LEAD Resource Requirement Notes

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DRAFT

This document tries to capture the resource needs of the LEAD static workflow as known today. This is meant to guide discussion on resource management and scheduling for LEAD workflows.

Background:
Atmospheric modeling and weather prediction systems today are serial, static and run in fixed configurations of the numerical models. Such a system is unable to respond to dynamic changes in the weather or new data that might become available. LEAD is a National Science Foundation project that is creating an integrated, scalable cyberinfrastructure for mesoscale meteorology research and education. The goal of LEAD is to provide a service oriented architecture that allows the system to be composed as workflow components allowing the system to rapidly react to changes in the atmosphere and resource behavior.

The workflow is initiated by real-time data arriving from radars which launches a number of pre-processing steps for terrain processing, interpolation, surface preprocessing, etc. For a truly accurate forecast it is important that the next step in the workflow, composed of the numerical models, is run with different initial conditions that represent the different physical parameters that are possible. Results from low resolution analysis might launch more model runs focused on specific geographic regions where weather phenomena might be occurring. As a final step the results from the model runs are analyzed and visualized, to possibly aid emergency response workers, decision makers and others.

The atmospheric modeling workflow has unique characteristics such as large data transfer, real-time data streams, huge computational demands, strict deadlines for workflow completion, need to steer external radars to collect new data, respond to weather phenomena. Thus, we need

- timely co-ordination of different types of resources to be able to meet soft real-time guarantees
- co-ordination across the layers to allocate, monitor and adapt in real-time while meeting strict performance and reliability guarantees.
- support for access and co-ordination of high-speed network (optical control links) for large data movements
- co-allocation of real-time data streams and computational resources
- multi-layered monitoring and adaptation to support the dynamic nature of workflows

Resource Requirements Discussion:

In a typical case, the user uses a portal interface and specifies the following for a workflow

- a central location (latitude & longitude at a point)
- a three dimensional grid around the central point by specifying the X,Y,Z sizes in kilometers
- resolution for the 3D grid (number of grid points within the box). (lesser the distance between grid points meaning richer resolution and need for more computing power and data storage)

The factors that determine the run time (and hence resource requirements) are: grid size, resolution, forecast duration.

Example 1: Resource requirements for a case study of Hurricane Katrina Forecast (Aug 29th 2005) in New Orleans area

- Forecast Dimensions: 183 X 163 X 51 around latitude 28.5 deg.N, longitude =-87.0 deg.E
- Resolution: 9 km
- Forecast duration: 30 hour prediction
- **Total Workflow execution time: ~ 128 mins**

The table captures the resource and data sizes for a workflow skeleton for a typical LEAD workflow for

Service Name	Application Description	Input Data		Output Data		Execution time (minutes, seconds)	Machine Name	No of processors used	Machine Specifications
		Data Description	Size	Data Description	Size				
Terrain Preprocessor	Terrain Data Preprocessor code named ARPSTRN Description: Performs analysis of terrain data and generates a terrain file by interpolating the data to the ARPS grid.	Terrain data sets and a terrain configuration file.	55M	Processed terrain data on forecast grid	2M	0 m, 4 secs	chinkapin.cs.indiana.edu	1	IU LEAD data testbed with - Dual 3.0 GHz processors with 2GB Memory

