ARPAE

Agenzia regionale per la prevenzione, l'ambiente e l'energia

dell'Emilia - Romagna

* * *

Atti amministrativi

Determinazione dirigenziale	n. DET-2017-266	del 24/03/2017
Oggetto	Servizio Idro-Meteo-Clima. Approvazione e sottoscrizione dell' Accordo di collaborazione con l'Università di Monaco nell'ambito del progetto di ricerca, denominato Waves to Weather (W2W).	
Proposta	n. PDTD-2017-271	del 24/03/2017
Struttura adottante	Servizio Idro-Meteo-Clima	
Dirigente adottante	Cacciamani Carlo	
Struttura proponente	Servizio Idro-Meteo-Clima	
Dirigente proponente	Dott. Cacciamani Carlo	
Responsabile del procedimento	Cacciamani Carlo	

Questo giorno 24 (ventiquattro) marzo 2017 presso la sede di Viale Silvani, 6 in Bologna, il Direttore del Servizio Idro-Meteo-Clima, Dott. Cacciamani Carlo, ai sensi del Regolamento Arpae sul Decentramento amministrativo, approvato con D.D.G. n. 75 del 13/07/2016 e dell'art. 4, comma 2 del D.Lgs. 30 marzo 2001, n. 165 determina quanto segue.

Oggetto: Servizio Idro-Meteo-Clima. Approvazione e sottoscrizione dell' Accordo di collaborazione con l'Università di Monaco nell'ambito del progetto di ricerca, denominato Waves to Weather (W2W).

RICHIAMATI:

- l'art. 15 della L. 7 agosto 1990, n. 241, ai sensi del quale le Pubbliche Amministrazioni possono concludere tra loro accordi per disciplinare lo svolgimento in collaborazione di attività di interesse comune;
- la L.R. 19 aprile 1995, n. 44 che istituisce l'Agenzia Regionale per la Prevenzione e l'Ambiente dell'Emilia-Romagna (ARPA) ed in particolare l'art. 5 che definisce le attività nell'ambito delle quali il Servizio Idro-Meteo-Clima di ARPA (ARPA-SIMC) opera;
- l'art. 5 della stessa legge che, al comma 2, prevede: "per l'adempimento delle proprie funzioni, attività e compiti, ARPA può definire accordi o convenzioni con Aziende ed Enti pubblici, operanti nei settori di Meteorologia, Climatologia dell'ambiente;
- la L.R. n.13/2015 del 30/07/2015 "Riforma del sistema di governo regionale e locale e disposizioni su città metropolitana di Bologna, Province, Comuni e loro unioni" ; in particolare, l'articolo 16 della Sezione II, della medesima Legge, che reca: "l'Agenzia regionale per la prevenzione e l'ambiente (ARPA) dell'Emilia-Romagna) è ridenominata "Agenzia regionale per la prevenzione, l'ambiente e l'energia" (Arpae);

PREMESSO:

- che l'Università di Monaco (LMU) ha, tra i propri obiettivi istituzionali, lo svolgimento di attività di ricerca nei campi della meteorologia, e in particolare, nella dinamica atmosferica e nello studio della sua prevedibilità;
- che LMU, insieme ad altre università e enti di ricerca tedeschi, è capofila di un importante di progetto di ricerca, denominato Waves to Weather (W2W), che ha lo scopo di studiare e migliorare la capacità previsionale;
- che LMU, nell'ambito di un sottoprogetto di W2W, ha proposto ad Arpae SIMC una collaborazione per lo sviluppo di un indice di prevedibilità degli eventi di precipitazione intensa, da applicare nella pratica quotidiana della previsione meteorologica e nelle conseguenti procedure di allertamento.
- che esiste un comune interesse allo sviluppo della ricerca finalizzata a carattere interdisciplinare, nonché l'esigenza di verificare, in termini operativi, l'impatto dei nuovi studi derivanti dall'attività di ricerca sopraindicata;

che, in particolare, Arpae SIMC svolge attività operative e di supporto nel settore della previsione meteorologica, idrologica, agrometeorologica, nella valutazione climatologica e della qualità dell'aria;

CONSIDERATO:

- che tale collaborazione scientifica potrà contribuire ad elevare il grado quantitativo e qualitativo del patrimonio informativo meteorologico e atmosferico, ottimizzando i compiti istituzionali di entrambi gli Enti;

RITENUTO

- pertanto, nell'interesse delle parti, di approvare e sottoscrivere l' Accordo di collaborazione con l'Università di Monaco Allegato A) che si allega quale parte integrante di tale atto per lo svolgimento di attività nei settori della meteorologia dinamica e dei suoi impatti operativi nell'ambito del progetto di ricerca, denominato Waves to Weather (W2W); dettagliato nell'Allegato Tecnico dello stesso Accordo;
- che tale Accordo avrà la durata di 3 anni dalla data di sottoscrizione con possibilità di rinnovo tramite accordo scritto fra le parti;
- che le attività saranno svolte mediante l'utilizzo di personale proprio e ogni altro onere economico dovrà essere preventivamente discusso ed approvato dalle parti;

SU PROPOSTA:

- del Dott. Carlo Cacciamani Direttore del Servizio Idro-Meteo-Clima il quale ha espresso parere favorevole in merito alla regolarità amministrativa e tecnica del presente atto, ai sensi del regolamento sul decentramento amministrativo approvato con D.D.G. n. 75 del 13.07.2016;

DATO ATTO:

- che il responsabile del presente Accordo per l'Università di Monaco è Mr. Frank Spiekermann (Capo Dipartimento del Budget e Finanze di LMU):
- che il responsabile del presente Accordo per Arpae Simc è il Direttore Dott. Carlo Cacciamani;
- che il referente scientifico per l'Università di Monaco è il prof. George Craig;
- che il referente scientifico per Arpae Simc è il dott. Federico Grazzini;

DETERMINA

1. di approvare e sottoscrivere l' Accordo di collaborazione con l'Università di Monaco (LMU allegato A) al presente atto quale parte integrante e sostanziale, per lo svolgimento di attività nei settori della meteorologia dinamica e dei suoi impatti operativi nell'ambito del progetto di ricerca, denominato Waves to Weather (W2W), dettagliato nell'Allegato Tecnico dello stesso Accordo,

2. di dare atto che l'Accordo avrà la durata di 3 anni dalla data di sottoscrizione, con possibilità di rinnovo tramite accordo scritto fra le parti;
3. di dare atto che il referente scientifico per l'Università di Monaco è il prof. George Craig e per Arpae Simc è il dott. Federico Grazzini;
4. di dare atto che le attività saranno svolte mediante l'utilizzo di personale proprio, e ogni altro onere economico dovrà essere preventivamente discusso ed approvato dalle parti.

