isotopes. Submitted to J. Geophys. Res.

Martins E., V. Noel, H. **Chepfer**, 2011: Properties of cirrus and subvisible cirrus from nighttime CALIOP, related to atmospheric dynamics and water vapor, J. Geophys. Res., J. Geophys. Res., 116, D02208.

Masson-Delmotte, V, P. Braconnot, G. Hoffmann, J. Jouzel, M. Kageyama, A. Landais, Q. Lejeune, C. **Risi**, L. **Sime**, J. Sjolte, D. Swingedouw, and B. Vinther. Sensitivity of interglacial Greenland temperature and delta18O to orbital and CO2 forcing: climate simulations and ice core data. Clim. Past Discuss. doi:10.5194/cpd-7-1585-2011

Rio, C., Hourdin, F., Grandpeix, J.-Y., and Lafore, J.-P. (2009). Shifting the diurnal cycle of parameterized deep convection over land. Geophy. Res. Lett., 36 :L07809, doi : 10.1029/2008GL036779.

Rio, C, **Grandpeix**, J-Y., Hourdin, F, Guichard, F., Couvreux, F, Lafore, J-P., Fridlind, A, Mrowiec, A, **Bony**, S, Rochetin, N, Roehrig, R, Idelkadi, A, Lefebvre, M-P., Musat, I. Control of deep convection by subècloud lifting processes : the ALP closure in the LMDZ5B general circulation model.

Risi, C., **Bony**, S., and Vimeux, F. (2008). Influence of convective processes on the isotopic composition (O18 and D) of precipitation and water vapor in the Tropics : Part 2 : Physical interpretation of the amount effect. J. Geophys. Res., 113 :D19306, doi : 10.1029/2008JD009943.

Risi, C., **Bony**, S., Vimeux, F., and Jouzel, J. (2010a). Water stable isotopes in the LMDZ4 General Circulation Model : model evaluation for present day and past climates and applications to climatic interpretation of tropical isotopic records. J. Geophys. Res., 115, D12118 :doi :10.1029/2009JD013255.

Risi, C., **Bony**, S., Vimeux, F., Chong, M., and Descroix, L. (2010b). Evolution of the water stable isotopic composition of the rain sampled along Sahelian squall lines. Quart. J. Roy. Meteor. Soc., 136 (S1) :227 242.

Risi, C., **Bony**, S., Vimeux, F., Frankenberg, C., and Noone, D. (2010c). Understanding the Sahelian waterbudget through the isotopic composition of water vapor and precipitation. J. Geophys. Res, 115 :D24, D24110.

C. **Risi**, D Noone, J **Worden**, C Frankenberg, G Stiller, M Kiefer, B Funke, K Walker, P Bernath, M **Schneider**, D Wunch, V Sherlock, N Deutsche, D. Griffith, P O. Wennberg, K Strong, D Smale, E Mathieu, S Barthlott, F Hase, O García, J Notholt, T Warneke, G Toon, D Sayres, S **Bony**, J Lee, D Brown, R Uemura, C Sturm. Process-evaluation of tropospheric humidity simulated by general circulation models using water vapor isotopologues. Part 1: comparison between models and observations. Submitted to J. Geophys. Res.,a

Risi, C., D Noone, J **Worden** , Christian Frankenberg , G Stiller, M Kiefer, B Funke, K Walker, P Bernath, M **Schneider**, S **Bony**, J Lee, D Brown, C Sturm. Process-evaluation of tropospheric humidity simulated by general circulation models using water vapor isotopic observations. Part 2: using isotopic diagnostics understand the mid and upper tropospheric moist bias in the tropics and subtropics. Submitted to J. Geophys. Res.,b

Risi et S. **Bony**. 2011. Évaluer les modèles de climat et leurs projections: la valeur ajoutée de la composition isotopique de l'eau. La Météorologie.

Schneider, M. and Hase, F.: Optimal estimation of tropospheric H2O and δD with IASI/METOP, Atmos. Chem. Phys., 11, 11207-11220, doi:10.5194/acp-11-11207-2011 , 2011.

Sime, L, **Risi**, C, Tindall, J C, Sjolter, J, Wolff, E. W., Masson-Delmotte, V. and Capron, E . Last interglacial isotopic changes across Greenland: observations and warm climate isotopic simulations. Submitted.