88D Radar Remapper	88D Radar Remapper code named 88D2ARPS Description: Converts raw NEXRAD Level II radar data in polar coordinates to Cartesian coordinates and remaps the data to the ARPS grid.	Observed WSR-88D Level–II radar data files and a application configuration file	N/A	Re-mapped data files onto forecast grid.	N/A	This application will be parallelized this month so the current numbers will be obsolete	chinkapin.cs.indiana.edu	1	IU LEAD data testbed with - Dual 3.0 GHz processors with 2GB Memory
NIDS Radar Remapper	NIDS Radar Data Remapper code named NIDS2ARPS Description: Converts WSR-88D Level-III raw velocity and reflectivity data and remaps it onto a sigma-Z Cartesian ARPS grid.	Observed WSR-88D Level–II radar data files and a application configuration file	N/A	Re-mapped data files onto forecast grid.	N/A	This application will be parallelized this month so the current numbers will be obsolete	chinkapin.cs.indiana.edu	1	IU LEAD data testbed with - Dual 3.0 GHz processors with 2GB Memory
Satellite Data Remapper	Satellite Data Remapper code named MCI2ARPS Description:	Observed data from satellites and	N/A	Re-mapped data files onto forecast grid.	N/A	This application will be parallelized this	chinkapin.cs.indiana.edu	1	IU LEAD data testbed with - Dual 3.0 GHz processors

	Remaps observed McIDAS GVAR AREA satellite data from the satellite-observed pixels to the ARPS grid.	application configuration file.				month so the current numbers will be obsolete			with 2GB Memory
3D Model Data Interpolator	3D Model Data Interpolator code named EXT2ARPS Description: Extracts and interpolates pertinent fields from a National Weather Service model forecast dataset to an ARPS grid to provide an ADAS analysis background or initial conditions and boundary conditions for an ARPS/WRF forecast. Output: Processed data files with fields on ARPS grid in standard ARPS history	Gridded data from external models like NCEP ETA, RUC and AVN and a configuration file	147MB	Interpolated data files onto forecast grid.	699 MB	11mins	Odin.cs.indiana.edu	32	272 Processor IU Research Cluster with 8 Head nodes and 128 Compute nodes of Dual 2.0 GHz Opterons with 4GB Ram