Allegato:

A) Accordo di collaborazione con Allegato tecnico

IL DIRETTORE DEL

SERVIZIO IDRO-METEO-CLIMA

(F.to Dott. Carlo Cacciamani)

Cooperation Agreement

The following Agreement is hereby concluded
between
Ludwig-Maximilians-Universität München
Geschwister-Scholl-Platz 1
80539 Munich, Germany
represented by the Head of Finance (Frank Spiekermann)

represented by the Administration of the Academic Research Institution on behalf of the

Institute:
Meteorological Institute - SFB TRR 165, Chair: Prof. Dr. George Craig, Atmospheric Science
Theresienstraße 37
80333 Munich, Germany

Project leaders:
Prof. Dr. George Craig
Meteorological Institute, Ludwig-Maximilians-Universität
Theresienstr. 37, 80333 Munich, Germany
phone: +49 89 2180-4570, email: george.craig@lmu.de
and
Prof. Dr. Volkmar Wirth
Institute for Atmospheric Physics, Johannes Gutenberg-Universität Mainz
Becherweg 21, 55128 Mainz, Germany
phone: +49 6131 3922868, email: vwirth@uni-mainz.de

- hereinafter referred to as the "University" -

and
ARPAE-SIMC Emilia-Romagna
Dott. Carlo Cacciamani (Director)
Viale Silvani 6, 40122 Bologna, Italy
phone: +39 051 6497510, email: ccacciamani@arpae.it

- hereinafter referred to as the "Company" -

Article 1 - Subject of the Cooperation Agreement

The Parties agree to conduct a research project ("Cooperation Project") entitled:

Development of a predictability index for severe weather events over Europe

jointly on the basis of and during the term of this Agreement.

The subject of the Cooperation Project is:

the verification and more accurate quantification of the previously identified link between long-lived Rossby Wave packets (RWPs) and heavy precipitation events over Europe, the study of how predictability is influenced by the presence of incoming RWPs, and the determination of how the presence of convection in the target region could modify or override the large scale signal. An aim of this project is to define an index that would provide guidance for how far into the future heavy precipitation events can be predicted.

The details of the project-related work are laid out in the work plans agreed between the Parties, as included in the proposal submitted to the DFG.

Article 2 - Contributions by the Parties

Each Party shall provide the staff and in-kind contributions required for the conduct of the Cooperation Project as is necessary on its part and bear the corresponding costs. The services to be provided by the University may be supplemented by funds from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation). The details of the services planned by the Parties are described in the proposal to the DFG.

Article 3 - Support by the DFG

(1) The Parties expect that the DFG shall decide on the support of the Cooperation Project once it has evaluated the proposal.

(2) The DFG's current guidelines for the use of funds, award letter and general guidelines shall be deemed as the basis of this Agreement and shall be acknowledged as binding by the Parties; however, the Company shall only acknowledge these guidelines and terms to the extent that it will be affected by them.

Article 4 - Cooperation

(1) The Parties shall use the time and care necessary for the implementation of the Cooperation Project as required and in consideration of the generally accepted rules of science and technology, in order to achieve an optimum result. The Parties shall conduct work-related discussions and agree on the progress of the work at reasonable intervals, involving the employees entrusted with the project-related work.

(2) Each Party shall name a contact person to be contacted with regard to all matters that will need to be agreed within the scope of the cooperation.

(3) Employees of either Party who work on defined tasks at the premises of the respective other Party for a limited time, within the scope of the project-related work, shall be subject to the instructions given by the employees responsible at the Party concerned, to the extent required for carrying out the work. The relationships under the relevant service regulations and employment contracts shall not be affected.

Article 5 - Work Results, Rights of Use

(1) All protectable and non-protectable work results generated under the Cooperation Project exclusively by the employees of one Party are the property of this Party.

(2) The Parties grant each other, for the duration and purposes of the Cooperation Project, the non-exclusive, non-transferable, non-sublicensable, irrevocable and royalty-free right of use to the protectable and non-protectable work results generated under the Cooperation Project.

(3) In addition, the Parties grant each other, for the duration and purposes of the Cooperation Project, the non-exclusive, non-transferable, non-sublicensable and royalty-free right of use to previously generated protectable and non-protectable work results to the extent necessary for the realisation of the Cooperation Project.

(4) The Parties shall agree on a case-by-case basis on the granting of further rights of use, particularly for purposes outside of the Cooperation Project and after the expiration of the Cooperation Project. Such rights shall be granted on terms customary in the market.

The University is willing in principle to grant the Company, on terms customary in the market, non-exclusive, or possibly exclusive, rights of use to the University's work results for purposes outside of the Cooperation Project or after the expiration of the Cooperation Project. The Parties shall come to the necessary agreements at the appropriate time.

In the event that the University grants the Company an exclusive right of use, the University shall retain for its own research and educational purposes a right of use that is non-exclusive, non-transferable, sublicensable only for research partnerships, irrevocable and royalty-free.

(5) Joint work results are work results in which employees from both Parties are involved and whose parts cannot be attributed to one Party alone. Rights of use shall be granted in accordance with Article 5, paragraph 7, sentences. 3 ff.

(6) Each Party may, according to its discretion, apply for a domestic and/or foreign patent or utility model for any invention made under the Cooperation Project based on work results generated by that Party, and claim the resulting industrial property rights.

(7) Joint inventions are inventions in which employees of both Parties are involved and whose parts cannot be the subject of industrial property rights applications filed separately by each Party. The Parties shall come to agreements on the treatment of joint inventions, especially the application for and maintenance of industrial property rights and on the responsibility for the associated costs. The Parties grant each other an irrevocable, worldwide, transferable, sublicensable and royalty-free right of use to these joint inventions for all uses, provided the other Party's contribution to the joint invention is greater than one-third. If this is not the case, the Parties grant each other a non-exclusive, non-transferable, sublicensable, irrevocable and royalty-free right of use for the purposes and duration of the Cooperation Project. For purposes outside of the Cooperation Project or after the expiration of the Cooperation Project, the right of use shall be granted on terms customary in the market.