Stubenrauch, C. J., A. Chédin, R. **Armante**, and N. A. Scott: Clouds as Seen by Satellite Sounders (3I) and Imagers (ISCCP): II) A New Approach for Cloud Parameter Determination in the 3I Algorithms. *J. Climate*, 12, 2214-2223 (1999).

Stubenrauch. C. J.. S. Cros. A. Guignard, and N. Lamquin, A six-year global cloud climatology from the Atmospheric InfraRed Sounder aboard the Aqua Satellite: statistical analysis in synergy with CALIPSO and CloudSat./Atmos. Chem. Phys., /10, 7197−7214 (2010).

Varble, A, Fridlind, A. M., Zipser, E., Ackerman, A. S., Chaboureau, J-P., Fan, J, McFarlane, S. A. , **Pinty**, J-P., Sipway, B. (2011). Evaluation of cloud resolving model intercomparison simulations using TWP-ice observations : precipitation and cloud structure.

F. Vimeux, G. Tremoy, C. **Risi**, R. Gallaire. A strong control of the South American SeeSaw on the intraseasonal variability of the isotopic composition of precipitation in the Bolivian Andes. Earth. Planet. Sci. Lett. doi:10.1016/j.epsl.2011.04.031

Worden, J., Noone, D., and Bowman, K. (2007). Importance of rain evaporation and continental convection in the tropical water cycle. Nature, 445 :528532.

Worden, J, Kulawik, S., Frankenberg, C., Bowman, K., Payne, V., Cady-Peirara, K., Wecht, K., Lee, J-E., Noone, D. (submitted). Profiles of CH4, HDO, H2O, and N2O with improved lower tropospheric vertical resolution from Aura TES radiances. Atmos. Meas. Tech. Discuss.

Zurovac-Jevtić, Dančе, Sandrine **Bony**, Kerry Emanuel, 2006: On the Role of Clouds and Moisture in Tropical Waves: A Two-Dimensional Model Study. *J. Atmos. Sci.*, 63, 2140–2155. doi:http://dx.doi.org/10.1175/JAS3738.1

7.2. OTHER PUBLICATIONS

Bessafi, Miloud, Matthew C. Wheeler, 2006: Modulation of South Indian Ocean Tropical Cyclones by the Madden–Julian Oscillation and Convectively Coupled Equatorial Waves. *Mon. Wea. Rev.*, **134**, 638–656.

Boyle, J., S. Klein, G. Zhang, S. Xie, X. Wei, 2008: Climate Model Forecast Experiments for TOGA COARE. *Mon. Wea. Rev.*, 136, 808–832.

Cassou, C (2008) Intraseasonal interaction between the Madden–Julian Oscillation and the North Atlantic Oscillation. Nature 455, 523-527

Grabowski, W. W. and Moncrieff, M. W (2001). Large scale organization of tropical convection in two-dimensional explicit numerical solutions. Quart. J. Roy. Meteor. Soc. 127 , 445-468

Grabowski, W. W. and Moncrieff, M. W (2002). Large scale organization of tropical convection in two-dimensional explicit numerical solutions. Effects of interactive radiation. Quart. J. Roy. Meteor. Soc. 128 , 2349-2375

Inness, PM, Slingo, JM, Woolnough, SJ, Neale, RB, Pope, VD (2001). Organization of tropical convection in a GCM with varying vertical resolution; implications for the simulation of the Madden-Julian Oscillation. Clim. Dyn. 17:777-793.

Kessler, W. S., 2001: EOF representations of the Madden–Julian oscillation and its connection with ENSO. J. Climate, 14,3055–3061.

Kim, D, Sobel, AH, Maloney, ED, Frierson, DMW, and Kang, I-S. Systematic Relationship between Intraseasonal Variability and Mean State Bias in AGCM Simulations. Submitted to J. Clim.

Kim, D, Sobel, AH, Del Genio, AD, Yonghua, C, Camargo, SJ, Yao, MS, Kelley, M, Nazarenko, L. The Tropical Subseasonal Variability simulated in the NASA GISS General Circulation Model. Submitted to J. Clim.