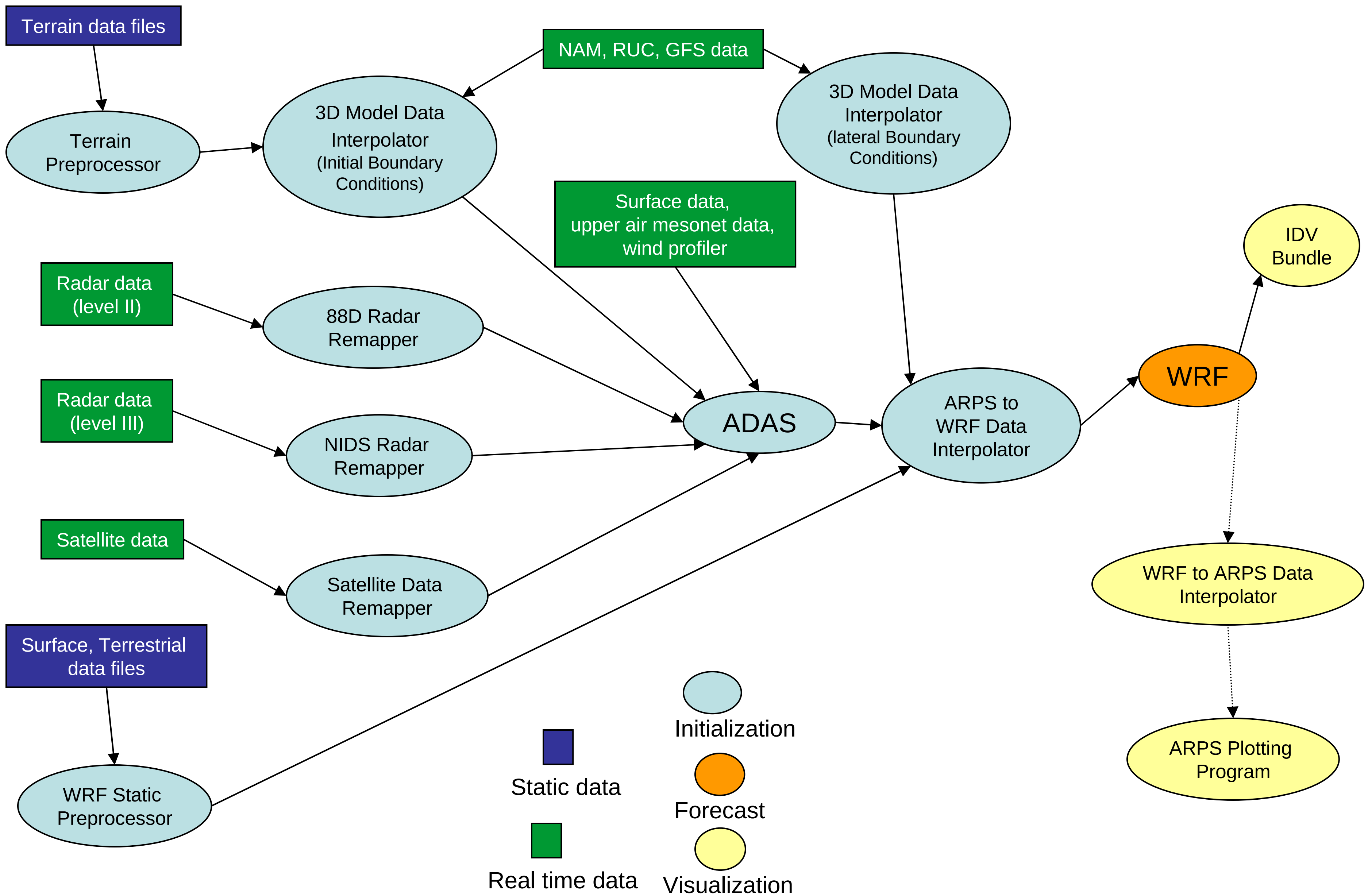
	format and external boundary conditions format.								
WRF Static Data Preprocessor	Surface Characteristics Preprocessor code named WRFSTATIC Description: Prepares the surface characteristic data set for use in ARPS and generates surface characteristic files with soil types, vegetation types, leaf area index and surface roughness.	A configuration file with soil type, vegetation type and vegetation fraction data files	4500 MB	Constructed set of surface and vegetation characteristic fields for the ARPS grid.	37MB	3 mins	chinkapin.cs.indiana.edu	1	IU LEAD data testbed with - Dual 3.0 GHz processors with 2GB Memory
ADAS-ARPS Data Analysis System	ARPS Data Analysis System – ADAS Description: Generates 3D gridded analysis of the current atmosphere by combining the observed information from NEXRAD radars,	Processed observational data from various data preprocessors and applica	170MB	ARPS history formatted analyzed data.	149 MB	19 mins	chinkapin.cs.indiana.edu	1	IU LEAD data testbed with - Dual 3.0 GHz processors with 2GB Memory

	wind profilers, satellites, surface observation networks and aircrafts with a background field created by external model data interpolator.	tion configuration file.							
ARPS-to-WRF Data Converter	ARPS to WRF data converter code named ARPS2WRF Description: Ingests data files in ARPS history format and generates WRF input and lateral boundary files.	Surface characteristic files and initialization files in ARPS data format and a application configuration file.	714MB	WRF input file, WRF lateral boundary file and WRF initialization files in NetCDF format.	198 MB	16	Odin.cs.indiana.edu	32	272 Processor IU Research Cluster with 8 Head nodes and 128 Compute nodes of Dual 2.0 GHz Opterons with 4GB Ram
WRF Model	WRF Model code named WRF Description: Performs storm, mesoscale and synoptic weather prediction by a	A configuration file, ADAS analysis data	293MB	Weather forecast output data netcdf files.	2300 GB	72 mins	Odin.cs.indiana.edu	64	272 Processor IU Research Cluster with 8 Head nodes and 128 Compute nodes of Dual