(8) If a Party is not interested in filing an application for industrial property rights, the other Party is free to pursue, at its own expense, the registration and exploitation of the relevant work results. The Party filing such an application shall release the other Party from having to pay inventor compensation (according to the German *Gesetz über Arbeitnehmererfindungen* (Law on Employee Inventions)).

(9) The Parties are not responsible for ensuring that the rights of use granted under this Agreement are free of third-party rights. If they become aware of any third-party rights, they shall inform the other contracting Party accordingly and without delay.

Article 6 - Confidentiality

(1) The Parties hereby agree that they will not disclose any recognisably confidential operational and business information that the respective other Party has become aware of during the Cooperation Project to any third party; this obligation shall also continue to apply for a period of three years beyond the term of this Agreement.

(2) This obligation (pursuant to Article 6, paragraph 1) shall not apply to information that

- is common knowledge through publications or the like,
- becomes common knowledge through no fault of the receiving Party,
- was demonstrably known to the receiving Party before the date on which it was provided,
- was generated by the receiving Party independently of such provision,
- was provided to the receiving Party by a third party without any obligation to confidentiality.

(3) The DFG is not deemed to be a "third party" within the meaning of this clause insofar as the DFG is entitled to such information according to its current grant conditions, award letter and general guidelines.

Article 7 - Publications

(1) Each Party shall have the right to publish the work results it has achieved within the scope of the Cooperation Project. However, the mutual protectable interests of either Party must also be taken into account.

(2) The Parties shall notify each other in due time about planned publications. Unless the other Party objects within a period of four weeks after it has received the proposed publication, its consent to the publication shall be considered granted. The publication date may be suspended for a limited time at the request of either Party, but no longer than for a period of five months, for example, in order to enable the respective Party to file an application for industrial property rights. In the event that the Parties are unable to reach an agreement on the content and/or the form of the planned publication within the said time limit, the publication in question may also be filed for publication without the consent of the other Party provided that the publication does not disclose the other Party's work results or confidential information.

(3) All publications shall refer explicitly to the Cooperation Project as the origin of the published results and to the DFG as the sponsor providing the funds.

(4) The employment rights and obligations of any staff members of the University with regard to publications shall not be affected. The Company shall take the legal obligations

and justified interests of doctoral and postdoctoral researchers into account to a reasonable extent, i.e. also by granting its consent to a shortening of the compulsory waiting period defined in Article 7, paragraph 2, if attainment of a doctorate or habilitation is affected by the work in the Cooperation Project.

(5) The rights of the DFG as the sponsor of this Cooperation Project, particularly its entitlement to report on the work and the results achieved within the scope of DFG funding, shall not be affected.

Article 8 - Warranty, Liability

(1) The Parties shall waive the enforcement of any warranty claims within the scope of the Cooperation Project with regard to the know-how provided and the achieved work results.

(2) Otherwise, each Party, to the extent permitted by law, shall only be held liable for any property damage or financial losses caused by wilful intent or gross negligence. Liability for consequential damages shall be excluded.

Article 9 - Term of Agreement and Termination

(1) This Agreement shall take effect upon the DFG's granting of funds to the University. The Agreement shall expire upon completion of DFG funding, unless any arrangements or obligations beyond the end date have been agreed.

(2) This Agreement may only be terminated early for good cause; termination must be made in writing. The DFG must be informed accordingly.

Article 10 - Final Provisions

If any individual provision of this Agreement is held to be or becomes ineffective, the validity of the remaining provisions shall not be affected. In such a case, the Parties shall endeavour to agree on a supplementary clause to this Agreement in the spirit of the initially intended purpose by mutual consent.

Any amendments or supplements to this Agreement must be made in writing and shall be subject to the prior consent of the DFG. This shall also apply to an amendment of the written form clause itself.

Munich, ... (Date)

...................… …….(University)

....
Frank Spiekermann
Leiter Dezernat Haushalt und Finanzen
(University Administration)

....
Prof. Dr. George Craig
Meteorological Institute (LMU)

Bologna, ... (Date)

.... (Company)

....
Dr. Carlo Cacciamani
Arpae-SIMC Director

Transfer project (new)

3.1 General information about Project T01

3.1.1 Title: Development of a predictability index for severe weather events over Europe

3.1.2 Research area:

Atmospheric Science (313-01)

3.1.3 Principal investigators:

Prof. Dr. George C. Craig, born 02/10/1961, Canadian
Meteorologisches Institut, Ludwig-Maximilians-Universität,
Theresienstr. 37, 80333 München, Germany
phone: +49 89 2180-4570; e-mail: george.craig@lmu.de

Prof. Dr. Volkmar Wirth, born 18/05/1961, German
Institute for Atmospheric Physics, Johannes Gutenberg-Universität Mainz,
Becherweg 21, 55128 Mainz, Germany
phone: +49 6131 3922868; e-mail: vwirth@uni-mainz.de

Do any of the above mentioned persons hold fixed-term positions? **No**

3.1.4 Application partner

ARPAE-SIMC Emilia-Romagna
Dott. Carlo Cacciamani (Director)
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Web: https://www.arpae.it/sim/

ARPAE-SIMC is the regional Hydro-Meteo-Climate Service belonging to the Regional Agency for Prevention and Environment and Energy of the Emilia-Romagna region, in northern Italy. It provides meteo-hydrological information and forecasting to users across the Region and the Po basin. The Service is structured in seven technical divisions: Hydrology, Climate and agricultural meteorology, Environmental meteorology, Operational

forecasting, Numerical Modelling, Radar meteorology and Nowcasting and Computing Division, accounting for about 90 staff people distributed between Bologna (headquarter) and Parma offices. It is one of the Center of Competence in Meteorology and Hydrology for the Italian Department of Civil Protection of the Presidency of the Council of Ministers.
ARPAE-SIMC manages a dense regional hydro-meteo-pluviometric network, produces daily weather forecasts using meteorological limited area models and maintains operational products for flood forecasting and water management. It carries out also development and implementation activities regarding : numerical model forecasting at high spatial resolution and the probabilistic forecasting system at the medium range for meteo-hydrological risks; nowcasting system for very short-range weather forecasts for extreme weather events; hydrological-hydraulic modelling to support the regional and interregional basins authorities; integrated systems, based on both GIS techniques and mathematical models to support decisions by the regional government in agro-environmental policies; monthly and seasonal forecasting techniques for regional and national purposes; regionalisation studies of global climate change. ARPAE-SIMC participates to the EU programmes, to the European Centre for Medium-range Weather Forecasts and to other international organisations and has already been beneficiary in over 30 international projects financed by EU in different programmes (FP5, FP6, FP7, LIFE Programmes, European Funds for Regional Development etc.).
ARPAE-SIMC will benefit of the project results increasing its capability of developing forecasting products for the regional stakeholders and within the coordinated system of regional hydro-meteorological services in Italy. Its annual budget is around EUR 9 million.