Klein, SA ; Jiang, X, Boyle, J, Malyshev, S, Xie, S (2006). Diagnosis of the summertime warm and dry bias over the U.S. Southern Great Plains in the GFDL climate model using a weather forecasting approach. Geophys. Res. Lett. 33:L18805.

Konsat, D, Dufresne, J-L, Chepfer, H, Idelkadi, A, Cesana, G. Evaluation of clouds simulated by the LMDZ5 GCM using A-train satellite observations (CALIPSO-PARASOL-CERES). Submitted to Clim. Dyn.

Lawrence, J. R., Gedzelman, S. D., Dexheimer, D., Cho, H.-K., Carrie, G. D., Gasparini, R., Anderson, C. R., Bowman, K. P., and Biggerstaff, M. I. (2004). Stable isotopic composition of water vapor in the tropics. J. Geophys. Res., 109 :D06115

Lin J-Y et al 2006. Tropical intra-seasonal variability in 14 IPCC AR4 climate models. Part 1 : convective signals. J. Climate 19 : 2665-2690.

Madden, R. A. and Julian, P. R (1993). Observations of the 40-50-Day Tropical Oscillation—A Review. Monthly Weather Review. 122:814-837

May, PT, Mather, JH, Vaughan, G, Jakob, C, McFarquhar, GM, Bower, KN, Mace, GG (2007). The tropical warm pool international cloud experiment. Bull. American Meteror. Soc. DOI:10.1175/BAMS-89-5-629

Moyer, E. J., Irion, F. W., Yung, Y. L., and Gunson, M. R. (1996). ATMOS stratospheric deuterated water and implications for troposphere-stratosphere transport. Geophys. Res. Lett., 23:23852388.

Petch, JC, Willett, RY, Wong, RY, Woolnough, SJ (2007). Modelling suppressed and active convection. Comparing a numerical weather prediction, cloud-resolving and single-column model. Quat. J. Roy. Meteor. Soc. 133:1087-1100

Raymond, David J., 2001: A New Model of the Madden–Julian Oscillation. *J. Atmos. Sci.*, 58, 2807–2819.

Slingo, J. M., Sperber, K. R., Boyle, J. S., Ceron, J.-P., Dix, M., Dugas, B., Ebisuzaki, W., Fyfe, J., Gregory, D., Gueremy, J.-F., and co authors (1996). Intraseasonal oscillations in 15 atmospheric general circulation models : results from an AMIP diagnostic subproject . Clim. Dyn, 12 (5) :325-357.

IPCC et al (2007. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor andH.L. Miller (eds.)., Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp, 2007.

Tompkins, A. M. (2001). Organization of tropical convection in low vertical wind shears : The role of water vapor. J. Atmos. Sci., 58 :529-545.

Webster, C. R. and Heymsfield, A. J. (2003). Water Isotope Ratios D/H, 18O/16O, 17O/16O in and out of Clouds Map Dehydration Pathways. Science, 302 :17421746.

Waliser, DE, Lau KM, Kim J-H (1999). The Influence of Coupled Sea Surface Temperatures on the Madden–Julian Oscillation: A Model Perturbation Experiment. J. Atmos. Sci. 56:333-358.

Wheeler, M. C., and J. L. McBride, 2005: Australian–Indonesian monsoon. *Intraseasonal Variability in the Atmosphere–Ocean Climate System,* W. K. M. Lau and D. E. Waliser, Eds., Springer Praxis, 125–173.

Woolnough, R. B., Blossey, P. N., Xu, K.-M., Bechtold, P., Chaboureau, J.-P., Hosomi, T., Icobellis, S. F., Luo, Y., Petch, J. C., Wong, R. Y., and Xie, S. (2010). Modelling convective processes during the suppressed phase of a Madden-Julian oscillation : Comparing single-column models with cloud-resolving models. Quart. J. R. Meteor. Soc., 136 (647) :333353.

Woolnough, S. J., Vitard, F., Balmaseda, M. A. (2007) The role of the ocean in the Madden–Julian Oscillation: Implications for MJO prediction. Quart. J. Roy. Meteor. Soc., 133 : 117–128

Zhang, C. (2005), Madden-Julian Oscillation, Rev. Geophys., 43, RG2003.