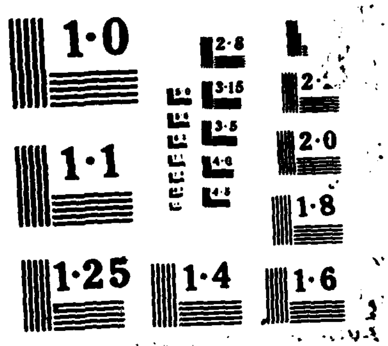
AD-A191 669 THE BEHAVIOR OF DROP-CONTAINING TURBULENT EDDIES(U) JET PROPULSION LAB PASADENA CA J BELLAN 30 NOV 87 AFOSR-TR-88-0252 AFOSR-ISSA-87-0025 1/1

UNCLASSIFIED F/G 20/4 NL


1·0
2·8
3·15
3·5
4·0
4·5
2·0
1·1
1·8
1·25
1·4
1·6

AD-A191 669

(2)

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

DTIC FILE COPY

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S): AFOSR-TR- 88-0252
6a. NAME OF PERFORMING ORGANIZATION: Jet Propulsion Laboratory, California Institute of Tech. — 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: AFOSR/NA
6c. ADDRESS (City, State, and ZIP Code): 4800 Oak Grove Drive, Pasadena, CA 91107	7b. ADDRESS (City, State, and ZIP Code): Building 410, Bolling AFB DC 20332-6448
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: AFOSR/NA — 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: ISSA 87-0025
8c. ADDRESS (City, State, and ZIP Code): Building 410, Bolling AFB DC 20332-6448	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO.
61102F	2308	A2	

11. TITLE (Include Security Classification)
(U) The Behavior of Drop-Containing Turbulent Eddies

12. PERSONAL AUTHOR(S)
Dr. Josette Bellan

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Annual Report	FROM 10/1/86 TO 9/30/87	1987, November, 30	4

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Dense sprays, Evaporation, Turbulence, Eddies (Fluid Mechanics); Turbulent boundary layer

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The effect of turbulent entrainment and mixing at the boundary of a cluster of evaporating drops has been studied. The results obtained by solving the model equations show that for dense clusters turbulence exchange processes are crucial in determining the lifetime of the drops in the cluster. In contrast, turbulence does not control the evaporation of dilute clusters of drops. The results also show that turbulence helps evaporate larger clusters of drops faster when the clusters are dense.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL: Julian M Tishkoff	22b. TELEPHONE (Include Area Code): (202) 767-4935 — 22c. OFFICE SYMBOL: AFOSR/NA

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

ANNUAL REPORT FY '87

1. AFOSR PROPOSAL NUMBER 81-2672

2. PERIOD COVERED BY REPORT: 1 October, 1986 - 30 September, 1987

3. TITLE OF PROPOSAL: The Modeling of Drop-Containing Turbulent Eddies

4. CONTRACT or Grant Number: NAS 7-918 Task Order RE 182 Amendment 480

5. NAME OF INSITITUTION: California Institute of Technology

6. AUTHOR OF REPORT: J. Bellan

7. LIST OF PRESENTATIONS AND MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER AFOSR SPONSORSHIP DURING THIS REPORTING PERIOD, INCLUDING JOURNAL REFERENCES:

(i) "Dispersion During Evaporation of Drops in Clusters", SIAM Conference on Numerical Combustion, March, 1987, San Francisco, CA.

(ii) "On the Behavior of Droplet Clusters," ILASS Meeting, June, 1987, Madison, WI.

(iii) "Turbulence Effects During Evaporation of Drops in Clusters" submitted for publication.

(iv) "An Analytical Study of Transport, Mixing and Chaos in an Unsteady Vortical Flow," V. Rom-Kedar, A. Leonard and S. Wiggins, submitted for the 40th Anniversary Meeting of the Divison of Fluid Dynamics of the American Physical Society.

(v) "Chaotic Mixing in a Stokes Flow Between Eccentric Rotating Cylinders," T. Kaper, S. Wiggins, submitted for the 40th Anniversary Meeting of the Division of Fluid Dynamics of the American Physical Society.

8. SCIENTIFIC PERSONNEL SUPPORTED BY THE PROJECT AND DEGREES AWARDED DURING THIS REPORTED PERIOD:

J. Bellan
K. G. Harstad
A. Leonard
V. Rom-Kedar
T. Kaper

Josette Bellan
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive, MS 125/214
Pasadena, CA 91109

INTRODUCTION

This report describes research performed during FY'87 at the Jet Propulsion Laboratory on the Modeling of Drop Containing Turbulent Eddies.

According to the Task Plan, the activities during FY'87 were devoted to the basic model formulation for evaporation of a cluster of drops which is embedded into a vortex.