3.1.5 Legal issues

This project includes:

(1) Research on human subjects or human material . . . . .no

(2) Clinical trials . . . . .no

(3) Experiments involving vertebrates . . . . .no

(4) Experiments involving recombinant DNA . . . . .no

(5) Research involving human embryonic stem cells . . . . no

(6) Research concerning the Convention on Biological Diversity . . . . no

3.2 Summary

Accurate and timely prediction of high impact weather, and in particular intense precipitation events, is essential to limit losses of life and property. Although predictability is fundamentally limited by the chaotic nature of the atmosphere, recent research in atmospheric dynamics has provided new insights into the processes the limit the accuracy of forecasts that may be of significant use in operational practice. The aim of this project is to evaluate some recently developed measures of how different atmospheric processes influence predictability, and to combine them to formulate a new forecasting methodology to provide guidance in the interpretation of forecasts of heavy precipitation.

The statistics of past basin/area heavy precipitation events will be investigated using the new released high resolution precipitation dataset ArCIS (Climatological Archive for Central Northern Italy). Rossby wave packet diagnostic tools, developed in the framework of Waves to Weather, will be applied to ECMWF analysis and forecast products in order to obtain a robust quantification of the presence and impact of upper level precursors to the heavy precipitation events. At the same a convective adjustment time scale will be computed to provide a measure of how closely the precipitation is couple to the large-scale weather pattern. Combining these statistics, we define define a predictability index that that reflects the degree of predictability imposed by the large scale, but diminished by the unpredictability of the small scale. This index, developed with a view to operational forecasting practice, will provide practiioners with a measure of which scales of motion can be accurately predicted for a particular weather forecast..

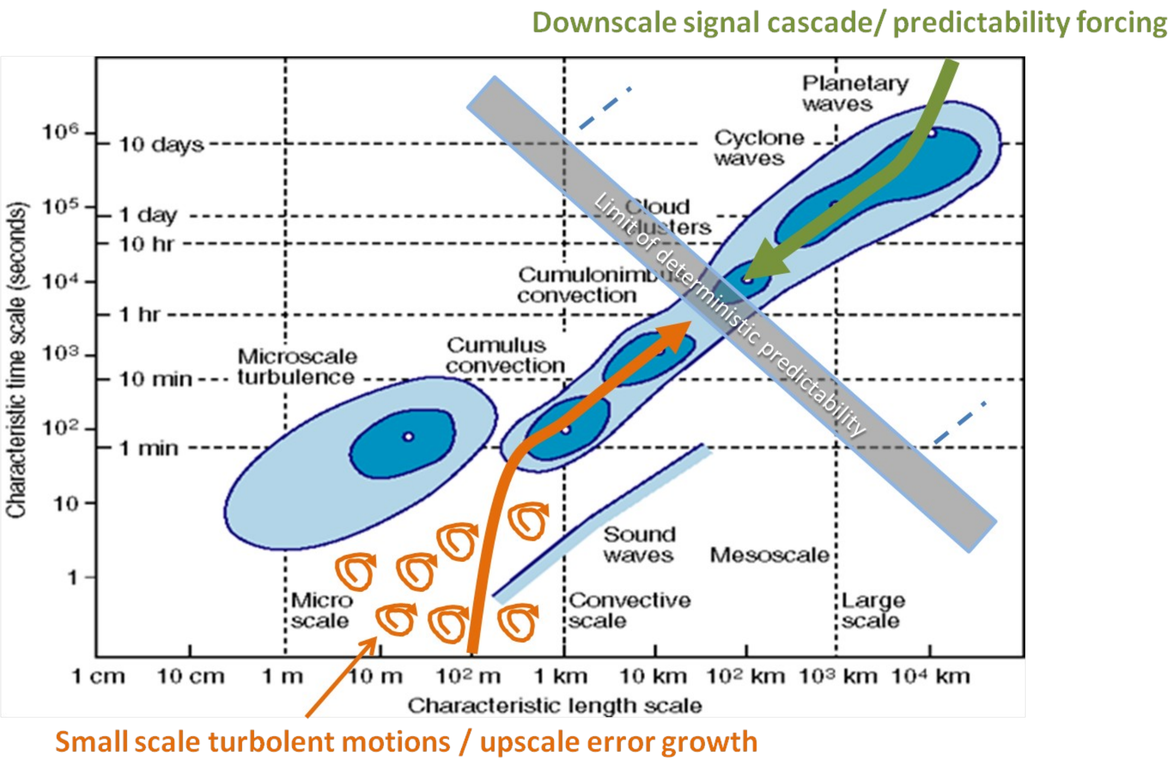

Figure 1: *Schematic illustrating the main contrasting factors regulating predictability. Large-scale predictability forcing could be modulated by the presence of RWPs. Upscale error growth could be detected using the convective time scale.*

3.3 Research rationale

3.3.1 Current state of understanding and preliminary work by participating researchers

Prediction of high impact weather events is a fundamental scientific challenge and of key importance to society. The scientific challenge comes from the complex interactions of different physical processes and different scales of atmospheric motion that combine over thousands of kilometers and many days to produce a highly localized event such as a flash flood. As shown schematically in Figure 1, large-scale, slowly evolving flows can be predictable over many days, but clouds and precipitation are also influenced by upscale error growth that limits predictability. A deeper understanding of how the large-scale atmospheric dynamics regulates local dynamical and precipitation processes is fundamental to make significant progress in extreme precipitation and flood forecasting (Lu et al. 2013).

