Improved Combustion Physics for the LANL Wildland Fire Prediction Model (FIRETEC)

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IGPP Focus Areas:
Solid Earth Geosciences
Complex Dynamical Earth Systems

1. Report Outline

The outline for this annual progress report is:

1. Report Outline
2. Summary of Objectives and Work Plan
3. Research Results for FY04
4. Challenges and Complications
5. Graduate Student Progress During FY04
6. Travel During FY04
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2. Summary of Objectives and Work Plan

The objective of this research is to continue to improve the combustion model used in the LANL Wildland Fire Prediction Model (FIRETEC), which was developed to predict the spread of wildland fires. In the development of FIRETEC, a simple empirical formulation was used to account for the combined reactions of solid and gas phase, and then a probability density function (PDF) was imposed to obtain a temperature distribution. This research seeks to improve the modeling of the physics of solid and gas phase combustion, as well as turbulence-chemistry interactions, without significant increases in computational requirements. We anticipate that an improved model can become a useful tool in predicting wildfire behavior including fire spread rate, ground-to-crown transitions, and flare-ups.

To realize the overall project objective, specific tasks must be accomplished:

1. The graduate student, Michael Clark, and the university PI, Professor Fletcher, must become familiar with the FIRETEC Fortran code.
2. Modifications to the FIRETEC code will be made to incorporate improved solid and gas phase combustion physics.
3. Evaluation of the resulting code will be performed by a) comparing model results to available experimental data, and b) assessing the computational cost of model improvements.

3. Research Results for FY04

During FY04, Mr. Clark spent a significant portion of his time on this project becoming familiar with the FIRETEC code, including time spent learning how to run a functional version of FIRETEC on an SGI supercomputer at the BYU campus. This would not have been possible without team meetings. A first meeting with Dr. Linn, Professor Fletcher, and Mr. Clark occurred January 6 on the BYU campus. In the meeting, Dr. Linn explained the current temperature PDF approach used in FIRETEC. This helped Mr. Clark and Professor Fletcher become familiarized with the current FIRETEC model. The mixture fraction

approach as applied to coal combustion was also discussed in detail during the meeting with the idea that the mixture fraction approach can be implemented in FIRETEC.

We met a second time in Riverside, California on June 3 at the USDA Forest Service Pacific Southwest Research Station. The main purpose of our travel to Riverside was to collaborate with a live fuels research group led by Dr. David Weise. Dr. Linn and Mr. Clark both made presentations to the live fuels research group, summarizing the FIRETEC model and our objectives to improve and validate this model. While in Riverside, Mr. Clark also met Dr. Bret Butler from the Missoula, Montana USDA Forest Service Fire Sciences Laboratory. Dr. Butler has provided us with access to experimental data from the Fire Sciences Laboratory that are critical to our efforts to validate FIRETEC.

Our third meeting occurred from June 29 to July 2. Mr. Clark traveled to Los Alamos and spent four days at LANL with Dr. Linn. During this visit, Dr. Linn and Mr. Clark went through the various Fortran subroutines within the FIRETEC code, so Mr. Clark could understand the basic structure of the model, and the nomenclature used in the code. Since FIRETEC is a research code, the time that Dr. Linn spent going through the code with Mr. Clark was critical to understanding the model. Mr. Clark was also able use an existing version of FIRETEC to run test cases on an SGI supercomputer at LANL. On July 1, Professor Fletcher joined Dr. Linn and Mr. Clark in a team meeting to discuss FIRETEC, and set some goals to improve the model. LANL personnel, Dr. Jonah Colman also joined us in this meeting. We outlined the components of what will become a base 2004 version of FIRETEC, which will include a solid combustion model that has been developed by Dr. Colman and an improved gas phase model developed at BYU. Evaluation of model predictions will be performed by comparison with experimental data available from the USDA Forest Service Missoula Fire Sciences Laboratory.

4. Challenges and Complications

Our proposed work plan for FY04 included implementation of a mixture fraction/PDF model for gaseous combustion as well as a separate solid combustion model. This is an ambitious project; currently no large scale, physics-based, wildland fire CFD code exists that independently describes solid and gas phase combustion. Implementation of the mixture fraction/PDF model is progressing, but has not yet been accomplished because we have encountered some complications that were not anticipated. Challenges are as follows:

First, the scale of the computational grid in FIRETEC is much larger than the scale used in typical combustion modeling that applies the mixture fraction/PDF approach. To incorporate the mixture fraction/PDF approach in FIRETEC, we must find a method to a) describe empirically, or b) solve for, the sub-grid variation in mixing in gaseous combustion.

Second, the FIRETEC code uses one overall reaction rate to account for both solid and gas phase combustion. Dr. Jonah Colman developed a version of FIRETEC with a separate three-component solid phase combustion model, but his work was never totally finished due to budget constraints. Before we can successfully apply a gas phase model, we need to implement a solid phase model that can track pyrolysis yields. We may initially apply a heat transfer limited model, while further development of the solid phase model will most likely stem from Dr. Colman's work.

Third, HIGRAD, the hydrodynamics solver to which FIRETEC is coupled, tracks energy in terms of potential temperature. In FIRETEC, energy is tracked in terms of internal energy. The mixture fraction/PDF approach we anticipate using would track energy in terms of enthalpy, the typical variable used in common combustion models and chemical equilibrium models. Therefore, during the development of HIGRAD/FIRETEC, we must deal with the challenge of conversions among internal energy, enthalpy, and potential temperature.

5. Graduate Student Progress During FY04

Since September 2003, Mr. Clark has completed core graduate courses in chemical engineering, and elective courses including combustion and numerical heat transfer and fluid flow. During Fall and Winter semesters (September 2003 through April 2004) Mr. Clark carried a full-time graduate course load. In February 2004, he passed the departmental graduate qualifier exams at the Ph.D. level. As of September 1, 2004, Mr. Clark has four remaining courses to satisfy the Ph.D. course requirements at BYU. These courses, which include combustion modeling, radiation and turbulence, will be taken when they are offered in 2005. It should be noted that from September 2003 through February, 2004, Mr. Clark's stipend was paid by a departmental teaching assistantship (TA) fellowship. This was unexpected cost-sharing on the project that paid half of Mr. Clark's time during Fall semester 2003.

6. Travel During FY04

January 6	Dr. Linn visited the BYU campus.
June 3	Dr. Linn, Professor Fletcher, and Mr. Clark met in Riverside, CA.
June 29 – July 2	Mr. Clark visited LANL.
July 1	Professor Fletcher visited LANL.
October 6	(early FY05) Mr. Clark visited Missoula Fire Sciences Lab

7. Facilities Used

1. Los Alamos SGI supercomputers were used during Mr. Clark's visit to LANL.
2. BYU SGI supercomputers were used while Mr. Clark learned to run the code, and will be used as we continue to work on FIRETEC.

8. Budget Details for FY04

		Campus	Los Alamos
1.	Salaries and Fringe Benefits	$22,000	
2.	Burden *(campuses, none)*	$0	
3.	Supplies	$500	
4.	Computer Usage	$0	
5.	Travel	$3000	$3000
6.	Equipment		
7.	Other		
	TOTALS	$25,500	$3000

Total Requested for Campus + Laboratory = $ 28,500__