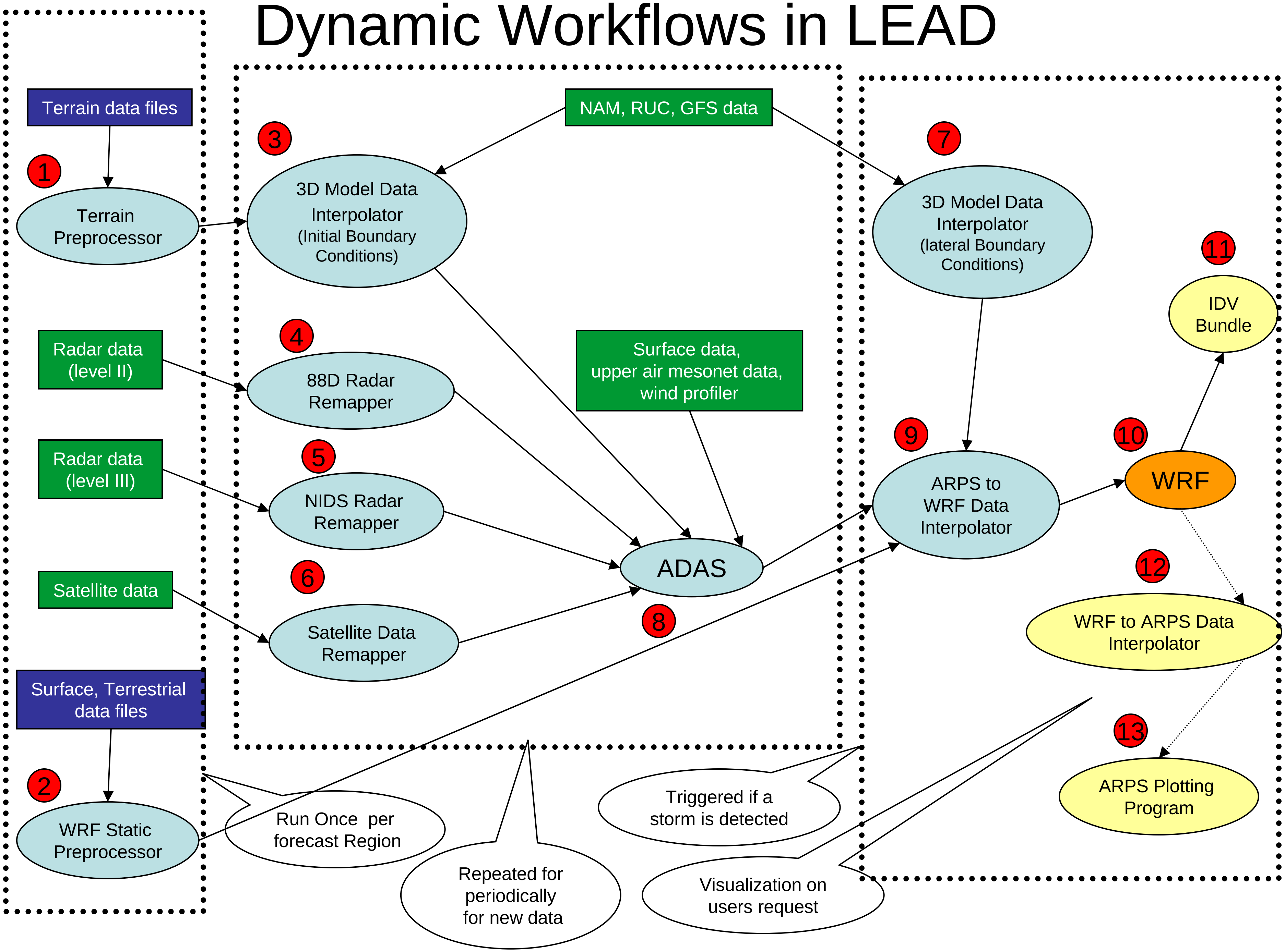
	non-hydrostatic, limited area model to study convection, baro-clinic waves, boundary layer turbulence, real-time weather phenomena.	and later boundary conditions generated by external model interpolator.							2.0 GHz Opterons with 4GB Ram
WRF-to-ARPS Data Converter	WRF to ARPS data converter code named WRF2ARPS Description: Converts WRF output to ARPS format to feed into ARPS post processing components.	Weather forecast output data netcdf files in WRF output format	2300 MB	WRF output in ARPS history format	2500 MB	17 mins	Odin.cs.indiana.edu	64	272 Processor IU Research Cluster with 8 Head nodes and 128 Compute nodes of Dual 2.0 GHz Opterons with 4GB Ram
ARPS Plotting Program	ARPS Plotting Program code named ARPSPLT Description: Generates contour and vector plots of 2D cross sections and vertical profiles. The graphical output is	Weather forecast output data netcdf files, mapdata files and a	2700 MB	Forecast output images.	35MB	9 mins	Odin.cs.indiana.edu	32	272 Processor IU Research Cluster with 8 Head nodes and 128 Compute nodes of Dual 2.0 GHz Opterons with 4GB Ram