More specifically, an association between large-scale anomalous meridional flow over Europe and heavy precipitation in the Alpine area have been previously identified by several authors, including one of the participants at this project (Massacand et al. 1998, Plaut et al. 2001, Grazzini and van der Grijn 2003, Grazzini 2007, Martius et al. 2008). Winshall (2013) has shown a high event-to-event variability in moisture supply in such events. Heavy precipitation in central Europe (usually occurring in summer) is mainly sensitive to land surface wetness conditions over European land, while Mediterranean and Alpine autumn events are more linked with convergence of moisture from remote regions (mainly the Atlantic and the subtropical regions) and direct evaporation from the Mediterranean sea. These latter events seems more sensitive to a large-scale preconditioning few days before. In addition Grazzini (2007) and Grazzini and Vitart (2015) have respectively shown that large-scale alpine precipitation events tend to be more predictable than average conditions and the highest predictability is obtained when wave packets can propagate from far upstream over the Pacific Ocean quasi-linearly.

These studies reinforces the hypothesis that some classes heavy precipitation events, the ones with a greater spatial extension and longer duration, could be tied to large scale dynamical precursors, like Rossby wave packets (RWPs). Broad precipitation areas, or the most affected river basins, could be identified, often, many days in advance. However, detailed precipitation prediction could remain uncertain even in the short-term due to intrinsic limitations introduced by upscale error growth from convective instability (Zhang et al. 2007). The limiting effect on predictability, of small convective upscale error growth, has been shown by Selz et al. (2016) with idealized simulations. There is, however, a controversy about its practical importance. Durran and Gingrich (2014) pointed out that due to the underlying kinetic energy spectrum of the atmosphere a small relative uncertainty in the initial state on large scales is still in amplitude much larger than a big relative error on smaller scales. On the other hand Rodwell et al. (2013) showed a relation between periods with bad forecasts over Europe and high convective activity upstream over the North-American continent. This indicates that the importance of upscale error growth is probably regime-dependent, being negligible in one case but with significant impact in another.

In the Collaborative Research Center 165 Waves to Weather (W2W), and previous studies, we have developed methods to quantify the different contributions of large-scale and local processes for specific weather events. In this project, we propose to evaluate them on a large data set of heavy precipitation events and develop a practical index that can be applied in operational weather prediction.

Traditionally Rossby wave packets (RWPs) have been diagnosed using Hovmoeller diagrams. At its core this technique is field-based, and it involves human intervention as part of the analysis. This has motivated several recent initiatives to design computer-based algorithms, which allow one to automatically identify and track RWPs without any human intervention. This opens entirely new opportunities, like systematically screening reanalysis data and producing statistics regarding specific RWP properties like their size, duration, and location of generation and decay. So far these new techniques have been based eithor on envelope reconstruction of the upper tropospheric meridional wind (Grazzini and Lucarini 2011, Glatt and Wirth 2014, Souders et al. 2014a) or on the small-amplitude wave activity flux of Takaya and Nakamura (2001). The added information about the direction of propagation turned out to be valuable in several cases investigated by Wolf and Wirth (2017, revised version). In one of our W2W-projects we start of make use of the finite amplitude wave activity of Nakamura and Zhu(2010) in order o avoid the dependence on the small amplitude assumption.

To quantify the degree of influence of the large-scale flow on convective precipitation, a convective adjustment timescale diagnostic has been developed (Done et al. 2006). The timescale is an estimate of how long the present rate of precipitation would need to continue before all of the convective available potential energy (CAPE) is exhausted. If this timescale is a few hours or less, the precipitation can only continue at the rate at which the large-scale flow generates new CAPE, while a longer timescale indicates that local triggers are regulating the initiation of convection. The convective timescale has been shown to correlate with size and lifetime of convective events (Molini et al. 2011) and with predictability as measured by spread in an ensemble prediction systems (Keil et al. 2013).

3.3.2 Current state of understanding and challenges in application

Of all the meteorological hazards, precipitation forecasts require perhaps the greatest accuracy in space, time and intensity. However NWP skill for these events has seen slower improvements over the years in comparison to other meteorological variables (William Gallus, personal communication). Precipitation is one of the most unpredictable variable, especially during the warm season when it often takes the form of cumulus convection. However, meteorological warnings and alerts are nowadays an integral part of territorial policies and a growing number of procedures and civil protection actions require meteorological information to be provided in ever greater detail (EU flood directive 2007/60/EC). A forecast error leading to a missing flood alert can turn a manageable situation into a natural disaster, but on the other hand, overconfidence in precipitation predictions could lead to many false alarms, seriously undermining the credibility of the national warning system. It is therefore vital, not only to discriminate between an ordinary event or a severe event, but also to adequately communicate the uncertainty related to a particular forecast, explaining to what degree we should have confidentce in the forecasts and which details we should disregard.

Unreliable forecast information can lead forecasters into typical subjective ("pendulum" like) errors. Following for example a failed forecast that missed a heavy precipitation event, forecasters might try to compensate for the error by artificially increasing the precipitation in the next event. But this could expose them to even larger errors, of opposite sign, if they are not able to associate a model bias to a particular feature in the forecasts. A characteristic example occurs in the summer season when the almost constant presence of convective instability over land, together with weak synoptic forcing, makes the precipitation prediction for the next day difficult and uncertain. Forecasters, to avoid false alarms, might tend to adopt a more conservative approach, in some cases disregarding detailed precipitation peaks predicted by the models. However a small increase in the synoptic forcing could turn the environment favorable for the organization of large convective systems, potentially able to trigger devastating flash floods (Magnusson et. al 2016). This subtle, but radical, change in the physical process that generates precipitation (i.e. from a single cell diurnal convection to MCS) might be not so evident in the available numerical prediction products. This motivates efforts to search for new forecasting tools that in addition to quantitative information will also give forecasters information about the predictability of the day's weather from a physical-process point of view. Such methods might provide a valuable complement to the ensemble products which, in convective scenarios, might suffer from limitations due to model inaccuracy in simulating interaction across scales (Nielsen and Schumacher 2016).

3.3.3 Project-related publications by participating researchers

Grazzini, F., and G. van der Grijn, 2003: Central European Floods during Summer 2002. *ECMWF Newsletter No. 96*, United Kingdom, ECMWF, 18–28.

Grazzini F. 2007. Predictability of a large-scale flow conducive to extreme precipitation over the western Alps. *Meteorol. Atmos. Phys.* 95: 123–138.