RESEARCH PROGRESS

The point of departure for this analysis was our existing model of droplet evaporation in a cluster exposed to a convective flow[1]. Some of the assumptions embedded in this model are:

- constant cluster volume (transient gas pressure)
- constant number of drops
- uniform gas density
- laminar gas flow
- adiabatically insulated cluster volume

To describe the behavior of drop-containing turbulent eddies some of these assumptions had to be relaxed so as to include the following effects:

- cluster volume change (constant gas pressure)
- non-uniform gas density
- turbulent gas flow
- mass and heat exchanges across the surface of the cluster.

The analysis was divided into 3 distinct problems which will have to be ultimately combined to yield the final model. These problems are in increasing levels of complexity:

(1) dispersion of evaporating particles in a cluster,

(2) mass and heat transfer across the surface of the cluster in situation (1), and

(3) turbulent eddy behavior coupled to (2)

The model available at the end of FY'87 describes the evaporation of clusters of drops embedded in a surrounding hot gas and the exchange processes in terms of heat, mass, species and momentum transfer between the cluster and its surroundings. The gas pressure inside the cluster remains constant during evaporation whereas the volume of the cluster varies.

The results obtained with this model[2] show in particular that: (1) for dense clusters there is substantial mass loss from the cluster during evaporation, most of it occuring during the initial stage and (2) if the cluster is dense, it collapses initially due to substantial internal cooling of gases (heat is transferred to the drops) after which the size of the cluster starts increasing again if turbulence is strong. For dilute clusters all these effects occur as well, although to a lesser extent.

One of the very important conclusions of the above work is that for dense cluster turbulence exchange processes are crucial in determining the lifetime of the drops in the cluster, as well as the behavior of the entire cluster. For dilute clusters the turbulence exchange processes are unimportant in determining the evaporation time. This is because the entire evaporation process is controlled by droplet heating and resulting gas phase cooling inside the cluster. For a denser cluster the gas phase will cool more and thus turbulence is crucial in bringing additional hot gas from the surroundings to maintain and/or promote evaporation. When the cluster is dilute, cooling is not important and consequently turbulence is not important either.

Another important conclusion of the above work(2) is that turbulence helps evaporate larger clusters of drops faster when the cluster is dense. When the initial drop number density is fixed, a larger cluster of drops has more drops in it. Thus, at same initial ambient gas and drop temperature the cooling off effect of the gas phase will be larger and thus turbulence plays a larger role. Moreover, since the initial relative velocity between drops and gases is the same, a larger cluster is less penetrated by the outer convective flow and thus evaporates rather in a diffusive mode when compared to a smaller cluster which evaporates in a convective mode. In a diffusive mode evaporation is slower and thus turbulence has again an important role to play.

For dilute clusters there is very little sensitivity to turbulence as the size of the cluster is varied and the reasons are again those described above.

The practical implications of these results are that turbulence is important in sprays in two respects. First it breaks up the spray into small clusters that evaporate faster than the larger clusters and second, it transports hot gases from the surroundings of the cluster into the cluster thus promoting evaporation.

FUTURE WORK

This picture of droplet evaporation in clusters as described above is different from our initial expectations before the work was started. It had not been foreseen that cooling of the gases would be so strong as to induce an initial collapse of the cluster. Instead, it was thought that the evaporated mass would remain inside the cluster, the cluster would expand trapping all new evaporated mass inside and dispersion of the drops would occur. The picture that emerges now is that of non-negligible mass loss from the cluster, the cluster size initially decreasing and subsequently increasing, and correspondingly the drop number density initally increasing and subsequently decreasing. In all our calculations the cluster never recovered to its initial size.

Thus, our first task will be to check the qualitative features of the results by improving our model of heat and mass transfer across the boundary of the cluster.

Second, in the above formulation we treated the turbulence exchange processes by using Nusselt number correlations for turbulent flow around a sphere. This treatment has two implications. First, it assumes that the cluster is surrounded by several vortices and second, it implies that the turbulence length scale is much smaller than that of the cluster. This is to say that what was modeled was the situation that occurs for relatively large clusters of drops.

Small clusters of drops, such as those that are embedded in a single vortex, are not generally amenable to this particular formulation because the length scale of turbulence is of the same order of magnitude as that of the cluster. For this reason, we shall consider alternative ways of modeling these transport processes.

Based upon the above, during FY'88 we shall explore two processes: (1) transfer across the surface of the cluster for clusters small enough as to be embedded into one vortex and (2) motion of the vortex into which the cluster is embedded and the possible ejection of drops from the vortex due to the centrifugal force created by the rotation of the vortex.

References

1. Bellan, J. and Harstad, K., "The Details of the Convective Evaporation of Dense and Dilute Clusters of Drops," Int. J. Heat Mass Transfer, 30, 6, 1083-1093, 1987.

2. Bellan, J. and Harstad, K., "Turbulence Effects During the Evaporation of Drops in Clusters," submitted for publication.

END
DATE
FILMED
5-88
DTIC