	in Postscript format.	application configuration files.							

LEAD Static Workflow



Dynamic Workflows in LEAD



Dynamic and Adaptive workflows in LEAD

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DRAFT: This document captures some of the dynamic and adaptive notions of LEAD that have been discussed. It will evolve with more discussions in the team.

Atmospheric modeling and weather prediction systems today are serial, static and run in fixed configurations of the numerical models. Such a system is unable to respond to dynamic changes in the weather or new data that might become available. The workflow is initiated by real-time data arriving from radars which launches a number of pre-processing steps for terrain processing, interpolation, surface preprocessing, etc. For a truly accurate forecast it is important that the next step in the workflow composed of the numerical models is run with different initial conditions that represent the different physical parameters that are possible. Results from low resolution analysis might launch more model runs focused on specific geographic regions where weather phenomena might be occurring. As a final step the results from the model runs are analyzed and visualized, to possibly aid emergency response workers, decision makers and others.

The LEAD workflow has dynamic and adaptive characteristics from mesoscale meteorology as well from the computer science perspective. From the weather perspective, the workflow has to adapt to changing conditions in the weather and processed or analyzed data. The goal of the LEAD system is to make sure that the workflows run so as to generate timely and accurate forecasts.

Here are ***some*** example situations where LEAD workflows might be dynamic and adaptive

Characteristic	**Impact**	**Additional notes**	**Workflow Implications [e.g. steps that will be repeated/in loop**	**Example resource management implications**	**Data Implications**
Numerical Model					
Adaptation in time: running successive forecasts more frequently in times of weather phenomena	Initial variation settles down to a more consistent solution	Grid and resolution is the same. The forecast length reduces progressively	3,4,5,6,8,7, 9,10 will run	Resource affinity from previous run, advanced reservation knowing new data will come	Real-time data. Data pre-processed from previous workflow iteration for the terrain can be reused
Adaptation in space: nested grid over region of interest	Used to focus on suspicious regions	Grid, resolution, forecast length can vary	Child workflow with possibly all elements.	Expand resource set	New data might need to be collected from radars, etc.
Ensemble forecasting: Multiple parallel runs	Study different initial conditions	Grid, resolution, forecast length is same	10 repeated	Co-allocation of resources	
Observing Systems					
Localized sensors: additional localized available				Different resource types, data streaming	Sensor data
CASA Radars: steer radar to collect localized data		Grid, resolution, forecast length will be different	Child workflow with possibly all elements. Subsequent iterations may not need all steps		
Cyberinfrastructure					

Performance: Underlying resource is not meeting the expectation and the deadline for entire workflow will not be met			Repeat the step and possibly reschedule and migrate tasks that come after the step in question.	Reschedule part of or entire workflow	
Reliability: Underlying resource MTTF is less than running time.			Migrate or overprovision a particular task		
Web Service: The service managing a workflow task is overloaded			The service needs to be replicated and load balancing needs to have in service selection at the BPEL workflow level		