Grazzini, F., and F. Vitart, 2015: Atmospheric predictability and rossby wave packets. *Quart.J.Roy. Meteor. Soc.*, 141 (692, A), 2793–2802.

Keil, C., and G. C. Craig, 2011: Regime-dependent forecast uncertainty of convective precipitation. *Meteor. Z.* , 20,145–151.

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3.4 Project plan

3.4.1 Objectives

Our working hypothesis is that predictability of heavy precipitation events is improved by large-scale flow features such as RWPs that persist for many days, but reduced by local meteorological phenomena such as cumulus convection where errors grow rapidly. The aim of this study is to quantify the effects of both RWPs and convective-scale uncertainty, by applying and extending methods developed within the Waves to Weather CRC. The methods will be evaluated and extended using state of the art data sets from operational weather services, and an index will be developed that can be employed by forecasters along side more conventional measures of predictability to provide improved guidance to decision-makers.

The objectives of the project are:

1. To verify and more accurately quantify the previously identified link between long-lived RWPs and heavy precipitation events over Europe, by using a larger and more recent data set.

2. To study how predictability is influenced by the presence of incoming RWPs, and to determine how the presence of convection in the target region could modify or override the large scale signal.

3. To define an index, based on the above competing processes, that would provide guidance for how far into the future heavy precipitation events can be predicted.

3.4.2 Work Program

Strategy

Our research will be centered around an extensive selection of heavy precipitation events for which we will compute the various diagnostic quantities, and use to infer a correlation predictability index. A selection of events will be used as examples to illustrate how these results could be transferred in operational practice.

This project is designed as a collaboration between LMU, Uni of Mainz and ARPAE-SIMC, who are one of the leading Italian agencies in the field of operational meteorology. ARPAE-SIMC will participate actively throughout the project, contributing with new and highly valuable dataset and along with staff time for data analysis. In addition to the part-time contribution of staff from the three institutions, the project will require a full-time 1 PhD position based in Munich, supervised by both PIs covering complementary fields. Prof. Craig will be the supervisor of record at LMU, with focus on upscale error growth and predictability, while Prof. Wirth will be primary supervisor of the work concerning RWP diagnostics (esp. WP 1.2, 1.4, 2.2). Funding is requested for regular visits to the partner institutions in Mainz and Bolgna.

Most of the analysis will be based on the new high-resolution reanalysis ERA5 from ECMWF (Dee et al., 2016). This will include also deterministic reforecasts as well as EPS reforecasts for the latest 20 years (Roberto Buizza personal communication). The heavy precipitation events will be selected from data coming from the high resolution precipitation network of Italy, that has been recently aggregated, quality controlled and gridded in the ArCIS database.

The timeline of the work-packages is given in the bar graph below.

	2017		2018				2019				2020	
	3	4	1	2	3	4	1	2	3	4	1	2
WP 1.1												
WP 1.2												
WP 1.3												
WP 1.4												
WP 2.1												
WP 2.2												
WP 3.1												
WP 3.2												

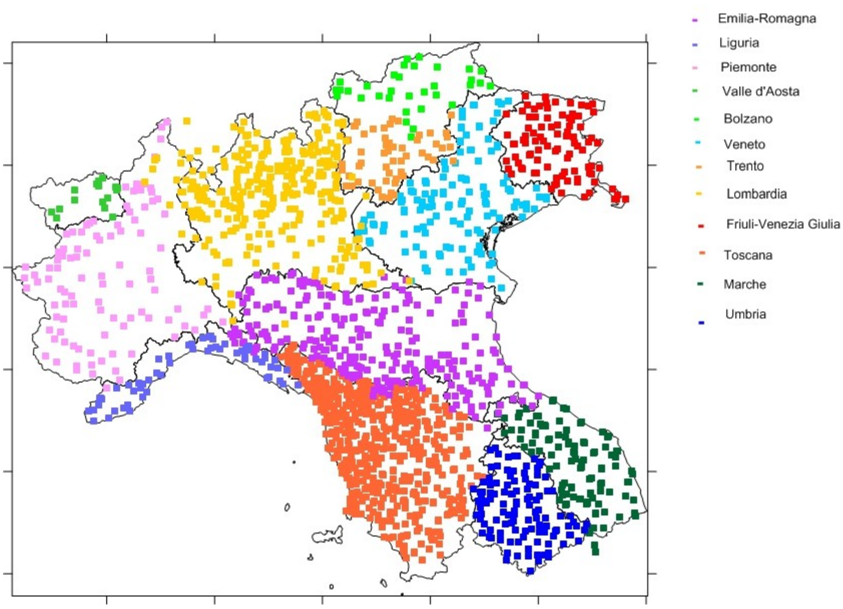

***Figure 2**: Observing precipitation stations used for the ArCIS reanalyses. The legend shows the contribution of each Italian region to the total network.*

Workpackage 1: Heavy precipitation and large-scale precursors

WP 1.1: Classification of severe precipitation events

Heavy precipitation cases will be identified using objective criteria. Owing to its climatological predisposition, we propose Northern Itay as a target area for heavy precipitation event selection. Of all the regions of Europe, this area has the highest frequency of heavy precipitation events. In contrast to areas such as the northern side of the Alps, where most of the annual rain is due to very frequent low intensity events, much of the total annual precipitation on the southern side falls from the most intense events, and these in turn are often associated with a prominent synoptic forcing (Isotta et al. 2013). The project will benefit from a newly available high resolution precipitation dataset focusing on this region: ArCIS (Pavan et al. 2013). This data set makes available quality controlled daily precipitation gridded data, from 1961 to the present, based on a very high density of observations (Fig. 2). To extend and more rigorously evaluate the statistical relationships found in two previous works (Grazzini 2007, Molini et al. 2011), the precipitation events will be classified according to intensity. A multiple percentile selection criteria will be applied to isolate days with moderate (75th), heavy (90th), and extreme (99th percentile of wet-day precip. values) precipitation. Catchment basins or climatologically homogeneous warning areas will be used for area averages to facilitate a direct application to operations.

WP 1.2: Selection of a RWP diagnostic on the basis of trial on test cases

Growing interest in Rossby wave packet dynamics has made available a number of diagnostic tools and RWPs tracking methods. PI Wirth has conducted extensive research in this area. He has suggested novel methods to diagnose Rossby wave packets (Glatt and Wirth, 2014; Wolf and Wirth, 2015) and conducted comparisons with other, more established methods (Glatt et al., 2011, Grazzini and Vitart 2015). The work of Wirth and Eichhorn (2014) showed a systematic connection between upper level Rossby wave trains and strong surface cyclones over Europe, which is another good example for the down scale connection between planetary-scale waves and local weather. In this workpackage we will apply the most recent methods developed in Project A1 of Waves to Weather. One is based on a modified version of Wave Flux Activity (Wolf and Wirth, 2017) and the other one is the local finite amplitude wave activity (LWA), proposed by (Ghinassi et al. 2016).

This latter technique will allow also to assess the non conservative effects during propagation which can help to better characterize RWPs. The different formulations described in these papers will be compared in order to define the most appropriate diagnostic to identify and track RWPs. This workpackage will focus on selected test cases in order to choose the best set-up for the analysis of the large data set in WP1.4. A close collaboration with the group of Uni Mainz will be required at this stage.

WP 1.3: Computation of Convective Time Scale associated with severe precipitation cases

In parallel to WP1.2, we start evaluating the convective time scale, as defined by Keil et al (2014), to assess the relative impact of local convection (and thus decrease in predictability) in these situations. In this area PI Craig has a long standing experience, and through the connection with W2W projects A1 and B3, this will help to better focus on how the error upscale can be more effectively individuated in operations. Selected test cases will be used to determine the correct configuration (in terms of representative area average and precipitation accumulation and averaging time), and then the mean convective time scale will be computed for each heavy precipitation event identified in WP 1.1. A potential byproduct of the systematic convective classification of heavy precipitation events might be the identification of long-term trends in the nature of precipitation that could have implications for predictability and operational forecasting practice. Such trends have been suggested for certain regions in Germany (Berg and Haerter, 2013) and Switzerland (Scherrer et al. 2016).

WP 1.4: Characterization of RWPs antecedent to heavy precipitation events

In this WP we will apply the RWP diagnostic identified in WP 1.2 systematically, for a period of up to ten days preceding each of the identified precipitation cases, both in the analysis and in forecasts. In particular we will compute RWP duration, starting point, mean intensity and 2D tracks, flux convergence/divergence, group and phase speed among other upper-level diagnostics. This will allow us to characterize the upper level forcing indicated schematically in Figure 3 by means of variable composites. This WP is expected to require the longest effort, due to the need to develop software and scripts for processing and for the organization of the output database.

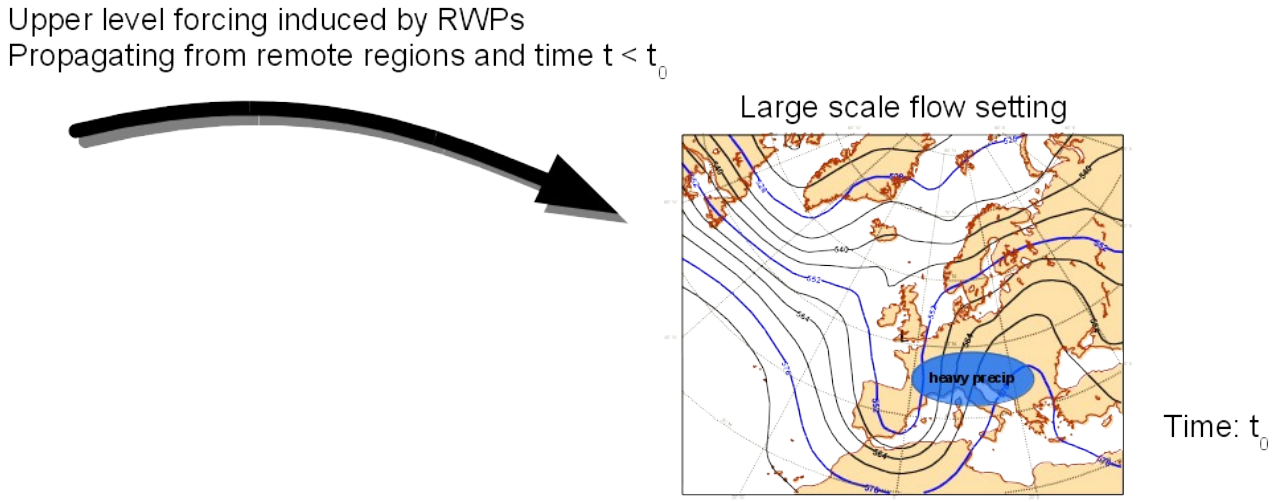

Figure 3*: Schema illustrating the hypothesized control that RWPs propagation might exert on heavy precip events.*

Workpackage 2: Multiscale predictability evaluation

WP 2.1: Evaluation of the predictive skill of the re-forecasts

In this workpackage, forecast skill metrics including RMSE and ACC will be evaluated at different lead time for upper level fields, possibly using the ECMWF precomputed package for Europe based on the Verify archive. The verification metrics will be computed on the basis of forecast area averages, compared against area averages derived by ArCIS observations. Contingency tables will be computed for different time steps and threshold values. For each event, we will compute the precipitation deterministic limit (Hewson, 2007) which measures, for each chosen threshold, the lead time beyond which these forecasts are more likely, on average, to be wrong than right.

WP 2.2: Correlation between predictive skill and RWPs

The RWP characteristics computed in WP1 will now be correlated with the measures of upper level forecast predictive skill from WP2.1. These results will be used to conduct a discriminatory analysis to determine a further stratification of the events, based on RWP presence and characteristics. For each of the identified sub-samples, we will compute the average convective time scale and the average precipitation deterministic limit for each threshold and for different spatial aggregations (i.e. starting with the individual warning areas currently used in operations, then aggregating them to form progressively larger

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regions. In this way we will evaluate the potential skill of warnings over larger regions when predictions show little skill at high spatial resolution.

WP 2.3: Measuring the downscale/upscale predictability propagation

The information from WP2.2 will be synthesized to build an index which will estimate the deterministic lead time (for a given precipitation threshold and reference area, but in principle generalizable to any defined meteorological event) as a function of the large-scale forcing (RWP index) and the local factors measured by the convective time scale.

Workpackage 3: Building and operational index of predictability

WP 3.1: Demonstration case studies

The predictability index identified in WP2.3 will be applied to selected case studies. We propose the twin heavy precipitation events in Piedmont 1994, and Piedmont 2016 (both characterized by an enhanced warm conveyor belt and widespread orographic precipitation) and the extreme Val Trebbia event (September 2015) with a stronger convective component induced by the large-scale. The 29th May convective event that led to the severe flash flood in Braunsbach (Baden-Wuerttemberg) will be analysed to test the methodology outside the calibration domain. The selected cases will illustrate the methodology in different conditions and provide concrete examples that can be presented to practitioners.

WP 3.2: Demonstration phase and application

To obtain feedback on the potential of the results of this project in operational applications, the work will be presented in seminars at regional meteorological offices in the Italian civil protection network and at the DWD. The forecaster’s feedback will be incorporated in a preliminary evaluation of the results.

3.5 Role within the Collaborative Research Centre

This is the first transfer project within the CRC Waves to Weather. The CRC conducts fundamental research into the mechanisms limiting the predictability of weather that is needed to provide a basis for producing the best possible forecasts in operational practice. In discussions with stakeholders, it became apparent that even the measures of predictability developed in the first phase of the CRC potentially had value in operations, and this transfer project was developed in cooperation with ARPAE-SIMC to explore that potential.

The project links closely with W2W Projects A1 and B3, where the RWP and convective timescale diagnostics are being developed and applied. The evaluation of the contributions of the large-scale environment forecast skill in comparison to local convective effects using a large data set makes a direct contribution to the first two research questions of Research Area C on predictability of high impact weather. The diagnostic tools developed and applied here and in A1 and B3 will be made available in the central W2W repository as part of the Cross-Cutting Activity Ensemble Tools, with the support of the central computing project Z2.

3.6 Differentiation from other funded projects

Since this project is a new application of methods developed in other W2W projects that focuses on evaluation and application to forecasting, it is complementary to those projects but there is no overlap.

3.7 Project funding

3.7.1 Previous funding

The project is currently not funded and no funding proposal has been submitted.

3.7.2 Contribution of the application partner

	2017/2	2018	2019	2020/1
Staff (in hours per week)	10	5	5	10
Funding for direct costs				
Major research instrumentation				

(Figures on direct costs and instrumentation in euros)

3.7.3 Requested funding

Funding for	2017/2	2018	2018	2020/1

Staff	Quantity	Sum	Quantity	Sum	Quantity	Sum	Quantity	Sum
PhD, 75%	0,5	30.300	1	60.600	1	60.600	0,5	30.300
<category, percentage>								
Total		30.300		60.600		60.600		30.300

Direct costs	Sum	Sum	Sum	Sum
Travel	900	1800	1800	900
Consumables / Pub. charges	1500	3000	3000	1500
Total	2400	4800	4800	2400

Major research equipment	Sum	Sum	Sum	Sum
<category>				
<category>				
Total				

Grand total	32.700	65.400	65.400	32.700

(All figures in euros)

3.7.4 *Requested funding for staff*

	Sequen-tial no.	Name, academic degree, position	Field of research	Department of university or non-university institution, collaboration partner	Project commitment in hours per week	Category	Funding source
Existing staff							
Research staff	1	George Craig		LMU	5		LMU
	2	Volkmar Wirth		JGU	2		JGU
Non-research staff	1	Robert Redl		LMU	2		TR165
Application partner staff							
Research staff	1	Gabriele Antolini	Climate and obs data analysis	ARPAE-SIMC	6		ARPAE
	2	Valentina Pavan	Climate and obs data analysis	ARPAE-SIMC	2		ARPAE
	3	M. Stefania	Model	ARPAE-SIMC	2		ARPAE

		Tesini	verification and operational forecasting				
Requested staff							
Research staff	1	Federico Grazzini	Predictabiliy, operational forecasting	LMU	36		Project

Existing Staff

Job descriptions of staff for the proposed funding period (supported through existing funds **LMU and JGU**):

Research Staff

1. Prof. George Craig (LMU): PI and primary supervisor of PhD student Federico Grazzini.
2. Prof. Dr. Volkmar Wirth (JGU): PI and co-supervisor of PhD student, with primary responsibility for WP 1.2 and 2.2.

Non-Research Staff

1. Dr. Robert Redl: Scientific computing support, funded through TR 165 Project Z1. Coordinating data transfers between all project partners, hosting of data on W2W servers, and integrating newly developed tools in the W2W software repository for wider availability.

Application Partner Staff

Job descriptions of staff for the proposed funding period (supported by application partner **ARPAE-SIMC**):

1. Dott. Gabriele Antolini: Setting up of scripting procedures to select the heavy precipitation events from the ArCIS database. Area averaging methods and in general activities related in wp1,1
2. PhD Valentina Pavan: Supervising observation data analysis and and verification procedures in wp1.1, wp2.1 and wp3.1
3. Dott. Maria Stefania Tesini: Setting up verification procedures to score precipitation forecasts against observations from ArCIS database. In general she will take care of most of the aspects related with wp2.1

Requested Staff

Job descriptions of staff for the proposed funding period (**requested funding**):

1. Dott. Federico Grazzini: We propose to employ Federico Grazzini as the doctoral student on the project (see attached CV). He is an employee of ARPAE-SIMC, who is currently on leave of absence in Munich and would be employed by the LMU for the duration of the project. His experience in operational weather prediction, and his research on Rossby wave trains at ECMWF make him an ideal candidate for this project. In return, he will have the opportunity to complete a doctoral degree. His specific duties are the following. To coordinate, in liaison with principal investigators research staff, all the different aspects of the project. To develop, in close collaboration with all participants, software, scripts, data analysis and other tools needed through work packages wp1 and wp2. In wp3 he will be the main key figure to establish a link and get feedbacks from forecasters, thought seminars at regional and national offices.

3.7.5 Requested funding for direct costs

	2017/2	2018	2019	2020/1
<if applicable, institution:> existing funds from <funding source>				
Application partner				
Sum of existing funds				
Sum of requested funds	2400	4800	4800	2400

(All figures in euros)

<category> for financial year <year/2>

<Description and justification of item>	EUR	<sum>
<Description and justification of item>	EUR	<sum>

<category> for financial year <year>

<Description and justification of item>	EUR	<sum>
<Description and justification of item>	EUR	<sum>

<etc.>

3.7.6 Requested funding for major research instrumentation

None